Chutes Part 4: Rock mattress linings

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short Term	✓
Steep Gradient	✓	Channel Lining		Medium-Long Term	✓
Outlet Control	[1]	Soil Treatment		Permanent	[2]

[1] Chutes can act as stable outlet structures for *Catch Drains* and *Flow Diversion Banks*.

[2] The design of permanent chutes may require consideration of issues not discussed here.

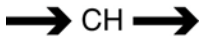
Symbol 

Photo 15 – Permanent rock mattress drainage chute

Photo 16 – Partially vegetated, rock mattress-lined batter chute

Key Principles

1. The critical design components of a chute are the flow entry into the chute, the maximum allowable flow velocity down the face of the chute, and the dissipation of energy at the base of the chute.
2. The critical operational issues are ensuring unrestricted flow entry into the chute, ensuring flow does not undermine or spill out of the chute, and ensuring soil erosion is controlled at the base of the chute.
3. Most chutes fail as a result of water failing to enter the chutes properly. It is critical to control potential leaks and flow bypassing, especially at the chute entrance.

Design Information

The material contained within this fact sheet has been supplied for use by persons experienced in hydraulic design.

The following information must be read in association with the general information presented in *Part 1 – General information*.

Part 4 of this fact sheet addresses design issues associated with rock mattress lined chutes.

The design procedure outlined within this fact sheet has been developed to provide a simplified approach suitable only for those involved in the regular design of temporary drainage chutes. The procedure is just **one** example of how chutes can be designed.

Maximum allowable flow velocities are presented in Table 27 for various wire-based rock mattress and gabion products. Allowable flow velocities for gabions and rock mattresses formed from products other than wire baskets, refer to the relevant manufacturer's advice.

Rock mattresses:

- Typically available in thicknesses of 170, 230, 300 and 500mm at a length of 6 metres and width of 2 metres.
- Heavily galvanised, PVC coated cages should be used within hydraulic structures.
- Mattresses should be laid over a filter fabric or properly designed gravel filter.

Rock-fill:

- Rock-fill should be angular and block-shaped.
- Nominal rock size as specified in Table 27.
- Minimum rock size around 1/3 the basket depth.
- Maximum rock size around 2/3 the basket depth.
- The rock should be uniformly graded with 80% by number greater than 100mm in size.
- Nominal rock size should be 200-300mm when used within the splash zone of weirs and drop structures.

Table 27 – Recommended rock size for rock mattresses and gabions [1]

Type	Thickness (m)	Rock size		Allowable flow velocity (m/s)
		Range (mm)	d_{50} (mm)	
Rock mattress	0.15–0.17	70–100	85	3.5
		70–150	110	4.2
	0.23–0.25	70–100	85	3.6
		70–150	120	4.5
	0.30	70–120	100	4.2
		100–150	125	5.0
Gabion	0.50	100–200	150	5.8
		120–250	190	6.4

[1] Sourced from Maccaferri (1988) *"Flexible gabion and Reno mattress structures in river and stream training works".*

Manning's roughness:

Manning's roughness of rock mattresses can be based on the equivalent roughness of loose rock assuming a rock size distribution of d_{50}/d_{90} = 0.8. Table 28 provides typical Manning's (n) roughness values for various rock sizes and flow conditions.

Table 28 – Manning's roughness of rock mattress lined chutes and channels [1]

R_h	Nominal mean rock diameter (d_{50})						
	85 mm	**100 mm**	**110 mm**	**120 mm**	**125 mm**	**150 mm**	**190 mm**
0.1m	0.047	0.052	0.055	0.058	0.060	0.068	0.080
0.15m	0.039	0.043	0.046	0.048	0.049	0.055	0.064
0.20m	0.036	0.039	0.041	0.043	0.044	0.049	0.056
0.25m	0.033	0.036	0.038	0.039	0.040	0.044	0.051
0.30m	0.032	0.034	0.035	0.037	0.038	0.041	0.047
0.40m	0.030	0.032	0.033	0.034	0.035	0.038	0.042
0.50m	0.030	0.030	0.031	0.032	0.033	0.035	0.039
1.00m	0.030	0.030	0.030	0.030	0.030	0.031	0.033
>1.00m	0.030	0.030	0.030	0.030	0.030	0.030	0.030

[1] Manning's roughness based on distribution of rock size represented by d_{50}/d_{90} = 0.8

Hydraulic design of rock mattress-lined chutes:

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

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

Step 3 Nominate the chute profile: e.g. trapezoidal or rectangular.

Step 4 Determine the maximum allowable approach flow depth, 'H' (relative to the inlet crest) upstream of the chute's inlet for the nominated design discharge.

Where necessary, design and specify appropriate *Flow Diversion Banks* or the like to appropriately control the approach flow and prevent any water bypassing the chute.

Step 5 Determine the required inlet geometry of the chute using an appropriate weir equation.

If the approach channel (the channel immediately upstream of the chute's crest) is short, then the relationship between the upstream water level (H) and discharge (Q) can be determined from one of the weir equations presented in Table 1 (*Part 1 – General information*). Tables 2 to 4 (Part 1) provide specific H–Q information for various chute profiles.

If the approach channel is long, and friction loss within this channel is likely to be significant, then an appropriate backwater analysis may be required.

Step 6 Ensure the entrance to the chute 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 mattresses).

Where necessary, detail appropriate measures to control scour at the entrance to the chute (see Part 1 of this fact sheet, including Figure 3).

Step 7 Determine the Manning's (n) roughness for sizes of rock fill and flow depth.

Step 8 Using Manning's equation, or Tables 29 to 36 (if appropriate), determine the uniform flow depth (y) and maximum flow velocity (V) down the chute.

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

Step 9 Determine the required size of the rock fill from Tables 29 to 36, or Table 27.

Check that the flow velocity is acceptable for the local conditions.

Step 10 Specify the required depth of the chute, 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 11 Design the required outlet energy dissipation structure at the base of the chute.

Refer to Part 1 of this fact sheet or the fact sheet on *Outlet Structures*.

Design example: rock mattress-lined chutes:

Design a rock mattress-lined chute suitable to carry a discharge of 750L/s on a 2:1 slope with a maximum allowable upstream water level (H) of 300mm.

Step 1 Design discharge given as 750L/s or 0.75m^3/s.

Step 2 The chute slope is given as, S = 50% (2:1).

Step 3 Try a trapezoidal profile with side slopes of 2:1

Step 4 The maximum allowable approach flow depth is given as, H = 0.3m

Step 5 Table 3 (Part 1) indicates that for an approach flow depth, H = 0.3m, a bed width of b = 3m is required to allow the design discharge of 750L/s to enter a trapezoidal chute with side slopes of 2:1

Step 6 To control water movement and erosion at the chute entrance, specify on the plans that the up-slope edge of rock mattresses must be recessed into the ground to allow the unrestricted entry of water.

Flow diversion banks will need to be constructed each side of the chute entrance to direct water into the chute with minimum height of, H + 0.3m = 0.3 + 0.3 = 0.6m

To control soil erosion near the entrance, the rock mattress will extend a distance of 5(H) = 1.5m upstream of the crest. Otherwise, suitable erosion control matting shall be placed over the soil and overlapping the upstream edge of the mattresses.

Step 7 For this example, there will be no need to choose a Manning's roughness for the rock mattresses because Tables 29 to 36 can be used to design the chute.

Step 8 Given the design discharge of 750L/s, the chute slope of 2:1, and a bed width, b = 3m, Table 30 indicates that flow velocity of around 2.6m/s (interpolated) will be achieved at a uniform flow depth of around 0.088m (interpolated).

Therefore the bed width, b = 3m obtained in Step 5 appears suitable.

Step 9 Table 30 indicates a required rock size, d_{50} = 85mm

Step 10 From Table 30 the uniform flow depth is expected to be 0.088m, however the expected flow turbulence is likely to result in a significant variation in this depth.

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 = 88 + 150 = 238mm.

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

Step 11 Design of outlet structure as per *Part 1 – General information*:

Given that the flow approaching the outlet structure is less than 100mm in depth, and the velocity is less than 3m/s, Table 5 (Part 1) indicates a rock size of 100mm.

Table 6 (Part 1) indicates a length of rock protection, L = 2.0m.

Table 7 (Part 1) indicates a dissipation basin recess depth, Z = 0.19m (interpolated)

The flow top width at the base of the chute, T = b + 2my = 3 + 2(2)0.088 = 3.35m

From Figure 6 (Part 1), W_1 = 3.35 + 0.6 = 3.95m, and W_2 = 3.35 + 0.4(2.0) = 4.15m

Let W_1 = 4.0m and W_2 = 4.2m

However, a more appropriate design is likely to be an energy dissipater constructed from rock mattresses of the size listed above.

Table 29 – Maximum allowable discharge and corresponding uniform flow depth

Trapezoidal Chute – lined with rock mattresses										
Manning's n = variable				Bed width = 2.0 metres				Side slopes 2:1 (H:V)		
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	1.13	0.229	3.14	0.379	4.80	0.467	7.95	0.615	18.6	0.952
10:1	0.72	0.156	1.83	0.245	2.69	0.296	4.27	0.385	9.34	0.588
6:1	0.53	0.119	1.30	0.183	1.86	0.218	2.88	0.281	6.02	0.423
5:1	0.48	0.109	1.16	0.166	1.65	0.197	2.53	0.253	5.20	0.378
4:1	0.43	0.098	1.01	0.147	1.43	0.174	2.17	0.222	4.39	0.330
3:1	0.37	0.085	0.86	0.127	1.20	0.149	1.80	0.190	3.57	0.279
2.5:1	0.34	0.078	0.77	0.116	1.07	0.135	1.61	0.172	3.16	0.252
2:1	0.30	0.071	0.69	0.104	0.95	0.121	1.41	0.153	2.72	0.223
1.75:1	0.28	0.066	0.64	0.097	0.88	0.113	1.30	0.143	2.50	0.207
1.67:1	0.28	0.065	0.62	0.095	0.86	0.110	1.27	0.139	2.43	0.202
1.5:1	0.26	0.062	0.59	0.090	0.81	0.105	1.19	0.132	2.27	0.191
1.25:1	0.24	0.057	0.54	0.083	0.73	0.096	1.08	0.120	2.04	0.174
1:1	0.22	0.052	0.48	0.074	0.65	0.086	0.96	0.108	1.79	0.155
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 30 – Maximum allowable discharge and corresponding uniform flow depth

Trapezoidal Chute – lined with rock mattresses										
Manning's n = variable				Bed width = 3.0 metres				Side slopes 2:1 (H:V)		
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	1.47	0.215	3.88	0.350	5.76	0.427	9.21	0.559	20.4	0.862
10:1	0.98	0.148	2.39	0.230	3.42	0.275	5.27	0.355	10.9	0.535
6:1	0.74	0.115	1.74	0.174	2.45	0.205	3.69	0.262	7.33	0.388
5:1	0.67	0.105	1.57	0.158	2.19	0.186	3.28	0.236	6.42	0.348
4:1	0.60	0.095	1.38	0.141	1.92	0.165	2.86	0.209	5.52	0.306
3:1	0.52	0.83	1.18	0.122	1.63	0.142	2.40	0.179	4.58	0.260
2.5:1	0.48	0.076	1.07	0.111	1.47	0.129	2.17	0.163	4.09	0.236
2:1	0.43	0.069	0.96	0.100	1.31	0.116	1.92	0.146	3.57	0.209
1.75:1	0.40	0.065	0.90	0.094	1.22	0.109	1.78	0.136	3.31	0.195
1.67:1	0.40	0.063	0.87	0.092	1.19	0.106	1.74	0.133	3.22	0.191
1.5:1	0.38	0.060	0.83	0.087	1.13	0.101	1.64	0.126	3.03	0.181
1.25:1	0.35	0.056	0.76	0.080	1.03	0.093	1.49	0.116	2.74	0.165
1:1	0.31	0.051	0.68	0.072	0.92	0.083	1.33	0.104	2.43	0.148
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 31 – Maximum allowable discharge and corresponding uniform flow depth

Trapezoidal Chute – lined with rock mattresses										
Manning's n = variable				Bed width = 4.0 metres				Side slopes 2:1 (H:V)		
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	1.84	0.208	4.66	0.333	6.82	0.405	10.6	0.526	22.6	0.805
10:1	1.24	0.145	2.96	0.222	4.19	0.265	6.33	0.339	12.6	0.504
6:1	0.95	0.113	2.19	0.169	3.05	0.199	4.53	0.252	8.74	0.369
5:1	0.87	0.103	1.98	0.154	2.75	0.180	4.05	0.228	7.73	0.332
4:1	0.78	0.093	1.76	0.137	2.42	0.160	3.56	0.202	6.71	0.293
3:1	0.68	0.081	1.51	0.119	2.07	0.139	3.03	0.174	5.63	0.250
2.5:1	0.62	0.075	1.38	0.109	1.88	0.127	2.74	0.159	5.06	0.227
2:1	0.56	0.068	1.23	0.098	1.68	0.114	2.43	0.142	4.46	0.203
1.75:1	0.53	0.064	1.15	0.092	1.57	0.107	2.27	0.133	4.14	0.189
1.67:1	0.52	0.063	1.13	0.090	1.53	0.104	2.22	0.130	4.03	0.185
1.5:1	0.49	0.060	1.07	0.086	1.45	0.099	2.10	0.124	3.81	0.175
1.25:1	0.45	0.055	0.99	0.079	1.33	0.091	1.91	0.113	3.46	0.160
1:1	0.41	0.050	0.89	0.071	1.20	0.082	1.72	0.102	3.08	0.144
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 32 – Maximum allowable discharge and corresponding uniform flow depth

Trapezoidal Chute – lined with rock mattresses										
Manning's n = variable				Bed width = 6.0 metres				Side slopes 2:1 (H:V)		
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	2.56	0.200	6.29	0.316	9.04	0.382	13.7	0.491	27.7	0.740
10:1	1.77	0.141	4.12	0.214	5.76	0.253	8.53	0.321	16.4	0.471
6:1	1.37	0.110	3.10	0.164	4.29	0.192	6.26	0.242	11.7	0.349
5:1	1.25	0.101	2.82	0.149	3.88	0.175	5.64	0.219	10.4	0.315
4:1	1.13	0.091	2.51	0.134	3.43	0.156	4.98	0.195	9.15	0.279
3:1	0.99	0.080	2.18	0.117	2.96	0.135	4.28	0.169	7.78	0.240
2.5:1	0.90	0.074	1.99	0.107	2.70	0.124	3.89	0.154	7.03	0.219
2:1	0.82	0.067	1.79	0.096	2.42	0.111	3.48	0.139	6.25	0.196
1.75:1	0.77	0.063	1.68	0.091	2.27	0.104	3.26	0.130	5.82	0.183
1.67:1	0.76	0.062	1.64	0.089	2.21	0.102	3.18	0.127	5.68	0.179
1.5:1	0.72	0.059	1.56	0.084	2.10	0.097	3.02	0.121	5.38	0.170
1.25:1	0.67	0.055	1.43	0.078	1.93	0.089	2.76	0.111	4.91	0.156
1:1	0.60	0.050	1.30	0.070	1.74	0.081	2.48	0.100	4.40	0.140
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 33 – Maximum allowable discharge and corresponding uniform flow depth

Rectangular Chute – lined with rock mattresses

Manning's n = variable	Bed width = 2.0 metres	

Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	0.92	0.229	2.37	0.395	3.52	0.503	5.76	0.720	14.70	1.470
10:1	0.62	0.154	1.48	0.246	2.10	0.301	3.22	0.402	6.75	0.675
6:1	0.47	0.118	1.09	0.182	1.52	0.217	2.27	0.284	4.47	0.447
5:1	0.43	0.108	0.98	0.164	1.37	0.195	2.02	0.253	3.93	0.393
4:1	0.39	0.097	0.87	0.146	1.20	0.172	1.77	0.222	3.38	0.338
3:1	0.34	0.084	0.75	0.125	1.03	0.147	1.50	0.188	2.82	0.282
2.5:1	0.31	0.077	0.68	0.114	0.93	0.134	1.36	0.170	2.53	0.253
2:1	0.28	0.070	0.61	0.102	0.83	0.119	1.21	0.151	2.22	0.222
1.75:1	0.26	0.066	0.57	0.096	0.78	0.111	1.13	0.141	2.06	0.206
1.67:1	0.26	0.064	0.56	0.094	0.76	0.109	1.10	0.138	2.01	0.201
1.5:1	0.24	0.061	0.53	0.089	0.72	0.103	1.04	0.130	1.90	0.190
1.25:1	0.23	0.056	0.49	0.082	0.66	0.094	0.95	0.119	1.72	0.172
1:1	0.20	0.051	0.44	0.074	0.59	0.085	0.85	0.107	1.53	0.153
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 34 – Maximum allowable discharge and corresponding uniform flow depth

Rectangular Chute – lined with rock mattresses

Manning's n = variable	Bed width = 3.0 metres	

Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	1.27	0.212	3.13	0.348	4.53	0.431	6.96	0.580	14.78	0.985
10:1	0.88	0.146	2.04	0.227	2.87	0.273	4.26	0.355	8.28	0.552
6:1	0.68	0.114	1.54	0.172	2.13	0.203	3.11	0.260	5.84	0.389
5:1	0.62	0.104	1.40	0.156	1.92	0.183	2.80	0.234	5.21	0.348
4:1	0.56	0.094	1.25	0.139	1.71	0.163	2.48	0.207	4.56	0.304
3:1	0.49	0.082	1.08	0.120	1.47	0.140	2.12	0.177	3.87	0.258
2.5:1	0.45	0.075	0.99	0.110	1.34	0.128	1.93	0.161	3.50	0.233
2:1	0.41	0.068	0.89	0.099	1.20	0.115	1.73	0.144	3.10	0.207
1.75:1	0.38	0.064	0.84	0.093	1.13	0.107	1.61	0.135	2.90	0.193
1.67:1	0.38	0.063	0.81	0.091	1.10	0.105	1.58	0.132	2.82	0.188
1.5:1	0.36	0.060	0.78	0.086	1.05	0.100	1.50	0.125	2.67	0.178
1.25:1	0.33	0.055	0.71	0.079	0.96	0.092	1.37	0.114	2.44	0.163
1:1	0.30	0.050	0.65	0.072	0.87	0.083	1.24	0.103	2.19	0.146
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 35 – Maximum allowable discharge and corresponding uniform flow depth

Rectangular Chute – lined with rock mattresses										
Manning's n = variable			Bed width = 4.0 metres							
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	1.64	0.205	3.96	0.330	5.63	0.402	8.46	0.529	16.90	0.845
10:1	1.14	0.143	2.63	0.219	3.65	0.261	5.35	0.335	10.10	0.505
6:1	0.89	0.111	2.00	0.167	2.74	0.196	3.98	0.249	7.32	0.366
5:1	0.82	0.102	1.82	0.152	2.49	0.178	3.60	0.225	6.56	0.328
4:1	0.74	0.092	1.63	0.136	2.22	0.159	3.19	0.200	5.78	0.289
3:1	0.64	0.081	1.41	0.118	1.92	0.137	2.75	0.172	4.94	0.247
2.5:1	0.59	0.074	1.29	0.108	1.75	0.125	2.51	0.157	4.49	0.225
2:1	0.54	0.067	1.16	0.097	1.57	0.112	2.25	0.141	4.00	0.200
1.75:1	0.51	0.064	1.09	0.091	1.48	0.106	2.11	0.132	3.74	0.187
1.67:1	0.50	0.062	1.07	0.089	1.44	0.103	2.06	0.129	3.65	0.183
1.5:1	0.47	0.059	1.02	0.085	1.37	0.098	1.96	0.122	3.46	0.173
1.25:1	0.44	0.055	0.94	0.078	1.26	0.090	1.80	0.112	3.16	0.158
1:1	0.40	0.050	0.85	0.071	1.14	0.081	1.62	0.101	2.84	0.142
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Table 36 – Maximum allowable discharge and corresponding uniform flow depth

Rectangular Chute – lined with rock mattresses										
Manning's n = variable			Bed width = 6.0 metres							
Chute slope (H:1)	Flow velocity down Chute									
	2.0 m/s		3.0 m/s		3.5 m/s		4.0 m/s		5.0 m/s	
	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)	Flow (m^3/s)	Depth (m)
20:1	2.38	0.198	5.62	0.312	7.92	0.377	11.7	0.486	22.3	0.742
10:1	1.67	0.140	3.80	0.211	5.25	0.250	7.61	0.317	14.0	0.466
6:1	1.31	0.109	2.92	0.162	3.99	0.190	5.72	0.239	10.4	0.345
5:1	1.21	0.101	2.66	0.148	3.62	0.173	5.20	0.217	9.33	0.311
4:1	1.09	0.091	2.39	0.133	3.23	0.154	4.63	0.193	8.28	0.276
3:1	0.95	0.080	2.08	0.116	2.81	0.134	4.01	0.167	7.13	0.238
2.5:1	0.88	0.074	1.91	0.106	2.57	0.122	3.67	0.153	6.48	0.216
2:1	0.80	0.066	1.72	0.096	2.31	0.110	3.29	0.137	5.81	0.194
1.75:1	0.75	0.063	1.62	0.090	2.18	0.104	3.09	0.129	5.44	0.181
1.67:1	0.74	0.062	1.58	0.088	2.13	0.101	3.02	0.126	5.31	0.177
1.5:1	0.70	0.059	1.51	0.084	2.03	0.097	2.87	0.120	5.05	0.168
1.25:1	0.65	0.054	1.39	0.077	1.86	0.089	2.64	0.110	4.63	0.154
1:1	0.59	0.050	1.26	0.070	1.69	0.080	2.39	0.100	4.17	0.139
Rock	d_{50} = 85 mm						d_{50} = 100 mm		d_{50} = 125 mm	

Common Problems

Rill erosion can occur along the upper edge of the mattresses if they are not properly set into the soil.

Long-term failure of a channel can result if the mattresses are placed directly on a dispersive soil.

Severe rilling along the sides of the chute can be caused by splash or lateral inflows being deflected by the edge of the chute.

Erosion at the base of the chute caused by inadequate energy dissipation.

Special Requirements

Flow Diversion Banks are often required to direct flows into the chute.

Good subsoil drainage and foundations are required to stabilise the chute lining.

Site Inspection

Check flow entry conditions to ensure no bypassing, undermining, sedimentation or erosion.

Ensure the chute is straight.

Check for erosion around the edges of the chute (top and sides).

Ensure the outlet is appropriately stabilised.

Check for piping failure, scour holes, or bank failures.

Installation (chute formation)

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. If the chute is temporary, then compact the subgrade to a firm consistency. If the chute is intended to be permanent, then compact and finish the subgrade as specified within the design plans.
7. Avoid compacting the subgrade to a condition that would prevent the turf from bonding with the subgrade.
8. Ensure the sides of the chute are no steeper than a 1.5:1 (H:V) slope.
9. Ensure the completed chute has sufficient deep along its full length.
10. Ensure the chute is straight from its crest to the toe of the chute.
11. On fill slopes, ensure that the soil is adequately compacted for a width of at least one metre each side of the chute to minimise the risk of soil erosion, otherwise protect the soil with suitable scour protection measures such as turf or erosion control mats.
12. Place and secure the turf as directed.
13. Install an appropriate outlet structure (energy dissipater) at the base of the chute (refer to separate specifications).
14. Ensure water leaving the chute and the outlet structure will flow freely without causing undesirable ponding or scour.
15. Appropriately stabilise all disturbed areas immediately after construction.

Additional specifications for the installation of the mattresses:

Installation procedures should be provided by the manufacturer or distributor of the product. A typical installation procedure is described below, but should be confirmed with the product manufacturer or distributor.

Materials

- Rock infill: 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.
- Geotextile fabric: heavy-duty, needle-punched, non-woven filter cloth, minimum bidim A24 or equivalent.

Installation

1. Refer to approved plans for location, extent and installation details. If there are questions or problems with the location, extent, or method of installation contact the engineer or responsible on-site officer for assistance.
2. Mattresses of different thicknesses should be stored on-site in separate piles and clearly labelled.
3. Clear the proposed channel area of trees, stumps, roots, loose rock, and other objectionable materials.
4. Excavate the treatment area to the lines and grades as shown on the plans. Over-cut the area to a depth equal to the specified mattress thickness such that the finished surface will be at the elevation of the surrounding land.
5. Place filter fabric directly on the prepared foundation. If more than one sheet of filter cloth 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.
6. Ensure the filter cloth is protected from punching or tearing during installation of the mattresses. 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.
7. Flatten out each mattress on a hard, flat surface, and stamp out any unnecessary creases. Edge creases will need to be stamped into the bottom of the 2nd and 4th internal diaphragms.
8. Ensure that each diaphragm is vertical and the correct height. Fold the sides and ends of the mattress to meet the top of the diaphragms. Fold the side panel flaps to lie adjacent to the diaphragms. Tack temporarily either by using short lengths of binding wire, or alternatively by twisting the top diaphragm wire over the flap selvedge wire.
9. The ends of the diaphragms must now be permanently laced to the sides of the mattress. At the four corners, bend the projected lengths of the end panels to overlap the sides, and lace up with binding wire.
10. When the mattress is placed over a geotextile, care must be taken to ensure that projecting ends of wire are bent upwards to avoid puncturing or tearing the cloth. Geotextile should be placed according to specifications.
11. Carry the wired-up mattress to its final position, and wire it securely to the adjacent mattresses. Mattresses should be placed and wired together empty as it is difficult to wire mattresses together when both are full of stone.
12. On slopes, the mattress should generally be laid with the diaphragm across the slope rather than up and down the slope. On chute and stream beds, the mattress should generally be laid with the diaphragm at right angles to the main direction of water flow.
13. All hand wiring must be done as a continuous lacing operation. Begin wiring by securing the binding wire to the corner of the panels to be joined by looping it through and twisting it together. Then lace with single loops and double loops in turn at 100mm intervals. Finally poke the loose end inside the mattress. Tightness of the mesh and wiring is essential at all times.
14. Place the fill material, by hand or mechanically, in the compartments, starting at the bottom if on a slope. The fill should be a hard, durable stone, in size between 80mm and two-thirds the thickness of the mattress, but generally no greater than 200mm.

15. Filling can be done unit by unit, but several units should be ready for filling at any one time.
16. For units with PVC coated wire mesh, particular care shall be taken to ensure that sharp edges of quarry stone are not placed against the mesh in order to avoid causing unnecessary abrasion.
17. Slightly overfill each mattress to allow for settlement. Tack the lid to the corners of the mattress, and then securely wire it to the tops of the sides, ends and diaphragms, using alternate single and double loops as specified above.
18. With more than one mattress filled, the edges of adjacent lids can be wired down in the same operation, saving both time and binding wire.
19. When the mattress is laid on a slope steeper than 1.5:1(H:V), it should be secured by star pickets or hardwood pegs driven into the ground just inside the upper end panel at two (2) metre centres or as necessary.
20. On soft or sandy slopes, pegs can be used to hold the mattress in position during filling.
21. Mattresses can be shortened where necessary, by cutting along the fold at the top of a diaphragm and removing the bottom spiral connections.
22. Always consult manufacturer's specifications and assembly instructions before modifying the shape of the mattress or wiring deformed mattress shapes.
23. Immediately upon completion of the channel, vegetate all disturbed areas or otherwise protect them against soil erosion.
24. Where specified, fill all voids with soil and vegetate in accordance with the approved plan.

Maintenance

1. During the construction period, inspect all chutes prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing storm events, or otherwise on a weekly basis. Make repairs as necessary.
2. Check for soil scour adjacent the chute. Investigate the cause of any scour, and repair as necessary.
3. Ensure sediment is not partially blocking flow entry into the chute. Where necessary, remove any deposited material to allow free drainage.
4. Dispose of any sediment in a manner that will not create an erosion or pollution hazard.
5. When making repairs, always restore the chute to its original configuration unless an amended layout is required.

Removal

1. When the soil disturbance above the chute is finished and the area is stabilised, the chute and any associated flow diversion banks should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any materials, sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area in preparation for stabilisation, then stabilise the area as specified in the approved plan.