Technical Bulletin

Streambed Restoration

Center for Dirt and Gravel Road Studies

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RESTORING NATURAL STREAMBED MATERIAL – Restoring the natural streambed material through a stream crossing replacement is a critical component of a successful project. Natural streambed material is the substrate that makes up the stream channel bottom. Field observations, longitudinal stream profile survey, grade control features, and shear stress calculations within the identified survey reach can all be used to inform decision making on depth and sizing of material.

WHY STREAMBED MATERIAL IS IMPORTANT

It is important to simulate the natural streambed through the reconstructed crossing to:

- Control permeability to prevent the streamflow from going sub-surface
- Provide continuity of slope and reconnect the stream channel
- Provide grade control
- Create varied velocities across the cross-section of the stream
- Dissipate energy and prevent excessive scour and material loss in the structure.
- Increase the lifespan of the structure

Maintaining streambed material in the structure is the only way to accomplish full Aquatic Organism Passage (AOP).

Figure 1: Streambed material is made up of surface and subsurface layers. The surface layer is typically coarser than the subsurface layer because of the scour of fines between the larger particles. The subsurface layer is finer than the surface layer because fines are present in the voids between the larger particles.

LOW FLOW CHANNEL AND BANK MARGINS

When reconstructing the streambed through the replacement structure, it is critical to build a low flow channel, bankfull channel, and bank margins (Figure 2). The cross section of the reconnected channel shall be designed to replicate the channel cross section shape that was collected during the site assessment (see Site Assessment Bulletin and *Stream Crossing Replacement Technical Manual*). A low flow and bankfull channel plus bank margins:

- reconnect the constructed channel to the existing channel
- allow for natural sediment movement
- ensure that AOP is possible through a range of flows and velocities

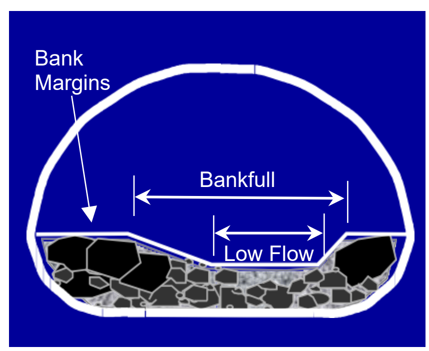

Figure 2: Schematic of a pipe arch with low-flow channel, bankfull channel, and bank margins.

It is easier to establish bank margins and low flow channels in structures that are larger than bankfull. If a low flow channel and bank margins are not established, it will increase the chance of sediment deposition within the structure due to a wide flat channel (Figure 3). If the channel inside the structure is wider than the natural streambed, then the stream will lose velocity inside the structure and its ability to transport the sediment through the crossing will decrease. The resulting sediment deposition can force water to the sides and increase velocities at the edge of the structure. The increased velocities encourage scouring in the structure, can jeopardize footers, and ultimately impact structural integrity.

Figure 3: The photo on the left shows a properly constructed streambed with a low flow and bankfull channel, along with bank margins. The photo on the right shows a structure that did not have a properly constructed channel, and the resulting sediment deposition at the inlet is forcing the flow to the side of the structure.

DESIGN AND CONTRACT CONSIDERATIONS FOR STREAMBED MATERIAL

- The DGLVR Stream Crossing Design & Installation Standard requires construction plans to include *"(VI. B.8.) Depth, gradation, and composition of material for streambed restoration."* Elements that must be depicted in the construction drawings include the streambed material thickness, and inlet and outlet bed elevations. The material gradation and composition must be noted, and if the native material onsite will be reused or if material will need to be imported. Drawings must include gradation, composition, and construction details for the low-flow channel, bankfull channel, and the bank margins.

- Minimum stream substrate depth (measured below the low flow channel at a grade control crest, to the structure invert or bottom of the footers) is to be based on the maximum pool depth in the reference reach with a minimum safety factor multiplier, as listed in Table 1. Alternatively, minimum bury depth can be determined using industry-accepted scour analysis and modeling tools for stream system analysis and/or bridges (storm sewer models are not acceptable for stream crossing scour analysis).

- The minimum substrate depth required shall be 24 inches or depth determined with scour analysis models or using the Anticipated Scour Depth, whichever is greater.

Table 1: Pool Depth Safety Factor Multiplier to establish Anticipated Scour Depth

Stream Slope	Pool Depth Multiplier
0% - 2.0%	1.5
2.1% - 4.0%	2.0
> 4.0%	2.5

- Structures installed on stream slopes >4.0% <u>must</u> be bottomless. The 2.5 safety factor multiplier is to establish the recommended minimum bottom of footing buried depth. Final footing buried depth is to be determined by the engineer in project design.

- The cross-sectional survey shall inform dimensions of features such as the low-flow channel, bankfull width, and bank margins to be used when reconstructing the channel through and around the new structure.

- The size of bed material and key grade control pieces will inform how wide bank margins need to be. At a minimum, the new structure must be 125% of bankfull width of the stream at the bankfull elevation. This allows space for proper construction of the low-flow channel, bankfull channel, and bank margins within it (see Structure Selection Technical Bulletin and *Stream Crossing Replacement Technical Manual*).

- To meet DGLVR Policy and the Stream Crossing Design & Installation Standard, grade controls and key pieces, including bank margins within the structure, shall be designed to be stable at the 100-year discharge (Q100). In design, the planner or engineer must use a suitable method for calculating a stable rock size to specify for construction of grade control features through the reconstructed reach, including within the replacement structure.

- Apart from sand- and silt-bed streams, natural streambeds typically consist of a well-graded substrate with a wide range of particle sizes. Among other functions, coarser (larger) particles provide roughness, and grade control, while finer particles contribute to compaction of the bed. This mix of particle sizes should replicate the natural stream bed and is critical to managing flood velocities and creating aquatic organism habitat. When specifying a bed material gradation, consider a mix that provides this natural range of small and larger particles to best mimic natural channel performance. For additional streambed material design guidance, see the *Stream Crossing Replacement Technical Manual.*

- During development of a grant application, careful consideration should be given to additional labor requirements and specialized equipment needs to place material within the proposed structure, such as mini excavators or walk-behind skid steers (Photos 1 and 2). If needed, a budget line item in the grant application should be provided to address these specialized equipment needs.

- It is also important to consider the extent of stream channel modifications or reconstruction required up and down gradient of the proposed replacement structure to reconnect the stream channel. This is determined by looking at a longitudinal profile to tie the proposed project into existing or constructed grade control features and ensure proper stream slope through the structure. If this work is performed outside of the stream crossing permit boundary, off-right-of-way permission must be obtained from the landowner in accordance with SCC policy, and additional permitting may be required.

- During the planning and design phase, identify the potential methods for placement and compaction of streambed material, including the appropriate water source for washing fines into the structure (see "Placement and Washing of Fine Material" below). Account for this construction activity in the grant application budget, Erosion and Sediment Control Plan (including a plan for stream diversion during construction and washing), and all subsequent plans and bidding documents.

- Once contracted, details pertaining to the grade control sizing, streambed mix design, and suggested methods of construction should be incorporated within the permit application and construction drawings. This information also needs to be detailed in the bid or contract documents as well.

- When installing structure without inverts (bottomless structures), it is critical to only disturb the part of the stream channel that is necessary to set and properly backfill the footers. The considerations described above, including minimum substrate depth, and the material placement process described below are applicable to structures with or without inverts.

STREAMBED MATERIAL AND PLACEMENT

Planning is an important part of a successful streambed restoration. Some questions to consider are:

- Is the structure tall enough to use standard or specialized equipment to place stream bed material? (Photos 1, 2)
- Is it possible to place material while assembling the pipe? (Photo 3)

If structure height is limiting, consider renting a walk-behind skid steer. In smaller pipes, the only option may be hand placement of the larger material and washing of fines.

Specification of a stable substrate matrix through the reconstructed reach should consider the natural tendency of streams to mobilize and transport bedload as well as the need to maintain material in the structure over the long term. Streambed reconstruction should include a mobile component as well as a larger component more capable of withstanding the anticipated range of flows over the lifespan of the new crossing. Fine materials (such as native streambed material excavated from the project site) can be added to provide compaction of void spaces in the larger rock and supplement the mobile surface layer of the finished streambed. Robust key pieces and/or grade controls sized for Q100 establish and maintain the finished streambed elevation, slope, and spacing of bed features through the reconstructed stream reach. The designer must develop a specified substrate mix that adequately reflects these components. In most stream settings, a well-graded aggregate of very fine, fine, and coarse bed material provides for both sediment transport and bed resiliency. These are augmented with placement of larger key pieces and grade controls at locations informed by the longitudinal profile. Refer to the *Stream Crossing Replacement Technical Manual* for recommended methods for streambed substrate design.

Photo 1: Placing larger material in a 15'w x 10'h pipe arch (squash pipe).

Photo 2: Placing fine material in a 8'w x 6'h bottomless arch with a walk-behind skid steer.

<u>Placement of Grade Control and Key Pieces</u>:
Often, the first step is placement of the large rock used as grade control and key pieces within the structure that will be stable at Q100 (Figure 4). In some cases, it may be best to build the streambed and grade controls simultaneously from structure inlet to outlet. In this case, streambed material and key pieces are placed until each grade control location is reached, and then the grade control is installed (Figure 5). All large material should be placed on a small amount of finer stream bed material to prevent damage to the structure invert during placement. Typically, the key pieces and grade control material should be larger than any visible native material to ensure stability under sheer stresses found at the maximum hydraulic capacity of the structure (Photo 4) (see Grade Control Technical Bulletin).

Photo 3: Placing fine material inside a bottomless concrete culvert with walk behind skid steer.

Photo 4: Large material placed in a 12'w x 6'h arch pipe before placing streambed.

<u>Placement of Bed Material</u>:
Streambed reconstruction should include a mobile component as well as a larger substrate that is stable at higher flows but not expected to be stable at Q100. In most stream settings, this is a well-graded mixture of very fine, fine, and coarse bed material that provides sediment transport and bed resiliency. Although substrate mix design will be site-specific, a three-part mix can be used as a framework suitable substrate for the reconstructed reach. An example would be a mix of R4 rock, 2A or 2RC stone with fines, and native material if deemed acceptable by the onsite construction supervisor or engineer. Refer to the *Stream Crossing Replacement Technical Manual* for recommended methods for streambed substrate design. This aggregate should be mixed, in equal parts, from stockpiles prior to being placed in the culvert or stream channel (Photo 5). In areas that require significant depth of fill, such as the outlet scour pool or streams with large scour potential, place the streambed material in lifts of approximately one foot. After placement, thoroughly compact mechanically and hydraulically in place before starting the next lift (Photo 4).

Mechanical compaction can be achieved with equipment such as a jumping jack tamper, vibratory plate compactor, or even the weight of machinery used to place the material such as a walk-behind skid steer. If the structure is too small for machinery, the fine material should still be hydraulically washed between lifts.

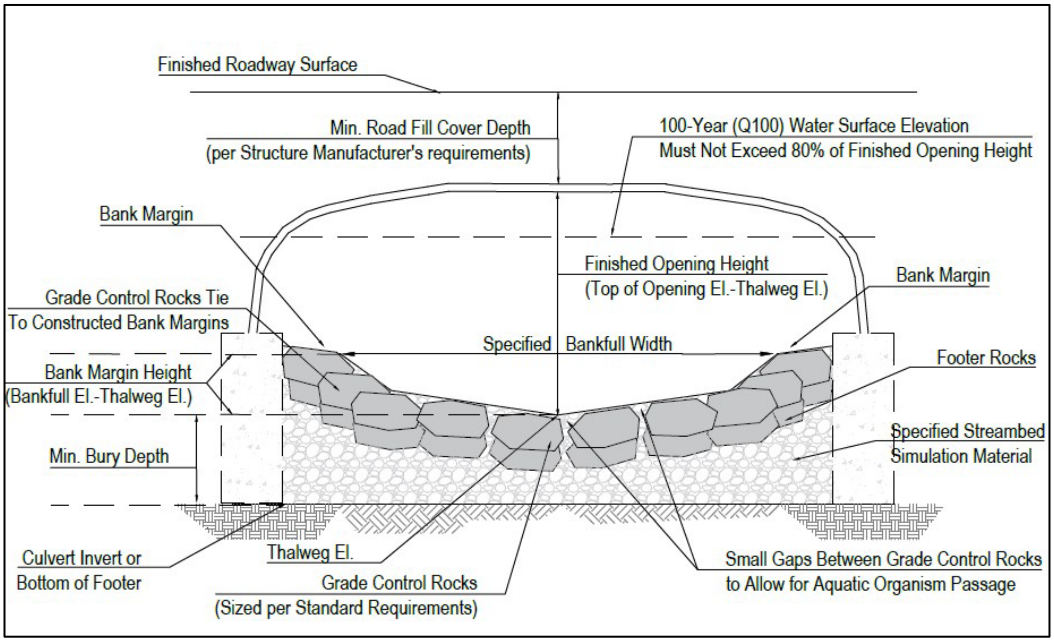

Figure 4: A typical cross section **at a grade control** showing channel shape through a culvert. The bottom line represents invert or recommended top of footing depth. The dashed line shows the water surface elevation of the 100-year discharge.

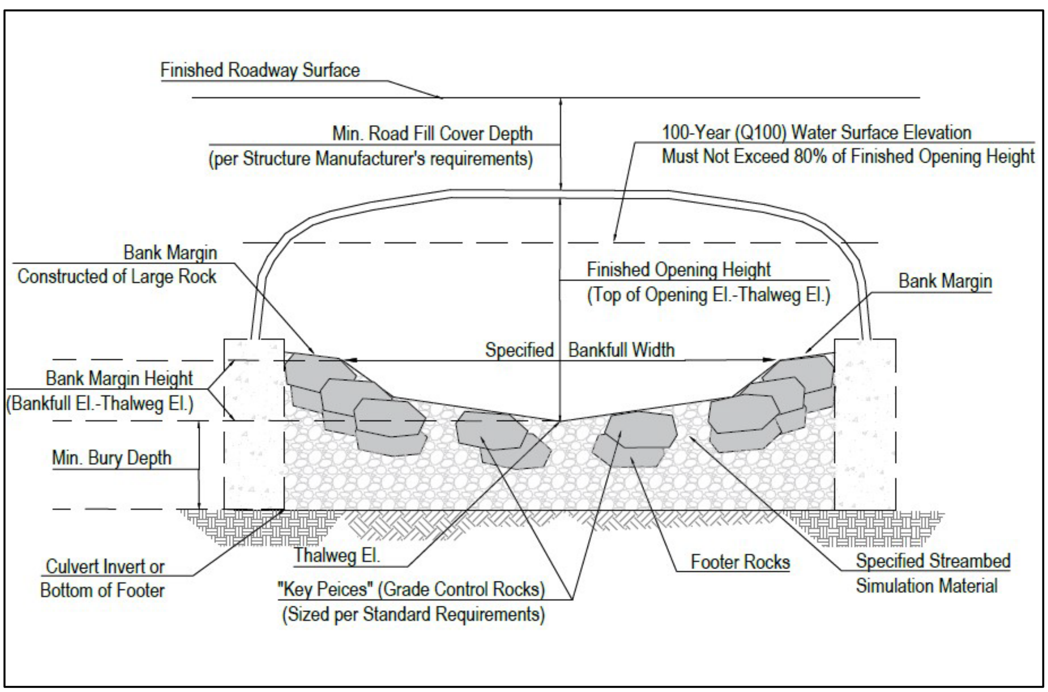

Figure 5: A typical cross section **between grade controls** showing channel shape through a culvert. The bottom line represents invert or recommended top of footing depth. The dashed line shows the water surface elevation of the 100-year discharge.

Placement and Washing of Fine Material:

Washing the fines is a critical part of rebuilding the streambed properly during a culvert replacement. Fine material such as native stream bed material or similar quarried material with adequate fines (e.g., 2RC) is placed on top of the larger material and compacted mechanically or hydraulically, as described above, to force fine sediments into the voids between larger particles. If not done properly, water will go subsurface and you will lose the ability to successfully reconnect aquatic organism passage. It is also important to consider and specify Erosion and Sedimentation requirements for washing materials in the plans.

Photo 5: Mixing native material and larger foundational stone prior to placement.

If significant depth of fill is required, place the large material and fines in lifts of approximately one foot and compact as described previously. If machinery cannot be used, it is typically easier to wash material in from the inlet of the structure (Figure 6). On longer crossings it might be necessary to wash from both the inlet and outlet. To begin washing, have the excavator place a bucket or two of fines at the inlet/outlet and wash the material into the structure until the fines are gone. Place a couple more buckets of material at the inlet/outlet and repeat as many times as needed. The best way to determine if the fines have filled the void spaces is when the water stays on top of the newly constructed stream bed and does not go subsurface.

The amount of water needed to properly wash the fines will vary from site to site. There are several variables that dictate the amount of water needed: size of stream crossing (length and width), composition of fines, quantities (tons/yards) of fines, and the number of lifts needed. During the planning phase it is critical to determine if an adequate water supply and pump capacity exists onsite, or if you will need a local water truck or fire company to supply the water. A tanker truck of 1,500 gallons or more from the local fire department is a great way to wash fines (Figure 4). If using the local fire company, plan accordingly, as they may not be able to provide a water truck during normal business hours if they are a volunteer service and they may be called away from the job site for emergency calls. Typically, a 3-inch pump with a fire nozzle or straight stream nozzle work well in most applications. If the stream is large enough to supply the water, a 6-inch pump is preferred because of the large volume of water they can provide. However, a 6-inch pump line can be extremely difficult to handle. There is a delicate balance between having enough pressure and volume of water. When in doubt, go with the pump that moves the greatest volume of water.

Figure 6: The photo on the left shows washing of fine material into a 6'w x 4'h pipe arch (squash pipe) using a fire truck. The photo on the right shows the washing process between tanker loads and view of a baffle grade control.

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