The Resources Agency of California
Department of Water Resources
California Cooperative Snow Surveys

Snow Survey Procedure Manual

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On the cover: Snowpacks of well below-average depth cover the Great Western Divide as viewed from above the Tyndall Creek drainage, March 26, 2013. Photograph by Randall Osterhuber.

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INTRODUCTION

By any measure, California's agriculture, hydroelectric production, domestic use, riparian health, and recreation all put tremendous demands on the state's often limited water resource. Because of California's Mediterranean climate, little significant precipitation occurs during the summer and autumn months. Accurate assessments of mid-winter precipitation, therefore, are a vital determinant of the state's available water. During most years, maximum snow water equivalent[1] (SWE) in the Sierra Nevada denotes the annual peak of surface water resource. Snow water equivalent is a key index not only for forecasting stream and river flow timing and amount, but for a wide variety of water management decisions targeted days and months into the future.

The goal of the snow survey is to obtain an accurate measure of SWE at predetermined locations: snow courses. Snow courses typically have between five and ten measurement points spread out over one or more straight-line transects. Transects can be short, or several hundred meters in length. Some snow courses are coincident with recording or data-transmitting weather instrumentation; many others stand alone in very wild and remote locations. Most snow courses are measured once per month throughout the winter (accumulation) and spring (ablation) seasons, though some may be measured at different frequencies. Several California snow course records go back to the 1920s (some to 1910). Data from the measurements are used to develop—and continuously refine—indices of stream flow for the respective watersheds. A critical first step in characterizing the spatial and temporal distribution of California's SWE is by measuring its 261 snow courses throughout the state.

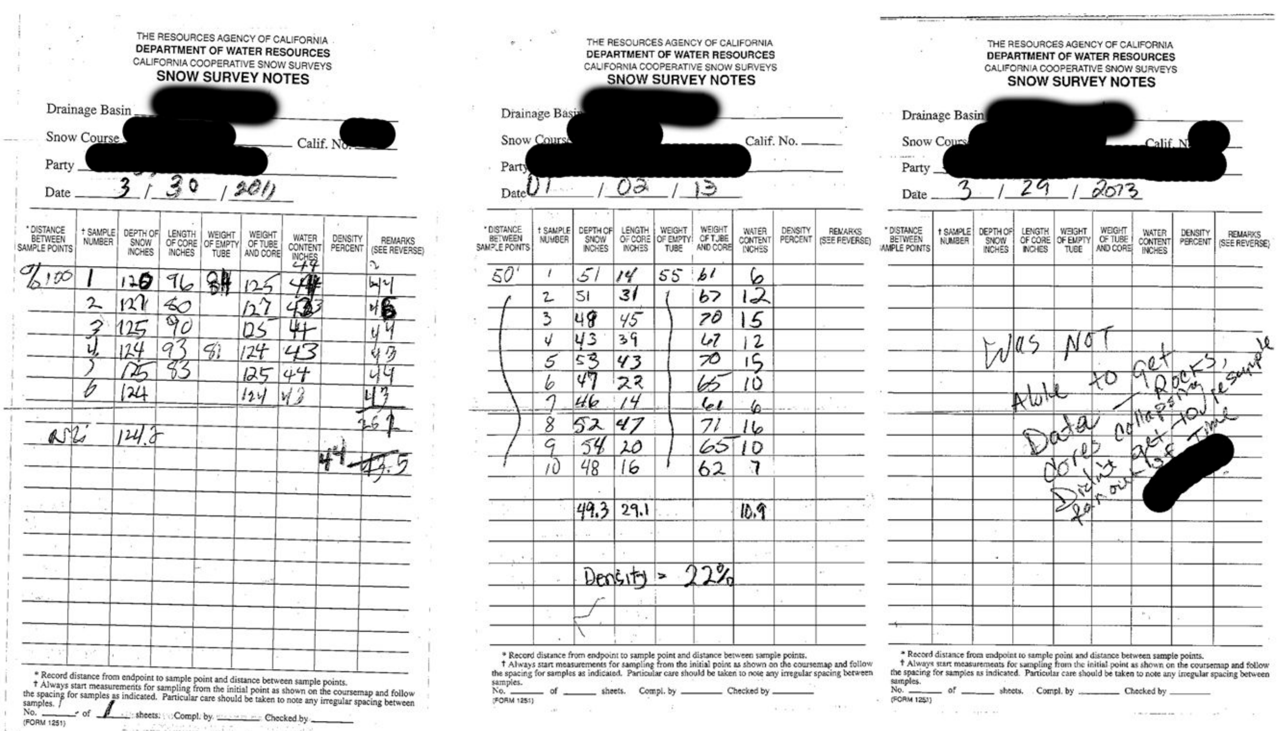
The aim of this document is to address snow survey procedure and equipment, review data collection, and discuss surveyor safety. While some subjects (avalanche safety, wilderness first aid) are, in their entirety, beyond the scope of this work, industry standards and procedures are presented. The author hopes this document will find utility as an office-based training manual for those new to snow surveys, as well as a field guide and reference to all who conduct snow surveys.

As of this writing, many advances in the remote sensing (by ground-, aircraft- and spacecraft-based instrumentation) of snow cover are being developed. No doubt these developments in both procedure and instrumentation will continue to advance. However, there currently exists no practical, automated technique with which to measure SWE at the number of locations and at the point-accuracy of ground-based, manual measurements. Manual measurements remain the standard for calibrating and "ground-truthing" automated instrumentation, and have the advantage that they can be obtained independent of most surface and weather conditions. For the foreseeable future, snow surveys will continue to be a vital part of the water management structure in California.

PURPOSE OF THIS MANUAL

California makes more seasonal snow measurements than any other state in the union, relying on a wide variety of cooperating agencies to collect this information[2]. The California Department of Water Resources (DWR) is the coordinating agency of the statewide Cooperative Snow Survey Program. DWR currently lists 53 unique agencies that conduct snow surveys and report the data to the state. These include federal, state, and county agencies, public and private utility companies, colleges and universities.

Over the years DWR personnel have been increasingly challenged to collect, manage, and interpret these data. Problems arise from several areas: key snow survey personnel from cooperating agencies retire or change position; personnel new to snow surveys take over measurements with little—if any—training; how snow courses are measured varies widely from


THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
CALIFORNIA COOPERATIVE SNOW SURVEYS
SNOW SURVEY NOTES

Drainage Basin [redacted]
Snow Course [redacted] Calif. No. [redacted]
Party [redacted]
Date 3 / 30 / 2011

* DISTANCE BETWEEN SAMPLE POINTS	† SAMPLE NUMBER	DEPTH OF SNOW INCHES	LENGTH OF CORE INCHES	WEIGHT OF EMPTY TUBE	WEIGHT OF TUBE AND CORE	WATER CONTENT INCHES	DENSITY PERCENT	REMARKS (SEE REVERSE)
~~0~~/100	1	120	96	84	125	44		44
	2	127	80		127	43		46
	3	125	90		125	44		44
	4	124	93	81	124	43		43
	5	125	83		125	44		44
	6	124			124	43		43
								261
avg		124.8						
							44	~~43.5~~

* Record distance from endpoint to sample point and distance between sample points.
† Always start measurements for sampling from the initial point as shown on the coursemap and follow the spacing for samples as indicated. Particular care should be taken to note any irregular spacing between samples.
No. ____ of 1 sheets. Compl. by ____ Checked by ____
(FORM 1251)

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
CALIFORNIA COOPERATIVE SNOW SURVEYS
SNOW SURVEY NOTES

Drainage Basin [redacted]
Snow Course [redacted] Calif. No. ____
Party [redacted]
Date 01 / 02 / 13

* DISTANCE BETWEEN SAMPLE POINTS	† SAMPLE NUMBER	DEPTH OF SNOW INCHES	LENGTH OF CORE INCHES	WEIGHT OF EMPTY TUBE	WEIGHT OF TUBE AND CORE	WATER CONTENT INCHES	DENSITY PERCENT	REMARKS (SEE REVERSE)
50'	1	51	14	55	61	6		
	2	51	31		67	12		
	3	48	45		70	15		
	4	43	39		67	12		
	5	53	43		70	15		
	6	47	22		65	10		
	7	46	14		61	6		
	8	52	47		71	16		
	9	54	20		65	10		
	10	48	16		62	7		
		49.3	29.1			10.9		

Density = 22%

* Record distance from endpoint to sample point and distance between sample points.
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No. ____ of ____ sheets. Compl. by ____ Checked by ____
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SNOW SURVEY NOTES

Drainage Basin [redacted]
Snow Course [redacted] Calif. No. [redacted]
Party [redacted]
Date 3 / 29 / 2013

* DISTANCE BETWEEN SAMPLE POINTS	† SAMPLE NUMBER	DEPTH OF SNOW INCHES	LENGTH OF CORE INCHES	WEIGHT OF EMPTY TUBE	WEIGHT OF TUBE AND CORE	WATER CONTENT INCHES	DENSITY PERCENT	REMARKS (SEE REVERSE)

Was NOT Able to get Data
Rocks, cores collapsing ... to resample
Didn't get ... [redacted]

* Record distance from endpoint to sample point and distance between sample points.
† Always start measurements for sampling from the initial point as shown on the coursemap and follow the spacing for samples as indicated. Particular care should be taken to note any irregular spacing between samples.
No. ____ of ____ sheets. Compl. by ____ Checked by ____
(FORM 1251)

agency to agency; and submitted field notes are illegible, incomplete, or do not comply with professional and industry standards.

In addition, approximately 50 percent of the snow course data submitted each month to DWR is in paper form only—not digitized. Before DWR water engineers can incorporate these data into stream flow forecasts, math must be checked, recording methods untangled, and surveyors' handwriting deciphered.

The most current snow survey manuals available today date from the Reagan (if not Eisenhower) administration. Updated, standardized training and reference materials are needed to ensure surveyors across the state collect snow course data that is accurate, timely, and consistent not only across agencies, but with national and international standards for snow measurement. This manual is a first step in that direction.

What hasn't changed in the past 100 years of snow surveying is the need for surveyor safety. Snow surveys are often conducted in remote locations and under the demanding conditions of short days, steep terrain, high altitude, cold temperatures, towering winds, heavy precipitation, low visibility, and deep snow. All of these present challenges that the surveyor—and the survey team—must anticipate and be trained for. This manual stresses a "culture of safety" with respect to the mountainous, winter environment.

Improved accuracy and efficiency in measuring and forecasting water supply for a state the size of California can be translated into millions of dollars or mega-joules of energy[3]. Small improvements in data collection at the top end—the snow survey—will make a significant impact.

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[1] Snow Water Equivalent is the amount of liquid water equivalent of a volume of snow. This is the sum of the ice and any liquid (free) water present in the snow. While typically expressed in linear units (mm, cm, inches), SWE is considered a volumetric quantity when integrated over some defined area.

[2] Ninety-two percent of California's 261 snow courses are measured by non-DWR personnel. In all western states except California, the USDA Natural Resource Conservation Service (NRCS) is responsible for managing snow surveys. Other western states and the percentage of snow courses measured by cooperating (non-NRCS) agencies: NV/00, UT/01, CO/37, WA/50, NM/54, OR/60, ID/70, MT/94.

[3] Examples: 1 percent of the SWE in a small 1200 hectare watershed with an average snow depth of 3.5 m and an average density of 450 kg/m^3 represents 192,000 m^3 of water. In 2007 (a below average precipitation year), 220 gigawatts of power were produced from just 1 percent of California's snowmelt.

SNOW SURVEY EQUIPMENT

TUBES

At the heart of the snow survey is the snow coring tube set. The three most common designs in use today include the "Federal Sampler" (manufactured in English and metric units), the heavier gauge "McCall" sampler, and the short fixed-length "Prairie" sampler (Figure 1). Though various manufacturers have employed slightly different materials and construction techniques, most samplers share common attributes.

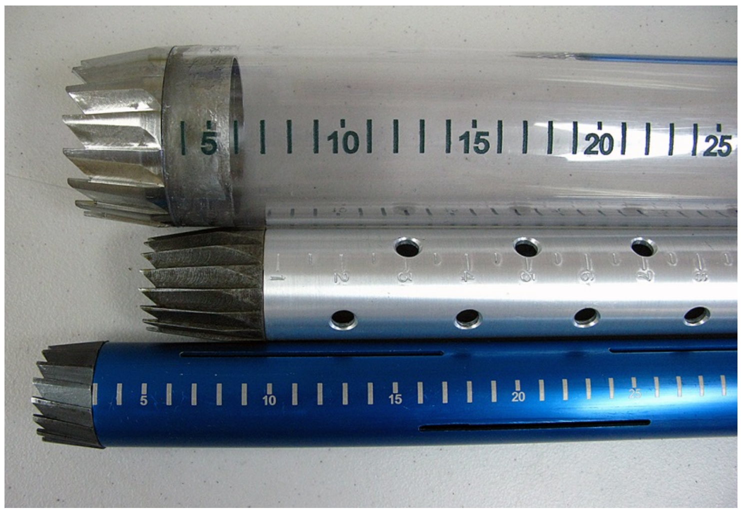

Figure 1. The three most common snow samplers in use today: Prairie, McCall, and Federal (top to bottom).

The sampler, an aluminum, steel, or plastic tube, is used to extract a core from the entire cross-section (depth) of the overlaying snow cover. The snow core is then weighed to attain the SWE. Tubes are assembled of approximately 30 inch (75 cm) sections, screwed together to a length appropriate for the snow height (HS[1]). The total length of the assembled tube should be at least 10 inches (25 cm) greater than anticipated HS. With the exception of a Prairie sampler, at least two sections of tube should be used for every measurement even if HS is modest: with most scales two tubes are necessary to register a tare weight greater than zero. The exterior of the tubes are scribed with a height scale—either inches or cm—from which HS is recorded to the nearest half inch or cm.

The first (bottom) section of the corer is fitted with cutting teeth that should be sharp prior to each snow survey[2]. A sharp cutter is especially important for sampling deep and/or dense snow, and is key to obtaining an accurate sample. Several cutter types (Figure 2) have been employed over the past decades of snow tube design in an effort to maximize ease of snowpack penetration while still obtaining a snow core of appropriate cross section. The inside diameter of the cutter is slightly smaller than that of the tube to facilitate extraction of the snow core from the tube. When cutter teeth become excessively worn from use the cutter should be replaced.

Figure 2.

Most tube sections have short slots or holes cut throughout their length. These openings serve several purposes: they provide attachment points for the driving wrench and keep the wrench from slipping; they provide a port for visual inspection of the snow core inside the tube, and they offer a means through which to clear a snow core frozen or stuck inside.

The couplings that join the tube sections can be on the inside (flush) or outside, depending on snow tube design. Flush couplings make for an assembly easier to push through the snowpack, but a thicker walled tube—and hence a heavier tube set—is necessary to accommodate this design. The threads on both the male and female couplings are fine and should be kept clean and lightly lubricated between surveys. Great care should be taken not to cross-thread when assembling tube sections. During storage and transport, thread protectors should be in place to protect the threads from damage.

When coring snow, the tube sets are subjected to great rotational forces, and the couplings are notorious weak points in the tube assembly. Couplings need to be riveted and heat pressed in order not to work loose. Riveting alone will not suffice. The bottom three sections of tube sets, and the couplings that connect them, suffer the most abuse as they are used more frequently throughout the snow season. If couplings become loose they should immediately be repaired or replaced by a qualified machinist. Snow tube sets provided by the California Cooperative Snow Surveys (CCSS) should be returned to CCSS for maintenance.

DRIVING WRENCH

When attached to the assembled tube, the driving wrench provides a handle for driving and removing the tube from the snowpack. If the tube is fitted with slots, the driving wrench should be attached so that its keel sits at the lowest (closest to the cutter end) point of a slot. This prevents the wrench from slipping downward when the tube is pushed or pulled into the snow. If the tube is fitted with holes, the driving wrench should be attached so that its stud sits firmly in a hole.

Driving wrenches are casted or weld-fabricated and may differ slightly in size and shape. It should be ensured that the inside collar of the driving wrench fit snug and flush around the outside of the tube. Wrenches that are too tight or too loose can become detached or damage the tube set.

Typically the driving wrench is attached to the upper end of the assembled tube, providing a handle when the tube is all the way into the snow. For especially deep snows and long tubes, the handle might have to be removed and reattached at a higher position as the tube is incrementally inserted into the snowpack. *Though tempting, the driving wrench should never be used as foot pegs to drive the tube.* Neither the tube nor driving wrench are designed to handle such loads.

Assembled tubes should be weighed (both tare and with snow core) with the driving wrench attached.

SNOW CORE CLEANING TOOL

The snow core cleaning tool is used to break up snow cores frozen or otherwise stuck inside the snow tube. It must be no thicker than the slot openings cut along the length of the individual snow tube sections. The core cleaning tool is also used to clean dirt and debris from the cutting end of the tube after extracting the core from the snowpack. Many surveyors use an old butter knife, though some new snow tube kits may be supplied with a dedicated cleaning tool. Some cleaning tools also have a short measurement scale scribed along their length to aid in measuring the length of a dirt plug. Care should be taken when cleaning out snow from inside the tube to avoid scoring or damaging the tube, as this is cumulative and a heavily scored tube is more prone to icing.

SCALES

Scales used to weigh a snow tube consist of a steel spring inside a double metal cylinder. Most tube sets have two scales of different ranges. The “softer” scale will bottom out with an excessively long tube and snow core; while a short tube with little snow core will not be heavy enough to register on the “stiffer” scales. It is therefore crucial that the scale with the correct range be used. A cradle is attached to the scale to accommodate holding a long tube. Non-rigid or “stretchy” connectors (bungee cords) should never be used to attach the scale to the cradle or the scale to a fixed object; only rigid connectors (carabiners, snap-links, split rings) should be used.

Weighing heavy snow tubes is eased if the scale is attached to a ski pole and held by one surveyor while the other reads the scale. For very heavy tubes, a ski pole can be planted on firm snow (or the surveyor’s boot or ski) and angled outward so the scale hangs plumb and away from the ski pole.

Snow tube scales are calibrated to the cross-sectional area of the snow tube, and read directly in inches (or cm) of SWE. The inside diameter of the tube is sized so that one inch (or one cm) of SWE will register 1 unit on the scale. The softer scales, for HS less than 12.5 feet (3.8 m), are designed to have a resolution of 0.5 inches or 1 cm of SWE, and should be read and recorded to this precision. The stiffer scales, for HS greater than 12.5 feet (3.8 m), should be read to the nearest 1 inch or 2 cm. Care should be taken to match the correct range scale(s) with the HS being measured.

It is important that scales remain linear throughout their entire range (Figure 3). An easy way to check scale linearity is to attach a bucket and record the scale readings with successive cumulative volumes (200, 400, 600 ml, for instance) of water. Scale readings plotted as a function of total water volume should reveal a linear relationship. Scales that show divergence from linearity within their range should be retired.

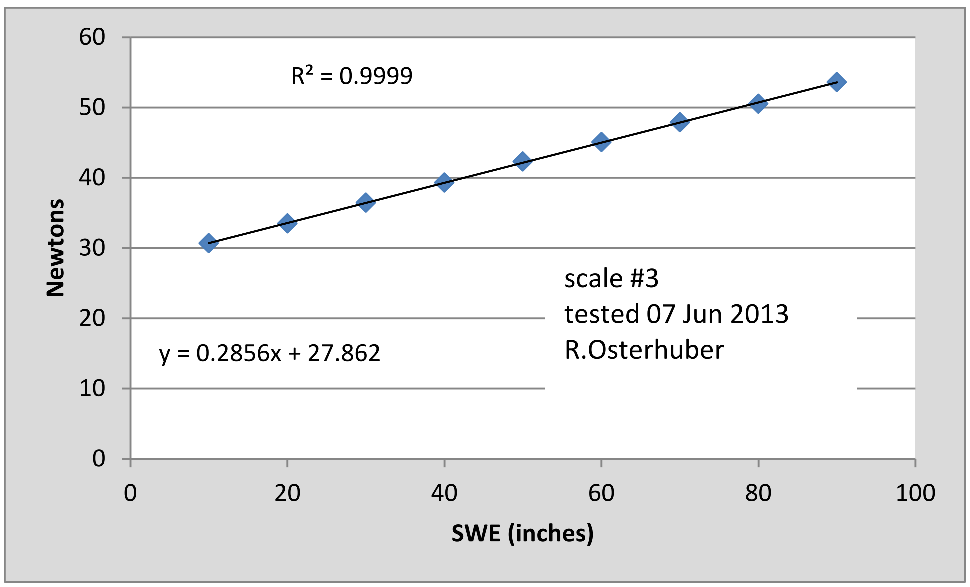

Figure 3. Testing of a scale with a force meter reveals a high linearity. The slope of the line (here 0.2856) should be consistent throughout its range.

A complete snow tube set for field use should consist of (at least) the following:

equipment case (rigid or fabric)
tubes (bottom two sections plus those needed for the HS)
thread protectors
driving wrench
scale(s)
scale cradle

spanning wrench (to disassemble tubes)
snow core cleaning tool (manufactured or custom; many surveyors use an old butter knife)
snow course map(s)
measuring tape (50 feet, 15 m)
tube lubrication (Teflon, silicon, Maxi-glide)
collapsible avalanche rescue probe (for aid in deicing a long snow tube)
writing implement (pencil, weather proof pen)
data recording sheets with core/HS-calculating nomogram[3]
waterproof nylon sack (if bulk sampling anticipated)
metal file
calculator
cloth rag

END OF THE SEASON

At the end of the snow season, snow coring equipment should be cleaned, dried, and inspected before storing. Tube sections can be cleaned with dish soap and warm water if needed, with special attention given to removing residue among coupling threads. Any equipment needs or repairs ought to be addressed promptly so that all gear is ready to go in the fall. Care should be taken not to store heavy objects on top of snow tube kits.

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[1] HS, "height of snow," is the international designation for total snow height with "0" height at the ground. "Snow depth," often used interchangeably with HS, differs in that "snow depth" references "0" depth at the snow surface.

[2] Some cutters are manufactured from steel harder than common sharpening files, and can only be sharpened with custom-shaped diamond sharpening wheels. Only those experienced with metal work should attempt to sharpen snow tube cutters.

[3] A graphical solution to an equation.

PHYSICS OF SNOW SAMPLING

The inside diameter (37.8 mm) of Federal and McCall snow tube cutters used today are designed and coupled with specific scales so that 1 ounce (28.4 g) of sampled snow will register 1 inch (2.54 cm) of SWE.

Extensive research[1] from the 1960s and 70s addressed different snow tube cutter designs, tube diameters, and the resulting cross sectional areas of the core removed from the snowpack. The goal was to refine the snow sampler design to better "ground truth" SWE.

Ground truth is synonymous with a practical measurement standard, a standard against which other (field or laboratory) measurements are compared. While many practitioners use snow samples on the order of 500 – 1000 cm^3 as a suitable volume for a SWE standard, these small-volume measurements are an inefficient way to sample the entire cross-section of deep, mountain snowpacks. The snow coring snow tube is today considered the standard for ground truthing SWE in deep snowpacks.

As a snow coring tube is thrust down into the snowpack, the leading edge (the cutting teeth) can encounter many different snow layers with highly disparate properties. The resistance the cutter edge encounters determines how efficiently it removes that section of core from the surrounding snow. In soft, moist snow, the cutter may separate the core from the surrounding snowpack with minimal deformation. Conversely, when the cutter must break through hard layers or dense crusts, the crusts may deform or break in an irregular fashion resulting in a sample volume different from that of the interior of the coring tube.

Most samplers used today over-sample the SWE relative to small-volume control samples. Ranges of over-measure are typically from 4 to 9 percent but may be as low as 0 to as high as 12 percent. Not only is this percentage a function of many factors (including HS[2], snow layer hardness and density, cutter sharpness, and temperature gradients[3] within the snowpack), it is very problematic to predict. While the snow surveyor has no control over the state of the snowpack, every effort must be made to reduce the variables within his or her power to control.

ICING

Aluminum, the most common material of snow tube design, is highly thermally conductive. The snow tube is therefore vulnerable to temperature changes from both the atmosphere and the snow. The deep, mid-winter snowpacks of the Sierra Nevada often contain strong temperature gradients, including warm (near 0º C, 32º F) snow layers. If warm snows are present, so usually are small amounts of melt water. As the highly conductive snow tube is thrust through these snow layers of different temperatures it becomes susceptible to icing.

Nothing will introduce difficulty—and error—into the snow survey like an icing tube. An iced tube cannot be inserted freely into the snowpack and cannot efficiently remove a core from the snow profile. All ice has to be removed from the tube, inside and out, before subsequent samples are attempted. Icing can be remedied by lubrication, sampling technique, or both.

A well-lubricated tube is a highly effective deterrent against icing. In the field, frequent and liberal application of a lubricant can help circumvent icing. Common lubricants used are silicon, Teflon, Maxi-Glide, and propylene glycol. The cutting teeth, around the couplings, and any interior areas that are heavily scratched or scored are common places for the tube to ice. In extreme cases, a rag taped to the end of an avalanche rescue probe can be saturated with lubricant and used to swab the interior of the tube. Note that heavy applications of lubricant may alter the tare weight of the tube.

Depending on the weather and state of the snowpack on any given day, it may be advantageous to keep the tube cold, or warm.

For cold snowpacks, cool the tube as much as possible before letting it contact snow. Keeping the tube in the shade between sample points, and carrying a snow core inside the tube between samples will help keep the tube from warming quickly in the sun. If the tube has to be carried in the sun, angling it so the sun shines through its length will minimize the angle of incidence on the metal exterior. Tubes can be placed on the snow surface to cool only if the shaded snow is hard; never place a warm tube onto a cold, soft snow surface. It is a good habit—especially in conditions prone to icing—to thrust the tube into and through the snowpack all the way to the ground as quickly as possible. The tube can be rotated clockwise (as viewed from above) to facilitate this, but a snow tube should *never* be rotated counter-clockwise, as this could unscrew sections sub-surface. If icing is occurring, note the depth at which the tube first encounters icing (resistance), and try to thrust the tube quickly through these layers on subsequent attempts. If temperature differentials are so great that icing is impossible to avoid, it may be necessary to resample either very early in the morning or very late in the afternoon to avoid the influence of warm air.

Ease of sampling may be facilitated with a warm tube if sampling hard, spring snow in the early morning. In the field, the only practical means by which to warm a snow tube is with direct sunlight.

CORE LENGTH

When sampling snow with a coring tube, it will be noted that the length of the snow core inside the tube is almost always less than HS. With very modest snow depths ($\leq$ 25 cm, 10 inches), core length may equal HS. Core length greater than HS is a physical impossibility and is indicative of a sampling error. Core length is less than HS due to the snow core being compressed during sampling. *The ratio of core length to HS is typically in the range of 0.80 but may vary depending on HS and density of the sampled snow*. The core length to HS ratio should be relatively consistent throughout the snow course measurements on any given day. There are three common reasons why this ratio may be inconsistent, including: widely varying HS, sampling very fresh snow over vegetation, and the presence of large amounts of free water[4] in the snow.

Snow courses that are subjected to high winds can result in great variation in HS as snow is distributed disproportionately during and after storms. The effect of snow densification by wind pressing can create very different structure than snow subjected to little wind. This can result in dissimilar core length/HS ratios across the snow course.

Widely varying HS may also be due to differential accumulation (and melting) under trees. During the ablation season some measurement points in the sun may become completely free of snow while shaded areas harbor significant depth.

Newly buried vegetation, be it small trees or brush, can harbor hollow areas that result in gaps in the extracted snow cores. As HS increases through the season, and the snowpack settles, these gaps tend to be reduced or eliminated, but special attention should be paid to the quality of the snow core when sampling around vegetation. Cutting/trimming brush or tree limbs in the sampling region during summer will eliminate problem areas (see *Snow Course Maintenance*).

Free water movement through snow is a complex and poorly modeled process. How water flows through snow is function of HS, grain size and type, layer density, and, most importantly, whether free water has previously established flow channels. Water can drain freely through one part of the snowpack while pooling in another. Dense layers or crusts can act as occlusive structure and cause free water to route laterally great distances. Water can even move upslope through capillary action. And while some snows remain dry, adjacent snows can be at or near their water holding capacity.

Old, late season snows tend to be comprised of much larger, warmer grains, near 0º C (32º F). These snows drain free water much more efficiently and uniformly than newly wetted, cold mid-winter snows. When intense melt or rain has occurred on cold snowpacks, dramatic snow surface expressions of water routing (local depressions, dimples, runnels) are usually visible. These are signs that large amounts of free water may be present in parts of the snowpack. Snow that has high free water content will typically have a markedly different average density and SWE than dry snow. If the snowfields being sampled have been subjected to recent rains, intense melt, or both, notable differences in sampling attributes may be observed across a snow course. In such instances, field notes should include descriptions of observed conditions.

[1] Summarized in *Metrication of Manual Snow Sampling Equipment*, *Final Report March 1983* westernsnowconference.org

[2]HS, "height of snow," is the international designation for total snow height with "0" height at the ground. "Snow depth," often used interchangeably with HS, differs in that "snow depth" references "0" depth at the snow surface.

[3] Temperature gradient ≡ change in temperature over some distance ($\Delta T/cm$).

[4] Liquid water present in the snow profile is referred to as "free water." Most snows have a maximum free water holding capacity—the point at which they are saturated—of about 10-11 percent by volume.

SNOW SURVEYOR SAFETY

Priority One on any snow survey is surveyor safety. Winter in the high mountains can—and eventually will—present some very challenging conditions for the snow surveyor. These can include low air temperatures, highly reflective snow, towering winds, high altitude, heavy precipitation, steep terrain, unstable snowpacks, rockfall, short days, low visibility, open water, partially frozen water bodies, and deep snows. While it is beyond the scope of this manual to address all safety concerns in detail, the goal here is to promote a *culture of safety*. A culture of safety addresses the responsibility of all individual members of the snow survey team, whether that be two people or an entire work group. It is each surveyor's responsibility to bring as much forethought, training, and preparation to the snow survey as they can. This ultimately produces a strong team. A highly trained and functioning team is the best way to recognize and avoid potential problems, and to efficiently deal with problems should they arise.

The culture of safety also extends to managers and supervisors who dispatch their employees into the field. Managers must endorse and promote the resources (time, money, equipment) necessary to field trained, prepared personnel.

At a minimum, each snow surveyor should have formal training in proper cold weather equipment, basic wilderness first-aid, snow avalanche safety, and backcountry navigation. In addition, those who travel to/from snow surveys in snow machines or aircraft need additional training specific to those vehicles. Snow surveyors should never work solo in the backcountry.

SNOW TUBE SAFETY

Driving, removing, and handling long, heavy snow tubes can be fatiguing. Sharing the sampling and recording duties among surveyors helps keep team fatigue to a minimum. *Surveyors should never stand or jump on the driving wrench in an attempt to drive the tube deep into the snow*. Neither the tube nor driving wrench are designed for this type of load. Surveyors should never position their face or head directly above the end of the snow tube when driving it or removing it from the snow. If the driving wrench slips, the end of the tube can cause serious injury. When handling the tube above snow, be aware of the sharp cutter end and those around you. Special care should be taken to lift heavy tubes out of the snow with as little bending over as possible, lifting with the legs instead of the back.

COLD WEATHER

Frostbite and hypothermia are both relatively simple to avoid, and both near impossible to treat effectively in the field. Prevention is therefore key, and is accomplished with proper clothing and surveyor health. Surveyors should wear modern, layered synthetic clothing—including waterproof/breathable outerwear—that promotes comfort in a wide variety of temperature and weather conditions. This includes base layers, insulation layers, hats, gloves, and sturdy, warm, waterproof boots. In addition, keeping well fed and hydrated throughout the snow survey is crucial to avoid cold weather injury.

FIRST AID

Many First Aid courses offered today specifically address the challenges of dealing with medical emergencies in backcountry environments. Wilderness First Aid (WFA), and Wilderness First Responder (WFR) are two such courses that emphasize first aid treatments with little specialized equipment. Wilderness Medical Associates International[1] (wildmed.com), as well as several others, provides training courses across the US and Canada.

SNOW AVALANCHE SAFETY

One of the primary skills necessary for avalanche safety is the ability to recognize avalanche terrain. All personnel must be made aware of avalanche terrain that is traversed during snow survey travel, and be trained in different travel techniques. Avalanche terrain can be identified during summer snow course maintenance trips and highlighted on topographic maps. Surveyors that spend any time near avalanche terrain should complete a multi-day classroom and field course on avalanche safety, and always carry avalanche rescue gear (transceiver, probe, shovel).

BACKCOUNTRY NAVIGATION

Each surveyor operating in a winter environment should be competent in the use of topographic maps, the magnetic compass, and a GPS (Global Positioning System) receiver. This includes being able to calculate and communicate positions using common coordinate systems (degrees, minutes, seconds; decimal minutes; decimal degrees; UTMs). At a minimum, each survey team should collectively carry navigation tools; ideally, each individual would carry their own. While a GPS may seem like overkill during clear, stable weather, being able to specifically identify and describe a location—without any ambiguity—during an emergency will prove key when communicating with rescue personnel. Snow surveyors should carry waterproof GPS units fitted with lithium batteries.

SNOW MACHINES AND AIRCRAFT

When snow surveyors travel on machinery into the backcountry they should be completely prepared to continue travel under their own power should the machine become disabled. Every surveyor who boards an aircraft or snow machine should do so with their full backcountry kit, including skis or snowshoes. Be aware that some aircraft operated by federal or state agencies have a strict safety dress code that may include fire retardant clothing and eight-inch high boots.

Snowmobiles, snowcats, and helicopters all have their very specific safety protocols that may be in addition to backcountry travel protocols. Specialized tools, equipment, and safety gear—and training in their use—are all required when operating machinery in the winter backcountry.

COMMUNICATION

With many snow survey routes laying well outside of cell phone coverage, communication can be problematic without a UHF or VHF radio, or satellite telephone. Remote smartphone/satellite communication technology is ever-evolving, but as of this writing satellite phones remain the best option for communicating from the backcountry. No snow survey team should be operating in the backcountry without the ability to communicate with the front country.

EMERGENCY GEAR

Emergency equipment, whether it be a first aid kit, avalanche rescue gear, or extra batteries, need not be heavy or cumbersome. Modern equipment is generally light and compact (cold-weather sleeping bags that pack smaller than a loaf of bread are now commonplace) and the burden of carrying some emergency gear can be shared among team members. Emergency gear, like other tools, should be inventoried, inspected, maintained, and replaced as appropriate. Though not complete, the following is a list of safety equipment commonly used by backcountry snow surveyors:

Extra cold weather clothing
Shade hat
Sunscreen, blister treatment
First-aid kit (including medicines, epi-pen)
Avalanche transceiver, probe, shovel
Dark glasses, goggles
Thermos with hot tea, soup, coffee
Map, compass (with sighting/signaling mirror), GPS
Bivouac sac (or one-time-use “space” blanket)
Foam pad (insulation, padding, splinting)
Knife or multi-tool
Extra ski binding parts, screws, 5-minute epoxy, hose clamps, wire ties
Tape (electrical, duct)
Lighter, waterproof matches, fire starter
Water purification tablets
Compact sleeping bag
Emergency rescue sled (1 lb, size of liter bottle)
Floorless tent (2 lb, pitch quick, pitch anywhere)
Small canister stove
Rescue rope (6 or 7 mm x 20 m)
Headlamp (extra batteries for headlamp, GPS, avalanche transceiver)
Cell phone, satellite phone (extra phone battery)
Adjustable nylon straps
Collapsible wood saw
Large plastic garbage bag

Chemical warming pouches (hand size to vest size available)
Keys and/or lock combination to nearby emergency shelters
Contact info (phone #s, email) for key personnel

[1] Listed as an example resource. No endorsement is necessarily implied.

STEP-BY-STEP GUIDE TO CONDUCTING A SNOW SURVEY

The following guide is intended to be used as both an office-based training tool and a manual to be brought into the field.

1. **Prepare Snow Survey Equipment**

A complete snow sampling kit should include (at least) the following. Make sure that tube sections are clean, in numerical order, properly lubricated, that coupling threads are clean and lubricated, and cutter is sharpened. Fill in headings on snow note, and review course maps to become familiar with distances from transect end/start points and between samples. These values come directly off the snow course map. Wait to fill in weather and snowpack observations until out in the field.

Snow Sampling Kit

- ☐ equipment case (rigid or fabric)
- ☐ tubes (bottom two sections plus those needed for anticipated height of snow (HS)
- ☐ coupling thread protectors
- ☐ driving wrench
- ☐ scale(s)
- ☐ scale cradle
- ☐ spanning wrench (to disassemble tubes)
- ☐ snow core cleaning tool (manufactured or custom; many surveyors use an old butter knife)
- ☐ snow course map(s)
- ☐ measuring tape (50 feet, 15 m)
- ☐ tube lubrication (Teflon, silicon, Maxi-glide)
- ☐ collapsible avalanche rescue probe (for aid in de-icing a snow tube)
- ☐ writing implement (pencil, weather-proof pen)
- ☐ data recording sheets with core/HS-calculating nomogram
- ☐ waterproof nylon sack or bucket (if bulk sampling anticipated)
- ☐ metal file
- ☐ calculator
- ☐ cloth rag

2. **Prepare Snow Surveyor Personal Equipment**

Surveyor personal equipment should include: proper clothing (for precipitation, cold, wind, sun) and eye protection, topographic map, compass, GPS, avalanche rescue gear (if travelling through avalanche terrain), food, water, first aid kit, communication devices (cell phone, satellite phone, VHF radio), and tools for over-the-snow travel (skis, snowshoes). Recommended additional equipment: knife/multi-tool, fire starter, lightweight emergency bivouac sac, lightweight sleeping bag, emergency sled, 20 m of rescue rope, thermos with hot drink, iodine tablets to purify water, collapsible wood saw, keys/lock combination to any nearby emergency shelters, chemical heat packs, duct tape, extra ski binding screws and parts, epoxy, small hose clamps. All surveyors should be trained and familiar with all team equipment.

3. **Approach Snow Course**

Identify snow course transect start and end points. If end marker signs are missing or in need of repair make note for future site visits. Avoid driving snow machines on snow course. Disturb snow on course as little as possible. If the snow course is to be measured several times (eg. each month) during the season, strategize so that sampling each month will follow a line approximately 3-6 feet (1-2 m) offset from the previous month. This avoids sampling previously tracked or compacted snow.

4. **Assemble Snow Sampling Equipment**

Screw tube sections together (hand tight) being careful to avoid cross-threading. Make sure numbers run consecutively through entire length. Use at least two tube sections, even for very shallow snows. Attach driving wrench as close as possible to (non-cutter) end of tube. Make sure driving wrench keel/stud is securely seated in slot or hole. Hand tighten. Attach cradle to scale and scale to ski pole (or equivalent). Make sure to use the appropriate range scale for current HS. If the snow tube has been carried in a snow machine, helicopter, or is otherwise warmer than air temperature it should be allowed to completely cool before coming in contact with the snow. Hanging the tube on the shady side of a tree may help.

5. **Locate Sampling Point**

Locate sampling point by measuring correct distance following the layout shown on the snow course map. It is not necessary to start the snow survey at point #1, though it may be most time and energy efficient to sample in some logical order. As one surveyor holds the "zero" end of the tape, they can sight the other surveyor on the correct sampling line relative to transect end markers.

6. **Obtain Snow Sample**

Making sure the tube is sufficiently cooled and completely clear of snow, ice, or debris, thrust the snow tube plumb (straight up and down) into the snowpack and drive it all the way to the ground. Turning the tube slightly clockwise (as viewed from above) while driving it may help cut through dense layers of snow and ice. The tube can be rotated in this fashion when inserting or removing it from the snowpack; it should *never* be rotated counter-clockwise (as viewed from above). The metal snow tube is highly conductive to heat, therefore the surveyor should always wear gloves, even on warm days. With the snow tube driven all the way to the ground, note HS to the nearest half-inch (or cm). After rotating the tube at least one half rotation, remove the snow tube from the snowpack by carefully lifting it straight up out of the cored hole. Check the cutter end of the tube for evidence of dirt or forest litter. In lieu of an impenetrable ice layer, evidence of driving the cutter all the way to the ground must be confirmed for every sample. If no dirt or debris is evident at the cutter end of the tube, the entire snowpack may not have been sampled. If this is the case re-sample in a new spot close to first hole. If multiple attempts are needed to obtain a good core from, say, sample point #7, data in the field notes should be recorded as 7A, 7B, etc.

7. **Remove Debris and Prepare to Weigh Snow Tube**

Move the snow tube away from the measurement transect so as not to drop dirt or debris on the snow course. With the snow tube cleaning tool, carefully remove any dirt or debris from inside the end of the tube noting the length of the dirt or debris plug. If the length of the debris plug is one half-inch (1 cm) or more, this value is subtracted from the HS noted when the tube was still in the snow. This adjusted value is HS for the sample and is recorded on the data sheet to the nearest half-inch (1 cm). For example, if the tube is thrust to the ground and the depth is noted as 98.0 inches, and a subsequent dirt plug of 1.5 inches is removed, HS for the sample is recorded as 96.5 inches. Next note the length of the core inside the tube to the nearest whole inch or cm. Remove any snow or ice from the exterior of the tube and from the driving wrench.

8. **Weigh Snow Tube and Core**

The scale should always be suspended from the ring on its end. With one surveyor holding the scale so that it hangs free, the other surveyor places the snow tube in the scale cradle so the tube is balanced. If using the "softer" scale (for HS < 12.5 feet, 3.8 m), record the weight of tube and core to the nearest half-inch (67.0, 67.5) or to the nearest whole cm. For the “stiffer” scale (for HS > 12.5 feet, 3.8 m), record the weight of the tube and core to the nearest inch. After weighing, empty the snow core from the tube (away from the measurement transect) and note/record the weight of empty tube to the nearest half-inch or inch as described above. If ease of coring is facilitated by keeping the tube as cold as possible, it may help to keep the previously sampled snow core in the tube until ready to core the next sample.

9. <u>Record Data</u>

Unless additional tube sections are added or removed during the survey, or the driving wrench is removed or changed, the weight of the empty tube usually stays constant. Periodically check to make sure empty tube weight has not changed. If the scale warms or cools considerably during the survey, spring tension may change and thereby affect scale readings. For each sampling point, the surveyor handling the tube will call out three values to be recorded: HS, snow core length, and weight of tube and core. The values should be called out and recorded in this order so as to avoid confusion. If HS is measured as 47 inches, it should be recorded in the HS column as 47.0. This shows that the data was being measured to the nearest half-inch. Snow core length is an important check of the quality of the sample. The ratio of core length to HS ought to be relatively consistent across a snow course. If not, re-sample any point that yields an inconsistent core/HS ratio. HS is *always* recorded to the nearest half-inch or cm. The sample snow water equivalent (SWE) is obtained by subtracting the weight of the empty tube from that of the tube and snow core. The core/HS ratio is obtained by dividing the length of core by HS and is recorded to the nearest hundredth (example: 0.89). **Example 1** shows the correct form of data recording from an eight-point survey. Note the:

- eight-digit date format (yyyymmdd);
- HS, tare weight, weight of tube + core, and SWE recorded to the nearest half-inch;
- core length recorded to the nearest whole inch;
- core/HS recorded to the nearest hundredth;
- average HS and average SWE recorded (rounded) to the nearest half-inch;
- sample # 6 re-measured due to low core length/HS ratio;
- reverse side of sheet completed with space for narrative comments.

For very shallow snows, core length may equal HS, but it can never exceed HS, if so, this is a measurement error. Make sure the tube is completely clear of ice, snow, and debris before obtaining the next sample.

Pencil or pen may be used to record data. As with all professional field notes, entries should never be erased or otherwise deleted. If a mistake is made or incorrect data recorded, a line should be drawn through the data to signify its omission.

10. Sample Remainder of Snow Course

Measure and sample the remaining points of the snow course as shown on the snow course map. Any anomalies, problems, or deviations from prescribed measurement protocols should be documented in the "Remarks" section of the snow course field notes. After all snow course points have been measured, calculate average HS by summing all HS measurements and dividing by the number of samples, even if some samples had zero snow depth. Calculate average SWE by summing all SWE measurements and dividing by the number of samples. Record HS and SWE averages to nearest half-inch (1 cm, or nearest inch (SWE) if using stiffer scale). Check all data for completeness, neatness, and accuracy. Fill in weather and snowpack observations on data sheets while still on site.

11. Disassemble Snow Coring Tube

Using the driving wrench as one handle and the spanner wrench as a second, unscrew each section carefully. This may take two people. If couplings are frozen, warm them to facilitate ease of disassemble. Do not force. Make sure no equipment is left on the snow.

12. Special Conditions: Snow Freezing or Icing in the Tube

Icing is common when tube temperature and snow temperature differ greatly, such as during a warm, sunny day after newly fallen cold snow. Icing may prevent the tube from obtaining a complete or representative sample of the snowpack and has to be remedied before good data can be collected.

A clean, smooth (non-scored), well lubricated tube and sharp cutter are first defenses against icing. In extreme cases, the tube may have to be lubricated before each snow sample is obtained. To reach deep inside a long tube, consider swabbing the inside of the tube with a lubricant-soaked rag taped or tied to the end of an avalanche rescue probe.

Make sure the tube is as clean and cold as possible before it contacts the snow. Cool it thoroughly after removing it from a warm snow machine cab or aircraft fuselage. Thrusting the tube as quickly as possible all the way through the snow—in one motion without stopping—may prevent icing. Sampling either in the early morning or late afternoon will minimize temperature gradients between the tube and snow.

Warped or loose couplings, a heavily scored tube interior, and dull cutter teeth all can exacerbate icing.

13. Special Conditions: Multiple Sampling

Multiple sampling involves extracting a snow core from a single sample point (and a single hole) in multiple, discrete steps. There is much room for error with this technique so *it should only be employed when obtaining a sample with a single snow core is not an option.* Multiple sampling may be required when sampling very deep and/or very dense snowpacks.

Thrust the tube into the snowpack as far as possible without icing or clogging the tube. Carefully remove the tube from the hole and weigh. Be careful not to step on or otherwise disturb the snow around the hole. Record weight and core length. Empty the tube and return it very carefully to the bottom of the hole. Thrust the tube into the snow again as far as possible. Remove and weigh and record as above. Repeat as many times as necessary to reach the ground. When multiple sampling, the fewer steps per hole the better (two samples/hole better than three). Record the sample point core length as the sum of all the incremental core lengths. The sample point SWE is the sum of all SWEs from each incremental core. **Example 2** shows proper field recording of a multiple sample (3 cores) with HS = 120.0 inches and SWE = 58 inches using a 1 inch (SWE) resolution scale. Note:

- tare weight, weight of tube + core, and SWE all recorded to nearest inch because using "stiffer" scale;
- HS is determined after the third coring reaches the ground;
- core length is the sum of the three incremental cores;
- SWE is the sum of the three core SWEs;
- difficulty in measuring is explained under back page remarks;
- "S4" (under remarks) means snowfall at 4 cm/hour;
- this survey required multiple data sheets (as multiple sampling often does).

14. Special Conditions: Bulk Sampling

Bulk sampling is preferred when HS and SWE across a snow course are modest. As a guideline, if SWE averages 2 inches (5 cm) or less, the snow course should be bulk sampled. Bulk sampling can be combined with standard sampling technique if HS varies greatly across a snow course. A container large enough to hold the collected snow cores (bucket, waterproof nylon sack) will be needed for bulk sampling.

For each sampling point, remove a snow core using standard technique and record HS and length of core for each sample. Make sure the empty bucket is heavy enough to record a tare (empty tube) weight. If not, additional weight (wrench, snow tube section) will have to be added. Empty each sampled snow core into the bucket or water-tight container large enough for all the sampled snow cores. After all points have been sampled, record the sum of all HS measurements. Subtract the weight of the empty bucket from the weight of bucket with all the snow cores to obtain the bulk SWE. **Example 3** shows proper field recording for an eight-point survey bulk sampled. Note:

- data collected to the nearest whole cm;
- average HS is derived from sum of all HS measurements divided by 8;
- average SWE is obtained by dividing total SWE by 8.

Example 1. The correct form of data recording for an 8-point survey.

Example 2. The correct form of data recording for a sample point multiple-sampled.

Example 3. The correct form of recording for an 8-point survey bulk sampled.

SNOW COURSE MAINTENANCE

Snow courses should be visited annually, if feasible, during the summer season to verify that course markers are intact and visible, vegetation is cut back from course transects, and that any major landform changes (floods, debris flows, rockfall, avalanches, wildfire, widespread tree mortality) around the snow course are well documented. It is recommended that snow courses be inspected early in the summer so as to allow time to complete maintenance projects before the next snow season. All maintenance actions at snow courses should be documented.

SIGNS, POSTS, POLES

Verify that transect end markers and informational signs are in place, in good shape, and visible from transect end points. Consider visibility when tree branches are heavily laden with snow. Signs should be above historic HS maximum. Marker posts and poles should be plumb.

VEGETATION

All vegetation should be cleared 20 feet (6 m) to either side of course transects (with extra attention around sample point locations) including downed trees, small trees, and brush. Ideally, vegetation is cut flush or just below ground surface. Cuttings should be removed from the transect. Make note of any large trees that cannot be cut/cleared and are believed to interfere with snow deposition or ablation. Overhead branches should be cut as high as practical. Permission should always be sought from landowners prior to any vegetation removal.

COURSE MAPS

Most snow course maps were produced long before modern survey technology. The GPS coordinates, using decimal degrees (example: 39.34567° N, 120.00454° W), should be recorded at sample point #1 of each snow course. Transect "true" bearings should be verified with a compass and checked for accuracy relative to landmarks (trails, roads, structures, large trees and rocks, etc.). Transect lengths and distances between sample points should be verified. Document any inconsistencies between course maps and ground surveys.

Photographs, with good descriptors (*"Standing at point #5 looking toward W endpoint."*), can be very valuable for documenting maintenance actions or landform changes at snow courses.

Snow Course Maintenance Checklist

Snow course #

Date: Visited by:

- ☐ End point signs/markers/poles in place/good shape
- ☐ GPS coordinates at sample point #1
- ☐ Transect bearings verified
- ☐ Accuracy of course map
- ☐ Vegetation cleared
- ☐ Documenting photographs

Remarks, Inconsistencies with Course Map, and Future Actions Needed:

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SNOW SURVEY/SENSOR CONTROL NOTES

DRAINAGE BASIN ______________________________

SNOW COURSE/SENSOR ______________ COURSE/SENSOR NO. ______________

SURVEYORS ______________________________

DATE YYYYMMDD ______________ UNITS: INCHES CM

DISTANCE BETWEEN POINTS	SAMPLE #	HS	CORE LENGTH	TARE WEIGHT	WEIGHT TUBE + CORE	SWE	CORE/HS	REMARKS* (OVER)

PAGE_____ OF_____ COMPL BY _____ CHECKED BY _____

PLEASE COMPLETE THE FOLLOWING OBSERVATIONS WHILE IN THE FIELD.
CIRCLE ALL THAT APPLY.

SURVEY START TIME: END TIME:

CLEAR P. CLOUDY OVERCAST RAIN SNOW BLOWING SNOW FREEZING
THAWING SLEET HAIL THUNDER/LIGHTNING RIME FOG

SNOW SAMPLES OBTAINED WITH:
EASE MODERATE DIFFICULTY* GREAT DIFFICULTY*

SNOW SURFACE : SUPPORTABLE WET RAIN RUNNELED HOAR GLASSY

GROUND UNDER SNOW: FROZEN DRY DAMP WET

SNOW IS MELTING ON: N and/or E SLOPES S and/or W SLOPES

EVIDENCE OF RECENT AVALANCHES: YES* N0

WATER IN SMALL STREAMS IS: RUNNING FROZEN PARTIALLY FROZEN
CLEAR MUDDY BRIDGED BY SNOW

***REMARKS:** ______________________________

SENSOR CONTROL

MANOMETER READINGS UNITS: INCHES CM

SNOW: ______________________

PRECIPT: ______________________

AIR TEMPERATURE UNITS: °F °C

CURRENT: ______________

MAXIMUM: ______________

MINIMUM: ______________

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DRAINAGE BASIN FAST RUNNING RIVER

SNOW COURSE/SENSOR PINE MEADOW COURSE/SENSOR NO. 999

SURVEYORS OSTERHUBER, KIRCHNER

DATE 20130131 UNITS: (INCHES) CM

DISTANCE BETWEEN POINTS	SAMPLE #	HS	CORE LENGTH	TARE WEIGHT	WEIGHT TUBE + CORE	SWE	CORE/HS	REMARKS* (OVER)
50	1	40.0	32	20.5	31.0	10.5	.80	
	2	39.5	31		31.0	10.5	.78	
	3	39.0	31		31.0	10.5	.79	
	4	32.0	26		28.5	8.0	.81	
	5	30.5	25		28.5	8.0	.82	
	~~6~~	~~33.5~~	~~18~~		~~26.0~~	~~5.5~~	~~.54~~	X
	7	38.5	30		30.5	10.0	.78	
	8	38.0	30		31.0	10.5	.79	
	6A	34.0	27		28.5	8.0	.79	
TOTAL:		291.5				76.0		
AVERAGE:		36.4				9.5		
ROUNDED AVERAGE:		36.5				9.5		

PAGE 1 OF 1 COMPL BY JK CHECKED BY RO

PLEASE COMPLETE THE FOLLOWING OBSERVATIONS WHILE IN THE FIELD.
CIRCLE ALL THAT APPLY.

SURVEY START TIME: 0800 END TIME: 0900

CLEAR P. CLOUDY (OVERCAST) RAIN SNOW BLOWING SNOW FREEZING (THAWING) SLEET HAIL THUNDER/LIGHTNING RIME FOG

SNOW SAMPLES OBTAINED WITH:
(EASE) MODERATE DIFFICULTY* GREAT DIFFICULTY*

SNOW SURFACE : SUPPORTABLE (WET) RAIN RUNNELED HOAR GLASSY

GROUND UNDER SNOW: FROZEN DRY (DAMP) WET

SNOW IS MELTING ON: N and/or E SLOPES (S and/or W SLOPES)

EVIDENCE OF RECENT AVALANCHES: YES* (NO)

WATER IN SMALL STREAMS IS: RUNNING FROZEN (PARTIALLY FROZEN) (CLEAR) MUDDY BRIDGED BY SNOW

*REMARKS: LOW CORE/HS RATIO – RESAMPLED POINT #6.

Example 1: Data recording example for an 8-point survey.

SE…
MAN…
SNOW…
PRECI…
AIR T…
CURR…
MAXI…
MINIMUM: -3.5

Data recording and rounding

Since the sampler has a half-inch (or 1 cm) resolution, *all* HS data should be recorded and rounded to the nearest half-inch, including when computing course average HS.

Examples:

36.2 is rounded to 36.0
36.8 is rounded to 37.0
37.7 is rounded to 37.5

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SNOW SURVEY/SENSOR CONTROL NOTES

DRAINAGE BASIN FAST RUNNING RIVER

SNOW COURSE/SENSOR PINE MEADOW COURSE/SENSOR NO. 999

SURVEYORS OSTERHUBER, KIRCHNER

DATE 20130401 UNITS: (INCHES) CM

DISTANCE BETWEEN POINTS	SAMPLE #	HS	CORE LENGTH	TARE WEIGHT	WEIGHT TUBE + CORE	SWE	CORE/HS	REMARKS* (OVER)
	MULTIPLE SAMPLED							
			29	15	33	18		
			19	↓	27	12		
			46	↓	43	28		
50	8	120.0	94			58	.78	X
X								
TOTAL:		1245.0				510		
AVERAGE:		155.6				63.8		
ROUNDED AVERAGE:		155.5				64		

PAGE 7 OF 7 COMPL BY JK CHECKED BY RO

PLEASE COMPLETE THE FOLLOWING OBSERVATIONS WHILE IN THE FIELD.
CIRCLE ALL THAT APPLY.

SURVEY START TIME: 0800 END TIME: 1300

CLEAR P. CLOUDY OVERCAST RAIN (SNOW) (BLOWING SNOW) (FREEZING)
THAWING SLEET HAIL THUNDER/LIGHTNING RIME FOG

SNOW SAMPLES OBTAINED WITH:
EASE MODERATE DIFFICULTY* (GREAT DIFFICULTY*)

SNOW SURFACE : SUPPORTABLE WET RAIN RUNNELED HOAR GLASSY

GROUND UNDER SNOW: FROZEN DRY DAMP (WET)

SNOW IS MELTING ON: N and/or E SLOPES S and/or W SLOPES

EVIDENCE OF RECENT AVALANCHES: (YES*) NO

WATER IN SMALL STREAMS IS: RUNNING (FROZEN) PARTIALLY FROZEN
CLEAR MUDDY (BRIDGED BY SNOW)

***REMARKS:** SNOWING S4 ALL DAY. DENSE, HARD SNOW LAYERS REQUIRED MULTIPLE SAMPLING. NEW-SNOW AVALANCHES OBSERVED ON STEEP N-FACING TERRAIN.

Example 2: Data recording example for a multiple-sampled sample point.

SENSOR

MANOMETER READINGS UNITS: (INCHES) CM

SNOW: 70.2

PRECIPT: 91.1

AIR TEMPERATURE UNITS: (°F) °C

CURRENT: 24.0

MAXIMUM: 48.1

MINIMUM: 19.5

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CALIFORNIA COOPERATIVE SNOW SURVEYS
SNOW SURVEY/SENSOR CONTROL NOTES

DRAINAGE BASIN: FAST RUNNING RIVER

SNOW COURSE/SENSOR: PINE MEADOW COURSE/SENSOR NO. 999

SURVEYORS: OSTERHUBER, KIRCHNER

DATE: 20121231 UNITS: INCHES (CM)

DISTANCE BETWEEN POINTS	SAMPLE #	HS	CORE LENGTH	TARE WEIGHT	WEIGHT TUBE + CORE	SWE	CORE/HS	REMARKS* (OVER)
X								
50	1	2	2					X
	2	3	2					
	3	6	4					
	4	4	3					
	5	2	2					
	6	6	4					
	7	9	6					
	8	2	2					
X								
TOTAL:		34		18	26	8		
AVE:		4				1		
ROUNDED AVE:		4				1		

BULK SAMPLED

PAGE 1 OF 1 COMPL BY JK CHECKED BY RO

PLEASE COMPLETE THE FOLLOWING OBSERVATIONS WHILE IN THE FIELD.
CIRCLE ALL THAT APPLY.

SURVEY START TIME: 0800 END TIME: 0820

(CLEAR) P. CLOUDY OVERCAST RAIN SNOW BLOWING SNOW (FREEZING) THAWING SLEET HAIL THUNDER/LIGHTNING RIME FOG

SNOW SAMPLES OBTAINED WITH: (EASE) MODERATE DIFFICULTY* GREAT DIFFICULTY*

SNOW SURFACE: SUPPORTABLE WET RAIN RUNNELED (HOAR) GLASSY

GROUND UNDER SNOW: (FROZEN) DRY DAMP WET

SNOW IS MELTING ON: N and/or E SLOPES S and/or W SLOPES

EVIDENCE OF RECENT AVALANCHES: YES* (NO)

WATER IN SMALL STREAMS IS: RUNNING (FROZEN) PARTIALLY FROZEN CLEAR MUDDY BRIDGED BY SNOW

***REMARKS:** ENTIRE SNOW COURSE BULK SAMPLED.

Example 3: Data recording example for an 8-point survey bulk sampled.

SENSOR CONTROL

MANOMETER READINGS UNITS: INCHES (CM)

SNOW: 1.1

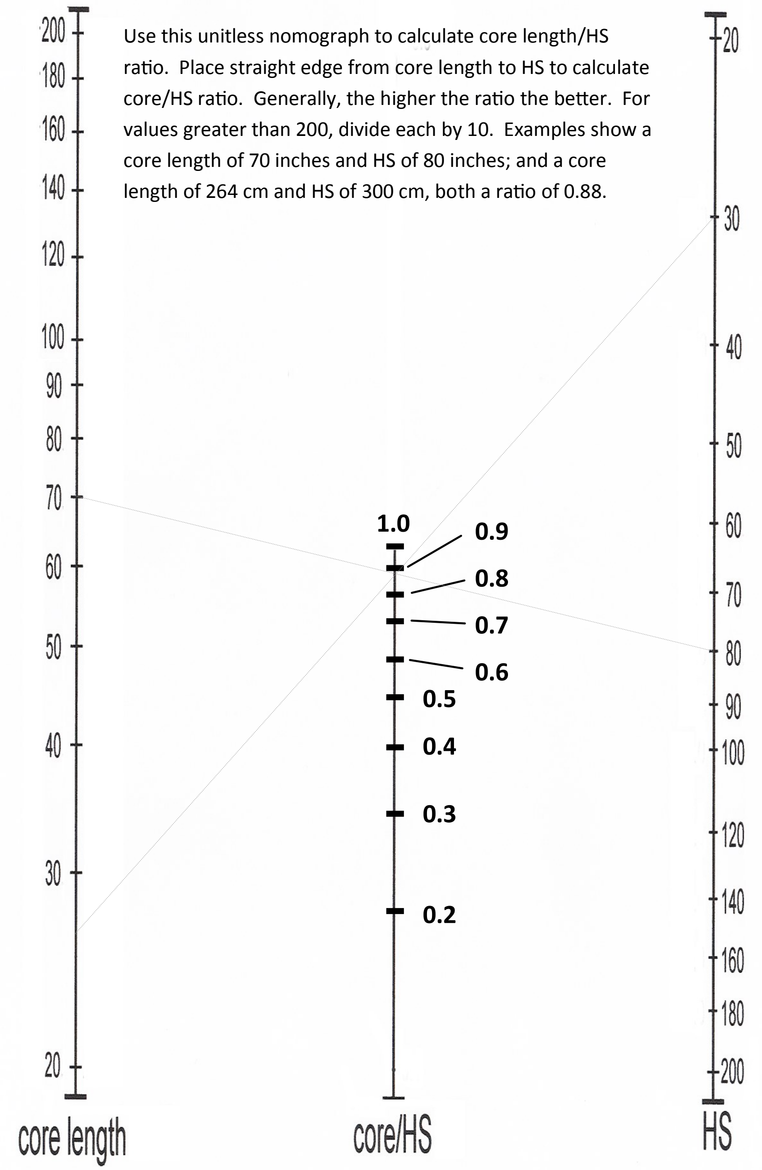
PRECIPT: 8.3

AIR TEMPERATURE UNITS: °F (°C)

CURRENT: -6.0

MAXIMUM: -2.2

MINIMUM: -21.0



Use this unitless nomograph to calculate core length/HS ratio. Place straight edge from core length to HS to calculate core/HS ratio. Generally, the higher the ratio the better. For values greater than 200, divide each by 10. Examples show a core length of 70 inches and HS of 80 inches; and a core length of 264 cm and HS of 300 cm, both a ratio of 0.88.
200
180
160
140
120
100
90
80
70
60
50
40
30
20
core length
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
core/HS
20
30
40
50
60
70
80
90
100
120
140
160
180
200
HS

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