# Floodplain Connectivity in Restoration Design

2015 Symposium on Restoration in a Contaminated Environment: Lessons Learned and Challenges in Moving Forward Part II

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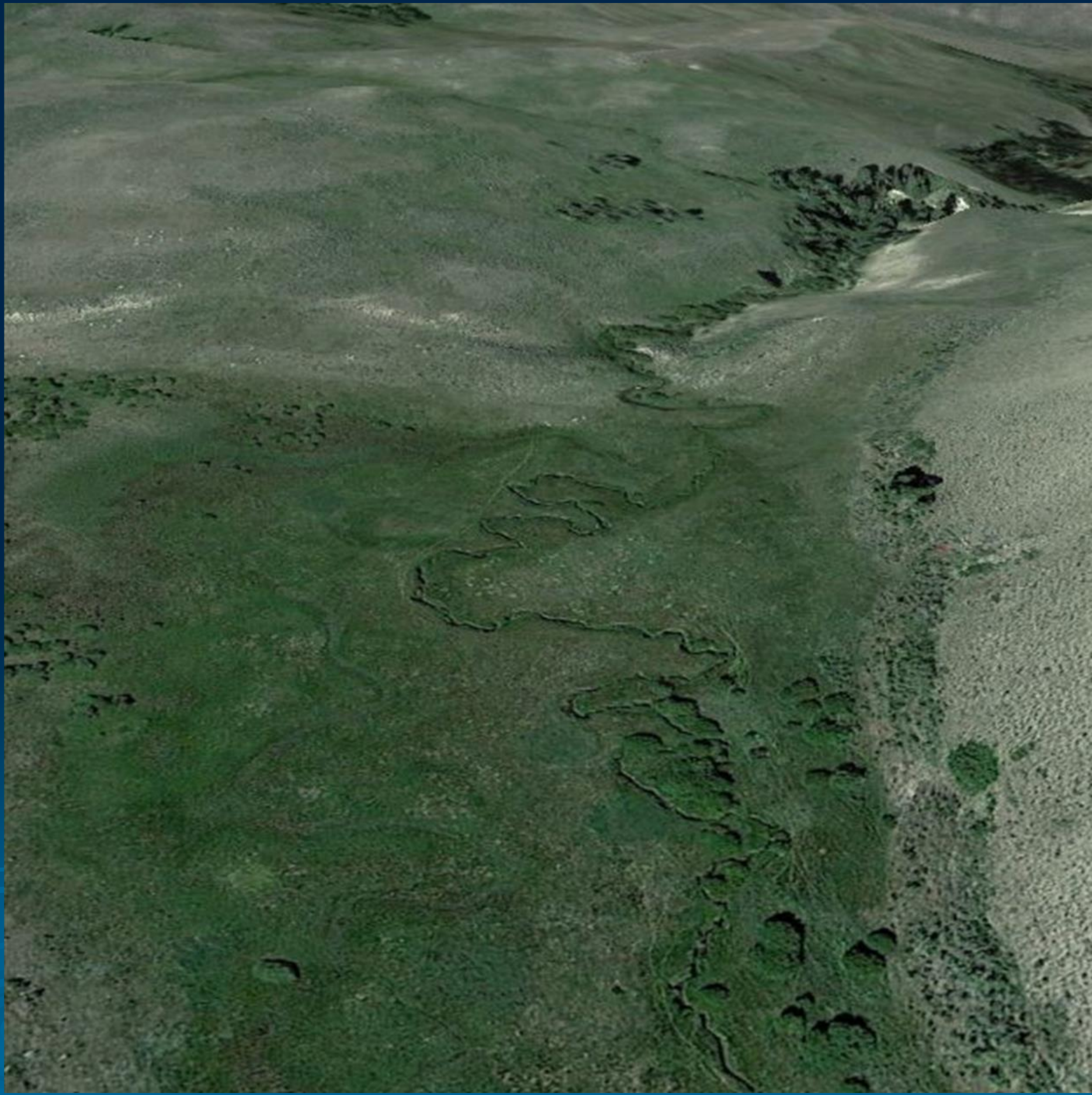
# Main Topics

- What Causes Floodplain Disconnection?
- Why Reconnect?
- How do you Hydrologically Reconnect?
- Specifically to the Clark Fork River Phase 1:
  - Disconnection Cause and Extent
  - Basis for Reconnection
  - Reconnection Design Criteria
  - Lessons Learned Since Implementation
  - Moving Forward

A floodplain is flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.

# A Disconnected Floodplain has Become *Hydrologically Separated* from its Stream

- Floodplain Surface is Inundated Less Frequently
- Floodplain Surface is Inundated Less Extensively
- Affects both Surface Water and Groundwater Hydrology



# Typical Causes of Floodplain Disconnection

1. *Incision/Downcutting* of a Stream Channel

2. *Flow Alterations*

3. *Physical Barriers* on the Floodplain Surface

4. *Deposition/ Aggradation* on the Floodplain

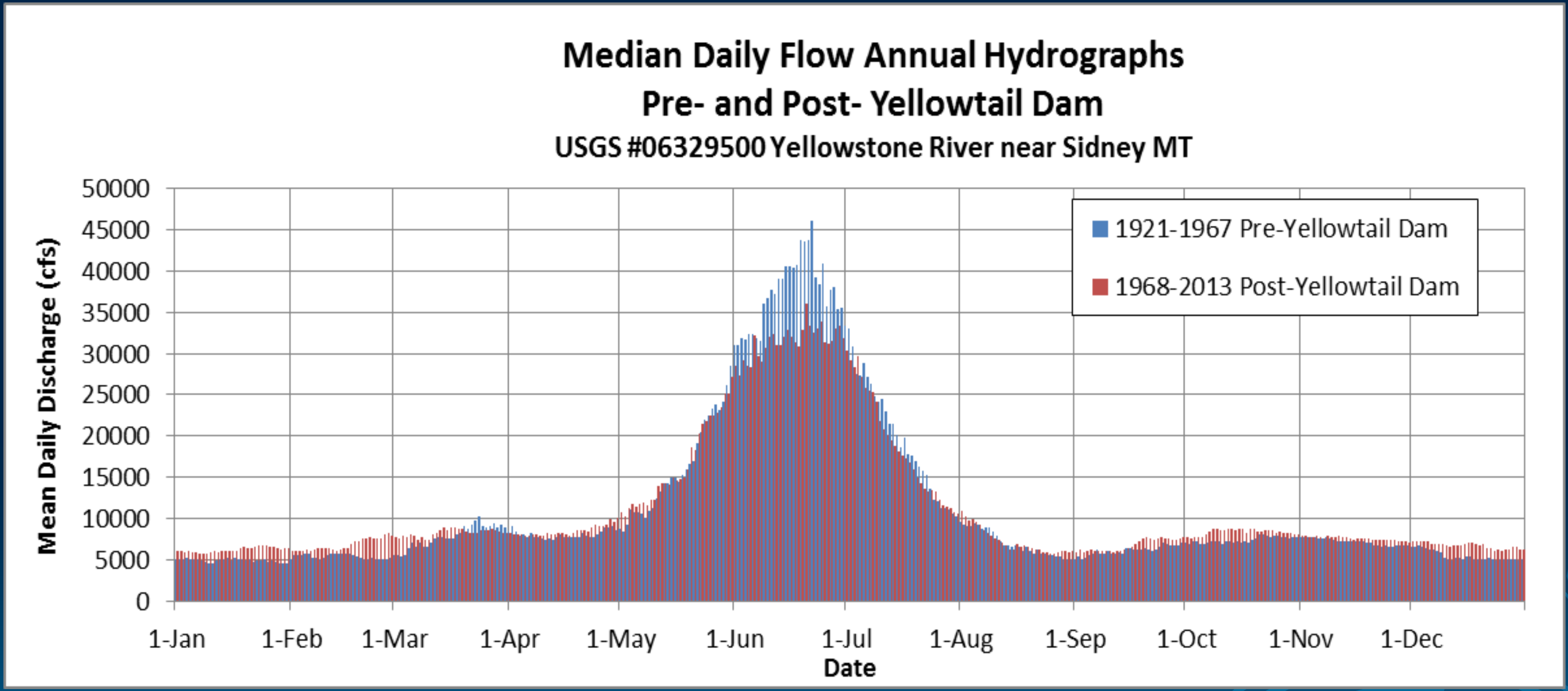
# Channel Incision

- *Straightening*--- Channelization and Steepening
- *Base Level Lowering*--- Local or Systemic
- *Beaver Eradication*--- Common in Northern Rockies
- *Sediment Load Reductions*---Below Dams
- *Flow Increases* --- Urban Runoff

Perching of Floodplain as a Terrace

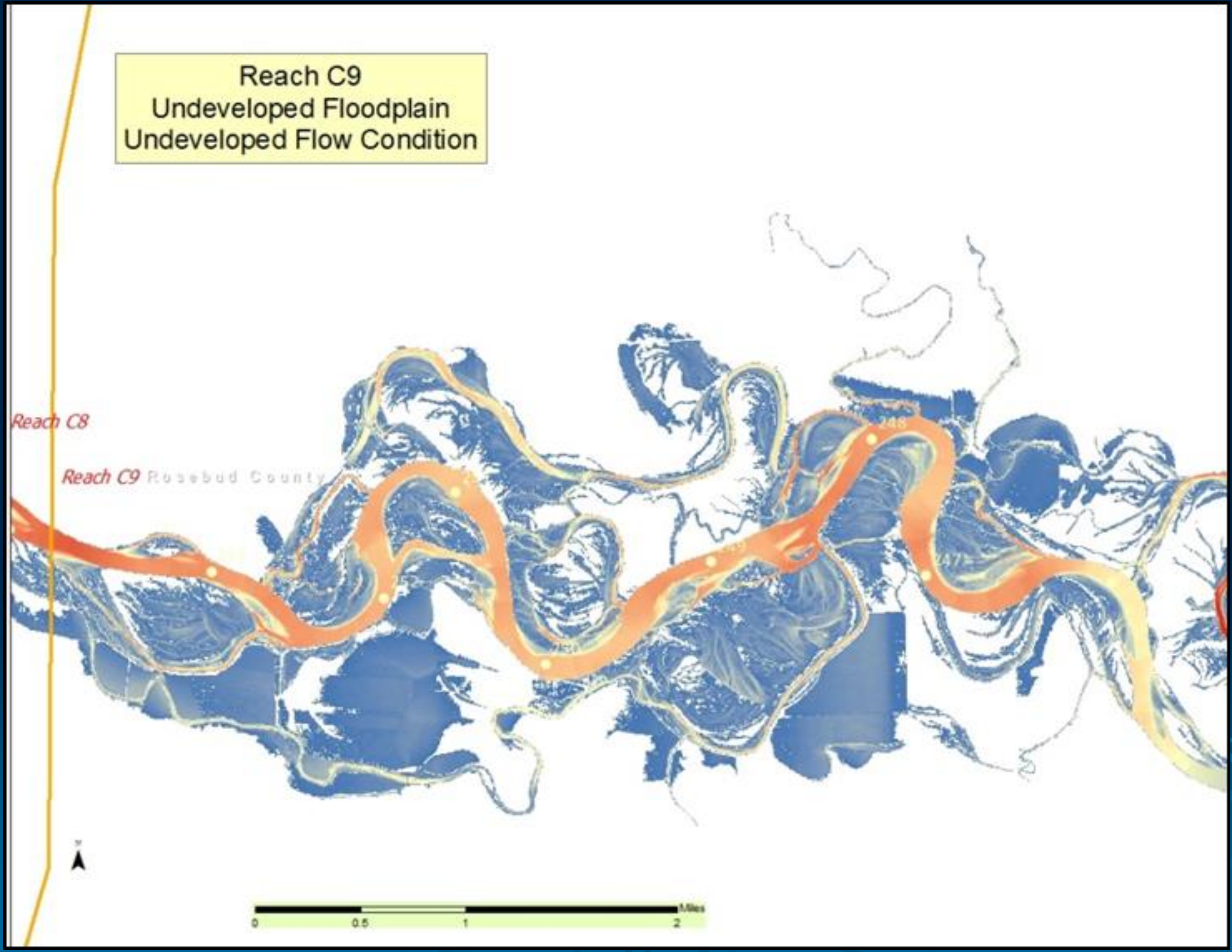
# Flow Alterations

- *Dams*
- *Consumptive Water Use*

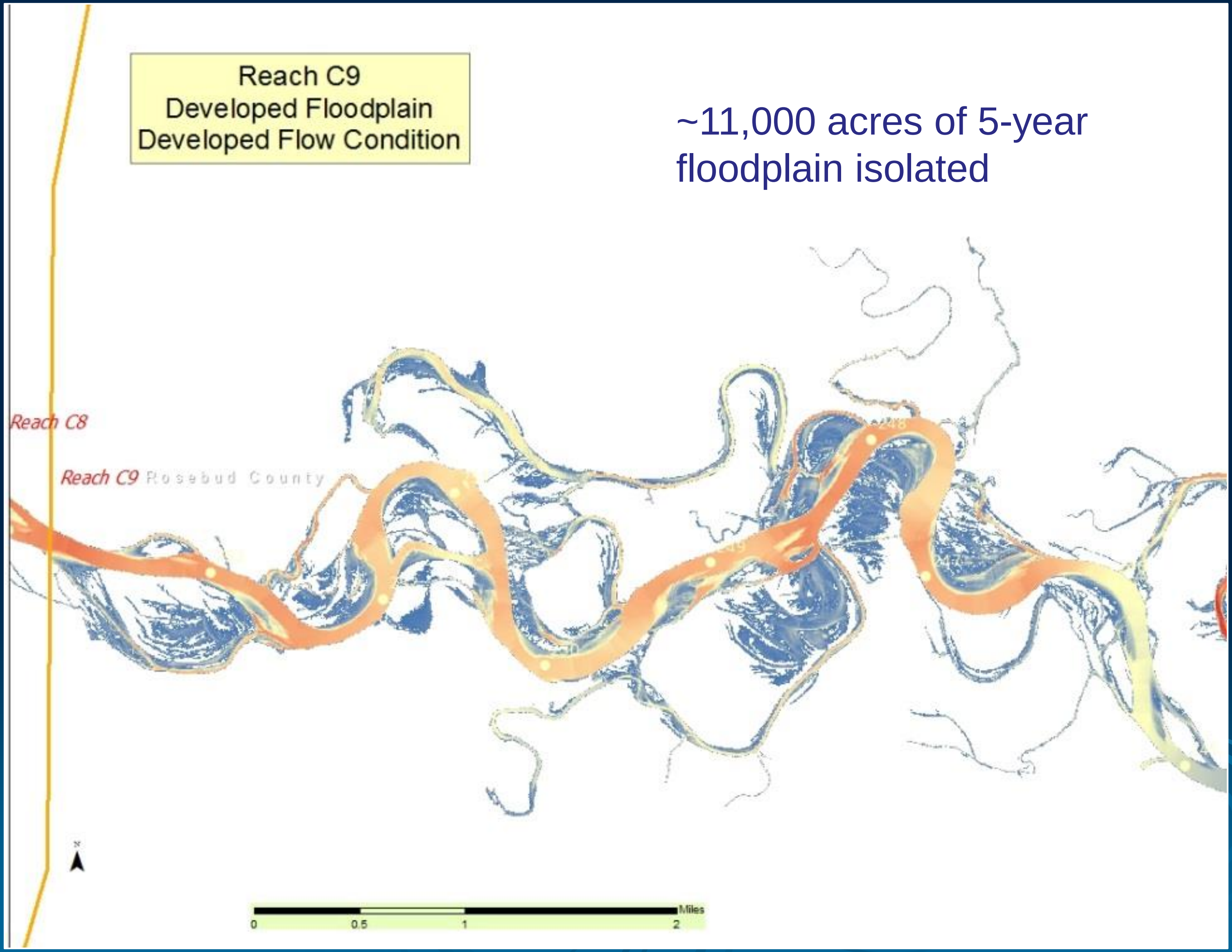



Yellowstone River:  8,600 acres of 100-year floodplain isolation due to flow alterations

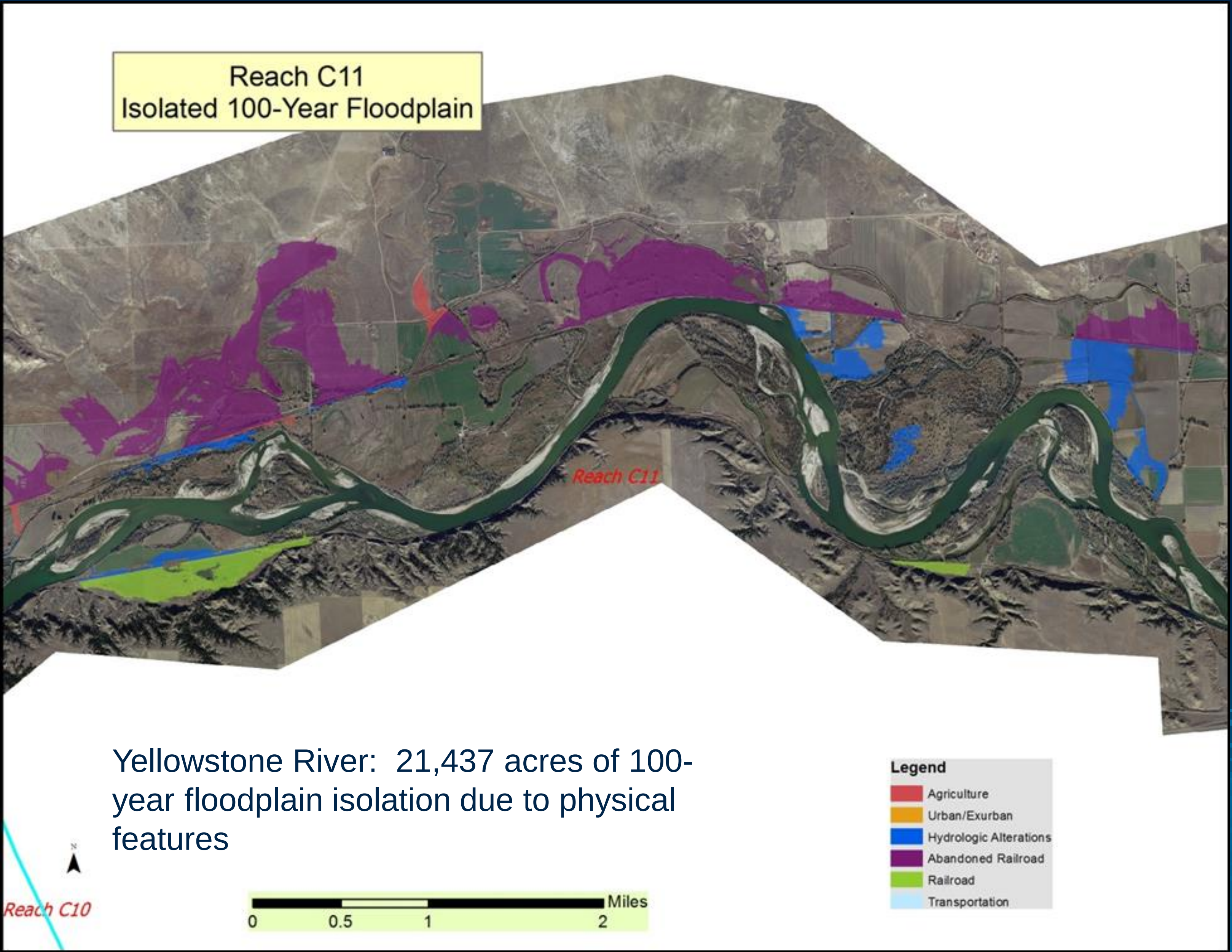
# 5-Year Floodplain: Yellowstone River



# 5-Year Floodplain:  Yellowstone River



# Physical Isolation




Yellowstone River: 21,437 acres of 100-year floodplain isolation due to physical features

# Floodplain Aggradation

- *Deposition of Natural Levees*
- *Wholesale Floodplain Deposition Due to Sediment Loading (Clark Fork River, Musselshell River)*

# Why Reconnect?


- Flood Mitigation
- Hydrologic Buffering
- Groundwater Recharge
- Vegetation/Habitat Recovery
- Channel Stability

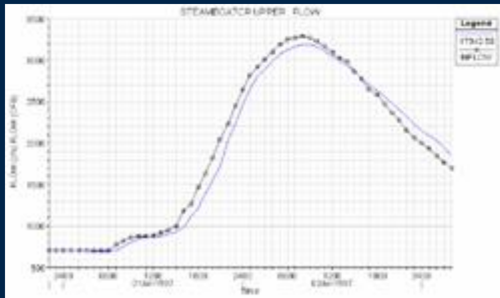
# Flood Mitigation

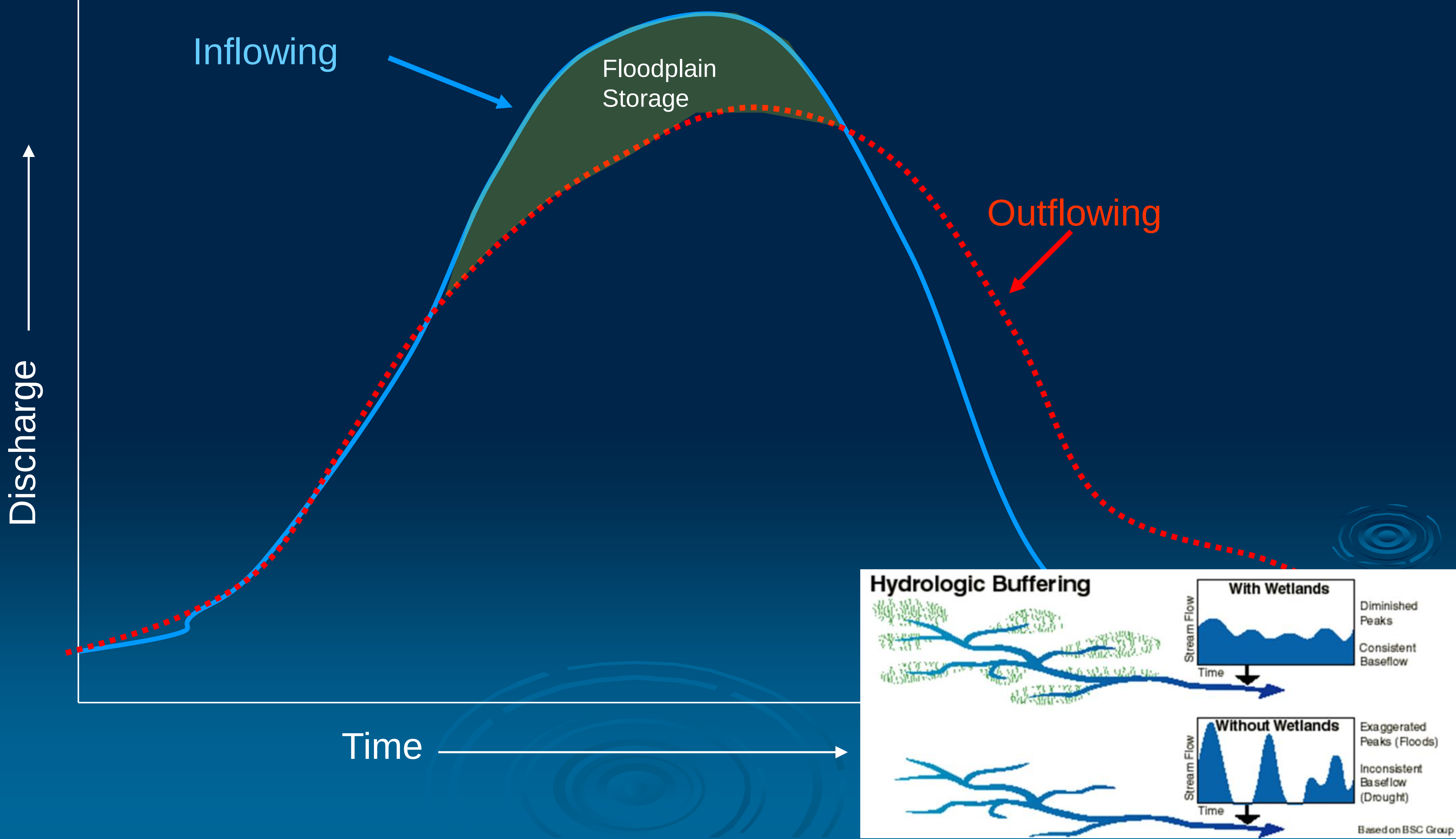
Inflowing


Outflowing

Fraser River 1948

# Floodplain Storage Reduces Peaks Improves Late Season Flows





# Connectivity and Storage

## Floodplain Restoration Efforts in the Upper Mississippi Basin

- A one acre wetland can typically store about three acre-feet of water, or one million gallons.
- In the Upper Mississippi River Basin Federal Levees isolated 2.3 million acres of floodplain from their parent rivers.
- Holding three feet of water in restored floodplain wetlands could provide 16.5 million acre-feet of flood storage.

---Flood Damage Reduction in the Upper Mississippi River Basin: An Ecological Alternative

# Connectivity and Habitat

- Increased Habitat Area
- Expanded Disturbance Regime
- Improved Groundwater Access
- Greater Sediment Storage Potential
- Greater Nutrient Flux

# Connectivity and Channel Stability

- Energy Distribution During Floods
- Riparian Vigor on Floodplain

# How do you Reconnect a Floodplain?

## Incised Streams

- Re-route the channel to a higher surface
- Raise the channel

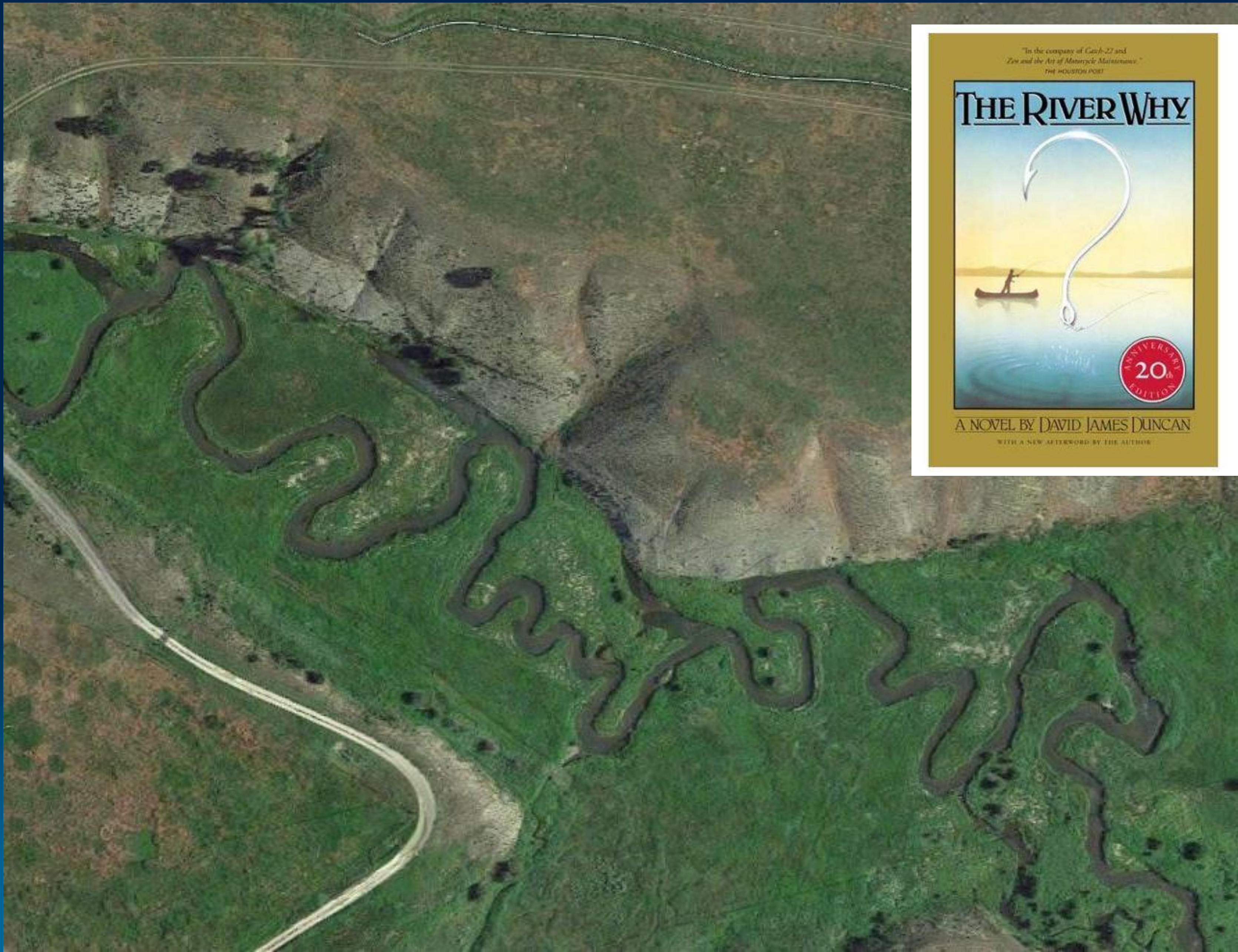
OR

- Excavate a new floodplain at a lower elevation

# How do you reconnect a floodplain?

- Re-route the river to a higher surface

Restore appropriate slope (length)
Abandon channelized segment as wetland



# Raise the River

- Pond and Plug (controversial)


“Beaver Mimicry”
“Deformable Grade Controls”

# Adopt Historic Floodplain as a Terrace and Excavate a New Inset Floodplain

--or sit back and wait

# Physical Features: Breach, Remove, Set Back, or Wait

# Clark Fork River Reach A Phase 1

## Reconnecting an Aggraded Floodplain: Opportunity and Risk

- Aggraded Floodplain
- Contaminated Floodplain
- Lost Floodplain Connectivity
- Lost Riparian Vigor

# Clark Fork River
# Purpose and Objectives of Remedial Action

- Remove Tailings and Replace with Clean Soils
- Stabilize Streambanks
- Revegetate Floodplain
- Incorporate Long-Term Deformability

# Clark Fork River
# Components of Remedial Action

- Remove Tailings and Replace with Clean Soils
- Stabilize Streambanks
- Revegetate Floodplain
- Incorporate Long-Term Deformability

# Clark Fork River
# Revegetation of Remediated Floodplain

- Design Floodplain to Optimize Long-Term Riparian Health
- Rely on Riparian Corridor to Provide Floodplain Stability

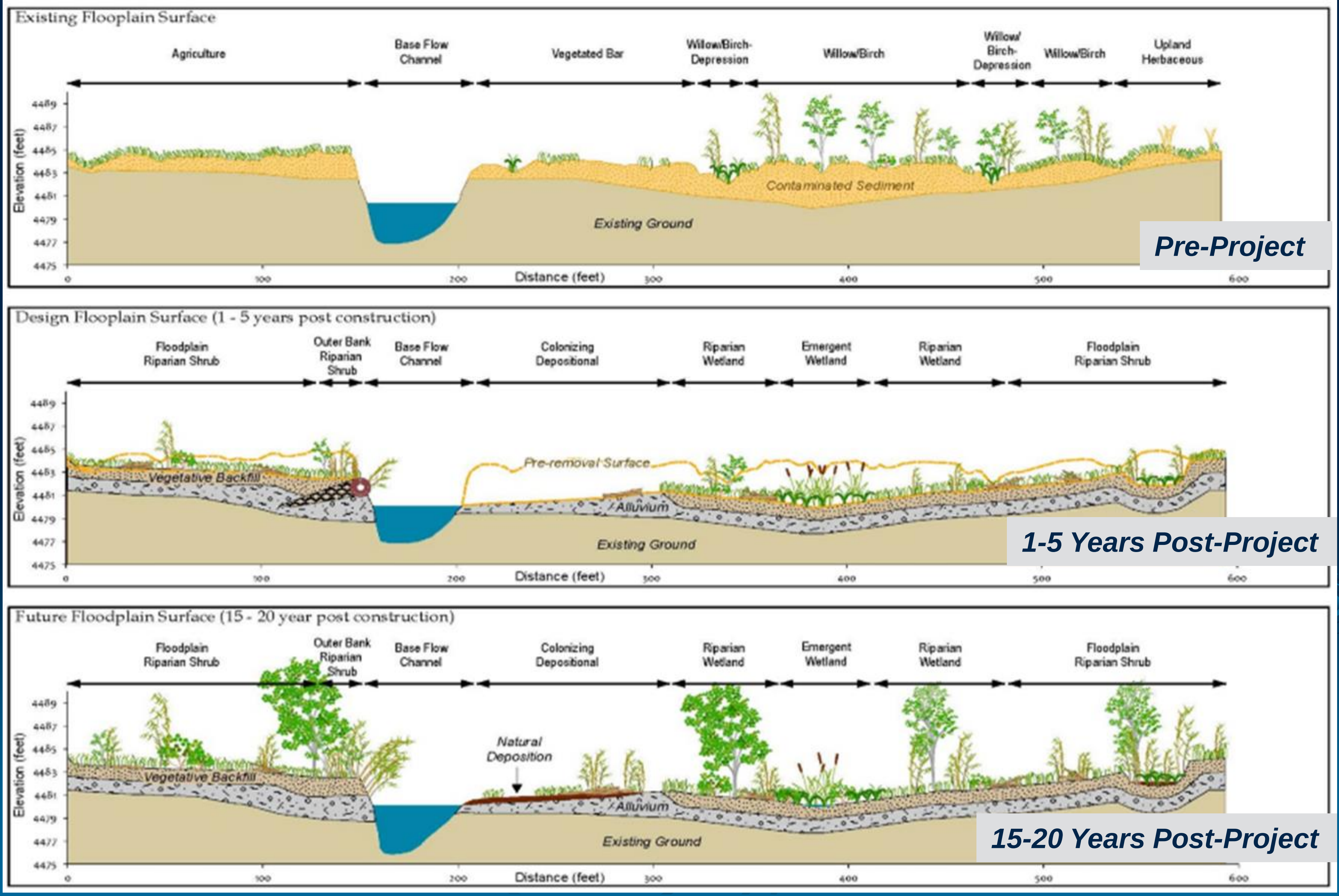
# Clark Fork River
# Revegetation of Remediated Floodplain

- Design Floodplain to Optimize Long-Term Riparian Health
- Rely on Riparian Corridor to Provide Floodplain Stability

➡ Floodplain Connectivity is a Prerequisite for Sustainable Remedy

# Phase 1 Floodplain Objectives

Geum Environmental



# Phase 1 Floodplain Objectives

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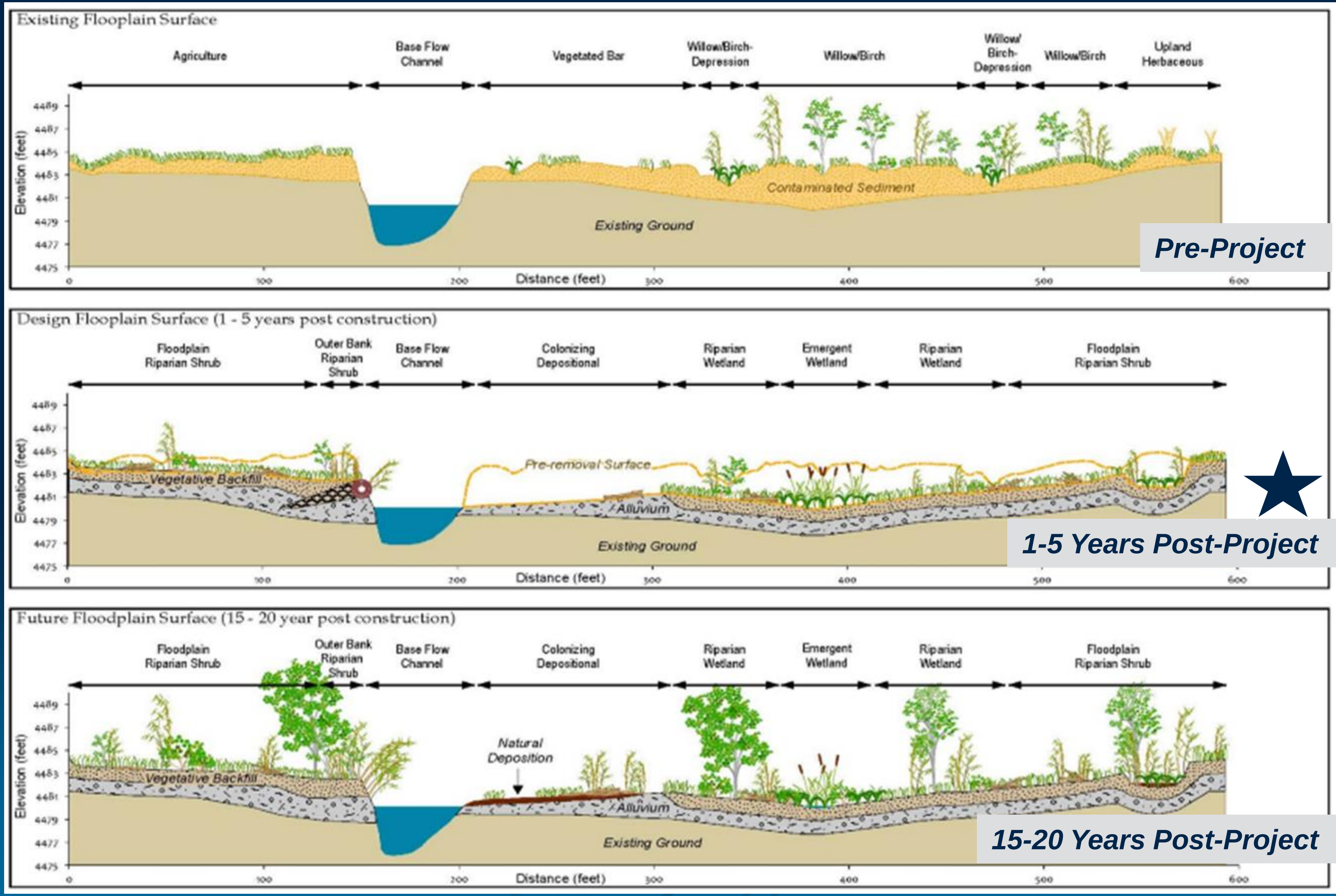



56 acres of removal
W:112° 46' 16.45"
N:046° 11' 00.49"

# Clark Fork River
# Several Floodplain Design Elements

- Elevation of Floodplain Surface
- Shape of Floodplain Surface
- Types of Floodplain Treatments

→ Balancing Function and Risk

# Design Flow For Floodplain Access
## 2-Year Flood Event

| Hydrologic Parameter | Phase 1 |
|---|---|
| 2-Year Discharge (Q2; cfs) | 522 |
| Percent of time Q2 equaled or exceeded | 2.9% |
| Average number of days Q2 exceeded per year | 10.7 |
| Maximum number of Days Q2 exceeded in any given year | 51 (1997) |

3% Duration Flow as “Dominant Discharge” (Andrews and Nankervis, 1995)

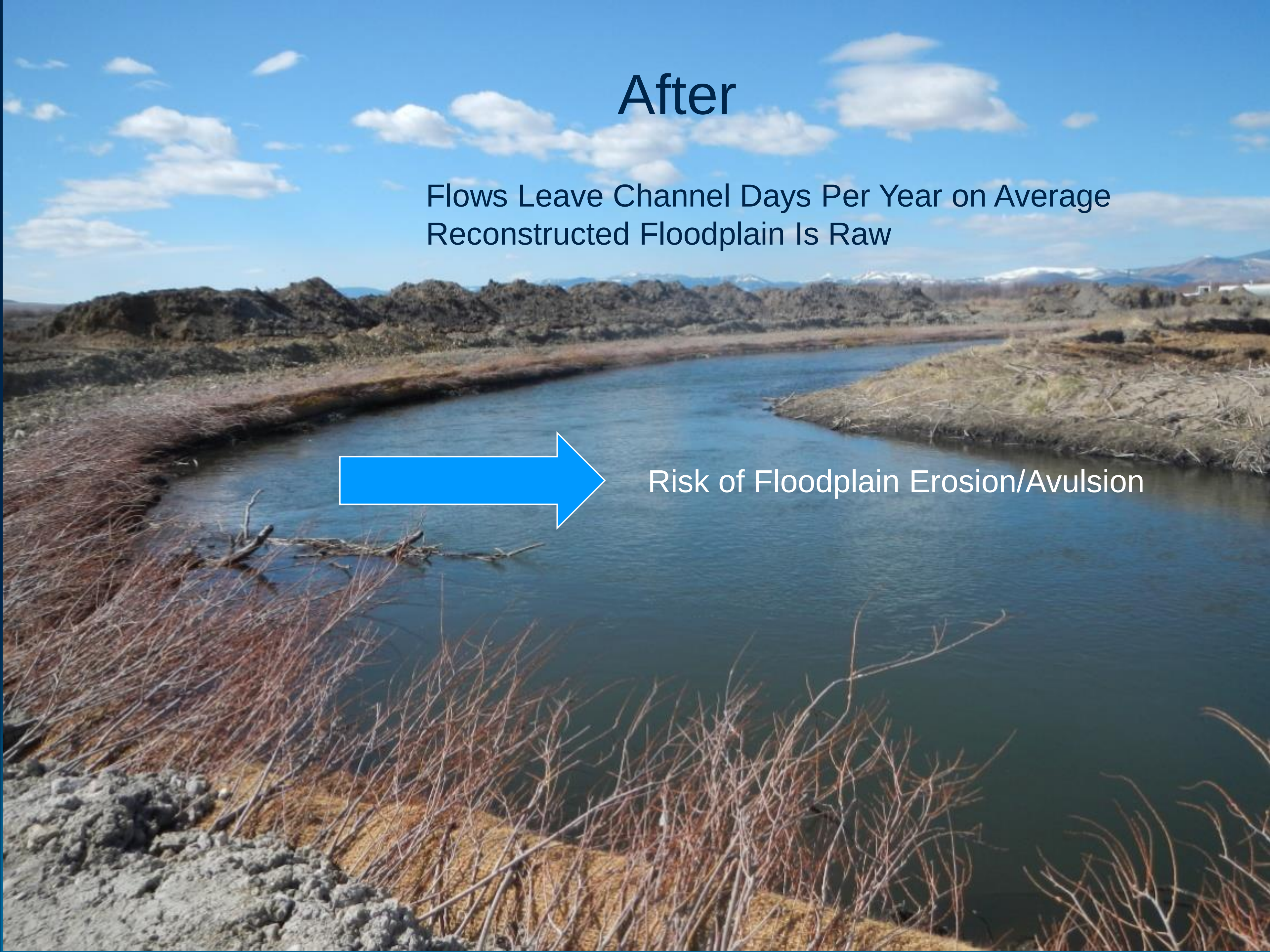
Out of Bank Flow Duration Sufficient for Riparian Recovery

Out of Bank Flow Duration Sufficient for Risk Management

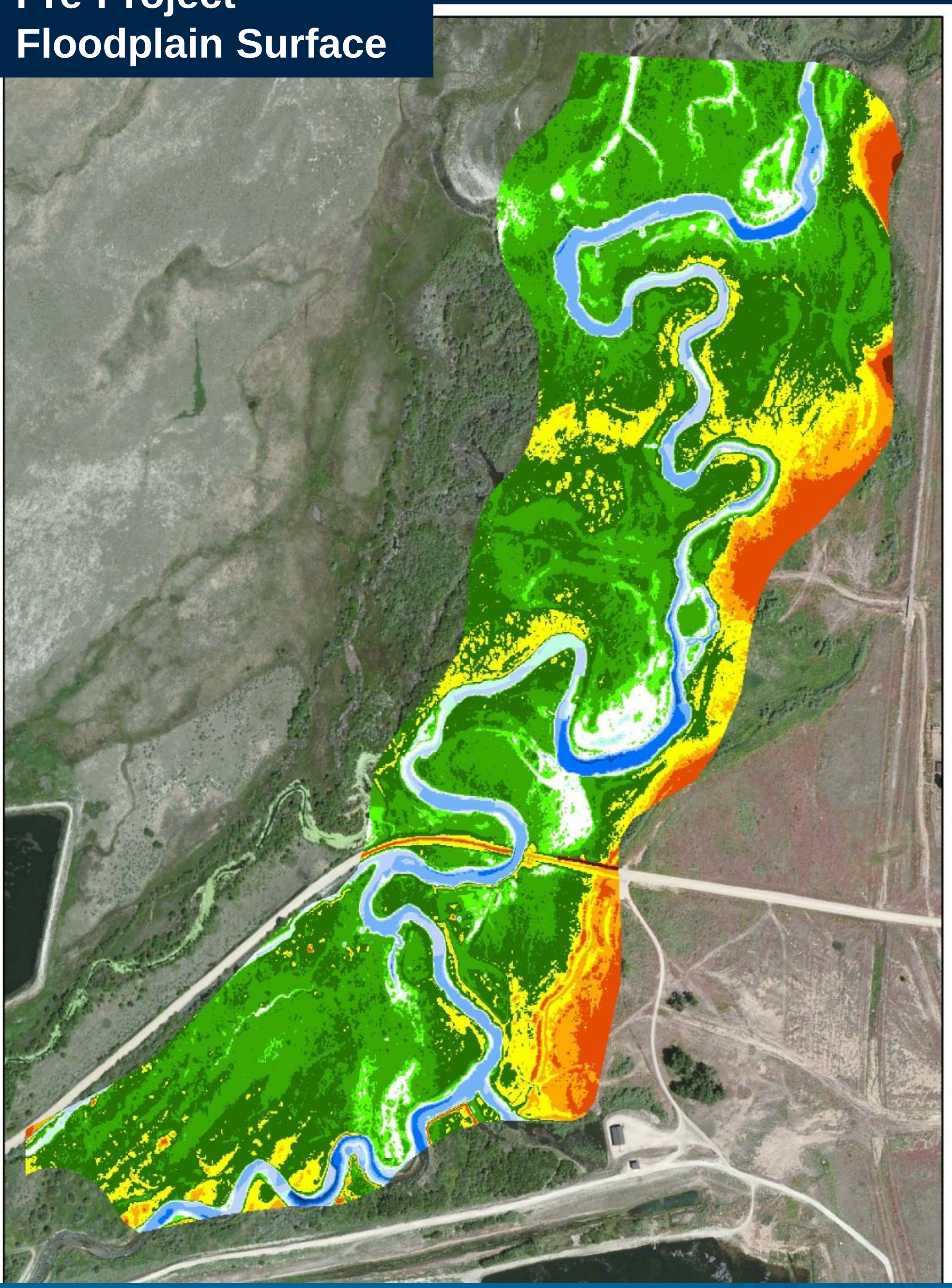

Before
Flows Rarely Leave the Channel
Perched Floodplain Has Some Roughness

# After

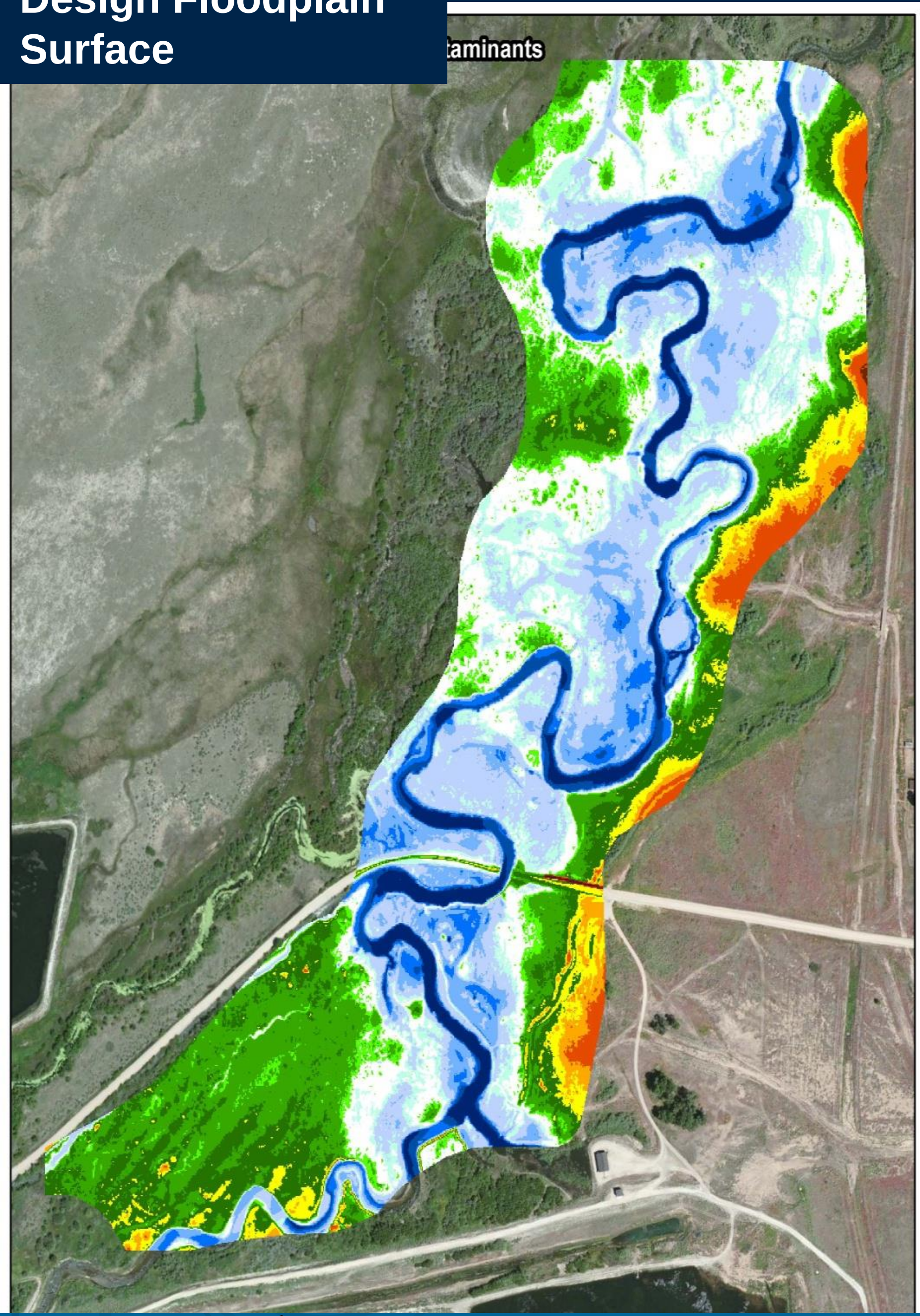
Flows Leave Channel Days Per Year on Average
Reconstructed Floodplain Is Raw



## Pre-Project Floodplain Surface

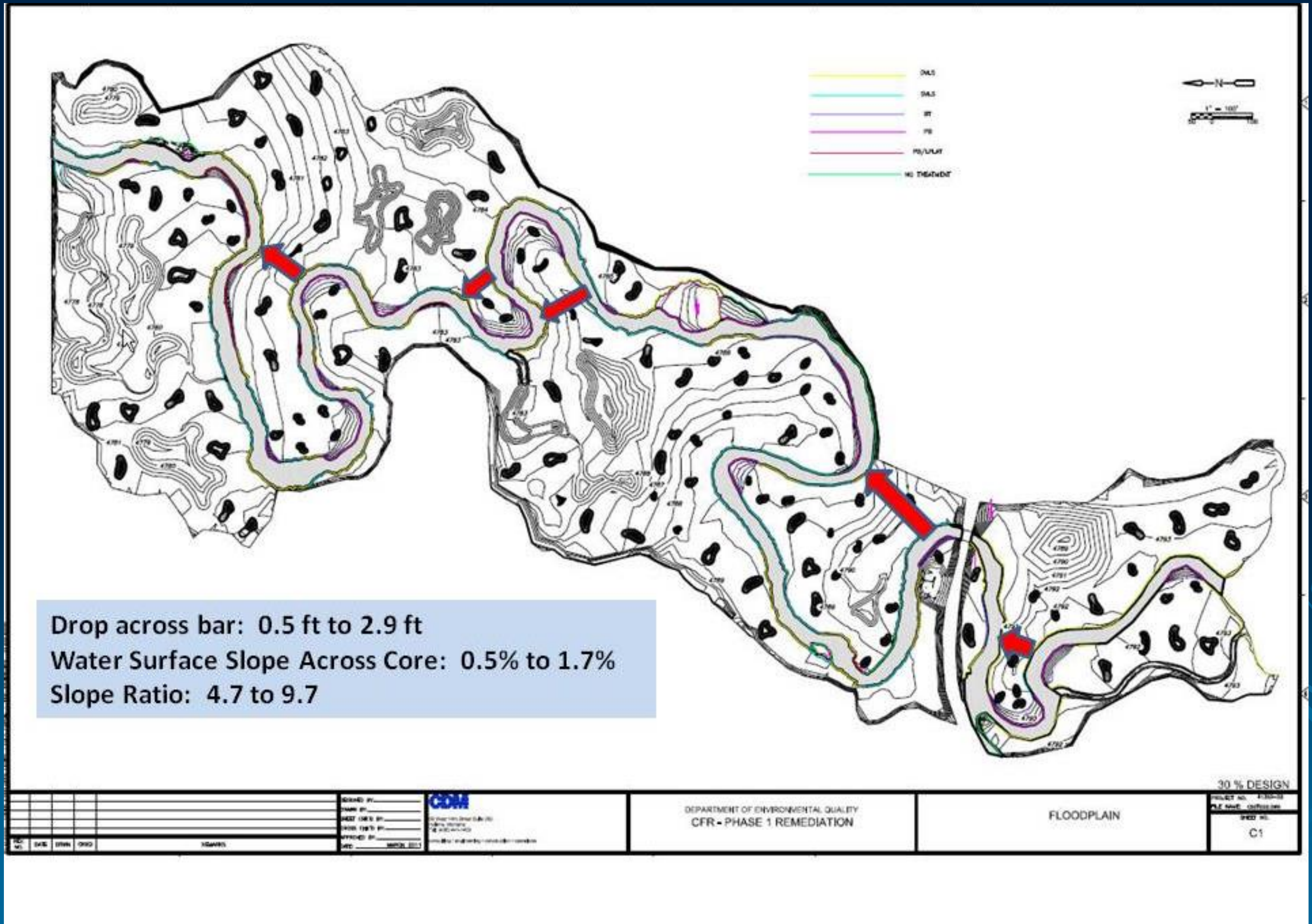


## Design Floodplain Surface



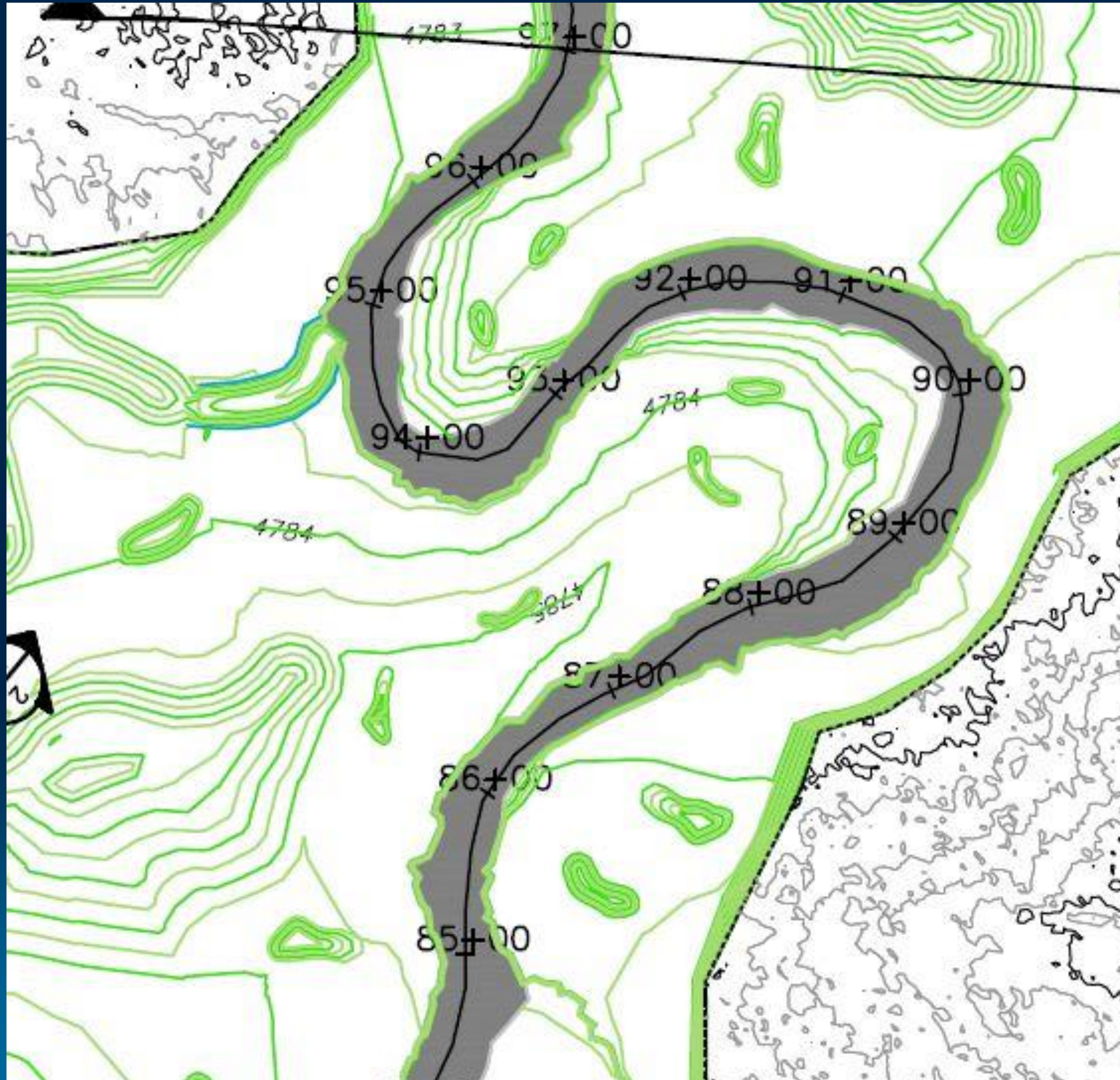
# Managing Avulsion Risk:

## Identify Meander Cores at High Risk



# Treat High Risk Avulsion Paths With Discreet Criteria

- Raised banks on outside meander bends
- Raised topography within meander core
- Increased roughness
- Dense plantings
- Robust bank treatments on downstream limb where headcutting might occur



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95+00
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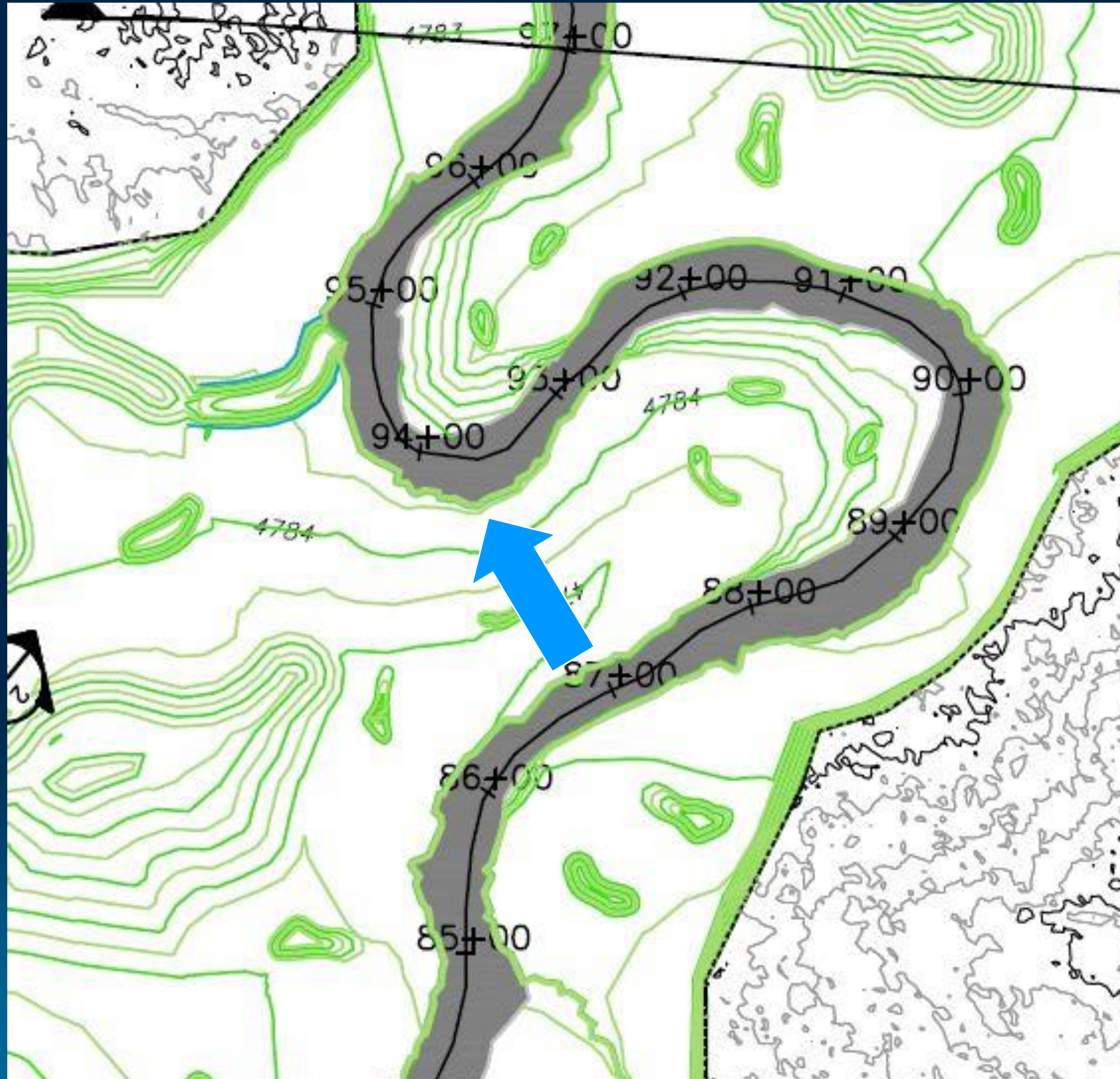

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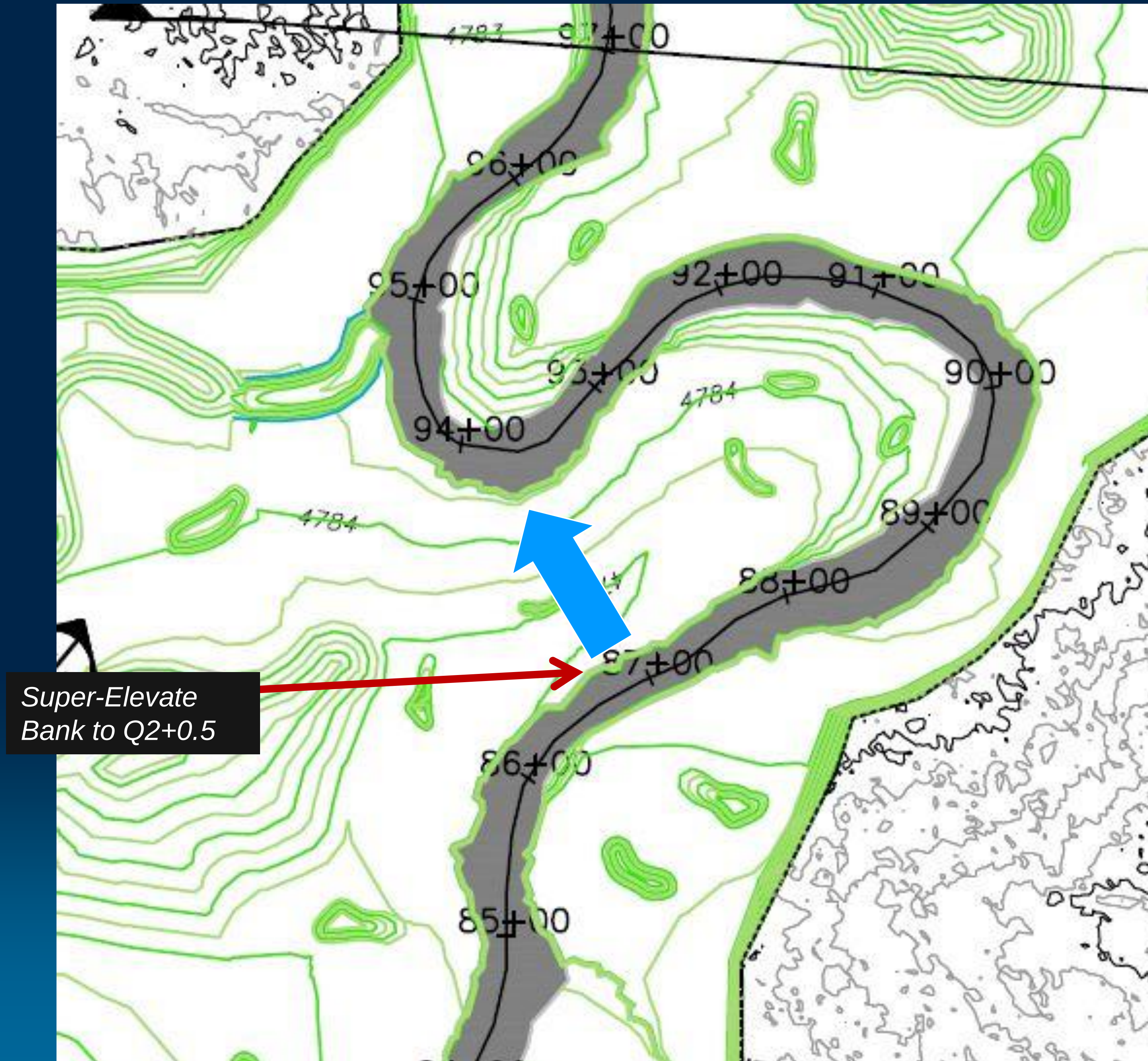

Super-Elevate
Bank to Q2+0.5
95+00
94+00
92+00
90+00
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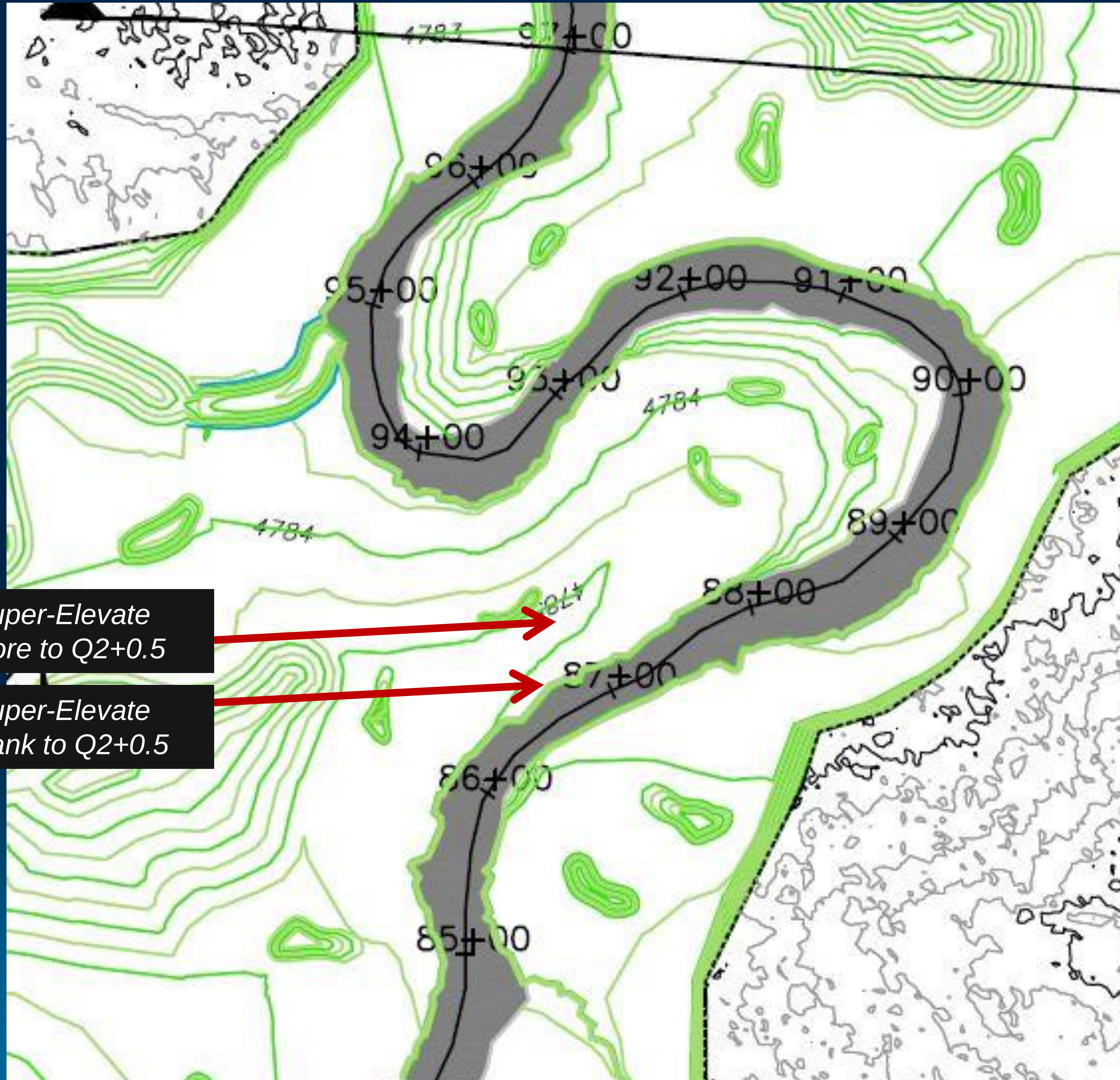
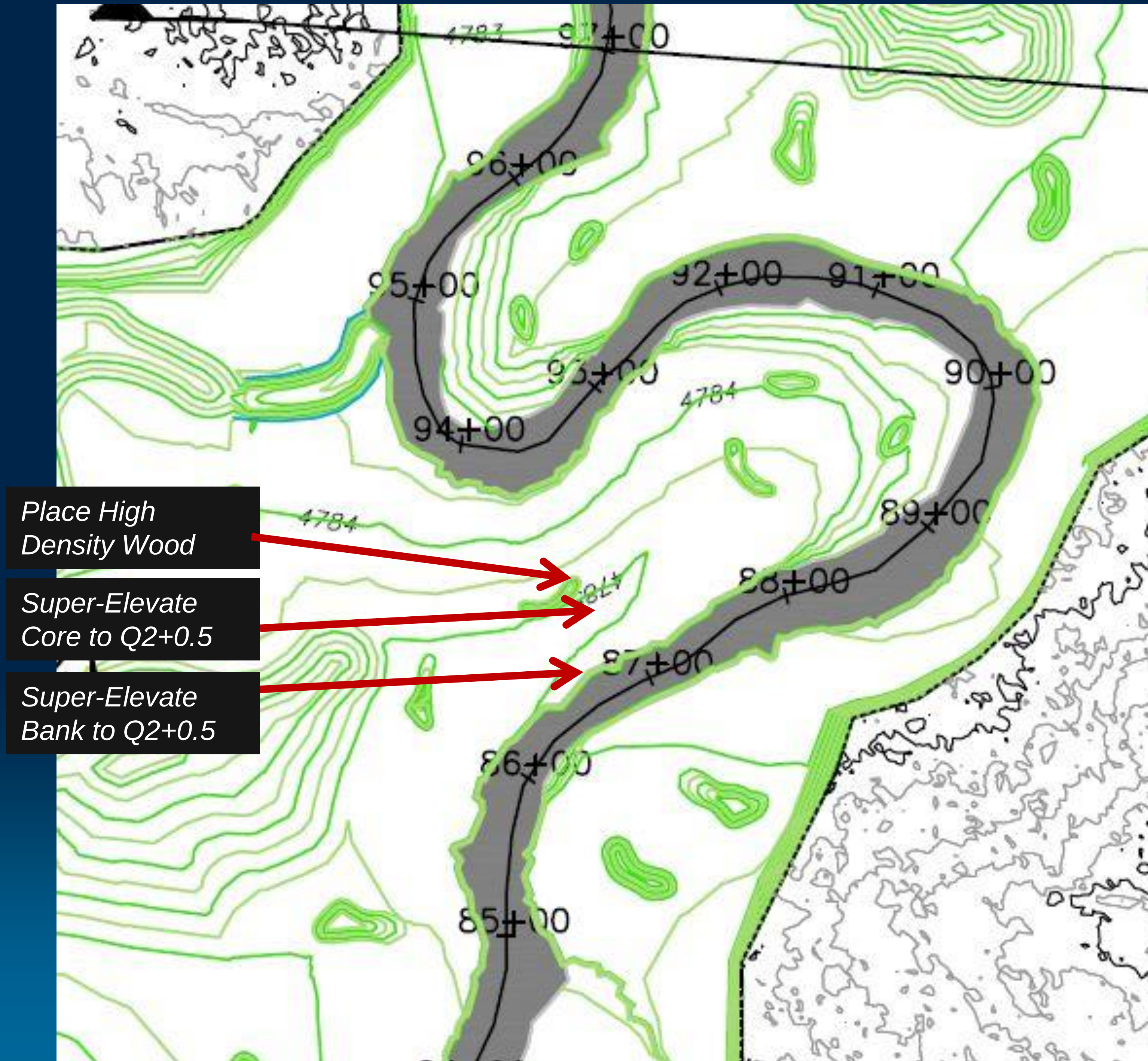



*Super-Elevate Core to Q2+0.5*

*Super-Elevate Bank to Q2+0.5*


Place High Density Wood
Super-Elevate Core to Q2+0.5
Super-Elevate Bank to Q2+0.5
4783
96+00
95+00
94+00
92+00
90+00
89+00
88+00
87+00
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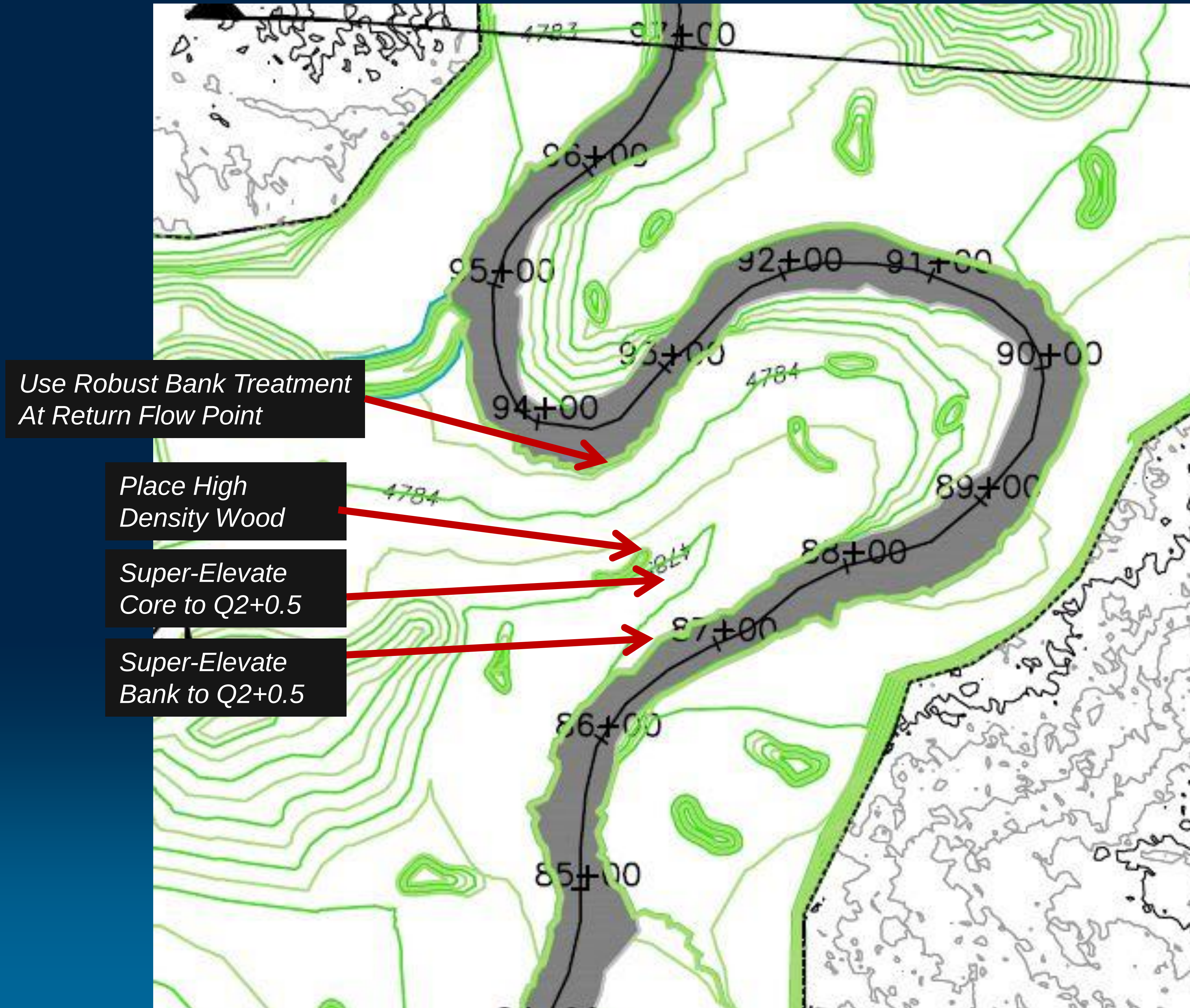
Use Robust Bank Treatment At Return Flow Point
Place High Density Wood
Super-Elevate Core to Q2+0.5
Super-Elevate Bank to Q2+0.5
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94+00
92+00
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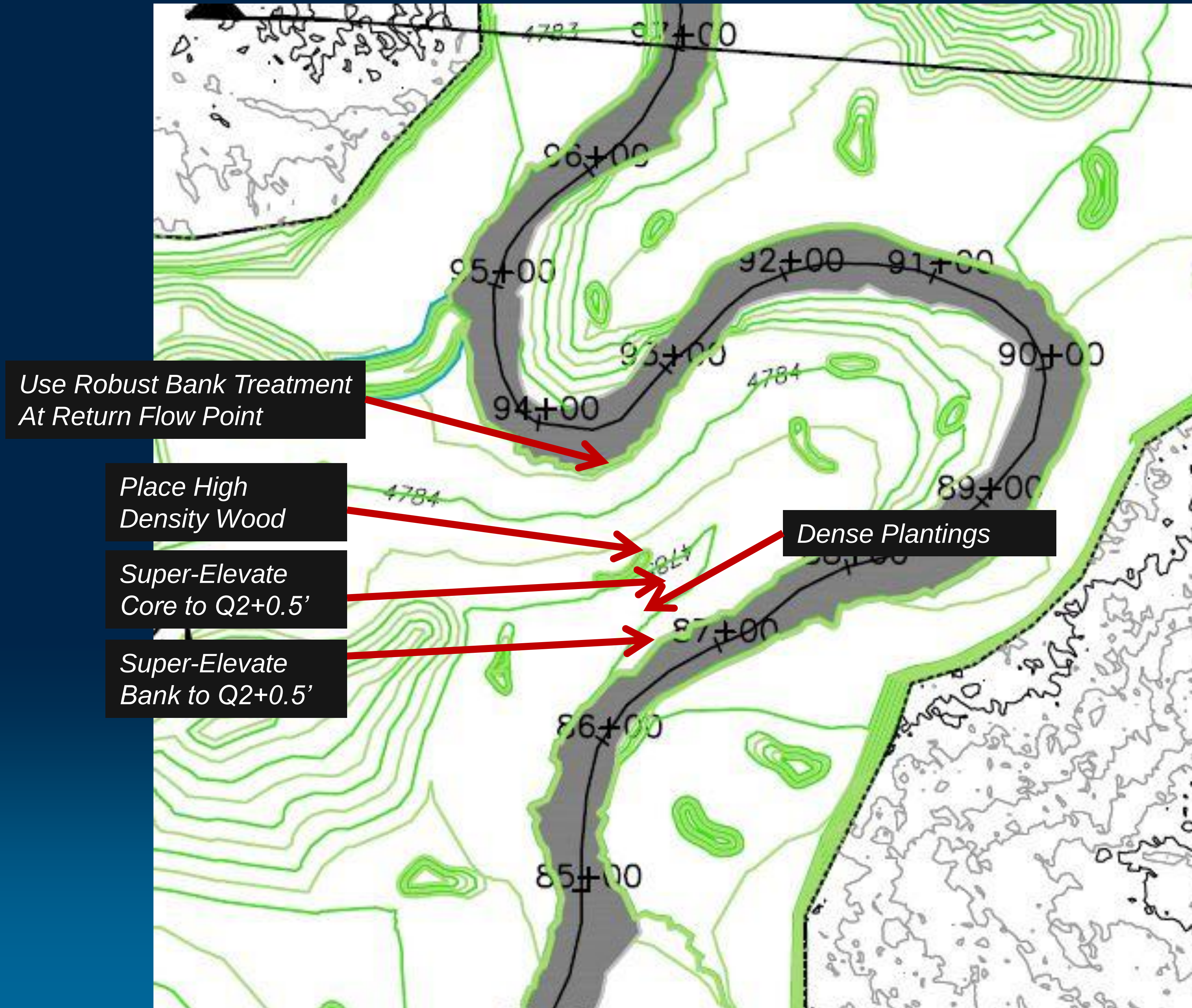

Use Robust Bank Treatment At Return Flow Point
Place High Density Wood
Super-Elevate Core to Q2+0.5’
Super-Elevate Bank to Q2+0.5’
Dense Plantings
4783
96+00
95+00
94+00
92+00
90+00
89+00
87+00
86+00
85+00
4784
4784

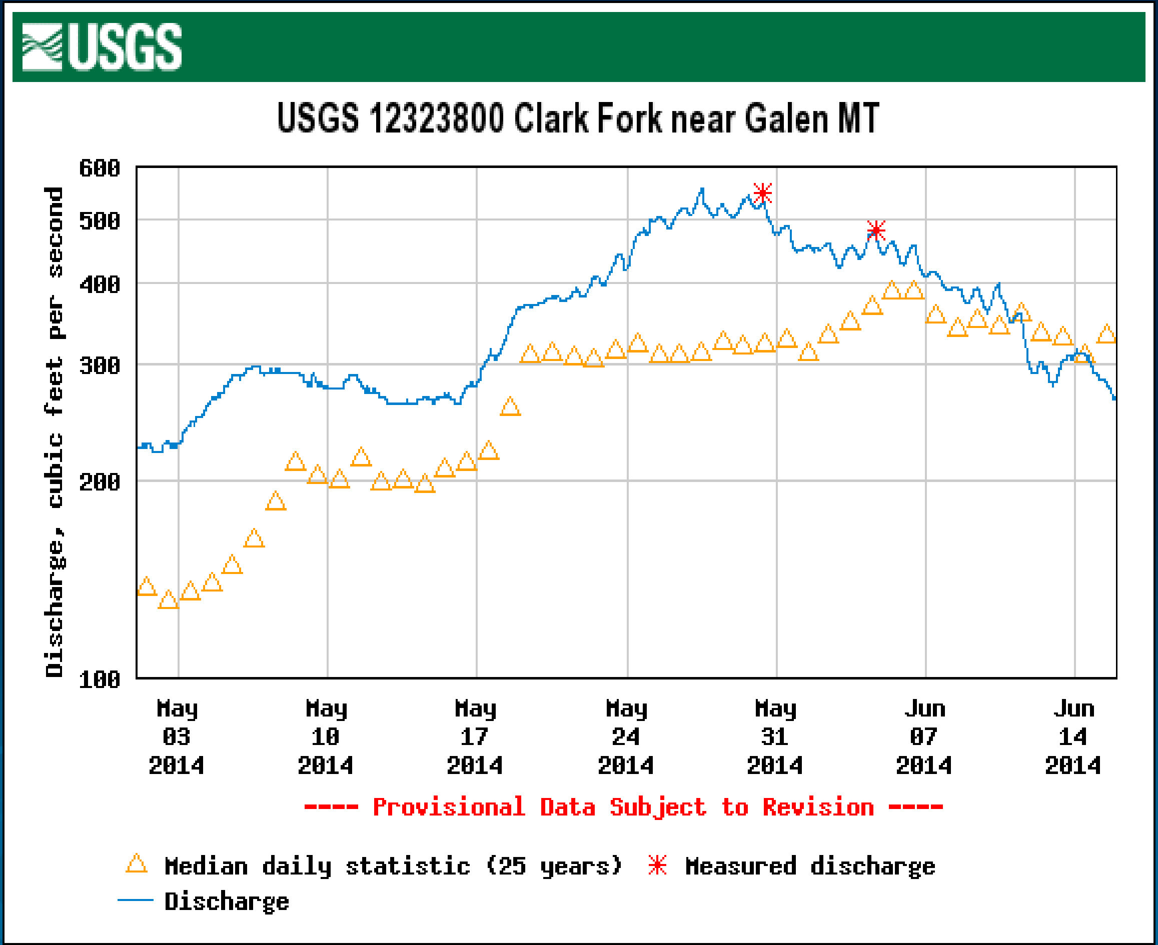
Super-Elevated Bank
Dense Woody Plantings

Elevated Core
Woody Debris

Double Lift

# Spring 2014

~4 Days Exceeding 500cfs



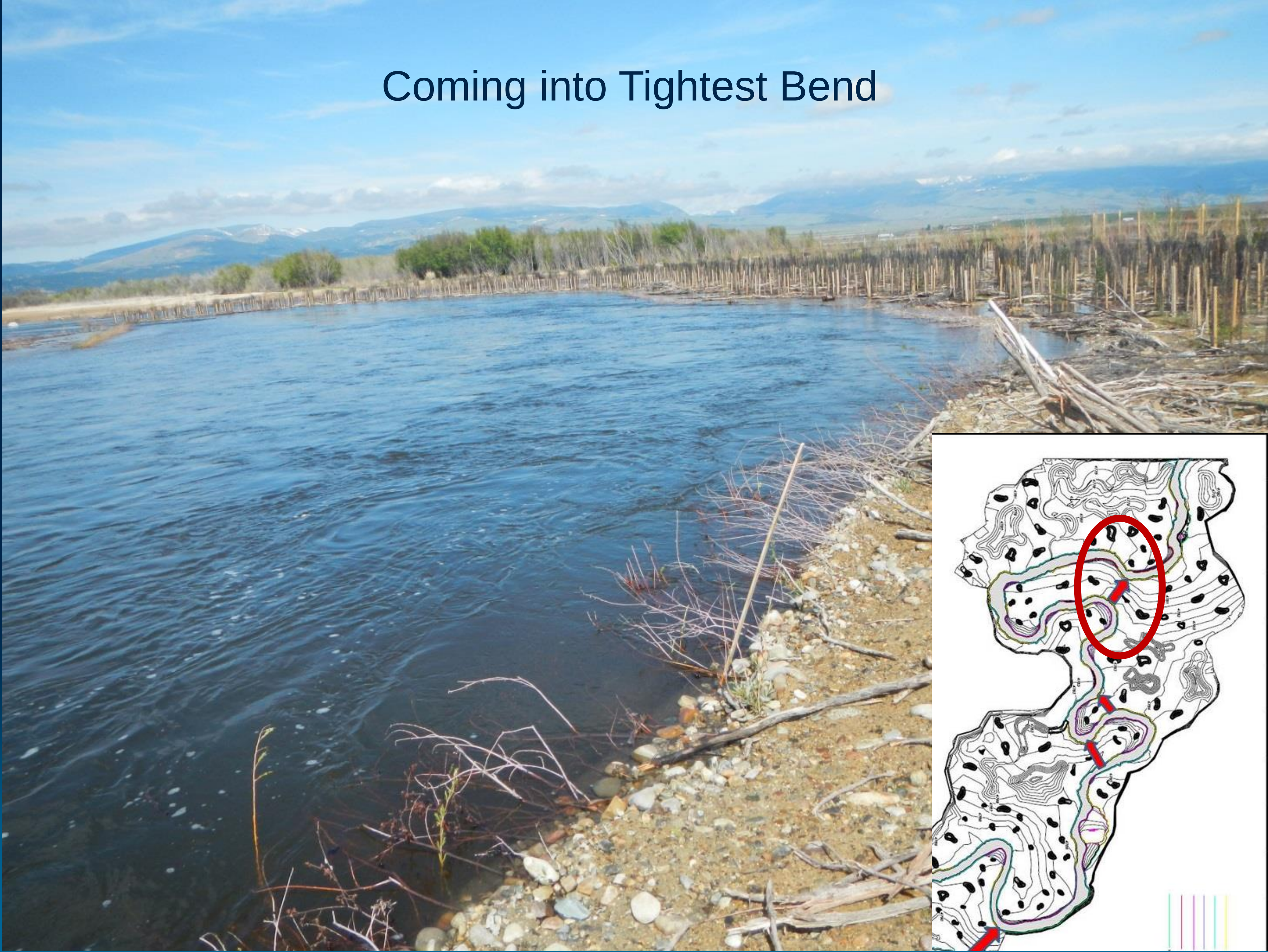

May 26 2014

# Connectivity Accomplished!

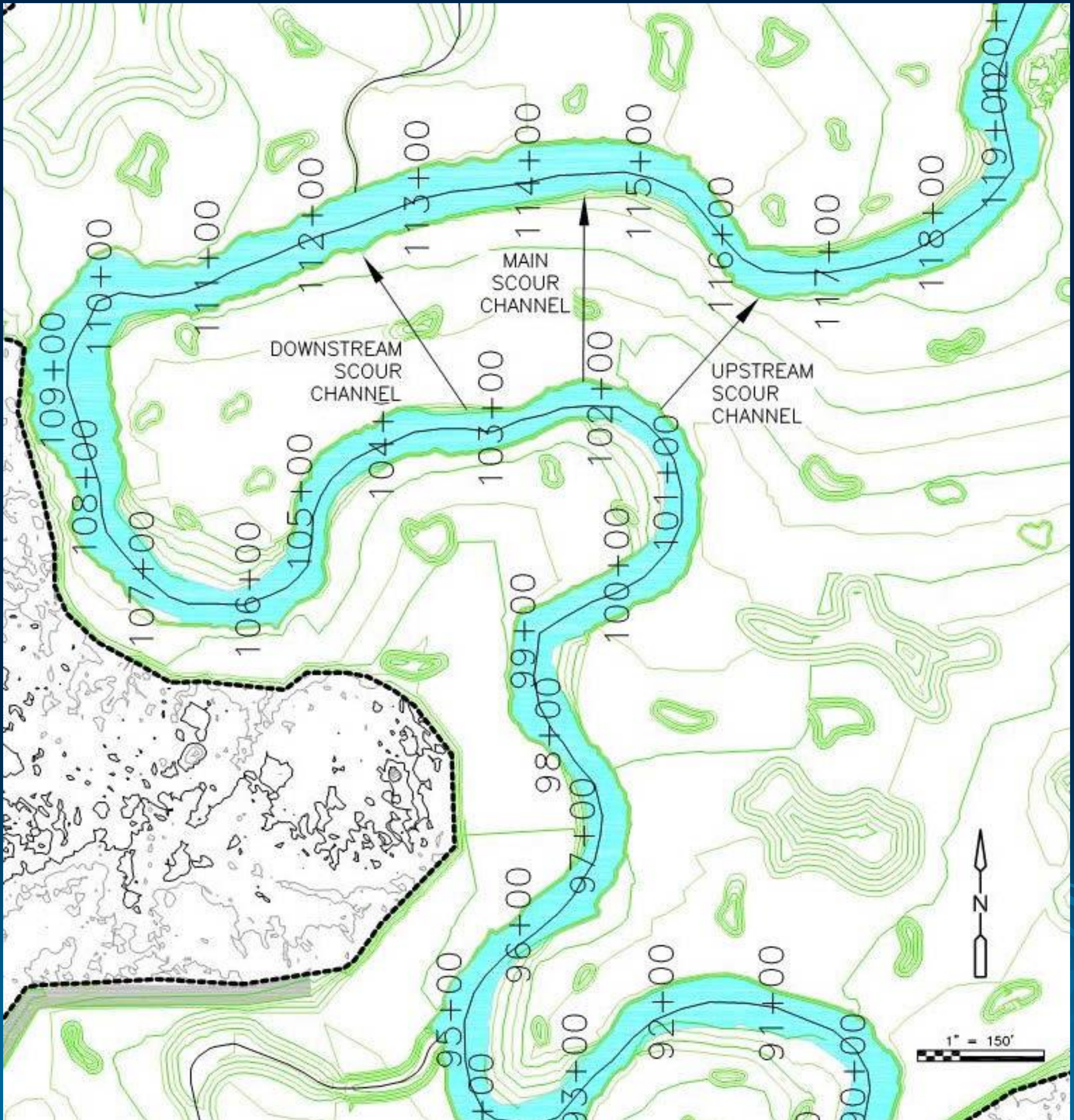

Outer Bank Plantings

# Vegetative Backfill Totally Saturated

# Coming into Tightest Bend



# Channelized Flow Across Core Creating Avulsion Risk


DOWNSTREAM SCOUR CHANNEL
MAIN SCOUR CHANNEL
UPSTREAM SCOUR CHANNEL
N
1" = 150'

# Overbank Flows Immediately Following Construction Provided Test of Avulsion Risk Reduction Measures

- Super-Elevated Outer Banks
- Elevated Meander Core
- Dense Plantings
- Coarse Wood
- Micro Topography
- Downstream Bank Treatment

# Super-Elevated Bank Tapered Too Early?


Outer Bank Shrubs Hadn't Been Planted Yet

# Use Vegetative Backfill for Elevated Core

- Material Eroded or Slurried Out

Alluvial Backfill Coarsened Bed

# Floodplain Woody Debris?

- Debris washed out and spread flows downstream

## Bank Treatments at Return Flow Points?

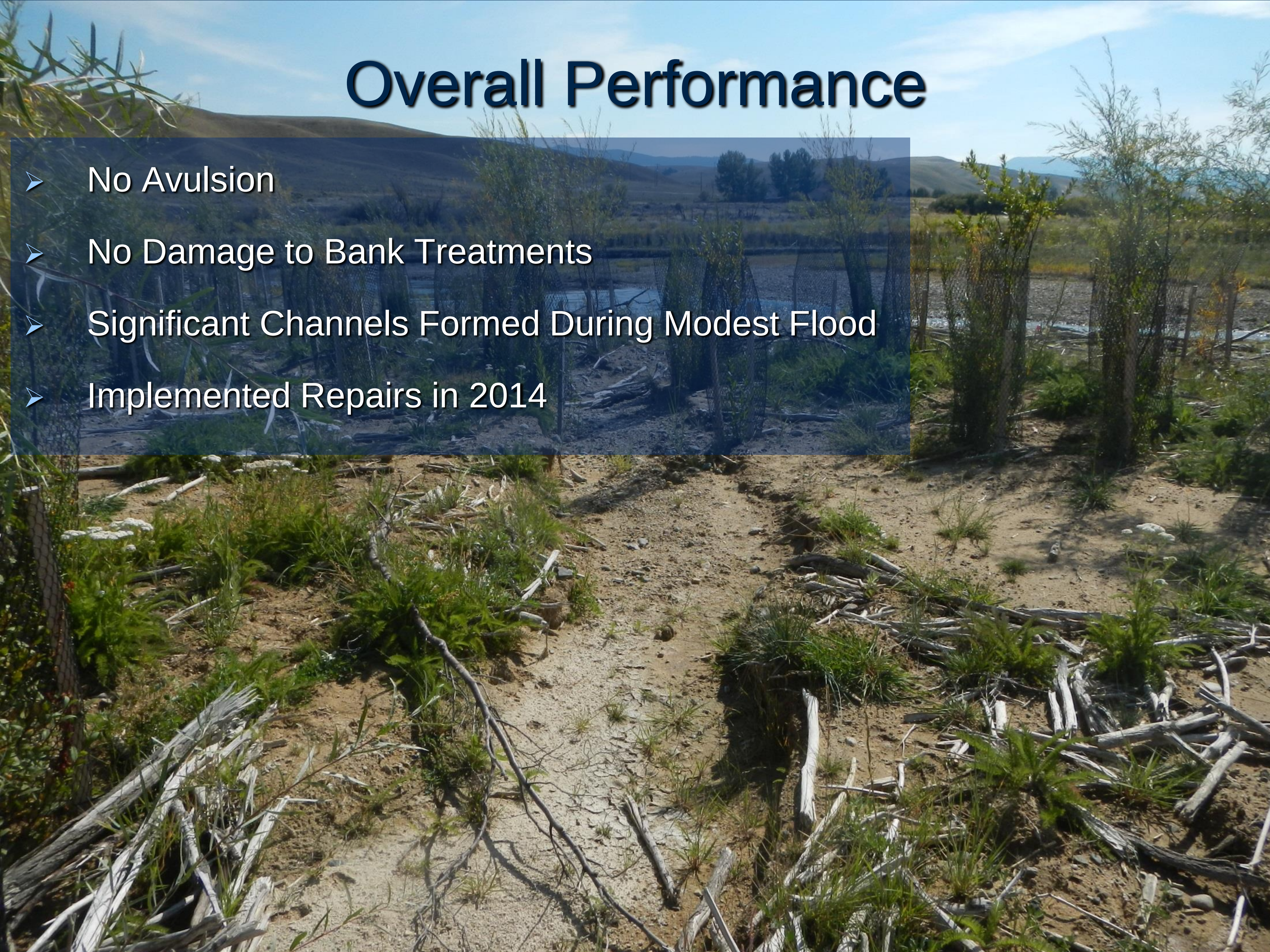
- No Headcutting
- PV Banks Held Up Well
- Brush Trenches Spread Flows
- Woody Debris Spread Flows

# Bank Treatments at Return Flow Points?

- Important Consideration

# Overall Performance

- No Avulsion
- No Damage to Bank Treatments
- Significant Channels Formed During Modest Flood
- Implemented Repairs in 2014



# Proposed Changes

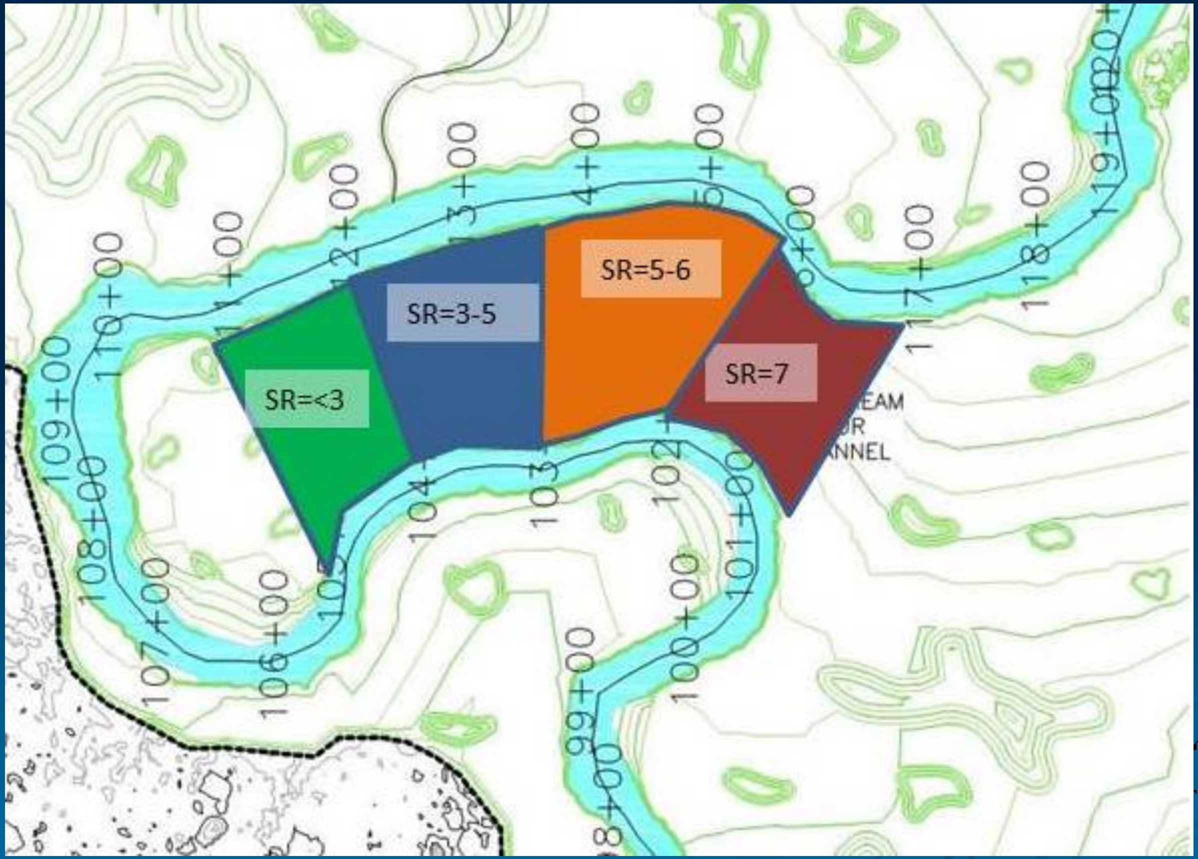
- Carry the super-elevated bank (0.5 feet high) through the entire downstream bend length before returning to the 2-year water-surface elevation.
- Construct elevated meander cores with floodplain alluvium or floodplain alluvium mixed with some vegetative backfill
- Construct wider flatter point bars on bends that feed high risk avulsion paths.
- Install higher density woody debris in areas of higher avulsion risk (i.e., 2 x the density of coarse wood).
- Consider incorporating willow plantings in all return flow areas to trap debris and decrease return flow velocities.

# Lessons Learned

- Minor Events Can Shed Light on Criteria/Performance
- Multi-Prong Measures Work
- Elevations Matter
- Materials Matter
- Need to Balance Risk, Cost, Outcome

# Moving Forward

- Assign Quantitative Criteria To Help Define Pathways
- Further Consider Risk, Cost, Outcome



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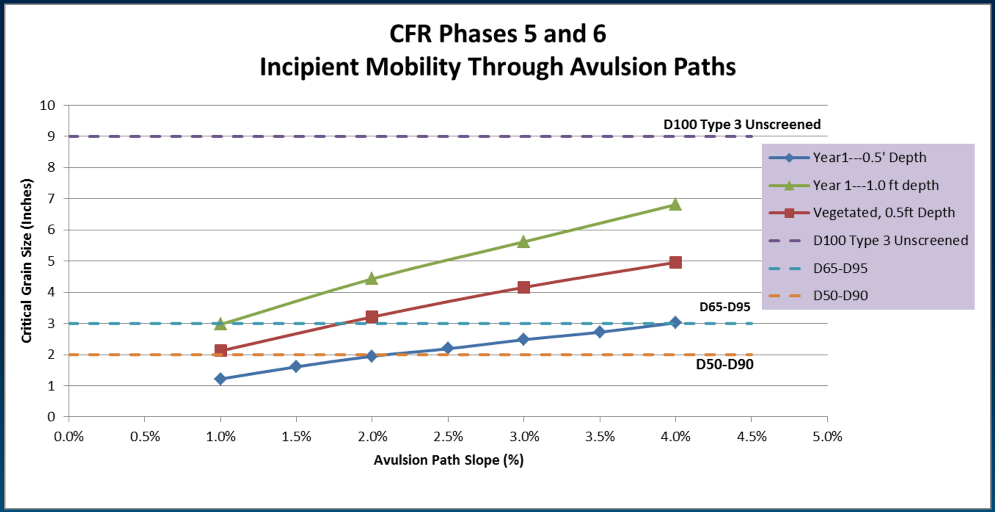


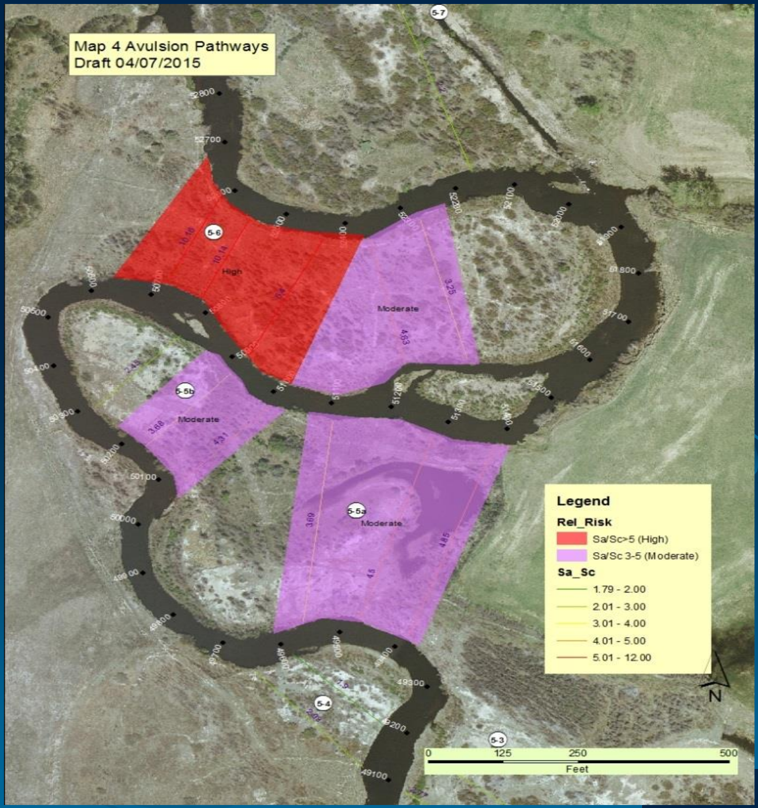

# Summary

- Floodplain connectivity is becoming recognized as an important, achievable outcome
- Reach A provides a large-scale opportunity to meet remedial objectives by restoring connectivity
- CFR floodplain disconnection process is atypical such that Reach A has specific design challenges/risks

# And…
# Cutoffs Happen

Before

After

Questions?