Photos: SB Rood

# Reconnecting Channels and Floodplains: Approaches and Responses

Brian Bledsoe

Department of

Civil and Environmental Engineering,

Graduate Degree Program in

# Outline

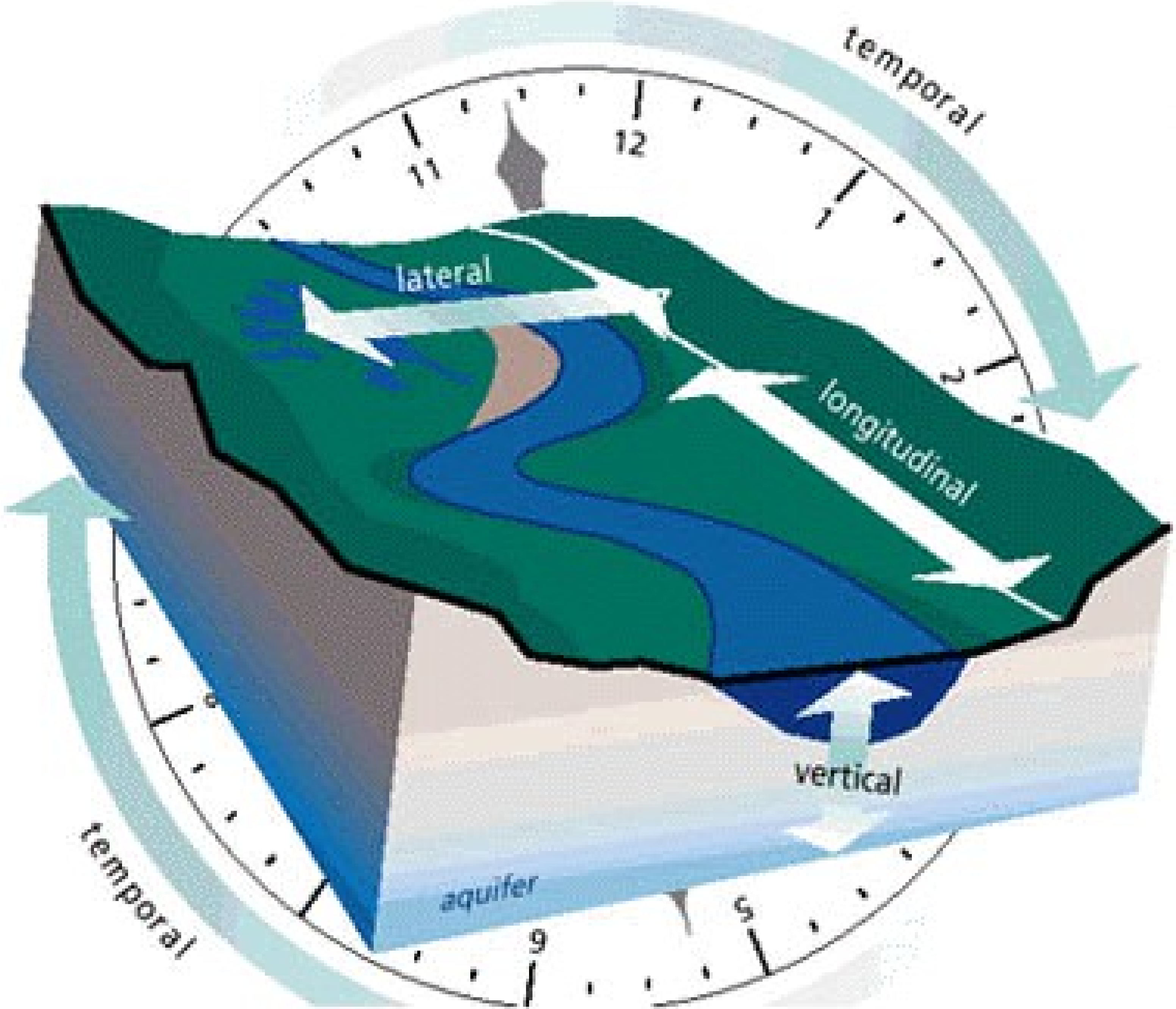
- Definitions
- Benefits of floodplain connectivity
- Disconnected floodplains
- Approaches to floodplain reconnection
- Responses - a few quick case studies
- Final thoughts

# Floodplain

- A geomorphic feature that is:
  - periodically inundated by water from an adjacent river or stream; and
  - formed and influenced by streamflows and alluvial sediments upon which ecosystems develop and operate.

# Connected (Functional) Floodplain

- Exchanges flow, sediment, nutrients, and organisms with its adjacent river.
- Interacts with a river flow regime with sufficient variability to provide the flow levels and events that support important floodplain processes.
- Sufficient spatial scale to allow important dynamic processes to occur and for benefits to accrue to a meaningful level.

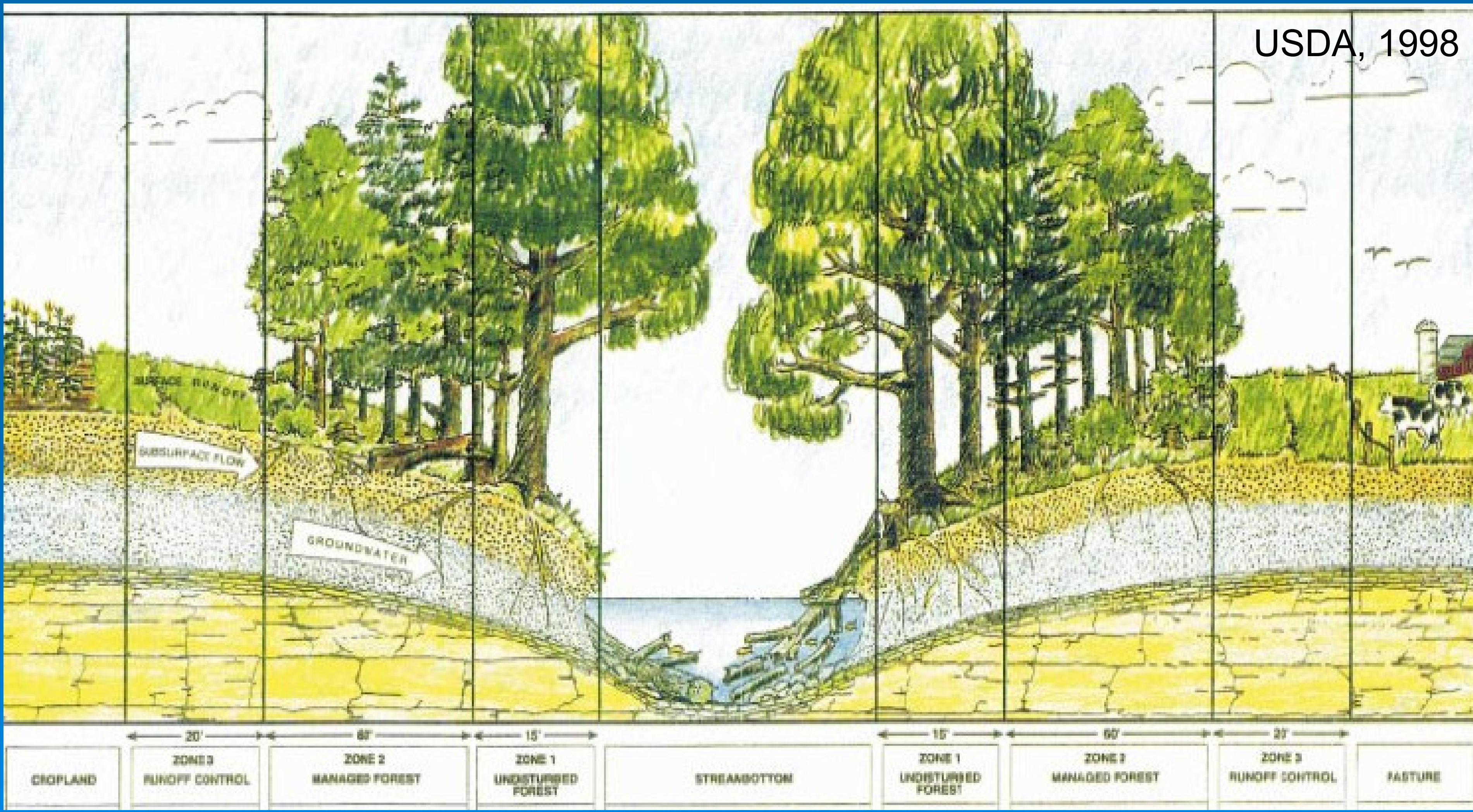


temporal
12
11
1
2
lateral
longitudinal
vertical
aquifer
5
6
temporal

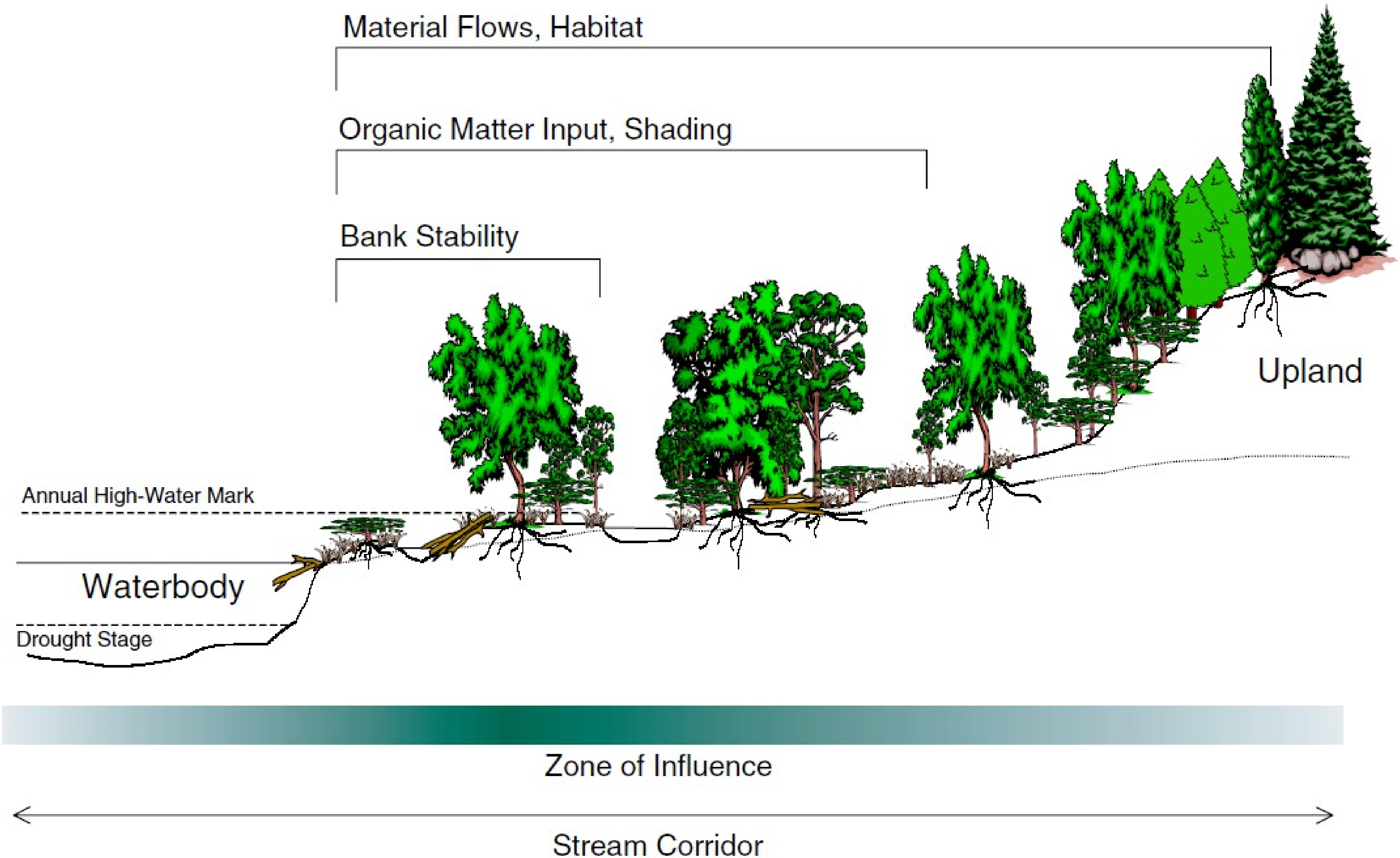
# Benefits of Connected Floodplains

# Floodplain Riparian Zones

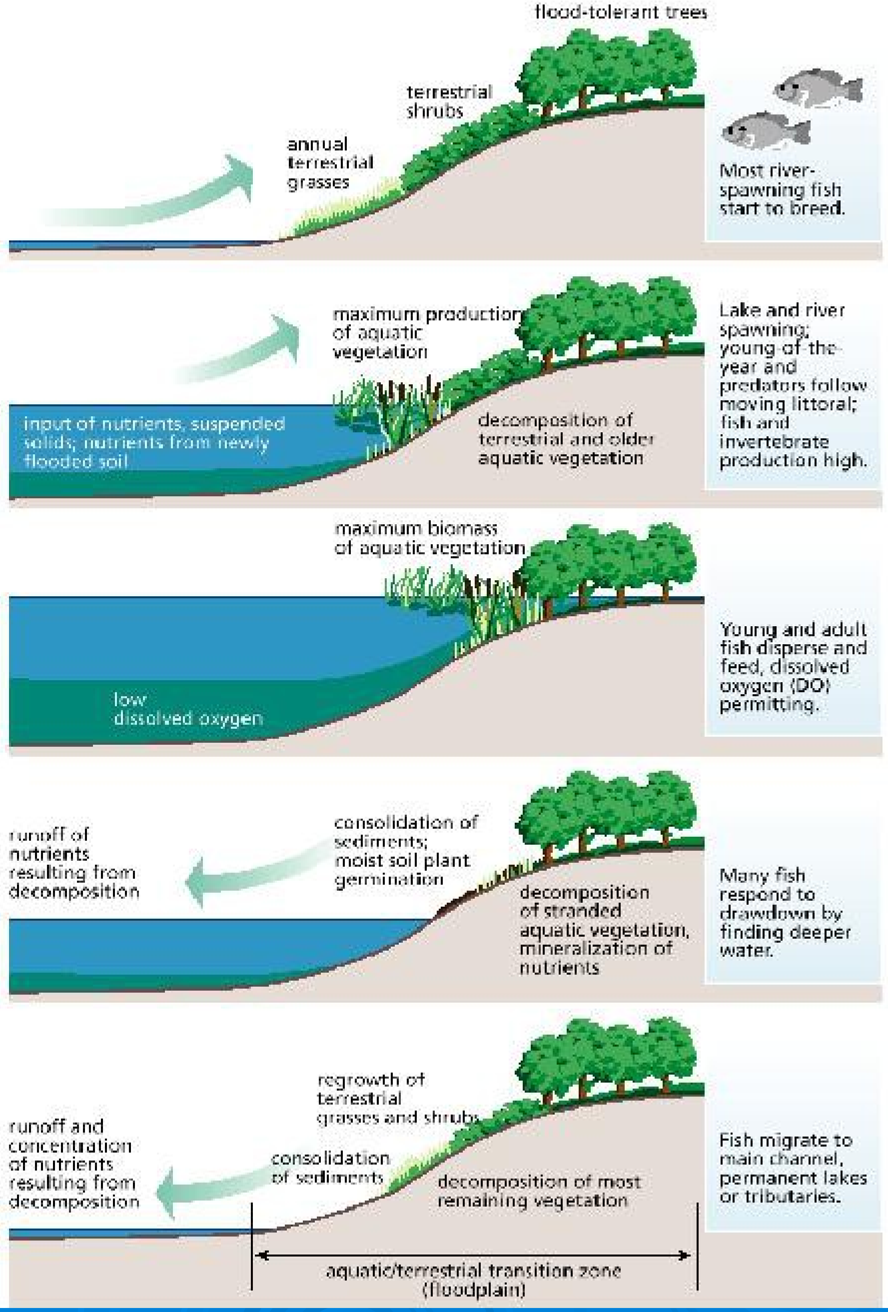
Filtering of nutrients & fine sediment, biodiversity, productivity, shading, bank stabilization, source wood & carbon, food web support, habitat, wildlife corridor, recreation, aesthetics…




USDA, 1998




National Academy of Science (2002)


flood-tolerant trees
terrestrial shrubs
annual terrestrial grasses
Most river-spawning fish start to breed.
maximum production of aquatic vegetation
input of nutrients, suspended solids; nutrients from newly flooded soil
decomposition of terrestrial and older aquatic vegetation
Lake and river spawning; young-of-the-year and predators follow moving littoral; fish and invertebrate production high.
maximum biomass of aquatic vegetation
low dissolved oxygen
Young and adult fish disperse and feed, dissolved oxygen (DO) permitting.
runoff of nutrients resulting from decomposition
consolidation of sediments; moist soil plant germination
decomposition of stranded aquatic vegetation, mineralization of nutrients
Many fish respond to drawdown by finding deeper water.
regrowth of terrestrial grasses and shrubs
runoff and concentration of nutrients resulting from decomposition
consolidation of sediments
decomposition of most remaining vegetation
Fish migrate to main channel, permanent lakes or tributaries.
aquatic/terrestrial transition zone (floodplain)

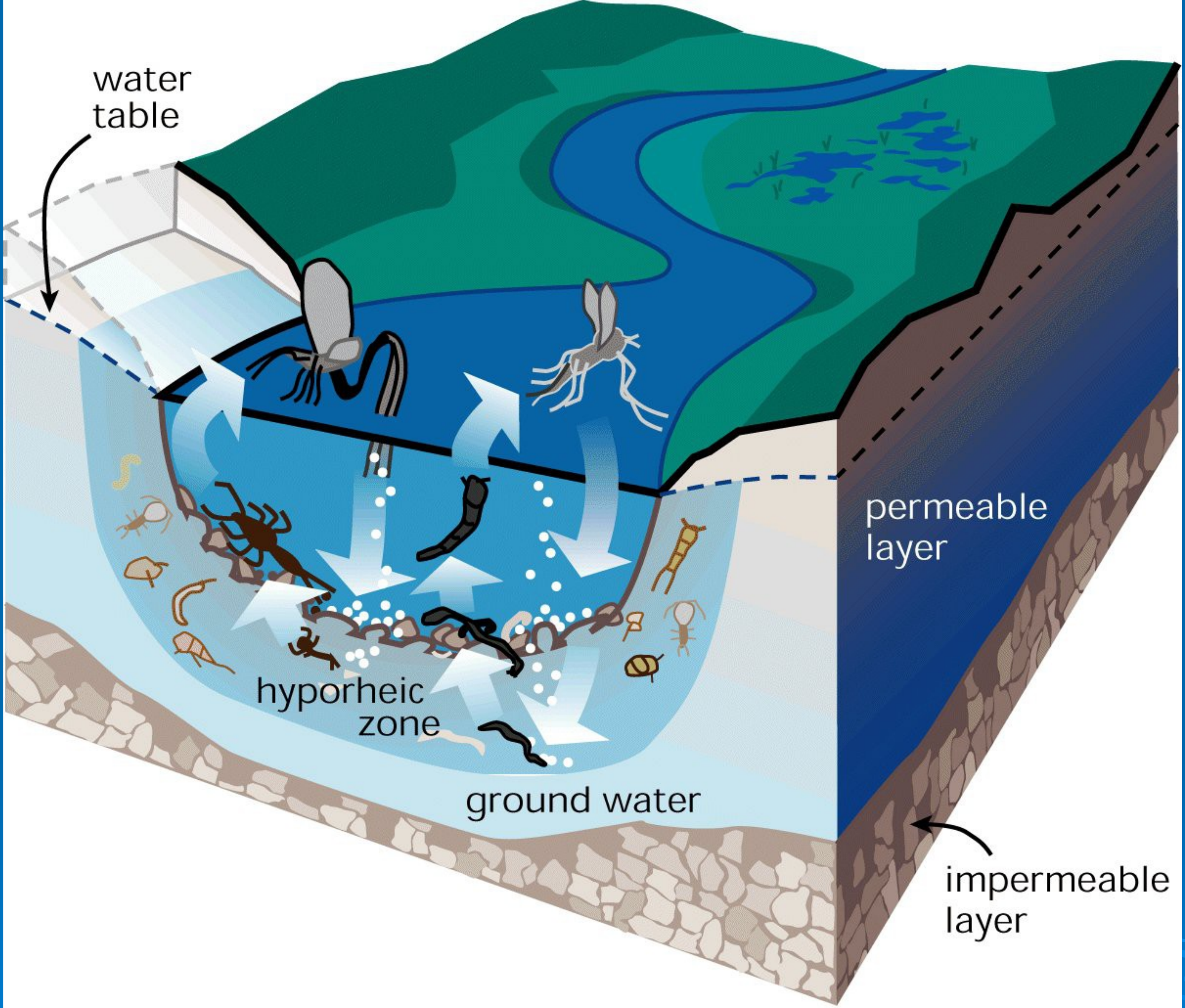
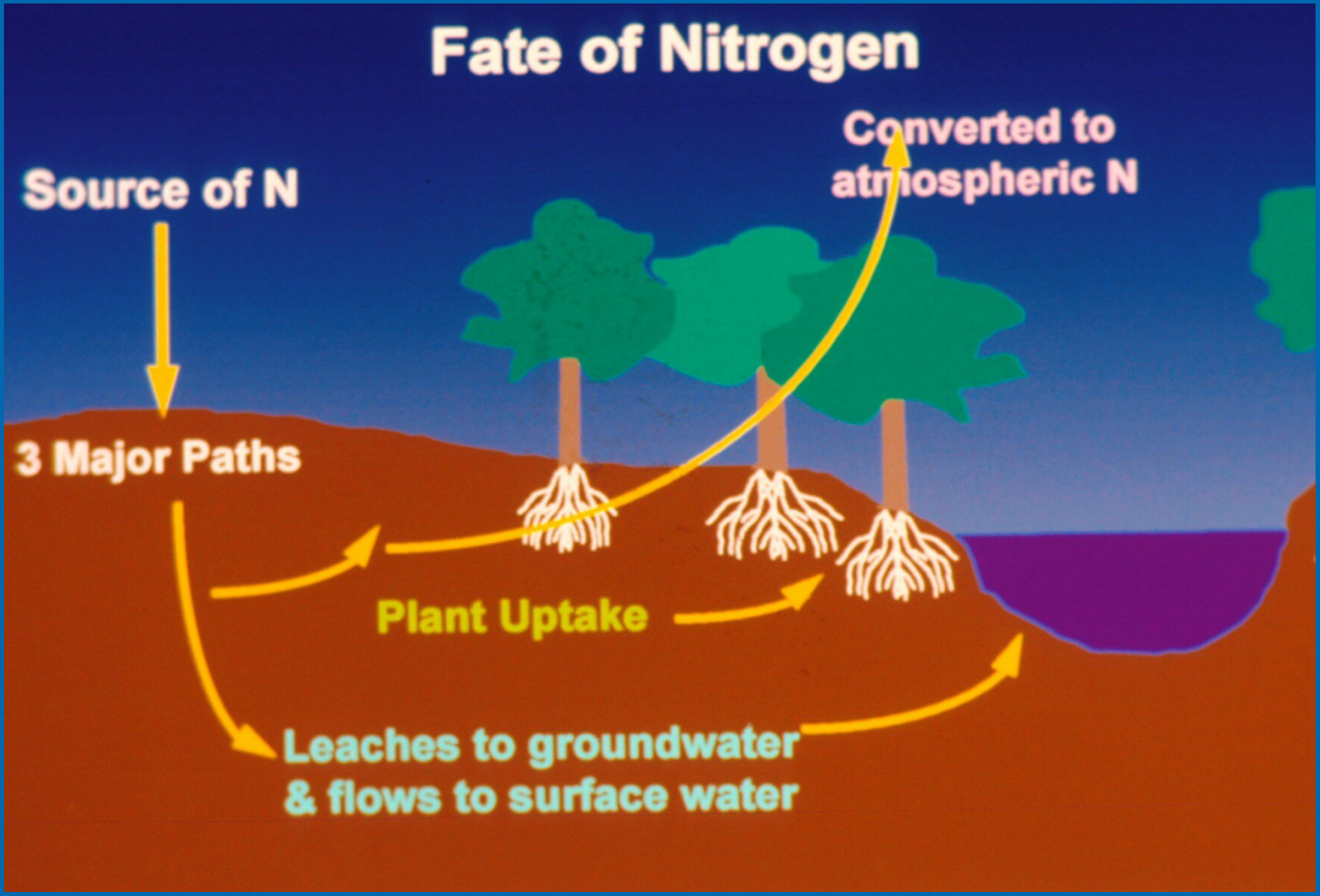



Fig. 2.35 -- Hyporheic zone. Summary of the different means of migration undergone by members of the stream benthic community.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

# Floodplain Functions

- ***Hydrology and Sediment Dynamics***
  - Stores surface water
  - Maintains a high water table
  - Accumulates and transports sediments
- ***Biogeochemistry and Nutrient Cycling***
  - Transforms and immobilizes pollutants
  - Produces organic carbon
  - Contributes to overall biodiversity
  - Sequesters carbon in soil


Fate of Nitrogen
Source of N
Converted to atmospheric N
3 Major Paths
Plant Uptake
Leaches to groundwater & flows to surface water


shallow, low flux
steep, high flux
restored
1%
5%
incised
Darcy says:
q = K*slope
K=1m/d

# Floodplain Functions

- ***Habitat and Food Web Maintenance***
  - Maintains floodplain vegetation
  - Biodiversity
  - Shading / temperature moderation
  - Mosaic of habitats
  - Wildlife corridors
  - Supports characteristic terrestrial and aquatic vertebrate populations

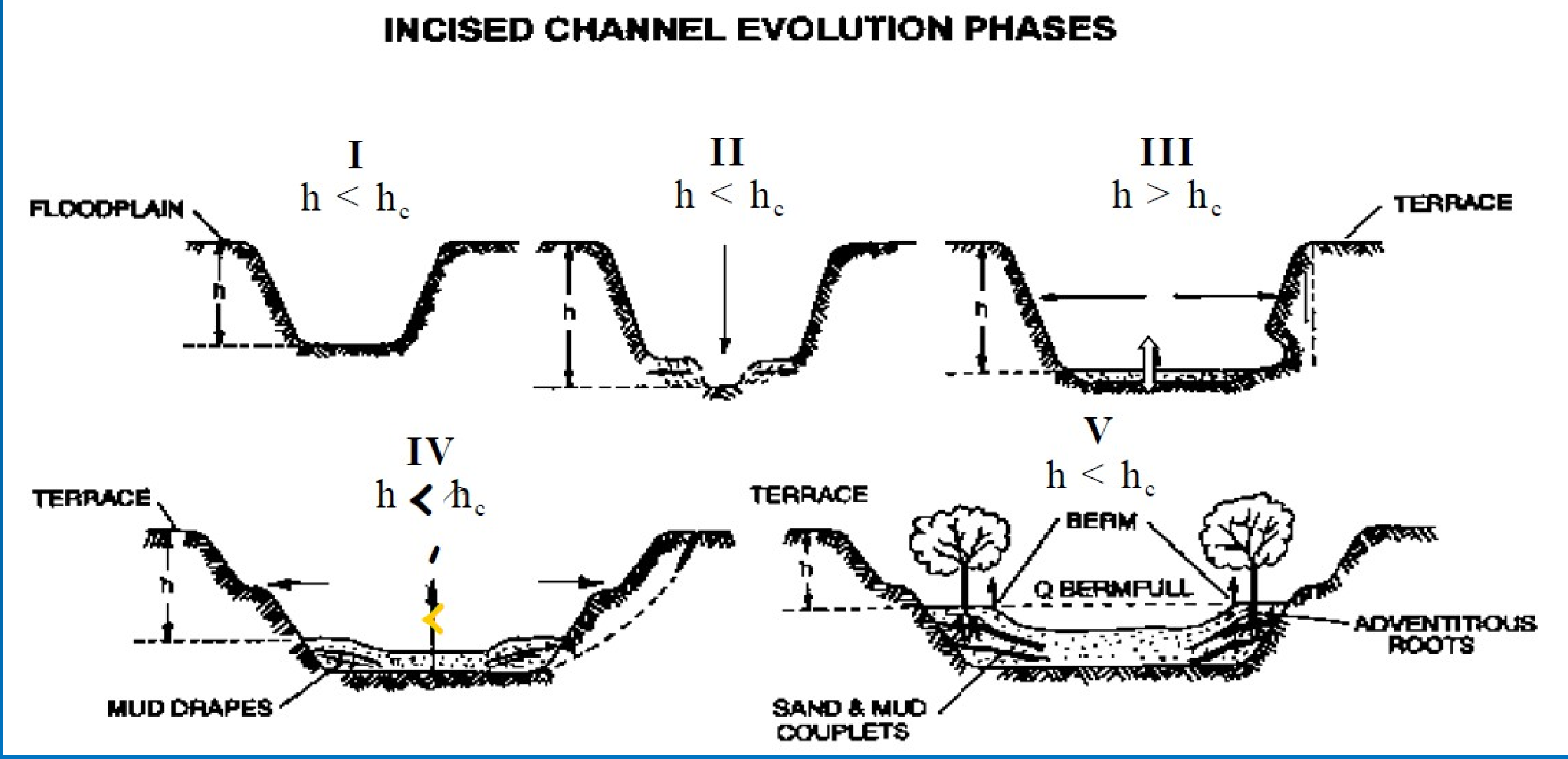
Don’t forget recreation and aesthetics

# Disconnected Floodplains

# Some Causes of Lateral Disconnection

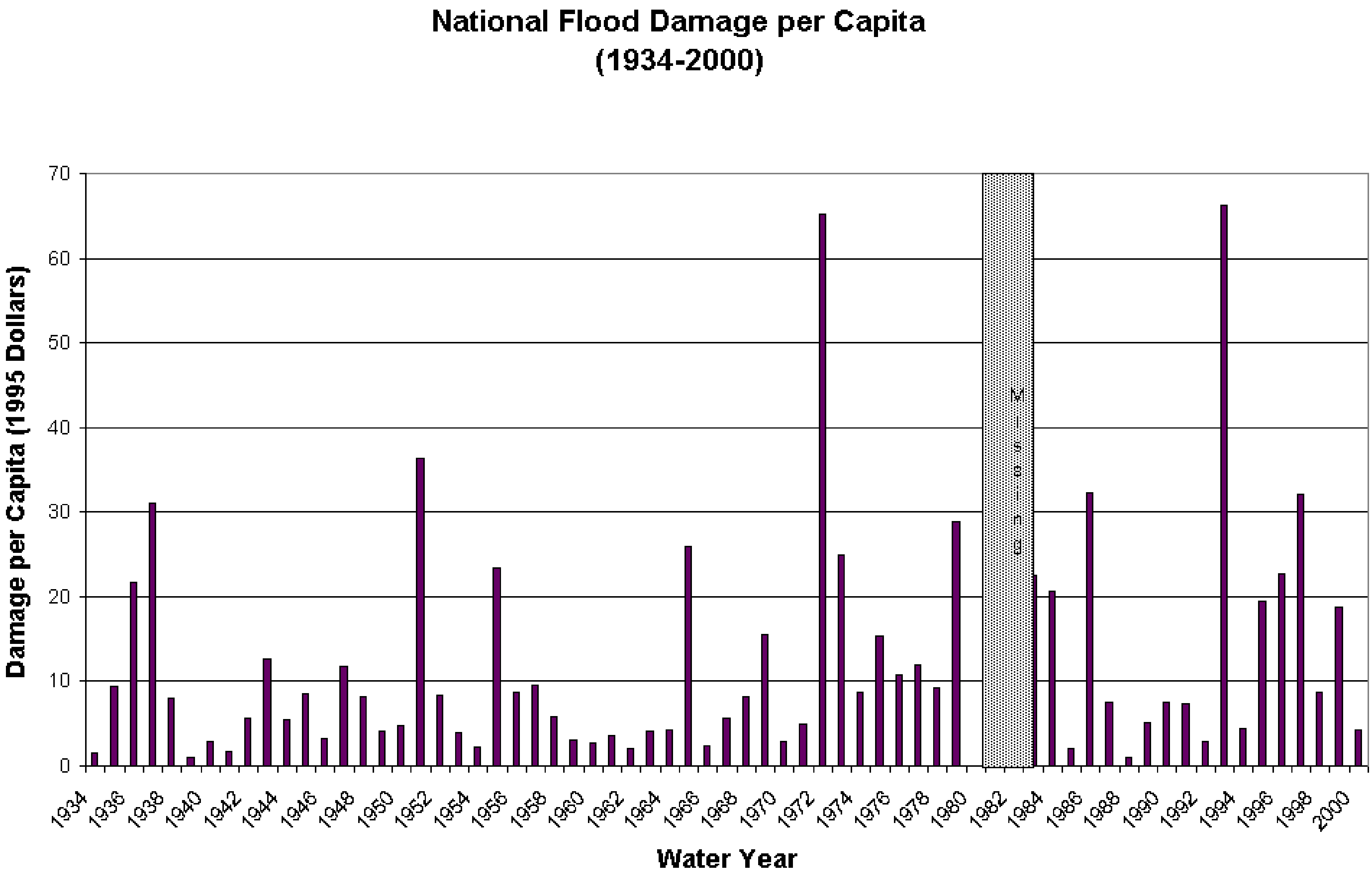
- Flow alteration / extraction
- Incision / channel enlargement
- Channelization
- Fill material, e.g. drainage, post-settlement alluvium
- Levees
- Armoring and riprap
- Other legacy effects

Big Lost River, ID
Rood et al. (2005)


INCISED CHANNEL EVOLUTION PHASES
I
h < hc
FLOODPLAIN
h
II
h < hc
h
III
h > hc
TERRACE
h
IV
h < hc
TERRACE
h
MUD DRAPES
V
h < hc
TERRACE
BERM
h
Q BERMFULL
ADVENTITIOUS ROOTS
SAND & MUD COUPLETS

# Walla Walla River Levees

- Click to edit Master text styles
  - Second level
  - Third level
    - Fourth level
      - Fifth level


National Flood Damage per Capita
(1934-2000)
Damage per Capita (1995 Dollars)
0
10
20
30
40
50
60
70
Missing
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Water Year

# Approaches to Floodplain Reconnection

# What are we connecting?

- Just add water?
  - Overbank vs. hillslope vs. groundwater inputs
  - Hyporheic zone
- Geomorphic connections
  - Lateral migration for plains cottonwood recruitment
  - Access to floodplain sediments
- Plant communities – water table, topsoil, seed source connections
- Wildlife, human connections

# A spectrum of approaches

?? Eco-benefit ??

Physical impact on existing system?

- Riparian buffers
- Allow channel evolution
- Remove / setback levees, riprap
- Bank lowering
- In-stream structures
- Channel blocking
- Liner to raise water table
- "Perched" re-construction
- Pond and plug
- Sediment removal and re-construction

# Approaches

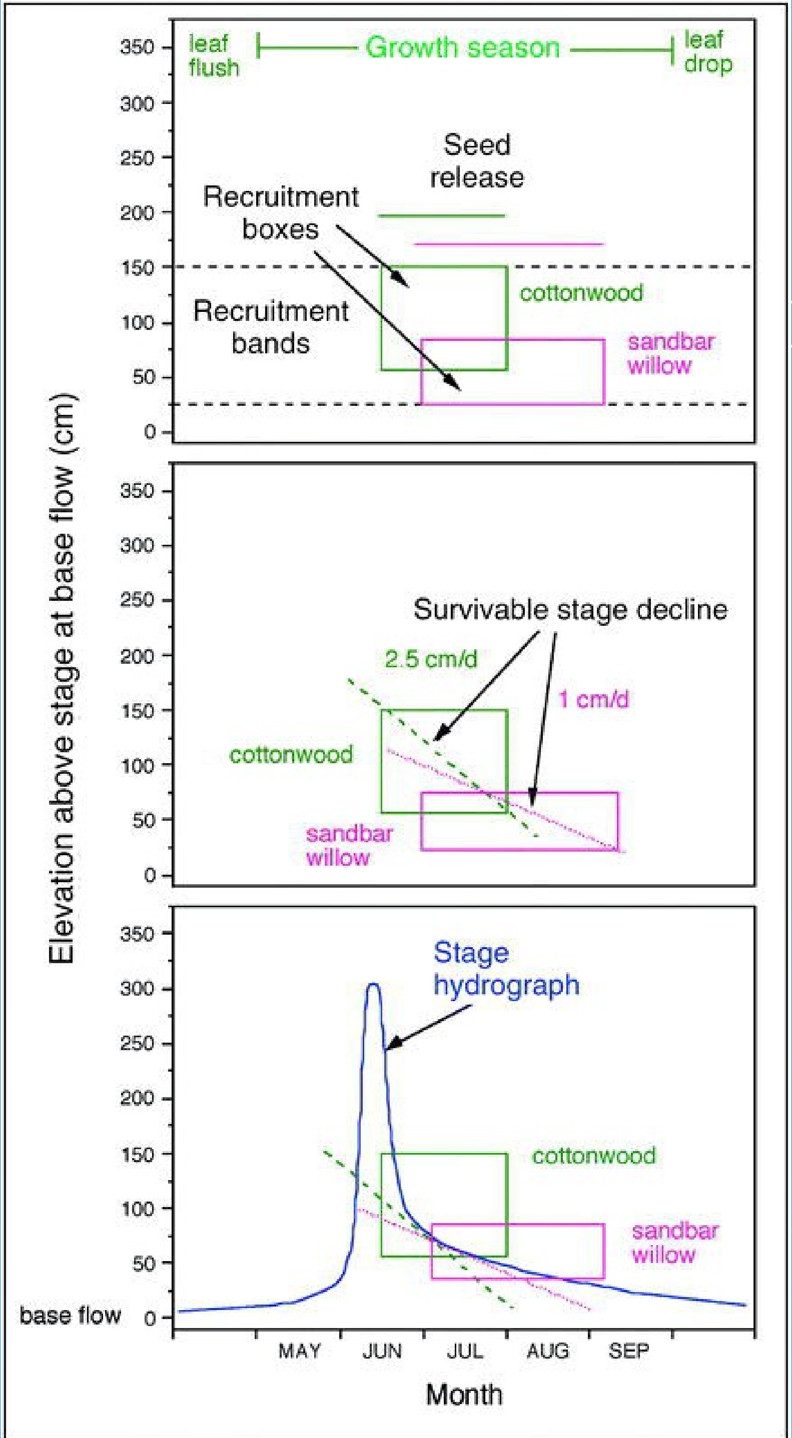
- Bring the water to the floodplain – e.g., environmental flows, structures, levee setbacks
- Bring the floodplain to the water – e.g., channel downscaling / miniaturization, floodplain lowering
- Incised channels
  - perched re-construction
  - 2-stage channels
  - bank lowering
  - passive approaches – channel evolution

# Constraints

- Available high flow regime
  - Magnitude, frequency, timing, duration
- Available space for dynamic channel
  - Lateral
  - Longitudinal
- Soils
  - Hydraulic conductivity of legacy sediments or fill materials
- Seed source – native vs. non-native species
- Potential for succession, self-organization

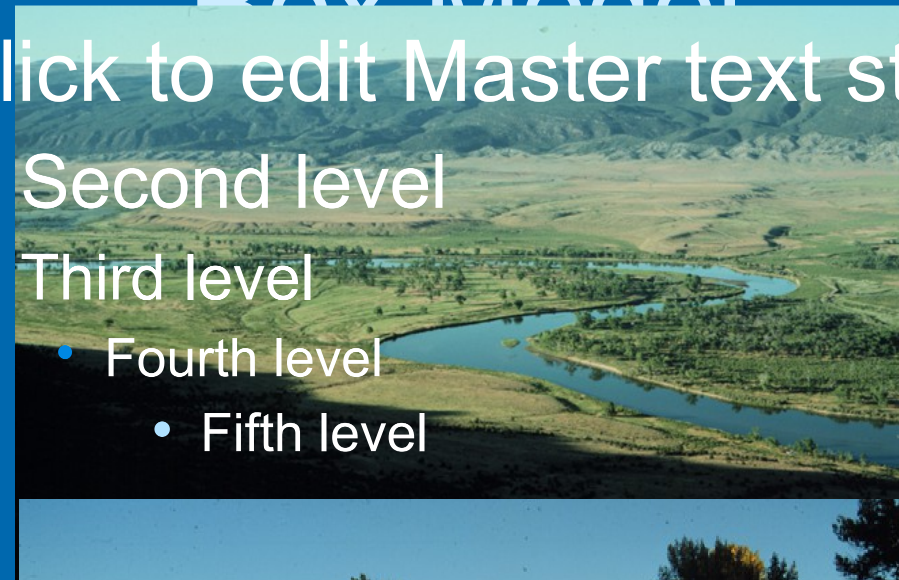
# Key considerations

- The inflows of water to the floodplain and understand the physical and geologic controls on these processes.
  - e.g., the relative importance of overbank flow versus hillslope runoff tends to increase with stream order.
- Water, soil and germination requirements of floodplain vegetation communities being targeted.

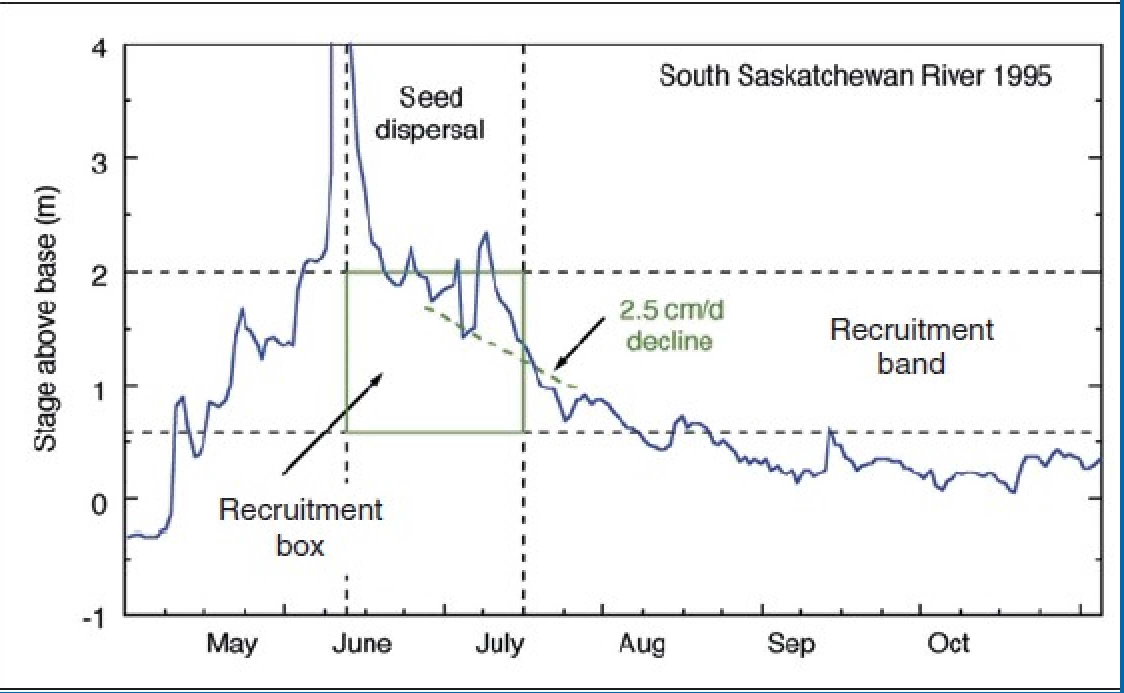



# Recruitment Box Model

- Click to edit Master text sty
  - Second level
  - Third level
    - Fourth level
      - Fifth level

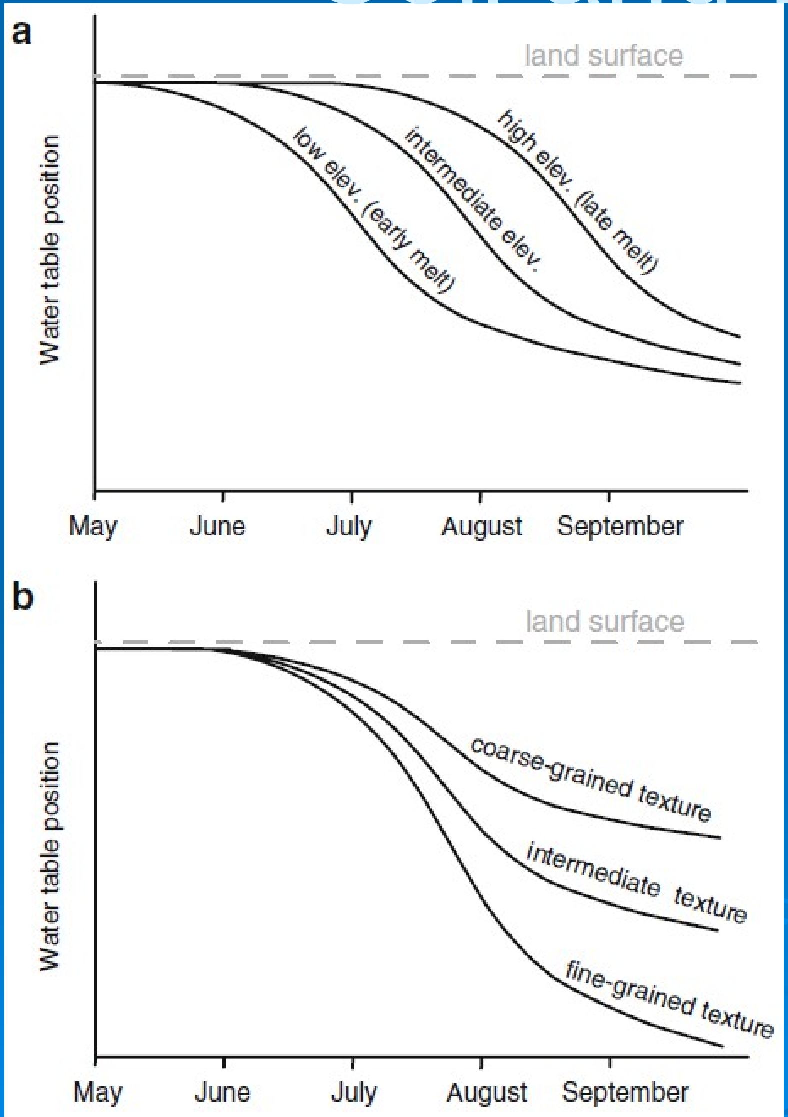


Photos: David Merritt




1995 along the South Saskatchewan River
Rood et al. (2005)

# Soil-Water-Plant Relations by Soil and Elevation




Elevation required by plants due to capillary fringe

# Floodplain plant response at elevational scales on the order of 10 cm

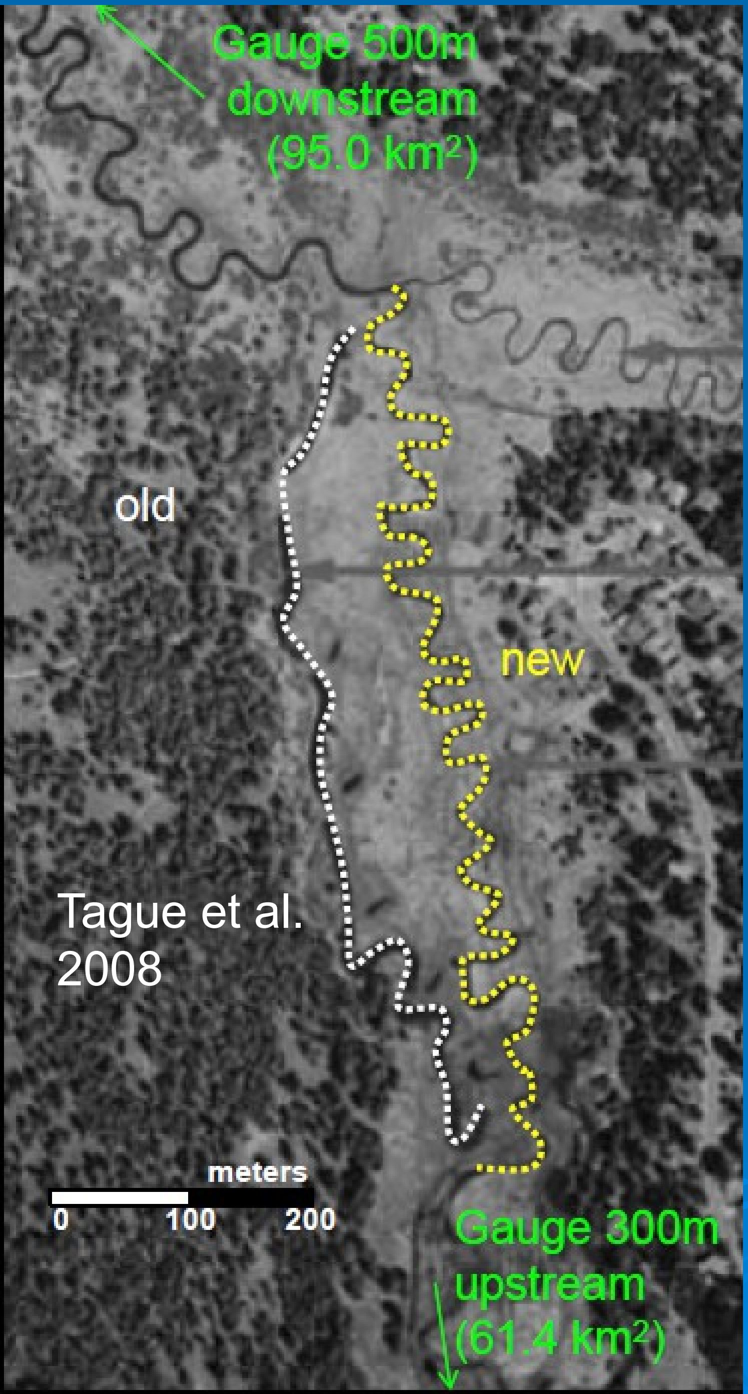
| Species | N | Mean Elevation | 2.46 | 2.61 | 2.76 | 2.92 | 3.07 | 3.37 | 3.68 | 4.14 | 4.59 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Elevational Increment | | | | | | | | |
| *Taxodium distichum* | 45 | 2.72 ± 0.12 | 24 77 | 12 42 | | 3 16 | | | | | |
| *Fraxinus caroliniana* | 121 | 2.74 ± 0.09 | 44 5 | 32 5 | 16 2 | 4 1 | | | | | |
| *Ulmus americana* | 3 | 2.81 ± 0.01 | | | 1 1 | | | | | | |
| *Quercus laurifolia* | 3 | 2.83 ± 0.10 | | 1 0 | 1 1 | | | | | | |
| *Nyssa aquatica* | 36 | 2.83 ± 0.17 | 9 18 | 7 11 | 5 7 | 5 10 | 2 7 | 1 3 | | | |
| *Fraxinus pennsylvanica* | 20 | 2.89 ± 0.18 | | 3 9 | 3 17 | 3 21 | 3 28 | | | | |
| *Leucothoe racemosa* | 22 | 2.92 ± 0.30 | | 6 0 | 2 0 | | 2 0 | 1 0 | 1 0 | | |
| *Ligustrum sinense* | 2 | 2.95 ± 0.18 | | | 0 0 | 1 0 | | | | | |
| *Acer rubrum* | 305 | 3.04 ± 0.44 | 18 1 | 30 17 | 43 18 | 45 22 | 37 23 | 19 12 | 23 26 | 8 4 | 9 0 |
| *Carpinus caroliniana* | 4 | 3.07 ± 0.12 | | | | 3 0 | 2 0 | | | | |
| *Liquidambar styraciflua* | 70 | 3.16 ± 0.62 | | 4 7 | 9 8 | 11 10 | 11 21 | 9 18 | 5 18 | 3 3 | 4 0 |
| *Cyrilla racemiflora* | 20 | 3.22 ± 0.41 | | 1 0 | 2 0 | 3 0 | 2 0 | 7 0 | 4 0 | | |
| *Nyssa sylvatica* var. *biflora* | 49 | 3.24 ± 0.53 | | 3 10 | 6 26 | 5 20 | 4 18 | 17 67 | 1 12 | 7 0 | 2 0 |
| *Itea virginica* | 6 | 3.31 ± 0.24 | | | | 3 0 | | 6 0 | | | |
| *Clethra alnifolia* | 37 | 3.43 ± 0.50 | 3 0 | 1 0 | 3 0 | | 2 0 | 12 0 | 16 0 | 2 0 | |
| *Ilex opaca* | 78 | 3.53 ± 0.77 | | 1 0 | 3 0 | 10 0 | 30 3 | 12 0 | | 15 2 | 13 2 |
| *Magnolia virginiana* | 11 | 3.64 ± 0.62 | | 1 0 | | | 2 0 | | 5 1 | 5 0 | |
| *Persea borbonia* | 31 | 3.69 ± 0.43 | | | 0 0 | 4 0 | 2 0 | 10 0 | 13 0 | 10 2 | |
| *Quercus nigra* | 5 | 3.95 ± 0.25 | | | | | | 1 0 | 2 14 | 3 1 | |
| *Vaccinium* spp. | 13 | 4.08 ± 0.46 | | | | | | 1 0 | 8 0 | 2 0 | 6 0 |
| *Quercus michauxii* | 7 | 4.14 ± 0.65 | | | | | 3 0 | 2 | 2 | | 6 27 |
| *Liriodendron tulipifera* | 11 | 4.37 ± 0.49 | | | | | | | 5 25 | 7 24 | 6 49 |
| *Leucothoe axillaris* | 2 | 4.39 ± 0.19 | | | | | | | | 3 0 | |
| *Hamamelis virginiana* | 5 | 4.46 ± 0.10 | | | | | | | | 7 0 | 2 0 |
| *Pinus taeda* | 5 | 4.64 ± 0.28 | | | | | | | | 5 63 | 4 13 |
| *Symplocos tinctoria* | 35 | 4.69 ± 0.77 | | | | | | | 12 0 | 16 0 | 28 0 |
| *Oxydendrum arboreum* | 13 | 5.09 ± 0.86 | | | | | | | | 8 0 | 15 1 |
| *Cornus florida* | 2 | 5.44 ± 0.02 | | | | | | | | | 4 0 |
| % annual flooding frequency: | | | 61 | 29 | 7 | 1 | <0.1 | 0 | 0 | 0 | 0 |
| % growing season flooding frequency: | | | 56 | 27 | 8 | 1 | <0.1 | 0 | 0 | 0 | 0 |
| number observed in increment: | | | 34 | 180 | 289 | 73 | 122 | 69 | 82 | 61 | 54 |
| species richness: | | | 6 | 13 | 15 | 13 | 13 | 13 | 13 | 15 | 14 |

# Seven essential requirements

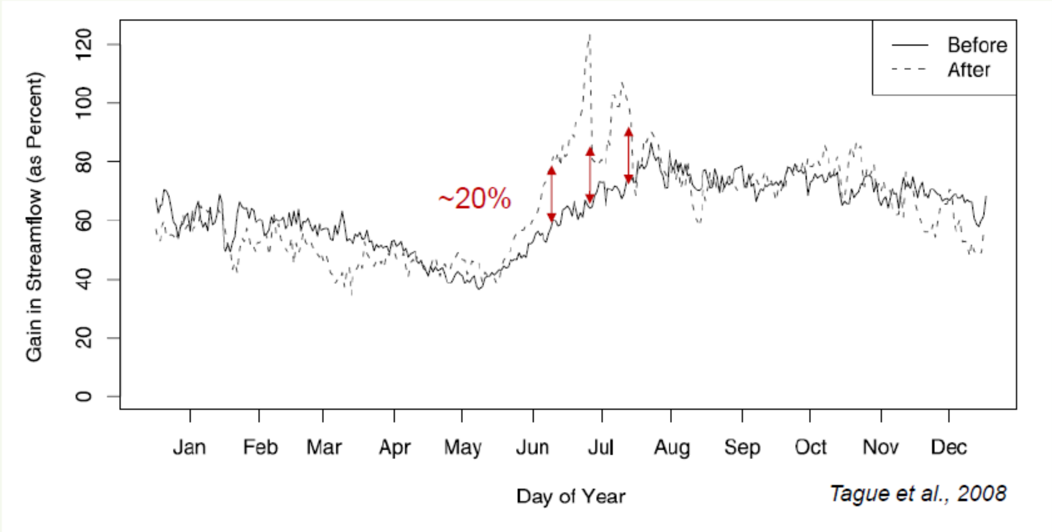
- Streamflows needed
- Geomorphic processes needed
- Water table–soil interactions needed
- Regeneration sites needed
- Propagation materials needed
- Safety
- Landowner / stakeholder support

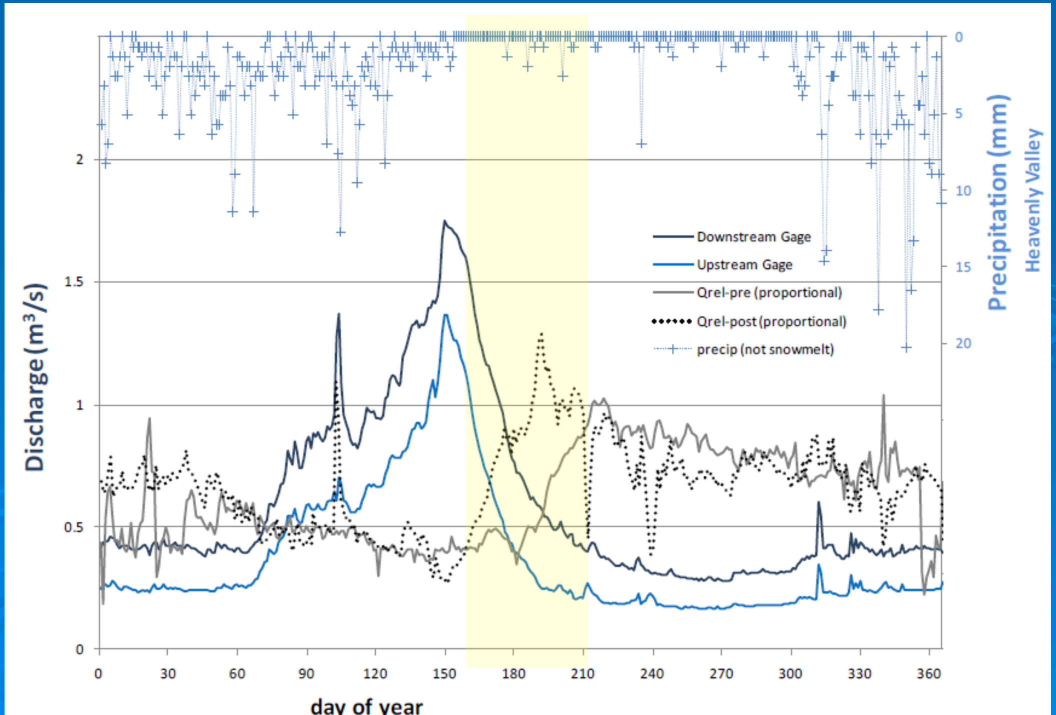
# Responses / Case Studies

# Trout Creek – near Lake Tahoe

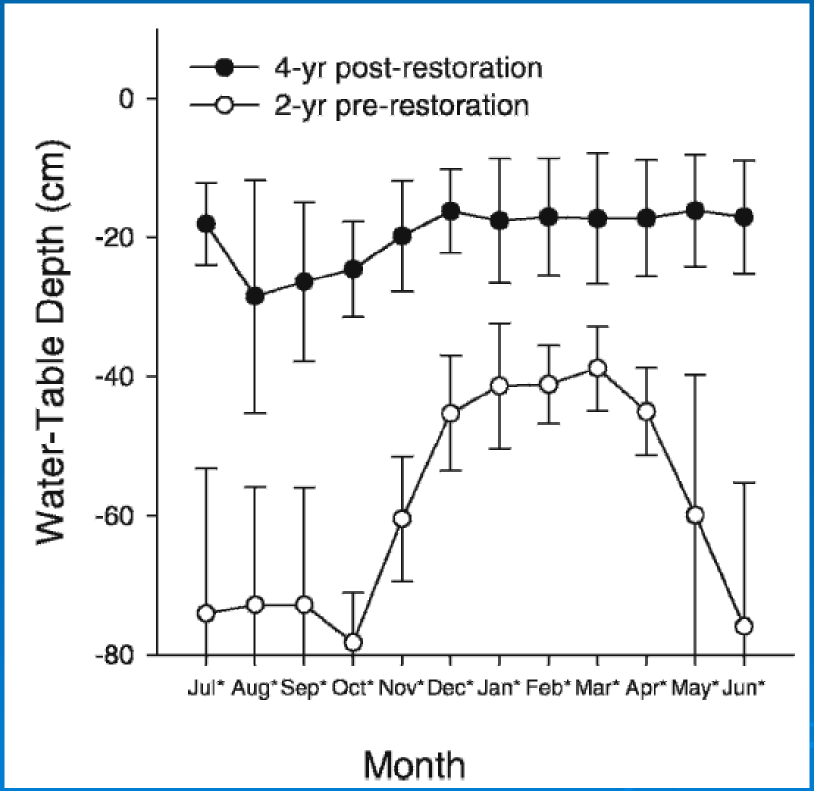


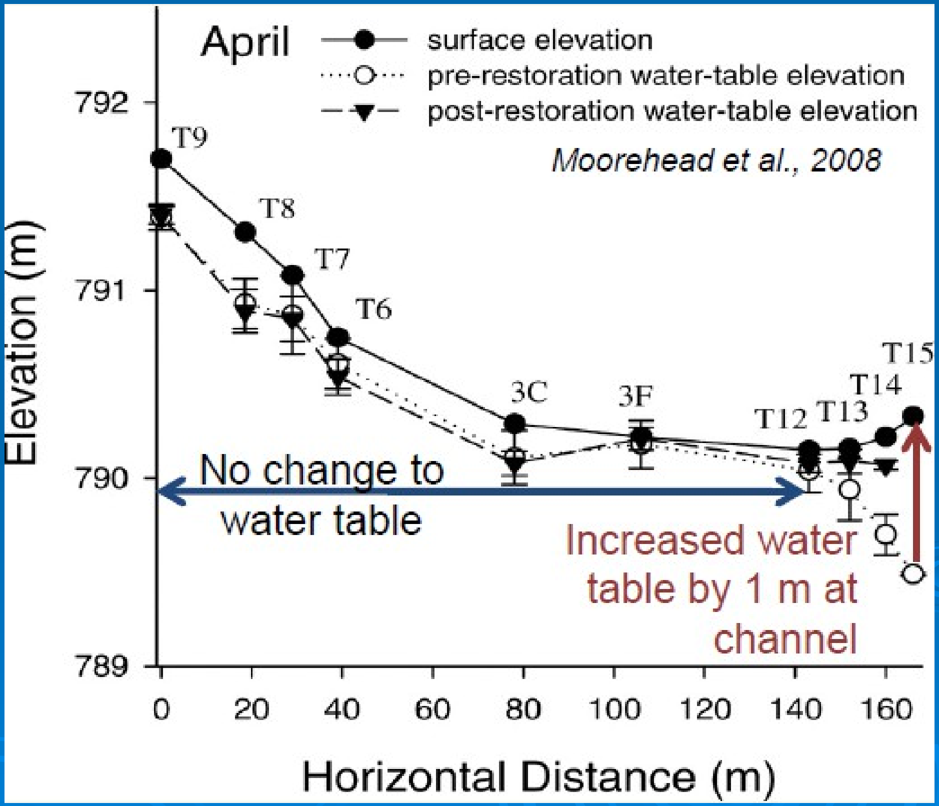

Gain in streamflow (Qrel) = (Downstream Q – Upstream Q) / Upstream Q



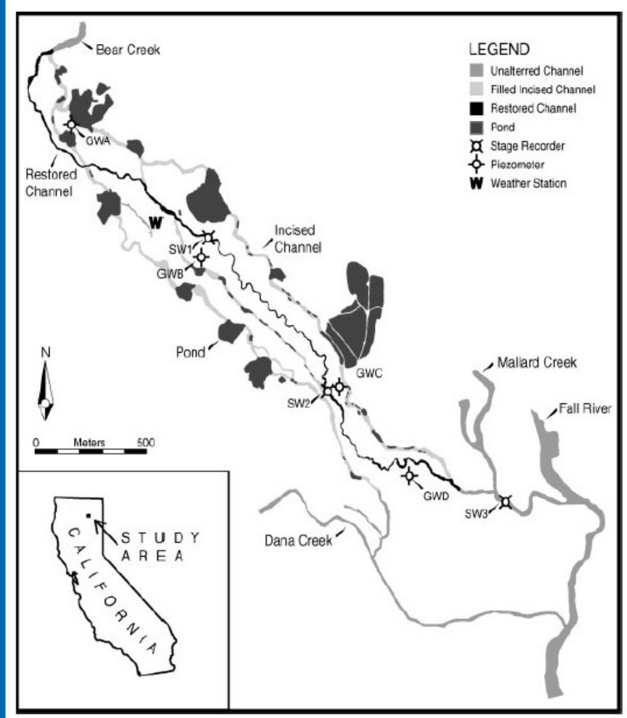



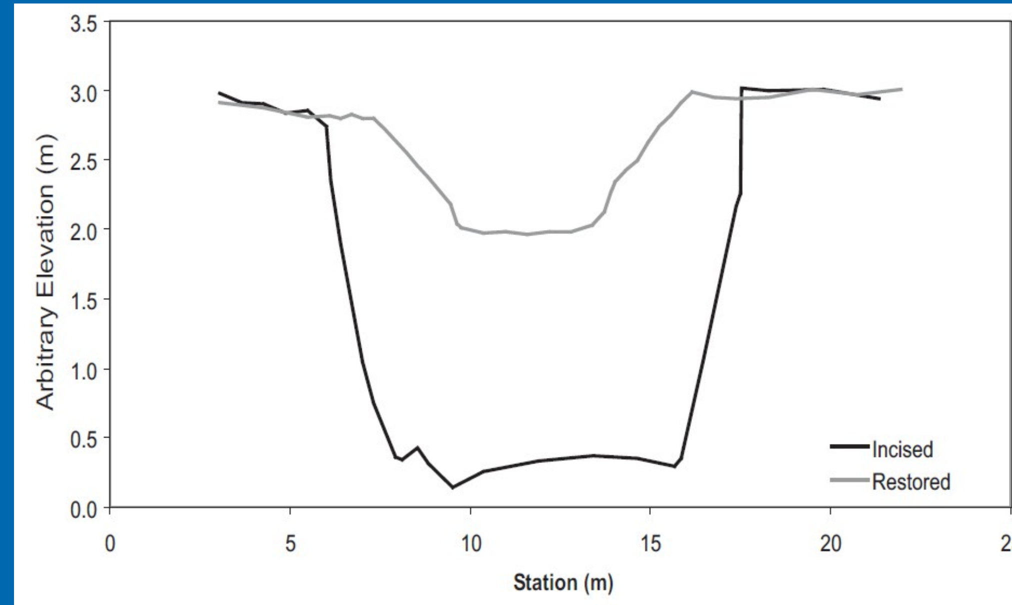
# Moorhead et al. (2008)

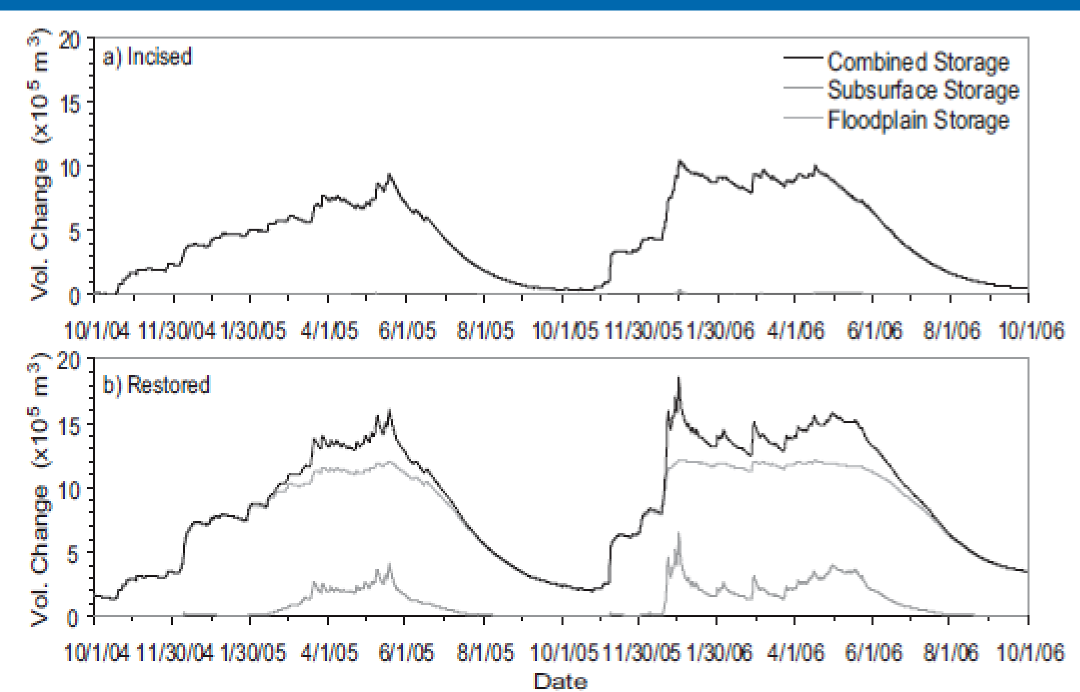


# Montane Meadow, Northern California



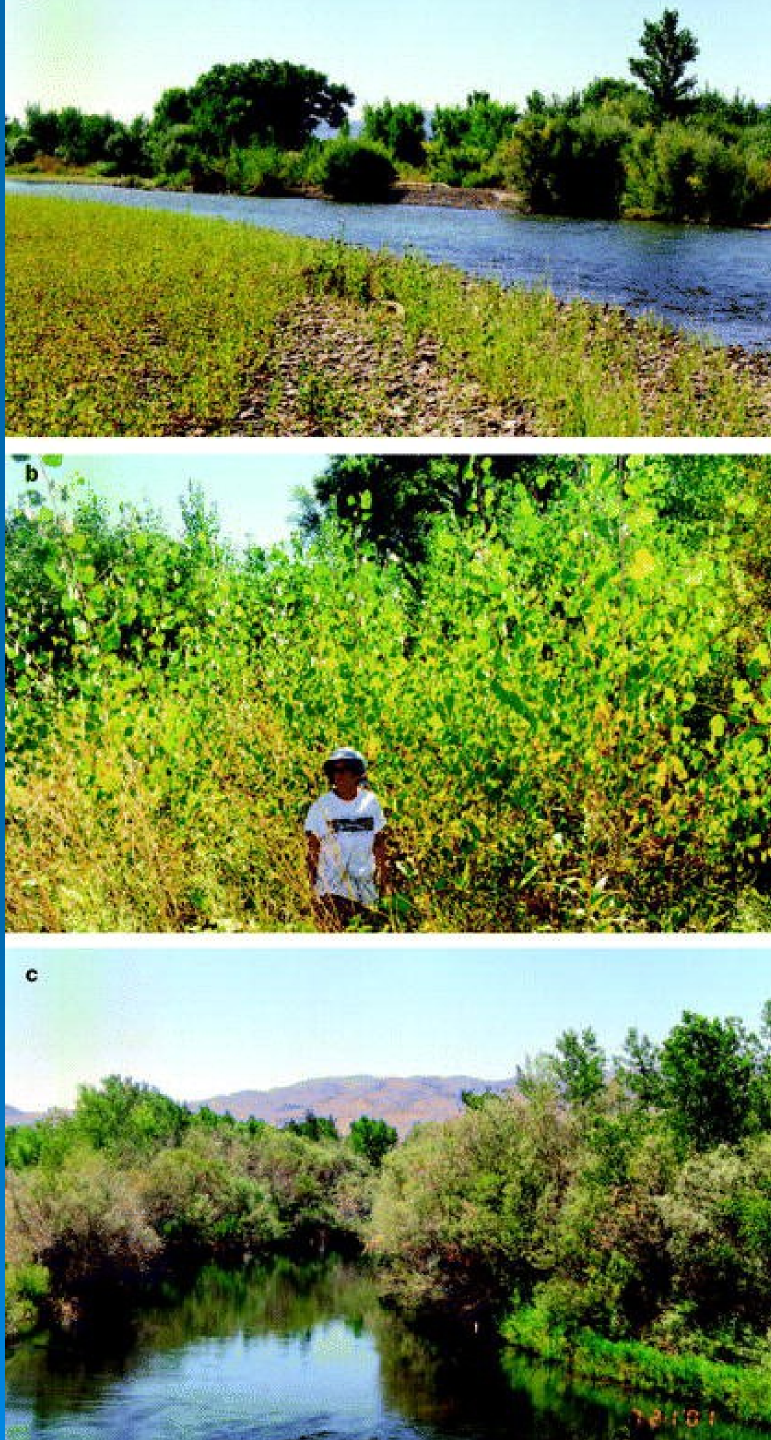



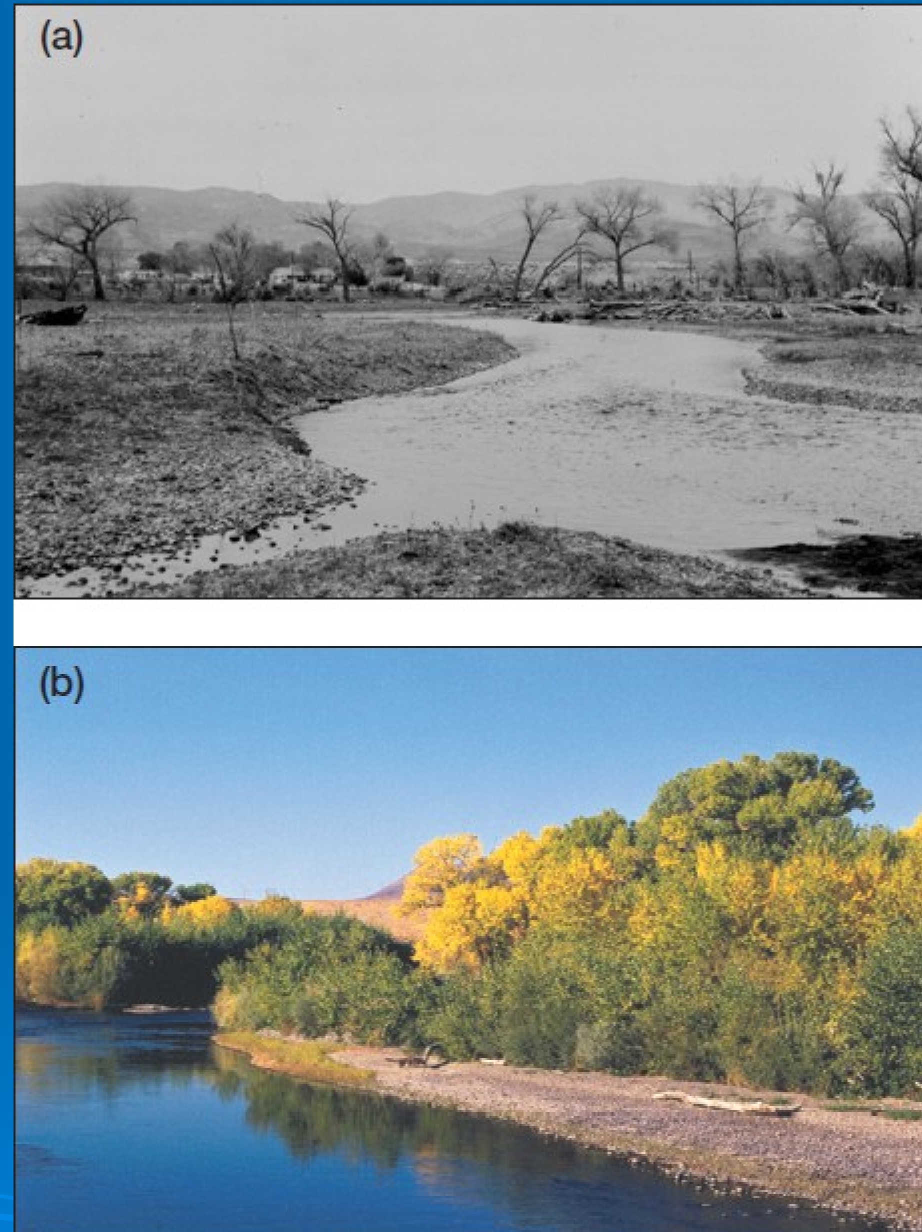




Improvements in water tables, vegetation but late season baseflows decreased→ additional storage and ET

Hammersmark et al. (2008)

# Truckee River, CA



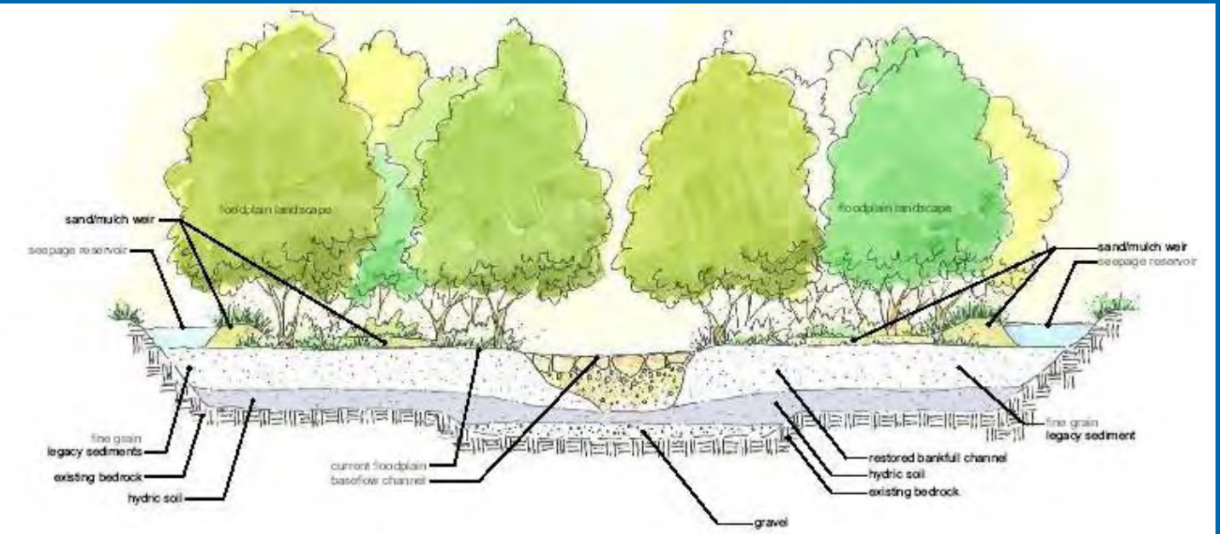



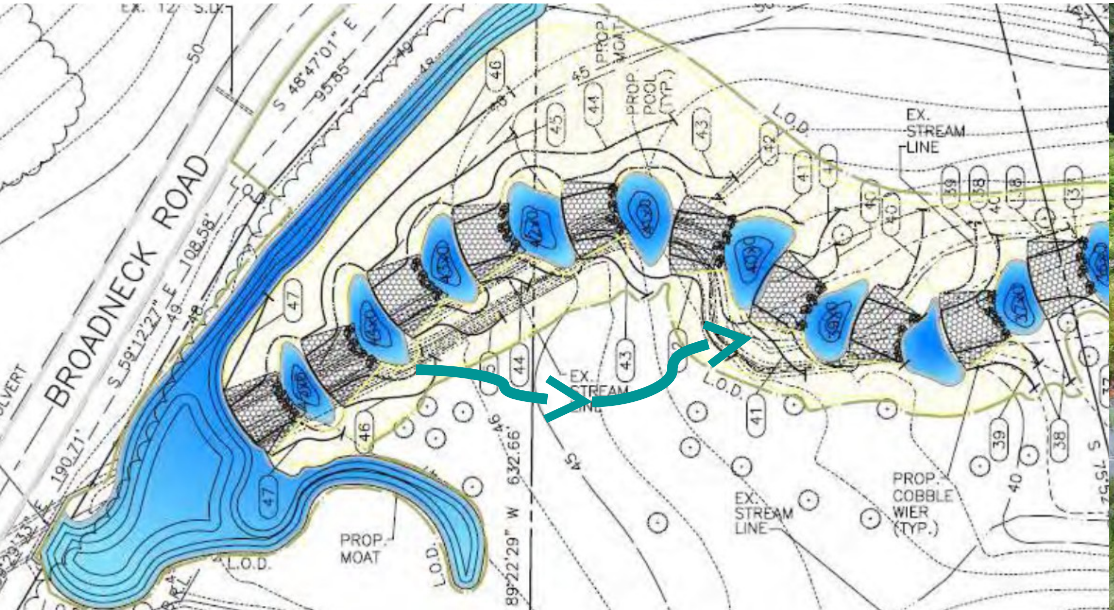

Truckee River California 1977 vs. 1997 - Rood et al. (2005)

# Post Settlement Alluvium Southeast USA

Photo credits: Ben Mater

# Channel Blocking (Biohabitats Inc.)

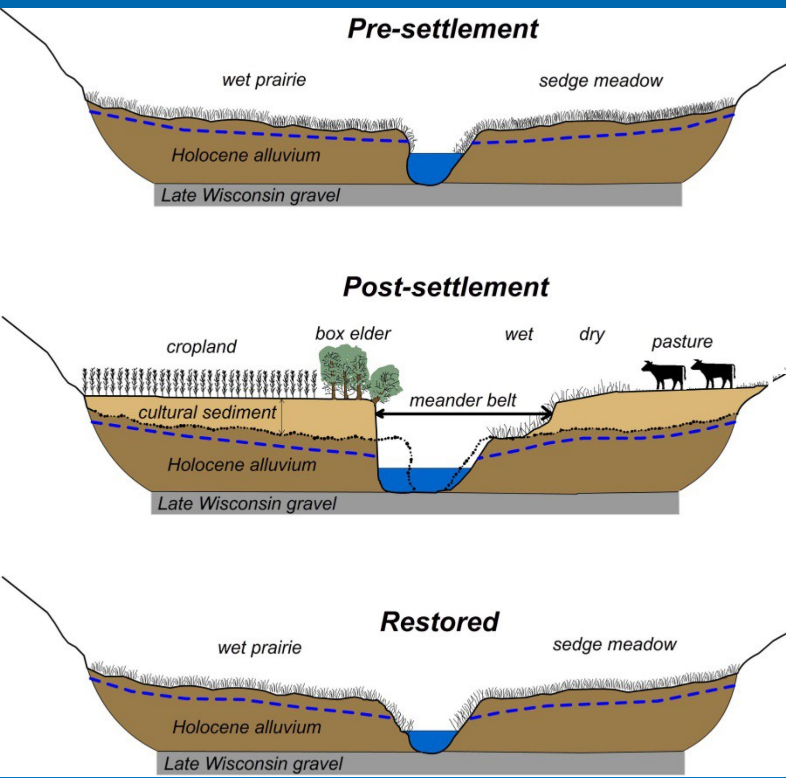





V. Sortman (Biohabitats Inc.)

# Bank Lowering



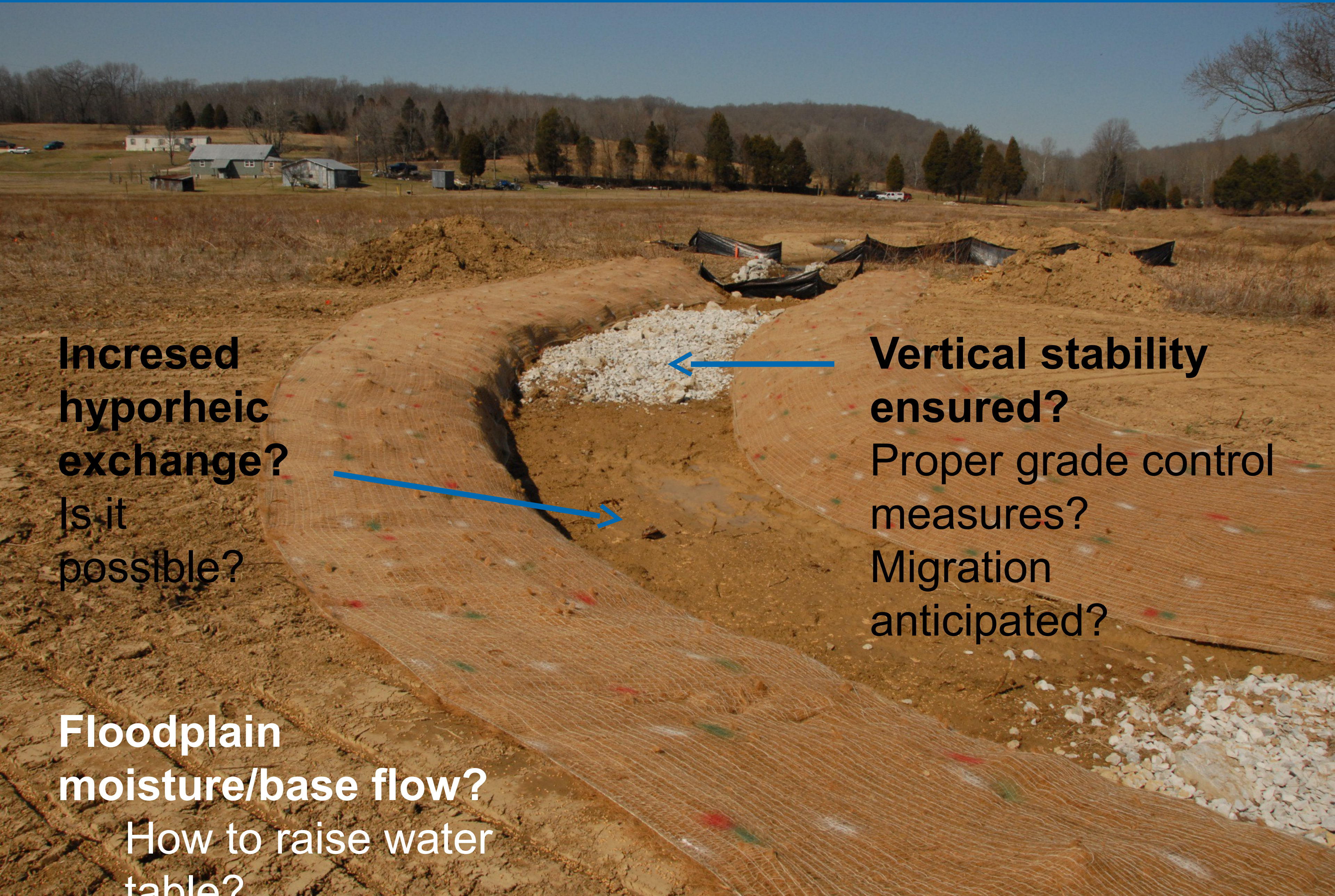


ast Branch Pecotonica headwaters

Booth et al. (2009)

11,000 cy removed

# “Perched” Re-construction



**Incresed hyporheic exchange?**
Is it possible?

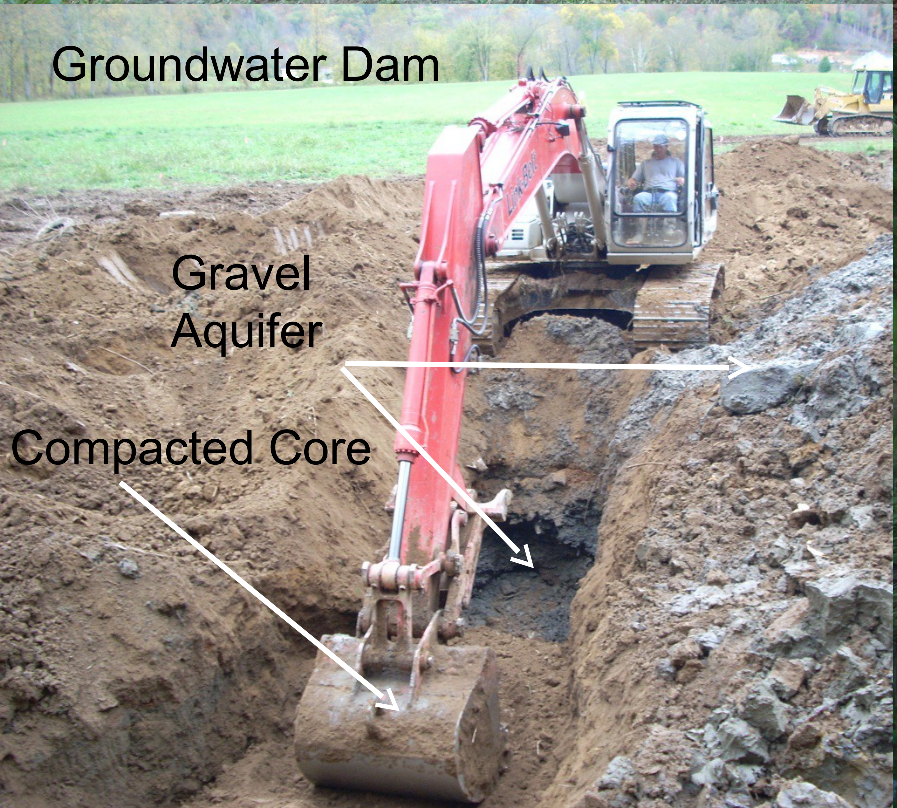
**Vertical stability ensured?**
Proper grade control measures?
Migration anticipated?

**Floodplain moisture/base flow?**
How to raise water table?

# Removal & Re-construction: Slabcamp Cr.

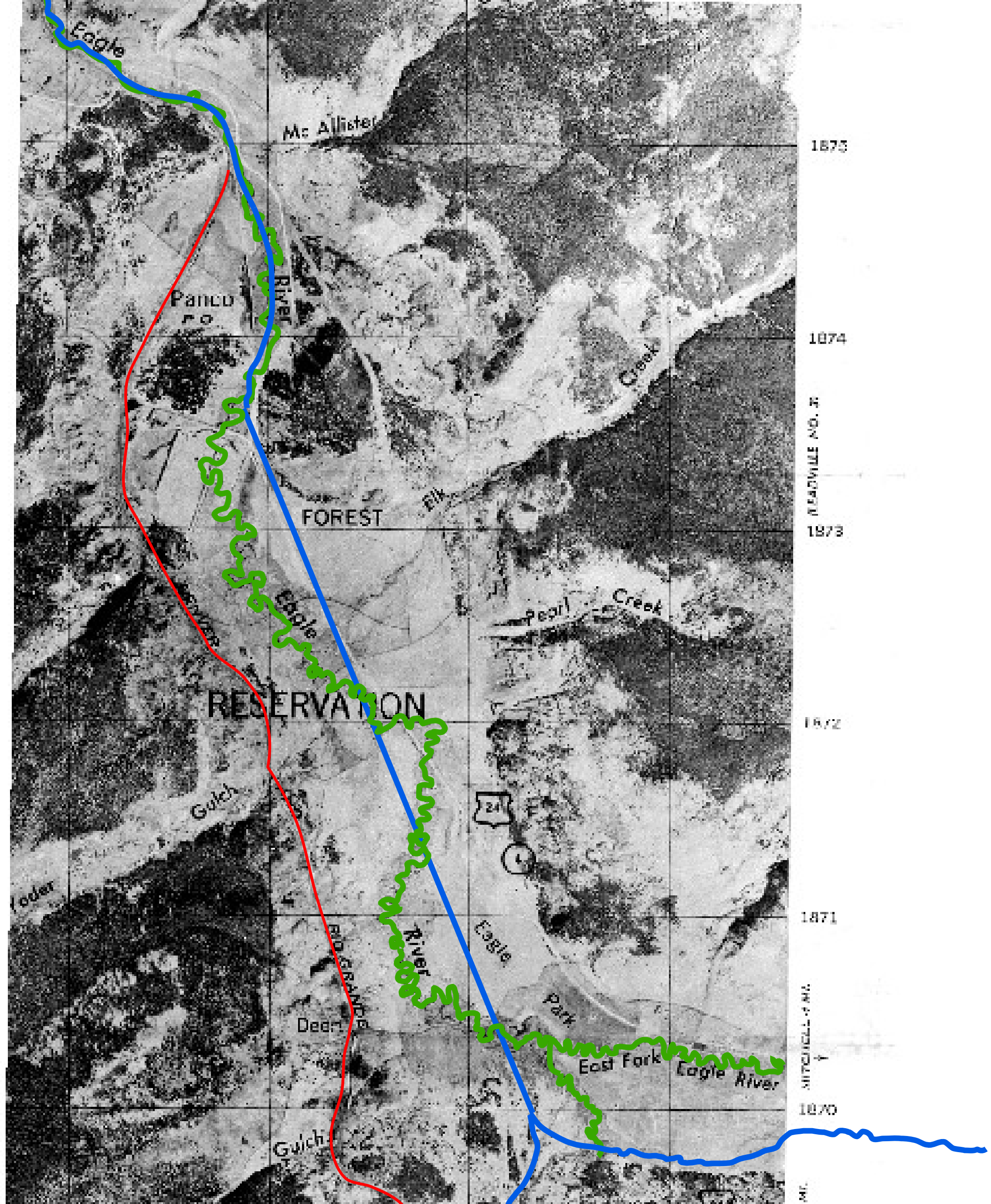
- Closest to “restoration”?
- Challenges to consider:
- Existing vegetation removed
- Sediment splay area needed
- Tributary tie-ins…
- Initial embeddedness


# “Perched” Re-construction: Mill Branch, KY (UofL)

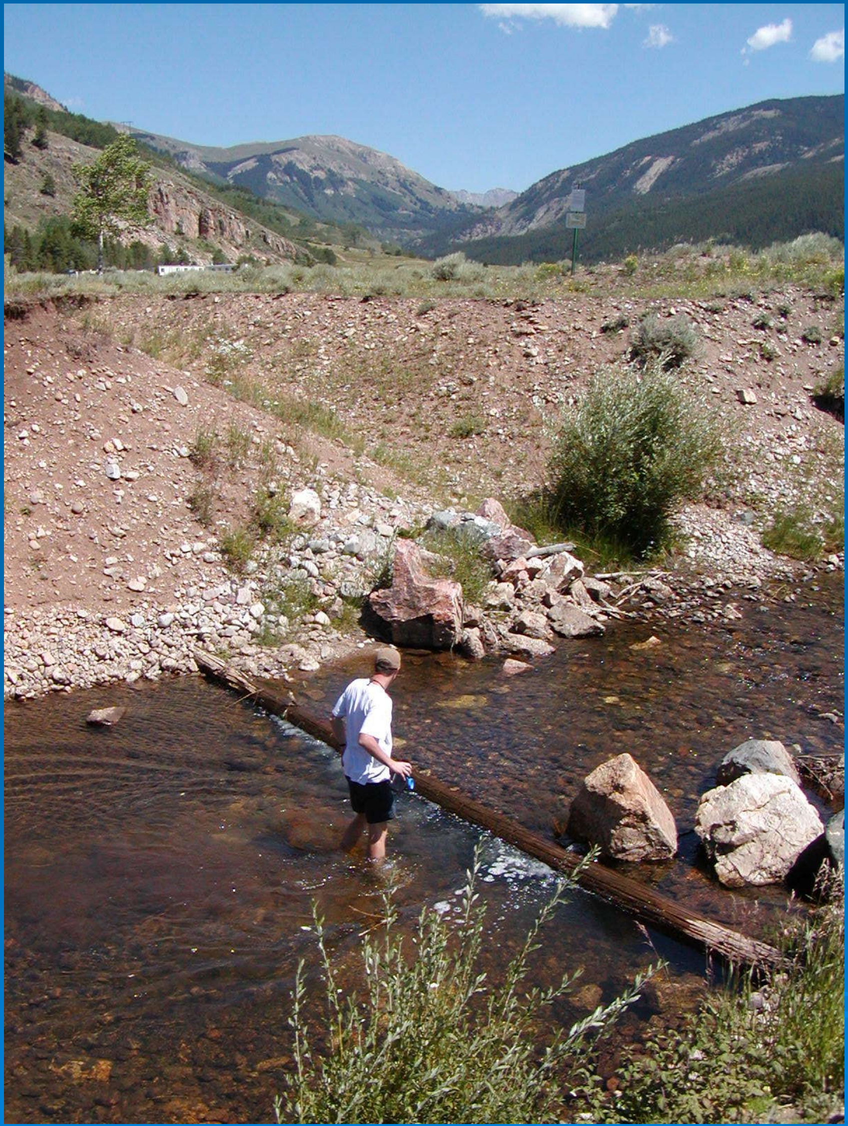




# Camp Hale – Eagle River, CO


3916


Eagle
Mc Allister
Pando
P.O.
River
Creek
Elk
FOREST
Pearl
Creek
Eagle
RESERVATION
24
Gulch
Yoder
River
Eagle
Park
Deer
Gulch
East Fork
Eagle
River
1875
1874
1873
1872
1871
1870

# Current State



# Ten Mile Creek – Copper Mtn.

Photos: Justin Anderson USFS

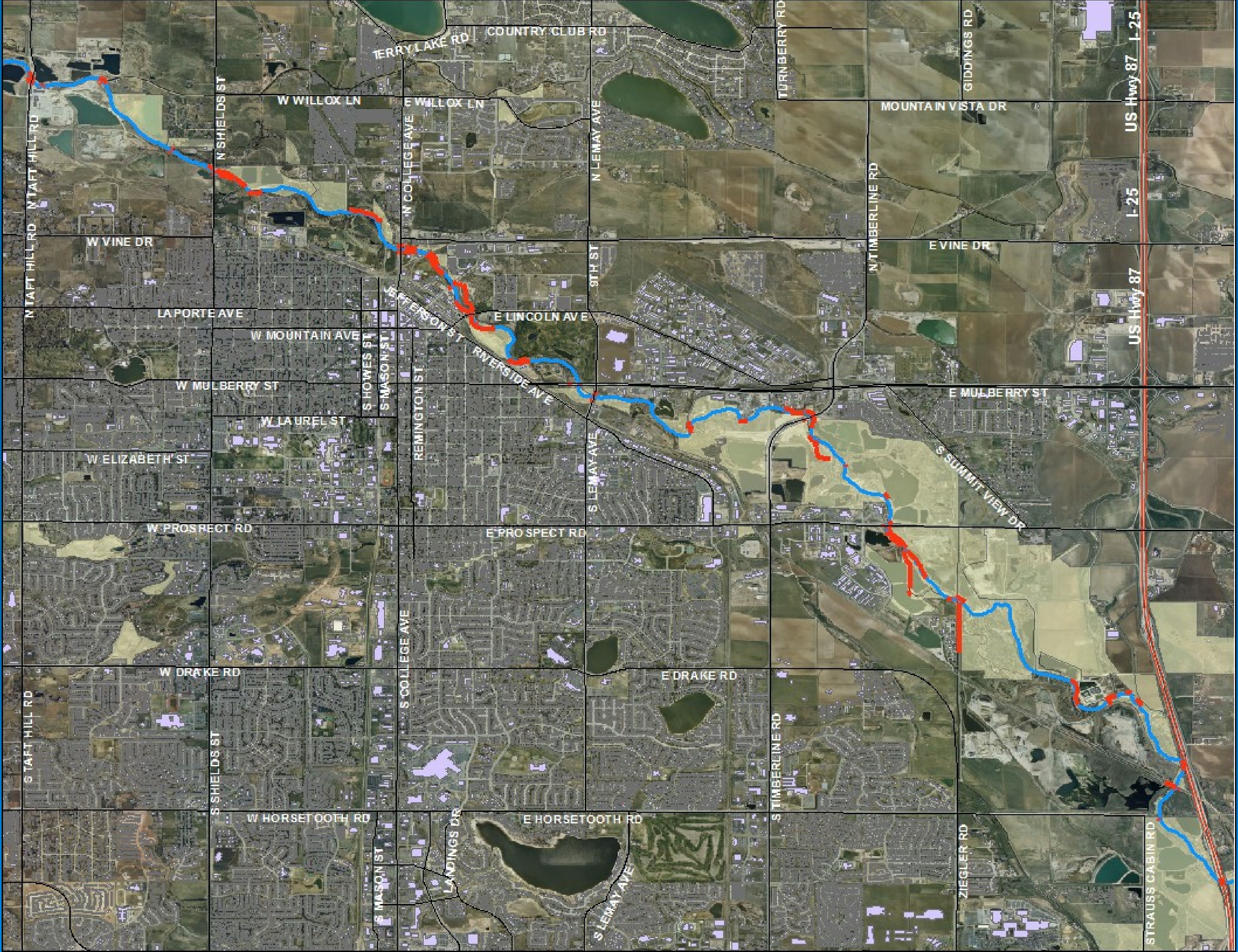

BE PREPARED TO STOP
WHEN FLASHING
TOURIST INFORMATION
GAS-PHONE
FOOD-LODGING


SPEED
LIMIT
35

# Little Snake River at 3 Forks Ranch – near Slater, WY


HITACHI

# Cache La Poudre River
# Fort Collins, CO


COUNTRY CLUB RD
TERRY LAKE RD
TURNBERRY RD
GIDDINGS RD
I-25
US Hwy 87
W WILLOX LN
E WILLOX LN
MOUNTAIN VISTA DR
N TAFT HILL RD
N SHIELDS ST
N COLLEGE AVE
N LEMAY AVE
N TIMBERLINE RD
W VINE DR
E VINE DR
9TH ST
JEFFERSON ST
LAPORTE AVE
E LINCOLN AVE
W MOUNTAIN AVE
RIVERSIDE AVE
S HOWES ST
S MASON ST
REMINGTON ST
W MULBERRY ST
E MULBERRY ST
W LAUREL ST
S LEMAY AVE
S SUMMIT VIEW DR
W ELIZABETH ST
W PROSPECT RD
E PROSPECT RD
S COLLEGE AVE
W DRAKE RD
E DRAKE RD
S TAFT HILL RD
S SHIELDS ST
S TIMBERLINE RD
W HORSETOOTH RD
E HORSETOOTH RD
LANDINGS DR
ZIEGLER RD
STRAUSS CABIN RD

# Assessing Opportunities for Re-connecting Urban Floodplains

## Characteristics of Rip Rap

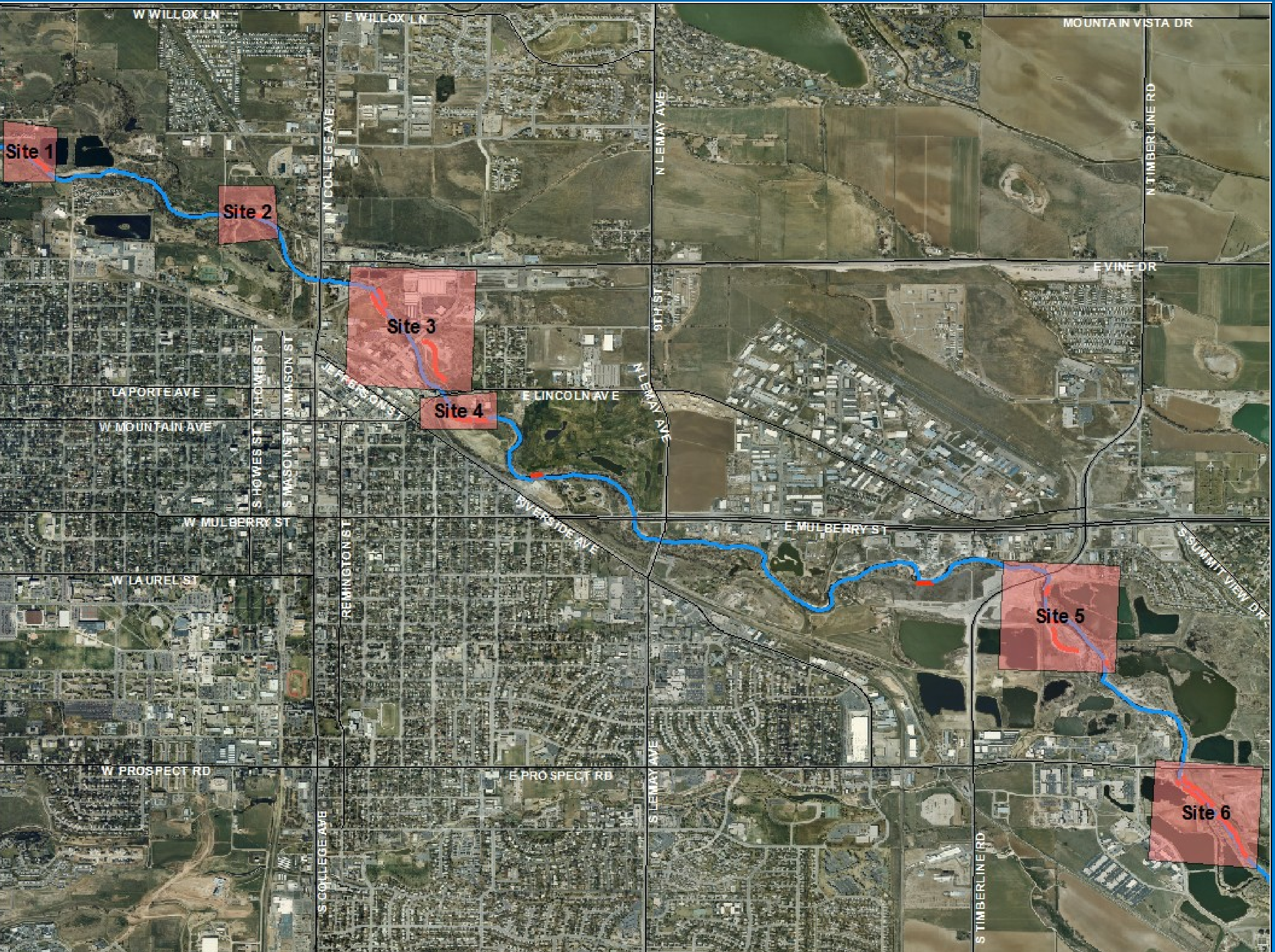
- Length
- Distance from Centerline

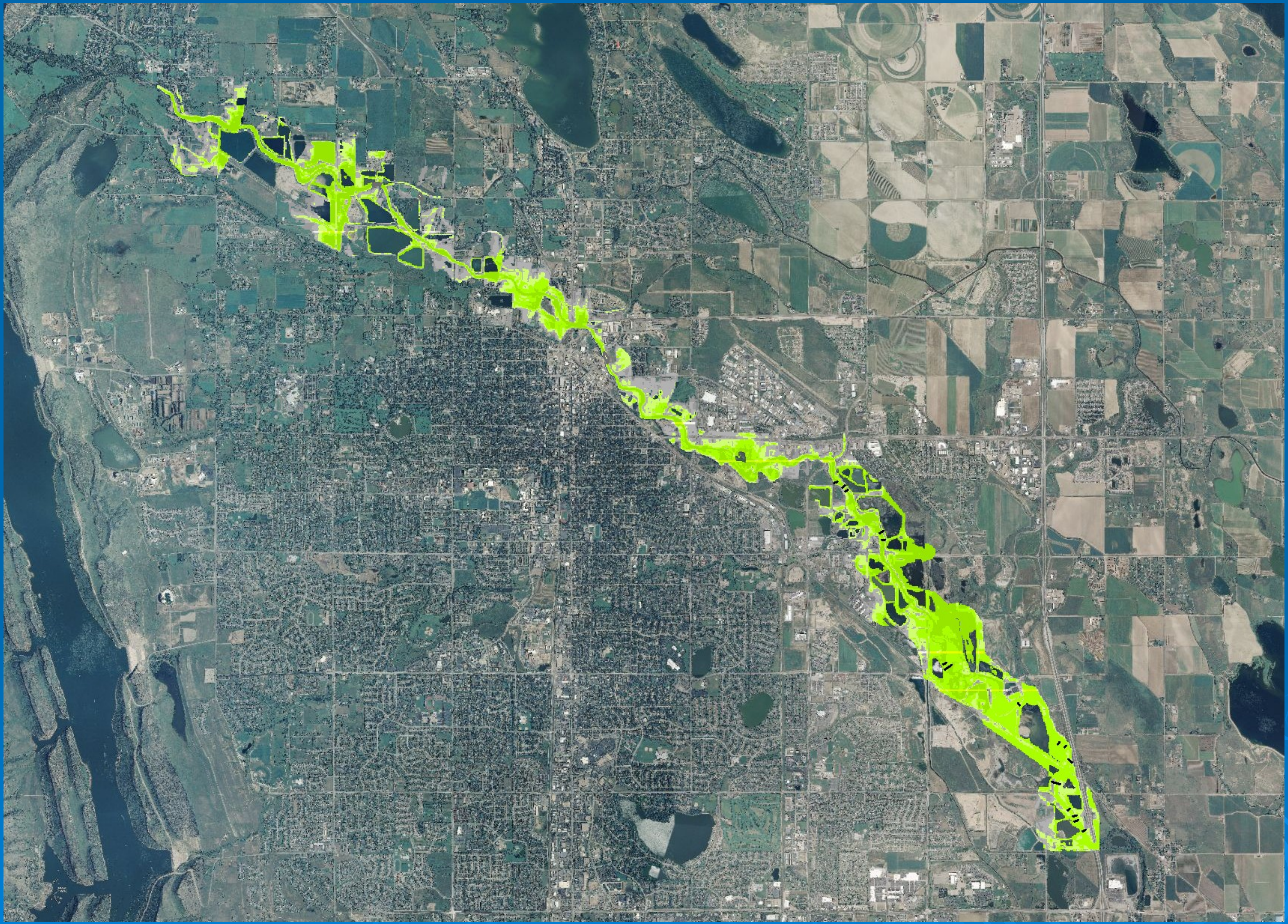
## Surrounding Topography

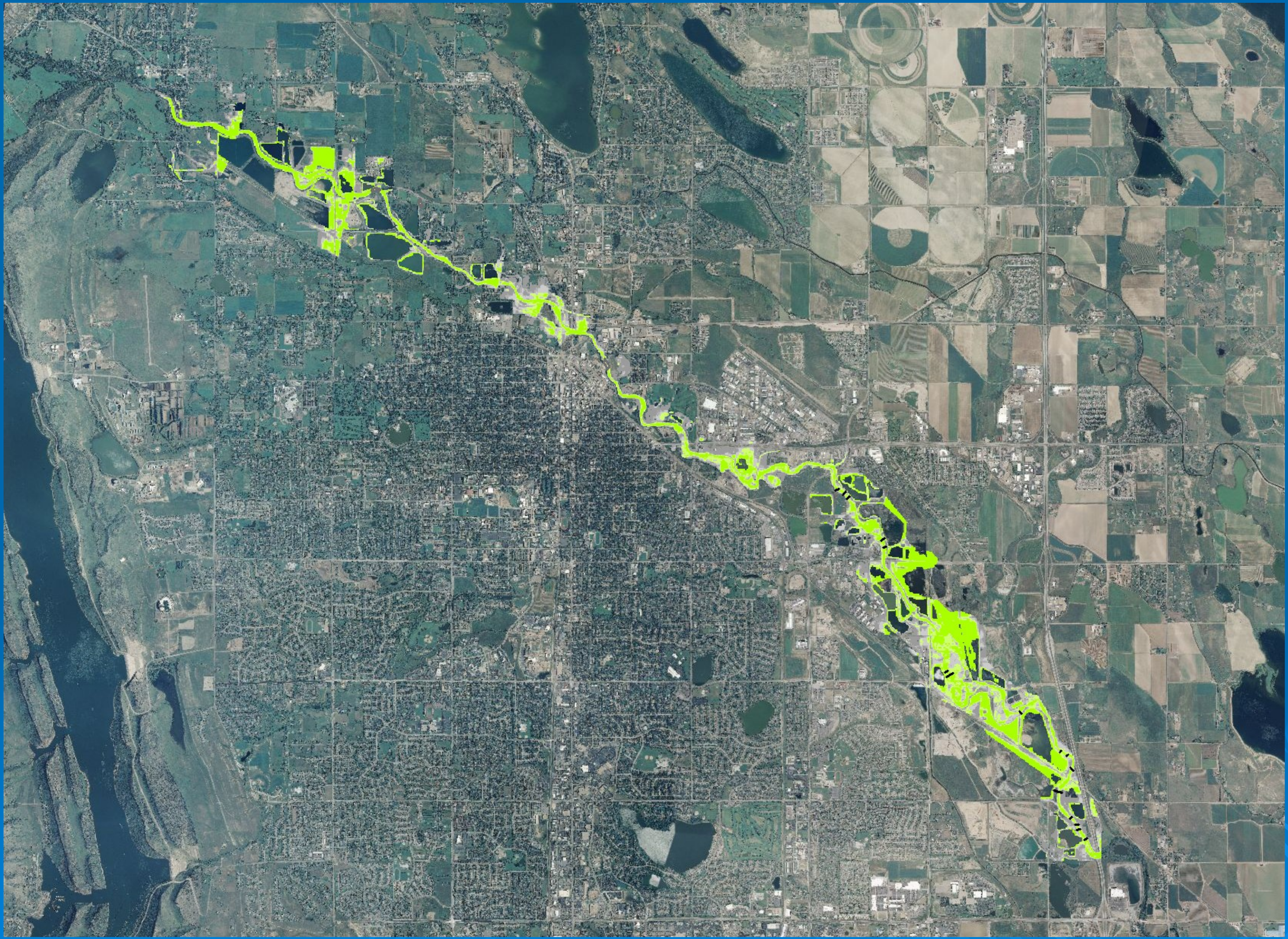
- Adjacent floodplain

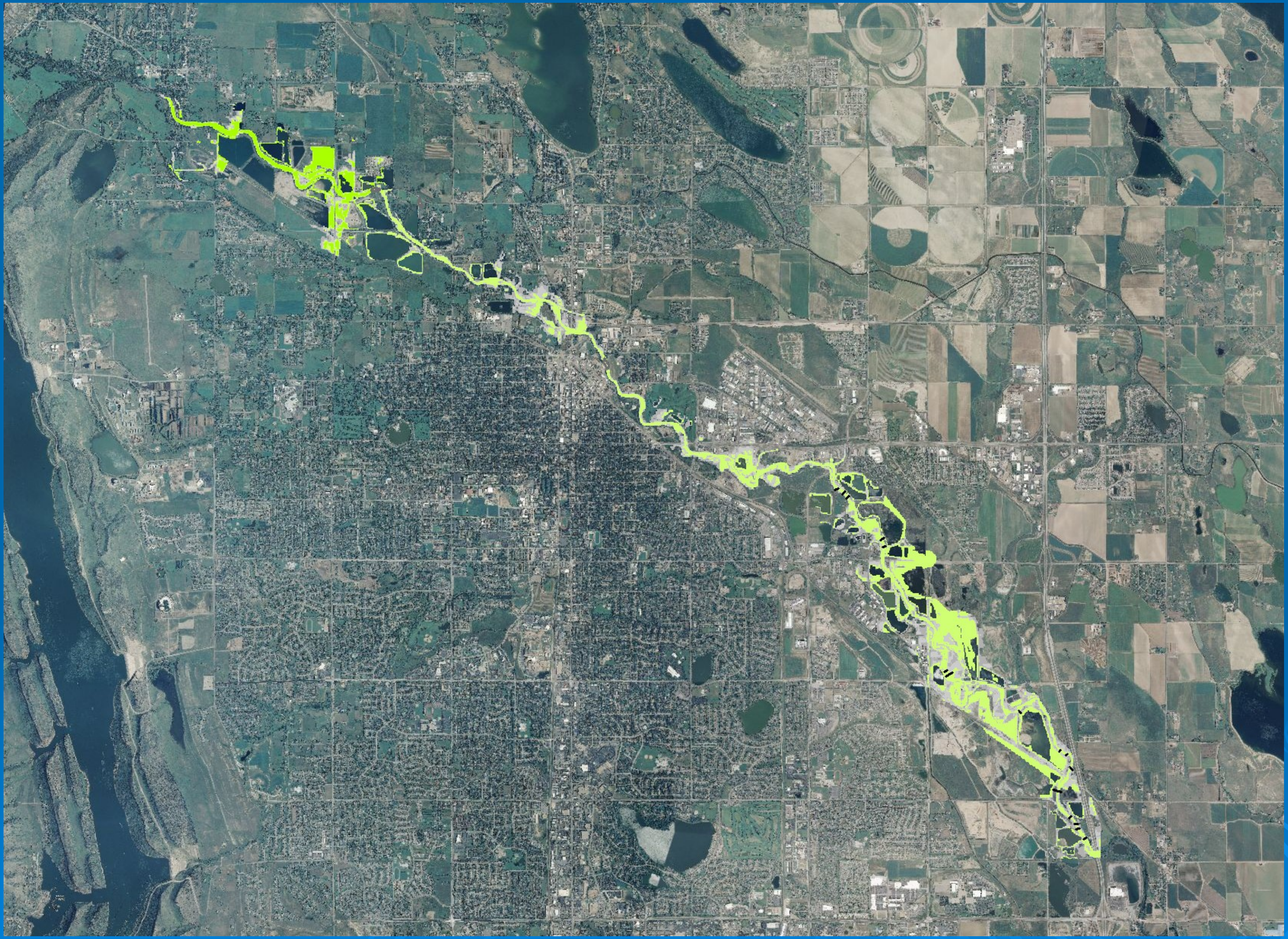
## Fundamental Constraints

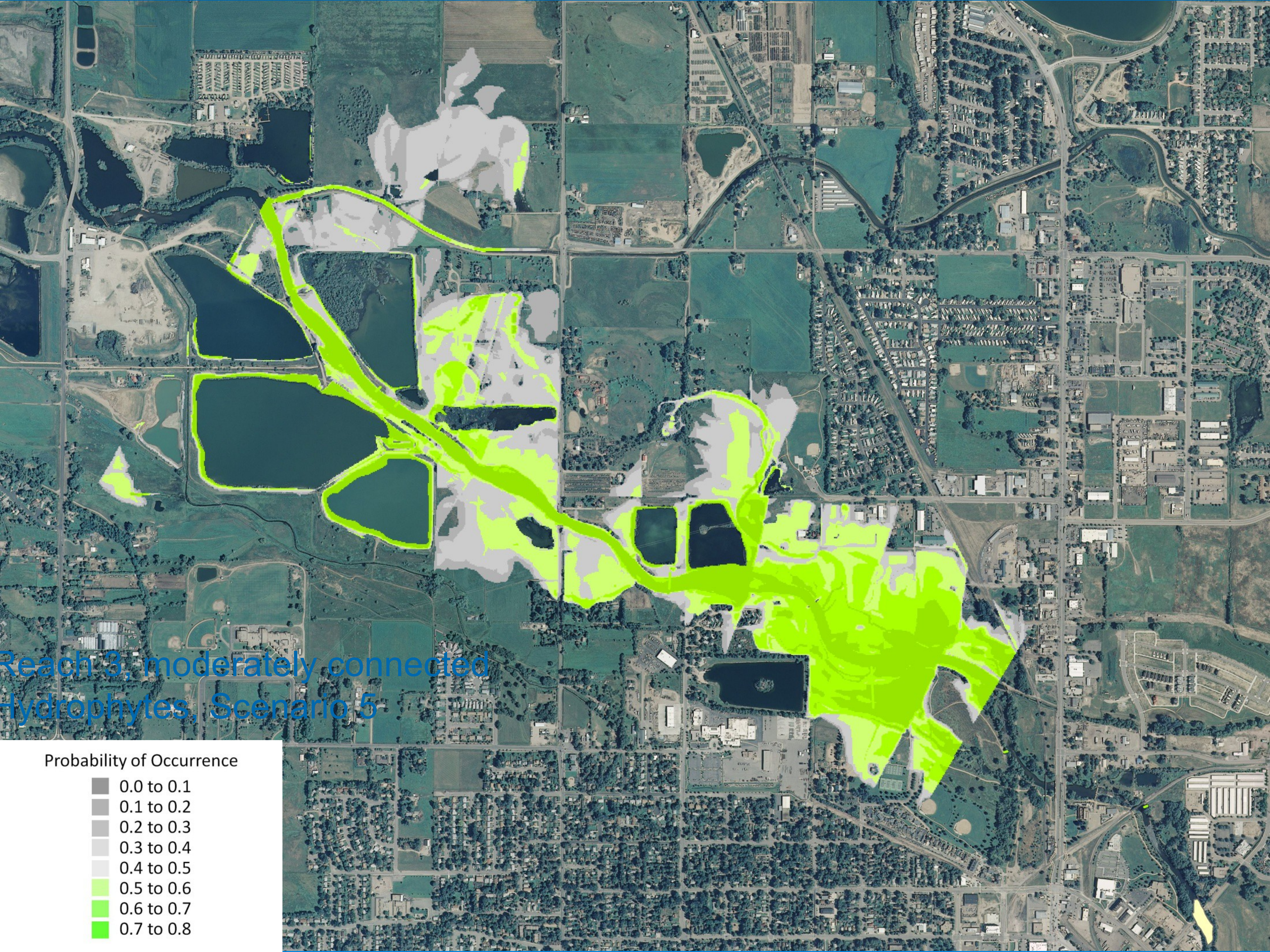
- Buildings
- Infrastructure


W WILLOX LN
E WILLOX LN
MOUNTAIN VISTA DR
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
N COLLEGE AVE
N LEMAY AVE
N TIMBERLINE RD
E VINE DR
9TH ST
LAPORTE AVE
N HOWES ST
N MASON ST
JEFFERSON ST
E LINCOLN AVE
W MOUNTAIN AVE
S HOWES ST
S MASON ST
W MULBERRY ST
E MULBERRY ST
RIVERSIDE AVE
S SUMMIT VIEW DR
W LAUREL ST
REMINGTON ST
W PROSPECT RD
E PROSPECT RD
S COLLEGE AVE
S LEMAY AVE
S TIMBERLINE RD

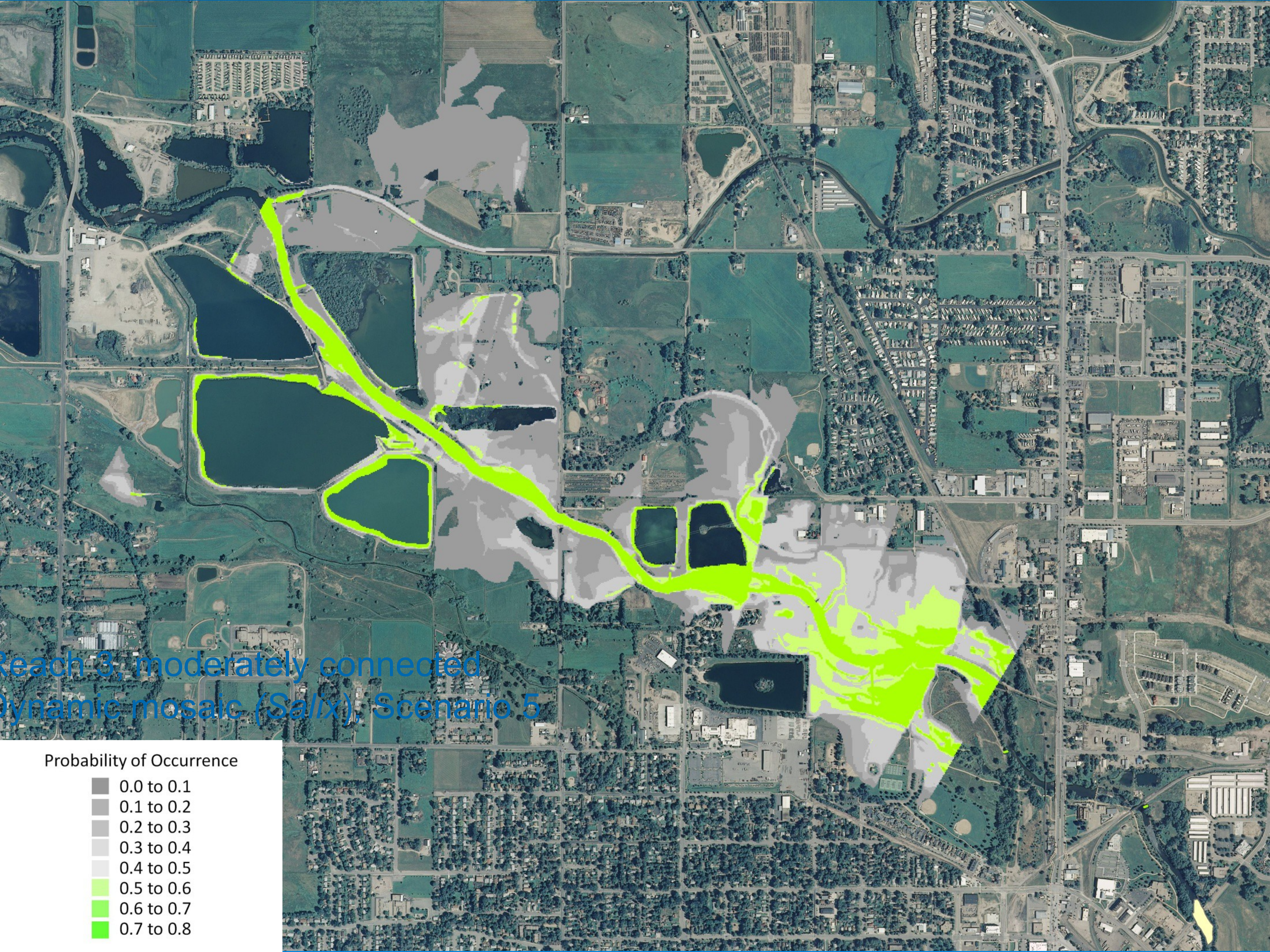


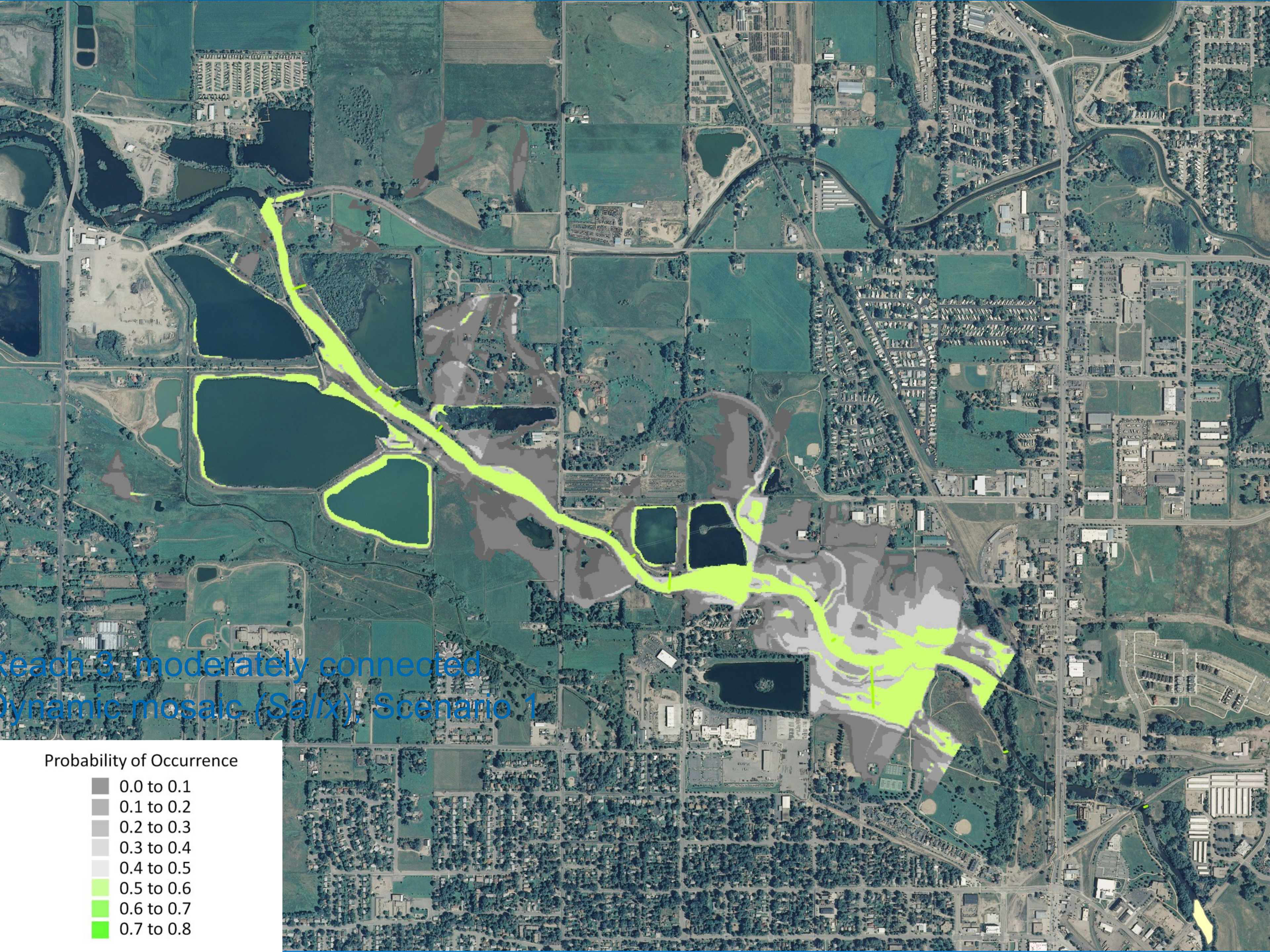


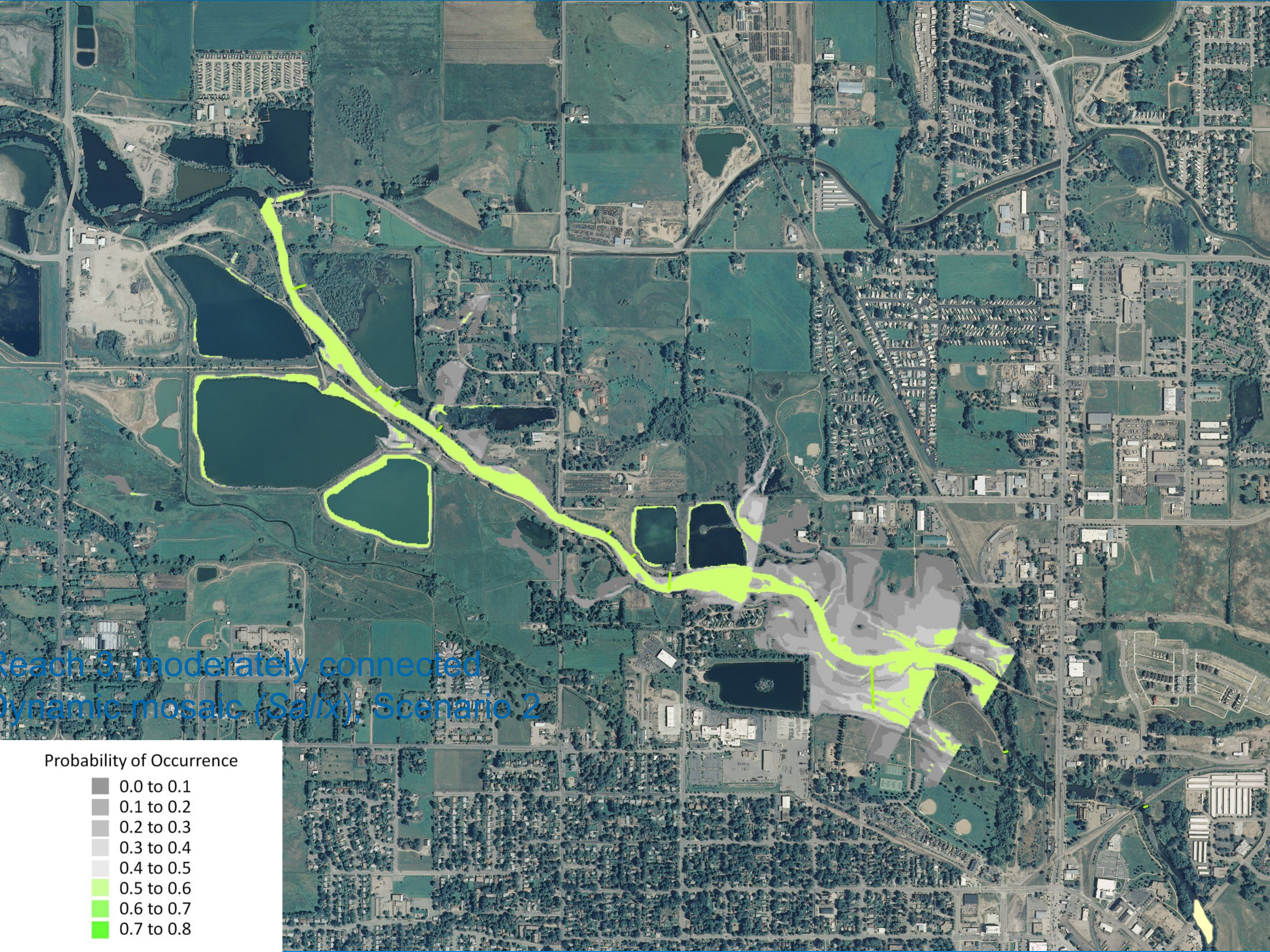




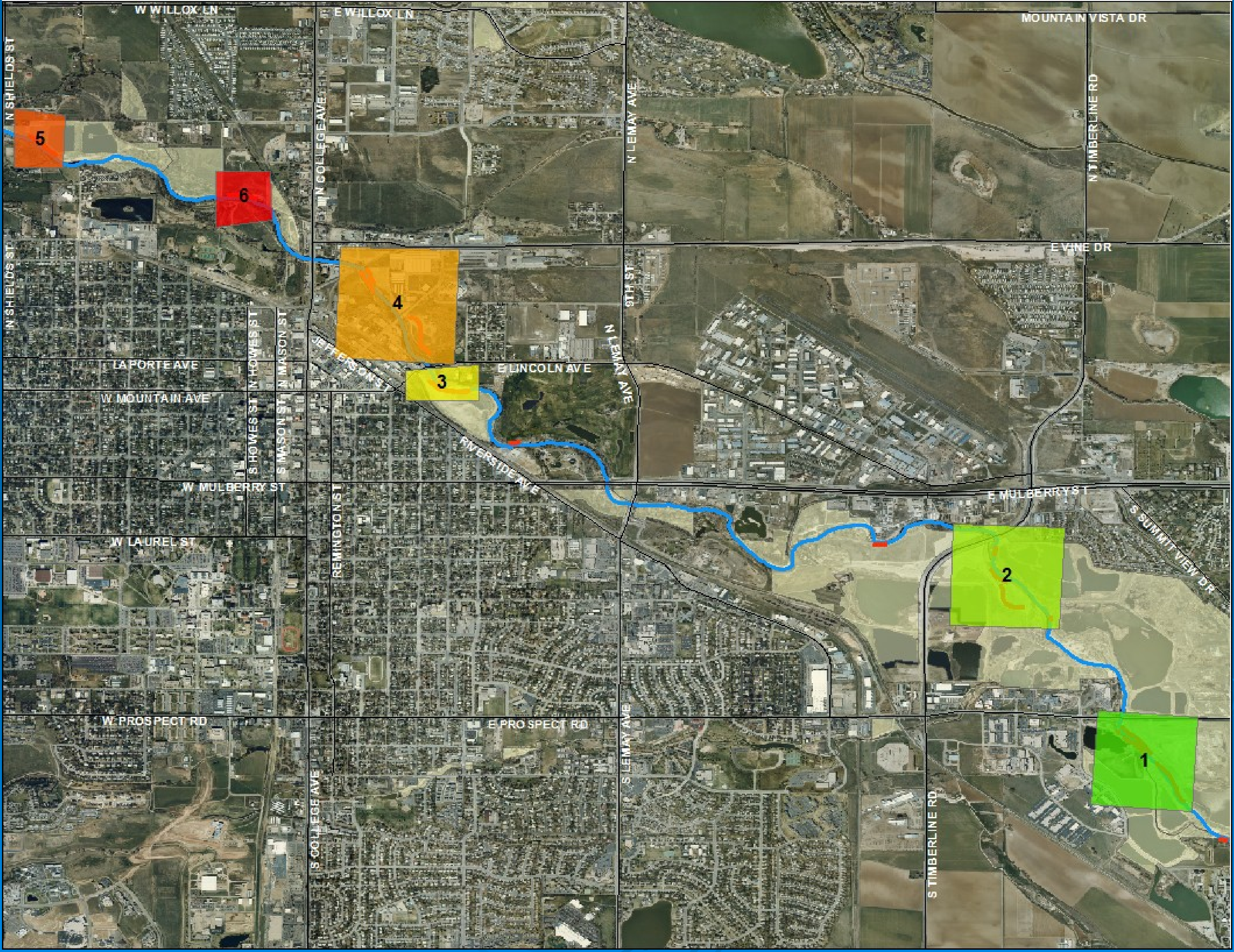
Reach 3, moderately connected
Hydrophytes, Scenario 5
Probability of Occurrence
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8


Reach 3, moderately connected
ynamic mosaic (*Salix*), Scenario 5
Probability of Occurrence
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8


Reach 3, moderately connected
Dynamic mosaic (Salix), Scenario 1
Probability of Occurrence
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8


each 3, moderately connected
ynamic mosaic (*Salix*), Scenario 2
Probability of Occurrence
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8


Reach 3, moderately connected
Dynamic mosaic (*Salix*), Scenario 3
Probability of Occurrence
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8



W WILLOX LN
E WILLOX LN
MOUNTAIN VISTA DR
N SHIELDS ST
5
6
N COLLEGE AVE
N LEMAY AVE
N TIMBERLINE RD
E VINE DR
N SHIELDS ST
4
9TH ST
LAPORTE AVE
N HOWES ST
N MASON ST
JEFFERSON ST
3
E LINCOLN AVE
N LEMAY AVE
W MOUNTAIN AVE
S HOWES ST
S MASON ST
RIVERSIDE AVE
W MULBERRY ST
REMINGTON ST
E MULBERRY ST
S SUMMIT VIEW DR
W LAUREL ST
2
W PROSPECT RD
E PROSPECT RD
S LEMAY AVE
1
S COLLEGE AVE
S TIMBERLINE RD

# Final thoughts

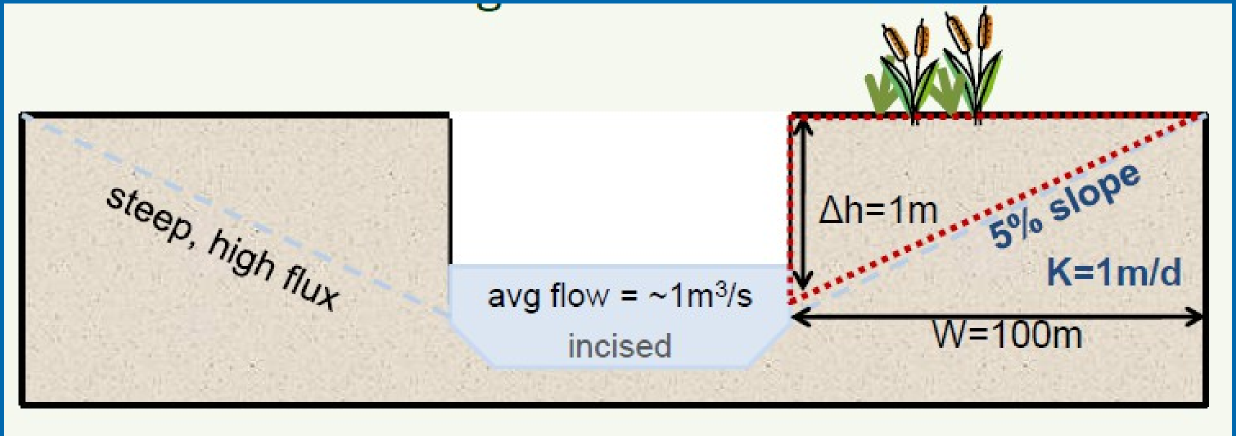
- Floodplain ecosystems are dependent upon naturally dynamic river-flow patterns and occasional floods
- For some degraded rivers, the recovery of appropriate seasonal flow patterns has lead to dramatic improvements in floodplain forests

# Final thoughts

- Floodplain reconnection is context-specific
- Requires clear goals and objectives
- Must work with available flows, space
- Plants, hydrology, soils have subtle inter-relationships operating at small scales
- Focus on getting moisture regime and soils right→ plants self-organize
- Prioritize for extent of lateral *and* longitudinal connectivity

# With Careful Design Floodplain Reconnection Can

- Reduce flood risks
- Increase ecosystem goods and services, and ecological functions, e.g.
  - Water quality
  - Habitat, fisheries, wildlife
- Improve resiliency to the potential effects of climate change




| Hydrologic effect | Cause |
|---|---|
| Raised GW levels | Reduced energy gradient on GW flow |
| Increased subsurface storage in the rooting zone | Reduced energy gradient on GW flow |
| Increased frequency of floodplain inundation | Channel capacity reduced, flow reaches floodplain at lower flow levels |
| Decreased flood peaks | Overbank flows temporarily stored on floodplain |
| Increased surface storage | Microtopography, depression storage |
| Decreased duration of baseflow | Reduced gradient, GW flow slow<br>Increased ET many times > GW flux |
| Increased ET | Plants now have access in root zone |
| Decreased total annual runoff | Increased subsurface storage and ET |