



# **How Much is Too Much? Sampling Density in Stratified Sediment Bedforms for Estimating Surface-Area Weighed Average Concentrations**

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**woodplc.com**

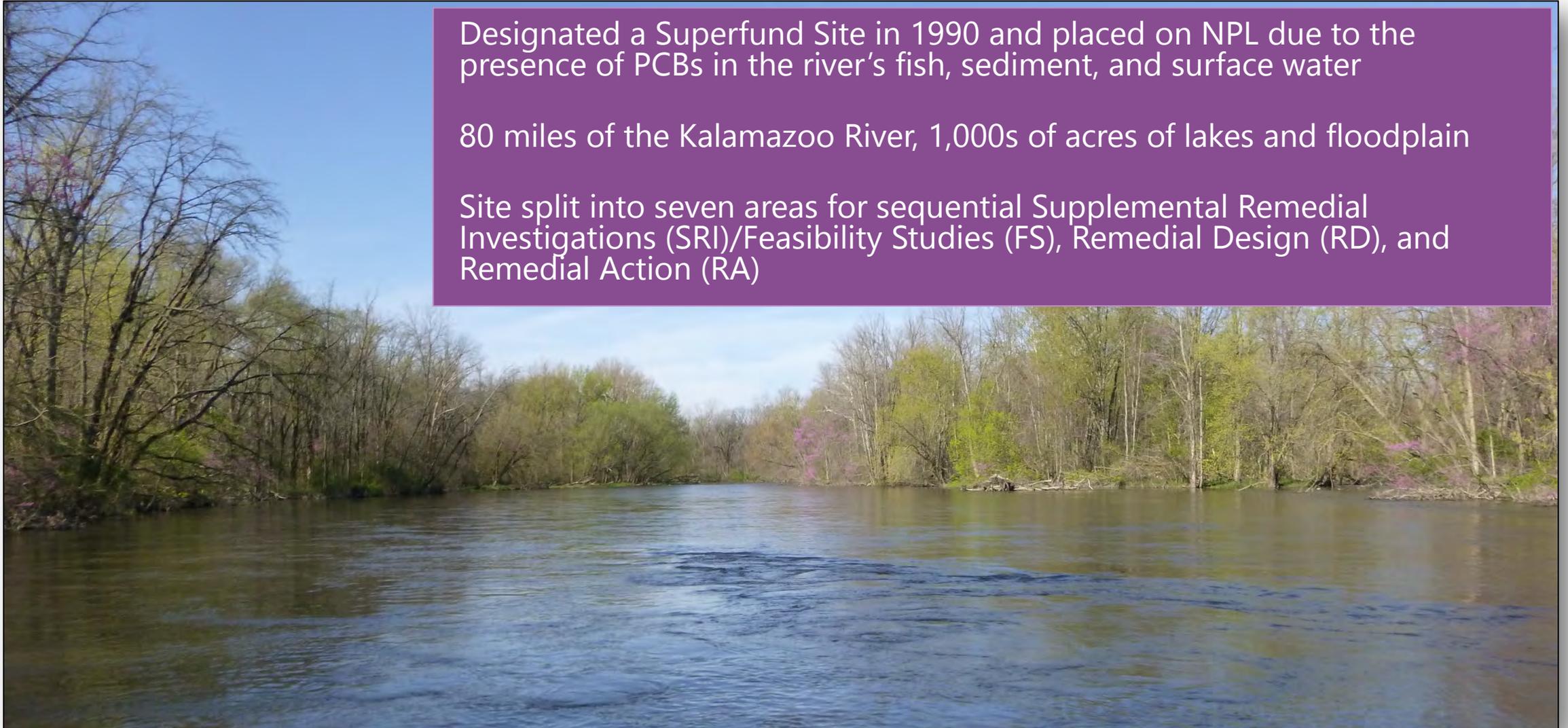


# Kalamazoo River Superfund Site – Michigan

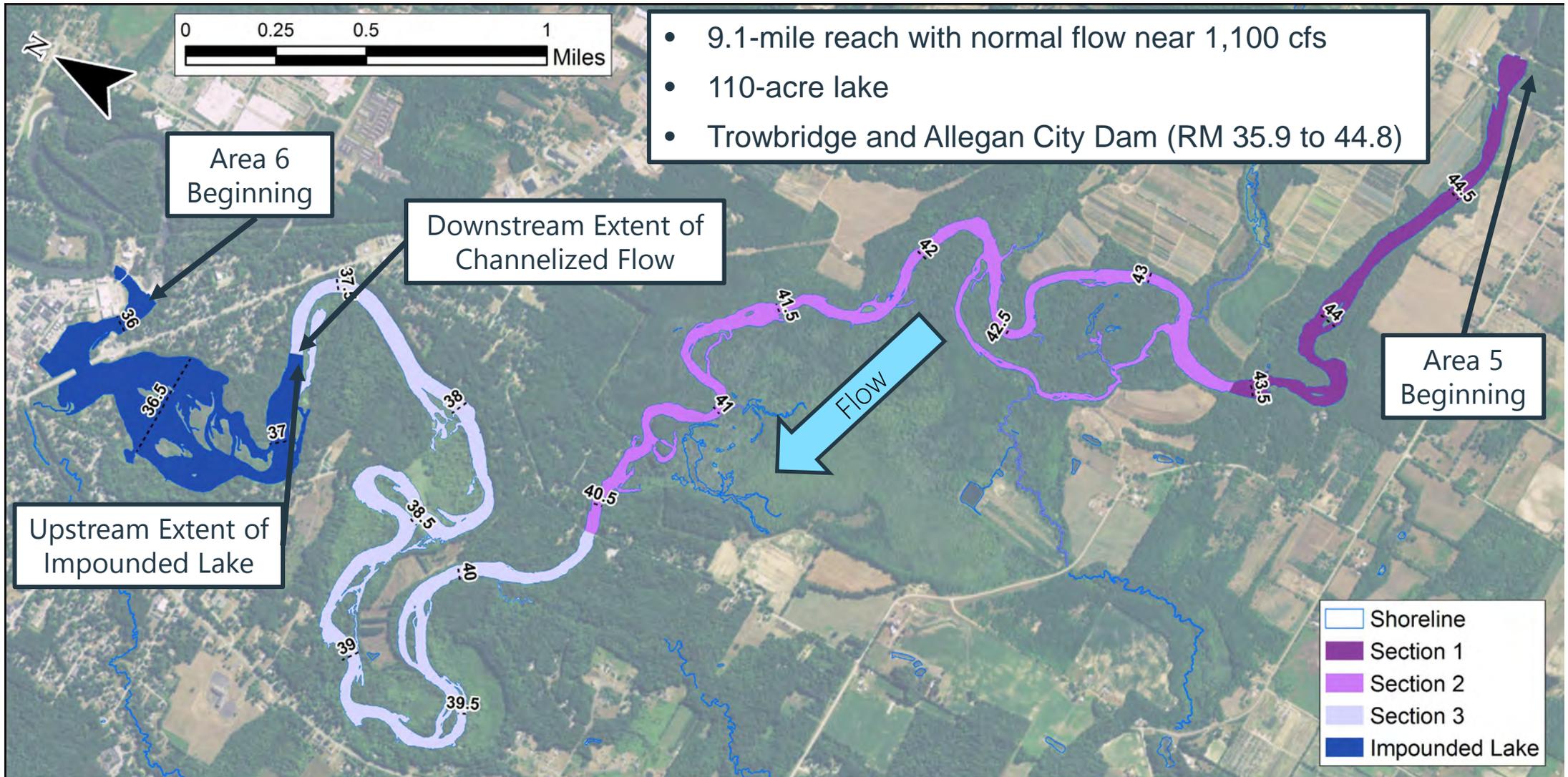
Designated a Superfund Site in 1990 and placed on NPL due to the presence of PCBs in the river's fish, sediment, and surface water

80 miles of the Kalamazoo River, 1,000s of acres of lakes and floodplain

Site split into seven areas for sequential Supplemental Remedial Investigations (SRI)/Feasibility Studies (FS), Remedial Design (RD), and Remedial Action (RA)



# Area 5



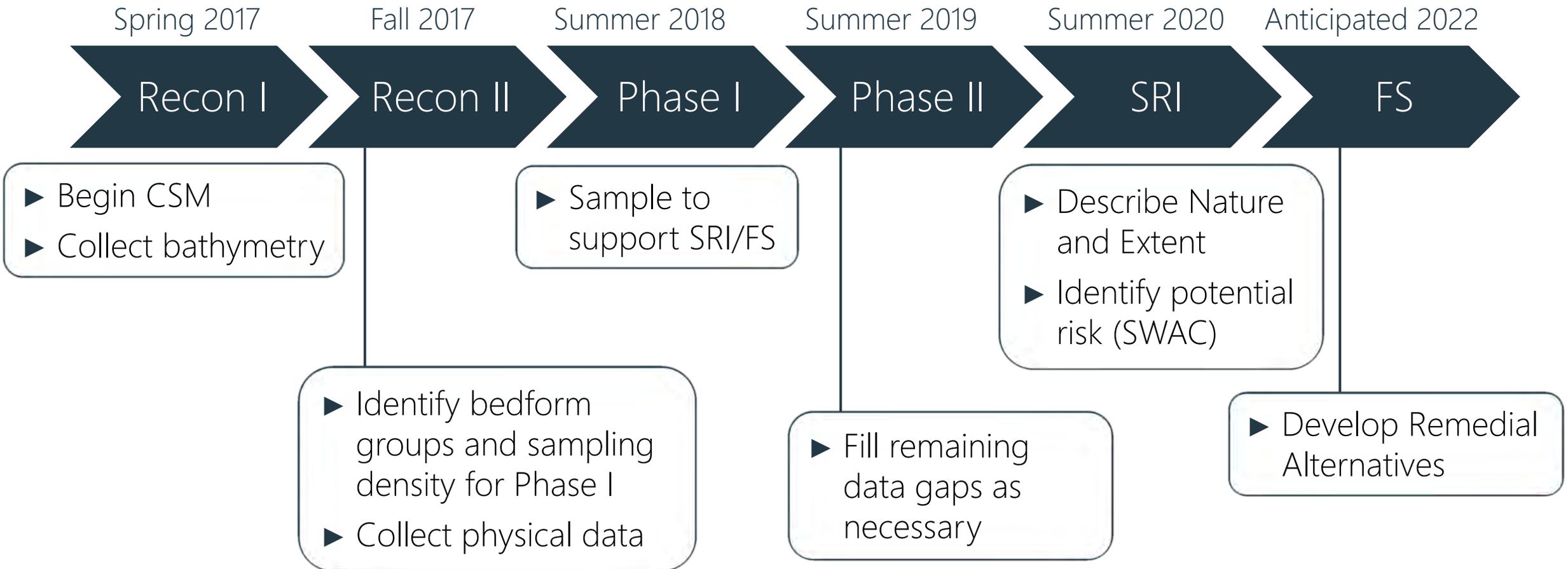
# Sampling objectives

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- Unbiased investigation strategy that is defensible, reproducible and provides a robust dataset for statistical evaluation at the level needed to make decisions in a Feasibility Study (FS) and inform future remedial design sampling
- Optimize sampling plan by using
  - higher density sampling where variance is higher to reduce uncertainty
  - lower density sampling where variance is less and uncertainty is already low



# Area 5 timeline

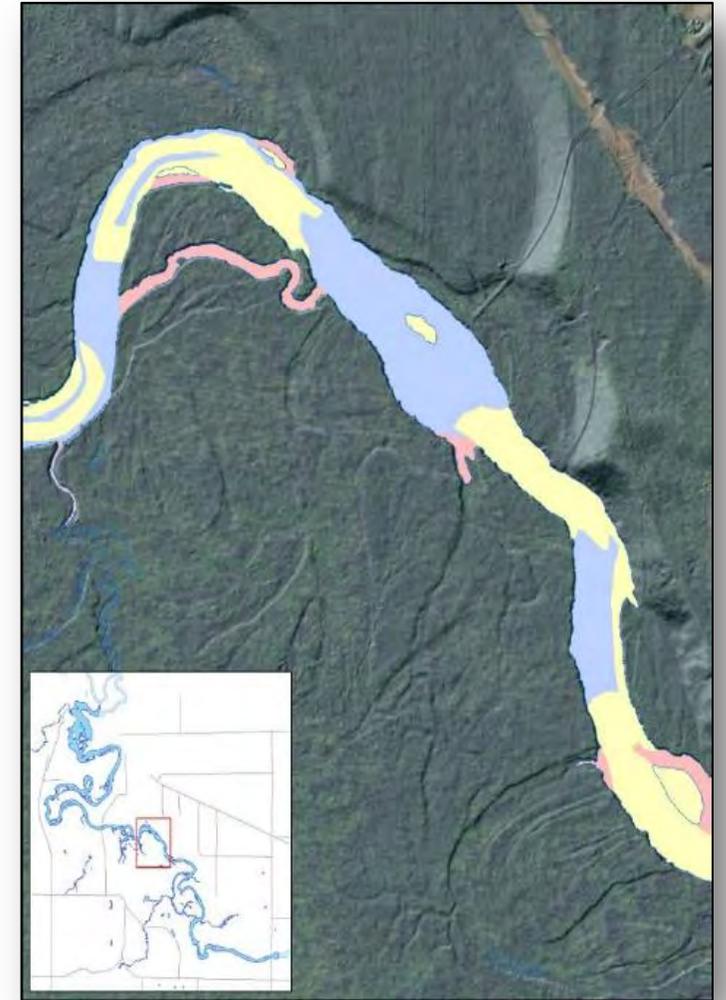


# Approach

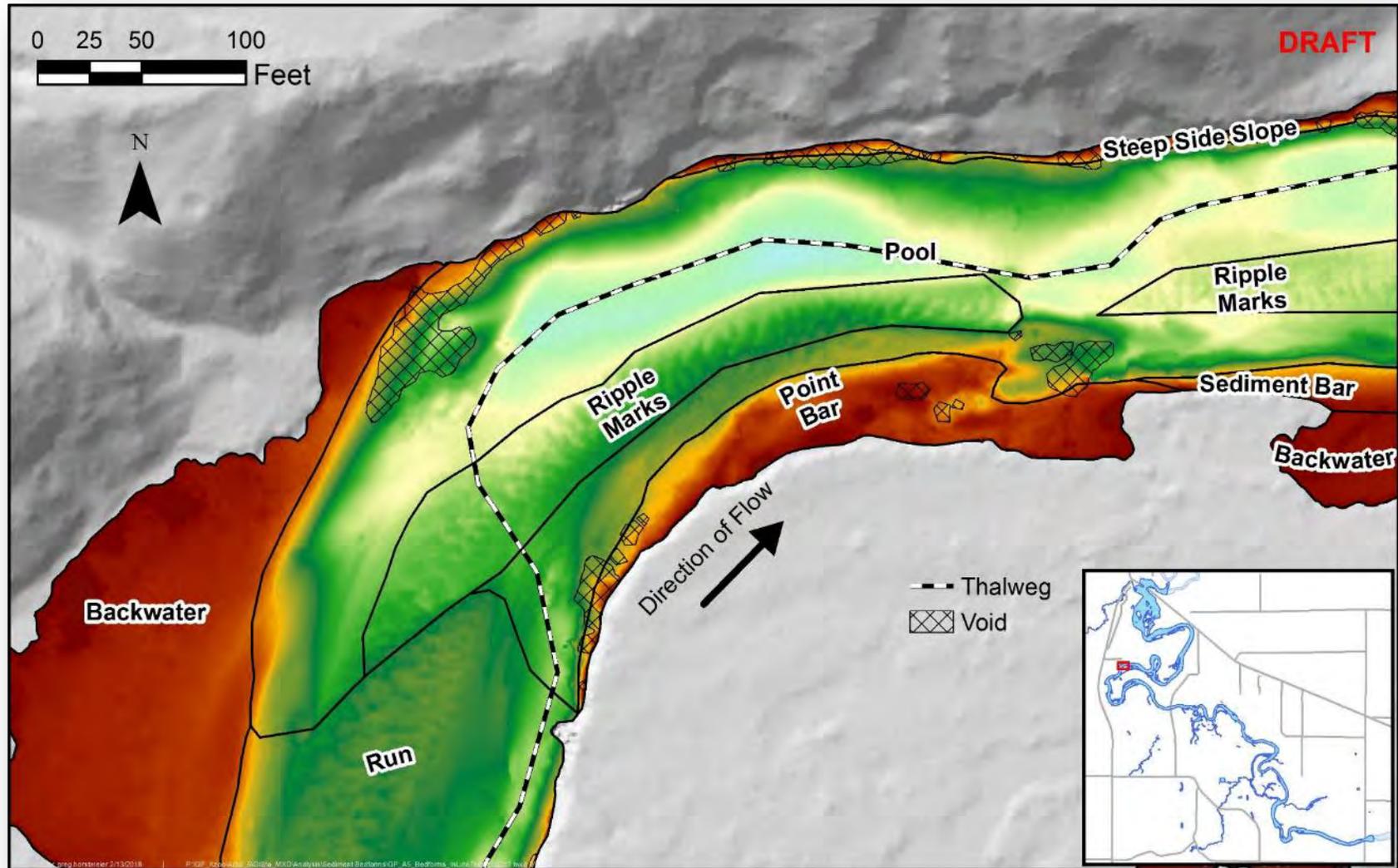


# Recon with sample design in mind

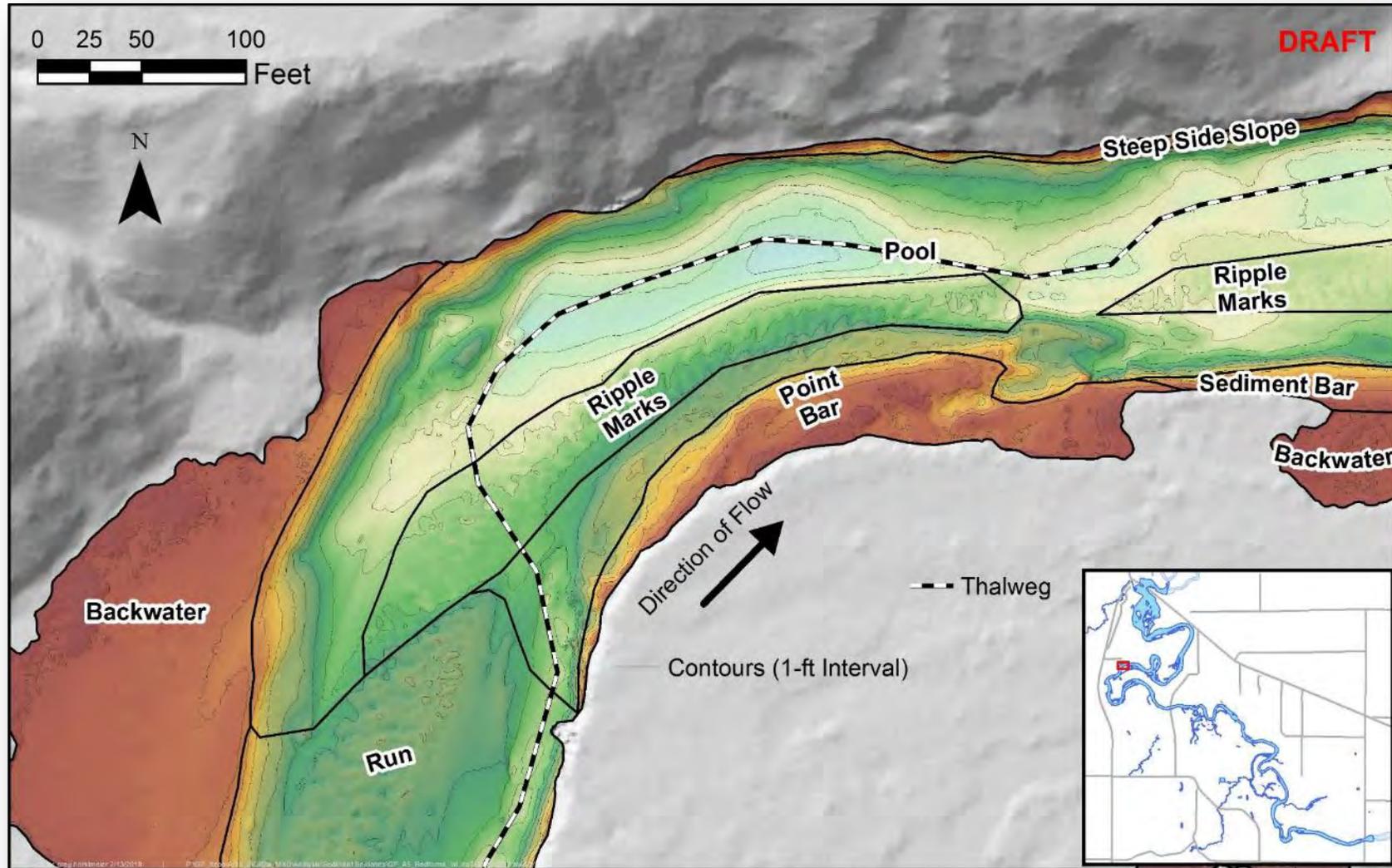
- Stratified, random sampling
  - Strata = Bedforms based on similar characteristics
  - Sample core density based on bedform group
- Recon Activities
  - Collect bathymetry data
  - Limited sediment cores with physical characteristics and PCB analysis to quantify variability



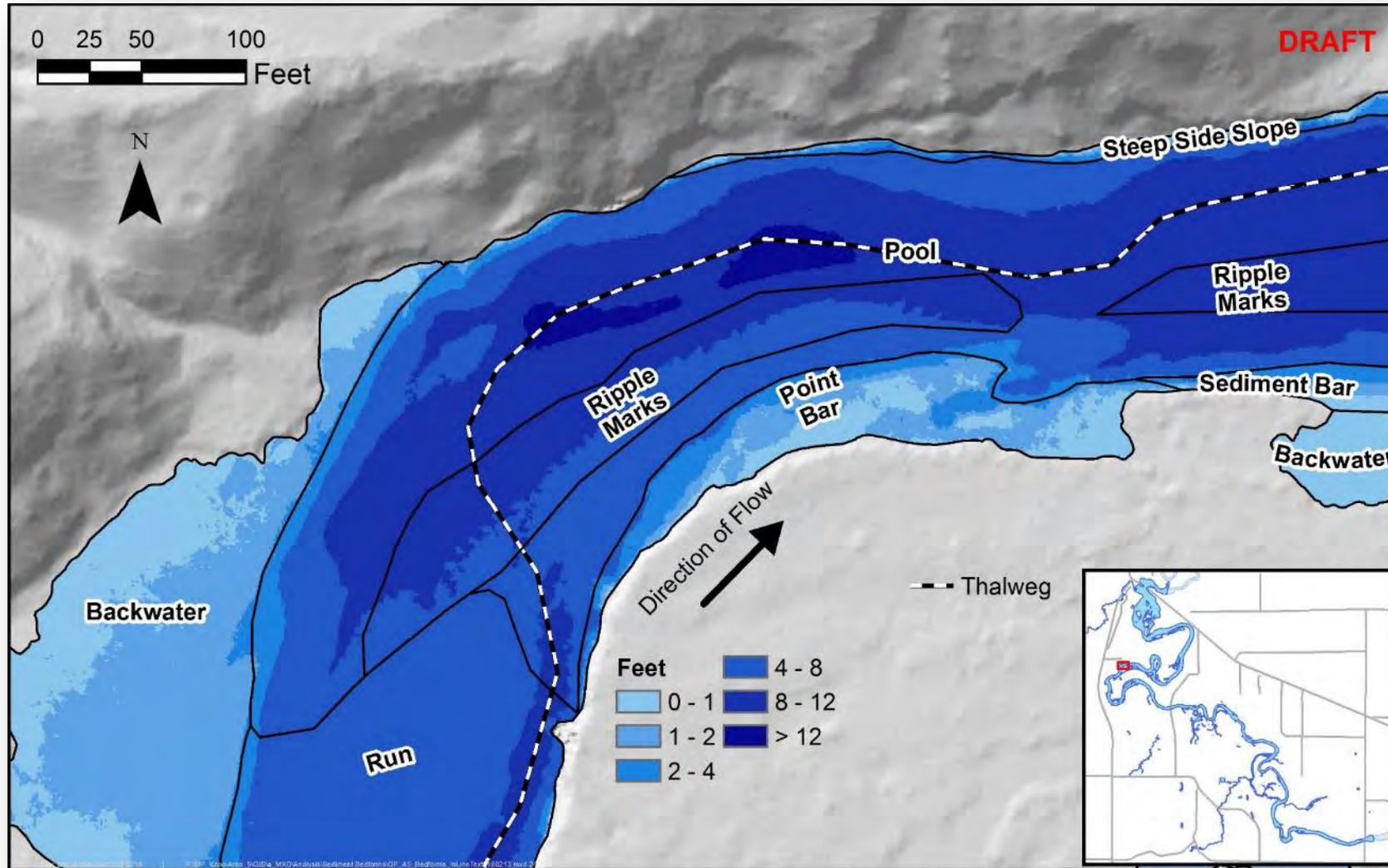
# Bathymetry



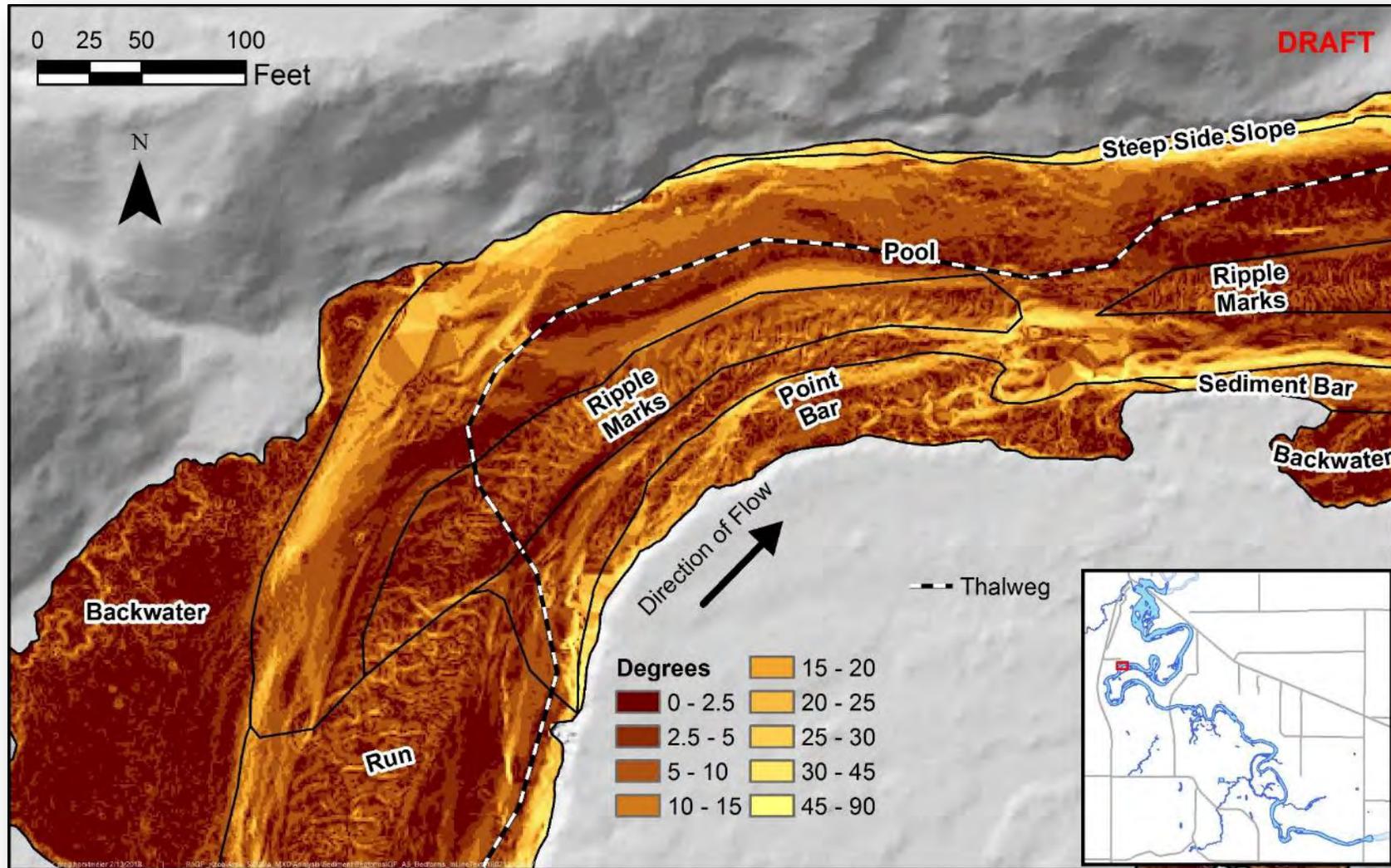
# Contour over bathymetry



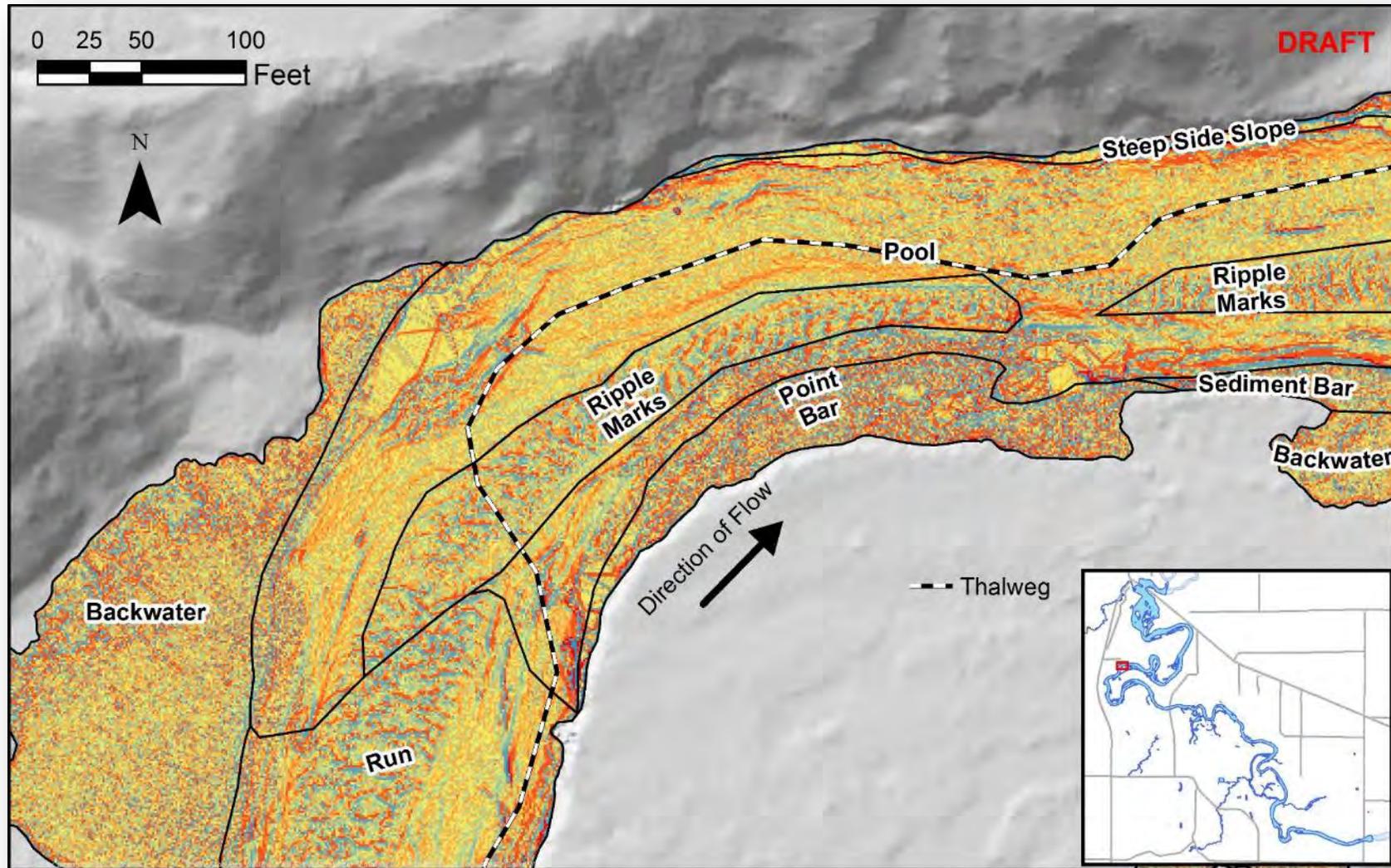
# Water depth



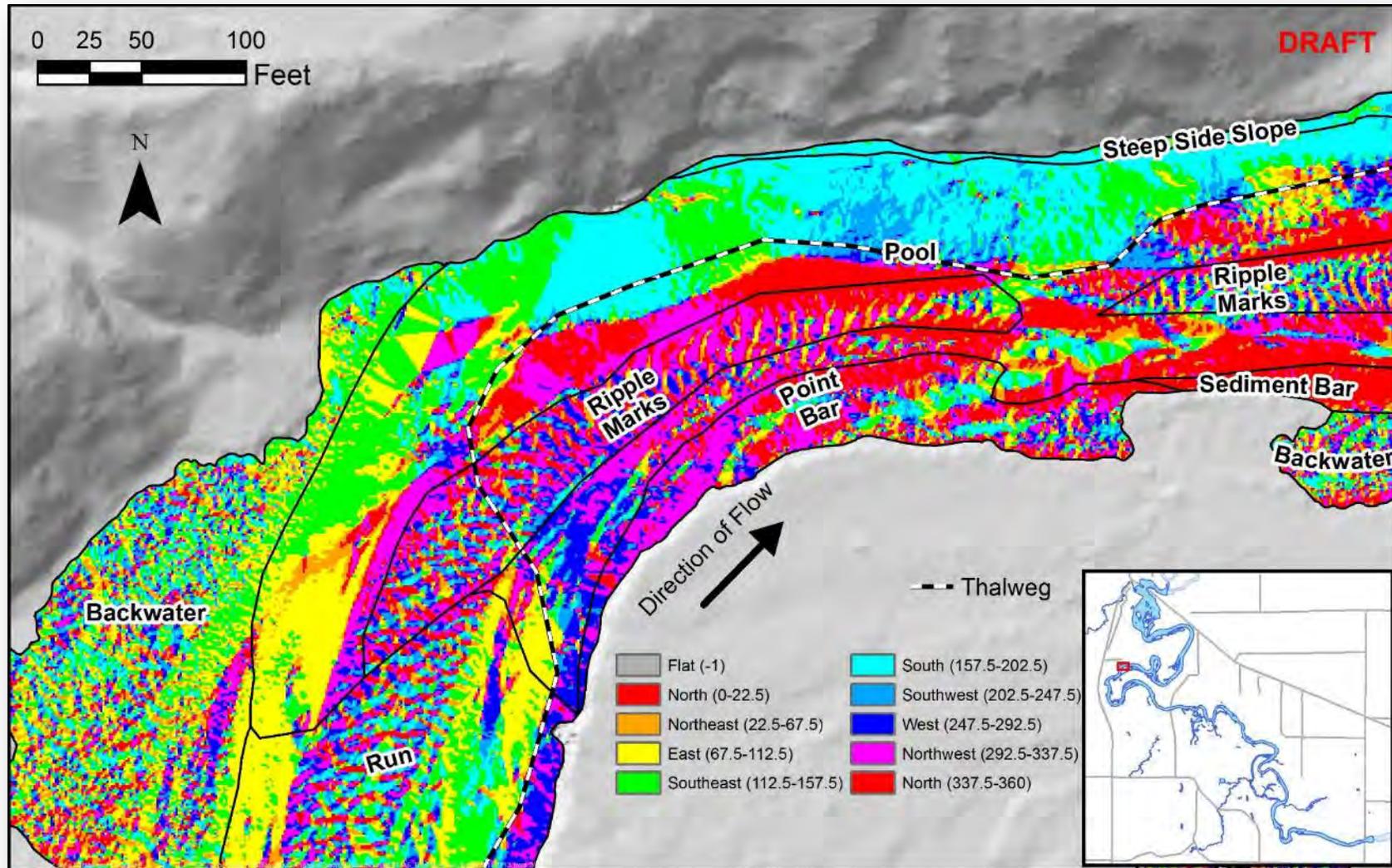
# Slope



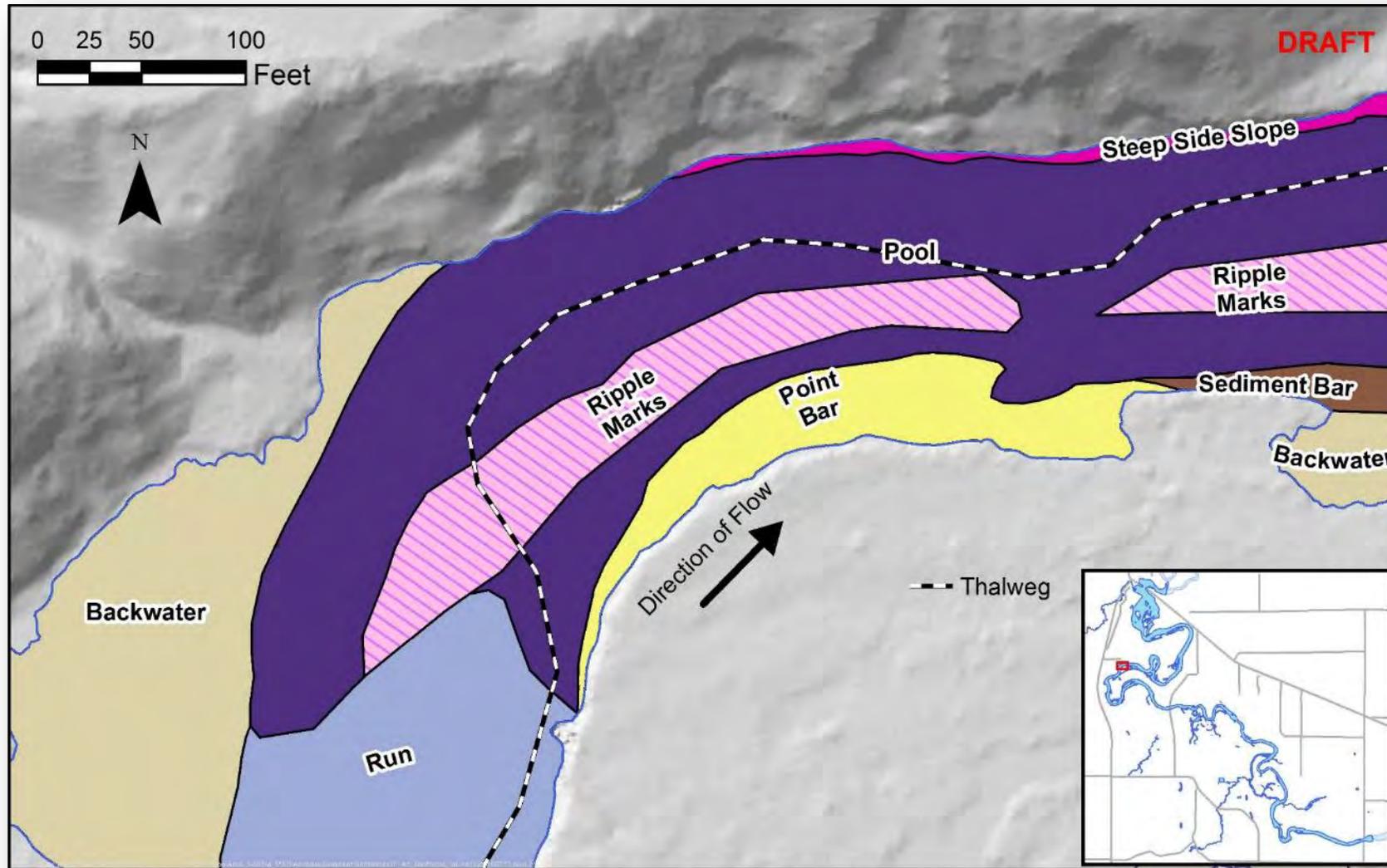
# Curvature



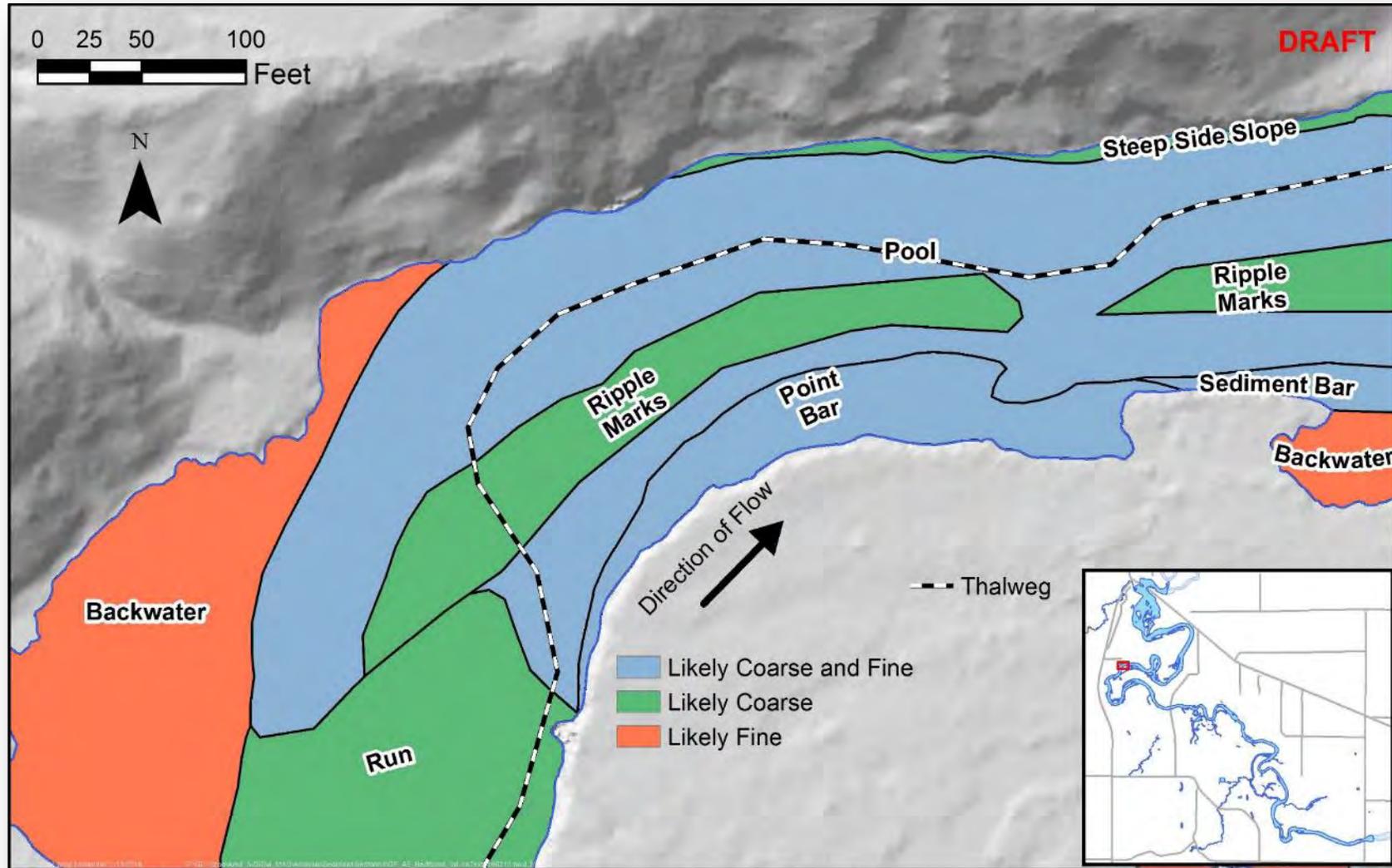
# Aspect



# Individual bedform mapping



# Simplified bedform mapping



# Bedform classifications pre-Recon II

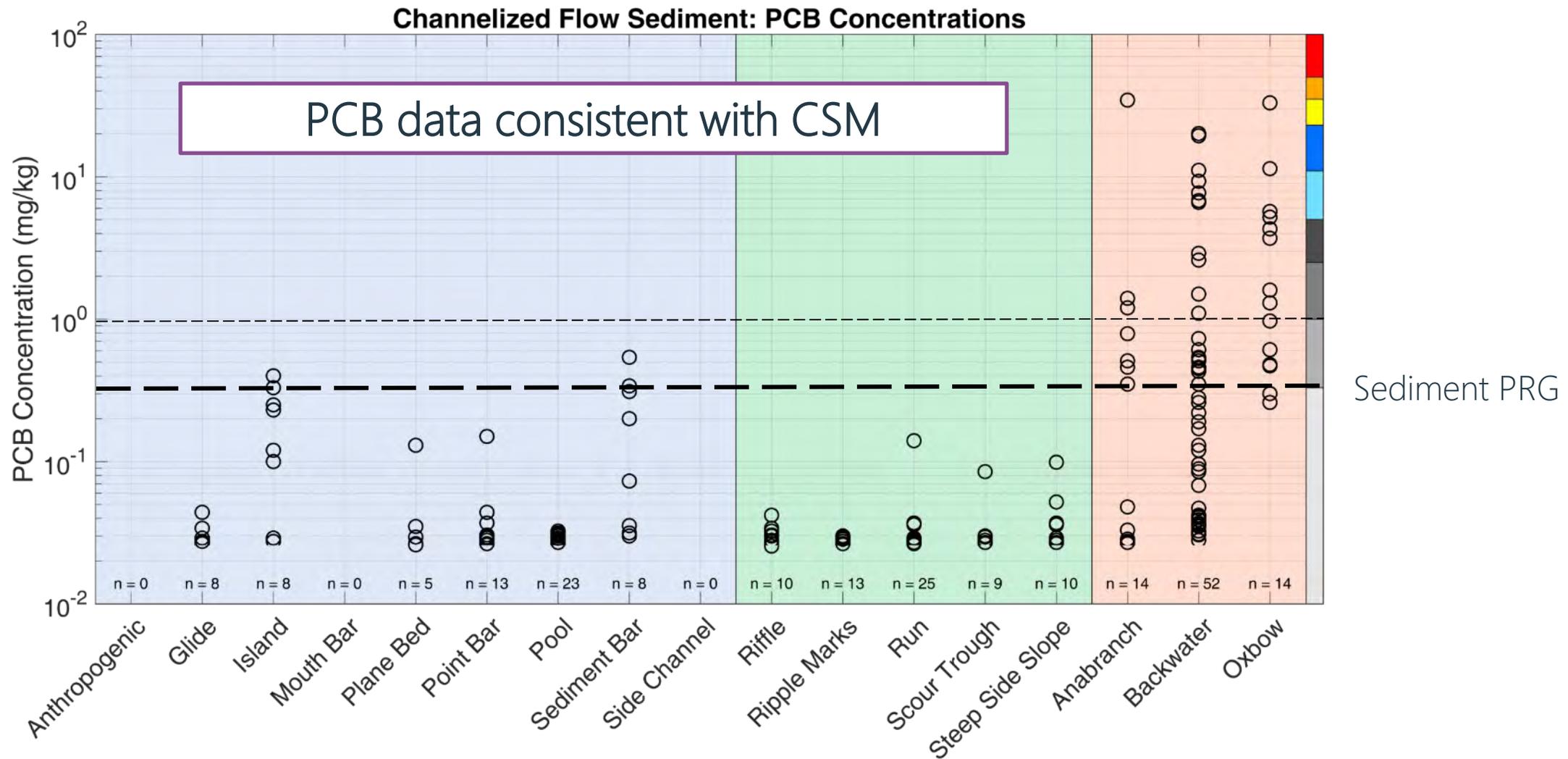
Bedform	Acreage	Simplified Category	Simplified Category Acreage
Riffle	27.8	Likely Coarse	105.9
Ripple Marks	7.7		
Run	53.6		
Scour Trough	5.0		
Steep Side Slope	11.9		
Anabranch	20.5	Likely Fine	60.2
Backwater	29.3		
Oxbow	10.4		
Anthropogenic	11.1	Likely Coarse and Fine	168.4
Glide	8.4		
Island	18.8		
Mouth Bar	34.6		
Plane Bed	5.0		
Point Bar	18.7		
Pool	46.1		
Sediment Bar	13.6		
Side Channel	12.2		
<b>Sums</b>	<b>334.5</b>		<b>334.5</b>



# Recon II Results



# PCB distributions by bedform



# Cluster analysis of channelized flow multivariate data

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## Data used in cluster analysis

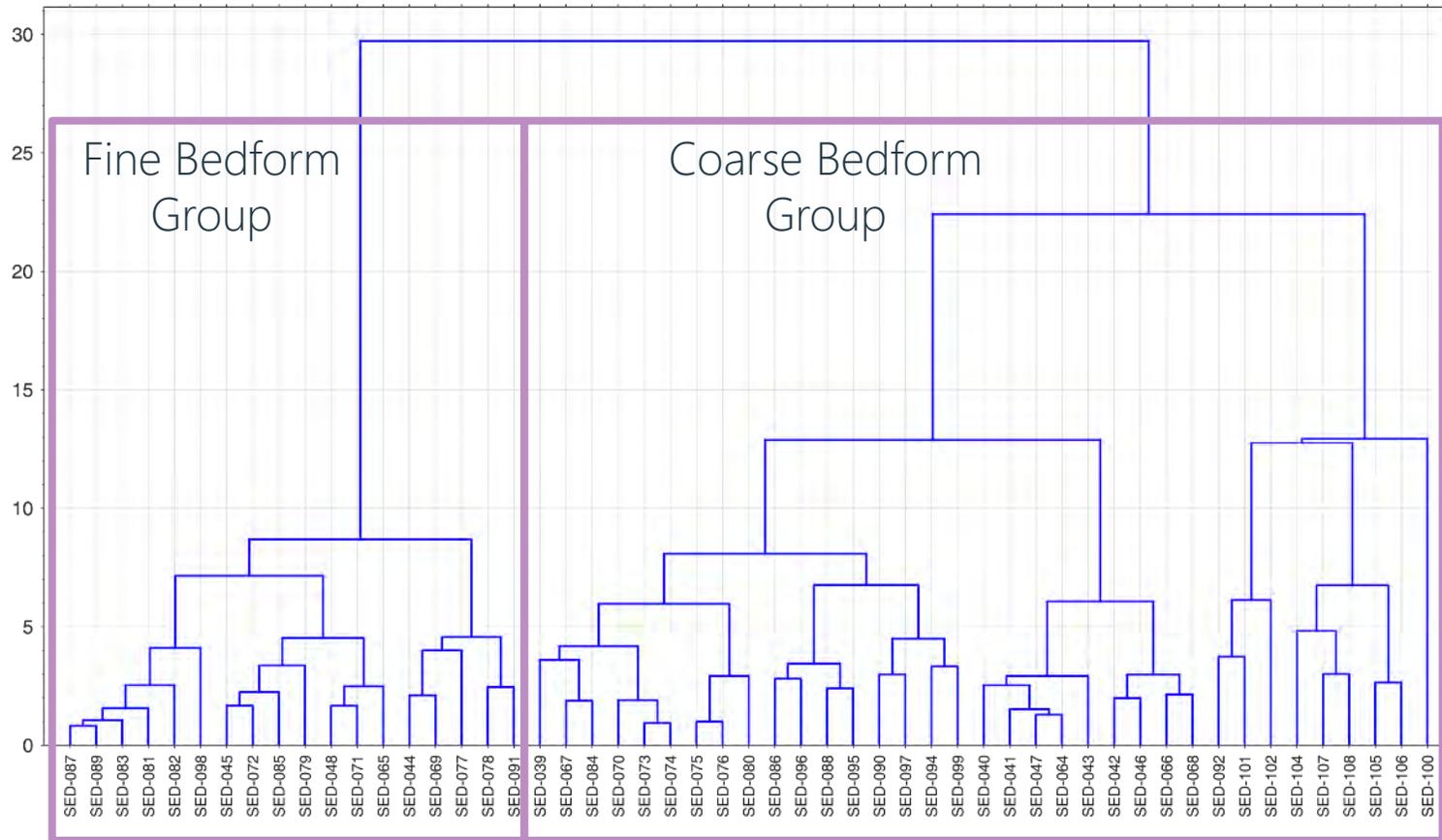
- Sediment thickness
- Surface gradation
  - Percent fines
  - Percent fine sand
  - Percent medium sand
  - Percent coarse sand or greater
- Hydrodynamic Model Results (1100, 3200, 4900, 8400, 12000 cfs)
  - WSE
  - Water depth
  - Velocity
  - Shear stress

## Data not used in cluster analysis

- PCB concentrations
- Bathymetry and derivatives (e.g., slope, aspect, curvature)



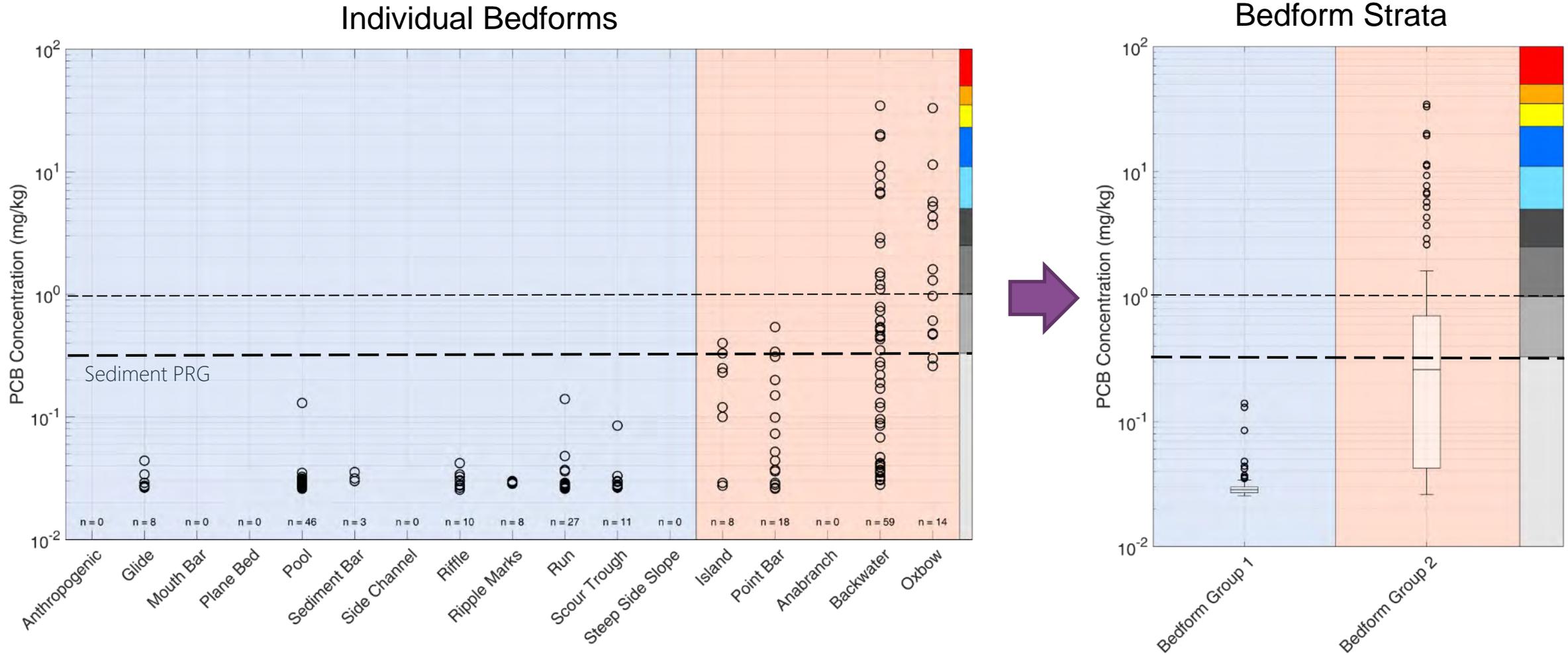
# Individual sample hierarchical cluster analysis



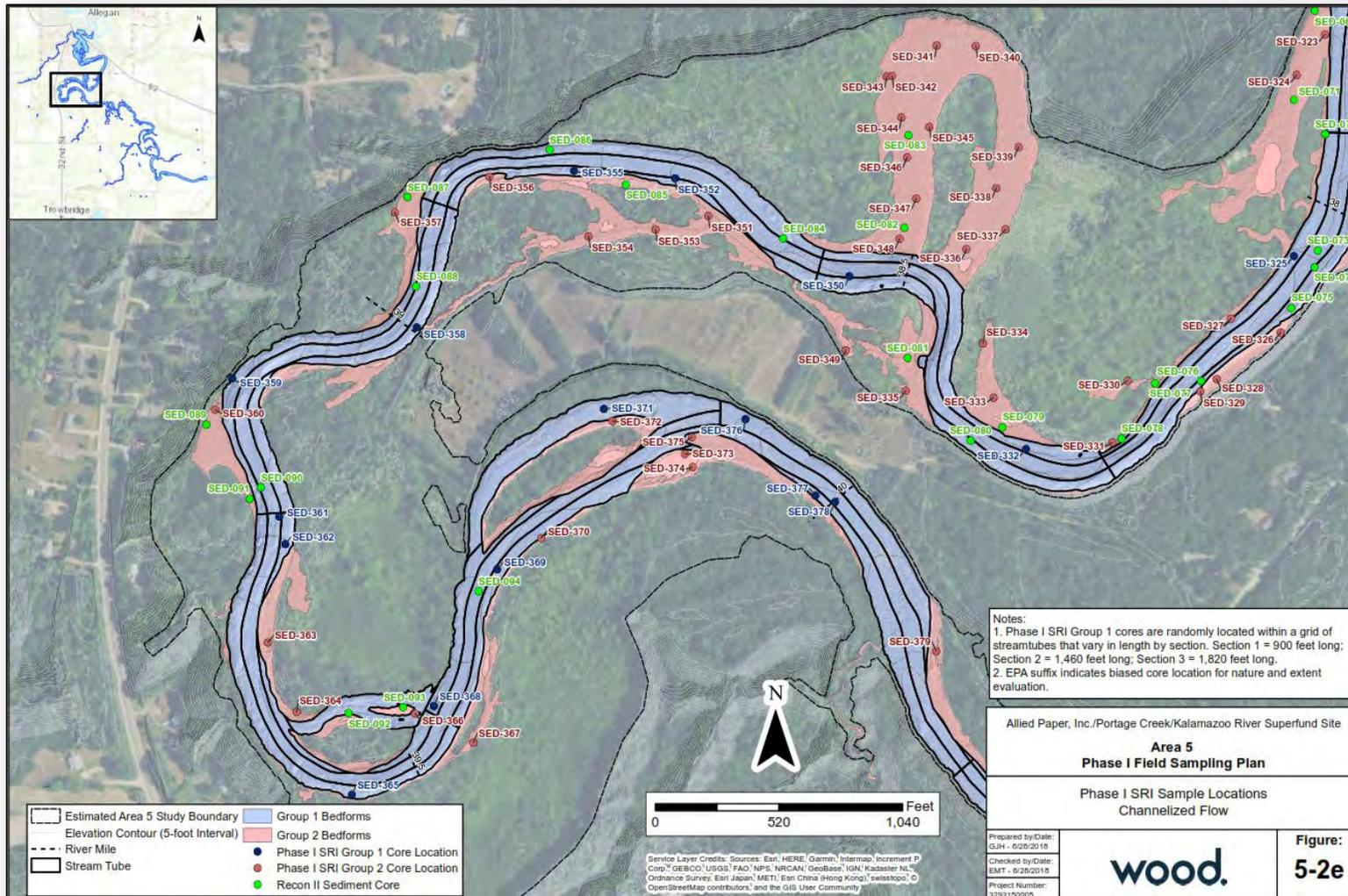
	Fine Bedform Group	Coarse Bedform Group
Steep Side Slope	0	0
Side Channel	1	0
Sediment Bar	1	1
Scour Trough	0	4
Run	0	11
Ripple Marks	0	2
Riffle	0	2
Pool	0	10
Point Bar	2	2
Plane Bed	0	0
Oxbow	2	0
Mouth Bar	0	0
Island	0	0
Glide	0	3
Backwater	12	0
Anabranh	0	0



# PCB population statistics by cluster



# Phase I sampling design for channelized flow



238 locations

- 194 Phase I locations
  - 73 in Coarse Bedform Group
  - 121 in Fine Bedform Group
- 44 Recon II locations
  - 24 in Coarse Bedform Group
  - 20 in Fine Bedform Group

Coarse Bedform layout with streamtubes

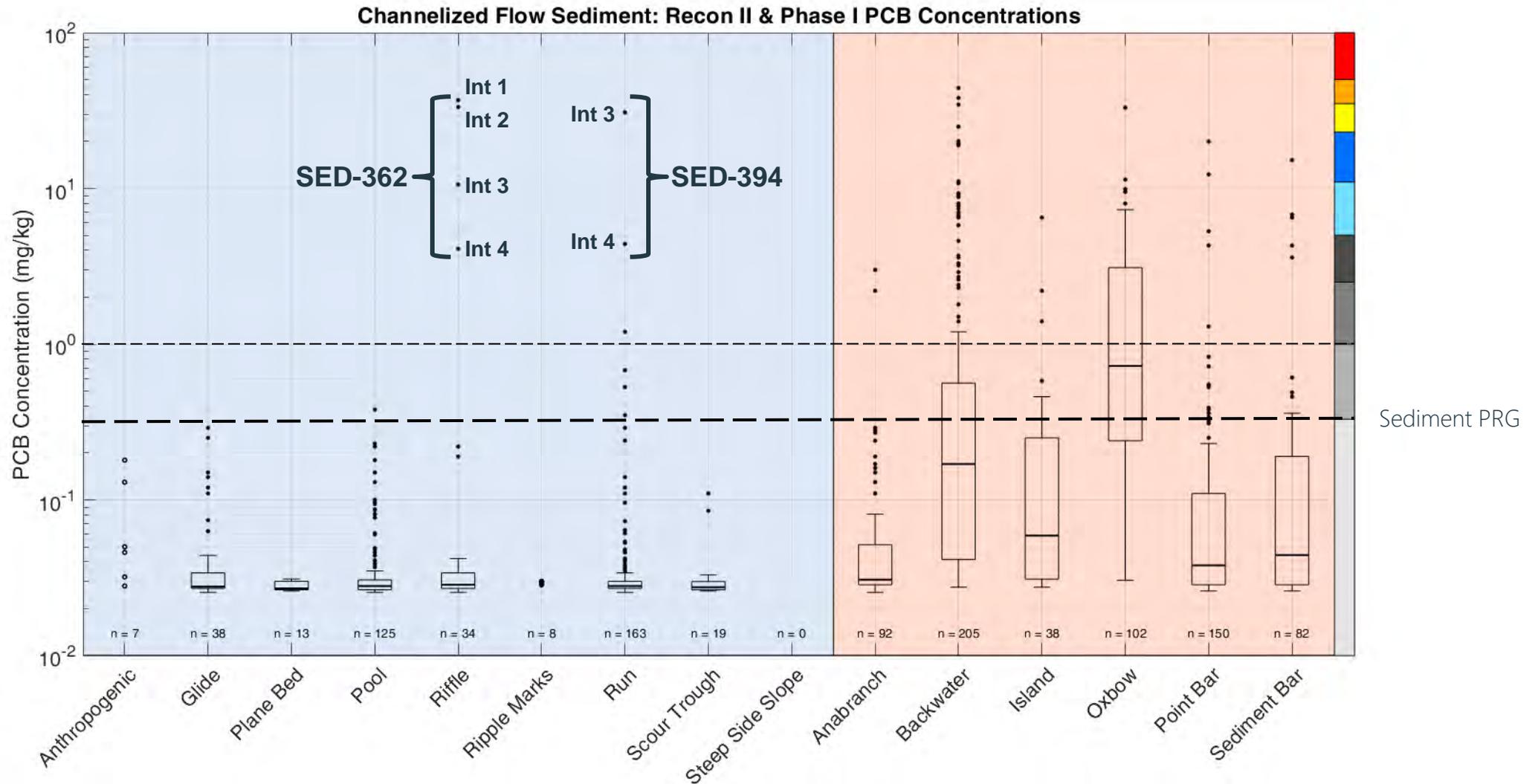
Fine Bedform layout as stratified sampling in bedforms



# Phase I Results



# Recon II & Phase I PCBs by bedform – channelized flow sediments





# Conclusions

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- Sampling results support conceptual site model (CSM)
- Fine bedforms have variable PCB concentrations
- Coarse bedforms tend to have low PCB concentrations and low variability
- Reduced sample density overall and reduced uncertainty
- Useful in defining remedial footprints in FS



# Questions?

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