The April 2008 Snettisham Avalanche Cycles

Prepared 200805012
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Introduction

The need for immediate response to the April 2008 avalanche damage to the Snettisham power line has had the Alaska Avalanche Specialists team working long hours to take care of urgent operational needs. We have not had much time to write, but here is a quick snapshot of avalanche program status and preliminary studies, current as of May 12.

Weather and Avalanche History

The winter of 2007-08 in most of northern Southeast Alaska was characterized by heavy snowfall in the mountains. Temperatures were cool, with a notable lack of major mid-winter thaws. Juneau temperatures stayed below 6°C (43°F). Almost no thaws reached above 600 m (2,000'), though rain and snow alternated as they commonly do at sea level in Juneau.

Precipitation came in unusually small increments this winter. Most storms brought less than 1.0 cm (0.4") of water equivalent precipitation to the Juneau airport and only one storm all winter brought 3.0 cm (1.2"), until the mid-April storm that triggered the avalanche cycles.

The mountain snowpacks were dry this winter and the snow was low density, settled to the 200 Kg/m^3 range. The usual thawed and refrozen layers were largely and notably absent above 600m (2,000').

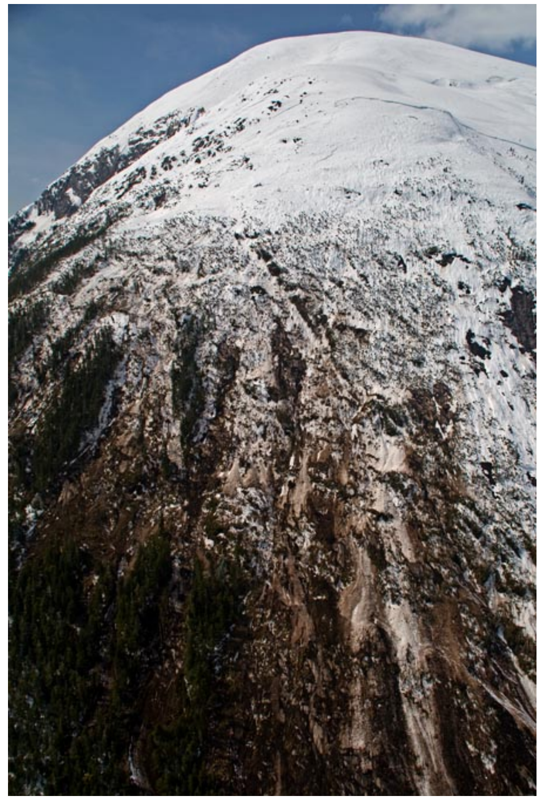
The first slides in the series that damaged the Snettisham power line at about 3am on April 16 were rain-triggered glide avalanches releasing the full snowpack depth of two to four meters where it lay over areas of smooth gneiss

Bride Peak
Crater Peak
East Crater Bowl
Speel Shoulder
The Balcony
Speel Arm
3/4
3/5
4/1
4/2
4/3
4/4
4/5
4/6
5/1

bedrock. Glide cracks had formed throughout the region this year as thick snowpack slid downslope wherever the ground surface did not hold it in place. The glide avalanches came as heavy rain reached the 300 m (1,000’) elevation, weakening the bonds between snowpack and ground as water dripped to ground level through the open cracks, and damaged tower 4/6, causing the initial break in the line.

Shortly after the glide avalanche cycle began, the snow level rose further, bringing the first rain to previously-dry snow at 600 m (2,000’) elevations and triggering a series of moderate-sized 1.0 to 1.5 m (3 to 5’) thick dry slab avalanches from the lower to mid-elevation slopes.

These first two cycles caused the damage to the power line in the transmission structure 4/6 area



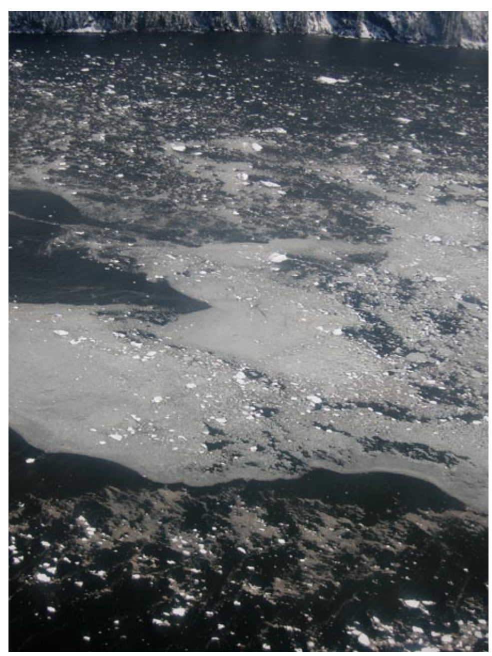
At right, glide avalanche releases from the first avalanche cycle are visible as dark bare dirt and rock patches among the dirty snow streaks on the lower slopes of Speel Shoulder.

The line of a rain-triggered slab avalanche crown face at mid-elevation from the second avalanche cycle is visible higher, midway up the clean snow on the crest of Speel Shoulder.

Below, the lines of crown faces from rain-triggered low and mid-elevation slabs from the second avalanche cycle cross the slopes below The Balcony.

below Speel Shoulder and to transmission structure 3/5 in East Crater Bowl.

As the storm progressed, heavy snowfall and wind-transported snow rapidly loaded slopes above 600m (2,000') and triggered a major region-wide slab avalanche cycle that did the final damage. These were big avalanches, averaging 2.5 m (8') thick, and often 2 to 4 Km (1.2 to 2.5 mi.) wide.



These large, fast-moving dry snow avalanches encountered and entrained large volumes of wet snow as they reached lower elevations. Because this snow had for the most part been dry until this storm, it had few refrozen layers to give it strength.

The longest runout distances recorded in northern Southeast Alaska have been produced by fast-moving dry slab avalanches encountering rotten wet snow low in their tracks. This cycle was no exception. It tore out the remaining transmission structures in East Crater Bowl and one adjacent transmission structure outside the avalanche zone as the lines went down, and filled Speel Arm with avalanche debris. Overall, the avalanche cycle destroyed a total of 4.5 Km (2.8 miles) of power line.

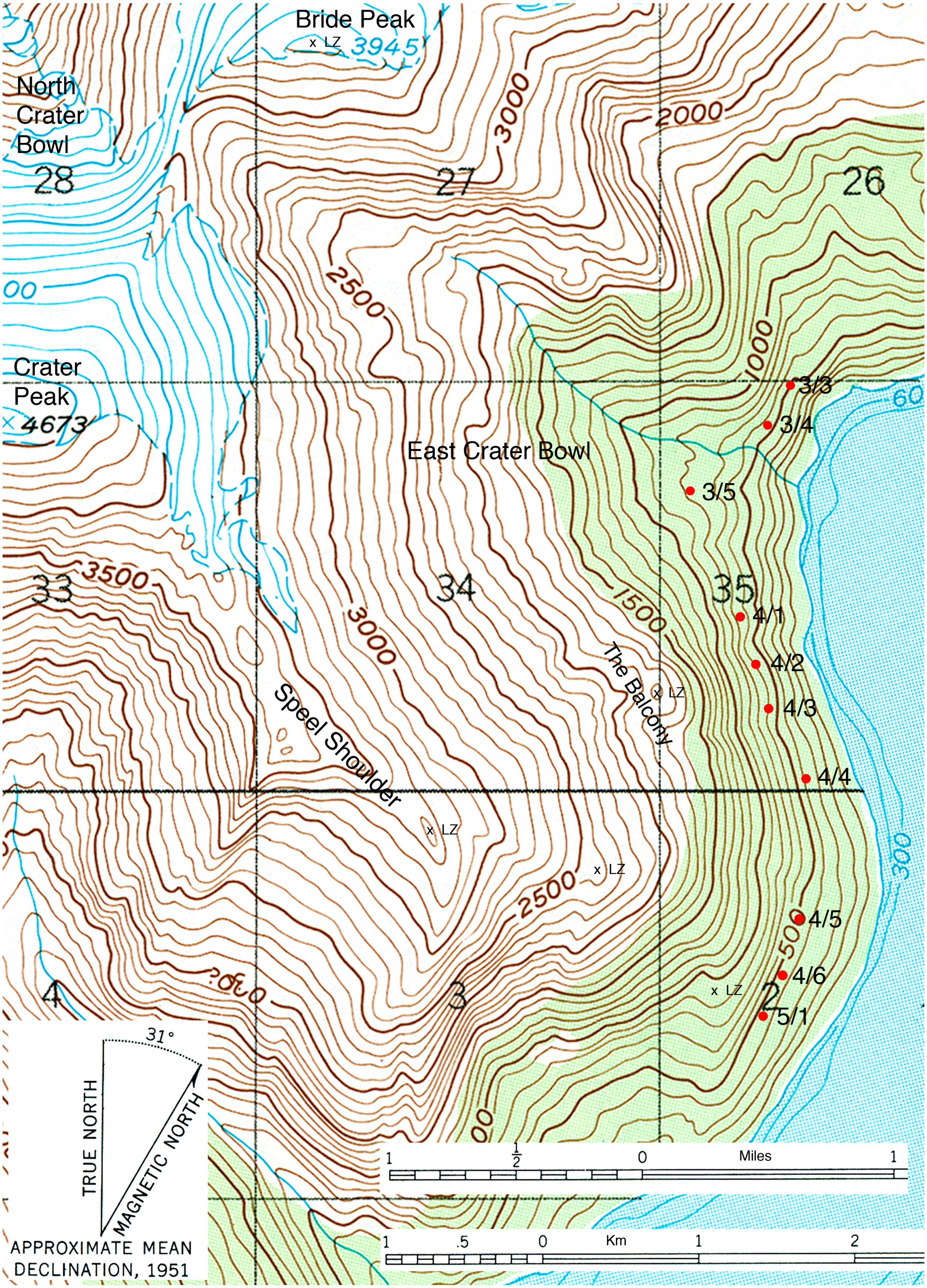
The weak layers undoubtedly varied throughout the region, but when we profiled the 2.6 m deep East Crater Bowl fracture at right, we found buried surface hoar on the bed surface of the large Snettisham slide on East Crater Bowl.

Surface hoar is the sparkly stuff that forms on the snow surface during clear nights or cold days. Once buried, it is the most common weak layer involved in widespread and large scale instability. It is likely that sugary near-surface faceted grains formed during the same clear period before the storm were also involved.

The East Crater Bowl slide initiated on slopes in the classic 35-50° slope angle range, but propagated 3 Km (2 miles) wide into areas as shallow as 25°. Fractures pulling out into unusually low-angle slopes were common throughout the region in this cycle.

The precipitation at the Juneau airport in the six days leading up to the large avalanche cycle was heavier than it had been most of the winter, yet it was still much lighter than that at Snettisham. Airport precipitation totaled 4.8 cm (1.89”) or 0.80 cm (0.31”), reaching a maximum of 1.5 cm (0.59”) water equivalent per day.

Snettisham lived up to its reputation as a zone of big snow and rainfall. Sea level totals for the same period there were almost five times as heavy at 22.9 cm (9.0”) or 3.81 cm (1.5 “ per day) and reaching a maximum of 6.35 cm (2.50”) per day. Given weak layers in the snowpack, this heavy rate of loading is a virtual guarantee of a large avalanche cycle.



Bride Peak
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East Crater Bowl
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Speel Shoulder
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MAGNETIC NORTH
APPROXIMATE MEAN
DECLINATION, 1951
1
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2

Size

Avalanche Size Classification

There are two systems used for avalanche size classification in the US, one based on sizing relative to path capability, and one based on destructive potential regardless of path size. We use both to classify the size of a slide.

Relative Size Classification

R1 (small) to R5 (large), based on path capability

Destructive Size Classification

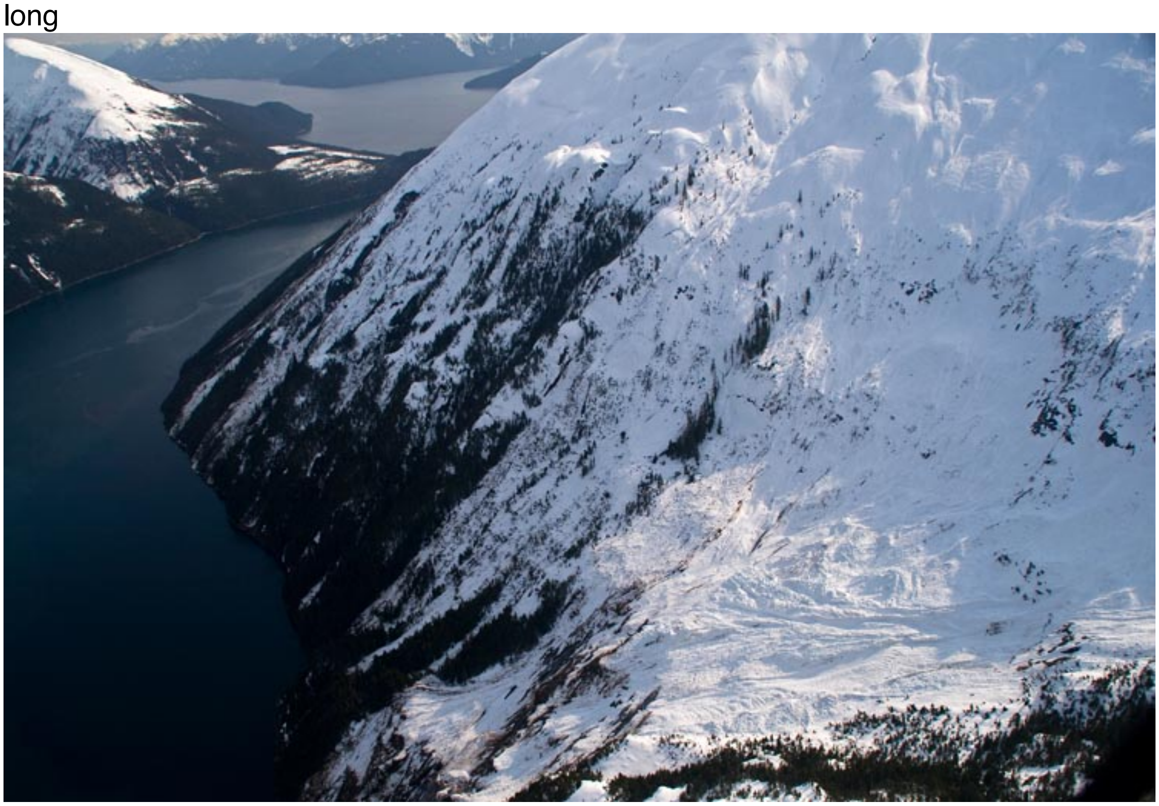
D1 relatively harmless to people; <10 tons; ~10 m long

D2 could bury, injure, or kill a person; ~10^2 tons; ~100 m long

D3 could bury & destroy a car, damage a truck, destroy a wood frame house, or break a few trees; ~10^3 tons; ~1,000 m long

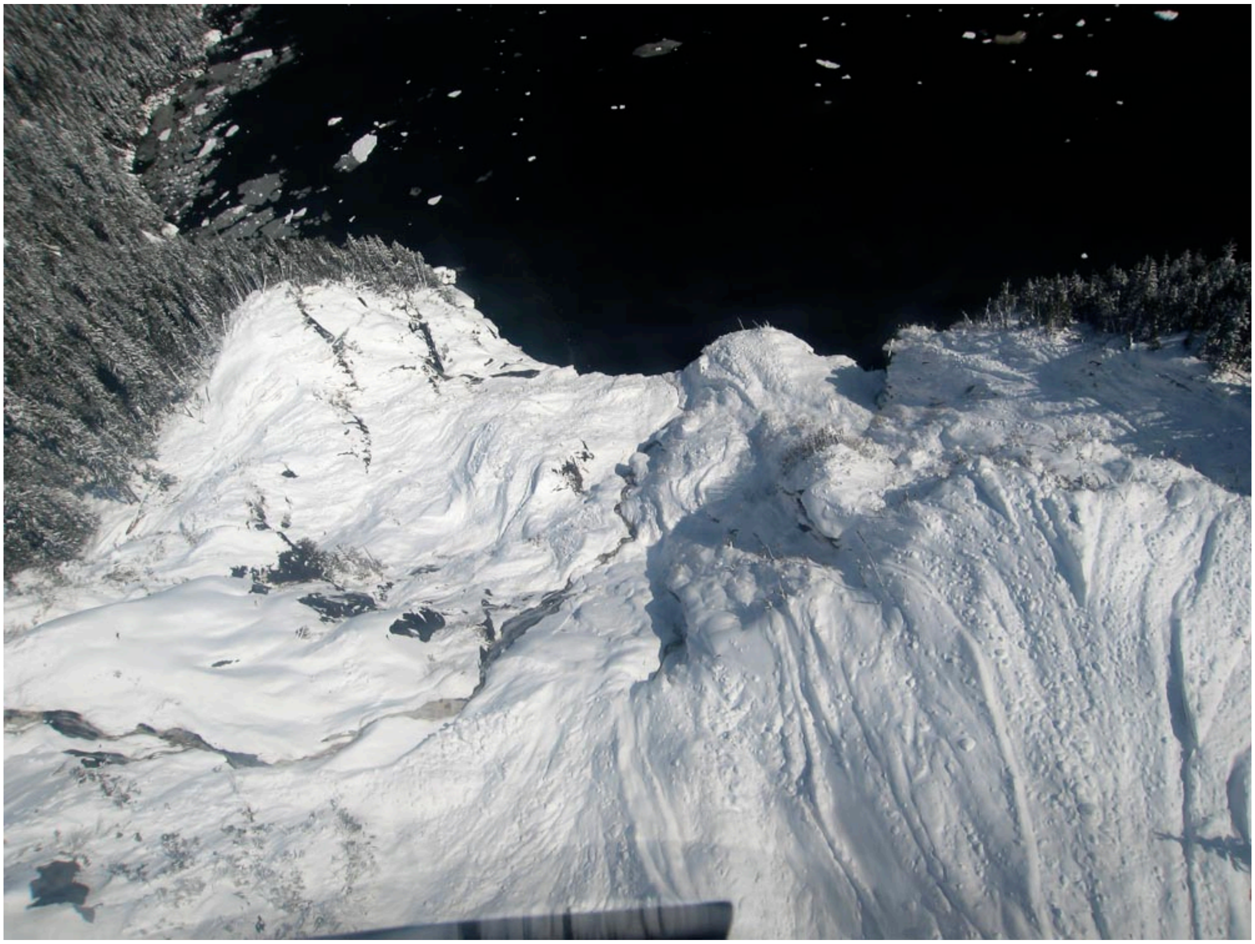
D4 could destroy a railway car, large truck, several buildings, or a substantial amount of forest; ~10^4 tons; ~2,000 m long

D5 could gouge the landscape, largest snow avalanches known; ~10^5 tons; ~3,000 m long



Snettisham Avalanche Sizes

In total, the avalanches in the Speel Shoulder area enlarged the paths, thus they are R5s, and they took out substantial amounts of forest while gouging the landscape and running in the 3,000m length range, with volumes in the 10^5 ton range, so they were D5s as well.



The avalanches in the East Crater Bowl ran in a larger and more frequent path, but they were still at full path capability, placing them collectively in the R5 classification. Their impressive volume, length, and landscape-gouging performance also place them solidly in the D5 range.

Frequency

Return Intervals

Avalanches are also classified by their frequency, or return interval. This is a measure of how often avalanches occur at a given location, averaged over long term time. Return intervals are often misunderstood. The common misunderstanding is that we are ”overdue for” if a slide has not occurred during the expected return period, or conversely that we have a free ride and can expect no slides for the rest of a return period after one slide has occurred.

Return intervals don’t work that way. We have such examples as 30 year avalanches occurring in three consecutive years. All the 30 year return interval means is that the frequency will work out to 30 years if we average over a long enough time. There is no guarantee for the short term.

Avalanche frequencies are calculated in rough order of magnitude increments. We break them into events that occur several times a year, once yearly, every three years, every ten years, every 30 years, every 100 years, and every 300 years. More-detailed scales are really not valid, given the limited time span and other limitations of the available data.

History

Our historical investigation is still incomplete, but we have made a good start. The line was built and run for many years by the federal government, so records are not at our fingertips today, but these are the currently known avalanche events affecting the Snettisham line, from a list put together by Scott Willis of AEL&P:

April 7, 1976 – An Alaska Power Authority (APA) letter dated April 12, 1976 notes *"Power was interrupted April 7, 1976, when a snowslide sheared a free-standing aluminum tower about 5 miles from the Speel River Powerhouse installation."* This appears to be tower 4/6. APA set a replacement or repaired tower on the existing foundation later that month.

April 1979 – APA annual report notes "Inspection of avalanche area by Barry Wright, BPA consultant". This appears to be in response to the 1976 avalanche damage. We are working with the federal librarians to get a copy of this report.

July 1981 – Transmission structure 4/5 was raised and snow legs were added by the APA. Transmission structure 4/6 was relocated 95m (313 feet) ahead and snow legs were added. Transmission structure 4/7 was removed. Work began in August 1981 and was completed in July 1982. This also appears to be in response to the 1976 damage.

January 25, 1989 , 7:28 a.m. Minor damage to Transmission structure 3/5.

A report by the Alaska Power Administration describes this January 25, 1989 slide:

"The tower was moved off its base by an avalanche at approximately 0728, January 25, 1989. The tower lies just southerly of the main avalanche path. A small spur split off from the main path carrying a medium size tree and hooked through the bases of the three structures. B phase [wire conductor] was moved from its base and the tower tilted downhill into the top of the C phase structure. No significant damage to the structures could be observed from the wind blown helicopter. The lower end of the displaced structure was buried in about 10 to 12 feet of snow. The bases of the other two structures was visible just below the start of the taper. No upper structure damages were noted, but some insulator damage is almost certain. All guys appeared intact but the number 2 B phase was very slack."

Gunnar Noreen was hired to do the avalanche control work to make the site safe. Crews were digging at the transmission structure base by 1/27. They noted that the primary damage to the center phase was due to a medium sized tree that had struck the base of the center tower. Crews just removed the damaged base, set the tower on the snow, and tied it off to the other two towers. They were able to reenergize the line on January 31. Final repairs took place on February 17 and 18.

Photo strip captions:

23. Closer view showing the small avalanche trail and the tree that impacted the base of the tower 3/5 B phase.

24. Another view showing the displaced tower base moved slightly down hill and up line. The trail of debris shows that very little energy remained in this avalanche as it passed through the base of the towers.

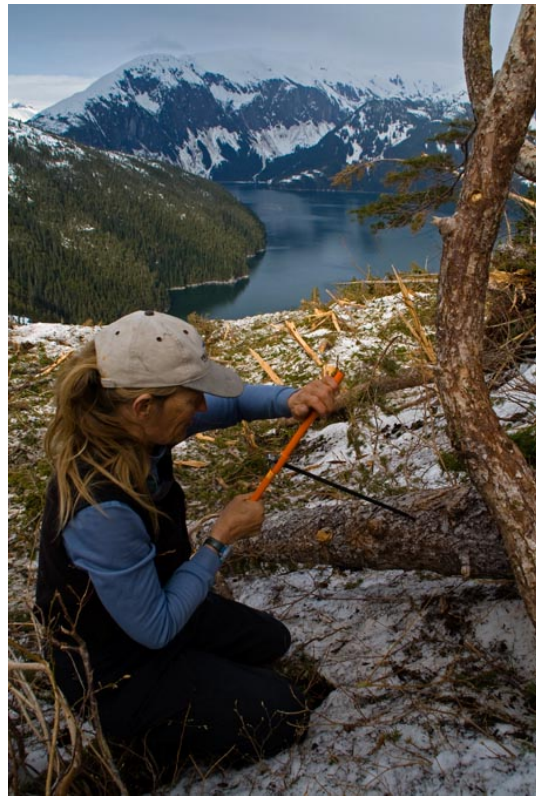
22. View of 3/5 tower site and small spur avalanche that carried a tree into the base of the B phase tower.

The Snettisham project was designed in the 1960s and began operations in 1972, 35 years ago. It appears that there have been three instances of avalanche damage serious enough to appear in the Alaska Power Authority records.

That is one event per 11.67 years. In round figures, that means that ten year avalanches affect the line as originally built, and the most recent avalanche cycle shows that the vulnerability may have been reduced with repairs and relocations, but it is not yet eliminated.

Snettisham Avalanche Frequencies

The Snettisham line goes through severe avalanche terrain. The Corps of Engineers located it quite well given the state of the art in the 1960s when it was designed, but from an avalanche standpoint several transmission structures are not located optimally and the line remains vulnerable to avalanche damage. Other technologies like splitting wedges, diversion berms, reinforced transmission structures, avalanche-specific transmission structure and conductor design, and active avalanche release were known at the time, but were not in common use on power lines in North America then.



There are areas on the line where smaller yearly avalanches may do minor damage and ten and thirty year avalanches have damaged or destroyed unprotected transmission structures, as demonstrated by historical records and tree ring analyses. The April 2008 avalanches were much larger, on the order of 100 year events.

Historical airphoto study and vegetation analysis are still incomplete, but we used an increment bore as shown in the photo to core and a and chain saw to section enough downed and damaged trees in the Speel Shoulder and East Crater Bowl areas to yield preliminary frequency data.

Final tree ring counts await drying and polishing the samples, but we were able to make estimates from the raw cores and sections.

Our provisional sample in newly cleared low-frequency portions of the Speel Shoulder area yields tree ages ranging from 108 to 418 years, averaging 218 years old.

In higher-frequency areas of the Speel Shoulder, the range is from 20 to 21 years, averaging 21 years.

In the East Crater Bowl area, the age range is from 63 years for a tree that was previously broken in a higher-frequency area and continued growing, up to 177 years in lower-frequency areas. The average for the lower-frequency areas within East Crater Bowl was 152 years.

Some of these trees we cored sustained obvious avalanche damage and continued growing, so their age does not translate directly into avalanche frequency. Time to reforest a slope and resistance to avalanche damage also limit the precision of dendrochronology as a dating tool for avalanches.

The older trees are representative of the greatest extent of damage rather than the average. Thus 100 years is the best estimate for the frequency of the 2008 cycles over the entire slide area, but some sub-areas are clearly subject to damage from 30 year and 10 year or lower cycles.

Avalanche defenses are not usually designed to withstand large, long return interval events. Definitive answers will have to await avalanche dynamics modeling and impact force calculations, but our preliminary analysis suggests strongly that conventional avalanche defenses would have been inadequate to protect against these very large 100 year plus slides.

Snettisham Reconstruction Avalanche Program

Mobilization

Our immediate concern has been to serve the needs of the crew of linemen working to rebuild the lines so they can restore power as rapidly as possible. To that end, we had fieldworkers onsite immediately after the avalanches and working through the first weather break to assess the situation. We began avalanche blasting two days later.

Within six days, as repair crews were mobilized, we participated in meetings to evaluate the full spectrum of interim and long-term repair alternatives. A line with avalanche defenses is obviously preferable to one without and AEL&P is considering a number of alternatives for longterm avalanche protection, but all redesigned alternatives would take years rather than months to complete. Rebuilding the existing line was the only practical option to restore power in a reasonable time.

Nine days after the slides, we were training crews and setting up the avalanche program as the crews were assembling and staging their field offices, tools, and supplies at the Snettisham powerplant camp.

Avalanche Program

Alaska Avalanche Specialists has assembled a working team of four avalanche forecasters and three field assistants. Two avalanche specialists, including at least one forecaster, are in the field every day and a third is on town rotation. The in-town rotation includes time off and time to tend field notes, photos,and reports. One full time and one part time administrative staffer in town run our logistical and administrative support.

We have drawn on the top avalanche workers in the country for staff. All our forecasters are American Avalanche Association professional members, and all have field experience in the 20-year range. Our forecasters are senior journeymen in the field, among those who train aspiring avalanche professionals.

We have given all the linemen and other field workers on the job a minimum four-hour project-specific avalanche training, including two hours of avalanche rescue practice in the field.

Avalanche gear including beacons or RECCO belts, probes, shovels, and emergency medical kits is required for any work in the avalanche zones. A rescue plan and cache including RECCO detectors, beacons, shovels, probes, and the camp's emergency medical supplies is in place.

We have full avalanche blasting capability, as well as all other avalanche mitigation technologies, and all related permitting requirements are met. We have delivered about 900 Kilos (2,000 lbs) of explosives to date and expect to deliver an additional 700 Kilos (1500 lbs) through the end of the avalanche season.

We are fortunate to be working with a skilled, hard-working, well-educated, and highly motivated repair crew on this job. To maximize efficiency and minimize risk, we work closely with the crew

to produce avalanche evaluations and risk management plans tailored to the work requirements as they evolve every day. We are onsite or on call close by, monitoring the radio and changing conditions every moment that our crew is in the field.

Longterm Snettisham Avalanche Program

What we Inherited

It is important to recognize that the standards for avalanche design in the U.S. are set by practice, an accepted standard of care, not by statute. In the sixties, when the Snettisham project was designed and built by the federal government, that standard of care was lower than it is today. We as a community inherited the line's avalanche vulnerability from a previous generation.

At the time the line was built, diesel fuel was cheap. With adequate alternate generating capacity, hydroelectric outages were not a major concern. Given the severe avalanche terrain, the Corps of Engineers designers located the transmission structures quite well. Splitting wedges would have been a good idea, but they were just starting to be used in North America then, and the economics of the time would not have strongly favored their use.

Upgrading

Final answers will have to await the results of engineering and design studies we are now just beginning, but is probable that a combination of structural and active operational avalanche mitigation can protect the line well against 30 year and moderately well against up to 100 year events. This level of protection is consistent with design standards for other common sources of power line failure.

Alternatives are already being evaluated for an initial program that would protect the line until construction of a replacement avalanche-toughened line is complete. Simple diversion structures and an active avalanche forecasting and release program are among the low cost measures that could be used to reduce avalanche vulnerability in the short term.

Long-term options are also already being evaluated. Alaska Avalanche Specialists is obtaining advanced Swiss-developed avalanche modeling and design capabilities that no one else in North America has yet. We collaborate internationally with the most experienced avalanche engineers in the world, who have designed power lines and diversion structures like those above in Iceland.

AEL&P is already working with top power line design engineers on reconstruction and redesign. The process of analysis, evaluation, design, and remote-site construction in difficult field conditions will require years rather than months.

The option of an avalanche-toughened aerial line with modern avalanche mitigation features can be compared with such alternatives as rerouting to avoid avalanche areas, using submarine cable, or going underground. Common modern avalanche mitigation measures include artificial release, splitting wedges, diversion berms, impact-engineered transmission structure, widely spaced conductors, long spans across threatened areas, starting zone support structures such as snow bridges or nets, and remote controlled exploders.

Above left, snow bridge starting zone support structures in Davos, Switzerland. Above right, Gaz-Ex propane-oxygen remote controlled exploder, Teton Pass, Wyoming.

Transmission structure Status and Avalanche Threat Level, 20080512

This section is included as a more-technical current sample of detailed status description for each transmission structure. Metric units are used here without calculating their imperial equivalents and the language is left in technical form.

The descriptions that follow were accurate on May 12, 2008. Abundant rainfall, sustained warm weather with non-freezing nights, or abundant snowfall can change the avalanche threat level to the transmission structures in a matter of hours to days. Continuous field monitoring and explosive testing and avalanche hazard reduction will be ongoing, until the snowpack has made the transition to a summer snowpack. Please see the glossary for definitions.

Tower 3/4

WORK STATUS: Work continues on anchors and tower construction (in the yard). Old tower wreckage has been removed. Continued access is needed.

AVALANCHE THREAT: Minimal. There are some small glide cracks in the right of way on the Snettisham side on terrain convexities. Directly below the tower site there is some steep rocky terrain with glide activity, but this is out of the work zone. Rock outcrops above the worksite have shed most of their snow and do not offer significant hazard.

ACCESS: Unrestricted.

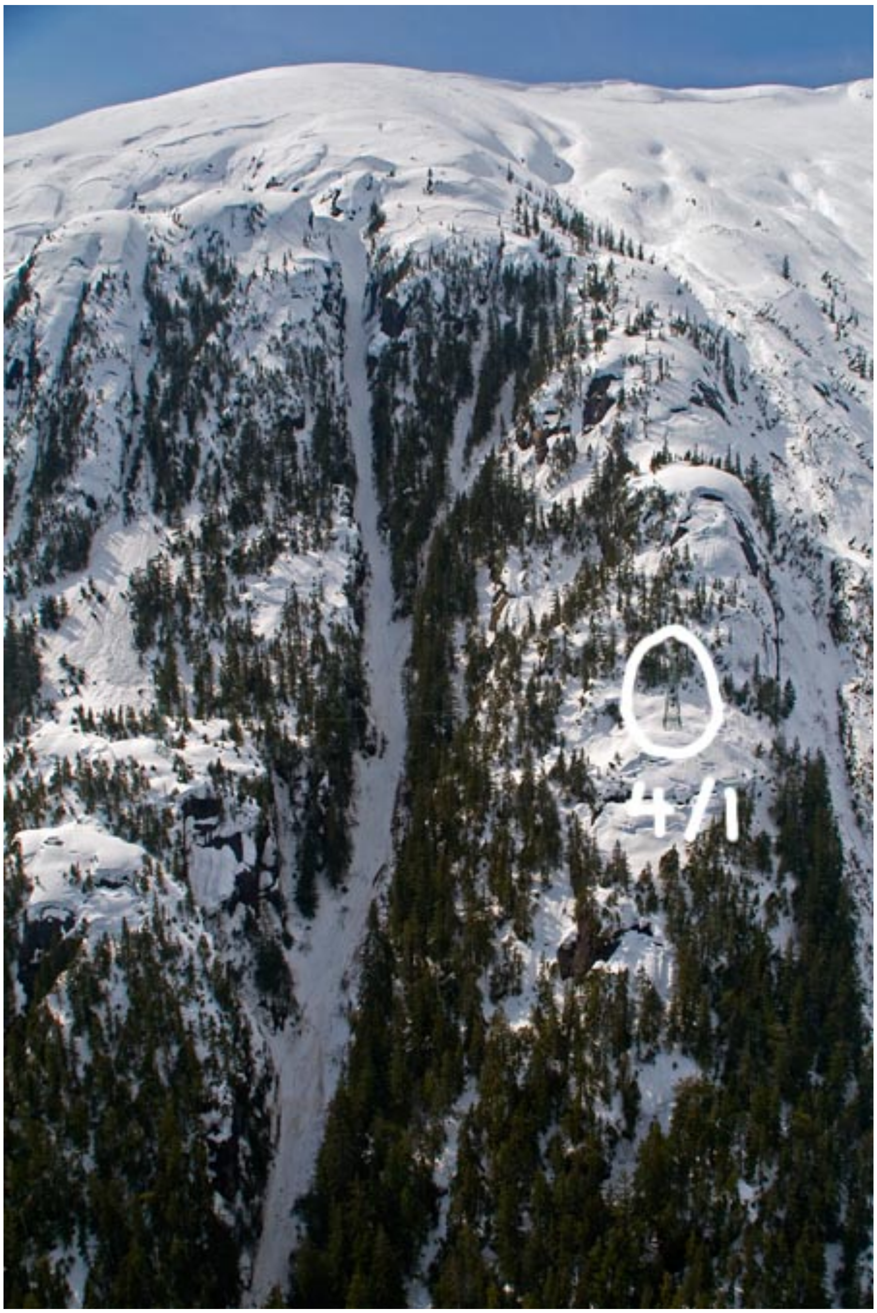
Tower 3/5

WORK STATUS: The three towers and guy supports have been destroyed. Anchor points for towers (three) and guys (twelve) were surveyed and avalanche debris covers all but two anchor points. Snow depths over the anchors vary from 1.3 meters to 4.6 meters. The debris contains high density snow, ice, and many broken trees. It will take time to excavate the tower foundations and guy anchor points. Some guy anchor points may need to be relocated or reinforced.

AVALANCHE THREAT: Limited. The large bowl that extends 2500' above the tower site still has a lot of thawing snow in it (>4-5 meters in most areas). The south side of the bowl (facing ENE to NE) is comparatively low angle down to 2200' and then steepens to the mid 30's. Ski cutting of wet loose slides involved significant volumes of snow, but these slides stopped well short of the work site (~700 vertical feet above). Without copious rainfall, or snow loading over a very slick weak layer, this site will likely not be hit again this season.

ACCESS: Currently no restrictions. High intensity rainfall could change the status. We will continue to ski cut the surface layers on warm days, so that there is less snow on the higher angle slopes.

Tower 4/1

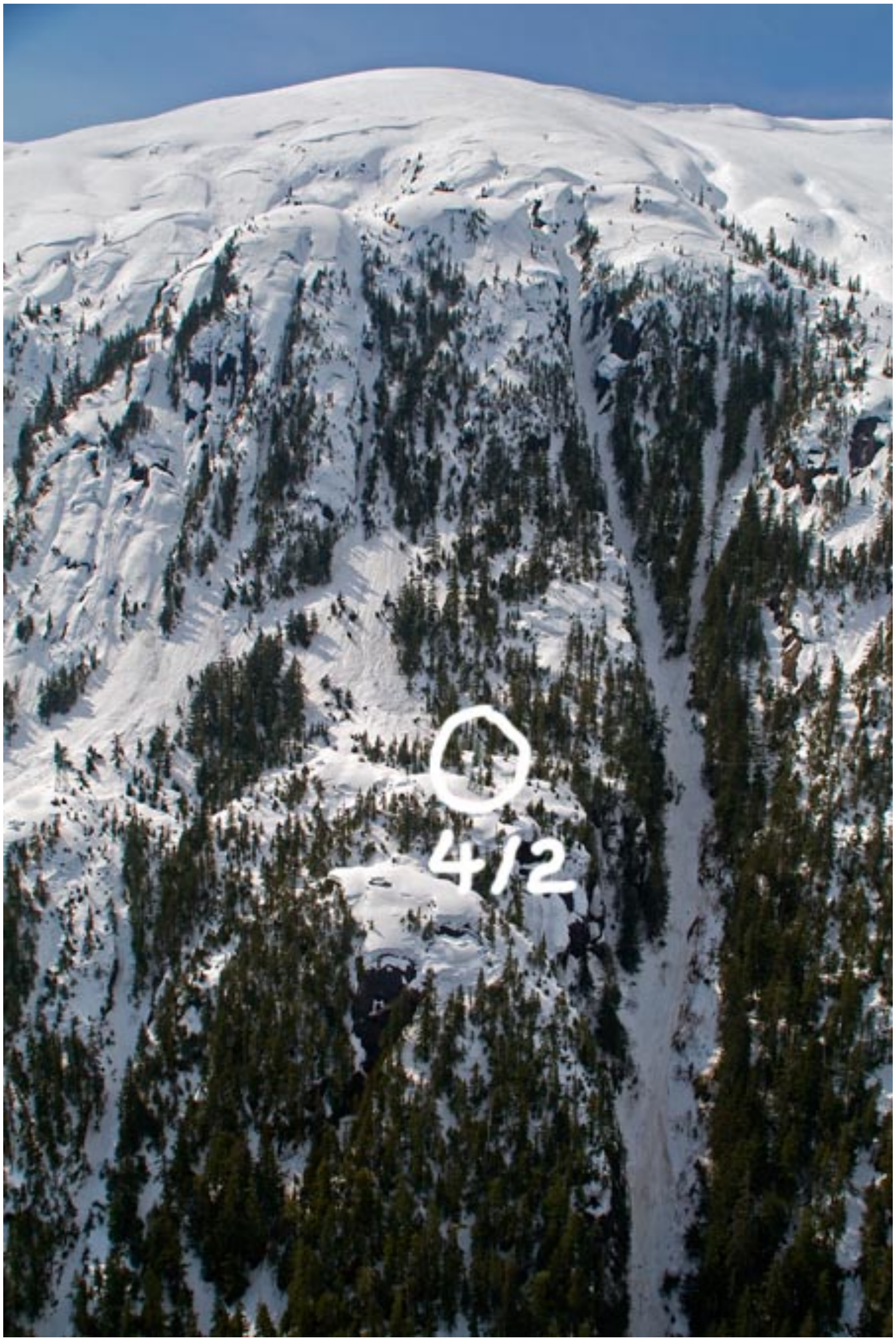


WORK STATUS: Tower intact. Bells and travelers need to be hung.

AVALANCHE THREAT: Minimal. There is some bottom supported glide debris 50 vertical feet above the tower with a band of trees in between. There is no exposed LZ pad at this site, so the current LZ is a snow pad that is in the path of surface slides and glide debris (not too much) from 150’ above.

ACCESS: Currently no restrictions. We will continue to target the glide slab that threatens this site, but the threat is small and there are safe zones on the Juneau side of the tower.

Tower 4/2



WORK STATUS: Tower intact. Bells and travelers need to be hung.

AVALANCHE THREAT: Minimal. The tower site is in a good location. There is a berm and a band of trees to deflect and catch avalanche debris from above. 100 yards to the Juneau side of the tower, at the end of the trees, workers will be more exposed in this area to surface slides and glide avalanches.

ACCESS: Unrestricted. Workers need to stay within 100 yards of the tower to avoid avalanche threats from above.

Tower 4/3

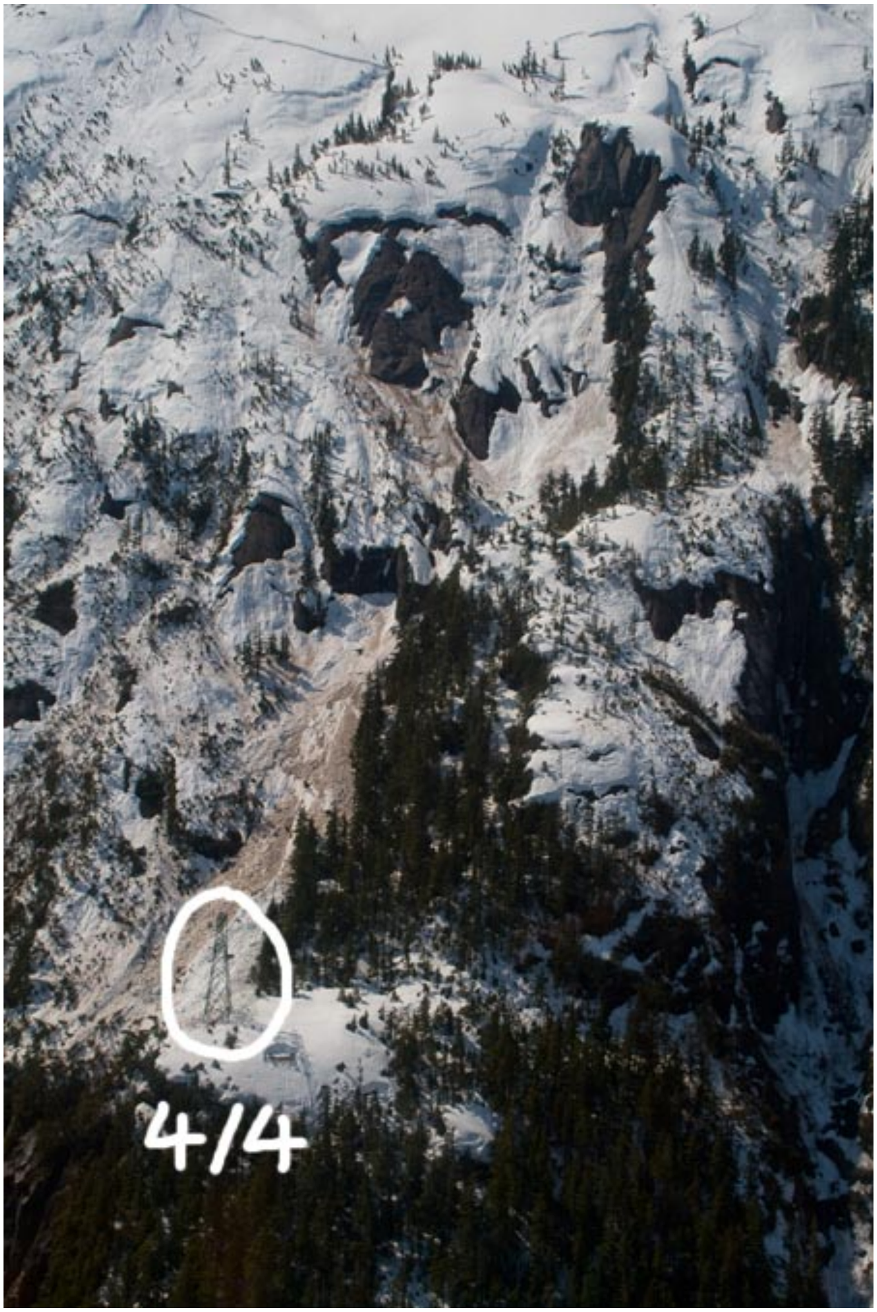
WORK STATUS: Bells and travelers need to be hung.

AVALANCHE THREAT: Severe. This tower is exposed to several slide paths with significant hanging glide slabs. Debris has fanned on all sides of the tower from avalanches as recent as May 6.

ACCESS: OFF LIMITS, until the rocks have shed most of the glide avalanche hazard. This area will be high priority for further avalanche control missions.


4/3

Tower 4/4



WORK STATUS: Bells and travelers need to be hung.

AVALANCHE THREAT: Severe. This tower has avalanche debris that extends from the gully to the south (Juneau side) to the north legs (Snett side). There is significant glide slab hazard on the rocks above the site. This site is also still exposed to avalanches from above 2200’ where start zones >35º exist. Currently these upper slopes are stable other than surface slides that are easily ski cut.

ACCESS: Conditional. Currently, the only restrictions are to stay off the avalanche debris under the tower and to the south, except to access the tower for climbing.

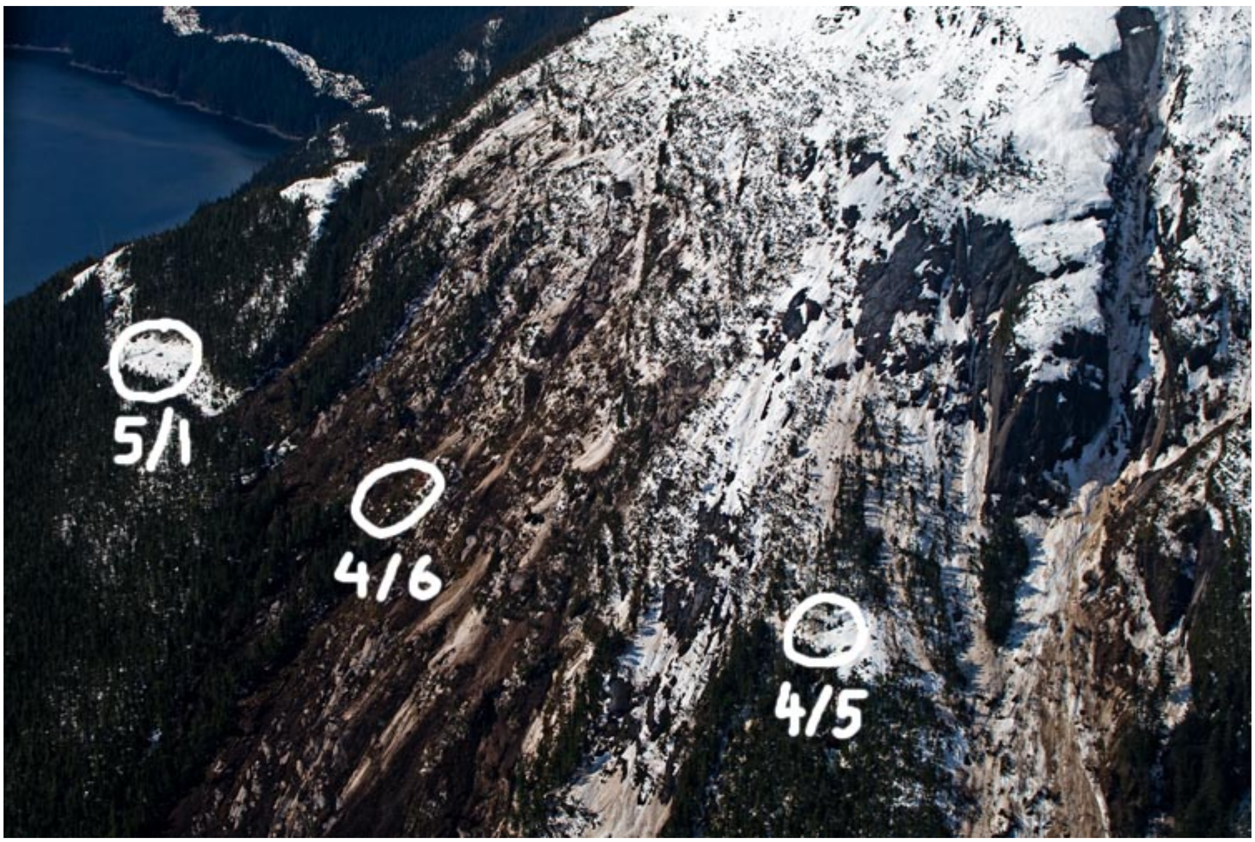
Tower 4/5

WORK STATUS: A few broken struts, swing arm has been replaced, bells and travelers need to be hung.

AVALANCHE THREAT: Minimal. This tower has avalanche debris underneath it. All of the lower start zones over the rock slabs have cleared out. There is a low chance that wet loose surface slides could make it through the trees, but that is a very remote possibility. The upper start zone that threatens 4/4 and 4/6 could also hit this area, so if there is a potential for large deep releases in the upper start zone, then access to this site would be rescinded.

ACCESS: Currently, no restrictions. Best safe zone is to the Snettisham side of the tower toward the landing pad.

Tower 4/6



WORK STATUS: Destroyed tower. Foundations intact.

AVALANCHE THREAT: Minimal. This site is still exposed to avalanches from above 2200’ where start zones >35° exist. Currently these upper slopes are stable other than surface slides that are easily ski cut. These wet loose slides have been stopping before they made the transition to the steeper terrain above the tower.

ACCESS: Currently, no restrictions. It should be noted that abundant rainfall could expose this site to small mud slides and rolling trees from above. If deep slab stability decreases significantly above 2200’, access to towers 4/4, 4/5, and 4/6 will be suspended, pending avalanche control and/or more favorable weather conditions.

Tower 5/1

WORK STATUS: Wires snubbed. No further work needed until wires are strung.

AVALANCHE THREAT: None.

ACCESS: Unrestricted.

GLOSSARY

NUMBERING - The power line transmission structures, or towers, are numbered by miles, starting at the powerplant and moving forward toward Juneau. Within each mile, each tower is numbered consecutively, thus 4/3 is the third tower from the Snettisham side in the fourth mile of the line.

PHASE - Each of the three big conductor wires is called a phase. They may be designated A, B, and C or simply in our case “ocean, center, and mountain” phases.

SUMMER SNOWPACK - A snowpack that has gone through enough melt-freeze cycles and melting to develop a good structure to drain excess liquid water from melting or additional rain. Grain sizes are large and homogenous, very little layering exists within the snowpack.

This snowpack will either melt off entirely through the summer, or continue to densify and become nevé, the transition between seasonal snow and permanent snow and ice. Generally, a summer snowpack presents little avalanche hazard, other than limited surface sluffing and new snowfalls releasing at the summer snow interface with the new snow.

SURFACE SLUFFING - Sluffing occurs when non-cohesive grains of snow no longer can hold on the slope angle that they rest upon. Sluffing can occur in dry and wet snow to varying depths. Wet snow sluffs (abbreviated as WL) can occur with the natural introduction of more liquid water to the snow surface, either from melting or rain.

Typical artificial triggers of sluffs are skiers cutting across a slope, linemen hiking up a slope, or gear being tossed onto wet loose surface snow of sufficiently high angle (typically >30º). Common natural triggers include sustained sunshine or warm temperatures, even under cloud cover, and rain.

Wet loose slides or sluffs typically move slowly and only below the trigger point, but are very dense and hard to escape once caught.

GLIDE AVALANCHE - Typically glide cracks develop in sharp breaks in slope angle (convexities) and over smooth surfaces such as glacially polished rock or tundra, or over wet soil. The snowpack moves as a cohesive unit on the smooth surface, until the downslope movement exceeds the friction at the bed surface. Rain events and very warm days accentuate glide failure, but glide avalanche release is notoriously hard to predict and control.