Multi-scale Physical Classification of Western Streams

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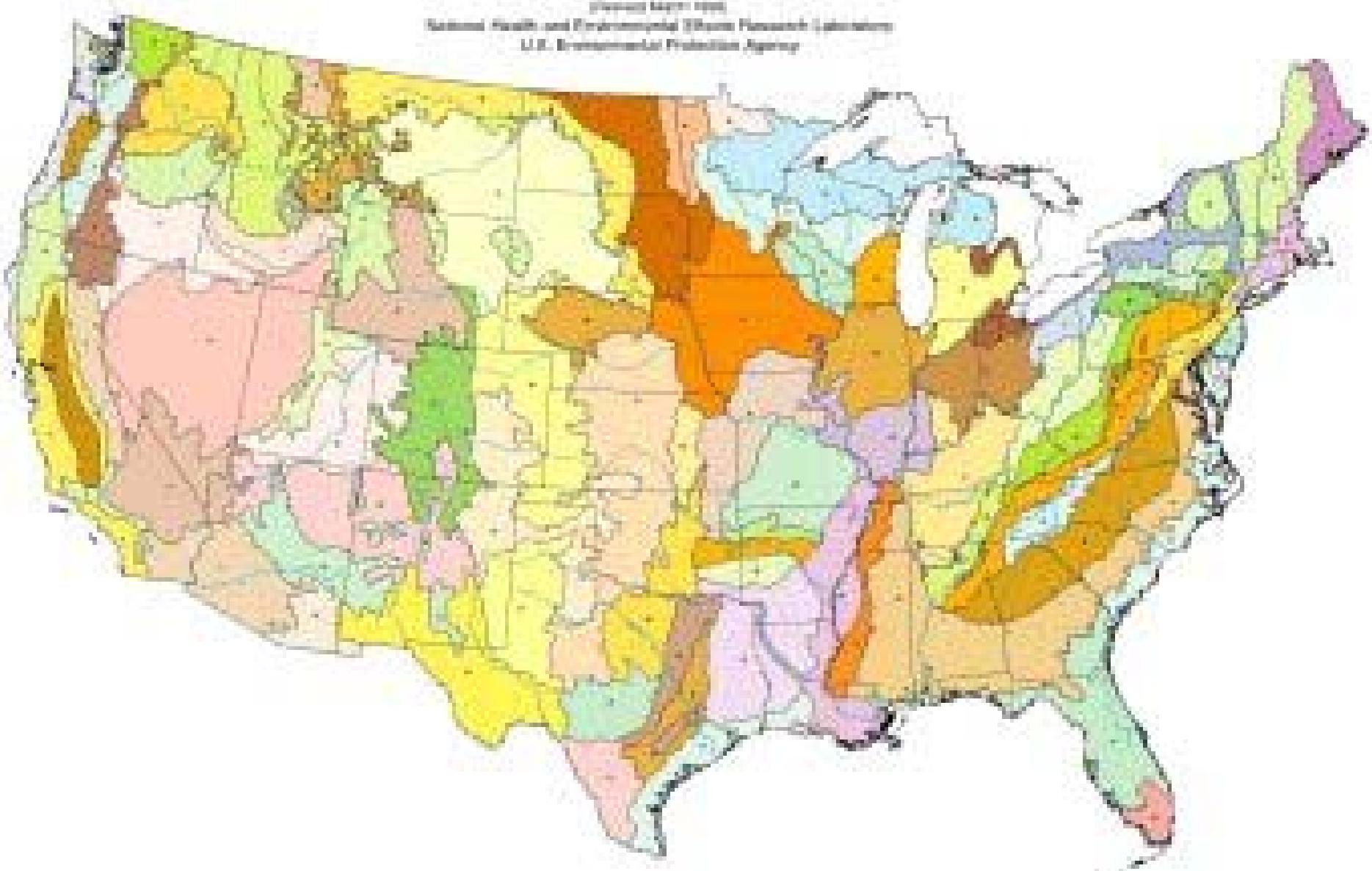
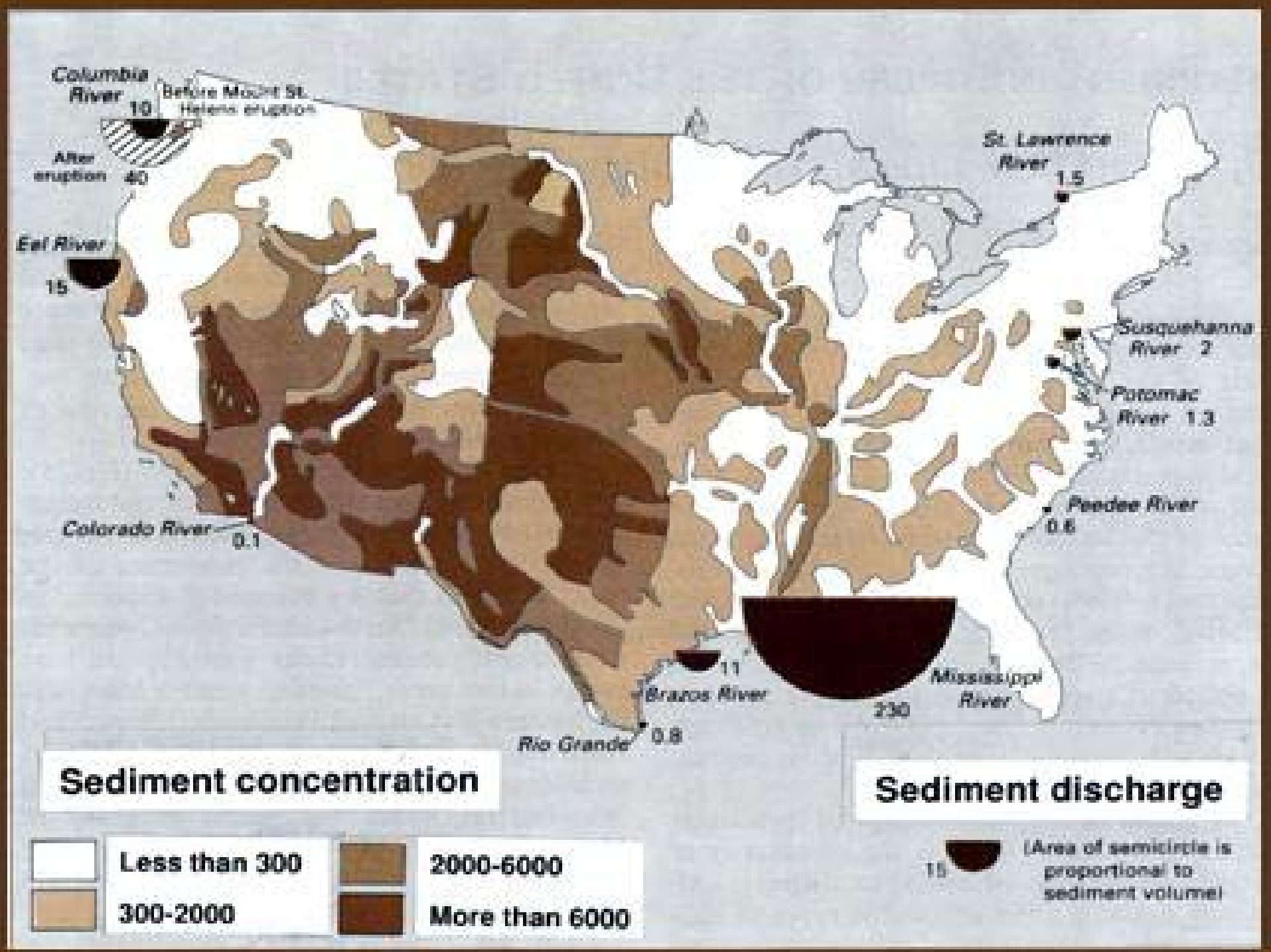
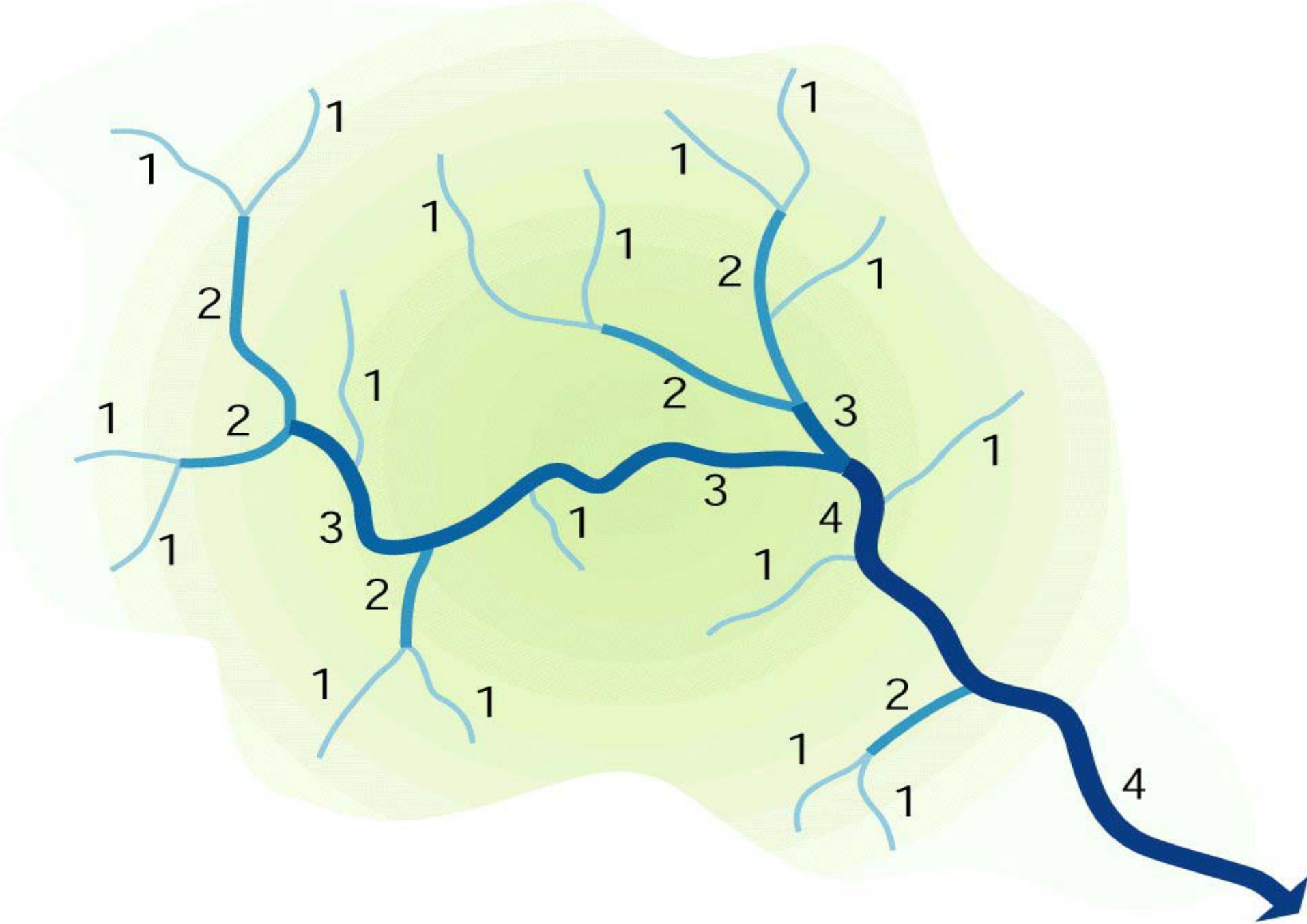
Classification in Biomonitoring

- Group distinct environments and prevent comparisons of “apples and oranges”
- Partition variation at the most relevant spatial scales
- Include static and dynamic features
- Minimize the number of types and effort required to apply the classification

Level III Ecoregions of the Continental United States




Columbia River
10
Before Mount St. Helens eruption
After eruption
40
Eel River
15
Colorado River
0.1
St. Lawrence River
1.5
Susquehanna River 2
Potomac River 1.3
Peedee River
0.6
11
Brazos River
230
Mississippi River
Rio Grande
0.8
Sediment concentration
Less than 300
300-2000
2000-6000
More than 6000
Sediment discharge
15
(Area of semicircle is proportional to sediment volume)


1
1
1
1
1
1
2
1
2
1
2
1
2
3
1
3
1
3
4
1
1
2
1
1
2
1
1
4

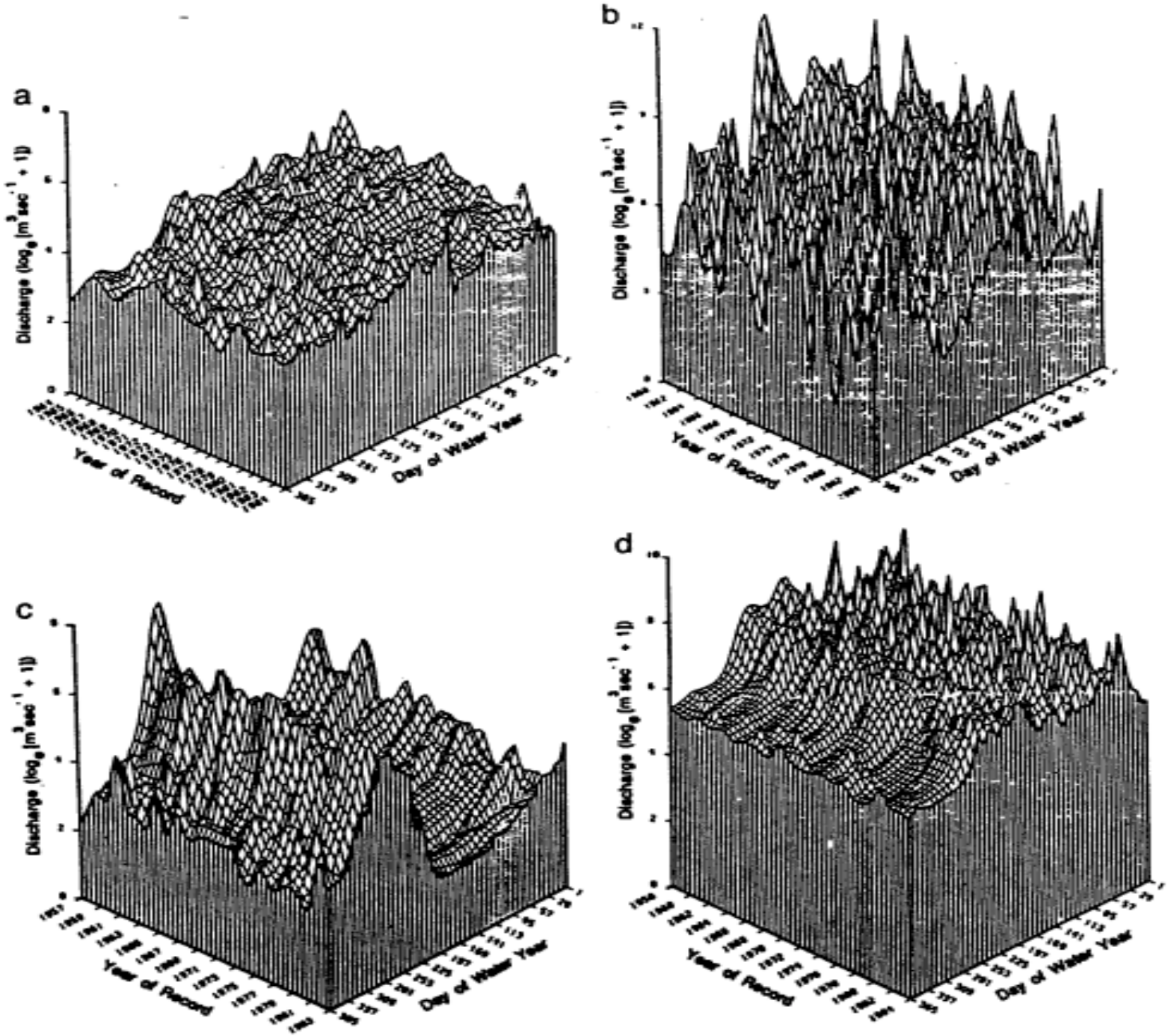
Basic Concepts

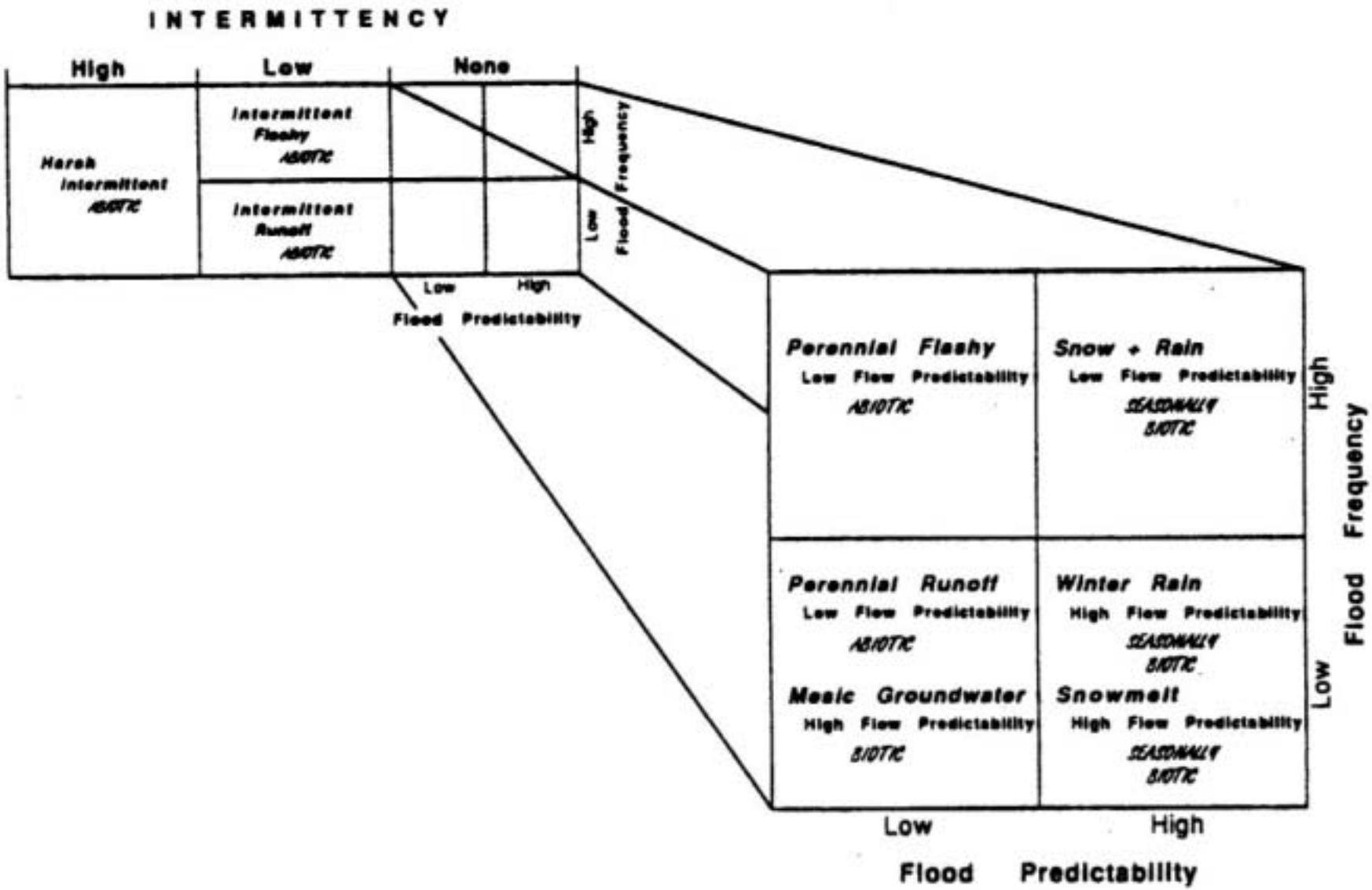
Physical classification of streams should include primary environmental drivers:

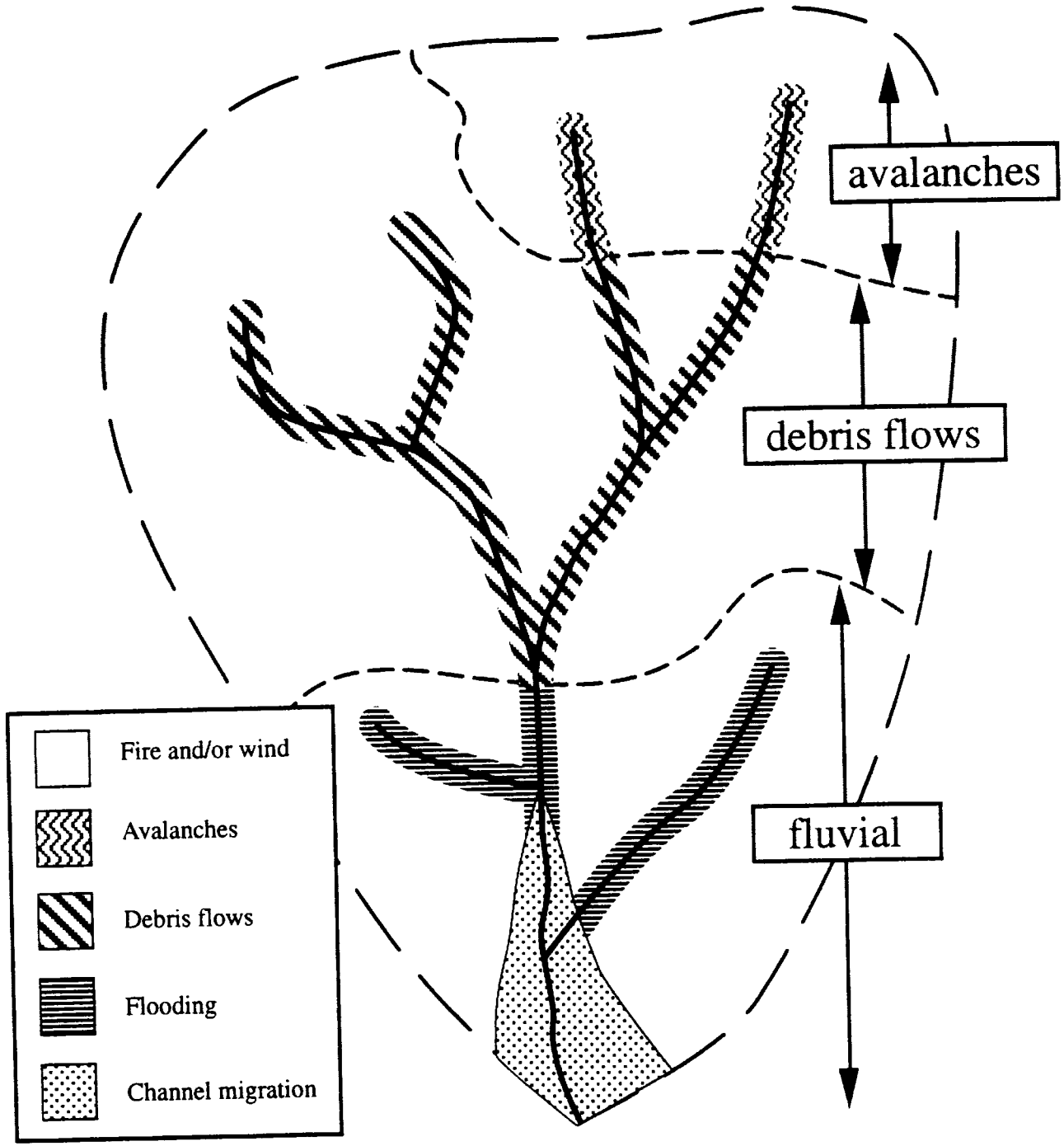
- Hydrologic regime
- Intermediate-scale geomorphic context
- Anthropogenic influences

Flow Regime

- 5 key characteristics:
  - Frequency
  - Magnitude
  - Duration
  - Timing
  - Rate of Change
- Importance of extremes (e.g., high and low flows)


a
b
c
d
Discharge ($\log_e[m^3 sec^{-1} + 1]$)
Year of Record
Day of Water Year

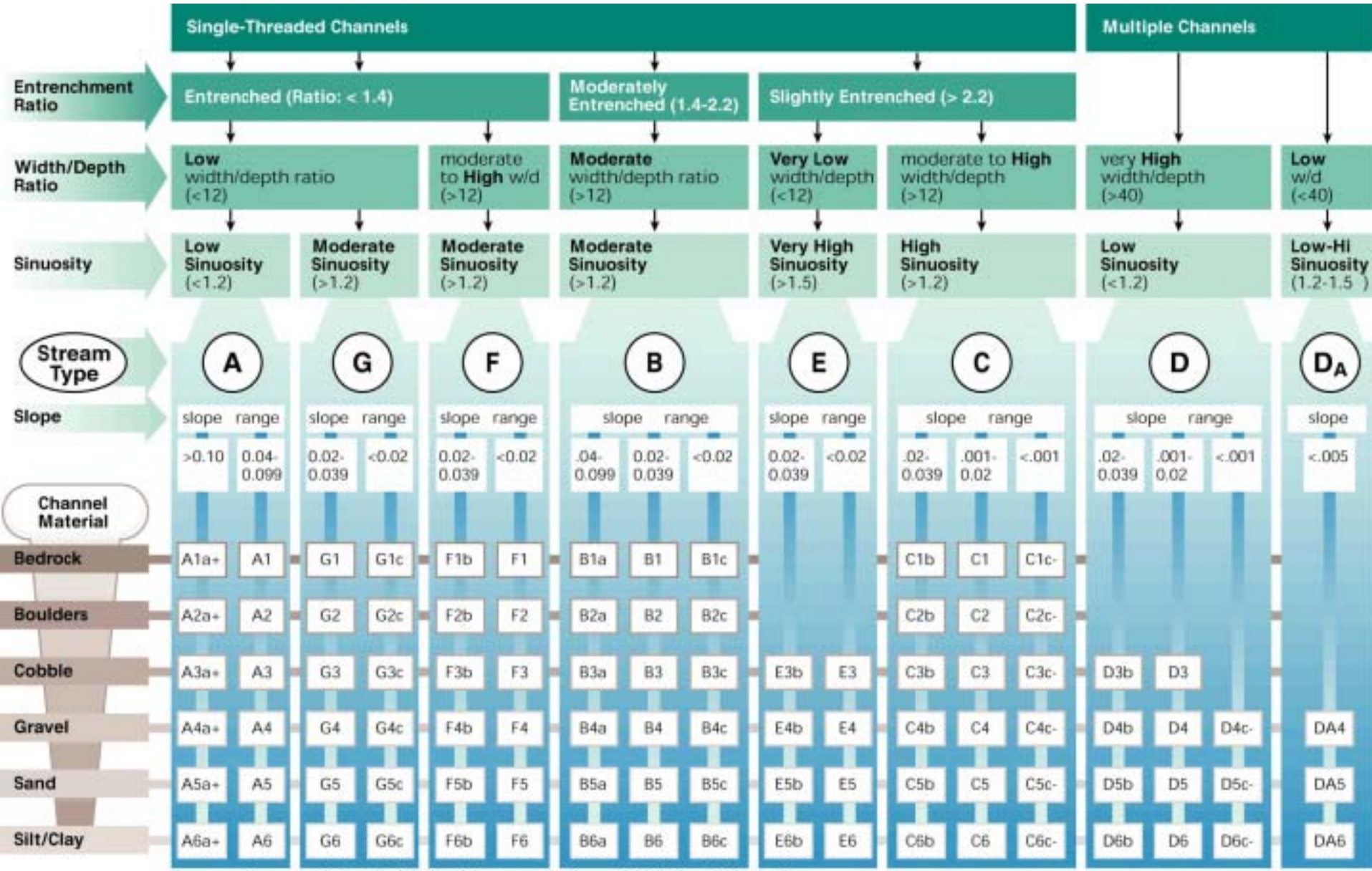

INTERMITTENCY
High
Low
None
Harsh Intermittent ABIOTIC
Intermittent Flashy ABIOTIC
Intermittent Runoff ABIOTIC
High
Low
Flood Frequency
Low
High
Flood Predictability
Perennial Flashy
Low Flow Predictability
ABIOTIC
Snow + Rain
Low Flow Predictability
SEASONALLY BIOTIC
Perennial Runoff
Low Flow Predictability
ABIOTIC
Winter Rain
High Flow Predictability
SEASONALLY BIOTIC
Mesic Groundwater
High Flow Predictability
BIOTIC
Snowmelt
High Flow Predictability
SEASONALLY BIOTIC
High
Low
Flood Frequency
Low
High
Flood Predictability


avalanches
debris flows
fluvial
Fire and/or wind
Avalanches
Debris flows
Flooding
Channel migration

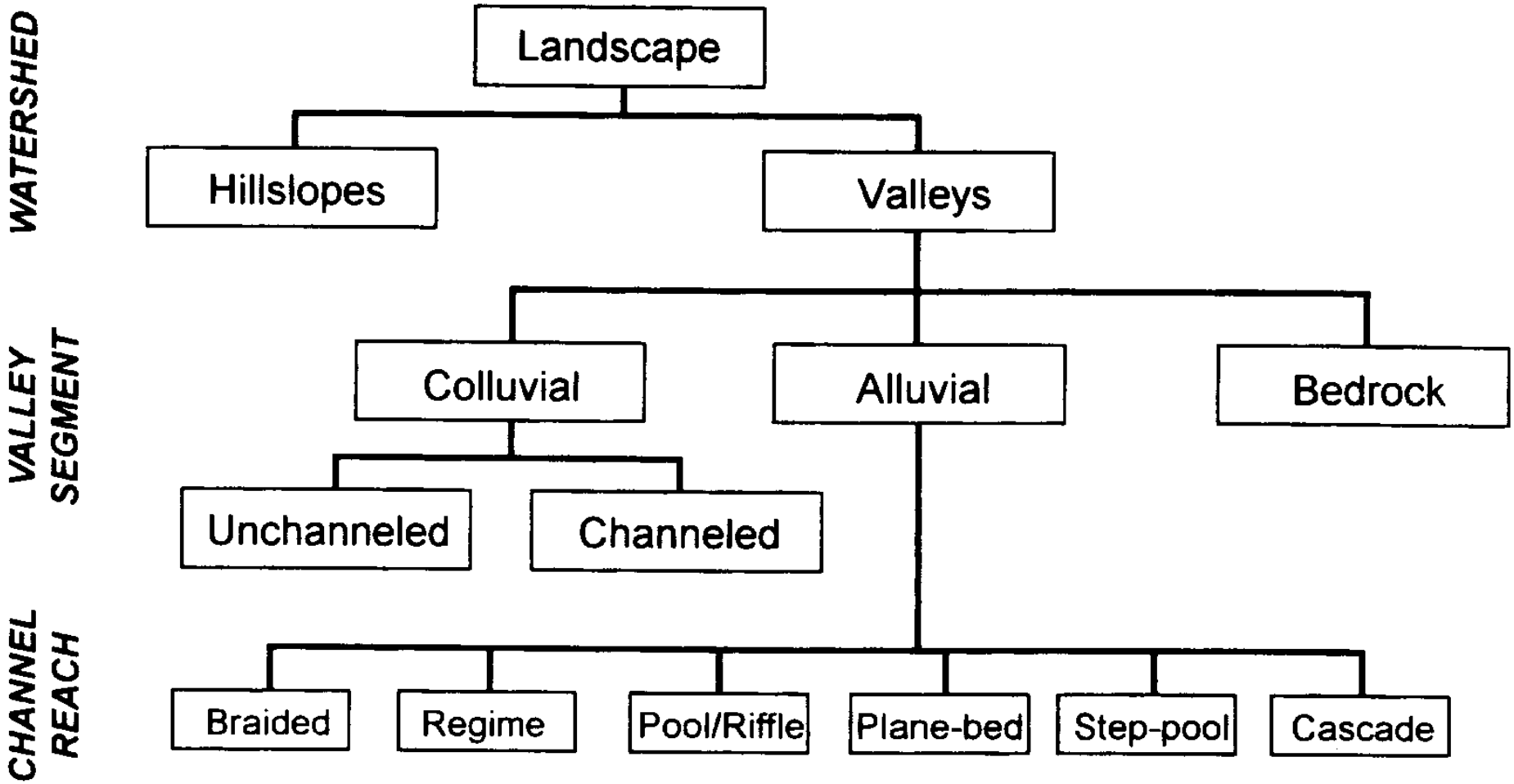
Upshot

- The current emphasis is on ecoregional and local scales in biomonitoring protocols

- Integration of hydrologic and geomorphic classifications at multiple spatial scales (watershed, valley bottom / geomorphic process domain, and reach) does not exist, despite the fact that such integration may be a powerful way to stratify habitats and predict biotic condition



Source: Rosgen 1996. Published by permission of Wildland Hydrology.

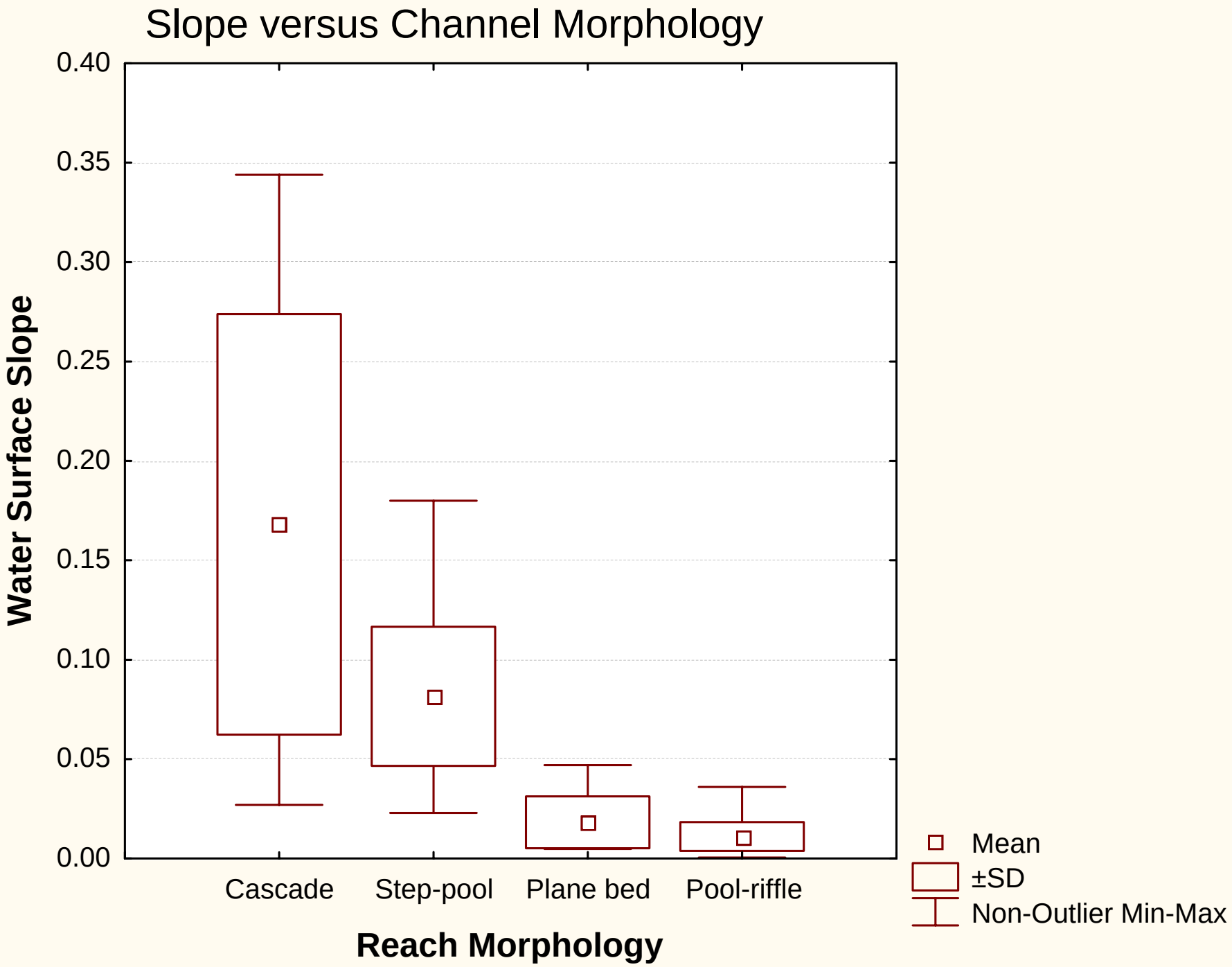

WATERSHED
VALLEY SEGMENT
CHANNEL REACH
Landscape
Hillslopes
Valleys
Colluvial
Alluvial
Bedrock
Unchanneled
Channeled
Braided
Regime
Pool/Riffle
Plane-bed
Step-pool
Cascade

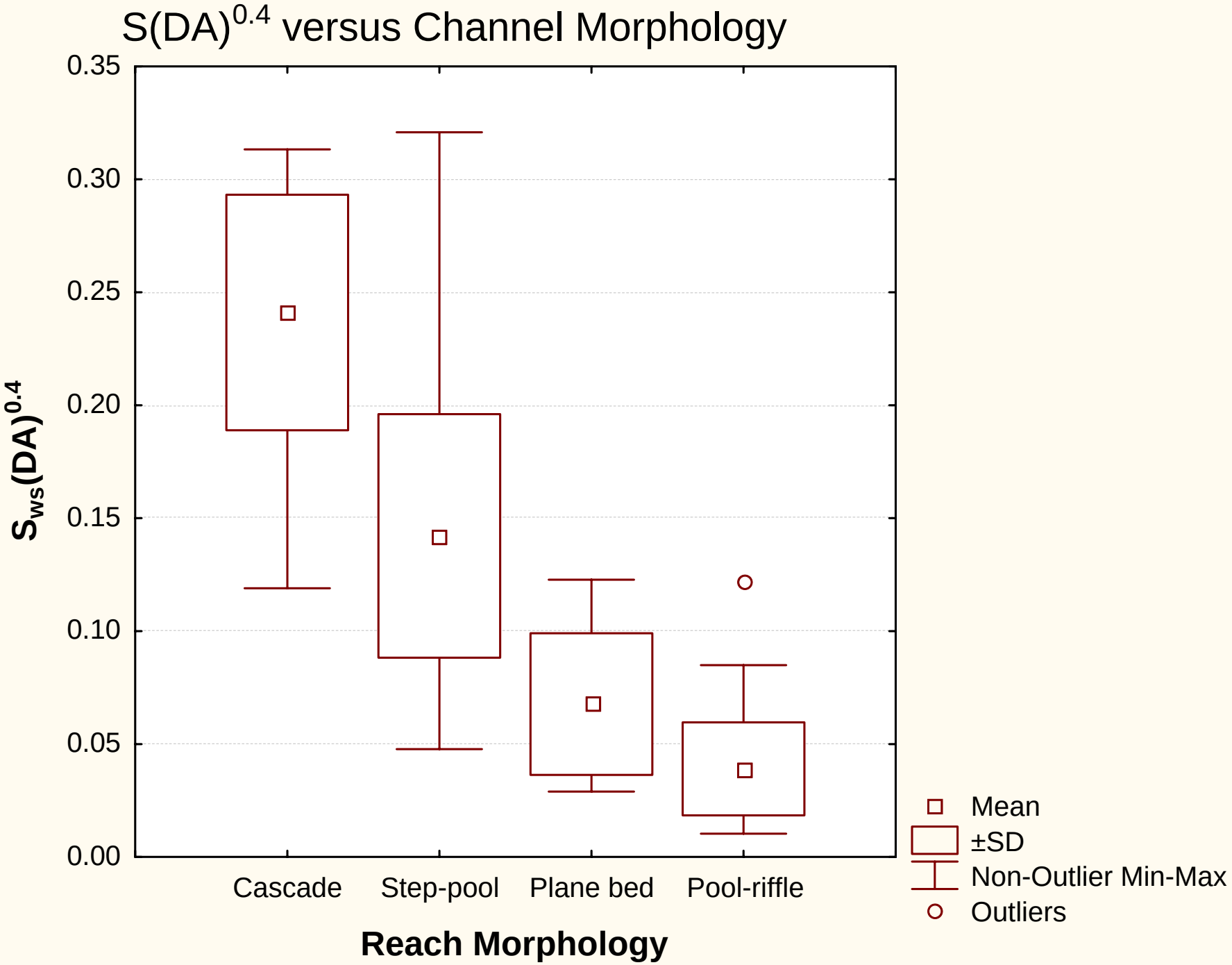
Hack (1957)

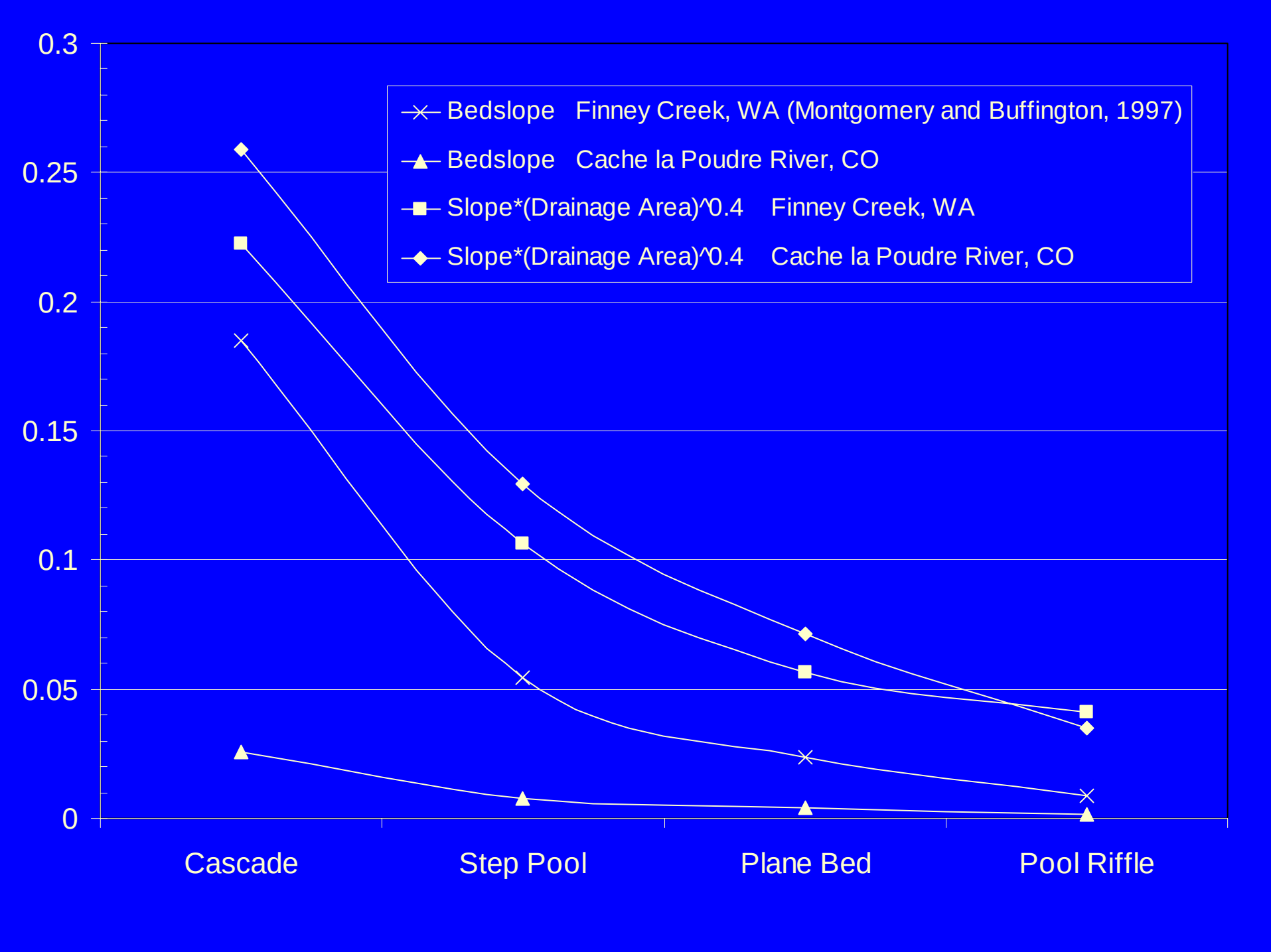
$$S = \alpha \left(\frac{d_{50}}{DA} \right)^{\beta}$$

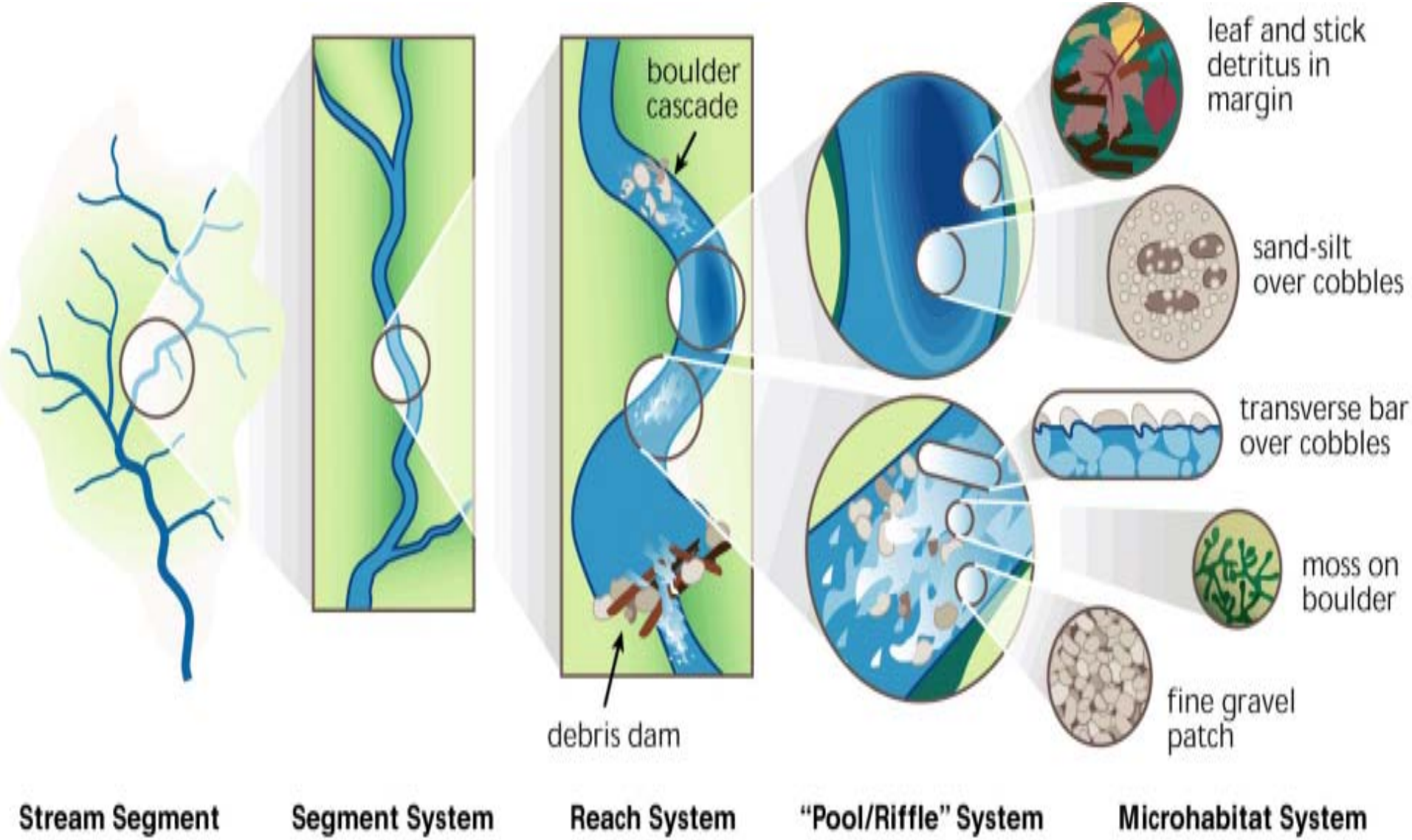
Interesting...

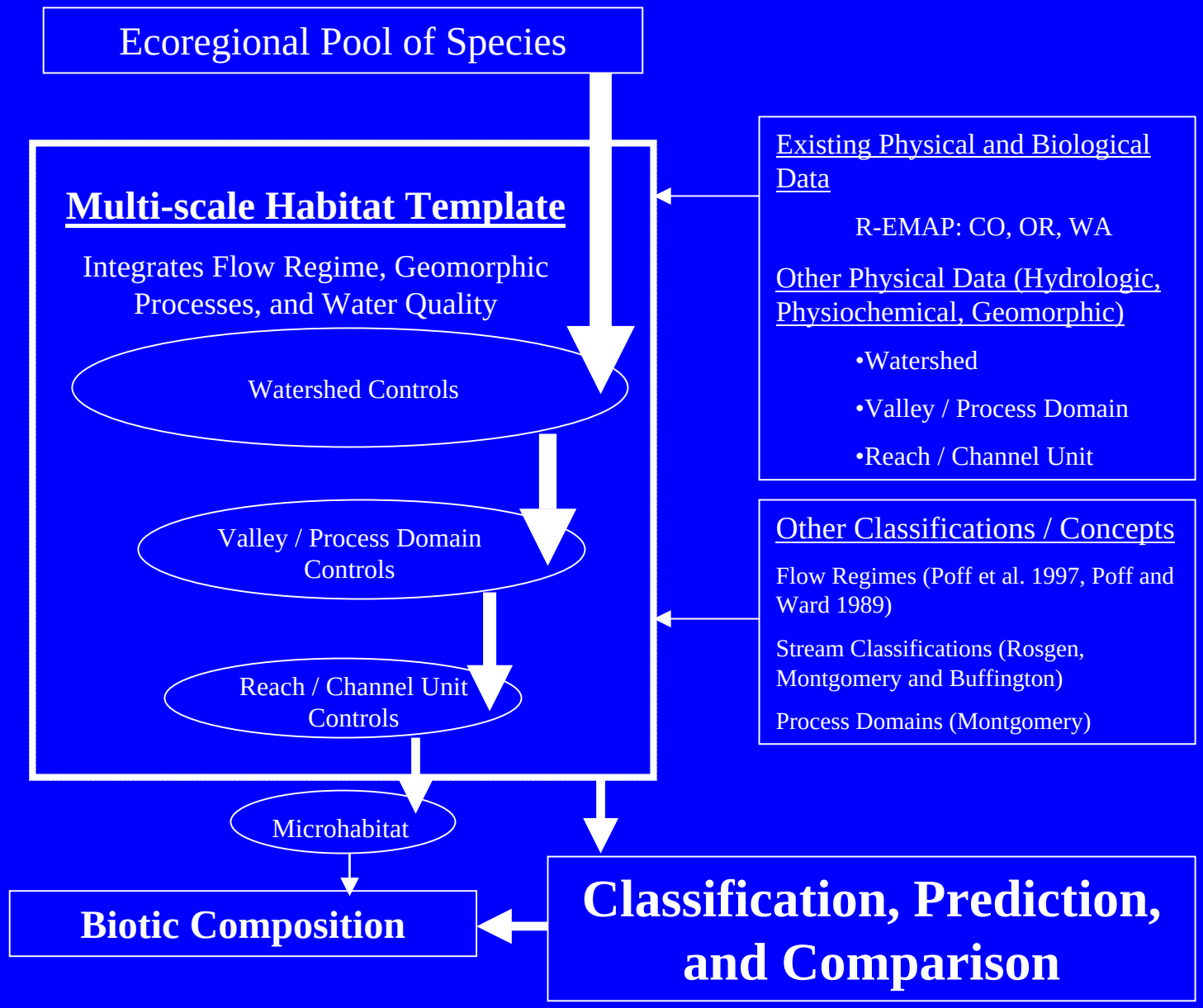
$$S(DA)^{\beta} \propto (d_{50})^{\beta}$$


Slope versus Channel Morphology
Water Surface Slope
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Cascade
Step-pool
Plane bed
Pool-riffle
Reach Morphology
Mean
±SD
Non-Outlier Min-Max


S(DA)0.4 versus Channel Morphology
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SWS(DA)0.4
Cascade
Step-pool
Plane bed
Pool-riffle
Reach Morphology
Mean
±SD
Non-Outlier Min-Max
Outliers


0.3
0.25
0.2
0.15
0.1
0.05
0
Bedslope Finney Creek, WA (Montgomery and Buffington, 1997)
Bedslope Cache la Poudre River, CO
Slope*(Drainage Area)^0.4 Finney Creek, WA
Slope*(Drainage Area)^0.4 Cache la Poudre River, CO
Cascade
Step Pool
Plane Bed
Pool Riffle


boulder cascade
debris dam
leaf and stick detritus in margin
sand-silt over cobbles
transverse bar over cobbles
moss on boulder
fine gravel patch
Stream Segment
Segment System
Reach System
"Pool/Riffle" System
Microhabitat System


Ecoregional Pool of Species
Multi-scale Habitat Template
Integrates Flow Regime, Geomorphic Processes, and Water Quality
Watershed Controls
Valley / Process Domain Controls
Reach / Channel Unit Controls
Microhabitat
Biotic Composition
Existing Physical and Biological Data
R-EMAP: CO, OR, WA
Other Physical Data (Hydrologic, Physiochemical, Geomorphic)
•Watershed
•Valley / Process Domain
•Reach / Channel Unit
Other Classifications / Concepts
Flow Regimes (Poff et al. 1997, Poff and Ward 1989)
Stream Classifications (Rosgen, Montgomery and Buffington)
Process Domains (Montgomery)
Classification, Prediction, and Comparison

Objectives

- Develop a multi-scaled physical habitat classification of western US streams, in order to derive predictive statistical models relating biotic condition to multi-scaled environmental variables.

- Demonstrate the explanatory power and flexibility of the classification within and across diverse western US ecoregions.

Existing R-EMAP Sites

Ecoregions:

Southern Rockies, Coast Range, Puget Lowland, Willamette Valley, Cascades, and Columbia Basin.

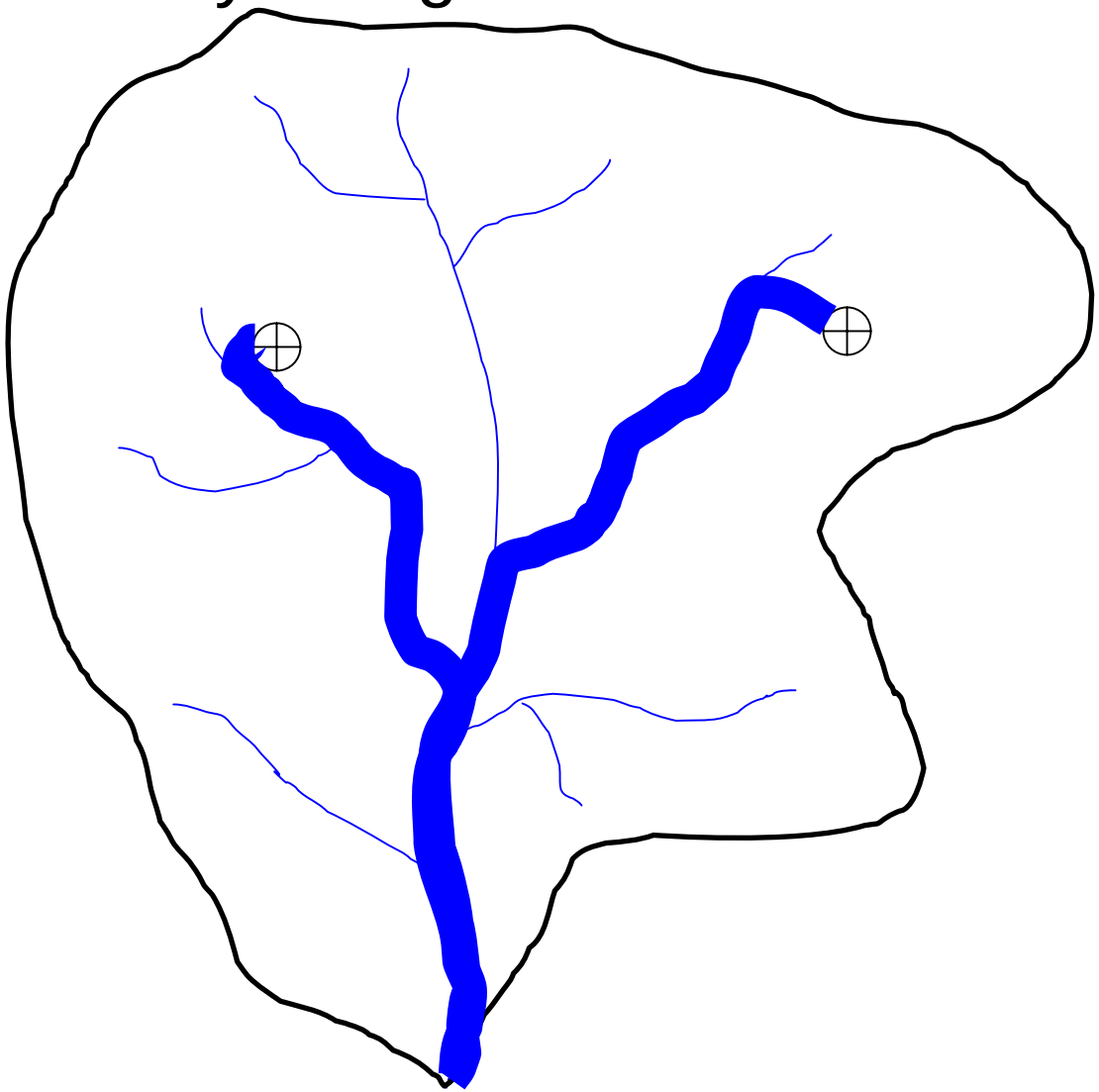
Watersheds:

Yakima and Chehalis Basins in WA, the Deschutes and Willamette Basins in OR, and the Platte, Colorado, Arkansas, and Rio Grande Basins in Colorado.

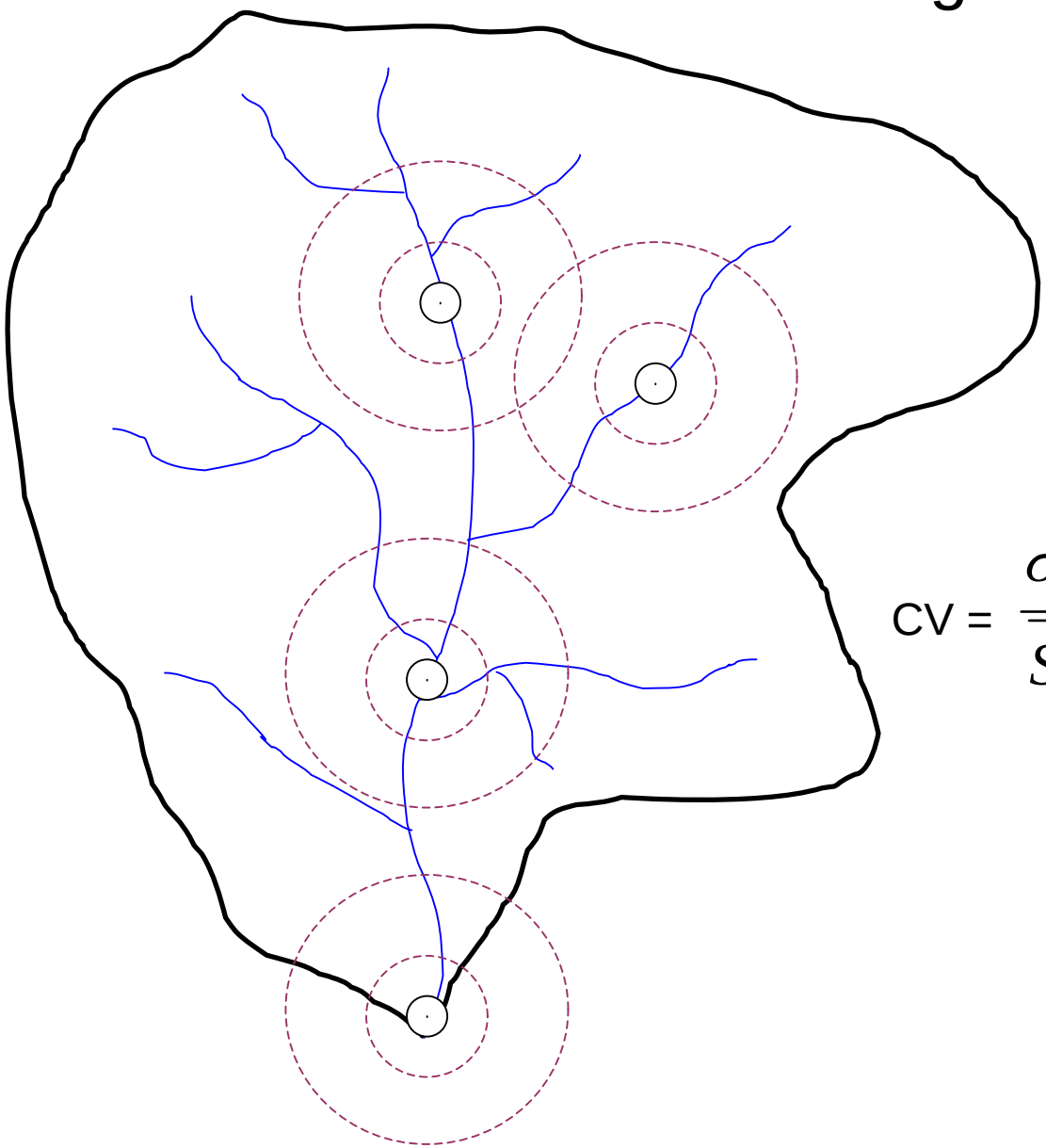
Project Status

- Systematic inventory of landscape and valley scale metrics
- Landscape metrics computed for actual drainages
- Field verification of stream types
  - Montgomery and Buffington
  - Rosgen
- Bed stability metrics

Hydrologic Distance



Network Heterogeneity

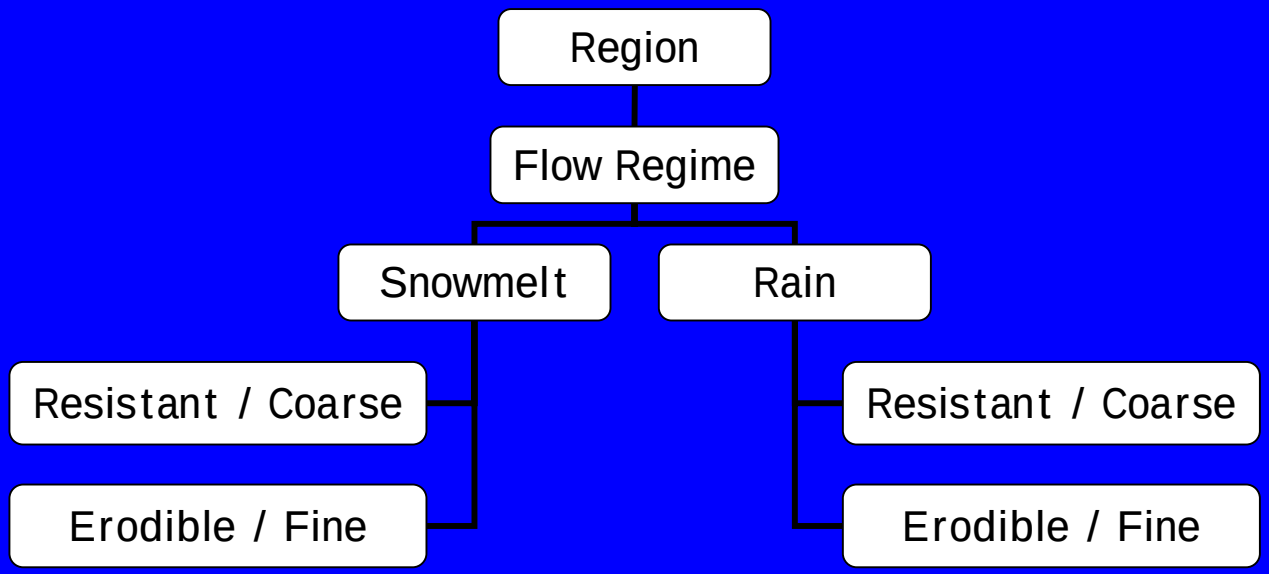


$$CV = \frac{\sigma_{SA^{0.4}}}{\overline{SA^{0.4}}}$$ in stream cells

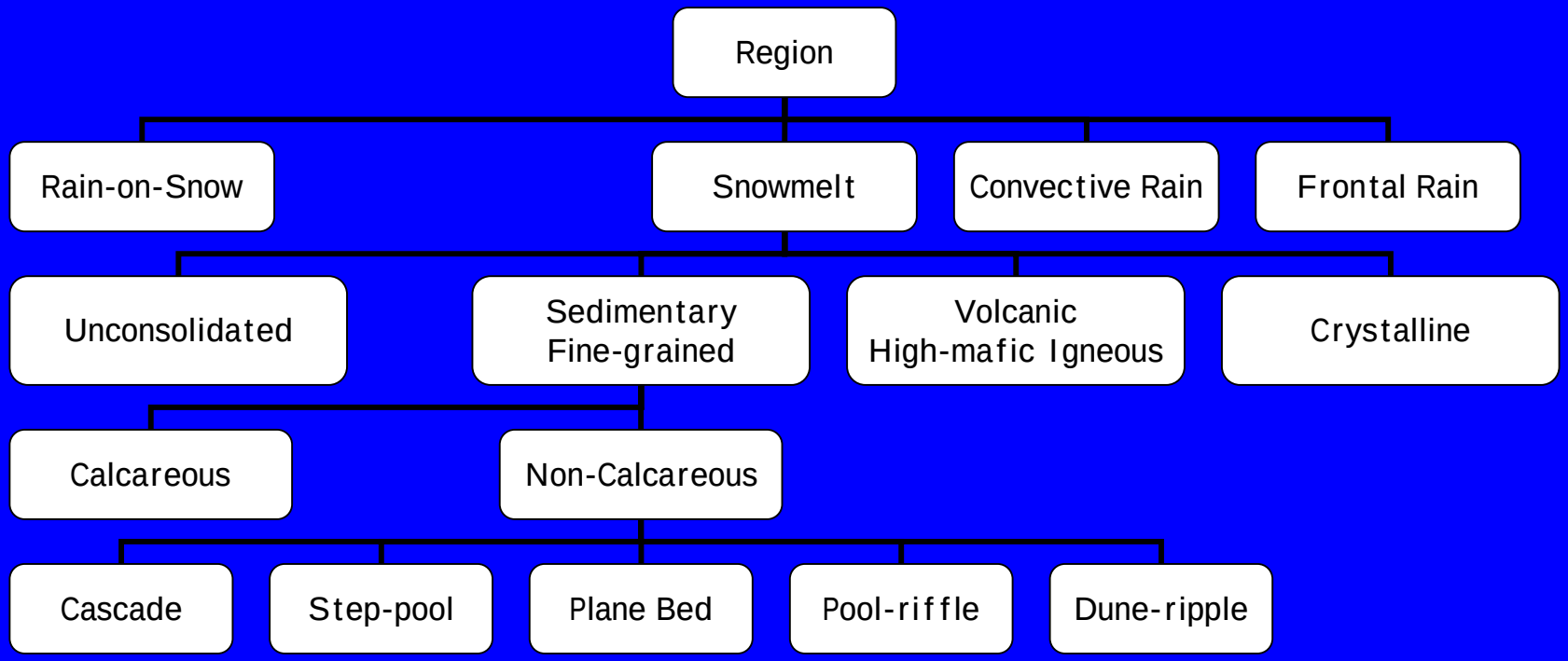
Project Status

- Functional traits of insects
- Hydrologic modeling – streamflow gages / TOPMODEL
- Prediction of morphology using GIS
- Classification and Regression Tree (CART) approach
- Collaboration with STARMAP

Hydrologic / Geologic Classification

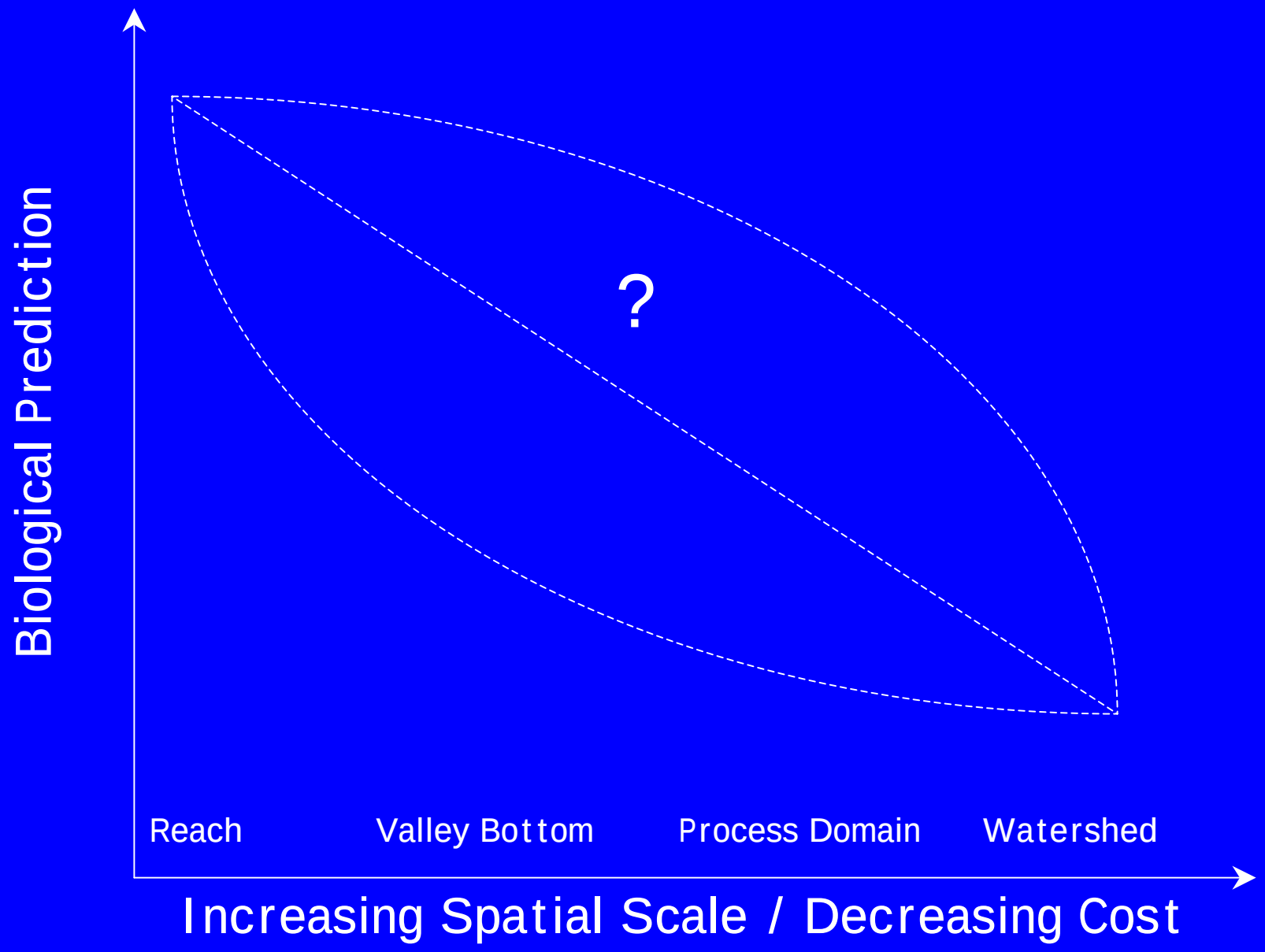


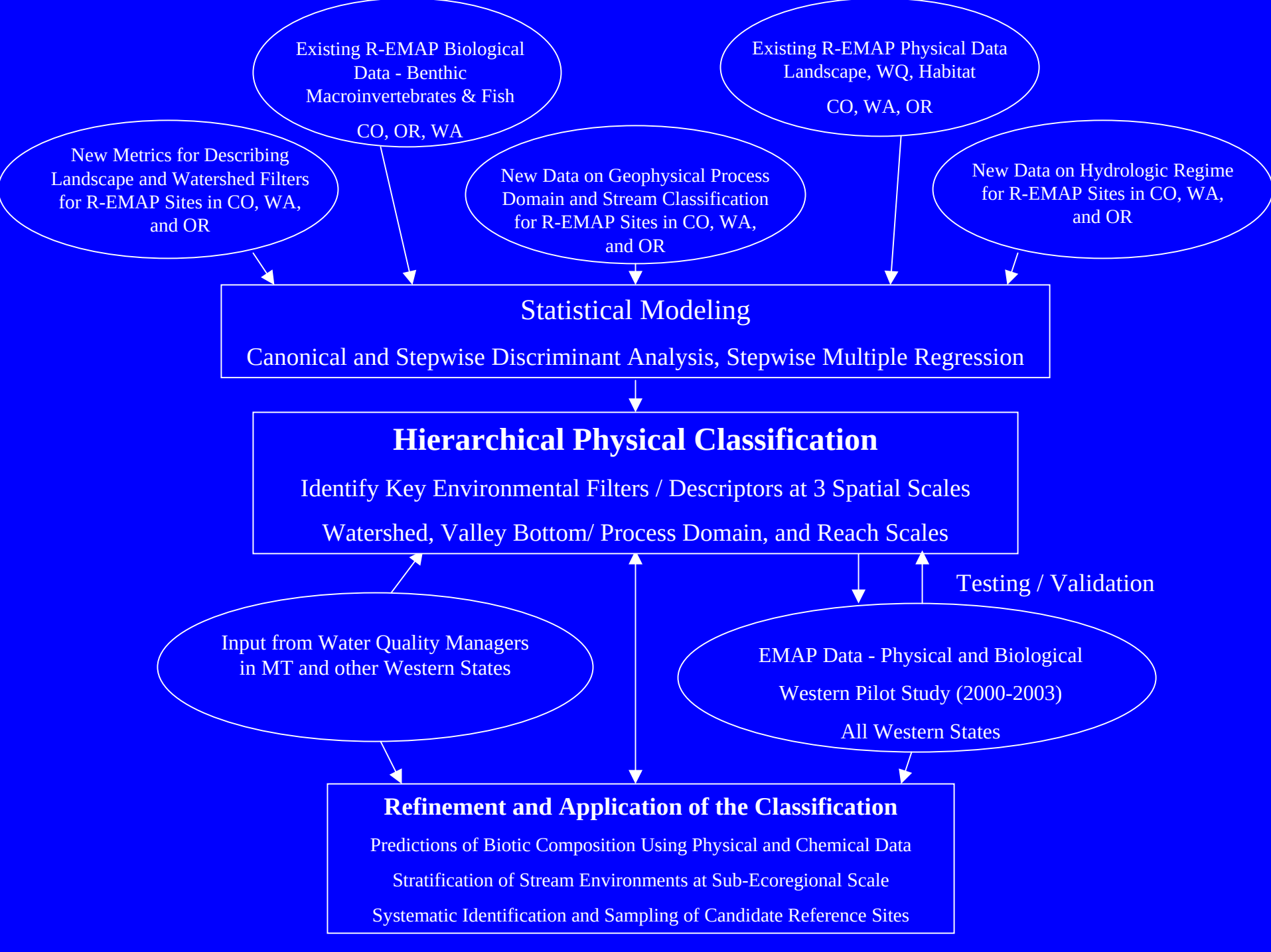
Hydrogeomorphic Classification



Expected Benefits

- Determining the right scales for classification
- Assessing the relative benefits of different levels of physical description in explaining biological variation
- Identifying reference sites in a defensible and objective manner


Biological Prediction
?
Reach
Valley Bottom
Process Domain
Watershed
Increasing Spatial Scale / Decreasing Cost


Existing R-EMAP Biological Data - Benthic Macroinvertebrates & Fish
CO, OR, WA
Existing R-EMAP Physical Data Landscape, WQ, Habitat
CO, WA, OR
New Metrics for Describing Landscape and Watershed Filters for R-EMAP Sites in CO, WA, and OR
New Data on Geophysical Process Domain and Stream Classification for R-EMAP Sites in CO, WA, and OR
New Data on Hydrologic Regime for R-EMAP Sites in CO, WA, and OR
Statistical Modeling
Canonical and Stepwise Discriminant Analysis, Stepwise Multiple Regression
Hierarchical Physical Classification
Identify Key Environmental Filters / Descriptors at 3 Spatial Scales
Watershed, Valley Bottom/ Process Domain, and Reach Scales
Testing / Validation
Input from Water Quality Managers in MT and other Western States
EMAP Data - Physical and Biological
Western Pilot Study (2000-2003)
All Western States
Refinement and Application of the Classification
Predictions of Biotic Composition Using Physical and Chemical Data
Stratification of Stream Environments at Sub-Ecoregional Scale
Systematic Identification and Sampling of Candidate Reference Sites