Conceptualizing the Downstream Ecological Effects of Reservoir Sediment Release

EMRRP

Presenter: Darixa D. Hernandez-Abrams

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US Army Corps of Engineers

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- Interests: ecosystem restoration, ecological modeling, evaluating environmental effects of USACE projects

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- Interests: marine sciences, biodiversity, ecological dynamics

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Other members of the ERDC-EL project Team: Dr. Aubrey Harris co-lead phase III, Samantha Wiest (hydraulic and sediment transport modeling), Susan Bailey

OVERVIEW

Report content

Chap 1 Introduction

- Hydrological and sediment regimes
- Gen effects of reservoirs as sediment traps
- Need for sustainable practices
- Objectives and approach

Chap 2 Geomorphic Effects

- Sec CWA 404
- Effects on ecosystem habitat
- CEMs

Report content (cont.)

Chap 3 Water Quality Effects

- CWA Sec 401
- Effects on WQ and impacts on ecosystem
- Conceptual ecological model

Chap 4 Aquatic Organism Effects

- ESA Sec 7 and 9
- Effects of WQ and fluvial geomorphology
- CEM

Chap 5 Gaps and Recommendation

OVERVIEW

Other Topics (not in report)

Broad Look at Case Study: Water Injection Dredging

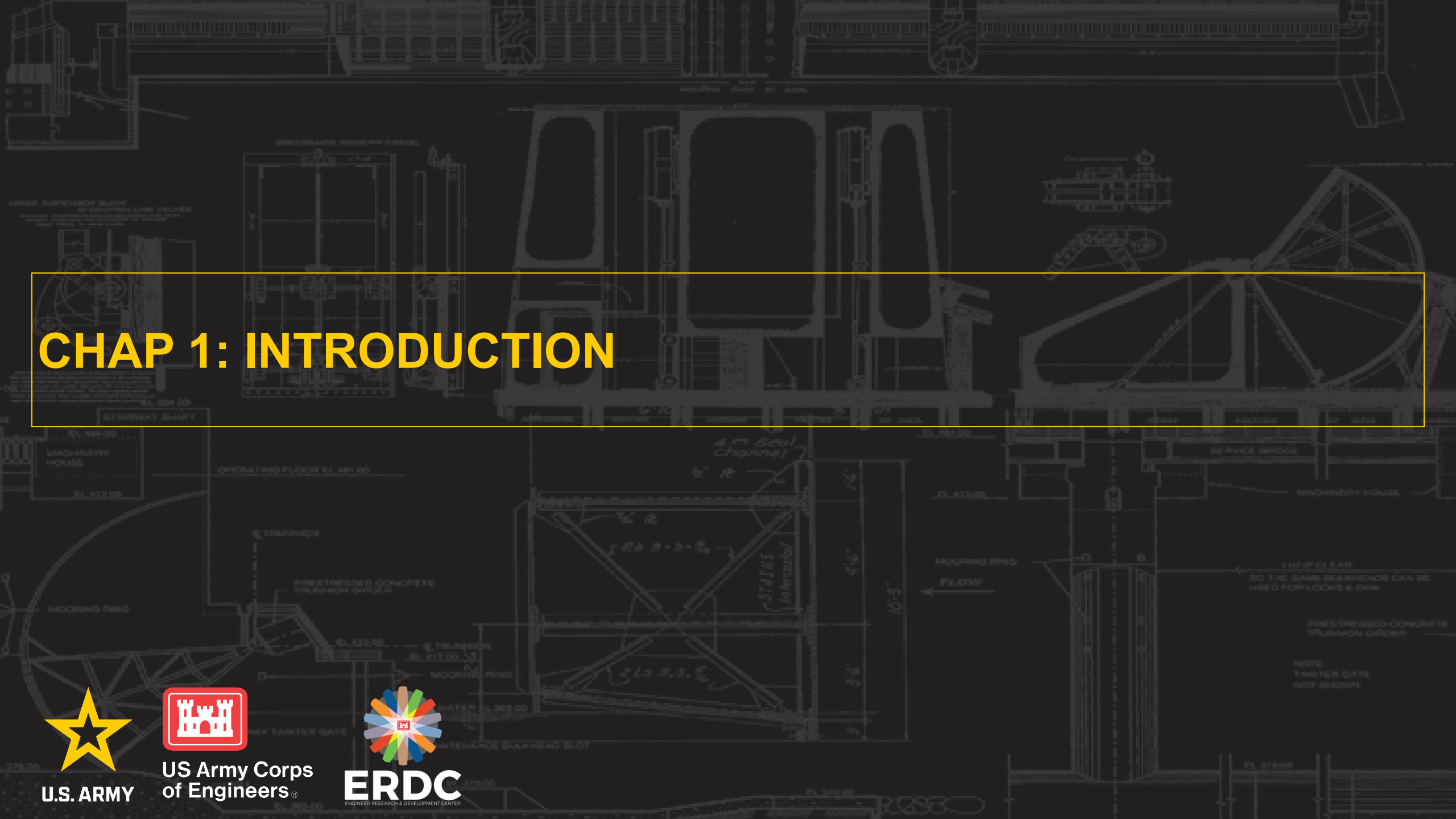
- Monitoring
- Modeling
- Future directions

Acknowledgements

References

Q&A

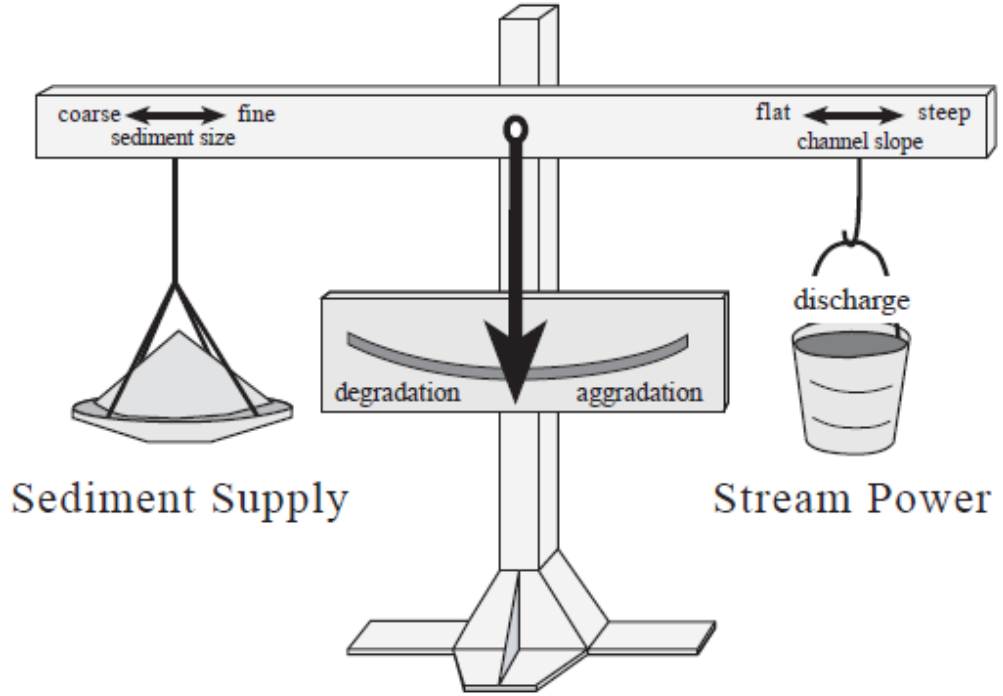
CHAP 1: INTRODUCTION



INTRODUCTION

Hydrological and sediment regimes

Natural sediment regime
river sediment dynamics before anthropogenic alteration



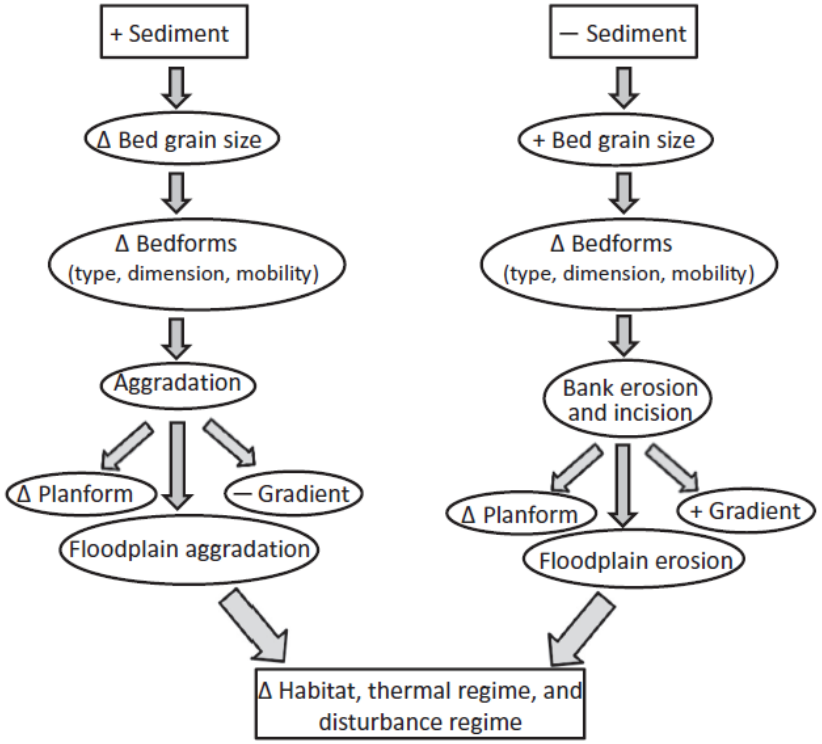
Modified by Blum et al. 2000 from Lane's Balance Equation (1955)

Natural sediment regime
riverine natural flow variations over time

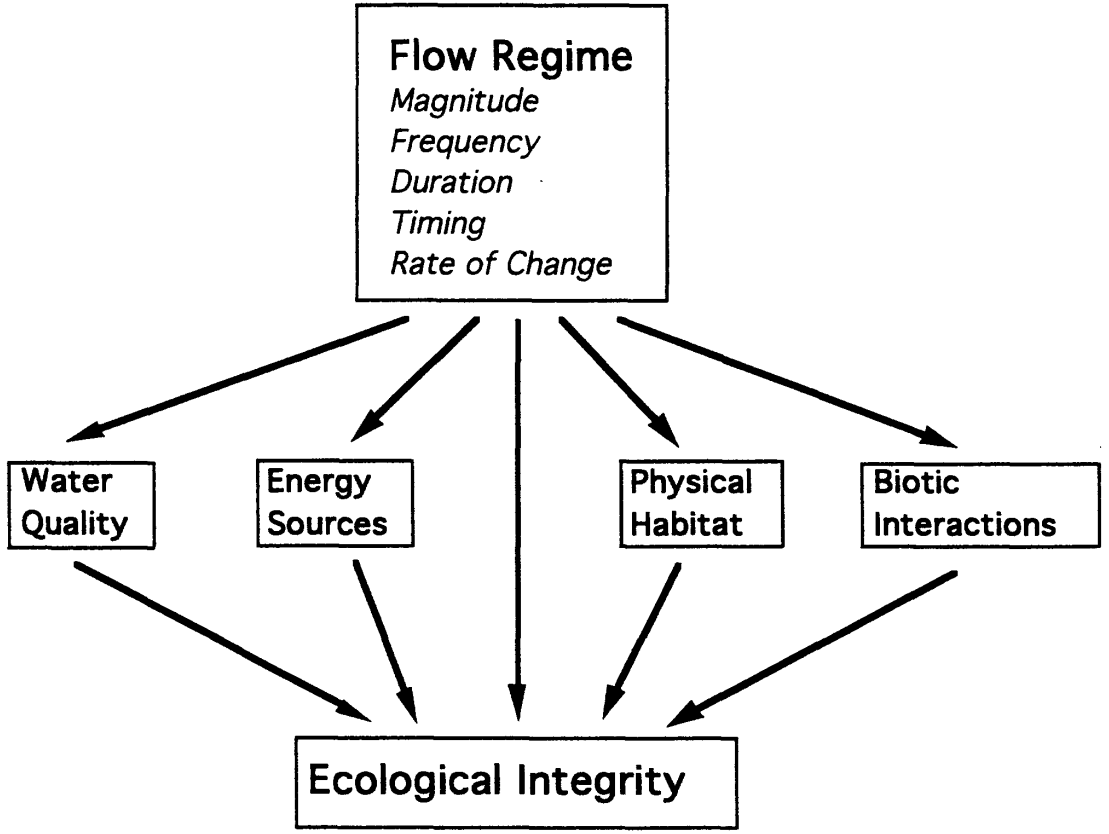
Regime – magnitude, timing duration, frequency, rate of change

INTRODUCTION

Hydrological and sediment regimes



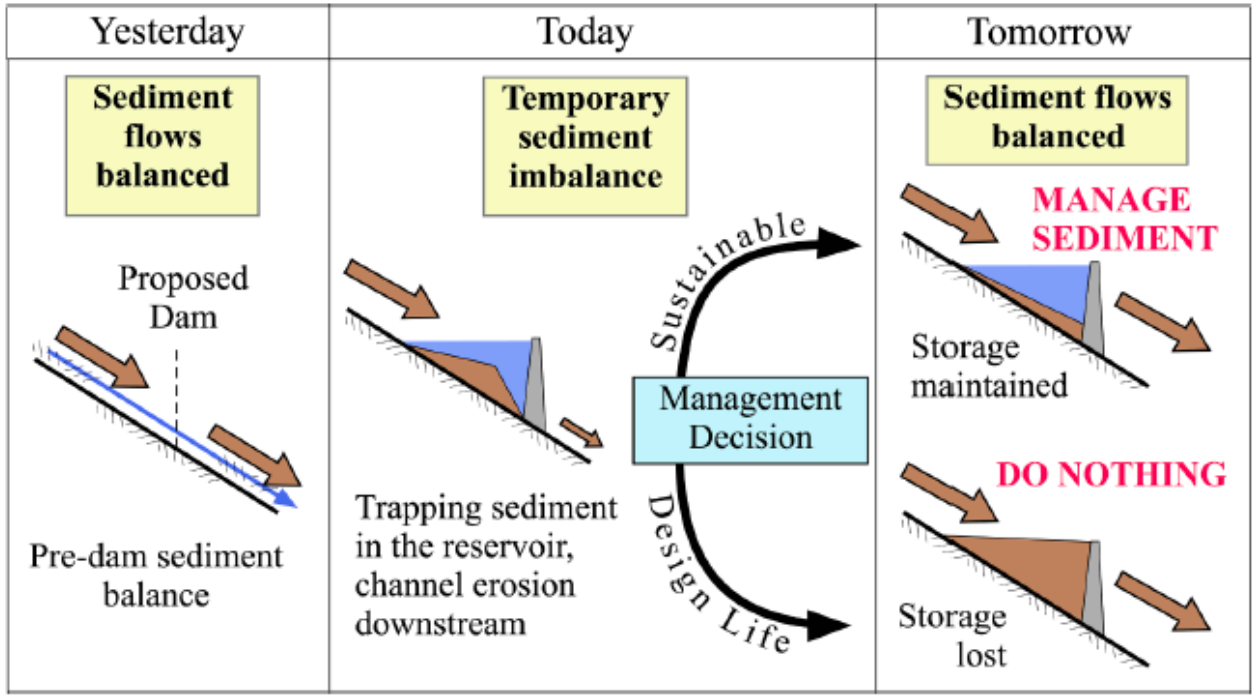
Wohl et al. (2015)



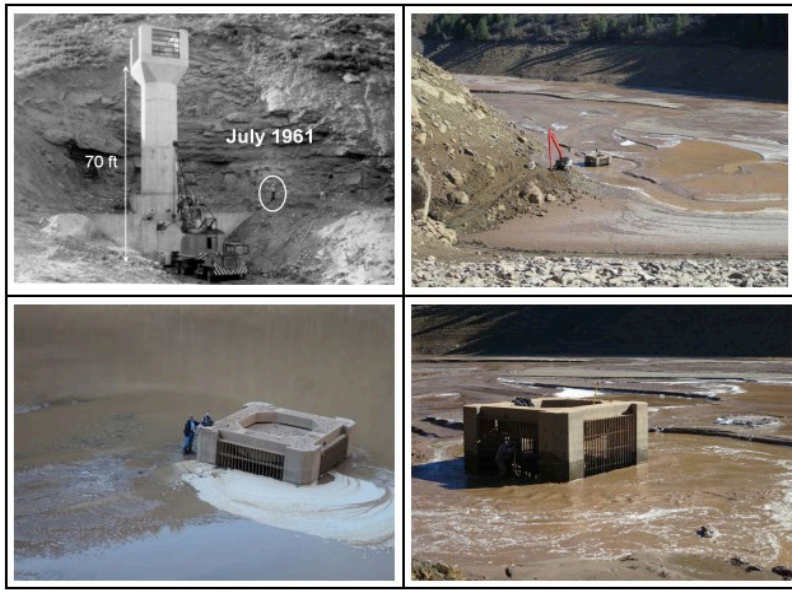
Poff et al. (1997)

INTRODUCTION

Sedimentation effects in reservoirs

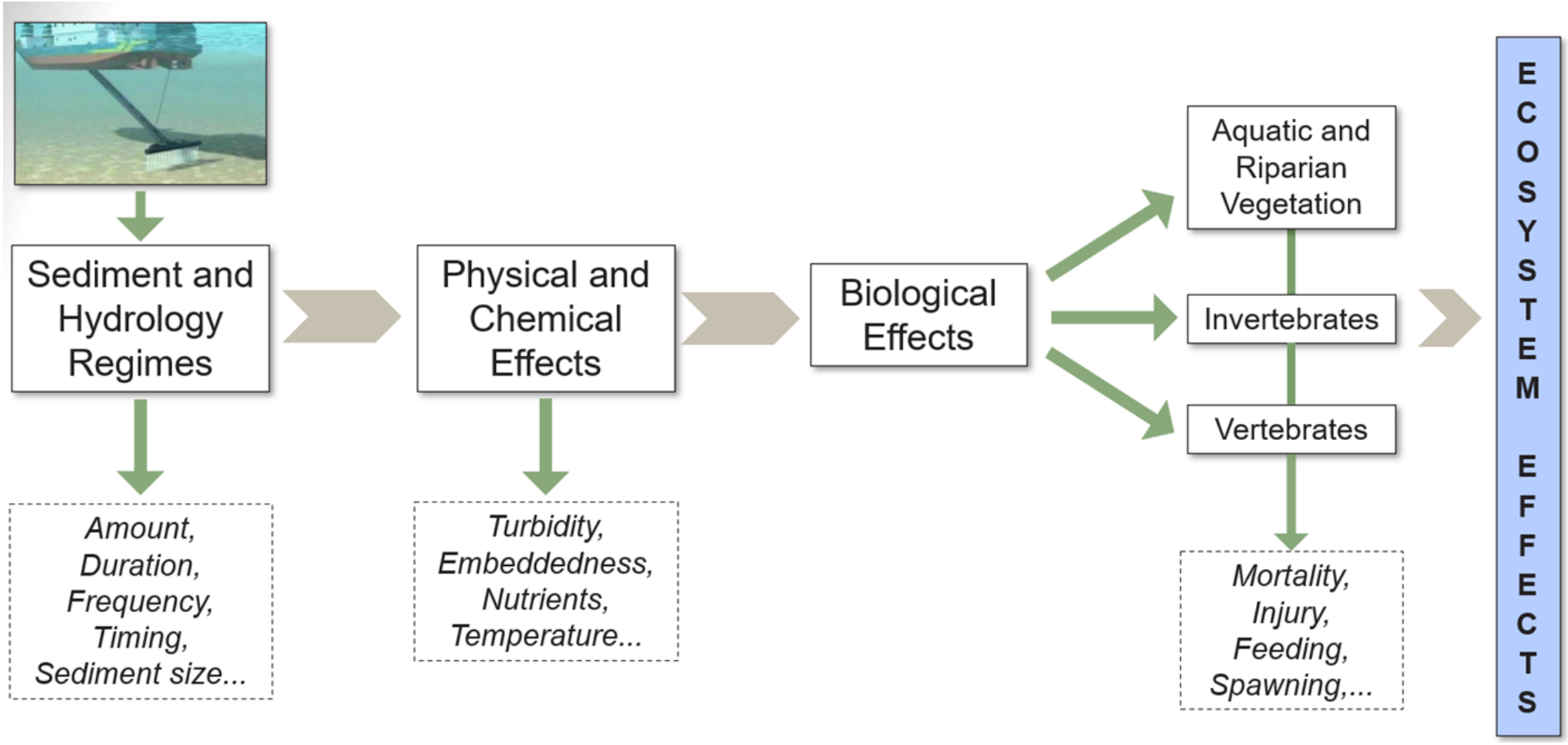


Morris (2020)



Paonia Reservoir, Colorado (Randle et al. 2019)

INTRODUCTION



INTRODUCTION

Report objectives and approach

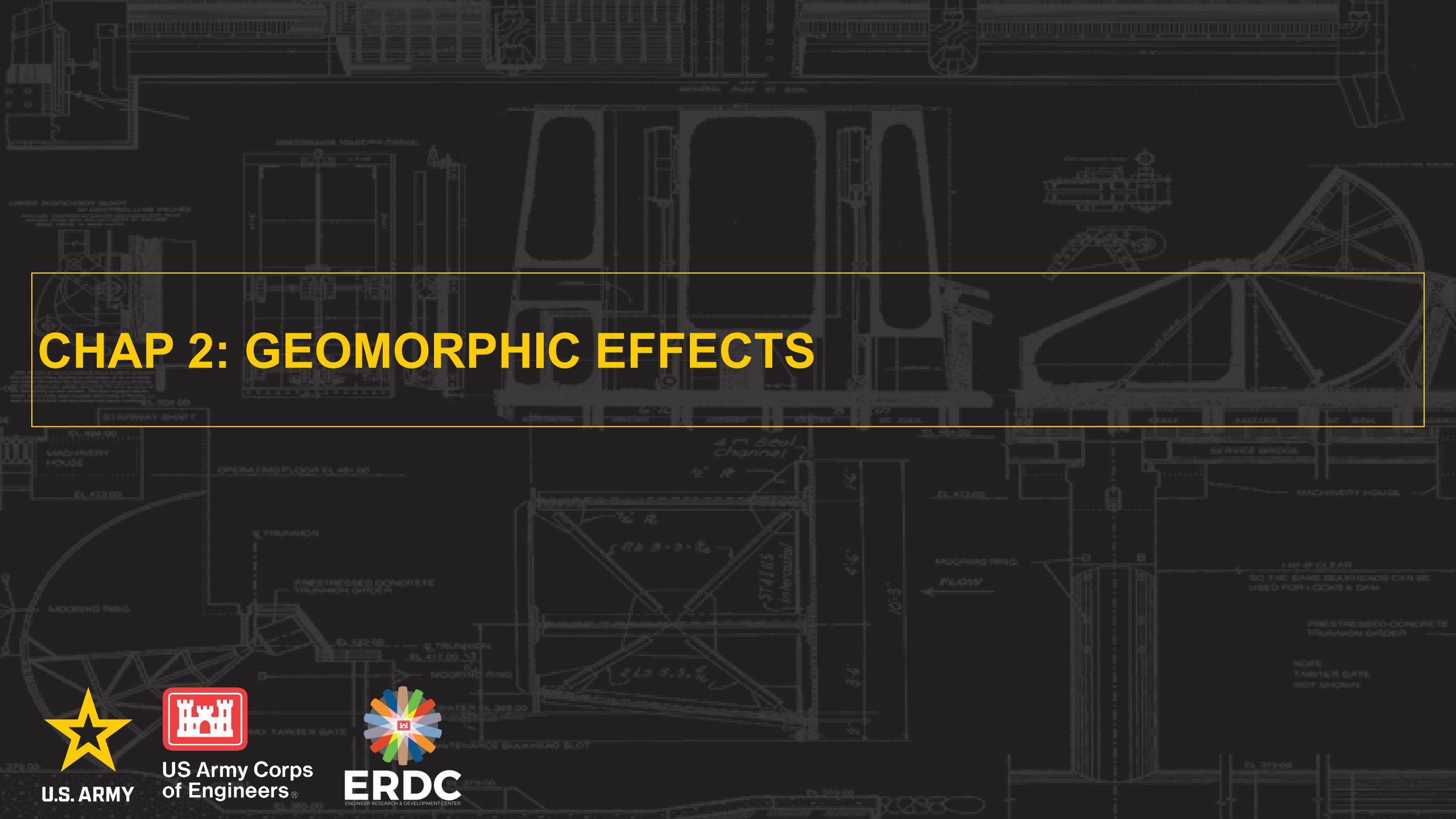
Objectives

- Research state of science
- Provide information to researchers and practitioners from a regulatory lens
- Identify future research priorities

Approach

- Literature review on existing studies of fluvial geomorphological effects on ecosystems
- Workshops and meetings- members from National Reservoir Sedimentation and Sustainability Team and other experts on needs to improve state of practice
- Linked to regulatory needs
- Developed conceptual models reflecting geomorphic, water quality, and aquatic organism effects (following Fischenich 2008)

CHAP 2: GEOMORPHIC EFFECTS



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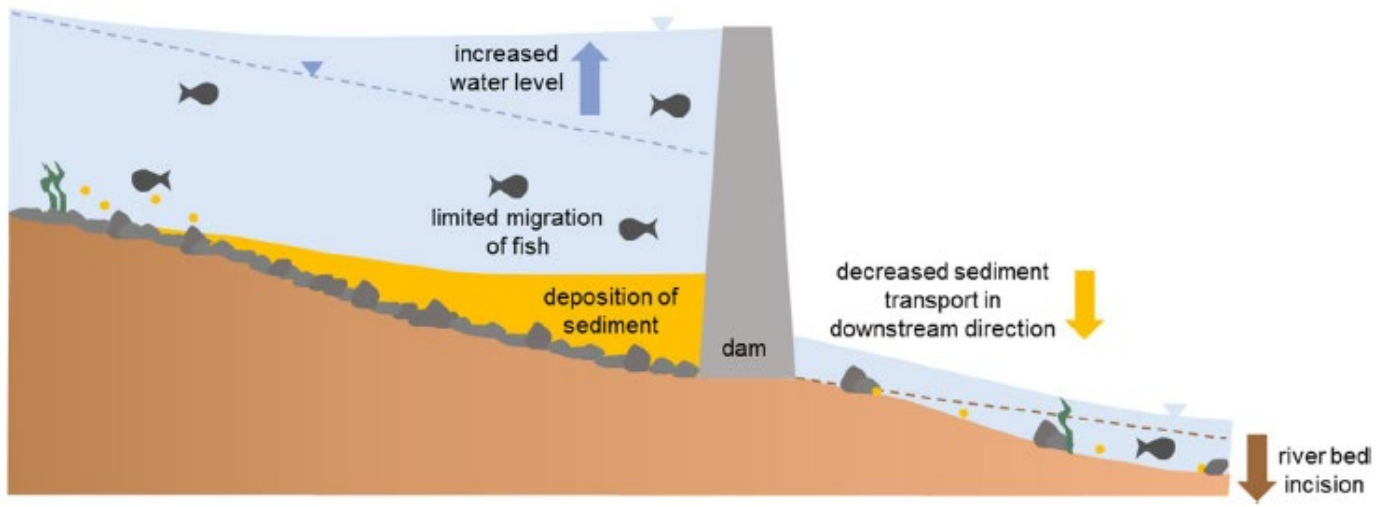
GEOMORPHIC EFFECTS

Section 404 of the Clean Water Act

- CWA - meant to protect and ecosystem integrity
- Sect 404 - requires a permit for discharges of dredged or fill material into the waters of the United States, including wetlands
- Regulates activities that may result in sediment altering aquatic ecosystem integrity (e.g., excessive sediment released into water)
- Information needed for least damaging practice alternative analysis, avoidance, minimization, mitigation plan, monitoring, etc.



MaaB et al. 2021

GEOMORPHIC EFFECTS

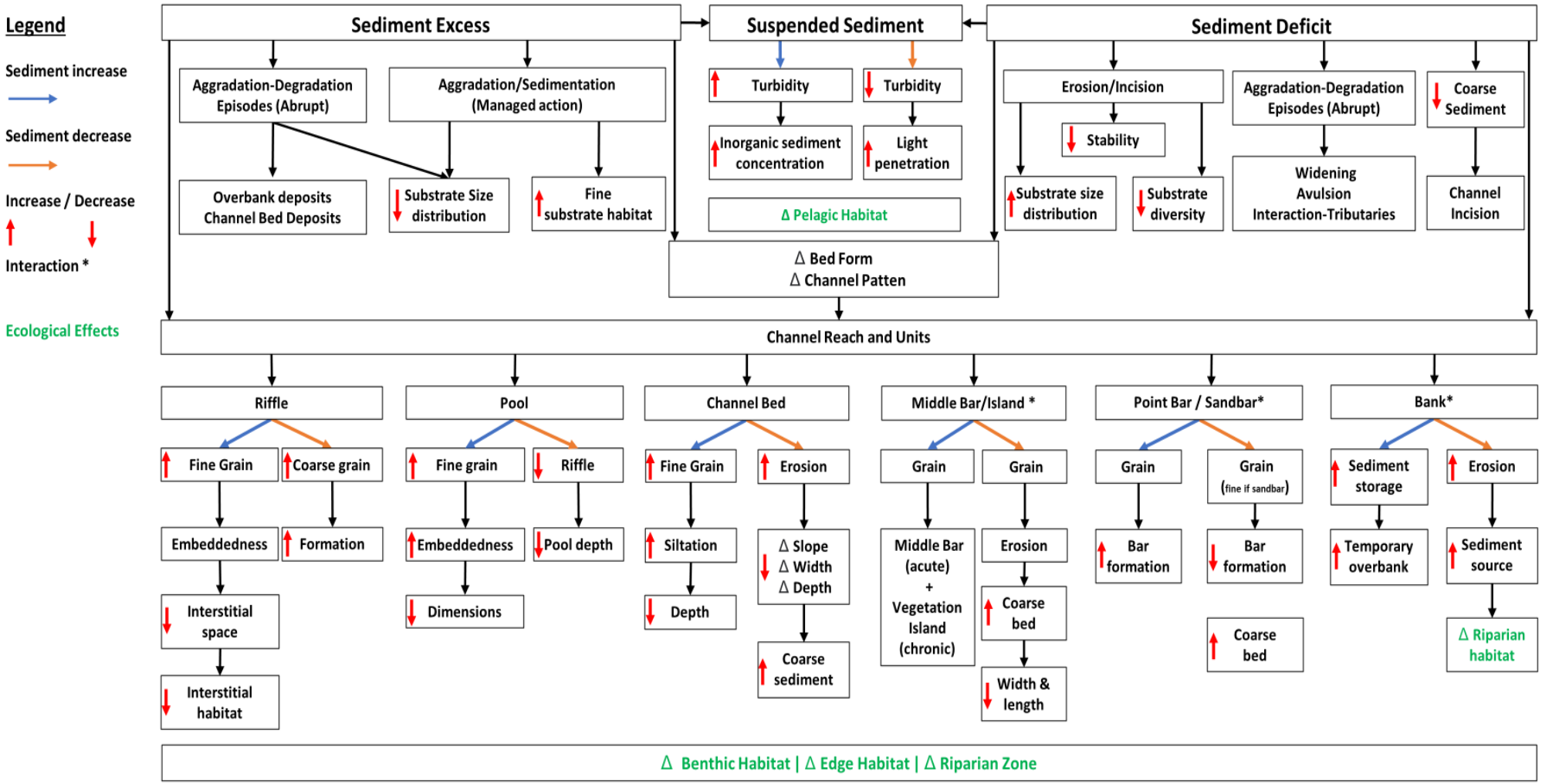
Cases	Geomorphological Changes							
	Terrace	Riffle	Pool	Bed level	Channel Form			Water velocity (after form changes)
					Width	Depth	Grain size	
Equal Q L<K	Formation	Erosion	Erosion	D	+/-	+	+/-	+/-
Decreased Q L<K	Formation	Erosion	Erosion OR deposition	0/D	+/-	+/-	+/-	+/-
Increased Q L<K	Disintegration	Erosion	Erosion	D	+/-	+/-	+/-	+/-
Increased Q L>K	Formation	Deposition	Deposition	A	+/-	+/-	+/-	+/-
Decreased Q L>K	Formation	Deposition	Deposition	A	+/-	+/-	+/-	+/-
Equal Q L=K	0	0	0	0	0	0	0	0
Decrease Q L=K	0	Erosion	Deposition	0	-	-	-	+/-
Increase Q L=K	Disintegration	Deposition	Erosion	0	+	+	+	+/-

Table adapted from Brandt (2000) and Bledsoe (personal communications)

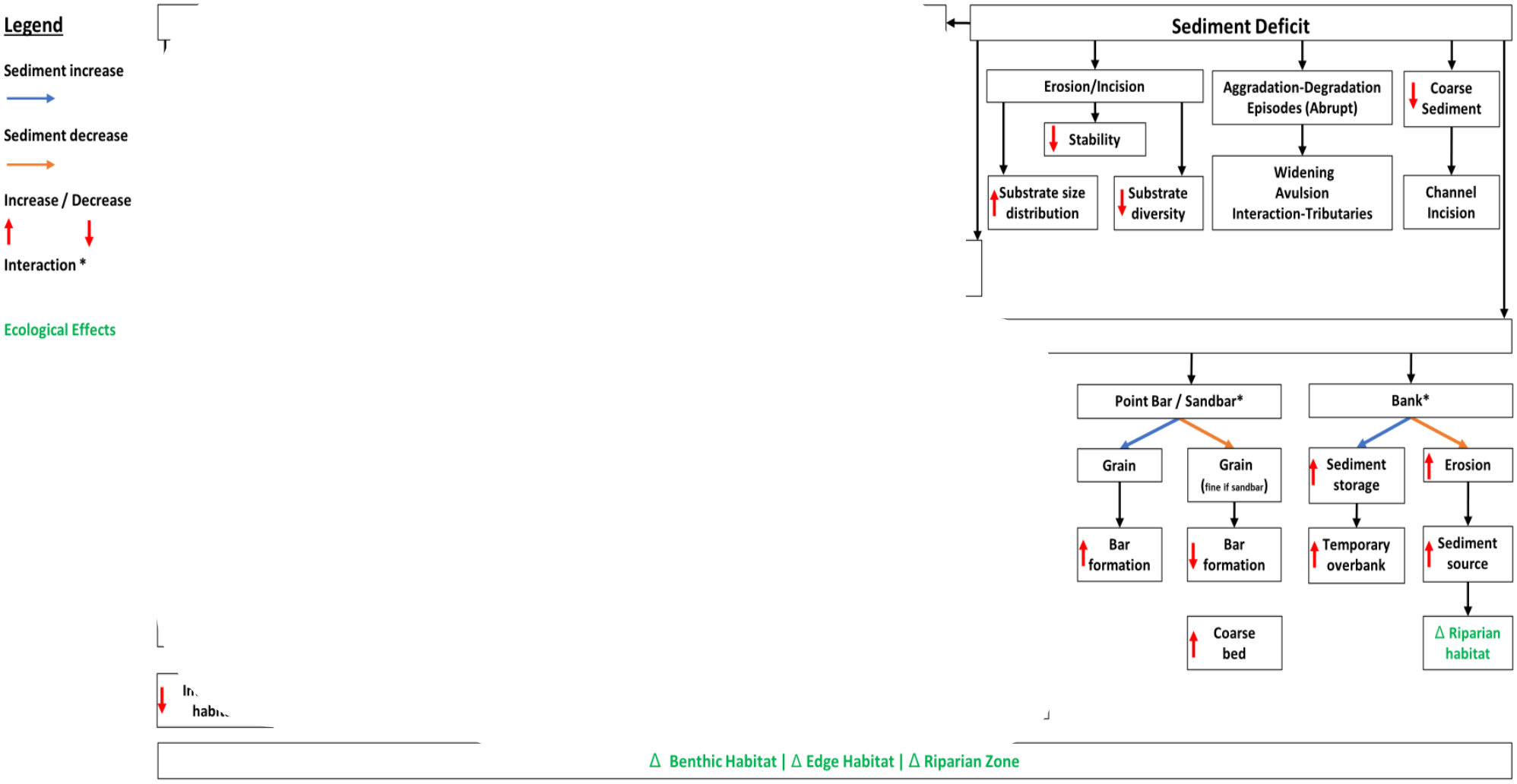
GEOMORPHIC EFFECTS

Cases	Geomorphological Changes							
	Terrace	Riffle	Pool	Bed level	Channel Form			Water velocity (after form changes)
					Width	Depth	Grain size	
Increased Q L<K	Disintegration	Erosion	Erosion	D	+/-	+/-	+/-	+/-
Increased Q L>K	Formation	Deposition	Deposition	A	+/-	+/-	+/-	+/-

GEOMORPHIC EFFECTS



GEOMORPHIC EFFECTS



CHAP 3: WATER QUALITY EFFECTS

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WATER QUALITY EFFECTS

Clean Water Act Section 401

- Requires permits for pollutant discharge into navigable waters to certify compliance with water quality standards.

- States, tribes, or the EPA issue these certifications to ensure the discharge meets local water quality requirements.

- Certification also includes monitoring, limits, and other conditions to ensure compliance with the CWA and local laws.

WATER QUALITY EFFECTS

EPA Water Quality Standards

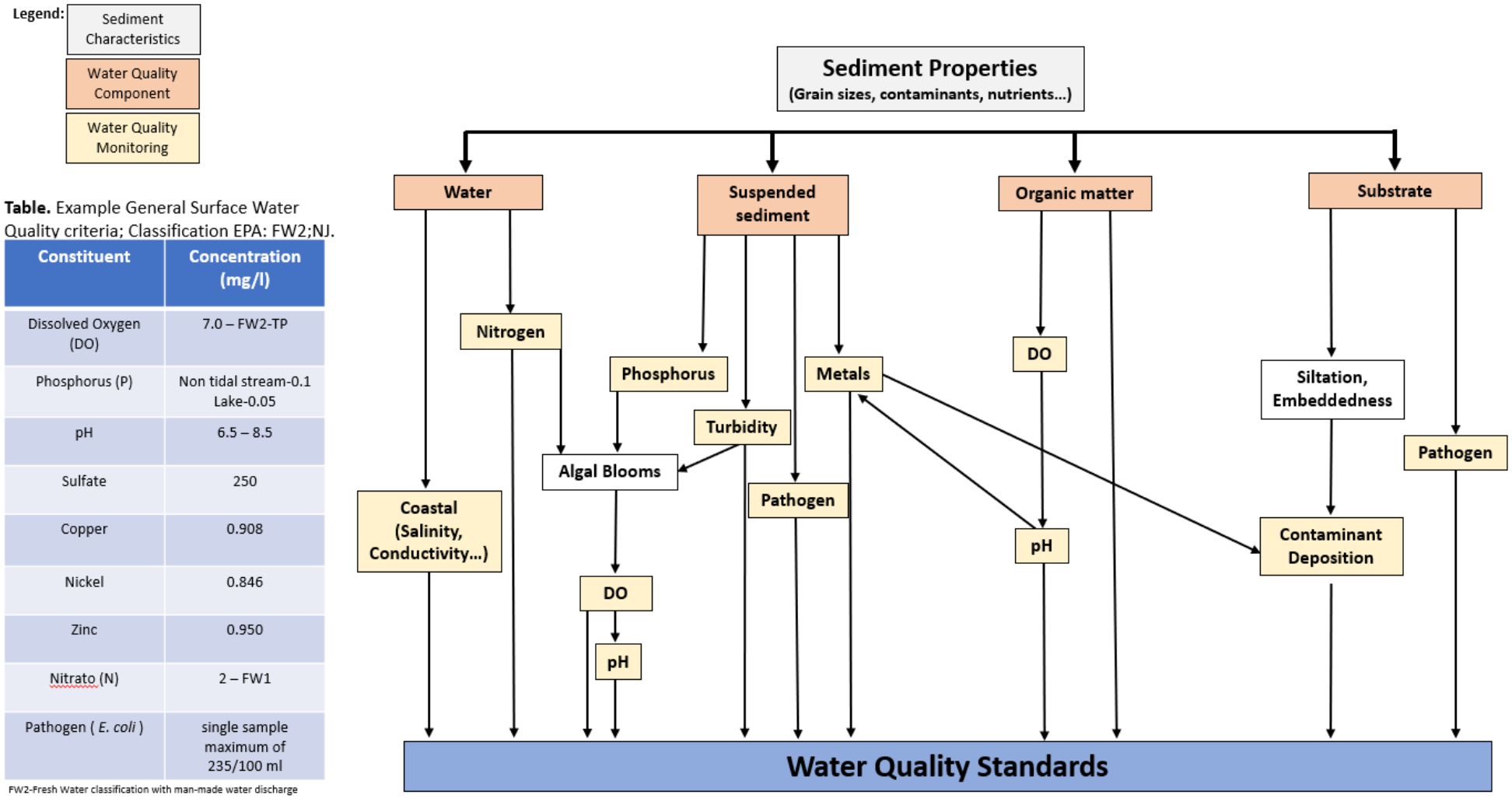


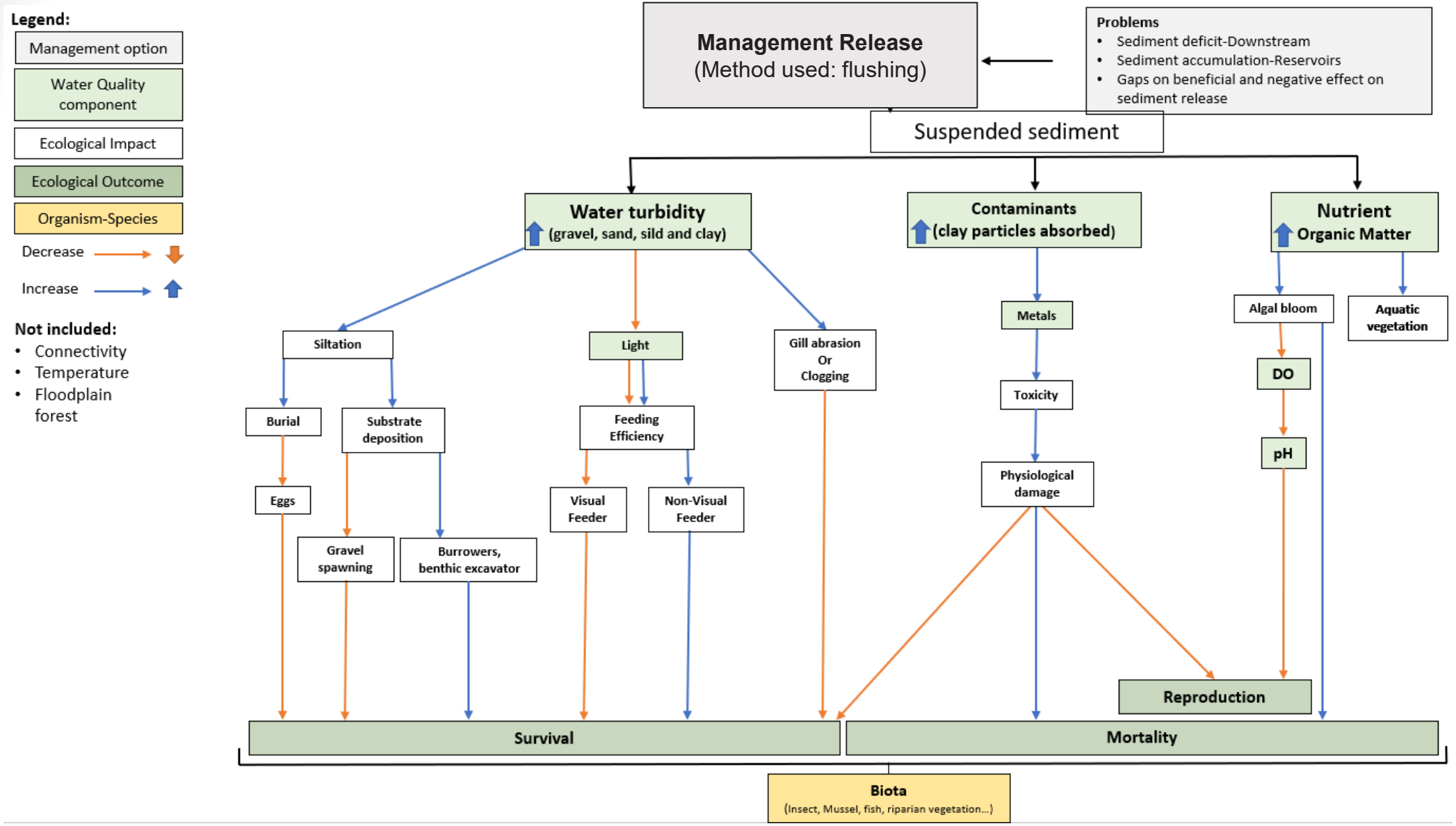
Table. Example General Surface Water Quality criteria; Classification EPA: FW2;NJ.

Constituent	Concentration (mg/l)
Dissolved Oxygen (DO)	7.0 – FW2-TP
Phosphorus (P)	Non tidal stream-0.1 Lake-0.05
pH	6.5 – 8.5
Sulfate	250
Copper	0.908
Nickel	0.846
Zinc	0.950
Nitrato (N)	2 – FW1
Pathogen (*E. coli*)	single sample maximum of 235/100 ml

FW2-Fresh Water classification with man-made water discharge

Ref. Ref. (Effective July 29, 2020) Surface water classifications, designated uses, quality criteria and policies and procedures for the waters of the State of New Jersey

WATER QUALITY EFFECTS



CHAP 4: AQUATIC ORGANISM EFFECTS

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AQUATIC ORGANISM EFFECTS

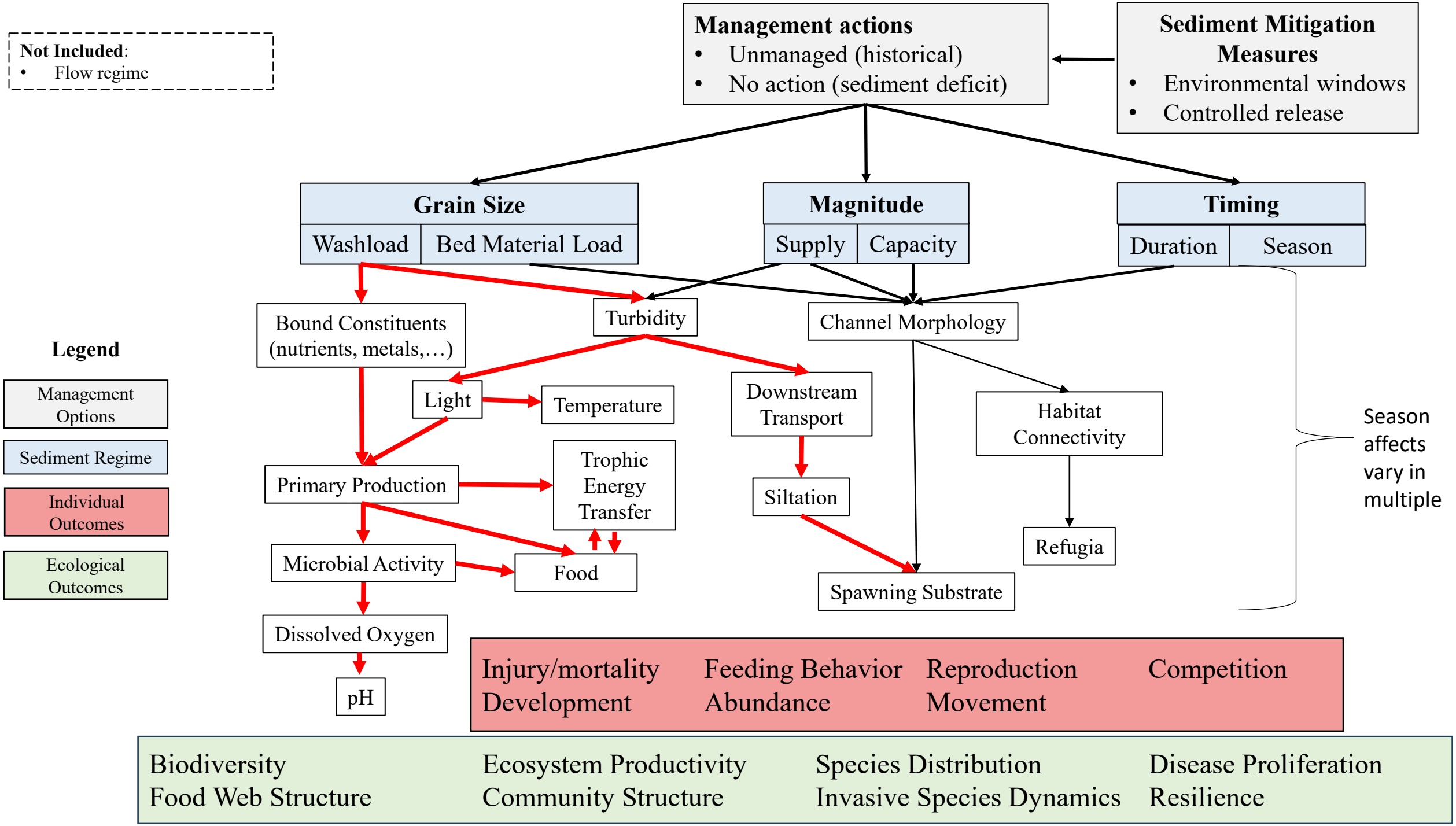
Endangered Species Act

- Protects endangered species and their habitats, requiring consultation with the U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS)

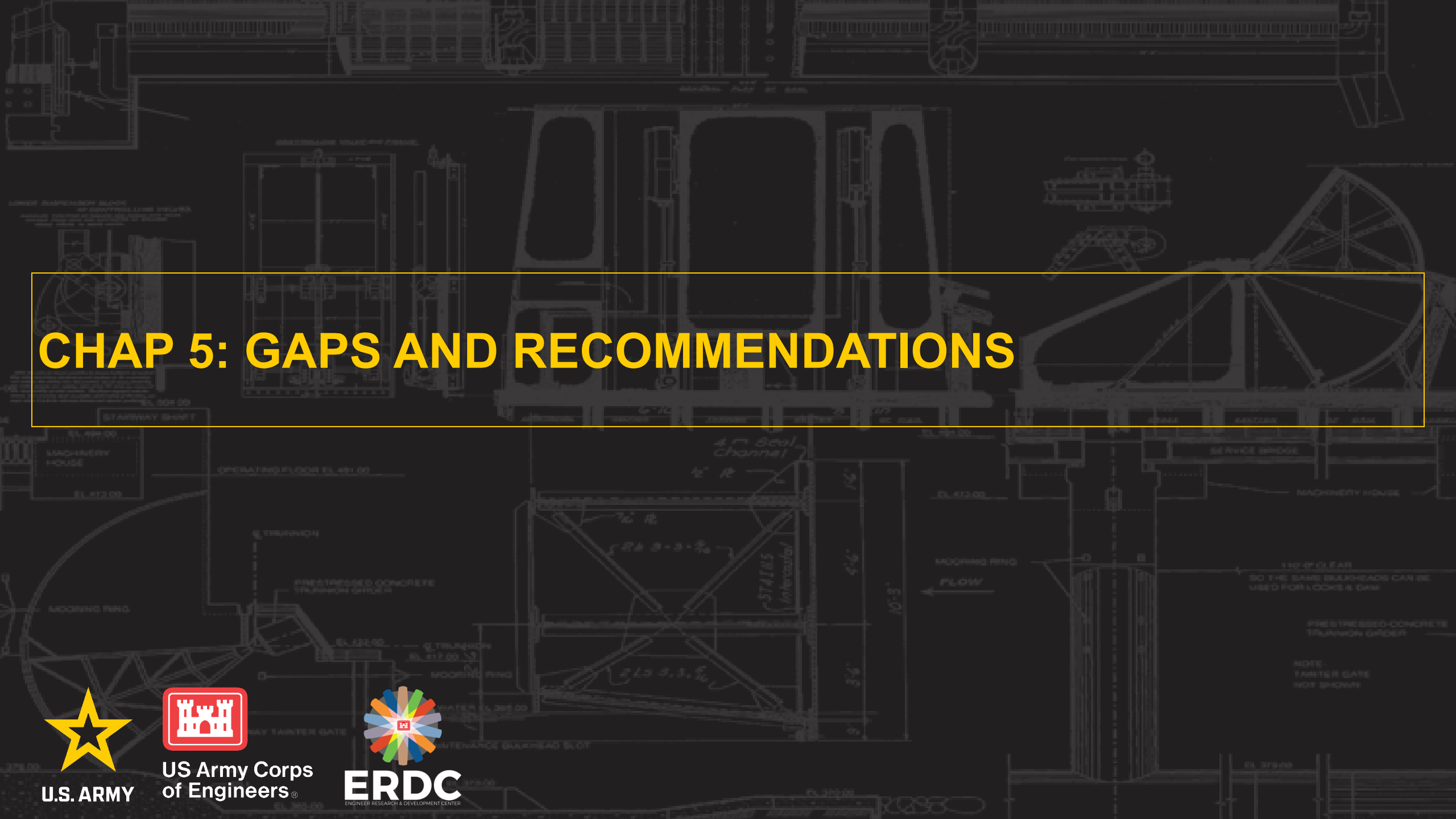
- **ESA Section 7** mandates that federal agencies ensure their actions do not jeopardize endangered species or habitats
  - requires a multi-step consultation process with USFWS and NMFS, potentially including a Biological Assessment and formal consultation

- **ESA Section 10** governs non-federal activities that may affect endangered species
  - requires an Incidental Take Permit and a Habitat Conservation Plan (HCP) to minimize impacts on species and habitats

- Information and monitoring guidance needed for sustainable reservoir sediment management practices


Not Included:
• Flow regime
Management actions
• Unmanaged (historical)
• No action (sediment deficit)
Sediment Mitigation Measures
• Environmental windows
• Controlled release
Grain Size
Washload
Bed Material Load
Magnitude
Supply
Capacity
Timing
Duration
Season
Bound Constituents (nutrients, metals,…)
Turbidity
Channel Morphology
Light
Temperature
Downstream Transport
Habitat Connectivity
Primary Production
Trophic Energy Transfer
Siltation
Microbial Activity
Food
Refugia
Spawning Substrate
Dissolved Oxygen
pH
Season affects vary in multiple
Legend
Management Options
Sediment Regime
Individual Outcomes
Ecological Outcomes
Injury/mortality
Development
Feeding Behavior
Abundance
Reproduction
Movement
Competition
Biodiversity
Food Web Structure
Ecosystem Productivity
Community Structure
Species Distribution
Invasive Species Dynamics
Disease Proliferation
Resilience

CHAP 5: GAPS AND RECOMMENDATIONS



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GAPS IN STATE OF SCIENCE/PRACTICE

• No direct regulatory guidance on releases

• **Long-Term Impact Gaps**: Insufficient data on long-term effects and species recovery after sediment disturbances.

• **Compound Effects:** Insufficient information on compound effects (e.g., climate change, reservoirs in series.

• **Lack of case studies:** Not many documented studies reservoir releases from different management alternatives, reservoir design, or geographic variability
•**Focus on Salmonids**: Most research centers on salmonids, with limited studies on other endangered aquatic species or other aquatic organisms.

• **Lack of Species-Specific Data**: Few studies address sediment effects on species adapted to low-visual or sediment-rich environments.

• **Unclear Sediment Release Thresholds**: The optimal sediment release volumes that balance ecological benefits and species safety are not well defined.

RECOMMENDATIONS

- Modify regulatory guidance
- Develop short and long-term monitoring programs
- Diversify sediment release case studies
- Develop comprehensive tools for management and decision-making
- Expand research beyond salmonids
- Species-specific research
- Define optimal sediment release volumes
- Research on compound effects

CONCLUSION

CHALLENGES AND OPPORTUNITIES

	Impact?	Benefit?
Added sediment	A “pollutant”	Crucial to riverine function
Turbidity	May cause gill abrasion	Helps avoid predation
Deposition	Affects spawning and food sources	Floodplain reconnection, sand bar habitat creation

DEPENDS!

OVERVIEW OF CASE KANSAS STUDY

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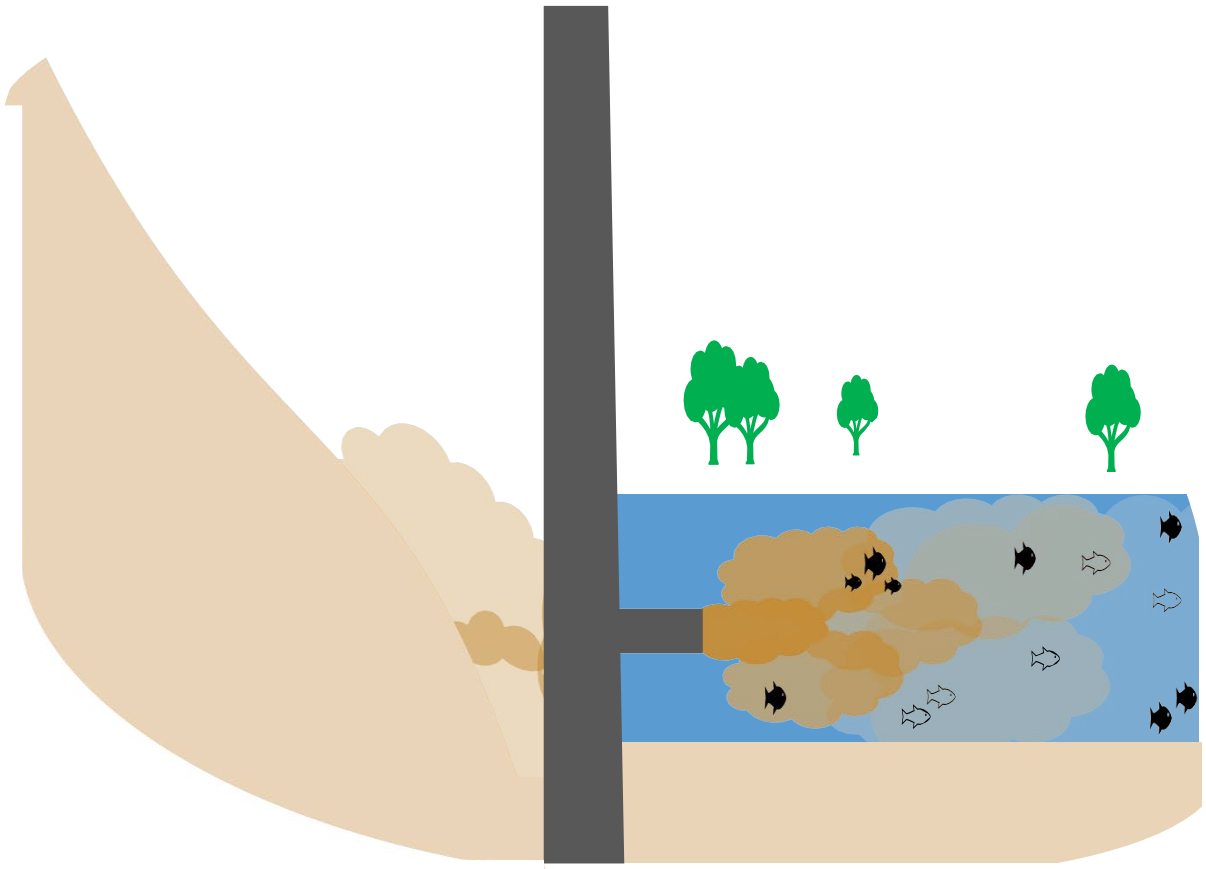
PILOT PROJECT: WATER INJECTION DREDGING



Tuttle Creek

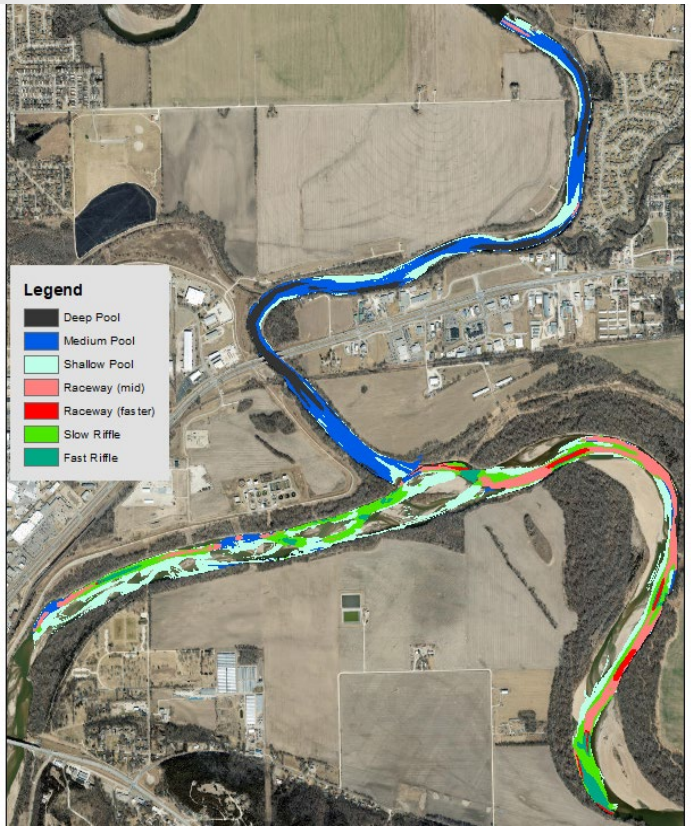
- 47.9% of its storage capacity is lost due to sedimentation
- Expected to fill within 40 years
- Incised channels downstream
- Prairie stream species T&E

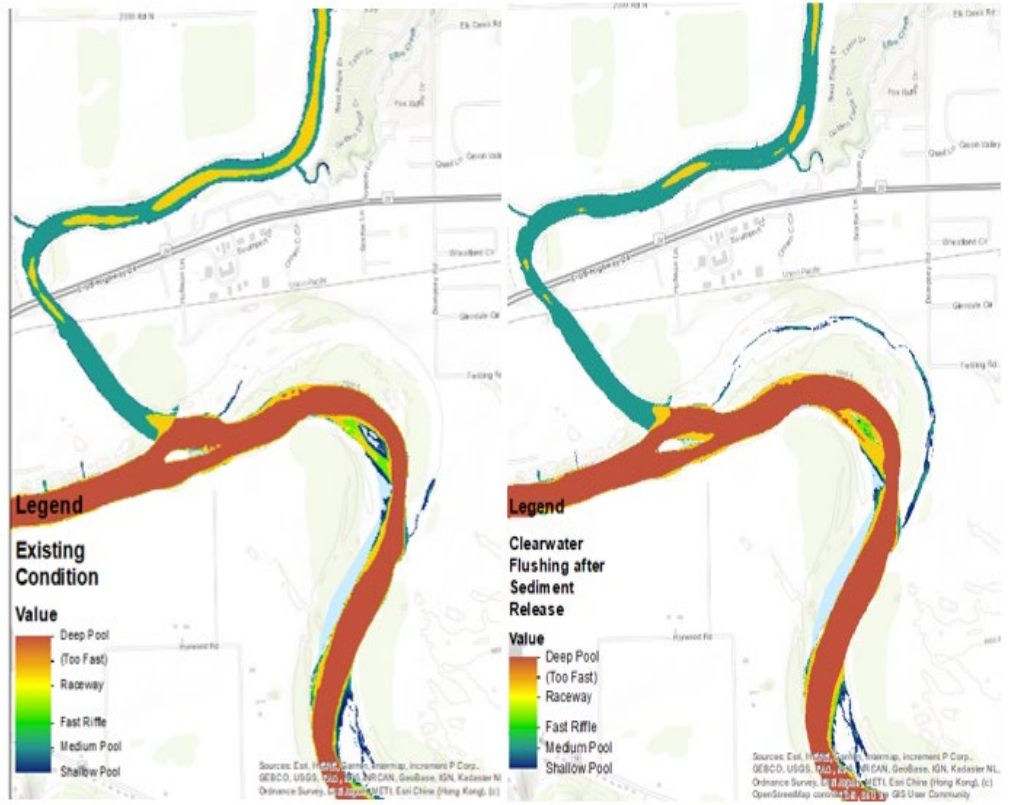
WID Pilot to start Spring 2025

- First time in the world

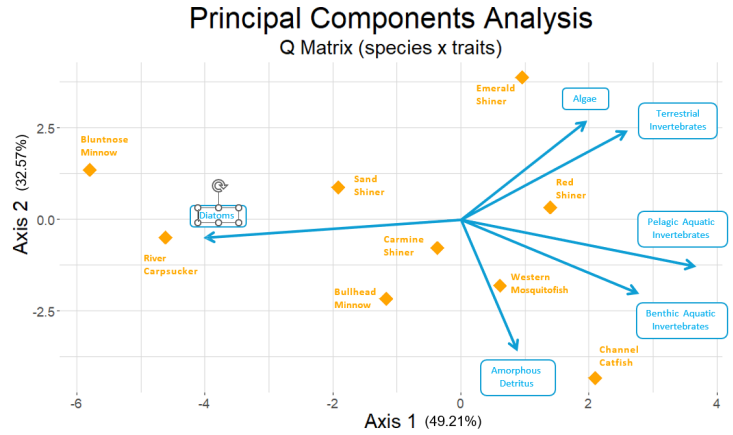
Figure: Rowley and Gido 2024 SFS Conference

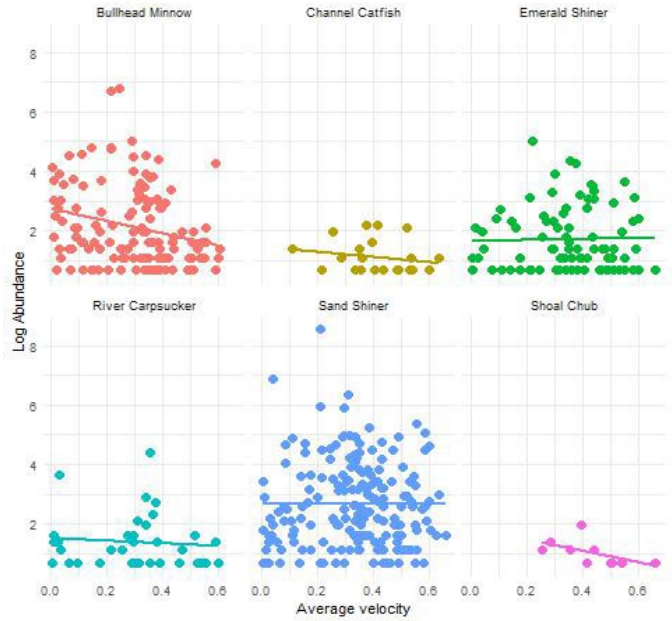
BRIDGING DISCIPLINES





2D Hydraulic and sediment transport models at confluence (Harris and Wiest)





PCA fish diets
Abundance vs. Vel (Rowley and Gido)

PUBLISHED WORK

Wiest, S.R., Harris, A.E., and Hernandez, D.D. (2024). Hydraulic model (HEC-RAS) of downstream of Tuttle Creek Reservoir at the confluence of the Big Blue River and the Kansas River near Manhattan, KS. Dryad. https://datadryad.org/stash/dataset/doi:10.5061/dryad.k3j9kd5gr

Harris, A.E., and Hernandez-Abrams, D.D. (2024). Monitoring Geomorphology to Inform Ecological Outcomes Downstream of Reservoirs Impacted by Sediment Release. Engineer Research and Development Center Vicksburg MS Environmental Lab. https://hdl.handle.net/11681/48470

Hernandez-Abrams, D.D., Bailey, S.E., and McKay, S.K. (2022). Environmental Effects of Sediment Release from Dams: Conceptual Model and Literature Review for the Kansas River Basin. Technical note created by Engineer Research and Development Center Environmental Lab, Vicksburg, MS. https://hdl.handle.net/11681/44880

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- Kansas State University: (Dr. Keith Gido/ Logan Rowley, Gido Lab
- Kansas City District: Dr. John Shelley, Laura Totten, Marvin Boyer, K. Bingham, M. Mansfield, J. Albrecht, D. Wansing
- UGA River Basin Center
- Feedback: Drs. Rollin Hotchkiss, Matthias Kondolf, Gregory Morris, Eric Sommerville, Lisa Gordon, Kyle Gordon, Mary Freeman, Seth Wenger, Amy Rosemond, Desiree Tullos…

QUESTIONS

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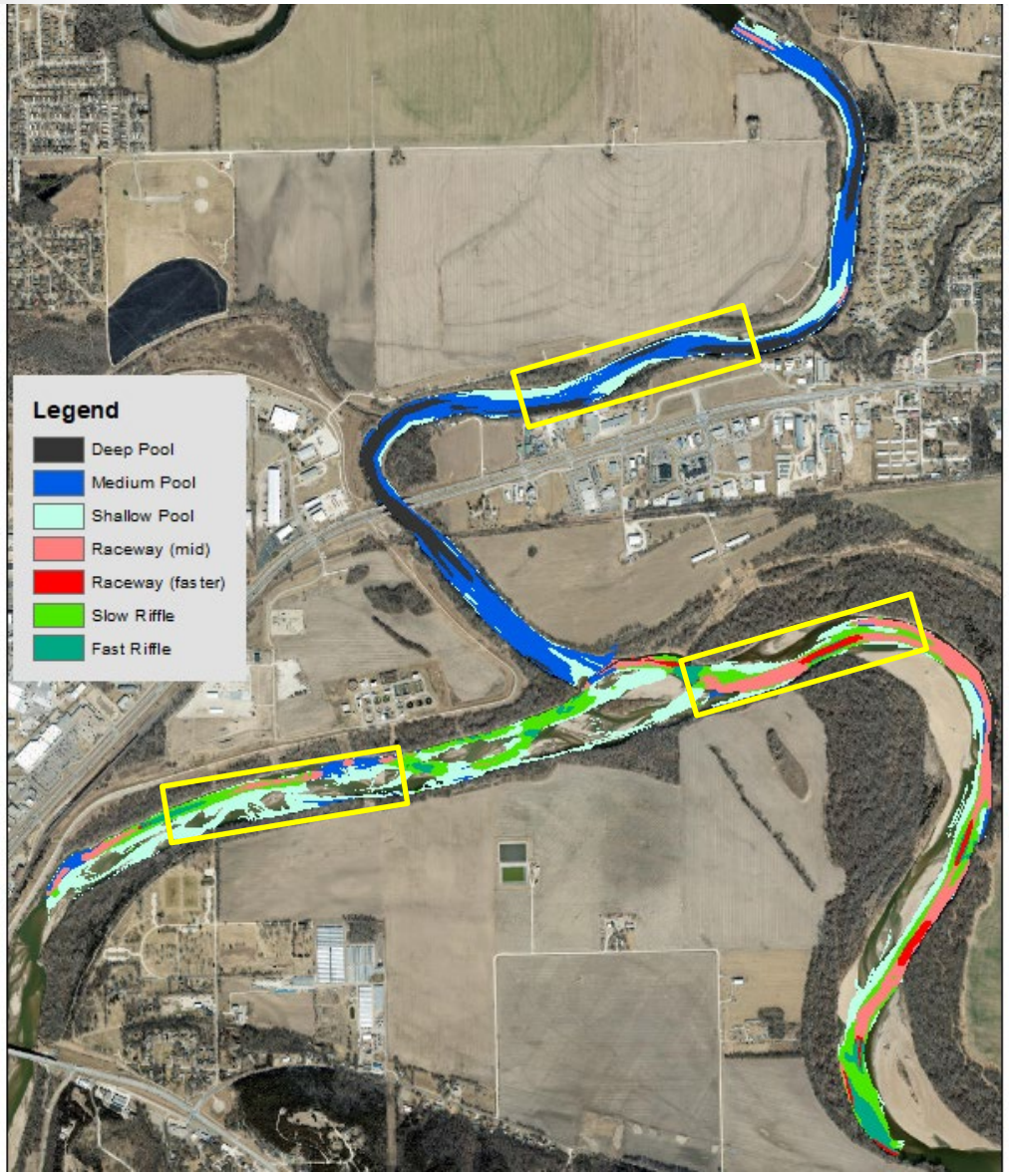
FUTURE DIRECTIONS



Linking hydraulics with ecology

- Mesohabitat classes from hydraulic model results.
- Diversity and type of mesohabitat compared with fish surveys (Rowley and Gido, KSU).
- Forecast change in mesohabitat availability and implications on aquatic species.

Model technical report with ecological implications (Harris et al.)

Geospatial analysis journal paper (Cordero and Harris)