MILLTOWN RESTORATION

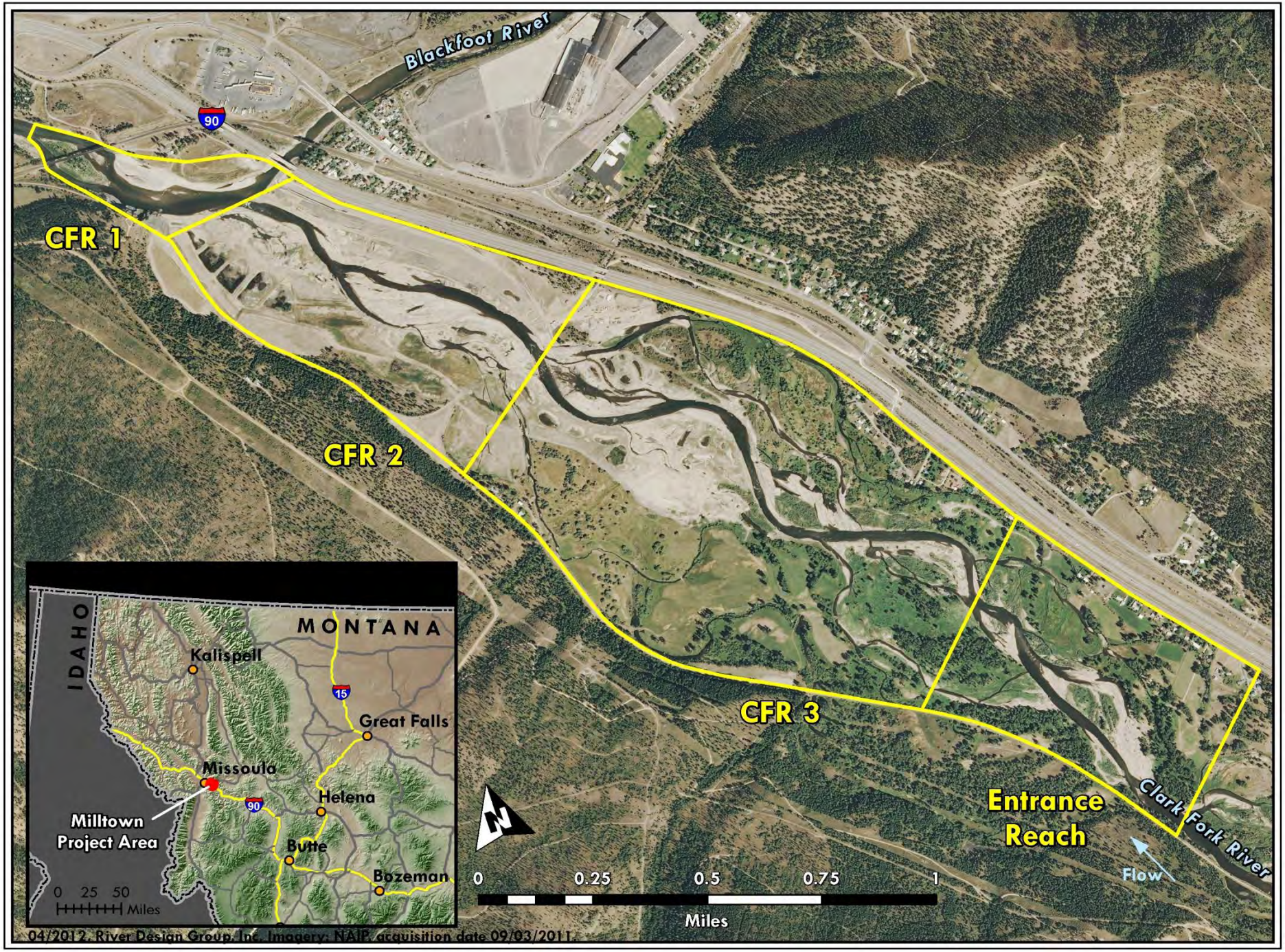
Lessons Learned

Symposium on Riparian Restoration
in a Contaminated Environment
April 2012

Montana Department of Justice
Natural Resource Damage Program

Presentation Overview

- Summarize the project history
- Describe the 2010 and 2011 floods
- Review project performance
- Discuss lessons learned
- Reflect on initial project uncertainty
- Identify next steps and future expectations



04/2012, River Design Group, Inc. Imagery: NAIP, acquisition date 09/03/2011.

History of Impacts

Beaver trapping

Milltown Dam

1908 flood of record

Reservoir filled

Infrastructure

Floodplain alteration

Ice jams and fish kills

1800s

1900s

1950s

1980s

Mining

Logging

Railroads and agriculture

Contaminated aquifer


REMOVE THE DAM.
RESTORE THE RIVER.
Help clean up Milltown Reservoir.
www.clarkfork.org


REMOVE
THE DAM.
Help clean up Milltown Reservoir.
RESTORE
THE RIVER.
www.clarkfork.org


REMOVE
MISSOULA.
RESTORE
THE VALLEY.
Help clean up Montana.

Project Goals

- Goal 1 - maintain water quality.
- Goal 2 - restore a naturally functioning system that is appropriate for the geomorphic setting and site constraints.
- Goal 3 – provide preferred habitat for native fish and wildlife.
- Goal 4 – establish floodplain conditions that will allow the development of wetlands and diverse native plant communities.
- Goal 5 – provide visual and aesthetic values consistent with restoring the natural condition.
- Goal 6 – provide safe recreational opportunities compatible with the other goals and objectives.

Integrated Remediation & Restoration

EPA Record of Decision

Settlement Agreement

Bypass channel

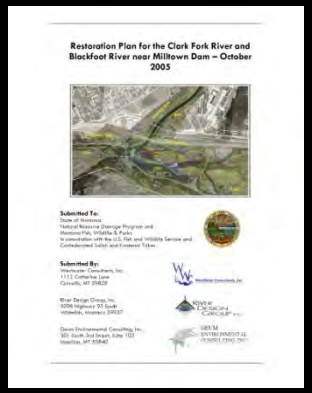
2007-2009: Sediment removal
2.2M cubic yards

March 2008: dam removal

Repositories & reclamation

2005 2006 2007 2008 2009 2010 2011

Restoration Plan



Peer review

2005-2007:
Data collection and feasibility analysis

2008-2011:
Design and bid documents

2008-2012 Implementation

Grading Plan

Restoration Plan for the Clark Fork River and Blackfoot River near Milltown Dam

Features

- Main Channel
- Secondary Channel
- Point Bar
- Wetland
- Bankfull Floodplain (bankfull elevation to 2 ft. above bankfull)
- Low Terrace (2 to 3 ft. above bankfull)
- High Terrace (greater than 3 ft. above bankfull*)
- Existing Floodplain Surface (to remain undisturbed)
- Deer Creek Tributary (pending final design)
- Existing Spring
- Existing Secondary Channel

*Final elevation to be determined based on final cut/fill quantities.

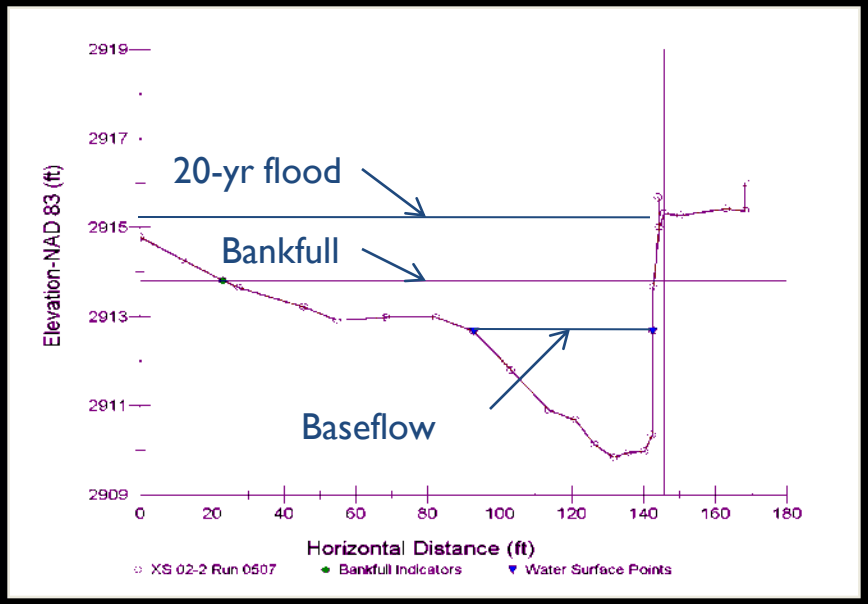
Multi-stage Hydraulic Geometry

Geomorphic features tied to river stage

Baseflow channel ~ 1/3 of bankfull channel for fish passage

Active channel contains bankfull discharge

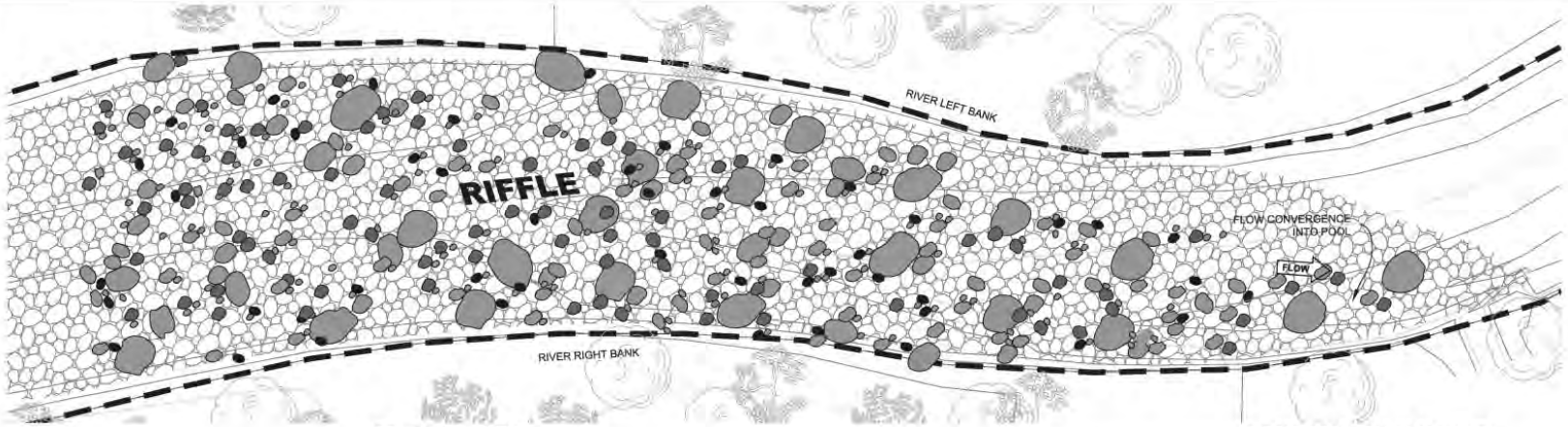
Low terraces contain 10-20 year flood



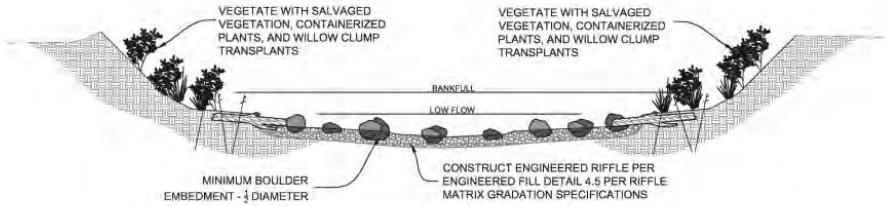
Riverbed Reconstruction

- Engineered riffles
- Grade controls
- Maintain floodplain connection

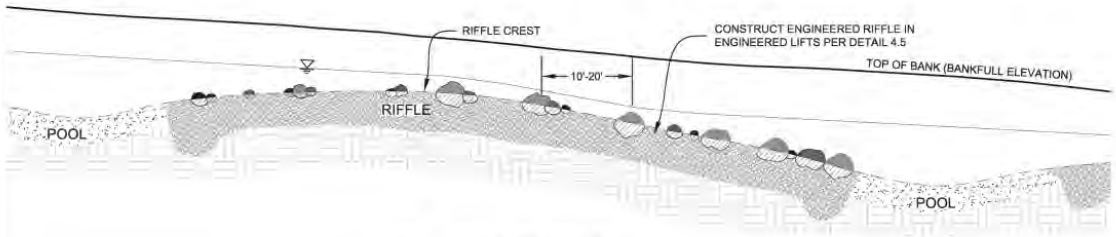
Example Construction Drawing



1 **PLAN VIEW** NOT TO SCALE



2 **RIFFLE SECTION** NOT TO SCALE



3 **RIFFLE PROFILE** NOT TO SCALE

CONSTRUCTION NOTES

BOULDER PLACEMENT BEGINS NEAR THE DOWNSTREAM END OF THE POOL TO PROVIDE LARGE SCALE ROUGHNESS DURING HIGH FLOW AND HYDRAULIC VARIABILITY UNDER LOW FLOW CONDITIONS. HYDRAULIC EFFECT INCLUDES SPAWNING MATERIAL RETENTION AND DEPOSITION. BOULDERS PLACED ALONG THE RIFFLE PROVIDE DISRUPTION OF AVERAGE VELOCITY GRADIENTS AND SERVE A GRADE CONTROL FUNCTION FOR THE OVERALL GEOMORPHIC UNIT. PARTICULAR CARE SHOULD BE EMPLOYED WITH ELEMENT PLACEMENT TO REINFORCE THE RIFFLE - POOL TRANSITIONAL SLIP FACE.

BOULDERS SHOULD BE PLACED IN RANDOM PATTERNS THAT REPLICATE NATURAL STREAM CONDITIONS AS DIRECTED BY THE PROJECT INSPECTOR.

SEE GRADATION SCHEDULES ON THIS SHEET FOR CONSTRUCTED RIFFLE MATRIX GRADATION AND HABITAT BOULDER REQUIREMENTS. SUFFICIENT FINES (SAND FRACTION OR FINER) SHALL BE DEVELOPED FROM ON-SITE EXCAVATIONS AND WASHED INTO THE PLACED RIFFLE MATRIX BOULDER FEATURE.

ENGINEERED RIFFLE TO BE CONSTRUCTED IN 6 TO 12 INCH VERTICAL LIFTS WITH FINES ADDED AND WASHED. SUCCESSFUL WASHING WILL BE DETERMINED BY MINIMIZATION OF VOIDS WITHIN PLACED MATRIX SUCH THAT PONDING OCCURS ON TOP OF LIFT WITH LITTLE TO NO PERCOLATION LOSSES OCCURRING THROUGH THE ENGINEERED RIFFLE.

TO REDUCE UPSTREAM AND DOWNSTREAM RIFFLE SCOUR, EXCAVATE A TRENCH 10 FEET LONG AND 2 TIMES THE MATRIX THICKNESS DEEP AND FILL WITH BOULDERS AND RIFFLE MATRIX MATERIAL.

ENGINEERED RIFFLE SCHEDULE

BOULDER ELEMENT SIZE (FT.)	ER #1 L=350'	ER #2 L=300'	ER #3 L=250'
2.5'	55	30	25
3.0'	55	30	25
3.5'	35	45	40
4.0'	35	45	40

ENGINEERED RIFFLE MATRIX GRADATION

PERCENT PASSING	LOWER LIMIT (INCHES)	UPPER LIMIT (INCHES)
100	17.0	22.5
85	14.5	20.0
50	11.0	17.0
30	6.5	10.5
15	3.5	5.5

MATRIX THICKNESS (T) = 24 INCHES

RIVER DESIGN GROUP INC
5098 Hwy 93 South
Whitefish, MT 59937
406.862.4927
311 SW Jefferson Avenue
Corvallis, OR 97333
541.738.2920

ENGINEERED RIFFLE

NO.	DATE	BY	DESCRIPTION	CHK
0	11/12/10	RB	ISSUED FOR PERMIT	TB

PROJECT NUMBER RDG-10-013

DRAWING NUMBER 4.3

Drawing 17 of 24

Large Wood Structures

LWD Function

- Bank protection
- Emulate naturally occurring stable accumulations of wood debris
- Flow steering
- Pool development
- Energy dissipation

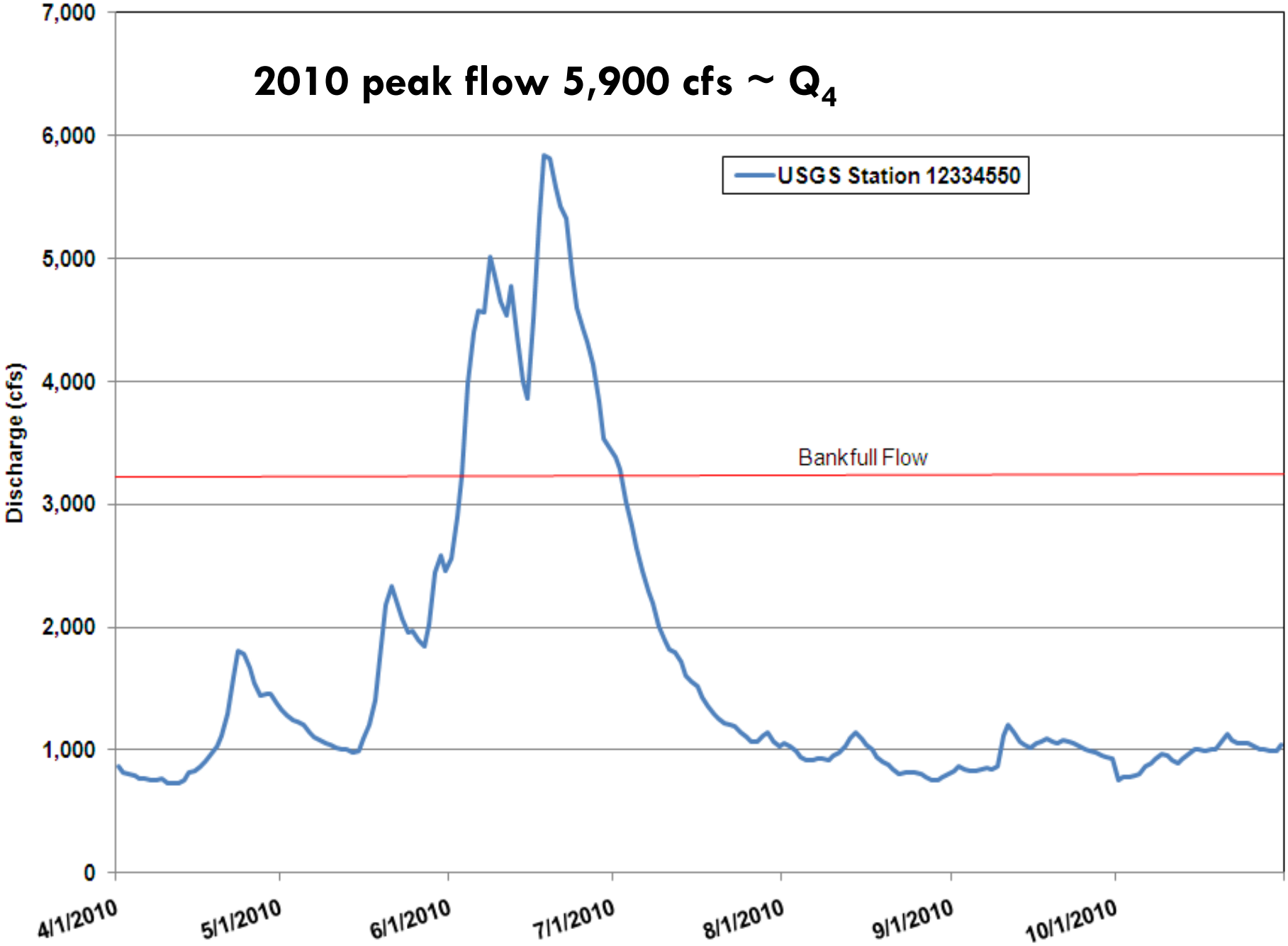
Bioengineering Bank Construction

Vegetated Soil Lift Function

- Revegetation technique
- Short term bank protection
- Reduce erosion
- Promote vegetation
- Adds habitat

Microtopography Grading

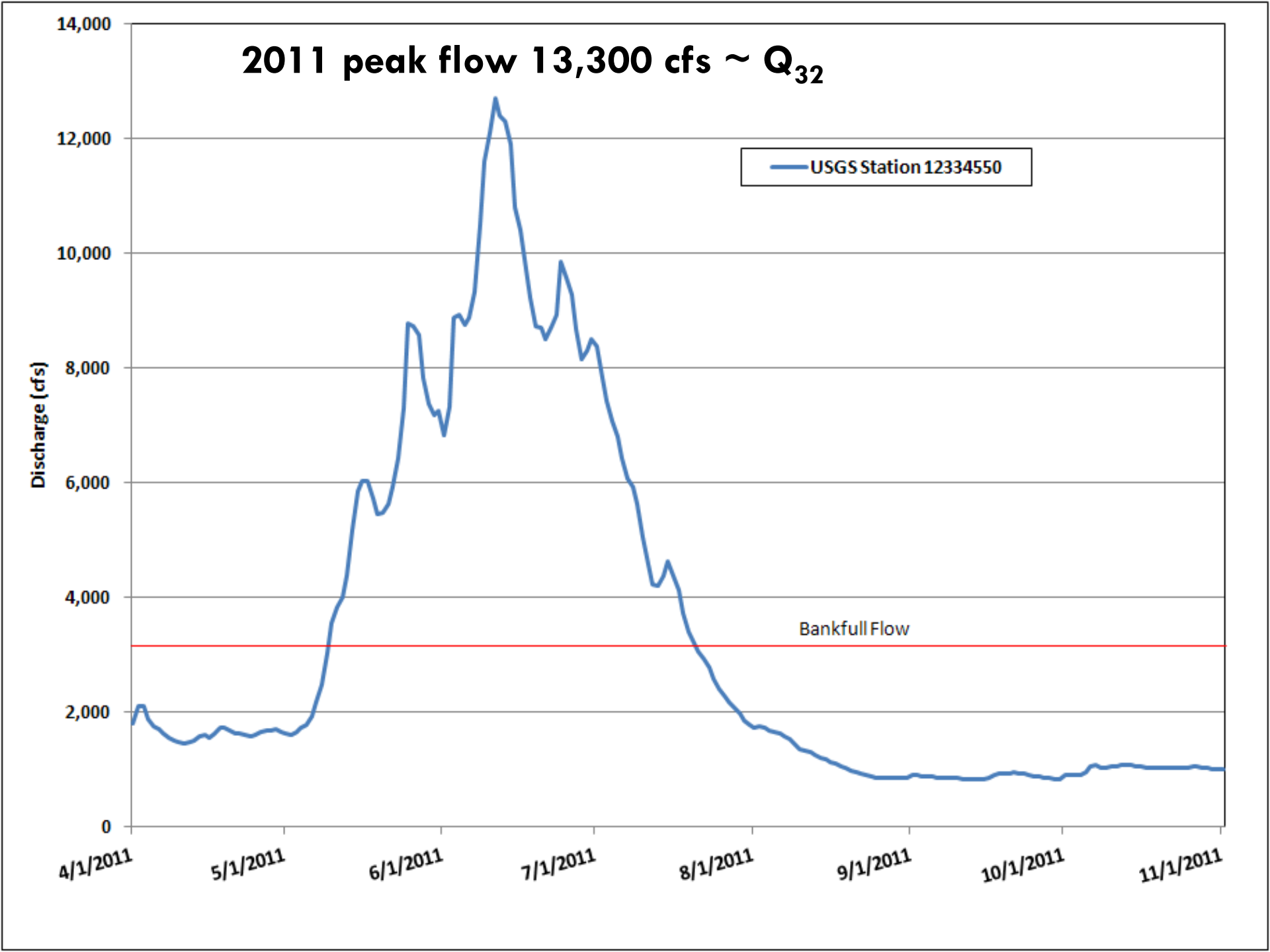
- Roughness
- Large organic debris
- Sediment trapping
- Seed recruitment
- Flood attenuation


2010 peak flow 5,900 cfs ~ Q_4
USGS Station 12334550
Bankfull Flow
Discharge (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
4/1/2010
5/1/2010
6/1/2010
7/1/2010
8/1/2010
9/1/2010
10/1/2010


2009 Construction


2010 Runoff ~ 3,200 cfs Bankfull


2010 Runoff ~ 6,000 cfs


2011 peak flow 13,300 cfs ~ Q32
USGS Station 12334550
Bankfull Flow
Discharge (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
4/1/2011
5/1/2011
6/1/2011
7/1/2011
8/1/2011
9/1/2011
10/1/2011
11/1/2011


April 2011
Photo: Gary Matson


May 2011
Photo: Gary Matson

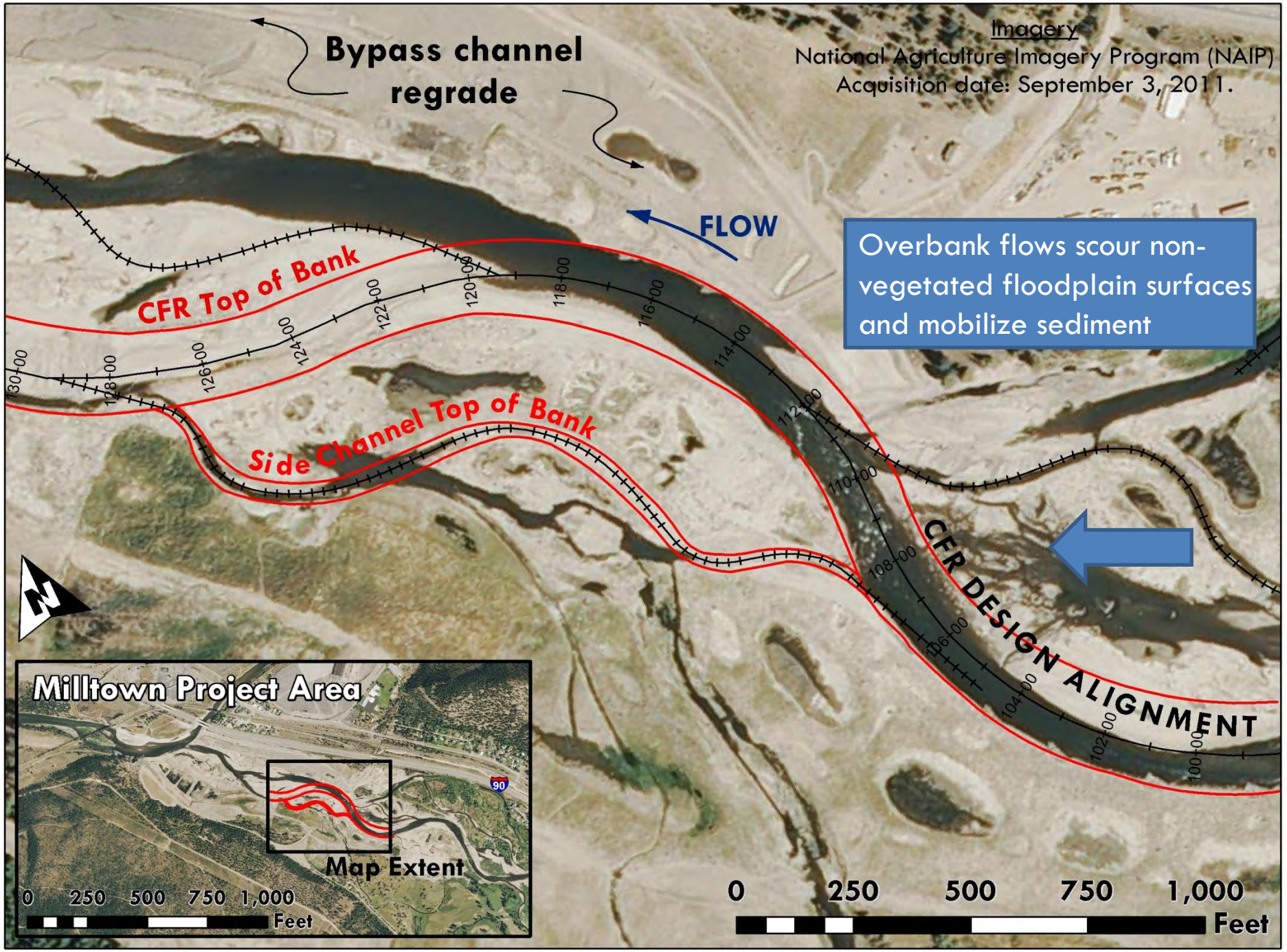

June 2011
Photo: Gary Matson

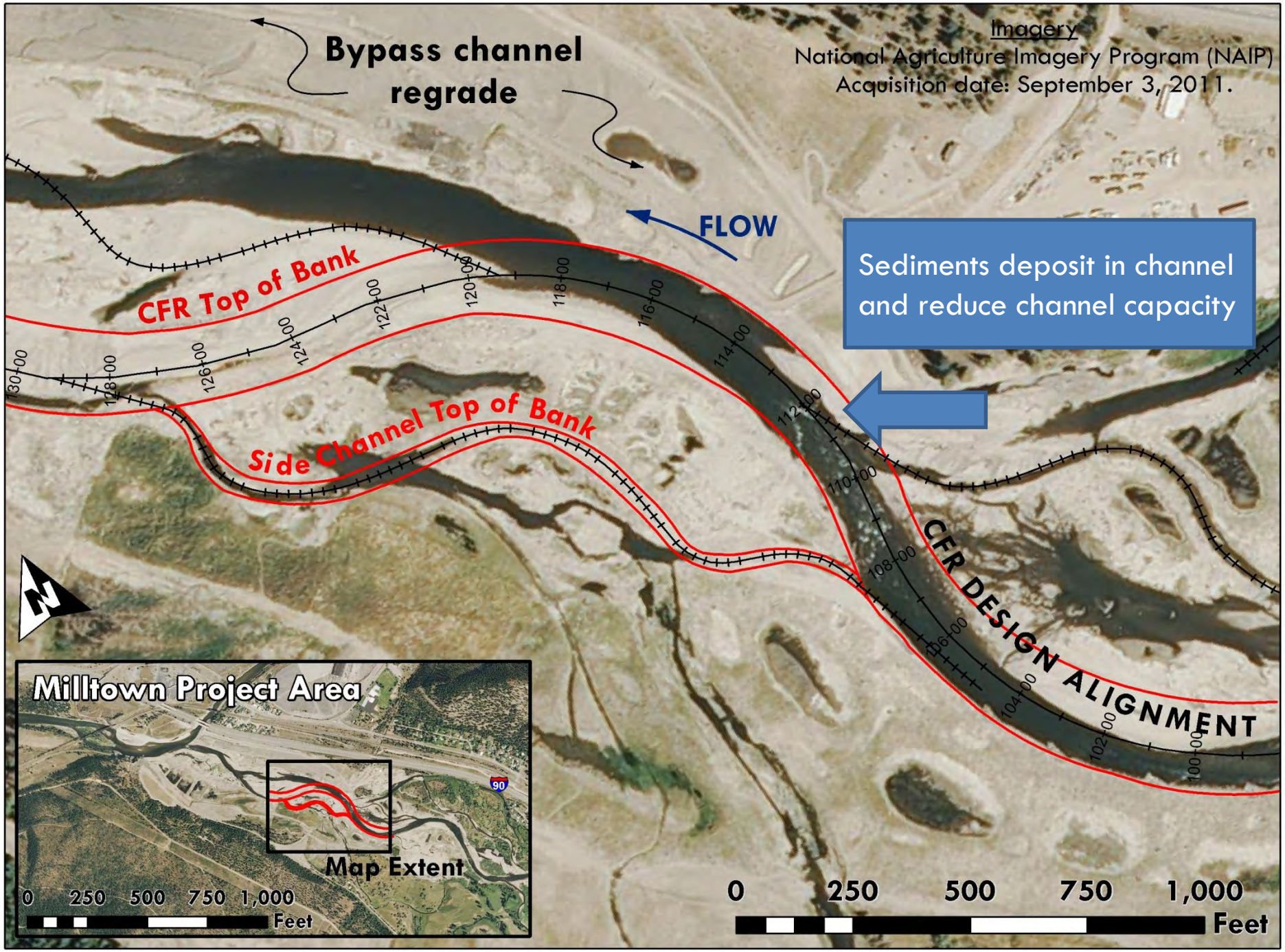
Peak flow 2011

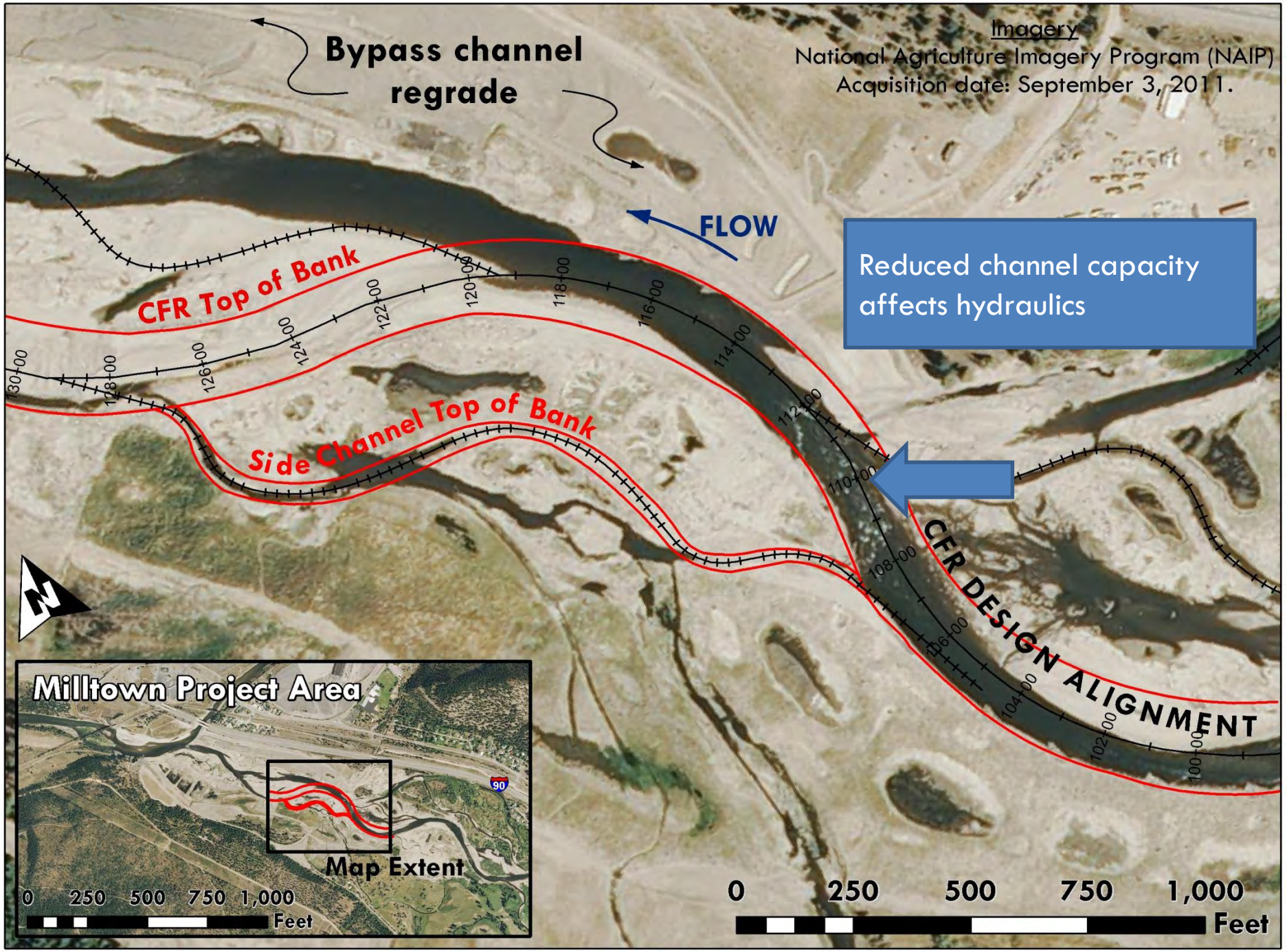
Photo: Gary Matson

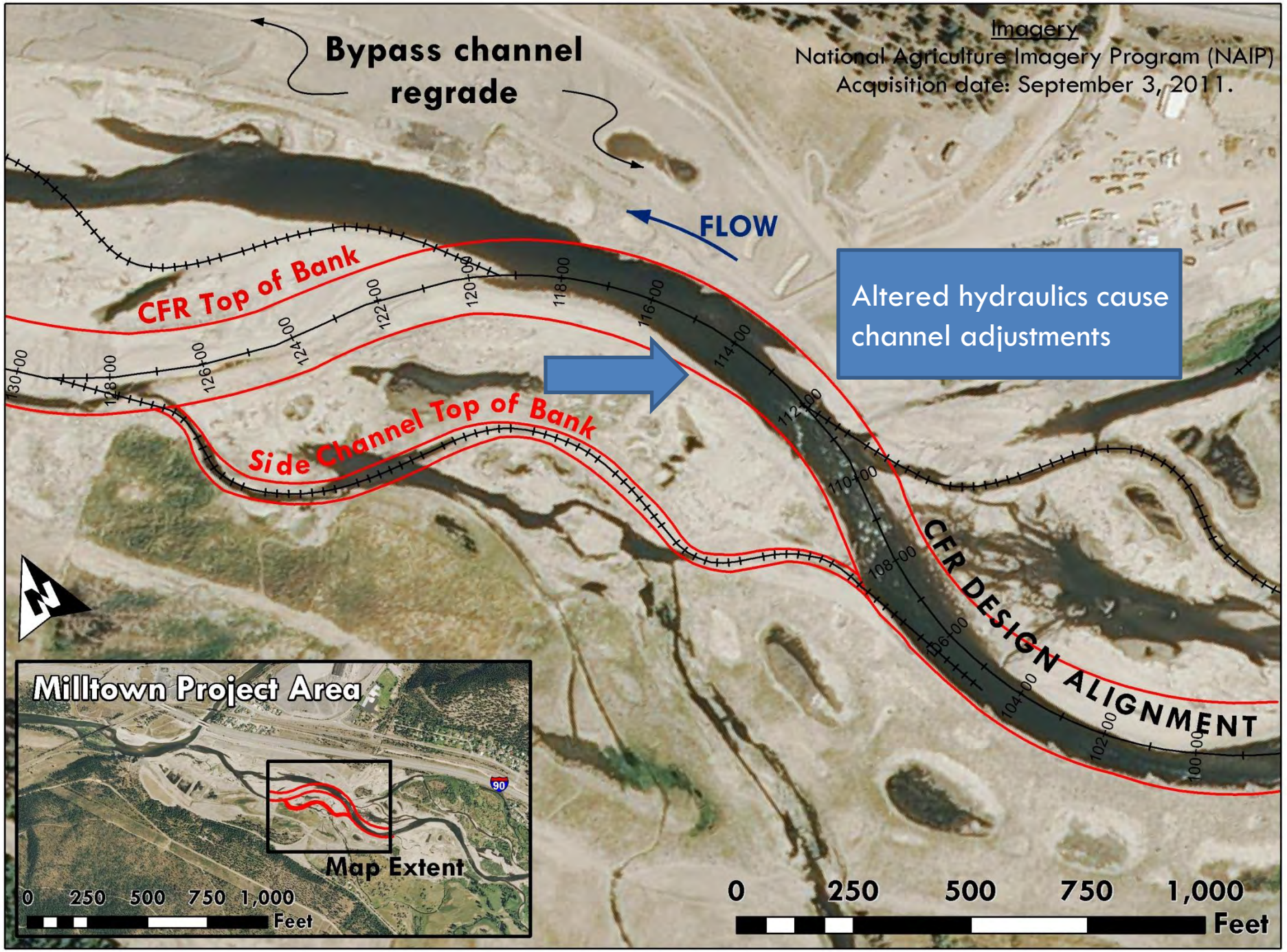

August 2011
Photo: Gary Matson

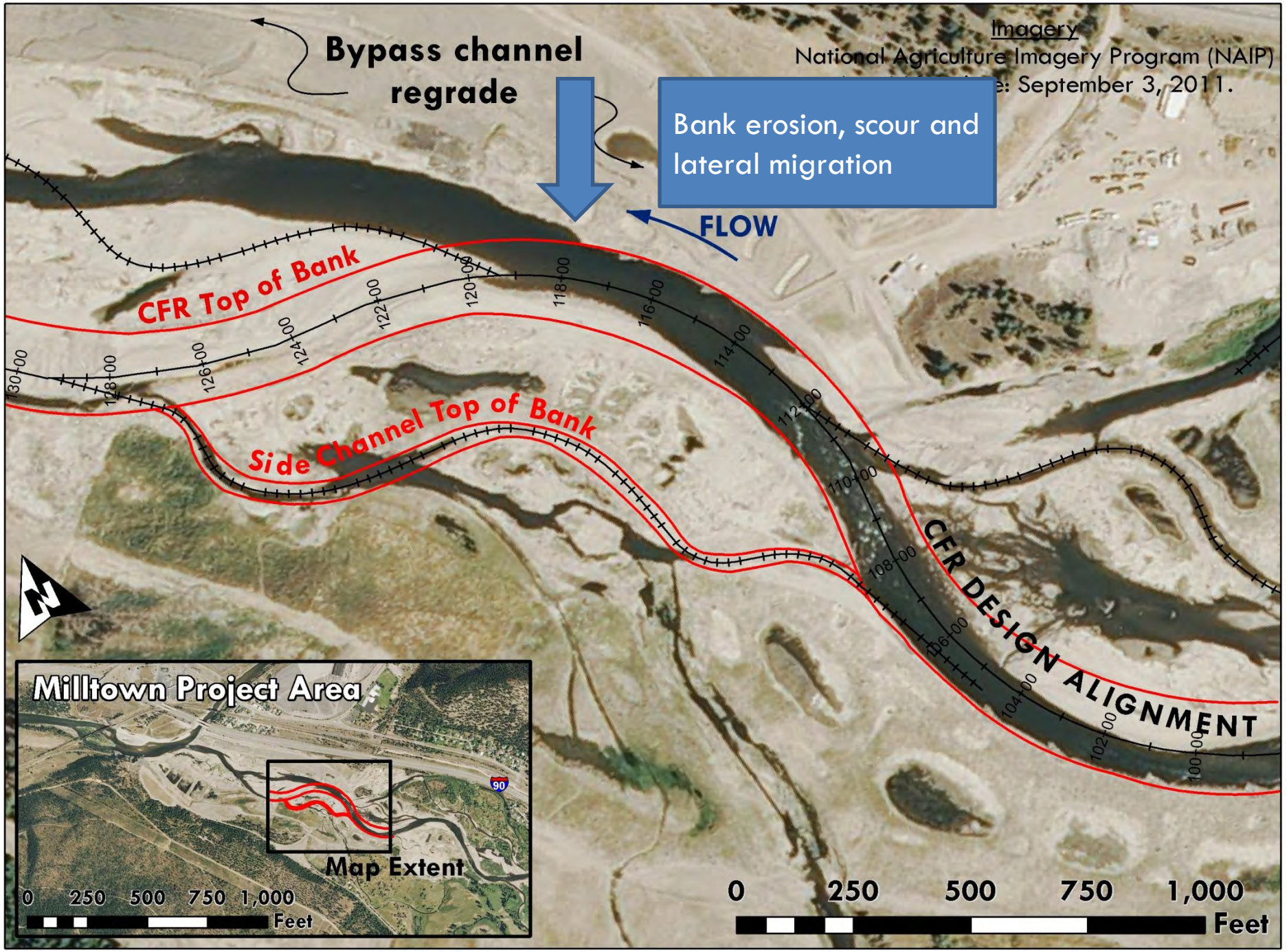

November 2011
Photo: Gary Matson

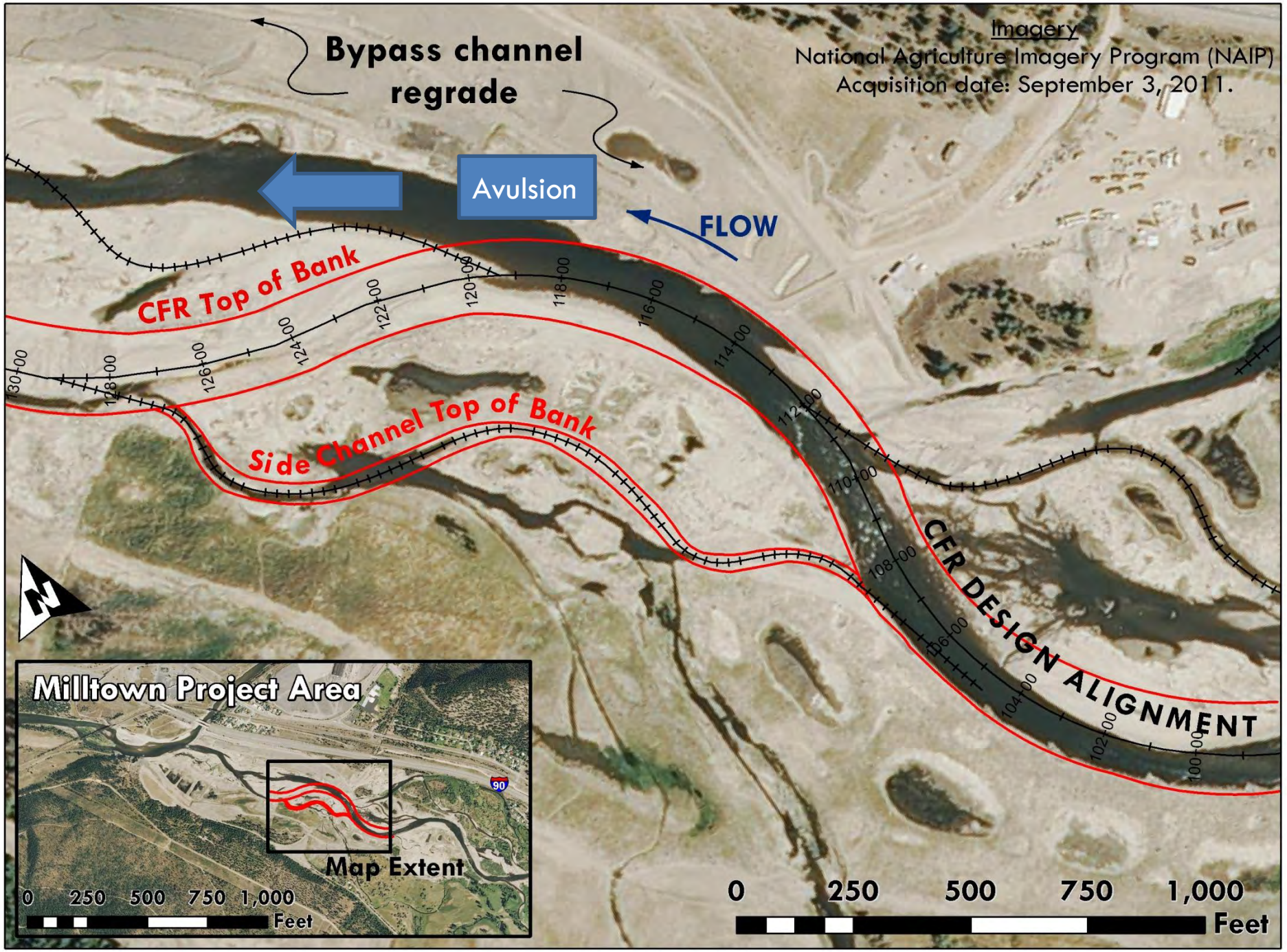

Bypass channel regrade
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.
FLOW
Overbank flows scour non-vegetated floodplain surfaces and mobilize sediment
CFR Top of Bank
Side Channel Top of Bank
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
90
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet

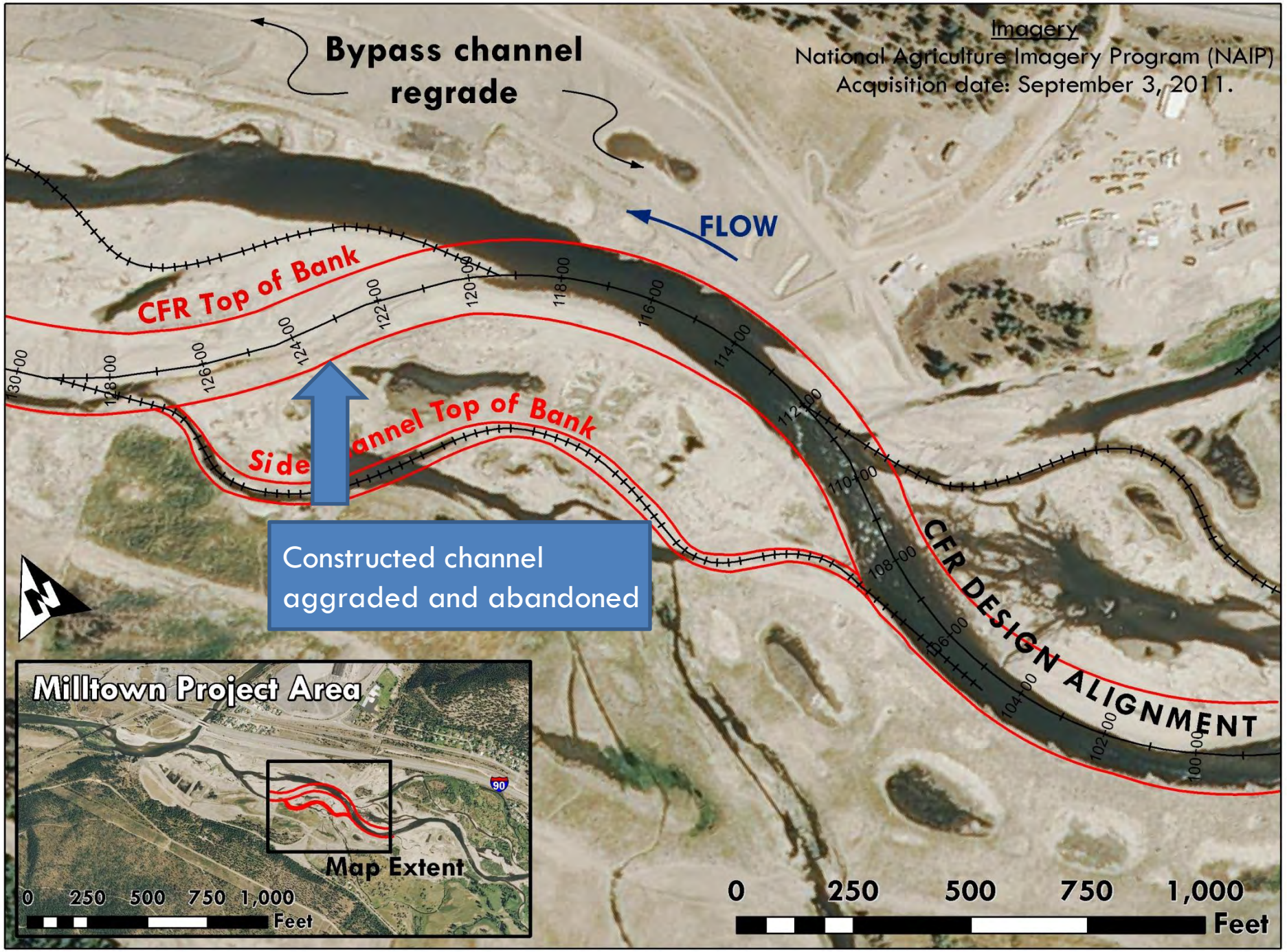

Bypass channel regrade
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.
FLOW
Sediments deposit in channel and reduce channel capacity
CFR Top of Bank
Side Channel Top of Bank
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
90
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet


Bypass channel regrade
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.
FLOW
CFR Top of Bank
Side Channel Top of Bank
Reduced channel capacity affects hydraulics
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
90
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet


Bypass channel regrade
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.
FLOW
CFR Top of Bank
Side Channel Top of Bank
Altered hydraulics cause channel adjustments
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
90
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet


Bypass channel regrade
Bank erosion, scour and lateral migration
FLOW
Imagery
National Agriculture Imagery Program (NAIP)
e: September 3, 2011.
CFR Top of Bank
Side Channel Top of Bank
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
90
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet


Bypass channel regrade
Avulsion
FLOW
CFR Top of Bank
Side Channel Top of Bank
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.


Bypass channel regrade
Imagery
National Agriculture Imagery Program (NAIP)
Acquisition date: September 3, 2011.
FLOW
CFR Top of Bank
Side Channel Top of Bank
Constructed channel aggraded and abandoned
CFR DESIGN ALIGNMENT
130+00
128+00
126+00
124+00
122+00
120+00
118+00
116+00
114+00
112+00
110+00
108+00
106+00
104+00
102+00
100+00
N
Milltown Project Area
Map Extent
0 250 500 750 1,000
Feet
0 250 500 750 1,000
Feet

Maintenance Evaluation Process

A. Document visual inspections of changes and identify potential maintenance sites.

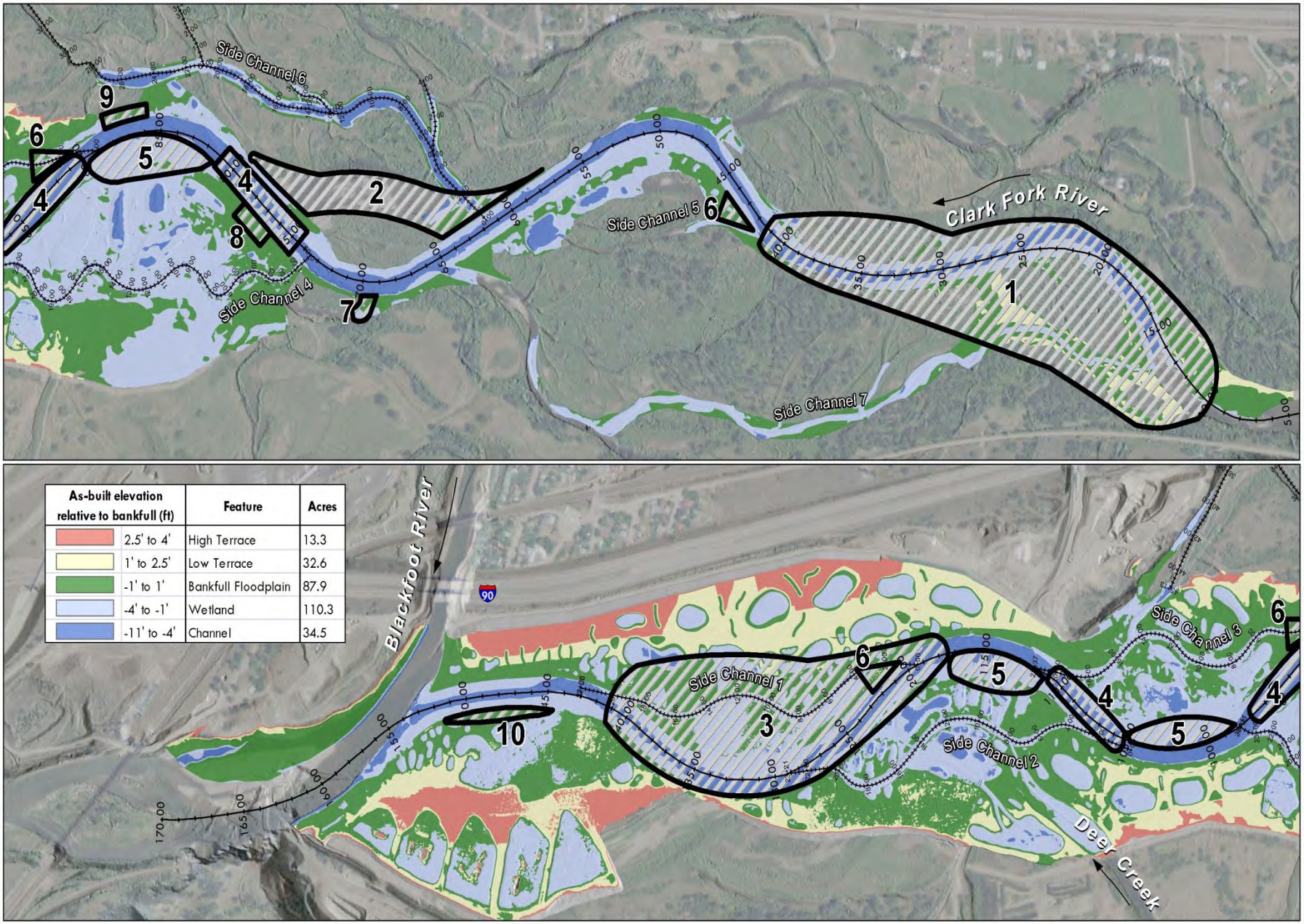
B. Hypothesize causes of changes, trends and risk in the context of project objectives.

C. Confirm/reject hypotheses with data and analyses, if needed.

D. Assign risk to potential maintenance sites based on judgment and/or performance criteria.

E. Solicit input from peer reviewers for critical uncertainties.

F. Identify maintenance alternatives and priorities.



As-built elevation relative to bankfull (ft)	Feature	Acres
2.5' to 4'	High Terrace	13.3
1' to 2.5'	Low Terrace	32.6
-1' to 1'	Bankfull Floodplain	87.9
-4' to -1'	Wetland	110.3
-11' to -4'	Channel	34.5

MILLTOWN RESTORATION

MAINTENANCE SITES

Maintenance Site

0 500 1,000 1,500 2,000 Feet

August 2011. S.Ammondt, River Design Group, Inc. Imagery: NAIP 2009 (precedes construction).

Montana Department of Justice
Natural Resource Damage Program

Initial Uncertainty & Peer Review

- Elevation of pre-dam floodplain
- Alluvium characteristics of pre-dam floodplain
- Performance of floodplain transitions
- Performance of side channels
- Stability of Entrance Reach and upstream reach
- Sediment transport characteristics
- Confluence hydraulics
- Overall project performance??

Performance Criteria

- Goal 2 - restore a naturally functioning system that is appropriate for the geomorphic setting and site constraints.
- Objective – reconstruct a meandering channel and broad floodplain that gradually transitions to an confined channel with a narrow, sloping floodplain.
- Performance Criteria – range of natural variability; +/-20% of design metrics.
- Design Criteria – morphology is similar to reference conditions.
- Metrics – channel and floodplain geometry.

Timeframes for Expectations

Short Term Expectations (0-15 Years)	*Long Term Expectations (15+ Years)*
Structures control channel form, which in turn, dictates lateral and vertical channel stability	Vegetation dictates lateral channel stability. Channel armoring processes dictate vertical stability
Vegetation provides stability on floodplain surface and along streambanks	Vegetation communities are established and provide habitat and other riparian/wetland functions
Structures are stable	Structures decompose & become buried
Habitat enhanced by bank stabilization and grade control structures	Habitat created by bed forms & vegetation
Bank erosion rates are low	Bank erosion rates are low
Natural processes are maintained	Natural processes govern

Pre-dam Floodplain

Stumps found at varying elevations

Alluvium characteristics variable

Unable to identify pre-dam channel

Groundwater correlated to river surface water

Performance of Floodplain Transitions

Structure Performance

Discharge exceeded design criteria

Bioengineering and toe damage

Large Woody Debris structures intact

Engineered riffles damaged, but held grade

Designing for Failure

- Select hydraulic criteria from flood events less than 100-yr
- Design bank toe protection at depths less than scour
- Use biodegradable fabrics, plant material and wood
- Specify round versus angular rock
- Allow bed mobility up to D_{84} size class
- Integrate side channels
- Maintain floodplain connection at less than Q_2

Side Channel Performance

Multiple design configurations

Discharge exceeded design criteria

Variable performance

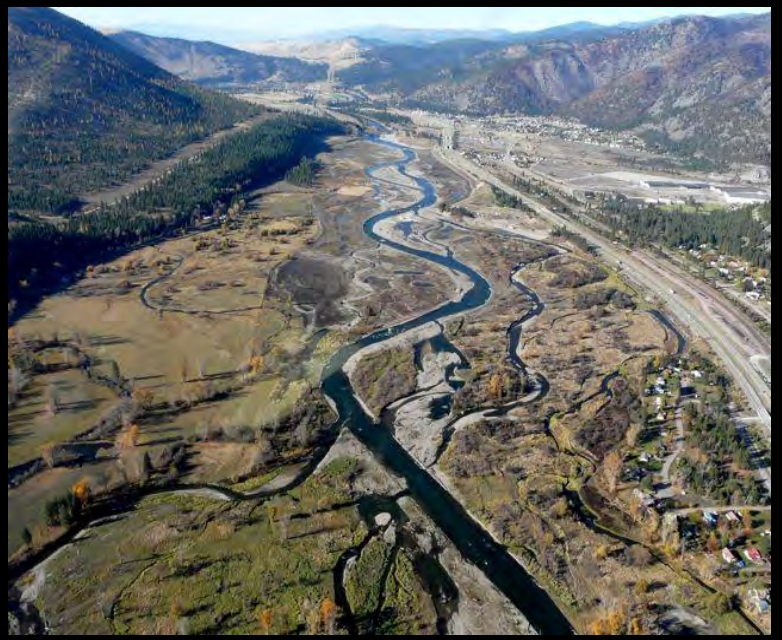
Entrance damage and debris buildup

Conveyed more flow than expected

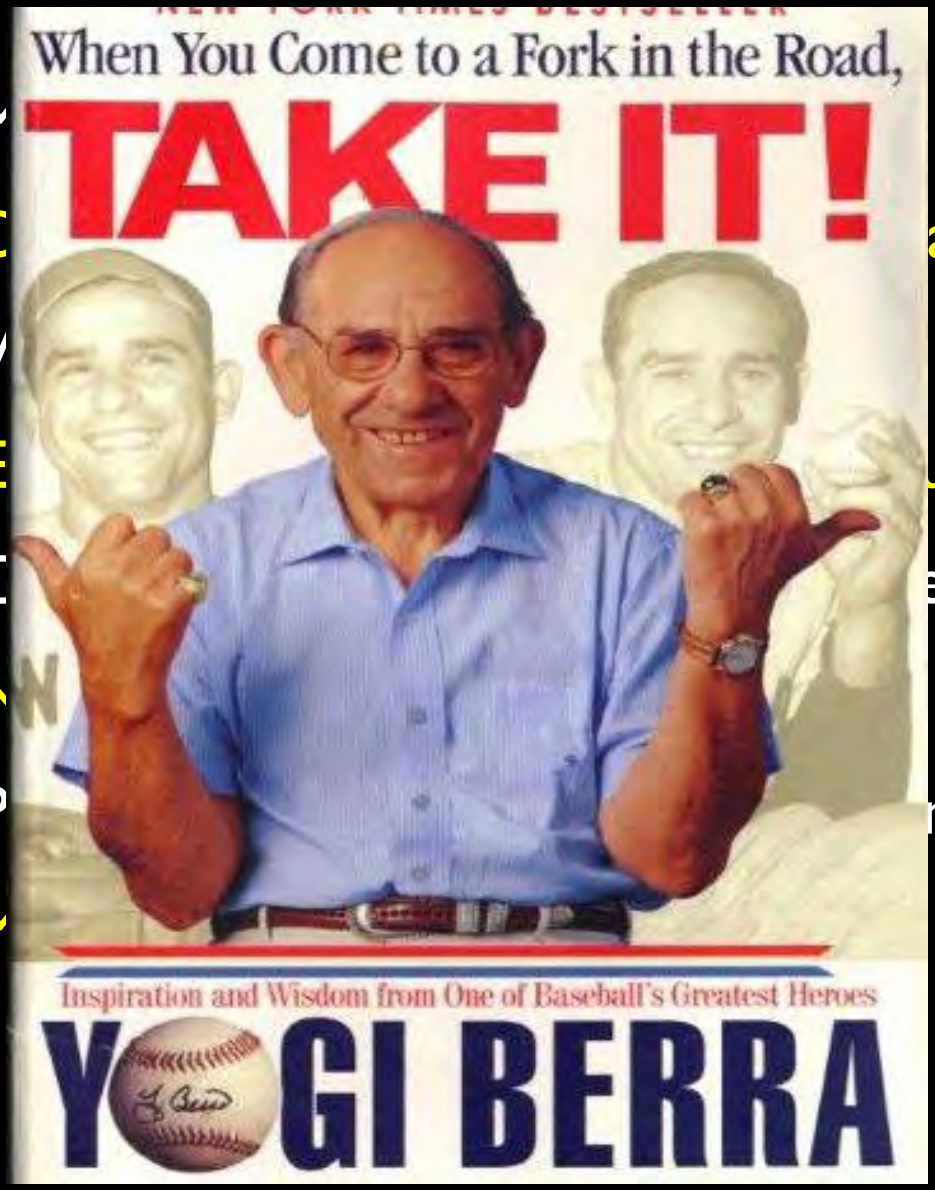
New side channels formed

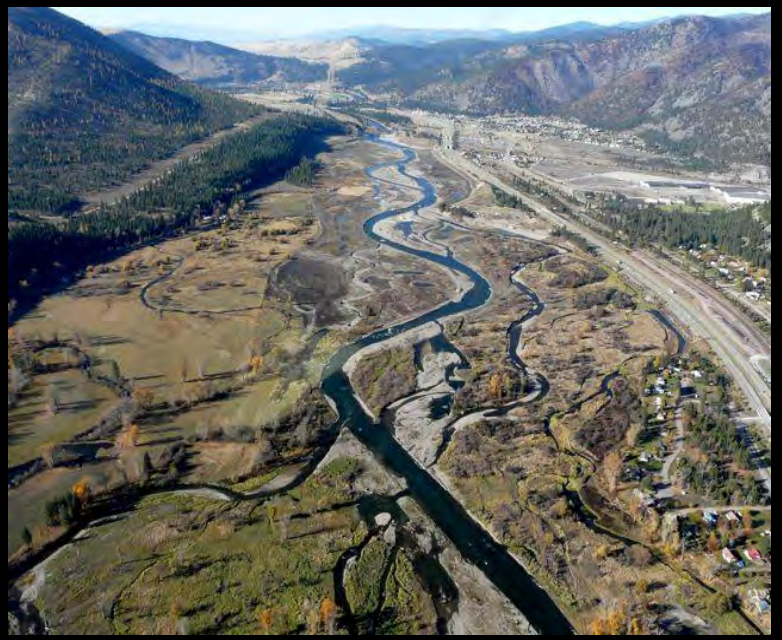
Provided relief valves for main stem

Modified design criteria for maintenance



Side Channel Performance



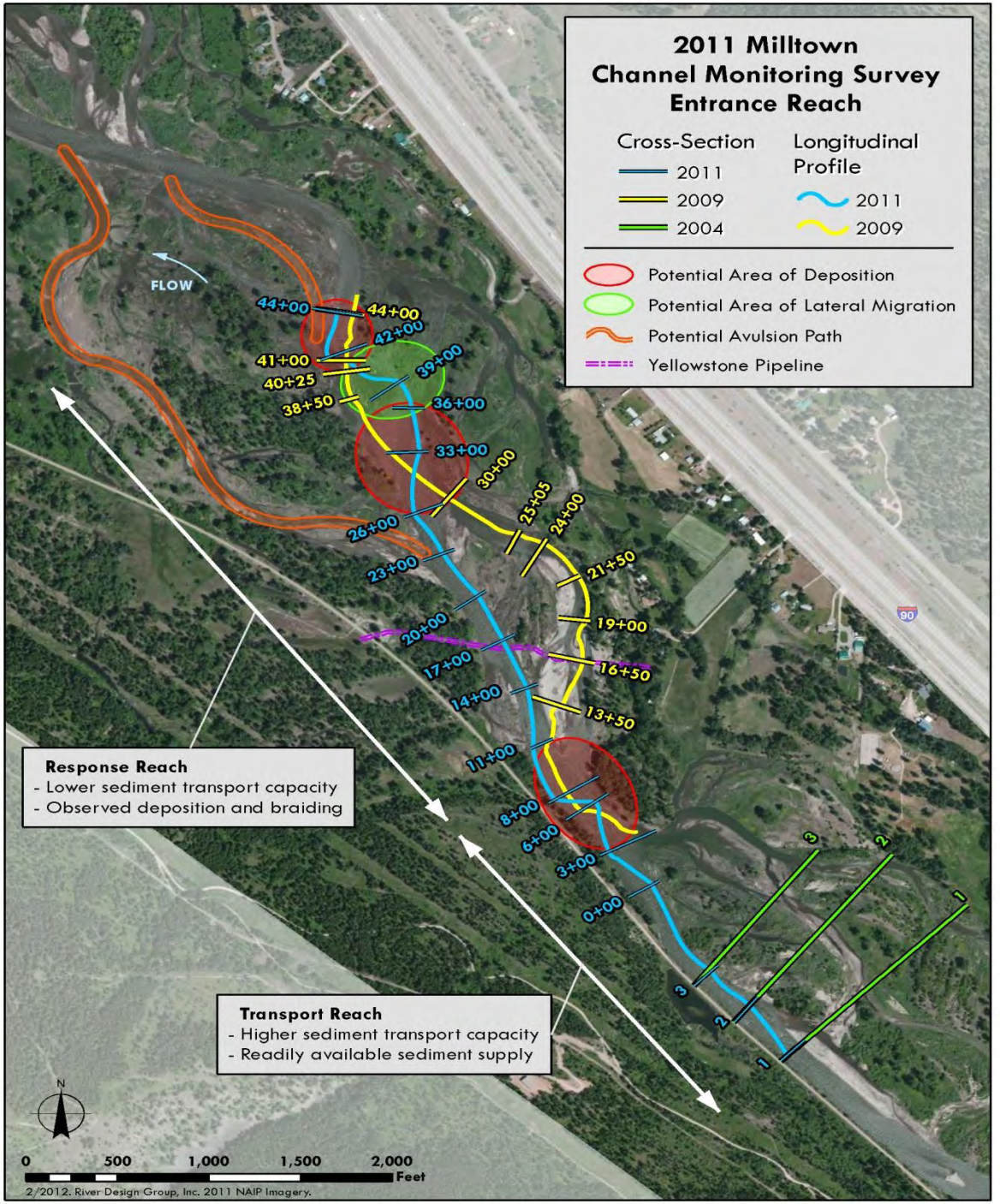


Confluence Hydraulics

Confluence Hydraulics

Stability of Entrance Reach

- Sediment transport discontinuity
- Avulsion
- Lateral migration
- Floodplain connection
- Habitat is adequate
- Wetlands present
- Navigable for recreation



Conclusions

- An inter-disciplinary, coordinated & collaborative approach is critical at every stage of analysis, design & implementation
- Peer review is essential
- Establish expectations up front
- Adaptive management needs to occur at the planning, design, & implementation stages
- More time needed to evaluate overall success
- Current performance trends are positive

Next Steps

- Final implementation phase currently underway
- Re-development – parks, trails and river access
- Open for recreation in near future
- Continued monitoring and maintenance

Acknowledgements

State of Montana Natural Resource Damage Program

Montana Fish, Wildlife and Parks

Confederated Salish and Kootenai Tribes

Montana Department of Environmental Quality

U.S. Environmental Protection Agency

WestWater Consultants, Inc.

Geum Environmental Consultants, Inc.

Envirocon, Inc.