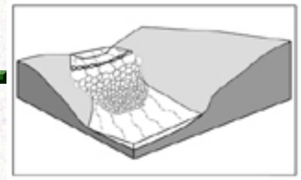
NEWBURY ROCK RIFFLES



1. CATEGORY

3.0 – Riparian Buffer and Stream Corridor Opportunities

2. DESIGN STATUS

Level II

3. ALSO KNOWN AS

Gaboury rock riffles or ramps.

4. DESCRIPTION

Newbury rock riffles are ramps or low weirs with long aprons made from riprap or small boulders that are constructed at intervals approaching natural riffle spacing (5 to 7 channel widths). The structures are built by placing rock fill within an existing channel. The upstream slope of the rock fill is typically much steeper than the downstream slope, which creates a longitudinal profile quite similar to natural riffles.

5. PURPOSE

These structures provide limited grade control, pool and riffle habitat, and visual diversity in otherwise uniform channels.

6. PLANNING

Newbury riffles are primarily used for habitat enhancement and rehabilitation and not for erosion control. However, a series of well-designed riffles can be used to counteract mild channel bed degradation and erosion. Headcuts exceeding about 1 m (3.3 ft) in height will usually trigger failure of such structures unless they are constructed with features typical of grade control structures such as large, well-protected stilling basins and deeply embedded stone toes and keys.

Useful for Erosion Processes:

- Toe erosion with upper bank failure
- Scour of middle and upper banks by currents
- Local scour
- Erosion of local lenses or layers of noncohesive sediment
- Erosion by overbank runoff
- ✓ General bed degradation
- ✓ Headcutting
- Piping
- Erosion by navigation waves
- Erosion by wind waves
- Erosion by ice and debris gouging
- ✓ General bank instability or susceptibility to mass slope failure

Spatial Application:

- ✓ Instream
- Toe
- Midbank
- Top of Bank

Hydrologic / Geomorphic Setting

- Resistive
- Redirective
- Continuous
- ✓ Discontinuous
- Outer Bend
- Inner Bend
- ✓ Incision (mild)
- Lateral Migration
- Aggradation

Conditions Where Practice Applies:

Most experience with this practice has been in cobble/boulder bed streams (Newbury and Gaboury, 1993a and b), but guidelines are available for gravel bed streams (Newbury et al., 1999). This technique is best suited to adding habitat diversity to an otherwise uniform reach.

Complexity:

Moderate.

Design Guidelines / Typical Drawings:

Newbury et al. (1999) encourage the use of surveys of natural rapids and riffles to develop design templates. A 10-step design process based on study of undisturbed or lightly-altered reference reaches is available (Newbury and Gaboury, 1993a and b), but this approach may break down in watersheds where reference reaches are not available or where land use changes have radically altered the hydrology. Many riffles constructed in boulder channels in British Columbia were built with crest heights of 0.6 m (2 ft), upstream face slopes of 1V:4H and downstream slopes of 1V:20H. More gradual slopes were used for riffles in streams in the Midwestern states of the U.S. (Newbury et al., 1999). Riffle crests and downstream surfaces should be V-shaped to direct the flow towards the channel centerline. This reduces bank scour at the riffle site and maintains depth in the center of the downstream pool. Banks should be protected with riprap from the channel centerline up to top bank. Alternative design guidelines are provided by Wittler (1996), who describes design and construction of 11 structures with slopes of 1V:10H and hydraulic head between 0.4 m (1.2 ft) and 0.8 m (2.8 ft) in Muddy Creek, Montana, which has a bed of fine-grained dispersive clay. A geotextile was used underneath the stone structures to prevent leaching of fine material. Wittler suggests an upstream-pointing arch for the planform of the structure instead of a V-shape. Wittler emphasizes excavating the bed and keying in the structure about 1 m (3 ft) below original grade.

Design of grade control structures similar to Newbury riffles but with hydraulic heads between 1 m (3.3 ft) and 1.2 m (4 ft) for a sand-bed stream are described by Tate (1988).

Riffle spacing should be based on natural pool-riffle spacing (usually 5-7 channel widths), but riffles should not be so high or close together that backwater from the downstream pool drowns out critical flow over the upstream riffle during base flows.

Conventional wisdom regarding the hydraulic effect of riffles indicates that they act as broadcrested weirs at low flow, but have little hydraulic effect when they are "drowned out," or deeply submerged by high flows. However, careful measurements made by Walker et al. (2002) in four cobble-gravel bed streams in British Columbia indicated that Newbury riffles had significant effects on head loss during high flows and thus on flood elevations and sediment transport. Hydraulic effects were proportional to riffle amplitude-the vertical distance between adjacent riffle crests.

Newbury Rock Riffles Typical Drawing

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7. ENVIRONMENTAL CONSIDERATIONS / BENEFITS

Pools and riffles are common features found in natural or lightly altered streams. Newbury Riffles are intended to replace pool and riffle habitat lost due to channelization or other types of stream alterations. They provide benthic habitat and contribute to bed stability. Although the coarse material that comprises Newbury Riffles is not intended to be mobile during higher flows like natural riffle material, correctly-designed structures function similar to natural features. Post-construction monitoring of Newbury riffles is highly recommended to ensure that erosion and sedimentation processes do not negate habitat benefits.

8. HYDRAULIC LOADING

Permissible shear and velocity for rock structures is related to the size of rock used in construction. Other factors, such as the angularity of the stone, the thickness of the layers of stone, and the angle at which the faces of the stone structure are constructed also come into play. See information regarding stone sizing below under materials and equipment.

9. COMBINATION OPPORTUNITIES

A variety of techniques can be used to add bank vegetation and attendant shade and cover to Newbury riffle projects. **Live Siltation**, **Live Brushlayers**, **Willow Posts and Poles**, **Live stakes**, and **Live Fascines** may be incorporated into stone bank protection (**Vegetated Riprap**) or planted up- or downstream from riffle structures. **Live Brush Mattresses**, **Vegetated Articulated Concrete Blocks**, **Soil and Grass Covered Riprap**, **Vegetated Gabion Mattress**, or **Cobble or Gravel Armor** may be used to provide protection from local scour adjacent to these structures. **Vegetated Buffer Strips** may be used to provide additional protection and terrestrial habitat on middle and upper banks. In some cases, **Vanes with J- Hooks**, **Cross Vanes**, or **Boulder Clusters** may be placed in reaches between or adjacent to riffles to enhance benthic and water column habitats.

10. ADVANTAGES

Newbury riffles are very natural-looking and provide habitat benefits in otherwise uniform channels.

11. LIMITATIONS

Riffles are not suitable for reaches where rapid bed degradation (lowering) is likely, or where scour depths adjacent to the toe will be greater than the height of the toe. They should be used with greatest care in channels where flooding is likely to be an issue (Walker et al., 2002). Use in streams with channels wider than 50 m (165 ft) is not recommended, and applications to streams with beds containing significant amounts of material finer than gravel should be done with great care (Wittler, 1996). Riffles should not be placed in extremely sluggish or stagnant reaches or those with baseflow depths much greater than 0.6 m (2 ft).

12. MATERIALS AND EQUIPMENT

Stone for the structure should be well graded and properly sized. Newbury and Gaboury (1993a) built riffles using large (up to 1 m (3.3 ft)) fieldstone from land adjacent to the channel. Newbury et al. (1999) suggest the following formula for computing D_S, the stone size in cm: $D_S = 1500HS$, where H is the depth of flow in m under design conditions and S is the slope of the downstream face of the riffle. Using this formula, a riffle designed for a design flow 2 m (6.5 ft) deep with a downstream slope of 5% (1V:20H) would require stone with a diameter of 150 cm (4.9 ft). Wittler (1996) suggests use of formulas by Abt et al. (1988) for minimum and maximum stone size. Median stone size, D_{50} (in ft), is given by

$$D_{50} \geq 0.43 q^{0.56} S^{0.43}$$

where q = discharge per unit width (discharge/crest width) in $ft^3/s/ft$, and S is the slope of the downstream face of the ramp in ft/ft. For a total discharge of 91 m^3/s (3,200 ft^3/s) and a width of 7.6 m (25 ft), and a ramp slope of 10%, the above equation gives D_{50} of 0.7 m (2.4 ft).

13. CONSTRUCTION / INSTALLATION

Riffles may be constructed using track hoes with buckets large enough to accommodate the stone sizes selected for construction. Loaders and dump trucks are usually needed for hauling stones.

14. COST

Twenty-one Newbury riffles were constructed in the East Fork of Mill Creek, Butler County, Ohio in 2000 for $52,500 plus the cost of stone ($25 per US ton). The channel was about 20 m (35 ft) wide.

Six Newbury riffles were constructed in the South Branch of the Waukegan River, in Waukegan, Illinois, in 1996 for $17,600 (material, equipment and labor) (Newbury et al., 1999). Channel width was about 6 m (20 ft).

Twenty-seven riffles were constructed in Mink Creek, British Columbia in 1985-1986 (Newbury and Gaboury, 1993a and b), using locally-available fieldstone, which was free, and machine rentals, which cost $20,500 in 1986 dollars. The channel was about 22 m (73 ft) wide by 1.6 m (5 ft) deep.

15. MAINTENANCE / MONITORING

Features that should be monitored are similar to those for all stone structures: loss of stone due to subsidence, leaching of underlying sediments, and raveling or excessive loss of stone due to scour. Monitoring fish and invertebrate populations and habitat variables is recommended.

16. COMMON REASONS / CIRCUMSTANCES FOR FAILURE

Riffles may be weakened if stones are undersized and are removed during high flows. Also, riffles may be flanked during extremely high flows if tiebacks are spaced too widely or are constructed with inadequate amounts of stone. Extreme scour or bed lowering on the downstream end of the structure can lead to progressive or sudden failure as the scour migrates through the riffle. Riffles should be used with greatest care in actively incising channels, channels with beds finer than cobble, and in urbanizing watersheds.

17. CASE STUDIES AND EXAMPLES

Three case studies based on Canadian streams are provided by Newbury and Gaboury (1993a, pp. 93-148). An additional case study of an urban stream in the US is provided by Newbury et al. (1999) pp. 5-25 through 5-38.

18. RESEARCH OPPORTUNITIES

More information is needed regarding hydraulic and ecological design criteria for unstable streams with bed material finer than coarse gravel.

19. REFERENCES

Abt, S.R., Wittler, R.J., Ruff, J.F., LaGrone, D.L., Khattak, M.S., Nelson, J.D., Hinkle, N.E., & D.W. Lee, (1988). *Development of Riprap Design Criteria by Riprap Testing in Flumes: Phase II*. U.S. Nuclear Regulatory Commission, NUREG/CR-4651, Washington, DC., May 113.

Newbury, R. W. & Gaboury, M. N. (1993a). Newbury Hydraulics Ltd. *The Manitoba Stream analysis and fish habitat design: A field manual*. Habitat Heritage Corp., Manitoba Fisheries branch, Gibsons, B.C., Canada.

Newbury, R. W. & Gaboury, M. W. (1993b). Exploration and rehabilitation of hydraulic habitats in streams using principles of fluvial behavior. *Freshwater Biology 29*:195-210.

Newbury, R. W., Gaboury, M. W., and Watson, C. (1999). Field manual of urban stream restoration. *Illinois State Water Survey*, Champaign, Illinois.

Tate, C. H. (1988). Muddy Creek grade control structures, Muddy Creek, Mississippi and Tennessee. *Technical Report HL-88-11*, US Army Corps of Engineers Waterways Experiment Station, Vicksburg , Miss.

Walker, D. R., Millar, R. G., & Newbury, R. W. (2002). Hydraulic and design aspects of constructed rock riffles in gravel-cobble bed rivers. In D. Bousmar and Y. Zech, eds. *River Flow 2002, Proceedings of the international conference on fluvial hydraulics*. A. A. Balkema Publishers, Tokyo, pp. 497-506.

Wittler, R. J. (1996). Features of a chevron weir rock ramp. *Proceedings of the North American Water and Environment Congress*. American Society of Civil Engineers, Reston, Virg., CD-ROM.