Gully Erosion – Part 3

DESIGN OF ROCK CHUTES FOR GULLY STABILISATION

Photo 1 – A series of short rock chutes constructed within a stormwater drain (Qld)

Photo 2 – Rock chute formed at the head of an urban gully (Qld)

The material contained within this fact sheet has been supplied specifically for use by persons experienced in hydraulic design. Guidance is not provided within this fact sheet on the provision of suitable fish passage conditions within rock chutes.

Introduction

Rock chutes are an essential item in the stabilisation of gullies. Wherever practical, erosion problems should be stabilised using natural components such as soil, rock and vegetation. Engineered structures and synthetic materials should only be used in circumstances where natural-based solutions fail to achieve the required stability.

Even though rock chutes have been apart of gully stabilisation practices for many decades, failures are still quite common. Most rock chute failures results from either:

- poor construction practices;
- water passing around or under the rocks (causing soil erosion and slippage of the rocks); or
- the use of inadequately sized rock (as a result of either a design or construction problems).

Rock chutes are usually most susceptible to damage during the first two years following construction. This high-risk period can be significantly reduced if all voids are filled with soil and pocket planted at the time of rock placement (Photos 5 & 6).

Design Information

The critical components of a rock chute design are:

- control of flow entry into the chute;
- determination of an appropriate rock size; and
- the design of energy dissipation measures at the base of the chute to prevent undermining of the chute and damage to the gully banks.

The upper surface of the rock chute must blend with the surrounding land to allow water to freely enter the chute without being diverted along the edge of the rock lining.

The rock size must be based on flow conditions down the chute, the slope of the chute, the shape of the rocks (i.e. round or angular), and the degree of variability in rock size. The recommended mean rock size for long, straight chutes may be determined from Equation 1.

Equation 1 can also be used to size rock placed on the sides (banks) of the chute provided the bank slope (relative to the horizontal) does not exceed a gradient of 2:1. Rock size should be increased 25% for steeper bank slopes up to 1.5:1.

Equation 1 represents the recommended design formula for sizing rock on the bed and banks of chutes. Tables 6 and 7 provide mean rock size (based on Equation 1 and rounded up to the next 0.1m unit) for safety factors of 1.2 and 1.5 respectively.

$$d_{50} = \frac{1.27 . SF . K_1 . K_2 . S_o^{0.5} . q^{0.5} . y^{0.25}}{(s_r - 1)} \quad \text{(Eqn 1)}$$

where:

d_{50} = nominal rock size (diameter) of which 50% of the rocks are smaller [m]

K_1 = correction factor for rock shape

= 1.0 for angular (fractured) rock, 1.36 for rounded rock (i.e. smooth, spherical rock)

K_2 = correction factor for rock grading

= 0.95 for poorly graded rock ($C_u = d_{60}/d_{10} < 1.5$), 1.05 for well graded rock ($C_u > 2.5$), otherwise $K_2 = 1.0$ ($1.5 < C_u < 2.5$)

q = flow per unit width down the embankment [m^3/s/m]

s_r = specific gravity of rock

S_o = bed slope = $\tan(\theta)$ [m/m]

SF = factor of safety (refer to Table 1)

y = depth of flow at a given location [m]

Wherever practical, the unit flow rate 'q' (m^3/s/m), flow velocity 'V' (m/s), and flow depth 'y' (m) used to determine rock size should be based on 'local' flow conditions (i.e. unit flow rate, flow depth and flow velocity at the location of the rock), rather than values averaged over the full cross-section.

Table 1 – Recommended safety factor (SF) for use in determining rock size

Safety factor (SF)	Recommended usage	Example site conditions
1.2	• Low risk structures. • Failure of structure is most unlikely to cause loss of life or irreversible property damage. • Design of permanent rock chutes with all voids filled with soil and pocket planted.	• Rock chutes located within most rural gullies and low-risk urban gullies. • Permanent rock chutes that are likely to experience significant sedimentation and vegetation growth before experiencing high flows.
1.5	• High risk structures. • Failure of structure may cause loss of life or irreversible property damage. • Gullies where failure of the chute is likely to cause ongoing, severe gully erosion and/or damage to assets.	• Rock chutes in urban gullies located close to homes. • Rock chutes designed for a storm frequency less than 1 in 10 years.

Typical relative densities (s_r) of various types of rock are provided in Table 2.

Table 2 – Typical relative density (specific gravity) of rock

Rock type	Relative density (s_r)
Sandstone	2.1 to 2.4
Granite	2.5 to 3.1, commonly 2.6
Limestone	2.6
Basalt	2.7 to 3.2

(a) Rock type, size and grading

The rock should be durable and resistant to weathering, and should be proportioned such that neither the breadth nor the thickness of a single rock is less than one-third its length. Crushed (angular) rock is generally more stable than rounded stone.

The maximum rock size should generally not exceed twice the nominal (d_{50}) rock size.

Table 3 provides a typical rock size distribution for use in preliminary design. Table 3 is provided for general information only, it does **not** represent a recommended design specification.

Table 3 – Typical distribution of rock size [1]

Rock size ratio	Assumed distribution value
d_{100}/d_{50}	2.00
d_{90}/d_{50}	1.82
d_{75}/d_{50}	1.50
d_{65}/d_{50}	1.28
d_{40}/d_{50}	0.75
d_{33}/d_{50}	0.60
d_{10}/d_{50}	> 0.50

[1] Wide variations in the rock size distribution can occur unless suitably controlled by the material contract specifications.

(b) Manning roughness of rock-lined surfaces

The Manning's (n) roughness for rock-lined surfaces may be determined from Equation 2 (Witheridge, 2002) or Table 4.

$$n = \frac{{d_{90}}^{1/6}}{26\left(1 - 0.3593^{(X)^{0.7}}\right)} \qquad \text{(Eqn 2)}$$

where:
X = $(R/d_{90})(d_{50}/d_{90})$
R = Hydraulic radius of flow over rocks [m]
d_{50} = mean rock size for which 50% of rocks are smaller [m]
d_{90} = mean rock size for which 90% of rocks are smaller [m]

For ‘natural’ rounded stone extracted from streambeds the relative roughness value (d_{50}/d_{90}) is typically in the range 0.2 to 0.5. For quarried rock the ratio is more likely to be in the range 0.5 to 0.8.

Table 4 – Manning’s (n) roughness of rock-lined surfaces

	d_{50}/d_{90} = 0.5				**d_{50}/d_{90} = 0.8**			
d_{50} =	**200mm**	**300mm**	**400mm**	**500mm**	**200mm**	**300mm**	**400mm**	**500mm**
R (m)	Manning’s roughness (n)				Manning’s roughness (n)			
0.2	0.10	0.14	0.17	0.21	0.06	0.08	0.09	0.11
0.3	0.08	0.11	0.14	0.16	0.05	0.06	0.08	0.09
0.4	0.07	0.09	0.12	0.14	0.04	0.05	0.07	0.08
0.5	0.06	0.08	0.10	0.12	0.04	0.05	0.06	0.07
0.6	0.06	0.08	0.09	0.11	0.04	0.05	0.05	0.06
0.8	0.05	0.07	0.08	0.09	0.04	0.04	0.05	0.06
1.0	0.04	0.06	0.07	0.08	0.03	0.04	0.05	0.05

The Manning’s roughness values presented in Table 4 have been developed from Equation 2.

(c) Thickness of rock protection

The thickness of the rock protection should be sufficient to allow at least two overlapping layers of the nominal (d_{50}) rock size.

The thickness of rock protection must also be sufficient to accommodate the largest rock size.

In order to allow at least two layers of rock, the minimum thickness of rock protection (T) maybe approximated by the values presented in Table 5.

Table 5 – Minimum thickness (T) of rock lining

Min. Thickness (T)	Size distribution (d_{50}/d_{90})	Description
1.4 d_{50}	1.0	Highly uniform rock size
1.6 d_{50}	0.8	Typical upper limit of quarry rock
1.8 d_{50}	0.67	Recommended lower limit of distribution
2.1 d_{50}	0.5	Typical lower limit of quarry rock

(d) Use of backing material or filter layer

Non-vegetated armour rock must be placed over a layer of suitably graded filter rock or geotextile filter cloth (minimum ‘bidim’ A24 or the equivalent). The geotextile filter cloth must have sufficient strength and must be suitably overlapped to withstand the placement of the rock.

Armour rock that is intended to be vegetated (i.e. by appropriately filling all voids with soil and pocket planting), generally will not require the use of an underlying filter layer. The exception would be those circumstances where the long-term viability of the vegetation is questionable due to possible high scour velocities, or where limited natural light or rainfall conditions exist.

(e) Placement of rock

The failure of rock-lined chutes most frequently results from the inappropriate placement of the rock, either due to inadequate design detailing, or poor construction practices. Rock-lined chutes are usually most vulnerable to hydraulic damage during the first year or two following placement, especially while the voids remain open and free of sedimentation.

When constructing rock chutes it is important to ensure that the top of the rock surface is level with, or slightly below, the surrounding land surface to allow the free entry of water, including lateral inflows (if required), as shown in Figure 2. Rill erosion can occur along the upper edge of the rocks if they are not properly set into the soil.

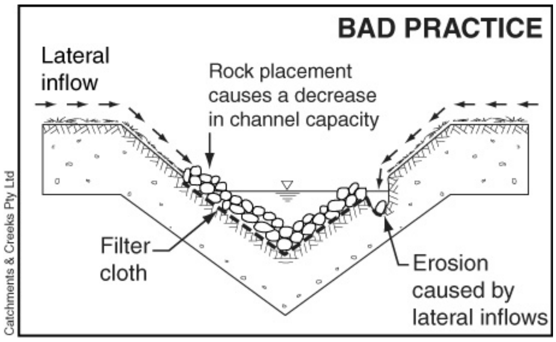

Figure 1 – Incorrect placement of rock causing loss of flow area and erosion along the outer limits of the rock

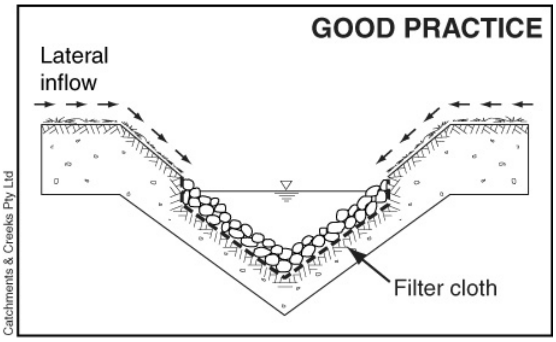

Figure 2 – Rock recessed into the soil to allow the free entry of lateral inflows

(f) Alignment of the chute’s crest

Unlike rock weirs, the crest of a rock chute must be level across its full width (Photo 3) and must be perpendicular to the face of the chute. If the crest is damaged or otherwise develops a cross-fall, then water flow will concentrate down the lower side of the crest (Photo 4). If the crest is not set perpendicular to the chute, then the flow will move towards the gully bank causing bank erosion.

Photo 3 – Rock chute showing flat crest (note; the rock has not been extended sufficiently up the sides of the chute, SA)

Photo 4 – Rock chute with the crest sloping to the left resulting in bank erosion (visible on left, Qld)

Filling the voids between the rocks with soil (Photo 5) and pocket planting (Photo 6) will reduce hydraulic pressure under the rocks (thus reducing uplifting forces), and will help to lock-in the rocks to increase the chute's overall stability.

Photo 5 – Construction of rock chute with voids filled with soil (Qld)

Photo 6 – Same chute (left) with plants established within voids (Qld)

Round rocks (Photo 7) are less stable than angular (quarried) rocks. Typically, round rocks need to be 36% larger than highly angular rocks to achieve the same degree of stability. The grouting of round rocks can significantly increase their stability (Photo 8).

Photo 7 – Rounded rock can be significantly less stable than angular, fractured rock, especially when placed on steep slopes (Qld)

Photo 8 – Grouting boulders in place allows the use of smaller rock sizes in high shear stress chutes (Qld)

(g) Scour protection upstream of the crest

If the chute is established at the head of the gully, then it is important to ensure adequate scour protection exists immediately upstream of the chute's crest. Typically this consists of rock protection extending a distance of at least 5 times the depth of the approaching flow (H) upstream of the crest (Figure 5). This scour protection should be suitably recessed into the ground to allow the free passage of water.

(h) Maximum bank gradient

The recommended maximum desirable side slope of a large rock-lined chute is 2:1(H:V); however, side slopes as steep as 1.5:1 can be stable if the rock is individually placed rather than being bumped.

(i) Placement of chutes within dispersive soils

If the soils adjacent to the rock surface are dispersive (e.g. sodic soils), then prior to placing the filter cloth or aggregate filter layer, the exposed soil must first be covered with a layer of non-dispersive soil (Figure 4). The typically minimum thickness of non-dispersive soil is 200mm, but preferably 300mm.

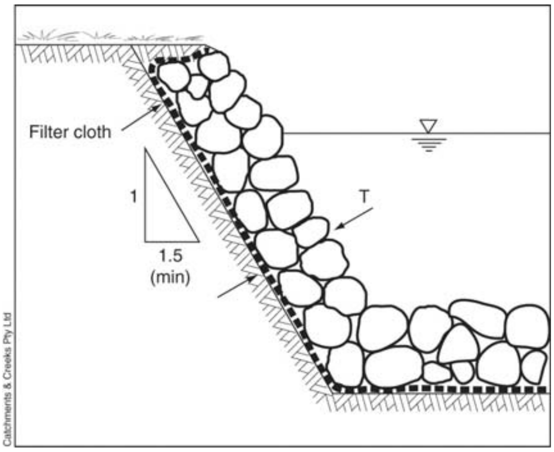

Figure 3 – Rock placement, without vegetation, on non-dispersive soil (cross-sectional view of sidewall and bed)

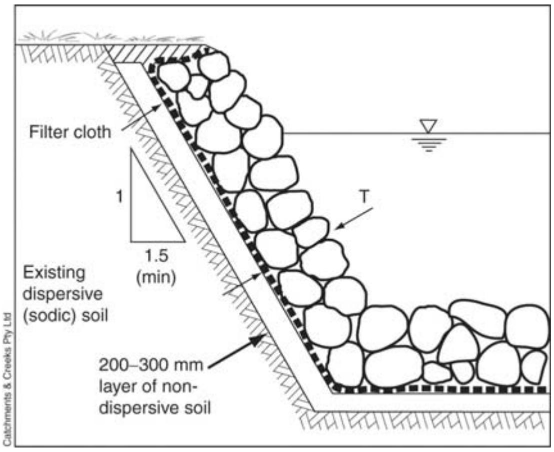

Figure 4 – Rock placement, without vegetation, on dispersive soil (cross-sectional view of sidewall and bed)

(j) Placement of vegetation over the rock chute

Where appropriate, rock-lined chutes should be topped with a light covering of soil and planted to accelerate the integration of these structures into the surrounding environment.

Revegetation is however not always advisable, and should be assessed on a case-by-case basis.

Weed invasion of the rock protection can become unsightly. The control of weed growth can be an expensive, labour intensive exercise.

(k) Design of energy dissipation at the base of the chute

The design of energy dissipaters is too complex to be covered within this fact sheet. The need for specialist hydraulic advice will depend on the complexity of the gully erosion, and the risks associated with ongoing gully erosion.

Typically, rock at the base of the chute must:

- extend along the bed of the gully a distance at least 10 times the depth of the flow passing down the chute (Figure 5) ; and
- extend up the banks of the gully a distance of at least twice the depth of the flow (y) passing down the chute.

Hydraulic design of rock-lined chutes:

Step 1 Determine the design discharge (Q) for the chute.

Step 2 Determine the slope (S) of the chute from the gully geometry. The face of the chute should be straight, with no bends or curves, from the crest to the base of the chute.

Step 3 Determine the required geometry of the chute's crest using an appropriate weir equation.

Ensure the chute's crest is suitably designed to allow the free flow of water into the chute (i.e. flow is not diverted along the up-slope edge of the rocks).

Step 4 Determine the design unit flow rate (q). This may be estimated by dividing the design discharge by the crest width determined in Step 3.

This assumes that the main chute will have the same width as crest of the chute (which is strongly recommended).

Step 5 Determine the likely density (specific gravity, s_r – Table 2), and a size distribution (d_{50}/d_{90}, – Table 3) of the rock to be used on the chute.

Where necessary, contact the relevant rock supplier for this information.

Step 6 Nominate the design safety factor (SF) using Table 1 as a guide.

Step 7 Using Manning's equation, or Tables 6 or 7, determine the uniform flow depth (y) and required size of the rock size (d_{50}) for the chute.

Manning's equation: $Q = A.V = (1/n)\, A\, .\, R^{2/3} .\, S^{1/2}$

Step 8 The depth of the chute provides an indication of the minimum height of rock protection up the side of the gully immediately adjacent the chute. In many cases the rock protection will need to extend to the top of the gully each side of the chute (as per Photo 8).

The required depth of the chute (Y), being the greater of:

(i) 300mm (unless a lower depth is supported by expected flow conditions);

(ii) 0.67(H) plus minimum freeboard of 150mm; ('H' determined from Step 4)

(iii) the uniform flow depth (y) plus a minimum freeboard of 150mm, or the equivalent of the flow depth, whichever is smaller.

Step 9 Design the required outlet energy dissipation structure at the base of the chute.

The 'local' uniform flow velocity (V) down the chute may be estimated by dividing the design unit flow rate (q) by flow depth (y). This flow velocity will be slightly greater than the average flow velocity, which is equal to the total discharge (Q) divided by the total flow area (A).

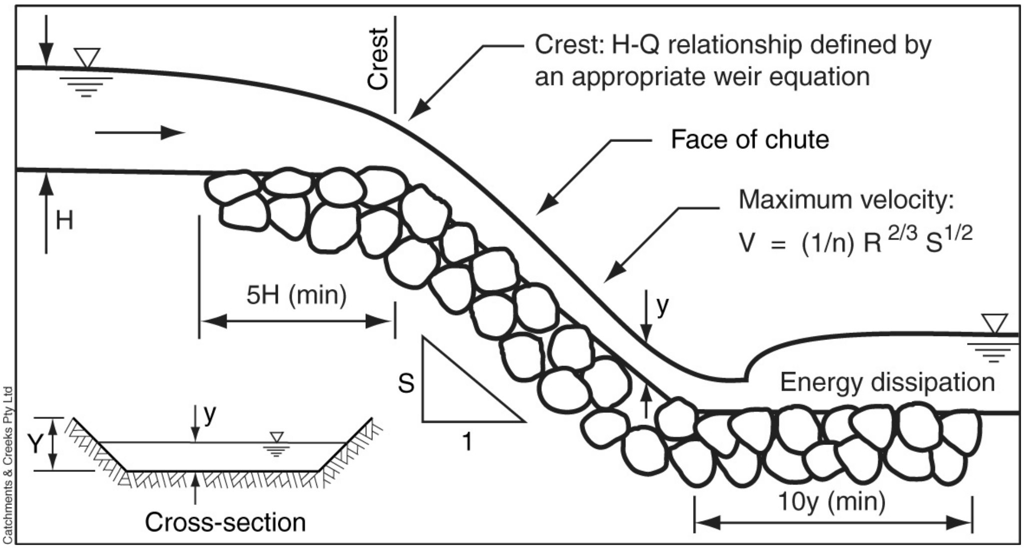

Figure 5 – Typical profile of a rock chute

Design example: rock-lined chutes:

Design a rock-lined chute located at the head of a gully that will be able to carry a discharge of 1m^3/s down a 3:1 slope.

Step 1 Design discharge is given as, Q = 1.0m^3/s.

Step 2 The chute slope is given as, S = 0.333.

Step 3 for the crest and face of the rock chute, try a trapezoidal profile with side slopes of 2:1

Assume the depth of the approaching flow at the design discharge of 1m^3/s is 0.3m.

Based on the weir flow equation for a trapezoidal chute with side slopes of 2:1, a crest (bed) width of b = 3.2m is required for a flow rate of 1.0m^3/s and an approaching flow head, H = 0.3m. (Note; hydraulic weir flow analysis is required to achieve this result—such weir flow analysis has not been discussed within this fact sheet).

To control soil erosion near the entrance, the rock will need to extend a distance of 5(H) = 1.5m upstream of the crest.

Step 4 As a first trial, the unit flow rate may be estimated by dividing the design discharge by the bed width determined in Step 3.

Trial unit flow rate, q = Q/b = 1.0/3.2 = 0.313m^2/s (approximation)

Step 5 Assume rock is available with a specific gravity, s_r = 2.6, and a size distribution, d_{50}/d_{90} = 0.5

Step 6 From Table 1, choose a safety factor, SF = 1.2 because the chute is assumed to exist in a non-critical location.

Step 6 Given the estimated unit flow rate of 0.313m^2/s, and a chute slope of 3:1, Table 6 indicates that the required mean rock size, d_{50} = 300mm.

It is noted that Table 6 is applicable for rock with a specific gravity of 2.4, thus the results are considered conservative for rock with a specific gravity of 2.6.

If it is assumed that this rock size is available on the site, then the bed width, b = 3.2m obtained in Step 3 appears suitable.

Step 10 From Table 6 the uniform flow depth (y) is expected to be 0.19m (interpolated), however, there is expected to be significant variation in this depth due to flow turbulence.

The required depth of the chute should be the greater of:

(i) 300mm;
(ii) 0.67(H) plus freeboard of 150mm = 0.67(300) + 150 = 351mm;
(iii) y + 150mm = 190 + 150 = 340mm.

Thus, choose a total chute depth, Y = 350mm.

Step 11 Design of outlet structure:

Detailed design issues are not covered within this fact sheet.

Table 6 – Flow depth [1], y (m) and mean rock size, d_{50} (m) for SF = 1.2

Safety factor, SF = 1.2			**Specific gravity, s_r = 2.4**			**Size distribution, d_{50}/d_{90} = 0.5**		
Unit flow rate (m^3/s/m)	**Bed slope = 5:1**		**Bed slope = 4:1**		**Bed slope = 3:1**		**Bed slope = 2:1**	
	y (m)	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**
0.1	0.09	**0.10**	0.09	**0.10**	0.09	**0.20**	0.09	**0.20**
0.2	0.15	**0.20**	0.14	**0.20**	0.14	**0.20**	0.14	**0.30**
0.3	0.19	**0.20**	0.19	**0.20**	0.19	**0.30**	0.18	**0.30**
0.4	0.23	**0.30**	0.23	**0.30**	0.23	**0.30**	0.22	**0.40**
0.5	0.27	**0.30**	0.27	**0.30**	0.26	**0.40**	0.26	**0.40**
0.6	0.31	**0.30**	0.30	**0.40**	0.30	**0.40**	0.29	**0.50**
0.8	0.37	**0.40**	0.37	**0.40**	0.36	**0.50**	0.35	**0.60**
1.0	0.43	**0.40**	0.42	**0.50**	0.42	**0.60**	0.41	**0.70**
1.2	0.49	**0.50**	0.48	**0.50**	0.47	**0.60**	0.46	**0.70**
1.4	0.54	**0.50**	0.53	**0.60**	0.52	**0.70**	0.51	**0.80**
1.6	0.59	**0.60**	0.58	**0.70**	0.57	**0.70**	0.56	**0.90**
1.8	0.64	**0.60**	0.63	**0.70**	0.62	**0.80**	0.60	**1.00**
2.0	0.68	**0.70**	0.67	**0.70**	0.66	**0.90**	0.65	**1.00**
3.0	0.89	**0.90**	0.88	**1.00**	0.87	**1.10**	0.85	**1.30**
4.0	1.08	**1.00**	1.07	**1.20**	1.05	**1.30**	1.02	**1.60**
5.0	1.26	**1.20**	1.24	**1.30**	1.22	**1.50**	1.19	**1.80**

[1] Flow depth is expected to be highly variable due to whitewater (turbulent) flow conditions.

Table 7 – Flow depth [1], y (m) and mean rock size, d_{50} (m) for SF = 1.5

Safety factor, SF = 1.5			**Specific gravity, s_r = 2.4**			**Size distribution, d_{50}/d_{90} = 0.5**		
Unit flow rate (m^3/s/m)	**Bed slope = 5:1**		**Bed slope = 4:1**		**Bed slope = 3:1**		**Bed slope = 2:1**	
	y (m)	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**
0.1	0.10	**0.20**	0.10	**0.20**	0.10	**0.20**	0.10	**0.20**
0.2	0.16	**0.20**	0.16	**0.20**	0.15	**0.30**	0.15	**0.30**
0.3	0.21	**0.30**	0.21	**0.30**	0.20	**0.30**	0.20	**0.40**
0.4	0.25	**0.30**	0.25	**0.40**	0.25	**0.40**	0.24	**0.50**
0.5	0.29	**0.40**	0.29	**0.40**	0.28	**0.50**	0.28	**0.50**
0.6	0.33	**0.40**	0.33	**0.40**	0.32	**0.50**	0.31	**0.60**
0.8	0.40	**0.50**	0.40	**0.50**	0.39	**0.60**	0.38	**0.70**
1.0	0.47	**0.60**	0.46	**0.60**	0.45	**0.70**	0.44	**0.80**
1.2	0.53	**0.60**	0.52	**0.70**	0.51	**0.80**	0.50	**0.90**
1.4	0.58	**0.70**	0.58	**0.80**	0.57	**0.90**	0.55	**1.00**
1.6	0.64	**0.70**	0.63	**0.80**	0.62	**0.90**	0.60	**1.10**
1.8	0.69	**0.80**	0.68	**0.90**	0.67	**1.00**	0.65	**1.20**
2.0	0.74	**0.80**	0.73	**0.90**	0.72	**1.10**	0.70	**1.30**
3.0	0.97	**1.10**	0.96	**1.20**	0.94	**1.40**	0.92	**1.70**
4.0	1.17	**1.30**	1.16	**1.50**	1.14	**1.70**	1.11	**2.00**
5.0	1.36	**1.50**	1.34	**1.70**	1.32	**1.90**	1.29	**2.30**

[1] Flow depth is expected to be highly variable due to whitewater (turbulent) flow conditions.

Material specifications

- Rock: hard, angular, durable, weather resistant and evenly graded with 50% by weight larger than the specified nominal rock size. The diameter of the largest rock size should be no larger than 1.5 times the nominal rock size. Specific gravity to be at least 2.5.
- Geotextile fabric: heavy-duty, needle-punched, non-woven filter cloth, minimum 'bidim' A24 or equivalent.

Typical installation specification

1. Refer to approved plans for location and construction details. If there are questions or problems with the location or method of installation, contact the engineer or responsible on-site officer for assistance.
2. Ensure all necessary soil testing (e.g. soil pH, nutrient levels) and analysis has been completed, and required soil adjustments performed prior to planting.
3. Clear the location for the chute clearing only what is needed to provide access for personnel and equipment for installation.
4. Remove roots, stumps, and other debris and dispose of them properly.
5. Construct the subgrade to the elevations shown on the plans. Remove all unsuitable material and replace with stable material to achieve the desired foundations.
6. Compact and finish the subgrade as specified within the design plans. Avoid compacting the subgrade to a condition that would prevent the turf from bonding with the subgrade.
7. Ensure the sides of the chute are no steeper than a 1.5:1 (H:V) slope.
8. Ensure the completed chute has sufficient deep along its full length.
9. Ensure the chute is straight from its crest to the toe of the chute.
10. Over-cut the channel to a depth equal to the specified depth of rock placement such that the finished rock surface will be at the elevation of the surrounding land.
11. Rock must be placed within the chute as specified within the approved plans, including the placement of any specified filter layer.
12. If details are not provided on the rock placement, then the primary armour rock must be either placed on:

- a filter bed formed from a layer of specified smaller rock (rock filter layer);
- an earth bed lined with filter cloth;
- an earth bed not lined in filter cloth, but only if all voids between the armour rock are to be filled with soil and pocket planted immediately after placement of the rock.

13. If a rock/aggregate filter layer is specified, then place the filter layer immediately after the foundations are prepared. Spread the filter rock in a uniform layer to the specified depth but a minimum of 150mm. Where more than one layer of filter material has been specified, spread each layer such that minimal mixing occurs between each layer of rock.
14. If a geotextile (filter cloth) underlay is specified, place the fabric directly on the prepared foundation. If more than one sheet of fabric is required to over the area, overlap the edge of each sheet at least 300mm and place anchor pins at minimum one metre spacing along the overlap.
15. Ensure the geotextile fabric is protected from punching or tearing during installation of the fabric and the rock. Repair any damage by removing the rock and placing with another piece of filter cloth over the damaged area overlapping the existing fabric a minimum of 300mm.
16. Where necessary, a minimum 100mm layer of fine gravel, aggregate or sand may be placed over the fabric to protect it from damage.
17. Placement of rock should follow immediately after placement of the filter layer. Place rock so that it forms a dense, well-graded mass of rock with a minimum of voids.
18. Place rock to its full thickness in one operation. Do not place rock by dumping through delivery chutes or other methods that may cause segregation of rock sizes.
19. The finished surface should be free of pockets of small rock or clusters of large rocks. Hand placing may be necessary to achieve the proper distribution of rock sizes to produce a relatively smooth, uniform surface.

20. Ensure the finished rock surface blends with the surrounding area. No overfall or protrusion of rock should be apparent.
21. Immediately upon completion of the chute, vegetate all external disturbed areas or otherwise protect them against soil erosion.
22. Where specified, fill all voids with soil and vegetate the rock surface in accordance with the approved plan.
23. Where directed, install an appropriate outlet structure (energy dissipater) at the base of the chute.
24. Ensure water can enter the chute freely without causing undesirable ponding or scour.

Reference

Witheridge, G.M. 2002, *Fish Passage Requirements at Waterway Crossings – Engineering Guidelines.* Catchments & Creeks Pty Ltd, Brisbane.

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