Use of Channel Migration Zone Analysis to Evaluate Effects of Channelization and Identify Opportunities for Restoration: Upper Yellowstone River, Park County, Montana

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Helena MT

River Restoration North West

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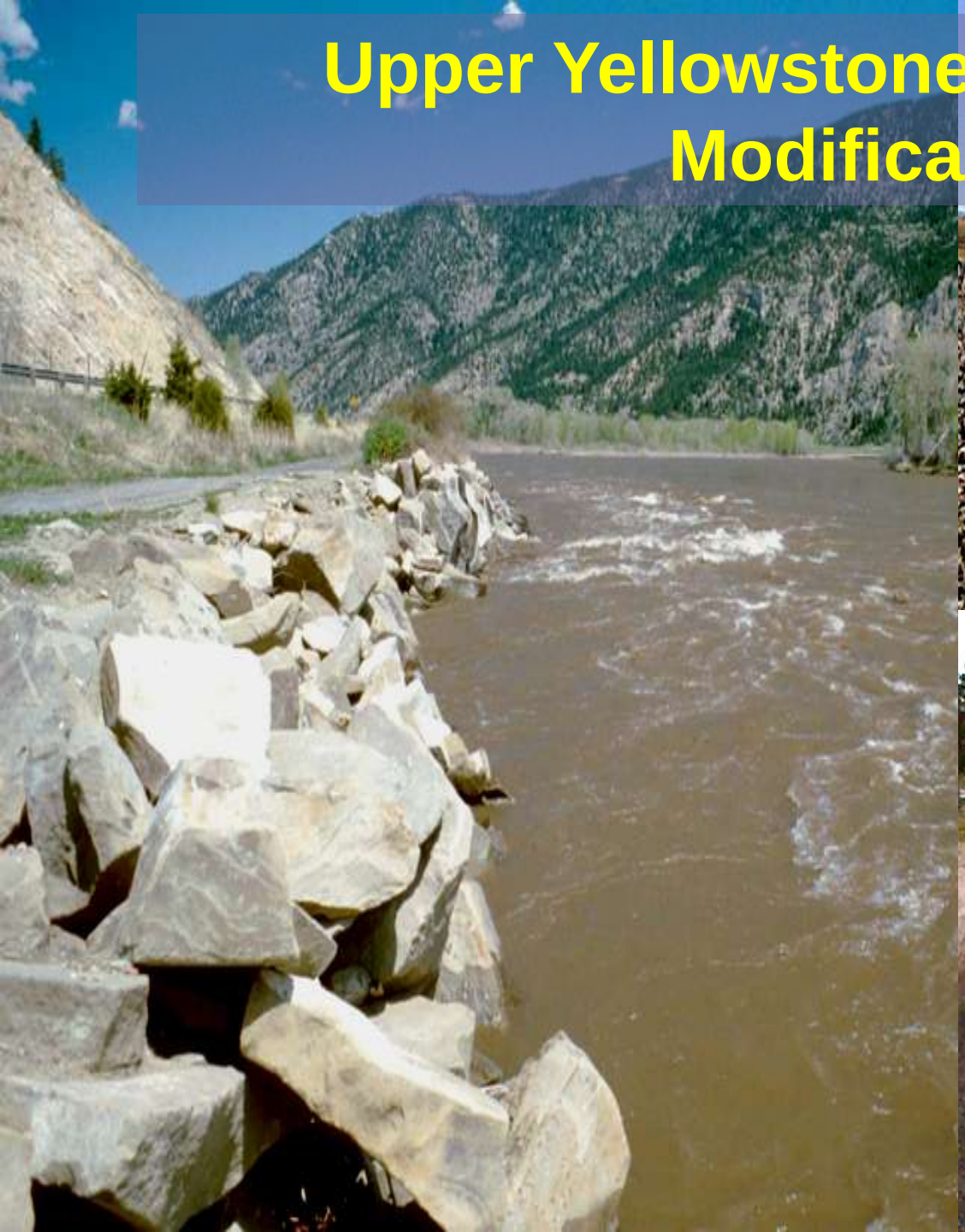
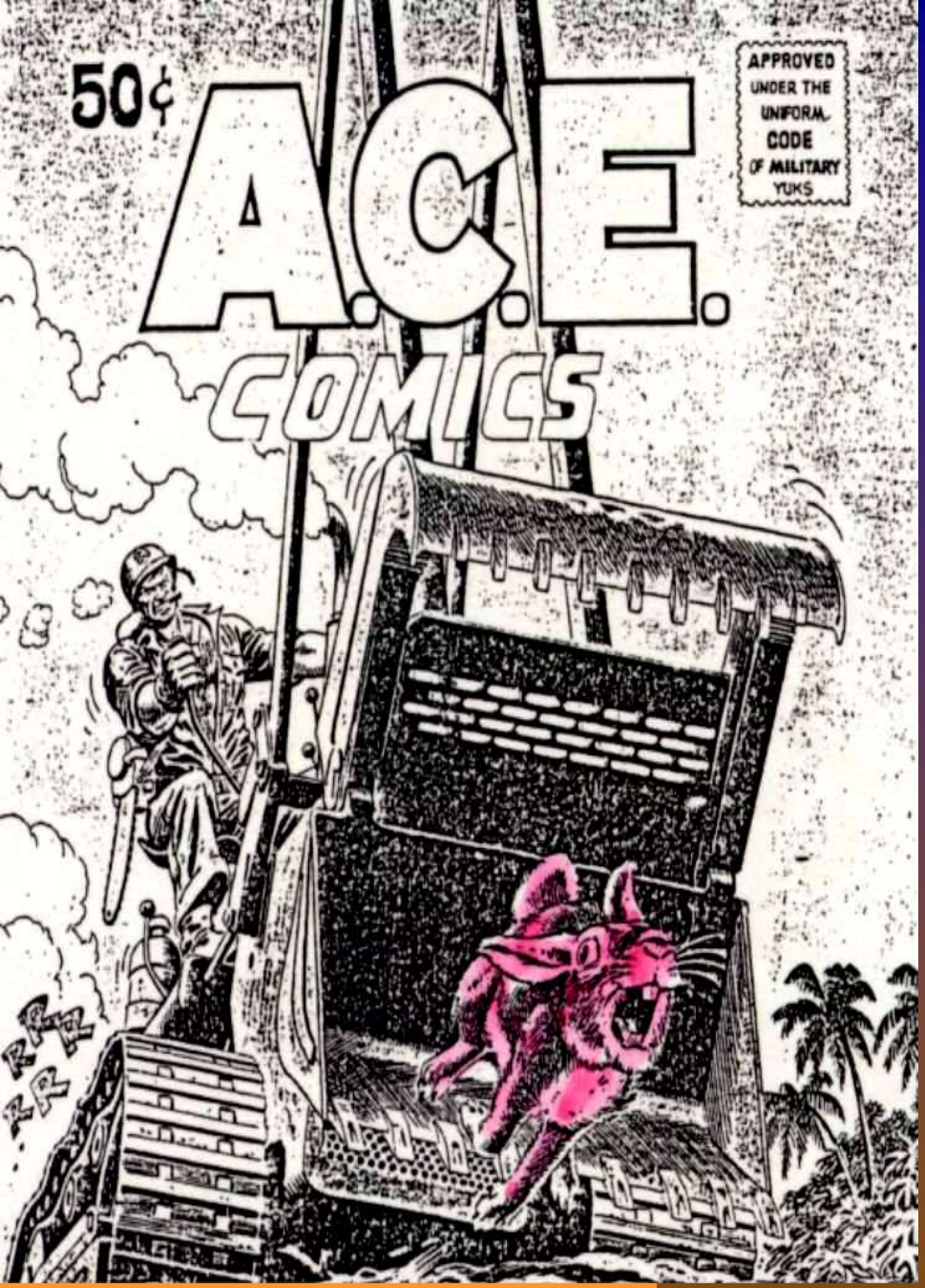
Upper Yellowstone River Channel Modifications





Principal response of alluvial channels to bank stabilization:

Vertical changes:

- --channel incision, downcutting
- --disconnection of main channel and floodplain

Lateral changes:

- --reduce or eliminate channel migration
- --alter channel alignment
- --alter downstream/upstream processes

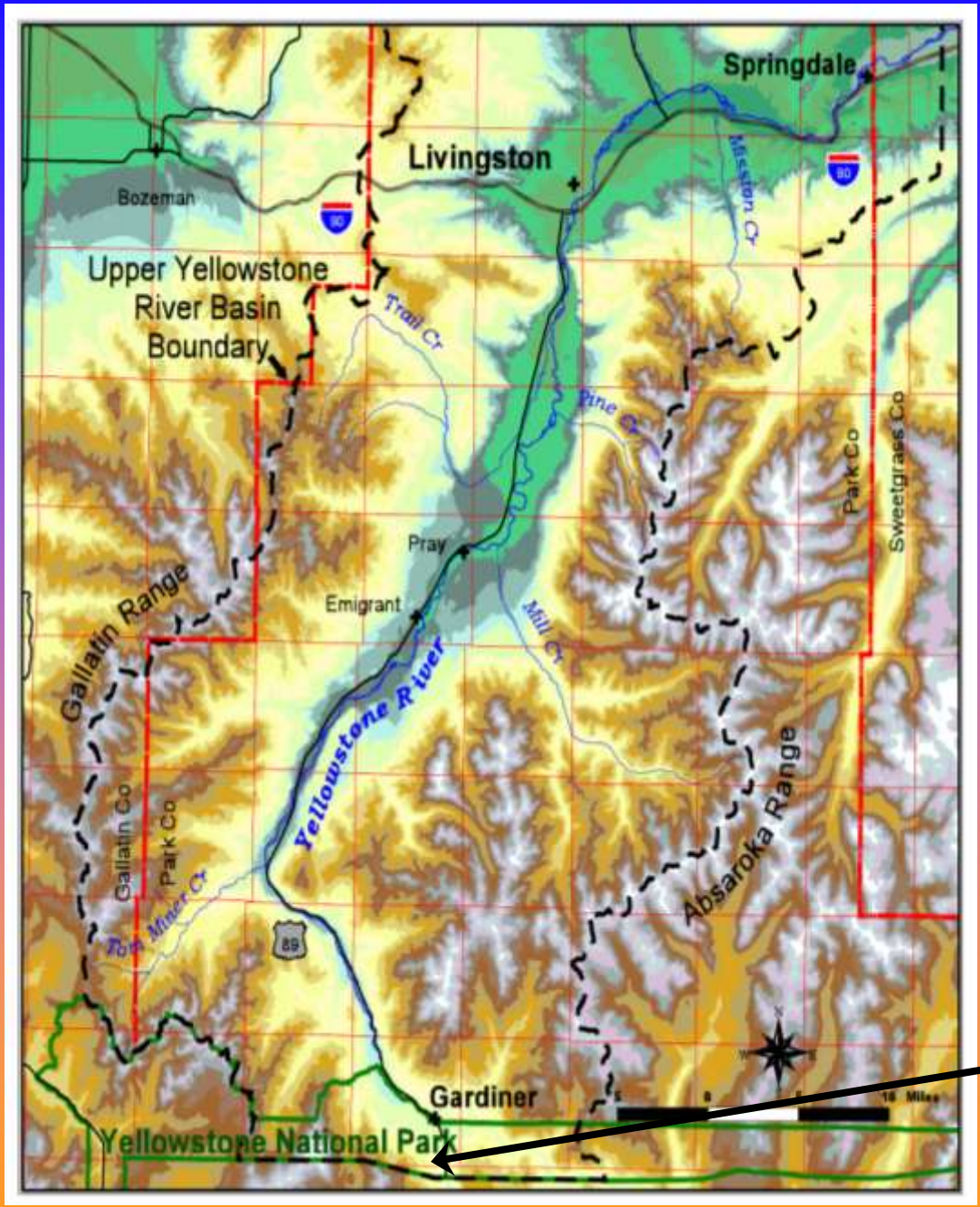
OVERVIEW

1. Delineate CMZ for Upper Yellowstone River ;

2. Examine extent of CMZ relative to Holocene and Pleistocene alluvium;

3. a) Estimate effect of historic and,
   b) future channel confinement on extent of pre-development CMZ;

4. Identify opportunities for restoration.

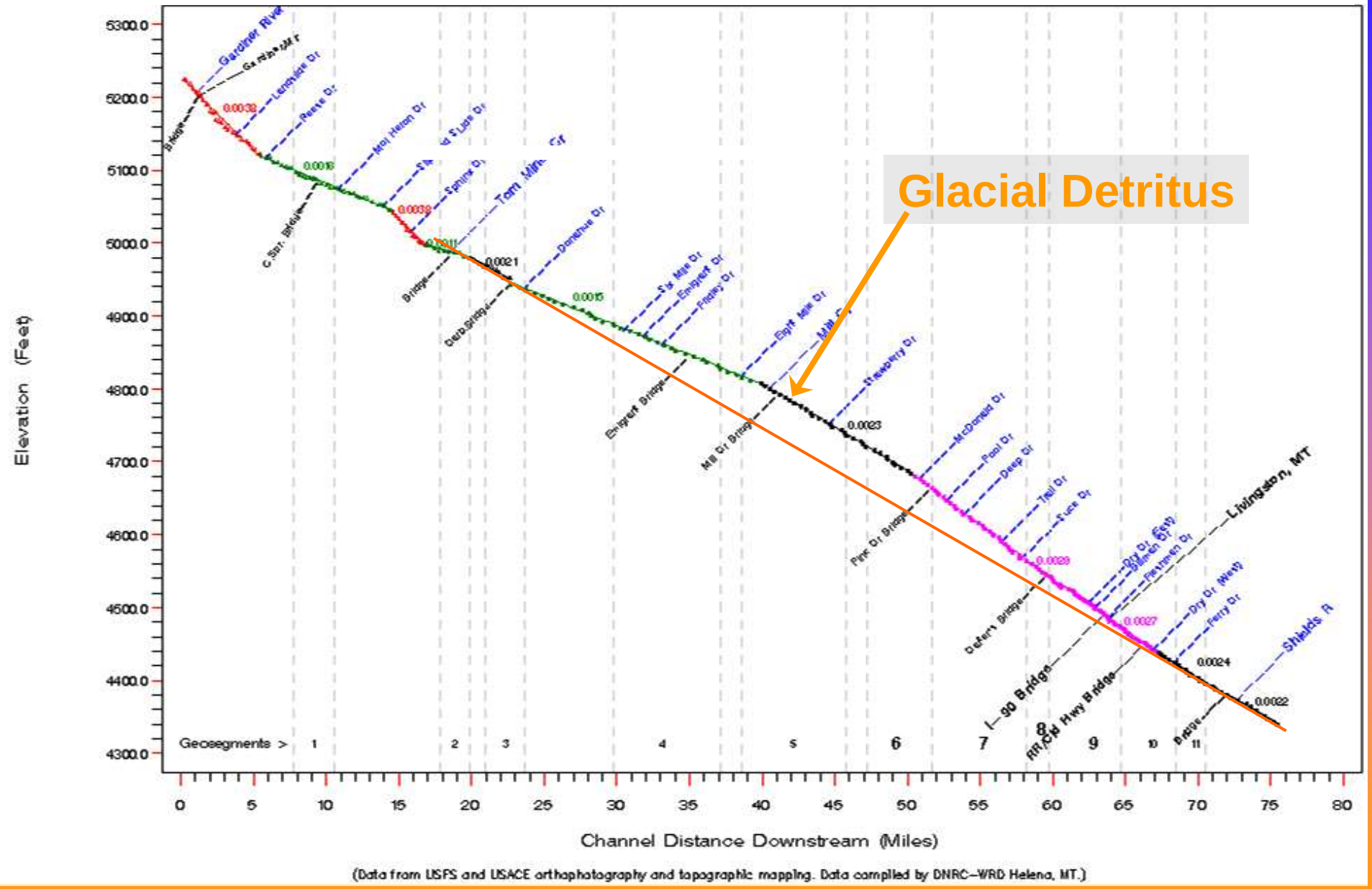


Location and Channel Characteristics:

- 75 mile segment
- Gravel-Cobble, Boulder Bed
- Bed-slope 0.001 to 0.005
- Q_2 =20,000 cfs (560 m^3/s)

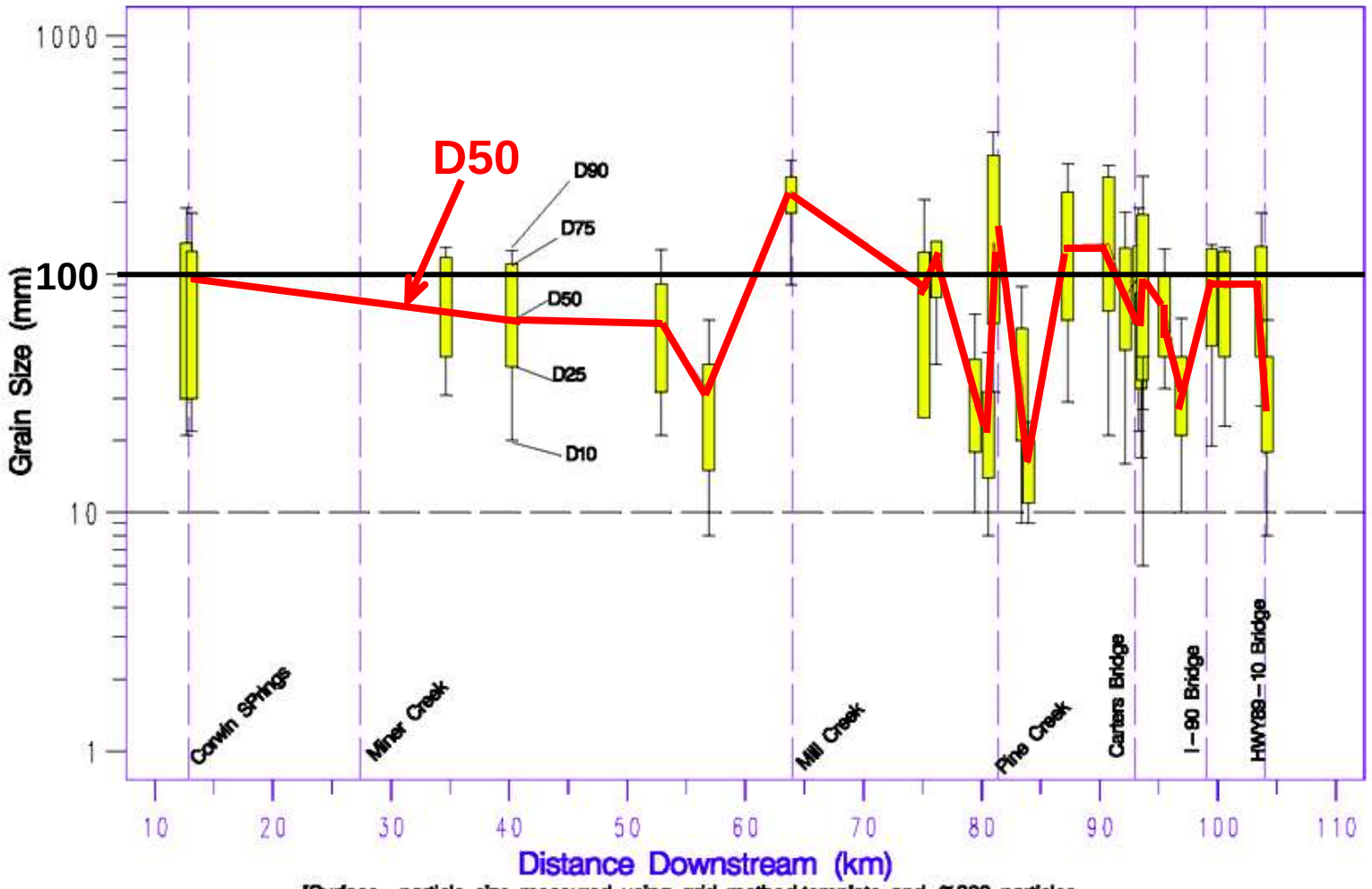
Yellowstone National Park

Longitudinal Channel Profile: Gardiner to Springdale Montana



(Data from USPS and USACE orthophotography and topographic mapping. Data compiled by DNRC–WRD Helena, MT.)

Particle – Size Distribution: Selected Sites Upper Yellowstone River
Corwin Springs to Livingston, MT
(Upstream end of alternate bars and point bars)

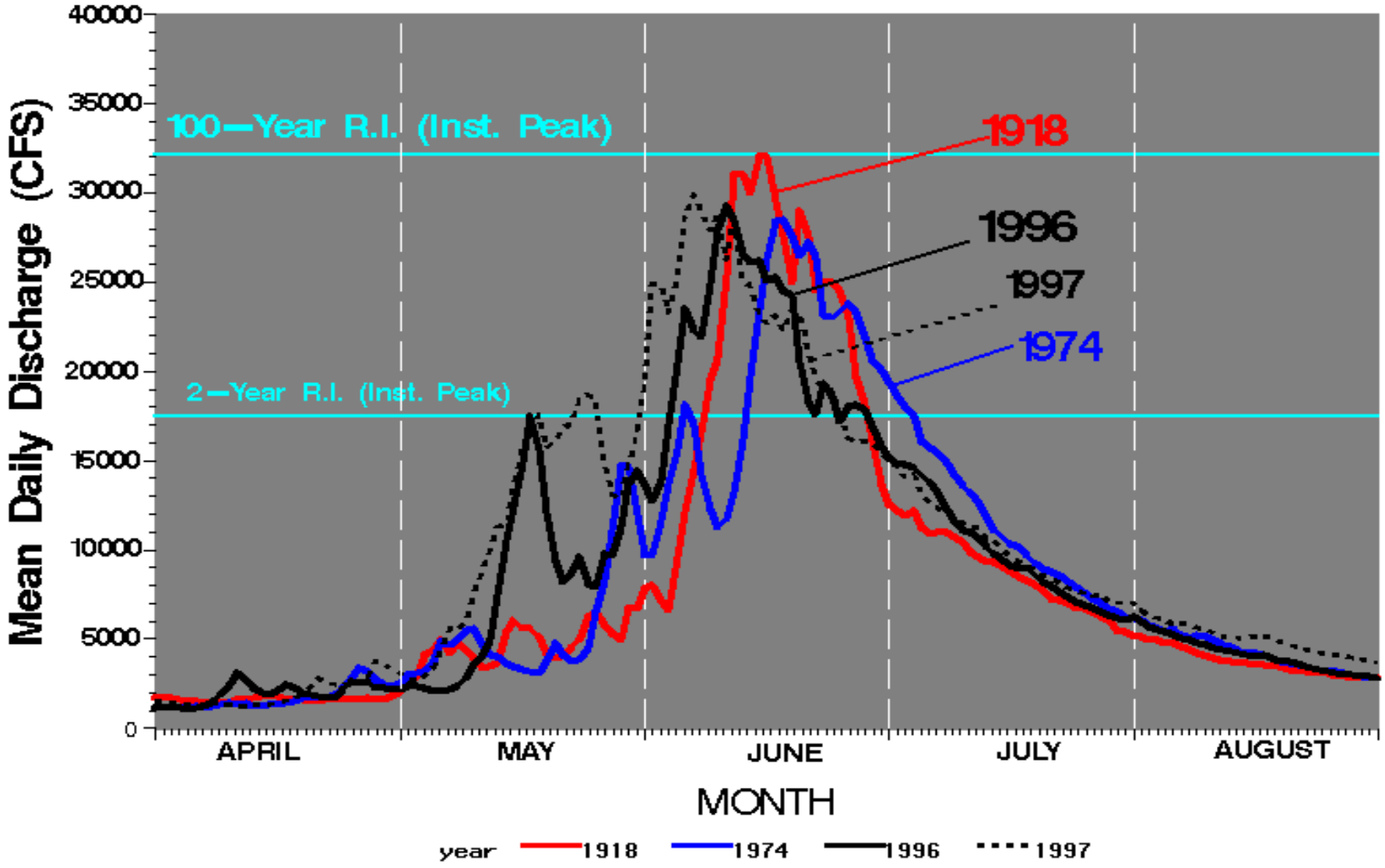


[Surface – particle size measured using grid method,template and ~300 particles
Channel Distance measured from USGS – WRD X – sec 160, D.S. Gardiner Bridge]

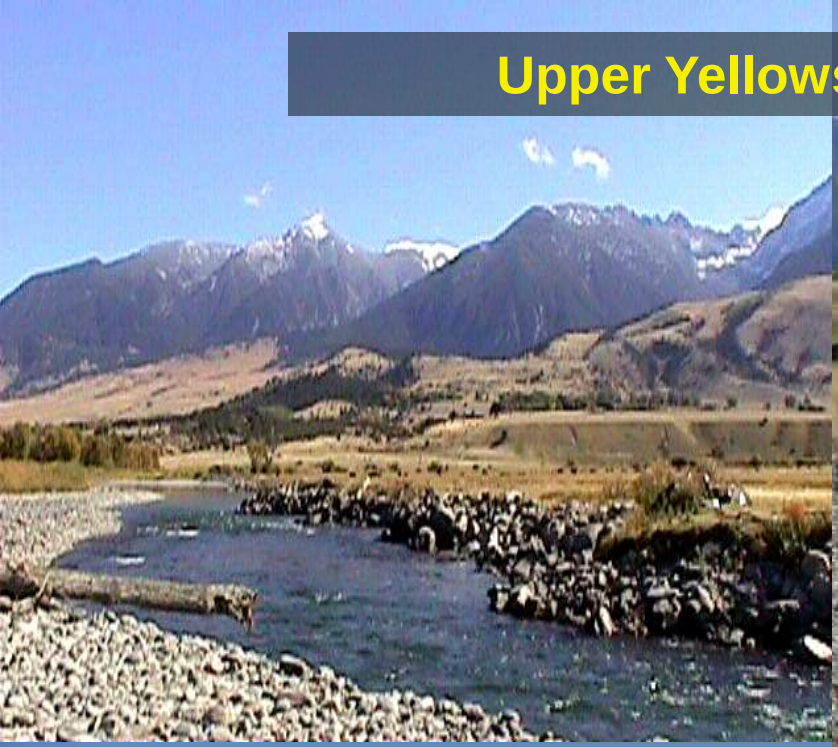
Coarse-bed channel

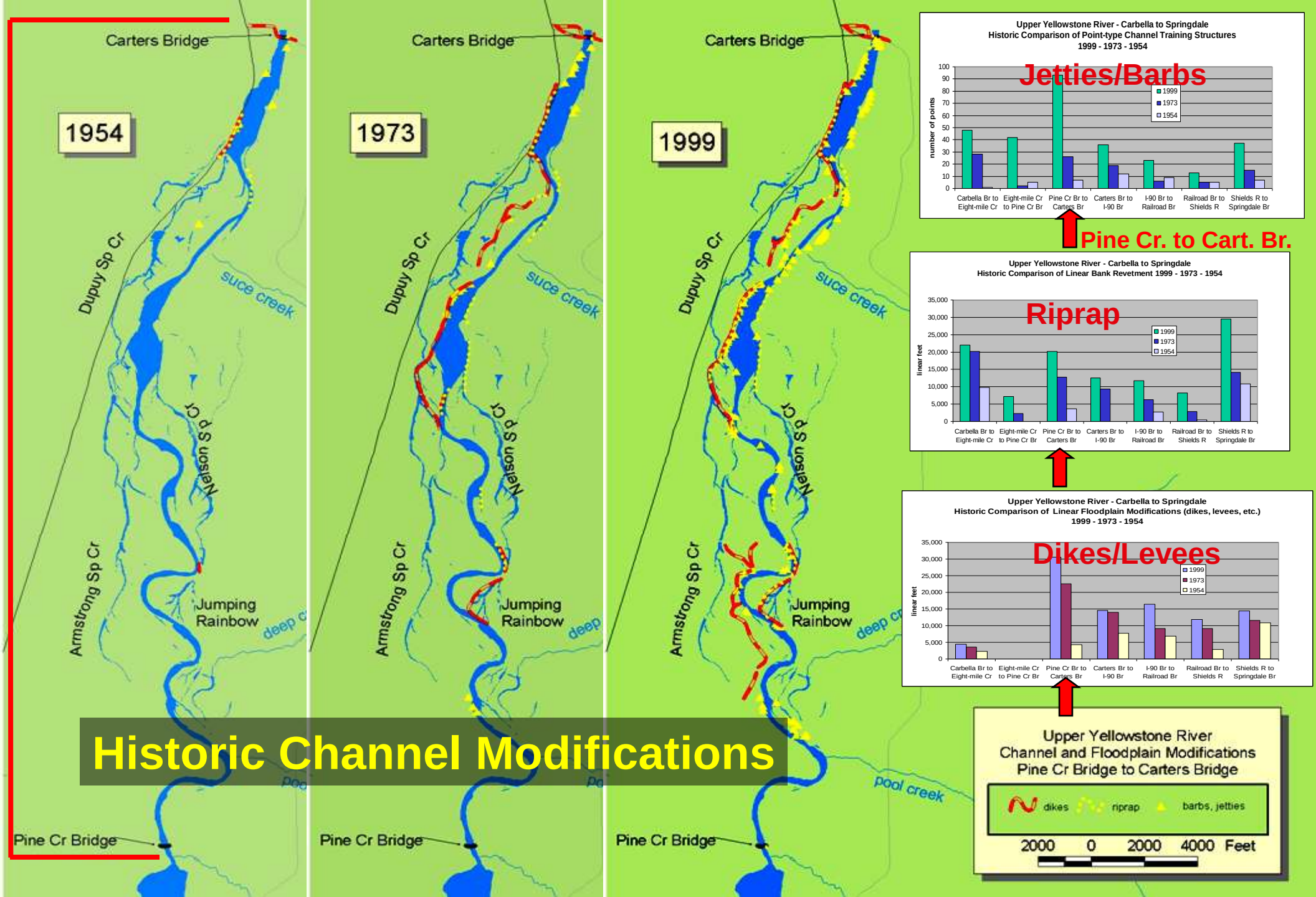
Hydrographs of Four Largest Upper Yellowstone River Floods

U.S. Geological Survey Station 06191500-- Yellowstone River at Corwin Springs MT



Upper Yellowstone River Channel Modifications



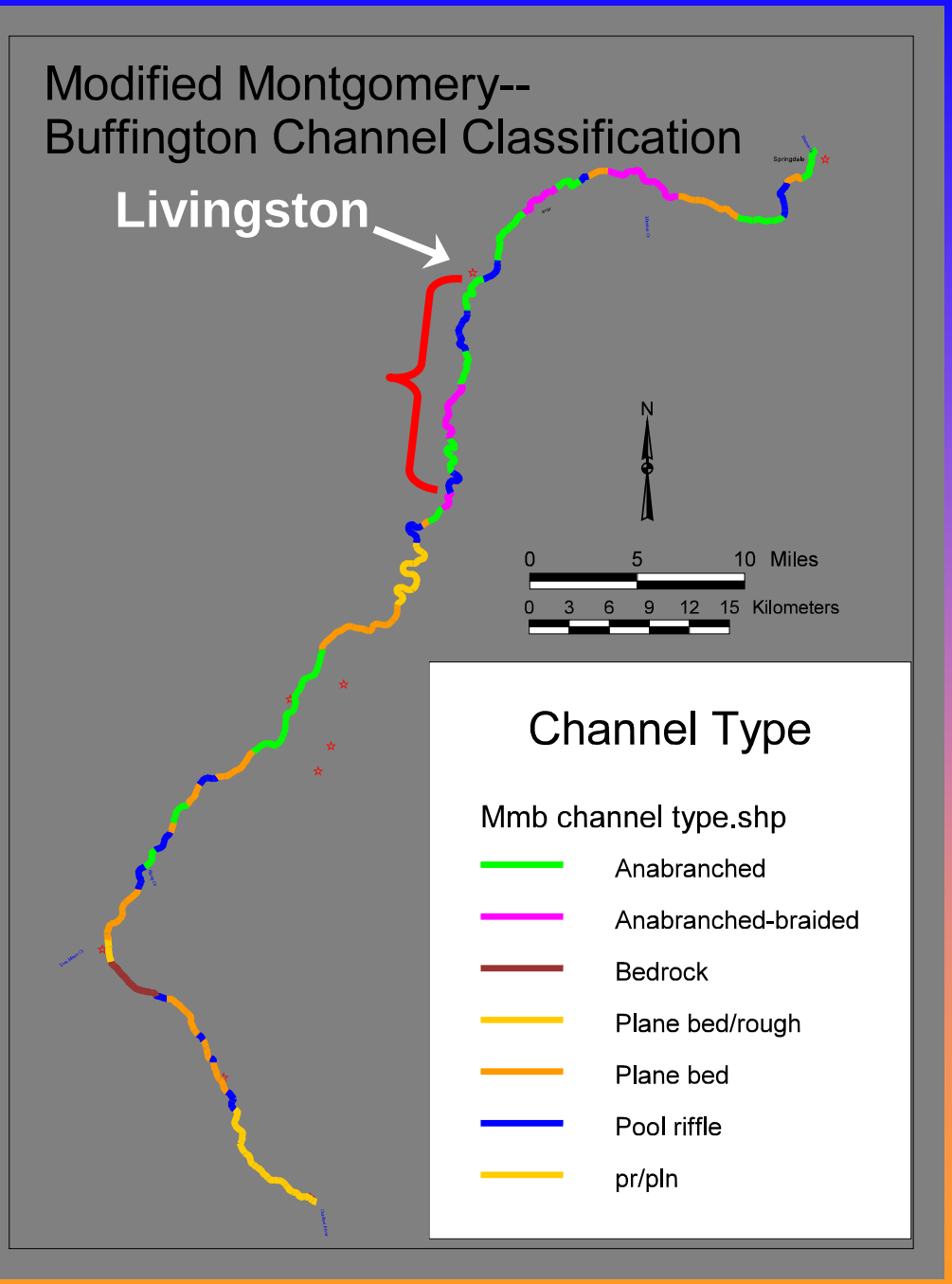

Carters Bridge
1954
1973
1999
Dupuy Sp Cr
suce creek
Nelson Sp Cr
Armstrong Sp Cr
Jumping Rainbow
deep cr
pool creek
Pine Cr Bridge
Historic Channel Modifications
Upper Yellowstone River - Carbella to Springdale
Historic Comparison of Point-type Channel Training Structures
1999 - 1973 - 1954
Jetties/Barbs
number of points
1999
1973
1954
Carbella Br to Eight-mile Cr
Eight-mile Cr to Pine Cr Br
Pine Cr Br to Carters Br
Carters Br to I-90 Br
I-90 Br to Railroad Br
Railroad Br to Shields R
Shields R to Springdale Br
Pine Cr. to Cart. Br.
Upper Yellowstone River - Carbella to Springdale
Historic Comparison of Linear Bank Revetment 1999 - 1973 - 1954
Riprap
linear feet
Upper Yellowstone River - Carbella to Springdale
Historic Comparison of Linear Floodplain Modifications (dikes, levees, etc.)
1999 - 1973 - 1954
Dikes/Levees
linear feet
Upper Yellowstone River
Channel and Floodplain Modifications
Pine Cr Bridge to Carters Bridge
dikes
riprap
barbs, jetties
2000 0 2000 4000 Feet

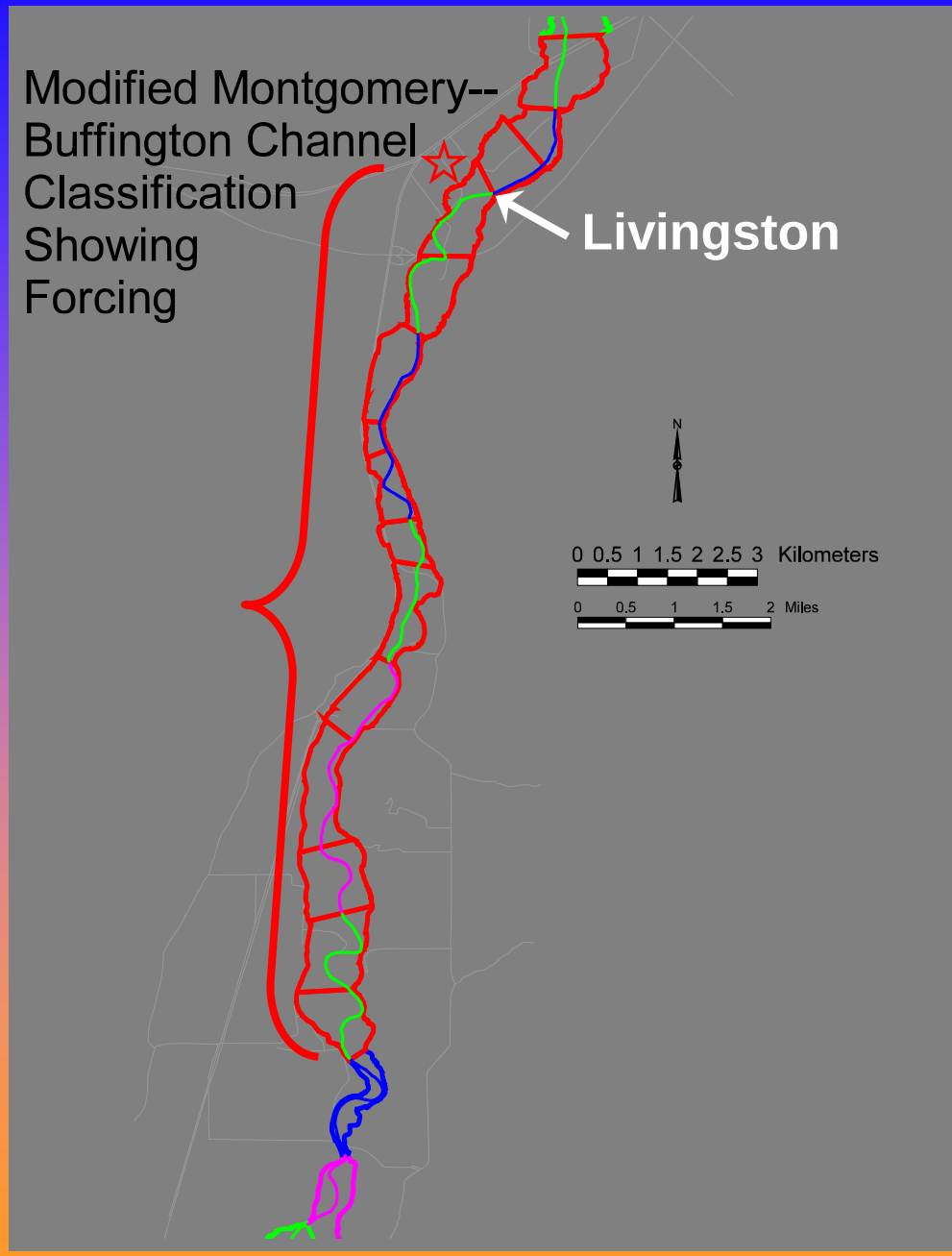
1954-1999 Historic Analysis of Channel Modifications:

Dikes and levees > 265% (35,000 to 92,000
Riprap > 400% (28,000 to 111, 000 feet)

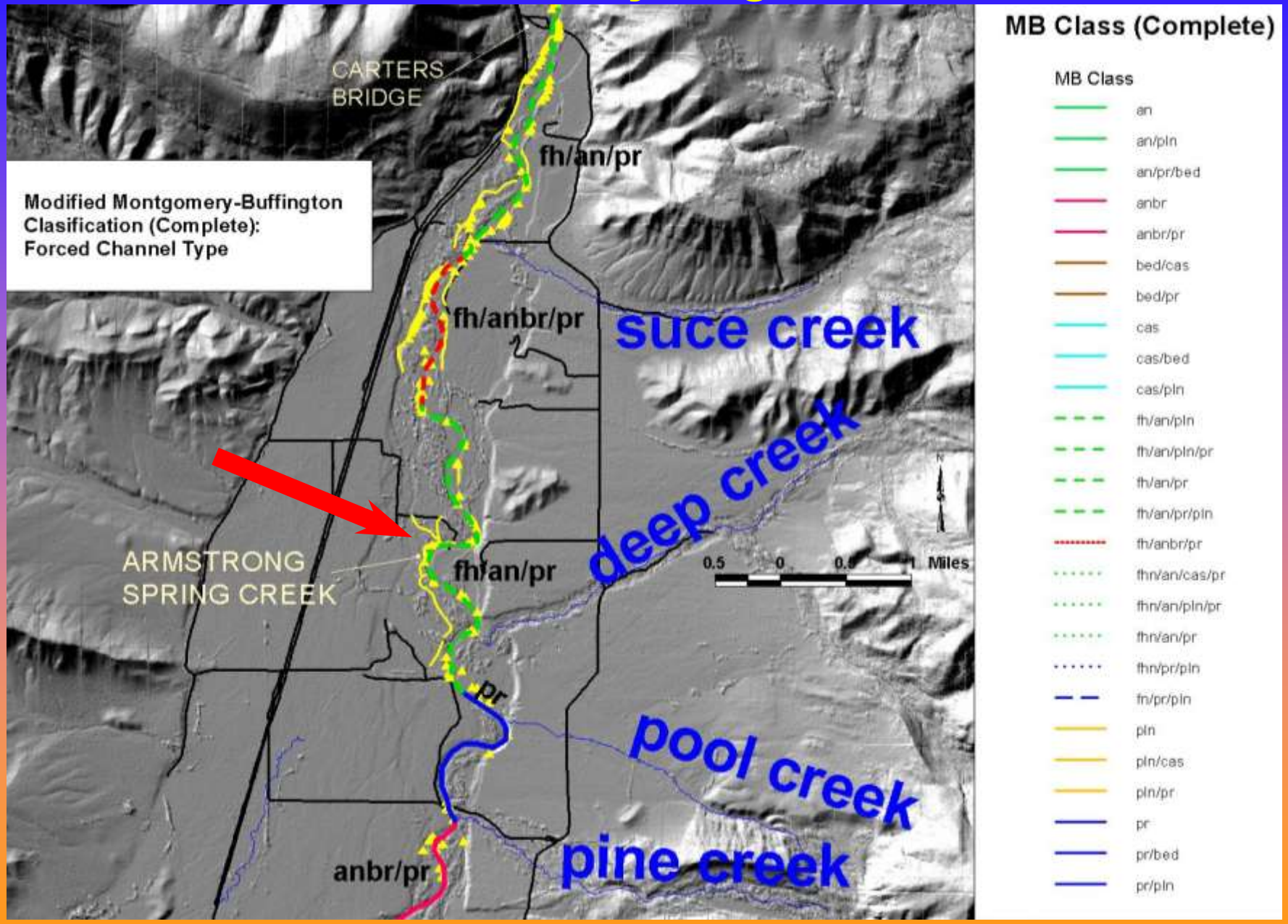
Point structures
(i.e. jetties and barbs) >600% (from 50 to 290).

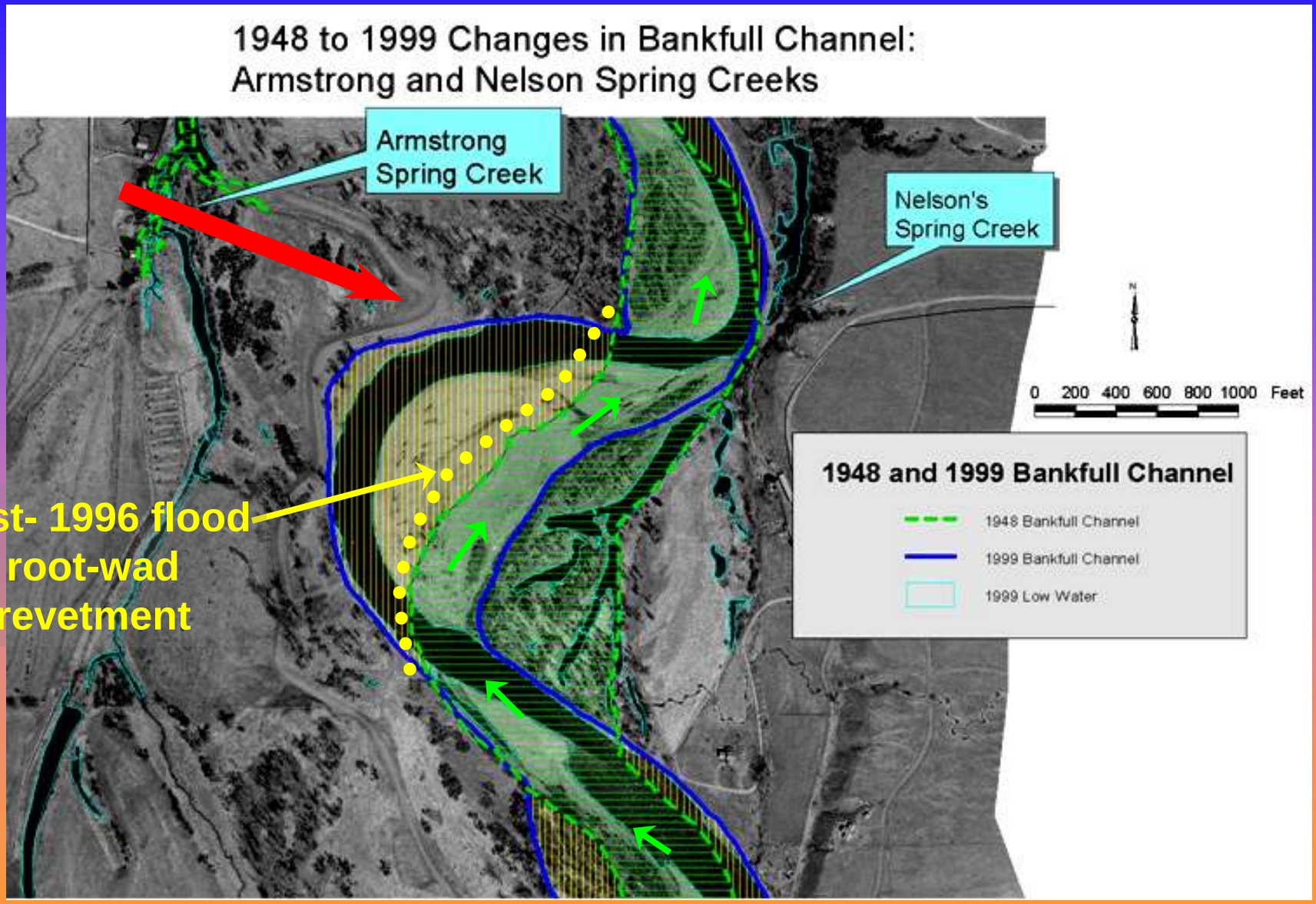
How much of Gardiner to Springdale study area is significantly affected by channel modifications ?

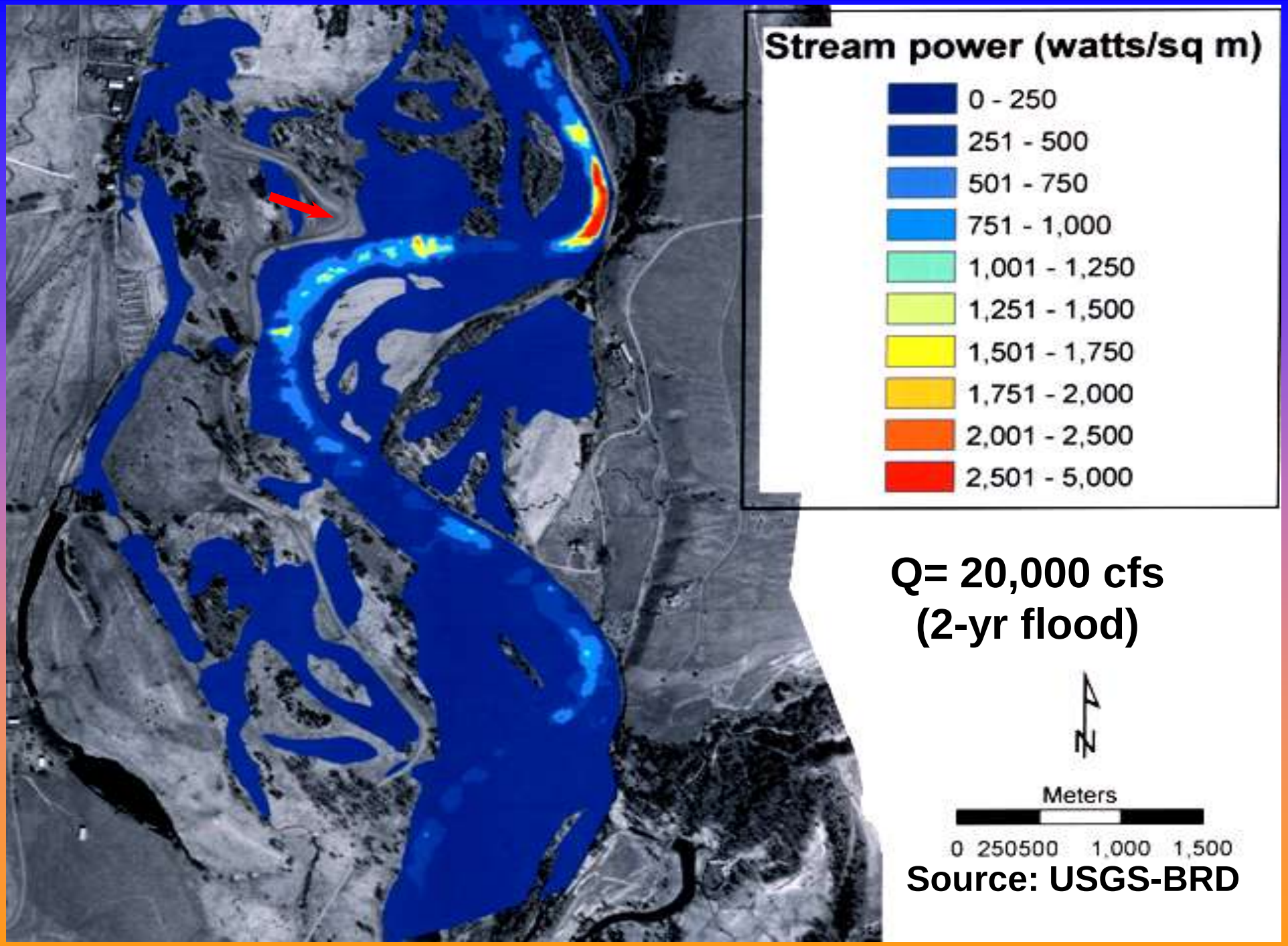

Modified Montgomery--
Buffington Channel Classification
Livingston
N
0 5 10 Miles
0 3 6 9 12 15 Kilometers
Channel Type
Mmb channel type.shp
Anabranched
Anabranched-braided
Bedrock
Plane bed/rough
Plane bed
Pool riffle
pr/pln


Modified Montgomery--
Buffington Channel
Classification
Showing
Forcing
Livingston
N
0 0.5 1 1.5 2 2.5 3 Kilometers
0 0.5 1 1.5 2 Miles

Paradise Valley Segment




1948 to 1999 Changes in Bankfull Channel:
Armstrong and Nelson Spring Creeks
Armstrong Spring Creek
Nelson's Spring Creek
Post- 1996 flood root-wad revetment
0 200 400 600 800 1000 Feet
1948 and 1999 Bankfull Channel
1948 Bankfull Channel
1999 Bankfull Channel
1999 Low Water


Stream power (watts/sq m)
0 - 250
251 - 500
501 - 750
751 - 1,000
1,001 - 1,250
1,251 - 1,500
1,501 - 1,750
1,751 - 2,000
2,001 - 2,500
2,501 - 5,000
Q= 20,000 cfs
(2-yr flood)
N
Meters
0 250500 1,000 1,500
Source: USGS-BRD

1. Delineate CMZ for Upper Yellowstone River

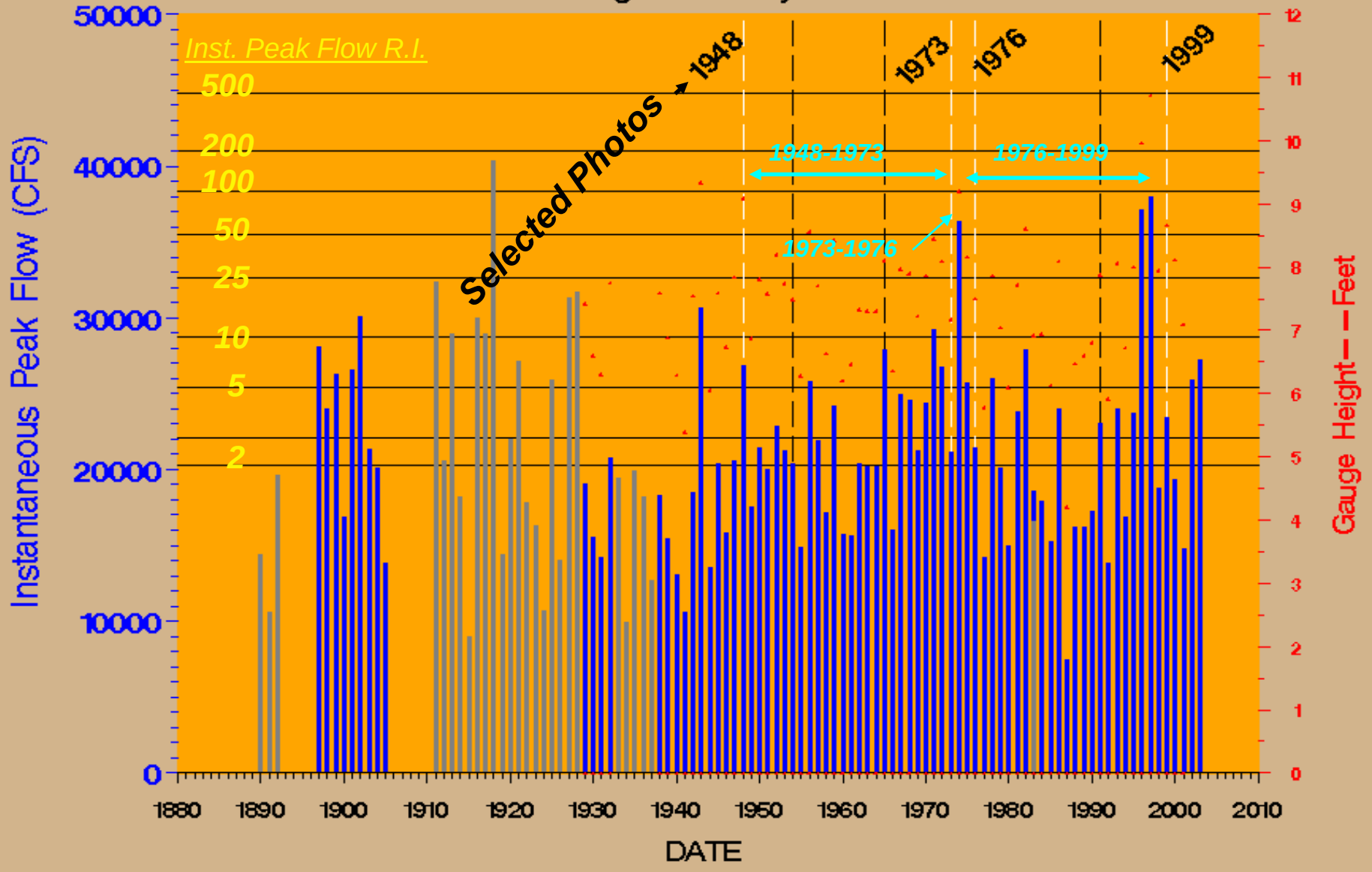
- Selection of Historical Aerial Photos
- Mapping of Historic Migration Zone
- Mapping of Avulsion Hazard Zone
- Estimation of Erosion Hazard Area

CMZ= HMZ +AHZ + EHA - DMA

(Rapp and Abbe (2003)—Washington State Method)

Figure . Historic Annual Peak Flows: Yellowstone River near Livingston, MT

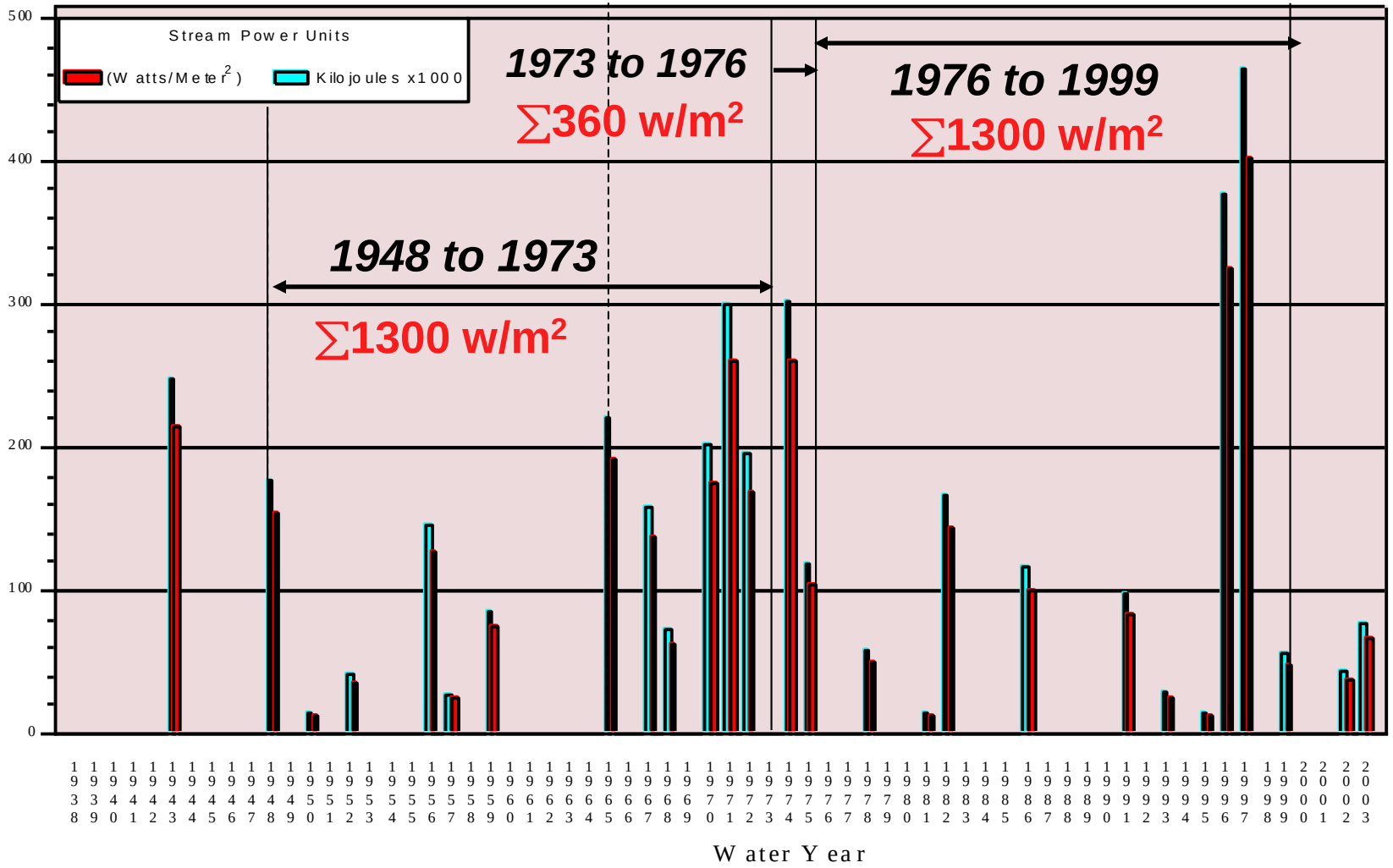
U.S. Geological Survey Station 06192500



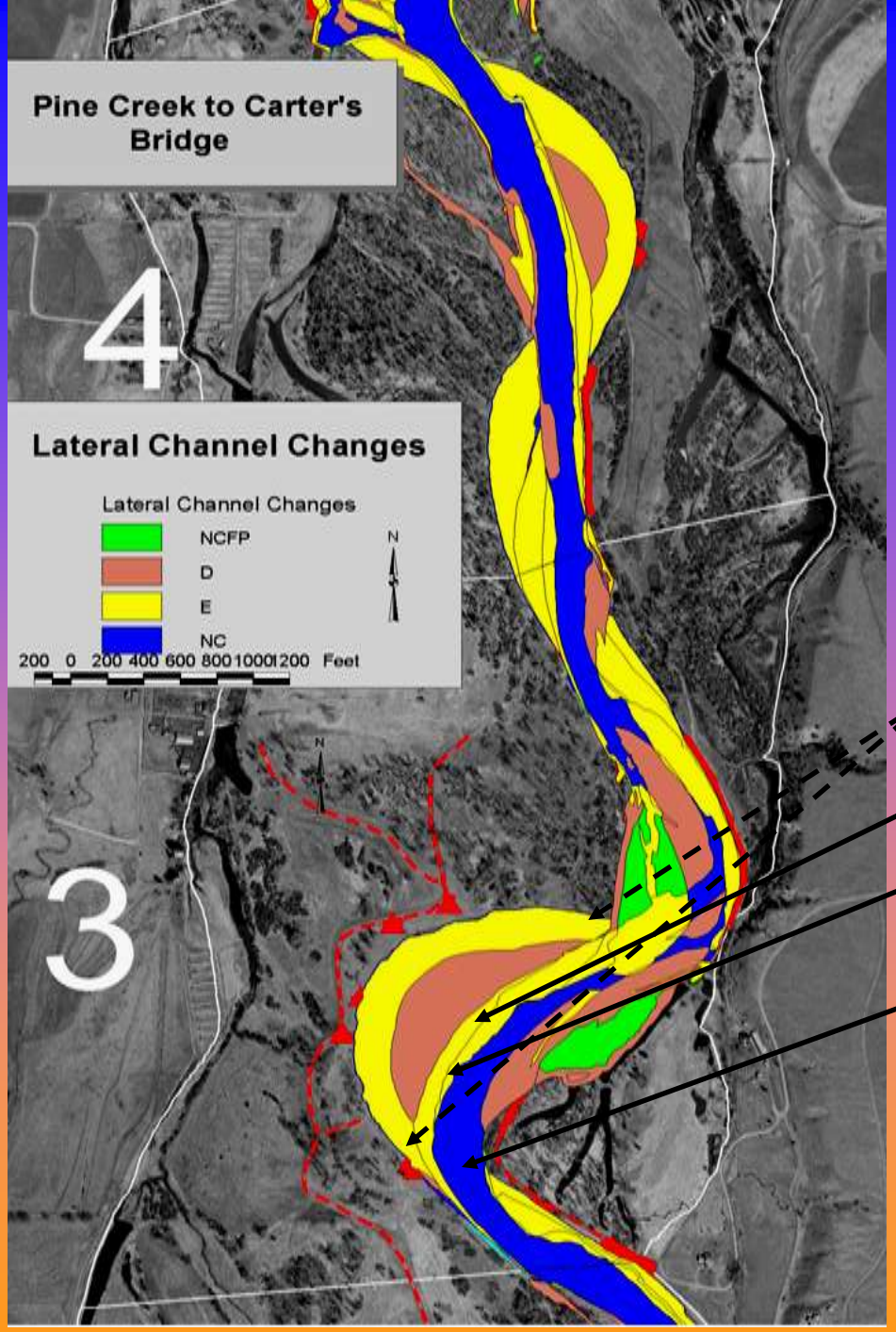
Observed data (for 1897—1905, 1929—1932, 1938—2001) and flood frequency recurrence intervals from USGS—WRD Helena, MT.

Missing record estimated by correlation with Corwin Springs station from Merigliano 2001

Figure . Annual sum of Mean (Specific) Stream Power for water years with mean daily discharge greater than 20,300 cfs (~bankfull discharge) -- Yellowstone River near Livingston Montana: U.S. Geological Survey Station 06192500)



Note: Average energy per unit area expended over water year calculated as, $\Omega = \int \gamma Q S / w \, dt$ *where*, γ = specific weight of water (9800 N/m^2), Q = mean daily stream discharge (m^3), S = energy gradeline, w = width of flow (m), t = time (*days*). Assumed constants = γ *and* S (0.0024), mean daily flow width estimated from LOESS fit of water-surface width against historic instantaneous discharge measurements for period of record 1938 to 2003.



"Bankfull" channel

1999

1976

1973

1948

ERROR ANALYSIS in MAPPING HISTORIC LATERAL EROSION

Uncertainty derives from three principal sources

- positional error in image data;
- delineation (or digitizing) error; and,
- feature identification error.

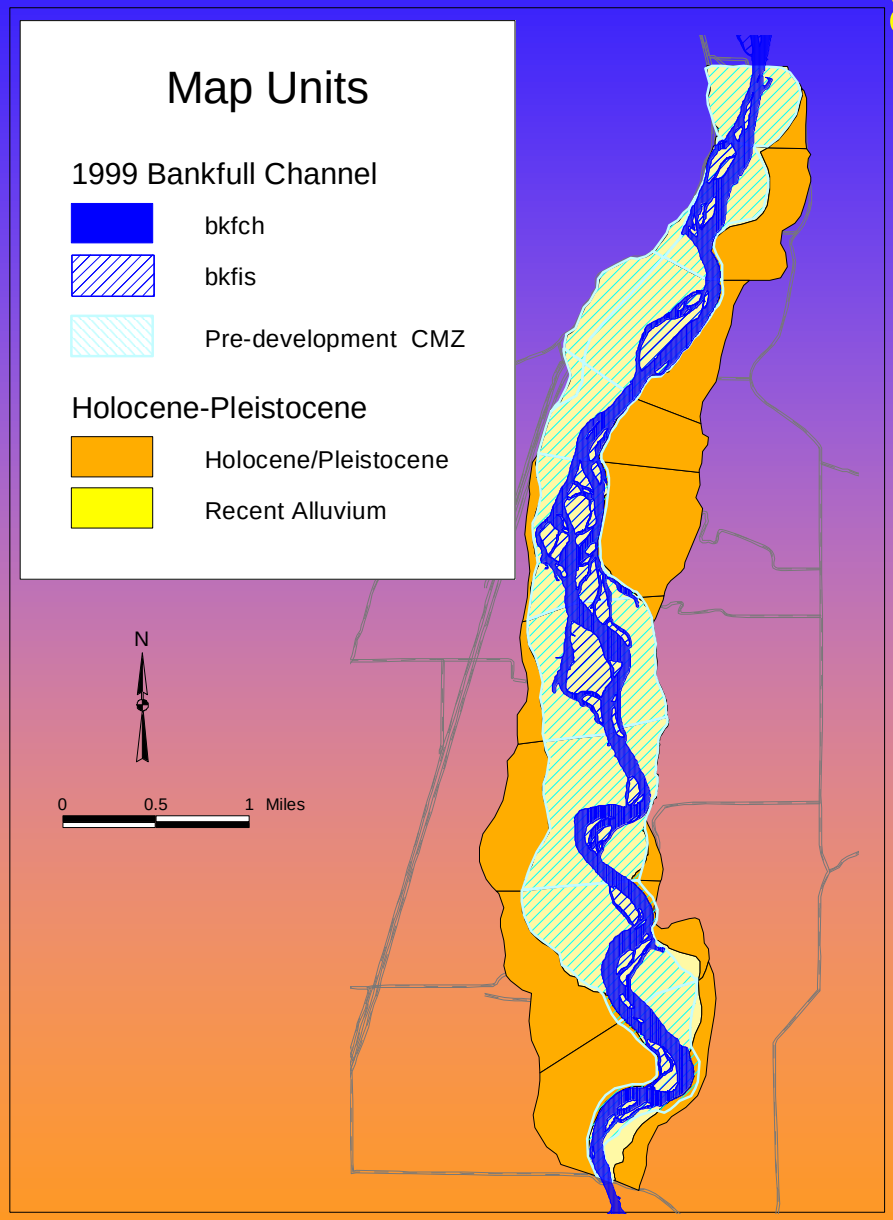
Channel changes measured on temporal sequences of rectified images (e.g. aerial photos) are valid only if the amount of change exceeds errors inherent in successive traces of features (e.g. bankfull banklines) compared over time

Total error: ± 33 to ± 57 feet :

15 to 20% of CMZ width at narrowest (500 ft)

<1% at widest (3500 feet).....but **± ~60 feet can be significant !**

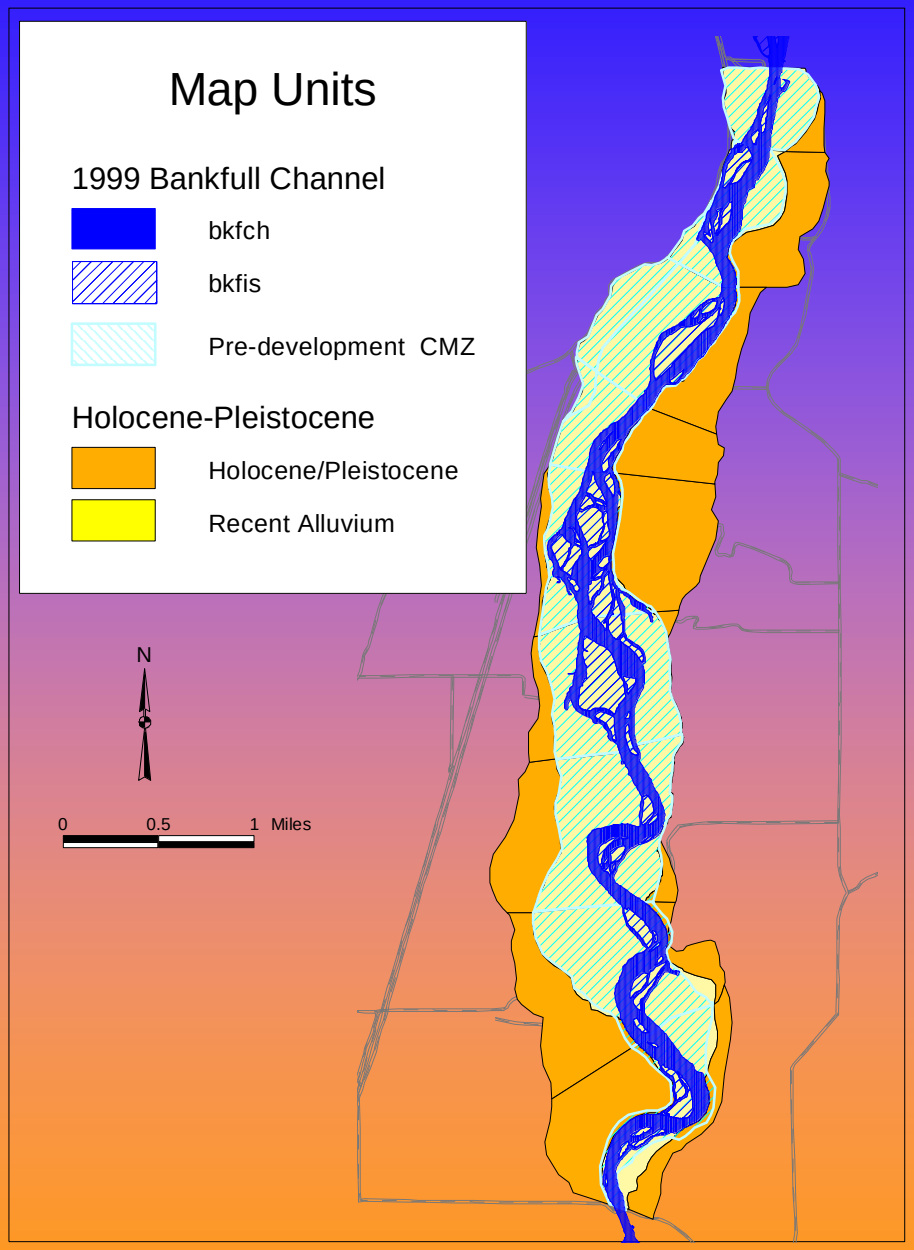
2. Extent of CMZ relative to Holocene and Pleistocene alluvium;



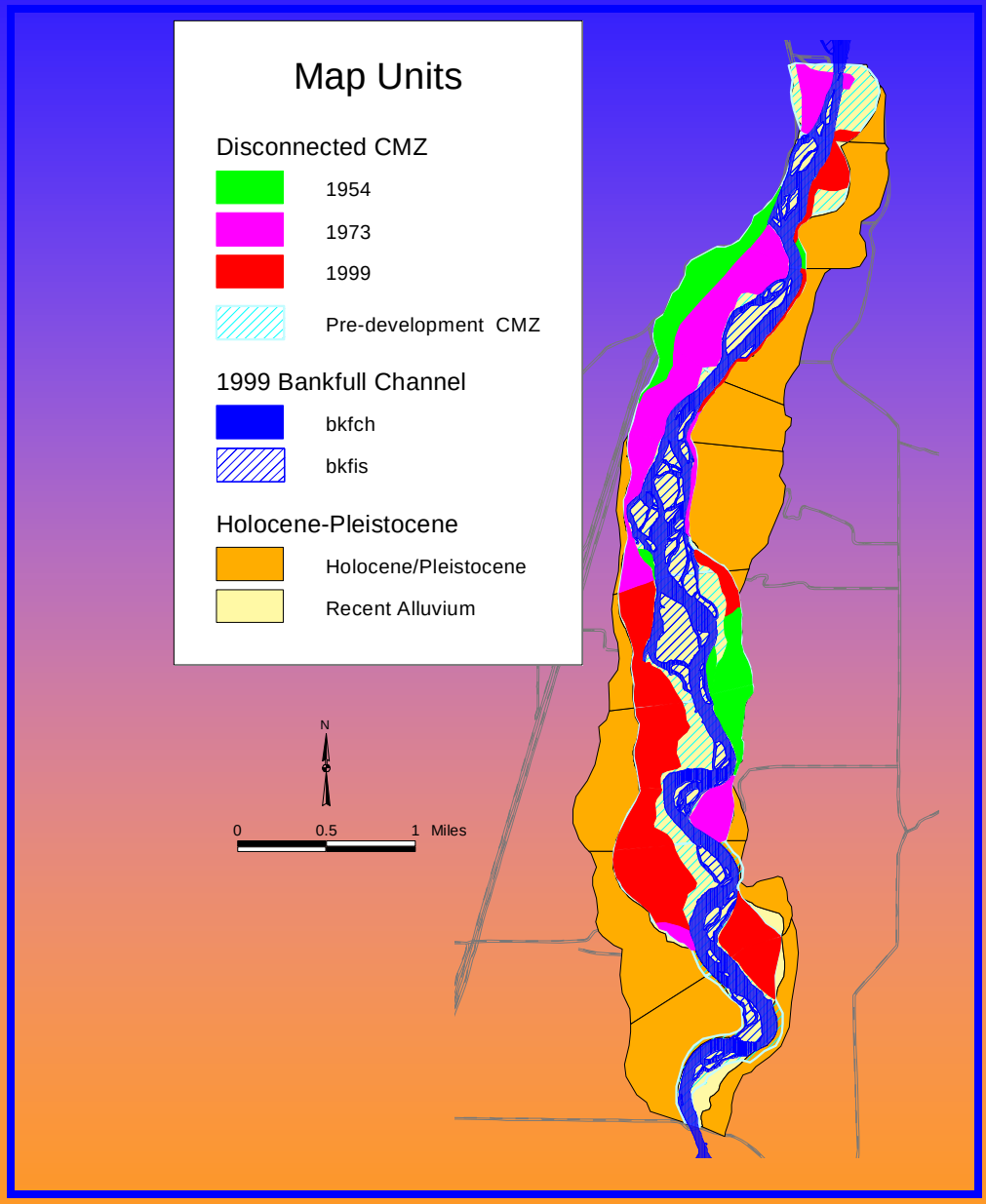
- Pre-development CMZ=54% of geologic floodplain (recent and Holocene/Pleistocene fluvio-glacial alluvium), and 90% of recent (~1500 year) floodplain;

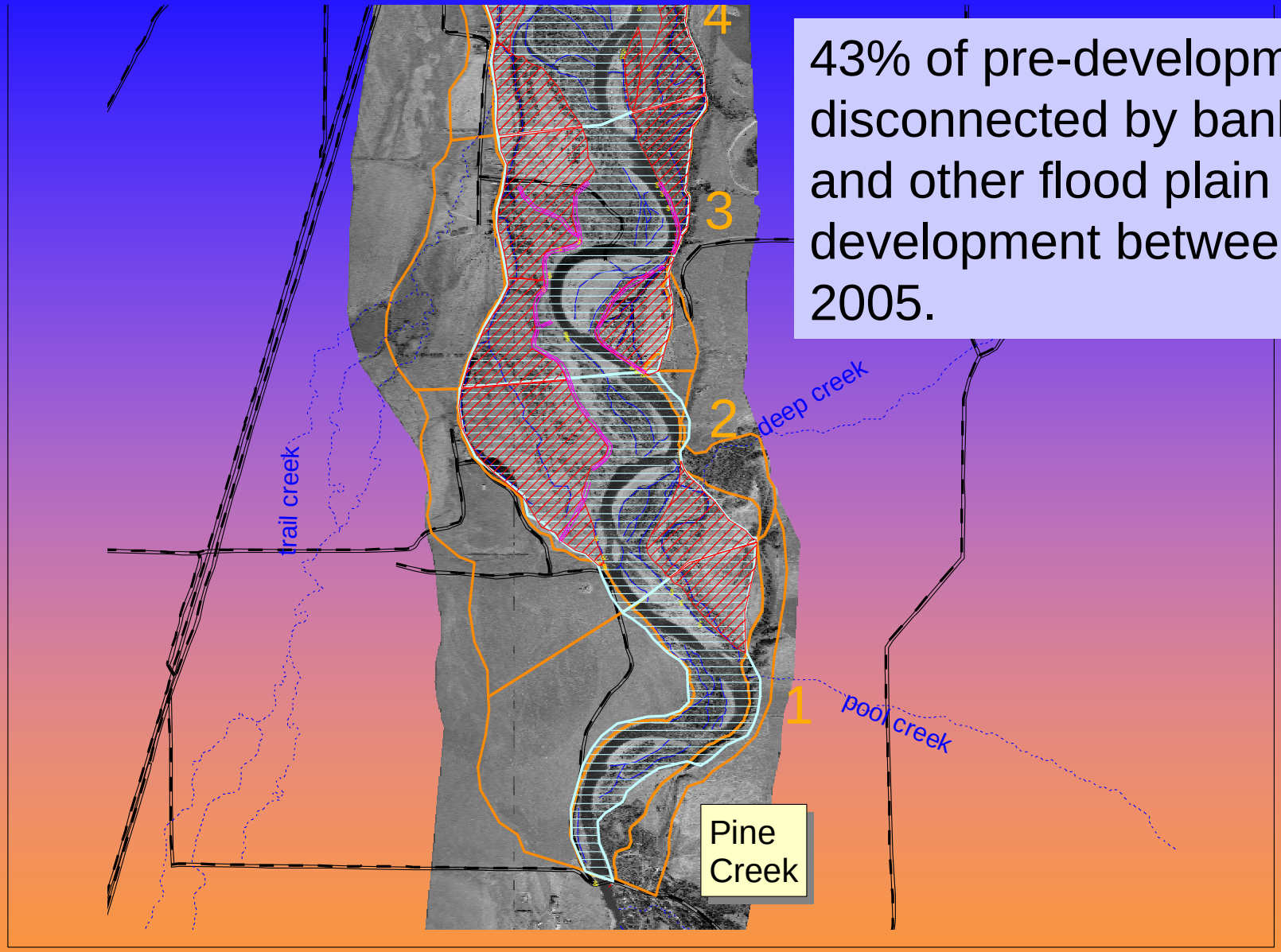
3a. Estimate effect of historic channel confinement on extent of pre-development CMZ.

Pre-Flood plain Development CMZ



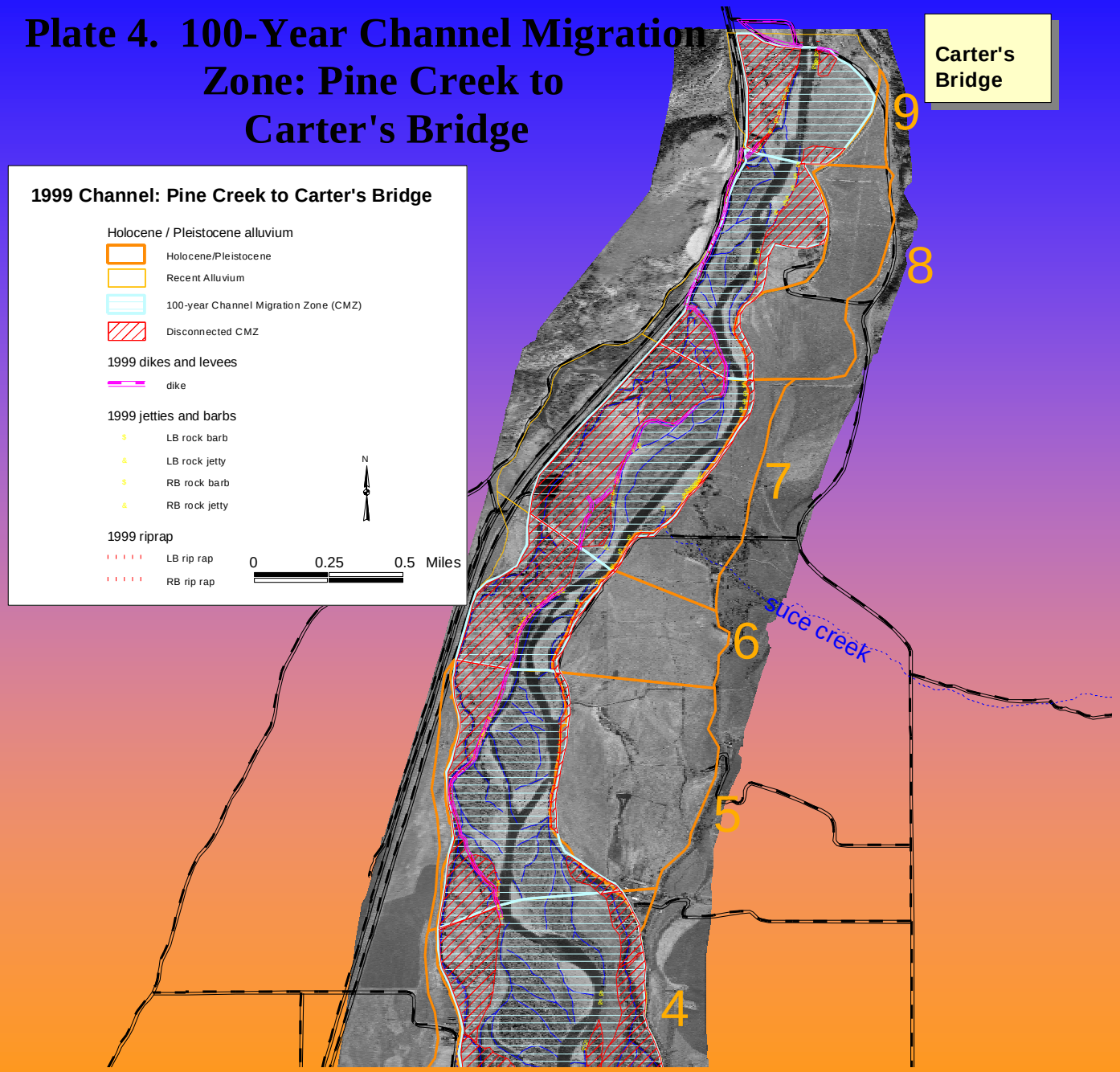
CMZ Disconnection 1954, 1973, 1999

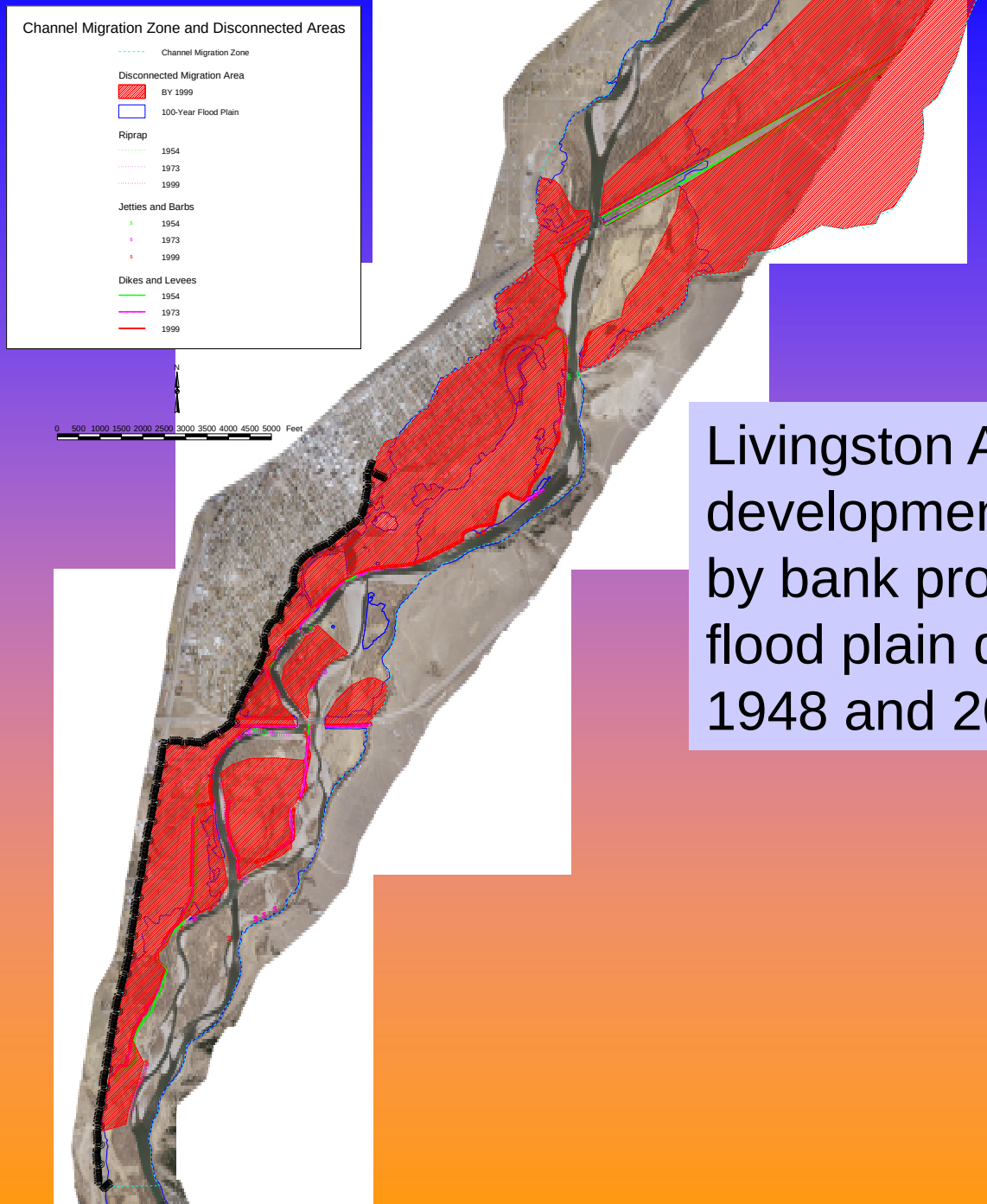




43% of pre-development CMZ disconnected by bank protection and other flood plain development between 1948 and 2005.

Plate 4. 100-Year Channel Migration Zone: Pine Creek to Carter's Bridge

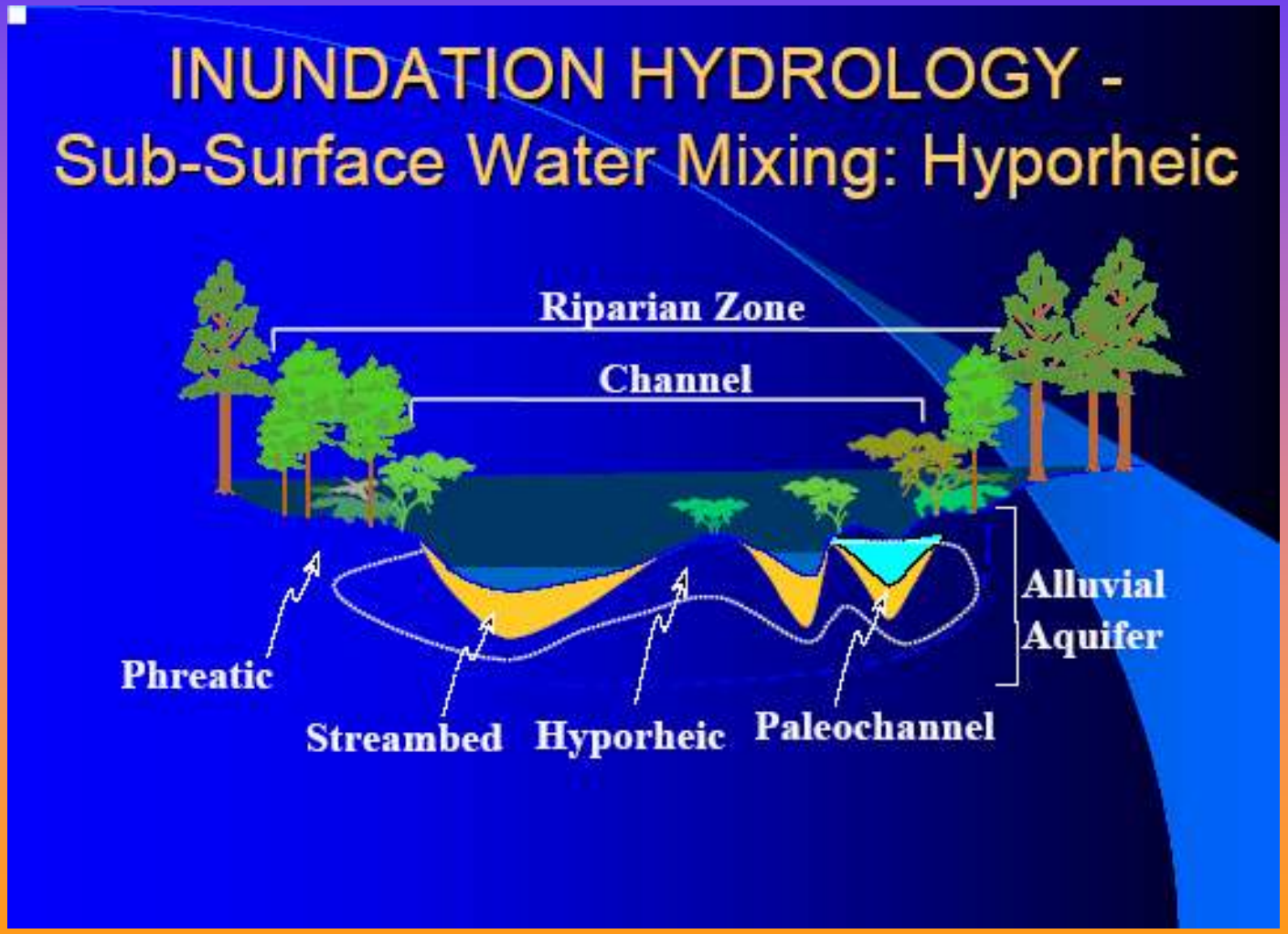




Livingston Area: ~80 % of pre-development CMZ disconnected by bank protection and other flood plain development between 1948 and 2005.

Flood plain and channel benefits* scale directly with width of "active" flood plain (Power et al. 1995)

* hyporheic exchange, nutrient cycling, water temperature cooling, aquatic and terrestrial wildlife habitat



3.b. Estimate Effect of Future Flood Plain Development On Channel Migration Zone

A. Overlay subdivision platts, and eroding bank inventory—assume developed “high” erosion risk sites will eventually protect banks;

B. Assume illustrative future levels of subdivision and Trophy home development, and associated floodplain transportation corridors;

C. Estimate additional disconnected migration area associated with development

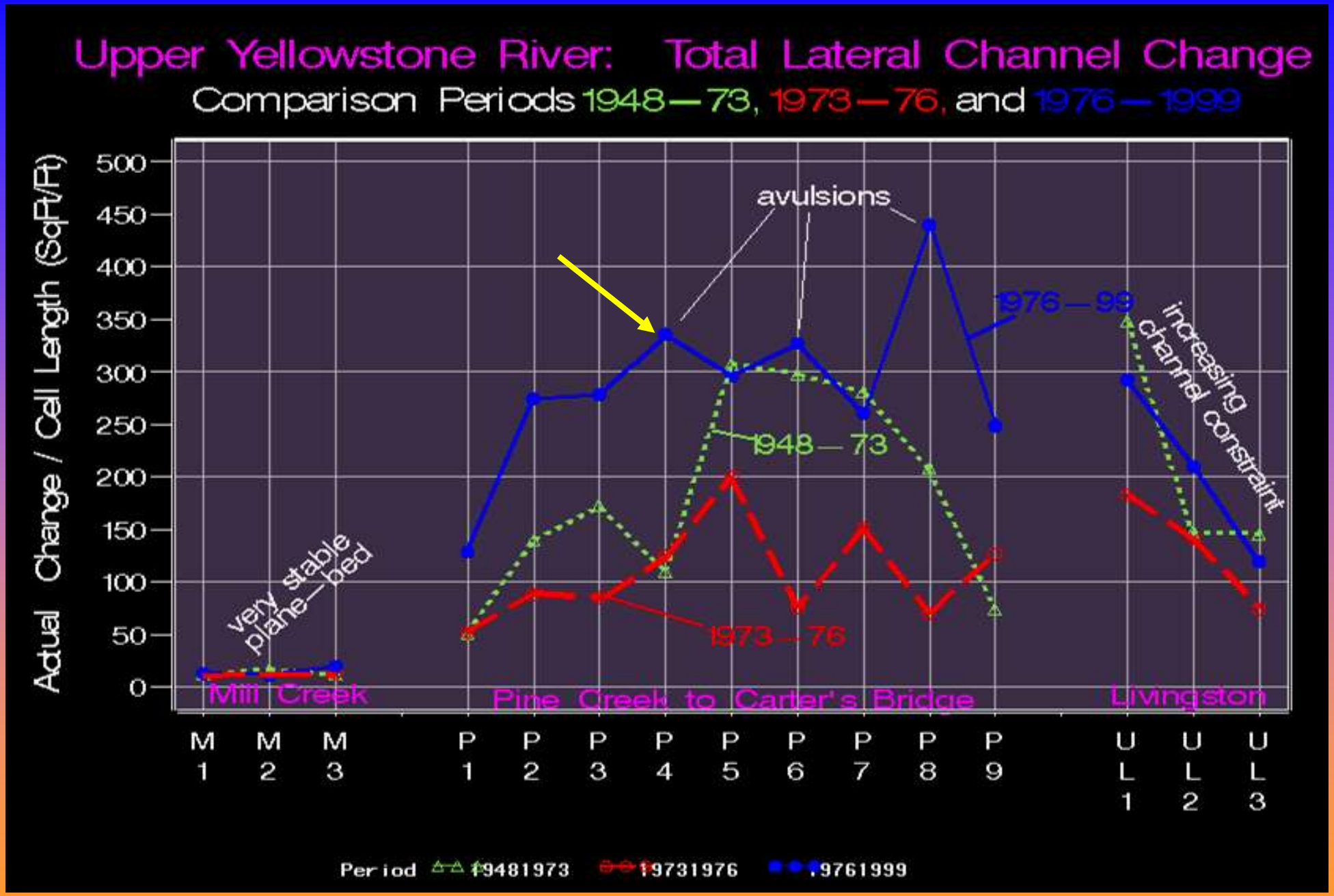
4. Opportunities for Restoration

- **Improve permitting process (do no further harm):**
  1. Recognition of importance of maintenance of CMZ;

  2. Identify segments of "special concern", where the level of design, permit scrutiny, and monitoring are robust:

- **Conservation Easements**: Work with locals and conservation groups to establish restoration management zones (easements) that permit lateral erosion through use of "alternative" restoration treatments and removal of revetment;

Thank You !


Upper Yellowstone River: Total Lateral Channel Change
Comparison Periods 1948—73, 1973—76, and 1976—1999
Actual Change / Cell Length (SqFt/Ft)
500
450
400
350
300
250
200
150
100
50
0
avulsions
1976—99
1948—73
1973—76
increasing channel constraint
very stable plane—bed
Mill Creek
Pine Creek to Carter's Bridge
Livingston
M 1
M 2
M 3
P 1
P 2
P 3
P 4
P 5
P 6
P 7
P 8
P 9
UL 1
UL 2
UL 3
Period 1948 1973
1973 1976
1976 1999