LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

Utah State University
RESTORATION CONSORTIUM

POCKET FIELD GUIDE

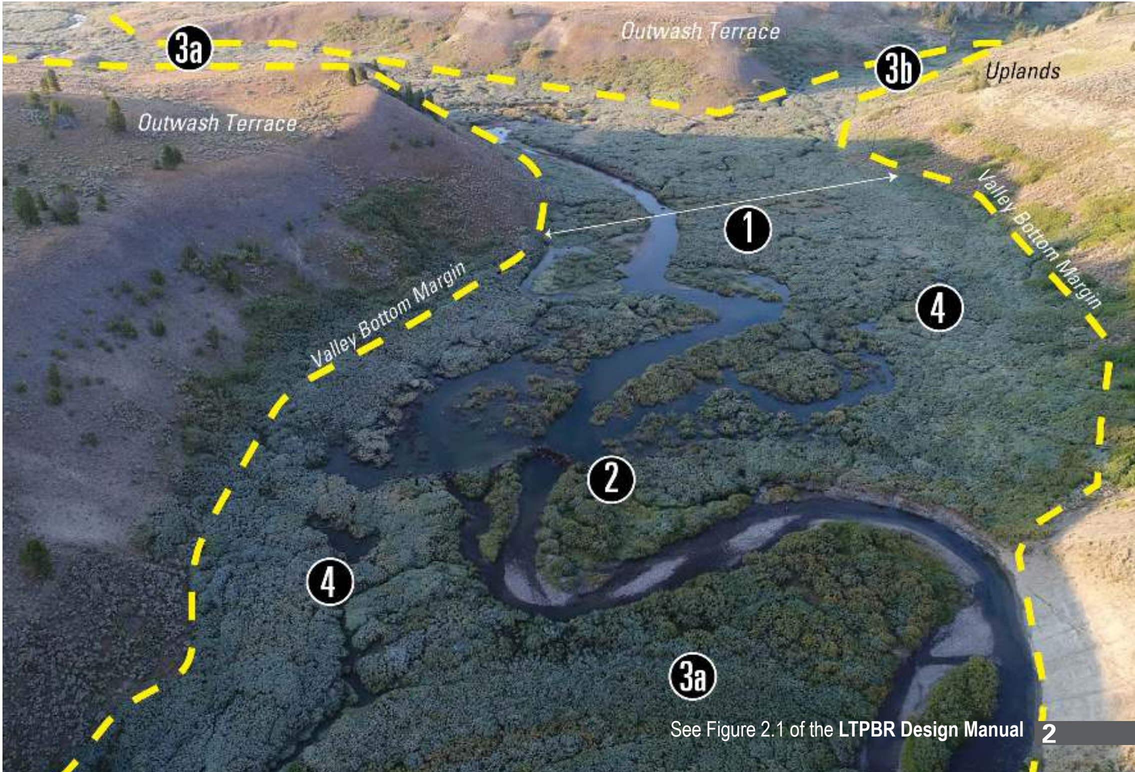
RIVERSCAPES PRINCIPLES:

1. **Streams need space.** Healthy streams are dynamic, regularly shifting position within their valley bottom, re-working and interacting with their floodplain. Allowing streams to adjust within their valley bottom is essential for maintaining functioning riverscapes.

2. **Structure forces complexity and builds resilience.** Structural elements, such as beaver dams and large woody debris, force changes in flow patterns that produce physically diverse habitats. Physically diverse habitats are more resilient to disturbances than simplified, homogeneous habitats.

3. **The importance of structure varies.** The relative importance and abundance of structural elements varies based on reach type, valley setting, flow regime and watershed context. Recognizing what type of stream you are dealing with (i.e., what other streams it is similar to) helps develop realistic expectations about what that stream should or could look (form) and behave (process) like.

4. **Inefficient conveyance of water is often healthy.** Hydrologic inefficiency is the hallmark of a healthy system. More diverse residence times for water can attenuate potentially damaging floods, fill up valley bottom sponges, and slowly release that water later elevating baseflow and producing critical ecosystem services.



See Figure 2.1 of the **LTPBR Design Manual**

RESTORATION PRINCIPLES:

5 **It's okay to be messy.** When structure is added back to streams, it is meant to mimic and promote the processes of wood accumulation and beaver dam activity. Structures are fed to the system like a meal and should resemble natural structures (log jams, beaver dams, fallen trees) in naturally 'messy' systems. Structures do not have to be perfectly built to yield desirable outcomes. Focus less on the form and more on the processes the structures will promote.

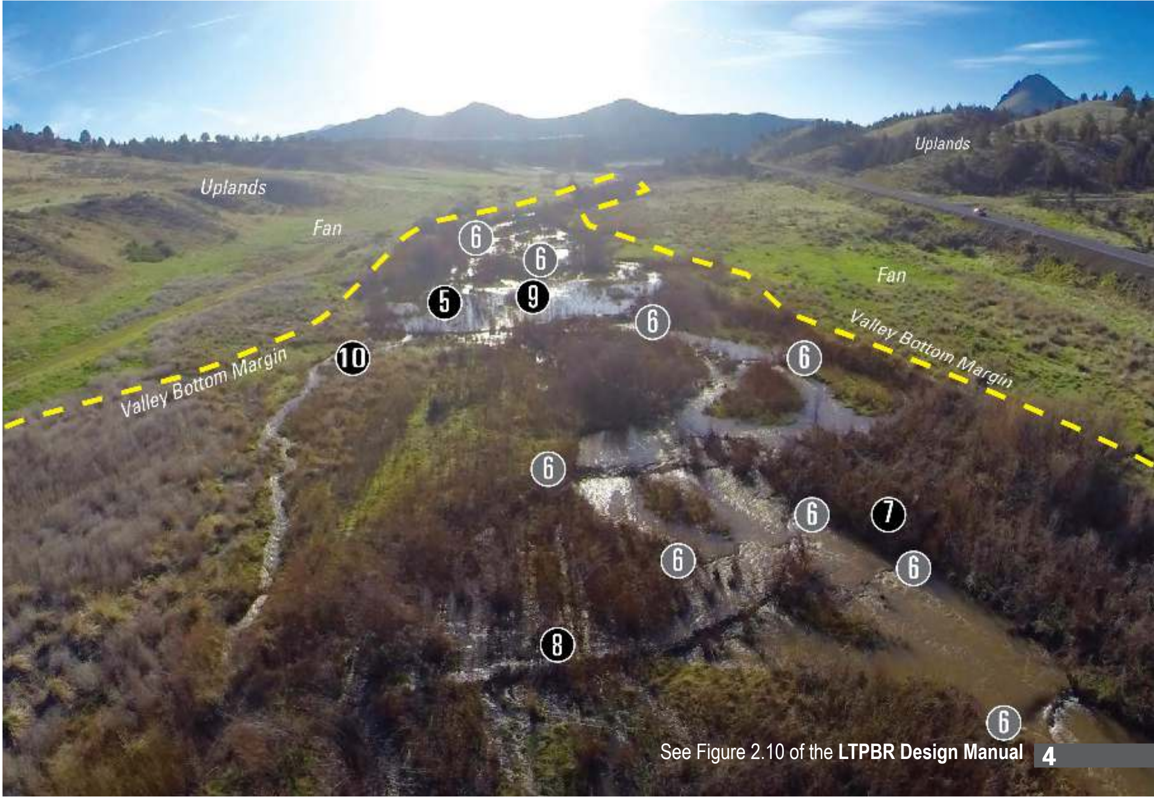
6 **There is strength in numbers.** A large number of smaller structures working in concert with each other can achieve much more than a few isolated, over-built, highly-secured structures. Using a lot of smaller structures provides redundancy and reduces the importance of any one structure. It generally takes many structures, designed in a complex to promote the processes of wood accumulation and beaver dam activity that lead to the desired outcomes.

7 **Use natural building materials.** Natural materials should be used because structures are simply intended to initiate process recovery and go away over time. Locally sourced materials are preferable because they simplify logistics and keep costs down.

8 **Let the system do the work.** Giving the riverscape and/or beaver the tools (structure) to promote natural processes to heal itself with stream power and ecosystem engineering, as opposed to diesel power, promotes efficiency that allows restoration to scale to the scope of degradation.

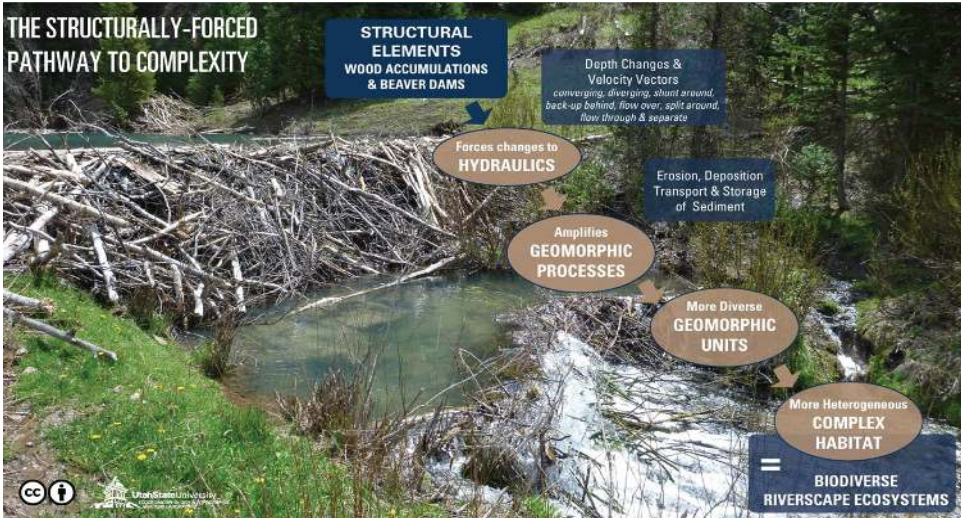
9 **Defer decision making to the system.** Wherever possible, let the system make critical design decisions by simply providing the tools and space it needs to adjust. Deferring decision making to the system downplays the significance of uncertainty due to limited knowledge. For example, choosing a floodplain elevation to grade to based on limited hydrology information can be a complex and uncertain endeavor, but deferring to the hydrology of that system to build its own floodplain grade reduces the importance of uncertainty due to limited knowledge.

10 **Self-sustaining systems are the solution.** Low-tech restoration actions in and of themselves are not the solution. Rather they are just intended to initiate processes and nudge the system towards the ultimate goal of building a resilient, self-sustaining riverscape.



See Figure 2.10 of the **LTPBR Design Manual**

STRUCTURALLY-FORCED PROCESSES

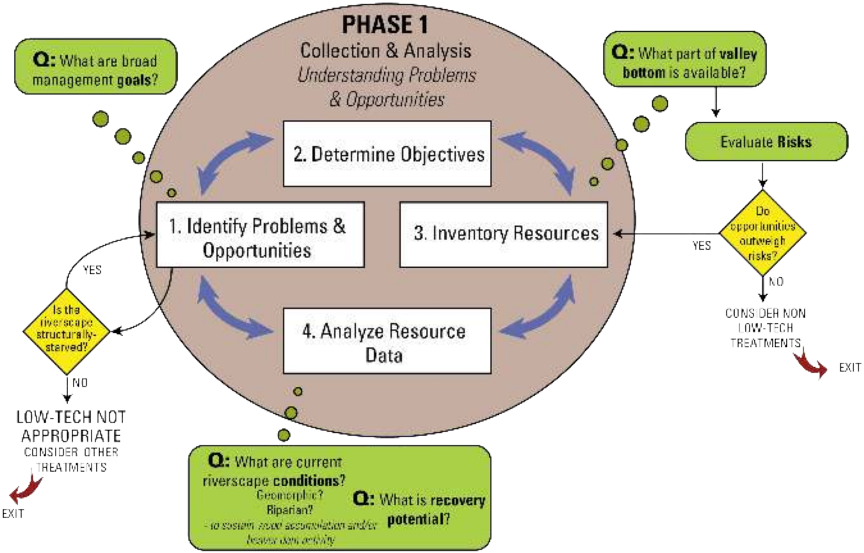


The concept of the structurally-forced pathway to complexity underlying **Riverscapes Principle 2** *(page 3)*. Two key processes critical to the health of most riverscapes are structural forcing from beaver dam activity, and wood accumulation *(page 8)*.

See Figure 2.4 of the **LTPBR Design Manual**

TWO KEY PROCESSES:

KEY PLANNING CONSIDERATIONS



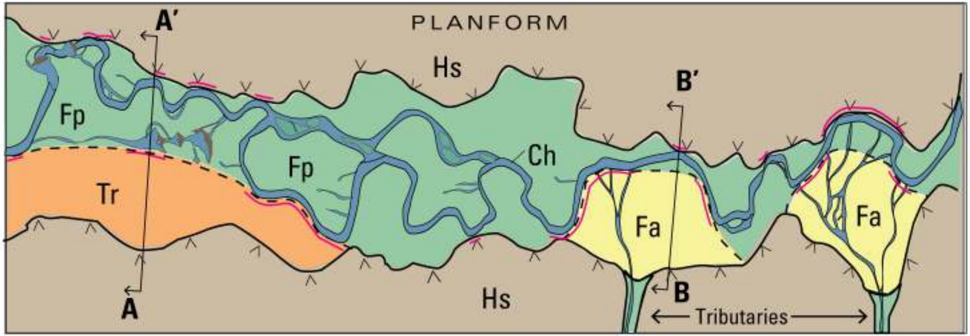
See Figure 3.3 of the **LTPBR Design Manual**

THE IMPORTANCE OF STRUCTURE VARIES

The relative importance of wood accumulation and beaver dam activity varies based on geomorphic setting, ecosystem and flow regime.

Adapted from 2.7 **LTPBR Design Manual**

VALLEY BOTTOM
THE KEY TO READING RIVERSCAPES



GEOMORPHIC UNIT KEY

Valley
- Ch = Channels
- Fp = Floodplain
- Fa = Fan
- Tr = Terrace
- Hs = Hillslope

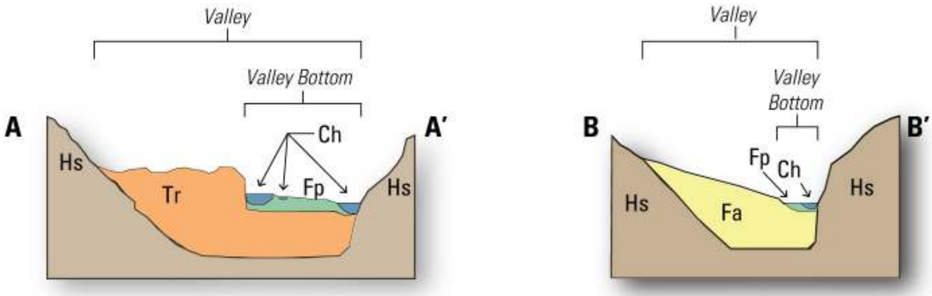
Ch, Fp – *Valley Bottom*; Ch, Fp, Fa – *Riverscapes*; Tr – *Former Valley Bottom*

The valley bottom is comprised of areas that could plausibly flood in the contemporary flow regime.

MARGIN TYPES

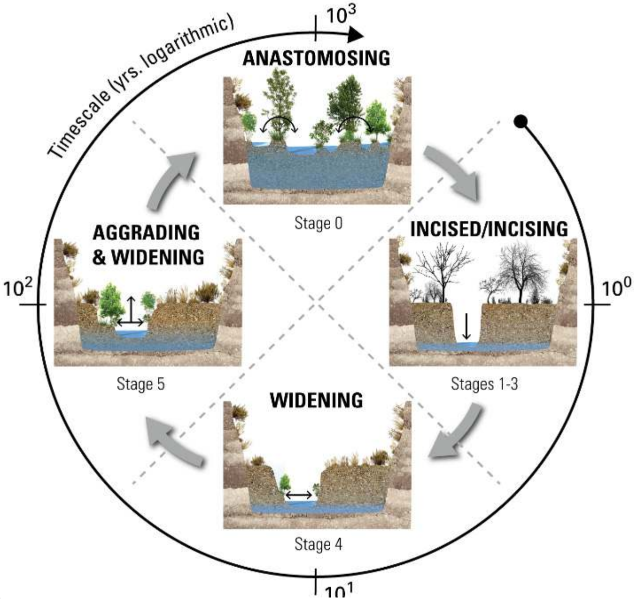
- Valley Margin
- Valley Bottom Margin
- Active Confining Margin

VALLEY CROSS SECTIONS



Adapted from Wheaton et al. (2015)

RIVERSCAPE EVOLUTION MODEL



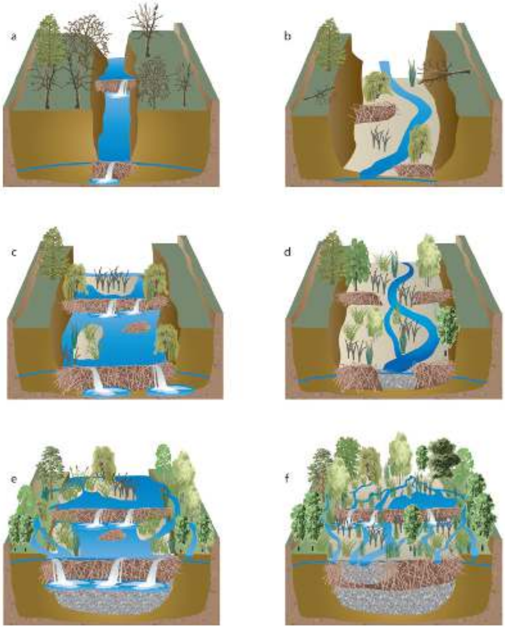
Q: What are current riverscape **conditions**?
Geomorphic?
Riparian?
- to sustain wood accumulation and/or beaver dam activity

Q: What is **recovery potential**?

- Historically, most healthy riverscapes were in an anastomosing geomorphic condition (i.e., Stage 0; *see page 2)*.
- Flows would have been dispersed into multiple channels spread out across a valley bottom, separated by well-vegetated floodplain wetlands and forests, boasting regular structurally-forced flooding.
- Due to a variety of impairments, many such riverscapes rapidly incised, and are locked in degraded incised states.
- Recovery to an anastomosing Stage 0 condition, is achieved by widening (with lateral bank erosion) and aggradation. The lateral erosion process helps rebuilding valley bottom topography with connected floodplains by creating the accommodation space, a source of sediment to build new floodplains in that space, and wider areas for flood-flows to spread out onto.

See Figure 1.5 of the **LTPBR Design Manual & Cluer & Thorne (2014):** DOI: 10.102.rra.2631

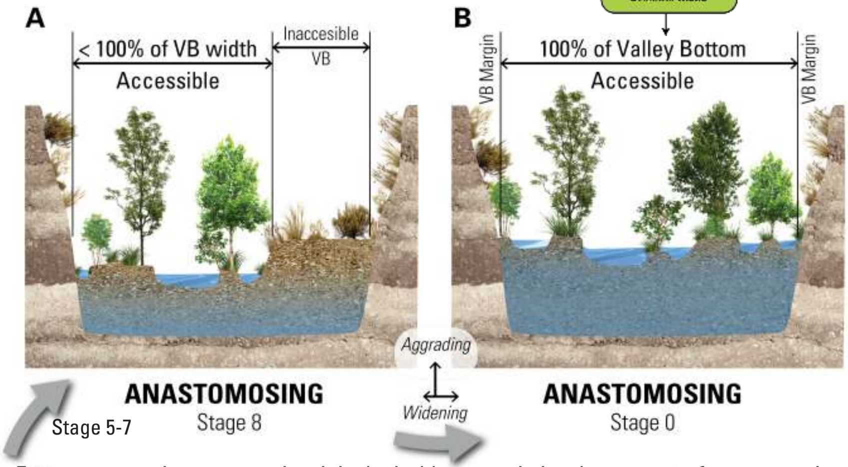
BEAVER CAN ACCELERATE RIVERSCAPE EVOLUTION



When beaver build dams in an incised channel, those dams often fail by end-cutting, which accelerates the process of channel evolution (see Pollock et al., 2014; Cluer and Thorne, 2013), and floodplain reconnection.

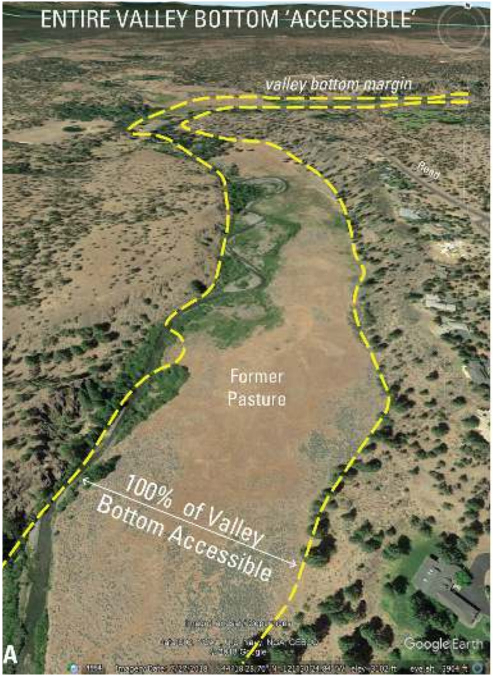
See Figure 4 from **Pollock et al. (2014):** *DOI: 10.1093/biosci/biu036*

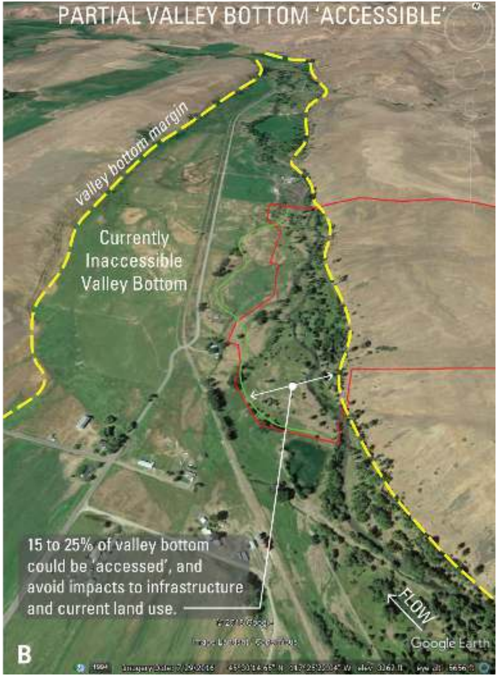
HOW MUCH OF THE VALLEY BOTTOM IS AVAILABLE FOR RESTORATION?



From a restoration perspective, it is desirable to maximize the amount of anastomosing within the valley bottom. Where this is possible, this is a Stage 0 target. However, from a conservation planning perspective, practical constraints within a valley bottom (e.g., infrastructure or incompatible land use) may mean that anastamosing is only appropriate in part of the valley bottom (i.e., a Stage 8 target).

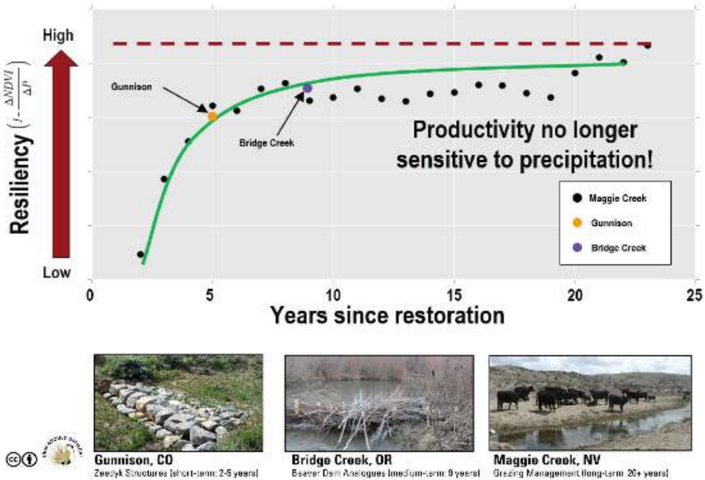
See Figure 1.6 of the **LTPBR Design Manual**





Adapted from Figure 3.8 of the **LTPBR Design Manual**

STRUCTURALLY-FORCED RESILIENCE TO DROUGHT



Resilience is the lack of sensitivity to a disturbance. Low-tech process-based restoration has been shown to create a situation where dry season valley bottom vegetation productivity (i.e., greenness) is no longer sensitive to fluctuations in drought. Figure adapted from Silverman et al. (2014).

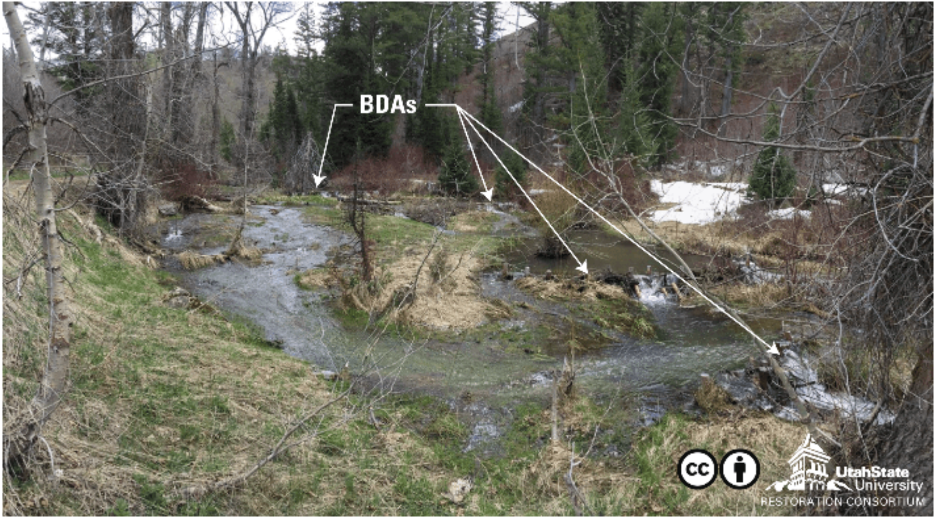
See Figure 2.5 of the **LTPBR Design Manual**

STRUCTURALLY-FORCED RESILIENCE TO FIRE

Example of **structurally-forced resilience** to fire where beaver dam activity kept parts of the riverscape from burning, providing critical wildlife and livestock refugia during the fire, and assisting in post-fire recovery. Example from Baugh Creek, Idaho.

See Figure 2.6 of the **LTPBR Design Manual**

SELF-SUSTAINING PROCESSES

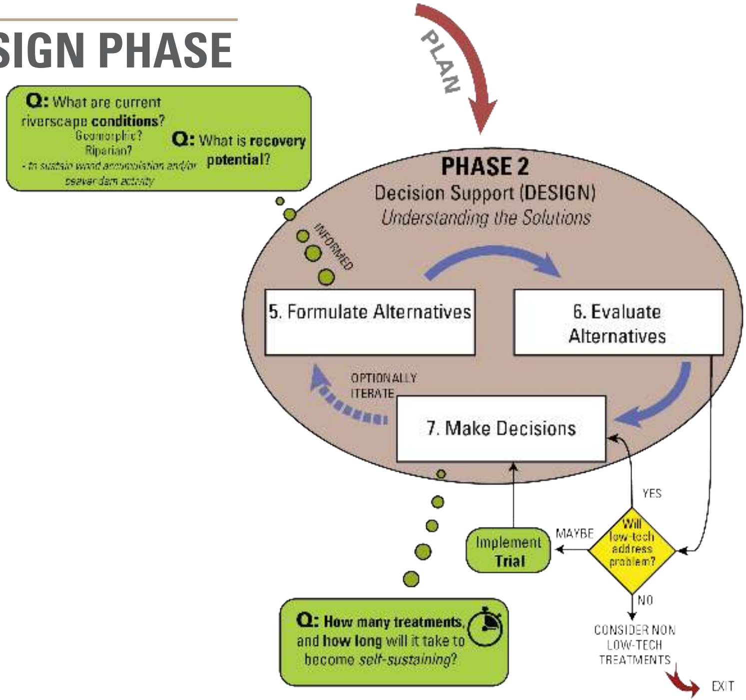


In this example, BDAs (n = 25) were built in a system where beaver had been extirpated for over 30 years. BDAs were built to mimic beaver dams for the immediate release of translocated beaver (n=9). Within 3 years , beaver maintained and expanded 22 of the BDAs and built an additional 140+ dams.

See Figure 4.12 of the **LTPBR Design Manual**

An example from Goldfarb (2018) of achieving a self-sustaining condition where meals of beaver dam analogues (BDAs) mimic beaver dam activity, and then the maintenance and expansion of beaver dam activity is taken over by actual beaver and they maintain a complex system state. Figure © Science by V. Altounian

DESIGN PHASE



See Figure 5.1 of the **LTPBR Design Manual**

RECOMMENDED MINIMUM DESIGN PACKAGE

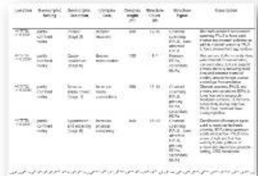
Project-Scale Map(s)
(Drainage Network)

Shows complex locations on drainage network.

Complex-Scale Map(s)
(One for each complex)

Shows structure locations within each complex, complexes zone of influence, structure types, & valley bottom extents.

Complex Design Tables
(Clear Complex Objectives & Hypotheses)



Note, structure design tables are possible but not always necessary as during construction not all structures are built exactly as designed, and flexibility is key (e.g. 12-15 structures specified).

Typical Structure Schematics

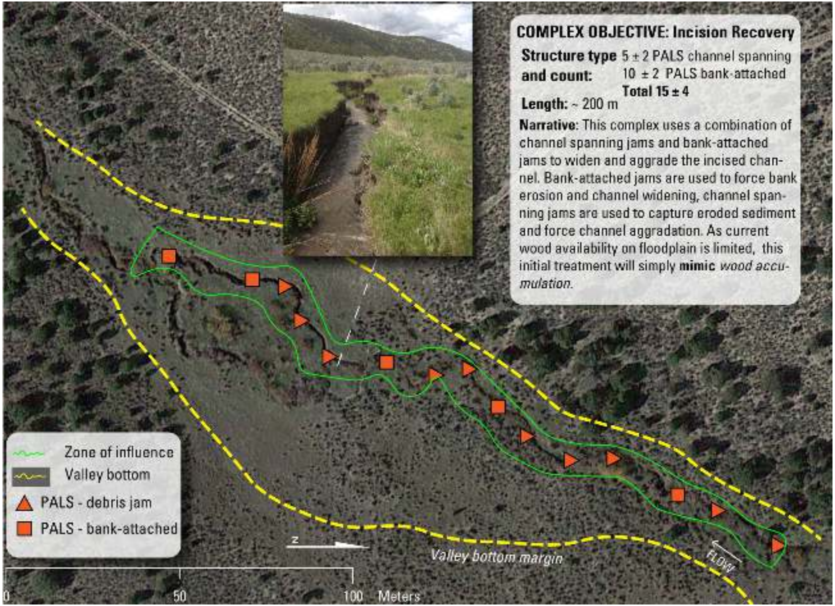
Schematics of planfoms, cross-sections, & profiles are helpful to convey what typical structures will look like, but need not be followed rigidly.

EXAMPLE OF A PROJECT-SCALE MAP

A project-scale map shows location and upstream and downstream extent of complexes, symbolized by their primary objectives. A **complex** is a group of structures designed to work together to mimic and promote specific processes to achieve specific restoration objectives.

Adapted from Figure 5.6 of the **LTPBR Design Manual**

EXAMPLE OF A COMPLEX DESIGN



- The zone of influence (ZOI) is the area or extent that a complex is capable of influencing hydraulically or geomorphically
- Delineating the ZOI during design represents a transparent, testable design hypothesis

LOW-TECH STRUCTURE DEFINITIONS

P A L S

POST-ASSISTED LOG STRUCTURES

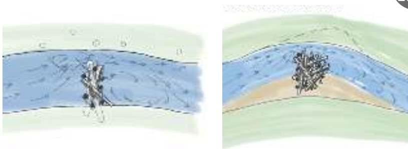
- PALS are handbuilt structures that mimic and promote the processes of **wood accumulation.**
- Woody material of various sizes pinned together with untreated wooden posts driven into the substrate.

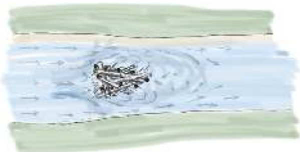
B D A s

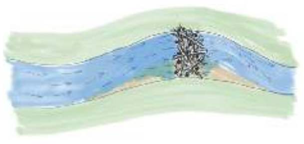
BEAVER DAM ANALOGUES

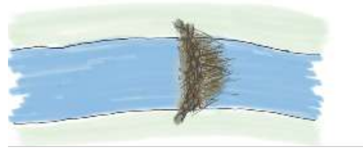
- BDAs are handbuilt structures that mimic and promote the processes of **beaver dam activity.**
- BDAs are a permeable, channel-spanning structure with a constant crest elevation, constructed with a mixture of woody debris and fill material to promote temporary ponding of water.

SCHEMATIC TABLE OF CONTENTS









POST-ASSISTED LOG STRUCTURES

HOW TO BUILD PALS

1. Decide location of PALS, configuration (e.g., orientation and type of PALS) as part of the design of a complex of structures (multiple structures working together).
2. Position larger logs on the base of the structure to make the general shape of structure.
3. Limb branches from one side of the logs so that much of the log comes in contact with the bed to increase interaction between the flow and the structure, even at low flows.
4. Pin large pieces in place with posts; drive posts at angles and downstream to help hold wood in place at high flows.
5. Add more logs, and pack and wedge smaller material to fill spaces in the structure.
6. Build up the structure to desired crest elevation, but crest elevation need not be uniform.

OPTIONS & CONSIDERATIONS

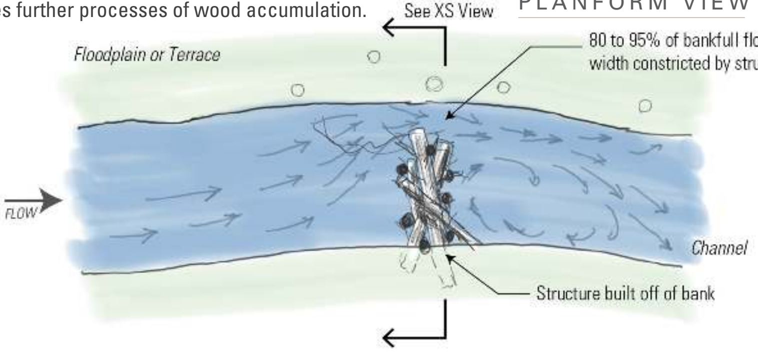
- Consider how much hydraulic purchase (interaction with flow) you want the structure to have and what flows (e.g., baseflows, typical floods, rare floods) it should engage with.
- Build PALS with irregular shapes and branches and small debris sticking out in multiple directions (i.e., make a mess).
- For PALS where flow over the top is anticipated, consider constructing a mattress of woody material on downstream side to dissipate pour over flow energy over-top of structure. Alternatively, if the intention is to encourage formation of a plunge pool, maybe build mattress incompletely, or not at all.
- When building bank-attached and channel-spanning PALS, extend the structures onto the floodplain by wedging structure material into existing vegetation, trunks, roots or boulders on the floodplain.Build bank-attached PALS with a broader base (streamwise) where the structure attaches to the bank, to better shunt flows to the opposite bank
- Locate bank-attached PALS across from hard features like boulders or roots to force a scour pool.
- Build a broad base (streamwise) for channel-spanning structures relative to channel width so that the structure is not narrow and “wall like”. Use multiple lines of offset posts to build it wide.
- Build mid-channel PALS with large and wide logs perpendicular to the flow on the upstream end of the structure to act like a natural root wad.
- In general, the larger the structure relative to the channel width (i.e., constriction width), the larger effect it will have on hydraulics, and subsequently geomorphic change during high flows.
- Not all woody structures need to have posts (i.e., ALS – assisted log structures). Large cobble and boulders, or wedging key pieces between existing trees, roots, can all serve the ‘temporary pinning’ function of posts if available.

BANK-ATTACHED PALS

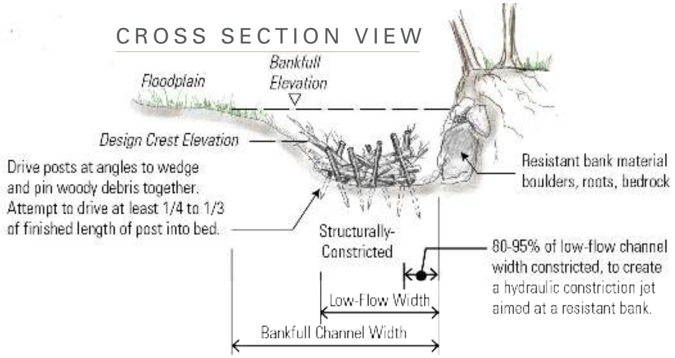
VARIATION 1: TO FORCE A CONSTRICTION JET

- Creates convergent jet of flow between bank- or margin-attached structure and a resistant feature (e.g., bedrock bank, roots, wood) on opposite bank.
- Forces more variable hydraulics, which typically create a backwater eddy upstream of the structure, a large eddy in the wake of the structure, and divergent flow paths where the jet weakens.
- Promotes structurally-forced pool, riffle growth at the divergent jet, and eddy bar formation in the eddies. Upstream deposition stabilizes and grows the structures.
- Promotes further processes of wood accumulation.

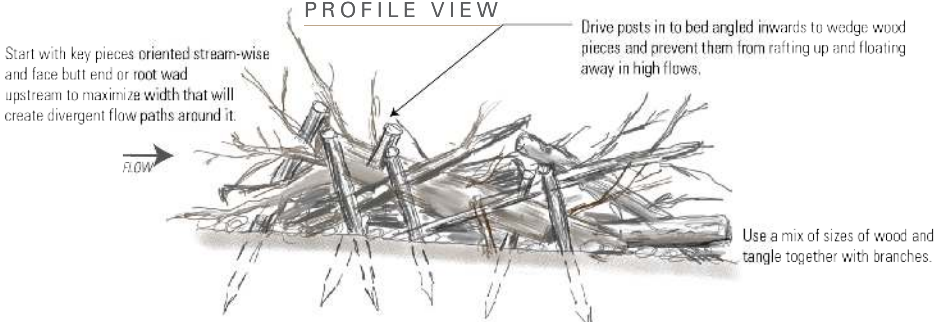
PLANFORM VIEW



CROSS SECTION VIEW



PROFILE VIEW

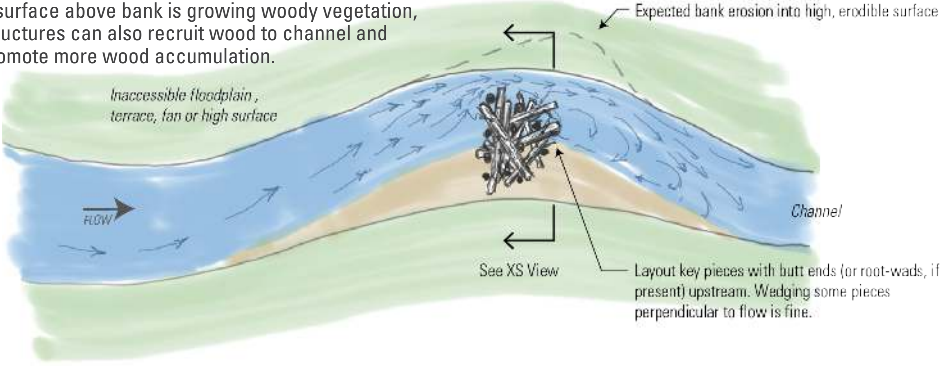


See Figure 4.23 of the **LTPBR Design Manual**

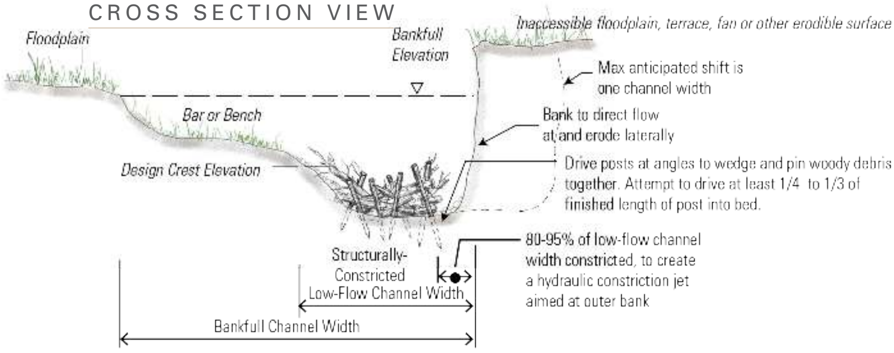
BANK-ATTACHED PALS:
VARIATION 2: BANK BLASTER

- Accelerates lateral widening via bank erosion of an erodible bank opposite of the structure.
- Shunting of flow forces more variable hydraulics, which typically create a backwater eddy upstream of the structure, an eddy downstream of structure, and temporary jet aimed at opposite erodible bank.
- Leads to lateral shift of channel (no more than one channel width typically). Further lateral migration occurs if bar growth continues on inside bend, further natural woody debris accumulates on structure, or subsequent treatment is extended off structure.
- If surface above bank is growing woody vegetation, structures can also recruit wood to channel and promote more wood accumulation.

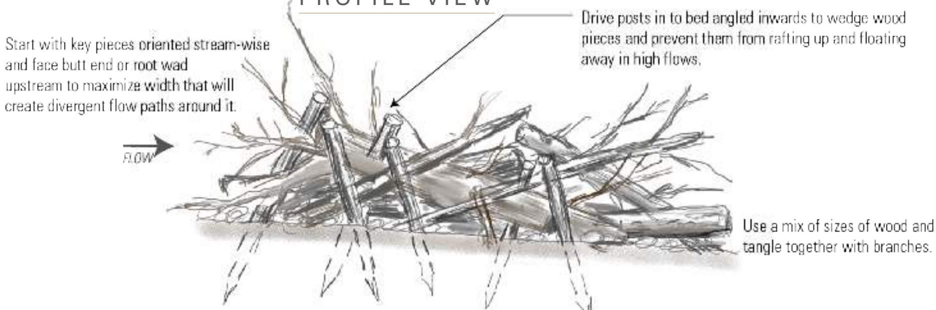
PLANFORM VIEW



CROSS SECTION VIEW



PROFILE VIEW

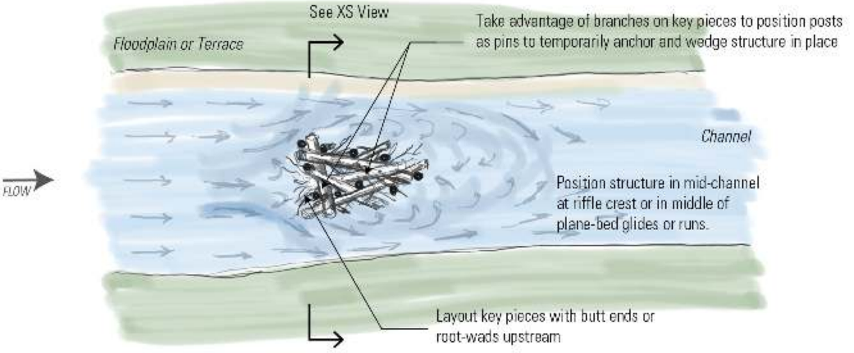


See Figure 4.24 of the **LTPBR Design Manual**

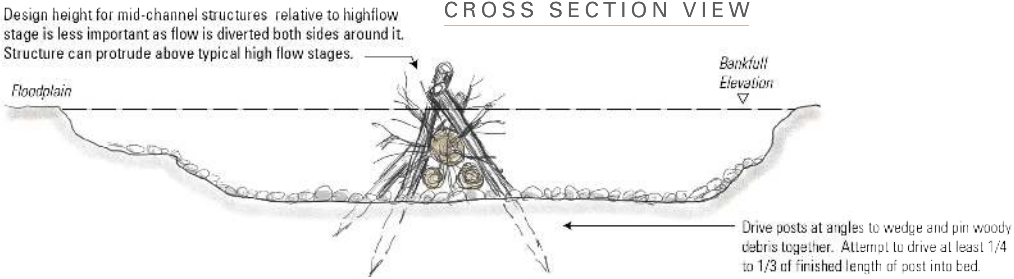
MID-CHANNEL PALS

- Installed mid-channel to split flow around the structure.
- Forces more variable hydraulics, which creates an eddy downstream of structure.
- Can promote mid-channel bar development in place of planebed morphologies, encourage or promote diffluences, convert riffles into mid-channel bars and/or to dissipate flow energy.
- In larger channels, multiple mid-channel PALS can be used in close proximity and are often more effective than a single large structure.
- In all cases, the mid-channel PALS can promote the process of wood accumulation on the structure itself.

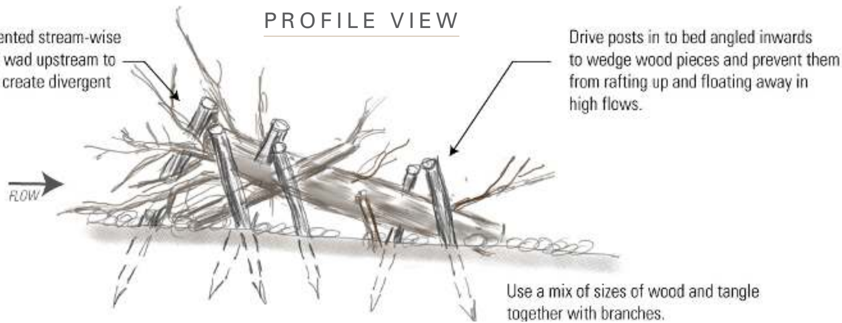
PLANFORM VIEW



CROSS SECTION VIEW



PROFILE VIEW

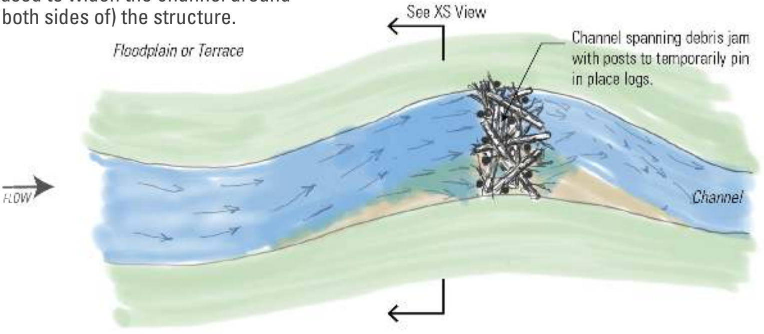


See Figure 4.25 of the **LTPBR Design Manual**

CHANNEL-SPANNING PALS

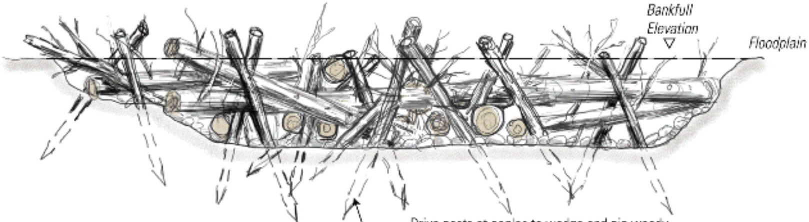
- Bank-attached on both sides, such that even at low-flow there is some hydraulic purchase across most of the channel, acting to back-water flow behind it. Unlike a beaver dam (with a uniform crest elevation), channel-spanning PALS can have a variable crest elevation and rougher finish, and are generally built with much greater porosity.
- Over time, increased water depth and decreased velocity upstream of PALS encourages more wood accumulation, organic accumulation and sediment deposition, all of which can act to stabilize the structure.
- If crest elevations are higher than adjacent floodplain(s), it can increase frequency of floodplain inundation, force new diffluences, and/or promote avulsions.
- Can be used to widen the channel around (one or both sides of) the structure.

PLANFORM VIEW



Design height for channel-spanning structures is important. If it is intended Structure can protrude above typical high flow stages.

CROSS SECTION VIEW

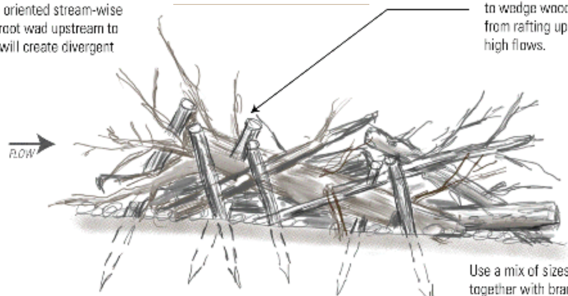


Drive posts at angles to wedge and pin woody debris together. Attempt to drive at least 1/4 to 1/3 of finished length of post into bed.

PROFILE VIEW

Start with key pieces oriented stream-wise and face butt end or root wad upstream to maximize width that will create divergent flow paths around it.

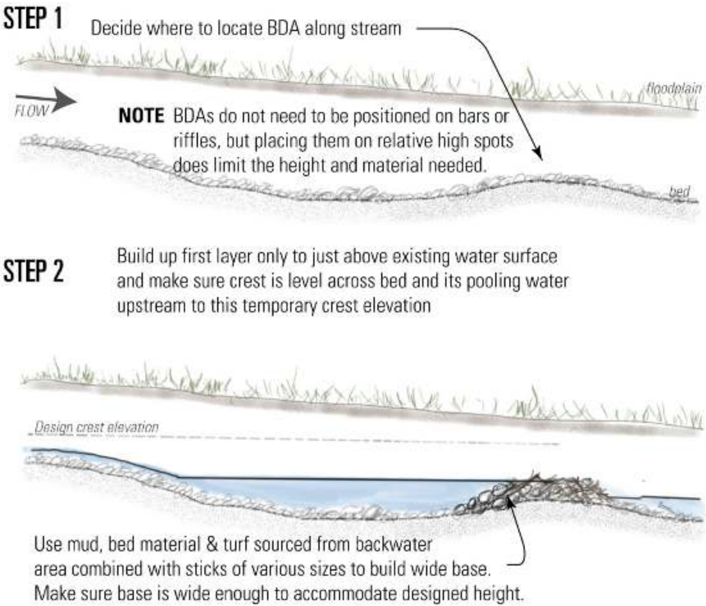
Drive posts in to bed angled inwards to wedge wood pieces and prevent them from rafting up and floating away in high flows.



Use a mix of sizes of wood and tangle together with branches.

See Figure 4.26 of the **LTPBR Design Manual**

BEAVER DAM ANALOGUES



See Figure 4.31 in the **LTPBR Design Manual**

HOW TO BUILD BDAs

1. Decide location of BDA dam crest orientation, configuration (e.g., straight or convex downstream), and crest elevation (use landscape flags if necessary). Position yourself with your eye-level at the proposed crest elevation of the dam (make sure it is < 5' in height). 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 (water surface elevation difference) 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. Build up first layer or course by widening base upstream and downstream of crest to flat height of 6 to 12" above existing water surface, and make sure it holds back water.

   a. If larger key pieces (i.e., larger logs, cobble or small boulders) are locally abundant, these can be used to lay out the crest position across the channel. Optionally, they can be 'keyed' in by excavating a small trench (no need to be deeper than ~1/3 of the height of key piece diameter) and place key pieces in and pack with excavated material.

   b. Lay out first layer of larger fill material, being careful not to go to higher than 6" to 12" above existing water surface. The first layer should be just high enough to backwater a flat water surface behind it.

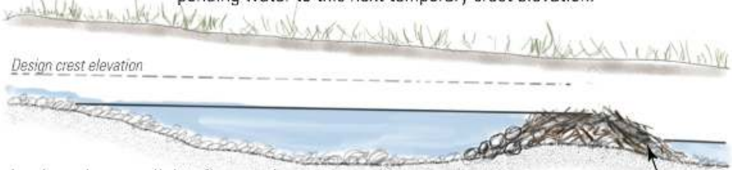
   c. Using mud, bed material & turf (typically sourced from backwater area of pond) as fine fill material to plug up leaks, combine with sticks and branches of various sizes to build a wide base. Make sure base is wide enough to accommodate anticipated dam height (most dams will have a 1.5:1 to 3:1 (horizontal : vertical) proportions.

   d. Build up first layer only to top of key pieces from first layer. Make sure the crest is level across the channel and water is pooling to this temporary crest elevation.

continued >>

STEP(S) 3

Build up subsequent layer(s) in 6 to 12" lifts, packing well with mud, turf, leaves, needles, sediment and other material until ponding water to this next temporary crest elevation.



Lay branches parallel to flow on downstream side and build up a mattress to dissipate overflow

FINISHING STEP

Bring dam up to desired design crest elevation. Make sure crest of dam is perfectly level (so no preferential flow or weir exists). If stream is flowing, water should be backed up and ponding, but flow over and through dam should equilibrate so that flow into pond equals flow out (over and through leaky dam).

See Figure 4.31 in the **LTPBR Design Manual**

HOW TO BUILD BDAs *(continued)*

3 Build up subsequent layer(s) in 6" to 12" lifts, packing well with fine fill material until ponding water to its next temporary crest elevation.

> Repeat step 3 as many times as necessary to build up to design crest elevation.

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

> If desired, and time permits, attempt to plug up BDA with mud and organic material (small sticks and turf) 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

- The temptation is always to build up (in height) quickly without making sure each layer is holding back water well and is stable. A better dam results in building up to the design crest elevation slowly.
- Overall dam height is best not to exceed the height of the people constructing it.
- It is easier to build in systems that already have a perennial water source and flowing water, as you can see instantly how well your structure backs up water. It is possible to build in intermittent channels or areas you expect to receive water in the future, but you will not immediately mimic a beaver pond in such situations.
- Much of the 'strength' of the dam comes from the messy carbon fiber matrix you are building with a mix of size and type of materials combined. Similar to concrete, the cement by itself is not strong, but the aggregate and/or reinforcing rebar is what gives the structure its strength.
- 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 designed to accommodate such a response. Often, BDAs that blow out or breach provide improved and more complex habitat.
- If upstream fish passage is a concern, consider building features that make for flow variability that facilitate typical pathways through, over and around natural beaver dams. These can include ensuring overflow side channels that act as fish ladders, sloppier mattresses with micro pools, more branches in the mattress laid parallel to the flow, decreasing head drop for crest elevation of large dams, by building secondary dam(s) downstream that backwater up to base, leaving some porous pathways through dam for fish (and water) to get through.
- Design life: < 1 year (note actual life may last many years or even decades).

OPTIONS, CONSIDERATIONS & VARIATIONS

» For **Step 2a,** it is not necessary to build with larger key pieces. Often building with a mix of smaller woody material and fine fill material is stronger. If woody key pieces are used, consider limbing (cut off branches) on side in contact with bed.

» For **Step 2b**, if key pieces are limbed on the side that is in contact with bed, the branches removed from the other side can be used to help weave and wedge material in subsequent layers in. If this is done, make sure that limbs are trimmed at completion to design crest elevation.

» Just like natural beaver dams, there are a huge number of variations in the woody fill material and fine fill material. In some riverscapes that lack woody riparian vegetation, or nearby woody material, beaver build very strong beaver dams out of nothing more than fine fill material.

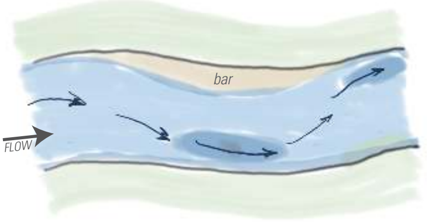
» If building a 'primary' dam (larger dam that tends to be deep enough to support an underwater entrance to a beaver lodge, consider backwater inundation extents relative to good bank-lodging opportunities (e.g., overhanging banks, vegetation and cover from predation).

» If building multiple dams (typically secondary) in series, the dams within a complex tend to be positioned (spacing downstream) and built to heights that support flatwater from the crest of the downstream dam all the way upstream to the base of the next dam upstream *(see page 22).*

DAM CREST ORIENTATIONS

UNDAMMED REACH

At low flows, and in the absence of dams, flow paths within the bankfull channel follow the thalweg and are shunted by bars.



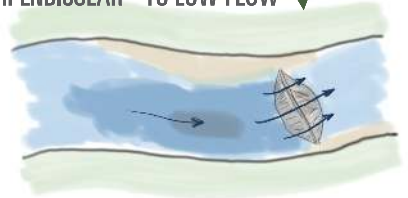
Since dams are built to a constant crest elevation, they essentially are a contour. Water flows perpendicular to the contour and over the dam crest, when the dam is maintained and/or intact.

Adapted from Figure 4.39 in the **LTPBR Design Manual**

PERPENDICULAR - STRAIGHT ✔

When dam crests span the bankfull channel, but are lower elevation than the adjacent floodplain, low flows are contained within the channel. Perpendicular orientations will back water up, and alter the flow paths to that of bankfull flows.

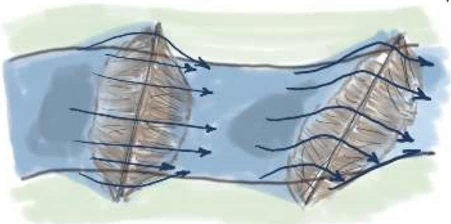
PERPENDICULAR - TO LOW FLOW ✔



Smaller dams that just backup the low-flow channels often have an orientation perpendicular to the low flow, but at an angle to the bankfull flow patterns.

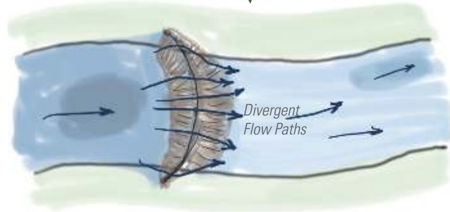
PERPENDICULAR-STRAIGHT ✓

ANGLED-STRAIGHT ✓



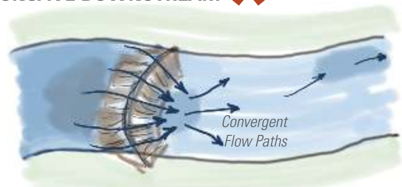
When dam crests are higher than bankfull and extend out onto floodplains,they can direct overflow onto those floodplains. However, a perpendicular, straight dam will direct most flow straight downstream. By contrast an angled dam will direct flow to one side of the channel (however the head drop tends to dissipate most of the flow energy).

CONVEX DOWNSTREAM ✓



Beaver dams are sometimes curved in a convex downstream orientation across the channel, which creates divergent flow paths over the dam. This flow pattern is effective at dissipating energy.

CONCAVE DOWNSTREAM ✗

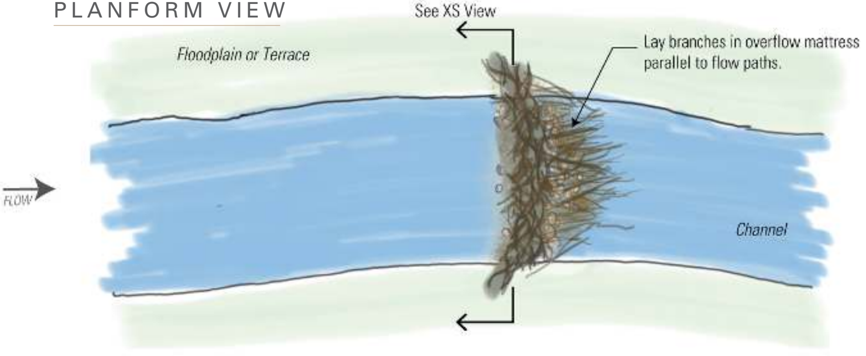


Beavers rarely build dams like Hoover Dam (and Hoover was not designed to withstand spill over the top). Concave downstream crests concentrate flow at the base of the dam, scouring out a deep pool, but also potentially undermining the dam integrity.

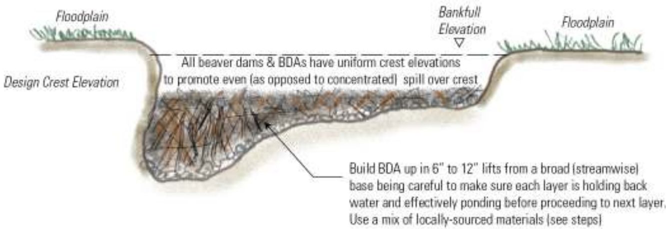
POSTLESS BDA

- BDAs are built to initially mimic a natural beaver dam (i.e., backwater upstream, such that a pond is created), but most BDAs are intended to promote beaver dam activity at some point thereafter.
- Many of the benefits of natural beaver dams, come from their ephemeral nature, and whether dams are actively maintained, blown-out, breached, filled in and/or abandoned.
- Postless BDA design are inspired by how beavers build dams; without fence posts, a hydraulic post pounder or heavy equipment. Like natural beaver dams, the postless BDA is appropriate in areas that can already support beaver dams.

PLANFORM VIEW



CROSS SECTION VIEW



NOTE

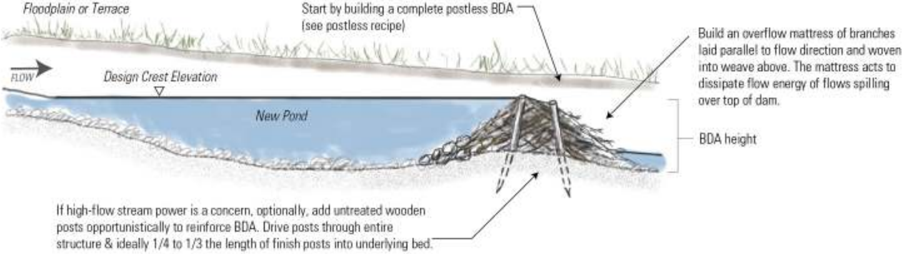
The crest elevation is a critical consideration. In general, primary dams are taller than secondary dams, and usually wider (either extending onto bars, inset benches or floodplains, as to lower unit stream power). Secondary dams tend to just be tall enough to back-water up to the base of the next upstream dam. Secndary dams can be built higher to lower the head (elevation) drop of an upstream dam.

PROFILE VIEW

POST-ASSISTED BDA

- Posts can provide some temporary anchoring and stability to help with initial dam stability during high flows in systems with flashier flow regimes or that produce larger magnitude floods.
- For situations where additional support during high flows is deemed necessary, our suggested practice is to start out following the instructions to build a postless BDA, and then simply add posts as extra reinforcement after the fact.

PROFILE VIEW WITH POSTS

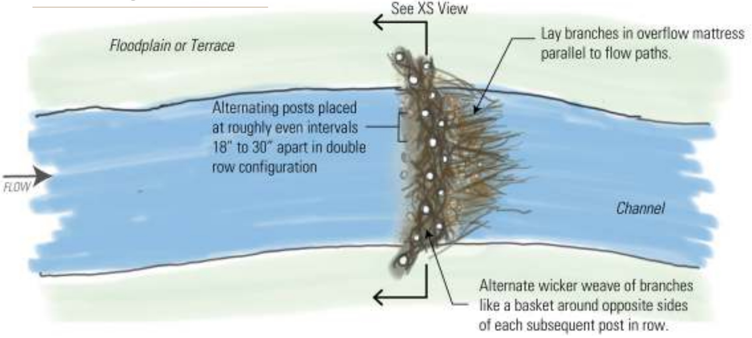


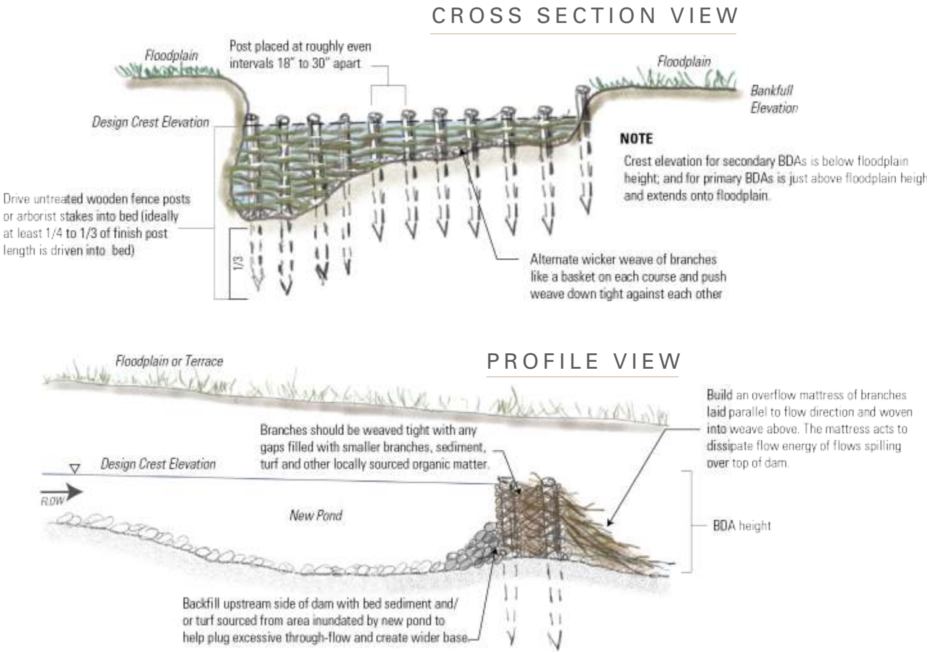
See Figure 4.34 of the **LTPBR Design Manual**

POST-LINE WICKER WEAVE

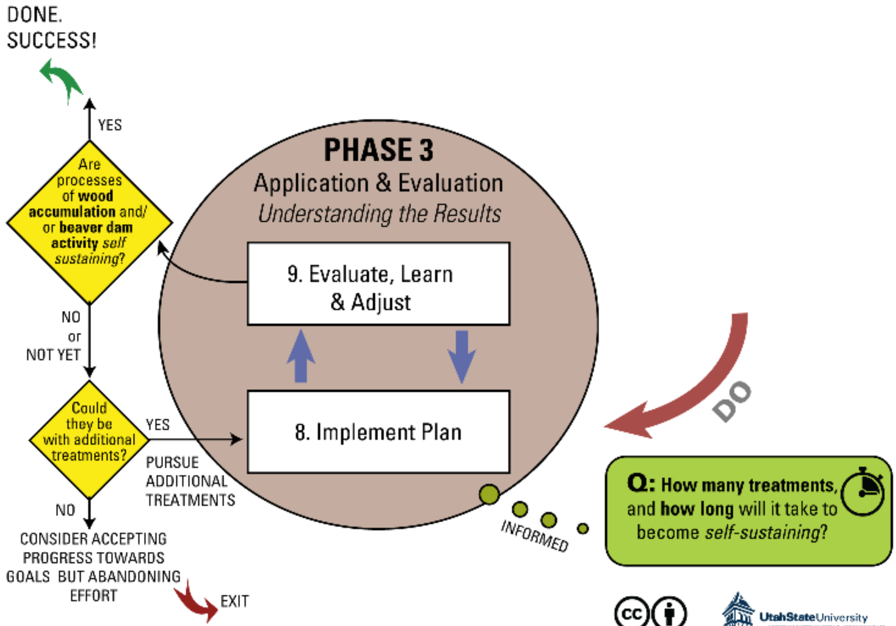
- BDAs can be constructed using post-line wicker weaves, to initially mimic beaver dam activity and later promote it.
- Posts used to layout a crestline, and long branches are woven between the posts to provide most of the structure.
- Post-line wicker weaves have been used for at least 150 years as instream structures, but have most often been used in check-dam or weir designs, which have higher crest elevations along the banks, and concentrate flow over the middle of the structure. By contrast, post-line wicker weave BDAs have a constant crest elevation as to not concentrate flow at any point.

PLANFORM VIEW



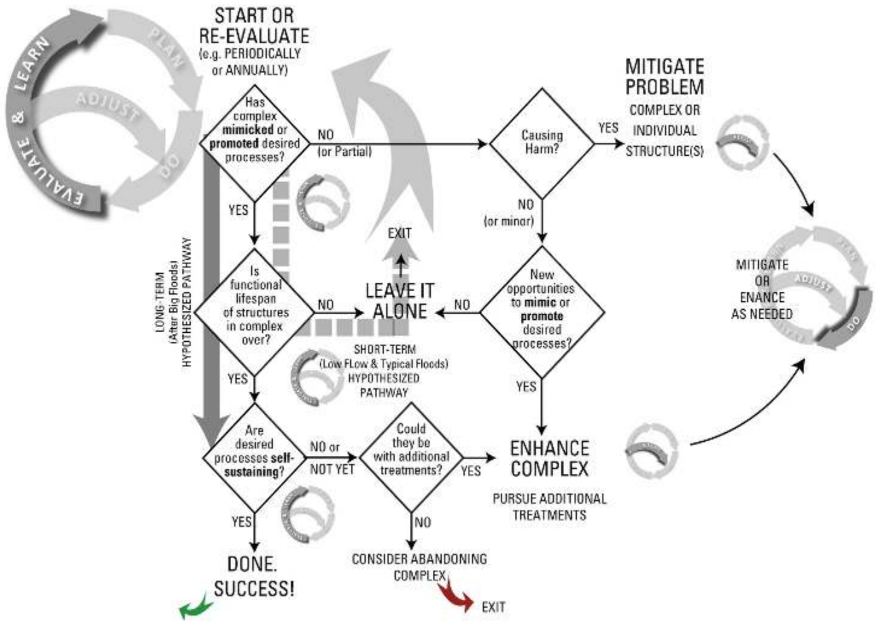

CROSS SECTION VIEW
Floodplain
Post placed at roughly even intervals 18" to 30" apart
Floodplain
Bankfull Elevation
Design Crest Elevation
NOTE
Crest elevation for secondary BDAs is below floodplain height; and for primary BDAs is just above floodplain height and extends onto floodplain.
Drive untreated wooden fence posts or arborist stakes into bed (ideally at least 1/4 to 1/3 of finish post length is driven into bed)
1/3
Alternate wicker weave of branches like a basket on each course and push weave down tight against each other
PROFILE VIEW
Floodplain or Terrace
Build an overflow mattress of branches laid parallel to flow direction and woven into weave above. The mattress acts to dissipate flow energy of flows spilling over top of dam.
Branches should be weaved tight with any gaps filled with smaller branches, sediment, turf and other locally sourced organic matter.
Design Crest Elevation
FLOW
New Pond
BDA height
Backfill upstream side of dam with bed sediment and/ or turf sourced from area inundated by new pond to help plug excessive through-flow and create wider base.

IMPLEMENTATION PHASE



See Figure 6.1 of the **LTPBR Design Manual**

EVALUATION OF COMPLEX - ADAPTIVE MANAGEMENT



TOOLS TYPICALLY USED

» PPE (personal protective equipment): closed-toe work boots, full pants, gloves, hardhat, eye protection and ear protection; optionally: dry suit or waders
» Cutting tools: loppers; optionally: chainsaw, hand saw(s), and pruning shears – for sourcing, trimming and cutting to size woody fill material
» Digging tools: shovel(s); optionally: pick-axe and/or digging bars – for sourcing finer fill material
» Five-gallon buckets: for filling and moving finer fill material from source areas to BDA
» Cam straps (optional): helpful to bundle together branches for easier hauling

POST DRIVER OPTIONS

	Sledge Hammer	Post Driver Manual Powered	Hand Operated Gas Powered	Hand Operated Hydraulic Powered	Tractor-Mounted Hydraulic Powered
Equipment Cost	*$*	*$*	*$$*	*$$$*	*$$$$*
Operator Expertise	*Unskilled*	*Unskilled*	*Moderate*	*Moderate*	*Skilled*
Ease of Deployment	*Easy*	*Easy*	*Easy*	*Moderate*	*Difficult*
Max Diameter of Post	*0.5 - 2"*	*0.5 to 2.5"*	*1" to 2.5"*	*1" to 4"*	*1" to 6"*
Effectiveness / Scalability	*Low*	*Low*	*Moderate*	*High*	*High (access limited)*

Post drivers are used to drive posts into the streambed and provide temporary anchoring of low-tech structures. Drivers come in a variety of options, but each have trade-offs in terms of equipment cost, operator expertise required, ease of deployment, maximum diameter of posts they can drive (varies with substrate) and their overall effectiveness and scalability when doing 10's to 100's of structures over many miles of streams.

See Figure 6.16 of the **LTPBR Design Manual**

TYPICAL LOW-TECH INGREDIENTS

- As with natural beaver dams and wood accumulations, a diversity of ingredients can be used. The "best" ingredients are those that can be sustainably sourced on-site, and would naturally be found there *(see* **Restoration Principle 7** *on page 3)*.
- Hauling material in from off-site can drive costs up. If locally sourced alternatives can be used (e.g., wood removed as part of conifer removal or fuels reduction).
- If building BDAs for beaver, and desirable woody species (i.e., those that can be used by beaver as food source and building material) are in short supply, use less desirable species (e.g., conifers) or more abundant species.

Conifer removal can provide an excellent source of woody material for structurally-starved systems.

PALS INGREDIENTS

» **Branches, limbs, small logs, brushy fill:** generally < 6-15′ long and 6-16″ diameter (i.e., can be carried by 1-3 people and constructed by crew of 2-4)

» **Untreated wooden posts:** 6 - 8′ long and 2-4″ diameter; can sometimes be built on site with small diameter trees and/or branches, but may not be practical for building hundreds of structures

BDA INGREDIENTS

» **Woody fill material:** branches, limbs, small logs, brushy fill

» **Finer fill material (organic)**: e.g., turf mats, roots, leaves, conifer needles, grass, etc.

» **Finer fill material (inorganic)**: e.g., fine bed sediment, silt, clay, soil, gravel

» Optional if available onsite: key pieces: logs, cobbles or small boulders

» Optional: untreated wooden posts if post-assisted (*see page 45*)

POST OPTIONS

Posts are used to provide temporary stability or pins when building many low-tech restoration structures. There are many commercially-available post options (e.g., fence posts), but a premium price is charged for consistency, larger diameter, and straight poles (e.g., peeler cores and lodge pole). Smaller diameter (e.g., 2” to 3”) posts and/or tree stakes (1.5” to 2” diameter) are cheaper, and often available from fuels reduction or non-commercially viable slash from timber harvest operations. Since posts are driven into substrate, they need to be pointed at tips. Pointing can be done by supplier or by an experienced chainsaw operator with four cuts.

Adapted from Figure 6.4 of the **LTPBR Design Manual**

PARKING LOT BDA EXERCISE

PURPOSE: To simulate many of the safety, design and construction considerations encountered when building post-line wicker weave low-tech structures (e.g., beaver dam analogues).

INGREDIENTS

- 4 - 6 Untreated wooden fence posts (nominal diameter of 3" and cut to 4' to 5' in length)
- 4 - 6 Five-gallon buckets
- Willow weave material (long, i.e., > 4 ft), limbed branches of ¼" to 2" diameter willow branches
- Cobble fill (to fill each bucket about half way up with post)

TOOLS

- Personal Protective Equipment:
    - Closed-toed shoes
    - Work gloves
    - Eye protection (e.g., safety glasses)
    - Hard Hat

INSTRUCTIONS

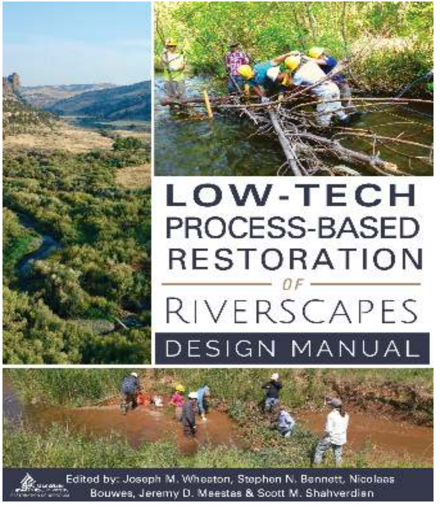
1. Decide location of BDA dam crest, configuration (e.g., straight or convex downstream), and crest elevation. Position yourself with your eye level at proposed crest elevation of dam (make sure it is < 1.5 meters in height), and look upstream to find where the pond will backwater to. Adjust crest elevation as necessary to achieve desired size of pond, inundation extent, and overflow patterns.
2. Put one post in each five gallon bucket, hold post plumb in center of bucket, and fill bucket half way up with cobble to keep post upright.
3. Place posts roughly one to two bucket widths apart in desired dam crest configuration.
4. Weave willow branches in between posts across the channel. Alternate weave pattern and pack branches down to minimize voids. Build up to desired design crest elevation.
5. Work a willow mattress (laying branches parallel to flow) into dam on downstream side and build to provide energy dissipation to overtopping flows.

CONSULTATION & PERMITTING

Below are some tips for project planners to keep in mind when navigating regulatory consultations for low-tech restoration:

- Understand the intent of the governing regulations.
- Put yourself in the shoes of the regulator.
- Establish a rapport with your regulators and earn their trust.
- Communicate regularly and clearly.
- Be realistic about time frames.
- Ask to permit for complexes not structures.
- Even if permit is not required, let regulator make that decision.
- Seek permit(s) for staged implementation & maintenance.
- Attend local permitting workshops.

The content in this Pocket Guide is sourced from the **Low-Tech Process-Based Restoration of Riverscapes: Design Manual**.



Full manual available at:
http://lowtechpbr.restoration.usu.edu
in print and free online

REFERENCES

Bouwes, N., Bennett, S. and Wheaton, J., 2016. Adapting Adaptive Management for Testing the Effectiveness of Stream Restoration: An Intensively Monitored Watershed Example. Fisheries, 41(2): 84-91

Cluer, B. and Thorne, C., 2014. A stream evolution model integrating habitat and ecosystem benefits. River Research and Applications, 30(2): 135-154. DOI: 10.1002/rra.2631

Goldfarb, B., 2018. Beavers, Rebooted: Artificial beaver dams are a hot restoration strategy, but the projects aren't always welcome. Science, 360(6393): 1058-1061. DOI: 10.1126/science.360.6393.1058

Pollock, M.M., Beechie, T.J., Wheaton, J.M., Jordan, C.E., Bouwes, N., Weber, N. and Volk, C., 2014. Using Beaver Dams to Restore Incised Stream Ecosystems. Bioscience, 64(4): 279-290. DOI: 10.1093/biosci/biu036

Silverman, N.L., Allred, B.W., Donnelly, J.P., Chapman, T.B., Maestas, J.D., Wheaton, J., White, J. and Naugle, D.E., 2018. Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semi-arid rangelands. Restoration Ecology. DOI: 10.1111/rec.12869

Wheaton, J., Fryirs, K., Brierley, G.J., Bangen, S.G., Bouwes, N. and O'Brien, G., 2015. Geomorphic Mapping and Taxonomy of Fluvial Landforms. Geomorphology, 248: 273-295. DOI: 10.1016/j.geomorph.2015.07.010

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