DEFINING ECOSYSTEM RESTORATION POTENTIAL USING A MULTIPLE REFERENCE CONDITION APPROACH: UPPER MISSISSIPPI RIVER SYSTEM, USA

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US Army Corps of Engineers

IIHR Hydroscience & Engineering

Why the Upper Mississippi River System?

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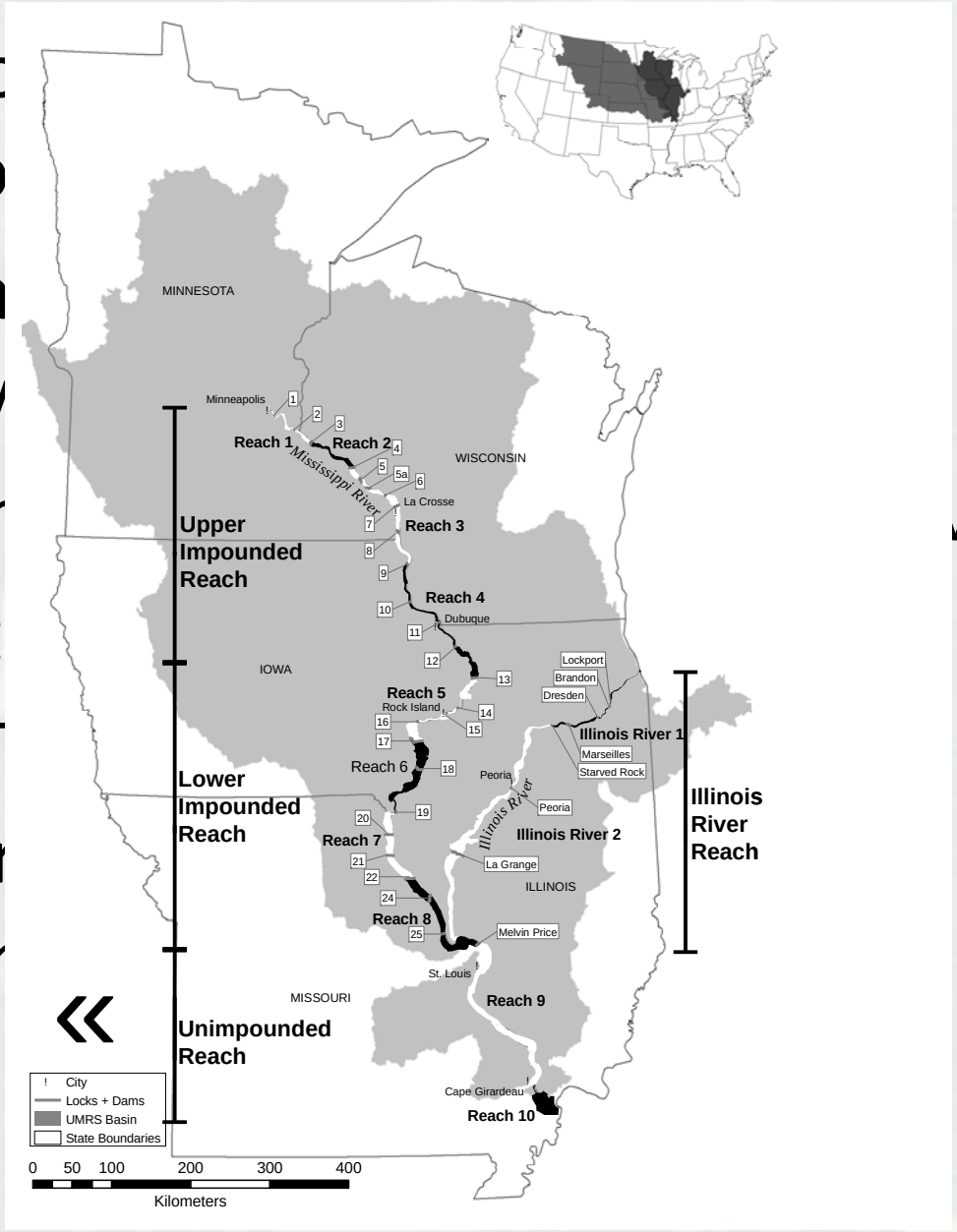


Need Better Planning Tools

Because:

- Lack a Suitable Reference
- Environmental Benefits Analysis
- Adaptive Management Needs
- Competition for ER Funding
- National Need

Based on Theory:

- River Continuum Concept
- Serial Discontinuity Concept
- Flood Pulse Concept
- Network Dynamics Hypothesis
- Riverine Productivity Theory
- Hierarchical Landscape Ecology

That Quantify Process and Function Criteria:

- Rates
- Dynamic Attributes
- Essential Ecosystem Characteristics
- Sustainability

Management Objective

Support Upper Mississippi River restoration planning by establishing physical landscape and plant community relationships for several environmental reference conditions, including the virtual reference

- Geomorphic Assessment
- Aquatic Area Analysis
- River Stage Impact Analysis
- Floodplain Inundation Analysis
- Land Cover Analysis
- Hydro-Geomorphic Land Cover Integration
- Evaluation of Ecosystem Restoration Objectives
- Recommendations for Ecosystem Restoration

Research Objective

Test tenets of the Riverine Ecosystem Synthesis

Distribution of Species:

H_0: Can hydrogeomorphic patches be defined on the scale of the UMRS?

H_0: Can functional process zones be defined for the UMRS?

H_0: Does development change functional process zones?

H_0: Is ecological diversity greatest at Nodes?

H_0: Does community complexity increase with increased hydraulic retention?

Community Regulation:

Ecosystem and Riverine Landscape Processes

H_0: Does primary production vary with hydraulic residence time?

H_0: Does dynamic hydrology support diverse habitat?

H_0: Do UMRS landscape classes demonstrate flood-linked evolution?

H_0: Does biocomplexity peak at intermediate levels of connectivity?

H_0: Do landscape patterns characterize UMRS functional process zones?

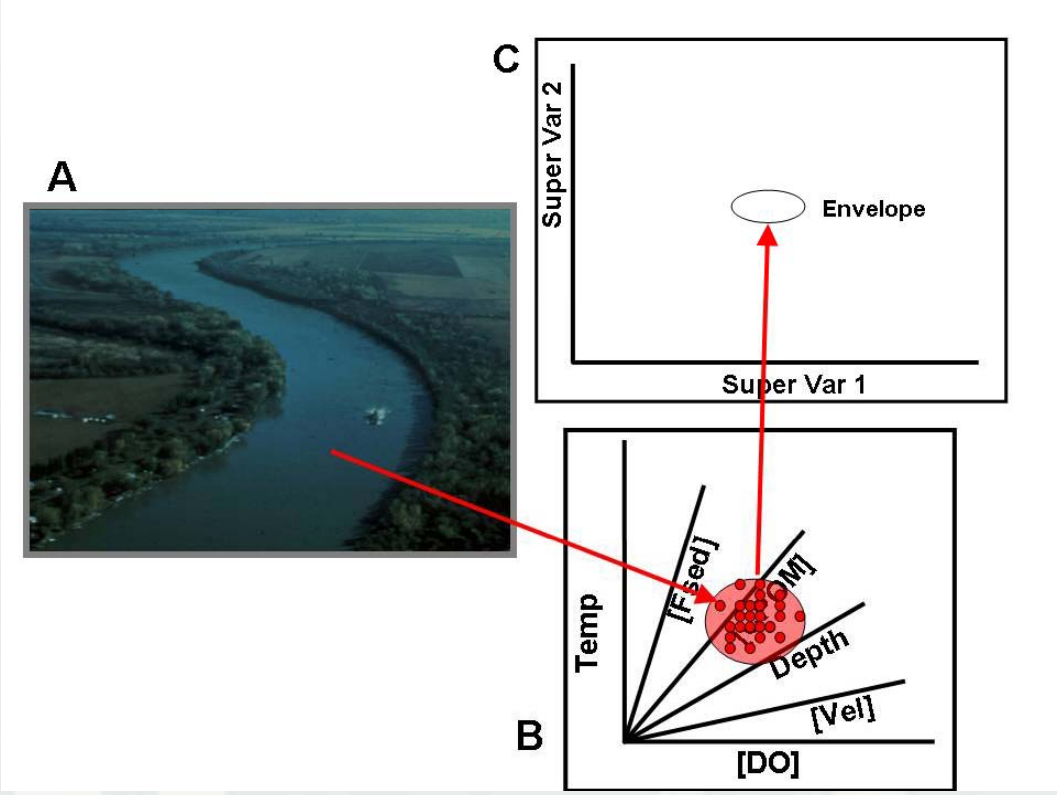
Research Objective

Test aspects of the Network Dynamics Hypothesis:

H_0: Do tributaries influence hydrogeomorphic characteristics in the UMRS floodplain?

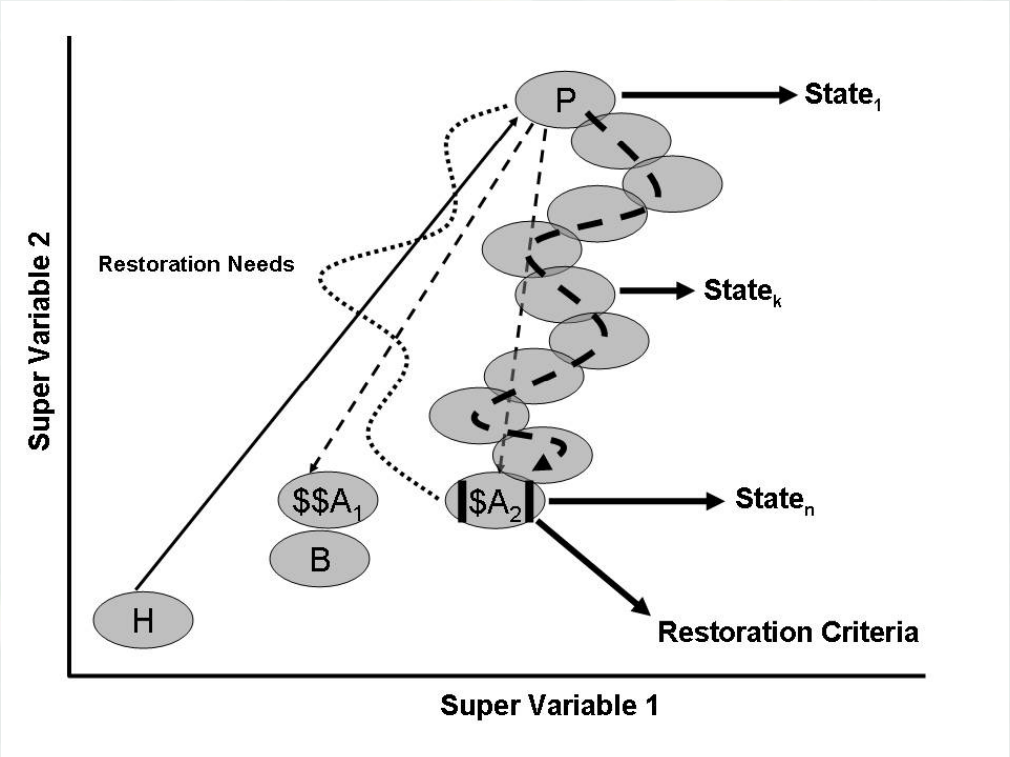
H_0: Does increased hydraulic residence at tributary alluvial fans increase habitat diversity?

Multiple Reference Condition Analysis



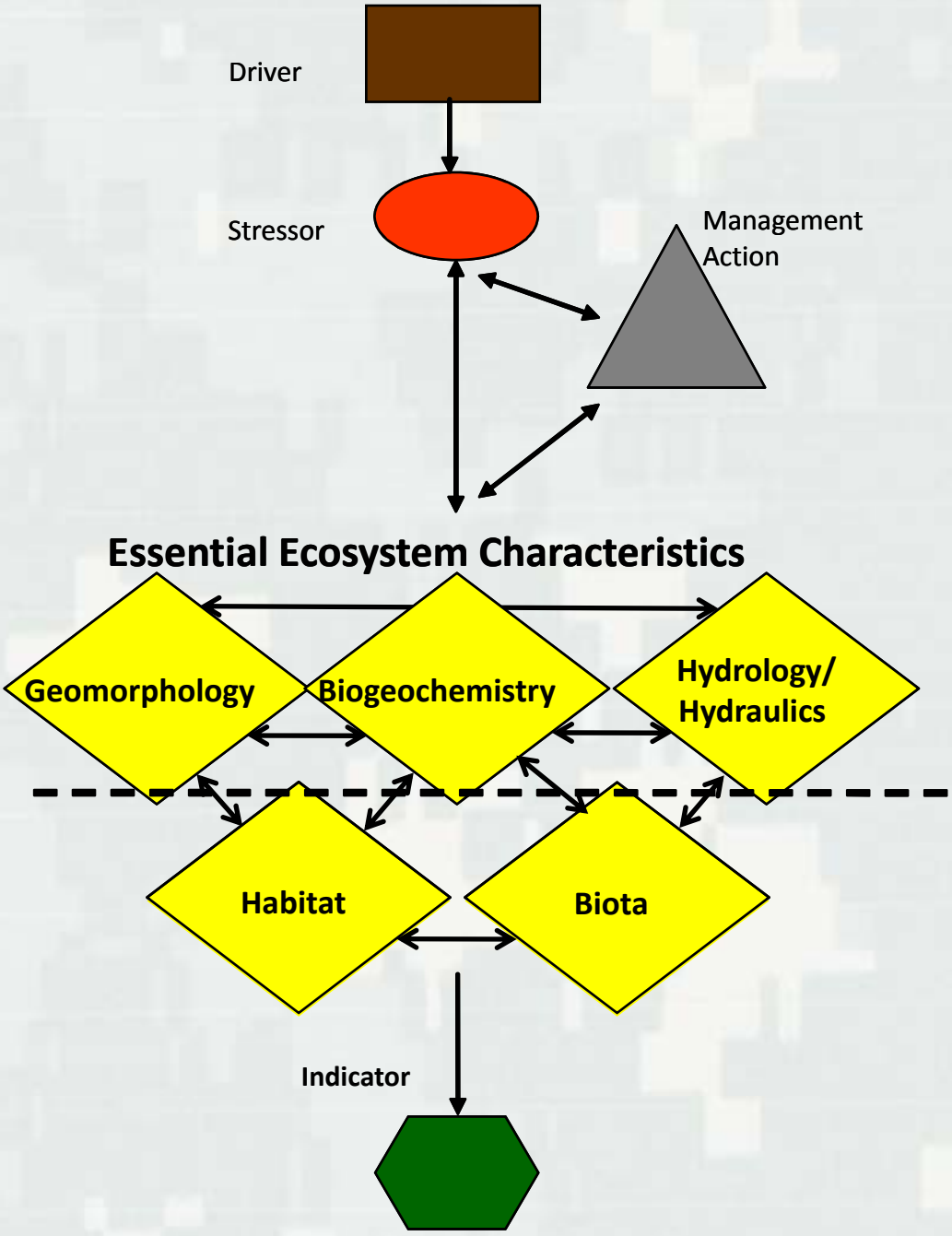
Each reference condition can be characterized by multiple environmental parameters that likely fall within a narrow range of values represented by an envelope

Tracking Ecosystem Condition Trajectory Among Multiple Reference Conditions

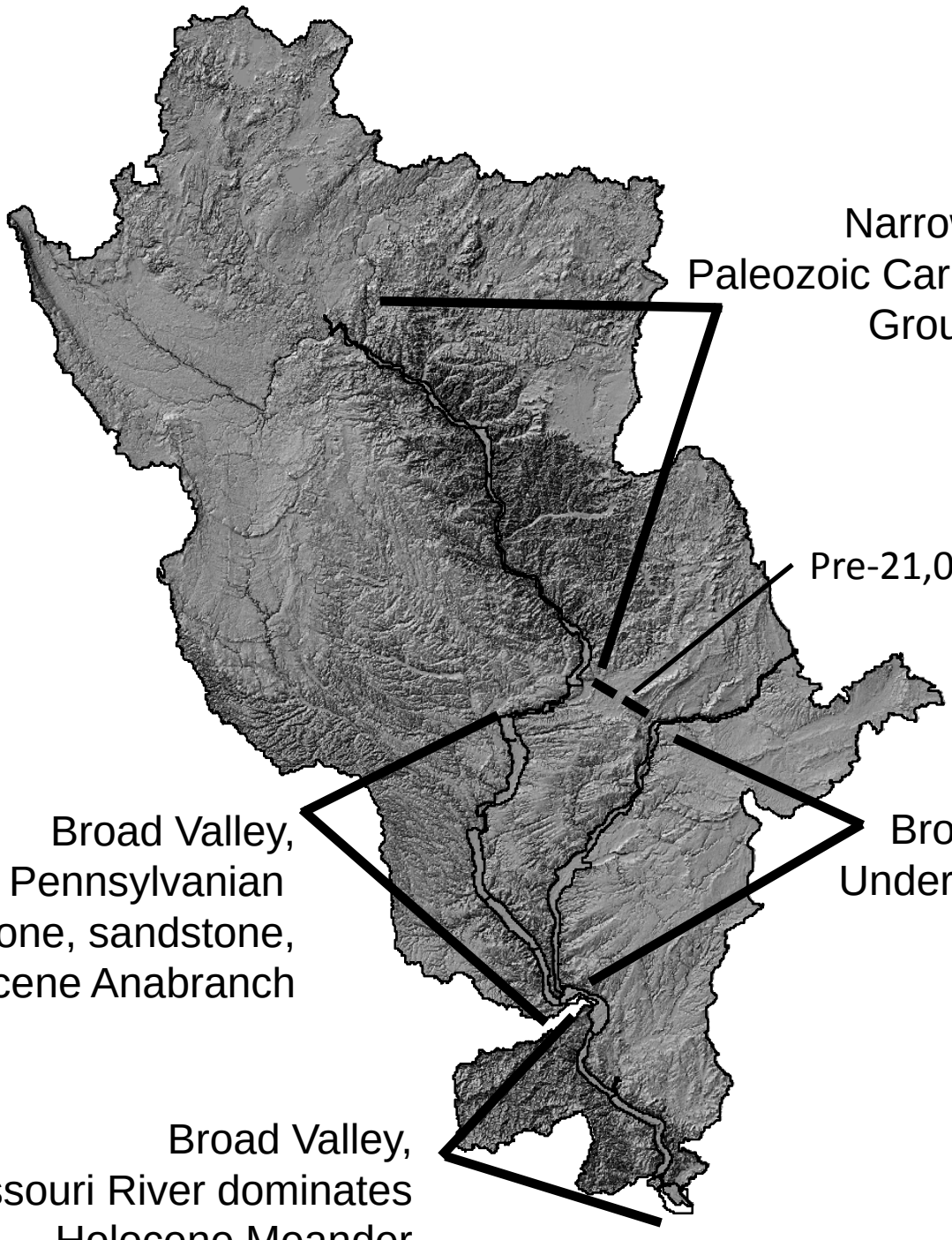


Legend: H = Historical (“Natural”), B = “Best Achievable State”, Ai = Competing Alternatives, P = Present.

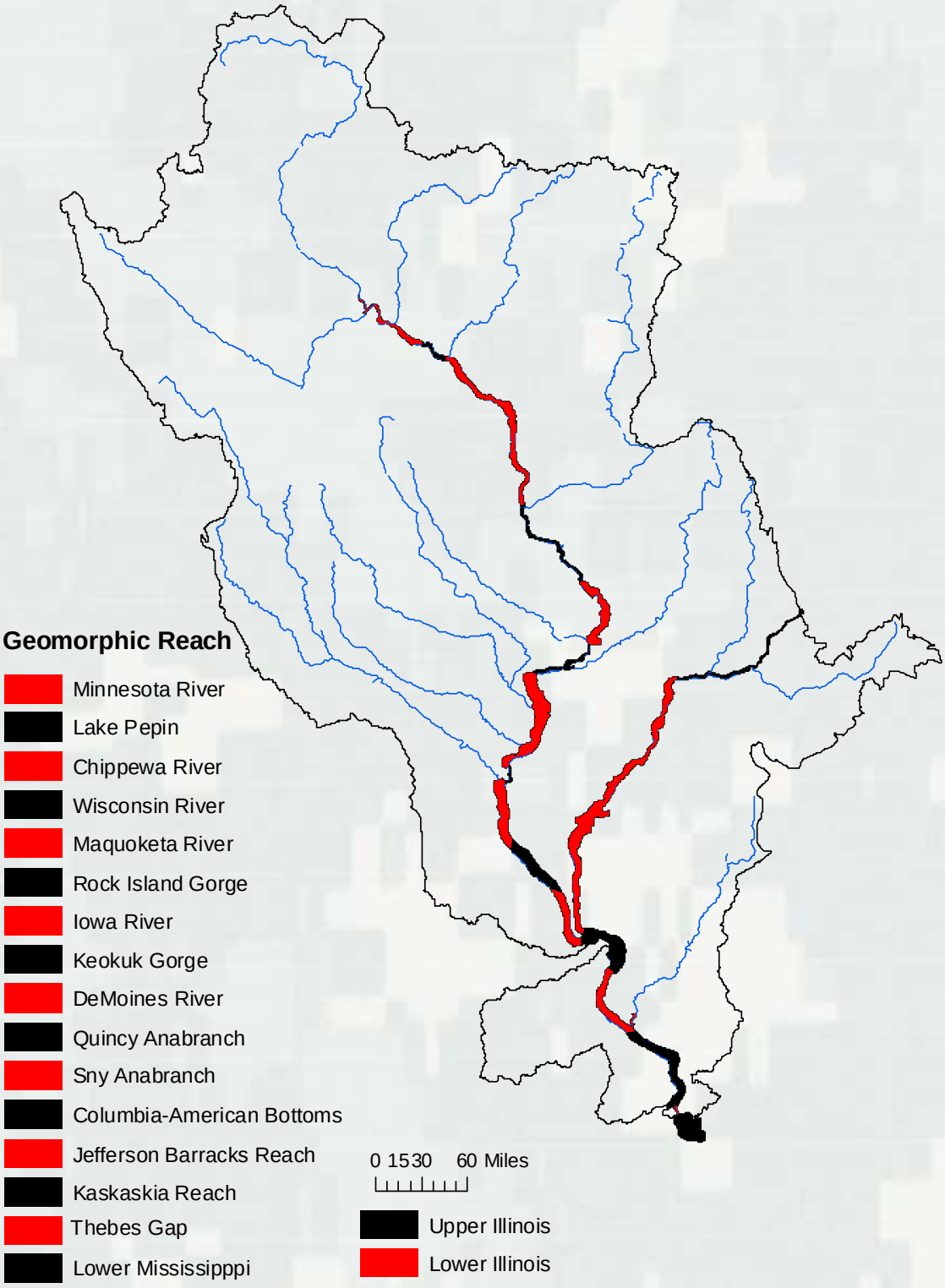
Reference Conditions are Represented as Essential Ecosystem Characteristics from UMRS Ecosystem Conceptual Model

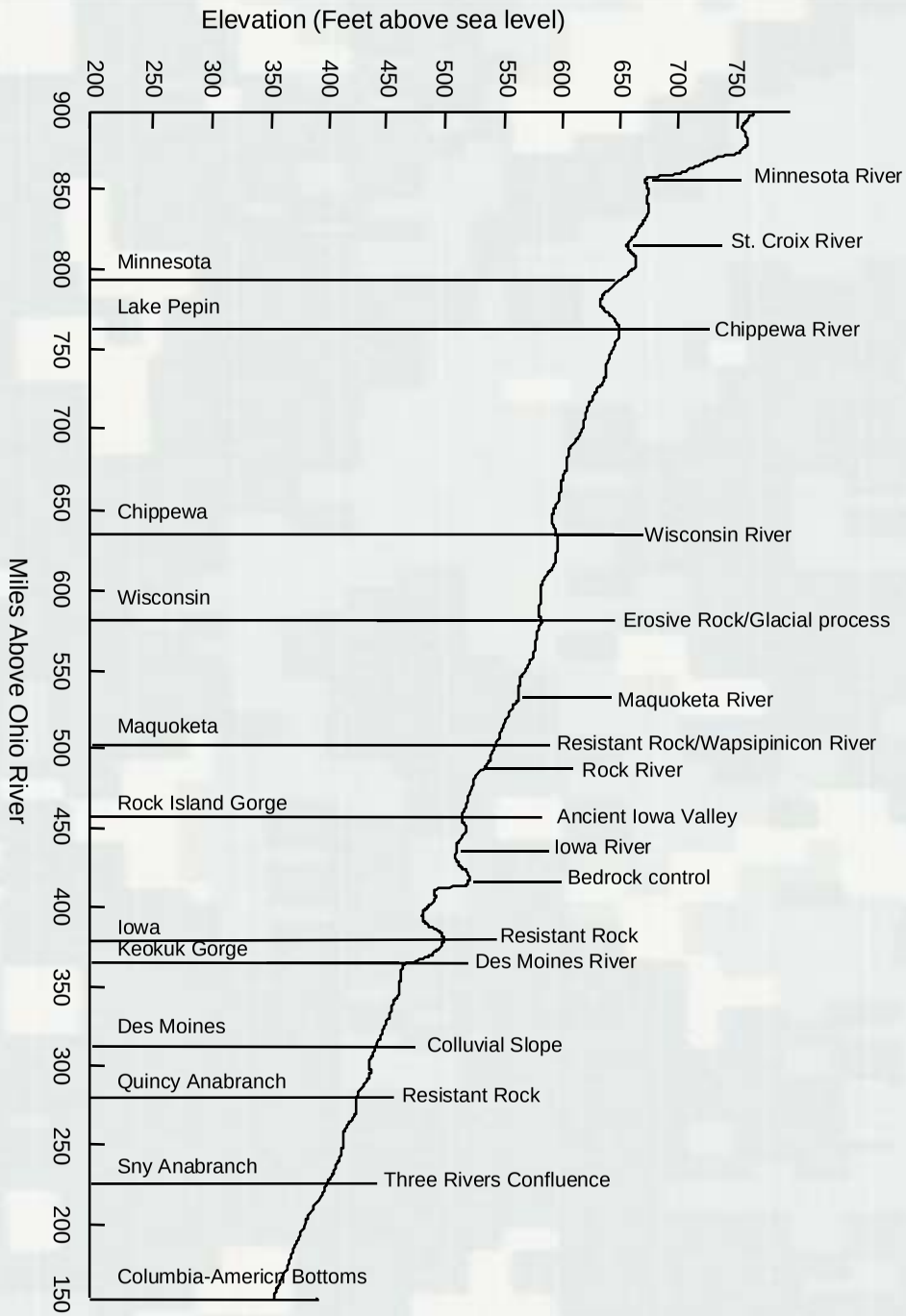


Glacial Geology
(Floodplain Reach = Drainage Basin)

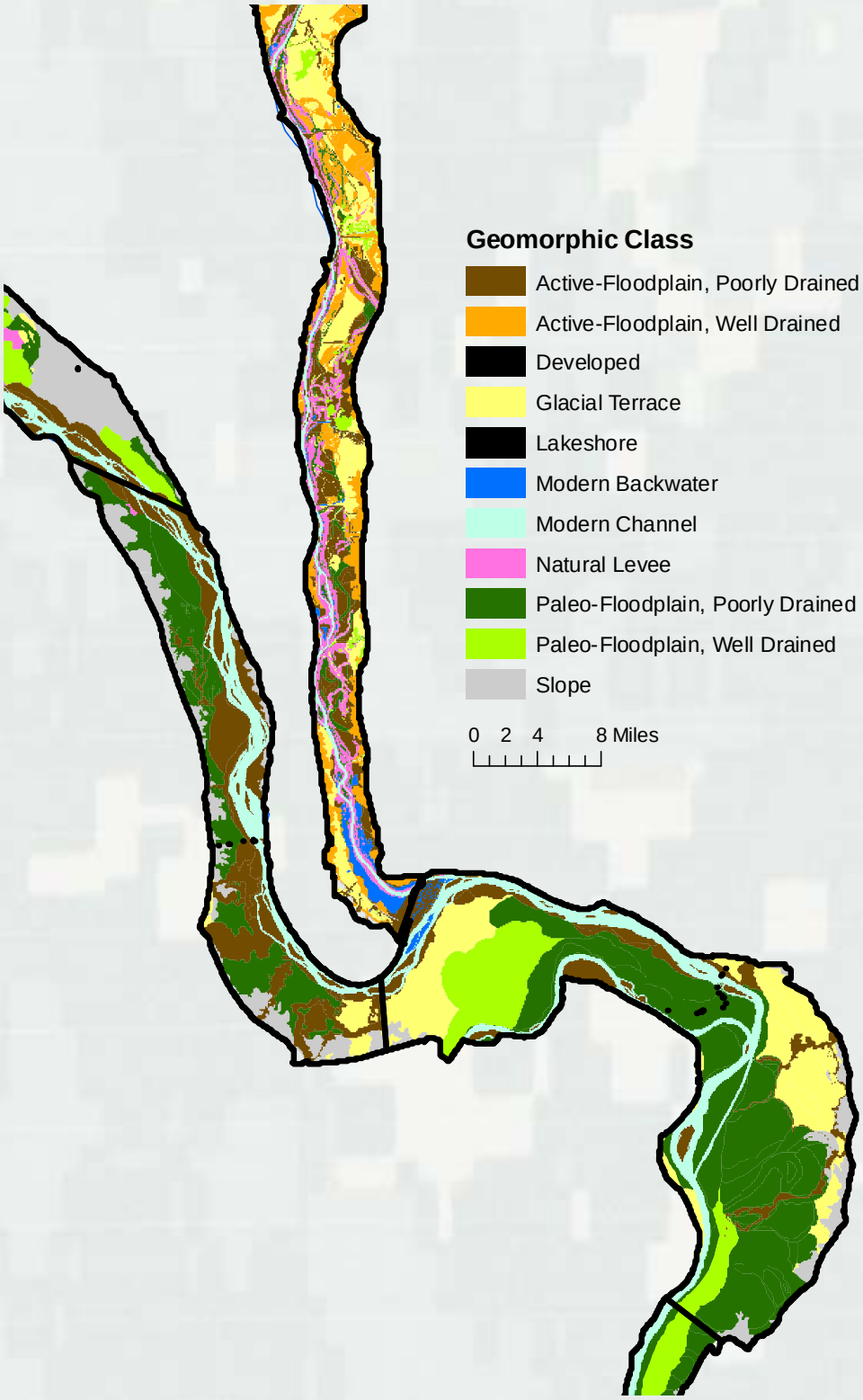


Holocene Geology
(Geomorphic Reach = Functional Process Zone)



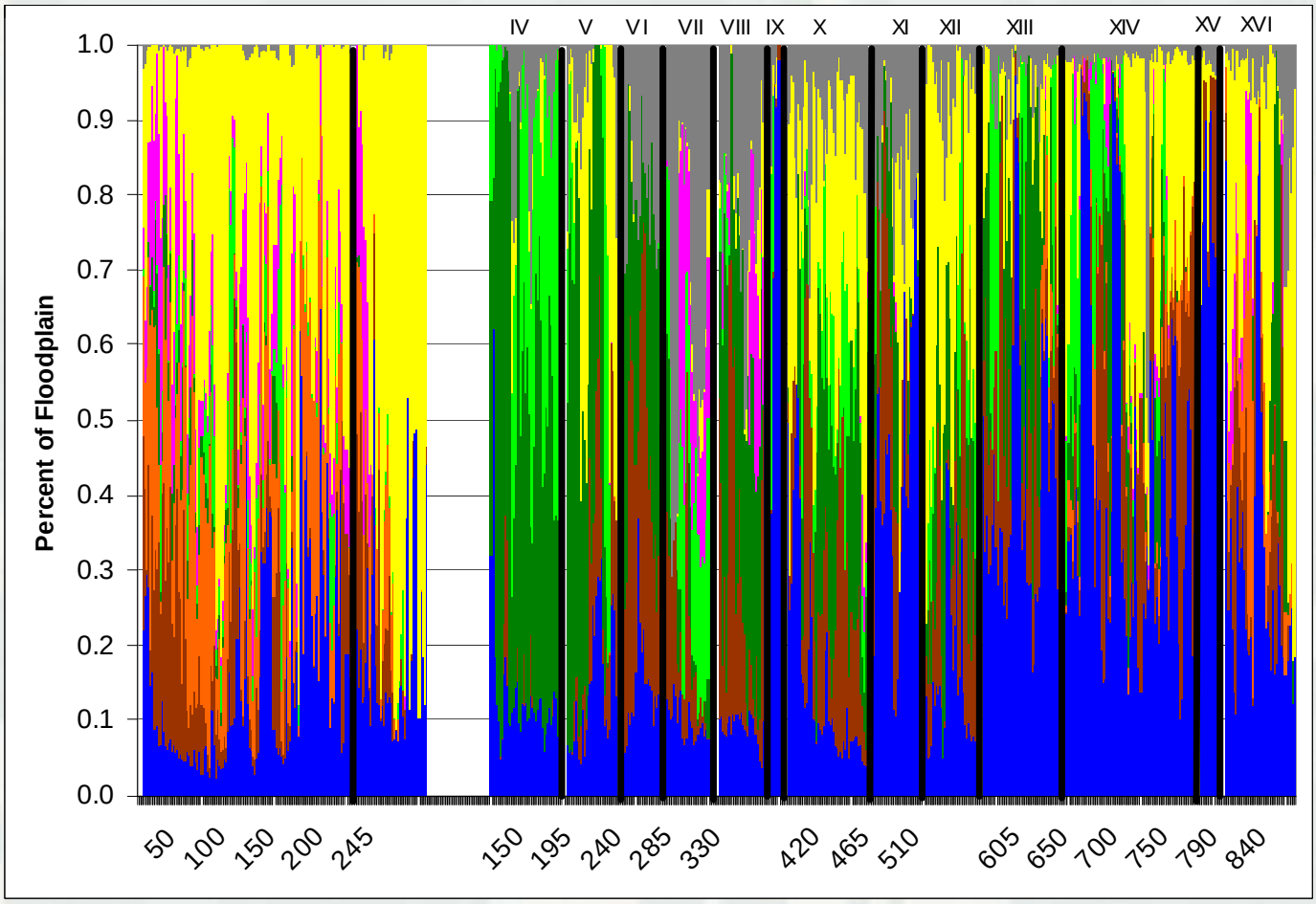

Elevation (Feet above sea level)
200
250
300
350
400
450
500
550
600
650
700
750
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
Miles Above Ohio River
Minnesota River
St. Croix River
Minnesota
Lake Pepin
Chippewa River
Chippewa
Wisconsin River
Wisconsin
Erosive Rock/Glacial process
Maquoketa River
Maquoketa
Resistant Rock/Wapsipinicon River
Rock River
Rock Island Gorge
Ancient Iowa Valley
Iowa River
Bedrock control
Iowa
Resistant Rock
Keokuk Gorge
Des Moines River
Des Moines
Colluvial Slope
Quincy Anabranch
Resistant Rock
Sny Anabranch
Three Rivers Confluence
Columbia-American Bottoms

Geomorphic Classification



Sny Anabranch, Columbia-American Bottoms, and Lower Illinois (partial) geomorphic reaches, Upper Mississippi River System.

Geomorphic Class Distribution



Active FP - Wet

Active FP - Dry

Paleo FP - Wet

Paleo FP - Dry

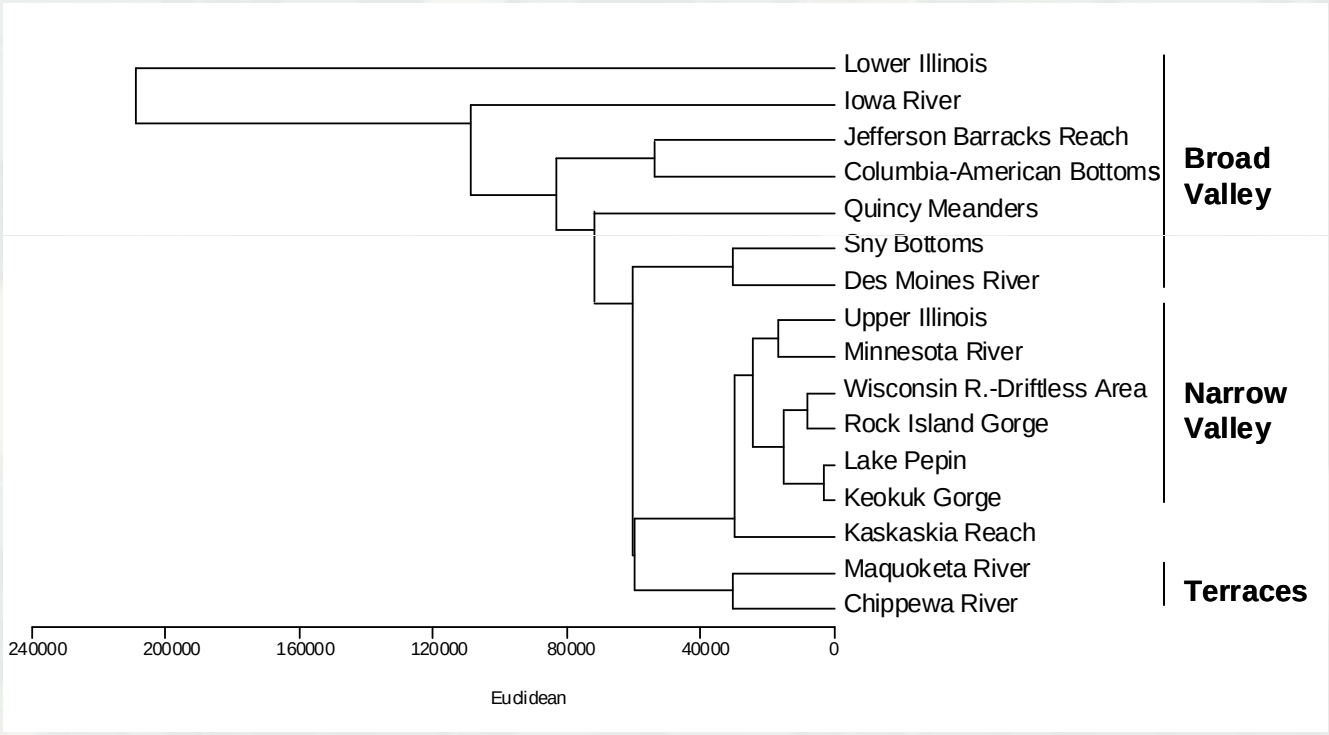
Modern Water

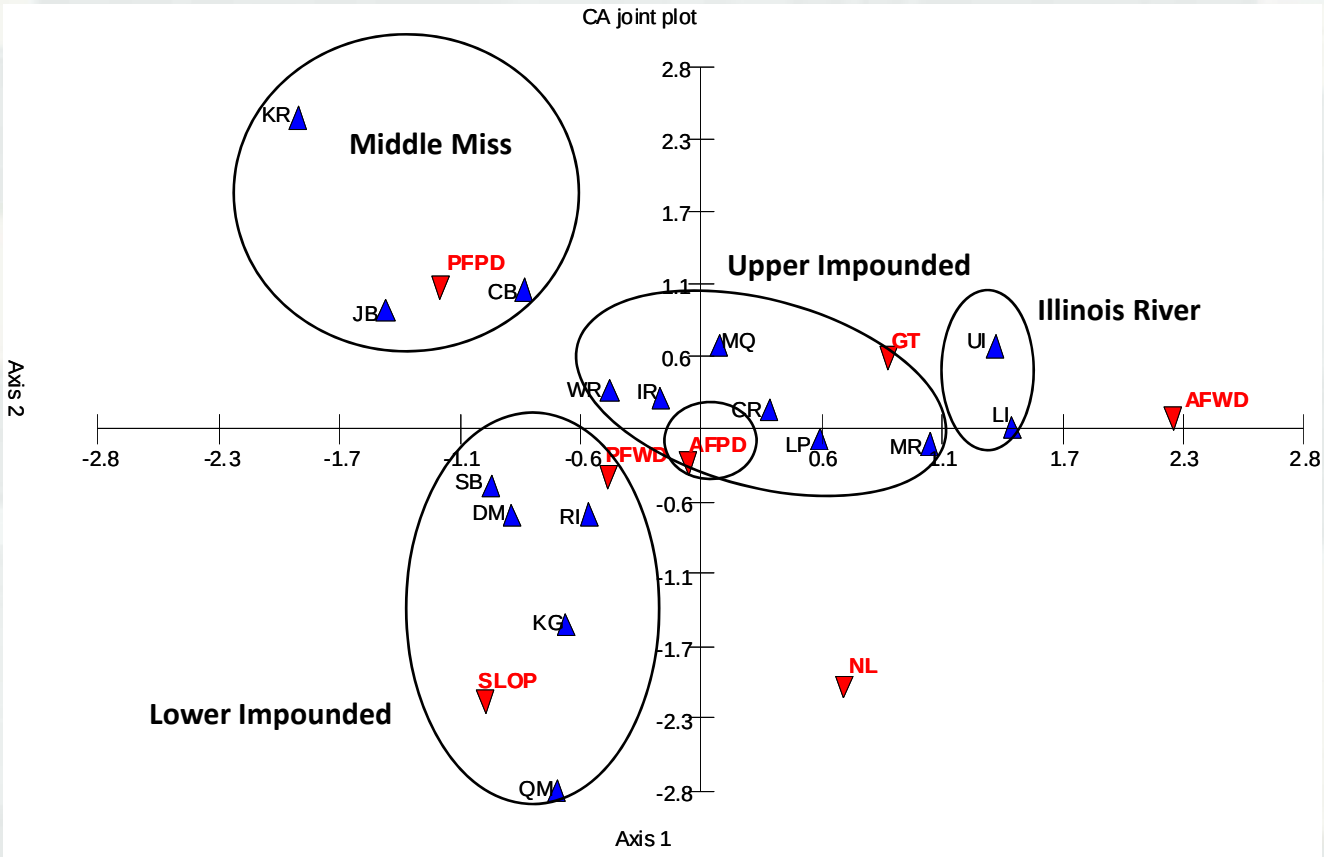
Natural Levee

Terrace

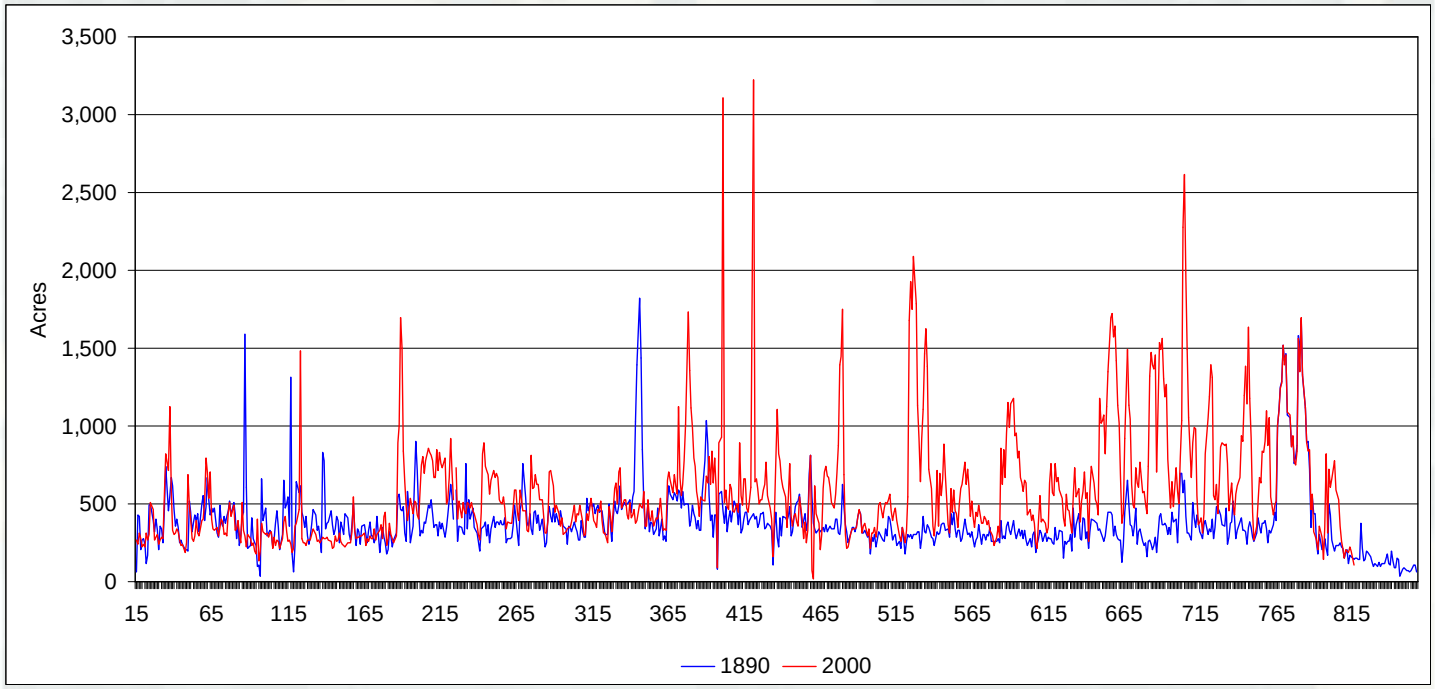
Slope

Geomorphic Classes

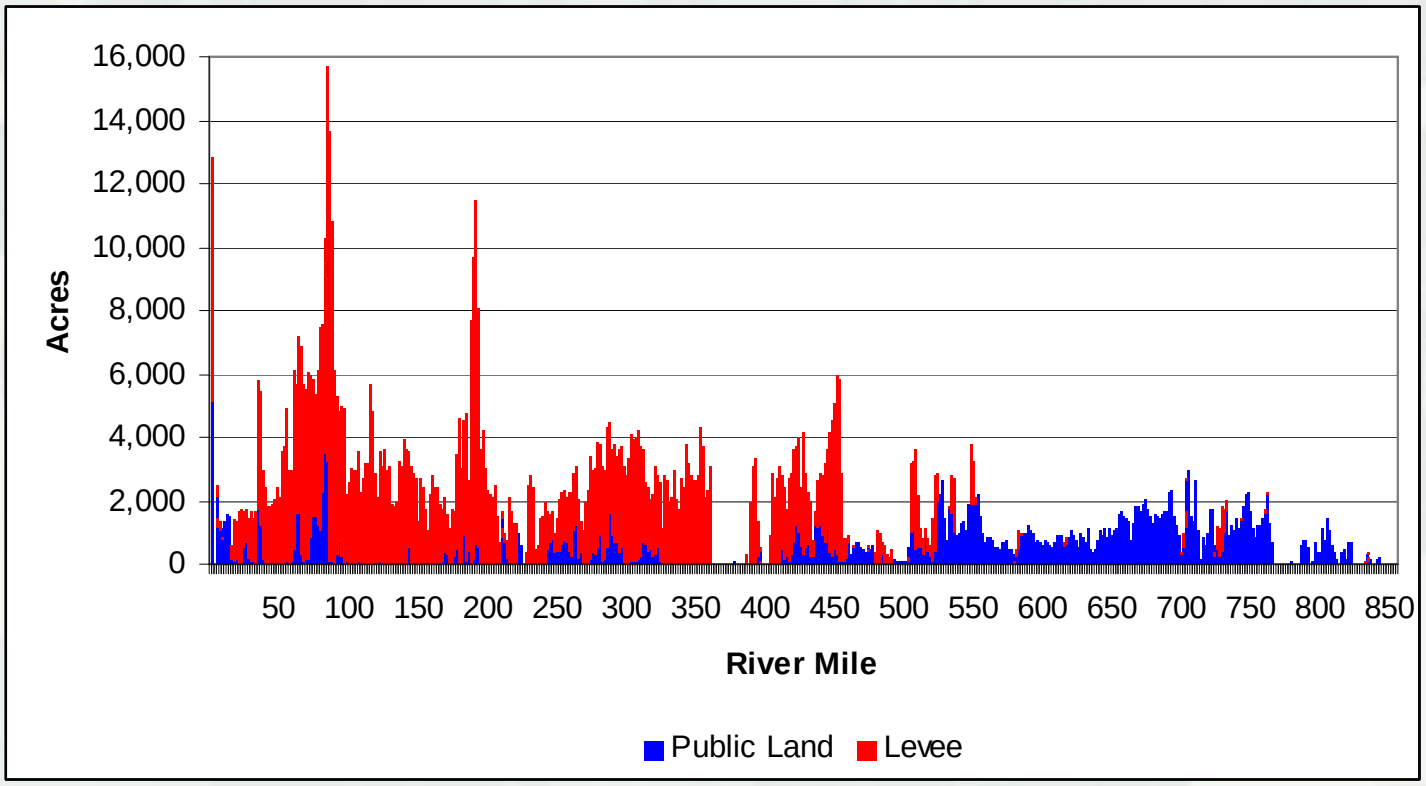




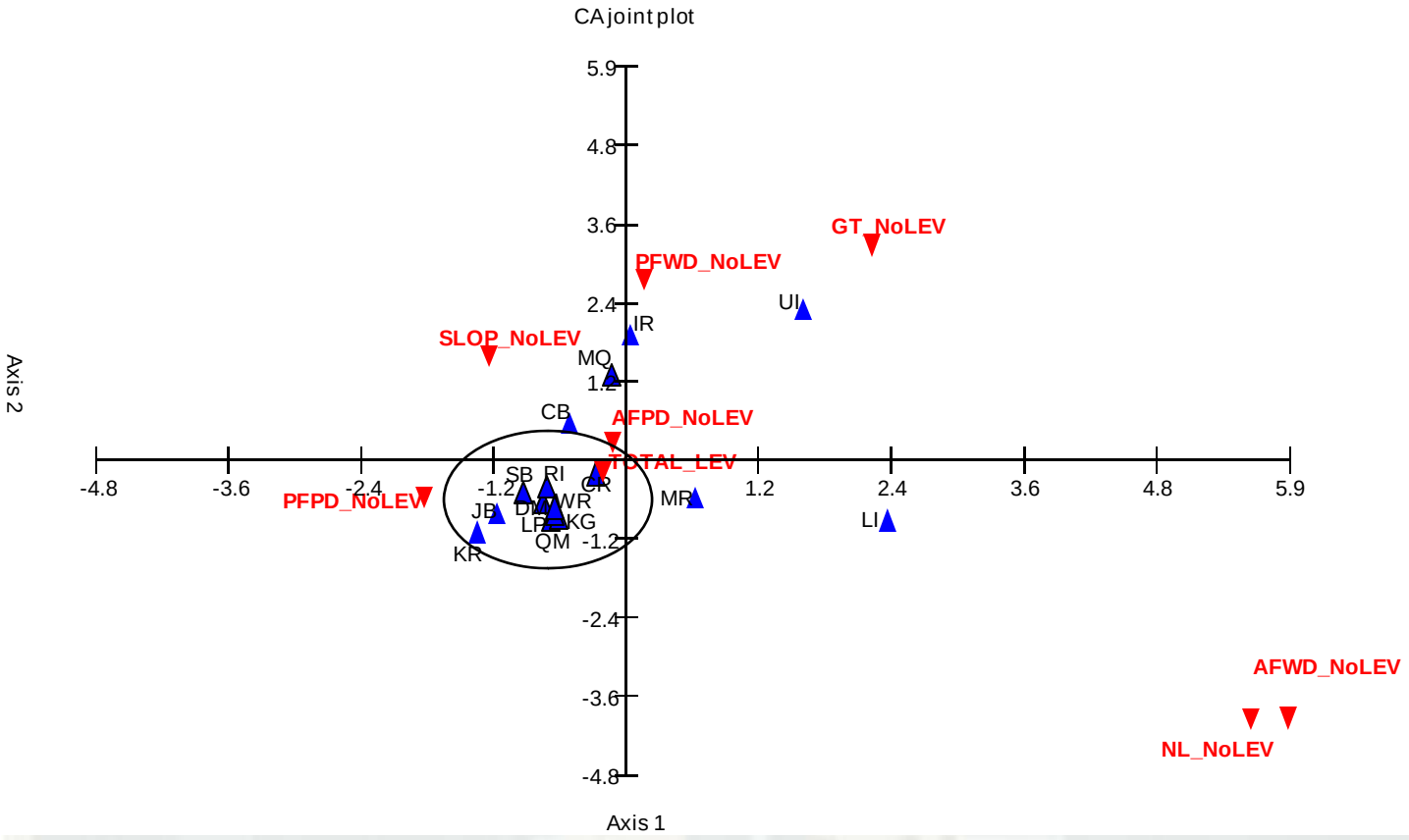
UMRS Hydrologic Changes



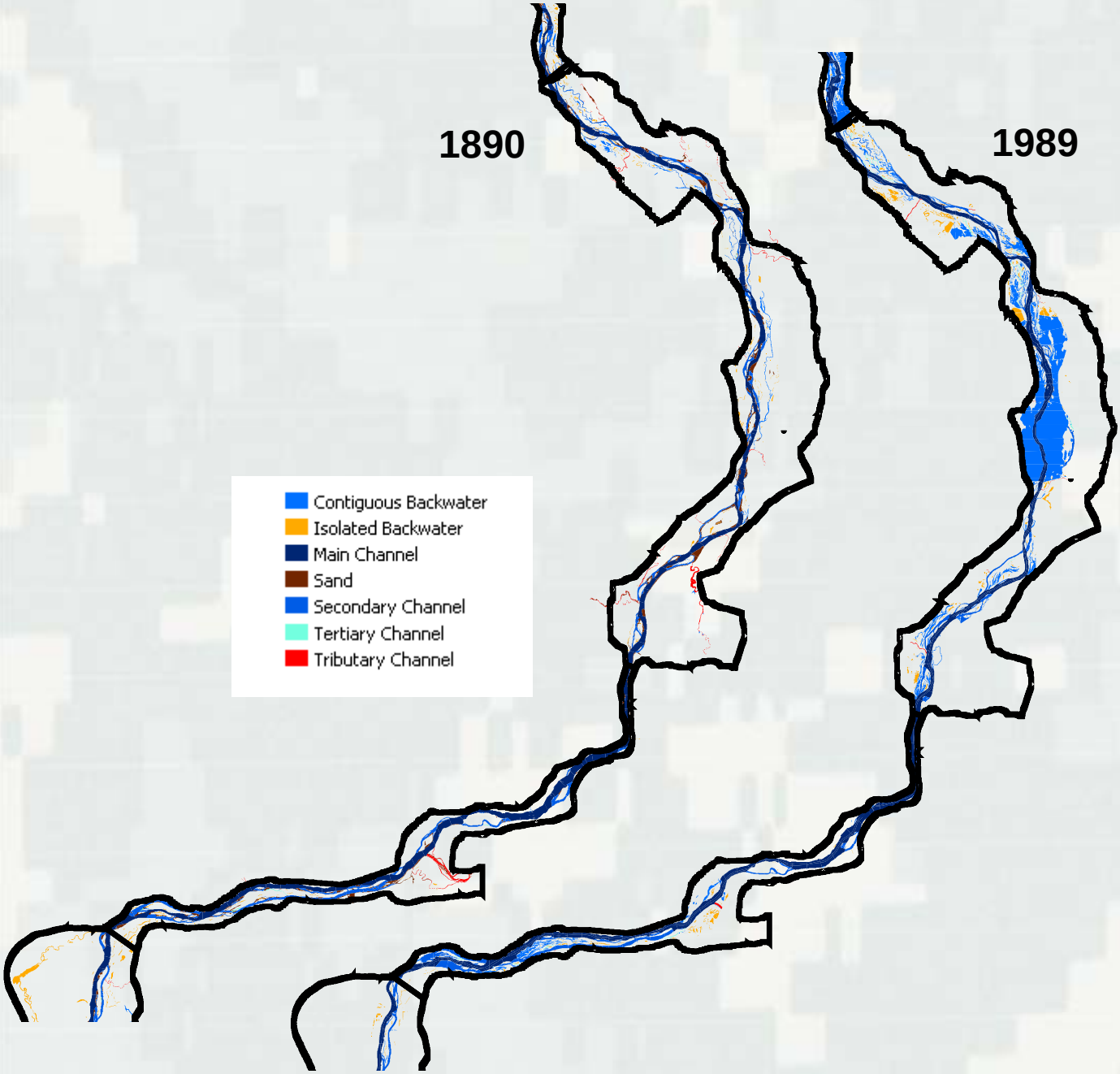
UMRS Geomorphic Changes



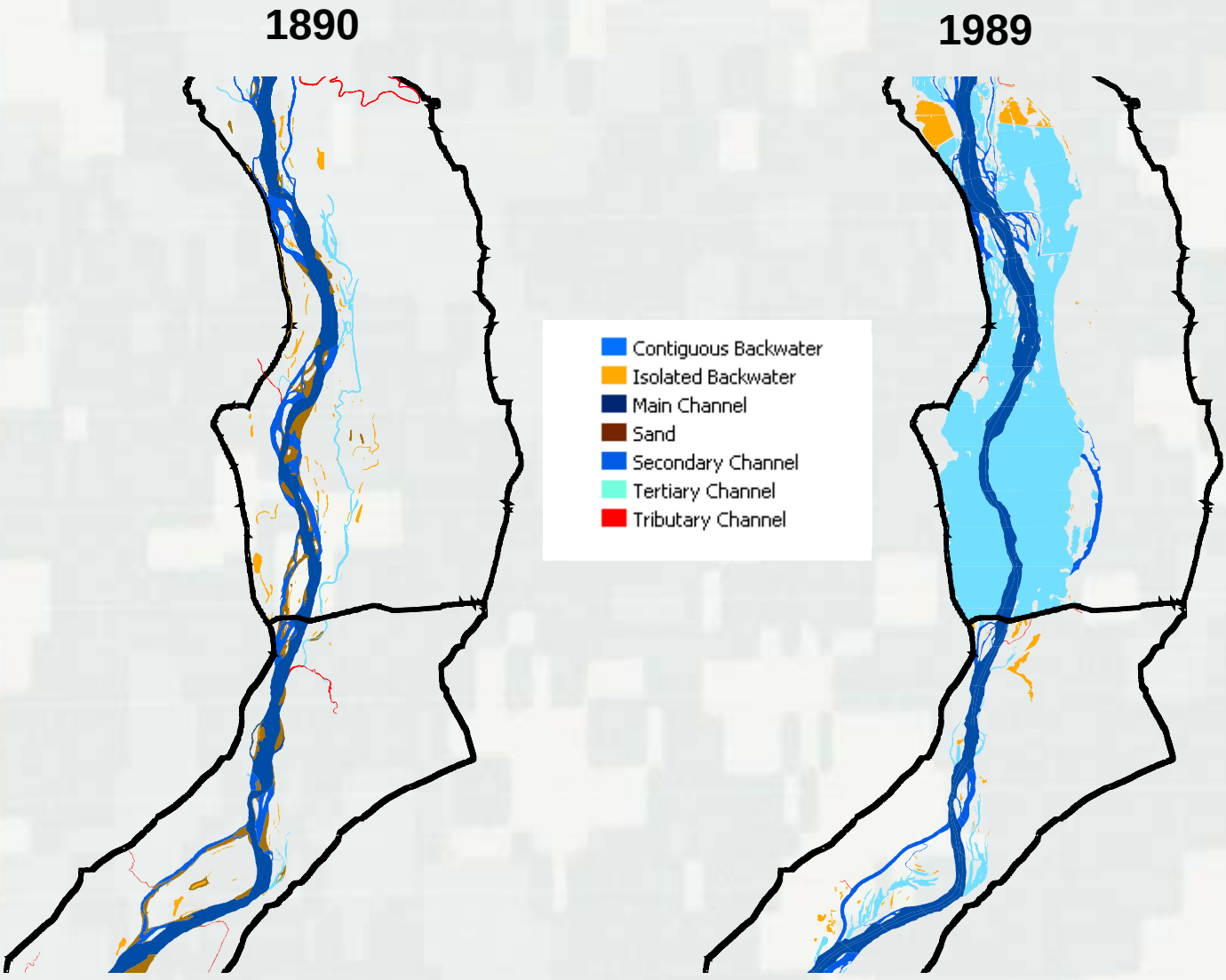
Connected and Leveed Floodplain



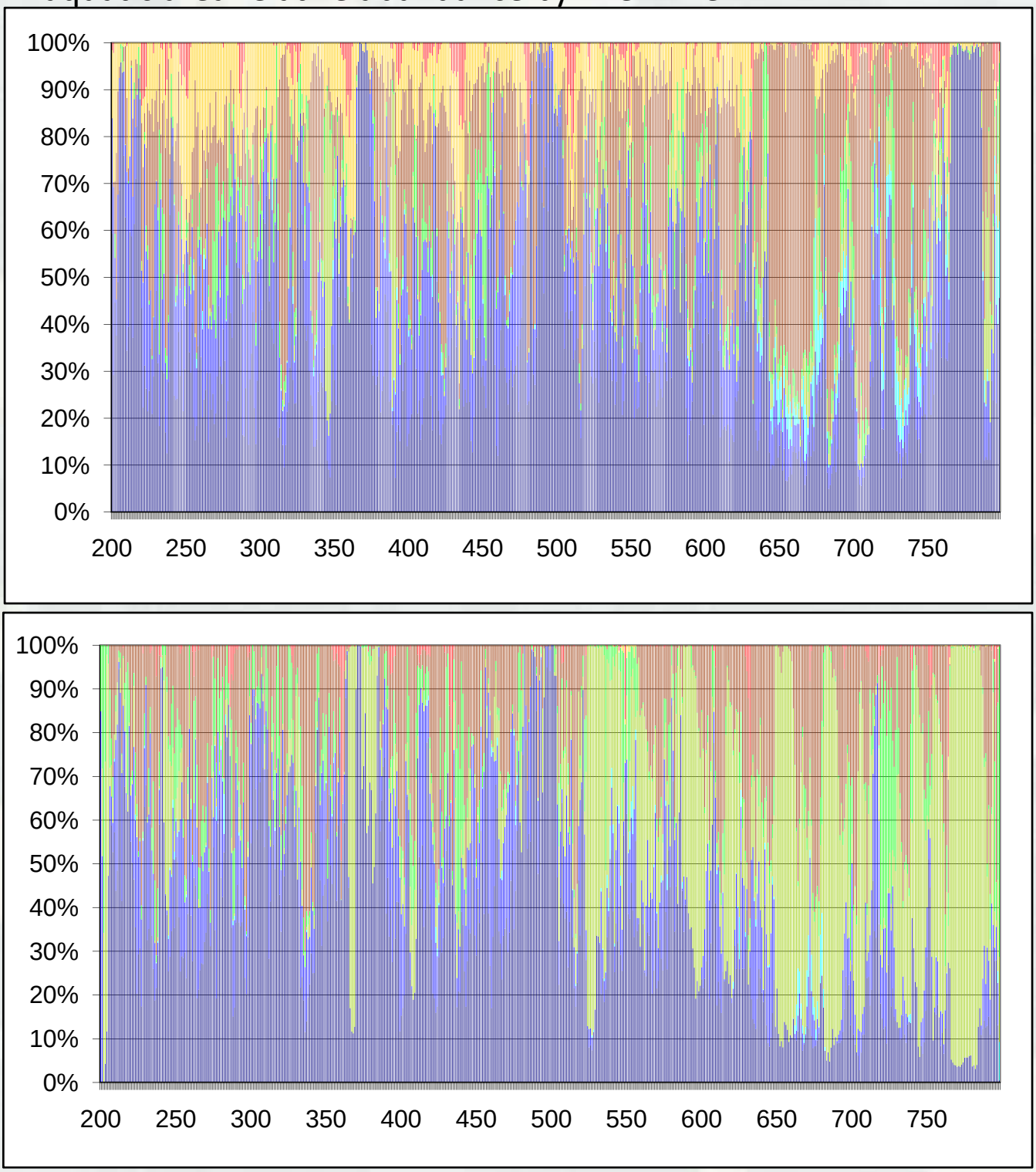
Aquatic Area Classes



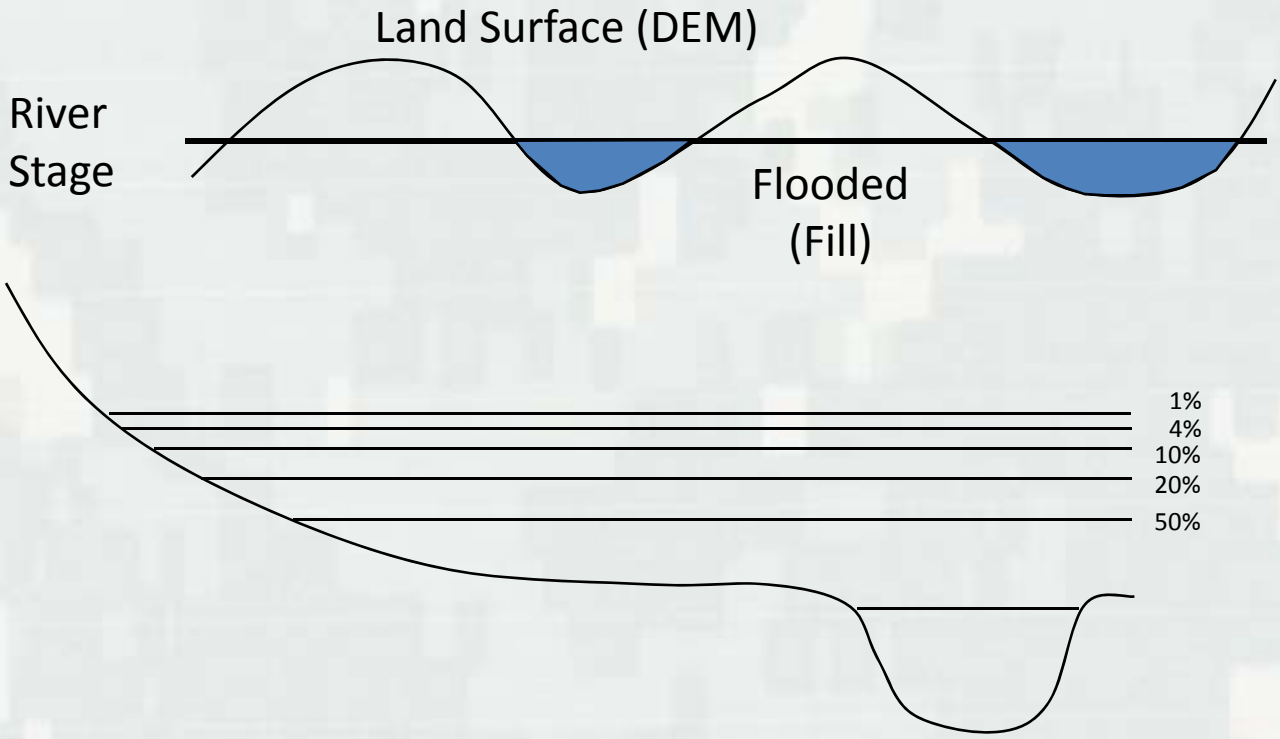
Aquatic Area Classes



Historic Mississippi River Commission (ca. 1890, top) and contemporary (1989, bottom) Upper Mississippi River System aquatic area relative abundance by river mile.



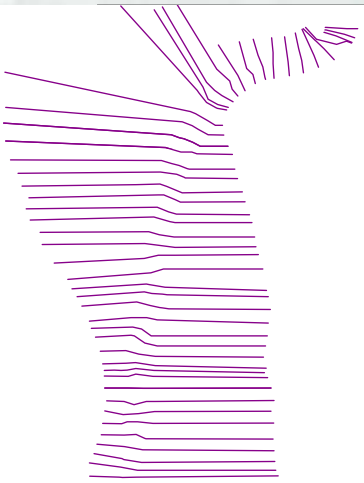
Floodplain Inundation



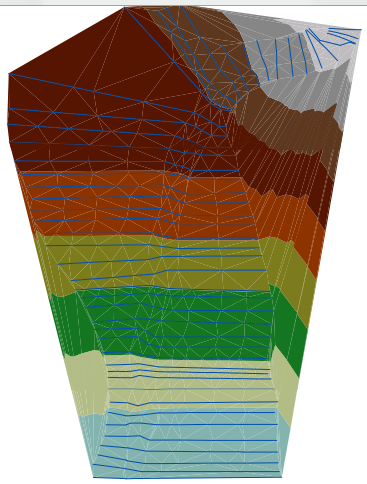
- Increasingly larger floods inundate larger areas, but the most frequent floods could potentially inundate large portions of the floodplain in the absence of impoundment or levees.

Analysis layers used in flood inundation mapping

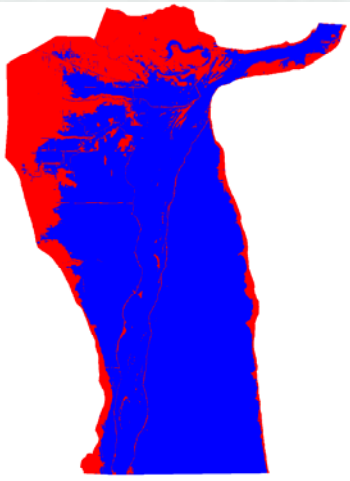
USGS Seamless Data



USACE Flow Frequency Cross Sections

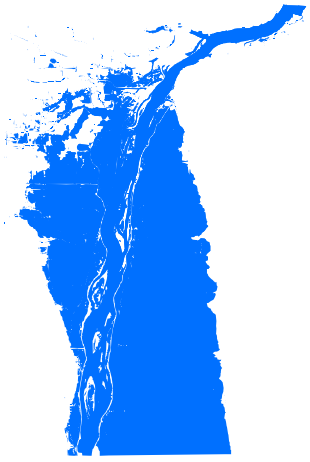


Flow Frequency TIN Conversion



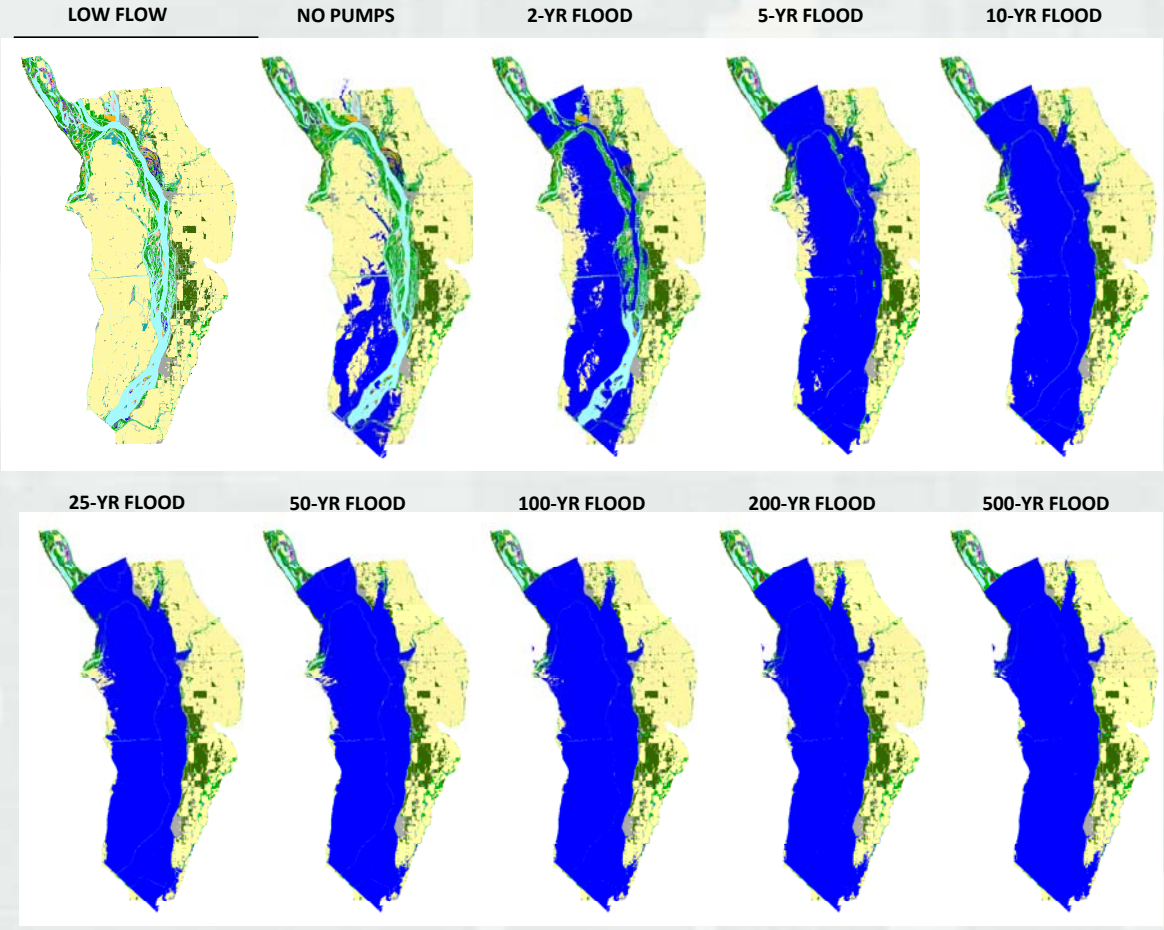
Topo/TIN Cut-Fill

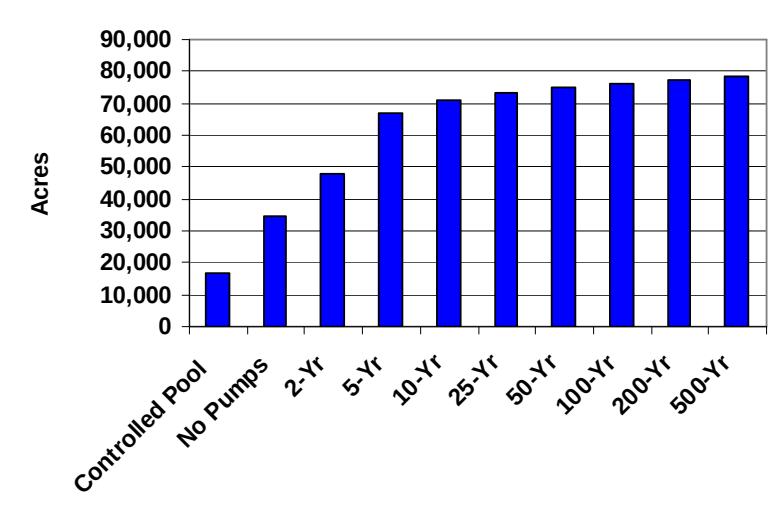
Conditional GRID

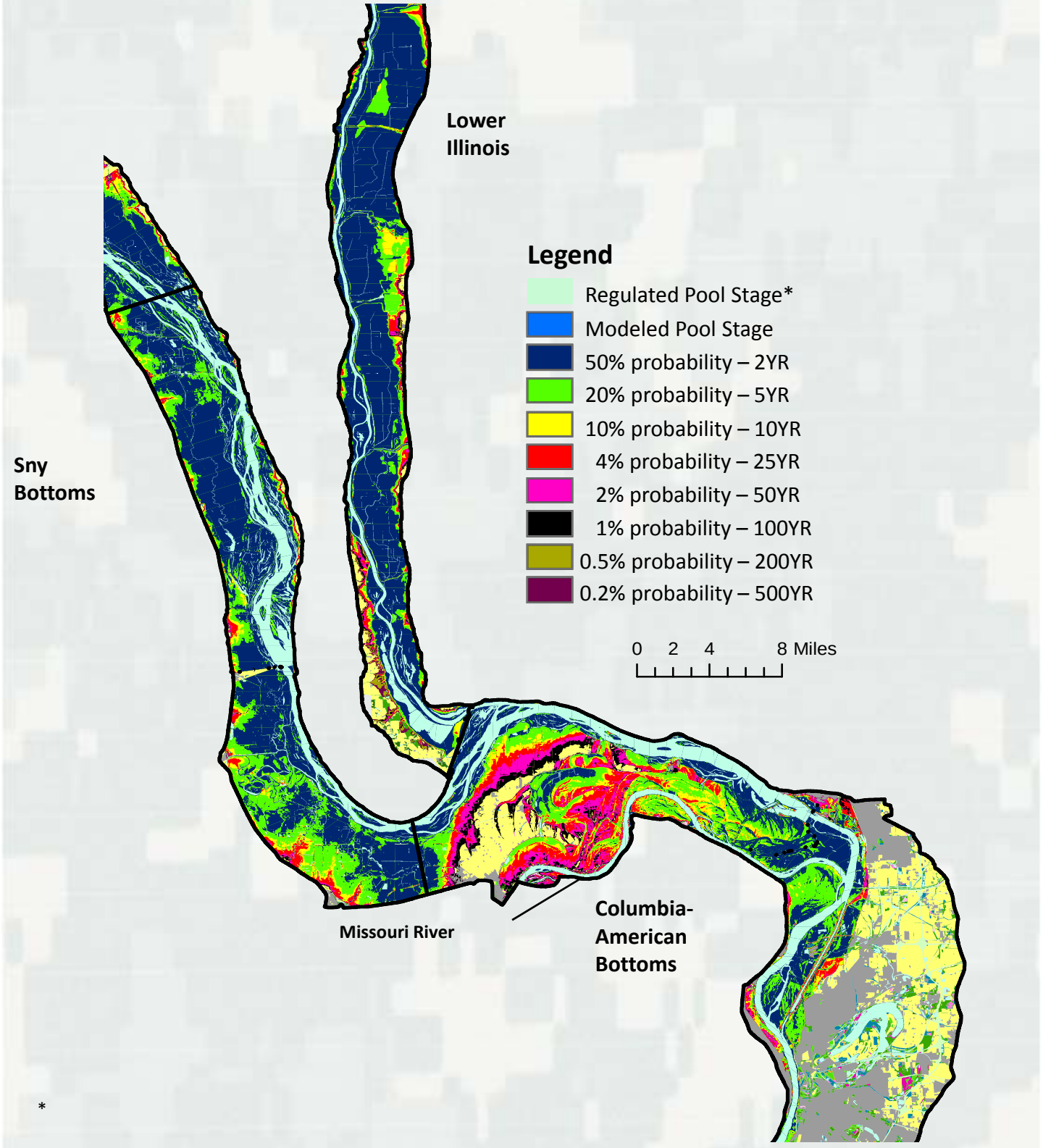


Conditional Shapefile

Flood Inundation Surfaces for Pool 18

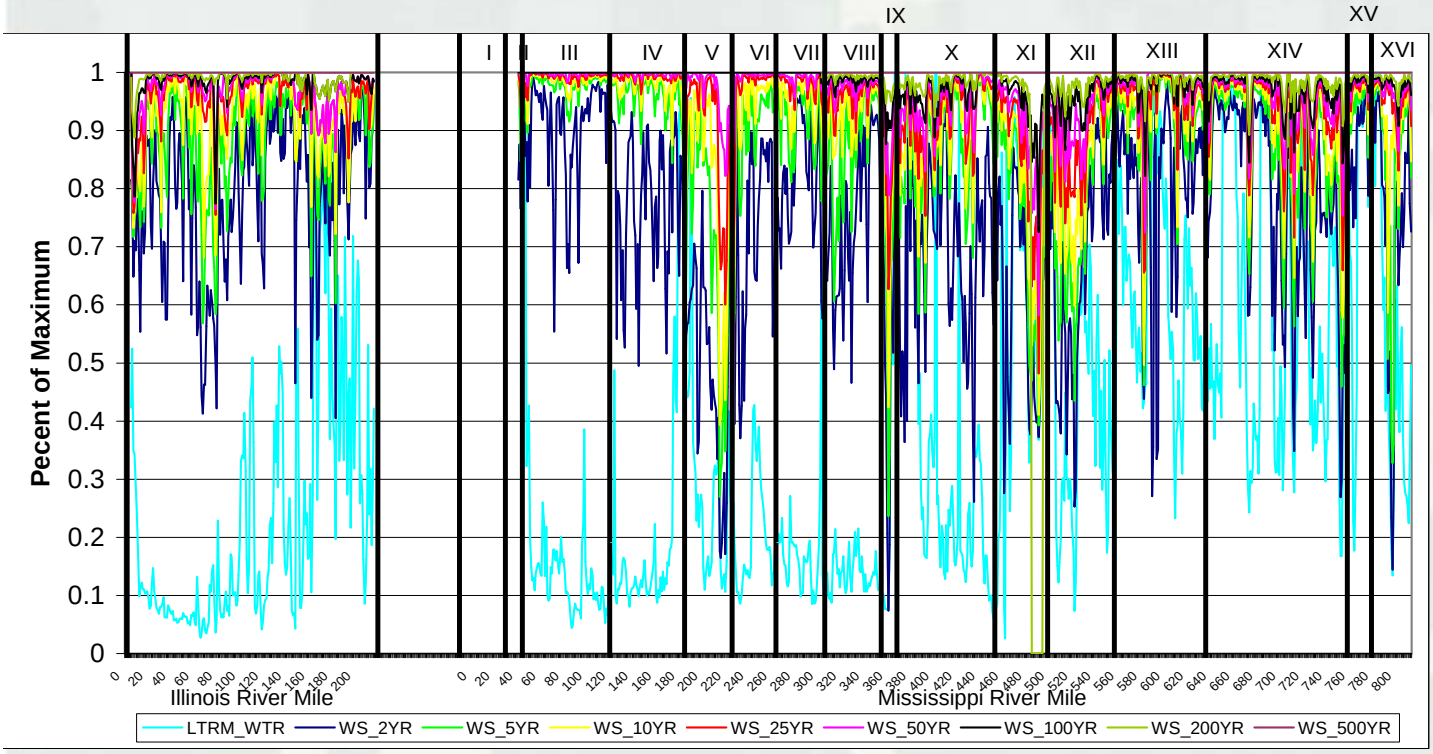






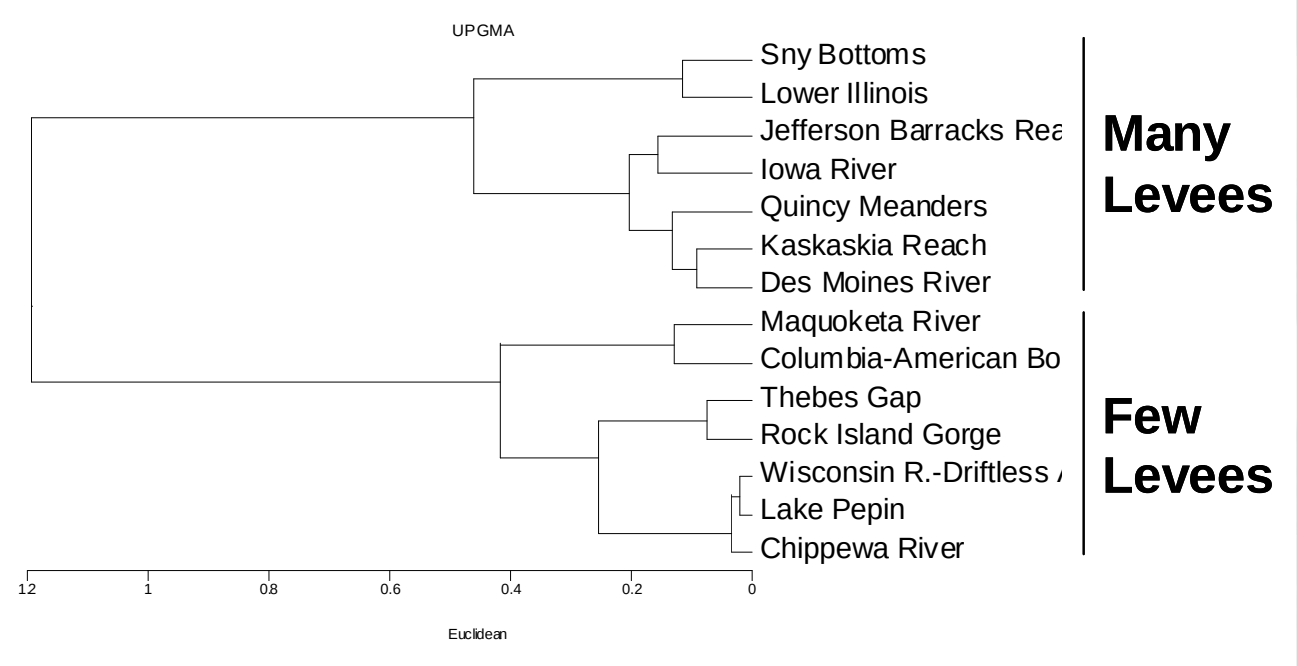
A regional perspective helps visualize hydraulic associations among large geomorphic features.

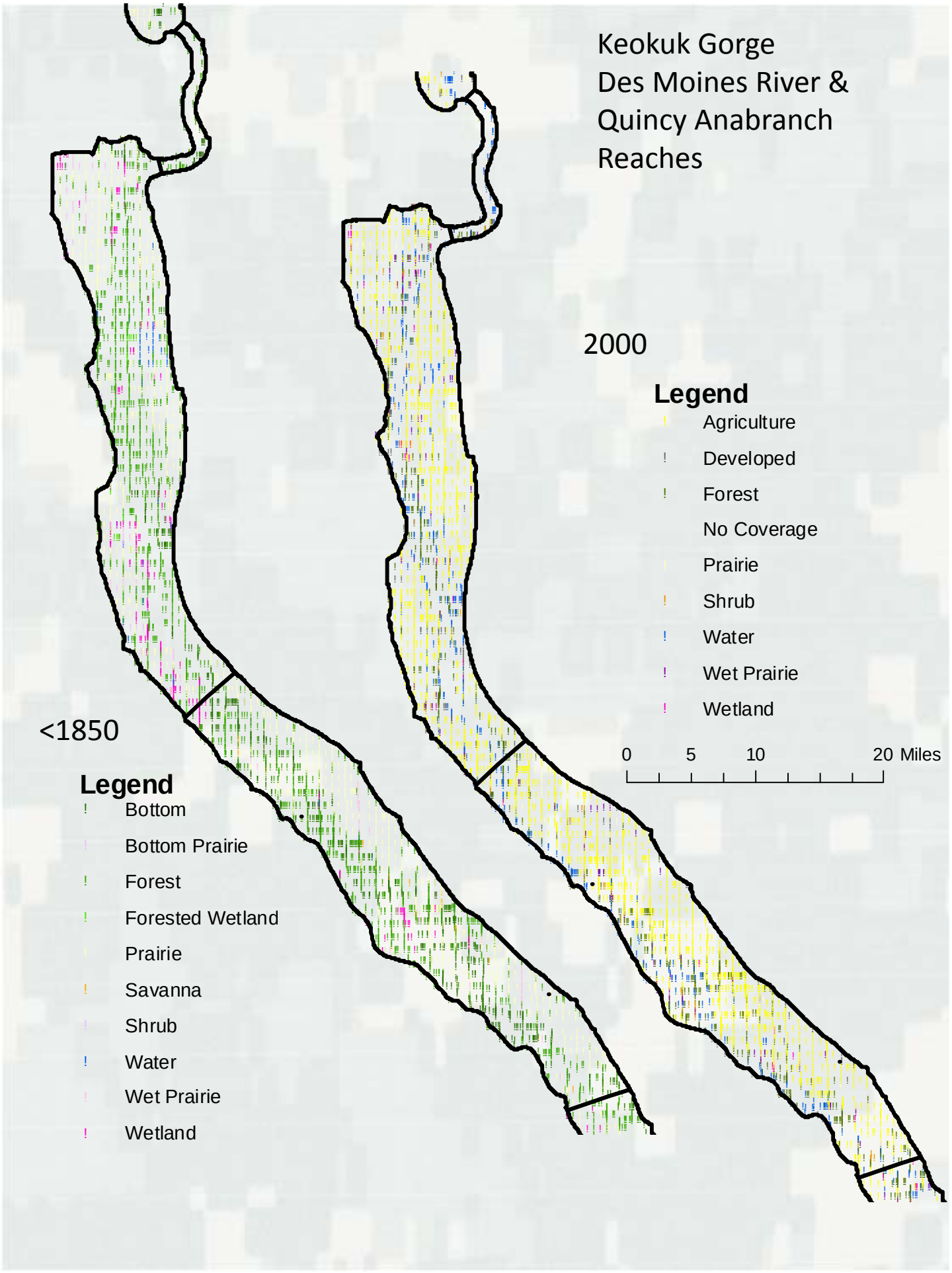
Flood Inundation as Proportion of Floodplain Area



Floodplain inundation (percent of floodplain) by river mile for the Illinois and Upper Mississippi Rivers overlayed with Mississippi River geomorphic reaches.

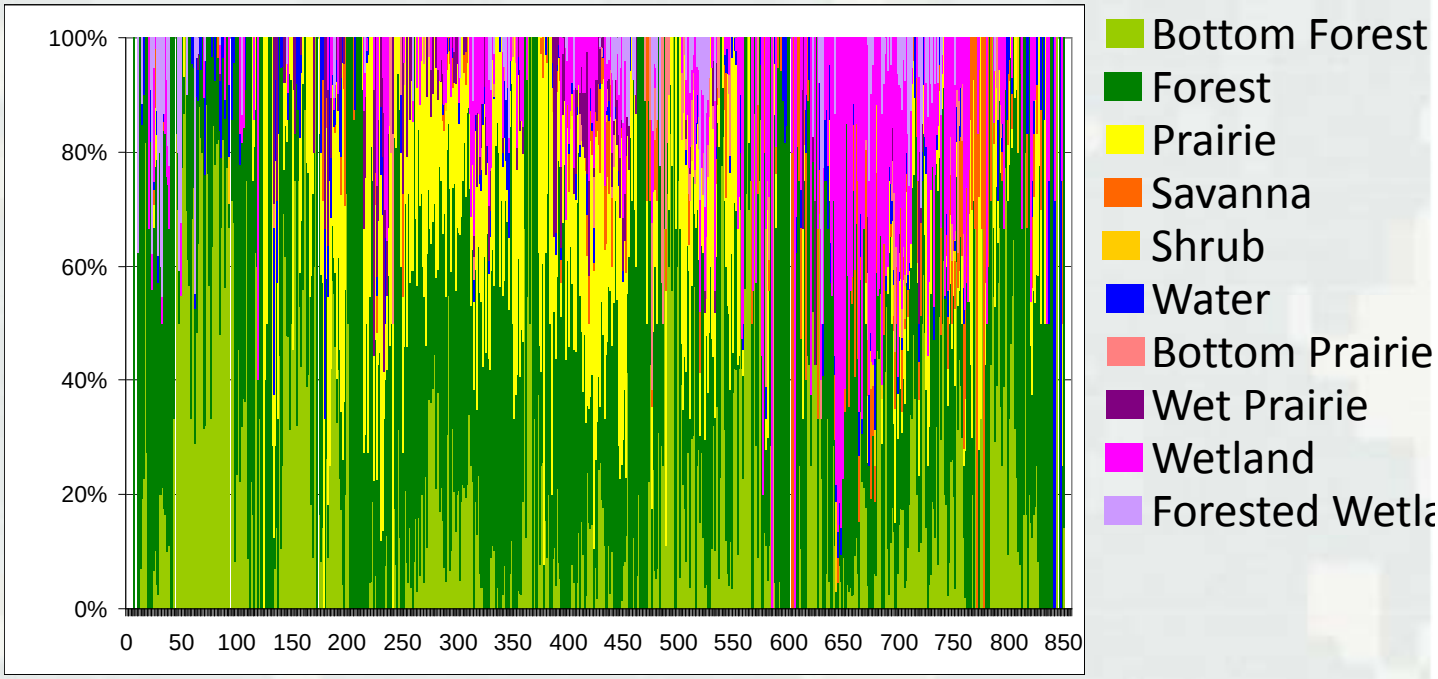
Proportion of Floodplain Reach Inundated by 2- to 100-Year Flood



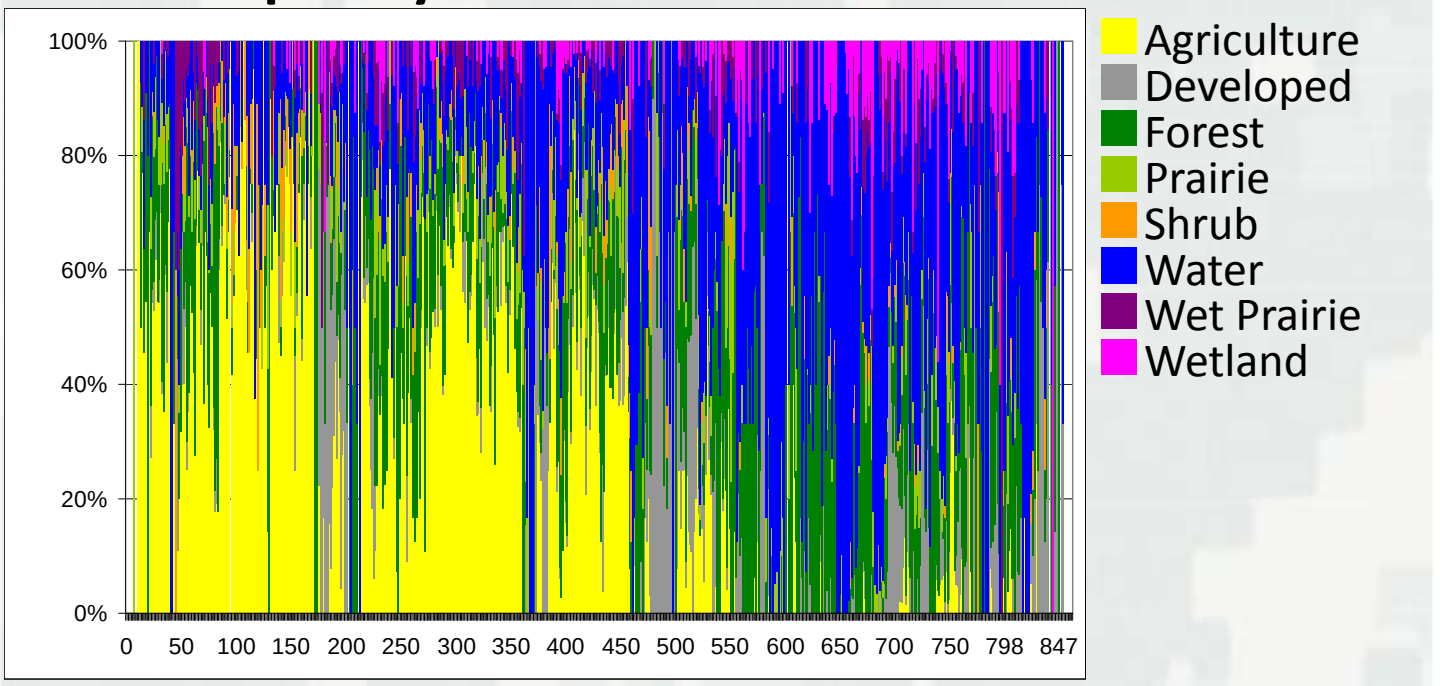

Keokuk Gorge
Des Moines River &
Quincy Anabranch
Reaches
2000
Legend
Agriculture
Developed
Forest
No Coverage
Prairie
Shrub
Water
Wet Prairie
Wetland
0
5
10
20 Miles
<1850
Legend
Bottom
Bottom Prairie
Forest
Forested Wetland
Prairie
Savanna
Shrub
Water
Wet Prairie
Wetland

UMR Land Cover References

Presettlement

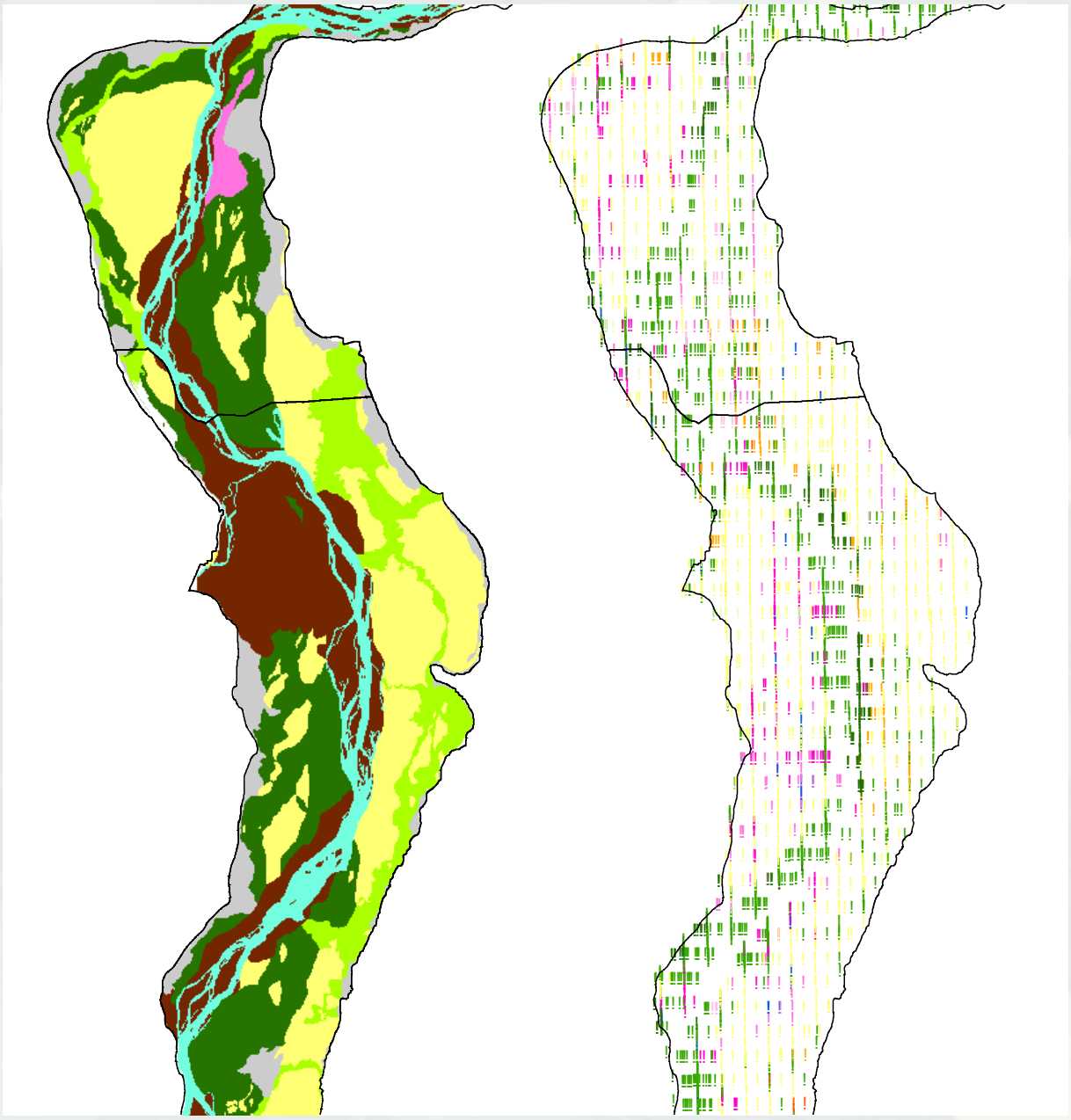


Contemporary

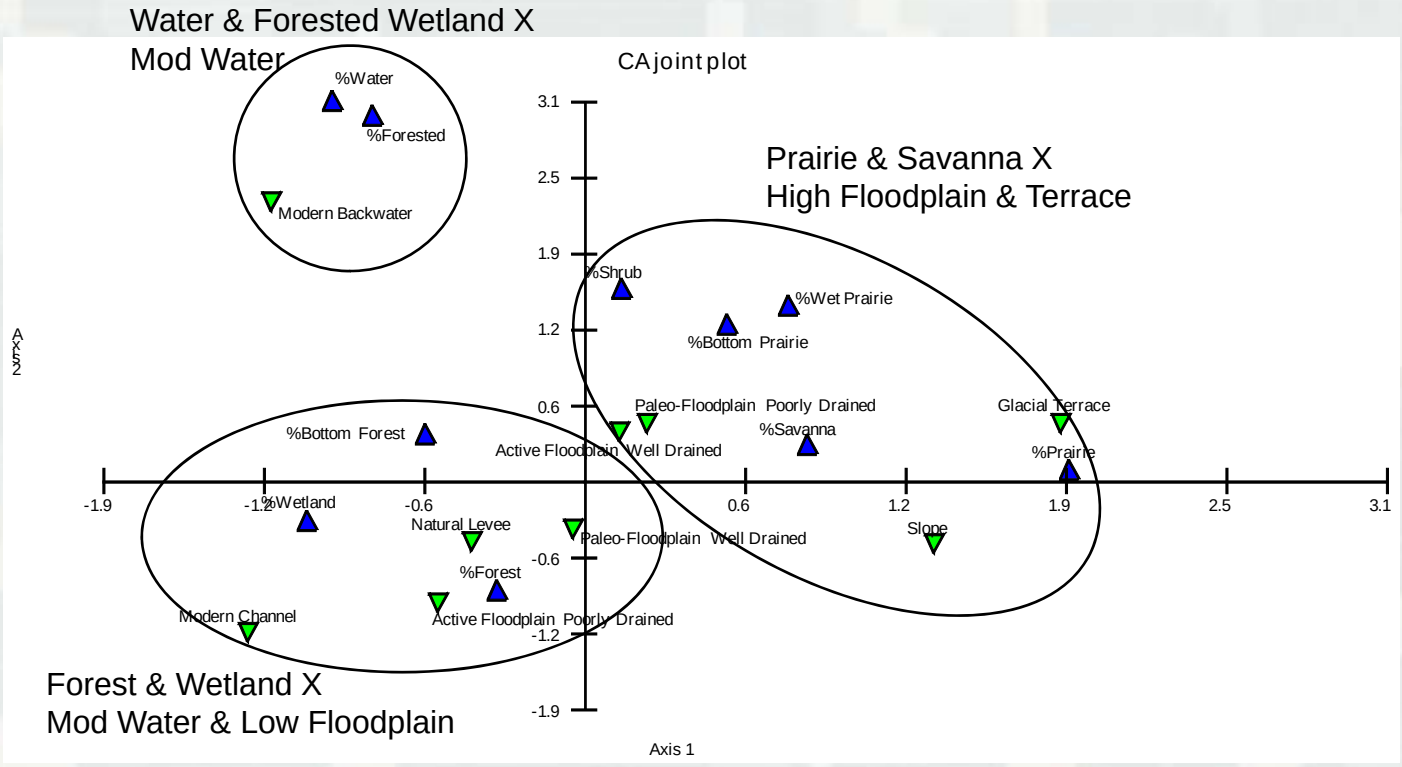


Geomorphic Class and Land Cover Association

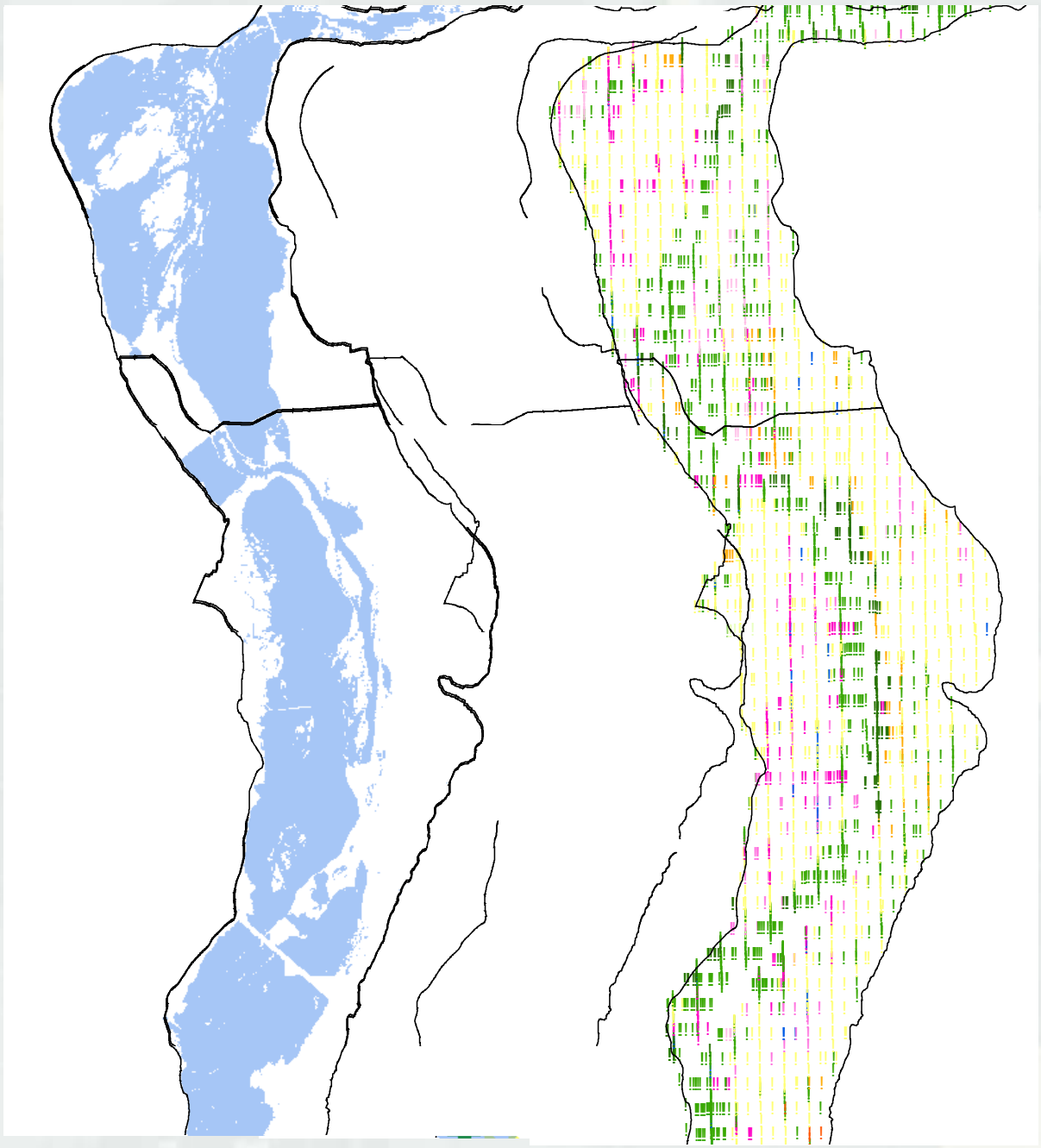
Geomorphology 1850 Land Cover



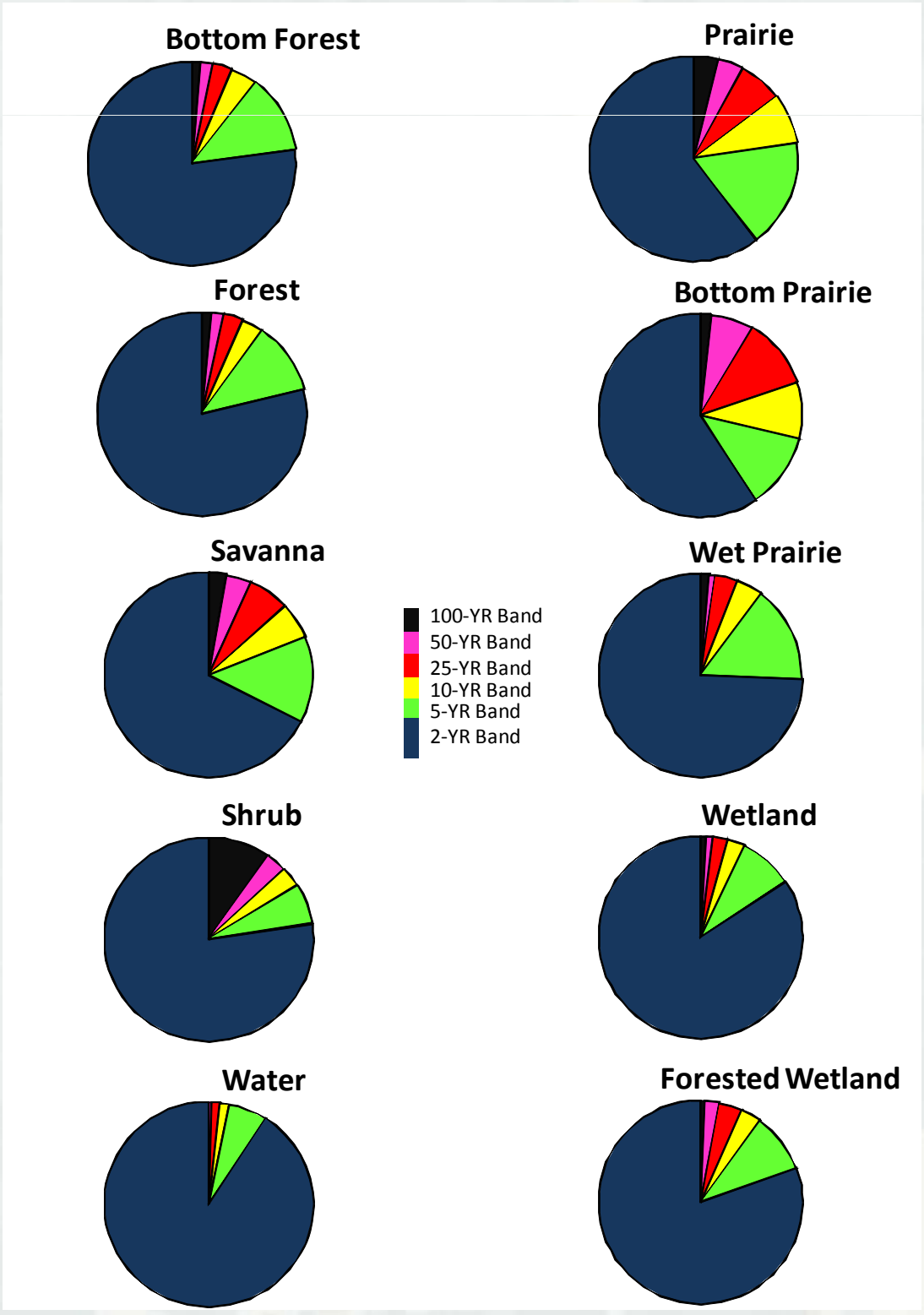
Geomorphic Class and Historic Land Cover Association



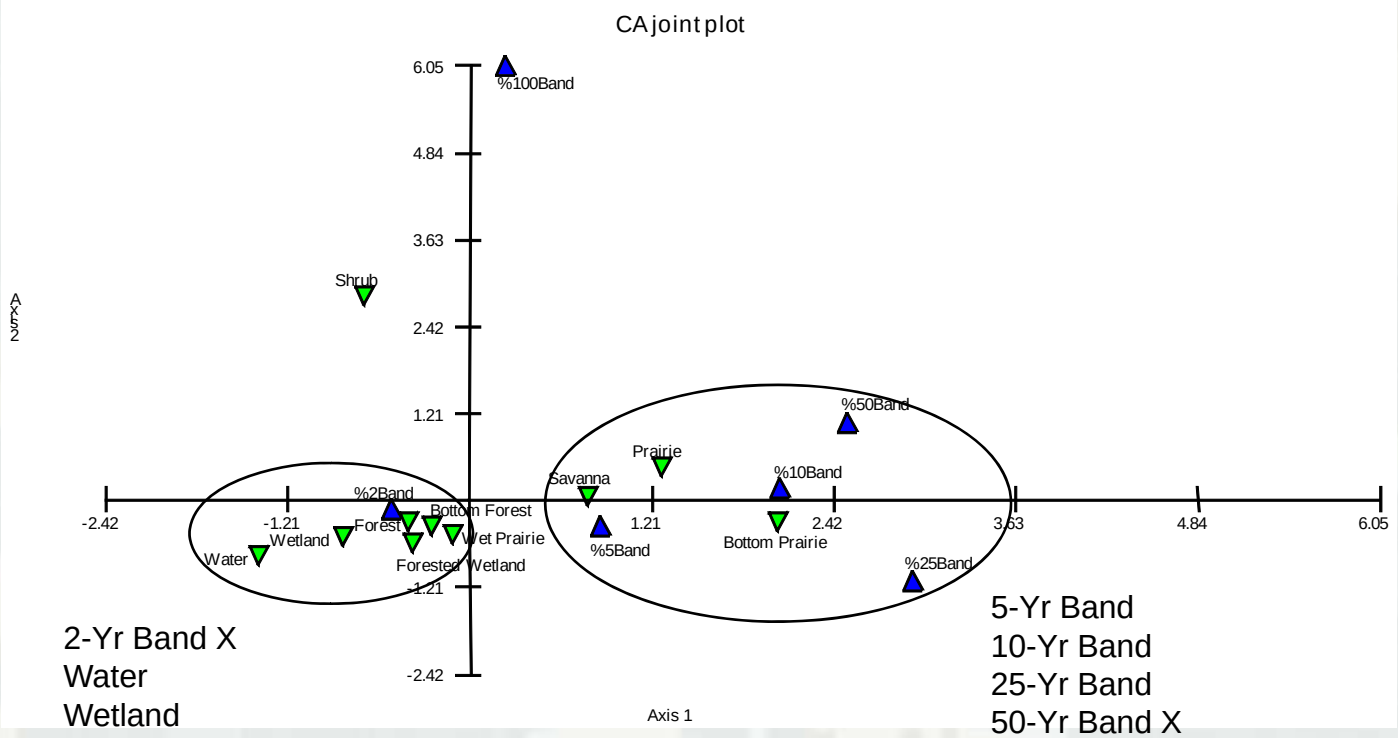
Presettlement Land Cover Distribution Relative to Modern 2-Year Flood Zone Estimate



Presettlement Land Cover Distribution Among Modern Flood Zone Estimates



Flood Zone and Historic Land Cover Association



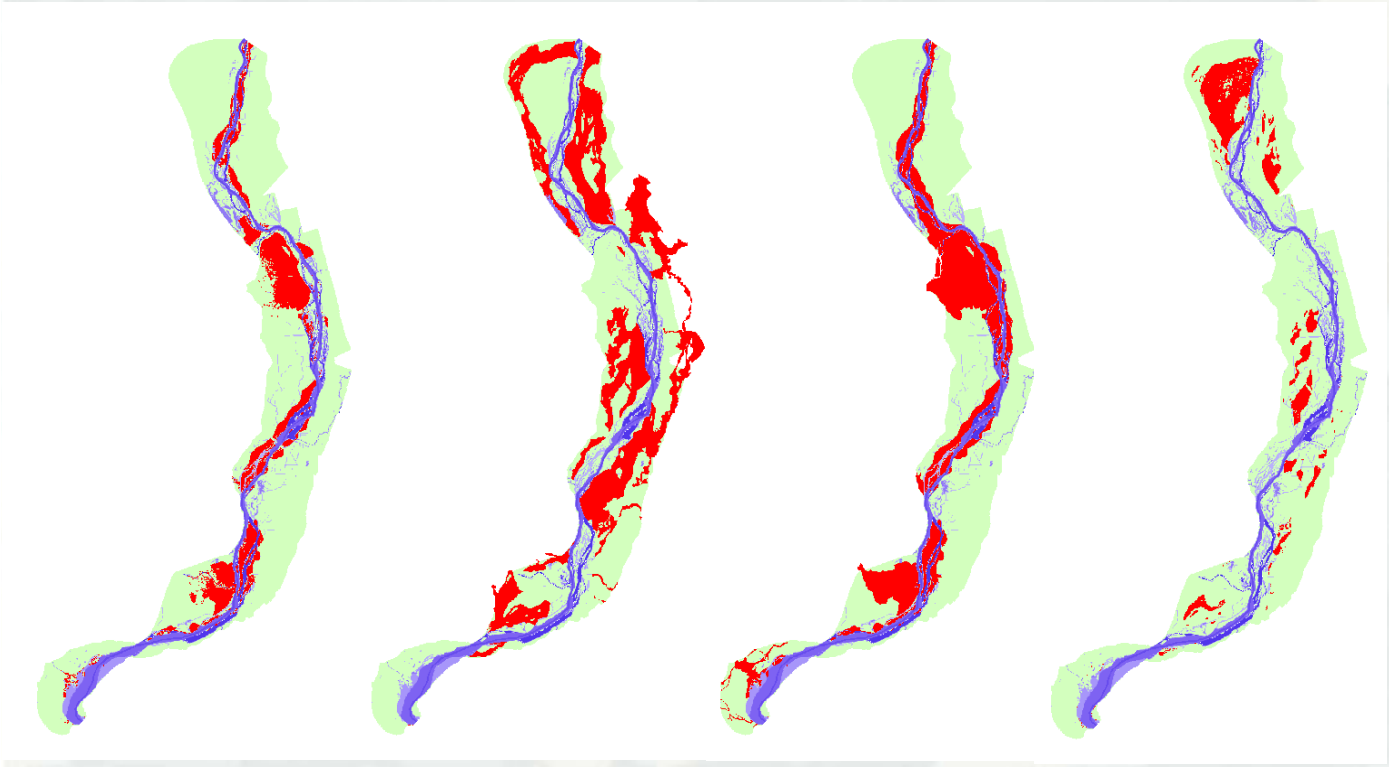
2-Yr Band X
Water
Wetland
Forest
Forested Wetland
Bottom Forest
Forested Wetland

5-Yr Band
10-Yr Band
25-Yr Band
50-Yr Band X
Savanna
Prairie
Bottom Prairie

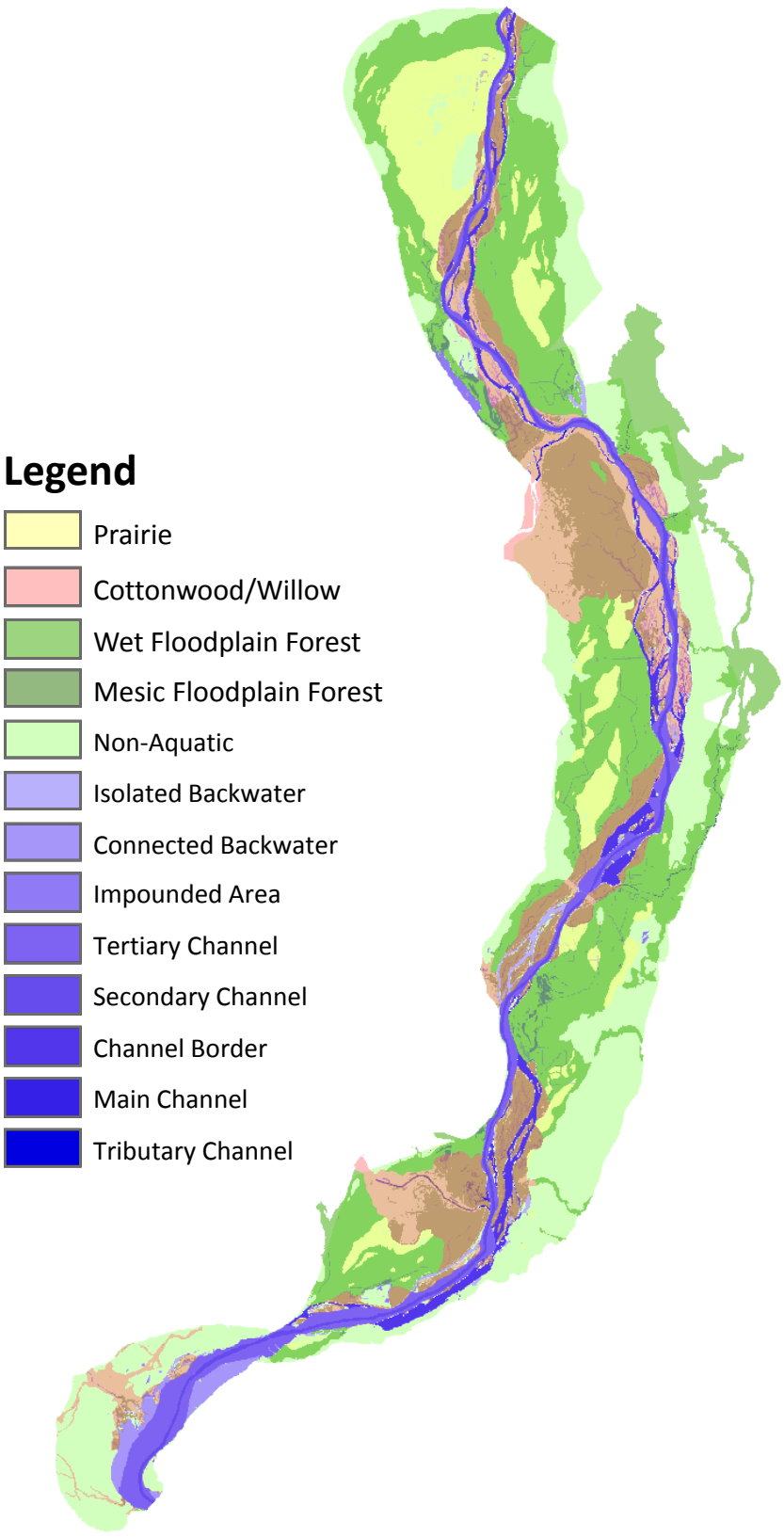
Potential Vegetation

(Deterministic Models)

Wet Floodplain Forest	Mesic Floodplain Forest	Populus/ Salix	Prairie



Potential Vegetation



Database Conclusions

- PLS data are a good undeveloped reference condition for UMRS reach scale
- Development caused large scale change over the entire region
- Regional differences can be detected
- Relationships between geomorphology and hydrology can be demonstrated
- Deterministic models for potential vegetation mapping and Environmental Benefits Evaluation can be improved
- Quantitative ecologists could use this framework as basis for probabilistic models using forestry data

UMRS Ecosystem Restoration Reach Planning

("and a miracle happens here" – Jean O'Neil)

- **All future restoration projects will be derived from and will contribute to attaining ecosystem objectives**

- **Objectives >> Spatial Assessment of Stressors/Drivers Affecting Obj. >>> Potential Management Actions >> Potential Areas for Implementation**

- **Reach Planning Teams will:**
  - **Identify future restoration projects**
  - **Identify ecological reasons for project sequencing**
  - **Prepare reach plans for ecosystem restoration**
  - **Prepare project proposals**

Upper Mississippi River Ecosystem-wide Vision & Goal

Vision:

"To seek long-term **sustainability** of the economic uses and ecological integrity of the Upper Mississippi River System"

Overarching NESP Ecosystem Goal:

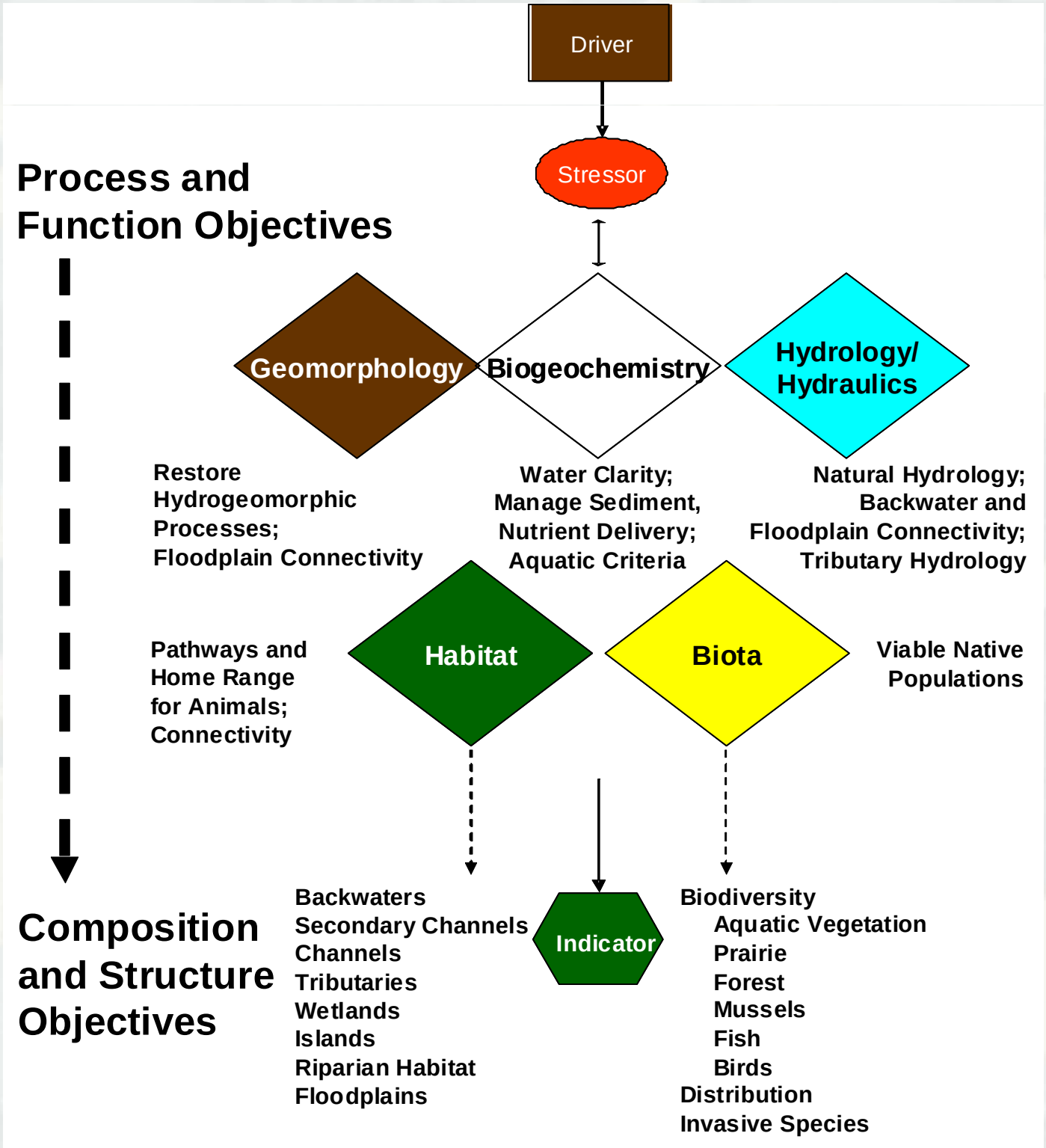
To conserve, restore, and maintain the ecological **structure and function** of the Upper Mississippi River System to achieve the vision of the Navigation and Ecosystem Sustainability Program.

Upper Mississippi River System-wide Goals

Manage for:

- A more natural hydrologic regime (**hydrology & hydraulics**);
- Processes that shape a diverse and dynamic river channel (**geomorphology**);
- Processes that input, transport, assimilate, and output materials within UMR basin river-floodplains: water quality, sediments, and nutrients (**biogeochemistry**);
- A diverse and dynamic pattern of habitats to support native biota (**habitat**), and;
- Viable populations of native species and diverse plant and animal communities (**biota**).

UMRS Ecosystem Restoration Objectives



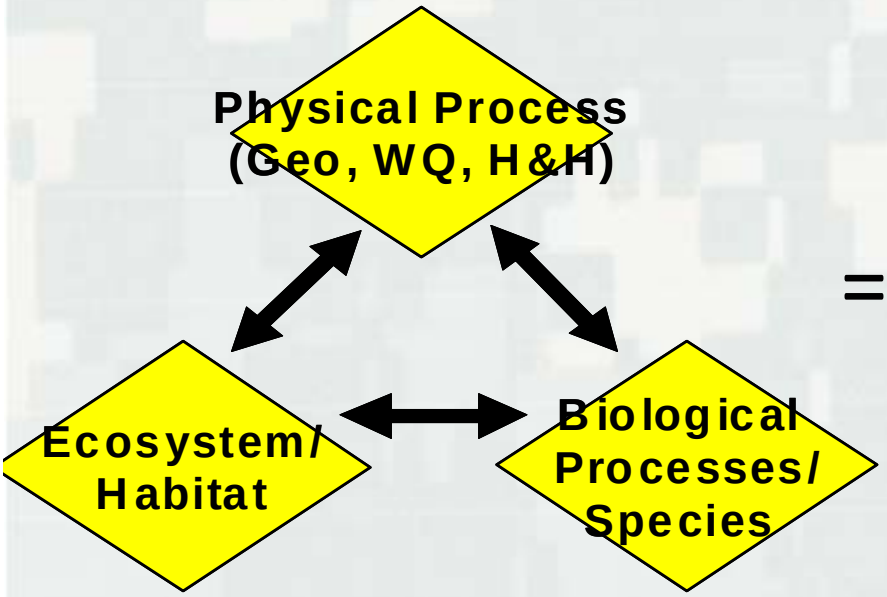
Reach-Scale Ecosystem Restoration Objectives

Reach Plan

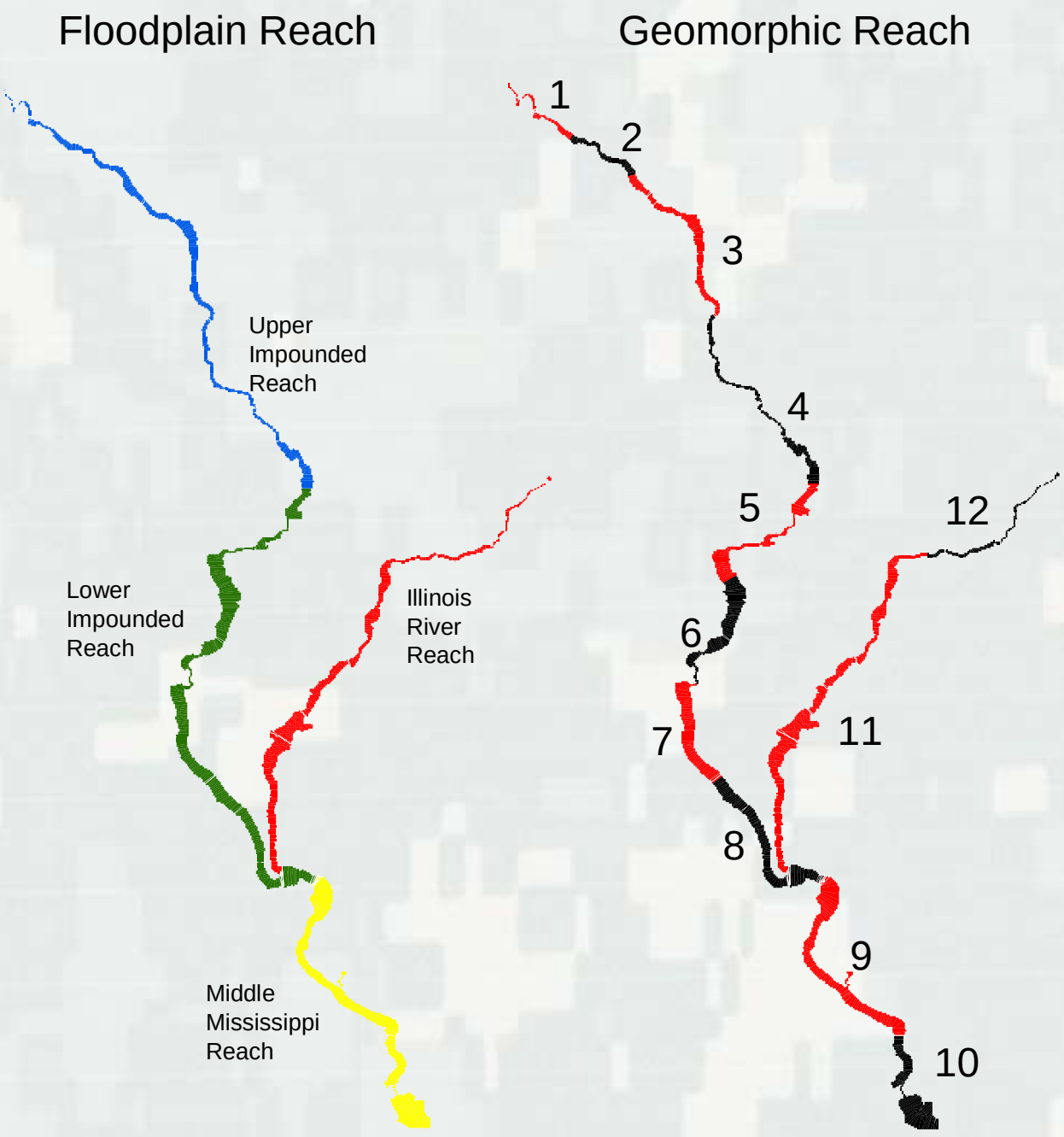
- A more natural stage hydrograph
- Restored hydraulic connectivity
- Increase storage and conveyance of flood water on the floodplain
- Restored backwaters
- Restored secondary channels and islands
- Restore a sediment transport regime so that transport, deposition, and erosion rates and geomorphic patterns are within acceptable limits
- Improved water clarity
- Naturalize the hydrologic regime of tributaries
- Restored lower tributary valleys

Scale and Process Relationships

NESP Vernacular		River Ecosystem Synthesis Terms
Geomorphic Reach - 12	=	Functional Process Zones
Geomorphic Areas	=	Functional Sets
Physical Process (Geo, WQ, H&H) / Ecosystem/ Habitat / Biological Processes/ Species	=	Ecosystem and Riverine Landscape Processes

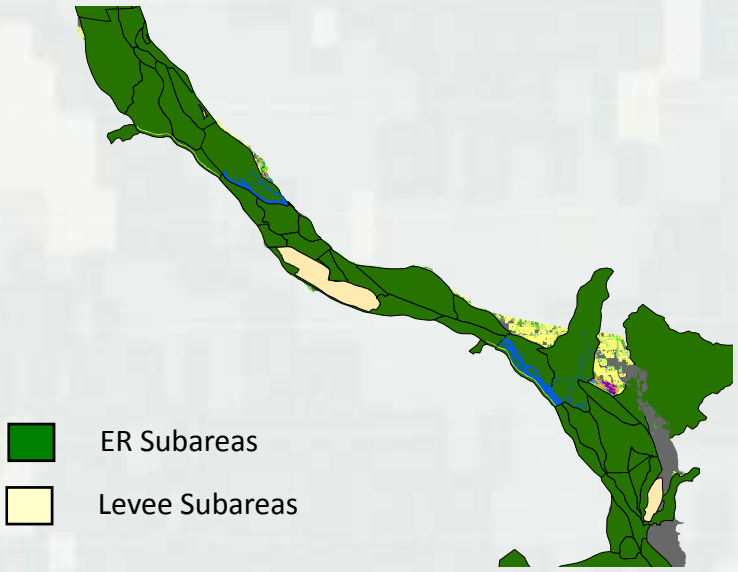


UMRS Planning Scales

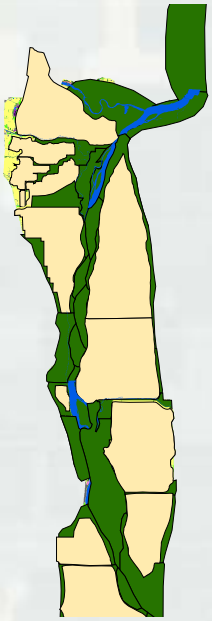


To Subareas where we can meet Ecosystem Restoration objectives

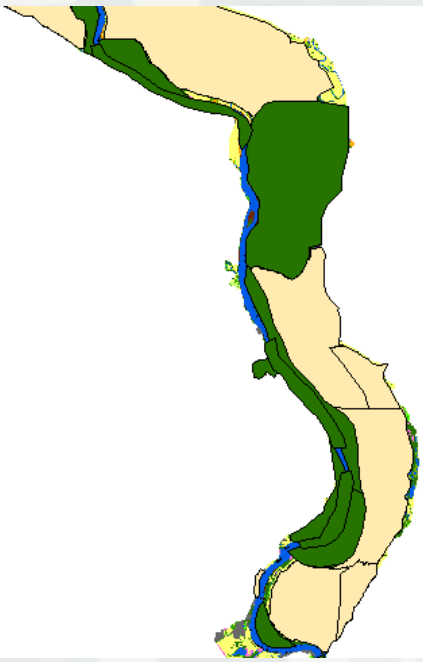
Upper Impounded Reach



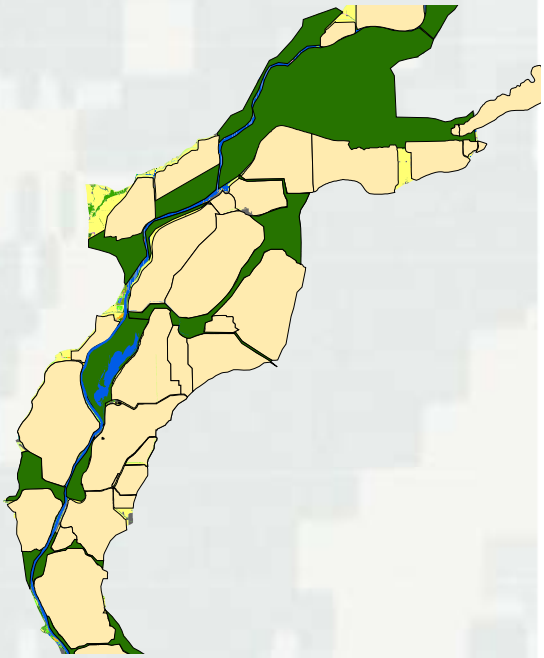
Lower Impounded Reach



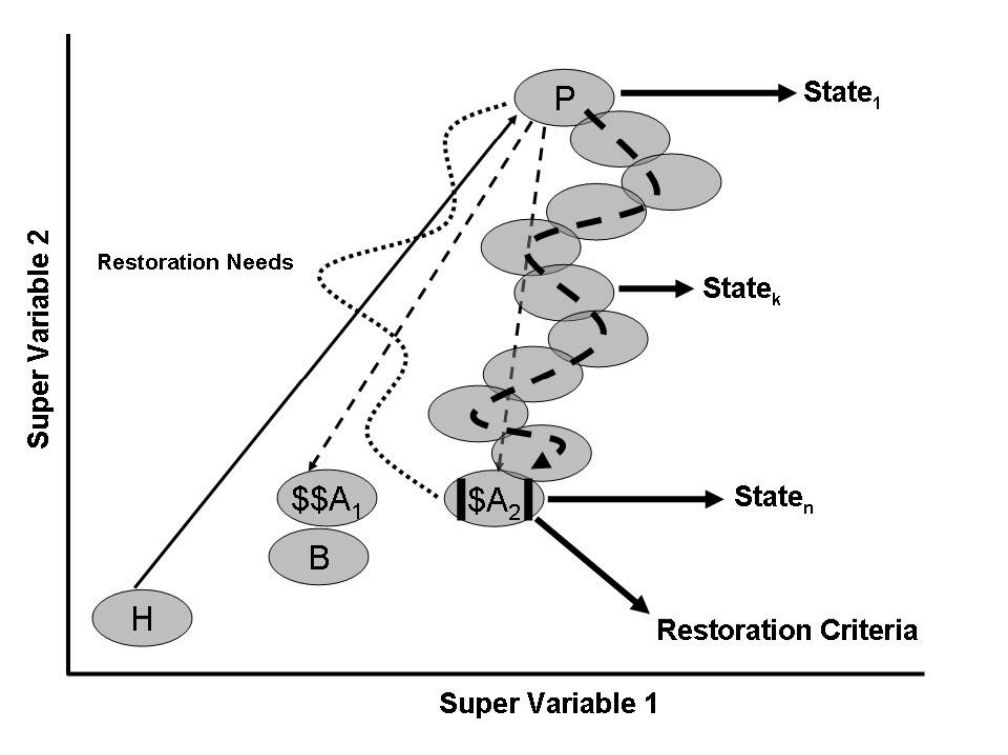
Unimpounded Reach



Illinois River Reach



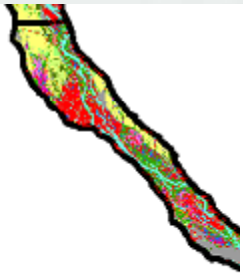
Multiple Reference Condition Analysis

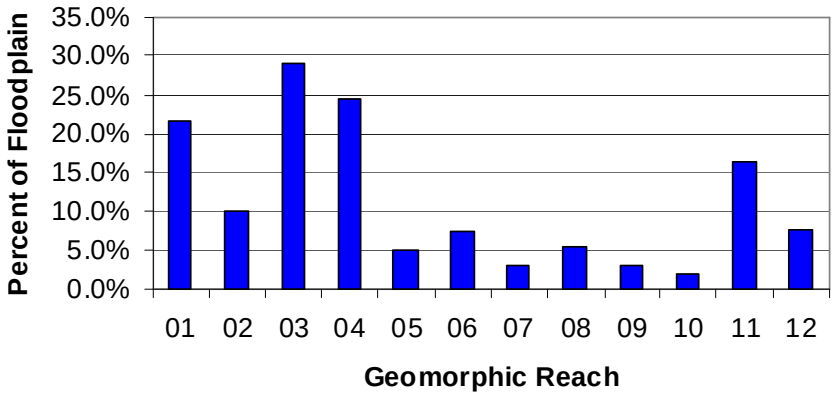


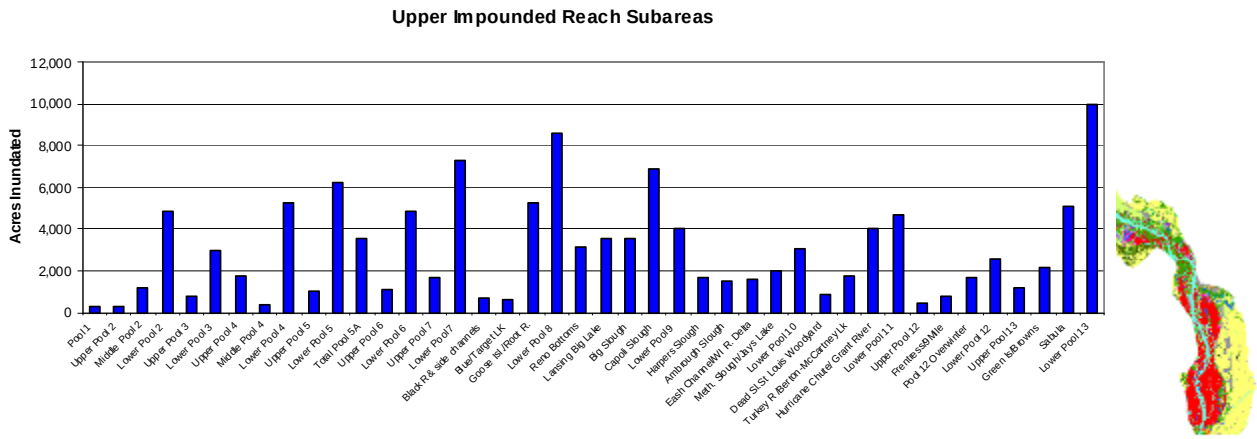
Legend: H = Historical ("Natural"), B = "Best Achievable State", Ai = Competing Alternatives, P = Present.

Ecosystem Restoration Objective:

A More Natural Stage Hydrograph





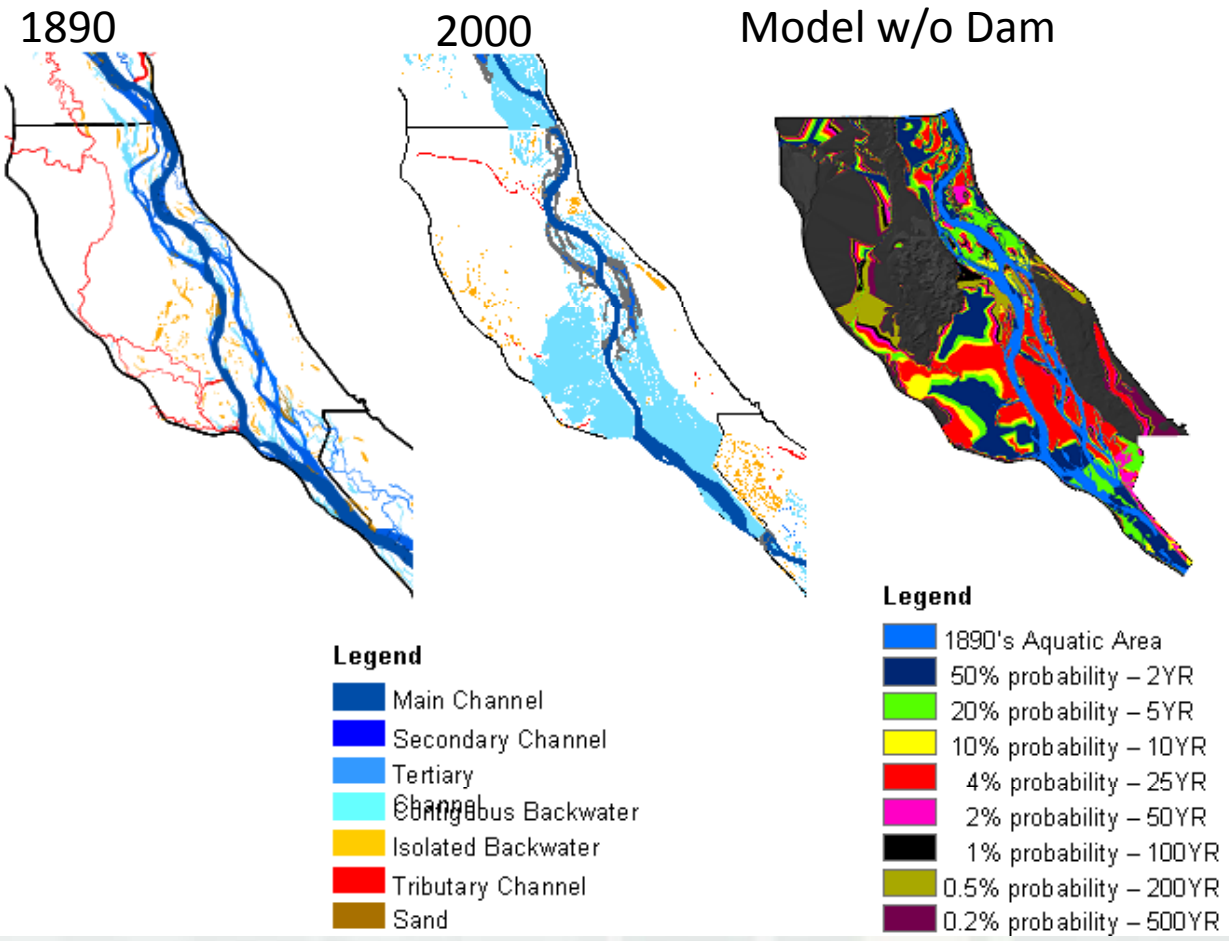


Inundated by Dams

Ecosystem Restoration Objective:

Restored Hydraulic Connectivity

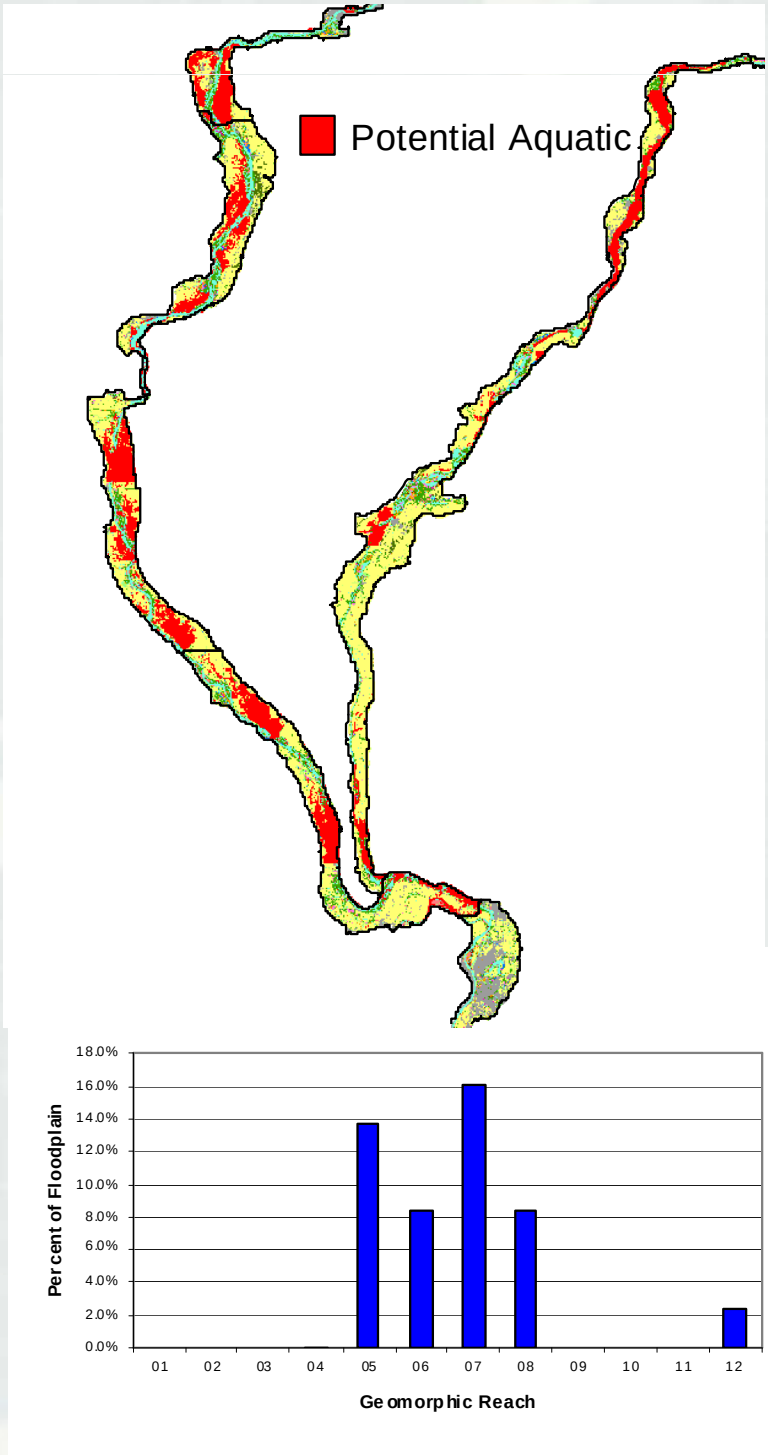
Aquatic Areas and Potential Inundation
Pool 5



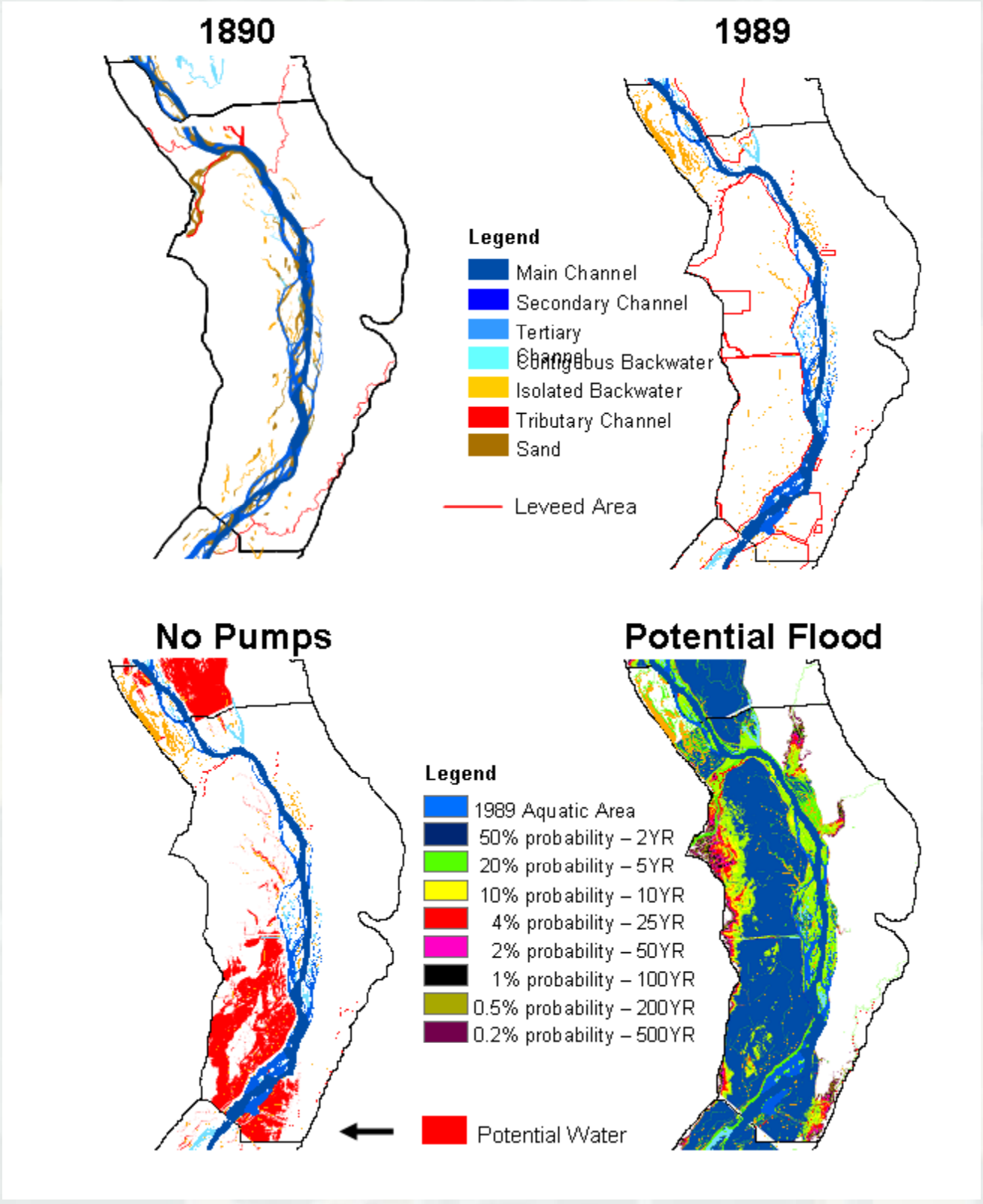
Multiple References

Ecosystem Restoration Objective:

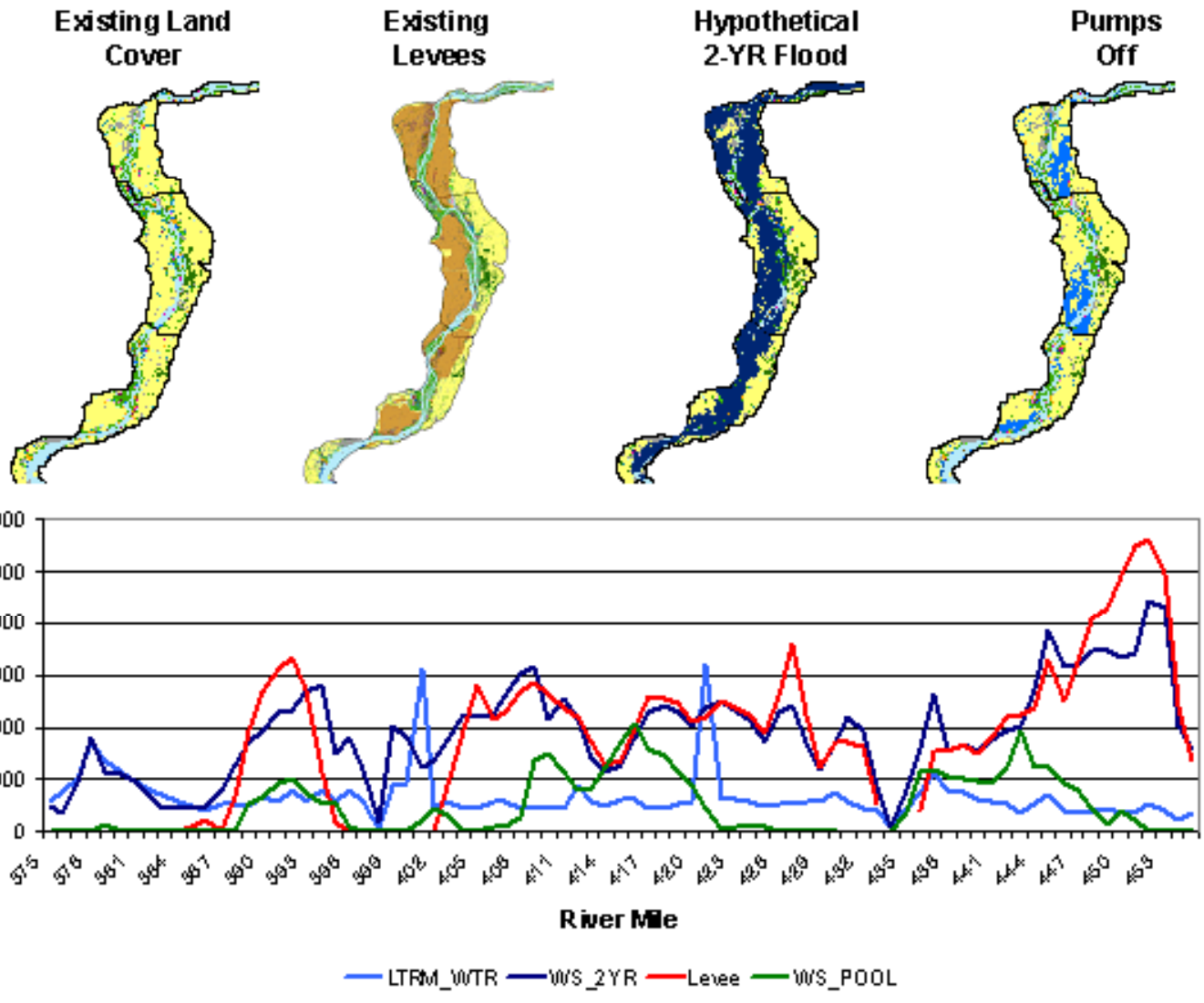
Increased Floodplain Connectivity



Multiple References – Increased Floodplain Connectivity

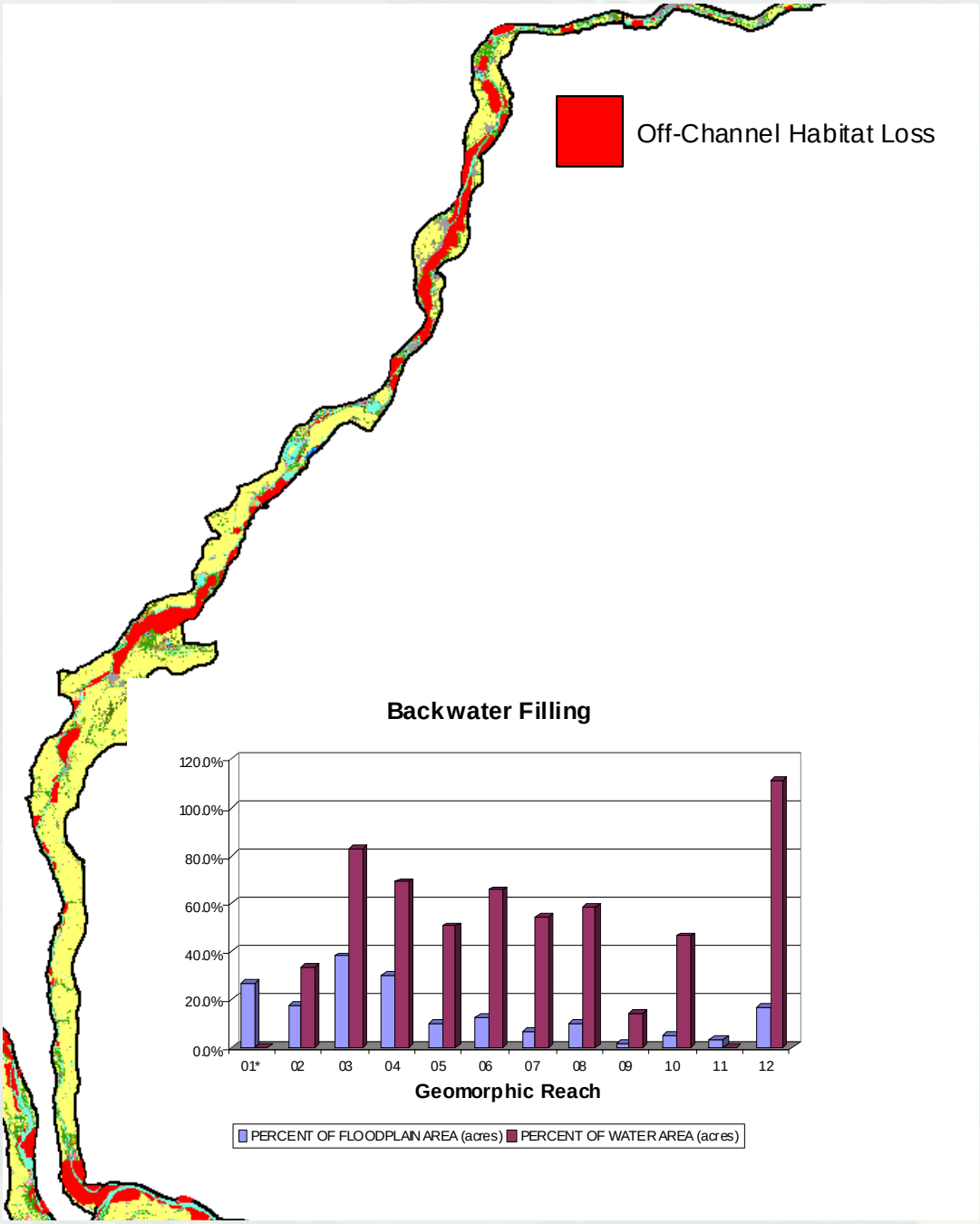


Environmental Benefits Analysis – Increased Floodplain Connectivity



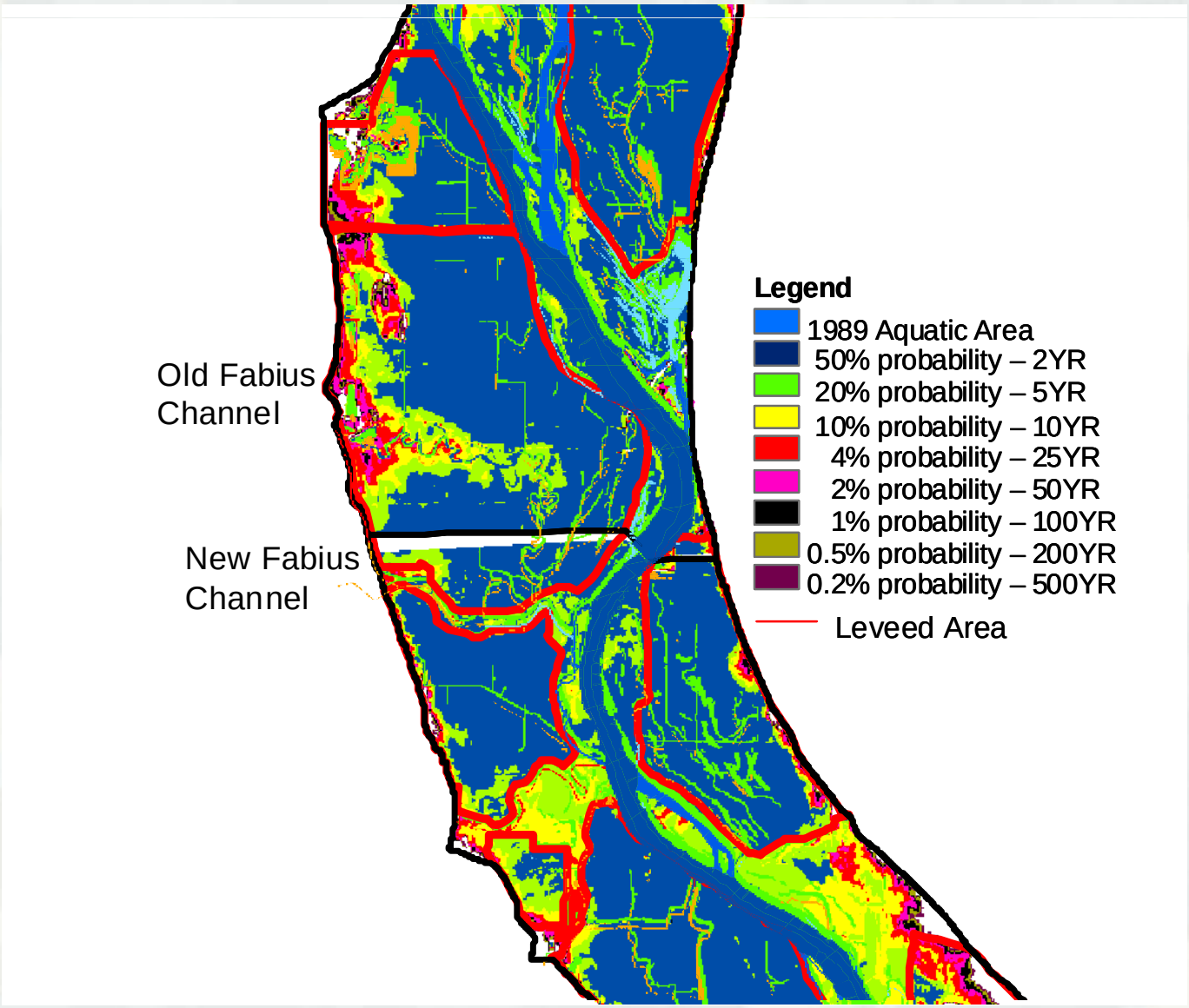
Ecosystem Restoration Objective:

Restored Backwaters



Ecosystem Restoration Objective:

Naturalized Hydrologic Regime and Lower Tributary Valleys



Ecosystem Restoration Objective:

Naturalized Hydrologic Regime and Lower Tributary Valleys

Reach Planning Conclusions

- These are good tools for ecosystem restoration planning and environmental benefits analysis
- Some actions will be regional, others will be widespread
- Many actions will be possible within subareas.
- Restoration project proposals (Fact Sheets, Requests for Projects) will sort out project features.
- Activities will be coordinated:
  - Dredging for islands
  - Structures for Nav. and Env.
  - Wetlands in Ag. Land

Scientific Value

- These data layers can help quantify ecological criteria at many scales
- These data and spatial structuring schemes will support more intensive ecological investigations
- These data layers visualize fluvial geomorphic and hydrologic processes; comparable to first system-wide land cover
- These large scale data will nicely compliment new models developed on smaller scales
- This approach is transferable

UMRS Ecosystem Restoration Recommendations

- A return to something similar to the St. Paul District pre-1973 water regulation operating manual to allow pool-scale drawdowns in the Upper Impounded Reach
- Incorporate small-scale, temporary backwater drawdowns in Lower Impounded and Illinois River Reaches
- Increase structural diversity (geomorphic pattern) system-wide through multiple site specific projects
- Emphasize land conversion from crops to native communities
- Implement mixed use floodplain management to achieve multiple benefits within the existing levee and drainage district infrastructure.

- Develop contingency plans & funding to acquire land following floods rather than immediate return to *status quo* as under P.L. 84-99.
- Middle Mississippi River and Alton Pool secondary channels should be high priority for restoration.
- Target tributary confluences to capitalize on the diverse environment, “hot spots,” provided by natural tributary deltas