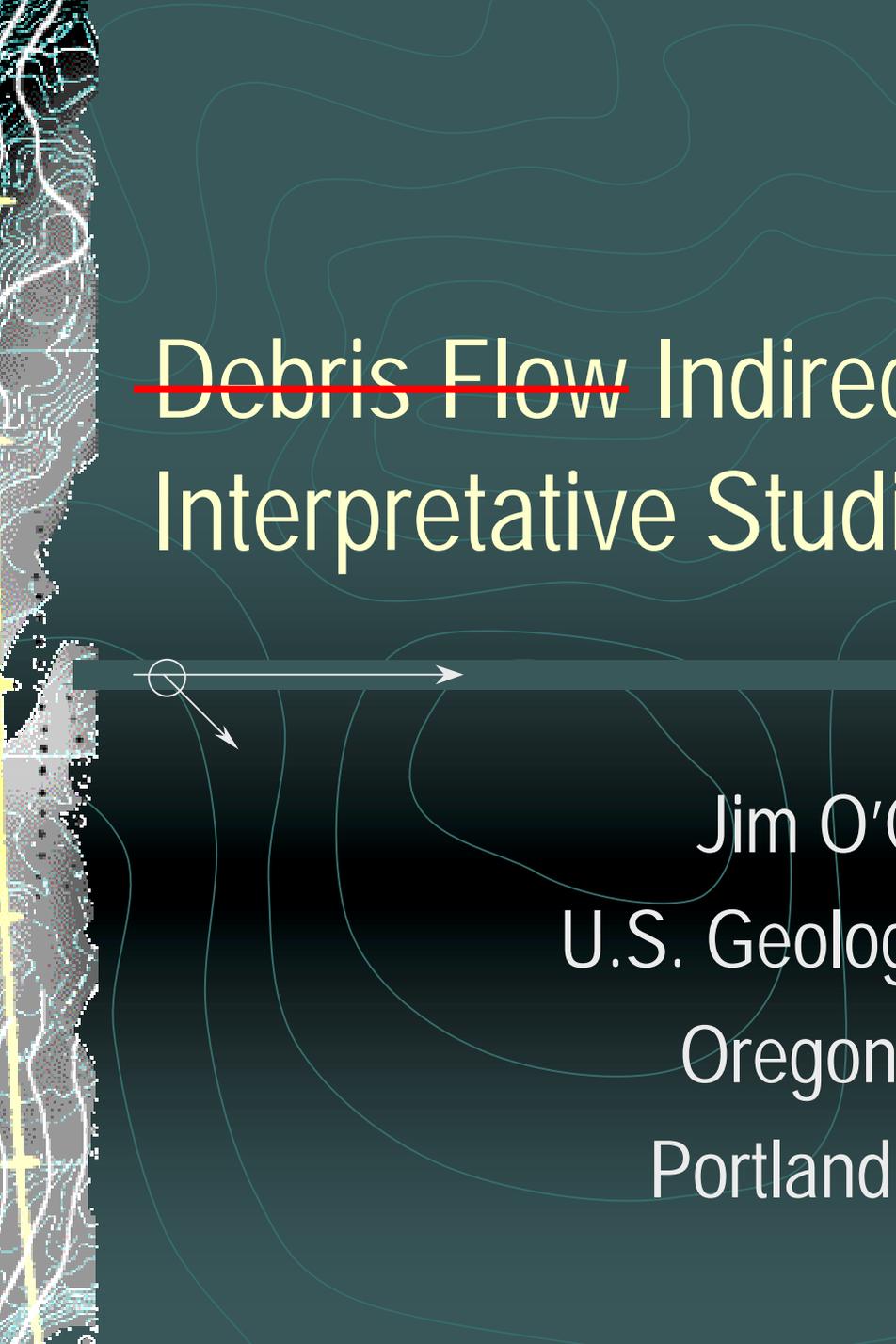
A topographic map of a mountainous region, likely in the Pacific Northwest, showing contour lines and a debris flow path highlighted in yellow. A white arrow with a circle at its tail points to the right, indicating the direction of the debris flow. The map is partially obscured by a dark teal vertical bar on the left side.

Debris Flow Indirects

Jim O'Connor
U.S. Geological Survey
Oregon District
Portland, Oregon



~~Debris Flow~~ Indirects for Interpretative Studies

Jim O'Connor
U.S. Geological Survey
Oregon District
Portland, Oregon



Major Points:

- Indirect discharge measurements can aid a wide variety of interpretative studies.
- Flexibility and versatility are required so as to be responsive to both the variety of questions and the variety of field situations.
- In some environments, critical flow constraints lead to robust and easily obtained discharge estimates.



Discharge Values



Streamflow
Analysis



Discharge Values

Direct Measurements
Indirects



Streamflow
Analysis



Discharge Values

Direct Measurements
Indirects



Streamflow
Analysis

Flow Volume
Flow Duration
Flood Frequency



Discharge Values

Understanding
Processes

Streamflow
Analysis



Discharge Values

U.S.G.S. Surface-water data
Other measurements

Understanding
Processes

Streamflow
Analysis



Discharge Values

U.S.G.S. Surface-water data
Other measurements

Understanding
Processes

Physical limits
to Floods
Extreme-flow recurrence
Aspects of non-stationarity

Streamflow
Analysis



Discharge Values

U.S.G.S. Surface-water data
Other measurements

Understanding
Processes

Streamflow
Analysis

Other Questions

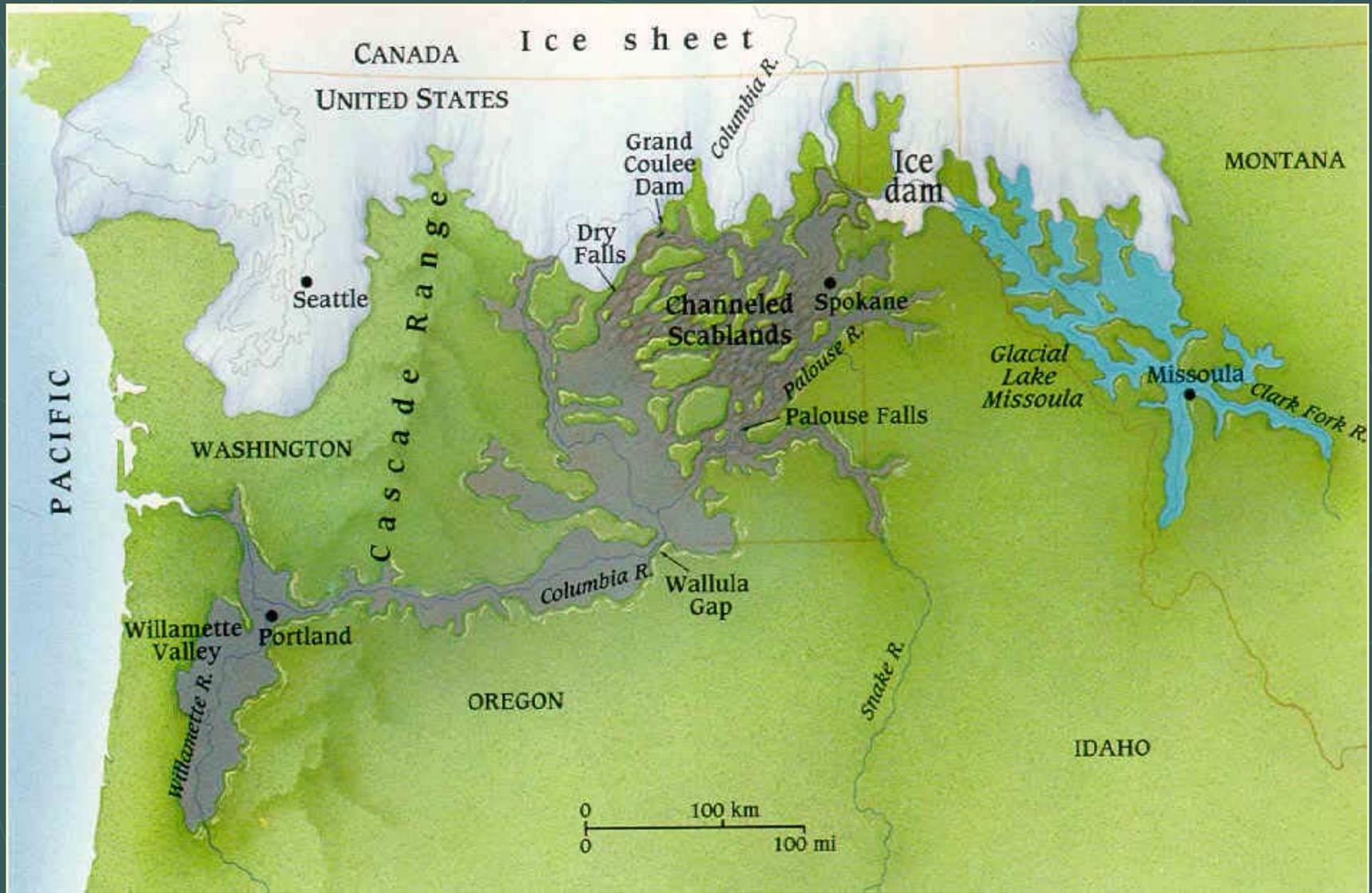
Flood geomorphology
Debris flow behavior

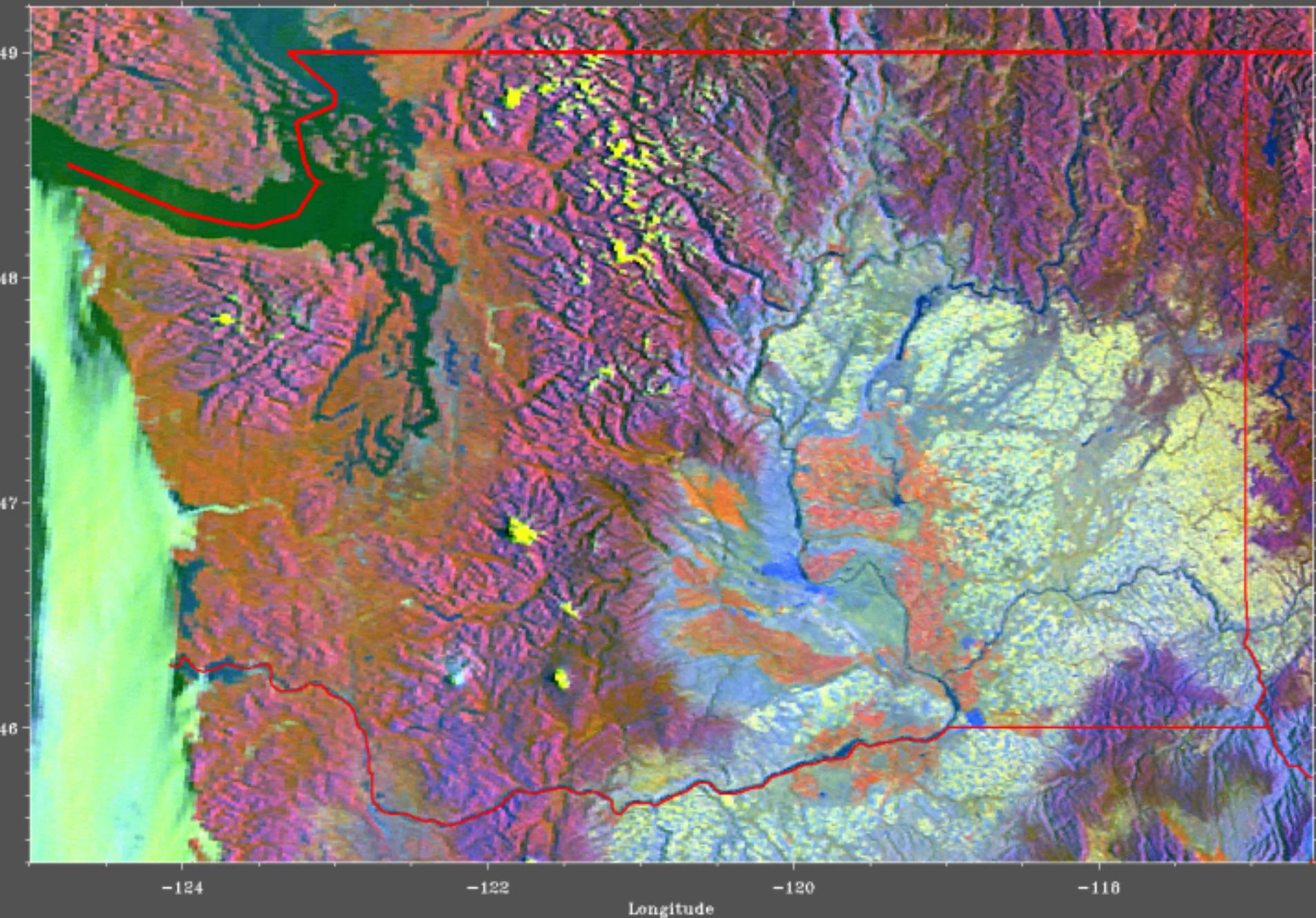


Indirects and Flood Geomorphology

- Channel structure and morphology
- Alluvial fan processes
- Cataclysmic flood hydrology, hydraulics, and geomorphology
- Martian landscape development
- Depositional environments of stratigraphic sequences

The Missoula Floods





-124

-122

-120

-118

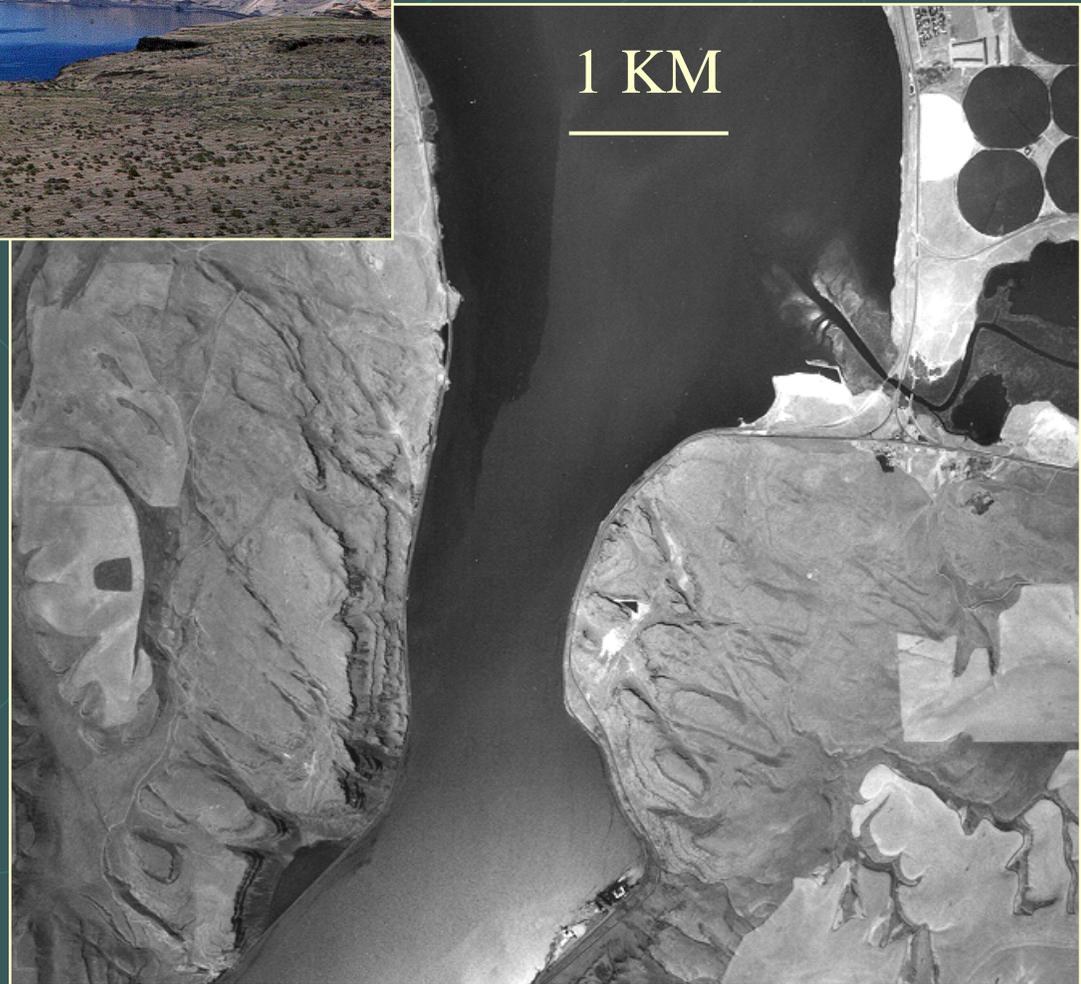
Longitude

AVHRR Color Composite
NOAA-18, AVHRR 18 Dec 31 01:00 GMT RED=CH 2 GREEN=CH 1 BLUE=CH 3

The Missoula Floods...Wallula Gap



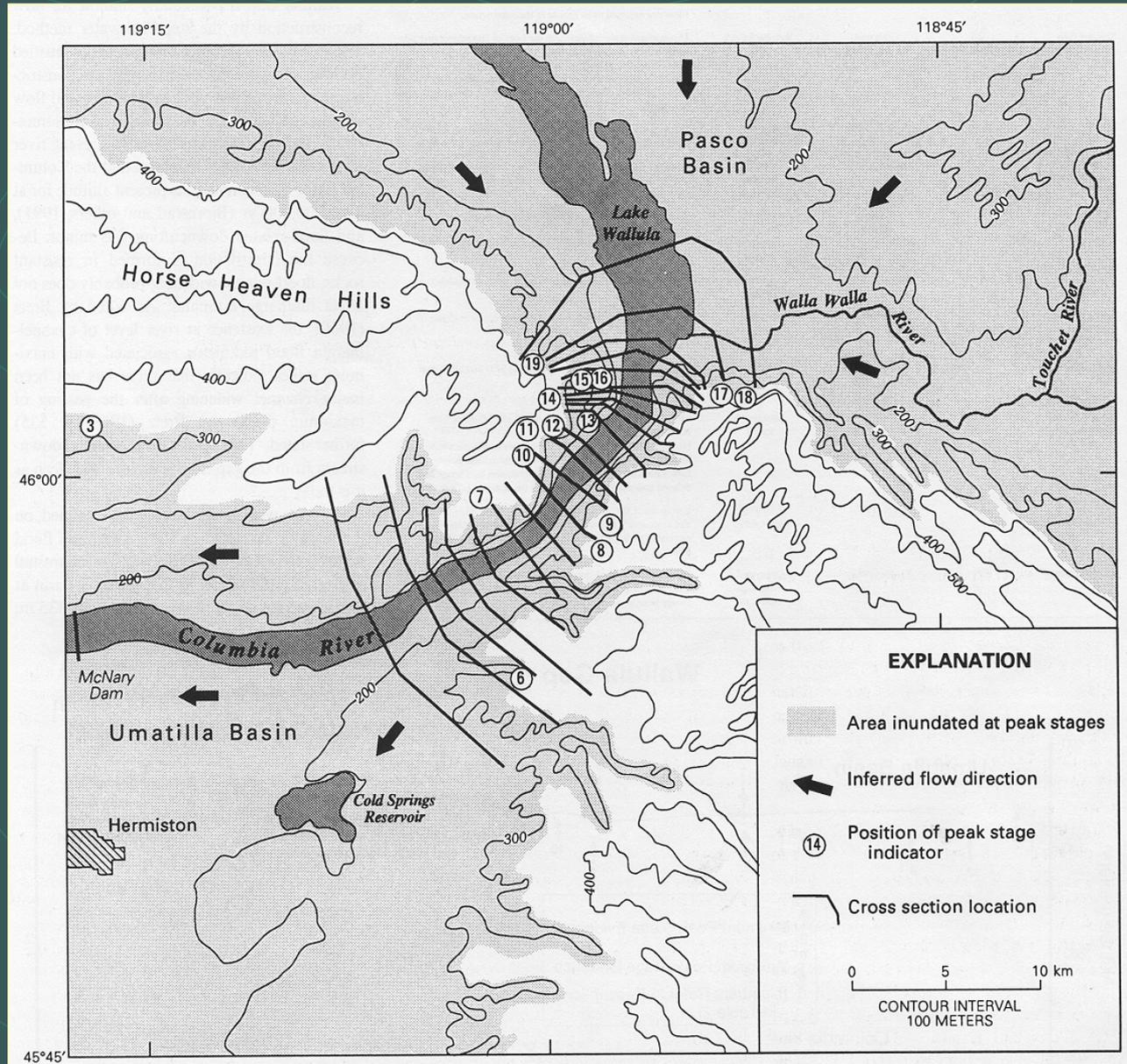
Wallula Gap



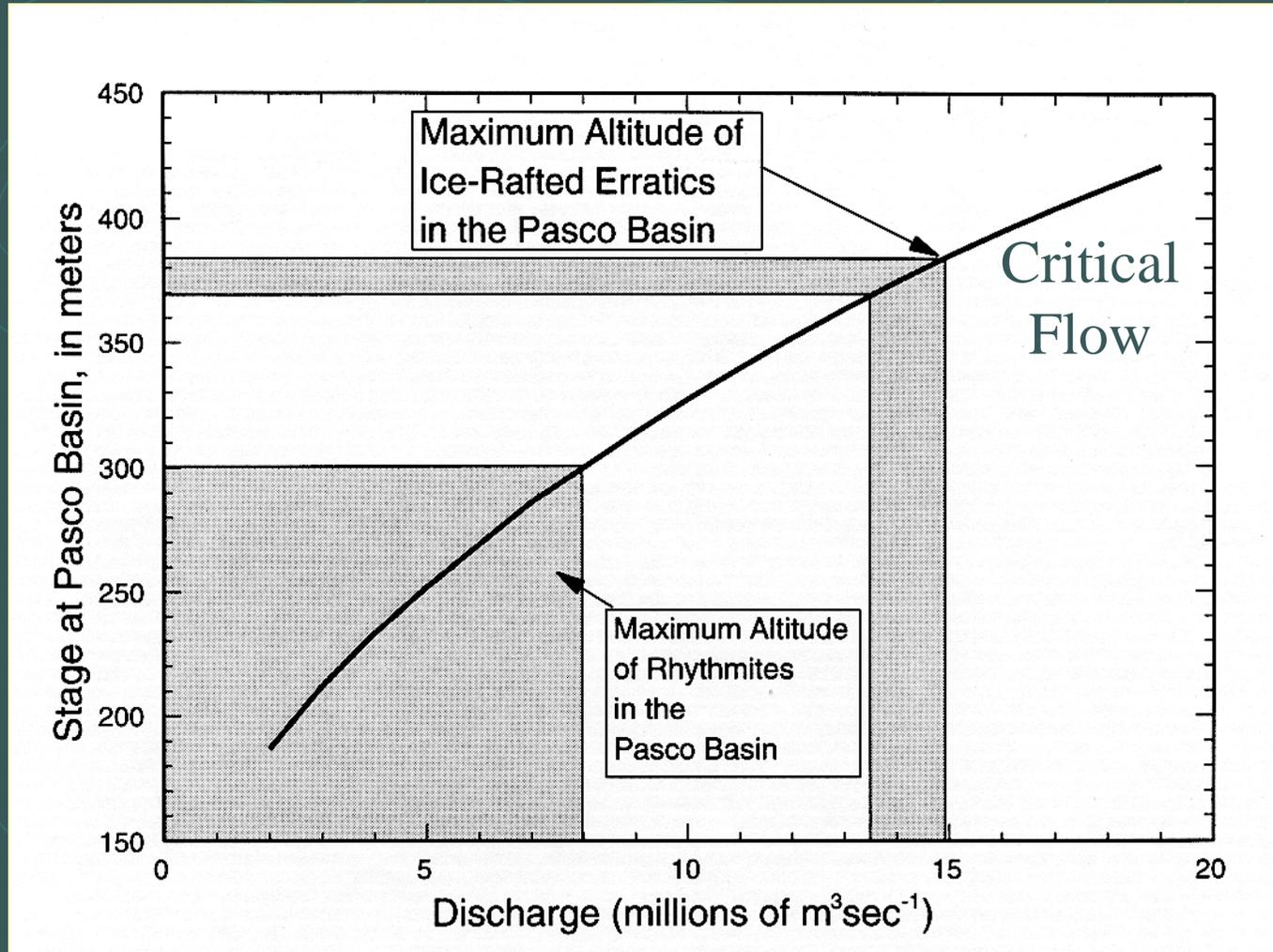
Wallula Gap...Flood marks



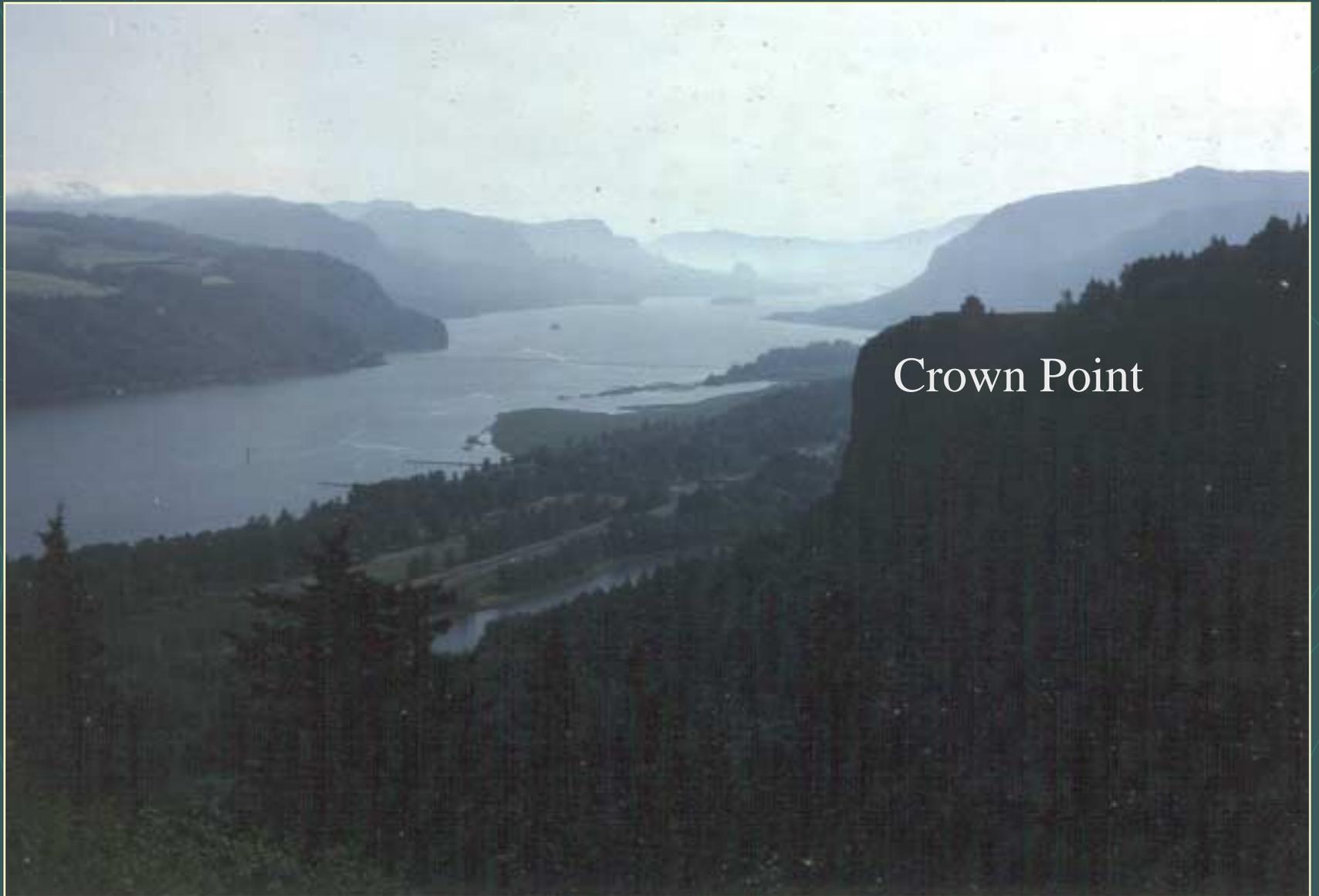
Wallula Gap...step-backwater modeling



Wallula Gap...results

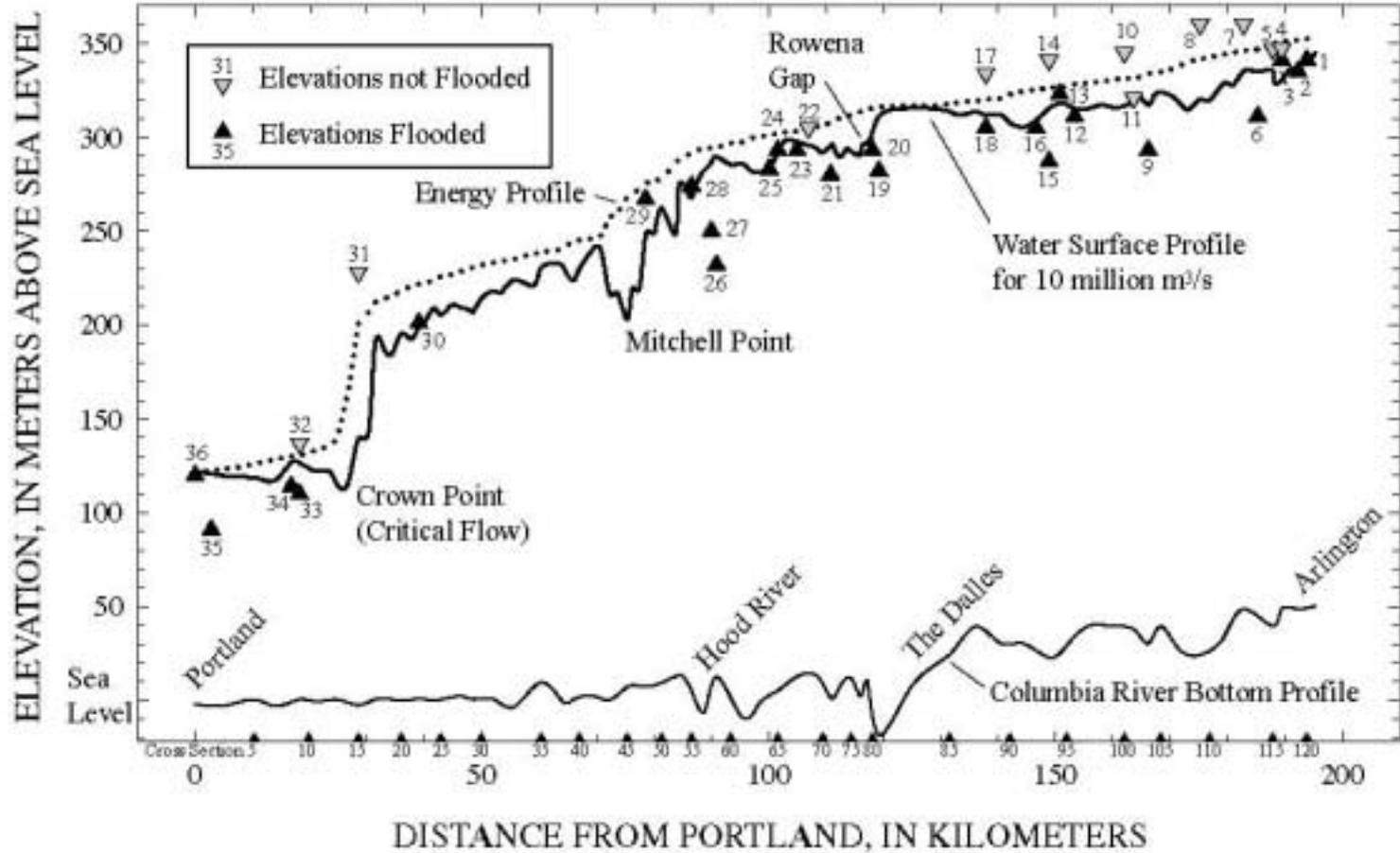


Columbia River Gorge

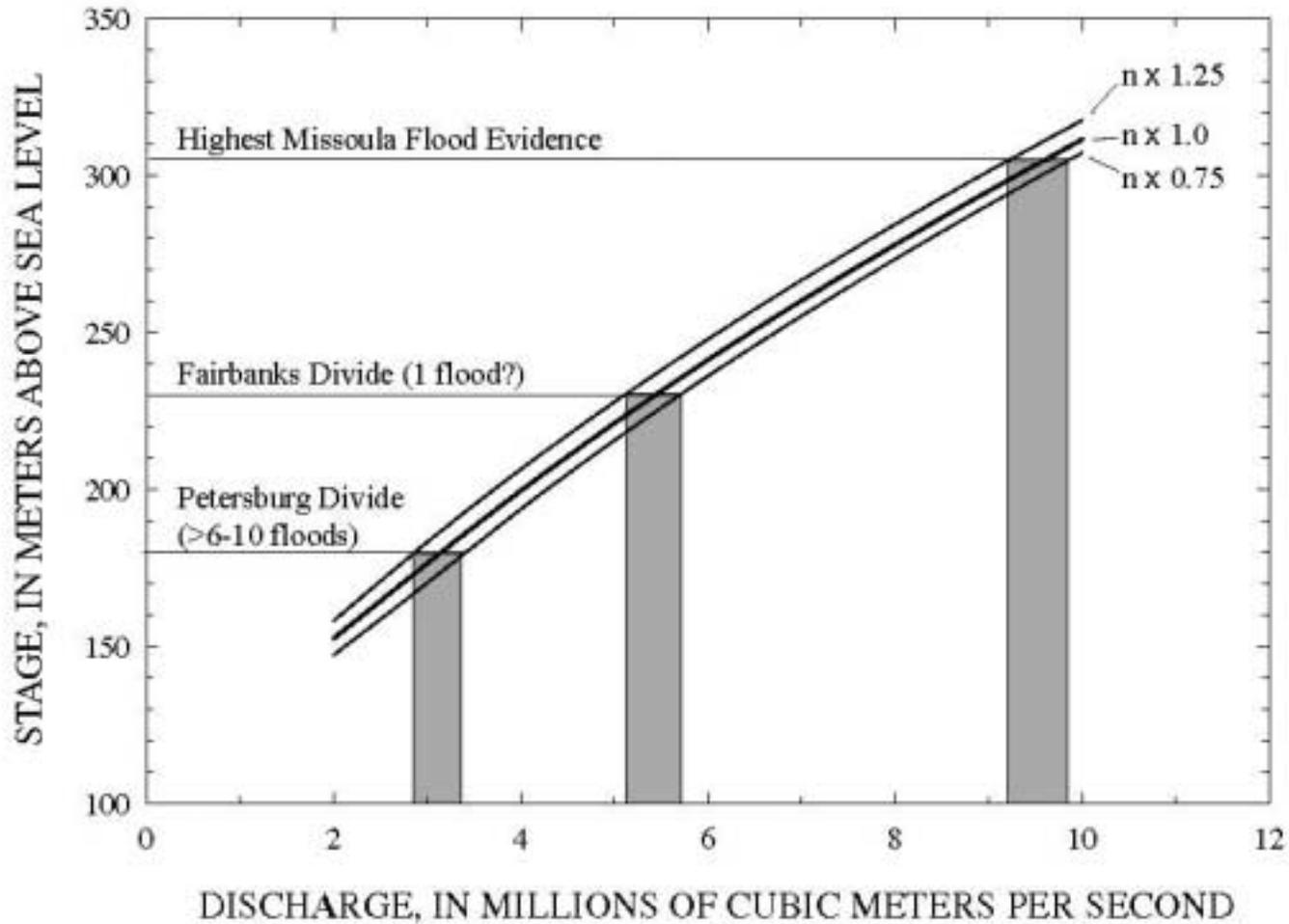


Crown Point

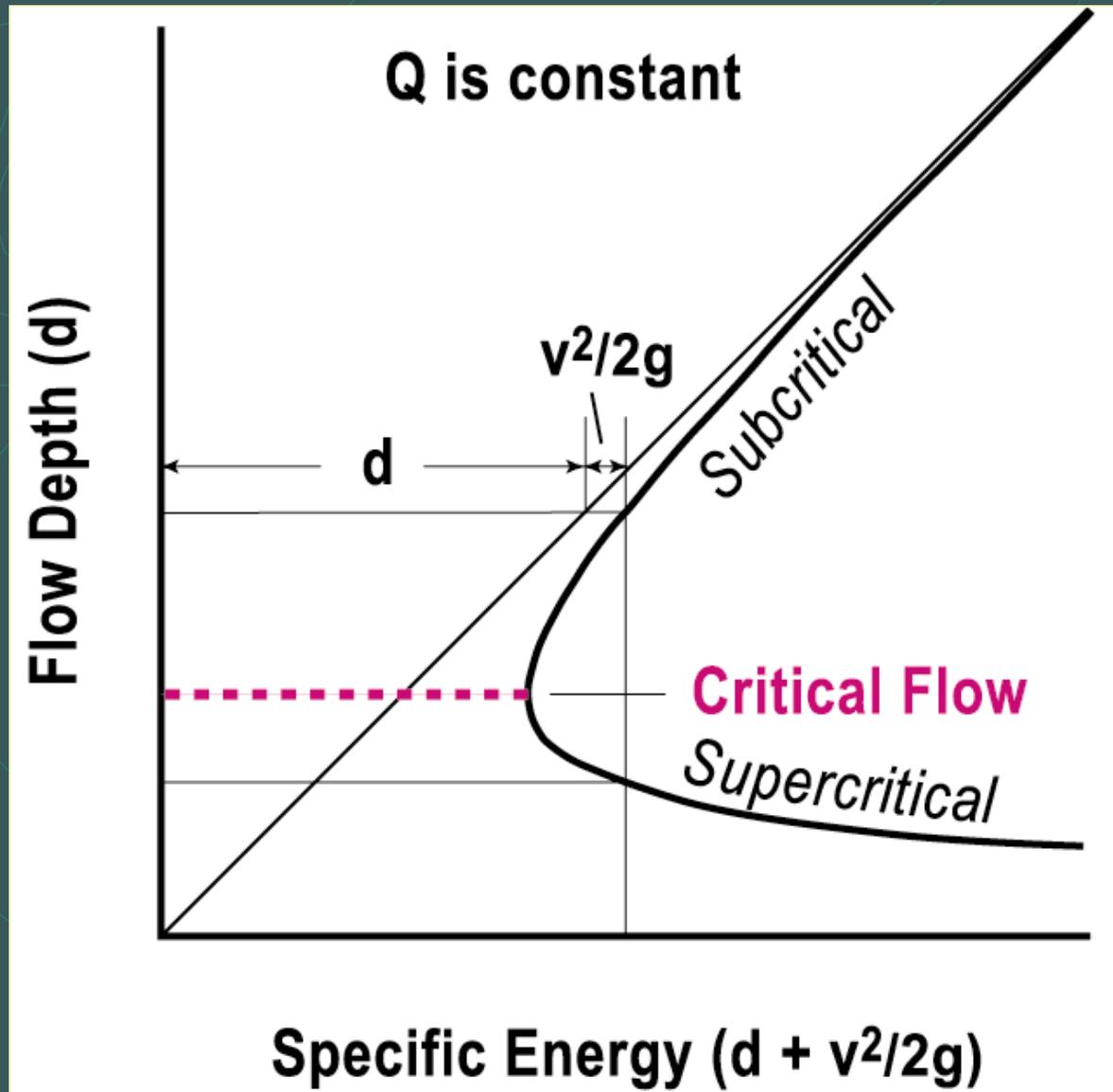
Columbia River Gorge



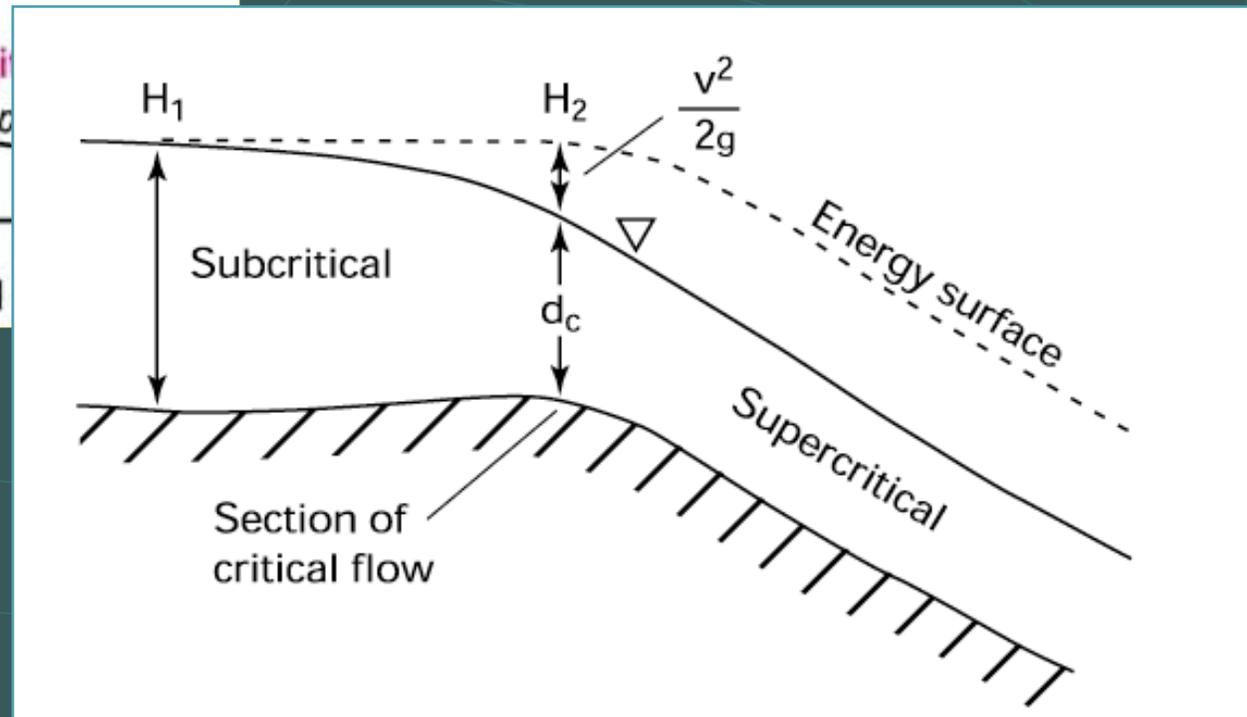
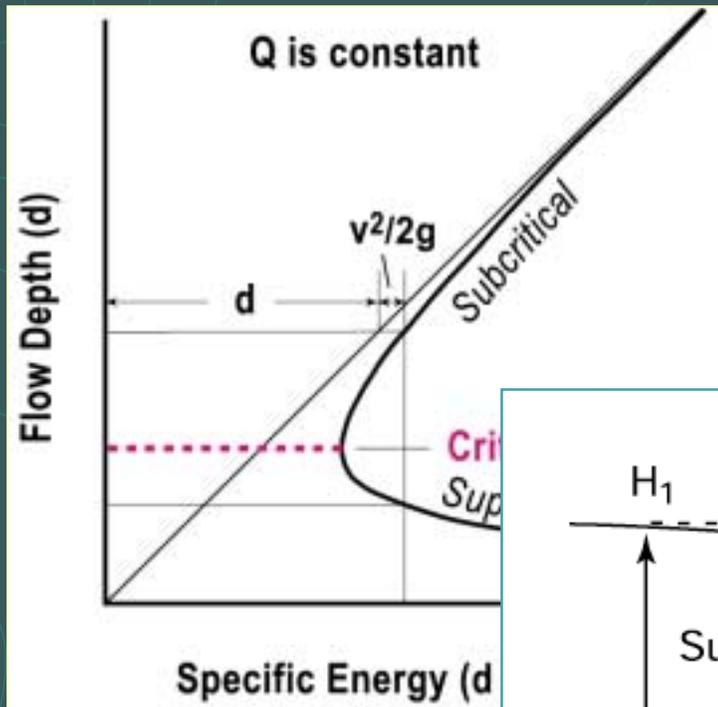
Columbia River Gorge



Critical Flow...specific energy relations



Critical Flow...profile





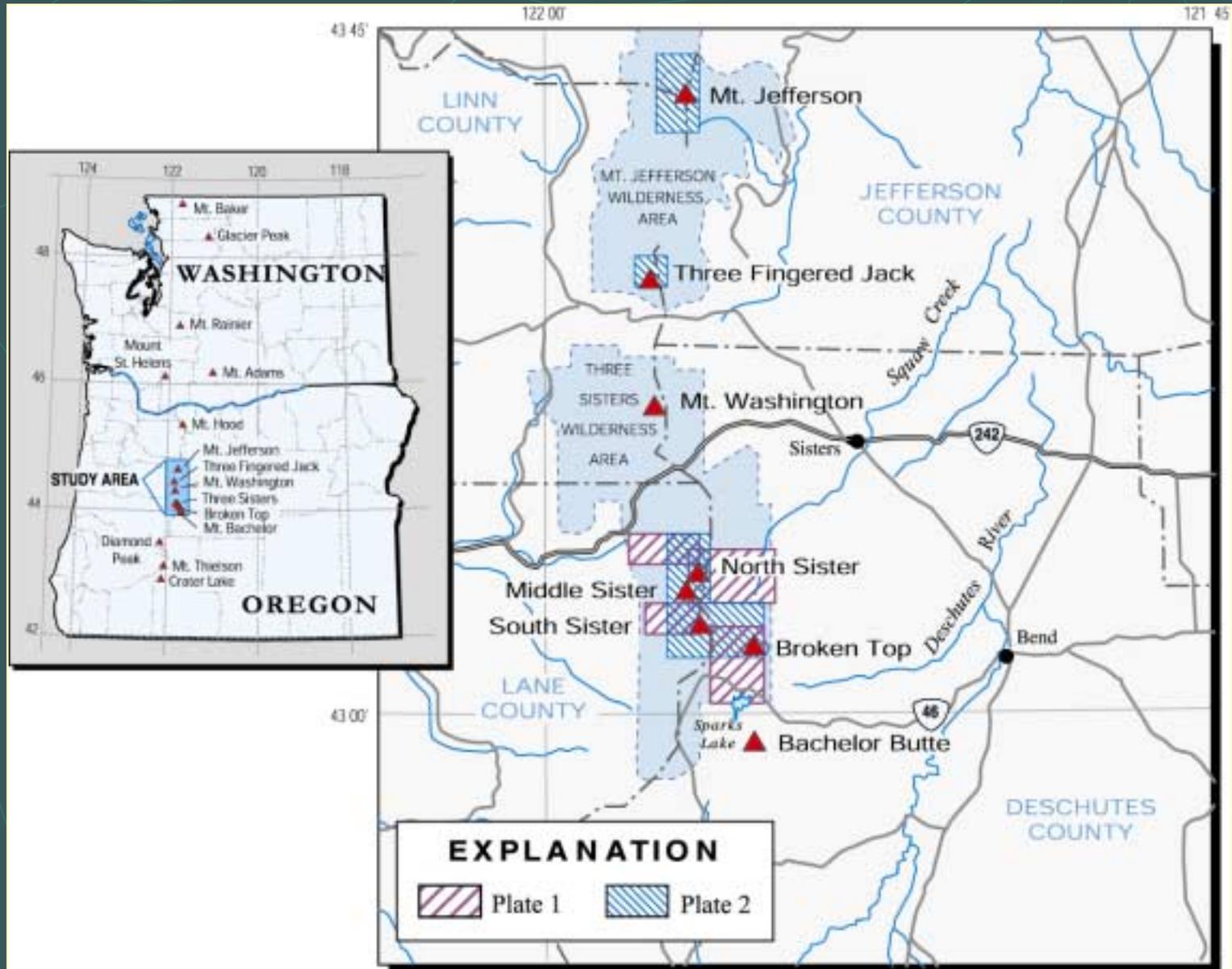
Critical Flow...important attributes

- Maximum possible discharge for a given specific energy.
- Flow solely a function of cross-section geometry.
- Applies to any free-surface gravitationally driven flow of constant density, regardless of rheology.
- Energy waves do not translate through critical flow transitions.

Indirects and Debris Flows



Three Sisters Wilderness Area



Moraine-dammed lakes have breached





resulting in 11 debris flows...

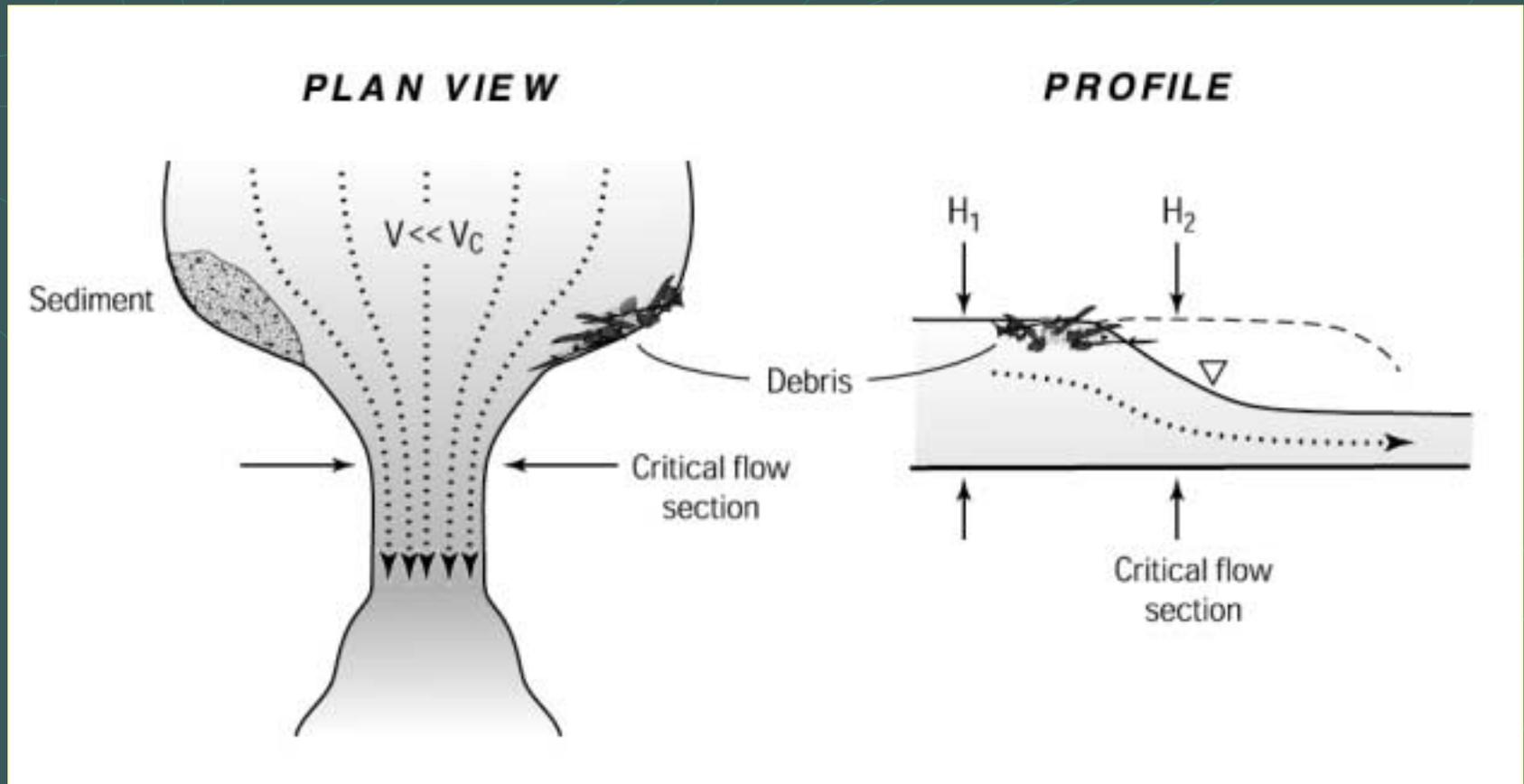
- between 1933 and 1970
- from lake releases as large as 1 million cubic meters
- that traveled up to 10 km
- with peak discharges as great as 500 m³/s
- with peak discharges which increased and decreased over short distances in conjunction with erosion and deposition

Debris flow indirects...

- Velocity-area estimates
- Critical flow estimates
- ~~Superelevation~~

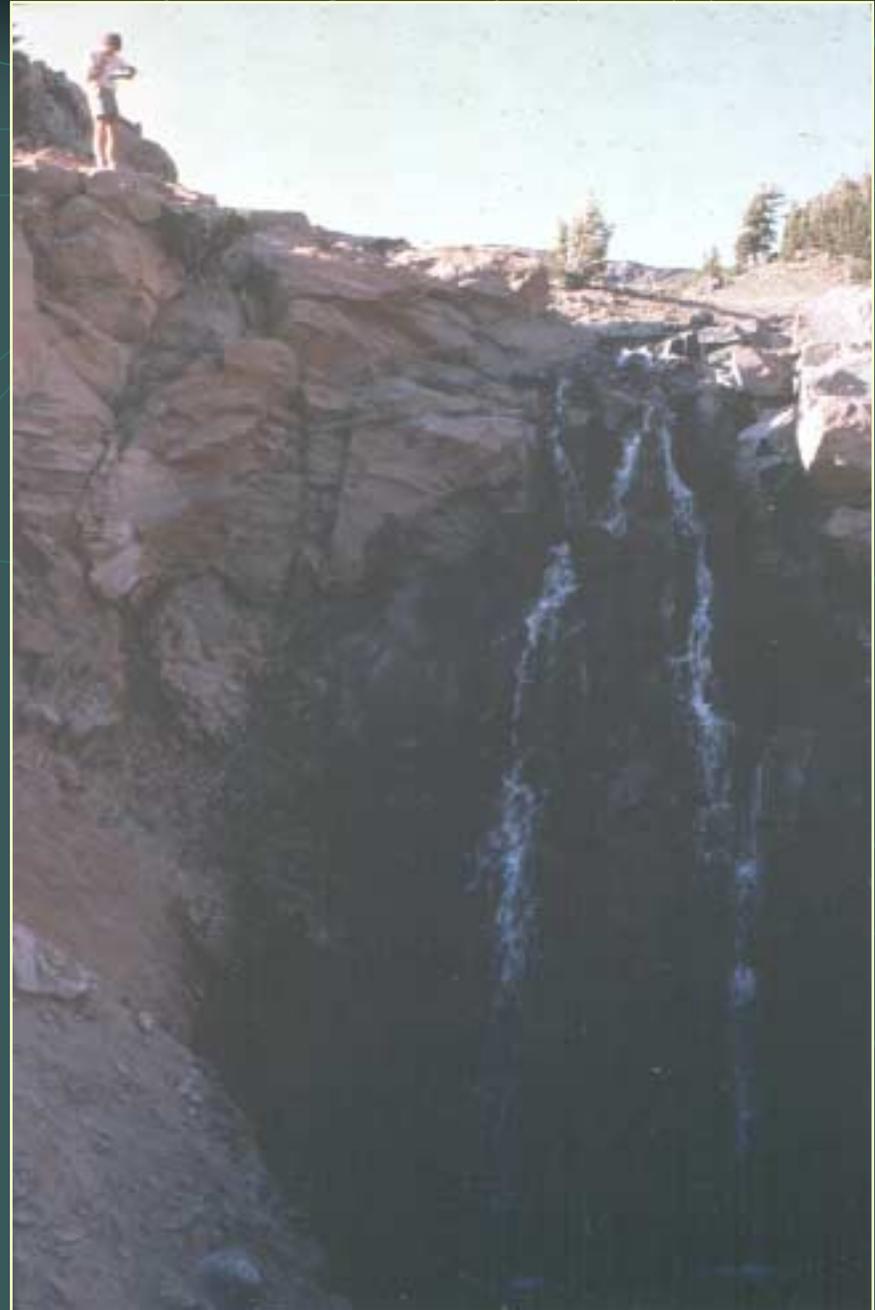


Critical-flow estimates



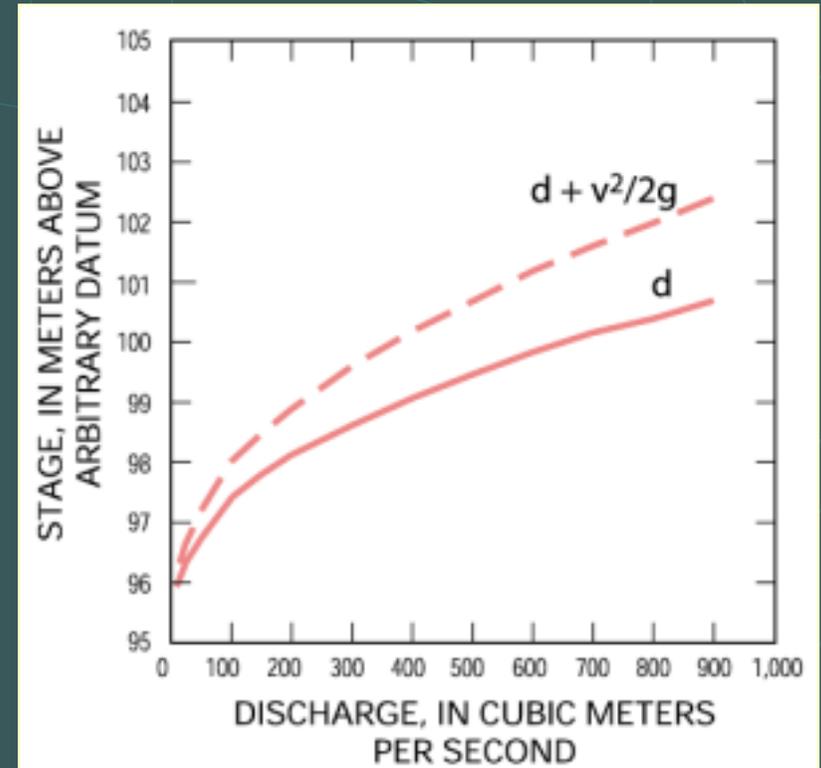
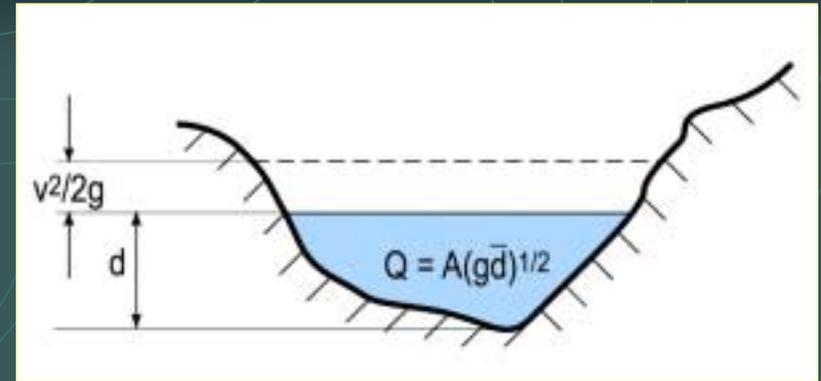
In the field...

- Survey single section at choke point or drop-off.
- Survey elevation of highest debris in upstream ponded reach (relative to critical flow section).



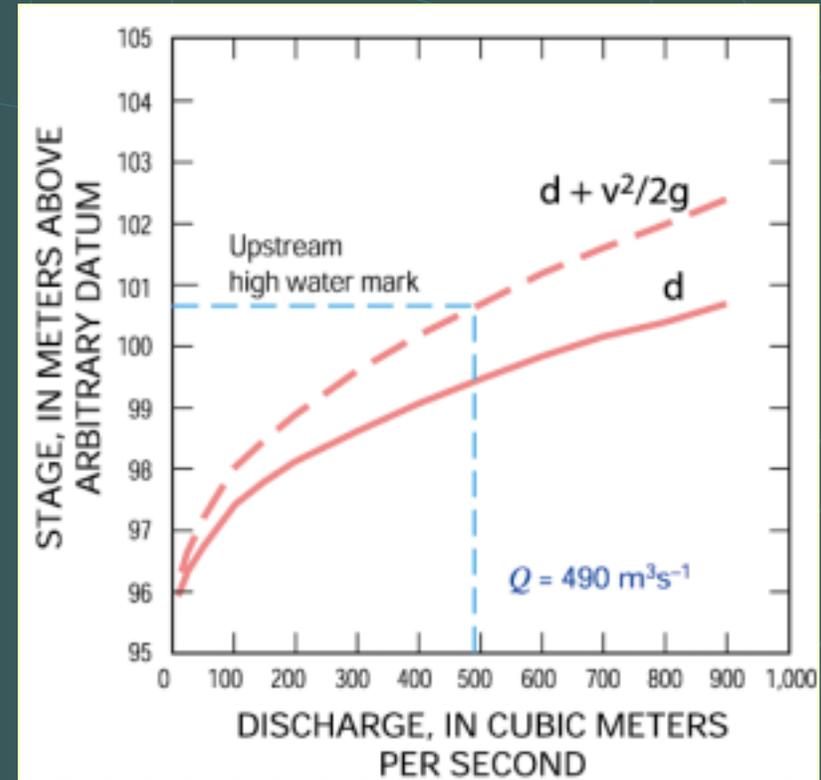
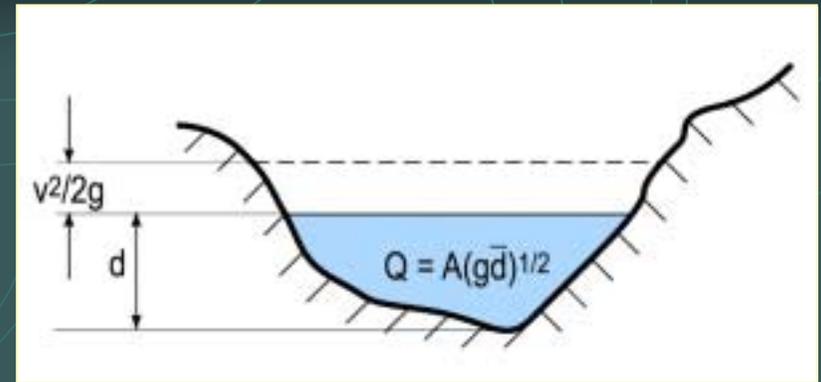
In the office...

- Construct critical flow rating curve for the surveyed section.
- Relate surveyed maximum stage to the energy surface at the critical flow section.



In the office...

- Construct critical flow rating curve for the surveyed section.
- Relate surveyed maximum stage to the energy surface at the critical flow section.





Assumptions and potential errors...

...related to hydraulic conditions

- Flow was critical.
- Minimal energy loss between site of maximum stage evidence and control section.
- One-dimensional flow ($\alpha = 1$).

Assumptions and potential errors...

...related to hydraulic conditions

- Flow was critical.

Regardless, estimate is firm maximum.

Tested by assessing downstream flow.

- Minimal energy loss between site of maximum stage evidence and control section.
- One-dimensional flow ($\alpha = 1$).



Assumptions and potential errors...

...related to hydraulic conditions

- Flow was critical.
- Minimal energy loss between site of maximum stage evidence and control section.

Energy loss equivalent to $0.5(v^2/2g)$ results in 32 percent overestimate of discharge.

- One-dimensional flow ($\alpha = 1$).

Assumptions and potential errors...

...related to hydraulic conditions

- Flow was critical.
 - Minimal energy loss between site of maximum stage evidence and control section.
 - One-dimensional flow ($\alpha = 1$).
- If $\alpha = 2$, discharge overestimated by 54 percent.
- If $\alpha = 1.5$, discharge overestimated by 24 percent.
- Can be assessed by subdividing cross section.



Assumptions and potential errors...

...related to field conditions

- Significant velocity in approach area such that highwater evidence is lower than energy surface.
- Maximum preserved stage evidence is lower than actual maximum water surface.



Assumptions and potential errors...

...related to field conditions

- Significant velocity in approach area such that highwater evidence is lower than energy surface.
If upstream velocity is 50 percent of the control section velocity, discharge will be underestimated by less than 12 percent.
- Maximum preserved stage evidence is lower than actual maximum water surface.

Assumptions and potential errors...

...related to field conditions

- Significant velocity in approach area such that highwater evidence is lower than energy surface.
- Maximum preserved stage evidence is lower than actual maximum water surface.

If the highest surveyed evidence under-represents actual maximum stages by 25 percent (of the total flow specific energy), the discharge will be underestimated by 35 percent.

Assumptions and potential errors...

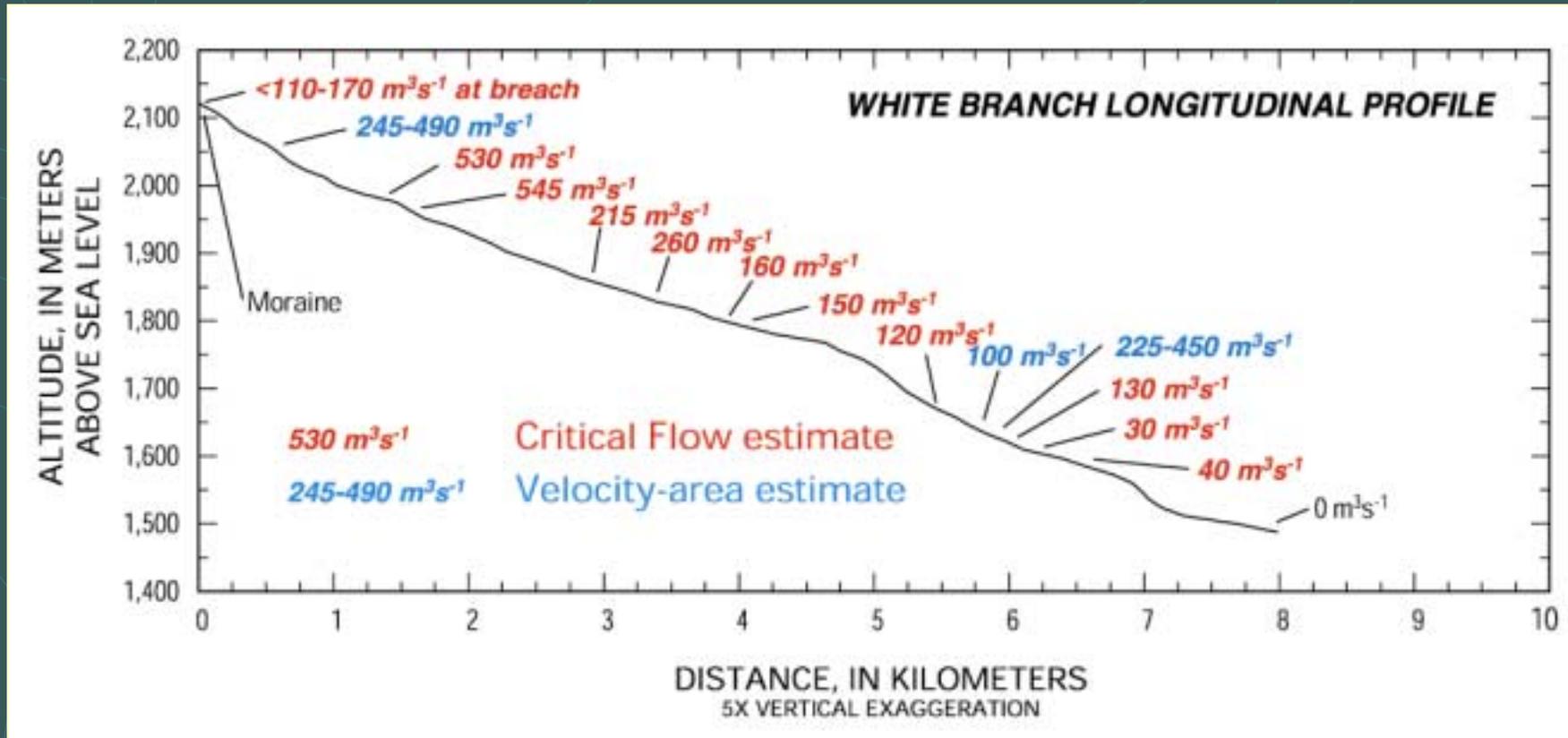
...summary

- Assumptions and uncertainties pertaining to hydraulic conditions can result in discharge overestimation by as much as about 50 percent.
- Reasonable uncertainties resulting from typical field conditions can result in discharge underestimation by as much as about 35 percent.

An application... 1942 White Branch Debris Flow

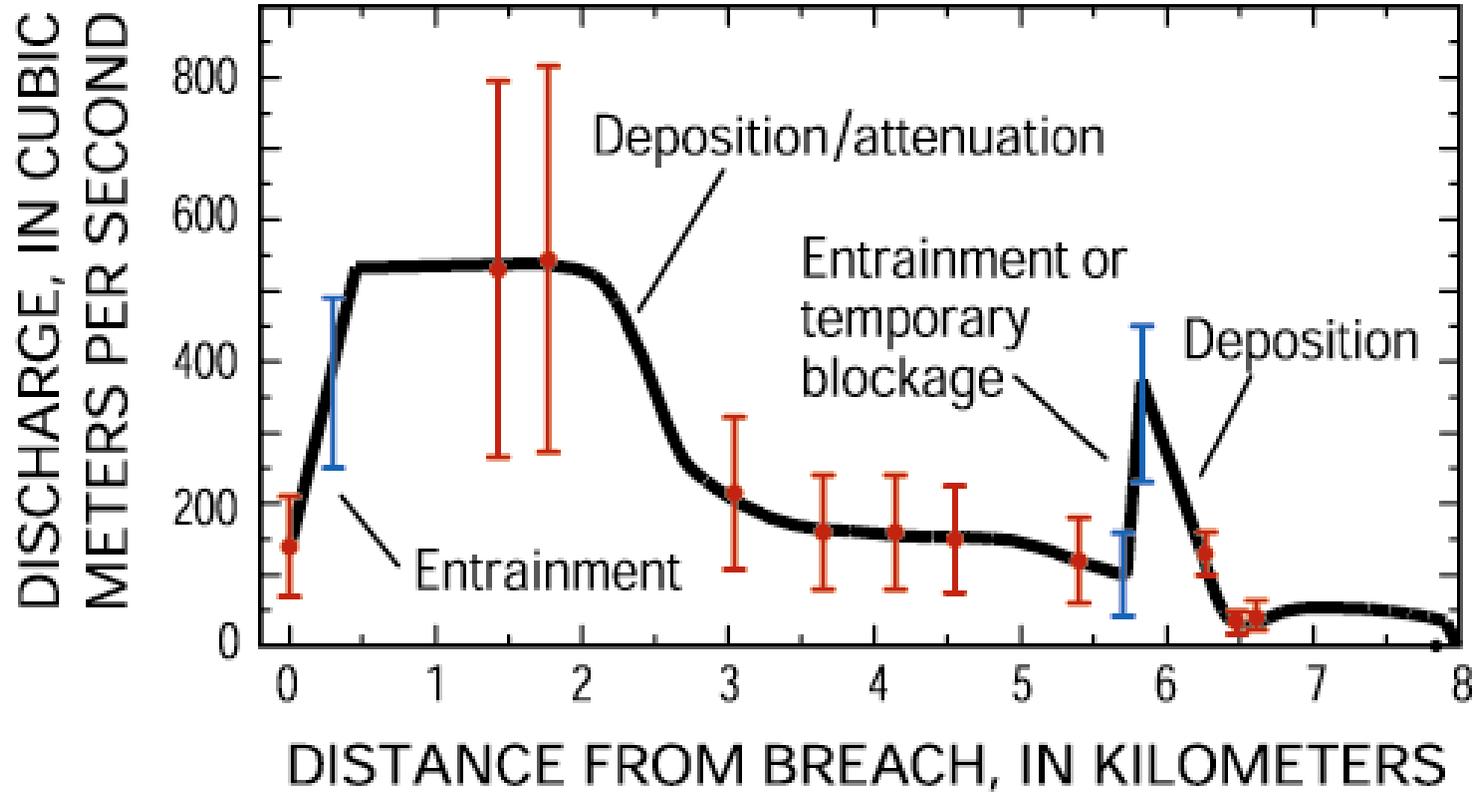


1942 White Branch Debris Flow



- 11 Critical flow measurements
- 3 Velocity area measurements

1942 White Branch Debris Flow





Major Points:

- Indirect discharge measurements can aid a wide variety of interpretative studies.
- Flexibility and versatility are required so as to be responsive to both the variety of questions and the variety of field situations.
- In some environments, critical flow constraints lead to robust and easily obtained discharge estimates.