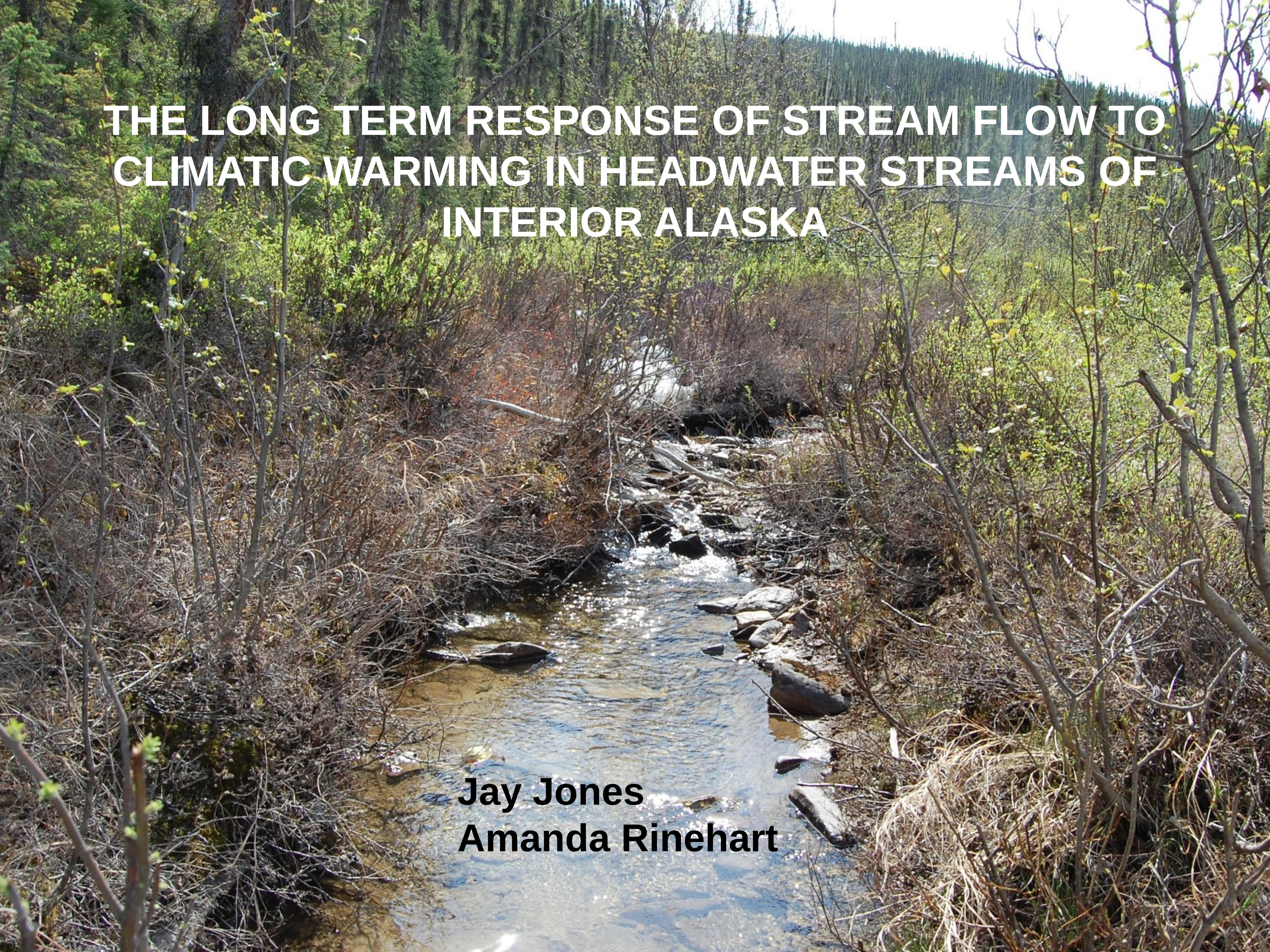
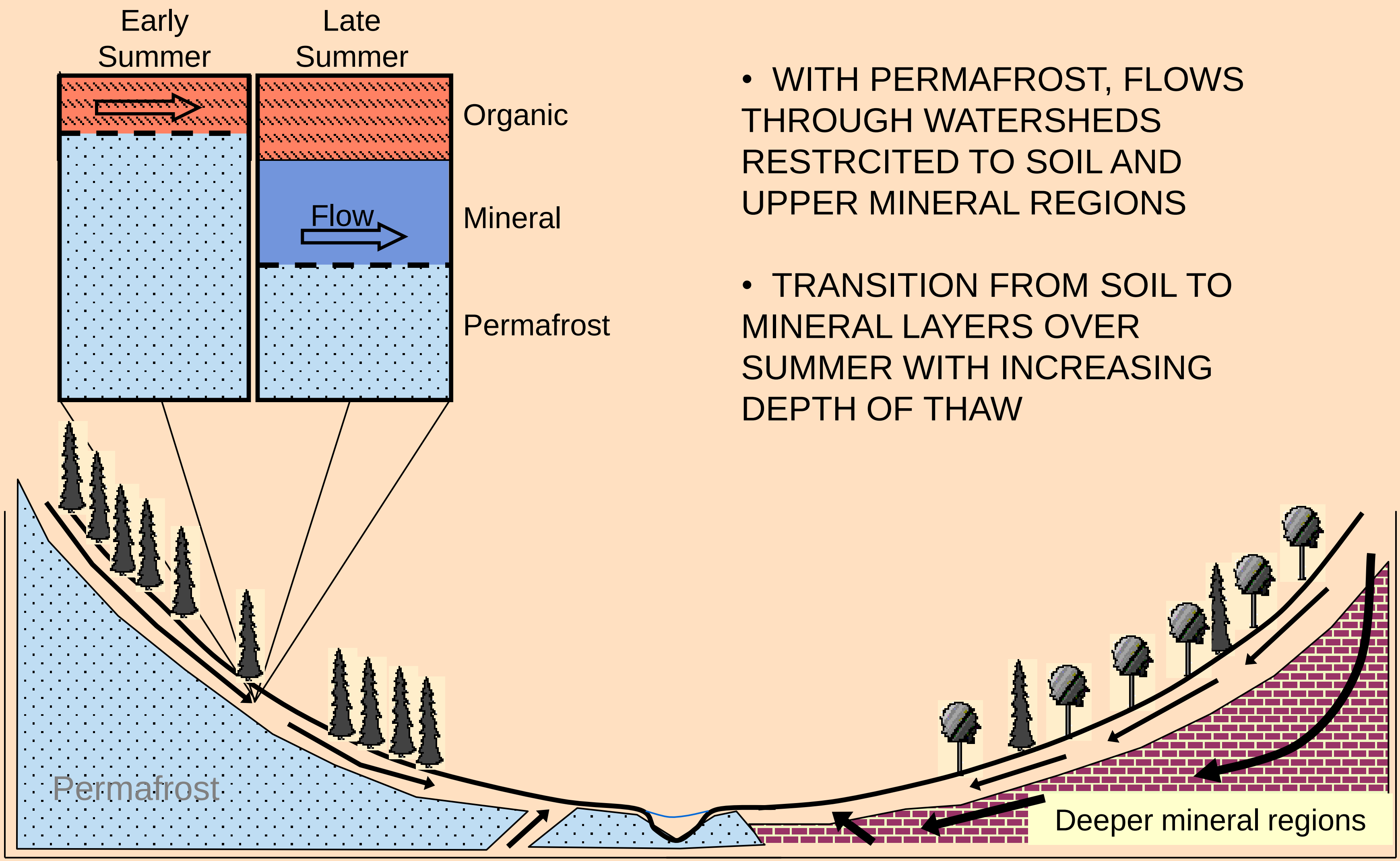


THE LONG TERM RESPONSE OF STREAM FLOW TO CLIMATIC WARMING IN HEADWATER STREAMS OF INTERIOR ALASKA

Jay Jones
Amanda Rinehart

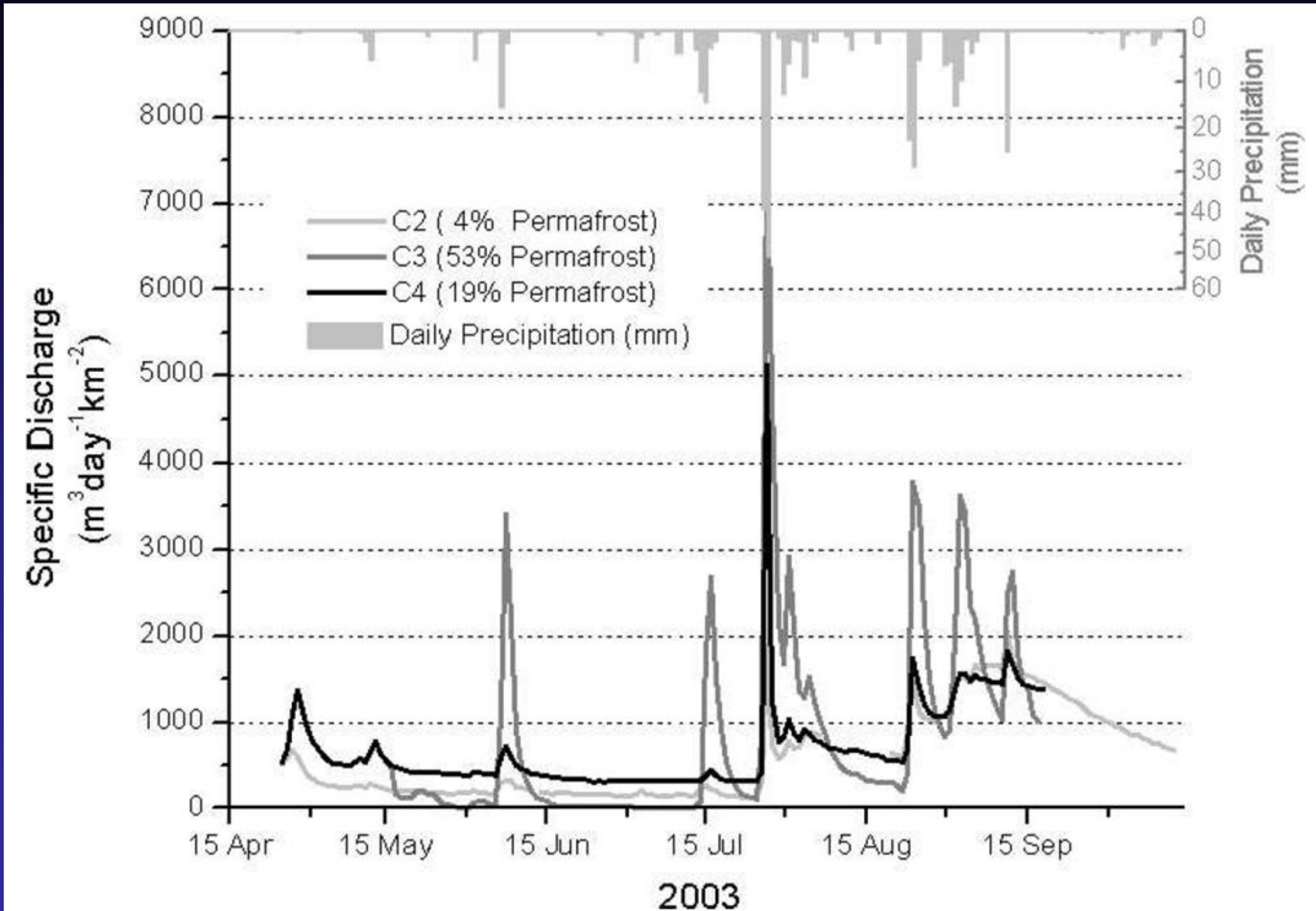
WATERSHED HYDROLOGY WITH DISCONTINUOUS PERMAFROST



- WITH PERMAFROST, FLOWS THROUGH WATERSHEDS RESTRCITED TO SOIL AND UPPER MINERAL REGIONS

- TRANSITION FROM SOIL TO MINERAL LAYERS OVER SUMMER WITH INCREASING DEPTH OF THAW

STREAM HYDROLOGY WITH DISCONTINUOUS PERMAFROST



Bolton 2006

STORM FLOW HYDROLOGY

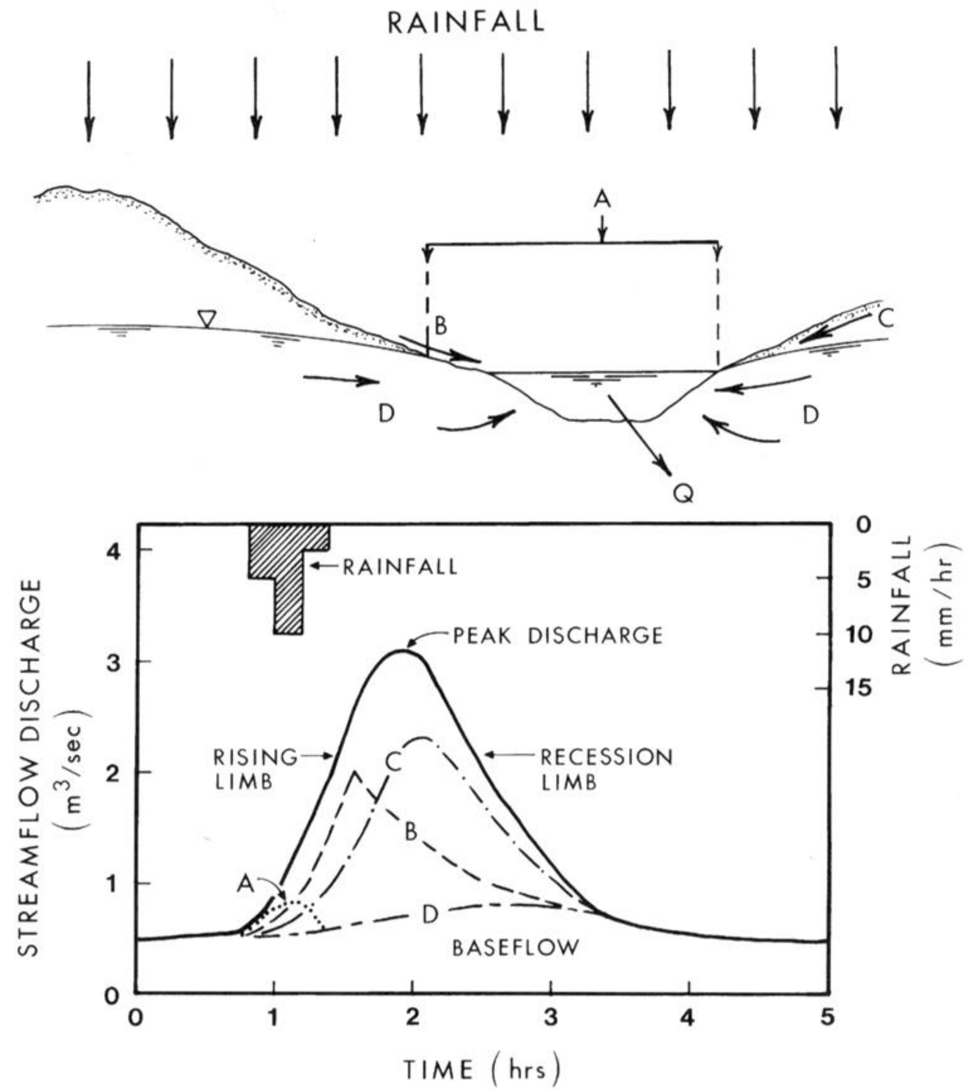
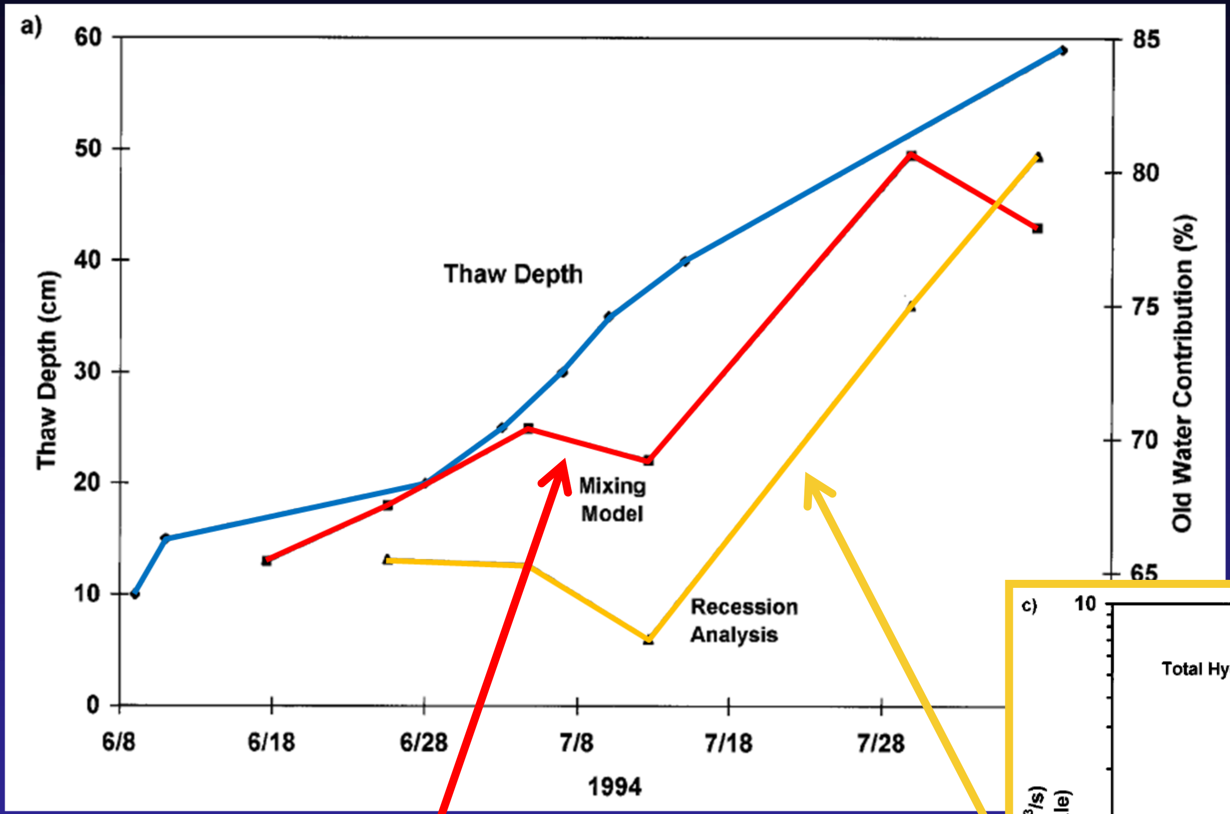


Figure 4.9. Relationship between pathways of flow from a watershed and the resultant streamflow hydrograph: A = channel interception; B = surface runoff, or overland flow; C = subsurface flow, or interflow; D = groundwater, or baseflow; Q = streamflow discharge.

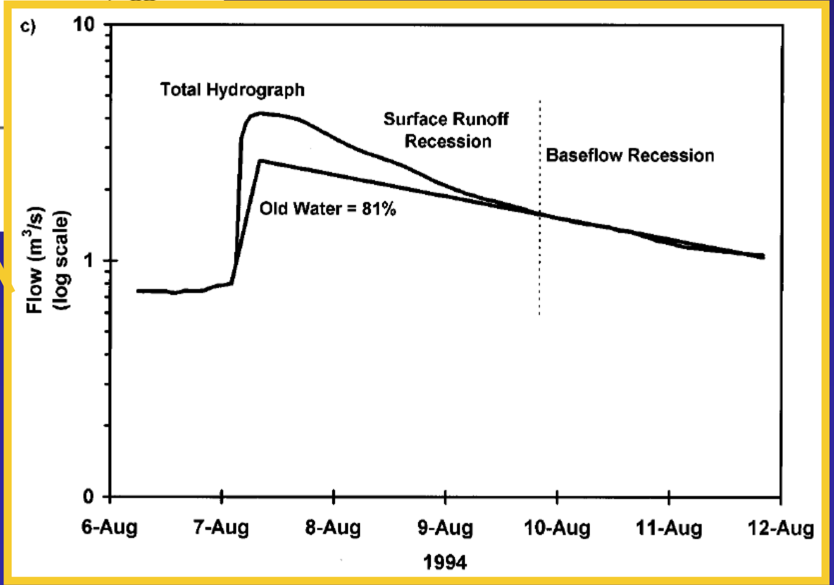
SEASONAL CHANGES IN STORM FLOW RESPONSE CONTINUOUS PERMAFROST



$$Q_s(t) = Q_o(t) + Q_n(t)$$

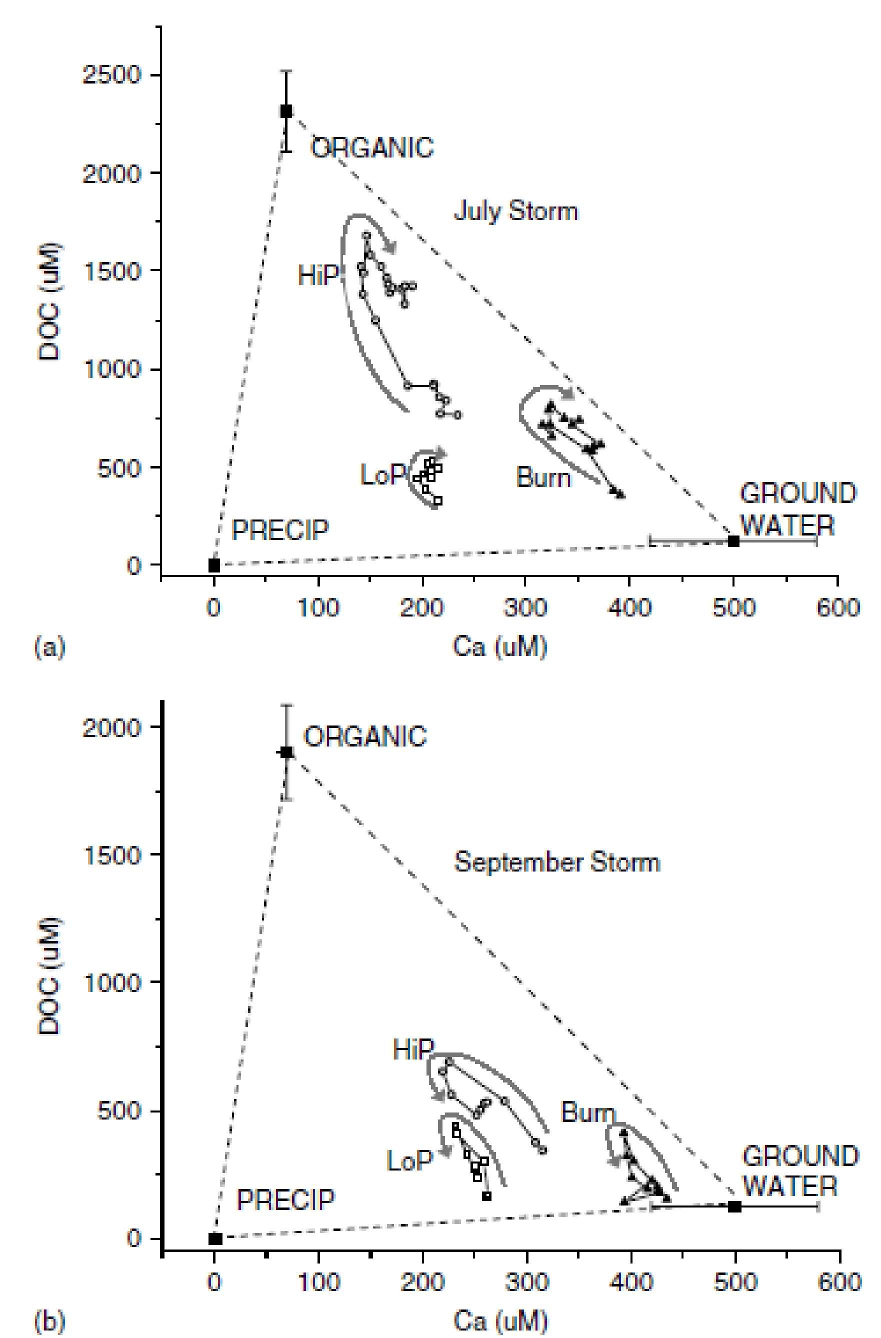
$$Q_s(t)C_s(t) = Q_o(t)C_o(t) + Q_n(t)C_n(t)$$

Tracer: Electrical conductance
Old water: Stream water during base flow
New water: Water tracks



McNamara et al. 1997

CPCRW STORM FLOW END MEMBER SEPARATION



$$f_{gw} + f_{org} + f_{precip} = 1 \quad (1)$$

$$[Ca]_{gw} f_{gw} + [Ca]_{org} f_{org} + [Ca]_{precip} f_{precip} = [Ca]_{stream} \quad (2)$$

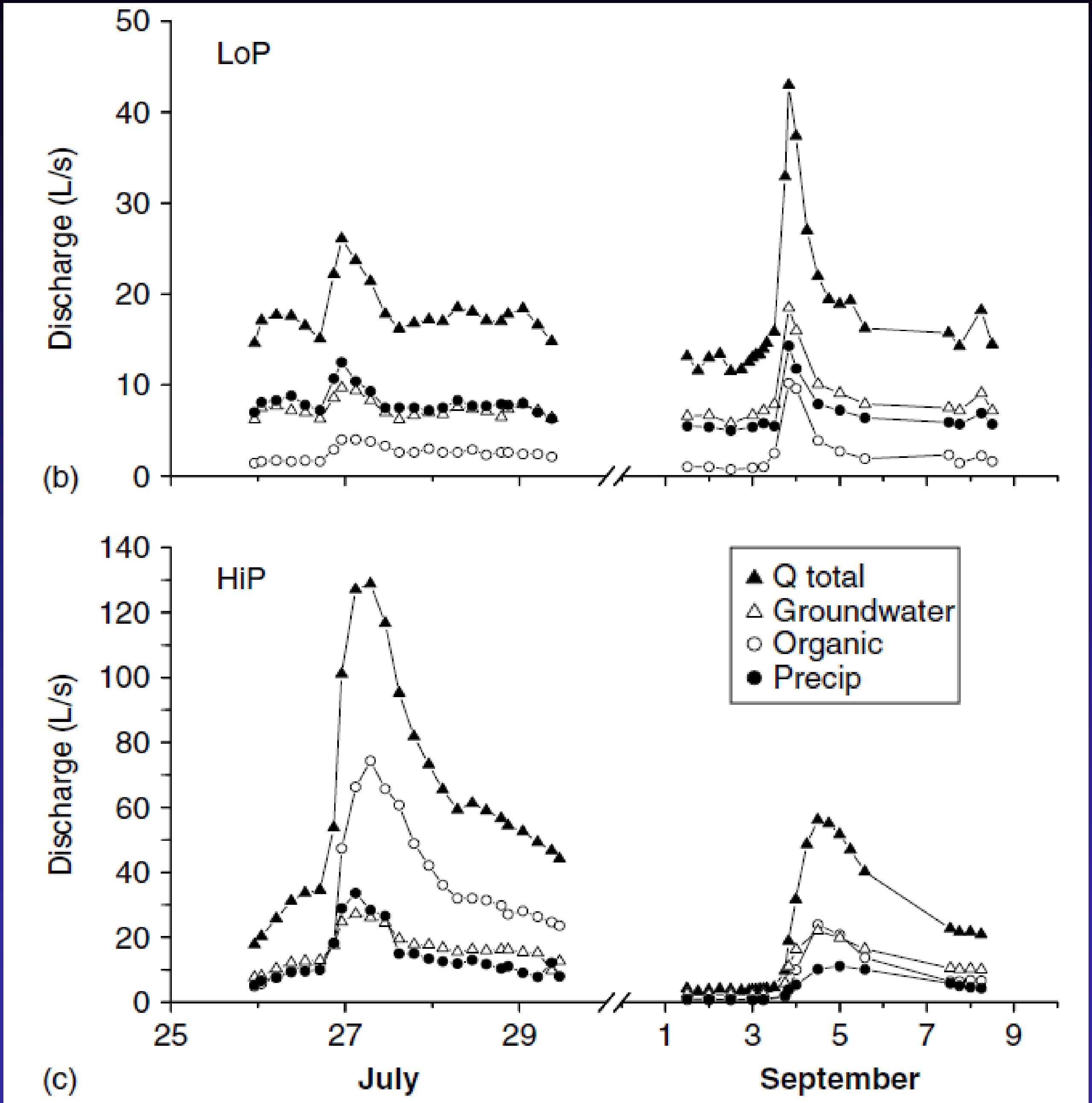
$$DOC_{gw} f_{gw} + DOC_{org} f_{org} + DOC_{precip} f_{precip} = [DOC]_{stream} \quad (3)$$

Tracers: DOC and Ca^{2+}

End members: Precipitation, soil water, and ground water

Petrone et al. 2007

CPCRW STORM FLOW END MEMBER SEPARATION



Petrone et al. 2007

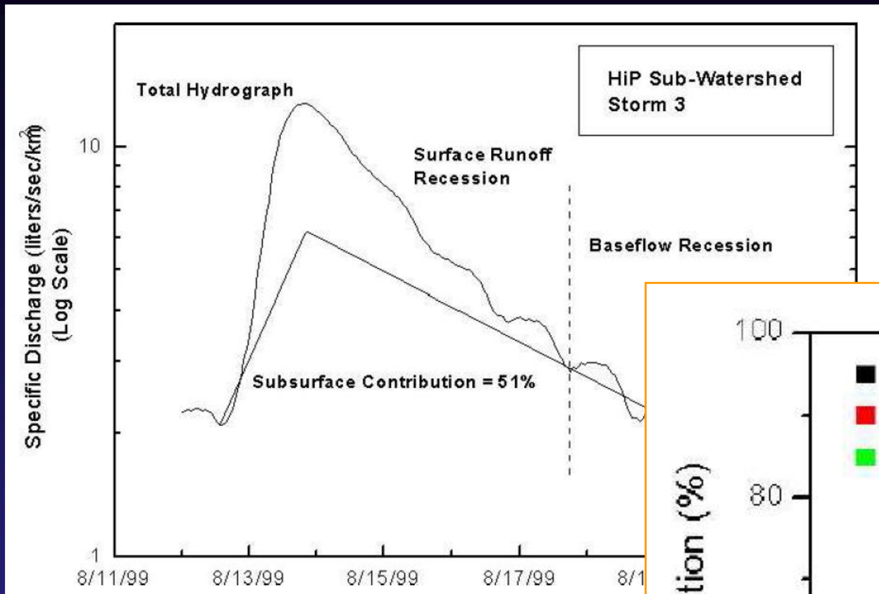
CPCRW STORM FLOW END MEMBER SEPARATION

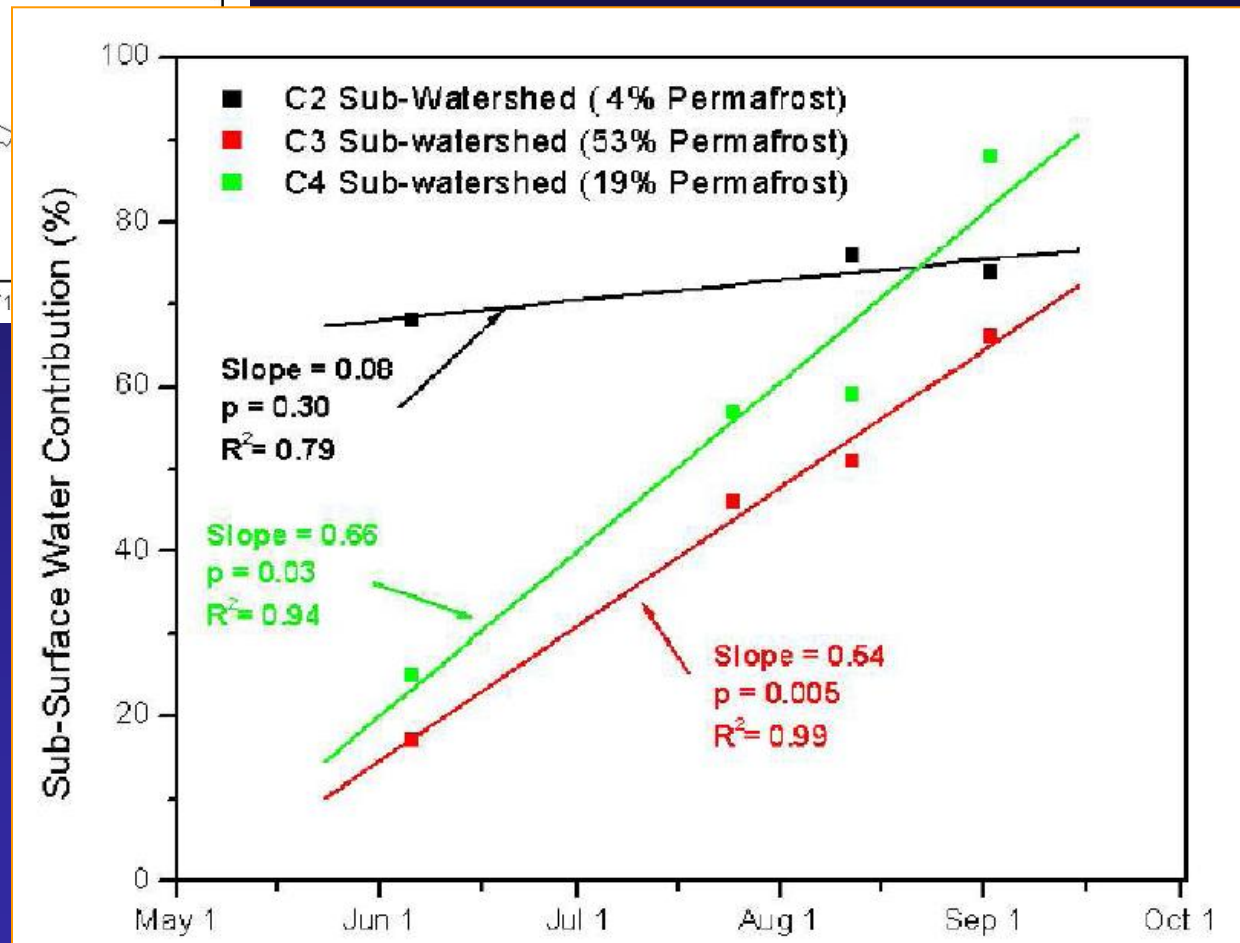
Table II. Hydrograph separation results from the three end-member mixing model for the burn, low-permafrost (LoP), and high-permafrost (HiP) watersheds for the July and September 1999 storm events[a]

Site	Total storm discharge (m^3)	Precipitation		Discharge						TSWCA (ha)	TSWCA/ Watershed area (%)
		Total (mm)	Max. (mm h^{-1})	Groundwater		Organic		Precipitation			
				m^3	% of total	m^3	% of total	m^3	% of total		
July											
Burn	15 331	22·6	11·4	10 635	69·4	3446	22·5	1250	8·2	5·5	0·5
Low permafrost	1867	22·6	11·4	749	40·1	317	17·0	801	42·9	3·5	0·7
High permafrost	18 649	22·6	11·4	4828	25·9	10 740	57·6	3081	16·5	13·6	2·4
September											
Burn	28 169	22·9	22·4	22 452	79·7	2549	9·0	3168	11·2	13·8	1·3
Low permafrost	5232	22·9	22·4	2529	48·3	610	11·7	2093	40·0	9·1	1·8
High permafrost	12 808	22·9	22·4	6461	50·4	2977	23·2	3370	26·3	14·7	2·6

Petrone et al. 2007

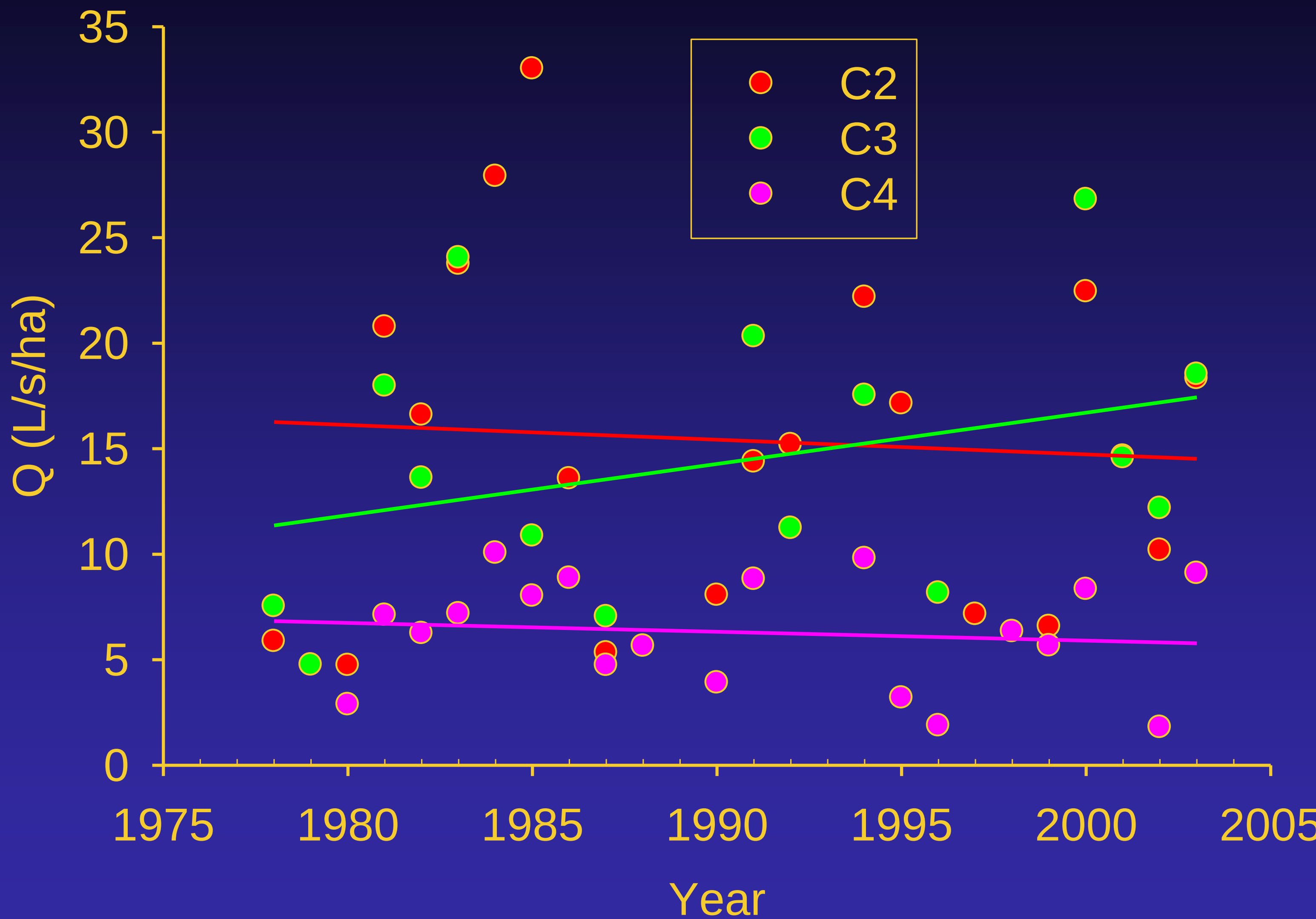
CPCRW SEASONAL CHANGE IN STORM FLOW CONTRIBUTIONS





Bolton 2006

LONG-TERM PATTERNS IN TOTAL DISCHARGE



Bolton et al. 2004

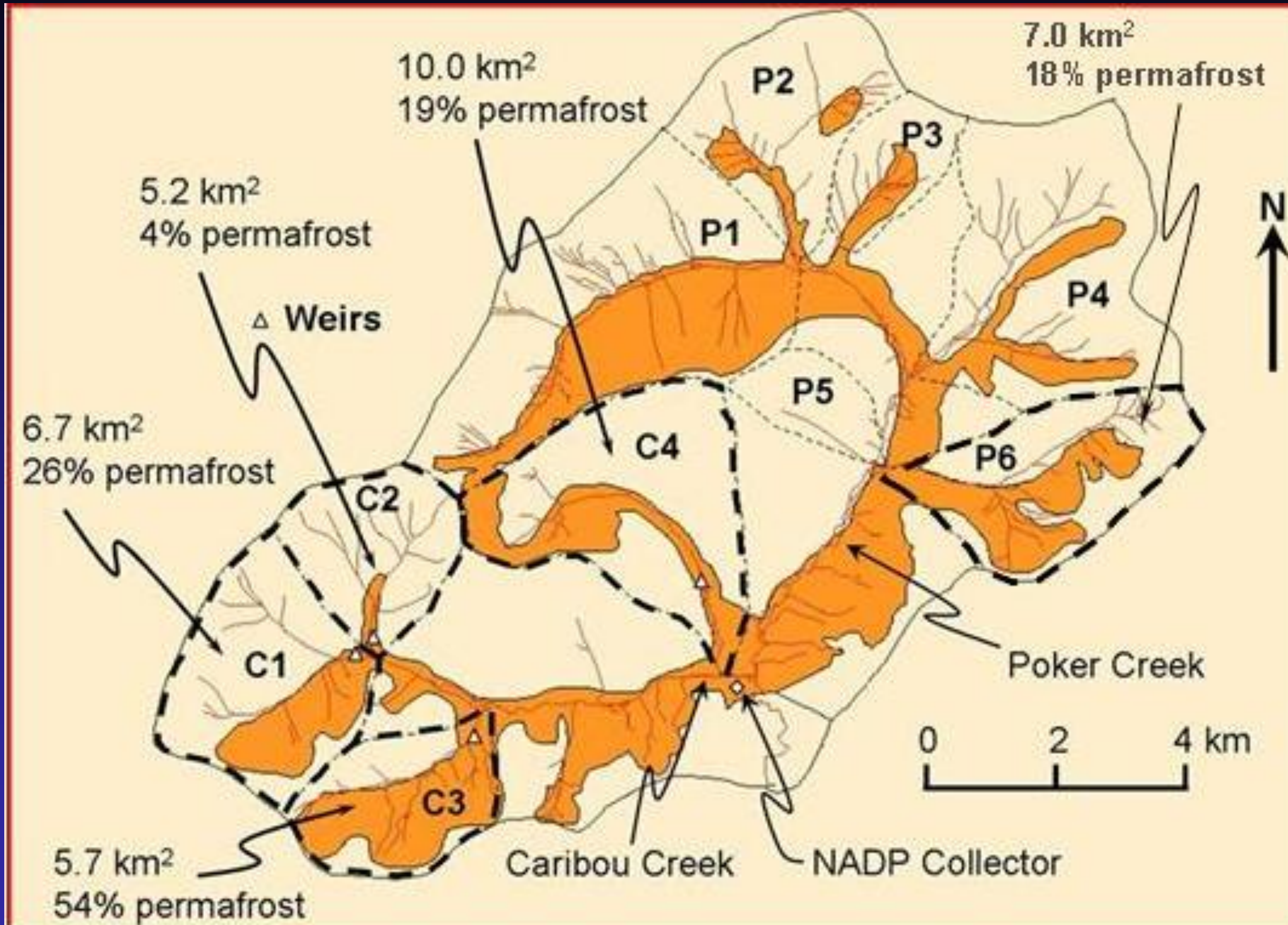
OBJECTIVES

1) Determine how stream flow varied among streams draining watersheds with varying extents of permafrost

2) Evaluate if stream hydrology is changing with loss of permafrost.

Can we detect a change in source water contribution with loss of permafrost?

STUDY SITES

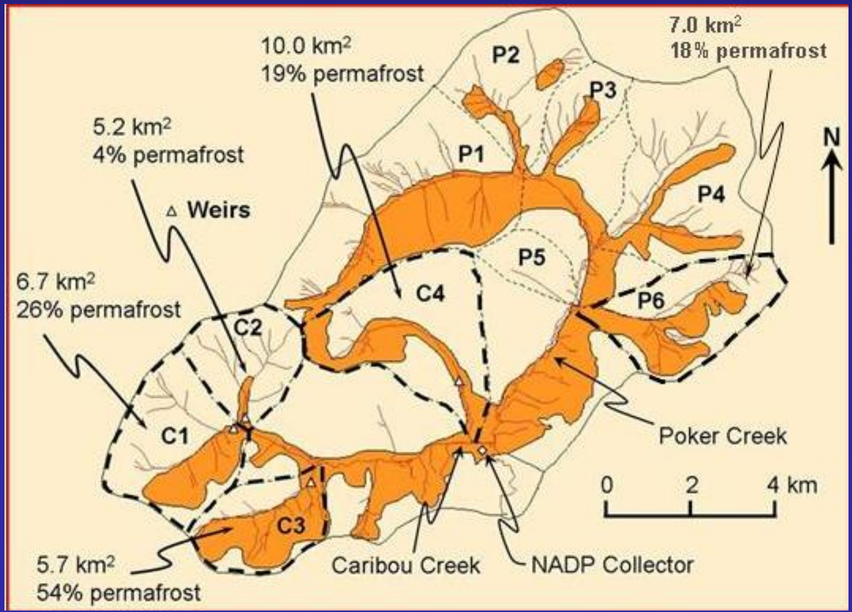


10.0 km2
19% permafrost
7.0 km2
18% permafrost
5.2 km2
4% permafrost
Weirs
6.7 km2
26% permafrost
5.7 km2
54% permafrost
P1
P2
P3
P4
P5
P6
C1
C2
C3
C4
N
Poker Creek
0
2
4 km
Caribou Creek
NADP Collector

DATA SOURCES

Data :

- C2 & C3: 1978 – 2007
- C4: 1980 to 2007
- Pressure transducers and data loggers
- Flumes - C2, C3, C4
- Stage height data logged every 15 minutes to 1 hour
- June 1 – September 30 (defined as active season)



HYDROGRAPH SEPARATION
LOCAL-MINIMUM METHOD

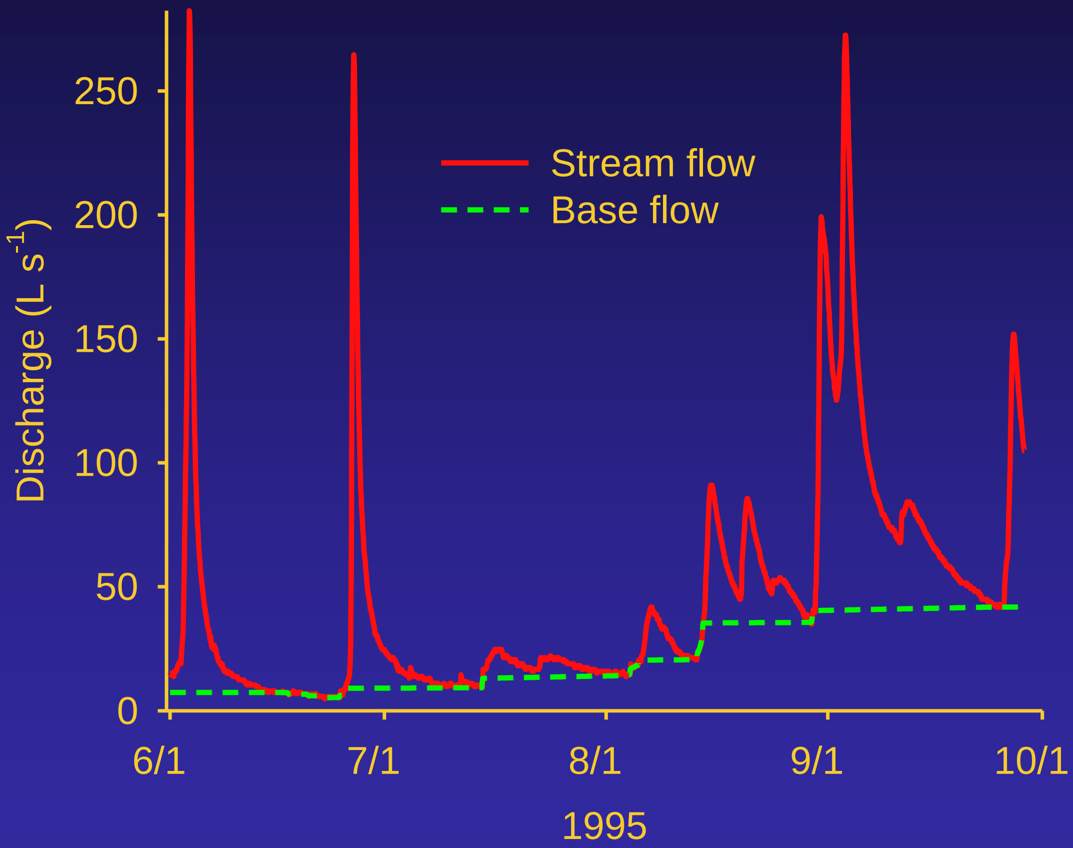
H_1: The rate at which precipitation and storm flows are transmitted to streams is governed by the extent of permafrost and thus the extent of a confining layer in watersheds

- Base and storm flow separated with a sliding window to identify local minimums in flow

- Size of window defined by watershed size ($I = 10\ Area^{0.1}$)

- Baseflow calculated by linearly interpolating runoff between consecutive notes of minimum flow

- Prediction: The streams draining the lower permafrost watersheds will have a greater baseflow contribution

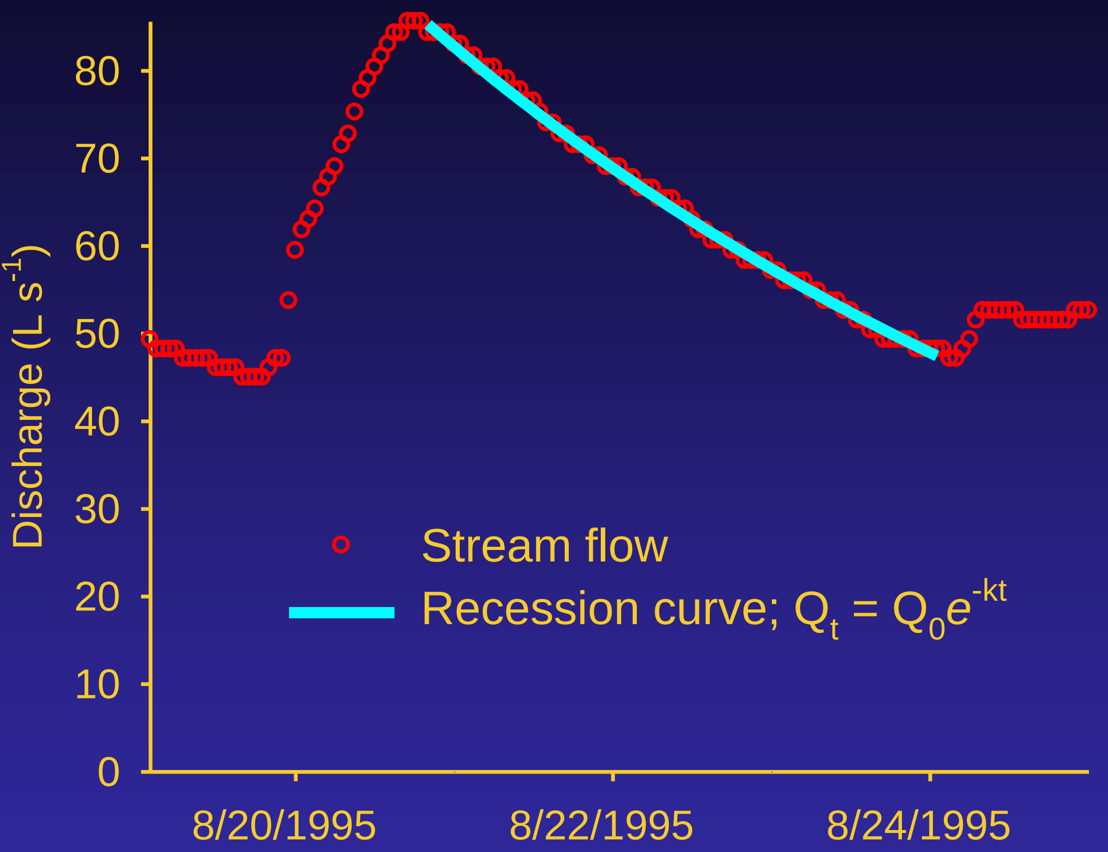


STORM FLOW RECESSION ANALYSIS

H_2: The rate at which storm flows are released from storage will decline over the active season as the depth of seasonal soil thaw deepens and storage zone volume increases

H_3: Over longer time scales, with a loss of permafrost, stream flows will become less responsive to precipitation as storage zone increases, and storm flows will contribute less to overall stream discharge

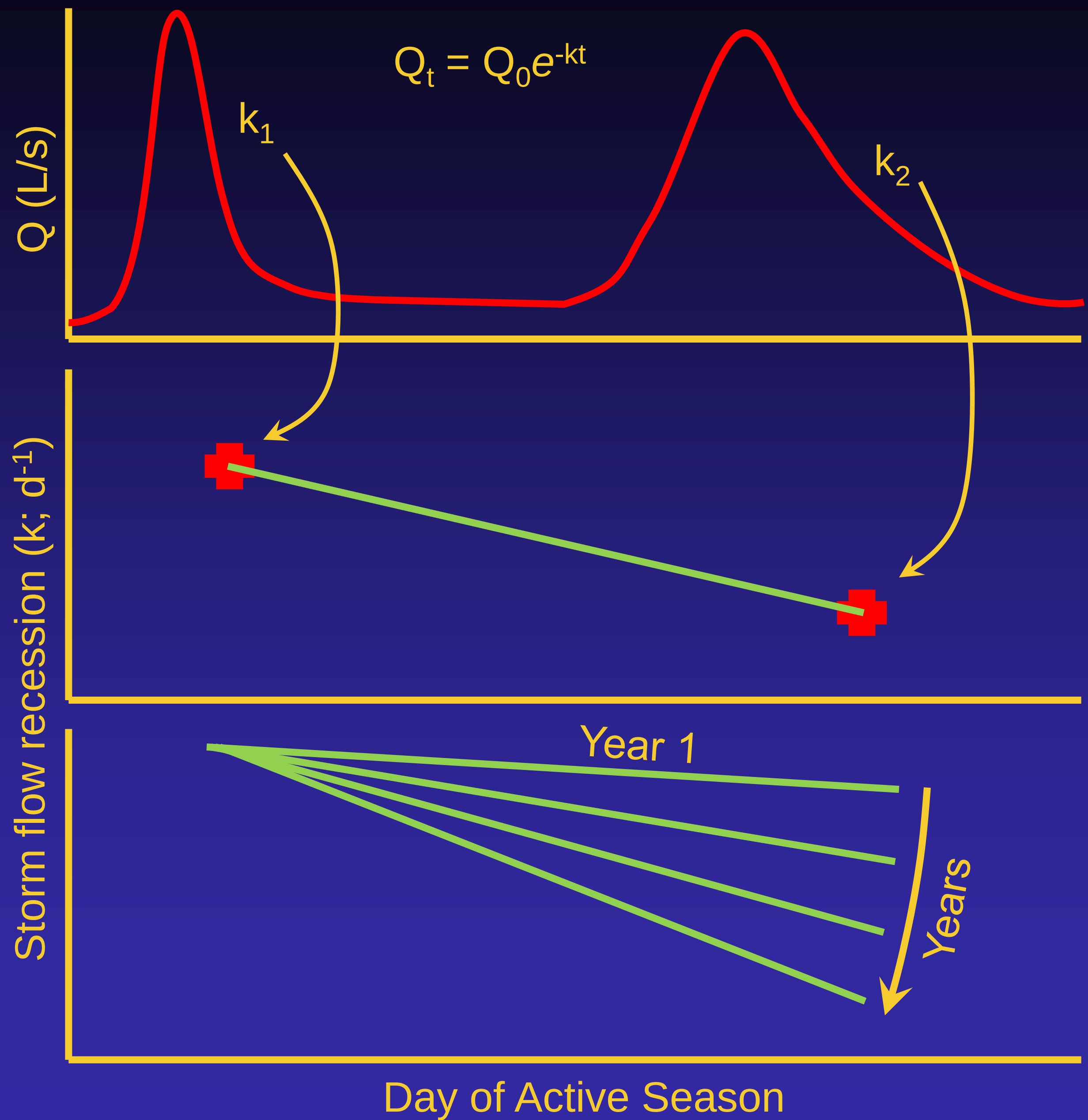
- Flood recessions analyzed for all storms lasting longer than 12 hours



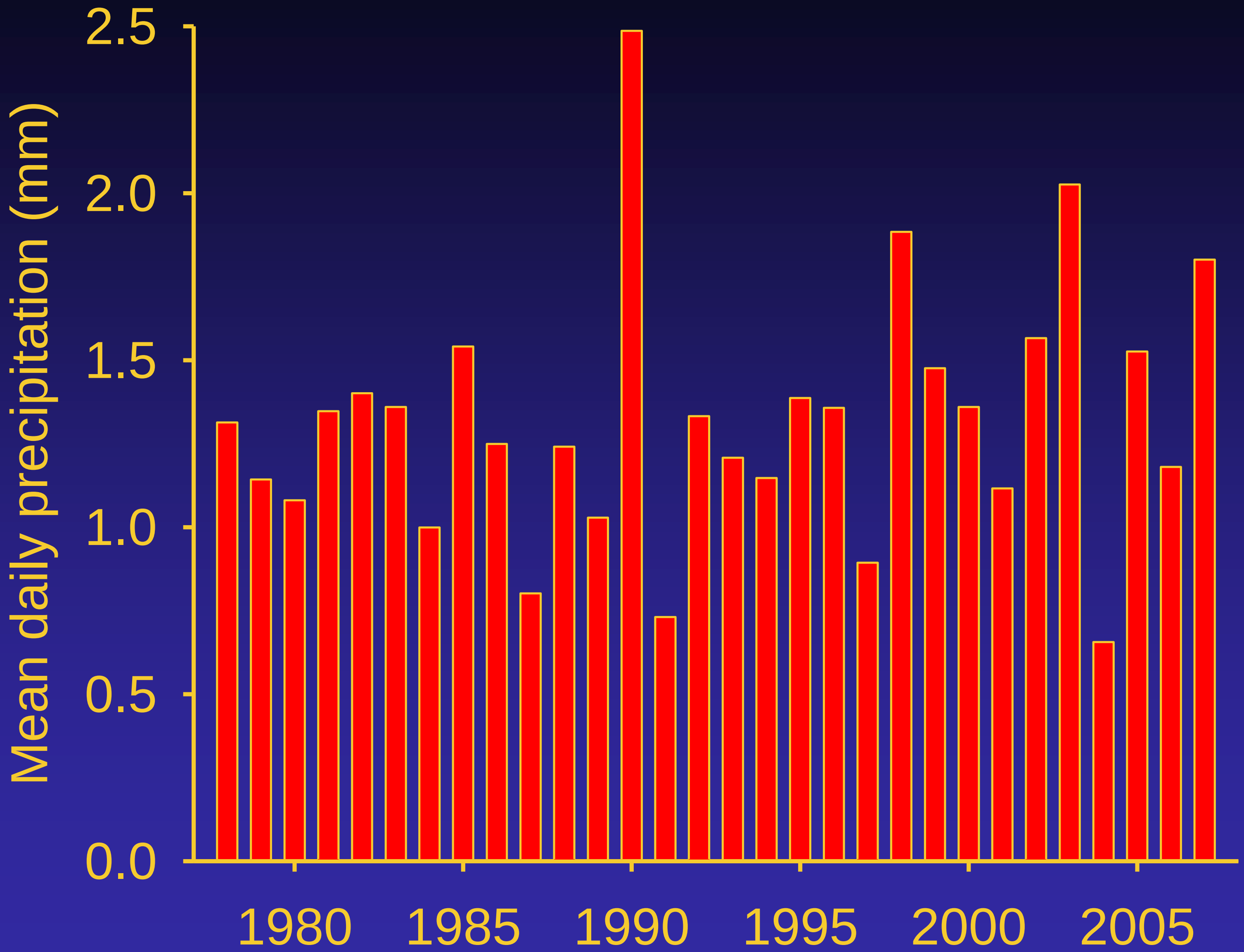
STORM FLOW RECESSION ANALYSIS

Prediction: The storm flow recession curve coefficient (k) will decline over the active season

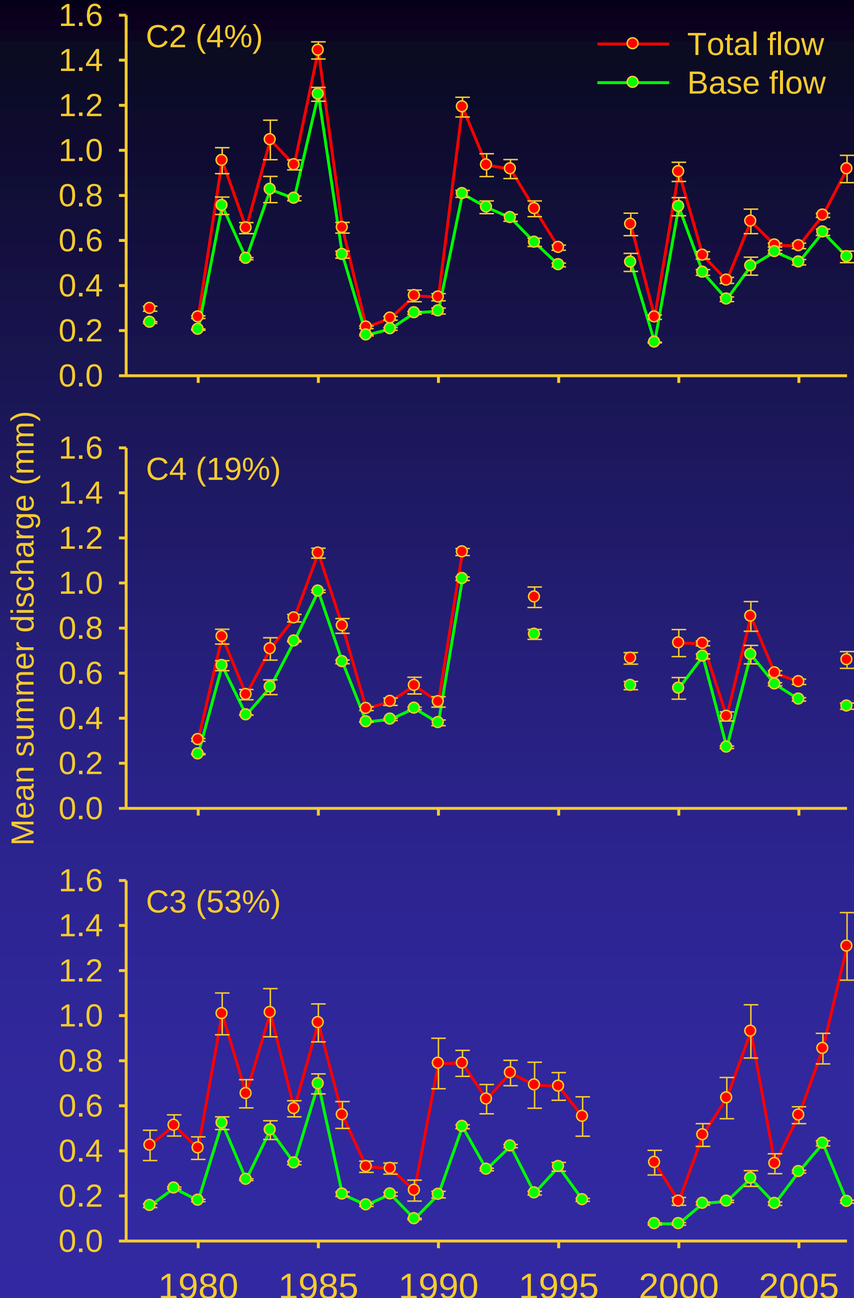
Prediction: If permafrost thaw is affecting stream discharge, then across years, the seasonal change in storm flow recessions will increase as active layer depth increases and permafrost in valley bottoms degrades.



PRECIPITATION



HYDROGRAPH SEPARATION

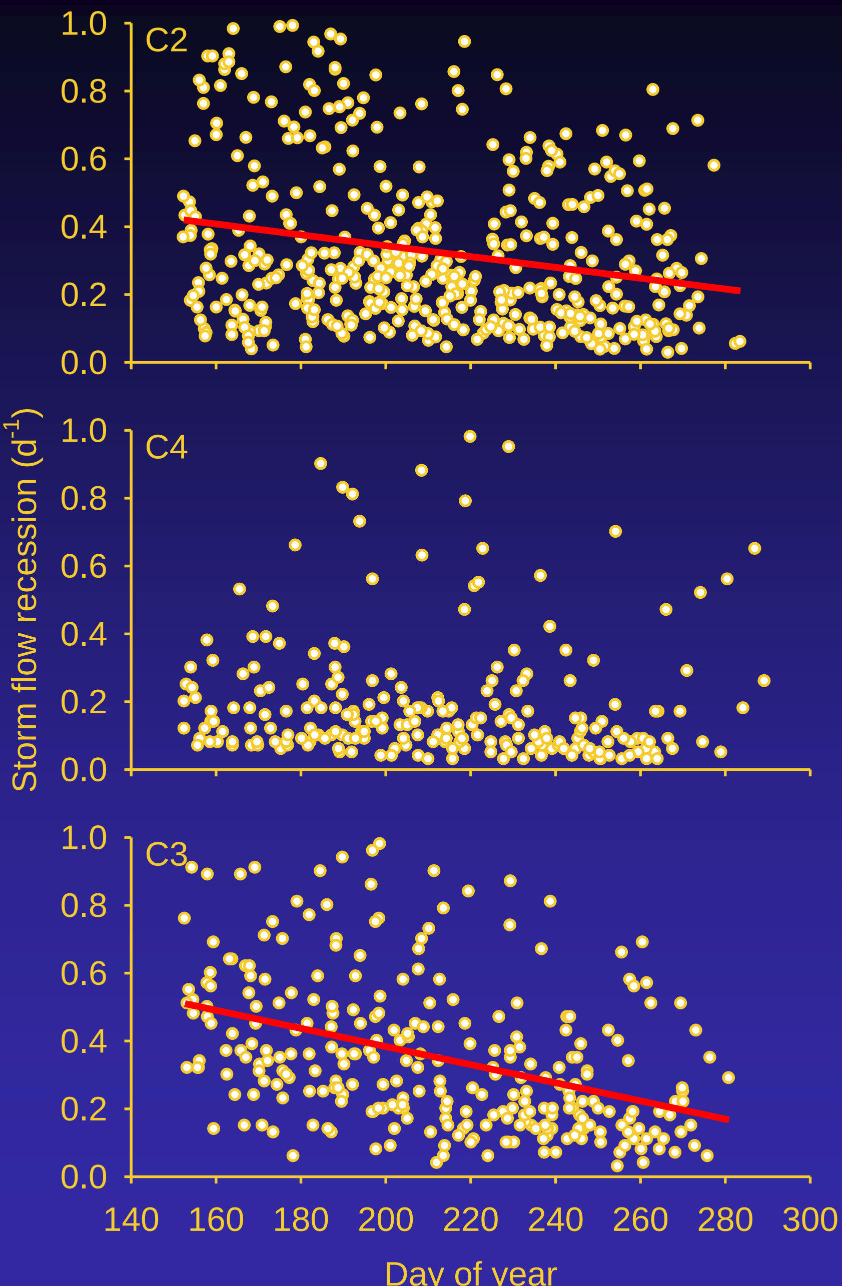


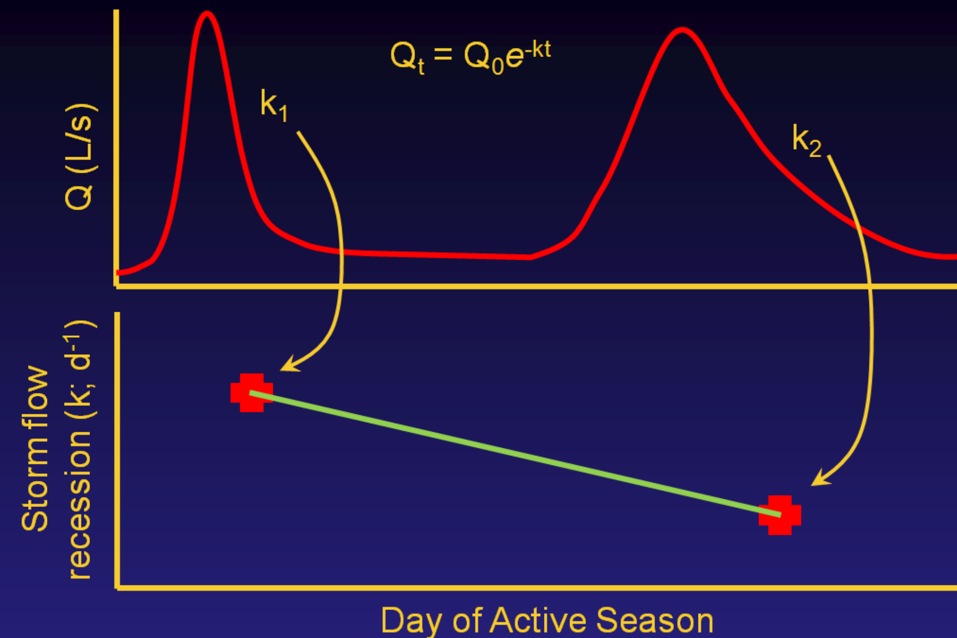
	(mm d^{-1})	(%)
Total	0.58	
Base flow	0.46	79
Storm flow	0.12	21

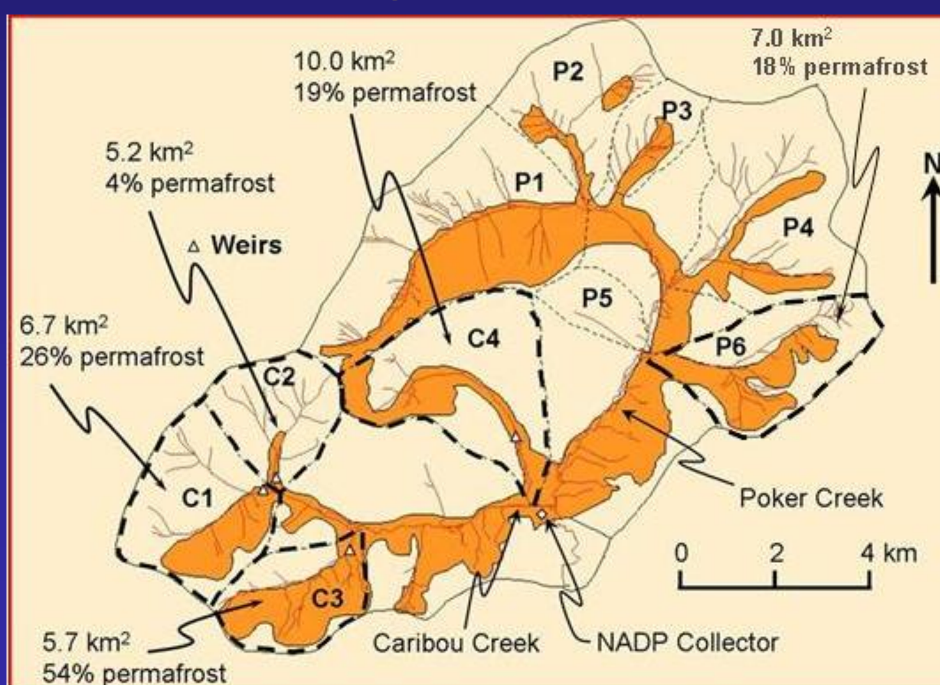
	(mm d^{-1})	(%)
Total	0.60	
Base flow	0.49	82
Storm flow	0.11	18

	(mm d^{-1})	(%)
Total	0.52	
Base flow	0.23	44
Storm flow	0.29	66

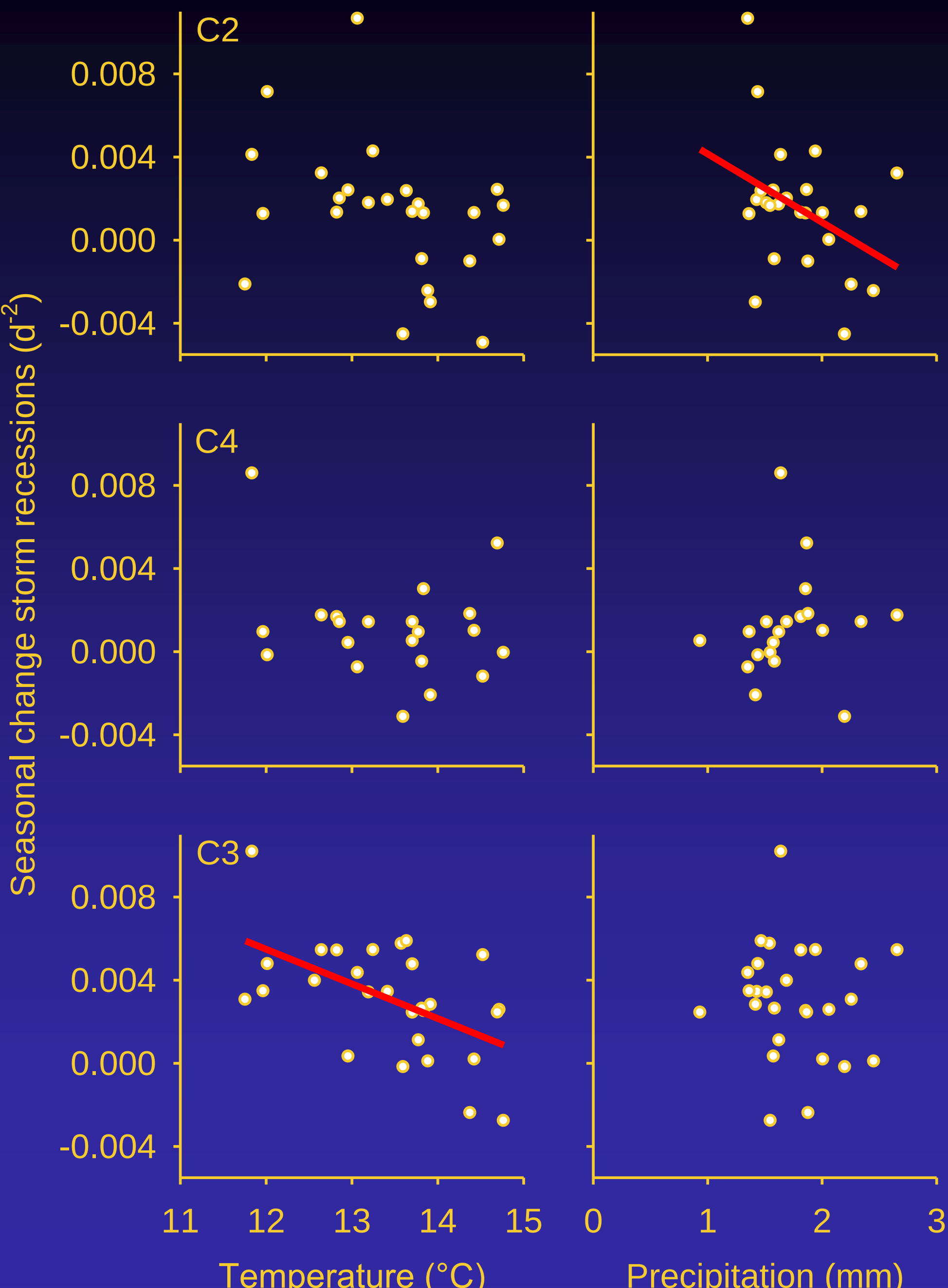
STORM FLOW RECESSION

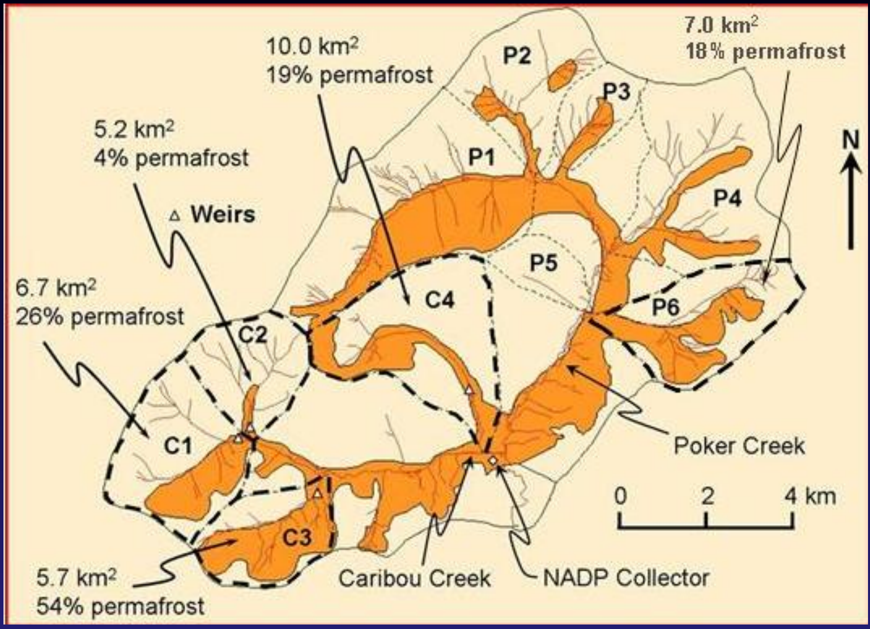




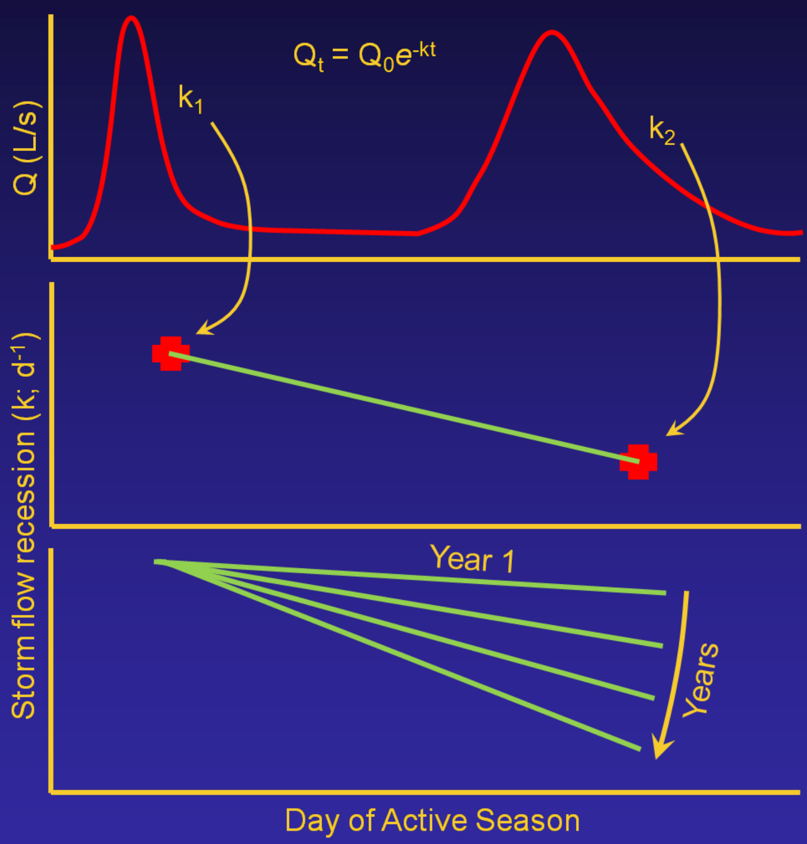


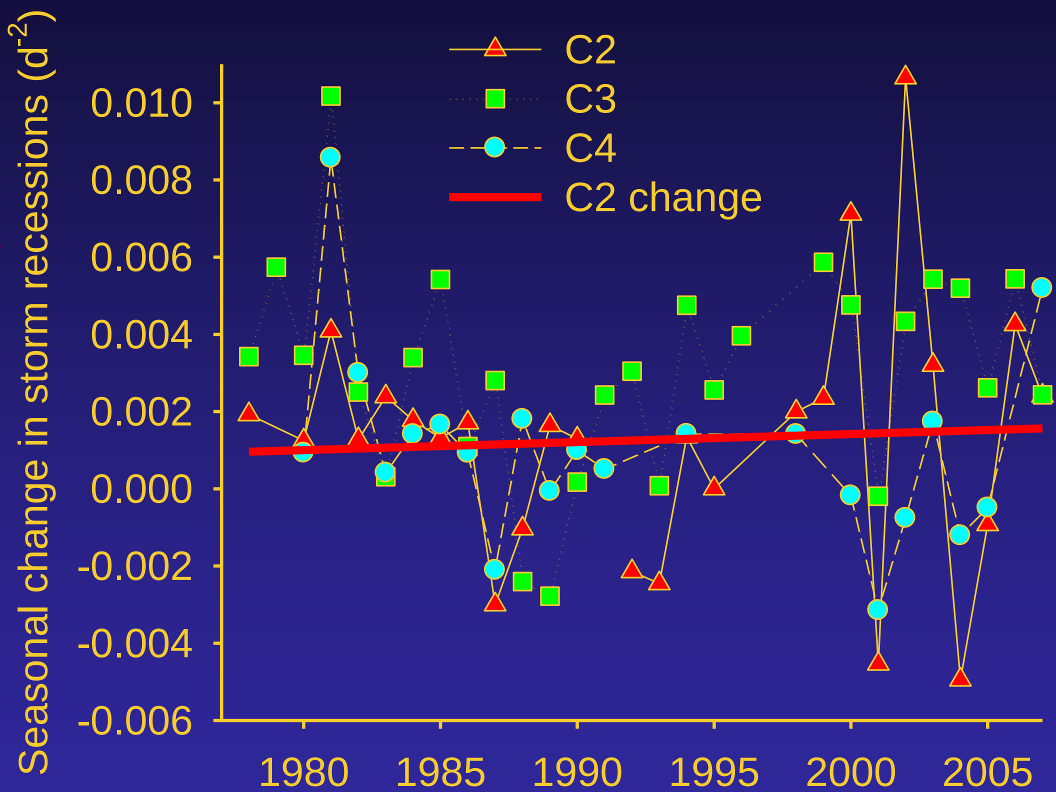
STORM FLOW RECESSION – INTERANNUAL CONTROLS





STORM FLOW RECESSION LONG-TERM CHANGES





CONCLUSIONS

- The loss of permafrost will have fundamental impacts on streams in the boreal forest of interior Alaska

- While we did not detect significant inter-annual changes in most measures of stream flow in CPCRW, we did observe distinct differences in summer runoff among streams

- The patterns among streams of CPCRW are consistent with inter-annual hydrologic changes observed throughout the subarctic including changes in the seasonal distribution of river flow (Walvoord and Striegl 2007), size of ponds (Riordan et al. 2006), glacial recession (Kaser et al. 2006), and declines in snow cover duration (Brown and Braaten 1998)

- With climate warming and loss of permafrost, upland headwater stream flow will likely become less responsive to precipitation and streams may become ephemeral

- These changes in stream flow are one component of broader hydrologic change across the boreal forest of Alaska.