Definition and Purpose

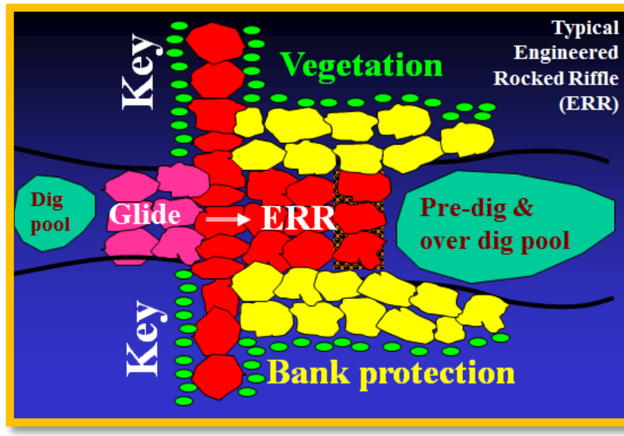

Figure 1: Typical Engineered Rocked Riffle (ERR) diagram. Dave Derrick.

Grade Control Structures (GCS) are typically placed across a stream channel and keyed into both banks, oriented approximately perpendicular to flow for the purpose of controlling, or raising, the bed of the stream and preventing streambed degradation on-site and upstream. Stream discharge flows over the GCS from a higher to lower elevation in a controlled fashion. There are literally hundreds of GCS designs. Many of the rigid (non-adjusting) designs have fallen out of fashion, and many vertical or steep-sloped designs are a barrier to fish passage and are difficult to permit. Typically GCS will form an energy dissipating pool at their downstream ends. Many grade control designs will incorporate a pre-dug and overdug pool at the downstream end to help dissipate this energy.

There are dozens of different types of GCS, including “At-Grade,” “Hinged,” and “Underground.” At-Grade GCS are used to hold the bed of the stream at its current elevation (not allowed to degrade) by having the crest of the structure’s stone equal to the bed of the stream. At-Grade GCS is also designed to arrest advancing headcuts by building it with a sufficient calculated volume of stone at the downstream end, so once the headcut reaches the structure, this stone at the downstream end is undercut and adjusts into a rock ramp from the GCS to the headcut. Hinged GCS are typically built of Articulating Concrete Mattress that adjusts and self-heals to undercutting foundation failure due to headcutting at the downstream end of the structure. Underground GCS are a typical ERR built completely under the bed of the stream to stop a known height of headcut(s) from moving past the structure, but the stone is not required to self-adjust, or launch. The headcut simply uncovers the buried ERR. The required stream, and possibly watershed-wide functions needed, will dictate the type of GCS installed.

Image 1: ERR has a 20 to 1 slope on the downstream face for stability, to entrain air, for fish passage, and to dissipate energy. Camp Miakonda. Kyle Spicer.

> ***Engineered Rock Riffles will become the steepest section of the stream once installed. Several low GCS are better than one large GCS, resulting in cheaper overall costs and better fish passage.***

Grade Control

Methods Sheet

Practice Applicability

Typically, grade control is needed in response to overall bed lowering of several interconnected rivers, streams, and tributaries over a fairly large area, and in many cases a watershed-wide area. Usually, a series of structures are designed and installed as a system, sometimes with each performing different, but compatible and complimentary functions.

Image 2: Typical ERR. Designed to raise the bed of the stream up approximately one ft. Camp Miakonda in Sylvania, OH. Kyle Spicer

Straightened streams typically have enough energy to degrade (lower) the bed, in some cases up to several feet or more. This systematic instability can result in millions of dollars in damage to infrastructure (bridges, low water road crossings, undermined culverts, pipelines, other exposed utilities), and can result in significant land loss due to stream widening. A patchwork of bank protection works for this threatened infrastructure can cost millions over the years, without addressing the main cause of the instability! Understand the system before setting the path forward can result in a fully functioning system.

Engineered Rock Riffles (ERR) are a type of Grade Control Structure (GCS). The successful GCS built within the greater Toledo Area projects have all been stone ERRs since they mimic the natural riffles found in these pool-riffle-pool regime streams.

Image 3: Using a log to raise grade on Hartman Ditch. Rigid object (log was the only material on hand) was later undercut and failed, Camp Miakonda. Kristina Patterson.

Grade Control Structures have been implemented all over the U.S.A. Several restoration projects in the Maumee Area of Concern (AOC) are among those success stories. Camp Miakonda in Sylvania, Ohio, has several different types of Grade Control, including At-Grade ERR to stabilize the overflow channel of a restored lake, one typical ERR on Cunningham Ditch to stop a headcut from forming; five on Hartman Ditch: one providing fish passage on an existing vertical concrete headwall, one to raise the bed of the stream to lower bank heights and reconnect the stream with its historic floodplain; one to raise the bed up to the pre-headcut elevation; and two to raise the bed to prevent undercutting a large road culvert. Preventing and protecting against bed lowering (head cut migration) proved successful while also reducing the potential sediment load into local tributaries, rivers, and a restored historic WPA hand-dug lake. Other local restoration projects with Grade Control include Highland Dam (two ERR in series to drown out a dam for public safety and fish passage), three at Toledo Botanical Gardens to maintain grade after two vertical concrete dames were removed, and Secor Dam (At-Grade) to maintain the bed elevation after a concrete dam was removed. All ERR mimicked natural riffles in these pool-riffle-pool type regime streams and rivers.

Methods typically combined with Grade Control:

- Longitudinal Peaked Stone Toe Protection (LPSTP) or other bank protection attached to the GCS both upstream and downstream
- Bioengineering
- Pre-dug and Overdug energy dissipation pools

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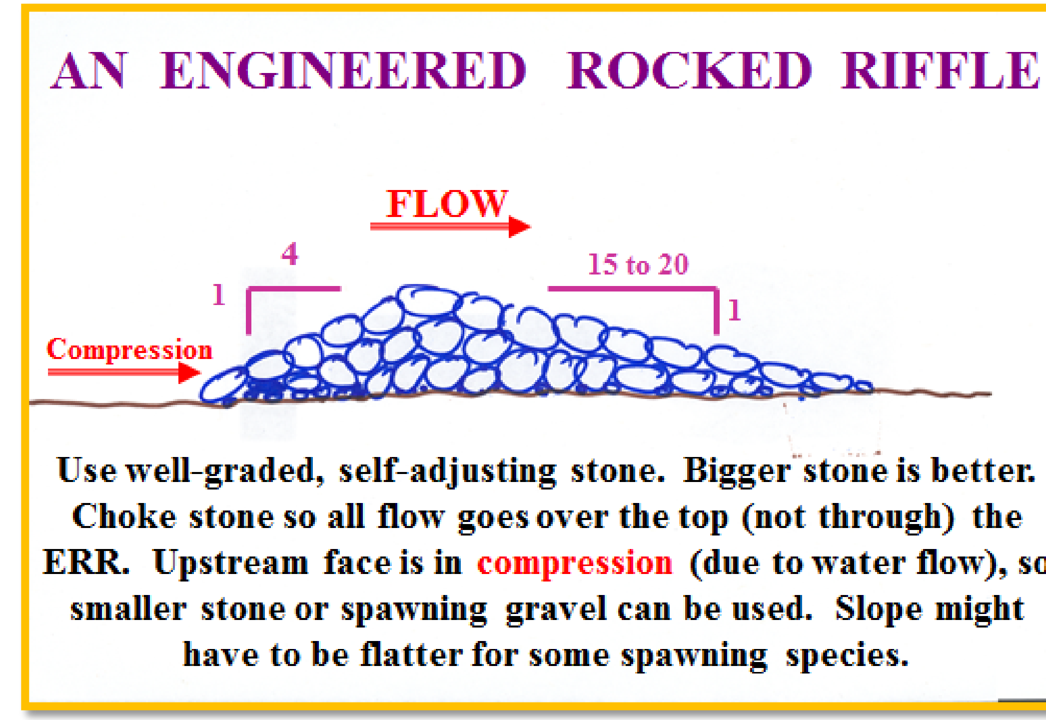
Preparing for Grade Control

Conceptually, stabilize headcuts first, and then worry about bank instability second. Key all grade control structures into both banks. All GCS will require bank protection on both banks. Considering Grade Control Structures brings in a host of options to analyze before design is initiated. A reach wide, or watershed wide analysis needs to be undertaken to understand the area where Grade Control is needed. How will GCS affect the local hydrology, water table, flooding, tribs, and drainage, including effects on existing surrounding bodies of water? Will the water level rise affect geotechnical instability (saturate sand lenses)? Will increases in flood elevations affect infrastructure? Will bridge abutments and piers be more stable? Will sediment storage upstream of GCS starve the downstream reach? Will bank stability be increased due to shorter bank heights? How much bank instability will not occur due to the elimination of headcut migration? How much wetland can be created? How many overbank areas can be hydraulically reconnected to the stream?



Limitations

- If the stream or river is FEMA flood mapped, the "no net rise" rule will be in effect, i.e., the 100 year flood elevation of the stream cannot be raised more than 1/100 of a ft., unless the increased flood elevation area is contained within the borders of the builders land.
- GCS are like small, low-elevation dams, and conceptually must be thought of as such.
- Stable tall banks must be available for the GCS to be keyed into.
- Never build a GCS under another structure (bridge) where repairs are impossible to implement.

General Guidelines for Construction

- Hydraulic Consideration: What maximum flow must be passed?
- Geotechnical Consideration: Is there a narrow area with stable banks? Danger of piping under the GCS?
- Flood Control Impacts: Can flood storage be integrated into the project?
- Tributary Impacts: Typically GCS are located downstream of the confluence of the rib and main stream, to stabilize both water bodies.
- Infrastructure Impacts: Underground utilities protected? Infrastructure flooded?
- Environmental Impacts: Fish passage maintained or enhanced? Sediment storage could change.
- Geologic Controls: Are there stable bed and banks to tie GCS into?
- Local Drainage: Needs to be controlled so GCS is not flanked.
- Channel Alignment: Locate GCS in straight crossing area of stream so flow does not impinge into bends.
- Grade Control structures are typically built where riffles or drops in bed elevation naturally occur, in the straight sections of stream between bends. Spacing between riffles should be 5 to 7 channel widths apart (measured at bankfull stage), and ideally have a bend in-between

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Example Construction Sequence

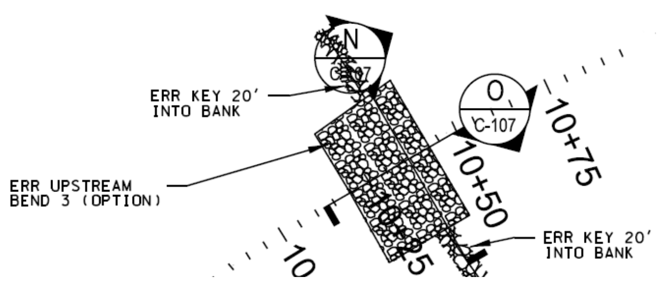
Dirt work "roughing in" location for ERR for lake overflow from historic hand-dug lake at Camp Miakonda.

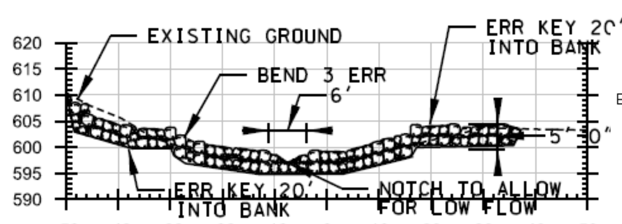
Bank protection starts with plugs and/or poles before it receives soil to cover base ends of poles, then stone will be placed.

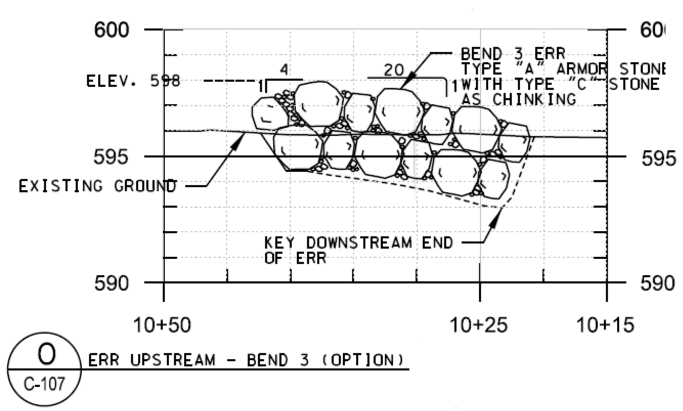
Bed protection of pool begins first, roughing in stone based on project needs (elevation control, fish passage [slope], and energy dissipation).

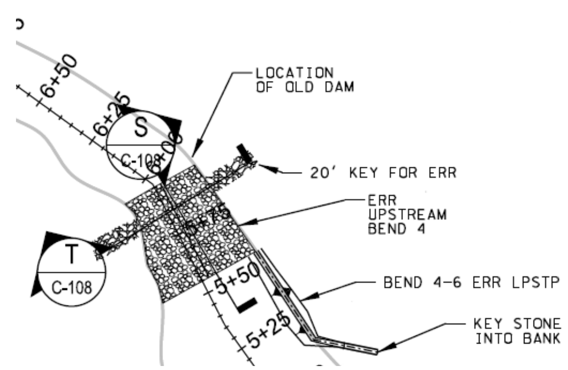
Finished ERR is sloped at 20 to 1, built of a well-graded, self-adjusting, self-filtering stone that was well-choked with smaller stone and gravel-cobble to fill in voids.

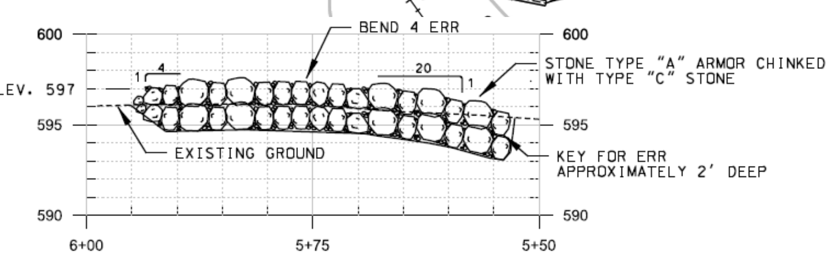
Example Plans and Drawings

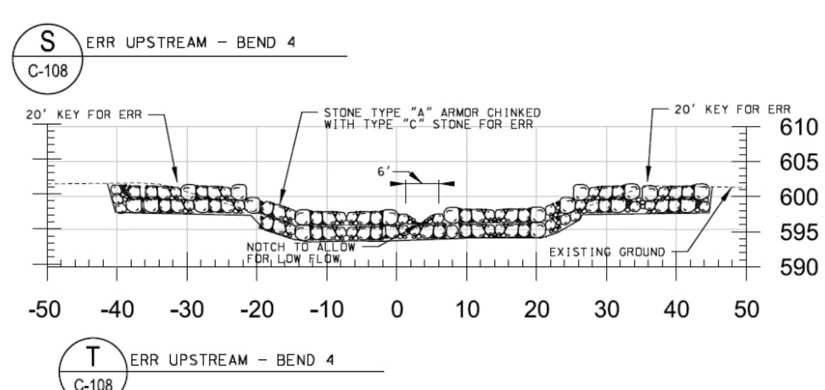












Estimating Your Time and Materials

Grade Control is never cheap, but a systematic, well-designed comprehensive project in most cases will save money in the long run (project life cycle) compared to a Band-Aid helter-skelter approach. As the project increases in scope, and the need for GCS expands to a longer stretch of river or stream, keep in mind a series of smaller structures will typically cost less than one larger one.

Maintenance and Monitoring

Due to their complexity, all Grade Control projects should have an As-Built Survey performed immediately after construction to accurately measure exactly what was built. This provides base-line data for monitoring comparisons. With any structure, flanking is of utmost concern. Robust, well-constructed keys up both banks, that go "up the hill into roughness" should reduce those concerns, but bank stability and channel meandering upstream of the GCS should be closely monitored. As with any stone structure, subsidence can be a concern, although effective filters, or the use of self-filtering stone, can possibly mitigate this concern. Scour or deposition patterns within the scour hole should be closely monitored, especially at the downstream end of the GCS. Monitoring condition of vegetation should be watched and underperforming sections of plants analyzed, and either replaced or augmented. Possibly the initial plant species used was inappropriate and needs to be changed.