WS 250 - Snow Hydrology
Avalanches Lecture

I. Introduction
   A. Safety
   B. Yield Management

II. Classification

III. Mechanics

IV. Yield Management Potential

V. Safety Considerations

VI. Selected References


Avalanche Lecture - WS 250

I. Interest
   a) Safety
   b) Induced for yield met.

II. Classification
   a) (Vu Graph slide of page 27 in avalanche Hdbk)
   b) Sec 3 and Sch. Notes

III. Mechanics
   a) (Vu Graph slide)
   b) Section 3 and Sch. Notes - Triggers

IV. Yield Management
   a) Beef up natural accumulation areas and combine with surface treatments
   b) Large and timing effect
   c) Grime - natural accumulation mechanism

V. Safety Considerations
   a) Release - 1) explosives
      2) sound waves

VI. Safety Considerations
   a) Route finding - mtnaco (enlarged
      using Sec 19 and Sch. notes)
   b) Procedure if caught (ABC - La Chapelle)
   c) Search and rescue (ABC - La Chapelle)
   d) Equipment - Sectional hoke, shovel, cord.
ROUTE - FINDING IN AVALANCHE TERRAIN

How to select safe routes of travel in avalanche country

1. Gather latest information on weather - snowfall, temperatures, and wind. This will give you some idea as to the type of avalanches to expect - loose, dry, damp, wet, or slab.

2. Recognize slide paths.
   A. Steep gullies
   B. Long openings in timber, running parallel to the fall line.
   C. Steep open slopes

3. Always be observant. Small slopes may show signs such as cracking, settling - while skiing. This indicates the large slopes have possible slab avalanches.
   A. Watch the shadows, they will point to a slope like warning fingers. Sun action is maximum.
   B. Ridges running parallel to the fall line tend to modify the orientation of a slope so that one side may be stabilized by sun and wind while the other is an accumulation zone for slab.
   C. Watch the weather. Any sudden change is dangerous. (Especially warming or rain)

4. Don't travel during a severe storm.
   A. Travel is possible during first few hours of storm. Use the time to get out of avalanche terrain.
   B. Travel in the spring in the early morning hours. Traveling is dangerous between 10:00 a.m. and sundown.

5. Avoid known hazardous slopes. Traverse a doubtful slope one skier at a time, either as high as possible or as far from the toe as possible. The crest of a ridge is a safe route, but don't walk on the overhang or a cornice. Travel in heavy timber, windbeaten slopes and terrain barriers.

6. If you must traverse an avalanche path let one man test ski it, protected by a safety rope and avalanche cord and wrist straps should be off and ski bindings loosened if not release type. Don't be satisfied with one test. Avalanches have a cynical habit of picking off the third skier in line, otherwise known as the hangfire.

c) Estimation of characteristics and processes in area of interest

Process interception

Soil moisture - infiltration

Sweat - melt

Peak flow: Is more efficient?
Increasing demands for information on the distribution of runoff requiring consideration of:

Temperature

Aerial coverage

Soil moisture - Classical works of Nelson et al, 1953 (TAGU 12: 240-280) on Columbia increases rainfall caused from 0.74 to 0.94

Rainfall - Swift - Powder Study

Evaporation - cooling the soil

Movie:

Waters From the Mountain 20 min color

USBR Snow Measurement Program
\[ H \rightarrow H_2O \rightarrow \overset{\text{Outfit}}{\rightarrow} H_2O \]
I Snow as an environmental factor:
   Effects of Snow:

   Water cycle - runoff, water yields, storage
   Energy exchanges (heat)
   Aesthetics and sport
   Mobility - man & animals
   Communications
   Animal habitat - food, shelter, cover, insulation of streams
   Safety - avalanches

   Effects on plants:
   Soil moisture
   Phenology
   Mechanical disruption - loading, creep, avalanche disease
   Energy exchange

II Factors influencing snow distribution
   Meteorological
   Physiographic
   Vegetation
   Analogy in interpretation to soil moisture availability

III Influence of Forests on Snow - Process analysis on chalkboard - Input

IV Snow-forest management
Process analysis - 3 slides on redistribution

3 slides on snow falling and melting at Pinetree 5/68

III slides

8 on snow of 12-1-67 taken on 12-9-67

11" at Pinetree on ground
5" new snow with 0.45" H2O

11" on snow of 11-13-68 taken on 11-15-68 - new sign of redistribution before now (ties in with movies)

4 on Sierra Snow Lab 12/66

8

11 on observations in first New Brunswick

3 on mist
Water Yields - Snowpack Timber Zone

I. Problem Approach

A. Research
   Fraser

B. Process interpretation
   Interception
   Snow capture
   Snow melt
   Soil moisture - disposition
   Peak flow R.O. more efficient?

C. Extrapolation
   Characteristics and Processes on area of interest

II. Research Results

A. Fraser - Fool Creek (Paper Chart)
   80% dense coniferous
   Streams flow to north
   Average 30"~2/3 snow
   40% of area cut (50% of commercial timber); logging debris left.
   Cut in strips 1,2,3, and 6 chains wide.
   Increase in excess of 25% since 1956
   Peaks increased some years; small increase in summer and early fall.

   Processes
   Increased snow in openings; total area snowpack same
   Melt R.O. on pack
   Reduced transpiration
   Reduced interception?
   What is role of evaporation from snowpack in open areas??

B. Wagon Wheel (Paper Charts)
   Dominantly aspen: only 23% sparse spruce and Doug Fir
   Streams flow to east
   Average precipitation 21"~3 snow
   Cleared of all trees over 1' in height by cutting followed by burning.
   Average water yield increased about 1 area-inch over 7 years or about 16%
   Earlier, more rapid rising, and higher peak along with slight increase in summer streamflow.
(Lecture 9 cont.)

(B. Cont)

<table>
<thead>
<tr>
<th></th>
<th>Forested</th>
<th>Denuded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total precip</td>
<td>21.1</td>
<td>20.8</td>
</tr>
<tr>
<td>Transpiration</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Interception (snow)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Loss from ground &amp; snow</td>
<td>7.4</td>
<td>9.1</td>
</tr>
<tr>
<td><strong>TOTAL LOSS</strong></td>
<td><strong>14.9</strong></td>
<td><strong>13.6</strong></td>
</tr>
<tr>
<td>Steamflow</td>
<td>6.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

C. **Fraser - Plots**  
(Paper Chart)

20 5-acre plots - treatment in 1940 - 16 selective wt

<table>
<thead>
<tr>
<th>Reserve Stand</th>
<th>Water Content of Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 1941-43</td>
</tr>
<tr>
<td>BD ft/AC</td>
<td></td>
</tr>
<tr>
<td>11,900 uncut</td>
<td>100</td>
</tr>
<tr>
<td>6,000</td>
<td>119</td>
</tr>
<tr>
<td>4,000</td>
<td>129</td>
</tr>
<tr>
<td>2,000</td>
<td>143</td>
</tr>
<tr>
<td>0</td>
<td>144</td>
</tr>
</tbody>
</table>

after 24 years growth, fairly dense 15-20' reproduction on clearcuts

Wilm and Dunford

1) Initial storage of snow increased 26% cleared to 5% (TSI)
2) Snow disappeared from all plots at about same time
3) Cut-over plots increased by 31% the amount of $H_2O$ available for streamflow
4) Estimated snow evaporation in spring in cut-over (open)=2.00"  
5) Losses from soil??
6) Estimated transpiration ~7" out of 24\frac{1}{2}"

D. **Packer**

Snow water content (max) was affected uniformly by changes in forest canopy regardless of elevation, aspect, or magnitude of snowfall. It increased 4.2 inches with a change from completely open to completely closed.

**Ponderosa Pine Type**

E. **Yuba Pass, Calif.**  
Progress Rft 1965

Red fir and pine in north slope at 7,000 ft. alternate 2- and 4-chain strips E-W 4-6 chains of uncut timber between strips.
Results to date indicate that strip should be oriented so that the south side of tree trunks are always covered by shade, that is, N-S cut strips on a north slope.

"We believe snow is taken from the forest to leeward of a cut strip, or opening, and piled up in the opening.

Processes: Redistribution & LW radiation melt

F. Beaver Creek, Arizona  (Folliott, Hansen, Zander)

Ponderosa Pine
24" precipitation ~ ½ during Nov. 15 - April 15
Water equivalent measured on day after storm.

Results
1) Sapling and pole stand held most snow just prior to spring runoff and had high melt rate in spring (Maximizing yield)

2) Small amount held thru winter in uneven-aged stand with basal area of 135 ft² melted slowly in spring (extended timing)

3) Snow held in a "zone of retention" in openings thru the winter out to distances of 1½ - 2 H

Processes: Distribution and melt

G. Berndt - Bighorn N.F. Wyoming  (Thesis)

Mature lodgepole cut in clearcut blocks 5, 10, and 20 acres (1 spring) 1961
Snowpack H₂O equivalent began in March 31
Precip. > 20" ~ 60%

Results
1) 2.5" increase in water equivalent with greatest effect on eastern aspect (3.2")

2) Snow on S & E aspects disappeared 10 to 14 days ahead of uncut areas; slight retention advantage on 5-acre blocks.

3) On N exposures, disappearance was simultaneous

4) On W aspect, snow persisted slightly longer in 20-acre block.

Processes: Distribution and melt
(lecture 9 cont.)

H. Blue Mountains of E. Oregon (PNWFRES Res. Note 153 1957)

Lodgepole pine, 70 yr. old
140 ft²/acre - all trees basal area

**Results**

1) Gages on forested plots average 76% as small openings.

2) Water equivalent of snow averaged 55% of meadow

3) Rate of melt after March 18
   - open meadow: 0.30"/day
   - Lodgepole: 0.12"/day

**Processes:** Interception & melt rate
H. Blue Mountains of E. Oregon  (PNWFRS Res. Note 153 1957)

Lodgepole pine, 70 yr. old
140 ft²/acre - all trees basal area

Results

1) Gages on forested plots average 76% as small openings.

2) Water equivalent of snow averaged 55% of meadow

3) Rate of melt after March 18
   open meadow: 0.30"/day
   Lodgepole: 0.12"/day

Processes: Interception & melt rate
II Research Results

A) Fraser - Foot Creek

(PAPER CHART)

80% dense coniferous
Streams flow to north
avg 30" ~ 3/3 snow
40% of area cut (50% commercial timber); logging debris left.
Cut in strips 1, 2, 3, and 6 chains wide

Increase in excess of 25% since 1956
Peaks increased some years; small increase in
summer and early fall

Processes

Increased snow in openings; total area snowpack same
Melt rate on peak
Reduced transpiration
Reduced interception

What is role of evaporation from snowpack
in open areas?
B) Wagner Wheel

(Paper Chart)

Dominantly aspen; only 23% spruce, pine & Doug fir

Streams flow to east
Any precip 21" ~ ½ snow

Cleared of all trees over 1' in height by cutting followed by burning

Any water yield increased about 1 area-inch over 7 yrs of about 16%.

Earlier, more rapid rising, and higher peaks along with slight increase in summer streamflow.

<table>
<thead>
<tr>
<th></th>
<th>Forested</th>
<th>Demuded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total precip</td>
<td>21.1</td>
<td>20.8</td>
</tr>
<tr>
<td>Transpiration</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>interception (snow)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Loss from ground &amp; snow</td>
<td>7.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Total loss</td>
<td>14.9</td>
<td>13.6</td>
</tr>
<tr>
<td>Streamflow</td>
<td>6.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>
Fraser - Plots

20 5-acre plots - treatment in 1940 - 16 selective cut

<table>
<thead>
<tr>
<th>Reserve Stand</th>
<th>Water Content of Snow</th>
<th>1964</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,900 current</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6,000</td>
<td>119</td>
<td>117</td>
</tr>
<tr>
<td>4,000</td>
<td>129</td>
<td>131</td>
</tr>
<tr>
<td>2,000</td>
<td>143</td>
<td>142</td>
</tr>
<tr>
<td>0</td>
<td>144</td>
<td>140</td>
</tr>
</tbody>
</table>

after 24 yrs growth, fairly dense 15-20' refills on clearcuts

Intercepted Snow

Wilkerson and Dunford

1) Initial storage of snow increased 26% to 57% (151)
2) Snow disappeared from all plots at about same time
3) Cut-over plots increased by 31% theнят of 11,000 available for streamflow
4) Estimated snow and in spring in cut-over cut-over (in.) = 2.00
5) Losses from soil ??
6) Estimated transpiration = 7" out of 24½"
D. Packer

Snow water content (mat) was affected uniformly by changes in forest canopy regardless of slope, aspect, or magnitude of snowfall. It increased 4.2 inches with a change from completely open to completely closed.
Ponderosa pine type

E) Yuba Pass, Calif.  Progress Rpt 1965

Red fir and pine on north slope at 7,000,
alternate 2- and 4-chain strips E-W
4-6 chains of uncut timber between strips

Results to date indicate that strips should
be oriented so that the south side of tree
trunks are always covered by shade, that is,
N-S cut strips on a north slope.

"We believe snow is taken from the forest
to leeward of a cut strip, opening, and piled
up in the opening"

Processes:

Redistribution & LW radiation melt
Beaver Creek, Arizona (Ejkleth, Hansen, Zunder)

Ponderosa Pine
24" spacing - 1/2 during Dec 15 - April 15
Water equivalent measured on day after full storm

Results

1) Sapling and pole stand held most snow just prior to spring runoff and had high melt rate in spring (limiting yield)

2) Small amount held through winter in uneven-aged stand with basal area of 135 ft² melted slowly in spring (extended timing)

3) Snow held in "zone of retention" in openings than the winter out to distances of 1/2 - 2/1

Processes

Distribution of melt
Mature lodgepole cut in clearcut blocks 5, 10, and 20 acres (1 spring) 1961
Snowflock 800 equiv. began on March 31
Precip > 20" ~ 60% snow

**Results**

1. 2.5" increase in snow water equivalent with greatest effect on eastern aspect (3.0")

2. Snow on S and E aspects disappeared 10 to 12 days ahead of uncut areas; slight retention advantage on 5-acre blocks

3. On N exposures, disappearance was set simultaneously

4. Snow on W aspect snow persisted slightly longer in 20-acre block.

**Processes**

Distribution and melt
Blue Hills of E. Oregon

Lodgepole fir, 70 yr old
190 ft²/acre - all trees basal area

Results

1) Ages on small forested plots avg. 76% as small openings

2) Water equivalent of snow averaged 55% of meadow

3) Rate of melt after March 15
   - Open meadow: 0.30"/day
   - Lodgepole: 0.12"/day

Processes:

Interception & melt rate
Precipitation

Rain or Snow

Snow Interception: Yes

Intercepted R & D

Loss by Volatilization: Yes

Loss during Transport: Yes

No Transport: Yes

Atm Vapor

Ground System
Review of Course

1) Hydrologic significance of metamorphism and their changes.
2) Energy budget - processes in snowmelt
3) Runoff modeling
4) Degree day and temperature indexes
5) Snow management - water yields
6) Underlying basic concepts pertaining to above

Question types
- Problem and situation analyses
- Short answer + analytical/descriptive
- Comparison - Pros and cons
- Definition and relevance
- Equations - recognition (more to complex)
- Open-ended
<table>
<thead>
<tr>
<th>LINE</th>
<th>FULL COURSE NUMBER</th>
<th>COURSE TITLE</th>
<th>INSTRUCTOR</th>
<th>COL</th>
<th>CLASS DPT</th>
<th>MAJ</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>571-94-4116</td>
<td>SNOW HYDROLOGY</td>
<td>MEIMAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>295-42-9108</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>449-94-4044</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>522-86-4894</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>524-82-1852</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>149-44-3627</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>227-58-4012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>538-52-1024</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>539-54-5100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>557-70-6976</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>123-34-0094</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>105-44-8197</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>534-48-3365</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>433-86-0717</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>312-48-2634</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>523-56-7001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. Formation and Composition of Snow
   A. Formation
   B. Deposition
   C. Metamorphism

II. Mechanical Properties
   A. Grain size
   B. Density, porosity, and void ratio
   C. Bonding and disaggregation
   D. Rapid loading characteristics
   E. Sustained loading characteristics

III. Thermal Properties and Radiation Characteristics
   A. Heat transfer through snow
   B. Temperature changes
   C. Convection and diffusion in snow
   D. Vapor transfer
   E. Absorption and scattering of radiation in a snowmass
   F. Longwave emission from snow

IV. Electrical Properties
   A. Deposited snow
   B. Falling and blowing snow

No text, selected readings of current papers
I. Physical Characteristics
   A. Mechanical properties
   B. Thermal properties
   C. Spectral properties

II. Precipitation and Snow Accumulation
   A. Meteorological factors
   B. Terrain effects
   C. Elevation effects
   D. Point precipitation measurements
   E. Point snow measurements
   F. Relation of point to areal distribution
   G. Relation of point measurement to basin H₂O flow

III. Water Balance in Areas of Snow Accumulation
   A. Precipitation
   B. Interception loss
   C. Snowpack H₂O equivalent
   D. Evapotranspiration
   E. Soil moisture
   F. Groundwater storage and runoff

IV. Melting of Snowpack
   A. Radiation theory
   B. Solar radiation
   C. Terrestrial radiation
   D. Turbulent exchange
   E. Condensation and evaporation
   F. Conduction of heat from ground
   G. Heat content of rainwater
   H. Interrelationship between component melts

V. Prediction Practices
   A. Temperature index or degree day method
   B. Recession analysis
   C. Generalized snowmelt equivalent
   D. Index plots regression equivalent

Text: No text, selected readings of current papers
Course Outline
SNOW MANAGEMENT
ER 579

I. Snow Hydrology
1. Physical characteristics
   a) Mass/phase properties
   b) Thermal properties
   c) Acoustical properties
   d) Spectral properties
2. Accumulation and redistribution processes
   a) Snow precipitation processes
   b) Transport dynamics
   c) Terrain and surface influences
3. Ablation Processes
   a) Energy balance
   b) Water balance
   c) Phase changes

II. Snow Measurement
1. Standard methods
   a) Snow tube/snow pillows
   b) Universal gages
2. Remote sensing
   a) Gamma attenuation
   b) Microwave
   c) Photogrammetry
   d) Satellite imagery
3. Telemetry

III. Management Practices
1. Water yield
   a) Silvicultural practices
   b) Snow fences
   c) Melt enhancement
   d) Weather modification
2. Avalanche control
   a) Snow fences/terrain modification
   b) Induced avalanches
   c) Warning systems
   d) Zoning
3. Construction
   a) Highway design
   b) Buildings
4. Recreation
   a) Ski slopes
   b) Cross country
   c) Snow-mobiles
5. Wildlife
   a) Winter mobility
   b) Weather modification

6. Dry-land Agriculture
   a) Wind breaks
   b) Snow fences
   c) Crop stubble

7. Forecasting streamflow
   a) Data acquisition/telemetry
   b) Standard methods
   c) Snowmelt models
   d) Rain-on-snow floods

Teaching materials: Selected readings from symposia proceedings, current literature, federal documents, and contract reports. No text available.