



Water Quality and Streamflow Monitoring Protocol

Version FQ – 2022.1, Southeast Alaska Network

Natural Resource Report NPS/SEAN/NRR—2022/2403



ON THE COVER

Monitoring instrument in the Indian River, Sitka National Historical Park.

Photograph by: NPS/CHRIS SERGEANT

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Version FQ – 2022.1, Southeast Alaska Network

Natural Resource Report NPS/SEAN/NRR – 2022/2403

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Standard Operating Procedures (SOPs)

The standard operating procedures (SOPs) that accompany this protocol document are provided separately in the NPS IRMA Data Store at

<https://irma.nps.gov/DataStore/Reference/Profile/2287688>.

SOP 1: Sonde Operation and Field Procedures

SOP 2: Uploading and Delivering Monthly Sonde Data

SOP 3: Site Visit Files (FQ_C Creation)

SOP 4: Maintenance Records (FQ_D Creation)

SOP 5: Sonde Raw Data (FQ_E Creation)

SOP 6: Aquarius Configuration and Data Import

SOP 7: Data Evaluation and Grading in Aquarius

SOP 8: Aquarius Time Series Data Package (FQ_Q Creation)

SOP 9: Annual and Synthesis Reporting (FQ_G and FQ_H Creation)

SOP 10: Field Safety

SOP 11: Protocol Revision (FQ_A Creation)

SOP 12: Quality Assurance Plan

Abstract

Water quality and streamflow are important indicators of freshwater and terrestrial ecosystem health and hydrologic dynamics in Southeast Alaska. This protocol provides the information necessary to implement and sustain a long-term monitoring program, including the context and justification for water quality and streamflow sampling, description of the sampling methodologies, and listing of staff roles. Detailed instructions for all aspects of field set-up, maintenance, data collection, storage, analysis, and reporting are provided in the complementary suite of Standard Operating Procedures (SOPs). Data and reports generated by this program are publicly available through the SEAN NPS website (<https://www.nps.gov/im/sean/index.htm>) and NPS Integrated Resource Management Applications (IRMA) Data Store (<https://irma.nps.gov/DataStore/>). These deliverables inform park staff, managers, and outside parties of the status and trends of basic river conditions and describe the timing and magnitude of seasonal and annual variation of each parameter.

Each year, from at least May 1 through October 31, water temperature, specific conductance, pH, dissolved oxygen, and streamflow data are collected hourly from one river in each SEAN park unit: the Salmon River (Glacier Bay National Park and Preserve), Taiya River (Klondike Gold Rush National Historical Park), and Indian River (Sitka National Historical Park). To capture glacial influence on sediment loading, turbidity is also measured for the Taiya River.

Annual updates and synthesis reports are defined to ensure that future products consistently connect to the program objectives outlined in this protocol. Data management procedures, including quality assurance, quality control, and data grading, are implemented to provide a properly archived, high-quality deliverables.

Acknowledgments

The authors extend their sincere appreciation to people that helped create the inaugural SEAN Water Quality Monitoring Protocol. B. Moynahan provided the original vision and program oversight during the development of this protocol, while M. Bower guided the SEAN and this effort for much of its first decade. W. Johnson established the SEAN's data management systems. C. Sergeant led the water quality project for eight years, authoring protocols and analyses that served as the program's foundation. E. Hood and S. Nagorski contributed to the protocol and helped establish data collection sites. Field site management by C. Soiseth and C. Murdoch (Glacier Bay), D. Schirokauer, J. Wilbarger, C. Thole, J. Hinrichs, and J. Simmons (Klondike Gold Rush), and C. Smith, G. Smith, S. Paustian, B. Carter, and C. Amundson (Sitka) have been essential to the continuity of this program. J. Shearer of the Southwest Alaska Network provided peer review input and a framework that helped shape the selected approach. E. Starkey from the Southeast Coast Network spent considerable time discussing his water quality monitoring experience and ideas. We also thank P. Burger (NPS), R. Irwin (NPS), and C. McGee (ADEC) for their helpful peer reviews of the original protocol.

1 Background and Objectives

1.1 Protocol Synopsis

The Southeast Alaska Network (SEAN) is one of 32 National Park Service (NPS) Inventory and Monitoring networks. The SEAN comprises four park units: Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLGO), Sitka National Historical Park (SITK), and coastal portions of Wrangell-St. Elias National Park and Preserve (Figure 1). Water Quality and Streamflow are among the core vital signs prioritized by the SEAN for long-term resource monitoring based on their natural value and/or vulnerability to alteration by human stressors (Moynahan et al. 2008). Presently, the network does not conduct water quality monitoring in coastal WRST due to staffing, financial, and logistical constraints; the Central Alaska Inventory and Monitoring Network tracks a combination of stream temperature, water chemistry, habitat characteristics, benthic invertebrates, and eDNA at a number of locations in interior WRST (Simmons 2017).



Figure 1. Southeast Alaska Inventory and Monitoring Network (SEAN) park units. Interior Wrangell-St. Elias National Park and Preserve is covered by the Central Alaska Inventory and Monitoring Network; SEAN monitoring efforts occur in coastal areas, though no water quality sites are yet established.

This document describes the context and justification for water quality and streamflow sampling, details field methodologies, and prescribes staff roles and data management and communication. The

Standard Operating Procedures (SOPs) referenced throughout this narrative contain detailed instructions for all aspects of field set-up, equipment maintenance and storage, data collection, quality control, analysis, and reporting. Together, the protocol narrative and SOPs contain the information necessary to implement and sustain a long-term monitoring program.

Components of this protocol were developed with significant methodological contributions from SEAN staff, other NPS monitoring networks, other federal agencies, and instrument manufacturers. Some ideas and step-by-step instructions are derived from the SEAN oceanography monitoring protocol (particularly data management; Danielson et al. 2010), the Southwest Alaska Network freshwater flow system monitoring protocol (Shearer et al. 2015), monitoring protocols developed by the U.S. Geological Survey (USGS; notably Wagner et al. 2006), and instrument manuals from YSI Incorporated. The national scale NPS environmental settings monitoring protocol (DeVivo et al. 2018) informed development of streamflow monitoring and reporting components.

1.2 Hydrologic Setting

Water bodies in the SEAN are diverse and numerous, including upland and subalpine lakes, wetlands and ponds, groundwater aquifers, and glacial and non-glacial streams. Each is influenced by natural forces, such as geology, climate, and glaciers, at multiple spatial and temporal scales. GLBA, the largest unit in the SEAN, has more than 310 streams (Soiseth and Milner 1995, NPS 2005) flowing over 3,380 km (2,100 mi). Two large, glacial, trans-boundary rivers flow through KLGO, and the lowest portion of one river is within the boundaries of SITK. The wet and moderate marine climate in the SEAN region is dominated by a strong Aleutian Low in the northern Gulf of Alaska in the fall, winter, and spring, and by weak high pressure systems in the summer. Low elevation areas are dominated by temperate rainforest while higher elevations in GLBA and KLGO have significant and rapidly changing glacial coverage. NPS Coastal Watershed Assessments (Eckert et al. 2006a, Eckert et al. 2006b, Hood et al. 2006) and Natural Resource Condition Assessments (Bernatz et al. 2010, Stark et al. 2012, Nadeau et al. 2017) provide descriptions and evaluations of the physical environments and waters in SEAN.

1.3 Purpose of Sampling

River water quality and streamflow are important indicators of Southeast Alaska aquatic and terrestrial ecosystem health. This is reflected in the SEAN's foundational conceptual models, which illustrate the current understanding of important ecological processes within network parks (Moynahan et al. 2008). All SEAN units are concerned about the potential effects of climate change, human disturbance, and contaminants on water quality. Other threats include urban development adjacent to watersheds within park boundaries and invasive or nuisance freshwater species. This program measures the core water quality indicators required for monitoring by all NPS networks: temperature, pH, dissolved oxygen (DO), and specific conductance (conductivity at 25°C). Additionally, because of glacial influence on sediment transport, turbidity is measured in the Taiya River. Methodologies for measuring these core parameters are well developed and relatively affordable.

Rivers and streams transport precipitation, including mountain snowpack, to lower elevation ecosystems, the coastal ocean, and community water users. Watershed hydrologic dynamics,

including streamflow, depend on land characteristics, soils, regional weather conditions, and human activity (DeVivo et al. 2018, Curren 2020). As such, rivers integrate their surrounding environments with far-reaching downstream impacts, and are important indicators of change; freshwater monitoring provides data integral to interpretation of other SEAN core vital signs as well as proactive insight to potential climate and/or human-driven concerns. This program tracks the status and trends of river stage (height) and, by computation, discharge (volume of water moving per unit of time; Turnipseed and Sauer 2010).

1.4 Rationale for Selecting this Resource to Monitor

The SEAN chose to monitor the water quality of rivers, instead of lakes, ponds, or muskegs, because they widely integrate physical and chemical attributes of the terrestrial landscape, provide habitat to a large variety of organisms, and discharge to marine waters. NPS scientists and managers will use long-term river monitoring to evaluate potential water quality changes due to natural and human stressors, check for continued compliance with state and federal aquatic health standards, and analyze conditions relative to variation in river discharge, climate patterns, aquatic invasive species, and other vital signs. Temporal trends in streamflow from climate/landcover change and water withdrawals for municipal supply and fish hatchery use are of particular interest to SEAN parks due to the ecological impacts of altered flow regimes.

Although some NPS vital signs are concerned with visitor impacts on park resources, these are minimal for river water quality in the SEAN. Portions of both the Salmon (GLBA) and Indian (SITK) Rivers flow through human-inhabited areas, and stretches of all three monitored systems are accessible at least partially by trail, but visitor activities are unlikely to directly influence basic stream chemistry. Indirect impacts may result from the introduction of invasive species, trampling of streamside vegetation, and bank erosion. The Salmon River may be affected by household waste as it passes, slightly developed, through the town of Gustavus downstream of GLBA, but the upper portion monitored under this vital sign experiences light visitor use. Along the Taiya River (KLGO), there is relatively high visitor use of the Chilkoot trail during the summer months when flows are highest, but no urbanization. Composting toilets have been installed to help mitigate potential problems associated with groundwater contamination from human waste. At the Indian River, park visitors are generally restricted to improved trails and a footbridge crossing the river, so their impacts on stream chemistry are likely minimal. A significant interval of hypoxia (very low dissolved oxygen) in 2013, concurrent with low streamflow and high numbers of spawning salmon (Sergeant et al. 2017), emphasized the potential for rapid fluctuations in Indian River conditions; monitoring these aspects of anadromous fish habitat remain critically important although no additional hypoxic events have occurred since.

1.5 Measurable Objectives

The SEAN's long-term water quality and streamflow monitoring program will fulfill the following objectives:

- Track the status and trends of each core water quality parameter during the ice-free season (May through October).

- Describe the timing and magnitude of seasonal variation for each core water quality parameter.
- Evaluate whether relevant state and/or federal water quality standards are met or exceeded.
- Track the status and trends of seasonal and annual streamflow by financially supporting USGS stream gage operations.

1.6 The Value of Monitoring Each Parameter

1.6.1 Specific Conductance

Specific conductance, measured in mS/cm, measures the ability of the water to conduct an electrical current at 25°C. Conductivity is the same measurement but uncorrected for ambient water temperature. Specific conductance is easily measured and usually well correlated with the proportion of ionic components in dissolved solids. High specific conductance measurements typically represent strong groundwater influence, while low measurements may represent runoff events due to rain and snowmelt containing small amounts of dissolved ions. Currently, there are no State of Alaska standards for conductivity (ADEC 2020).

1.6.2 pH

pH is a unit-less measure of acidity or alkalinity and is dependent on the activity of hydronium ions ($-\log_{10}$ of H_3O^+) in the solution. Typical stream pH values range from 6.5 to 8.0. Changes in pH can affect the dissolved concentrations of major ions, total organic carbon, and trace metals by influencing their partitioning between dissolved and solid phases. These concentrations may regulate biogeochemical processes, including sulfate reduction, N_2 fixation, and organic matter decomposition. Freshwater pH values typically display diel variation due to photosynthesis-respiration reactions and variable ground and surface water interactions. The most stringent State of Alaska standards are for the growth and propagation of fish, shellfish, other aquatic life, and wildlife, which state that pH may not be less than 6.5, greater than 8.5, or vary more than 0.5 pH units from natural conditions (ADEC 2020).

1.6.3 Dissolved Oxygen (DO)

DO in a stream is typically regulated by water and air temperature, atmospheric pressure, hydraulic stream characteristics, photosynthetic or respiratory activity of stream biota, and the quantity of organic matter present (Hem 1985). Adequate DO is essential for the survival of most aquatic organisms, including salmon and other fish species indigenous to Southeast Alaska. State of Alaska water quality standards assert that DO must be greater than 7 mg/L in water used by anadromous or resident fish, and in no case may DO be less than 5 mg/L to a depth of 20 cm in the interstitial waters of gravel used by these fish or their eggs and juveniles (ADEC 2020). The SEAN monitors only water column DO, not interstitial.

1.6.4 Water Temperature

Water temperature plays an important role in physiological and biological processes of stream organisms, affecting fish metabolism, growth rates, and oxygen solubility. Water temperature trends often mirror those of air temperature, except in glacially influenced streams where persistent warm air may trigger cold glacial melt episodes. Furthermore, water temperature patterns are often

correlated with the timing and magnitude of streamflow as both are directly influenced by climate change, which may alter the frequency of extreme weather events and the magnitude and timing of precipitation. State of Alaska water quality standards state that temperature may not exceed 20°C at any time, 13°C for egg and fry incubation and spawning areas, and 15°C in migration routes and rearing areas (ADEC 2020).

1.6.5 Turbidity

Turbidity is a measure of water clarity (Nephelometric Turbidity Units – NTU or Formazin Nephelometric Units – FNU depending on the sensor, but these units are numerically equivalent). It may be influenced by algal photosynthesis, primary productivity, or, most important for the glacially influenced Taiya River, suspended solid concentrations. Non-glacial streams in Southeast Alaska typically measure <3 NTU, while glacially influenced waters may demonstrate turbidities ranging from hundreds to thousands of NTU. State of Alaska turbidity standards vary based on designated uses, but the most stringent are related to water recreation, where turbidity may not increase more than 10% when natural conditions are greater than 50 NTU, not to exceed 15 NTU (ADEC 2020). Turbidity is monitored only at the Taiya River due to the strong glacial influence on its hydro-chemical characteristics (Current 2020) and the concern that local turbidity dynamics may be influenced by climate change.

1.6.6 Streamflow

Streamflow (river discharge) is defined as the volume of water passing a given point over a given unit of time and is usually expressed in cubic feet per second (ft³/s, or cfs; Turnipseed and Sauer 2010). Discharge dynamics are influenced by rainfall and runoff patterns, watershed topography and landcover, groundwater, and human-driven flow alterations; over longer time periods, water management and climate processes effect streamflow trends. Southeast Alaska is geologically diverse, thus the three watersheds monitored by the SEAN vary in degree of aquifer recharge, wetland storage, and snowmelt, as well as relative influence of groundwater flux versus surface water runoff inputs. USGS streamflow data from gages co-located with or proximal to the SEAN's continuous water quality monitoring stations permit evaluation of the inherent links between river level and chemical characteristics. Particularly important are the frequency and water quality impacts of extreme runoff events, glacial melt intervals, and peak summer low flow periods. There are no state or federal standards for streamflow.

1.7 Overview of Prior Water Quality and Streamflow Sampling

At the time of publication, 11 years of continuous, ice-free season water quality data have been collected by the SEAN. Previously, a small number of brief studies within SEAN units provided water quality observations, and none included long-term or continuous monitoring efforts (Eckert et al. 2006a, Eckert et al. 2006b, Hood et al. 2006, Nagorski and Hood 2007, Bernatz et al. 2010, Stark et al. 2012, Nadeau et al. 2017). These limited data illustrate that overall historic conditions in the SEAN were very high. The only stream the State of Alaska has designated as 303(d) impaired is Pullen Creek (ADEC 2020), a portion of which flows through the Skagway Historic Unit (in KLGO) but is not under NPS jurisdiction or part of the Taiya River watershed. A brief summary of water

quality and streamflow status as well as relevant references for SEAN monitored streams are provided below.

1.7.1 Glacier Bay National Park and Preserve

The most recent comprehensive reviews of GLBA water resources include the Water Quality Synopsis Report (Nagorski and Hood 2007), NPS Water Resources Division (WRD) Coastal Watershed Assessment Report (Eckert et al. 2006a), and NPS Natural Resources Condition Assessment (Nadeau et al. 2017). Earlier compilations include results of all water quality research from the 1960s to 1995 (NPS 1995) and studies relating to Falls Creek and the Falls Creek Hydroelectric Project (Gustavus Electric Company 2004). Rapid deglaciation in GLBA has stimulated numerous studies of physical, chemical, and biological succession in watersheds following ice retreat (e.g., Chapin et al. 1994, Engstrom et al. 2000, Milner et al. 2007).

The freshwater system monitored in GLBA is the Salmon River, a 32.7 km long stream within an 11,552 ha watershed that hosts runs of steelhead trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki clarki*), Dolly Varden (*Salvelinus malma*), and pink (*O. gorbuscha*), coho (*O. kisutch*), and chum (*O. keta*) salmon. The Salmon River's lowermost portion (river km 0.0 to 9.0) is outside of NPS boundaries and within the town of Gustavus. Before the SEAN program, existing water quality information for the Salmon River was limited to a cooperative USGS-NPS two-year field study on mercury contamination (also included Rink Creek and Good River), several unpublished spot measurements taken at a tidally influenced site between January and July 2006, and one series of water chemistry assessments by USGS in 2010. The SEAN has annually summarized water quality data collected in the Salmon River from 2010 through 2020 (available under <https://irma.nps.gov/DataStore/Reference/Profile/2182282>).

Since May 2014, USGS has monitored stage, discharge, and water temperature every 15 minutes at station #15057596 (Salmon River at Gustavus AK; 58°26.7'N, 135°44.4'W; datum 6.9 m (22.8 ft) above NAVD88). This location is ~1 km downstream from the park boundary and the SEAN water quality sonde (no significant tributaries exist between these two sites) and 6 km upstream from the river mouth. Field measurements by USGS staff, several times yearly since 2014, reconfirm the channel shape, rating curve, and discharge calculations (Turnipseed and Sauer 2010). For water years 2014 – 2020, annual mean discharge from the Salmon River ranged from a minimum of 4.0 m³/s (143 cfs) in 2019 to a maximum of 6.1 m³/s (217 cfs) in 2020. Peak flows typically occur in September and October. Historic and current data are available through USGS's National Water Information System (NWIS) at https://waterdata.usgs.gov/nwis/uv?site_no=15057596.

1.7.2 Klondike Gold Rush National Historical Park

The most recent and comprehensive reviews of KLGO water resources are the Nagorski and Hood (2007) report, the NPS WRD Coastal Watershed Assessment Report (Hood et al. 2006), and the NPS Natural Resource Condition Assessment (Bernatz et al. 2010). Earlier summaries include portions of the NPS Baseline Water Quality Inventory (NPS 1998a), the Pullen Creek Action Plan (Taiya Inlet Watershed Council 2006), and Pullen Creek Total Maximum Daily Load Report (ADEC 2010). Additionally, a single sampling event collected core water quality parameters, mercury, and

persistent organic pollutants in water, sediment, and tissues of benthic macroinvertebrates and juvenile salmon from the Taiya and Skagway rivers in July 2007 (Nagorski et al. 2011).

The freshwater system monitored in KLGO is the Taiya River, located west of Skagway. Approximately 29.2 km long, the Taiya drains a 48,200 ha watershed that was, as of 2010, ~29% glacier covered (Sergeant and Nagorski 2014; RGI Consortium 2017). Chum, pink, and coho salmon as well as Dolly Varden populations are supported; eulachon (*Thaleichthys pacificus*) run up the river in the spring (Hood et al. 2006). The majority of previously available Taiya River water quality data comes from USGS sampling in the lower river at the bridge crossing where the Chilkoot Trail begins. Measurements include water temperature, specific conductance, pH, color, DO, dissolved CO₂, acid neutralizing capacity, alkalinity, hardness, turbidity, suspended solids, nutrients, trace metals, major cations, and major anions, collected on one to several occasions per year in most years from 1969 to 1977 and again since 2004. Sampling is intermittent and not always holistic across this suite of parameters. The SEAN has annually summarized water quality data collected in the Taiya River from 2011 through 2020 (available under <https://irma.nps.gov/DataStore/Reference/Profile/2182282>).

Since October 2003, USGS has monitored stage, discharge, and water temperature every 15 minutes at station #15056210 (Taiya River Near Skagway; 59°30.7'N, 135°20.7'W; datum 2.1 m (7.0 ft) above NAVD88); an earlier interval of measurement occurred between October 1969 and November 1977. Presently, an interagency agreement between the USGS and the NPS/SEAN partially supports gaging station operations with additional contributions from the Municipality of Skagway (see additional details in Section 2.1). The gage location is on the downstream side of the highway bridge adjacent to the SEAN water quality sonde and 3.5 km upstream from the river mouth. Field measurements by USGS staff, several times yearly for multiple decades, reconfirm the channel shape, rating curve, and discharge calculations (Turnipseed and Sauer 2010). For water years 1970 – 2020, annual mean discharge from the Taiya River ranged from a minimum of 24.9 m³/s (880 cfs) in 1973 to a maximum of 43.6 m³/s (1,540 cfs) in 2015. Peak flows typically occur from June through September. Historic and current data are available through USGS's NWIS at http://waterdata.usgs.gov/nwis/uv?site_no=15056210. A recent USGS report describes the hydrology, geomorphology, and channel dynamics of the Taiya River (Curren 2020).

1.7.3 Sitka National Historical Park

The Indian River in SITK was included in the Coastal Watershed Assessment Report (Eckert et al. 2006b), NPS Baseline Water Quality Inventory (NPS 1998b), Water Quality Synopsis for NPS (Nagorski and Hood 2007), and Natural Resource Condition Assessment (Stark et al. 2012). The USGS last assessed Indian River water quality in 2001-2002 (Neal et al. 2004) and has intermittently maintained one or two gaging stations since 1981. An environmental site assessment of the Indian River Asphalt Site (Shannon & Wilson, Inc. 1995) and subsequent monitoring (1996–2006) of water quality and soil from two stream locations adjacent to the site provide another source of information. Since 2007, other sporadic studies by SITK staff have included measurements of temperature, DO, pH, and specific conductance. A single sampling event collected core water quality parameters, mercury, and persistent organic pollutants in water, sediment, and tissues of benthic macroinvertebrates and juvenile salmon from the Indian River in June 2007 (Nagorski et al. 2011).

The freshwater system monitored in SITK is the Indian River, which supports many fish species including coho, pink, chum, and Chinook salmon (*O. tshawytscha*), steelhead, Dolly Varden, rainbow trout (*O. mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (Eckert et al. 2006b). The Indian River is approximately 20.8 km long within a steep and well-drained 3,100 ha watershed. A USGS report (Neal et al. 2004) contains some of the most detailed information on historic Indian River water quality. Two sites were sampled every 6 to 8 weeks from January 2001 to September 2002 for pH, specific conductance, temperature, DO, alkalinity, cations, anions, nutrients, and total suspended solids. Physical habitat, algae, macroinvertebrates, and sediments were sampled during single events. Sediments were analyzed for heavy metals, arsenic, 65 organic compounds, and organic carbon. The SEAN has annually summarized water quality data collected in the Indian River from 2010 through 2020 (available under <https://irma.nps.gov/DataStore/Reference/Profile/2182282>). Water quality monitoring remains important in the Indian River watershed as urbanization continues to spread upstream of park boundaries (discussed further in Section 7.3).

Since February 2016, USGS has monitored stage, discharge, and water temperature every 15 minutes at station #15087700 (Indian River at Sitka; 57°03.2'N, 135°18.9'W; datum 9.1 m (30.0 ft) above NGVD29); earlier intervals of measurement occurred from 1980 to 2006 (USGS managed) and June 2007 to April 2016 (NPS coordinated). Presently, an interagency agreement between the USGS and the NPS/SEAN partially supports gaging station operations with additional contributions from the City and Borough of Sitka (see additional details in Section 2.1). The gage location is on the right bank 150 m (500 ft) upstream from Sawmill Creek Road adjacent to the SEAN water quality sonde and 1 km upstream from the river mouth. Field measurements by USGS staff, several times yearly from 1998 to 2003 and since 2016, reconfirm the channel shape, rating curve, and discharge calculations (Turnipseed and Sauer 2010). For water years 1999 – 2020, annual mean discharge from the Indian River ranged from a minimum of 2.2 m³/s (79 cfs) in 2001 to a maximum of 3.4 m³/s (120 cfs) in 2020. Peak flows typically occur in September and October. Historic and current data are available through USGS's NWIS at https://nwis.waterdata.usgs.gov/nwis/uv?site_no=15087700.

2 Sampling Design

2.1 Streamflow Collaboration

The SEAN relies on existing USGS stream gages for river discharge monitoring, with many advantages from expert site selection and equipment purchase and upkeep, to real-time data broadcast with easy and open access, to already-developed rating curves and an archive of historic data. Establishing and installing new stations dedicated solely to network activities was out of reach both financially and with regards to staff time and expertise.

Interagency Agreements between the USGS and NPS/SEAN are in place for the Indian River (City and Borough of Sitka an additional partner) and the Taiya River (Municipality of Skagway an additional partner). The cost sharing agreement for the Indian River was established in 2016 to streamline the previous multi-agency partnership coordinating gage operations; in 2021, it was extended for another five-year period through fiscal year 2025. The current cost sharing agreement for the Taiya River gage was originally established in 2010 for a period of five years and then extended for two additional five-year periods (through 2024). Through these arrangements, the SEAN partially funds station operation and maintenance, providing streamflow data for resource monitoring and flood warning. The USGS remains responsible for all data management (QA/QC, daily and annual statistics, field measurements and rating curve updates) as well as serving real-time data on NWIS; procedures follow Turnipseed and Sauer (2010).

All three USGS-operated stream gages co-located with SEAN water quality monitoring sites measure river stage and water temperature every 15 minutes. Data are transmitted to the USGS by GOES satellite telemetry every hour. Leveraging an extended and routinely verified suite of field measurements capturing the river channel's cross-sectional shape and area plus current velocity, hydrologists have generated site-specific rating curves to describe the local relationship between stage and discharge. Continuous streamflow (discharge) values are computed by applying these curves to the stream stage readings (Turnipseed and Sauer 2010).

2.2 Rationale for Site Selection and Sampling Design

The three rivers were chosen for water quality and streamflow monitoring based on dependable site access and the ability to co-locate sondes sites with related SEAN monitoring efforts such as freshwater contaminants. Site access is an important consideration in the SEAN, and GLBA especially, where the lack of roads and trails, challenging terrain, and typically cold and wet climate greatly restrict the ability to safely and successfully access most park watersheds. Co-located streamflow gaging strengthens trend assessments related to climate, improves interpretive accuracy for parameters that are flow dependent, and supports investigation of aquatic resource management issues related to seasonal or event-driven conditions. For these reasons, the SEAN Technical Committee agreed that the use of randomly or probability-based site selection could not be implemented for river monitoring.

High-resolution (hourly readings over six or more months per year) water quality data collected at a single fixed location will generally capture the integrated status and trends of the upstream reach and can potentially represent some portion downstream. The program's scope of inference is limited to

no more than a single watershed and may be altered by major changes in adjacent land use, forest type, physical/chemical modifications upstream, or changes to station location.

2.3 Water Quality Site Selection within each SEAN Unit

The SEAN Technical Committee agreed that at least one stream from each SEAN unit should be represented in the water quality monitoring effort (Table 1). Funding and staffing limitations have not allowed program expansion beyond three sites, even though GLBA covers a vastly greater surface area than SITK and KLGO with hundreds of streams of various types and sizes.

Table 1. SEAN water quality monitoring site information

Site Code	Site Name	Park Unit	Watershed area (ha)	Bankful width (m)	Latitude (N)	Longitude (W)	Began Operation	Directions
IN	Indian River	SITK	3,185	5	57.052797	-135.317486	5/26/2010	At the Indian River and Sawmill Creek Blvd (S-933) crossing, head upstream from the overpass along the river's right bank (looking downstream). There is a trail that follows a diversion pipe along this bank. The sonde is approximately 50 m from the overpass.
SA	Salmon River	GLBA	11,552	7	58.452350	-135.740900	6/5/2010	Travel north from Four Corners on Wilson Rd for ~2 miles. Turn left off Wilson Rd at the borrow ponds and drive 0.1 mile north along the west side of the two borrow ponds to the back pond. Park next to the pond. Walk the old road along the northwest side of the back pond and travel ~0.3 miles north to the next pond. Take another left on the old road along the northwest corner of this second V-shaped, older pond. Follow the old road ~0.3 miles northwest to the Salmon River. Hike ~0.25 miles upstream along the river's left bank (looking downstream) until the NPS boundary markers and associated survey cut transecting the stream are encountered. The sonde is located on the Glacier Bay National Park boundary.
TA	Taiya River	KLGO	46,361	48	59.511975	-135.346363	4/25/2011	Travel north out of Skagway on State Street, which turns into Klondike Hwy outside of town. After ~1 mile on Klondike Hwy, turn left onto Dyea Rd. Follow Dyea Rd for ~7 miles until the Taiya River Bridge and park on the left before crossing. The sonde is just downstream of the bridge on the river's left bank (looking downstream).

At SITK, the Indian River is the only freshwater body present, so no other option was available. The site location was driven by the presence of a USGS gaging station near a bridge at the northern boundary of the park (Figure 2).



Figure 2. SEAN monitoring site and co-located USGS gaging station on the Indian River at SITK. Location map (left), sonde (center), and immediate downstream reach (right).

Two rivers are present in KLGO, the Taiya and Skagway. The Taiya River was chosen because it encompasses a larger watershed area with heavier visitor use (especially along the Chilkoot Trail), has a maintained USGS gaging station within the park, and extends to the intertidal zone (Figure 3).



Figure 3. SEAN monitoring site and co-located USGS gaging station on the Taiya River at KLGO. Location map (left), sonde (center), and immediate downstream reach (right).

In GLBA, the choice was more difficult. After extensive discussion, SEAN staff decided that the Salmon River (Figure 4), rather than a randomly selected stream or the relatively well-studied Bartlett River, should be targeted for monitoring because it is:

- accessible by foot year-round from Gustavus roads

- large enough to encompass a variety of physical features (e.g., peatlands, forested uplands)
- habitat for Dolly Varden, coho, pink, and chum salmon, and cutthroat and steelhead trout
- representative of other similarly sized, coastal, non-glacial streams in GLBA
- part of a prior USGS/NPS study that monitored core water quality parameters
- potentially a good candidate for future cooperative monitoring with the town of Gustavus

The Bartlett and Alsek rivers were additional strong candidates for long-term monitoring in GLBA. Although NPS scientists have invested several years of effort in fish surveys and water quality/quantity profiles on the Bartlett River, the main logistical weakness is the river's lengthy trail access (over four miles from Headquarters to above the tidally influenced zone). Park staff felt that it would be more difficult to commit to monthly site visits at the Bartlett than the Salmon River. The Alsek River was not selected for monitoring primarily because it is expensive and difficult to access on the Outer Coast, and its particularly large size (drainage area 2,000,000 ha) is anomalous even for GLBA. Established USGS gaging station #15129120 (59°11.6'N, 138°20.0'W; datum 15.2 m (50.0 ft) above NGVD29) collects basic water quality data, with an expanded sensor suite added in 2020. Alsek River data are available at https://waterdata.usgs.gov/ak/nwis/uv?site_no=15129120.

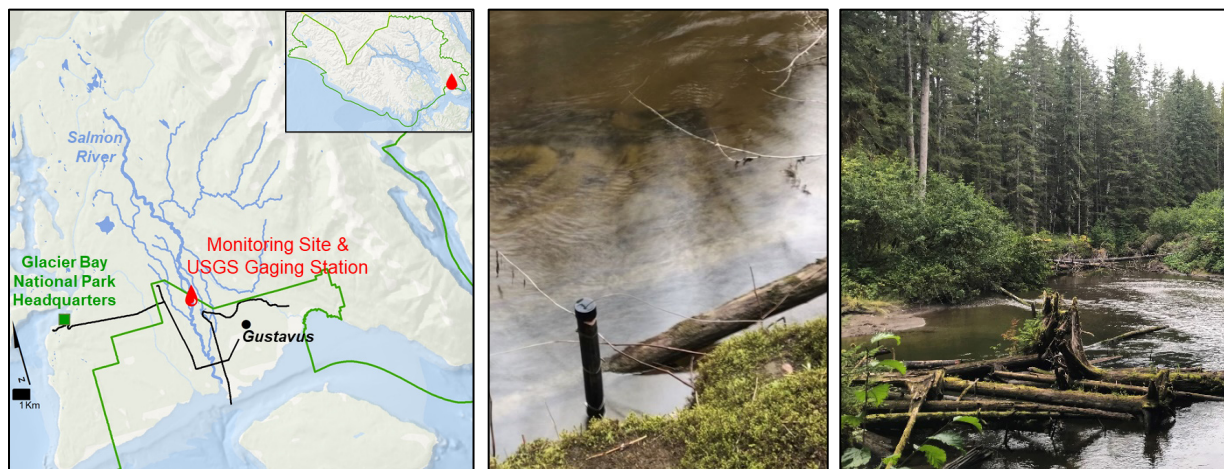


Figure 4. SEAN monitoring site on the Salmon River at GLBA. Note the USGS gaging station is ~1km downstream from the sonde, with no major tributaries between. Location map (left), sonde (center), and immediate upstream reach (right).

2.3 Sampling Frequency and Replication

Because changes in water quality can be rapid and short-lived, this monitoring program employs a continuous (hourly) sampling design to track seasonal variability in the status and trends of core parameters. Diel fluctuations in measured values are controlled largely by instream photosynthetic activity, outside air temperature, precipitation events, surface and groundwater interactions, transpiration by floodplain vegetation, and upstream gains or losses of source waters with varying physicochemical characteristics. While a 15-minute sampling interval would result in a highly detailed record synchronous with USGS gaging stations, this timing would also require more

intensive management and frequent battery changes, with little to no added value to the long-term dataset. The chosen hourly measurement interval, extended over the ice-free portion of the year (May thru October), provides a manageable yet highly informative dataset that adequately addresses the monitoring objectives. This seasonal timing allows optimal instrument function in above-freezing temperatures, provides better site access, captures the majority of variation in physicochemical characteristics, and eliminates the risk of equipment damage due to freezing or ice impact. With the YSI EXO sondes and selected sensor suite, hourly measurements can be obtained using a single set of batteries for approximately 60 days, assuming fairly warm weather conditions, improving the likelihood that the data set remains continuous if logistical issues result in a missed monthly site visit.

2.4 Trend and Variability Detection

Hourly measurements provide high resolution for short- and long-term changes in basic physicochemical stream characteristics. Even with occasional readings that do not pass quality assurance/quality control (QA/QC) criteria, hourly data from six months of each year provides a robust record for evaluating seasonal to decadal status and trends. Stringent QA/QC standards (SOPs 7 and 12) dictate the margin of allowable error in the accuracy and precision of each instrument and validity of detected changes over time. The NPS Inventory and Monitoring Division's Central Office assesses 211 hydrologic metrics each water year for rivers in all NPS units through DeVivo et al.'s (2018) Environmental Settings Monitoring Protocol, thus detailed streamflow analyses are not part of the SEAN's analytical scope.

3 Overview of Field Methods

Water quality monitoring field methods are summarized here, with complete details provided in SOPs 1 and 2. Gaging stations operated by the USGS follow river discharge, rating curve, and streamflow calculation methods in Turnipseed and Sauer (2010).

The SEAN Project Leader is responsible for the management, administration, and productivity of the water quality and streamflow monitoring program. The Project Leader relies on designated park staff (Park Leads) for monthly site visits, sensor checks, and data collection. The Project Leader and Park Leads are supported by the SEAN Data Manager. Specific roles and responsibilities are described in section 5 and the relevant SOPs.

3.1 Instrument Selection and Set-up

As of 2021, this program uses instruments manufactured by YSI Incorporated (www.ysi.com). As technology changes, monitoring equipment may be replaced or augmented. Instrument configuration and field season instructions are in SOP 1, with sensor data quality metrics in SOP 12.

The SEAN currently employs:

- EXO3 Multiparameter sonde with four ports (#599503)
- EXO Wiped Conductivity/Temperature digital smart sensor (#599827)
- EXO Optical Dissolved Oxygen digital smart sensor (#599100)
- EXO pH (unguarded) digital smart sensor (#577602)
- EXO Turbidity digital smart sensor (#599101)
- EXO Central Wiper for anti-fouling (#599090)
- EXO Handheld display (#599960)
- EXO Field cable (10m) (#599040)
- KorEXO Software

3.2 Installation of Monitoring Stations

A properly installed monitoring station is secure, minimally visible to park visitors, stable and operational under a variety of water levels and flow velocities, and safely accessible to personnel for calibration checks, battery replacements, and data downloading. A four-inch diameter perforated rigid plastic pipe serves as the sonde housing (Figure 5). The pipe is either mounted to an immobile stream structure such as a boulder or attached to an angle-iron rod securely placed into the streambed (Figures 2, 3, and 4). A bolt is inserted through the pipe at the targeted probe depth. The sonde is inserted into the installed housing and the base of the sensor guard rests on the bolt. A disk or cylinder of hard-cell foam is used to keep the sonde centered in the housing. A cable and carabiners serve as a back-up tether, fixing the sonde itself to an eyebolt ashore. When the sonde is not being serviced, the housing is capped to protect against vandalism and sediment accumulation. The EXO Handheld and field cable are connected to the sonde during each site visit and otherwise stored in the park office.



Figure 5. Example of sonde housing and installation accessories from the Taiya River. Housing cap, foam (with duct tape reinforcing shape), and tether shown alongside plastic pipe housing and EXO3 multiparameter sonde with calibration cup.

3.3 Field Season Preparations

Each winter, the Project Leader receives the sondes from the Park Leads and sends them to the manufacturer for cleaning, recalibration, and performance checks. Although pH, DO, specific conductance, and turbidity can be recalibrated fairly easily by NPS personnel, temperature and barometric pressure are difficult to verify with high accuracy and must be evaluated by the manufacturer. After field deployment, instrument probes and components may accumulate sediment and/or biofouling in screw threads and other crevices. The SEAN typically relies on the manufacturer to loosen, clean, and replace these sensitive areas as needed, because improper handling during cleaning or repair by NPS personnel may void instrument warranties.

Park Leads, with the support of the Project Leader, are responsible for maintaining adequate supplies of data sheets, calibration standards, extra batteries, field notebooks, pens and pencils, sensor cleaning materials, and hard copies of the protocol and pertinent SOPs (full equipment list in SOP 1). The SEAN Project Leader ensures that replacement supplies are delivered promptly as needed.

Each year, the Project Leader trains Park Leads on instrument calibration, use, and maintenance. Due to the potential for losing up to a month of data between site visits, it is extremely important that staff collecting water quality data closely follow these protocols (SOPs 1 and 2) and receive proper training before each season. A pre-season inspection of the station infrastructure confirms that no components were damaged or lost during the winter. At the Indian and Taiya Rivers, bolts on support structures are checked. At the Salmon River, the stabilizing angle-iron rod is reinstalled. The initial inspections at SITK and KLGO are conducted at least one month (approximately April 1) in advance of instrument deployment to allow for potential repairs.

3.4 Field Operations

Under normal conditions, sondes will be installed and logging before May 1 each year. Each monitoring station is visited on a monthly basis by the Park Lead to download data and conduct sensor checks, maintenance, and calibration. Downloading data on the last or first day of each month is preferable, but a five-day calendar day window for the monthly site visit is acceptable. SOPs 1 and 2 provide detailed procedures for each visit.

In intervals of extreme weather and high-flow conditions, the sondes will be temporarily pulled out of operation if there is substantial risk of damage or loss. In such cases, Park Leads should make their best effort to track daily conditions and reinstall sondes as soon as safe. If removed, the sonde is properly stored according to the procedures described in SOP 1. Installation or removal should never occur under conditions that endanger park personnel.

3.5 Data Transmission

Following each monthly site visit, Park Leads transmit raw data to the Project Leader using the procedures in SOP 2. Outlined steps include uploading data from sonde to computer, file name and format, transfer of site visit files, and contacting the Project Leader with questions or any repairs. The Project Leader ensures accurate data transmission, stores the data within the specified directories, and officially acknowledges receipt of files from the Park Lead. Monthly raw data and site visit files are stored until end-of-season processing and reporting.

3.6 End-of-Season Procedures

At the end of every deployment season (around October 31), Park Leads retrieve the sondes and conduct a complete sensor check, then appropriately store, package, and ship all field equipment to the Project Leader. The Project Leader inventories and cleans instruments before sending to the manufacturer for annual service, as described in SOP 1.

4 Data Handling, Analysis, and Reporting

This section describes the general approaches to generating, maintaining, and disseminating the data products created under this monitoring protocol. Detailed procedures and product definitions are provided in product-specific SOPs.

4.1 Overview of Information Architecture

Water quality monitoring program data are managed according to the standard methods used by all network programs, as described in the SEAN Data Management Plan (Johnson and Moynahan 2008). The framework from which these methods were derived is illustrated in Figure 6.

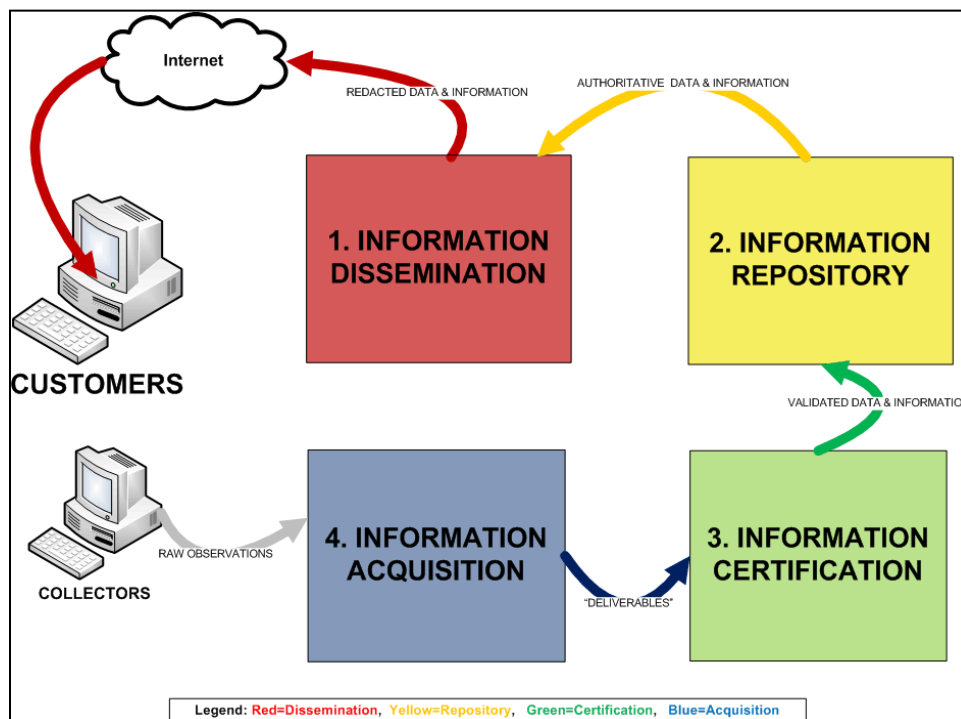


Figure 6. The SEAN data management framework overview. Publication services (red) provide all deliverables to customers using the SEAN website and IRMA Data Store. Repositories (yellow) store the certified deliverables as described in the protocol SOPs. Certification processes (green) assure repositories have the highest quality data and that sensitive items are restricted to authorized users. Information acquisition processes (blue) led by SEAN and park staff as well as cooperators range from collecting raw data to producing reports on long-term trends.

All water quality deliverables are published through the SEAN NPS website and partner sites, including the NPS Integrated Resource Management Applications (IRMA) Data Store, USGS National Water Information System (NWIS), and Aquarius. Reports follow NPS resource brief, web article, and natural resource report (NRR) formats.

4.2 Overview of Data Deliverables

The water quality program creates and maintains seven deliverables, each of which:

- Originates from a single authoritative source
- Contains content that is comprehensively documented in the parent protocol
- Is discoverable and deliverable to all users on the internet
- Is always certified to be at a level of quality defined in the parent protocol
- Is permanently backed up and also archived in an appropriate repository

Each deliverable is published in the IRMA Data Store and linked from the SEAN NPS website; some are also made available on partner websites. The IRMA Data Store is the single authoritative source for SEAN deliverables. In the event that a data product distributed by a partner diverges from that published directly by the SEAN, the IRMA Data Store version should be used.

Water quality deliverables are provided in a variety of file formats and frequencies, and each has a single SOP detailing its creation (Table 2; SOPs 3, 4, 5, 8, 9, and 11). Streamflow data from river gaging stations supported by the SEAN are managed, analyzed, and published as formal deliverables on NWIS by the USGS (Turnipseed and Sauer 2010). As such, only water quality sonde data are included in program deliverables.

4.3 Data Acquisition: Scheduling Deliverable Creation

Prerequisite processes exist for most deliverables; many program outcomes are dependent on prior certification of other deliverables, which in turn have their own dependencies. SOPs are sequenced in the typical order of field season operations and deliverable creation (Table 3).

Table 2. The SEAN water quality monitoring program deliverables.

Deliverable	Description	Published As	Frequency Produced	SOP
FQ_A: Protocol	Detailed narrative plus a suite of SOPs that define the water quality monitoring program; each revision exhibits a unique protocol ID.	Individual .PDF files for narrative and each SOP	As needed, prior to the field season for which it becomes effective.	11
FQ_C: Site Visit Files	One file per site visit documenting actions taken (e.g., sensor cleaning and recalibration), calibration values, and Aquarius-formatted import data.	Windows files in MS Excel (.XLSX) format, packaged into a single .ZIP file.	One .ZIP file per year, containing all visits to all sites.	3
FQ_D: Maintenance Records	Scans of sonde maintenance records.	One .PDF file for all instruments covering a full calendar year.	Once per year, following return of sondes from service vendor.	4
FQ_E: Sonde Raw Data	The season's collection of raw sonde output in proprietary YSI .BIN format. These files are extracted during each site visit, and again after the sonde is pulled from service for the season. No corrections are applied to this product.	Data files of sonde output in proprietary .BIN format, in a single .ZIP file.	One .ZIP file per year, containing records from all sites.	5
FQ_G: Annual Update Resource Brief	Annual update summarizing operations and highlighting the season's data, compiled as a resource brief.	.HTM web article on SEAN NPS page and linked in IRMA Data Store, and .PDF version by park	Once per year, after certification of the FQ_Q deliverable.	9
FQ_H: Synthesis Report	Trend analysis reviewing long-term patterns in collected parameters.	One .PDF file.	Once every ten years, following completion of the latest FQ_G annual report.	9
FQ_Q: Aquarius Time Series Data Package	The cumulative archive of sonde data in .CSV format having duplicate readings removed, data adjustments applied, and quality grades assigned. This dataset is also viewable through the SEAN Aquarius Web Portal.	One .CSV data file and one .XML metadata file for each sonde, in a single .ZIP file.	Once per year, per site, following completion of Aquarius data and grading (SOP 7).	8

Table 3. Typical sequence of SEAN water quality deliverable production.

Time Period	Responsible Party	Location	Description
Pre- Season	Project Leader	At SEAN office	Send sondes out for annual maintenance and calibration.
	Project Leader	At SEAN office	Compile maintenance records (FQ_D deliverable)
Field Season, monthly	Park Lead	At field site	Transfer .BIN data from sonde to handheld, and visually verify successful
	Park Lead	At field site	Record sensor check values on paper site visit worksheet
	Park Lead	In park office	Enter sensor check values into .XLSX site visit file (FQ_C component)
	Park Lead	In park office	Transfer .BIN data from handheld to computer with KorEXO software, and visually verify record complete (FQ_E component)
	Park Lead	In park office	Transmit .XLSX site visit and .BIN data files to Project Leader
	Project Leader	At SEAN office	Review all .BIN data files
	Project Leader	At SEAN office	Review all .XLSX site visit files and validate
Post-Season	Park Lead	At field site	Remove sonde from site and return to Project Leader
	Project Leader	At SEAN office	Compile all site visit and .XML files for year into .ZIP (FQ_C deliverable)
	Project Leader	At SEAN office	Compile all .BIN data files for year into .ZIP (FQ_E deliverable)
	Project Leader	At SEAN office	Evaluate, grade, and correct all sonde data in Aquarius (FQ_Q component)
	Data Manager	At SEAN office	Export cumulative sonde data record from Aquarius, validate, and package in .ZIP with .XML metadata (FQ_Q deliverable)
	Project Leader	At SEAN office	Prepare annual update resource brief once FQ_Q is certified (FQ_G deliverable)
As Needed	Project Leader and others	At SEAN office	Prepare synthesis report every ten years from latest certified FQ_Q and other data sources (FQ_H deliverable)
	Project Leader and others	At SEAN office	Revise protocol (narrative and/or SOPs; FQ_A deliverable)

4.4 Deliverable Validation and Certification

Park Leads collect their respective data components during monthly site visits. Observations are verified during data entry by checking the accuracy of computerized records against the original paper datasheets. The electronic version of the site visit record, along with cumulative sonde data file and any supporting documentation, is forwarded to the Project Leader (SOP 2). The Project Leader verifies that all components were delivered; if any required component is missing, the Project Leader consults with the Park Lead for correction and resubmission. Complete items are accumulated by the Project Leader in a designated work zone on the SEAN's file server.

The Project Leader inspects the contents of all submitted monthly site visit and .BIN data files as an initial quality assurance step. Verification identifies and corrects generic errors in the data record (i.e., missing, mismatched, or duplicate records). Once confirmed, the Project Leader forwards the files to the Data Manager, who utilizes the SEAN data management website application to perform an automated pre-validation of the site visit data. This serves as an extra quality assurance step. If any discrepancies are detected, the Project Leader works with the Park Lead to resolve issues, and quality assurance steps are repeated as necessary. After monthly data are verified and validated, the approved electronic files are used for subsequent grading, analysis, and reporting.

At the end of the monitoring season, the Project Leader assembles and formats program deliverables per their respective detailed procedures (Table 2; SOPs 3, 4, 5, 8, 9, and 11). The Project Leader and Data Manager then validate and certify each deliverable, in the order shown in Table 3, ensure each meets mandatory quality control criteria as defined in SOP Appendix As. The certification task sequence is generically depicted in Figure 7. Upon certification, the Data Manager publishes the deliverable to the IRMA Data Store and ensures a link to this Data Store reference is visible on the SEAN NPS website. The SEAN Data Management Plan describes the approach to validation and certification (Johnson and Moynahan 2008).

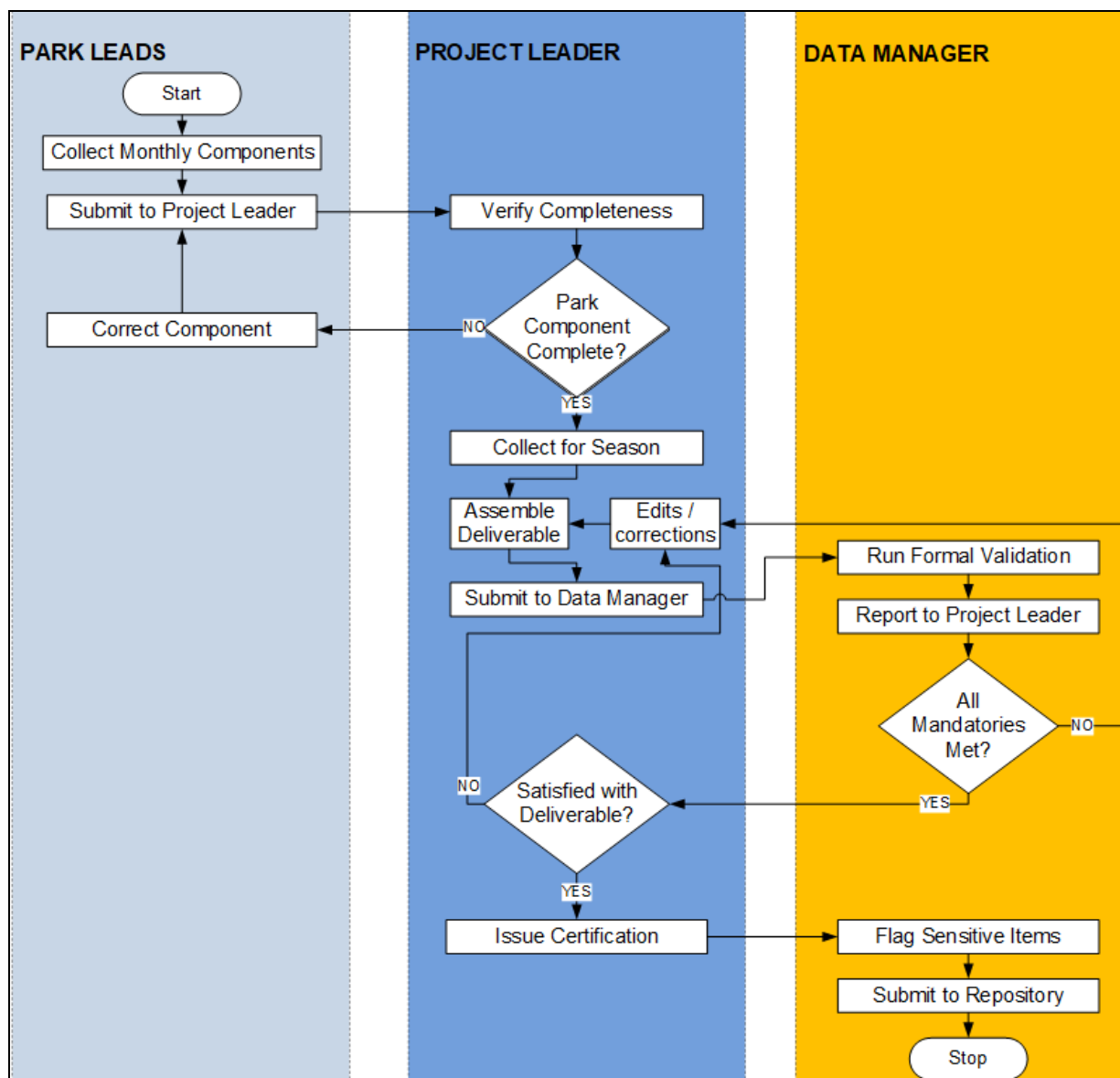


Figure 7. Sequence of tasks and staff responsibilities used in the SEAN certification process.

4.5 Metadata Maintenance

Complete metadata facilitates data longevity, helps publicize the existence of program deliverables, and enables effective access to data by future users. Raw and corrected versions of all water quality monitoring data will be accompanied by metadata documentation including information about dataset identification, data quality, source entity and attribution, spatial reference, publication, and point(s) of contact.

The Data Manager is responsible for maintaining Federal Geographic Data Committee (FGDC) compliant metadata for the FQ_C (Site Visit Files) and the FQ_Q (Aquarius Time Series .CSV data export) deliverable. The SEAN stores metadata as .XML files and publishes them on the IRMA Data Store as part of the cumulative Aquarius Time Series Data Package (FQ_Q deliverable; SOP 8).

Absent official I&M policy for metadata standards or tools for its creation, the SEAN has followed I&M and FGDC guidance to generate the compliant files. Metadata considerations are further addressed in chapter 8 of the SEAN Data Management Plan (Johnson and Moynahan 2008).

4.6 Publication of Program Deliverables

In keeping with the SEAN and national data management policies, users access all water quality deliverables directly from the IRMA Data Store (Figure 8). Data Store references contain metadata and useful ancillary information, as well as references to relevant published and gray literature. SEAN deliverables published on the Data Store are to be considered the authoritative source.

Data Store
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Project - (Code: 2182282)

Title SEAN Freshwater Water Quality Monitoring

Description SEAN vital sign freshwater water quality monitoring of selected streams is conducted in Southeast Alaska national parks. Core parameters collected include temperature, dissolved oxygen, pH, conductivity, and turbidity.

Water quality is an indicator of aquatic and terrestrial ecosystem health in Southeast Alaska, a rainforest landscape dominated by a wet and mild maritime climate. The Southeast Alaska Network (SEAN) of the National Park Service (NPS) has prioritized Freshwater Water Quality as one of 12 Vital Signs for long-term ecological monitoring based on its vulnerability to alteration by human stressors and sensitivity for detecting fundamental environmental changes (Moynahan et al. 2008). Trends in water quality can signify chronic or developing watershed issues within national parks. The SEAN water quality monitoring program has the following objectives: 1) Track the status and trends of each core water quality parameter (conductivity, dissolved oxygen, pH, and water temperature); 2) Describe the timing and magnitude of seasonal and annual variation for each core water quality parameter; 3) Evaluate whether state and/or federal water quality standards are met or exceeded. The SEAN water quality monitoring protocol (Sergeant et al. 2013) includes an extended description of each water quality parameter (Sections 1.3-1.7) and a discussion of future priorities for expanding the monitoring program (Section 7.0). We expect future monitoring to include an expanded stream temperature monitoring component and potentially add water quality sondes to additional rivers within the SEAN.

The initial sampling goal of the monitoring program was to track water quality status and trends in at least one river in each of the three SEAN parks. In 2010, sondes were installed in the Salmon (GLBA) and Indian (SITK) Rivers. The Taiya River (KLGO) was added in 2011. Sampling sites were chosen based on park prioritization and dependable site access.

Citation SEAN Freshwater Water Quality Monitoring. 2010

Visibility Public

Citation with All Authors SEAN Freshwater Water Quality Monitoring. 2010

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Products Created By This Project (10)

File Count	Code	Type	Display Citation	Title	Year
1	2248423	Resource Brief	Sergeant C. 2015. SE Alaska freshwater water quality resourc...	SE Alaska freshwater water quality resource brief	2015
2	2257521	Assemblage	SEAN freshwater water quality monitoring protocols as define...	SEAN freshwater water quality monitoring protocols as define...	
13	2257760	Notes	Sergeant C and Others. 2021. SE Alaska water quality site visi...	SE Alaska water quality site visit worksheets (FQ_C)	2021
12	2257761	Generic Docum...	Sergeant C and Others. 2020. SE Alaska water quality instru...	SE Alaska water quality instrument maintenance log images (...)	2020
11	2257762	Generic Dataset	Bower M and Others. 2020. SE Alaska water quality raw sond...	SE Alaska water quality raw sonde data (FQ_E)	2020
8	2257517	Assemblage	Southeast Alaska freshwater water quality annual reports (FQ...	Southeast Alaska freshwater water quality annual reports (FQ...	
11	2284120	Generic Dataset	Sergeant CJ. 2021. SE Alaska national parks water quality acc...	SE Alaska national parks water quality accepted observations ...	2021
10	2257755	Assemblage	SE Alaska water quality monitoring program permits. NPS SE...	SE Alaska water quality monitoring program permits	

Figure 8. SEAN water quality monitoring program authoritative source deliverables served on the IRMA Data Store.

In the SEAN data management framework (Figure 5), the Project Leader is also a customer. When creating a product (e.g., annual updates or synthesis reports) based on earlier data packages, the Project Leader uses as source material the certified SEAN deliverables published on the IRMA Data Store, not the Project Leader's local work files. This process assures that deliverable creation processes only use authoritative data and, thereby, are reproducible.

No deliverables of the water quality monitoring program are currently considered sensitive. Should a future policy revision classify some as sensitive, the availability of such deliverables shall be determined by future I&M guidance. The IRMA Data Store contains a mechanism to limit the visibility of sensitive products to internal (to NPS) and/or specific individuals only; each deliverable SOP contains instructions on configuring sensitive Data Store references if needed.

4.7 Repository: Data Archiving

The SEAN's water quality program data are maintained on equipment located in the SEAN office in Juneau, Alaska, including a production file server, backup server, SQL Server database, and a suite of data management applications. The SEAN Data Management Plan, SOPs 204 and 1101 detail the comprehensive Juneau backup and restore mechanism (Johnson and Moynahan 2008), and chapter 11 covers the philosophy of records management. The authoritative source of deliverables contained in outside repositories (*e.g.*, Aquarius data via the NPS Water Resources Division) are those version-tracked and published on the IRMA Data Store.

4.8 Reporting

Water quality data will be summarized in annual updates (in the form of resource briefs) and synthesis reports (NRR format; SOP 9) produced by the Project Leader. Both types of reports will be published to the IRMA Data Store and made available through the SEAN NPS website.

Annual updates summarize results of a single continuous sampling season for all three parks (GLBA, KLGO, and SITK) and are completed by the Project Leader by the end of the same calendar year. Using web article format to enhance reporting timeliness and accessibility to a broad audience, the SEAN's annual updates visualize daily mean values for core water quality parameters overlaid on the full historic record. Daily mean streamflow from the co-located USGS gage and daily total precipitation from the closest weather station provide valuable context. Key findings and seasonal patterns are highlighted for each park, as well as any exceedances of Alaska Department of Environmental Conservation water quality standards. A concise table provides descriptive statistics for the annual record of each parameter.

Synthesis reports, beginning in 2022 and every ten years thereafter, include more detailed analyses of long-term trends in SEAN water quality data using Mann-Kendall, generalized additive modeling, or other time series approaches. Additional regional weather and streamflow datasets will be integrated to consider environmental influences on chemical conditions. Data will be examined for each park individually as the program sampling design and watershed differences do not support statistical analysis between sites.

4.9 Data Management Applications

The SEAN has developed several data management applications for quality control and generation of deliverables. The technical details of deliverable preparation are addressed in the respective SOPs. Specific tasks fit in the network's general data management framework as described in the SEAN Data Management Plan, SOP 303 (Johnson and Moynahan 2008). Understanding framework operation is a prerequisite to performing FQ protocol-specific processes.

In order for users to have access to I&M products via the internet, SEAN deliverables must be published to the IRMA Data Store. IRMA references are logically named and strategically organized following I&M guidance for easier user browsing. Entries are verified and updated annually, ensuring deliverable descriptions and citations are accurate, and files/links open correctly.

In addition, the NPS Water Resources Division maintains the Aquarius application as its primary source of content. The SEAN imports raw data and site visit information into Aquarius, then utilizes the software's tools to perform quality control and corrections on the raw data. Once approved, the data is made publicly available on the Aquarius WebPortal. Monitoring site descriptions and data review status/approvals in Aquarius are updated annually after the monitoring season. However, the authoritative source of SEAN water quality data is the IRMA Data Store where the published, certified cumulative data deliverable (FQ_Q; SOP 8) adheres to I&M guidelines requiring data packages containing a tabular data set and standardized metadata.

5 Personnel Requirements and Training

5.1 Roles and Responsibilities

Installation, monthly maintenance, and end-of-season decommissioning of monitoring equipment is performed by the Park Leads, overseen by the Project Leader, and detailed in SOP 1. Data downloads from the sondes are conducted by the Park Leads, who then forward those data to the Project Leader (SOP 2). The Project Leader and Data Manager are responsible for creating specific data deliverables that are the outcome of this monitoring program (SOPs 3 – 9). The Data Manager and the Project Leader are jointly responsible for the data validation processes associated with those deliverables, which are published to the IRMA Data Store and linked on the SEAN NPS website.

5.1.1 SEAN Project Leader

- Ensure completion of preparations prior to the field season, including
 - coordinate annual sonde maintenance during winter
 - confirm setup of sondes, power, memory/display/logging and handheld configurations
 - order and stock calibration standards, batteries, printed site visit worksheets, spare sonde parts, and other field items
 - ensure that Park Leads are adequately trained
 - ensure that monitoring stations are in good structural condition before and throughout the season
- Train new Park Leads in water quality monitoring procedures
- Schedule and execute safe and successful deployments of water quality sondes at each site with Park Leads
- Track monthly station checks and data downloads by Park Leads
- Coordinate needed repairs and troubleshoot technical problems
- Declare monitoring stoppages due to weather or river conditions for the safety of personnel and equipment (this does not preclude Park Leads making independent decisions based on real-time conditions at the time of data download or station checks)
- Perform monthly data error checks, resolve issues, and submit site visit files for validation
- Evaluate, grade, annotate, and approve all sonde data in Aquarius at season's end
- Assemble and submit all data deliverables to the Data Manager
- Correct deliverables as needed to meet mandatory validation criteria
- Formally certify deliverables that pass mandatory validation
- Assemble and publish program metadata with the Data Manager
- Collaborate with the SEAN Quantitative Ecologist on data analyses and reporting
- Recommend protocol improvements to the Program Manager and lead revision process

5.1.2 GLBA, KLGO, and SITK Park Leads

- Ensure completion of preparations prior to the field season, in coordination with the Project Leader, including:
 - return sondes to Project Leader at the end of the monitoring season
 - track supplies of calibration standards, batteries, printed site visit worksheets, and other field items
 - ensure proper storage of monitoring equipment when not deployed
 - undergo protocol training with the Project Leader, when needed
 - identify equipment and/or logistical issues to Project Leader and collaborate to implement solutions
- At KLGO and SITK, visit the site around April 1 to check overwinter condition of the sonde housing and hardware; work with Project Leader to complete any repairs prior to May 1
- Deploy sonde at the beginning of the monitoring season (before May 1)
- Complete site visit files at each monthly station check and immediately communicate issues with the Project Leader (e.g., unstable structures or inoperable probes)
- Perform monthly sensor checks, recalibrations, and data downloads
- Properly transfer downloaded data from the sonde to the Project Leader each month
- Recommend protocol improvements to the Project Leader

5.1.3 SEAN Data Manager

- Validate quality of deliverables against formal criteria
- Assemble, maintain, and publish metadata
- Utilize Aquarius to import data and site visit information, and manage location configurations, time series metadata, and the SEAN Aquarius WebPortal
- Export Aquarius data using the internal SEAN website application
- Track program progress and adhere to deliverable schedules
- Archive data and metadata as appropriate on the IRMA Data Store
- Coordinate corrections so that deliverables posted to external archives continue to represent the best consistent project data
- Recommend protocol improvements to Program Manager

5.1.4 SEAN Program Manager

- Oversee program
- Review and approve annual updates and synthesis reports
- Supervise Project Leader and Data Manager

- Coordinate with each park's Chief of Resources (or other divisions where appropriate) to secure commitments for Park Leads' time and responsibilities
- Oversee, coordinate, and approve protocol revisions

5.2 Qualifications

5.2.1 SEAN Project Leader

- Knowledge of:
 - General aquatic field survey logistics, protocols, and safety
 - Water quality monitoring instruments, data collection, deployment, and software
 - Downloading, evaluating, and processing water quality data
- Demonstrated ability to:
 - Recognize and correct errors detected in data deliverables
 - Compile and analyze monitoring data for annual updates and synthesis reports
 - Manage projects and collaborating personnel

5.2.2 GLBA, KLGO, and SITK Park Leads

- Knowledge of:
 - General aquatic field survey logistics, protocols, and safety
 - Water quality monitoring instruments, data collection, deployment, and software
- Demonstrated ability to:
 - Check and calibrate sondes
 - Download data from the sonde to a computer and email to Project Leader and Data Manager

5.2.3 SEAN Data Manager

- Expertise in:
 - Database administration
 - IIS administration
 - Web and database programming
 - Spreadsheets (Microsoft Excel)
 - Data processing, validation, reporting, and archiving
 - Metadata management
 - Project management

5.3 Training Requirements

5.3.1 SEAN Project Leader

- Field station and sonde operation and maintenance

- Sonde calibration techniques
- Monthly Park Lead-transmitted data quality checks
- Record-keeping procedures
- Data processing, evaluation, and grading in KorEXO and Aquarius
- Data analysis and reporting
- Inventory and Monitoring Division required course covering methods for discrete and continuous water quality monitoring techniques, offered in conjunction with USGS

5.3.2 GLBA, KLGO, and SITK Park Leads

- Field station and sonde operation and maintenance
- Sonde calibration techniques
- Site visit record-keeping procedures
- Use of KorEXO software
- Data downloading and transmission

5.3.3 SEAN Data Manager

- Database administration
- Web and database development
- Sonde data processing software capabilities and operations
- I&M Data Management policy and guidance
- Aquarius configuration and operation

6 Operational Requirements

6.1 Annual Workload and Field Schedule

The field season is May 1 through October 31, though in some years river conditions may permit earlier deployment in the spring and recovery later in the fall. In the winter, sondes are sent back to the manufacturer for recalibration, routine maintenance, and any needed repairs. After returning from the manufacturer, the Project Leader ensures that all sondes are operating properly and ready for deployment. Sondes must be deployed and logging data before May 1.

Installation and decommissioning of the sondes at the continuous monitoring stations takes one field day each, assuming stations have been checked and needed repairs effected in the weeks prior. Once the sondes are operational, about one half day of work is required to access the monitoring site, visually check station integrity, download the data, and check sensor calibrations. More time may be needed for on-site minor repairs or recalibration.

Each park unit is strongly recommended to have more than one person trained to perform monthly water quality monitoring activities. Redundancy reduces the burden on one individual and ensures operational continuity in the case of schedule conflict, absence, or turnover. While the Project Leader can assume the full duties of the Park Lead, travel expenses for the Project Leader regularly traveling from Juneau to each site are high and were not included in the SEAN budget.

Project Leader duties will require approximately 20 days per year:

- 2 days coordinating annual sonde maintenance and supply orders
- 6 days visiting each park to check on station integrity and host training sessions
- 3 days resolving technical difficulties at the stations
- 1 day planning sampling logistics
- 2 days evaluating and grading data in Aquarius
- 1 day validating and certifying all data deliverables
- 1 day documenting and reviewing site visit files and clarifying notable events
- 4 days producing the annual update

Approximately 20 days are required for synthesis report preparation. More days may be required to finalize scope and specific objectives of the report, and for publication procedures.

Park Lead duties will require approximately 7 days per year:

- 2 days of pre-deployment tasks at the start of the monitoring season
- 3.5 days (approximately four hours on seven field days) for monthly site visits, data download, and sensor maintenance and calibration
- 0.5 days communicating data and station condition updates to the Project Leader and Data Manager

- 2 days for general station maintenance and repair in addition to above duties, and for storing and shipping the sonde to the Project Leader at the end of the season
- In some years, an additional 1–3 days may be required to check and service sites during adverse weather or river conditions.

Data Manager duties will require approximately 8 days per year:

- 1 partial day per monthly site visit to run file validation
- 1 day to validate and publish site visit files
- 1 partial day to validate and publish maintenance logs
- 1 partial day to validate and publish sonde raw data files
- 3 days to validate, export, and publish Aquarius time series data packages
- 1 day to update IRMA Data Store links to reports/resource briefs
- Occasional hours for purchasing and shipping supplies
- Additional days required if SOP and/or protocol updates become necessary

6.2 Facility and Equipment Needs

At each park unit:

- Water quality monitoring infrastructure (established in 2010 and varies by park)
- Water quality sonde with deployment sensor guard
- Handheld device and sonde-to-handheld connector cable
- Calibration-only sensor guard
- Calibration solutions for turbidity (KLGO only), pH, and conductivity, and a NIST-traceable thermometer
- Sonde and sensor cleaning supplies
- Deionized or distilled water
- Field notebooks and printed site visit worksheets
- Hard copy of protocol and field SOPs
- Cell phone
- Covered storage area for sondes, calibration solutions, cables, cleaning supplies, miscellaneous hardware, and spare parts
- Computer with USB port for retrieving data from the handheld, and YSI USB-to-microUSB cable
- Access to NPS network server for reliably storing raw sonde data

At the SEAN Juneau office:

- Backup sonde components, calibration solutions, and other accessories

- NPS-networked IT infrastructure
- Aquarius login credentials for Project Leader and Data Manager

6.3 Start-up Costs and Budget Considerations

Monitoring program start-up costs were far greater than those for normal annual operations (Table 4). Miscellaneous expenses associated with building site infrastructure for the monitoring stations in spring 2010 were estimated at \$1,500, not including labor and travel costs for personnel contracted to do the work. In 2010, three water quality sonde packages were purchased for approximately \$30,000, with two backup systems also acquired for approximately \$15,000. Application development to automate the data processing was about 0.1 person-years of data manager time, approximately \$10,500. These durable equipment and implementation costs were paid for by SEAN in FY09 through FY11 funds.

In 2020, an upgraded equipment suite was purchased to replace the YSI 6-series sondes and sensors that had been in use since the program began. No backup systems were acquired, though a sensor replacement contingency was built into the annual budget. All sondes and sensors are serviced by YSI annually, with key probe modules (pH, DO) and central wiper brushes replaced each year per manufacturer recommendation. Other annual costs are primarily consumables such as calibration solutions and cleaning supplies (Table 4). A decade into this monitoring effort, the initial physical infrastructure at each site remains effective and stably installed; no significant changes or expenses have been required.

The SEAN portion of established Interagency Agreements with USGS to support river gaging stations in SITK and KLGO (described in Section 2.1) is \$10,000 annually per site.

Table 4. Estimated equipment and supply costs for the water quality monitoring program (updated 2022).

Category	Item	Price/Unit	Units	Total	Comments
Start-up Costs	500 mL squirt bottle	\$ 15	6	\$ 90	Replace every few years
	Scrub brushes, large and small	\$ 10	3	\$ 30	Replace every few years
	Site infrastructure and installation	\$ 200	3	\$ 600	Pipe, caps, bolts, steel rod, drill bits, hose clamps, etc.
	Assorted cleaning supplies	\$ 40	3	\$ 120	Resupply as needed
	Assorted calibration supplies	\$ 30	3	\$ 90	Chemical waste bucket, bottles, etc.
	Covered clipboards	\$ 35	3	\$ 105	–
	Binder with printed protocol	\$ 50	3	\$ 150	–
	Nitrile gloves	\$ 23	3	\$ 69	1 box per park
	NIST thermometers	\$ 45	3	\$ 135	Replace/recalibrate every two years
YSI Sondes and Sensors	EXO3 sonde	\$ 4,999	3	\$ 14,997	–
	EXO handheld	\$ 2,765	3	\$ 8,295	–
	Field cable	\$ 645	3	\$ 1,935	–
	Conductivity/Temperature sensor	\$ 1,700	3	\$ 5,100	–
	Dissolved Oxygen sensor	\$ 1,999	3	\$ 5,997	–
	pH sensor	\$ 670	3	\$ 2,010	–
	Turbidity sensor	\$ 1,845	1	\$ 1,845	–
	Central wiper	\$ 1,226	3	\$ 3,678	–
Annual Sonde and Sensor Service by YSI	EXO3 sonde service	\$ 500	3	\$ 1,500	–
	DO sensor cap replacement	\$ 200	3	\$ 600	–

Table 4 (continued). Estimated equipment and supply costs for the water quality monitoring program (updated 2022).

Category	Item	Price/Unit	Units	Total	Comments
Annual Sonde and Sensor Service by YSI (continued)	pH sensor module replacement module	\$ 250	3	\$ 750	–
	Central wiper service	\$ 50	3	\$ 150	–
Annual Consumables	pH 4 buffer (case of 6 pints)	\$ 82	5	\$ 410	10 per park
	pH 7 buffer (base of 6 pints)	\$ 82	5	\$ 410	10 per park
	pH 10 buffer (case of 6 pints)	\$ 82	5	\$ 410	10 per park
	Conductivity 1,000 µs/cm standard (case of 8 pints)	\$ 128	5	\$ 640	12 per park
	Turbidity 124 FNU standard (1 gallon)	\$ 340	1	\$ 340	KLGO only
	Distilled water (1 gallon)	\$ 3	9	\$ 27	3 per park
	Rite in the Rain paper for site visit worksheets	\$ 35	1	\$ 35	–
	D batteries for sonde (pack of 12)	\$ 16	4	\$ 64	16 batteries per park
	Replacement wiper brushes	\$ 65	12	\$ 780	4 per park
	YSI maintenance kit	\$ 50	3	\$ 150	One per year per park
Annual Shipping	–	\$ 400		\$ 400	Between SEAN office, parks & YSI
Annual Contingency	For sensor failure/repair	–		\$ 2,000	–
Annual Streamflow Monitoring	Interagency Agreements with USGS for Taiya and Indian River gaging stations	\$ 10,000	2	\$ 20,000	–

6.4 Protocol Revision Process

This protocol may be updated or revised as new knowledge and technologies become available. Updates may also correct significant errors in the document or refine reporting approaches. Annual end-of-season assessments and formal protocol reviews once every five years both can prompt protocol modifications. Revisions will balance the advantages of new monitoring approaches with the possibility of disrupted data continuity. Every effort will be made to ensure that a complete, certified protocol is available before the start of a new monitoring season.

This protocol consists of a narrative and a suite of standard operating procedures (SOPs). The SOPs are intended to be living documents and revised as needed, while the narrative remains static; as such, the SOPs are published separately. All revisions require review for scope, clarity, and technical soundness. Minor edits to existing protocol documents – for example, formatting, simple clarifications of existing content, small changes in the task schedule or project budget, or general updates to information management handling – may be reviewed internally and approved by the SEAN Program Manager. Major revisions to project objectives, data collection, analysis techniques, or sampling design trigger external peer review coordinated by the Alaska Region Inventory and Monitoring Program Manager.

The protocol is deliverable FQ_A; revision processes are described in SOP 11.

7 Other Considerations

This monitoring program has been designed to document basic water quality and streamflow status and trends in selected SEAN rivers. By tracking seasonal and annual variations in core parameters at a fine temporal scale, meaningful comparisons with current and future vital sign monitoring programs can be established.

7.1 Expansion of the Existing Program

The water quality and streamflow monitoring effort can grow with increased future staffing, scope, and budget. The first priority for additional funding would be enhanced spatial coverage by establishment of identical core parameter monitoring stations at other waterbodies, especially in GLBA where there is high diversity of stream age, size, and type. The rapidly changing influence of glacial meltwater on GLBA watersheds raises pressing environmental questions and fuels interest and value. USGS water quality data exists for the Alsek River between Alsek Lake and the mouth near Dry Bay, but a smaller glacial stream in upper Glacier Bay would be the best candidate for an NPS-led monitoring station, though still posing considerable logistical challenges for routine access and lacking a proximal source of discharge data.

Generally, linking the patterns noted in water quality parameters to co-located streamflow gages enhances data impact and interpretation. In KLGO, the Skagway River could be included for future monitoring if a gaging station were added. The current Taiya River site may need to be modified or temporarily decommissioned if the existing Dyea Road bridge is replaced.

In SITK, there are no other stream options for monitoring, but the current site on the Indian River, just outside the NPS boundary, might experience vandalism or other issues because of its proximity to a population center. If issues arise, the park footbridge could function as a potential site, although a location with consistent, adequately deep water may not be available. The park is interested in better understanding how water quality conditions vary from the SEAN sonde downstream to the river mouth, and a complementary sampling program could enhance both monitoring data interpretation and management impact.

Another priority for program augmentation is expanding the spatial and/or temporal sampling of the streams already selected for monitoring. A number of point measurements above and below and a cross-section at the fixed stations would offer insight to the variability of water quality parameters in adjacent reaches.

7.2 Adding New Sampling Strategies

One relatively easy and low-cost program improvement would be to establish water temperature monitoring in multiple GLBA streams. Low-cost temperature loggers (such as Onset HOBO TidbiTs, about \$140 each as of 2021) could be placed in streams and left unattended for many months before downloading. Each TidbiT can store nearly 40,000 data points at custom time intervals over five years of battery life before downloading is necessary. Once downloaded, the memory can be reset. These would provide a valuable water temperature record for streams exposed to important environmental forces such as glacial melt and long-term climate change. Water temperature can be

linked to other important environmental parameters such as changes in water chemistry or organism growth and survival (e.g., maturation timing of salmonid eggs). Before pursuing expanded water temperature monitoring in GLBA, a more formal scoping process would need to be initiated between the SEAN and park staff.

7.3 Integrating Water Quality and Streamflow Data with Other Studies

As the SEAN water quality and streamflow dataset grows over time, there will be opportunities for using this information to support investigations extending beyond the scope of annual updates and synthesis reports. Cumulative water temperature data from all three monitored rivers was included in the Inventory and Monitoring Division Aquatics Working Group's project entitled, "Water temperature under a changing climate: regional and watershed-scale patterns and their ecological drivers in US National Parks." The full study record has also been shared with other agencies monitoring Alaskan rivers, upon request.

The effects of development may be apparent from water quality trends. The Indian River is partially urbanized upstream of the SITK boundary. Some water diversion (presently unquantified) occurs in the Indian River with potential harmful ecological effects. Water temperatures may rise during summer low flow intervals and drop more abruptly with freezing air temperatures in the winter. DO may decline due to increased fine sediment inputs, algal growth, reduced water levels, and/or increased summer temperatures. In August 2013, the lowest reach of the Indian River experienced a multi-week hypoxic event, with DO levels reaching a minimum of 1.7 mg/L (16% saturation; Sergeant et al. 2017). Low streamflows, high spawning salmon counts, and increased fish mortality occurred during the same period. Hypoxic conditions have not been observed in other summers (2010 – 2021) with similarly concurrent influential extremes, and the role of spawning salmon respiration may warrant further study. Watershed development may drive runoff impacts due to increased impervious surfaces and lead to chronic and/or acute influxes of contaminants such as oil and grease. In addition to water quality impacts, urban development can alter in-stream habitat by decreasing the recruitment of large woody debris (LWD), increasing bank erosion, modifying natural flow regimes, and increasing the probability of introducing invasive species. The SEAN's Environmental Contaminants vital sign (Sergeant et al. 2018) complements ongoing water quality work, tracking mercury in riverine Dolly Varden as well as a broad suite of metals, polycyclic aromatic hydrocarbons, and persistent organic pollutants in marine mussels. Two sites within the Indian River watershed are sampled for Dolly Varden and one coastal location in SITK for mussels.

In KLGO, the Taiya River watershed landscape is changing under climate influences and as glaciers recede (36% coverage in 2001 to 29% in 2010; RGI Consortium 2017). Actively deglaciating basins are highly dynamic with regards to their surface runoff, snow/ice melt influx, sediment sources, and potential for outburst floods (Curran 2020). Significant bank erosion has occurred during storm-driven high streamflow events, yielding pulses of fast-moving, very turbid water with tremendous scouring capacity and certain, albeit unstudied, impacts to river biota and habitats. The SEAN's Water Quality, Weather and Climate (Sousanes et al. 2021), and Glacier Dynamics (in development) vital signs together track temporal patterns in atmospheric, riverine, and ice conditions within the park. Future data analyses could emphasize shifting seasonality of streamflow (both precipitation-

and melt-driven) and turbidity, as well as links between upper elevation weather and downstream river responses.

The invasive diatom *Didymosphenia geminata*, of considerable concern at SITK, may spread and thrive at warmer temperatures and suppress DO levels in streams. Research on linkages between terrestrial and aquatic systems suggests that elevated surface temperatures and carbon dioxide levels will affect the distribution and productivity of plants, in turn affecting the amount and quality of leaf litter and woody debris entering streams and causing fluctuations in stream oxygen levels (Meyer and Pulliam 1992, Sweeney et al. 1992). In addition, surface water quality could also be altered by predicted changes in the frequency of disturbances such as windstorms and coastal floods (Meyer and Pulliam 1992, Parson et al. 2000). Ultimately, changes to the quality and quantity of runoff from terrestrial ecosystems may affect nearshore marine systems in and around SEAN parks, especially in terms of supporting anadromous fish populations and supplying important terrestrial nutrients to coastal regions (Hood and Scott 2008). All of these hypotheses can be investigated using the future SEAN water quality data set.

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