AFFORDABLE TOOLS IN RIPARIAN RESTORATION
CEDAR CITY, UTAH 2018
WORKSHOP FIELD NOTEBOOK

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Prepared for:

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SYLLABUS & WEB RESOURCES

This handout only contains copies of supplemental information we will use during the workshop in the field for exercises and reference. Participants should refer to the workshop webpages for complete information, including:

Workshop Webpage:

http://beaver.joewheaton.org/nrcs---utah.html

Design Manual
Available later this summer!


Where to Get More Help:

http://beaver.joewheaton.org/need-help-planning-designing--building.html
YOUR INSTRUCTION TEAM

For bios, see links from http://beaver.joewheaton.org/nrcs---utah.html

The above is your cheat sheet for pretending you remembered all our names.
GEOMORPHOLOGY EXERCISE

The valley bottom consists of the areas that could plausibly flood (i.e. floodplain). The building blocks of the valley bottom include the floodplain, and where present the channel(s) flowing through them, standing water bodies (ponds, lakes, etc.) and wetlands (Fryirs et al., 2015). By contrast, valleys can include not just the valley bottom, but fans (alluvial and colluvial), terraces (inactive floodplain), moraines (lateral and terminal). The hillslopes bound the valley, and can bound the valley bottom but don’t always. Being able to identify these landforms, and in particular the valley bottom, helps build realistic expectations for the maximum extent of plausible riparian habitat (e.g. including mesic habitat and wet meadows that occupy valley bottoms).

We will do an exercise in class to help you identify these features on a map, and then attempt to apply that same lens out in the field.

For more information see:

- Design Manual: Chapter
CONTINUUM OF CONFINEMENT

From: Fryirs et al. (2015) – ESPL; DOI: 10.1002/esp.3893
EXERCISE 2 - VALLEY SETTING

South Fork Asotin Creek
Reach SF_01
River Mile 1.5 to 2.2
From Cluer and Thorne (2012) we get a series of conceptual channel evolution models helpful for understanding how streams incise and typical geomorphic responses, and how those can be used in process-based restoration.

Figure 1. Schumm et al. (1984) Channel Evolution Model with typical width-depth ratios (F). The size of each arrow indicates the relative importance and direction of the dominant processes of degradation, aggradation and lateral bank erosion. (Redrawn with permission from Water Resources Publications)

Figure 4. Stream Evolution Model based on combining the Channel Evolution Models in Figures 1–3, inserting a precursor stage to better represent pre-disturbance conditions, adding two successor stages to cover late-stage evolution and representing incised channel evolution as a cyclical rather than a linear phenomenon. Dashed arrows indicate ‘short-circuits’ in the normal progression, indicating for example that a Stage 0 stream can evolve to Stage 1 and recover to Stage 0, a Stage 4–3–4 short-circuit, which occurs when multiple head cuts migrate through a reach and which may be particularly destructive. Arrows outside the circle represent ‘dead end’ stages, constructed and maintained (2) and arrested (3s) where an erosion-resistant layer in the local lithology stabilizes incised channel banks.
In Pollock et al. (2014) we adapted these concepts to look at how both natural beaver dams, and beaver dam analogues could accelerate this ‘recovery’ process in incised streams.
Figure 3 - Examples on left of acceleration of aggradation and recovery of incised channel with beaver dams and on right with BDAs. The big difference is who does the maintenance and when its done.
ASSESSING BEAVER ACTIVITY EXERCISE

In the Chapter 4 of the Riverscapes Restoration Design Manual, we provide a series of basic and advanced forms for monitoring beaver activity, beaver dams, and beaver dam complexes. These are fully described there and word documents also exist.

These forms are straight forward to modify and build into useful field Apps with database applications like FileMaker (Camp and Wheaton, 2014), or GIS data collectors like ESRI’s Survey 123.

Figure 4 – Screen shots from Survey 123 Apps.
BEAVER ACTIVITY MONITORING FORM

OBSERVATION INFO
Observer Name: ____________________________
Site ID: ____________________________
Observation Date: ____________________________

OBSERVATION TYPE:
□ Beaver Dam
□ BDA
□ Beaver Activity (no dam)

OBSERVATION CHRONOLOGY
○ New Observation of New Feature
○ First Observation of Existing Feature
○ First Observation of Relic Feature
○ Repeat Observation of Existing Feature

POSITIONAL ATTRIBUTES
GPS UTM Easting: ____________________________
GPS UTM Northing: ____________________________
Stream Name: _________________________________

NOTES:

BEAVER ACTIVITY LOCATIONS RELATIVE TO CHANNEL(S)
□ On Main Channel
□ On Right Side Channel(s)
□ On Left Side Channel(s)
□ On Left Floodplain
□ On Right Floodplain

RECENT (PAST 3 MONTHS) BEAVER ACTIVITY:

**Dam Expansion**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Dam Construction**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Dam Maintenance**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Scent Mound**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Canal Digging**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Pond Excavation**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Dam Notching**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Draining/Flushing**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Corn on the Cob (Foraging)**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Felling of Trees**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Harvesting of Branches**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Skid Trail Usage**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Primary Wood Harvested**
○ Aspen  ○ Cottonwood
○ Willow  Other Hardwoods
○ Conifers  ○ No active harvesting

**Above Ground Lodge Maintenance or Construction**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity

**Bank Lodge Maintenance or Construction**
○ Certain - Documented Evidence  ○ Probable - Strong Evidence
○ Possible - Anecdotal or Inconclusive Evidence
○ Unsure - Just a guess  ○ No Evidence of Activity
**Beaver Dam Monitoring Form - Basic**

### Observation Info

- **Observer Name:** ____________________________
- **Site ID:** ____________________________
- **Observation Date:** ____________________________

### Beaver Built Dam?
- ○ Beaver Dam
- ○ Beaver Dam Analogue (manmade)

### Dam Type:
- ○ Primary (has lodge... typically larger)
- ○ Secondary (typically smaller – part of complex)

### Status
- ○ Active
- ○ Abandon
- ○ Historic/Relic

### Confidence in Status
- ○ Certain - Documented Evidence
- ○ Probable - Strong Evidence
- ○ Possible - Anecdotal or Inconclusive Evidence
- ○ Unsure - Just a guess

### Positional Attributes

- **GPS UTM Easting:** ____________________________
- **GPS UTM Northing:** ____________________________
- **Stream Name:** ____________________________

### Notes &/or Sketch
# BEAVER DAM COMPLEX MONITORING FORM - BASIC

## OBSERVATION INFO

| Observer Name: | ____________________________ |
| Site ID: | ____________________________ |
| Observation Date: | ____________________________ |

## BEAVER BUILT DAMS?

- Beaver-only Built Dams
- Beaver Dam Analogue (manmade)
- Mix of beaver-built and manmade

## COMPLEX TYPE:

- Single Dam only
- Primary + One or More Secondary
- Multiple Possible Primaries + One or More Secondary

## STATUS

- Active
- Abandon
- Historic/Relic

## CONFIDENCE IN STATUS

- Certain - Documented Evidence
- Probable - Strong Evidence
- Possible - Anecdotal or Inconclusive Evidence
- Unsure - Just a guess

## POSITIONAL ATTRIBUTES

### LOCATION OF PRIMARY DAM

| GPS UTM Easting: | ____________________________ |
| GPS UTM Northing: | ____________________________ |

### COMPLEX SIZE

| Number of Primary Dams: | ____________________________ |
| Number of Secondary Dams: | ____________________________ |

### POSITION OF DAMS

Primary Dam Location:  □ Top □ Bottom □ In-between

| Number of Secondary Dams Upstream of Primary: | _______ |
| Number of Secondary Dams Downstream of Primary: | _______ |

## NOTES & / OR SKETCH
ASSESSING BEAVER DAM BUILDING CAPACITY

In Macfarlane et al. (2015) we presented a method for modelling the capacity of a riverscape to support dam building activity by beaver. In other words, the model predicts the upper limit of how many dams can be built in a reach.

This model is part of the BRAT – Beaver Restoration Assessment Tool. It is part of a family of open-source tools our lab built and are available through the Riverscapes Consortium. See: http://brat.riverscapes.xyz


EXERCISE

In the field, we will ask the same questions that the BRAT capacity model asks, and use the inference system (a rule table) to assess capacity. The actual model uses GIS data to provide approximate quantitative answers to the same questions and a fuzzy inference system to do the math. Fill out the form on the next page and answer use the look up tables.

We will stick to a simple version of this form here, but in Chapter 4 of the Riverscapes Restoration Design Manual, we provide a series of basic and advanced forms and full description of how to use them. There is also a field Survey 123 App that allows you to do the same thing on a tablet or phone, or from a browser.
**OBSERVATION INFO**

Observer Name: ____________________________
Reach ID: ____________________________

**LOCATION OF ASSESSMENT REACH**

GPS UTM Easting: ____________________________
GPS UTM Northing: ____________________________

**LENGTH OF REACH**

Length ____________ meters OR _______ x bankfull widths

**VEGETATION CAPACITY TO SUPPORT DAM BUILDING ACTIVITY**

**SUITABILITY OF STREAMSIDE VEGETATION**

- Unsuitable
- Barely Suitable
- Moderately Suitable
- Suitable
- Preferred

Vegetation within 30 m of water’s edge

What vegetation types are abundant?
- Desirable woody (e.g. Aspen, Willow, Cottonwood)
- Other woody (e.g. conifers, sagebrush)
- Grasses
- Crops
- Ornamentals
- Developed

**SUITABILITY OF RIPARIAN/UPLAND VEGETATION**

- Unsuitable
- Barely Suitable
- Moderately Suitable
- Suitable
- Preferred

Vegetation within 100 m of water’s edge

What vegetation types are abundant?
- Desirable woody (e.g. Aspen, Willow, Cottonwood)
- Other woody (e.g. conifers, sagebrush)
- Grasses
- Crops
- Ornamentals
- Developed

**DAM DENSITY CAPACITY ASSESSMENT BASED ON SUITABILITY OF VEGETATION ONLY (USE TABLE 1)**

- None (no dams)
- Rare (0-1 dams/km)
- Occasional (1-4 dams/km)
- Frequent (5-15 dams/km)
- Pervasive (15-40 dams/km)

**COMBINED CAPACITY TO SUPPORT DAM BUILDING ACTIVITY**

**CAN BEAVER BUILD A DAM AT BASEFLOWs?**

- Probably can build dam
- Can build dam
- Can build dam (saw evidence of recent dams)
- Could build dam at one time (saw evidence of relic dams)
- Cannot build dam (streampower really high)

**HOW DOES THE REACH SLOPE IMPACT THEIR ABILITY OR NEED TO BUILD DAMS?**

- So steep they cannot build a dam (e.g. > 20% slope)
- Probably can build dam
- Can build dam (inferred)
- Can build dam (evidence or current or past dams)
- Really flat (can build dam, but might not need as many as one dam might back up water > 0.5 km)

**IF BEAVERS BUILD A DAM, CONSIDER WHAT HAPPENS TO THE DAM(S) IN A TYPICAL FLOOD (E.G. MEAN ANNUAL FLOOD)?**

- Blowout
- Occasional Blowout
- Occasional Breach
- Dam Persists

**COMBINED DAM DENSITY CAPACITY ASSESSMENT BASED ON ALL (USE TABLE 2)**

- None (no dams)
- Rare (0-1 dams/km)
- Occasional (1-4 dams/km)
- Frequent (5-15 dams/km)
- Pervasive (15-40 dams/km)

Maximum Dam Density (dams/km)

0 - None  0 - 1 Rare  1 - 4 Occasional  5 - 15 Frequent  16 - 40 Pervasive
INFERENCESYSTEM OF CAPACITY BASED ON VEGETATION ONLY:

Table 1. Rule table for two input inference system that models the capacity of the reach to support dam building activity (in dam density) using the suitability of streamside vegetation and suitability of riparian/upland vegetation as inputs.

<table>
<thead>
<tr>
<th>Rules</th>
<th>Inputs</th>
<th>Output Dam density capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suitability of streamside vegetation &amp; Suitability of riparian/upland vegetation</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Unsuitable &amp; Unsuitable</td>
<td>then None</td>
</tr>
<tr>
<td>2</td>
<td>Unsuitable &amp; Barely suitable</td>
<td>then Rare</td>
</tr>
<tr>
<td>3</td>
<td>Unsuitable &amp; Moderately suitable</td>
<td>then Rare</td>
</tr>
<tr>
<td>4</td>
<td>Unsuitable &amp; Suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>5</td>
<td>Unsuitable &amp; Preferred</td>
<td>then Occasional</td>
</tr>
<tr>
<td>6</td>
<td>Barely suitable &amp; Unsuitable</td>
<td>then Rare</td>
</tr>
<tr>
<td>7</td>
<td>Barely suitable &amp; Barely suitable</td>
<td>then Rare</td>
</tr>
<tr>
<td>8</td>
<td>Barely suitable &amp; Moderately suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>9</td>
<td>Barely suitable &amp; Suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>10</td>
<td>Barely suitable &amp; Preferred</td>
<td>then Occasional</td>
</tr>
<tr>
<td>11</td>
<td>Moderately suitable &amp; Unsuitable</td>
<td>then Rare</td>
</tr>
<tr>
<td>12</td>
<td>Moderately suitable &amp; Barely suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>13</td>
<td>Moderately suitable &amp; Moderately suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>14</td>
<td>Moderately suitable &amp; Suitable</td>
<td>then Frequent</td>
</tr>
<tr>
<td>15</td>
<td>Moderately suitable &amp; Preferred</td>
<td>then Frequent</td>
</tr>
<tr>
<td>16</td>
<td>Suitable &amp; Unsuitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>17</td>
<td>Suitable &amp; Barely suitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>18</td>
<td>Suitable &amp; Moderately suitable</td>
<td>then Frequent</td>
</tr>
<tr>
<td>19</td>
<td>Suitable &amp; Suitable</td>
<td>then Frequent</td>
</tr>
<tr>
<td>20</td>
<td>Suitable &amp; Preferred</td>
<td>then Pervasive</td>
</tr>
<tr>
<td>21</td>
<td>Preferred &amp; Unsuitable</td>
<td>then Occasional</td>
</tr>
<tr>
<td>22</td>
<td>Preferred &amp; Barely suitable</td>
<td>then Frequent</td>
</tr>
<tr>
<td>23</td>
<td>Preferred &amp; Moderately suitable</td>
<td>then Pervasive</td>
</tr>
<tr>
<td>24</td>
<td>Preferred &amp; Suitable</td>
<td>then Pervasive</td>
</tr>
<tr>
<td>25</td>
<td>Preferred &amp; Preferred</td>
<td>then Pervasive</td>
</tr>
</tbody>
</table>
### Table 2. Rule table for four input inference system that models the capacity of the reach to support dam building activity (in dam density) using the vegetation dam density capacity (output of Table 1 model), the two-year flood stream power, baseflow stream power and reach slope.

<table>
<thead>
<tr>
<th>Rules</th>
<th>Vegetation dam density capacity</th>
<th>2-year flood stream power</th>
<th>Baseflow stream power</th>
<th>Reach slope</th>
<th>Dam density capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>, then None</td>
<td>None</td>
</tr>
<tr>
<td>2. If None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>, then None</td>
<td>Rare</td>
</tr>
<tr>
<td>3. If None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>, then None</td>
<td>Rare</td>
</tr>
<tr>
<td>4. If Rare</td>
<td>&amp; Dom persists</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>5. If Rare</td>
<td>&amp; Dom persists</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>6. If Rare</td>
<td>&amp; Occasional breach</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>7. If Rare</td>
<td>&amp; Occasional breach</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>8. If Rare</td>
<td>&amp; Occasional blowout</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>9. If Rare</td>
<td>&amp; Occasional blowout</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>10. If Rare</td>
<td>&amp; Blowout</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>11. If Rare</td>
<td>&amp; Blowout</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>12. If Occasional</td>
<td>&amp; Dom persists</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>13. If Occasional</td>
<td>&amp; Dom persists</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>14. If Occasional</td>
<td>&amp; Occasional breach</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>15. If Occasional</td>
<td>&amp; Occasional breach</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>16. If Occasional</td>
<td>&amp; Occasional blowout</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>17. If Occasional</td>
<td>&amp; Occasional blowout</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>18. If Occasional</td>
<td>&amp; Blowout</td>
<td>&amp; Can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>19. If Occasional</td>
<td>&amp; Blowout</td>
<td>&amp; Probable can build dam</td>
<td>&amp; NOT Cannot build dam</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>20. If Frequent</td>
<td>&amp; Dom persists</td>
<td>&amp; Can build dam</td>
<td>&amp; Really flat</td>
<td>, then Occasional</td>
<td>Occasional</td>
</tr>
<tr>
<td>21. If Frequent</td>
<td>&amp; Dom persists</td>
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<td>35. If Frequent</td>
<td>&amp; Occasional blowout</td>
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<td>36. If Frequent</td>
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BIRCH CREEK RESTORATION

Improving Instream Habitat and Riparian Areas to Benefit Bonneville Cutthroat Trout and Sage Grouse

Birch Creek, UT looking upstream. Photo credit: Scott Shahverdian, September 2017.

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Prepared for:
Utah Division of Wildlife Resources and Bureau of Land Management

June 2018
Improving Instream Habitat and Riparian Areas to Benefit Bonneville Cutthroat Trout and Sage Grouse

THE NEED FOR RESTORATION

Birch Creek is currently characterized by simplified instream habitat (e.g. limited pool-riffle habitat), channel incision, and limited riparian vegetation. In order to assess the current riparian and geomorphic conditions along Birch Creek we used a combination of remote sensing and field surveys. Here we present the results from a suite of remote-sensing tools as well as field surveys.

VALLEY BOTTOM DELINEATION AND RIPARIAN CONDITION

Riparian condition was assessed using a suite of remote sensing tools, including the Valley Bottom Extraction Tool (V-BET) (Gilbert, et al., 2016), Riparian Vegetation Departure (RVD) index (Macfarlane, et al., 2017), Riparian Vegetation Conversion Type (RVCT) (Macfarlane, et al., 2017), and Riparian Condition Assessment (RCA) tool (Macfarlane, et al., 2018). Assessing the current condition and conversion can inform how restoration activities may benefit riparian...
Assessing the valley bottom extent is important because it establishes the maximum possible extent that can be influenced by stream restoration. A valley bottom is defined as the contemporary stream channel and its current floodplain (i.e. excludes terraces) (Wheaton, et al., 2015). The valley bottom for the South Creek watershed and the restoration reach in Birch Creek is shown in Figure 2.

The \textit{riparian vegetation departure} (RVD) index is a ratio that is similar to the ‘observed’ to ‘expected’ (‘O/E’) metrics used in environmental condition assessments. RVD characterizes riparian vegetation for a given stream reach as the ratio of existing riparian vegetation to an estimation of pre-European settlement riparian vegetation coverage. Current and historic vegetation data was obtained from LANDFIRE biophysical setting data (https://www.landfire.gov/). To estimate this departure at the reach level, the Valley Bottom Extraction Tool (V-BET; Gilbert et al., 2016) was used to delineate the valley bottom, which was then separated into analysis polygons that act as the boundaries for characterizing vegetation departure (Figure 3). The proportion of each area that contains native riparian vegetation (current and historic) was calculated (Figure 3). An estimate of riparian condition was then made by dividing the historic proportion by the existing proportion (Figure 3).
Figure 3 illustrates the process of determining RVD; Figure 4 shows the results for the South Creek watershed and the restoration reach along Birch Creek. Within the restoration area, almost three quarters (72%) of Birch Creek has experienced significant departure from historic vegetation conditions.

Figure 3 - A conceptual diagram of the riparian vegetation departure index showing how mid points of the drainage network (1) are used to generate Thiessen polygons (2) and how these polygons are buffered by the resolution of the vegetation data to ensure that vegetation data is completely contained within the valley bottom in headwater reaches (3). Riparian vegetation departure is calculated using the ratio of existing area of native riparian vegetation (4) to historic area of native riparian vegetation (5) and the output is a segmented drainage network containing riparian departure from historic condition scores (6). Figure from Macfarlane et al., 2017 (Figure 1).

While RVD provides information on the change from historic conditions, it does not provide information on the most likely causes of that change. The riparian vegetation conversion type (RVCT) compares current land cover to historic land cover within the same area, which can provide insights into the potential causes of departure from historic conditions. Understanding the reasons for riparian vegetation departure is important when assessing restoration, as the conversion type may limit the streams ability to recover. For example, riparian areas that have been converted to agriculture or development are less likely to be restored than those that have experienced conversion to upland species as the result of fire suppression or grazing. Specifically, we compare current and historic land cover on a pixel-by-pixel basis to determine whether a conversion has occurred (Figure 5). Within each Thiessen polygon the proportion of each vegetation conversion type was calculated, and these values were attributed to the drainage network output with a unique field for each conversion type (e.g., conifer encroachment, conversion to agriculture, conversion to grass/shrubland, conversion to invasive, devegetation, development, and no change) For symbolization, if the proportion of “no change” for a reach was 0.85 or greater, the reach was symbolized as “no change.” Otherwise, it was symbolized by the next most dominant conversion type. When symbolized with a conversion type, a reach was sub-categorized into minor, moderate or significant conversions (e.g., ‘minor conifer encroachment’) based on the proportion associated with the conversion. If the dominant conversion’s proportion was less than or equal to 0.25, it was categorized as minor. If the proportion was between 0.25 and 0.5, it was categorized as moderate, and if it was greater than 0.5, it was categorized as significant (Figure 6). The output stream network was attributed with fields containing proportions for each type of conversion for each reach in the stream network.
In the South Creek watershed the major conversion types are conversion to agriculture (34%), conifer encroachment (26%), and negligible or minor conversion (23%). In general, conversion to agriculture is more significant in the lower portions of the watershed and conifer encroachment dominates at mid-to-upper elevations. Within the project area, conifer encroachment is the dominant conversion type (58%) and is found throughout the upper reaches while negligible change is found in the lower reaches (Figures 6 and 7).

It is important to note that in the lower reaches, dominated by a ‘negligible’ conversion, instream habitat complexity is low and the extent of riparian vegetation is still limited (Figure 7) and in need of restoration. We expect the lower reaches are capable of a quicker return to a more complex state than the upper reaches, however they would still benefit from active restoration.
Improving Instream Habitat and Riparian Areas to Benefit Bonneville Cutthroat Trout and Sage Grouse

Figure 5 – Conceptual illustration of the Riparian Vegetation Conversion Tool. Current and historic vegetation data from LANDFIRE are compared on a per-pixel basis and classified by conversion type. The dominant conversion type within each polygon is then symbolized on the corresponding stream segment. Inset boxes 1 and 2 illustrate two conversion types: conversion to agriculture and negligible conversion.

Figure 6 – Riparian Vegetation Conversion Type in the South Creek watershed and the restoration area along Birch Creek. Within the restoration area conifer encroachment represents the dominant riparian conversion type. The lower reaches within the restoration area are characterized by negligible changes to the riparian area.
Figure 7 – Aerial imagery that is characteristic of the upper reaches (top) and lower reaches (bottom) along Birch Creek, September 2017. The upper reaches are characterized by significant conifer encroachment and little to no woody riparian vegetation. Note that in the top photo neither the stream, nor any woody riparian vegetation is visible. In the lower reaches (bottom), woody riparian vegetation is present, though limited, and conifers do not dominate the valley bottom. Photo
Two pressure transducers (U20L Onset Corporation) were installed in the pond created upstream of each weir to monitor water levels. Pressure transducers were programmed to record the water level at 1 hour intervals, which was deemed sufficient to monitor streamflow in Birch Creek. A third pressure transducer was located at the upstream weir and used to monitor atmospheric pressure in order to correct water levels during data processing.

U20L pressure transducers are accurate to 0.1% (Onset Corporation, http://www.onsetcomp.com/products/data-loggers/u20l-01). Water levels were recorded in the field by measuring the height of water above the weir crest in order to provide a reference water level for processing stage measurements. An additional measurement was recorded when the data was downloaded in April 2018 in order to corroborate initial field measurements. Specific data processing notes and inputs will be provided upon request.

The maximum stage that can be measured at the upstream weir before flow overtops the weir is 1.38 ft, which corresponds to a flow of 5.6 cfs. The maximum stage that can be measured at the downstream weir is 1.51 ft which corresponds to a flow of 7.0 cfs.

Data was downloaded from all pressure transducers on May 5, 2018. Data was processed using Hoboware (Onset Corporation) and included correcting for barometric pressure using Barometric Compensation Assistant (Hoboware, Onset Corporation). Stage was converted to discharge using a general equation flow through 90 degree v-notch weirs (Equation 1).

\[
CFS = 2.5 \ H_{ft}^{2.5}
\]

Eq. 1
RESTORATION IMPLEMENTATION

Restoration was implemented in September and October 2017 by Utah Division of Wildlife (UDWR), Anabranch Solutions (AS) and Bureau of Land Management (BLM) personnel. UDWR was responsible for restoration using heavy equipment along two reaches in the upper section (Figure 11 and 12), and AS, with help from BLM implemented a suite of restoration structures on both the upper and lower sections of Birch Creek (Figure 11 and 13).

Figure 11 – Location of restoration structures and types, mechanized restoration reaches and control reaches on Birch Creek. For full implementation report see Shahverdian and Wheaton (2017).
Figure 12 - UDWR personnel used heavy machinery to restore two reaches along the upper section of Birch Creek, September 2017.
Improving Instream Habitat and Riparian Areas to Benefit Bonneville Cutthroat Trout and Sage Grouse

Figure 13 – BLM personnel, with oversight from Anabranch Solutions, built 66 restoration structures including Beaver Dam Analogues (BDAs) and Post-Assisted Log Structures (PALS) in October 2017.

Restoration design and implementation was led by Anabranch Solutions. For a complete description of restoration design and implementation see Shahverdian and Wheaton (2017).

RESULTS

HYDROLOGY

Discharge records from October 2017 through May 2018 show that following installation flow measured at the upstream weir was roughly equal to that measured at the bottom of the restoration reach. Higher flows experienced during December 2017 and culminating in a high flow event in January 2018 experienced significant attenuation through the restoration reach (Figures 14 – 16). Following peak flows, the restoration reach functions as a gaining reach (i.e., flows measured at the downstream weir exceed flows coming into the restoration reach) (Figures 14 – 16). The largest gains are seen immediately following peak flows, however Birch Creek remains a gaining stream through the end of the flow monitoring period.
Figure 14 – Discharge from mid October 2017 to early May 2018 in Birch Creek. Discharge was calculated by measuring flow through 90-degree v-notch weirs installed at the top and bottom of the restoration reach. The upstream weir is capable of measuring flows up to 5.5 cfs before overtopping, represented by the grey dashed line. Values above 5.6 cfs are therefore underestimates. Below average snowpack in 2017-2018 resulted in the absence of a spring runoff. High flows occurred in December 2017 and January 2018. Discharge data shows significant flow attenuation during high flow events coupled with increased baseflow from mid-January to April.

Figure 15 – A zoomed-in view of the hydrograph that illustrates the increase in baseflow following high flow events in December 2017 and January 2018. Discharge measured at the downstream weirs aligns with inputs at the upstream weir but remain elevated until the end of the monitoring period.
Evaluating the effects of restoration on streamflow is challenging due to the absence of pre-restoration data. It is likely that some degree of flow attenuation took place prior to restoration. The lower restoration reaches are characterized by a wider valley bottom and higher channel-floodplain connectivity that would allow spring runoff/storm flows access to the floodplain and result in flow attenuation. Further complicating our assessment of the influence of restoration on discharge is the knowledge that Birch Creek is a losing stream. Field observations prior to restoration revealed that Birch Creek was dry where the stream crossed South Creek Road, approximately 3 km downstream of our treatment reach. Because we do not have pre-restoration data we cannot determine the magnitude of loss through the project area or the reaches downstream of the project area. However, given that field observations show that Birch Creek is a losing stream, our results that show a switch to a gaining stream, no matter how small, may be of increased significance.

Based on a combination of discharge data and field observations we can suggest a number of plausible explanations for flow attenuation through the restoration area. Following restoration there was an immediate increase in the areal extent of surface water (Figure 17). This can be seen in orthographic imagery collected before and after restoration as well as from pre and post pool habitat surveys (Table 1). Observations of sub-surface flow downstream of restoration structures suggest that restoration structures are forcing recharge of groundwater due to overbank flows and infiltration as far as 150 m downstream of restoration structures. While quantification of this storage is beyond the scope of this report, these observations provide preliminary evidence for a mechanism of flood attenuation, increased storage and increased baseflows.

![Figure 16 - The difference in discharge measured between the downstream and upstream gaging sites. Values shown represent subtracting the upstream discharge from the downstream discharge such that negative values reflect flow attenuation and storage and positive values reflect gains in discharge.](image-url)
Figure 17 – Pre and post restoration water surface extent at a BDA complex in the lower reach along Birch Creek. A primary BDA forced flows overbank where they occupied a historic channel and inundated a significant portion of the floodplain. In addition to an increase in surface water, evidence of increased groundwater storage and subsurface flow was seen along a cutbank approximately 150 m downstream of the primary BDA forcing overbank flows. These observations suggest that Birch Creek can provide temporary storage of water that will aid in flow attenuation and may be able to slow the delivery of water downstream.

Pre and post water surface extent polygons were digitized in ArcGIS using orthorgraphic imagery obtained from drone flights and processed by Drone deploy software (https://www.dronedeploy.com/) and used to compare pre and post restoration surface water extents to provide insight into water storage. Figure 17 provides an example of the changes in surface water extent at one BDA complex in the lower section of Birch Creek. Across the entire restoration reach, including control reaches and mechanized treatments, the pre restoration areal extent of surface water was 2432 m². Post restoration, the areal extent of surface water increased to 2841 m², a 16% increase. Increased surface water suggests both an increase in temporary water storage, and increased water resources available to promote riparian expansion and mesic habitats, as well as increased quantity of fish habitat. Changes in pool count and pool characteristics (next section) provide an additional line of evidence for the increased temporary storage and pool habitat caused by restoration actions.

**GEOMORPHIC CONDITION**

Post restoration habitat surveys to identify pools were performed in May 2018 by USU personnel. Here, we limit our analysis to the extent of pre-restoration surveys in order to compare in the influence of restoration. Both mechanized reaches and the control reach were also surveyed in order to provide a baseline survey for future monitoring work and will be publicly available online.
MITIGATING SOME UNDESIREABLE BEAVER ACTIVITY

While the threats to infrastructure within Birch Creek are limited, there are some areas where roads, diversions, canals and critical infrastructure are either in the valley bottom or directly adjacent to the channel and beaver could cause problems.

Once beaver activity has been determined to be sufficiently damaging or threatening as to require management intervention there are a number of tools that can be used. All management decisions require resources, whether financial or temporal.

Living with Beaver Strategies

Traditionally, beaver management has relied on lethal trapping to prevent threats to infrastructure posed by beaver dam building activity. The increased awareness of the ecosystem benefits provided by beaver activity and their ability to help achieve a number of restoration goals has spurred the development of approaches capable of mitigating the negative results of beaver activity in order to retain the benefits such activity produces. Here we summarize a number of ‘living with beaver’ strategies. Perhaps the most authoritative resources on living with beaver strategies can be found at the Beaver Institute: https://www.beaverinstitute.org/
Breach Dam
Breaching or partial breaching (i.e., notching) a dam is an effective way to mitigate the risk of flooding due to a specific dam, if that dam is no longer being actively maintained by beaver. Breaching, rather than full removal, allows managers to effectively control the water height of the dam while retaining the ecosystem services provided by such a dam. Breaching a dam is not an effective strategy if the dam is being actively maintained, given beavers’ ability to repair breaches within short periods of time (i.e., hours to days).

![Flow chart illustrating a monitoring and evaluation protocol for potential risk posed by beaver activity. Chart highlights decisions and evaluations in diamonds, and recommends management actions in CAPITALS. Figure from (Wheaton, 2013).](image-url)
Notch Dam and Install Beaver Deterrent

In areas where an actively maintained dam is posing a threat of flooding but has not reached a critical level, notching the dam to reduce the pond height and installing a beaver deterrent may reduce the threat of flooding. A beaver deterrent is simply a white sheet that is strung between two fence posts and placed just upstream of the notched dam, such that it can move freely in the wind. The sheet is cut vertically to create strips that can blow in the wind. The movement of the sheet deters beaver from repairing the notched dam. This approach is very inexpensive and an excellent first approach to dealing with potentially threatening pond heights.

Construction Details: Beaver Deterrent
(View looking upstream from below dam)

Construction Notes
1. Notch dam to desired pond level height.
2. Pound 6-8 ft. metal fenceposts just upstream of dam notch. Fencepost length depends on depth of pond/height of dam.
3. Attach 11-gauge or baling wire between the tops of fenceposts.
4. Affix white sheet or Tyvek house wrap to wire between fenceposts ~1-2 inches above pond water level. Clamps, clothespins, or sewing a sleeve can all be used to attach the sheet to wire.
5. Cut slits into the sheet spaced ~2ft.

Figure 6 – Schematic of a beaver deterrent used to control pond height.

Install Pond Leveler to Control Pond Height

Pond levelers are another way managers and land owners can mitigate the risk of flooding due to beaver activity while allowing beaver to remain in a given area. Pond levelers installation typically requires a half-day of labor for 2-3 people and materials cost approximately $600 – 1000 depending on site-specific conditions. A pond leveler consists of a flexible, perforated plastic pipe that has an inflow protected by a large metal cage and is anchored to the bottom of the pond, and runs through the dam, and is set at the desired water level height. It may be necessary to notch the dam in order to set the pipe at the desired pond height. Following installation, we recommend placing additional material over the end of the pipe in order to prevent beaver from clogging the outflow. Examples of a pond leveler installation performed by Anabranch Solutions personnel are shown in Figure 11.
Figure 7 – Pond leveler installation. From left: securing flexible pipe in cage to protect inflow from being clogged; placing pipe into beaver pond; rebuilding beaver dam after setting pipe into notched dam at desired water height.

Beaver Deterrent to Prevent Culvert/Irrigation Diversion Clogging
As shown above beaver deterrents (Figure 10) can be used pre-emptively in order to prevent beaver from becoming active in areas that are determined to be high risk. In Grouse Creek, we recommend using beaver deterrents where streams are diverted for irrigation.
Safety
Partnering with Beaver in Restoration Design

Summary
Projects that ‘partner with beaver’ often take place in remote settings, where definitive care is not immediately available. Implementing stream restoration projects incorporates risks of working with traditional hand and power tools, such as shovels, loppers, chainsaws and hydraulic post pounders, with risks unique to working in stream environments. This section addresses safety concerns that need to be addressed for all restoration projects.

Equipment
- Hard hats
- Ear protection
- Eye protection
- Gloves
- Chaps (chainsaw operator and swampers)
- Waders

Construction Hazards
- Post driver weight ~ 90 lbs
- Many people working in small area

Stream Hazards
- Swift and/or deep water during high flow conditions
- Steep, unstable banks
- Poor footing
- Introduced tripping hazards

Managing Risk
- Pre-project and daily safety meetings
- Proper Personal Protective Equipment (PPE)
- Project foreman/safety officer to provide oversight
- 3-4 people are necessary to safely operate the post-pounder
- DO NOT lift post-driver above your shoulders
- All chainsaw operators must have proper training
- Ensure that medically trained personnel are on-site

Many agencies have their own safety procedures, trainings and certifications. Be familiar with agency-specific requirements.

Limiting the number of people working on any structure reduces the chances of an accident.
## BDA Post Pounder Summary

<table>
<thead>
<tr>
<th>Brand</th>
<th>Cost</th>
<th>Minimum Crew</th>
<th>Maximum Post Diameter</th>
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<tr>
<td><strong>Atlas Copco</strong></td>
<td>$9000</td>
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### Driver
- **Type**: Hydraulic
- **Weight lbs.**: 75
- **Example Model**: LPD-T HBP

### Power Supply
- **Type**: Gas Generator
- **Example Model**: LP-13-30 P

### Application
Largest and most powerful system that has worked in most situations. Can be challenging to move in heavily vegetated or steep systems.

### Comments
in larger streams a cheap plastic canoe ($100) cab be used to transport the system and posts downstream; Larger tires and handles can also be added to the power pac to make it easy to move/carry

### URL
https://www.atlascopco.com/en-us

---

<table>
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<tr>
<th>Brand</th>
<th>Cost</th>
<th>Minimum Crew</th>
<th>Maximum Post Diameter</th>
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<tr>
<td><strong>Skidrill</strong></td>
<td>$5000</td>
<td>2</td>
<td>4</td>
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</table>

### Driver
- **Type**: Hydraulic
- **Weight lbs.**: 70
- **Example Model**: HP 20

### Power Supply
- **Type**: Gas Generator
- **Example Model**: P38

### Application
Will drive most posts in most situations except in difficult situations such as large embedded cobble and hard clay

### Comments
in larger streams a cheap plastic canoe ($100) cab be used to transport the system and posts downstream; Larger tires and handles can also be added to the power pac to make it easy to move/carry

### URL
http://skidrill.com
**Brand** Rhin**o**  **Cost** $2000

<table>
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<th>Minimum Crew</th>
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<tbody>
<tr>
<td>1</td>
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</table>

**Driver**

- **Type**: Pneumatic
- **Weight lbs.**: 50 - 100

**Power Supply**

- **Type**: Compressor
- **Weight lbs.**: None

**Comments**

- *We have not used these but could be useful in some situations such as with larger posts in easy access situations.*

**URL** [https://www.airpostdrivers.com/air-post-driver-parts.htm](https://www.airpostdrivers.com/air-post-driver-parts.htm)

---

**Brand** Redi  **Cost** $1500 - 2500

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<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

**Driver**

- **Type**: Gas
- **Weight lbs.**: 40

**Power Supply**

- **Type**: Gas Engine
- **Weight lbs.**: None

**Application**

- *Good for small projects in relatively easy situations; very portable but does NOT have the power for difficult sites or driving hundreds of post/day*

**Comments**

- *Handy for T-posts and maintenance of structures.*

**URL** [https://redidriver.com/all-about-redi-driver-inc/](https://redidriver.com/all-about-redi-driver-inc/)
# BDA Post Pounder Summary

<table>
<thead>
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<th>Brand</th>
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<td>Kiwi &amp; others</td>
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<th>Driver</th>
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</thead>
<tbody>
<tr>
<td>Type</td>
<td>Air/Hydraulic</td>
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<tr>
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<tr>
<td>Weight lbs.</td>
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<tr>
<td>Example Model</td>
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<td></td>
<td>&gt; 500</td>
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<td></td>
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</tr>
</tbody>
</table>

**Application**

*Good for tough jobs when road access is available*

**Comments**

**URL** [http://www.kencove.com/fence/Post+Drivers_products.php](http://www.kencove.com/fence/Post+Drivers_products.php)
POST-ASSISTED BEAVER DAM ANALOGUE RECIPE

For more information on BDAs, see:
- Chapter 11 – Beaver Dam Analogues of Design Manual

Ingredients:
- Untreated wooden fence posts (as many as needed to space 30 – 50 cm apart and staggered)
- Willow weave material (long (i.e. > 1 m), limbed branches of ¼” to 2” diameter willow branches)
- Cobble, gravel, sand and mud

Instructions:
1. Decide location of BDA dam crest, configuration (e.g. straight or covex downstream), and crest elevation (use landscape flags if necessary). Position yourself with your eye-level at proposed crest elevation of dam (make sure it is < 1.5 meters in height), and look upstream to find where the pond will backwater to. Adjust crest elevation as necessary to achieve desired size of pond, inundation extent, and overflow patterns. If concerned about head drop
over BDA, build a secondary BDA downstream with a crest elevation set to backwater into base of this BDA (and lessen head drop or elevation difference between water surface in pond and water surface downstream of BDA).

2. Install posts with hydraulic post pounder into stream bed and banks in configuration as shown.

3. Trim (with chainsaw) posts to level, desired crest elevation

4. Weave willow branches in between posts across the channel. Pack stream substrate from area to be ponded against upstream face of dam to ‘plug’ up.

5. Work a willow mattress (laying branches parallel to flow) into dam on downstream side and build to provide energy dissipation to overtopping flows.

6. If desired and time permits, attempt to plug up BDA with mud and organic material (small sticks and turf) in order to flood pond to crest elevation. Optionally, you can leave this for maintenance by beaver or for infilling with leaves, woody debris and sediment.

Notes
- Resist the temptation to overbuild the BDA.
- A BDA that ‘breaches’ or ‘blows out’, just like natural beaver dams do, is not a ‘failure’ if you’ve designed to accommodate such a response. Often, BDAs that blow out or breach provide improved and more complex habitat.
- Design life: < 1 year (note actual life may last many years or even decades).

OTHER DIAGRAMS OF BDAS

These are from Chapter 6 of the Beaver Restoration Guidebook:
https://www.fws.gov/oregonfwo/Documents/2018BRGv.2.01.pdf
Figure 9 – Part of Figure 26 from Beaver Restoration Guidebook... Showing BDA as a wall. Figure 26 from Pollock et al. (2018).
Figure 10 – Example of staged, implementation of BDAs on top of an old BDA complex once the ponds aggrade. Figure 28 from Pollock et al. (2018).
Figure 11 – There are lots of ways to drive posts into streambed, but hydraulic assistance is typically used. Hand operated post pounders like we use in this workshop are far lower impact and don’t require a track-mounted excavator or backhoe with access. In addition to the downsides of riparian and instream disturbances, there can be tendency to over-build and ‘over engineer’ with too much focus on ‘structure stability’ presumably by using larger material posts. Figure 27 from Pollock et al. (2018).
Logistics
Partnering with Beaver in Restoration Design

Summary
Restoration that partners with and/or mimics beaver activity can be scaled up to address large (~10^2 km) spatial extents. Restoration over large spatial extents is likely to encounter a range of geomorphic and riparian conditions that affect restoration design and implementation. Furthermore, site accessibility and access, which exerts an important control on project design and implementation is often variable. Because restoration projects that ‘partner with beaver’ rely on a high density and total number of structures over large extents, logistics present a special challenge. Planning, design and efficient implementation enables the construction of a greater number and density of structures, which is essential to achieving restoration goals. This section addresses the logistic concerns that need to be considered during the planning and implementation phases of any restoration project.

Planning

Materials
• To post or not to post?
• What woody material is available onsite?

Equipment
• Post pounder
• Hand tools e.g. shovels, loppers, buckets
• Chainsaw
• Grip hoist

Site Accessibility
• Vehicle
• Post-pounder

Permits and Regulations
• 401 & 404 permits (Clean Water Act)
• State permits (e.g. Nevada Working in Waterways permit)
• County permits (e.g. Blaine County)
• Industrial Fire Precaution Level (i.e., Hoot owl)
• Spawning season regulations

Project Management

Group Management
• How many people are onsite?
• What level of training do they have?

Implementation
• Working upstream vs. working downstream
• High flow and low flow construction considerations
Recommended Citation:

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Funding & Acknowledgements:
This report was prepared for Stan Beckstrom at the Utah Division of Wildlife Resources (UDWR), Southern Region office as part of requisition RQS 560 185600000000006 in response to solicitation AS18027. The contract was to:

‘a) Prepare a restoration design to install a mix of large woody debris (LWD) and in-stream habitat structures (rock and LWD) scattered throughout the designated project stream reach that will provide an overall increase in stream habitat complexity (increase the amount of pools, riffles, backwater habitats and cover within the stream channel); b) Implement and construct the restoration design and; c) Provide documentation of the design and as built conditions.’

The contract was awarded in August of 2017, the design and implementation (a & b) was completed in collaboration with UDWR staff, Utah State University staff, and Bureau of Land Management (BLM) staff between September and October of 2017. This report fulfils deliverable c. This contract was part of a broader Utah Watershed Restoration Initiative project (Project ID 3688: Birch Creek - Bonneville Cutthroat Trout and Riparian), led by Dan Fletcher (BLM).

We are grateful to Justin Jimenez (BLM), Dan Fletcher (BLM), Wally Macfarlane (USU), and Elijah Portugal for their vision for this project and pursuing the WRI funding to make it a reality. We thank Stan Beckstrom (UDWR) for his efforts in administering the WRI contracting, leading the design and construction of the mechanized treatments, and being a fantastic collaborator. Stan Beckstrom, Richard Hepworth and Gary Bezzant (all UDWR) as well as James Whelan (USFS) were all critical in working with Dan Fletcher and Justin Jimenez (BLM) to keep the project rolling. Wally Macfarlane, Elijah Portugal and Gary O’Brien were engaged collaborators from Utah State University, who provided helpful BRAT, VBET and RCAT models and planning documentation that were instrumental in helping build an efficient design. Jimenez, Fletcher and Macfarlane were also instrumental in helping lead an army of 10-20 volunteers and BLM staff each day for a week in October to construct the hand-built structures. We are indebted to hard work and manual labor of many staff and volunteers from various organizations including: Erica Anderson (BLM), Douglass Bayles (BLM), Rhett Boswell (UDWR), Jessica Bulloch (BLM), Michelle Campeau (BLM), Jamison England (BLM), Steve Flinders (USFS), Korby Fraughton (BLM), Michael Golden (USFS), Jared Goodell (BLM), Amy Greenwood (BLM), Leisel Grisman (BLM), Stephanie Grischkowsky (BLM), Ethan Hooper (BLM), Chad Hunter (BLM), Dave Jacobson (BLM), Jeremy Jarnecke (BLM), Daniel Keller (UDWR), Shaunna Leavitt (USU), Cassie Mellon (BLM), Christine Pontarolo (BLM), Dustin Schaible (BLM), Brooklyn Shotwell (BLM), Jamie Smith (SUU), Jason Stewart (BLM), Jens Swensen (USFS), Christina Tinsley (SUU), Kalli Tyler (BLM), James Whelan (USFS), Clint Wirick (US Fish & Wildlife Service) and others we failed to mention. Finally, thank you to Wally Macfarlane and Adrea Wheaton for their editorial comments and input to this report.
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Figure 11 – Primary beaver dam analog designed to create extensive deep water pool habitat and access abandoned side-channel on river right. .............................................................................................................................................................................................. 22
EXECUTIVE SUMMARY

This report describes the design and implementation of a stream restoration project (bid AS 18027) along Birch Creek, near Beaver, Utah. Birch Creek is a demonstration project designed to highlight a range of low cost, simple restoration structures, including Beaver Dam Analogs (BDAs), Post-Assisted Log Structures (PALS) as well as other woody structures that increase in-channel roughness and complexity, as well as promote incision recovery and channel-floodplain connectivity. As part of the demonstration, the Utah Division of Wildlife Resources (UDWR) also performed restoration work along two segments of Birch Creek using an excavator. The goals of restoration along Birch Creek are to improve in-stream habitat for native Bonneville cutthroat trout (*Oncorhynchus clarki Utah*) and increase native riparian vegetation. Previous surveys have shown Birch Creek is home to BCT, which are considered a species of greatest conservation need (Utah Wildlife Action Plan 2015). BCT found in Birch Creek have been used as an important source population for BCT reintroductions in other streams in the Beaver River and Sevier River watersheds (Hadley et al., 2011). Current and historic land management practices as well as natural limitations (e.g., low flow conditions) contribute to current low quality BCT habitat in Birch Creek.

A restoration design plan was developed by Anabranch Solutions during August and September 2017. Implementation of restoration using heavy equipment was designed and performed by UDWR personnel on September 11-12, 2017. Implementation of the ‘cheap and cheerful’ restoration designed by Anabranch Solutions was performed by Bureau of Land Management (BLM) staff and volunteers from October 16-20, 2017 with direction and construction observation from Anabranch Solutions personnel. The UDWR treated two ~150 m segments along the upper section of Birch Creek. Anabranch Solutions and BLM built 60 restoration structures along roughly 1.75 km of stream. Two small sections, roughly 150 m in length were left untreated as control segments.

In order to evaluate the influence of restoration on streamflow, 90-degree V-notch weirs were installed at the upstream extent of the treatment area and below the restoration area by Utah State University. For a complete description of the restoration site and recommended monitoring actions associated with this restoration we refer readers to the Restoration and Monitoring Plan for Bonneville Cutthroat Trout and Riparian Vegetation on Birch Creek, Beaver County, Utah (Macfarlane et al., USU, in Preparation).

BACKGROUND

Birch Creek, a 2nd order stream that drains the west side of Birch Creek Mountain, near Beaver, Utah is currently characterized by low instream complexity and limited riparian vegetation. Intensive grazing, historic extirpation of beaver, and conifer encroachment have all contributed to the current condition of Birch Creek. Birch Creek has been identified as home to a population of native Bonneville Cutthroat Trout (BCT) a species of special concern in Utah. Previous restoration efforts date back to 1976 and include habitat improvement structures designed to increase pool habitat throughout Birch Creek as well as fencing exclosures intended to limit grazing pressure in the stream and riparian area. The current restoration effort represents phase II of an ongoing restoration effort funded through Utah’s Watershed Restoration Initiative (project ID 3688) and focuses on increasing instream complexity as well as restoring riparian areas through increased channel-floodplain connectivity. Phase I of restoration along Birch Creek focused on promoting native riparian plants by reducing conifer encroachment through selective removal.
of pinyon and juniper. (Some juniper were left near the stream in order to provide shading to reduce stream temperatures and provide cover for BCT.) For documentation of prior restoration efforts see Tucker (1987).

Field reconnaissance for phase II began in June 2016 and a comprehensive restoration proposal and monitoring report was developed by Utah State University personnel (See Macfarlane et al., in Preparation). Anabranch Solutions LLC was contracted (bid AS 18027) to design and implement a restoration plan to “improve riparian vegetation and in-stream aquatic habitat” along Birch Creek. As part of the contract, Anabranch Solutions is required to submit documentation of the design and as built conditions, reported in this document.

The remainder of this report is structured as follows: a brief description of BDAs, PALS and other woody restoration structures is provided (for a more comprehensive discussion of BDAs and the benefits of beaver to stream restoration we refer readers to Pollock et al., 2012 and Pollock et al., 2014); a brief survey of riparian and geomorphic conditions along Birch Creek is presented; and the locations and specific design hypotheses for all restoration structures is presented.

BEAVER DAM ANALOGS

Beaver dam analogs (Pollock et al., 2014; Pollock et al., 2012) have been used across a range of physiographic settings to address a variety of different degraded stream conditions. Beaver dam analogs mimic the form and function of natural beaver dams and can be used to capture some of the physical and ecological benefits associated with natural beaver dams as well as promote successful beaver translocation by creating immediate habitat conditions required by beaver, most notably deep water habitat. The influence of beavers as ecosystem engineers has been well documented, though significant gaps remain (Kemp et al., 2012). Naturally occurring and/or mimicking beaver activity is of interest to the restoration community because of the influence beaver dams have on physical and ecological stream characteristics. Specifically, beaver dams have been demonstrated to influence local water table elevations (Westbrook et al., 2006), accelerate channel incision recovery (Pollock et al., 2007; Pollock et al., 2014), decrease peak runoff and increase baseflows (Nyssen et al., 2011), promote sediment retention (Butler and Malanson, 1995; Butler and Malanson, 2005), increase species richness of the riparian zone (Westbrook et al., 2011) and at the landscape scale (Wright et al., 2002), and influence instream temperatures and surface water-ground water interactions (Weber et al., 2017). These impacts are often directly related to stream restoration goals which focus on restoring instream habitat for fish.

Previous studies have cited beaver dams as an impediment to fish movement (Kemp et al., 2012). However, in an extensive review Kemp et al. (2012) found that 78% of all claims that beaver dams act as impediments to movement were speculative rather than data driven. Recent work has shown that fish are capable of passing natural beaver dams (Bouwes et al., 2016; Lokteff et al., 2013) and BDAs (Bouwes et al., 2016) in both the upstream and downstream directions. Furthermore, Bouwes et al. (2016) documented how increased beaver activity and increases in both natural and man-made beaver dams increased the density, survival, and production of juvenile steelhead at the ecosystem scale.
Beaver dam analogs can be built using a variety of materials including riparian species such as willow, as well as upland woody species such as sagebrush and juniper. In degraded riparian areas woody riparian vegetation may not be present or limited, and relying on locally available woody material such as sagebrush, pinyon and juniper reduces the time and resources required to gather and import materials. Reducing the resources spend collecting materials enables more effort to be spend building structures resulting in a larger restoration footprint. When working in streams with high stream power untreated wooden posts may be used to provide additional stability and prevent dams from breaching or blowing out during high flows. Untreated, sharpened, wooden posts approximately 10 cm in diameter are driven into the streambed and banks using a hydraulic post pounder (Figure 1 and Figure 2). Posts can be driven before or after BDA construction. Installing posts for BDA construction requires a stream alteration permit from the Utah Division of water rights. (Stream alteration permits were acquired by BLM personnel prior to restoration implementation.) Wooden posts are used in stream reaches where there is significant concern that BDAs will not persist through annual peak flows. BDAs are not designed to be permanent.

Figure 1 – Cross sectional and planform view of a generic beaver dam analog structure. In practice beaver dam analogs may include posts or be built without posts depending on site specific considerations and the dam crest elevation will depend on the local setting and structure objectives. (Credit: Elijah Portugal)
structures. They are intended to have lifespans similar to natural beaver dams (i.e., typically 3-10 years). The lifespan of a single BDA depends on the sediment and flow regime, as well as maintenance (by hand crews or better yet, by beaver). Dams may breach during high flow events, or fill with sediment over the course of many years. Unlike engineered log jams (ELJs) that are sometimes designed intended to have long life-spans, restoration that relies on BDAs recognizes that streams are dynamic systems that change through time and that restoring the conditions and processes capable of creating and maintaining physical complexity is what defines successful restoration. Furthermore, BDAs that have been breached or blown out may still create quality instream habitat for fish.

In addition to woody material, local cobble and gravel are placed at the upstream base of the structure in order to limit scour and improve stability. BDAs construction mimics natural beaver dam construction and uses sediment to promote upstream pond formation by reducing dam porosity. In areas where upstream pond formation is not a structure objective, BDAs may use only woody material and forego the use of sediment.

Beaver dam analogs can be described by their dam crest elevation (below, equal to, or greater than bankfull); and whether or not they are intended to create extensive upstream ponding. Our restoration design utilized four main types of BDAs 1) primary dams, 2) secondary dams, 3) channel-spanning non-ponding dams, and 4) constriction dams. The characteristics of each of these structures are outlined in table 1.
Our restoration design used primary dams and secondary dams to create extensive pond habitat, raise water tables locally, and increase channel-floodplain connectivity. We utilized channel-spanning (non-ponding) dams and constriction dams to accelerate channel incision recovery, increase lateral (i.e., channel-floodplain) connectivity, increase geomorphic complexity and increase hydraulic complexity (i.e., depth and velocity of flow). In general, primary and secondary dams require more resources to construct because they tend to be larger than other BDA types and require the use of sediment to reduce dam porosity to form extensive upstream ponding. We use “channel spanning (non-ponding)” to refer to dams
where the objective of the structure was not explicitly to form an upstream pond, and we therefore did not focus on decreasing the dam’s porosity by incorporating sediment. However, in many instances simply introducing woody vegetation (i.e., roughness) into the stream was enough to form small ponds.

We refer readers to Pollock et al., 2012 and Pollock et al., 2014 for additional information on the use of BDAs in stream restoration.

Table 1 – Crest elevation and structure objective of different type of beaver dam analogs used as part of the Birch Creek restoration project.

<table>
<thead>
<tr>
<th>Beaver Dam Analog Type</th>
<th>Crest Elevation</th>
<th>Structure Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Dam</td>
<td>equal to or above bankfull</td>
<td>Create extensive deep water habitat; force overbank flows; cause aggradation</td>
</tr>
<tr>
<td>Secondary Dam</td>
<td>equal to or below bankfull</td>
<td>Extend pond habitat; support primary dam by reducing hydraulic gradient</td>
</tr>
<tr>
<td>Channel spanning dam</td>
<td>equal to or below bankfull</td>
<td>Force overbank flows during peak runoff; alter local hydraulics to increase geomorphic complexity; increase instream roughness to cause channel widening and incision recovery; increase water depth</td>
</tr>
<tr>
<td>Constriction dam</td>
<td>equal to or below bankfull</td>
<td>Force channel widening to increase channel incision recovery, create hydraulic diversity</td>
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</table>

BEAVER DAM ANALOG COMPLEXES

Beaver dam analogs are clustered into complexes that generally consist of 2-8 individual structures. While individual structures may exert significant local influence, broader restoration goals are better achieved when individual structures are designed to work in concert with other structures. BDA complexes mimic natural beaver dam activity and increase the footprint of restoration activities. BDA complexes can be designed to achieve specific restoration goals such as channel incision recovery, increasing channel-floodplain (i.e., lateral) connectivity, or increasing deep water habitat for beaver. As such, specific restoration objectives and design hypotheses are articulated at both the complex and individual structure level. Building BDAs in complexes leverages the impact of a single structure to increase the scale of influence to meet restoration goals. Clustering structures reduces the importance of any single structure and furthermore can improve the stability of all structures by influencing reach scale hydrology. For example, a secondary BDA built below a primary BDA can be used to form a pond that extends upstream to the base of the primary structure in order to reduce the hydraulic gradient above and below the primary dam to improve its stability and reduce the likelihood of scour. In some instances, the dam pond formed by a secondary dam may help fish passage by providing both a resting area as well as deep water necessary for jumping the primary dam. Furthermore, it increases the extent of ponded area, which increases the
safe access to forage and dam building materials for beaver. For more examples of specific complex goals in restoration see (Portugal et al., 2015).

**POST-ASSISTED LOG STRUCTURES**

In addition to BDAs we constructed a number of post assisted log structures (PALS). PALS are designed to mimic naturally occurring large woody debris. In degraded stream systems, channels may lack large wood inputs due to historic and/or current land use and management that has limited riparian extent and decreased the recruitment and/or retention of LWD. Degraded channels that are characterized by homogenization and a lack of in-stream roughness and structural elements are also less likely to retain LWD and it may be exported from the reach.

Both BDAs and PALS alter hydraulics (i.e., depth and velocity) to create a geomorphic response. Unlike BDAs, PALS are not intended to create extensive upstream ponding. In our restoration design PALS rely more heavily than BDAs on high flows in order to affect the desired geomorphic changes. They also tend to use larger diameter material, more characteristic of large woody debris than the material found in beaver dams. Similar to BDAs PALS can be built with or without posts, they can be channel spanning, located in the middle of the channel or be attached to a bank, similar to a constriction BDA.

**SITE DESCRIPTION**

Birch Creek is a second order stream that drains the west side of Birch Creek Mountain in the Tushar Mountains (Figure 4). Table 2 shows the two, five and ten-year recurrence peak flows at the restoration site, as estimated by StreamStats using regional regression curves. Throughout the restoration site Birch Creek has bankfull width < 1 m. The gradient through the restoration reach ranges from 0.02 to 0.07 m/m.
BIRCH CREEK RESTORATION DESIGN

Figure 4 – Birch Creek is a 2nd order stream tributary to South Creek. The restoration segment of Birch Creek is located on BLM land immediately downstream of US Forest Service land approximately 15 km southeast of Beaver, UT.

Table 2 – Two, five and ten year recurrence interval flows along the restoration reach on Birch Creek (Streamstats).

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>Peak flow (cfs)</th>
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<tr>
<td>2 yr</td>
<td>24.1</td>
</tr>
<tr>
<td>5 yr</td>
<td>53.7</td>
</tr>
<tr>
<td>10 yr</td>
<td>77.8</td>
</tr>
</tbody>
</table>

Geomorphic and riparian conditions vary throughout the restoration area. In general, above the road crossing (referred to as the ‘upper section’ in this report) Birch Creek is characterized by low amounts of riparian vegetation. Where present, riparian vegetation is dominated by river birch and some willow. In the uppermost section, there is an aspen grove. Encroachment by pinyon and juniper is present along the length of the stream (Figures 5 and 6). The stream is dominated by planar features (e.g., cascades, rapids and runs) and pool-riffle habitat is limited. The channel has incised and is disconnected from its historic
floodplain, but has developed an inset floodplain capable of supporting riparian vegetation (Figure 5). There are historic secondary channels across the valley bottom, which is approximately 20 m wide. Evidence of these channels can be seen both by obvious channel morphology as well as preferential selection of those sites for riparian vegetation. The section below the road crossing (the ‘lower section’) is characterized by less channel incision, a wider valley bottom, more accessible floodplain and greater abundance of riparian vegetation, especially willow. The channel throughout the lower section is dominated by planar geomorphic units. In general, the lower section is better suited to promoting the expansion of riparian vegetation due to the higher degree of channel-floodplain connectivity, while the upper section has a higher potential to create deeper, more extensive pool habitat.
Figure 5 – Birch Creek is a narrow, low-sinuosity stream dominated by planar geomorphic units that is characterized by low amounts of riparian vegetation. Historic and current land management practices have promoted juniper and pinyon pine encroachment. The stream is disconnected from its historic floodplain, but has built an inset floodplain along much of its length, that can serve as a recruitment site for riparian vegetation. Photo credit: Scott Shahverdian, October 20, 2017.
BIRCH CREEK RESTORATION DESIGN

Figure 6 – Aerial imagery of the upper section of the restoration area along Birch Creek. Flow is from top to bottom. Significant conifer encroachment reflects altered hydrological conditions that promote the establishment of upland species such as juniper, within the valley bottom.

RESTORATION DESIGN

Our restoration design reflects our restoration goals and site-specific geomorphic conditions. For example, when attempting to increase channel-floodplain connectivity we selected sites with accessible floodplain. When attempting to create extensive deep water pond habitat we selected sites where the channel-geometry allowed us to form deep pools without building valley-spanning dams. Our design purposefully incorporates a number of different structure types. There are two reasons for the diversity of structures in our design. First, because the Birch Creek restoration is intended as a demonstration project we wanted to highlight the diversity of ‘cheap and cheerful’ structures that can be built by restoration practitioners and the variety of methods and materials that can be used. Second, while our restoration goals are focused on improving fish habitat, specifically pool habitat, and creating conditions...
to improve the riparian area, we recognize that creating physical heterogeneity is essential. For example, we do not seek to replace a system dominated by plane-bed morphology to one dominated by pools. Rather we assess the stream at the reach scale and attempt to create a physically complex environment that will influence instream and floodplain patterns of erosion and deposition to create and maintain that complexity. In addition, different structures are intended to respond to different flow events. Some structures will exert a significant influence on flow during baseflow conditions, others are intended to cause geomorphic responses during high flow conditions. As such, the effects of our restoration design may not be fully realized until a number of high flow events take place. Inevitably, restoration designs that are intended to influence processes rely on flow regimes that are not deterministic. However, the majority of structures we designed and built as part of the restoration at Birch Creek are intended to cause hydraulic, hydrologic and geomorphic responses during annual spring runoff and baseflow conditions.

We built 60 restoration structures, including primary dams, secondary dams, constriction dams, debris jams, and channel-spanning (non-ponding) structures (Figure 7). Specific structure characteristics and objectives are located in the Appendix of this report and available as an online supplement KMZ (viewable in Google Earth).

**Figure 7 – Restoration structure types and locations along Birch Creek.**

**LOGISTIC CONSIDERATIONS**

Our restoration design was intended to maximize our restoration footprint (i.e., the number of structures built) during a one-week construction window. As such, we sourced all our materials (save, untreated wooden posts supplied by the BLM) within 50 m of each structure. This negated the need to import materials from off-site, saving time and money. Previous juniper removal (as part of Phase I of the WRI
project to improve sage grouse habitat) provided ready-to-use material, and we selectively harvested additional juniper from within the valley bottom. We deliberately left some trees to provide shading and cover; others were felled to provide material for restoration structures. Moreover, opening up the Juniper canopy and cover in the valley bottom was intended to provide opportunities for native riparian vegetation to get established (an easier task now with raised water tables). We constructed both post-less structures and structures that used posts. We believe that structures in Birch Creek do not require posts to persist through annual spring runoff. However, we wanted to both 1) build some structures that could persist and become geomorphically effective high flow events and 2) illustrate the variety of building approaches that can be used as part of a ‘cheap and cheerful’ restoration strategy. In the lower segments of Birch Creek where UTV access was limited transporting the hydraulic post pounder would have required significant time and effort, which would have limited our ability to build structures. In this area, all structures were built without posts.

**FUTURE WORK AND RECOMMENDATIONS**

Successful long-term restoration along Birch Creek will likely require future work. The restoration design and implementation performed in Fall 2017 was designed to both create immediate improvements for BCT habitat and also to influence the geomorphic and hydrologic processes that create and maintain physical complexity in stream and riparian systems. It is essential to recognize that some structures, specifically BDAs are unlikely to maintain their present form and function without some degree of ongoing maintenance. Much like natural beaver dams are continually maintained in order to maintain pond heights by limiting dam porosity, BDAs will likely begin to ‘leak’ without maintenance, until the resemble abandoned beaver dams. Such dams can still provide significant benefits to Birch Creek, however if the desired conditions is an intact dam, maintenance will be necessary. The most effective way to promote the continued benefits is to effectively task beaver with the maintenance. Beaver translocation is the cheapest and most effective way to ensure that the physical and ecological benefits of restoration are realized. If translocation efforts are pursued, it is advisable to pruse further coordination with downstream water users and consideration of their potential concerns for impacts (positive or negative) from beaver.

A monitoring program that addresses instream habitat, riparian zone, and structure integrity and persistence is highly recommended in order to learn from and build on the restoration performed in October 2017. Such a plan, followed within and adaptive management framework will allow BLM personnel to learn from the current restoration effort and use lessons learned to further improve instream and riparian habitat along Birch Creek.
REFERENCES

Bouwes, N. et al., 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (Oncorhynchus mykiss). Scientific reports, 6: 28581.


APPENDIX

Selected photos of restoration structures on Birch Creek.

Figure 8 – Constriction dam that designed to force channel widening.
Figure 9 – Primary dam built without using posts, designed to create deep pool habitat.
Figure 10 – Debris jam extending onto floodplain designed to capture sediment/force aggradation in channel and overbank. Fresh sediment deposition and/or scoured surfaces provide establishment sites for riparian vegetation.
Figure 11 – Primary beaver dam analog designed to create extensive deep water pool habitat and access abandoned side-channel on river right.
Table 3 – Structure types and objectives at Birch Creek. Structures are numbered from upstream to downstream.

<table>
<thead>
<tr>
<th>Structure No.</th>
<th>Complex</th>
<th>Type</th>
<th>Posts (no.)</th>
<th>Crest Elevation</th>
<th>Primary Objective</th>
<th>Secondary Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>constriction</td>
<td>4</td>
<td>na (incised)</td>
<td>widen channel</td>
<td>increase hydraulic diversity</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>constriction</td>
<td>N</td>
<td>na (incised)</td>
<td>widen channel</td>
<td>increase hydraulic diversity</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>primary dam</td>
<td>13</td>
<td>bankfull</td>
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</tr>
<tr>
<td>4</td>
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<td>secondary dam</td>
<td>6</td>
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<td>connect to secondary channel</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>secondary dam</td>
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<tr>
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<td>1</td>
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<td>(confined)</td>
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<td>force aggradation</td>
</tr>
<tr>
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<td>1</td>
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<tr>
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<td>2</td>
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<td>5</td>
<td>&gt; bankfull</td>
<td>increase undercut river right</td>
<td>increase hydraulic diversity</td>
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<tr>
<td>9</td>
<td>2</td>
<td>debris jam</td>
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<td>&gt; bankfull</td>
<td>increase lateral connectivity</td>
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<tr>
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<td>2</td>
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<td>increase hydraulic diversity</td>
<td>force lateral channel migration</td>
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<td>&gt; bankfull</td>
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</tr>
<tr>
<td>20</td>
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Road Crossing

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<td>pool habitat</td>
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<td>pool habitat</td>
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</table>
| 32  | 7     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | pool habitat | increase hydraulic diversity  
| 33  | 7     | constriction  | N > bankfull | force undercut river right | increase hydraulic diversity |  
| 34  | 7     | primary dam   | 7 na (incised) | pool habitat | force channel aggradation |  
| 35  | 8     | primary dam   | N > bankfull | pool habitat | increase lateral connectivity | pool habitat |  
| 36  | 8     | secondary dam | N bankfull | support primary | increase lateral connectivity |  
| 37  | 8     | secondary dam | N bankfull | pool habitat | increase lateral connectivity |  
| 38  | 9     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | increase hydraulic diversity |  
| 39  | 9     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | increase hydraulic diversity |  
| 40  | 9     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | increase hydraulic diversity |  
| 41  | 9     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | increase hydraulic diversity |  
| 42  | 9     | channel spanning (non-ponding) | N bankfull | increase lateral connectivity | increase hydraulic diversity |  

**BIRCH CREEK RESTORATION DESIGN**
<table>
<thead>
<tr>
<th>Channel</th>
<th>Spanning (non-ponding)</th>
<th>N</th>
<th>Bankfull</th>
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<th>Increase hydraulic diversity</th>
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<td>increase lateral connectivity during high flow</td>
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*Table 4 – Primary and secondary objectives for complexes on Birch Creek.*
**ADAPTIVE MANAGEMENT OPTIONS**

With ‘Cheap and Cheerful’ restoration, where you are working with fluvial and ecological processes, we always advocate using Adaptive Management. For an overview of affordable adaptive management options, see: [http://www.anabranchsolutions.com/adaptive-management.html](http://www.anabranchsolutions.com/adaptive-management.html)

In Bouwes et al. (2016) we lay out our vision for how adaptive management can move beyond something only the biggest projects with the healthiest budgets can afford, to something we can and should as routine practice on almost every restoration project.


**EXAMPLES OF ADAPTIVE MANAGEMENT PLANS**

All these reports are licensed with Creative Commons Licenses, so with citation you can use them as templates.

- Portugal E., Wheaton, JM., Bouwes, N. 2015. **Spring Creek Wetland Area Adaptive Beaver Management Plan.** Prepared for Walmart Stores Inc. and the City of Logan. Logan, Utah. 25 Pages. DOI: [10.13140/RG.2.2.2075.3361](10.13140/RG.2.2.2075.3361)
TRANSPARENT, REPEATABLE, HYPOTHESIS DRIVEN DESIGN

In Chapters 7, 11 and 12 of the Riverscapes Restoration Design Manual, we provide a detailed overview of these design forms and how to use them. As part of the design process, we focus on tying individual structure design, to the design of a complex of structures (designed to work together). We also advocate identifying specific design hypotheses about the hydraulic, geomorphic, habitat and ecological responses in the:

- Immediate, short-term (i.e. baseflow)
- In response to typical floods (i.e. 1-2 year RI flows)
- In response to larger, rarer floods

The design is meant to not only capture where to build, and what materials are necessary, but also the design intent through articulation of these design hypotheses. This maximizes the opportunity for learning, and allows for multiple alternative responses.

Figure 12 – Examples of predicted hydraulic and geomorphic responses associated with PALS (post assisted log structures) from (Camp, 2015).
**BDA OR PAL STRUCTURE DESIGN FORM**

### DESIGN INFO
- **Designer Name(s):** ____________________________
- **Structure ID:** ____________________________
- **Observation Date:** ____________________________

### DESIGN TYPE:
- **Beaver Dam Analogue**
- **Post Assisted Log Structure**
- **Unanchored/Pinned Wood Addition**

### DESIGN VIDEO: ____________________________

### DESIGN FLOW CONDITIONS:
- **Baseflow**
- **Spring runoff**
- **Flood**
- **Post Flood**

### POSITIONAL ATTRIBUTES
- **GPS UTM Easting:** ____________________________
- **GPS UTM Northing:** ____________________________

### STRUCTURE LOCATION RELATIVE TO CHANNEL(S)
- **On Main Channel**
- **On Right Side Channel(s)**
- **On Left Side Channel(s)**
- **On Left Floodplain**
- **On Right Floodplain**

### PART OF COMPLEX?
- **Complex ID** ____________________________
- **Part of new dam complex**
- **Expansion of existing dam complex**
- **NA - Isolated Dam**
- **NA - Non-Dam**

### STRUCTURE DESIGN
#### STRUCTURE POSITION
- **River Right Margin Attached**
- **River Left Margin Attached**
- **Channel Spanning (i.e. BDA or Debris Jam)**
- **Mid-Channel**

#### STRUCTURE ORIENTATION
- **Perpendicular to Flow**
- **Angled Flow Downstream**
- **Angled Flow Upstream**
- **Diamond**
- **Triangle pointing Upstream**
- **Triangle pointing Downstream**

### CHANNEL CONSTRUCTION (% OF BANKFULL WIDTH)
- **100% BFW**
- **95-99%**
- **85-95%**
- **75-85%**
- **50-75%**
- **25-50%**
- **< 25%**

### STRUCTURE MATERIALS
- **Posts:** Approx. Count: ______
- **Willow Weave**
- **Key piece (completely limbed)**
- **Key piece (limbed on bottom side only)**
- **Root wad**
- **Small Woody Debris**
- **Woody branches (single limbed) > 15 cm diameter**
- **Woody branches (single limbed) < 15 cm diameter**
- **Mud**
- **Grass / Reeds**
- **Other organic**
- **Cobble or Boulders**
- **2-3 Guy Woody Debris**
- **Turf**
- **Dowelled or Twine tied Simple Logs**
- **Materials Sourced on-site?**
- **Materials Imported**

### STRUCTURE DIMENSIONS
- **Max dam/structure height (m) +/- 0.1 m _________**
- **Max pond depth (m if applicable) +/- 0.1 m _________**
- **Water Surface Difference (m if applicable) +/- 0.1 m**
- **Structure Length (m) +/- 1 m _________**
EXISTING FEATURES

GEOMORPHIC UNITS AT STRUCTURE LOCATION

- Planar
- Convexity (bar) type: ________
- Saddle (riffle)
- Concavity (true pool)
- Trough (shallow thalweg or chute)
- Wall: Bank
- Wall: Bar edge

How are above used? (grow (deposit), shrink (erode), maintain, build, destroy, protect)

STRUCTURAL ELEMENTS AT STRUCTURE LOCATION

- Roots
- Live Trees/Shrubs
- Aquatic Vegetation
- Boulder(s)
- Woody Debris
- Wall: Bank
- Wall: Bar edge

How are above used? (exploit, anchor, deflect, attack, protect)

ANTICIPATED HYDRAULIC RESPONSES

LOW FLOW BEHAVIOR

For Channel Spanners:
(Specify Value 0-100%; Sum should be 100%)
Flow Over Top _____
Basal Flow _____
Throughflow _____
Flow Around Left _____
Flow Around Right _____
Total Check = 100%?

For Non-Channel Spanners:
(Specify Value 0-100%; Sum should be 100%)
Shunted Flow Left _____
Shunted Flow Right _____
Flow Through (sieve) _____
Flow Over Top _____
Flow Under _____
Total Check = 100%?

TYPICAL FLOOD BEHAVIOR

- In-tact
- Minor breach (< 25 cm height) on left
- Minor breach (< 25 cm height) on right
- Minor breach (< 25 cm height) on center
- Minor basal breach
- Major breach (> 25 cm height) on left
- Major breach (> 25 cm height) on right
- Major breach (> 25 cm height) on center
- Major basal breach
- Blowout (whole height of dam breached)

BIG FLOOD BEHAVIOR

- In-tact
- Minor breach (< 25 cm height) on left
- Minor breach (< 25 cm height) on right
- Minor breach (< 25 cm height) on center
- Minor basal breach
- Major breach (> 25 cm height) on left
- Major breach (> 25 cm height) on right
- Major breach (> 25 cm height) on center
- Major basal breach
- Blowout (whole height of dam breached)

ESTIMATED UPSTREAM ZONE OF HYDRAULIC INFLUENCE

- < 1 BFW
- 1-2 BFW
- 2 – 5 BFW
- 5 -10 BFW
- > 10 BFW

ESTIMATED DOWNSTREAM ZONE OF HYDRAULIC INFLUENCE

- < 1 BFW
- 1-2 BFW
- 2 – 5 BFW
- 5 -10 BFW
- > 10 BFW

SIDE CHANNELS FORCED?

- None
- Single Left
- Multiple Left
- Single Right
- Multiple Right

POND EXTENT

- Contained within bankfull channel
- Expanding out onto floodplain
- Drained

FLOODPLAIN INUNDATION

- During Extreme Floods - River Right
- During Extreme Floods - River Left
- During Seasonal Floods - River Right
- During Seasonal Floods - River Left
- Year Round Inundation - River Right
- Year Round Inundation - River Left
ANTICIPATED GEOMORPHIC RESPONSES

POND CAPACITY (FIRST YEAR FLOODS)
- Clean
- Minor Sedimentation
- Partial Filling (upto 50% of original pond capacity)
- Major Filling (50% to 95% of original pond capacity)
- Full of sediment (no longer a pond)

POND CAPACITY (IF BIG FLOODS)
- Clean
- Minor Sedimentation
- Partial Filling (upto 50% of original pond capacity)
- Major Filling (50% to 95% of original pond capacity)
- Full of sediment (no longer a pond)

Dominant Substrate in Deepest

EXPECTED DOMINANT SUBSTRATE UPSTREAM OF STRUCTURE
- Fines (clays and silts)
- Sands
- Gravels
- Cobble
- Food Cache & Fines

EXPECTED DOMINANT SUBSTRATE DOWNSTREAM OF STRUCTURE
- Fines (clays and silts)
- Sands
- Gravels
- Cobble
- Food Cache & Fines

EXPECTED GEOMORPHIC UNITS AT STRUCTURE LOCATION
- Planar
- Convexity (bar) type: ________
- Saddle (riffle)
- Concavity (true pool)
- Trough (shallow thalweg or chute)
- Wall: Bank
- Wall: Bar edge

How are above used? (grow (deposit), shrink (erode), maintain, build, destroy, protect)

EXPECTED STRUCTURAL ELEMENTS AT STRUCTURE LOCATION
- Roots
- Live Trees/Shrubs
- Aquatic Vegetation
- Boulder(s)
- Woody Debris
- Wall: Bank
- Wall: Bar edge

How are above used? (accumulate remain, recruit)

NOTES & SKETCH
## DESIGN INFO

| Designer Name(s): | ____________________________ |
|-------------------|____________________________|
| Structure ID:     | ____________________________ |
| Observation Date: | ____________________________ |

### DESIGN TYPE:
- Beaver Dam Analogue
- Post Assisted Log Structure
- Unanchored/Pinned Wood Addition

### DESIGN VIDEO:

### DESIGN FLOW CONDITIONS
- Baseflow
- Spring runoff
- Flood
- Post Flood

## POSITIONAL ATTRIBUTES

| GPS UTM Easting: | ____________________________ |
|------------------|____________________________|
| GPS UTM Northing:| ____________________________ |

### STRUCTURE LOCATION RELATIVE TO CHANNEL(s)
- On Main Channel
- On Right Side Channel(s)
- On Left Side Channel(s)
- On Left Floodplain
- On Right Floodplain

### PART OF COMPLEX?
- Complex ID ____________________________
- Part of new dam complex
- Expansion of existing dam complex
- NA - Isolated Dam
- NA - Non-Dam

## STRUCTURE DESIGN

### STRUCTURE POSITION
- River Right Margin Attached
- River Left Margin Attached
- Channel Spanning (i.e. BDA or Debris Jam)
- Mid-Channel

### STRUCTURE ORIENTATION
- Perpendicular to Flow
- Angled Flow Downstream
- Angled Flow Upstream
- Diamond
- Triangle pointing Upstream
- Triangle pointing Downstream

### CHANNEL CONSTRUCTION (% OF BANKFULL WIDTH)
- 100% BFW
- 95-99%
- 85-95%
- 75-85%
- 50-75%
- 25-50%
- < 25%

### STRUCTURE MATERIALS
- Posts: Approx. Count: ______
- Willow Weave
- Key piece (completely limbed)
- Key piece (limbed on bottom side only)
- Root wad
- Small Woody Debris
- Woody branches (single limbed) > 15 cm diameter
- Woody branches (single limbed) < 15 cm diameter
- Mud
- Grass / Reeds
- Other organic
- Cobble or Boulders
- 2-3 Guy Woody Debris
- Turf
- Dowelled or Twine tied Simple Logs
- ____________________________
- Materials Sourced on-site?
- Materials Imported

### STRUCTURE DIMENSIONS
- Max dam/structure height (m) +/- 0.1 m ___________
- Max pond depth (m if applicable) +/- 0.1 m ___________
- Water Surface Difference (m if applicable) +/- 0.1 m ___________
- Structure Length (m) +/- 1 m ___________
EXISTING FEATURES

GEOMORPHIC UNITS AT STRUCTURE LOCATION

- Planar
- Convexity (bar) type: ________
- Saddle (riffle)
- Concavity (true pool)
- Trough (shallow thalweg or chute)
- Wall: Bank
- Wall: Bar edge

How are above used? (grow (deposit), shrink (erode), maintain, build, destroy, protect)

STRUCTURAL ELEMENTS AT STRUCTURE LOCATION

- Roots
- Live Trees/Shrubs
- Aquatic Vegetation
- Boulder(s)
- Woody Debris
- Wall: Bank
- Wall: Bar edge

How are above used? (exploit, anchor, deflect, attack, protect)

ANTICIPATED HYDRAULIC RESPONSES

LOW FLOW BEHAVIOR

For Channel Spanners:
(Specify Value 0-100%; Sum should be 100%)

- Flow Over Top __________
- Basal Flow __________
- Throughflow __________
- Flow Around Left __________
- Flow Around Right __________

Total Check = 100%?

For Non-Channel Spanners:
(Specify Value 0-100%; Sum should be 100%)

- Shunted Flow Left __________
- Shunted Flow Right __________
- Flow Through (sieve) __________
- Flow Over Top __________
- Flow Under __________

Total Check = 100%?

TYPICAL FLOOD BEHAVIOR

- In-tact
- Minor breach (< 25 cm height) on left
- Minor breach (< 25 cm height) on right
- Minor breach (< 25 cm height) on center
- Minor basal breach
- Major breach (> 25 cm height) on left
- Major breach (> 25 cm height) on right
- Major breach (> 25 cm height) on center
- Major basal breach
- Blowout (whole height of dam breached)

BIG FLOOD BEHAVIOR

- In-tact
- Minor breach (< 25 cm height) on left
- Minor breach (< 25 cm height) on right
- Minor breach (< 25 cm height) on center
- Minor basal breach
- Major breach (> 25 cm height) on left
- Major breach (> 25 cm height) on right
- Major breach (> 25 cm height) on center
- Major basal breach
- Blowout (whole height of dam breached)

ESTIMATED UPSTREAM ZONE OF HYDRAULIC INFLUENCE

- < 1 BFW
- 1-2 BFW
- 2 – 5 BFW
- 5 -10 BFW
- > 10 BFW

ESTIMATED DOWNSTREAM ZONE OF HYDRAULIC INFLUENCE

- < 1 BFW
- 1-2 BFW
- 2 – 5 BFW
- 5 -10 BFW
- > 10 BFW

SIDE CHANNELS FORCED?

- None
- Single Left
- Multiple Left
- Single Right
- Multiple Right

POND EXTENT

- Contained within bankfull channel
- Expanding out onto floodplain
- Drained

FLOODPLAIN INUNDATION

- During Extreme Floods - River Right
- During Extreme Floods - River Left
- During Seasonal Floods - River Right
- During Seasonal Floods - River Left
- Year Round Inundation - River Right
- Year Round Inundation - River Left
## Anticipated Geomorphic Responses

### Pond Capacity (First Year Floods)
- Clean
- Minor Sedimentation
- Partial Filling (upto 50% of original pond capacity)
- Major Filling (50% to 95% of original pond capacity)
- Full of sediment (no longer a pond)

### Pond Capacity (If Big Floods)
- Clean
- Minor Sedimentation
- Partial Filling (upto 50% of original pond capacity)
- Major Filling (50% to 95% of original pond capacity)
- Full of sediment (no longer a pond)

Dominant Substrate in Deepest

### Expected Dominant Substrate Upstream of Structure
- Fines (clays and silts)
- Sands
- Gravels
- Cobble
- Food Cache & Fines

### Expected Dominant Substrate Downstream of Structure
- Fines (clays and silts)
- Sands
- Gravels
- Cobble
- Food Cache & Fines

### Expected Geomorphic Units At Structure Location
- Planar
- Convexity (bar) type: ________
- Saddle (riffle)
- Concavity (true pool)
- Trough (shallow thalweg or chute)
- Wall: Bank
- Wall: Bar edge

How are above used? (grow (deposit), shrink (erode), maintain, build, destroy, protect)

### Expected Structural Elements At Structure Location
- Roots
- Live Trees/Shrubs
- Aquatic Vegetation
- Boulder(s)
- Woody Debris
- Wall: Bank
- Wall: Bar edge

How are above used? (accumulate remain, recruit)

### Notes & Sketch
Complex Setting
Active channel sits between low elevation and largely unvegetated active floodplain (~0.3 m) consisting of multithreaded high flow channels. Channel substrate is largely unconsolidated cobbles likely leading to infiltration and loss of surface flow. High (> 0.5 m) unvegetated old terraces sit above active floodplain.

Complex Restoration Objective
Increase surface water storage with intent to increase water table elevation. Active trapping of sediment to aid in establishment of riparian vegetation.
Complex 02 - Structure 08

Date Designed 7/28/17
Total Posts 30
Crest Elevation 0.40
Latitude 44.629701
Longitude -120.333379

Repeat Photo Location
Photo Facing Upstream
Standing River Right
Distance (m) 10

Channel Setting
Plain bed channel, lack of vegetation on banks may lead to endcut. Location little more than wet rocks at install. Long low gradient stretch above should offer extensive pond creation.

Construction and Design Elements
Standard built with three lines of posts at height of low river right terrace. Posts cut to river right terrace elevation.

Structure Functional Objective
Extensive pond creation for beaver habitat. Increase water table elevation for increase riparian vegetation on river right low terrace. Increase high flow dispersion on river right terrace.
Complex 02 - Structure 09

Structure Type: Primary Ponding

Date Designed: 7/28/17
Total Posts: 30
Crest Elevation: 0.33
Latitude: 44.629727
Longitude: -120.333195

Repeat Photo Location
- Photo Facing: Upstream
- Standing: River Left
- Distance (m): 10

Channel Setting
Wide plain bed channel with moderate gradient. Lack of vegetation on banks may lead to end cuts.

Construction and Design Elements
Standard construction specifications. Bit lower than upstream 08. Low terrace elevation river left may allow high flows to escape and avoid scour.

Structure Functional Objective
Ponding, aggradation, beaver attraction. Increase water surface height. But, also to provide redundancy for next upstream structure.
Complex 02 - Structure 10

Channel Setting
Bottom of complex 02. More vegetated banks than 08 & 09 should increase stability. Willows throughout channel also provide support. Gradient just downstream hopefully won't cause headcut.

Construction and Design Elements
Built through existing willow line for and bank support.

Structure Functional Objective
Ponding in low gradient section to increase water storage, raise groundwater elevation. Dissipate gradient from upstream structures.
Complex 02 - Structure 11

Structure Type: Floodplain Expansion  
Date Designed: 8/4/17

Total Posts: 20
Crest Elevation: 0.30
Latitude: 44.630009
Longitude: -120.333147

Repeat Photo Location
- Photo Facing: Upstream
- Standing: River Left
- Distance (m): 10

Channel Setting
Structure just below steep constriction, and just downstream of high flow side channel river right. Some willow on banks should provide bank stability.

Construction and Design Elements
Standard design that incorporates willow on banks.

Structure Functional Objective
Cause ponding in upstream low gradient run. But, mostly increase duration of flow in river right high-flow side channel to increase riparian expansion and groundwater recharge.
Complex 02 - Structure 12

Structure Type  Secondary Support

Date Designed  8/4/17
Total Posts  20
Crest Elevation  0.25
Latitude  44.630055
Longitude  -120.333082

Repeat Photo Location
Photo Facing  Upstream
Standing  Mid-Channel
Distance (m)  10

Channel Setting
Adjacent to low unvegetated alluvial gravel bars and high flow channels river right. Low gradient active floodplain zone.

Construction and Design Elements
River left willow should protect bank. Low elevation of river right bars and channels may allow diversion of high flow without structural integrity loss.

Structure Functional Objective
Low flow pond creation upstream, support for structure 11 upstream, increase flow duration across river right unvegetated alluvial bars and channels.
Complex 02 - Structure 13

Structure Type: Primary Ponding

Date Designed: 8/9/17
Total Posts: 29
Crest Elevation: 0.45
Latitude: 44.630265
Longitude: -120.332659

Repeat Photo Location
- Photo Facing: Upstream
- Standing: River Right
- Distance (m): 10

Channel Setting
High terrace on river right with unstable bank. Toward bottom of braided active floodplain.

Construction and Design Elements
Roughly 23 m wide structure spanning multiple braided high flow channels. Uses some existing willow for support.

Structure Functional Objective
Creation of big pond and intended to trap sediment in braided mobile channel for establishment of riparian vegetation leading to increased channel roughness.
Complex 02 - Structure 14

Structure Type: Primary Ponding
Date Designed: 8/9/17
Total Posts: 28
Crest Elevation: 0.40
Latitude: 44.630262
Longitude: -120.332606
Repeat Photo Location:
- Photo Facing: River Right
- Standing: River Left
- Distance (m): 5

Channel Setting
Structure sits between lower terrace on river left and high river right terrace. Spans entire broad - braided - unvegetated - active floodplain.

Construction and Design Elements
Standard construction, but wide structure spanning pinch point of active braided floodplain.

Structure Functional Objective
Creation of large pond, and acts as "cap" at lower end of floodplain. Structure should trap mobile sediment during high flows for vegetation establishment.
Confined by high terraces both banks. Channel has extensive willow and extremely stable (i.e. cement) bed composition.

Construction and Design Elements
Uses only 5 posts and relies on weave and fill being added to existing vegetation.

Structure Functional Objective
Step down grade control designed to support upstream primary structures.
DESIGN MANUALS

BEAVER RESTORATION GUIDEBOOK

The Pollock et al. (2018) version 2 of the beaver restoration guidebook is a good source of basic information on beaver-based restoration techniques.

  

HAND-BUILT STRUCTURES FOR RESTORING DEGRADED MEADOWS IN SAGEBRUSH RANGELANDS

For those interested in the Zeedyk techniques, particularly for ephemeral and intermittent washes, the NRCS just prepared Range Technical Note No. 40.


Available at: https://www.sagegrouseinitiative.com/starter-guide-for-healing-incised-meadows-with-hand-built-structures-in-sagebrush-country/
As part of this workshop series, we are preparing a design manual for more detail and specifics on these ‘cheap and cheerful’, low-cost techniques. This is made possible thanks to the generous support of the Natural Resource Conservation Service’s Sage Grouse Initiative and Working Lands for Wildlife Initiative, a grant through Pheasants Forever to Joe Wheaton’s ET-AL lab at Utah State University. The Riverscape Restoration Design Manual for streams and riparian areas (i.e. riverscapes) shows how to embrace process-based restoration, low-cost restoration techniques and a ‘cheap and cheerful ethos’. This effort started as a design manual by the Wheaton ETAL group for the Utah Division of Wildlife Resources and the Utah Watershed Restoration Initiative.


The chapters include:

- Chapter 1 – Background and Purpose
- Chapter 2 – The Role of Meals and Exercise in Restoring Healthy Lifestyles for Riverscapes
- Chapter 3 – Impairments: what are they, how did we get here, and how can cheap and cheerful help?
- Chapter 4 - Condition Assessment
- Chapter 5 – Overview of Cheap & Cheerful Recipes – a growing list
- Chapter 6 – Planning & Prioritization For Working in the Right Places Effectively
- Chapter 7 – Design Principles for Cheap & Cheerful Restoration
- Chapter 8 – Permitting Cheap & Cheerful Restoration
- Chapter 9 – Construction & Implementation 95
- Chapter 10 - Adaptive Management
- Chapter 11 – Beaver Dam Analogues
- Chapter 12 – High Density Large Woody Debris
- Appendices – Case Studies

The manual is nearing completion and will be available later this Summer (2018) at: http://beaver.joewheaton.org/restoration-manual.html
GOOD BOOKS ON BEAVER

There are a variety of good books on beaver if you're interested. We maintain a list at: http://beaver.joewheaton.org/beaver-literature.html

The most recent addition to the list is Ben Goldfarb's new Eager (announcement on following pages).
Eager
The Surprising, Secret Life of Beavers and Why They Matter

Ben Goldfarb
foreword by Dan Flores

$24.95 • Hardcover
6 × 9 • 304 pages
Black-and-white illustrations throughout,
8-page color insert
ISBN 978-1-60358-739-6
Pub Date: July 20, 2018

“This book is going to make you look out on the world and see our wildlife story with new eyes.”
—DAN FLORES, New York Times bestselling author of Coyote America (from the foreword)

Award-winning journalist Ben Goldfarb has traveled the world writing about wildlife conservation and the environment. He has chased endangered woodpeckers through war games on a North Carolina military base and withstood a bluff charge from a Yellowstone grizzly bear. He has tagged sea turtles, radio-tracked bats, and hand-lined sharks. Now, he turns his attention to nature’s most ingenious architects—the beaver.

Did you know beavers create habitat for countless species from salmon to trumpeter swans to river otters and bats? This super power makes beavers a keystone species, meaning their protection will help all other members of their biological communities thrive. Goldfarb describes beavers as ecological and hydrological swiss army knives, capable, in the right circumstances, of tackling many landscape-scale problems.

Trying to mitigate floods or improve water quality? There’s a beaver for that. Hoping to capture more water for agriculture in the face of climate change? Add a beaver. Concerned about sedimentation, salmon runs, or wildfire? Take two families of beaver and check back in a year.

In his new book Eager, Goldfarb tells the powerful story of how these ecosystem engineers have shaped our world, and how they can help save it—if we let them.

Check out the reverse side of this page for 8 Beaver Facts you need to know right now. For more information about Ben Goldfarb and his writing go to www.bengoldfarb.com or follow him on Twitter @ben_a_goldfarb.


http://media.chelseagreen.com/eager
Beaver Facts

- Beaver fur is so thick that a stamp-sized patch of skin is carpeted with 125,000 individual hairs—more than the average human has on their entire head!
- A beaver tail is lined with a web of blood vessels, called a rete mirabile, that exchange heat and regulate body temperature.
- Beavers secrete castoreum, a musky oil the rodents spray to delineate their territories. Castoreum contains salicylic acid, which beavers derive from willow—and which happens to be the active ingredient in aspirin.
- Beavers create ponds, wetlands, and damp meadows, creating habitat for countless other species, from river otters to pileated woodpeckers to silver-haired bats.
- When Europeans arrived in North America, as many as 400 million beavers swam the continent’s rivers and ponds; by 1900, fur trapping had reduced the continent’s population to just 100,000.
- Remarkably, beavers are capable of fighting both floods and droughts. By slowing down stream flows, forcing water onto floodplains, and soaking it into the ground, beaver dams and ponds can reduce both the volume and speed of water, protecting downstream farms and towns.
- In dry regions like the American West, beaver ponds store water during dry seasons, in some cases capturing hundreds of millions of gallons for the use of wildlife and farmers.
- Trying to tell a male beaver from a female? Good luck. Almost unique among mammals, beavers hide their genitalia within modified cloacas—fleshy vents that do triple duty in the departments of urine disposal, scent secretion, and reproduction.
- For more: @ben_a_goldfarb

Eager Beaver

The Surprising, Secret Life of Beavers and Why They Matter
REFERENCES


