ASSESSING THE IMPACTS OF CLIMATE CHANGE ON FLOODING IN THE SKAGIT RIVER BASIN

Dr. Alan F. Hamlet
Dr. Jon Riedel

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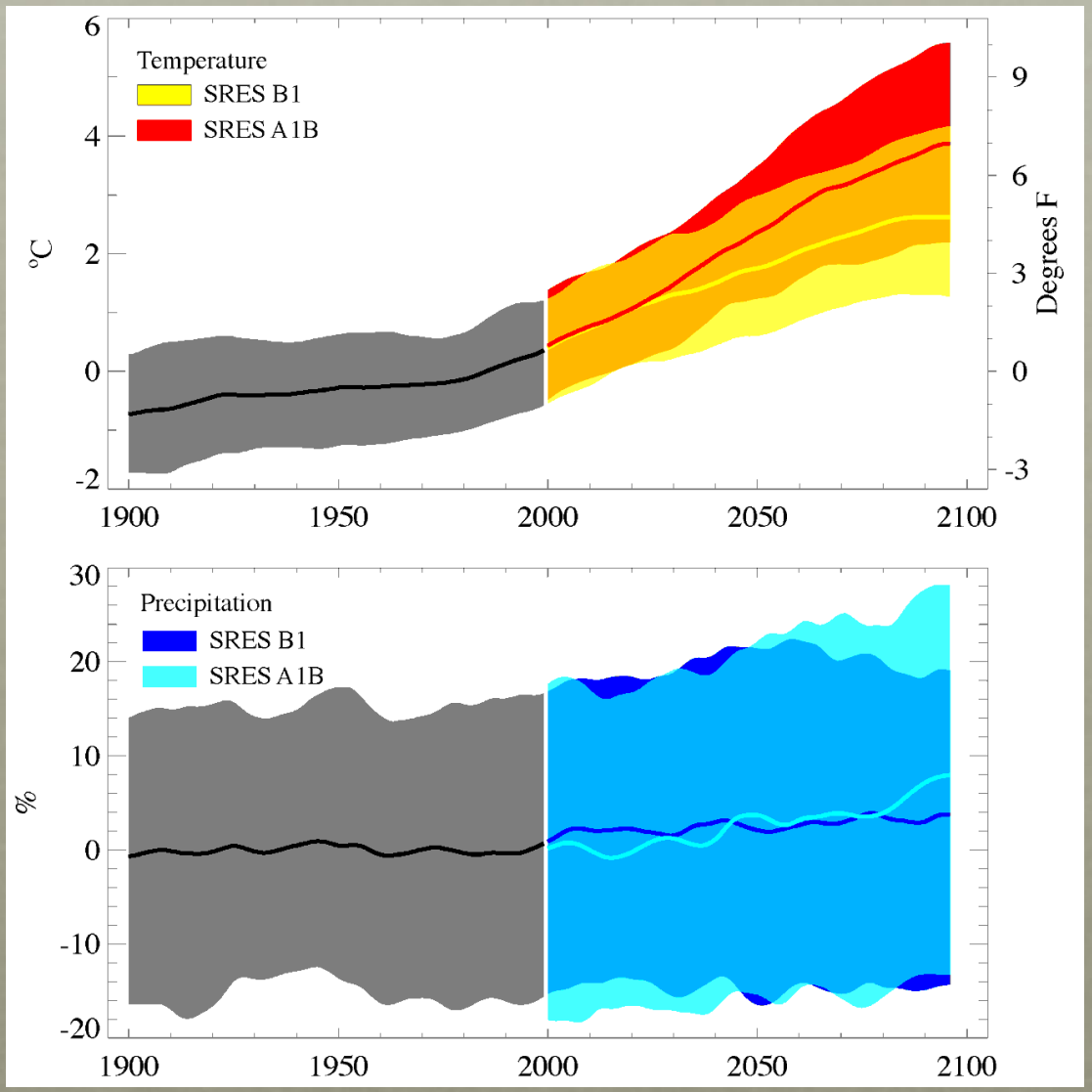
WSU, Mt. Vernon

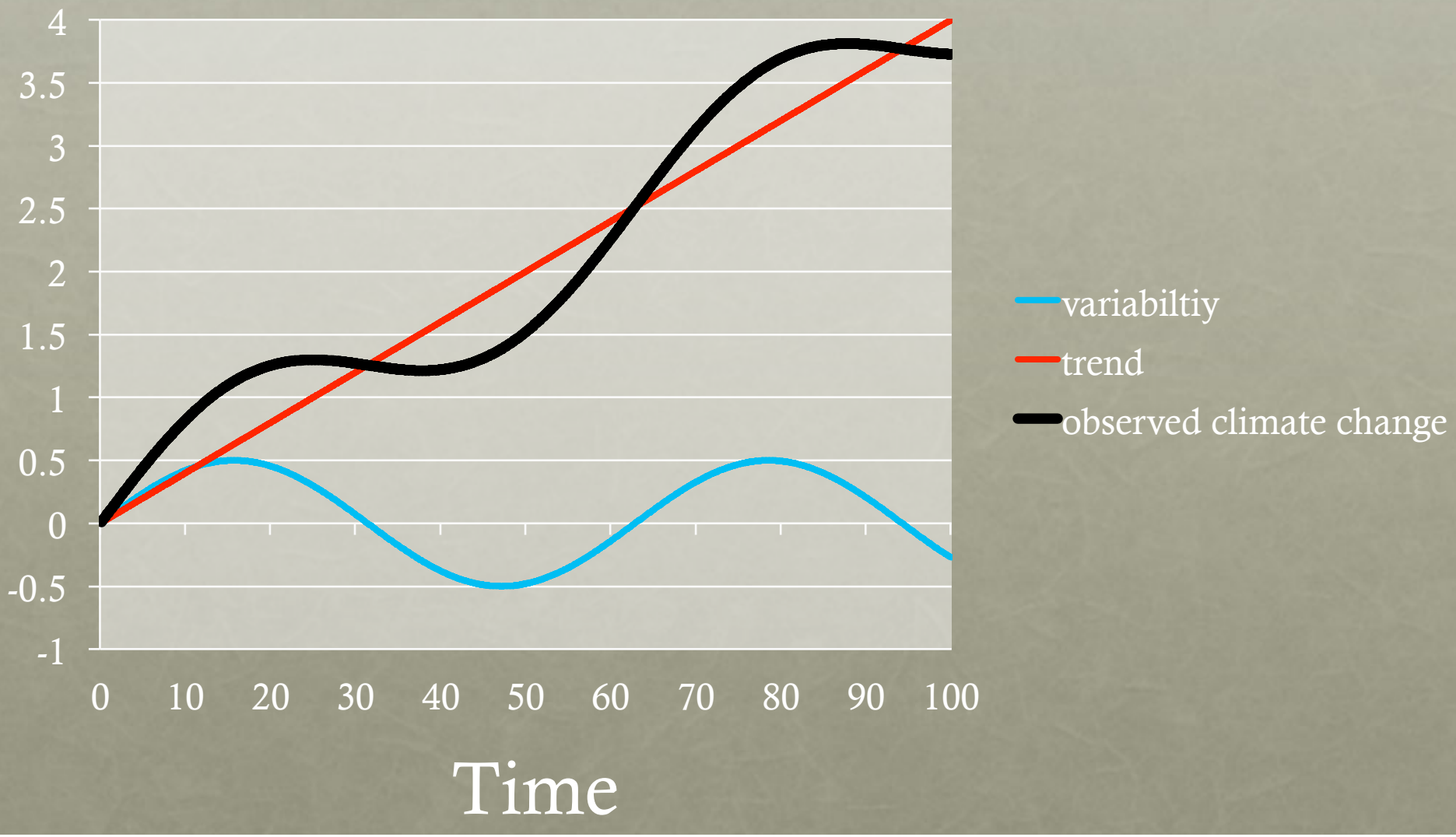
PNW TEMPERATURE AND PRECIPITATION SCENARIOS



Model Consensus:

- Strong Warming: All Seasons, Especially Summer
- Relatively Small Changes in Annual Precipitation
- Wetter Falls, Winters, and Springs
- Drier Summers

CLIMATE CHANGE WILL EXPRESS ITSELF AS A COMPLEX COMBINATION OF VARIABILITY PLUS TREND



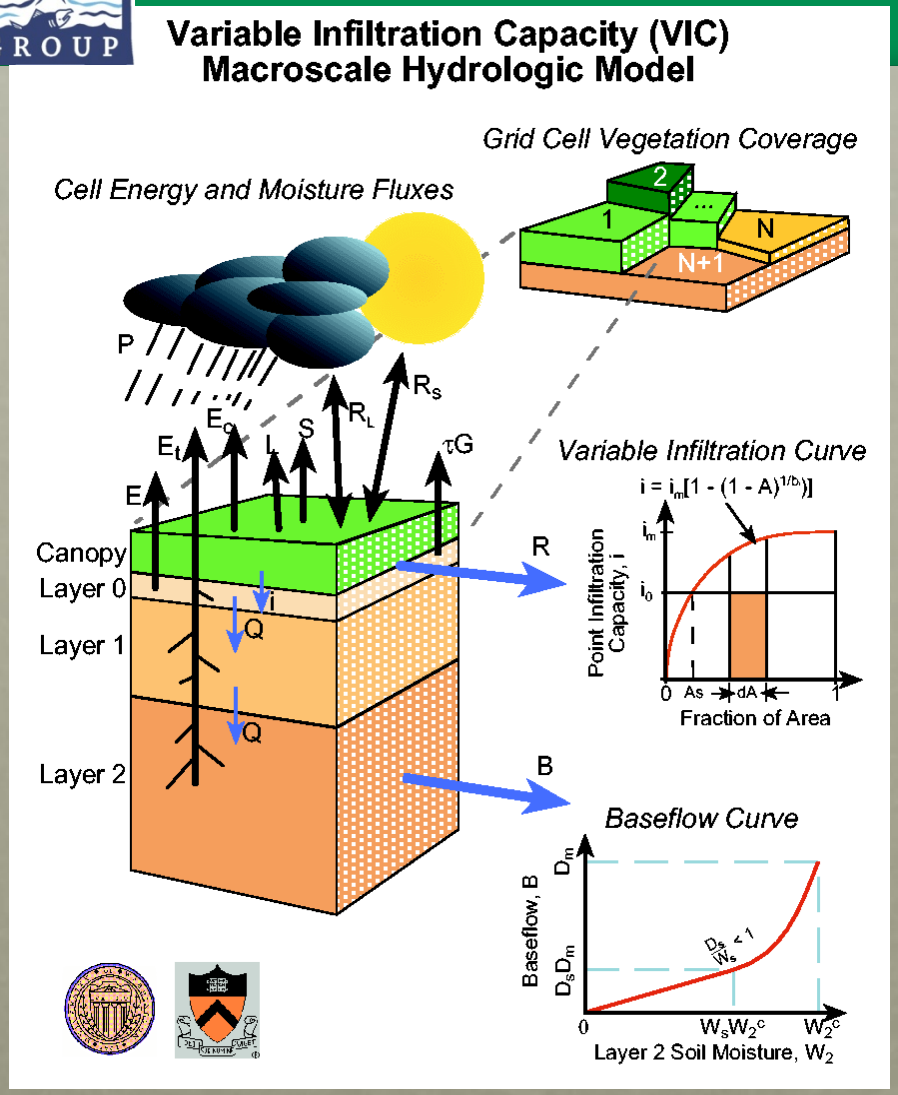
How will the Skagit Basin respond to a changing climate?

CHANGING HYDROLOGY AND HYDROLOGIC EXTREMES

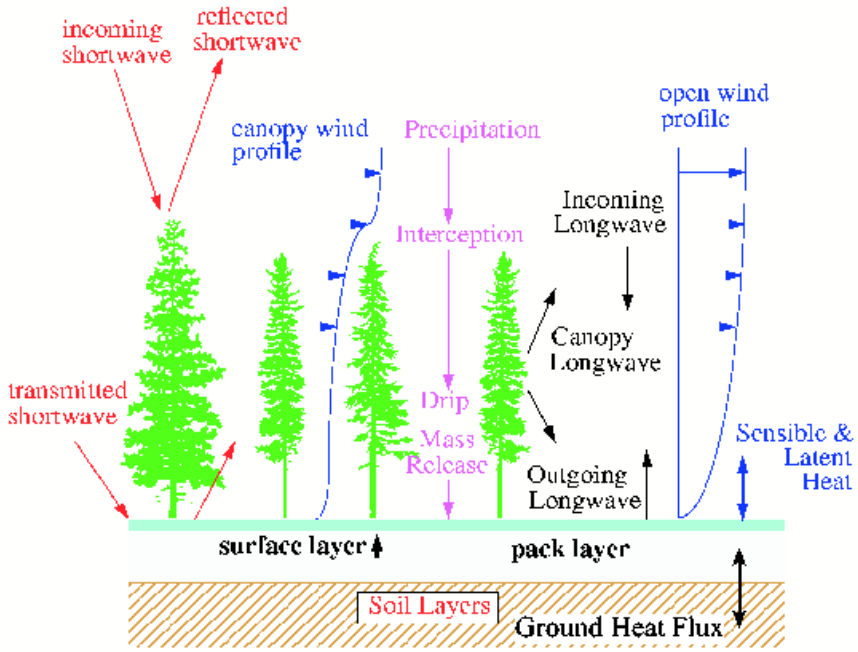
Hydrologic Modeling:

A "Translation" Between Climate Impacts and Water Impacts

Schematic of VIC Hydrologic Model

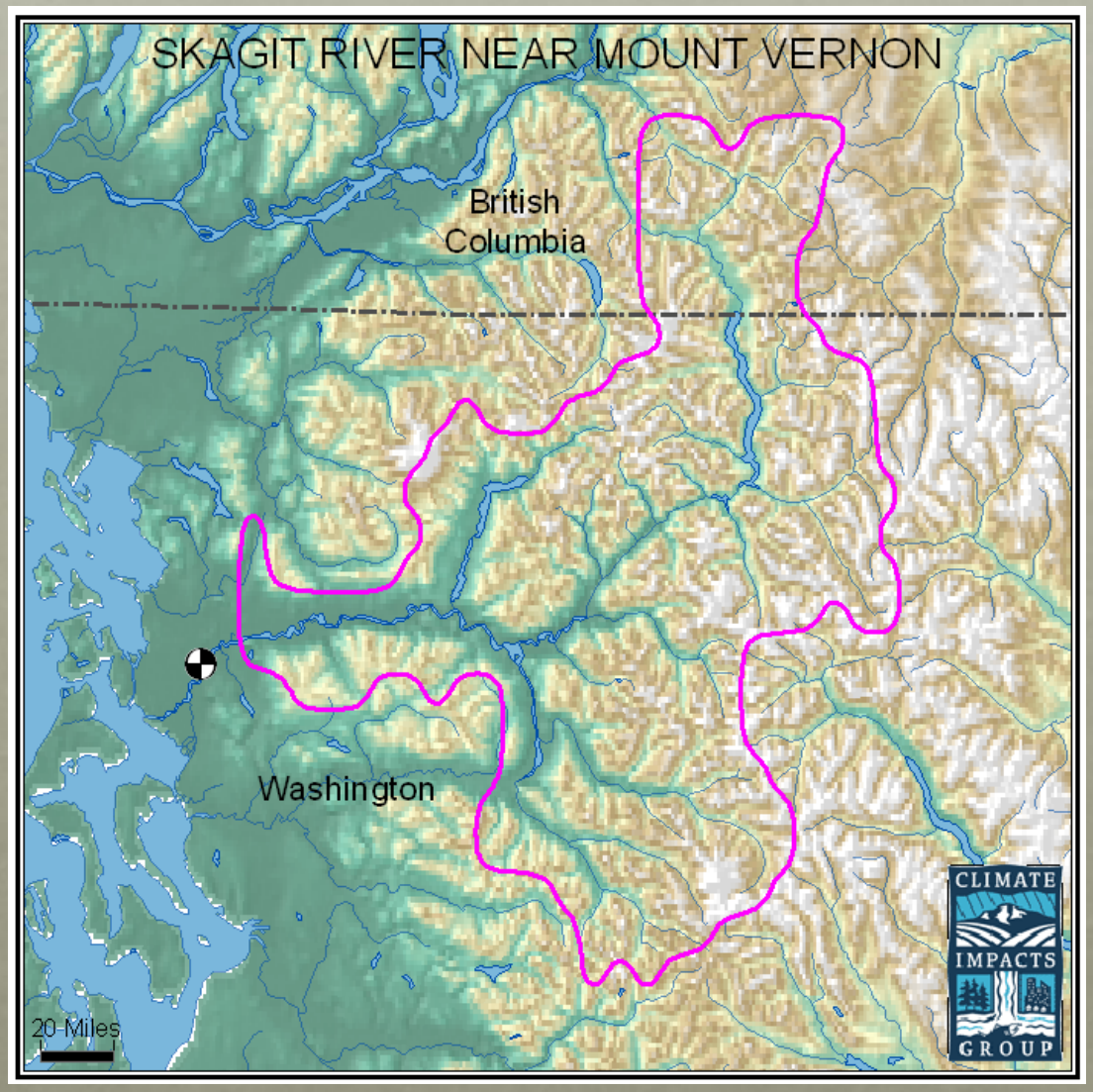


General Model Schematic

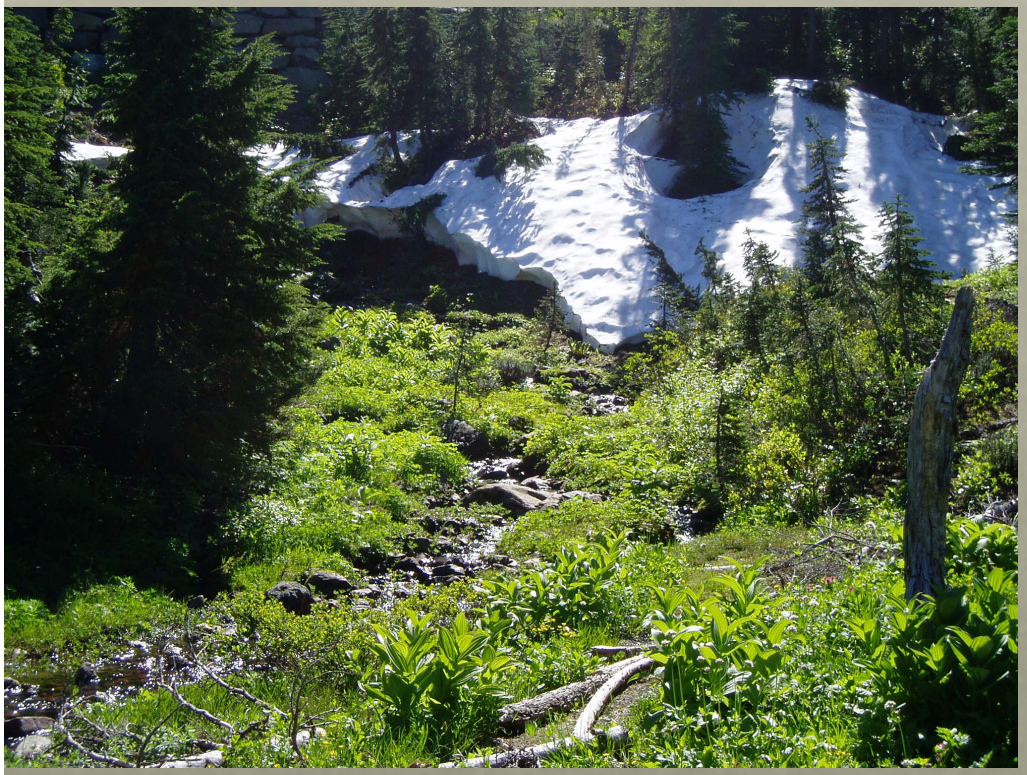


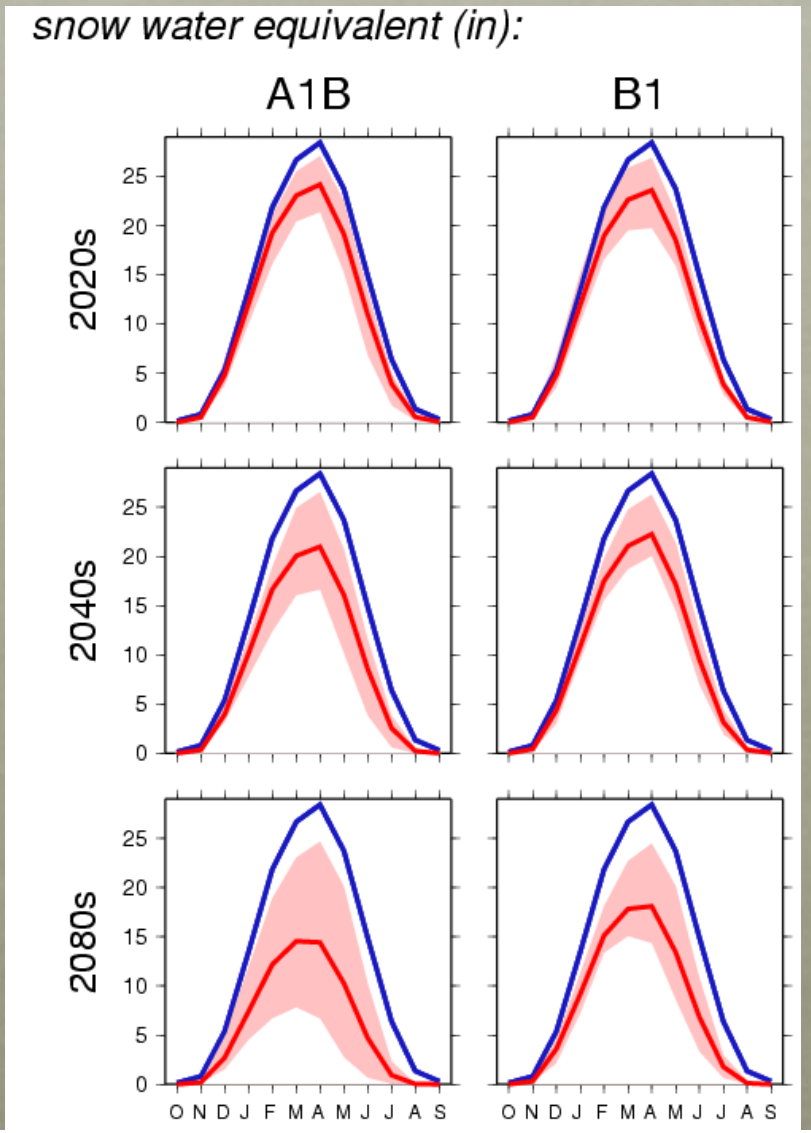
Snow Model

CHANGING HYDROLOGY IN THE SKAGIT BASIN

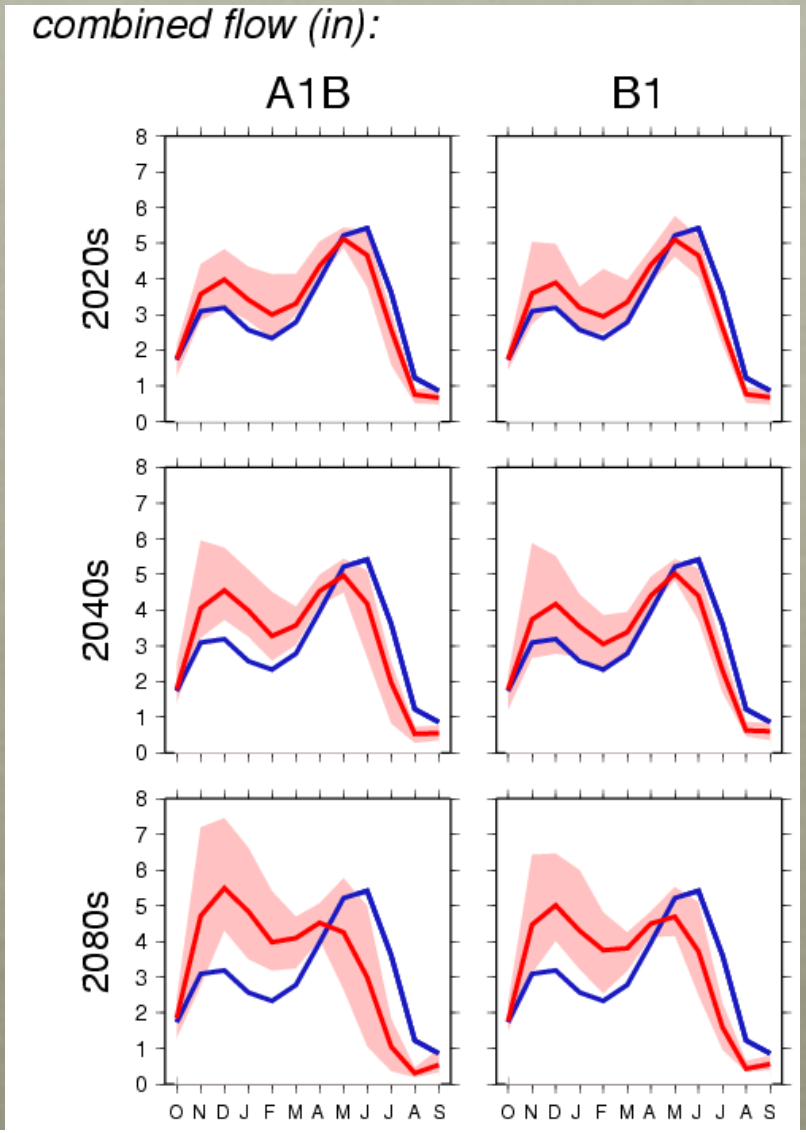


REDUCTIONS IN SNOWPACK

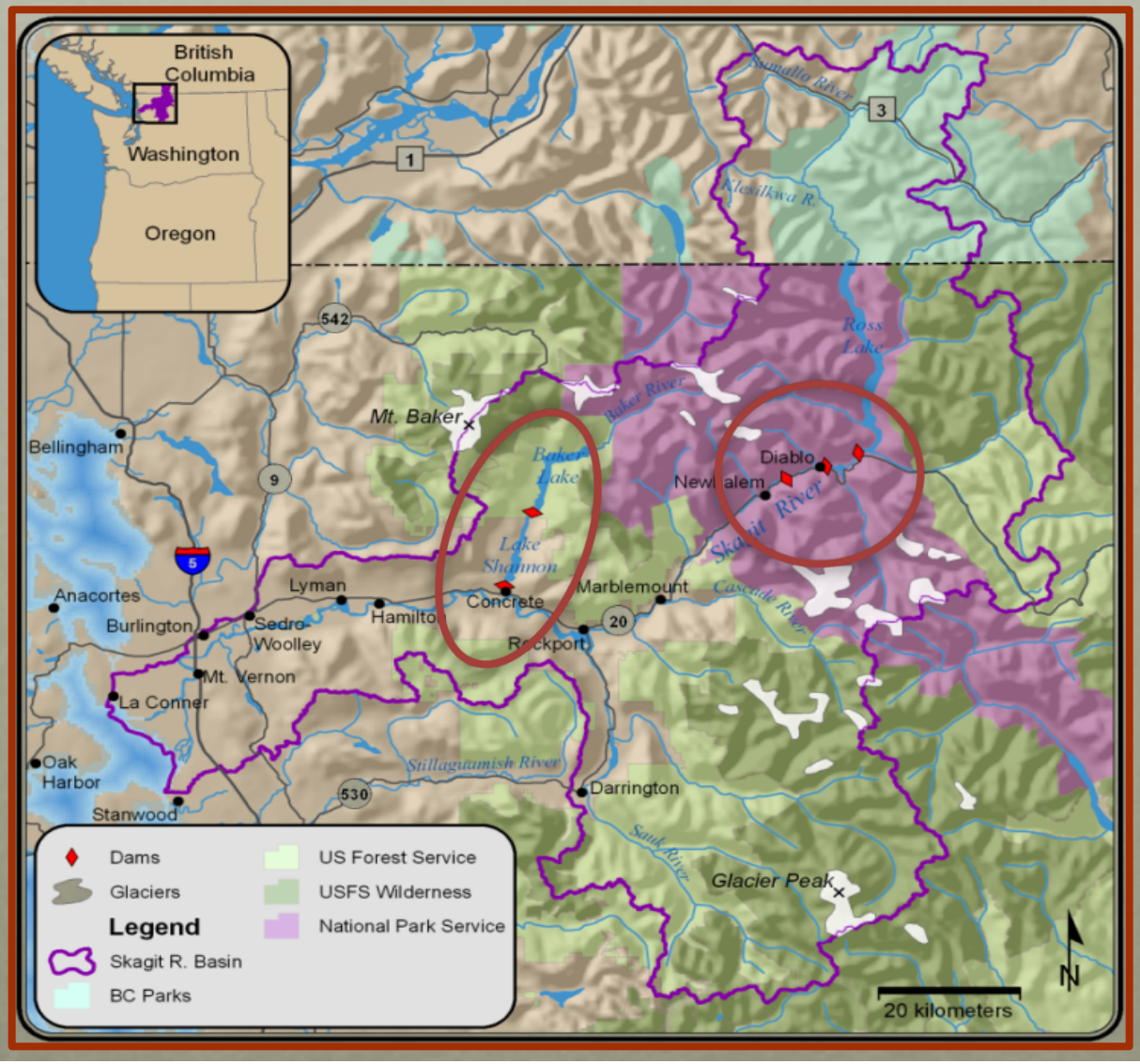




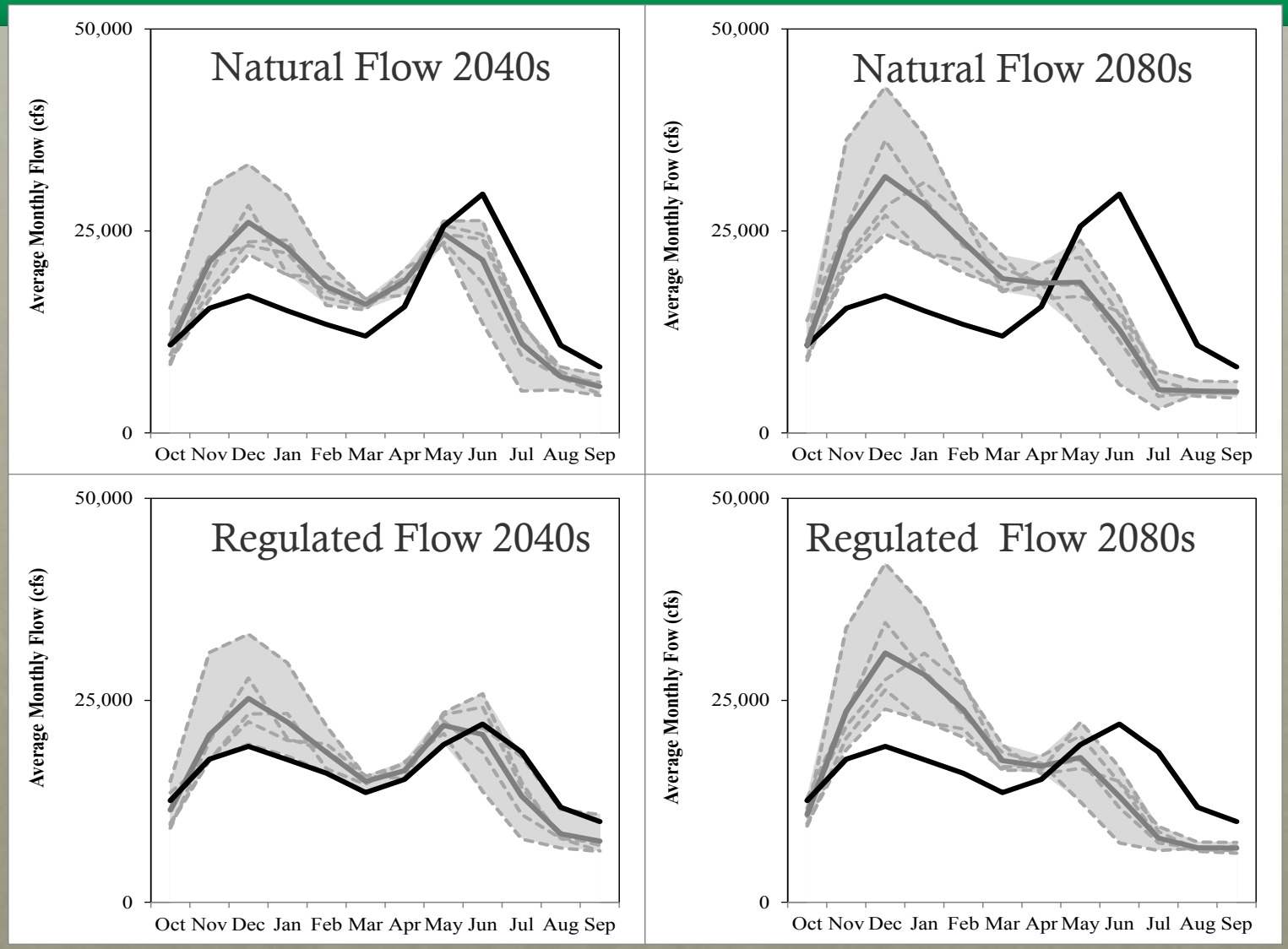
CHANGES IN MAGNITUDE AND SEASONAL TIMING OF STREAMFLOW



RESERVOIR OPERATIONS MODELS "TRANSLATE" DAILY *NATURAL* FLOW INTO DAILY *REGULATED* FLOW BY SIMULATING DAM OPERATIONS AT FIVE SKAGIT DAMS



CHANGES IN NATURAL VS. REGULATED FLOW



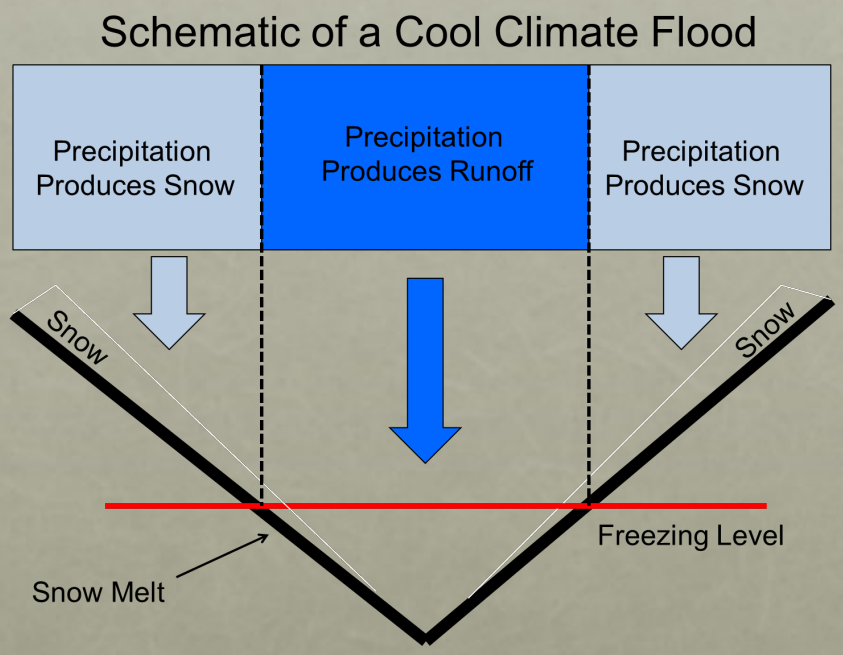
Source: Lee and Hamlet (in preparation)

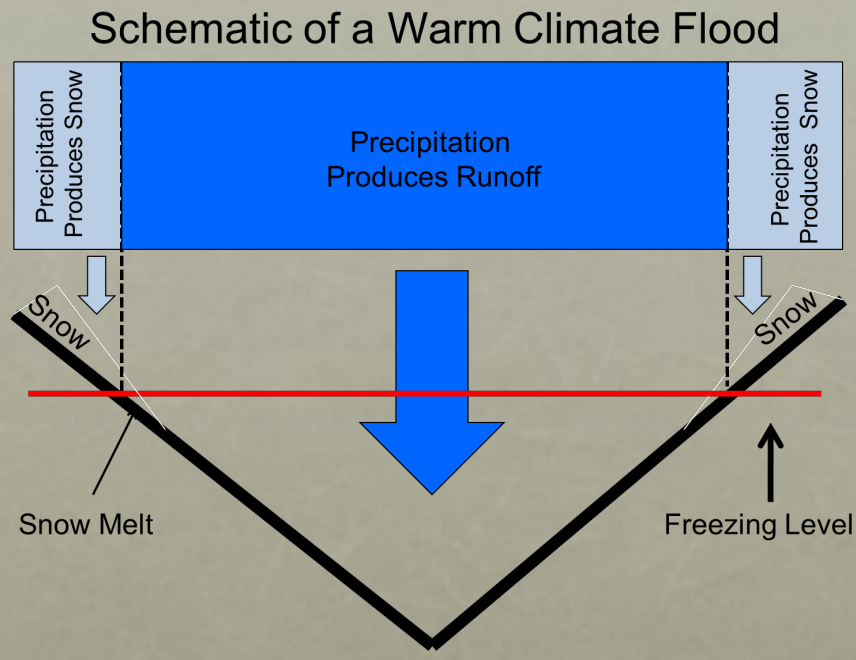
CHANGING HYDROLOGIC EXTREMES

Two primary factors increase flooding in future projections:

- Warmer temperatures increase contributing basin area during storms (and can also change the seasonal timing of flooding).
- Increasing winter precipitation increases both the storm intensity and antecedent winter soil moisture.

EFFECTS OF CHANGING SNOW LINE ON EFFECTIVE BASIN AREA





Since 1959 the average winter freezing elevation is estimated to have risen more than 600 feet in the Skagit basin. A higher freezing elevation increases the effective basin area that produces runoff during winter storms.

CHANGES IN THE REGULATED DAILY AVERAGE 100-YEAR FLOOD

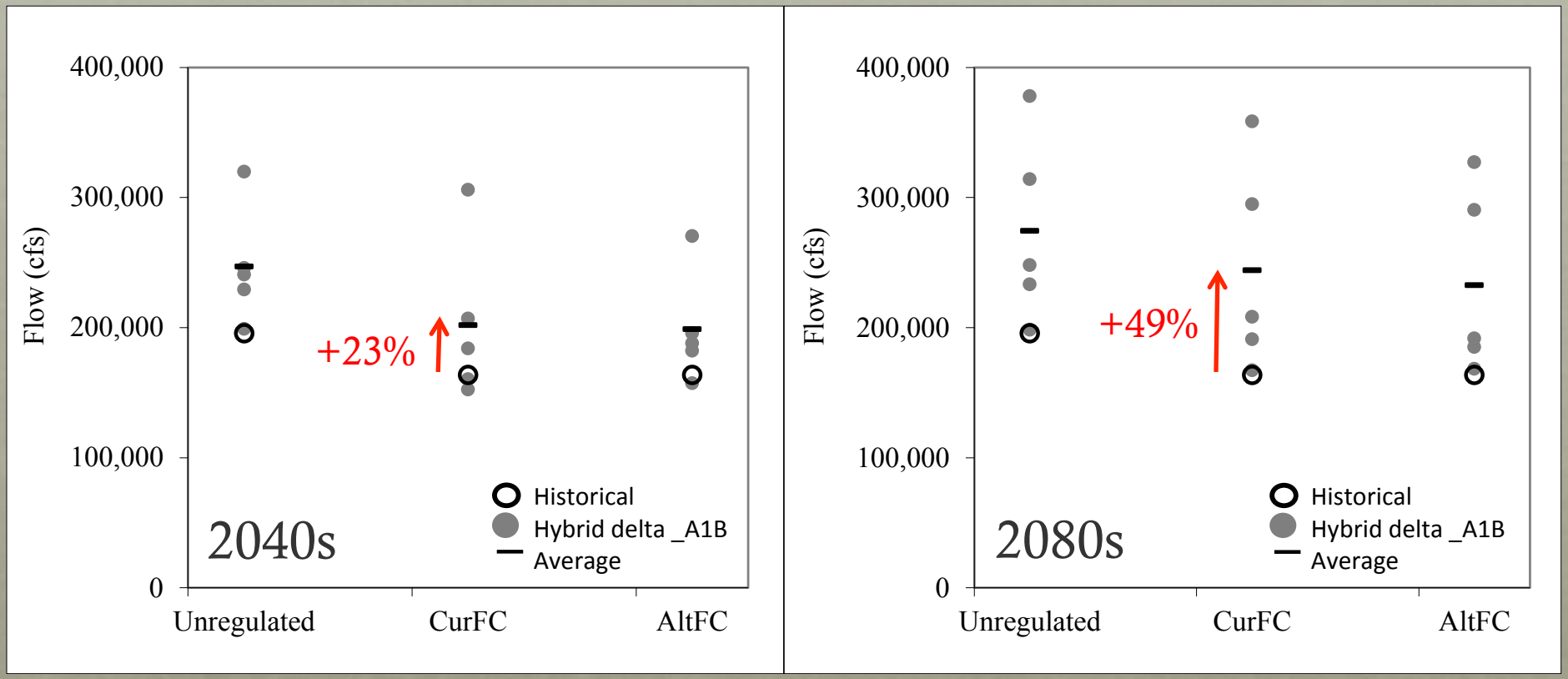


Figure 10. The magnitude of 100-year floods at the Skagit River near Mount Vernon for unregulated flows and for regulated flows under current flood control operations (CurFC) and alternative operations (AltFC) for the 2040s (left) and the 2080s (right). The open circles represent the historical values, the gray dots show the range of values from five climate change scenarios for A1B emissions scenario, and the solid line represents the average of the five future ensemble.

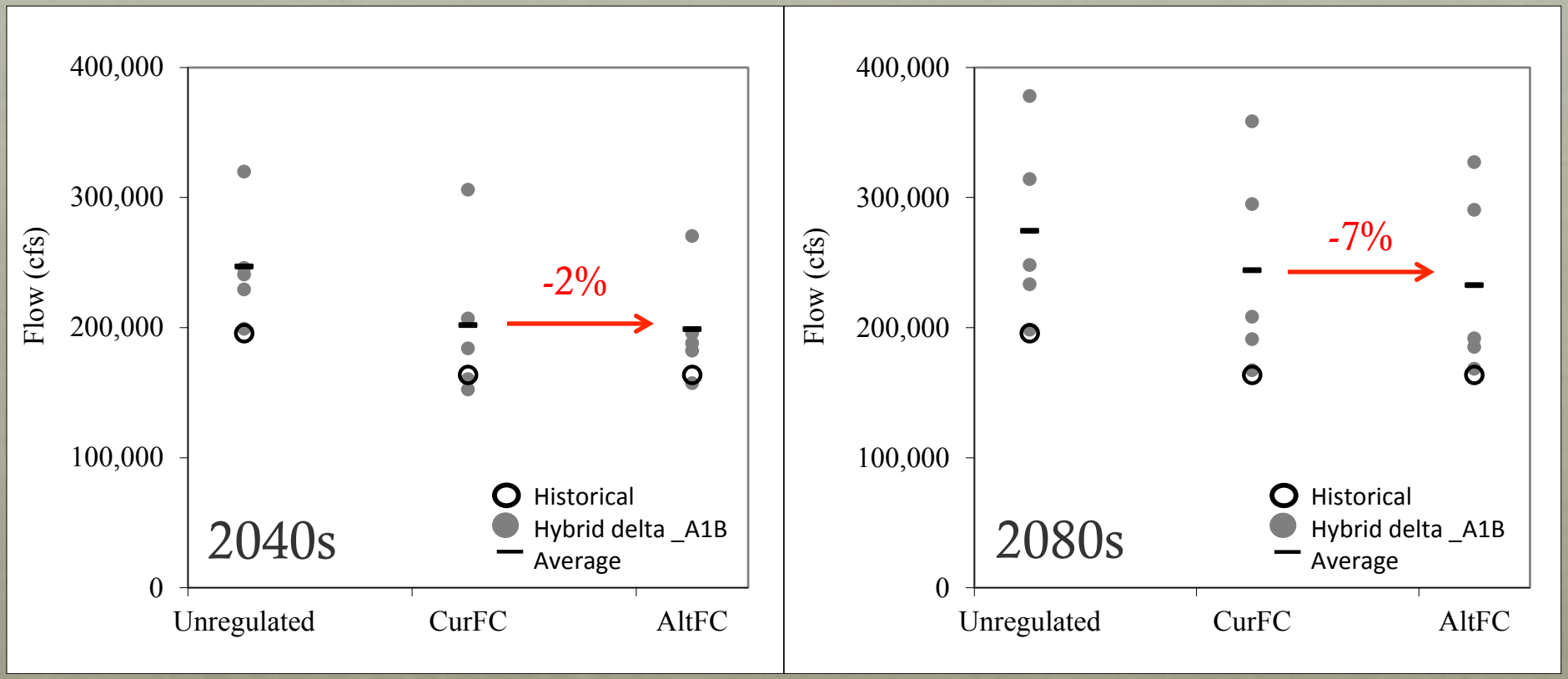
Source: Lee and Hamlet (in preparation)

SUMMARY OF REGULATED FLOOD IMPACTS

By the 2040s the historical 100-year event is projected to become a 22-year event.

By the 2040s the historical 30-year event is projected to become an 7-year event.

INCREASING RESERVOIR STORAGE DOES NOT SUBSTANTIALLY REDUCE FLOODING IN THE SIMULATIONS



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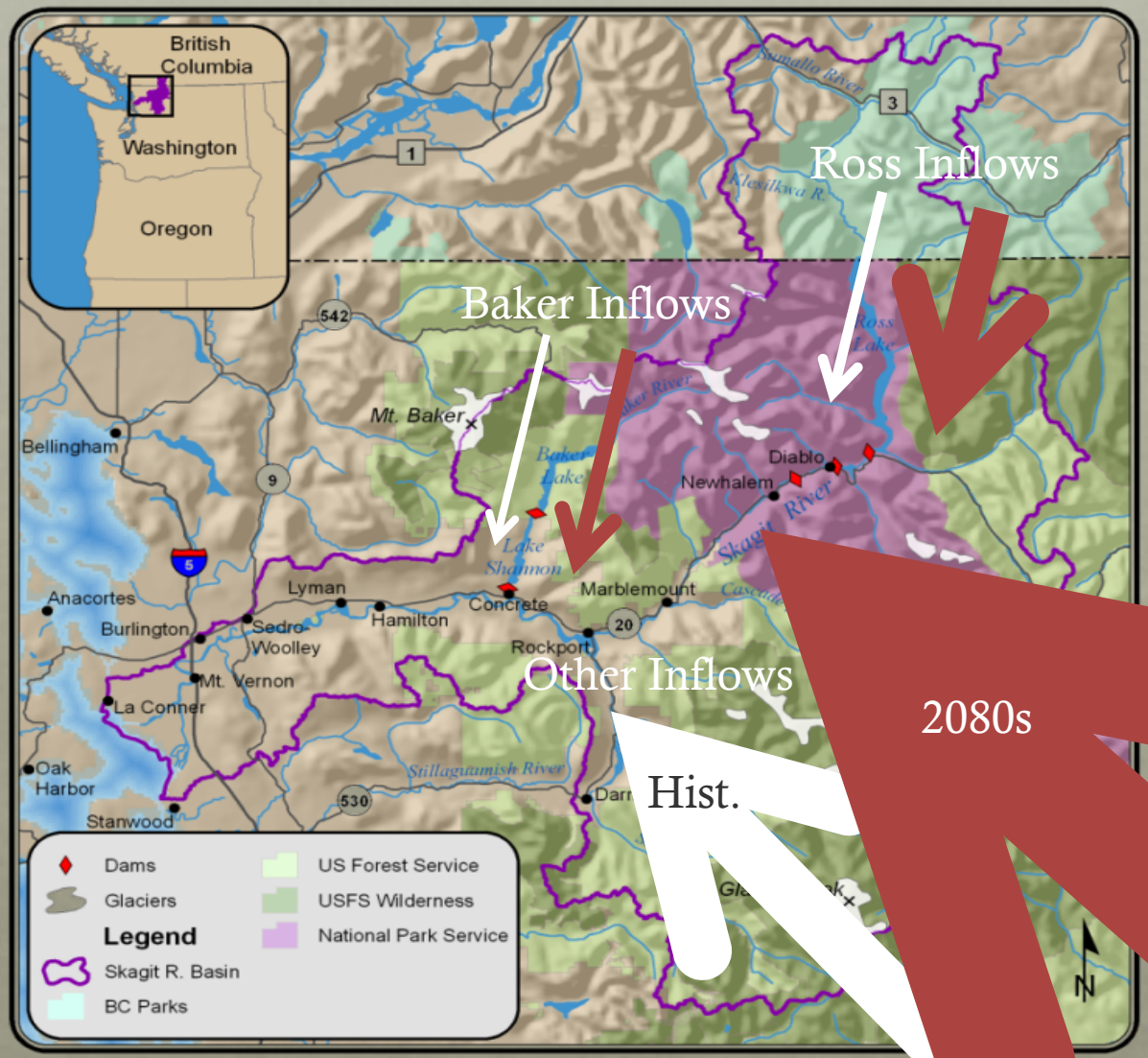
Source: Lee and Hamlet (in preparation)

MOST OF THE RUNOFF PRODUCTION DURING FLOODS IS DOWNSTREAM OF HEADWATER DAMS, WHICH LIMITS THE EFFECTIVENESS OF ADDING MORE HEADWATER STORAGE



Flow Breakdown of Simulated Natural Flood "Jan, 2006"

	Historical	2080s
Ross	12	42
Baker	9	19
Other	69	159

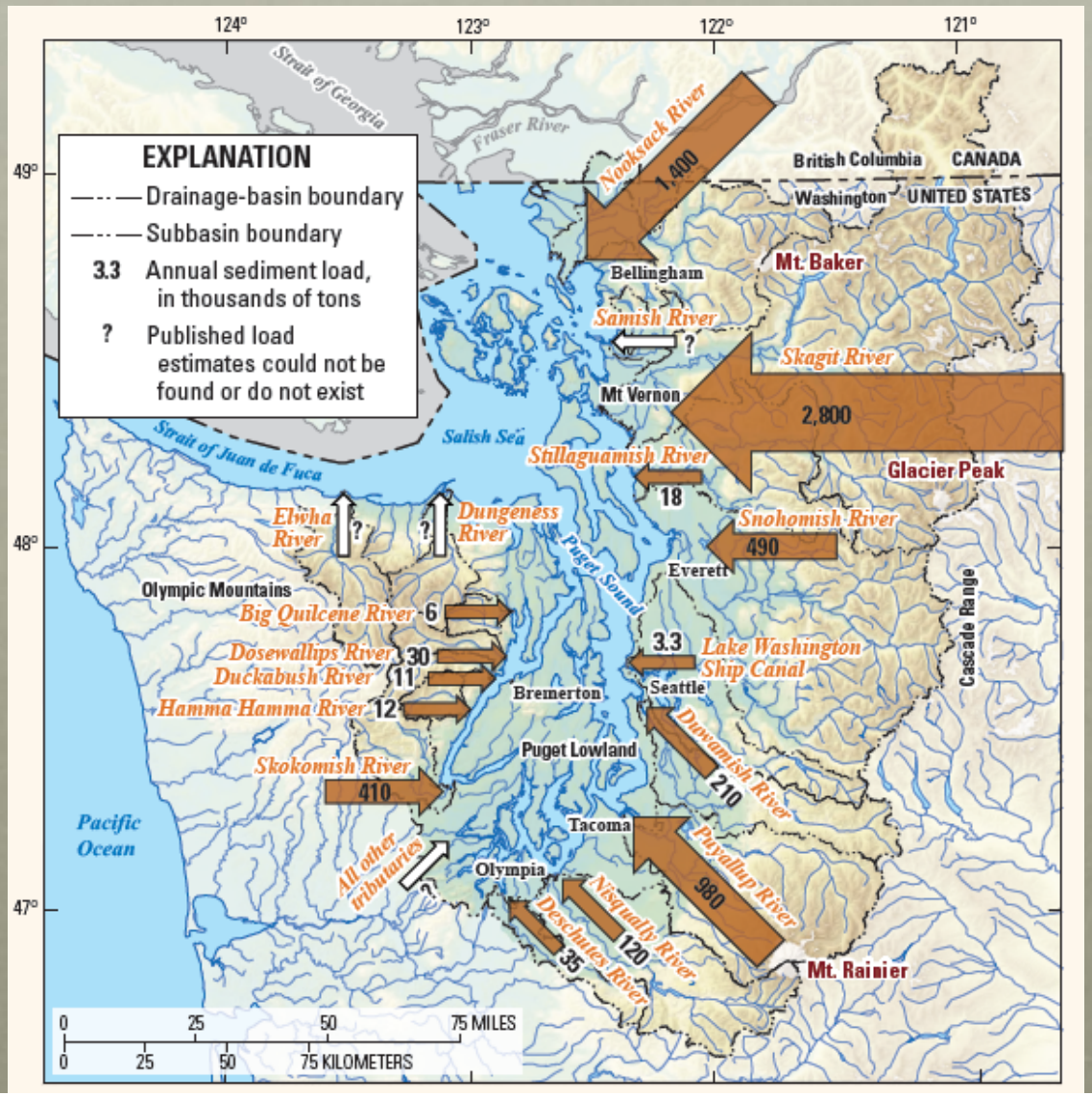
kcfs

KEY CONCLUSIONS

- The combination of warmer temperatures (increasing contributing basin area), wetter soils, and increasing winter precipitation are projected to dramatically alter flood regimes in the Skagit.
- By the 2040s, the historical 100-year regulated flood could become a 22-year event.
- By the 2040s, the historical 30-yr regulated flood could become a 7-year event.
- Skagit dam operations reduce flooding, but most of the runoff production during floods is downstream of headwater dams, which limits the role that reservoir operations can play in protecting the lower basin from projected larger floods in the future. Increasing available flood storage only reduces the regulated 100-year event by 2-7 percent in the simulations.

PROJECTED IMPACTS TO SEDIMENT TRANSPORT RATES

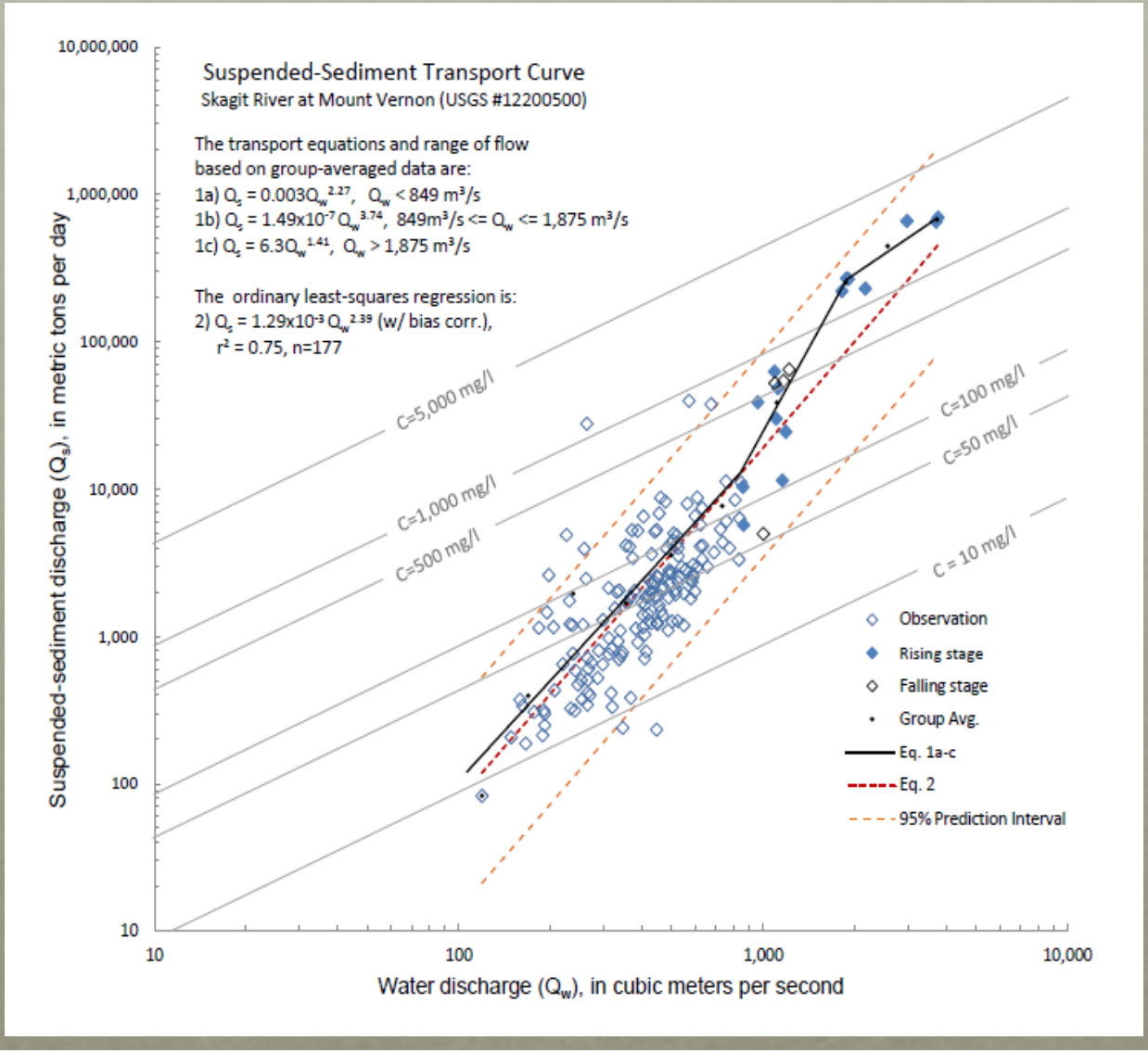
IMPORTANCE OF SKAGIT SEDIMENT TRANSPORT



The Skagit River already moves a tremendous amount of sediment in comparison with other Puget Sound rivers.

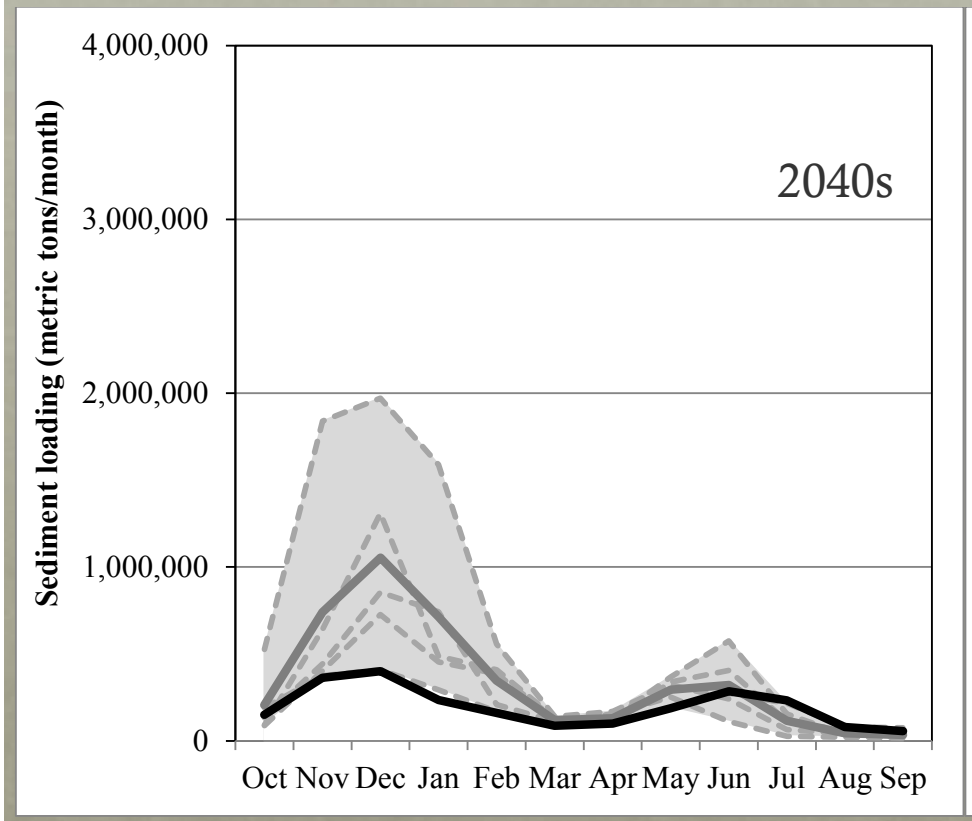
Increasing peak flows, retreating glaciers, declining snowpack and increased fire frequencies are hypothesized to increase sediment production in the future.

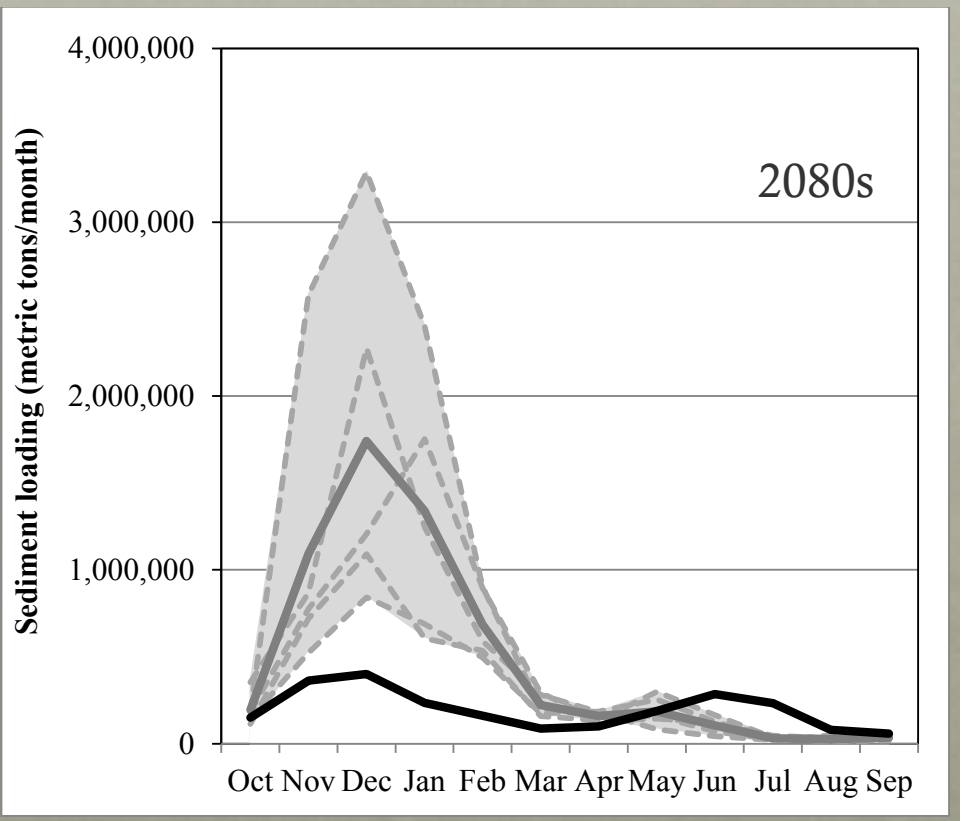
CURRENT SEDIMENT RATING CURVE AT MT. VERNON



(Source: Curran, Grossman et al. 2011)

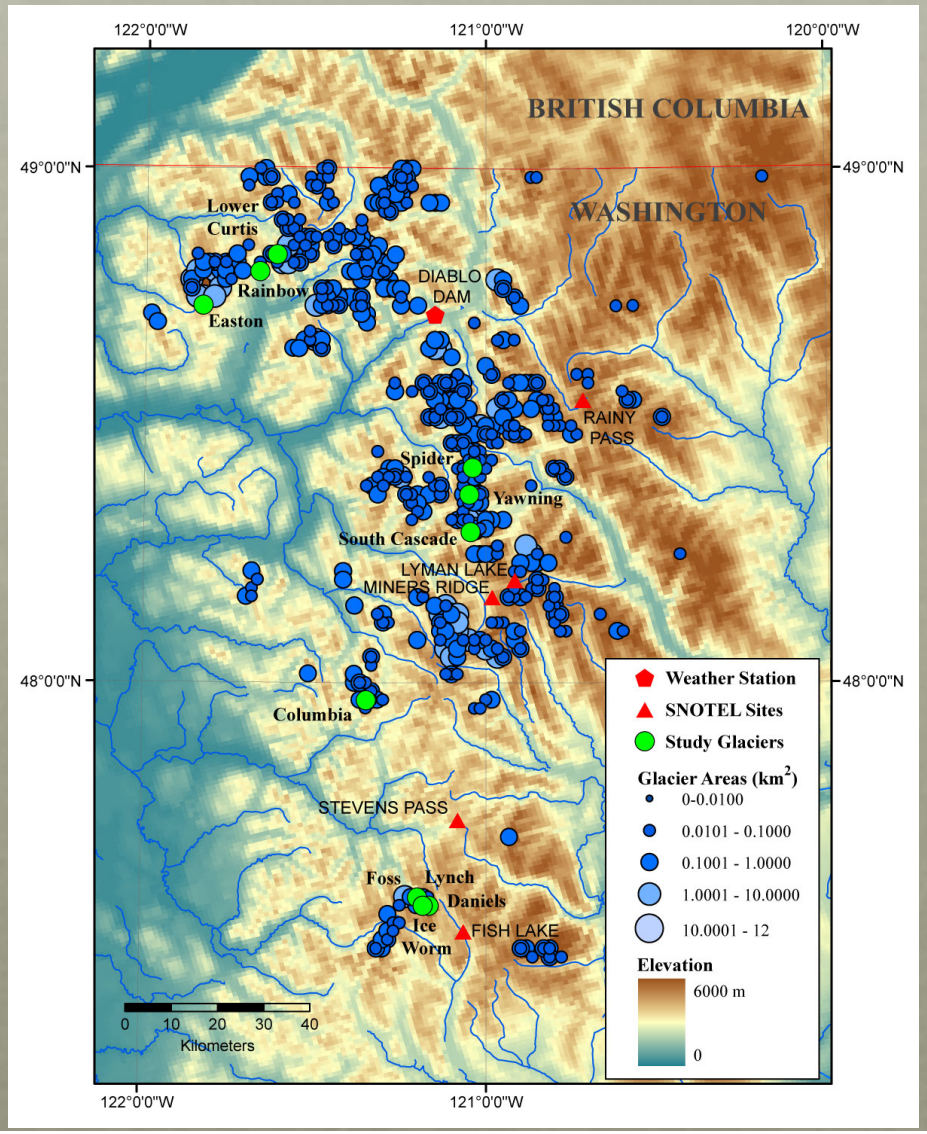
CHANGING DAILY FLOW REGIME ALONE ALTERS SEDIMENT TRANSPORT





Black lines show historical suspended sediment loading
Grey shading and lines show the range and average of 5 climate change scenarios

CHANGING GLACIERS



There are approximately 394 glaciers in the Skagit Watershed (Post et. Al 1971)

Between 1900-1998 the North Cascades lost ~ 50% of its glacial area (Granshaw, 2002)

SILVER GLACIER

1958 2006

Sediment Impacts Caused by Glacial Recession

RAINIER'S ROCKS ARE FILLING RIVERBEDS

Dr. Tim Abbe 01.04.10 Restoration 2 Comments

Paul Kennard, NPS [by Steve Ringman, Seattle Times]

The fallout from Mount Rainier's shrinking glaciers is beginning to roll downhill, and nowhere is the impact more striking than on the volcano's west side.

By Sandi Doughton
Seattle Times science reporter

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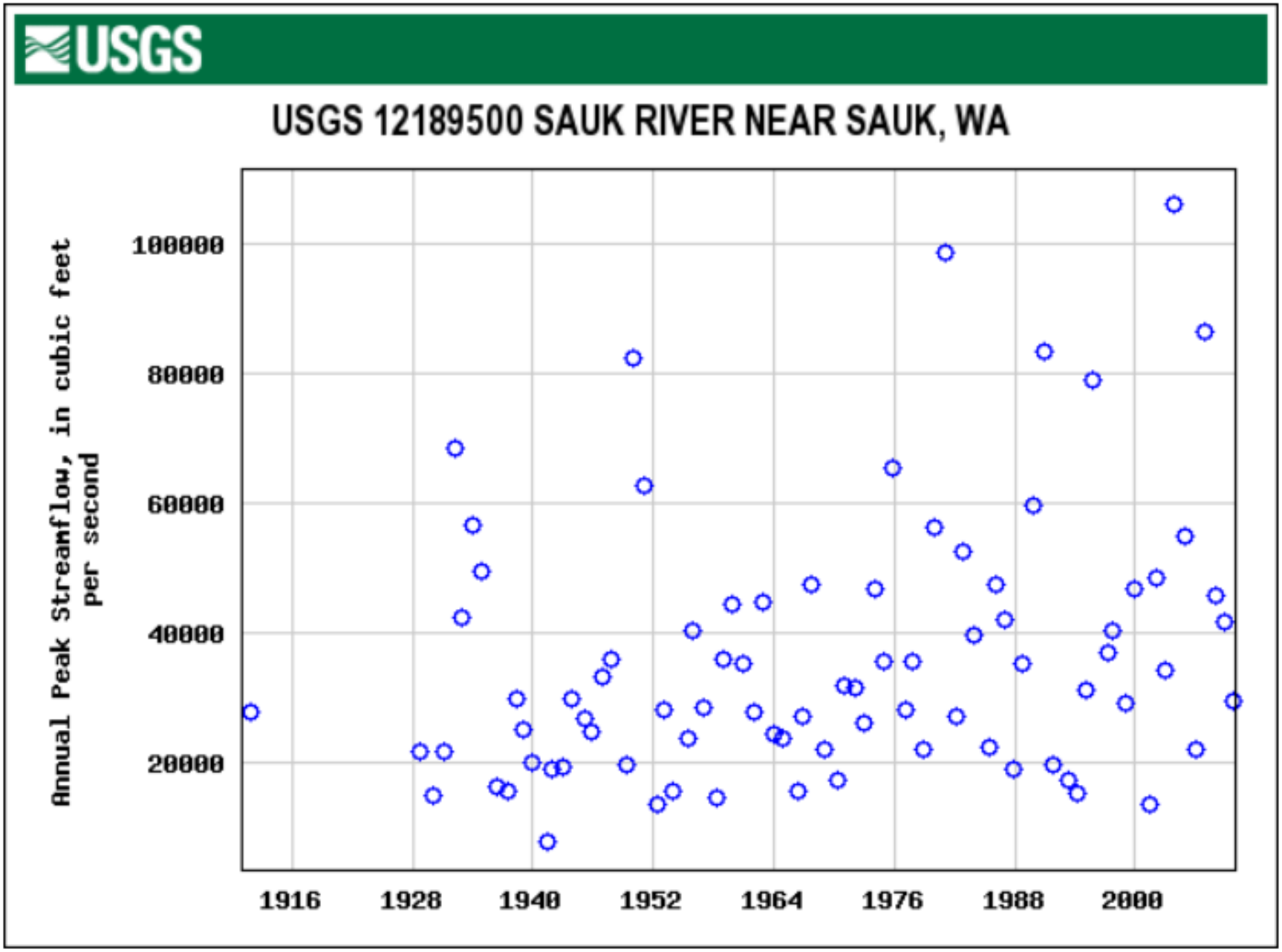
The fallout from Mount Rainier's shrinking glaciers is beginning to roll downhill, and nowhere is the impact more striking than on the volcano's west side.

"This is it in spades," said Park Service geologist Paul Kennard, scrambling up a 10-foot-tall mass of dirt and boulders bulldozed back just enough to clear the road.

As receding glaciers expose crumbly slopes, vast amounts of gravel and sediment are being sluiced into the rivers that flow from the Northwest's tallest peak. Much of the material sweeps down in rain-driven slurries called debris flows, like those that repeatedly have slammed Mount Rainier National Park's Westside Road.

Observed Changes in Flooding in the Skagit Basin and West-Slope Cascades

Evidence of Changing Flood Statistics



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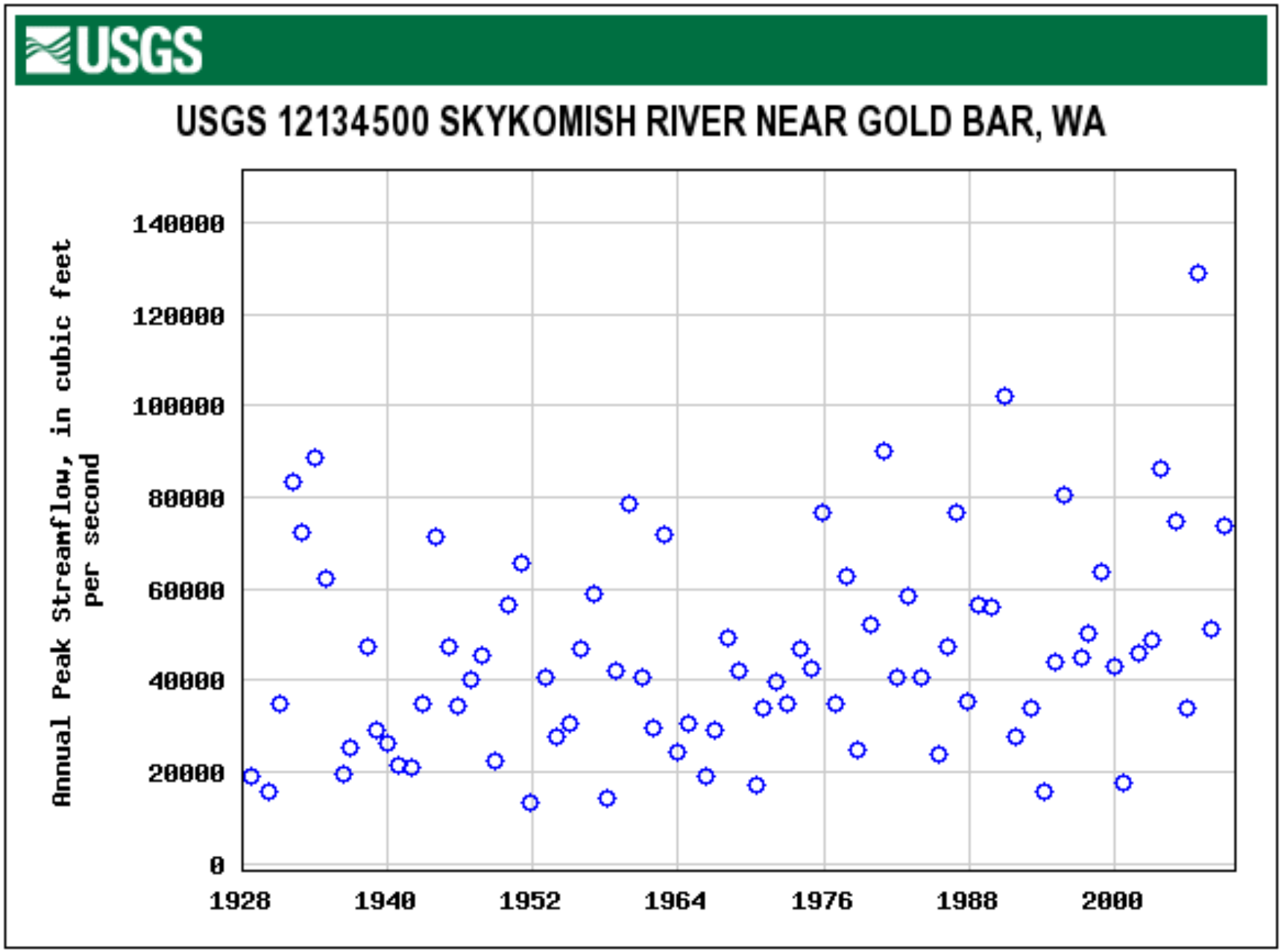

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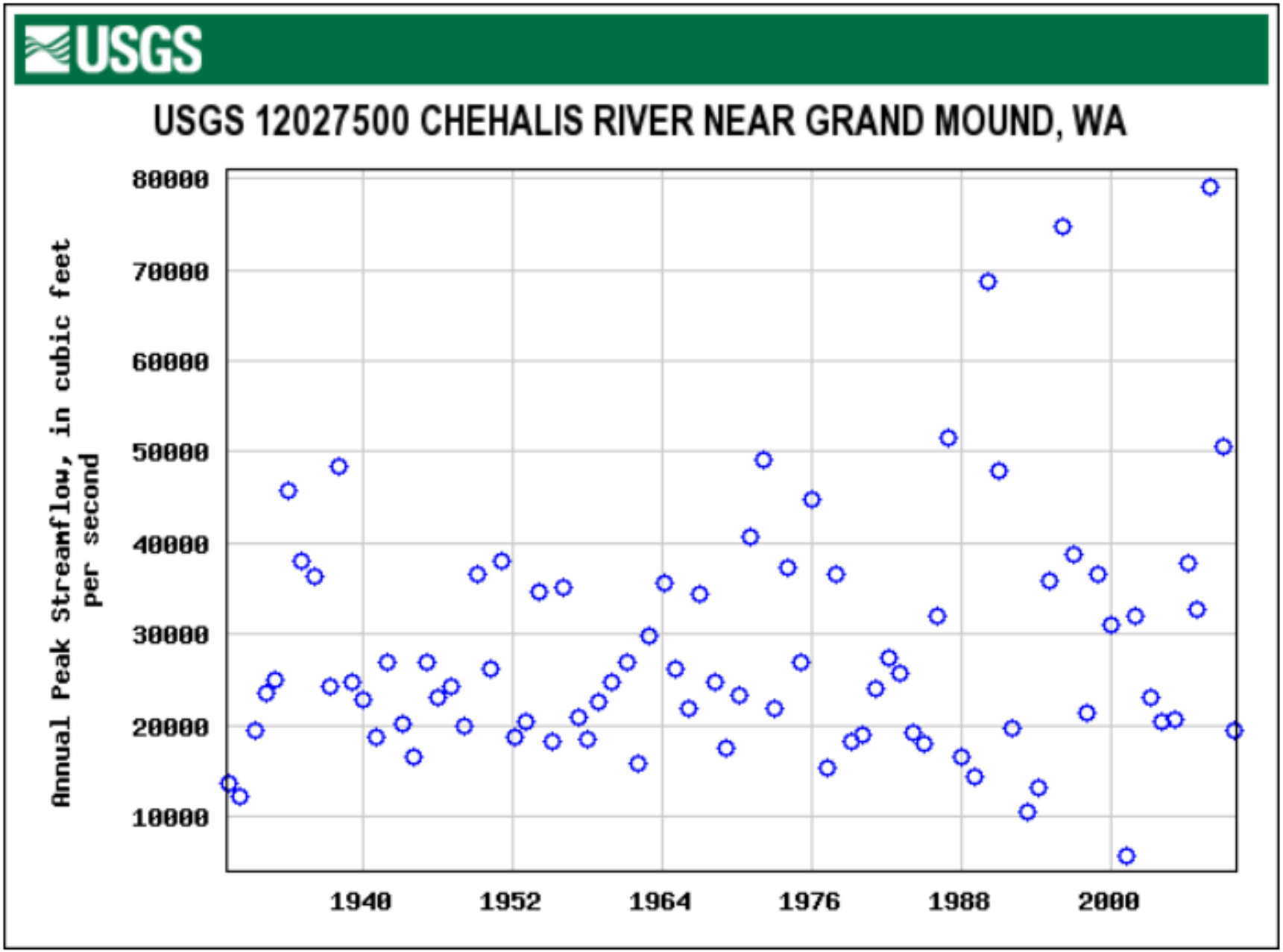

KEY CONCLUSIONS

- Since the mid-1970s, the variance of observed annual peak flows has increased markedly in many west-side rivers in the PNW, and statistically significant changes in the mean annual flood have been widely observed in different basins on the west slopes of the Cascades. The largest 3-5 annual peak flows on record have typically occurred in the last 35 years or so, and these largest events have been strongly associated with atmospheric rivers.

- Although land use change has been a factor in some basins, the observational evidence points primarily to climate and not land use as the cause of increasing flood risk. (Disturbed and undisturbed basins show similar changes.)

- It is unclear how much of the observed change in flood risk can be attributed to global climate change, and how much is due to natural variability. Observed warming (35-60% of which has been associated with climate change) has likely increased the contributing basin area in the Sauk and Skykomish, for example, but this effect is relatively minor in the Chehalis. Changes in extreme precipitation are not clearly related to climate change per se, although observed changes are broadly consistent with future projections of wetter winters.