



Protocol Implementation Plan for Monitoring Wet Deposition in Southwest Alaska Network Parks

Version 1.0

Natural Resource Report NPS/SWAN/NRR—2017/1463



ON THE COVER

Wet deposition monitoring station AK97, located in King Salmon, Alaska near Katmai National Park and Preserve headquarters (NPS/CARISSA TURNER).

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Natural Resource Report NPS/SWAN/NRR—2017/1463

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June 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Bartz, K. K., and K. M. Junghans. 2017. Protocol implementation plan for monitoring wet deposition in Southwest Alaska Network Parks: Version 1.0. Natural Resource Report NPS/SWAN/NRR—2017/1463. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Acknowledgments.....	ix
List of Acronyms	xi
Background.....	1
Conceptual Framework for Monitoring	5
Measurable Objectives.....	7
Methods.....	9
Field Methods.....	9
Laboratory Methods	10
Sampling Design, Monitoring Schedule, and Quality Assurance.....	11
Sampling Design	11
Monitoring Schedule	12
Quality Assurance	12
Data Management, Processing, Analysis, and Reporting	15
Data Management and Processing.....	15
Analysis and Reporting	16
Personnel Requirements and Training.....	19
Roles and Responsibilities.....	19
Training Procedures.....	19
Budget.....	21
Safety	23
Standard Operating Procedures.....	23
Literature Cited	25
Appendix A.....	29

Figures

	Page
Figure 1. Map of five park units included in the Southwest Alaska Network.	3
Figure 2. Conceptual model of human activities from the SWAN Vital Signs Monitoring Plan.	6
Figure 3. The precipitation collector (left) and raingage (right) used to monitor wet deposition at AK97.	9
Figure 4. Location of AK97, relative to the other 3 active NADP/NTN sites in Alaska (shaded dark gray) and the other 266 active sites in the rest of North America.	11
Figure 5. Annual map of sulfate ion concentrations for the year 2013.	16
Figure 6. Trend plot showing annual precipitation-weighted mean concentrations of nitrate at AK97.	18
Figure A1. The CloudGate LTE 1 gateway, with the three LED lights to the right of the central Ethernet port lit.	31

Tables

	Page
Table 1. Four nationwide networks used by the National Park Service for monitoring air quality.	1
Table 2. Anthropogenic factors affecting air quality in or near SWAN park units, and potential measures for Vital Signs monitoring. One potential measure – wet deposition – is included in this Protocol Implementation Plan; others are being (or could be) addressed externally through monitoring by NPS or partners.	5
Table 3. Monitoring objectives, sampling methods, and data collected at the AK97 site through participation in the NADN/NTN.	10
Table 4. Summary of operating requirements for NADP/NTN sites.	11
Table 5. Documents supporting the NADP Quality Management System (adapted from Table 1 in NADP 2016a).	13
Table 6. List of NTN-specific note codes and the associated quality rating (QR) code for each.	14
Table 7. Data processing and certification matrix for wet deposition monitoring at AK97.	15
Table 8. Three NADP Completeness Criteria tabulated for each full year on record at AK97, with asterisks (*) indicating years when minimum thresholds for meeting these criteria were not met.	17
Table 9. Tabular data sets that are downloadable from the NADP website.	18
Table 10. Estimated annual operating costs (based on FY2017 dollars) for implementing the NPS ARD protocol at AK97.	21
Table 11. Standard Operating Procedures required to execute this Protocol Implementation Plan.	23
Table A1. Initial costs (based on FY2015 dollars) to start telemetry at AK97. The gateway and antennae were purchased through GCI.	32
Table A2. Monthly costs (based on FY2015 dollars) to run telemetry at AK97. Taxes and surcharges do not apply because the internet is unregulated.	32

Acknowledgments

This document leans heavily on many previously published manuals and protocols, particularly those by E. Porter and K. Morris (of the NPS Air Resource Division) and Z. Richter (of the NPS Arctic Network). D. Gay and R. Larson (of the National Atmospheric Deposition Program) provided technical guidance throughout the writing process; J. Lawler, P. Neitlich, and A. Miller offered helpful reviews toward the end. Finally, we wish to acknowledge the employees of Katmai National Park and Preserve, who enable AK97 to operate year round, specifically M. Sturm, T. Hamon, C. Turner, A. Reischauer, K. Griffin, J. Livingston, C. Billock, and many others.

List of Acronyms

ALAG	Alagnak National Wild River
ANIA	Aniakchak National Monument and Preserve
ARD	Air Resources Division
Ca ²⁺	calcium ion
CAL	Central Analytic Laboratory
CASTNet	Clean Air Status and Trends Network
Cl ⁻	chloride ion
cm	centimeter(s)
DCU	Device Configuration Utility
EPA	Environmental Protection Agency
FORF	Field Observer Report Form
FY	fiscal year
GCI	General Communication Inc.
hr	hour(s)
IMPROVE	Interagency Monitoring of Protected Visual Environments Network
in	inch(es)
K ⁺	potassium ion
KATM	Katmai National Park and Preserve
KEFJ	Kenai Fjords National Park
kg/ha/yr	kilograms per hectare per year
LACL	Lake Clark National Park and Preserve
LAN	local area network
M2M	machine-to-machine
MDN	Mercury Deposition Network
Mg ²⁺	magnesium ion
mg/L	milligrams per liter
mL	milliliter(s)
mo	month(s)
N	nitrogen
Na ⁺	sodium ion
NADP	National Atmospheric Deposition Program
NH ₄ ⁺	ammonium ion
NO ₃ ⁻	nitrate ion
NPS	National Park Service
NTN	National Trends Network
PDA	Personal Digital Assistant
PIP	Protocol Implementation Plan
PSTN	Public Switched Telephone Network
QA	Quality assurance
QC	Quality control

List of Acronyms (continued)

SO ₄ ²⁻	sulfate ion
SOP	Standard Operating Procedure
SWAN	Southwest Alaska Network
USGS	United States Geological Survey
VoIP	Voice over Internet Protocol
WAN	wide area network
wk	week(s)
μm	micrometer(s)

Background

Atmospheric deposition is the process by which airborne pollutants reach the earth's surface. This occurs either through wet deposition from rain, snow, sleet and fog, or through dry deposition from complex atmospheric processes such as settling, impaction and absorption. Deposition can include a wide variety of natural and anthropogenic pollutants, such as inorganic elements (e.g., sulfur, nitrogen, mercury and other metals) and both inorganic and organic compounds (e.g., sulfate, nitrate and ammonium, as well as pesticides and herbicides).

Once deposited, pollutants can have a variety of ecosystem effects. Nitrogen and sulfur compounds, for example, can result in acidification of terrestrial and aquatic habitats, eutrophication of freshwater, estuarine and marine waterways, soil nutrient and base cation leaching, and loss of sensitive species (Porter and Morris 2007). Arctic and subarctic ecosystems are particularly vulnerable to impacts from the deposition of excess nitrogen and sulfur (Sullivan et al. 2011a).

The National Park Service (NPS) is responsible for the protection and conservation of the areas it manages in order to “leave them unimpaired for the enjoyment of future generations,” as directed by the Organic Act of 1916 (16 U.S.C. §1). The NPS also has an affirmative responsibility under the Clean Air Act of 1977 to protect parks and their resources from sources of air pollution and to participate in national and regional initiatives to control air pollution (42 U.S.C. §7470(2)).

Since the late 1970s, the NPS Air Resources Division (ARD) has managed a comprehensive air quality program, emphasizing the collection of credible air quality information to support scientifically sound resource management decisions in parks. In general, air quality monitoring in parks, including monitoring of wet deposition, is conducted in conjunction with several multi-partner national networks (Table 1). Cooperation between the NPS and these national networks has succeeded in producing high quality, defensible data that are spatially and temporally comparable. This document addresses monitoring of wet deposition, in collaboration with the National Atmospheric Deposition Program's National Trends Network (NADP/NTN).

Table 1. Four nationwide networks used by the National Park Service for monitoring air quality.

Network	Measured Parameters	Information and Data
National Atmospheric Deposition Program/National Trends Network (NADP/NTN)	Wet deposition of sulfate, nitrate, ammonium, calcium, magnesium, potassium, sodium, chloride; acidity, conductivity	http://nadp.sws.uiuc.edu/NTN/
National Atmospheric Deposition Program/Mercury Deposition Network (NADP/MDN)	Wet deposition of mercury	http://nadp.sws.uiuc.edu/MDN/
Clean Air Status and Trends Network (CASTNet)	Dry deposition of sulfate, nitrate, ammonium, nitric acid, sulfur dioxide; ozone	http://www.epa.gov/castnet/
Interagency Monitoring of Protected Visual Environments Network (IMPROVE)	Fine and coarse particle mass; sulfate, nitrate, organic and elemental carbon; other elements; scenic views, scattering, absorption	http://vista.cira.colostate.edu/improve/

The NADP/NTN began operation in 1978 and currently includes 270 active monitoring sites nationwide. Precipitation samples are collected using a standardized protocol and are analyzed in a centralized laboratory for several chemical constituents using uniform procedures. The chemical constituents include sulfate, nitrate, ammonium, chloride, calcium, magnesium, potassium, sodium, conductivity, and acidity (pH). Resulting data are presented in terms of “concentration” and “wet deposition.” Concentration data, expressed in milligrams per liter (mg/L) of precipitation, are useful in determining spatial and temporal trends because they are not dependent on the amount of precipitation at each site, which can vary substantially from year to year. Wet deposition data, expressed in kilograms per hectare per unit time (kg/ha/yr or season), are calculated by taking into account both the concentration and the amount of precipitation at each site. Years or seasons with higher amounts of precipitation will yield higher levels of wet deposition. Wet deposition data provide the total amount of pollutants actually deposited on the ground via precipitation and quantify the pollutant input to ecosystems. The ARD recommends a threshold of <1 kg/ha/yr for wet deposition of nitrogen or sulfur to protect sensitive ecosystems (NPS ARD 2013).

In 1998, the NPS initiated a natural resource Inventory and Monitoring Program. The purpose of the program was to develop a baseline inventory of significant natural resources in national parks, and to monitor key ecological indicators – known as Vital Signs – over time. Now the program includes more than 270 park units organized into 32 ecoregional networks. The Southwest Alaska Network (SWAN) is one of four networks established within Alaska under the Inventory and Monitoring Program. It consists of five park units: Lake Clark National Park and Preserve (LACL), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), Alagnak National Wild River (ALAG), and Aniakchak National Monument and Preserve (ANIA). Collectively, these units comprise 3.8 million hectares and extend over 650 km of the Alaska and Kenai Peninsulas (Figure 1).

During a series of scoping workshops in 2002-2003, experts within and outside the NPS identified air quality as a Vital Sign category that warranted long-term monitoring in SWAN park units (Bennett et al. 2006). However, the resulting Monitoring Plan included only one air quality-related Vital Sign (visibility and particulate matter), which was slated for monitoring by others independently of the SWAN (Bennett et al. 2006). Then, in 2009, the SWAN changed course and installed a NADP/NTN site in King Salmon, Alaska for monitoring air quality via wet deposition. It remains the only air quality monitoring site that SWAN directly funds and oversees.

This Protocol Implementation Plan (PIP) outlines the means by which wet deposition data are collected, managed, and reported at that site. In short, the SWAN will implement a peer-reviewed protocol published by the ARD (Porter and Morris 2007), which follows a nationally implemented protocol published by the NADP/NTN (NADP/NTN 2015). The SWAN will employ the ARD protocol in its entirety, with minor modification to the methods to account for its implementation at a particular site in King Salmon, known as AK97. This modification pertains to the means by which data are transmitted. Specifically, data collected from the AK97 raingage are no longer submitted manually on a weekly basis to the NADP. Rather, data are uploaded automatically in near real time, because the raingage was converted to telemetry in 2015, as described in Appendix A.

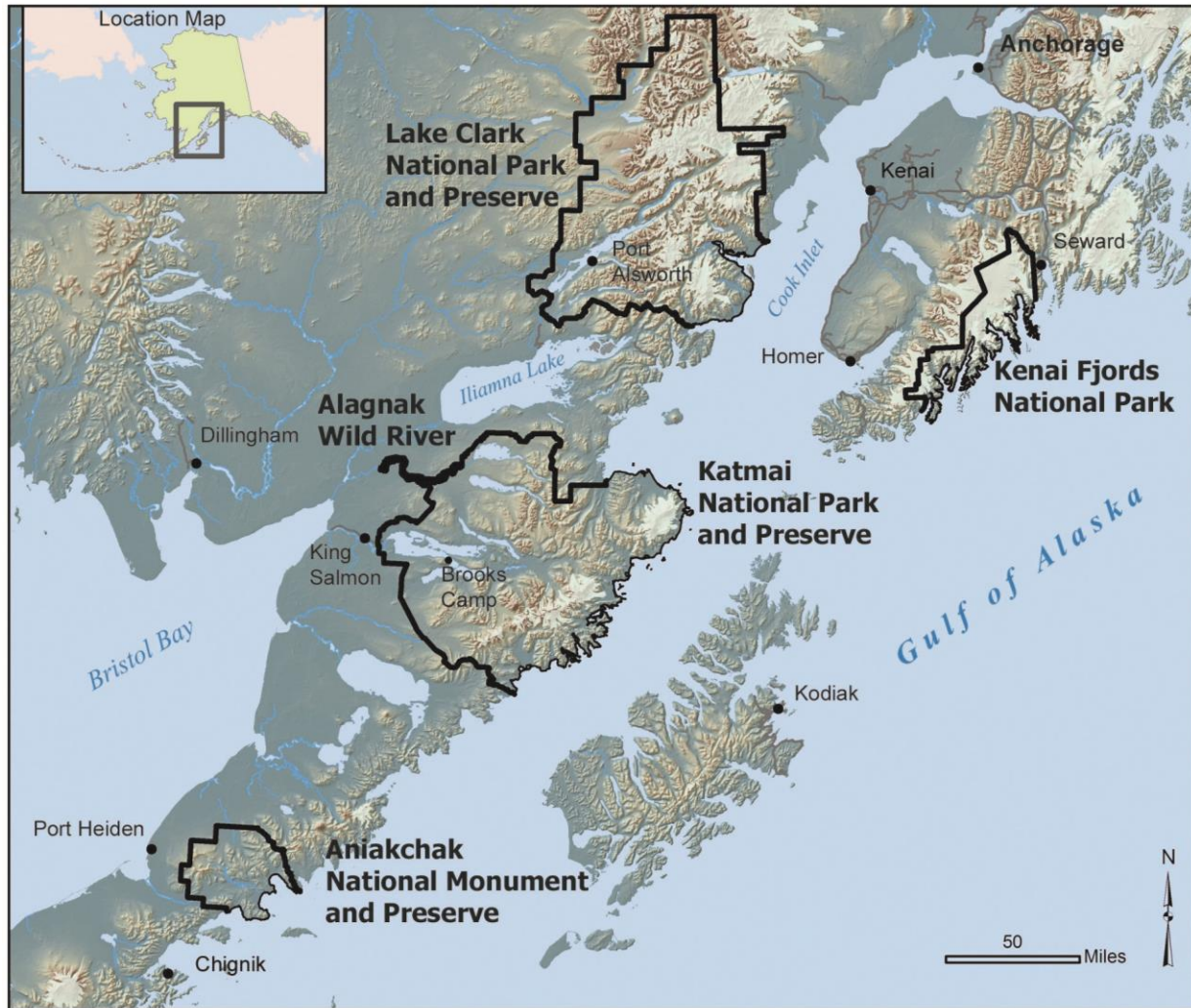


Figure 1. Map of five park units included in the Southwest Alaska Network.

Conceptual Framework for Monitoring

Air quality in SWAN park units is considered pristine by national standards, but airborne pollutants associated with increasing regional and global industrialization have the potential to degrade current conditions (Table 2). Threats to air quality related to industrialization include mining, coal-fired power production, and oil and gas development, followed by atmospheric transport of the pollutants generated by these activities (Bennett et al. 2006). Limited monitoring of fine particulates ($< 2.5 \mu\text{m}$) in KATM from 1987 to 1992 suggested sources from long-range transported anthropogenic aerosol, sea-salt aerosol, and local soil dust, as well as elevated concentrations of lead and bromide, indicative of emissions from motor vehicles burning leaded gasoline (Polissar et al. 1998). With continued regional and global industrialization, atmospheric deposition of airborne pollutants is expected to increase (Arnold et al. 2016, Peters et al. 2011).

Table 2. Anthropogenic factors affecting air quality in or near SWAN park units, and potential measures for Vital Signs monitoring. One potential measure – wet deposition – is included in this Protocol Implementation Plan; others are being (or could be) addressed externally through monitoring by NPS or partners.

Factors	Management Issues	Potential Measures
Air pollution from anthropogenic causes, particularly regional and global industrialization	Air pollution can adversely impact physical conditions, ecological processes, and health of wildlife and humans	The ARD focuses on several air quality indicators, including wet deposition, visibility, ozone, and mercury

A conceptual model of human activities was developed during the series of workshops in 2002-2003, mentioned above. The model was later included in the SWAN Vital Signs Monitoring Plan (Bennett et al. 2006). This model related far-field and near-field influences on the environment to human-induced threats and their potential ecological effects (Figure 2). Specifically it linked wet deposition of atmospheric pollutants from global industrialization to changes in abundance, distribution, and diversity of resident and migratory species. It also linked the release of pollutants from regional development of oil, gas, and mineral resources to bioaccumulation of pollutants in food chains and direct mortality of aquatic and/or terrestrial organisms.

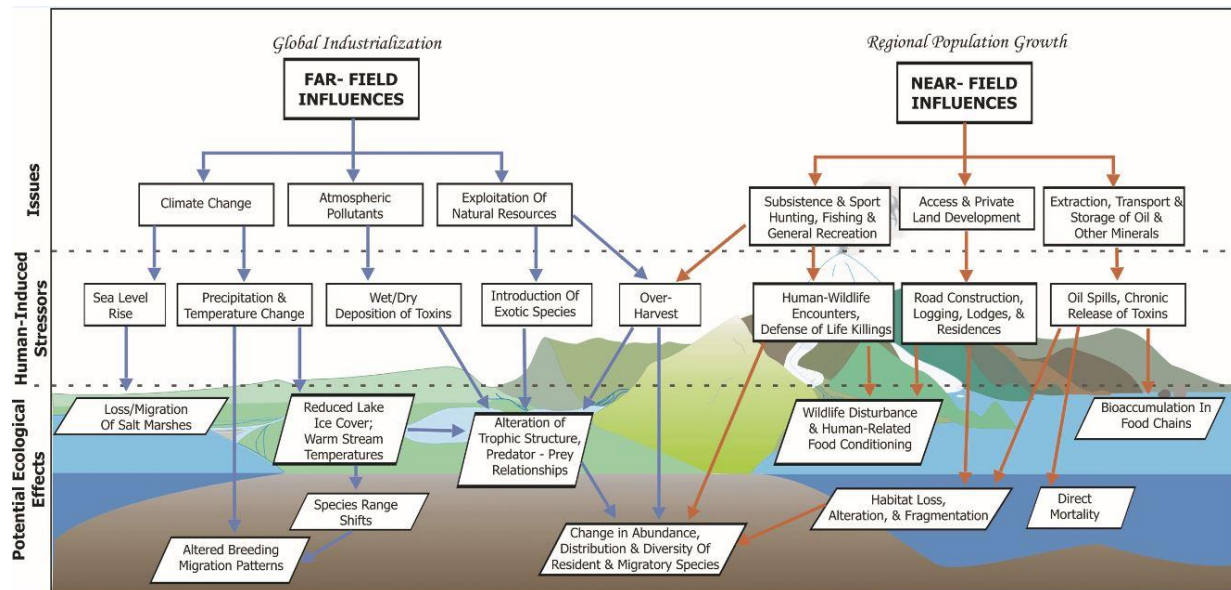


Figure 2. Conceptual model of human activities from the SWAN Vital Signs Monitoring Plan.

While not depicted in the conceptual model, the effects of nitrogen and sulfur deposition are manifold. Effects can be grouped broadly as pertaining to acidification or fertilization. Acidification effects include changes in soil and water chemistry that ultimately cause sensitive species to decline, altering community composition and biodiversity in terrestrial and aquatic ecosystems (Sullivan et al. 2011a). In addition to acidification, nitrogen deposition causes fertilization. Fertilization, like acidification, can favor certain species over others, altering community composition, reducing biodiversity, and facilitating invasion of nonnative species (Sullivan et al. 2011b).

Certain ecosystems are known to be particularly vulnerable to acidification and/or fertilization. Ecosystems sensitive to acidification include remote high-elevation lakes, steep headwater streams, and terrestrial communities characterized by base-poor soils (Sullivan et al. 2011a). Remote high-elevation lakes are also sensitive to nitrogen fertilization, as are arctic and alpine plant communities, wetlands, meadows, and semi-arid or arid lands (Sullivan et al. 2011b). Many lichen species are especially sensitive, with negative effects documented even at low levels of nitrogen loading (3 kg/ha/yr; Fenn et al 2003). Ecosystems in KATM are rated as very highly sensitive to acidification and moderately sensitive to fertilization (Sullivan et al. 2011c and 2011d).

Given the effects of atmospheric deposition on sensitive ecosystems, and the existence of those ecosystems in SWAN park units, other Vital Signs are likely to be affected by changes in air quality. For example, the “water quality” Vital Sign could show changes in lake pH and chlorophyll due to acidification and fertilization, respectively. The “vegetation composition and structure” and “sensitive vegetation communities” Vital Signs could show changes in plant community distribution, composition, and diversity due to fertilization and/or acidification.

Measurable Objectives

The overarching goal of participating in the NADP/NTN is to produce reliable wet deposition data with a nationwide context, enabling inter- and intra-site comparisons over time. The following specific objectives will be addressed by this monitoring:

- 1) Determine the status and trends in the concentrations of select chemical constituents in precipitation at the study site in King Salmon.
- 2) Determine the status and trends in the loadings of select chemical constituents deposited on the ground (annually or seasonally) via precipitation at the study site in King Salmon.

Chemical constituents include sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) ions; as well as conductivity (as $\mu\text{S}/\text{cm}$) and acidity (as pH). Note that this PIP does not cover other airborne pollutants, such as semi-volatile organic compounds or mercury.

The first objective utilizes the NADP/NTN concentration data (mg/L), whereas the second objective utilizes the wet deposition data and is expressed in terms of chemical loading (kg/ha/yr or season). The ARD protocol (Porter and Morris 2007) does not list objectives in “SMART format,” as defined by Doran (1981), so the objectives above are adopted with minor modification from other NPS air quality protocols (Richter 2012, NPS 2010).

Methods

Field Methods

The SWAN will monitor wet deposition using the same field methods described in the ARD protocol (Porter and Morris 2007). These methods rely on two key pieces of equipment: a precipitation collector and a raingage (Figure 3). The collector opens automatically during wet weather, allowing precipitation to fall into a sample bucket, and then closes as soon as the wet weather stops. The raingage measures the amount of precipitation that falls. It also records when the collector is in sampling mode to assess whether it opened and closed properly during wet and dry periods.



Figure 3. The precipitation collector (left) and raingage (right) used to monitor wet deposition at AK97.

At most NADP/NTN sites, the field methods are as follows. Every Tuesday morning at 0900 local time year round, a site operator retrieves the sample bucket from the collector, replaces it with a new one, checks the raingage, downloads the raingage data onto a personal digital assistant (PDA), completes a Field Observer Report Form (FORF), weighs and packages the sample, mails the sample to the NADP Central Analytical Laboratory (CAL), and emails the raingage data to the CAL. These procedures take approximately 30 to 60 minutes, not including travel time to/from the site. The NADP/NTN Site Operations Manual describes these methods in detail (NADP 2015). It also includes information on site maintenance and troubleshooting.

At AK97, telemetry has omitted the need to download the raingage data to a PDA and then email the data to the CAL. Appendix A describes installation, operation, and troubleshooting of telemetry at AK97.

Laboratory Methods

Precipitation samples are analyzed for various chemical constituents at the CAL, run by the Illinois State Water Survey and located in Champaign, Illinois (Table 3). Conductivity and pH are measured directly on unfiltered aliquots using conductivity and pH meters. For other constituents, the samples are filtered into pre-washed 60-mL high-density polyethylene bottles using 0.45 μm pore-size polyethersulfone filters. The filtrate is then measured via spectrometry, colorimetry, or chromatography. For additional details on laboratory methods see the CAL Quality Assurance Plan (Gartman 2014) and the laboratory SOPs (available upon request from the NADP).

Table 3. Monitoring objectives, sampling methods, and data collected at the AK97 site through participation in the NADN/NTN.

Objectives	Sampling Methods	Data Collected	Analysis Tools	Data Derived
1. Determine the status and trend in the concentrations of select chemical constituents at AK97	Precipitation collector and raingage ^A	Precipitation sample; precipitation depth (cm) ^B	Chemical analysis of the precipitation sample by the NADP Central Analytical Laboratory ^C	Concentrations of Ca^{2+} , Mg^{2+} , K^{+} , Na^{+} , NH_4^{+} , NO_3^{-} , Cl^{-} and SO_4^{2-} (mg/L); acidity (H^{+} as pH) and specific conductivity ($\mu\text{S}/\text{cm}$); precipitation volume (mL) ^D
2. Determine the status and trend in the loadings (wet deposition) of select chemical constituents at AK97	Precipitation collector and raingage ¹	Precipitation sample; precipitation depth (cm) ^B	Chemical analysis of the precipitation sample by the NADP Central Analytical Laboratory ^C	Wet deposition of Ca^{2+} , Mg^{2+} , K^{+} , Na^{+} , NH_4^{+} , NO_3^{-} , Inorganic N, Cl^{-} and SO_4^{2-} (kg/ha/yr or season); acidity (H^{+} as pH); precipitation volume (mL) ^D

^A Aerochem Metrics collector and ETI Instrument Systems NOAH IV raingage.

^B Total amount of precipitation (cm) measured by the raingage during the summary period.

^C Analytical tools include Ion Chromatography, Flow Injection Analysis Colorimetry, and Inductively Coupled Plasma-Optical Emission Spectroscopy, among others.

^D Total volume of precipitation (mL) accumulated by the collector for valid samples during the summary period.

Sampling Design, Monitoring Schedule, and Quality Assurance

Sampling Design

The SWAN operates one NADP/NTN site, AK97, which is located in King Salmon, Alaska at 58.6794 °N and 156.6664 °W (Figure 4). Operating requirements for NADP/NTN sites are outlined briefly below (Table 4). Additional information is available at the NADP website, where the manuals and SOPs are posted. The NADP Site Selection and Installation Manual, in particular, contains spatially explicit rules and guidelines governing site choice and equipment set-up (NADP 2011).

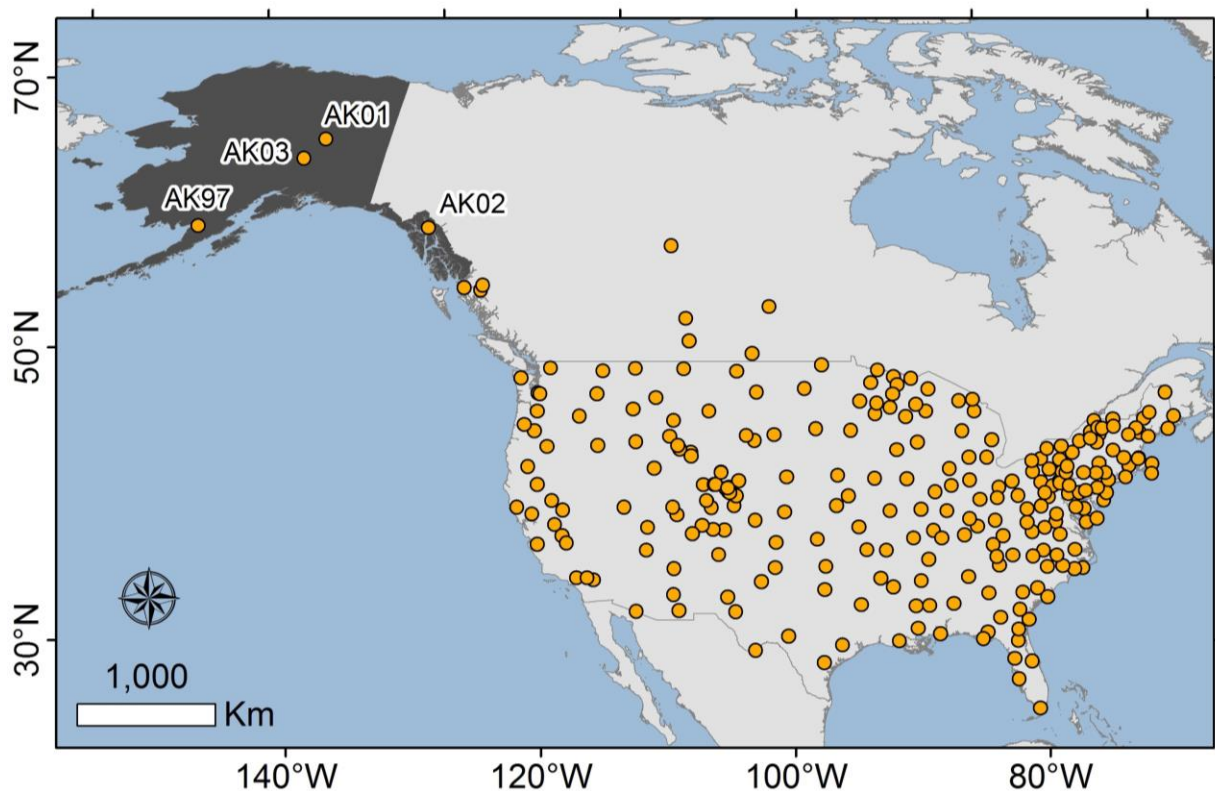


Figure 4. Location of AK97, relative to the other 3 active NADP/NTN sites in Alaska (shaded dark gray) and the other 266 active sites in the rest of North America.

Table 4. Summary of operating requirements for NADP/NTN sites.

Data Collection	Siting Criteria	Utilities Required	Shelter Required	Operator Effort	Annual Cost
Weekly	Rigid	AC or solar	None	~1 hr/wk ^A	\$11,093 ^B

^A Excluding travel time to/from the monitoring site.

^B See the Budget section for details.

Monitoring Schedule

Precipitation samples are retrieved from NADP/NTN sites year round on Tuesdays at 0900 local time. Ideally, sample buckets are retrieved after 168 hours on the collector (i.e., 24 hrs/day * 7 days). However, samples are still considered valid as long as they do not exceed 194 hours on the collector.

Shipment of samples to the CAL is also time-sensitive. Samples received by the CAL less than 16 days after retrieval from the collector are analyzed as normal. Those received 16 to 60 days after retrieval are flagged, but remain valid unless other issues are present. After 60 days, sample chemistry is automatically invalidated.

Quality Assurance

The NADP has a well-documented Quality Management System governing the quality assurance (QA) and quality control (QC) activities within the program and its networks. Documents supporting the Quality Management System include, but are not limited to, the NADP Quality Management Plan (NADP 2016a), the NADP Network Quality Assurance Plan (NADP 2016b), and the CAL Quality Assurance Plan (Gartman 2014). Additional QA/QC activities are detailed in the annual CAL QA reports, as well as external QA reports by the U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA). See Table 5 for details.

Table 5. Documents supporting the NADP Quality Management System (adapted from Table 1 in NADP 2016a).

Document(s)	Topics Covered						URL ^B
	Project organization/ management	Quality assurance policy/ general requirements	Data validation/ verification	Laboratory analysis/ quality assurance	Public data release protocols	External quality assurance assessment ^A	
NADP Quality Management Plan	✓	✓	—	—	✓	—	http://nadp.sws.uiuc.edu/lib/qaplans/NADP_QMP.pdf
NADP Quality Assurance Plan	✓	✓	✓	✓	✓	✓	http://nadp.sws.uiuc.edu/lib/qaplans/NADP_Network_Quality_Assurance_Plan.pdf
NADP Data Management Manual	—	—	✓	—	✓	—	http://nadp.sws.uiuc.edu/lib/manualsSOPs.aspx ^C
CAL Quality Assurance Plan	—	—	✓	✓	—	—	http://nadp.sws.uiuc.edu/lib/qaplans/qapCal2014.pdf
CAL quality assurance reports	—	—	✓	✓	—	—	http://nadp.sws.uiuc.edu/lib/qaReports.aspx#CAL
USGS and EPA quality assurance reports	—	—	—	—	—	✓	https://bqs.usgs.gov/precip/ and http://nadp.sws.uiuc.edu/lib/qaReports.aspx#EXTQA

^A The NADP relies on various external QA assessments, including the USGS's Precipitation Chemistry Quality Assurance Project and the EPA's Site Systems and Performance Survey Program.

^B All URLs were accessed on March 10, 2017.

^C This document is currently in review and will be posted online later in 2017.

As part of the NADP Quality Management System, data validation flags (or “note codes”) are assigned to samples by the CAL and then verified by the program office. Each note code has an associated quality rating (QR) code (Table 6). Samples with QR codes of A or B are considered valid data with no or minor issues, respectively, while samples with QR codes of C are considered invalid data.

Table 6. List of NTN-specific note codes and the associated quality rating (QR) code for each.

QR Codes	Note Codes	Note Code Descriptions	Note Code Causes
B	a	Incomplete laboratory analysis	Insufficient sample volume for complete chemistry (≤ 12 mL)
	d	Visible debris in sample	1+ boxes in the Sample Condition block of the FORF indicated visible contamination
	h	Sample handling issue	Sample bottle leaked during shipment from the site to the CAL
	i	Low sample volume	Sample volume was low (>12 but < 30 mL), so sample was diluted to allow analysis
	m	Missing data on FORF	Incomplete information was contained in the field form
	z	Site operation issue	Sample record indicated sensor and motorbox did not operate properly
C	b	Bulk sample	Collector configured to be open continuously for any portion of the sampling period
	c	Gross contamination	Sample appearance and analytical results indicated significant contamination of the sample
	e	Extended sampling period	Sample duration exceeded the maximum 194 hour limit
	f	Field protocol problem	Problem in the field compromised the integrity of the sample
	l	Lab protocol problem	Problem in the laboratory compromised the integrity of the sample
	n	Sample not received within 30 days	No bucket deployed, or sample was lost in transit or received >30 days after removal
	p	Precipitation value unknown	Raingage data was missing so precipitation amounts were not known
	u	Undefined sample	Collector was open for extended periods of time when no precipitation was observed
	v	Low collection efficiency	Raingage indicated >0.03 in. of precipitation, but the bucket catch was <1.5 mL *

* Or (bucket catch) / raingage $< 10\%$.

Data Management, Processing, Analysis, and Reporting

Data Management and Processing

Data management and processing are handled exclusively by the NADP/NTN. Partners, such as the NPS, have no role from the time their precipitation samples are mailed to the time the certified data are posted online, 5-6 months later. However, information regarding data management and processing by the NADP/NTN is readily available at <http://nadp.sws.uiuc.edu/lib/qaPlans.aspx>. In particular, see the NADP Data Management Manual (NADP 2017).

The NADP/NTN generates three broad types of data: concentration data, wet deposition data, and precipitation data. Concentration data (mg/L) are useful for examining spatial and temporal trends of pollutants, as concentrations are not dependent on precipitation quantities. Wet deposition data (kg/ha/yr or season) are useful for evaluating the amounts of pollutants delivered to an ecosystem over a fixed period of time. Wet deposition, however, is dependent on precipitation quantity (i.e., wet deposition = concentration x precipitation) and may therefore differ significantly from year to year. Precipitation data (in/unit time) are the only type of provisional data that are readily available from the NADP/NTN. A data processing and certification matrix for these three data types is provided (Table 7).

Table 7. Data processing and certification matrix for wet deposition monitoring at AK97.

		Data Processing Level ^A				
		Level 0	Level 1	Level 2	Level 3	Level 4
Data Quality Level	Raw	Field Observer Report Form metadata	B	B	C	C
	Provisional	15-minute precipitation data ^D	B	B	Hourly or daily precipitation data ^D	B
	Certified	C	Weekly concentration and precipitation data; weekly reports	Weekly wet deposition data	Concentration and wet deposition data at various time scales (monthly, seasonally, annually)	Monthly reports; annual reports

^A Level 0 = unprocessed; Level 1 = entered/validated; Level 2 = value added; Level 3 = rescaled; Level 4 = modeled/synthesized.

^B Not available from the NADP/NTN, except by special request.

^C Not applicable.

^D Unprocessed (in/15 min) and rescaled (in/hr or day) precipitation data from the raingage, posted at <http://nadp.sws.uiuc.edu/siteOps/ppt/>.

Analysis and Reporting

Several ready-made figures are available on the NADP/NTN website, including annual maps of multiple sites and trend plots of individual sites. In addition to these figures, concentration, deposition, and precipitation data can be downloaded directly from the NADP website. These data and figures can be used by NPS Inventory and Monitoring networks for analyses and reporting.

Annual maps represent gridded interpolations in which grid points within 500 km of each site are used in computations. Alaskan sites are not pictured in the maps; rather they are listed in the legend (Figure 5). To access the maps from the NADP homepage (<http://nadp.sws.uiuc.edu/>), select the “Maps & Data” tab and the “Annual Maps” link. Then choose the network (“NTN maps”), map type (“Annual gradient maps”), year (1985-2015), parameter (concentration, deposition, or precipitation), analyte (specify the anion or cation), and file type (pdf, kmz, or grid). These maps are useful tools for comparing values at a given site to values elsewhere in the country. However, they have limited utility for AK97, because they are restricted to sites that meet the three NADP Completeness Criteria, and thus far AK97 has only met those criteria in 2013 and 2016 (Table 8).

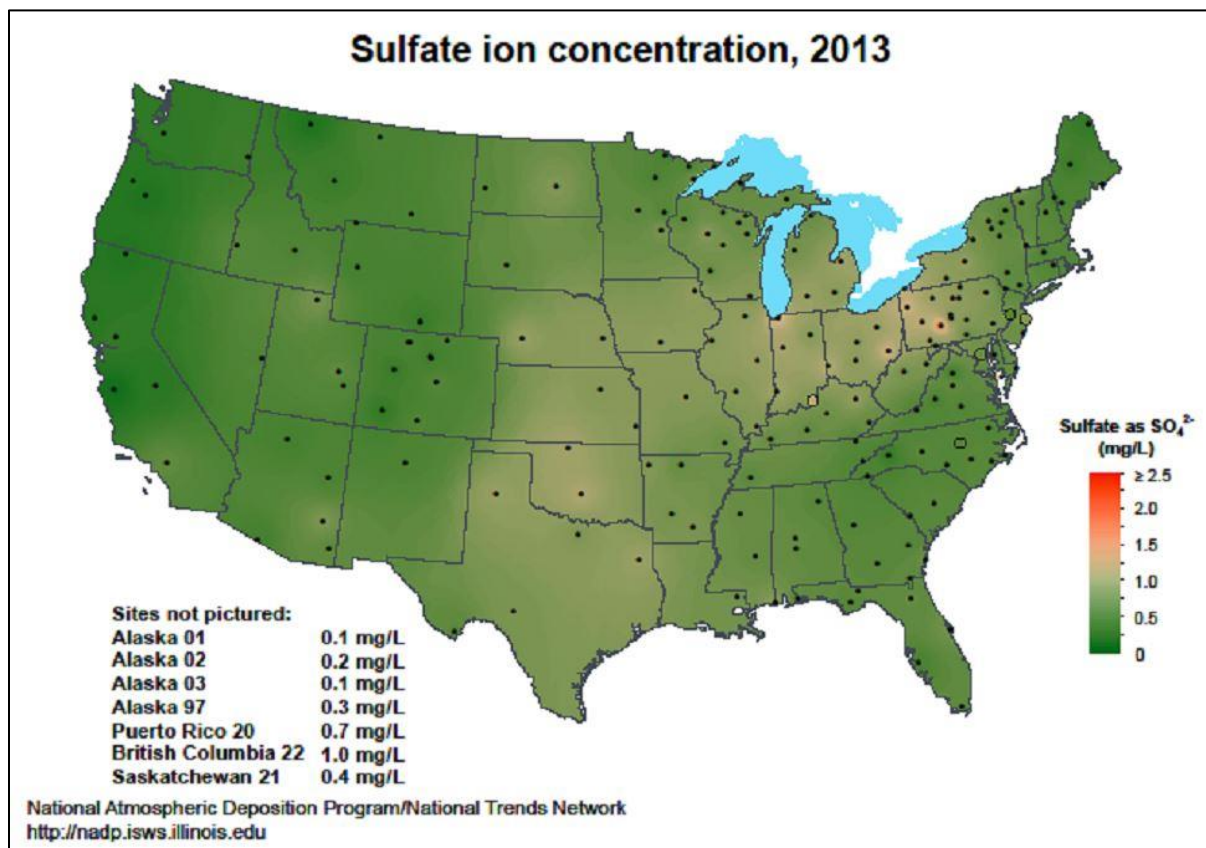


Figure 5. Annual map of sulfate ion concentrations for the year 2013.

Trend plots depict annual concentration, deposition, or precipitation data, characterized as meeting or not meeting the NADP Completeness Criteria (Figure 6). The trend line is a smoothed 3-year moving average with a 1-year time step, which only displays when the minimum completeness thresholds are

met. To access the trend plots from the NADP homepage, select the “Maps & Data” tab and the “NTN Data” link. From there, use the site list or interactive map to choose a site of interest, and select the “Data” tab, followed by the “Trend Plots” link. A plot will appear with interactive tabs for various parameters and analytes. Plots can be copied and pasted into reports or presentations.

Concentration, deposition, and precipitation data summarized over various time scales are available from the NADP website in tabular format (Table 9). To access the data from the NADP homepage, select the “Maps & Data” tab and the “NTN Data” link. From there, use the site list or interactive map to choose a site of interest, and select the “Data” tab, followed by the link to the desired time scale (e.g., daily, weekly, monthly, etc.). Enter the starting and ending months and years, and choose the parameter and report format. Finally, specify the intended use, examine the “Explanatory Notes,” and select “Get Data.” Tabular data can be used to perform time series analyses, evaluate spatio-temporal patterns, and create customized figures for one or more sites.

Table 8. Three NADP Completeness Criteria tabulated for each full year on record at AK97, with asterisks (*) indicating years when minimum thresholds for meeting these criteria were not met.

Year	Completeness Criteria		
	1 Percentage of the summary period for which there are valid records	2 Percentage of the summary period for which precipitation amounts are available	3 Percentage of the total measured precipitation associated with valid records
2010	59% *	96%	66% *
2011	74% *	100%	80%
2012	74% *	100%	79%
2013	83%	100%	79%
2014	79%	100%	70% *
2015	69% *	100%	84%
2016	81%	100%	89%
Minimum Threshold	75%	90%	75%

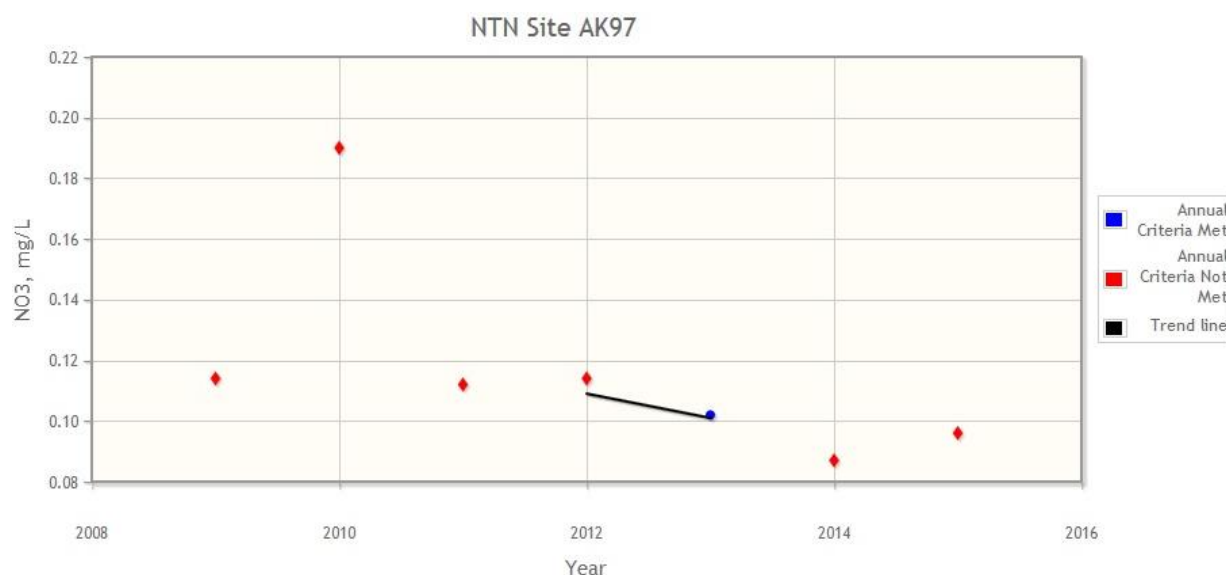


Figure 6. Trend plot showing annual precipitation-weighted mean concentrations of nitrate at AK97.

Table 9. Tabular data sets that are downloadable from the NADP website.

Time Scales	Data Sets
Daily	Precipitation amount (in)
Weekly	Concentration (mg/L)
Monthly	Precipitation-weighted mean concentration (mg/L)
Seasonal	Precipitation-weighted mean concentration (mg/L); wet deposition (kg/ha/season)
Annual *	Precipitation-weighted mean concentration (mg/L); wet deposition (kg/ha/yr)

* The user can specify calendar year or water year.

Data from the NADP website and customized figures will be incorporated into air quality resource briefs and synthesis reports in order to document monitoring at AK97. Resource briefs will be short documents written biennially for a mixed audience. Synthesis reports will be longer, written every five years, and targeted toward park managers and scientists interested in a more in-depth evaluation, including summary statistics and time series analysis. Resource briefs and synthesis reports will be posted on the SWAN website (<https://science.nature.nps.gov/im/units/swan/>).

Personnel Requirements and Training

Personnel are required for on-site sampling and maintenance, as well as for off-site data downloading, processing, analysis, and reporting. At least one primary and one backup site operator is needed for on-site work.

Roles and Responsibilities

On-site sampling and maintenance are the responsibility of SWAN staff during the field season (typically early May through late October), when seasonal employees are stationed in King Salmon. During the remainder of the year, KATM staff have assumed these responsibilities — an arrangement that has been re-negotiated annually between the SWAN Program Manager and the KATM Superintendent.

Off-site downloading, processing, analyzing, and reporting of data generated by AK97 are the responsibility of SWAN staff (currently the Aquatic Ecologist). Technical support is provided upon request by ARD or NADP/NTN employees.

Training Procedures

Site operators typically are trained on the job by other NPS staff experienced with the procedures. This on-the-job training is supplemented with additional training, as needed, during site inspection visits by EPA contractors every three years.

Budget

Since the inception of AK97 in fiscal year (FY) 2010, the annual operating budget has varied with the costs of personnel and laboratory services. Table 10 outlines these basic costs in FY2017. See Appendix A for details on the costs of starting and maintaining telemetry.

Table 10. Estimated annual operating costs (based on FY2017 dollars) for implementing the NPS ARD

Category	Costs ^A	Notes
Personnel	—	—
SWAN Aquatic Ecologist	\$ 2,155	1.0 hour per week, 12 months per year, GS-11 ^A
SWAN Hydrologic Technician	\$ 756	1.5 hours per week, 6 months per year, GS-06 ^A
KATM GIS Specialist / Biologist	\$ 1,243	1.5 hours per week, 6 months per year, GS-11 ^A
Telemetry	\$ 348	See Appendix A for details
Fuel	\$ 50	2.4 miles round trip per week via NPS vehicle ^B
Program coordination	\$ 1,500	—
Central Analytical Laboratory services	\$ 4,264	—
Network Equipment Depot fee	\$ 182	\$3.50 per week for equipment repair services
Overhead	\$ 595	10% (only applies to the 3 rows above this) ^C
Total	\$ 11,093	—

^A See https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/salary-tables/pdf/2017/AK_h.pdf.

^B Based on estimated fuel efficiency and costs of 20 miles per gallon at \$8 per gallon, respectively.

^C The NPS pays overhead to the National Institute of Food and Agriculture, which funds the NADP.

Safety

There are few safety concerns anticipated with implementation of the NPS ARD protocol at AK97. However, NPS staff will follow standard safety guidelines when undertaking sampling, as defined in the NPS Occupational Safety and Health Program Reference Manual 50B (Director's Order #50B, September, 2008).

Standard Operating Procedures

To ensure consistent implementation of this PIP over time, the Standard Operating Procedures (SOPs) below will be followed, in addition to the more general guidance offered in the ARD protocol (Porter and Morris 2007) and the NADP/NTN manuals governing site selection and installation (NADP 2014) and site operation (NADP 2015). These SOPs are adopted from procedures approved and implemented by the NADP/NTN or NPS (Table 11). Collectively, these SOPs and the documents listed above provide guidance for completing all phases of wet deposition monitoring, according to NADP/NTN requirements.

Table 11. Standard Operating Procedures required to execute this Protocol Implementation Plan.

Topic	Citation	Notes	Link to Published Document
On-site monitoring – bucket changing	National Atmospheric Deposition Program (NADP). 2012. NTN sample change-out, Aerochem Metrics bucket collector. Version 1.1. Illinois State Water Survey, Champaign, IL.	AK97 uses this type of collector. This process is performed weekly.	http://nadp.sws.uiuc.edu/lib/manuals/NTN_Sample_Changeout_ACM_v_1-1.pdf
On-site monitoring – bucket decanting	National Atmospheric Deposition Program (NADP). 2013. Sample decanting SOP, NTN. Version 1.7. Illinois State Water Survey, Champaign, IL.	This process is performed weekly.	http://nadp.sws.uiuc.edu/lib/manuals/NTN_Sample_Decanting_v_1-7.pdf
On-site monitoring – raingage winterizing	National Atmospheric Deposition Program (NADP). 2012. Raingage winterization, NOAA-IV. Version 1.1. Illinois State Water Survey, Champaign, IL.	AK97 uses this type of raingage. This process is performed annually.	(Not available online)
Data acquisition and reporting	National Park Service. 2010. Air quality monitoring protocol and standard operating procedures for the Northern Colorado Plateau Network. Natural Resource Report NPS/NCPN/NRR-2010/239. National Park Service, Fort Collins, CO.	See SOP#1. SWAN air quality reports will focus on NADP/NTN data only.	https://science.nature.nps.gov/im/units/ncpn/publications.cfm?tab=1
Safety	National Park Service. 2008. Occupational safety and health program: reference manual 50B. National Park Service. Washington, DC.	See Sections 1-6, in particular.	https://www.nps.gov/policy/RM50Bdoclist.htm
Modifications	Bartz, K. K., and K. M. Junghans. 2017. Protocol implementation plan for monitoring wet deposition in Southwest Alaska Network parks: Version 1.0. National Park Service, Fort Collins, Colorado.	This document. See Appendix A.	https://science.nature.nps.gov/im/units/swan/publications.cfm?tab=3

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Appendix A

Data from the AK97 raingage are not submitted manually on a weekly basis to the NADP. Rather, they are transmitted automatically every 15 minutes using telemetry. This represents a minor change to the ARD wet deposition protocol (Porter and Morris 2007), which was implemented in 2015 after being suggested by the NADP and funded by the ARD. Appendix A documents the equipment needed to run telemetry, ways to troubleshoot the equipment, and the budget required to purchase and operate it.

It is worth noting at the outset that connectivity options for supporting telemetry are limited at AK97. The NADP phone system uses “Voice over Internet Protocol” (VoIP) – not “Public Switched Telephone Network” (PSTN) – technology, so a wireless connection rather than a land line is needed. General Communication Inc., or GCI, is currently the only wireless provider in King Salmon. GCI’s wireless network in this region of Alaska is 2G.

Equipment

Telemetry at AK97 relies on two key pieces of equipment: a modem/gateway and an adapter. The modem/gateway (hereafter simply “gateway”) is a CloudGate “machine-to-machine” (M2M) device built by Option and purchased from GCI. M2M refers to devices other than cell phones that use the wireless network to communicate with other devices or networks – in this case, the NADP network. Specifications for the CloudGate are available online at <http://www.option.com/wp-content/uploads/2014/11/CloudGate-DataSheet-A3-v1.3.2-Preview.pdf>.

The adapter is an NL-121 made by and purchased from Campbell Scientific. It is needed to link the CloudGate gateway to the NOAH IV raingage, because the CloudGate has an Ethernet port and the NOAH IV has a serial port. NADP staff suggested adding an Ethernet port to the NOAH IV (via the NL-121), rather than adding a serial port to the CloudGate (via an expansion card) for various reasons. With the expansion card, the change from an analog signal (RS-232) to a digital signal (TCP/IP) would occur over a proprietary serial link which is unfamiliar to NADP staff, and therefore problematic. With the NL-121, the signal change would occur in equipment that handles such switches routinely, and that is regularly used by NADP staff.

Both pieces of equipment (the CloudGate gateway and the NL-121 adapter) are ruggedized for operating year round in wide temperature ranges. Their performance in rain, snow, and ice is less certain, so we house them inside the outer shell of the raingage. This minimizes direct exposure to moisture, as well as the need for additional wiring.

The NL-121 adapter connects directly to the proprietary “peripheral port” on the raingage. An embedded screw holds the adapter in place, and neither a serial cable nor a power cable is required. The CloudGate gateway connects to the adapter through a short Ethernet cable. The gateway is powered by connecting its AC cable to an AC plug in the raingage. Two antennae, attached to the gateway, are also housed inside the raingage shell, along with a 12 volt battery that provides backup power.

Set-up and Configuration

The gateway should be set up and configured in the office, prior to deployment. Set-up involves installing the antennae, plugging in the AC cable, and connecting the Ethernet cable to a computer. It also requires activation by GCI. Once set-up is complete, NADP staff can configure the gateway remotely via the internet as follows:

- the Ethernet port is the local area network (LAN);
- the LTE interface is the wide area network (WAN);
- the IP addresses are 192.168.1.1 (LAN) and 66.223.158.206 (WAN).

Two port forwarding rules are also defined during configuration. First, anything coming in from the internet on Port 7000 will be redirected to the raingage datalogger (192.168.1.50) on Port 6785. Second, anything coming in on Port 7001 will be redirected to the raingage datalogger on Port 80.

Deployment

After configuration, the gateway is ready for on-site deployment. As with configuration, deployment involves several steps:

- disconnecting power from the raingage;
- attaching the adapter to the peripheral port on the raingage;
- restoring power to the raingage;
- connecting to the raingage with a laptop via the Device Configuration Utility (DCU) application;
- selecting the TCP/IP tab in the DCU and adding the following settings:
 - IP address: 192.168.1.50
 - Netmask: 255.255.255.0
 - Gateway: 192.168.1.1
- saving the settings and then closing the DCU;
- connecting the gateway to the adapter with an Ethernet cable; and
- attaching power to the gateway.

Operation

To access the data transmitted via telemetry, go to the NADP website where preliminary precipitation data are posted (<http://nadp.sws.uiuc.edu/siteOps/ppt/>). Select the Site ID (AK97) and Time Format (Standard or Daylight Savings), and then input the desired start and end dates and times. Finally, under “Data Tables,” select the time scale of interest (daily, hourly, or 15 minutes) and choose “View Data.” To complete Box 7 of the FORF using the website, enter the previous and current Tuesdays as start and end dates, input the hours when the bucket was changed on those two dates as start and end times, and select the “Daily” radio button.

Troubleshooting

Telemetry at AK97 occasionally stops working. Isolating the issue may require input from the NPS site operator, NADP database manager, and GCI tech support. As an initial check, the site operator

should note if the gateway has power, and which (if any) of its LED lights are lit or flashing (Figure A1). If the three lights to the right of the Ethernet port are lighted and green, the gateway should be working. However, it might need to be re-booted by unplugging and then reconnecting its power cable. Note that re-booting might take 15+ minutes to have a noticeable effect on the website where the data are posted.



Figure A1. The CloudGate LTE 1 gateway, with the three LED lights to the right of the central Ethernet port lit.

If these steps do not solve the problem, the site operator should assess whether the issue is isolated to the gateway, or whether it is related to the NL-121 adapter. This can be accomplished by unplugging the Ethernet cable from the NL-121, plugging it into a laptop, and then checking whether the laptop has internet connectivity. If it does have connectivity, then the NL-121 is likely the problem.

A similar check involves accessing the gateway's built-in website from a computer connected to the internet. To perform the check, navigate to <https://66.223.158.206:1800>. Enter the username and password, available from the NADP data manager. If this website is functioning, then the NL-121 needs to be examined.

The problem might be a decrease in the strength of GCI's cellular signal. To assess this possibility, the site operator should remove the outer shell of the raingage, and then evaluate whether telemetry function is improved. If telemetry works with the shell off but not on, then the existing small antennae need to be replaced with larger antennae, mounted outside the shell.

A more complicated check involves removing the gateway (along with its antennae and power cable) from the site, and taking them to the office (or elsewhere with power, phone service, and a strong cellular signal). From there, the NADP database manager can try to access the gateway via internet.

If the gateway is accessible at the office but not in the field, then the issue is likely an insufficient cellular signal on site.

If the gateway still cannot be accessed at the office, several other possibilities should be explored. First, the gateway might have lost its configuration. Troubleshooting this would require attaching a computer to the gateway and examining its configuration via the built-in web page. Alternatively, the issue could be a hardware failure with the gateway or a frozen account with GCI.

Budget

Initial and monthly costs to start and then run telemetry at AK97 are provided in Tables A1 and A2. The monthly costs are based on GCI's pricing for its "Simply Share" wireless data-only plan, which allows users to share 1 to 50 GB of data per month across multiple devices. All monthly costs can be pre-paid as far in advance as desired.

Table A1. Initial costs (based on FY2015 dollars) to start telemetry at AK97. The gateway and antennae were purchased through GCI.

Item	Make	Model	Serial number	Cost
Gateway	Option	CloudGate LTE 1	355802060041258	\$399.00
Adapter	Campbell Scientific	NL-121	—	\$200.00
Antennae (2)	Sierra Wireless	1810075	—	\$46.00
Set-up fee *	GCI	—	—	\$35.00
Total	—	—	—	\$484.00

* The set-up fee includes addition of a SIM card programmed to interface with GCI's network.

Table A2. Monthly costs (based on FY2015 dollars) to run telemetry at AK97. Taxes and surcharges do not apply because the internet is unregulated.

Service	Cost
1 GB data	\$14.99
Nationwide mobile broadband service	\$9.99
Static/public IP address *	\$3.99
Monthly total	\$28.97

* Dynamic IP addresses are standard, but NADP requires a static address.

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

NPS 953/138793, June 2017

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