DE – NT0005684, National Energy Technology Laboratory

Using Artificial Barriers to Augment Water Supplies in Shallow Arctic Lakes

presented by Sveta Berezovskaya

UNIVERSITY OF ALASKA FAIRBANKS

Project kick–off meeting, Pittsburgh, Pennsylvania, Feb 19th 2009

OUTLINE

- Introduction to collaborative group
- Relevant background for the project
- Objectives
- Description of the work to be performed
- Expected impact of the project
- Project schedule and milestones

Team Members

Sveta Berezovskaya – *PI*

Doug Kane - *Co-PI*

Ken Irving - *Research Tech.*

Matthew Sturm - *Collaborator*

Chris Hiemstra - *Collaborator*




Snow is central to activities on ANS

Image courtesy: U.S. Department of Energy's Atmospheric Radiation Measurement Program

image courtesy of www.morooka.com

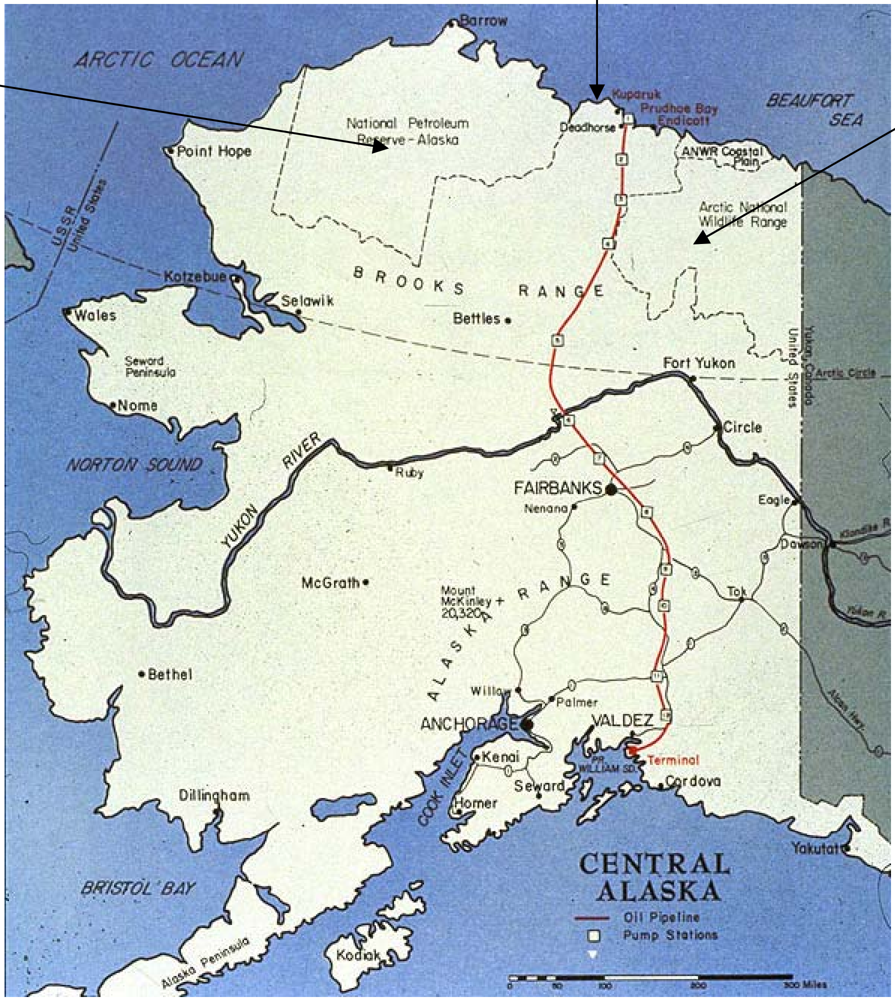
Harvesting Snow to Augment Water Supplies

RELEVANT BACKGROUND

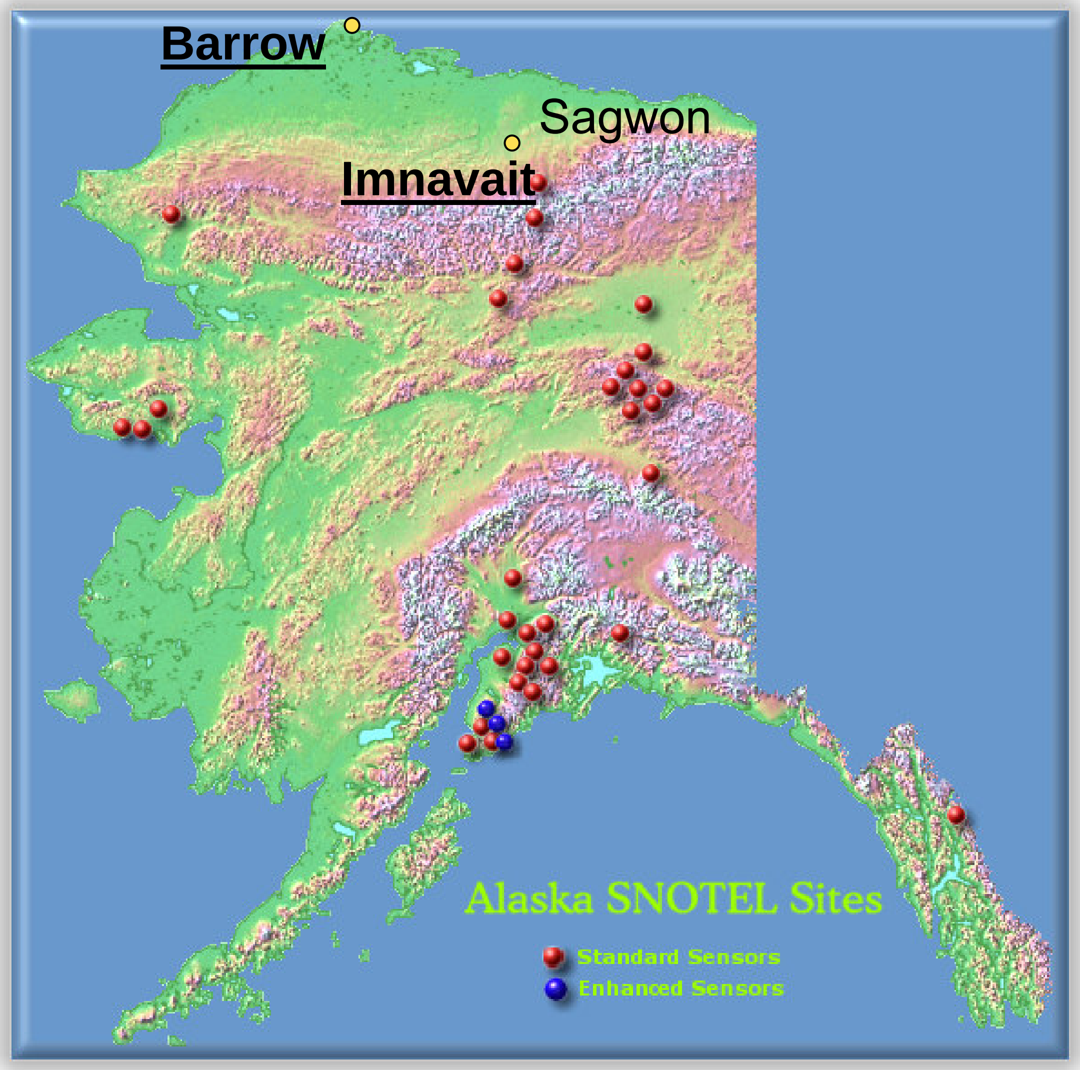
Petroleum-rich North Slope

National Petroleum Reserve - Alaska

Arctic National Wildlife Refuge



Snow-Net: System for measuring arctic winter precipitation and snow cover, NSF Arctic Observing Network project



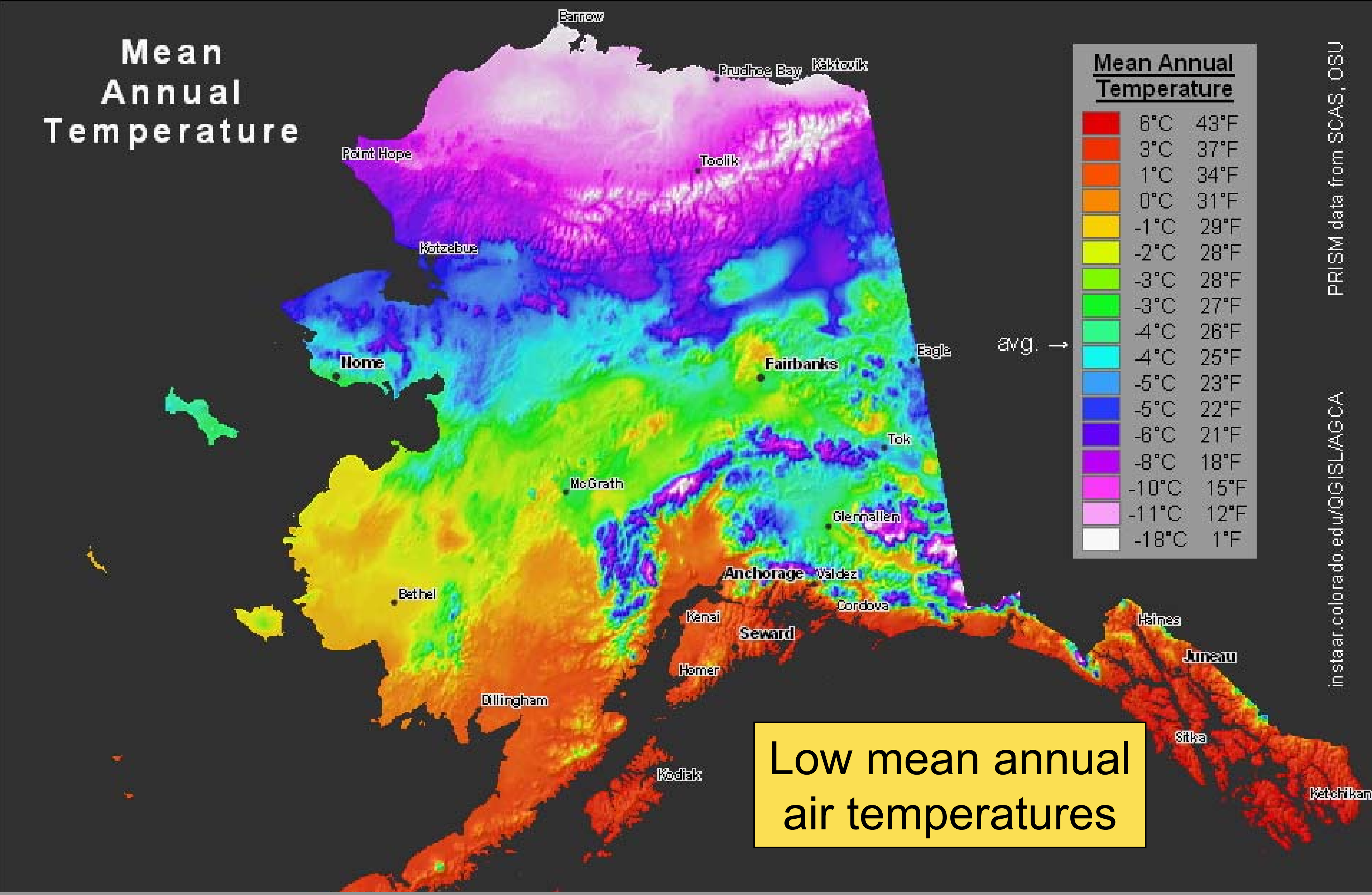
This map of Alaska is from the Natural Resources Conservation Service (NRCS) http://www.nrcs.org

RELEVANT BACKGROUND

Difficulties in domestic water supplies are associated with

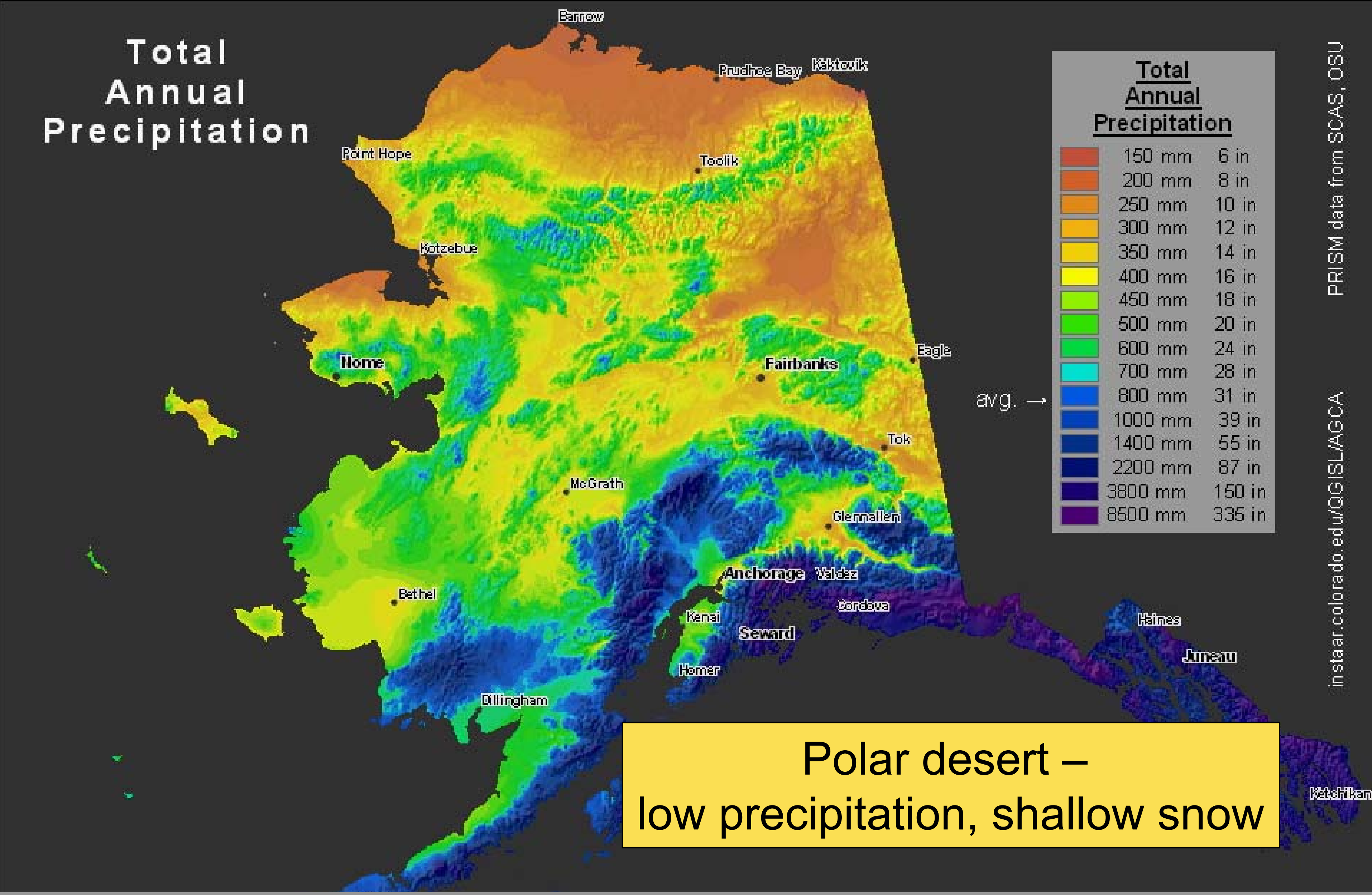
- Short open-water seasons
- Engineering problems encountered with water storage and distribution systems in permafrost terrain
- Severe winter climates
- High operational costs

Slaughter,C. W. ; Mellor,M. ; Sellmann,P. V. ; Brown,J. ; Brown,L., 1975. CRREL, Hannover, Special report.



Low mean annual air temperatures

Manley, W.F., and Daly, C., 2005, Alaska Geospatial Climate Animations of Monthly Temperature and Precipitation: INSTAAR, University of Colorado, http://instaar.colorado.edu/QGISL/AGCA.

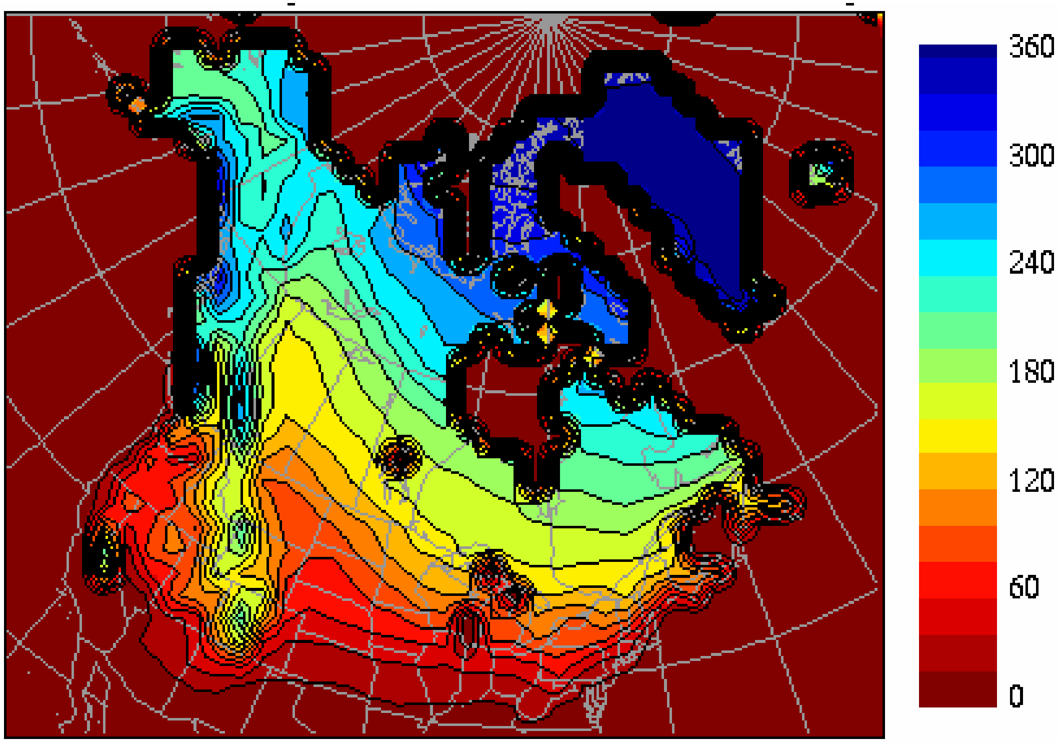


Polar desert –
low precipitation, shallow snow

Manley, W.F., and Daly, C., 2005, Alaska Geospatial Climate Animations of Monthly Temperature and Precipitation: INSTAAR, University of Colorado, http://instaar.colorado.edu/QGISL/AGCA.

Mean duration of snow cover (days) over the 1972-94 period

as computed from satellite-derived maps of weekly snow cover extent.



Source: R. Brown, Environment Canada (data supplied by D. Robinson, Rutgers University).
Published on http://www.msc.ec.gc.ca/crysys/education/snow/snow_edu_e.cfm

Snow is there to harvest during these 9 months!

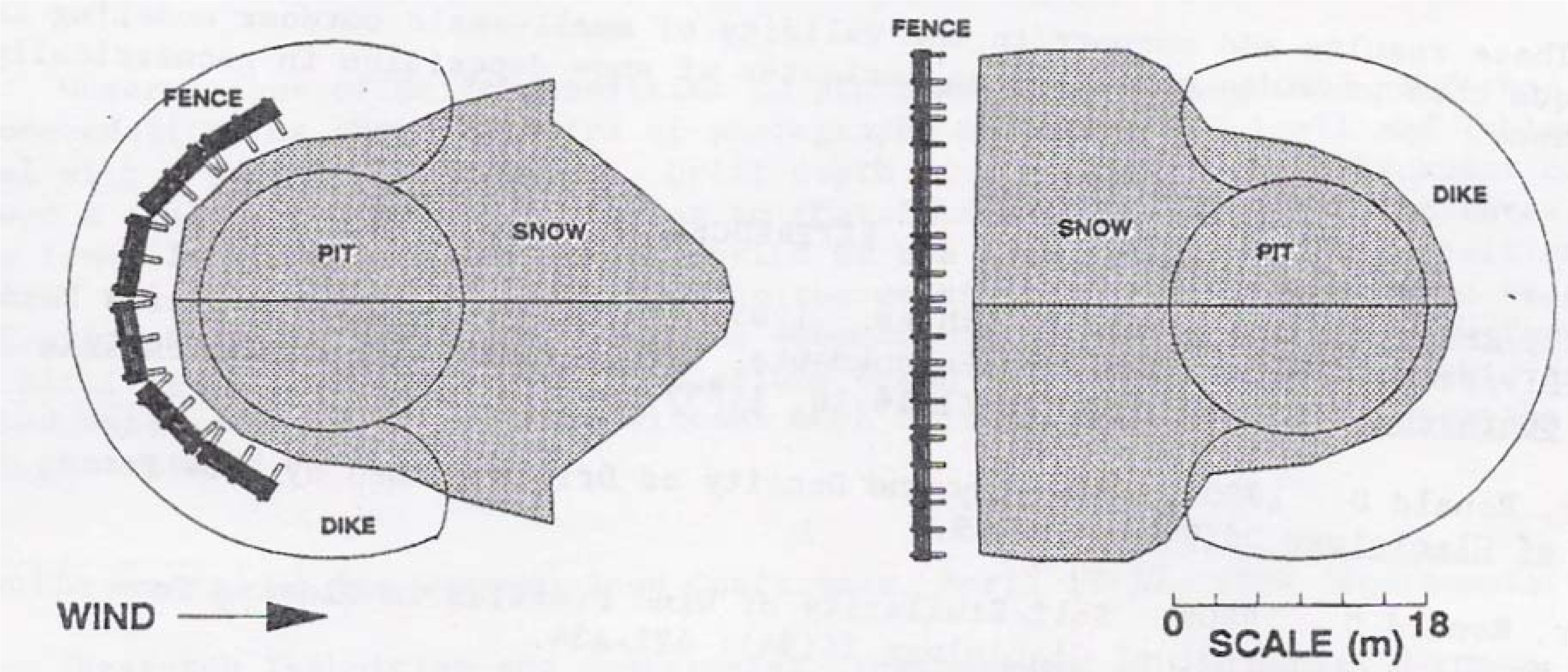
Accumulating Snow to Augment Water Supply in Barrow, 1975

By Slaughter,C. W. ; Mellor,M. ; Sellmann,P. V. ; Brown,J. ; Brown,L., 1975. CRREL, Hannover, Special report.

- The ability to accomplish increased snow deposition by fencing was clearly demonstrated
- There remains a question of optimal snow fence location and number of fences
- Recommendation to concentrate a drift adjacent to stream channel

Design of Reservoirs and Snow Fences

By Robert Jairell and Ronald Tabler, 53th Western Snow Conference, 1985 and Robert Jairell and R.A. Schmidt, 58th Western Snow Conference, 1990

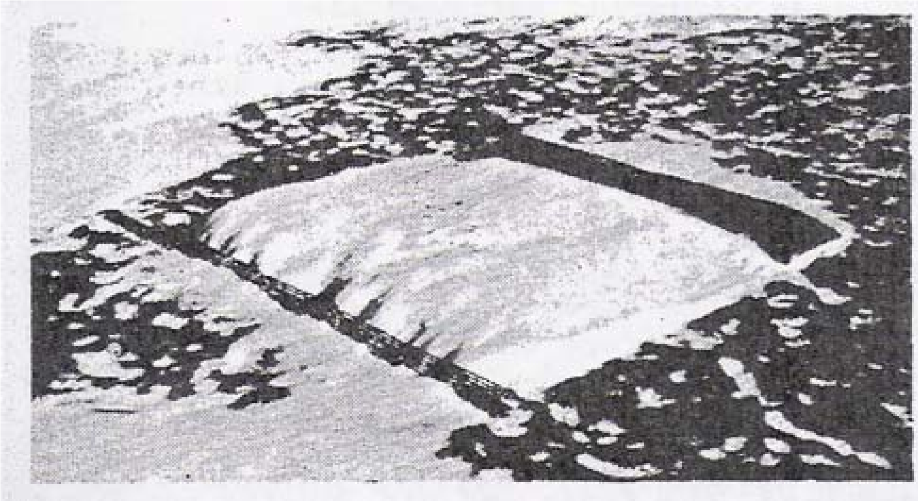


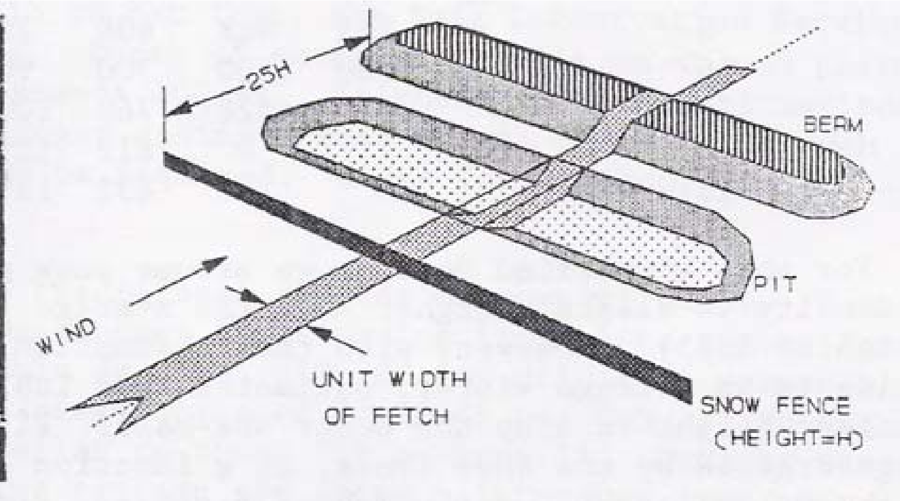
Snow Fence on dike upwind of pond

Snow Fence upwind of pond and dike

Design of Reservoirs and Snow Fences

By Robert Jairell and R.A. Schmidt, 60th Western Snow Conference, 1992



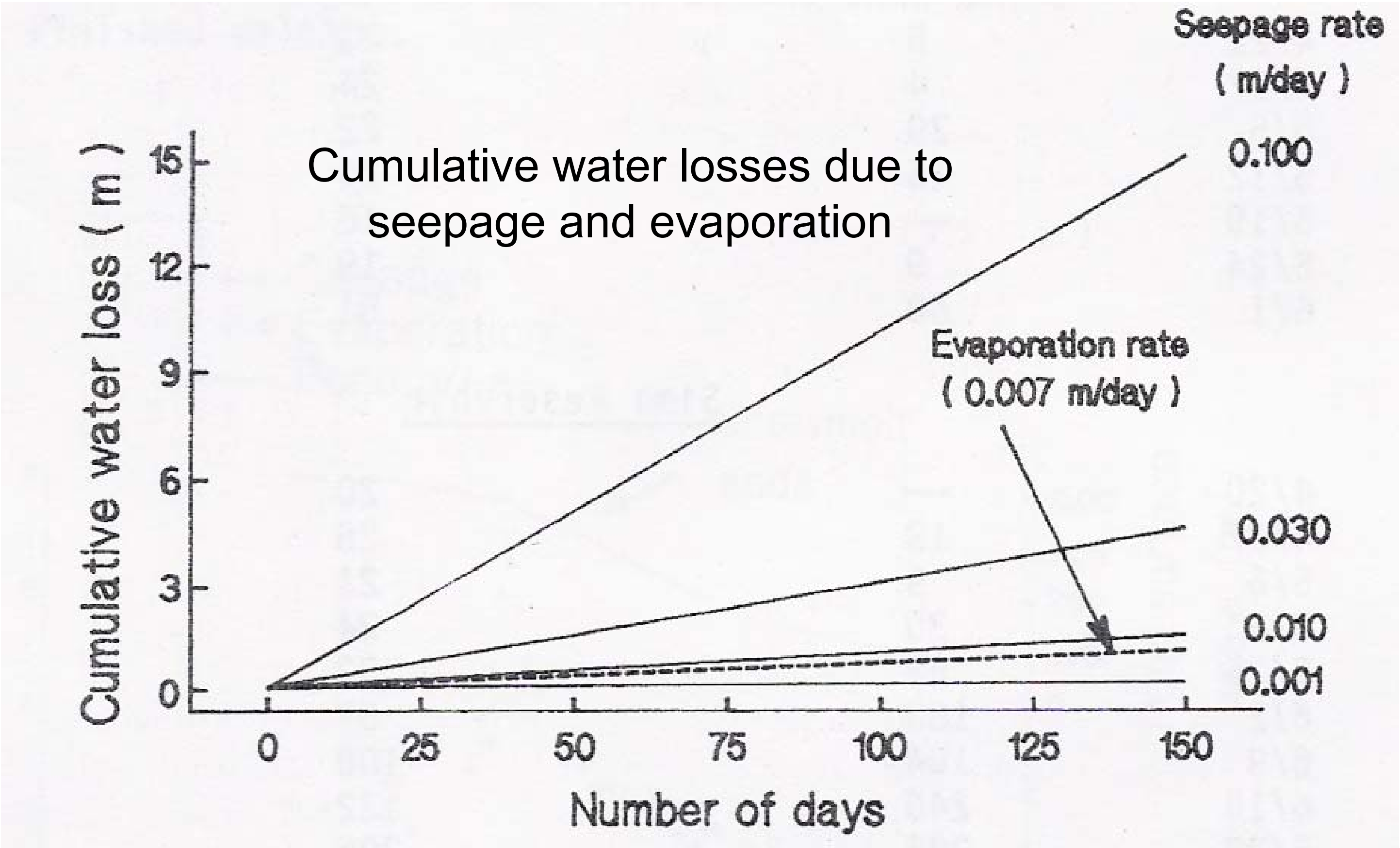


A 1:30 scale model of the snow fence-pit-berm combination

The combination that maximizes snow drift storage

“Snow fence may deposit a large quantities of snow, but the reservoir is often dry by the time water is needed.”

By David Sturges, 57th Western Snow Conference, 1989



What are the recognized obstacles for delivering snow drift water to the reservoir on the coastal plain?

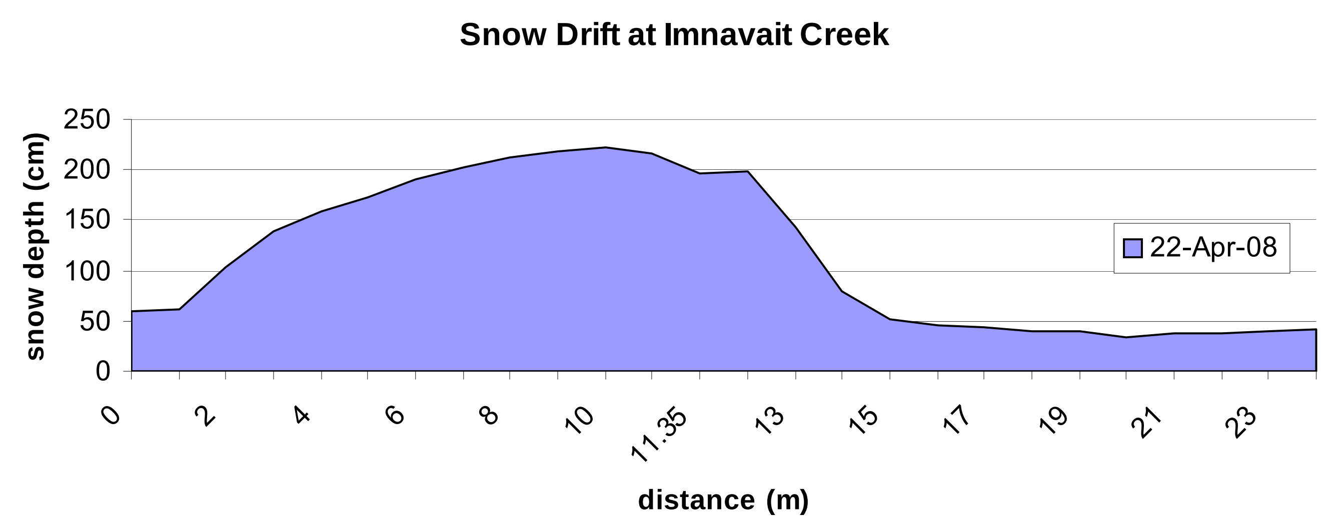
- Low gradient terrain - water stays where it melts and evapotranspirates during the summer
- Evaporation from the reservoir surface
- Seepage loss – in some cases water moves through continuous permafrost (i.e. talik zone)

OBJECTIVES

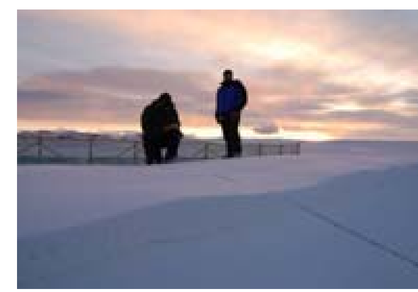
1) Enhance snow drift formation in the area surrounding water source
2) Assess the effects of artificial barriers on 'new' water available due to reduced sublimation losses from blowing particles
3) Find optimum location for the snow drift to ensure that melt water reaches the reservoir
4) Assess the reservoir-volume net increase and the cost of additional water

OBJECTIVE 1

Enhance snow drift formation in the area surrounding water source.

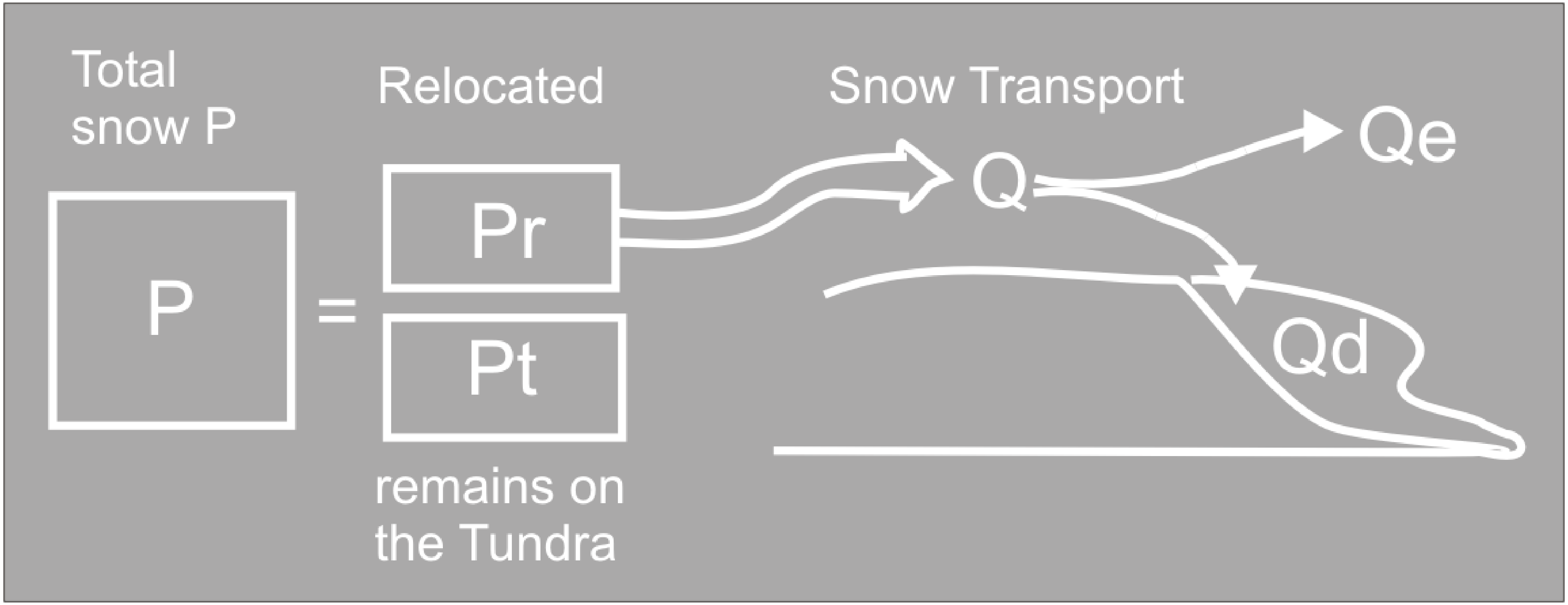


Drift volume is 8 tonnes of SWE or 27.8 cubic m of snow per 1m of snow drift



OBJECTIVE 2

Assess the effects of artificial barriers on 'new' water available due to reduced sublimation losses from blowing particles.



“Reassessment of winter precipitation on Alaska’s Arctic” by Carl Benson, 1982

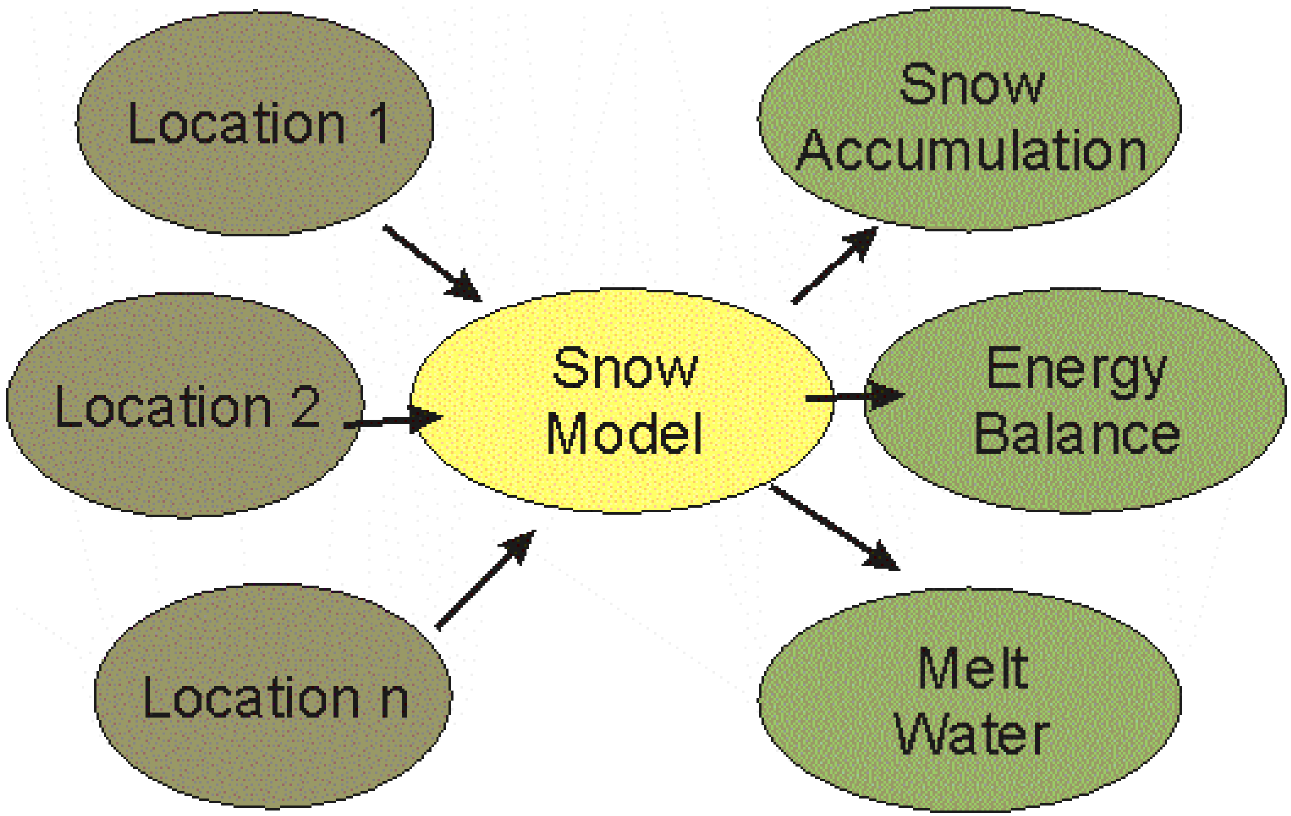
Sublimation in Arctic, literature review

Location	Sublimationmin (S, mm/yr)	Sublimationmax (S, mm/yr)	Precipitation (P, mm/yr)	Min S/P (%)	Max S/P (%)	Source
Tiksi (tundra)	33	96				Hirashima et al., 2004
Yakutsk (tundra)	12		74	16		Pavlov, 1984
Kuparuk Basin	0	47	140	0	34	Bowling et al., 2004
Kuparuk Basin	20	95	180	18	50	Liston and Sturm, 2004
Western Canada				15	40	Woo et al., 2000

Courtesy of Anna Wagner and Mathew Sturm, CRREL

OBJECTIVE 3

Find optimum location for the snow drift to ensure that melt water reaches the reservoir.



OBJECTIVE 4

Assess the reservoir-volume net increase and the cost of additional water.

Coast of installation /
Reservoir-volume net increase

=

Coast of additional water

WORK TO BE PERFORMED

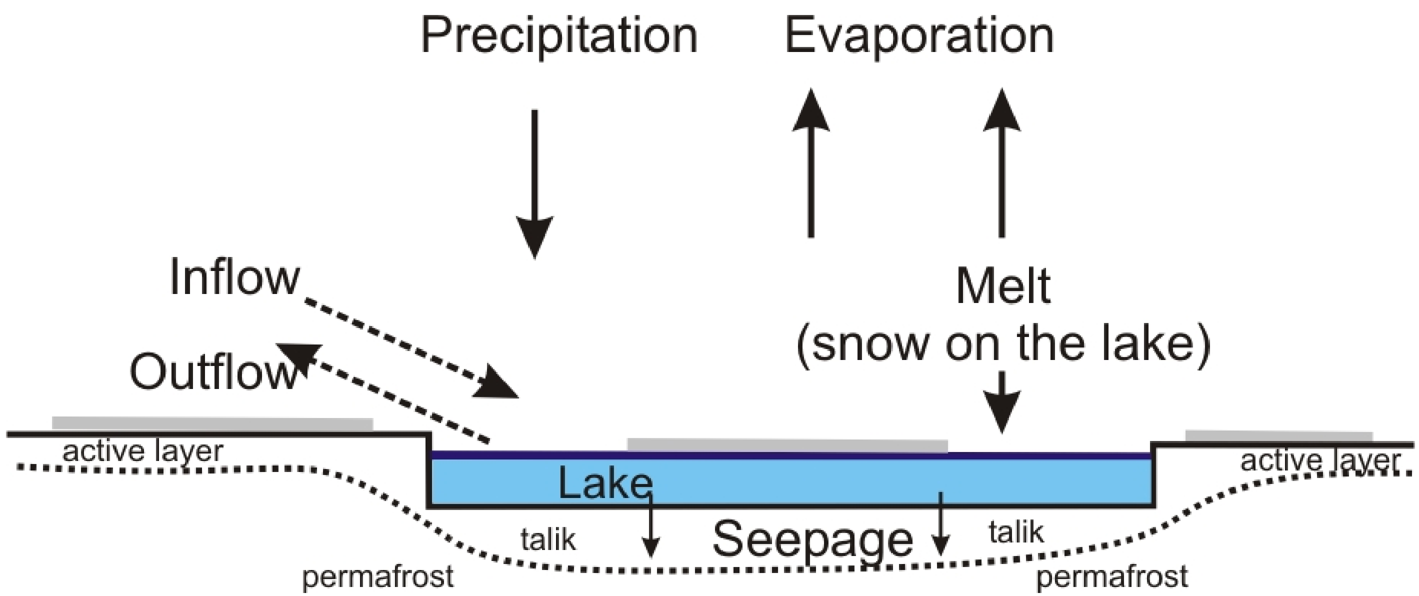
- Estimation of Pretreatment Water Balance
- Artificial Barrier Design and Location
- Assessment of Hydrologic Response
- Assessment of Environmental Impact
- Feasibility Study

Pretreatment Water Balance

$P = Q + E + \Delta S$

$V_t = V_{t-1}$ + Inflow + P – Outflow – E – Seepage

V – water volume in the reservoir, P – precipitation, E – evaporation from the water surface, ET – evapotranspiration, SWE – Snow Water Equivalent



Snowmelt Inflow = SWE – Storage – ET

Summer Inflow = R – Storage - ET

Snow Water Equivalent (SWE)

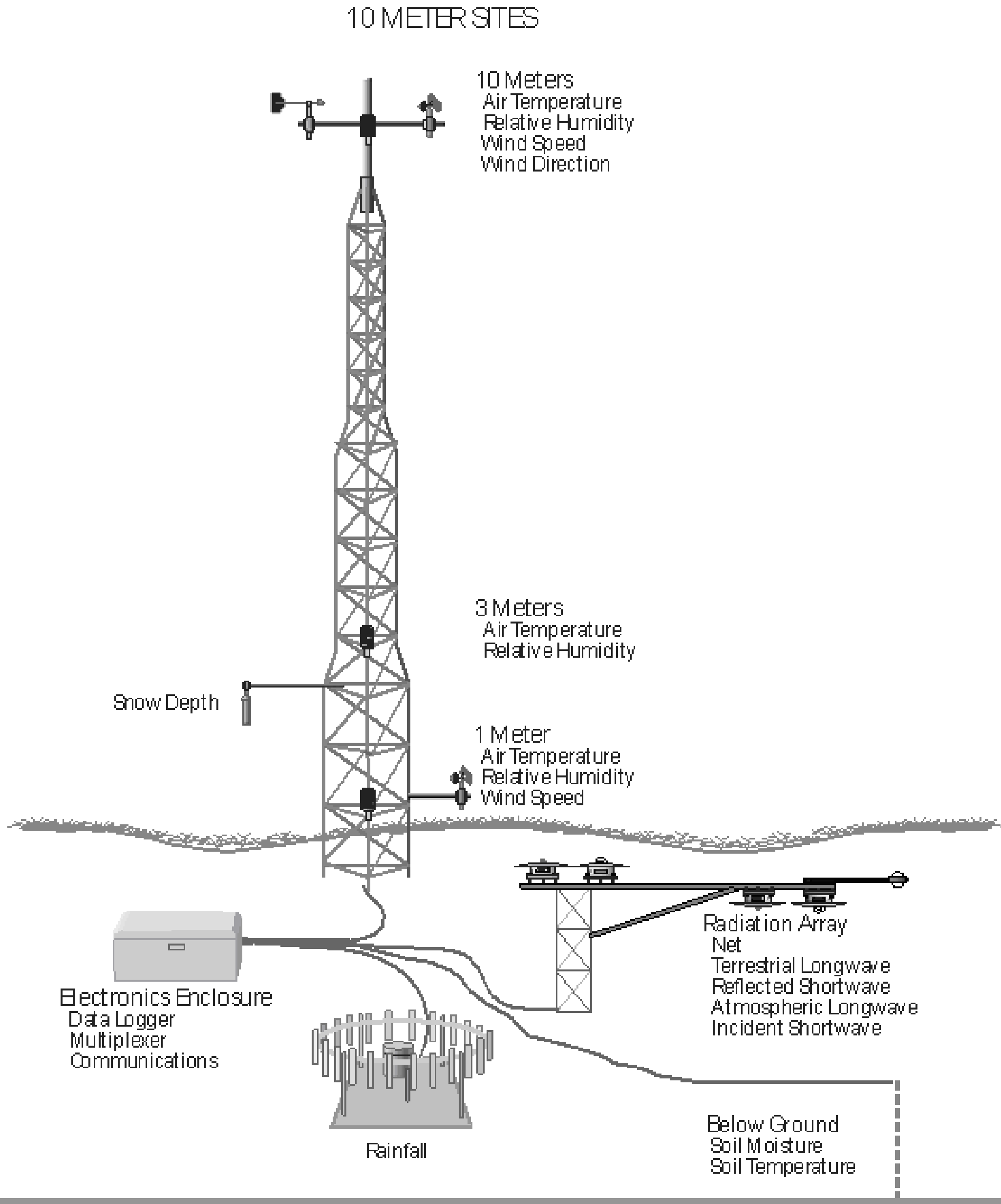
Snowmelt Inflow = SWE – Storage – ET

Field work: End-of-winter snow survey and snowmelt

Pretreatment Water Balance

Summer Inflow =

P – Storage - ET

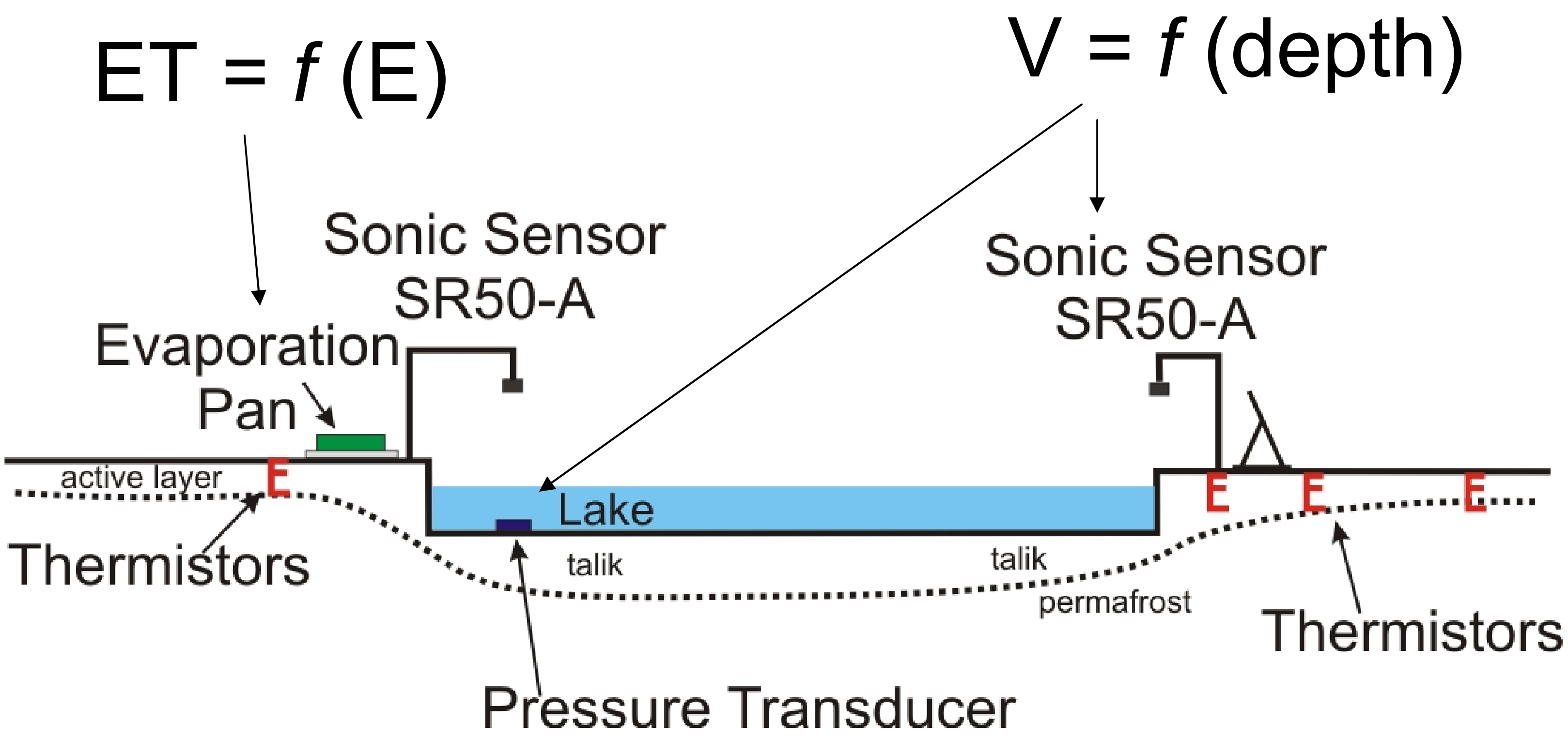


Weather stations through NSF Arctic Observing Network project:

Long-term observations in the Kuparuk River Basin.

PI Douglas L. Kane

Pretreatment Water Balance



$$V_t - (V_{t-1} + \text{Inflow} + \text{Rain} - \text{Outflow} - \text{Evap}) = \text{Seepage} + \text{Error}$$

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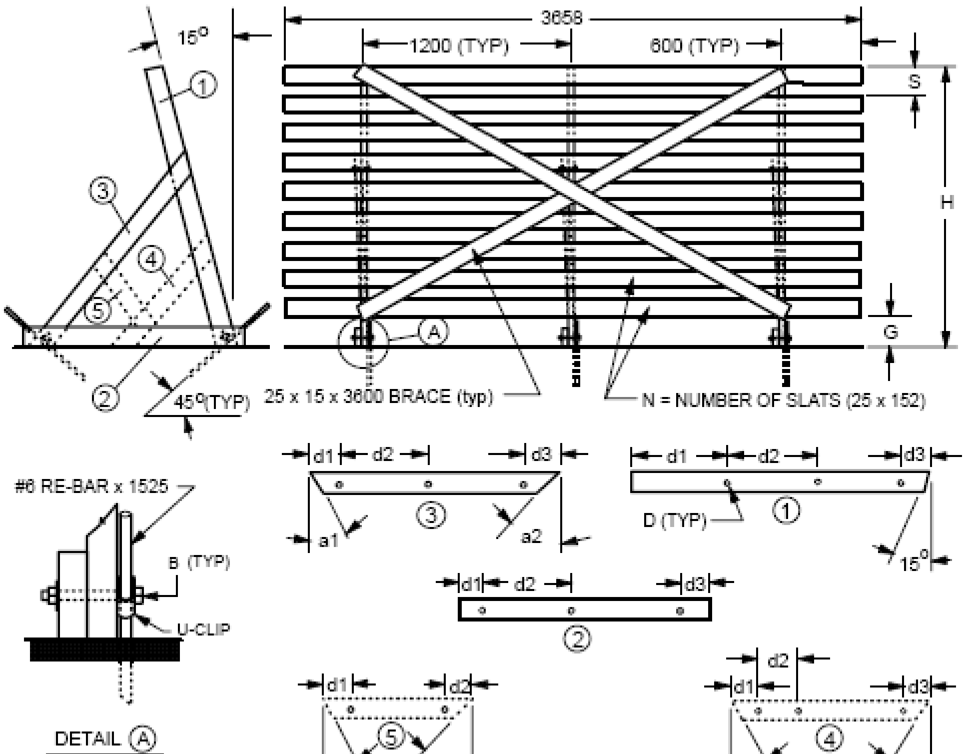
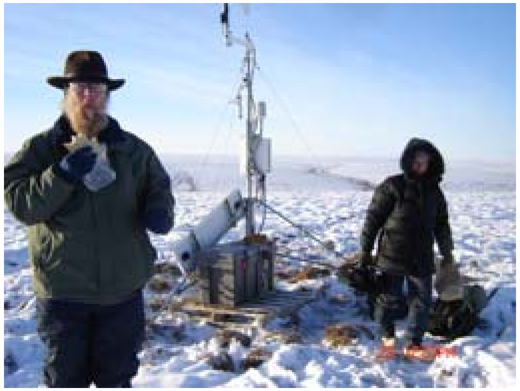
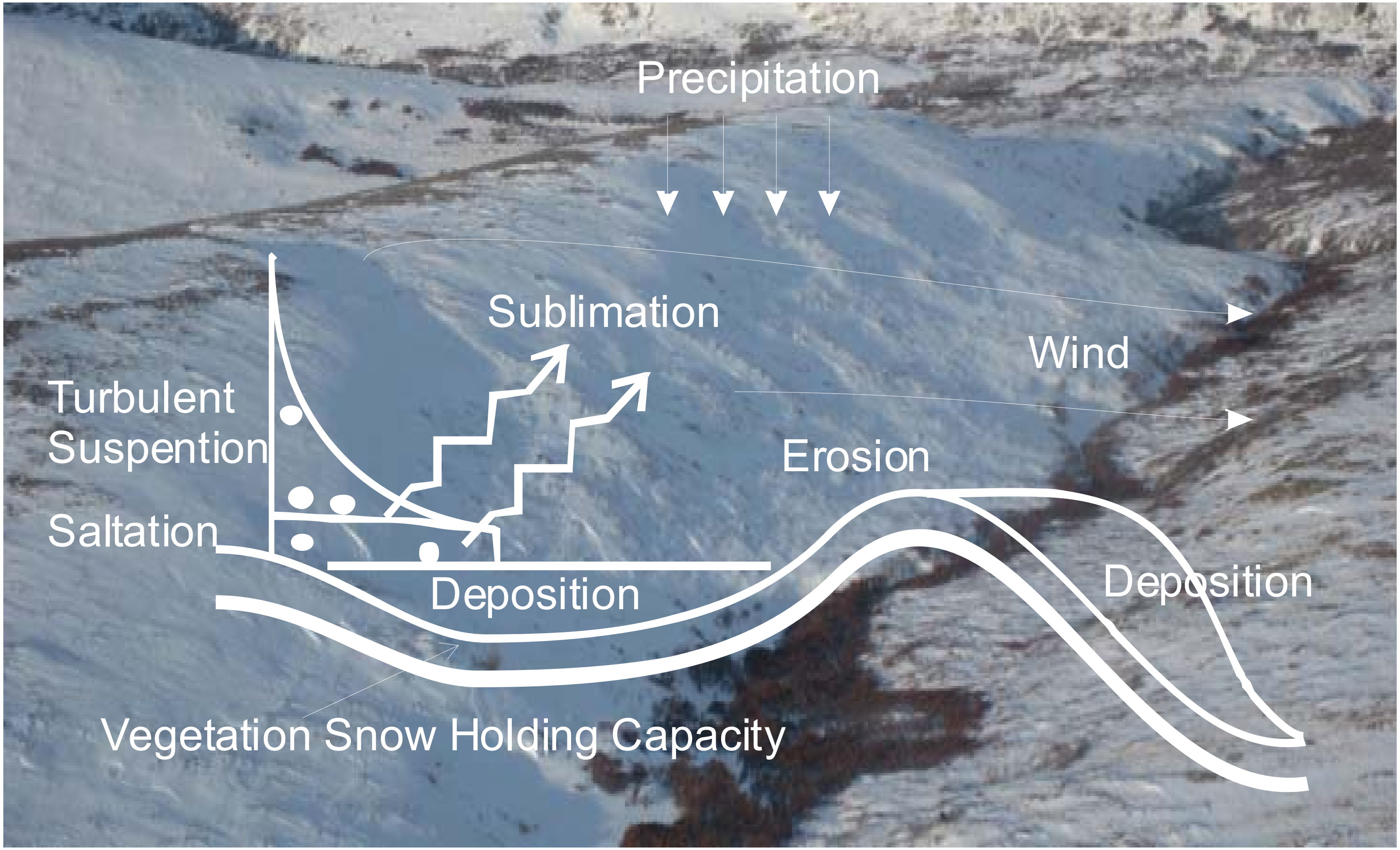
Artificial Barrier Design





Tabler R.D., 1994. Design Guidelines for the Control of Blowing and Drifting Snow.

Artificial Barrier Location: SnowModel

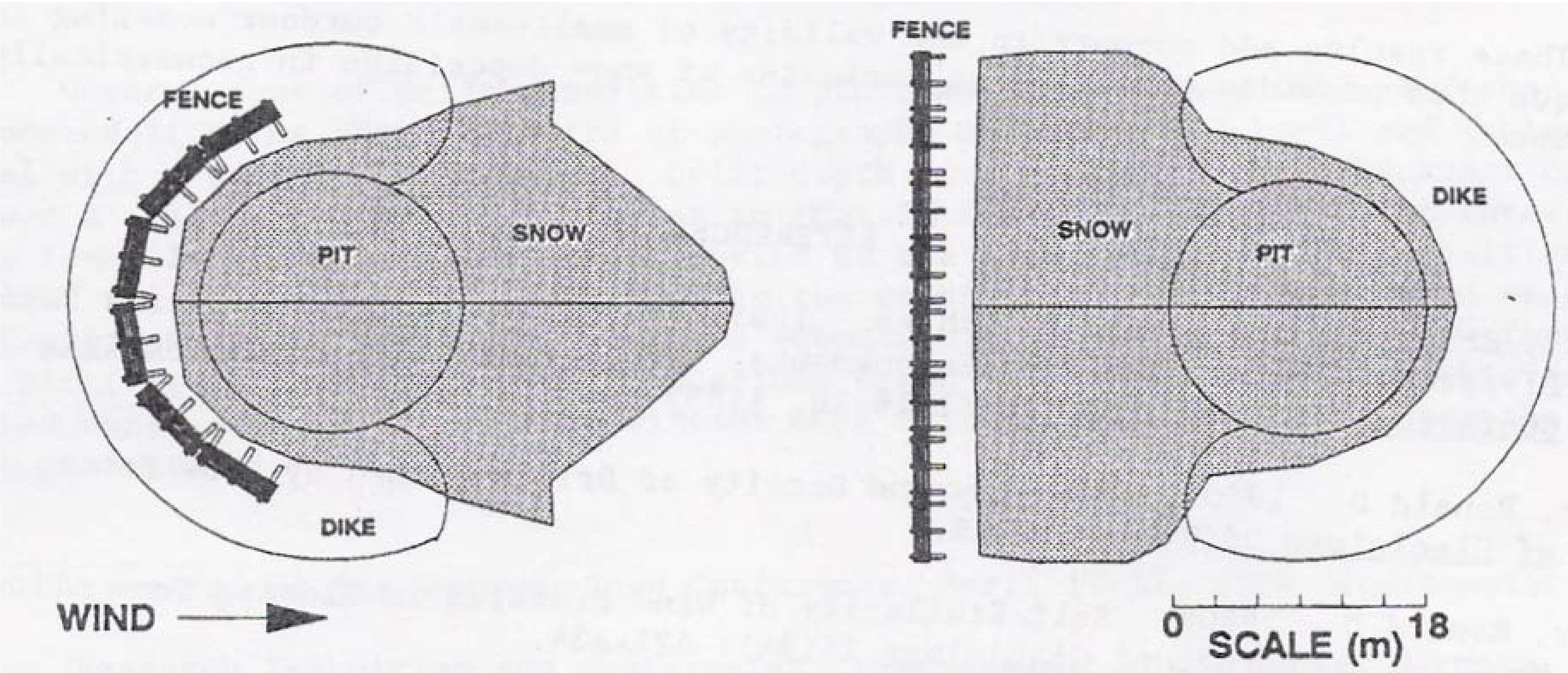


Liston and Sturm (1998), J,Glaciology, 44, 498-516; Liston et al (2007) J,Glaciology

Artificial Barrier Location: SnowModel

Implementation using approach suggested

By Robert Jairell and Ronald Tabler, 53th Western Snow Conference, 1985
and Robert Jairell and R.A. Schmidt, 58th Western Snow Conference, 1990



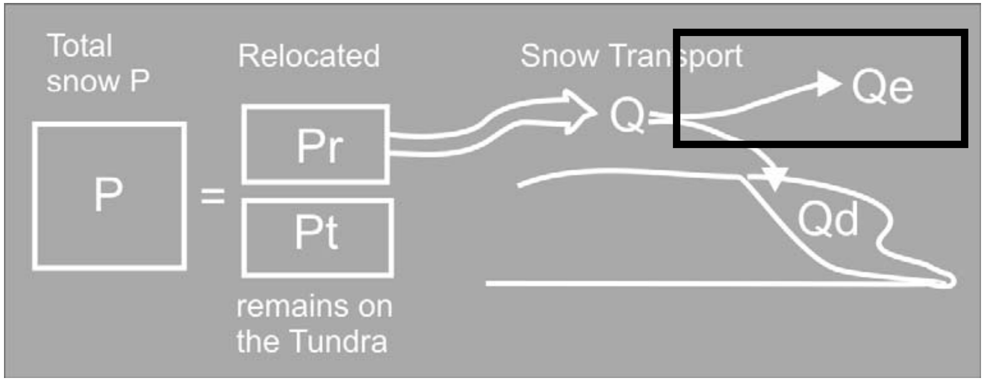
Snow Fence on dike upwind of pond

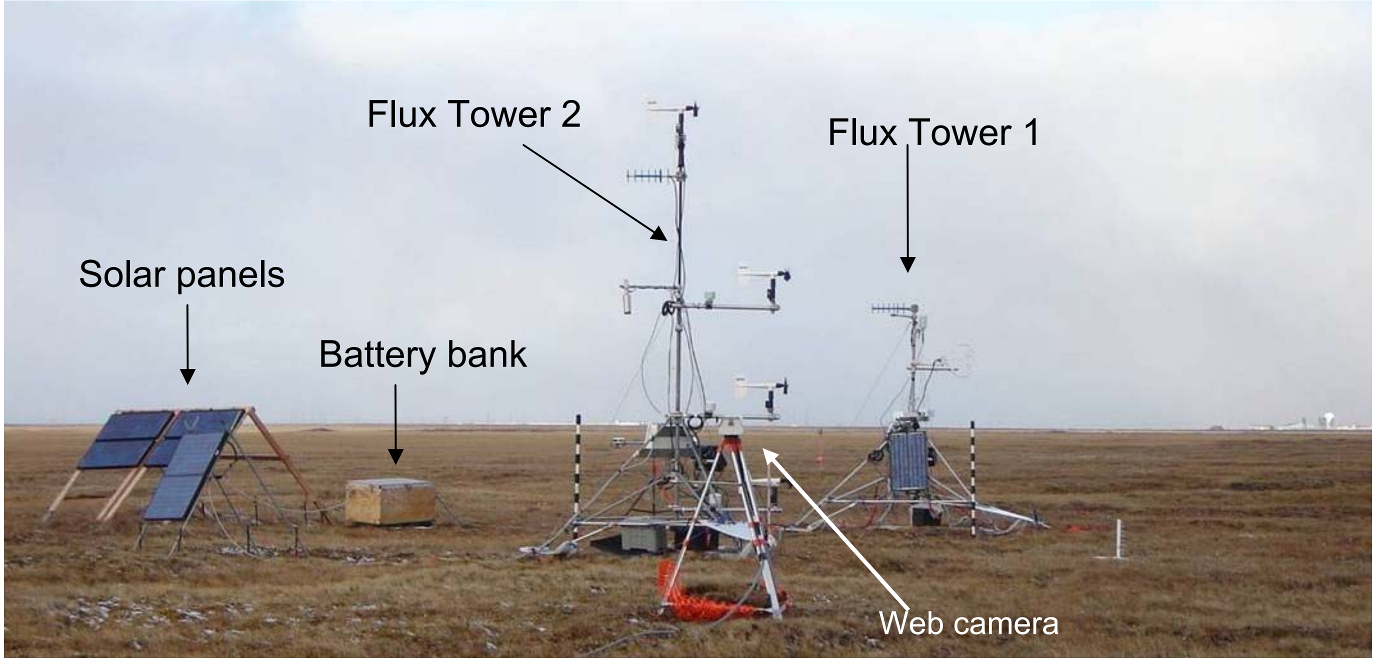
Snow Fence upwind of pond and dike

SnowNet Barrow Instrumentation: Sublimation

Flux Tower 1
eddy covariance method

Flux Tower 2
aerodynamic method





(Box and Steffen, 2001; Stull 1988)

Photo by Art Gelwin

WORK TO BE PERFORMED

- Estimation of Pretreatment Water Balance
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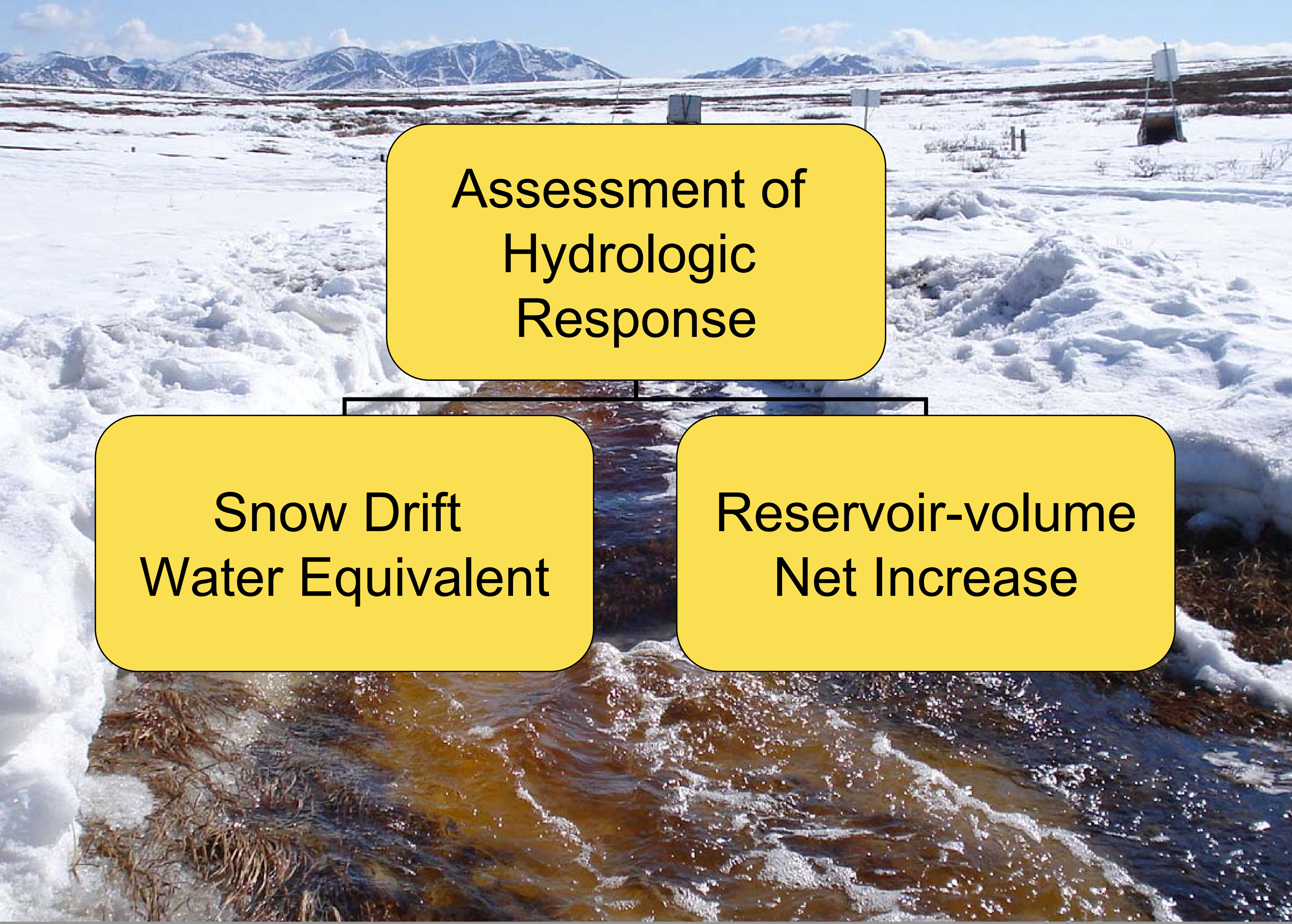
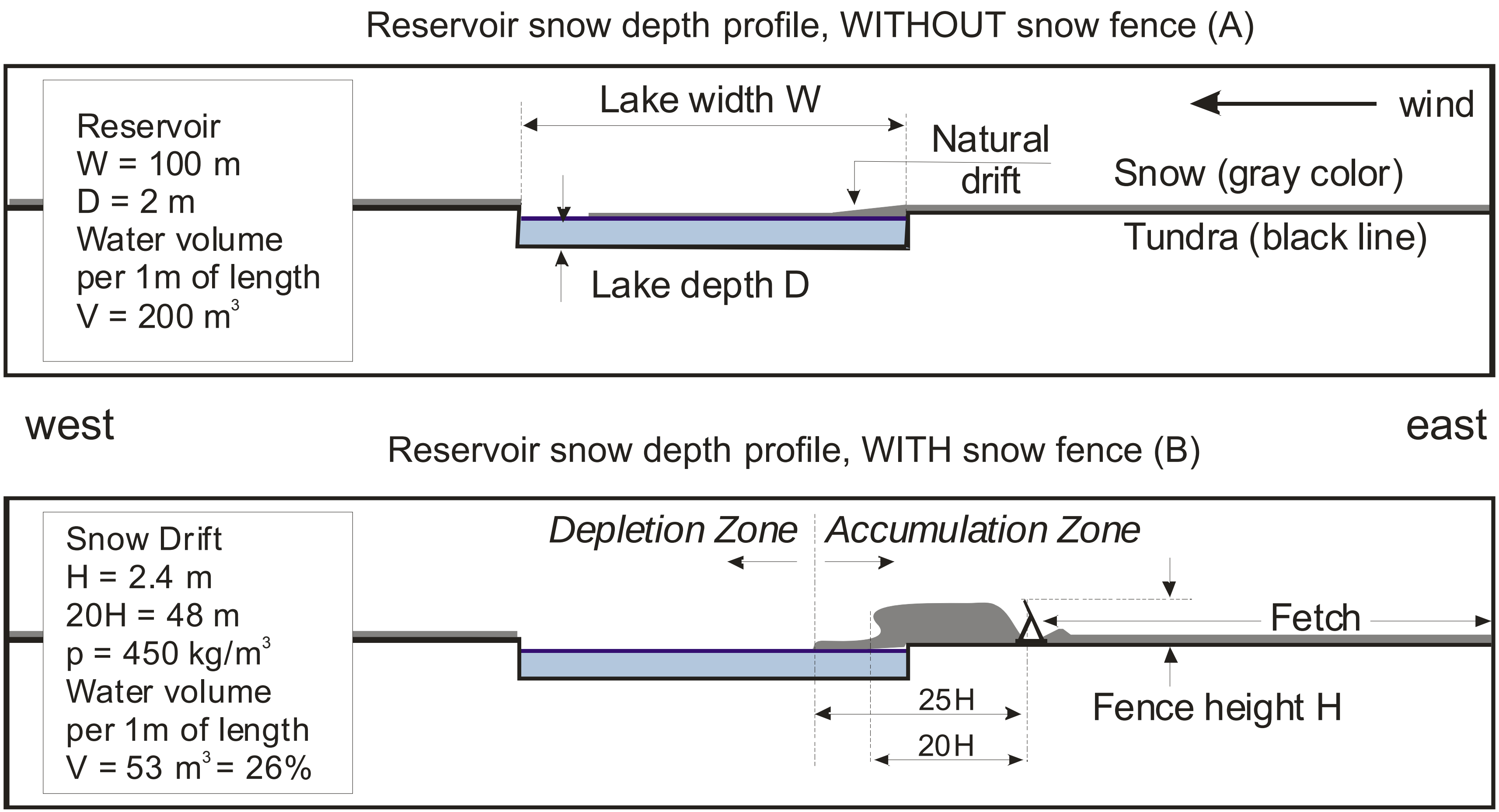
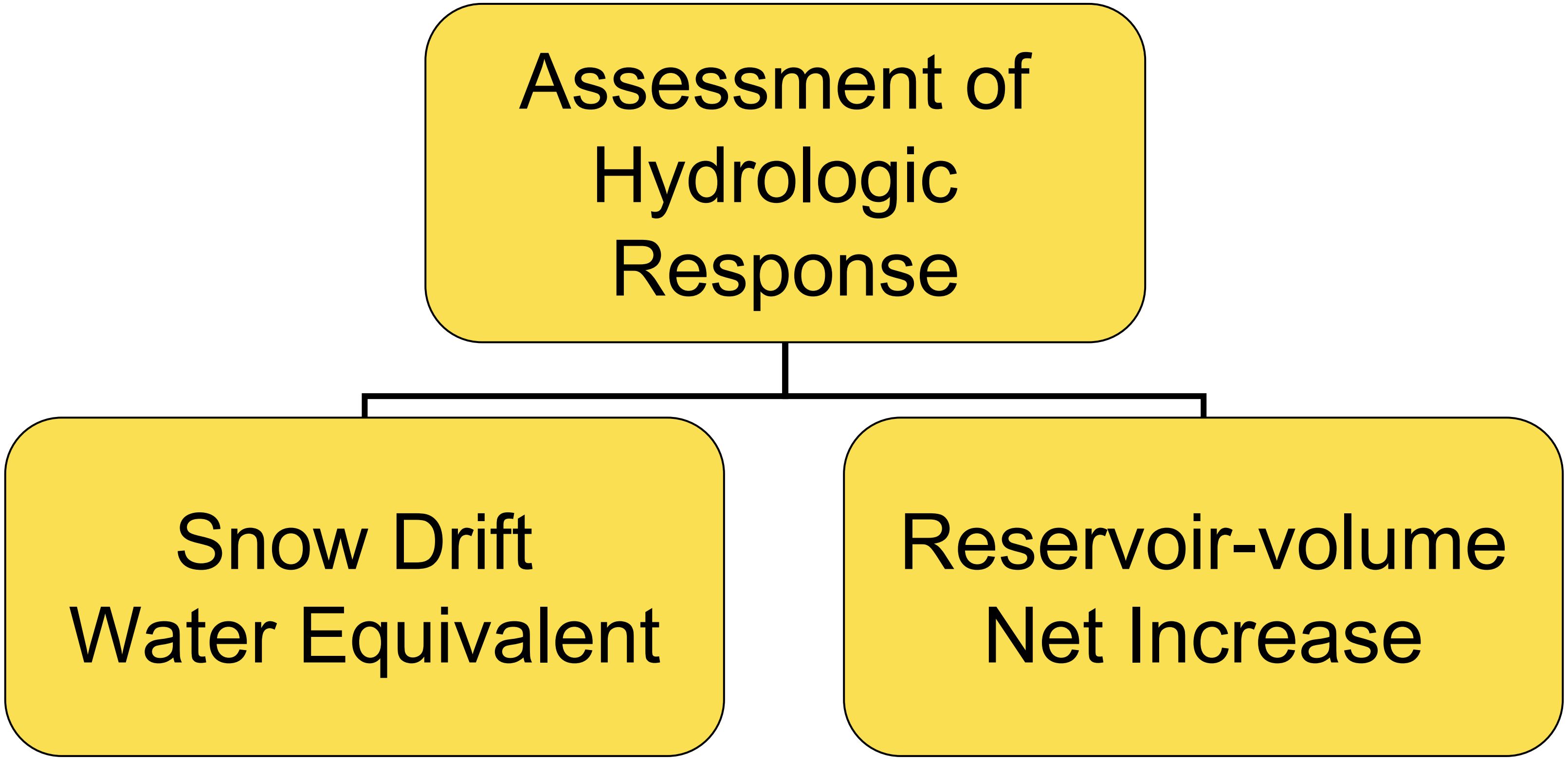
- Assessment of Hydrologic Response
- Assessment of Environmental Impact
- Feasibility Study


Assessment of Hydrologic Response
Snow Drift Water Equivalent
Reservoir-volume Net Increase

Snow Drift Water Equivalent





$$V_{net\_increase} = V_{with\_drift} - V_{without\_drift}$$

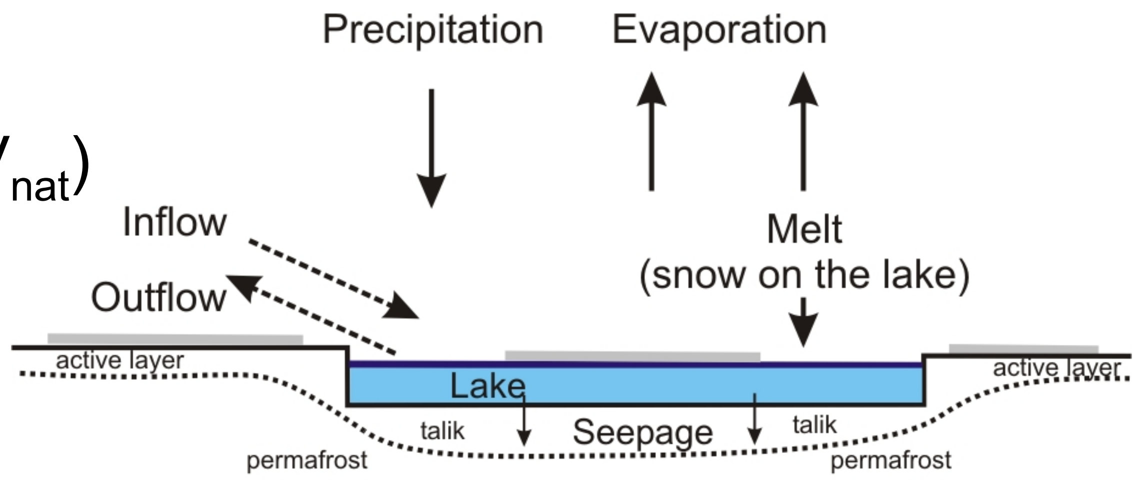
$$V = f\,(\text{Inflow, Rain, Outflow, ET})$$

How to find reservoir volume without drift?

Experimental and Natural Reservoirs

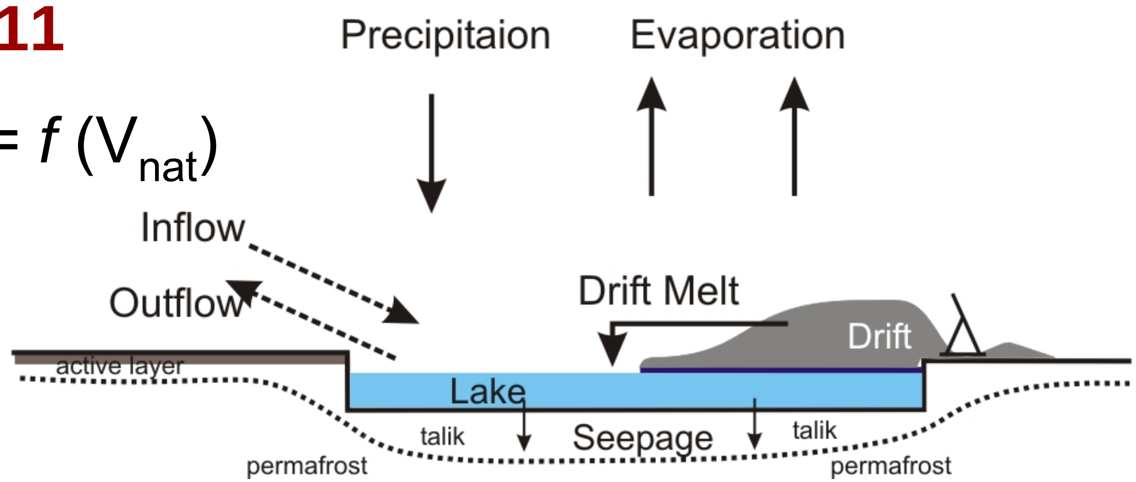
2009

$$V_{exp} = f\,(V_{nat})$$



2010, 2011

$$V_{without\_drift} = f\,(V_{nat})$$



$$V_{net\_increase} = V_{with\_drift} - V_{without\_drift}$$

WORK TO BE PERFORMED

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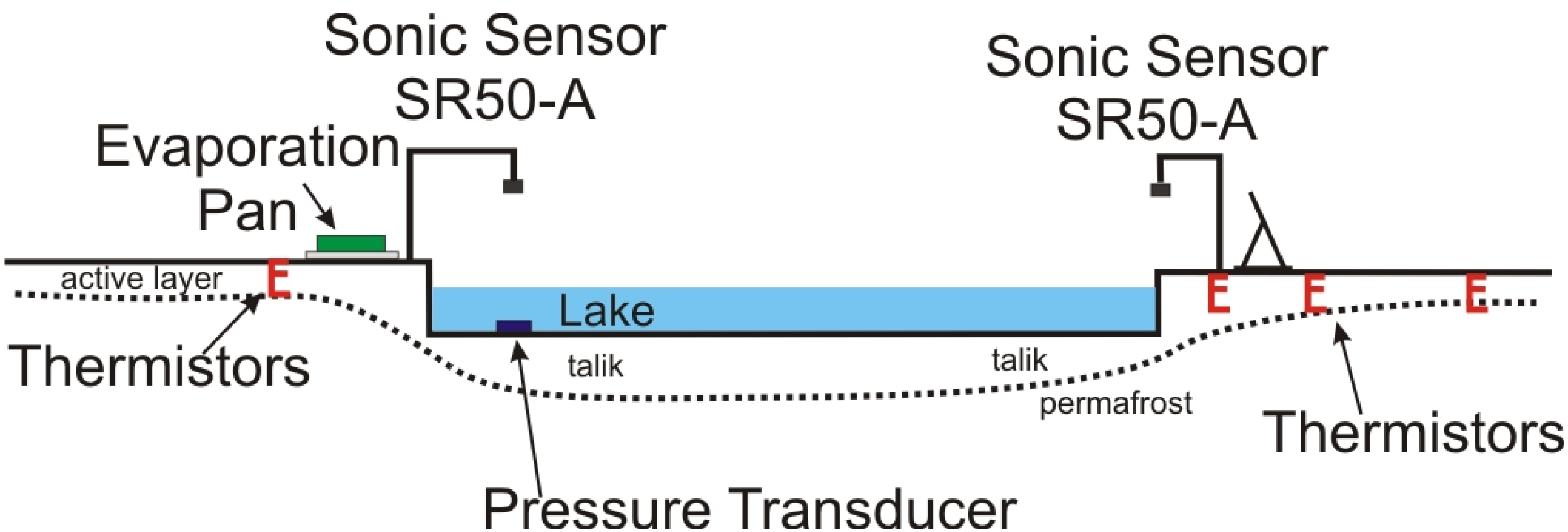
Assessment of Environmental Impact



WORK TO BE PERFORMED

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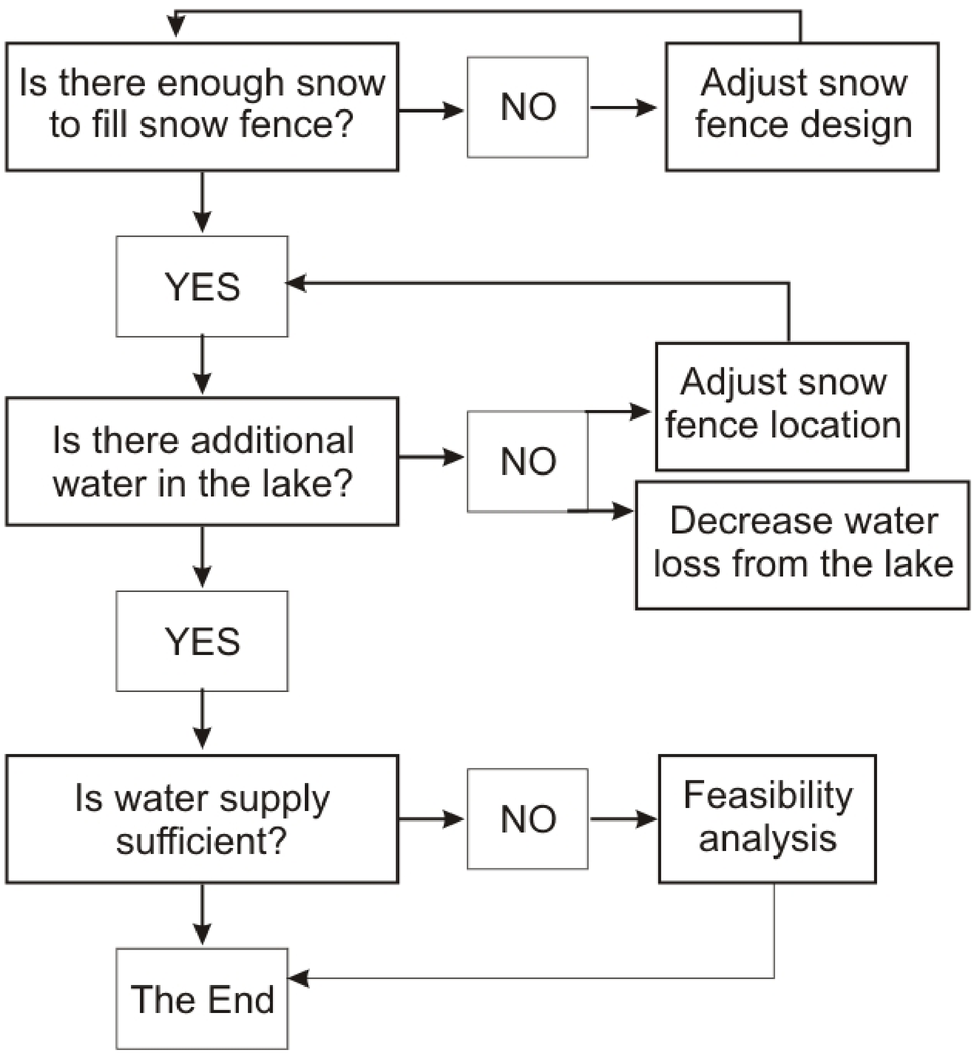
Feasibility Study

1. Cost of additional water

2. Practical recommendations on using snow fences for ANS water resources management



Expected impacts

- creating 'new' water by reducing sublimation losses from blowing particles
- prolonging snowmelt runoff due to increased snow depth
- lowering the costs for additional water by recharging a local source

Expected impacts

- applications of the depletion zone of the snow fence could be to enhance frost penetration
- accumulation zone of the snow fence could increase initial snow accumulation for the road
- our data will be available to committee decision makers and researchers

Schedule

Theoretical preparation

Practical Solutions

Interpretations

Feasibility

Pretreatment water balance

Assessment of Hydrologic Response

Snow Fence Design and Location

Environmental impact

SnowModel sensitivity simulations to define optimum snow fence location	Stage relationship between control and experimental lakes	Snow fencing effect on partitioning of the lake water balance, increased duration of snow melt recharge and 'net' lake-volume change.	Assessment of impact on land cover and permafrost	Cost of additional water

Field work

Field work

Field work

2009				***2010***				***2011***			
Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec

MILESTONES

Milestone		Initiation Date	Completion Date
YEAR 1 We are planning to allocate experimental and control reservoir (1), provide recommendation on optimum snow fence location (2) and set-up observational program (3, 4).			
1	Allocate experimental and control reservoir. To evaluate changes in experimental , the control and experimental lakes have to have similar natural water balances.	October 1st, 2008	April 1st, 2009
2	Run SnowModel sensitivity simulation to define prime snow fence location.	January 1st, 2009	August 31st , 2009
3	Initiate spring melt observational program, which includes work in the field to measure end-of-winter snow survey and snowpack ablation (April-May, 2009). First year data would reflect natural conditions for experimental lake.	April 20th, 2009	June 30th, 2009
4	Purchase, test and install instrumentation to monitor water balance, soil temperatures and vegetation length at the experimental and control sites. Build snow fence at the experimental lake and install snow depth sensors on the leeward side of the drift.	April 1st, 2009	September 30th, 2009
5	Work with DOE manager on documentation required by DOE to manage the project.	September 1st, 2008	September 30th, 2009


MAY 20, 2008 12:00
MAY 31, 2008 12:00
JUN 06, 2008 12:00
JUN 11, 2008 12:00
JUN 13, 2008 12:00
JUN 15, 2008 12:00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Thank you