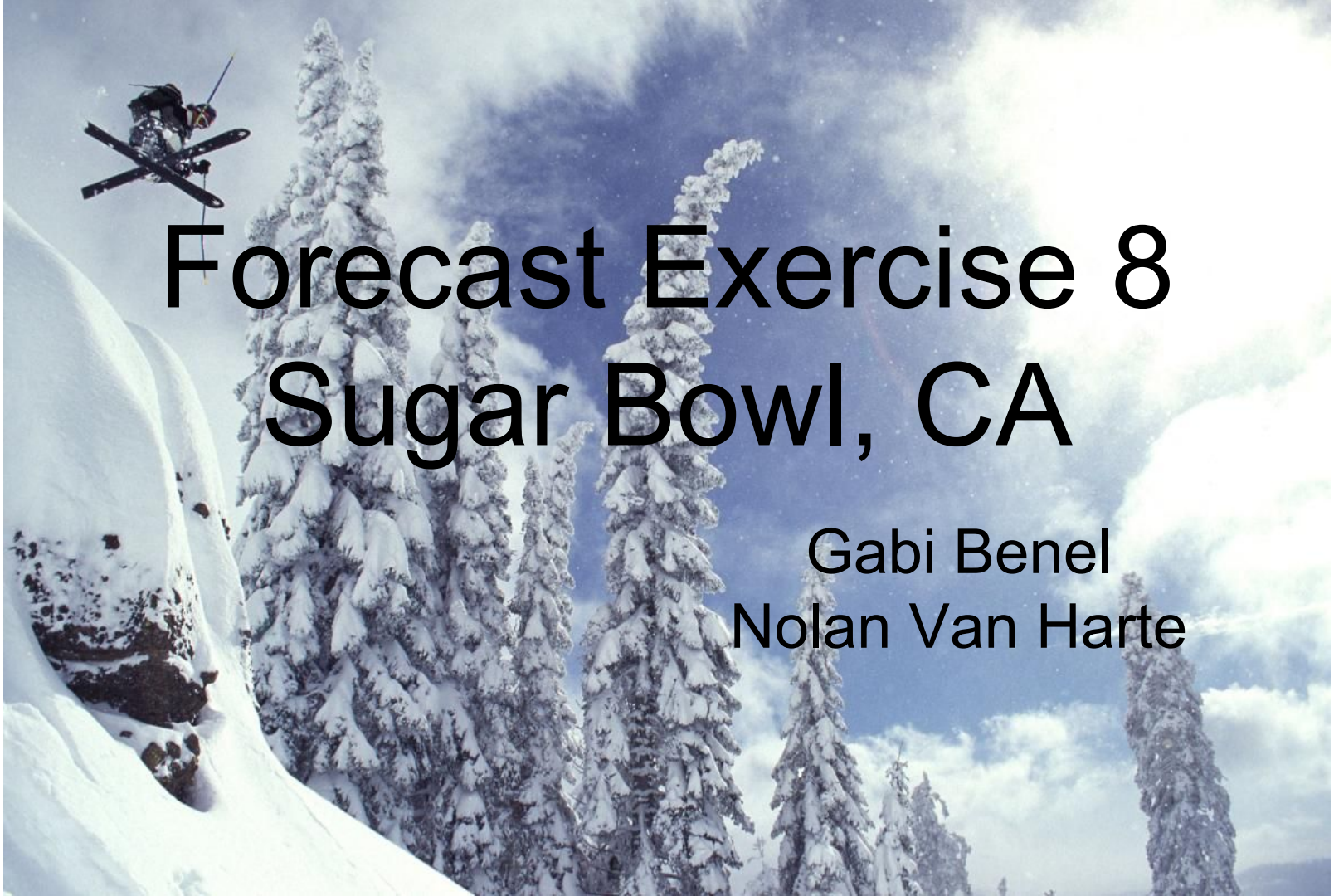
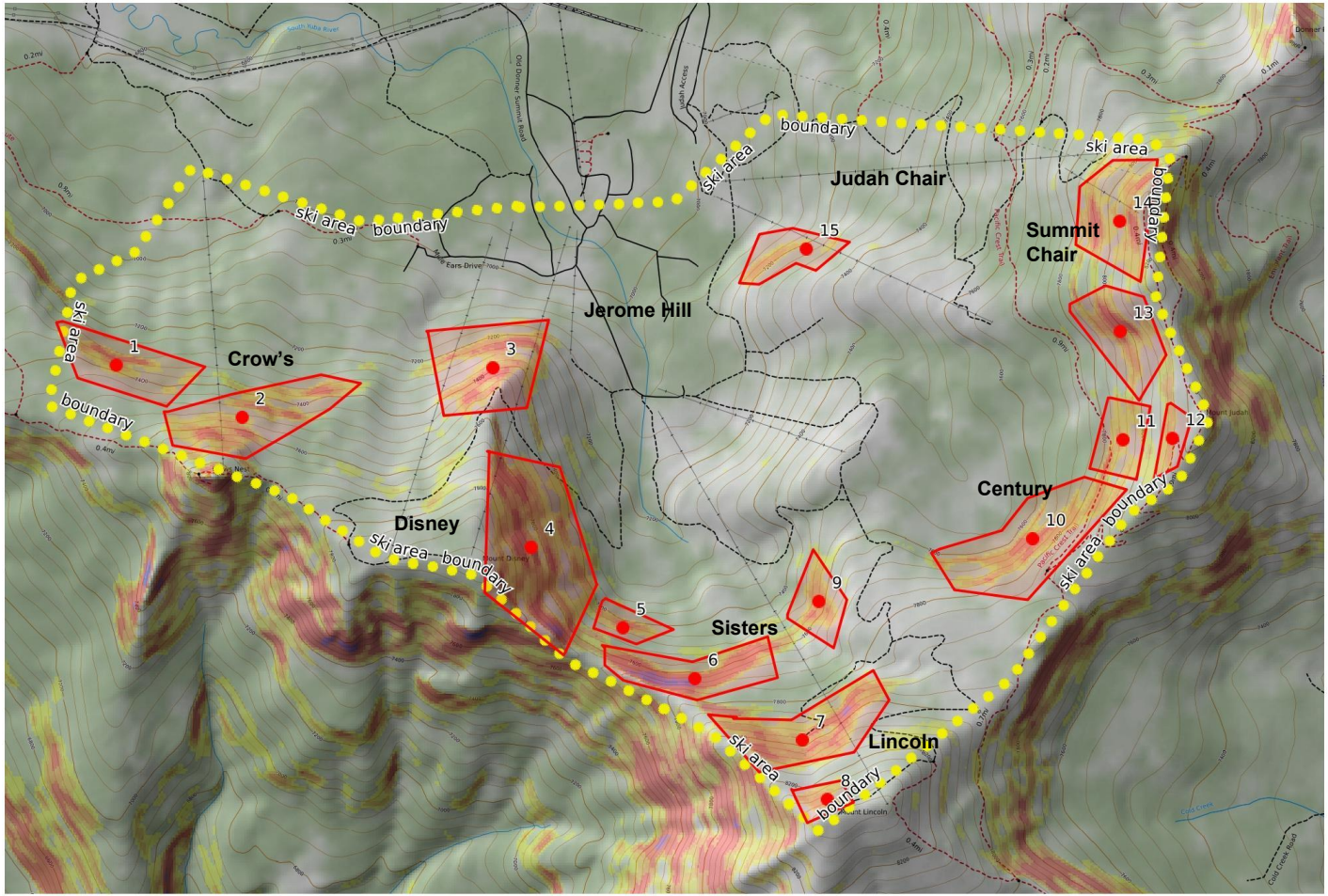


Forecast Exercise 8
Sugar Bowl, CA

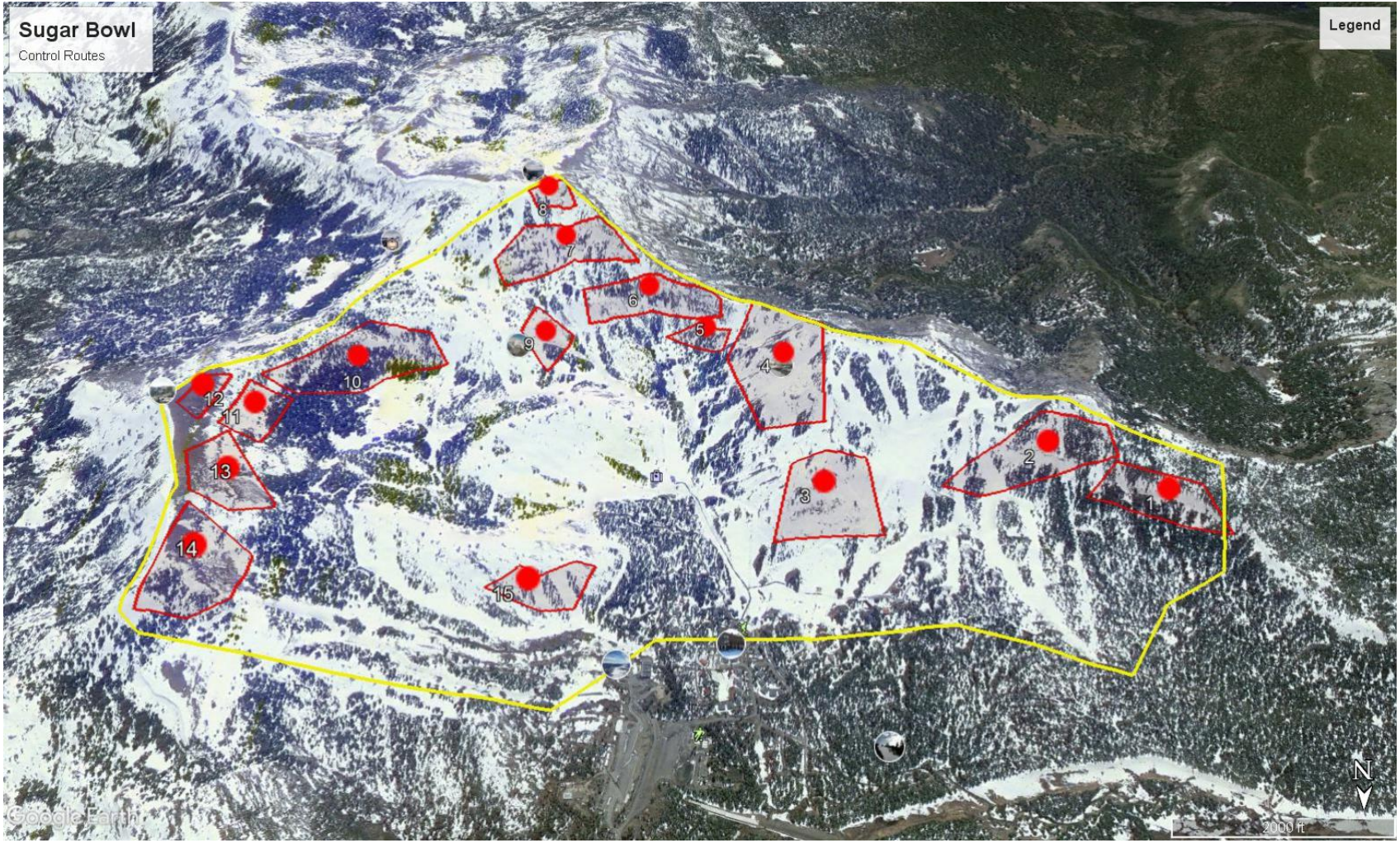
Gabi Benel
Nolan Van Harte

Identified Avalanche Paths.

-numbered for easier reference when making control plans

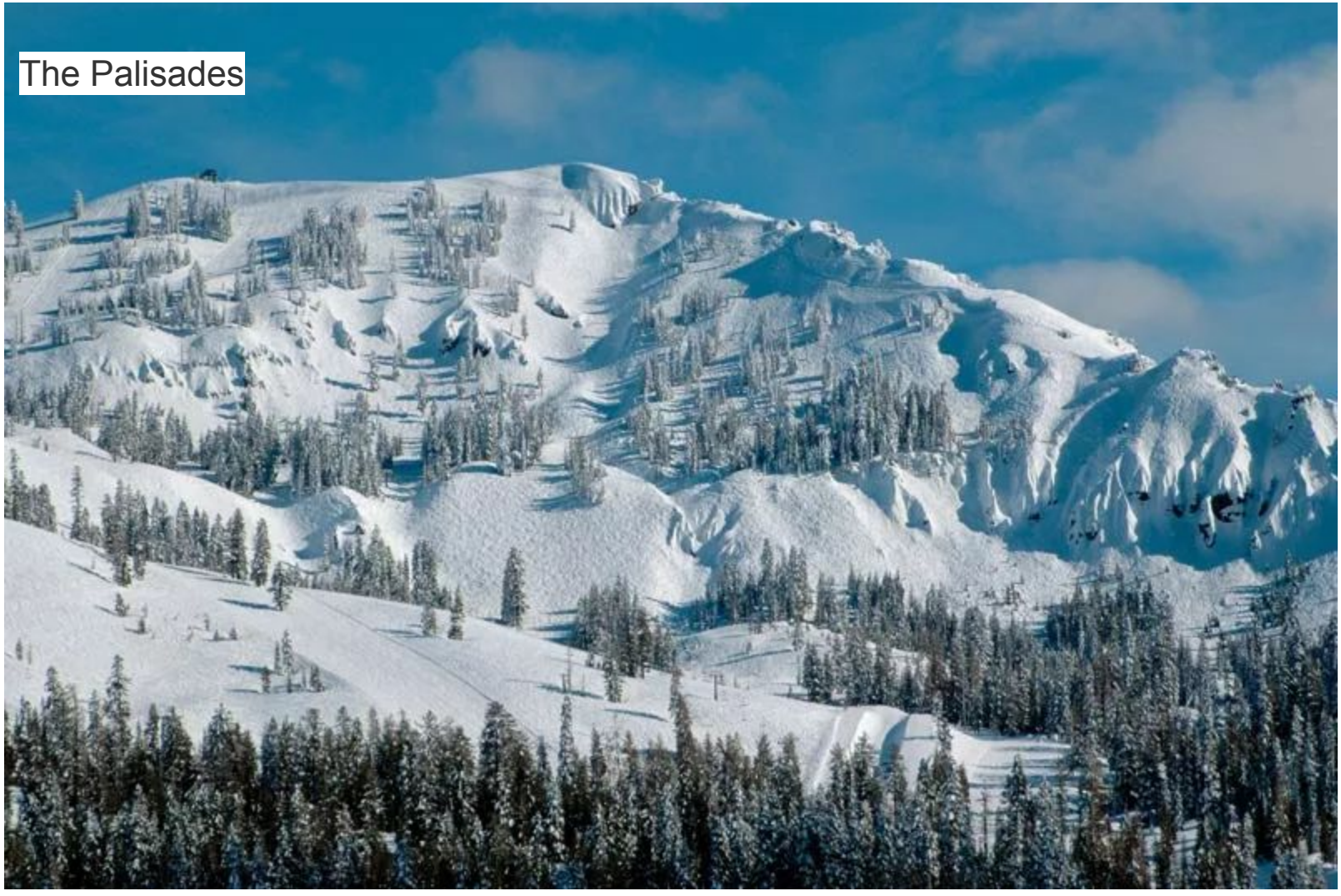


Mercator Projection
WGS84
USNG Zone 10SGJ
0.5 1.0 1.5 2.0 2.5 km
0.5 1.0 1.5 mi
CalTopo.com
Scale 1:15526 1 inch = 1294 feet
N MN 13°


Sugar Bowl
Control Routes
Legend
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
N
2000 ft
Google Earth

Sugar Bowl Resort

Top elevation	8,383 ft (2,555 m)
Base elevation	6,883 ft (2,098 m)


The Palisades

Sources used

1. Larry Heywood and Carolyn Craig, SKI AREA AVALANCHE CONTROL A SUMMARY OF METHODS, PROCEDURES AND MANPOWER, ISSW 1992
2. https://www.wrh.noaa.gov/rev/avalanche/
3. https://www.sierraavalanchecenter.org/
4. http://www.sugarbowlskipatrol.com
5. Paul Baugher and Karl W. Birkeland, DECISION-MAKING AND AVALANCHE MITIGATION DURING A RAPID ONSET WET SLAB AVALANCHE CYCLE, Proceedings of the 2014 International Snow Science Workshop, Banff, Alberta

SKI AREA SEASONAL EXPLOSIVE USE

Eleven Largest Users

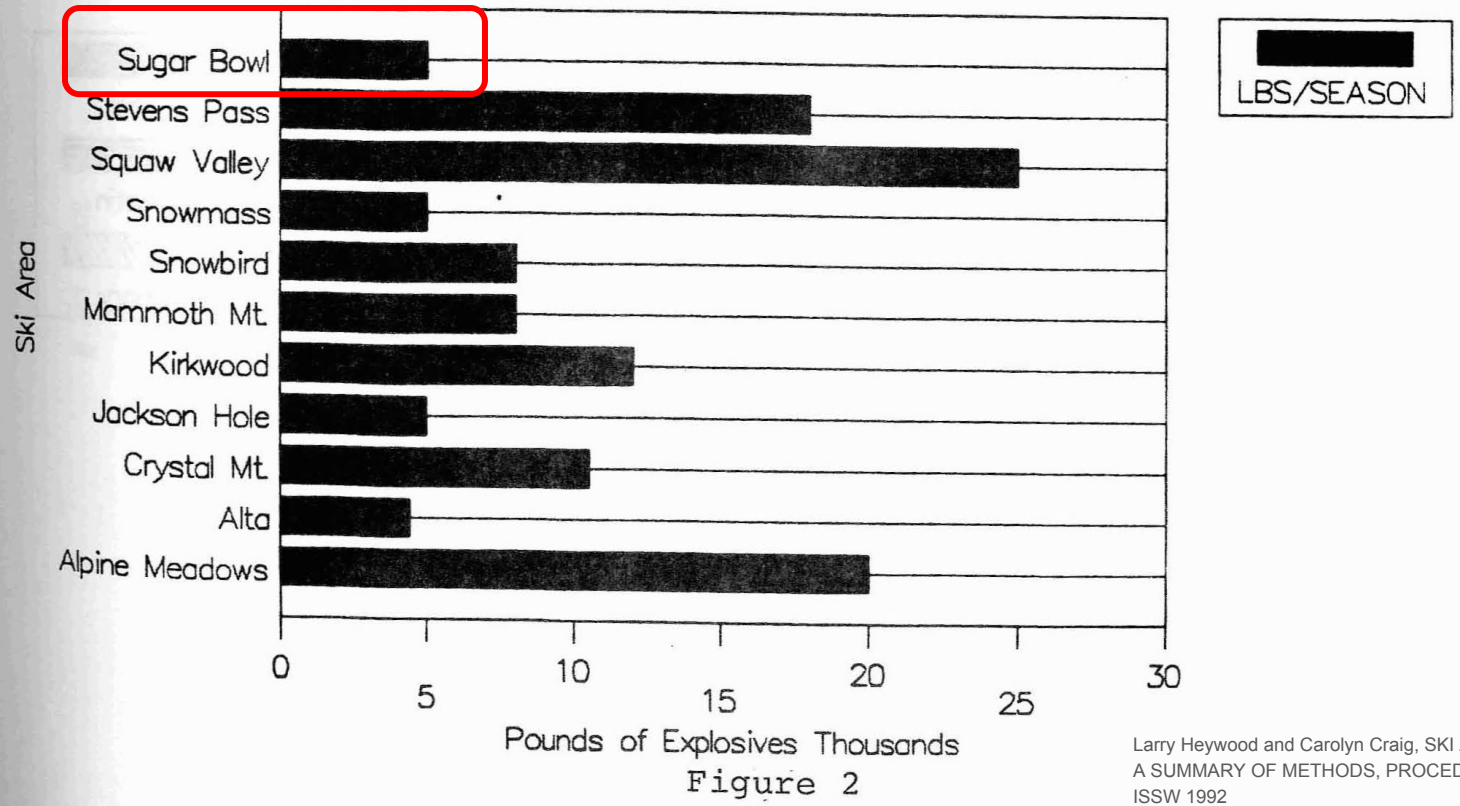


Figure 2

Larry Heywood and Carolyn Craig, SKI AREA AVALANCHE CONTROL A SUMMARY OF METHODS, PROCEDURES AND MANPOWER, ISSW 1992

What is the purpose of this avalanche safety operation?

The goal of the Snow Safety Program is to reduce guest and employee risk resulting from avalanche hazard. It is recognized that access to avalanche prone terrain is very desirable to our guests. It is also recognized that avalanche risk cannot be entirely eliminated on these steep, snow covered slopes. We will therefore strive to find balance between accessibility and security.

What is the element at risk for this avalanche safety operation?

Guests and employees inside the ski area boundary. They will be travelling on skis, foot, snowmobiles, snowcats and other vehicles.

Ski area infrastructure (lift towers, etc).

What avalanche trigger types do you need to worry about for this application (use all codes that apply and describe how they will impact your element at risk)?

For this application we need to worry about natural and artificially triggered avalanches. It is unlikely that an avalanche will be triggered artificially by a vehicle. All avalanches can be caused with c,u,r and y releases

N

- Natural avalanches could occur inbounds, especially loose wet.

Artificial, human: AS, AR, AC (if cornices are present).

- Avalanches could be initiated by a human trigger either unintentionally or intentionally via ski cuts

Artificial, explosive: AE, AB, AC (unable to find if AA, AL used)

- Avalanche mitigation work with explosive work by ski patrol

What D size avalanches to you need to worry about for this application (describe why)?

Any avalanche greater than a D1 should be mitigated as a priority to prevent guests from involvement with avalanches that could cause severe injury or death. D1 size avalanches should be mitigated as a second priority to minimize possibility of injury to guests.

What past weather events will affect your forecast for March 22 and 23?

Previous Week: 3/10-3/16

- Weak warm storm with little precip passes through the area on Sat-Sun (3/10 - 3/11)
- Warming and clearing Mon (3/12)
- Significant storm on Tuesday-Wed (3/13-3/14). Starting with rain up to at least 9200 probably higher. Ending with 15 to 22 inches of snow by Thursday morning (3/15)
- Small break in the weather on Thursday morning (3/15) before another significant storm starts Thursday afternoon and runs through Sat. (28 to 50 inches of new snow) (3/17)
- Strong to gale force SW winds during the storms.

Current Week (through wed night):

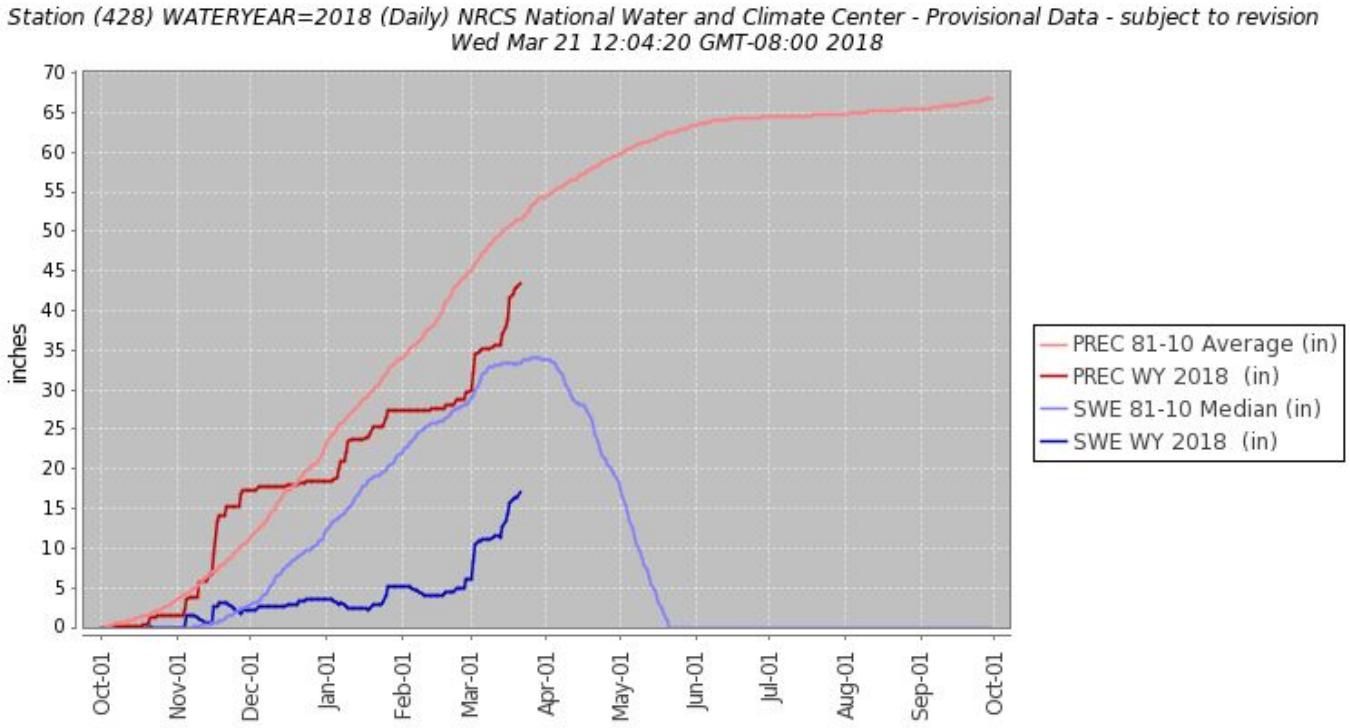
- Initial wave moved through late Tuesday (3/20) and earlier in the night with most of the region receiving between 1/4 and 3/4`s of an inch o rain.
- Snow level radars at Chico and Colfax indicate the snow level remains above 8000 feet.
- Current temperatures are very mild ranging from the upper 30s and 40s in the mountains to the upper 40s to mid 50s across the Central Valley.
- Precipitation expected to increase across the region tonight into early Thursday (3/22) as the surface front approaches and moisture transport from the south increases. Much of the valley expected to see around an inch of rain with 2-4 inches over the mountains where orographic enhancement will increase.

What past weather events will affect your forecast for March 22 and 23? Cont'd

I80 at Donner Lake

I80 at Donner Summit

SWE and precip season to date



What snowpack elements will affect your forecast for March 22 and 23?

3/10/2018 to 3/16/2018

General Snowpack Structure:

- PWL gains strength most evidence points to layer going dormant with a few outliers
- Slab above PWL continues to consolidate
- Added rain crusts to snowpack above the snow from the beginning of March.
- Friday adds storm snow and wind slabs to snowpack above the rain crust.

Most recent observations:

1. **Weak layer of graupel on top of melt-freeze at base of recent storm snow (~200cm from ground)**
2. 20180321 - Donner Summit - Rain/snow line at 8800'. **4 to 8 inches of new dense moist snow existed on top of the lighter snow that was on the surface**. Ski kicks on small sheltered test slopes triggered **some shooting cracks**. On one steeper test slope another kick resulting in a **small storm slab 6 to 8 inches deep sliding down the test slope**. In more exposed near and **above treeline terrain active, wind-loading was occurring** and **very large and heavy cornices had built out over wind loaded slopes**. On smaller test slopes these **cornices were fragile and easy to trigger and some of them did produce shooting cracks in the wind slabs on the slopes below them**. They did not produce wind slab failures, but we avoided getting close enough to the edges of the larger cornices to trigger them. **Ski kicks on small wind-loaded test slopes also triggered long shooting cracks**.

What past avalanche occurrence events will affect your forecast for March 22 and 23?

Observations from the Sierra Avalanche Center:

1. 20180321 - Donner Summit - Rain/snow line at 8800'. **4 to 8 inches of new dense moist snow existed on top of the lighter snow that was on the surface**. Ski kicks on small sheltered test slopes triggered **some shooting cracks**. On one steeper test slope another kick resulting in a **small storm slab 6 to 8 inches deep sliding down the test slope**. In more exposed near and **above treeline terrain active, wind-loading was occurring** and **very large and heavy cornices had built out over wind loaded slopes**. On smaller test slopes these **cornices were fragile and easy to trigger and some of them did produce shooting cracks in the wind slabs on the slopes below them**. They did not produce wind slab failures, but we avoided getting close enough to the edges of the larger cornices to trigger them. **Ski kicks on small wind-loaded test slopes also triggered long shooting cracks**.

2. 20180321 - **Large loose wet avalanche** occurred around 11:30am in Emerald Bay and closed Hwy. 89. Loose wet avalanche ran through a treed gully and **hit the road at 6600'.** Slope was **N/NE aspect and was receiving up to moderate to heavy rain overnight and through the morning hours.** 10 to 15' of debris was on the road and covered both lanes for up to 200'.

3. **Weak layer of graupel on top of melt-freeze at base of recent storm snow (~200cm from ground) has resulted in several slides in Mt. Rose area and Proletariat this past week. Whumphing and collapsing noted when observers investigating avalanche crown. Cracks were propagating.**
   3 avalanches have occurred from this graupel layer that we know about and all have been in the Mt. Rose area on E aspects above 9000'. 2 natural avalanches and 1 skier triggered avalanche on Sunday. Snowpack tests on the crown line of this avalanche indicate that this layer remains weak and that propagation is likely if failure can be initiated. This specific avalanche had very wide propagation taking out some trees with areas of deep debris-D3 avalanche.

4. 20180320 - Donner Pass - **Glide cracks opening, or about to open.**

5. 20180319 - Donner Summit NE ATL - Cornice fall (probably natural) leading to slide

What past avalanche occurrence events will affect your forecast for March 22 and 23? Cont'd

Earlier:

3/10/2018 to 3/16/2018

Avalanche Problems:

- **Wind Slabs** - Reported avalanches - Numerous natural and human triggered on March 16
- **Storm Slabs** - Reported avalanches - Numerous natural and human triggered on March 16
- **Deep Slabs** - Reported avalanches - 0 Reported
- **Loose Wet** - Reported avalanches - Minor loose wet reported

Weather Forecast Synopsis – 7:00 AM PDT March 22, 2018 to 7:00 PM PDT March 23, 2018

A strong cold front will sweep southeast around midday Wednesday with snow levels lowering rapidly in its wake during the afternoon. Confidence in the exact timing of frontal passage and lowering snow levels is not high at this time and some changes to details are likely.
A moderate to strong atmospheric river storm will bring widespread rain and high elevation snow throughout the central Sierra over the next couple days.

Thursday: Rain and snow. High near 35. South southwest wind 21 to 23 mph, with gusts as high as 33 mph. Chance of precipitation is 100%. New snow accumulation of 12 to 18 inches possible.

Thursday night: An additional 2” snow likely. Low 22F, winds SW 15 to 20 mph, gusting to 35mph.

A brief break in the wet weather is possible late Thursday night and Friday morning before a colder system brings potential heavier snow to the mountains Friday into Saturday. Southwest wind 15 to 20 mph, with gusts as high as 35 mph. Ridge top winds to 60 mph possible. High of 33F.

Avalanche Problem(s) – March 22

Problem Type	Natural Avis	Triggered Avis	Sensitivity	Distribution	D Size
Wet Slab	Several	Several	Reactive	Widespread	**D2 - D3**
Wind Slab	Few	Several	Reactive	Specific	**D2**
Deep Persistent Slab	None	None	Stubborn	Isolated	**D3**
Cornice	None	Several	Reactive	Isolated	**D1**

From CAIC: “Wet Slab avalanches happen when a weak layer or interface becomes moist, wet, or saturated. The wet snow loses strength, and the snow above fails and avalanches. Wet Slabs fail because of a decrease in layer strength, compared to dry avalanches that often fail because of an increase in load.”
Rain followed by dry snow can produce PWL through melt layer near surface faceting.
An avalanche in the new snow is likely to break into the old snow (could break into March 15 snow or deeper)
*Don’t want to miss a wet slab problem. It may turn out to be a storm slab

Wind slab size will vary depending on how much snow was available for transport vs. rain

The DPS comes from the graupel layer ~200cm from ground

Assuming we have been controlling the cornices all season so they have not gotten huge.

Avalanche Problem(s) – March 23

Problem Type	Natural Avis	Triggered Avis	Sensitivity	Distribution	D Size
Storm Slab	Several	Several	Reactive	Widespread	**D1**
Wind Slab	Few	Several	Reactive	Specific	**D2**
Deep Persistent Slab	None	None	Stubborn	Isolated	**D3**
Cornice	None	Several (If not triggered previous day)	Reactive	Isolated	**D1**

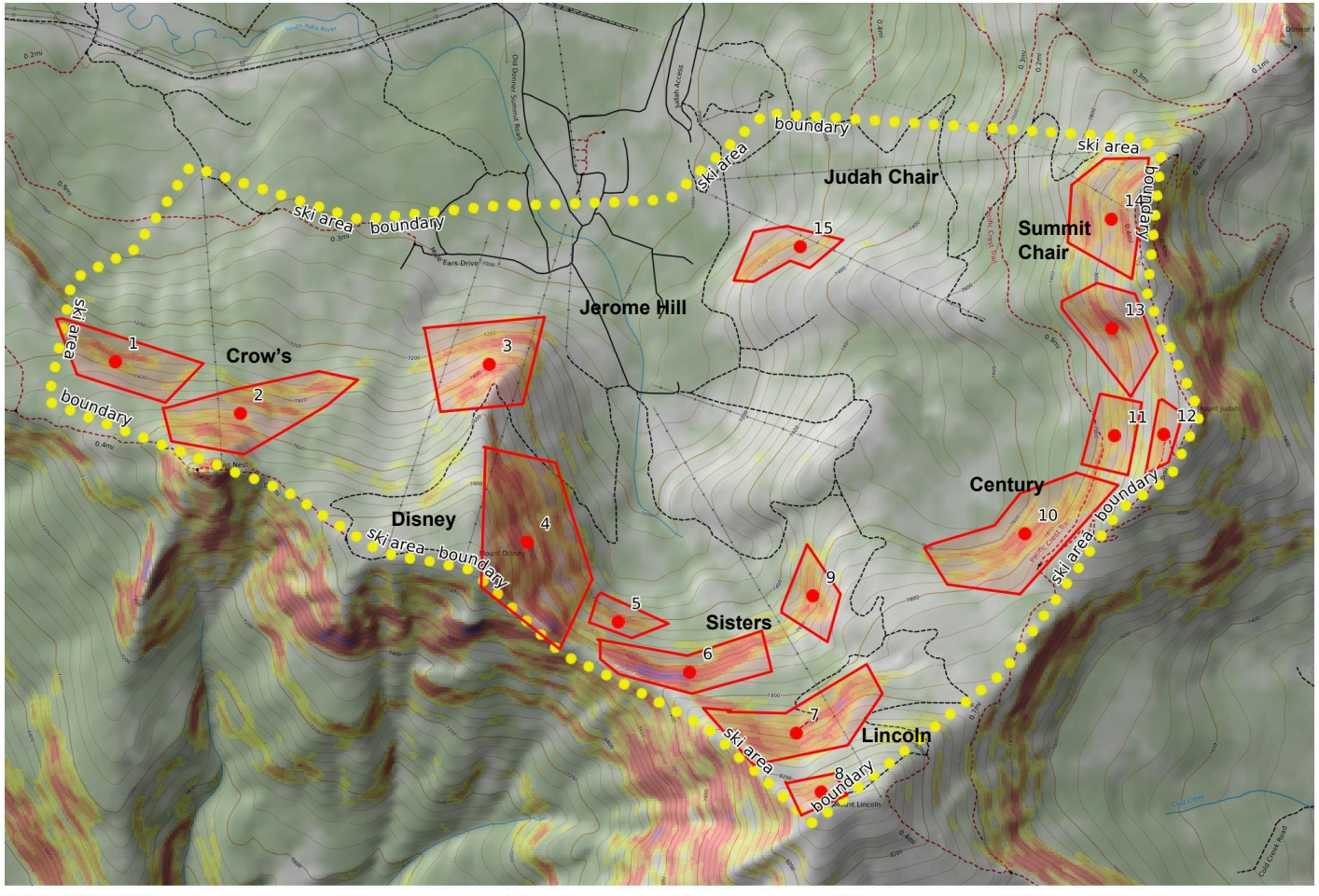
Concerns for Wet Slab Avalanches

1. Onset can be rapid
2. Continual testing of the snowpack during warming and rain on snow events is critically important
3. Wet slabs require using larger explosive charges for testing and hazard reduction, or simply closing all associated terrain
    a. Air blasts are more effective
    b. Smaller charges not very effective
4. During wet slab cycles, some paths may run much farther than expected.
5. There is a risk associated with not attempting to reduce the hazard.

Paul Baugher and Karl W. Birkeland, DECISION-MAKING AND AVALANCHE MITIGATION DURING A RAPID ONSET WET SLAB AVALANCHE CYCLE, Proceedings of the 2014 International Snow Science Workshop, Banff, Alberta

Avalanche Assessment at 7:00AM on March 22, 2018

Priority	Avalanche Problem Types	Likelihood	D Size
1	Wet Slab	Likely	Up to D3
2	Wind Slab	Likely	D2
3	Storm Slab	Likely	D1



Mercator Projection
WGS84
USNG Zone 10SGJ

0.5 1.0 1.5 2.0 2.5 km

0.5 1.0 1.5 mi

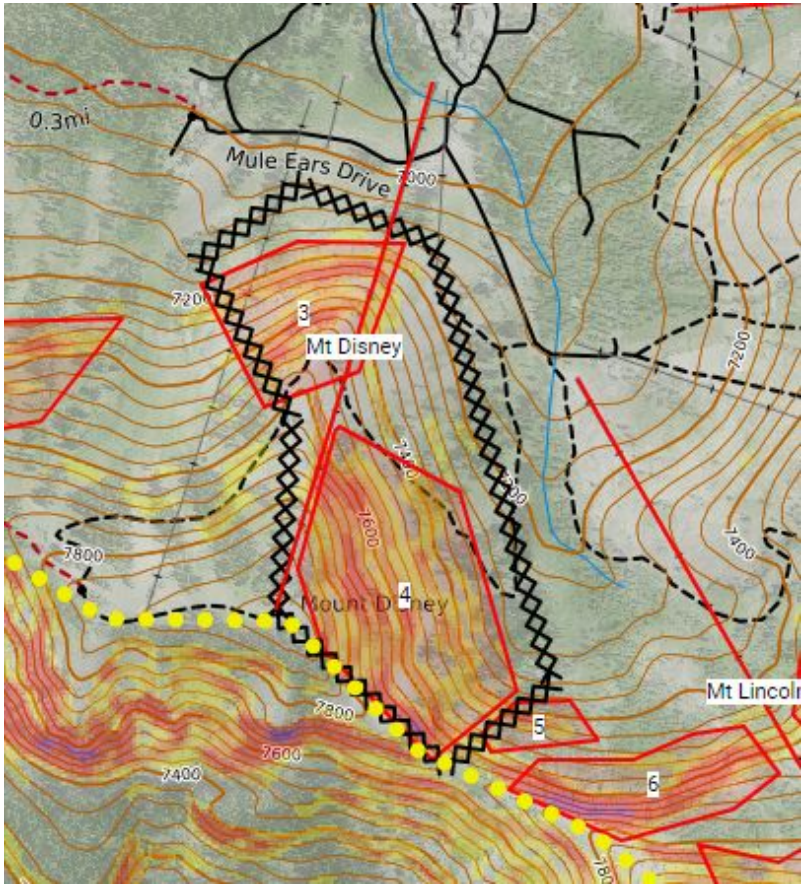
CalTopo.com

Scale **1:15526** 1 inch = 1294 feet

N MN 13°

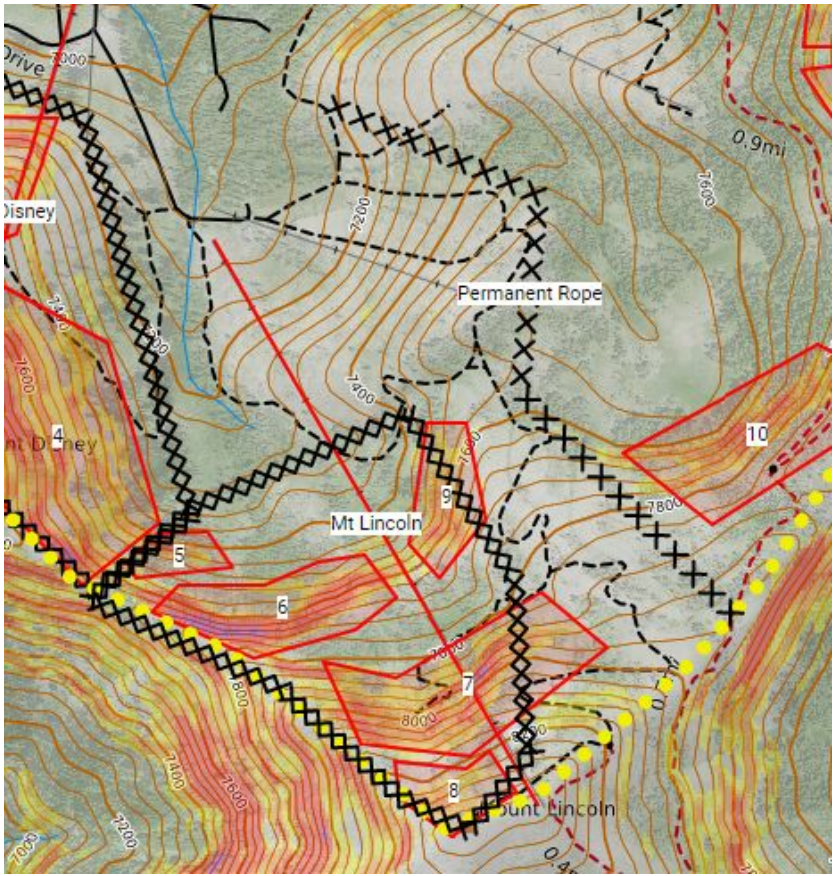
Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Mt Disney Express	1 - One team will assess the wet instability throughout Mt Disney, focusing on mitigation areas 3 and 4. If boot penetration is greater than boot-top depth, terrain will be closed until snowpack becomes stable again with colder temps. Rope closures may need to be set up to allow access to the less steep slopes.



Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Mt Lincoln Express	2 - Assess how wet the snow is at base of lift and at summit, and try to determine the rain/snow line. If boot penetration is greater than boot-top depth, terrain will be closed until snowpack becomes stable again with colder temps. Rope closures may need to be set up to allow access to the less steep slopes. If wet instability is not an issue in this upper elevation terrain, we may need to think about ski cutting and/or shooting any pockets that may have formed in the AM, otherwise try to get skier compaction ASAP.



Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Crows Nest Peak	3 - Assess wet instability at top of lift. Close lift and all associated terrain if water in the snowpack is of concern.
Summit Chair	4 - Although low priority, terrain needs to be evaluated in the AM to determine if it is safe to open the Mt Judah Express. Assess wet instability.

List the discussion points for your AM team meeting

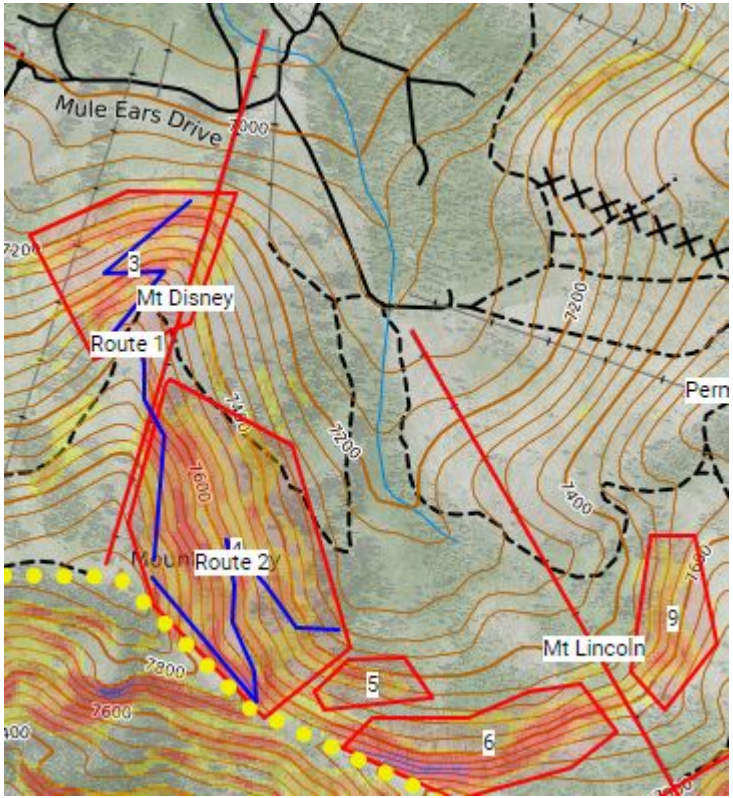
- **Wet instability**
    - Is foot penetration greater than boot top depth?
    - Do we need to close terrain due to wet loose concern?
- **Load of new snow/rain**
    - Are we getting more snow than expected?
    - Has the wind changed from the forecast?
    - What terrain isn’t getting compacted and may require more attention?

Avalanche Assessment at 7:00AM on March 23, 2018

Priority	Avalanche Problem Types	Likelihood	D Size
1	Wind Slab	Likely	D2
2	Storm Slab	Likely	D1
3	Cornice	Likely	D1

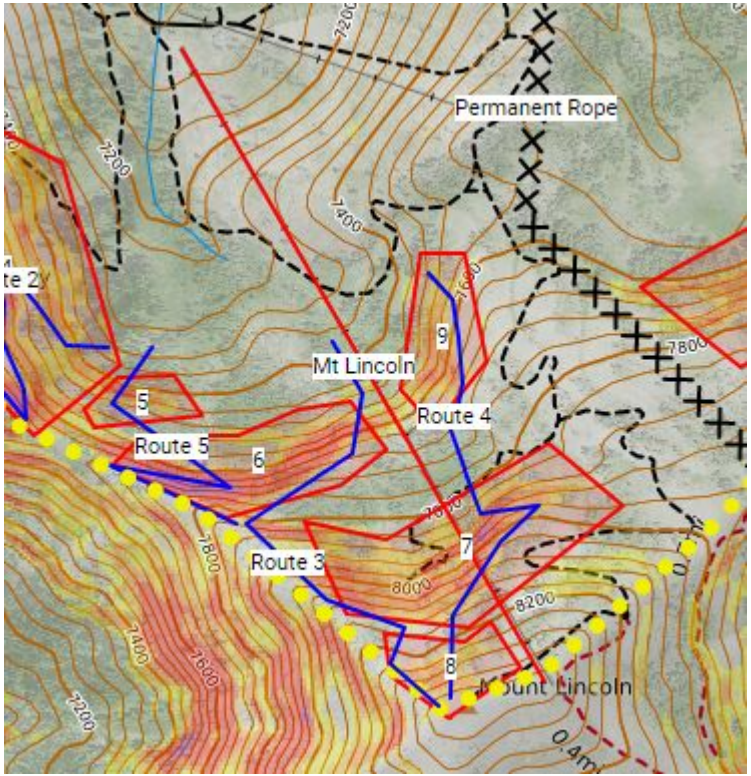
Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Mt Disney Express	1 - One team of 2 will ski cut down route 1, hitting the top of zone 4, and then drop into zone 3; they will have two 2lb hand charges for isolated pockets. Another team of two will ski cut down route 2 into zone 4 and will also have two 2lb hand charges for isolated pockets.



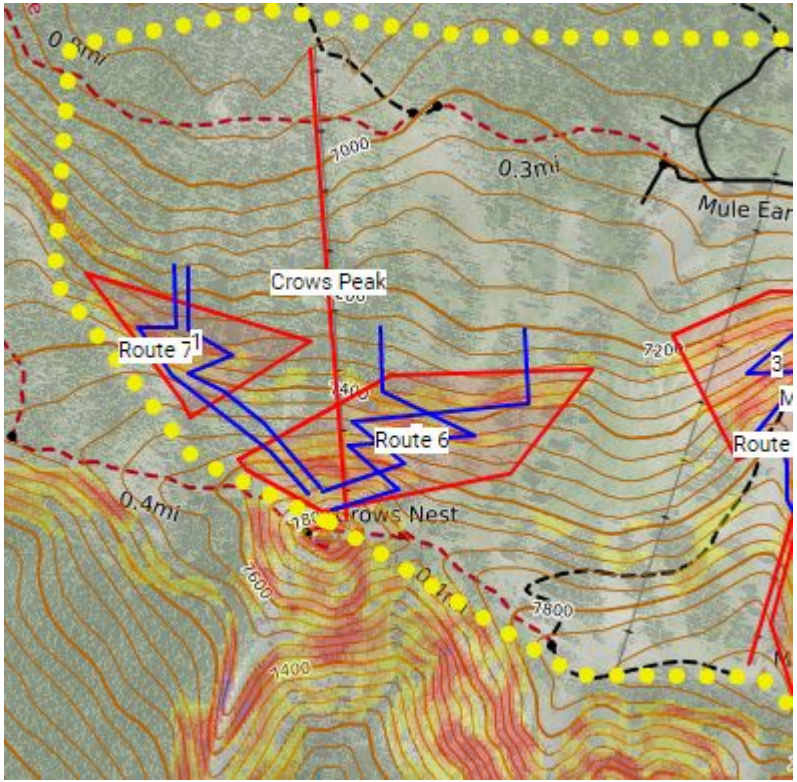
Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Mt Lincoln Express	2 - One team of two will work the west ridge and will have a total of four 2lb and two 5lb explosives. Two shots for zone 8, two shots for zone 7, and two shots for top of zone 6. Another team of two will drop into zone 8 (Fuller's) with one shot, then work zone 7 (Sisters) with 3 or 4 shots, and finish with zone 9 with cutting and one shot. This team will have three 2lb and two 5lb exposives. Last priority will be the Palisades. One team of two will have one 3lb and two 2lb shots, and will work the west side of zone 6 and all of zone 5.



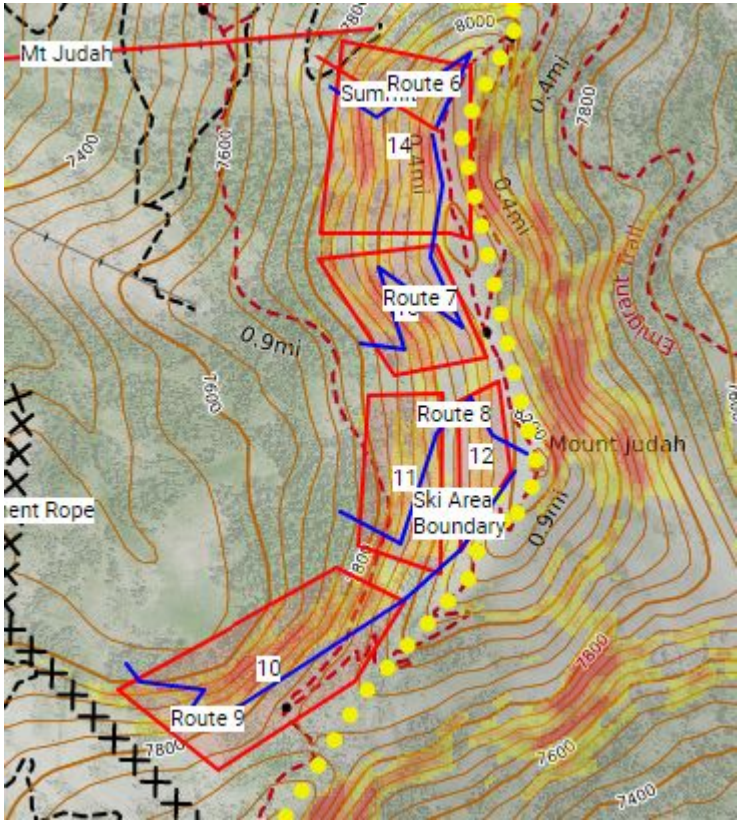
Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Crows Nest Peak	3 - One team of two will make multiple laps on Crows Peak. First lap will be ski cuts down route 6 in zone 2. Second lap will be ski cuts down route 7 into zone 1. This team will have two 2lb explosives. Also, team members will always stay within sight of each other while ski cutting



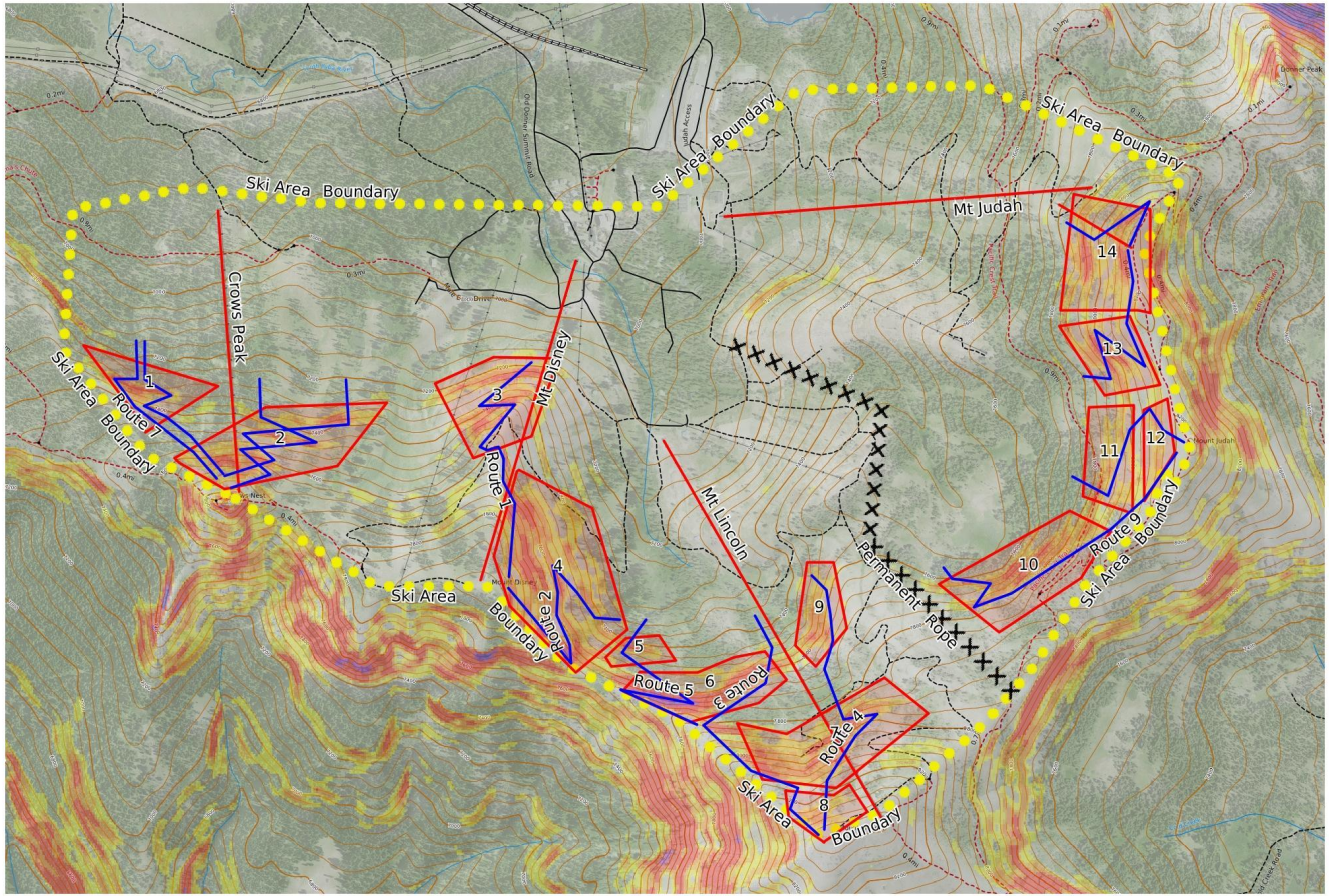
Avalanche Mitigation Plan

Area Name	Mitigation Plan and Priority
Summit	4 - Lowest priority due to mainly being hike-to terrain and consisting of 4 routes, and explosive use will be minimal due to slopes being scoured by wind direction. First team will follow route 6 into north zone 14, clearing the hazard above Mt Judah Express. Next team will follow route 7 into south zone 14 and into zone 13. If time allows, we will work into Mt Judah (Zone 10, 11, and 12). One team will follow route 8 into north zone 12 and into zone 11. Next team will follow route 9 into south zone 12 and all of zone 10.



List the discussion points for your AM team meeting

- New snow and high winds
  - Have we identified aspects to shoot based on wind loading?
  - Bed surface beneath new snow will be very firm and planar in spots
  - Cornice fall can trigger a larger wind or storm slab
  - Flush out the cornice to prevent it from growing larger
- Mitigation
  - Beacon checks
  - Snow will be very reactive
  - Don’t undercut any hazard
    - Use more shots if unsure about a safe egress or more load than predicted
  - Good communication between teams working same or nearby zones.
  - Communicate any pertinent results on radio
- Safety is a higher priority than opening terrain; there’s always tomorrow.



Sugar Bowl Mitigation
WGS84
USNG Zone 10SGJ

0.5 1.0 1.5 2.0 2.5 km
0.5 1.0 1.5 mi

CalTopo.com

Scale **1:16000** 1 inch = 1333 feet

N MN 13°

https://caltopo.com/m/A5V6