

CAN BEAVER DAMS AGGRADE INCISED STREAMS TO THE POINT OF FLOODPLAIN RECONNECTION AND RECOVERY?



Joe Wheaton
Florie Consolati
Kenny DeMeurichy
Nick Bouwes



Michael Pollock
Chris Jordan
Carol Volk



A FEW YEARS AGO...

- All I knew was that...



THEN I MET THESE GUYS...



Nick Bouwes



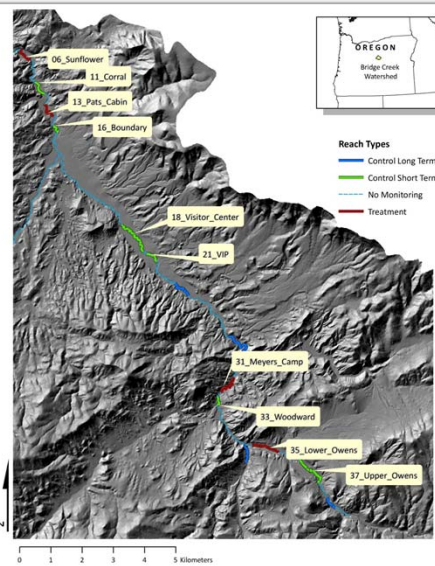
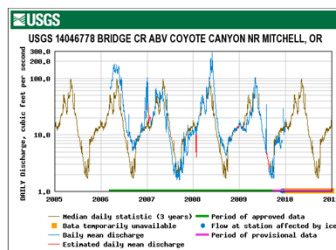
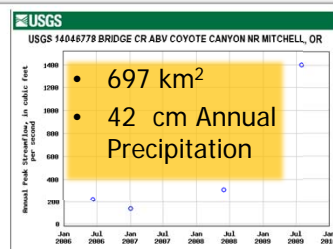
Michael Pollock



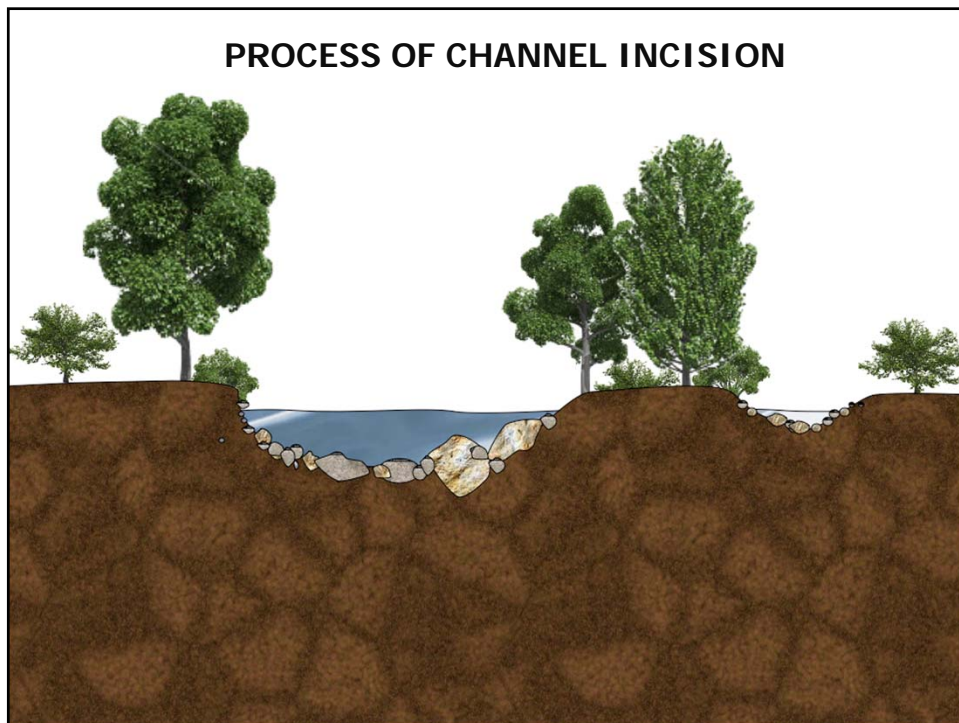
Chris Jordan



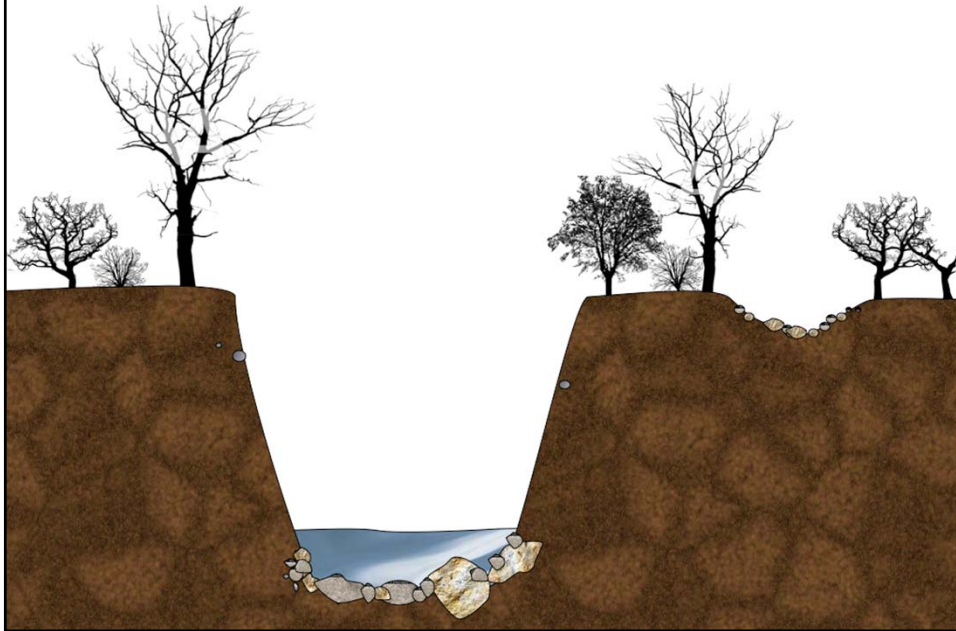
BRIDGE CREEK EXPERIMENTAL WATERSHED





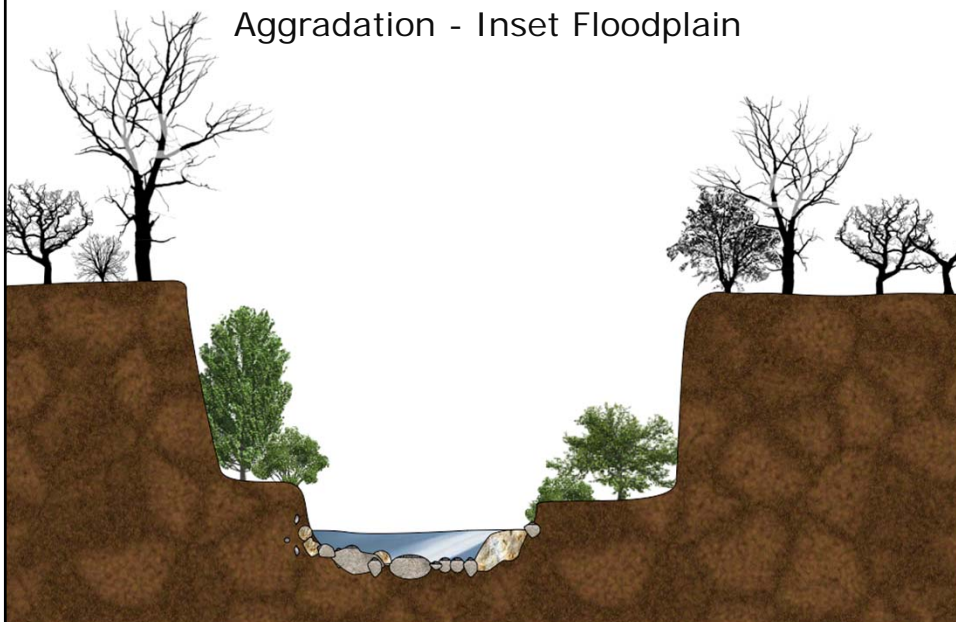


INCISION – DISCONNECTED FLOODPLAIN



LATERAL EROSION

Aggradation - Inset Floodplain



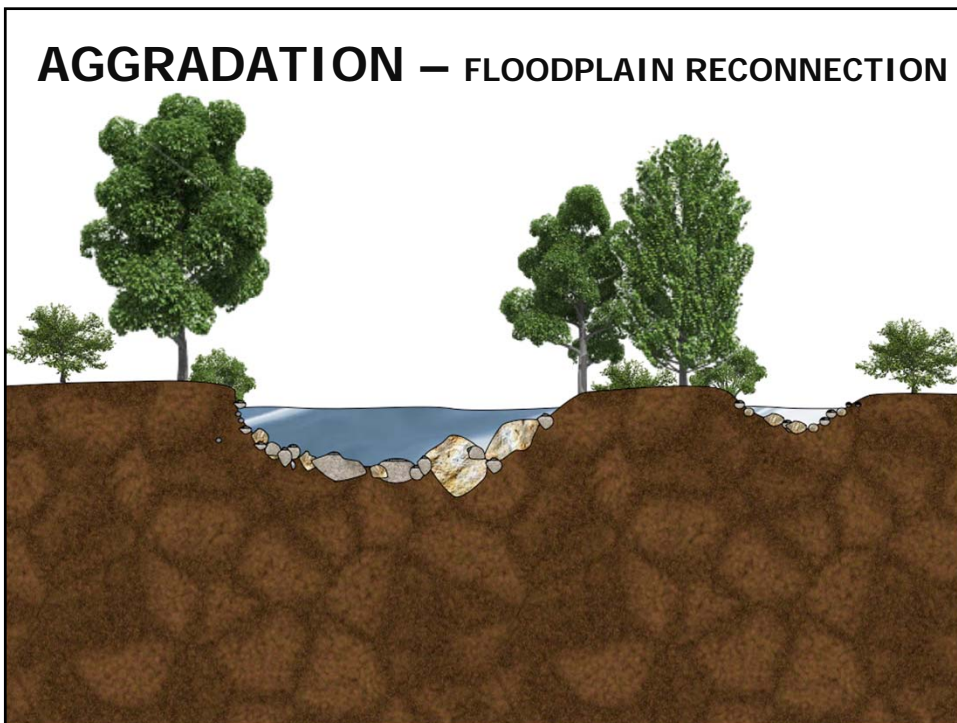


Figure 1 consists of three black and white photographs (a, b, c) and a bar chart. Photograph (a) shows a small dam with water flowing over it. Photograph (b) shows a larger dam with a pool of water upstream. Photograph (c) shows a dam with a significant amount of debris and brush. The bar chart, titled 'Number of Beaver Dams' on the y-axis and 'Year' on the x-axis, displays the total number of inventoried beaver dams per year from 1980 to 2004. The y-axis ranges from 0 to 120 in increments of 20. The x-axis lists years from 1980 to 2004. The data shows a general increase in the number of dams over the period, with a notable peak in 1987 and 1988.

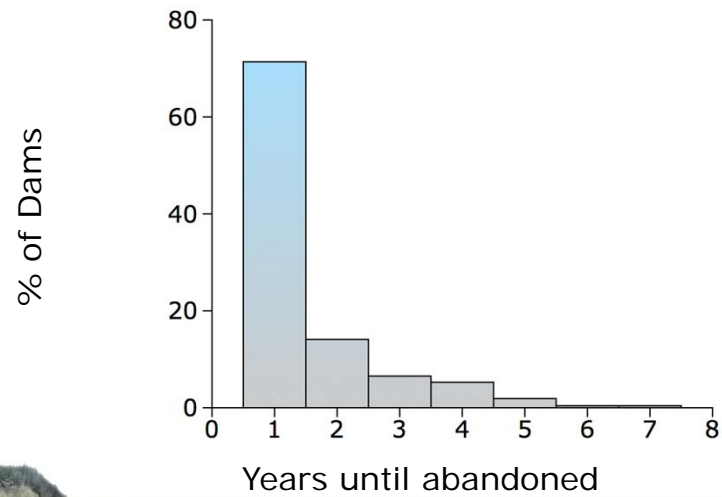
Year	Number of Beaver Dams
1980	35
1981	15
1982	25
1983	50
1984	100
1985	35
1986	95
1987	50
1988	25
1989	15
1990	10
1991	15
1992	40
1993	45
1994	60
1995	65
1996	45
1997	40
1998	45
1999	40
2000	45
2001	40
2002	45
2003	40
2004	45

Figure 1. Total number of inventoried beaver dams, by year, along 25.4 km of Bridge Creek in central Oregon.

Northwest Science, Vol. 82, No. 4, 2008 309

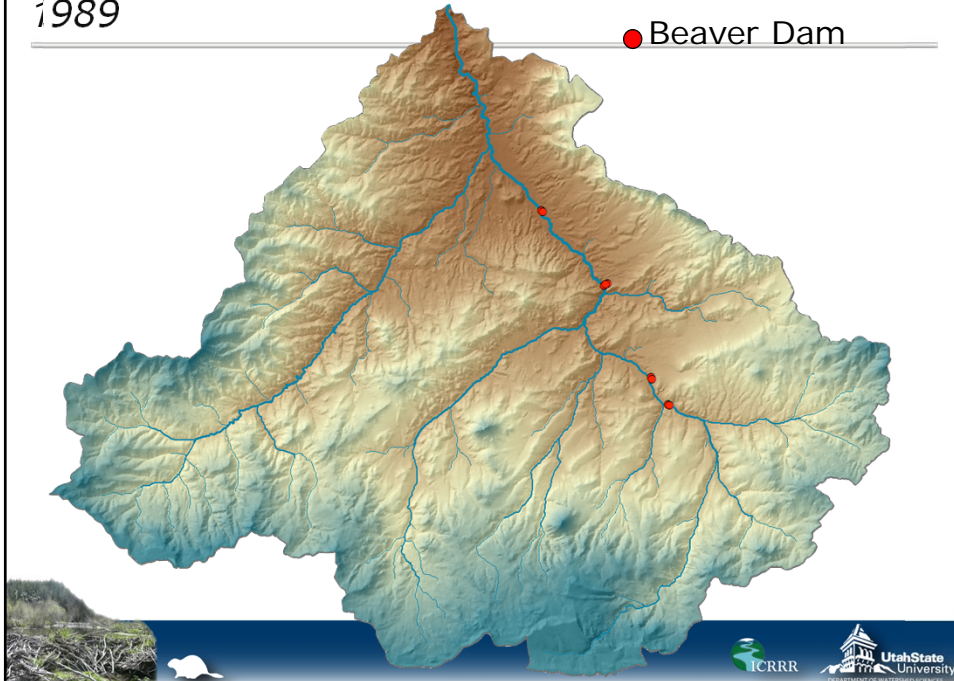


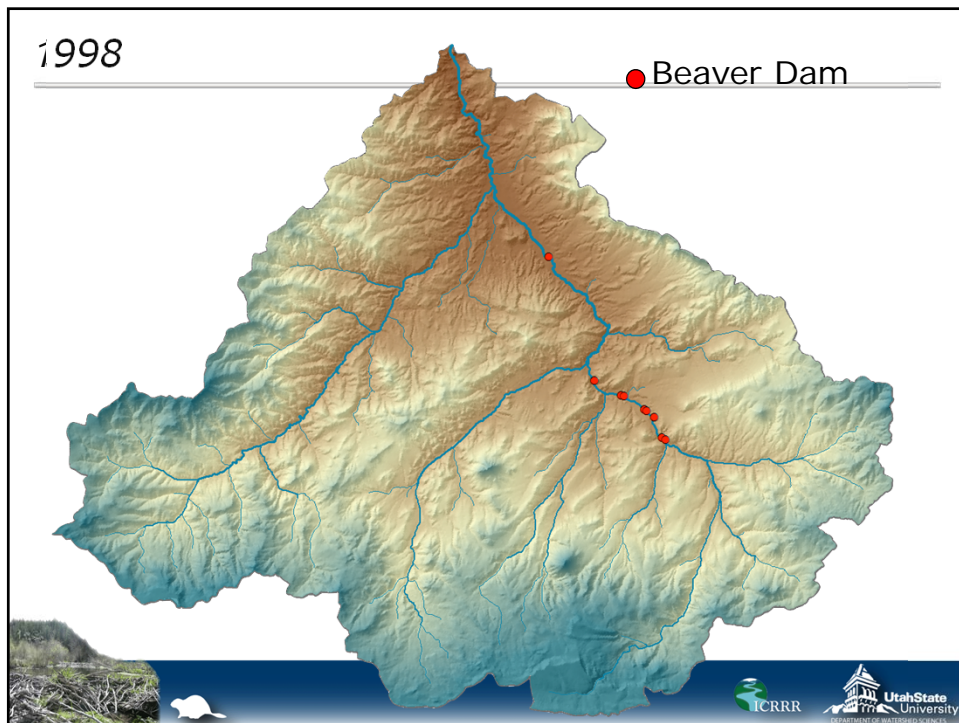
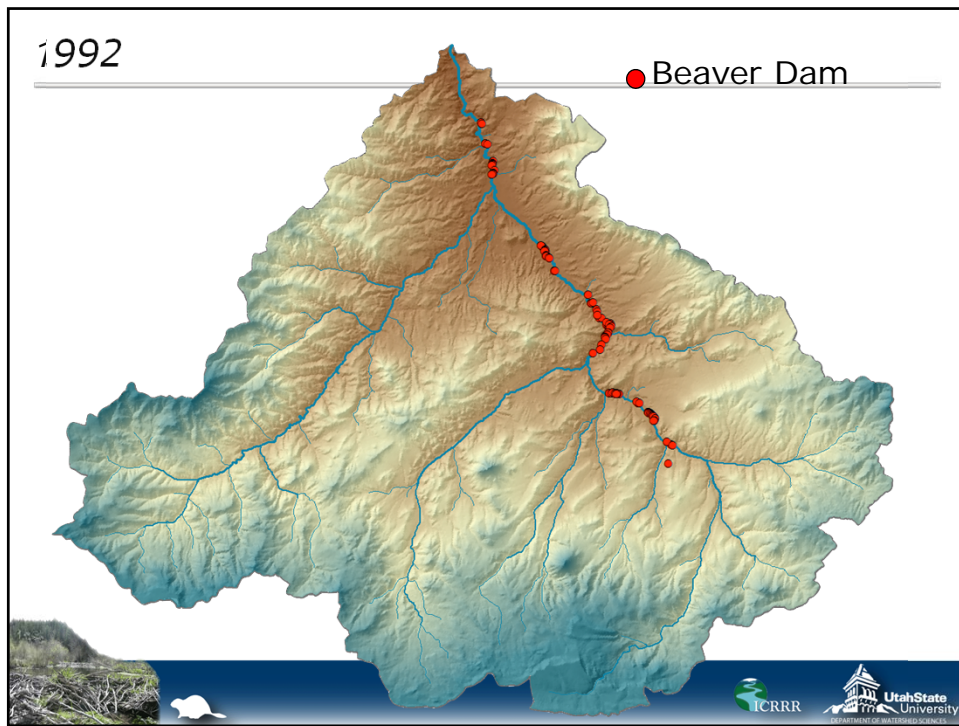
BRIDGE CREEK DAM PERSISTENCE 1988 - 2005



1989

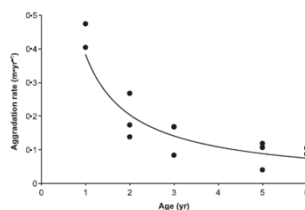
● Beaver Dam







IN POLLOCK ET AL (2007) ARGUED...



channel with adjacent reaches where no dams existed. We found that there was five times more area within 0.5 m elevation of the channel upstream of beaver dams, presumably because sediment accumulation had aggraded the channel. Our results suggest that restoration strategies that encourage the recolonization of streams by beaver can rapidly expand riparian habitat along incised streams. Copyright © 2007 John Wiley & Sons, Ltd.

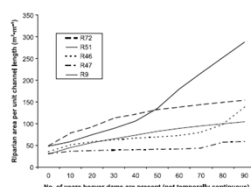


Figure 4. Estimated increase in stream-adjacent area within 0.5 m of the channel bed (i.e. the riparian area) as a function of the number of years for which the reach has active beaver dams, for five reaches on Bridge Creek that currently contain beaver dams. An aggradation rate of 0.5 mm/yr for each year for which beaver dams are present is assumed. The rate of increase of riparian area varies as a result of different degrees of incision and post-incision channel widening.

Earth Surface Processes and Landforms
Earth Surf. Process. Landforms 32, 1174–1185 (2007)
Published online 3 July 2007 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/esp.1553

Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon

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Abstract

Channel incision is a widespread phenomenon throughout the dry interior Columbia River basin and other semi-arid regions of the world, which degrades stream habitat by fundamentally altering natural ecological, geomorphological and hydrological processes. We examined the extent of incised aggradation behind beaver dams in an incised stream in the interior Columbia River basin to assess the potential for using beaver, *Caster canadensis*, dams to restore such channels, and the effect of the aggradation on riparian habitat. We estimated aggradation rates behind 13 beaver dams between 1 and 4 years old on Bridge Creek, a tributary to the John Day River in eastern Oregon. Vertical aggradation rates are initially rapid, as high as 8.47 m yr⁻¹, on the unincised channel floor, then level off to 0.72 m yr⁻¹ by year six as the sediment builds up surrounding the adjacent terrace. We found that a 0.5 m elevation contour above the stream channel approximately coincided with the extent of new riparian vegetation establishment. Therefore, we compared the area surrounding reaches upstream of beaver dams that were within 0.5 m elevation of the stream channel with adjacent reaches where no dams existed. We found that there was five times more area within 0.5 m elevation of the channel upstream of beaver dams, presumably because sediment accumulation had aggraded the channel. Our results suggest that restoration strategies that encourage the recolonization of streams by beaver can rapidly expand riparian habitat along incised streams. Copyright © 2007 John Wiley & Sons, Ltd.

Received 1 October 2006
Revised 10 January 2007
Accepted 17 February 2007

Keywords: incision; aggradation; *Caster canadensis*; riparian; Oregon

Introduction

Channel incision is a common occurrence in stream channels throughout the semi-arid regions of the interior Columbia River basin, where a fragile balance between climate, vegetation and geology makes the vertical stability of channels highly vulnerable to changes in hydrologic erosion, stream discharge and loss of human resistant elements (Cooke and Warren, 1970; Weiler, 1991; Peacock, 1994). We define incision as a rapid downcutting and lowering of the stream bed such that it reduces the frequency and duration of flooding onto the adjacent floodplain (Cooke and Warren, 1970; Weiler, 1991; Peacock, 1994). Incision is a common response of streams to land use changes throughout much of the semi-arid regions of the American West and in other regions of North America, Africa, Australia, Europe, Asia, the Middle East and South America (Cooke and Warren, 1970; Schumm et al., 1984; Nagle, 1995; Pomeroy et al., 1994; Simon et al., 1995; Vanlaningham et al., 2000).

Incision has degraded instream and riparian habitat throughout the Columbia River basin, suggesting that recolonization of such streams would benefit numerous species. Of particular interest is improving habitat for salmonids, because many of the Columbia River stocks are listed under the United States Endangered Species Act. Many streams in the Columbia River basin that historically supported salmon no longer do so, and habitat conditions are severely degraded in these incised streams (Hedden et al., 1991; Emmer et al., 1994; Weiler, 1994). Incision can drastically affect stream habitat for salmon and other fishes by the lowering of stream-adjacent riparian habitat and the subsequent loss of riparian vegetation. The loss of above-ground vegetation reduces shading and organic inputs to the stream (Beechie and Ferguson, 1975; Kilham et al., 2000), while the loss of below-ground roots increases the erodibility

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SO HELP 'EM OUT... BUY THEM ~~POSTS~~ TIME

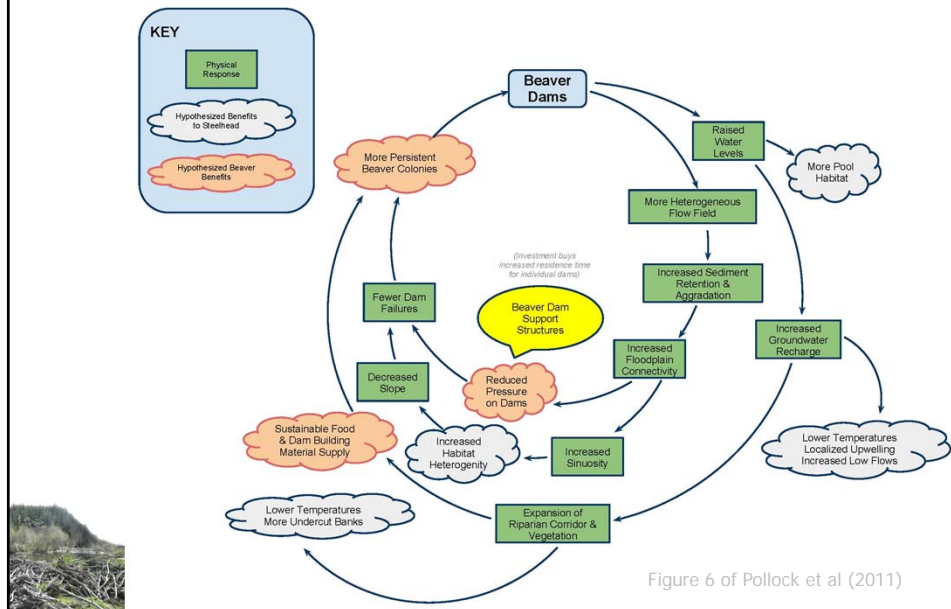


OVERARCHING HYPOTHESIS

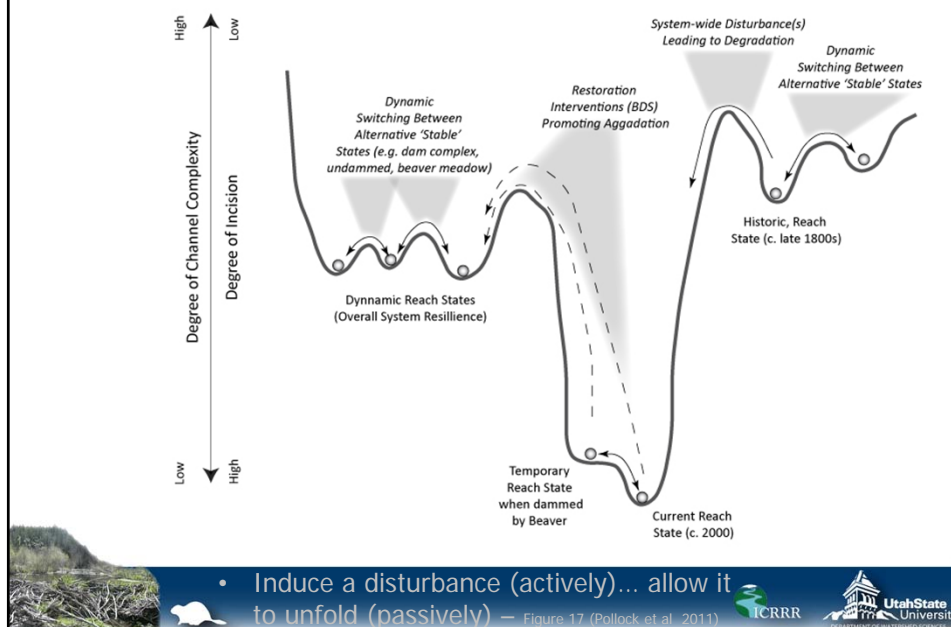
- At Watershed Scale:
 - We can concentrate enough restoration activity within a single watershed such that there is a measureable population-level change in the steelhead that utilize the system
- At Reach Scale:
 - *These* physical changes will result in several positive feedback loops that will result in improved habitat conditions for beaver that in turn will lead to the construction of more beaver dams...

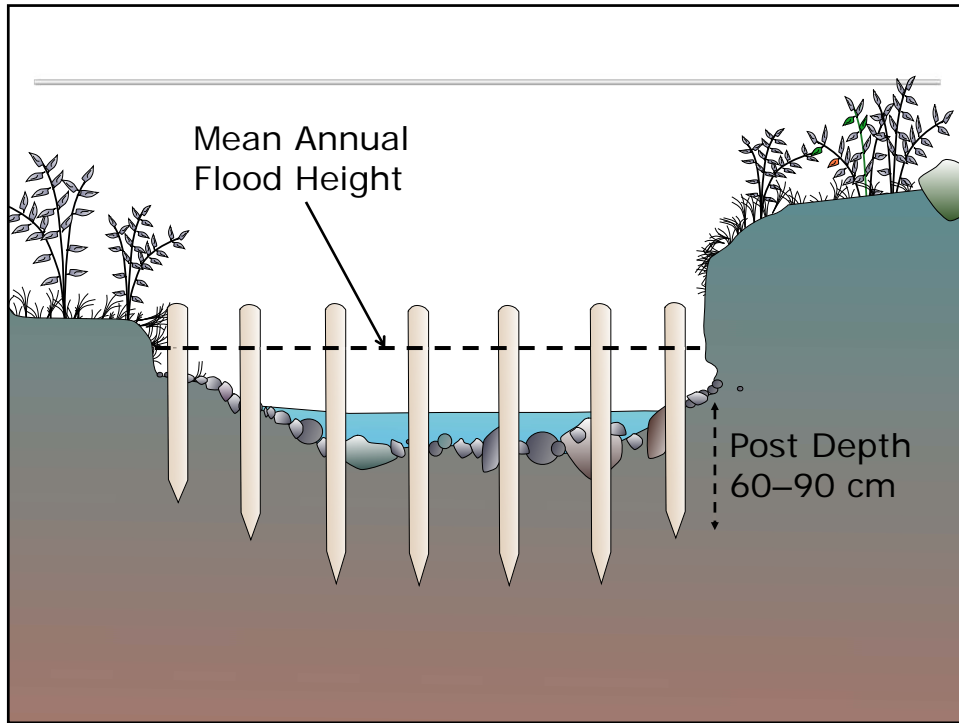


BEAVER DAM FEEDBACK LOOPS...



DESIGN CONCEPT





FOUR STRUCTURE TYPES



Figure 10. A typical starter dam (DF-17 at Safflower) with willow branches woven between vertical posts and the back side sealed with rock and clay. Note the dam height is sufficient to divert flow onto the 60 terrace, mimicking a stable beaver dam.



Figure 12. The purpose of a post line is to provide a site where beaver can build a stable dam. They generally create little or no geomorphic changes unless utilized by beaver.



Figure 11. A post line with willow weave is similar to a starter dam, but acts more like a weir in that water is allowed to flow through the willow branches such that one does not overtopping the structure and the woven branches may not extend to the top of the posts. These may naturally seal up by trapping sediment and organic material moving downstream or they may be utilized by beaver. Note that beaver have started to colonize this point, as evidenced by the chewed stems on the right of the photograph, angled parallel to the flow.

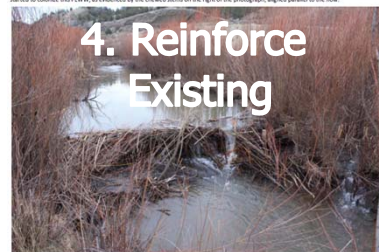


Figure 13. Any active dams within the treatment areas were strengthened with posts to lengthen their functional life, since most dams along the Inland Bridge Creek have been shown to last less than a year (Patterson and Bechta, 2006). The structure was one of four dams built in sequence at Lower Owens to form a new colony. Within one year, all four dams had been sealed with willows, which improved floodplain connectivity and habitat complexity, but made the site unusable for beaver. However, because we had installed additional post lines just downstream the beaver were able to use them to build new dams which allowed the colony to persist.



BASIC DESIGN CONCEPTS...

- Structures placed at frequency to capitalize on all opportunities to promote aggradation and floodplain reconnection through time
- Overseed reaches (relative to current population)
- Structure work in concert with each other to
 - Avoid overly abrupt gradient drops
 - Resilience of reach/colony; demphasizes importance of any single structure
- Designed to be dynamic (posts will break down eventually)
- Sediment supply is fundamental





WHERE TO PUT POSTS?



STRUCTURE SITING – PATS & SUNFLOWER

BDSS Type

- 20
- Pats Cabin Beaver Dam
- Pats Cabin Dam
- Roadcrossed Abandoned Dam
- Roadcrossed Existing Dam
- Stone Dam
- Sunflower Dam

Bridge Creek - Pats Cabin Beaver Dam Support Structures

BDSS Type

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- Pats Cabin Beaver Dam
- Pats Cabin Dam
- Roadcrossed Abandoned Dam
- Roadcrossed Existing Dam
- Stone Dam
- Sunflower Dam

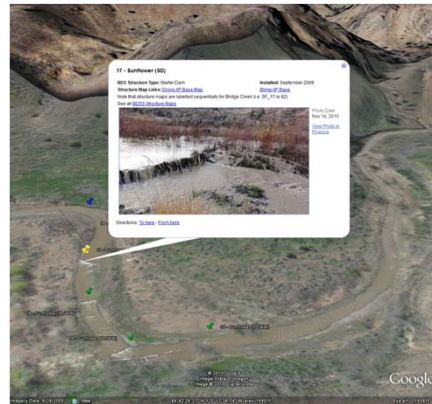
Bridge Creek - Sunflower Beaver Dam Support Structures

ICRRR

Utah State University
DEPARTMENT OF WATERSHED SCIENCES

[illegible]

- 84 Structures installed in four reaches in 2009
 - 5 Reinforced existing dams
 - 4 Reinforced abandon dams
 - 10 Starter Dams
 - 44 Post lines with Wicker Weaves
 - 21 Post lines only



BRIDGE CREEK MONITORING

- I. Hypothesis Testing at Reach Scale
- II. Hypothesis Testing at Structure Scale
- III. What we still don't know

- Pre-Project beaver monitoring (Since 1988)
- Pre-Project baseline monitoring (Since 2005)
- Post-Project monitoring (planned for 10+ years)



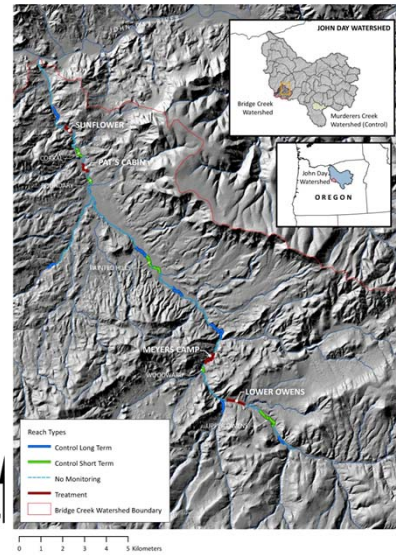
UNDERLYING RESEARCH QUESTIONS?

- Can it work? Can beaver really 'restore' an incised channel and reconnect it with its floodplain?
- What will be the impact on fish?
- How long will it take?
- How long might it last?
- If the beaver (or their dams) fail or abandon, are all the presumed benefits of damming lost?

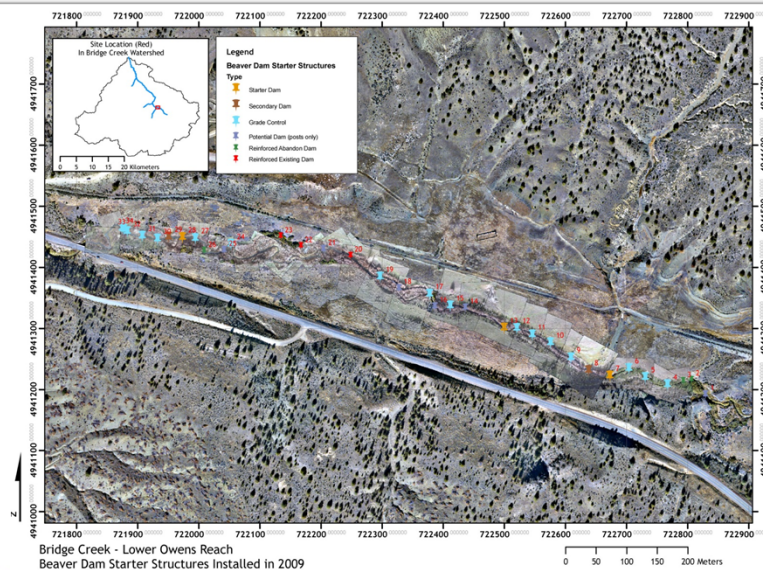


WHAT WE'RE DOING TO ADDRESS THESE QUESTIONS...

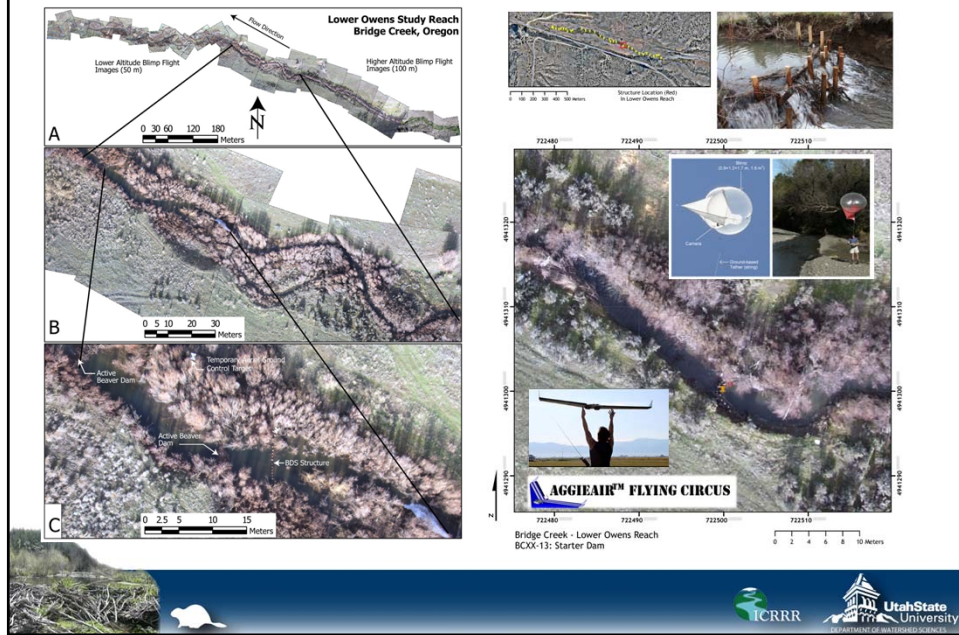
- 4 Treatments & 6 Controls (25 km)
- Slough of things...
 - BDSS Monitoring
 - Repeat Aerial Surveys
 - Repeat Topographic Surveys
 - Beaver Monitoring
 - Fish Habitat Surveys
 - Fish growth, survival & movement
 - Fish diets



BDSS INVENTORY & MONITORING



HIGH RESOLUTION IMAGERY





DRONE IMAGERY

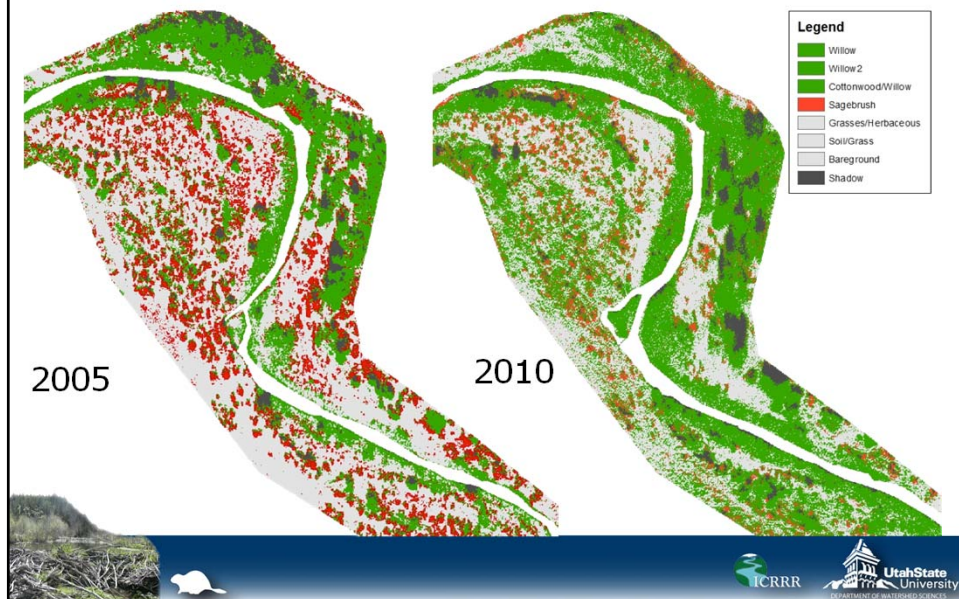
0.5 m Naip



0.1 m Drone



DRONE IMAGERY VEGETATION CLASSIFICATION



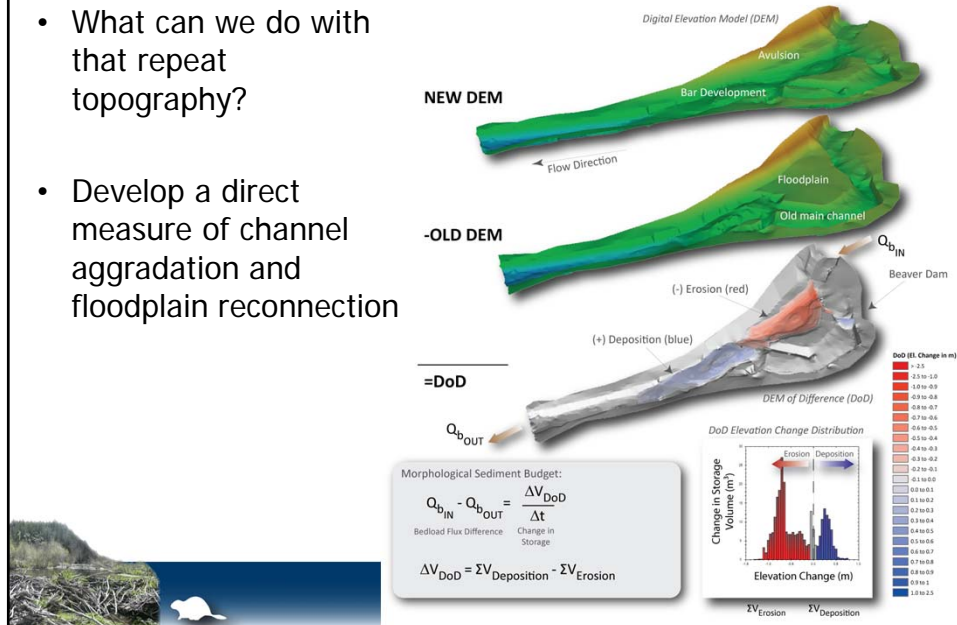
REPEAT TOPOGRAPHY

F1



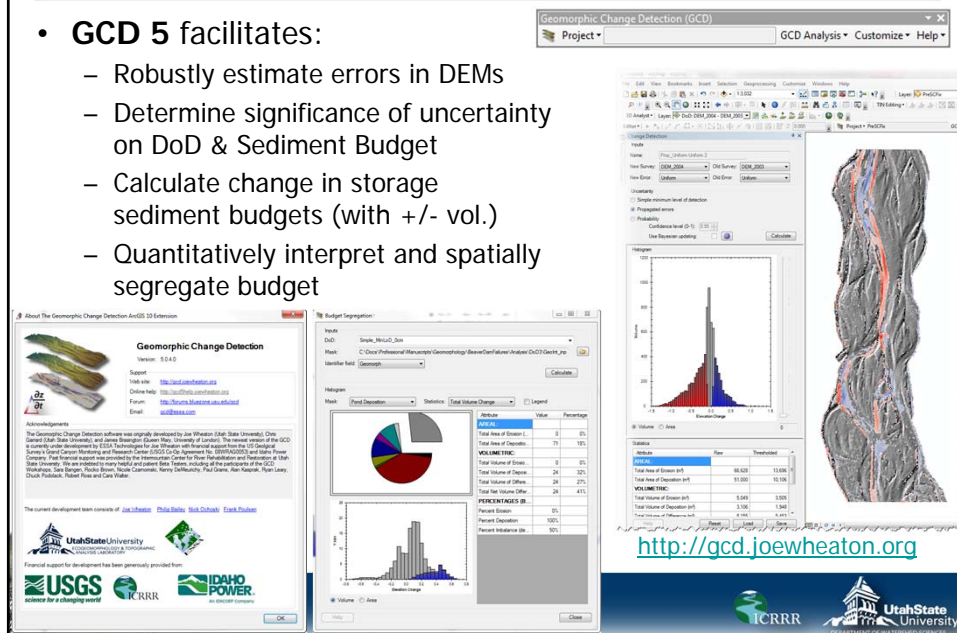
GEOMORPHIC CHANGE DETECTION

- What can we do with that repeat topography?
- Develop a direct measure of channel aggradation and floodplain reconnection



ANALYSIS DONE IN GCD 5

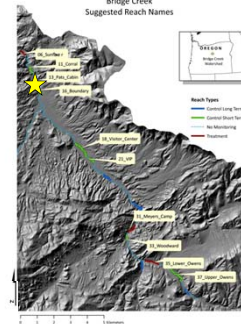
- **GCD 5** facilitates:
 - Robustly estimate errors in DEMs
 - Determine significance of uncertainty on DoD & Sediment Budget
 - Calculate change in storage sediment budgets (with +/- vol.)
 - Quantitatively interpret and spatially segregate budget



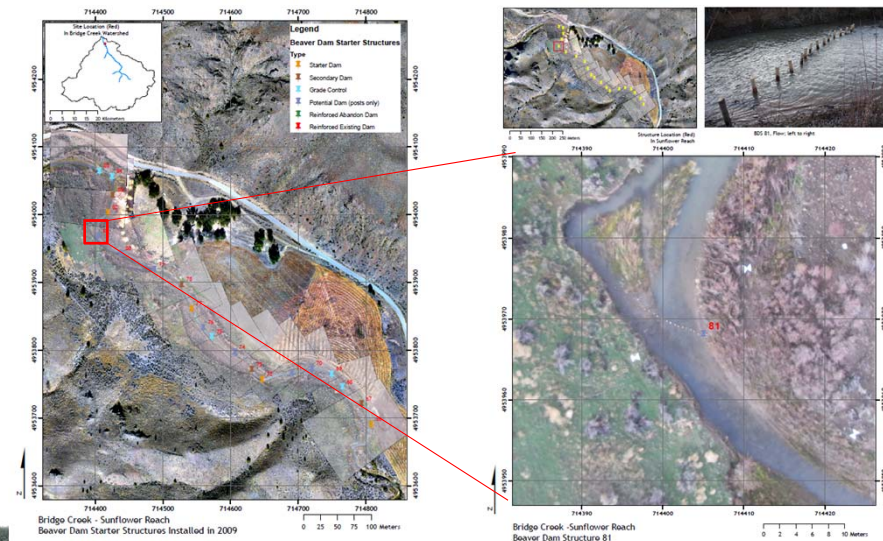
LETS LOOK AT ONE TREATMENT

Pat's Cabin Reach

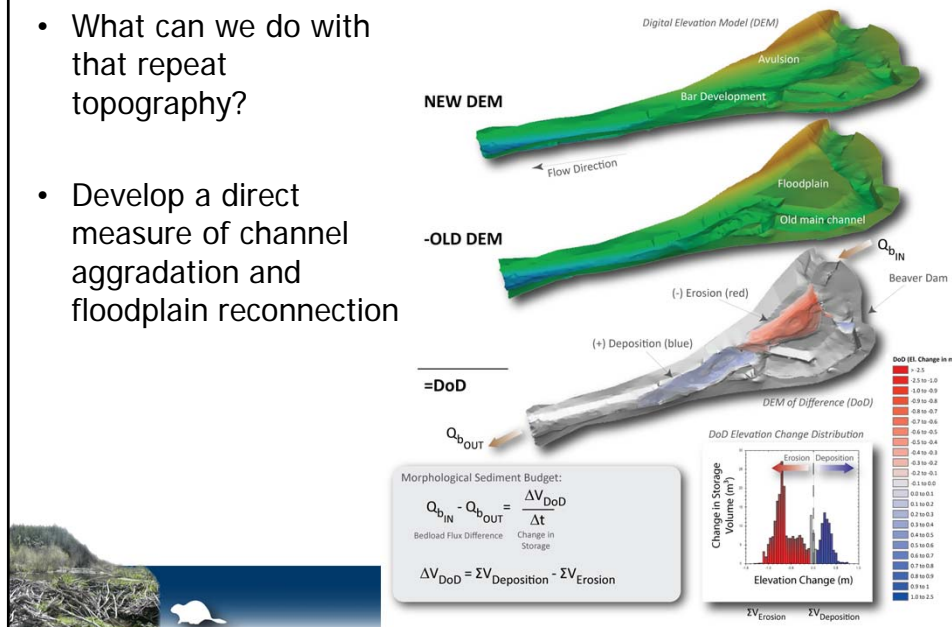
- Can it work? **Can beaver really 'restore' an incised channel and reconnect it with its floodplain?**
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- How long will it take?



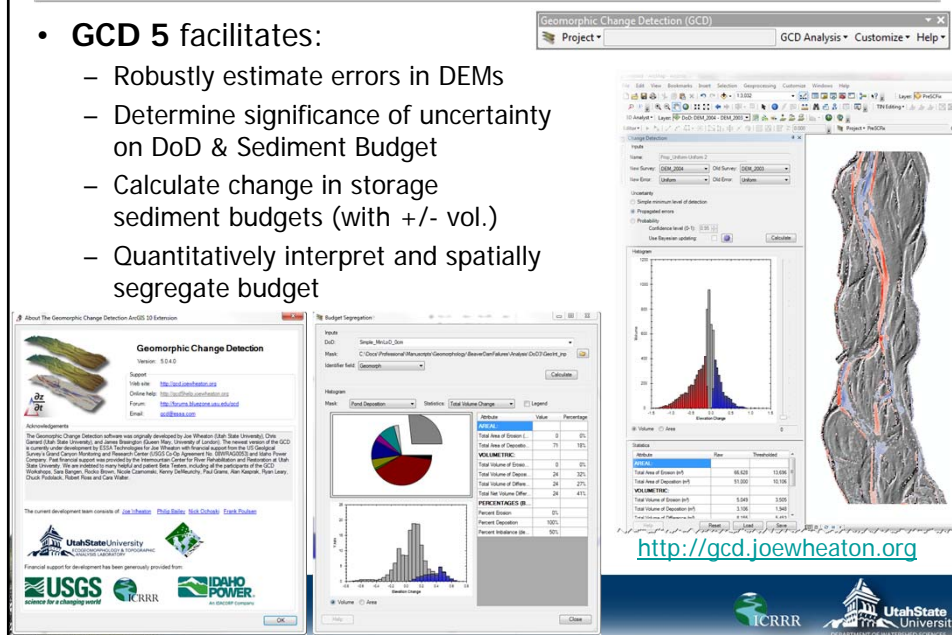
SUNFLOWER: BDSS PLACEMENT



- What can we do with that repeat topography?
- Develop a direct measure of channel aggradation and floodplain reconnection



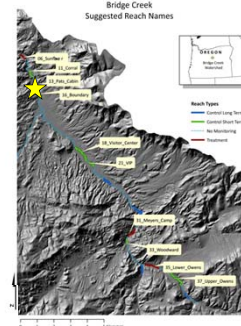
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LETS LOOK AT ONE TREATMENT

Pat's Cabin Reach

- Can it work? **Can beaver really 'restore' an incised channel and reconnect it with its floodplain?**
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STARTER DAM OCCUPIED...



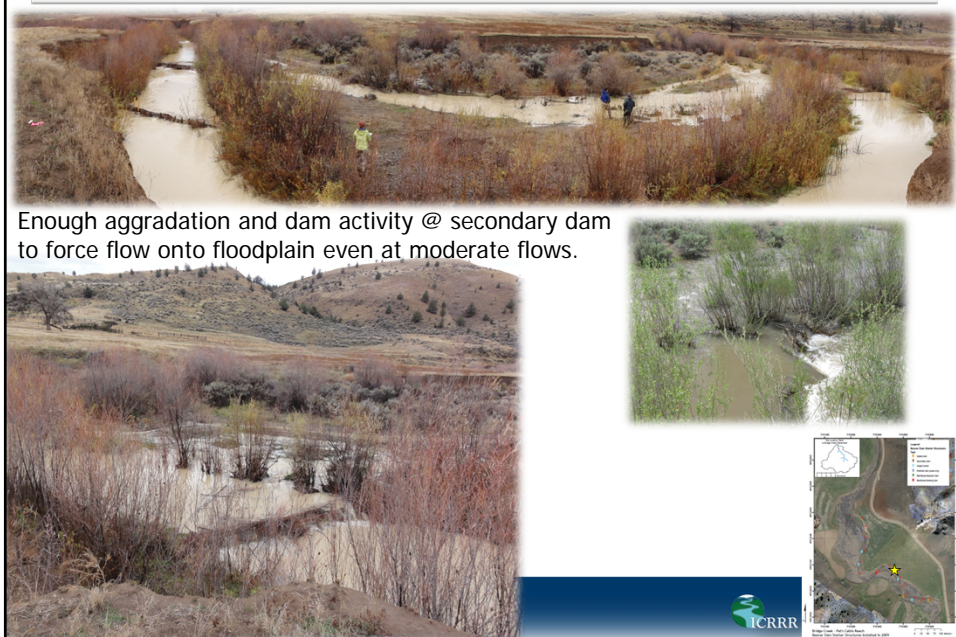
Installed September 2009, Occupied by November 2009



ANOTHER STARTER DAM OCCUPIED



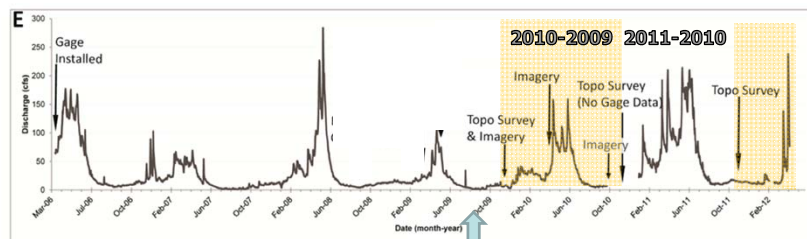
FLOW FORCED ONTO FLOODPLAIN



STARTER DAM UPSTREAM OF FAILED DAM



BRIDGE CREEK FLOWS...



BDSS INSTALLED (Sept. 2009)

- Limited gage record (USGS: 14046778)
- Spring snow-melt dominated hydrograph
- 1st Year above average; 2nd Year sustained high flows

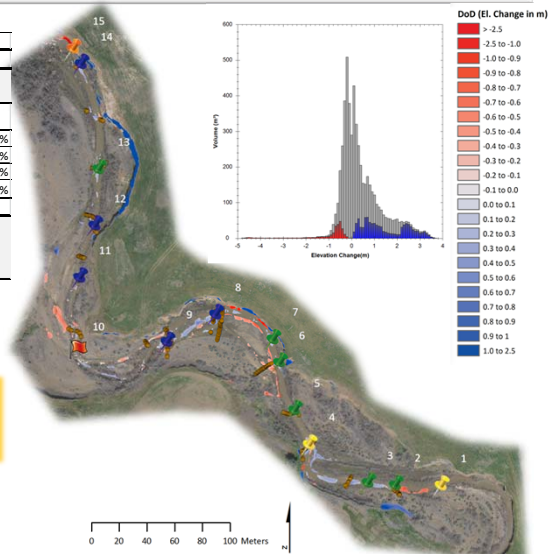


1st YEAR (2010-2009): OVERALL DoD

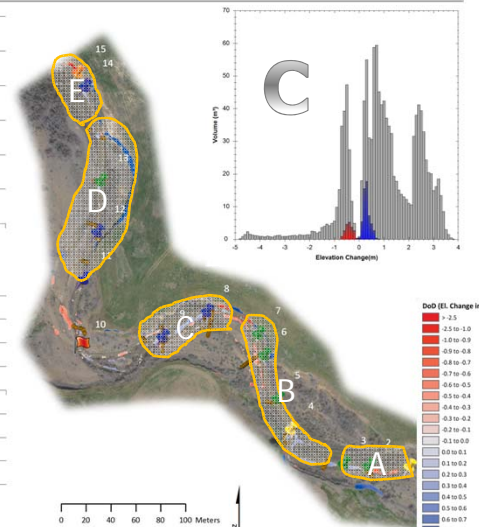
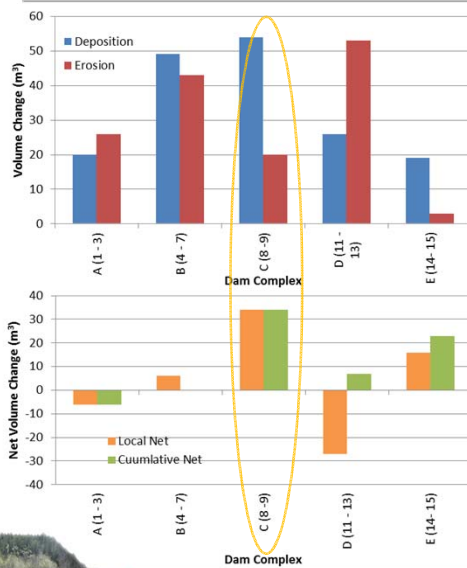
Attribute	Raw	Thresholded DoD Estimate:		
AREAL:				
Total Area of Erosion (m ²)	15,383	461		
Total Area of Deposition (m ²)	178,117	1,151		
VOLUMETRIC:				
Total Volume of Erosion (m ³)	2,035	260 ± 83	32%	
Total Volume of Deposition (m ³)	3,485	967 ± 300	31%	
Total Volume of Difference (m ³)	5,520	1,227 ± 383	31%	
Total Net Volume Difference (m ³)	1,450	707 ± 311	44%	
PERCENTAGES (BY VOLUME)				
Percent Erosion	37%	21%		
Percent Deposition	63%	79%		
Percent Imbalance (departure from equilibrium)	13%	29%		

IN CHANNEL ONLY

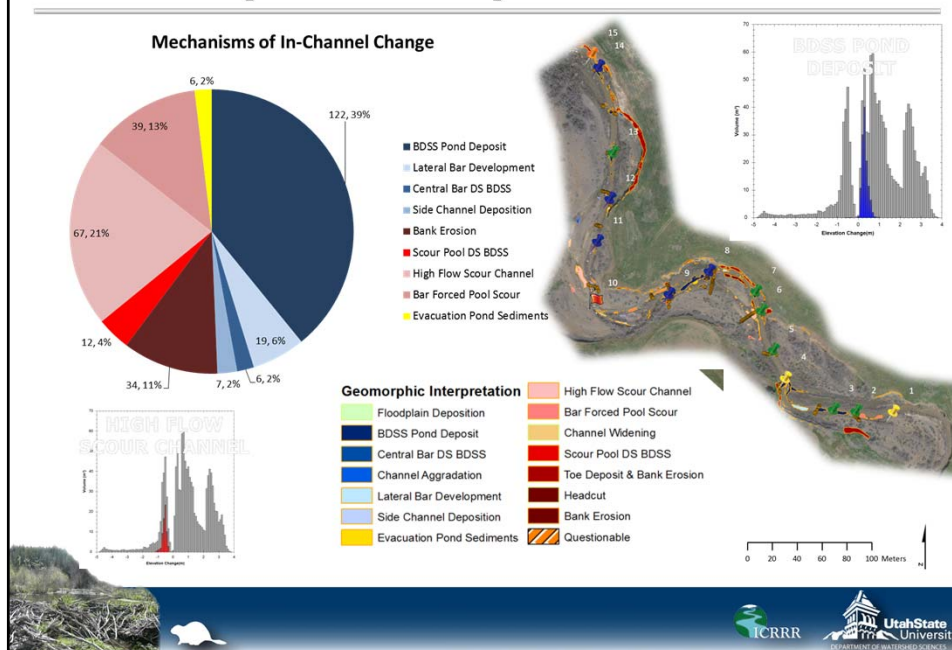
Erosion: 169 m³ +/- 54
 Deposition: 176 m³ +/- 58
 NET: + 7 m³ (+/- 79)



1st YEAR (2010-2009): BY COMPLEX



1st YEAR (2010-2009): BY MECHANISMS

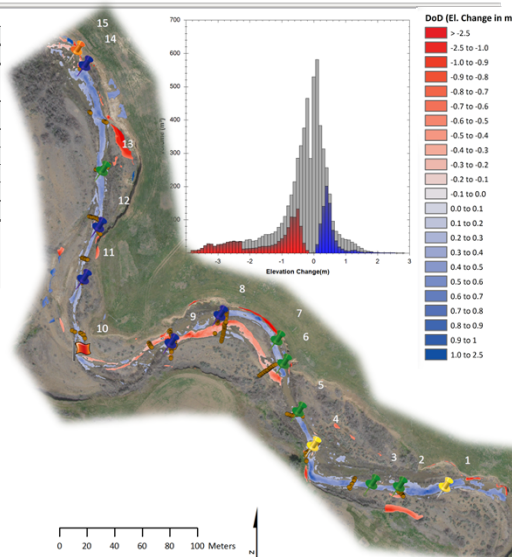


2nd YEAR (2011-2010): OVERALL DoD

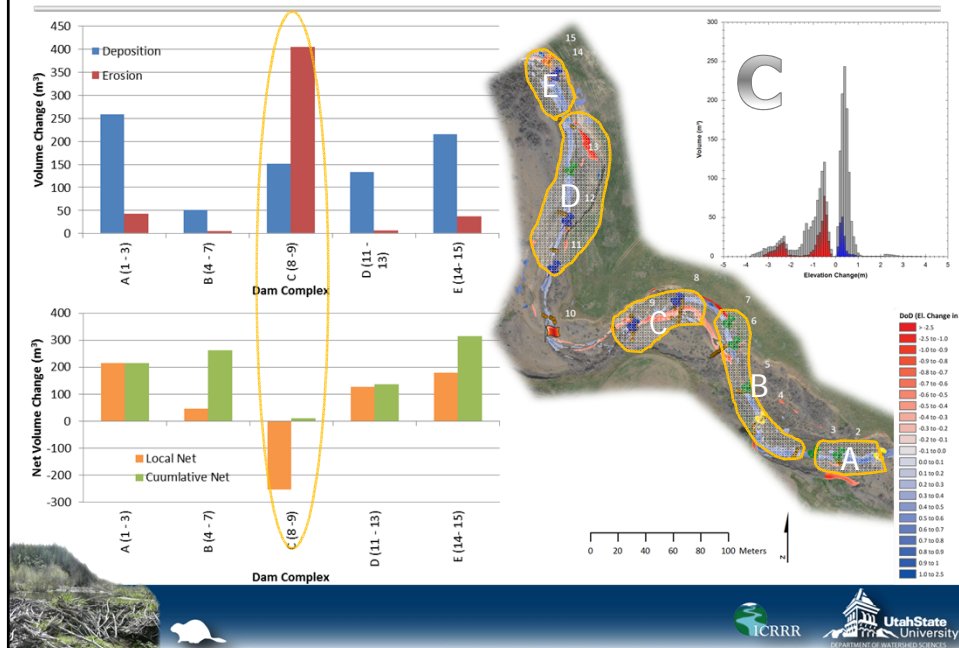
Attribute	Raw	Thresholded DoD Estimate:		
AREAL:				
Total Area of Erosion (m²)	14,626	1,582		
Total Area of Deposition (m²)	178,874	1,872		
VOLUMETRIC:				
			± Error	% Error
Total Volume of Erosion (m³)	3,468	1,281 ± 362		28%
Total Volume of Deposition (m³)	2,715	808 ± 208		26%
Total Volume of Difference (m³)	6,183	2,089 ± 570		27%
Total Net Volume Difference (m³)	-752	-473 ± 418		-88%
PERCENTAGES (BY VOLUME)				
Percent Erosion	56%	61%		
Percent Deposition	44%	39%		
Percent Imbalance (departure from	-6%	-11%		

IN CHANNEL ONLY

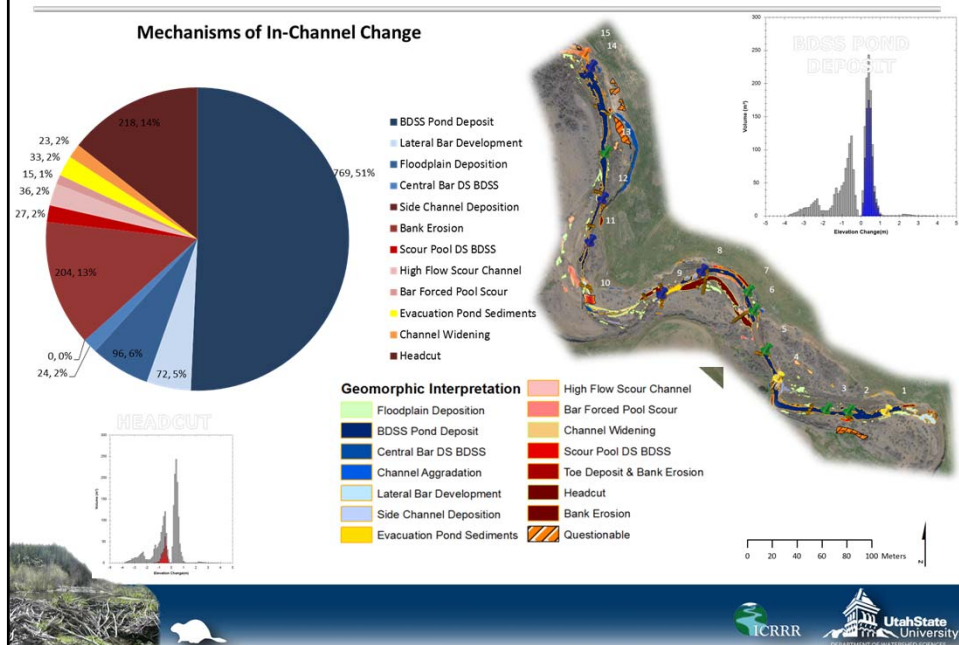
Erosion: 512 m³ +/- 143
 Deposition: 927 m³ +/- 241
 NET: + 415 m³ (+/- 280)



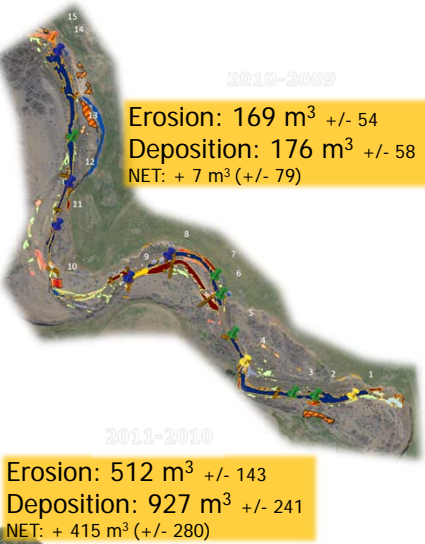
2nd YEAR (2011-2010): BY COMPLEX



2nd YEAR (2011-2010): BY MECHANISMS



WHAT WE TAKE AWAY FROM PATS CABIN...




2010-2009

Erosion: $169 \text{ m}^3 \pm 54$
Deposition: $176 \text{ m}^3 \pm 58$
NET: $+ 7 \text{ m}^3 (\pm 79)$

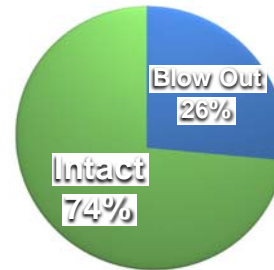
2011-2010

Erosion: $512 \text{ m}^3 \pm 143$
Deposition: $927 \text{ m}^3 \pm 241$
NET: $+ 415 \text{ m}^3 (\pm 280)$

- 1st year budget indeterminant or equilibrium
- 2nd year budget strong depositional signal despite major headcuts & breaches
- Longitudinal patterns highlight role of local supply
- BDSS Pond aggradation rapid and consistent
- Many former terraces are now inset floodplains
- If it works, its cheap!
- Beaver do the maintenance!

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BDSS PERSISTENCE



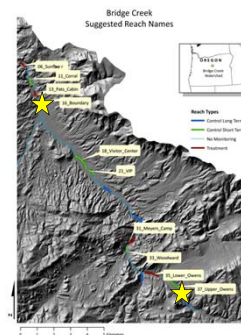
From Nick Weber



NEXT LETS LOOK AT 'FAILURES'...

Upper Owens & Boundary

- If the beaver (or their dams) fail or abandon, are all the presumed benefits of damming lost?



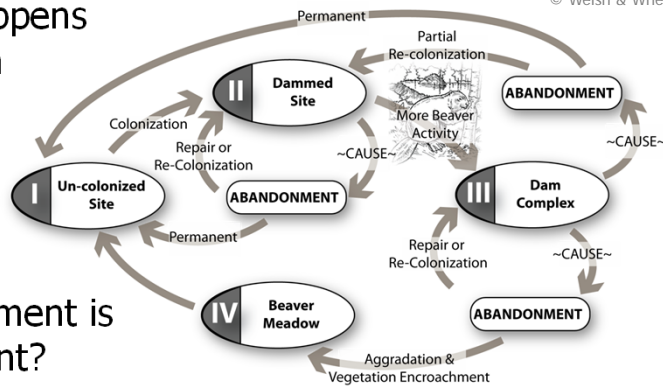
When a dam fails, what happens to the pond deposit that was reconnecting the floodplain?



ROLE OF ABANDONMENT & FAILURE

- What happens post dam failure?

- What if abandonment is permanent?



Typical Causes of Abandonment

*Causes with potential for repair or later recolonization by same individual(s)

Temporary	Permanent
<ul style="list-style-type: none"> Seasonal Migration (temporary) Exhaustion of Food/Building Materials (permanent or temporary) Decreased Functionality (e.g. pond aggradation; permanent or temporary) Predation (natural; permanent or temporary) 	<ul style="list-style-type: none"> Dam Breach/ Failure (permanent or temporary) Permanent Migration (permanent) Trapping (human; permanent) Mortality (natural; permanent)

UPPER OWENS

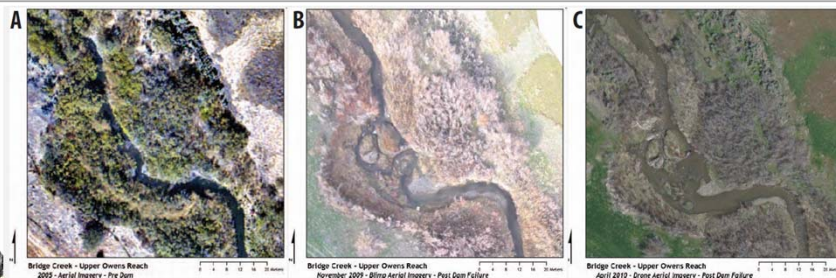
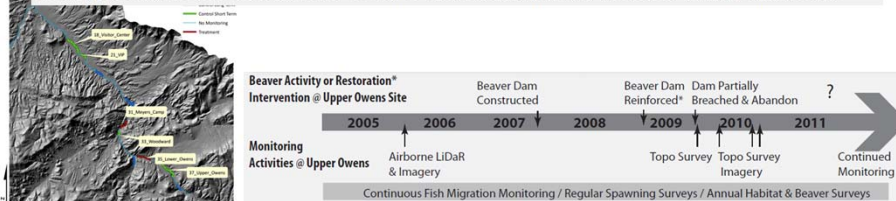
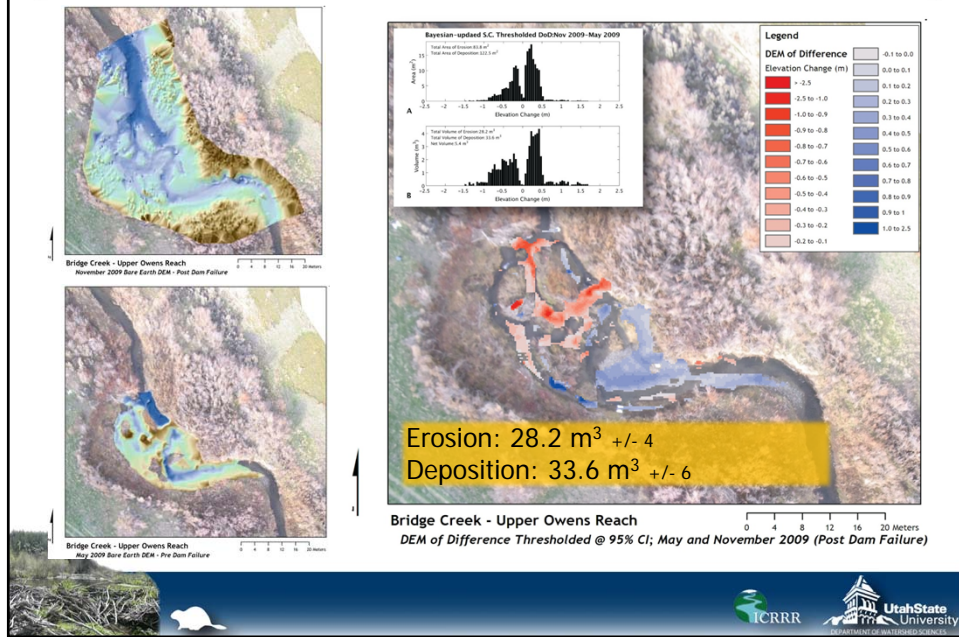


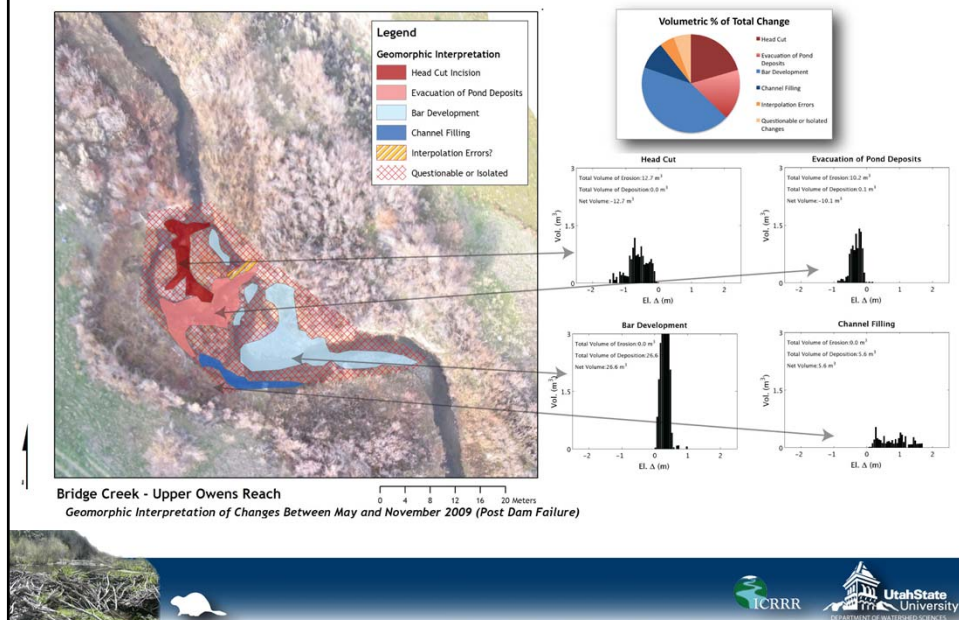
Figure 10: Progression of reach at upper Owens through a period without a dam (A; 2005), with an active, partially breached dam (B; Nov 2009), to an abandon, partially breached dam (C; April 2010).



CAPTURED THE POST FAILURE RESPONSE



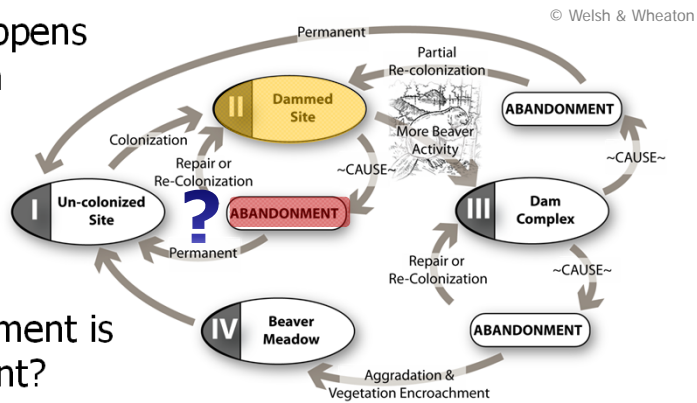
MORE INTERESTING....



ROLE OF ABANDONMENT & FAILURE?

- What happens post dam failure?

- What if abandonment is permanent?



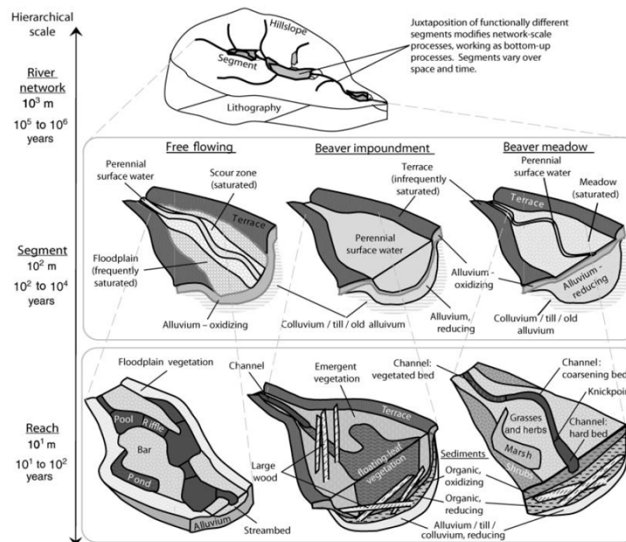
Typical Causes of Abandonment

*Causes with potential for repair or later recolonization by same individual(s)

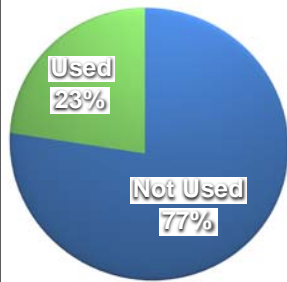
In both instances, the short term (one year) response is that of net aggradation & a net increase in channel complexity over time

*Predation (natural, permanent or temporary)

DYNAMICS MATTER!



BEAVER USE

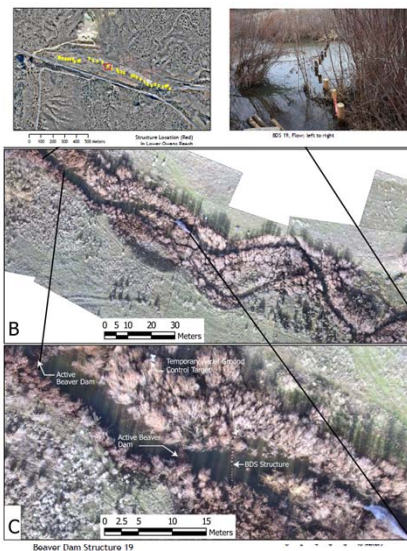


From Nick Weber

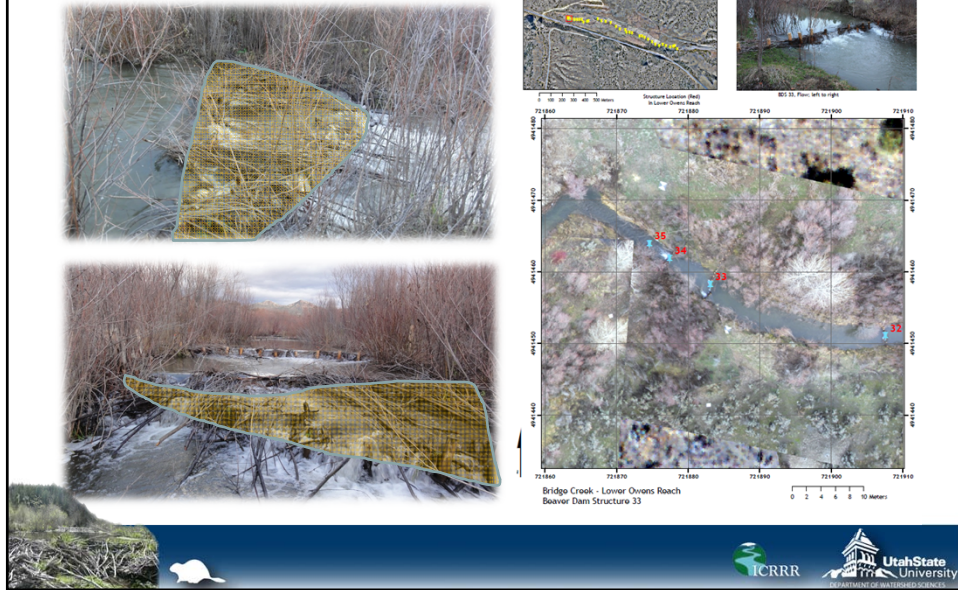


SIDE NOTE: THEY'LL BUILD WHERE THEY DAM WELL PLEASE

- Posts go in Sept 2009
- Beaver ignore posts and build their own dam 10 m downstream by Nov 2009
- By Nov 2010, their dam has completely aggraded, then they build on BDS 19



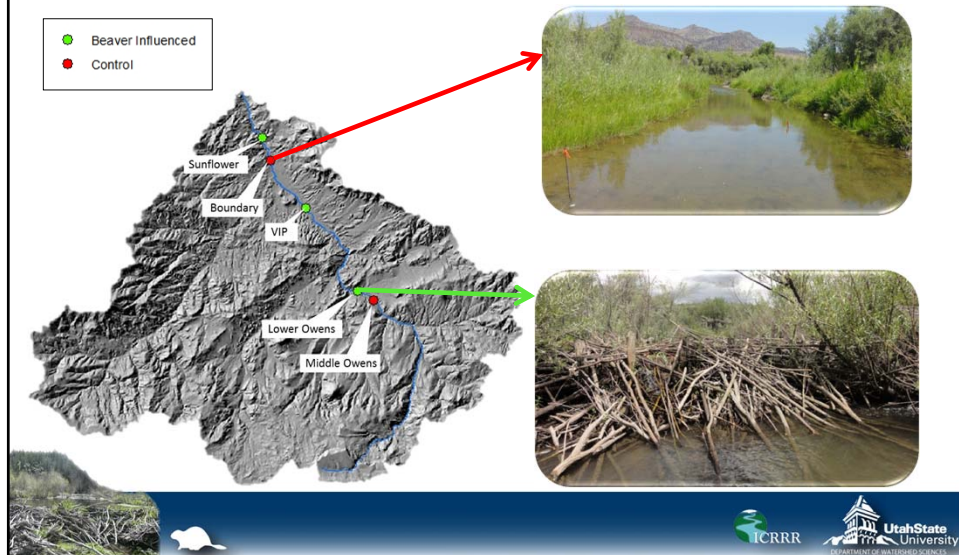
SIDE NOTE: THEY'LL BUILD WHERE THEY DAM WELL PLEASE



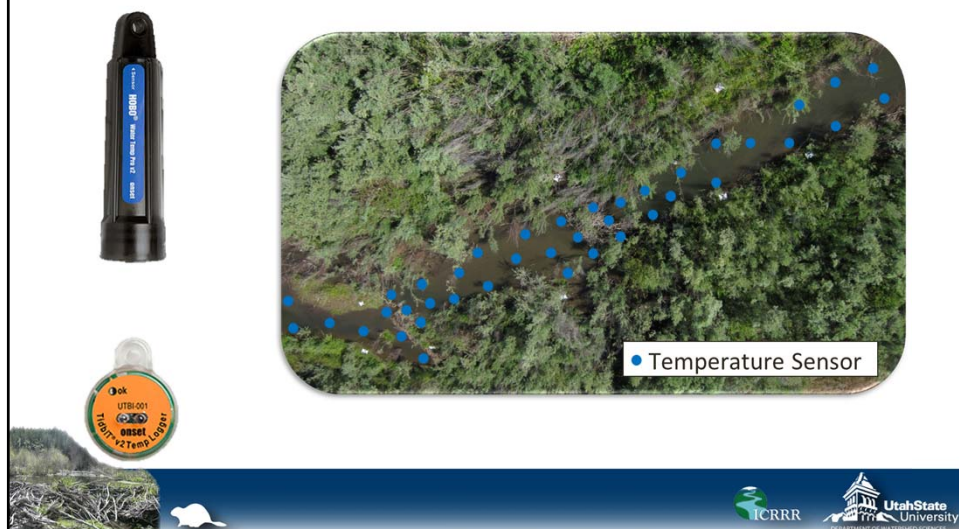
SIDE NOTE: THEY'LL BUILD WHERE THEY DAM WELL PLEASE



THERMAL SITES



METHODS: TEMPERATURE SENSORS



METHODS: TEMPERATURE PROBE

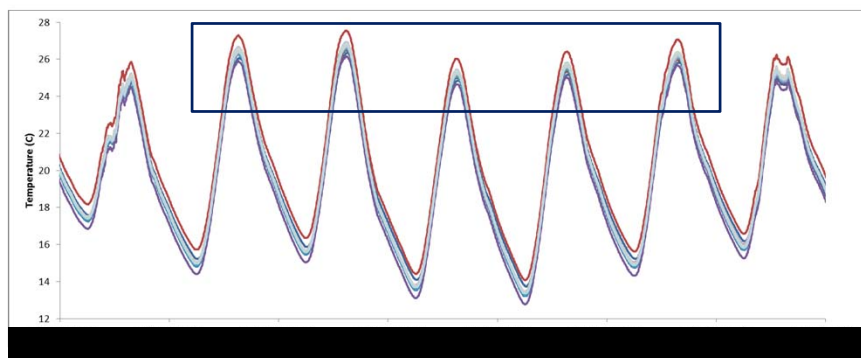
- Attached temperature probe to rtkGPS
- Allowed for high resolution mapping of temperature at snapshot in time



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THERMAL HETEROGENEITY



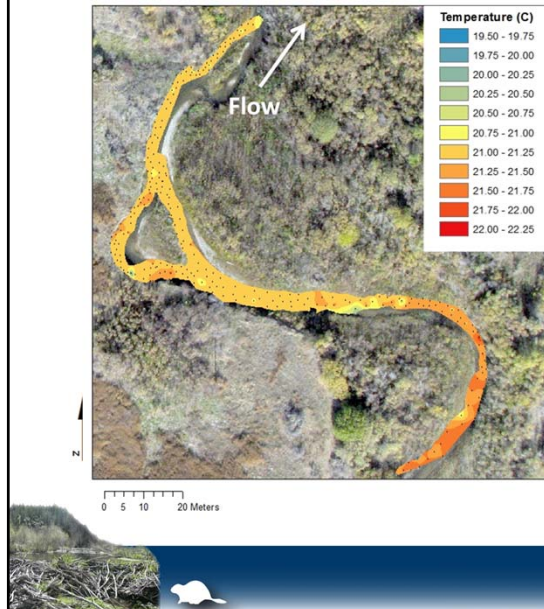
Day 7



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DIGITAL TEMPERATURE MODEL



Boundary:
Control Reach

Maximum Temp =

22.25 C

Minimum Temp =

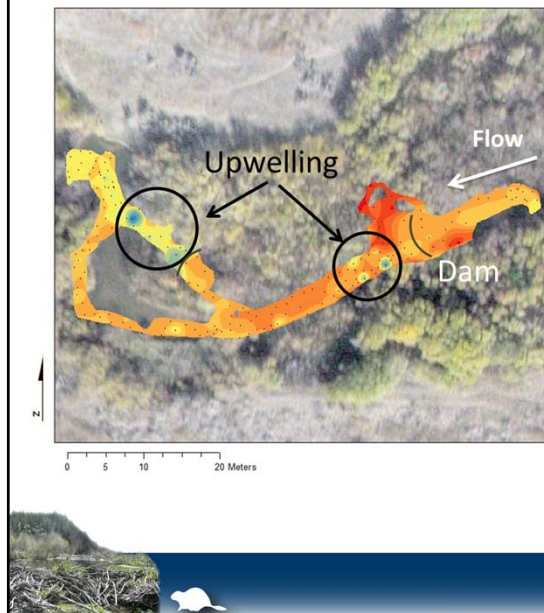
19.50 C

Difference = 2.75
degrees

August 18, 2012



DIGITAL TEMPERATURE MODEL



Lower
Owens:
Beaver
Influenced
Reach

August 20, 2012

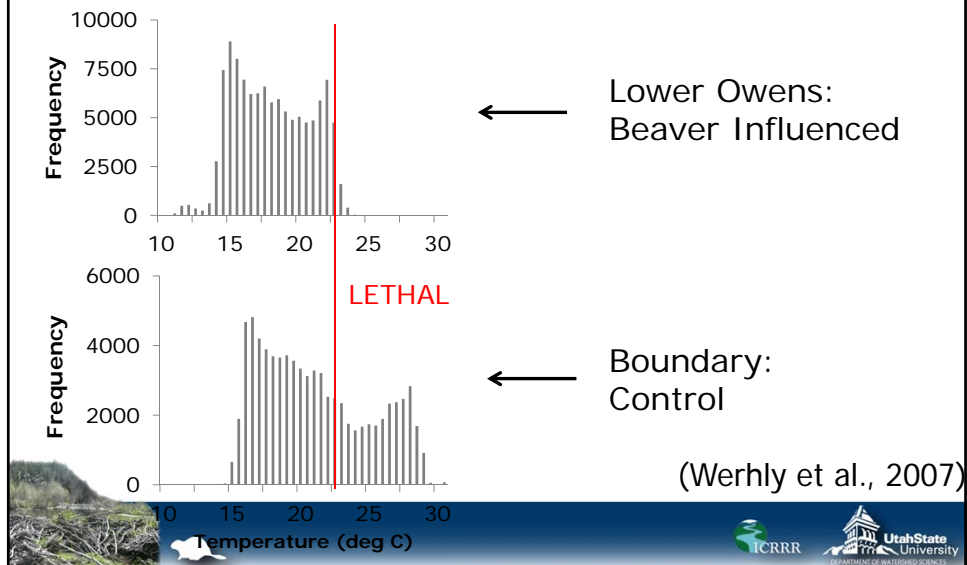
Maximum Temp = 23.25 C

Minimum Temp = 12.00 C

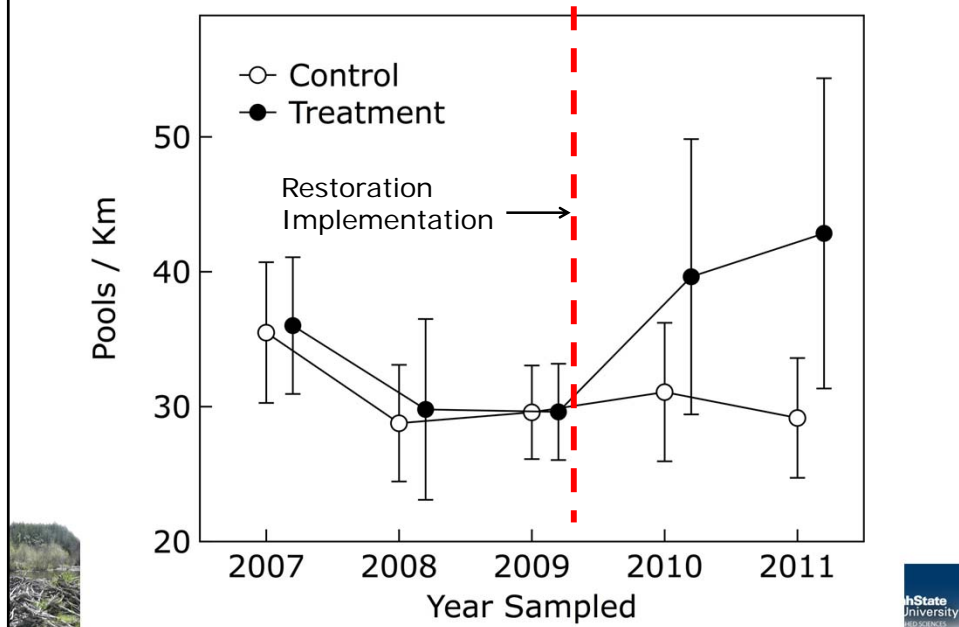
Difference = 11.25 C



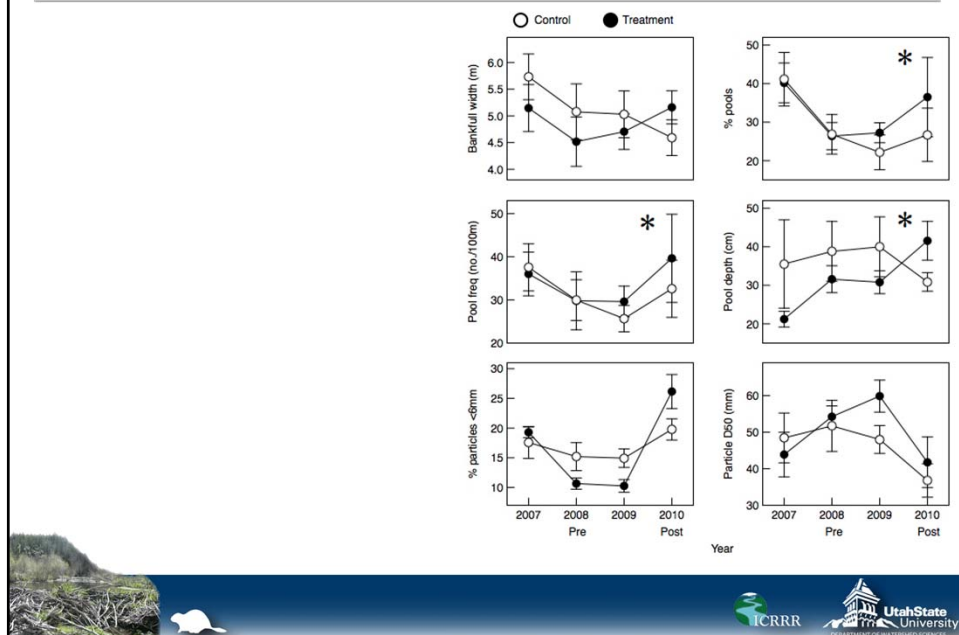
TEMPERATURE FREQUENCIES: AUGUST 13-21, 2012

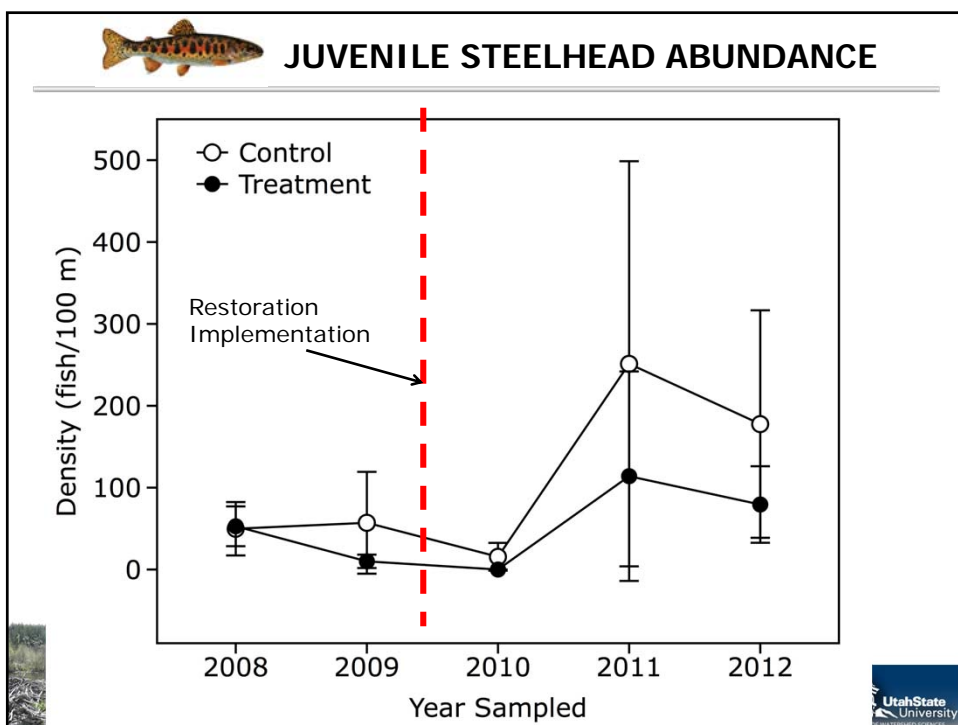
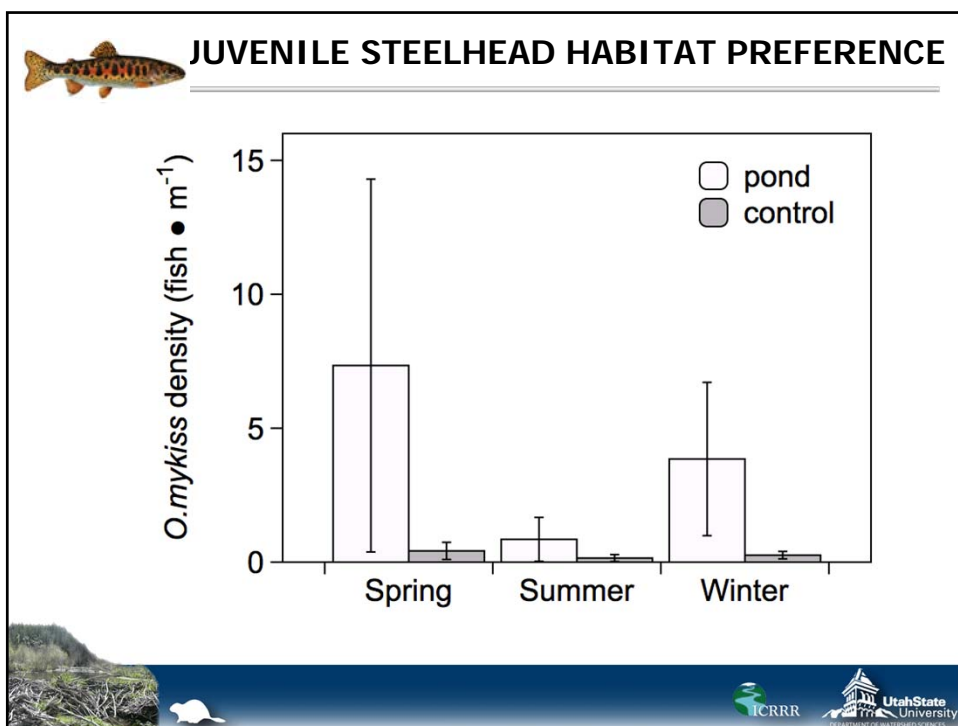


POOL HABITAT ABUNDANCE



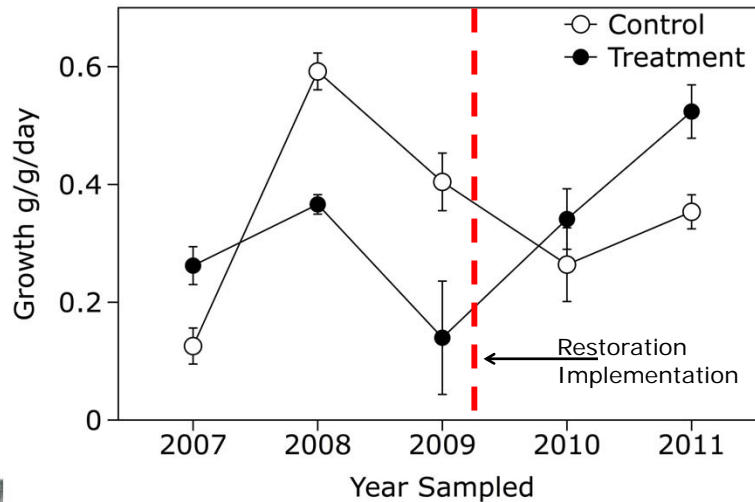
HABITAT CHARACTERISTICS







JUVENILE STEELHEAD GROWTH



SOME PRELIMINARY CONCLUSIONS

- Rapid colonization of BDSS after installation
- Rapid response working with beaver to restore incised channel & reconnect with floodplain in the right direction.... Will it last?
- Dramatic improvements in habitat complexity
- Too early for fish population response
- Treatment is cheap...


STRUCTURE SITING – MEYERS CAMP

Bridge Creek - Meyer's Camp Beaver Dam Support Structures

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YOUR TURN... BOUNDARY REACH




USGS 14046778 BRIDGE CR ABV COYOTE CANYON NR MITCHELL, OR

Annual Peak Streamflow, in cubic feet per second

697 km²

42 cm Annual Precipitation

Jan 2006 Jul 2006 Jan 2007 Jul 2007 Jan 2008 Jul 2008 Jan 2009 Jul 2009 Jan 2010



USGS 14046778 BRIDGE CR ABV COYOTE CANYON NR MITCHELL, OR

DAILY Discharge, cubic feet per second

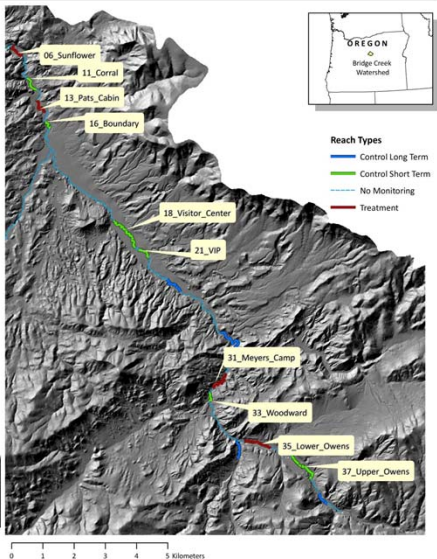
Median daily statistic (3 years) Period of approved data

Date temporarily unavailable Flow at station affected by ice



Daily mean discharge Period of provisional data

Estimated daily mean discharge

2005 2006 2007 2008 2009 2010 2011



0 1 2 3 4 5 Kilometers



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YOUR TURN

DESIGN EXERCISE - Boundary Reach

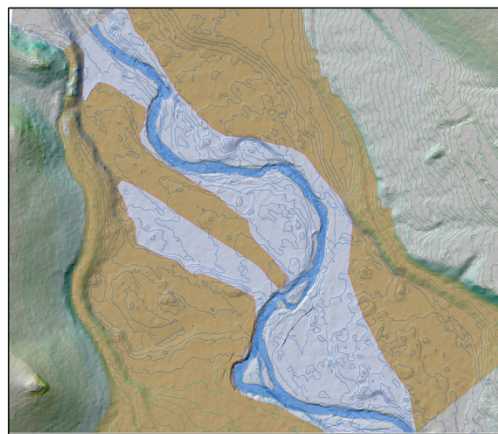


Flow direction is up the page (NW)

- Choose BDSS types:
 - PLWW
 - PL Only
 - Starter Dam
 - Reinforce Existing Dam
- Place them on map
- Draw orientation of posts
- Set crest elevation
- Diagram hypothesized response
- Draw detail (optional)



YOUR TURN



Legend

LiDaR 25 cm Contours

Elevation (m)

- 540.25 - 545.00
- 545.01 - 550.00
- 550.01 - 555.00
- 555.01 - 560.00
- 560.01 - 565.00
- 565.01 - 570.00

Landforms

Geomorphic

- Floodway
- In Channel
- Upper Terrace or Upland



0 20 40 60 80 100 Meters

Instructions:

1. Use different symbols to place different BDSS types.
2. Identify location, crest elevation and inundation extents for each structure.

