When Wandering Rivers Meet Critical Infrastructure: Rivers, River Restoration and Your Drinking Water Supply

May 13, 2016

Drinking Water Source Protection Conference

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This is a Caption

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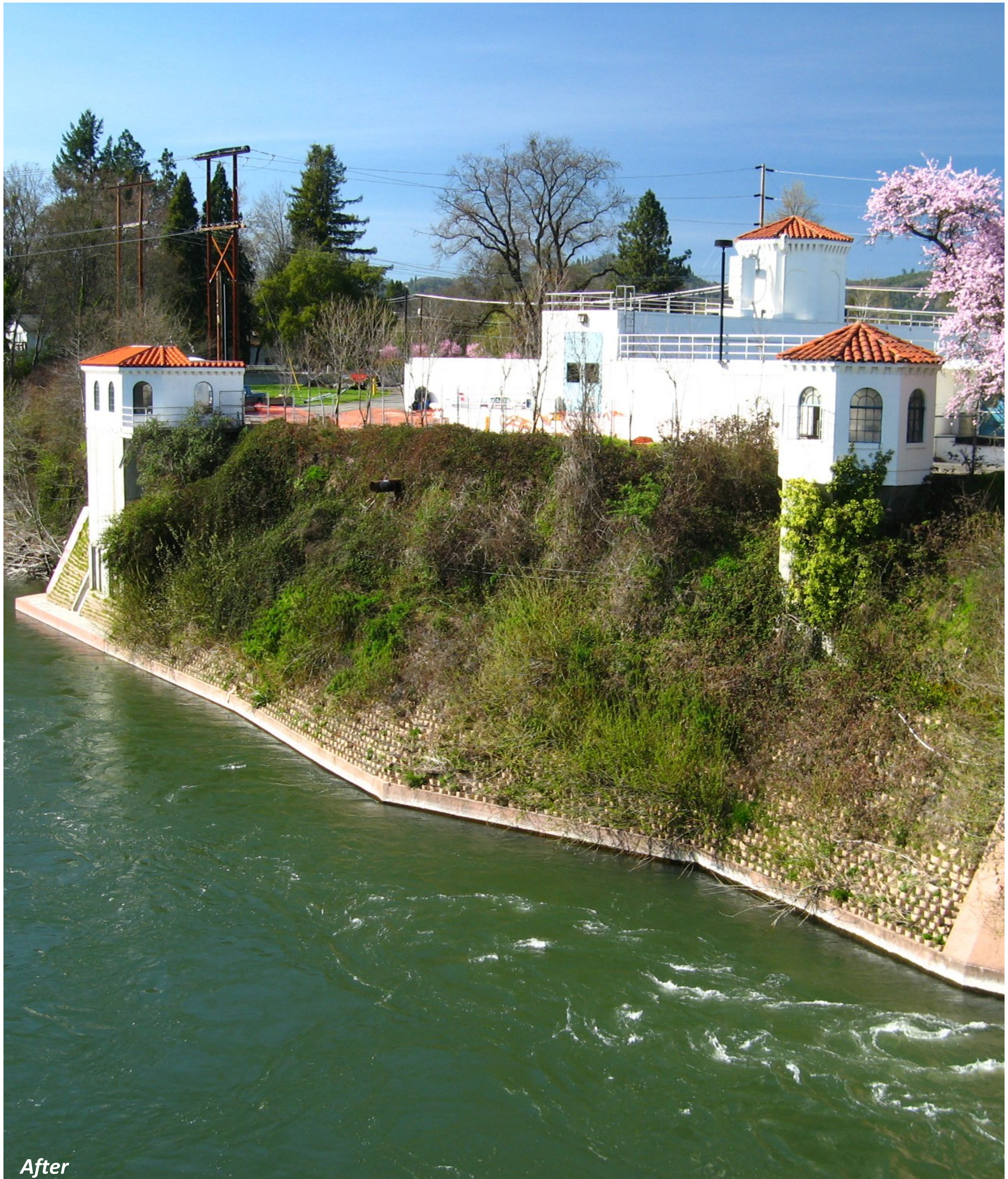
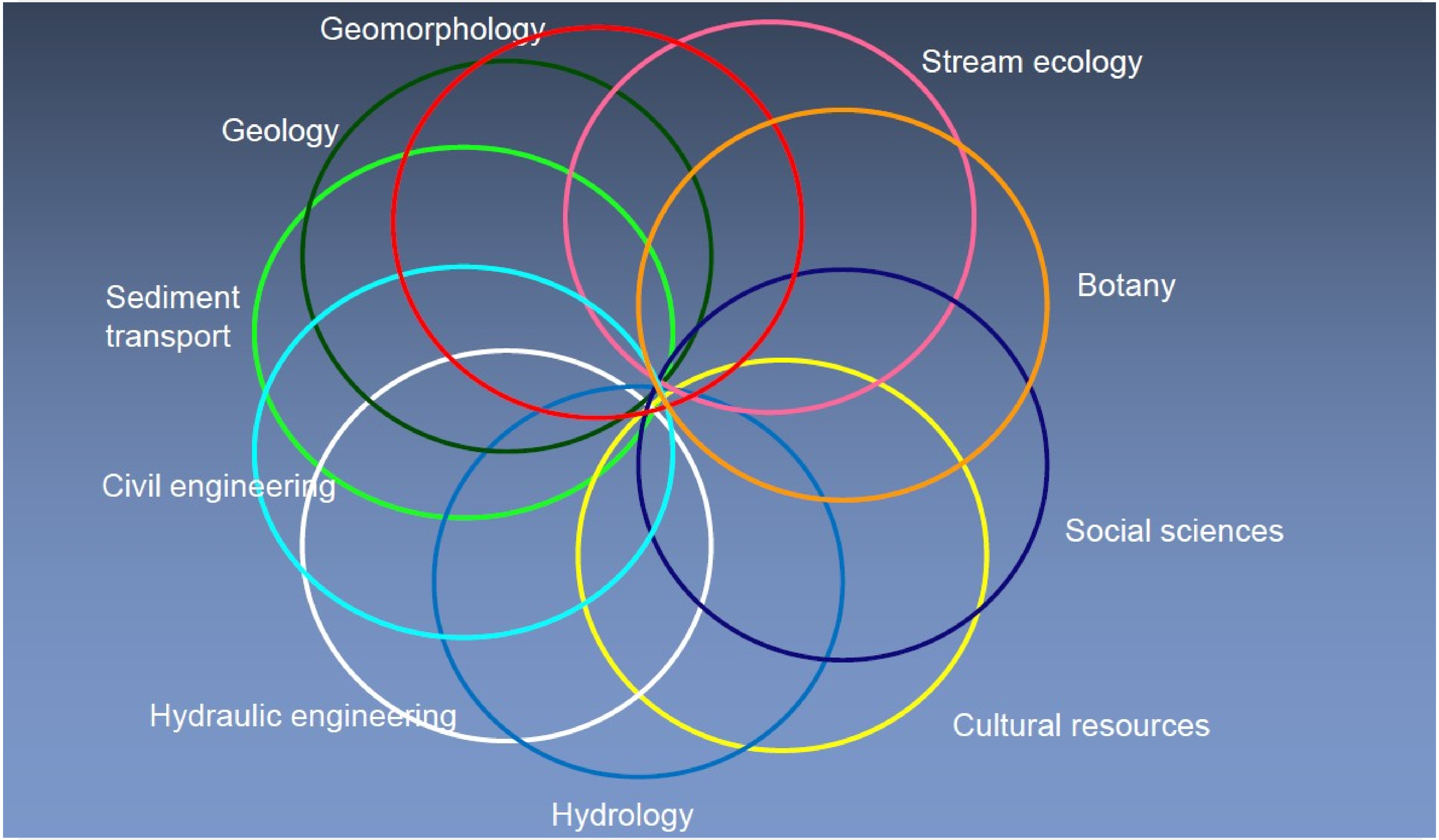


Take Home Messages

- Rivers connect – what happens upstream impacts areas downstream
- Understand the watershed as a whole, rather than isolated sections
- Rivers are naturally mobile, sometimes catastrophically
- Bed or bank stabilization measures will result in adjustments upstream or downstream or adjacent to the work

Rivers are complex, requiring an understanding of many disciplines



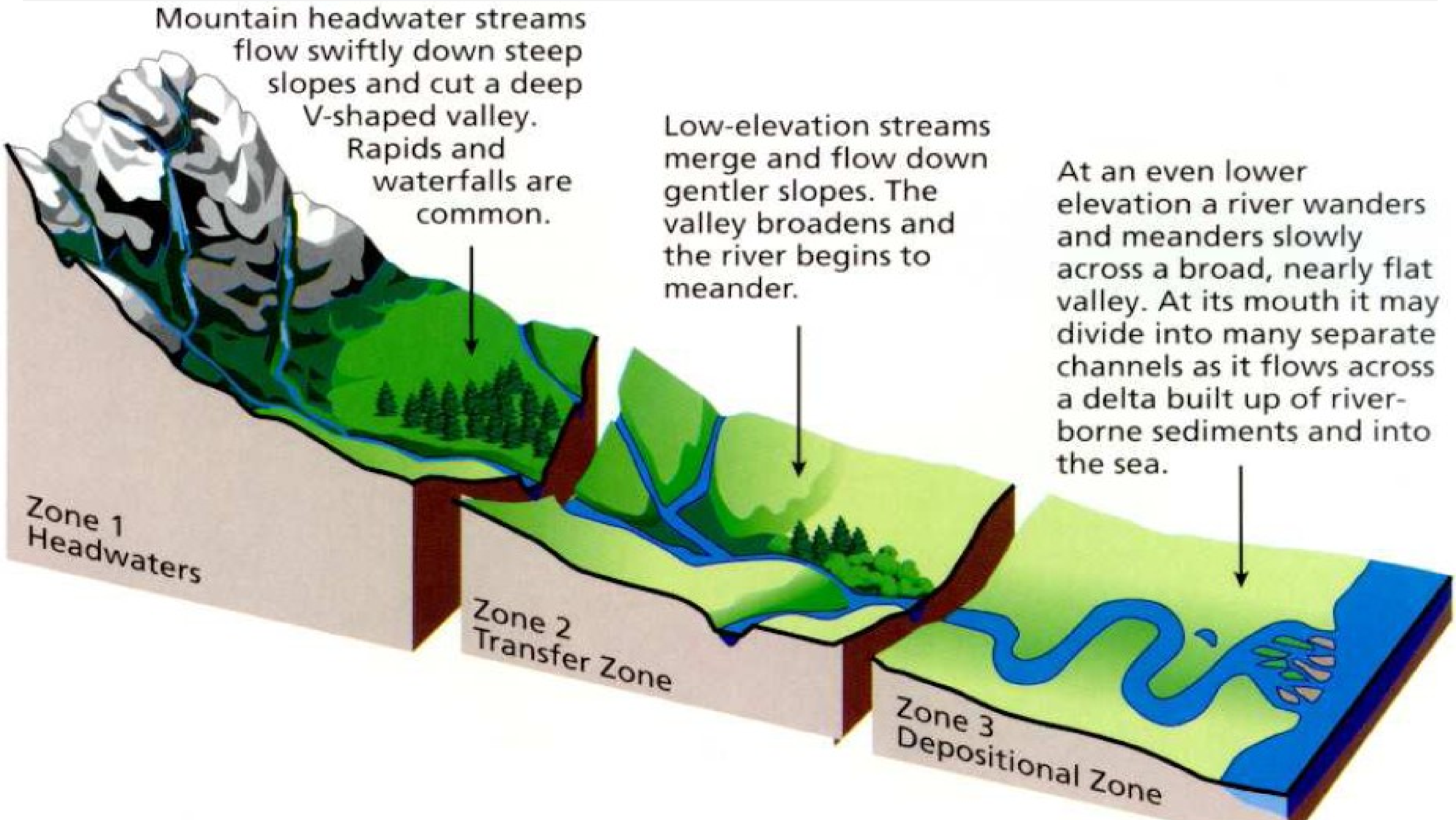
Fluvial Geomorphology Defined

- **Fluvial** = pertaining to a river
- **Geomorphology** = the study of the origin of topographic features, which are carved by erosion and built up from erosional debris
- **Fluvial Geomorphology** = study of river related processes and landforms

River Form

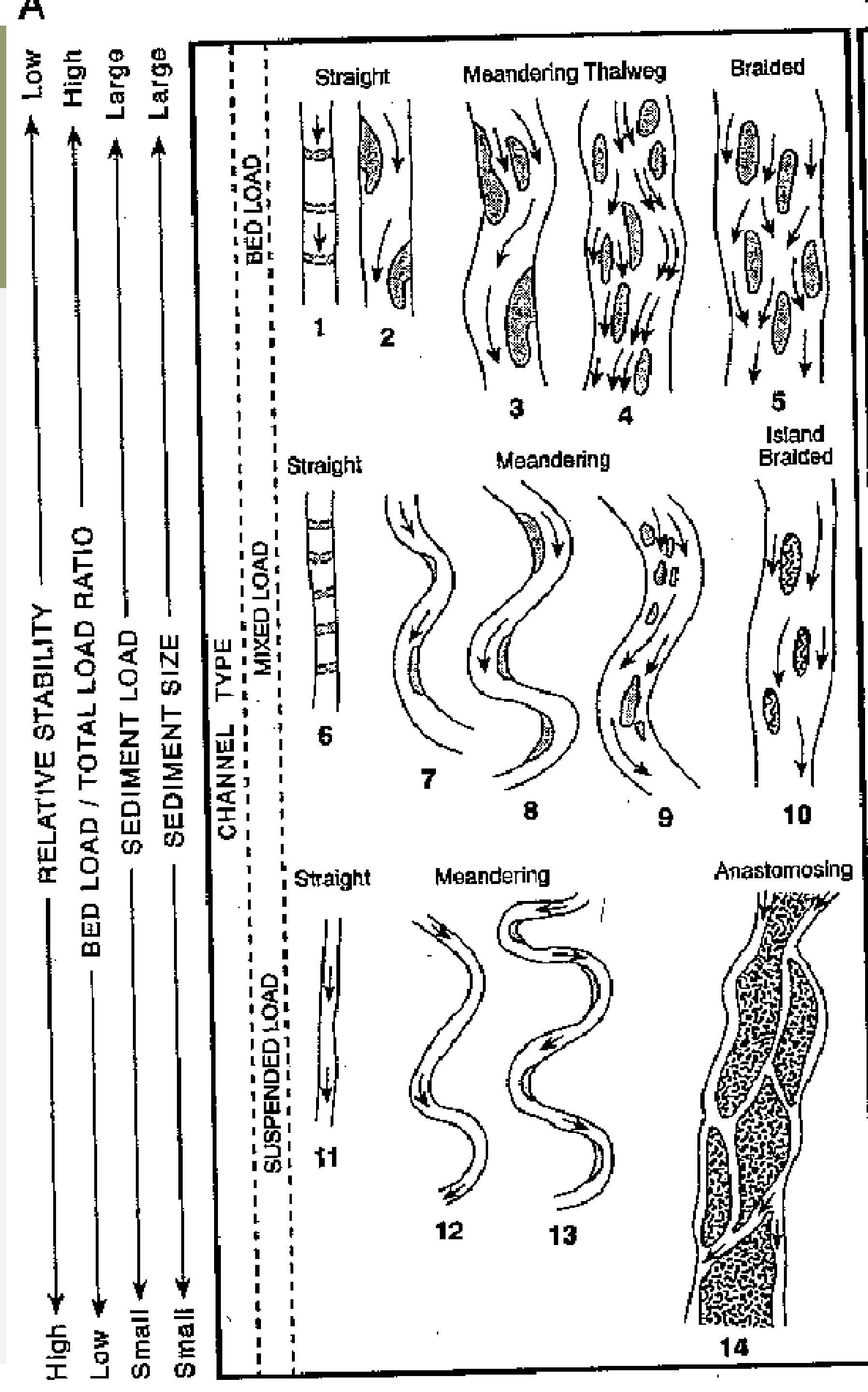
- Watershed zones
- Channel Planform
- Channel cross section

Segment Scale: Watershed Zones



Channel Planform

- Straight
- Meandering
- Braided
- Anastomosing



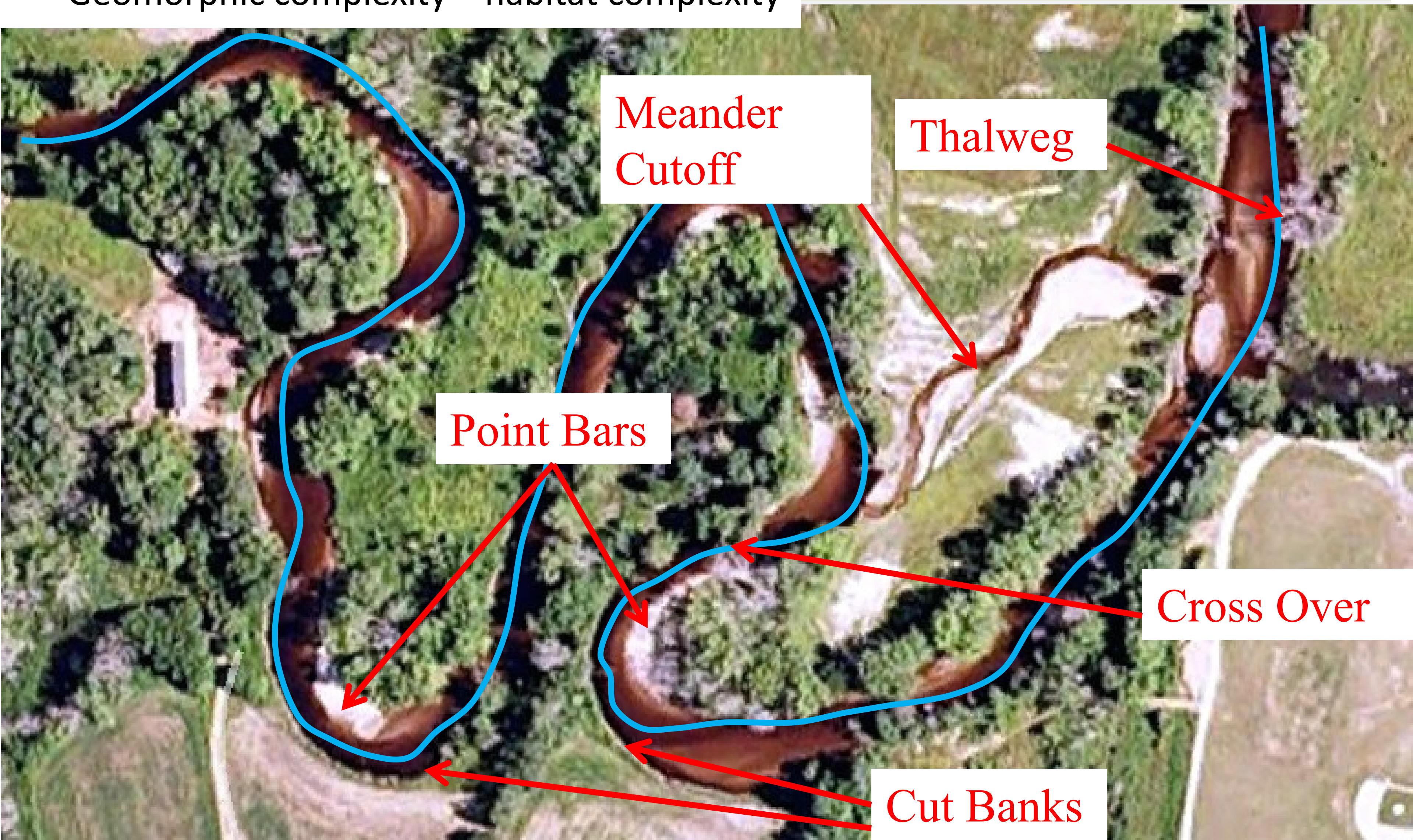
Schumm, 1981

Straight Channels

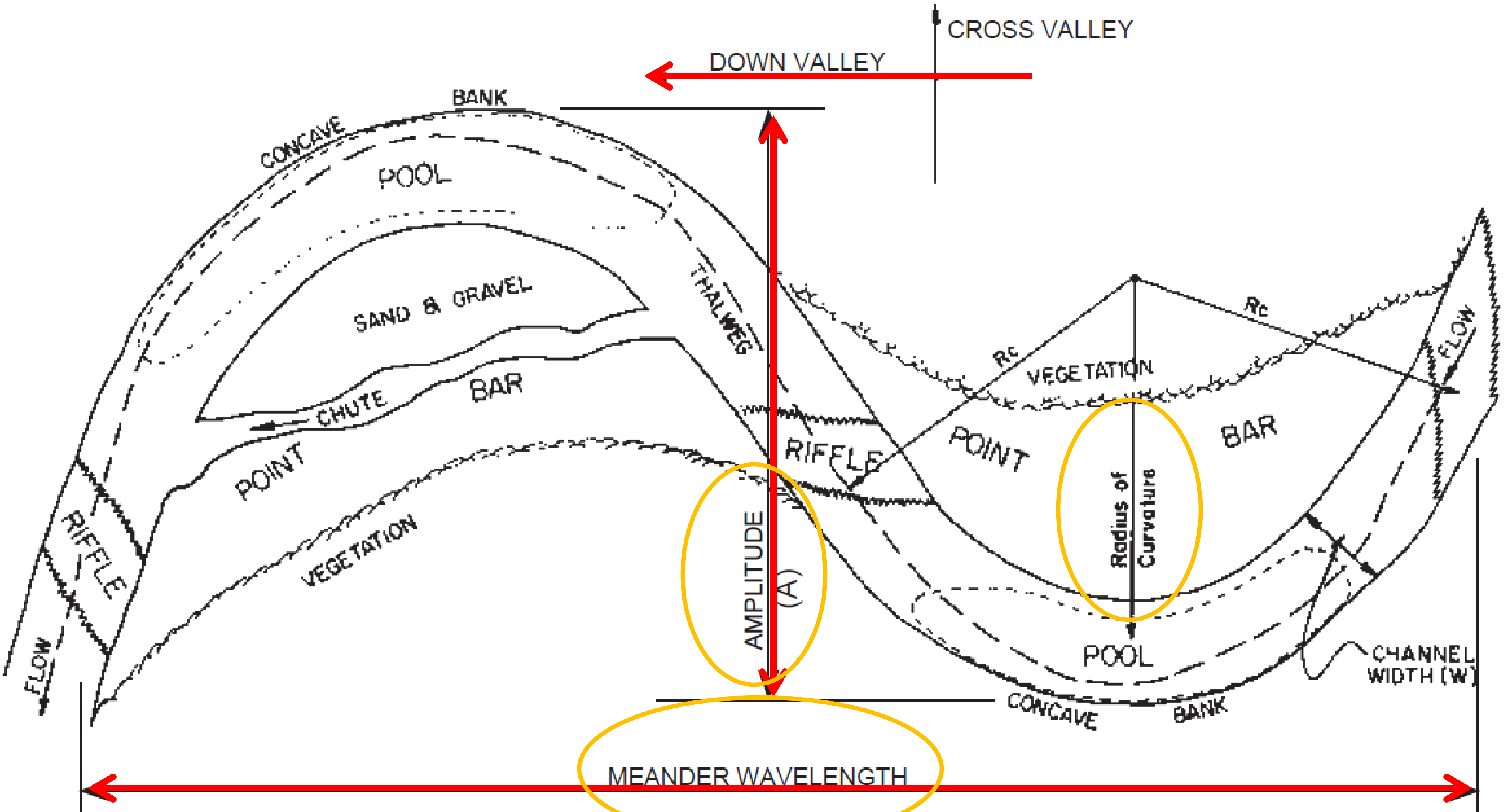
- Human-induced
  - Agriculture
  - Urban
- Uniform channel geometry
- Consistent channel bed material
- Limited habitat variability

Meandering

- Low to Moderate Slopes
- Bank erosion/bar deposition
- Variable flow velocity
- Variable channel substrate
- Geomorphic complexity = habitat complexity



Meander Radius, amplitude, wavelength, sinuosity

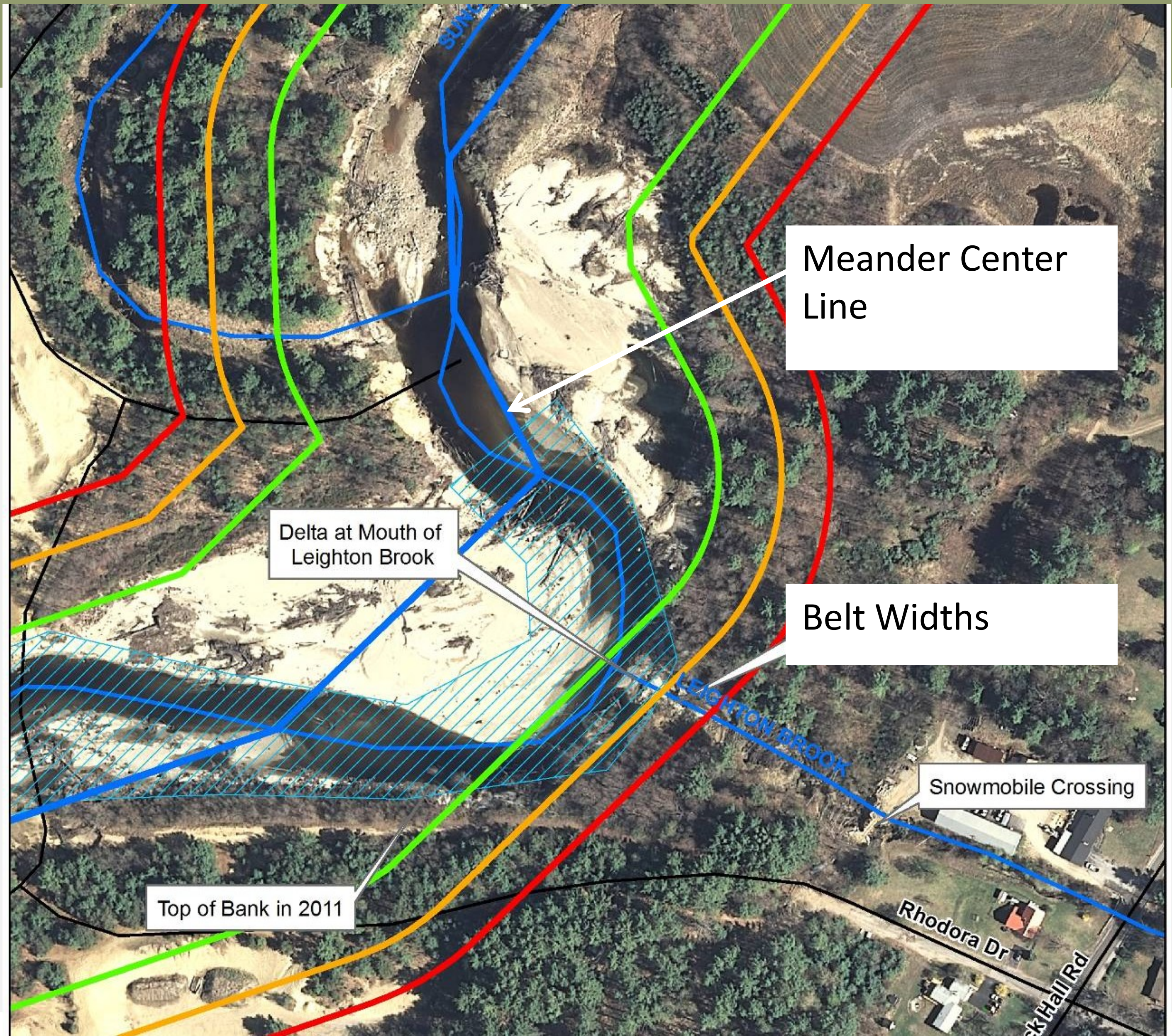


Lagasse et al., 2004

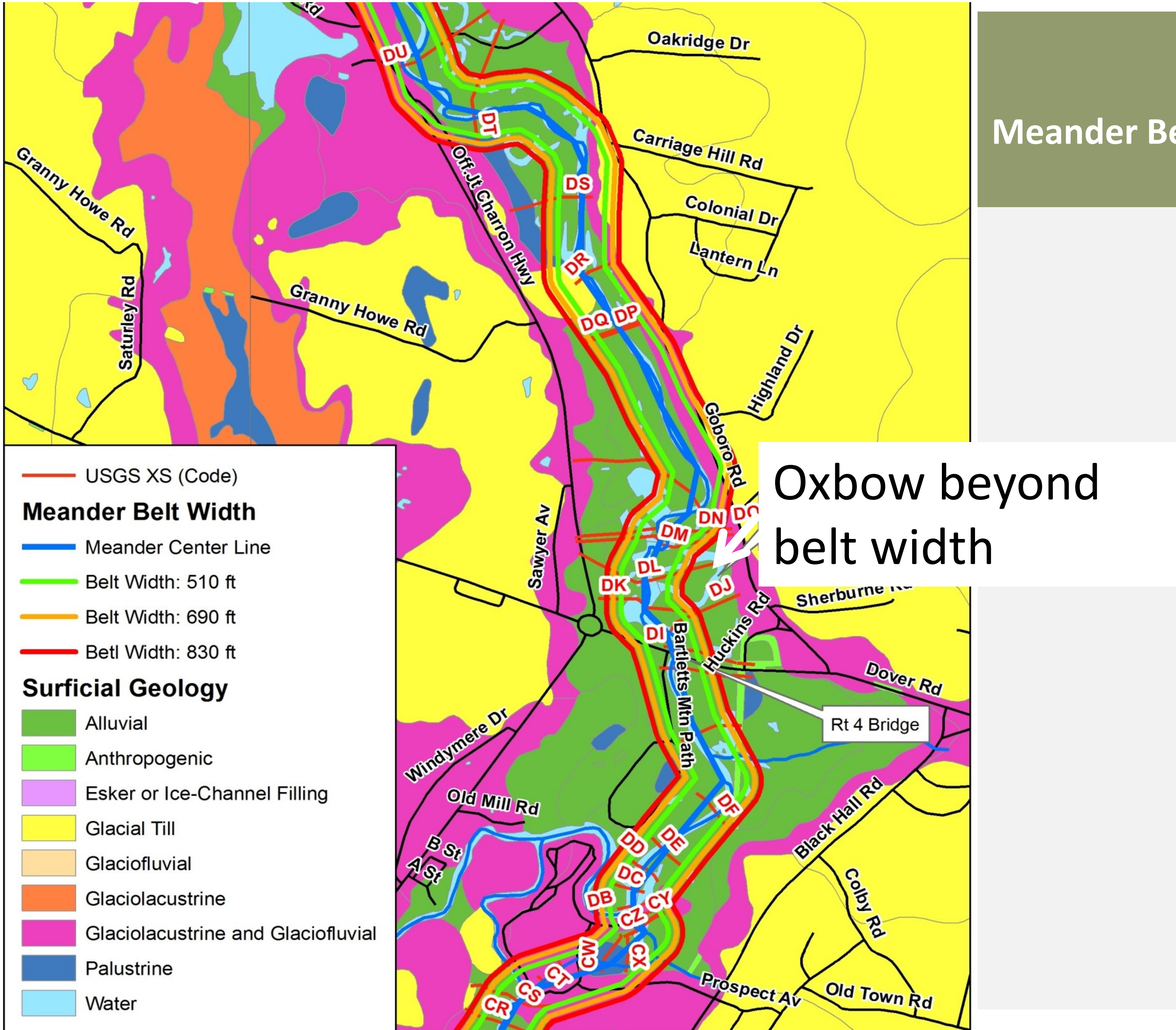
Stream Corridors

- Meander belt width: approximates the corridor within which an active stream may meander
  - VT DEC River Management Program:
    - 6x the channel width
  - Williams, 1986: $B = 3.7W^{1.12}$
    - B = belt width
    - W = channel width

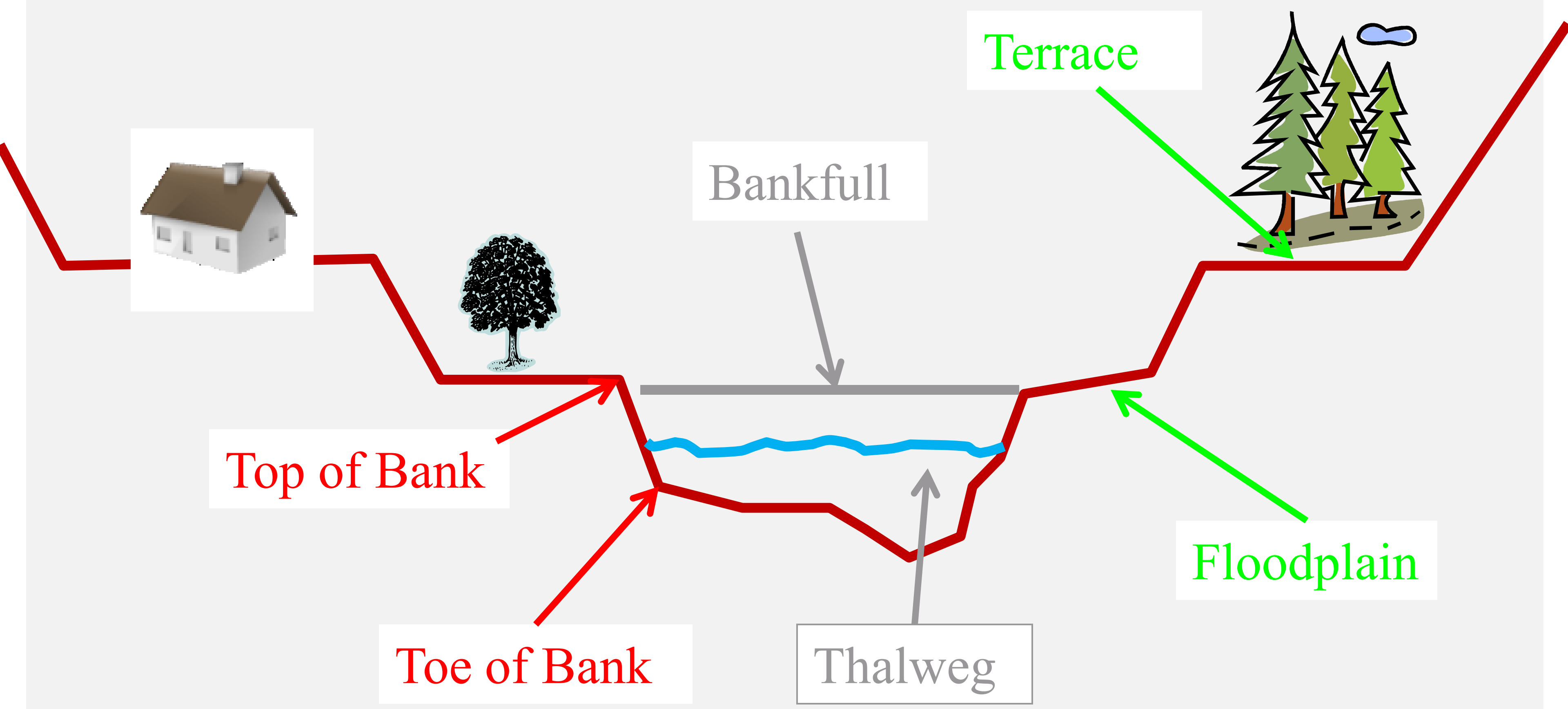
Meander Belt Width



Meander Belt Width



Channel Cross Section



River Processes

- Discharge
- Hydraulic analyses
- Stream Power
- Sediment transport
- Erosion and Deposition

- Rivers are in constant state of adjustment
- Moving towards equilibrium

Water Discharge

Continuity of Flow

$$Q = VA$$

Discharge = velocity x cross sectional area

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110

Flow Resistance: Manning's Roughness Coefficient

$$U = \frac{K * \left(R^{\frac{2}{3}}\right) * \left(S^{\frac{1}{2}}\right)}{n}$$

Roughness in Channel

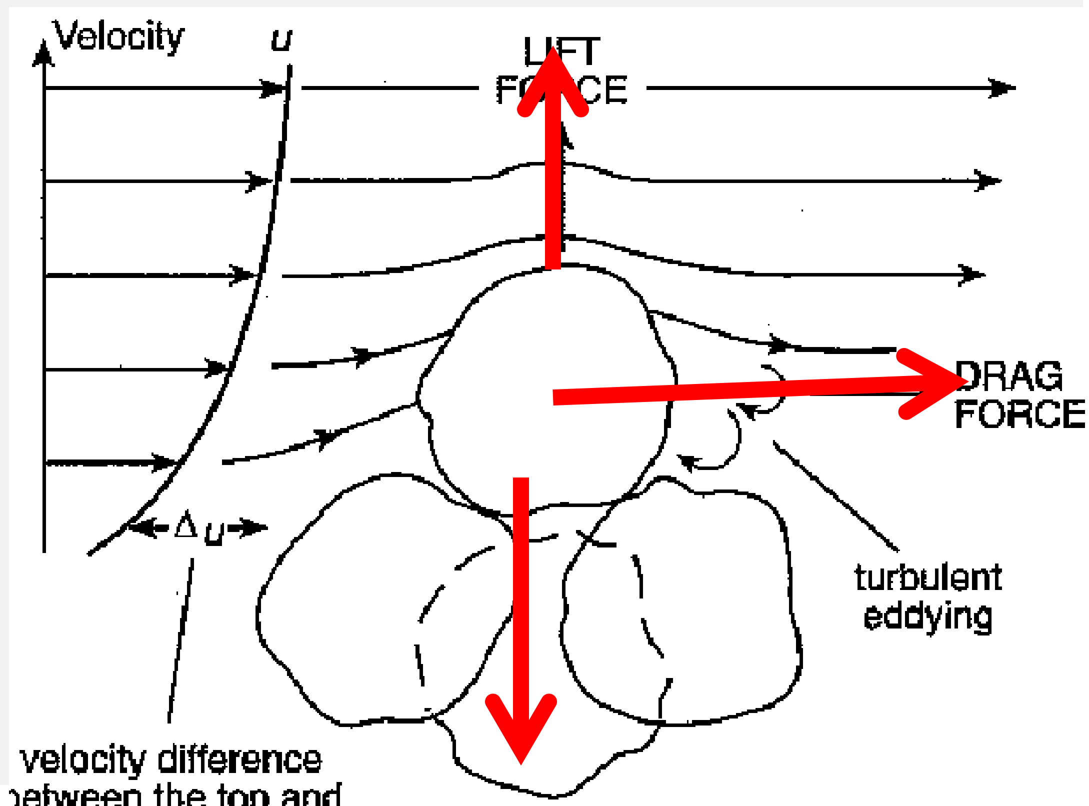
Roughness on Floodplains

Fluvial Processes: Stream Power and Sediment Transport

– Stream power: rate at which streams can do work

– Shear stress = stress acting on channel substrate

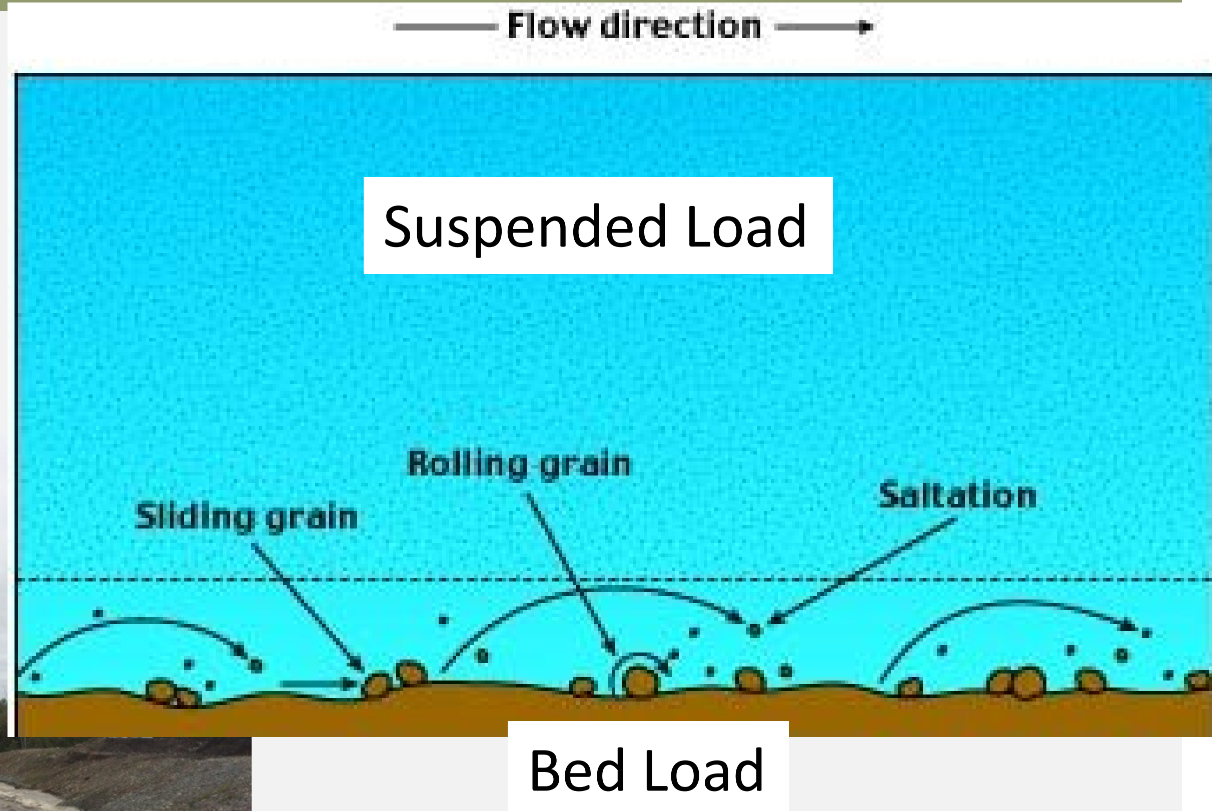
– Critical shear stress: point at which substrate begins to move



Knighton

Sediment Transport

- Suspended load
- Bed load



Erosion

- Bed and bank erosion is a natural fluvial process
- Water volume, velocity or shear stress is greater than the volume or size of the sediment
- Impact – hydraulic action removes material from land surfaces and channel bed and banks
- Abrasion – heavy material dragged along the channel bottom to erode channel bed and banks

Deposition

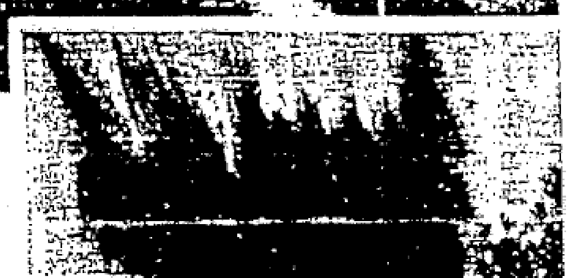
- Sediment deposition is a natural fluvial process
- Volume or size of material is too great for water to move
- Heavy materials deposited first
- Point bar deposition
- Bed aggradation

Rivers vs Infrastructure

- Straightening
- Levees
- Infrastructure protection – bed and bank stabilization

How DYNAMITE *streamlines streams*

Straightening of Pequest River in New Jersey by CCC workers stopped its yearly floods. Location of new channel is seen at right. Note temporary dam at left to pro-

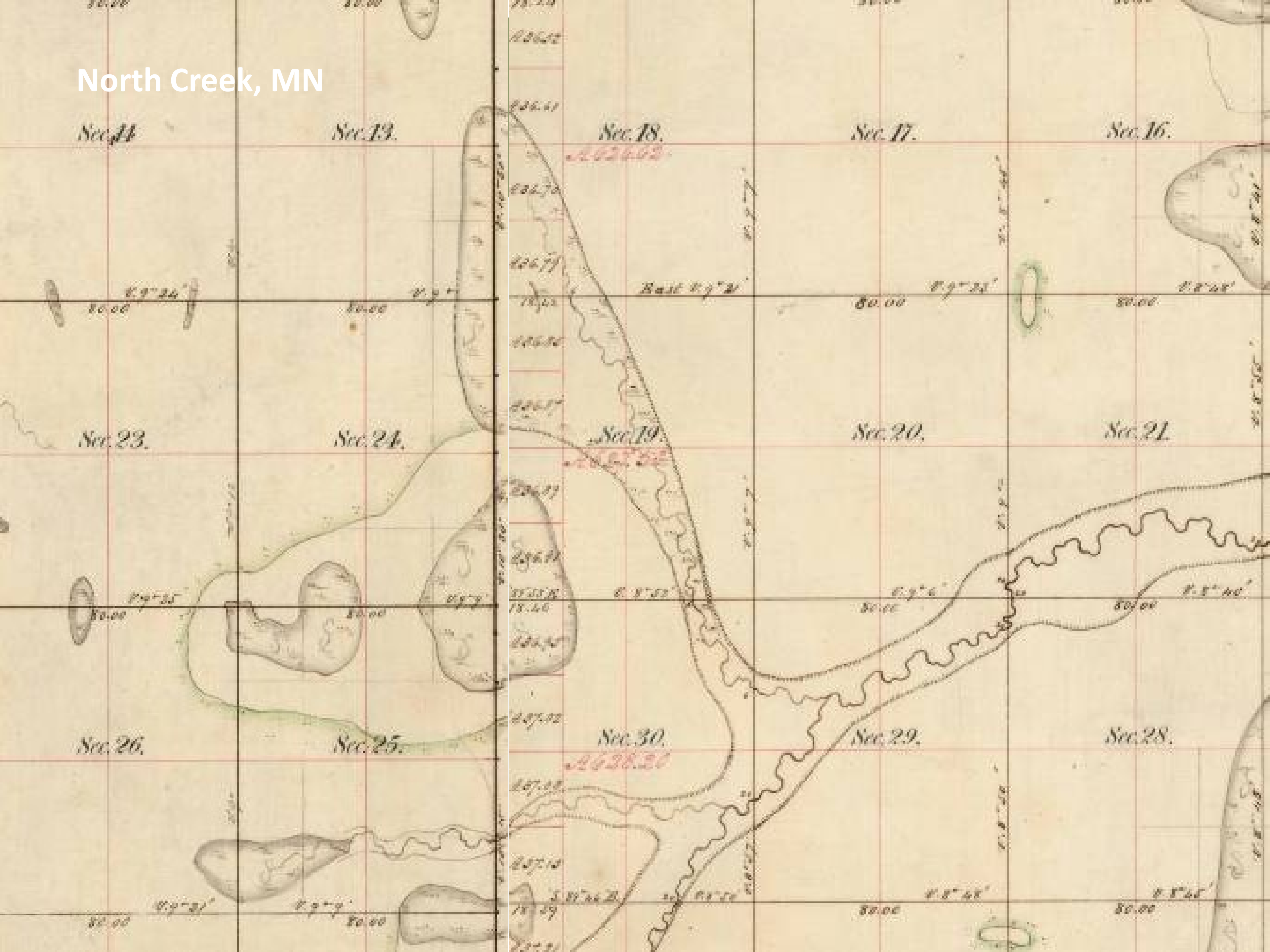


CROOKED STREAMS are a menace to life and crops in the areas bordering on their banks. The twisting and turning of the channel retards the flow and reduces the capacity of the stream to handle large volumes of water. Floods result. Crops are ruined. Lives are lost. Banks are undermined, causing cave-ins that steal valuable acreage.

In many instances straightening out a stream has doubled its capacity for disposing of run-off water.

DYNAMITE may be used most efficiently and economically in taking the kinks out of a crooked stream. The dynamite is loaded along the length of "cut-off" channel. When fired, the dirt and other debris is heaved high in the air and is scattered over the adjoining territory—leaving prac-

- Flood conveyance
- Development
- Agriculture


North Creek, MN
Sec.14
Sec.13
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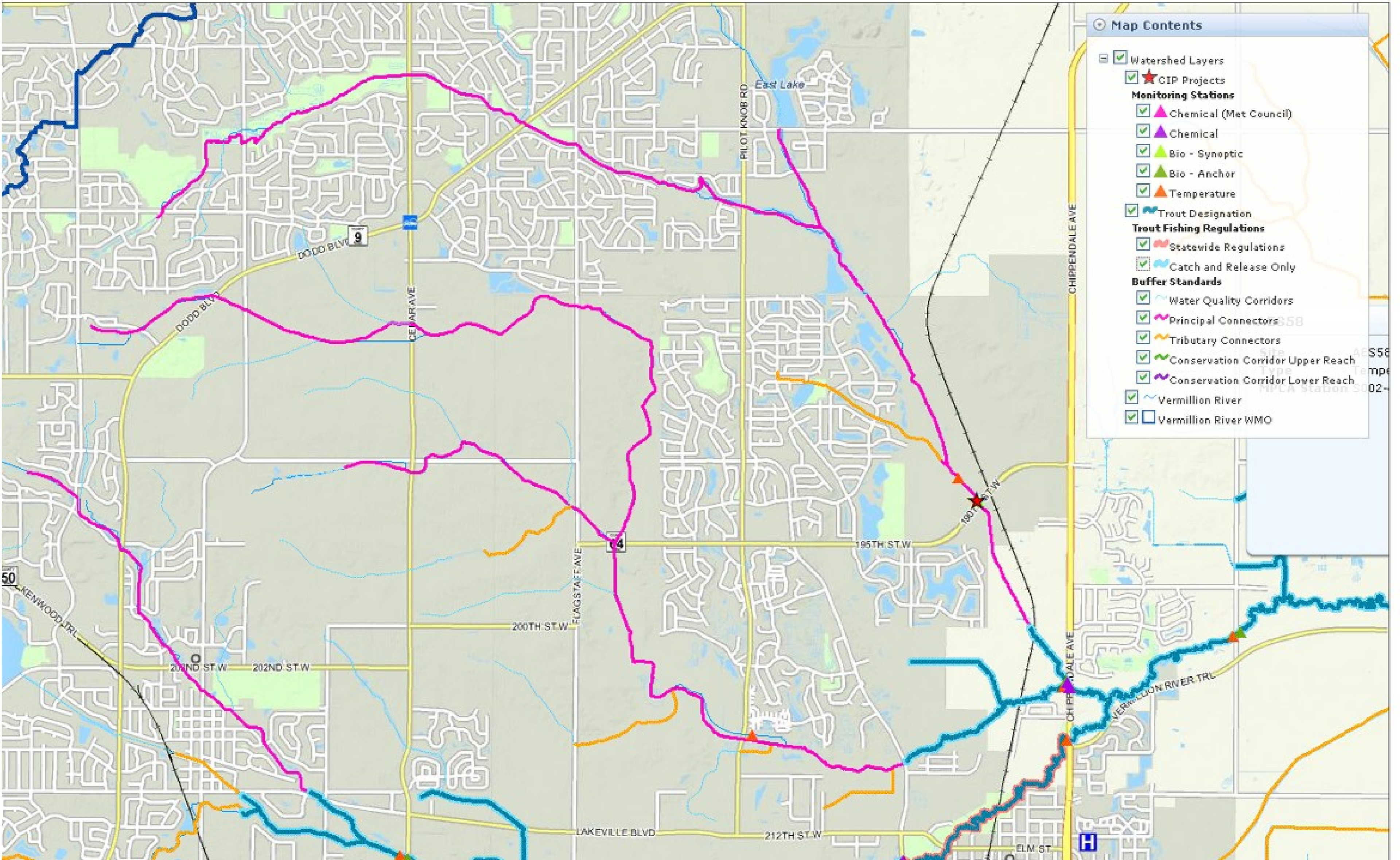
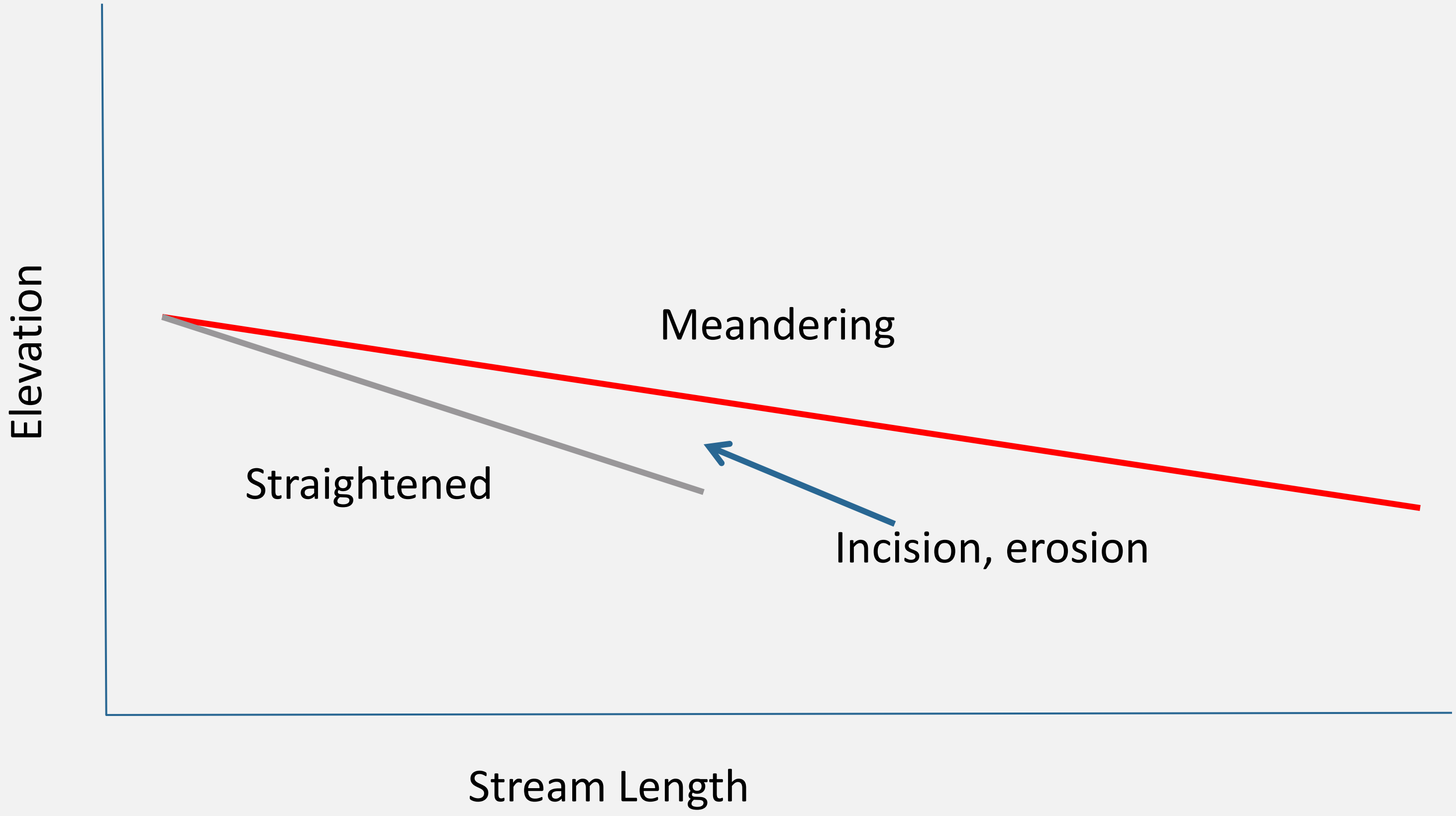
North Creek, MN



Straightening Decreases Stream Length



Incision/Knickpoints

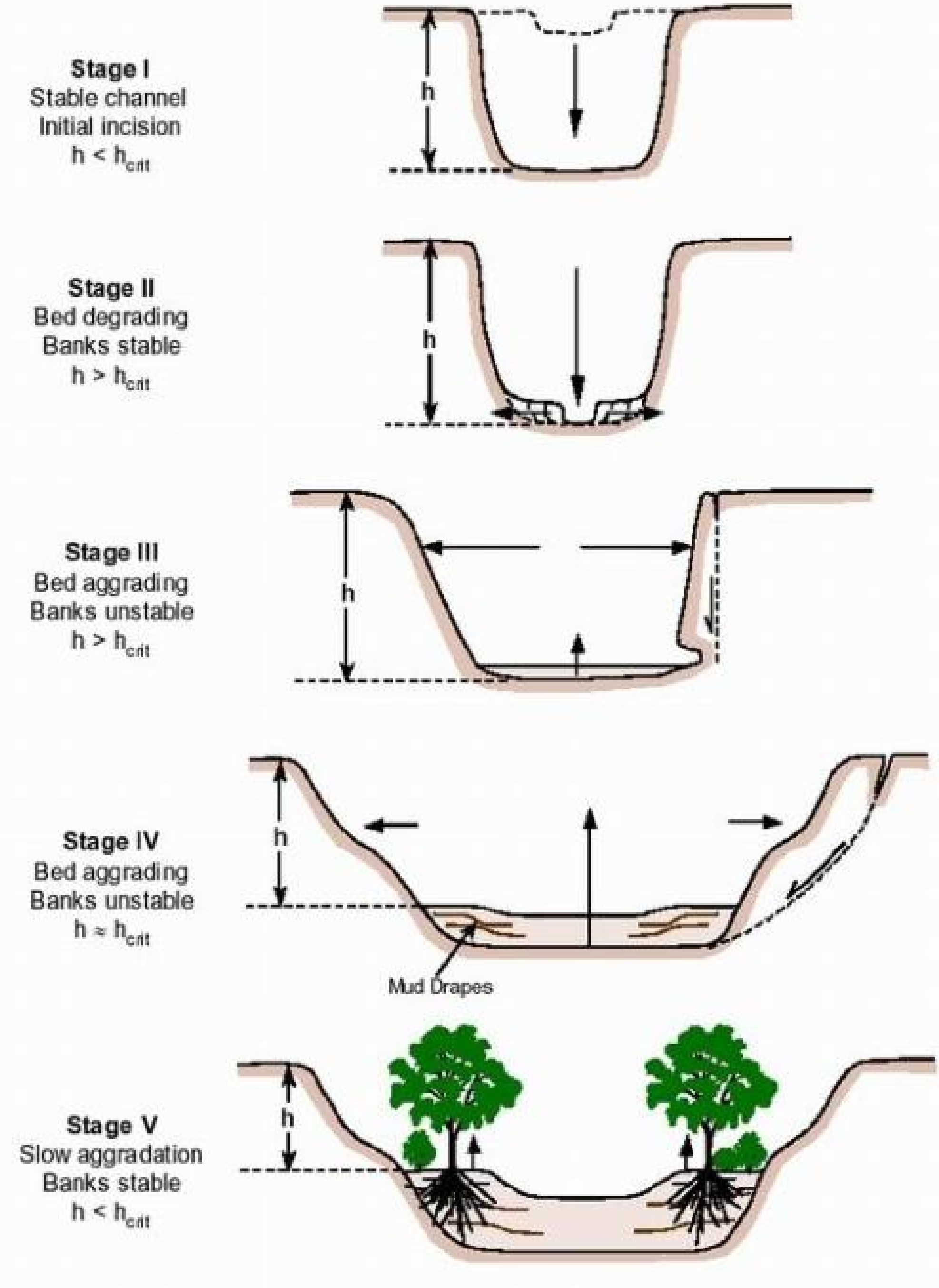
Caused by:
1) Decrease in sediment load
2) Increase in water volume
3) Lowering of base level elevation

Farming in Nebraska

Meander Cutoff

Channel Evolution

- Schumm evolution model
- Natural process of attaining equilibrium

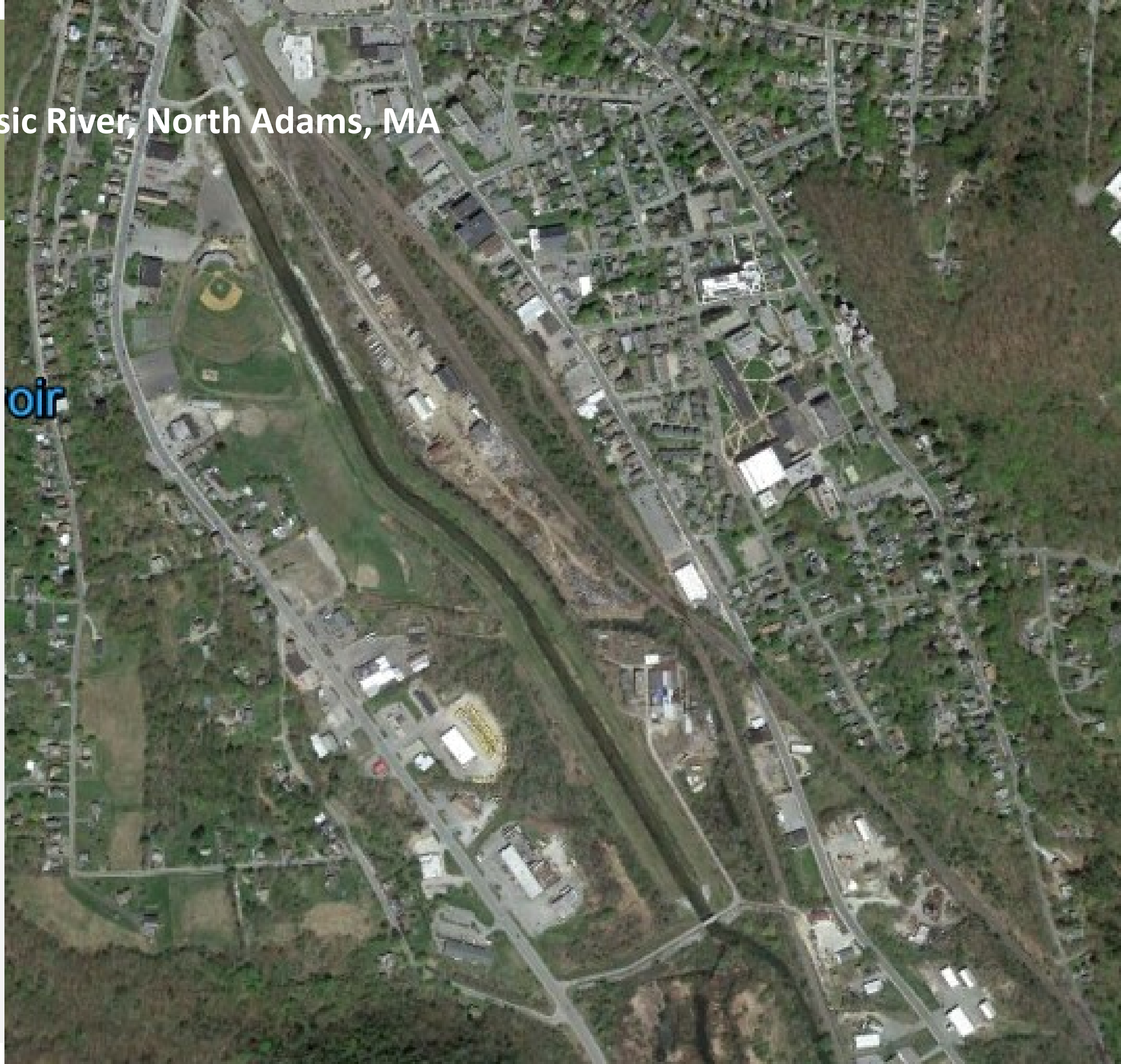


Adapted from Schumm/Simon

Levees

- Abandoned floodplains
- Change in vegetation and riparian community
- Can build and farm closer to the river because you are ‘protected’
- Calculated risk – New Orleans

Hoosic River, North Adams, MA



Infrastructure Protection (bed and bank stabilization)

- Sheetpile
- Concrete
- Riprap
- Gabions
- Geocells
- Bioengineering:
  - Fabric encapsulated soil lifts
  - Large wood

Sheet Pile

- Scour depth
- Embedment is important
- No habitat

- Wire-encased rock
- Bed and bank stability
- Wire corrodes and fails
- No Habitat

Deforming Gabions

Biotechnical Bank Stabilization
Grants Pass Water Treatment Facility
Rogue River, Oregon

Biotechnical Bank Stabilization

Grants Pass Water Treatment Facility

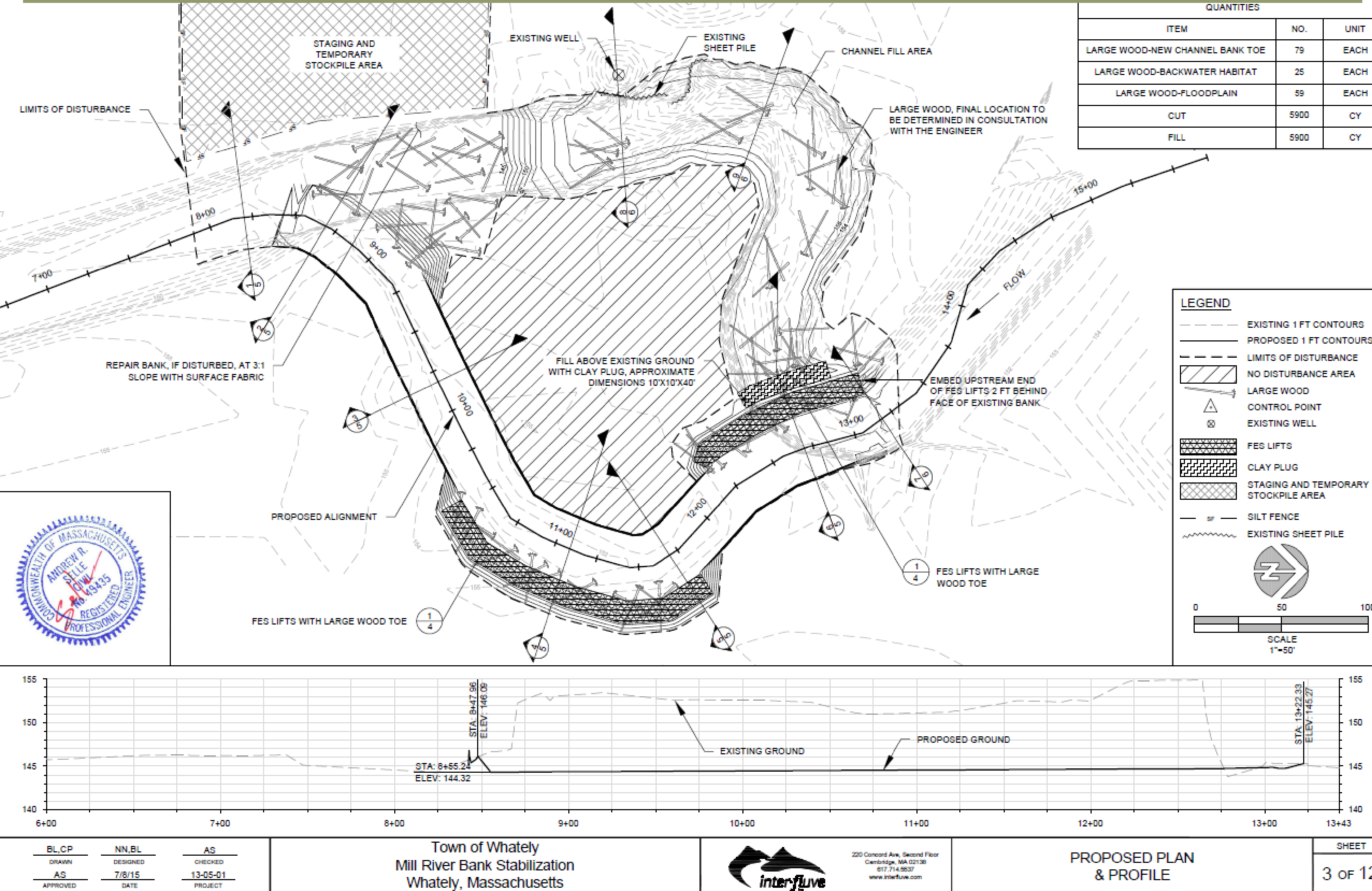
Rogue River, Oregon

Alternative Designs: Mill River, Whately, MA

Municipal Drinking Water Wells

Geomorphic Assessment: Identified Relic Meander Bend

Restoration/Stabilization Designs



QUANTITIES

ITEM	NO.	UNIT
LARGE WOOD-NEW CHANNEL BANK TOE	79	EACH
LARGE WOOD-BACKWATER HABITAT	25	EACH
LARGE WOOD-FLOODPLAIN	59	EACH
CUT	5900	CY
FILL	5900	CY

Construction Access


KOMATSU
PC
200
HD
KOMATSU

Old Channel Fill

Old Channel Fill

Floodplain Roughness: Large Wood Installation in Channel Fill

Channel Fill Roughness

Channel Fill from Well Site

Channel Fill Around Sheetpile and Riprap

Channel Fill and Large Wood at Upstream End of Former Channel

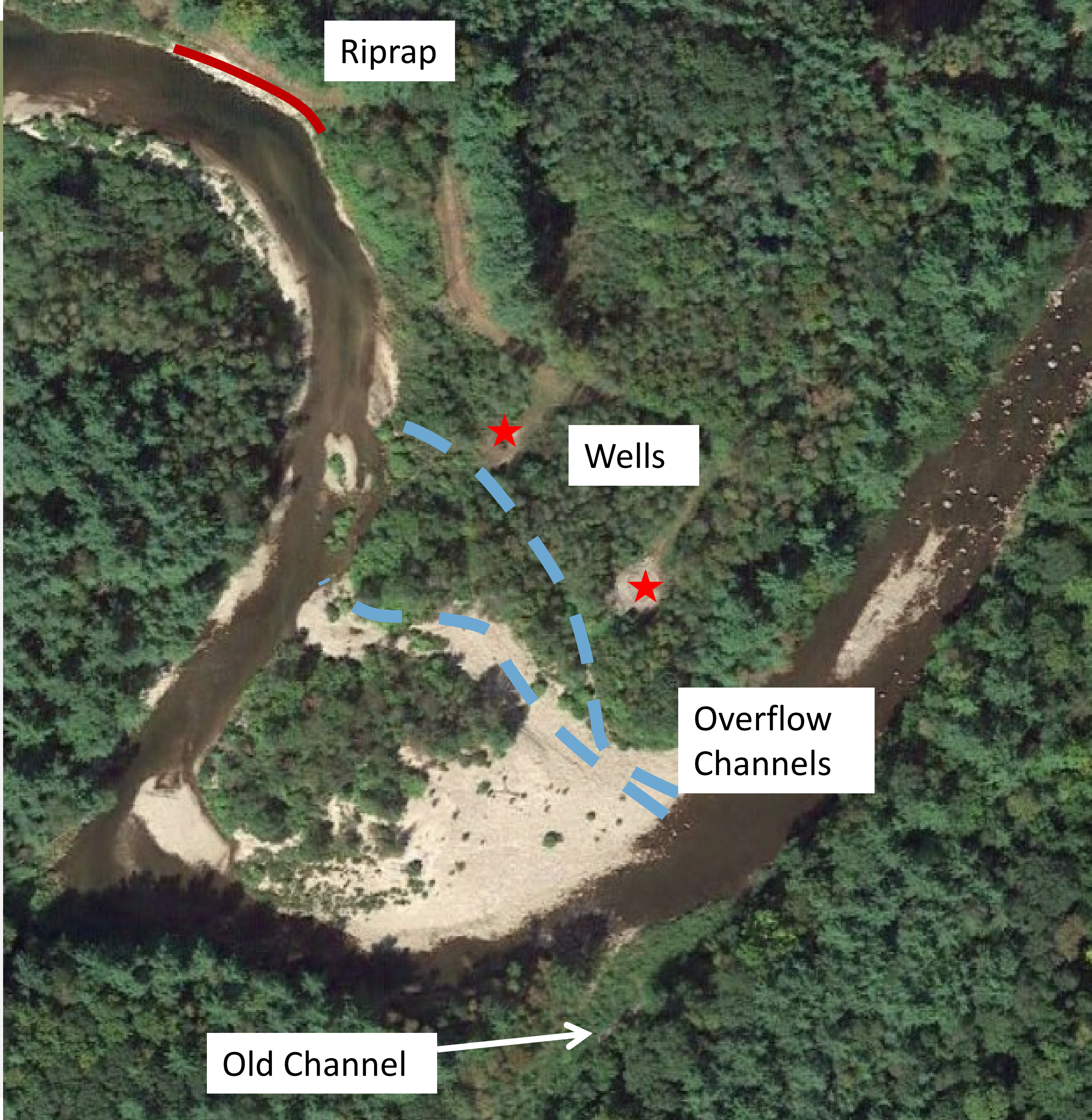
Large wood toe with fabric encapsulated soil (FES) lifts above

Mad River, Campton, NH

Pemigewasset River

Wells

Municipal Wells

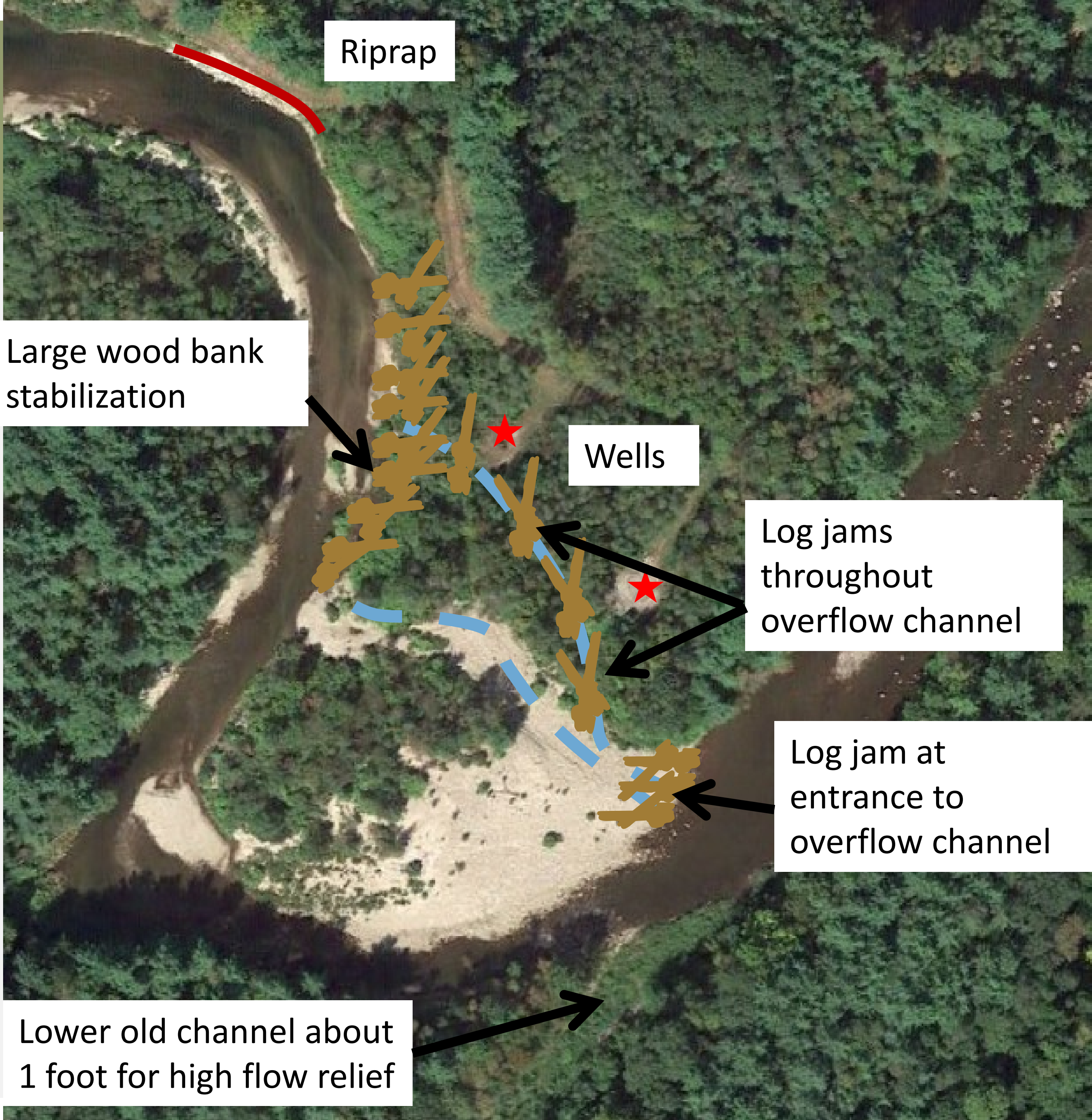


Overflow Channels

Old Channel

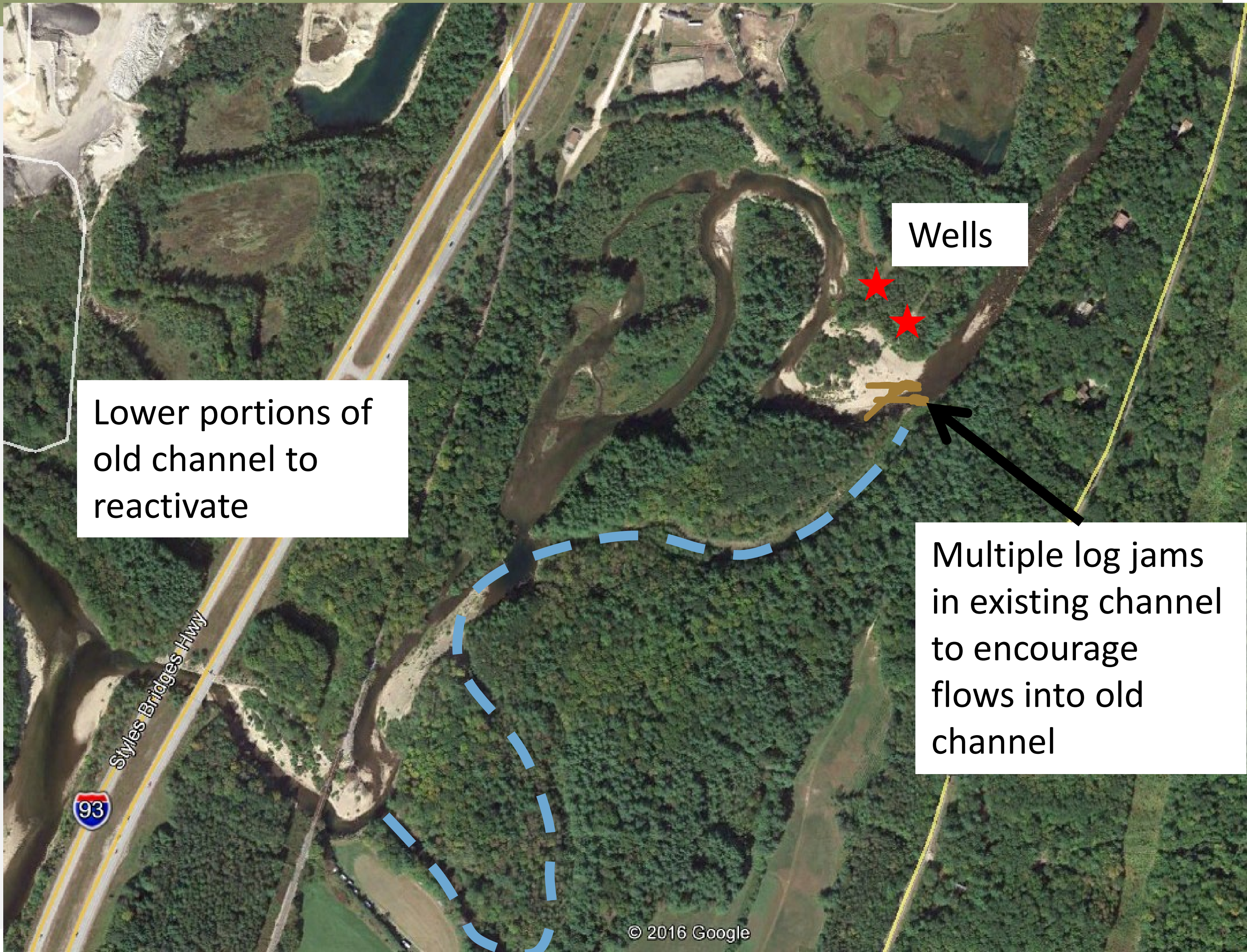
Alternative 1: Bioengineering

- Bioengineering using large wood design considerations
- Increase roughness
- Activate old channel at lower floods to alleviate pressure



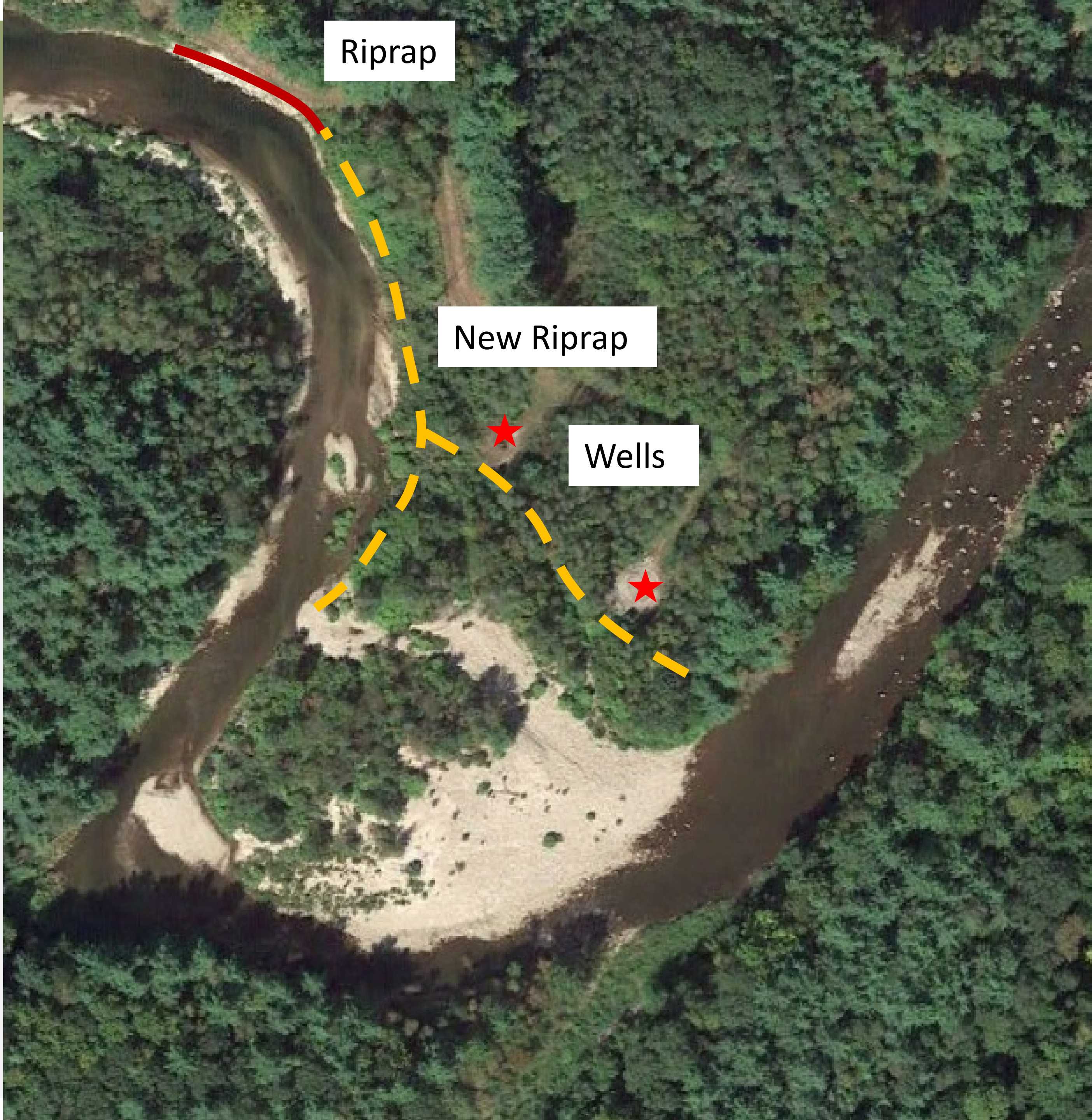
Alternative 2 – Systems approach

- Move active flows to old channel
- Maintain some flow in existing channel
- Large wood installations for roughness



Alternative 3 - Riprap

- Traditional approach
- Additional riprap
  - Adjacent to wells
  - Along eroding bank
  - Connects with existing riprap



Objectives

- Protect municipal wells
- Use geomorphology to guide designs
- Use large wood and other bioengineering designs if possible
- Long-term stability and long-term geomorphic and ecologic form and functionality
- End product to blend into river corridor and not be an obvious designed feature

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