National Park Service
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Natural Resource Stewardship and Science

North Coast and Cascades Network Water Quality Monitoring Protocol

Natural Resource Report NPS/NCCN/NRR—2012/571



ON THE COVER
Students observe a redside shiner at Ross Lake, North Cascades National Park
Photograph by: Amy Brown, North Cascades Institute

North Coast and Cascades Network Water Quality Monitoring Protocol

Natural Resource Report NPS/NCCN/NRR—2012/571

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Revision History Log

The following table lists all edits and amendments to this protocol narrative document and its accompanying Standard Operating Procedures (SOPs) since the original publication date. Information entered in the log must be complete and concise. Users of this protocol narrative will promptly notify the Project Lead about recommended and required changes. The Project Lead must review and incorporate all changes, complete the revision history log, and change the date on the title page. For complete instructions, please refer to SOP 19: Revising the Protocol.

Protocol Narrative or SOP	Revision Date	Author of Revision and Affiliation	Changes Made, Location in Document	Reason for Change

Glossary

303(d)	Section of the Clean Water Act mandating that states submit a list of water bodies not meeting or not expected to meet water quality standards.
305(b)	Section of the Clean Water Act mandating that states submit a comprehensive report on water quality to the EPA.
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.
Coefficient of variation (CV)	Standard deviation / mean
Clean Water Act	1972 statute that established structure for regulating pollutant discharges into and quality standards for surface waters of the U.S.
Ecological condition	Defined by the EPA as "the state of physical, chemical and biological characteristics of the environment, and the processes and interactions that connect them."
Ecoregion	Ecological regions having similar climate, vegetation, soil type, and geology. Ecoregions as defined by the EPA are areas within which ecosystems (and the type, quality, and quantity of environmental resources) are generally similar.
Impaired waters	Waters that are listed under section 303(d) of the Clean Water Act.
Index period	The index period is the period of time that water quality samples should be collected to minimize seasonal and diel variation.
Intermittent (ephemeral) waters	Streams that flow only during part of the year, such as in the spring and early summer after snowmelt; or ponds and wetlands that seasonally dry out.
National Hydrography Dataset	Comprehensive set of digital spatial data containing information on surface water features such as streams, rivers, lakes, and ponds. Data are based on U.S. Geological Survey 1:24,000 and
O/E (Observed/Expected)	A ratio of 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.
Perennial stream	A stream that flows continuously throughout the year.
Reach	A discrete segment of a stream.

Glossary (continued)

Reference condition	Represents the least human disturbed condition available in the NCCN for a given habitat. Reference condition waters are only found in watersheds free of the impacts resulting from lasting ground disturbance or land clearing, including maintained trails, and are used as benchmarks to compare the condition of other waters in the NCCN.
Relative Standard Deviation (RSD)	(Standard deviation / mean) x 100
Sample reach	A segment of stream delineated in a manner equivalent to the EPA's EMAP "support reach," which is defined as 40 times the mean wetted width.
Species of concern	A term used to describe a species about which the park is concerned because the species is vulnerable to population or habitat loss within the park but does not appear on federal or state ESA listings.
Status	Some statistic of a parameter over all monitoring sites within a single or well-bounded window of time.
Stressor	Environmental or anthropogenic factor that adversely affects, and thus degrades, aquatic resources. Stressors may be chemical (e.g., excess nutrients), physical (e.g., excess sediment or increased temperature), or biological (e.g., non-native species)
Trend	A non-cyclic, directional change in a response measurement that can be with or without pattern.
Threatened waters	Waters that are ranked into high risk categories based on the watershed condition assessment (Section 1.4.2) and using informed risk criteria (Section 1.6.3).
Wadeable stream	A stream that is small and shallow enough to adequately sample by wading, without a boat.
Water of management concern	Any water body where little or no water quality information exists, and where human activities may contribute to degradation of water quality.
Watershed condition assessment	The process of ranking NCCN watersheds, or those adjacent to NCCN parks, for potential to impact the aquatic resources within NCCN parks, based on four primary sources of stress.

Acronyms and Abbreviations

ANC	Acid neutralizing capacity
cfu/100 mL	colony-forming unit per 100 milliliters
CWA	Clean Water Act
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
DO	Dissolved oxygen
DOE	Washington Department of Ecology
DQI	Data Quality Indicator
EBLA	Ebey's Landing National Historical Reserve
EMAP	Environmental Monitoring and Assessment Program
EPA	United States Environmental Protection Agency
FOVA	Fort Vancouver National Historic Site
GIS	Geographic Information System
GPS	Global Positioning System
I&M	National Park Service's Inventory and Monitoring Program
LEWI	Lewis and Clark National Historical Park
µS/cm	microSiemens per centimeter
mg/L	milligrams per liter
MQO	Measurement Quality Objective
MOE	British Columbia Ministry of Environment
MORA	Mount Rainier National Park
NCCN	North Coast and Cascades Network
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NOCA	North Cascades National Park Service Complex
NPS	National Park Service

Acronyms and Abbreviations (continued)

NPSTORET	NPS desktop version of EPA's STORET database
NTU	Nephelometric turbidity unit
NWI	National Wetlands Inventory
NWQL	National Water-Quality Lab
OLYM	Olympic National Park
PCB	Polychlorinated biphenyls
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RIVPACS	River Invertebrate Prediction and Classification System
RPD	Relative Percent Difference
SAJH	San Juan Island National Historical Park
SOC	Semi-volatile organic compounds
SOP	Standard operating procedure
STORET	"Storage and Retrieval" - EPA's national water quality database
TDS	Total dissolved solids
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TSI	Trophic State Index
USGS	United States Geological Survey
USFS	United States Forest Service
WRD	Water Resources Division (NPS)
WRD STORET	NPS database instance of EPA's STORET, maintained by WRD and from which NPS water quality data are uploaded monthly to STORET
WRIA	Water Resource Inventory Areas (Washington Department of Ecology)
YSI	Yellow Springs Instrumentation

Executive Summary

The high abundance of rivers and streams is a defining characteristic of the North Coast and Cascades Network (NCCN). Ninety-four percent of NCCN land area is federally-designated wilderness and contains some of the best remaining aquatic habitats in the Pacific Northwest. The prevalence of these resources gives water quality a high ecological, management and legal significance for the network. NCCN aquatic resources support 38 native fish and 17 native amphibian species as well as human uses, including contact and non-contact recreation and water supply.

These aquatic systems integrate the physical, chemical, and biological characteristics of the watersheds they drain; this puts them at an increased risk to a variety of environmental stressors including atmospheric pollution, changes in flow regimes due to climate change, and more localized disturbances related to land management activities and recreational use.

This document outlines a strategy for monitoring water quality in a selection of the most at risk wadeable rivers and streams in the NCCN. It documents the decision making processes involved in prioritizing individual water bodies for monitoring, selecting sample sites, and selecting the parameters to monitor along with their associated methods. It is intended to be a work in progress summarizing available information, identifying an initial set of priority water bodies for monitoring, and highlighting gaps in NCCN data and knowledge regarding impaired and potentially impaired waters.

The Water Quality monitoring project employs a cost-efficient, comprehensive approach using multiple indicators representing key physical, chemical, and biological attributes, which will serve to address current management issues as well as future emerging threats. The project will assist park managers in complying with the Clean Water Act (CWA) for the waters that will be sampled. The Water Resources Division (WRD) of the National Park Service (NPS) has mandated that a set of core water quality parameters, temperature, dissolved oxygen, pH, and specific conductance be measured in park aquatic resources. These core parameters will be collected from NCCN water bodies in addition to several other physical, chemical and biological water quality parameters as listed below.

Physical parameters	Chemical parameters	Biological parameters
Continuous air temperature	Dissolved oxygen*	Benthic macroinvertebrates
Continuous water temperature	pH*	
Rapid habitat assessment	Specific conductance*	
Stream/river physical habitat		
Temperature*		
Turbidity		

*WRD “Core parameters.”

The protocol uses a judgment sample to provide information on specific water bodies identified as the most threatened, and the data from any targeted site will only apply to the site that was sampled. Sampling will occur once a year during the seasonal low water period that ranges from late July to early October. This “index period” maximizes the safety of field crews and increases comparability with regional and national monitoring programs (Hayslip 2007) and those conducted by the Oregon Department of Environmental Quality, and the Washington

Department of Ecology. Excursions in dissolved oxygen and water temperature are most likely to occur during this time as well.

Measureable objectives for this protocol include:

1. Determine the status and trends of the ecological conditions in selected wadeable rivers and streams found within the boundaries of the NCCN that are listed as impaired under section 303(d) of the Clean Water Act.
2. Determine the status and trends of the ecological conditions in selected wadeable rivers and streams found within the boundaries of the NCCN that are at a high risk of impairment. These waters are believed to be some of the most imperiled water bodies in the NCCN, and many have little or no water quality information that can be used to ascertain their ecological condition. These waters will typically require the initiation of monitoring by the NCCN.
3. Compare water temperature data against state standards for chronic exceedance on a weekly, monthly, seasonal and annual basis.
4. Compare indices of biological integrity against state standards for chronic exceedance on an annual basis.

Information management and the communication of monitoring results are fundamental components of the NPS Inventory and Monitoring (I&M) program and this protocol. To facilitate the transfer of information from the I&M program to Park-based Aquatic Program Leads, park superintendents and the public, a comprehensive process of data storage, analysis and reporting has been developed. The process is initiated via data entry into the NPS database application NPSTORET, which is uploaded on an annual basis to the Environmental Protection Agency's nation-wide water quality database STORET. Incorporating the data from this protocol into STORET will ensure they are widely accessible to tribal, state and municipal agencies, as well as outside researchers. The results from data analysis will be incorporated into resource briefs, Annual and Five-year Summary reports, and natural resource summary tables. These reports will provide park managers and the public information about the condition of the wadeable rivers and streams facing the greatest threats to water quality in the NCCN.

Acknowledgments

The authors would like to thank the Greater Yellowstone and Klamath Networks for providing excellent examples of water quality monitoring protocols that were used as templates in developing this document. We also wish to acknowledge other agencies that have gone before us in developing protocols and standard operating procedures to assess aquatic resources. We drew heavily from their work and strove to provide credit in the appropriate locations. We would also like to thank Trent McDonald and other staff at Western Ecosystems Technology Inc. for their assistance in power analysis and analysis methods.

1.0 Background and Objectives

1.1 Purpose and Scope

This document outlines a strategy for monitoring water quality in the wadeable rivers and streams in the North Coast and Cascades Network (NCCN) of the National Park Service (NPS). In 2000, the NPS Inventory and Monitoring Program (I&M) was established to provide scientifically sound information on natural resources by documenting the current status and long term trends in the composition, structure, and function of park ecosystems and to determine how well current management practices are sustaining those ecosystems (Fancy et al. 2009). The I&M program is organized nationally around 32 monitoring networks including approximately 270 park units. As one of these networks, the NCCN is composed of seven NPS units (Figure 1.1).

This protocol documents the decision making processes involved in prioritizing individual water bodies for monitoring, selecting sample sites, and selecting the parameters to monitor along with their associated methods. It is intended to be a work in progress summarizing available information, identifying an initial set of priority water bodies for monitoring and highlighting gaps in the NCCN's data and knowledge regarding its surface waters. Additional documentation of the development of this protocol is provided in Appendix A: Administrative History.

It also includes a characterization of the NCCN's aquatic resources (Table 1.1) and the watershed conditions affecting these resources. The project area delineated for this protocol contains all NCCN lands and areas adjacent to NCCN jurisdictional boundaries when these areas possess the potential to impact NCCN aquatic resources.

Many of the SOPs in this protocol are directly adapted from peer reviewed state and federal water quality monitoring protocols. These protocols were adapted to fit the need of this monitoring project and to meet Environmental Protection Agency (EPA) data quality standards. Other I&M network protocols were also consulted for consistency in protocol format and content.

1.1.1 Monitoring Goals

The primary goals of the NCCN water quality monitoring project are to:

1) Determine the status and trends in the ecological conditions for a selection of wadeable rivers and streams distributed throughout the NCCN that are at a high risk of impairment.

2) Provide timely and high quality data to park managers.

3) Identify and detect new and emerging threats to water quality.

4) Improve the understanding of the basic chemical, physical and biological processes that affect environmental quality of these surface waters and determine if they are within their natural chemical and biological ranges.

1.1.2 Monitoring Questions

1) What are the existing chemical and biological ranges in water quality within selected wadeable streams and rivers in the NCCN?

2) What are the long-term trends in the ecological condition for selected wadeable rivers and streams in watersheds that are at the highest risk of impairment?

3) Is the water quality in NCCN water bodies, as indicated by the selected wadeable rivers and streams, in compliance with the state designated beneficial uses?

4) What are the point and non-point pollution sources within the watersheds affecting the water quality of NCCN water bodies?

1.1.3 Measurable Objectives

1. Determine the status and trends in key ecological conditions (water temperature, dissolved oxygen, specific conductance, pH, turbidity, benthic invertebrates and the presence of invasive species) for selected wadeable rivers and streams found within the boundaries of the NCCN that are listed as impaired under section 303(d) of the Clean Water Act.

2. Determine the status and trends in key ecological conditions (water temperature, dissolved oxygen, specific conductance, pH, turbidity, benthic invertebrates and the presence of invasive species) for selected wadeable rivers and streams found within the boundaries of the NCCN that are at a high risk of impairment.

   These waters are believed to be some of the most imperiled water bodies in the NCCN, many have little or no water quality information that can be used to ascertain their ecological condition. These waters will typically require the initiation of monitoring by the NCCN.

3. Compare water temperature data against state standards for chronic exceedance on a weekly, monthly, seasonal and annual basis.

4. Compare indices of biological integrity against state standards for chronic exceedance on an annual basis.

5. Compare measurements of dissolved oxygen, pH and turbidity against state standards for chronic exceedance on an annual basis

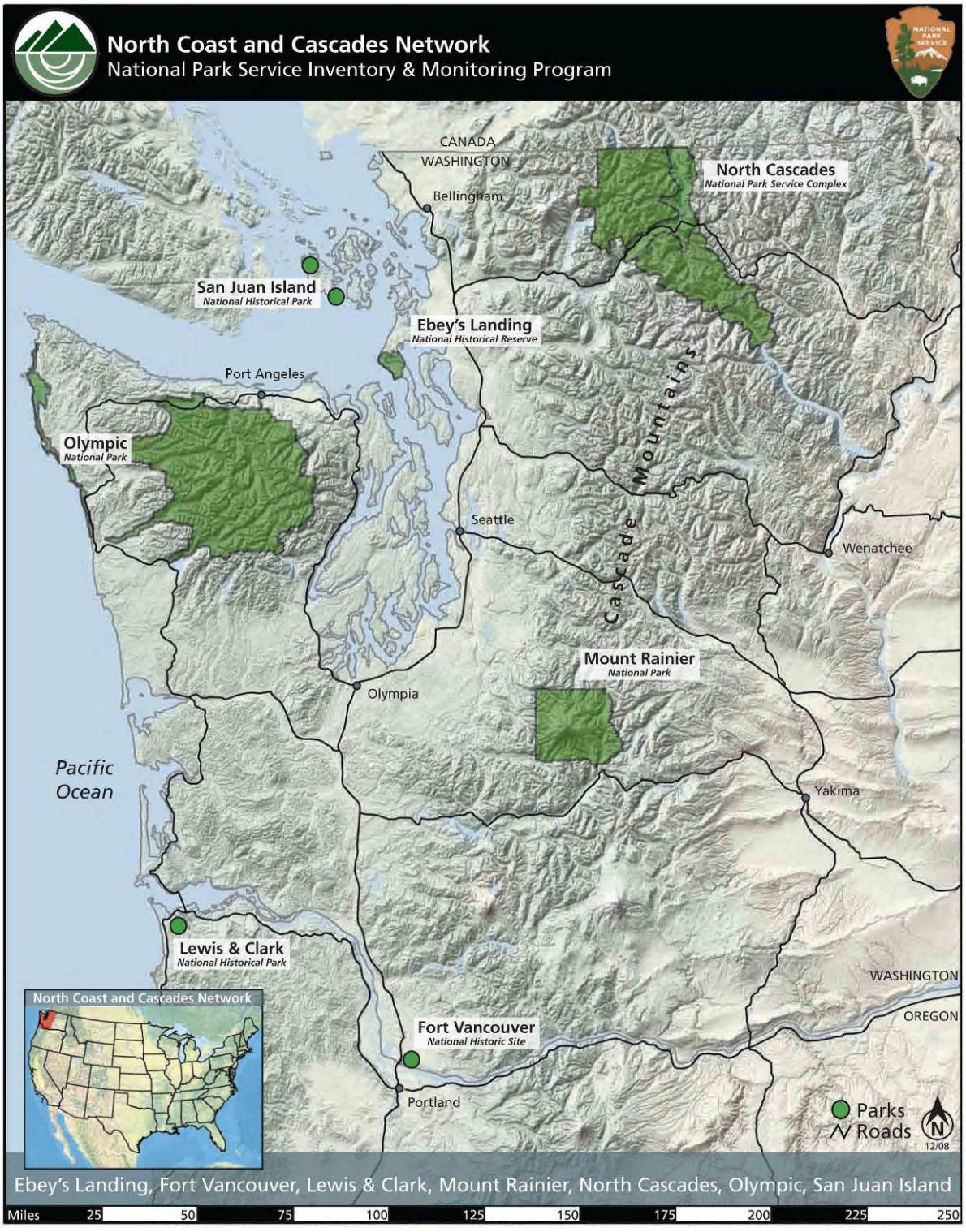


Figure 1.1. Map of North Coast and Cascades Network.

Table 1.1. Overview of aquatic resources in North Coast and Cascades Network parks.

Park	Park code	State	Size (acres)	Freshwater resources	Other aquatic resources
Ebey's Landing National Historical Reserve	EBLA	WA	17,400	Small lake, wetlands	Estuaries, coastal and marine habitat
Lewis and Clark National Historical Park	LEWI	WA/OR	3,567	Wetlands, small lakes, ponds, streams, large rivers	Coastal habitat, estuaries
Fort Vancouver National Historic Site	FOVA	WA	210	None	None
Mount Rainier National Park	MORA	WA	235,612	Mountain lakes, ponds, large rivers, streams, wetlands	Glaciers
North Cascades National Park Service Complex	NOCA	WA	684,000	Large lakes, mountain lakes, ponds, large rivers, streams, wetlands	Glaciers
Olympic National Park	OLYM	WA	922,651	Large lakes, mountain lakes, ponds, large rivers, streams, wetlands	Coastal habitat, glaciers
San Juan Island National Historical Park	SAJH	WA	1,752	Wetlands, ephemeral stream, springs	Coastal habitat, estuaries

1.2 Rationale for Selecting this Resource to Monitor

A high abundance of rivers and streams is one of the defining characteristics that are shared by all of the parks in the NCCN. The abundance of these resources gives water quality a high ecological, management and legal (Figure 1.2) significance for the network. These resources support a variety of threatened and endangered species (Table 1.2) and human uses, including contact and non-contact recreation and water supply. Due to their position in the landscape these systems integrate the physical, chemical, and biological characteristics of the watersheds they drain. This position puts them at an increased risk to a variety of environmental stressors. These stressors can include changes in flow regimes due to climate change, atmospheric pollution and more localized disturbances related to land management activities and recreational use.

The primary federal laws governing aquatic resources management include the Clean Water Act, the National Environmental Policy Act, the Rivers and Harbors Act, the Endangered Species Act, the Wilderness Act, the Wild and Scenic Rivers Act, the Coastal Zone Management Act, and the Fish and Wildlife Coordination Act. Management of aquatic resources is further addressed in various provisions of the Estuary Protection Act, the Federal Power Act, the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, the Safe Drinking Water Act, the Food Security Act of 1985, and the Coastal Barrier Resources Act. Park water resources are also identified as air quality related values which require protection under the Clean Air Act for Class I parks (MORA, NOCA, OLYM).

Due to impairment, some waters do not support, or only partially support the high ecological values representative of National Park lands. When such a watershed is primarily under NPS

ownership, significant and tangible management actions can be taken by the NPS to improve the water quality and to ensure that the high quality aquatic ecosystems of NCCN are preserved. When a watershed is managed by private interests or other government agencies, the information generated from this protocol can be used to initiate the Total Maximum Daily Load (TMDL) process as part of the Clean Water Act. TMDL implementation plans provide information on what point and nonpoint sources contribute to the impairment and how those sources are being controlled, or should be controlled in the future.

Two complementary water quality related protocols are being implemented in the NCCN, the Mountain Lakes Monitoring Protocol and this Water Quality Monitoring Protocol. The NCCN Mountain Lakes Monitoring Protocol is specifically focused on the NPS Water Resource Program (WRD) objective of maintaining the ecological integrity of relatively pristine waters, as represented by the target population of lakes located in high forest/subalpine regions of MORA, NOCA and OLYM. In contrast, the primary focus of the NCCN Water Quality Monitoring Protocol is to monitor the wadeable rivers and streams that are of the highest management concern among all of the park units in the network and are comprised of waters that are 1) listed as impaired or potentially impaired under sections 303(d) and 305(b) of the Clean Water Act and 2) other waters that are believed to be at risk of impairment by NPS managers. At this time, the resources are not currently available for the NCCN to address large rivers, lakes, wetlands and ponds in this protocol.

Desired Condition: The Service will perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial ecosystems.

Source:
Federal Water Pollution Control Act (commonly referred to as Clean Water Act)
Executive Order 11514
NPS Management Policies

Desired Condition: The Service will determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks.

Source:
Federal Water Pollution Control Act (commonly referred to as Clean Water Act)
Executive Order 12088
NPS Management Policies

Desired Condition: Natural floodplain values are preserved or restored.

Source:
Executive Order 11988
Rivers and Harbors Appropriations Act of 1899
Federal Water Pollution Control Act (commonly referred to as Clean Water Act)
NPS Management Policies
National Environmental Policy Act

Desired Condition: Natural and beneficial values of wetlands are preserved and enhanced.

Source:
Executive Order 11990
Rivers and Harbors Appropriations Act of 1899
Federal Water Pollution Control Act (commonly referred to as Clean Water Act)
NPS Management Policies

Figure 1.2. Current laws and policies mandating water quality monitoring. (Excerpted from http://workflow.den.nps.gov/11_Laws/servicewide_by_topic_water.htm, accessed 3 March 2011).

Table 1.2. Federal and State status for listed aquatic species in the North Coast and Cascades Network.

Latin name	Common name	Federal status	WA status	OR status
Ascaphus truei	Tailed frog	None	Monitor	None
Bufo boreas	Western toad	Species of Concern	Candidate	None
Catostomus catostomus	Salish Sucker and Longnose Sucker	None	Monitor	None
Dicamptodon copei	Cope's giant salamander	None	Monitor	None
Plethodon dunni	Dunn's salamander	None	Candidate	None
Plethodon vandykei	Van Dyke's salamander	Species of Concern	Candidate	None
Rana cascadae	Cascades frog	Species of Concern	Monitor	None
Rana luteiventris	Columbia spotted frog	None	Candidate	None
Rhyacotriton cascadae	Cascade torrent salamander	None	Candidate	None
Rhyacotriton kezeri	Columbia torrent salamander	Species of Concern	Monitor	None
Rhyacotriton olympicus	Olympic torrent salamander	Species of Concern	Monitor	None
Cottus cognatus	Slimy sculpin	None	Monitor	None
Cottus gulosus	Riffle sculpin	None	Monitor	None
Cottus perplexus	Reticulate sculpin	None	Monitor	None
Lampetra ayresi	River lamprey	Species of Concern	Candidate	None
Lampetra richardsoni	Western brook lamprey	Species of Concern	None	None
Lampetra tridentata	Pacific lamprey	Species of Concern	Monitor	None
Novumbra hubbsi	Olympic mudminnow	None	Sensitive	None
Oncorhynchus keta	Chum salmon (Hood Canal and Lower Columbia)	Threatened	Candidate	None
Oncorhynchus kisutch	Coho salmon (Lower Columbia and Southwest WA)	Candidate	None	Endangered
Oncorhynchus mykiss	Steelhead (Lower Columbia and Puget Sound)	Threatened	Candidate	None
Oncorhynchus nerka	Sockeye salmon (Ozette Lake)	Threatened	Candidate	None
Oncorhynchus tshawytscha	Chinook salmon (Puget Sound)	Threatened	Candidate	None
Prosopium coulteri	Pygmy whitefish	Species of Concern	Sensitive	None
Salvelinus confluentus	Bull trout (Coastal, Puget Sound and Columbia Basin)	Threatened	Candidate	None
Thaleichthys pacificus	Eulachon	None	Candidate	None
Soliperla fenderi	Fender's soliperlan stonefly	Species of Concern	None	None

1.3 Resource Characterization

1.3.1 Overview of NCCN Parks and Setting

Ebey's Landing National Historical Reserve (EBLA) was designated by Congress in 1978 as the first historical reserve in the National Park System. It was designated "to preserve and protect a rural community which provides an unbroken historic record from 19th century exploration and settlement in Puget Sound to the present time." The 25 square mile reserve is located in the Olympic Rainshadow subdivision of the Puget Lowland Ecoregion (Omernik 1995) in northwestern Washington State. It is a mixture of state, private, and federal lands and waters, with the majority in private ownership. Agricultural and open space constitute 42% of the Reserve, woodlands compromise 36%, residential use accounts for 11.4%, wetlands occupy 5%, and urban and commercial uses constitute 1%. The climate is moderate, and the Reserve lies within the rain shadow of the Olympic Mountains, receiving only 20 inches of precipitation annually (PRISM 2006).

Lewis and Clark National Historical Park (LEWI) originally established as Fort Clatsop National Memorial (FOCL) on 125.2 acres, LEWI has expanded to over 3,500 acres, extending across 40 miles of the coast. The Park complex is made up of 12 units spread across the Coast Ecoregion (Omernik 1995). Habitats range from estuarine mudflats and tidal marshes, to shrub and forested swamps and upland coniferous rainforest, dominated by Sitka spruce. Nearly a quarter of LEWI is comprised of wetlands. Other water resources consist of the Lewis and Clark and Skipanon Rivers, low-gradient brackish sloughs, freshwater ponds, and several small streams and springs. The park is affected by adjacent land-use including water withdrawals from the Skipanon and Lewis and Clark Rivers.

Fort Vancouver National Historic Site (FOVA) encompasses 170 acres. The natural environment of the site has been heavily impacted over time by the Hudson's Bay Company and by development, primarily by the U.S. Army, which moved into the area in 1849. As a result of these impacts, almost none of the site's historic natural environment remains. This park contains no surface water features and is not included in the NCCN water quality monitoring project.

Mount Rainier National Park (MORA) contains the headwaters for the Puyallup, White, Nisqually, and Cowlitz Rivers, and 97% of its land area is federally designated wilderness. MORA lies within the Cascades Ecoregion (Omernik 1995), a mountainous area underlain by Cenozoic volcanic geology which has been highly affected by alpine glaciations. The topography is characterized by steep ridges and river valleys and active volcanism. Its moist, temperate climate supports extensive and highly productive coniferous forests. Elevations range from 1,750 to 14,410 feet with 185 inches of precipitation falling annually on the southern slopes of Mount Rainier and 50 inches a year of precipitation falling in the northeast corner of the Park (PRISM 2006).

North Cascades National Park Service Complex (NOCA) is comprised of North Cascades National Park and the Ross Lake and Lake Chelan National Recreation Areas. The Complex drains into the Columbia River, Puget Sound, and the Fraser River in Canada, and most of the land base (93%) is federally designated wilderness. NOCA is unique among the three largest NCCN parks (MORA, NOCA and OLYM) in having the largest number of non-NPS managed watersheds that drain into the park and affecting its aquatic resources. The Park and Recreation

Areas all lie in the North Cascades Ecoregion (Omernik 1995), a landscape composed of high, rugged mountains. It contains the greatest concentration of active alpine glaciers in the conterminous United States and has a variety of climatic zones. A dry continental climate occurs in the east, and mild, maritime, rainforest conditions are found in the west. It is underlain by sedimentary and metamorphic rock, in contrast to the adjoining southern Cascades which are composed of volcanics. Elevations range from 350 to 9,220 feet. The minimum and maximum annual precipitations of 17 and 155 inches/year, respectively, are both found in the southeastern portion of the complex (PRISM 2006).

Olympic National Park (OLYM) encompasses 922,651 acres in the center of Washington's Olympic Peninsula and along a 65-mile strip of wilderness coastline on the Pacific Ocean, and 96% of this area is federally designated wilderness. While the main body of park lands is contiguous, comprised of a high percentage of the watersheds under NPS management, the coastal strip receives inputs from watersheds that are not managed by the NPS. Olympic National Park straddles the Puget Lowland, North Cascades (High Olympics subdivision), and Coast Range Ecoregions (Omernik 1995), the latter being dominated by highly productive, rain-drenched coniferous forests. Sitka spruce forests originally dominated the fog-shrouded coast, while a mosaic of western red cedar, western hemlock, and seral Douglas-fir were found further inland. Elevations range from sea level to 9,570 feet, and weather patterns, which generally track from the southwest to northeast, create a precipitation gradient ranging from 270 inches/year in the highest elevations to 50 inches/year in the lower elevations of the northeast section of the Park (PRISM 2006).

San Juan Island National Historical Park (SAJH) consists of two park units, American and English Camps, protecting 1,752 acres on San Juan Island in Puget Sound. Freshwater resources on San Juan Island are limited due to the area's geology and limited rainfall of 30 inches/year (PRISM 2006). Although some streams exist, water resources inside the park are limited to groundwater, wells, small springs, lagoons and other shoreline features. The park, which is entirely within the Puget Lowland Ecoregion (Omernik 1995), contains 6.1 miles of shoreline and intertidal habitat, including three marine lagoons.

1.3.2 Aquatic Habitats within NCCN Parks

Understanding how key aquatic habitats are distributed throughout the NCCN is an important step in establishing monitoring priorities and developing an implementation strategy. To ensure that accurate comparisons were made across the parks in the network, a standardized set of Geographic Information System (GIS, ESRI ArcGIS v9) data layers were used and modified to conduct an inventory of aquatic habitats (Table 1.3). The standardized hydrographic data sets were then overlaid with the park boundaries to identify the mapped lentic and lotic aquatic habitats for each park (Tables 1.4 and 1.5).

The NCCN contains 10 lakes that are larger than 45 hectares (ha) (Table 1.6). All of these water bodies are significant due to their size, the composition of their biological communities and/or the amount of visitor use they receive which elevates their management status.

Table 1.3. Geographic Information Systems data used to inventory North Coast and Cascades Network aquatic habitats.

Coverage	Scale	Source	Notes
Streams	1:24,000	U.S. Geological Survey National Hydrography Dataset High Resolution	Modified to include only those streams mapped on 1:24,000 USGS topographic maps
Lakes	1:24,000	U.S. Geological Survey National Hydrography Dataset High Resolution	Data based on 1:24,000 USGS topographic maps
Wetlands	1:24,000	U.S. Fish and Wildlife Service National Wetlands Inventory	Data based on interpretation of aerial photography, not field verified

Table 1.4. Summary of lentic and lotic open fresh water habitats in North Coast and Cascades Network parks derived from National Hydrography Data excluding wetlands. Values in parentheses are based on aerial photo interpretation conducted within each park unit.

	Streams and rivers		Lakes <45 ha					Lakes >45ha
					Size (ha)			
Park unit	Total length (km)	Density (km/km^2)	Number	Density (#/km^2)	Min.	Median	Max.	Number
EBLA	<1	-	1	<0.001	1.36	1.36	1.36	0
FOVA	0	-	0	0.000	-	-	-	0
LEWI	26	2.02	25	0.017	0.09	0.38	20.69	0
MORA	983	1.03	420(383)	0.004	0.00214	0.12	13.93	1
NOCA	3,130	1.13	294(561)	0.001	0.00325	0.36	39.30	7
OLYM	4,387	1.17	772(646)	0.002	0.00104	0.11	13.28	2
SAJH	0	-	0	0.000	-	-	-	0

Table 1.5. Summary of fresh water and estuarine wetland habitats in North Coast and Cascades Network parks.*

			% Contribution			
Park unit	Total area (ha)	Area covered (%)	Lacustrine	Riverine	Palustrine	Estuarine
EBLA	208	3	4	0	34	62
FOVA	0	0	0	0	0	0
LEWI	318	22	<1	0	93	6
MORA	1,500	2	19	47	35	0
NOCA	7,968	3	84	3	12	0
OLYM	9,432	3	25	26	47	0
SAJH	39	6	0	0	76	24

* Data are from the National Wetlands Inventory (NWI).

Table 1.6 Summary of large lakes (>45 hectares) in North Coast and Cascades Network parks.

Lake name	Park	Surface area (ha)	Max. depth (m)	Elevation (m)	Type
Berdeen	NOCA	51	66	1,524	Glacial Scour/Cirque
Chelan	NOCA	13,500	453	335	Glacial Scour
Crescent	OLYM	2,030	190	180	Landslide Dam
Diablo	NOCA	315	63	366	Reservoir
Gorge	NOCA	94	36	82	Reservoir
Mowich	MORA	45	60	1,501	Glacial Scour/Cirque
Ozette	OLYM	3,007	101	9	Glacial Scour
Ross	NOCA	5,000	160	489	Reservoir
Silver	NOCA	65	159	2,061	Glacial Scour/Cirque
Trapper	NOCA	60	49	1,270	Glacial Scour/Cirque

Discrepancies exist within the standardized data for lakes among NCCN parks, and understanding these discrepancies is important in interpreting the results. For example, MORA has updated its lake data to include information identifying intermittent lakes and has also mapped water bodies as small as 0.001 hectares from aerial photographs. Using this information, MORA has identified 323 permanent and 83 intermittent lakes ranging in size from 0.001 to 45 hectares. Additionally, since the National Hydrography Dataset (NHD) data were created using 1:24,000 USGS topographic maps developed in the 1950's, many lake boundaries have changed and many new lakes have emerged due to melting snow and ice. This has affected the number of lakes currently identified at NOCA, which has on an opportunistic basis been continually updating its lakes GIS data. At this time, NOCA has identified an additional 87 lakes, ranging in size from 0.003 to 39.30 hectares, not found in the NHD data set. Moreover, when considering smaller lakes and ponds (between 0.001 and 45 hectares), NOCA has identified a total of 561 lakes and ponds, almost twice as many as found in the NHD data set.

The inventory also provided a rough idea about the number and locations of wetlands in the NCCN (Table 1.5). Since this analysis used National Wetlands Inventory (NWI) data that were developed using aerial photo interpretation, not on-the-ground surveys, the results for the majority of the NCCN should be considered a starting point and likely a low-end estimate. On-the-ground wetland inventories often find significantly more wetlands than are present in the NWI data. For example, after ground-truthing 20% of the 1978 NWI data, it is estimated that at MORA an additional 451 hectares of wetlands are actually present, representing a 30% increase over the NWI estimate.

The inventory of NCCN aquatic resources was further refined by establishing a set of definitions to clearly delineate the various aquatic habitat types that are found in the network (Table 1.7).

Table 1.7. Definitions used to delineate the aquatic habitats in the North Coast and Cascades Network. All surface area and depth measurements reflect low flow or seasonally dry periods.

Habitat type	Definition
Wadeable streams/rivers	Wetted width is generally less than 25 m, and most non-pool habitat is less than 1 m deep during summer low flows. The stream can be safely crossed in multiple locations.
Gravel/cobble	Active scour is present in the channel, i.e. fine particles have been removed or pushed to the side and larger substrate is visible.
Low gradient	Active scour is not evident. Stream bed is primarily sand, silt and/or vegetation.
Large rivers	Wetted width is generally more than 25 m and most non-pool habitat is more than 1 m deep during summer low flows. Gravel/cobble substrates inaccessible, >30 cm deep or absent from reach.
Lakes	Surface area is comprised of at least 0.4 ha of open water habitat that is non-vegetated and the maximum depth is at least 2.5 m.
Lakes smaller than 50 ha	Surface area is between 0.4 and 50 ha of open water habitat that is non-vegetated and the maximum depth is at least 2.5 m.
Lakes larger than or equal to 50 ha	Surface area is equal to or greater than 50 ha of open water habitat that is non-vegetated and the maximum depth is at least 2.5 m.
Wetlands/ponds	Areas that are at least periodically saturated or covered with water. Surface area is comprised of less than 0.4 ha of open water that is non-vegetated and the maximum depth is less than 2.5 m.
Estuarine wetlands	Deepwater tidal habitats and adjacent tidal wetlands that are semi-enclosed by land but have open, partly obstructed or sporadic access to marine waters. Marine water is at least occasionally diluted by freshwater. Include lagoons.

1.3.3 Biological Resources

The NCCN has documented the presence of 49 fish and 18 amphibian species associated with aquatic habitats (Tables 1.8 and 1.9) (NPSpecies 2008). Twenty-six of these species (Table 1.2) are officially recognized by either state or federal authorities for special management consideration. In many cases, the NCCN provides the best available habitat within the region for these species and consequently supports the most robust populations.

Ebey's Landing National Historic Reserve

Water resources within EBLA are predominantly marine and are composed of Penn Cove, which is fully encompassed by EBLA, as well as marine shorelines along the eastern Strait of Juan de Fuca, Admiralty Inlet, and Admiralty Bay. Associated with these marine areas are smaller lagoons and brackish lakes. Surface freshwater resources are restricted to Lake Pondilla, a few adjacent wetlands that have formed in kettle holes, and a freshwater wetland in the vicinity of Prairie Center. The biota of Lake Pondilla remains largely unstudied (Klinger et al. 2007b). Five species of aquatic breeding amphibians have been documented within the Reserve as part of the North Coast and Cascade Amphibian Inventory.

Lewis and Clark National Historic Park

The Park's extensive and diverse wetlands provide valuable habitat for a diversity of mammals, birds, reptiles, amphibians and fish. Of nine confirmed aquatic breeding amphibian species, two are species of concern. Imperiled due to habitat loss, the Columbia torrent salamander (*Rhyacotriton kezeri*) is an aquatic inhabitant of small cold streams and is listed as a federal Species of Concern, and has not been documented in any other NCCN park. The Cope's giant salamander (*Dicamptodon copei*), considered a State Monitor Species in Washington State, has also been documented in LEWI. Several lower Columbia River salmonid fish stocks are

federally listed or candidates to be listed. Of these, coho (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), and cutthroat trout (*Oncorhynchus clarkii clarkii*) have been found in park streams and sloughs (Brenkman 2008, Brenkman et al. 2008).

Mount Rainier National Park

The Park contains 26 named glaciers across nine major watersheds, with over 400 lakes and ponds, 470 rivers and streams, and over 3,000 acres of other wetland types. Aquatic ecosystems provide habitat for several Species of Concern. Amphibian inventories have documented the presence of 12 aquatic breeding amphibians, including several species of concern because they are vulnerable to population or habitat loss within the park complex itself but no longer appear on federal or state ESA listings.

Ten freshwater species of bivalves occur west of the Rocky Mountains; only five species of them are known to occur in the state of Washington. Of the five, three are known to occur within MORA: the Oregon floater (*Anodonta oregonensis*), the western floater (*Anodonta kennerlyi*), and the western pearlshell (*Margaritifera falcata**)*** (Frest and Johannes 2005). The remaining two, the western ridge mussel (*Gonidea angulata*) and the California floater (*Anodonta californiensis*), potentially occur within the park. All five mussels are Washington State Monitor species, and the California floater is currently a federal Species of Concern.

The Fender's soliperlan (*Soliperla fenderi*) stonefly is listed as a species of special concern in the state of Washington. The distribution is limited to Mount Rainier, where it was first discovered, and Mount Adams. The larval form of this species is found in small headwater streams and requires clean, clear, oxygen rich water to survive.

At least eight species of native fish occur within the park. The park also provides stream habitat for five native fish species that are either federally listed threatened species or proposed for listing: bull trout (*Salvelinus confluentus*), steelhead (*Oncorhynchus mykiss),* and Chinook (*Oncorhynchus tshawytscha*) are federally listed threatened species; coho and coastal cutthroat trout are both proposed for listing. All five have been documented in park streams.

North Cascades National Park Service Complex

The Park contains 26 species of naturally occurring native fish and 11 species of aquatic breeding amphibians. Three large river systems provide anadromous fisheries habitat that support all five species of Pacific salmon, as well as anadromous and resident forms of rainbow trout (*Oncorhynchus mykiss*), bull trout, Dolly Varden (*Salvelinus malma*) and coastal cutthroat trout. The protected status of these watersheds provides an important refuge within the rapidly urbanizing Puget Sound and Fraser River valleys of the United States and Canada, respectively. Within this area, two distinct populations of sockeye spawn in the Chilliwack and Baker Rivers. A quarter of the Skagit River's summer Chinook spawn in park waters that lie between Copper and Newhalem Creeks, making this a regionally significant stretch of habitat for the recovery of this species.

Isolated from the anadromous reaches of the Skagit River by three large dams, the watersheds of Ross, Diablo and Gorge Lakes support robust populations of bull trout and Dolly Varden, as well as resident rainbow trout. The northern portion of Lake Chelan is also located in the park. Lake Chelan is the largest lake in Washington State and the third deepest lake in the United States.

The Stehekin River, which lies wholly within the boundaries of NOCA, is the largest tributary to the lake and provides 75% of the inflow. Bull trout were once abundant in the Stehekin River but have not been documented since 1957. However, the Stehekin system supports a unique and isolated population of native westslope cutthroat trout.

Of the eleven aquatic amphibian species documented in the park, three are federal Species of Concern and two are candidates for state listing.

Olympic National Park

The Park contains several large river valleys that support all five species of Pacific salmon, as well as anadromous and resident forms of rainbow trout, coastal cutthroat, bull trout and Dolly Varden. Natural structure and function in the upper reaches of these river valleys remains largely intact. Because of this, the park harbors high quality spawning and rearing habitat for these highly sought-after and ecologically valuable species outside of Canada and Alaska. Overall, Olympic National Park contains 31 native species of fish, and at least 70 unique populations of Pacific salmonids.

There are several notable fish populations within the park. Among them, the anadromous sockeye salmon in the Ozette Lake Basin comprise a unique stock that is genetically distinct from all other sockeye populations on the Washington coast and in Puget Sound (Gustafson et al. 1997). The anadromous stock of sockeye in Lake Ozette Lake was listed as threatened under the Endangered Species Act in 1999. One of most significant potential effects of water quality on Lake Ozette sockeye salmon is mortality or decreased fitness resulting from temperature stress (Haggerty et al. 2009). Another example is the Beardslee trout population, a unique subspecies of rainbow trout, endemic to Lake Crescent. The population in Lake Crescent has declined to low levels causing park management to change fishing regulations to allow only catch and release angling for Lake Crescent and all its tributaries.

Of twelve aquatic amphibian species documented in the Park, five are federal Species of Concern and two are candidates for state listing. Olympic torrent salamanders (*Rhyacotriton olympicus*), one of the five federal Species of Concern, are restricted to the region of the Olympic Peninsula. Surveys of Olympic National Park (Bury and Adams 2000) showed the species to be widespread within the boundary of the park, occurring largely on the west side of the park.

San Juan Island National Historical Park

The major surface water resources in the park are three tidal lagoons located along the north shore of American Camp's Griffin Bay. Freshwater resources are limited in the park and consist small springs, a perennial pond, intermittent ponds or wetlands, and an intermittent stream. The perennial pond and intermittent ponds are the primary sources of freshwater that provide habitat to wildlife populations such as migratory birds and the three species of aquatic amphibians documented in the Park.

Table 1.8. Amphibian species documented in the North Coast and Cascades Network which are known to be associated with aquatic habitats.

Species	Common name	EBLA	FOVA	LEWI	MORA	NOCA	OLYM	SAJH
Ambystoma gracile	Northwestern salamander	X		X	X	X	X	
Ambystoma macrodactylum	Long-toed salamander	X	X		X	X	X	
Ascaphus truei	Tailed frog				X	X	X	
Anaxyrus boreas	Western toad				X	X	X	
Dicamptodon copei	Cope's giant salamander			X	X		X	
Dicamptodon tenebrosus	Pacific/Coastal giant salamander				X	X		
Plethodon dunni	Dunn's salamander			X				
Plethodon larselli *	Larch mountain salamander				X			
Plethodon vandykei	Van Dyke's salamander				X		X	
Plethodon veniculum	Western red-backed salamander			X	X	X	X	
Pseudacris regilla	Pacific (Chorus) tree frog	X	X	X	X	X	X	X
Rana aurora	Red-legged frog	X		X	X	X	X	X
Rana cascadae	Cascade frog				X	X	X	X
Rana catesbeiana **	Bull frog			X				
Rana luteiventris	Columbia spotted frog					X		
Rhyacotriton kezeri	Columbia torrent salamander			X				
Rhyacotriton olympicus	Olympic torrent salamander						X	
Taricha granulosa	Rough-skinned newt	X		X	X	X	X	

* Dependence on aquatic habitats is unknown.

** Non-native species.

Table 1.9. Fish species documented in the North Coast and Cascades Network known to be associated with freshwater aquatic habitats. Habitat information derived from Scott and Crossman (1973) and Wydoski and Whitney (2003).

Family	Latin name	Common name	Habitat	LEWI	MORA	NOCA	OLYM
Acipenseridae	*Acipenser transmontanus*	White sturgeon	Anadromous	X			
Catostomidae	*Catostomus catostomus*	Longnose sucker	Lakes, streams			X	X
Catostomidae	*Catostomus catostomus*	Salish Sucker	Lakes, streams			X	
Catostomidae	*Catostomus columbianus*	Bridgelip Sucker	Lakes, streams			X	
Catostomidae	*Catostomus macrocheilus*	Largescale sucker	Lakes, rivers			X	X
Centrarchidae	*Micropterus salmoides* *	Largemouth bass	Lakes				X
Clueidae	*Alosa sapidissima* *	American shad	Anadromous	X			X
Cottidae	*Cottus alueticus*	Coastrange sculpin	Streams, lakes	X		X	X
Cottidae	*Cottus asper*	Prickly Sculpin	Streams, lakes	X	X	X	X
Cottidae	*Cottus cognatus*	Slimy Sculpin	Streams, lakes			X	X
Cottidae	*Cottus confusus*	Shorthead sculpin	Streams		X	X	X
Cottidae	*Cottus gulosus*	Riffle sculpin	Streams, rivers	X			X
Cottidae	*Cottus perplexus*	Reticulate sculpin	Streams	X			X
Cottidae	*Cottus rhotheus*	Torrent sculpin	Streams, lakes		X	X	X
Cottidae	*Leptocottus armatus*	Pacific staghorn sculpin	Estuaries, inlets	X			
Cyprinidae	*Acrocheilus alutaceus*	Chiselmouth	Rivers, streams, lakes	X			
Cyprinidae	*Mylocheilus caurinus*	Peamouth	Lakes	X		X	X
Cyprinidae	*Ptychocheilus oregonensis*	Northern pikeminnow	Lakes, streams			X	X
Cyprinidae	*Rhinichthys cataractae*	Longnose dace	Streams			X	X
Cyprinidae	*Rhinichthys osculus*	Speckled dace	Rivers				X
Cyprinidae	*Richardsonius balteatus*	Redside shiner	Lakes, streams			X	X
Cyprinodontidae	*Fundulus diaphanus*	Banded killifish	Lakes, rivers	X			
Gadidae	*Lota lota*	Burbot	Lakes, streams, rivers			X	
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback	Streams, lakes, estuaries	X		X	
Ictaluridae	*Ictalurus natalis* *	Yellow bullhead	Ponds, lakes, streams				X
Osmeridae	*Spirinchus thaleichthys*	Longfin smelt	Lakes	X			

Table 1.9. Fish species documented in the North Coast and Cascades Network known to be associated with freshwater aquatic habitats. Habitat information derived from Scott and Crossman (1973) and Wydoski and Whitney (2003) (continued).

Family	Latin name	Common name	Habitat	LEWI	MORA	NOCA	OLYM
Osmeridae	*Thaleichthys pacificus*	Eulachon	Anadromous	X			
Percidae	*Perca flavescens* *	Yellow perch	Lakes				X
Petromyzontidae	*Lampetra richardsoni*	Western brook lamprey	Streams	X		X	X
Petromyzontidae	*Lampetra tridentata*	Pacific lamprey	Anadromous				X
Salmonidae	*Oncorhynchus aguabonita* *	Golden trout	Lakes, streams			X	
Salmonidae	*Oncorhynchus clarkii*	Cutthroat trout	Rivers, lakes, streams				X
Salmonidae	*Oncorhynchus clarkii clarkii*	Coastal cutthroat trout	Rivers, lakes, streams	X	X	X	
Salmonidae	*Oncorhynchus clarkii bouvieri* *	Yellowstone cutthroat trout	Rivers, streams, lakes		X	X	
Salmonidae	*Oncorhynchus clarkii lewisi* †	Westslope cutthroat trout	Streams, rivers, lakes		X	X	
Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon	Anadromous			X	X
Salmonidae	*Oncorhynchus keta*	Chum salmon	Anadromous	X		X	X
Salmonidae	*Oncorhynchus kisutch*	Coho salmon	Anadromous	X	X	X	X
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout/Steelhead	Anadromous	X	X	X	X
Salmonidae	*Oncorhynchus nerka*	Sockeye salmon	Anadromous		X	X	X
Salmonidae	*Oncorhynchus nerka* †	Kokanee salmon	Lakes, rivers, streams		X	X	X
Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon	Anadromous	X	X	X	X
Salmonidae	*Prosopium coulterii*	Pigmy whitefish	Lakes, streams			X	X
Salmonidae	*Prosopium williamsoni*	Mountain whitefish	Streams, lakes		X	X	X
Salmonidae	*Salvelinus confluentus*	Bull trout	Streams, lakes		X	X	X
Salmonidae	*Salvelinus fontinalis* *	Brook trout	Streams, lakes		X	X	X
Salmonidae	*Salvelinus malma*	Dolly Varden	Anadromous			X	X
Salmonidae	*Salvelinus namaycush* *	Lake trout	Lakes, rivers			X	
Salmonidae	*Salmo trutta* *	Browm trout	Lakes, streams			X	

* Non-native species.

† Species that is native to NCCN project area but introduced to MORA.

1.4 Stressor Characterization

1.4.1 Existing and Potential Ecosystem Stressors

Readily apparent ecosystem stress to NCCN aquatic resources originates from seven fundamental sources: 1) land management activities within and adjacent to NCCN parks, 2) climate change, 3) atmospheric deposition of pollutants and nutrients, 4) aquatic and riparian non-native invasive species, 5) large and small scale hydroelectric projects or dams inside or outside but restricting flow into the NCCN, 6) visitor use activities, and 7) marijuana cultivation operations. A detailed stressor analysis for these activities is beyond the scope of this document; however, some of the primary issues are briefly discussed below.

Land Management:

Land management activities within and adjacent to NCCN parks consist of forestry, urban and residential development, livestock and agriculture, active and historic mining, the development and maintenance of park infrastructure, and the presence of roads and highways.

Roads are the most widespread source of stressors in the NCCN and are responsible for increases in both physical and chemical stressors to aquatic resources. Road networks change flow regimes, increase fine sediment deposition, raise water temperatures, isolate stream channels from their flood plains, and impede fish passage (Beschta et al. 1987, Bilby et al. 1989, Hicks et al. 1991, Beechie et al. 1994, Gucinski et al. 2001, Keppeler et al. 2003). Chemical toxins can enter streams from herbicide applications, deicing compounds, dust abatement, oil drippings and accidental spills (Furniss et al. 1991, Norris et al. 1991, Idaho Department of Transportation 1996, Gucinski et al. 2001). Road maintenance also impacts streams through increased nutrient delivery due to a lack of vegetation on road surfaces, adjacent berms, and in ditches (Gucinski et al. 2001). Large amounts of hydraulic modifications in forested landscapes are often associated with roads and generally consist of rip-rap, culverts, bridge abutments and channelization. All of these developments tend to increase erosion downstream from their location and reduce available habitat for aquatic species (Gucinski et al. 2001).

Roads also contribute to metals loading in aquatic resources through storm water run-off. Of particular concern is the deposition of copper from vehicle exhaust and brake pad wear. In the western U.S., exposure to non-point source pollutants such as copper is an emerging concern for many populations of threatened and endangered Pacific salmon (*Oncorhynchus* spp.) that spawn and rear in coastal watersheds and estuaries (Hara et al. 1976, Sandahl et al. 2007). Studies of the effect of copper (and other metals such as mercury and zinc) on salmonids has shown that even very low concentrations of the metal in aquatic habitats led to neurophysiological and histological changes in the olfactory system (Dethloff et al. 1999, Hansen et al. 1999) and resulted in impaired immune parameters (Dethloff and Bailey 1998). Salmonids in studies also displayed olfactory-mediated behavioral changes including reduced sensitivity in detecting and evading predators (Sandahl et al. 2007) and avoiding tributaries with higher metals concentrations along spawning migration routes (Goldstein et al. 1999).

Forest harvesting and roads have similar effects on stream conditions and they are highly correlated, and are often evaluated together as forestry operations. While the majority of hill slope failures, sediment transport, and changes in hydrologic patterns are linked with roads (Gucinski et al. 2001), the removal of forest cover adds additional stress to aquatic systems. The

loss of canopy cover changes both summer low flows and peak flows (Moore and Wondzell 2005), increases slope failures (Swanson 1974), and increases nutrient flux (Fredriksen et al. 1973, Dahlgren 1998).

Historic hard rock mining is a source of stress due to the sulfides and heavy metals present in acid mine drainage and water leaching through mine tailings. Historic mining activity can continue to be a source of pollution for hundreds of years after the abandonment of active mining operations. Over 600 abandoned mines have been identified as potential sources of stress to the aquatic resources in the NCCN. Two of these operations require clean up under the authority of the Superfund Act (CERCLA), and an additional site, adjacent to Silver Daisy Creek in British Columbia, requires action to mitigate acid mine drainage. Active mining in the watersheds draining to the NCCN consists of recreational placer mining and exploratory mining related to the development of the Copper Giant Mine in British Columbia. Some of the placer mining tends to push the boundaries of "recreational" due to the amount of large woody debris removed and associated stream bank erosion. Furthermore, the streambeds in areas of recreational placer mining are also highly altered because gravel and fine sediment is removed up to 4 meters deep and cast back into the streams. Refueling of the mining equipment that is located directly in the stream channel poses additional threats in the form of spills. Other chemicals left over from mining and milling operations, such as cyanide, diesel and fuel oil, pose additional secondary threats.

Urban, residential, and park developments can introduce a variety of pollutants either directly as storm runoff or into groundwater through septic systems. Storm water runoff is a source of pollutants such as oxygen-demanding waste (biological oxygen demand, or BOD) and fecal coliform bacteria. Storm water can impact water quality as both a non-point source (runoff and overland flow into streams) or as a point source when collected and discharged through a storm sewer system. Pollutants typically found in storm water runoff can include pathogens from human and animal waste, heavy metals, organic debris, oil and grease, petroleum hydrocarbons, suspended sediments, and a variety of fertilizers, herbicides, and pesticides. In some areas, the non-commercial use of pesticides was found to pose a greater risk to aquatic life than commercial agricultural application (Pedersen et al. 2006, Weston et al. 2009). Additionally, storm water runoff can also increase the temperature of a receiving stream during warm weather.

Livestock can impact water quality through direct pollution and indirectly by removing riparian vegetation that can in turn increase sediment loading to surface waters. Direct pollution by livestock increases nutrient loads and can also introduce pathogens such as *Cryptosporidium parvum*. Additionally, as organic materials decompose, they place an oxygen demand on the receiving waters. The agricultural use of pesticides, herbicides and fertilizers can introduce pollutants to surface waters through surface runoff or groundwater leaching.

Climate Change:

One of the defining characteristics of the NCCN is the large amount of cold water fish habitat supporting all five species of salmon as well as the two species of native char, Dolly Varden and bull trout. This cold-water habitat could be reduced by as much as 36% under a climate change scenario of a doubling of atmospheric CO_2 (Mohseni et al. 2003). For example, increased temperature in the Fraser River in British Columbia has been linked to increased sockeye salmon mortality (BC MOE 2002). Higher energy expenditures and increased rates of infection due to

warmer water temperatures led to decreased sockeye migration and spawning success. Sockeye may be more sensitive to climate change than other salmon species due to their preference for colder temperatures and summer migration when temperatures are warmest.

Ecological responses to climate change include changes in the ranges and distribution of species as well as their community structures; changes in phenology; and changes in morphology and behavior (USEPA 2008). Aquatic fish and invertebrates tolerate rather narrow ranges in temperature, which determines their distribution. Shifts in species ranges to more northern or higher elevations are expected with temperature regime changes, which could result in local extinctions, especially for species already at the southern limits of their ranges or blocked from higher elevation habitats. Barriers to dispersal due to habitat fragmentation from deforestation and dams may prevent some aquatic species from migrating to more favorable habitats (Hawkins et al. 1997, Poff et al. 2002). Aquatic species restricted to stream headwaters or small geographic ranges may be most vulnerable due in part to population fragmentation. Poff et al. (2002) suggest that increases in water temperature could accelerate aquatic invertebrate growth rates resulting in earlier maturation. Evolutionary adaptation to climate change will likely be only a small factor in species' response to climate change except for the most short-lived species; range shifts and extinctions are the more likely response for most aquatic biota.

Atmospheric Deposition:

Atmospheric deposition of a variety of contaminants is widely recognized as a potential threat to terrestrial and aquatic ecosystems. The transport, fate, and ecological effects of anthropogenic contaminants in particular are of great concern in NCCN parks. Metals, particularly mercury and lead, as well as the byproducts of combustion, sulfur and nitrogen compounds, are emitted by human activities and can be transported long distances from their sources. Where deposited, they can persist in the environment and bioaccumulate. Other pollutants that are solely of anthropogenic origin can similarly be deposited long distances from their source and include persistent organic pollutants (POPs) and semi-volatile organic compounds (SOCs) (Landers et al. 2008). These types of pollutants can be toxic to aquatic biota as well as have indirect negative effects by altering other water chemistry parameters that subsequently have deleterious impacts on aquatic biota or degrade habitat.

The Western Airborne Contaminants Assessment Project (WACAP), initiated by the NPS to assess the deposition of airborne contaminants (primarily SOCs and metals) in western national parks, determined that contaminants generally increased with elevation (Landers et al. 2008). Consequently, high elevation aquatic resources in NCCN parks may be at higher risk to these contaminants. For the eight "core" western parks in the study, which included MORA and OLYM, 70 SOCs were found at detectable levels in snow, water, vegetation, sediment, and/or fish. Average mercury levels in fish tissues exceeded all wildlife health thresholds at the two OLYM lakes and one of the two MORA lakes studied. Some individual fish samples exceeded human health thresholds for mercury in those same three lakes, and in an additional study, mercury levels were as high as 262 µg/kg in Green Lake at NOCA (Moran et al. 2007). Contaminants generally accumulated based on proximity to individual sources. For example, pesticide concentrations (for both historic and current use pesticides) were highest in park watersheds closest to agricultural areas. Concentrations of industrial pollutants (polycyclic aromatic hydrocarbons, or PAHs, and mercury) were highest in parks adjacent to local or regional sources of these contaminants. Contrary to expectation, trans-Pacific contaminant

contribution of SOCs from Eastern Europe and Asia in western parks was small compared to regional sources closer to the parks.

The high elevation aquatic systems of NCCN parks are sensitive to atmospheric deposition of sulfur and nitrogen due to the thin or poorly developed soils and sparse vegetation. While sulfur appears to be declining, nitrogen compounds are increasing in the region. Abundant rainfall and snowmelt facilitate the rapid movement of these pollutants through the soils and into aquatic resources. Clow and Campbell (2008) documented a positive relationship in NOCA lakes between nitrate concentration and elevation, suggesting nitrogen deposition may be affecting these sensitive aquatic systems. Long-term trend analyses indicated wet deposition of inorganic nitrogen was relatively stable during 1986–2005. In contrast, wet deposition of sulfur declined substantially during that period, and notable after 2001, when emissions controls were added to a large power plant upwind from MORA. Similar declines in sulfur deposition were observed in surface waters of northern and eastern regions of the U.S. following the 1990 amendments to the Clean Air Act, which resulted in reduced sulfur emissions (Stoddard et al. 2003). Evidence of episodic acidification due to preferential elution of acidic components from melting snow was documented, and while the scale of episodic acidification is unknown, it could have detrimental effects on aquatic life and amphibians (Clow and Campbell 2008). Midwinter rain-on-snow events may also contribute to episodic acidification.

Non-native Invasive Species:

Non-native aquatic species pose well documented risks to aquatic biodiversity and ecosystem function (Fahnenstiel et al. 1995, Liss et al. 1995, Knapp et al. 2001, Parker et al. 2001, Boersma et al. 2006). These invasive species threaten aquatic ecosystems by disrupting community composition, altering food web dynamics, and outcompeting native species. For example, non-native riparian vegetation species such as reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*) and Himalayan blackberry (*Rubus discolor*) pose indirect risks to aquatic habitats and direct risks by altering nutrient inputs and diminishing future large woody debris accumulation by eliminating the regeneration of riparian trees.

Predator-prey and competitive interactions with introduced animal species may have significant impacts on local communities, with possibly detrimental impacts on threatened and endangered species. Non-native animal species documented or likely to be emerging threats in the NCCN include: brook trout (*Salvelinus fontinalis*) and other introduced, non-native fish, American bullfrog (*Rana catesbeiana*), and non-native crayfish species (*Procambarus clarkii, Orconectes virilis*, and *Orconectes rusticus*). Of particular concern at the national level are three invasive invertebrate species, the New Zealand mudsnail (*Potamopyrgus antipodarum*), zebra mussel (*Dreissena polymorpha*), and quagga mussel (*Dreissena bugensis*). These species pose significant threats due to their ability to spread rapidly and infest aquatic systems, impact native species abundance and community structure through competition and physical displacement, and hamper commercial and recreational boat use. They are also very difficult to control and eradicate. Invasive species known or expected to be significant ecosystem stressors for parks in the NCCN are listed in Table 1.10.

Table 1.10. Documented and potential invasive species of concern in North Coast and Cascades Network parks.

Common name	Scientific name	Documented in park[1]	Probably present in park
Invertebrates			
quagga mussel	*Dreissena bugensis*		
zebra mussel	*Dreissena polymorpha*		
ringed crayfish	*Orconectes neglectus*		
rusty crayfish	*Orconectes rusticus*		
northern crayfish, virile crayfish	*Orconectes virilis*		
New Zealand mudsnail	*Potamopyrgus antipodarum*		
red swamp crayfish	*Procambarus clarkii*		
Aquatic plants and algae			
giant reed	*Arundo donax*		
Didymo	*Didymosphenia geminata*		
Brazilian elodea	*Egeria densa*		
hydrilla, waterthyme	*Hydrilla verticillata*		
yellow flag	*Iris pseudacorus*	LEWI	OLYM
parrot feather watermilfoil	*Myriophyllum aquaticum*	LEWI	
Eurasian watermilfoil	*Myriophyllum spicatum*	NOCA	
Common reed	*Phragmites australis*	LEWI, OLYM	
Riparian plants			
garlic mustard	*Alliaria petiolata*		
old man's beard	*Clematis vitalba*	NOCA	
English ivy	*Hedera helix*	LEWI, NOCA, OLYM, SAJH	
giant hogweed	*Heracleum mantegazzianum*	FOVA, MORA	NOCA
purple loosestrife	*Lythrum salicaria*		LEWI, OLYM
reed canary grass	*Phalaris arundinacea*	EBLA, FOVA, LEWI, MORA, NOCA, OLYM, SAJH	
Japanese knotweed	*Polygonum cuspidatum*	MORA, NOCA, OLYM	
cultivated knotweed	*Polygonum polystachyum*	OLYM	
giant knotweed	*Polygonum sachalinense*	OLYM	NOCA
Himalayan blackberry	*Rubus discolor*	EBLA, FOVA, LEWI, NOCA, OLYM, SAJH	
Vertebrates			
American bullfrog	*Rana catesbeiana*	LEWI	
eastern brook trout	*Salvelinus fontinalis*	MORA, NOCA, OLYM	

[1] Park status from NPSpecies, accessed 2/18/2010.

Hydroelectric Power Generation:

Two small scale and four large scale hydroelectric projects are located in the NCCN. These developments impose a large number of cumulative stressors including altering flow regimes, channelization, land clearing and the construction of weirs. The large scale hydropower facilities also introduce additional risk for protecting water quality due to their industrial nature. For example, on June 19, 2008, approximately 150 gallons of transformer cooling oil containing

polychlorinated biphenyls (PCBs) leaked from a heat exchange unit at the Ross Power House into Diablo Lake in NOCA. Additionally, Seattle City Light is also planning on drilling a second penstock for the Gorge powerhouse which will involve removing 130,000 cubic yards of material, adding another large scale industrial operation within NCCN boundaries.

Visitor Use:
Recreational use is a highly variable activity, ranging from areas with no trails or roads and only backcountry travel, to areas with numerous day-use trails, developed recreational facilities, drive-in campgrounds and dispersed recreation. Recreational use is a source of a number of different stressors including: human and animal waste, gray water discharge, habitat degradation due to bank erosion and instream modifications, accidental spills, increased sedimentation from increased road use, removal of riparian vegetation, leakage from older pit toilets, and garbage. Endocrine disrupting compounds may also be introduced into aquatic resources through visitor use of detergents, waterproofing compounds, and pharmaceutical products (birth control pills, insect repellents, and others). Visitors can also act as vectors spreading invasive species and aquatic borne pathogens to fish and amphibians.

Marijuana Cultivation Operations:
The increasing frequency and magnitude of illegal marijuana growing operations is an emerging threat to water quality in many NPS units in the Pacific West Region. Illegal grow operations pose numerous threats by diverting flow from streams, increasing erosion and sedimentation as well as introducing fertilizers, herbicides and other pesticides into surface waters. Since many of these sites are also occupied for multiple years they also increase the risk of human waste entering waters used by recreational users downstream. In 2008, the first marijuana grow complex was discovered in the NCCN at NOCA. Typical of these operations, over 1,000 pounds of garbage consisting of fertilizers, pesticides, herbicides and irrigation equipment was removed from a site draining into Ruby Creek, a tributary to Ross Lake. It is believed that this location was used for several years before its discovery. Damage included cutting trees, clearing vegetation and terracing the land for grow sites, impounding creeks, constructing living quarters and fences along with spreading garbage and human waste.

1.4.2 Watershed Conditions
To better understand the current conditions of watersheds in the NCCN and to help identify those most at risk of impairment, a watershed assessment was conducted (Appendix B). The goal of this assessment was to inventory and characterize the watersheds that lie entirely within NCCN boundaries or have the potential to impact the aquatic resources within NCCN boundaries. This assessment was diagnostic and was meant to provide information to help identify water bodies with the highest potential for impairment and prioritize sites for monitoring. It should be acknowledged that the scale of this assessment is biased towards the larger parks in the NCCN, and the small sizes of EBLA, FOVA and SAJH need to be considered when interpreting the results. To complement the watershed-scale assessment, it is recommended that a site-specific assessment be conducted for these small historical parks.

The watershed assessment was conducted primarily at the catchment or seventh field hydrologic unit scale (USDA-NRCS 1992). The watershed boundaries at this level were delineated using protocols (USDA-NRCS 1992) based on the topographic divides visible at the 1:24,000 scale. Most of the land within the NCCN is mountainous and contains the headwaters for many of the

aquatic resources of concern. In many situations, the NPS wholly manages the land contained in the headwater areas and has the ability to maintain and/or improve the water quality in these areas. However, five conditions exist where the NPS only partially manages the land within a watershed or is on the receiving end of watersheds entirely managed by other agencies or privately held land. These areas are 1) most of the land managed by LEWI, 2) the coastal strip of OLYM, 3) the Skagit watershed in NOCA, 4) the Stehekin River watershed in NOCA that contains numerous private in holdings, and 5) smaller dispersed private and municipal in holdings located within the jurisdictional boundaries of MORA, NOCA, and OLYM. In these situations waters and land management activities on non-NPS managed lands can directly impact NCCN aquatic resources. For these reasons many of the watersheds that are included in this assessment were located outside of the NCCN.

Four hundred and sixty five watersheds were identified as having the ability to directly affect the water quality and biological resources on NCCN managed lands (Appendix B). These watersheds covered a total of 14,152 square kilometers, an area nearly twice as large as the area managed by the NPS (Table 1.1). Following methods similar to those used by the United States Forest Service (USFS) for watershed assessments (Winters et al. 2006), a composite score was derived from five metrics that were used to assess four primary sources of stress (Table 1.11) in each watershed. The composite scores for the watersheds were then ranked across the NCCN and within each individual park unit. These rankings (Appendix B) were used to prioritize the risk posed to NCCN watersheds and water bodies.

Table. 1.11. Metrics and data sources used to assess the four primary landscape scale sources of stress to North Coast and Cascades Network resources.

Stressor	Data source	Scale	Metric
Roads	U.S. BLM and B.C. MOE	1:24,000	Road density (km/km2)
			# Road crossings / stream km
Recreational use	NCCN	1:24,000	Trail density (km/km^2)
Mining	USGS	1:24,000	Mines / hectare
Land-use	NOAA (C-CAP)	1:24,000	% Area developed

1.5 Water Quality Standards and Protected Uses

The NCCN includes parks that lie within Washington and Oregon States and receive water draining from 711 square kilometers from the Province of British Columbia. Water quality standards have been established by each of these jurisdictions for the fresh waters contained within their boundaries. One of the goals of this water quality monitoring plan is to ensure that the waters of the NCCN meet federal and state water quality criteria, and this section illustrates how the U.S. Federal Clean Water Act (CWA) and Canadian water quality guidelines apply to the NCCN. Additionally, the NPS Water Resources Division (WRD) has mandated a suite of core water quality parameters that parks are to measure as part of water quality monitoring. These core parameters include temperature, pH, dissolved oxygen, and specific conductance and have been selected because they are useful basic indicators and are typically necessary for analyzing and interpreting other water quality parameter measurements.

Water quality standards are a core element of the CWA; they define the goals for a water body by designating its human and ecological significance, setting criteria to protect those elements,

and establishing provisions to protect water quality from pollutants. To meet these requirements, states must develop an assessment methodology which: 1) identifies the designated beneficial uses for each water body, 2) establishes water quality criteria to protect these uses, and 3) establishes an antidegradation program for all aquatic resources.

As part of the CWA, states are required to identify all waters that do not meet, or are not expected to meet, the water quality standards for a given water body. Every two years, states must submit a listing of these waters to the EPA pursuant to Section 303(d) of the CWA. In conjunction with 303(d) reporting, states are also mandated to submit a comprehensive report on water quality under Section 305(b). Washington's water quality standards are promulgated through the Washington Department of Ecology (DOE), and Oregon's are developed by the Oregon Department of Environmental Quality (DEQ). Washington and Oregon follow a similar process for reporting on water quality and establishing a list of impaired waters and have opted to submit Integrated Reports, combining the 305(b) and 303(d) reports, to the EPA (Figure 1.3). Both states list the water quality status for a particular location in one of five categories as recommended by the EPA (Table 1.12) (ODEQ 2006, WDOE 2006a).

The 303(d) and 305(b) reports also serve as guidance documents for establishing Total Maximum Daily Load (TMDL) criteria. The TMDL is essentially a watershed management plan that establishes a method for water quality recovery and maintenance by determining the amount of pollutant loading a given water body can receive and still meet water quality standards. The TMDL provides the basis for states to establish water quality-based controls which should provide the pollution reduction necessary for a water body to meet water quality standards. Waters assessed by Oregon or Washington as Category 5 and thus reported under 303(d) require TMDLs.

Updating the 305(b), 303(d) and TMDL status for the water bodies within the NCCN will be a component of the water quality monitoring project. In addition to the state proposed lists, we will use a watershed scale disturbance and function evaluation to identify potentially impaired watersheds. Surface waters with high disturbance category rankings will be incorporated into the NCCN water quality monitoring project. Of significant note is that much of the historical NCCN water quality monitoring data has not been included in Washington State databases used when considering 303(d) status. An objective of the NCCN water quality monitoring efforts is to ensure that these historic and future data are entered into the NPS and EPA water quality databases (WRD STORET and STORET, respectively), which will make data available to states.

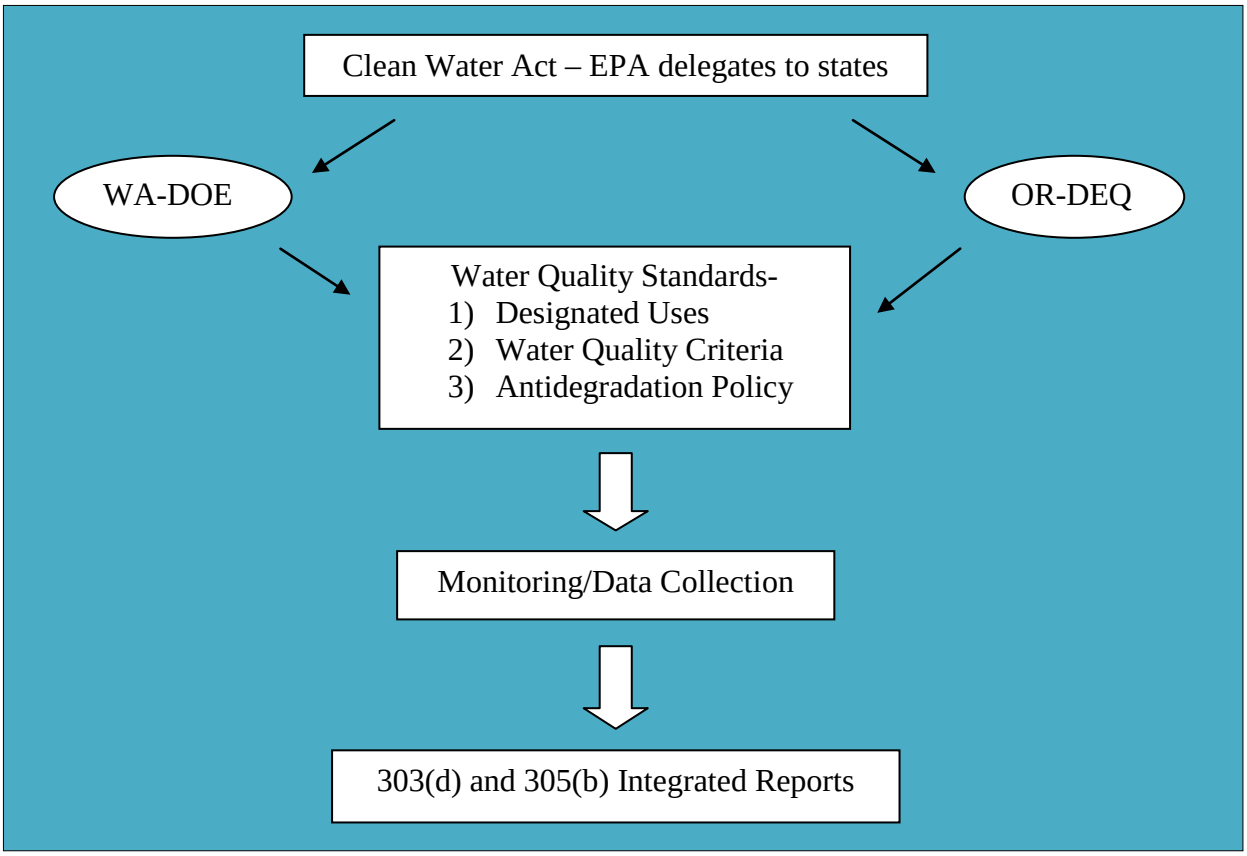


Figure 1.3. Diagram illustrating the Environmental Protection Agency and state process for developing the 305(b) report and 303(d) listed water bodies.

Table 1.12. Washington and Oregon State water quality impairment assessment categories, based on Environmental Protection Agency guidelines.

Washington and Oregon categories			**TMDL process**
Category 1	Meets tested standards for clean waters, all designated uses are met	Not considered to be impaired	EPA approved TMDL not required or already developed and approved.
Category 2	Waters of concern, some designated uses met but data insufficient about others		
Category 3	Insufficient data		
Category 3b	Oregon only: Insufficient data but some data indicate non-attainment of a criterion and a potential concern		
Category 4	Impaired but does not require TMDL because:	Impaired	
Category 4a	Already has approved TMDL		
Category 4b	Has other pollution control program to address non-attainment		
Category 4c	Impaired by a non-pollutant		
Category 5	The 303(d) List		EPA approved TMDL required but yet to be developed or approved

1.5.1 Designated beneficial uses

The CWA requires all states to establish protected use, also called designated beneficial use, classifications for all water bodies within their boundaries. Since most of the land area of the NCCN is located in Washington State, the streams, rivers and lakes of the NCCN primarily need to support the beneficial uses established by the Washington DOE (WDOE 2008). Wetlands need to support existing beneficial uses as well, generally interpreted as wetland functions and values in Washington State (WDOE 1996). LEWI is an exception to this condition. Since LEWI consists of several park units that are located in Washington and Oregon, it contains fresh water resources that fall under the jurisdiction of the Oregon DEQ (ODEQ 2008a) and Washington DOE. Oregon and Washington states' designated uses for fresh water as applicable in NCCN parks include uses for aquatic life, recreation, water supplies and other miscellaneous uses (Table 1.13).

Table 1.13. Washington and Oregon States designated use categories applicable to North Coast and Cascades Network parks.

Use category	Washington State designated uses	Oregon State designated beneficial uses
Aquatic Life Uses	Char Spawning/Rearing	Salmon and Trout Rearing and Migration
	Core Summer Habitat	Core Cold-Water Habitat
	Spawning/Rearing	
	Rearing/Migration Only	
Recreation Uses	Extraordinary Primary Contact	Water Contact Recreation
	Primary Contact	
	Secondary Contact	
Water Supply Uses	Domestic Water	Public and Private Domestic Water Supply[1]
	Industrial Water	Industrial Water Supply
	Agricultural Water	Irrigation
	Stock Water	Livestock Watering
	Wildlife Habitat	Wildlife and Hunting
Miscellaneous Uses	Harvesting	Fishing
	Commerce/Navigation	Commercial Navigation and Transportation
	Boating	Boating
	Aesthetics	Aesthetic Quality

[1] With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards.

The Washington DOE has divided the state's freshwater resources into Water Resource Inventory Areas (WRIA) while Oregon's are divided into U.S. Geological Survey third-field hydrologic units, or basins. Designated uses for individual water bodies by NCCN WRIAs and basins are listed in Appendix C. The units of LEWI located in Washington State are contained within the Willapa WRIA; the units located in Oregon are within the North Coast and Lower Columbia basins (Appendix C). While the Columbia River is adjacent to several units of LEWI, it is not within the park's administrative boundaries, and it is not within the purview of this protocol to monitor its water quality. Of note, however, is the designation of the mouth of the Columbia as a salmon and steelhead migration corridor by the Oregon DEQ (ODEQ 2008b).

1.5.2 Water quality criteria

Water quality criteria are numeric values or narrative descriptions of the physical, chemical, and biological characteristics of waters necessary to support their designated beneficial uses. These criteria include parameters such as temperature, dissolved oxygen, pH, turbidity, alkalinity, nutrients, bacteria and toxic chemicals. Washington (WDOE 2006b) and Oregon (ODEQ 2010) states have established criteria for streams and rivers for three of the WRD core water quality parameters: temperature, pH, and dissolved oxygen (Tables 1.14, 1.15). Neither state has established criteria for the fourth WRD core parameter, specific conductance. However, a turbidity standard has been designated.

Table 1.14. Washington State fresh water quality criteria for Water Resources Division core parameters applicable in North Coast and Cascades Network parks.

Designated use	Temperature (highest 7-day avg. daily max.)[1]	Dissolved oxygen (lowest 1-day min.)[2]	pH
Aquatic life			
Char spawning	9°C		
Char spawning and rearing	12°C	9.5 mg/L	6.5 - 8.5 [3]
Salmon and trout spawning	13°C		
Core summer salmonid habitat	16°C	9.5 mg/L	6.5 - 8.5 [3]
Salmonid spawning, rearing, and migration	17.5°C	8.0 mg/L	6.5 - 8.5 [4]
Salmonid rearing and migration only	17.5°C	6.5 mg/L	6.5 - 8.5 [4]

[1] Washington DOE has identified water bodies, or portions thereof, which require special protection for spawning and incubation in DOE publication 06-10-038 (Payne 2006). This document indicates where and when additional temperature criteria are to be applied to protect the spawning and incubation of native char, salmon, and trout.
[2] Instantaneous measurement.
[3] Human-caused variation within this range must be <0.2.
[4] Human-caused variation within this range must be <0.5.

Table 1.15. Oregon State fresh water quality criteria for Water Resources Division core parameters applicable in North Coast and Cascades Network parks.

Designated use	Temperature (7-day avg. max.)	Dissolved oxygen (mg/L, min.)	pH
Aquatic life			
Salmon and steelhead spawning [1]	13.0 °C	11.0 mg/L [2]	
Core cold-water habitat	16.0 °C	8.0 mg/L [3]	
Salmon and trout rearing and migration	18.0 °C		
All uses			6.5 - 8.5

[1] For dissolved oxygen criterion, this designated use includes resident trout species as well.
[2] If minimum intergravel dissolved oxygen, measured as a spatial median, is ≥8.0 mg/l, then dissolved oxygen criterion is 9.0 mg/l. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/l or 9.0 mg/l criteria, dissolved oxygen levels must not be <95 % saturation. Spatial median intergravel dissolved oxygen must not be <8.0 mg/l.
[3] Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen may not be <90 % saturation. At Oregon DEQ's discretion and determination that adequate information exists, the dissolved oxygen may not be <8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a seven-day mean minimum, and may not be <6.0 mg/l as an absolute minimum.

Washington and Oregon have established state criteria for lakes for only a few parameters (Table 1.16). Washington has established nutrient criteria for lakes, however (Table 1.17). The full suite of Washington and Oregon water quality criteria are available from the DOE and DEQ websites, respectively.

Table 1.16. Washington and Oregon States lake water quality criteria for Water Resources Division core parameters applicable in North Coast and Cascades Network parks.

State	Designated use	Temperature	Dissolved oxygen
Washington	Aquatic life	Human actions considered cumulatively may not increase the 7-day average daily maximum temperature >0.3°C above natural conditions	Human actions considered cumulatively may not decrease the dissolved oxygen >0.2 mg/L below natural conditions
Oregon	Aquatic life	For natural lakes: may not be increased by >0.3 °C above the natural condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life	None

Table 1.17. Washington State lake water quality criteria for nutrients (total phosphorus) applicable in North Coast and Cascades Network parks.

Coast Range and Puget Lowlands Ecoregions		
Trophic state	If ambient TP (µg/l) range of lake is:	Then criteria should be set at:
Ultra-oligotrophic	0 - 4	4 or less
Oligotrophic	>4 - 10	10 or less
Lower mesotrophic	>10 - 20	20 or less
	Action value: >20	lake specific study may be initiated
Cascades Ecoregion		
Trophic state	If ambient TP (µg/l) range of lake is:	Then criteria should be set at:
Ultra-oligotrophic	0 - 4	4 or less
Oligotrophic	>4 - 10	10 or less
	Action value: >10	lake specific study may be initiated
Columbia Basin Ecoregion		
Trophic state	If ambient TP (µg/l) range of lake is:	Then criteria should be set at:
Ultra-oligotrophic	0 - 4	4 or less
Oligotrophic	>4 - 10	10 or less
Lower mesotrophic	>10 - 20	20 or less
Upper mesotrophic	>20 - 35	35 or less
	Action value: >35	lake specific study may be initiated

1.5.3 Antidegradation Policy

Tribes and states are directed by the EPA to implement an antidegradation policy at three levels of protection to prevent the unnecessary lowering of water quality (except when specific conditions apply) in all aquatic resources:

- Tier I (called Water Quality Limited Waters in Oregon) – ensures that existing and designated uses are maintained and protected for all water bodies. Problems are corrected through regulatory and TMDL processes.

- Tier II (called High Quality Waters in Oregon) – ensures protection of water bodies where water quality already exceeds standards.

- Tier III (called Outstanding Resource Waters in Oregon) – applies to water bodies constituting an outstanding state or national resource and ensures that they are protected against all pollution sources.

Washington and Oregon have antidegradation policies that adhere to the EPA three-tiered approach of classifying and protecting surface waters (WDOE 2006b, ODEQ 2010). However, these policies differ in the classification of water bodies within this three-tiered system in one critical way. In Oregon, if a water body fails to attain the water quality criterion for one parameter in its current level of protection, it can no longer be classified in that tier. In contrast, in Washington (and most states), classification within the three levels of protection is on a parameter-by-parameter basis. A water body could be simultaneously classified as Tier I, Tier II, or Tier III for each of three different parameters in Washington.

1.5.4 Pristine Waters

Pristine waters support the full suite of naturally occurring biological communities expected to occur at a given location and are self-sustaining and self-regulating. For example, they have complete food webs, a full complement of native species that can maintain their populations, and naturally functioning ecological processes. These waters have the potential to be designated as Outstanding Resource Waters as part of the Clean Water Act.

In both Oregon and Washington, a water body can qualify as an Outstanding Resource Water (Tier III in Washington) if it is relatively pristine, is located in a protected area (such as state and national parks, national wild and scenic rivers, state scenic waterways, state and national wildlife refuges, wilderness areas), or represents critical or rare habitats. Once a water body is designated as an Outstanding Resource Water, high standards and limitations on activities may occur.

The majority of aquatic resources in the NCCN are classified as Tier II (or High Quality Waters in Oregon). In Washington, any action meeting specific criteria and with potential to cause measureable change in water quality to one of these water bodies must undergo a Tier II analysis. This analysis consists of an evaluation of whether or not the degradation of water quality that would result from a proposed action would be both necessary and in the overriding public interest. Measurable change, as defined by the DOE, is based on best professional judgment rather than a detection limit or instrument sensitivity estimate (Susan Braley, WA DOE, Pers. Comm., 7/29/2010), as:

- Temperature increase of 0.3°C or greater

- Dissolved oxygen decrease of 0.2 mg/L or greater

- Bacteria level increase of 2 cfu/100 mL or greater

- pH change of 0.1 units or greater

- Turbidity increase of 0.5 NTU or greater

- Any detectable increase in the concentration of a toxic or radioactive substance

Oregon limits measurable change for the following water quality parameters (see the OR DEQ website and Oregon Administrative Rule 340-041-0028 for more information about when and where these apply):

- Temperature increase of 0.3°C or greater
- Dissolved oxygen decrease of a 0.1 mg/l or greater

Information about measurable change specifications for Oregon water quality criteria was not available.

1.5.5 Water quality guidelines for British Columbia, Canada

The headwaters of the Skagit River originate in British Columbia and flow into NOCA; consequently the water quality status of and potential regulatory mitigation of future impairment to these waters are of great interest to Park and Network staff. At the national level, Canadian water quality guidelines have been developed to establish maximum and minimum values for physical, chemical and biological characteristics of water to prevent detrimental effects from occurring to a designated water use. The Canadian Council of Resource and Environment Ministers, now the Canadian Council of Ministers of the Environment (CCME), first published national water quality guidelines in 1987, but these have since been replaced by an integrated set of national environmental quality guidelines, The Canadian Environmental Quality Guidelines (CCME 2007). These guidelines may be adopted by provincial or other jurisdictions to become standards for permitting discharges.

In British Columbia, the Ministry of Environment (MOE) has developed province-wide ambient water quality guidelines for parameters that are important in the surface waters of British Columbia and are largely informed by the CCME guidelines (BC MOE 2010). In addition to the criteria for select priority water quality constituents that have been approved by the Deputy Minister for use in British Columbia, working water quality guidelines for criteria not yet approved have been developed (Nagpal et al. 2006). These guidelines apply to designated water uses similar to those of Washington and Oregon and include aquatic life, wildlife, drinking water (prior to treatment), recreation, irrigation and livestock watering. British Columbia water quality criteria for the NCCN core water quality parameters as well as alkalinity are presented in Table 1.18.

In cases where the conditions at a site exist that make the guidelines inappropriate, site-specific guidelines may be developed. Neither guidelines nor the site-specific objectives which are derived from them have any legal standing. The objectives, however, can be used to calculate allowable limits or levels for contaminants in waste discharges. These limits are set out in waste management permits and thus may be enforced under existing legislation. The objectives are not usually incorporated as conditions of the permit.

Water quality data for Canadian aquatic resources are not readily available through a national database system similar to the EPA's STORET Data Warehouse. This, in conjunction with the lack of a well-implemented legal system of documenting and enforcing the mitigation of

impaired aquatic resources, present challenges to NOCA staff in addressing potential Upper Skagit River water quality issues. Maintaining regular communication with British Columbia Ministry of Environment staff to stay abreast of any water quality studies or monitoring conducted on the Canadian reaches of the Skagit will be imperative.

Table 1.18. British Columbia fresh water quality criteria for Water Resources Division core parameters and alkalinity.

Designated use	Temperature (°C)	Dissolved oxygen (instantaneous minimum / 30-day mean)	pH	Specific conductivity[1] (µS/cm)	Alkalinity[1] (mg/L, total $CaCO_3$)
Drinking water supply	Max. =15		6.5-8.5		
Freshwater aquatic life		5 / 8 mg/L	6.5-9.0 [2]		
Streams with bull trout and/or Dolly Varden	Max. daily =15 Incubation range =2-10 Max. spawning =10				
Streams with known fish distribution	<1 change from optimum range for each life history phase of most sensitive salmonid species present[3]				
Streams with unknown fish distribution	Max. 7-day average =18 Max. incubation =12 (spring and fall)				
Lakes and impoundments	<1 change from natural ambient background				
Buried embryo/alevin life stages		9 / 11 mg/L			
Buried embryo/alevin life stages (interstitial water)		6 / 8 mg/L			
Wildlife and livestock watering supplies	<1 change from natural ambient background			1400-4200 (max.), species dependent[4]	
Irrigation water supply	<1 change from natural ambient background			700-5000, soil and crop dependent	
Industrial water supply	<1 change from natural ambient background			0.7-8000, boilers, process dependent; 140-4000, cooling, process dependent	0.5-1000, process dependent (see guidelines)
Recreation and aesthetics	Max. =30		5.0-9.0		

[1] Criteria are from British Columbia Ministry of Environment's Working Guidelines (Nagpal et al. 2006).
[2] Caution should be used if pH change causes CO2 concentrations to exceed 10 µmol/L minimum or a 1360 µmol/L maximum for the impact on phytoplankton community structure and toxicity to fish, respectively. For waters with pH naturally <6.5, there should be no decrease but increases are permitted as long as unique acidophilic flora or fauna are not present, in which case site-specific water quality objectives are recommended. For waters with pH naturally >9.0, short-term increases to 9.5 are permitted for lake restoration projects provided treatment is not toxic to aquatic life.
[3] See additional tables on B.C. Ministry of Environment website (http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html)
[4] Criterion is for livestock watering supply only.

1.6 Current Status and Monitoring History

1.6.1 Overview of Monitoring History

Historical water quality monitoring within the NCCN varies. The large parks (MORA, NOCA and OLYM) have conducted numerous water quality related research projects occurring over the years. Lewis and Clark National Historic Park has implemented monitoring of core water quality indicators (temperature, pH, conductivity and dissolved oxygen) since 1994 (Larson and Ek 1998) in several locations within the Fort Clatsop unit but water quality data are limited for the newly acquired park sites. Historical water quality monitoring for both EBLA and SAJH focused on marine waters, with limited monitoring of freshwater. The Water Resources Division of the National Park Service completed Baseline Water Quality Data Inventory and Analysis reports for MORA, NOCA, SAJH, OLYM, EBLA, FOCL and FOVA (NPS 1995a, 1995b, 1995c, 1999, 2000a, 2000b, 2000c). These inventories compiled available surface water quality data, including marine, from seven of the EPA's national databases. A brief overview of historical monitoring by park is provided below. It is important to note that very little historical water quality data for lakes, streams and rivers was included in the early reports, because these data are not yet included in the EPA national databases. These historical data need to be imported into the NPSTORET database and uploaded to WRD STORET and then to the EPA STORET Data Warehouse.

In 1998, the Washington State Legislature passed the Watershed Management Act, which provided for locally-based watershed planning, with the goal of giving local interests a voice and a forum for collaboration. The intent of this legislation was to allow citizens, governments, and tribes to develop solutions to water issues in their own watershed, thus providing a more complete picture of the status of water resource availability and environmental integrity in each watershed. Watershed Management Plans have been developed for several watersheds. These plans are intended to serve as locally-supported, long-term plans focusing on water availability, and also addressing water quality, habitat, and instream flows. The water quality component of some of these Watershed Plans addresses water quality in the watershed by synthesizing current available data, and gathering metadata on current and historical water quality programs and studies. WRIA-wide and local approaches are then developed for monitoring and TMDL implementation. The purpose of other Watershed Plans are to identify and resolve problems associated with sources of nonpoint water pollution and to protect beneficial uses of water in the watershed.

<u>Ebey's Landing National Historic Reserve:</u>
The entire Reserve and Island County are designated as a sole source aquifer. This designation provides the aquifer with the state of Washington's highest level of regulatory protection. Island County regularly monitors for groundwater quality, including saltwater intrusion, conductivity, and mineral content. Historical monitoring of surface water is limited to a number of studies (Klinger et al. 2007a).

Island County Health Department has implemented a long term surface water monitoring plan for Whidbey Island. Five sites on Whidbey Island are monitored twice a month by Island County, including a perennial stream located within EBLA (Keeler and Kearsley 2003). The Ebey monitoring station receives drainage from the Ebey's watershed, where land use is approximately 95% agriculture and 5% residential. High concentrations of nitrate and nitrite,

ammonia, phosphorus and fecal coliform bacteria have been measured at this site (Herrera Environmental Consultants 1998, Keeler and Kearsley 2003, WDOE 2010). Island County Health Department has conducted periodic storm water sampling within the town of Coupeville. Limited water chemistry was collected in association with amphibian surveys completed in 2002-2003 as part of the North Coast and Cascade Amphibian Inventory.

As part of Washington State's Watershed Planning Act of 1998, a watershed plan was developed by Island County for Island County WRIA 6, which covers lands within EBLA, and was approved by the Board of Island County Commissioners on June 20, 2005. The report is available from the DOE Watershed Planning website at: http://www.ecy.wa.gov/programs/eap/wrias/Planning/index.html. The Salmon Habitat Limiting Factors Report for WRIA 6 was published in 2000 and describes factors limiting production of salmon in the watershed. This report is available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

Lewis and Clark National Historic Park:
A water quality baseline inventory of Fort Clatsop National Memorial was initiated in 1995 and continued through 1997 (Larson and Ek 1998). Park staff have conducted intermittent water quality monitoring at the Fort Clatsop National Memorial site since the initial inventory. Limited water chemistry was collected in association with amphibian surveys completed in 2002-2003 as part of the North Coast and Cascade Amphibian Inventory. Water resource data collection and analysis of the newly acquired park sites are limited (Klinger et al. 2007b).

In August 1996, water quality surveys were undertaken by the NPS for the Lewis and Clark River near Fort Clatsop National Memorial (Tetra Tech, Inc. 1996). In August 2000, Bischoff et al. (2000) released the Youngs Bay Watershed Assessment (incorporating data from 1965 to 1999 inclusive), which contains information on Youngs Bay, the Lewis and Clark River, and the Lower Columbia River ecosystem. Throughout the entire watershed, nutrients and bacteria were found to be moderately degraded. At both Youngs Bay Mouth and the Lower Lewis and Clark River, temperature was found to be degraded.

The Lewis and Clark River near Fort Clatsop National Memorial has been intermittently monitored by Oregon Department of Environmental Quality since 1969 at two locations upstream (0.5 mile upstream of Peterson Slough and at Stavebolt Lane) and one location downstream (Old Highway 101 bridge) of Fort Clatsop National Memorial. Lewis and Clark River at Stavebolt Lane shows good water quality in the summer and poor water quality during the fall, winter, and spring. Concentrations of some parameters (total solids, fecal coliforms, phosphates, and biochemical oxygen demand) are high due to organic materials washed from fields and stream banks into the river during periods of heavy or extended precipitation (ODEQ 1995, 2008c).

While no watershed planning has occurred in WRIA 24, which includes the Washington state units of LEWI, the Salmon Habitat Limiting Factors Report was published for WRIA 24 and describes factors limiting production of salmon in the watershed. The report is available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

Mount Rainier National Park:
Mountain lakes and ponds in MORA have been studied for over two decades. Water quality related studies have focused on atmospheric deposition concerns, recreational use impacts, and characterization of physical, chemical and biological attributes of mountain lakes, ponds, palustrine and riverine wetlands. Chemical data are available for approximately 225 lakes and ponds and includes information on pH, alkalinity, specific conductance, dissolved oxygen, and some data on nutrients, cations, anions, and metals. Data on air toxins is available for seven lakes. Biological data are also available for many of the park's mountain lakes and ponds and include information on zooplankton (75 lakes), phytoplankton (20 lakes), fish (225 lakes), and amphibians (225 lakes). In addition, benthic macroinvertebrate data are available for at least 50 lakes and ponds. Paleolimnological data (diatoms, invertebrates, and sediment characteristics) are available for approximately 15 lakes and ponds.

Historical stream chemistry data for MORA include data 18 sites from 1985-1988 as reported in Larson et al. (1990), from chemistry analyses associated with park amphibian inventories (Tyler et al. 2003), and in limited amounts from stream chemistry work associated with fish inventories. The park has monitored three sites on the Nisqually and Ohanapecosh since 1985 with a break in monitoring from 1996-1997.

Surface waters within MORA, until recent years, were thought to be mostly pristine throughout the park's lands designated wilderness (Larson et al. 1992, 1994, 1998, 1999, Larson 2000). However, external influences such as air pollution (acidic deposition, air toxics), climate change, and management activities affect these ecosystems. Recent studies have documented air toxins in park lakes (Moran et al. 2007, Landers et al. 2008) and atmospheric deposition may be affecting some sensitive lakes in the park (Clow and Samora 2003, Clow and Campbell 2008). Some waters immediately adjacent to the wilderness boundary and near the park's developed areas (roads, facilities) are less than pristine due to road and storm runoff, presence of roads through lake watersheds, and problems with facilities (sewage, oil spills) (Hill and Samora 2002). Several developments are located in and adjacent to aquatic ecosystems. To address these concerns, two intensive bioassessment projects were implemented to assess lotic and lentic habitats within the park. As part of these projects 75 lakes and 64 wadeable streams and rivers were sampled for benthic invertebrates and zooplankton (lakes only) and a series of habitat specific bioassessment models were developed (Rawhouser 2011a, 2011b).

Watershed Plans have been developed for two of the three WRIAs located within the park. The individual reports for these WRIAs, the Nisqually and Cowlitz (WRIAs 11 and 26, respectively), are available from the DOE Watershed Planning website at: http://www.ecy.wa.gov/programs/eap/wrias/Planning/index.html. For the Puyallup-White (WRIA 10), a watershed assessment was prepared by the DOE, and the report is available at: http://www.ecy.wa.gov/pubs/95008.pdf. Salmon Habitat Limiting Factors Reports have also been published for these three WRIA's and are available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

North Cascades National Park Service Complex:
NOCA staff conducted stream habitat surveys in selected stream survey reaches of the Thunder Creek and Chilliwack River basins and in the Stehekin River from 1995-2004 (Zyskowski, in

prep.). During these surveys, water chemistry parameters (Thunder Creek only, 1995-1996) and water temperature (Thunder Creek, 1995-1996; Chilliwack River, 1998-1999; Stehekin River, 2000-2003) were measured. Continuous temperature was also recorded at 20 sites in the Thunder Creek and Chilliwack River basins and the Stehekin River. Temperatures in all sites met state criteria. Additional historical and real-time data on stream temperature, stream discharge, and lake water level can be obtained from the USGS gauging stations located on four creeks and rivers and four reservoirs in NOCA (Table 1.19). An additional gauging station is located just west of the park at Bacon Creek, whose watershed is predominantly in the park.

Table 1.19. U.S. Geological Survey gauging stations in or immediately adjacent to North Coast and Cascades Network parks.

		Parameter (period of record)				
Park	**Station**	**Water level**	**Discharge**	**Gage height**	**Temperature**	**Turbidity**
NOCA	Ross Reservoir near Newhalem	1961-present				
NOCA	Diablo Reservoir near Newhalem	1982-present				
NOCA	Gorge Reservoir near Newhalem	1982-present				
NOCA	Lake Chelan at Purple Point	1985-present				
NOCA	Thunder Creek near Newhalem		1930-present	1998-present		
NOCA	Skagit River at Newhalem		1908-present	1985-present	1999-present	
NOCA	Newhalem Creek near Newhalem		1961-present	1996-present		
NOCA	Skagit River above Alma Creek near Marblemount		1950-1995			
NOCA	Bacon Creek below Oakes Creek near Marblemount		1943-present	1998-present)		
NOCA	Stehekin River at Stehekin		1910-present			
OLYM	Elwha River above Lake Mills		1994-present	1994-present		2003-2005
OLYM	Lake Mills at Glines Canyon	2000-2008				
OLYM	NF Skokomish River		1924-present	1985-present	1989-2006	

NOCA has also developed several bioassessment models to assess the wadeable rivers and streams in the park and on adjacent U.S. Forest Service lands. Two of these models, a multimetric index of biological integrity, follow traditional bioassessment methods (see Section 2.4.5), and a third, experiential model, was developed using machine learning and multivariate techniques (Rawhouser 2008). Additionally, the Skagit Environmental Endowment Commission funded the development of a wadeable stream bioassessment model that has been incorporated by Environment Canada into a national framework of stream bioassessment models (Perrin and Bennett 2009).

Between 1971 and 2009, approximately 200 mountain lakes and ponds in the park have been surveyed; data include water transparency and temperature profiles. Water chemistry data have been collected at roughly190 lakes and ponds and include information on pH, alkalinity, specific conductance, dissolved oxygen, nutrients, cations, anions, and metals. Biological data are available for many of the park's lakes and include information on zooplankton (106 lakes), phytoplankton (66), fish presence/absence and relative abundance (246), and amphibian presence/absence and relative abundance (298). In addition, benthic macroinvertebrate data are available for 120 lakes and predictive assessment models are currently being updated. Data on air toxins are available for five lakes.

As part of the Ambient Water Quality Monitoring Program, the Washington DOE has a long-term water quality monitoring station on the Skagit River at Marblemount and has been monitoring water quality monthly for nearly 50 years. Generally, the water quality has been in the moderate or good categories. The DOE Environmental Monitoring and Trends Section has also been collecting continuous water temperature at this station from June through September since 2001.

The USFS conducts routine monitoring in the Boulder Creek (Stehekin River) and Fisher Creek (Thunder Creek) watersheds as part of the Aquatic and Riparian Effectiveness Monitoring Program (AREMP). The goal of this program is to assess the effectiveness of the Northwest Forest Plan in protecting lotic aquatic habitats. Field based monitoring is conducted in wadeable streams where a comprehensive array of parameters are collected to assess water chemistry, fish populations, biological integrity, large woody debris and stream habitat.

Watershed planning has been initiated for Lake Chelan (WRIA 47) within NOCA and Salmon Habitat Limiting Factors Reports have been published for WRIAs 1 and 4 (Nooksack and Upper Skagit, respectively) and are available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

Olympic National Park:
Streams in OLYM have been monitored as part of EPA's Environmental Monitoring and Assessment Program (EMAP) (17 streams 1995-96) and Regional Environmental Monitoring and Assessment Program (REMAP) (25 streams 1993-1995). An 18-year data set of detailed water quality information exists from West Twin Creek in the Hoh (1986-2004) to look at long term trends in stream chemistry and precipitation (Edmonds and Blew 1997). Stream water quality data also exists from two decades of various fish studies conducted throughout the park by park staff and partnering agencies, including eight tribes who have traditional associations to lands now in Olympic National Park. Three USGS gauging stations are located inside the park, two on the Elwha and one on the Skokomish and several outside the park boundaries (Table 1.19).

Lake Ozette and Lake Crescent have been the focus of numerous studies ranging from water quality (Meyer and Brenkman 2001, Meyer and Fradkin 2002, WDOE 2007) to fish populations (Jacobs et al. 1996, Currens et al. 2009) to mercury contamination of fish and sediment (Moran et al. 2007, WDOE 2007, Landers et al. 2008). Studies are currently underway by USGS to develop a nutrient budget for Lake Crescent, partly as a result of benthic algal growth in the lake,

possibly indicating nutrient enrichment may be occurring. Basic water quality parameters have been collected at Lake Crescent intermittently since the early 1980s. Since 2007, OLYM has implemented the Large Lowland Lake Monitoring Protocol (Fradkin 2008) outside of the I&M program and will continue to do so as funding allows.

Historical data on other lakes within OLYM is limited, mainly due to the remote nature of the lakes and difficulty in accessing them. Five lakes have been monitored annually since 2004 as part of the NCCN Mountain Lakes project. Prior to the NCCN Mountain Lakes project, lake research was limited to surveys of exotic fish in a subset of the mountain lake population (Hagen 1961, Olson and Meyer 1994), physical/chemical/biological characterizations of relatively accessible lake districts (Larson et al. 1995), and contaminant studies of a few select, highly accessible lakes (Moran et al. 2007, Landers et al. 2008). Of the 616 identified lakes, fish presence data are available from approximately 50 lakes, amphibian data from approximately 84 lakes, and physical/chemical data from fewer than 20 lakes. Contaminant data are available from seven OLYM lakes. Water quality studies on the Sol Duc and Olympic Hot Springs occurred in the 1970s (Meyer et al. 1995).

On a larger scale, watershed plans for four WRIAs located within the park are available from the Washington DOE, which provide existing information on water resources. The individual reports for these WRIAs, which include the Skokomish-Dosewallips, Elwha-Dungeness, Lyre-Hoko, and Sol Duc-Hoh (WRIAs 16 and 18-20, respectively), are available from the DOE Watershed Planning website at: http://www.ecy.wa.gov/programs/eap/wrias/Planning/index.html. Salmon Habitat Limiting Factors Reports have been published for five WRIA's located within the park and describe factors limiting production of salmon in the watershed. The individual reports for these WRIAs, which include the Skokomish-Dosewallips, Elwha-Dungeness, Lyre-Hoko, Sol Duc-Hoh, and Queets-Quinalt (WRIAs 16 and 18-21, respectively) are available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

San Juan Island National Historical Park:
A 1995 analysis of existing water quality information for San Juan Island National Historical Park (NPS 1995c) indicated that very little water quality data were available for the park. Consequently, the NPS contracted with the U.S. Geological Survey to conduct a "Level 1" Water Quality Inventory and Monitoring synoptic study for San Juan Island National Historical Park in 1999 – 2000. Conclusions of the report indicate that overall quality of groundwater and surface water in the study area is generally good. However, there is some evidence that land use activities might be affecting water quality at the park. The well at American Camp had elevated conductance and chloride concentrations, indicating seawater intrusion. Samples from all surface water sites had concentrations of bacteria, and *Escherichia coli* was found in samples from water at American Camp spring and English Camp spring indicating possible sewage or organic waste contamination. Nitrate concentrations in the spring and stream were also elevated (USGS 2000, Flora and Fradkin 2004).

The San Juan Water Resource Management Plan was completed by the San Juan County Water Resource Management Committee in 2004 for WRIA 2, which includes SAJH and is available from the DOE Watershed Planning website at:
http://www.ecy.wa.gov/programs/eap/wrias/Planning/index.html. This document provides

information and management strategies for water resources within WRIA 2. The Salmon Habitat Limiting Factors Reports for WRIA 2was published in 2002 and describes factors limiting production of salmon in the watershed. This report is available from the Washington State Conservation Commission website at: http://www.scc.wa.gov/index.php/174-Salmon-Habitat-Limiting-Factors-Reports/View-category/Page-6.html.

1.6.2 Waters Listed in 303(d) and 305(b) Integrated Reports

Pursuant to Section 305(b) of the CWA, on alternating years states are required to provide the EPA with a report summarizing their state's water quality conditions, further explained in Section 1.5, Water Quality Standards and Protected uses. Included in the report are listings of water quality status for a particular location placed in one of five categories as recommended by the EPA (Table 1.12). Water bodies that are listed as impaired under 303(d) of the Clean Water Act in 2008 with the potential to affect NCCN aquatic resources are provided in Tables 1.20, 1.21, and 1.22.

Table 1.20. Water bodies listed as impaired under 303(d) of the Clean Water Act in 2008 with the potential to affect Lewis and Clark National Historical Park aquatic resources.

Park	Water body	Category	Parameter	Medium	Within NCCN
LEWI	Lewis and Clark River	5	Fecal coliform	Water	Yes
LEWI	Lewis and Clark River	4A	Temperature	Water	Yes
LEWI	Skipanon River	5	Dissolved oxygen	Water	Yes
LEWI	Skipanon River	5	E. Coli	Water	Yes
LEWI	Sunset Lake / Unnamed Lake	5	Aquatic weeds or algae	Habitat	No
LEWI	Columbia River	5	PCBs and DDE	Tissue	No
LEWI	Columbia River	5	Fecal coliform	Water	No
LEWI	Columbia River	4C	Invasive exotic species	Habitat	No
LEWI	Columbia River	4A	Total dissolved gas	Water	No
LEWI	Columbia River	4A	Dioxin	Tissue	No

Table 1.21. Water bodies listed as impaired under 303(d) of the Clean Water Act in 2008 with the potential to affect North Cascades National Park Service Complex aquatic resources.

Park	Water body	Category	Parameter	Medium	Within NCCN
NOCA	Newhalem Creek	4C	Instream flow	Habitat	Yes
NOCA	Lake Chelan	5	4,4'-DDT	Tissue	Yes
NOCA	Lake Chelan	5	Chlordane	Tissue	Yes
NOCA	Lake Chelan	5	Dieldrin	Tissue	Yes
NOCA	Lake Chelan	5	Dioxin	Tissue	Yes
NOCA	Lake Chelan	5	Total PCBs	Tissue	Yes
NOCA	Lake Chelan	4C	Invasive exotic species	Habitat	Yes
NOCA	Lake Chelan	4A	Total phosphorus	Water	No

Table 1.22. Water bodies listed as impaired under 303(d) of the Clean Water Act in 2008 with the potential to affect Olympic National Park aquatic resources.

Park	Water body	Category	Parameter	Medium	Within NCCN
OLYM	Alder Creek	5	Temperature	Water	No
OLYM	Bear Creek	5	Dissolved oxygen	Water	No
OLYM	Beaver Creek	5	Temperature	Water	No
OLYM	Big River	5	Dissolved oxygen	Water	Yes
OLYM	Big River	5	pH	Water	Yes
OLYM	Bogachiel River	5	Temperature	Water	No
OLYM	Calawah River, S.F.	5	Temperature	Water	Yes
OLYM	Coal Creek	5	pH	Water	Yes
OLYM	Coal Creek	5	Temperature	Water	Yes
OLYM	Crooked Creek	5	pH	Water	Yes
OLYM	Crooked Creek	5	Temperature	Water	Yes
OLYM	Crooked Creek, N.F.	5	Temperature	Water	No
OLYM	Dickey River	5	Fecal coliform	Water	No
OLYM	Dickey River, E.F.	5	Temperature	Water	No
OLYM	Dickey River, M.F.	5	Temperature	Water	No
OLYM	Dickey River, W.F.	5	Temperature	Water	No
OLYM	Elwha River	5	Temperature	Water	Yes
OLYM	Elk Creek	5	Temperature	Water	No
OLYM	Fisher Creek (McQuarry Creek)	5	Temperature	Water	No
OLYM	Hoh River	5	Fecal coliform	Water	No
OLYM	Kalaloch	5	Temperature	Water	Yes
OLYM	Lake Creek	5	Temperature	Water	No
OLYM	Lake Creek	5	Dissolved oxygen	Water	No
OLYM	Line Creek	5	Temperature	Water	No
OLYM	Maple Creek	5	Temperature	Water	No
OLYM	Matheny Creek	5	Temperature	Water	No
OLYM	Maxfield Creek	5	Temperature	Water	No
OLYM	Owl Creek	5	Temperature	Water	No
OLYM	Ozette Lake	4C	Fish habitat	Water	Yes
OLYM	Ozette Lake	5	Mercury	Tissue	Yes
OLYM	Ozette River	5	Temperature	Water	Yes
OLYM	Ozette River	5	Temperature	Water	Yes
OLYM	Peabodody Creek	5	Fecal coliform	Water	Yes
OLYM	Queets River	5	PCB	Tissue	Yes
OLYM	Quinault River	5	PCB	Tissue	No
OLYM	Sams River	5	Temperature	Water	Yes
OLYM	Siebert Creek, W.F.	5	Dissolved oxygen	Water	Yes
OLYM	Sitkum River	5	Temperature	Water	Yes

Table 1.22. Water bodies listed as impaired under 303(d) of the Clean Water Act in 2008 with the potential to affect Olympic National Park aquatic resources (continued).

Park	Water body	Category	Parameter	Medium	Within NCCN
OLYM	Siwash Creek	5	Dissolved oxygen	Water	Yes
OLYM	Soleduck River	5	Temperature	Water	Yes
OLYM	Soleduck River	5	pH	Water	Yes
OLYM	South Creek	5	Dissolved oxygen	Water	Yes
OLYM	Split Creek	5	Temperature	Water	No
OLYM	Trout Creek	5	Temperature	Water	No
OLYM	Umbrella Creek	5	Temperature	Water	No
OLYM	Willoughby Creek	5	Temperature	Water	Yes
OLYM	Winfield Creek	5	Temperature	Water	No

1.6.3 Threatened Waters

A network-wide process of ranking waters considered to be at risk of impairment was conducted to arrive at the list of threatened waters, or those considered being the most imperiled. First, the network compiled a list of waters of management concern (based on professional opinion) as well as waters already listed (i.e. 303(d) under the CWA). These waters were widely distributed across the NCCN and represent a broad range of habitat types (Table 1.23). Also included were waters selected based on knowledge of adjacent and potentially degrading land uses and/or point sources of pollution with potential to impact NCCN aquatic resources. The list then underwent an informed risk ranking by park staff, which was based on the criteria in Table 1.24. The results of this informed risk ranking are reported in Appendix D. Finally, any waters that could be classified into any of the following groups were designated as threatened waters:

- Waters classified as Category 4, 4a, 4b or 5 from the 303(d) report that are within or drain into NCCN parks or,
- Streams that drain from watersheds classified as being at a high risk of impairment in the watershed assessment (Section 1.4.2) or,
- Waters ranked at a high risk level in the informed risk assessment (Table 1.24) or,
- Water bodies within the NCCN that receive water from any of the above sources, even if those sources are outside park boundaries.

The NCCN currently has 103 threatened waters (Table 1.25), and most have no information that can be used to determine their status.

Table 1.23. The distribution of the waters of management concern among North Coast and Cascades Network parks and habitat types.

Park	Lake (>50 ha)	Large river	Lake (<50 ha)	Wadeable river/ stream	Wetland/ pond	Total
EBLA	0	0	1	1	0	2
LEWI	0	1	3	3	0	7
MORA	0	0	25	35	0	60
NOCA	4	2	70	32	0	108
OLYM	2	3	5	40	0	50
SAJH	0	0	0	0	1	1
All parks	6	7	104	111	1	228

[1] See Table 1.7 for definitions of aquatic habitat types.

Table 1.24. The criteria used for informed risk ranking of the waters of management concern for North Coast and Cascades Network parks.

Level of risk	Description of stressor
Minimal (Reference Condition)	No current or historic human activity related to resource extraction, agriculture, road building, fish stocking or recreational development including trails and backcountry camps. Sources of stress are primarily airborne pollutants and cross country recreational travel.
Minor	Stressors are dispersed over a large area and resources would return to reference conditions without implementing restoration activities if stressors ceased. Sources of stress are similar to those at the minimal level of risk but also include additional backcountry recreational use facilitated by trails, backcountry camps or in the absence of trails, sites that are located within a 2 km radius from vehicle access and involve less than 300 m of elevation change in cross country travel.
Moderate	Stressors are readily apparent and measureable, but with limited spatial extent. Sources of stress are similar to the previous categories with the addition of one of the following stressors: roads (paved or unpaved), stock use or grazing, extensive bare ground adjacent to the water body (>0.2ha), forest harvest (>20 years old), historic mining (<5 adits with no milling) or front country campgrounds with limited infrastructure. Management action is required to mitigate impacts to resources and to restore resources to reference conditions.
High	Stressors are substantial and measureable, highly noticeable and affect a large area. These can include any combination of roads (paved or unpaved), stock use or grazing, forest harvest (<20 years old), historic mining (<5 adits with no milling) or front country campgrounds with limited infrastructure. Single sources of stress placing a water body in this category consist of: historic mining (>5 adits); historic milling sites; high road densities (>0.15 km/km^2); active forest practices; cultivated agriculture and pasture lands; residential, urban or municipal development; large or small scale hydropower; dump sites; marijuana grow operations; or front country campgrounds, visitor centers and concessions with developed infrastructure such parking lots and septic systems or other point sources of pollution. Management action is required to mitigate impacts to resources. Restoration would need to be aggressive and/or of a large scale. Ecosystem recovery, if possible, would take at least 100 years.

Table 1.25. The distribution of the threatened waters among North Coast and Cascades Network parks and habitat types.[1]

Park	Lake (>50 ha)	Large river	Lake (<50 ha)	Wadeable river/ stream	Wetland/ pond	Total
EBLA	0	0	1	1	0	2
LEWI	0	1	3	3	0	7
MORA	0	0	4	14	0	18
NOCA	4	2	4	24	0	34
OLYM	2	4	2	34	0	42
SAJH	0	0	0	0	0	0
All parks	6	7	14	76	1	103

[1] See Table 1.7 for definitions of habitat types.

2.0 Sample Design

2.1 Target Population

The goal of this protocol is to determine the status and trends in the ecological condition of a specific river or stream location without making any inference to other locations. Park based resource managers selected a judgment sample consisting of locations that were determined to be at the highest risk of impairment based on the ranking process outlined in Section 1.6.3. To distribute the sample effort as evenly as possible throughout the NCCN, seven locations were selected in each of the largest parks (MORA, NOCA and OLYM), three locations were selected in LEWI, and one location was selected in EBLA (Table 2.1). Neither FOVA nor SAJH will be sampled since these parks do not contain any wadeable rivers or streams.

Following guidance provided by Irwin (2008), the target population for this protocol is defined as a sample that consists of the potential values that might be measured between 10:00 am and 2:00 pm for selected water quality parameters at the selected sample locations during the “index period.”

Table 2.1. Locations where water quality and biological samples will be collected for the NCCN Water Quality Monitoring Protocol.

Park	Stream Name	303(d) Listed	Watershed Risk*	Informed Risk*	UTM-E	UTM-N	Elevation (ft)
EBLA	Ebey's Watercourse	No	High	High	522,414	5,337,596	90
LEWI	Colewort Creek	No	High	High	431,761	5,108,414	30
LEWI	Megler Creek	No	High	High	433,434	5,122,375	100
LEWI	Skipanon River	Yes	High	High	428,900	5,108,113	30
MORA	Nisqually River at boundary	No	High	High	582,547	5,176,721	2,000
MORA	Nisqually River at Longmire	No	High	High	591,000	5,177,902	2,300
MORA	Nisqually River at Gl. Bridge	No	Moderate	High	594,426	5,181,640	3,800
MORA	Ohanapecosh River	No	High	High	608,776	5,176,093	1,780
MORA	Paradise River	No	High	High	595,713	5,180,856	4,440
MORA	White River at boundary	No	High	High	611,568	5,202,381	2,830
MORA	White River at littorals	No	Moderate	High	607,363	5,194,530	3,640
NOCA	Bridge Creek	No	High	High	669,552	5,372,799	3,990
NOCA	Company Creek	No	Moderate	High	668,415	5,357,750	1,270
NOCA	Goodell Creek	No	High	High	627,701	5,392,724	490
NOCA	Newhalem Creek	Yes	High	High	628,400	5,392,342	490
NOCA	North Fork Cascade River	No	High	High	636,221	5,370,874	1,930
NOCA	Ruby Creek	No	High	High	649,023	5,396,941	1,680
NOCA	Stehekin River	No	High	High	671,263	5,354,646	1,200
OLYM	Barnes Creek	No	Moderate	High	440,316	5,322,873	590
OLYM	Umbrella Creek	Yes	High	High	379,061	5,332,361	65
OLYM	Kalaloch Creek	Yes	High	High	397,043	5,273,646	20
OLYM	Matheny Creek	Yes	High	High	416,710	5,269,696	180
OLYM	Ozette River	Yes	High	High	375,803	5,334,899	20
OLYM	South Fork Calawah River	Yes	High	High	406,863	5,311,836	405
OLYM	Sol Duc River	Yes	High	High	434,802	5,313,576	1,550

* Discussions of watershed risk and informed risk can be found in Section 1.6.3.



Figure 2.1. Map detailing the sample location and the watershed above the sample location for Ebey's Landing National Historic Preserve.

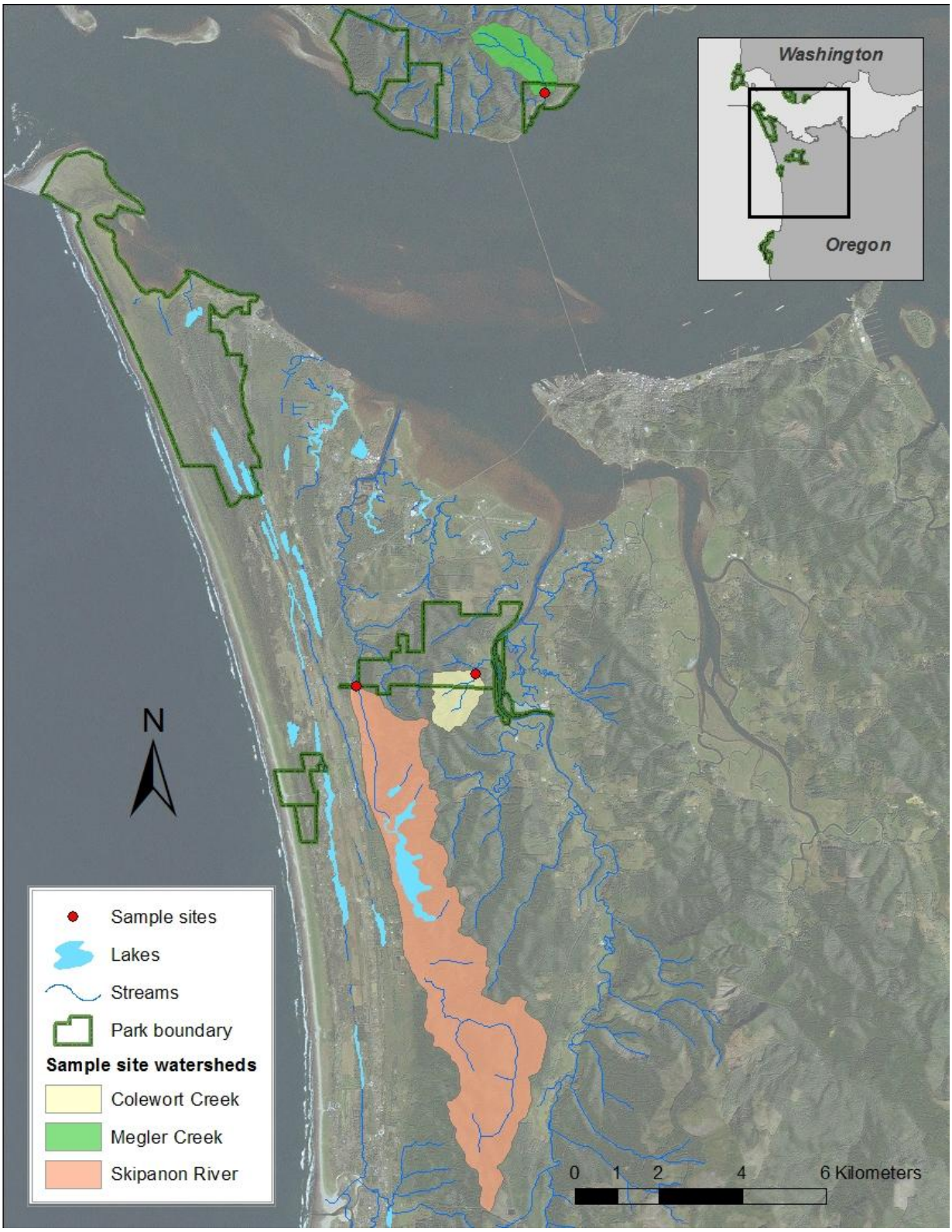


Figure 2.2. Map detailing the sample locations and the watersheds above them for Lewis and Clark National Historic Park.

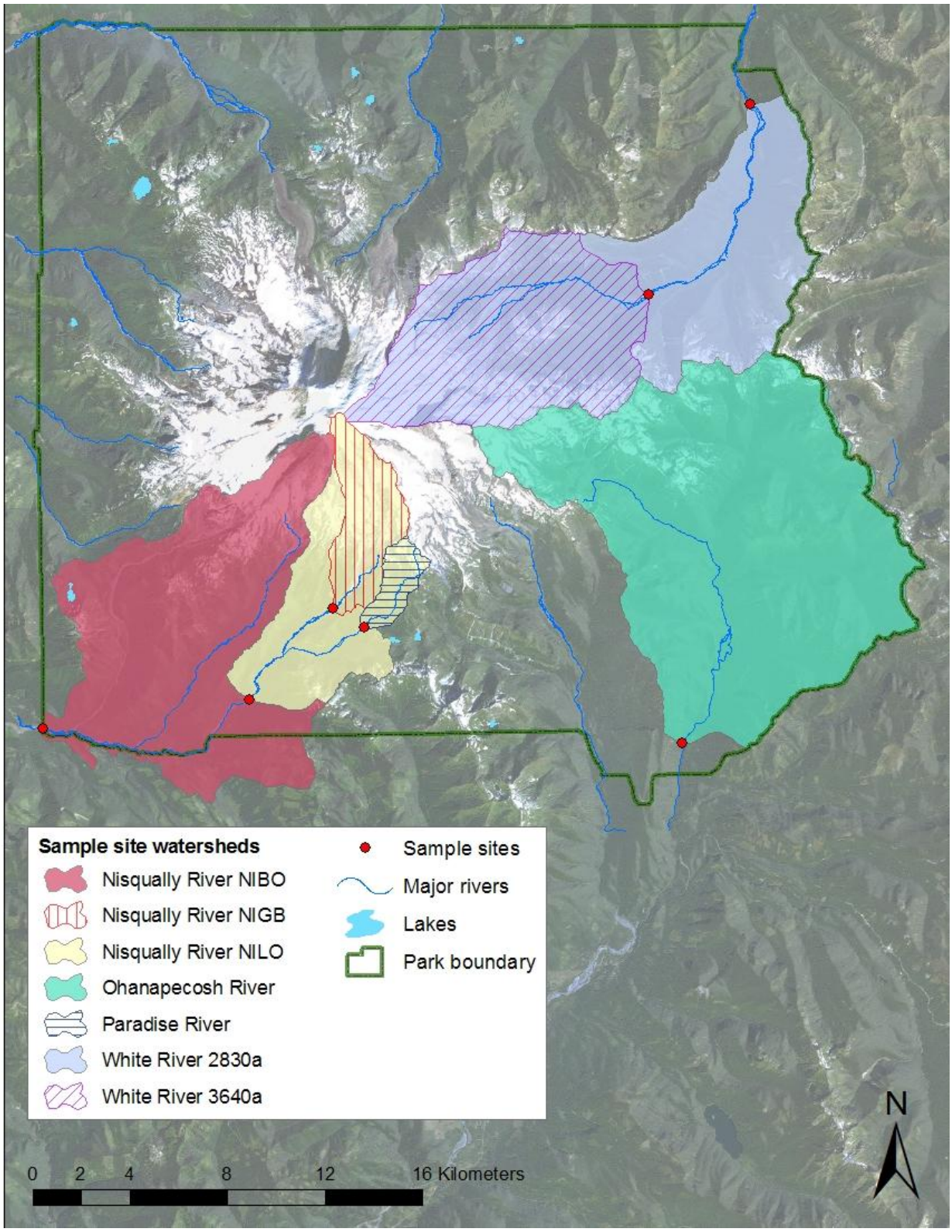


Figure 2.3. Map detailing the sample locations and the watersheds above them for Mount Rainier National Park.

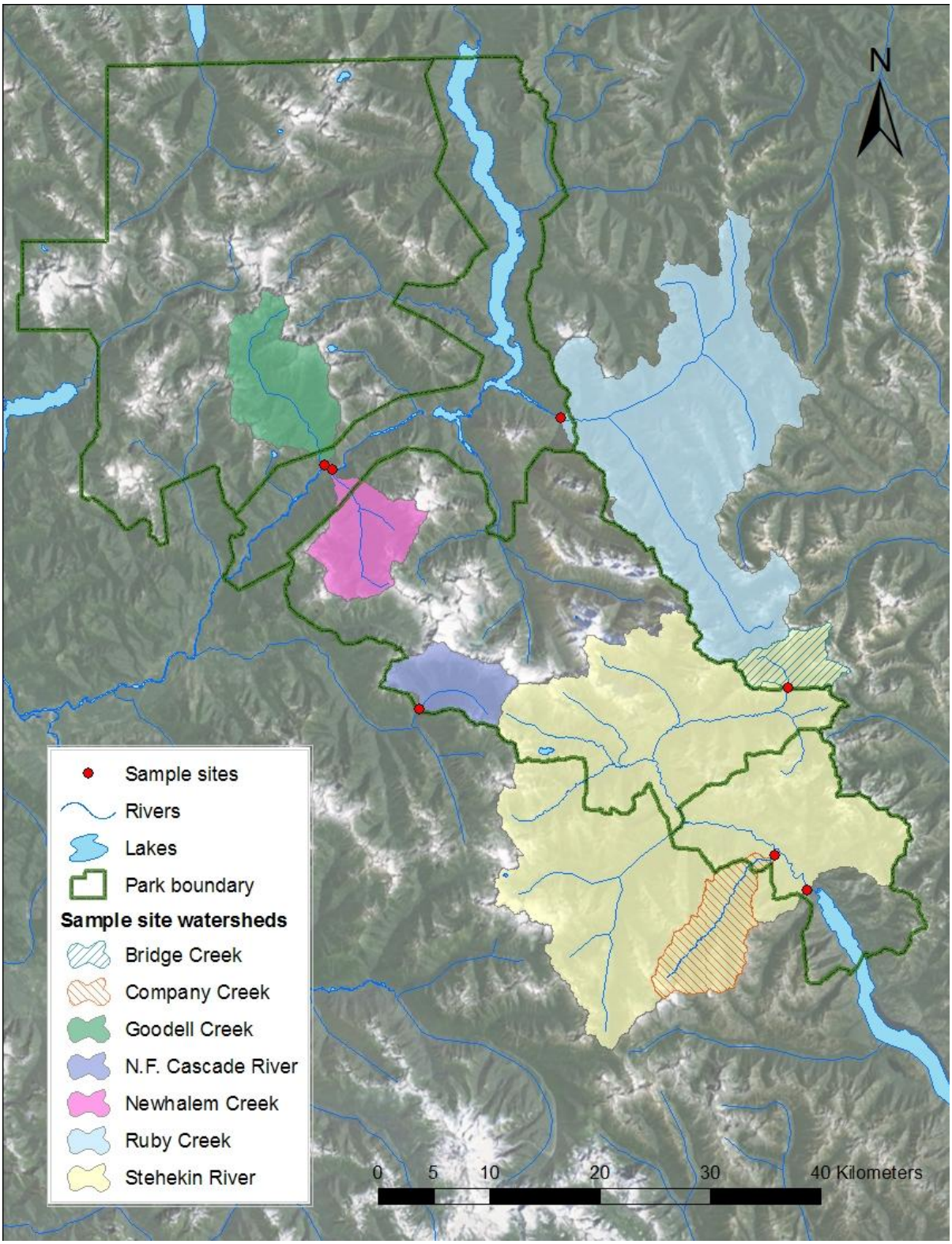


Figure 2.4. Map detailing the sample locations and the watersheds above them for North Cascades National Park Service Complex.

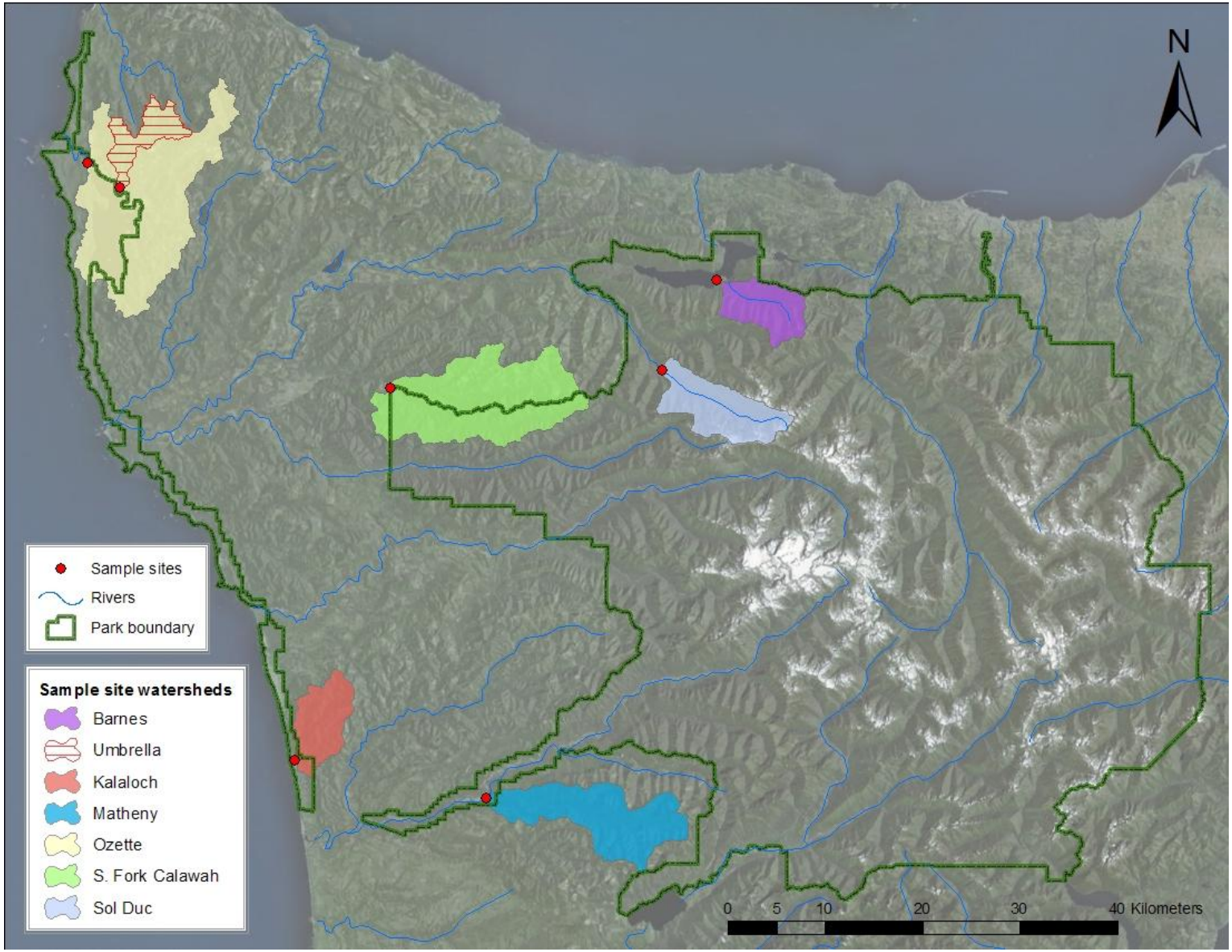


Figure 2.5. Map detailing the sample locations and the watersheds above them for Olympic National Park.

2.2 Frequency and Timing of Sampling

Streams and rivers will be sampled using an always revisit design where all 25 sample locations will be sampled every year. Sampling will be conducted once a year during an "index period" occurring during the seasonal low water period that ranges from late July to early October. Conducting field work during this time of year maximizes the safety of field crews and increases comparability with regional monitoring programs (Hayslip 2007) and those conducted by the USFS (AREMP and PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO)), the EPA (EMAP), the Oregon DEQ, and the Washington DOE. Additionally, excursions in dissolved oxygen and water temperature will most likely occur during this time.

Supplemental sampling will be implemented during events of increased storm run-off if staffs are available. For example: a stream may be sampled during a storm event to measure turbidity when water quality criteria are most likely to be exceeded due to increased surface water run-off. However, since floods and other high water events influence water chemistry and can block access to sample locations, initial baseline sampling will take place at least 48 hours after high water events.

To control for seasonal and diurnal patterns in water chemistry and the community structure of benthic invertebrates, the timing of sample events will be kept as constant as possible. Individual sites that are revisited will be sampled at the same time of year and within a ten day sample window of the initial sample event date. Water chemistry samples will be collected at approximately the same time of day (between 10:00 am and 2:00 pm). Benthic invertebrate samples will only be collected once during the late summer/fall index periods to comply with regionally established monitoring guidelines (Hayslip 2007).

2.3 Rationale for Selection of Sample Design

A judgment sample was considered to be the most flexible and most cost effective means that allowed park managers to assess specific threats occurring at specific locations. A judgment sample also enabled the NCCN to continue monitoring rivers and streams that have a history of sampling. Due to limited funding making broader inference was not possible, and therefore a probabilistic sample was not drawn. However, it should be noted that sampling will represent the watershed conditions above the sample location.

An always revisit design was selected because: 1) it is the simplest to implement, 2) requires the least amount of initial reconnaissance and setup time, 4) decreases costs, and 5) improves the likelihood that consistency can be maintained over time as staff turns over. In the future, if more resources become available this design can be augmented to include more always revisit sample locations or to include the addition of serially alternating panels.

2.4 Water Quality Parameters

2.4.1 Temperature

Water temperature is a critical component of water quality as it affects the rates of chemical processes and nutrient cycling in the water column. It also directly influences the metabolic rates, physiology, behavior, distribution, growth, and survival of aquatic biota. Fish, invertebrates, zooplankton and phytoplankton have preferred temperature ranges making them susceptible to both increases and decreases in water temperature. These organisms can also be directly or

indirectly affected by changes in water temperature as it subsequently alters water chemistry, in particular dissolved oxygen concentration and the toxicity of many compounds.

Water temperature also affects lake stratification and mixing. Due to density differences between water masses of different temperatures, the water column can become stratified during summer and potentially during winter in some systems. Stratification can lead to the accumulation of nutrients and decreases in dissolved oxygen in the hypolimnion. Spring and fall mixing of the water column can lead to nutrient releases that fuel food web productivity.

In lotic waters, stream temperature is also directly related to discharge. This means that any process that influences either the heat entering a stream or the amount of water moving through the channel will alter the stream temperature.

Water temperature will become increasingly important in NCCN parks as they may provide the majority of cold-water refugia for temperature-sensitive species (salmonids) in the face of climate change. Areas that currently provide suitable habitat for these species may become uninhabitable with permanent shifts in temperature regimes. Significant loss of cold-water and cool-water habitats is projected due to the warming anticipated with a doubling of atmospheric CO_2 concentrations (Mohseni et al. 2003).

2.4.2 Dissolved Oxygen

Dissolved oxygen (DO) is a water quality component critical to aquatic biota. DO concentration is influenced by temperature, flow, and biological processes that require oxygen such as respiration and decomposition. DO levels can vary throughout the day, season, and with depth. Flow is also important to the respiration rate for some invertebrate species, thus DO concentration in conjunction with flow can influence the distribution of these species. Moreover, influx of many pollutants will increase the biochemical oxygen demand and thus deplete DO. This becomes increasingly important in the face of watershed development or other land-use changes that increase runoff.

2.4.3 pH and Acid Neutralizing Capacity

pH is the measure of hydrogen ion concentration in the water column and has important ramifications to aquatic plant and animal life. Aquatic organisms exist within a narrow range of pH values deviation from which can result in changes in species composition and relative abundance. In addition, pH strongly influences the availability of nutrients and the solubility of metals and other toxic pollutants. Most species prefer a neutral pH but can withstand a range of 6.5 to 8.5, which is typically set by states in their criteria. pH is affected by acidic inputs (through runoff and deposition) as well as reduction of acid neutralizing capacity (ANC).

ANC is the overall buffering capacity of water against acidification and is largely related to the amounts of carbonate ions. Water bodies with low ANC are more susceptible to acidification through atmospheric deposition, acid mine drainage and other anthropogenic sources. Water bodies such as mountain lakes where surrounding geology is likely of igneous origin typically have low buffering capacity and are particularly susceptible. States typically do not set criteria for ANC.

2.4.4 Specific Conductance

Conductivity is a measure of the capacity of water to conduct an electrical current and is a measure of dissolved ions (such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron) in the water column. When normalized to a unit length for a specific temperature, conductivity is expressed as specific conductance (and will be reported as such for this monitoring protocol). This parameter can also be used as an estimate of total dissolved solids (TDS). It is typically not regulated for water quality attainment.

Natural sources of dissolved ions include rocks and soils, and waters with low pH can increase the rate of the release of these ions from the landscape. Different concentrations of these ions reflect variation in the geology, vegetation, and weathering processes in the watershed. In volcanic areas, sulfate is more common in the natural environment and can result in increased conductivity. However, conductivity is also often associated with the presence of pollutants. Drainage from abandoned mine sites (iron, sulfate, copper, cadmium, arsenic), agricultural run-off (phosphate and nitrate), and run-off from roads (sodium chloride and magnesium chloride) are primary anthropogenic sources. Atmospheric deposition is another source of many of these ions. Increases in specific conductance associated with increased mineral salts can exert osmotic pressure on, and ultimately be toxic to, aquatic organisms.

2.4.5 Bioassessment

Benthic macroinvertebrates inhabit the sediment and bottom substrates of streams and lakes, and due to the relatively long life cycles (one or more years) and sedentary nature of these organisms, changes in their community structure typically reflects changes in the condition of the aquatic environments they inhabit. Benthic macroinvertebrate assemblages integrate the effects of point and non-point source pollutants over spatial and temporal scales and have thus been successfully used to assess the overall condition of (and detect trends in) the ecological integrity of the streams and lakes they inhabit (Barbour et al. 1999).

As the trophic link between primary producers and larger consumers (fish and amphibians), macroinvertebrate abundance or richness changes may also indicate changes in food-web dynamics that could negatively affect both aquatic and terrestrial ecosystems. The EPA summary report on biological assessment programs and biocriteria development states that, “Because biological communities are affected by all of the environmental factors to which they are exposed over time, bioassessments provide information on perturbations not always revealed by water chemistry measurements or toxicity tests. Thus, they are crucial for determining not only biological health but the overall health, or ecological integrity, of a water body” (USEPA 2002). Forty states and tribes, including Washington and Oregon use bioassessment to help determine aquatic life use support for their 305(b) reporting (USEPA 2002).

Two methods have been primarily used in the United States to evaluate the condition of aquatic communities and to develop biological criteria. Initially developed in England and Australia, River Invertebrate Prediction and Classification System (RIVPACS) type models are derived using cluster and discriminate analysis to predict the invertebrate taxa expected to occur in a water body given certain physical characteristics. This prediction is then used to ascertain a water body’s condition based on the presence or absence of the expected taxa (Norris 1996, Hawkins et al. 2000, Clarke et al. 2003). The other widely used method is multimetric modeling, which combines the taxonomic composition and functional characteristics of the invertebrate

community into a single index value (Karr 1991, Barbour et al. 1999). Both of these methods rely on comparing reference sites to sites that are assumed to be degraded by human influence.

Oregon has implemented a biomonitoring program in some streams and is currently developing criteria and updating beneficial uses, pending EPA approval, for their water quality program. Washington is in the process of developing RIVPACs and multimetric based water quality criteria.

2.4.6 Sediment and Turbidity

Turbidity is a measure of water clarity; high turbidity is generally associated with suspended solids or high productivity. If sediment load is the source of high turbidity, this may indicate increased erosion and runoff in the watershed. High turbidity as a result of suspended solids has a negative impact on the ability of fish to see their prey and on plants to photosynthesize. High turbidity can degrade fish habitat (as well as clog fish gills) and can indicate other potential pollutants. In the NCCN, turbidity will primarily be measured in streams using a turbidimeter and reported in nephelometric turbidity units (NTUs).

2.4.7 Stream Habitat and Riparian Conditions

To help provide a context for in-stream habitat and riparian conditions, a series of observations and measurements are made to characterize the stream reach where the samples are collected. Qualitative observations, based on standardized criteria, are made to characterize stream flow, document evidence of torrent events, identify the channel's fluvial pattern, and classify in-stream and riparian habitat conditions. Wetted width, bankfull width, valley width, and thalweg depth are measured at each sample event. Categories of human influence and the presence of invasive species are documented based on their proximity to the wetted edge along both banks of the delineated reach for streams and rivers.

2.5 Level of Change That Can be Detected

Two types of analyses will be used to summarize the response data collected for the Water Quality Monitoring Project: 1) abrupt change analyses applied to a single location to determine if a significant change in the mean value of a response has occurred during the current year compared to the pattern of mean values from previous years, and 2) analyses designed to detect long-term steady changes within a water body. Levels of change and corresponding sample sizes are estimated for trends, but not for abrupt change analyses. Because abrupt change analyses and long-term trend analyses use generally similar methods (regression on time for site specific analyses and a mixed models approach for park and network-wide analyses), it is expected that sample size requirements will be relatively similar.

The overall objective for the trend analyses is to detect an average annual change of $\leq$3% with 80% probability (1-β) while accepting a 20% probability of incorrectly asserting a trend (α). A 3% annual change amounts to a proportional change of approximately 45% of the initial value in a 15-year period. We used a higher α than those that are typically and arbitrarily prescribed because we felt the consequences of failing to detect real changes in a stream's ecological condition were more important than incorrectly asserting that a change had occurred. Analyses designed to detect long-term steady changes within a water body will be applied to five response variables (temperature, dissolved oxygen, pH, specific conductance and bioassessment values). As such, this set of response variables represents a range of possible variability dependent on the

particular parameter being evaluated. It is expected that some parameters will do better than the stated objective (above) while others will require more years of data collection before a trend can be realized.

Data from a representative sample of locations that can be used to assess the power of the sample design were not available; therefore a power analysis based on data simulation was used to assess power. This simulation was used to estimate the sample size required to detect a 2 to 4% annual trend with 80% power is based on testing the hypothesis H_0: $\beta_1 = 0$ versus the one-sided alternative H_1: $\beta_1 < 0$ in the linear regression $y_i = \beta_0 + \beta_1 x_i$, where y_i is the response value for any parameter of interest and x_i is the year. The response y_i is assumed to be normally distributed, and as such sample sizes (*n*) are the same when testing for H_1: $\beta_1 > 0$. Trend is detected if the null hypothesis of no trend is rejected in favor of H_1. The parameters used to conduct the simulation consisted of the: 1) range of desired power, 2) range of *n* values, 3) within year variance of a response, 4) overall average response, 5) correlation between $year_i$ and $year_{i+1}$, and 6) the number of consecutive years sampled. This analysis is only intended to give us an idea of sample sizes required for estimating trends, and actual sample size requirements will be evaluated in subsequent Five-year Summary Reports.

Results of the simulations were summarized for distinct ranges of variation. Mean coefficient of variation (CV = standard deviation/mean) values were calculated for response variables using historical data collected from MORA and NOCA (Table 2.2). The within year variance parameter of the power analysis routine was derived from the CV value for a mean response standardized at 1 (i.e., the variance parameter for a CV of 0.2 with a mean of 1 = 0.04). The year-to-year correlation parameter (*r*) was arbitrarily set at 0.5. Higher correlation values tend to increase required sample size and lower correlations reduce them. Examination of year-to-year correlation for chemical parameters from eleven MORA lakes exhibited average *r* values ranging from -0.01 to 0.12. For responses that in reality have similar (low) year-to-year correlation, estimates of derived sample size will be conservative because we assumed an r of 0.5. Detailed information concerning the power analysis is presented in Appendix E: Power Analysis.

Table 2.2. Potential variation (CV) for a subset of proposed North Coast and Cascades Network water quality response variables.

Response variables	Coefficient of Variation (CV)	
	≤0.10	0.11 - 0.20
Water temperature (single measure)	X	
Dissolved oxygen	X	
Specific conductance		X
pH	X	
Bioassessment, (O/E)	X	

Interpretations of performance are based on collecting a single sample on an annual basis at one location. The simulation results do not apply to responses in water temperature since this parameter is being measured continuously using data loggers. Results of the power analysis indicate that up to nine years of sampling will be required to detect a potential 3% change in the average response of a parameter with a CV of 0.1, with an 80% probability of detecting a trend and a 20% probability of incorrectly asserting a trend. Parameters with a CV of 0.2 will require

up to twelve years of sampling to detect a 3% trend with an 80% probability of detecting a trend and a 20% probability of incorrectly asserting a trend.

The actual ability to detect trends versus those estimated above may vary for the following reasons:

1. Two methods were required to calculate CVs from historical datasets (see Appendix E: Power Analysis) in order to approximate variation for the response variables used in this evaluation. Methods for the core water quality parameters relied on data collected during the same temporal window but from different years, likely resulting in inflated variances for calculating CVs and overestimating the required sample size.

2. Application of simple linear regression provides only a conservative approach for estimating power to detect a trend if a trend is present (Larsen et al. 2004). Methods proposed for trend analysis in SOP 19: Data Analysis and Reporting are likely to exhibit greater trend estimation sensitivity as they are also capable of fitting curvilinear and polynomial trends in the regression.

3. Auxiliary covariates that are known to affect responses can be incorporated into the trend analyses procedures documented in SOP 19: Data Analysis and Reporting, improving precision by removing some of the coherent (year) variation (Urquhart et al. 1998).

4. Year to year variations in weather patterns (e.g., precipitation and temperature) are not accounted for in the analysis and will be highly concordant among sites resulting in underestimates of the number of years required to determine a trend.

3.0 Field and Laboratory Methods

3.1 Field Season Preparation

Tasks and responsibilities for field crew preparations are described in detail in SOP 1: Field Season Preparations and Crew Training. Pre-season data management preparation is discussed in SOP 2: Project Workspace and Records Management. Generally, field season preparation tasks include the following:

1. Administrative procedures including preparation of budget and seasonal hiring are completed, and any compliance needs are addressed.
2. Any revision to the protocol is discussed and completed based on experiences from the previous year. Identify safety issues and potential mitigations.
3. Sample site list is reviewed to determine if sites need to be added or removed based on NCCN monitoring results or other information meeting the requirements of the Quality Assurance and Control Plan (SOP 15).
4. Pre-season data management needs are addressed as described in SOP 2: Project Workspace and Records Management.
5. All equipment and supplies are inventoried and replaced as needed. Sampling equipment is calibrated and tested.
6. All personnel carefully review the protocol, including all SOPs, and instructions for use of all water quality probes used in data collection.
7. All aspects of training (SOP 1: Field Season Preparations and Crew Training) are completed including: GPS navigation and mapping (SOP 3: GPS Data Collection), use of equipment, field and laboratory methods, and safety.
8. Field sampling schedule is established.

3.2. Sequence of Events during the Field Season

A field season generally consists of up to six sampling tours conducted from August through October (Section 2.2: Frequency and Timing of Sampling). A typical field tour includes pre-tour preparation, site access, data collection, post-tour debriefing, sample processing and data handling, and equipment maintenance.

3.2.1 Field Tour Preparation

The following steps are taken immediately preceding each field tour:

1. Necessary contacts are made with the park-based Aquatic Program Leads and park communications centers.
2. Waterproof copies of SOPs, field forms, equipment manuals, maps and aerial photos are prepared.
3. Equipment lists are double checked as all gear is packed. Equipment needs for each field protocol are listed in each of the SOPs.
4. Complete Project Operations Plan and Risk Assessment (Appendix J).

5. Perform required pre-tour instrument calibrations.
6. Water and air temperature loggers are programmed for delayed starts.

3.2.2 Site Access and Data Collection

All sample locations are accessible by foot and located in front country locations accessible within one day's travel from a road. Typically two people, the Lead Technician or the Project Lead accompanied by a Field Crew Member, will complete a field tour in two to four days depending on the distance between sample locations. Once at the site, field data collection can be completed in three to four hours.

A general description of the sample elements, location and timing is found in Section 2: Sample Design. Field data collection procedures are described in detail in SOPs 3-13. Each SOP includes details on procedures, sample timing, sample location, equipment operations and calibration, data recording requirements, and specific quality control concerns. Prior to leaving a field site, all data forms are reviewed for completion and all samples are checked for proper labeling.

3.2.3 Post Tour Tasks

The following steps are completed following return from the field:

1. All benthic macroinvertebrate samples are immediately inventoried, checked for proper preservation, and refrigerated.
2. Data forms are reviewed for errors and completeness. Quality control concerns are documented and data forms are filed. If time permits between successive tours, data are entered into the project database (SOP 16: Data Entry and Verification).
3. Digital photos, GPS data, and continuous water temperature data are downloaded and processed (SOP 3: GPS Data Collection, SOP 9: Continuous Water Temperature Sampling in Streams and Rivers, and SOP 12: Digital Photo Acquisition and Management for Streams and Rivers).
4. Equipment is unpacked, dried, and cleaned. Required maintenance is performed.
5. Decontamination of sampling equipment and waders (SOP 13: Decontamination of Equipment) is required following each sample site visit.
6. Review and debrief field operations. Identify safety issues and potential mitigations.

3.3. Post Field Season Activities

End of the season procedures are described in SOP 14: Post Field Season Activities, SOP 16: Data Entry and Verification, SOP 17: Data Quality Review and Certification, and SOP 18: Product Delivery, Posting, and Distribution. These include: sample processing and shipping, data entry and verification, photographic image management, data quality review and certification, equipment inventory and maintenance, field season debriefing, and follow up on quality assurance/control.

3.3.1 Benthic Macroinvertebrate Sample Handling and Shipping

BMI samples are delivered to contractors either as the field season progresses or immediately after the field season ends. All NCCN staff collecting and handling samples are required to

adhere to quality control procedures to ensure sample integrity. Benthic macroinvertebrates are stored in 95% ethanol to ensure adequate preservation of samples.

Prior to shipment samples are logged on the shipping form (Appendix F) and all sample labels are checked for completeness. Samples are packaged and shipped according to instructions described in SOP 8: Benthic Macroinvertebrate Sampling. Following shipment, confirmation of their arrival should be obtained from the contractor.

3.3.2 Data Review and Management

All field data are reviewed as soon as possible after the field season by the Lead Technician and/or the Project Lead. All quality control/assurance issues related to field data collection are documented (*see* SOP 15: Quality Assurance and Control Plan). Digital photos taken during the field season should be downloaded and labeled as soon as possible when returning from the field. They should be reviewed by each participating crew member again at the end of the season to ensure that they were labeled properly.

Temperature logger post deployment calibration is performed and the results of the pre and post deployment calibration are evaluated, verifying the accuracy of the temperature loggers. Any need for calibration adjustment should be applied to the collected data set (SOP 9).

3.3.3 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) procedures are integral components of the individual SOPs. Following the guidance outlined in the SOPs will ensure that the objectives of the Quality Assurance and Control Plan (SOP 15) are met. The Quality Assurance and Control Plan for the NCCN Water Quality Monitoring Protocol is designed to meet the data quality requirements of the NPS Water Resources Division (Irwin 2004), the Washington Department of Ecology and the Oregon Department of Environmental Quality. In total, the SOPs address the requirements of measurement quality objectives, sample collection, field measurements, sample handling, instrument calibration, and quality control audits.

QA/QC review and compliance occurs at various stages during the year. Immediately following the field season these procedures are reviewed to evaluate problems and ensure compliance related to data collection and sample processing. QA/QC procedures and objectives are found in SOP 15: Quality Assurance and Control Plan, and in field sampling and data management SOPs (SOPs 2-12, and 16-18). Results of this review are documented in the database and included in annual and five-year summary reporting.

3.3.4 Equipment Inventory, Maintenance and Storage

Following the field season all equipment should be cleaned, repaired if necessary, and stored in a safe, orderly manner. The operation manuals for all instruments should be consulted for recommended maintenance. Batteries should be removed. All cleaning, storage and repairs completed should be documented. An inventory of all equipment and supplies should be completed following the field season and repeated prior to the start of the next season. Lists of equipment and supplies are found at the end of each field SOP (SOPs 3-13). Any items requiring repair or replacement should be documented. All chemicals should be stored in proper containers in their proper storage cabinet. The chemical inventory log should be updated and expiration dates of chemicals should be noted. Any chemical waste should be disposed of according to

Material Safety Data Sheets (MSDS) recommendations, and local waste disposal authority requirements.

3.3.5 Field Season Debriefing and Quality Control Review

At the end of the season field crews, the Lead Technician, the Program Lead, and Data Managers should meet and discuss any problems that occurred during the field season. Changes that may be relevant for future monitoring are documented and considered in the process of revising the protocol according to SOP 21.

4.0 Data Management, Analysis and Reporting

This chapter describes the procedures for data management, analysis, and report development. Additional details and context for this chapter are provided in the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. The NCCN website (http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) also contains guidance documents on various information management topics (e.g., report development, GIS development, GPS use).

4.1 Project Information Management Overview

Project information management may be best understood as an ongoing or cyclic process, as shown in Figure 4.1. Specific yearly information management tasks for this project and their timing are described in Appendix H: Yearly Task List, which Summarizes annual tasks and responsibilities for implementation of the NCCN water quality monitoring protocol. Readers may also refer to each respective chapter section for additional guidance and instructions.

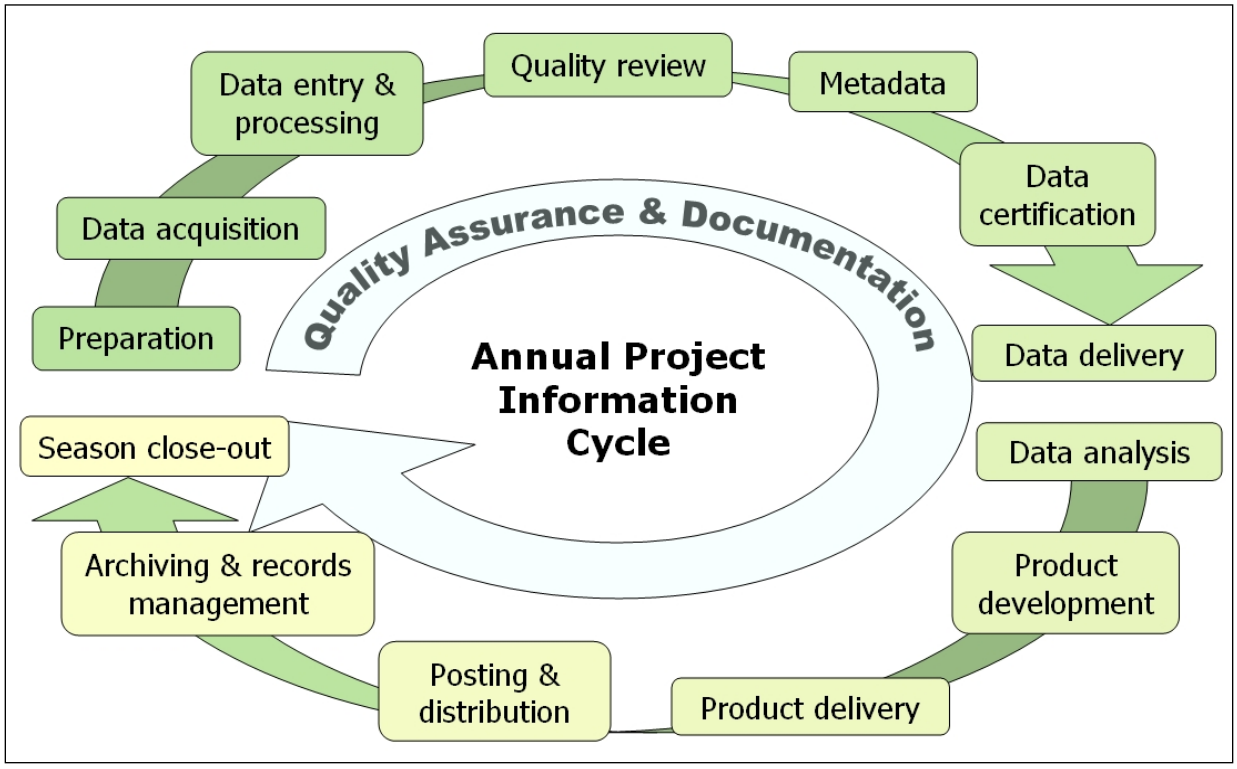


Figure 4.1. Idealized flow diagram of the cyclical stages of project information management, from pre-season preparation to season close-out. Note that quality assurance and documentation are thematic and not limited to any particular stage.

The stages of this cycle are described in greater depth in later sections of this chapter, but can be briefly summarized as follows:

- *Preparation* – Training, logistics planning, print forms and maps
- *Data acquisition* – Field trips to acquire data

- *Data entry & processing* – Data entry and database uploads, GPS data processing, etc.
- *Quality review* – Data are reviewed for structural integrity, completeness, and logical consistency
- *Metadata* – Documentation of the year's data collection and results of the quality review
- *Data certification* – Data are certified as complete for the period of record
- *Data delivery* – Certified data and metadata are delivered archiving
- *Data analysis* – Data are summarized and analyzed
- *Product development* – Reports, maps, and other products are developed
- *Product delivery* – Deliver reports and other products for posting and archiving
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses
- *Archiving & records management* – Review analog and digital files for retention (or destruction) according to NPS Director's Order 19. Retained files are renamed and stored as needed.
- *Season close-out* – Review and document needed improvements to project procedures or infrastructure, complete administrative reports, and develop work plans for the coming season

4.2 Pre-season Preparations for Information Management

4.2.1 Set Up Project Workspace

A section of a networked file server is reserved for this project, and access privileges are established so that project staff members have access to needed files within this workspace. Prior to each season, the Project Lead should make sure that network accounts are established for each new staff member, and that the Data Manager is notified to ensure access to the project workspace and databases. Additional details are provided in SOP 2: Project Workspace and Records Management.

4.2.2 GPS Loading and Preparation

The GIS Specialist and Project Lead should work together to ensure that target coordinates, background imagery and data, and data dictionaries are loaded into the GPS units prior to the onset of field work, and that GPS download software is available and ready for use. Additional details on GPS use and GPS data handling may be found in SOP 3: GPS Data Collection and in NCCN GPS Data Acquisition and Processing (NCCN 2009).

4.2.3 Project Database Application

Prior to the field season, the Data Manager will update the project database application as needed to ensure proper access on the part of the project staff. Refer to Section 4.3 for additional information about the database design and implementation strategy.

4.3 Overview of Database Design

The NPS Water Resource Division (WRD) requires that all I&M water quality monitoring data be compatible with, and uploaded annually to, the EPA's STORET database. To facilitate this, the WRD maintains a Microsoft Access database tool, NPSTORET, which duplicates most of the data and table structures in EPA STORET. NPSTORET will be used to enter and store all NCCN water quality data; data will be entered, reviewed, certified, and sent to WRD on an annual basis

for upload into EPA STORET. The NPSTORET application also has built-in tools for data summarization and output that will be used when generating summary reports.

Additional information on vital signs water quality data management and archiving, as well as a copy of NPSTORET, can be obtained at:
http://www.nature.nps.gov/water/infoanddata/index.htm.

We also maintain a customized relational database application to store and manipulate other data associated with this project that are not currently accommodated by NPSTORET (e.g., continuous temperature data and macroinvertebrate data). The design of this database is consistent with NPS I&M and NCCN standards. The Data Manager is responsible for development and maintenance of the database, including customization of data summarization and export routines.

The database is divided into two components – one for storing data in a series of related tables composed of fields and records (i.e., the "back-end database"), and another that acts as a portal or user interface through which data may be entered, viewed, edited, error-checked, summarized and exported (i.e., the "front-end application"). By splitting the database into front-and back-end components, multiple users may interact with the data simultaneously, and user interface updates can be implemented without service disruptions.

The back-end database schema (tables, fields and relationships) is documented in Appendix G: Database Documentation. The back-end database is implemented in Microsoft SQL Server to take advantage of the automated backup and transaction logging capabilities of this enterprise database software.

The front-end is implemented in Microsoft Access. It contains the forms, queries, and formatted report objects for interacting with the data in the back-end. Its features and functionality are customized using Visual Basic for Applications (VBA) programming code. The application has separate forms for data entry that mirror the layout of hard-copy field forms used during data collection. There are also forms for browsing and editing data, for completing the annual quality review, and for summarizing and exporting data to other software (e.g., for analysis and graphics production).

4.4 Data Entry and Processing

During the field season, the project crew will be provided with a copy of the project database front-end, through which they enter, process, and quality-check data for the current season (refer to the next section and SOP 16: Data Entry and Verification).

After each field trip, technicians should enter data in order to keep current with data entry tasks, and to identify any errors or problems as close to the time of data collection as possible. The front-end database application is found in the project workspace. For enhanced performance, it is recommended that users copy the front-end onto their workstation hard drives and open it there. This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as a pointer to the data that reside in the back-end database. Whenever updates to the front-end application are made available by the Data Manager, an updated front-end should be copied from the project workspace to the workstation hard drive.

The functional components of the front-end application are described in SOP 16: Data Entry and Verification. Each data entry form has built-in quality assurance components such as pick lists and validation rules to test for missing data, outliers, or illogical combinations. Users are strongly encouraged only to use these pre-built forms as a way of ensuring maximum data quality.

4.4.1 Regular Data Backups

NPSTORET can create a .zip format backup file every time a user closes the application once this option is set from the 'set defaults' utility. This file includes a copy of the backend, including any associated images and documents, and is placed in the 'backups' subfolder of the NPSTORET application.

For other project data, automatic database backups are scheduled in the SQL Server database management system to help prevent data loss in case of user error, drive failure, or database file corruption. Full backups are scheduled on a weekly basis, with daily transactional backups to enable restore operations to a point in time within a moving eight-week window. Weekly backups and transaction files are retained for eight weeks to conserve drive space. Full monthly backups are stored for at least one year after data have been certified. Snapshot backup copies of certified data, made at the time of certification, are retained indefinitely.

4.4.2 Data Verification

As data are being entered, the person doing the data entry should visually review them to make sure that the data on screen match the field forms. This should be done for each record prior to moving to the next form for data entry. At regular intervals and at the end of the field season the Lead Technician should inspect the data being entered to check for completeness and perhaps identify avoidable errors. The Lead Technician will periodically use the report function in NPSTORET that supports reporting on portions (e.g., 10%) of randomly selected records within a set of data (this step is described in greater detail in Narrative Section 4.5 and also in SOP 17: Data Quality Review and Certification).

4.4.3 Field Form Handling Procedures

As field data forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content (refer to SOP 2: Project Workspace and Records Management). If changes to data on the forms need to be made subsequent to data collection, the original values should not be erased or otherwise rendered illegible. Instead, changes should be made as follows:

- Draw a horizontal line through the original value, and write the new value adjacent to the original value with the date and initials of the person making the change.
- All corrections should be accompanied by a written explanation in the appropriate notes section on the field form. These notes should also be dated and initialed.
- If possible, edits and revisions should be made in a different color ink to make it easier for subsequent viewers to be able to retrace the edit history.
- Edits should be made on the original field forms and on any photocopied forms.

These procedures should be followed throughout data entry and data revision. At the end of each field season, the data sheets should be scanned as PDF documents and archived (refer to SOP 2:

Project Workspace and Records Management). The PDF files may then serve as a convenient digital reference of the original if needed.

4.4.4 Image Handling Procedures

Digital images acquired during the course of conducting project-related activities will be managed and stored in the project workspace along with other project data. Refer to SOP 12: Digital Photo Acquisition and Management for Streams and Rivers for details on image management.

4.4.5 GPS Data Procedures

The following general procedures should be followed for GPS data (see SOP 3: GPS Data Collection):

- GPS data should be downloaded by the GIS Specialist from the units at the end of each field trip and stored in the project workspace as described in SOP 2.
- The GIS Specialist will process the raw GPS data and store the processed data in the project workspace.
- The GIS Specialist will upload corrected coordinate information into the database and create or update any project GIS data sets as needed.

The Lead Technician will periodically review the processed GPS data to make sure that any errors or inconsistencies are identified early.

4.5 Data Quality Review

After the data have been entered and processed, they need to be reviewed by the Project Lead for structural integrity, completeness and logical consistency. The front-end application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case a description of the resulting errors and why edits were not made is then documented and included in the metadata and certification report (see Sections 4.6 and 4.7, and SOP 17: Data Quality Review and Certification).

The Project Lead and GIS Specialist may work together to review the surveyed coordinates and other geospatial data for accuracy. The purpose of this joint review is to make sure that geospatial data are complete and reasonably accurate, and also to determine which coordinates will be used for subsequent mapping and field work.

4.6 Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, condition and other characteristics of a given data set. Additionally, metadata provide the means to catalog and search among data sets, thus making them available to a broad range of potential data users. Metadata for all NCCN monitoring data will conform to Federal Geographic Data Committee (FGDC) guidelines and

will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized.

NPSTORET requires complete documentation of monitoring protocol procedures. Before any results can be entered into the system, NPSTORET must be populated with metadata documenting the field sampling/measurement procedure; gear configurations; sample preservation, transport, and handling; field/laboratory analytical procedure; laboratory sample preparation; complete detail about the characteristics measured; laboratory information; staff and their roles; and any literature citations pertinent to the monitoring effort. Such internal metadata only needs to be entered once before entering results.

At the conclusion of the field season, the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the Data Manager (see the schedule in Appendix H). The Data Manager and GIS Specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses.

An up-to-date metadata record is a required deliverable that should accompany each season's certified data. For long-term projects such as this one, metadata creation is most time consuming the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect changes in contact information and taxonomic conventions, to include recent publications, to update data disposition and quality descriptions, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for creating, parsing and posting the metadata record are provided in NCCN Metadata Development Guidelines (NCCN 2007a). General procedures are as follows:

1. After the annual data quality review has been performed and the data are ready for certification, the Project Lead (or a designee) updates the metadata interview form.

    a. The metadata interview form greatly facilitates metadata creation by structuring the required information into a logical arrangement of 15 primary questions, many with additional sub-questions.

    b. The first year, a new copy of the NCCN Metadata Interview form (available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) should be downloaded. Otherwise the form from the previous year can be used as a starting point, in which case the Track Changes tool in Microsoft Word should be activated in order to make edits obvious to the person who will be updating the XML record.

    c. Complete the metadata interview form and maintain it in the project workspace. Much of the interview form can be filled out by cutting and pasting material from other documents (e.g., reports, protocol narrative sections, and SOPs).

    d. The Data Manager can help answer questions about the metadata interview form.

2. Deliver the completed interview form to the Data Manager according to the product delivery instructions in SOP 18: Product Delivery, Posting and Distribution.

3. The Data Manager (or GIS Specialist for spatial data) will then extract the information from the interview form and use it to create and update an FGDC- and NPS-compliant metadata record in XML format. Specific guidance for creating the XML record is contained in NCCN Metadata Development Guidelines (NCCN 2007a).

4. The Data Manager will post the XML record and certified data to the NPS Data Store, and maintain a local copy of the XML file for subsequent updates. The Data Manager will also coordinate submission of the NPSTORET data file to NPS WRD.

5. The Project Lead should update the metadata interview content as changes to the protocol are made, and each year as additional data are accumulated.

4.6.1 Identifying Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information, which is partly defined as the specific locations of rare, threatened or endangered species. Prior to completing the metadata interview form, the Project Lead and Data Manager should work together to identify any sensitive information in the data after first consulting Sensitive Information Procedures found at the website below. Their findings may be documented and communicated through the metadata interview form.

4.7 Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that: 1) the data are complete for the period of record (i.e. the annual field season), 2) they have undergone and passed the quality assurance checks (Section 4.5), and 3) they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data 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 the primary person responsible for completing an NCCN Project Data Certification Form, available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form should be submitted with the certified data according to the annual task list timeline in Appendix H. Refer to SOP 17: Data Quality Review and Certification, and SOP 18: Product Delivery, Posting, and Distribution for specific instructions.

4.8. Data Analysis

Data analyses are designed to extract useful information and facilitate conclusions regarding the project's objectives by examining statistical relationships in the data. At this time, no data have been collected as part of the NCCN Water Quality Monitoring Protocol. Therefore, this discussion should be viewed as a general set of options that will be narrowed or augmented as data compilation and descriptive analysis progress. While the questions asked of data and types of analyses can vary depending on the current needs of the parks, it is important to describe analyses that meet overarching analytical goals which include the following:

1. Determining the status of a water body in relation to CWA criteria
2. Estimation of current (or past) values of a parameter at individual sample locations
3. Detecting significant abrupt changes in a parameter at individual sample locations
4. Detecting long-term steady trends and step trends in a parameter at individual sample locations.

Detailed descriptions of specific analyses and reporting guidelines can be found in SOP 19: Data Analysis and Reporting. However, it should be noted that future analyses are not be limited to the statistical procedures given in SOP 19: Data Analysis and Reporting. Additional tests or improvements in analysis may prove to be more applicable in future evaluations. It is expected that consultation with a statistician will be required preceding the completion of Five-year Summary Reports, for changes in sampling design, and for significant modifications of sampling methods.

All water quality data collected will be uploaded to the EPA's STORET database. In this format, data will be available to interested parties outside of the NPS including the Washington Department of Ecology and Oregon Department of Environmental Quality. The guidance provided in the Quality Assurance and Control Plan (SOP 15) is designed to assure that the data collected as part of the NCCN Water Quality Monitoring Project meet the requirements established by the EPA, WA DOE and OR DEQ.

4.9 Reporting and Product Development

4.9.1 Report Content and Format

The reporting schedule includes production of annual reports and five-year summary reports. Annual reports will be issued every year in which sampling was conducted, after field data collection and sample processing. Annual reports will contain routine data summaries of site status and statistical analyses designed to detect abrupt changes at specific sites. The first annual report would be issued after year 1 of the project, but would contain only data summaries (figures and tables) because change detection is not possible after one year.

The five-year summary reports will be completed in the year following each sampling panel cycle. These reports will contain routine data summaries and statistical analyses to detect abrupt changes that normally appear in an annual report, as well as long-term trends. An annual report will not be produced for the last year of the sample panel cycle as this information will be included in the five-year summary report. A description of the report contents follows:

4.9.1.1 Annual Reports:

- List project personnel and their roles.
- List of water bodies sampled including location and dates of sampling.
- Provide overview of data collected with references to filenames and data storage locations.
- Description of analysis methods used.
- Describe current status of resource at each site using descriptive statistics and graphical representations of the data.

- Site specific abrupt change analyses will be added to the annual report following the 3rd year of data collection.
- Site specific trend analyses will be added to the annual report following the 5th year of data collection.
- Quality Assurance/Quality Control compliance and concerns will be documented (see SOP 15: Quality Assurance Project Plan).
- Changes in protocol will be documented following SOP 21: Revising the Protocol.
- Monitoring results and summaries of activities will be communicated with other park and NCCN Network staff.

4.9.1.2 Five-year summary reports:

- Routine data summaries and statistical analyses that normally appear in an annual report with the addition of long-term trends.
- Examination of relationships between monitoring project response variables and their covariates.
- Development and revision of reference site groups and criteria thresholds.
- Evaluation of precision and sampling bias for all response variables and make recommendations.
- Re-evaluation of sample size requirements for detection of trends and estimations of status.
- Quality Assurance/Quality Control compliance summary.
- Acquire peer review and make necessary changes as needed.
- Develop management and research recommendations.
- Interpret data for public and upper level managers at Park, Network, and National levels.

4.9.1.3. Standard Report Format:

Annual reports and Five-year reports will be published in the NPS Natural Resource Publications series, using pre-formatted Microsoft Word template documents based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template, and trend analysis and other peer-reviewed technical reports will use the Natural Resource Report (NRR) template. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

4.9.1.4. Sensitive Information:

Certain project information related to the specific locations of rare or threatened taxa may meet criteria for protection and as such should not be shared outside NPS except where a written confidentiality agreement is in place prior to sharing. Before preparing data in any format for sharing outside NPS, including presentations, reports, and publications, the Project Lead should refer to the guidance in Sensitive Information Procedures found at http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm (NCCN 2007b). Certain

information that may convey specific locations of sensitive resources may need to be screened or redacted from public versions of products prior to release.

4.9.2 Product Delivery, Posting and Distribution

A complete schedule for project deliverables and the people responsible for them are found in the annual project task list (Appendix H). To package products for delivery, refer to SOP 16: Data Entry and Verification, Handling and Custody section. Upon delivery products such as reports and GIS data sets will be posted to NPS websites and clearinghouses (e.g., the NPS Data Store) according to SOP 17: Product Delivery, Posting, and Distribution. The water quality data entered into NPSTORET will be delivered annually to WRD for upload to EPA's STORET Data Warehouse (see SOP 17: Product Delivery, Posting, and Distribution, Annual Data Transfer to WRD STORET section).

4.9.2.1. Holding Period for Project Data:

To permit sufficient time for priority in publication, certified project data will be held upon delivery for a period not to exceed two years after data certification. After the two-year period has elapsed, all certified, non-sensitive data will be posted to the NPS Data Store. Note: This hold only applies to raw data, and not to metadata, reports or other products which are posted to NPS clearinghouses immediately after being received and processed.

4.9.2.2. Special Procedures for Sensitive Information:

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources – most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the observation. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of products containing sensitive information are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (i.e., the full data set that includes sensitive information) may be shared only after a confidentiality agreement has been established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm for more information.

All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

4.10 Archiving and Records Management

4.10.1 Project File Review

All project files should be reviewed and organized by the Project Lead on a regular basis (e.g., annually in January). Unneeded draft documents and other intermediate files should be deleted to conserve space and maintain a clear and unambiguous record for future project staff. Decisions on what to retain and what to destroy should be made following guidelines stipulated in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm),

which provides a schedule indicating the amount of time that the various kinds of records should be retained. Refer to SOP 2: Project Workspace and Records Management.

4.11 Season Close-out

Because this is a long-term monitoring project, good records management practices are critical for ensuring the continuity of project information. Files will be more useful to others if they are well organized, well named, and stored in a common format. Details for handling project files are described in SOP 2: Project Workspace and Records Management. In addition, files containing sensitive information must be stored in a manner that will enable quick identification. Refer to Section 4.6.1, Sensitive Information.

After the conclusion of the field season, the Project Lead, Data Manager, and GIS Specialist should meet to discuss the recent field season, and to document any needed changes to the field sampling protocols, to the database structure or front-end application, or to any of the SOPs associated with the protocol.

5.0 Personnel Requirements and Training

5.1 Roles and Responsibilities

The workload and decision making process for the NCCN Water Quality Monitoring protocol follows a dispersed model where NCCN staff provide technical, analytical, reporting and science communication support to park based staff. The roles and responsibilities outlined below are intended to reflect that relationship.

Oversight and implementation of the NCCN Water Quality Monitoring Project is the responsibility of a park-based Aquatic Ecologist, also referred to as the Project Lead. The Project Lead is responsible for managing the day-to-day activities of the Water Quality Project; establishing safety procedures; supervising the Water Quality Project Lead Technician; overseeing and planning data collection; verifying, validating and analyzing data; and completing all Annual and 5-year summary reports. The Project Lead receives direct oversight from the Aquatics Program Manager at NOCA with input proved by the other park-based Aquatics Leads (EBLA NPS Representative, LEWI Resource Management Director, MORA Aquatic Program Manager, and the OLYM Fisheries Biologist) in developing the Project's sample design as well as coordinating field activities.

NCCN Data Managers and GIS Specialists are responsible for the development and maintenance of associated databases, production of maps and spatial data products, production of reports, and archiving data products.

The field crew will consist of up to four members: the Lead Technician and four Field Crew Members. The Lead Technician is supervised by the Project Lead and is responsible for the day-to-day operations of implementing the Water Quality Monitoring Protocol including: pre-season inventories to ensure that adequate supplies and operational equipment are available, laboratory management, training field staff, ensuring safety procedures are implemented, calibrating instruments, conducting field surveys, entering data into the database, and inventorying and properly storing supplies and equipment at the end of the field season. The Lead Technician also participates in annual meetings to discuss protocol improvements or changes. Field Crew Members are made up of experienced Biological Technicians and student interns. Field crews are responsible for field work preparation, collecting field data, laboratory processing of samples, and data entry. The Lead Technician is responsible for verifying accurate data collection and data entry. A detailed description of roles and responsibilities is presented in Table 5.1.

Table 5.1. Roles and responsibilities for the Water Quality Monitoring Protocol.

Role	Responsibilities	Position
Project Lead	• Project administration, oversight and implementation • Track project objectives, budget, requirements, and progress toward meeting objectives • Coordinate and ratify changes to protocol • Train and ensure safety of field crew • Certify each season's data for quality and completeness • Assist in performing data summaries and analysis, assist interpretation and report preparation • Complete reports, metadata, and other products according to schedule • Maintain and archive project records	Aquatic Ecologist
Data Analyst	• Perform data summaries and analysis, assist interpretation and report preparation	Aquatic Ecologist
Lead Technician	• Facilitate logistics planning and coordination • Train and ensure safety of field crew • Plan and execute field visits • Acquire and maintain field equipment • Oversee data collection and entry, verify accurate data transcription into database • Review reports, data and other project deliverables • Complete a field season report • Laboratory management	Aquatic Ecologist
Field Crew Members	• Collect, record, enter and verify data	NPS Biological Technicians and interns
Data Manager	• Consultant on data management activities • Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule • Maintain and update database application • Provide database training as needed	NCCN Data Manager*
GIS Support	• Consultant on spatial data collection, GPS use, and spatial analysis techniques • Facilitate spatial data development and map output generation • Work with Project Lead and Data Analyst to analyze spatial data and develop metadata for spatial data products • Primary steward of GIS data and products •	NCCN GIS Specialist*
Network Program Manager	• Review annual reports for completeness and compliance with I&M standards and expectations	NCCN Network Program Manager
Park Curator	• Receive and catalogue voucher specimens • Receive and archive copies of annual reports, 5-year analysis report, and other publications • Facilitate archival of other project records (e.g., original field forms)	Park-based Curator

Table 5.1. Roles and responsibilities for the Water Quality Monitoring Protocol (continued).

Role	Responsibilities	Position
USGS Liaison	• Consultant on technical issues related to project sampling design, statistical analyses, or other issues related to changes in protocol and SOPs	Ecologist, USGS-FRESC
Statistical Consultant	• Consultant on technical issues related to project sampling design, statistical analyses, or other issues related to changes in protocol and SOPs	NPS Statistician

* These individuals coordinate and serve as primary points of contact related to data management activities for this project. Their responsibility is to facilitate communication among network and park staff and to coordinate the work which may be shared among various staff to balance work load and to enhance the efficiency of information management. Refer to the NCCN Data Management Plan (Boetsch et al. 2009) for additional explanation of shared data stewardship.

5.2. Qualifications

The Project Lead and Lead Technician for the Water Quality Monitoring protocol are GS-7/9/11 staff who are highly skilled field biologists or ecologists with experience conducting ecological and water quality surveys in a variety of lotic habitats in the Pacific Northwest. They should have a familiarity with Pacific Northwest invertebrate, amphibian and fish communities. Familiarity with one or more of the NCCN parks is also desirable. Ideally, the Lead Technician will have supervised field crews before and/or previously served as an NCCN mountain lakes or water quality monitoring crew member. Lead project staff should be comprised of employees who have the knowledge and experience to identify and mitigate the risks associated with working in the aquatic environments of NCCN.

Field Crew Members are GS-5 or 6 Biological Technicians and may also include student interns. At least one Biological Technician will have prior water quality survey experience, including substantial experience with NCCN aquatic species and habitats. In addition, one Biological Technician will have some experience in fish, amphibian and invasive species identification or the ability to learn quickly how to identify the primary species present in park aquatic habitats. All staff collecting field data must also be physically fit and prepared to spend extended periods of time working outside. Substantial experience with backpacking, wilderness first-aid, and conducting aquatic field surveys is also desirable.

5.3. Training Procedures

A comprehensive and well-designed training program is critical to the success of this project, as it will maximize observer consistency within and between years. Past experience has shown us that particularly experienced or talented crew members can be adequately trained in using the Mountain Lakes Protocol in two weeks or less. It is recommended, however, that up to two weeks be allowed for the training period to maximize the likelihood that all observers will be qualified to conduct all of the water quality monitoring components at the end of the training session, and to allow ample time for any required meetings between the crew, Lead Technician, Project Lead, Data Manager, and GIS Specialist. Additional training time will be required to participate in and complete required general park training sessions (e.g., computer training, ethics, purchasing, personnel, supervisory, radio operation, park-based safety trainings).

5.3.1. Training New or Inexperienced Employees

Classroom training and field certification will be required for all new or inexperienced crew members. The objective of this training is to provide a basic understanding of the field SOPs rather than memorizing them. **Note**: In the field, all crew members will be required to always read the applicable sections of the protocol prior to data collection for any monitoring component.

Training requirements and procedures are discussed in detail in SOP 1: Field Season Preparations and Crew Training and the following subjects are covered:

1. Background on program objectives, sampling design, and data analysis
2. Field sampling methods and QA/QC concerns
3. Equipment operation and maintenance
4. Field and laboratory sample processing and handling
5. Invasive species identification
6. Recording data
7. Safety (e.g., first aid and CPR, the GAR Model of NPS Operational Leadership, defensive driving, backcountry travel, etc. See SOP 20: Field and Laboratory Safety, and Appendix I: Job Hazard Analysis)
8. Orienteering
9. Backcountry rules and ethics
10. Computer data entry and data management

For field certification, all new or inexperienced crew members will be required to work with the Lead Technician until they are certified to work on their own. Field certification will be required for each SOP, and will be based on knowledge of sample collection and processing methods, correct operation of equipment, adherence to field QA/QC and safety guidelines, identification of fish and amphibian species, and where possible comparison of results between inexperienced and experienced observers.

5.3.2. Experienced Crew Member Protocol Review and Training

The Lead Technician and Field Crew Members (with two or more years of experience) will be required to review all materials discussed in 1-10 above. Returning employees must maintain currency in all park required training.

5.4. Safety

The NCCN I&M Program places the highest emphasis on ensuring the safety and well-being of its staff as well as any person affiliated with implementing the Water Quality Project. The NCCN I&M Program Manager, Project Lead and Lead Technician will strive to provide a safe working environment that fosters a sense of professional responsibility and cohesion among all staff, interns and volunteers. Training in Operational Leadership will be required for any staff leading or overseeing field work. Training in defensive driving will be required for all staff who could potentially operate motor vehicles while on duty. An assessment of best practices in the field and

laboratory to ensure safety with respect to conditions in NCCN parks are outlined in the Job Hazard Analysis (Appendix I), and these will also be covered in detail during pre-season training.

All supervisory staff should work towards creating a work environment that:

- Encourages everyone to work together towards a common goal.
- Assigns roles and responsibilities to ensure clear lines of communication and create cohesive field operations.
- Facilitates all staff members feeling free to voice their observations and concerns related to planned or ongoing field activities. Supervisors are encouraged to incorporate staff feedback into field operations when appropriate and beneficial.
- Encourages professional development and a sense of ownership in the project and the tasks assigned to staff members.
- Stresses that each member of a field crew is responsible for the safety and well-being of the entire group and emphasizes open communication about past, present, and future safety issues among and between all staff.

6.0 Operations Requirements

6.1 Annual Workload and Field Schedule

Necessary tasks for implementing this protocol are presented in Appendix H: Yearly Task List. Preparation for each field season begins in January of that year with an initial planning session to outline the work load for the coming season. At this time, park based staff will meet with the Project Lead and Lead Technician to discuss staffing, equipment and supply needs and the annual budget.

Park-based activities for the upcoming field season include recruiting, hiring, and training field crew members (including NPS and park based training). The majority of field work will be accomplished during August and September, and park based staff in conjunction with the Project Lead and Lead Technician are responsible for developing a detailed field schedule. During this time, data entry is also initiated as prescribed in the SOPs. It is essential that during the field season the NCCN Water Quality Project Lead and Lead Technician communicate on a regular basis to troubleshoot sampling problems and other data collection issues. Given the difficulty of working in remote locations, it is recommended that these informal communications are initiated twice a month. Post field season activities, including data review and management, sample processing and shipping, equipment inventory and maintenance, and field season debriefing, start immediately upon return from the last field tour. Numerous data management and analysis tasks involved with report preparation and product delivery occur beginning immediately after the field season ends and continuing to the following November.

6.2 Facility and Equipment Needs

Facilities required for this protocol include office space with access to computers, laboratory facilities for biological sample processing, and seasonal housing. All of these facilities are available at LEWI, MORA, NOCA and OLYM. Costs for laboratory and office space are provided through park-based Operation of the National Park System (ONPS) funds, but replacement of instrumentation will require periodic funding from the Inventory and Monitoring Program. Seasonal housing is generally paid for by the employee with the exceptions of Student Conservation Association (SCA) volunteers and student interns.

A large amount of equipment including various sampling and measuring devices, temperature data loggers and water chemistry meters, personal safety equipment, and various supplies and materials are required for this protocol. Large amounts of this equipment has been purchased in the last five years; however funding will be needed to purchase additional data loggers, and three multi-parameter water quality meters to collect core water quality parameters over the first three years of implementation. Additionally, a moderate rate (10 to 15%) of equipment loss should be expected for data loggers left *in situ* for long periods of time. Complete equipment lists needed for field work are included at the end of each of the field SOPs.

6.3 Budget Considerations

The NCCN Water Quality Monitoring Protocol is principally funded by WRD, and the budget was developed based on the amount of funding allocated in fiscal year 2011 which was $78,800 (Table 6.1).This budgetary figure does not include the costs of the Park-based Aquatic Leads and the in-kind contributions of park-based Field Crew Members to complete portions of the training and field work.

An additional $20,000 will be required on every 5th year for completion of the Five-year Summary Report. The majority of these costs will be needed to pay for additional pay periods for the project lead. Some statistical consultation will be required to assist with the more complex trend analysis procedures used for continuous temperature data analyses, abrupt change, and long-term steady trend detection. It is expected that statistical consultation costs will be approximately $5,600 (40 hours) for assistance in preparation of the first Five-year Summary Report and should be less in subsequent five-year reporting intervals.

Table 6.1. Budget for the first three years of implementing the North Coast and Cascades Network Water Quality Monitoring Protocol.

Budget components	**Total $**
1. Salary and Benefits	
1 GS-11 (Project Lead): 13pp @ $3586/pp	$46,618
1 GS-7 Term (Lead Technician): 6pp @ $2400/pp	$14,400
1 GS-5 (Field Crew): 4pp @ $1400/pp	$5,600
Salary and Benefits Subtotal:	$66,618
2. Travel	
1 GSA Vehicle ($200/mo; $0.19/mi)	$1,000
Per Diem (Backcountry @ $20/day)	$700
Travel Subtotal	$1,700
3. Supplies and Equipment	
Consumables	$600
Waders, Boots, Packs and Safety Equipment	$400
Hobo Water Temp. Pro v2 (10@ $120/ea)	$1,200
Instrument Maintenance and Repair	$700
Misc. Stream Survey Equipment	$200
Hardware and Tools	$200
Supplies and Equipment Subtotal	$3,300
4. Analytical Costs	
Streams (27 BMI Samples @ $250/site)	$6,250
QA/QC (4 Samples)	$1,000
Analytical Costs Subtotal	$7,250
Total	$78,868

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SOP 1. Field Season Preparations and Crew Training

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This Standard Operating Procedure (SOP) explains the procedures and topics to cover in field season preparation and in training field crews to collect data for the NCCN Water Quality Monitoring project at EBLA, LEWI, MORA, NOCA, and OLYM. Material in this SOP was adapted from material in SOP 1 of the NCCN Mountain Lakes Monitoring Protocol (Glesne et al. 2012).

Field Season Preparations

The Water Quality Monitoring project consists of a suite of pre-season tasks that must be conducted each year. The list of pre-season tasks, staff responsibilities, and timing of execution are identified in Appendix H: Yearly Task List (see "Preseason operations" section)(SOPs are referenced as applicable).

Training New or Inexperienced Employees

Review and training will be provided for all water quality monitoring staff immediately preceding the field season. Each year all new or inexperienced staff will participate in training on every aspect of the Water Quality Monitoring protocol prior to conducting field work. Training will include reading the protocol, discussion of sections with the Lead Technician and/or Project Lead, and practicing each field exercise in a front country setting to gain familiarity with each task. New or inexperienced staff will not conduct any task unsupervised by the Lead Technician and/or Project Lead until they have demonstrated their ability to conduct tasks competently.

Pre-season training will include the following subjects:

Background on project objectives, sampling design, and data analysis

The purpose of this training is to provide background information on project objectives and sampling design (protocol narrative), and general information about how the data will be analyzed (SOP 19: Data Analysis and Reporting). The impact of poor field data collection practices on the ability to analyze and interpret data and achieve project objectives (e.g. missing data affect on sample size) will be discussed.

Field data collection and processing

The details of all field sample collection methods found in SOPs 3-13 will be covered in this training as well as specific Quality Assurance/Quality Control concerns identified in each field SOP.

As field data forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content. Field Crew Members should be trained to follow these procedures throughout data entry and data revision:

1. Field data will be collected on forms printed on waterproof paper.
2. All field data collected will be recorded on standardized field data entry forms that include metadata to be entered into the NPSTORET database.

3. Data forms will be scanned in the office, immediately after return from a field tour, or upon receipt from a contract laboratory (this is also true of data from continuous temperature data loggers). See SOP 18: Product Delivery, Posting, and Distribution (File Naming Standards section), and SOP 2: Project Workspace and Records Management, for details on naming and archiving scanned documents.
4. Data will be more thoroughly reviewed within a week after each sampling event for inconsistencies related to field personnel, how well SOPs are followed, and how timing and logistics of sample collection and transport to laboratories may be affecting sample data.
5. Field data will not be entered into the database until laboratory results have arrived.
6. Field and laboratory data sheets will be copied and stored in a "data to be entered" folder.
7. Original copies of datasheets and laboratory chain of custody forms will be stored in the respective park resource management offices.

Equipment operation and maintenance

This training provides specific information on the operation and maintenance of equipment used for sample collection. Reference material will include SOPs as well as equipment manuals. The following specific topics will be covered:

1. Hand held radios
2. GPS equipment (SOP 3)
3. Laser rangefinder (SOP 6)
4. Compass (SOP 5)
5. Dissolved oxygen, specific conductance, temperature, pH, and turbidity meters (SOP 7)
6. Macroinvertebrate nets (SOP 8)
7. Decontamination of nets and waders (SOP 13)
8. Cameras (SOP 12)

Pre-season and periodic maintenance checks of water quality meters should be documented in the appropriate calibration log (Appendix F: Conductivity, Dissolved Oxygen and pH Lab Calibration Log, Stream Temperature Calibration Check Form, and Temperature Logger Pre/Post Deployment Record Sheet).

Sample processing and handling

This training addresses field processing of macroinvertebrate samples (SOP 8).

Species identification, including non-native and invasive species

Observers must be fully competent at identifying aquatic vertebrate species, including fish and amphibians, as well as priority non-native and invasive species that occur or have the potential to occur in NCCN parks. Soon after being hired, new Field Crew Members will be given species lists (see Table 10-1 in SOP 10: Documenting Invasive Species Occurrence) and other training materials, and should begin preparing themselves prior to the training session. Trainers will provide a brief classroom overview of priority non-native species with potential to occur in each park, their habitats, life histories, and identifying characteristics. They will also cover native aquatic vertebrates, focusing on fish and amphibians.

Field guides will be provided which the Field Crew Members should refer to in the training session and throughout the field season. Additional on-site training will be conducted in the field, before and during the sampling season. Field Crew Members must show competency through the combination of an exam using photographic images and field identifications verified by a qualified Lead Technician or Field Crew Member.

Recording data

New Field Crew Members must be instructed how to complete each of the data forms and have an opportunity to practice completing them during training so that any questions or issues that arise can be resolved before field data collection begins. Additional details are provided in SOP 16: Data Entry and Verification.

Safety

Safety training will include all components of SOP 20: Field and Laboratory Safety, Appendix I: Job Hazard Analysis and and Appendix J: Project Operations and Risk Management Planning. Crew members will work together for up to a week at a time in remote, rugged areas of the three large parks (MORA, NOCA and OLYM), with a substantial portion of each day spent working off-trail. It is therefore essential that everyone be prepared for and know how to proceed in, emergency situations and use park-based communication systems. This preparation includes mandatory park safety training, review of job hazard analysis information (Appendix I), and routine safety tailgate sessions throughout the field season.

Orienteering

During the training session all Field Crew Members must become proficient at off-trail orienteering, including the proper use of a compass, altimeter, and GPS unit, and the ability to read topographic maps. GPS signals are frequently unavailable in the NCCN parks, so observers must become proficient at determining their own location as well as traveling to a distant, unseen destination using only a compass and topographic map. These skills should be practiced until all observers are proficient.

Backcountry Rules and Ethics

New Field Crew Members will receive instruction on backcountry regulations, including permit requirements and procedures, campsite restrictions, food storage, radio communications, etc. Note that some of these rules differ among the parks.

Computer data entry

During the pre-season training program, new and returning Field Crew Members must receive adequate instruction on general data management practices and specific data entry procedures (see SOP 16: Data Entry and Verification), so that they can complete data entry during the field season. If NPS computers are to be used for data entry, new crew members will need security clearance or other specific authorization, and complete required NPS Information Technology security training.

Experienced Crew member Protocol Review and Training

The Lead Technician and Field Crew Members (with two or more years of experience) will be required to review all materials discussed in items 1-11 above. Returning employees must be current in all Park- and NPS-required training.

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SOP 2. Project Workspace and Records Management

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes how and where project files and records are managed by project staff. Workspace structure, naming conventions, and procedures for handling project files are included.

NCCN File Workspace

NCCN has a centralized file system and project workspaces available for use by field crews and project staff at: \\inpolymfs\parkwide\NCCN. This will help avoid the problem of NCCN projects having several versions of files on different servers around the network. These folders are set up so that park and network staff members at the network parks all have read privileges throughout the directory structure. Project leads and a few other individuals associated with each project have full privileges for their project folder so they can manage their own permissions. These workspaces are intended to be a more familiar and convenient way of storing information, as an adjunct to the NCCN SharePoint site. Apart from reports and protocols, which are to be maintained in the NCCN Digital Library (a section of the NCCN SharePoint site), project leads will decide what is to be stored locally in these project workspaces as opposed to on the team SharePoint site. Examples of files kept in these project workspaces include: working files for project field crews, GPS downloads, GIS map files, database files, and other project records.

The NCCN file workspace is organized as follows under four main folders: Libraries, Projects, Temp, and Workspace. Project staff members will primarily be working in one or more of the project folders under Projects, and may wish to make desktop shortcuts to one or more of the project subfolders by right-clicking on the desired folder and selecting Send To > Desktop (create shortcut).

Project staff members should create a network shortcut to the project workspace by going to the Desktop in Windows Explorer and adding a new network place under My Network Places. Project staff located at OLYM will typically already have this path available to them via a mapped drive (e.g., the I:\ drive); however, they should still create this network shortcut where multiple parks are concerned for the sake of communications and consistency among parks. Performance is the main rationale for using network shortcuts instead of mapped drives at other parks.

<u>Instructions for creating a network shortcut to the NCCN workspace</u>:

1. Open an instance of Windows Explorer. One way is from the Start menu, go to: All Programs > Accessories > Windows Explorer. Another is to open My Documents, My Computer, or any other folder browser shortcut.
2. Navigate to the Desktop, and then to My Network Places.
3. Double-click the Add Network Place option to open the setup wizard.
4. Choose the option to specify the network location, then under network address, type in: \\inpolymfs\parkwide\NCCN
5. When prompted for a name for the network place, enter “NCCN” (or something similarly brief and meaningful).

6. This network place shortcut should now be available each time you log in to that particular computer, and can be accessed when navigating within most Windows software.

Project Workspace

A section of the NCCN workspace is reserved for this project. The recommended file structure within this workspace is shown in Figure 1-1. Certain folders, especially those for GPS data and images, should be retained in separate folders for each calendar year as shown in Figure 1-1. This will make it easier to identify and move these files to the project archives at the end of each season.

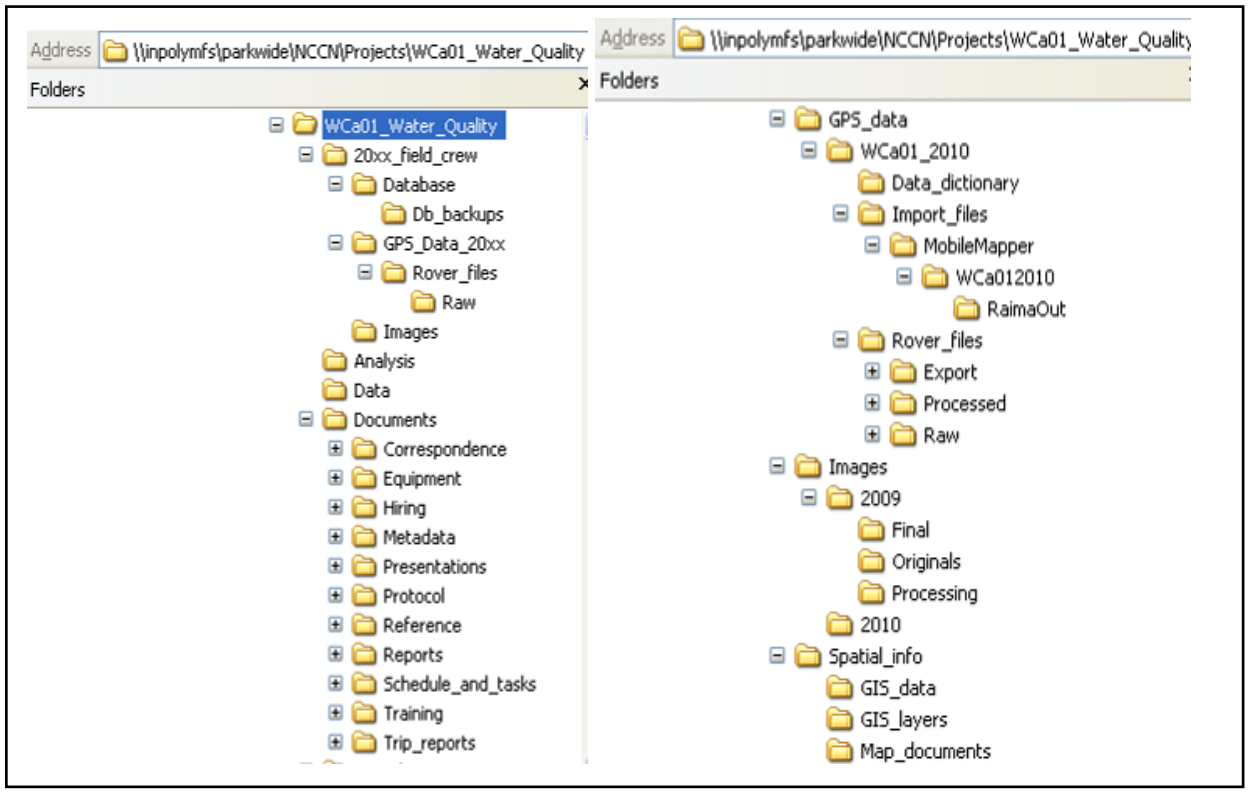


Figure 1-1. Recommended file structure for project workspace. Note that the workspace folder name includes 'WCa01', the North Coast and Cascades Network project code. The same code is also under the GPS_data folder to make it easier to select the correct project folder within the GPS processing software.

Each major subfolder is described as follows:

- Analysis – Contains working files associated with data analysis.
- Data – Contains the front-end database application file for the season. The back-end database for the project is maintained in Microsoft SQL Server. Database exports and other intermediate summary information can be stored here as well; these files are most effectively managed within subfolders named by calendar year.

- Documents – Contains subfolders to categorize documents as needed for various stages of project implementation. Additional folders and subfolders may be created as needed to arrange information in a way that is useful to project staff.
- GPS data – Contains GPS data dictionaries, and raw and processed GPS data files. This folder contains subfolders to arrange files by year. Each of these subfolders also contains the project code to make it easier to select the correct project folder within the GPS processing software.
- Images – For storing images associated with the project. This folder has subfolders named by calendar year to make it easier to identify and move files to the project archives at the end of each season. Refer to SOP 12: Digital Photo Acquisition and Management for Streams and Rivers, for more details.
- Spatial info – Contains files related to visualizing and interacting with GIS data.
    - GIS data – New working shapefiles and coverages specific to the project.
    - GIS layers – Pointer files to centralized GIS base themes and coverages.
    - Map documents – Map composition files (.mxd).

Seasonal Workspace

In addition to these permanent folders, a temporary seasonal workspace is established at the beginning of each field season (e.g., "2012_field_crew"). This temporary workspace provides a place for field crew members to create and modify files while limiting access privileges for the remainder of the project workspace. Subfolders are created for Images and GPS data to allow field crew members to process incoming files as needed. Temporary workspaces may also be established on other servers to provide local access to crews stationed at other parks. At the end of the season, files in these temporary workspaces are then filed in the appropriate permanent folder(s).

Folder Naming Standards

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name.
- Use the underbar ("_") character to separate words in folder names.
- Try to limit folder names to 20 characters or fewer.
- Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions).

File Naming Standards

Unless otherwise specified, file names should follow these guidelines:

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
- Dates should be formatted as YYYYMMDD.
- Correspondence files should be named as YYYYMMDD_AuthorName_subject.ext.

Workspace Maintenance Procedures

Prior to each season, the Project Lead should:

1. Make sure that network accounts are established for each new staff member, or reactivated for returning staff members. By default, the IT staff puts new user accounts into a group that has read-only access to all files.
2. Create new folders named by year under the Images and GPS data sections.
3. Create the seasonal workspace, with subfolders for Images and GPS data.
4. Add user logins for the seasonal crew members to the seasonal workspace, with modify privileges. This can be done by right-clicking on the seasonal workspace folder, selecting Properties > Security, then adding users one at a time and checking the box in the Allow column for Modify privileges.
5. Provide the Data Manager with a list of user logins that need access to the database.

After each season, the Project Lead should:

1. Review the workspace organization and clean up any temporary files and subfolders that are no longer needed.
2. Move files from the seasonal workspace folders into the appropriate permanent folder(s) and archive or delete the seasonal workspace folders as desired. See SOP 12: Digital Photo Acquisition and Management for Streams and Rivers, for specific instructions for images.
3. Compare older files against the retention schedule in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm). Dispose of files that are beyond their retention schedule if they are no longer needed. As a long-term project, many files associated with this project are likely to be scheduled for permanent retention. This makes it all the more imperative to clean out unneeded files before they accumulate and make it harder to distinguish the truly useful and meaningful ones.
4. Convert older files to current standard formats as needed to maintain their usefulness.
5. Identify files that may contain sensitive information (as defined in Section 4.6.1, Identifying Sensitive Information). Such files should be named and filed in a way that will allow quick and clear identification as sensitive by others.
6. Post final documents and files to the NCCN Digital Library for long-term storage. See SOP 18: Product Delivery, Posting and Distribution.
7. Send analog (non-digital) materials to the park collections for archiving.

SOP 3. GPS Data Collection

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP provides information on GPS data collection specific to implementing the NCCN Water Quality Monitoring protocol in streams and rivers. The material in this SOP should be used in conjunction with the step-by-step instructions for collecting and exporting GPS data using Trimble GeoXT, Trimble ReconXB, and Thales MobileMapper GPS receivers in the NCCN Global Positioning System Data Acquisition and Processing guidance document (NCCN 2009) available on the NCCN internet site at: http://science.nature.nps.gov/im/units/nccn/dm_docs/NCCN_GPS_Guidelines.pdf.

General Practices for GPS Data Collection

Training

Field crews are required to receive GPS training for the particular make and model of GPS unit they will be using prior to conducting field work. Contact the park GIS staff to schedule training in advance of the field season start.

Important Considerations for GPS Data Collection

The data collection standards outlined in Section 6 of the NCCN Global Positioning System Data Acquisition and Processing guidance document (see link above) apply to all types of GPS units and must be followed. This will produce the most accurate data and eliminate most frustrations associated with inability to obtain strong and accurate satellite signals. Whenever possible, the real-time correction option should be selected on the GPS unit to increase positional accuracy of the data.

The NCCN uses the Universal Transverse Mercator (UTM) coordinate system, zone 10 North (10N), and North American Datum of 1983 (NAD83) for all spatial data sets. Satellites broadcast positional information using the World Geodetic System 1984 (WGS84) datum, but most GPS units can be configured to display the position coordinates in UTM, NAD83. Be sure to set the GPS unit display to this coordinate system and datum (refer to the NCCN GPS Data Acquisition and Processing guidance document).

GPS data file names should be recorded on the field data forms or on field computers. File names should begin with the letter that has been assigned to and that uniquely identifies the GPS unit being used. The GPS field coordinates (coordinates displayed on the GPS unit in the field) and datum (NCCN uses NAD83) should also be recorded on field data forms. These coordinates will become the best measure of spatial location in the event a GPS data file is lost or corrupted. Be aware that these coordinates read from the GPS unit display in the field cannot be post-processed and are in the coordinate system and datum that were selected for the unit's display.

Office Preparations Prior to Field Data Collection

Contact NCCN GIS staff to schedule GPS unit use for the season, and to have those units prepared for field use (loading background imagery, sample site target coordinates, data dictionaries, etc). Refer to the Appendices in the NCCN Global Positioning System Data Acquisition and Processing guidance document for specific GPS unit operation details.

Also contact NCCN GIS staff to have MobileMapper Office or Trimble Pathfinder Office software installed on the office computer, and if needed, assistance with creating the appropriate GPS data folders within the Water Quality Monitoring project directory structure (Figure 3-1). In this example, "N:\" is a network drive (or computer hard drive that has a regular backup schedule). The GPS-related folders are organized by year and include: "Data_dictionary" for any GPS data dictionary files, "Import" for background layers or maps to display on the GPS unit, and "Rover_data" for the data collected with the GPS unit. The "Rover_data" subfolders include: "Base" for base station files used in differential correction, "Export" for GPS data exported to GIS or database formats, "Processed" for GPS files that have been post-processed, and "Raw" for the original, un-processed GPS rover (data) files.

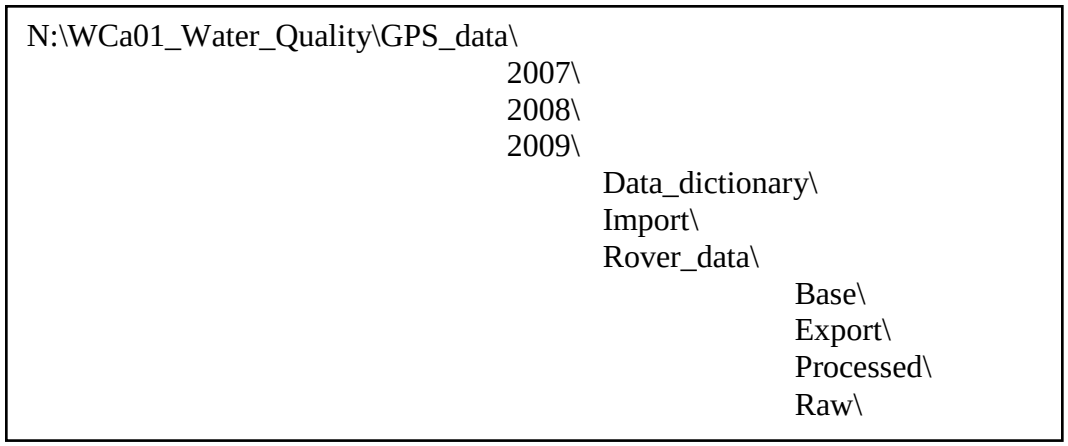


Figure 3-1. Example of folder organization for GPS data within project directory structure.

Field Data Collection

Navigation with the GPS

The GPS unit can be used for navigating to remote sample sites if the route to the site is not on an established trail or is difficult to follow. Identification of such sites should be done in the office prior to scheduled field work so that the site's target coordinates can be loaded onto the GPS unit for navigation purposes. Contact the GIS Specialist for loading the target coordinates on the GPS unit. The GIS Specialist is also responsible for loading any background layers (such as trails) and imagery, if available, onto the GPS units. The images should be clipped from the most recent NAIP 1-meter resolution imagery and saved in MrSid format to minimize image size. See the "Office Procedures" section of SOP 5: Site Evaluation and Establishment, for details on office evaluation of site accessibility.

While the GPS is an excellent tool for navigation, it should not be exclusively relied upon for this purpose. It displays a straight-line azimuth and distance to targets and will not necessarily indicate the safest navigation route (for example, following ridge lines, safely crossing rivers or circumnavigating cliffs). At times the GPS unit may not function due to location (i.e. in a canyon), low satellite coverage, or battery power loss. Always use a map and compass (and altimeter if available), in addition to the GPS for navigation. Refer to the Appendices in the NCCN Global Positioning System Data Acquisition and Processing guidance document for detailed instructions on navigating with the GPS unit.

Mapping Site Features

A variety of features will be mapped with GPS at each sample site. To assist with this, the GPS will have a data dictionary for mapping reference points at all sites, invasive species infestations, and other features of interest. The park GIS Specialist is responsible for updating and loading the data dictionaries onto the units prior to GPS training and field data collection. Verify that the data dictionary WCa01_XXXX.ddf is loaded if using a Trimble GPS unit and the data dictionary WCa01_XXXX.mmf is loaded if using a MobileMapper GPS unit (where XXXX denotes the sampling year). Refer to the Appendices in the NCCN Global Positioning System Data Acquisition and Processing guidance document for detailed instructions on mapping a point with the GPS unit.

Sample Site Reference Point

At all Water Quality Monitoring sample sites, a site "reference point" must be mapped with the GPS (See SOP 5: Site Evaluation and Establishment). This establishes the coordinates of the sample site to use for all future monitoring activities.

Invasive Species

Small infestations of invasive species will be mapped with the GPS. See SOP 10: Documenting Invasive Species Occurrence, for more detail.

Transferring GPS Receiver Field Data to a Computer

After each tour of duty, field crews are responsible for transferring raw GPS files from the GPS units to computers or network servers that are routinely backed-up. Files should be transferred to the "Raw" folder in the relevant park's Water Quality Monitoring project directory structure. Detailed instructions on data transfer for each type of GPS unit are documented in the Appendices of the NCCN Global Positioning System Data Acquisition and Processing guidance document.

Post-processing GPS Data

NCCN GIS staff will be responsible for post-processing raw GPS files and exporting them to GIS format as needed. Detailed instructions on data processing for each type of GPS unit are documented in the Appendices of the NCCN GPS Data Acquisition and Processing guidance document. Post-processed files should be saved in the "Processed" folder, and the subsequently created GIS shapefiles should be saved in the "Export" folder within each park's Water Quality Monitoring project directory structure.

Quality Control

- Conduct pre-season training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable and that the coordinates for any GPS-mapped positions are also documented on the field forms.
- Note any discrepancies or measurement problems on the field data form.

Equipment List

- Pen/pencil
- Clipboard
- Field data sheets
- Field maps (topographic and aerial photos)
- GPS unit and operating instructions/SOP

References

North Coast and Cascades Network (NCCN). 2009. NCCN Global positioning system data acquisition and processing. U.S. Department of Interior, National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm (accessed 31 March 2010).

SOP 4. Order of Operations

Version 2/1/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

The NCCN Water Quality Monitoring protocol will be implemented in wadeable rivers and streams within the boundaries of NCCN parks. The water quality parameters and how they are measured in these aquatic habitats have the potential to impact other parameters at a given site; thus it is imperative that the order of field and laboratory procedures will be diligently followed. The specifics of these parameters and associated field and laboratory methods are detailed in the relevant Standard Operating Procedures (SOP) for this protocol.

This SOP identifies the list of SOPs that will be implemented for water quality monitoring in wadeable rivers and streams and identifies the order of operations for field activities.

Order of Operations for Field Procedures

Wadeable Streams and Rivers

1. Site evaluation and establishment (SOP 5)
2. Stream and river reach delineation (SOP 6)
3. Collect core water quality and turbidity measurements (SOP 7)
4. Collect benthic invertebrates (Gravel/Cobble Systems) (SOP 8)
5. Conduct reach rapid habitat assessment and human activity check-list (includes photo documentation) (SOPs 11, 12)
6. Install continuous temperature station, retrieve station or download data from existing station (SOP 9)
7. Document invasive species encountered (SOP 10)
8. Decontamination of equipment (SOP 13)

Quality Control

- Conduct pre-season training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.

SOP 5. Site Evaluation and Establishment

Version 2/1/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

The NCCN Water Quality Monitoring Project will sample a series of wadeable streams and rivers that are at a high risk of impairment. Park-based aquatic leads have selected specific sites within these streams and rivers that are at the greatest risk of impairment, provide the safest access and/or have a history of monitoring. This SOP documents sample site evaluation and establishment procedures for a site selected from the monitoring project sampling frame.

This SOP contains three basic steps:

1. Office procedures to locate and evaluate the accessibility of the sample site using maps and aerial photographs.
2. Navigation to sample site.
3. Field verification of the habitat type and establishing a "reference point" for the sample site.

The procedures have been adapted from the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) and the Wadeable Streams Assessment, part of the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) (USEPA 2004a, and USEPA 2004b, AREMP 2007).

Definitions

- Wetted width – the width of the stream at the time of the survey.
- Bankfull width – the width of the channel at bankfull discharge.
- Bankfull discharge – the dominant channel forming flow (peak flow), with a recurrence interval seldom outside the 1- to 2-year range.

Office procedures

Locate site on map and verify NCCN Site ID

The Project Lead will consult with the Data Manager and GIS Specialist to obtain coordinates for selected sample sites. The Project Lead or Lead Technician will locate a selected site on a 1:24,000 topographic map or using GIS to display orthoimagery (NCCN parks currently have National Agriculture Imagery Program (NAIP) imagery for 2006 and 2009) to verify that the site's coordinates align with the actual water body of interest. At this stage, the Lead Technician should also ensure that road maps are also available to assist field crew in driving to the general vicinity of the sample site.

Sample sites will be identified using the NCCN Site ID. These identifiers are a combination of the Park acronym (EBLA, LEWI, MORA, NOCA or OLYM), a water body code (e.g. rv = river, st = stream), the water body name if one is available, and the elevation of the sample location in feet above sea level. For example, Newhalem Creek, a wadeable stream in NOCA is sampled at near its mouth at an elevation of 490 feet, would have 'NOCA_st_Newhalem_490' as its official NCCN site ID. Water bodies that have not been named should be identified as "unnamed." Do not use the moniker "No Name" since this is the official name of some NCCN lakes and streams.

All sample labels will also contain the date the sample was taken. This information will comply with NPSTORET requirements. See SOP 16.A: Data Entry and Verification for more detail on NPSTORET file naming conventions in assigning sample sites their unique "Site ID." Note: in situations where a park has a history of collecting data from a particular location the existing/established identifier can be used in place of the water body name.

Examples:

- MORA_rv_Nsqually_2300… for a previously established monitoring location in the Nisqually River (near Longmire) at an elevation of 2300 feet beginning at river mile 75 in MORA.

- LEWI_st_Megler_100… for a sample reach located at 100 feet elevation in Megler Creek in LEWI.

Site accessibility evaluation

The site should be evaluated for accessibility with respect to steepness of terrain, proximity to trails, potential river crossings, and any other features that prevent safe travel. All sites should be located within at least one day's travel by foot from the nearest road or trailhead, and field crews should not have to cross terrain features that pose more than a minimal amount of severity (NPS 2011). These terrain features could include:

- Stream or river crossings greater than one meter deep

- Cliff bands and/or canyons with valley walls that present a falling hazard greater than two meters

- Stream or river crossings that present risks associated with large woody debris (sweepers) and/or significant white-water that cannot be mitigated

- Travel on snow or glaciers

- Travel along or crossing (by foot) busy roadways with vehicles traveling greater than 35 miles per hour

This evaluation can be conducted using GIS. Once a site has been determined to be accessible, field maps with the sample site overlaid should be printed for use in the field. The GIS Specialist can assist with the accessibility evaluation and the creation of field maps. The Project Lead or Lead Technician will consult with the GIS Specialist to have the site coordinates loaded onto a GPS unit for navigation and site mapping purposes. For more information on GPS use, see SOP 1: Field Season Preparations and Crew Training and SOP 3: GPS Data Collection.

Field procedures

Order of operations

1. Navigate to sample site location.

2. Verify habitat type and determine habitat suitability for sample collection.

3. Determine if sample timing is suitable for data collection.

4. Map reference point with GPS to establish the sample site and start of the sample reach, photograph reference point.

Site verification

The crew will navigate to the sample site using topographic maps and a GPS unit. See SOP 3: GPS Data Collection, for general information about GPS data collection, and refer to the step-by-step instructions for navigating and collecting GPS positions using various GPS receivers in the NCCN Global Positioning System Data Acquisition and Processing document (available at: http://science.nature.nps.gov/im/units/nccn/dm_docs/NCCN_GPS_Guidelines.pdf).

Upon arriving at the sample site determine that the habitat is indeed a wadeable river or stream following NCCN established definitions and document whether it is a "Gravel/Cobble" or "Low Gradient" system (Table 5-1).

Table 5-1. NCCN aquatic habitat definitions.

Habitat type	Definition
Wadeable streams/rivers	Wetted width is generally less than 25 m and most non-pool habitat is less than 1 m deep during summer low flows. The stream can be safely crossed in multiple locations.
Gravel/cobble	Active scour in present in the channel, i.e., fine particles have been removed or pushed to the side and larger substrate is visible.
Low gradient	Active scour is not evident. Stream bed is primarily sand, silt and/or vegetation.
Large rivers	Wetted width is generally more than 25 m and most non-pool habitat is more than 1 m deep during summer low flows. Gravel/cobble substrates inaccessible, >30 cm deep or absent from reach.

Next, the Lead Technician will evaluate the site for safety and has the authority to exclude or relocate a site if he or she deems it unsafe to access and sample. When a site is relocated for any reason, consideration should be given to the monitoring objectives for that location. For example, if the objective is to determine the potential impacts of a point source of stress than the sample site should not be located above the source of the stress. If the site is deemed safe to sample, the crew will then proceed with the site evaluation based on the habitat-specific criteria below.

After the site has been determined to be safe and meets the criteria below (or has been moved to meet the criteria), the GPS will be used to map the site and obtain updated coordinates. This location mapped in the field with the GPS will serve as the 'reference point' for the sampling event and will be used to relocate the site during future monitoring activities. The reference point will be the start (downstream end) of the sample reach. This 'reference point' must be drawn on sketched site map on the NCCN Stream Water Quality Field Form (Appendix F) and the GPS coordinates recorded in the "UTM E" and "UTM N" boxes of the data form.

Whenever possible, approach the site from downstream and navigate to the site coordinates using the GPS unit. The sample site will be established at the start of a reach and will be located in the middle of the stream channel, assuming this can be done safely. If the middle of the stream channel cannot be accessed safely, continue to the closest location up or downstream until a site

can established in the middle of the stream. Once the start of the sampling reach has been established, map the location as the reference point with the GPS. Photograph the reference point from an easily recognized landmark to facilitate relocating the site. Also take a photograph looking upstream and downstream from the reference point and record photograph details on the Streams and Rivers Trip Photo Log.

Criteria for determining suitability of a stream or river reach for sampling:

1. Active scour must be present in the channel, i.e., fine particles have been removed or pushed to the side and larger substrate is visible. Ephemeral streams that flow over vegetation are not sampled. Reaches that can be sampled include:

    - Wadeable reaches where >25% of the reach is wadeable and water flow is continuous.
    - Partial wadeable reaches where between 10 to 25% of the reach can safely be sampled by wadeable stream protocols.
    - Wadeable reaches with interrupted flow where water flow is not continual, but there is water in the sample reach.
    - Altered channels where there is a stream at the selected site, but the stream channel does not appear as it does on the map. An example is channel rerouting following a flood event. Establish a new sample reach start at the same relative position in the altered channel. Make careful notes and sketches of the changes on the field data sheets.

    Reaches that cannot be sampled include:

    - Dry channels where a discernible stream channel is present but there is no water within a 150-m reach centered on the sample site.
    - Impounded stream reaches where the stream is submerged under a lake or pond due to man-made or natural (e.g., beaver dam) impoundments. If the impoundment is natural, move to a new location that will allow achieving the monitoring objectives.
    - Other reasons where the site is non-target for reasons other than those above. Examples include underground pipelines, non-target canals, or map error, i.e. there is no evidence a stream channel or water body was ever present. For procedures following a significant rain event at a site otherwise eligible for sampling, see Sample Timing section below.
2. There must be well-defined bankfull indicators present signifying that the site is an active stream channel. An active channel will have some combination of the following bankfull indicators (Figure 5-1)(AREMP 2007):

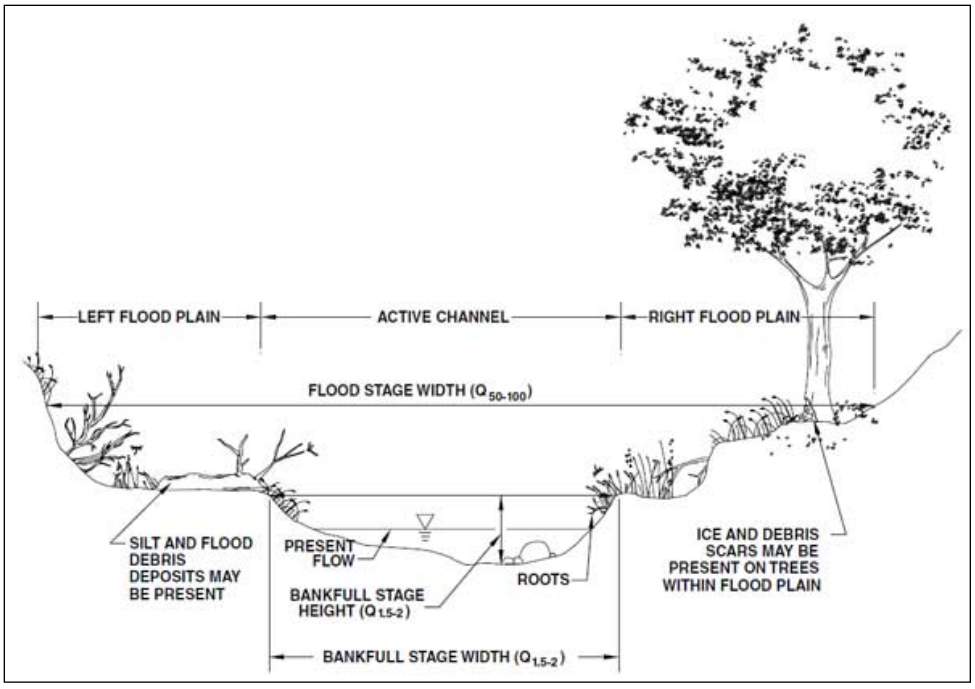


Figure 5-1. Illustration of bankfull width and its relation to the flood plain (USFS Technology and Development Program Publications, http://www.fs.fed.us/eng/pubs/htmlpubs/htm10232808/page03.htm).

- Active floodplain. This is a relatively flat, depositional area that is commonly vegetated and above the bankfull elevation.
- Depositional features such as point bars. The highest elevation of a point bar usually indicates the lowest possible elevation for bankfull stage. However, depositional features can form both above and below the bankfull elevation when unusual flows occur during years preceding the survey. Large floods can form bars that extend above bankfull whereas several years of low flows can result in bars forming below bankfull elevation.
- A break in slope of the banks and/or change in the particle size distribution from coarser bed load particles to finer particles deposited during bank overflow conditions.
- Elevation where mature key riparian woody vegetation exists. The lowest elevation of birch, alder, and dogwood can be useful, whereas willows are often found below the bankfull elevation.
- Ceiling of undercut banks. This elevation is normally below the bankfull elevation.
- Stream channels actively reform bankfull features such as floodplains after shifts or down cutting in the channel. Be careful not to confuse old floodplains and terraces with the present indicators.

3. In order to sample for macroinvertebrates the reach must have a minimum wetted width of 1 meter, a minimum depth of 0.1 meter and riffle habitat present.

4. In order to collect instrumented water quality data there must be flowing water with sufficient depth to completely submerge the water meter's probes.

5. The optimum reach for sampling is a stretch of stream 40 times the wetted width in length. If conditions at the site preclude the sampling of a full reach, the Lead Technician should review the parameters for which data are to be collected and determine whether to continue with some form of modified data collection (refer to the relevant data collection SOPs in making this decision).

Sample Timing

Storm events can skew water quality data, create conditions hazardous to field crews, make habitat delineation difficult, and damage expensive water quality sampling equipment. It is important to recognize high flow events and to refrain from sampling aquatic resources during such episodes.

During high flow events, the primary concern about surveying stream and river habitats is the safety of the field crew. Streams which are wadeable one day can rise dramatically overnight to a discharge volume that is too swift or deep for safe sampling. It is the field crew's responsibility to assess the size and velocity of streams and their potential hazard.

High flow events create chemical and biological conditions different than those at base flows. For sites that have been previously visited, the decision not to sample following a high flow event can often be made in the office. However, it is nearly impossible to determine "strict base flow" with any certainty at an unstudied stream, and such a restriction would also greatly shorten the period in which a site could be sampled. Thus some compromise is necessary regarding whether to sample a given stream or river due to storm events. To a great extent, this decision is based on the judgment of the field crew. The following criteria for determining whether to sample after a rain event are adapted from the EPA (2004a):

1. Monitor weather reports and rainfall patterns. Do not sample aquatic resources during periods of prolonged heavy rains.
2. If a stream or river is running at bankfull discharge or the water seems much more turbid than typical for the class of stream, do not sample that day.
3. Do not sample a stream if it is temporarily unsafe to wade in the majority of the stream reach. If the majority of the stream reach is permanently unsafe, then classify it as "partially-wadeable" stream and sample the portions that can be safely waded.
4. If a stream seems to be close to normal summer flows, and does not seem to be unduly influenced by storm events, it should be sampled (even if it has rained or is raining).

Quality Control

- Conduct on-site training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data forms.

Equipment List

- Pencil
- Clipboard
- Field data forms: NCCN Stream Water Quality Data Form, Streams Trip Photo Log
- Field maps (topographic and aerial photos)
- 50- or 100-m tape measure or laser range finder
- GPS unit
- Compass
- Camera
- Radio
- First aid kit
- Wading equipment (waders, boots, throw bag)

Specific Safety Considerations

Safety of field personnel is of the utmost importance. Some sites may have conditions that preclude full sampling of all areas due to water depth or flow speed, but it may still be possible to do the various assessments that do not require getting in the water (bank characterization, riparian vegetation and disturbance, stream/river assessment, rapid habitat assessment). It is also usually possible to collect instrumented water quality data near the bank. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Sketch a site map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

Aquatic and Riparian Effectiveness Monitoring Program (AREMP). 2007. Field protocol manual: 2007 field season. Regional interagency monitoring for the Northwest Forest Plan. U.S. Forest Service, Pacific Northwest Regional Office, Portland, OR.

NPS. 2011. Operational Leadership Participant Manual. USDI National Park Service, North Cascades National Park Service Complex. Available at: http://www.noca.nps.gov/safety/default.aspx

U.S. Environmental Protection Agency (USEPA). 2004a. Wadeable stream assessment: Field operations manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 2004b. Wadeable stream assessment: Site evaluation guidelines. EPA841-B-04-006. U.S. Environmental Protection Agency, Washington, D.C.

SOP 6. Reach Delineation and Habitat Characterization for Streams and Rivers

Version 2/1/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes the procedures for delineating stream and river reaches for sampling after a sample site has been verified as eligible and the reference point has been established per specifications in SOP 5: Site Evaluation and Establishment. These methods have been adapted from the U.S. Environmental Protection Agency's (EPA) Wadeable Stream Assessment: Field Operations Manual (USEPA 2004).

Unlike instrumented water quality data, which can be measured at a point, most of the biological and habitat structure measures require sampling a certain length of a stream or river to get a representative picture of the ecological condition. A length of 40 times the wetted width of a stream is necessary to characterize the habitat and biotic assemblages associated with the sampling reach. After establishing the sample reference point (SOP 5: Site Evaluation and Establishment) and mapping it with the GPS (SOP 3: GPS Data Collection), the following procedures are used for delineating the sample reach.

Note: Refer to SOP 5: Site Evaluation and Establishment for the definitions of "wetted width" and "bankfull width" used in this SOP.

Sample Reach Delineation

A sample reach will be delineated above the reference point as a length of stream that is 40 times its average wetted width. Minimum and maximum reach lengths are 150 and 500 m, respectively.

Determine average wetted width and sample reach length

Starting at the reference point, use a tape measure or laser range finder to determine the wetted width of the channel at three locations considered to be of typical width. Collect these measurements from an area within approximately five channel widths of the reference point. Average the three measurements and round to the nearest 1 m. If the average width is less than 4 m, use 150 m as a minimum sample reach length. For channels with interrupted flow, estimate the width based on the unvegetated width of the channel (again, with a 150 m minimum). For streams or rivers with an average wetted width greater than 13 m use 500 m as the reach length to sample. Record the wetted width used to determine the reach length on the NCCN Stream Water Quality Field Form along with the length of the sample reach (Appendix F).

Note: When working upstream of the reference point, try to minimize the amount of time spent in the wetted channel until after the benthic macroinvertebrates are collected.

Wetted width in braided streams

Determining the mean width of extensively braided systems for purposes of laying out the sample reach length is challenging. For braided systems, calculate the mean width as the bankfull channel width. For relatively small streams (mean bankfull width ≤15 m) the sampling reach is defined as 40 times the mean bankfull width. For larger streams, (>15 m), sum up the actual wetted width of all the braids and use that as the width for calculating the 40 times wetted width reach length. The purpose of the 40 channel width reach length is to sample enough stream

length to incorporate the variability in habitat types, i.e. to sample a long enough segment to include 2 to 3 meander cycles (about 6 pool-riffle habitat sequences).

This modification is intended to avoid sampling an excessively long stretch of stream. In a braided system where there is a 100 m wide active channel (giving a 4 km reach length based on the standard procedure) and only 10 m of actual wetted width (for example, five 2-m wide braids), a 400 m long sample reach length is likely to be sufficient, especially if the system has fairly homogenous habitat throughout its length. If in doubt about appropriate reach length for a braided system, it is better to err on the excessive side, and remember that the minimum reach length is always 150 m. Make detailed notes and sketches on the field data form about how this reach delineation was made.

Lay out sample reach

Check the condition of the channel upstream of the reference point (start of sample reach), continuing enough for visual verification up to the distance of 40 times the average wetted width (a minimum of 150 m) as determined in above. Scouting the sampling reach ensures it is clear of obstacles that would prohibit sampling and data collection activities. Determine whether the sample site start needs to be adjusted due to confluences with tributaries that contribute >10% of the stream flow to the sample reach, impoundments (lakes, reservoirs, ponds), physical barriers (e.g., waterfalls, cliffs), or because of access restrictions to a portion of the reach.

If such a confluence, barrier, or access restriction is present, note the distance and flag the confluence, barrier, or restriction point as the endpoint of the reach. Move the reference point of the reach an equivalent distance downstream from the original starting location. These steps should be completed so that the total reach length does not change. In this situation, a new sample site start is designated at the lower boundary of the reach. Be sure to re-GPS and record on the field data form the coordinates of the *new* sample site start following the methods in SOP 3: GPS Data Collection.

Special considerations for adjusting the sample site start and reach layout:

- If the sample site has been targeted due to a known point source of pollution, any adjustment to the sample site start must also ensure that the entire sample reach is completely downstream of the point source.

- Do not adjust the reach layout to avoid man-made obstacles such as bridges, culverts, rip-rap, or channelization, or in streams with interrupted flow to obtain more inundated areas to sample.

- When possible, avoid changing Strahler stream order (at the 1:100,000 scale), i.e. do not proceed upstream into a lower order stream or downstream into a higher order stream when laying out the stream reach. If you have to change the stream order, move the end of the sample reach to the confluence with the tributary as described above.

Before leaving the stream, sketch a map of the stream reach sampled on the field data form. In addition to any other interesting features that should be marked on the map, note any landmarks and directions that can be used to find the sample site start for future visits. Photograph the “reference point” from an easily recognized landmark to facilitate relocating the site. Also take a

photograph looking upstream and downstream from the reference point. Record photograph details on the Trip Photo Log and document completion of this task on the NCCN Stream Water Quality Field Form (Appendix F).

Physical Habitat Characterization

Wetted width, bankfull width, thalweg depth, human influence, channel constraint, and debris torrents/recent floods are the physical habitat characteristics that will be assessed. These assessments can be conducted simultaneously with laying out the sample reach (see above), beginning at the reference point and moving upstream to the upper end of the reach. Be sure to document with photographs any notable human disturbances or other unique physical habitat features and record on the Trip Photo Log.

Measuring wetted width, bankfull width and thalweg depth

Wetted width and thalweg depth are measured together systematically at each of ten locations, and bankfull width is measured at three locations within the sample reach that have the best bankfull indicators (see SOP 5: Site Evaluation and Establishment for and illustration of the bankfull channel and descriptions of bankfull indicators). The first wetted width and thalweg depths measurements are made at the reference point and subsequent measurements are made at equally-spaced intervals upstream. The length of the intervals is set at one tenth of the total reach length, rounded to the nearest meter. For example, a reach that is 168 m long would have intervals that are 17 m long, and measurements would be made at 0 (reference point), 17, 34, 51 m, etc. Interval distances can be measured along either the right or left bank using a tape measure or laser range finder. Measurements should be made as close to the interval locations as possible to avoid bias in the measurements.

Wetted Width Measurements

Wetted width is the width of the wetted channel at the time of the survey and is measured as the linear distance between the left and right bank perpendicular to the flow. Wetted width can be measured with either a tape measure or laser range finder. When using a range finder, kneel at the edge of wetted channel and “shoot” the distance to the opposite bank’s wetted edge. Measurements should be recoded to the nearest tenth of a meter.

Thalweg Measurements

The thalweg is the path of a stream that follows the deepest part of the channel. It can be visualized as the line of steepest decent along the stream. Wade into the stream perpendicular to the flow, and using the stadia rod (measuring rod), probe the streambed to locate the deepest part of the channel. Record this maximum depth measurement as the thalweg depth.

Bankfull Measurements

Bankfull width is the width of a stream channel at the point where over-bank flow begins during a flood event. See SOP 5: Site Evaluation and Establishment for an illustration of the bankfull channel and descriptions of bankfull indicators. Straight, low-gradient riffles with uniform banks are best for identifying bankfull stage and therefore, bankfull width. To make the measurement, first flag the edges of the bankfull channel using well defined bankfull indicators on both banks and then make measurements using either a tape measure or laser range finder following the same methods as for wetted width. Bankfull width cannot be measured in situations where the

channel is anastomosing or where there is no clear line of sight. Measurements should be recoded to the nearest tenth of a meter.

Human Influence

Evaluate the presence and proximity of various types of human activity both within the stream or river channel and in the adjacent riparian areas on both banks. The assessment is qualitative; look for evidence of human disturbance and determine into which of the four proximity classes (identified in Table 6-1) any disturbance is observed. Twenty categories of human disturbance activity are identified in Table 6-2. For each type of disturbance listed in the table, record the proximity class on the NCCN Stream Water Quality Field Form (Appendix F). If a disturbance is within more than one proximity class, record the one that is closest to the stream or river (e.g., "C" takes precedence over "P").

Table 6-1. Four proximity classes of human disturbance for streams and rivers.

Proximity class code	Proximity class description
B ("Bank")	Present in the stream or river and/or on the bank
C ("Close")	Present within the 10 m of the bankfull channel riparian area
P ("Present")	Present but outside the 10 m from bankfull channel riparian area
O ("Absent")	Not present within or adjacent to the 10 m from bankfull channel riparian area

Table 6-2. Categories of human disturbance that potentially could occur in stream and river sample sites.

Evidence of human influence
Backcountry campsite
Building
Campground
Culvert
Dam/Diversion
Dike/Riprap
Land clearing
Landfill/Dump
Lawn
Logging
Mine
Pasture/Hayfield
Pavement
Pipe (inlet)
Pipe (outlet)
Rangeland/Grazing
Road/Railroad
Row crop
Trash

Channel Constraint, Debris Torrents, and Recent Floods

Channel Constraint

Envision the stream or river at bankfull flow and evaluate the degree, extent and type of channel constraint, using the procedures outlined below.

1. Classify the stream or river reach channel pattern as predominantly a single channel, an anastomosing channel, or a braided channel.

- Single channels may have occasional in-channel bars or islands with side channels, but feature a predominant single channel or a dominant main channel with a subordinate side channel.

- Anastomosing channels have relatively long major and minor channels (but no predominant channel) branching and rejoining in a complex network, diverging and converging around vegetated islands.

- Braided channels also have multiple branching and rejoining channels, separated by unvegetated bars. These sub-channels are generally smaller, shorter, and more numerous, often with no obvious dominant channel.

2. Determine whether the channel is constrained within a narrow V-shaped valley, constrained by local features (incision) within a broad valley, free to move about but within a relatively narrow valley floor, or free to move about and unconstrained in a broad floodplain.

3. Determine the bank and valley features that constrain the stream river. Choices for the type of constraining features include bedrock, hillslope, terrace/alluvial fan, human alteration (e.g., road, dike, landfill, rip-rap, etc.), and none.

4. Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels, this is 0%).

5. Estimate the "typical" bankfull channel width, and estimate the average width of the valley floor. Note: If you cannot directly estimate the valley width (e.g., it is further than you can see, or view is blocked by vegetation), record the distance you can see and check the appropriate box on the field data form.

Debris Torrents and Recent Major Floods

Major floods substantially overtop the banks of streams and rivers and occur with an average frequency of less than once every 5 years for streams and up to 100 years for large rivers. They may scour away or damage riparian vegetation on banks and gravel bars that are not frequently inundated. These floods typically transport large woody debris and bedload sediment and alter the streambed and banks through scouring and deposition. In contrast, debris torrents are flood waves of higher magnitude and shorter duration, and their flow is comprised of a dense mixture of water and debris that exerts tremendous scouring forces on streambeds. In NCCN parks, debris torrents will occur primarily in steep drainages and are relatively infrequent, occurring typically less than once in several centuries. They are typically started by the release of a large volume of water upon the breaching of a natural or human-constructed impoundment, a process often initiated by mass hillslope failure during high rainfall or rapid snowmelt.

To evaluate the stream or river reach for evidence of torrents or major floods, examine the reach for any of the characteristics listed on the field data form. It may also be beneficial to examine the channel upstream and downstream of the actual sample reach. Areas of torrent scour

upstream may point to the sample reach being a torrent deposition area, and conversely, massive deposits of logs and debris downstream may indicate the sample reach is a torrent scour area.

Quality Control

- Conduct on-site training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.

Equipment List

- Pen/pencil
- Clipboard
- Field data forms: NCCN Stream Water Quality Field Form, Trip Photo Log
- Field maps (topographic and aerial photos)
- GPS unit
- Camera
- 50- or 100-m tape measure or laser range finder
- Stadia rod
- Radio
- Wading equipment (waders, boots, throw bag)
- First aid kit
- Flagging

Specific Safety Considerations

Safety of field personnel is of the utmost importance. Some sites may have conditions that preclude full sampling of all areas due to water depth or flow speed. For example, it might be impossible to do thalweg depth profiles and flow measurements, but it may still be possible to do the various assessments that do not require getting in the water (bank characterization, riparian vegetation and disturbance, stream/river assessment, rapid habitat assessment). It is also usually possible to collect a water chemistry sample near the bank. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Sketch a site map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

U.S. Environmental Protection Agency (USEPA). 2004. Wadeable stream assessment: Field operations manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

SOP 7. Instrumented Water Quality Parameter Measurements for Streams and Rivers

Version 2/1/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP details the process used for measuring instantaneous temperature, pH, dissolved oxygen (DO), specific conductance and turbidity. These parameters will be measured in the field during every sampling event. The NPS Water Resources Division (WRD) mandates the measurement of temperature, DO, pH and specific conductance for all water quality vital signs monitoring. In addition to the WRD-mandated parameters, the NCCN Aquatics program also measures water clarity (turbidity) at every sample event. Methods have been adapted from the Aquatic and Riparian Effectiveness Monitoring Program (AREMP 2007) and the U.S. Environmental Protection Agency's (EPA) Wadeable Stream Assessment: Field Operations Manual (USEPA 2004). Temperature is also measured continuously using data loggers that record water temperature every hour (SOP 9: Continuous Water Temperature Sampling in Streams and Rivers).

Temperature, DO, pH and specific conductance are sampled *in situ* using a multi-parameter digital meter through the use of different probes that can be attached. Two types of multi-parameter digital meters, either a Hach or YSI meter, are used among the parks in the NCCN for measuring the temperature, DO, pH, and specific conductance. The instrument used for these parameter measurements needs to meet the measurement quality objectives outlined in Table 15-3 of SOP 15: Quality Assurance and Control Plan. Refer to the User Manual of the particular meter being used for the number and type of batteries required. Water clarity is measured using optical-based Hach turbidimeters that meet the measurement quality objectives outlined in Table 15-3 of SOP 15: Quality Assurance and Control Plan.

Office Procedures and Calibration

Prior to every sampling site visit, the meters used to measure the core water quality parameters should be properly calibrated according to the manufacturer specifications. Refer to the meter's User Manual for the procedures. Use 1413 µS/cm and 100 µS/cm solutions for calibrating specific conductance. pH can be calibrated using a two point calibration with either a pH 4 and 7 buffer solutions or pH 7 and 10 buffer solutions. Following each visit, the meters must be carefully cleaned and stored according to manufacturer instructions.

Field Procedures

Measurements of temperature, DO, pH, specific conductance and turbidity should be completed before any in-stream field work is conducted. Most meters used in the NCCN have attachment locations for two probes and can thus record data for three of the four parameters simultaneously (the DO, pH, and conductivity probes also measure temperature). For this reason, it is recommended that the conductivity probe be used first to obtain the specific conductance and temperature measurements and then the DO and pH probes will be attached to collect data for DO and pH.

Selecting Location for Meter Placement

Upon arrival at the sampling site, the sampling reach will be delineated according to instructions in SOP 6: Reach Delineation and Habitat Characterization for Streams and Rivers. When this is

completed, the first step in the sampling order of operations is to collect the instrumented water quality parameter measurements. Select a place for meter placement and sample collection at the downstream end of the reach, unless a tributary contributing >10% of the flow enters the reach. In such cases, place the meter five wetted widths downstream of the tributary junction. When placing the probe in the water, choose a location as close to the center of the stream as is practical, away from the banks, in an area such as a riffle or pool tail crest where the water flowing past the probe is representative of the water in the stream. Avoid placing the probe in a turbulent area or pool. In turbulent areas such as those with white water, the DO will be elevated, and pools do not have adequate mixing to have representative values for DO or temperature.

For streams with interrupted flow, if the upstream end of the reach is dry and there is water elsewhere in the sample reach, take the measurements from the location nearest to the upstream end of the reach having water with a surface area greater than 1 m^2 and a depth greater than 10 cm. A site upstream of where habitat and biological sampling will occur is preferable as these activities can affect the water quality measurements. If deviations are made in the collection location, be sure to document on the field forms that the measurements did not occur at the designated reach end and record the new location on the field forms and map. Do not collect water quality data if there is no acceptable location within the sampling reach; note this on the NCCN Stream Water Quality Field Data Form (Appendix F) and explain why the measurements were not obtained in the "Additional Notes" section of the form.

Pre-Sampling Check

Before collecting data in the field, the instrument should be checked against the calibration buffers to ensure the instrument is reading accurately. Conduct a measurement in the field at the sample location using 100 µS/cm buffer solution for conductivity and pH 7 buffer solution for pH. Record these measurements on the data form and calculate the relative percent difference (RPD) for each using the following equation:

$$\text{RPD} = \left[\frac{S_1 - S_2}{(S_1 + S_2)/2} \right] \times 100$$

Where: S_1 = known value (reported on bottle) of the calibration solution, and S_2 = measured value of the calibration solution.

In order to proceed with data collection, the RPD needs to be less than 20%. If your RPD is >20%, measure the calibration solution again. Allowing the probe to equilibrate longer may correct the problem. If these do not correct the problem you will need to re-calibrate the meter in the field before proceeding. If the re-calibration does not improve the RPD, then record the data and flag the values as QA/QC concerns.

Data Collection

1. Attach the conductivity probe to the meter and collect seven measurements for specific conductance and temperature. Allow the reading to stabilize or lock before recording the values on the data form. Record the time of measurement on the data form. Remove the probe from the meter.

2. Attach the DO and pH probes to the meter and collect seven measurements for DO and pH. Allow the reading to stabilize or lock before recording the values on the data form. Record the time of measurement on the data form. Remove the probes from the meter. Note: pH is difficult to measure in the low ionic strength waters found throughout most of the NCCN. If the reading will not lock, record seven measurements that appear to be the most stable.

3. Finally, obtain a series of seven turbidity measurements. These samples should be collected at mid-depth using the sample vials provided with the instrument. Make sure to triple-rinse the vial before collecting the samples. When collecting the sample, hold the vial upside down, submerse it to the appropriate depth, and then turn it right side up until the vial fills. After removing the vial from the stream, dry it with a soft cloth that will not scratch it. In situations where the water is very cold, condensation will develop on the outside of the vial; care must be taken to ensure that moisture is not present since this will give an erroneously high turbidity reading. Either warm the vial in the sun or hold it in hand to prevent condensation. Next, insert the vial into the turbidity meter, close the cap, and record the measurement when stabilized.

Post-Sampling Check

After you have completed the data collection for pH and specific conductance, post-sampling checks should be made using 100 μS/cm and pH 7 buffer solutions. Record these values on the Stream Water Quality Data Form.

Quality Control

- All meters require calibration before use at each site visited.
- Inspect probes for any damage prior to each site visit.
- Conduct on-site training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.
- Multi-parameter digital meter User Manual recommendations for maintenance, calibration, probe cleaning and storage are followed and documented both prior to and after each site visit.

Equipment List

- Pen/pencil
- Clipboard
- Field data forms: NCCN Stream Water Quality
- Field maps (topographic and aerial photos)
- Hach or YSI multi-parameter digital meter (and User Manual)
- Hach or YSI probes for DO, pH, conductivity, and temperature
- Batteries for Hach or YSI multi-parameter meter (NOTE: Some Hach meters can also use nickel metal hydride batteries – but do not mix battery types!)
- Portable Hach turbidimeter

- Soft, non-scratching cloth for drying turbidimeter sample vial
- 50- or 100-m tape measure or laser range finder
- Radio
- Wading equipment (waders, boots, throw bag)
- First aid kit
- Flagging

Specific Safety Considerations

Safety of field personnel is of the utmost importance. If a sample reach is not fully wadeable, use care in selecting areas to sample. Measurements may still be made from near the bank. Only sample or measure what can be accomplished safely. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Use the sketched map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

Aquatic and Riparian Effectiveness Monitoring Program (AREMP). 2007. Field Protocol Manual: 2007 field season. Regional interagency monitoring for the Northwest Forest Plan. U.S. Forest Service, Pacific Northwest Regional Office, Portland, OR.

U.S. Environmental Protection Agency (USEPA). 2004. Wadeable stream assessment: Field operations manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

SOP 8. Benthic Macroinvertebrate Sampling in Lotic Gravel/Cobble Habitats

Version 5/17/2011

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Benthic macroinvertebrates (BMI) are organisms that live in the bottom of streams, rivers and lakes. This SOP outlines the steps necessary to collect benthic macroinvertebrates from wadeable streams and rivers with gravel/cobble substrates. The methods in this SOP have been adapted from the Pacific Northwest Aquatic Monitoring Partnership protocol for benthic macroinvertebrate collection and analysis (Hayslip 2007).

Field Procedures

Sample Locations

Benthic macroinvertebrates are collected using a 'kick sample' technique at four randomly selected points within the stream reach. A 'sample' is defined as the composite of the BMI collected at these four points. For QA/QC purposes, multiple samples may need to be collected from the same stream reach. If these additional samples are taken, then another four randomly selected points must be chosen and the BMI collected combined into another composite sample.

1. Riffles are the primary habitat type recommended for sampling macroinvertebrates. Riffle areas have relatively fast currents, moderate to shallow depth, and cobble/ gravel substrates. These areas generally have the most diverse macroinvertebrate assemblage. Also standardization of field methods is simplified by using a single, readily identifiable habitat type.

2. Four 2 ft^2 areas are sampled from each stream reach for a total of 8 ft^2 of stream bottom. These sample sites are located in the first four distinct riffles encountered as one progresses upstream within the reach. If a riffle is over 50 meters in length, it is appropriate to collect two samples from this riffle.

3. To determine net placement within the sampled riffle, generate two random numbers between zero and nine for each site. The first number (multiplied by 10) represents the percent of the habitat's length upstream to where the sample will be located. The second number (multiplied by 10) represents the percent of the stream's width from left bank to where the sample will be located. Estimate by eye where the length and width distances intersect and take the BMI sample at this location. If it is not possible to sample at the selected location (e.g. a log is in the way or the stream is too deep) draw additional random numbers until a suitable location is selected.

4. A 500-μm mesh D-frame kick net is used to collect macroinvertebrates from the stream bottom. The base of the net is placed on the stream bottom and a 2 ft x 1 ft metal frame is placed in front of the net to delineate 2 ft^2 of substrate. This substrate is then thoroughly disturbed to a depth of 4 to 6 inches, and the larger pieces of substrate are rubbed by hand while submerged in the stream to remove invertebrates. The disturbed organisms and detritus float downstream into the net and are thus collected. Disturbance of the substrate in front of the net occurs for as long as is necessary to dislodge macroinvertebrates from the 2 ft^2 area.

5. In streams with high amounts of fine particulate organic matter, the net should occasionally be lifted from the water allowing the organic matter to settle. This will facilitate clearing the net and allow the water to flow through the mesh rather than over the edges of the mouth as it sits in the stream.

Field Sample Processing and Preservation

1. All the contents (i.e., substrate, woody debris and organisms) of the sample in the net are emptied directly into a bucket or tray.

2. Ensure the entire sample contents are removed from the net. Make a close inspection of the net for any remaining organisms, which can be removed with forceps if necessary.

3. Samples with large amounts of debris can be elutriated in a white photographic or similar tray to remove large pieces of wood and other debris. This is accomplished by agitating the sample and pouring off the smaller sized organic particles that are washed through a hand-held 500-µm mesh net. Be sure to inspect all discarded debris for organisms. This process reduces the amount of organic matter from the sample and insures better specimen preservation.

4. If Step 3 is not necessary pour the entire sample into the small hand held mesh net.

5. Gently squeeze the sample in the mesh cone to remove excess water.

6. Repeat this process for each of the randomly selected sample locations.

7. Samples can be individually bagged, split into more than one bag, or field composited depending on the amount of material in the sample. All samples must be double bagged in WHIRL-PAK® bags, labeled (duplicate labels—one in each bag) and preserved with 95% ethanol which should fill the WHIRL-PAK® to more than one inch above the sample.

8. Labels will include NCCN Site ID, sample number (#1, #2, #3, etc.), number of bags for each sample, sample date, and initials (First, Middle, Last) of collector(s).

9. All sample location numbers will be recorded on a field map along with other pertinent information from other SOPs.

10. Record number of sample containers for the primary sample and for the replicate sample, if taken, in the BMI section of the NCCN Stream Water Quality Field Form (Appendix F).

11. If additional samples are being collected for QA/QC purposes, repeat all of the steps above (Sample Locations 1 through 5 and Field Sample Processing and Preservation 1 through 10) and sequentially label each composite sample.

Laboratory Processing and Specimen Identification

1. Sample Log-In Procedure:

a. When benthic macroinvertebrate samples are brought in from the field, the sample containers should be inspected for leaks and checked to ensure that the ethanol covers the sample by at least 3 cm. If samples are to be left for long periods of time before they are processed, the alcohol in the samples should be decanted and replaced with fresh 95% ethyl alcohol.
b. Check to ensure that sample labels are visible and legible. If necessary, re-label the samples.
c. Each sample should be logged in using the Stream BMI Sample Log Form (Appendix F). The information should be recorded as follows:

- NCCN Site ID = See SOP 5: Site Evaluation and Establishment ("Locate site on map and verify NCCN Site ID" section)
- Watershed Name = name of the watershed
- Sample # = For example, #1, #2, #3, etc.
- Collection Date = record the date the sample was collected in the YYYYMMMDD format (example: 2007AUG02 would signify August 2, 2007)
- Number of Containers = the number of containers holding each sample
- Notes = any relevant information related to deviations from this SOP

d. Immediately refrigerate (4°C) all samples.

2. BMI sample sorting procedure: The goal of these processing and subsampling procedures is to select an unbiased, random representation of BMI specimens from a composite of the four benthic kick samples taken from each stream. Sorted samples will be used to develop reporting output variables based primarily on taxa richness and composition related metrics (Note: sample collection procedures are semi-quantitative, therefore an estimate of the density of organisms in the samples is not one of the data analysis objectives). A minimum of 500 organisms should be removed from each composited sample using an area-based sieve splitting approach. Methods are adapted from those developed by the USGS (Cuffney et al. 1993, Moulton et al. 2000), and the Utah State University Bug Lab (http://www.usu.edu/buglab/SampleProcessing/labProcedures.cfm, accessed 31 March 2011).

a. Gather all the samples from a sampled water body, checking the total number of sample containers against the sample log.
b. Combine all the samples in a bucket and cover with water. Make sure each sample container is empty of all contents before proceeding.
c. Assign the sample an ID. This should consist of the Site ID, followed by an underscore plus the Sample Date in the YYYYMMMDD format (example: 2006AUG02), followed by an underscore plus the Sample Type (comp = composited subsamples and Rcomp = composited replicate subsamples). See Step (l) below for an example of a Sample ID.
d. Elutriate the composited sample and pour it through a 500μm mesh cone, rinsing thoroughly with fresh water until most of the fine sediments and silt are flushed. Large debris can be rinsed into the mesh cone and discarded. If the sample contains significant amounts of sand and gravel, you will need to swirl and decant it several times to separate the mineral and large organic material. The sand and gravel can be

discarded after it has been closely examined for caddisflies, snails, clams, or other organisms which should be added to those in the cone. At the end of this step, the organisms and organic matter should be separated from the majority of the sand and gravel.

e. Decide if the sample requires splitting. Samples with little debris and with less than approximately 600 organisms do not require splitting, otherwise splitting is required.
f. The first step in splitting the sample is to place a framed sheet of 500μm mesh net into a tray and add approximately 3 cm of water to facilitate the even distribution of debris. The mesh should be evenly divided into 5 cm x 5 cm blocks. Each block should be permanently delineated and numbered to facilitate accurate identification of the subsample size.
g. Evenly distribute the material from the cone on the surface of the mesh and gently lift it out of the water. Roll dice or use another method to select a random number corresponding to one of the marked squares. Using a knife or spatula, separate the sample material along the marked line of the randomly selected block and remove this material, placing it in a tray for sorting. Leave the rest of the sample intact on the screen.
h. Remove all organisms from the sorting tray using a lighted 3 to 10x magnifying lens and place into a vial containing a preservative of 70 to 90% alcohol. If you are introducing small droplets of water into the vial with the specimens you will need to decant the vial and refill with the concentrated preservative.
i. Oligochaetes should be picked and preserved but are not counted as part of the 500 organism total. Oligochaetes tend to break into several pieces in the preservation process. If possible, try to remove 25 intact or mostly intact samples for this group.
j. Once you start a sorting a block, you must finish it in its entirety.
k. Continue to randomly select blocks from the screen until all of the blocks have been removed or you have reached the 500 organism total, whichever comes first. However, once you start a sorting a block you must finish it in its entirety.
l. Label every vial using “rite in the rain”® paper and a pencil. It is important to use pencil as ink can dissolve in denatured alcohol. Each label should contain the NCCN Site ID, Sample #, total number of vials, collection date, and the initials of person who collected the sample.

NOCA WQ BMI Sample
Vial 1 of 5
Water Body Name: Lonesome Creek
NCCN Site ID: NOCA_ST_Lonesome
Sample #: #2
Collection Date: 10AUG2011
Collected by: RSD

m. Before discarding any processed debris it must be checked by another person to ensure that no organisms are being lost. If you are processing samples by yourself, put the debris in a WHIRL-PAK® with preservative to be held until a second party can look through the debris.
n. When you have removed 500 organisms, spread the remaining unprocessed fraction of the sample evenly throughout the sorting pan. Systematically search this pan and

remove any organisms that you think you might not have found in your split samples. Look for new or different bugs and large crustaceans having different colored head capsules, body postures, sizes or coloration. When in doubt, pick it out; it is better to pick up duplicates than to miss something. (NOTE: Keep these organisms in a separate vial and label them as "qualitative").

o. After completing the qualitative subsampling, discard the remaining debris.
p. If the organisms fill more than one vial, combine all of the vials from the same sample together with a rubber band.
q. Record the following information on the Stream BMI Sample Processing Bench Sheet (Appendix F): Park Code, Water Body Name, Sample ID, total number of vials for each category, percentage of sample sorted, total number of specimens sorted, the initials of the person who processed the sample, and the date the sample was processed.

3. Sample packaging and shipping:

a. Prior to packing, the caps of all vials are checked to see if they are secure.
b. All vials from the same sample are individually wrapped with padded packaging material and bound together with tape or a rubber band.
c. All samples are placed in a shipping container with additional packing material placed around them and with a copy of the Stream BMI Sample Processing Bench Sheet.
d. All samples must be hand delivered to the contractor performing the specimen identification work. Private shipping companies cannot be used because of the training and high cost required to meet their regulations concerning transport of alcohol. The delivery date should be discussed and confirmed with the contractor. A receipt of the samples should be provided by the contractor at the time of delivery.

4. Specimen identification:

a. BMI specimen samples are counted and identified by the following contractor:

Dr. Robert Wisseman
Aquatic Biological Associates, Inc.
3490 NW Deer Run Rd.
Corvallis, OR 97330
Phone: (541) 752-1568
Email: wisseman@aquaticbio.com

b. All specimens (including chironomids) are identified to the lowest possible taxonomic level. When necessary the contractor consults with specialists from throughout North America concerning identification/verification of rare and/or problematic specimens.
c. Data outputs provided by the contractor include Excel spreadsheets containing the specimen counts for each taxon. Taxa should be identified by their scientific name and Taxonomic Serial Number (TSN) specified by the Integrated Taxonomic Information System (http://www.itis.gov/). The contractor will ensure that specimen

samples are properly labeled and that a record of specimen identifications and abundance, by their Sample ID, is maintained. The contractor will also provide, or maintain on file, all Stream BMI Sample Processing Bench Sheets for future reference if needed.

d. Following completion of identification work, all specimens will be returned to the park. In addition, the contractor will provide a reference/synoptic series of specimens of each taxa identified.

Quality Assurance/Quality Control Procedures

- Conduct on-site training in BMI sample collection and field processing and laboratory sample processing for new employees
- Do not rely on memory – always read the relevant SOPs
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable
- Note any discrepancies or measurement problems on the field data form

Equipment List

Field sampling

- Pen/pencil
- Clipboard
- Field maps (topographic and aerial photos)
- Field data forms: NCCN Stream Water Quality Data Form, Stream BMI Sample Log Form, Stream BMI Sample Processing Bench Sheet, Stream BMI Identification Quality Control Summary Form
- Camera
- Rite in the Rain® labels
- D-frame kick net (500-µm mesh, 305 by 254-mm mouth opening, 2-m handle)
- Hand held 500-µm mesh net
- Plastic bucket (plastic, 5 gallon recommended)
- WHIRL-PAK® bags (4.5 x 9 inches recommended)
- Photographic/sorting tray (white, plastic)
- Forceps (both flat and pointed tipped)
- 95% ethanol (use 1 liter for streams with low amounts of organic debris, 2 liters for streams with high amounts of organic debris)
- 50- or 100-m tape measure or laser range finder
- Radio
- Wading equipment (waders, boots, throw bag)
- First aid kit
- Flagging

Laboratory processing

- Photographic/sorting tray (white, plastic)
- Forceps (both flat and pointed tipped)

- 95% ethanol
- 500 micron sieves or cones
- Framed sheet of 500µm mesh net (sized to fit sorting trays)
- Small bucket
- Spatula
- Plastic spoon and cups
- Alcohol filled squeeze bottle
- Water filled squeeze bottle
- Binocular dissecting microscope (7-20x magnification)
- Fiber optic light source
- Clicker/counter
- Vial holder (vial sized holes drilled into a wooden block)
- Scintillation vials (4 and 15 ml)
- Desk lamp with magnified circular lens (3-10x)
- Waterproof label paper
- Rubber bands
- Lab bench sheet

Safety Considerations

Safety of field personnel is of the utmost importance. Only sample or measure what can be accomplished safely. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Use the sketched map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia
- Laboratory Procedures and Chemical Handling

References

Cuffney, T. F., M. E. Gurtz, and M. R. Meador. 1993. Methods for collecting benthic invertebrate samples as part of the national water-quality assessment program. United States Geological Survey Open-File Report 93-406, U.S. Geological Survey, Raleigh, NC.

Hayslip, G., editor. 2007. Methods for the collection and analysis of benthic macroinvertebrate assemblages in wadeable streams of the Pacific Northwest. Pacific Northwest Aquatic Monitoring Partnership, Cook, WA.

Moulton, S. R. II, J. L. Carter, S. A. Grotheer, T. F. Cufney and T. M. Short. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory - processing, taxonomy, and quality control of benthic macroinvertebrate samples. U.S. Geological Survey Open-File Report 00-212. U.S. Geological Survey, Denver, CO.

SOP 9. Continuous Water Temperature Sampling in Streams and Rivers

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Water temperature is a major regulator of physical, chemical and biological processes within streams and rivers. It governs physiological functions in aquatic organisms. It also acts in conjunction with other water quality constituents to affect aquatic species diversity. The primary objective of continuous water temperature monitoring is to ensure that state water quality criteria are being met. Any aquatic resources not meeting state water quality criteria can be identified and addressed immediately. The secondary objective is to characterize stream temperature patterns over time and across watersheds. Furthermore, water temperature data provide valuable information for evaluating changes in stream condition and the impacts of climate change.

Continuous water temperature data are collected from all stream sample sites in the water quality monitoring project. Continuous air temperature data are also collected at these sites to aid in the interpretation of water temperature variations. The air temperature data also supplement the NCCN climate monitoring project by adding instrumentation and increasing spatial understanding of temperature variations within NCCN parks. This SOP details how to calibrate, deploy, retrieve and download data from the temperature data loggers. Procedures have been adapted from Schuett-Hames et al. (1999) and Ward (2003).

Temperature Loggers

Continuous temperature loggers must be lightweight, self contained, rugged, and waterproof. The loggers should have a minimum battery life of 4-5 years. Memory capacity must allow at least 36 months of data to be stored.

In addition, each of these instruments must meet the following criteria:

- waterproof to 30 m
- temperature accuracy of ±0.2°C
- operational range of -20° to 30°C
- resolution of 0.1°C at 0°C
- response time of 5 minutes in water
- stability (drift) of less than 0.1°C per year

NCCN parks currently use two sensors manufactured by Onset Computer Corporation, the TidbiT® v2 Temp Logger (Onset Part # UTB-001) and the HOBO® Pro v2 Water Temperature Data Logger (Onset Part # U22-001).

Prior to every sampling site visit in which the continuous temperature data logger is to be installed, the data logger should be properly calibrated according to the manufacturer specifications. The instrument used for continuous temperature measurement must meet the measurement quality objectives outlined in Table 15-3 of SOP 15: Quality Assurance and Control Plan. Refer to operating manual for the procedures and standards. Following each visit, the data logger must be carefully cleaned and stored according to manufacturer instructions.

Office Procedures (Pre-Deployment)

Pre- and Post-Field Calibration Checks

Calibration checks are used to document logger bias and performance to assure the quality of the data. Calibration checks are completed in advance of logger deployment and the post-deployment calibration checks are done shortly after the sampling results have been downloaded and backed up. **Note**: other field thermometers or thermistor thermometers used in the study to collect site temperature measurements also need to be checked during this process so any necessary correction factors can be applied to results from these devices.

1. Temperature loggers undergoing a calibration check should be programmed for a delayed start and set to record point measurements every (1) minute (refer to temperature logger manufacturer's software manual).

2. Temperature loggers should be calibrated in at least two water bath temperatures that bracket the expected sampling range (0^oC and roughly 20^oC) during calibration checks. The preferred method is to place one open cooler half full of water over night in a room that has a constant air temperature near the upper end of the temperature sampling range. For the lower end of the temperature range, crushed ice with a little water is placed in an insulated container (the container is placed in a refrigerator during the calibration check).

3. At least ten measurements per temperature logger at one minute intervals should be obtained at each of the two target temperatures. The temperature loggers are started and given about 15 minutes of acclimation time after they have been transferred into a water bath (the sensor end of the logger should be placed down and completely submerged). The water should be gently stirred to ensure a uniform temperature.

4. A Certified Reference Thermometer must be used to obtain accurate temperature measurements that can be used to evaluate the logger results. Time and temperature measurements from the Reference Thermometer are recorded for each of the one minute intervals on the Temperature Calibration Check Form (Appendix F: Field and Laboratory Data Forms).

5. Logger results should be downloaded soon after the testing process has been completed and the loggers should be shut off to minimize battery life impacts. Logger results are then evaluated by calculating the mean absolute value of the difference between the logger measurements and the Reference Thermometer. This difference indicates the accuracy range of the instrument.

6. Temperature loggers evaluated during a pre-deployment check that have a mean absolute value difference beyond 0.2°C for water sampling (-5°C to +37°C Stow-Away TidbiT®, -0°C to +50°C HOBO® Water Temp Pro) or 0.4°C for air sampling (-20°C to +50°C Stow-Away TidbiT®, -20°C to +70°C HOBO® Water Temp Pro) should be rejected for use until the calibration error has been corrected and the logger passes another calibration check. **Note**: Only those temperature loggers that pass the calibration check requirements may be programmed for deployment.

7. If a temperature logger fails a post-sampling calibration check, then another calibration check must be performed. If it fails a second calibration check, then the raw data should be adjusted by the mean difference of the pre- and post- calibration check results to correct for the instrument bias (Schuett-Hames et al.1999). If batteries should fail during deployment, the manufacturer (Onset Computer Corporation) can perform a post-sampling calibration check by comparison with a Standard Reference Material (SRM) certified by the National Institute of Standards and Technology (NIST).

8. Make sure all calibration and deployment information is recorded on the Stream Temperature Calibration Check Form and the Water Quality Temperature Logger Pre/Post Deployment Record Sheet for every continuous data logger.

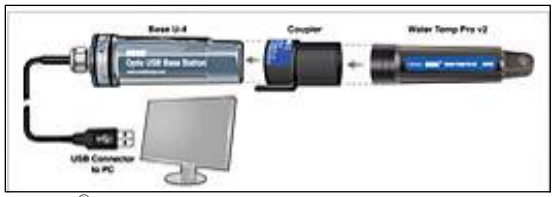
Pre-Deployment Programming

Temperature loggers should be programmed prior to departure to the field using HOBOware® Pro software. Before starting the program, the computer clock should be checked to ensure that the time and date are accurate. The date should be correct and time should be accurate within ±1 minute of the Official Pacific Standard Time as determined by NIST. The data logger and the optic shuttle both reference the computer time during launch and download of data, so accurate date and time on the computer is very important.

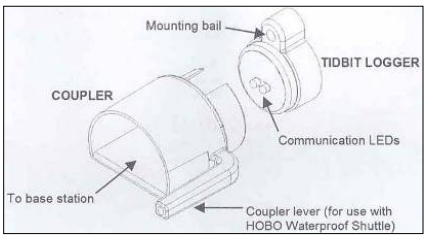
1. Connecting a data logger to shuttle/computer
   a. Open the HOBOware® Pro program on the computer,
   b. Unscrew the clear, center cap on the HOBO® Waterproof Shuttle (which also serves as a base station for the Tidbit® v2 logger) and plug the small end of the black USB interface cable into the USB port on the shuttle. Connect the other large end of the USB cable into a USB port on a computer. (Note: both the Onset USB Base Station and HOBO® Waterproof Shuttle can be used for the HOBO® Pro v2 logger),
   c. Attach appropriate coupler to the HOBO® Waterproof Shuttle,



Tidbit® v2 logger coupler assembly


HOBO® Pro v2 logger coupler assembly

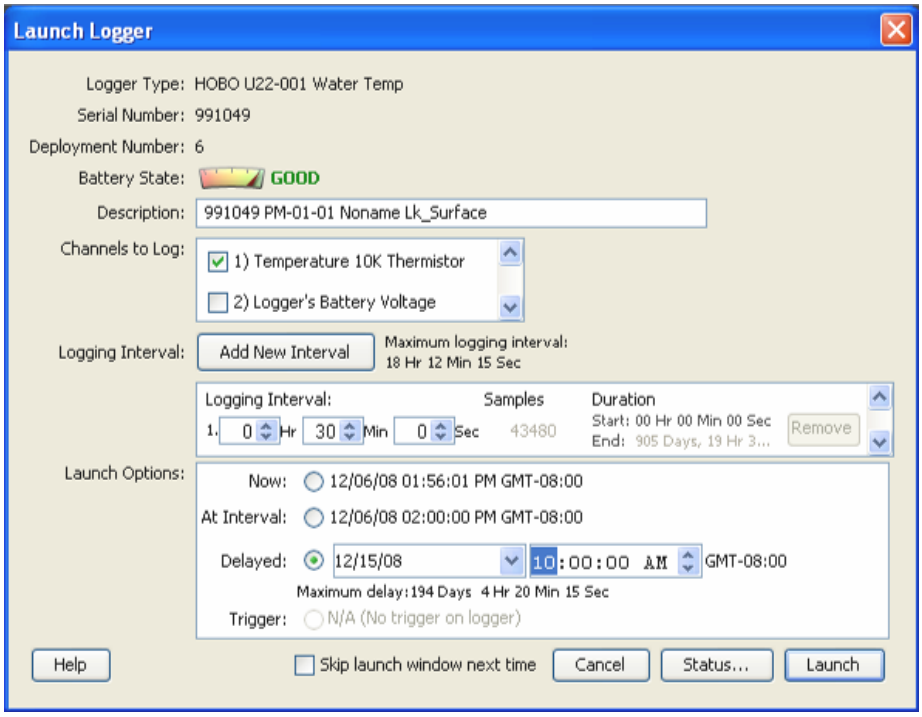
d. Insert the temperature logger into the coupler with the LEDs facing into the coupler as shown in the diagram,



e. When properly seated, the logger should be nearly flush with the top of the coupler,
f. Briefly press the coupler lever to put the shuttle into "base station mode" and allow the shuttle to recognize the logger. The computer will make a noise and the green **OK** light on the side of the shuttle will light up (and remain on until the logger is removed). If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer. Once the device is detected the connection will be displayed at the bottom of the HOBOware® Pro face page.

2. Launching a data logger in the lab

a. Under the **Device** tab in the drop-down menu, select **Launch**. A **Select Device** screen will pop up. If the computer recognizes the HOBO® logger, the logger Serial Number will be shown and is the default selection. Press **Ok**. If the computer does not recognize the logger, reinsert the logger into the coupler and press in the magnetic black bar on the coupler once so that the green light on the shuttle blinks a green **OK,**
b. Once you select the logger, a **Launch Logger** screen will appear,



c. Record the Serial Number of the logger, Site_ID, and if applicable, other use for deployment (e.g., air temperature or backup), Launch Date, Launch Time and Launch Location on the Continuous Temperature Deployment/Retrieval Form (Appendix F). **Note**: After deployment in the field, field crew will also record Deployment Date and Deployment Time on the Continuous Temperature Deployment/Retrieval Form (Appendix F),
d. Check the battery level to be sure that the logger is functioning at full capacity. Depending on conditions, batteries will last for 5 to 6 years (loggers must be sent back to the factory for battery replacement),
e. Change the **Description** field to indicate the deployment location, Site_ID, and logger serial number,
f. Make sure that the **Channels to Log** field has the **Temperature 10 K Thermistor** checked,
g. Uncheck the **Logger's Battery Voltage** (if checked, it will reduce the number of temperature recordings available),
h. Set the **Logging Interval** field to log at **1 hour, 0 minutes, and 0 seconds** interval,
i. Change the **Launch Options** field to either sample **Now** if you are heading out into the field immediately, or **Delayed** if you want the logger to have a delayed start time. If using the delayed time feature, input the appropriate date and time to start the logger and record it on the Continuous Temperature Deployment/Retrieval Form (Appendix F),
j. Click the **Status** button at the bottom of the screen and double check the settings that you have programmed on the data logger,
k. Click the **Launch** button at the bottom of the screen to begin logging and the red light on the logger will begin to blink. The rate of the blinking light will indicate the status of the logger,

When:	The "OK" light:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample
The logger is awaiting a start because it was launched in Start At Interval or Delayed Start mode	Blinks once every eight seconds until logging begins

l. The **Launching Logger** screen will appear, indicating that the **Logger is now logging**, **do not unplug while logger is being configured**. When this screen disappears, it is safe to remove the logger from the coupler. When you disconnect the logger from the coupler, the green, LED **OK** light on the shuttle should turn off,
m. Once programmed, label each logger with a piece of tape and indicate the sample site name or Site_ID and, if applicable, other use for deployment (e.g., air temperature or backup). In addition, the office phone number of the Water Quality Project Lead should be written on the logger with permanent ink.

3. Repeat these pre-deployment programming steps on a backup logger which will be taken into the field in case issues arise with the deployment of the first logger.

Field Procedures

Deployment Timing and Site Selection

Loggers will be deployed during the water quality sampling index period (late summer to early fall). This window may change depending on weather, stream flows, and stream access and staff availability.

Water Temperature Logger Deployment Assembly and Installation

The water temperature logger will generally be installed in a shaded location at the lower end of the sample reach. The logger deployment location must be in a place that is safe to access and where representative stream temperature data may be obtained during lower flows. In general 600 meters (~2000 feet) of similar conditions are required for establishing a thermal reach; this distance can change depending on the stream conditions. In small streams, the water temperature logger should be placed as close to the thalweg as possible and 6 inches from the stream bottom, however deep enough to avoid exposure to air should the water level drop further during the low flow period. In larger streams, be sure to avoid areas of potential temperature stratification (resulting from eddies, groundwater, or tributaries). In addition, a 2-2.5 foot deep location downstream or alongside a landmark rock or stream bed feature improves the chance of it staying submerged during its deployment period and being relocated for retrieval (Figure 9-1).



Figure 9-1. Continuous temperature location in stream showing boulder downstream of which logger will be placed.

The deployment assembly consists of:

1. A calibrated and programmed temperature logger with good battery life.

2. A 6" piece of 2" diameter steel pipe with 1/4-3/8" diameter holes drilled through it (to allow water flow through the pipe) as well as two 1/4-3/8" diameter holes drilled opposite each other just below the top edge for securing the logger.



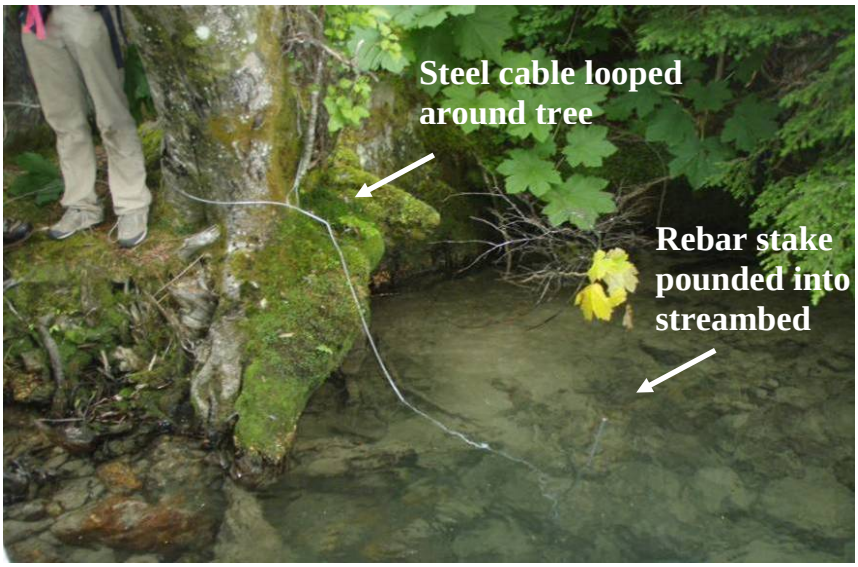
3. One 2.5-3" long bolt (1/4") and nut for securing logger inside the steel pipe and to which steel cable attaches.



4. 2-3 foot length of 3/8" rebar for anchoring the logger/pipe assembly in the streambed.

5. 6 zip ties for securing logger/pipe assembly to the rebar anchored in the streambed.

6. 30 feet of stainless steel cable and crimping hardware to secure the logger/pipe assembly to a stable location on the bank, such as a large tree.



To install the continuous temperature logger in the stream:

1. Locate a large tree near the bank as close to the stream deployment site as possible. Loop the cable around the tree (crimp a loop in the end of the cable).

2. Pound the rebar stake securely into the streambed with a hammer. Ideally, pound all but eight inches of rebar into the streambed.

3. Attach the free end of the cable to the logger by passing through the logger's attachment hole (plastic loop on the top of the logger) and crimping the cable back on itself with pliers to create a secure loop about 2" in diameter.

4. Secure the logger (now attached to the cable) inside the steel pipe by passing the bolt through the one hole at the top of the pipe, through the 2" loop in the end of the cable, and then through the other hole at the top of the pipe.

5. Make sure the logger has a green blinking light signaling **OK**. If the logger is not blinking green use the backup logger and record the backup logger number on the Continuous Temperature Deployment/Retrieval Form.

Air Temperature Logger Installation

The air temperature logger should be placed as close to the water temperature logger as possible but 3 to 10 feet into the riparian zone from the bankfull width, as well as 3 feet off the ground. The air temperature logger should be placed in a shaded and sheltered area. In higher elevation areas, avoid placing the logger near potential avalanche chutes or areas of high snow drift. A clump of mature trees is generally preferred.

1. Secure the air temperature logger to the tree using the nylon cable ties.

2. Make sure the logger has a green blinking light signaling **OK**. If the logger is not blinking green use the backup logger and record the backup logger number on the Continuous Temperature Deployment/Retrieval Form.

Record Water and Air Temperature Logger Deployment Information

Record all field data on the Continuous Temperature Deployment/Retrieval Form including: watershed name, NCCN Site ID, logger type (air or water) and serial number, location description, deployment details (launch or delayed launch date and time), and a sketch of the deployment location. Record site visit date and time, GPS coordinates of the site, and for water temperature loggers, water depth and logger deployment depth. Also record the distance and bearing to the logger deployment location from a landmark feature at the sample site. Make sure all information on the form is complete.

Take photographs of the site, any landmarks at the site as well as the approach to the site if off-trail, and the logger deployment location to aid in relocating the logger on future visits. Document what photographs were taken and pertinent details on the Trip Photo Log. Flagging landmark features near the site will assist in relocation as well.

Continuous Temperature Logger Retrieval

Depending on the type of stream being sampled, the continuous temperature data will be downloaded from the loggers once every year or three years (see Section 2.2.3, Frequency and Timing of Sampling, in the protocol). Park staff will upload temperature data from the temperature loggers to a shuttle device that will be taken back to the office for data download to a computer. The retrieval process should go quickly if the logger locations were relatively undisturbed during deployment period and if deployment locations were well documented.

Continuous Temperature Data Retrieval

1. Remove the logger from its installation assembly. If an air temperature logger, simply clip the nylon cable ties holding it to the tree. For a water temperature logger, clip the nylon cable ties securing the logger/pipe assembly to the rebar and then remove the bolt in the top of the steel pipe that secures the logger inside the pipe.

2. Shade the temperature logger and check for the blinking red LED indicating that the logger is running. The logger should first be gently cleaned to remove any bio-fouling or sediment that may affect its ability to communicate optically during the downloading process. Cleaning can be done with a little water and a soft cloth or soft bristled brush.

3. Make sure the shuttle's large cap and center cap are closed securely. Tighten the center cap until it is just flush with the large cap, or until the O-ring is no longer visible. Check that the communication end of the shuttle is clean.

4. Attach the coupler to the shuttle and insert the logger into the coupler.

5. Momentarily press the coupler lever and the data should upload immediately. The amber **Transfer** LED light on the shuttle will blink continuously while the readout is proceeding and re-launch is in progress. Do not remove the logger while the amber **Transfer** LED light is still blinking. When it is done uploading, the green LED **OK** light on the shuttle will blink. Check to make sure that the red **OK** light on the data logger is still logging. Now it is okay to disconnect the logger from the coupler. **Note**: If data upload fails, try it a second time. The communication ends of both the logger and the

shuttle may need to be cleaned more thoroughly. If it fails again, remove the logger and replace with a backup.

6. Data including sampling event information, time logger was removed from the water, logger serial number, deployment depth, and any other observations need to be recorded on the Continuous Temperature Deployment/Retrieval Form that was used for the initial deployment during the deployment site visit. **NOTE**: Be sure to indicate on the data form if the logger has moved or been disturbed in any way.

7. Reinstall the logger in its proper location. Check that the rebar stake in the streambed is still solidly in place, and if not, pound in again.

Logger Replacement

When gathering hourly temperature data, a typical logger will have a battery life of 5 years. Despite this, loggers should be replaced every 3 years to ensure that there is no data loss from early battery failure. Also, if a logger has been destroyed or otherwise stopped working, it will need to be replaced with a new, pre-programmed logger.

Office Procedures (Post-Deployment)

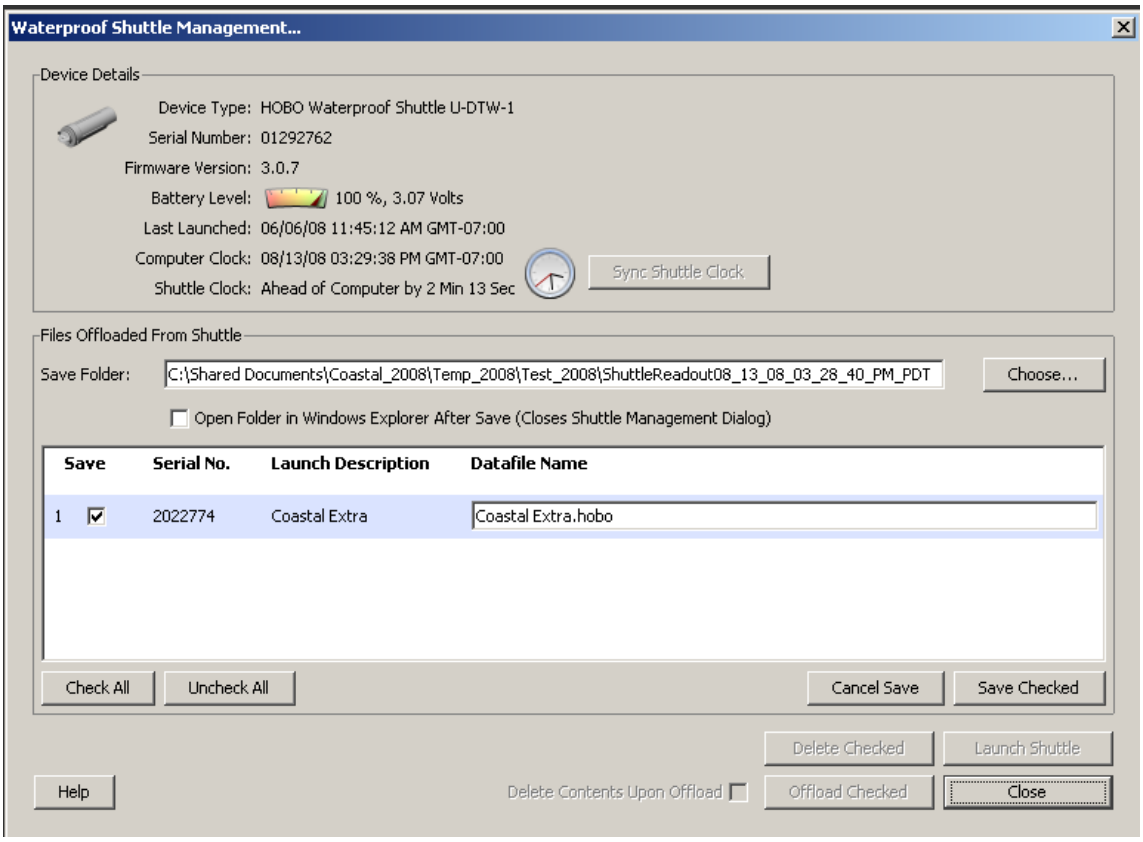
Data Download from Shuttle to Computer

1. Prior to downloading the temperature loggers, verify that the office computer clock is accurate for the Pacific Time Zone.

2. Connect the shuttle to the computer using the black USB cable. Follow the procedures under Step 1, "Connecting a data logger to shuttle/computer" in the Pre-Deployment Programming section above. The HOBOware® Pro software should automatically launch. If the program issues a warning that it needs updates, allow it to do so before attempting to download the data.

3. Under the **Device** tab in the drop down menu, select **Readout**. A **Select Device** screen will pop up. If the computer recognizes the shuttle, the **HOBO® Waterproof Shuttle, S/N**: **_____** will appear as the default selection. Press **OK**. If the computer does not recognize the shuttle, reinsert the black USB cable into the shuttle and press in the magnetic black bar on the coupler once so that the green light on the shuttle blinks a green **OK** (and makes a noise).

4. A **Waterproof Shuttle Management…** screen will appear and allow you to select which data file you want to download from the shuttle to the computer.



5. On this screen, the **Device Details** will be displayed for the shuttle (i.e., **Device Type, Serial Number, Firmware Version, Battery Level, Last Launched** date, **Computer Clock** time, and **Shuttle Clock** time). In the **Files Offloaded from Shuttle** box, you can specify into which folder you want to save downloaded data files; click the **Choose…** button to navigate to the desired location. Select which **Data Filename** you want to download and select **Save Checked.**

6. Clicking the **Save Checked** button will refresh the **Waterproof Shuttle Management…** screen. At this point you will be able to **Sync the Shuttle Clock** so that it reads **Matches the Computer**. This is only necessary if the program is showing you that the shuttle clock is ahead of the computer clock.

7. If you select the **Offloaded** file from the **Files on Shuttle** section of this screen, you can select the **Delete Checked** option and remove all the files from the shuttle that have already been saved to the computer.

8. A small **HOBOware**® pop-up screen will appear asking you "**Are you sure you want to delete the selected banks.**" Make sure to check that your files have been correctly saved to the computer before selecting **YES** and deleting all the files from the shuttle

9. Once completed, disconnect the shuttle from the computer.

Post-Deployment Calibration Check

Following the download of the data, the post-deployment calibration check should be completed as detailed in Pre- and Post-Field Calibration Checks section above. If the logger does not meet the requirements specified in Step 6 of these procedures after two separate calibrations, then the raw data should be adjusted by the mean difference of the pre- and post-calibrations to correct for the instrument bias (Schuett-Hames et al. 1999).

Quality Control Procedures

- Water temperature data, recorded before and after the deployment period, must be identified and deleted from each raw data set based on the information noted on the Continuous Temperature Deployment/Retrieval Form.
- The accuracy of the temperature loggers needs to be verified by evaluating the results of pre- and post-deployment calibration checks. If the results indicate a consistent bias of more than 0.2ºC, then the raw data may need to be adjusted or flagged with the appropriate data qualifier.
- Anomalous data from the deployment period related to equipment malfunctioning, movement of the logger assembly, or other reasons, may be identified by reviewing a plot of water temperature data and field notes. Questionable results may be deleted from the record, provided the reason has been noted on the both the Continuous Temperature Deployment/Retrieval Form and the electronic version of the data record.
- Conduct on-site training for new employees.
- Do not rely on memory – always read protocol.
- Immediately following a survey and before leaving a sampling site, verify that all forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.

Equipment List

- Pen/pencil
- Clipboard
- GPS unit
- Field maps (topographic and aerial photos)
- Lab and field data forms: Temperature Calibration Check Form, Water Quality Temperature Logger Pre/Post Deployment Record Sheet, Continuous Temperature Deployment/Retrieval Form, Trip Photo Log
- Camera
- 50- or 100-m tape measure or laser range finder
- Three pre-programmed temperature data loggers (water, air, and backup). NCCN commonly uses the following from the Onset Corporation:
    - HOBO Water Temperature Pro v2 data logger (Onset Part # U22-001),
    - HOBOware software (Onset Part # BHW-PC),
    - HOBO® Waterproof Shuttle with appropriate coupler
- Certified Reference Thermometer (HB Instruments, -8°C to 32°C, 0.1^{o}C accuracy, and 0.1^{o}C reporting limit, VWR Part # 61099-035).

- Section of 2" diameter steel pipe, roughly 5" in length.
- Anchoring material:
    - 2 to 3 foot piece of #4 rebar (3/8" diameter)
    - 30 feet of stainless steel cable (1/8")
    - mall cable clips (bolt-on type, 1/8")
    - copper swag/sleeve (1/8")
    - stainless steel bolt (1/4" x 2 ½") w/ stainless nylon lock-nut and washers
- Nylon cable (zip) ties (8" long)
- 4# hammer
- Pliers (8"), wrenches(5/16 and 7/16"), vice grips (10 and 5"), wire cutters (8")
- Flagging for sites in hard to find locations
- Knife
- Watch
- Radio
- First aid kit
- Wading equipment (waders, boots, throw bag)

Safety Considerations

Safety of field personnel is of the utmost importance. Only sample or measure what can be accomplished safely. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Use the sketched map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

Schuett-Hames, D., A. E. Pleus, E. Rashin, and J. Mathews. 1999. TFW monitoring program method manual for the stream temperature survey. Prepared for Washington State Department of Natural Resources under the Timber Fish and Wildlife Agreement, TFW-AM9-99-005. Olympia, WA.

Ward, W. 2003. Continuous temperature sampling protocols for the Environmental Monitoring and Trends Section. Publication No. 03-03-052. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA.

SOP 10. Documenting Invasive Species Occurrence

Version 5/17/2011

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Non-native riparian and aquatic plants such as Eurasian watermilfoil, hydrilla, purple loosestrife, and reed canary grass quickly establish themselves, displacing native vegetation and impairing water quality and fish and wildlife habitat. Aquatic resources are also threatened by non-native invertebrate and vertebrate species such as quagga mussels and American bullfrogs, which outcompete native mollusc and amphibian species, respectively. Opportunistic, visual encounter surveys for these invasive species will be conducted to document their occurrence during habitat assessments in wadeable streams and rivers for the NCCN Water Quality monitoring project. This SOP details how surveys for a prioritized list of invasive species will be conducted at all NCCN Water Quality Monitoring sample sites.

Office Procedures

At the start of each season, NCCN Water Quality monitoring staff will check with the network Exotic Plant Management Team and the NPS Water Resources Division for new and emerging invasive plant and aquatic species threats. This information will be used to update the current list of NCCN documented or potential invasive species (Table 10-1) and will be provided to field crews in a Checklist format (Appendix F).

Field Procedures

Because invasive species often first invade travel corridors (for example, roads, hiking trails and boat launch sites), it may be beneficial to target searches for the species prioritized in the Checklist along these routes. Be alert to the presence of potential invasive species as you travel the route to the sample site. Their presence along the route could indicate a higher likelihood of infestation at the site. Also consider what type of habitats individual invasive species on the prioritized list prefer and scrutinize these areas for potential infestations.

Once at a sample site, much of the search for invasive species can be completed while conducting other water quality parameter measurements. Walk around the sample site and search for any of the potential species expected to invade the type of habitat available at the site. Search within the littoral zones as well as the riparian areas.

During reach establishment at wadeable streams or rivers, walk along the lengths of both banks, if possible, for the length of the sample reach. If both banks are not easily or safely accessible, be sure to scan the inaccessible bank while working your way upstream or downstream along the accessible bank. Again, be sure to scan for aquatic species in the stream channel as well as riparian species along the banks. This survey technique mostly targets vertebrates and aquatic and riparian plants.

While conducting the benthic macroinvertebrate sampling, the kick net samples should also be thoroughly examined for the presence of non-native crayfish, snails, Didymosphenia, and mussels.

Photo-documentation

When invasive species are present in a sample site, two types of photographs should be taken, 1) to document the aerial extent of the infestation, and 2) to clearly illustrate the species of interest for identification purposes. All photographs taken and pertinent details should be recorded on the Trip Photo Log.

Photo-documentation of the aerial extent should capture the site context in which the infestation occurs. Try to frame the photo to show distinguishing features of the location that would assist with relocating the site for future management actions. Take several photos if needed, and if the infestation is relatively small, try to show the margins of the infestation.

Photo-documentation is essential for verification of invasive species that might be confused with native species. During AREMP's 2008 field season, the most commonly misidentified species were garlic mustard, and giant hogweed (Gruendike and Lanigan 2009). Photo documentation allowed experts to examine the data and eliminate misidentified species from the dataset. When taking a photo of a species for identification purposes, try to capture the diagnostic features. For example, if it is a plant, take several photos if necessary to capture the flowers and seed heads, if present, and the leaf structure.

Mapping Invasive, Non-native Species Occurrence

If any non-native or invasive species is observed at a sample site, draw the location on the sketched map of the sample site on the NCCN Stream Water Quality field form. Indicate the species name and approximate spatial extent of the infestation and/or number of individuals. If the species is a plant (or otherwise not highly mobile species) and the infestation is relatively isolated (i.e. in the initial establishment phase of invasion versus in the spread/equilibrium phase and thus more widespread) obtain a GPS point for the location. This will be helpful in relocating the site if management action is indicated.

Non-native Species Spread Prevention

If invasive, non-native species are present in the sample site, take care while moving around within the area not to facilitate the spread of any invasive species that are present by checking your clothing and footwear for seeds or organisms. Check again before leaving the site to prevent the transport of this species to other areas. See SOP 13: Decontamination of Equipment, for more information about preventing the spread of non-natives species and disease while sampling in the field.

Table 10-1. Documented and potential invasive species of concern in North Coast and Cascades Network parks.

Common name	Scientific name	Present in park[1]	Probably present in park
Invertebrates			
quagga mussel	*Dreissena bugensis*		
zebra mussel	*Dreissena polymorpha*		
ringed crayfish	*Orconectes neglectus*		
rusty crayfish	*Orconectes rusticus*		
northern crayfish, virile crayfish	*Orconectes virilis*		
New Zealand mudsnail	*Potamopyrgus antipodarum*		
red swamp crayfish	*Procambarus clarkii*		
Aquatic plants and algae			
giant reed	*Arundo donax*		
Didymo	*Didymosphenia geminata*		
Brazilian elodea	*Egeria densa*		
hydrilla, waterthyme	*Hydrilla verticillata*		
yellow flag	*Iris pseudacorus*	LEWI	OLYM
parrot feather watermilfoil	*Myriophyllum aquaticum*	LEWI	
Eurasian watermilfoil	*Myriophyllum spicatum*	NOCA	
White waterlily	*Nymphaea odorata*	LEWI, OLYM	
Common reed	*Phragmites australis*	LEWI, OLYM	
Riparian plants			
garlic mustard	*Alliaria petiolata*		
old man's beard	*Clematis vitalba*	NOCA	
English ivy	*Hedera helix*	LEWI, NOCA, OLYM, SAJH	
giant hogweed	*Heracleum mantegazzianum*	FOVA, MORA	NOCA
purple loosestrife	*Lythrum salicaria*		LEWI, OLYM
reed canary grass	*Phalaris arundinacea*	EBLA, FOVA, LEWI, MORA, NOCA, OLYM, SAJH	
Japanese knotweed	*Polygonum cuspidatum*	MORA, NOCA, OLYM	
cultivated knotweed	*Polygonum polystachyum*	OLYM	
giant knotweed	*Polygonum sachalinense*	OLYM	NOCA
Himalayan blackberry	*Rubus discolor*	EBLA, FOVA, LEWI, NOCA, OLYM, SAJH	
Vertebrates			
American bullfrog	*Rana catesbeiana*	LEWI	
eastern brook trout	*Salvelinus fontinalis*	MORA, NOCA, OLYM	
brown trout [2]	*Salmo trutta*	NOCA	

[1] Park status ('Present in park' and 'Probably present in park') from NPSpecies, accessed 1/4/2011.

[2] Documented in NOCA in 2010.

Quality Control

- Conduct on-site training for new employees.
- Provide photographs of invasive species.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.

Equipment List

- Pen/pencil
- Clipboard
- Field maps (topographic and aerial photos)
- GPS unit and operating instructions/SOP
- Field data forms: NCCN Stream Water Quality Data Form, Water Quality Invasive Species Checklist, Trip Photo Log
- Exotic species identification guides
- Checklist of NCCN documented and potential invasive species (Table 10-1 of this SOP)
- Camera
- Radio
- Wading equipment (waders, boots, throw bag)
- First aid kit

Safety Considerations

Safety of field personnel is of the utmost importance. Only sample or measure what can be accomplished safely. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Use the sketched map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

Gruendike, P., and S. Lanigan. 2009. Aquatic invasive species survey report: 2008 field season. Aquatic and Riparian Effectiveness Monitoring Program. USDA Forest Service Pacific Northwest Regional Office and Bureau of Land Management Oregon State Office, Portland, OR.

SOP 11. Rapid Habitat Assessment in Streams and Rivers

Version 5/17/2011

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Rapid Habitat Assessments will be conducted at wadeable streams and rivers. After the stream or river reach has been delineated the field crew members should collectively conduct a visual-based qualitative assessment of the riparian and in-stream habitat for the reach. The purpose of the rapid habitat assessment is to integrate information on several key in-stream and riparian habitat characteristics. The procedures in this SOP have been adapted from the EMAP Wadeable Stream Assessment: Field Operations Manual (USEPA 2004) and Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999).

The rapid habitat assessment is broken into two parts, one for high gradient streams and one for low gradient streams or rivers. Based on observations made while laying out and collecting samples and measurements from the sample reach, the reach is classified based on the prevalent habitat as either “riffle/run” or “glide/pool.” This classification is based on which habitat type occupies the majority of the length of the sample reach. Landscapes of moderate to high gradient typically contain riffle/run streams, which under natural conditions, contain primarily coarse substrates (i.e., coarse gravel or larger) or numerous areas dominated by coarse substrates along the reach. Landscapes of low to moderate gradient are characterized by glide/pool streams or rivers, which are dominated by finer substrates (fine gravel or smaller) or with occasional areas of coarser sediments along the reach (Barbour et al. 1999). The entire sample reach is classified as one or the other and specific habitat parameters are evaluated for each.

A different section of the Rapid Habitat Assessment Form (Appendix F: Field and Laboratory Data Forms) is completed depending upon the prevalent habitat type. For each stream type, ten habitat parameters (Table 11-1) are assessed. Most of the parameters are evaluated similarly for both types of stream habitats. In three cases, a parameter is evaluated differently, or a different (but ecologically equivalent) parameter is evaluated in riffle/run prevalent versus glide/pool prevalent streams. Substrate embeddedness is evaluated in riffle/run prevalent streams, while pool substrate composition is evaluated in glide/pool prevalent streams. The presence of four potential types of microhabitat types based on combinations of depth and current velocity is evaluated in riffle/run prevalent streams, while the presence of four potential types of pool microhabitat based on depth and area are evaluated in glide/pool prevalent streams. The frequency of riffles is evaluated in riffle/run prevalent streams, while channel sinuosity is evaluated in glide/pool prevalent streams. For three parameters, each bank is evaluated separately and the cumulative score (right and left) is used for the reach.

Table 11-1. Parameters used in the rapid habitat assessment of streams and rivers*.

Habitat Parameter (Prevalent Habitat Type: R = Riffle/Run, G = Glide/Pool)	Description and Rationale
1. Epifaunal Substrate / Available Cover (R, G)	Includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs are critical for maintaining a variety and abundance of insects in most high-gradient streams and serving as spawning and feeding refugia for certain fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in high-gradient streams. Riffles and runs offer a diversity of habitat through variety of particle size, and, in many small high-gradient streams, will provide the most stable habitat. Snags and submerged logs are among the most productive habitat structure for macroinvertebrate colonization and fish refugia in low-gradient streams. However, “new fall” will not yet be suitable for colonization.
2A. Embeddedness (R)	Refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (shelter, spawning, and egg incubation) is decreased. Embeddedness is a result of large-scale sediment movement and deposition, and is a parameter evaluated in the riffles and runs of high-gradient streams. The rating of this parameter may be variable depending on where the observations are taken. To avoid confusion with sediment deposition (another habitat parameter), observations of embeddedness should be taken in the upstream and central portions of riffles and cobble substrate areas.
2B. Pool Substrate Characterization (G)	Evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support far fewer types of organisms than a stream that has a variety of substrate types.
3A. Velocity and Depth Regimes (R)	Patterns of velocity and depth are included for high-gradient streams under this parameter as an important feature of habitat diversity. The best streams in most high-gradient regions will have all 4 patterns present: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. The general guidelines are 0.5 m depth to separate shallow from deep, and 0.3 m/sec to separate fast from slow. The occurrence of these 4 patterns relates to the stream’s ability to provide and maintain a stable aquatic environment.
3B. Pool Variability (G)	Rates the overall mixture of pool types found in streams, according to size and depth. The 4 basic types of pools are large-shallow, large-deep, small-shallow, and small-deep. A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community. General guidelines are any pool dimension (i.e., length, width, oblique) greater than half the cross-section of the stream for separating large from small and 1 m depth separating shallow and deep.

*Adapted from USEPA (2004) and Barbour et al. (1999).

Table 11-1. Parameters used in the rapid habitat assessment of streams and rivers* (continued).

Habitat Parameter (Prevalent Habitat Type: R = Riffle/Run, G = Glide/Pool)	Description and Rationale
4. Sediment Deposition (R, G)	Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. Deposition occurs from large-scale movement of sediment. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow decreases, such as bends. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.
5. Channel Flow Status (R, G)	The degree to which the channel is filled with water. The flow status will change as the channel enlarges (e.g., aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed, the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, riffles and cobble substrate are exposed; in low-gradient streams, the decrease in water level exposes logs and snags, thereby reducing the areas of good habitat. Channel flow is especially useful for interpreting biological condition under abnormal or lowered flow conditions. This parameter becomes important when more than one biological index period is used for surveys or the timing of sampling is inconsistent among sites or annual periodicity.
6. Channel Alteration (R, G)	Is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control or irrigation purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than do naturally meandering streams. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances; when dams and bridges are present; and when other such changes have occurred. Scouring is often associated with channel alteration.
7A. Frequency of Riffles (or Bends) (R)	Is a way to measure the sequence of riffles and thus the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna, therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community. For high gradient streams where distinct riffles are uncommon, a run/bend ratio can be used as a measure of meandering or sinuosity (see 7b). A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in some streams, a longer segment or reach than that designated for sampling should be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps. The “sequencing” pattern of the stream morphology is important in rating this parameter. In headwaters, riffles are usually continuous and the presence of cascades or boulders provides a form of sinuosity and enhances the structure of the stream. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).

*Adapted from USEPA (2004) and Barbour et al. (1999).

Table 11-1. Parameters used in the rapid habitat assessment of streams and rivers* (continued).

Habitat Parameter (Prevalent Habitat Type: R = Riffle/Run, G = Glide/Pool)	Description and Rationale
7B. Channel Sinuosity (G)	Evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in low gradient streams, a longer segment or reach than that designated for sampling may be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps. The “sequencing” pattern of the stream morphology is important in rating this parameter. In "oxbow" streams of coastal areas and deltas, meanders are highly exaggerated and transient. Natural conditions in these streams are shifting channels and bends, and alteration is usually in the form of flow regulation and diversion. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).
8. Bank Stability (Condition of Banks) (R, G)	Measures whether the stream banks are eroded (or have the potential for erosion). Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately from 0-10, and the cumulative score (right and left) is used for this parameter.
9. Bank Vegetative Protection (R, G)	Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. This parameter is made more effective by defining the native vegetation for the region and stream type (i.e., shrubs, trees, etc.). In some regions, the introduction of exotics has virtually replaced all native vegetation. The value of exotic vegetation to the quality of the habitat structure and contribution to the stream ecosystem must be considered in this parameter. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.
10. Riparian Vegetated Zone Width (R, G)	Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and rangeland are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores. For variable size streams, the specified width of a desirable riparian zone may also be variable and may be best determined by some multiple of stream width (e.g., 4 x wetted stream width). Each bank is evaluated separately from 0-10 and the cumulative score (right and left) is used for this parameter.

*Adapted from USEPA (2004) and Barbour et al. (1999).

Procedures for Conducting Assessment

For each of the 10 parameters, visually evaluate and rate the overall quality of the sample reach on a scale of 0 to 20, with 0 being the lowest quality and 20 being the highest quality, i.e. representing optimal habitat conditions. For riffle/run prevalent streams, record your scores for each parameter on the riffle/run section of the Rapid Habitat Assessment Form by circling the assessed value (Appendix F: Field and Laboratory Data Forms). If the stream is classified as a glide/pool prevalent stream, record your scores for each parameter on the glide/pool section of the Rapid Habitat Assessment Form by circling the assessed value (Appendix F: Field and Laboratory Data Forms). Record the scores assigned for each parameter in the box in the left-hand column of the forms. The scores will be summed during data entry. The steps in this process follow below:

1. Based on observations during sample collection and field measurement activities, classify the sampling reach as predominantly flowing water habitat (riffle/run) or slow water habitat (glide/pool).

2. Use the appropriate section of the Rapid Habitat Assessment Form (Riffle/Run Prevalence or Glide/Pool Prevalence) based on the classification in Step 1.

3. For each of the 10 habitat parameters, determine the general quality category (POOR, MARGINAL, SUB-OPTIMAL, or OPTIMAL) of the entire sample reach. Use the descriptions on the Rapid Habitat Assessment Form to assign a score from the values available within each quality category. Circle the assigned score for each parameter on the form.

- For parameters #1 through #7, the sampling reach can be scored from 0 (worst) to 20 (best).

- For parameters #8 through #10, each bank is evaluated separately (from 0 to 10), and the cumulative score for both right and left banks is used for the reach.

4. After the sampling reach has been scored for all parameters, transfer the score circled for each category to the corresponding SCORE box in the HABITAT PARAMETER column of the Rapid Habitat Assessment Form.

Quality Control

- Conduct on-site training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable.
- Note any discrepancies or measurement problems on the field data form.

Equipment List

- Pen/pencil
- Clipboard

- Field data form: Rapid Habitat Assessment Form
- Field maps (topographic and aerial photos)
- Camera
- 50- or 100-m tape measure
- Radio
- Wading equipment (waders, boots, throw bag)
- First aid kit
- 50- or 100-m tape measure or laser range finder
- Flagging

Specific Safety Considerations

Safety of field personnel is of the utmost importance. Some sites may have conditions that preclude full sampling of all areas due to water depth or flow speed. For example, it might be impossible to do thalweg depth profiles and flow measurements, but it may still be possible to do the various assessments that do not require getting in the water (bank characterization, riparian vegetation and disturbance, stream/river assessment, rapid habitat assessment). It is also usually possible to collect a water chemistry sample near the bank. Make detailed comments on the field data forms describing what the conditions were like and how much sampling could actually be done. Sketch a site map to indicate problem areas and where samples were collected if not collected in planned areas.

See SOP 20: Field and Laboratory Safety

- Water Safety (wading)
- Hypothermia

References

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SOP 12. Digital Photo Acquisition and Management for Streams and Rivers

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes procedures for acquiring, downloading, processing, and naming photographic images collected by project staff or volunteers during the course of conducting project-related activities.

Images that are acquired by other means (e.g., downloaded from a website or those taken by a cooperating researcher) are not project records and should be stored separately and named in such a way that they can be readily identified as non-NPS images and not be mistaken for project records.

To effectively manage potentially hundreds of photographic images requires a consistent method for downloading, naming, editing and documenting. The general process for managing data photos proceeds as follows:

- Prepare image workspace – Set up the file organization for images prior to acquisition
- Acquire images
- Download and process
    - Download the files from the camera
    - Rename the image files according to convention detailed below
    - Copy and store the original, unedited versions
    - Review and edit the photos; delete unneeded or poor quality photos
    - Move into appropriate folders for storage
- Deliver image files for final storage

Data Photos Defined

Care should be taken to distinguish data photographs from incidental or opportunistic photographs taken by project staff. Data photographs are those taken for the following reasons:

- To document a particular feature or perspective for the purpose of site relocation
- To capture site characteristics and to document gross structural and compositional changes over time
- To document a species detection that is also recorded in the data

Data photographs are often linked to specific records within the database, and are stored in a manner that permits the preservation of those database links. Other photographs – e.g., showing field crew members at work, or documenting the morphology of a particular species – may also be retained but are not necessarily linked with database records.

Image Workspace Setup

1. Workspace Setup: Prior to data collection for any given year, the Project Lead (or a designee) will need to set up a new set of image folders, both under the Images section of the project workspace as well as under the current season year section of the seasonal workspaces (refer to SOP 2). The workspace subfolders are as follows:

[Year]	The appropriate year – 2012, 2013, etc.
[Park code]	Arrange files by park – OLYM, NOCA, etc.
1_Originals	Unedited versions of image files
[Site_ID]	Arranged by site ID, for images taken at streams
[Date]	Arranged by date, for images not taken at streams
2_Processing	Temporary processing workspace
3_Data	Data images
[Site_ID]	Arranged by site ID, for stream images
[Date]	Arranged by date, for images not taken at streams
4_Miscellaneous	Non-data images taken by project staff
[Site_ID]	Arranged by site ID, for stream images
[Date]	Arranged by date, for images not taken at streams
5_Not-NPS	Images acquired from other sources

This folder structure permits data images to be stored and managed separately from non-record and miscellaneous images collected during the course of the project. It also provides separate space for image processing and storage of originals. For additional information about the project workspace, refer to SOP 2: Project Workspace and Records Management.

2. Folder Naming Standards:
   In all cases, folder names should follow these guidelines:

   - No spaces or special characters in the folder name
   - Use the underbar ("_") character to separate words in folder names
   - Try to limit folder names to 20 characters or fewer
   - Dates within folder names should be formatted as YYYYMMDD (for better sorting)
   - NCCN Water Quality Monitoring Site IDs entered in NPSTORET (and called "Station ID" in NPSTORET) are limited to a 15-character alpha-numeric code that includes the park code, an abbreviation of water body type, and water body name, or abbreviation thereof to meet 15-character limit (e.g., NOCA_st_Deer). See SOP 16.A: Data Entry and Verification for more detail on NPSTORET file naming conventions.

Image Acquisition

1. General:
   Capture images at an appropriate resolution that balances space limitations with the intended use of the images. Although photographs taken to facilitate future navigation to a site do not need to be stored at the same resolution as those that may be used to indicate gross environmental change at a site, it may be more efficient initially to capture all images at the same resolution. A recommended minimum raw resolution is 1600 x 1200 pixels (approximately 2 megapixels). Higher resolutions may be available but are undesirable from the perspective of data storage and information content.

   Photographs will be taken to document invasive species (SOP 10: Documenting Invasive Species Occurrence) and human disturbances or unique physical habitat features (SOP 6: Reach Delineation and Habitat Characterization for Streams and Rivers). Photos will also be taken upstream and downstream from the "reference point" (SOP 5: Site Evaluation

and Establishment) and at continuous temperature logger installation sites (SOP 9: Continuous Temperature Sampling for Streams and Rivers).

2. Timing of Photos:
   Day-end lighting (morning/evening) shows subtle landscape variations best; however, azimuthal differences (into/away from the sun) can be very pronounced. Important detail can be lost from photos taken early or late in the day, or into the sun. Direct sunlight can also create shadows that interfere with details of landscape features. For these reasons, morning through mid-day to afternoon lighting is best for landscape documentation combined, if possible, with overcast days without shadows. Maintenance trips that will include 5 year documentation photos should be planned so as to maximize appropriate lighting conditions.

3. Focal Length and Resolution:
   In general, digital photos should be taken using the widest angle lens setting available, except for distance photos designed to compress distance and show spatial relationships. Wide angle lenses, equivalent to 28 and 35 mm focal lengths of traditional film cameras, work the best; however they are not yet available on many digital cameras.

   A 35 mm focal length lens typically requires about 12 overlapping photos to pan 360º around the horizon and back to the starting point. Six to eight overlapping photos will suffice for a 180º pan of the station and surroundings. To ensure the same sequence of photos in subsequent years, always start from the north or northernmost azimuth and work clockwise around the compass.

   With digital cameras, typically medium or higher resolution is preferred. This should results in photos that are about 1000 Kb or more in .jpg format that can be somewhat enlarged.

Download and Processing Procedures

1. Under the appropriate “Originals” subfolder, create a subfolder for the download date (e.g., 20120615). Other suffixes may be used to distinguish downloads when multiple sites or parks are downloaded on the same date.
2. Download the raw, unedited images from the camera into the new subfolder. Depending on the operating system used by the person downloading, it may be possible to greatly reduce the time and effort it takes to rename the images in subsequent steps.
   - Plug in the camera to the USB port and turn the camera on.
   - From the Start menu, select All Programs > Accessories > Scanner and Camera Wizard (or select this option if a dialog box appears upon plugging in the camera).
   - Follow screen prompts until reaching the 'Picture Name and Destination' screen. You will be able to select name prefix/suffix, image format, and photo destination.
     - For name prefix, use the naming conventions indicated later in this SOP.
     - For image file format, select the default (JPG).
     - For photo destination, browse to the appropriate “Originals” subfolder.
3. Copy the images to the “Processing” folder and set the contents under “Originals” as read-only by right clicking in Windows Explorer and checking the appropriate box.

These originals serve as backups in case of unintended file alterations (e.g., incorrect names applied, file deletion, loss of resolution, or loss of image metadata upon rotation).

4. Finish renaming the images in the "Processing" folder according to convention (refer to the image naming standards section).
   - If image file names were noted on the field data forms, be sure to update these to reflect the new image file name prior to data entry. Field form annotations should be done in a different color ink from the original notation, after first drawing a line through the original entry (for more information, refer to **Section 4D, Data Entry and Processing**).
   - Renaming may be most efficiently done as a batch using image processing software such as Microsoft Office Picture Manager, which allows a standard prefix or suffix to be added to the camera file name. After batch renaming, a descriptive component may be added manually to each file name.
5. Process the images in the "Processing" folder, using the edit features built into image software programs such as ThumbsPlus or Microsoft Office Picture Manager. At a minimum, the following processing steps should be performed on all image files:
   - Delete photographs of poor quality – e.g., out of focus, poor light levels, etc. Low quality photographs might be retained if the subject is highly unique, or the photo is an irreplaceable data photo.
   - Duplicates should also be deleted unless they provide unique information. Other non-data photographs should be evaluated for their potential long-term value.
   - Rotate images to make the horizon level.
   - Remove 'red eye' glare in photographs of people.
   - Crop non-data images to remove edge areas that grossly distract from the subject.
6. Optional processing steps may include enhancing contrast or brightness, or resizing images to make them small enough for use in documents or on the web. These steps are not recommended for data photos.
7. When finished processing the current download, move the image files that are to be retained to the appropriate folder – i.e., data images to the appropriate "Data" subfolder, other images under the appropriate "Miscellaneous" folder.
8. Photos of potential interest to a greater audience should be uploaded to the NCCN Digital Library.
9. Delete files from the "Processing" folder between downloads to minimize the chance for accidental deletion or overwriting of needed files.

Image File Naming Standards

In all cases, image names should follow these guidelines:

- No spaces or special characters in the file name
- Use the underbar ("_") character to separate file name components
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters
- Park code and year should either be included in the file name (preferred), or specified by parent folders in the directory structure
- Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions)

The image file name should consist of the following parts, separated by an underbar character:

- The date on which the image was taken (formatted as YYYYMMDD)
- The NCCN Site ID, which begins with the park alpha-code
- Optional: a brief descriptive word or phrase
- Optional: a sequential number if multiple images were captured
- Optional: time (formatted as HHMM)

Examples:

- 20090621_MORA_st_Tenas_downsamplesite.jpg = downstream of sample site at Tenas Creek on June 21, 2009.
- 20090621_LEWI_st_Megler_0_yellowflaginv.jpg = invasive species yellowflag documented at Megler (stream), first photo on June 21, 2009.

Post-season Cleanup Procedures

At the end of the season, field crew members should organize images within the seasonal workspace and notify the Project Lead, after making sure that all processing folders are empty. For crew members stationed at remote parks who need to work on local copies, a CD or DVD should be prepared and delivered to the Project Lead.

After each season, the Project Lead (or a designee) should:

1. Review the seasonal workspace folders to make sure that all images are properly named, filed, and accounted for.
2. The "Processing" folder should be empty and may be deleted.
3. Files in the "Not_NPS" folder may be refiled as appropriate.
4. The contents of the "Originals" folder may be deleted once all desired files are accounted for. Originals of data images may be retained as desired, depending on the size of the files and storage limitations. If storage space is limiting, originals may be stored on a local hard drive or external drive.
5. Copy the entire contents of the "Images" subfolder from the seasonal workspace to the main project workspace, and delete the images subfolders from the seasonal workspace.
6. Set the images in the project workspace to read-only to prevent unintended changes.

Uploading Images to STORET

1. Preparations:

   - Photos are stored in the Images folder in the project workspace (\\inpolymfs\parkwide\NCCN\Projects\WCa01_Water_Quality\Images). Final links with NPSTORET should only be established after the images have been named and migrated from the seasonal workspace to the final Images folder to avoid broken links.

2. Import and linking:

   - In the NPSTORET database on the Station Entry Template go to the tab titled “Pictures” (Figure 12-1). This will bring up a sub-form with the Station ID and

Station Name at the top. If no picture is linked to the station number there will be a message “No pictures are currently linked to this record for this station.

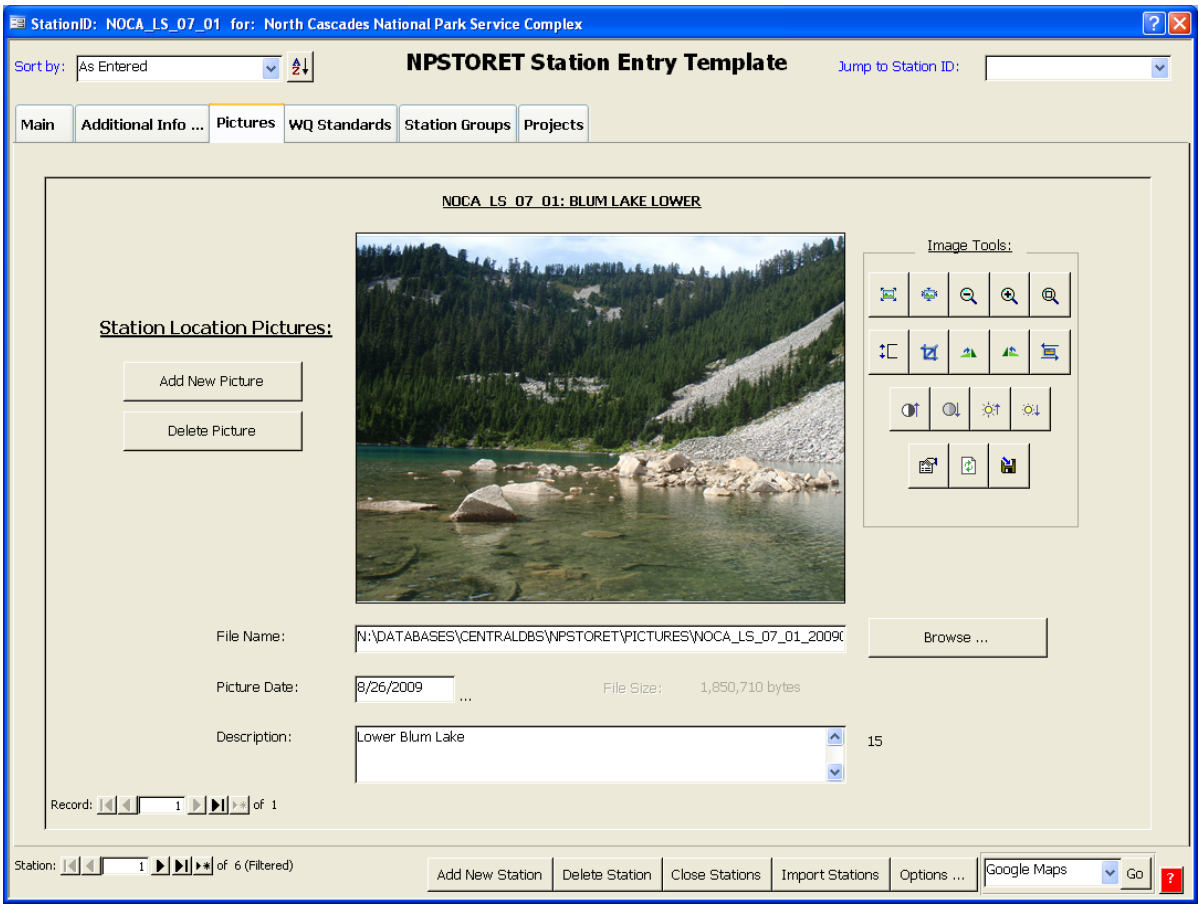


Figure 12-1. NPSTORET database station entry template showing picture linking and image tools form.

- Use the Browse button or type the path and filename of a valid picture below.” The browse button will take you to the Pictures folder where the appropriately named photos relating to stations are stored.
- Select a picture with the Station ID prefix in the photo filename which is the same as the Station ID you want to link it to.
- There are data entry cells for the Picture Date: and Description: These should be filled in upon adding the photo.

3. Browsing through Photos in NPSTORET:

- In the bottom left of the Pictures form is a navigation counter where you can move between records of Stations.

- In the Station Location Pictures: sub-form, bottom left there is another navigation counter that moves through the photos related (linked) to a particular Station.

Quality Control

- Conduct training for new employees.
- Immediately following a survey and before leaving a sampling site, verify that all field data forms are complete and readable, noting any discrepancies or problems on form.

SOP 13. Decontamination of Equipment

Version 5/17/2011

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP provides general decontamination procedures for field crews to minimize the risk of accidental transport of all species, native and aquatic invasive species, and transmission of pathogens and contaminants between water bodies during water quality monitoring activities.

Aquatic invasive species (AIS) are waterborne, non-native organisms that often out-compete, prey upon or bring diseases or parasites to native species, often adversely changing the ecosystem in the process. Humans unwittingly assist the spread of these organisms by transferring them from one body of water to another on footwear, waders, nets, and other equipment. Decontamination of equipment will help prevent the transport of aquatic invasive species and the transmission of pathogens and contaminants between water bodies. Table 13-1 provides a list of documented and potential invasive species of concern in NCCN parks. The following AIS pathogens are also of concern to water bodies within the NCCN:

***Whirling Disease** (WD)* is a parasitic infection caused by the non-native microscopic parasite, *Myxobolus cerebralis* and threatens native trout populations. The WD pathogen has been confirmed in Washington State, but not the disease itself. Most salmonids (salmon, trout and whitefish) are susceptible to infection. Some rainbow and cutthroat trout appear to be more susceptible than other trout species.

Chytridiomycosis (chytrid fungal disease), caused by the fungal pathogen *Batrachochytrium*, is a recently emerged infectious disease implicated for amphibian population declines and extinctions on multiple continents (Berger et al. 1998, Bosch et al. 2001, Lips et al. 2006, Rachowicz et al. 2006, and Byrne et al. 2008). The Declining Amphibian Population Task Force, established in 1991 by the Species Survival Commission (SSC) of the World Conservation Union (IUCN), and other amphibian focused organizations have recommended the need for a hygiene protocol for field workers to minimize the spread of the Chytrid fungus and other pathogens among sites where frogs occur and between individual frogs and/or tadpoles (Speare et al. 2004).

Table 13-1. Documented and potential invasive species of concern in North Coast and Cascades Network parks.

Common name	Scientific name	Present in park[1]	Probably present in park
Invertebrates			
quagga mussel	*Dreissena bugensis*		
zebra mussel	*Dreissena polymorpha*		
ringed crayfish	*Orconectes neglectus*		
rusty crayfish	*Orconectes rusticus*		
northern crayfish, virile crayfish	*Orconectes virilis*		
New Zealand mudsnail	*Potamopyrgus antipodarum*		
red swamp crayfish	*Procambarus clarkii*		
Aquatic plants and algae			
giant reed	*Arundo donax*		
Didymo	*Didymosphenia geminata*		
Brazilian elodea	*Egeria densa*		
hydrilla, waterthyme	*Hydrilla verticillata*		
yellow flag	*Iris pseudacorus*	LEWI	OLYM
parrot feather watermilfoil	*Myriophyllum aquaticum*	LEWI	
Eurasian watermilfoil	*Myriophyllum spicatum*	NOCA	
Common reed	*Phragmites australis*	LEWI, OLYM	
Riparian plants			
garlic mustard	*Alliaria petiolata*		
old man's beard	*Clematis vitalba*	NOCA	
English ivy	*Hedera helix*	LEWI, NOCA, OLYM, SAJH	
giant hogweed	*Heracleum mantegazzianum*	FOVA, MORA	NOCA
purple loosestrife	*Lythrum salicaria*		LEWI, OLYM
reed canary grass	*Phalaris arundinacea*	EBLA, FOVA, LEWI, MORA, NOCA, OLYM, SAJH	
Japanese knotweed	*Polygonum cuspidatum*	MORA, NOCA, OLYM	
cultivated knotweed	*Polygonum polystachyum*	OLYM	
giant knotweed	*Polygonum sachalinense*	OLYM	NOCA
Himalayan blackberry	*Rubus discolor*	EBLA, FOVA, LEWI, NOCA, OLYM, SAJH	
Vertebrates			
American bullfrog	*Rana catesbeiana*	LEWI	
eastern brook trout	*Salvelinus fontinalis*	MORA, NOCA, OLYM	
brown trout [2]	*Salmo trutta*	NOCA	

[1] Park status ('Present in park' and 'Probably present in park') from NPSpecies, accessed 2/18/2010.

[2] Documented in NOCA in 2010.

Disinfection Procedures

The following procedures were directly adapted from the Southwest Alaska Network Standard Operating Procedure #9: Field Equipment Decontamination of Aquatic Invasive Species (Shearer and Moore 2009), Upper Columbia Basin Network Standard Operating Procedure #8: Decontamination of Equipment for Aquatic Invasive Species (Starkey et al. 2009), and Sierra Nevada Network Standard Operating Procedure #7: Equipment Disinfection (Schweizer 2007).

The following procedures must be followed before entering any water body for sampling purposes. Additionally, these procedures must be followed when sampling is complete on one water body but before sampling begins on a different water body. All sampling equipment that may have come in contact with site water must be decontaminated, including but not limited to:

- Waders
- Shoes/boots (including water sandals)
- Neoprene socks
- Dip nets
- Rulers and other instruments
- Specimen bags/containers
- Gillnets
- Plankton nets
- Macroinvertebrate nets
- Rafts

Chemical Disinfection

Chlorine bleach is used to disinfect. Granulated chlorine bleach is preferred over liquid because it is lighter and easier to transport. Granulated chlorine bleach can be purchased at swimming supply stores. All equipment must be disinfected prior to going in the field and while in the field, between two different water bodies. We recognize that felt wading soles provide a good media for transporting aquatic invasive and are more difficult to disinfect. We will continue to investigate safe options and focus extra attention to thoroughly scrub and disinfect felt soles.

Disinfection in the Field

1. Prior to going into the field, package and label the disinfectant.
   a. Get labels and containers to package the dry bleach. Containers can be plastic storage bags, plastic bottles, etc. If using plastic storage bags, put all bags for the trip into one dry bag, stuff sack, or hard sided container that can protect the plastic storage bags from being punctured.
   b. Measure 1 cup of 56% available dry chlorine bleach (to get a 2% bleach solution when added to a 60% full 3 gallon bucket of water in the field).
   c. Place dry bleach in plastic storage bag.
   d. Label plastic storage bag.
   e. Label the puncture resistant bag (stuff sack, dry bag, or hard sided container).
   f. Repeat to have individual pre-measured containers for each lake.

2. The first step in the field is to thoroughly clean equipment.

a. Remove all organic matter (mud, plants, algae, etc.). Particular attention should be given to the treads of boots, sandals, and waders. A stiff brush should be used if needed (disinfected). Run hand up and down ropes attached to all equipment and anchor to dislodge mud, plant material, and organisms
b. Ensure no water remains in any equipment by removing any residual water from all pumps, hoses, etc.
c. Dry as thoroughly as possible. When practical and appropriate, wipe dry.
d. Let all equipment air dry as long as possible.

3. After the equipment is thoroughly cleaned, use the following steps to disinfect.

4. For small equipment, such as dip nets and ropes:

   a. Use a 2% solution of bleach.
   b. Fill the 3 gallon collapsible bucket a little over half (60% full) with water at the new survey site.
   c. Mix the pre-measured quantity of dry bleach into the water in the bucket.
   d. Soak all items (that have been cleaned of mud, etc.) for 2 minutes.
   e. If the solution becomes noticeably dirty, dispose of it and mix up a new batch.
   f. After disinfecting your gear, rinse with water from the new survey site.

5. For large equipment that cannot be soaked, such as float tube, boat, and waders:

   a. Use the 2% solution of bleach.
   b. Fill spray bottle with solution.
   c. Spray cleaned surfaces. If needed, use a sponge to make sure all surfaces get covered with the spray solution.
   d. Let air dry.
   e. Rinse thoroughly with water from the new survey site to remove all disinfectant to avoid sample contamination, and getting bleach on clothing, etc.

6. Dispose of bleach solution at least 100 meters from water over organic matter where the compound will break down (e.g., trail soil, decomposing log, duff).

Disinfection in the lab

Follow steps 2-5 listed above. Clean and rinse with tap water.

Physical Treatment

If using a decontamination solution is not practical, physical treatments may be applied. In all instances, remove all organic matter (mud, plants, algae, etc.). Particular attention should be given to the treads of boots, sandals, and waders. A clean, stiff brush should be used if needed. Then:

- Freeze gear overnight at 26°F (-3°C) or below

  Or

- Soak for at least 10 minutes in hot water (at least 140°F) NOT RECOMMENDED FOR GORETEX.

Or

- Dry gear at least 48 hours under low humidity (or 2 hours in a clothes dryer). Gear must be completely dry at least 24 hours, so total drying time may be 3-5 days. Felt-soled waders require additional drying time.

Equipment List

- Plastic bucket with handle for sterilization and holding cleaning gear or 3 gallon collapsible bucket or dry bag
- Dry chlorine bleach 56% (pre-measured, labeled packages for each sample site)
- Two stiff scrub brushes with handles, one for sterilization, and one for cleaning off mud/dirt
- Rubber dishwashing gloves or latex gloves
- Spray bottle

Quality Control

- Conduct on-site training for new employees.

Specific Safety Considerations

SOP 20: Field and Laboratory Safety.

- Chemical handling MSDS sheets

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SOP 14. Post Field Season Activities

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This Standard Operating Procedure provides details on the events that need to follow the field season. These events help clear up any loose ends that may have developed over the course of the field season. Data sheets are double checked, field and lab equipment is cleaned and properly stored, paying close attention to probe storage requirements. Staff will follow through on sample shipping to ensure samples reach the proper laboratory in sufficient time. This also encourages continuing discussion on protocol improvement and double checks the quality assurance/quality control process. These methods have been adapted from Welch and Glesne (2011).

Data Review and Management

1. Data Sheets: Review of data sheets should be conducted after every field day, every trip and again at the end of the season. It is always helpful to have more than one person review, reducing potential data gaps or mistakes. Reviewing should be done as soon as possible, increasing the rate of information recovery.

2. Digital Photos: Digital photos taken during the field season should be downloaded and labeled as soon as possible when returning from the field. They should be reviewed by each participating crew member again at the end of the season to ensure that they were labeled properly (see SOP 12: Digital Photo Acquisition and Management for Streams and Rivers).

3. Continuous Temperature Data: Downloaded data from the continuous temperature monitoring array (SOP 9: Continuous Water Temperature Sampling for Streams and Rivers) should be reviewed to detect anomalous data signifying a temperature data logger malfunction. The results of the pre and post deployment calibration must be evaluated verifying the accuracy of the temperature loggers. Any need for calibration adjustment should be applied to the collected data set. This procedure is described in detail in SOP 9: Continuous Water Temperature Sampling in Streams and Rivers. More detailed information concerning post field season data handling is given in SOP 16: Data Entry and Verification.

Sample Processing and Shipping

1. Benthic Macroinvertebrate Samples:
    a. Sample sorting: Sample sorting is conducted in the post-field season by the participating crew. The goal is to remove an unbiased, random representation of BMI specimens from a composite of the five benthic kick samples taken from each lake. The procedure is outlined in detail in SOP 8: Benthic Macroinvertebrate Sampling in Lotic Gravel/Cobble Habitats.
    b. Sample shipment: Sorted samples will be either hand delivered or packaged and shipped to the contracting lab according to SOP 8: Benthic Macroinvertebrate Sampling in Lotic Gravel/Cobble Habitats, and confirmation of their arrival should be obtained from the contractor.

Equipment Inventory, Maintenance and Storage

1. General gear treatment: Any repairs or replacement to equipment should be made after the field season ends. Ropes and nets should be stretched out, dried and coiled up in an orderly fashion. If available, gear should be cleaned and placed back in protective storage containers. All gear should be cleaned and stowed in a safe orderly manner. This will add to the life of equipment and aid in gear collection in the following pre-season preparations. All chemicals should be stored in proper containers in their proper storage cabinet. The chemical inventory log should be updated and expiration dates of chemicals should be noted. Any chemical waste should be disposed of according to MSDS recommendations, and local waste disposal authority's requirements.

2. Decontamination of Equipment: SOP 13: Decontamination of Equipment outlines steps to be taken designed to stop the possible transfer of contaminated water from one site to another. It provides a complete list of equipment and materials to be cleaned.

3. Instrument Storage: YSI Model 30, 55, 550A, 556, 650, 600XLM and Hach Sension 156 and Hach HQ40d multi-parameter operations manual maintenance and probe cleaning recommendations are followed and documented. Dissolved Oxygen probes can be cleaned with a Kimwipe and rubbing alcohol. Make sure that the sponge inside the chamber is always kept moist. Batteries should be removed and refer to original manual for details. Documentation of maintenance will help explain or support any unusual data. Post-season maintenance checks should be documented in the appropriate calibration log.

4. Inventory Equipment and Supplies: An inventory of all equipment and supplies should be completed following the field season. Lists of equipment and supplies are found at the end of each Field SOP. Any items requiring repair or replacement should be documented.

Protocol Revisions

The field crew, Project Lead, and Data Manager should meet and discuss any problems that arose during the field season and changes that may be relevant for future monitoring. Any changes suggested will be discussed among the park natural resource representatives who will make the final decision, and document this according to the guidelines detailed in SOP 19: Revising the Protocol.

Quality Assurance/Quality Control

Proper care of lab and field instruments and sampling equipment helps to provide the best quality data. Follow up on QA/QC for each SOP should be conducted to ensure the highest quality work possible (*see* SOP 15: Quality Assurance Project Plan).

References

Welch, C., and R. S. Glesne. 2011. Standard operating procedure #17: Post field season activities. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, CO.

SOP 15: Quality Assurance and Control Plan

Version 1/20/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Suggested citation:

Rawhouser, A. K., R. S. Glesne, and L. P. Grace. 2012. Standard operating procedure #19: Quality assurance and control plan. *In* Rawhouser, A. K., L. P. Grace, R. A. Lofgren, R. S. Glesne, R. E. Holmes, C. A. Welch, B. A. Samora, and P. Crain. 2012. North Coast and Cascades Network water quality monitoring protocol. Natural Resource Report NPS/NCCN/NRR—2012/XXX. National Park Service, Fort Collins, Colorado.

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Overview

This SOP is the functional equivalent of a quality assurance project plan (QAPP) for the NCCN Water Quality Protocol. The purpose of a QAPP is to provide a project-specific "blueprint" for obtaining the type and quality of environmental data needed for a specific decision or use. The QAPP also documents how quality assurance (QA) and quality control (QC) are applied to an environmental data operation to assure that the results obtained are of the type and quality needed and expected (USEPA 2001).

Quality assurance is the planned and systematic pattern of all actions necessary to provide adequate confidence, or assurance, that a project outcome optimally fulfills expectations. It encompasses the broad management concept of maintaining the ability to furnish reliable information and incorporates all peripheral, yet essential, operations, such as field and laboratory systems for sample collection and measurement, survey design, equipment preparation, maintenance tasks, data handling and personnel training (O'Ney 2006, Irwin 2008).

Quality control is the systematic evaluation of the various aspects of a project to ensure, or control, that the standards of quality are being met. Quality control involves specific tasks undertaken to determine the reliability of field and laboratory data. Together, quality assurance/quality control (QA/QC) is a substantial part of any monitoring program. The objective of QA/QC is to ensure that the data generated by a project are meaningful, representative, complete, precise, comparable, scientifically defensible, and reasonably free from bias (Irwin 2008).

Applicability

The procedures in this SOP will be implemented during all work pertaining to NCCN water quality monitoring as described in the protocol narrative. The goals of this QAPP are 1) to assure that all data obtained will contribute quality information to an understanding of the ecological condition of the waters monitored and 2) to aid federal and state regulatory agencies in assessing data compatibility. Specific QA/QC issues are addressed in pertinent SOPs and will be referred to when necessary to avoid redundancy. For example the calibration of continuous temperature monitoring data loggers is detailed in SOP 9: Continuous Temperature Monitoring for Streams and Rivers, training is covered in the protocol narrative and SOP 1: Field Season Preparation and Training, and data management and analysis procedures are described in SOP 16: Data Entry and Verification, SOP 17: Data Quality Review and Certification, SOP 18: Product Delivery, Posting, and Distribution, and SOP 19: Data Analysis and Reporting.

Contracted laboratories conducting invertebrate identification will follow guidelines established by the National Environmental Laboratory Accreditation Program when applicable.

Revisions

This QAPP should be reviewed on an annual basis by park staff and Project Lead and revised as necessary. The steps for changing the protocol are outlined in the procedures for protocol revision (SOP 21: Revising the Protocol). Only after the revision has been received and approved

(at least verbally with written follow-up) by Project Lead and the WRD staff involved with the initial review, shall the change be implemented.

Project Management

Project/Task Organization

This is intended to be a long-term plan and will be implemented and largely managed by LEWI, MORA, NOCA and OLYM personnel with technical assistance from the NPS Water Resources Division (WRD) and local experts when necessary. A summary of project tasks and responsibilities is shown in Appendix H The water quality monitoring project will remain adaptive to changing park and network needs. Future decisions regarding water quality monitoring will continue to be informally made by the consensus of the NCCN Aquatic Technical Committee. This group consists of key network staff and includes the Aquatic Leads from MORA, NOCA and OLYM and the Network Program Manager. Broader-based, long-term decisions are approved by the NPS-WRD. These include approval of WRD-funded staff work plans and approval of the overall monitoring plan.

Background

A detailed description covering the background and objectives, the rationale for selecting this resource to monitor, a stressor characterization, and the protected uses for the waters of the NCCN can be found in the protocol narrative (Section 1).

Project and Task Descriptions

Project tasks, descriptions, and time lines are detailed in the protocol narrative (Sections 3 and 5) and individuals SOPs.

Data Quality Objectives and Criteria for Measurement Data

Data Quality Objectives (DQOs) are qualitative and quantitative statements of the quality of data needed to support specific decisions or actions. DQOs are also used to assess the adequacy of data in relation to their intended use. Data acceptability criteria are also included in the DQOs. The purpose of DQOs are to document 1) the intended use of the data in order of importance, 2) decisions to be made when data are obtained, and 3) the decision makers who will use the data.

All the data from this project have the same intended use since they all help identify the effects of environmental stressors on the aquatic resources of the NCCN. Specific details relating to the intended use of the data and relevant management actions can be found in the protocol narrative, SOP 19: Data Analysis and Reporting, and other relevant SOPs.

Recommendations based on data collected as part of this protocol will be developed by the WQ Project Lead and Park Aquatic Leads. These recommendations, in the form of annual reports or data summaries, will be presented to managers such as the Directors of Resource Management and Park Superintendents who primarily act as the final decision makers for the respective parks. The decision makers for OLYM, MORA and NOCA will generally be the same for each parameter; however, other decision makers may include other federal, local and state agencies.

Data quality objectives will be achieved in a number of ways including:

- Developing SOPs with standardized field and laboratory methods.
- Forming and convening a NCCN external scientific review committee which will serve to bring together scientists that are external to the NPS as well as internal to provide on-going peer review of all NCCN monitoring activities, with QA oversight being one of the primary focuses.
- Documenting the comparability of laboratory and field methods that are consistent with the DQOs.

The intent of these objectives is to provide the minimum standards and guidelines that NCCN parks should utilize, with strong encouragement to use more stringent criteria and to adopt methodologies that improve upon these minimum standards. Revising the Protocol (SOP 21) is aimed specifically at these modifications and improvements. The major goal that this QAPP can accomplish is to have representative, comparable, accurate and precise data that are reasonably free of bias and that can be shared state and nationwide.

QA/QC requirements specific to a measurement task, collection technique and sample handling can be found in the individual SOPs for each parameter.

Data quality will be attained by maximizing and documenting the Data Quality Indicators (DQIs) for the methods used. DQIs are qualitative and quantitative descriptors used in interpreting the degree of acceptability or utility of data. For the purposes of this project the principal DQIs will be defined as precision, accuracy, representativeness, comparability, completeness, bias (systematic error), and sensitivity. However, it should be noted that precision and bias are often placed into a separate category as measurement quality indicators. Establishing acceptance criteria for the DQIs sets quantitative goals for the quality of data generated in the analytical measurement process. DQIs may be expressed for entire measurement systems, but it is customary to allow DQIs to be applied only to laboratory measurement processes.

Measurement Precision

The precision of data are determined by particular actions of the analytical laboratory and field staff. For this project, measurement precision will be considered as the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions. Two methods for calculating measurement precision can be used in the implementation of this SOP (Table 15-1). Both methods are based on calculation of Relative Percent Difference (RPD). This is a less rigorous measure than sensitivity using AMS (sample size of two rather than seven), but is used more frequently to assure that measurements are in ‘control’ where seven replicates are not practical. For laboratory analyses of water chemical parameters RPD is calculated from duplicate measurements of the same sample and is simply referred to as ‘Precision’ (Table 15-1). The alternative measurement of precision is referred to as ‘Precision PLUS or (+)’ (Table 15-1) for which RPD is calculated from duplicate measurements of different but closely related samples in time and space. Precision (+) is used for most parameters measured in the field or for those where duplicate measurements cannot be taken from the same sample (e.g. benthic macroinvertebrates).

The frequency that measurement precision is calculated varies with the type of parameter (Table 15-2). Measurement precision for parameters measured in the field (pH, specific conductance, dissolved oxygen, temperature) will be calculated from duplicate samples collected during every

field deployment. Measurement precision (RPD+) for continuous temperature loggers will be calculated for one or more sets of two consecutive measurements taken during the pre- and post-season calibration checks when water temperatures are held at nearly constant temperature. Duplicate (2) benthic macroinvertebrate samples will be collected for at least 10 percent of the samples collected each year.

MQOs for the parameters shown in Table 15-2 represent a starting point for assessing precision in this project and will be re-evaluated in the future. Current RPD criteria were selected based on what others have found to be acceptable and/or from analysis of duplicate samples collected during the pre-implementation sampling phase of this project (benthic macroinvertebrates).

Unless otherwise flagged and justified, precision MQOs specified in Table 15-2 will be used as data acceptance/rejection criteria. Generally data completeness objectives can be maintained by taking new measurements in the field or re-analyzing samples in the laboratory. Equipment maintenance and calibration checks may be required prior to re-sampling.

Any changes in procedures due to equipment changes or to improved precision and accuracy will be documented. Wherever possible, there should be overlap in sampling methods as well as overlap of staff when turnover occurs.

Systematic Error/Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction. Percent difference (PD) will be used as the primary method for assessing bias and represents the difference between a measured result and a known correct or expected value. The description and method of calculation of PD is shown in Table 15-2 of this SOP. MQOs for assessment of bias attributed to laboratory sample processing, field instrument calibration and observer error are described in Table 15-2 and are discussed in the following sections.

Blank and Spike Control Bias

Core water quality parameters will always be measureable; therefore blank control MQOs for these parameters will need to be based on some minimum acceptable concentration instead of an MDL. The MQO will be developed in the future when more information regarding low values for core water quality parameters is available for the network parks.

Field Instrument Calibration (pH, Specific Conductivity, and Temperature)

Field calibration procedures using NIST traceable standards are given in the YSI 600XLM and Hach HQ40d operation manuals. Comparisons of pre-mobilization, field and post-calibration check results will be used to minimize bias in field measurements of pH and specific conductivity using multiparameter probes. PD is calculated as the difference between the measured value of the instrument, when immersed in the standard, and the value of the standard (see Table 15-1). PD values should not exceed the MQO of 10% (Table 15-2). If this MQO is violated the Field Crew Member must either determine the source of the problem and ensure that it did not jeopardize previous sample run data or discard the data and resample after steps are taken to resolve the issue (e.g., maintenance procedures in the operator manual). Calibration details are recorded on the Stream Water Quality Field Form (Appendix F).

Temperature calibration procedures are given in SOP 9: Continuous Air and Water Temperature Sampling. Calibration check methods apply to continuous temperature loggers, the YSI 600XLM

datasonde, and the Hach HQ40d temperature probe. Calibration checks are conducted prior to the first sampling event of each year and at the end of the season. Thermistors are calibrated at 0°C (ice bath) and 20°C using an NIST certified reference thermometer. The mean acceptable absolute difference for both calibration temperatures should be ≤0.2oC for water temperature measurement and ≤0.4°C for air temperature measurement (SOP 9). Continuous temperature loggers that fail the first pre-deployment check are calibrated a second time. If the logger fails both tests it is rejected for use. If the datasonde temperature probe fails both pre-deployment tests then maintenance procedures in the operator manual should be followed or the probe should be replaced. Similar calibration checks are completed at the end of the field season. If a thermistor fails both of the post-season calibration checks, then the raw data should be adjusted, prior to analysis, by the mean difference of the pre- and post-season calibration tests to correct for instrument bias. Temperature calibration data are recorded in the Continuous Temperature Calibration Check Form (Appendix F).

Observer Bias

Field observer variability related to the estimation of habitat variables in SOPs 5 and 6, the interpretation of categorical rating criteria (see SOP 11: Rapid Habitat Assessment in Streams and Rivers), and species identification will be estimated by pairing an expert observer/technician with a less experienced technician. The technique and observations of the expert (Field Leads and Lead Aquatic Ecologists) will be considered to be correct/unbiased 100% of the time and provide the basis evaluating the PD (percent difference) MQO in Table 15-2 (data will be considered unbiased when the PD does not exceed ±20%).

Proper training of field personnel represents a critical aspect of minimizing bias attributed to observer error. Details of staff training are presented in the protocol narrative and in SOP 1. Staff competency in field sampling and measurement methods will be evaluated on an individual basis by park Lead Aquatic Ecologists or Field Leads. PD for observer bias will be used to evaluate individual observer competency for the appropriate field SOPs prior to allowing them to work independently. An additional field check will be conducted during mid-season. Observer Bias results will be recorded on duplicate SOP data forms noting results of the technician on one form and results of the expert on the other form.

All field identification of invasive species, fish and amphibians will require verification by the Field Lead until repeated consistent agreement is obtained. Voucher specimens will be collected if species verification in the field cannot be documented.

Bias in the identification of benthic macroinvertebrate specimens will be evaluated by having a second taxonomic specialist identify 10% of the samples collected at three year intervals. Bias will be calculated as PD by comparing the results of both taxonomists for metrics based on the number of taxa (e.g., Total taxa, EPT taxa, etc.). PD should not be greater than ±10%. In any case, taxonomists will work together to reach agreement on questionable identifications and if agreement cannot be reached a third taxonomist will be consulted.

Accuracy

Accuracy is the measure of the overall agreement of a measurement to a known value. It is a combination of random error (precision) and systematic error (bias) which are both components

of sampling and analytical operations. The accuracy of an analysis can also be considered how much of the constituent actually present is determined.

Representativeness

Representativeness is a qualitative term that expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness starts at the monitoring plan design level with the identification of the target population and sample selection process and addresses both spatial and temporal aspects of sampling at several scales. In addition, adding the condition of randomness in selection of sampling locations provides statistical relevance regarding the entire population of sites that the samples were drawn from. Examples of design level steps regarding representativeness for this monitoring project include:

1. An initial large number of potential sample locations were considered for monitoring and later reduced to a smaller, more manageable set of sample locations using a standardized set of criteria.

2. At the site scale, some parameters are fixed to a specific location in a given habitat type (e.g., instrumented water quality parameters measured at the upper end of the sample reach, SOP 7) while other parameters are collected from random sub-sampling locations distributed within the delineated sample unit (e.g., benthic macroinvertebrates, SOP 8).

3. Temporal aspects of the monitoring plan design also assure representativeness of the timing of annual site visits and timing of sample collection within a given day (e.g., parameters exhibiting diel fluctuations).

Spatial and temporal aspects related to monitoring plan design representativeness are discussed in more detail in the protocol narrative (Sections 1 and 2) and related SOPs.

Good QA/QC practices and calibration practices will help assure that the measured values are representative of the magnitude of the signal being measured at the particular time and place of measurement. The Field Lead should have knowledge of the range of values expected at any given site, with results from previous sampling trips being annually updated and included in materials brought to the field. Strict adherence to methods given in the SOPs and equipment manuals must be followed with copies of these always available in the field.

Comparability

Comparability is a qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made. The comparability of data produced across NCCN park units is predetermined by the commitment of its staff and contracted laboratories to use standardized methods, where possible, including EPA and USGS approved analytical methods, or documented modifications that provide equal or better results. Sampling bias related to changes in sampling and laboratory methods or observers will be documented, with measures taken to assure future comparability.

Completeness

The completeness of data is basically relationships of how much of the data are available for use compared to the total potential data before any conclusion is reached. Ideally, 100% of the data

should be available. However, the possibility of data becoming unavailable due to laboratory error, insufficient sample volume, or samples broken in shipping must be expected. Also, unexpected situations may arise where field conditions do not allow for 100% data completeness. Therefore, 90% data completeness is required by NCCN parks for data usage in most cases. The Project Lead and Lead Technician are primarily responsible for determining that the 90% data completeness criteria are met or for justifying acceptance of a lesser percentage.

Sensitivity

Measurement Sensitivity

Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest. Sensitivity is a concern for water quality parameters that are present in very low levels or for those parameters that are likely to change in very small amounts over time. This is measured as the method detection level (MDL) or minimum level of quantitation (ML) (see Table 15-1). The MDL is the lowest value that can be distinguished from zero and the ML is the lowest value that can be reliably measured. The ML is simply an expression of the MDL with 99% confidence. NPS monitoring program standard methods for calculating MDL and ML values, following EPA guidance, are given by Irwin (2008). These values will be updated and reported at least once a year and when methods change and will become part of the permanent data record. Values below the MDL and ML will be reported as per the NPS guidance (Irwin 2008) which follows the recommendations of Helsel (2005). Measurement Quality Objectives (MQO) for sensitivity are given in Table 15-2 of this SOP.

With field measurements the lower limits are not a concern. For example, specific conductance in a natural stream cannot be zero; there are always ions present, and this results in some level of electrical conductivity. Measurement Sensitivity is used for laboratory parameters while the term “Alternative Measurement Sensitivity” (AMS and AMS+) is used for field parameters. The AMS is more specifically defined as “the measurement precision uncertainty based on a sample size of seven environmental samples (not blank) and 99% confidence” (Irwin, 2008). Calculate the AMS for each parameter at the beginning of the field season and at the end of the field season. Once a consistent range is developed, this can be conducted annually.

The AMS and AMS+ are calculated as follows:

A. Follow the steps outlined in the appropriate SOP for equipment equilibration, stabilization, and taking a water quality measurement.
B. Take seven distinct measurements for each parameter at regular intervals.
C. Take the standard deviation of the seven samples (this can be calculated in Excel) and multiply by 3.707, the *t* value for a 99% confidence interval and a sample size of seven (six degrees of freedom). This number is taken from a standard table of *t* distribution critical values.

It is the responsibility of the Project Lead to verify that the data are representative while the analytical data's precision, accuracy, and comparability are mainly the responsibility of the contracted laboratories. The specific objectives of the principal DQIs are discussed further

below, and the methods for calculating each DQI are located in Table 15-1. The measurement quality objectives for the variables of interest can be found in Table 15-2.

Monitoring Design Sensitivity

Factors influencing sensitivity at the monitoring plan design level are primarily focused on minimizing total variation which can be moderated by project design choices. Larson et al. (2004) provide a breakdown of variance components for consideration at the design level including: a) residual variation - accounting for measurement precision, observer bias, and short term variation (e.g., diel fluctuations), b) site variation – persistent differences among sample locations across a region (for example, stream channel type, size, depth, and catchment characteristics will vary across the landscape), c) year variation – synchronous yearly variation among all sites in the network (e.g., regional-scale climate changes or broad-scale disturbances), and d) interaction variation – independent, desynchronized yearly variation among all sites in a network, subject to local-scale influences. For example, runoff into some streams or rivers may be greater than in others in some years where the reverse may be true in other years. Residual variation can be controlled by application of QA/QC procedures for sample collection and measurement. Site and interaction variance components can be controlled by increasing sample size and incorporating patterned revisits (annual visits). The year component of variation can be moderated by data analysis procedures that identify explanatory attributes that affect interpretation of changes in response variables.

In addition to implementing QA/QC procedures, several different design based strategies were chosen for this protocol to reduce total variability, consequently enhancing our ability to detect a difference where one exists. These include:

1. Implementing an annual sampling project with visits standardized to the same time period each year. Sampling times for parameters exhibiting diel fluctuations were also standardized. Both of these design choices help to reduce both within-site and between-site variability (Narrative Section 2.3).

2. Selecting response variables with a previous record of having acceptable levels of measurement precision and true variability in the environment.

3. Selecting analysis methods for detecting changes that can incorporate explanatory environmental attributes that contribute to the ‘year’ component of variation (SOP 19: Data Analysis and Reporting).

Minimum Detectable Difference (MDD) can be used to estimate monitoring design sensitivity and represents the smallest difference or change in a mean or median result that is statistically different given stated power, significance level, and sample size. It is influenced by variability of measurement results and when solved for sample size rather than power it determines the duration of fixed frequency sampling required to detect a change of a given magnitude. Our MDD objective for trend analysis is to detect an average annual increase or decrease in the average response of monitoring parameters of ≤3% with an 80% probability of detecting a trend and a 10% probability of incorrectly asserting a trend in a ≤15 year period (approximately a 45% change over 15 years). Results of the power analysis in the Narrative (Section 2.5) indicate that this objective is reasonable for most of our response variables.

Table 15-1. Guidance for calculating the data quality indicators for water chemistry parameters and biological indicators.

Data Quality Indicator	Metric Acronym	Metric + Brief STORET Note	Minimum Frequency of Reporting	Description	Sample Size	Equation
Sensitivity EPA, State, and some USGS labs Low level sensitivity as detection limits (usually lab)	MDL: for control of very low level sensitivity. This is the standard MDL.	Method Detection Level. Put MDL in the detection limit field. If the result is <MDL, STORET Detection Condition is "Not Detected."	1/year or when methods change.	Lowest value that can be differentiated from zero, the lower Semi-Quantitative type of detection limit, based on short term data.	Seven	Obtain MDL from laboratory. For field work calculate as 3.134*SD of a blank or very low signal solution.
Sensitivity USGS NWQL Low level sensitivity as detection limits (usually lab)	LT-MDL: NWQL control of very low level sensitivity.	Long Term Method detection level. USGS Long-Term version of MDL.	Every few years.	Lowest value that can be differentiated from zero, but based on long-term data.	High, based on multi-year data. Get the LT-MDL from USGS.	Obtain from USGS laboratory, Based on F-pseudosigma rather than SDs.
Sensitivity EPA and State quantitative sensitivity as detection limits (usually lab)	ML: Higher than this. Values are quantitative.	Minimum level of quantitation, In STORET, record at LQL.	1/year or when methods change.	Lowest quantitative value above the ML values are quantitative	Based on single MDL.	3.18 * (MDL)
Sensitivity (usually field, or whenever MDL is NA)	AMS: Lowest change possibly real.	Alternative Measurement Sensitivity, For + STORET "analytical procedure description" field.	Beginning and end of field seasons.	Determines instrument noise in both directions (up or down). How big of a change is real?	Seven measurements from the same field sample.	3.708*SD, where SD = Sample Standard Deviation.
Sensitivity AMS Plus (usually field, or whenever MDL is NA)	AMS+: Total variability of close replicates.	Alternative Measurement Sensitivity Plus, Record in STORET as stated above if no other form of AMS is reported.	Beginning and end of field seasons	Includes instrument noise and natural heterogeneity	Seven measurements of nearby but not identical samples, in-situ for sondes only	3.708*SD, where SD = Sample Standard Deviation.

Table 15-1. Guidance for calculating the Data Quality Indicators for water chemistry parameters and biological indicators (continued).

Data Quality Indicator	Metric Acronym	Metric + Brief STORET Note	Minimum Frequency of Reporting	Description	Sample Size	Equation
Precision (lab and field)	RPD: QC Precision Control	Relative Percent Difference. In STORET include both values RPD was based on and optionally include RPD as a comment.	One for every 20 samples, lab or field. In the field, also used for every core parameter calibration.	Variability of repeated measures (precision).	One sample but two values (one comparison of two values measured on one single sample).	RPD = $\left[\frac{S_1 - S_2}{(S_1 + S_2)/2}\right] \times 100$
Precision Plus (usually for field measurements only)	RPD: QC Precision + Control	Relative Percent Difference: Include in STORET as suggested above in no other form of precision is reported.	One for every 20 samples, lab or field. Done instead of precision or in addition to precision.	Variability of repeated measures (precision) PLUS potentially some additional true variability (two samples not one).	Two (one comparison of two values, measurements of two samples collected in close proximity but not one sample).	RPD = $\left[\frac{S_1 - S_2}{(S_1 + S_2)/2}\right] \times 100$
Bias (Lab and field)	PD: QC Bias Control	Percent difference: In STORET, include both values PD was based on and optionally include PD as a comment, choose reference sample or field spike.	QC control 1 for every 20 samples, lab or field. In the field, also used for every core parameter calibration.	Difference between measured result and expected result based on a reference sample standard or a spike.	Two (one comparison of two values, one of which is a known correct or expected value and the other is the measurement result).	PD = [Y - X) / X] * 100, where X is the known (usually "correct" or "expected") or spiked amount, and Y is the measured conc.
Bias Blank Control Bias (Usually for lab measures only)	PD: QC Blank Control Bias	Percent difference, but no blank contamination. Positive bias is reported unless the value meas. is higher than the MDL. Record both meas. value and MDL in STORET.	No less stringent than the State, often QC blank sample once every 20 lab samples or once per field site.	Difference between measurement result and blank sample expected result (usually no greater than the MDL.	Two (one comparison of two values, one of which is the expected value [no greater than the MDL] and the other of which is a measurement of the blank sample.	PD = [Y - X) / X] * 100, where X is the MDL and Y is the measured concentration.

Table 15-2. Measurement quality objectives (MQOs) as acceptance/rejection criteria (*see* Table 15-2 for more detail on Quality Control parameter descriptions, frequency of reporting, sample size and calculation).

Parameter	Instrument or Method	Precision: Relative Percent Diff. (RPD)	Precision (+) Relative Percent Diff. (RPD+)	Field Blanks % Diff. (PD) <MDL	Bias / Systematic Error: % Diff. (PD)	Alternate Measurement Sensitivity (AMS)	Alternate Measurement Sensitivity (+) (AMS+)	Method Detection Limit (MDL)	Minimum Level of Quantitation (ML)
pH	Orion 370 (lab)	RPD ≤10% One set of duplicates taken from every 6-8 samples/yr	NA	NA	PD ±10%, comparison of pre- and post-calibration check results	TBD, once at the beginning and end of field season	NA	NA	NA
	YSI 600XLM Hach HQ40d (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	PD ±10%, comparison of pre-mobil, field and post-calibration check results (SOP 7)	NA	TBD, once at the beginning and end of field season	NA	NA
Specific conductance	Hach SensION 7 (lab)	RPD <10% One set of duplicates taken from every 6-8 samples/yr	NA	NA	PD ±10%, comparison of pre- and post-calibration check results	TBD, once at the beginning and end of field season	NA	NA	NA
	YSI 600XLM Hach HQ40d (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	PD ±10%, comparison of pre-mobil, field and post-calibration check results (SOP 7)	NA	TBD, once at the beginning and end of field season	NA	NA

Table 15-2. Measurement quality objectives (MQOs) as acceptance/rejection criteria (*see* Table 15-2 for more detail on Quality Control parameter descriptions, frequency of reporting, sample size and calculation) (continued).

Parameter	Instrument or Method	Precision: Relative Percent Diff. (RPD)	Precision (+) Relative Percent Diff. (RPD+)	Field Blanks % Diff (PD) <MDL	Bias / Systematic Error: % Diff (PD)	Alternate Measurement Sensitivity (AMS)	Alternate Measurement Sensitivity (+) (AMS+)	Method Detection Limit (MDL)	Minimum Level of Quantitation (ML)
Dissolved oxygen	YSI 600XLM Hach HQ40d (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	TBD	NA	TBD, once at the beginning and end of field season	NA	NA
Temperature	YSI 600XLM Hach HQ40d (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	See SOP 9, Pre- and Post-Field Calibration	NA	TBD, once at the beginning and end of field season	NA	NA
	HOBO® U22 v2, HOBO® Tidbit (field)	NA	RPD ≤10% One set of duplicates taken once at the beginning and end of field season	NA	See SOP 9, Pre- and Post-Field Calibration	NA	TBD, once at the beginning and end of field season during calibration checks	NA	NA
Benthic macro-invertebrates	Taxa richness, metric values SOP 8	NA	RPD <40% One set of duplicates taken from every 6-8 samples/yr	NA	PD ±10% taxa ID between two experts for one out of every 10 samples/yr	NA	TBD, once every 2 years	NA	NA

Personnel Training

Proper training of field personnel represents a critical aspect of quality assurance. Details of staff training are presented in the protocol narrative and in SOP 1. Staff competency in field sampling and measurement methods will be evaluated on an individual by individual basis by Project Lead or Lead Technician. Whenever possible, there will be overlap of staff when turnover occurs.

Additionally, all technical staff involved in data collection will have an educational background in biological or physical sciences. The Park's Supervisory Aquatic Ecologist will have specialized experience in water quality or closely related aquatic resource management activities. Where necessary (e.g., with staff turnover, adoption of new methods, etc.) local technical experts (universities/agencies) will be called upon for training assistance.

Contracted Laboratories

Meetings, whether by phone or in person, will be held with the laboratory contacts at regular intervals to review QA/QC procedures and to make recommendations for future revisions to the NCCN QAPP. Frequent interactions with laboratory staff will facilitate better understanding of key issues and identification of problems as they arise as well as the steps necessary to correct them. Issues such as timing of sample transport and analysis and lab capability and capacity for samples are important to QA/QC data completeness objectives.

Documents and Records

The most recent version of the QAPP will be included in all copies of the NCCN Water Quality protocol and will be reviewed annually as part of training field crews and preparation for the field season.

Details related to data handling, verification, archiving, reporting and retention of records can be found in SOP 2: Project Workspace and Records Management, SOP 3: GPS Data Collection, SOP 12: Digital Photo Acquisition and Management for Streams and Rivers, SOP 16: Data Entry and Verification, SOP 17: Data Quality Review and Certification, SOP 18: Product Delivery, Posting, and Distribution, and SOP 19: Data Analysis and Reporting.

Data Generation and Acquisition

Sampling Process and Design

The NCCN water quality monitoring protocol uses a judgment-based sampling design (Section 2.0 Sampling Design). The schedule for sampling and analytical activities along with the total number of samples, number of sampling locations, number of samples at each location, number of composites, support for the sample number of field and lab replicates, and the plan for obtaining replacement samples essential to the integrity of this project are detailed in the protocol narrative (Sections 2 and 3) and in the associated SOPs.

Sampling Methods

Consistent methods are important to long-term quality data. All measurements and sampling associated with monitoring activities will be conducted according to the protocol narrative and the associated SOPs. When changes in the protocol, such as a change in sampling method, equipment, or staff, occur, efforts will be made to overlap methods and personnel where possible.

Specific methods regarding collection techniques, equipment requirements, sample area, sample volumes, containers, storage and preservation methods, as well as data summary and analysis techniques can be found in the relevant SOPs.

Site Locations

To insure the correct location is sampled, each field visit will be verified with at least two lines of evidence. This can include 1:24,000 maps, aerial photographs, altimeters and/or coordinates derived with a GPS unit. Instructions from SOPs 3 and 5 will be followed to locate correct sampling locations and deviations from standard sampling locations will be documented by field personnel.

Handling and Custody

One part of proper data and sample handling procedures is to provide a complete record of the methods and procedures followed. Complete records are important to long-term monitoring so that anyone using the data may trace the sampling history. Chain-of-custody documentation will be maintained by the Water Quality Project Lead. The chain-of-custody will include not only the data forms, but all references to the sample in any form, document, or log book that allow tracing the sample back to its collection, and document the possession of the samples from the time they were collected until the sample analytical results are received. The handling of field data forms, use of unique site and sample identity codes, data entry, as well as holding and transfer specifications for biological and water quality samples are covered in detail in the relevant SOPs. The general flow of samples and data will follow a sequence of:

1. Sample collection and data acquisition
2. Field preservation of samples
3. Transporting samples and data sheets to local NPS laboratories and resource management offices
4. Logging samples into local NPS lab for temporary storage
5. Preparation and processing of samples for contracted taxonomists
6. Documenting the sample preparation and processing
7. Packaging and logging samples to be sent to contracted facilities
8. Compiling shipping manifest
9. Documenting receipt of samples at contracted facilities
10. Documenting receipt of data from contacted laboratories
11. Data entry into NPS database which includes verification of accurate transcription, data validation and data certification.

Field personnel will have custody of samples during field sampling. Upon returning from the field all samples will be logged into the LEWI, MORA, OLYM and NOCA labs receiving/storing the samples. Chain of custody forms will accompany all samples during transport/shipment to the contract laboratories. Field personnel will enter sampling time and other relevant data on the chain of custody forms. Biological samples will be transported to the contracted laboratories directly by the field crew. Shipping requirements are detailed in relevant SOPs for all samples.

Field Documentation

The following items will be recorded on data sheets for each sampling station:

- Time and date of sample collection
- Sample ID numbers
- The results of any field measurements (temperature, DO, pH, specific conductance turbidity) and the time that measurements were made
- Qualitative descriptions of relevant water conditions (e.g., color, flow level, clarity) or weather (e.g., wind, rain) at the time of sample collection
- A description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality
- The number of containers holding the sample (for biological collections)

Laboratory Sample Custody Log

The following items will be recorded for each sample:

- Unique sample ID
- Type of sample
- Time and date sample was collected
- Initials of collector(s)
- Number, type and size of containers holding the sample
- Location of sample
- Initials of the person logging the sample into the laboratory
- Date sample was logged into laboratory

Shipping Manifest

One copy of the shipping manifest will be sent with the samples to the contracted laboratory and one copy will be held at each respective park. It is also advisable to transmit electronic copies of the shipping manifest to contracted laboratories in advance of shipment. The following will items will be included as part of the shipping manifest:

- Unique sample ID
- Type of sample
- Date sample was collected
- Initials of collector(s)
- Number, type and size of containers holding the sample
- Initials of the person packaging and compiling the shipping manifest
- Date sample was packaged and shipped

Contracted Laboratory Custody Log

Laboratories chosen will be expected to maintain custody logs sufficient to track each sample submitted and to analyze or preserve each sample within specified holding times.

Analytical Methods

The analytical procedures for taking habitat and water quality measurements in the field and in NPS laboratories are identified in each associated SOP. Data summary and analysis methods can be found in SOP 19: Data Analysis and Reporting. Field equipment and contract laboratories are likely to change during the course of this long-term monitoring project. Documentation will be

maintained regarding each instrument and contract laboratory's ability to meet the data quality objectives of this project.

Quality Control

Laboratories providing analytical support for biological analyses will have the appropriate facilities to store, prepare and process samples as well as the appropriate instrumentation and expertise to provide data of the required quality within the timeframe dictated by the project.

Laboratories will be able to provide information documenting their ability to conduct the analyses with the required level of data quality. Such information might include results from inter-laboratory calibration studies, control charts, summary of QA/QC checks and results from certified reference material analyses. Laboratories will also provide a QAPP for their operations.

Duplicate samples will be collected in the field for all core water quality parameters and for at least 10% of the benthic invertebrate samples collected annually. The duplicate sample will be collected in the same manner and as close in time as possible to the original sample. This effort is an attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the situation.

Instrument Calibration Frequency, Inspection and Maintenance

To minimize or avoid downtime of measurement instruments, all field sampling and laboratory equipment will be maintained in good working order. Also, spare equipment or common spare parts (e.g., batteries, DO membranes, pH electrodes) will be available so that repairs or replacement can be made as quickly as possible and measurements will not be lost. All field equipment having manufacturer-recommended schedules of maintenance will receive preventive maintenance according to that schedule (*see* SOP 1: Field Season Preparations and Training Crews and SOP 14: Post Field Season Activities). After use in the field, all equipment will be re-checked for needed maintenance and stored according to manufacturer specifications.

Cumulative Bias

It is expected that equipment, staff, field methods and parameters may change over time. In order to ensure comparability of data in the future it is extremely important to quantify how any of these changes affect pre-existing data. The following discussion provides an overview of possible changes, and how they can be mitigated or reported to ensure change detection is due to environmental conditions rather than observer, instrument or methodology.

Changes in Staff, Instruments, Methods, Indicators and Design

Changes in Field Staff: In addition to training, new employees will be required to demonstrate competency (as described in the previous section) for all assigned activities. Single (identical) samples will be measured by old and new personnel at least seven times when the only thing changing is staff doing the measuring or observations.

Changes in Instruments: For changes in instruments or an individual sensor, a minimum of 30 overlap measurements will be made on the same sample with each instrument. Samples for datasonde measurements should be placed in a container to avoid natural variation. Dissolved Oxygen measurements should be made in an agitated sample. The same calibration standard should be used for both instruments.

Changes in Methods or SOPs: Changes in methods or SOPs may be necessary as new techniques are developed and proven to be superior to older ones. When a change in method or SOPs occurs at least 30 paired measurements will be made.

Changes in an Indicator or in One Surrogate Measure to Estimate Another: At least 50 overlap measurements will be made and results recorded. The bigger the method or SOP change, the more repeat sampling may be appropriate. Sampling overlap for surrogate measures and indicators that are sampled only once a year will require replication within and among years to meet the goal of obtaining a sample of 50 paired measurements.

Changes in taxonomic resolution for macroinvertebrates represent a special case worth noting and which will likely happen throughout the future of the monitoring project. Changes in resolution from parent taxa (existing level of resolution) to increased levels of resolution (e.g., family to genus or genus to species) will be documented in the protocol database. Incorporation of higher levels of resolution of individual taxa used in calculating community metrics will be carefully considered prior to any changes in existing indicator metrics. Voucher specimens of parent taxa from previous samples, for all sample sites, must be re-examined to ensure accurate separation of parent taxa into new taxonomic units before indicator metrics can be changed. Metrics would then be re-calculated for all samples from all years.

Changes in Sampling Design: Statistical consultation will be required regarding any significant future changes to the sampling design. Types of design changes considered here include selection of additional sites, replacement of existing sites or any substantial change in how sample sites are selected. Statistical consultation will be used to evaluate the need and consequences of design changes on interpretation of existing trend data and provide methods for separating the effect of these changes to ensure future comparability of trend data. For sampling design changes, 30-50 overlapping measurements under the old and new designs are recommended by NPS Water Resource Program (Irwin 2008).

Cumulative Bias Documentation Requirements

Following recommendations made by NPS WRD documentation required for evaluating bias shall be archived in the protocol database (Irwin 2008). In addition, changes will be documented in the appropriate SOP Revision History Log (SOP 21: Revising the Protocol), entered as part of the metadata record in NPSTORET, reported in Annual Reports as they occur, and summarized in Five-year Summary Reports. Specific bias data and other QC data documentation requirements for NPSTORET are described in SOP 17: Data Quality review and Certification, and by NPS WRD (Irwin 2008). NOTE: It is important that adjustments to data only be made during the analysis process – only original data is recorded in the long-term databases (NPSTORET). The following are documented for all changes:

- The sample size, standard deviation, and average % bias change from the old measurement system to the new, calculated as an average of percent difference.
- In the case of sample sizes of less than 25 pairs of old and new data, the results of a paired t-test of the differences of the two means, based on alpha of 0.10, power of no less than 90%.
- The measurement precision as reproducibility of repeatability of RPDs or RSDs.

- Measurement sensitivity, as either MDL (if some measurements are near or below the MDL) or AMS (if all measurements are well above the MDL) for both the old and new measurement systems.
- The date that the overlapping measurements started.
- The date the overlapping measurements stopped.
- The date that the average percent difference bias change from old to new measurements was calculated.
- All paired raw values, should future statisticians desire to normalize values a different way when estimating trends.
- A clear statement about the direction of the bias (positive or negative).

Trends are then based on values normalized to the original numbers. If the average PD based on the 30 samples was a plus 5% (the new meter on average read 5% higher than the old meter), for purposes of trend analyses, the new values can then be normalized to old by multiplying the new values times the calculated fraction of change, so one would multiply the new values times 0.95.

Assessment and Oversight

Field personnel will be evaluated on their field performance during field QA audits conducted by the Supervisory Aquatic Ecologist and other park aquatic professionals. Field performance audits are recommended every two years, or more often if necessary. If any deficiencies within a crew are noted during this QA audit, they will be documented and remedied prior to the resumption of field sampling. This can be accomplished by additional training or by changing personnel, but verification of correction of any deficiencies must be documented in writing prior to the resumption of further sample collection activities.

Meetings will be held with the laboratory contacts at regular intervals to review QA/QC procedures and make recommendations for future revisions to the QAPP. The more frequent the interactions with laboratory staff the better the understanding of any key issues or correction of problems will be. Issues such as timing of sample transport and analysis and lab capability and capacity for samples are important to QA/QC data completeness objectives.

Corrective actions which require modifying or establishing new SOPs will follow the methods outlined in SOP 21: Revising the Protocol.

Data Management and Data Quality Assessment

Details related to data handling, verification, quality review and verification, archiving, reporting and retention of records can be found in Section 4.0 of the protocol narrative and in SOP 2: Project Workspace and Records Management, SOP 3: GPS Data Collection, SOP 12: Digital Photo Acquisition and Management for Streams and Rivers, SOP 16: Data Entry and Verification, and SOP 17: Data Quality Review and Certification.

Data Quality Assessment

Data quality review and assessment (SOP 17: Data Quality Review and Certification) are conducted following data entry/verification (SOP 16). Data quality assessment includes a holistic evaluation of the data including assurances that:

1. Proper field methods were followed (Field QA checks and observer comments).

2. Equipment was in good condition and working properly (maintenance records, calibration results, observer comments).

3. Replicates had acceptable values (see MQOs for sensitivity, precision, and bias in SOP 15: Quality Assurance and Control Plan, Table 15-1).

4. Holding times were not exceeded (see SOP 15: Quality Assurance and Control Plan, Handling and Custody section).

5. Data completeness goals were met. (see SOP 15: Quality Assurance and Control Plan, Completeness section).

6. Data were quality controlled and uploaded with appropriate flags if necessary.

7. Cumulative bias has been evaluated and controlled or data normalized prior to analysis (see SOP 15: Quality Assurance and Control Plan, Cumulative Bias section and SOP 19: Data Analysis and Reporting).

Violation of MQOs

Quantitative acceptance/rejection measurement quality objectives (MQOs) representing field and laboratory assessments of sensitivity, precision, and bias are presented in Table 15-2. The following summarizes corrective actions taken for measurements that do not meet the standards given in Table 15-2.

It must be realized that simply rejecting data for parameters (e.g. benthic macroinvertebrate) that cannot be re-sampled within season (results are not available until the post-season laboratory analysis is completed) would result in the complete loss of all data for that year. In addition, QC results for precision and sensitivity calculated for this type of parameter only represent a fraction of the samples collected in any given year and do not necessarily represent the quality of all of the samples collected. For this situation, data will be flagged in the database rather than automatically rejected based on precision and sensitivity QC results. However, QC results will be used to document the quality of the data, as represented by the sub-sample of replicates, and to verify sample collection and laboratory analysis procedures is consistent problems occur.

Sensitivity

Water chemistry results that are higher than the MDL but lower than the ML will be recorded in the database as “Present, below Quantification Limit.” Handling of nondetects in the data analysis will follow recommendations in Helsel (2005) as discussed in SOP 19: Data Analysis and Reporting, Evaluating Assumptions of Potential Statistical Tests section.

Historically data has typically not been censored based on AMS or other expanded uncertainty values. However, as a statistical analysis strategy for looking at a single data point only, one could take the worst case end of the range (Irwin 2008) and flag those measurements that exceed the criterion. Flagged data would be reviewed prior to analyses and recommendations for evaluating sampling procedures may be warranted in the future.

Measurement Precision

Unless otherwise flagged and justified, precision MQOs specified in Table 15-2 will be used as data acceptance/rejection criteria. If RPD exceeds the MQO in Table 15-2, then the other values associated with that batch will be discarded, with the exception of parameters previously discussed at the beginning of this section. Generally data completeness objectives can be maintained by taking new measurements in the field or re-analyzing samples in the laboratory. Equipment maintenance and calibration checks may be required prior to re-sampling.

Bias/Cumulative Bias/Field Blanks and Spikes

Corrective actions for bias related error are discussed under the section for Data Quality Objectives and Criteria for Measurement Data of this SOP.

Data Quality Certification

Data quality certification is described in SOP 17: Data Quality Review and Certification. NPSTORET provides a reporting function (SOP 17) which identifies records requiring attention by the Lead Aquatic Ecologists and is useful in producing the final NPS Project Data Certification Form.

References

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SOP 16. Data Entry and Verification

Version 1/30/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes the general procedures for entry and verification of field data into NPSTORET (for basic water quality parameters) and in the project database application (for additional data). For related guidance, refer to Section 4.3, Overview of Database Design, and Section 4.4, Data Entry and Processing. The following are general guidelines:

1. Data should be entered as soon after data collection as possible so that field crews remain current with data entry tasks, and identify any errors or problems as close to the time of data collection as possible.
2. The front-end database application (both NPSTORET and the project application for additional data) is a Microsoft Access file maintained in the project workspace (see SOP 2). This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as an interface with data residing in the back-end database. It contains the forms, queries, and formatted report objects for interacting with the data in the back-end.
3. The primary back-end database (NPSTORET) for this project is implemented in Microsoft Access. The back-end database for additional non-core parameters (e.g., continuous data, macroinvertebrate data) is implemented in Microsoft SQL Server to take advantage of the automated backup and transaction logging capabilities of this enterprise database software.
4. Each data entry form is patterned after the layout of the field form, and has built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged only to use the pre-built forms as a way of ensuring the maximum level of quality assurance.
5. As data are being entered, the person entering the data should visually review each data form to make sure that the data on screen match the field forms. This should either be done for each record prior to moving to the next form for data entry, or preferably as a separate step after all of the data for a sampling trip has been entered. Important: It is a requirement that all events must be entered and verified at the end of the field season.
6. At regular intervals and at the end of the field season the Crew Lead should inspect the data that have been entered to check for completeness and perhaps identify avoidable errors. The Crew Lead may also periodically run the Quality Assurance Tools that are built into the front-end application to check for logical inconsistencies and data outliers (this step is described in greater detail in Section 4.5, Data Quality Review and also in SOP 17: Data Quality Review and Certification).

Database Instructions

Getting Started

The first action to be taken is to make sure the project workspace is set up properly on a networked drive. Refer to SOP 2 for instructions on how to set up and access the project workspace.

Important Reminders for Daily Database Use

- If accessing the database from a remote park (i.e., other than OLYM), do not open and use the front-end application outside the remote desktop environment as it will run very slowly and likely stall. Instead, refer to the following instructions on remote access before using the application.
- If accessing the database from OLYM, do not open and use the front-end application on the network as this makes it run more slowly. Instead, copy the front-end file from the project workspace to your local desktop and open it there. This copy can be replaced with new versions as they are released.
- New versions of the front-end application may be released as needed through the course of the field season. When this happens, you may see a notification about a new release when opening the current or older versions of the front-end. Copies of the outdated version of the front-end file should be deleted and replaced with the new version, which will be named in a manner reflecting the update (e.g., Water_Quality_2012_v2.mdb).
- Upon opening the front-end application for the first time, there may be a need to reconnect the front-end to the back-end, depending on how the project workspace is mapped on your computer. This database connection update should only need to be done once for each new release of the front-end database.

Remote Connections for Data Entry and Database Access

Most of our project databases are hosted on a server at OLYM. Due to bandwidth limitations, project database users accessing these databases from other parks (or from remote locations at OLYM) may encounter slow performance or application errors when accessing the database directly via a networked drive or a local front-end file. Therefore, to make data entry as smooth and efficient as possible, such users will typically need to use a remote desktop connection each time they need to access the database.

Remote desktop connections access what is called a “terminal server” at OLYM. In doing so, all of the processing is occurring on a server collocated with the database server, thus minimizing the negative effects of bandwidth on application performance. Through such a connection, the remote user is essentially sending mouse moves and keystrokes to the terminal server, and receiving screen updates in return. There may be some noticeable lag time in mouse moves and screen updates, but the performance is often much better than when accessing the data through other means.

Instructions for Using Remote Desktop

1. From the Start menu, go to: All Programs > Accessories > Communications > Remote Desktop Connection. You may wish to create a desktop shortcut by right clicking on the Remote Desktop Connection icon in the menu and selecting Send To > Desktop.
2. With the Remote Desktop window open, type in the terminal server name: “inpolymts1”.



3. Click on the Connect button.
4. Enter your NPS login and password. Note that the login must be preceded by "NPS\", for example: "NPS\gwashington".
5. The remote desktop session will open and you will see a blank desktop that represents what you would see if you were sitting at the computer at OLYM. The first time you use it you may need to map network drives you use frequently and create other useful shortcuts (e.g., to the project workspace), and you will need to use the Access 2010 first-time setup instructions (see the following section) so that the project database functions properly. These initial setup steps should only need to be done once, however.
6. You may switch back and forth between your remote session and your local session (i.e., on your local workstation) using the connection bar across the top of the remote desktop screen.
7. When using the project database, you may need to make a copy of the front-end application if someone else is already using the file (evidenced by a ".ldb" lock file with the same name and in the same folder as the front-end file). You may also want to create your own subfolder in the project workspace for your own front-end copy to avoid these conflicts with other users.
8. When you are finished with your remote session, log off by clicking on Start > Log Off.

The first time you use Remote Desktop, you may wish to select Options from the first Remote Desktop Connection screen to enter more specific information for your frequent remote desktop sessions (e.g., enter "inpolymts1" for the computer, your NPS login, and "NPS" for the domain so you don't have to enter "NPS\" in front of your login each time). Do NOT enter your password or check the box to save your password, as this may present a security risk.

Special Instructions for Access 2010

If you are going to be using Access 2010, make sure the security settings will allow the database to function properly. This is necessary because Access 2010 may have been installed in a very restrictive security mode that disables the functionality built into the project database. Note: This setting change should only need to be performed once. However, if you move to a different workstation, these steps may need to be repeated to allow the database to perform properly. You will know the difference if none of the buttons or form functions on the main database switchboard form work properly, or if you get the following warning message across the top of the window:



To enable the database content to run properly on a consistent basis, do the following:

1. Prior to using the front-end database, open Access 2010 from the Start menu.
2. Go to Start > All Programs > Microsoft Office > Microsoft Office Access 2010.
3. In the upper left corner, click on the Office Button.
4. At the bottom of the menu page, click the Access Options button.
5. Select the Trust Center category on the left panel.
6. In the lower right, click the Trust Center Settings button.
7. Select the Macro Settings category on the left panel.
8. Select the option “Enable all macros”. Then hit OK, and exit Access.
9. From this point forward the project database application should function properly on that computer.

User Roles and Privileges

The database application provides different levels of access privileges: read-only, data entry, power user, and administrator. These privileges are assigned based on user login by the Project Lead or a designee at the beginning of each field season. Most field crew users will be granted “data entry” rights, which allow one to enter and edit data for the current field season only. Certified data and lookup domains may only be edited by users with power user or administrator privileges. If a user name is not granted explicit rights to the database, the application will open in “read-only” mode.

NPSTORET Data Entry

A series of NPSTORET training videos are located in a folder in the project workspace at \\inpolymfs\parkwide\NCCN\Projects\WCa01_Water_Quality\Data\NPSTORET\Help\ which contain individual training videos for each of the main forms within the NPSTORET database. Project staff, especially those entering, summarizing or analyzing data, need to study these training videos to become familiar with the NPSTORET database functioning.

Unique identifiers for each sampling location (Station ID used in NPSTORET) are developed by combining Park code and Site Codes. The format is: four letter park code, underbar, two character water body prefix, and the local site code (PPPP_ww_ccccccc [15 character limit total]). The local site code is the water body name (or abbreviation thereof to meet the 15-character limit). For example: LEWI_st_Megler is the Station ID for Megler Creek at LEWI. This Station ID is also the sampling “Site ID.” A list of Station IDs is generated by the GIS Specialist working in conjunction with the Project Lead. Consult these staff before entering any new Station IDs.

Overview of Project Application Components

The front-end application has multiple functional components, which are accessed from the main application switchboard form that opens automatically when the application starts. Several buttons are found on the form to provide access to different components of the application, and are arranged in functional categories:

- Data Entry and Edits
  - Enter / edit data – Opens a form to confirm default settings (e.g., park, coordinate datum) prior to continuing to the project-specific data entry screens.
  - Task list – Keeps track of unfinished tasks associated with sample locations (for example, forgotten equipment, unfinished data collection) that one field crew can use to communicate with a future field crew.

- Database Admin
  - Db connections – Manage and update the connections to the back-end database(s).
  - Set user roles – Manage the list of users who may view, enter and edit the database. Provides four levels of access: read-only, data entry, power user, and admin. This button is only enabled for power users and administrators.
  - View db objects – Allows the user to view and edit database objects (tables, queries and forms). This button is only enabled for power users and administrators.
  - Backup data – Makes a zipped copy of the back-end file and stores this backup in a subfolder. This button is visible only when one or more of the back-end databases is implemented in Microsoft Access.

- Management Tools
  - Data browser – Opens a tabbed form that provides comprehensive access to data arranged by sampling location. This form has headers for filtering by park, location code, location type and status.
  - Lookup tables – Opens a tool for managing the lookup values for the project data set (e.g., species list, list of project personnel).
  - Sampling schedule – Opens a form to view and edit the sampling schedule.
  - QA checks – Opens the data validation and quality review tool, which shows the results of pre-built queries that check for data integrity, missing data, and illogical values, and allows the user to fix these problems and document the fixes. See SOP 17: Data Quality Review and Certification.
  - Edit log – Opens a form for documenting edits to certified data records.

- Summaries and Output
  - Data summaries – Opens a form for viewing and exporting summary queries for data exploration, analysis and reporting.
  - Task list report – Generates a report of tasks that need to be accomplished for a specified park or sample location (default is for all locations).
  - Quality review report – Generates the data quality review results for a selected year or all years.
  - Navigation report – Generates the field season Navigation Report used to relocate sample locations and brief the crew on tasks that need to be accomplished.
  - Navigation coords – Provides current, best navigation target coordinates for sample locations so these can be loaded into GPS units for navigation, or GIS for display and map production.

Verifying Data Records

Field crews must verify all sampling events throughout the field season. The recommended approach is for one crew member to do all of the data entry for one sample location, then have another crew member review and verify records for that location. The current record status for each sampling event is shown in the Data Gateway Form. To see all of the sampling events in the database, be sure to turn off the filters to show all of the sampling points and events. By double-clicking on the record status field in the Data Gateway Form, the appropriate data entry form will be opened for verification.

To complete the verification step: After all data for a given transect have been entered completely, the database entries should be compared against the original field forms. Each of the main data entry screens has a footer containing fields for storing quality assurance information about the event, and information on who created the sampling event record, who last updated it, etc. When all data for the sampling location have been verified, click on the button that says "Verify this sampling event" to indicate that the event record is complete and accurately reflects the field forms. Clicking this button instantly updates the record status in the Data Gateway for that sampling event. Remember that both transect and quadrat data will need to be verified before clicking the "Verify" button on the main Data Entry form.

SOP 17. Data Quality Review and Certification

Version 1/30/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes the procedures for validation and certification of data in the project database. Refer also to protocol narrative Section 4.3, Overview of Database Design, Section 4.5, Quality Review, and Section 4.7, Data Certification and Delivery for related guidance.

A critical part of project quality assurance is the year-end data quality review and certification. After the season's field data have been entered and processed, they need to be reviewed and certified by the Project Lead before they can be used for analysis and reporting. Data validation is the process of rigorously testing data for completeness, structural integrity, and logical consistency. Although the front-end data entry forms have built-in quality assurance measures – such as domain lookup pick lists, defined range limits for numeric data, and checks for missing values – not all errors can be caught during the data entry step. The following are a few of the general sources of data problems that might be identified during the validation:

1. The response design is ambiguous or insufficiently documented to prevent data gaps and logical inconsistencies.
2. There were logistics problems or a change of plans that prevented a complete sample (e.g., weather conditions, staffing changes).
3. Field crew members did not collect or properly record one or more data elements in the field.
4. Data were entered incorrectly or incompletely.
5. Database records were edited incorrectly or deleted after entry.
6. There is a design flaw in the front-end application that causes data errors during or after data entry.

Given the varied sources of data problems, there is a need for a thorough check of data quality on a regular basis as a means of ensuring continued data quality throughout the span of the project. The front-end database application includes a Quality Review Tool to facilitate the review process by showing the results of pre-built queries that check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed (e.g., missing response variable values), in which case documentation of the resulting errors and why records were not fixed is included in the metadata and certification report.

Once the data have been through the validation process and metadata have been developed for them, the Project Lead should certify the data by completing the NCCN Project Data Certification Form, available on the NCCN website.

Data Quality Review

Validation Queries

The database application has a set of validation checks that are performed on the data set. Each pre-built database query checks for potential problems in the data set, including data outliers, missing values, and illogical values. The set of queries is customized to match project requirements and the structure of the underlying data model. Each query is classified in one of three categories:

1. Critical – These queries check for structural integrity problems or gaps in critical information. This category might include queries that check for missing primary key values, mismatches between data values and lookup domain values, duplicate records, or illogical data combinations. Records returned by these queries fail to meet basic project requirements or structural requirements of the data model, and must be fixed so that they do not return any records before the data can be certified.

2. Warning – These queries represent problems that range in importance, but in any case have the potential to compromise data usability or representativeness if they are not addressed or at least made known to the end user. This category might include queries that check for missing response variables (e.g., substrate or cover class) or values that are beyond a reasonable range; alternatively, it may include queries that require follow-up on data records that can only be done after the field season (e.g., changing status of a monitoring location from "Proposed" to "Active"). The person performing the quality review should make efforts to fix as many of these records as possible by reviewing hard-copy data forms or otherwise following up. However, it may frequently be the case that records in this category cannot be fixed because the reviewer does not have the information needed to fix the record. In such cases the reviewer should provide documentation about which records were not fixed and why using the space provided in the quality review tool (see below). If there are numerous records that cannot be fixed, a general description such as "80 records" or "all stream sites, 43 records", along with a statement of why these were not fixed, will suffice. Documentation will help future data users to know that reasonable efforts were made to address the problems.

3. Information – These queries provide information that can be used to evaluate the completeness and logical consistency of the data set – for example, the number of plots visited per park in a given season, the range of dates for sampling visits, or the number of species recorded during a sampling event. This category may also include checks for missing values in less-vital or optional fields, where a large number of missing values may be anticipated on a regular basis (i.e., as an alternative to making these Warning queries that require follow-through and documentation).

The queries are named and numbered hierarchically so that high-order information – for example, from tables on the parent side of a parent-child relationship such as sample locations – is addressed before low-order information (e.g., individual species observation records). The rationale for this is that one change in a high-order table affects many downstream records, and so proceeding in this fashion is the most efficient way to isolate and treat errors.

The set of queries may need to be augmented or changed as project requirements shift. The Data Manager is also available to revise queries or construct new database queries as needed. Throughout the quality review, the person performing the review should remain vigilant for problems that may not be caught by the validation queries. One task that cannot be automated is the process of making sure that all of the data for the current season are in fact entered into the database. This will often involve manual comparisons between field forms or other lists of the sites visited against the results of queries showing the sites for which data exist.

Using the Quality Review Tool

Open the front-end database application and hit the button labeled “QA checks” to open the quality review form. Upon opening, the quality review form automatically runs the validation queries and stores the results in a back-end database table (tbl_QA_Results). Each time the query results are refreshed, the number of records returned and the run times are updated so that the most recent result set is always available. Reviewer name and remedy descriptions are retained between query runs. Together, these results form the basis of documentation in the certification report output as shown below.

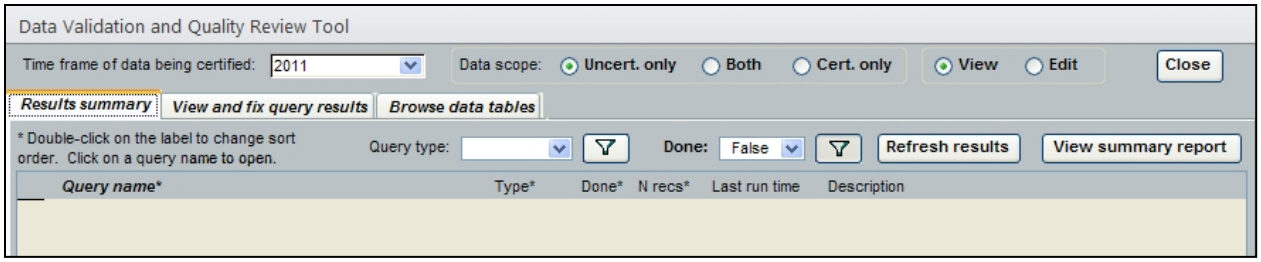
Across the very top of the form are indicators of the time frame (i.e., sample year) and scope of the data being validated. Data scope has three options:

- Uncertified data only (default) – Only uncertified events (i.e., those from the current sampling year) will be considered in validation queries. Note that by design, certain queries will evaluate for problems in records are associated with certified data anyway – for example, all location records are evaluated for duplicate location codes, even those associated only with certified sampling events.
- Both uncertified and certified data – All database records will be included, including certified event data from previous years.
- Certified data only – Only certified events from previous seasons will be considered in the validation queries.

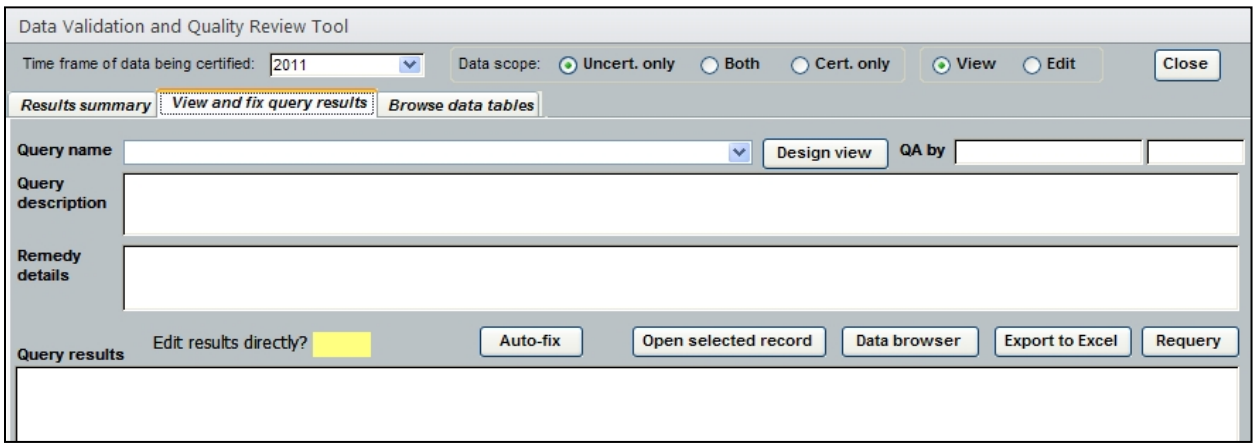
Changing the data scope will show only results for that scope – in other words, results and fixes associated with one scope will be retained even if the scope is changed and the results are refreshed.

The first tab of the quality review form contains a results summary showing each validation query, the type of query (i.e., Critical, Warning or Information), the number of records returned by the query, the most recent query run time, and the description. At the top of the page, there is a button for refreshing the full set of results, which may need to be done periodically as changes in one part of the data structure may change the number of records returned by other queries. Records default to sort by query name, but can be sorted by double-clicking on any of the column headings indicated with an asterisk.

There is also a “Done” checkbox that the reviewer can use as an indicator that they are finished looking at that particular query. Critical and Warning queries that return zero records from the start are automatically set to “Done”. The results records may be filtered by query type and/or by whether or not the query has been marked as “Done”. Note that updating records in one query may change the number of records returned by another query; if the number of records returned by a query changes, the “Done” indicator will be switched off automatically.



Upon double-clicking a particular query name, the second page will open up to show the results from that query. The "Query description" field will indicate the kind of records returned, and may also include a suggested remedy.



In the upper-right is a switch that allows the user to put the form in either view mode (default) or edit mode. Upon changing to edit mode, the form changes color to provide a visual reminder that edits are possible. At this point the query results may be modified and any documentation may be entered in the "Remedy details" section. If certain records in a query result set are not to be fixed for whatever reason, this is also the place to document that. Reviewer name is automatically filled in (if it was blank) once the user updates the documentation. If the reviewer does not have sufficient information to fix one or more records returned by a query, s/he should describe which records were not fixed and why. If there are numerous records that cannot be fixed, a general description such as "80 records" or "All reconnaissance sites, 43 records", along with a statement of why these were not fixed, will suffice. Documentation will help future data users to know that reasonable efforts were made to address the problems.

Some of the other functions of this second page of the Quality Review Tool:

- Edit results directly? – A flag to indicate whether the results for the selected query can be edited directly inside the query results subform. Queries that contain complex joins, subqueries, or grouping functions cannot be edited directly, and instead must be edited in the original data entry form.
- Auto-fix – A button that runs an action query for bulk updates if such a solution is appropriate and available (e.g., replacing all missing values with a code for "Unknown"). Not all validation queries contain references to a bulk update query.

- Open selected record – Opens the selected record returned by the query in the appropriate form. This is useful for quickly moving to the place where the fix can be made most efficiently and taking advantage of existing quality assurance functionality.
- Data browser – Opens the Data Browser form, which provides comprehensive access to data arranged by sampling location.
- Export to Excel – Exports the validation query results to Excel. This can be helpful when there is a need to follow up on complex problems or to verify that all data have been entered.
- Requery – Reruns the validation query and updates the results set.

On this page is also a button labeled “Design view”, which will open the currently selected query in the design interface in Access. In this manner, the user can verify that the query is in fact filtering records appropriately. Note: Please contact the Data Manager before making any changes to query structure or names.

Finally, the third page of the Quality Review Tool is for viewing and editing data tables directly if needed. This page is only available for those with power user or administrator privileges to the database. Important: As with all edits performed during the quality review, these types of direct edits in the data tables should be made with extreme care as many of the quality assurance measures built into the data entry forms are not present in the tables themselves. It is possible, therefore, to make edits to the tables that may result in a loss of data integrity and quality.

Quality Review with NPSTORET Tools

NPSTORET has a number of reporting functions that can be used to facilitate the completion of data quality review.

A random report consisting of 10% of the delineated data can be created using the “Reports and Statistics” tool in NPSTORET. On the “Reports” tab (Figure 17-1), choose "Results” and then choose “Random Sample” of 10% under “Data To Include”. Under “Filter Options,” select the “Date Ranges” of interest. Finally, click on “View Report” to produce the results. All activities and all characteristics can be included in a single report. The report will identify records requiring the attention of the Project Lead, and the results generated can be used as an aid to producing the NCCN Project Data Certification Form. The Project Lead will make all possible effort to recover missing data and/or information and to correct existing incomplete or inaccurate information which is identified in this report.

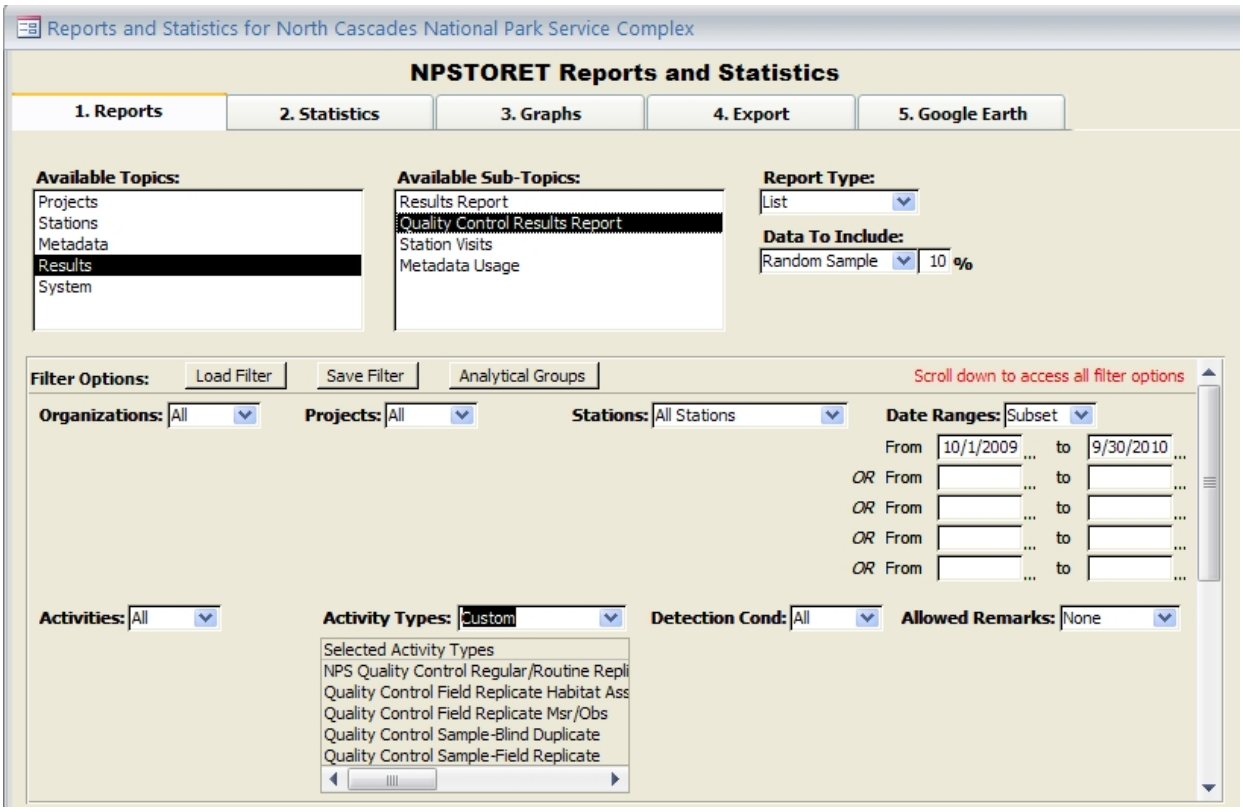


Figure 17-1. Example of how to generate a random report that consists of 10% of data in NPSTORET.

Graphic Data Output

Datasets can be graphed in NPSTORET using the "Reports and Statistics" tool. From the “Graphs” tab, specify the project, station, and date range as shown in Figure 17-2. Once all desired selections are made, click on “Generate Graphs” at the page bottom to bring up a MS Excel worksheet containing the data range and specified graph (Figure 17-3).

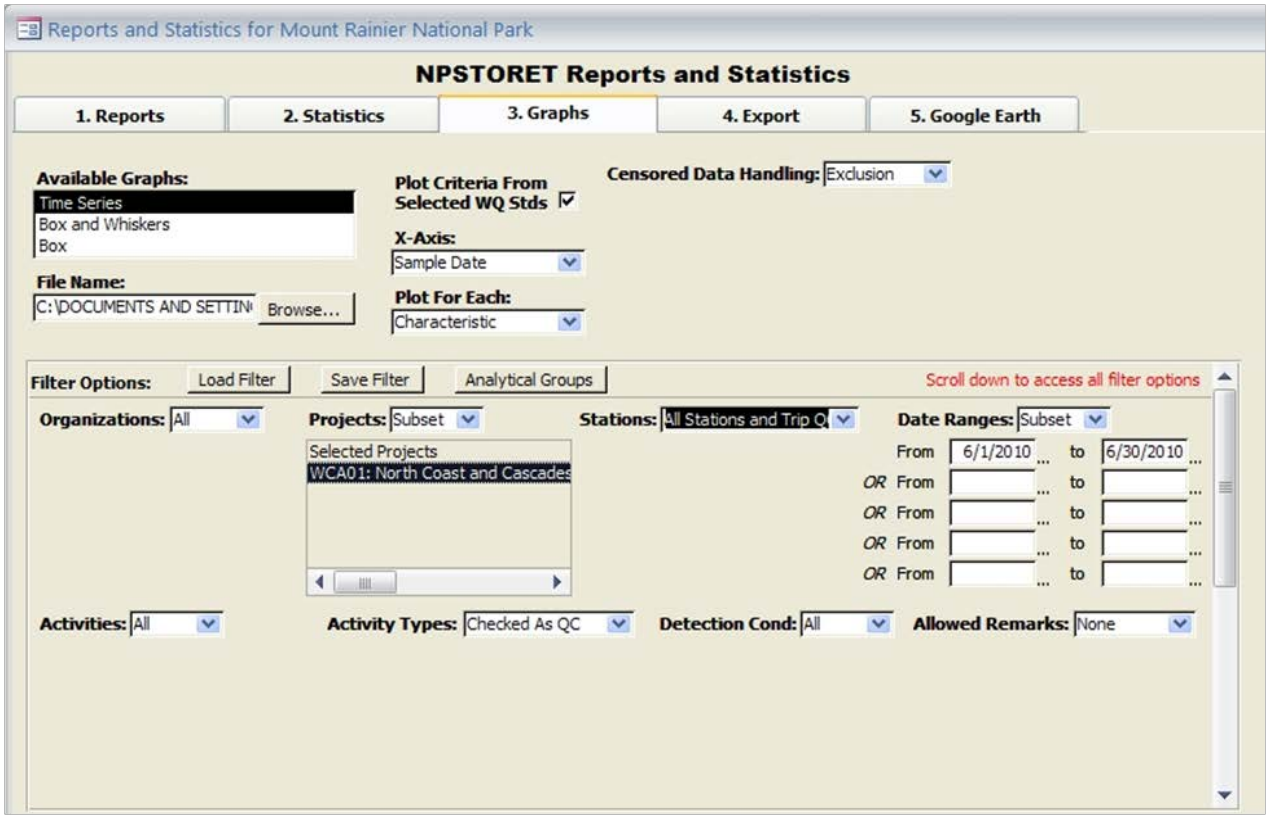
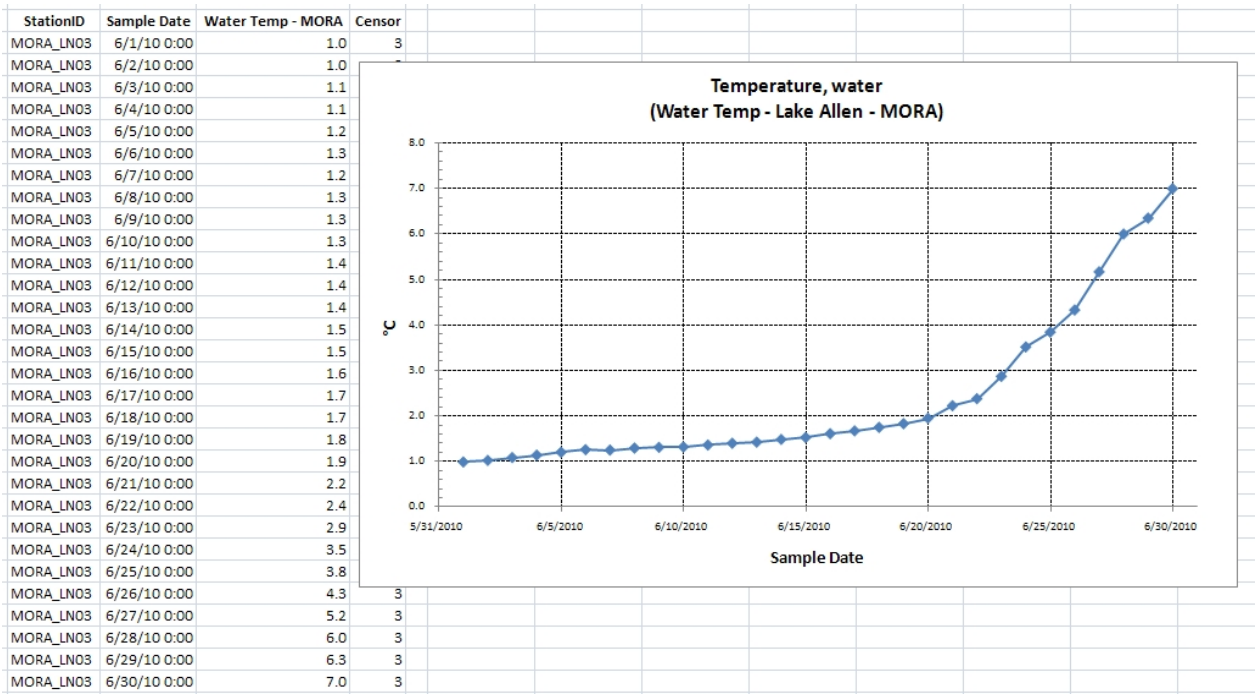


Figure 17-2. Graphing options in the Reports and Statistics tool.



StationID	Sample Date	Water Temp - MORA	Censor
MORA_LN03	6/1/10 0:00	1.0	3
MORA_LN03	6/2/10 0:00	1.0	
MORA_LN03	6/3/10 0:00	1.1	
MORA_LN03	6/4/10 0:00	1.1	
MORA_LN03	6/5/10 0:00	1.2	
MORA_LN03	6/6/10 0:00	1.3	
MORA_LN03	6/7/10 0:00	1.2	
MORA_LN03	6/8/10 0:00	1.3	
MORA_LN03	6/9/10 0:00	1.3	
MORA_LN03	6/10/10 0:00	1.3	
MORA_LN03	6/11/10 0:00	1.4	
MORA_LN03	6/12/10 0:00	1.4	
MORA_LN03	6/13/10 0:00	1.4	
MORA_LN03	6/14/10 0:00	1.5	
MORA_LN03	6/15/10 0:00	1.5	
MORA_LN03	6/16/10 0:00	1.6	
MORA_LN03	6/17/10 0:00	1.7	
MORA_LN03	6/18/10 0:00	1.7	
MORA_LN03	6/19/10 0:00	1.8	
MORA_LN03	6/20/10 0:00	1.9	
MORA_LN03	6/21/10 0:00	2.2	
MORA_LN03	6/22/10 0:00	2.4	
MORA_LN03	6/23/10 0:00	2.9	
MORA_LN03	6/24/10 0:00	3.5	
MORA_LN03	6/25/10 0:00	3.8	
MORA_LN03	6/26/10 0:00	4.3	3
MORA_LN03	6/27/10 0:00	5.2	3
MORA_LN03	6/28/10 0:00	6.0	3
MORA_LN03	6/29/10 0:00	6.3	3
MORA_LN03	6/30/10 0:00	7.0	3

Figure 17-3. North Coast and Cascades Network water temperature graph generated from NPSTORET.

Spatial Data Review

NPSTORET contains a tool for reviewing geospatial records on stations using the Google Earth® application. From the "Station Entry" form, the user can load station coordinate data into Google Earth® to display station plots on a satellite image. The image (Figure 17-4) can be zoomed and multiple stations can be saved and displayed if desired. The shape of the icon used to mark the station location is determined by the Station Primary Type as follows:

- Circle = Well or Spring or Cave or Land
- Square = Lake or Great Lake or Ocean or Reservoir
- Triangle = River/Stream or any other type



Figure 17-4. North Coast and Cascades Network lake site in Google Earth.

Completing Data Certification

Data certification is a benchmark in the project information management process that indicates that the data 1) are complete for the period of record, 2) have undergone and passed the quality assurance checks (protocol Section 4.5), and 3) are appropriately documented and in a condition for archiving, posting, and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data 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 the primary person responsible for completing an NCCN Project Data Certification Form available

on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form and the certified data should be submitted according to the timeline in the annual project task list (Appendix H). Refer to SOP 18: Product Delivery, Posting and Distribution for delivery instructions.

Generating Output for the Certification Report

The first page of the Quality Review Tool in the project database application has a button labeled "View summary report". This button opens the formatted information for each query, the last run time, the number of records returned at last run time, a description and any remedy details that were typed in by the user. This report can be exported from the project database application and included as an attachment to the certification report.

SOP 18. Product Delivery, Posting, and Distribution

Version 1/30/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP provides a schedule, product specifications, and instructions for delivering completed data sets, reports, and other project deliverables for long-term storage (see Table 18-1 of this SOP). Details are also provided on posting products to websites and clearinghouses, and on responding to data requests.

Table 18-1. Product Delivery Schedule and Specifications.

Deliverable Product	Primary Responsibility	Target Date	Instructions
Field season report	Lead Technician	November 15 of the same year	Upload digital file in Microsoft Word format to the NCCN Digital Library.
Raw GPS data files	Lead Technician	October 15 of the same year	Store in appropriate sections of the project workspace
Processed GPS data files	GIS Specialist	November 30 of the same year	
Digital photographs	Project Lead	November 30 of the same year	Organize, name and maintain photographic images in the project workspace according to SOP 12: Digital Photo Acquisition and Management
Certified back-end database	Project Lead	November 30 of the same year; data are not published until two years after the certification date	Refer to the following sections (of this SOP) on delivering certified data and related materials.
Certified NPSTORET .zip archive	Project Lead		
Certified geospatial data	Project Lead with GIS Specialist		
Data certification report	Project Lead		
Metadata interview form	Project Lead		
Full metadata (parsed XML)	Data Manager and GIS Specialist	July 15 of the following year	Upload the parsed XML record to the NPS Data Store[1].
Annual I&M report	Project Lead	June 30 of the following year	Refer to the following section on reports and publications.
5-year analysis report	Project Lead	Every 5 years by June 30 of the following year	
Other publications	Project Lead,	As completed	
Field data forms	Project Lead	Every 6 years by May 31 of the following year	Scan original, marked-up field forms as PDF files and store in the project workspace. Hard copy originals go to the Park Curator for archiving 6 years after data collection.
Specimen curation	Project Lead	November 30 of following year	Label, package and send to Park Curator for archiving. See the section in this SOP on Park Collections.

Table 18-1. Product Delivery Schedule and Specifications (continued).

Deliverable Product	Primary Responsibility	Target Date	Instructions
Other records	Project Lead	Review for retention every January	Retain or dispose of records following NPS Director's Order #19 [2]. Organize and send analog files to Park Curator for archiving. Digital files that are slated for permanent retention should be uploaded to the NCCN Digital Library.

[1] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Information Management Applications (IRMA) portal (http://irma.nps.gov).

[2] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm.

NCCN Digital Library

The NCCN Digital Library is a document management system maintained in a Microsoft SharePoint environment at: http://imnetsharepoint/nccn/default.aspx. The primary purpose of this system is to maintain important digital files – such as reports, protocol documents, and select project images – within a content management system, and to make them available to NCCN and NPS users. NCCN users may view, post and edit documents within this system; other NPS users have read-only access to these files, except where information sensitivity may preclude general access.

To enable discovery and long-term usability of key documents, certain information about each file needs to be filled in as files are uploaded, for example:

- Document title
- Project code (e.g., "WCa01" for Water Quality Monitoring)
- Park(s) to which the file(s) apply; multiple parks may be selected for each upload
- Document type (e.g., formal report, database, protocol, etc.)
- Date of publication or last revision
- Author name(s)
- Sensitivity: Sensitive, NPS Only, or Public. Sensitive files will not be viewable without permission. For a definition of sensitive information, see Section 4.6.1, Identifying and Handling Sensitive Information.
- Description - Document abstract, additional authors and credits, special use instructions, etc.

For project staff without access to the NPS intranet, files may be sent by email or CD/DVD to the Project Lead or Data Manager for upload, along with the above information in a text file or accompanying email.

Park Collections

The collections at NOCA will serve as the park of record for the NCCN Water Quality Monitoring Project. Voucher specimens, hardcopy field forms, and printouts of annual reports, technical reports, and other publications will be filed there. In addition, other hard copy project records should be reviewed and organized on an annual basis (or at the conclusion of a project), and sent to park collections for long-term storage.

The Project Lead should contact the Park Curator during the project planning if voucher specimens will be collected. All specimens must be labeled with NPS accession and catalog numbers, and with advance notice the Park Curator can help to provide these numbers ahead of time so they can be included in label printouts. Specimen label information will be entered by the Park Curator into the ANCS+ database. The Park Curator will help to decide which and how many specimens can be maintained at the park versus sent to another institution or collection. Collected materials remain NPS property even if they later reside in a non-NPS collection (e.g., university herbarium).

Delivering Certified Data and Related Materials

Data certification is a benchmark in the project information management process that indicates that the data a) are complete for the period of record, 2) have undergone and passed the quality assurance checks, and 3) are appropriately documented and in a condition for archiving, posting and distribution as appropriate. To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data.

The following deliverables should be delivered as a package:

- *Certified back-end database* – Database containing data for the current season that has been through the quality assurance checks documented in SOP 17: Data Quality Review and Certification. Delivery of this item is only applicable in cases where the back-end database is implemented in Microsoft Access and/or is deployed outside the NPS firewall during the quality review. In all other cases, the Data Manager will already have access to the certified data.
- *Certified geospatial data* – GIS themes in ESRI shapefile or geodatabase format. Refer to NCCN GIS Development Guidelines (NCCN 2009) and NCCN GIS Product Specifications (NCCN 2007a) for more information (available at on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm).
- *Data certification report* – A brief questionnaire in MS Word that describes the certified data product(s) being submitted. A template form is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- *Metadata interview form* – The metadata interview form is an MS Word questionnaire that greatly facilitates metadata creation. It is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. For more details, refer to Section 4.6, Metadata Procedures.

Packaging Certification Materials for Delivery

After the quality review is completed, the Project Lead should package the certification materials for delivery as follows:

1. Create a compression file (using WinZip® or similar software, or by right-clicking in Windows Explorer). This file should be named in accordance with general file naming standards, and the name should include the project code (WCa01), park code if applicable, and the year or span of years for the data being certified. For example: WCa01_2012_certification_pkg.zip.
2. Add the back-end database file to the compression file. Note: NPSTORET automatically creates a .zip format backup file every time a user closes the application (**Note**: this is an option that needs to be set from the 'set defaults' utility). This file includes a copy of the back-end, including any associated images and documents, and is placed in the network 'backups' subfolder of the NPSTORET application. The front-end application does not contain project data and as such should not be included in the delivery file.
3. Add the completed metadata interview and data certification forms to the compressed file. Both files should be named in a manner consistent with the naming conventions described elsewhere in this document.
4. Add any geospatial data files that aren't already in the possession of the GIS Specialist. Geospatial data files should be developed and named according to NCCN GIS Naming Conventions (NCCN 2007b).
5. Deliver the compressed file containing all certification materials to the \Data\Archive folder of the project workspace and notify the Data Manager by email. If the Project Lead does not have network access, then certification materials should be delivered as follows:
   a. If the compressed file is under 9 mb in size, it may be delivered directly to the Data Manager by email.
   b. If the compressed file is larger than 9 mb, it should be copied to a CD or DVD and delivered in this manner. Under no circumstances should products containing sensitive information be posted to an FTP site or other unsecured web portal. For more information refer to Sensitive Information Procedures at http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm).

Upon receiving the certification materials, the Data Manager will:

1. Review them for completeness and work with the Project Lead if there are any questions.
2. Check in the delivered products using the NCCN project tracking application.
3. Notify the GIS Specialist if any geospatial data are submitted. The GIS Specialist will then review the data, update any project GIS data sets and metadata accordingly, and file those products in the project workspace.
4. Work with the GIS Specialist to finalize coordinate data and any GIS-derived fields therein (e.g., elevation, slope, aspect).
5. Archive the certified products in the project workspace.
6. Notify the Project Lead that the year's data have been successfully reviewed and processed. The Project Lead may then proceed with data summarization, analysis and reporting.
7. Develop, parse and post the XML metadata record to the NPS Data Store.

8. After a holding period of two years, the Data Manager will upload the certified data to the NPS Data Store. This holding period is to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems.

No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Only products that are intended for public/general-use may be posted to public websites and clearinghouses – these may not contain sensitive information.

Instructions for Reports and Publications

Annual reports and trend analysis reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template, and trend analysis and other peer-reviewed technical reports will use the Natural Resource Report (NRR) template. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

The procedures for annual reports, technical reports, and publications are as follows. (Note: This is optional for field season reports, which are intended to be internal communications only.)

1. The Project Lead or Data Analyst formats the document according to the NPS Natural Resource Publications standards.
   a. Formatting according to NPS standards is easiest when using the report template from the very beginning, as opposed to reformatting an existing document.
   b. When creating the file, use appropriate naming standards (described in this document). If creating the document in SharePoint (e.g., the NCCN Digital Library), attribute the file as a draft; otherwise add “DRAFT” to the file name.
   c. Open the document and add “DRAFT” to the header or document watermark as appropriate.
2. The document should be peer reviewed at the appropriate level. For example, I&M Annual Reports should be reviewed by other members of the project work group. The Network Program Manager will also review all annual reports for completeness and compliance with I&M standards and expectations. Before sending the document for review, rename the document by adding a date stamp to the end of the file name using the YYYYMMDD format.
3. Upon completing the peer review, the Project Lead should acquire a publication series number from the appropriate regional or national key official. Instructions for acquiring a series number are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.
4. The Project Lead should finalize the document:
   a. Ensure that the publication/version date (last saved date field code in the document header, if used) and file name (field code in the document footer, if used) are updated properly throughout the document.
   b. Remove the word “DRAFT” from watermarks, document headers, and file name.
   c. Remove any previous date stamp from the file name.

d. If the document has been developed and maintained in SharePoint (e.g., the NCCN Digital Library), update the document attribute to "Final".
e. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
f. Create a PDF version of the document and upload the final file and PDF copy to the NCCN Digital Library for long-term storage.
g. Store both the Word document and PDF copy in the appropriate section of the project workspace (see SOP 2).

5. Notify the Park Curator and Data Manager that the report is available, and send a printout to the Park Curator to add to the host park collections.
6. The Data Manager (or a designee) will create a bibliographic record and upload the PDF copy to the NPS Data Store according to document sensitivity.

File Naming Standards

Prior to delivering or uploading digital products, files should be named according to the naming conventions appropriate to each product type.

Reports and Publications

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
- Dates should be formatted as YYYYMMDD.
- As appropriate, include the project code (e.g., "WCa01"), network code ("NCCN"), and year in the file name.

Examples:

- NCCN_WCa01_2012_Annual_report.pdf
- NCCN_WCa01_2012_Field_season_report.doc
- NCCN_WCa01_2012_Certification_report.doc

Other Files

General naming standards as described in SOP 2 apply to all deliverables. When delivering files to the NCCN Digital Library, file names should be modified as needed to include the project code (e.g., "WCa01"), network code ("NCCN") or park code, and year as appropriate (e.g., NCCN_WCa01_2012_cert_package.zip). Specific standards for images are described in SOP 12: Digital Photo Acquisition and Management for Streams and Rivers, and in SOP 21: Revising the Protocol for protocol documents.

Product Posting

Once digital products have been delivered and processed, the Data Manager or a designee will post them to or otherwise update the following applications to make them generally available:

1. The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov). Refer to the section on sensitive information in Section 4J, Identifying and Handling Sensitive Information for information on options for flagging products containing sensitive information within the system, or for modifying products prior to posting so that they no longer contain sensitive information and can therefore be shared broadly. Full metadata records will be posted to the NPS Data Store as they are created; data sets will be posted after a two-year hold to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems. For reports and other publications, an online record is created after first verifying that one does not already exist. The digital report file in PDF format is then uploaded.

2. The EPA STORET Data Warehouse (http://www.epa.gov/storet/dw_home.html) is an online system for nation-wide water quality data collected by states, federal agencies, volunteer monitoring groups, and other entities. Under the Clean Water Act, states are responsible for ensuring that waters within their boundaries (including waters in National Park units) meet or exceed their designated beneficial uses. On an annual basis, after data certification, the NCCN NPSTORET database file(s) will be sent to the NPS Water Resources (WRD) staff contact who will quality check the data and, in consultation with the Project Lead, make any edits/modifications necessary to upload the data into the WRD copy of STORET. If necessary – due to data revisions or back-end version upgrades – WRD will return a revised version of the data in NPSTORET to NCCN. On a monthly basis, WRD will transmit data to the EPA for inclusion in the STORET Data Warehouse, where the data will be accessible to the states, other entities, and the public via the internet.

3. NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov). Species observations will be extracted from project data sets and uploaded into NPSpecies.

4. NCCN Web Site is maintained by NCCN staff as part of the NPS Inventory and Monitoring web site (http://science.nature.nps.gov/im/units/nccn) to describe our program, the vital signs selected for monitoring, and to highlight certain products and information derived from inventory and monitoring work at NCCN. The site has both internet and intranet components. Select products such as annual reports and technical reports will be posted to the web site.

These applications serve as the primary mechanisms for sharing reports, data, and other project deliverables with other agencies, organizations, and the general public.

Holding Period for Project Data

To protect professional authorship priority and to provide sufficient time to complete quality assurance measures, there is a two-year holding period before posting or otherwise distributing certified project data. This means that certified data sets are first posted to publicly-accessible

websites (i.e., the NPS Data Store and EPA STORET) approximately 24 months after they are certified (e.g., data collected in June 2012 and certified in January 2013 becomes generally available through the NPS Data Store in January 2015). In certain circumstances, and at the discretion of the Project Lead and Park Biologists, data may be shared before a full two years have elapsed. (**Note**: This hold only applies to raw data, and not to metadata, reports or other products which are to be posted to NPS clearinghouses in a timely manner as they are received and processed.)

Responding to Data Requests

Occasionally, a park or project staff member may be contacted directly regarding a specific data request from another agency, organization, scientist, or from a member of the general public. The following points should be considered when responding to data requests:

- For all Inventory and Monitoring projects in NCCN, NPS is the originator and steward of the data, and the NPS Inventory and Monitoring Program should be acknowledged in any professional publication using the data.
- NPS retains distribution rights; copies of the data should not be redistributed by anyone but NPS.
- The data that project staff members and cooperators collect using public funds are public records and as such cannot be considered personal or professional intellectual property.
- No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to the section in this document about sensitive information and also to http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- For quality assurance, only the certified, finalized versions of data sets should be shared with others. In exceptional cases where a provisional data set needs to be shared with others prior to certification:
    - Any accompanying communications should clearly indicate that the data set is provisional and subject to change according to our quality review process.
    - File names and the media it is sent on should be clearly labeled as containing provisional data not for distribution.

The Project Lead will handle all data requests as follows.

1. Discuss the request with other network and park staff members (e.g., Park Biologists) as necessary to decide on an appropriate response to the request.
2. Notify the Data Manager if s/he is needed to facilitate fulfilling the request in some manner.
3. Respond to the request in an official email or memo.
4. In the response, refer the requestor to the NPS Data Store and the IRMA Portal (http://irma.nps.gov), so they may download the necessary data and/or metadata. If the request cannot be fulfilled in that manner – either because the data products have not

been posted yet or because the requested data include sensitive information – work with the Data Manager to discuss options for fulfilling the request directly (e.g., writing data to CD or DVD). Ordinarily, only certified data sets should be shared outside NPS.

5. It is recommended that documents be converted to PDF format prior to distribution. This is to maximize portability and to reduce the ability for others to alter and redistribute files.
6. If the request is for data that may reveal the location of protected resources, refer to Section 4 (below) and the Sensitive Information Procedures at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
7. After responding, provide the following information to the Data Manager, who will maintain a log of all requests in the NCCN project tracking database
    - Name and affiliation of requestor
    - Request date
    - Nature of request
    - Responder
    - Response date
    - Nature of response
    - List of specific data sets and products sent (if any)

Freedom of Information (FOIA) Requests

All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources, most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the occurrence. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of the unedited version of products are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (e.g., the full data set that includes sensitive information) may be shared only after a confidentiality agreement is established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to the website below for more information:
http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

Documenting Sample Transfer

1. Lead Technicians fill out the chain-of-custody (COC) forms that include the following from Appendix F: Field and Laboratory Data Forms.
    a. BMI Sample Processing Bench Sheet

The COC form is used to document the taking, shipment, and receipt of samples. The laboratory will use the COC forms to check samples into the analytical process.

2. The contracted laboratory will maintain custody logs sufficient to track each sample submitted.

3. COC documentation will be maintained by the Project Lead. The COC will include not only the form, but all references to the sample in any form, document, or log book that allow tracing the sample back to its collection, and documents the possession of the samples from the time they were collected until the sample analytical results are received.

Annual Data Transfer to WRD STORET

Overview

Annual transfer of the NPSTORET park master versions and associated files to NPS WRD satisfies the Natural Resource Challenge-Water Quality STORET reporting requirement. Public distribution as well as long-term archival of water quality data, is provided by the NPS WRD STORET database and the National EPA STORET Data Warehouse and their associated online interfaces.

Upon completing data certification, the Project Lead will work with the Data Manager to submit a copy of the certified NPSTORET data file to NPS WRD. The submission will include the necessary information resources that are not stored within the NPSTORET database, such as images and reference documents. A copy of the submitted master data file at each park will be archived in the project workspace. NPS WRD staff will normally return the park's validated master WQ data file between one and three weeks after submission. During this period they will communicate as required with project staff and the Data Manager to address errors and/or issues, and they will upload the validated data to WRD STORET (an NPS database instance of STORET). Once the data is in WRD STORET, it is harvested every month to populate and/or update the EPA STORET Data Warehouse.

Data Transfer to WRD

The following steps are recommended to accomplish the annual submission and return process:

1. Perform validation and data flagging procedures on preliminary data
2. Complete data certification.
3. Retrieve the backup file from the NPSTORET ‘backup’ folder
4. Rename the archived file ‘NCCN_NPSTORET_yyyy_WRD_submitted<mm_dd_yyyy>.zip’ where ‘yyyy’ is the sampling year
5. Forward a copy of the archived file to WRD
6. Set read-only permission for the archived data file in the NPSTORET folder; this file serves as a record of what has been submitted to WRD
7. Set read-only permission for the master back-end data file in the NPSTORET folder
8. Upon return of the validated data file from WRD, replace the master file with the validated file

9. Update any analysis and reporting based on corrections made by WRD

References

North Coast and Cascades Network (NCCN). 2007a. GIS Product Specifications. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

North Coast and Cascades Network (NCCN). 2007b. GIS Naming Conventions. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

North Coast and Cascades Network (NCCN). 2009. GIS Development Guidelines. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

SOP 19. Data Analysis and Reporting

Version 1/23/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

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Adapted from:
McDonald, T. 2005. NPS North Coast and Cascades Network (NCCN) wadeable stream data analysis protocol. West Inc., Cheyenne, WY.

McDonald, T. L., and R. S. Glesne. 2009. Standard operating Procedure #21: Data analysis and reporting. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, CO.

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Introduction

This SOP outlines the statistical analyses planned for the data collected as part of the NCCN Water Quality Monitoring Project. The sampling and analysis of the rivers and streams for this protocol uses a judgment sample that is targeted to assess specific locations that are at a high risk of impairment, and it is not intended to provide inference beyond the location that is sampled.

Overall, these analyses are designed to extract useful information and facilitate conclusions regarding the project's objectives by examining statistical relationships in the data. At this time, no data have been collected as part of the NCCN Water Quality Monitoring Protocol. Therefore, this SOP should be viewed as a general set of options that will be narrowed or augmented as data compilation and descriptive analysis progress. While the questions asked of data and types of analyses can vary depending on the current needs of the parks, it is important to describe analyses that meet overarching analytical goals which include the following:

5. Determining the status of a water body in relation to CWA criteria
6. Estimation of current (or past) values of a parameter at individual sample locations
7. Detecting significant abrupt changes in a parameter at individual sample locations
8. Detecting long-term steady trends and step trends in a parameter at individual sample locations.

Future analyses will not be limited to the statistical procedures given in this SOP. Additional tests or improvements in analysis may prove to be more applicable in future evaluations. It is expected that consultation with a statistician will be required preceding the completion of Five-year Summary Reports, for changes in sampling design, and for significant modifications of sampling methods.

The following sections discuss the initial review and preparation of the data, routine data summaries, and methods for statistical analyses designed to evaluate changes and trends at individual sample locations. In addition, the development of criteria for bioassessment and chemical attributes of aquatic resources are discussed. Reporting schedules and content are given in the last section.

Preliminary Data Review and Preparation

Data Management Error Checking

Prior to data analyses, error checking procedures found in SOP 17: Data Quality Review and Certification are performed and reported by the Project Lead. These procedures provide (using standard queries) information regarding transcriptional errors, missing data, preliminary screening of out of range values, and flagging entries that are below detectable limits (nondetects). These procedures provide (using standard queries) information regarding transcriptional errors, missing data, preliminary screening of out of range values, and flagging entries that are below detectable limits (nondetects). During this process, only known transcriptional errors are corrected by the person entering or verifying the data, after cross-checking the original data. Additionally, data forms should be reviewed to flag records and comments regarding atypical weather conditions, equipment failures and calibration issues, and problems concerning sample processing, storage, and preservation, etc. Decisions regarding

quality control violations of MQOs (SOP 15: Quality Assurance and Control Plan) and the need for adjustments related to changes in observers, instruments, methods, indicators, or sampling design should be evaluated and corrected prior to analysis (see SOP 15: Quality Assurance and Control Plan, Cumulative Bias section).

Exploratory Data Analyses

Exploratory data analyses apply basic analyses and statistical tests to 1) identify whether the data support underlying assumptions of potential statistical tests, 2) examine relationships between dependent variables and potential explanatory attributes or ancillary variables, 3) classify sample locations into homogeneous subsets based on similarities in biological and/or environmental characteristics, and 4) determine if modifications are necessary prior to further statistical analysis. Modification of data prior to analysis includes treatment of outliers, data below detection limits (censored data), missing data, and transformation of data to meet test assumptions. Ideally, potential statistical tests and their assumptions should be identified prior to the exploratory analysis step, as they must also be considered prior to making judgments concerning handling of outliers, missing data, censored data, and the application of data transformations.

Much of the following discussion and methods generally follow those from the USEPA (2006) document, Data quality assessment: Statistical methods for practitioners QA/G-9S, http://www.epa.gov/quality/qs-docs/g9s-final.pdf (accessed 14 March 2011). Discussion and methods concerning basic statistical quantities and graphical representations are found in Chapter 2, and specific information on statistical tests, their assumptions and limitations can be found in Chapters 3 and 4 of USEPA (2006).

Basic Statistical Quantities and Graphs

Basic statistical quantities and graphs are generated by the data analyst to learn about the structure of the data, identify patterns and relationships, or potential anomalies in the data. Statistical quantities numerically describe the data set. Examples include a mean, median, percentile, range, inter-quartile range, t-distribution, standard deviation, and skewness (Table 19-1). They can be used to provide a mental picture of the data and are useful for making inferences concerning the population from which the data were drawn.

Graphical representations (Table 19-2) are used to identify patterns and relationships within the data and identify potential problems. For example, a normal probability plot may allow an analyst to quickly discard an assumption of normality and may identify potential outliers. It is useful to look at these measures during the EDA process, but it is not always necessary to report all of them. Some examples of graphical representations of the data, used to identify patterns and relationships within the data and identify potential problems, are described in Table 19-2. Brief summaries and examples for these plots are given below. Additional information and examples for some of the following plots (as well as others not mentioned here) are presented in USEPA (2006) and in the NIST e-Handbook of Statistical Methods, available at the following website: http://www.itl.nist.gov/div898/handbook/eda/section3/eda33.htm (accessed 15 March 2011).

Table 19-1. Basic statistical quantities.

Measure	Description
Measures of Relative Standing	Percentile of data ≤ or ≥ to a given percentage of data values. Median, Upper and Lower Quartiles.
Measures of Central Tendency	Mean, Median, Mode
Measures of Dispersion	Range, Variance, Sample Standard Deviation, Coefficient of Variation, Interquartile Range, t-distribution, confidence interval.
Measure of Asymmetry	Skewness
Measures of Association	Pearson's Correlation Coefficient, Spearman Rank Correlation Coefficient.

Table 19-2. Graphical presentations and their application.

Plot Type	Application
Histogram	Assessing location, shape and spread of the data depicting symmetry and potential outliers.
Box- and-Whisker Plot	Schematic of statistical quantities including interquartile range, sample median and mean, outliers. Assessment of symmetry of data.
Cumulative Frequency Distribution Plot	Plot of running total of frequencies for a parameter. Useful for assessing status where the value of the cumulative frequency indicates the number of elements in the dataset that lie below a threshold or criterion.
Ranked Data and Quantile Plots	Assessment of variability and symmetry showing all data points in rank order.
Normal Probability Plot	Determine how well the data are modeled by a normal distribution.
Scatter Plots	Assessing relationships between two or more variables.
Time Plot	Plot of data over time for initial examination of overall trend, cyclical patterns, changing variability over time.
Lag Plot	Determines if the randomness of dataset or time series and provides interpretation of serial correlation, cyclical patterns, and outliers.
Plot of Autocorrelation Function (Correlogram)	Used to display serial correlation when data are collected at equally spaced intervals.
Multivariate Methods (Ordination and Classification)	Examining complex datasets for relationships between species composition patterns and the underlying environmental gradients which influence these patterns

Histograms - A histogram (Figure 19-1) is a bar graph depicting the frequency of data collected into groups providing an overall visual representation of the shape and spread of the data distribution, number of modes, and potential outliers.

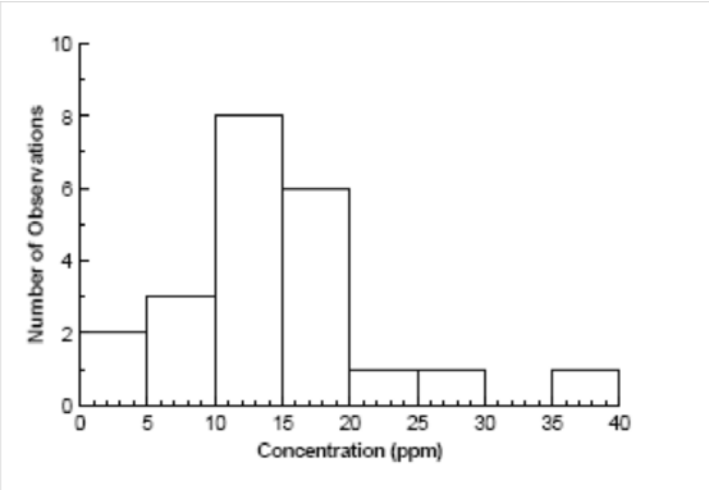


Figure 19-1. Example of a histogram. From USEPA (2006).

Box- and-Whisker Plots - Box and whisker plots (Figure 19-2) provide a visual summary of the data distribution including measures of central tendency (mean and/or median), dispersion (range of values and interquartile range), and potential outliers. The shape of the data is represented by examination of the whiskers. If the upper and lower whiskers are similar in length, then the data are distributed symmetrically. Skewness in the data is present if the whiskers are different in length. If both the mean and median values are presented in the box-plot, then a comparison of these provides insight on symmetry of the distribution (USEPA 2006).

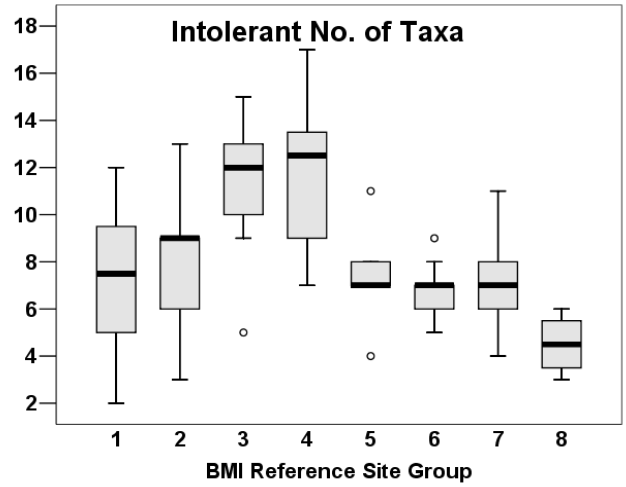


Figure 19-2. Box-plots representing differences in basic statistical quantities of benthic macroinvertebrate number of intolerant taxa among NOCA stream reference groups (horizontal bar = mean, box = central 50% of the data, whiskers = min and max values, open circle = potential outlier).

Box-plots are also useful for initial interpretation of differences among groups for a particular variable of interest. For example, in Figure 19-2 the number of intolerant taxa in reference site groups 3 and 4 appear to be different than in reference site groups 5-8 as evidenced by the lack of overlap in the boxes (central 50%).

Cumulative Frequency Distribution Plot - Cumulative frequency represents a running total of frequencies and can also be defined as the sum of all previous frequencies up to the current point. The cumulative frequency is important when analyzing data, where the value of the cumulative frequency indicates the number of elements in the dataset that lie below an established or proposed criterion (Figure 19-3). The cumulative frequency plot is also useful in depicting percentile values for the dataset.

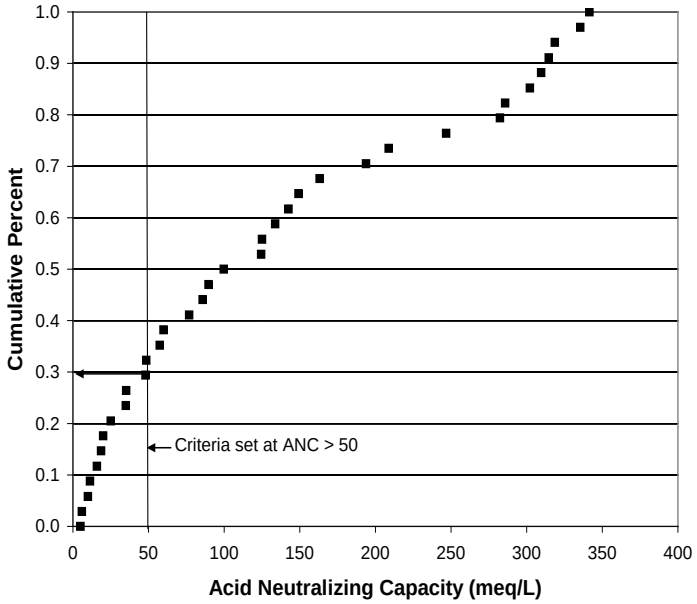


Figure 19-3. Example of a cumulative frequency distribution for acid neutralizing capacity (ANC) from 35 lakes sampled in a 5-year reporting period. From the graph, 70% of the sample locations met a criterion of ANC >50 and 30% of the sample locations (ANC ≤50) may be considered as sensitive to lake acidification.

The cumulative distribution function (CDF) provides a statistical method of interpreting values derived from a cumulative frequency distribution. CDF describes the probability that a random variable *X* with a given probability distribution will be found at a value less than or equal to *x*, and is proposed for statistical assessments of the status of a sample site in this protocol.

Ranked Data and Quantile Plots - These are additional options used to visualize the location, shape and spread of the data based on displays of ranked data. More details are presented in USEPA (2006).

Normal Probability Plot (Normal q-q Plot) - This plot provides a visual method for determining how well the data match the theoretical normal distribution and may allow an analyst to quickly discard an assumption of normality in order to pursue other options for analyzing the data (e.g., transformations or non-parametric tests). An example normal probability plot is shown in Figure

19-4. Methods for generating and interpreting normal probability plots are given in USEPA (2006).

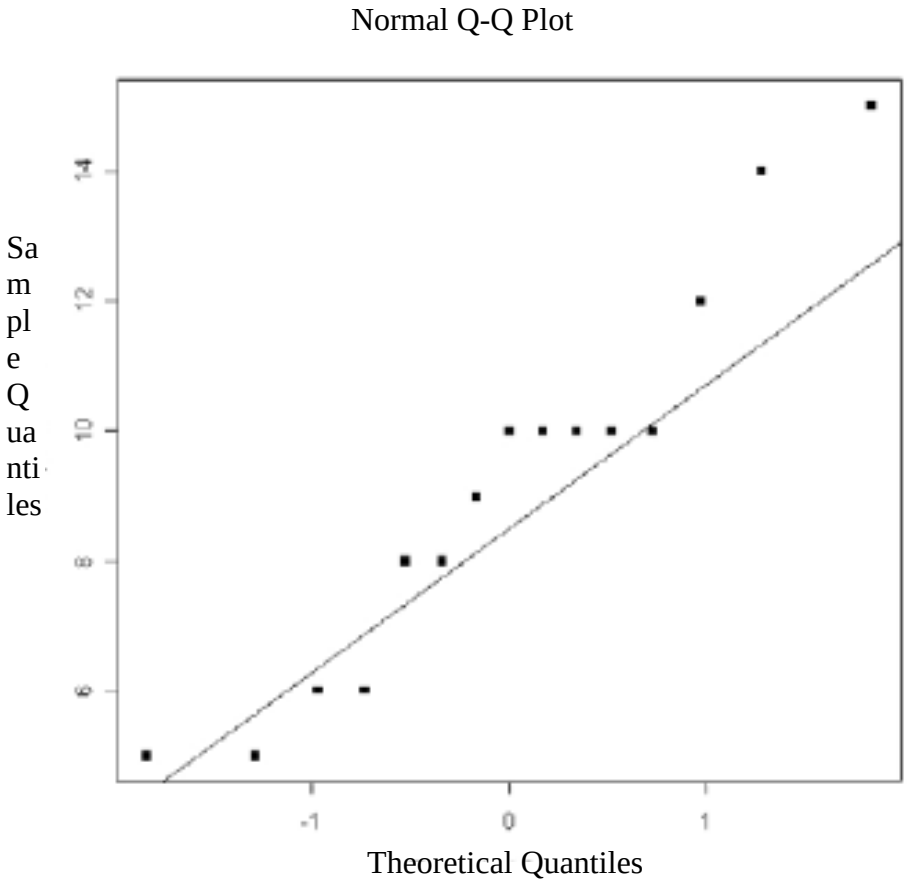


Figure 19-4. A normal probability plot is a graph of the quantiles of data compared with the quantiles of a standard normal distribution. Normality of data distribution may be assumed if the points in the graph roughly follow a straight line, however a formal test of normality should be performed. A solid line is drawn through the first and third quartiles to provide a guide to evaluate the linear fit. Points in the graph appear to be linear but deviate from the quartile line in the upper tail. From USEPA (2006).

Scatter Plots - Construction of a scatter plot is a common exploratory data analysis procedure used to evaluate relationships between two or more variables and is usually done before working out a linear correlation coefficient or fitting a regression line. It gives a good visual picture of the relationship between the two variables, and it aids in the interpretation of the strength and direction of the relationship (correlation coefficient) and type of regression model (e.g., linear, non-linear).

Time Plots - Time plots simply represent the data collected over specific equal time periods. They provide a quick assessment of the possible presence and direction of trends, cyclical patterns (stationarity), and changing variability over time. The addition of a LOWESS smoothed line (Cleveland 1979, Cleveland and Devlin 1988) fitted to the points in the scatter plot can aid in interpretation of seasonally changing data.

Lag Plots - Lag plots determine if the structure of the data is non-random, as indicated by pattern in the dataset. Linear patterns in the plot indicate a directional trend, and elliptical patterns indicate that the data contain a seasonal component. Non-random patterns are associated with data that are autocorrelated, indicating serial correlation. Serial correlation is a measure of the strength of the relationship between successive observations. If serial correlation exists, then the relationship must be accounted for in the data analysis. Examples of lag plots exhibiting random and non-random structure are shown in Figure 19-5.

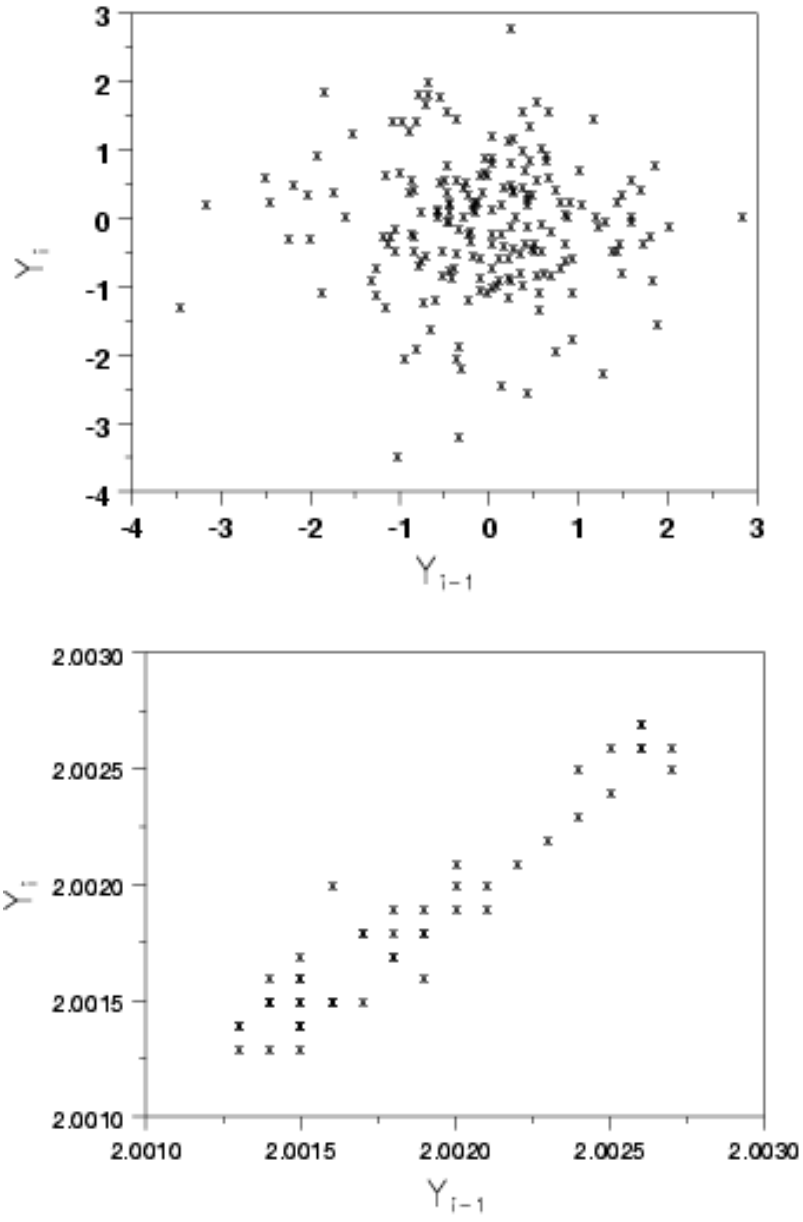


Figure 19-5. Lag plots without pattern (top) indicating the data are random and that there is no autocorrelation, and (bottom) with a linear pattern showing that the data are strongly non-random and suggesting that the data may be autocorrelated. From NIST e-Handbook of Statistical Methods website.

Plot of Autocorrelation Function (Correlogram) - In addition to the lag plot, the correlogram (Figure 19-6) is another plot that is used to display serial correlations when the data are collected at equally spaced time intervals. The autocorrelation function used for constructing a correlogram provides a summary of the serial correlations of data where the 1st sample autocorrelation coefficient, $r1$, is the correlation between points at lag 1 (points that are 1 time unit apart), $r2$ is the correlation between points at lag 2, etc. A correlogram is a plot of the sample autocorrelation coefficients, rk, versus time k (USEPA 2006). For a large independent data sequence of n time points, autocorrelations are approximately normally distributed with mean zero and variance $1/n$. Therefore, to determine if the time points are independent, first plot the approximate 95% confidence lines $\pm 2 / n$ (shown as dashed lines in Figure 19-6) on the correlogram. If any of the autocorrelations lie outside the confidence lines, then there is evidence of serial correlation, and it can be concluded that the time points are not independent (USEPA 2006).

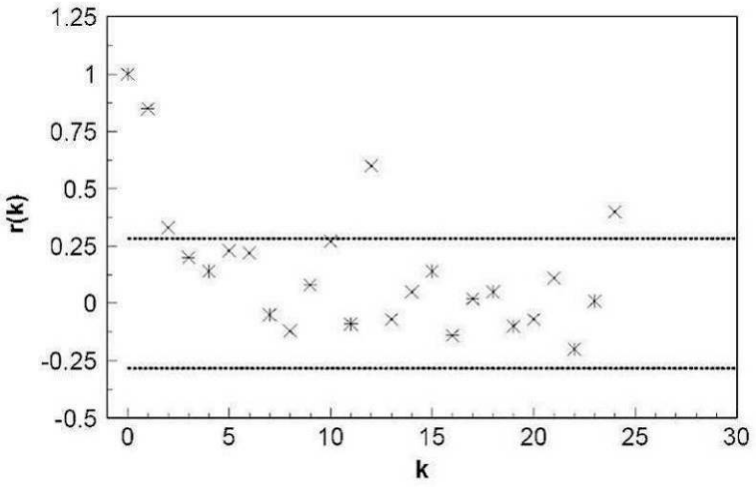


Figure 19-6. Correlogram plot showing evidence of serial correlation with points located outside of the 95% confidence limits (dashed lines). From USEPA (2006).

Multivariate Methods (Ordination/Classification) - Multivariate graphical procedures including ordination and cluster analysis are important exploratory tools for examining relationships between species composition patterns and the underlying environmental gradients which influence these patterns, including those that are otherwise too complicated to interpret. Ordination and classification (or clustering) are the two main types of multivariate methods that community ecologists employ. To some degree, these two approaches are complementary. Classification, or putting samples into (perhaps hierarchical) classes, is often useful when one wishes to assign names to, or to map, ecological communities. However, ordination is generally considered to be a more appropriate approach, given the continuous nature of communities.

A common approach to classification and ordination of species community data is to first conduct a cluster analysis to initially group biological community samples by sample locations or years (Figure 19-7), followed by conducting ordination with samples coded by cluster results (Figure 19-8). Comparisons of the spatial representations of samples by both methods may provide additional support for interpretation of the results (e.g., comparisons of Figures 19-7 and

19-8, which were constructed with the same sample data, showed similar results in the grouping of replicate samples and differences among samples by year).

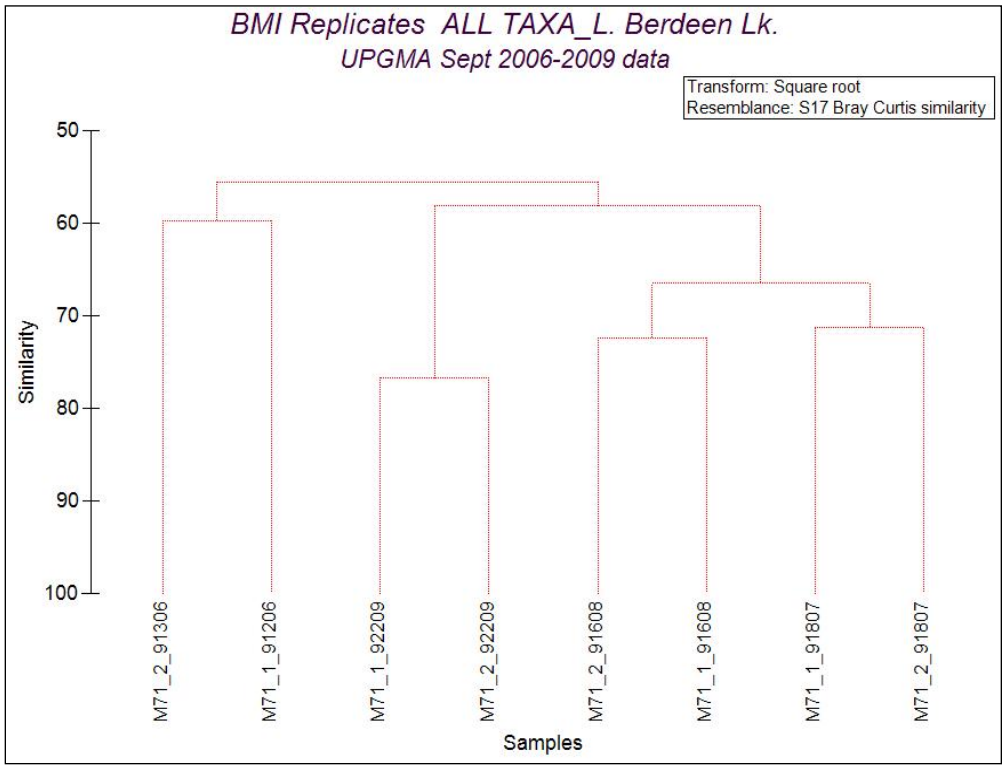


Figure 19-7. UPGMA cluster analysis dendrogram of replicated benthic macroinvertebrate (BMI) samples, collected prior to non-native fish removal (2006) and after removal (2007-2009), Lower Berdeen Lake, North Cascades National Park Service Complex (sample year = last two digits of label code).

There are numerous ordination methods to choose from representing both indirect gradient and direct gradient analyses. Indirect gradient analysis utilizes only the species by sample matrix. Interpretation of environmental attributes occurs after indirect gradient analysis. Direct gradient analysis utilizes external environmental data in addition to the species data, providing information about the relationship between species composition and measured environmental attributes, similar to regression. Excellent general references concerning multivariate techniques in community ecology include the following publications: Gauch (1982), Pielou (1984), Digby and Kempton (1987), and Jongman et al. (1995).

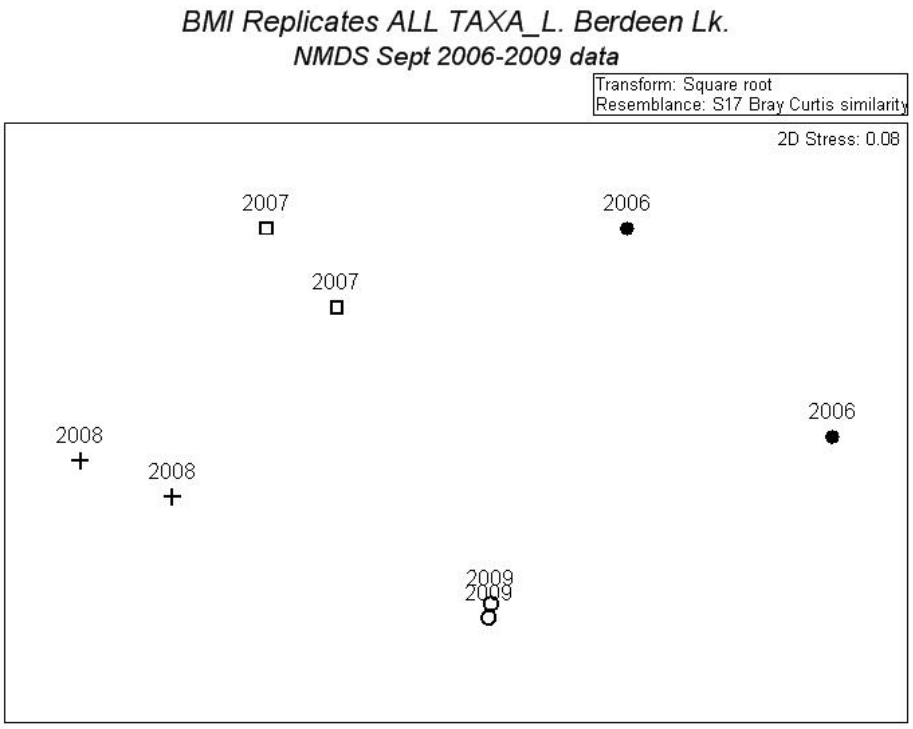


Figure 19-8. Non-metric multidimensional scaling (NMDS) plot of replicated benthic macroinvertebrate (BMI) samples, collected prior to non-native fish removal (2006) and after removal (2007-2009), Lower Berdeen Lake, North Cascades National Park Service Complex. (Note: same sample data as used in Figure 19-7).

Legendre and Legendre (1998) describe numerous measures of ecological distance (similarity) used in many ordination procedures. Primer-E software (Clarke and Warwick 2001) provides a range of alternatives for examining species community and environmental attribute data and is currently being used by ecologists at OLYM and NOCA (e.g., Figures 19-7 and 19-8).

Evaluating Assumptions of Potential Statistical Tests

In some situations, graphical information from the preliminary data review may serve as sufficiently strong evidence to support the assumptions of a given statistical test. However, in most cases, assumptions about distributional form, independence (including serial and spatial correlation), and dispersion should be formally verified using such statistical tests as those described in USEPA (2006) and other statistical references. All statistical tests require that the data constitutes a random sample of the population. In addition, the ability of a statistical test to handle outliers and nondetects must also be considered (see Section 3 and 4, below). In general, non-parametric methods handle outliers and nondetects better than parametric methods. Specific tests used to verify assumptions should be documented for statistical methods used in final analyses.

Outliers

Outliers are measurements that are extremely large or small relative to the rest of the data. Outliers may result from transcription errors, data-coding errors, or measurement system problems such as instrument breakdown. However, outliers may also represent true extreme

values of a distribution and indicate more variability in the population than was expected. Not removing true outliers and removing false outliers both lead to a distortion of estimates of population parameters.

Graphs such as the box and whisker plot, ranked data plot, normal probability plot, and time plot can all be used to identify observations that are implausibly larger or smaller than the rest of the data. In addition, a rapid approach used by many investigators for identifying potential outliers simply looks at points that are 2 or more standard deviations from the mean.

Statistical outlier tests give the analyst probabilistic evidence that an extreme value (potential outlier) does not "fit" with the distribution of the remainder of the data; however, these tests should only be used to identify data points that require further investigation. Tests recommended by the EPA based on sample size are shown in Table 19-3.

Table 19-3. Environmental Protection Agency (2006) recommendations for selecting a statistical test for outliers.

Sample Size	Test	Assumes Normality	Multiple Outliers
n ≤25	Extreme Value Test	Yes	No/Yes
n ≤50	Discordance Test	Yes	No
n ≥25	Rosner's Test	Yes	Yes
n ≥50	Walsh's Test	No	Yes

The decision to discard or include an outlier data point should be based on scientific reasoning in addition to the results of the statistical test. For instance, data points containing transcription errors should be corrected, whereas data points collected while an instrument was malfunctioning may be discarded. One should never discard an outlier based solely on a statistical test. Instead, the decision to discard an outlier should be based on some scientific or quality assurance basis. Discarding an outlier from a data set should be done with extreme caution, particularly for environmental data sets which often contain legitimate extreme values. If an outlier is discarded from the data set, all statistical analysis of the data should be applied to both the full and truncated data set so that the effect of discarding observations may be assessed. If scientific reasoning does not explain the outlier, it should not be discarded from the data set. The entire process should be documented.

Censored Data (Nondetects)

Data that include a combination of both detected and non-detected results are called "censored data" in the statistical literature. Treatment of censored data to meet NPS Data Quality Objectives is discussed in Irwin (2008). Data generated from chemical analysis may fall below the detection limit (ML; Minimum Level of Quantitation, see also SOP 15: Quality Assurance and Control Plan) of the analytical procedure. These measurement data are generally described as not detected, or nondetects, rather than as zero or not present. Reporting nondetects is usually accompanied by the appropriate limit of detection. In cases where measurement data are described as not detected, the concentration of the chemical is unknown although it lies somewhere between zero and the ML. Nondetect data are recorded in NPSTORET as present, but below the quantification limit ("Present<QL").

There are a variety of ways to evaluate data that include values below the ML. However, there are no general procedures that are applicable in all cases; it is no longer appropriate to report nondetects as one half of the ML value (Helsel 2005). For most cases data handling and transformation (censoring) recommendations found in Helsel (2005) will be followed.

If the degree of censoring (the percentage of data below the ML) is relatively low, reasonably good estimates of means, variances and upper percentiles can be obtained. However, if the rate of censoring is very high (≥50%) then little can be done statistically except to focus on some upper quantile of the parameter's distribution or on some proportion of measurements above a certain critical level that is at or above the censoring limit (USEPA 2006). Solutions for studies where all data or most data are below detection limits are discussed in Helsel (2005).

For datasets with multiple detection limits for a single parameter, the Kaplan-Meier (KM) method often works the best (Irwin 2008). KM transformations of nondetects and subsequent summary statistics (mean, median, standard deviation, and percentiles) can be performed within NPSTORET.

For compliance related objectives where comparisons are made with water quality criteria or other protection benchmarks, the NPS guidance (Irwin 2008) recommends censoring nondetects to the quantification detection limits (ML) before averages or confidence intervals are calculated. This provides a higher level of certainty to account for the possibility of reporting that a certain analyte or contaminant is absent when, in fact, it is present.

In selection of statistical procedures used for final analyses, the analyst must consider the method's suitability for use with nondetects. A number of nonparametric alternative tests are relatively insensitive to nondetects. Some examples of one- and two-sample hypothesis tests include the Wilcoxon Signed Rank Test, the Sign Test, and tests for proportions (USEPA 2006). Alternative nonparametric trend tests that are relatively insensitive to nondetects include the Sen's Slope Estimate, used for determining the magnitude of a trend, the Seasonal Kendall (SK) and Seasonal Kendall with Serial Dependence (SKSD) tests, and the Mann-Kendall test (Irwin 2008).

Missing Data

Missing data points can arise from a number of factors such as physical loss of data, malfunctions in equipment, unreconciled transcriptional errors, damage to samples in the laboratory or in transit, and improper preservation and storage. Results of missing data reduce the sample size with consequent reduction of inferential power. NPS DQOs for "Completeness" (Irwin 2008) require that estimates of missing data be included in the analysis of sample requirements needed to meet analysis objectives for each response parameter.

Traditional options available for handling missing data are found in many statistical software programs and include listwise, casewise, or pairwise data deletion, and mean substitution. However, there are additional methods available that perform much better. A good summary of assumptions and procedures is presented by the Information Technology Services Program at the University of Texas, General FAQ #22: Handling missing or incomplete data (http://ssc.utexas.edu/software/faqs/general#General_22) (accessed 20 March 2011).

The Water Quality Monitoring Protocol includes multiple response variables and analysis procedures. This, coupled with a variety of treatments for missing data, their assumptions, and effects on each particular analytical procedure will require consultation with a statistician.

Data Transformations

Most statistical tests and procedures contain assumptions about the data to which they will be applied. For example, some common assumptions are that the data are normally distributed, variance components of a statistical model are additive, two independent data sets have equal variance, and a data set has no trends over time or space. If the data do not satisfy such assumptions, then the results of a statistical procedure or test may be biased or incorrect. Fortunately, data that do not satisfy statistical assumptions may often be converted or transformed mathematically into a form that allows standard statistical tests to perform adequately. However, some statisticians recommend bootstrap methods over "normalizing" transformation for two reasons. First, bootstrap methods utilize original measurement units that do not need to be back-transformed for interpretation, and second, confidence intervals based on transformations only approximate confidence intervals produced by bootstrapping (Manly 1997). Another alternative is to use distribution free, non-parametric methods for analyses.

Some commonly used transformations include:

Logarithmic (Log X or Ln X)

This transformation may be used when the original measurement data follow a lognormal distribution or when the variance at each level of the data is proportional to the square of the mean of the data points at that level. For example, if the variance of data collected around 50 ppm is approximately 250 ppm, but the variance of data collected around 100 ppm is approximately 1000 ppm, then a logarithmic transformation may be useful. The logarithmic base (e.g., either natural or base 10) needs to be consistent throughout the analysis, but otherwise is inconsequential. If some of the original values are zero, it is customary to add a small quantity to make the data value non-zero as the logarithm of zero does not exist. The size of the small quantity depends on the magnitude of the smallest non-zero data and the consequences of potentially erroneous inference from the resulting transformed data.

Square Root (X)

This transformation may be applied to small whole numbers, such as the occurrence of rare events, or the number of times a parameter exceeds a criteria over a set period of time. The underlying assumption is that the original data follow a Poisson-like distribution in which case the mean and variance of the data are equal. It should be noted that the square root transformation overcorrects when very small values and zeros appear in the original data. In these cases, $\sqrt{X+1}$ is often used as a transformation.

Arcsine (Arcsine $\sqrt{p}$)

This transformation may be applied to binomial proportions (p) based on count data to achieve stability in variance with a distribution that is nearly normal. The resulting transformed data are expressed in radians. Special tables must be used to transform the proportions into degrees or multiplied by 57.29577…. degrees. The arcsine transformation should be used with caution and the understanding that it causes nominal scale data to appear continuous and lead to inappropriate application of statistical tests. When possible it is advisable to use non-parametric

tests or to conduct testing with the appropriate link function after determining the distribution (e.g., binomial, Poisson etc.) of the data.

These are the most commonly used transformations but others are available and may require consultation with a statistician concerning their application and limitations. Once the data have been transformed, all statistical analysis must be performed on the transformed data. No attempt should be made to transform the data back to the original form because this can lead to biased estimates. For example, estimating quantities such as means, variances, confidence limits, and regression coefficients in the transformed scale typically leads to biased estimates when transformed back into original scale. It also may be difficult to understand or apply results of statistical analysis expressed in the transformed scale.

Routine Data Summaries

Multiple field measures representing physical, chemical, and biological characteristics are collected from each waterbody. Routine data summaries of field measures are required to produce a single summarizing value called the “response variable” which is then applied in exploratory and final data analyses (i.e., determining status). An overview table of measures, data summaries, response variables, reporting periods, and final data analyses are shown in Tables 19-4 through 19-7.

Table 19-4. Routine data summaries and analyses for continuously recorded water and air temperature responses measured in each North Coast and Cascades Network water body.

Measures	Measurements Per Water Body	Calculation/Response Variables	Reported By:	Data Analyses
Daily max.	1 location each, 24-48 measurements/day	Maximum value of Daily Maximum Temp. (MDMT)	All locations - month and season	Status (site)
Daily max.	Same as above	Average MDMT	All locations - month	Same as above
Daily max.	Same as above	Maximum Weekly Maximum Temp. (MWMT) Average over warmest consecutive 7 day period.	All locations - month, season and Year	Same as above
Daily min.	Same as above	Average of Daily Minimum Temp. (ADMinT)	All locations - month	Same as above
Daily min and max	Same as above	Max Diurnal Fluctuation (MAXDIURN). Maximum daily minus minimum daily temperatures.	All locations - month and season	Same as above
Daily average	Same as above	Average of Daily Average Temp. (ADAT)	All locations - month	Same as above
Daily average	Same as above	Maximum value of Daily Average. Temp. (MDAT)	All locations - month and season	Same as above
Daily average	Same as above	Max Weekly Average Temp. (MWAT) 7-day moving average of daily average temperatures.	All locations - year	Same as above
Daily average	Same as above	Degree-days (DEGDAY) derived as Sum of differences between daily average temp. and base temp. of 0°C.	All locations - year (starting Jan 1) and season	Same as above

Table 19-5. Routine data summaries and analyses for benthic macroinvertebrates from North Coast and Cascades Network streams.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Macro-invertebrates	Benthic community	1 measurement, 8 sq. ft. of benthos for streams	1) O/E RIVPACS Score, 2) Multimetric Index Value, 3) Richness, 4) Community structure and composition, and 5) Dominance measures	Location by sampling event	1) Status and trend (site) and 2) Abrupt change (site)

Table 19-6. Routine data summaries and analyses for channel morphology and riparian characteristic responses measured for North Coast and Cascades Network wadeable river and stream locations.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Morphology	Wetted width	5 locations, 1 measurement per location	Mean width	Location by sampling event	1) Explanatory attribute
	Channel constraint	1 measurement (reach)	Categorical classification	Location by sampling event	1) Explanatory attribute
	Amount of constraint	1 measurement (reach)	% area constrained	Location by sampling event	1) Explanatory attribute
	Debris torrent	1 measurement (reach)	Categorical classification	Location by sampling event	1) Explanatory attribute
	Mean thalweg depth	5 locations, 1 measurement per location	Mean depth value	Location by sampling event	1) Explanatory attribute
	Rapid habitat	1 measurement (reach)	Qualitative assessment	Location by sampling event	1) Explanatory attribute
River and stream riparian zone characteristics	Invasive species	Entire shoreline	Presence	Location by sampling event	1) Status (site)
	Human influence	Entire shoreline within 3 shoreline proximity classes	Presence/absence	Location by sampling event	1) Explanatory attribute

Table 19-7. Water chemistry routine data summaries and analyses for responses measured from North Coast and Cascades Network wadeable river and stream sample locations.

Monitoring Component	Measures	Measurements Per Location	Calculation/Response Variables	Reported By:	Data Analyses
Water chemistry	Dissolved oxygen (DO)	1 location, 7 measurements	Mean concentration (mg/L)	Location by sampling event.	1) Status and trend (site) 2) Abrupt change (site)
	pH	1 location, 7 measurements	Mean pH	Location by sampling event.	1) Status and trend (site) 2) Abrupt change (site)
	Specific conductance	1 location, 7 measurements	Mean specific conductance (µS/cm)	Location by sampling event.	1) Status and trend (site) 2) Abrupt change (site)
Water clarity	Turbidity	1 location, 7 measurements	Mean transmittance (NTU)	Location by sampling event.	1) Status and trend (site) 2) Abrupt change (site)

Some responses may only represent a single measurement from a single waterbody (e.g. wetted width) or a single value from a collection of sub-samples taken from several locations and pooled into one sample (e.g., macroinvertebrate metrics and riparian disturbances). Other responses are derived from multiple measurements at one or more locations (e.g., continuous water temperature response variables). In addition, some types of data are processed into indices representing the condition of the habitat or structure of biological communities (e.g., IBI, O/E etc.).

Continuous Water Temperature

Data loggers are used to continuously monitor temperature throughout the year at each sample location. Logger memory limitations allow 48 measurements per day when downloaded annually. Definitions for continuous water temperature response variables are shown in Table 19-8.

Table 19-8. Definitions for continuous air and water temperature response variables.

Response Variable	Calculation
MDMT	Maximum value of daily maximum temperatures recorded during the reporting period.
ADMT	Average of daily maximum temperatures for the reporting period.
MWMT	Maximum weekly maximum temperature-representing the highest 7-day moving average of daily maximum temperatures during the year. Also labeled as the 7-day average maximum temperature.
ADMinT	Average of daily minimum temperatures for the reporting period.
MAXDIURN	Maximum diurnal fluctuation- maximum value for the reporting period of daily maximums minus daily minimums.
ADAT	Average of daily average temperatures for the reporting period.
MDAT	Maximum value of daily average temperatures recorded during the reporting period.
MWAT	Maximum weekly average temperature-representing the highest 7-day moving average of daily average temperatures during the year.
DEGDAY	Degree days derived from the sum of differences between daily average temperatures and a base temperature of $0^{o}C$.

Stream Habitat and Riparian Zone Characteristics

To help provide a context for the conditions of each sample location a series of observations and measurements are made to characterize the stream reach where the samples are collected. Qualitative observations, based on standardized criteria, are made to characterize stream flow, weather, torrent evidence, the channel's pattern along with observations classifying in-stream and riparian habitat conditions. The measured parameters include wetted width, bankfull width, valley width and thalweg depth. Categories of human influence and the presence of invasive species are documented based on their proximity to the wetted edge along both banks of the delineated reach for streams and rivers. Analysis for these response variables will only consist of documenting presence and single values. If invasive species are documented the aquatic resource lead or director of resource management for the appropriate NCCN park unit will be notified within one month by the NCCN water quality Project Lead.

Water Chemistry and Clarity

Responses variables for streams and rivers are reported as a single measured value. The mean is reported for water bodies when more than one measurement is made for a location during a sampling event.

Dissolved Oxygen (DO)

The last seven measurements following stabilization will be used to calculate the mean and standard deviation for the sample event (mg/L). QC documentation of precision (RPD+) and sensitivity (AMS+) are described in SOP 15: Quality Assurance and Control Plan.

Specific Conductance

The last seven measurements following stabilization will be used to calculate the mean and standard deviation for the sample event (µS/cm). QC documentation of precision (RPD+) and sensitivity (AMS+) are described in SOP 15: Quality Assurance and Control Plan.

pH

The last seven measurements following stabilization will be used to calculate the mean and standard deviation for the sample event. QC documentation of precision (RPD+) and sensitivity (AMS+) are described in SOP 15: Quality Assurance and Control Plan.

Turbidity

The last seven measurements following stabilization will be used to calculate the mean and standard deviation for the sample event (NTU). QC documentation of precision (RPD+) and sensitivity (AMS+) are described in SOP 15: Quality Assurance and Control Plan.

Benthic Macroinvertebrates (BMI)

Collection, lab processing, and taxonomy of BMI data collected as part of the NCCN Water Quality Monitoring Project will follow the guidelines established by the Pacific Northwest Aquatic Monitoring Partnership (Hayslip 2007). Basic data summaries for benthic macroinvertebrates are derived from a single composite sample that consists of four individual samples collected from different riffle habitats within a sample reach. A standard sample of 500 organisms is randomly sorted from the composite sample during laboratory processing. Response variables are reported as the single measured value using the subsample of 500 organisms (Barbour and Gerritsen 1996, Ostermiller and Hawkins 2004). The mean is reported when composited samples are duplicated.

Observed to Expected Taxa Ratio (O/E Score)

An O/E score is a measure of biological completeness calculated using predictive models. These models are derived using cluster and discriminate analysis to predict the invertebrate taxa expected to occur in a waterbody given physical characteristics that are not affected by human activity. A waterbody's condition is assessed based on the presence or absence of the expected taxa. Several O/E predictive models have been developed for the region encompassing the NCCN following established peer reviewed methods (Norris 1996, Hawkins et al. 2000, Clarke et al. 2003). Park specific predictive models have been developed for wadeable streams and rivers (<50 ha) (Rawhouser 2011a), MORA lakes (<50ha) (Rawhouser 2011b) and for NOCA streams and rivers (Reed Glesne, NPS, presentation to WRD, October 12, 2004). Regional predictive models have been developed for the area surrounding LEWI by the OR DEQ and for OLYM by the Western Center for Monitoring and Assessment of Freshwater Ecosystems. In

2012 the WA DOE is expected to complete a predictive model specifically for the Olympic Peninsula, which is expected to provide more precision and accuracy in bioassessments for OLYM streams (Karen Adams, WA Department of Ecology, pers. comm., January 2010). Reporting for O/E response variables will also include information identifying the predictive model used to develop the O/E score.

Multimetric Index Value

Multimetric indices, such as the Index of Biologic Integrity (IBI), incorporate multiple biological community characteristics and measure the overall response of the community to environmental stressor (Karr et al. 1986, Barbour et al. 1995). Metric selection and development of multimetric indices have been described in numerous publications (Plafkin et al. 1989, Barbour et al. 1996, USEPA 1998, Barbour et al. 1999, Stribling et al. 2000) and will be followed as part of this SOP. Individual metrics are generally derived from community assemblage data including: taxa richness and diversity measures, composition measures for identity and dominance, tolerance measures to represent sensitivity to perturbations, trophic measures for information on feeding strategies and guilds, and life history strategies.

Additionally, since many metrics have unique responses that are dependent on the source and type of the stressor, a suite of metrics can be used to diagnose the causes of impairment using a weight of evidence approach (Kerans and Karr 1994).

Temperature Score and Fine Sediment Score

Macroinvertebrate assemblage data can also be used to calculate two additional indices: the Temperature Score (TS) and Fine Sediment Score (FSS). Both of these indices use invertebrate taxa that are present at a sample location and use their abundance to infer stream temperature values and the amounts of fine sediment. Both of these indices are calculated using similar means (ter Braak and Barendregt 1986, Reylea 2000) and have been successfully implemented in the Lower Columbia basin (Mulvey and Borisenko 2008).

The guidance provided in the Quality Assurance and Control Plan (SOP 15) is designed to assure that the data collected as part of the NCCN Water Quality Monitoring Project meet the requirements established by the NPS (Irwin 2008), WA DOE and OR DEQ.

Data Analysis

Strictly speaking, statistical inference from the procedures outlined below is for the index period of August through September and applies only to the locations listed in the sampling frame. Statistical inference is not possible to other water bodies or locations other than those sampled. A detailed description of the target population and sample selection can be found in the Narrative, Section 2: Sample Design.

The general statistical procedures proposed to accomplish each type of analysis are listed in Table 19-9. Several methods are proposed for each statistical test to provide alternatives when specific test assumptions cannot be met or corrected. It must be noted that running several tests on the same data set can affect the interpretation of the Type I error rate. McDonald et al. (2009) provide the following recommendations if multiple trend analysis tests are used on the same data set:

> "When possible, we recommend deciding a priori which trend analysis to apply and sticking to it. If assumptions of the analysis selected a priori turn out to be violated, and another analysis is chosen, authors are duty bound to report this fact and reasons for the switch. When multiple tests are desired or unavoidable, perhaps due to questionable assumptions in all candidate analyses, we recommend correcting (reducing) the level at which individual tests are performed in order to control the experiment's overall Type I error rate. This is a well-known problem in statistical hypothesis testing, and the standard Bonferroni correction in which individual tests are conducted at $\alpha B = \alpha / k$, where k is the number of tests, is one relatively simple solution."

Many of the procedures are time series analyses because they analyze a single value per site, and repeated measurements through time are required to assess variation.

Table 19-9. Summary of the analytical procedures which will be used to detect abrupt and steady change at sample locations.

Statistical Test	Analysis Goal	Description
Mean and median and confidence Interval.	Status	Mean/median and CI summarized by replicated samples in a given year and samples over years.
One-sample hypothesis tests: t-tests, Wilcoxon signed rank test, sign test.	Status	One-sample tests for comparison of a mean (*t*-Test, Wilcoxon Signed Rank) or median (Wilcoxon Signed Rank, Sign Test) to a fixed threshold value.
Distribution estimation: histograms, box plots, cumulative frequency distribution plots, Cumulative Distribution Functions (CDF).	Status	Graphical representations of data distributions. Cumulative distribution function estimation methods provide an estimate of the proportion of samples that fall above or below a fixed threshold value and place a confidence interval around the estimate.
Prediction intervals, linear regression on time, mixed linear model for temperature logger data.	Abrupt Change	Abrupt change represents a rapid shift or significant departure from the "norm". Abrupt change would be detected if the measured value at a site for the current year fell outside of prediction intervals established from the pattern of the previous years of data.
Mixed or fixed effect linear regression on time, Mann-Kendall and Seasonal Kendall with slope estimators.	Steady Trend Detection	For steady trend detection all years including the current year are included in the analysis. Trend significance, direction, confidence intervals, and magnitude of rates of change are determined.
Two-sample t-test, Mann-Whitney-Wilcoxon rank sum test and the Associated Hodges-Lehmann Estimator Of Trend Magnitude	Step Trend Detection	Comparison of two sets of data for a response variable from non-overlapping time periods at a site.

Software Applications

To assist and facilitate application of these analyses, Dr. Trent McDonald and Michelle Bourassa Stahl of West Inc. have developed a set of menu-driven 'R' routines to run the analyses envisioned in Table 19-9. Some of the more complicated analyses, particularly those recommended for occasions when standard assumptions do not hold, are not present. These routines and documentation are maintained by the NCCN Data Managers. The programs are

designed to work with 'R' statistical software that can be freely downloaded from a number of sites on the internet. Information on the 'R' software and downloading instructions can be found at the following website address: http://www.r-project.org/ (accessed 2 January 2010).

There are numerous statistical software packages, including the 'R' program, that can be used for calculating measures of central tendency, dispersion, parametric and nonparametric one- and two-sample hypothesis tests, and for generating basic graphical representations of the data. Nonparametric trend procedures described in Table 19-5 can also be calculated using 'R' Software. In addition, the USGS provides documentation (Helsel et al. 2006) and a computer program (Kendall.exe) for the Kendall family of trend tests, including LOWESS procedures and the Regional Kendall test. Software documentation for this program is located at http://pubs.usgs.gov/sir/2005/5275/pdf/sir2005-5275.pdf, and the program can be downloaded from the following website: http://pubs.usgs.gov/sir/2005/5275/downloads/ (accessed 24 March 2011). Cumulative distribution functions can be estimated following methods developed specifically for probability surveys by Diaz-Ramos et al. (1996). User's guides and S-Plus and 'R' Software statistical routines for these methods are available at the following EPA website: http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm, (accessed 27 March 2011).

Incorporation of Covariates into Analyses

The basic analysis to detect both long-term trend and abrupt change of a parameter is regression. These regressions will include time as one factor and will account for any potential auto-correlation in residuals through time using mixed models such as restricted maximum likelihood (REML), see below. Trend or abrupt change will be detected if the coefficient of time in these models is significantly different from zero. To increase the statistical power of these analyses to detect trend or change, it is advisable to include other important explanatory covariates in the regression model. Examples of such covariates include elevation of sample location, annual or seasonal precipitation, annual or seasonal summaries of temperature, wetted width, catchment area, aspect, etc. The only requirement for these covariates is that they be consistently measured and applicable to individual sample locations. Large scale discrete factors, such as precipitation or elevation stratum, can also be used as covariates.

The climatic and the geophysical setting of a sample location influence many water quality parameters, and variables representing these conditions should be considered as a covariates in many of the regression models that attempt to detect trend or change. Continuous temperature data is collected year-long, using data loggers, at each of the selected sample locations. Precipitation data is not currently measured at each waterbody. However, predicted precipitation values, such as those from the PRISM model (http://www.prism.oregonstate.edu), are acceptable for use as covariates provided the predictions are highly correlated with actual values. It is not necessary that predicted or modeled precipitation exactly match actual precipitation. To increase correlation of predicted precipitation values with actual values, predicted annual precipitation values from the PRISM model can be calibrated using actual precipitation data. The NCCN Climate Monitoring Protocol (Lofgren et al. 2010) lists sites where precipitation data are being collected within the NCCN as well as recently installed and proposed future site locations. Calibration entails regressing predicted values onto actual values using a small number of locations where actual precipitation values are known. This regression is then used to predict precipitation at all sample locations.

Status Estimation Procedures

In every annual report, it is recommended that the current status of the responses be estimated for the smallest useful reporting units (Tables 19-4 through 19-7). This section describes, in general, analyses designed to estimate a parameter's value at a particular point in time.

Mean, Median, and Measures of Dispersion

For responses that are replicated within a site, the simplest estimates of current status involve calculating the mean or median value of the response with appropriate measures of dispersion (e.g., standard deviation, standard error, confidence intervals, interquartile range, etc.). For example, water clarity as measured by the depth that a Secchi disk disappears from view will be measured three times at one location within a lake. An estimate of the current average Secchi depth is simply the average of the three depth measurements taken. An estimate of the variation in Secchi depth is the standard deviation or standard error of these three numbers. A 95% confidence interval for the true mean response is:

$$\bar{X} \pm 1.96 se(\bar{X})$$

if individual measurements are approximately normally distributed. If a particular response is not approximately normal, bootstrap methods (Manly 1997) should be employed to construct appropriate confidence intervals. Bootstrap methods are recommended over "normalizing" transformation for two reasons. First, bootstrap methods utilize original measurement units that do not need to be back-transformed for interpretation, and second, confidence intervals based on transformations only approximate confidence intervals produced by bootstrapping. In other words, bootstrap methods are preferred because they do not rely on normality, and while transformations may be successful in improving the distribution of the response, they cannot make distributions perfect. Alternatively, distribution-free methods could be applied such as calculating the median value and interquartile range of the data or by calculating the confidence interval for the median as described by Helsel and Hirsch (2002, Chapter 3), available at the following website: http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 3 April 2011).

For responses that produce one number per site, (such as benthic invertebrate samples), the current estimate of status is the observed number. In some cases it may be possible to compute a standard error for this number based on a model or past data, but in general, variation of these responses will be assessed through time.

One-Sample Hypothesis Tests

Application of these tests is proposed for comparing a mean or median with a fixed threshold or criterion value and can be applied to responses derived from either multiple observations or a single observation taken at a site during each annual sampling visit. However, at least five or more years of data may be required for evaluating responses represented by a single observation for each year.

The proposed one-sample nonparametric tests for comparing a median value to a threshold include the Sign test and the Wilcoxon Signed Rank test (also used for mean values). The *t*-Test provides a parametric alternative one-sample test for comparing a mean value with a threshold. Test assumptions, limitations (e.g., outliers, nondetects, sample size, etc.), and example calculations are given in Chapter 3 of USEPA (2006).

Distribution Estimation

For responses that are measured many times within a single site (e.g., continuous temperature data) it may be possible to construct plots that depict the response's entire distribution. These plots include histograms, box and whisker plots, and cumulative frequency distribution plots. Standard histograms divide the range of a response into a number of bins and plot the number of measurements in each bin. Box and whisker plots show outliers and the 25th, 50th, and 75th quartiles of the distribution of a response. Cumulative distribution functions (CDF) plot the proportion of measurements below all observed levels of a response and can be constructed from smoothed or non-smoothed histograms. Cumulative distribution functions can also be estimated using the methods of Diaz-Ramos et al. (1996; *see* following discussion on CDFs, below). Initially, it is anticipated that few responses will be replicated enough times within a sample location to make distributional estimates useful.

Abrupt Change Detection Procedures

Abrupt change represents a rapid shift or significant departure from the "norm" and would be detected if the measured value at a site for the current year fell outside of prediction intervals established from the pattern of the previous years of data. Abrupt change can be applied for responses measured at a single site, for all sites in a park, or all sites in the network. The discussions on park-wide and network-wide abrupt change detection require some interpretation related to the stratified sampling design of the monitoring project.

Parametric and Nonparametric Prediction Intervals

Prediction intervals represent a statement of the likelihood that a single data point with a specified magnitude comes from the population under study (Helsel and Hirsch 2002). These methods provide a simple way to evaluate if a current year response value from a sample location is likely to have come from the distribution of data collected from previous years. Prediction intervals are developed from the individual data values rather than a summary statistic (e.g., mean) and, as a result, are wider than a corresponding confidence interval. For interpretation, a new value is considered to be different if found to be outside of the prediction interval calculated from the previously collected data. The likelihood of a current value being different is dependent on the choice of α.

These procedures work better if the data from previous years does not exhibit a trend. The width of the prediction interval would be greater if a significant trend is present and not accounted for, possibly increasing the chance of a Type II Error in the interpretation of current values. For this reason, results from graphical procedures and tests for trends should be examined prior to calculation of the prediction intervals. If a trend is present, then the methods described for 'Regression on Time' (below) should be applied. Methods for calculation of parametric and nonparametric prediction intervals are described by Helsel and Hirsch (2002) and are found at the following website: http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 3 April 2011).

Regression on Time

The following single-site abrupt change analyses are applicable to the time series of data collected at a sample location. To be classified as 'missing data', data are "randomly missing" for the response of interest and cannot be predicted when the response was not measured. For example, if a sample was lost in shipping to a contractor, it is unlikely that the distribution of the response that year could depend on the probability of failing to measure the response.

Assume a response can be summarized into a single number every year it is sampled. Typically this single number will be the estimated mean or total for that year. In this section, the single summarizing number associated with a site will be called “the response,” even though in some cases “the response” will be a mean or composite of several measures. The methods of this section also assume that an estimated standard error of the response is available. If a standard error is not available, the methods are still applicable because standard error estimates are primarily used as weights in the analysis, and it is always possible to give equal weight to all years when standard errors are unavailable.

Assuming the response of interest is approximately normally distributed and that statistical errors are uncorrelated, abrupt change can be detected by fitting a weighted regression to past data, constructing a 95% prediction interval for the current value, and observing whether the measured value is outside this interval (Figure 19-9). If serial (through time) correlation in response values is appreciable, it will be necessary to apply mixed linear model methods such as REML (Littell et al. 1996) to correctly compute prediction intervals. Alternatively, blocked bootstrapping (Lahiri 2003) can be used if serial correlation is high.

While the following regression approach assumes that the long term trend at a site is linear, linearity is not necessary because curvilinear or polynomial trends can be fit in the regression. If auxiliary variables, such as temperature, are known to effect responses, they can also be incorporated into the model to explain variation and improve precision. If the residuals from the regression analysis are not normally distributed, bootstrapping (Manly 1997) should be used to construct the final prediction confidence interval. In this case, past residual values (and weights) should be randomly sampled with replacement, added back to the original predicted value for each year, and the regression re-fitted. This yields new (bootstrap) predicted values for the past and current years. For the current year, a single residual from past data should be selected at random and added to the new (bootstrap) predicted value for the current year. This value should be stored and the entire procedure repeated 1000 times to yield 1000 typical values for the current year. Finally, the 2.5 and 97.5 percentiles of the 1000 typical values for the current years should be computed and used for the current year’s prediction interval.

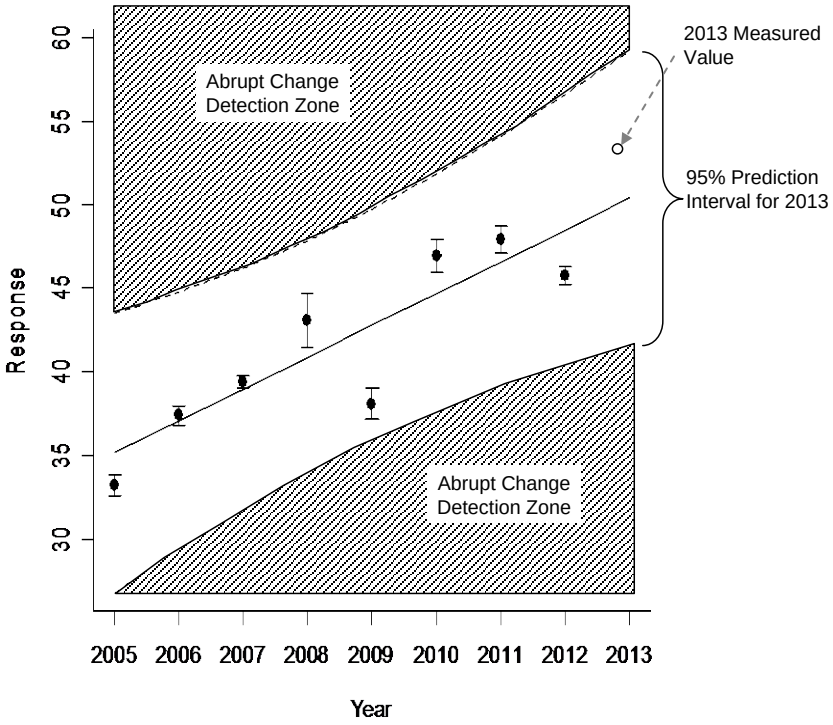


Figure 19-9. Illustration of the regression method for detecting abrupt change. Filled circles are previous estimates of the response. Bars are ±1 standard error. Assuming uncorrelated errors, weighted regression can be used to fit a linear regression to data from 2005 through 2012, and a prediction interval for 2013 can be constructed. Abrupt change would be detected if the measured value for 2013 fell outside this interval (i.e., in one of the 'Abrupt Change Detection Zones').

Mixed Linear Model

While relatively simple regression analyses can be applied to most responses, continuous water and air temperature data require special attention because they are recorded several times per day throughout a season. Most other responses are recorded once during a season. When analyzing water temperature for abrupt change, it will likely be necessary to model patterns of natural change within a season. Modeling intra-seasonal natural variation can be accomplished by fitting polynomials or smoothing splines effects in a least-squares regression (Hastie 1992). These effects will estimate the natural pattern of changes in water temperature within a single season; and abrupt change in the current year, if present, would cause the pattern of changes in the current season to be different from the pattern in previous years, or a shift in the mean of the pattern. In addition to fitting curvilinear effects, temperature is measured so often that the correlation in individual measurements must be accounted for when deciding whether change has occurred.

Estimation proceeds as above (Parametric and Nonparametric Prediction Intervals) except that mixed linear model procedures (e.g., REML) should be used to estimate the coefficients in β. In this process an appropriate model for the correlation of observations has to be estimated and used.

Long-Term Steady Trend Analyses

Regression on Time

Long-term steady trend in a response collected at a single site can be detected using a mixed or fixed effect linear model that is similar to the linear model for abrupt change. The primary differences between this and the abrupt change model are that all responses, including those from the current year, are included in the response vector, and interest is in inference toward the slope parameter. The coefficient vector is estimated using an appropriate technique (either least-square, the REML method for correlated data), and inference about the single slope parameter is made. If the slope parameter β_1 is significantly different from zero, significant trend has been detected. If residuals of the model are not normally distributed, bootstrapping or permutation methods (Manly 1997, 2001) should be used. Multiple explanatory variables can be included in the model. For example, elevation can be included in the linear model, in addition to time, to account for differences in the response at different elevations.

Variables, either the response or predictors, can be transformed to improve linearity or normalize a distribution without ill effects on the procedure; however, it must be kept in mind that transformations often change the nature of what coefficients measure and the functional form of trend. For example, fitting a linear model to logarithmically transformed response variables means that the "slope" coefficient is a multiplier of time in the exponent, i.e., trend is exponential. Transformations are not necessary if non-parametric techniques such as bootstrapping or permutation are used.

Some responses can be "below detection limits" and thus constitute censored values. Analysis of data containing censored values is difficult and for most cases data handling and transformation recommendations found in Helsel (2005) will be followed. Consultation with a professional statistician may be required in cases regarding some of the more complex procedures.

Mann-Kendall and Sen's Slope Estimator Procedures

As an alternative to ordinary least squares regression, responses with single and multiple observations per time period from a single site can be analyzed for steady trend detection using the nonparametric Mann-Kendall (MK) test (Mann 1945, Kendall 1975). This test is based on the Kendall's tau value (Kendall 1975) which is a rank correlation measure of the strength of linear dependence between the ranks of data. The MK test estimates a robust trend line that is the median slope for the set of lines joining all possible pairs of points in a time series. For samples with multiple observations per time period, a summary statistic (e.g., median) can be computed and applied in the Mann-Kendall test (*see* Section 4.3.4.2 in USEPA 2006).

The MK test is paired with the Sen's slope estimator (Sen 1968), where the MK test is used to determine the average direction of yearly changes and the Sen's slope estimator is applied to determine the magnitude of trend (unit change per year) and confidence limits. A response is reported as statistically significant only when significant upward or downward trends are found for both the MK and Sen's procedures.

The MK test is rank-based, which doesn't assume normality, is resistant to outliers, and admits censored data because only ranks are used. Data can also be adjusted to remove the effects of an ancillary variable before testing for trend. A LOWESS smooth (Locally Weighted Scatterplot

Smooth, Cleveland and Devlin 1988) is used to describe the relation between the Y variable (response) and the ancillary variable. Residuals from the smooth therefore have the relation between Y and the ancillary variable subtracted, removing the effect of the ancillary variable from the Y variable data. The Kendall test is then computed on the residuals from the LOWESS smooth, to test for trend after removing the effect of the ancillary variable. This procedure is available for use with the Seasonal Kendall and Mann-Kendall tests and is discussed, among other options, by Helsel and Hirsch (2002).

The assumption of independence for MK test is violated if serial correlation is present. Alternatives for handling serial correlation in Kendall tests are discussed by Hirsch and Slack (1984) and Yue and Wang (2004).

Seasonal Kendall and Sen's Slope Estimator Procedures

Temporal data collected over extended periods of time may often show cyclic patterns that repeat over time. For example, temperature data will show cyclic patterns at several temporal scales within a year (e.g., day, month, and season). These patterns may affect the interpretation of trends for a particular response variable of interest if they are unaccounted for in the trend analysis. The Seasonal Kendall (SK) test for trends is proposed as an alternative to the Mixed Linear Model approach described for application with temperature data, and it replaces the MK test when temporal cyclic patterns are found in the data.

The SK test was initially developed by the USGS (Hirsch et al. 1982) and later modified by Hirsch and Slack (1984) to account for serial correlation. The SK test performs separate MK tests for individual seasons of the year and then combines the individual results into one overall test for whether the response (Y) variable changes in a consistent direction (monotonic trend) over time. As with the MK test, the Sen's slope estimator is applied to determine the magnitude of trend (unit change per year) and confidence limits. The SK test can analyze responses with single and multiple observations per time period from a single site and can handle ancillary variables (Figure 19-10) as described for the MK procedure, above. Additional information on application of SK and MK test procedures are given in Helsel and Hirsch (2002), Helsel et al. (2006), and USEPA (2006).

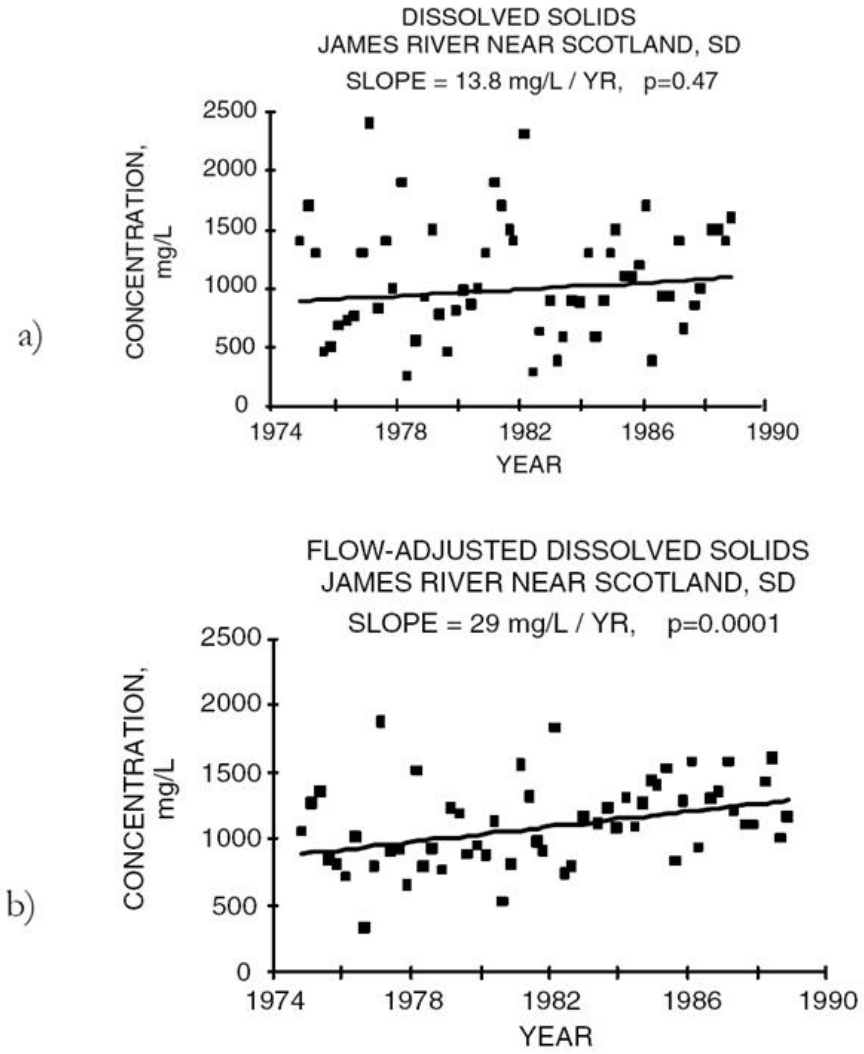


Figure 19-10. Comparison of Seasonal Kendall tests for trends in dissolved solids concentrations, before (a) and after (b) removing the effects of flow. The Sen estimate of linear trend associated with the Seasonal Kendall test is shown by the solid line. The trend in unadjusted data (a) is not statistically significant (p=0.47). Using the same data, the trend following the removal of flow-related variability in dissolved solids concentrations is highly significant (p=0.0001). The estimate of the magnitude of trend in flow-adjusted concentrations is about twice the estimate of the trend magnitude in raw concentrations. From Hirsch et al. 1991.

Step Trend Procedures

Step trends compare two sets of data for a response variable from non-overlapping time periods at a site. These analyses are more limited in application to this protocol when compared to steady long-term trend procedures. However, they can be useful in interpreting short-term changes occurring over longer records of time and for documenting changes occurring to a response variable following a known event that occurred at a specific time during the record. Example events could include improved access to lake by construction of a new trail resulting in more visitor use, the introduction of a non-native species to a site, or a natural disturbance such as a mass-wasting event that entered a stream.

The basic parametric test for step trends is the two-sample t-test with estimates of change magnitude based on the difference in sample means. The nonparametric alternatives are the Mann-Whitney-Wilcoxon Rank Sum test (Bradley 1968) and the associated Hodges-Lehmann (H-L) estimator of trend magnitude (Hodges and Lehmann 1963). The H-L estimator is the median of all possible differences between data in the "before" and "after" periods. Procedures for adjusting for seasonality and ancillary variables are available for both parametric and nonparametric tests (Helsel and Hirsch 2002). An example plot of the Mann-Whitney-Wilcoxon Rank Sum test is shown in Figure 19-11.

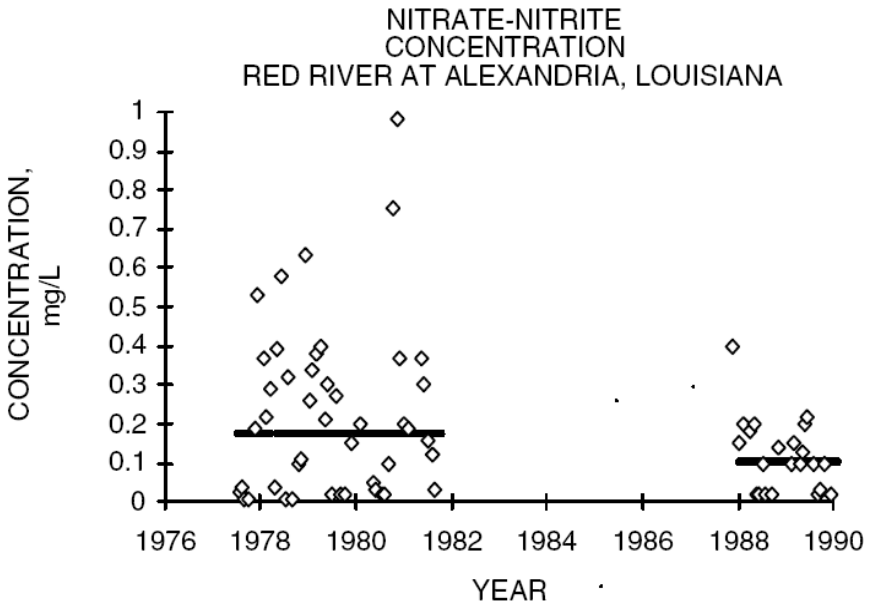


Figure 19-11. Significant step trend (p=0.085) as measured by the rank sum test. Solid lines are group medians. From Hirsch et al. 1991.

Step trend procedures should only be used in two situations. The first is when the records being analyzed are naturally broken into two distinct time periods with a relatively long gap between them. In general, if the within-period trends are small in comparison to the between-period differences (see Figure 19-11), then step-trend procedures should be used. In the second situation, a step-trend is used when a known event has occurred at a specific time during the record which is likely to have changed a response variable. The record is first divided into “before” and “after” periods at the time of this known event. It is imperative that the decision to use step trend procedures not be based on examination of the data, or on a computation of the time which maximizes the difference between periods (Helsel and Hirsch 2002).

Reporting

The reporting schedule includes production of annual reports and five-year summary reports. Annual reports will be issued every year after field data collection and sample processing is completed. These reports will contain routine data summaries of site status and statistical analyses designed to detect abrupt changes at specific sites. The first annual report would be

issued after year 1 of the project but would contain only data summaries (figures and tables) because change detection is not possible after one year.

The five-year summary reports will be completed in the year following each cycle. These reports will contain routine data summaries and statistical analyses to detect abrupt changes that normally appear in an annual report. Reports will be organized and formatted according to NPS Natural Resource Program Center guidelines (NPS 2010).

Annual reports will include:

- List of project personnel and their roles
- List of water bodies sampled including location and dates of sampling
- Provide overview of data collected with references to filenames and data storage locations
- Description of analysis methods used
- Description of resource current status at each site using descriptive statistics and graphical representations of the data
- Site-specific abrupt change analyses following the 3rd year of data collection
- Site-specific trend analyses following the 5th year of data collection
- QA/QC compliance and concerns (*see* SOP 15: Quality Assurance and Control Plan)
- Changes made to the protocol, if any, and documentation following SOP 21: Revising the Protocol
- Monitoring results and summaries of activities communicated to Aquatic Park Leads

Five-year summary reports will include:

- Routine data summaries and statistical analyses that normally appear in an annual report with the addition of analysis of abrupt change, and long-term trends
- Selection of statistical tests following detailed exploratory analysis focused on evaluations of test assumptions and other concerns (missing data, nondetects, seasonality, etc.).
- Examination of relationships between monitoring project response variables and their covariates
- Evaluation of precision and sampling bias for all response variables and recommendations concerning future utility of response variables with poor precision
- Re-evaluation of sample size requirements for detection of trends and estimations of status
- QA/QC compliance summary
- Acquisition of project peer review and incorporation of necessary changes
- Development of management and research recommendations
- Interpretation of data for public and upper level managers at Park, Network, and National levels

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SOP 20. Field and Laboratory Safety

Version 2/1/2012

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

Assembling a field crew of safe and responsible individuals is a top priority of the Project Lead and Lead Technician. The Lead Technician should have substantial field and supervisory experience. Crew members should be capable of living and working cooperatively with others under often stressful and challenging conditions in rugged and isolated areas for extended periods. Under these conditions, risk of personal injury increases and crews are often hours or days removed from emergency medical help. Although the field crew's primary objective is to gather data at aquatic habitats, individuals are responsible for personal safety and the safety of other crew members while maintaining positive work relationships. In addition to field safety, laboratory procedures have been developed to ensure sample analyses are conducted in a safe manner.

Field and laboratory procedures will be conducted in accordance with park and NPS safety requirements including the Project Operation and Risk Management Template and associated Job Hazard Analyses found in Appendix I. In addition, Hazard Communication and Chemical Hygiene Plans for NOCA are maintained at Park Headquarters. Comprehensive project pre-season safety training will be conducted and documented and routine safety sessions will be held during the field season.

Access to Sampling Sites

Prior to leaving on all field trips the field crew along with the Project Lead will complete an Project Operations and Risk Management Plan (Appendix J) following guidelines established as part of the NPS Operational Leadership program (NPS 2011).

Management regulations of National Parks and Wilderness Areas exclude the use of off-road mechanized transportation (e.g., motorcycles and bicycles), so hiking is the primary method used for accessing backcountry aquatic habitats. Potential obstacles to safe and easy access to backcountry sites include the ruggedness of the terrain and the vagaries of summer weather in montane areas (especially early and late summer snowstorms and thunderstorms). Safety related information pertinent to backcountry travel is found in Appendix I.

Several miles of hiking with heavy packs is necessary to reach many sites. Field personnel must be competent in basic wilderness survival skills in order to be fully prepared to handle all conditions and situations that may arise. Safety tailgate sessions are presented at the beginning of and during the field season, covering topics such as prevention of overuse type injuries, safe stream crossing, thermoregulation, physical response to cold, hypothermia, frostbite, insulation qualities of clothing types, and bear and mountain lion safety, etc.

Field personnel must be competent at map reading, compass and GPS use, and orienteering because cross-country hiking is frequently required to access field sites. Field personnel must determine and mark on a topographic map the exact location at which unmapped sites were sampled; use maps, landmarks and compasses to locate and travel to field sites where no trails exist; and determine the orientation of field sites. Personnel must also be prepared to navigate in poor weather conditions, and so must be proficient in the use of a compass. Competency in these

skills is essential for safe wilderness travel. Field personnel will also be trained in proper radio communication procedures.

Sampling Crew Safety

A two-person crew is generally adequate for safe and efficient sampling of most NCCN aquatic habitat sites. Additional crew members may be needed periodically if the amount or weight of equipment increases due to additional sampling needs or extended periods in the field.

Samplers will exercise extreme caution in selecting foot placements and in movement when conducting field sampling at night or in poor light. A headlamp will be used to allow freedom of hand movement for balance and for handling instruments.

Safety training increases the safety awareness of crew members and prepares them for responding to potential medical emergencies. Each crew member should be trained, skilled, and/or certified in:

- Basic first aid and cardiopulmonary resuscitation (CPR)
- Swimming
- Backpacking skills, wilderness survival, and orienteering
- Use of handheld communication devices
- Bear safety and food handling
- Completing risk mangement plans according to Operational Leadership Guidelines.

Crew members also will be oriented to and trained in the safe and proper use of sampling equipment and chemicals used for water-quality analysis or organism preservation.

Crew Safety Training

Crew training will include development and completion of a Job Hazard Analysis (JHA), a Project Operations Plan and Risk Assessment for each field trip. This should include all planed activities: packing equipment, transporting equipment to a field site, work at a field site, return trip, and processing samples in the park laboratory (see Appendix I and Appendix J). Each field crew member is responsible for completing a Risk Assessment (Appendix J) for each field trip during the field season. The Field Crew Lead is responsible for completing a Project Operations Plan (Appendix J) for every field trip and ensuring that the Project Lead is given a copy. Crews will be required to have a park safety orientation, training in use of radios, safe river crossing, vehicles, accident and injury prevention, accident reporting, map, compass, GPS use, and laboratory safety including safe handling of chemicals and use of Material Safety Data Sheet (MSDS) information.

Laboratory Safety

Analysis of all samples will be conducted in accordance with park safety plans and guidelines (Chemical Hygiene Plan, Hazard Communication). Material Safety Data Sheets (MSDS) are detailed informational documents which describe the physical and chemical properties of hazardous chemicals. These documents are prepared by the manufacturer of the chemicals. The Hazard Communication Standard (Federal Standard 29 CFR 1910.1200 or for Washington State WAC 296-62-054) also known as the "Right -to-Know" law enacted in 1985 sets forth the following requirements:

1. It is the responsibility of the manufacturer of a material to determine what hazards are associated with the material, to prepare an MSDS for the material, and to provide the MSDS to any recipients of the material.

2. It is the responsibility of an employer to provide MSDS and training in their interpretation to the employees. MSDS for hazardous materials must be readily available in the workplace.

3. It is the responsibility of the employees to read and understand the MSDS of any chemical used on the job.

Chemical Hygiene Plans with MSDS for every chemical used as a part of this monitoring project will be kept on file in the park laboratories for all crew members to review at the beginning of and during the sampling season.

References

National Park Service (NPS). 2011. Operational Leadership Participant Manual. USDI National Park Service, North Cascades National Park Service Complex. Available at: http://www.noca.nps.gov/safety/default.aspx

SOP 21: Revising the Protocol

Version 5/17/2011

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Overview

This SOP describes how to make and track changes to the NCCN Water Quality Monitoring Protocol, including its accompanying SOPs. Project staff should refer to this SOP whenever edits are necessary, and should be familiar with the protocol versioning conventions in order to identify and use the most current versions of the protocol documents. Required revisions should be made in a timely manner to minimize disruptions to project operations.

Peer Review

This protocol attempts to incorporate the best and most cost-effective methods for monitoring and information management. As new technologies, methods, and equipment become available, this protocol will be updated as appropriate, by balancing current best practices against the continuity of protocol information.

All edits require review for clarity and technical soundness. Small changes to existing documents – e.g., formatting, simple clarification of existing content, minor changes to the task schedule or project budget, or general updates to information management SOPs – may be reviewed in-house by project and NCCN staff. However, changes to data collection or analysis techniques, sampling design, or response design are usually more significant in scope and impact and will typically trigger an outside review to be coordinated by the Pacific West Regional Office of the National Park Service.

Document Life Cycle

Protocol documents may be maintained as separate files for each component (e.g., narrative, SOPs, appendices in separate document files) or unified into a single document file. During its life cycle, each document file can be classified in one of six life cycle stages:

1. Draft documents – Documents that have been drafted or revised but have not been reviewed and approved yet.
2. Review documents – Draft documents that have been sent out for peer review or administrative review.
3. Active documents – The current, reviewed and accepted version of each protocol component in Microsoft Word format. These documents have been reviewed and approved at the appropriate level, and are currently implemented for active monitoring projects.
4. Inactive documents – Older versions of approved protocol components that are no longer in active implementation.
5. Archived documents – Comprehensive set of active protocol components plus older, inactive versions of approved protocol components in Microsoft Word format. These are stored as read-only and have a date stamp to identify their approval date. The history of the protocol versions through time should be entirely traceable from within the document archive.

6. Distribution copies – PDF versions of approved, date-stamped protocol components, used to post to websites or otherwise share outside NPS.

Protocol documents are stored in the project workspace in separate subfolders named for each life cycle stage, except for inactive documents which are filed together with date-stamped copies of active documents in the archive folder. See SOP 2: Project Workspace and Records Management, for additional details about the project workspace.

Document Versioning Conventions

Rather than using a sequential numeric versioning convention, we use date stamps to distinguish document versions because they are more intuitive and informative than version numbers. Date stamps are embedded within the document header and are also included in the document name.

Document Header

Within each document, the upper right section of the document header should show the date that the document was last saved. By using save date instead of current date, printouts and document previews will show the correct version number. The following is the field code to be used within the header to indicate the version number:

SAVEDATE } \@ "MMMM d, yyyy"

File Naming Conventions

All documents *except for active documents and draft documents* should include the last edit date as a suffix, using the YYYYMMDD format so that documents will sort by date rather than month or day (e.g., NCCN_Water_Quality_Protocol_DRAFT_20100923.doc for the review draft on 9/23/2010).

Active documents and draft documents that have not been shared with others (as review documents) should not include the date because – unlike documents in other life cycle stages – they are not "point in time" document snapshots. By omitting the date stamp from these documents, they can more easily be distinguished from review drafts and archive or distribution copies. Draft documents should clearly contain the word "DRAFT" in the file name.

Revision Procedures

Proposed changes to protocol components should be discussed among project staff prior to making modifications. It is especially important to consult with the Data Manager prior to making changes because certain types of changes may jeopardize data set integrity unless they are planned and executed with the continuity of the data set in mind. Because certain changes may require altering the database structure or functionality, advance notice of changes is important to minimize disruptions to project operations. Consensus should be reached on who will be making the agreed-upon changes and in what timeframe.

The protocol narrative contains a Revision History Log, located just before the narrative ‘Introduction,’ that will be filled out each time the narrative or any SOP is revised to document when and why the change was made, who authored the change, and to assign a new Version

Date to the revised protocol or SOP. Each SOP also has its own Revision History Log with the same fields to be populated. The new version of the protocol narrative and/or SOP will then be archived in the in the project workspace in the appropriate folder as well as in NCCN Digital Library.

Note: A change in one document may also necessitate other changes elsewhere in the protocol. For example, a change in the narrative may require changes to several SOPs; similarly renumbering an SOP may mean changing document references in several other sections of the protocol. The project task list and other appendices also may need to be updated to reflect changes in timing or responsibilities for the various project tasks.

The Project Lead is the primarily responsible for making edits and ensuring document review at the appropriate level. The process for creating and revising protocol documents is shown in Figure 21-1, and outlined below:

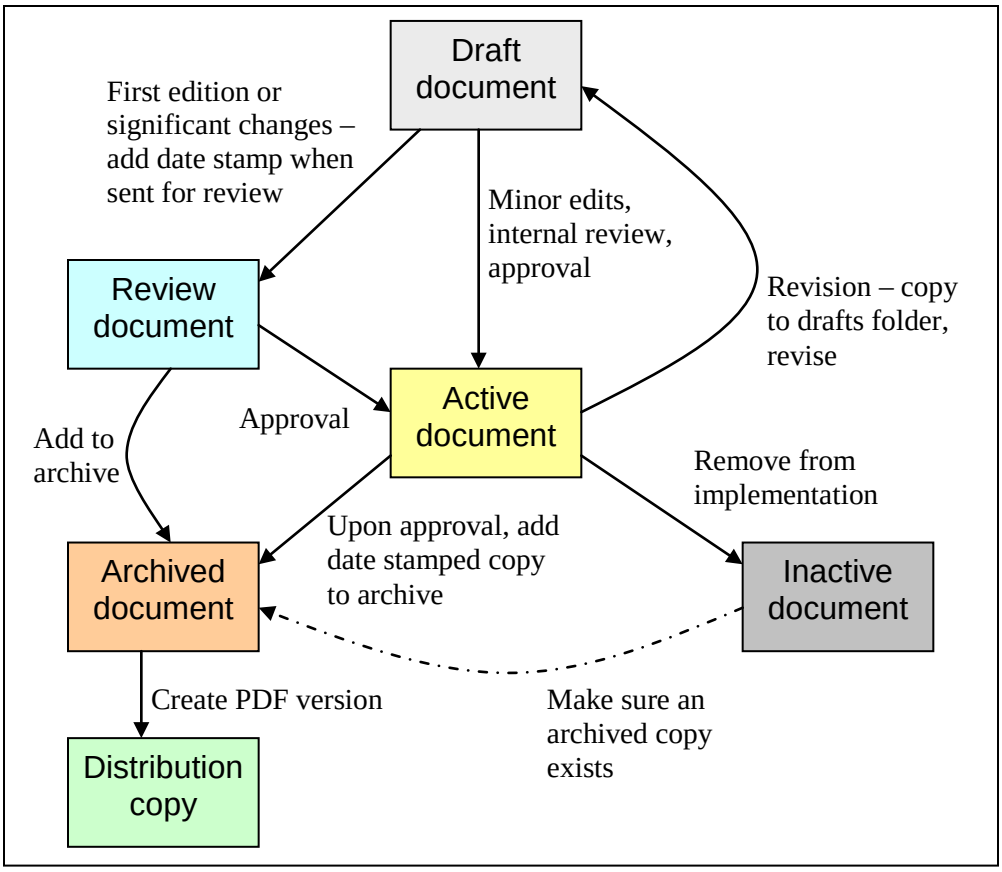


Figure 21-1. Process for creating and revising protocol documents. Boxes represent document life cycle stages, and connecting arrows indicate procedures.

1. Create the draft document in Microsoft Word format. If modifying an existing document (usually an active document), copy the document to the draft document folder, remove any date stamp from the name. Add "DRAFT" to the file name. Open the document and add "DRAFT" to the header or document watermark as appropriate.

2. Track revision history. If modifying an existing document, document all edits in the Revision History Log embedded in the protocol narrative and each SOP. Log changes only for the section of the document being edited (i.e., if there is a change to an SOP, log those changes only in the revision history log for that SOP). Record the date of the changes (i.e., the date on which all changes were finalized), author of the revision, describe the change and cite the paragraph(s) and page(s) where changes are made, and briefly indicate the reason for making the changes.

3. Document review. Circulate the changed document for internal review among project staff and cooperators. If the changes are significant enough to trigger peer review (as defined above), create a review document by adding a date stamp to the end of the file name using the YYYYMMDD format, copy the file to the archive folder, and submit the document for peer review according to current instructions.

4. Finalize and archive. Upon approval and final changes:
    a. Ensure that the version date (last saved date field code in the document header) and file name (field code in the document footer, if used) are updated properly throughout the document.
    b. Move the approved document to the active folder. Remove the word "DRAFT" from watermarks, document headers, and file name. Remove any previous date stamp. This is now an active, implemented document.
    c. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
    d. Create a copy of the file and add the revision date to the end of the file name using the YYYYMMDD format. Move this copy to the archive folder.
    e. Inform the Data Manager so the new version number can be incorporated into the project metadata.

5. Create distribution copies. As needed, create a PDF version of the archived document to post to the internet and share with others. These PDF versions should have the same date-stamped name as the archived Microsoft Word file. Post the distribution copy to the NCCN Digital Library and forward copies to all individuals who had been using a previous version of the affected document.

6. Remove from implementation. If it is decided that a document needs to be removed from implementation – either because it is no longer necessary (e.g., an unneeded SOP), or because it has been superseded by a more recent version – this can be easily done by removing the document from the active document folder, after first checking that a copy of that version already exists in the archive folder.

Appendix A. Administrative History of North Coast and Cascades Network Water Quality Monitoring Protocol.

The following administrative history briefly summarizes the process used to develop the NCCN Mountain Lakes and Water Quality monitoring protocols and associated set of standard operating procedures (SOPs) (Table A-1). This history also identifies the documents used to develop the protocol and SOPs, and provides a list of these documents.

Table A-1. Summary of administrative history for development of North Coast and Cascades Network Water Quality Monitoring Protocol.

Task	Date Initiated	Date Completed	Results
NOCA Proposal for Lakes and Rivers Monitoring in response to the NPS Long Term Ecological Monitoring (LTEM) Program.	1992	1992	PNWRO submitted as one of two Regional proposals to go forward to NPS-WASO
NOCA and OLYM selected as two of the eleven Service-wide "prototype" parks in NPS LTEM program. NOCA was selected to represent lakes and rivers and OLYM was selected to represent the coniferous forest biome.	1993	1993	Although selected to represent an ecosystem “type”, no funding was provided to implement the LTEM program at NOCA
Development of NOCA bioassessment protocols.	2000	2004	Additional funding was obtained through NPS-WRD and other sources to develop benthic macroinvertebrates bioassessment models for streams in NOCA and surrounding USFS lands.
NCCN Vital Signs funded	2001	Present	Funding received to initiate the NCCN vital signs monitoring to include 7 parks.
WRD Funds NCCN water quality monitoring	2001	Present	$82,000/yr received for water quality planning efforts (to meet goals of monitoring impaired, potentially impaired and pristine surface waters).
Initial water quality monitoring plan developed.	2001	2004	NCCN plan developed and submitted to NPS-WRD. Plan approved to identify impaired, potentially impaired and pristine surface waters. A large portion of the $82,000/yr received from NPS-WRD during this period was included in the development cost of the NCCN Mountain Lakes protocol, as this protocol was seen to address pristine waters at the time and water quality monitoring was to be incorporated into Mountain Lakes, Wadeable Streams, and Large Rivers protocols. Water quality has since been more thoroughly addressed in a separate NCCN protocol.

Table A-1. Summary of administrative history for development of North Coast and Cascades Network Water Quality Monitoring Protocol (continued).

Task	Date Initiated	Date Completed	Results
Development of MORA bioassessment protocols.	2003	2006	Additional funding was obtained through NPS-WRD and other sources to develop benthic macroinvertebrates and zooplankton bioassessment models for lakes and streams in MORA.
Initial landscape assessment of potential threats to water quality in the NCCN.	2003	2004	Completed land use maps and geo-referenced databases for MORA, NOCA, FOCL, EBLA, SAJH and FOVA
Phase III NCCN Vital Signs Monitoring Plan	2004	2005	Information compiled for water quality information included in NCCN Phase 3 Plan. 303(d) waters identified for NCCN parks (as of 2005)
Catchment scale relative risk assessment completed for all NCCN parks.	2008	2009	All watersheds managed by NCCN or draining to NCCN waters were assessed for threats to water quality. Information was updated for 303(d) and 305(b) listed waters (as of 2008).
NCCN Water Quality Protocol draft prepared	2009	2010	A draft protocol following Oakley et al (2003) was prepared for peer review.
Peer-review comments received and Water Quality protocol revisions made	2010	2011	Initial response to the 1st NCCN Peer-Review.
Second round of peer-review comments received and Water Quality protocol revisions made	2011	2012	This document represents the response and reconciliation to the 2nd NCCN Peer-Review. Implementation is based on assumption that the WRD will continue to fund the protocol to the minimum level of $78,800/yr.

Appendix B. Watershed Condition Assessment Methods and Results.

Watershed Assessment Methods

Methods have been excerpted and modified from Winters et al. (2006)

Anthropogenic Influence Analysis: Process and Portrayal

Numerous anthropogenic activities occur throughout the basin, landscape, management and reach/site spatial scales associated with the NCCN. The complexity associated with the extent and pattern of anthropogenic disturbances warrants the need for a simplification of these activities into a meaningful spatial context. Meaningful comparisons across the landscape should be valuable for setting restoration and reference areas by management personnel. The analysis of potential anthropogenic influences serves several purposes:

- To characterize the nature, extent, and potential influence of anthropogenic activities at each analysis scale,
- To portray the results in a simple, aesthetically appealing manner,
- To present a "likelihood" or "potential" for disturbance to aquatic, riparian or wetland environments based upon amount and distribution of an identified anthropogenic activity present in an individual watershed, and
- To provide a common framework to develop a comparative assessment of the catchments not only associated with one administrative unit, but across several.

In order to satisfy these requirements, several procedural steps were involved:

- The ranking and percentile assignment of each NCCN catchment based upon that particular metric,
- The agglomeration of percentiles into four categories representing similar potentials for being influenced by anthropogenic activities,
- The cartographic representation of the analysis results, and
- The synthesis of the information into an additive effects analysis for the specific activity category (e.g., water quality) as well as for all beneficial uses.

Ranking and Percentile Assignment

A geographic information system (GIS) analysis was performed to calculate dimensionless metrics within the individual hydrological units (HUs, also called catchments). For example, the number of road crossings per stream km in each 7th field catchment was identified as an appropriate and applicable metric. Thus, the total stream length (in km) was calculated, the number of road crossings was summarized, and the ratio of road crossings to stream km was calculated for each catchment. After metric calculation, the catchments were ranked by the metric's value, percentiles calculated, and then categorized by percentile value (Table B-1). A

rank of one was given to the highest metric value. The lowest rank was given to the catchment with the lowest metric value greater than zero. Those catchments where the metric value equaled zero were not ranked. The percentile for each ranked catchment was then calculated. In order to simplify the results for display purposes and further analysis, all of the catchments comprising the analysis scale were then divided into four categories. This procedure was used to provide another way of illustrating the relative amount of an activity across the landscape; obviously these ranks could be divided into more or fewer categories. Catchments whose percentile value was between 100 and 75% were considered to be at a high risk of impairment. Catchments whose percentile value was between 75 and 50% were considered to be at a moderate risk of impairment. Catchments whose percentile value was between 50 and 25% were considered to be at a low risk of impairment. Catchments whose percentile value was between 25 and 0% were considered to be at a minimal risk of impairment. Catchments whose percentile value was equal to 0% were considered to be in a reference condition.

Table B-1. Example of the metrics calculated, percentiles determined and category assignment for the number of road crossings per stream kilometer in Lewis and Clark National Historical Park at the 7th field catchment level.

Catchment name	Total stream length (km)	Total crossings (#)	Crossings / stream kilometer	Crossing rank	Crossing percentile
Cranberry Marsh	14.65	19	1.30	13	0.93
Cullaby Creek	25.13	21	0.84	7	0.50
Hortill Creek	31.56	18	0.57	3	0.21
Hungry Harbor	30.86	20	0.65	5	0.36
L. Chinook River	49.47	23	0.46	2	0.14
L. Circle Creek	47.73	49	1.03	11	0.79
L. Lewis and Clark River	63.36	41	0.65	4	0.29
L. Skipanon River	34.69	38	1.10	12	0.86
Neacoxie Creek	4.55	9	1.98	14	1.00
Neawanna Creek	32.93	33	1.00	9	0.64
Shweeash Creek	24.70	17	0.69	6	0.43
U. Chinook River	15.70	3	0.19	1	0.07
U. Circle Creek	17.89	18	1.01	10	0.71
Wallacut River	17.40	17	0.98	8	0.57

These categories are meant to narrow the focus of management attention, in terms of potential areas influenced by an activity. Values that are considerably more or less than the general trends observed in the ranking process should be considered important for understanding elevated levels or uninfluenced areas. This analysis should be utilized by resource managers to prioritize further reach/site investigations and restoration efforts. The relative influence of an activity within a particular catchment compared to one throughout the assessment area should help focus efforts within the NCCN. In addition, as other assessments are made throughout the NCCN new comparisons could be made at different scales.

Additive Effects Analysis

Analysis of each activity category included an additive ranking. The purpose of the additive ranking analysis was to produce a value that qualifies an "overall likelihood" of a watershed being influenced by anthropogenic activities for all five landuse metrics. For each catchment, the activity category percentile values were summed and then ranked to give a cumulative rank. The range of additive category values was then divided into quartiles using the previously discussed methods (Table B-2).

Table B-2. Human activity metrics and risk category for all of the watersheds lying within the North Coast and Cascades Network or draining into the North Coast and Cascades Network.

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
EBLA	North Puget Sound	Clover Valley	0.00	2.42	0.56	9.8	4	High
EBLA	North Puget Sound	Crescent Harbor	0.00	2.78	0.47	7.7	1	High
EBLA	North Puget Sound	Deception Pass	0.00	2.32	0.00	1.2	0	Minimal
EBLA	North Puget Sound	North Admiralty Bay	0.00	2.94	1.97	2.2	0	High
EBLA	North Puget Sound	Northeast Holmes Harbor	0.00	2.40	1.12	0.6	0	Low
EBLA	North Puget Sound	Northwest Holmes Harbor	0.00	3.06	1.34	4.1	0	High
EBLA	North Puget Sound	Oak Harbor	0.00	4.30	0.42	5.5	1	Moderate
EBLA	North Puget Sound	Penn Cove	0.00	2.68	0.84	2.0	1	Moderate
EBLA	North Puget Sound	Possession Sound	0.00	2.65	1.25	2.3	0	Moderate
EBLA	North Puget Sound	Scatchet Head	0.00	2.08	0.81	2.2	1	Low
EBLA	North Puget Sound	Silver Lake	0.00	1.89	1.19	1.1	0	Minimal
EBLA	North Puget Sound	Smith Prairie	0.00	1.67	0.00	4.1	0	Minimal
EBLA	North Puget Sound	South Admiralty Bay	0.00	2.54	1.05	1.7	1	High
EBLA	North Puget Sound	Southeast Holmes Harbor	0.00	2.64	1.13	6.0	0	Moderate
EBLA	North Puget Sound	Southwest Holmes Harbor	0.00	2.26	0.94	1.2	0	Low
EBLA	North Puget Sound	Southwest Saratoga Passage	0.00	2.22	0.93	2.3	0	Low
FOVA	Salmon Ck.	Camas Slough	0.01	5.86	2.40	5.6	1	High
FOVA	Salmon Ck.	Columbia Rv. - Fort Vancouver	0.00	12.39	0.00	3.8	0	Low
FOVA	Salmon Ck.	Curtin Ck.	0.00	5.84	1.14	16.6	2	High
FOVA	Salmon Ck.	Flume Ck.	0.00	1.97	0.30	1.2	0	Minimal
FOVA	Salmon Ck.	Gee Ck.	0.00	3.30	1.26	8.8	0	Minimal
FOVA	Salmon Ck.	L. Burnt Bridge Ck.	0.00	9.33	2.09	10.0	0	High
FOVA	Salmon Ck.	L. Middle Salmon Ck.	0.00	3.27	1.13	12.9	1	Low
FOVA	Salmon Ck.	L. Salmon Ck.	0.00	6.35	1.39	13.4	0	Moderate
FOVA	Salmon Ck.	Mill Ck.-Salmon Ck.	0.00	3.56	1.10	14.8	0	Moderate
FOVA	Salmon Ck.	Rock Ck.	0.04	4.11	1.93	2.5	0	Moderate
FOVA	Salmon Ck.	U. Burnt Bridge Ck.	0.00	9.41	2.01	9.6	0	High

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
FOVA	Salmon Ck.	U. Middle Salmon Ck.	0.00	3.43	1.07	14.8	0	Low
FOVA	Salmon Ck.	U. Salmon Ck.	0.14	3.81	1.44	1.8	0	Moderate
FOVA	Salmon Ck.	Vancouver Lake	0.00	3.21	0.55	1.9	2	Low
FOVA	Salmon Ck.	Whipple Ck.	0.00	2.87	1.02	8.8	0	Minimal
LEWI	Chinook Rv.	Hungry Harbor	0.00	1.90	0.65	0.0	2	Minimal
LEWI	Chinook Rv.	L. Chinook Rv.	0.03	2.19	0.46	0.3	0	Minimal
LEWI	Chinook Rv.	U. Chinook Rv.	0.00	2.39	0.19	0.2	1	Low
LEWI	Chinook Rv.	Wallacut Rv.	0.04	2.80	0.98	1.6	0	Moderate
LEWI	Long Beach	Cranberry Marsh	0.12	4.53	1.30	2.0	1	High
LEWI	Necanicum Rv.	L. Circle Ck.	0.19	2.74	1.03	0.8	0	Moderate
LEWI	Necanicum Rv.	Neacoxie Ck.	0.24	3.36	1.98	6.2	0	High
LEWI	Necanicum Rv.	Neawanna Ck.	0.11	3.82	1.00	4.8	0	High
LEWI	Necanicum Rv.	U. Circle Ck.	0.00	2.80	1.01	1.1	0	Low
LEWI	Youngs Rv.	Cullaby Ck.	0.13	2.89	0.84	1.8	0	Moderate
LEWI	Youngs Rv.	Hortill Ck.	0.23	2.11	0.57	0.0	0	Minimal
LEWI	Youngs Rv.	L. Lewis and Clark Rv.	0.06	2.65	0.65	0.4	0	Low
LEWI	Youngs Rv.	L. Skipanon Rv.	0.11	3.78	1.10	3.0	0	High
LEWI	Youngs Rv.	Shweeash Ck.	0.40	2.24	0.69	0.0	0	Moderate
MORA	Carbon Rv.	Chenuis Ck.	0.26	0.24	0.13	0.0	1	Low
MORA	Carbon Rv.	Ipsut Ck.	0.69	0.07	0.03	0.0	0	Low
MORA	Carbon Rv.	Moraine Ck.	0.42	0.00	0.00	0.0	0	Minimal
MORA	Carbon Rv.	Ranger Ck.	0.36	0.52	0.35	0.0	5	High
MORA	Carbon Rv.	Tolmie Ck.	0.20	1.77	0.47	0.0	0	Moderate
MORA	Headwaters Cowlitz Rv.	Chinook Ck.	0.53	0.35	0.11	0.0	0	Moderate
MORA	Headwaters Cowlitz Rv.	Deer Ck.	0.12	0.18	0.13	0.0	0	Low
MORA	Headwaters Cowlitz Rv.	Dewey Ck.	0.94	0.91	0.42	0.0	0	High
MORA	Headwaters Cowlitz Rv.	Headwaters Ohanapecosh Rv.	0.17	0.00	0.00	0.0	0	Minimal
MORA	Headwaters Cowlitz Rv.	Kotsuck Ck.	0.36	0.00	0.00	0.0	0	Minimal

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
MORA	Headwaters Cowlitz Rv.	Laughingwater Ck.	1.12	0.03	0.06	0.0	0	Low
MORA	Headwaters Cowlitz Rv.	L. Ohanapecosh Rv.	0.39	1.28	0.67	0.0	0	High
MORA	Headwaters Cowlitz Rv.	Middle Ohanapecosh Rv.	0.73	0.35	0.22	0.0	0	High
MORA	Headwaters Cowlitz Rv.	Nickel Ck.	0.24	0.08	0.04	0.0	0	Low
MORA	Headwaters Cowlitz Rv.	Panther Ck.	0.36	0.00	0.03	0.0	0	Minimal
MORA	Headwaters Cowlitz Rv.	Stevens Ck.	0.65	0.37	0.15	0.0	0	Moderate
MORA	Headwaters Cowlitz Rv.	Taos Ck.	0.22	0.16	0.15	0.0	0	Low
MORA	Headwaters Cowlitz Rv.	U. Muddy Fork Cowlitz Rv.	0.00	0.00	0.00	0.0	0	Reference
MORA	Headwaters Cowlitz Rv.	U. Ohanapecosh Rv.	0.36	0.00	0.00	0.0	0	Minimal
MORA	U. Cowlitz Rv.	U. Butter Ck.	0.46	0.22	0.18	0.0	0	Moderate
MORA	U. Nisqually Rv.	Goat Ck.	0.17	1.86	0.56	0.0	0	High
MORA	U. Nisqually Rv.	Horse Ck.	0.69	1.84	0.69	0.0	4	High
MORA	U. Nisqually Rv.	Kautz Ck.	0.52	0.13	0.04	0.0	0	Low
MORA	U. Nisqually Rv.	L. Tahoma Ck.	0.33	0.55	0.24	0.0	0	Moderate
MORA	U. Nisqually Rv.	Paradise Rv.	1.63	1.17	0.25	0.0	1	High
MORA	U. Nisqually Rv.	U. Tahoma Ck.	0.61	0.00	0.00	0.0	0	Minimal
MORA	U. Nisqually Rv.	Van Trump Ck.	0.54	0.37	0.17	0.0	0	Moderate
MORA	U. Puyallup Rv.	Middle Mowich Rv.	0.38	1.78	0.15	0.0	0	Moderate
MORA	U. Puyallup Rv.	North Mowich Rv.	0.50	0.02	0.04	0.0	0	Low
MORA	U. Puyallup Rv.	North Puyallup Rv.	0.49	0.51	0.00	0.0	0	Low
MORA	U. Puyallup Rv.	Rushingwater Ck.	0.34	2.13	0.66	0.0	1	High
MORA	U. Puyallup Rv.	South Mowich Rv.	0.07	0.00	0.00	0.0	0	Minimal
MORA	U. Puyallup Rv.	Swift Ck.	0.15	2.20	0.41	0.0	0	High
MORA	U. Puyallup Rv.	Tahoma Glacier - South Puyallup Glacier	0.52	0.14	0.14	0.0	0	Moderate
MORA	U. Puyallup Rv.	U. South Puyallup Rv.	0.67	1.08	0.24	0.0	0	High
MORA	U. White Rv.	Crystal Ck. - White Rv.	0.46	0.28	0.23	0.0	1	Moderate
MORA	U. White Rv.	Deadwood Ck.	0.21	0.43	0.41	0.0	0	Moderate
MORA	U. White Rv.	Emmons Glacier	0.00	0.00	0.00	0.0	0	Reference

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
MORA	U. White Rv.	Fryingpan Ck.	0.41	0.07	0.04	0.0	0	Low
MORA	U. White Rv.	Inter Fork White Rv.	1.61	0.39	0.17	0.0	1	High
MORA	U. White Rv.	Middle Huckleberry Ck.	0.29	0.05	0.03	0.0	0	Minimal
MORA	U. White Rv.	Shaw Ck.	0.40	0.90	0.16	0.0	1	High
MORA	U. White Rv.	Sunrise Ck.	0.56	0.01	0.00	0.0	0	Low
MORA	U. White Rv.	U. Huckleberry	0.34	0.00	0.00	0.0	0	Minimal
MORA	U. White Rv.	U. West Fork White Rv.	0.52	0.00	0.00	0.0	0	Minimal
MORA	U. White Rv.	U. White Rv.	0.05	0.73	0.10	0.0	0	Moderate
MORA	U. White Rv.	Van Horn Ck.	0.69	0.00	0.00	0.0	0	Minimal
NOCA	Baker Rv.	Baker Lake	0.00	0.16	0.45	0.0	0	Moderate
NOCA	Baker Rv.	Bald Eagle Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Blum Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Crystal Ck. - Baker Rv.	0.00	0.00	0.00	0.0	1	Minimal
NOCA	Baker Rv.	Hidden Ck. - Baker Rv.	0.00	0.01	0.09	0.0	0	Minimal
NOCA	Baker Rv.	Lake Ck. - Baker Rv.	0.31	0.19	0.12	0.0	0	High
NOCA	Baker Rv.	Mineral Ck. - Baker Rv.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Noisy Ck.	0.09	0.00	0.00	0.0	0	Minimal
NOCA	Baker Rv.	Pass Ck. - Baker Rv.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Picket Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Scramble Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Baker Rv.	Shuksan Ck.	0.07	0.10	0.08	0.0	0	Moderate
NOCA	Baker Rv.	Sulphide Ck.	0.01	0.00	0.00	0.0	7	Low
NOCA	Cascade Rv.	L. North Fork Cascade Rv.	0.00	0.19	0.14	0.0	6	High
NOCA	Cascade Rv.	Marble Ck.	0.00	0.05	0.02	0.0	2	Low
NOCA	Cascade Rv.	U. North Fork Cascade Rv.	0.19	0.18	0.24	0.0	39	High
NOCA	Diablo Lake	Diablo Lake	0.30	0.36	0.18	0.0	2	High
NOCA	Diablo Lake	L. Fisher Ck.	0.31	0.00	0.00	0.0	1	Low
NOCA	Diablo Lake	L. Thunder Ck.	0.43	0.00	0.00	0.0	0	Low

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	Diablo Lake	Middle Thunder Ck.	0.22	0.00	0.00	0.0	1	Moderate
NOCA	Diablo Lake	Neve Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Diablo Lake	Skagit Queen Ck.	0.01	0.00	0.00	0.0	10	Moderate
NOCA	Diablo Lake	U. Fisher Ck.	0.21	0.00	0.00	0.0	0	Minimal
NOCA	Diablo Lake	U. McAllister Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Diablo Lake	U. Thunder Ck.	0.49	0.00	0.00	0.0	13	Moderate
NOCA	Gorge Lake	Azure Lake	0.02	0.00	0.00	0.0	0	Minimal
NOCA	Gorge Lake	Gorge Ck.	0.00	0.39	0.28	0.1	0	High
NOCA	Gorge Lake	L. Goodell Ck.	0.00	0.56	0.27	0.3	0	High
NOCA	Gorge Lake	L. McAllister Ck.	0.00	0.00	0.00	0.0	0	Minimal
NOCA	Gorge Lake	L. Stetattle Ck.	0.41	0.02	0.03	0.0	0	Moderate
NOCA	Gorge Lake	Pyramid Ck.	0.14	0.50	0.21	0.0	0	High
NOCA	Gorge Lake	Terror Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Gorge Lake	West Fork Thunder Ck.	0.00	0.00	0.00	0.0	1	Minimal
NOCA	Lake Chelan	Castle Ck.	0.02	0.00	0.00	0.0	1	Minimal
NOCA	Lake Chelan	Devore Ck.	0.40	0.00	0.00	0.0	1	Low
NOCA	Lake Chelan	Fourmile Ck.	0.37	0.00	0.00	0.0	0	Low
NOCA	Lake Chelan	Purple Ck.	0.58	0.14	0.16	0.0	1	High
NOCA	Lake Chelan	U. Lake Chelan	0.00	0.01	0.00	0.0	0	Minimal
NOCA	Lightning Ck.	Boundary Ck.	0.07	0.00	0.00	0.0	4	Low
NOCA	Lightning Ck.	Castle Fork of Three Fools Ck.	0.49	0.00	0.00	0.0	0	Low
NOCA	Lightning Ck.	Cinnamon Ck.	0.01	0.00	0.00	0.0	0	Minimal
NOCA	Lightning Ck.	Freezeout Ck.	0.02	0.00	0.00	0.0	0	Minimal
NOCA	Lightning Ck.	L. Lightning Ck.	0.42	0.00	0.00	0.0	0	Low
NOCA	Lightning Ck.	L. Three Fools Ck.	0.37	0.00	0.00	0.0	0	Low
NOCA	Lightning Ck.	Passage Ck.	0.20	0.00	0.00	0.0	0	Minimal
NOCA	Lightning Ck.	Shull Ck.	0.08	0.00	0.00	0.0	0	Minimal
NOCA	Lightning Ck.	Trouble Ck.	0.13	0.00	0.00	0.0	0	Minimal

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	Lightning Ck.	U. Lightning Ck.	0.44	0.57	1.14	0.0	0	High
NOCA	Lightning Ck.	Willow Lake	0.37	0.00	0.00	0.0	0	Low
NOCA	Chilliwack Rv.	U. Silesia Ck.	0.10	0.00	0.00	0.0	0	Minimal
NOCA	N.F. Nooksack Rv.	N. Fork Nooksack Rv. Headwaters	0.10	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	39-Mile Ck.	0.14	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	Arctic Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ross Lake	Desolation - Ross Lake	0.34	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	Dry Ck. - Ross Lake	0.43	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	Hozomeen Ck.	0.21	0.20	0.24	0.0	0	High
NOCA	Ross Lake	L. Big Beaver Ck.	0.21	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	L. Devils Ck.	0.26	0.00	0.00	0.0	1	Low
NOCA	Ross Lake	L. Little Beaver Ck.	0.43	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	Luna Ck.	0.00	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	McMillan Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ross Lake	Mist Ck.	0.21	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	No Name Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ross Lake	Pass Ck. - Little Beaver Ck.	0.42	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	Perry Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ross Lake	Pierce Ck.	0.66	0.00	0.00	0.0	2	Moderate
NOCA	Ross Lake	Redoubt Ck.	0.01	0.00	0.00	0.0	0	Minimal
NOCA	Ross Lake	Roland Ck.	0.25	0.00	0.00	0.0	1	Low
NOCA	Ross Lake	Silver Ck. - Ross Lake	0.00	0.00	0.00	0.0	5	Low
NOCA	Ross Lake	Skymo Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ross Lake	U. Big Beaver Ck.	0.26	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	U. Devils Ck.	0.36	0.00	0.00	0.0	0	Low
NOCA	Ross Lake	U. Little Beaver Ck.	0.30	0.00	0.00	0.0	1	Moderate
NOCA	Ross Lake	U. Ross Lake NW	0.00	0.39	0.26	0.0	0	Moderate
NOCA	Ross Lake	U. Ross Lake SW	0.00	0.00	0.00	0.0	0	Reference

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	Ruby Ck.	Crater Ck.	0.12	0.10	0.09	0.0	8	High
NOCA	Ruby Ck.	East Ck.	0.54	0.00	0.00	0.0	3	Moderate
NOCA	Ruby Ck.	Gabriel Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ruby Ck.	L. Canyon Ck.	0.73	0.00	0.00	0.0	15	Moderate
NOCA	Ruby Ck.	L. Granite Ck.	0.00	0.21	0.13	0.0	4	High
NOCA	Ruby Ck.	L. Panther Ck.	0.43	0.01	0.04	0.0	0	Moderate
NOCA	Ruby Ck.	L. Middle Granite Ck.	0.05	0.17	0.13	0.0	0	Moderate
NOCA	Ruby Ck.	Middle Canyon Ck.	0.45	0.00	0.00	0.0	17	Moderate
NOCA	Ruby Ck.	Middle Panther Ck.	0.06	0.00	0.00	0.0	0	Minimal
NOCA	Ruby Ck.	Mill Ck. - Canyon Ck.	0.74	0.00	0.00	0.0	7	Moderate
NOCA	Ruby Ck.	North Fork Canyon Ck.	0.37	0.00	0.00	0.0	10	Moderate
NOCA	Ruby Ck.	Ruby Ck.	0.44	0.29	0.32	0.0	5	High
NOCA	Ruby Ck.	Slate Ck.	0.39	0.60	0.34	0.0	72	High
NOCA	Ruby Ck.	South Fork Slate Ck.	0.30	0.00	0.00	0.0	4	Moderate
NOCA	Ruby Ck.	Swamp Ck.	0.29	0.04	0.06	0.0	0	Moderate
NOCA	Ruby Ck.	U. Canyon Ck.	0.42	0.01	0.00	0.0	11	High
NOCA	Ruby Ck.	U. Granite Ck.	0.15	0.15	0.11	0.0	1	High
NOCA	Ruby Ck.	U. Panther Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Ruby Ck.	U. Middle Granite Ck.	0.10	0.21	0.18	0.0	0	High
NOCA	Skagit Rv.	Alma Ck.	0.00	0.01	0.05	0.0	2	Low
NOCA	Skagit Rv.	Babcock Ck.	0.10	0.94	0.20	0.0	1	High
NOCA	Skagit Rv.	Copper Ck. - Skagit Rv.	0.00	0.62	0.07	0.5	7	High
NOCA	Skagit Rv.	County Line Ponds	0.00	0.66	0.26	0.0	5	High
NOCA	Skagit Rv.	Crescent Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Skagit Rv.	Damnation Ck.	0.00	0.27	0.08	0.0	0	Moderate
NOCA	Skagit Rv.	East Fork Bacon Ck.	0.00	0.03	0.10	0.0	0	Low
NOCA	Skagit Rv.	East Fork Newhalem Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Skagit Rv.	Falls Ck.	0.00	0.14	0.27	0.0	0	Moderate

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	Skagit Rv.	Ladder Ck.	0.00	0.03	0.00	0.0	0	Minimal
NOCA	Skagit Rv.	L. Bacon Ck.	0.00	1.42	0.49	0.0	0	High
NOCA	Skagit Rv.	L. Newhalem Ck.	0.00	0.36	0.27	0.0	0	High
NOCA	Skagit Rv.	Thorton Ck.	0.44	0.09	0.28	0.1	0	High
NOCA	Skagit Rv.	Triumph Ck.	0.00	0.00	0.00	0.0	0	Minimal
NOCA	Skagit Rv.	U. Diobsud Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Skagit Rv.	U. Newhalem Ck.	0.00	0.12	0.09	0.0	0	Moderate
NOCA	Skagit Rv.	West Fork Bacon Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Stehekin Rv.	Agnes Ck.	0.18	0.00	0.00	0.0	1	Minimal
NOCA	Stehekin Rv.	Boulder Ck. - Stehekin Rv.	0.35	0.00	0.02	0.0	0	Low
NOCA	Stehekin Rv.	Cabin Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	Stehekin Rv.	Grizzly Ck.	0.02	0.00	0.00	0.0	1	Minimal
NOCA	Stehekin Rv.	Hilgard Ck.	0.46	0.00	0.00	0.0	1	Moderate
NOCA	Stehekin Rv.	Junction Ck.	0.03	0.22	0.16	0.0	3	High
NOCA	Stehekin Rv.	L. Bridge Ck.	0.22	0.03	0.04	0.0	0	Moderate
NOCA	Stehekin Rv.	L. Company Ck.	0.34	0.01	0.04	0.0	1	Moderate
NOCA	Stehekin Rv.	L. Flat Ck.	0.00	0.08	0.02	0.0	0	Low
NOCA	Stehekin Rv.	L. South Fork Agnes Ck.	0.19	0.00	0.00	0.0	4	Low
NOCA	Stehekin Rv.	L. Stehekin Rv.	0.06	0.30	0.14	0.0	0	High
NOCA	Stehekin Rv.	Maple Ck.	0.03	0.00	0.00	0.0	0	Minimal
NOCA	Stehekin Rv.	Margerum Ck.	0.34	0.36	0.04	0.0	0	High
NOCA	Stehekin Rv.	McAlester Ck.	0.43	0.00	0.00	0.0	0	Low
NOCA	Stehekin Rv.	Middle Bridge Ck.	0.30	0.00	0.00	0.0	0	Low
NOCA	Stehekin Rv.	North Fork Bridge Ck.	0.25	0.00	0.00	0.0	7	Moderate
NOCA	Stehekin Rv.	Park Ck.	0.36	0.01	0.03	0.0	0	Moderate
NOCA	Stehekin Rv.	Rainbow Ck. - Stehekin Rv.	0.57	0.03	0.05	0.0	0	Moderate
NOCA	Stehekin Rv.	South Fork Bridge Ck.	0.29	0.00	0.00	0.0	0	Low
NOCA	Stehekin Rv.	Trapper Lake	0.33	0.01	0.03	0.0	17	High

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	Stehekin Rv.	U. Bridge Ck.	0.67	0.22	0.16	0.0	0	High
NOCA	Stehekin Rv.	U. Company Ck.	0.00	0.00	0.00	0.0	3	Low
NOCA	Stehekin Rv.	U. South Fork Agnes Ck.	0.51	0.00	0.00	0.0	1	Moderate
NOCA	Stehekin Rv.	U. Stehekin Rv.	0.07	0.40	0.22	0.0	2	High
NOCA	Stehekin Rv.	West Fork Agnes Ck.	0.09	0.00	0.00	0.0	0	Minimal
NOCA	U. Chilliwack Rv.	Bear Ck. - Chilliwack Rv.	0.01	0.00	0.00	0.0	0	Minimal
NOCA	U. Chilliwack Rv.	Beaver Pond	0.26	0.06	0.17	0.0	0	Moderate
NOCA	U. Chilliwack Rv.	Brush Ck.	0.40	0.00	0.00	0.0	0	Low
NOCA	U. Chilliwack Rv.	Copper Lake - Chilliwack Rv.	0.77	0.00	0.00	0.0	0	Moderate
NOCA	U. Chilliwack Rv.	Indian Ck. - Chilliwack Rv.	0.08	0.00	0.00	0.0	1	Minimal
NOCA	U. Chilliwack Rv.	Little Chilliwack Rv.	0.00	0.00	0.00	0.0	0	Minimal
NOCA	U. Chilliwack Rv.	U. Chilliwack Rv.	0.55	0.00	0.00	0.0	3	Moderate
NOCA	U. Chilliwack Rv.	U. Depot Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	U. Skagit Rv.	Big Burn Ck.	0.00	0.66	0.41	0.0	0	High
NOCA	U. Skagit Rv.	Chittenden Bar	0.17	0.10	0.07	0.0	0	Low
NOCA	U. Skagit Rv.	East Snass Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	U. Skagit Rv.	Ferguson Ck.	0.00	1.39	0.93	0.0	0	High
NOCA	U. Skagit Rv.	Galene Ck.	0.03	0.58	0.05	0.0	0	Moderate
NOCA	U. Skagit Rv.	Grainger Ck.	0.00	0.00	0.00	0.0	0	Reference
NOCA	U. Skagit Rv.	L. Klesilkwa Rv.	0.00	0.23	0.09	0.0	0	Low
NOCA	U. Skagit Rv.	L. Maselpanik Ck.	0.00	1.15	0.86	0.0	0	High
NOCA	U. Skagit Rv.	L. Nepopekum Ck.	0.00	0.07	0.02	0.0	0	Minimal
NOCA	U. Skagit Rv.	L. Skaist Rv.	0.00	0.22	0.13	0.0	0	Low
NOCA	U. Skagit Rv.	L. Sumallo Rv.	0.00	0.16	0.13	0.0	0	Low
NOCA	U. Skagit Rv.	L. Middle Sumallo Rv.	0.00	0.36	0.13	0.0	0	Moderate
NOCA	U. Skagit Rv.	Marmotte Ck.	0.00	0.24	0.11	0.0	0	Low
NOCA	U. Skagit Rv.	Mcnaught Ck.	0.00	0.00	0.00	0.0	1	Minimal
NOCA	U. Skagit Rv.	Middle Klasilkwa Rv.	0.00	0.67	0.49	0.0	0	High

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
NOCA	U. Skagit Rv.	Middle Skaist Rv.	0.00	0.00	0.00	0.0	0	Reference
NOCA	U. Skagit Rv.	Shawatum Ck.	0.00	0.65	0.37	0.0	0	Moderate
NOCA	U. Skagit Rv.	Silverdaisy Ck.	0.00	0.38	0.20	0.0	0	Moderate
NOCA	U. Skagit Rv.	Skagit Rv. Headwaters	0.00	0.49	0.32	0.0	0	Moderate
NOCA	U. Skagit Rv.	Snass Ck.	0.00	0.14	0.14	0.0	0	Low
NOCA	U. Skagit Rv.	St Alice Ck.	0.00	0.02	0.01	0.0	0	Minimal
NOCA	U. Skagit Rv.	Twentysix Mile Ck.	0.00	0.07	0.05	0.0	0	Minimal
NOCA	U. Skagit Rv.	U. Klesilkwa Rv.	0.00	0.71	0.82	0.0	0	High
NOCA	U. Skagit Rv.	U. Maselpanik Ck.	0.00	1.14	0.78	0.0	0	High
NOCA	U. Skagit Rv.	U. Nepopekum Ck.	0.08	0.31	0.17	0.0	0	High
NOCA	U. Skagit Rv.	U. Skaist Rv.	0.01	0.21	0.09	0.0	0	Low
NOCA	U. Skagit Rv.	U. Sumallo Rv.	0.02	0.82	0.61	0.0	0	High
NOCA	U. Skagit Rv.	U. Middle Sumallo Rv.	0.00	0.93	0.51	0.0	0	High
OLYM	Bogachiel Rv.	All-in Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Bogachiel Rv.	Bear Ck. - Bogachiel Rv.	0.01	1.48	0.21	0.0	0	Low
OLYM	Bogachiel Rv.	Dowans Ck.	0.01	1.91	0.32	0.0	0	Moderate
OLYM	Bogachiel Rv.	Hades Ck.	0.22	0.14	0.00	0.0	0	Minimal
OLYM	Bogachiel Rv.	Headwaters Bogachiel Rv.	0.29	0.00	0.00	0.0	0	Minimal
OLYM	Bogachiel Rv.	Maxfield Ck.	0.00	2.76	0.26	0.0	0	Low
OLYM	Bogachiel Rv.	Mill Ck. - Bogachiel Rv.	0.00	2.91	0.28	1.6	1	High
OLYM	Bogachiel Rv.	Mosquito Ck. - Olallie Ck.	0.33	0.00	0.00	0.0	0	Minimal
OLYM	Bogachiel Rv.	Murphy Ck. - Bogachiel Rv.	0.01	2.70	0.33	0.0	0	Moderate
OLYM	Bogachiel Rv.	North Fork Bogachiel Rv.	0.39	0.00	0.00	0.0	0	Low
OLYM	Bogachiel Rv.	Tumwata Ck.	0.33	0.02	0.00	0.0	0	Low
OLYM	Calawah Rv.	Calawah Rv.	0.00	2.94	0.21	1.8	0	High
OLYM	Calawah Rv.	Elk Ck. - Calawah Rv.	0.00	1.70	0.14	0.0	0	Moderate
OLYM	Calawah Rv.	L. North Fork Calawah Rv.	0.32	1.13	0.24	0.0	0	Moderate
OLYM	Calawah Rv.	L. Sitkum Rv.	0.06	2.12	0.54	0.0	0	Moderate

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	Calawah Rv.	L. South Fork Calawah Rv.	0.08	0.28	0.00	0.0	0	Minimal
OLYM	Calawah Rv.	Middle North Fork Calawah Rv.	0.18	1.23	0.39	0.0	0	Low
OLYM	Calawah Rv.	Middle Sitkum Rv.	0.00	1.30	0.28	0.0	0	Low
OLYM	Calawah Rv.	Middle South Fork Calawah Rv.	0.14	0.00	0.00	0.0	0	Minimal
OLYM	Calawah Rv.	N. Fork Calawah Rv. Headwaters	0.11	2.36	0.18	0.0	0	Moderate
OLYM	Calawah Rv.	Short Ck. - Canyon Ck.	0.14	1.37	0.33	0.0	0	Moderate
OLYM	Calawah Rv.	South Fork Calawah Rv.	0.18	1.80	0.43	0.0	0	High
OLYM	Calawah Rv.	U. Sitkum Rv.	0.04	1.03	0.30	0.0	0	Low
OLYM	Calawah Rv.	U. South Fork Calawah Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Clearwater Rv.	East Fork Kalaloch Ck.	0.00	2.64	0.41	0.0	0	Moderate
OLYM	Clearwater Rv.	South Beach	0.04	1.89	0.64	0.0	0	High
OLYM	Clearwater Rv.	U. Kalaloch Ck.	0.00	2.62	0.17	0.0	0	Low
OLYM	Clearwater Rv.	West Fork Kalaloch Ck.	0.05	2.69	0.42	0.0	0	High
OLYM	Coastal	Ocean	0.44	0.00	0.00	0.0	7	Moderate
OLYM	Coastal	Ozette Rv.	0.11	1.98	0.73	0.0	3	High
OLYM	Dickey Rv.	Big Joes Lake	0.00	3.41	0.49	0.0	0	Moderate
OLYM	Dickey Rv.	Coal Ck.	0.00	3.11	0.61	0.0	0	Moderate
OLYM	Dickey Rv.	Colby Ck.	0.00	2.61	0.45	1.2	0	High
OLYM	Dickey Rv.	Dickey Lake	0.16	3.01	0.63	0.0	0	High
OLYM	Dickey Rv.	East Fork Dickey Rv.	0.12	2.89	0.60	0.0	0	High
OLYM	Dickey Rv.	Ellen Ck.	0.01	1.94	0.27	0.0	5	Moderate
OLYM	Dickey Rv.	L. Dickey Rv.	0.03	2.98	0.42	0.0	0	Moderate
OLYM	Dickey Rv.	L. West Fork Dickey Rv.	0.03	3.15	0.45	0.0	0	Moderate
OLYM	Dickey Rv.	Thunder Ck. - E. Fork Dickey Rv.	0.10	2.81	0.34	0.0	0	Moderate
OLYM	Dosewallips Rv.	Headwaters Dosewallips Rv.	0.48	0.00	0.00	0.0	1	Low
OLYM	Dosewallips Rv.	Hidden Ck. - Twin Ck.	0.37	0.00	0.00	0.0	1	Low
OLYM	Dosewallips Rv.	Silt Ck.	0.00	0.00	0.00	0.0	0	Reference

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	Dosewallips Rv.	U. Dosewallips Rv.	0.24	0.13	0.12	0.0	6	Moderate
OLYM	Dosewallips Rv.	West Fork Dosewallips Rv.	0.34	0.00	0.00	0.0	1	Low
OLYM	Duckabush Rv.	Crazy Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Duckabush Rv.	Headwaters Duckabush Rv.	0.75	0.00	0.00	0.0	0	Low
OLYM	Duckabush Rv.	Middle Duckabush Rv.	0.19	0.00	0.00	0.0	0	Minimal
OLYM	Duckabush Rv.	U. Duckabush Rv.	0.55	0.00	0.00	0.0	0	Low
OLYM	Dungeness Rv.	Cameron Ck.	0.40	0.00	0.00	0.0	0	Low
OLYM	Dungeness Rv.	Grand Ck.	0.78	0.04	0.00	0.0	0	Low
OLYM	Dungeness Rv.	Heather Ck.	0.25	0.00	0.00	0.0	0	Minimal
OLYM	Dungeness Rv.	Royal Ck.	0.31	0.00	0.00	0.0	0	Minimal
OLYM	Dungeness Rv.	Slide Ck.	0.48	0.00	0.00	0.0	0	Low
OLYM	Dungeness Rv.	U. Grey Wolf Rv.	0.31	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Boulder Ck. - Elwha Rv.	0.50	0.05	0.03	0.0	0	Low
OLYM	Elwha Rv.	Buckinghorse Ck.	0.16	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Cat Ck.	0.02	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Delabarre Ck.	0.36	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Elwha Rv. above Lake Mills	0.80	0.06	0.00	0.0	0	Low
OLYM	Elwha Rv.	Elwha Rv. below Lake Mills	0.18	0.50	0.22	0.0	2	Moderate
OLYM	Elwha Rv.	Fairchild Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Elwha Rv.	Hayes Rv.	0.26	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Headwaters Elwha Rv.	0.20	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Hughes Ck.	0.10	0.00	0.00	0.0	1	Minimal
OLYM	Elwha Rv.	Lake Mills	0.40	0.51	0.29	0.0	0	Moderate
OLYM	Elwha Rv.	Little Rv.	0.01	1.77	0.60	0.0	0	Moderate
OLYM	Elwha Rv.	Long Ck.	0.31	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Lost Rv.	0.11	0.00	0.00	0.0	1	Minimal
OLYM	Elwha Rv.	L. Godkin Ck.	0.02	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	L. Goldie Rv.	0.22	0.00	0.00	0.0	0	Minimal

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	Elwha Rv.	L. Lillian Ck.	0.24	0.37	0.00	0.0	0	Low
OLYM	Elwha Rv.	Middle Elwha Rv.	0.28	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	South Branch Little Rv.	0.35	0.17	0.05	0.0	21	Moderate
OLYM	Elwha Rv.	U. Elwha Rv.	0.36	0.00	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	U. Godkin Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Elwha Rv.	U. Goldie Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Elwha Rv.	U. Lillian Ck.	0.05	0.05	0.00	0.0	0	Minimal
OLYM	Elwha Rv.	Wolf Ck. - Hurricane Ck.	0.28	0.10	0.11	0.0	2	Moderate
OLYM	Goodman/Mosquito Ck.	L. Goodman Ck.	0.14	1.72	0.21	0.1	0	High
OLYM	Goodman/Mosquito Ck.	Minter Ck.	0.00	2.17	0.00	0.0	0	Low
OLYM	Goodman/Mosquito Ck.	North Fork Mosquito Ck.	0.03	2.64	0.52	0.0	0	Moderate
OLYM	Goodman/Mosquito Ck.	South Fork Mosquito Ck.	0.21	1.39	0.22	0.0	0	Low
OLYM	Goodman/Mosquito Ck.	U. Goodman Ck.	0.04	2.67	0.43	0.0	0	Moderate
OLYM	Hamma Hamma Rv.	Lena Ck.	0.57	0.00	0.03	0.0	4	Moderate
OLYM	Hamma Hamma Rv.	Middle Hamma Hamma Rv.	0.06	0.39	0.22	0.0	1	Moderate
OLYM	Hoh Rv.	Braden Ck.	0.00	1.73	0.43	0.0	0	Moderate
OLYM	Hoh Rv.	Cedar Ck.	0.04	2.39	0.53	0.0	1	High
OLYM	Hoh Rv.	Elk Ck. - Hoh Rv.	0.00	2.52	0.52	0.0	0	High
OLYM	Hoh Rv.	Glacier Ck.	0.20	0.00	0.00	0.0	0	Minimal
OLYM	Hoh Rv.	Headwaters South Fork Hoh Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Hoh Rv.	Jackson Ck.	0.06	0.14	0.05	0.0	0	Minimal
OLYM	Hoh Rv.	Lost Ck.	0.00	2.32	0.33	0.0	0	High
OLYM	Hoh Rv.	L. Headwaters Hoh Rv.	0.16	0.00	0.00	0.0	0	Minimal
OLYM	Hoh Rv.	L. Middle Headwaters Hoh Rv.	0.62	0.00	0.00	0.0	0	Low
OLYM	Hoh Rv.	L. Mount Tom Ck.	0.06	0.00	0.00	0.0	0	Minimal
OLYM	Hoh Rv.	L. South Fork Hoh Rv.	0.06	1.66	0.35	0.0	0	Low
OLYM	Hoh Rv.	L.-middle South Fork Hoh Rv.	0.09	0.00	0.00	0.0	0	Minimal
OLYM	Hoh Rv.	Middle Headwaters Hoh Rv.	0.24	0.00	0.00	0.0	0	Minimal

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	Hoh Rv.	Nolan Ck.	0.00	2.49	0.67	0.0	0	High
OLYM	Hoh Rv.	Owl Ck.	0.00	2.46	0.29	0.0	0	Low
OLYM	Hoh Rv.	Spruce Ck.	0.03	1.78	0.48	0.0	0	Moderate
OLYM	Hoh Rv.	Tower Ck.	0.02	1.97	0.52	0.0	0	Moderate
OLYM	Hoh Rv.	Twin Ck.	0.00	0.26	0.06	0.0	0	Minimal
OLYM	Hoh Rv.	U. Headwaters Hoh Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Hoh Rv.	U. Mount Tom Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Hoh Rv.	U. Middle South Fork Hoh Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Hoh Rv.	Winfield Ck.	0.00	2.45	0.43	0.0	0	High
OLYM	Lake Crescent	Barnes Ck.	0.50	0.02	0.05	0.0	9	Moderate
OLYM	Lake Crescent	L. Lake Crescent	0.25	0.48	0.54	0.0	20	High
OLYM	Lake Crescent	Middle Lake Crescent	0.45	0.33	0.36	0.0	1	High
OLYM	Lake Crescent	U. Lake Crescent	0.28	1.06	0.56	0.0	3	High
OLYM	Makah Bay	Grimes Ck.	0.00	2.78	0.56	0.0	0	High
OLYM	Makah Bay	Miller Ck.	0.00	3.41	0.67	0.0	0	Moderate
OLYM	Makah Bay	Petroleum Ck.	0.18	2.67	0.72	0.0	2	High
OLYM	Makah Bay	Pilchuck Ck.	0.00	3.96	0.72	0.0	0	Moderate
OLYM	Makah Bay	Snag Ck. - Sooes Rv.	0.00	3.81	1.16	0.0	0	Moderate
OLYM	Makah Bay	U. Sooes Rv.	0.00	3.94	0.78	0.0	0	High
OLYM	Ozette Lake	Crooked Ck.	0.05	3.29	0.56	0.0	0	Moderate
OLYM	Ozette Lake	L. Big Rv.	0.07	3.20	0.48	0.0	0	High
OLYM	Ozette Lake	North Ozette Lake	0.13	0.92	0.75	0.0	0	High
OLYM	Ozette Lake	South Ozette Lake	0.00	1.87	0.39	0.0	0	Low
OLYM	Ozette Lake	Umbrella Ck.	0.00	4.08	0.60	0.0	0	High
OLYM	Ozette Lake	U. Big Rv.	0.00	3.54	1.27	0.0	2	High
OLYM	Port Angeles Harbor	Maiden Ck.	0.08	0.30	0.00	0.0	0	Low
OLYM	Port Angeles Harbor	Middle Morse Ck.	0.29	0.70	0.25	0.0	0	High
OLYM	Port Angeles Harbor	Peabody Ck.	0.00	6.79	1.23	4.6	2	High

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	Port Angeles Harbor	U. Ennis Ck.	1.30	0.63	0.58	0.0	0	High
OLYM	Port Angeles Harbor	U. Morse Ck.	0.22	0.33	0.13	0.0	0	Moderate
OLYM	Port Angeles Harbor	U. Siebert Ck.	0.05	1.09	0.25	0.0	0	Low
OLYM	Port Angeles Harbor	West Fork Maiden Ck.	0.01	0.02	0.00	0.0	0	Minimal
OLYM	Queets Rv.	Alta Ck.	0.04	0.00	0.00	0.0	0	Minimal
OLYM	Queets Rv.	Harlow Ck.	0.12	0.00	0.00	0.0	0	Minimal
OLYM	Queets Rv.	Headwaters Tshletshy Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Queets Rv.	Headwaters U. Queets Rv.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Queets Rv.	L. Salmon Rv.	0.00	2.83	0.45	0.0	0	High
OLYM	Queets Rv.	L. Sams Rv.	0.00	1.34	0.28	0.0	0	Low
OLYM	Queets Rv.	L. Tshletshy Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	Queets Rv.	Matheny Ck.	0.00	2.64	0.54	0.0	0	High
OLYM	Queets Rv.	McKinnon Ck.	0.00	2.52	0.47	0.0	0	High
OLYM	Queets Rv.	Middle Salmon Rv.	0.00	1.78	0.16	0.0	0	Low
OLYM	Queets Rv.	North Ck.	0.00	0.88	0.22	0.0	0	Minimal
OLYM	Queets Rv.	North Fork Salmon Rv.	0.00	1.89	0.18	0.0	0	Low
OLYM	Queets Rv.	Paradise Ck.	0.20	0.00	0.00	0.0	0	Minimal
OLYM	Queets Rv.	Queets Rv. above Sams Rv.	0.27	0.02	0.00	0.0	0	Minimal
OLYM	Queets Rv.	Saghalie Ck.	0.04	0.00	0.00	0.0	0	Minimal
OLYM	Queets Rv.	South Fork Matheny Ck.	0.00	1.58	0.31	0.0	0	Moderate
OLYM	Queets Rv.	South Fork Salmon Rv.	0.00	2.04	0.40	0.0	0	Moderate
OLYM	Queets Rv.	Tacoma Ck.	0.00	2.62	0.48	0.0	0	Moderate
OLYM	Queets Rv.	Ticket Ck.	0.00	1.98	0.55	0.0	0	Moderate
OLYM	Queets Rv.	U. Matheny Ck.	0.00	1.41	0.29	0.0	0	Moderate
OLYM	Queets Rv.	U. Sams Rv.	0.00	0.80	0.38	0.0	0	Low
OLYM	Skokomish Rv.	Dry Ck. – N. Fork Skokomish Rv.	0.38	0.29	0.18	0.0	20	High
OLYM	Skokomish Rv.	Four Stream	0.09	0.45	0.18	0.0	1	Moderate
OLYM	Skokomish Rv.	Headwaters North Fork	0.32	0.00	0.00	0.0	5	Low

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
		Skokomish Rv.						
OLYM	Skokomish Rv.	U. North Fork Skokomish Rv.	0.61	0.00	0.00	0.0	3	Moderate
OLYM	Sol Duc Rv.	Alckee Ck.	0.00	0.46	0.21	0.0	0	Minimal
OLYM	Sol Duc Rv.	Bear Ck. - Sol Duc Rv.	0.00	1.21	0.24	0.0	1	Low
OLYM	Sol Duc Rv.	Beaver Ck.	0.26	2.07	0.45	0.0	5	High
OLYM	Sol Duc Rv.	Blackwood Ck.	0.48	0.19	0.20	0.0	0	Moderate
OLYM	Sol Duc Rv.	Camp Ck.	0.50	1.96	0.20	0.0	0	High
OLYM	Sol Duc Rv.	Confluence Sol Duc Rv.	0.10	3.35	0.37	0.0	0	High
OLYM	Sol Duc Rv.	Goodman Ck.	0.00	2.16	0.45	0.0	0	Moderate
OLYM	Sol Duc Rv.	Gunderson Ck.	0.03	2.73	0.41	0.4	0	High
OLYM	Sol Duc Rv.	Kugal Ck.	0.06	1.93	0.25	0.3	15	High
OLYM	Sol Duc Rv.	Lake Ck. - Sol Duc Rv.	0.00	2.82	0.62	0.3	0	High
OLYM	Sol Duc Rv.	Littleton Ck.	0.69	1.66	0.63	0.1	41	High
OLYM	Sol Duc Rv.	L. Bear Ck. - Sol Duc Rv.	0.00	1.77	0.29	0.1	7	High
OLYM	Sol Duc Rv.	L. North Fork Sol Duc Rv.	0.38	0.01	0.02	0.0	0	Low
OLYM	Sol Duc Rv.	Quillayute Rv.	0.10	2.54	0.07	0.1	1	High
OLYM	Sol Duc Rv.	Sol Duc Rv. - Shuwah Ck.	0.12	2.33	0.35	0.0	0	Moderate
OLYM	Sol Duc Rv.	South Fork Sol Duc Rv.	0.31	2.00	0.61	0.0	0	High
OLYM	Sol Duc Rv.	Tassel Ck.	0.00	2.30	0.41	0.7	0	High
OLYM	Sol Duc Rv.	U. Headwaters Sol Duc Rv.	0.48	0.00	0.00	0.0	0	Low
OLYM	Sol Duc Rv.	U. North Fork Sol Duc Rv.	0.30	0.00	0.00	0.0	3	Low
OLYM	Sol Duc Rv.	U. Sol Duc Rv. below Snider Ck.	0.08	3.09	0.40	0.4	9	High
OLYM	Sol Duc Rv.	U. Sol Duc Rv. below Snider Ck.-Lake Ck.	0.09	3.04	0.32	0.5	0	High
OLYM	U. Quinault Rv.	Finley Ck.	0.00	0.40	0.07	0.0	0	Minimal
OLYM	U. Quinault Rv.	Fire Ck.	0.22	0.00	0.00	0.0	0	Minimal
OLYM	U. Quinault Rv.	Fletcher Ck.	0.14	0.40	0.12	0.0	1	Low
OLYM	U. Quinault Rv.	Graves Ck.	0.37	0.00	0.00	0.0	0	Low
OLYM	U. Quinault Rv.	Headwaters Quinault Rv.	0.57	0.00	0.00	0.0	0	Low

Park	Watershed name	Catchment name	Trail density	Road density	Road crossings / stream km	Developed area (%)	Mines (#)	Category
OLYM	U. Quinault Rv.	Howe Ck.	0.00	0.03	0.04	0.0	0	Minimal
OLYM	U. Quinault Rv.	Kimta Ck. - Geoduck Ck.	0.24	0.00	0.00	0.0	0	Minimal
OLYM	U. Quinault Rv.	L. Big Ck.	0.00	0.13	0.13	0.0	0	Minimal
OLYM	U. Quinault Rv.	L. North Fork Quinault Rv.	0.21	0.17	0.00	0.0	0	Low
OLYM	U. Quinault Rv.	Middle North Fork Quinault Rv.	0.50	0.00	0.00	0.0	1	Low
OLYM	U. Quinault Rv.	North Shore Quinault Lake	0.00	0.91	0.34	0.1	1	Moderate
OLYM	U. Quinault Rv.	Oneil Ck.	0.00	0.00	0.00	0.0	0	Reference
OLYM	U. Quinault Rv.	Quinault Rv. above Quinault Lake	0.05	0.47	0.11	0.0	0	Low
OLYM	U. Quinault Rv.	Rustler Ck.	0.00	0.00	0.00	0.0	1	Minimal
OLYM	U. Quinault Rv.	U. Big Ck.	0.46	0.00	0.00	0.0	0	Low
OLYM	U. Quinault Rv.	U. North Fork Quinault Rv.	0.59	0.00	0.00	0.0	0	Low
OLYM	U. Quinault Rv.	U. Quinault Rv.	0.24	0.00	0.00	0.0	0	Minimal
OLYM	U. Quinault Rv.	U. Quinault Rv. below Graves Ck.	0.05	0.35	0.17	0.0	0	Low
OLYM	Wynoochee Rv.	U. Wynoochee Rv.	0.19	1.40	0.58	0.0	1	High
SAJH	San Juan Island	Beaverton Valley	0.00	3.12	1.26	1.7	0	Moderate
SAJH	San Juan Island	North San Juan Island	0.05	3.07	1.38	1.0	8	High
SAJH	San Juan Island	North San Juan Valley	0.15	1.78	0.82	0.0	3	Moderate
SAJH	San Juan Island	South San Juan Island	0.00	2.78	1.83	2.3	0	High
SAJH	San Juan Island	South San Juan Valley	0.00	1.67	0.46	0.9	2	Minimal
SAJH	San Juan Island	Sportsman Lake	0.00	2.00	1.35	0.1	4	Low

Appendix C. Fresh Water Designated Beneficial Uses by WRIA (WA) and Basin (OR) as Applicable in North Coast and Cascades Network Parks.

		Aquatic Life Uses					Recreation Uses		Water Supply Uses				Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Columbia River	Columbia River from mouth to the Washington-Oregon border (river mile 309.3)[2]			X				X	X	X	X	X	X	X	X	X	X
Nooksack - 1	Chilliwack River and Little Chilliwack River: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Nooksack - 1	Depot Creek and tributaries	X					X		X	X	X	X	X	X	X	X	X
Nooksack - 1	Silesia Creek and all tributaries south of Canadian border	X					X		X	X	X	X	X	X	X	X	X
San Juan - 2*	There are no specific water body entries for this WRIA																
Upper Skagit - 4	Bacon Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Baker Lake and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Big Beaver Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Cascade River and Boulder Creek: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Upper Skagit - 4	Diobsud Creek and the unnamed tributary at longitude -121.4414 and latitude 48.5850: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Goodell Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Hozomeen Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Illabot Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Lightning Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Little Beaver Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Newhalem Creek, and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Ruby Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Silver Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Stetattle Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Thunder Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Upper Skagit - 4	Skagit River and tributaries, except where listed otherwise for this WRIA[3]		X				X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Island - 6	There are no specific water body entries for this WRIA																	
Puyallup-White - 10	Carbon River and tributaries above latitude 46.9998 longitude -121.9794 that are in or above the Snoqualmie National Forest or Mount Rainier National Park	X	#	#			X		X	X	X	X	X	X	X	X	X
Puyallup-White - 10	Greenwater River from junction with White River to headwaters (including all tributaries)	X	#	#			X		X	X	X	X	X	X	X	X	X
Puyallup-White - 10	Puyallup River at and including Mowich River: All waters (including tributaries) above the junction	X	#	#			X		X	X	X	X	X	X	X	X	X
Puyallup-White - 10	Voight Creek and Bear Creek: All waters (including tributaries) above the junction that are in or above the Snoqualmie National Forest or Mount Rainier National Park	X	#	#			X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses			
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Puyallup-White - 10	White River from and including West Fork White River: All waters (including tributaries) above the junction	X	#	#			X		X	X	X	X	X	X	X	X	X
Nisqually - 11	Big Creek and all tributaries	X					X		X	X	X	X	X	X	X	X	X
Nisqually - 11	Nisqually River and Tahoma Creek: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Nisqually - 11	Nisqually River from Alder Dam (river mile 44.2) to Tahoma Creek (including tributaries) except where designated Char		X				X		X	X	X	X	X	X	X	X	X
Skokomish-Dosewallips - 16	Skokomish River, North Fork, from latitude 47.4160 longitude -123.2233 (below Cushman Upper Dam) to headwaters (including tributaries)	X					X		X	X	X	X	X	X	X	X	X
Skokomish-Dosewallips - 16	Dosewallips River and tributaries		X				X		X	X	X	X	X	X	X	X	X
Skokomish-Dosewallips - 16	Duckabush River and tributaries		X				X		X	X	X	X	X	X	X	X	X
Skokomish-Dosewallips - 16	Hamma Hamma River and tributaries		X				X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Elwha-Dungeness - 18	Boulder Creek: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Dungeness River and Canyon Creek: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Elwha River and Cat Creek: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Griff Creek and the unnamed tributary at latitude 48.0135 longitude -123.5440 (Sect. 11 T29N R7W): All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Hughes Creek and the unnamed tributary at latitude 48.0298 longitude -123.6322 (Sect. 6 T29N R7W): All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Little River and all tributaries	X					X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Elwha-Dungeness - 18	Wolf Creek and the unnamed tributary at latitude 47.9654 longitude -123.5374 (Sect. 35 T29N R7W): All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Elwha River and tributaries from mouth to Cat Creek, except where designated Char		X				X		X	X	X	X	X	X	X	X	X
Elwha-Dungeness - 18	Ennis Creek and tributaries lying above the Olympic National Park Boundary		X				X		X	X	X	X	X	X	X	X	X
Lyre-Hoko - 19*	There are no specific water body entries for this WRIA																
Soleduc - 20	Hoh River and South Fork Hoh River: All waters above the junction	X					X		X	X	X	X	X	X	X	X	X
Soleduc - 20	Soleduck River and all tributaries above Canyon Creek	X					X		X	X	X	X	X	X	X	X	X
Soleduc - 20	Hoh River and tributaries from mouth to South Fork Hoh River		X				X		X	X	X	X	X	X	X	X	X
Soleduc - 20	Quillayute River		X				X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Soleduc - 20	Soleduck River and tributaries from mouth to Canyon Creek		X				X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Matheny Creek and the unnamed tributary at latitude 47.5592 longitude -123.9538: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Queets River and tributaries above the junction with Tshletshy Creek	X					X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Quinault River and North Fork Quinault: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Salmon River, Middle Fork, and the unnamed tributary at latitude 47.5208 longitude -123.9899: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Sams River and the unnamed tributary at latitude 47.6059 longitude -123.8941: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses			
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
Queets-Quinault - 21	Tshletshy Creek and the unnamed tributary at latitude 47.6585 longitude -123.8668: All waters (including tributaries) above the junction	X					X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Queets River and tributaries from mouth to Tshletshy Creek		X				X		X	X	X	X	X	X	X	X	X
Queets-Quinault - 21	Quinault River and tributaries from mouth to the junction with the North Fork Quinalt River		X				X		X	X	X	X	X	X	X	X	X
Willapa - 24	Megler Creek[4]		X	#				X	X	X	X	X	X	X	X	X	X
Cowlitz - 26	Cowlitz River, and tributaries from base of Riffe Lake Dam (river mile 52.0) to headwaters		X				X		X	X	X	X	X	X	X	X	X

		Aquatic Life Uses					Recreation Uses		Water Supply Uses					Misc. Uses				
WRIA/Basin Name - Number	Location	Char spawning/rearing (WA)	Core summer habitat (WA)	Spawning/rearing (WA) / salmon /steelhead spawning (OR)	Core cold-water habitat (OR)	Salmon and trout rearing and migration (OR)	Extraord. primary contact (WA)	Primary contact (WA) / water contact recreation (OR)	Domestic water[1]	Industrial water	Agricultural/irrigation water	Stock water	Wildlife habitat (WA) / wildlife and hunting (OR)	Harvesting/fishing	Commerce/navigation	Boating	Aesthetics
North Coast/Lower Columbia - 11-21	Includes Lower Columbia (including Lewis and Clark and Skipanon Rivers) and Necanicum subbasins			X	X	X		X	X	X	X	X	X	X		X	X
Chelan - 47	Stehekin River		X				X		X	X	X	X	X	X	X	X	X

[1] In Oregon: with adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards.

[2] In Washington, temperature shall not exceed a 1-day maximum (1-DMax) of 20.0°C due to human activities. When natural conditions exceed a 1-DMax of 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed 0.3°C due to any single source or 1.1°C due to all such activities combined. Dissolved oxygen shall exceed 90 percent of saturation. Special condition - special fish passage exemption as described in WAC 173-201A-200 (1)(f). In Oregon, this segment of the Columbia River is designated a Salmon and Steelhead Migration Corridor (OR DEQ 2010).

[3] Skagit River (Gorge by-pass reach) from Gorge Dam (river mile 96.6) to Gorge Powerhouse (river mile 94.2). Temperature shall not exceed a 1-DMax of 21°C due to human activities. When natural conditions exceed a 1-DMax of 21°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C, nor shall such temperature increases, at any time, exceed $t = 34/(T + 9)$.

[4] Megler Creek at Dismal Nitch was not specifically identified but the designated uses for the entire WRIA are assumed to apply.

NPS proposed Designated Use

Appendix D. Risk Rankings for Waters of Management Concern.

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
EBLA	Ebey's Watercourse	Coastal (WA)	Wadeable Stream	High	High	Yes
EBLA	Lake Pondilla	Coastal (WA)	Lake (<50 ha)	High	High	Yes
LEWI	Yeon Lake	Coastal (OR)	Lake (<50 ha)	High	High	Yes
LEWI	Ecola Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
LEWI	McKenzie Head Lagoon	Coastal (WA)	Lake (<50 ha)	High	High	Yes
LEWI	O'Neil Lake	Coastal (WA)	Lake (<50 ha)	High	High	Yes
LEWI	Megler Creek	Columbia River	Wadeable Stream	High	High	Yes
LEWI	Lewis and Clark River	Lewis And Clark River	Non-wadeable River	High	High	Yes
LEWI	Skipanon River	Skipanon River	Wadeable River	High	High	Yes
MORA	Carbon River (Ipsut)	Carbon River	Wadeable River	Low	Minor	-
MORA	Carbon River (Ranger)	Carbon River	Wadeable River	High	High	Yes
MORA	Chenuis Creek	Carbon River	Wadeable Stream	Low	High	Yes
MORA	Chenuis Lake #1 (lc29)	Carbon River	Lake (<50 ha)	Low	Minor	-
MORA	Green Lake (lc07)	Carbon River	Lake (<50 ha)	High	Moderate	-
MORA	Ipsut Creek	Carbon River	Wadeable Stream	Low	Moderate	-
MORA	Moraine Creek	Carbon River	Wadeable Stream	Minimal	Minor	-
MORA	Ranger Creek	Carbon River	Wadeable Stream	High	Minor	-
MORA	Unnamed Lake (lc14)	Carbon River	Lake (<50 ha)	Minimal	Minor	-
MORA	Windy Gap Lake (lc34)	Carbon River	Lake (<50 ha)	Low	Minor	-
MORA	Bench Lake (lz27)	Cowlitz River	Lake (<50 ha)	Moderate	Minor	-
MORA	Cowlitz Park Creek	Cowlitz River	Wadeable Stream	Reference	Reference	-
MORA	Louise Lake (lz21)	Cowlitz River	Lake (<50 ha)	Moderate	Moderate	-
MORA	Marsh Lake (lz25)	Cowlitz River	Lake (<50 ha)	Low	Minor	-
MORA	Reflection Lake	Cowlitz River	Lake (<50 ha)	Moderate	High	Yes
MORA	Snow Lake (lz29)	Cowlitz River	Lake (<50 ha)	Moderate	Moderate	-
MORA	Tipsoo Lake	Cowlitz River	Lake (<50 ha)	Moderate	High	Yes
MORA	Unnamed Lake (lz04)	Cowlitz River	Lake (<50 ha)	Low	Minor	-

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
MORA	Golden Lake (lm17)	Mowich River	Lake (<50 ha)	High	Minor	-
MORA	Mowich Lake	Mowich River	Lake (<50 ha)	Low	High	Yes
MORA	Allen Lake (ln03)	Nisqually River	Lake (<50 ha)	Moderate	Minor	-
MORA	Barn Flats	Nisqually River	Wadeable Stream	High	High	Yes
MORA	Fish Creek	Nisqually River	Wadeable Stream	Moderate	Moderate	-
MORA	Kautz Creek	Nisqually River	Wadeable Stream	Low	High	Yes
MORA	Narada Falls Creek	Nisqually River	Wadeable Stream	High	High	Yes
MORA	Nisqually River (NIBO)	Nisqually River	Wadeable River	High	High	Yes
MORA	Nisqually River (NIGB)	Nisqually River	Wadeable River	Moderate	High	Yes
MORA	Nisqually River (NILO)	Nisqually River	Wadeable River	High	High	Yes
MORA	Pyramid Creek	Nisqually River	Wadeable Stream	Low	Minor	-
MORA	Tahoma Creek (lower)	Nisqually River	Wadeable Stream	Moderate	Moderate	-
MORA	Tahoma Creek (upper)	Nisqually River	Wadeable Stream	Moderate	Moderate	-
MORA	Fir Lake (lo24)	Ohanapecosh River	Lake (<50 ha)	High	Minor	-
MORA	Kotsuck Creek	Ohanapecosh River	Wadeable Stream	Minimal	Minor	-
MORA	Laughingwater (lo28)	Ohanapecosh River	Lake (<50 ha)	Low	Minor	-
MORA	Ohanapecosh (OHCA)	Ohanapecosh River	Wadeable River	High	High	Yes
MORA	Ohanapecosh River (mid)	Ohanapecosh River	Wadeable River	High	Moderate	-
MORA	Unnamed Lake (lo05)	Ohanapecosh River	Lake (<50 ha)	Minimal	Minor	-
MORA	Unnamed Ohana VC Stream	Ohanapecosh River	Wadeable Stream	High	High	Yes
MORA	South Puyallup River	Puyallup River	Wadeable River	High	Moderate	-
MORA	Unnamed 1 North Puyallup	Puyallup River	Wadeable Stream	Low	Minor	-
MORA	Unnamed Lake (lp19)	Puyallup River	Lake (<50 ha)	High	Minor	-
MORA	Deadwood Creek (lower)	White River	Wadeable Stream	Moderate	Moderate	-
MORA	Eleanor Creek	White River	Wadeable Stream	Minimal	Minor	-
MORA	Fryingpan Creek	White River	Wadeable Stream	Low	Minor	-
MORA	Ghost Lake (lw40)	White River	Lake (<50 ha)	Moderate	High	Yes
MORA	Inter Fork	White River	Wadeable River	High	Minor	-
MORA	Lake James (lf05)	White River	Lake (<50 ha)	Minimal	Minor	-

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
MORA	Lower Deadwood (lw31)	White River	Lake (<50 ha)	Moderate	Minor	-
MORA	Mystic Lake (lf12)	White River	Lake (<50 ha)	Minimal	Minor	-
MORA	Owyhigh Lake (lw43)	White River	Lake (<50 ha)	High	Minor	-
MORA	Shaw Creek	White River	Wadeable Stream	High	Minor	-
MORA	Sunrise Creek	White River	Wadeable Stream	High	High	Yes
MORA	Unnamed 1 Huckleberry Creek	White River	Wadeable Stream	Minimal	Minor	-
MORA	Unnamed Lake (lh11)	White River	Lake (<50 ha)	Minimal	Minor	-
MORA	Unnamed Lake (lh25)	White River	Lake (<50 ha)	Minimal	Minor	-
MORA	Unnamed Sunrise Creek	White River	Wadeable Stream	High	High	Yes
MORA	West Fork White River 3	White River	Wadeable River	Minimal	Minor	-
MORA	White River	White River	Wadeable River	High	High	Yes
MORA	White River (littorals)	White River	Wadeable River	Moderate	High	Yes
MORA	White River (upper)	White River	Wadeable Stream	Reference	Reference	-
NOCA	Baker River	Baker River	Wadeable River	High	Moderate	-
NOCA	Blum Lake Lower (LS-07-01)	Baker River	Lake (<50 ha)	Reference	Reference	-
NOCA	Blum Lake Upper (M-11-01)	Baker River	Lake (<50 ha)	Reference	Reference	-
NOCA	Green Lake	Baker River	Lake (<50 ha)	Reference	Reference	-
NOCA	Ipsoot Lake (LS-06-01)	Baker River	Lake (<50 ha)	Minimal	Reference	-
NOCA	Lake Creek	Baker River	Wadeable Stream	High	Moderate	-
NOCA	Hidden Lake (SB-01-01)	Cascade River	Lake (<50 ha)	High	Moderate	-
NOCA	Hidden Lake Tarn (EP-14-01)	Cascade River	Lake (<50 ha)	High	Moderate	-
NOCA	Monogram Lake (M-23-01)	Cascade River	Lake (<50 ha)	Moderate	Moderate	-
NOCA	Monogram Tarn (M-23-11)	Cascade River	Lake (<50 ha)	Moderate	Moderate	-
NOCA	N.F. Cascade River	Cascade River	Wadeable River	High	High	Yes
NOCA	Colonial Creek	Diablo Lake	Wadeable Stream	High	High	Yes
NOCA	Deer Creek	Diablo Lake	Wadeable Stream	High	High	Yes
NOCA	Diablo Lake	Diablo Lake	Lake (>50 ha)	High	High	Yes
NOCA	Panther Potholes	Diablo Lake	Lake (<50 ha)	Low	Minor	-
NOCA	Pyramid Creek	Diablo Lake	Wadeable Stream	High	High	Yes

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
NOCA	Thunder Lake	Diablo Lake	Lake (<50 ha)	High	High	Yes
NOCA	Gorge Lake	Gorge Lake	Lake (>50 ha)	High	High	Yes
NOCA	Pyramid Lake	Gorge Lake	Lake (<50 ha)	High	Minor	-
NOCA	Stetattle Creek	Gorge Lake	Wadeable Stream	Moderate	High	Yes
NOCA	Boulder Creek	Lake Chelan	Wadeable Stream	Moderate	Moderate	-
NOCA	Lake Chelan	Lake Chelan	Lake (>50 ha)	High	High	Yes
NOCA	Purple Creek	Lake Chelan	Wadeable Stream	High	High	Yes
NOCA	Willow Lake (HM-04-01)	Lightning Creek	Lake (<50 ha)	Low	Minor	-
NOCA	Firn Lake (MP-02-01)	Ross Lake	Lake (<50 ha)	Minimal	Minor	-
NOCA	Happy Flats Creek	Ross Lake	Wadeable Stream	High	Moderate	-
NOCA	Hozomeen Creek	Ross Lake	Wadeable Stream	High	High	Yes
NOCA	Hozomeen Lake (HM-02-01)	Ross Lake	Lake (<50 ha)	High	Moderate	-
NOCA	Lightning Creek (boundary)	Ross Lake	Wadeable Stream	Low	High	Yes
NOCA	Lightning Creek (mouth)	Ross Lake	Wadeable Stream	Low	Moderate	-
NOCA	No Name Lake (PM-01-01)	Ross Lake	Lake (<50 ha)	Reference	Reference	-
NOCA	Ridley Lake (HM-03-01)	Ross Lake	Lake (<50 ha)	High	Minor	-
NOCA	Ross Lake	Ross Lake	Lake (>50 ha)	High	High	Yes
NOCA	Ruby Creek	Ross Lake	Wadeable Stream	High	High	Yes
NOCA	Skymo Lake (PM-03-01)	Ross Lake	Lake (<50 ha)	Reference	Reference	-
NOCA	Sourdough Lake (PM-12-01)	Ross Lake	Lake (<50 ha)	Moderate	Minor	-
NOCA	Sweet Pea Lake (ML-02-01)	Ross Lake	Lake (<50 ha)	Reference	Reference	-
NOCA	Torment Lake (ML-03-01)	Ross Lake	Lake (<50 ha)	Reference	Reference	-
NOCA	Bacon Creek	Skagit River	Wadeable Stream	High	High	Yes
NOCA	Berdeen Lake (M-08-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Berdeen Lake Lower (M-07-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Berdeen Lake Upper (M-09-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Bouck Lake Lower (DD-04-01)	Skagit River	Lake (<50 ha)	High	Minor	-
NOCA	Bouck Lake Upper (DD-05-01)	Skagit River	Lake (<50 ha)	High	Minor	-
NOCA	Copper Creek	Skagit River	Wadeable Stream	High	High	Yes

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
NOCA	County Line Pond SW	Skagit River	Lake (<50 ha)	High	High	Yes
NOCA	Diobsud Lake Lower (LS-02-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Diobsud Lake Pothole (LS-01-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Diobsud Lake Upper (LS-03-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Doug's Tarn (M-21-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Goodell Creek	Skagit River	Wadeable Stream	High	High	Yes
NOCA	Green Lake (M-04-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Hi-Yu Lake (M-01-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Jeanita Lake (DD-01-01)	Skagit River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Lower Wilcox Lake (EP-05-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Nert Lake (M-05-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Newhalem Creek (abv. divr.)	Skagit River	Wadeable Stream	Moderate	Moderate	-
NOCA	Newhalem Creek (mouth)	Skagit River	Wadeable Stream	High	High	Yes
NOCA	Newhalem Ponds East	Skagit River	Lake (<50 ha)	High	High	Yes
NOCA	Newhalem Ponds West	Skagit River	Lake (<50 ha)	High	High	Yes
NOCA	Panther Potholes (RD-05-02)	Skagit River	Lake (<50 ha)	Low	Moderate	-
NOCA	Quill Lake Lower (M-24-02)	Skagit River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Quill Lake Upper (M-24-01)	Skagit River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Skagit River (Copper Ck)	Skagit River	Non-wadeable River	High	High	Yes
NOCA	Skagit River (Newhalem)	Skagit River	Non-wadeable River	High	High	Yes
NOCA	Stout Lake (EP-09-02)	Skagit River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Stout Lake Lower (EP-09-01)	Skagit River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Thornton Creek	Skagit River	Wadeable Stream	High	Moderate	-
NOCA	Thornton Lake Lower (M-20-01)	Skagit River	Lake (<50 ha)	High	Minor	-
NOCA	Thornton Lake Middle (M-19-01)	Skagit River	Lake (<50 ha)	High	Minor	-
NOCA	Triumph Lake (M-17-01)	Skagit River	Lake (<50 ha)	Minimal	Minor	-
NOCA	Upper Wilcox Lake (EP-06-01)	Skagit River	Lake (<50 ha)	Reference	Reference	-
NOCA	Battalion Lake (MLY-02-01)	Stehekin River	Lake (<50 ha)	High	Minor	-
NOCA	Bowan Lake (MR-12-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
NOCA	Bridge Creek (upper)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Company Creek (hydro)	Stehekin River	Wadeable Stream	Moderate	High	Yes
NOCA	Coon Lake	Stehekin River	Lake (<50 ha)	High	Minor	-
NOCA	Coon Lake (MM-10-01)	Stehekin River	Lake (<50 ha)	High	Moderate	-
NOCA	Dagger Lake (MR-04-01)	Stehekin River	Lake (<50 ha)	Low	Minor	-
NOCA	Dee Dee Lake, Lower (MR-15-02)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Dee Dee Lake, Upper (MR-15-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Doubtful Lake (CP-01-01)	Stehekin River	Lake (<50 ha)	Moderate	Moderate	-
NOCA	Kettling Lake (MR-05-01)	Stehekin River	Lake (<50 ha)	Low	Minor	-
NOCA	McAlester Lake (MR-10-01)	Stehekin River	Lake (<50 ha)	Low	Minor	-
NOCA	Rainbow Creek	Stehekin River	Wadeable Stream	Moderate	Moderate	-
NOCA	Rainbow Lake Lower (MR-14-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Rainbow Lake Upper S. (MR-13-02)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Rainbow Lake Upper W. (MM-11-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Stehekin (Junction)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Stehekin River (Flat)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Stehekin River (McGregor)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Stehekin River (mouth)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Stehekin River (orchard)	Stehekin River	Wadeable River	High	High	Yes
NOCA	Stehekin River (side channel 1)	Stehekin River	Wadeable Stream	High	High	Yes
NOCA	Stehekin River (side channel 2)	Stehekin River	Wadeable Stream	High	High	Yes
NOCA	Stiletto Lake (MR-01-01)	Stehekin River	Lake (<50 ha)	Low	Minor	-
NOCA	Trapper Lake (GM-01-01)	Stehekin River	Lake (<50 ha)	Moderate	Moderate	-
NOCA	Unnamed Lake (MR-09-01)	Stehekin River	Lake (<50 ha)	Low	Minor	-
NOCA	Unnamed Lake (MR-11-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Unnamed Lake (MR-16-01)	Stehekin River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Skagit Queen Creek	Thunder Creek	Wadeable Stream	Moderate	High	Yes
NOCA	Thunder Creek (upper)	Thunder Creek	Wadeable Stream	Moderate	High	Yes
NOCA	Triplet Lake Lower (SM-02-01)	Upper Chelan	Lake (<50 ha)	Low	Minor	-

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
NOCA	Triplet Lake Upper (SM-02-02)	Upper Chelan	Lake (<50 ha)	Low	Minor	-
NOCA	Bear Lake (MC-12-01)	Upper Chilliwack River	Lake (<50 ha)	Minimal	Reference	-
NOCA	Copper Lake (MC-06-01)	Upper Chilliwack River	Lake (<50 ha)	Moderate	Minor	-
NOCA	Hanging Lake (MC-08-01)	Upper Chilliwack River	Lake (<50 ha)	Reference	Reference	-
NOCA	Kwahnesum Lake (MC-07-01)	Upper Chilliwack River	Lake (<50 ha)	Minimal	Reference	-
OLYM	S.F. Calawah River	Calawah River	Wadeable River	Minimal	Minor	-
OLYM	Sitkum River	Calawah River	Wadeable River	No Data	High	Yes
OLYM	Cedar Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	Ellen Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	Ennis Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	James Pond	Coastal (WA)	Lake (<50 ha)	Moderate	Moderate	-
OLYM	Kalaloch Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	Morse Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	Mosquito Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	P.J. Lake	Coastal (WA)	Lake (<50 ha)	High	Minor	-
OLYM	Peabody Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	Petroleum Creek	Coastal (WA)	Wadeable Stream	High	High	Yes
OLYM	W.F. Siebert Creek	Coastal (WA)	Wadeable Stream	High	Moderate	Yes
OLYM	Dickey River	Dickey River	Non-wadeable River	High	High	Yes
OLYM	Elwha River	Elwha River	Wadeable River	High	High	Yes
OLYM	Little River	Elwha River	Wadeable Stream	High	High	Yes
OLYM	Hoh Lake	Hoh River	Lake (<50 ha)	Minimal	Minor	-
OLYM	S.F. Hoh River	Hoh River	Non-wadeable River	Moderate	High	Yes
OLYM	Taft Pond	Hoh River	Lake (<50 ha)	Moderate	High	Yes
OLYM	West Twin Creek	Hoh River	Wadeable Stream	Low	Minor	-
OLYM	Barnes Creek	Lake Crescent	Wadeable Stream	High	High	Yes
OLYM	Lake Crescent	Lake Crescent	Lake (>50 ha)	High	High	Yes
OLYM	Lyre River	Lake Crescent	Wadeable River	High	High	Yes
OLYM	Erickson's Pond	Lake Ozette	Lake (<50 ha)	High	Moderate	Yes

Park	Water body name	Watershed	Habitat type	Relative risk	Informed risk	Threatened water
OLYM	Piedmont Creek	Lyre River	Wadeable Stream	High	High	Yes
OLYM	Big River	Ozette Lake	Wadeable River	High	High	Yes
OLYM	Crooked Creek	Ozette Lake	Wadeable Stream	High	High	Yes
OLYM	Ozette Lake	Ozette Lake	Lake (>50 ha)	High	High	Yes
OLYM	Ozette River	Ozette Lake	Wadeable River	High	High	Yes
OLYM	Quinn Creek	Ozette Lake	Wadeable Stream	High	High	Yes
OLYM	Siwash Creek	Ozette Lake	Wadeable Stream	Moderate	High	Yes
OLYM	South Creek	Ozette Lake	Wadeable Stream	Moderate	High	Yes
OLYM	Umbrella Creek	Ozette Lake	Wadeable Stream	High	High	Yes
OLYM	Coal Creek	Ozette River	Wadeable Stream	High	High	Yes
OLYM	Bob Creek	Queets River	Wadeable Stream	Minimal	Minor	-
OLYM	Hibbard Creek	Queets River	Wadeable Stream	High	High	Yes
OLYM	Matheny Creek	Queets River	Wadeable Stream	High	High	Yes
OLYM	Mud Creek	Queets River	Wadeable Stream	High	High	Yes
OLYM	Queets River	Queets River	Non-wadeable River	High	High	Yes
OLYM	Salmon River	Queets River	Wadeable River	High	High	Yes
OLYM	Sams River	Queets River	Wadeable River	Moderate	High	Yes
OLYM	Finley Creek	Quinault River	Wadeable Stream	Moderate	Minor	-
OLYM	Quinault River	Quinault River	Non-wadeable River	Moderate	High	Yes
OLYM	Four Stream	Skokomish River	Wadeable Stream	High	High	Yes
OLYM	N.F. Skokomish River	Skokomish River	Wadeable River	High	High	Yes
OLYM	Canyon Creek	Sol Duc River	Wadeable Stream	Moderate	Minor	-
OLYM	Goodman Creek	Sol Duc River	Wadeable Stream	High	High	Yes
OLYM	Mink Lake Creek	Sol Duc River	Wadeable Stream	Moderate	Minor	-
OLYM	S.F. Sol Duc River	Sol Duc River	Wadeable Stream	High	High	Yes
OLYM	Sol Duc River	Sol Duc River	Wadeable River	High	High	Yes
OLYM	Sol Duc River (slough 1)	Sol Duc River	Wadeable Stream	High	High	Yes

Appendix E. Power Analysis.

Table E-1. Mean coefficient of variation (CV) values for proposed NCCN stream monitoring response variables. Data was collected at Mount Rainier National Park and North Cascades National Park Service Complex (A. Rawhouser, Nov. 2011 NOCA files).

Response variables	Number of Streams	Number of Data Sets	Mean CV	Evaluation Method
Water temperature (single measure)	6	3	0.05	1
Dissolved oxygen	6	3	0.09	1
Specific conductance	6	3	0.11	1
pH	6	3	0.06	1
Bioassessment, (O/E)	7	22	0.10	2

Evaluation Method: 1) Replicates were collected from the same location and the same month but over different years, 2) CV is based on variation within a stream reach where mulitle samples were collected at the same sample event.

Description of the power analysis methods for detection of trends (Trent McDonald).

This appendix contains methods for power analyses designed to estimate number of sites needed to achieve 80% power. Sample size (number of sample locations) required to detect a 2 to 5% annual trend with 80% power is based on testing the hypothesis H_0: $\beta_1 = 0$ versus the one-sided alternative H_1: $\beta_1 < 0$ in the following linear regression: $y_i = \beta_0 + \beta_1 x_i$, where y_i is the response of interest and x_i is year. Errors in this regression model were assumed to be correlated through time if they occurred on the same sample location. Sample sizes were the same if we had tested H_1: $\beta_1 > 0$ because responses were assumed to follow the normal distribution. Trend is detected if the null hypothesis of no trend is rejected in favor of H_1. Assuming σ^2 is known, the null hypothesis H_0: $\beta_1 = 0$ will be rejected if the statistic $t = \hat{\beta}_1 / \sigma_{\beta,n}$ is less than the $(1-\alpha)^{th}$ quantile of a T distribution with $m = (n_{yrs}n-2)$ degrees of freedom, where n_{yrs} is number of years and n is number of sample locations. The standard deviation of trend, $\sigma_{\beta,n}$, is the square root of the second diagonal element in the variance-covariance matrix,

$$\sigma_{\beta,n} = \sqrt{\sigma^2 (\underset{\sim}{X}' \underset{\sim}{R}^{-1} \underset{\sim}{X})^{-1}}$$

where R is the (block diagonal) correlation matrix for observations measured on the same sample location through time. Sample locations were assumed independent. The correlation between observations made in consecutive years was arbitrarily set at 0.5. Assuming lag 1 autocorrelation was ρ, the correlation of observations separated by k ($k \geq 1$) years was assumed to be ρk.

Assuming the random variable $\hat{\beta}_1$ follows a non-central T distribution with mean $\Delta = (0.05)\,\bar{Y}$ (= observed annual change of 5% of the original mean value) and variance $\sigma^2_{\beta,n}$, we calculate sample size as the smallest *n* such that

$$\Pr\left(\frac{\hat{\beta}_1}{\sigma_{\beta,n}} < t_{m,0.1}\right) = \Pr\left(\frac{\hat{\beta}_1}{\sigma_{\beta,n}} - \frac{\Delta}{\sigma_{\beta,n}} < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right) = \Pr\left(T_m < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right) = 0.8$$

where T_m follows a central T distribution with *m* degrees of freedom and $t_{m,0.1}$ denotes the critical value in a central T distribution corresponding to a test of size alpha = 10%. Letting $t_{m,0.8}$ denote the value of the central T distribution such that 80% of its area is to the left, sample size to obtain 80% power is calculated as the smallest value of *n* satisfying

$$t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}} = t_{m,0.8}$$

Note that *n* denotes the number of sample locations and the total number of points in the regression is $n_{yrs}n$.

Power analysis script (for R statistical software) for detection of trends (adapted from Trent McDonald 2004).

```
############
# Compute the sample size needed to achieve 1-beta power to detect a slope of 'slope'
# using linear regression with correlated errors after nyears years. Var-Covar of observations
# involves var.obs and corr.obs.
#
# Input:
# slope = slope coefficient desired to detect (% Annual Change)
#THESE ARE PERCENTAGES OF XBAR!!
# var.obs = the variance parameter of an individual observation in the regression
# corr.obs = correlation year-to-year of observations measured on the same sampling unit
# n = number of sample sites/units to assess power for
# xbar = overall average level of density
# alpha = Type I error rate
# nyears = number of consecutive years of measurements at each site.
# one.sided = T or F depending on whether one or two sided test desired
#
# output:
# Table giving power for various sample sizes
# Use this to derive the number of sample units to use.
#
# Original S+ Source Code  by TLM - 22jul04
# modified for R by AKR Jan2012
##########

F.trend.eff.power=function( slope, var.obs, corr.obs, n.range, xbar, nyears, alpha, one.sided){

n.all=s.all=p.all=NULL
slope=slope/100
slope.real=xbar*slope
print(slope.real)
for(slp in slope.real){
  print(slp)
  for(n in n.range ){
          p.all=c(p.all, F.trnd.power(slp, var.obs, corr.obs, n, nyears, alpha, one.sided ))
          n.all=c(n.all, n)
          s.all=c(s.all, 100*slp/xbar)
  }
}

ans=data.frame(s.all, n.all, p.all)
names(ans)=c("beta", "n", "power")

ans
}
```

```
##########################
# compute power of linear model to detect slope for one value of n
F.trnd.power=function(slope, var.obs, corr.obs, n, nyears, alpha, one.sided){


# correlation matrix, exponential form
r=diag(nyears)   # identity matrix
for(i in 1:(nyears-1)){
        r[abs(row(r)-col(r))==i]=corr.obs^i
}

# Big correlation matrix
big.r=kronecker(diag(n), r)

# The design matrix
big.n=nrow(big.r)
# print(big.n)
x=cbind(rep(1, big.n), rep(1:nyears, n))

# compute std error of slope
sig.beta=t(x)%*%solve(big.r)%*%x
sig.beta=solve(sig.beta)*var.obs
# print( sig.beta )
sig.beta=sqrt( sig.beta[2,2] )

# Compute t stat and power
if(one.sided){
        # assume lower tail is of interest, but everything symmetric, so doesn't matter.
        t.alpha=qt(1-alpha, big.n-2)

        t.stat=-t.alpha-(slope/sig.beta)
        pow2=pt(t.stat, big.n-2)   # lower tail probability

        pow=pow2

} else {
        t.alpha=qt(1-(alpha/2), big.n-2)

        t.stat=t.alpha-(slope/sig.beta)
        pow1=1-pt(t.stat, big.n-2)   # upper tail probability

        t.stat=-t.alpha-(slope/sig.beta)
        pow2=pt(t.stat, big.n-2 )   # lower tail probability

        pow=pow1+pow2
```

```
}
}

#############
# Plot the results of a call to F.trend.eff.power
F.plot.power=function(power1, main.title, lab.x){

# plot negative slopes as positive declines
power1$beta=-power1$beta

plot(range(power1$beta), range(power1$power), type="n", xlab="Annual decline in average
response (%)", ylab="", ylim=c(0,1),cex=2)
mtext("Power for Trend Dection", side=2, line=3, cex=1)
title(main=main.title, cex=2)
for(n in sort(unique(power1$n)) ){
        tmp.ind=power1$n==n
        lines(power1$beta[tmp.ind], power1$power[tmp.ind] )
        tmp.y=approx(power1$beta[tmp.ind], power1$power[tmp.ind], xout=lab.x)$y
        if(n!=max(power1$n)){
                text(lab.x-.02, tmp.y+.02, n, adj=1)
                #text(-6.3, tmp.y+.02, n, adj=1)
        } else {
                text(lab.x-.02, tmp.y+.02, paste("n=",n), adj=1)
        }

}

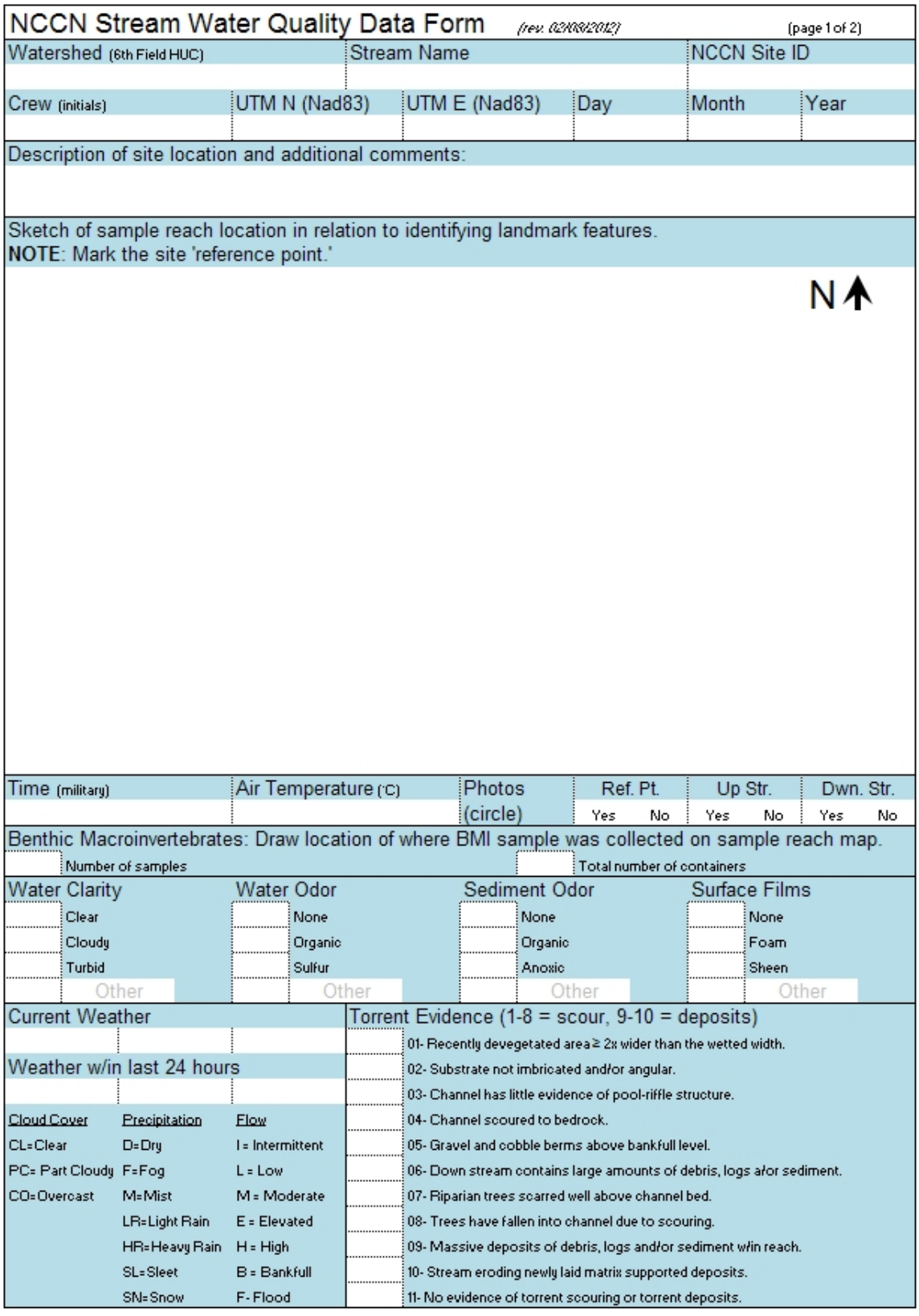
abline(h=.8, lty=2)
abline(v=3, lty=2)

invisible()
}

################
# User Input for power analysis to dectect a 4 to 2% Change over 5 years with alpha=0.20
# sample size ranging from 1 to 5 sites with a response variance of 0.1

power1=F.trend.eff.power(slope=seq(-4,-2,by=0.5), var.obs=0.01, corr.obs=0.5,
n.range=c(1,2,3,4,5), xbar=1.0, nyears=5, alpha=0.20, one.sided=T)
F.plot.power(power1, "NCCN Example", lab.x=3.8 )
power1
```

Appendix F. Field and Laboratory Data Forms.



NCCN Stream Water Quality Data Form (rev. 02/08/2012) (page 1 of 2)

Watershed (6th Field HUC)	Stream Name	NCCN Site ID

Crew (initials)	UTM N (Nad83)	UTM E (Nad83)	Day	Month	Year

Description of site location and additional comments:

Sketch of sample reach location in relation to identifying landmark features.
NOTE: Mark the site 'reference point.'

N

Time (military)	Air Temperature (°C)	Photos (circle)	Ref. Pt.		Up Str.		Dwn. Str.	
			Yes	No	Yes	No	Yes	No

Benthic Macroinvertebrates: Draw location of where BMI sample was collected on sample reach map.

	Number of samples		Total number of containers

Water Clarity		Water Odor		Sediment Odor		Surface Films	
	Clear		None		None		None
	Cloudy		Organic		Organic		Foam
	Turbid		Sulfur		Anoxic		Sheen
	Other		Other		Other		Other

Current Weather

Weather w/in last 24 hours

Cloud Cover	Precipitation	Flow
CL=Clear	D=Dry	I = Intermittent
PC= Part Cloudy	F=Fog	L = Low
CO=Overcast	M=Mist	M = Moderate
	LR=Light Rain	E = Elevated
	HR=Heavy Rain	H = High
	SL=Sleet	B = Bankfull
	SN=Snow	F- Flood

Torrent Evidence (1-8 = scour, 9-10 = deposits)

	01- Recently devegetated area ≥ 2x wider than the wetted width.
	02- Substrate not imbricated and/or angular.
	03- Channel has little evidence of pool-riffle structure.
	04- Channel scoured to bedrock.
	05- Gravel and cobble berms above bankfull level.
	06- Down stream contains large amounts of debris, logs a/or sediment.
	07- Riparian trees scarred well above channel bed.
	08- Trees have fallen into channel due to scouring.
	09- Massive deposits of debris, logs and/or sediment w/in reach.
	10- Stream eroding newly laid matrix supported deposits.
	11- No evidence of torrent scouring or torrent deposits.

Figure F-1. North Coast and Cascades Network Stream Water Quality Field Form.

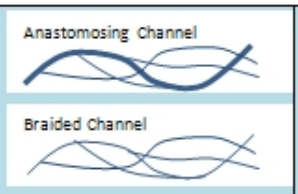
NCCN Stream Water Quality Data Form

(page 2 of 2)

Watershed (6th Field HUC)	Stream Name	NCCN Site ID

Notes:

Channel Constraint



Channel Pattern (check one)

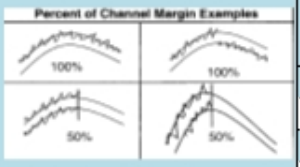
- One channel
- Anastomosing channel
- Braided channel

Channel Constraint (check one)

- Very constrained in V-shaped valley
- Broad valley but constrained by incision
- Narrow valley but not very constrained
- Broad valley and unconstrained

Constraining Feature (check one)

- Bedrock
- Hillslope
- Terrace/alluvial fan
- Human alteration
- None



Percent of channel length in contact with constraining feature

	Wet. Width (m)	Thal. Depth (r	Bnkfl Width (m)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Valley width (m) - visually estimated average

Note: Be sure to measure distances to both sides of valley!

If you cannot see the valley borders, record the distance you can see and check this box.

Human Influence (within sample reach)

Dike/Riprap	Dam/Diversion	Building	Pavement	Land Clearing	Road/RR	Campground	Campsite BC
Culvert	**Pipe (outlet)**	**Pipe (inlet)**	**Trash**	**Lawn**	**Logging**	**Mining**	**Row crop**
Landfill/Dump	**Rangeland/Grazing**		**Pasture/Hayfield**				

B = in the stream and/or on bank C = present w/in 10m of bankfull P = present but outside 10m of bankfull O = not present

Water Quality Core Parameters - obtain 7 measurements for each parameter

Time of water quality core parameters collection (record in military time)

Start time: End time:

Specific Conductance (record in µS/cm)

Buffer check 100 µS/cm	1	2	3	4	5	6	7	Buffer check 100 µS/cm

pH

Pre buffer check (pH 7)	1	2	3	4	5	6	7	Post buffer check (pH 7)

Dissolved oxygen (record in µ/L)

1	2	3	4	5	6	7

Temperature

°C or °F	1	2	3	4	5	6	7

Turbidity NTUs (this may be entered in the lab if not measured *in situ* with a portable meter)

1	2	3	4	5	6	7

Figure F-1. North Coast and Cascades Network Stream Water Quality Field Form (continued)

NCCN Water Quality Invasive Species Checklist

Water Body Name:_____ NCCN Site ID:_____

Observers:_____ Date: ____ /____ /_____

Common name	Scientific name	Observed at sample site? (check if yes)	Estimated no. of individuals	Approx. area of infestation (m2)
Invertebrates				
quagga mussel	*Dreissena bugensis*			
zebra mussel	*Dreissena polymorpha*			
ringed crayfish	*Orconectes neglectus*			
rusty crayfish	*Orconectes rusticus*			
northern crayfish, virile crayfish	*Orconectes virilis*			
New Zealand mudsnail	*Potamopyrgus antipodarum*			
red swamp crayfish	*Procambarus clarkii*			
Other _____	Other _____			
_____	_____			
Aquatic plants and algae				
giant reed	*Arundo donax*			
Didymo	*Didymosphenia geminata*			
Brazilian elodea	*Egeria densa*			
hydrilla, waterthyme	*Hydrilla verticillata*			
yellow flag	*Iris pseudacorus*			
parrot feather watermilfoil	*Myriophyllum aquaticum*			
Eurasian watermilfoil	*Myriophyllum spicatum*			
Common reed	*Phragmites australis*			
Other _____	Other _____			
_____	_____			
Riparian plants				
garlic mustard	*Alliaria petiolata*			
old man's beard	*Clematis vitalba*			
English ivy	*Hedera helix*			
giant hogweed	*Heracleum mantegazzianum*			
purple loosestrife	*Lythrum salicaria*			
reed canary grass	*Phalaris arundinacea*			
Japanese knotweed	*Polygonum cuspidatum*			
cultivated knotweed	*Polygonum polystachyum*			
giant knotweed	*Polygonum sachalinense*			
Himalayan blackberry	*Rubus discolor*			
Other _____	Other _____			
_____	_____			
Vertebrates				
American bullfrog	*Rana catesbeiana*			
eastern brook trout	*Salvelinus fontinalis*			
Other _____	Other _____			
_____	_____			

Figure F-2. Checklist of documented and potential invasive species in North Coast and Cascades Network parks.

RIFFLE/RUN STREAMS - RAPID HABITAT ASSESSMENT FORM

NCCN Site ID:_____ Observers:_____ Date: __/__/____

HABITAT PARAMETER	CATEGORY			
	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential; (i.e., logs/snags that are NOT new fall and NOT transient.)	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is less than 0.3 m/s, deep is greater than 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increases in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material; increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills over 75% of the available channel; or less than 25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (> past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Figure F-3. Rapid Habitat Assessment forms for streams and rivers, riffle/run.

RIFFLE/RUN STREAMS - RAPID HABITAT ASSESSMENT FORM				Page 2 of 2
NCCN Site ID:_____		Observers:_____		Date: _ _/ _ _/ _ _ _ _
HABITAT PARAMETER	**CATEGORY**			
	OPTIMAL	**SUB-OPTIMAL**	**MARGINAL**	**POOR**
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream greater than 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by width of stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by width of stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by width of stream is a ratio of over 25.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) NOTE: determine left or right bank by facing upstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. Less than 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% if the streambank surfaces covered by native vegetation; but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruptions obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetated Zone Width (score each bank)	Width of riparian zone greater than 18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted the zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone less than 6 meters; little or no riparian vegetation due to human activities.
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0

Figure F-3. Rapid Habitat Assessment forms for streams and rivers, riffle/run (continued).

GLIDE/POOL STREAMS - RAPID HABITAT ASSESSMENT FORM

NCCN Site ID:_____ Observers:_____ Date: _ _/ _ _/ _ _ _ _

HABITAT PARAMETER	CATEGORY			
	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e. logs/snags that are NOT new fall and NOT transient.)	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small shallow, small-deep pools present.	Majority of pools large-deep; very few shallows.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 20% of the bottom affected by sediment deposition.	Some new increases in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material; increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills over 75% of the available channel; or less than 25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Figure F-4. Rapid Habitat Assessment forms for streams and rivers, glide/pool.

GLIDE/POOL STREAMS - RAPID HABITAT ASSESSMENT FORM					Page 2 of 2
NCCN Site ID:_____		Observers:_____		Date: _ _/ _ _/ _ _ _ _	
HABITAT PARAMETER	**CATEGORY**				
	OPTIMAL	**SUB-OPTIMAL**	**MARGINAL**	**POOR**	
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note- channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.	
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0	
8. Bank Stability (score each bank) NOTE: determine left or right bank by facing upstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. Less than 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.	
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0	
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0	
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% if the streambank surfaces covered by native vegetation; but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruptions obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.	
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0	
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0	
10. Riparian Vegetated Zone Width (score each bank)	Width of riparian zone greater than 18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted the zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone less than 6 meters; little or no riparian vegetation due to human activities.	
Left Bank Score:	Left Bank: 10 9	8 7 6	5 4 3	2 1 0	
Right Bank Score:	Right Bank: 10 9	8 7 6	5 4 3	2 1 0	

Figure F-4. Rapid Habitat Assessment forms for streams and rivers, glide/pool (continued).

WQ Temperature Logger Pre/Post Deployment Record Sheet

NCCN SiteID	Position	Serial #	Launch Date	Launch Time	Launch Location	Deploy Date	Deploy Time	Removal Date	Post-deploy Calibration Result
	Water, Air or Extra			(24hr)	Lab or Field		(24hr)		Suspect? Y/N

Figure F-5. Water Quality Temperature Logger Pre/Post Deployment Record Sheet.

Stream Continuous Temperature Deployment/Retrieval Form

Watershed Name: _____ NCCN Site ID: _____

Logger Type: _____

(Note: use military time, all depths recorded in meters - 0.1 units)

Location Description (GPS, bearing and distance from landmark, distance and direction from major confluence) Draw map on back

Air Temperature Logger Serial no.:_____ Measurement interval (min.):_____

Programmed Deployment → Date:___/___/____ Time:_____

Field Deployment→ Date:___/___/____ Time:_____ Height abv. stream:_____ Crew:_____

Retrieval→ Date:___/___/____ Time:_____ Height abv. stream:_____ Crew:_____

Water Temperature Logger Serial no.:_____ Measurement interval (min.):_____

Programmed Deployment → Date:___/___/____ Time:_____

Field Deployment→ Date:___/___/____ Time:_____ Water depth:_____ Dist. fr. bottom: _____ Crew:_____

Retrieval→ Date:___/___/____ Time:_____ Water depth:_____ Dist. fr. bottom: _____ Crew:_____

Additional Notes:

Figure F-6. Stream Continuous Temperature Deployment/Retrieval Form.

Stream Temperature Calibration Check Form

Pg ____ of ____

Park Name: **Instrument Model No:**
NIST Ref. SN: **Thermister/Thermometer SN:**
Test # (Second test required if Test 1 fails):

Pre-Calibration				Post- Calibration			
Low Range Water Bath (approx. 0°C)				Low Range Water Bath (approx. 0°C)			
Date:		Start Time:		Date:		Start Time:	
Time	NIST Ref. °C	Therm.°C	Abs. Diff.	Time	NIST Ref. °C	Therm.°C	Abs. Diff.
1 min.				1 min.			
2 min.				2 min.			
3 min.				3 min.			
4 min.				4 min.			
5 min.				5 min.			
6 min.				6 min.			
7 min.				7 min.			
8 min.				8 min.			
9 min.				9 min.			
10 min.				10 min.			
High Range Water Bath (approx. 20°C)				High Range Water Bath (approx. 20°C)			
Date:		Start Time:		Date:		Start Time:	
Time	NIST Ref. °C	Therm.°C	Abs. Diff.	Time	NIST Ref. °C	Therm.°C	Abs. Diff.
1 min.				1 min.			
2 min.				2 min.			
3 min.				3 min.			
4 min.				4 min.			
5 min.				5 min.			
6 min.				6 min.			
7 min.				7 min.			
8 min.				8 min.			
9 min.				9 min.			
10 min.				10 min.			
		Mean Difference:				Mean Difference:	
		Required Accuracy:	0.2			Required Accuracy:	0.2
Suspect ? (Do Not Deploy) ☐				Suspect ? (Flag Data) ☐			

Comments: (Provide manufacturer post-calibration results for loggers with dead batteries and other comments)

Figure F-7. Temperature Calibration Check Form

Stream BMI Sample Log Form *(rev. 05/13/2011)*

NCCN Site ID	Watershed Name	Sample #	Collection Date	# of Containers	Notes

Figure F-8. Stream Benthic Macroinvertebrate (BMI) Sample Log Form.

Stream BMI Sample Processing Bench Sheet *(rev. 05/13/2011)*

Park Code:		Sample Year:					
NCCN Site ID	Sample #	# of Vials	% of sample sorted	Total # of organisms sorted	Sorted by (initials)	Sort Date	Notes
Sorting Efficiency QC Checks:							
Sorter Name	NCCN Site ID + Sample #		QC Investigation Number Remaining	Total No.	% of org. missed	QC Investigation Name/Check Date	

QC Process: During each year, three samples from from each sorter are checked by QC person. Following the initial sort the QC person will examine the subsample fraction for additional organisms that were missed. If none of the three samples, for each sorter, exceed 10%, then QC checks are no longer required for that sorter. Sorters that exceed 10% missed organisms and any new employees will be required to have QC checks on all samples until the QC investigator decides that they are not needed (based on consistent sorts with <10% missed).

Figure F-9. Stream Benthic Macroinvertebrate (BMI) Sample Processing Bench Sheet.

Stream BMI Specimen Identification Quality Control Summary Form *(rev. 05/13/11)*

Park Code:	**Sample Year:**	**QC Investigator:**
Contractor Name: **Address:**	**QC1 Contr. Name:** **Address:**	**QC2 Contr. Name:** **Address:**

Sample ID Code	Specimen ITIS Code	Specimen Identification			Final ID Code	Systematic Name Change* Specimen ID	Action Code	Correction Date
		Primary Contractor	QC-1 Contractor	QC-2 Contractor				

Comments:

Systematic Name Change: Record new scientific name and apply Action Code 4

Final ID Code:	**Action Code**:
1) Accept primary contractor ID	1) Primary Contractor ID accepted - no change in data.
2) Accept QC-1 ID	2) Edit changes in current year bench sheet and spreadsheet for specific water body.
3) Accept QC-2 ID	3) Edit changes in bench and spreadsheets for all current year water body locations where specific taxa is found.
4) List at higher taxa level (ie. *Genus* instead of *Genus species*)	4) Document changes in spreadsheets and edit corresponding output variables (for those affected) for all years.
5) List Unident. - early instar	5) Other actions (explain in comments)
6) List Unident. - damaged specimen	
7) List Unident. - other (explain in comments)	

Correction Date: Record completion date for follow up of required action.

Figure F-10. Stream Benthic Macroinvertebrate (BMI) Specimen Identification Quality Control Summary Form.

Streams and Rivers Trip Photo Log

Watershed Name: ______________________ NCCN Site ID: ____________________________________

Observers: ____ Date: ____ / ____ / ________

Photo Codes: REF - Site reference point, HD - Human disturbance, HAB - notable physical habitat features, INV - invasive species, SP - specimen photos (*not* invasive spp), NAV - site navigation landmarks, DEP - logger deployment, OT - other

Photo #	Code	Date	Time	Description (note if site/upstream/downstream view for REF, species/spatial extent view for INV, air/water logger for DEP, or any other pertinent details about the photo subject)

Figure F-11. Trip Photo Log

Appendix G. Database Documentation.

The database for this project consists of three types of tables: core tables describing the "who, where and when" of data collection, project-specific tables, and lookup tables that contain domain constraints for other tables. Although core tables are based on NCCN standards, they may contain fields, domains or descriptions that have been added or altered to meet project objectives.

The database includes the following standard tables:

tbl_Locations	Sample locations - places where data collection occurs
tbl_Schedule	Schedule for monitoring locations
tbl_Sample_Periods	The span of dates during which data collection occurs
tbl_Events	Data collection event for a given location
tbl_Target_Coords	Target coordinates for sample locations
tbl_Coordinates	Coordinate data collected during sampling events
tbl_GPS_Info	GPS information associated with sampling event coordinates
tbl_Observers	Observers for each sampling event
tbl_QA_Results	Quality assurance query results for the working data set
tbl_Edit_Log	Edit log for changes made to data after certification
tbl_Images	Images associated with sampling events
tbl_Analysis_Notes	Sample location-specific comments related to data analysis

The following are project-specific data tables:

tbl_BMI_Data	Benthic macroinvertebrate (BMI) data observations
tbl_BMI_Sample_Log	Log of benthic macroinvertebrate (BMI) samples
tbl_Calibration_Data	Data logger instrument calibration data
tbl_Continuous_Data	Continuous (hourly or other sub-daily) data from automated instruments at monitoring locations
tbl_Data_Loggers	Data logger instruments
tbl_Event_Conditions	Observed weather conditions for the sampling event
tbl_Event_Log	Events-specific conditions and site descriptions
tbl_Event_Tasks	Checklist of tasks performed during a sampling event
tbl_Habitat_Assessment	Habitat assessment ratings
tbl_Human_Influence	Human influence category ratings made during a sampling event
tbl_Invasive_Obs	Invasive species observations
tbl_Logger_Events	Data logger events - deployments, downloads and retrievals
tbl_Summary_Data	Summary data generated from continuous data recorded with automated instruments
tbl_Task_List	Checklist of tasks to be completed at sampling locations
tbl_Unit_Calibration	Data logger instrument calibration events
tbl_Width_and_Depth	Width and depth measurements
tbl_WQ_Obs_Data	Observed water quality core parameters

The following are a few of the more prominent, standard lookup tables:

tlu_Project_Crew	List of personnel associated with a project

tlu_Project_Taxa	List of species associated with project observations
tlu_Park_Taxa	Park-specific attributes for taxa

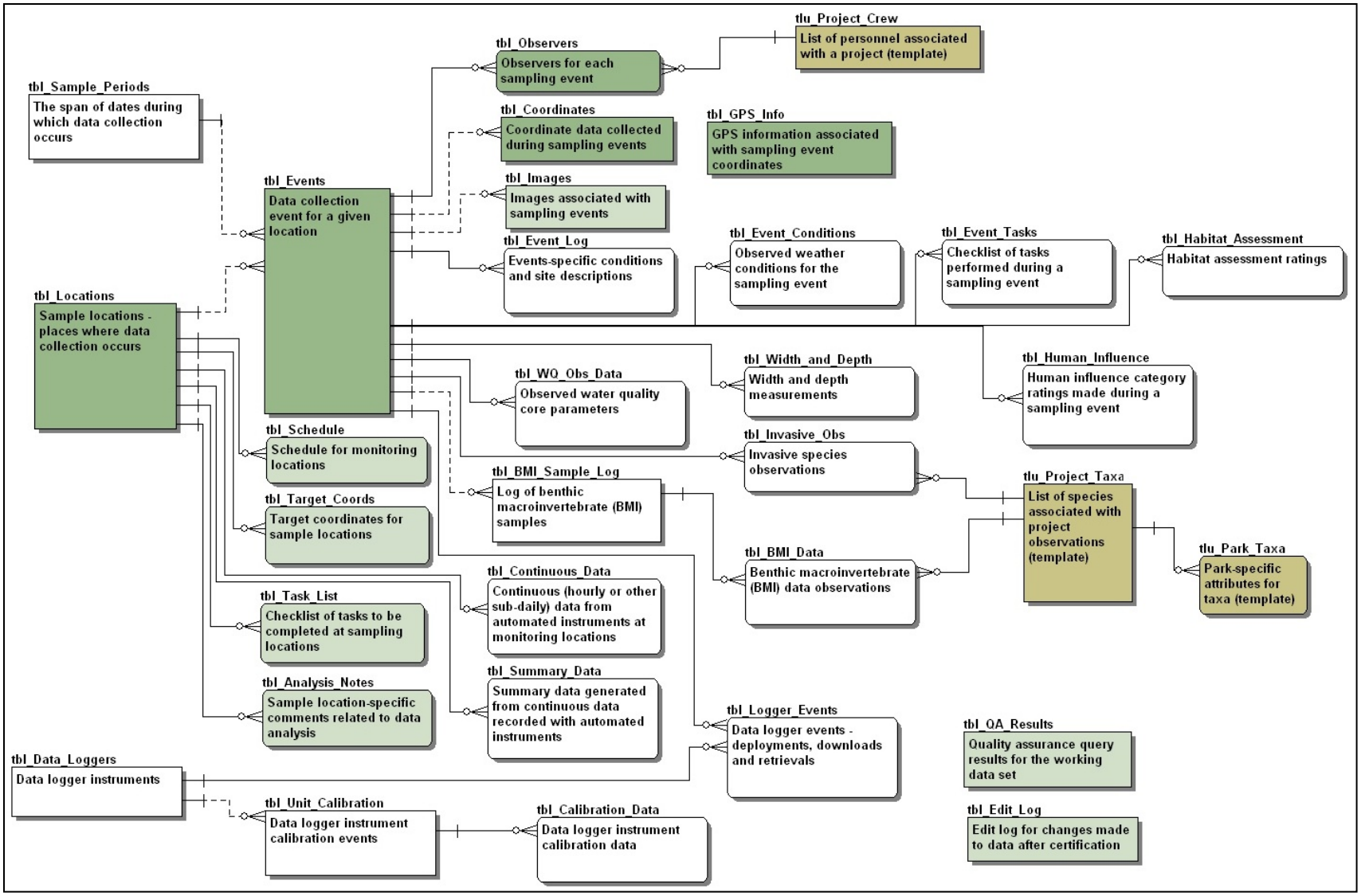


Figure G-1. Entity relationship diagram for the project database. Relationships between tables are represented by lines. Dark green tables represent core standard tables; light green represents extended standard tables; light brown are standard lookup tables. Project-specific tables are unshaded.

Data Dictionary
File name: Water Quality Monitoring Database (WCa01)
Report date: 5/22/2012 10:23:18 PM

Required fields are denoted with an asterisk (*).

tbl_Analysis_Notes - Sample location-specific comments related to data analysis

Index	*Index columns*
Location_ID	Location_ID
pk_tbl_Analysis_Notes (primary)	Location_ID, Analysis_year

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	text (50)	Sampling location
Analysis_year	primary *	text (4)	Analysis year (e.g., 2010)
Analysis_notes		memo	Comments about this sample location related to the specified analysis year

tbl_BMI_Data - Benthic macroinvertebrate (BMI) data observations

Index	*Index columns*
Alt_taxon	Alt_taxon
pk_tbl_BMI_Data (primary)	Source_ID, Sample_ID, Taxon_ID
Sample_ID	Sample_ID
Source_ID	Source_ID
Taxon_ID	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Source_ID	primary *	text (50)	Data source for sample sorting and identification
Sample_ID	primary (FK)*	text (50)	Benthic macroinvertebrate sample identifier
Taxon_ID	primary (FK)*	text (50)	Taxon observed
N_obs		smallint	Number of individuals counted in the sample
Is_excluded	*	smallint	Flag to indicate whether this observation should be excluded from data summaries
	Default: 0		
	Constraint: 0 Or -1		
Alt_taxon	indexed	text (50)	Alternative taxon for data aggregation during summarization; typically a higher-level grouping
Rec_notes		text (50)	Comments about the record

tbl_BMI_Sample_Log - Log of benthic macroinvertebrate (BMI) samples

Index	*Index columns*
Event_ID	Event_ID
pk_tbl_BMI_Sample_Log (primary)	Sample_ID
Sample_code	Sample_code

Field name	*Index/key*	*Data type*	*Description*
Sample_ID	primary *	text (50)	Benthic macroinvertebrate sample identifier
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Sample_code	indexed *	text (25)	Assigned sample code
Event_ID	indexed (FK)*	text (50)	Sampling event
N_containers		tinyint	Number of sample containers that make up the sample
Sample_notes		text (255)	Comments about the sample

tbl_Calibration_Data - Data logger instrument calibration data

Index	*Index columns*
Calibration_ID	Calibration_ID
pk_tbl_Calibration_Data (primary)	Calibration_ID, Time_min
Time_min	Time_min

Field name	*Index/key*	*Data type*	*Description*
Calibration_ID	primary (FK)*	int	Instrument calibration event identifier
Time_min	primary *	tinyint	Time elapsed, in minutes
Ref_temp_C		single	Reference temperature observed value, in Celsius
Instr_temp_C		single	Instrument temperature observed value, in Celsius

tbl_Continuous_Data - Continuous (hourly or other sub-daily) data from automated instruments at monitoring locations

Index	*Index columns*
Location_ID	Location_ID
Log_time	Log_time
Param_ID	Param_ID
pk_tbl_Continuous_Data (primary)	Location_ID, Log_time, Param_ID
QA_flag	QA_flag

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	int	Monitoring location identifier
Log_time	primary *	datetime	Recorded log date and time
Param_ID	primary (FK)*	smallint	Parameter measured
Param_val		single	Recorded parameter value
QA_flag	indexed *	text (1)	Data quality flag value assigned to the record during the quality review
	Default: 0		
Certified	*	bit	Indicates whether this record has been through a documented quality review process
	Default: False		

tbl_Coordinates - Coordinate data collected during sampling events

Index	*Index columns*
Coord_label	Coord_label
Coord_type	Coord_type
Coord_updated	Coord_updated
Datum	Datum
Event_ID (unique)	Event_ID
Field_coord_source	Field_coord_source
pk_tbl_Coordinates (primary)	Coord_ID

Field name	*Index/key*	*Data type*	*Description*
Datum	indexed	text (5)	Datum of UTM_east and UTM_north
	Default: "NAD83"		
Est_horiz_error		double	Estimated horizontal error (meters) of UTM_east and UTM_north
Elevation_m		single	Elevation in meters, derived from GIS using final UTMs
Slope_deg		single	Slope steepness in degrees, derived from GIS using final UTMs
Aspect_deg		single	Slope aspect in degrees, derived from GIS using final UTMs
Coord_label	indexed	text (25)	Name of the coordinate feature (e.g., plot center, NW corner)
Field_UTME		double	UTM easting (zone 10N) as recorded in the field
Field_UTMN		double	UTM northing (zone 10N) as recorded in the field

Field_datum		text (5)	Datum of field coordinates
Field_horiz_error		double	Field coordinate horizontal error (m)
Field_offset_m		double	Distance (meters) from the field coordinates to the target
	Constraint: Is Null Or >=0		
Field_offset_azimuth		smallint	Azimuth (degrees, declination corrected) from the coordinates to the target
	Constraint: Is Null Or (>=0 And <=360)		
Field_coord_source	indexed	text (12)	Field coordinate data source
GPS_file_name		text (50)	GPS rover file used for data downloads
GPS_model		text (25)	Make and model of GPS unit used to collect field coordinates
Source_citation		text (250)	Name, date and scale of the source map
Coordinate_notes		memo	Notes about this set of coordinates
Coord_created_date		datetime	Time stamp for record creation
	Default: Now()		
Coord_updated	indexed	datetime	Date of the last update to this record
Coord_updated_by		text (50)	Person who made the most recent edits
Coord_ID	primary *	text (50)	Unique identifier for each coordinate record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Event_ID	unique (FK)*	text (50)	Sampling event of coordinate data collection
Is_best		bit	Indicates whether this set of coordinates is the best available for this location
UTM_east		double	Final UTM easting (zone 10N, meters), including any offsets and corrections
UTM_north		double	Final UTM northing (zone 10N, meters), including any offsets and corrections
Coord_type	indexed	text (20)	Coordinate type stored in UTM_east and UTM_north: target, field, post-processed

tbl_Data_Loggers - Data logger instruments

Index	*Index columns*
Model_num	Model_num
pk_tbl_Data_Loggers (primary)	Unit_ID
udx_tbl_Data_Loggers (unique)	Serial_num
Unit_type	Unit_type

Field name	*Index/key*	*Data type*	*Description*
Unit_ID	primary *	text (50)	Data logger unit identifier
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Serial_num	unique *	text (50)	Unit serial number
Model_num	indexed *	text (50)	Unit model number
Unit_type	indexed	text (10)	Unit type
Is_active	*	smallint	Flag to indicate whether the unit is still available for use, whether deployed or not
	Default: -1		
	Constraint: 0 Or -1		
Unit_notes		memo	Comments about the data logger unit

tbl_Edit_Log - Edit log for changes made to data after certification

Index	*Index columns*
Edit_date	Edit_date
Edit_type	Edit_type
pk_tbl_Edit_Log (primary)	Data_edit_ID
Project_code	Project_code
Table_affected	Table_affected
User_name	User_name

Field name	*Index/key*	*Data type*	*Description*
Data_edit_ID	primary *	text (50)	Unique identifier for each data edit record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "WCa01"		
Edit_date	indexed *	datetime	Date on which the edits took place
	Default: Now()		
Edit_type	indexed *	text (12)	Type of edits made: deletion, update, append, reformat, tbl design
Edit_reason	*	text (100)	Brief description of the reason for edits
User_name	indexed *	text (50)	Name of the person making data edits
Table_affected	indexed	text (50)	Table affected by edits
Fields_affected		text (200)	Description of the fields affected
Records_affected		text (200)	Description of the records affected
Data_edit_notes		memo	Comments about the data edits

tbl_Events - Data collection event for a given location

Index	*Index columns*
Certified_date	Certified_date
Entered_date	Entered_date
Location_ID	Location_ID
Period_ID	Period_ID
pk_tbl_Events (primary)	Event_ID
Start_date	Start_date
udx_tbl_Events (unique)	Location_ID, Start_date
Updated_date	Updated_date
Verified_date	Verified_date

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary *	text (50)	Unique identifier for each sampling event
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Location_ID	unique (FK)*	text (50)	Sampling location for this event
Project_code	*	text (10)	Project code, for linking information with other data sets and applications
	Default: "WCa01"		
Period_ID	indexed (FK)*	text (50)	Sample period during which this event occurred
Start_date	unique *	datetime	Start date of the sampling event
Start_time		datetime	Start time of the sampling event
WQ_start_time		datetime	Start time of water quality core data collection
WQ_end_time		datetime	End time of water quality core data collection
Declination		text (25)	Declination correction factor for measurement of compass bearings
Logistics_notes		memo	Comments about logistics for reaching and sampling this location
Event_notes		memo	Comments about the sampling event
Entered_by		text (50)	Person who entered the data for this event

Entered_date	indexed	datetime	Date on which data entry occurred
	Default: Now()		
Updated_by		text (50)	Person who made the most recent updates
Updated_date	indexed	datetime	Date of the most recent edits
Verified_by		text (50)	Person who verified accurate data transcription
Verified_date	indexed	datetime	Date on which data were verified
Certified_by		text (50)	Person who certified data for accuracy and completeness
Certified_date	indexed	datetime	Date on which data were certified
Is_excluded		bit	Flag to exclude the sampling event from data summary output
	Default: False		
QA_notes		memo	Quality assurance comments for the selected sampling event

tbl_Event_Conditions - Observed weather conditions for the sampling event

Index	*Index columns*
Event_ID	Event_ID
pk_tbl_Event_Conditions (primary)	Event_ID, Timeframe
Timeframe	Timeframe

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Timeframe	primary *	text (20)	Observation timeframe: [Current, Last 24 hours]
Cloud_cover		text (2)	Cloud cover conditions: [Clear, Partly cloudy, Overcast]
Precipitation		text (2)	Precipitation conditions: [Dry, Fog, Mist, Light rain, Heavy rain, Sleet, Snow]
Flow		text (2)	Water flow conditions: [Intermittent, Low, moderate, Elevated, high, Bankfull, Flood]

tbl_Event_Log - Events-specific conditions and site descriptions

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Air_temp_C		single	Ambient air temperature, in Celsius
N_BMI_samples		tinyint	Number of macroinvertebrate samples collected during the event
N_BMI_containers		tinyint	Number of macroinvertebrate sample containers collected during the event
Water_clarity		text (10)	Observed water clarity: [Clear, Cloudy, Turbid, Other]
Water_odor		text (10)	Observed water odor: [None, Organic, Sulfur, Other]
Sediment_odor		text (10)	Observed sediment odor: [None, Organic, Sulfur, Other]
Surface_film		text (10)	Observed water surface film: [None, Foam, Sheen, Other]
Torrent_evidence		text (2)	Stream torrent disturbance evidence rating
Channel_pattern		text (20)	Channel pattern: [Single, Anastomosing, Braided]
Channel_constraint		text (20)	Channel constraint: [V-shaped constrained, Broad valley, Narrow unconstrained, Broad unconstrained]
Constraining_feature		text (20)	Constraining feature: [Bedrock, Hillslope, Terrace/alluvial fan, Human alteration, None]
Percent_constrained		tinyint	Percent of channel length in contact with constraining feature
	Constraint: Is Null Or (>=0 And <=100)		
Valley_width_m		single	Estimated valley width, in meters
Edge_not_visible		smallint	Flag to indicate that the observer could not see the valley borders; recorded distance represents visible distance
	Constraint: Is Null Or 0 Or -1		

tbl_Event_Tasks - Checklist of tasks performed during a sampling event

Index	*Index columns*
Event_ID	Event_ID
pk_tbl_Event_Tasks (primary)	Event_ID, Task_ID
Task_ID	Task_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Task_ID	primary *	int	Event task identifier
Completed		smallint	Indicates whether the task was completed
	Constraint: Is Null Or 0 Or -1		
Task_notes		text (25)	Brief comments about the task completion

tbl_GPS_Info - GPS information associated with sampling event coordinates

Index	*Index columns*
Coord_ID	Coord_ID
Corr_type	Corr_type
Datum	GPS_datum
Feat_name	Feat_name
Feat_type	Feat_type
GPS_date	GPS_date
GPS_file	GPS_file
Location_ID	Location_ID
Num_sat	Num_sat
pk_tbl_GPS_Info (primary)	GPS_ID

Field name	*Index/key*	*Data type*	*Description*
GPS_ID	primary *	text (50)	Unique identifier for the GPS record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Coord_ID	indexed	text (50)	Coordinate identifier
Location_ID	indexed	text (50)	Sample location, used for temporary links
Feat_name	indexed	text (50)	Feature name in data dictionary
Flag	*	bit	Internal flag used to identify records while matching with tbl_Coordinates during post-season processing
	Default: False		
GPS_file	indexed	text (50)	GPS file name
GPS_date	indexed	datetime	Date GPS file was collected
GPS_time		datetime	Time GPS file was collected
Corr_type	indexed	text (50)	GPS file correction type
GPS_UTME		double	UTM easting in GPS unit
GPS_UTMN		double	UTM northing in GPS unit
UTM_zone		text (5)	UTM projection system zone
	Default: "10N"		
GPS_datum	indexed	text (5)	Datum of GPS coordinates
Feat_type	indexed	text (20)	Feature type (point, line, or polygon) collected with GPS
	Default: "Point"		
Data_dict_name		text (50)	Data dictionary name used to collect feature
Elev_m		double	Elevation (meters) in GPS unit
Num_sat	indexed	smallint	Number of satellites tracked by GPS unit during data collection
GPS_duration		text (25)	Length of time GPS file was open
Filt_pos		smallint	Number of GPS positions exported from GPS file
PDOP		double	Position dilution of precision scale
HDOP		double	Horizontal dilution of precision scale
H_err_m		double	Horizontal error (meters)
V_err_m		double	Vertical error (meters)

Std_dev_m		double	Standard deviation (meters)
GPS_process_notes		text (255)	GPS file processing notes
Is_better	*	bit	Indicates that the field crew thought this coordinate record to be an improvement over the current Is_best coordinate
		Default: False	

tbl_Habitat_Assessment - Habitat assessment ratings

Index	*Index columns*
Event_ID	Event_ID
Hab_param_ID	Hab_param_ID
Habitat_type	Habitat_type
pk_tbl_Habitat_Assessment (primary)	Event_ID, Habitat_type, Hab_param_ID, Scope
Scope	Scope

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Habitat_type	primary *	text (1)	Habitat type: [Glide, Riffle]
Hab_param_ID	primary *	int	Habitat parameter
Scope	primary *	text (1)	Scope of the habitat assessment rating value: [Full width, Left bank, Right bank]
Rating		tinyint	Assigned rating score value

tbl_Human_Influence - Human influence category ratings made during a sampling event

Index	*Index columns*
Event_ID	Event_ID
Influence_ID	Influence_ID
pk_tbl_Human_Influence (primary)	Event_ID, Influence_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Influence_ID	primary *	int	Human influence item identifier
Rating		text (1)	Rating code assigned

tbl_Images - Images associated with sampling events

Index	*Index columns*
Event_ID	Event_ID
Image_label	Image_label
Image_quality	Image_quality
Image_type	Image_type
pk_tbl_Images (primary)	Image_ID
Sort_order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Image_ID	primary *	text (50)	Unique identifier for each image record
		Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())	
Event_ID	indexed (FK)*	text (50)	Sampling event
Image_type	indexed	text (20)	Type of image
		Default: "Ground photo"	
Image_label	indexed	text (25)	Image caption or label
Image_desc		text (255)	Brief description of the image bearing, perspective, etc.
Frame_number		text (10)	Frame number for photographic images
Image_date		datetime	Date on which the image was created, if different from the sampling event date
Image_source		text (50)	Name of the person or organization that created the image
Image_quality	indexed	tinyint	Quality of the image

Is_edited_version		bit	Indicates whether this version of the image is the edited (originals = False)
Object_format		text (20)	Format of the image
Orig_format		text (20)	Format of the original image
Image_edit_notes		text (200)	Comments about the editing or processing performed on the image
Image_is_active		bit	Indicates whether the image is still being used for navigation or interpretation
	Default: True		
Image_root_path		text (100)	Drive space location of the main project folder or image library
Image_project_path		text (100)	Location of the image from the main project folder or image library
	Default: "images\"		
Image_filename		text (100)	Name of the image including extension (.jpg) but without the image path
Image_notes		memo	Comments about the image
Sort_order	indexed *	int	Sort order for displaying records in the order they were entered

tbl_Invasive_Obs - Invasive species observations

Index	*Index columns*
Event_ID	Event_ID
pk_tbl_Invasive_Obs (primary)	Event_ID, Taxon_ID
Taxon_ID	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Taxon_ID	primary (FK)*	text (50)	Taxon observed
N_est		smallint	Estimated number of individuals observed
Area_est_m2		single	Approximate area of infestation, in square meters
Photo_taken		smallint	Flag to indicate that photos were taken
	Constraint: Is Null Or 0 Or -1		
Obs_notes		text (50)	Comments about the invasive species observation

tbl_Locations - Sample locations - places where data collection occurs

Index	*Index columns*
Loc_updated	Loc_updated
Location_code	Location_code
Location_status	Location_status
Location_type	Location_type
Park_code	Park_code
Park_region	Park_region
pk_tbl_Locations (primary)	Location_ID
Public_offset	Public_offset
udx_tbl_Locations (unique)	Park_code, Location_code
Watershed_name	Watershed_name

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary *	text (50)	Unique identifier for each sample location
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Park_code	unique *	text (4)	Park code
	Default: "OLYM"		
Location_code	unique *	text (10)	Alphanumeric code for the sample location
Location_type	indexed *	text (20)	Indicates the type of sample location
Location_status	indexed *	text (10)	Status of the sample location

	Default: "Active"		
Location_name		text (50)	Brief colloquial name of the sample location (optional)
Watershed_name	indexed *	text (50)	Watershed in which the sample location is found
Park_region	indexed	text (25)	Region of the park or surrounding area in which the monitoring location is situated
Reach_length_m		single	Stream reach length in meters
UTME_public		double	UTM easting (zone 10N, meters). Note: in addition to any measurement error, these coordinates may have been offset up to 2 km from their actual position.
UTMN_public		double	UTM northing (zone 10N, meters). Note: in addition to any measurement error, these coordinates may have been offset up to 2 km from their actual position.
Public_offset	indexed	text (50)	Type of processing performed to make coordinates publishable
Travel_notes		memo	Directions for relocating the sample location
Location_desc		memo	Environmental description of the sampling location
Location_notes		memo	Other notes about the sample location
Loc_established		datetime	Date the sample location was established
Loc_discontinued		datetime	Date the sample location was discontinued
Loc_created_date		datetime	Time stamp for record creation
	Default: Now()		
Loc_updated	indexed	datetime	Date of the last update to this record
Loc_updated_by		text (50)	Person who made the most recent edits

tbl_Logger_Events - Data logger events - deployments, downloads and retrievals

Index	*Index columns*
Action	Action
Event_ID	Event_ID
Medium	Medium
pk_tbl_Logger_Events (primary)	Event_ID, Unit_ID, Medium, Action
Unit_ID	Unit_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Unit_ID	primary (FK)*	text (50)	Data logger unit identifier
Medium	primary *	text (5)	Deployment medium: [Air, Water]
Action	primary *	text (10)	Action taken: [Deployment, Download, Retrieval]
Action_time		datetime	Time at which the action was taken
Height_m		single	Height above water level (air deployment) or bottom (water deployment), in meters
Water_depth_m		single	Water depth, in meters (water deployments only)
Programmed_start		datetime	Date and time at which the data logger was programmed to start recording (deployments only)
Interval_mins		smallint	Instrument recording interval, in minutes
Comments		text (255)	Comments about the logger event

tbl_Observers - Observers for each sampling event

Index	*Index columns*
Contact_ID	Contact_ID
Event_ID	Event_ID
Observer_role	Observer_role
pk_tbl_Observers (primary)	Event_ID, Contact_ID, Observer_role

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event identifier
Contact_ID	primary (FK)*	text (50)	Observer identifier

Observer_role	primary *	text (25)	Role of the observer during data collection (optional)
Observer_notes		text (200)	Comments about the observer specific to this sampling event

tbl_QA_Results - Quality assurance query results for the working data set

Index	*Index columns*
Data_scope	Data_scope
pk_tbl_QA_Results (primary)	Query_name, Time_frame, Data_scope
Query_name	Query_name
Query_result	Query_result
Query_type	Query_type
Time_frame	Time_frame

Field name	*Index/key*	*Data type*	*Description*
Query_name	primary *	text (100)	Name of the quality assurance query
Data_scope	primary *	tinyint	Scope of the data included in queries: 0=Uncertified events only, 1=Both certified and uncertified, 2=Certified events only
Time_frame	primary *	text (30)	Field season year or range of dates for the data being passed through quality assurance checks
Query_type	indexed	text (20)	Severity of data errors being trapped: 1=Critical, 2=Warning, 3=Information
Query_result	indexed	text (50)	Query result as the number of records returned the last time the query was run
Query_run_time		datetime	Run time of the query results
Query_description		memo	Description of the query
Query_expression		memo	Evaluation expression built into the query
Remedy_desc		memo	Details about actions taken and/or not taken to resolve errors
Remedy_date		datetime	When the remedy description was last edited
QA_user		text (50)	Name of the person doing quality assurance
Is_done	*	bit	Temporary flag to indicate that the user is done reviewing this query even if some records remain

tbl_Sample_Periods - The span of dates during which data collection occurs

Index	*Index columns*
Period_updated	Period_updated
pk_tbl_Sample_Periods (primary)	Period_ID
Protocol_version	Protocol_version
Start_date	Start_date

Field name	*Index/key*	*Data type*	*Description*
Period_ID	primary *	text (50)	Unique identifier for each sample period
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Start_date	indexed *	datetime	Start date of the sample period
End_date	*	datetime	End date of the sample period
Trip_purpose		text (200)	Brief description of the purpose of the trip
Protocol_version	indexed	text (100)	Version of the protocol used for sampling
Trip_notes		memo	Details about the trip
Period_created		datetime	Time stamp for record creation
	Default: Now()		
Period_updated	indexed	datetime	Date of the last update to this record
Period_updated_by		text (50)	Person who made the most recent edits

tbl_Schedule - Schedule for monitoring locations

Index	*Index columns*
Calendar_year	Calendar_year
Location_ID	Location_ID
pk_tbl_Schedule (primary)	Calendar_year, Location_ID

Field name	*Index/key*	*Data type*	*Description*
Calendar_year	primary *	text (10)	Calendar year for scheduled sampling (not necessarily actually sampled)
Location_ID	primary (FK)*	text (50)	Monitoring site
Schedule_notes		text (255)	Comments about this schedule item (especially for out-of-rotation sites)

tbl_Summary_Data - Summary data generated from continuous data recorded with automated instruments

Index	*Index columns*
Location_ID	Location_ID
Log_time	Log_time
Param_ID	Param_ID
pk_tbl_Summary_Data (primary)	Location_ID, Log_time, Param_ID
QA_flag	QA_flag

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	int	Monitoring location identifier
Log_time	primary *	datetime	Recorded log date and time
Param_ID	primary (FK)*	smallint	Parameter measured
Param_val		single	Recorded parameter value
QA_flag	indexed *	text (1)	Data quality flag value assigned to the record during the quality review
	Default: 0		
Certified		bit	Indicates whether this record has been through a documented quality review process
	Default: False		
Uploaded		bit	Indicates whether this record has been uploaded to the publication server
	Default: False		

tbl_Target_Coords - Target coordinates for sample locations

Index	*Index columns*
pk_tbl_Target_Coords (primary)	Location_ID
Target_updated	Target_updated

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	text (50)	Sample location
Target_UTME		double	Target UTM easting (zone 10N)
Target_UTMN		double	Target UTM northing (zone 10N)
Target_datum		text (5)	Target coordinate datum
	Default: "NAD83"		
Target_notes		memo	Notes about the target coordinates
Target_created_date		datetime	Time stamp for record creation
	Default: Now()		
Target_updated	indexed	datetime	Date of the last update to this record
Target_updated_by		text (50)	Person who made the most recent edits

tbl_Task_List - Checklist of tasks to be completed at sampling locations

Index	*Index columns*
Date_completed	Date_completed
pk_tbl_Task_List (primary)	Location_ID, Request_date, Task_desc
Task_status	Task_status

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	text (50)	Sampling location
Request_date	primary *	datetime	Date of the task request
	Default: Now()		
Task_desc	primary *	text (100)	Brief description of the task
Requested_by		text (50)	Name of the person making the initial request
Task_status	indexed *	text (50)	Status of the task
	Default: "Active"		
Date_completed	indexed	datetime	Date the task was completed
Followup_by		text (50)	Name of the person following up on or completing the task
Task_notes		memo	Notes about the task
Followup_notes		memo	Comments regarding what was done to follow-up on or complete this task

tbl_Unit_Calibration - Data logger instrument calibration events

Index	*Index columns*
Calibration_date	Calibration_date
Event_type	Event_type
pk_tbl_Unit_Calibration (primary)	Calibration_ID
Range	Range
Test_num	Test_num
udx_tbl_Unit_Calibration (unique)	Unit_ID, Calibration_ID, Event_type, Range, Test_num
Unit_ID	Unit_ID

Field name	*Index/key*	*Data type*	*Description*
Calibration_ID	primary *	int	Instrument calibration event identifier
Unit_ID	unique (FK)*	text (50)	Data logger unit identifier
Calibration_date	indexed	datetime	Calibration date
Test_num	unique *	tinyint	Test replicate number
	Default: 1		
Event_type	unique *	text (5)	Type of calibration: [Pre, Post]
Range	unique *	text (5)	Calibration temperature range: [High, Low]
NIST_ref_SN		text (50)	NIST reference thermometer serial number
Start_time		datetime	Time at which the calibration was started
Suspect	*	smallint	User flag to indicate suspect results
	Default: 0		
	Constraint: 0 Or -1		
Calibration_notes		memo	Comments about the calibration test

tbl_Width_and_Depth - Width and depth measurements

Index	*Index columns*
Event_ID	Event_ID
Meas_type	Meas_type
pk_tbl_Width_and_Depth (primary)	Event_ID, Meas_type, Rec_num
Rec_num	Rec_num

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Meas_type	primary *	text (20)	Measurement type: [Wetted width, Thalweg depth, Bankfull width]

Rec_num	primary *	tinyint	Sequential measurement record number
Value_m		single	Recorded value, in meters

tbl_WQ_Obs_Data - Observed water quality core parameters

Index	*Index columns*
Event_ID	Event_ID
Param_ID	Param_ID
pk_tbl_WQ_Obs_Data (primary)	Event_ID, Rep_num, Param_ID
QA_flag	QA_flag
Rep_num	Rep_num

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Rep_num	primary *	int	Replicate series number (0=pre-series buffer check, 99=post-series buffer check)
Param_ID	primary *	smallint	Parameter measured
Obs_val		single	Recorded parameter value
QA_flag	indexed *	text (1)	Data quality flag value assigned to the record during the quality review
	Default: 0		
Obs_notes		text (50)	Comments about the observation

tlu_Coord_Source - List of coordinate data sources (standard)

Field name	*Index/key*	*Data type*	*Description*
Coord_source	primary *	text (12)	
Coord_source_desc		text (100)	
Sort_order		tinyint	

tlu_Coord_Type - List of coordinate types (standard)

Field name	*Index/key*	*Data type*	*Description*
Coord_type	primary *	text (20)	
Coord_type_desc		text (100)	
Sort_order		tinyint	

tlu_Data_Category - List of data sources/types handled by the application

Index	*Index columns*
Category_name (unique)	Category_name
pk_tlu_Data_Category (primary)	Data_category

Field name	*Index/key*	*Data type*	*Description*
Data_category	primary *	tinyint	
Category_name	unique *	text (10)	
Category_desc		text (100)	

tlu_Datum - List of coordinate datum codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Datumprimary *	text (5)		
Datum_desc		text (50)	
Sort_order		tinyint	

tlu_Edit_Type - List of the types of post-certification edits made to data (standard)

Field name	*Index/key*	*Data type*	*Description*
Edit_type	primary *	text (12)	
Edit_type_desc		text (100)	
Sort_order		tinyint	

tlu_GPS_Model - List of GPS devices used to collect coordinate data (template)

Field name	*Index/key*	*Data type*	*Description*
GPS_model	primary *	text (25)	
Sort_order		tinyint	

tlu_Image_Format - List of image, map, and photographic formats (template)

Field name	*Index/key*	*Data type*	*Description*
Image_format	primary *	text (12)	
Image_format_desc		text (100)	
Sort_order		tinyint	

tlu_Image_Quality - List of quality ranks for images (template)

Field name	*Index/key*	*Data type*	*Description*
Quality_code	primary *	tinyint	
Image_quality	*	text (20)	
Image_quality_desc		text (100)	

tlu_Image_Type - List of image types (template)

Field name	*Index/key*	*Data type*	*Description*
Image_type	primary *	text (12)	
Image_type_desc		text (100)	
Sort_order		tinyint	

tlu_Location_Type - List of location type codes (template)

Field name	*Index/key*	*Data type*	*Description*
Location_type	primary *	text (20)	
Loc_type_desc		text (200)	
Sort_order		tinyint	

tlu_Observer_Role - List of observer role assignments (template)

Field name	*Index/key*	*Data type*	*Description*
Observer_role	primary *	text (25)	
Role_desc		text (100)	
Sort_order		tinyint	

tlu_Origin_Code - List of origin codes for park taxa (standard)

Field name	*Index/key*	*Data type*	*Description*
Origin_code	primary *	text (16)	
Origin_desc		text (100)	
NPSpp_ID		smallint	
Sort_order		tinyint	

tlu_Parameters - List of parameters for which data are manipulated and stored

Index	*Index columns*
Data_category	Data_category
Param_group	Param_group
pk_tlu_Parameters (primary)	Param_ID
Source	Source
udx_tlu_Parameters (unique)	Param_name
Units	Units
Updated_date	Updated_date

Field name	*Index/key*	*Data type*	*Description*
Param_ID	primary *	smallint	Unique parameter identifier
Param_name	unique *	text (25)	Parameter name
Source	indexed *	text (20)	Source program, agency or organization

Is_active		bit	Indicates that the parameter record is currently in use
	Default: True		
Data_category	indexed	tinyint	Category indicating the measurement interval for the parameter
Param_group	indexed	text (20)	Grouping field for parameters
Units	indexed	text (25)	Parameter units (or blank if unitless)
Avg_parameter		smallint	Parameter that the current record relates to when deriving range averages during summarization
Min_parameter		smallint	Parameter that the current record relates to when deriving range minima during summarization
Max_parameter		smallint	Parameter that the current record relates to when deriving range maxima during summarization
Total_parameter		smallint	Parameter that the current record relates to when deriving range sums during summarization
Min_value		single	Threshold minimum value below which records are flagged as suspect during load operations
Max_value		single	Threshold maximum value above which records are flagged as suspect during load operations
Parameter_desc		memo	Definition of the parameter
Updated_by		text (50)	Person who made the most recent updates
Updated_date	indexed	datetime	Date of the most recent edits

tlu_Parks - List of NCCN parks and park codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Park_code	primary *	text (4)	
Park_name		text (50)	

tlu_Park_Taxa - Park-specific attributes for taxa (template)

Index	*Index columns*
Park_origin	Park_origin
Park_status	Park_status
pk_tlu_Park_Taxa (primary)	Taxon_ID, Park_code
Record_status	Record_status

Field name	*Index/key*	*Data type*	*Description*
Taxon_ID	primary (FK)*	text (50)	Taxon identifier
Park_code	primary *	text (4)	Park code
Park_status	indexed	text (16)	Status of the taxon in this park (from NPSpecies)
	Default: "Unknown"		
Park_origin	indexed	text (16)	Origin of the taxon in this park (from NPSpecies)
	Default: "Unspecified"		
Local_list		bit	Indicates that the taxon is the preferred one for use at the park (from NPSpecies)
Local_accepted_TSN		int	Taxonomic serial number of the local preferred taxon (from NPSpecies)
Preferred_sci_name		text (255)	Preferred scientific name of the taxon at the park (from NPSpecies)
Park_taxon_notes		memo	Comments about the taxon specific to this park
Record_status	indexed	text (16)	Indicates the status of the record in terms of synchrony with master databases
	Default: "New record"		
Created_date		datetime	Time stamp for record creation
	Default: Now()		
Updated_date		datetime	Date of the last update to this record
Updated_by		text (50)	Person who made the most recent edits

tlu_Park_Taxon_Status - List of codes for park species occurrence (standard)

Field name	*Index/key*	*Data type*	*Description*
Taxon_status_code	primary *	text (16)	
Taxon_status_desc		text (250)	
NPSpp_ID		smallint	
Sort_order		tinyint	

tlu_Project_Crew - List of personnel associated with a project (template)

Index	*Index columns*
Contact_location	Contact_location
Contact_updated	Contact_updated
First_name	First_name
Last_name	Last_name
Organization	Organization
pk_tlu_Project_Crew (primary)	Contact_ID
Project_code	Project_code

Field name	*Index/key*	*Data type*	*Description*
Contact_ID	primary *	text (50)	Unique identifier for the individual (Lastname_Firstname_MI)
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "WCa01"		
Last_name	indexed *	text (24)	Last name
First_name	indexed	text (20)	First name
Middle_init		text (4)	Middle initials
Organization	indexed	text (50)	Employer (e.g., NPS-MORA)
Position_title		text (50)	Position title held by the individual
Email	text (50)	Email address	
Work_voice		text (25)	Work phone number
Work_ext		text (5)	Work extension number
Mobile_voice		text (25)	Mobile phone number
Home_voice		text (25)	Home phone number
Fax	text (25)	Fax number	
Contact_location	indexed	text (255)	Where the individual is located
Contact_notes		memo	Notes about the contact
Contact_created		datetime	Time stamp for record creation
	Default: Now()		
Contact_updated	indexed	datetime	Date of the last update to this record
Contact_updated_by		text (50)	Person who made the most recent edits
Contact_is_active		bit	Indicates that the contact record is currently available for data entry pick lists
	Default: True		

tlu_Project_Taxa - List of species associated with project observations (template)
Constraints: : ([Taxon_is_active] And [Refers_to] Is Null) Or ([Taxon_is_active]=False And [Refers_to] Is Not Null)

Index	*Index columns*
Accepted_TSN	Accepted_TSN
Category	Category
pk_tlu_Project_Taxa (primary)	Taxon_ID
Project_code	Project_code
Record_status	Record_status
Scientific_name (unique)	Scientific_name
Species_code (unique)	Species_code
Subcategory	Subcategory
Taxon_type	Taxon_type
TSN	TSN

Field name	*Index/key*	*Data type*	*Description*
Taxon_ID	primary *	text (50)	Unique identifier for each taxon
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "WCa01"		
Species_code	unique *	text (20)	Unique field code for each project taxon
Scientific_name	unique *	text (100)	Scientific name of the taxon (from ITIS/NPSpecies)
Common_name		text (100)	Common name for the taxon (from ITIS/NPSpecies)
Pref_com_name		text (100)	Preferred common name for this project
TSN	indexed	int	ITIS taxonomic serial number or a provisional number (from NPSpecies)
Accepted_TSN	indexed	int	ITIS taxonomic serial number of the accepted name for this taxon (from NPSpecies)
Category	indexed *	text (20)	General category of the taxon (from NPSpecies)
	Default: "Unspecified"		
Subcategory	indexed	text (20)	Subcategory specific to the needs of each taxonomic discipline (from NPSpecies)
Authority		text (60)	Taxonomic authority (from ITIS)
Authority_subsp		text (60)	Taxonomic authority for subspecific taxa (from ITIS)
Family		text (60)	Taxonomic family (from ITIS)
Taxon_type	indexed *	text (12)	Indicates the taxonomic resolution and certainty represented by this record
	Default: "Specific"		
Taxon_notes		memo	General notes about the taxon
Created_date		datetime	Time stamp for record creation
	Default: Now()		
Updated_date		datetime	Date of the last update to this record
Updated_by		text (50)	Person who made the most recent edits
Taxon_is_active		bit	Indicates that the record is currently available for data entry pick lists
	Default: True		
Record_status	indexed	text (16)	Indicates the status of the record in terms of synchrony with master databases
	Default: "New record"		
Refers_to		text (50)	Valid taxon the record should refer to for analysis and summaries
Rec_status_notes		text (255)	Notes about the disposition of the record
Project_taxon_notes		memo	Project-specific comments about the taxon

tlu_QA_Flag - List of data quality flags

Index	*Index columns*
Flag_code (unique)	Flag_code
pk_tlu_QA_Flag (primary)	Flag_ID

Field name	*Index/key*	*Data type*	*Description*
Flag_ID	primary *	text (1)	
Flag_code	unique *	text (50)	
Flag_desc		text (200)	

tlu_Site_Status - List of status codes for sampling stations (standard)

Field name	*Index/key*	*Data type*	*Description*
Site_status	primary *	text (10)	
Site_status_desc		text (200)	
Sort_order		tinyint	

tlu_Taxon_Category - List of taxonomic categories (standard)

Field name	*Index/key*	*Data type*	*Description*
Category	primary *	text (20)	
Category_desc		text (100)	
NPSpp_ID		smallint	
Sort_order		tinyint	

tlu_Taxon_Rec_Status - List of status codes for taxon records (standard)

Field name	*Index/key*	*Data type*	*Description*
Record_status_code	primary *	text (16)	
Record_status_desc		text (200)	
Sort_order		tinyint	

tlu_Taxon_Type - List of taxon resolution codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Taxon_type	primary *	text (12)	
Taxon_type_desc		text (200)	
Sort_order		tinyint	

tlu_Watersheds - List of major watersheds used for grouping and summarization (standard)

Index	*Index columns*
Park_code	Park_code
pk_tlu_Watersheds (primary)	Watershed_name, Park_code
Watershed_GIS	Watershed_GIS
Watershed_name	Watershed_name
WRIAID	WRIA_ID

Field name	*Index/key*	*Data type*	*Description*
Watershed_name	primary *	text (25)	Name of the watershed
Park_code	primary *	text (4)	Park in which the watershed is found
Larger_basin		text (25)	The larger watershed basin in which this watershed is found
Huc4_basin		text (25)	Crosslink field for the Hydrologic Universal Code 4th field names
WRIA_ID	indexed	smallint	Crosslink field for the Water Resource Inventory Area number of the watershed
On_park_list		bit	Indicates that the watershed is normally part of the park pick list
Is_grouped		bit	Indicates that the watershed represents a grouping of natural watersheds, typically of small coastal streams that drain to salt water

Watershed_notes		text (255)	Comments regarding this watershed record
Watershed_GIS	indexed	smallint	GIS ID code for the watershed

tsys_App_Releases - Application table - Application release history

Index	*Index columns*
pk_tsys_App_Releases (primary)	Release_ID
udx_tsys_App_Releases (unique)	Release_date, Database_title, Version_number

Field name	*Index/key*	*Data type*	*Description*
Release_ID	primary *	text (50)	Unique identifier for the release
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Release_date	unique *	datetime	Date of the release
Database_title	unique *	text (100)	Title of the database
Version_number	unique *	text (20)	Version control number
File_name		text (50)	Filename, used to identify older versions of the database
Release_by		text (50)	Person who issued the release
Release_notes		memo	Release notes, which may include a summary of revisions
Is_supported	*	tinyint	Indicates the support level of this release: 0=user must use a newer version; 1=supported but newer available; 2=full support, current version
	Default: 2		

tsys_Bug_Reports - Application table - Application bugs and development history

Index	*Index columns*
Fix_date	Fix_date
pk_tsys_Bug_Reports (primary)	Bug_ID
Release_ID	Release_ID
Report_date	Report_date

Field name	*Index/key*	*Data type*	*Description*
Bug_ID	primary *	text (50)	Unique identifier for each bug record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Release_ID	indexed (FK)*	text (50)	Database release version of the report
Report_date	indexed *	datetime	Date the bug was reported
	Default: =Date()		
Found_by		text (50)	Person who found the bug
Reported_by		text (50)	Person who filled out this bug report
Report_details		memo	Nature of the bug report
Fix_date	indexed	datetime	Date the bug was fixed
Fixed_by		text (50)	Person who fixed the bug
Fix_details		memo	Notes on fix

tsys_Logins - Application table - Log of user access to the database through the front-end

Field name	*Index/key*	*Data type*	*Description*
Time_stamp	primary *	datetime	Time stamp of activity record
	Default: Now()		
User_name	primary *	text (50)	Login name of the user
Action_taken		text (50)	Action taken by the user

tsys_User_Roles - Application table - Determines user access privileges through the front-end

Field name	*Index/key*	*Data type*	*Description*
User_name	primary *	text (50)	Network login
User_role	*	text (50)	Database application role, used to determine the access level

Appendix H. Yearly Task List.

Table H-1. Summary of annual tasks and responsibilities for implementation of the North Coast and Cascades Network Water Quality Monitoring protocol.

Task description	Responsibility	Timing
Preseason operations		
Meet (or conference call) to recap past field season, discuss the upcoming field season, and document any needed changes to field sampling protocols or the project database structure or front-end application.	Project Lead, Park-based Aquatic Leads, Lead Technician, Data Manager, GIS Specialist	January
Initiate announcements for seasonal technician positions and begin hiring.	Park-based Aquatic Leads, Lead Technician	January
Develop annual work plan for Project Lead	Project Lead, I&M Manager	January
Plan budget and enter into AFS.	Project Lead, Park-based Aquatic Leads, I&M Manager	March
Ensure all project compliance needs are completed for the coming season.	Park-based Aquatic Leads, Lead Technician	March
Plan schedule and logistics, including initial inventory and ordering of equipment and supplies.	Project Lead, Park-based Aquatic Leads, Lead Technician	April
Acquire bids and complete contracts for taxonomy and sample analysis.	Project Lead, Lead Technician	April
Generate list of sample sites and coordinates from the sample frame, gather aerial photos, print field maps and generate field navigation reports (SOP 5).	Project Lead, Lead Technician, GIS Specialist	May
Compile available historic data, maps and photographs for each sample location.	Lead Technician	May
Ensure that project workspace is ready for use (SOP 2).	Project Lead, Data Manager	May
Update and deploy project database application for data entry.	Data Manager	June
Initiate computer access and key requests (may need park-specific dates).	Lead Technician	June
Provide staff email addresses and user logins to Data Manager. Grant modify access to project workspace once crew user logins are known.	Lead Technician	July
Conduct initial inventory of field equipment, instrumentation and supplies.	Lead Technician	July
Check operation and condition of field equipment (e.g. macroinvertebrate nets). Replace or make repairs as needed (SOPs 5-13).	Lead Technician, Field Crew Members	July
Training: Safety and Water Quality Instrumentation	Lead Technician	July

Table H-1. Summary of annual tasks and responsibilities for implementation of the North Coast and Cascades Network Water Quality Monitoring protocol (continued).

Task description	Responsibility	Timing
Preseason operations		
Calibrate and test water quality instrumentation, check batteries and probe membranes. Calibrate temperature data loggers (or multi-parameter meters) and other thermistors.	Lead Technician, Field Crew Members	July
Complete final inventory of equipment and supplies to ensure everything needed for field sampling is available and update inventory checklist.	Lead Technician	July
Training and certification: Field Safety, Backcountry Travel, Species Identification (including prioritized non-native species) and Protocol Implementation.	Project Lead, Lead Technician, Field Crew Members	July
Training: Data management, database use and GPS use (SOPs 2, 3, and 16).	Data Manager, GIS Specialist	July
Develop field sampling schedule.	Park-based Aquatic Leads, Lead Technician	July
Enter previous year's data from contract laboratory analyses	Field Crew Members	July
Field operations		
Collect samples, record field observations and GPS data during field trips.	Lead Technician, Field Crew Members	August and September
Review data forms for completeness and accuracy.	Lead Technician, Field Crew Members	Daily
Regular safety, trouble shooting and logistic briefings.	Project Lead, Lead Technician, Field Crew Members	Before and after each tour
Revise field schedule and order supplies.	Project Lead, Lead Technician	As needed
Data entry and processing		
Download GPS data and provide to GIS Specialist for processing.	Field Crew Members	Once - after site establishment
Download and process digital images.	Field Crew Members	After each tour
Enter data into the database.	Field Crew Members	After each tour
Verify the accurate transcription of data entered	Lead Technician, Field Crew Members	After each tour
Correct GPS data and relate any problems to Lead Technician and Project Lead for review.	GIS Specialist	Once - after site establishment
Review GPS location data and database entries for completeness and accuracy.	Lead Technician	Once - after site establishment

Table H-1. Summary of annual tasks and responsibilities for implementation of the North Coast and Cascades Network Water Quality Monitoring protocol (continued).

Task description	Responsibility	Timing
Data entry and processing		
Scan all field forms and file in the project workspace	Lead Technician	By October
Confirm that data entry and data verification is complete, and notify the Project Lead and Data Manager.	Lead Technician	By October
Complete field season report, send to Project Lead, Park Aquatic Resource Representatives; submit to the NCCN Digital Library [1] when finalized.	Lead Technician	By October
Merge, correct, and export GPS data. Upload processed and verified coordinates to database.	GIS Specialist	Once - after site establishment
Sample/specimen processing		
Ensure biological samples are adequately preserved and stored.	Lead Technician, Field Crew Members	After each tour
Organize samples and specimens, log, and mail to contractors for analyses.	Lead Technician	October and as needed.
Quality Review		
Complete data quality review and data validation using database tools.	Project Lead	November
Prepare GIS layers and data sets as needed for spatial data review.	Project Lead, GIS Specialist	Once - after site establishment
Metadata		
Identify any sensitive information contained in the data set.	Park-based Aquatic Leads, Project Lead	November
Update project metadata records.	Project Lead	November
Data certification and delivery		
Certify the season's data and complete the certification report.	Project Lead	November
Deliver certification report, certified data, digital photographs, and updated metadata to Data Manager.	Project Lead	November
Store certified data files in the project workspace.	Data Manager	Upon delivery
Notify Project Lead of uploaded data ready for analysis and reporting.	Data Manager	March
Finalize and parse metadata records, store in the project workspace.	Data Manager, GIS Specialist	April

Table H-1. Summary of annual tasks and responsibilities for implementation of the North Coast and Cascades Network Water Quality Monitoring protocol (continued).

Task description	Responsibility	Timing
Data analysis		
Preliminary review and preparation of data.	Project Lead	April
Develop Statistics input file and export from database.	Project Lead	May
Import data into Statistics program and run analyses.	Project Lead	May
Export and reformat Statistics output for import into database and other analytical tools.	Project Lead	May
Export park-specific statistical outputs for each response variable. Import into database.	Project Lead	May
Reporting and product development		
Export automated summary queries and reports from database.	Project Lead	June
Provide informed interpretation of automated summaries and reports as well as statistical analysis.	Project Lead	June
Produce park-wide and site-specific map outputs for archives.	Project Lead	June
Generate high quality map output for reports.	Project Lead	June
Acquire the proper report template from the NPS Natural Resource Publications Management website,	Project Lead	June
Screen all reports and data products for sensitive information.	Project Lead	June
Prepare draft report and distribute to Park-based Aquatic Leads for preliminary review.	Project Lead	June
Product delivery		
Submit draft report to Network Coordinator for review.	Project Lead	By June 30
Review report for formatting and completeness, notify Project Lead of approval or need for changes.	Network Program Manager	By July 30
Revise report as necessary.	Project Lead	August
Upload completed report to NCCN Digital Library[1], notify Data Manager.	Project Lead	Upon approval
Deliver other products according to the delivery schedule and instructions in SOP 18.	Project Lead	Upon completion
Product check-in.	Data Manager	Upon receipt

Table H-1. Summary of annual tasks and responsibilities for implementation of the North Coast and Cascades Network Water Quality Monitoring protocol (continued).

Task description	Responsibility	Timing
Posting and distribution		
Submit metadata to the NPS Data Store.[2]	Data Manager	By July 15
Create an online reference record and upload PDF document to the NPS Data Store.[2]	Data Manager	Upon receipt
Update NPSpecies[2] records according to data observations.	Data Manager	August
Submit certified tabular and geospatial data sets to the NPS Data Store.[2]	Data Manager	November (hold for 2 years after certification)
Submit certified NPSTORET data to WRD for upload to EPA's STORET Data Warehouse.	Data Manager	November (hold for 2 years after certification)
Archiving and records management		
Store finished products slated for permanent retention in NCCN Digital Library.[1]	Data Manager	Upon receipt
Review, clean up and store and/or dispose of project files according to NPS Director's Order 19.[4]	Project Lead	January
Move hard-copy data forms and voucher specimens to park collections after making sure that all forms have been scanned and all species records are entered into NPSpecies.[3]	Project Lead	January
Season Close-out		
Inventory equipment and supplies.	Lead Technician	October
De-brief field crew concerning safety, logistics, and data concerns.	Project Lead, Lead Technician	October
Meet to discuss the recent field season and to document any needed changes to field methods, quality assurance methods, or data management practices.	Project Lead, Park-based Aquatic Leads, Lead Technician, Data Manager, GIS Specialist	October-November

[1] The NCCN Digital Library is a document management system implemented in Microsoft SharePoint for maintaining important digital files (reports, protocol documents, and selected project images) within a content management system, and to make them available to NCCN and NPS users.

[2] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).

[3] NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov).

[4] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm

Appendix I. Job Hazard Analysis for the North Coast and Cascades Network Water Quality Monitoring Project.

MOUNT RAINIER, OLYMPIC and NORTH CASCADES NATIONAL PARKS;
LEWIS AND CLARK and SAN JUAN ISLAND NATIONAL HISTORICAL PARKS;
EBEY'S LANDING NATIONAL HISTORICAL RESERVE

JOB SAFETY ANALYSIS

JOB TITLE Water Quality Monitoring		DATE: 11/12/2007	NEW
TITLE OF PERSON WHO DOES JOB: Ecologist Biological Technician	SUPERVISORS: Barbara Samora, Steve Fradkin, and Reed Glesne	ANALYSIS BY: Ashley Rawhouser Rebecca Lofgren	
LOCATION: LEWI, MORA, NOCA, and OLYM	DIVISION: Resource Management	REVIEWED BY:	
REQUIRED AND/OR RECOMMENDED PPE: See **Recommended Action or Procedure**		APPROVED BY:	

SEQUENCE OF JOB STEPS	POTENTIAL HAZARDS	RECOMMENDED ACTION OR PROCEDURE
Office Work - Computer use for email and data entry, report writing	Muscle and eye strain, repetitive stress injury	Maintain proper posture and use of ergonomic furniture. Take breaks every hour.
Field Work Preparation - Packing and loading gear/equipment	Unpreparedness, straining muscles/back	Use check lists, check radio batteries, pack carefully, prepare itinerary and pack appropriate food, clothing and shelter.
Vehicle Travel - Driving to/from site	Break-downs/Vehicle failure	Be licensed to operate vehicle and be familiar with controls before driving. Pre-operational checks of lights, tires, windows, mirrors, body damage, fluids on ground, vehicle fluid levels, vehicle belts and general vehicle condition. Make sure you have clear vision from windows and mirrors are clean and adjusted. Make sure safety equipment is available and in good condition (first aid kit, fire extinguisher, flares, wheel chocks, tire changing equipment). Make sure seat belts are working and adjusted properly.

Vehicle Travel - Driving to/from site (continued)	Break-downs/Vehicle failure (continued)	Make sure engine is operating properly. Do not use a vehicle that is unsafe to operate.
	Driving on highway and unpaved roads to job site	Use Defensive Driving Techniques. Do not drive aggressively. Avoid driving fatigue. Switch drivers when possible or pull off road and rest for a while. Do not drive if not feeling well or on medication or in any condition which could affect judgment. Always drive with headlights on. Stay alert to the type and pattern of traffic around you. Follow all traffic regulations-do not exceed speed limit or tailgate. Watch ahead to anticipate traffic or object hazards and adjust speed accordingly. Make sure you are seen by large trucks and allow them plenty of room for their turning radius. Drive at a safe speed for road, traffic and terrain type. Drive at a safe speed for the type of roadway and its surface conditions. Be alert to changing road conditions and adjust speed and driving techniques accordingly.

Vehicle Travel - Driving to/from site (continued)	Driving on highway and unpaved roads to job site (continued)	Be aware of the capabilities, power and clearance of the vehicle you are operating. If the road ahead is too narrow, rough, muddy, brushy or snow is too deep, do not push vehicle capabilities. Park and walk to destination or use another means of transportation or another route. Watch out for animals, anticipate their actions and slow down or stop. Drive at a speed that is safe for weather and visibility conditions. Carry tire chains for snow and ice conditions and use them. Use visor and sun glasses to shield glare. Keep windshield clean and ensure wipers work properly. Take proper clothing with you in case your vehicle breaks down and you are stranded for a while. Keep window cracked if idling engine for any length of time. Move away from and avoid large trees during windstorms.
	Backing and parking vehicles	Get out of vehicle and walk behind it to look for objects and hazards. Have a passenger be a spotter and guide you. Always face danger with front of vehicle when turning around. Ensure adequate sight distance while turning around i.e., don't turn around on blind corners. Avoid backing down steep grades-especially on loose gravel, snow and ice. Park vehicle in a safe location. Back vehicle in to park.

Vehicle Travel - Driving to/from site (continued)	Backing and parking vehicles (continued)	Ensure there is adequate clearance for passing traffic. Put vehicle in park or lowest gear in direction of roll, set parking brake turn front wheels into curb or cutbank, place chock blocks in front of, or behind tires. Do not park in a truck turn-around.
Foot Travel – Hiking to and from job site	Sprains, strains, broken bones (injuries from slipping/falling)	Always travel in teams of two or more. Wear sturdy laced boots which support the ankles for support. Boots should have slip resistant soles and heels (Vibram) and be comfortable. Wear cuffless pants with narrow bottoms to prevent catching on sticks etc. Watch footing-especially under wet conditions. Avoid stepping on downed logs and branches, especially when they point downhill. Do not run and avoid jumping. Be aware of slippery leaves and loose rocks. Do not lean into the hill when contouring steep slopes. Be aware of your surroundings. Look ahead and check your footing before shifting weight and avoid stepping where the ground cannot be seen. Check for upslope and downslope hazards (rolling rocks, logs, leaning trees, cliffs etc.) avoid potentially unsafe routes. Watch for hazards at eye level (limbs, branches etc.) and keep your distance when following co-workers. Be sure to keep your body aligned and footing stable and avoid twisting motions.

Foot Travel – Hiking to and from job site (continued)	Sprains, strains, broken bones (continued)	Use your hands to catch yourself if you fall-review proper falling techniques. Do not travel directly up or down slope if the potential for dislodging rocks or other debris exists.
	Stream Crossings – drowning, sprains, strains, broken bones, hypothermia	Cross during periods of low flow (morning/evening) if necessary. Follow safe crossing techniques: unhook your pack, link arms, use a brace such as a stick, travel diagonally upstream against flow, watch for debris and other hazards. Take your time and be aware of cold exposure. Waterproof items in pack, especially the bottom. Be careful on slippery logs. Use personal judgment when crossing streams. Choose areas with less depth and flow such as shallow low gradient riffles or tailouts of pools. Make sure there is a way out if you do fall, check downstream before crossing. Do not cross if you cannot see bottom. Use a pole for stability but do not rely on it. Avoid crossing in areas where you might be swept under a log jam if footing is lost. Use care when navigating log jams. Be aware of areas of loose rock and avoid them or use caution in going through them. Avoid working in flooding conditions, be aware of forecast.
	Scratches, bruises, cuts, punctures, abrasions, sunburn, insect bites	Wear long sleeved shirts and pants of sturdy materials.

Foot Travel – Hiking to and from job site (continued)	Scratches, bruises, cuts, punctures, abrasions, sunburn, insect bites (continued)	Wear gloves to protect hands. West Nile Virus is in the PNW. Use insect repellant. Alert crew members to possible problems with allergens. Be alert for toxic plants and alert to common bee and wasp nesting habitat and activity- especially the person in front. Carry Benadryl, epi-pen or other anti-histamine Use sunscreen and wear brimmed hat and sun glasses to limit exposure to sun. Prevent blisters and have blister treatments (moleskin, tape etc.) accessible
	Carrying equipment in the field	Keep objects where they will not hinder your mobility. Store especially sharp objects to avoid injury when falling. Carry tools and equipment in down slope hand when crossing side slopes. Maintain a safe walking distance (10 feet minimum) between each person. Carry heavy objects in properly fit backpack if possible. Keep pack weights as light as possible to limit falling and prevent long-term overuse injuries. Pay attention to how you put your pack on (avoid twisting motions- get help or place pack on surface or against tree) Make sure your pack is properly fitted and balanced. Use trekking poles to maintain balance and reduce overuse injuries.
General Field Hazards	No emergency contact	Carry and use radios. Do radio checks at new jobsites.

General Field Hazards (continued)	No emergency contact (continued)	Check radio contact on daily basis. Carry extra batteries. Know dead zones.
	Getting lost	Have map and compass and other navigational aids and know how to use them. Travel together when off-trail. Make sure members of the team are aware of location, and can find route out if they are separated. When trail hiking, plan stops at trail junctions to regroup. Arrange meeting places and times -all crew members must wear a watch. Have a travel plan for each day and make sure it is understood by all crew members. Stay in communication via radio, voice or stay in sight. If lost, follow prearranged procedures (most likely to stay put). Have emergency equipment (food, shelter, heat, clothing) to survive spending time on your own. If lost for a long period, consider moving to an area where you can be seen by helicopter (gravel bar or ridge top). Do not leave your gear if you travel. Do not panic. Have a mental plan for what to do if lost.
	Dehydration/Heat exhaustion	Always carry plenty of water (minimum 1 liter). Replace bodily fluids and salts regularly (every 15 minutes). Rest in cool, shady places during periods of high temperatures.
	Hypothermia	Wear proper equipment- and have extra layers for cold conditions in waterproof bags. Do not rely on cotton clothing for warmth.

General Field Hazards (continued)	Hypothermia (continued)	Remove wet clothing immediately after hiking, carry spare layers in accessible part of pack. Recognize the signs of hypothermia in yourself and others. Have shelter such as tent, sleeping bag or emergency shelter. Have the means to create heat such as matches or a stove. Carry and eat high-calorie foods, stay well-hydrated.
	Wind	Never work in a forested area during high winds when blow down is likely. Never work near burned trees or snags during high winds; watch for falling trees, bark branches. Be aware that standing dead trees become more hazardous through time. Anchor tents and inflatable boats using large rocks and stakes to avoid loss.
	Lightning	Do not stand under trees or next to rock outcrops. Get off ridges and other high points. Get/stay out of water and away from other conductors. If you are in a vehicle, stay completely inside, don't touch metal parts of vehicles. Turn off electronic devices. Get rid of any metal on your person. If on horses dismount. If caught in the open or in a tent squat on sleeping pad.
	Illness from Giardia, *E. coli* or other bacteria	Do not drink any water unless it has been filtered, boiled or treated in some fashion.

General Field Hazards (continued)	Illness from Giardia, *E. coli* or other bacteria (continued)	Do not create more contaminated areas- urinate away from streams and water, dig a cat hole for solid waste and bury toilet paper. Wash hands when possible and carry hand cleaner. Clean cooking implements during and between tours with hot water. Use soap between tours.
	Hazardous animals and plants	Keep updated on specific hazards in your area. Be able to identify hazardous plants. Advise supervisor/co-workers of allergies. Apply proper first aid methods and wash thoroughly following exposure. Be aware of the presence of potentially hazardous animals in your working environment. Be familiar with signs implicating their presence. Keep your distance from animals especially if they act unusual (rabies). Don't touch wild animals. Make noise (radio squelch etc.) if you cannot stay out of the way of bears or other large animals. Store food in bear safe containers or hang from trees 15 ft. high and 4 ft. from tree and branches. Do not store food near sleeping areas.
	Public contact where personal safety is uncertain due to: hostile people, domestic disputes, apparent intoxication or impaired judgment or presence of weapons	Do not make contact. Seek law enforcement assistance. Contact communications center. Position vehicle for easy departure. Leave personal escape routes. Do not get boxed in. Establish personal space

Communications	Public contact where personal safety is uncertain (continued)	Establish check-in and check-out procedure prior to field work. Set up procedure with a contact person at communications center Establish overdue procedures. Contact person calls head ranger if overdue. Tailgate safety session before beginning work to reemphasize the hazards and control factors particular to the day's work.
Working from inflatable boats	Drowning and hypothermia	Be aware of hypothermia. Ensure at least one other person knows your location or is making visual contact with you at all times. Make sure you have access to dry clothing and a heat source.
Working in Laboratory	Exposure to hazardous chemicals	Review and follow the Lab Hygiene Plan and MSDS sheets before working in the laboratory. Work with another person or notify co-workers if you will be working in the lab alone. Use appropriate personal protective equipment at all times. Keep counter-tops clean and uncluttered.
	Muscle and eye strain, repetitive stress injury	Proper posture and use of ergonomic furniture Take breaks every hour

Appendix J. Project Operations and Rrisk Management Planning.

Project Operations Plan and Risk Assessment

Before conducting field work, the field crew, along with the project lead, should complete a project operations plan (Figures 1 and 2) and a Green, Amber, Red, (GAR) Risk Assessment (Figures 3 and 4) for each field trip. Copies of the project operations plan and final GAR should be retained by the Project Lead, the home unit's supervisor, the receiving park's point of contact and the field crew lead. These forms should also filed electronically on NCCN I&M Sharepoint site. A copy of the project operations plan should also be sent to the communications center of the receiving park if it is fully staffed. The field crew should remember to notify the park's point of contact and/or the communications center if operations are cancelledor the itinerary changes and when they leave for their duty station.

Project Profile Information			
Project Name:		Prepared by:	
Project Purpose/Description			
Project Goal(s)			
Destination(s)			
Departure Location:		Return Location:	
Departure Date/Time:		Return Date/Time:	
SOP, JHA, Other			
List and/or attach to document all relevant SOP's, JHA's, including the receiving park's safety SOPs etc...			
Emergency Contacts (all 24 hour and staff contacts must receive copy of plan)			
Dispatch/Comm. Center Contact Info.	Park:	Number:	
	Park:	Number:	
	Park:	Number:	
24 hour contact other than dispatch (include name, title, day and evening phone)	Name: Title: Day Number: Evening Number:		
Staff contacts (this section is designed to identify key points of contact in home and/or receiving park if work is being completed outside of home unit)			
Name	Title	Number	
Medical			
Nearest Hospital	Name: Address: Phone Number:		

Figure J-1. Page one of the Project Operations Plan.

Crew	Role	Radio Call number/Cell Phone

Vehicle Make/Model, Color and License # _____

Schedule/Itinerary (if multiple weeks attach additional itinerary to back)
Tour dates_____

Day	Location	Duties
Sunday		
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		

Figure J-2. Page two of the Project Operations Plan.

Green Amber Red (GAR) Risk Assessment (excerpted and modified from NPS (2010))

The GAR Risk Assessment is good for a general assessment of a task or operation. If there is a concern for high risk levels in one or more of the elements related to completing a project, a second assessment using the Severity, Probability, Exposure (SPE) Risk Assessment should be done for each element of concern, since the SPE Risk Assessment is designed for more specific assessments. All hazards should be ranked from the highest to the lowest risk levels to target areas of greatest concern first.

> The ability to assign numerical values or "color codes" to hazards using either the SPE Risk Assessment or the GAR Risk Assessment is not the most important part of risk assessment. What is critical in this process are team discussions leading to an understanding of the risks and how they will be managed.

Risk Ratings

Different parks can have different interpretations for "Green," "Amber," and "Red." Because a Low/Moderate/High scale is a widely used standard throughout the safety industry, risk level discussions between various National Park Service activities may also be in terms of Low, Medium, and High to facilitate communications during joint operations. However, each community will define the meaning of Low, Moderate, and High risk in terms that are meaningful to their personnel. We should state here that this program is meant to ultimately achieve consistency in how risk is managed National Park Service wide.

More general risk concerns that involve operational planning or re-assessing specific risks can be addressed using the GAR Risk Assessment. In reviewing National Park Service accidents it was found that there were nine key elements that affect risk in operations.

1. Supervision
2. Planning
3. Team Selection
4. Team Fitness
5. Communication
6. Contingency Resources
7. Environment
8. Event or Operational Complexity
9. Severity

These elements are incorporated into the GAR Risk Assessment Risk Assessment Model. This model provides the team with a means of assessing risk.

To complete a GAR Risk Assessment use the worksheet provided in Figures 1 and 2. It outlines a simple process where:

1. Each individual provides their personal assessment for each of the nine factors.
2. They then get together with their team and discuss their assessment.

3. The team next agrees on a new assessment (usually by consensus).
4. The group then identifies and considers mitigation factors.
5. Finally the team conducts a new assessment considering the mitigation factors

STEP 1: Define the Mission or Task

- Clearly identify the mission or task and state your desired outcome. The GAR Risk Assessment involves looking at multiple hazards.

STEP 2: Define the Hazards

- Identify the hazards of the mission in general terms. Since we are looking at a mission or task there will be multiple hazards. Focus on the ones you think pose the greatest risk.

STEP 3: Assess Risk & Assign a Numerical Value

- Use the nine mission risk factors to evaluate the threats. If an activity produces an accident, it will generally be because of weaknesses in one or more of these areas. Conversely, if a team improves these elements, the probability of an accident will likely decrease.

- Assign a numerical value of 0 (For No Risk) through 10 (For Maximum Risk) for each project risk factor.

    - **Supervision:** Supervisory Control should consider How qualified the supervisor is. It's not about subject matter expertise it's about supervising. You need to determine whether effective supervision is taking place. Is there someone there to provide supervision? Even if a person is qualified to perform a task, supervision acts as a control to minimize risk. This may simply be someone checking what is being done to ensure it is being done correctly. The higher the risk, the more the supervisor needs to be focused on observing and checking. A supervisor who is actively involved in a task (doing something) is easily distracted and should not be considered an effective safety observer in moderate to high-risk conditions.

    - **Planning:** Planning and preparation should consider how much information you have, how clear it is, and how much time you have to plan the activity or evaluate the situation. Planning includes the development and use of pre-defined plans, training programs, operating procedures, SOPs, operational guidelines, JHAs, etc.

    - **Team Selection:** Team selection should consider the qualifications and experience level of the individuals used for the specific event. The participants in a mission or activity should have the skills and experience necessary to perform tasks/assignments including the ability to use specialized equipment, make decisions, use judgment, and operate effectively in a team environment. Individuals may need to be replaced during the activity and the experience level of the new team members should be assessed. Teams should have an adequate number of qualified members from which to choose for any single mission or activity.

- **Team Fitness:** Team fitness should consider the physical and mental state of the team. This is often a function of the amount and quality of rest a team member has had and basic physical fitness as it relates to the task or mission. Quality of rest considers conditions slept in, potential sleep length, and any interruptions. Fatigue normally becomes a factor after 18 hours without rest; however, lack of quality sleep builds a deficit that worsens the effects of fatigue. Other factors to consider are physical preparedness and personal life factors that may impede the outcome of the operation or activity.

- **Communication:** Good communications ensure clear and accurate sending and acknowledging of information, instructions, commands, and useful feedback. This includes interpersonal communications and the physical communication equipment if personnel are not within immediate voice contact. Communication should consider radio/cellular capability, dispatching and overall infrastructure and operational reliability. In addition to the technical means to communicate you should also consider the communication culture of the organization.

- **Contingency Resources:** Contingency resources are not necessary as an immediate part of the operation, but would be needed should conditions change or an emergency occur. They should be those pre-defined resources that a team will call in an emergency or when incident or activity demands exceed the capability of existing resources. You should consider whether you have the ability to activate the resources, whether they will respond in the expected timeframe, and whether there are pre-plans in place for those resources.

- **Environment:** Environment considers factors affecting human performance and factors affecting the performance of equipment being operated. This includes, but is not limited to, time of day, temperature, humidity, precipitation, altitude, etc.

- **Event or Incident Complexity:** Event/Incident complexity should consider both the required time and the situation. Generally, the longer one is exposed to a hazard, the greater are the risks. However, each circumstance is unique. Factors to consider include: how long environmental conditions will remain stable; whether the activity requires specialized skills, whether there are dynamic and changing conditions, or whether team members are required to divide their attention while performing multiple tasks; whether a fast-paced activity and sense of urgency induces stress; whether pre-plans and operating procedures cover a high percentage of the activities, or whether team members must use judgment and experience to respond appropriately to novel circumstances. Generally, simple, repetitive tasks occurring in highly structured and controlled work environments have the lowest complexity.

- **Severity:** Would an accident result in 1) Minor non-immobilizing injury or trauma not requiring hospital treatment, 2) Non-immobilizing injury or trauma but requiring hospital treatment, 3) Immobilizing injury or trauma requiring hospital treatment, 4) Severe injury or trauma requiring urgent hospital treatment or a life-threatening event.

STEP 4: Compute the overall level of risk

To compute the total level of risk sum the numerical values assigned for each risk factor. This is your personal estimate of the risk. Add the risk scores to come up with a Total Risk Score for the overall job, task, or project.

> KEY POINT: We use a number because it makes you think about the risk factors. It's the process that's important; assigning a number is the way to get you there. If conditions change make sure to "check in" with team members and discuss how this affects your planned work activities.

Color Coding Risk: Mission risk can be visualized using the colors of a traffic light. If the total risk value falls in the GREEN ZONE (1-38), risk is rated as low. If the total risk value falls in the AMBER ZONE (39-67), risk is moderate and you should consider adopting procedures to minimize the risk. If the total value falls in the RED ZONE (68-90), you should implement measures to reduce the risk prior to starting the event or operation. See Figure 3 for an example of a GAR Risk Assessment completed to assess the risk associated with conducting Rainbow Trout spawning surveys for two streams that feed into Ross Lake in North Cascades National Park. Note: The field crew members are all NPS certified boat handlers who have worked for NOCA for at least two field seasons. The field crew lead has four years of experience working for NOCA aquatics.

OPERATIONAL/MISSION RISK ASSESSMENT WORKSHEET					
Risk rated for each category. Mitigations should be considered for any category rated higher than 5. **Overall Mission Risk** 0-38 Green 39-67 Amber 68 -90 Red	Individual Assessment	Group Discussion	New Assessment	Mitigation	New Assessment
Supervision: Presence or accessibility of leadership/supervision for all teams and personnel. Clear chain of command.		→		Y/N	
Planning: Current SOP/Operational Guidelines, team trained in conducting planned activities. Adequate information and planning time. Required equipment, training is provided. Brief/debriefs planned, team input solicited.		→		Y/N	
Contingency Resources: Resources available if needed. MOUs in place with participating cooperators. Planning accomplished with cooperators. Shared communications plan and radio frequencies.		→		Y/N	
Communication: Radio communications possible throughout area of operations. Communication's plan established and rehearsed.		→		Y/N	
Team Selection: Level of individual training and experience. Cohesiveness and atmosphere that values input/self critique.		→		Y/N	
Team Fitness: Level of overall physical fitness of team. Level of team member's rest/fatigue and overall morale. Team members with major life distractions.		→		Y/N	
Environment: Extreme temperatures, elevation, difficulty of terrain (snow cover, high flows, dangerous rapids, foliage, slope, cliffs, waterfalls etc.)		→		Y/N	
Incident Complexity: Whether the activity requires specialized skills, whether there are dynamic and changing conditions, or whether team members are required to divide their attention while performing multiple tasks; whether fast-paced activity and sense of urgency induces stress; whether plans and procedures cover a high percentage of the activities, or whether team members must use judgment and experience to respond appropriately to novel circumstances.		→		Y/N	
Severity: Would an accident result in 1) Minor non-immobilizing injury or trauma not requiring hospital treatment, 2) Non-immobilizing injury or trauma but requiring hospital treatment, 3) Immobilizing injury or trauma requiring hospital treatment, 4) Severe injury or trauma requiring urgent hospital treatment or a life-threatening event.		→		Y/N	
TOTAL					

Figure J-3. Page one of the GAR Risk Assessment form.

MITIGATION FACTORS
Supervision:
Planning:
Contingency Resources:
Communication:
Team Selection:
Team Fitness:
Environment:
Incident Complexity:
Severity:

Figure J-4. Page two of the GAR Risk Assessment form.

OPERATIONAL/MISSION RISK ASSESSMENT WORKSHEET

Risk rated for each category. Mitigations should be considered for any category rated higher than 5.

Overall Mission Risk
0-38 Green
39-67 Amber
68 -90 Red

	Individual Assessment	Group Discussion	New Assessment	Mitigation	New Assessment
Supervision: Presence or accessibility of leadership/supervision for all teams and personnel. Clear chain of command.	2	→	2	Y (N)	2
Planning: Current SOP/Operational Guidelines, team trained in conducting planned activities. Adequate information and planning time. Required equipment, training is provided. Brief/debriefs planned, team input solicited.	3	→	3	Y (N)	3
Contingency Resources: Resources available if needed. MOUs in place with participating cooperators. Planning accomplished with cooperators. Shared communications plan and radio frequencies.	2	→	2	Y (N)	2
Communication: Radio communications possible throughout area of operations. Communication's plan established and rehearsed.	1	→	1	Y (N)	1
Team Selection: Level of individual training and experience. Cohesiveness and atmosphere that values input/self critique.	2	→	2	Y (N)	2
Team Fitness: Level of overall physical fitness of team. Level of team member's rest/fatigue and overall morale. Team members with major life distractions.	2	→	2	Y (N)	2
Environment: Extreme temperatures, elevation, difficulty of terrain (snow cover, high flows, dangerous rapids, foliage, slope, cliffs, water falls etc.)	6	→	7	(Y) N	5
Incident Complexity: Whether the activity requires specialized skills, whether there are dynamic and changing conditions, or whether team members are required to divide their attention while performing multiple tasks; whether fast-paced activity and sense of urgency induces stress; whether plans and procedures cover a high percentage of the activities, or whether team members must use judgment and experience to respond appropriately to novel circumstances.	5	→	5	(Y) N	3
Severity: Would an accident result in 1) Minor non-immobilizing injury or trauma not requiring hospital treatment, 2) Non-immobilizing injury or trauma but requiring hospital treatment, 3) Immobilizing injury or trauma requiring hospital treatment, 4) Severe injury or trauma requiring urgent hospital treatment or a life-threatening event.	8	→	8	(Y) N	4
TOTAL	31		32		24

MITIGATION FACTORS

Supervision:

Planning:

Contingency Resources:

Communication: Check in with comm center.

Team Selection:

Team Fitness: Very possible to walk 10+ Hz Day. Keep track of time.

Environment: Rain Gear, Waders, Use larger Boot in inclement weather, Be observant (wind), Buddy system, Life Jackets, Throw Bags, (High Flows) Dry suits

Incident Complexity: Assign Roles, Boat Handler, Comm. Center Check In

Drive → Hike → Boat → Hike → survey

Severity: Drowning, Hypothermia, mitigated

Figure J-5. Example of completed GAR Risk Assessment.

Severity, Probability, Exposure (SPE) Risk Assessment

Risk for a specific hazard identified when completing the GAR Risk Assessment can be assessed using a SPE Risk Assessment (Figure 6). See Figure 7 for an example of a completed SPE Risk Assessment.

STEP 1: Identify the hazard

Clearly identify and define the specific hazard and state the outcome you are concerned with. Do not use multiple hazards.

Example of a Hazard Definition: Crossing a steep slope above a cliff band exposes a field crew to a fall hazard.

STEP 2: Assess the severity, probability and exposure of the hazard

Assess the Severity, Probability, and Exposure of the hazard and assign a number for each based on the tables below.

1. Severity: If what you said could happen in Step 1 happens, how bad is it going to be?

    - Think like this: If 100 people tripped and fell how bad would the injuries be. Don't think of the worst case scenario.

Accident Severity	
Value	Description
1	Slight • Acceptable or of little consequence
2	Minimal • Nuisance • Use of emergency procedures • Minor non-immobilizing injury or trauma not requiring hospital treatment
3	Significant • A significant reduction in safety margins, a reduction in the ability of the operator to cope with adverse conditions as an increase in workload, or as a result of conditions impairing their efficiency. • Serious incident • Non-immobilizing injury or trauma but requiring hospital treatment
4	Major • A large reduction in safety margins, physical distress or a workload such that the operator cannot be relied upon to perform their tasks accurately or completely • Immobilizing injury or trauma requiring hospital treatment • Major equipment damage
5	Catastrophic • Critical equipment destroyed • Severe injury or trauma requiring urgent hospital treatment or a life-threatening event • Fatalities

2. Probability: What is the chance that someone crossing the slope will trip and fall?

- Think like this: If 100 people cross the slope how many of them will trip and fall?

Accident Probability	
Value	Description
1	Unlikely: Almost inconceivable that the event will occur, but it is assumed it can and does happen.
2	Seldom: Very unlikely to occur, instances have been rarely recorded, several things must go wrong.
3	Occasional: Unlikely under existing conditions with current personnel, but possible to occur, you may or may not get through your task without it happening.
4	Likely: Likely to occur, has occurred several times although infrequently.
5	Frequent: Likely to occur, has occurred frequently, known to happen regularly.

3. Exposure: What is the exposure to our people? Consider how many people will cross the slope, how often it be crossed to perform the planned activity.

Accident Exposure	
Value	Description
1	Below average amount of exposure.
2	Average exposure.
3	Above average exposure.
4	Great exposure.

Step 3: Compute total risk

Compute the total risk for the task by multiplying the values for severity, probability and exposure together. Risk = Severity x Probability x Exposure

Determine whether the overall risk is acceptable.

Total Score	Risk Level	Action
80-100	Very High	Discontinue, Stop
60-79	High	Immediate Correction
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed
1-19	Slight	Possibly Acceptable

Step 4: Manage, control or eliminate the risk

Manage, control or eliminate the risk following some of the examples below.

Severity: Personal protective equipment, first aid, pre-accident plans, etc.

Probability: Training, awareness, attitude change, briefings, etc., are used to control probability. If the probability is a natural occurrence it may not be possible to change the probability (weather, avalanche, etc.).

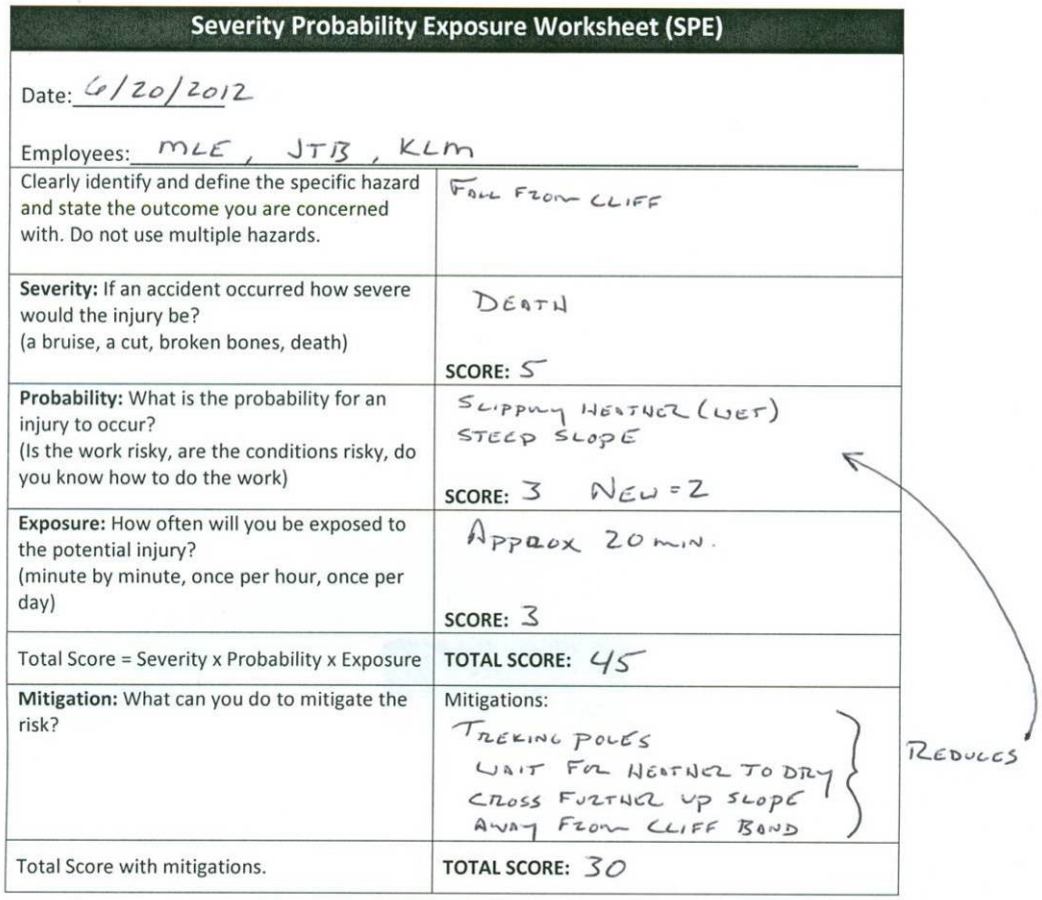
Exposure: Exposure is usually controlled by reducing the number of people involved, the number of events, cycles, evolutions, amount of time exposed to the hazard, etc.

Step 6: Monitor and re-evaluate

Monitor the situation and evaluate the risk control measures selected. Re-evaluate the risk if necessary.

Severity Probability Exposure Worksheet (SPE)	
Date:_____ Employees:_____	
Clearly identify and define the specific hazard and state the outcome you are concerned with. Do not use multiple hazards.	
Severity: If an accident occurred how severe would the injury be? (a bruise, a cut, broken bones, death)	**SCORE:**
Probability: What is the probability for an injury to occur? (Is the work risky, are the conditions risky, do you know how to do the work)	**SCORE:**
Exposure: How often will you be exposed to the potential injury? (minute by minute, once per hour, once per day)	**SCORE:**
Total Score = Severity x Probability x Exposure	**TOTAL SCORE:**
Mitigation: What can you do to mitigate the risk?	Mitigations:
Total Score with mitigations.	**TOTAL SCORE:**

Figure J-6. The SPE Risk Assessment form.



Severity Probability Exposure Worksheet (SPE)

Date: 6/20/2012

Employees: MLE, JTB, KLM

Clearly identify and define the specific hazard and state the outcome you are concerned with. Do not use multiple hazards.	FALL FROM CLIFF
Severity: If an accident occurred how severe would the injury be? (a bruise, a cut, broken bones, death)	DEATH SCORE: 5
Probability: What is the probability for an injury to occur? (Is the work risky, are the conditions risky, do you know how to do the work)	SLIPPERY WEATHER (WET) STEEP SLOPE SCORE: 3 NEW = 2
Exposure: How often will you be exposed to the potential injury? (minute by minute, once per hour, once per day)	APPROX 20 MIN. SCORE: 3
Total Score = Severity x Probability x Exposure	**TOTAL SCORE:** 45
Mitigation: What can you do to mitigate the risk?	Mitigations: TREKING POLES WAIT FOR WEATHER TO DRY CROSS FURTHER UP SLOPE AWAY FROM CLIFF BAND
Total Score with mitigations.	**TOTAL SCORE:** 30

REDUCES

Severity	Probability	Exposure
1 None or Slight	1 Unlikely	1 None or below average
2 Minimal	2 Seldom	2 Average
3 Significant	3 Occasional	3 Above average
4 Major	4 Likely	4 great
5 Catastrophic	5 Frequent	

Total Score	Risk level	Action
80-100	Very High	Discontinue, Stop
60-79	High	Immediate Correction
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed
1-19	Slight	Possibly Acceptable

Figure J-7. An example of a completed SPE Risk Assessment for crossing a steep slope above a cliff band in the early morning.

Literature

NPS. 2011. Operational Leadership Participant Manual. USDI National Park Service, North Cascades National Park Service Complex. Available at: http://www.noca.nps.gov/safety/default.aspx

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.

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