LIVING & WORKING WITH BEAVER

Klamath Watershed Partnership Workshop:

October 14-15, 2014
3. RESTORATION ALTERNATIVES WITH BEAVER

Joe Wheaton

LIVING & WORKING WITH BEAVER WORKSHOP
October 14-15, 2014
3. RESTORATION ALTERNATIVES WITH BEAVER

I. Underlying Principles
II. Various Alternatives
   I. Conservation / Promotion
   II. Accidental Restoration
   III. Transplant to area that with suitable capacity
   IV. Restore riparian -> Followed by Transplant
   V. Help beaver out – Beaver Dam Analogues
   VI. Mimic Beaver....

III. Call for Adaptations to Recipes
IV. Take Aways
3. RESTORATION ALTERNATIVES WITH BEAVER

I. Review

II. Underlying Principles

III. Various Alternatives
   I. Conservation / Promotion
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   III. Transplant to area that with suitable capacity
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V. Take Aways
REALISTIC EXPECTATIONS ARE CRITICAL

- Remember... You’re relying on a rodent
- Don’t take too narrow of a focus on individual dams or one dam complex... take a broader view
- Beaver come and go... and with that we get dynamism
- How ‘instant’ the gratification depends on the physiographic setting...
- Expect the unexpected...
- How vulnerable is project to predation, poaching, etc.?
- IF you have an invasive problem, you have an invasive problem
START WITH PILOTS!

• Don’t boldly and arrogantly proceed with full blown implementation
• Put in a trial and wait a year or so...
• Design some to fail!
• Test a handful of treatments in the diversity of situations you will encounter at full implementation

• You’ll learn about:
  – Feasibility, timing and cost of installation
  – Subtle nuances that can save you a ton of time and money
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AT LEAST 6 TYPES OF ‘BEAVER’ RESTORATION

1. ‘Allow’ beaver to stay & promote/protect them (i.e. living with beaver / conservation)
2. Accidental Beaver Restoration
3. Transplant beaver from one area to an area where they are not currently & let them have at it
4. Riparian restoration & land use changes followed by transplanting beaver
5. In areas where beaver alone are not enough, help out with beaver dam analogues (BDAs), then hope beaver take over maintenance
6. Mimic beaver dam impacts with BDAs and artificially maintain...
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IV. Take Aways
FIND AN AREA IN GOOD SHAPE

Wrap it up and put a bow on it...

What to look for...

- Area with moderate to high densities of dams & high capacity to support ‘rotations’
- Keep eye on conservation measures to sustain:
  - Grazing management
  - Harvest management/protection
LOOKS GOOD…. BUT...

- Part of this is the result of a grazing exclosure in 2005
- & permitee is still grazing
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IV. Take Aways
CURTIS CREEK

• Stream was restored in 2004ish using a Rosgen Restoration...
• Beaver came along and made it better...
Figure 2. A) Aerial image of lower section of Curtis Creek study reach showing the channel in 2006 (before beaver colonization). B) Aerial near infrared image of Curtis Creek study reach in spring 2011 showing new beaver dams, ponds, and flow paths created over the study period.
Figure 1. Aerial image from 2006 and beaver dams (also visible in Figure 2B) constructed between 2009 and 2010. The main beaver dams are numbered from 1 to 10 from upstream to downstream and the time of dam construction is noted in the table. The study reach was further divided into 6 sub-reaches. The spatial scales investigated are illustrated below the map.
SUMMER CHANGES IN FLOW & TEMP

Figure 7. Change in discharge ($\Delta Q$) and temperature ($\Delta T$) over the study reach from 2008 to 2010. The $\%\Delta Q$ and $\%\Delta T$ are relative to the discharge and temperature at PT515. The $\%\Delta Q$ were averaged over a one hour interval, while $\%\Delta T$ represents 5-minute temperature values.
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IV. Take Aways
A FIRST CUT

• Focus on areas deemed ‘suitable’ for restoration
• How much effort?
WHERE TO PLACE?

• Tailor short term expectations to existing capacity

• Consider long term potential capacity with historic capacity and riparian recovery potential

• Don’t overseed beaver relative to capacity...
TRANSLOCATION

• Find a source population of nuisance beaver OR area with ample population...

• Relocate to areas with no or limited population & high capacity

Kent Sorenson
(UDWR)
• Building a starter lodge for translocated beaver to settle into their new surroundings can increase the chances they do work where you want them to.

http://wdfw.wa.gov/living/beavers.html#preventingconflicts
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IV. Take Aways
IS THIS GOOD BEAVER HABITAT?
BDAs MAY BE USED PRIOR TO BEAVER TO PROMOTE RIPARIAN RECOVERY
RESOURCES AVAILABLE NOW
3. RESTORATION ALTERNATIVES WITH BEAVER

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(5) e.g. INCISED STREAMS ARE UBIQUITOUS
INCISION – DISCONNECTED FLOODPLAIN
LATERAL EROSION

Aggradation - Inset Floodplain
AGGRADATION — FLOODPLAIN RECONNECTION
THE INCISION-AGGRADATION CYCLE

Figure from Pollock et al. (2014) Bioscience. DOI: 10.1093/biosci/biu036
THE INCISION-AGGRADATION CYCLE

Adapted from Cluer and Thorne 2013

Figure from Pollock et al. (Accepted) Bioscience
THE INCISION-AGGRADATION CYCLE WITH BEAVER DAMS & BEAVER DAM ANALOGUES
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
BRIDGE CREEK EXPERIMENTAL WATERSHED

- 697 km²
- 42 cm Annual Precipitation
BEAVER DAMS JUST DON’T LAST IN BRIDGE

Recent History (1988-2004) of Beaver Dams along Bridge Creek in Central Oregon

Abstract

Bridge Creek is a low-gradient stream in the John Day River basin of eastern Oregon. After decades of grazing, riparian vegetation along a 31.7 km reach was sparse, and low in diversity. Vegetated floodplains were typically narrow, and the stream was relatively wide and shallow. Cattle grazing within this reach was reduced in 1998, irrigation diversion ditches were replaced with culverts in 1999, and beaver (Castor canadensis) trapping was discontinued after 1991. Between 1985 and 2004, we inventoried beaver dams and ponds twice a year and estimated their dimensions. Field notes and photographs were used to document habitat use and better understand the potential role of beaver with regard to channel morphology and riparian plant communities. The annual number of beaver dams present in the study reach ranged from 9 to 100. On average, dams were nearly 8 m in height with ponds extending upstream 20 m. We also found that beaver damming, over time, typically accumulated sediment, improved conditions for establishment and growth of riparian plants, and altered channels. Dams that breached during periods of high flow often contributed to long-term increases in channel complexity through the formation of new meanders, pools, and riffles. Exposed sediment deposits associated with breached dams provided fresh substrates for regeneration of willows (Salix spp.), black cottonwood (Populus balsamifera subsp. trichocarpa), and other riparian plants. Although portions of the study reach were periodically abandoned by beaver following heavy utilization of streamside vegetation, within a few years dense stands of woody plants naturally occupied a large portion of the floodplain. Observations over a period of 17 yrs indicate that beaver facilitated recovery of riparian vegetation, floodplain functions, and stream channels.

Introduction

Although beaver (Castor canadensis) once ranged across nearly all of North America, furt harvesting in the 1700s and 1800s decimated their populations across most of the United States (Hill 1982). With the loss of beaver and their dams along streams in the American west, in conjunction with increasing levels of herbivory from livestock, channel incision and widening often occurred causing dramatic reductions in subsurface water storage along floodplains and loss of wetland habitats associated with riparian ecosystems (Forsy 2003). In the Ochoco Mountains of central Oregon, Finley (1937, p. 256) observed that, “with no beaver engineers left to take care of the dams, the ponds disappeared; grassy meadows built up by sub-irrigation died out.” Beaver historically have been identified as destroyers of trees, roads, crops, and habitats (Bump 1941, Youker and Hill 1954, Hill 1982, Avery 1983, DeByle 1985, Baker and Barrett 1987). More recent studies, however, have established their capability to improve watersheds, stream systems, and habitats (Brayton 1984, Naiman et al. 1988, Wright et al. 2002, Baker and Hill 2003). Even with increasing knowledge regarding the ecological benefits of beaver (Kay 1994, Ringer 1994, Sharps 1996, Wright et al. 2002), public agencies and private landowners were often reluctant to protect them from continued exploitation. This was perhaps due, in part, to damage complaints from landowners that occurred when beaver reoccupied portions of their former range (Hill 1986, Laoma 1996). In the John Day River basin of central Oregon, the effect of beaver on stream systems was controversial in the late 1980s and thus they were widely trapped. Along Bridge Creek, a tributary of the John Day River, trapping kept populations at relatively low levels since ranchers were apprehensive about potential impacts to crops and irrigation facilities (Fechilch et al. 2003). Similarly, various local, state, and federal land managers were concerned that failed beaver dams would contribute to bank damage and riparian impacts, especially where cattle grazed in riparian areas. In light of this controversy, we annually monitored...
BRIDGE CREEK DAM PERSISTENCE
1988 - 2005

% of Dams

Years until abandoned

0 1 2 3 4 5 6 7 8

0 10 20 30 40 50 60 70 80
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 reclamation of streams by beaver can rapidly expand riparian habitat along incised streams. Copyright © 2007 John Wiley & Sons, Ltd.

Figure 6. 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 0-05 m 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.
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...
• Induce a disturbance (actively) ... allow it to unfold (passively) – Figure 17 (Pollock et al 2011)
FOUR STRUCTURE TYPES

1. Starter Dam

Figure 10. A typical starter dam (J7+17 at Sunflower) 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 fl1 terrace, mimicking a stable beaver dam.

2. Post Line Only

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.

3. Post Line w/ Willow Weave

Figure 11. A post line with woven weave is similar to a starter dam, but acts more like a weir as water is allowed to flow through the willow branches such that low flows are 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 P/LWW as evidenced by the chewed stems on the right of the photo which is an active outfall to the flow.

4. Reinforce Existing

Figure 13. Any active dams within the treatment areas were strengthened with posts to lengthen their functional life, since most dams along the initial Bridge Creek had been shown to last less than a year (Deneen and Eppich, 2015). This structure was one of four dams built in sequence in Lower Owens to form a new colony. Within one year, all four dams had backfilled with sediment, which improved floodplain connectivity and habitat complexity, but made the site unsuitable 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?

BDS Structures
STRUCTURE SITING – PATS & SUNFLOWER

Bridge Creek - Pats Cabin Beaver Dam Support Structures

Bridge Creek - Sunflower Beaver Dam Support Structures
Figure 10. A typical starter dam (SF-17 at Sunflower) 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 RL terrace, mimicking a stable beaver dam.
STRUCTURE TYPES – STARTER DAMS

- Generally, they were placed in locations where:
  1. The water elevation upstream of the dam could be raised to the level of a terrace, so that flow would be dispersed across the terrace and it would be less likely that the structural integrity of the dam would be compromised.
  2. The incision in the surrounding area was generally less than 1-1.5 m so that additional dams that were built were more likely to be stable.
  3. The backwater from the pond would provide access to soft banks upstream of the dam, which would act as suitable locations for bank lodges
  4. There was adequate access to existing food ad building supplies (e.g. existing wood and riparian vegetation)
  5. There was no existing beaver colony nearby (i.e. within 300 m)
STRUCTURE TYPES – POST LINE WITH WICKER WEAVE

- Mimic Functional impact of beaver dams in short term & invoke geomorphic response whether or not colonized by beaver in short term
- Also intended to
  - Increase stream sinuosity
  - Increase number of pools
  - Provide potential sites for future dam construction
STRUCTURE TYPES – POST LINES

• Post lines placed where future beaver dam was desired and where geomorphic conditions suitable

• Limited to sites where minimal risk if no aggradation occurred

• Not intended to be functional unless beaver utilized them to build 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.
• All active or intact abandoned beaver dams within the treatment area were stabilized with posts to lengthen their functional life.
For all structures, the following rules (where applicable) were applied.

1. Within the incision trench, the planform shape of the post line should either be straight or convex downstream (i.e. the center of the post line within the bankfull channel is the most downstream post) with the ends of the post line extending upstream along the bank(s), typically 5-10 m, when bank erosion is not desired. A straight post line perpendicular to the main flow promotes parallel streamlines. A straight post line angled toward one bank can promote the shunting of flow to one side of the channel or the other. A convex downstream shape promotes divergent flow and keeps flow from concentrating in the thalweg downstream of the BDSS and creating excessive scour, which can undermine the posts.

2. Where possible, post lines extended roughly perpendicular to stream flow along any low terraces within one meter elevation of the low flow channel, extending no more than 15 cm above the terrace elevation, sufficient to disperse flow across the terrace and help create a more tortuous path for the flow to follow prior to returning to the main channel (Figures 10 and 14). Where appropriate, a gap was left on the terrace post line for a new channel to flow through once the channel aggraded to the elevation of the terrace. Gaps were strategically placed to take advantage of any depressions or old channels on the terrace and existing riparian vegetation, and to increase stream sinuosity. However, in some cases, beaver dammed up gaps, but this typically resulted in dispersed flow in multiple channels across the terrace downstream from the beaver dam, as typically happens with natural beaver dams extending across a low terrace.

3. The distance between structures roughly approximated the natural distance between beaver dams, and was a function of channel slope. Generally, structures were placed close enough to each other that the pool formed by one structure backed up water to the base of the next structure upstream. This helped to ensure that beaver have safe upstream-downstream access while the pool exists, and also that most of the length of the bed will aggrade once the pools fill in. Having a pool form on the downstream end of a structure also lessened the vertical distance between the water level at the top and bottom of the structure, helping to reduce scour depth and the potential for the BDS structure to be undermined by excessive scour.

4. Where there was a structural gap within an abandoned beaver dam (e.g. a portion of the dam had breached), posts were installed in the gap.

5. Within the bankfull channel, posts were pounded 1-m deep into the bed where possible, but this target depth could not always be achieved, primarily due to the presence of large cobble.
SUMMARY

• 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

• Additional 35 Structures installed as ‘maintenance’ / Adaptive Management
Focus first at dam complex scale....
Don’t be too reactionary! Some failures are good/necessary!
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

Site Location (Red) In Bridge Creek Watershed

Legend

Beaver Dam Starter Structures
Type:
- Starter Dam
- Secondary Dam
- Grade Control
- Potential Dam (posts only)
- Reinforced Abandon Dam
- Reinforced Existing Dam

Bridge Creek - Lower Owens Reach
Beaver Dam Starter Structures Installed in 2009
HIGH RESOLUTION IMAGERY

Lower Owens Study Reach
Bridge Creek, Oregon

A

0 30 60 120 180 Meters

Lower Altitude Blimp Flight Images (50 m)
Higher Altitude Blimp Flight Images (100 m)

B

0 5 10 20 30 Meters

C

0 2.5 5 10 15 Meters

Active Beaver Dam
Temporary Stream Control
Control Target
Active Beaver Dam
eds Structure

AGGIEAIRSM FLYING CIRCUS

Bridge Creek - Lower Owens Reach
BCXX-13: Starter Dam

Structure Location (Red)
In Lower Owens Reach

0 100 200 300 400 500 Meters

0 10 20 30 40 Meters

722480 722500 722516

4941300 4941310

4941290 4941300

722490 722500

4941310

722490 722516

4941300

4941310

4941290 4941300

0 2 4 6 8 10 Meters
DRONE IMAGERY VEGETATION CLASSIFICATION

Legend:
- Willow
- Willow 2
- Cottonwood/Willow
- Sagebrush
- Grasses/Herbaceous
- Soil/Grass
- Bareground
- Shadow

2005

2010
GEOMORPHIC CHANGE DETECTION

- What can we do with that repeat topography?

- Develop a direct measure of channel aggradation and floodplain reconnection

Morphological Sediment Budget:

\[ Q_{b,\text{IN}} - Q_{b,\text{OUT}} = \frac{\Delta V_{\text{DoD}}}{\Delta t} \]

Bedload Flux Difference

\[ \Delta V_{\text{DoD}} = \Sigma V_{\text{Deposition}} - \Sigma V_{\text{Erosion}} \]
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?
• What will be the impact on fish?
• How long will it take?
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?**
• What will be the impact on fish?
• How long will it take?
STARTER DAM OCCUPIED...

Installed September 2009, Occupied by November 2009
ANOTHER STARTER DAM OCCUPIED
FLOW FORCED ONTO FLOODPLAIN

Enough aggradation and dam activity @ secondary dam to force flow onto floodplain even at moderate flows.
• Prior to project there was one abandon, breached dam in this reach...
• One year later, there are eleven (15 BDSS) with 2-4 active colonies
BRIDGE CREEK FLOWS...

- 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

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Raw</th>
<th>Thresholded DoD Estimate:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AREAL:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Area of Erosion (m²)</td>
<td>15,383</td>
<td>461</td>
</tr>
<tr>
<td>Total Area of Deposition (m²)</td>
<td>178,117</td>
<td>1,151</td>
</tr>
<tr>
<td><strong>VOLUMETRIC:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Volume of Erosion (m³)</td>
<td>2,035</td>
<td>260 ± 83</td>
</tr>
<tr>
<td>Total Volume of Deposition (m³)</td>
<td>3,485</td>
<td>967 ± 300</td>
</tr>
<tr>
<td>Total Volume of Difference (m³)</td>
<td>5,520</td>
<td>1,227 ± 383</td>
</tr>
<tr>
<td>Total Net Volume Difference (m³)</td>
<td>1,450</td>
<td>707 ± 311</td>
</tr>
<tr>
<td><strong>PERCENTAGES (BY VOLUME)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Erosion</td>
<td>37%</td>
<td>21%</td>
</tr>
<tr>
<td>Percent Deposition</td>
<td>63%</td>
<td>79%</td>
</tr>
<tr>
<td>Percent Imbalance (departure from equilibrium)</td>
<td>13%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Erosion: 169 m³ ± 54
Deposition: 176 m³ ± 58
NET: + 7 m³ (± 79)
1st YEAR (2010-2009): BY COMPLEX

Volume Change (m³)

<table>
<thead>
<tr>
<th>Area</th>
<th>Deposition</th>
<th>Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(1-3)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>B(4-7)</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>C(8-9)</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>D(11-13)</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>E(14-15)</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

Net Volume Change (m³)

<table>
<thead>
<tr>
<th>Area</th>
<th>Local Net</th>
<th>Cumulative Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(1-3)</td>
<td>10</td>
<td>-10</td>
</tr>
<tr>
<td>B(4-7)</td>
<td>5</td>
<td>-5</td>
</tr>
<tr>
<td>C(8-9)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>D(11-13)</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>E(14-15)</td>
<td>40</td>
<td>-10</td>
</tr>
</tbody>
</table>

Elevation Change (m)

<table>
<thead>
<tr>
<th>Dam Complex</th>
<th>Elevation Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(1-3)</td>
<td>-1.5</td>
</tr>
<tr>
<td>B(4-7)</td>
<td>-2.0</td>
</tr>
<tr>
<td>C(8-9)</td>
<td>0.5</td>
</tr>
<tr>
<td>D(11-13)</td>
<td>1.5</td>
</tr>
<tr>
<td>E(14-15)</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

Map showing regions A, B, C, D, E with elevation and volume change data.
1st YEAR (2010-2009): BY MECHANISMS
<table>
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<th>Thresholded DoD Estimate:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AREAL:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Area of Erosion (m²)</td>
<td>14,626</td>
<td>1,582</td>
</tr>
<tr>
<td>Total Area of Deposition (m²)</td>
<td>178,874</td>
<td>1,872</td>
</tr>
<tr>
<td><strong>VOLUMETRIC:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Volume of Erosion (m³)</td>
<td>3,468</td>
<td>1,281 ± 362, 28%</td>
</tr>
<tr>
<td>Total Volume of Deposition (m³)</td>
<td>2,715</td>
<td>808 ± 208, 26%</td>
</tr>
<tr>
<td>Total Volume of Difference (m³)</td>
<td>6,183</td>
<td>2,089 ± 570, 27%</td>
</tr>
<tr>
<td>Total Net Volume Difference (m³)</td>
<td>-752</td>
<td>-473 ± 418, -88%</td>
</tr>
</tbody>
</table>

**PERCENTAGES (BY VOLUME)**

- Percent Erosion: 56% - 61%
- Percent Deposition: 44% - 39%
- Percent Imbalance (departure from equilibrium): -6% - 11%

IN CHANNEL ONLY

Erosion: 512 m³ +/- 143
Deposition: 927 m³ +/- 241
NET: + 415 m³ (+/- 280)
2nd YEAR (2011-2010): BY COMPLEX

[Bar chart showing volume change (m³) for different areas labeled A, B, C, D, and E.]

[Map showing elevation change (m) with color codes for different ranges.]

[Image of a landscape with areas marked A, B, C, D, and E, indicating deposition and erosion areas.]
2nd YEAR (2011-2010): BY MECHANISMS

Mechanisms of In-Channel Change

- BDSS Pond Deposit: 218, 14%
- Lateral Bar Development: 33, 2%
- Floodplain Deposition: 15, 1%
- Central Bar DS BDSS: 36, 2%
- Side Channel Deposition: 27, 2%
- Bank Erosion: 24, 2%
- Scour Pool DS BDSS: 0, 0%
- High Flow Scour Channel: 96, 6%
- Bar Forced Pool Scour: 72, 5%
- Evacuation Pond Sediments: 0, 0%
- Channel Widening: 51, 51%
- Headcut: 0, 0%

Geomorphic Interpretation
- High Flow Scour Channel
- Bar Forced Pool Scour
- Channel Widening
- Toe Deposit & Bank Erosion
- Headcut
- Bank Erosion
- Questionable
WHAT WE TAKE AWAY FROM PATS CABIN…

- 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, it's cheap!
- Beaver do the maintenance!

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

**Erosion: 169 m³ +/- 54**
**Deposition: 176 m³ +/- 58**
**NET: + 7 m³ (+/- 79)**
ELSEWHERE... WE SEE SIMILAR RESULTS

- 84 Structures installed in four reaches (in 2009); Now 110
  - 5 Reinforced existing dams
  - 4 Reinforced abandon dams
  - 10 Starter Dams
  - 44 Post lines with Wicker Weaves
  - 21 Post lines only
BDSS PERSISTENCE

From Nick Weber
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?
• What happens post dam failure?

• What if abandonment is permanent?

**Typical Causes of Abandonment**

<table>
<thead>
<tr>
<th>Causes with potential for repair or later recolonization by same individual(s)</th>
<th>Permanent Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Migration (temporary)</td>
<td>Permanent Migration (permanent)</td>
</tr>
<tr>
<td>Dam Breach/ Failure (permanent or temporary)</td>
<td>Trapping (human; permanent)</td>
</tr>
<tr>
<td>Exhaustion of Food/Building Materials (permanent or temporary)</td>
<td>Mortality (natural; permanent)</td>
</tr>
<tr>
<td>Decreased Functionality (e.g. pond aggradation; permanent or temporary)</td>
<td></td>
</tr>
<tr>
<td>Predation (natural; permanent or temporary)</td>
<td></td>
</tr>
</tbody>
</table>
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).

<table>
<thead>
<tr>
<th>Monitoring Activities @ Upper Owens</th>
<th>Beaver Dam Constructed</th>
<th>Beaver Dam Reinforced*</th>
<th>Dam Partially Breached &amp; Abandon</th>
<th>Continuous Fish Migration Monitoring / Regular Spawning Surveys / Annual Habitat &amp; Beaver Surveys</th>
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</thead>
<tbody>
<tr>
<td>Airborne LiDaR &amp; Imagery</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
<td>2009</td>
</tr>
<tr>
<td>Topo Survey Imagery</td>
<td>2010</td>
<td>2011</td>
<td>?</td>
<td>Continuous Monitoring</td>
</tr>
</tbody>
</table>
CAPTURED THE POST FAILURE RESPONSE

Erosion: 28.2 m³ +/- 4
Deposition: 33.6 m³ +/- 6
MORE INTERESTING....

Legend

- Geomorphic Interpretation
  - Head Cut Incision
  - Evacuation of Pond Deposits
  - Bar Development
  - Channel Filling
  - Interpolation Errors?
  - Questionable or Isolated

Volumetric % of Total Change
- Head Cut
- Evacuation of Pond Deposits
- Bar Development
- Channel Filling
- Interpolation Errors
- Questionable or Isolated Changes

Bridge Creek - Upper Owens Reach

Geomorph Interpretation of Changes Between May and November 2009 (Post Dam Failure)
**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)*

<table>
<thead>
<tr>
<th>Cause</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predation (natural; permanent or temporary)</td>
<td></td>
</tr>
<tr>
<td>Exhaustion of Food/Building</td>
<td></td>
</tr>
<tr>
<td>Abandonment (human; permanent)</td>
<td></td>
</tr>
<tr>
<td>Increased Functionality</td>
<td></td>
</tr>
<tr>
<td>Decreased Functionality</td>
<td></td>
</tr>
<tr>
<td>Permanent</td>
<td></td>
</tr>
<tr>
<td>Transhumance (human; permanent)</td>
<td></td>
</tr>
<tr>
<td>Stability (water; permanent)</td>
<td></td>
</tr>
<tr>
<td>Aggradation &amp; Vegetation Encroachment</td>
<td></td>
</tr>
</tbody>
</table>

In both instances, the short term (one year) response is that of net aggradation & a net increase in channel complexity over time.
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
What About the Fish?
FISH SAMPLING

electroshocking

Passive Instream Antenna

Pressure Transducer

Mobile Antenna
POOL HABITAT ABUNDANCE

![Graph showing the comparison of Control and Treatment pools per km from 2007 to 2011, with a notable increase post-restoration implementation in 2009.](image)
JUVENILE STEELHEAD HABITAT PREFERENCE

O. mykiss density (fish • m⁻¹)

Spring  | Summer  | Winter  
-------|---------|--------
|        |        |        |

Comparison of pond and control conditions across seasons.
JUVENILE STEELHEAD GROWTH

![Diagram showing growth g/g/day over years 2007 to 2011 with control and treatment groups. The graph indicates growth increases after restoration implementation in 2009.]
Survival of *O. mykiss* in Bridge and Murderers (trt and cntrl)

**Pre-restoration**

**Post-restoration**

- **Bridge (trt)**
- **Murderers (cntrl)**

Ratio of Survival *O. mykiss* in Bridge and Murderers (trt/cntrl)

Geomean $\hat{R}$-pre and $\hat{R}$-post restoration ($p<0.001$)

- **Pre-restoration**
- **Post-restoration**

$\hat{R}$-pre

$\hat{R}$-post

Slide from Nick Bouwes
Ratio of *O. mykiss* survival between Bridge and Murderers (trt / cntrl)
Geomean $D$-pre and $D$-post restoration ($p<0.0001$)
Difference of *O. mykiss* density between Bridge and Murderers (trt - cntrl)
Average D-pre and D-post restoration (p=0.007)
GROWTH DIFFERENCE

Difference in \( O. \text{mykiss} \) growth between E.
Average \( \Delta \text{pre} \) and \( \Delta \text{post} \) results.

Bridge Creek
Density Dependent Growth

\[
\gamma = -0.0031x + 0.1871
\]
\[R^2 = 0.4082\]
STEELHEAD PRODUCTION

- Production = Survival * Abundance * Growth

![Graph showing difference in O. mykiss production between Bridge and Murderers (trt - cntrl) during D-pre and D-post restoration (p=0.10).]
SOME BRIDGE CREEK 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
• Positive fish population response
• Treatment is cheap…
3. RESTORATION ALTERNATIVES WITH BEAVER

I. Review

II. Underlying Principles

III. Various Alternatives
   I. Conservation / Promotion
   II. Accidental Restoration
   III. Transplant to area that with suitable capacity
   IV. Restore riparian -> Followed by Transplant
   V. Help beaver out – Beaver Dam Analogues

VI. Mimic Beaver....

IV. Call for Adaptations to Recipes

V. Take Aways
SAME AS BDAs, BUT W/O BEAVER

- Key difference is who does maintenance
- Resist tendency to over engineer
- Porosity is everything.... Think about what you want
3. RESTORATION ALTERNATIVES WITH BEAVER

I. Review

II. Underlying Principles

III. Various Alternatives
   I. Conservation / Promotion
   II. Accidental Restoration
   III. Transplant to area that is with suitable capacity
   IV. Restore riparian -> Followed by Transplant
   V. Help beaver out – Beaver Dam Analogues
   VI. Mimic Beaver....

IV. Call for Adaptations to Recipes

V. Take Aways
JUST LIKE THE SHEET IN THE WIND...

• We need lots of recipes and local adaptations
• Follow a recipe when you’re getting started to learn basics in a pilot
• Once you understand the key drivers, don’t be afraid to experiment
• Get creative...
• SHARE your recipes please!
3. RESTORATION ALTERNATIVES WITH BEAVER

I. Review

II. Underlying Principles

III. Various Alternatives
   I. Conservation / Promotion
   II. Accidental Restoration
   III. Transplant to area that with suitable capacity
   IV. Restore riparian -> Followed by Transplant
   V. Help beaver out – Beaver Dam Analogues
   VI. Mimic Beaver....

IV. Call for Adaptations to Recipes

V. Take Aways
TAKE AWAYs

• DON’T apply blanket, uniform approach across landscape
• Tailor solutions to local adaptations
• Results are promising... but not full proof
• Posts are good and cheap, but don’t overuse. They make sense in situations where:
  – Medium term dam stability a problem (e.g. incised channels)
  – To help

For more information, visit: http://beaver.joewheaton.org
TWO FUN READS...

1913   vs.   2011
WANT TO LEARN MORE?

• Visit [http://beaver.joewheaton.org](http://beaver.joewheaton.org)

For more information on BRAT, visit: [http://brat.joewheaton.org](http://brat.joewheaton.org)
EXTRA SLIDES ON
MAIN PARTNERS... on

Nick Bouwes  Steve Bennett  Reid Camp

Snake River Salmon Recovery
Eco Logical Research, Inc.
Science Driven Solutions

NOAA
ASOTIN CREEK WATERSHED

- Intensively Monitored Watershed (IMW)
- Very important *O. Mykiss* population
- LWD & pool habitat limiting
- LWD restoration proposed...
- How to do it?
IMPRESSIONS OF ASOTIN

• Riparian not all that bad... compared to some places
• Nothing like what it once was
• Habitat highly simplified
  – Armored... Dominated by plane bed
  – Few pools / Not much large wood
  – Few active bars
BUT OCCASIONALLY...

Where wood & variations in channel width and accommodation space are present....

Rich and complex habitat heterogeneity results
SIZE (OF LWD) MATTERS?

- Yes, because bigger stuff costs more and requires big equipment
- Density matters more!
- Channel spanners don’t buy immediate responses
- If density is high enough, when it moves, it won’t move that far
- Increase system roughness
CONCEPTUAL DESIGN – SYSTEM SCALE

CURRENT CONDITION
VERY STABLE DEGRADED STATE

High flows can alter system state temporarily, but a normal flood knocks it back down to degraded condition.

DYNAMIC REACH STATES
(OVERALL SYSTEM RESILIENCE)

Dynamic Switching Between Alternative ‘Stable’ States

1. Introduction of DWS alters hydraulics, CHANGES system parameters, to allow normal high flows to shape a more complex system.

2. The shift to a new system state, promotes a change in the riparian and LWD loading, which over time adjusts the system parameters making it difficult to revert back to previous state.

3. Eventually, natural LWD loading replaces role of DWS allowing system to respond and adjust to both high magnitude and regular floods, which may change the system state, but allows dynamic switching between alternative ‘stable’ states, with higher degree of channel complexity.

LEGEND

- Potential System State
- Mean annual Flood
- High magnitude, rare flood (e.g. > 25 Year RI)
- System parameters (e.g. Riparian conditions, LWD inputs, etc.)
- System Variables (Outside our Control)
SECTION VIEW

1/3 of post length exposed above bed. Post tops set approximately to height of mean annual flood.

Drive posts to a depth of roughly 2/3 their length (c. 60 to 100 cm).

PLANFORM VIEW

EXPECTED NEW POOL

Channel Width

Wooden fence posts; staggered placement; roughly 30 to 50 cm apart; Constricting 40 to 70% of flow width.

LWD of various sizes and complexity can optionally be woven into DWS.

90° to 135°

FLOW DIRECTION

DWS (Posts Only)

DWS with LWD
**SIMPLE HYPOTHESESIZED RESPONSE**

**Initial Condition**

- Flow

**Design Placement**

- Flow

  - Ex. Boulder or bank irregularity
  - Dynamic Woody Structure constricts between 40% to 70% of flow width
  - Undercut bank forms, may promote recruitment of new LWD from riparian
  - Elongated Constriction-Forced Pool Forms

**Dynamic Response**

- Flow

  - Eddy bar deposit forms in shadow of structure
  - Central bar forms where flow diverges again; may promote channel widening downstream and further LWD recruitment from riparian

**LEGEND**

- Velocity Vectors
- Wooden Posts (driven into bed)
- Woody debris of various sizes, shapes & complexity
- 12" to 18" diameter logs (variable length of 4' to 6' and can be handled by two people)
Most structures took 30-60 min to install. This may be cheap, but this is hard work!
TYPICAL DWS STRUCTURES
MOST PIECES ARE TWO-GUY WOOD
PILOTS 2011

- 15 structures on all three creeks (5 each)
- Installed August 2011
- Subjected to
  - 2nd largest flood on 3/20/12
  - largest flood on 4/2/12
- Subjected to a snotty peer-review in 3/12

Figure 35. Annual peak discharge by year (red bars) at USGS gauge # 13334450 downstream of the confluence of the North Fork and South Fork Asotin Creeks. Blue bars are two large flows in March 2012 and the gray bar represents the average annual peak flow at the site.
REVIEWER: “THIS WILL NOT WORK!”

• “...some of the structures will look ok during a couple of years of lower flow persistence then will be obliterated during the first bankfull or slightly higher event.”
• Transparently document design intent
• Articulate explicit, testable design hypotheses (THE EXPERIMENT)
• Combines design, installation & monitoring into one App
WHEN IT DOES NOT FIT IN THE FORM...

- A geotagged video or voice note captures the observations...
- Don’t let technology stifle the power of observation
- Designers record video & optionally installation crew records video
TYPICAL YouTube CAT DESIGN VIDEO

• Not going to win any
EFFECTIVENESS CENSUS

- Restoration actions on Asotin:
  - HDLWD – High Density Large Woody Debris

<table>
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<th>Response Type</th>
<th>Label</th>
<th>Description on App</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>Shunting Flow</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>2</td>
<td>Splitting Flow</td>
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<tr>
<td>Hydraulic</td>
<td>3</td>
<td>Convergent Jet DS</td>
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<td>Eddy DS</td>
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<td>Erosion Bar Edge Trim</td>
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<td>Erosion Plunge</td>
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