



# Weather station maintenance in Southwest Alaska Network parks

*Summary for the 2011 hydrologic year*

Natural Resource Data Series NPS/SWAN/NRDS—2011/196



**ON THE COVER**

The McArthur Pass remote automated weather station, Kenai Fjords National Park  
Photograph by: Chuck Lindsay

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# **Weather station maintenance in Southwest Alaska Network parks**

*Summary for the 2011 hydrologic year*

Natural Resource Report NPS/SWAN/NRDS—2011/196

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October 2011

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:

Lindsay, C. 2011. Weather station maintenance in Southwest Alaska Network parks: Summary for the 2011 hydrologic year. Natural Resource Data Series NPS/SWAN/NRDS—2011/196. National Park Service, Fort Collins, Colorado.

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## Abstract

Field maintenance of climate monitoring stations is necessary to provide for the continuous acquisition of quality meteorological data, retrieval of complete station data, and fulfilling the station standards issued by respective climate monitoring programs. Currently, the Southwest Alaska Network (SWAN) maintains 10 Remote Automated Weather Stations (RAWS) in three network parks. This report summarizes all work (annual maintenance, unscheduled maintenance, and new installations) for the 2011 hydrologic year (October 1, 2010 to September 30, 2011) and includes up-to-date sensor metadata.

## Acknowledgments

Successfully maintaining 10 weather stations in three park units wouldn't have been possible without the cooperation, field assistance, and air support from Leon Alsworth, Stephanie Anderson, Heather Coletti, Sarah Cowell, Elsie Dillewaard, Mike Fell, Bruce Giffen, Allen Gilliland, Vera Gilliland, Kirk Hoessle, Nathan Husbyn, Ginger Irvine, Arnie Johnson, Mark Kansteiner, Fritz Klasner, Deb Kurtz, Kathryn Ladig, Ryan McDonald-O'lear, Claudette Moore, Rogan Parker, John Pedon, Doug Peratrovich, Port Graham Corporation, Chuck Redd, Rich Richotte, Jeff Shearer, Michael Shephard, Cuyler Smith, Llyod Stiasny, Mike Tetreau, Jamie Thomson, Elizabeth Wasserman, and Leslie Witter.

## List of Acronyms

|                  |                                                                            |
|------------------|----------------------------------------------------------------------------|
| <b>AKDST</b>     | Alaska Daylight Savings Time                                               |
| <b>AMD</b>       | Aviation Management Directorate                                            |
| <b>ARA</b>       | Aircraft Rental Agreement                                                  |
| <b>AT-RH</b>     | Air Temperature – Relative Humidity                                        |
| <b>AWA</b>       | Alaska Wildland Adventures                                                 |
| <b>B206</b>      | Bell 206 helicopter                                                        |
| <b>CS</b>        | Campbell Scientific                                                        |
| <b>C185</b>      | Cessna 185 airplane                                                        |
| <b>C206</b>      | Cessna 206 airplane                                                        |
| <b>DLP</b>       | Data Logger Program                                                        |
| <b>FTS</b>       | Forest Technology Systems                                                  |
| <b>GOES</b>      | Geostationary Operational Environmental Satellites                         |
| <b>GPS</b>       | Global Positioning System                                                  |
| <b>I&amp;M</b>   | Inventory and Monitoring                                                   |
| <b>KATM</b>      | Katmai National Park and Preserve                                          |
| <b>KEFJ</b>      | Kenai Fjords National Park                                                 |
| <b>LACL</b>      | Lake Clark National Park and Preserve                                      |
| <b>M/V</b>       | Motor Vessel                                                               |
| <b>NESDIS ID</b> | National Environmental Satellite, Data, and Information Service Identifier |
| <b>NIFC</b>      | National Interagency Fire Center                                           |
| <b>NPS</b>       | National Park Service                                                      |
| <b>RAWS</b>      | Remote Automated Weather Station                                           |

## List of Acronyms – Continued

|              |                                                     |
|--------------|-----------------------------------------------------|
| <b>RG-TB</b> | Rain Gauge – Tipping Bucket                         |
| <b>R44</b>   | Robinson 44 helicopter                              |
| <b>SD</b>    | Snow Depth                                          |
| <b>SDI</b>   | Serial Digital Interface                            |
| <b>SR</b>    | Solar Radiation                                     |
| <b>STEP</b>  | Single-skid, Toe-in, and hover Exit/entry procedure |
| <b>SWAN</b>  | Southwest Alaska Network                            |
| <b>WD</b>    | Wind Direction                                      |
| <b>WFMI</b>  | Wildland Fire Management Information                |
| <b>WRCC</b>  | Western Regional Climate Center                     |
| <b>WS</b>    | Wind Speed                                          |

# Weather Station Locations

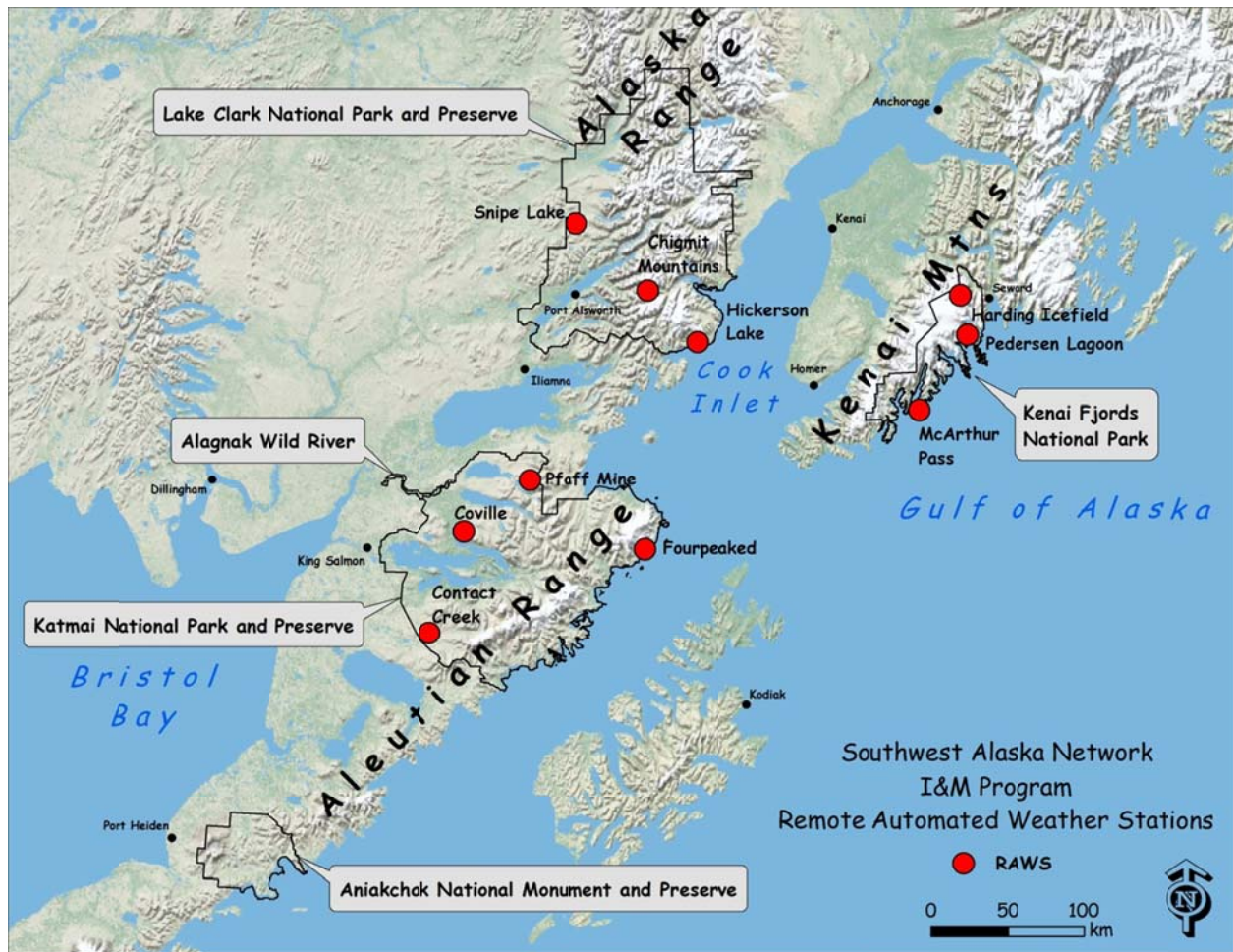


**Figure 1.** Map showing locations of weather stations operated and maintained by the SWAN.

**Table 1.** Metadata for weather stations operated and maintained by the SWAN.

| Station name      | Park | Station type | NESDIS ID no. | Lat. N  | Lon. W   | Elev ft. | Start date |
|-------------------|------|--------------|---------------|---------|----------|----------|------------|
| Chignik Mountains | LACL | RAWS         | FA6544FC      | 60.2249 | 153.4675 | 4658     | 7/2009     |
| Contact Creek     | KATM | RAWS         | 32803738      | 58.2076 | 155.9225 | 657      | 6/2008     |
| Coville           | KATM | RAWS         | 3280B12C      | 58.8025 | 155.5629 | 1567     | 6/2008     |
| Fourpeaked        | KATM | RAWS         | 328135C2      | 58.7057 | 153.5179 | 1074     | 6/2009     |
| Harding Icefield  | KEFJ | RAWS         | FA656210      | 60.1325 | 149.7820 | 4335     | 7/2004     |
| Hickerson Lake    | LACL | RAWS         | 3280C7BC      | 59.9148 | 152.8925 | 1048     | 6/2008     |
| McArthur Pass     | KEFJ | RAWS         | 3280244E      | 59.4726 | 150.3337 | 1266     | 6/2008     |
| Pedersen Lagoon   | KEFJ | RAWS         | 326AD012      | 59.8944 | 149.7308 | 624      | 8/2011     |
| Pfaff Mine        | KATM | RAWS         | FA65578A      | 59.1109 | 154.8367 | 2018     | 6/2008     |
| Snipe Lake        | LACL | RAWS         | 328041A8      | 60.6103 | 154.3199 | 2315     | 6/2008     |



# **Weather Station Maintenance Summaries**

## **Chigmit Mountains Weather Station – Annual Maintenance**

Date: June 30, 2011

Time of visit: 1530-1730

Personnel: Chuck Lindsay (SWAN), Michael Shephard (SWAN)

Mode of transport: B206 helicopter from Homer (Pathfinder Aviation)

Purpose of trip: Annual maintenance

Weather: Mostly sunny, 45 F, Winds E 8 mph gusting to 15 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Wind speed

Wind direction

Solar radiation

Snow depth

Narrative:

Access to the Chigmit Mountains RAWs by park ski plane (from Port Alsworth) in March was prohibited by poor weather and other work commitments, so a helicopter from Homer was used for access instead (Figure 2). Scheduled maintenance called for replacement of AT-RH, WS, and WD sensors. Initial inspection of the weather station showed that one of the threaded wind sensor mounts on the wind sensor arm was stripped and that the SR sensor mount was very loose. Otherwise, the station was in great shape. All data were downloaded from the station. The AT-RH sensor was replaced. The WS and WD sensors were replaced along with the wind sensor support arm. The four cardinal directions on the new WD sensor were checked. The SR sensor was also replaced (the mounting bracket was loose and couldn't be fixed without disassembling the sensor). The existing SR50 snow depth sensor was replaced with a SR50A sensor. The data logger program was replaced with one compatible with the SR50A sensor. The new data logger program running is CHMO\_DLP\_SR50A\_20110630.prg. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Cuyler Smith in Anchorage and relayed by satellite phone. Before departure the station was photographed (Figure 3) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 4) was also photographed.



**Figure 2.** The ridge on which the Chigmit Mountain RAWS (circled) is sited.



**Figure 3.** Chigmit Mountain RAWS photographed from the south.



**Figure 4.** Inside of instrument enclosure just before departure (Chigmit Mountain RAWS).

## **Contact Creek Weather Station – Annual Maintenance**

Date: June 14, 2011

Time of visit: 1000-1330

Personnel: Chuck Lindsay (SWAN), Claudette Moore (SWAN)

Mode of transport: C185 (on wheels) from King Salmon (park aircraft)

Purpose of trip: Annual maintenance

Weather: Mostly cloudy, 49 F, Winds SE 4 mph gusting to 12 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Rain gauge tipping bucket

Solar radiation

Snow depth

GOES antenna

Solar Panel and cable

Narrative:

The weather station stopped transmitting observations on June 4, 2011. Scheduled maintenance called for replacement of AT-RH, RG-TB, SR, and SD sensors. Initial inspection of the weather station showed there was significant damage to the station that was probably caused by a bear. The GOES antenna (Stevens V4th Antenna) was destroyed (Figure 5) along with the AT-RH sensor (Figure 6). The solar panel cable had bite marks that exposed the metal wires inside the cable housing. The solar radiation sensor support arm was bent. All data were downloaded from the station. The AT-RH sensor was replaced. The tipping bucket was replaced, tested, and the rain count was reset to zero. The Stevens GOES antenna was replaced with a Yagi GOES antenna oriented to 156° (true) with an inclination of 21°. The solar radiation sensor and sensor support arm were replaced. The snow depth sensor was replaced and zeroed to an average reading of -0.4 inches to account for fluctuation without reporting misleading snow depth readings. The solar panel and cable were replaced (it is faster to replace the panel and cable than it is to replace just the cable). All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Cuyler Smith in Anchorage and relayed by satellite phone. Before departure the station was photographed (Figure 7) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 8) was also photographed. The memory card and desiccant pack in the time lapse camera were replaced and the camera was refocused at the same zoom setting.



**Figure 5.** GOES antenna was destroyed and lying on the ground (Contact Creek RAWS).



**Figure 6.** AT-RH sensor was destroyed (Contact Creek RAWS).



**Figure 7.** Station photographed just before departure (Contact Creek RAWS).



**Figure 8.** Inside of instrument enclosure photographed just before departure (Contact Creek RAWS).

## **Coville Weather Station – Annual Maintenance**

Date: June 14, 2011

Time of visit: 1700-1930

Personnel: Chuck Lindsay (SWAN), Claudette Moore (SWAN)

Mode of transport: C185 (on floats) from King Salmon (park aircraft)

Purpose of trip: Annual maintenance

Weather: Overcast, 45 F, Winds SW 10 mph gusting to 12 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Rain gauge tipping bucket

Solar radiation

Snow depth SR50

Narrative:

There were no indications of any problems prior to station maintenance. Scheduled maintenance called for replacement of AT-RH, RG-TB, SR, and SD sensors. Initial inspection of the weather station showed there were no issues. All data were downloaded from the station. The AT-RH sensor was replaced. The tipping bucket was replaced, tested, and the rain count was reset to zero. The solar radiation sensor was replaced. The SR50 snow depth sensor was replaced with a SR50A model. A data logger program capable of operating the SR50A model snow depth sensor was uploaded to the station. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Cuyler Smith in Anchorage and relayed by satellite phone. Before departure the station was photographed (Figure 9) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 10) was also photographed. The memory card and desiccant pack in the time lapse camera were replaced and the camera was refocused at the same zoom setting.



**Figure 9.** Station photographed just before departure (Coville RAWS).



**Figure 10.** Inside of instrument enclosure photographed just before departure (Coville RAWS).

## **Fourpeaked Weather Station – Equipment Cache**

Date: June 6, 2011

Time of visit: unknown

Personnel: John Peden (Pathfinder Aviation)

Mode of transport: R44 helicopter from Homer (Pathfinder Aviation)

Purpose of trip: Transport tri-leg tower panel

Weather:

Sensors replaced:

None

Narrative:

During annual station maintenance in 2010 it was discovered that welds on one of the tri-leg tower panel sections (NE) panel were broken. FTS considered this part to be under warranty and provided a replacement panel section at no charge. Pathfinder Aviation delivered the panel section on June 6 (Figure 11). It was transported in a R44 with the backdoors off (only pilot on-board). Maintenance wasn't completed at this time because the necessary equipment had been sent to King Salmon and access was planned using the park wheel plane.



**Figure 11.** Replacement panel and weather station (Fourpeaked RAWS).

## **Fourpeaked Weather Station – Annual Maintenance**

Date: June 30, 2011

Time of visit: 0900-1200

Personnel: Chuck Lindsay (SWAN), Michael Shephard (SWAN)

Mode of transport: B206B3 helicopter from Homer (Pathfinder Aviation)

Purpose of trip: Annual maintenance, replace broken tri-leg tower panel section

Weather: Partly cloudy, 48 F, Winds NE 5 mph gusting to 12 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Rain gauge tipping bucket

Wind speed

Wind direction

Snow depth

Narrative:

During annual station maintenance in 2010 it was discovered that welds on one of the tri-leg tower panel sections (NE) panel were broken. FTS considered this part to be under warranty and provided a replacement panel section at no charge. Pathfinder Aviation delivered the panel section on June 6. Comparison of wind directions reported at the Fourpeaked RAWS and Shelikof Strait moored buoy indicated that there might be an issue with the wind direction sensor. The RH sensor stopped working on April 2, 2011. The SD sensor stopped working on September 21, 2010.

Access to the Fourpeaked RAWS by park wheel plane (from King Salmon) in mid-June was prohibited by poor weather and tidal constraints, so a helicopter from Homer was used for access instead. Scheduled maintenance called for replacement of AT-RH, WS, and WD sensors. Initial inspection of the weather station showed that two of four welds on the NW tri-leg tower panel section had broken (Figure 12) and that the tail of the WD sensor had broken (Figure 13). All data were downloaded from the station. The AT-RH sensor was replaced. The WS and WD sensors were replaced. Four cardinal directions on the new WD sensor and station orientation were checked. The tipping bucket was replaced, tested, and the rain count was reset to zero. The snow depth sensor was replaced. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Heather Coletti in Anchorage and relayed by satellite phone. Before departure the station was photographed (Figure 14) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 15) was also photographed.



**Figure 12.** Both welds on the south (left) corner of the NW tri-leg tower panel section were broken (Fourpeaked RAWS).



**Figure 13.** The tail (fletching) had broken off the wind direction sensor (Fourpeaked RAWS).



**Figure 14.** Fourpeaked RAWS photographed from the SE.



**Figure 15.** Inside of instrument enclosure just before departure (Fourpeaked RAWS).

## **Harding Icefield Weather Station – Annual Maintenance**

Date: May 2, 2011

Time of visit: 08:00-14:00

Personnel: Bruce Giffen (AKRO), Mike Tetreau (KEFJ)

Mode of Transport: B206 helicopter from Seward, skis

Purpose of trip: Conduct annual maintenance.

Weather: Sunny, 30 F, Winds E 5 mph, snow 8” on ground below the snow depth sensor

### **Sensors Replaced:**

Air temperature - relative humidity

Wind speed

Wind direction

Snow depth

### **Narrative:**

Arnie Johnson of Johnson Flying Service transported personnel, spare weather station sensors, 20 gallons of antifreeze and tools to the Harding Icefield weather station from the Seward airport in a helicopter. The helicopter landed on the approximately 200 feet downhill from the weather station on the nunatak. Upon arrival the station was in very good shape. It is noted that the amount of ice debris surrounding the station was much less than has been experienced in recent years. There were no bent sensor arms and the Yagi antenna was in good shape with no broken elements. All guy wires were snug. A few wind baffles on the precipitation gauge had flipped upside-down and were straightened.

All data was downloaded from the data logger, though some difficulty communicating with the data logger was experienced. Repeatedly received error messages “device already open” when downloading data. After four attempts without success, closed Toolbox software and restarted Toolbox and the download proceeded to completion.

Replaced sensors as scheduled (AT-RH, WS, WD, and snow depth). All replacement sensors were replaced without difficulties. Serviced the all-season precipitation gauge. Cleaned oil-mousse out of the top of the precipitation gauge and drained approximately 30 gallons of antifreeze. Pumped in approximately 18 gallons of new antifreeze into the precipitation gauge and covered with a thin film of fresh oil. “Zeroed” precip in data logger.

(Note: failed to disconnect the Rain Gauge cable from the data logger during precip gauge maintenance. This caused erroneous precipitation to be recorded on the data logger and transmitted. For May 2, 2011, no precipitation fell at the Harding Icefield weather station.)

All waste antifreeze, spare 5 gallon jugs, oil mousse, old sensors, tools and trash were transported back to the Seward airport with the helicopter. There is plenty of oil in the Knack box for future maintenance.

Replaced the Campbell Scientific (CS) SR50 snow depth (SD) sensor with the CS SR50A SD sensor to see if it might perform better than the previously installed SR50. Removed all snow from the ground surface and set the snow depth off-set into the new DLP designed for use with the SR50A. Tightened all bolts on sensor arms and the tower. Tightened the guy lines. Note that the Knaack box is not weather tight. Snow can and does get in as there was a good amount of ice inside the box. Addition supplies should be brought to the site during the next maintenance visit. Some of these could be left on-site in the Knack Box:

- 1-gallon zip lock bags
- Wide mount jug for oily mousse
- Zip-ties (11 inch)
- Ball valve for the end of the garden hose
- Shop towels
- Spare hose clamps for the antifreeze pump system

## **Hickerson Lake Weather Station – Annual Maintenance**

Date: July 7, 2011

Time of visit: 0930-1300

Personnel: Chuck Lindsay (SWAN), Jeff Shearer (LACL)

Mode of transport: C206 (floats) from Homer (Steller Air)

Purpose of trip: Annual maintenance

Weather: Mostly cloudy, 50 F, Winds SE at 5 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Solar radiation

Snow depth SR50

Rain gauge tipping bucket

GPS antenna

GOES antenna cable

Narrative:

Access to the Hickerson Lake RAWS by park float plane (from Port Alsworth) in mid-June was not possible because of poor weather and a chartered float plane from Homer was used for access instead. The station stopped transmitting on November 2, 2010 for unknown reasons.

Observations during over flights didn't reveal any obvious problems.

The hike from the lake shore up to the weather station took 1.5 hours with heavy packs. The hike back down took about 1 hour. This hike should not be attempted in rain or when the ground surface is wet because the lichen that covers the boulders will be slick. A fall on this hike could result in serious injury. There is no suitable helispot at or near the weather station. A STEP (Single-skid, Toe-in, and hover Exit/entry Procedure) would be required in order to directly access the weather station using a helicopter. These procedures are prohibited except when approved in writing by the NPS regional director. Exceptions may be requested for a project or annually for a park program.

Scheduled maintenance called for replacement of AT-RH, SR, SD, and RG-TB sensors.

Scheduled maintenance also called for battery replacement. Initial inspection of the weather station showed that the GPS antenna had bite marks and that the GPS antenna cable had been cut (Figure 16). The GOES antenna, WS sensor, and SD sensor cables also looked like they had been damaged, but were not cut. There was some damage to the plastic shielding on the AT-RH sensor (Figure 17).

All data were downloaded from the station. All sensor observations had been logged internally during the time that the station was not transmitting (the G5 GOES transmitter automatically stops transmitting 28 days after GPS time is lost, which happened when the GPS cable was cut). The AT-RH, SR, and RG-TB sensors were replaced. The tipping bucket was replaced, tested, and the rain count was reset to zero. The snow depth sensor was replaced with a SR50A sensor and a new cable. The GPS antenna and cable were replaced. The GOES antenna cable and WS

sensor cable were replaced. The data logger program was replaced with one that is compatible with the SR50A sensor. The new data logger program running is HILA\_DLP\_SR50A\_20110707.prg. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were not checked before departure because of time constraints (scheduled aircraft departure). Before departure the station was photographed (Figure 18) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 19) was also photographed. Rocks were piled on top of the instrument enclosure where sensor cables enter the flexible conduit to mitigate damage from bears.



**Figure 16.** The GPS antenna cable was cut (circled) and there were bite marks on the GPS antenna (Hickerson Lake RAWS).



**Figure 17.** Damage to the AT-RH sensor shielding (Hickerson Lake RAWS).



**Figure 18.** The station photographed from the east before departure (Hickerson Lake RAWS).



**Figure 19.** Inside of instrument enclosure just before departure (Hickerson Lake RAWS).

## **Hickerson Lake Weather Station – Unscheduled Maintenance**

Date: July 22, 2011

Time of visit: 0900-1400

Personnel: Chuck Lindsay (SWAN), Cuyler Smith (SWAN)

Mode of transport: C206 (floats) from Homer (Steller Air)

Purpose of trip: Unscheduled maintenance (station not transmitting)

Weather: Sunny, 70 F, Winds S at 7 mph

Sensors replaced:

GOES antenna cable

Narrative:

Annual maintenance was conducted on July 7, 2011. Station observations and GOES transmission quality were not checked on that date because of time constraints (scheduled aircraft departure). Station observations and GOES transmission quality were later checked upon return to the office and the station was not transmitting. Discussions with the RAWs Depot help desk and the NPS radio shop instructed that it was likely that the GOES antenna cable was bad. A new data logger (pre-programmed), power manager, GOES antenna and cable, GPS antenna and cable, and G5 transmitter (pre-programmed) were taken to the Hickerson Lake RAWs in case any of those components were not working.

Initial inspection of the weather station showed that there was no continuity on the inner conductor (copper wire) of the GOES antenna (coaxial) cable. A sharp radius bend in the cable where it entered the flexible conduit had probably broken the inner conductor, which is a solid copper wire. The GOES antenna cable was replaced. All data were downloaded from the station. Station observations and GOES transmission quality were checked. Observations and transmissions were verified from the WFMI website by Doug Peratrovich (NPS Radio Shop) in Anchorage and relayed by satellite phone. Rocks were piled on top of the instrument enclosure to mitigate damage from bears where the cables enter the flexible conduit (Figure 20).



**Figure 20.** Hickerson Lake RAWS viewed from the southeast.

## **McArthur Pass Weather Station – Unscheduled Maintenance**

Date: November 18, 2010

Time of visit: 11:00-13:00

Personnel: Chuck Lindsay (SWAN), Elizabeth Wasserman (LACL)

Mode of transport: B206 helicopter, Pathfinder Aviation

Purpose of trip: Fix power supply issue

Weather: Clear, 46 F, winds NW at 20 mph, snow 0" (below sensor), <2" around station

Sensors replaced:

Snow depth (removed but not replaced)

Solar radiation

Narrative:

An event on October 7, 2010 caused the station to power down and reset (confirmed by zeroing of rain count). Starting on this date, battery voltage and solar radiation exhibited anomalous behavior. There seemed to be a correlation between precipitation, battery voltage, and solar radiation (Figure 21). It was assumed that wet conditions were causing exposed electrical connections to short. Battery voltages that dropped to 12.4 V on sunny days raised concern that power issues might cause the station to shut down and stop operating.

Upon arrival the station appeared to be in good condition. Closer inspection revealed that the snow depth (SD) sensor cable was completely cut at the point where it enters the modified cable gland (Figure 22). It was also damaged in another location closer to the SD sensor (Figure 23). The SD sensor was removed and was not replaced (SD has proven difficult to measure at McArthur Pass because abundant precipitation coupled with high wind at this location forces water into the externally vented ultrasonic range finder where oxidation occurs, eventually rendering it inoperable). Although no damage to the solar radiation sensor or cable was visible, the sensor was replaced as planned. All data was downloaded from the weather station. The data logger program was not modified, so the station will misleadingly report 77.40 inches of snow depth (this is the tare value – the distance from the sensor to the ground surface used to calculate SD). While maintaining the station, the relative humidity / air temperature (RH/AT) sensor began anomalously reporting 100% RH. The RH was 23% when maintenance was initiated. This sensor wasn't handled during the maintenance so it is unclear why this problem developed. This issue is not resolved.

It isn't clear what damaged the SD sensor cable. Bears have damaged the station in the past; however precise damage to only one cable isn't characteristic of bear damage. An ermine repeatedly approached the field crew during a maintenance trip on August 17, 2010. Maybe this weasel chewed the wire. Recommendations to mitigate damage from wildlife include erecting an electric fence and/or armoring sensor cables with flexible conduit.

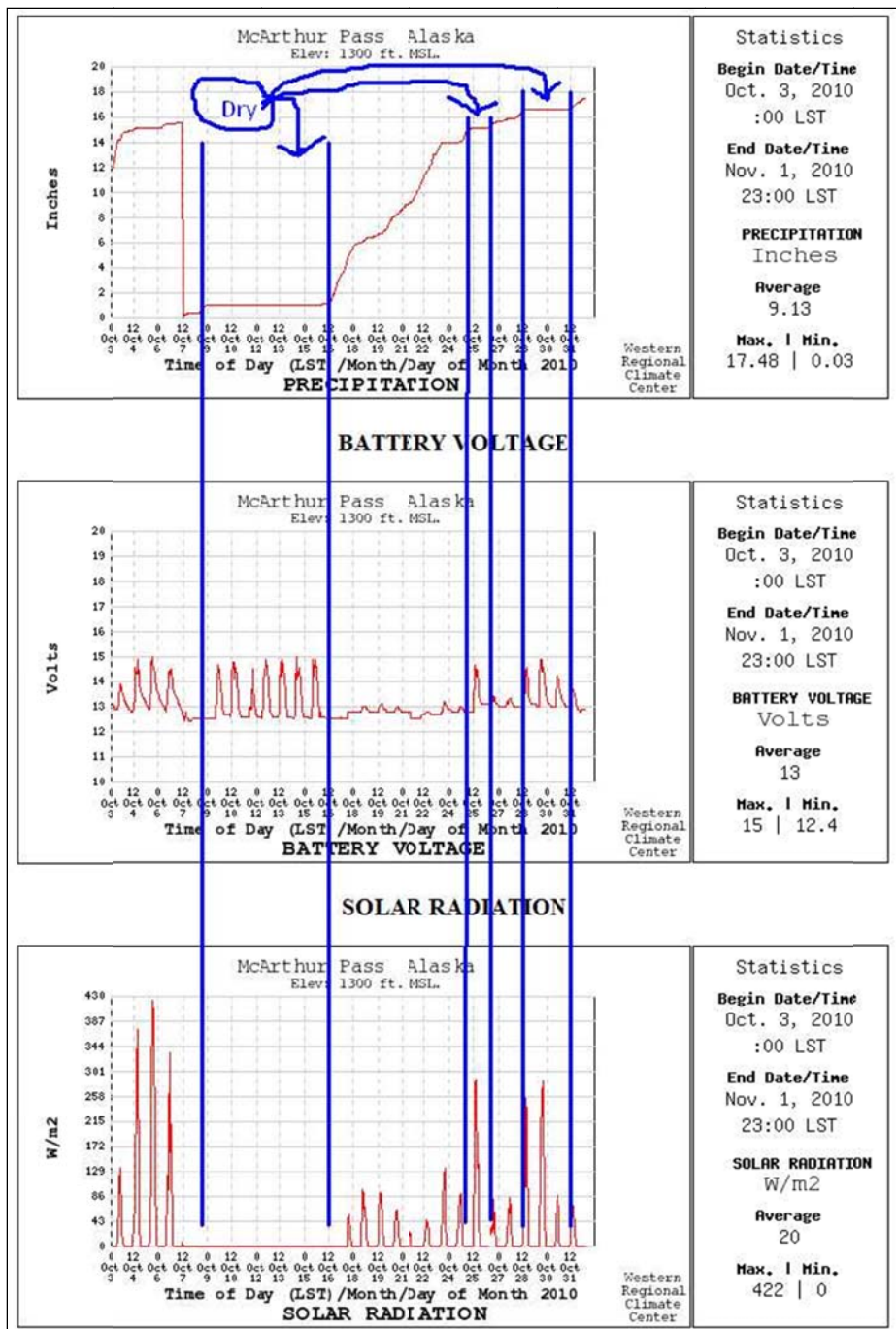


**Figure 21.** Precipitation, battery voltage, and solar radiation at McArthur Pass RAWS (Oct. 3 to Nov 1), dry periods are bracketed by blue vertical lines. Plots generated from the Western Regional Climate Center (WRCC) website.



**Figure 22.** Severed snow depth sensor cable (McArthur Pass RAWS).



**Figure 23.** Damaged snow depth sensor cable (McArthur Pass RAWS).

## **McArthur Pass Weather Station – Annual Maintenance**

Date: July 5, 2011

Time of visit: 0930-1400

Personnel: Chuck Lindsay (SWAN), Heather Coletti (SWAN)

Mode of transport: B206 helicopter from Homer (Pathfinder Aviation)

Purpose of trip: Annual maintenance

Weather: Sunny, 58 F, Winds SE at 10 mph

Sensors replaced:

Air temperature - relative humidity

Wind speed and cable

Wind direction and cable

Rain gauge - tipping bucket

GOES antenna

Mast, spreaders, and guylines

Snow depth SR50A

Wind sensor support arm

Narrative:

It appears that a combination of heavy icing and strong wind broke the GOES antenna on April 3, 2010 and the station hadn't transmitted since that date. Temperatures on April 3 ranged from 28 to 32 degrees F and winds peaked at 59 mph. Both the wind sensors seem to have stopped working on that day and it is likely that the mast broke at the same time as the GOES antenna. However, a satellite image dated April 16, 2011 (maybe this is the processing and not the acquisition date) on Google Earth (Figure 24) indicates that the mast was still standing when the imagery was acquired. Annual maintenance was scheduled for mid-August with a combination of boat and foot access. Because the station was not working and because large cumbersome parts were needed, a helicopter was used for access instead.

Scheduled maintenance called for replacement of AT-RH, WS, WD, SD, SR, and RG-TB sensors. Scheduled maintenance also called for battery replacement although it was determined that the batteries wouldn't be replaced and that their condition would be monitored and replacement considered after five years of operation (i.e. in 2013). Initial inspection of the weather station showed that the mast had broken and that the WS, WD, wind sensor support arm, and wind sensor cables were wrecked (Figures 25 and 26). The GOES antenna had also broken (Figure 27).

All data were downloaded from the station. Most sensor observations were logged internally during the time that the station was not transmitting; however wind direction and speed are missing from April 3 to July 7, 2011. A new 20 foot mast was installed and the three extra reinforcing guy lines were also replaced. The wind sensor support arm was replaced. The GOES antenna and antenna cable were replaced. The AT-RH, WS, WD, and RG-TB sensors were replaced. The four cardinal directions on the WD sensor were checked. The RG-TB was replaced, tested, and the rain count was reset to zero. The SR sensor was not replaced (it was left

off the list of things to do in the field). The SD sensor that was removed in November 2011 (the cable had been cut and the SDI was shorting) was replaced with a SR50A sensor and a new cable. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by satellite phone. Before departure the station was photographed (Figure 28) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 29) was also photographed.



**Figure 24.** Google Earth image (reportedly from April 16, 2011). The station's shadow is visible (McArthur Pass RAWS).



**Figure 25.** The wind sensors, 20 foot mast, and GOES antenna were wrecked (McArthur Pass RAWS).



**Figure 26.** The 20 ft mast broke at the junction weld (McArthur Pass RAWS). Upper 10 ft section and both halves of the junction are visible.



**Figure 27.** Broken GOES antenna (McArthur Pass RAWS).



**Figure 28.** The station photographed from the east before departure (McArthur Pass RAWS).



**Figure 29.** Inside the instrument enclosure before departure (McArthur Pass RAWS).

## **Pedersen Lagoon Weather Station – Initial Installation**

Date: August 9-10, 2011

Time of visit: 1100-1900

Personnel: Chuck Lindsay (SWAN), Deb Kurtz (KEFJ), Mark Kansteiner (KEFJ), Kathryn Ladig (KEFJ)

Mode of Transport: M/V Serac, B206 helicopter, foot

Purpose of trip: Install station

Weather: Sunny, 62 F, Winds NW 19 mph

### **Sensors Installed:**

Tri-leg tower and 20 ft. mast

Enclosure

F6 data logger, GOES transmitter, power manager

100 Ah sealed batteries

50W solar panel

GOES Yagi antenna

Ice-rated GPS antenna

Temperature/relative humidity

Wind speed

Wind direction

Rain gauge tipping bucket

Solar radiation

Snow depth

### **Narrative:**

The M/V Serac (crew: Jamie Thomson and Elsie Dillewaard) departed Seward on 9 August for Aialik Bay. A landing craft operated by Alaska Wildland Adventures (AWA) transported the weather station's aluminum frame, gabion cages, and a drum of Jet Fuel to the black sand beach in front of Pedersen Lagoon. After setting up a time lapse camera on Squab Island, Lindsay, Kurtz, and Ladig hiked up to the location where the weather station would be installed. This hike took about 1 hour each way. Kansteiner filled super sacks with rocks on the beach in front of the Aialik Bay Ranger Station. Lindsay, Kurtz, and Ladig used hand tools to brush an area approximately 25 ft in diameter (Figure 30). This location will require brushing each June, and maybe again later in the summer. Lindsay, Kurtz, and Ladig hiked back down the trail and gave a short presentation on the weather station installation, climate change, and changes in coastal glacier terminus locations to overnight guests at AWA's Glacier Lodge.

Lindsay, Kurtz, Ladig, and Kansteiner arrived at the black sand beach staging area at 0800 on the morning of 10 August. They loaded the weather station (552 lbs) into a sling net. Maritime Helicopter's Long Ranger (307MH) and pilot Nathan Husbyn arrived at the black sand beach at 0900. A mission-and pre-flight briefing was conducted. Lindsay, Kurtz, Ladig, Kansteiner, Husbyn (Maritime pilot), Sarah Cowell (KEFJ Ranger), Ryan McDonald-O'Lear (KEFJ Ranger), and Kirk Hoessel (AWA owner) attended the briefing. Lindsay, Kurtz, and Ladig flew up and landed at a helispot located approximately 100 ft south of the weather station site (Figure

31). After the helicopter departed, Kurtz and Ladig brushed the helispot to make cut down some taller alder branches on the edge of the helispot. The helicopter delivered the sling net containing the weather station and six super-sacks (500 lbs each) filled with beach rocks (Figure 32). Kansteiner hooked-up the weather station sling net on the black sand beach and Cowell and McDonald-O'Lear hooked-up sling loads on the Ranger Station beach. A long-line and remote hook were used. Lindsay coordinated delivery of sling loads to the weather station site. After external load operations were completed the helicopter ferried Kansteiner up to the weather station site and departed for an unrelated passenger ferry mission between Bear Glacier and Seward. After it returned, it stayed on-site at the helispot.

The weather station crew spent the next six hours assembling the weather station. The weather station was anchored to the ground using 3 ft steel stakes that were pounded through two of the weather station's feet. Guy lines from the stations SW and SE corners were attached to an expansion bolt placed in bedrock and a gabion, respectively (Figures 33 and 34). Three additional guy lines were attached to the 20 ft mast. These guy lines were attached to two expansion bolts placed in bedrock and the gabion. Two unused gabion cages and approximately 1500 lbs of unused beach rock remain on site.

A reflector surface for the sonic distance ranging sensor (snow depth) was constructed out of beach rocks and soil because the ground surface was uneven (Figure 35).

A 20 ft strand of barb wire was attached to the weather station, immediately above the sensor cables on the southern frame (Figure 36). The intent of the barb wire is to mitigate damage from wildlife (bears). This barb wire will need to be removed prior to station maintenance. Four unused 10-20 ft coils of barb wire remain on site. Rocks were piled on top of the instrument enclosure in order to mitigate damage to sensor cables where they enter the cable gland (Figure 37).

The station was completely assembled by 1815 (Figures 38 and 39). The first data transmission occurred at 18:28 (AKDST). Successful data transmission was verified by satellite phone with Fritz Klasner (KEFJ) who checked the NIFC WFMI website. Snow depth transmissions are below the physical minimum (0.0 inches) as intended in order to not transmit misleading snow depths when there is no snow present. Snow depth was set to a tare of -0.4 inches in order to account for thermal expansion of the reflector and sensor drift.

The helicopter ferried the weather station crew and equipment back to the black sand beach (two trips) and refueled from the drum. The helicopter was released at 20:15. People and all equipment (including fuel drum) were transported back to the M/V Serac and the operation was successfully completed by 21:30.



**Figure 30.** The weather station site after brushing alder and salmon berry (Pedersen Lagoon RAWS).



**Figure 31.** Long Ranger helicopter approaching the small helispot located 100 ft south of the weather station (Pedersen Lagoon RAWS).



**Figure 32.** Sling net containing weather station (partially unpacked) and super sack with 500 lbs of beach rock (Pedersen Lagoon RAWS). The Alaska Sea Life Center's remote camera telemetry site is visible in the background of the picture.



**Figure 33.** Guy lines from the station and mast attached to a 1500 lb gabion (Pedersen Lagoon RAWS).



**Figure 34.** Guy line attached to an expansion bolt in bedrock (Pedersen Lagoon RAWS).



**Figure 35.** Snow depth sensor (sonic distance ranger) and reflector surface constructed of beach rock and soil (Pedersen Lagoon RAWS).



**Figure 36.** Rain gauge, satellite antenna, and GPS antenna (Pedersen Lagoon RAWS). Barb wire was mounted above the sensor cables on the southern frame section in order to mitigate damage from wildlife (bears).



**Figure 37.** Rocks were piled on top of the instrument enclosure to help mitigate damage from wildlife (Pedersen Lagoon RAWS).



**Figure 38.** The inside of the instrument enclosure photographed prior to departure (Pedersen Lagoon RAWS).



**Figure 39.** The completed weather station atop the ridge located between Pedersen Lagoon and Aialik Bay.

## **Pedersen Lagoon Weather Station – Unscheduled Maintenance**

Date: September 27, 2011

Time of visit: 0900-1000

Personnel: Chuck Lindsay (SWAN), Deb Kurtz (KEFJ),

Mode of Transport: B206 helicopter

Purpose of trip: Replace air temperature – relative humidity sensor

Weather: Sunny, 49 F, Winds light and variable

Sensors replaced:

Air temperature - relative humidity

Narrative:

The AT-RH sensor on the Pedersen Lagoon weather station (Figure 40) was replaced on September 27. Something happened to this sensor on September 6. Temperatures reported September 6-27 are warmer than the actual temperatures, by approximately 10-15 degrees Fahrenheit (Figure 41). There was no visible damage (from wildlife or storms) to the sensor; it seems to have malfunctioned. Strands of barbed wire were also added above all sides of the tri-leg tower in order to mitigate possible damage from wildlife (Figure 42). The helicopter pilot requested that additional brushing occur at the helispot in the future so that departure to the northeast can take place without having to hover (out of ground effect) before departure.

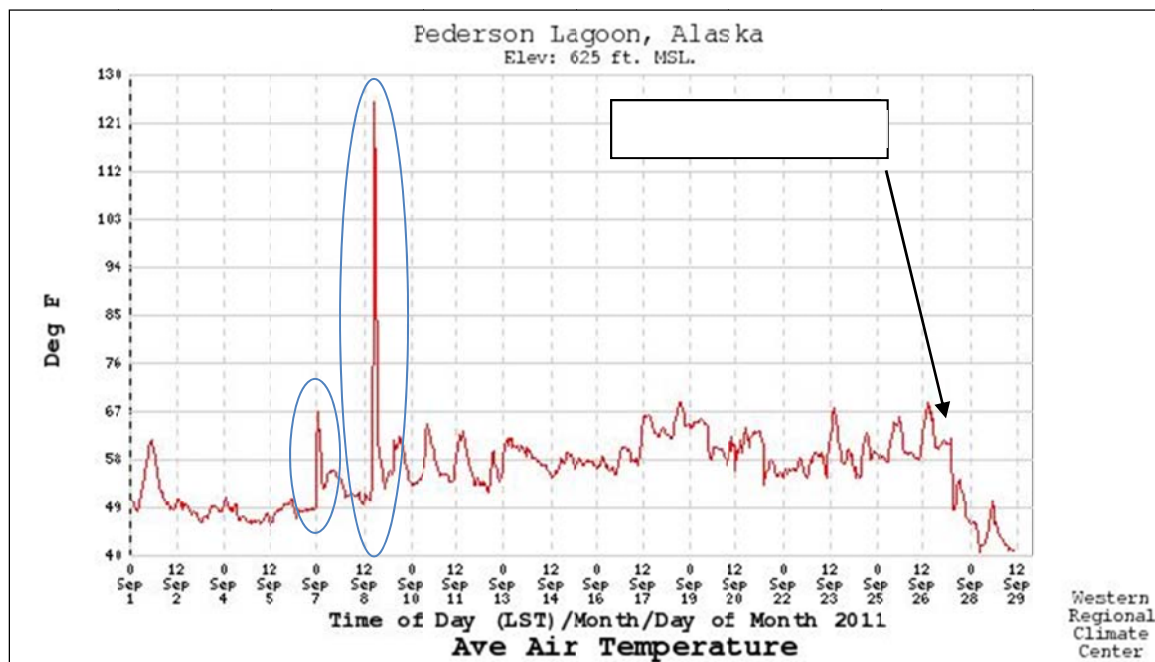


**Figure 41.** Air temperature recorded at the Pedersen Lagoon weather station September 1 to September 29, 2011. Blue circles indicate data spikes and sensor failure on September 6 and September 8. The arrow indicates sensor replacement on September 27, 2011.



**Figure 42.** Photograph of the station and Pedersen Glacier after maintenance was completed (Pedersen Lagoon RAWS). Barbed wire was added to the top of the tri-leg tower in order to protect sensor cables from damage by wildlife.

## **Pfaff Mine Weather Station – Annual Maintenance**

Date: June 15, 2011

Time of visit: 1530-1715

Personnel: Chuck Lindsay (SWAN), Claudette Moore (SWAN)

Mode of transport: C185 (on wheels) from King Salmon (park aircraft)

Purpose of trip: Annual maintenance

Weather: Partly cloudy, 45 F, Winds E 10 mph gusting to 15 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Rain gauge tipping bucket

Solar radiation

Snow depth

Narrative:

There were no indications of any problems prior to station maintenance. Scheduled maintenance called for replacement of AT-RH, RG-TB, SR, and SD sensors. Initial inspection of the weather station showed there were no issues. All data were downloaded from the station. The AT-RH sensor was replaced. The tipping bucket was replaced, tested, and the rain count was reset to zero. The solar radiation sensor was replaced. The SR50 snow depth sensor was replaced with a SR50A model. A data logger program capable of operating the SR50A model snow depth sensor was uploaded to the station. Snow depth was zeroed to an average reading of -0.4 inches to account for fluctuation without reporting misleading snow depth readings. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Cuyler Smith in Anchorage and relayed by satellite phone. Before departure the station was photographed (Figure 43) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 44) was also photographed.



**Figure 43.** Station photographed just before departure (Pfaff Mine RAWS).



**Figure 44.** Inside of instrument enclosure photographed just before departure (Pfaff Mine RAWS).

## **Snipe Lake Weather Station – Annual Maintenance**

Date: June 17, 2011

Time of visit: 1100-1600

Personnel: Chuck Lindsay (SWAN), Leslie Witter (SWAN)

Mode of transport: C185 (on floats) from Port Alsworth (park aircraft)

Purpose of trip: Annual maintenance

Weather: Mostly sunny, 60 F, Winds SE 12 mph gusting to 22 mph, snow 0" on ground

Sensors replaced:

Air temperature - relative humidity

Rain gauge tipping bucket

Solar radiation

Snow depth

Soil temperature sensors (installed, no replacement)

Analog input module (installed, no replacement)

Narrative:

There were no indications of any problems prior to station maintenance. Sensor drift resulted in snow depth reported one inch higher than actual. Scheduled maintenance called for replacement of AT-RH, RG-TB, SR, and SD sensors. Initial inspection of the weather station showed there were no issues. All data were downloaded from the station. The AT-RH sensor was replaced. The tipping bucket was replaced, tested, and the rain count was reset to zero. The solar radiation sensor was replaced. The snow depth sensor was replaced. Snow depth was zeroed to an average reading of -0.5 inches to account for fluctuation without reporting misleading snow depth readings. Soil temperature sensors were installed at depths of 4 inches (10 cm) and 20 inches (50 cm) (Figures 45 to 47). Soil at this location is a gravelly silt loam. The organic horizon and common rooting depth extends to a depth of approximately 4 inches (10 cm). A new data logger program (DLP) capable of operating the soil temperature sensors was uploaded. The current DLP operating is SNLA\_DLP\_SR50A\_SoilTemp\_20110617.prg. All bolts were checked and tightened if loose and cables were taped and zip-tied. Station observations and GOES transmission quality were checked before departure. Observations and transmissions were verified from the WFMI website by Ginger Irvine in Port Alsworth and relayed by satellite phone. The desiccant pack and memory card were replaced in the time lapse camera. The camera was refocused at the same zoom. Before departure the station was photographed (Figure 48) from eight directions (every 45°) and the inside of the instrument enclosure (Figure 49) was also photographed.

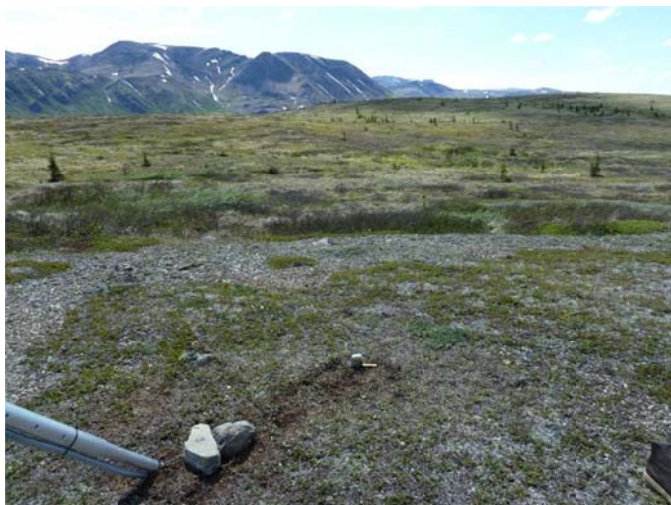


**Figure 45.** Soil temperature sensors are located beneath the tape measure (Snipe Lake RAWS).



**Figure 46.** Soil profile where soil temperature sensors were installed (Snipe Lake RAWS).



**Figure 47.** Configuration of the analog input module for the soil temperature sensors (Snipe Lake RAWS).



**Figure 48.** Station photographed just before departure (Snipe Lake RAWS).



**Figure 49.** Inside of instrument enclosure just before departure (Snipe Lake RAWS).



## Weather Station Sensor Metadata

**Table 2.** Sensor metadata for weather stations operated and maintained by the SWAN.

| Station name      | Sensor | Model          | Height<br>M | Serial<br>no | Asset<br>no | Start<br>date | Stop<br>date |
|-------------------|--------|----------------|-------------|--------------|-------------|---------------|--------------|
| Chigmit Mountains | AT-RH  | FTS THS-3      | 2.34        | 27061        | 110881      | 4/8/10        | 6/30/11      |
|                   | AT-RH  | FTS THS-3      | 2.34        | 31670        | 22267       | 6/30/11       | active       |
|                   | WD     | FTS 023-30     | 6.10        | J7039        | 30312       | 4/8/10        | 6/30/11      |
|                   | WD     | FTS 023-30     | 6.10        | 026473       | 127459      | 6/30/11       | active       |
|                   | WS     | FTS 013-30     | 6.10        | A6432        | 13668       | 4/8/10        | 6/30/11      |
|                   | WS     | FTS 013-30     | 6.10        | X1891        | 15799       | 6/30/11       | active       |
|                   | RG-TB  | FTS RG-T       | 2.18        | 29852        | n/a         | 6/30/09       | active       |
|                   | SR     | FTS SDI-SR-PYR | 2.29        | 7861         | n/a         | 6/30/09       | 6/30/11      |
|                   | SR     | FTS SDI-SR-PYR | 2.29        | 14519        | 7029        | 6/30/11       | active       |
|                   | SD     | CS SR50        | 1.67        | 8118         | n/a         | 6/30/09       | 6/30/11      |
|                   | SD     | CS SR50A       | 1.87        | 41916        | n/a         | 6/30/11       | active       |
| Contact Creek     | AT-RH  | FTS THS-3      | 2.21        | 28186        | 126063      | 6/17/10       | 6/14/11      |
|                   | AT-RH  | FTS THS-3      | 2.21        | 30875        | 22213       | 6/14/11       | active       |
|                   | WD     | FTS 023-30     | 2.34        | J7035        | 30308       | 6/17/10       | active       |
|                   | WS     | FTS 013-30     | 6.10        | 26458        | 127550      | 6/17/10       | active       |
|                   | RG-TB  | FTS RG-T       | 2.26        | 27561        | n/a         | 6/6/08        | 6/14/11      |
|                   | RG-TB  | FTS RG-T       | 2.26        | 93217        | 19574       | 6/14/11       | active       |
|                   | SR     | FTS SDI-SR-PYR | 2.29        | 28727        | n/a         | 6/6/08        | 6/14/11      |
|                   | SR     | FTS SDI-SR-PYR | 2.29        | 18427        | 7734        | 6/14/11       | active       |
|                   | SD     | CS SR50A       | 1.80        | 28268        | n/a         | 6/6/08        | 6/14/11      |
|                   | SD     | CS SR50A       | 1.80        | 41913        | n/a         | 6/14/11       | active       |
| Coville           | AT-RH  | FTS THS-3      | 2.06        | 31177        | 126131      | 6/15/10       | 6/14/11      |
|                   | AT-RH  | FTS THS-3      | 2.06        | 30040        | 21276       | 6/14/11       | active       |
|                   | WD     | FTS 023-30     | 6.10        | 28981        | 125651      | 6/15/10       | active       |
|                   | WS     | FTS 013-30     | 6.10        | 7081         | 16676       | 6/15/10       | active       |
|                   | RG-TB  | FTS RG-T       | 2.21        | 17197        | n/a         | 6/3/08        | 6/14/11      |
|                   | RG-TB  | FTS RG-T       | 2.21        | 1596         | 6808        | 6/14/11       | active       |
|                   | SR     | FTS SDI-SR-PYR | 2.21        | 17577        | n/a         | 6/3/08        | 6/14/11      |
|                   | SR     | FTS SDI-SR-PYR | 2.21        | 26378        | 127804      | 6/14/11       | active       |
|                   | SD     | CS SR50        | 1.52        | 18295        | n/a         | 6/3/08        | 6/14/11      |
|                   | SD     | CS SR50A       | 1.52        | 14911        | n/a         | 6/14/11       | active       |

**Table 2 continued.** Sensor metadata for weather stations operated and maintained by the SWAN.

| Station name     | Sensor | Model          | Height<br>m | Serial<br>no | Asset<br>no | Start<br>date | Stop<br>date |
|------------------|--------|----------------|-------------|--------------|-------------|---------------|--------------|
| Fourpeaked       | AT-RH  | FTS THS-3      | 2.34        | 28069        | 8832        | 6/18/10       | 6/30/11      |
|                  | AT-RH  | FTS THS-3      | 2.34        | 29470        | 123356      | 6/30/11       | active       |
|                  | WD     | FTS THS-3      | 6.10        | J7094        | 30323       | 6/18/10       | 6/30/11      |
|                  | WD     | FTS THS-3      | 6.10        | 17907        | 37232       | 6/30/11       | active       |
|                  | WS     | FTS 023-30     | 6.10        | 27967        | 125775      | 6/18/10       | 6/30/11      |
|                  | WS     | FTS 013-30     | 6.10        | 7667         | 127669      | 6/30/11       | active       |
|                  | RG-TB  | FTS RG-T       | 2.18        | 98251        | 4246        | 6/18/10       | 6/30/11      |
|                  | RG-TB  | FTS RG-T       | 2.18        | 97206        | 121220      | 6/30/11       | active       |
|                  | SR     | FTS SDI-SR-PYR | 2.29        | 32222        | n/a         | 6/9/09        | active       |
|                  | SD     | CS SR50A       | 1.78        | 32430        | n/a         | 6/9/09        | 6/30/11      |
|                  | SD     | CS SR50A       | 1.77        | 41917        | n/a         | 6/30/11       | active       |
| Harding Icefield | AT-RH  | FTS THS-3      |             | 028176       | 5407        | 4/24/10       | 5/2/11       |
|                  | AT-RH  | FTS THS-3      |             | 30622        | 22085       | 5/2/11        | active       |
|                  | WD     | FTS 013-30     | 6.10        | 17057        | 15993       | 4/24/10       | 5/2/11       |
|                  | WD     | FTS 013-30     | 6.10        | K4022        | 110651      | 5/2/11        | active       |
|                  | WS     | FTS 023-30     | 6.10        | 27969        | 120511      | 4/24/10       | 5/2/11       |
|                  | WS     | FTS 023-30     | 6.10        | R1548        | 123031      | 5/2/11        | active       |
|                  | RG-TB  | FTS RG-T       |             | 20173        | 122373      | 5/2/11        | active       |
|                  | SR     | FTS SDI-SR-PYR |             | 36485        | 30140       | 4/24/10       | active       |
|                  | SD     | CS SR50        |             | 15070        | n/a         | 6/3/09        | 5/2/11       |
|                  | SD     | CS SR50A       | 1.74        | 42006        | n/a         | 5/2/11        | active       |
| Hickerson Lake   | AT-RH  | FTS THS-3      | 2.49        | 30300        | 21104       | 6/21/10       | 7/7/11       |
|                  | AT-RH  | FTS THS-3      | 2.49        | 31673        | 22270       | 7/7/11        | active       |
|                  | WD     | FTS 013-30     | 6.10        | 33192        | 124122      | 6/21/10       | active       |
|                  | WS     | FTS 023-30     | 6.10        | U1323        | 1353        | 6/21/10       | active       |
|                  | RG-TB  | FTS RG-T       | 2.46        | 32313        | n/a         | 6/21/10       | 7/7/11       |
|                  | RG-TB  | FTS RG-T       | 2.46        | 1686         | 117213      | 7/7/11        | active       |
|                  | SR     | FTS SDI-SR-PYR | 2.54        | 7782         | n/a         | 6/29/09       | 7/7/11       |
|                  | SR     | FTS SDI-SR-PYR | 2.54        | 22383        | 126817      | 7/7/11        | active       |
|                  | SD     | CS SR50        | 1.65        | 15069        | n/a         | 6/8/08        | 7/7/11       |
|                  | SD     | CS SR50A       | 1.65        | 41910        | n/a         | 7/7/11        | active       |

**Table 2 continued.** Sensor metadata for weather stations operated and maintained by the SWAN.

| Station name    | Sensor | Model          | Height<br>m | Serial<br>no | Asset<br>no | Start<br>date | Stop<br>date |
|-----------------|--------|----------------|-------------|--------------|-------------|---------------|--------------|
| McArthur Pass   | AT-RH  | FTS THS-3      | 2.24        | 29640        | 125337      | 5/29/10       | 7/5/11       |
|                 | AT-RH  | FTS THS-3      | 2.24        | 30636        | 16586       | 7/5/11        | active       |
|                 | WD     | FTS THS-3      | 6.10        | U1407        | 125366      | 5/29/10       | 7/5/11       |
|                 | WD     | FTS THS-3      | 6.10        | 18390        | 37233       | 7/5/11        | active       |
|                 | WS     | FTS 023-30     | 6.10        | K1534        | 125746      | 5/29/10       | 7/5/11       |
|                 | WS     | FTS 013-30     | 6.10        | 30754        | 116184      | 7/5/11        | active       |
|                 | RG-TB  | FTS RG-T       | 2.39        | 27907        | n/a         | 6/18/08       | 7/5/11       |
|                 | RG-TB  | FTS RG-T       | 2.39        | 7978         | 119177      | 7/5/11        | active       |
|                 | SR     | FTS SDI-SR-PYR | 2.39        | 28728        | n/a         | 6/18/08       | 11/18/10     |
|                 | SR     | FTS SDI-SR-PYR | 2.39        | 1191         | 110129      | 11/18/10      | active       |
|                 | SD     | CS SR50        | 1.78        | 41101        | n/a         | 8/17/10       | 11/18/10     |
|                 | SD     | CS SR50A       | 1.96        | 41915        | n/a         | 7/5/11        | active       |
| Pedersen Lagoon | AT-RH  | FTS THS-3      | 2.14        | 41258        | n/a         | 8/10/11       | 9/27/11      |
|                 | AT-RH  | FTS THS-3      | 2.14        | 38207        | 33220       | 9/27/11       | active       |
|                 | WD     | FTS 013-30     | 6.03        | 40923        | n/a         | 8/10/11       | active       |
|                 | WS     | FTS 023-30     | 6.03        | 40636        | n/a         | 8/10/11       | active       |
|                 | RG-TB  | FTS RG-T       | 1.91        | 40718        | n/a         | 8/10/11       | active       |
|                 | SR     | FTS SDI-SR-PYR | 2.21        | 39327        | n/a         | 8/10/11       | active       |
|                 | SD     | CS SR50A       | 1.71        | 41908        | n/a         | 8/10/11       | active       |
| Pfaff Mine      | AT-RH  | FTS THS-3      | 2.03        | 32355        | 22122       | 6/6/10        | 6/15/11      |
|                 | AT-RH  | FTS THS-3      | 2.03        | 30303        | 21110       | 6/15/11       | active       |
|                 | WD     | FTS 013-30     | 6.10        | 6775         | 111660      | 6/6/10        | active       |
|                 | WS     | FTS 023-30     | 6.10        | 26322        | 29151       | 6/6/10        | active       |
|                 | RG-TB  | FTS RG-T       | 2.21        | 7675         | n/a         | 6/4/08        | 6/15/11      |
|                 | RG-TB  | FTS RG-T       | 2.21        | 14322        | 127660      | 6/15/11       | active       |
|                 | SR     | FTS SDI-SR-PYR | 2.21        | 14313        | n/a         | 6/4/08        | 6/15/11      |
|                 | SR     | FTS SDI-SR-PYR | 2.21        | 19009        | 102143      | 6/15/11       | active       |
|                 | SD     | CS SR50        | 1.51        | 8116         | n/a         | 6/4/08        | 6/15/11      |
|                 | SD     | CS SR50A       | 1.51        | 41909        | n/a         | 6/15/11       | active       |
| Snipe Lake      | AT-RH  | FTS THS-3      | 2.16        | 26746        | 25101       | 4/9/10        | 6/17/11      |
|                 | AT-RH  | FTS THS-3      | 2.16        | 31553        | 30462       | 6/17/11       | active       |
|                 | WD     | FTS 013-30     | 6.10        | A1582        | 1350        | 4/9/10        | active       |
|                 | WS     | FTS 023-30     | 6.10        | U1325        | 13667       | 4/9/10        | active       |
|                 | RG-TB  | FTS RG-T       | 2.26        | 17198        | n/a         | 6/7/08        | 6/17/11      |
|                 | RG-TB  | FTS RG-T       | 2.26        | 26640        | 127456      | 6/17/11       | active       |
|                 | SR     | FTS SDI-SR-PYR | 2.21        | 13970        | n/a         | 6/7/08        | 6/17/11      |
|                 | SR     | FTS SDI-SR-PYR | 2.21        | 15340        | 122043      | 6/17/11       | active       |
|                 | SD     | CS SR50A       | 2.11        | 28267        | n/a         | 6/7/08        | 6/17/11      |
|                 | SD     | CS SR50A       | 2.11        | 41914        | n/a         | 6/17/11       | active       |