NORTHERN MOUNTAIN HYDROLOGY AND CLIMATE CHANGE

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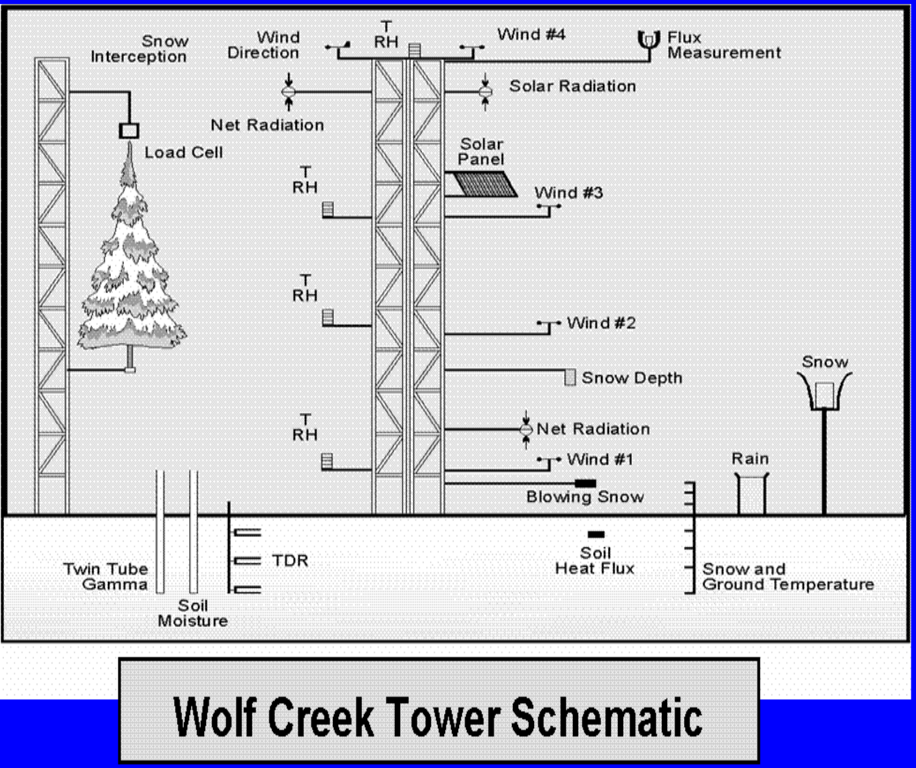
IP3 Final Meeting – Saskatoon, SK – September 7 – 9, 2011

IP3 - OBJECTIVES

- PROCESS
  - Summarize work carried out at Wolf Creek
- PARMERTIZATION
  - Discuss recent modelling initiatives
- PREDICTION
  - Document changes in Yukon hydrologic response to climate warming over the last 3 decades

WOLF CREEK - PROCESS

•Established 1992 for Hydrologic Model Development / Calibration Purposes



•Variable snow storage, redistribution, melt

•Cold soils affecting ET

•Frozen soil infiltration

•Variable permafrost distribution

•Thick organic layers affecting runoff

•Seasonality of energy inputs

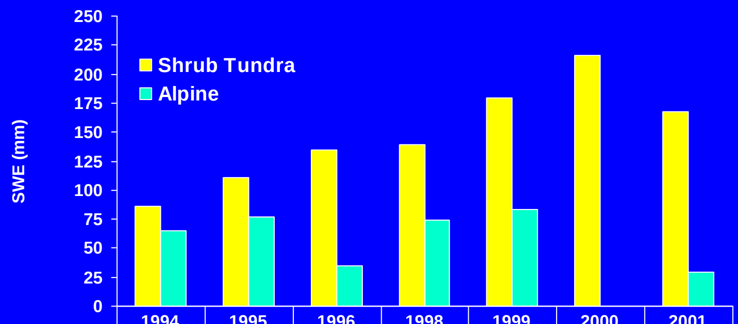
•Poorly defined drainage areas

WOLF CREEK - PROCESS

- IP3 – (CFCAS) Funding (other funding)
- Developed into an Integrated Study of Hydrometeorological Processes and Climate Research

PROCESS STUDIES

Snowpack Accumulation, Redistribution and Melt is Variable

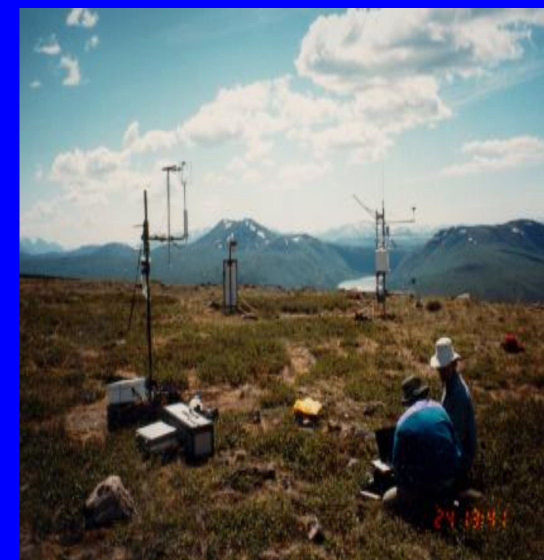


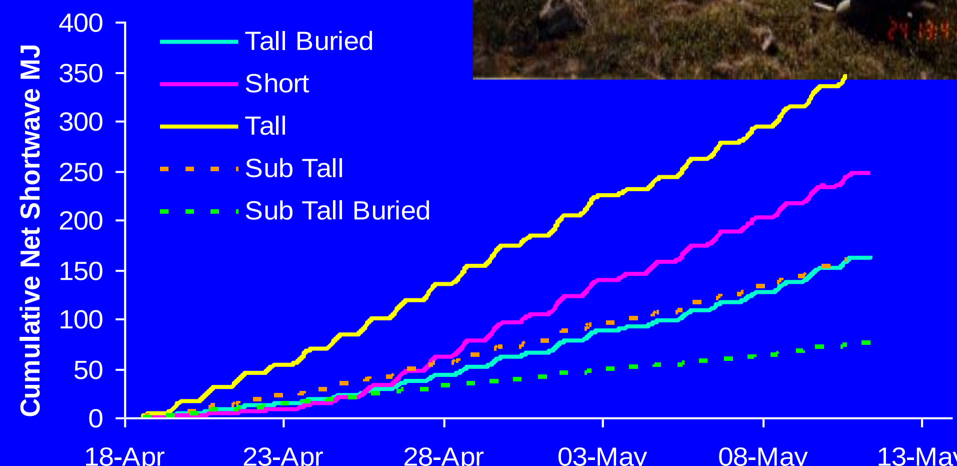
	1994	1995	1996	1998	1999	2000	2001
Shrub Tundra	87	111	134	139	179	216	168
Alpine	65	77	35	74	83		29

- Blowing snow transports 80 % from alpine
- Forest sublimation accounts for 60 % of snowfall
- Snowmelt is 300 % faster in the alpine than forest

PROCESS STUDIES

Evapotranspiration is 150 % Higher in Forest Compared to Alpine





PARAMERIAZATION

Hydrometeorological Process Algorithms Developed / Advanced / Tested

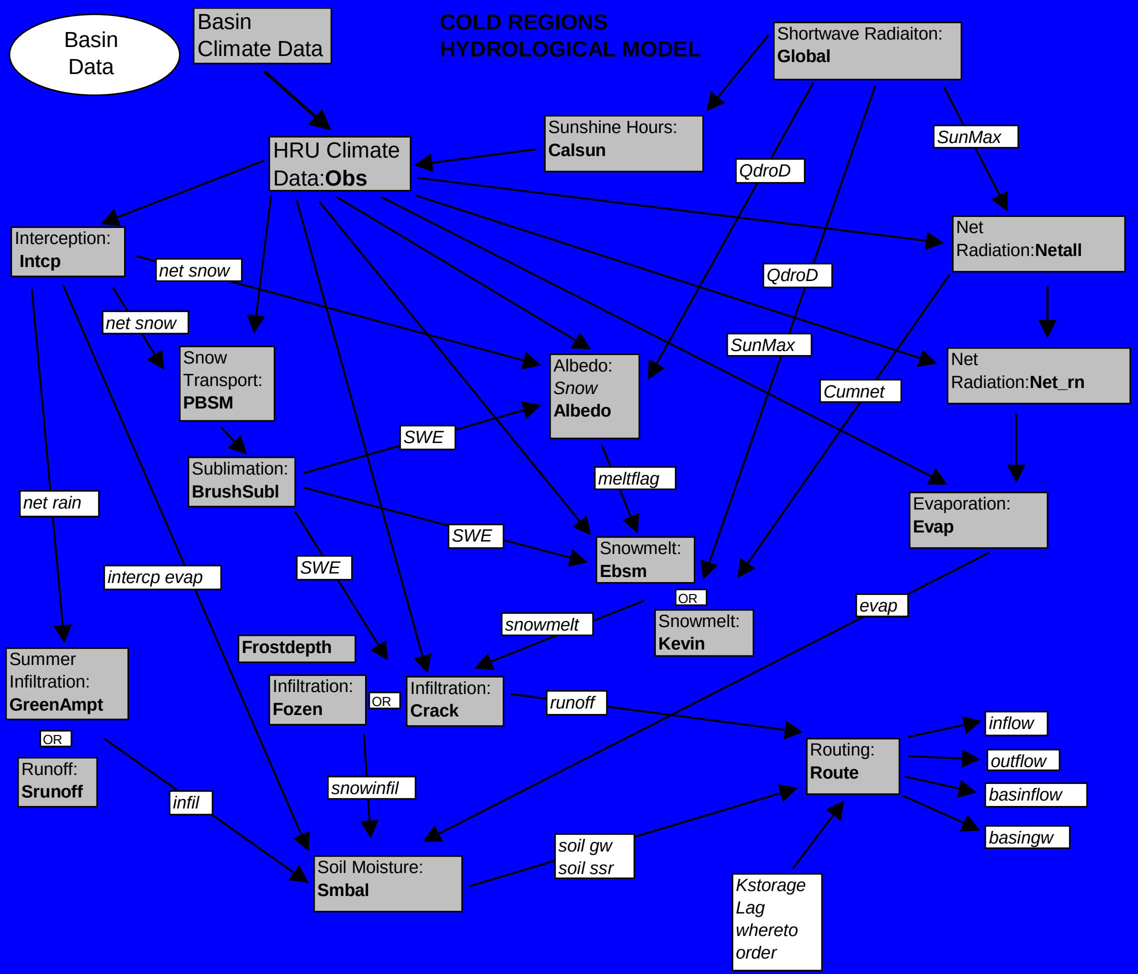
$$W_{sp} = 0.6\phi(1 - S_I)z_w$$

$$INF = C\, S_0^{2.92}\, (1 - S_I)^{1.64} \left(\frac{273.15 - T_I}{273.15} \right)^{-0.45} t_0^{0.44}$$

- **Blowing snow**
- **Sublimation**
- **Interception**
- **Radiation**
- **Evapotranspiration**
- **Infiltration**
- **Snowmelt**
- **Runoff**

PREDICTION

COLD REGIONS HYDROLOGICAL MODEL (CRHM)



ANVIL RANGE MINING CORPORATION
FARO MINE COMPLEX

- SRK Consulting Ltd
- Deloite & Touche
- Could we Transfer Wolf Creek Findings to Faro Waste Rock Dumps to Develop a Water Balance?

INVESTIGATION OF ANVIL RANGE MINING CORPORATION (FARO) WASTE DUMP

WATER BALANCE

Objective: Estimate Waste Rock Dump Recharge Determining Contaminant Seepage

- **Co-Investigators:** Raoul Granger & Newell Hedstrom (NWRI)

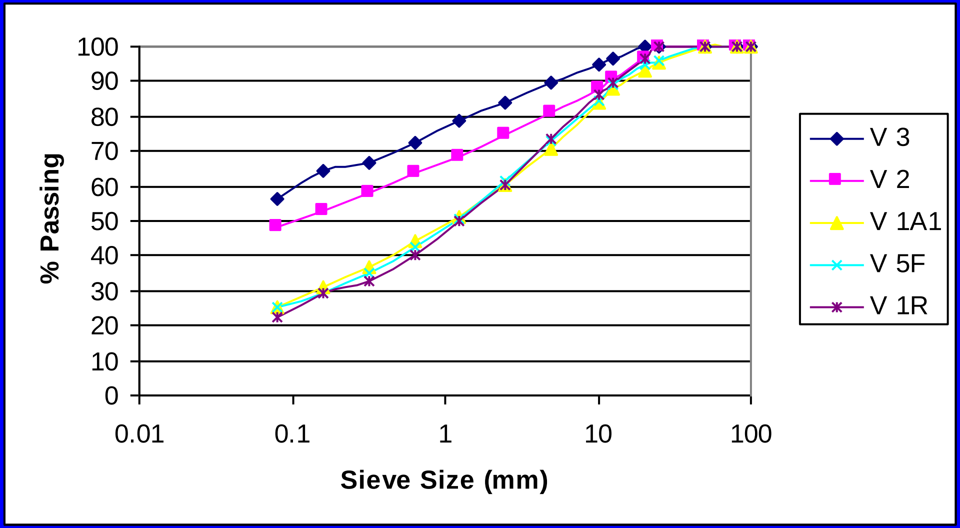
- 4 Year Study
  - Year 1: Develop Water Balance using Transposed Met Data
  - Year 2: Develop Water Balance using Site Meteorological Data
  - Year 3: Develop Estimates for Ave, Dry, Wet Scenario
  - Year 4: Apply Previous Work to Trial Covers

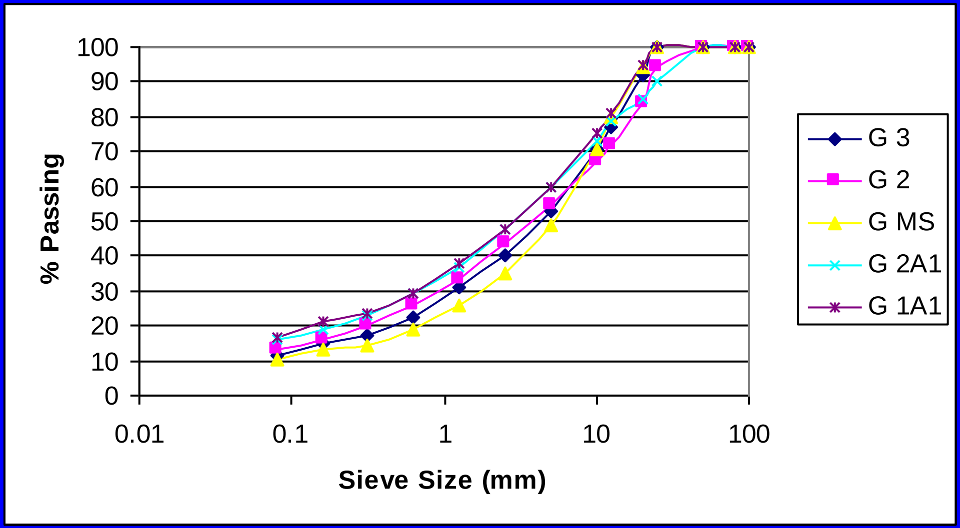
Met Stations

Snow Surveys

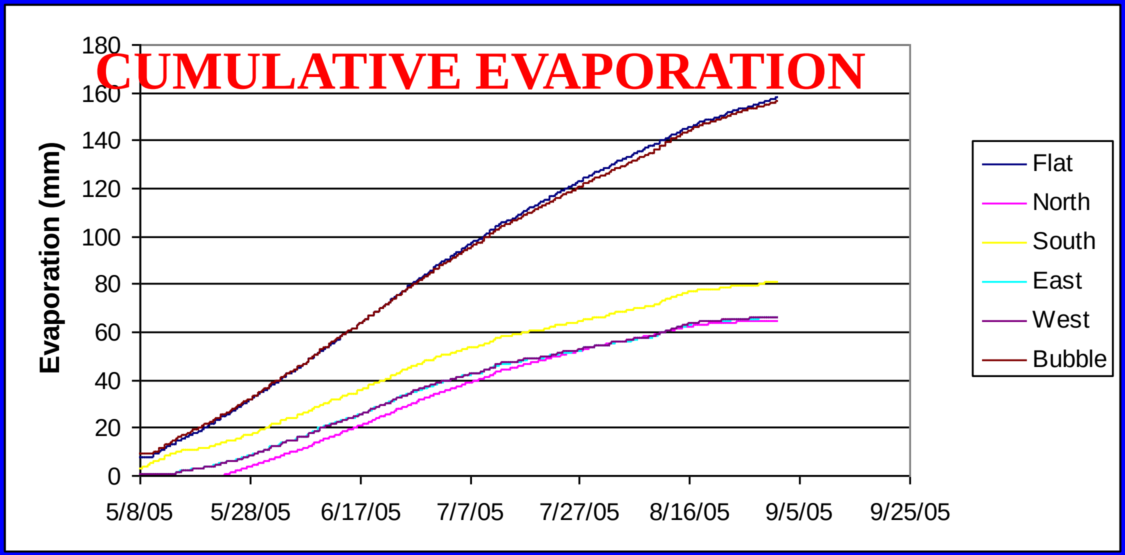
Infiltration Studies

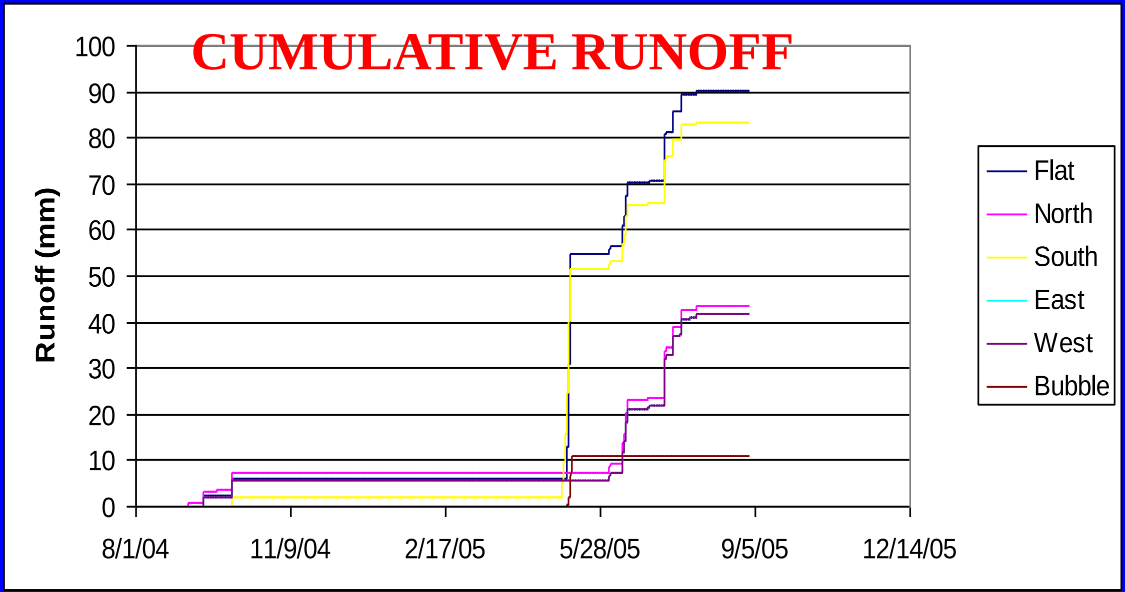
Material Characterization





RESULTS



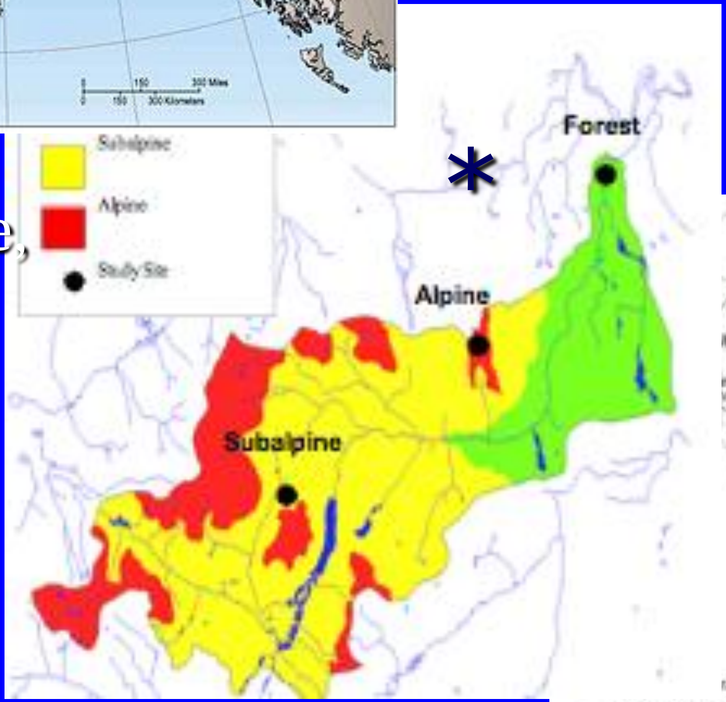


- Infiltration 45-55% precipitation
- Surface runoff 15% precipitation Evaporation 30-40% precipitation

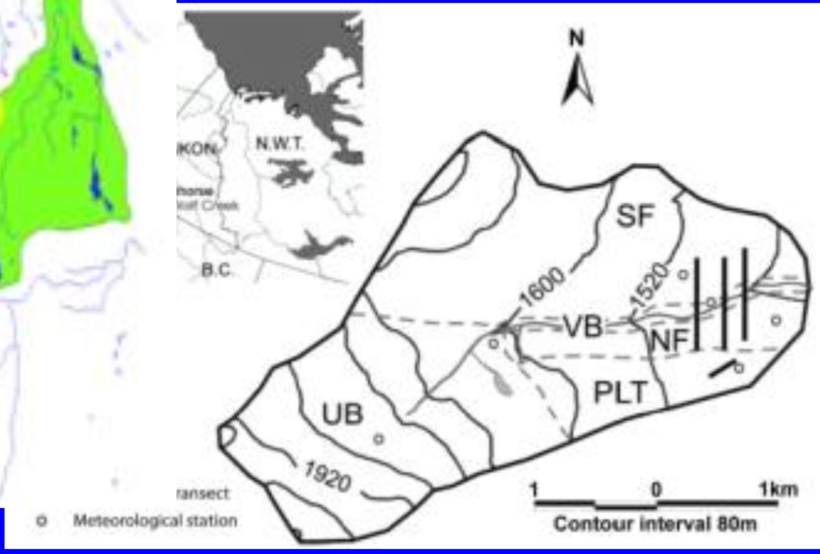
YUKON RIVER UPSCALING

- Environment Canada
- USGS
- Yukon Water Resources
- University of Saskatchewan
- State Hydrologistical Institute – St Petersburg

Yukon River at Eagle, 345 000 km^2

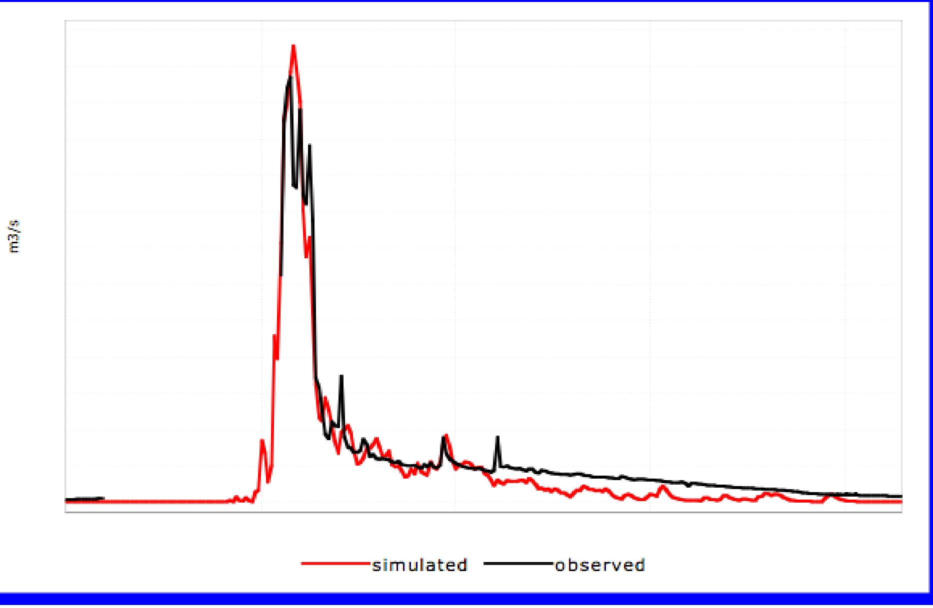


Wolf Creek Research Basin, 195 km^2

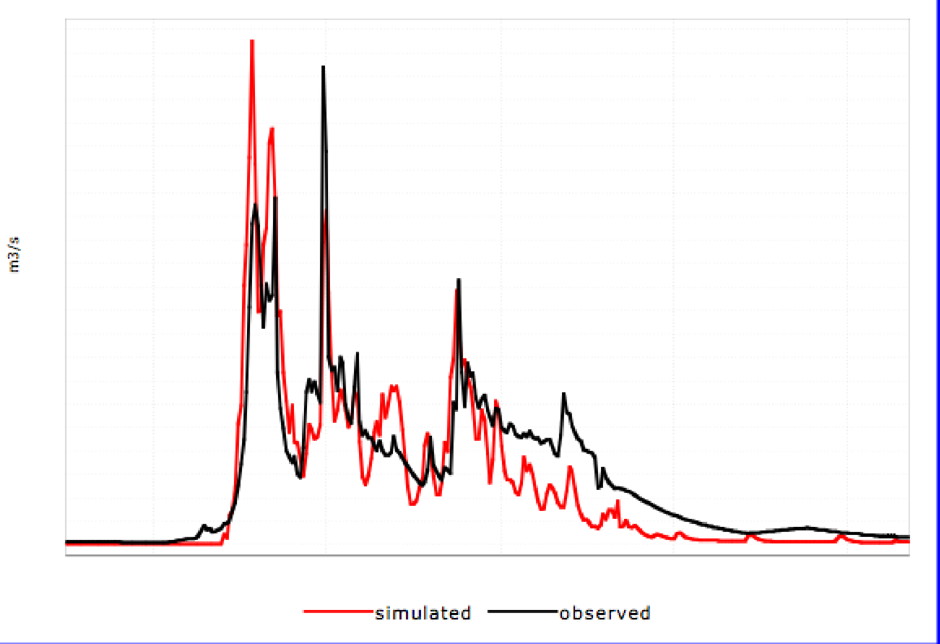


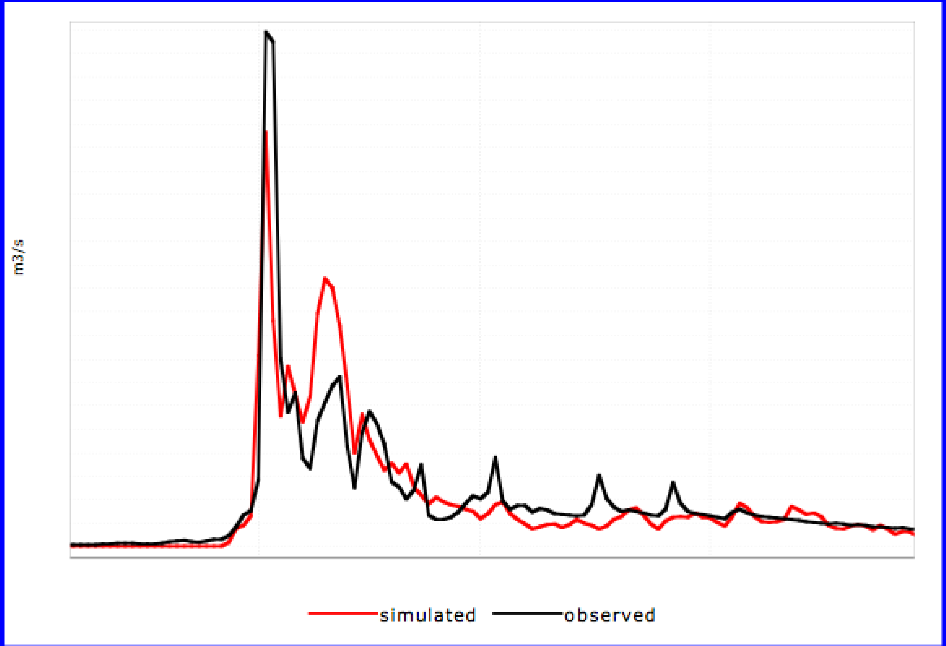
Granger watershed, 8 km^2

RUNOFF MODELLING - GRANGER WATERSHED – 1999 -2001



	NS
1999	0.93
2000	0.73
2001	0.79



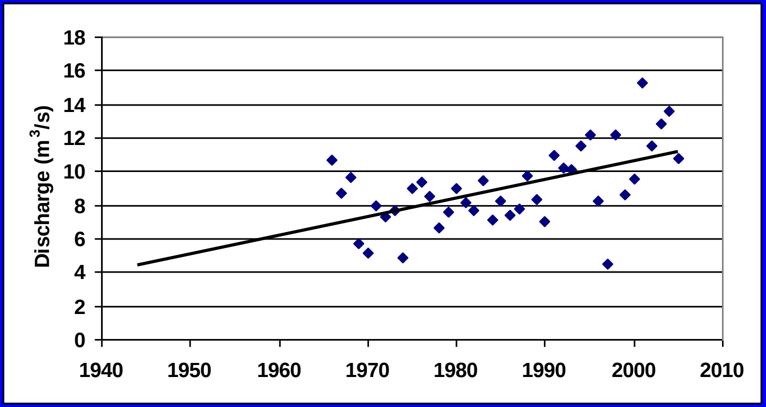


WOLF CREEK – CLIMATE WARMING LINKAGES

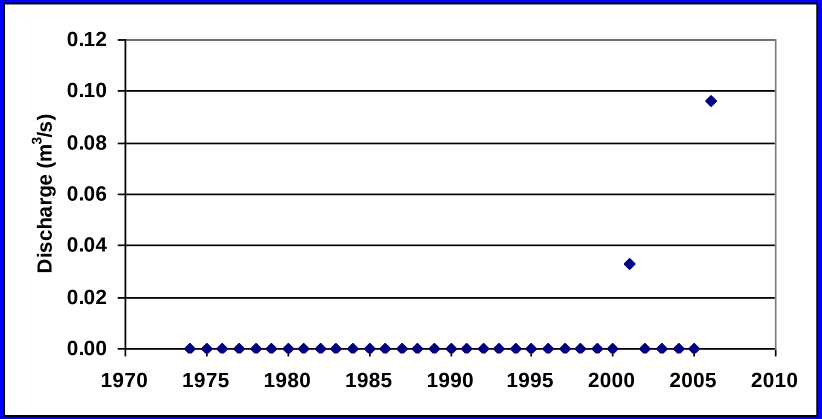
- Climate Change Issues Priority
- Strong GY Support
- 2007 /2009 Major Flooding
  - Linked to Climate Change
- Wolf Creek Climate Change Research (Process, CRHM Modelling)

CLIMATE WARMING IMPACTS PERMAFROST REGIME TRENDS

Winter Low Flows



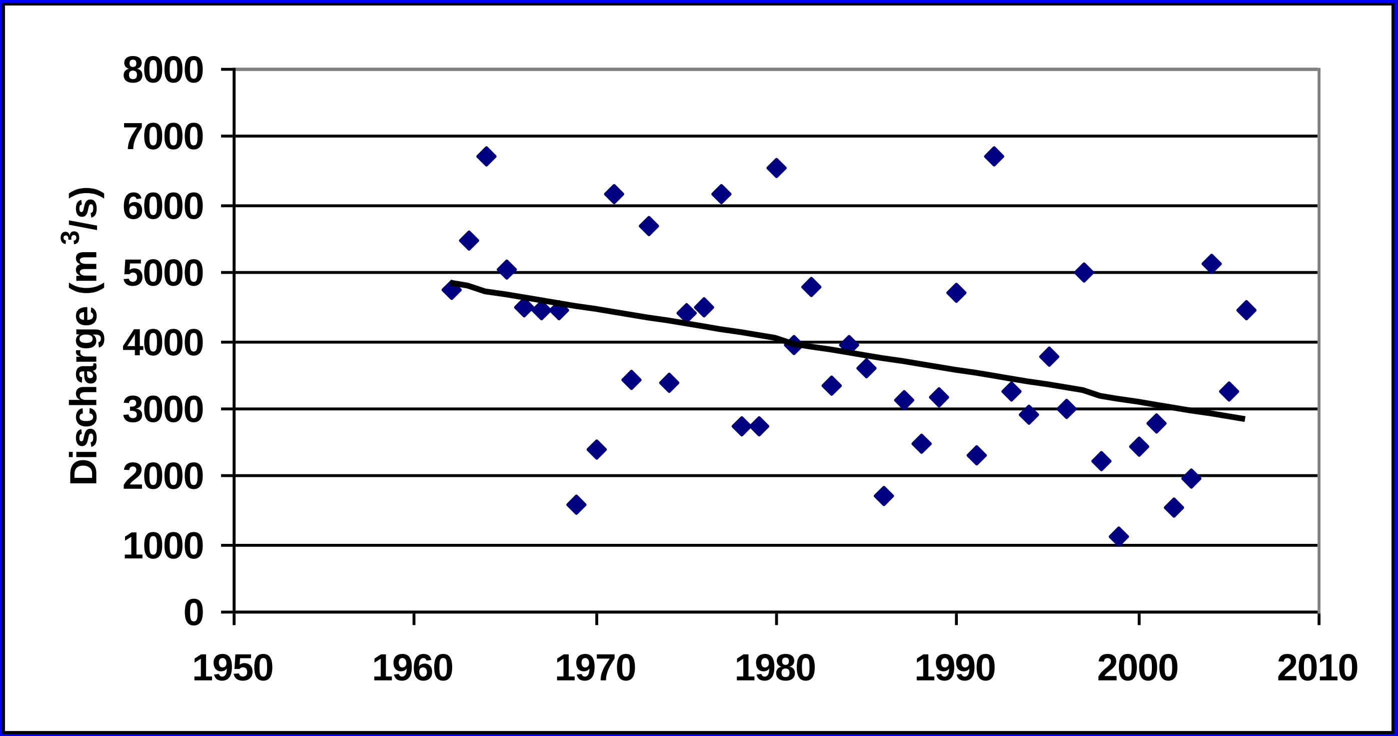
Klondike R ab Bonanza Cr



Rengleng R at Dempster Hwy

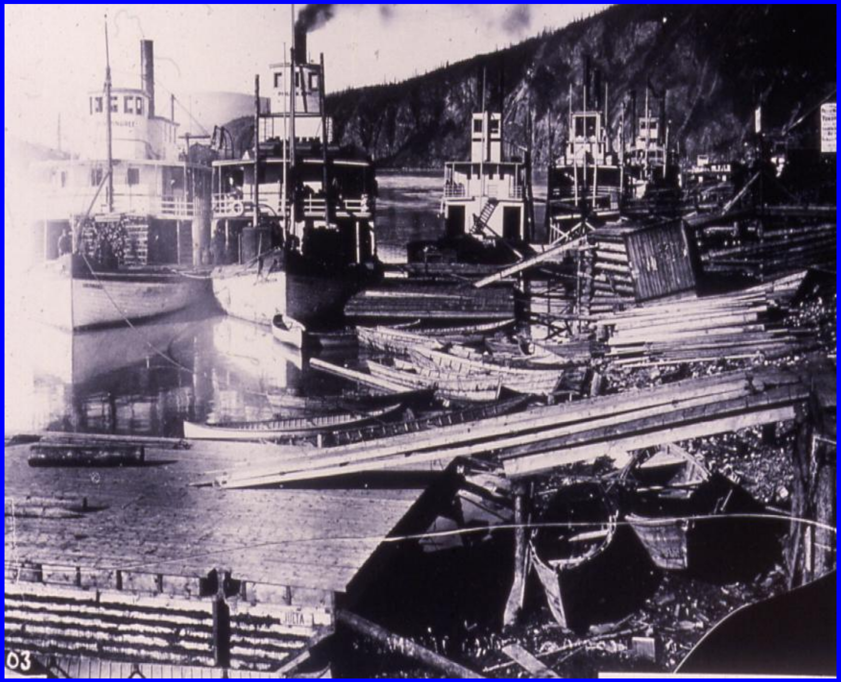
CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

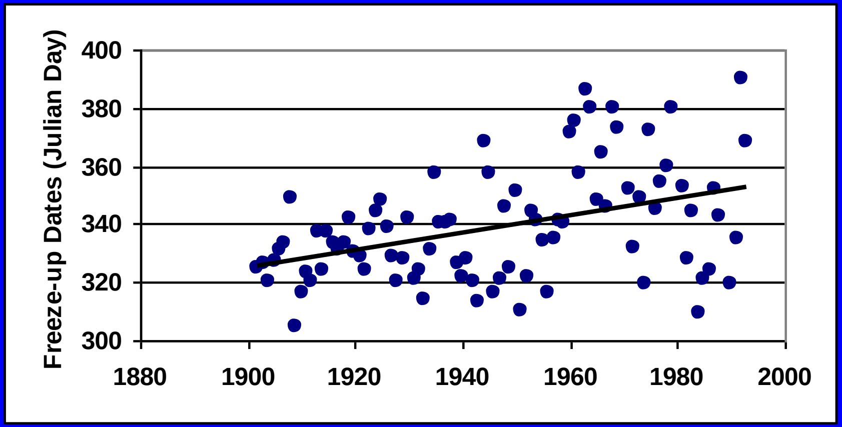
Mean Annual Maximum Flow – Peel River above Canyon Creek



RIVER ICE REGIME TRENDS

Freeze-up Timing



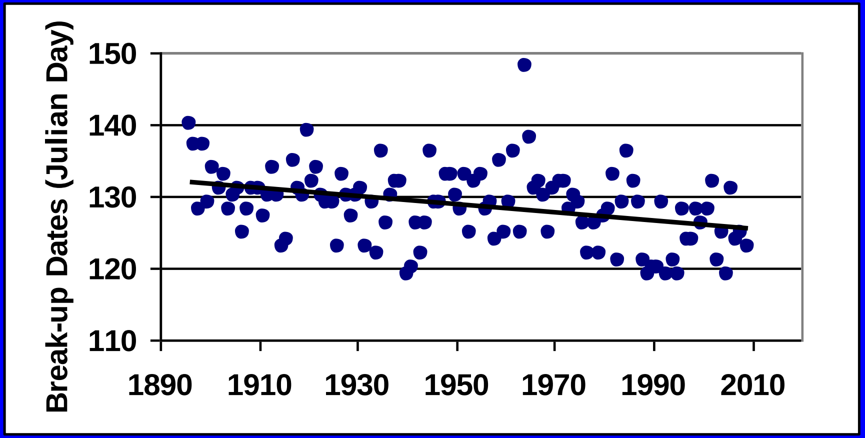


Yukon River at Whitehorse (1902-1993)

•Freeze-up timing delayed approximately 30 days since 1902

RIVER ICE REGIME TRENDS

Break-up Timing



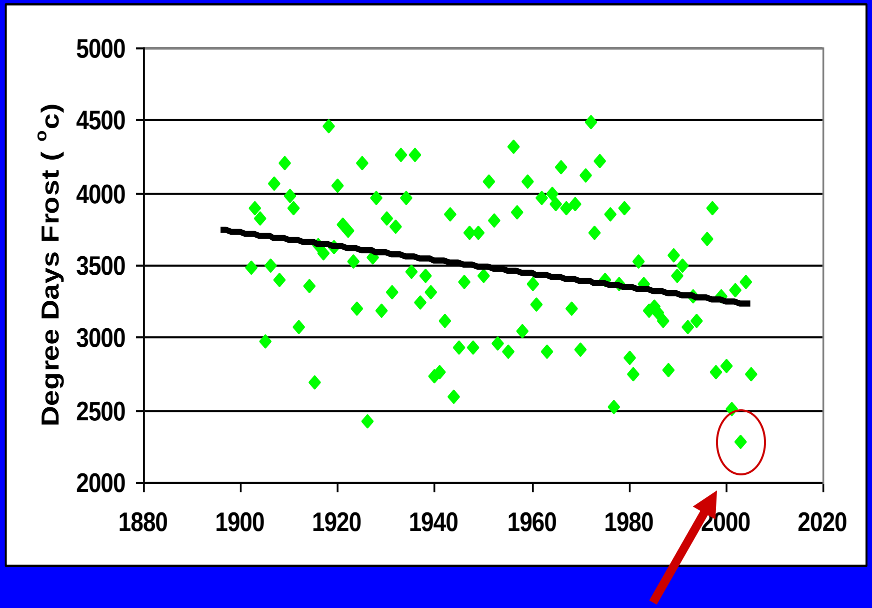
Yukon River at Dawson (1896-2011)

- Break-up Timing Advanced 6 days per century

RIVER ICE REGIME TRENDS

2002/03 Mid-Winter Klondike River Ice Jam and Flooding

Dawson City Winter Temperatures 1902 - 2005



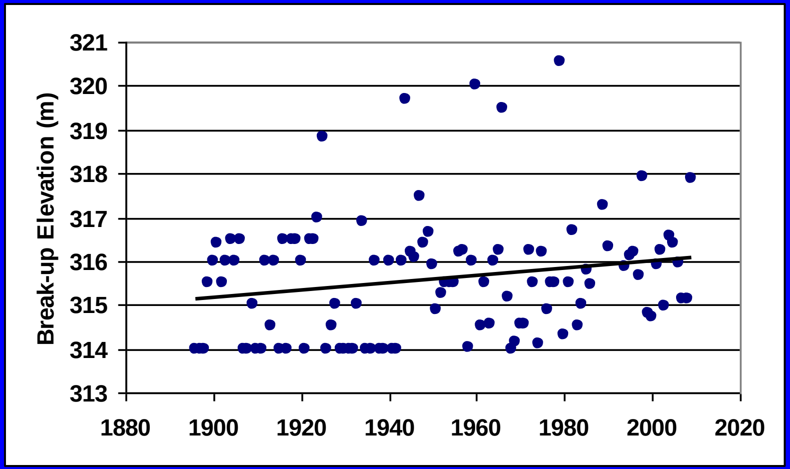
2002/03 warmest winter

Klondike River Ice Jam - 2003

RIVER ICE REGIME TRENDS

Dawson - 1979

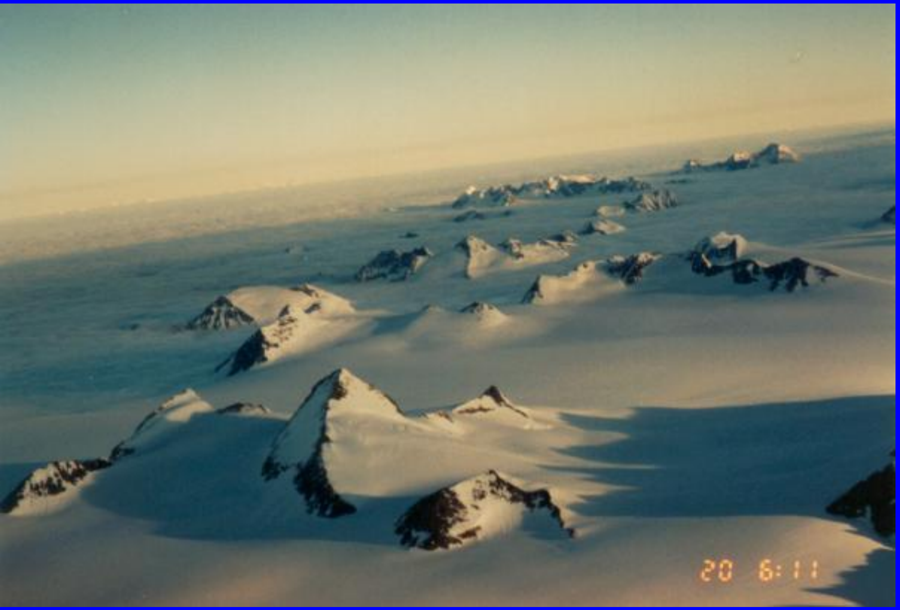
Break-up Severity



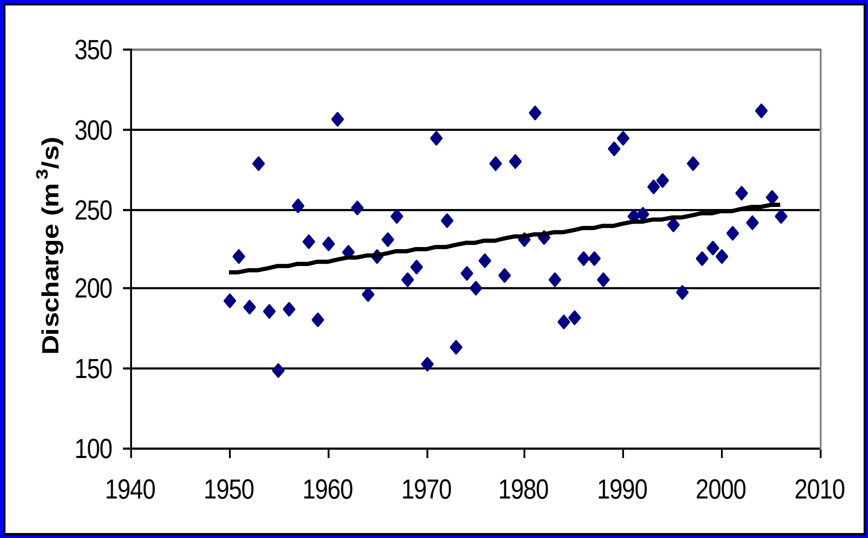
Yukon River at Dawson Annual Maximum Break-up Elevation (1896 - 2011)

CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

Increasing Peak Flows Due to Melting Glaciers

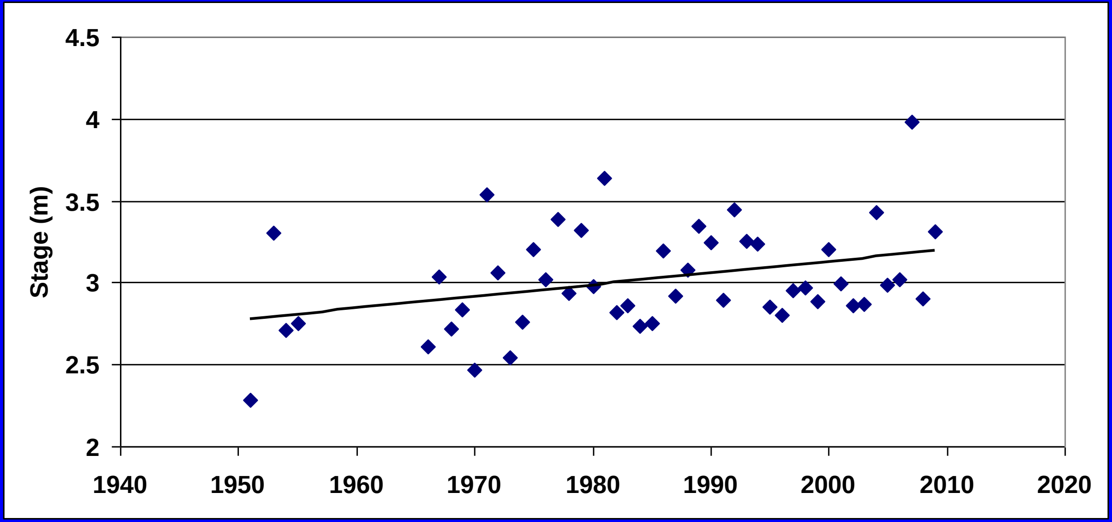


Atlin River nr Atlin



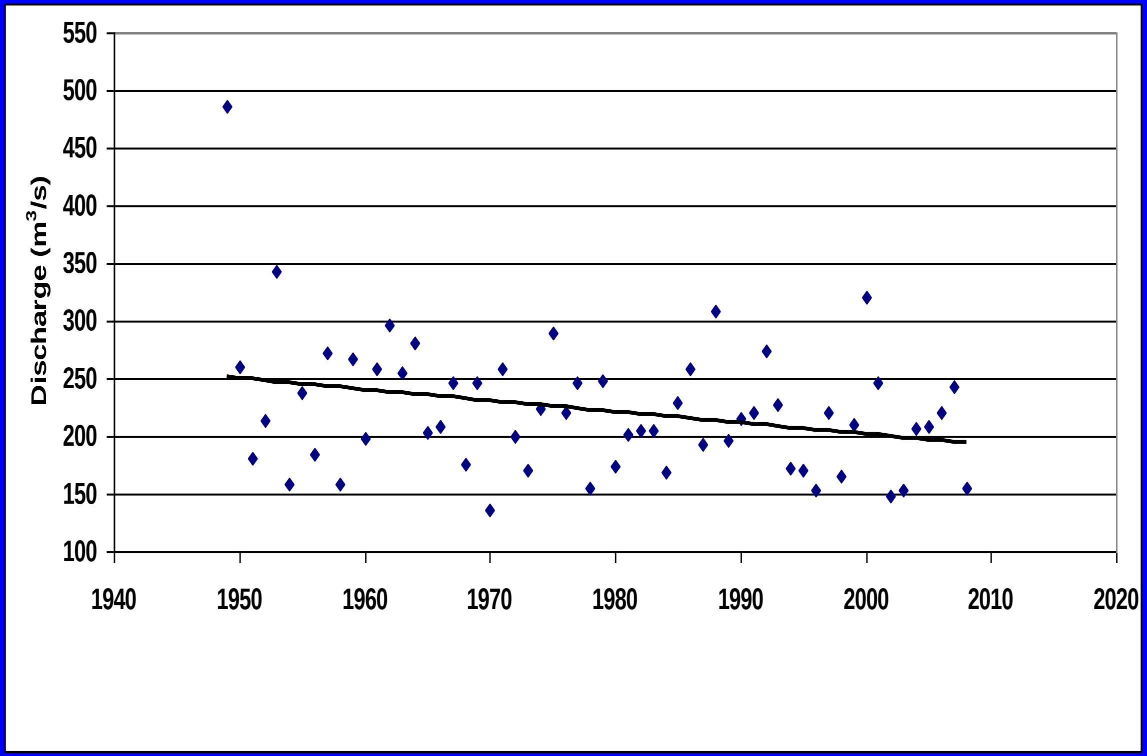
CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

MARSH LAKE ANNUAL MAXIMUM STAGE 1950 – 2011



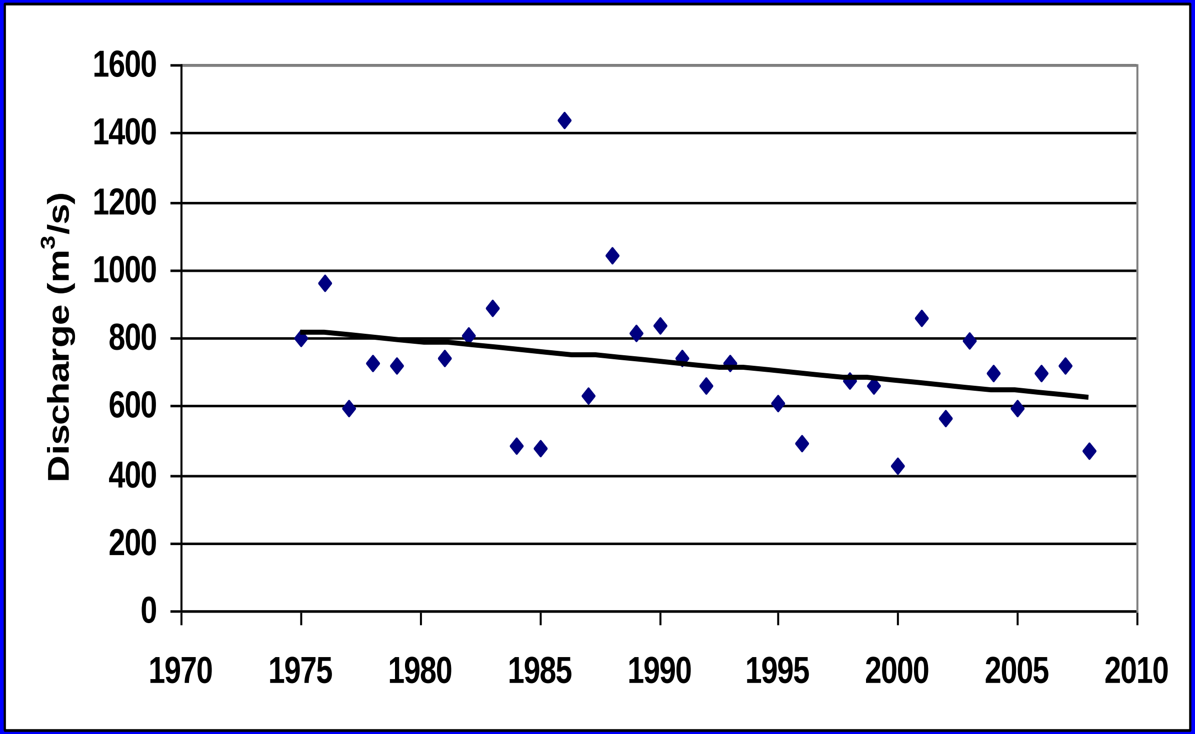
CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

Mean Annual Maximum Discharge
Takhini River near Whitehorse



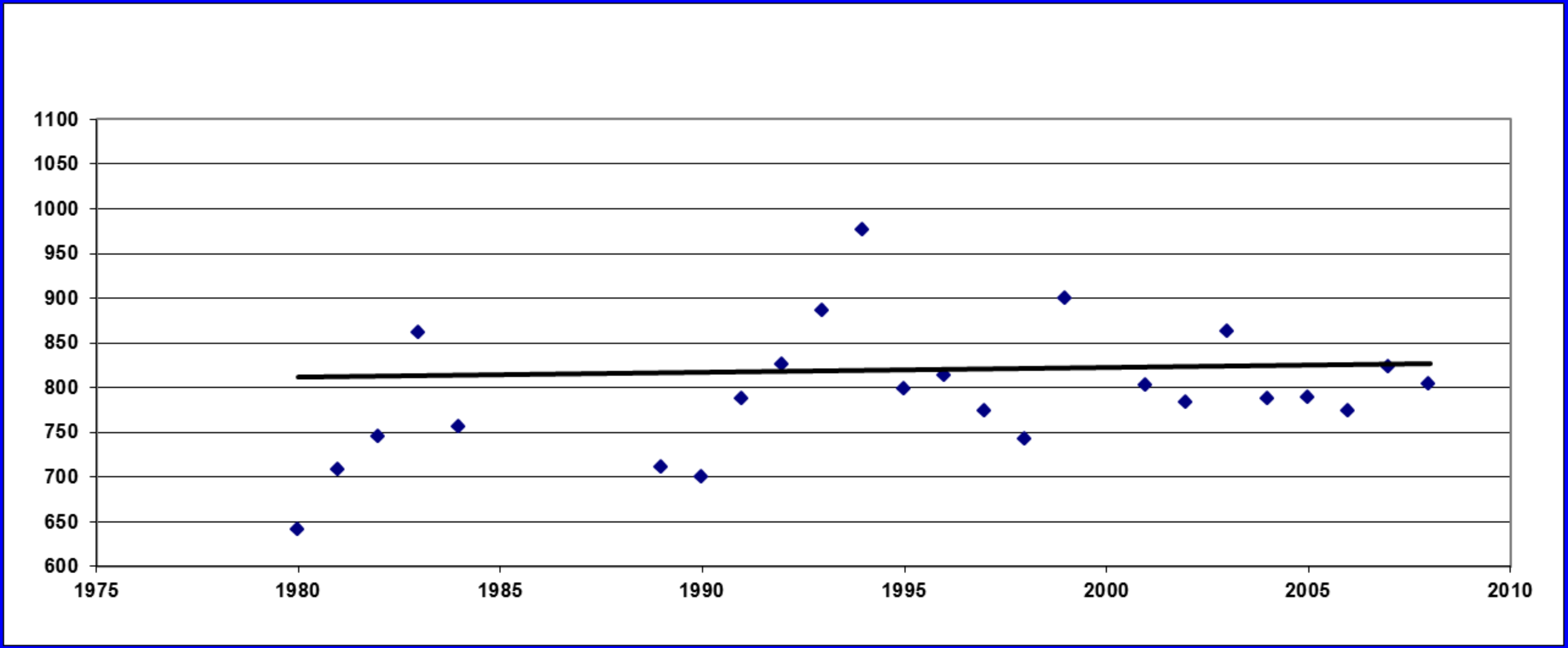
CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

Mean Annual Maximum Discharge
White River at Alaska Highway

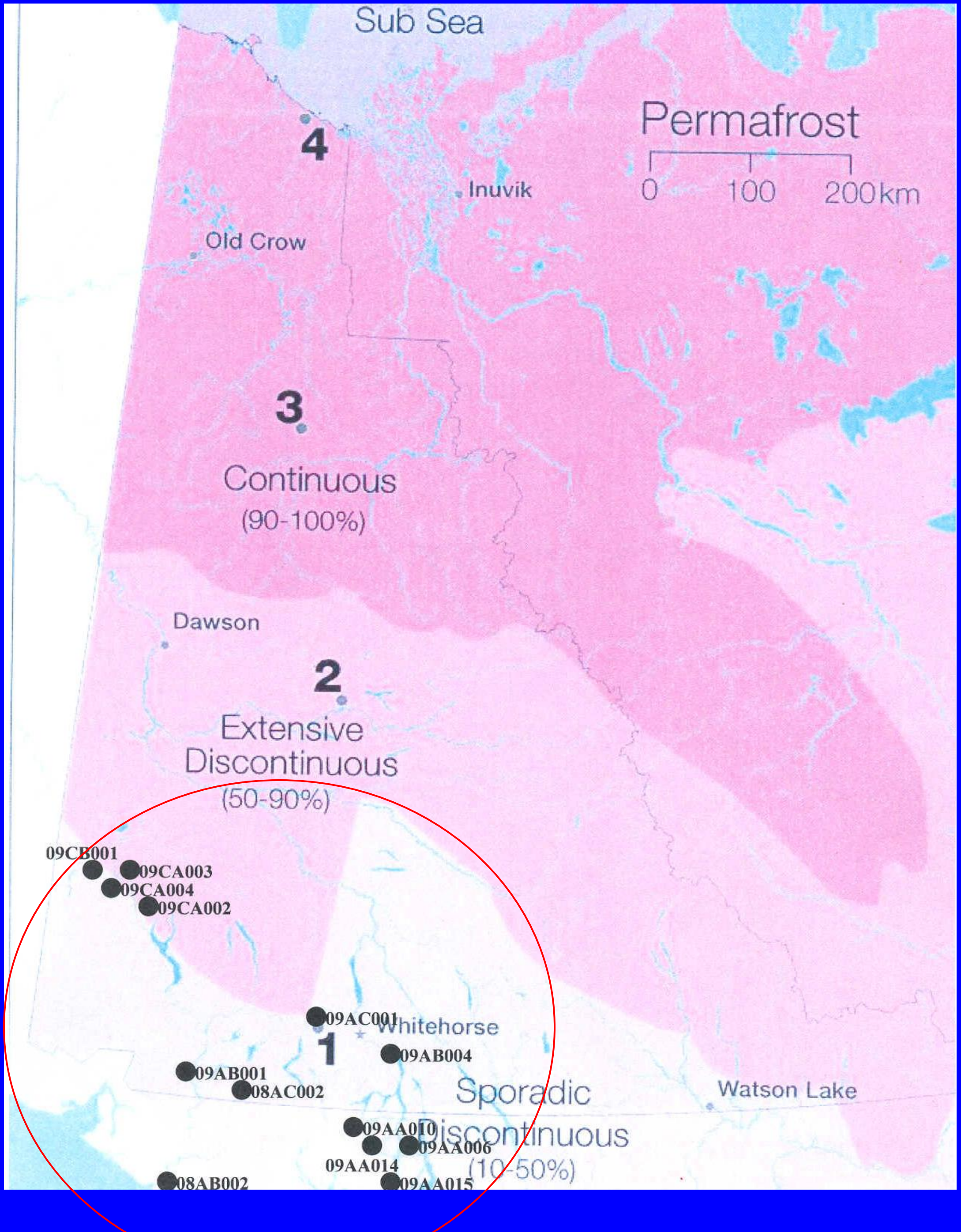


CLIMATE WARMING IMPACTS ON HYDROLOGIC RESPONSE

Mean Annual Maximum Flow – Donjek River below White River



Hydrometric Station Locations and Permafrost Zones



WATERSHED PARAMETERS

Station Name	Drainage Area (km^2)	Record Period	Glacier Area (%)	Mean Annual Temp (°C)
Atlin River nr Atlin	6810	1950-08	12.7	-0.6
Wann River nr Atlin	269	1956-93	19.7	-0.5
Fantail R at Outlet Fantail Lk	717	1956-93	33.2	-2.0
Lindeman Creek nr Bennett	240	1954-93	14.6	-1.7
Marsh Lake nr Whitehorse	19400	1950-09	8.3	-1.5
Takhini R nr Whitehorse	6930	1949-08	5.1	-3.0
Duke River nr Mouth	631	1981-08	9.5	-4.9
Kluane R at Mouth Kluane Lk	4950	1952-95	6.0	-5.7
Donjek River bl Kluane R	12400	1979-94	21.8	-8.3
White R at Alaska Hwy	6240	1975-08	38.6	-8.7
Tatshenshini R at Dalton Post	1750	1989-08	7.0	-2.5
Alsek R ab Bates R	16200	1975-08	21.0	-3.5
Alsek R nr Yakatat	28000	1993-08	31.9	-2.4

CONCLUSIONS
PERMAFROST DEGRADING

- Permafrost Degrading?
- Greater Groundwater Contributions to Baseflow
- Some Peak Flows Decreasing

SUMMARY

- RIVER ICE TRENDS
- Freeze-up Timing Delayed 30 Days
- Break-up Timing Advanced 6-day/century

•More Frequent Occurrence Mid-winter Break-up

  •Greater Frequency Ice Jam Flooding

•Greater Severity Ice Jam Flooding

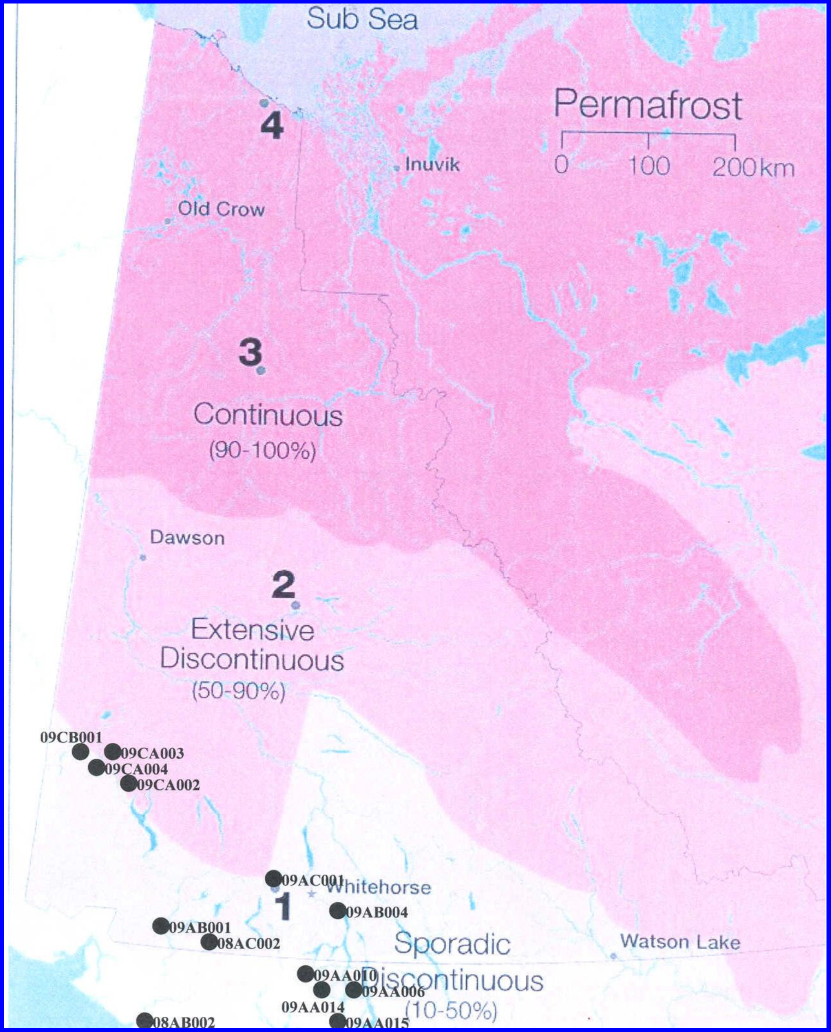
CONCLUSIONS
GLACIERS MELTING

- Peak Flows not Consistant

- Peak Flows Increasing / Decreasing

CONCLUSIONS

GLACIERS MELTING



Glacierized Regions – Little Permafrost

- Peak Flows Increasing Due to Glacier Melt

Glacierized Regions – Greater Permafrost

- Peak Flows Decreasing Due to Longer Pathways to Stream Channel

ACKNOWLEDGEMENTS

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THANK YOU!