EWN Engineering With Nature®

Introducing the Riverine Engineering Practice Guide for Floodplain Benching

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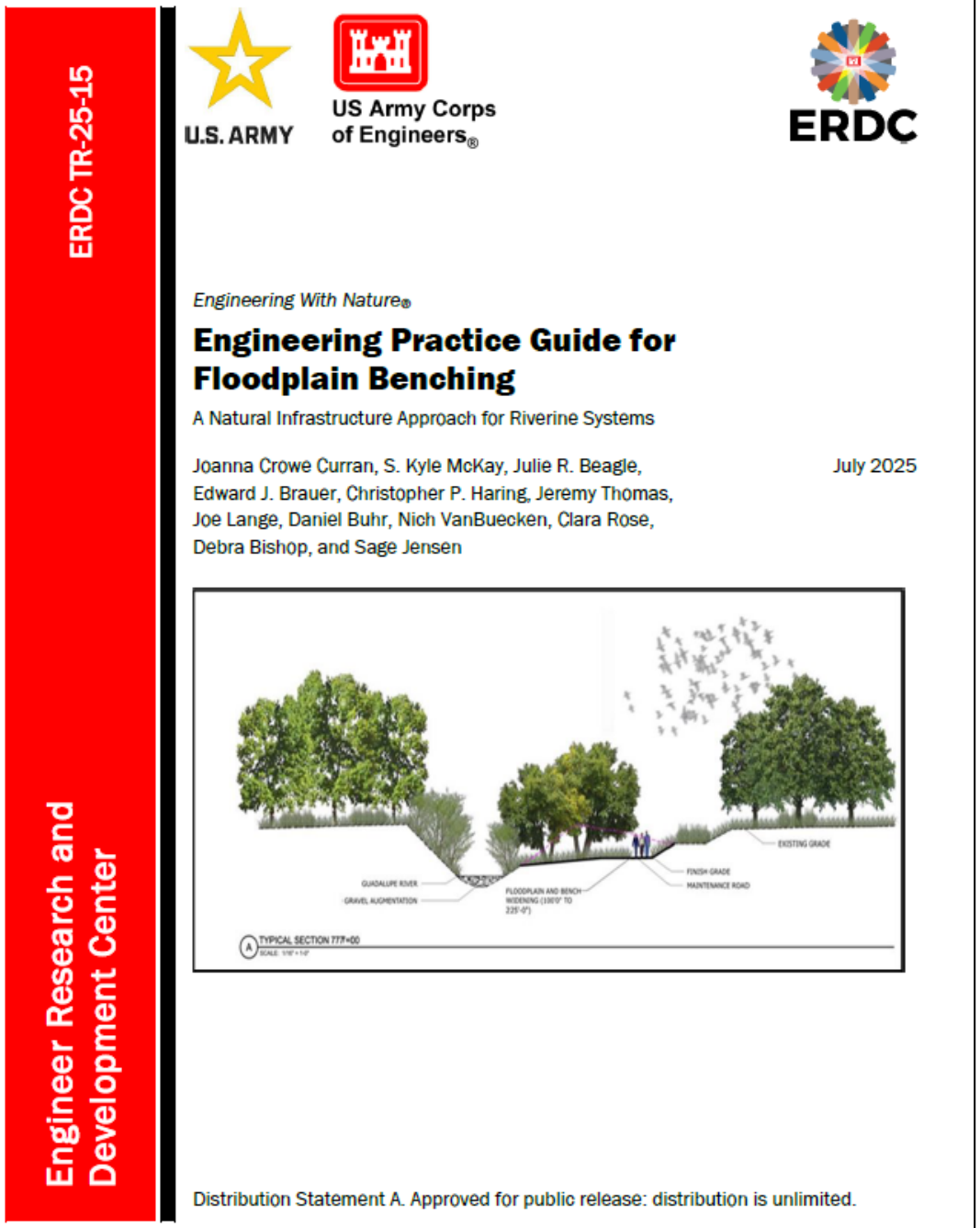
Image from : Azinheira, Scott, Hession, and Hester. 2014. WRR, 50, 6168–6190, doi:10.1002/2013WR014400.

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Team of Authors

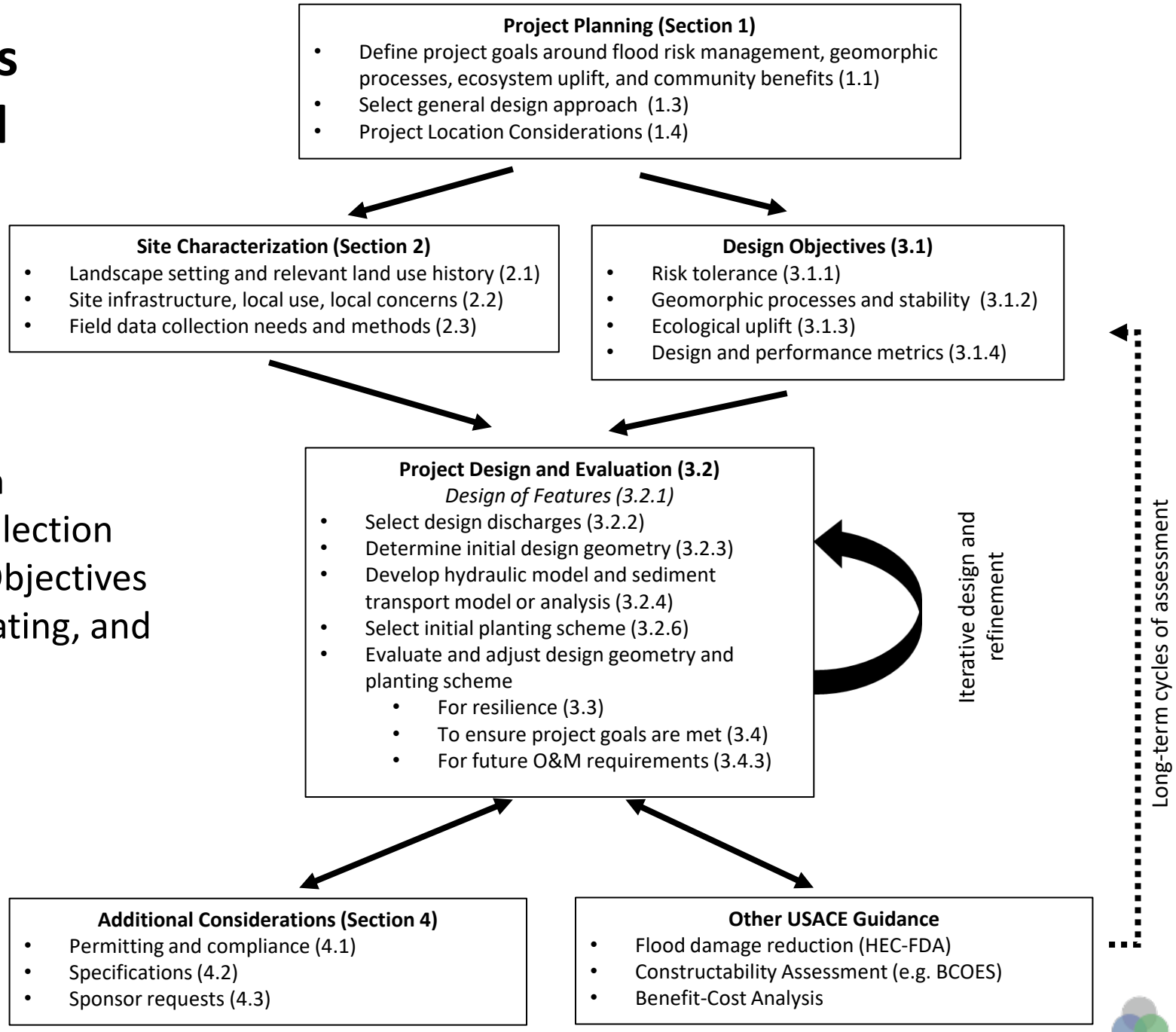
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https://ewn.erdc.dren.mil/engineering-practice-guides/



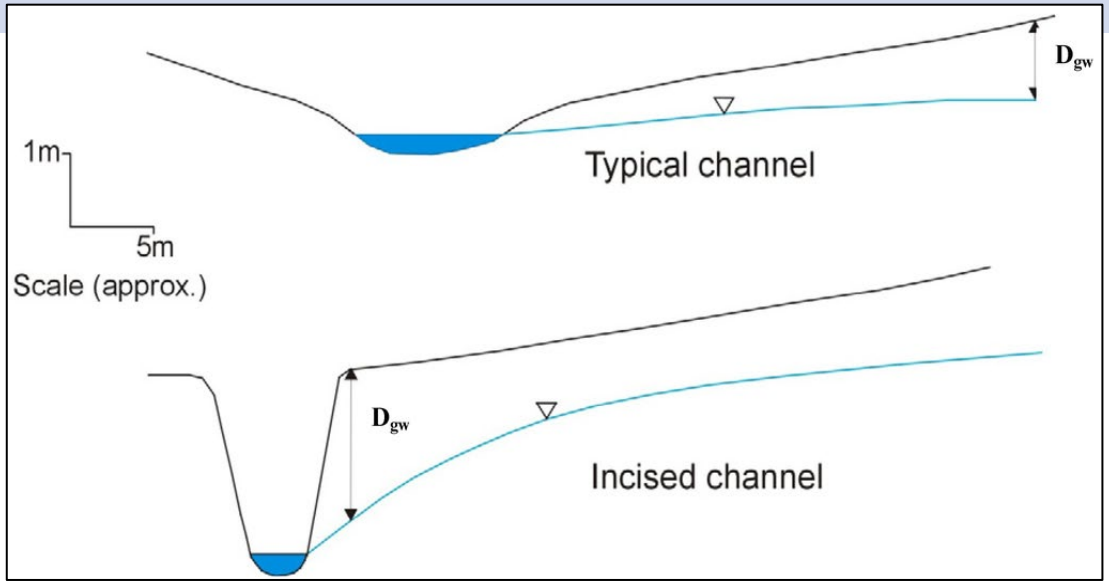
Practice Guide Follows the Workflow Defined for Designing a Floodplain Bench

1. Planning and Site Selection
2. Desktop and Field Data Collection
3. Setting Goals and Design Objectives Creating the Design, Evaluating, and Iterating to a Final Design



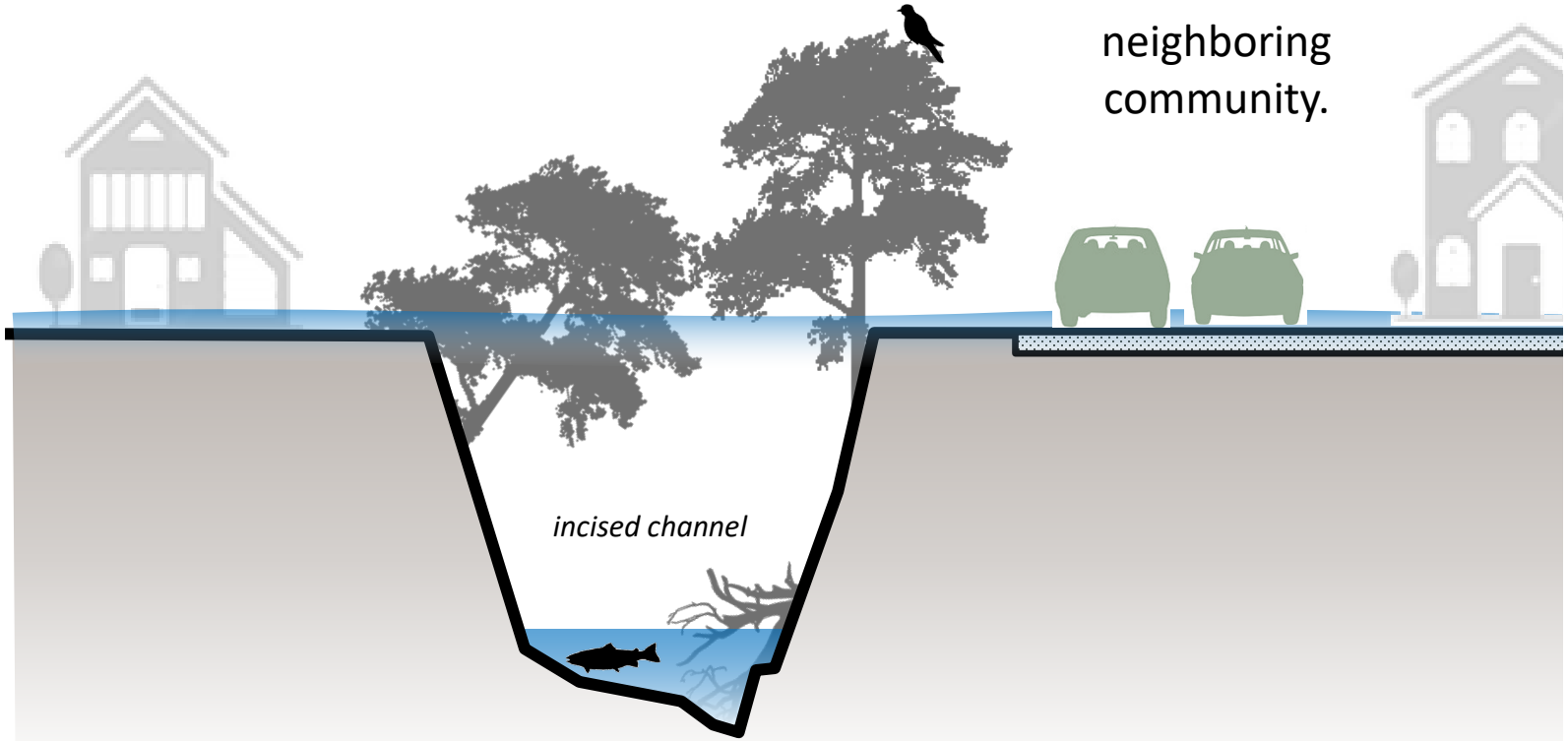
For inland river systems where incision causes riparian flows to occur only during floods to the community

- Vertical erosion and a lack of overbank flow can lead to a lowered water table, drying floodplain soils
- Intervene where channel incision is a result of changes in flow or sediment supply and planform is stable
- Incised and leveed channels are often good candidates

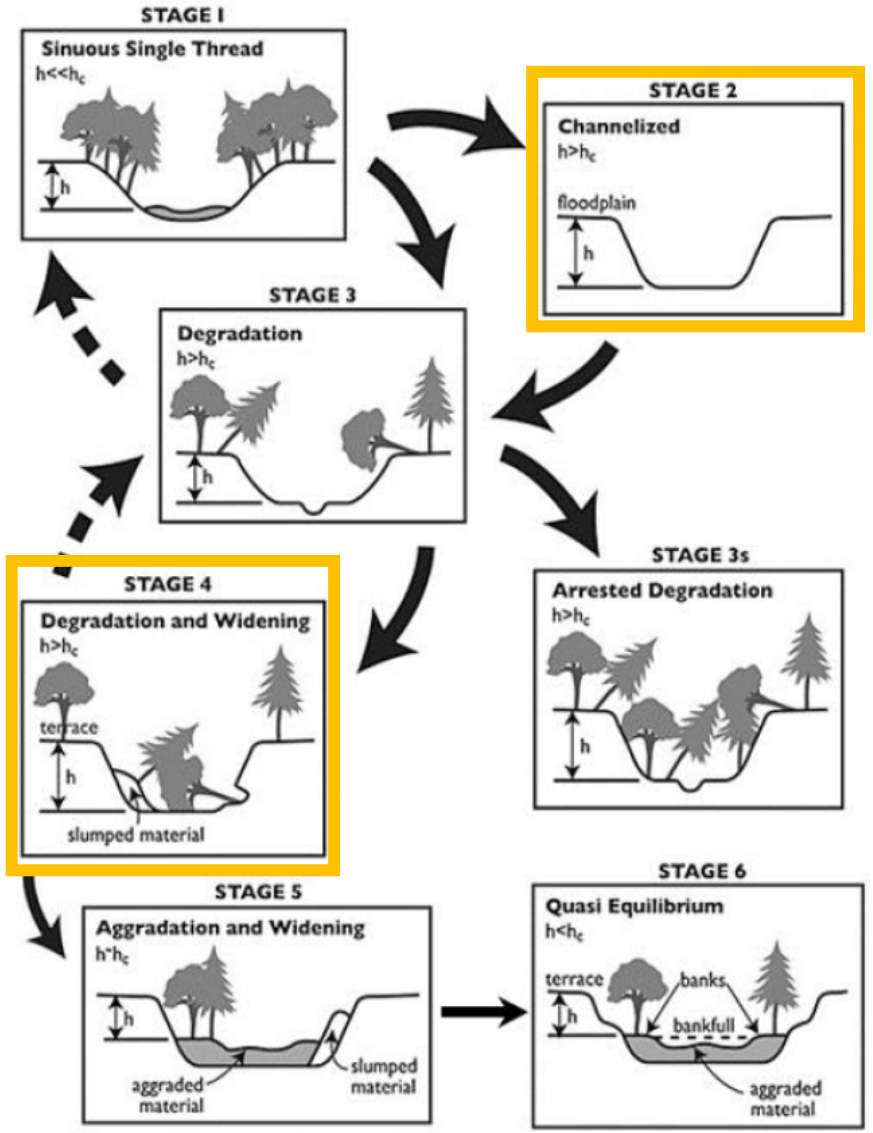




Consider Current Channel Morphology



Overbank water floods the neighboring community.

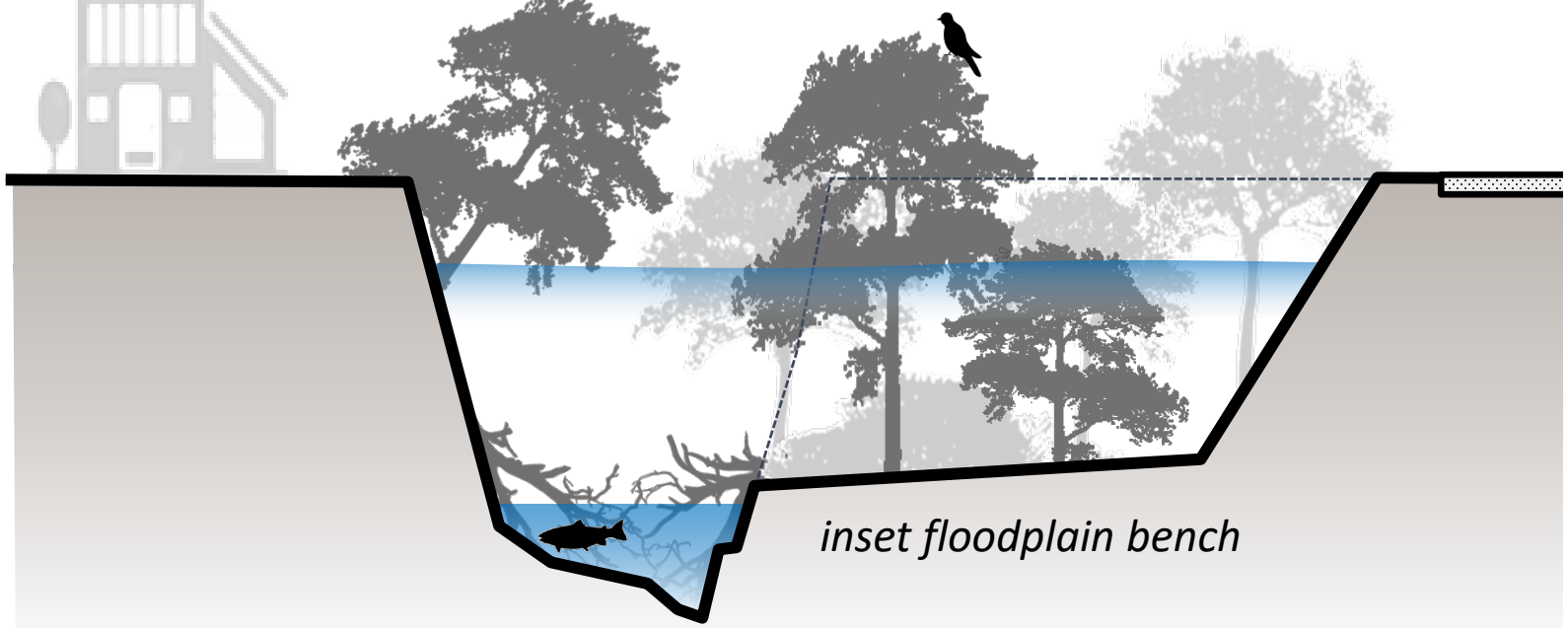


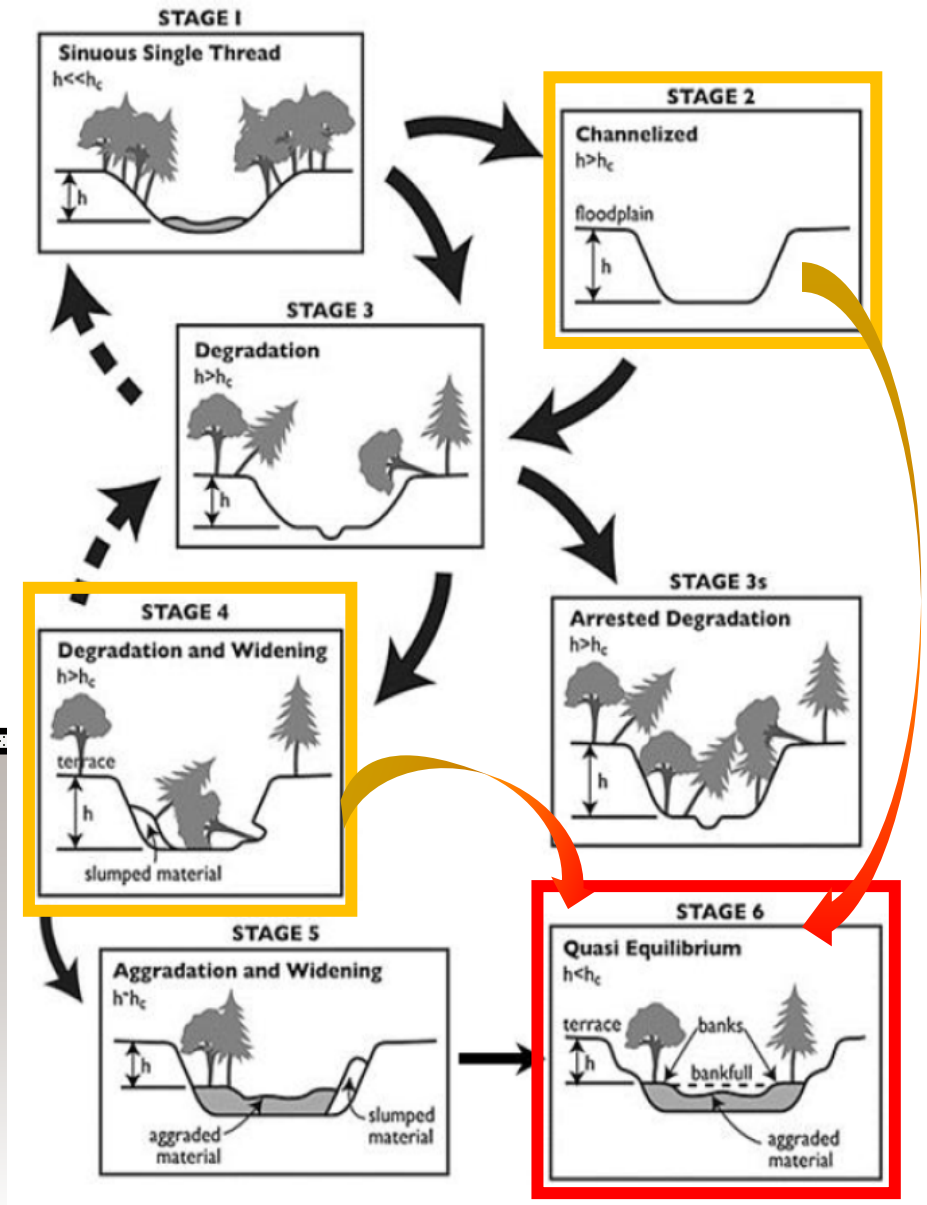
Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)

Define Desired Channel Morphology

A floodplain benching project skips in-between stages of river adjustment

River contained within the banks except at extreme flood events.





Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)

Goals Define the Project Purpose
All Goals are Given Equal Weight and Importance

Flood Risk Management (1.1.1) —space for low-level flooding, lower flood peaks and velocities downstream, maintain or reduce flood risk

Geomorphic Function (1.1.2) — a channel geometry matched to current and future flow and sediment regimes for geomorphic equilibrium

Ecological Uplift (1.1.3) —aquatic and terrestrial habitat benefits within a larger riparian corridor with greater hydraulic diversity

Community Benefits (1.1.4) —recreation, access; the priorities of the sponsor and neighbors bring to the project



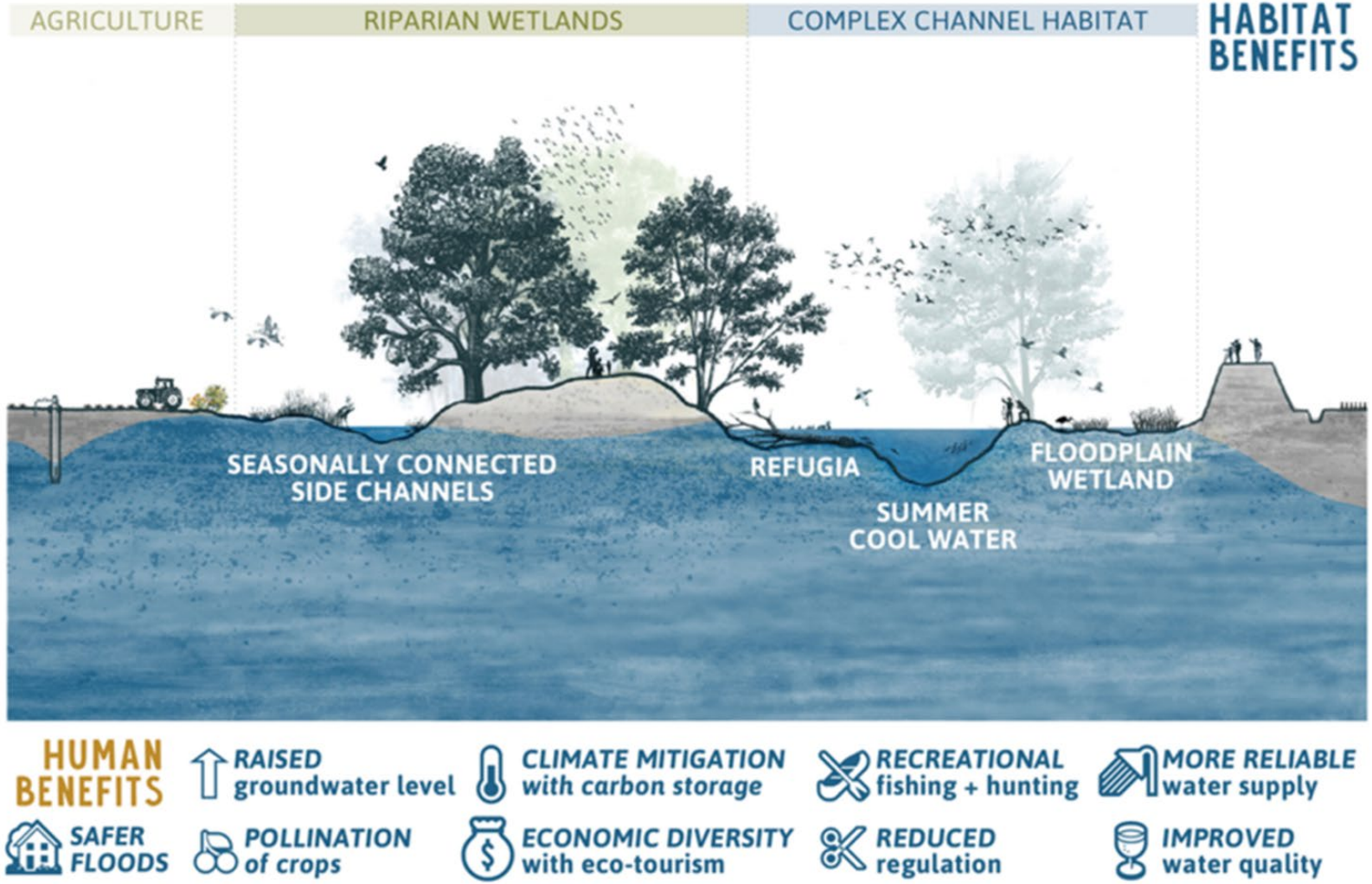
Equal Goal Consideration Created a Multiple Purpose Project

Existing conditions
- Incised flashy system
- Narrow, encroached riparian corridor

As a Single Purpose FRM Project:
- Build a levee away from river
- Plan to truck in borrow material needed for construction

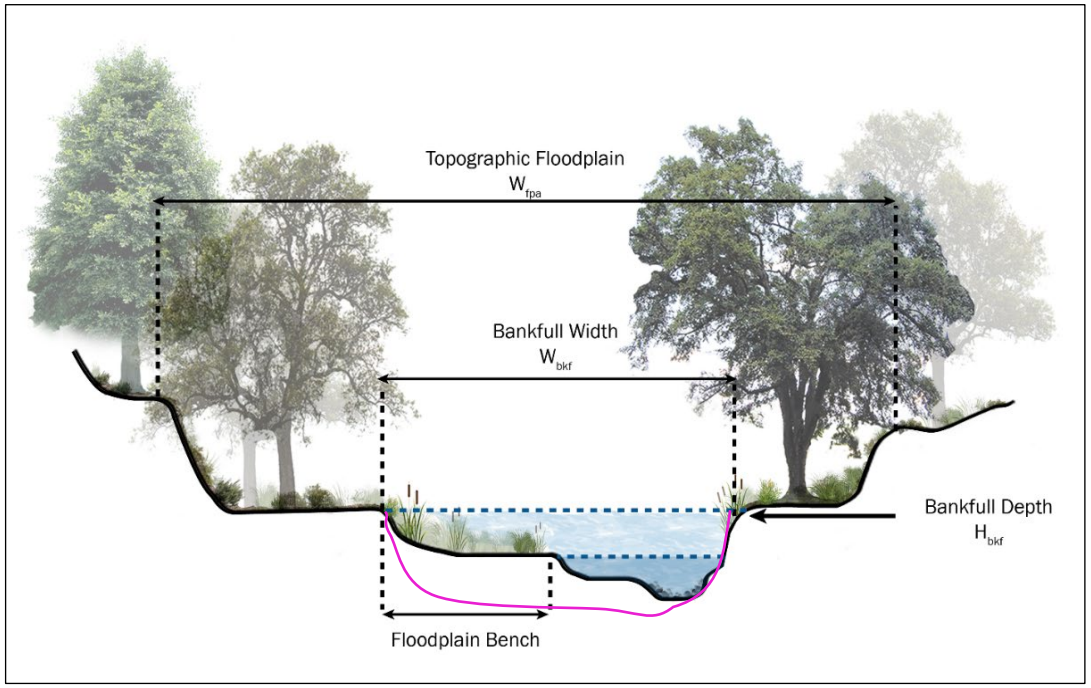
Community needs:
- Ground water depletion in valley
- Special status species needs
- Recreation
- FRM

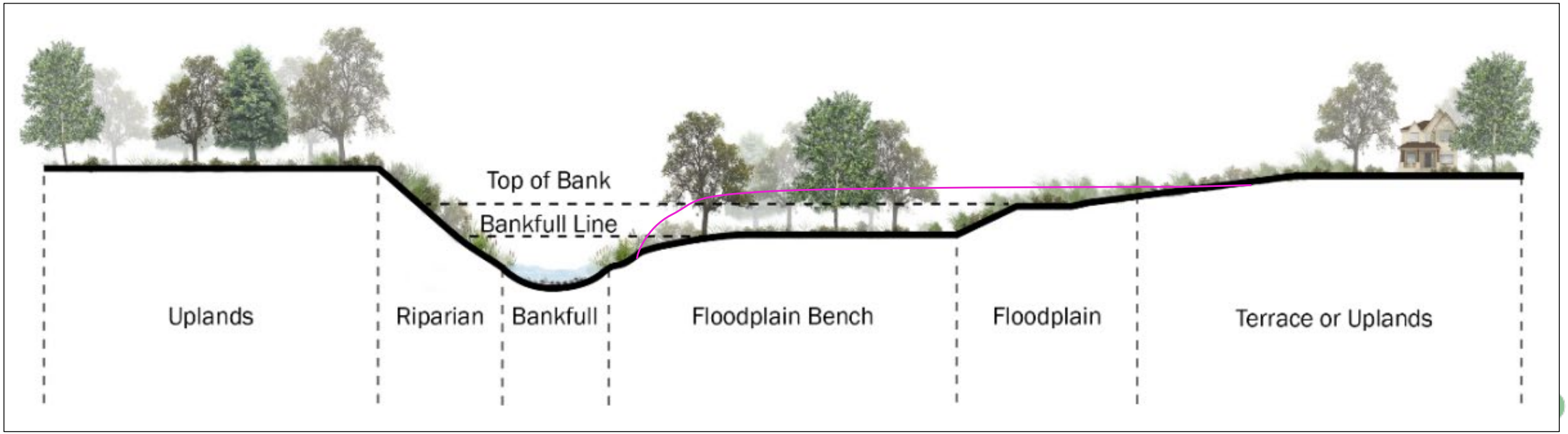
With Benching Project Added:
- Excavated bench supplies borrow material
- Riparian corridor with floodplain wetland
- Raised groundwater table and increased groundwater recharge



Two general methods to create bench

- Build a bench within the existing channel cross section
- Lower the adjacent floodplain to create a bench and wider total cross section

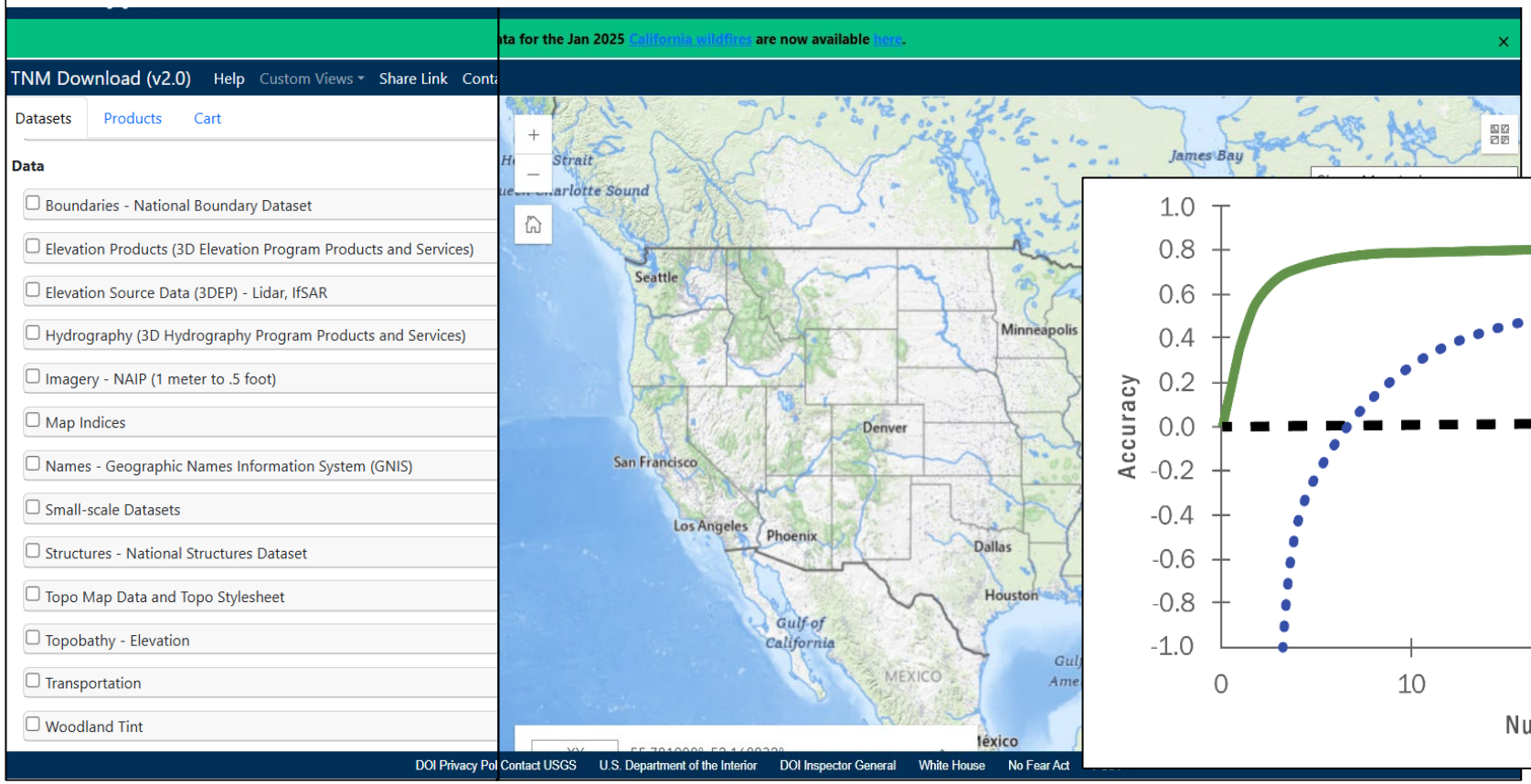


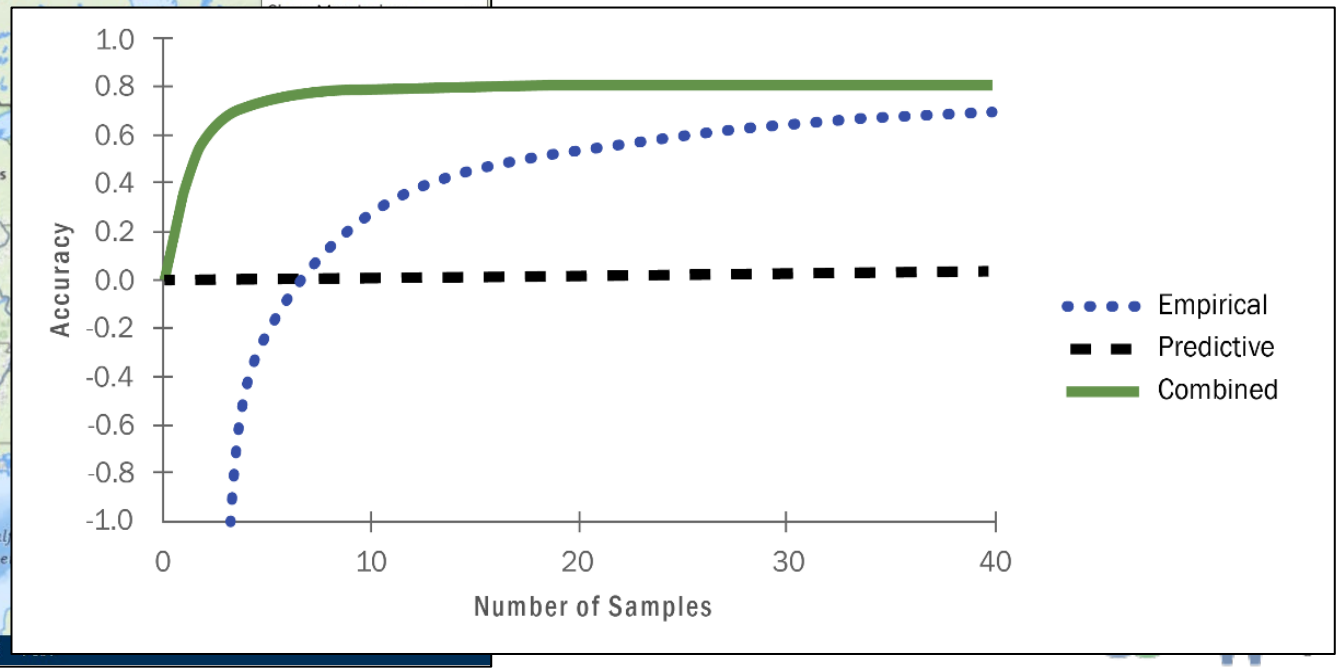


Identify Site Constraints and Available Data, and Begin Collecting Field Data

- 2.1 Desktop — gather what already exists and narrow the reach
- 2.2 Societal — past and future land use, infrastructure, and who to talk to
- 2.3 Field — collect only what the desktop work could not tell you







Ignoring Sediment Is a Common Driver of Failure

Is it a sand or gravel bed channel?

- Implications for field data collection methods

Will the bench elevation alter bedload transport?

- Implications for design







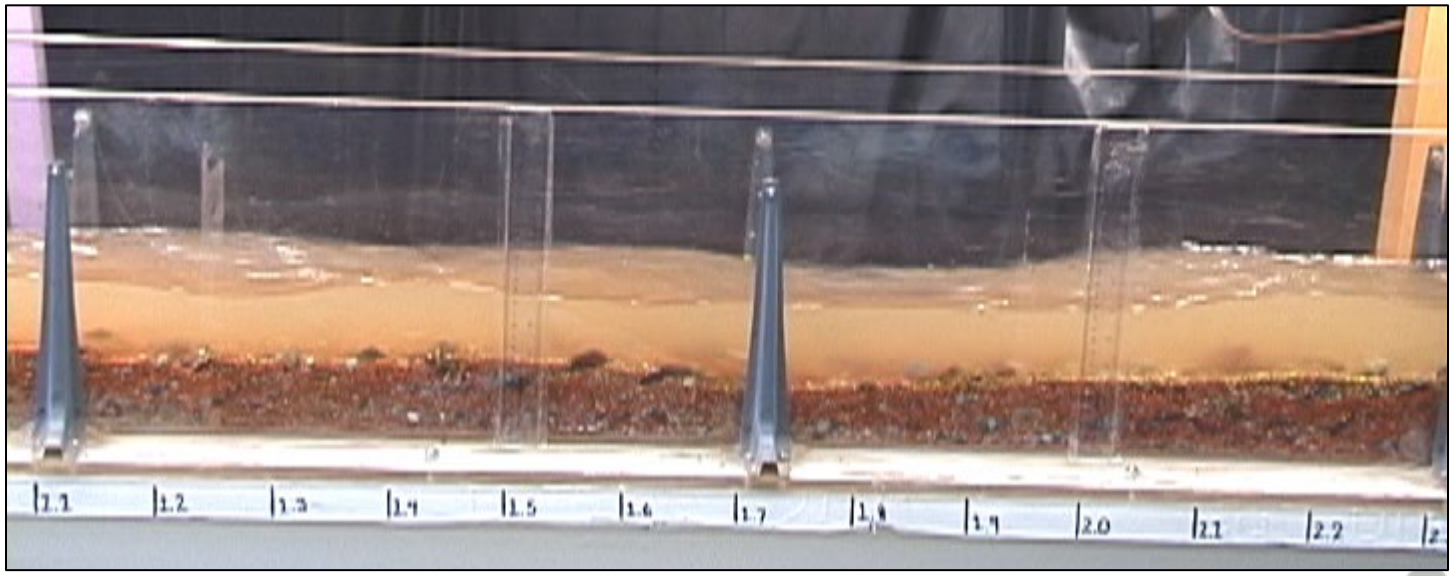
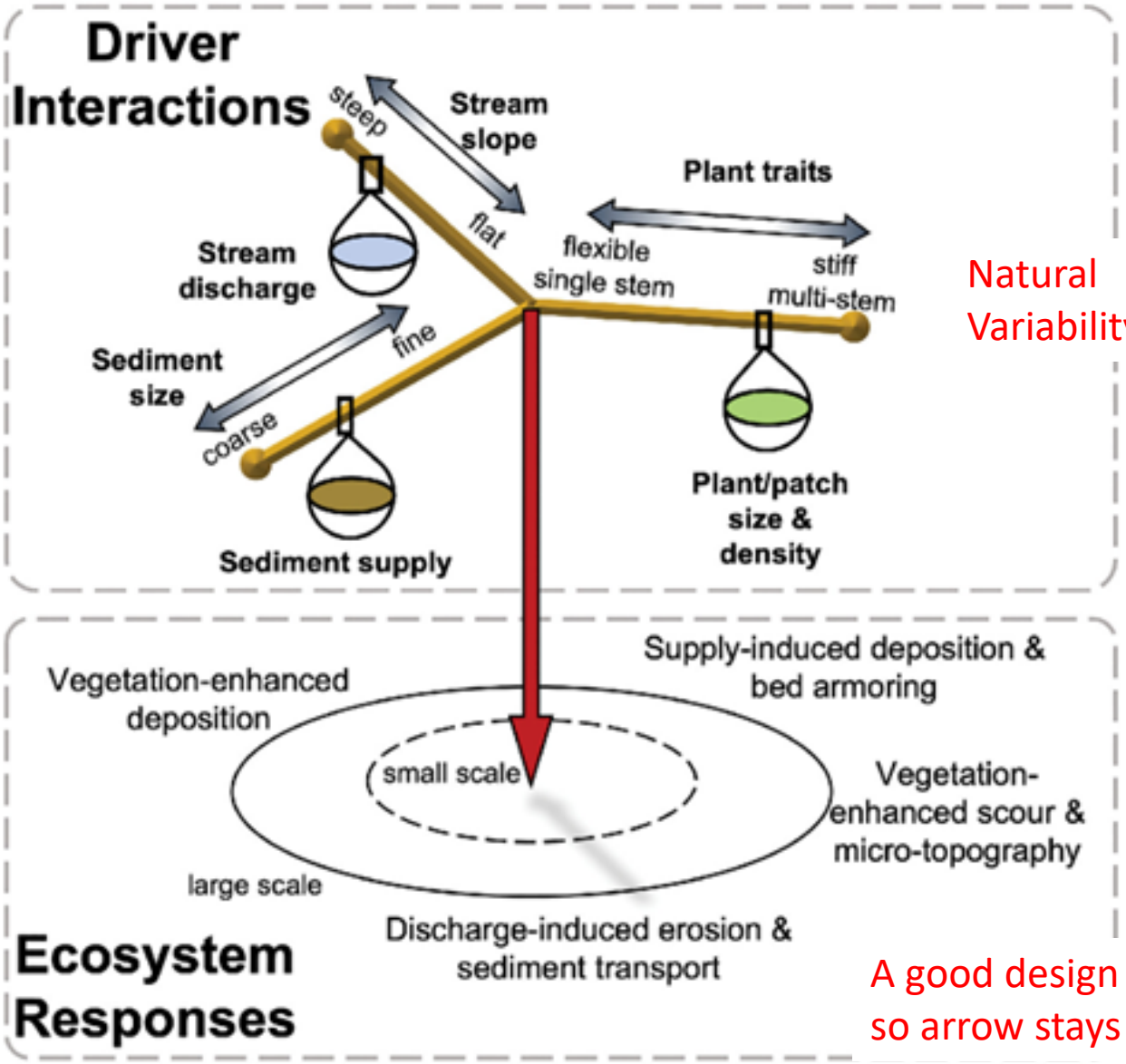


Table 1 — Data checklist at the end of Section 2

Question to Answer from Collected Data	Desktop	Field
What is the social context for floodplain benching (users, community needs, cultural context, societal motivations)?	2.2	
How does site physiography matter for project design?	2.1.1, 2.1.2	
How has the channel changed over recent history (10 years, 100 years)?	2.1.1, 2.1.3, 2.1.5	
What is the stage of channel evolution?	2.1.1, 2.1.3	2.3.1
What are estimated to be future levels of stability or dynamism under current channel geometry (pre-project)?	2.1.1, 2.1.3, 2.1.4	
How large is the floodplain?	2.1.4	
What are the channel width and longitudinal profile?	2.1.3	2.3.1
What are current uses of the floodplain? Are there notable societal assets to consider?	2.1.3, 2.2	verify
What aspects of historical or cultural significance should be considered in design?	2.2.3	
Is there infrastructure in the area that could impact design or the amount of acceptable risk?	2.2.1, 2.2.2	verify
Are there plant or animal species of concern or interest in the area?	2.1.5	2.3.6
What are the native forms of vegetation in the region?	2.1.5	2.3.5, 2.3.6
What soils are at the site, and what does that mean for excavation?	2.1.1	2.3.4
What is the grain size distribution of sediment on the channel bed?	2.1.2	2.3.2
What is the sediment supply?		2.3.3
What are the range of flows at the site and the different flow frequencies (10%, 50%, 90% flows)?	2.1.4	

Design Objectives are Defined so Project Meets Design Goals



Risk tolerance (3.1.1)
Geomorphic processes and stability (3.1.2)
Ecological uplift (3.1.3)

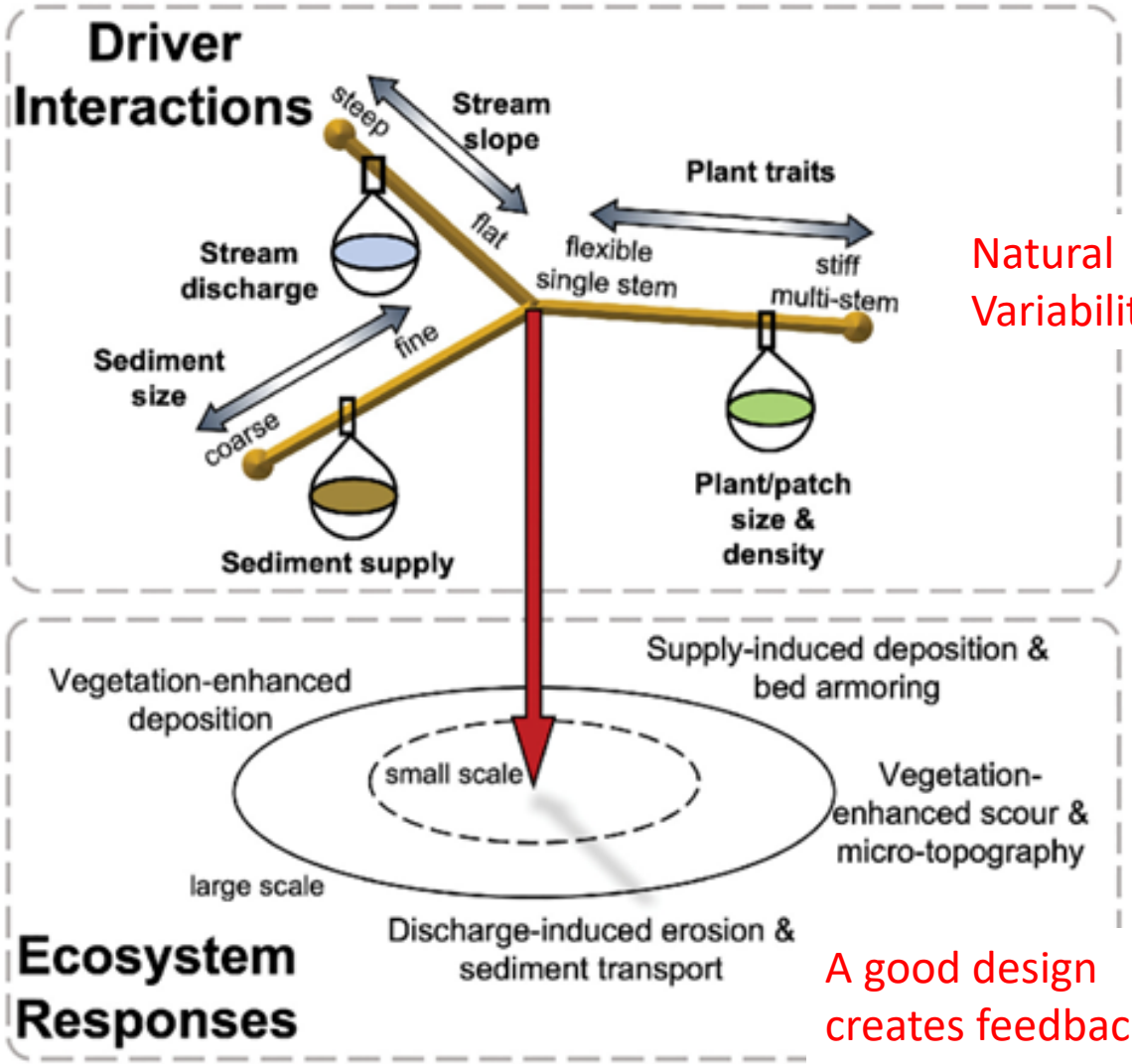
Design objectives connect to project goals and help define the risks that could lead to failure

- Bench erodes — too dry for the ecosystem goal
- Channel incises — bench floods too rarely
- Bank erosion upstream or downstream of the bench
- Bench aggrades — flood risk goal not met
- Invasives take over — habitat and conveyance lost
- Deposition or erosion reaches infrastructure or private property

A good design creates resilience so arrow stays small scale

Image from Bywater-Reyes, Diehl, Wilcox, Stella, and Kui. 2022. ESP&L, 47 (10): 2410–36. https://doi.org/10.1002/esp.5385.

Metrics Quantify Project Objectives and Build in Resilience



A good design creates feedback systems to minimize negative impacts

Metrics:

- define how much change can occur before project objectives are at risk
- reflect acceptable risk and natural variability
- identify what is more and less critical in the design
- establish criteria for evaluating the design
- set up future O&M
- set threshold for adaptive management

What is the tolerance level for erosion or deposition on the bench for the vegetation to survive and FRM met?

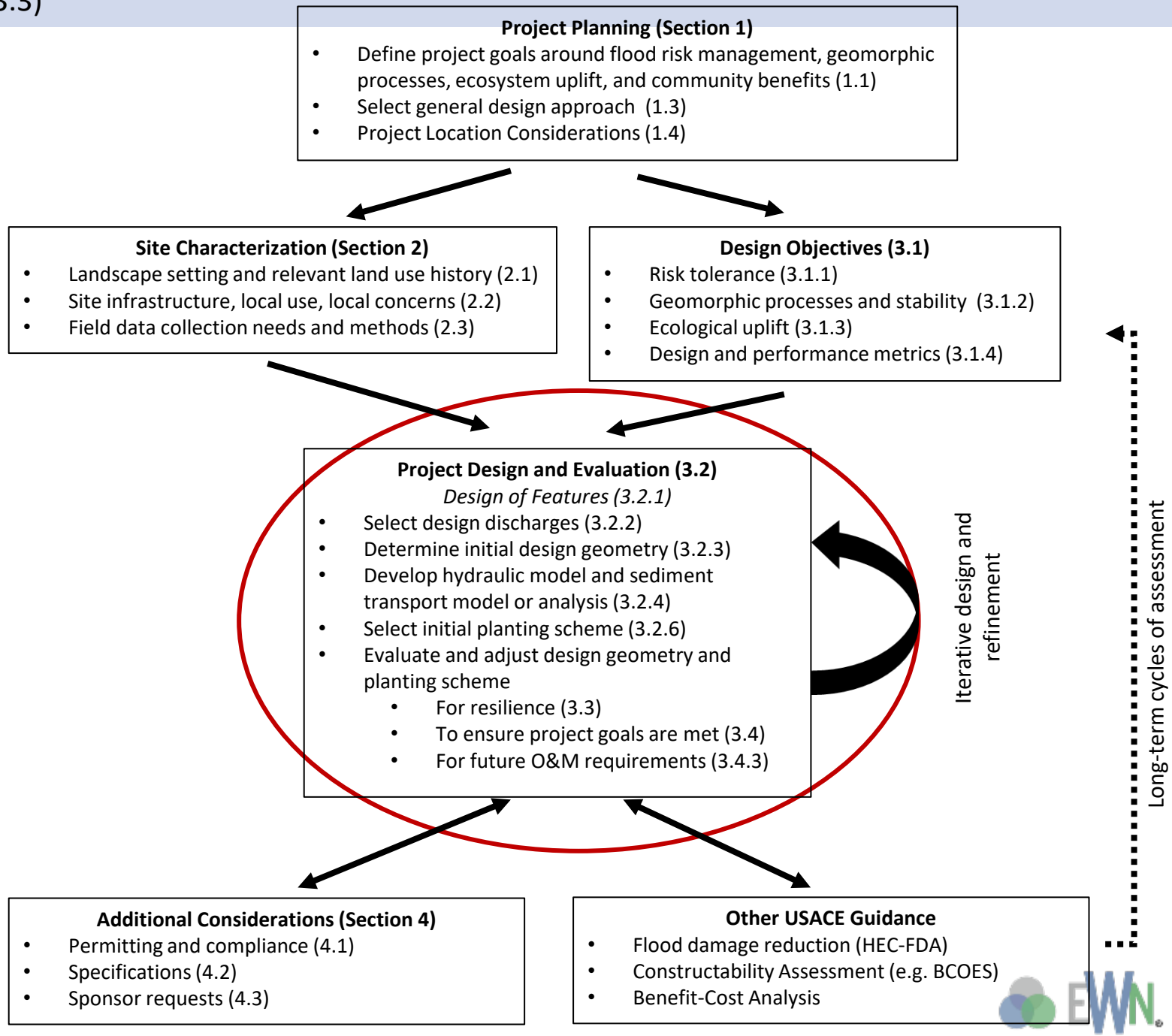
How much can the channel bed elevation change and the flows continue to inundate at the desired frequency and level before risking project goals?

What is the limit to planform change before impacting infrastructure or private property?

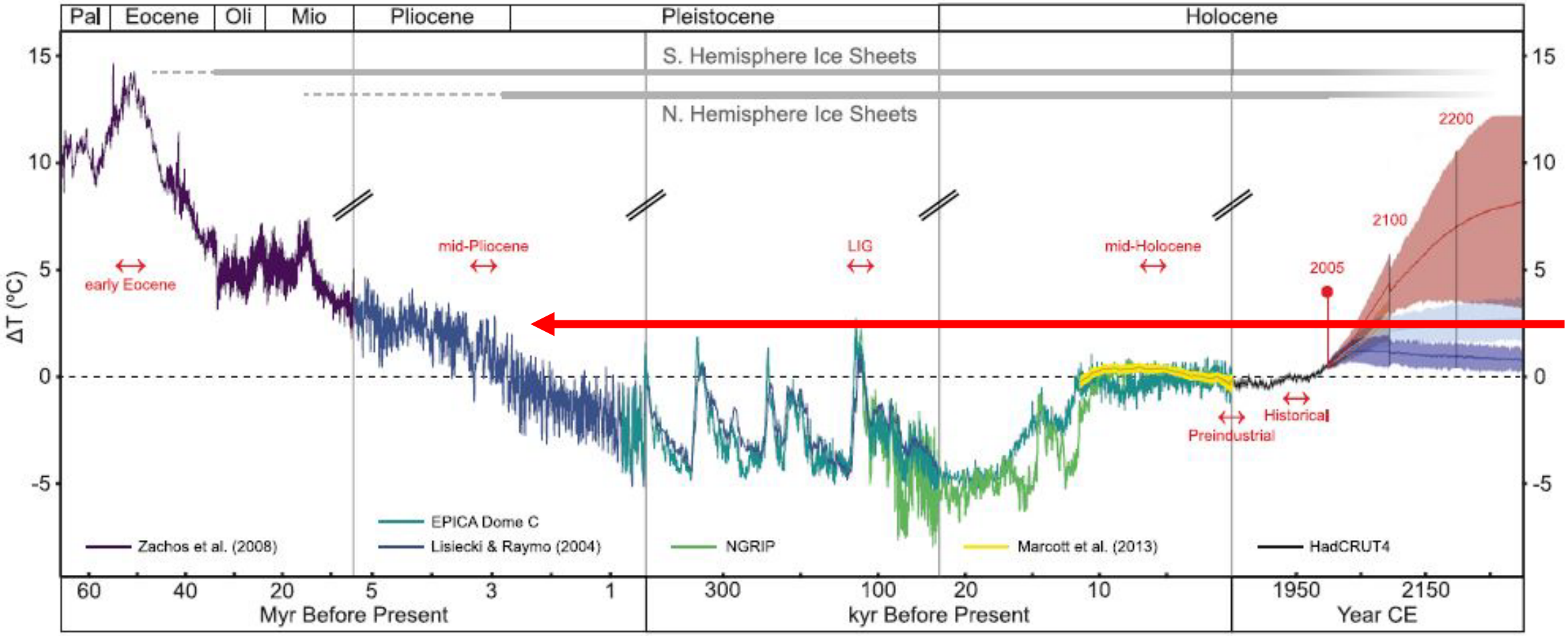
Define the minimum expected level of ecosystem diversity and abundance, FRM, and community benefits that need to be maintained

Design: Develop Floodplain Bench Design (Section 3.2-3.3)

Design Phase	Design Aspect	Specific Criteria	Data	Design
Establish Goals and Objectives	Risk Management	Inclusive of flood risk management and setting the criteria defining risk to project success	1.2.1	3.1.1
	Geomorphic Processes and Stability	Inclusive to those processes that can be improved as a result of changes to the independent parameters.	1.2.2	3.1.2
	Ecological Lift	Inclusive of all habitat and ecosystem features that can be improved with the project	1.2.3	3.1.3
	Community Benefits	Inclusive of the benefits to the surrounding community and future O&M at the project	1.2.4	3.4.1, 3.4.3
Develop Initial Design	Design discharge	Determine the discharges to be used in design	2.1.4, 2.1.3	3.2.2
	Bench width	Set an initial width to accommodate anticipated sediment supply and grain size distribution	2.3.2, 2.3.3.	3.2.3, 3.2.5
	Bench elevation	Set for inundation frequency and duration using the stage-discharge curve and the flow frequencies	2.3.1	3.2.3, 3.2.7
	Bench side slope	Set to avoid fish stranding, generally similar to existing floodplain slope or 5H:1V	2.3.1, 2.3.4	3.2.3, 3.2.8



Develop Initial Design for Current and Anticipated Future Flow and Sediment Supply Conditions



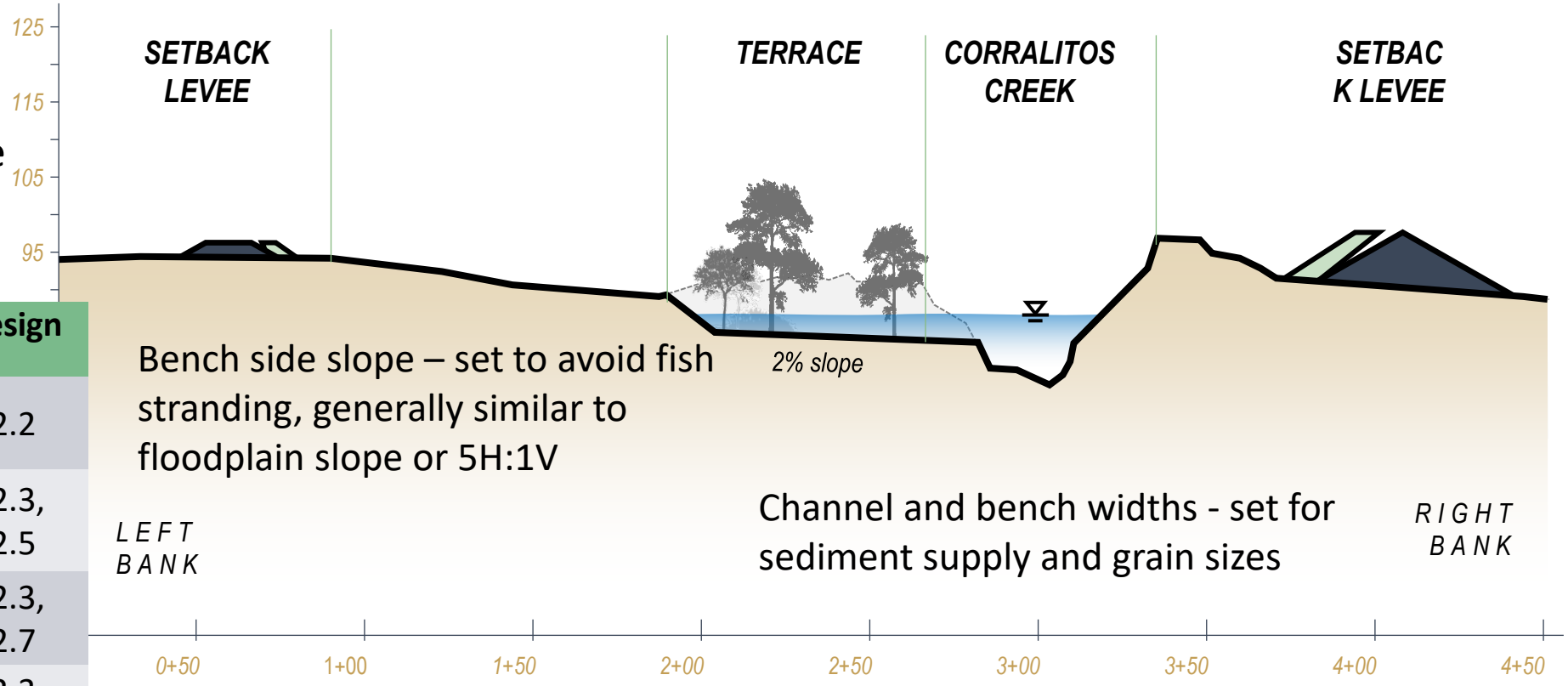
Burke et al., 2018, PNAS 115 (52): 13289

Initial Design Uses Design Discharges

Design discharges may include bankfull, recurrence interval, ecological, effective flow rates

Design Aspect	Data	Design
Design discharge	2.1.4, 2.1.3	3.2.2
Bench width	2.3.2, 2.3.3	3.2.3, 3.2.5
Bench elevation	2.3.1	3.2.3, 3.2.7
Bench side slope	2.3.1, 2.3.4	3.2.3, 3.2.8
Bench longitudinal slope	2.3.1	3.2.3
Channel side slopes	2.3.1, 2.3.4	3.2.3, 3.2.8

Corralitos Creek Example



Bench side slope – set to avoid fish stranding, generally similar to floodplain slope or 5H:1V

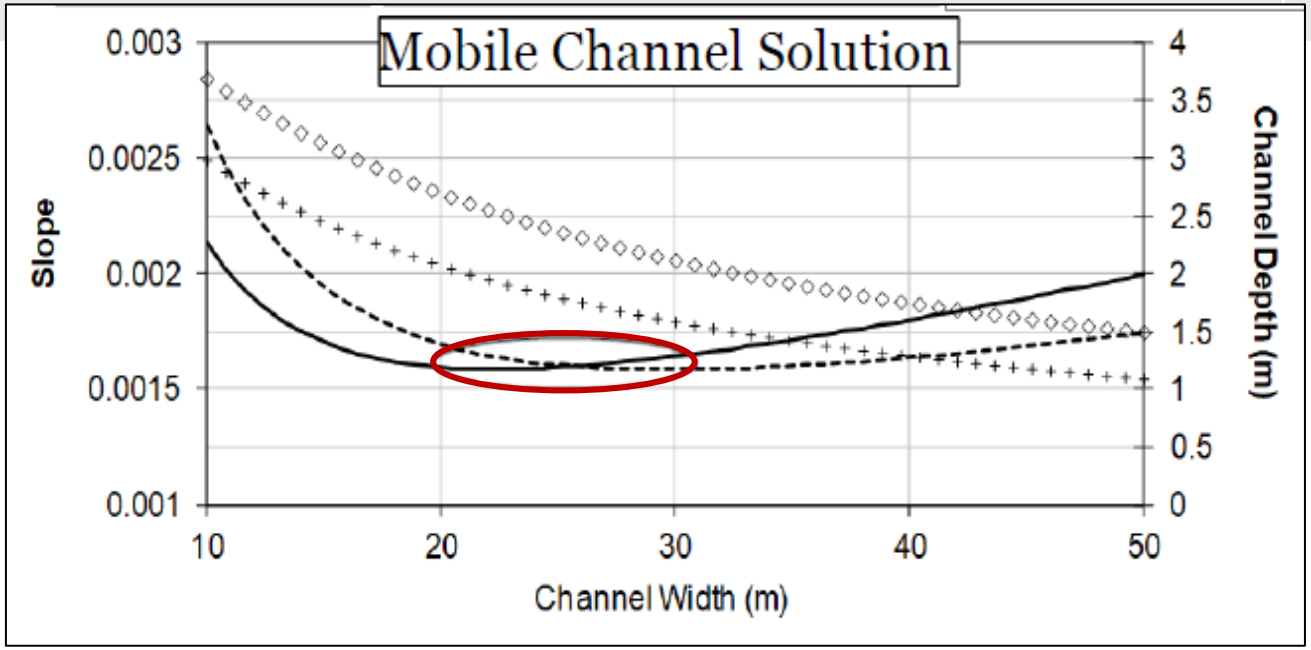
Channel and bench widths - set for sediment supply and grain sizes

Bench height – set for how long water should remain on bench

Bank slopes from bed to bench and bench to bank - set to fit area soils, planned plantings, generally below 2H:1V

Design Phase	Design Aspect	Specific Criteria	Data	Design
Evaluate Design	Hydraulic performance	Evaluate over multiple hydrographs that reflect existing and anticipated flow rates of importance for project success and to ensure flood risk management	2.1.4	3.2.4
	Sediment transport	Determine sediment sizes in transport above the bench elevation and if transport will affect bedload transport in the main channel; can be evaluated from the D_{50} on the bench and bed surface over multiple hydrographs	2.3.2, 2.3.3	3.2.5
	Deposition / erosion	Evaluate over multiple hydrographs to ensure topography changes are within risk tolerance		3.2.5, 3.2.6
	Flow velocities on bench	Ensure velocities on the bench surface will not prevent vegetation growth (typically less than 4 feet per second), which may be species-, season-, or life-stage dependent		3.2.6
	Seasonal vegetation	Evaluate over different seasons using roughness values to reflect anticipated level of growth	2.3.5, 2.3.6	3.2.6, 3.2.7
	Future resilience	Evaluate over multiple hydrographs and sediment supplies to evaluate design resilience to future change		3.3

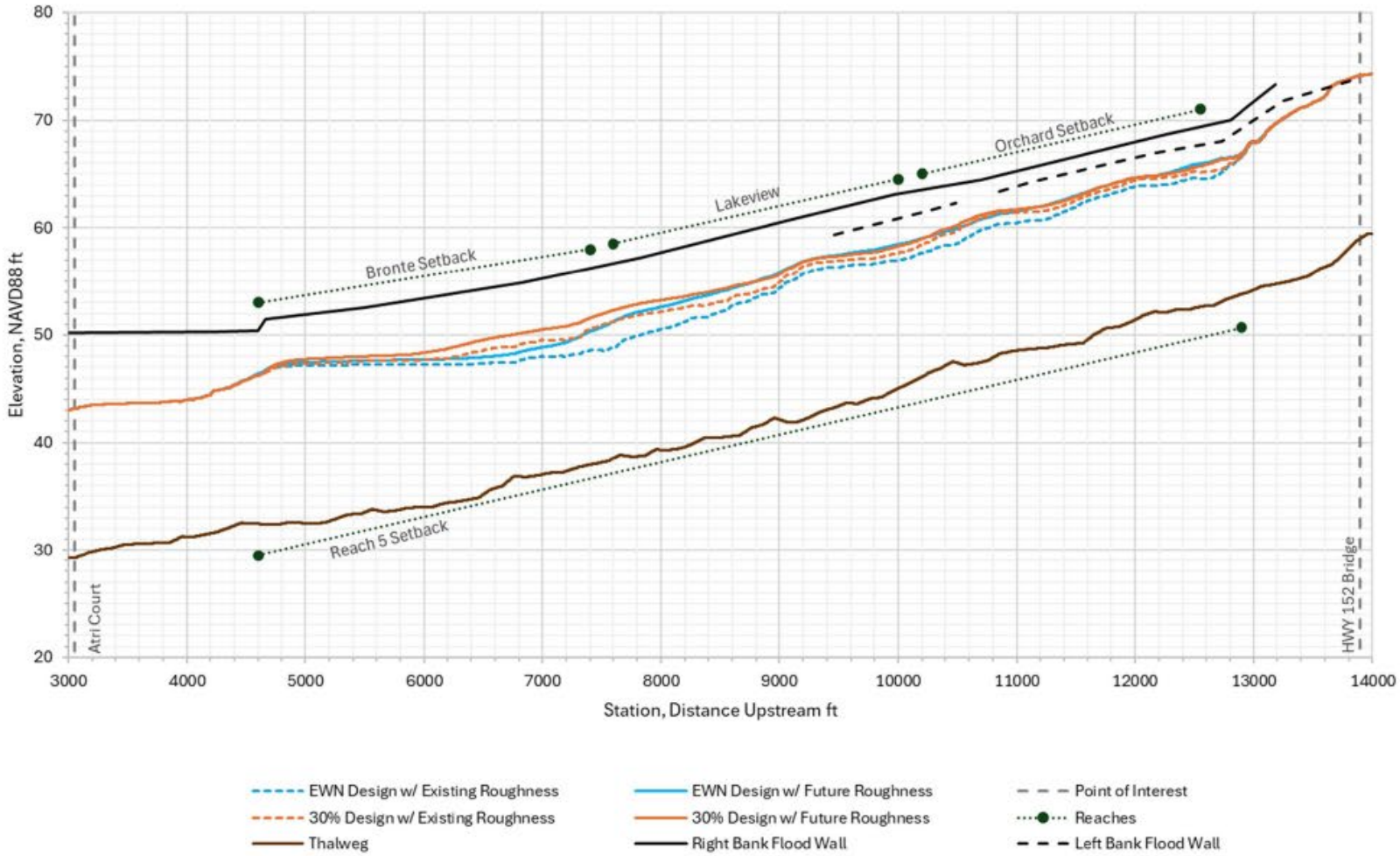
Iterate to find the channel and bench widths that create the geometry most resilient to changes in flow and sediment supply



Reach 5: Hydrodynamic Results

Hydrodynamic modeling results:

- The EWN design reduced WSE compared to the 30% design for existing roughness
  - EWN project design features increased the channel cross-sectional area with the proposed grading.
- Under future roughness, WSE reductions were similar in the Bronte and downstream Lakeview reaches, while the upstream Lakeview and Orchard reaches showed no change.

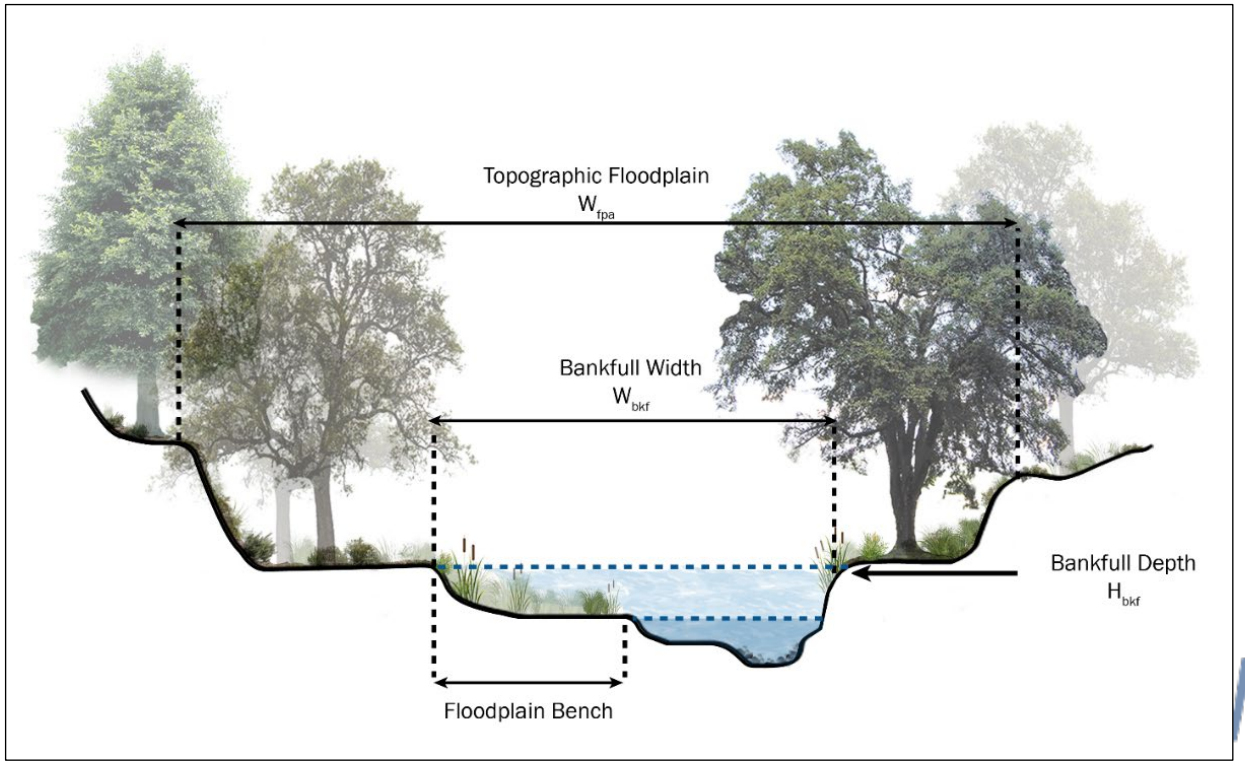


Case study: Pajaro River FRM — USACE San Francisco District (J. Beagle)

Design Phase	Design Aspect	Specific Criteria	Data	Design
Refine Design Iteratively	Bench width and elevation	Adjust to remain within risk tolerances		3.2.4
	Planting	Adjust species and distribution for risk tolerances		3.2.7, 3.4.2
	Bank and bench side slopes	Adjust with knowledge of planting and accompanying stability from planting		3.2.7, 3.2.8
	Bank Protection	Utilize bioengineering to enhance bank stability as needed in final design		3.2.8
	Ecological features	Add habitat features (bat boxes, topographic variability) to enhance ecological outcomes		3.2.7, 3.4.1
	Social features	Adjust design to accommodate use of the site by the surrounding communities		3.3.2, 3.4.1, 3.4.4

Other Benefits:

- Walking or Biking Paths
- Benches
- Park Space
- Increase local pollinator populations
- Attract birds of interest to bird watchers
- Optimized geometry and plants to encourage pollutant bioretention
- Reuse excavated materials in support of other infrastructure development

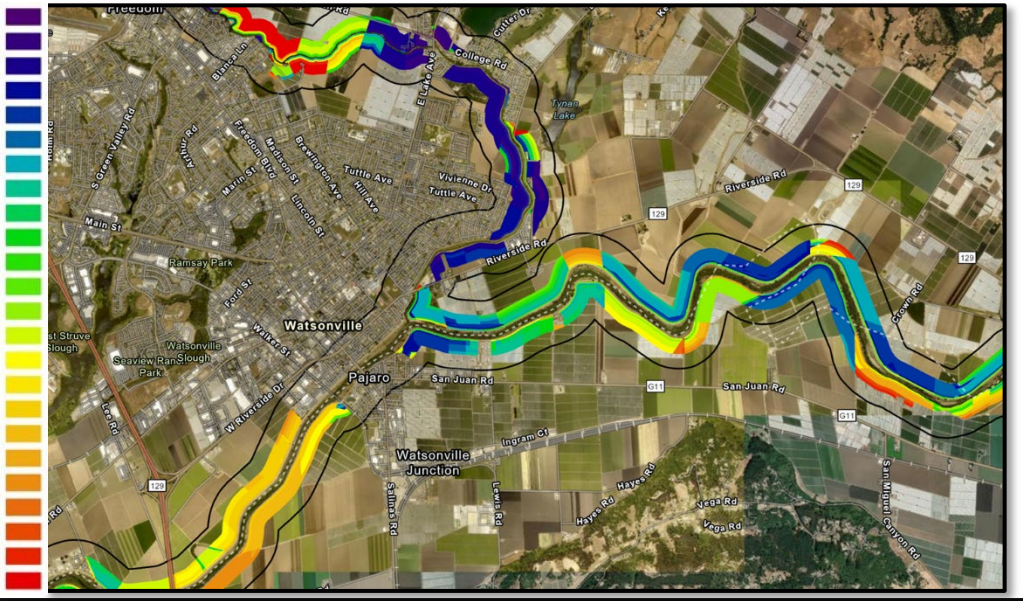


Optimize the project

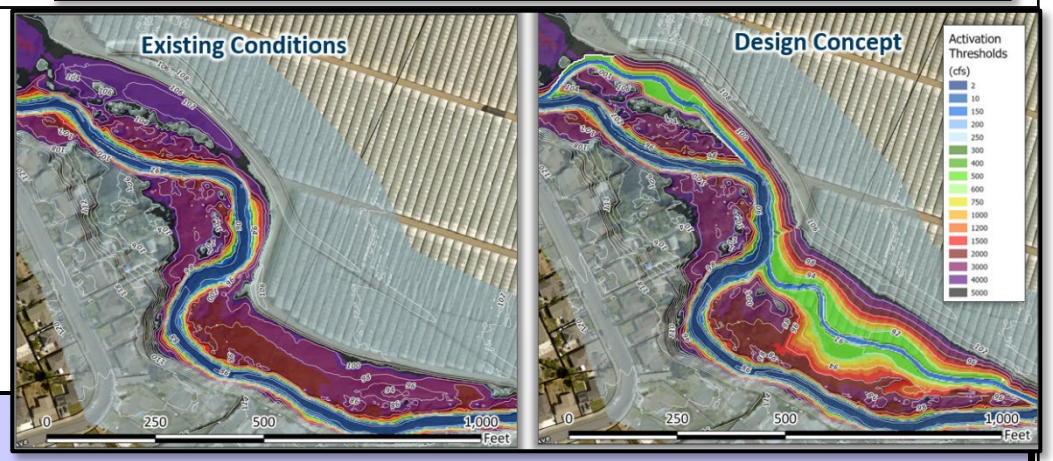
Where does floodplain reconnection make sense to maximize benefits to ecosystem and communities

https://storymaps.arcgis.com/stories/f899bf3c36a2403d9e0bd3c70dc2dfc5

Identification, Analysis, and Prioritization



From Ideas to Implementation



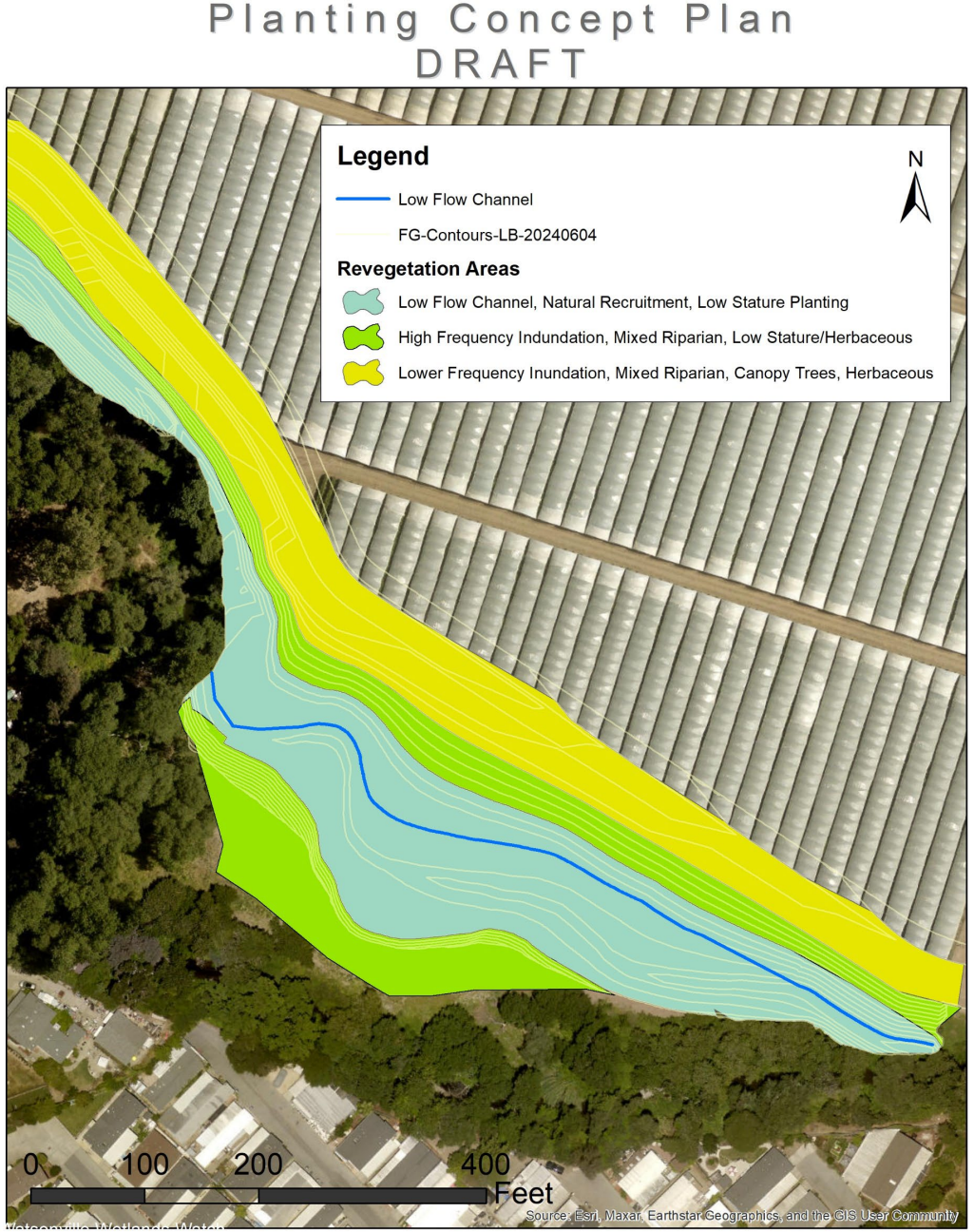
Metric	Baseline (EG)	Concept (FG)	Difference (FG - EG)
Inundation (Acre-days / WY)	1409	1416	7
Habitat (Acre-days / WY)	397	399	2
Recharge (Acre-feet / WY)	589	617	28

Future O&M requirements
Excavated sediment reuse
Sponsor requests

Set expectations for the first five years

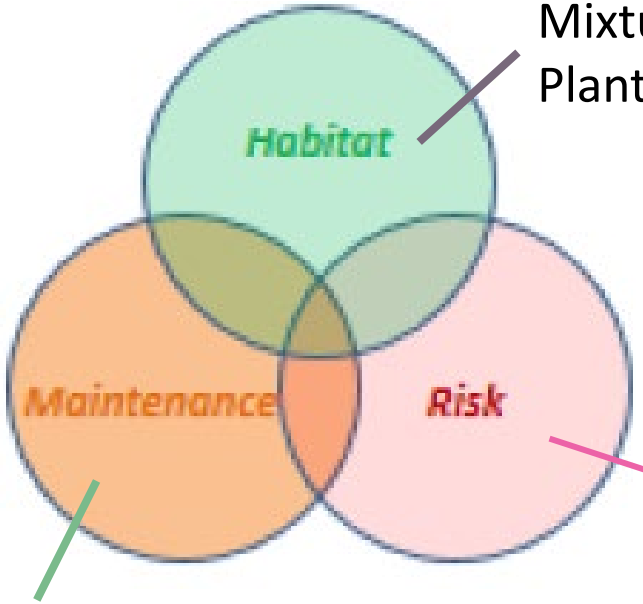
- Monitor bench elevation and width against geomorphic stability thresholds and risk tolerances
- Monitor channel and bench vegetation and habitat development
- Maintain and irrigate plantings for the first 3–5 years
- Expect channel adjustment and monitor around defined project metrics

Pajaro Example



Key Take Aways

Goal: floodplain benches with managed, native plant communities that recover ecological, societal, and engineering benefits of a healthy river while improving flood risk management



Mixture of Plants

Floodplain Bench Reduces Flood Risk

Require Equal or Less Maintenance

Set yourself and your project up for success

- Know your river first — sand or gravel
- Do the desktop work before the field work; it focuses your field time
- If bedload matters, get that data while you are in the field
- Design for natural geomorphic resilience
- Work with the sponsor to fulfill local goals and community benefits
- Plan for adaptive management and set metrics to identify when it is needed