United States Department of Agriculture
Natural Resources Conservation Service

Part 622 Snow Survey and Water Supply Forecasting National Engineering Handbook

Chapter 4 Site Installation

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Acknowledgments

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Editorial and illustrative assistance was provided by **Lynn Owens**, editor, **Wendy Pierce**, illustrator, and **Suzi Self**, editorial assistant, NRCS National Geospatial Center of Excellence, Fort Worth, TX.

Chapter 4 Site Installation

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622.0400 Introduction

This chapter contains the installation procedures and recommended sensor configuration protocols for manual snow courses and automated SNOw TELemetry (SNOTEL) snow sampling sites.

The information in this chapter supersedes information in "SCS National Engineering Handbook, Section 22, Snow Survey and Water Supply Forecasting," Soil Conservation Service, U.S. Department of Agriculture, Washington, DC, April 1972.

Trade names are used in the publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee of a product by the U.S. Department of Agriculture nor does it imply an endorsement by the Department over other products not mentioned.

622.0401 Snow course and aerial marker installation

Manual snow measurements are collected at established snow courses and aerial marker locations. This section covers installation of manual measurement sites and the access routes (trails) leading into the sites.

(a) Snow course installation

(i) Selecting a site

See Title 210, National Engineering Handbook (NEH), Part 622, Chapter 3, Site Selection (NEH 622.03), for a detailed description on selecting snow measurement sites.

(ii) Marking, mapping, and recording

When a satisfactory location has been found, the snow course and the trail to it should be marked, mapped, positioned with a Global Positioning System (GPS), and recorded to make them easy to locate under adverse winter conditions and deep snow.

Installation of a snow course may be as simple as marking the ends of a measured line on the ground. Mark the endpoints using the standard, snow course marker sign on a pipe, tree, or other relatively permanent fixture. Ensure it is high enough that it can be seen even during the deepest expected snowpack condition. Determine sample points by measuring from sample point number 1 using standard sample intervals described in the Snow Course Standard in NEH 622.08, Standards and Specifications.

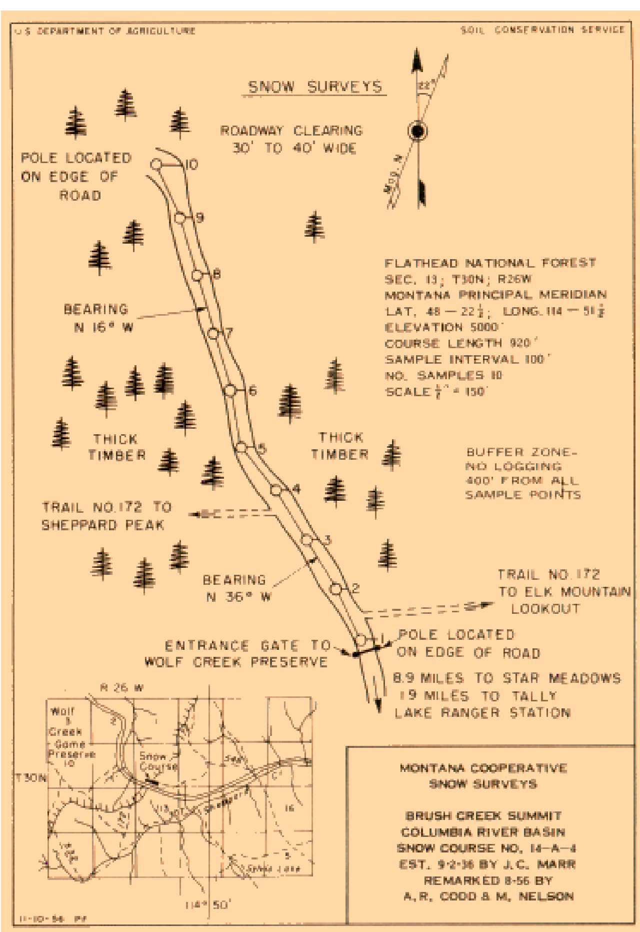
Individual sampling points may also be marked to facilitate locating the point each time it is sampled. If not, sampling points are defined on the site map and are located by measuring from the end marker each time the course is measured.

Standard snow course markers should be bolted securely to posts, with the posts painted orange, red, or yellow. Individual sampling points are often marked with numbered metal tags nailed to trees near the sampling point or to wood or metal poles set at the points as indicated. This method ensures accurate location of sampling points and is convenient for surveyors. Snow course marker design is defined in the Snow Course Marker Design Standard in NEH 622.08.

Once a snow course is installed, the State office in charge of the installation will ensure a snow course map is produced. A typical snow course map is shown in figure 4–1. Its three separate parts—site map, route map, and plot of sampling points—should be included to show surveyors the:

- sampling spacing and course layout
- general route from a well-defined point to the snow course
- relation of the snow course to the drainage pattern

Figure 4–1 Typical snow course map



All maps should have the standard map heading and title block. Pertinent data are recorded on a snow course biography form at the same time the course is mapped and marked. The completed form is kept in the Data Collection Office (DCO) supervisor's office. See figure 4–2.

Data collection procedures for snow courses are outlined in the Federal Snow Survey Sampling Guide, Agriculture Handbook 169.

(b) Aerial marker installation

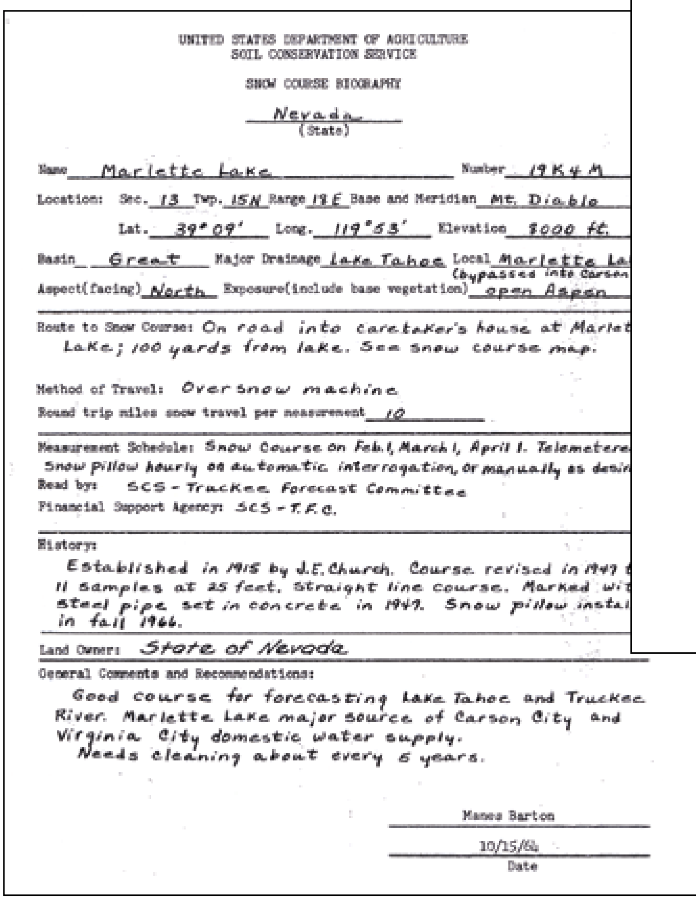
Observations of aerial markers are satisfactory substitutes for ground measurements of snow depth and snow water equivalence (SWE) during midwinter and early spring. Any lack of precision from using air-observed snow depth and estimated SWE instead of ground measurements is offset by seasonal variation in snowfall later in the year. In emergencies, observations from the air can be substituted at or near the time of maximum snow accumulation for measurements otherwise difficult to obtain.

Using aerial markers avoids the difficulties of over-snow transportation and the hazards of travel in remote regions to obtain ground measurements. These difficulties and hazards are greatest during the early and midwinter snow accumulation period when cold temperatures, deep powder snow, and avalanches are most prevalent. A number of aerial markers can be observed in the time required for one ground measurement.

During the snowmelt season, when high water, mud, and soft snow may make ground transportation difficult, aerial markers provide a means of periodically checking on the remaining snowpack. Such checks are important for short-term forecasts of streamflow for flood control and multiple-purpose reservoir operations.

Recommended data collection procedures for aerial markers are in Appendix 4B, Aerial Marker Data Collection.

Figure 4–2 Snow course biography form (older and new versions)



UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SNOW COURSE BIOGRAPHY

Nevada
(State)

Name Marlette Lake Number 19K4M

Location: Sec. 13 Twp. 15N Range 19E Base and Meridian Mt. Diablo

Lat. 39° 09' Long. 119° 53' Elevation 8000 ft.

Basin Great Major Drainage Lake Tahoe Local Marlette La (bypassed into Carson

Aspect(facing) North Exposure(include base vegetation) open Aspen

Route to Snow Course: On road into caretaker's house at Marlet Lake; 100 yards from lake. See snow course map.

Method of Travel: Over snow machine

Round trip miles snow travel per measurement 10

Measurement Schedule: Snow Course on Feb. 1, March 1, April 1. Telemetere snow pillow hourly on automatic interrogation, or manually as desir

Read by: SCS - Truckee Forecast Committee

Financial Support Agency: SCS - T.F.C.

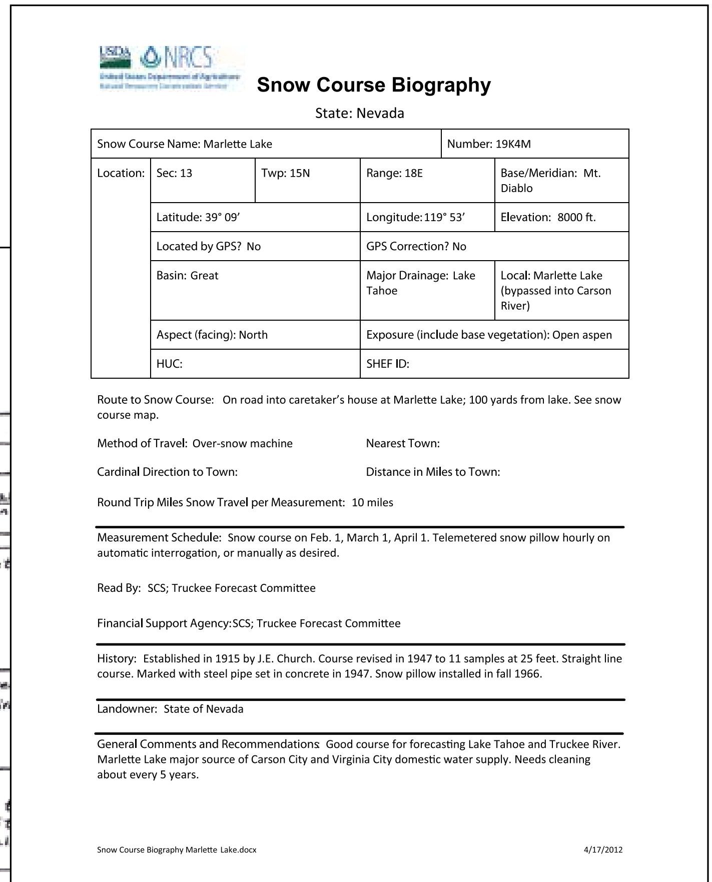
History:
Established in 1915 by J.E. Church. Course revised in 1947 t 11 samples at 25 feet, straight line course. Marked wit steel pipe set in concrete in 1947. Snow pillow instal in fall 1966.

Land Owner: State of Nevada

General Comments and Recommendations:
Good course for forecasting Lake Tahoe and Truckee River. Marlette Lake major source of Carson City and Virginia City domestic water supply.
Needs cleaning about every 5 years.

Manes Barton

10/15/64
Date



USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Snow Course Biography

State: Nevada

Snow Course Name: Marlette Lake				Number: 19K4M
Location:	Sec: 13	Twp: 15N	Range: 18E	Base/Meridian: Mt. Diablo
	Latitude: 39° 09'		Longitude: 119° 53'	Elevation: 8000 ft.
	Located by GPS? No		GPS Correction? No	
	Basin: Great		Major Drainage: Lake Tahoe	Local: Marlette Lake (bypassed into Carson River)
	Aspect (facing): North		Exposure (include base vegetation): Open aspen	
	HUC:		SHEF ID:	

Route to Snow Course: On road into caretaker's house at Marlette Lake; 100 yards from lake. See snow course map.

Method of Travel: Over-snow machine
Nearest Town:

Cardinal Direction to Town:
Distance in Miles to Town:

Round Trip Miles Snow Travel per Measurement: 10 miles

Measurement Schedule: Snow course on Feb. 1, March 1, April 1. Telemetered snow pillow hourly on automatic interrogation, or manually as desired.

Read By: SCS; Truckee Forecast Committee

Financial Support Agency:SCS; Truckee Forecast Committee

History: Established in 1915 by J.E. Church. Course revised in 1947 to 11 samples at 25 feet. Straight line course. Marked with steel pipe set in concrete in 1947. Snow pillow installed in fall 1966.

Landowner: State of Nevada

General Comments and Recommendations Good course for forecasting Lake Tahoe and Truckee River. Marlette Lake major source of Carson City and Virginia City domestic water supply. Needs cleaning about every 5 years.

Snow Course Biography Marlette Lake.docx 4/17/2012

(i) Aerial marker site installation

Perform site selection for aerial markers in keeping with the procedures described in NEH622.03, Site Selection. In addition, aerial marker sites should be near terrain features that are readily distinguishable in order to be easily located from the air.

The most important consideration for an aerial marker site is safe aircraft operations. There must be room for a safe, low-elevation approach and recovery, plus plenty of turn around room for additional fly-by observations.

(ii) Selecting a site

The ideal site for an aerial marker is a small clearing (approximately 120- to 160-ft-diameter circle) of one-quarter to one-half acre in size. The size of the clearing should depend on the height of the vegetation. The objective is to find locations where snowpack and/or dense brush can produce the desired effect.

Avoid locations where snow scouring, loading, or drifting occur, as the measurements are likely to be more associated with how much the wind blew rather than how much snow fell.

In the case of tall trees (80–100 ft) on a large site of a 200-foot- or more diameter circle (greater than one-half acre), the marker could be located anywhere in the opening. In a smaller opening of a circle 100 feet in diameter (less than one-fourth acre), the marker may need to be located near one edge to have an adequate clear window view for the aerial observation. In the case of sparse vegetation growth, these considerations may not be necessary.

At a chosen site, the specific spot to place the marker should be as smooth and level as possible, avoiding high spots, low spots, and bumpy, undulating ground. The area of consideration here is a 4- to 5-foot-diameter circle in the center of which the aerial marker is placed. If necessary, vegetative growth should be removed to ensure the selected spot is as flat and smooth as possible. Any brush within approximately 12 feet of the marker should be cut back (fig. 4–3).

(iii) Aerial marker construction

Aerial snow depth markers have a common design, but the materials used and the dimensions vary. A standard drawing of an aerial marker is in NEH622.08, appendix G.

The markers typically consist of a vertical support or post to which crossbars are attached at predetermined intervals. The post is usually a 2-inch wrought iron pipe, although a 4- by 4-inch treated post is preferable for areas in which permafrost may be a problem, such as in Alaska. Pipes of larger diameter are desirable where snow depth exceeds 150 inches. Telescoping aerial markers are acceptable in locations requiring this capability.

Horizontal crossbars are made of wood or sheet metal (about 16-gage) or one-fourth-inch steel plate. Standard dimensions for crossbars made of wood are 1- or 2-inches thick by 6-inches wide by 24 to 36 inches long. Crossbars are placed at 2-foot intervals on the post. A 1- by 3-inch-wide wood, sheet metal, or steel diagonal is placed between the outside edges of the horizontal crossbars for bracing. Diagonals cross the post midway between crossbars. An alternate design has 2- by 12-inch horizontal bars in lieu of diagonal bars.

Construct the vertical post in 4- to 8-foot sections. Use couplings to connect sections. Design the cross pieces so that they can be bolted to the support post with three-eights-inch bolts. This arrangement facilitates transport to field locations and replacement of damaged cross pieces.

The preferred paint for markers is bright orange enamel similar to that used for highway signs. Repaint markers every 3 to 5 years or as needed.

Figure 4–3 Aerial marker in snow-covered clearing, Hart Pass, WA

The support post should be set in concrete to a minimum of 24 inches or one-fourth the marker height. The marker may need support while the concrete sets. If concrete is deemed detrimental to stability, such as on frost-susceptible soils, there may be a need to design alternative support mechanisms.

On installation, record the total height of the marker and place it with other information on the snow course biography form. The total height of the marker should be 3 or 4 feet more than the maximum expected snow depth. If the marker is too long, counting extra crossbars increases the chance of error.

(iv) Placing the marker

Once the site is selected, installation should follow procedures outlined in the aerial marker standard in NEH622.08. The hole dug in the ground to stand the marker up should be as small as possible.

Take measurements once the marker is set in the hole and backfilled, and soil and rocks are tamped in as firmly as possible. Make the final measurement from ground surface to the middle of the first orange crossbar and record the measurement. If this measurement is not exactly 24 inches, add soil to the area to zero the correction factor. If not, bring in sand, gravel, etc. and make it a zero correction, or the difference becomes a permanent adjustment (correction factor). Usually this correction factor will be plus or minus 1 inch. Apply the correction factor to the final reading.

Markers often settle or heave by an inch over the first winter before stabilizing. Therefore, it is important to take another measurement the next summer season to determine any possible further adjustment to the correction factor.

Crossbars are normally placed parallel to the line of flight. Later, if it is discovered that the marker is not easy to spot from the air, by turning the marker 90 degrees so the bars are facing the oncoming aircraft, the marker can be spotted more quickly, giving the observer and pilot time for flight-line adjustments. These adjustments are sometimes necessary when a marker is placed within a scattered spruce forest, which has no natural opening in the forest to line up on in advance.

(v) Guying the marker

If possible, the use of guy lines should be avoided; however, conditions may dictate the use of guy lines. Reasons for guying the marker to keep it vertical may include:

- boggy ground
- permafrost
- a hole dug too large
- where bear activity is common

When guying the marker, use three cables per marker.

For permafrost ground with no trees, attach plastic-covered cable (which lasts much longer where cable is below ground) to an anchor. Drive the anchor along the same plane as the anchor cable. A homemade driver can be constructed by welding a 2-inch stub of a half-inch-diameter pipe to a 4-foot length of iron bar.

If trees are present, some of the stumps left when clearing could be used for anchors. Screw-in anchors work equally well in soft ground, but they are more expensive.

Tightening the cable between the anchor and marker is easily done by pulling on the cable end with vise grips as the cable clamp is tightened down. A turnbuckle may also be used to provide adjustment capability of the guy lines.

(vi) Photo documentation

After installation of an aerial marker, photo documentation of the site should be taken. At a minimum, photos of the site from the four cardinal directions to the site and four photos from the site in the cardinal directions should be taken. In addition, a photo with a stadia rod or other measuring device standing against the maker facing the optimum direction from where the aerial observation will be taken is very helpful. If sites are photo documented, a method to identify the sites from the air needs to be established. This may be numbers attached to the top of the pole (as per California DWR specifications) or the image may also have a GPS location included.

622.0402 SNOTEL station installation

(a) General site layout

See NEH 622.03, Site Selection, for a detailed description of SNOTEL station site selection.

Once an appropriate SNOTEL site has been selected and permitted with the landowner, the next step in the installation process is to assess the layout of the site to position each individual component (shelter, pillow, tower, precipitation gage, and soil moisture/soil temperature) correctly in relation to all other components. Attention to detail in this part of the process will ensure the best data quality.

Keep the overall footprint of the site as small as possible for two reasons:

- better data quality—When working with fluids in various types of tubing, the shorter the distance to the manometer and pressure transducer, typically the less data fluctuation is exhibited.
- smaller environmental impact

In addition to information presented in NEH 622.03, some factors to consider in the general site layout assessment are:

- extent of material and soil excavation and vegetation removal needed
- precipitation gage and snow pillow location, such that there is the greatest clear sky view while minimizing wind effects
- shelter location, such that the pillow and precipitation manometer heads are sufficient to provide at least 10 inches above the pressure transducer, typically 10 to 20 inches above the floor
- large rocks, bedrock, large trees, or other complicating factors that may dictate component locations
- station visibility
- proximity to steeper slopes that could cause creep problems
- minimizing potential wind impacts (fig. 4–4)

These factors are described in more detail in NEH 622.05, Calibration and Maintenance, and NEH 622.08, for additional details on SNOTEL sensors.

Figure 4–4 shows a typical SNOTEL site.

(b) Snow pillow location

The location of the snow pillow should be such that there is the greatest clear sky view while minimizing the effect of wind and snow creep. Some elevation relief is necessary between the snow pillow and the shelter in order to obtain sufficient fluid pressure on the snow pillow transducer. The type and number of pillows will determine the shape and size of the level area needed for snow pillow installation. See Snow Pillow Snow Water Equivalent Sensor Standard in NEH622.08, for the standards on snow pillow installation.

Figure 4–4 Typical SNOTEL site, Pepper Creek in Washington

(c) Storage precipitation gage location

There are four primary factors to consider in locating the storage precipitation gage: maximum clear sky view, placement to provide sufficient fluid pressure for the manometer and transducer, protection from wind, and distance from the gage to the instrument shelter.

The Field Manual for Research in Agricultural Hydrology, Agriculture Handbook 224, 1979, addresses general considerations for gage placement, as well as maximum clear sky view:

> “The location of the gage is the primary consideration for obtaining accurate precipitation measurements. An ideal exposure would eliminate all turbulence and eddy currents near the gage. Individual trees, buildings, fence, or other small groups of isolated objects near the gage may set up serious eddy currents, especially when their height above the gage is appreciable. As a rule, an isolated obstruction should not be closer to the gage than twice (preferably four times) its height above the gage. Obstructing objects usually provide a more accurate catch when they are so numerous and extensive that prevailing wind speed in the vicinity of the gage has been reduced and consequently, the turbulence and eddy currents have been reduced. The best exposures are found, therefore, in orchards, in openings in a grove of trees or bushes, or where fences and other objects form an effective windbreak.
>
> Sites on a slope or on ground sloping sharply away in one direction should be avoided especially if this direction is the same as that of the prevailing wind. The surrounding ground can be covered with short grass or be of gravel or shingle but a hard flat surface such as concrete causes excessive splashing and abnormally high surface temperatures.
>
> The growth of vegetation, trees and shrubbery, and manmade alterations to the surroundings may make an excellent exposure unsatisfactory in a relatively short time.
>
> The angle from the gage orifice to the top of any nearby object should not exceed 30 degrees, thus allowing for growth of vegetation. Under no circumstances should an obstruction be nearer to the gage than its own height, or 45 degrees. Wilson (40) felt, however, that a small clearing in uniform forests, having a diameter about equal to the height of the trees, was best because the measurement would gain more from the reduction of wind than it would lose from interception.
>
> A clearing of about a quarter acre is required to place a gage in a forest opening of 60-foot trees. If no such openings exist on a watershed where no cutting is allowed, measuring rainfall at the surface of the tree crown should be considered.”

When precipitation gages are installed at remote back-country sites, the clear sky view of 30 to 45 degrees from the gage orifice is sometimes difficult to achieve. Often, the taller the gage, the easier it is to obtain a clear view relative to various obstructions. Also, if the vegetation is relatively uniform in height and density, a higher angle may be acceptable (fig. 4–5).

See NEH622.08, for the standards for storage precipitation gages.

Figure 4–5 Typical SNOTEL storage precipitation gage

(d) Shelter location

The primary factors in determining shelter location are:

- elevation of the manometer/transducer head in relation to the snow pillow and the precipitation gage
- preventing wind eddy effect that could scour the snow on the pillow
- minimizing the site footprint
- visibility

Elevation of the manometer/transducer head in relation to the pillow is the first consideration. The pillow elevation should be at least 10 inches higher than the floor of the shelter. This will allow sufficient room for the plumbing for the manometer/transducer.

Sufficient head for the fluid inside the precipitation gage also needs to be considered. The final fluid level after the precipitation gage has been recharged should allow for a minimum head above the floor of the shelter of 10 inches.

Sufficient head may be available at several locations around the data collection area. The location that minimizes the site footprint (and thus the distance between the pillow and the shelter), as well as the precipitation gage and the shelter, is likely the best location. Shorter plumbing lengths ultimately produce better data and decrease the potential for damage to the plumbing systems.

If possible, the shelter should be located to the side and in a less visible location, perhaps near some trees or other vegetation. This will minimize the visibility of one of the largest site components.

Another potential constraint is whether a single tower is used or if dual towers are installed. When using dual towers, it is preferable to anchor the solar panel/antenna tower to the shelter. If only a meteorological ("met") tower near the pillows is installed, the distance between the tower and the instrument shelter also needs to be considered to account for voltage or other line losses in the cabling.

The shelter needs to provide adequate protection of the site electrical components, and provide year around access. This may dictate that the shelters in some locations be 12 or 16 feet tall. Access must be provided through additional doors on these taller shelters.

The shelters should be painted to blend into the surrounding environment. Most times brown paint or brown metal siding will be the color of choice. However, in areas of aspen trees or other light colored backgrounds, grey or white paint may be preferred (fig. 4–6).

(e) Vegetation removal

Vegetation at a SNOTEL site should be managed so that the site provides consistent data over long periods without changing vegetative influences. During instal-

Figure 4–6 SNOTEL configuration of shelter, snow pillow, storage precipitation gage, and "met" tower

Observe the shelter location relative to the pillow and precipitation gage. The first consideration was the location of the manometer head from both the pillow and the precipitation gage. The second consideration was minimizing the site footprint by keeping components as close to each other as possible. The third consideration was visibility. Therefore, a white shelter was designed to go in an aspen setting and was located closer to some of the trees.

lation, vegetation should be removed to install the sensors, towers and shelter, as well as to give necessary clear sky view for the snow pillow and precipitation gage.

After vegetation removal, the site must then be protected from encroachment. As trees surrounding the site grow, snow, precipitation, temperature, and soil moisture/temperature patterns may change. It is the goal to try and maintain the vegetation surrounding the site in as close a condition as to when the site was installed.

(f) Large rocks and other obstacles

Sites that are extremely rocky or have a shallow soil profile to bedrock present unique challenges to component placement. The shelter and precipitation gage both need solid foundations that are well anchored to the ground. Towers need to have at least 3 feet of depth or sufficient horizontal stabilization to be safe to climb. Rocks and other obstacles often dictate the location of not only the major components, but also the curvature and depth of plumbing and cable lines from components to the instrument shelter (fig. 4–7).

(g) Visibility

SNOTEL site components should be placed such that the site itself remains relatively inconspicuous within the forest opening. Locating the entire site or substantial components in the middle of a large meadow is not advisable as it will likely be more prone to vandalism as well as enhanced wind impacts. Blending the site into a background environment by site location and component colors is recommended. In some cases, this is not possible when a site is near a road or other highly travelled area. In these situations, mitigate impacts by using informational signage, etc.

The following represents a SNOTEL site incorporated into an interpretive park. The SNOTEL shown in figure 4–8 is such a site, with a paved recreational trail directly adjacent to it. Mitigation here consisted of a small footprint in all components—tower, precipitation gage, no fence, and a nonstandard shelter with appropriate signage.

Figure 4–7 Rocky SNOTEL site

Figure 4–8 Fallen Leaf SNOTEL site, NV

The interpretive kiosk is actually the instrument shelter and houses the full complement of all components inside. The smaller sign gives an overview of SNOTEL operations and benefits.

(h) Proximity to steep slopes

Steep slopes can be prone to snowpack creep, which can cause errors in SWE data collection. When viewing potential SNOTEL site location, areas to avoid are well-defined slope breaks, which may put the snow pillow device in either compression or tension, thus changing the SWE values without actually having any increase in snowfall. Clues to snow creep may be visible in the trees near the area, or perhaps bent marker poles from a preexisting snow course. However, snow creep locations may not be noticeable with just observations during snow-free conditions, and would not be until SWE data has been collected at some sites for a number of years. Steel pillows have been shown to be more sensitive to snow creep than fabric pillows.

Steps to mitigate snow creep include:

Step 1: Enlarge the pillow pad, cutting further into the uphill bank and adding to the lower side of the pillow pad.

Step 2: Replace steel pillows with fabric pillows.

Step 3: Move the sensor (either pillow or precipitation gage, since they can also be impacted by snow creep) to areas unaffected by the snow creep.

(i) Minimizing wind impact

The most efficient way to minimize wind impact is to ensure there is a consistent barrier of sufficient height and distance upstream of the prevailing wind direction. Vegetation is a very effective natural wind barrier, and should be used to reduce wind effects at SNOTEL sites whenever possible (fig. 4–9).

One problem encountered at many SNOTEL sites is that of SWE data outrunning precipitation data. Beyond the fact that these are two, independent, but related data parameters, in a normal context, SWE can outrun precipitation due to the fact that the pillow is a much more efficient collector of snow just from its size in relation to a 12-inch precipitation gage orifice. But, sometimes the difference may be due to wind redistribution of snowpack. Wind can accumulate or remove snowpack from a pillow location depending on direction and velocity and other factors, without deposition into the precipitation gage. In an ideal setting, this should be minimal. However, the reality is that it tends to be large at many sites. Care should be taken at site installation, particularly in locating the pillow area, to shelter it from wind impacts, particularly wind impacts that would remove snow from the pillow.

(j) Other site layout considerations

Common errors in site selection that should be avoided are:

- too much or too little elevation difference between the pillow and the shelter
- not clearing sufficient surrounding vegetation
- locating the site in an avalanche runout area
- locating the site in an area of flooding
- locating the site in an area of observed snow creep
- locating the site in an area prone to land use changes (fires, development, logging, etc.)

Figure 4–9 Windy SNOTEL site located in a meadow

622.0403 References

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Western Snow Conference. 1983. Metrication Report. Farnes, et al.

Appendix 4A Snow Course Data Collection Equipment

Appendix A describes snow course data collection equipment. Snow course data collection procedures are outlined in the Snow Survey Sampling Guide, Agriculture Handbook 169.

Federal snow sampler

The Federal snow sampler is the standard instrument used by NRCS to conduct snow surveys. It is constructed of duraluminum tubing, formed into 30-inch sections that can be attached together to form one long tube. The bottom section has a sharp cutter bit that helps a sampler to push the tube through the snowpack and extract a core to be weighed and determine the snow water equivalence (SWE). See figure 4A–1.

Slots in the tubes allow the sampler to observe the length of the core and determine the quality of the sample. A spring scale with a weighing cradle is used to weigh the tubes and snow sample in determining the SWE. Spanner wrenches are used to unscrew any sections that may tighten in place when sampling. The driving wrench is clamped on the tube to drive it into deep, hard, compact snow and to cut through layers of ice.

Figure 4A–1 Federal snow sampling set and related items

The Federal sampler tends to over measure snow water equivalent by 10 to 12 percent with a standard factory cutter bit. If the teeth of the cutter bit are sharpened to the inside, the over measurement is reduced to about 6 percent.

Complete standards, specifications, and drawings for the Federal snow sampler are in NEH622.08. Maintenance and calibration procedures for the sampler are in NEH622.05.

McCall sampler

The McCall sampler is another popular sampler used in the snow survey program. The McCall sampler is a modification of the Federal sampler, and is designed for use in maritime snowpacks. Maritime snowpacks can be very deep, dense and icy to the point that sampling with the Federal sampler becomes extremely difficult. McCall samplers are also well adapted to continental snowpacks.

The McCall tubes are constructed from aluminum stock which is twice as thick as that used in the Federal sampler. This allows the threads to be machined directly into the walls so there are no couplings and therefore a continuously smooth outer wall. The cutting head is also much heavier and longer, and its outside diameter is slightly wider than that of the tubes. This greatly enhances the sampler's ability to penetrate and be extracted from deep snow. The inside diameter of the cutter is the same as the Federal sampler (1.485 in).

The heavier gage construction allows for another important adaptation—the driving head. The driver is made up of a solid steel piece, approximately 2 inches in diameter and 3 inches tall, through which a five-eights-inch hole is drilled. This part screws onto the uppermost section of tubing. A guide rod attached to a weight of either 5 or 10 pounds slides up and down through the hole, thereby allowing a hammer action to drive the cutter downward. In this manner, the McCall sampler can penetrate ice layers and very dense snow layers that the Federal sampler may not be able to penetrate.

A critical step in assembling the tubes is to be certain that all sections and the driving head are screwed completely together so that the hammer blows are transmitted from section to section to the cutter through the juncture of the adjoining walls and not through the threads.

An important aid at a snow course is the depth stake. The McCall sampler may be inadvertently driven into the ground since all "feel" for the ground is lost during the hammering process.

The slots in the tube are replaced by three-eights-inch holes spaced at 1 inch, staggered intervals to incorporate a slip-proof set of driving wrenches. The wrenches are less important for driving but are more important for lifting the set out of the snowpack and replacing the spanner wrenches in disassembly. The driving head is equipped with a large ring at the top so that, as a last resort, a helicopter could lift the tube out.

A milk scale is used to weigh the McCall sampler since the standard Federal sampler scales lack the capacity for this much weight. A rugged accessories satchel is necessary to carry the scale, bail, driving head and hammer, hammer handles, lifting wrenches, and cleaning rags, in addition to the normal snow tube case.

The McCall sampler tends to overweigh snow by approximately 4 percent (Western Snow Conference "Metrication Report," 1983, Farnes, et al.).

Other samplers

In addition to Federal and McCall snow samplers there are several other types of samplers used by other organizations and NRCS for special snow conditions. Samplers can be grouped into two broad categories: small-diameter cutters (around 1.48 in) and large-diameter cutters (around 2.5 in or larger). These samplers include:

- Small-diameter samplers
- Federal
- Rosen
- Bowman
- McCall
- Large-diameter samplers
- Glacier
- Adirondack
- Meteorological Service of Canada (MSC)

The large-diameter samplers are better suited to shallow snowpacks (less than 40 in deep). The smaller diameter samplers are better suited to deeper snowpacks, but may be used on shallow snow if used carefully. In addition to differences in diameter, the various samplers differ in cutter bit or cutting edge design, coupling design, tube length, and type of weighing scale.

Appendix 4B Aerial Marker Data Collection

Safety

Safety must be the primary concern when observing aerial markers. The objective is to fly as low and slow as possible, within safe limits, usually approximately 200 to 300 feet above ground or tree tops. The controlling variable is always the local weather-of-the-moment.

On fair-weather days, some pilots may provide a glide-by at perhaps only 100 feet above the aerial marker, which provides a good view of crossbar/snow surface measurements. On the other hand, bumpy, windy conditions are often the norm, and that means the airplane must fly higher and faster for safe margins.

Accuracy

In relatively shallow snow conditions, it is difficult to be certain of the accuracy of the observation with only one pass. The first pass should concentrate on the number of orange crossbars visible, which will usually be four or five, and then whether the black crossbar is visible. Have the field book in hand and make the marks called for the moment the marker passes out of sight. On the second pass, concentrate just on the crossbar/snow surface relationship and mark all impressions it gives on the schematic. Make a third pass if anything needs to be verified. After some experience, reading with a single pass may be possible.

Snow conditions that can reduce accuracy of aerial maker data collection include:

- Sometimes immediately after a new snowfall, a settlement cone can be observed clinging to the marker, where the snow surface everywhere else has settled. The settled surface is the desired reading and may have to be estimated.
- A well-out or deep hole in the snow around the marker is common and normal around all markers during the snowmelt season. The desired reading is the snow surface away from the well.

Be sure to complete the entire observation sheet. If a well or settlement cone is present, try to sketch its relative dimensions. Fill any pertinent remarks, for example, the number of passes, bumpy or not, visible wind effect, well-out or cone, and if poor visibility is checked, state the specifics.

Appendix 4C SNOTEL Sensor and Component Recommended Installation

Following are some recommended installation procedures for the sensors and components of a SNOTEL station. Although some standards are mentioned for convenience sake, a complete description of installation standards is in NEH622.08. It is recognized that there are many ways to accomplish the same task. These recommendations are to help guide personnel through the installation process.

Air temperature sensor installation

Follow these procedures to ensure a properly installed air temperature gage. See NEH622.08 for installation standards and specifications.

Because the air temperature sensor must be mounted at least 24 inches away from the tower, it is advisable to mount the sensor onto the boom that will be used to extend the sensor away from the tower, before mounting the boom.

Step 1: The radiation shield usually holds the sensor in position. The white, 6-Gill shield can be mounted to a 4-inch nipple that is attached to the end of the boom (1-in galvanized pipe) using a 90-degree elbow and mounted on the north side of the tower.

Step 2: Affix the signal lead securely from the sensor along the length of the boom to where it can easily be accessed once the boom is positioned on the tower.

Step 3: Mount the boom to the tower at the specified height (which is dependent on the anticipated maximum snow depth). Orient the shield and sensor so that they are vertical.

Step 4: Secure the boom so it will not shift.

Step 5: Route the lead down the inside of a tower leg to a junction NEMA enclosure. It is preferable to run the lead inside electrical conduit to prevent the snow or wind from providing stress to the lead and breaking or disconnecting it. Alternately, use flex conduit and run the entire cable through the pipe and flex to the NEMA enclosure.

Step 6: Record the position and specific sensor information in the metadata form.

Considerations

Several styles and manufacturers of air temperature sensors are currently used at SNOTEL sites. Depending on the type and manufacturer, different algorithms must be used to convert the raw voltage values to engineering values. The correct algorithm must be used to provide accurate readings.

Plans and specifications

Plans and specifications for the tower and sensor installation are in NEH622.08.

Antenna installation

Follow these procedures to ensure a properly installed antenna. See Antenna in NEH 622.08 for installation standards and specifications.

Most SNOTEL antennas are for meteor burst communications transmission. They must be of YAGI-type construction and set up for the official NRCS SNOTEL transmit and receive frequencies. The official transmit frequency is 41.61 MHz; the official receive frequency is 40.67 MHz.

The direction of the antenna depends on the location of the station. Generally, the antenna should be pointed toward the midpoint bearing between two master stations (e.g., Boise and Dugway). This will help ensure the station will continue to report data even if one of the master stations has failed to operate. Sometimes the remote station will only report to one of the master stations. In this case, the best direction for the antenna would be directly toward the master station to which it will report. Often, obstacles, such as mountains, latitude position, or trees, interfere with the signal from the station and it becomes necessary to adjust the antenna horizontally or even vertically. In this case, it is hard to determine the optimal orientation of the antenna without trial and error. A spectrum analyzer may be used to help determine the optimal orientation, if one is available.

The coax cable from the antenna to the radio should be securely attached to the inside of the antenna tower. Bends should be kept to a minimum and should never be tight enough to put excess stress on the coax cable. Replace the coax cable if it is kinked.

The antenna should be attached to the top of the antenna tower, which is usually near the SNOTEL shelter. It may be mounted to a mast that can extend either though the center of the top section of the tower, or be mounted to the side of the top section.

Step 1: Assemble the antenna on the ground ensuring all the elements are parallel and positioned at the manufacturer's specified lengths along the boom.

Step 2: Attach the coax cable to the antenna. Ensure the connectors are well sealed with high-quality electrical tape or liquid electrical tape. Coil the coax and tape to the antenna boom so that it will be out of the way while lifting to the top and mounting to the tower, while ensuring it is still in a convenient position to access once the antenna is mounted.

Step 3: Prepare clamps and other mounting hardware to attach the antenna to the tower.

Step 4: Lift the antenna to the desired location to be mounted and secure it to the mast using clamps, U-bolts, etc.

Step 5: Ensure the horizontal position of the antenna is as level as possible. It often helps to have a person on the ground observe the antenna and guide the positioning to get it level. Tighten the mounting hardware to secure it in the level position.

Step 6: Orient the antenna to the desired direction. Tighten all hardware and ensure the antenna is secure in all directions.

Step 7: Route the coax cable along the boom and down a leg on the inside of the tower to the building. Running the coax down through electrical conduit is desirable to help prevent damage from snow, wind, or animals.

Step 8: Route the coax to the radio being sure to keep it clear of the work or traffic areas. Coil up any excess length to keep the work area uncluttered.

Barometric pressure sensor installation

Follow these procedures to ensure a properly installed barometric pressure sensor. See NEH622.08 for installation standards and specifications.

Installation

Mount the barometric pressure sensor to the back plate of the NEMA enclosure in a convenient location that will allow the sensor to be easily wired directly to the data logger.

Vent the sensor to the outside of the NEMA enclosure with a length of tubing. The tubing can be run out of the ports that are used to allow cables from other outside sensors to enter. See figure 4C–1.

Figure 4C–1 Barometric pressure sensor mounted between data logger and multiplexer

Battery installation

With sufficient solar power, the radio generally takes at least two batteries to maintain charge throughout the year. The data logger will generally operate all year with one battery.

Follow these procedures to ensure properly installed batteries. See “SNOTEL Battery” in NEH622.08 for installation standards and specifications.

Step 1: Batteries should be a 12- to 14-volt, 50- to 60-ampere-hours, sealed, nonspill, which are able to accept a wide range of charges from the solar panels and operate at extremely high and low temperatures.

Step 2: The batteries should be kept on the floor of the SNOTEL shelter with wiring coming into the building from the solar panels through a well-sealed conduit.

Step 3: The wiring to and from the batteries should be secured well out of the way.

Step 4: If corrosion is an issue, dielectric grease may be applied to the terminals for each battery. Do not apply grease unless corrosion is an issue.

Step 5: Banks of more than one battery should be wired in parallel to maintain the voltage output.

Data logger installation

Follow these procedures to ensure a properly installed data logger.

The data logger should be installed securely on the back plate of the NEMA enclosure. The data logger is usually located next to the radio, close enough to provide easy connections between the two, but leaving enough room around the logger to allow easy access to the sensor connections on the logger wiring panel.

The sensor wiring configuration to the data logger is dependent on the programming used at each station. It is advisable to make the programming as consistent as possible throughout the network. A wiring diagram can be a handy tool to have posted at each SNOTEL station to help in changing sensors or troubleshooting problems onsite.

Figure 4C–2 is an example wiring diagram for a data logger and optional Judd Board that uses good color coding to indicate each sensor’s wire color and the position it should be wired to the panel.

Precipitation gage (storage gage) installation

Numerous types of gages are used to collect precipitation. Those used in the SNOTEL data collection network at high elevations generally are of the storage type. The capacity of the gage selected for a given site depends on the maximum depth of snow, not on the equivalent depth of water, which can be expected to accumulate in the interval between visits to the site. Although no ice block will form if an adequate quantity of antifreeze is used, if the gage is allowed to become too full and the antifreeze too diluted for rapid snow melting during a heavy storm, snow also may fill the gage and a true catch is lost. The gage, therefore, should be capable of handling any snow accumulation that occurs between visits. See figure 4C–3.

Location

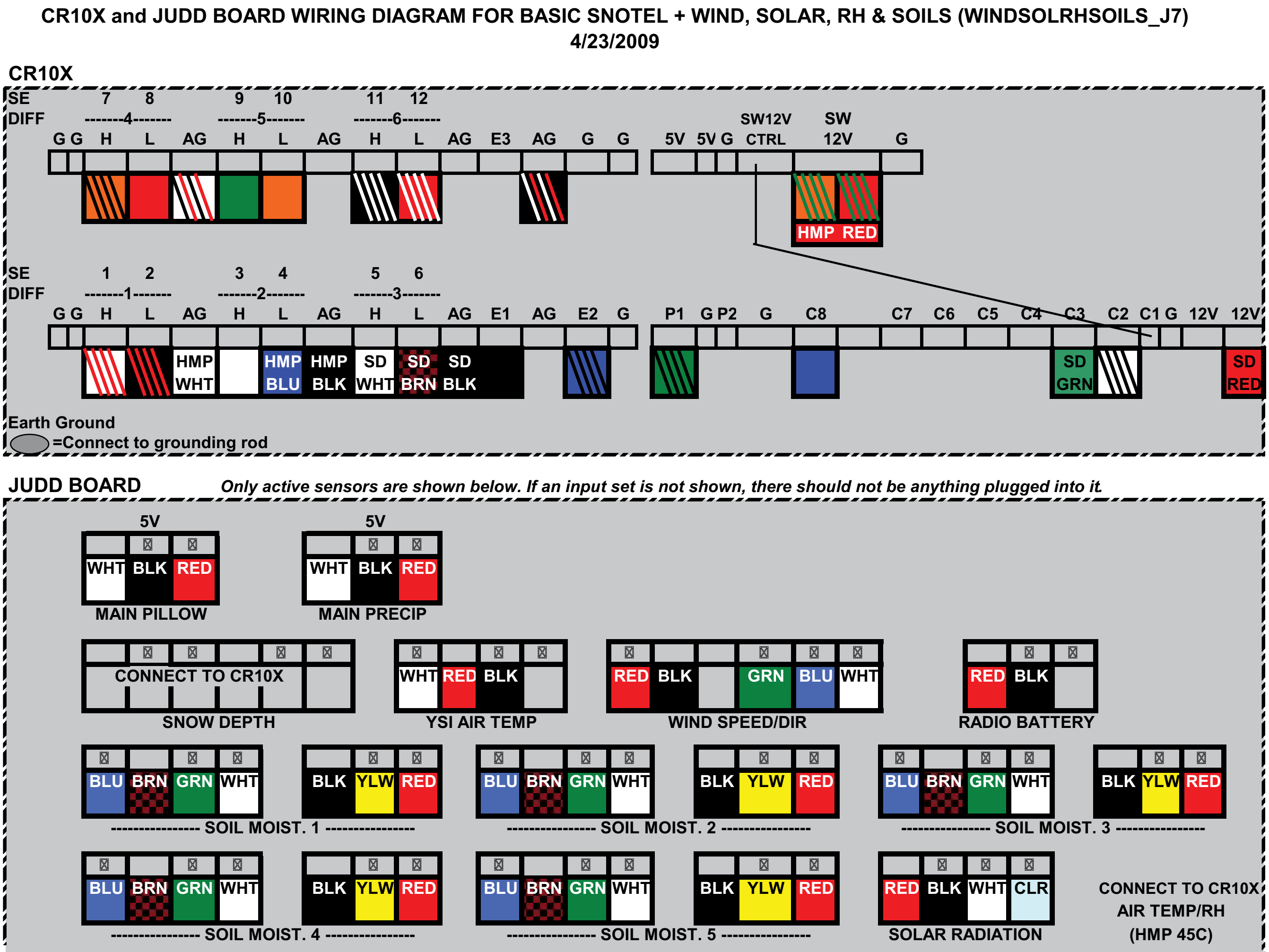
The recommended location of the precipitation gage should be such that it has the greatest open sky view within the overall site location. (See NEH622.08 for minimal opening.) Minimize the distance between the shelter and the gage to have a short plumbing run. The gage can be located inside or outside of the pillow fence and the general data collection area (primarily defined as the pillow and meteorological tower).

There are two primary slope considerations with respect to precipitation gage location:

- It must be sufficiently higher than the shelter to have readable head on the manometer inside.
- The ground slope should not interfere substantially with precipitation catch.

The head inside the shelter must be a minimum of 4 to 6 inches above the plumbing valve assembly such that it is easy to read and provides an easy year-to-year baseline reference for recharge. Except in rare cases, the head inside the shelter should not exceed 20 inches. As an example, given a standard 8- to 10-foot shelter, a maximum of 20 inches of head on the manometer would give room for at least 72 inches of precipitation catch, more than sufficient for annual ac-

Figure 4C–2 Example wiring diagram for data logger, optional interface board, and sensors



cumulation in most cases. On extremely steep slopes (>25 percent) this limits the location of the precipitation gage, as well as the pillow, to a contour just slightly above the shelter.

In preparing the final grade for the precipitation gage be sure to account for both the inside level of the shelter and the general height of the manometer assembly and put the fluid height 4 to 6 inches above that level. The following factors must be considered to ensure the head placement inside the shelter is appropriate:

- height of the base of the precipitation gage above ground level
- height of the inside of the shelter above ground
- level of fluid recharge inside the precipitation gage (approximately 2.1 inches of head per gallon of recharge) relative to the fluid height inside the shelter
- height of the mounting technique, whether concrete or wood

Installation

See the standards for installation and concrete footings under "SNOTEL Storage Precipitation Gage" in NEH622.08.

After the appropriate location is selected, use this procedure to ensure a properly installed storage precipitation gage:

Step 1: Prepare the gage for installation by installing the plumbing connections at the bottom of the gage and placing the alter shield at the top of the gage (fig. 4C–4).

Note: In some locations in areas of heavy snow, alter shields may be omitted.

Step 2: Excavate the foundation area so that the base will rest level on the surface and the gage will be plumb. Pay particular attention to the relative elevation of the gage in reference to the shelter so that there will be sufficient head in the manometer.

Figure 4C–3 Storage precipitation gage relative to shelter, pillow, and other sensors.

Figure 4C–4 Properly mounted alter wind screen

This site, Midway Valley, UT, experienced an extreme snow year in 2005 where the previous maximum snow accumulation was exceeded by 160 percent. This picture shows a section of gage being added in midevent to prevent the snowpack from topping the gage.

Step 3: Install the foundation footings (either concrete or railroad ties) and secure the gage to the footings.

a. When pouring concrete footings, use forms that will provide a foundation to meet standards stated NEH 622.08.

b. It is important to place the anchor bolts in the concrete immediately after pouring. Use the gage itself or a template to ensure the anchor bolts are positioned properly to fit through the anchor holes in the gage base.

c. Carefully secure the anchor bolts in place with nuts, but don't tighten them for at least 24 hours when the concrete has hardened sufficiently.

Step 4: Holes for the anchor bolts should be positioned and drilled through railroad ties and the anchor bolts installed before the ties are positioned.

Step 5: Once the footings are in place and secure, position the gage onto the footings and attach with the anchor bolts.

Step 6: Excavate a small trench from the precipitation gage to the SNOTEL shelter. Ensure that the trench is smooth with an even grade for the entire length. The line from the gage to the pressure transducer should be on a continuous downhill grade, and a continuous uphill grade from the low point to the transducer to avoid air lock (fig. 4C–5).

Step 7: Fittings to the precipitation gage and sensing devices vary. All connections must be made carefully with high-quality materials. The fluid-transfer line may be copper, rubber hose (Ortac® or similar quality), or plastic tubing. Tubing or pipe is preferred since rodents may damage rubber hose. Copper tubing corrodes in some soils.

Step 8: Install plumbing lines from the gage to the shelter. Ensure the plumbing rests evenly along the entire length of the trench without any undulations. Placing mounds of soil or rock to hold the line in place helps keep the length resting evenly on the bottom of the trench until it can be backfilled.

Step 9: Attach the plumbing to the gage and in the shelter. How this is done depends on the type of plumbing used. It is important not to create any kinks or other restrictions. Always check these connections for leaks after the gage has been charged with antifreeze solution. In locations of very high precipitation, there may need to be a shutoff valve to the manometer above the transducer, to prevent overtopping (figs. 4C–6 and 4C–7). See NEH622.08 for installation standards for pressure transducers.

Step 10: Backfill the area between the footings while leaving an area unfilled directly beneath the drain to prevent discharged fluid from flowing away from the gage (fig. 4C–8).

Step 11: Once the plumbing has been attached to the gage and to the plumbing configuration and manometer in the shelter, charge the gage with antifreeze solution (fig. 4C–9). Allow at least 1 gallon of solution to flow from the gage and through the plumbing in the shelter. Check for air bubbles as the solution runs out of the plumbing. Continue to run solution through the plumbing until no air bubbles are present. Once the gage is charged, add oil to prevent evaporation. See NEH622.08 and NEH622.05, "Maintenance and Calibration," storage precipitation gage recharge procedures.

Figure 4C–5 Precipitation gage plumbing line showing a smooth, continuous gradient

Note: The plumbing line should be free of loops, kinks, or other factors that may lead to air bubble entrapment.

Figure 4C–6 Manometer setup showing 3-valve system

Valve 1 (not shown) shuts off all flow from the precipitation gage. Valve 2 shuts off flow to the pressure transducer and valve 3 shuts off flow to the manometer. Having such a system allows options.

Figure 4C–7 Pressure transducer mounted at bottom of precipitation gage

Ideal mounting includes valve between transducer and gage to allow for transducer replacement without draining the gage.

Step 12: Check for any leaks at all the plumbing connections and along the length of the plumbing line.

Use of antifreeze solutions

Precipitation gages are generally serviced and maintained with an antifreeze solution (propylene glycol and a stabilizer mix) topped with a layer of light, environmentally safe, industrial oil to prevent evaporation of the solution. The amount of antifreeze solution (recharge) added to the gage (following flushing) is determined by the average annual precipitation (snow and rain) at the site. In other words, sites that receive greater rainfall or snowfall amounts will require more solution, and sites that receive lesser precipitation amounts will require a lesser amount (volume) of recharge (fig. 4C–9).

Figure 4C–8 Precipitation gage installed on railroad tie footings; front side unfilled

After filling in the front, this leaves a cavity approximately 8 to 10 inches deep and 2 feet by 2 feet to accommodate discharge of accumulated rain and recharge fluids.

An oil film is used to cover the charge in a gage to prevent loss of water by evaporation. See NEH622.05 for detailed recharge procedures.

Plans and specifications

Plans and specifications for the manufacture of storage precipitation gages are in NEH622.08.

Precipitation gage (tipping bucket gage) installation

Follow these procedures to ensure a properly installed tipping bucket precipitation gage. See “Tipping Bucket Precipitation Gage” NEH622.08 for installation standards and specifications.

Step 1: Tipping bucket gages are generally mounted at the end of a boom that is constructed from 1-inch galvanized pipe. The gage is attached to the end using a nipple that is perpendicular to the boom using a 90-degree elbow. Some gages are clamped to the nipple and others are screwed onto the end.

Step 2: Once the gage is attached to the end of the boom, ensure that it is level by placing a

Figure 4C–9 Pouring recharge into storage precipitation gage

bubble level across the top of the orifice. Some gages have a bubble level attached to the gage.

Step 3: Route the signal lead on the bottom of the boom and secure with tape or zip ties about every 20 inches. Secure the lead down the inside of the tower leg all the way to the junction box. Alternately, use flex conduit and run the entire cable through the pipe and flex to the NEMA enclosure.

Radio (meteor burst) installation

Follow these procedures to ensure a properly installed radio. See “SNOTEL Radio” in NEH622.08 for installation standards and specifications.

Install the radio securely to the back plate of the NEMA enclosure. The radio is usually located next to the data logger, close enough to provide easy connections between the two, but leaving enough room around the data logger to allow easy access to the sensor connections. Ensure the radio is properly grounded.

Relative humidity sensor installation

Follow these procedures to ensure a properly installed relative humidity sensor. See “Relative Humidity Sensor” in NEH622.08 for installation standards and specifications.

Step 1: This sensor must be mounted to the meteorological tower and is typically associated with the air temperature sensor.

Step 2: The sensor must be mounted to the meteorological tower using 1-inch galvanized pipe as a boom in a horizontal configuration.

Step 3: The boom should be attached to the tower legs with two Hollander-type clamps so that the relative humidity sensor is placed at the specified distance and height on the tower. A short nipple and a 90-degree elbow are often used to attach the sensor to the end of the boom.

Step 4: Attach the solar shield to the end of the boom as close to vertical as possible by eye.

Step 5: Insert the sensor into the shield and secure.

Step 6: Route the signal lead on the bottom of the boom and secure with tape or zip ties about every 20 inches. Secure the lead down the inside of the tower leg all the way to the junction box. Alternately, use flex conduit and run the entire cable through the pipe and flex to the NEMA enclosure.

Step 7: Record the height of the relative humidity sensor in the metadata.

Considerations

Several styles of relative humidity sensors are currently used at SNOTEL sites. Depending on the style, different algorithms must be used to convert the raw voltage values to engineering values. The correct algorithm must be used to provide accurate readings.

Shelter installation

Follow these procedures to ensure a properly installed shelter. See “SNOTEL Shelter” in NEH622.08 for installation standards, specifications, and drawings.

Most SNOTEL shelters are prefabricated buildings whose design is provided in NEH622.08, Appendix G, “Standard Drawings” (fig. 4C–10). The building may already be assembled, in which case the installation will not require the actual assembly of the building. Following is a short description of the steps required to install a building, including assembly in the field.

Step 1: Clear and level the area. Once the area is leveled, ensure the relative elevation of the floor of the building will be appropriate for the function of the snow pillow and the precipitation gages. This can be done by actually placing the floor portion on the location and running an elevation survey from the top of the floor to the base of the precipitation gage and the snow pillow using a hand level.

Step 2: Place the foundation material that the shelter will be attached to. Position anchor bolts so that the floor and walls will easily fit onto the foundation (fig. 4C–11).

Step 3: Position any conduit or plumbing so that it can easily fit up through the floor when it is put in place.

Step 4: Place the floor section onto the foundation fitting over the anchor bolts (fig. 4C–12).

Step 5: Determine the precise position for holes that will be used to bring in any conduit, cables, or plumbing. Ensure there is enough space for the bottom plate on the wall.

Step 6: Drill the holes into the floor.

Step 7: Install the back and side walls of the building. Loosely secure the walls in the two back corners with the carriage bolts (fig. 4C–13).

Step 8: Install the front of the building and secure loosely with the carriage bolts in the front corners and install the nuts on the anchor bolts.

Step 9: Install the top roof section of the building, fitting the roof snugly over the top of the four walls. Orient the slope down toward the back of the building.

Step 10: Once all the major sections have been assembled they can be secured by tightening all the anchor bolts on the floor, and carriage bolts in the corners and top.

Step 11: Bring conduit and cables into the building (fig. 4C–14).

Step 12: Caulk conduit, plumbing, cables, corners, and any open holes or cracks that may not seal out moisture.

Step 13: Attach molding covers to the corners.

Step 14: Install the NEMA enclosure inside the shelter. Mount the NEMA enclosure onto the back wall (fig. 4C–15).

Figure 4C–10 Prefabricated shelter

Step 15: Attach a ladder to the front of the building.

Note: For 16-foot shelters, preassemble the top and bottom sections on the ground. Then attach a "scab" board to provide additional temporary support until the walls are erected.

Snow depth sensor installation

Follow these procedures to ensure a properly installed snow depth gage. See "Snow Depth Sensor" in NEH622.08 for installation standards and specifications.

Step 1: Attach the depth sensor to the length of pipe to be used to extend the sensor out from the SNOTEL tower.

a. String the data cable through the pipe and screw the sensor onto the end of the 1-inch pipe using a bell reducer and a three-fourths-inch nipple. **Note:** the installation may need to be more robust in areas of heavy snow accumulation.

Step 2: Mount the pipe and sensor to the tower using clamps.

Step 3: Adjust the sensor so that it is properly positioned over the pillow and oriented perpendicular to the ground surface.

Step 4: Close up the end of the pipe opposite the sensor with duct seal or other sealant to protect

Figure 4C–11 Preparing a four-tie railroad foundation for a 12- or 16-ft shelter

Note steel "T" plates attaching perpendicular ties.

Figure 4C–12 Shelter base installed onto foundation

Figure 4C–13 Assembling the shelter onsite

Back and sides are attached to the floor first. Front panel lying on the ground ready to be attached.

the sensor from water. Alternately, ensure the pipe has a slight downslope to the open end, so water will not flow toward the sensor.

Step 5: For ease of replacement, a NEMA junction box should be mounted on the tower.

Step 6: Route the data cable inside the tower legs to the NEMA enclosure. Affix the cable securely to a tower leg. Alternately, use flex conduit and run the entire cable through the pipe and flex to the NEMA box.

Step 7: Use a fish tape to route the cable from the shelter to the tower junction box.

Step 8: Wire the sensor leads into the data logger/data wire bus and to the terminal strip in the junction box.

Snow pillow (snow water equivalent sensor) installation

Pressure pillows are designed to measure snow water equivalent by indirectly weighing the snow that falls on them. A pillow is a flat fluid container, round, polygonal, or rectangular. They are constructed from either polypropylene or stainless steel. When filled with an antifreeze solution, polypropylene pillows are 2 to 4 inches thick. Stainless steel pillows are one-half to one and one-half inches thick.

Surface area of the pillows ranges from about 20 to 120 square feet, depending principally on site conditions and depth of snow to be weighed. A pipe fitting near an edge on the bottom makes it possible to fill the pillow with antifreeze and to connect it to a pressure line. Another pipe fitting or other device in the top of the pillow vents air during filling.

Pressure transducers, electronic converters, and mechanical float devices are used to translate snow load into SWE for onsite recording and radio transmission.

Location

The location of the pillow should be as close to the shelter as possible to reduce the length of plumbing and increase data reliability. The required distance from pillows to abrupt slope changes or objects varies with the depth of snowpack, amount of land slope, surface area of the pillow, and the uniformity of snow

Figure 4C–14 Manometer assembly showing 3-valve configuration, transducer mounting, sensor cables in 2-in PVC

Figure 4C–15 NEMA enclosure protects radio, data logger, multiplexer board

density in the vicinity. Until additional testing determines the most desirable distance, which varies with each of these factors, the distance should be at least 15 to 20 feet. If snow is likely to be more than 10 feet deep, increase the distance to 1.5 to 2 times the maximum snow depth expected.

Size

The size of pillow required depends on the uniformity of the snow pressure surface overlying the pillow. If pillows are correctly located with respect to site conditions, and properly installed so that no stress is created within the snowpack that could cause pressure waves across the pillow, the size can be reduced. Under such conditions pillows as small as 16 to 20 square feet have been found to report snow water equivalents in excess of 80 inches reliably.

Because there is a greater probability of uneven pressure areas developing within deeper snowpacks, pillow surface area should be increased for the deeper snows. For this reason and because perfect site conditions cannot always be obtained, the minimum recommended pillow sizes are shown in table 4C–1.

Installation overview

While it is rare, new pillows can arrive with small defects that may cause leaks. It is wise to be prepared with a spare pillow or, if time allows, test pillows for leaks or damage before taking them to the field for installation. Testing for leaks can be done by filling pillows with air or liquid and applying an external pressure load to discover any leaks.

Install polypropylene pillows on a level site. Clear the ground surface of vegetation and debris from an area the size of the pillow and at least three feet more around the pillow. Remove larger brush, stumps, and rocks for at least 15 to 20 feet around the pillow.

Level the soil for the pillow foundation area. Remove any roots, large rocks, and stones. Add a layer of sand or native material under the pillow to help seat it. Dig a small trench near the edge of the pillow for an outlet and hose or pipe connection. Then fit the empty pillow onto the prepared foundation. (Some areas, such those found in Alaska, require the use of a wooden platform as a foundation.)

Where appropriate, snow pillows must be protected from rodents or other types of animals with hardware cloth or equivalent placed beneath and above the snow pillow. Where appropriate, snow pillows must also be protected from bears and other intruders by a fence or metal covering.

In areas where animal damage is possible, it has been advisable to use a quarter inch wire screen (4- by 4-in galvanized hardware cloth) on the bottom and top of the pillow. The screen is fastened around the edges to keep out rodents and reduce damage by animals.

Materials

Snow pillows should be constructed from polypropylene (preferred). The other satisfactory pillow material is stainless steel.

Connections

To avoid air lock, the line from the pillow outlet tube to the standpipe or pressure transducer should be on a continuous, downhill grade. The connection to the standpipe or transducer should be below the pillow outlet to provide a positive head for the zero-load pillow reading. Fittings to the pillow and sensing devices vary. All connections must be made carefully with high-quality materials. The fluid-transfer line may be copper, plastic tubing, or rubber hose (Ortac® or similar quality). Pipe or tubing are preferred materials, since rodents may damage rubber hose. Copper tubing corrodes in some soils.

See NEH622.08 for installation standards for pressure transducers.

Fluid density

For standpipe or manometer readouts, the density of the fluid in the pillow must be measured. Fluid density should be determined for each pillow since separate

Table 4C–1 Pillow size requirements

Expected annual SWE (in)	Minimum pillow surface area (ft^2)
10	28
30	40
50	60
75	80
>75	120

lots of the same kind of product often vary due to different additives included by manufacturers.

Measure fluid density by taking a sample (about a pint) and weighing a known volume such as 100 cubic centimeters. Density can also be measured using a hydrometer. Other methods for measuring fluid density are in chemical handbooks or by manufacturers of a specific product.

Slope considerations

The primary slope consideration for a snow pillow is that the location has to be sufficiently higher than the shelter in order to have readable head on the manometer inside the shelter. The head inside the shelter must be a minimum of 10 to 20 inches above the plumbing valve assembly such that it is easy to read and provides an easy year to year baseline reference. As an example, given a standard 8- to 10-foot shelter, a maximum of 20 inches of head on the manometer would give room for at least 72 inches of snow water equivalent, which is more than sufficient for annual accumulation in most cases.

In preparing the final grade for the snow pillow be sure to account for both the inside floor level of the shelter and the general height of the manometer assembly and put the fluid height 10 to 20 inches above that level. The following must be considered when ensuring the final head inside the shelter is appropriate:

- height of the base of the snow pillow pad and the elevation difference between the pad and the shelter
- height of the inside of the shelter above ground
- height of the mounting technique, whether concrete or wood

Polypropylene snow pillow installation

Polypropylene snow pillows are the primary instrument used for monitoring snow water content. Following is the installation procedure for polypropylene snow pillows:

Step 1: Standard applications use a 10-foot-diameter snow pillow. Use a 6-foot-diameter pillow where frost heave or space constraints limit the area available for the snow pillow.

Step 2: After the pad is prepared, place a 4- by 4-inch (1/4-in square) galvanized wire cloth (hardware cloth) over the area where the pillow is to be positioned. The wire cloth should extend a minimum of 3 inches beyond the edges of the pillow. However, 6 to 10 inches is preferable because it allows for multiple pillow replacements without hardware cloth replacement. Ensure no cuts are made in the wire cloth under the pillow as these cut ends can puncture the pillow and create small pinhole leaks. Overlap wire 2 to 3 inches, but do not wire the seams together as the weight of the pillow and fluid will keep the wire in place. The wire cloth on the bottom keeps rodents from burrowing into the pillow and provides a place to secure the wire cloth used to cover the top of the pillow.

Step 3: Place the pillow on the wire cloth with the outlet closest to the shelter. It is necessary to cut the wire cloth for the pillow outlet. Bend all cut edges downward and insert a piece of material between the pillow and hardware cloth to prevent punctures.

Step 4: Plumb pillows such that no lines run beneath pillow.

Step 5: Use Teflon® tape or pipe thread on all threaded pipe connections.

Step 6: Trenches for plumbing lines must be at least 6 inches deep for all lines around pillows and to the instrument house.

Step 7: Install and plumb a manometer of clear tubing in the shelter to remove air from lines and transducer.

Step 8: Fill pillows using a mixture of 50 percent water and 50 percent Propylene Glycol Ethanol (PGE).

Step 9: If not already premixed, add fluorescing dye to the fluid mixture to enhance fluid visibility in manometer tube.

Step 10: Use approximately 165 gallons (3 bbls) of total solution to fill a 10-foot pillow, or approximately 220 gallons (4 bbls) to fill a 12-foot pillow.

Step 11: Remove the plug on top of the pillow from the pillow and insert a 6-inch PVC nipple to vent as much air as possible during the filling operation.

Step 12: When all fluid is in the pillow, remove the air through the vent nipple with a vacuum pump or by rolling two 10-foot sections of 4-inch PVC well casing from the perimeter toward the vent nipple, being careful not to roll over the outlet fitting. Repeat until the sloshing sound stops (figs. 4C–16 and 4C–17).

Step 13: After removing the air, replace the vent nipple with the plug. Turn off the filler valve, disconnect the filler line, and cap the hose bib.

Step 14: Run one gallon of fluid through plumbing from pillow through manometer to purge air bubbles from system.

Step 15: Extract one quart of fluid from the manometer for specific gravity samples.

Step 16: Connect pressure transducer. Ensure all air has been removed.

Step 17: Check all connections for tightness and leaks prior to burial.

Step 18: Cut three sections of hardware cloth in lengths adequate to cover the pillow and leave a minimum of 10 inches extra on each end. Place one section on top of another and hog ring one common side together. Unfold the two sections thus joined and repeat with the other section hog ringed to the opposite side of the middle section. Place these three sections of joined wire cloth on top of the pillow, cut the perimeter of the top and bottom sections so they are congruent and hog ring the top and bottom sections together (fig. 4C–18).

Figure 4C–16 Filling snow pillow sensor with fluid

Note bottom hardware cloth under pillow and "burp" tube on top.

Figure 4C–17 Filler assembly and copper plumbing line

Figure 4C–18 "Hog ringing" the bottom and top hardware cloth panels together (top not finished)

Note optional, nonstandard white polypropylene cover, added for protection and reflectivity.

Step 19: For installations in areas where bears may be present: Rivet 26- or 28-gage galvanized metal sheets together and place them on top of the pillow. Bend galvanized flashing and place it around the edges. Install aircraft cable and deadman anchors to keep bears from lifting the pillows.

Step 20: Paint the installation brown to reduce glare and to blend in with surroundings. An alternative solution would be the installation of 6-foot cyclone fencing around the existing fence protecting the pillow.

Step 21: Fence the pillow if the potential for animal damage exists.

Figure 4C–19 shows a finished snow pillow with sample point markers.

Step 22: Locate ground truth sample areas at opposite ends of the pillow at a distance adequate to prevent accidental snow tube penetration. Install and number permanent reference poles as follows: number 1 is the sample closest to north with samples 2, 3, and 4 numbered in a clockwise progression from number 1. Use electrical tape to number the sample poles.

(ix) Steel snow pillow installation

Snowpacks of less than 45 inches SWE must have a minimum of three steel snow pillows plumbed together. Snowpacks expected to be in the 45 to 75 inch range must have four pillows. Areas where 75 or more inches of accumulated snow water equivalent may be expected must have six pillows. Figure 4C–20 shows how snow pillows should be configured for different installation scenarios.

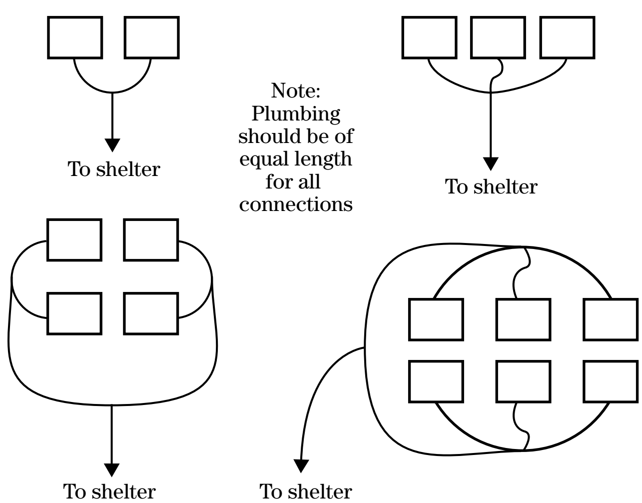
Step 1: Level an area large enough to provide at least a 3-foot border around the pillow system perimeter. When cut and fill is required to form the bed, the slope of the uphill cut and downhill fill must not be steeper than 2:1. Measure the 3-foot border from the pillow edge on the uphill side to the toe of the slope, and measure on the downhill side to the break of the slope.

Step 2: Provide adequate drainage channels so that melt water moves around the pillow bed and away from the site.

Figure 4C–19 Finished pillow

Note sample point markers. Also, note that two poles may be used because every pole used is an additional head source during the melt-out period.

Figure 4C–20 Steel snow pillow layout for different installation scenarios



Step 3: Prepare a level bed of sand or native mineral soil 1- to 2-inches deep over the entire pillow site, with finished elevation higher than the instrument shelter floor. The recommended elevation differential is 8 inches.

Step 4: Lay pillows onto the bed so the bottom surface is in full contact with the bedding surface when pillows are filled.

Step 5: Plumbing should be of equal length for all connections.

Step 6: Plumb pillows around outside perimeter. Don't run plumbing under sensor.

Step 7: Use Teflon® tape or pipe thread on all threaded pipe connections.

Step 8: Trenches for plumbing lines must be at least 6 inches deep for all lines around pillows and to the instrument house.

Step 9: Install the plumbing line from the shelter to the pillow with a gradual upward slope with no traps or loops that will develop air locks.

Step 10: Provide a fitting in the plumbing for putting fluid in the pillow system from the lowest point closest to the pillow.

Step 11: Install and plumb a manometer of three-eights-inch outer diameter clear tubing in the shelter to remove air from lines and transducer.

Step 12: Fill pillows using a mixture of 50 percent water and 50 percent PGE.

Step 13: Add fluorescing dye to the fluid mixture to enhance fluid visibility in the manometer tube.

Step 14: Remove the valve stem and place 6-inch clear tubing on the Schraeder valves of each pillow to vent displaced air as they fill.

Step 15: Fill the pillows with a gravity system, using care not to entrain air into the liquid during filling. Do not pump fluid. Air pressure in the top of the barrel is acceptable. Do not pump air into the fluid.

Step 16: When the pillows have been filled to a level approximately two inches above the top skin of the pillows, remove the fluid source and leave all pillows open until equalization has occurred.

Step 17: Work air out by flexing pillows.

Step 18: Replace valve stems in Schraeder valves.

Step 19: Disconnect filler line and connect plumbing.

Step 20: Run 1 gallon of fluid through plumbing from pillow through manometer to purge air bubbles from system.

Step 21: Extract 1 quart of fluid for specific gravity samples from the manometer.

Step 22: Connect pressure transducer, making sure all air has been removed.

Step 23: Check bedding and work sand under edges of the pillows as necessary to achieve full contact between the pillow undersurface and the bedding material.

Step 24: Check all connections for tightness and leaks prior to burial.

Step 25: Fence the pillows where the potential for animal damage exists.

Step 26: Locate ground truth sample areas at each corner of the pillow group. Install permanent reference poles and number as follows: number 1 is the sample closest to north with samples 2, 3, and 4 numbered in a clockwise progression from number 1.

See NEH622.05 for snow pillow maintenance details. See NEH622.08 for SWE pillow standards.

Soil moisture and soil temperature sensor installation

Follow these procedures to ensure properly installed soil moisture/soil temperature sensors. See "Soil Moisture and Soil Temperature Sensor" in NEH622.08 for installation standards and specifications.

General

The selection process for identifying station locations must involve the States to help ensure proper areas are represented. The local NRCS State office staff will provide valuable information required to implement a soil moisture/temperature program in their State.

Considerations and soil sampling criteria

Soil moisture/temperature site selection must be within 100 feet of the data logger and a minimum of 5 feet from any structure or antenna tower, unless a junction box is used to extend the distance. If the installation is greater than 50 feet, combine the black and yellow ground wires together. This is typically done at the data logger location and on the multiplexer. Combining the two ground wires on the longer runs reduces the chance of getting poor readings. Generally a power strip is used to supply power and ground for all of the multiplexer sensors. The power strip combines all of the 12-volt switched power supply and grounds used for the soil moisture/temperature sensors. See figure 4C–21.

A soil scientist will be able to assist in locating a suitable and representative location for the soil/moisture sensors. Once that location is determined, another location for the “soil pit” will need to be selected.

The soil pit is used for soil classification, description, and sampling, but generally not used to place the soil moisture and soil temperature probes in because of much greater potential for soil disturbance. A full characterization analysis will be performed by National Soil Survey Center (NSSC) personnel after the samples are sent to the lab. Ensure the soil sample bags are labeled correctly and include the word SNOTEL on the bag. This will ensure that priority is given to the processing of the samples. Bulk density samples must be taken too, as this is the only method to calculate water-holding capacity reliably.

It is important that the sensors not be placed in a depression area or in a small water channel area. If the sensors are installed away from the data logger, they should be placed above a junction box or NEMA enclosure to ensure water does not travel down the wires or conduit to the sensors. If the sensors are placed beyond 10 feet from the data logger, it is advisable to use a 30-wire conductor and 18-gauge, shielded, water-resistant cable between the outside NEMA enclosure and the data logger.

At the end of the 30-conductor wire run, a small plastic (preferred) NEMA enclosure is secured on a 1½-inch galvanized pipe that is about 4 feet in height. Two feet of the pipe are secured by concrete. The NEMA enclosure is then secured onto the pipe with U-bolts. Inside the NEMA enclosure is a set of terminal strips.

Soil moisture/temperature sensor placement

When possible, five depths of soil moisture/temperature sensors are installed at a site. The standard depths are 2, 8, and 20 inches; optional depths are 4 and 40 inches. Ensure that each soil moisture/temperature sensor is labeled at the end of the wire so they can be identified and wired to the data logger properly. This is important to ensure which sensor depth is identified with which wire.

Ideally, the sensors are installed in relatively small pits and holes at least 5 feet away from the station tower. Large backhoe pits are not recommended because the soil is usually heavily disturbed and the sensors are susceptible to being pulled out of position during backfilling and when the soil settles in the pit. If already in a pit or hole, install the sensors at the appropriate depths. If not in a pit or hole, the first sensor is placed using a 3 ¾-inch soil barrel auger to go down to about 39.5 inches deep. Place the first sensor in vertically using a 1-inch piece of PVC pipe to push the sensor into place with the wire through the PVC pipe (figs. 4C–22 and 4C–23).

Carefully remove the wire and set it aside for the moment. Then use the PVC pipe and push (carefully) the wire down along side of the sensor to provide a drip

Figure 4C–21 Inside the NEMA enclosure

loop. Then fill the hole back up with soil and use the PVC pipe as a tamp to compact the soil.

Soil tamping device

If the soil is heavy textured (high clay content) or if the soil is very dry, use some water and pour it into the bottom of the hole, and let it sit for a few minutes before attempting to place the soil moisture/temperature sensor at 40 inches. It is important to pack the soil inside the hole as much as possible to ensure that water does not travel down the sides of the hole.

Figure 4C–22 PCV pipe insertion tool

If water is used, the readings of soil moisture will not reflect true conditions for up to a month. If water is used to install the sensors, this must be noted on the metadata sheet. If the soil is too shallow to get down to the 40-inch depth, measure the distance and record that on the metadata sheet. This information will be placed into the height/depth code table in the Water and Climate Information System (WCIS) database.

Move away from the 40-inch hole and dig a small hole about 2-feet deep by 1.5-feet wide. It is good to square off one side of this small hole and on the opposite side of where the flex conduit and wires will be going to the soil NEMA enclosure or directly to the data logger.

Place the remaining sensors horizontally so they are in the least disturbed soil as possible. Place the center tine at the depth of installation. That is to say, for the 20-inch probe, place the center tine at 20 inches and insert it horizontally into the soil. All of the tines should be in the soil and not sticking out. It might require the use of the insertion tool to insert the sensor (fig. 4C–24).

Ensure a drip loop is made for each sensor and pack the soil around the sensor. Be careful to ensure the sensor is in good contact with the soil. Likewise it is important not to pull the sensor out while packing the soil around the sensor. If the soil is dry, use water to ensure the sensors make good contact. If water is used to help seat the sensor, this must be noted on the metadata sheet.

Figure 4C–23 Insertion tool in use

Figure 4C–24 Inserting the sensor

This same method is used all the way up the profile. The sensors are staggered up the soil profile to help ensure that the sensor above does not disturb the lower sensors and that it can still transport water to that sensor (fig. 4C–25).

The wires are placed opposite from where the sensors are placed. Use flex conduit and place the end near the edge of the small pit (fig. 4C–26). Run the soil moisture sensor wires through the conduit. If tape is used to hold the wires in place while putting them through the conduit, only use the tape near the end of the wire. Remove the tape after the wires are inside the NEMA enclosure.

Ensure each wire is labeled as to its position in the soil profile. The conduit is then run into the NEMA enclosure and connected to a terminal strip. The other half of the terminal strip is connected to the 30-conductor wire that runs to the data logger. If the wires are cut because they are too long, ensure that the wires are renumbered before they are trimmed. Use duct seal to close off the end of the flex conduit.

Figure 4C–25 Placement of the 2-, 4-, and 8-in sensors

Wiring considerations

The opposite end of the 30-conductor cable is placed inside the flex conduit and brought to the shelter or NEMA enclosure. The soil moisture/temperature sensor wires are generally connected to the multiplexer. See figure 4C–27. Other communication boards are acceptable such as Judd boards that use solid state multiplexer components.

Figure 4C–26 Inserting the soil moisture/temperature sensor

Figure 4C–27 Soil moisture/temperature sensor wiring

After all the sensors are in the ground, take a compass reading from the NEMA enclosure toward the sensors. Record the direction and measure the distance from the corner of the NEMA enclosure or shelter to the sensors. Record all this information on the station metadata form. In addition, take site photos of the installation, documenting every ditch and pipe.

If a sensor requires replacement, place the new sensor near where the old sensor was installed. The old sensor is generally not removed, so as not to disturb the other sensors. It is possible to use a metal detector to find the flex conduit and original sensors. In this way, the new sensor wire can be routed up through the existing conduit and wired onto the terminal strip or multiplexer.

At locations where soil depth from surface to parent material or bedrock is less than 40 inches, sensors must be inserted into the soil at the specified depths beginning at 2 inches, and continuing deeper, as specified, until parent material or bedrock is reached. A sensor may be placed at or in contact with parent material or bedrock as long as there is at least 2 inches of separation from the overlying sensor. This may be desirable if there is a significant change in the characteristics of the soil or if there is a reasonable expectation that the additional sensor will provide further insight into the soil moisture or soil temperature profile.

NEMA enclosure with terminal strip and wires installation

There is a wide variety of terminal strips available, but the NRCS recommends the Euro style terminal strip. These terminal strips will accept 18- or 20-gauge wire and are easy to attach the wires (fig. 4C–28).

The wires should be protected from wildlife and buried in the soil. Use flexible conduit or PVC pipe to protect the wires. Aluminum flex conduit works well and has bulkhead adapters that are used to make a secure attachment to a NEMA enclosure. Use duct seal to plug the open ends to keep mice and other animals out of the conduit (fig. 4C–29).

Soil characterization

Soil must be described, the soil classification determined, and samples for bulk density must be taken to support the interpretation of soil moisture monitoring data. When possible, these activities should occur simultaneously with sensor installation and be performed by State soils personnel. It is recommended

Figure 4C–28 NEMA terminal strip

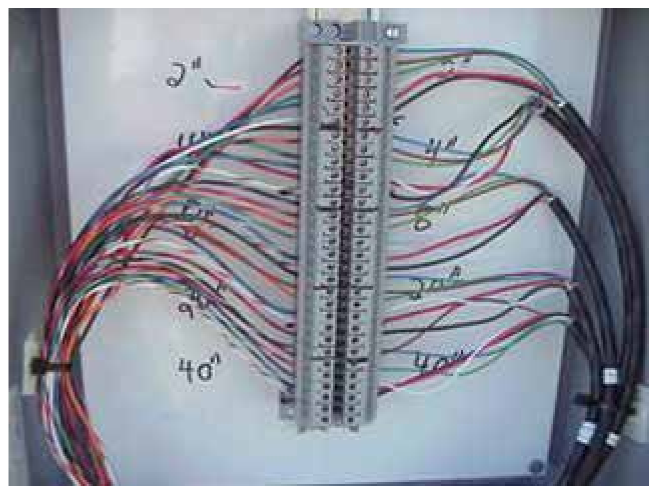


Figure 4C–29 Flex conduit with duct seal

that a soil scientist assist in selecting the sensor installation location (fig. 4C–30).

Solar panel installation

SNOTEL stations require solar power to operate because of their extremely remote locations. Photovoltaic cell solar panels are used to power the station indirectly through a bank of batteries. If more batteries are needed to power the station, then more solar panels or larger solar panels are required to keep the batteries charged. Although solar panels are available in extremely large sizes and power outputs, the physical size is a concern at SNOTEL installations for practical reasons of managing the panels with limited equipment. Also, solar panels can act as sails and create an undesirable wind load on the tower.

The number and size of the solar panels to keep the station operating depends on the setting of the station. Stations in higher latitudes require more solar panels to make up for a lack of daylight hours in the winter months. Stations in extremely wet and cloudy regions may require more panels. Often the radio and data logger are powered off separate batteries. Typically, a 50-watt panel is sufficient to operate the radio with two batteries, while a 10-watt panel will operate the data logger with one battery.

Figure 4C–30 Describing and sampling soil for characterization in a soil pit

Follow this procedure to ensure a properly installed solar panel. See “Solar Panel” in NEH 622.08 for installation standards and specifications.

Step 1: Panels must be installed well above the highest level that the snow depth would expect to reach.

Step 2: Panels should be securely attached to the antenna tower at least four feet from the antenna or any sensors (fig. 4C–31).

Step 3: The wiring should be run down from the panel on the inside of the tower legs and under any cross members.

Step 4: The angle of the sensor should be set approximately equal to the station’s location in latitude degrees.

Step 5: The direction should be south or in the direction for the best solar window available for maximum solar exposure.

Proper installation of solar panels includes the use of regulators to regulate the amount of voltage reaching the batteries to protect them and the electronic components from being damaged during the brightest times of the day.

Solar radiation sensor installation

Follow these procedures to ensure a properly installed solar radiation sensor. See “Solar Radiation Pyranometer Sensor” in NEH622.08 for installation standards and specifications.

Figure 4C–31 Solar panel mounted well above the antenna on the tower mast

Step 1: The sensor must be mounted to the meteorological tower in a horizontal and level configuration.

Step 2: The boom should be attached to the tower legs with two Hollander-type clamps so that the relative humidity sensor is placed at the specified distance and height on the tower. A short nipple and 90-degree elbow are often used to attach the sensor to the end of the boom, but many sensors now have a mounting bracket that allows the sensor to be mounted at any point along the boom.

Step 3: Using a hand bubble level or the bubble level attached to the mounting bracket, ensure that the sensor is mounted level so that the sensor is pointing directly vertical to the sky.

Step 4: Record the height of the solar radiation sensor in the metadata.

Considerations

Environmental conditions at remote sites are highly variable and uncontrollable. Extreme cold, heat, wind, rain, snow, and ice may cause unexpected reactions from the sensor. Unusually harsh conditions may require maintenance and calibration checks be performed more often than specified to ensure data quality.

Inconsistencies in electronic components and mounting configurations can affect sensor performance. Every effort should be taken to recognize any inconsistency that might account for performance problems and eliminate the inconsistency when possible.

Tower installation

Standard towers at a SNOTEL station are the antenna tower and the meteorological tower. The antenna tower is located near the SNOTEL shelter and typically only has an antenna and solar panels mounted on it. The meteorological tower is located near the snow pillow and has most of the atmospheric sensors on it, including snow depth and air temperature sensors. Towers are usually 20 feet in height, depending on the anticipated maximum snow depth.

The meteorological tower should be installed on the same side of the pillow that the shelter is on to avoid running conduit under or around the pillow. Otherwise, unnecessary bends might be necessary, which would make pulling the wires through the conduit more difficult.

Ensure the meteorological tower is approximately 2 feet away from the edge of the pillow. Orient the tower so that two of the legs are pointing in a north-south direction and the third leg pointing to the center of the pillow. This allows the temperature sensor to be pointing north and the depth sensor to hang over the center of the pillow.

Towers can be installed either fully assembled on the ground or starting with installing the base first and assembling the tower and mounting the sensors or other components after the cement foundation has set up to a point that it is safe to climb the tower.

Follow these procedures to ensure a properly installed tower. See “SNOTEL Tower” in NEH622.08 for installation standards and specifications.

Fully assembled tower installation

Step 1: Prepare foundation excavation according to engineering specifications.

Step 2: **This procedure requires at least three people to do safely**. Assemble the tower prior to pouring the concrete. Assemble the base, two 10-foot sections, top, and mast on the ground (fig. 4C–32). Place the base of the tower next to the hole. Attach three guy ropes to the legs about two-thirds up from the bottom of the tower. Slide the base of the tower over the hole (fig. 4C–33), and with an individual holding the base down, have the other individuals start at the top of the tower and “walk” (raise) the tower up. Truck winches, tripods, and come-alongs can also be used to raise the tower (fig. 4C–34). Secure the guy ropes to hold the tower when pouring the concrete (fig. 4C–35).

Step 3: Mix and pour the concrete into the hole.

Step 4: After pouring the concrete, ensure the tower is plumb with a level and the orientation is correct for the sensors. Allow the concrete to set a minimum of 24 hours before climbing the tower to hang the sensors.

Step 5: For the antenna tower, run a 2-inch conduit up the tower with a weather shield at the top.

Figure 4C–32 Assembled tower ready to stand in the foundation hole

Figure 4C–33 Standing the tower

Figure 4C–34 Standing the tower using a winch

Figure 4C–35 Guyed tower ready to have concrete poured

The antenna can be mounted and the coax fished through the conduit into the building.

Base first tower installation

Step 1: Prepare foundation excavation according to the engineering specifications.

Step 2: Place the 3.5-foot base section into the hole and orient the legs. Pour the concrete into the hole making sure the base section remains in the proper orientation and is plumb in the vertical position (fig. 4C–36).

Step 3: Allow the concrete to set a minimum of 12 hours before standing the remaining sections onto the base. Allow concrete to set a minimum of 24 hours before climbing the tower to install sensors or other components.

Step 4: Assemble the remaining sections of the tower, including the mast.

Step 5: **This procedure requires at least three people to do safely**. After the concrete has set (12 hours minimum), stand the assembled tower sections onto the base. Align the legs of the tower with the base legs. With an individual holding the lower end down on to the base, have the other individuals start at the top of the tower and walk (raise) the tower up (fig. 4C–37). Truck winches, tripods, and come-alongs can also be used to raise the tower.

Step 6: For the meteorological tower, run a 2 inch conduit up the tower with a junction box at the top of the conduit; typically above the maximum snow depth. The conduit can be run on the inside of the tower or the outside and attached with hose clamps or wire ties. At the bottom of the conduit, an elbow is glued on and sections of conduit are laid in a trench going to and into the shelter (fig. 4C–38). When conduit is finished and run into the shelter, temperature, depth, coax, and solar wire can be “fished” through the conduit to the junction box. The coax cable is then run up through the hole (predrilled and weather-tight connector inserted in the hole) in the top of the junction box.

Step 7: For the antenna tower, run a 2 inch conduit up the tower with a weather shield at the top. The antenna can be mounted and the coax fished through the conduit into the building.

Figure 4C–36 Tower set in concrete

Figure 4C–37 Standing the tower onto the base

Step 8: Wait a minimum of 24 hours before climbing the tower to install sensors or other components.

Wind speed and wind direction sensor installation

Follow these procedures to ensure a properly installed wind speed anemometer. See “Wind Speed and Wind Direction Sensor” in 210–NEH, Part 622, Chapter 8 (NEH 622.08), for installation standards and specifications.

Step 1: Assemble the sensor and ensure that all moving parts move freely and evenly.

Step 2: Mount the sensor on a boom using 1-inch or 1 1/2-inch galvanized pipe. The boom should be extended from the met tower at the specified height and distance listed under “Wind Speed and Wind Direction Sensor” in 210–NEH, Part 622, Chapter 8 (NEH 622.08).

Step 3: Attach the mounting pipe to the tower legs with two Hollander-type clamps.

Step 4: Attach a mounting pipe to the boom a minimum of 3 feet from the tower leg, ensuring that it is vertical.

Figure 4C–38 Checking the tower base for level and plumb

Step 5: Route the signal lead on the bottom of the boom and secure with tape or zip ties about every 20 inches. Secure the lead down the inside of the tower leg all the way to the junction box. Alternately, use flex conduit and run the entire cable through the pipe and flex to the NEMA enclosure.

Step 6: Record the height of the wind speed/ wind direction sensor in the metadata.

Considerations

Several styles and manufacturers of wind speed and wind direction sensors are currently used at SNOTEL sites. Depending on the type and manufacturer, different algorithms must be used to convert the raw voltage values to engineering values. The correct algorithm must be used to provide accurate readings.

Appendix 4D — Sensor Placement, Data Logger Reporting Frequency

Table 4D–1 provides general information on the placement and reporting frequency for SNOTEL station sensors.

Table 4D–1 Standard placement and reporting frequency for sensors

Parameter	Location	Sky clearance	Height/depth/other	Minimum distance	Data logger program reporting frequency
Telemetry radio	Inside shelter or NEMA enclosure				Time will be set to Pacific Standard Time. [1/]
Data logger	Inside shelter or NEMA enclosure				Time will be set to Pacific Standard Time. [1/]
Snow water equivalent (SWE) sensor used in conjunction with a pressure transducer	Slightly upslope from shelter on a level pad.	The canopy cover above the sensor should be clear for an area of ~30 degrees from vertical.		The SWE sensor pad must be level and the ground should be level with the SWE sensor for a minimum of 3 ft around pillow.	Every 60 min
Fluid used in SWE sensor	Inside fluid based snow pillow.		50/50 mixture of ethanol/water or methanol/water with 2% Polysorbate 20, and up to 4% other additives as desired by DCO.		
Marker pole for SWE sensor	A minimum of 3 ft away from the edge of the SWE sensor. This allows a minimum of two samples, one on either side of marker pole at least 1 ft away from marker pole for a total of four samples per sensor.		Marker pole height must be at least 3 ft above the maximum snow depth.		

1/ In Alaska, time will be set to Alaska Standard Time (AST).

Table 4D–1 Standard placement and reporting frequency for sensors—continued

Parameter	Location	Sky clearance	Height/depth/other	Minimum distance	Data logger program reporting frequency
Number of barrels of PGE per SWE sensor type			**Metal pillows:** 3 pillows – 48 gal 4 pillows – 64 gal 6 pillows – 96 gal **Polypropylene:** 6 ft – 1 barrel 10 ft – 3 barrels 12 ft – 4 barrels All barrels are mixed ~50:50 with water.		
Snow depth	On met tower, over the pillow edge or over the pillow.		On met tower at least 4 ft above maximum snow depth. Placement should not interfere with other meteorological sensors.		Every 60 min
Storage precipitation sensor (SNOTEL style)	Ensure the gage top is at least 3 ft above maximum snow depth.	The canopy cover above the sensor should be clear for an area of ~30 degrees from vertical.			Every 60 min
Fluid used in the storage precipitation (SNOTEL style) Sensor	Fluid used inside precipitation gage.		Propylene Glycol-Ethanol (PGE) Mixture. Equal portions of propylene glycol and ethanol with 2% Polysorbate 20, and up to 4% other additives as desired by DCO.		
Oil used in storage precipitation (SNOTEL style) sensor	Inside precipitation gage.		Mineral oil or Lubriplate hydraulic oil ~1 qt/12-in gage.		
Air temperature	On met tower and vertical. If using the HMP45C, this includes the RH sensor. Minimum 2 ft from tower leg. Ensure the sensor is at least 3 ft above the maximum expected snow depth.		7 ft ± 1 ft 18 ft ± 1 ft 28 ft ± 1 ft Above ground level (AGL)		15-min update frequency and will be used to compute current, maximum, minimum, and average temperature for each hour, if needed, or for the 24-h period.

Table 4D–1 Standard placement and reporting frequency for sensors—continued

Parameter	Location	Sky clearance	Height/depth/other	Minimum distance	Data logger program reporting frequency
Air temperature radiation shield	Associated with the air temperature sensor and protects the sensor from errors associated with direct sunlight on the sensors.		The shield will be a minimum of 6-vane Gill style and white in color if using a stand-alone air temperature sensor. If using an air temperature and relative humidity combined sensor, then the shield will be a minimum of 10-vane Gill style and white in color.		
Relative humidity	On met tower and vertical. If using the HMP45C, this includes the air temperature sensor. Minimum 2 ft from tower leg. Ensure the sensor is at least 3 ft above the maximum expected snow depth.		7 ft ± 1 ft 18 ft ± 1 ft 28 ft ± 1 ft Above ground level (AGL)		15-min update frequency and will be used to compute current, maximum, minimum, and average relative humidity for each hour, if needed, or for the 24-h period.
Relative humidity radiation shield	Typically associated with the air temperature sensor and may be included with the air temperature sensor. The shield protects the sensor from errors associated with direct sunlight on the sensors.		The shield will be a minimum of 10-vane Gill style and white in color.		

Table 4D–1 Standard placement and reporting frequency for sensors—continued

Parameter	Location	Sky clearance	Height/depth/other	Minimum distance	Data logger program reporting frequency
Wind speed	On met tower and typically opposite the solar radiation sensor. The sensor must be level.		At top of met tower when possible and at least 2 ft away from tower leg. If not at the top, then placed at: 10 ft ± 1 ft; 19 ft ± 1 ft; 29 ft ± 1 ft above ground. Severely sloping terrain may cause the height of the sensor to vary from the recommendations.		10-s update frequency. This will be used to produce current, hourly average, and hourly peak wind speed.
Wind direction	On met tower and typically opposite the solar radiation sensor. The sensor must be level.		At top of met tower when possible and at least 2 ft away from tower leg. If not at the top, then placed at: 10 ft ± 1 ft; 19 ft ± 1 ft; 29 ft ± 1 ft above ground. Severely sloping terrain may cause the height of the sensor to vary from the recommendations.		10-s update frequency. This will be used to produce current and hourly average wind direction.
Solar radiation	On met tower, generally at the top, on the south side. This is typically opposite of the wind speed and wind direction sensor. The sensor must be level.		At top of met tower on south side when possible and at least 2 ft away from tower leg. If not at the top, then placed at: 10 ft ± 1 ft; 19 ft ± 1 ft; 29 ft ± 1 foot above ground. Severely sloping terrain may cause the height of the sensor to vary from the recommendations.		10-s update frequency to produce an hourly average

Table 4D–1 Standard placement and reporting frequency for sensors—continued

Parameter	Location	Sky clearance	Height/depth/other	Minimum distance	Data logger program reporting frequency
Net radiometer	On the met tower and follow manufactures recommendations on the height above the ground for placement. The sensor must be level.		Sensor must be a minimum of 2 ft from tower leg and pointed in the direction that the manufacturer recommends.		10-s update frequency
Tipping bucket precipitation	May be on met tower or standalone support (usually with shield) and typically opposite the air temperature (and RH) sensor. Minimum 2 ft from tower leg. The orifice must be level.		7 ft ± 1 ft 18 ft ± 1 ft 28 ft ±1 ft Above ground level (AGL)		10 s
Soil moisture	Placement of the sensor is typically uphill from the met tower or soils junction box to limit drainage along the wires or conduit which might affect the readings.		2-, 8-, and 20-in minimum in mineral soil or until bedrock. It is recommended to include the 4- and 40-in zones. Sensor placement is belowground. A separate pit should be excavated to describe and do a full site characterization.		60 min for current measurement
Soil temperature	Placement of the sensor is typically uphill from the met tower or soils junction box to limit drainage along the wires or conduit which might affect the readings.		2-, 8-, and 20-in minimum in mineral soil or until bedrock. It is recommended to include the 4- and 40-in zones. Sensor placement is belowground. A separate pit should be excavated in order to describe and do a full site characterization.		60 min for current measurement