Practical Mapping, Channel Migration and Floodplains

Considering Connectivity and SAR in Stream Restoration Strategy Development

Enhancing Streamflows Through Shallow Aquifer Recharge

Technical Meeting

October 21, 2015

Karin Boyd
Applied Geomorphology, Inc.
Bozeman, MT

Primary Topics

1. Hydrologic connectivity has been progressively lost on streams in Montana, through both side channel loss and floodplain isolation

2. Restoration efforts have begun to increasingly focus on reconnection as a primary restoration objective

3. Shallow Aquifer Recharge (SAR) is only one of many benefits of restoring connectivity

SAR projects release water on or near the surface above the local water table. Recharge is done, typically on a seasonal basis, by diverting surface water into infiltration sites. Sites can be natural or man-made features such as fields, gravel pits, ponds, canals, ditches and shallow wells.
--Washington Department of Ecology

Some Causes of Hydrologic Connectivity Loss

1. Physical Barriers
2. Flow Alterations
3. Channel Incision
4. Floodplain Aggradation

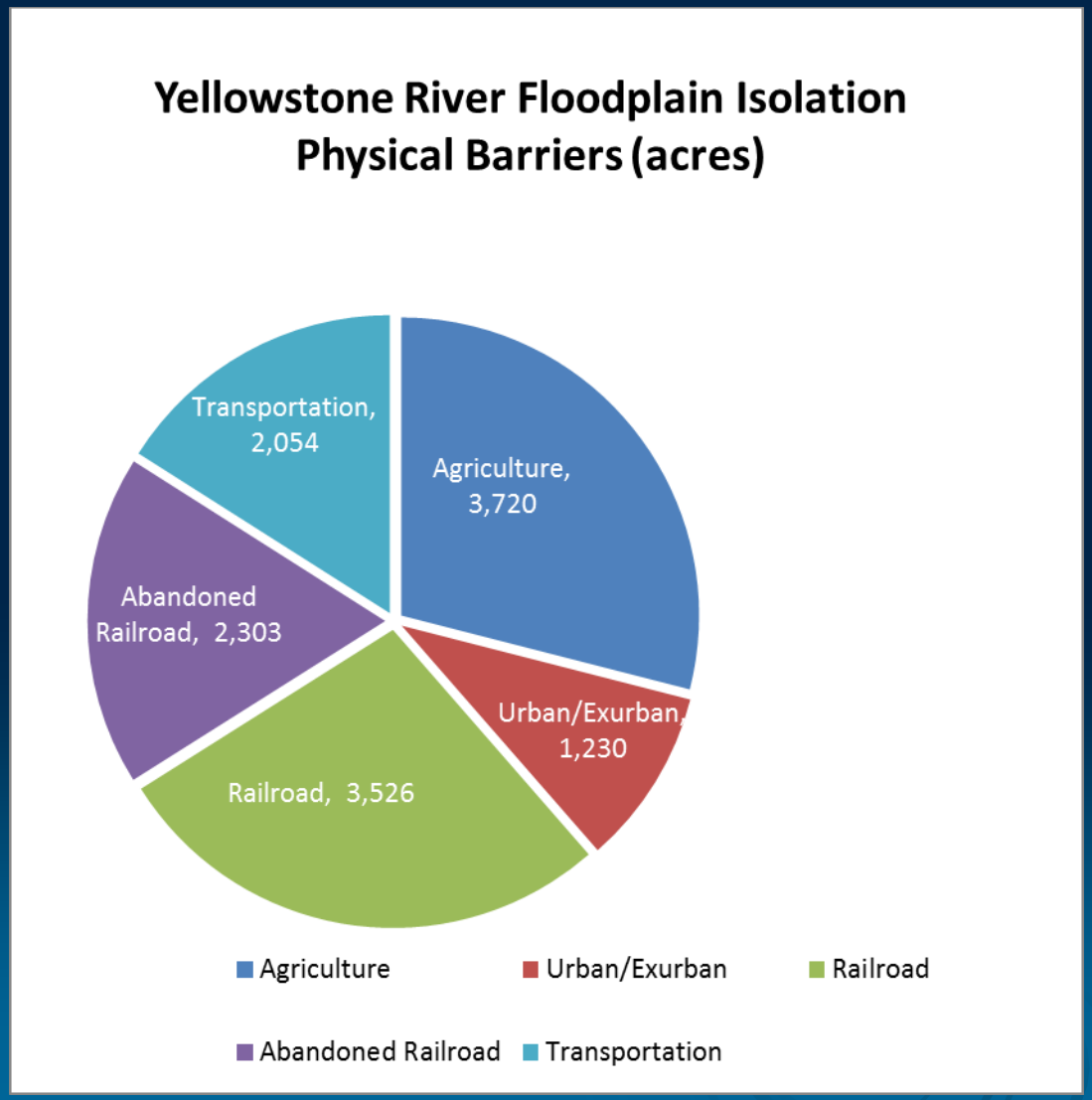
→ Loss of Floodplain Access
Loss of Side Channel Access

Some Examples of Hydrologic Connectivity Loss

1. Yellowstone River: Physical Barriers
2. Musselshell River: Physical Barriers and Incision
3. Ruby River: Flow Concentrations and Incision
4. Clark Fork River (Drummond to Milltown): Physical Barriers
5. Clark Fork River (Deer Lodge Valley): Floodplain Aggradation

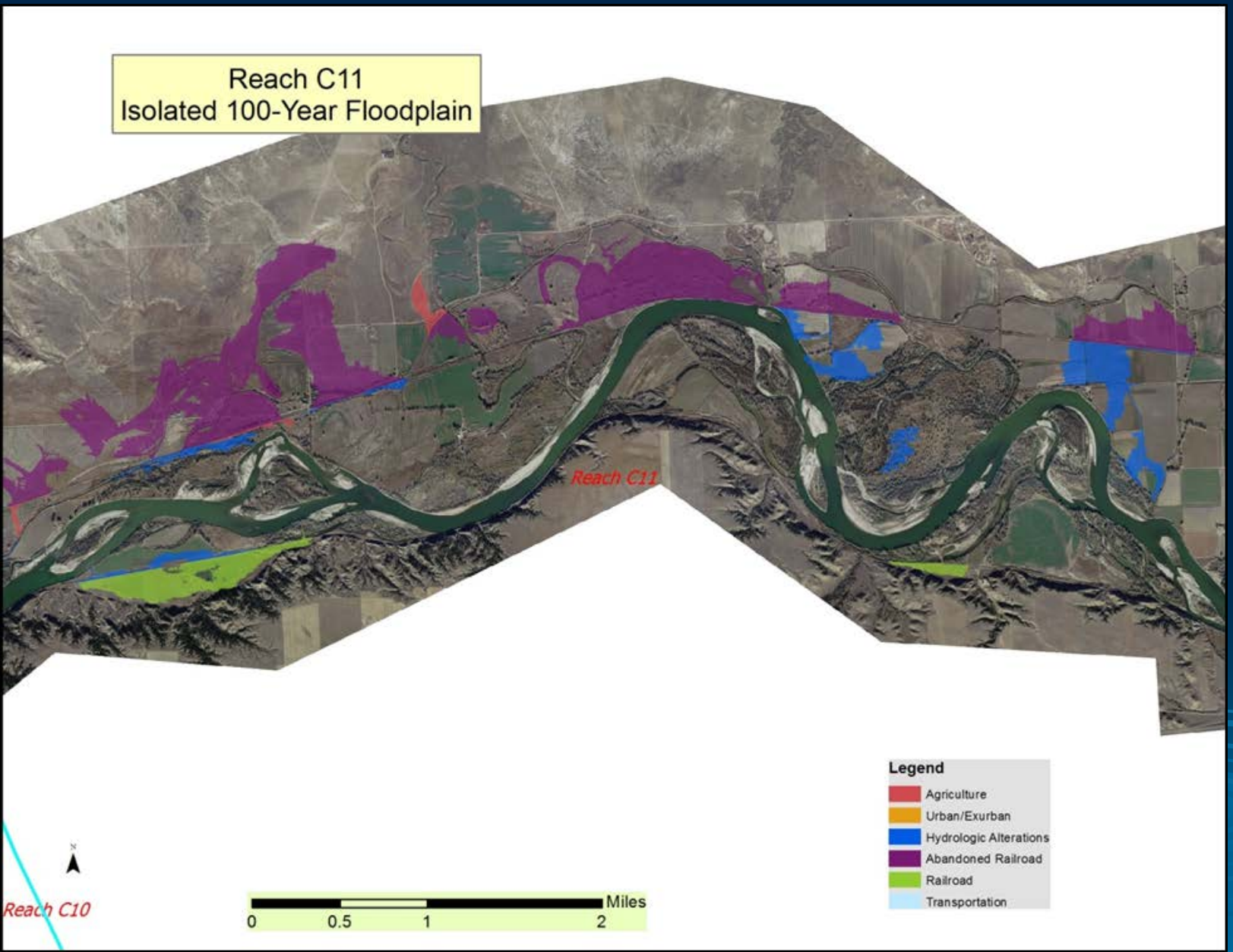
Restoration Strategies
Restoration Benefits

Yellowstone River: Physical Barriers

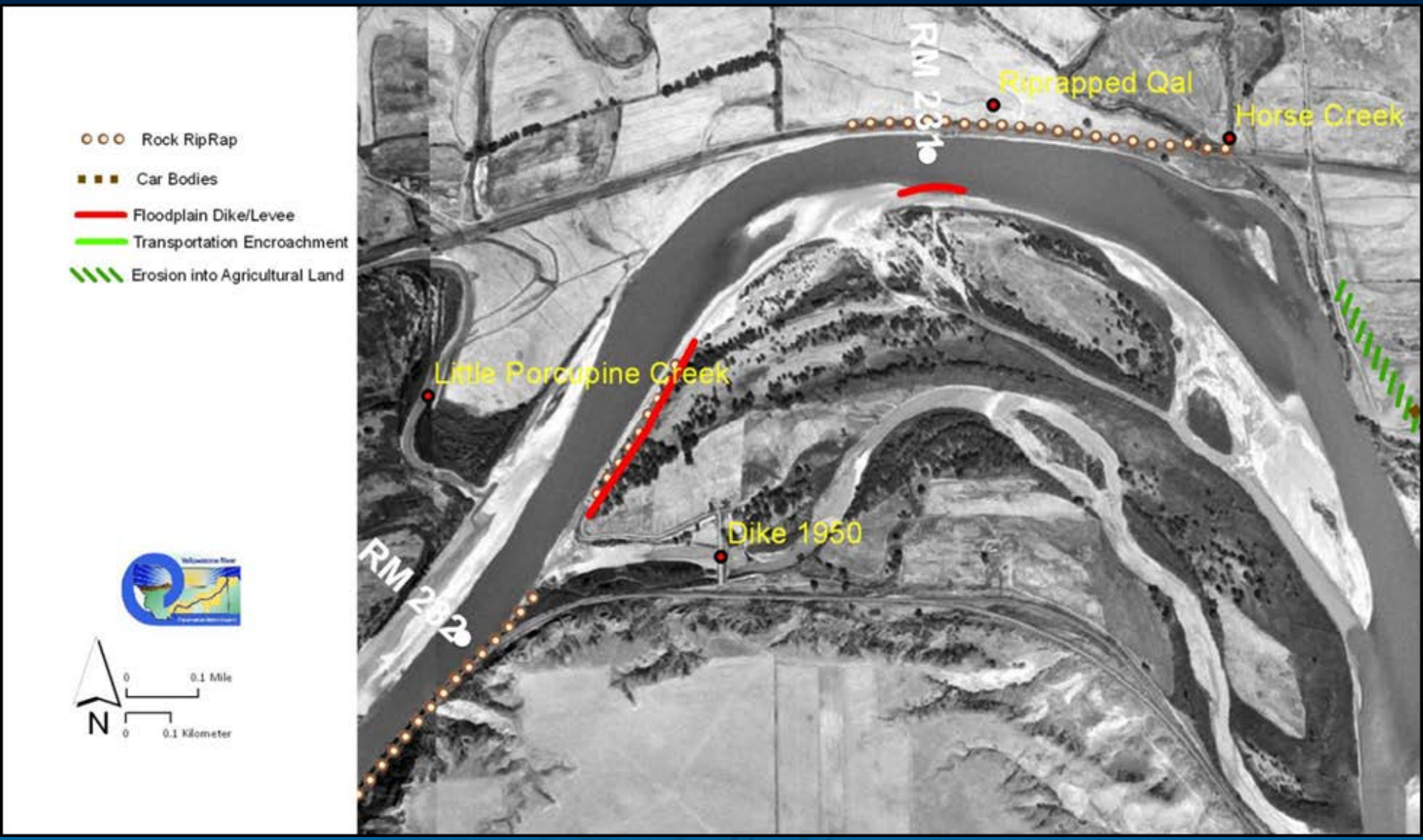


Yellowstone River: ~13,000 acres of 100-year floodplain isolation due to physical features

Yellowstone River: Physical Barriers

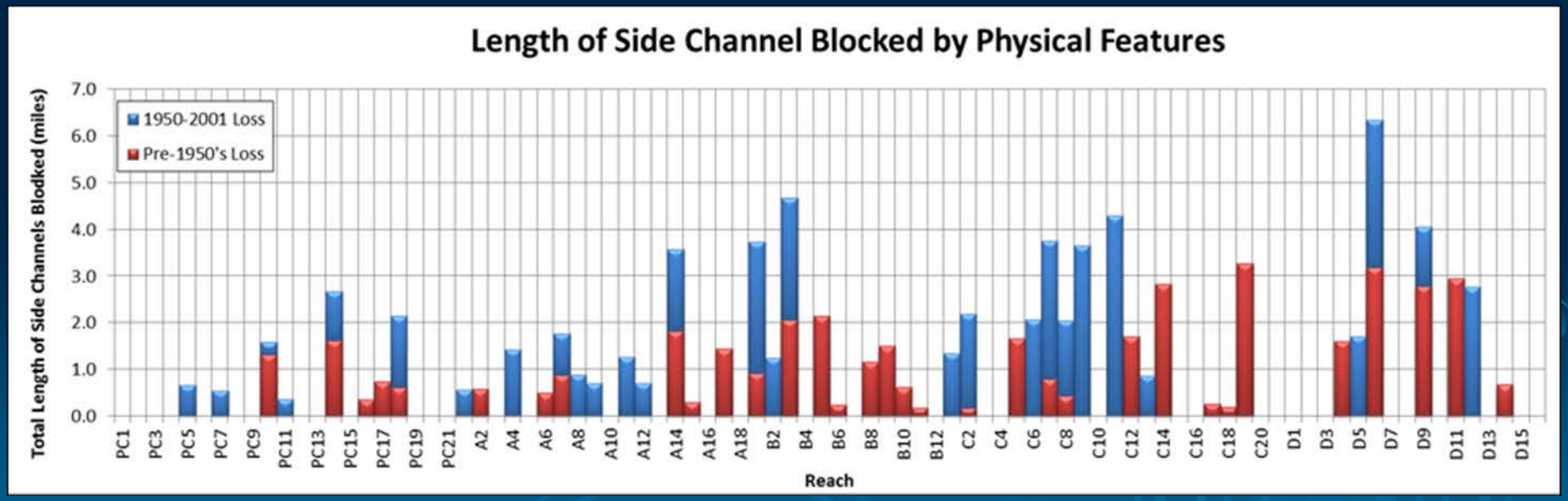


Yellowstone River: Physical Barriers



Yellowstone River: Physical Barriers

- ~97 Miles of Side Channel Blocked by Dikes



Yellowstone River: Floodplain Restoration Strategies

YRRP 1.2 - Floodplain Restoration
Active/Abandoned Railroads & Public Roads

Background

Transportation infrastructure (public roads and railroads combined) has a relatively small footprint on the 100-yr Yellowstone River floodplain (approximately 3%). Even so, transportation corridors in the Yellowstone River Valley have contributed to 37% of the total floodplain isolation.

The first railroad (Northern Pacific) entered the Yellowstone River Valley at Glendive in 1881. The Chicago, Milwaukee, & St. Paul Railroad, commonly referred to as the Milwaukee Railroad, entered the valley 27 years later. The original Northern Pacific grade (424 miles) that parallels the Yellowstone River is still in operation by Montana Rail Link (MRL) from Livingston to Huntley; and the Burlington Northern Santa Fe (BNSF) from Huntley to Fairview. There is an abandoned railroad grade between Livingston and Gardiner. The Milwaukee Railroad enters the valley west of Forsyth and exits west of Fallon (approximately 97 miles). It has been abandoned since 1980.

The active railroad grade (MRL and BNSF) intermittently crosses the historic Yellowstone River 100-yr floodplain for a total of 102 miles, isolating over 3,500 acres of floodplain. The abandoned railroad grade between Livingston and Gardiner has little effect because Highway 89 lies between the river and the old grade. The Milwaukee Railroad intersects the historic floodplain for a total of 25 miles leaving 2,300 acres of floodplain inaccessible to floods.

Public highways and county roads are more flexible in design and location so they are encroaching upon the river's floodplain less than the railroads. They are responsible for 2,050 acres of isolated floodplain. Most public roads in the floodplain are two-lane highways or county roads. The Interstate Highways 90 and 94, completed in the 1970s, make up nearly 415 miles of roadway in the Yellowstone River Valley although they have a relatively small effect on the floodplain because they are located primarily on the periphery of the river valley.

The abandoned Milwaukee Railroad grade crosses the historic floodplain west of Miles City. It is currently being used as an access road by the Fort Keogh Research Station.

Floodplain Restoration: Maintaining connectivity between tributaries, the historic floodplain and the river's active channel is critical. Values associated with a functional floodplain include:

1. *Water storage:* It is common for the floodplain to store at least 1 acre-foot of water per acre during a flood. Stored flood water will eventually return to the river augmenting summer and fall flows.
2. *Energy dissipation:* By dispersing high energy flows on the floodplain, flows are not as concentrated in the active channel; river bank erosion and channel scour are reduced and downstream flood damages lessened.
3. *Water quality:* Floodplain vegetation serves as a filtration system that removes excess sediment and nutrients from the water as it slowly crosses the floodplain.
4. *Riparian habitat:* Unique and important habitats are sustained for a wide variety of plants, insects, reptiles, amphibians, birds and mammals.

9

Seasonal, Managed Water Delivery to Isolated Floodplain Areas

- Water Storage
- Energy Dissipation
- Water Quality
- Riparian Habitat
- SAR

Yellowstone River: Side Channel Access Strategies

YRRP 1.3 - Side Channel Blockage Removal

Background

Numerous side-channels have been disconnected from the Yellowstone River's main channel over the last 120 years. The loss of these side channels is caused by physical blockages and the reduction in high flows. This YRRP focuses on side-channel blockage removal. Between Gardiner and the Missouri River confluence, 42 miles of side channels had been physically blocked on the mainstem Yellowstone River prior to 1950; another 48 miles were added between 1950 and 2001. This represents over 15% of the side channels along the Yellowstone River that have some form of blockage.

Functional, open side channels are one of the most important features on the Yellowstone River for maintaining healthy fish populations. The values associated with side-channels include:

1. *Habitat:* Side channels provide critical habitat and refuge for fish, amphibians, reptiles, birds, and other aquatic life on the Yellowstone River. During high flows, side channels tend to be shallower with slower velocities, warmer water temperatures, more habitat diversity, and higher productivity (fish recruitment and food sources) when compared to the main channel.
2. *Flood Relief:* Keeping side channels open to high flows helps disperse high energy flows. Allowing high water to access side channels lessens the concentrated flow in the main channel resulting in reduced bank erosion and channel scour, and less flood damage downstream.

Over the last century, side channels have been blocked for various reasons, often to provide access to lands along the river or to prevent high flows from damaging property on the adjacent floodplain.

Recommended Management Guidelines

This YRRP provides general guidelines for the removal or modification of physical blockages that would significantly benefit aquatic habitat and flood relief.

- **Total Blockage Removal:** Completely removing a side channel blockage to restore high water flow access is the best alternative when restoring side channel function and value. The pros and cons of implementing complete removal should be considered early on in the planning process.

- **Water Control Structures:** Where blockage removal presents too high a risk (flooding, river capture, bank destabilization), retrofitting or replacing the physical blockage with a water control structure (i.e. culvert, bridge, constructed overflow channel, etc.) to regulate high flow access and provide fish passage may be a viable option. This alternative would likely not provide full functionality to the side channel, but impacts to aquatic habitat may be reduced.

Seasonal, Managed Water Delivery to Blocked Side Channels

- Habitat
- Flood Relief
- SAR

Musselshell River: Physical Barriers

"In building the route [through the Musselshell River Valley], workers moved the river's channel more than 100 times".

"Approximately 140 meanders were shortened or cut off from the river".

Musselshell River

The 2011 floods breached the railroad berm in 31 places.

Musselshell River

The 2011 floods caused 59 avulsions that shortened the river by 28 miles

Musselshell River: Floodplain Connectivity Strategies

II. *Repairing Breached Berms/Dikes*

Many producers have plugged or reconstructed damaged berms to restore the function of the berm, be it road access, flood control, or irrigation management. With most low berms on agricultural fields, the hydrologic impact of these repairs is low. However, with larger berms, road crossings, or especially the railroad berm, repairs will re-isolate large floodplain areas. Whether or not the breaches are plugged should consider the overall need for the project, other breach locations and floodplain drainage patterns. Where berms overtopped from the landward side for example, flows were returning to the stream corridor over the berm because there was no better relief valve. In these areas especially, maintaining an overflow return point through the breach will reduce the risk of overbank flows becoming trapped on the floodplain and possibly damaging areas normally outside of the floodplain. These breaches can be reinforced as swales that still allow transportation access, and can be hardened as necessary to prevent erosion or headcutting.

Figure 8. View down-valley of multiple breaches; downstream breach serves as return flow point.

Figure 9. Railroad berm breach where flows overtopped from the backside of the berm.

III. Berm Removal

Levee setback and berm removal projects have become common around the country where levee systems have resulted in channel destabilization, habitat loss, high maintenance costs, and increased flood hazards within and downstream of the confined areas. In areas of dense floodplain development, levee removals or setbacks are extremely expensive, yet they are still being pursued because of the long-term net gain in restoring floodplain access. On the Musselshell River, the Milwaukee rail grade is an un-maintained, discontinuous floodplain berm that runs largely parallel to the river corridor upstream of Melstone. As the berm continues to naturally breach and decay, it will become an increasingly severe liability to corridor residents and agricultural producers. Relying on an unmaintained, locally breached berm as a de-facto flood protection measure is a poor

Strategic Breaching/Repair of Breached Berm

- Risk Reduction
- Floodplain Storage
- SAR

Musselshell River: Abandoned Channel Connectivity Strategies

Abandoned Channels (Avulsions)

Applicability

The following Best Management Practices ("BMPs") summarize several recommended approaches to managing abandoned channels within the Musselshell River stream corridor. The information is based upon the on-site evaluation of floodplain features and discussions with producers, and is intended for producers and residents who are living or farming in areas where abandoned channel segments exist.

Figure 1. 2011 avulsion, Musselshell River.

Description

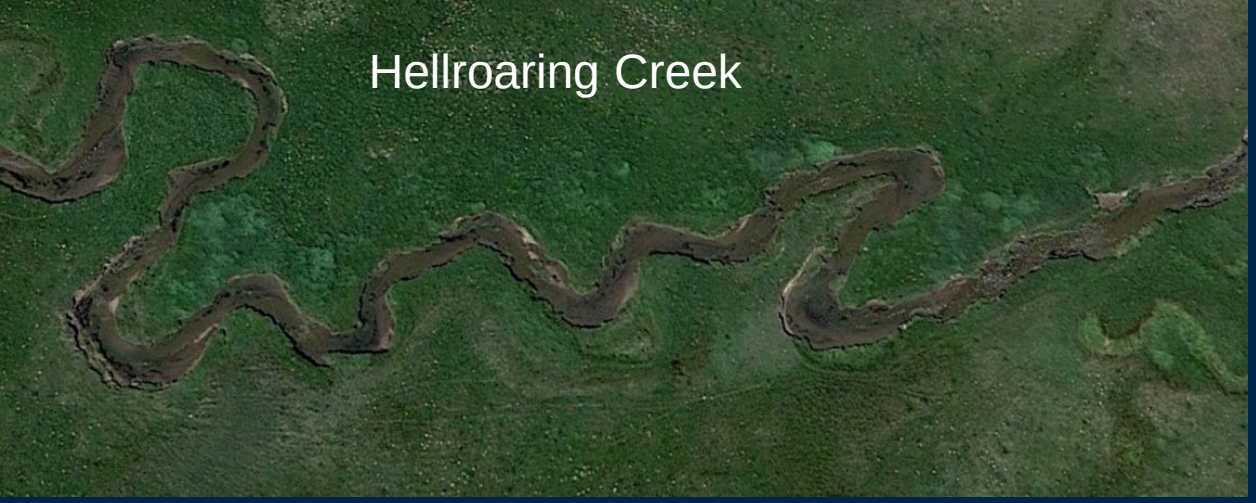
Perhaps the most dramatic 2011 flood impact on the Musselshell River was the number of avulsions that occurred over the period of a few weeks. An "avulsion" is the rapid formation of a new river channel across the floodplain that captures the flow of the main channel thread. River avulsions typically occur when rivers find a relatively steep, short flow path across their floodplain. When floodwaters re-enter the river over a steep bank, they form headcuts that migrate upvalley, creating a new channel, causing intense erosion, and sending a sediment slug downswtream. If the new channel completely develops, it can capture the main thread, resulting in a successful avulsion. If floodwaters recede before the new channel is completely formed, or if the floodplain is resistant to erosion, the avulsion may fail. From near Harlowton to Fort Peck Reservoir, 59 avulsions occurred on the Musselshell in the spring of 2011, abandoning a total of 39 miles of channel. The abandoned channel segments range in length from 280 feet to almost three miles. One of the reasons there were so many avulsions on the Musselshell River in 2011 is because the floodwaters stayed

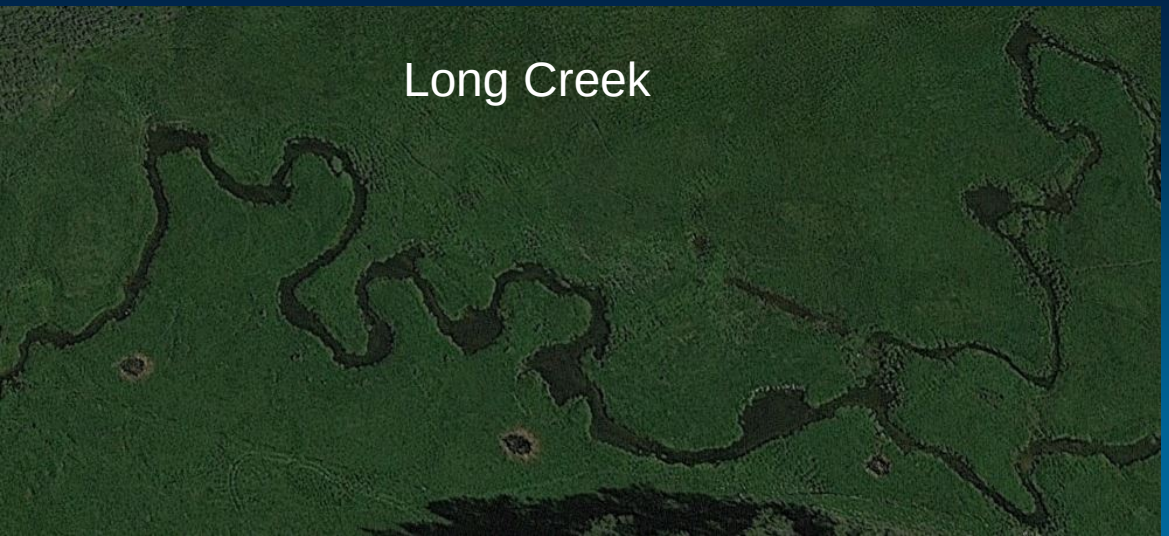
Figure 2. Upstream-migrating headcuts showing creation of avulsion path, 2011.

Maintenance of oxbows for infiltration

- Water Quality
- Water Quantity
- Flood Protections
- Habitat
- SAR

Ruby River: Flow Concentration and Incision





Channel Response to Shift from Multi-thread to Single Thread and Resulting Flow Concentration

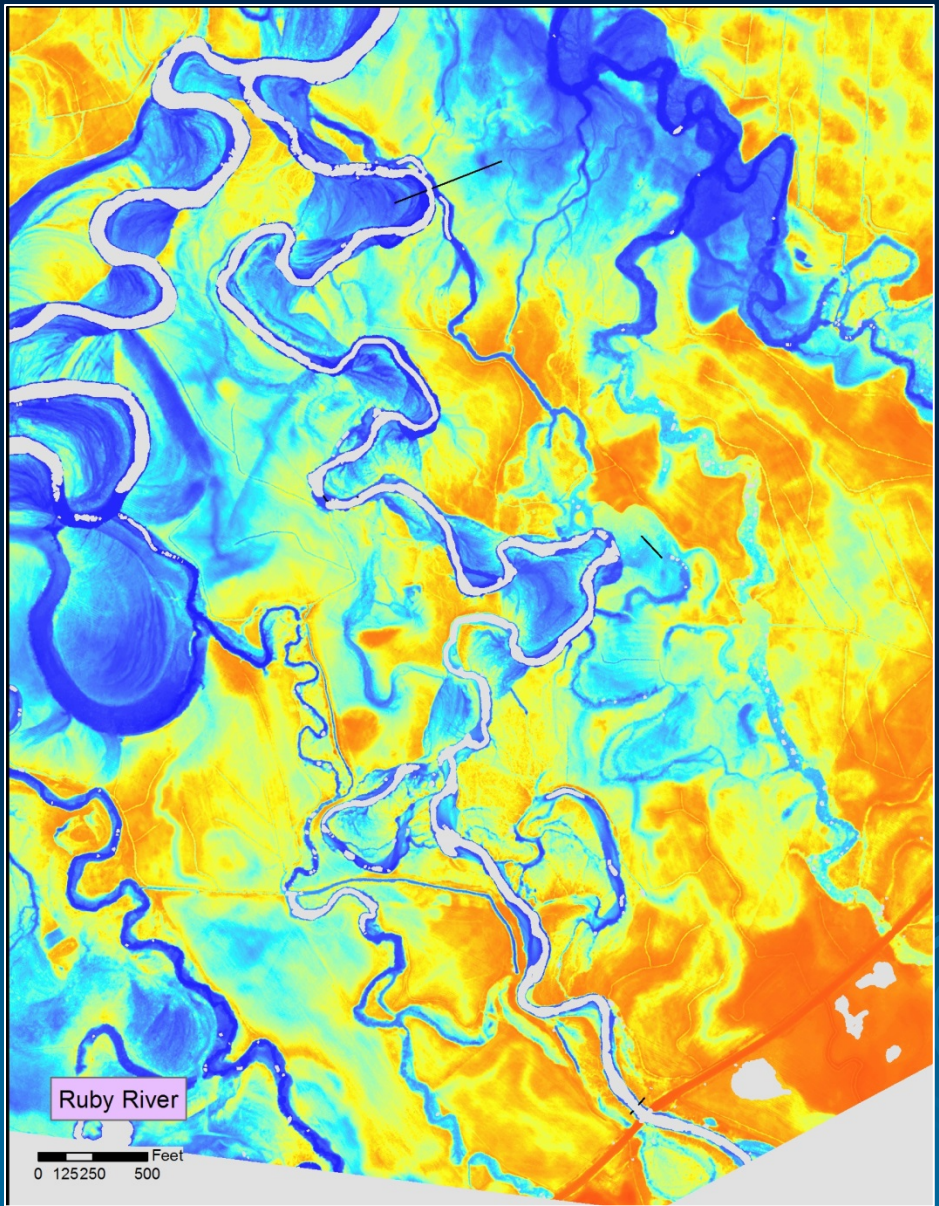
Increased Flow Drives Planform Adjustment and Reduction in Radius of Curvature

Ruby River: Flow Concentrations and Incision

Ruby River: Flow Concentrations and Incision

Ruby River: Flow Concentrations and Incision

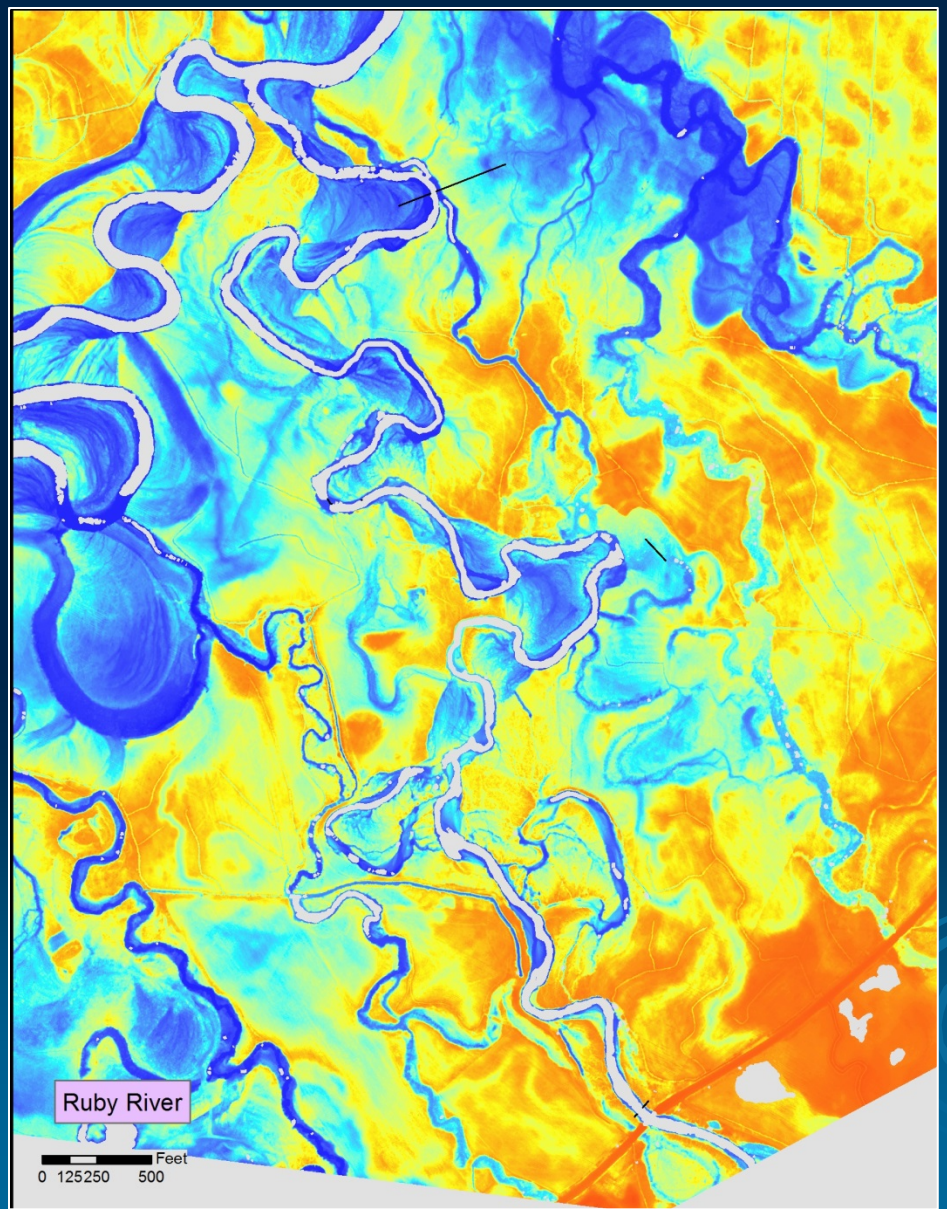
Restoration Strategy: Raise Grade to Access Historic Floodplain Channels



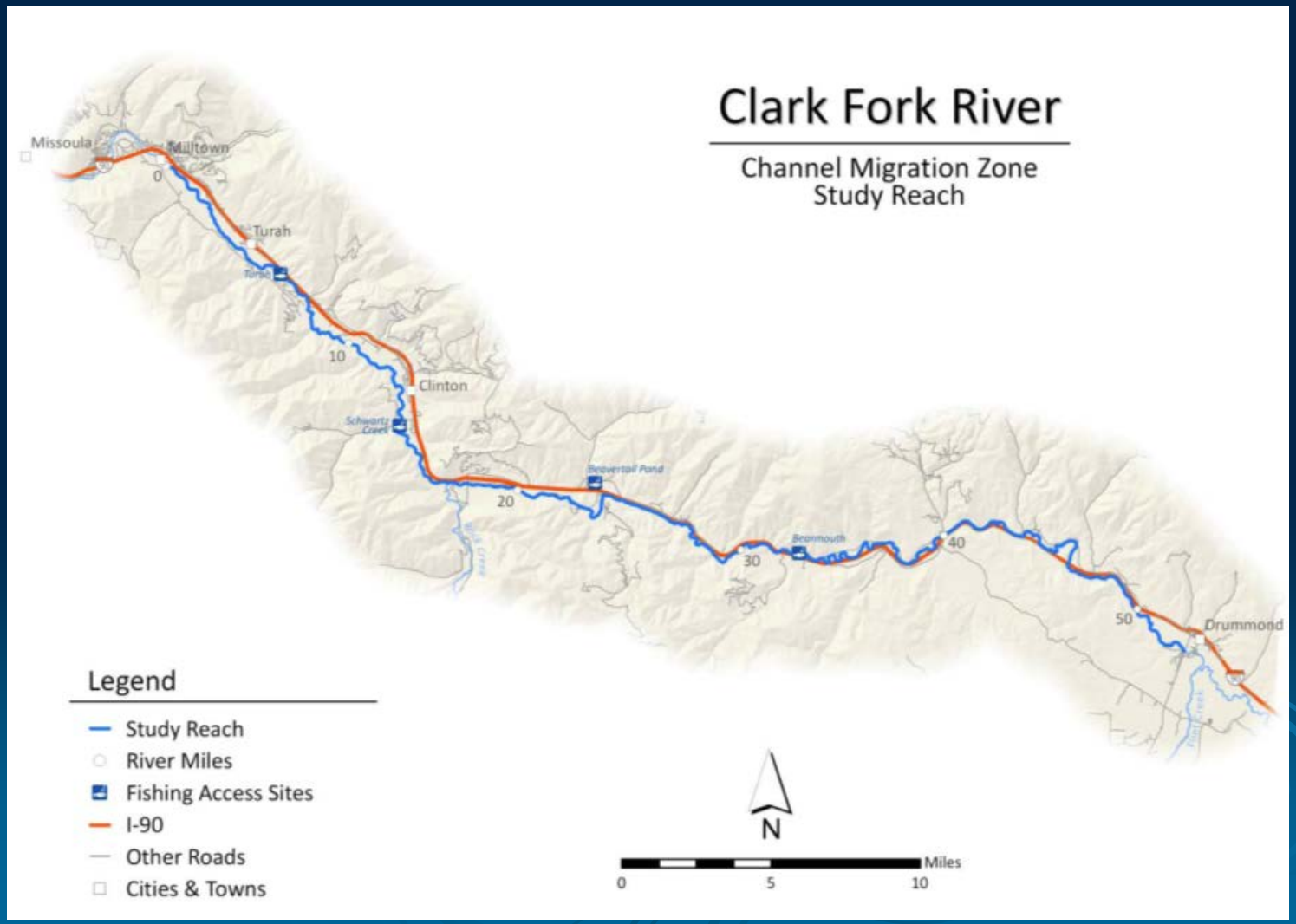
Ruby River: Flow Concentrations and Incision

Restoration Strategy: Raise Grade to Access Historic Floodplain Channels

- Habitat
- Channel Stability
- SAR

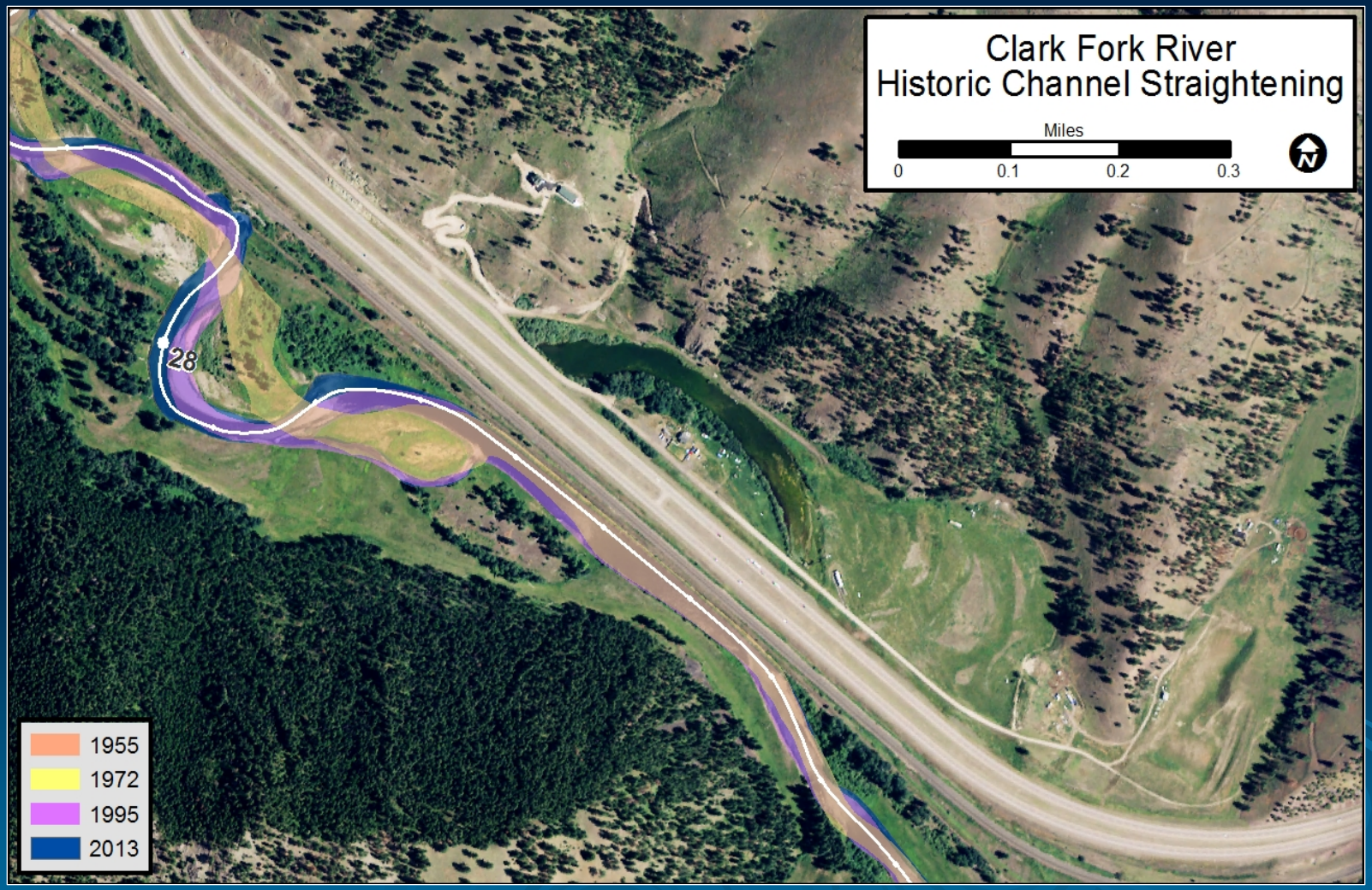


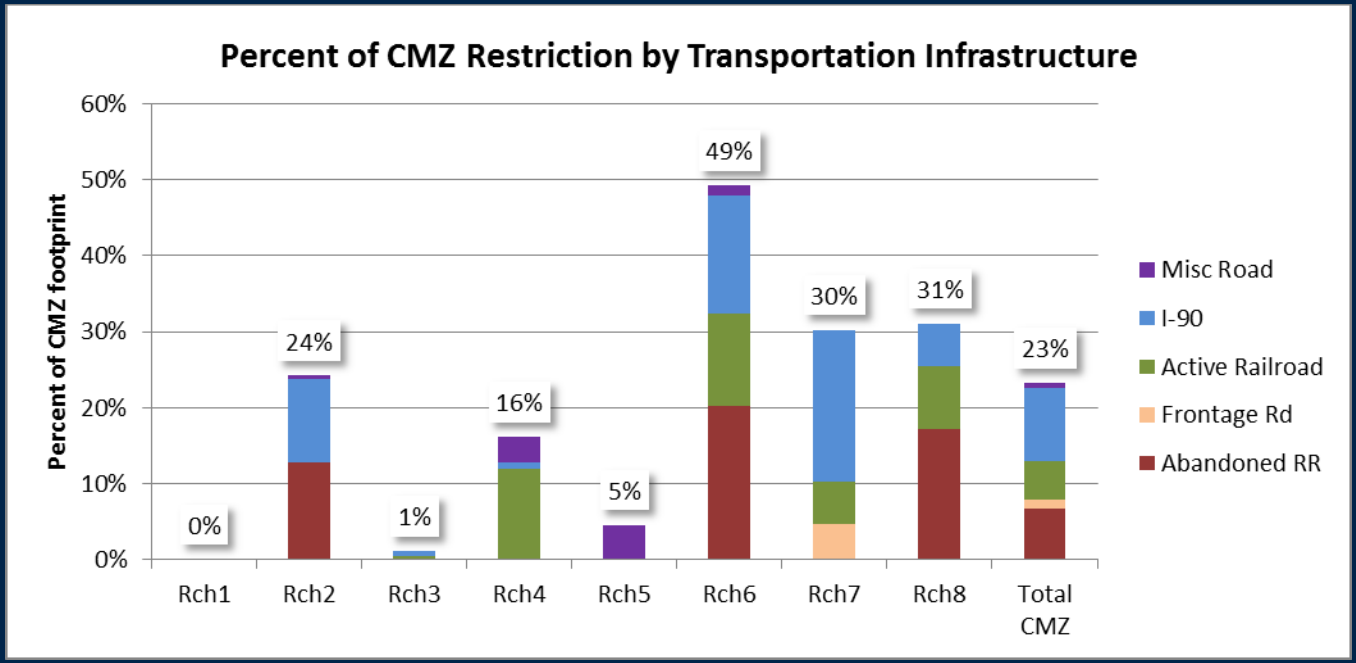
Clark Fork River: Drummond to Milltown

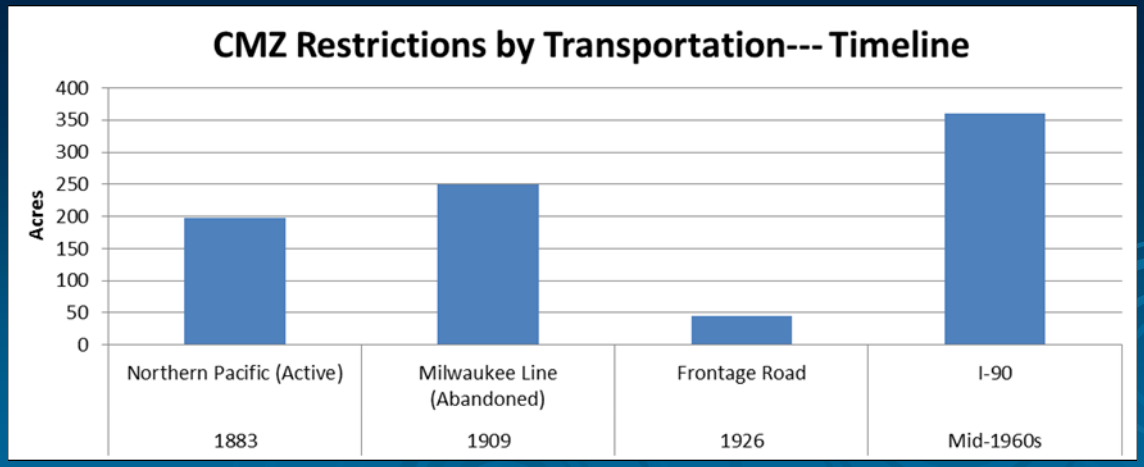


Clark Fork River: Drummond to Milltown

Clark Fork River: Drummond to Milltown


Clark Fork River
Historic Channel Straightening
Miles
0
0.1
0.2
0.3
N
28
1955
1972
1995
2013


Percent of CMZ Restriction by Transportation Infrastructure
Percent of CMZ footprint
60%
50%
40%
30%
20%
10%
0%
0%
24%
1%
16%
5%
49%
30%
31%
23%
Rch1
Rch2
Rch3
Rch4
Rch5
Rch6
Rch7
Rch8
Total CMZ
Misc Road
I-90
Active Railroad
Frontage Rd
Abandoned RR


CMZ Restrictions by Transportation--- Timeline
Acres
400
350
300
250
200
150
100
50
0
Northern Pacific (Active)
1883
Milwaukee Line (Abandoned)
1909
Frontage Road
1926
I-90
Mid-1960s

Clark Fork River: Drummond to Milltown

Restoration Strategy:

Restore Floodplain Access Wherever Possible for Channel Migration and Floodwater Storage

- Habitat
- Channel Stability
- SAR

Clark Fork River: Deer Lodge Valley

Before

After

Restoration Strategy:

Restore Floodplain Access Wherever Possible for System Recovery

- Riparian Recovery
- Reduced Tailings Entrainment
- Channel Stability
- SAR

May 26 2014

Summary

1. Restoring hydrologic connectivity is a fundamental aspect of many restoration projects

2. Benefits include:
   - Riparian Health
   - Water Quality
   - Flood Mitigation
   - Habitat
   - Risk Reduction
   - Shallow Aquifer Recharge (SAR)

“Within the last decade, different types of process-based restoration have increased in prominence, in concert with numerous calls from researchers to prioritize river function or process in restoration, rather than only river form. This has included restoration that has emphasized promoting channel-floodplain connectivity longitudinal connectivity and partial restoration of water and sediment fluxes.

As a broad generalization, our survey of river restoration suggests that reconnection efforts are more likely to be successful than reconfiguration efforts.

Wohl, Lane, and Wilcox, 2014. The Science and Practice of River Restoration: AGU Water Resources Research, 51: 5974-5997.

SAR projects release water on or near the surface above the local water table. Recharge is done, typically on a seasonal basis, by diverting surface water into infiltration sites. Sites can be natural or man-made features such as fields, gravel pits, ponds, canals, ditches and shallow wells.

--Washington Department of Ecology