Catch Drains Part 4: Geotextile-lined

DRAINAGE CONTROL TECHNIQUE

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

[1] The design of permanent catch drains requires consideration of issues not discussed within this fact sheet, such as maintenance requirements. This fact sheet should not be used for the design of permanent drains.

Symbol → CD →

Photo 11 – Roadside table drain lined with a temporary jute erosion control mat

Photo 12 – Roadside catch drain lined with an erosion control mat sealed with bitumen

Key Principles

1. Catch drains typically have standardised cross-sectional dimensions. Rather than uniquely sizing each catch drain to a given catchment, standard-sized drains are used based on a maximum allowable catchment area for a given rainfall intensity.
2. The **maximum** recommended spacing of catch drains down slopes (Table 3, *Part 1 – General information*) is based on the aim of avoiding rill erosion within the up-slope drainage slope. It should be noted that the **actual** spacing of catch drains down a given slope may need to be less than the specified maximum spacing if the soils are highly erosive soils, or if rilling begins to occur between two existing drains.
3. The critical design parameters are the spacing of the drains down a slope, the maximum allowable catchment area, the choice of lining material (e.g. earth, turf, rock or erosion control mats), and the required channel gradient.

Design Information

The following information must be read in association with the general information presented in *Part 1 – General information*. These design tables specifically address catch drains lined with non-vegetated erosion control mats. The design tables are also applicable to the initial establishment of mat-protected catch drains prior to development of the grass cover.

The design procedure outlined within this fact sheet has been developed to provide a simplified approach suitable for appropriately trained persons involved in the regular design of temporary catch drains. The procedure is just **one** example of how catch drains can be designed. Designers experienced in hydraulic design can of course, design a catch drain using the general principles of open channel hydrologic/hydraulic as outlined in IECA (2008) Appendix A – *Construction site hydrology and hydraulics*.

Common Problems

Erosion control mats can be incorrectly installed with the adjoining mats overlapping against the direction of flow. This can cause the mats to be torn from the channel bed during moderate flows.

Damage to associated flow diversion bank (rutting) caused by vehicles.

Catch drains not discharging to a stable outlet either causing downstream erosion, or initiating scour within the drain.

'Plastic' reinforced mats can entangle ground-dwelling wildlife such as lizards, snakes and birds.

Temporary mats can fail before adequate grass cover is established.

Special Requirements

The dispersive nature of the local subsoils should be investigated before planning or designing any excavated drains.

Straw bales or other sediment traps should **not** be placed within these drains due to the risk of causing surcharging of the drain.

Catch drain should drain to a suitable sediment trap if the diverted water is expected to contain sediment. 'Clean' water should divert around sediment traps.

The drain must have positive gradient along its full length to allow free drainage.

Sufficient space must be provided to allow necessary maintenance access.

Site Inspection

Check the direction of overlap of the mats and the spacing of anchor pins (staples).

Check that the drain has a stable, positive grade along its length.

Check for a stable drain outlet.

Check if the associated flow diversion bank (if any) is free of damage, i.e. damage caused by construction traffic.

Check that the drain has adequate hydraulic capacity given the catchment area (general observations based on past experience).

Check if rill erosion is occurring within the catchment area up-slope of the drain. If rilling is occurring, then the lateral spacing of the drains will need to be reduced. However, some degree of rill erosion should be expected if recent storms exceeded the intensity of the nominated design storm.

Inspect for evidence of water spilling out (overtopping) of the drain, or erosion down-slope of the drain.

Inspect for erosion along the bed of the drain (i.e. damage to the mat). Investigate the reasons for any erosion before recommending solutions. Bed (invert) erosion can result from either excessive channel velocities, or an unstable outlet, which causes bed erosion (head-cut) to migrate up the channel.

Possible solutions to channel erosion:

- reduce effective catchment area;
- increase channel width;
- increase channel roughness;
- replace erosion control mats;
- stabilise the outlet.

Installation (drain formation)

1. Refer to approved plans for location, extent, and construction 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. Clear the location for the catch drain, clearing only what is needed to provide access for personnel and equipment for installation.
3. Remove roots, stumps, and other debris and dispose of them properly. Do not use debris to build the bank.
4. Grade the drain to the specified slope and form the associated embankment with compacted fill. Note that the drain invert must fall 10cm every 10m for each 1% of channel gradient.
5. Ensure the sides of the cut drain are no steeper than a 1.5:1 (H:V) slope and the embankment fill slopes no steeper than 2:1.
6. Ensure the completed drain has sufficient deep (as specified for the type of drain) measured from the drain invert to the top of the embankment.
7. Ensure the drain has a constant fall in the desired direction free of obstructions.
8. Ensure the drain discharges to a stable outlet such that soil erosion will be prevented from occurring. Ensure the drain does not discharge to an unstable fill slope.

Installation (mat placement)

The method of mat installation varies with the type of mat. 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.

1. Erosion control mats must be stored away from direct sunlight or covered with ultraviolet light protective sheeting until the site is ready for their installation.
2. Vehicles and construction equipment must not be permitted to manoeuvre over the geotextile unless it has been covered with a layer of soil or gravel at least 150mm thick. Fill material shall not be mixed over the geotextile.
3. If the channel is to be grassed, prepare a smooth seed bed of approximately 75mm of topsoil, seed, fertilise, water and rake to remove any remaining surface irregularities.
4. Excavate a 300mm deep by 150mm wide anchor trench along the full width of the upstream end of the area to be treated.
5. At least 300mm of the mat must be anchored into the trench with the roll of matting resting on the ground up-slope of the trench.
6. Staple the fabric within the trench at 200 to 250mm spacing using 100mm wide by 150mm penetration length U-shaped, 8 to 11 gauge wire staples. Narrower U-sections may easily tear the matting when placed under stress.
7. When all mats have been anchored within the trench across the full width of the treated area, then the trench is backfilled and compacted. The mats are then unrolled down the slope such that each mat covers and protects the backfilled trench.
8. When spreading the mats, avoid stretching the fabric. The mats should remain in good contact with the soil.
9. If the channel curves, then suitably fold (in a downstream direction) and staple the fabric to maintain the fabric parallel to the direction of channel flow.
10. Staple the surface of the matting at 1m centres. On irregular ground, additional staples will be required wherever the mat does not initially contact the ground surface.
11. At the end of each length of mat, a new trench is formed at least 300mm up-slope of the end of the mat such that the end of the mat will be able to fully cover the trench. A new roll of matting is then anchored within this trench as per the first mat. After this new mat has been unrolled down the slope, the up-slope mat can be pinned in place fully covering the new trench and at least 300mm of the down-slope mat. The process is continued down the slope until the desired area is fully covered.
12. In high-velocity channels, intermediate anchor slots are usually required at 10m intervals down the channel.
13. Anchor the outer most edges (top and upper most sides) of the treated area in a 300mm deep trench and staple at 200 to 250mm centres.
14. If the channel was grass seeded prior to placement of the mats, then the mats should be rolled with a suitable roller weighing 60 to 90 kg/m, then watered.
15. The installation procedure must ensure that the mat achieves and retains good contact with the soil.
16. Damaged matting must be repaired or replaced.

Additional instructions for the installation of Jute Mesh (not jute blankets):

1. Ensure the jute mesh is laid on a firm earth surface that has been trimmed, topsoiled, watered, sown with seed and fertiliser.
2. The jute mesh is then either tamped or rolled firmly onto the prepared surface, avoiding stretching, watered to encourage the penetration of the bitumen emulsion, and finally sprayed with a top layer of bitumen at 1 to 3 litres per square metre.
3. The rate of emulsion application should be adjusted such that the emulsion just starts to pond in the mesh squares.

Additional requirements associated with use near airport pavements

1. Only erosion mats that are double netted shall be allowed within 3.0m of any airport pavement used by aircraft with the exception of airports classified as air carrier or corporate/transport. If the airport is classified as an air carrier or corporate/transport, there will be no erosion mats allowed within 9.0m of pavement used by aircraft.
2. Only biodegradable anchoring devices shall be allowed in the installation of any erosion mat for airport applications. No metal staples will be allowed.

Maintenance

1. Inspect all catch drains at least weekly and after runoff-producing storm events and repair any slumps, bank damage, or loss of freeboard.
2. Ensure fill material or sediment is not partially blocking the drain. Where necessary, remove any deposited material to allow free drainage.
3. Dispose of any sediment or fill in a manner that will not create an erosion or pollution hazard.

Removal

1. When the soil disturbance above the catch drain is finished and the area is stabilised, the drain and any associated banks should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area and smooth it out in preparation for stabilisation.
4. Stabilise the area by grassing or as specified within the approved plan.

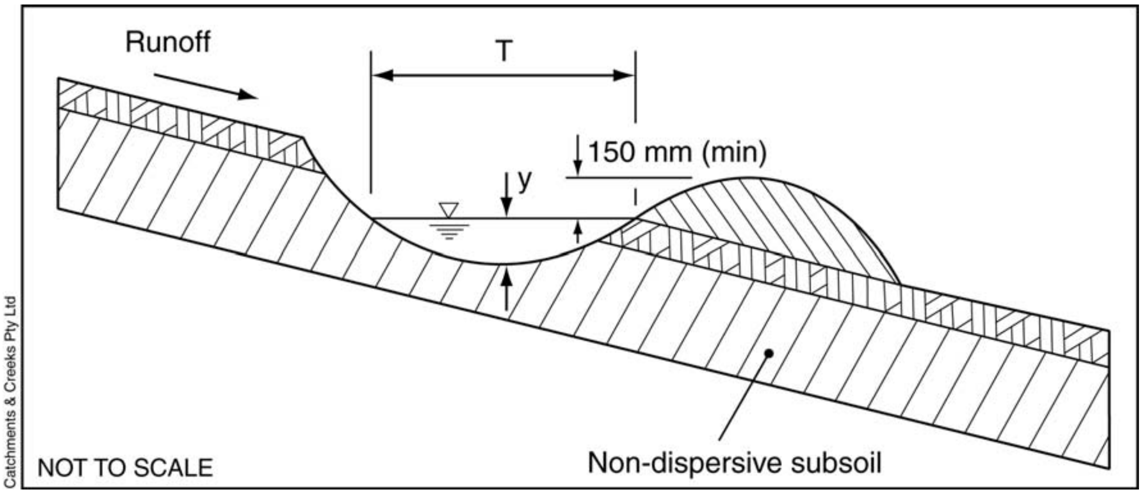

Figure 7(1) – Parabolic catch drain with bank

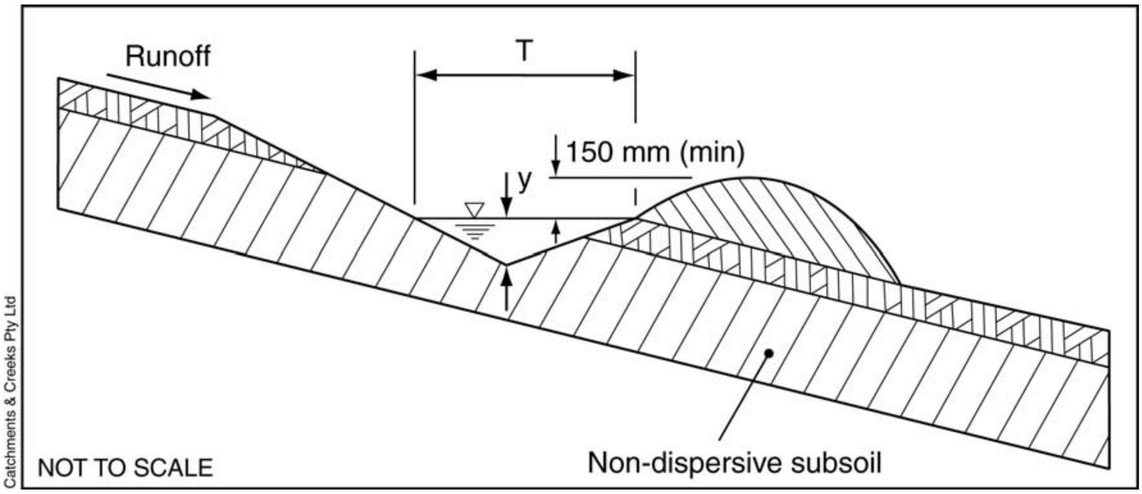

Figure 8(2) – Triangular V-drain with down-slope bank

Hydraulic design of mat-lined catch drains (using the Rational Method approach):

Step 1 Choose the preferred surface condition of the catch drain (in this case lined with a specified erosion control mat). With experience, the choice of erosion control mat can be based on the required allowable flow velocity determined from a quick review of the following design tables, but gaining this experience take time!

Step 2 Determine the allowable flow velocity (V_{allow}) for the chosen type of mat. The allowable flow velocity can be determined from Tables 28 and 29, or Tables 30 and 31 if the mat Class and/or allowable shear stress are known.

Step 3 Nominate the catch drain profile: parabolic or triangular (V-drain). Parabolic drains have a greater hydraulic capacity and are generally less susceptible to invert erosion, but can be slightly more time-consuming to construct.

Step 4 Choose a trial catch drain size (flow top width 'T', and depth 'Y') from Table 32 (parabolic drains), or Table 37 (triangular drains).

Step 5 Determine Manning's roughness (n) and required longitudinal gradient (S%) for the catch drain type, mat type, and allowable flow velocity from Tables 33 or 38.

Step 6 Determine the required *Average Recurrence Interval* (ARI) of the design storm for the given catch drain (i.e. 1 year, 2 year, 5 year, etc. – refer to Table 4.3.1 in Chapter 4, or Table A1 in Section A2 of Appendix A). Note, if a locally adopted design standard exists, then the ARI must be determined from that standard.

Step 7 Determine the appropriate *time of concentration* (t_c) for the catch drain (refer to Step 4 in IECA 2008, Appendix A, Section A2).

It is usually sufficient to assume a 5-minute time of concentration (conservative approach), otherwise use the locally adopted hydrologic procedures for determining the time of concentration, or the procedures presented in IECA (2008) Appendix A.

Step 8 Given the design storm ARI, and duration (t_c), determine the *Average Rainfall Intensity* (I) for the catch drain (refer to Step 6 in Section A2 of Appendix A).

To determine the average rainfall intensity it will be necessary to obtain the relevant *Intensity-Frequency-Duration* (IFD) chart for the given site location.

Step 9 Determine the *maximum unit catchment area* (A*) of the catch drain using Tables 34 to 36, or Tables 39 to 41 depending on the chosen drain type and profile.

The maximum unit catchment area (A*) is the maximum allowable catchment area based on a coefficient of discharge of unity (i.e. C = 1.0).

Step 10 Determine the actual *Coefficient of Discharge* (C) for the catchment contributing runoff to the catch drain (refer to Step 3 in IECA 2008, Appendix A, Section A2).

Note, it will be necessary to first determine the *Coefficient of Discharge* for a 10 year storm (C_{10}), and then the *Frequency Factor* (F_Y) for the nominated design storm frequency from Table A7 in Step 3, Section A2 of Appendix A, such that:

$$C = C_{10} \cdot F_Y \leq 1.0$$

Step 11 Determine the maximum allowable catchment area (A) for the catch drain based on the *Coefficient of Discharge* (C) determined in Step 10:

$$A = (A^*)/C \quad \text{(hectares)}$$

Step 12 Determine the maximum allowable horizontal spacing of the catch drains down the slope from Table 3 (*Catch Drain Part 1 – General information*).

Step 13 If the actual catchment area of the catch drain (measured from the Erosion and Sediment Control Plan) is **greater** than the maximum allowable area determined in Step 11, then return to Step 4 and select a larger catch drain profile.

If the actual catchment area of the catch drain is **less** than the maximum allowable area determined in Step 11, then either return to Step 4 and select a smaller catch drain profile; or determine the minimum allowable drain slope (S_{min}) which is limited by the maximum allowable flow depth (y), and maximum allowable drain slope (S_{max}) which is limited by the maximum allowable flow velocity V_{allow}.

Explanation of the design philosophy adopted within this fact sheet:

Given the cross-sectional dimensions of a given catch drain (A & R), its surface roughness (n), gradient (S), and required freeboard, it is possible (using Manning's equation) to determine the hydraulic capacity (Q) of the drain, as presented in Equation 1.

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

where: A = cross-sectional flow area of the catch drain

The Rational Method (Equation 2) can be rearrange to form Equation 3:

$$Q = (C.I.A)/360 \qquad \text{(Eqn 2)}$$

$$A.C = 360(Q / I) \qquad \text{(Eqn 3)}$$

where: A = catchment area (ha) of the catch drain (**not** the cross-sectional area of the drain)

If we define a new term called 'the unit catchment area' (A*) as the effective catchment area based on an **assumed** coefficient of discharge of unity (i.e. C = 1.0), then:

Maximum unit catchment area: $$A^* = 360(Q / I) \qquad \text{(Eqn 4)}$$

The relationship between flow velocity (V) and channel slope (S) is given by a modification of the Manning's equation (Equation 5):

$$V = \frac{1}{n}.R^{2/3}.S^{1/2} \qquad \text{(Eqn 5)}$$

For a given catch drain profile (represented by the hydraulic radius, R), and surface lining (represented by the Manning's roughness, n) we can determine the required drain slope (S) for a given allowable flow velocity. This information is presented in Tables 33 and 38. It is noted that at this channel slope, the maximum allowable flow velocity (V_{allow}) will be achieved when the channel is flowing at the maximum allowable flow depth (Y).

Also, for a given catch drain cross-sectional area (A), hydraulic radius (R), and maximum allowable flow velocity (V), we can determine the maximum allowable discharge (Q) from Equation 1. With this discharge, and the nominated design rainfall intensity (I), we can determine the maximum unit catchment area (A*) from Equation 4. This information is presented in Tables 34 to 36 for parabolic drains, and Tables 39 to 41 for drains with a triangular profile.

This means Tables 34 to 36 and 39 to 41 are independent of location, and thus can be used anywhere in the world. Rainfall intensity, I (mm/hr) being the only parameter that is location specific.

In order to determine the maximum allowable catchment area (A), it is necessary to determine the **actual** coefficient of discharge (C) for the adopted storm frequency (ARI), and catchment conditions (i.e. soil porosity). The maximum allowable catchment area (A) is determined from Equation 6.

Maximum allowable catchment area: $$A = A^*/C \qquad \text{(Eqn 6)}$$

Since the coefficient of discharge is always assumed to be less than or equal to unity, the maximum allowable catchment area (A) cannot exceed the maximum unit catchment area (A*).

If the actual catchment area is less than the calculated maximum catchment area (A) from Equation 6, then the catch drain can be constructed at a range of channel gradients such that:

$$S_{min} < S < S_{max}$$

where:

- S_{min} can be determined from Manning's equation based on the catch drain flowing full, but at a channel-full velocity less than the maximum allowable flow velocity;
- S_{max} can be determined from Manning's equation based on the catch drain flowing partially full, and at a velocity equal to the maximum allowable flow velocity.

Design example: Mat-lined catch drain

Design a temporary (< 24 months) jute mesh lined catch drain cut into a non-dispersive loam soil in Townsville with a desired length of 300m, catchment area of 1.5ha, and an average catchment land slope of 6%. The catch drain will be used to divert 'clean' water around a soil disturbance. The catchment consists of undisturbed, well-grassed, land, and the 'time of concentration' (t_c) for the catchment is known to be 15 minutes.

Step 1 The catch drain surface condition has been given as jute mesh. For the purpose of this example it will be assumed that the jute mesh will not be protected with bitumen emulsion.

Step 2 Given the non-dispersive loam soil is likely to have a low to moderate erosion potential, nominate an allowable flow velocity (V_{allow}) of 1.5m/s from Table 28.

Step 3 Choose a parabolic drain profile.

Step 4 Initially try a Type-B catch drain with dimensions: T = 1.8m, Y = 0.3m.

Step 5 Determine the Manning's roughness (n) and required longitudinal gradient (S) from Table 33 as S = 1.03% and n = 0.022 for a Type-B drain based on an allowable flow velocity, V_{allow} =1.5m/s.

Step 6 Nominate a 1 in 5 year ARI design storm from Table 4.3.1 (Chapter 4).

Step 7 The catchment time of concentration (t_c) is given as 15 minutes.

Step 8 Determine the average rainfall intensity: I = 132mm/hr for Townsville from Table A11 (Appendix A) for ARI = 5-year, and t_c = 15 minutes.

Step 9 Determine the maximum allowable unit catchment area as A* = 1.43ha from Table 35, given V = 1.5m/s, and I = 132mm/hr.

Step 10 Determine the coefficient of discharge (C_Y):

Given the catch drain's catchment area is open, undisturbed grass with medium permeability, 100% pervious surface area, and given that Townsville's 10 minute, 1-year rainfall intensity (${}^{1}I_{10}$) is 91.9mm/hr, the 10-year coefficient of discharge, C_{10} = 0.70 from Table A5 (Appendix A – *Construction site hydrology and hydraulics*).

Determine the frequency factor, F_Y = 0.95 for the 1 in 5-year ARI storm from Table A7 (Appendix A).

Calculate the effective coefficient of discharge (C) for the 1 in 5-year event using Equation A4 (Appendix A):

$$C = C_5 = F_Y .C_{10} = 0.95 \times 0.70 = 0.665 \leq 1.0 \text{ (OK)}$$

Step 11 Calculate the maximum allowable catchment area (A) for the catch drain:

$$A = (A^*)/C = 1.43/0.665 = 2.15\text{ha}$$

Thus the maximum allowable catchment area is greater than the actual catchment area of 1.5ha, OK.

Step 12 Because this catch drain is being used to collect and divert 'clean' water from an undisturbed catchment there is no need (in this case) to determine the maximum allowable spacing of the catch drains down the catchment slope.

So, a Type-B catch drain formed at a gradient of 1.03% will have a flow capacity significantly greater than is required for the specified 1.5ha catchment. At this point in the analysis we have the following options:

(i) stay with the current design (Type-B, 1.03% grade, lined with jute mesh);

(ii) stay with a Type-B drain, but calculate a suitable range of channel gradients;

(iii) try a smaller, Type-A catch drain, but this is unlikely to be large enough.

Step 5a For the purpose of this example, option (ii) will be chosen

Given that the actual catchment area is significantly less than the maximum allowable catchment area, the catch drain can be constructed at:

- a flatter gradient (S_{min} < 1.03%) limited by the maximum flow depth of 0.3m; or
- a steeper gradient (S_{max} > 1.03%) limited by the allowable velocity of 1.5m/s.

To determined flattest allowable gradient for this catch drain, first calculate the design 1 in 5-year flow at the end of the 300m long catch drain.

$$Q = C\ I\ A/360 = (0.665 \times 132 \times 1.5)/360 = 0.366 m^3/s$$

The **flattest** longitudinal gradient of the catch drain can be determined from the Manning's equation (Equation A16 in IECA 2008, Appendix A); where the flow top width (T) is 1.8m, and the flow depth (Y) is 0.3m.

It should be OK to assume that Manning's roughness remains close to n = 0.022 determined in Step 5, thus:

$$Q = 0.366 = (1/n).A.R^{2/3}.S^{1/2} = (1/0.022)(0.360)(0.186)^{2/3}.S^{1/2}$$

$$S_{min} = 0.47\%$$

Note, in the above equation, the term 'A' is the cross-sectional area of the catch drain at a depth of y = 0.3m (determined from Table 31), **not** the catchment area! Also, 'R' is the hydraulic radius for the drain flowing full (Y = 0.3m) which is also provided in Table 32.

The **steepest** longitudinal gradient of the catch drain can also be determined from Manning's equation (Equation A16 in Appendix A); however, in this case the drain will be flowing partially full with a flow top width (T) less than 1.8m, and the flow depth (y) less than 0.3m. *(Note, the drain would still be constructed with the same standard overall physical dimensions specified for all Type-B catch drains.)*

Now, for a parabolic Type-B drain the numerical relationship between the flow top width (T) and the flow depth (y) is given by the following equation (Table 4):

$$y = 0.0926\ T^2$$

and the cross sectional area of flow (A) is given by (Table A30b, Appendix A):

$$A = 0.67(T.y) = 0.062\ T^3 = Q/V = 0.366/1.5 = 0.244 m^2$$

Therefore, the flow top width, T = 1.581m; the flow depth, y = 0.231m; and the hydraulic radius (R) can be determined from (Table A29b, Appendix A):

$$R = \frac{2\,T^2.y}{3\,T^2 + 8\,y^2} = \frac{2(1.581)^2 \times 0.231}{3(1.581)^2 + 8(0.231)^2} = 0.146m$$

The maximum catch drain slope is given by rearranging the Manning's equation:

$$S_{max} = 100 \times (V^2 . n^2)/R^{4/3} = 100 \times (1.5^2 \times 0.022^2)/0.146^{4/3} = 1.42\%$$

Therefore, the Type-A catch drain can be constructed at any longitudinal gradient between 0.47% (maximum flow depth) and 1.42% (maximum flow velocity), and still provide the required hydraulic capacity for the 1 in 5 year design storm. It is noted that constructing the drain at the steeper gradient will result in a construction site with maximum drainage capacity.

Tables 28 and 29 provide guidance on the selection of an allowable flow velocity for various types of temporary and permanent erosion control mats. Wherever possible, the allowable velocity and/or allowable shear stress should be obtained from the manufacturer/distributor of the chosen product.

In circumstances where the manufacturer/distributor supplies only the allowable shear stress, then an equivalent allowable flow velocity can be determined from Table 31.

Table 28 – Allowable flow velocity for various erosion control mats

Type	Description	Allowable velocity	Comments
Erosion control blankets	Thick jute blankets	1.4m/s	• Typical design life of around 3 months.
	Coir blankets	Medium, say 1.5m/s	• Design life of 1 to 2 years depending on degree and duration of water saturation.
	Blankets reinforced with non UV-stabilised synthetic mesh	1.6 to 3.6m/s	• Allowable flow velocity depends on soil erodibility and strength of the mat. • Warning: wildlife (e.g. birds and reptiles) can become entangled in the mesh.
Erosion control mesh	Jute mesh	1.3 to 1.7m/s	• Typical design life of 1 year.
	Jute mesh sprayed with bitumen	Refer to Table 28	• Typical design life of 1 year. • Allowable flow velocity depends on the soil's erosion resistance.
	Coir mesh	1.7m/s	• Typical design life of 1 to 2 years. • Biodegradable after 4 to 10 years.
Turf reinforcing mats (TRMs)	Open face 2D synthetic mats	2.4 to 3.0m/s	• Refer to manufacturer's data.
	Bio-degradable mulch mats reinforced with UV-stabilised mesh	2.1 to 6.0m/s	• Refer to manufacturer's data. • Long-term reinforcement of grass, but can be subject to damage during periods of drought if the grass surface is damaged or lost.
	3D, fully synthetic, UV-stabilised mats on vegetated ground	5.5m/s for 30min duration to 3m/s for 50 hours duration	• Refer to manufacturer's data. • Long-term protection of soil surface.

Table 29 – Allowable flow velocity for temporary channel linings [1]

Anticipated inundation =	Less than 6 hours			Less than 24 hours		
Soil erodibility =	Low	Medium	High	Low	Medium	High
Jute or coir mesh sprayed with bitumen, and Coconut/jute fibre mats	2.3	2.0	1.7	1.7	1.5	1.3

[1] Sourced from Landcom (2004)

Erosion control blanket/mat classification system

A classification system for erosion control blankets and mats (e.g. Class 1, Type A) is provided in Table 30. In general terms, this classification system is based on the following distinctions.

Class 1 includes those temporary, light-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of 'sheet' flow, and thus are termed *Erosion Control Blankets*.

Class 2 includes those temporary, heavy-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of medium shear stress such as drainage channels. These products are termed *Blankets or Mats* depending on their use.

Class 3 comprises permanent, heavy-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of high shear stress such as drainage channels and spillways/chutes.

Class 3 - Type B, C and D 'Turf Reinforcement Mats' (TRM) are permanent, 100% synthetic, open-weaved mats that shall be continuously bonded at the filament intersections.

Table 30 presents the flow stability properties of erosion control blankets and mats in terms of permissible shear stress measured in units of Pascals (Pa). Permissible shear stress is considered a more reliable measure of blanket's resistance to damage by water flow and is the measure typically used within Europe and USA; however, allowable flow velocity is more commonly used within Australia.

Table 3 defines the relationship between allowable shear stress (Pa) and allowable flow velocity (m/s) for various values of hydraulic radius (R) and assumed Manning's n roughness presented within the table. The table is therefore appropriate for non-vegetated, three-dimensional turf reinforcement mat (TRM) such as Class 3, Types B, C and D mats.

Table 30 – Classification of erosion control mats

Class	1						2			3			
Type	**A**	**B**	**C**	**AU**	**BU**	**CU**	**A**	**B**	**C**	**A**	**B**	**C**	**D**
Permissible shear stress (Pa)	N/A	50	70	N/A	50	70	N/A	95	95	95	95	170	240

[1] For more information on this classification system, refer to the fact sheet on *Erosion Control Mats*.

Table 31 – Equivalent allowable flow velocity (m/s) for a given permissible shear stress (Pa) for non-vegetated turf reinforcement mats

Assumed Manning's roughness	Hydraulic radius (m)	Permissible shear stress (Pa)						
		50	**70**	**95**	**100**	**150**	**170**	**240**
0.06	**0.05**	0.65	0.72	0.79	0.85	0.91	0.97	1.02
0.04	**0.10**	1.09	1.22	1.33	1.44	1.54	1.63	1.72
0.036	**0.15**	1.29	1.45	1.58	1.71	1.83	1.94	2.05
0.033	**0.20**	1.48	1.66	1.81	1.96	2.09	2.22	2.34
0.031	**0.25**	1.64	1.83	2.00	2.16	2.31	2.45	2.59
0.029	**0.30**	1.80	2.02	2.21	2.38	2.55	2.70	2.85
0.026	**0.40**	2.11	2.36	2.58	2.79	2.98	3.16	3.33
0.023	**0.50**	2.47	2.77	3.03	3.27	3.50	3.71	3.91
0.02	**1.0**	3.19	3.57	3.91	4.23	4.52	4.79	5.05
0.02	**1.5**	3.42	3.82	4.19	4.52	4.83	5.13	5.40
0.02	**2.0**	3.59	4.01	4.39	4.74	5.07	5.38	5.67
0.02	**2.5**	3.72	4.16	4.56	4.92	5.26	5.58	5.88
0.02	**3.0**	3.84	4.29	4.70	5.07	5.43	5.75	6.07

Table 32 – Dimensions of standard parabolic catch drains

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain [1]	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-A	1.0m	0.15m	1.6m	0.30m	0.094m	0.100m^2
Type-B	1.8m	0.30m	2.4m	0.45m	0.186m	0.360m^2
Type-C	3.0m	0.50m	3.6m	0.65m	0.310m	1.000m^2

[1] Top width of the formed drain assumes the upper bank slope is limited to a maximum of 2:1.

Table 33 – Required longitudinal gradient (%) for parabolic cross-section catch drains lined with *Erosion Control Mats/Mesh*

Manning's roughness (n)	Allowable flow velocity along catch drain (m/s)									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
	Type-A catch drain: flow width (T) = 1.0 m and flow depth (Y) = 0.15 m									
Jute/Coir Mesh n=0.022	1.13	1.62	2.21	2.89	3.65	4.51	7.04	10.1	13.8	18.0
TRM without grass n=0.026	1.57	2.27	3.09	4.03	5.10	6.30	9.84	14.2	19.3	25.2
Straw mulch pinned with mesh n=0.033	2.54	3.65	4.97	6.49	8.22	10.1	15.9	22.8	31.1	40.6
Wood shaving blanket n=0.035	2.85	4.11	5.59	7.30	9.24	11.4	17.8	25.7	34.9	45.6
	Type-B catch drain: flow width (T) = 1.8 m and flow depth (Y) = 0.3 m									
Jute/Coir Mesh n=0.022	0.46	0.66	0.89	1.17	1.47	1.82	2.84	4.10	5.58	7.28
TRM without grass n=0.026	0.64	0.92	1.25	1.63	2.06	2.54	3.97	5.72	7.79	10.2
Straw mulch pinned with mesh n=0.033	1.02	1.47	2.01	2.62	3.32	4.10	6.40	9.22	12.6	16.4
Wood shaving blanket n=0.035	1.15	1.66	2.26	2.95	3.73	4.61	7.20	10.4	14.1	18.4
	Type-C catch drain: flow width (T) = 3.0 m and flow depth (Y) = 0.5 m									
Jute/Coir Mesh n=0.022	0.23	0.33	0.45	0.59	0.75	0.92	1.44	2.07	2.82	3.69
TRM without grass n=0.026	0.32	0.46	0.63	0.82	1.04	1.29	2.01	2.90	3.94	5.15
Straw mulch pinned with mesh n=0.033	0.52	0.75	1.02	1.33	1.68	2.07	3.24	4.66	6.35	8.29
Wood shaving blanket n=0.035	0.58	0.84	1.14	1.49	1.89	2.33	3.64	5.25	7.14	9.33

Table 34 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-A Catch Drain: Parabolic cross section										
Dimensions:				**Flow top width = 1.0 m**				**Flow depth = 0.15 m**		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	2.400	2.880	3.360	3.840	4.320	4.800	6.000	7.200	8.400	9.600
20	1.800	2.160	2.520	2.880	3.240	3.600	4.500	5.400	6.300	7.200
25	1.440	1.728	2.016	2.304	2.592	2.880	3.600	4.320	5.040	5.760
30	1.200	1.440	1.680	1.920	2.160	2.400	3.000	3.600	4.200	4.800
35	1.029	1.234	1.440	1.646	1.851	2.057	2.571	3.086	3.600	4.114
40	0.900	1.080	1.260	1.440	1.620	1.800	2.250	2.700	3.150	3.600
45	0.800	0.960	1.120	1.280	1.440	1.600	2.000	2.400	2.800	3.200
50	0.720	0.864	1.008	1.152	1.296	1.440	1.800	2.160	2.520	2.880
55	0.655	0.785	0.916	1.047	1.178	1.309	1.636	1.964	2.291	2.618
60	0.600	0.720	0.840	0.960	1.080	1.200	1.500	1.800	2.100	2.400
65	0.554	0.665	0.775	0.886	0.997	1.108	1.385	1.662	1.938	2.215
70	0.514	0.617	0.720	0.823	0.926	1.029	1.286	1.543	1.800	2.057
75	0.480	0.576	0.672	0.768	0.864	0.960	1.200	1.440	1.680	1.920
80	0.450	0.540	0.630	0.720	0.810	0.900	1.125	1.350	1.575	1.800
85	0.424	0.508	0.593	0.678	0.762	0.847	1.059	1.271	1.482	1.694
90	0.400	0.480	0.560	0.640	0.720	0.800	1.000	1.200	1.400	1.600
95	0.379	0.455	0.531	0.606	0.682	0.758	0.947	1.137	1.326	1.516
100	0.360	0.432	0.504	0.576	0.648	0.720	0.900	1.080	1.260	1.440
105	0.343	0.411	0.480	0.549	0.617	0.686	0.857	1.029	1.200	1.371
110	0.327	0.393	0.458	0.524	0.589	0.655	0.818	0.982	1.145	1.309
115	0.313	0.376	0.438	0.501	0.563	0.626	0.783	0.939	1.096	1.252
120	0.300	0.360	0.420	0.480	0.540	0.600	0.750	0.900	1.050	1.200
125	0.288	0.346	0.403	0.461	0.518	0.576	0.720	0.864	1.008	1.152
130	0.277	0.332	0.388	0.443	0.498	0.554	0.692	0.831	0.969	1.108
135	0.267	0.320	0.373	0.427	0.480	0.533	0.667	0.800	0.933	1.067
140	0.257	0.309	0.360	0.411	0.463	0.514	0.643	0.771	0.900	1.029
145	0.248	0.298	0.348	0.397	0.447	0.497	0.621	0.745	0.869	0.993
150	0.240	0.288	0.336	0.384	0.432	0.480	0.600	0.720	0.840	0.960
155	0.232	0.279	0.325	0.372	0.418	0.465	0.581	0.697	0.813	0.929
160	0.225	0.270	0.315	0.360	0.405	0.450	0.563	0.675	0.788	0.900
165	0.218	0.262	0.305	0.349	0.393	0.436	0.545	0.655	0.764	0.873
170	0.212	0.254	0.296	0.339	0.381	0.424	0.529	0.635	0.741	0.847
175	0.206	0.247	0.288	0.329	0.370	0.411	0.514	0.617	0.720	0.823
180	0.200	0.240	0.280	0.320	0.360	0.400	0.500	0.600	0.700	0.800
185	0.195	0.234	0.272	0.311	0.350	0.389	0.486	0.584	0.681	0.778
190	0.189	0.227	0.265	0.303	0.341	0.379	0.474	0.568	0.663	0.758
200	0.180	0.216	0.252	0.288	0.324	0.360	0.450	0.540	0.630	0.720
210	0.171	0.206	0.240	0.274	0.309	0.343	0.429	0.514	0.600	0.686
220	0.164	0.196	0.229	0.262	0.295	0.327	0.409	0.491	0.573	0.655
230	0.157	0.188	0.219	0.250	0.282	0.313	0.391	0.470	0.548	0.626
240	0.150	0.180	0.210	0.240	0.270	0.300	0.375	0.450	0.525	0.600
250	0.144	0.173	0.202	0.230	0.259	0.288	0.360	0.432	0.504	0.576
Q (m^3/s)	**0.100**	**0.120**	**0.140**	**0.160**	**0.180**	**0.200**	**0.250**	**0.300**	**0.350**	**0.400**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 33).

Table 35 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-B Catch Drain: Parabolic cross section

Dimensions:	Flow top width = 1.8 m	Flow depth = 0.3 m

Rainfall intensity (mm/hr)	Allowable flow velocity along catch drain (m/s)									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	8.640	10.368	12.096	13.824	15.552	17.280	21.600	25.920	30.240	34.560
20	6.480	7.776	9.072	10.368	11.664	12.960	16.200	19.440	22.680	25.920
25	5.184	6.221	7.258	8.294	9.331	10.368	12.960	15.552	18.144	20.736
30	4.320	5.184	6.048	6.912	7.776	8.640	10.800	12.960	15.120	17.280
35	3.703	4.443	5.184	5.925	6.665	7.406	9.257	11.109	12.960	14.811
40	3.240	3.888	4.536	5.184	5.832	6.480	8.100	9.720	11.340	12.960
45	2.880	3.456	4.032	4.608	5.184	5.760	7.200	8.640	10.080	11.520
50	2.592	3.110	3.629	4.147	4.666	5.184	6.480	7.776	9.072	10.368
55	2.356	2.828	3.299	3.770	4.241	4.713	5.891	7.069	8.247	9.425
60	2.160	2.592	3.024	3.456	3.888	4.320	5.400	6.480	7.560	8.640
65	1.994	2.393	2.791	3.190	3.589	3.988	4.985	5.982	6.978	7.975
70	1.851	2.222	2.592	2.962	3.333	3.703	4.629	5.554	6.480	7.406
75	1.728	2.074	2.419	2.765	3.110	3.456	4.320	5.184	6.048	6.912
80	1.620	1.944	2.268	2.592	2.916	3.240	4.050	4.860	5.670	6.480
85	1.525	1.830	2.135	2.440	2.744	3.049	3.812	4.574	5.336	6.099
90	1.440	1.728	2.016	2.304	2.592	2.880	3.600	4.320	5.040	5.760
95	1.364	1.637	1.910	2.183	2.456	2.728	3.411	4.093	4.775	5.457
100	1.296	1.555	1.814	2.074	2.333	2.592	3.240	3.888	4.536	5.184
105	1.234	1.481	1.728	1.975	2.222	2.469	3.086	3.703	4.320	4.937
110	1.178	1.414	1.649	1.885	2.121	2.356	2.945	3.535	4.124	4.713
115	1.127	1.352	1.578	1.803	2.029	2.254	2.817	3.381	3.944	4.508
120	1.080	1.296	1.512	1.728	1.944	2.160	2.700	3.240	3.780	4.320
125	1.037	1.244	1.452	1.659	1.866	2.074	2.592	3.110	3.629	4.147
130	0.997	1.196	1.396	1.595	1.794	1.994	2.492	2.991	3.489	3.988
135	0.960	1.152	1.344	1.536	1.728	1.920	2.400	2.880	3.360	3.840
140	0.926	1.111	1.296	1.481	1.666	1.851	2.314	2.777	3.240	3.703
145	0.894	1.073	1.251	1.430	1.609	1.788	2.234	2.681	3.128	3.575
150	0.864	1.037	1.210	1.382	1.555	1.728	2.160	2.592	3.024	3.456
155	0.836	1.003	1.171	1.338	1.505	1.672	2.090	2.508	2.926	3.345
160	0.810	0.972	1.134	1.296	1.458	1.620	2.025	2.430	2.835	3.240
165	0.785	0.943	1.100	1.257	1.414	1.571	1.964	2.356	2.749	3.142
170	0.762	0.915	1.067	1.220	1.372	1.525	1.906	2.287	2.668	3.049
175	0.741	0.889	1.037	1.185	1.333	1.481	1.851	2.222	2.592	2.962
180	0.720	0.864	1.008	1.152	1.296	1.440	1.800	2.160	2.520	2.880
185	0.701	0.841	0.981	1.121	1.261	1.401	1.751	2.102	2.452	2.802
190	0.682	0.819	0.955	1.091	1.228	1.364	1.705	2.046	2.387	2.728
200	0.648	0.778	0.907	1.037	1.166	1.296	1.620	1.944	2.268	2.592
210	0.617	0.741	0.864	0.987	1.111	1.234	1.543	1.851	2.160	2.469
220	0.589	0.707	0.825	0.943	1.060	1.178	1.473	1.767	2.062	2.356
230	0.563	0.676	0.789	0.902	1.014	1.127	1.409	1.690	1.972	2.254
240	0.540	0.648	0.756	0.864	0.972	1.080	1.350	1.620	1.890	2.160
250	0.518	0.622	0.726	0.829	0.933	1.037	1.296	1.555	1.814	2.074
Q (m^3/s)	**0.360**	**0.432**	**0.504**	**0.576**	**0.648**	**0.720**	**0.900**	**1.080**	**1.260**	**1.440**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 33).

Table 36 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-C Catch Drain: Parabolic cross section										
Dimensions:				**Flow top width = 3.0 m**				**Flow depth = 0.5 m**		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	24.00	28.80	33.60	38.40	43.20	48.00	60.00	72.00	84.00	96.00
20	18.00	21.60	25.20	28.80	32.40	36.00	45.00	54.00	63.00	72.00
25	14.40	17.28	20.16	23.04	25.92	28.80	36.00	43.20	50.40	57.60
30	12.00	14.40	16.80	19.20	21.60	24.00	30.00	36.00	42.00	48.00
35	10.29	12.34	14.40	16.46	18.51	20.57	25.71	30.86	36.00	41.14
40	9.00	10.80	12.60	14.40	16.20	18.00	22.50	27.00	31.50	36.00
45	8.00	9.60	11.20	12.80	14.40	16.00	20.00	24.00	28.00	32.00
50	7.20	8.64	10.08	11.52	12.96	14.40	18.00	21.60	25.20	28.80
55	6.55	7.85	9.16	10.47	11.78	13.09	16.36	19.64	22.91	26.18
60	6.00	7.20	8.40	9.60	10.80	12.00	15.00	18.00	21.00	24.00
65	5.54	6.65	7.75	8.86	9.97	11.08	13.85	16.62	19.38	22.15
70	5.14	6.17	7.20	8.23	9.26	10.29	12.86	15.43	18.00	20.57
75	4.80	5.76	6.72	7.68	8.64	9.60	12.00	14.40	16.80	19.20
80	4.50	5.40	6.30	7.20	8.10	9.00	11.25	13.50	15.75	18.00
85	4.24	5.08	5.93	6.78	7.62	8.47	10.59	12.71	14.82	16.94
90	4.00	4.80	5.60	6.40	7.20	8.00	10.00	12.00	14.00	16.00
95	3.79	4.55	5.31	6.06	6.82	7.58	9.47	11.37	13.26	15.16
100	3.60	4.32	5.04	5.76	6.48	7.20	9.00	10.80	12.60	14.40
105	3.43	4.11	4.80	5.49	6.17	6.86	8.57	10.29	12.00	13.71
110	3.27	3.93	4.58	5.24	5.89	6.55	8.18	9.82	11.45	13.09
115	3.13	3.76	4.38	5.01	5.63	6.26	7.83	9.39	10.96	12.52
120	3.00	3.60	4.20	4.80	5.40	6.00	7.50	9.00	10.50	12.00
125	2.88	3.46	4.03	4.61	5.18	5.76	7.20	8.64	10.08	11.52
130	2.77	3.32	3.88	4.43	4.98	5.54	6.92	8.31	9.69	11.08
135	2.67	3.20	3.73	4.27	4.80	5.33	6.67	8.00	9.33	10.67
140	2.57	3.09	3.60	4.11	4.63	5.14	6.43	7.71	9.00	10.29
145	2.48	2.98	3.48	3.97	4.47	4.97	6.21	7.45	8.69	9.93
150	2.40	2.88	3.36	3.84	4.32	4.80	6.00	7.20	8.40	9.60
155	2.32	2.79	3.25	3.72	4.18	4.65	5.81	6.97	8.13	9.29
160	2.25	2.70	3.15	3.60	4.05	4.50	5.63	6.75	7.88	9.00
165	2.18	2.62	3.05	3.49	3.93	4.36	5.45	6.55	7.64	8.73
170	2.12	2.54	2.96	3.39	3.81	4.24	5.29	6.35	7.41	8.47
175	2.06	2.47	2.88	3.29	3.70	4.11	5.14	6.17	7.20	8.23
180	2.00	2.40	2.80	3.20	3.60	4.00	5.00	6.00	7.00	8.00
185	1.95	2.34	2.72	3.11	3.50	3.89	4.86	5.84	6.81	7.78
190	1.89	2.27	2.65	3.03	3.41	3.79	4.74	5.68	6.63	7.58
200	1.80	2.16	2.52	2.88	3.24	3.60	4.50	5.40	6.30	7.20
210	1.71	2.06	2.40	2.74	3.09	3.43	4.29	5.14	6.00	6.86
220	1.64	1.96	2.29	2.62	2.95	3.27	4.09	4.91	5.73	6.55
230	1.57	1.88	2.19	2.50	2.82	3.13	3.91	4.70	5.48	6.26
240	1.50	1.80	2.10	2.40	2.70	3.00	3.75	4.50	5.25	6.00
250	1.44	1.73	2.02	2.30	2.59	2.88	3.60	4.32	5.04	5.76
Q (m^3/s)	**1.000**	**1.200**	**1.400**	**1.600**	**1.800**	**2.000**	**2.500**	**3.000**	**3.500**	**4.000**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 33).

Table 37 – Dimensions of standard triangular V-drains

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-AV	1.0m	0.15m	2.0m	0.30m	0.072m	0.075m^2
Type-BV	1.8m	0.30m	2.7m	0.45m	0.142m	0.270m^2
Type-CV	3.0m	0.50m	3.9m	0.65m	0.237m	0.750m^2

Table 38 – Required longitudinal gradient (%) for triangular cross-section V-drains lined with *Erosion Control Mats/Mesh*

Manning's roughness (n)	Allowable flow velocity along catch drain (m/s)									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
	Type-AV catch drain: flow width (T) = 1.0 m and flow depth (Y) = 0.15 m									
Jute/Coir Mesh n=0.022	1.62	2.33	3.18	4.15	5.25	6.48	10.1	14.6	19.9	25.9
TRM without grass n=0.026	2.26	3.26	4.44	5.80	7.33	9.05	14.1	20.4	27.7	36.2
Straw mulch pinned with mesh n=0.033	3.65	5.25	7.15	9.34	11.8	14.6	22.8	32.8	44.7	58.3
Wood shaving blanket n=0.035	4.10	5.91	8.04	10.5	13.3	16.4	25.6	36.9	50.3	65.6
	Type-BV catch drain: flow width (T) = 1.8 m and flow depth (Y) = 0.3 m									
Jute/Coir Mesh n=0.022	0.65	0.94	1.28	1.67	2.11	2.61	4.07	5.86	7.98	10.42
TRM without grass n=0.026	0.91	1.31	1.78	2.33	2.95	3.64	5.69	8.19	11.15	14.56
Straw mulch pinned with mesh n=0.033	1.47	2.11	2.87	3.75	4.75	5.86	9.16	13.19	17.96	23.45
Wood shaving blanket n=0.035	1.65	2.37	3.23	4.22	5.34	6.60	10.31	14.84	20.20	26.38
	Type-CV catch drain: flow width (T) = 3.0 m and flow depth (Y) = 0.5 m									
Jute/Coir Mesh n=0.022	0.33	0.47	0.65	0.84	1.07	1.32	2.06	2.97	4.04	5.27
TRM without grass n=0.026	0.46	0.66	0.90	1.18	1.49	1.84	2.88	4.14	5.64	7.37
Straw mulch pinned with mesh n=0.033	0.74	1.07	1.45	1.90	2.40	2.97	4.64	6.68	9.09	11.9
Wood shaving blanket n=0.035	0.83	1.20	1.64	2.14	2.70	3.34	5.22	7.51	10.2	13.4

Table 39 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-AV Catch Drain: V-drain cross section

Dimensions:				Flow top width = 1.0 m				Flow depth = 0.15 m		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	1.800	2.160	2.520	2.880	3.240	3.600	4.500	5.400	6.300	7.200
20	1.350	1.620	1.890	2.160	2.430	2.700	3.375	4.050	4.725	5.400
25	1.080	1.296	1.512	1.728	1.944	2.160	2.700	3.240	3.780	4.320
30	0.900	1.080	1.260	1.440	1.620	1.800	2.250	2.700	3.150	3.600
35	0.771	0.926	1.080	1.234	1.389	1.543	1.929	2.314	2.700	3.086
40	0.675	0.810	0.945	1.080	1.215	1.350	1.688	2.025	2.363	2.700
45	0.600	0.720	0.840	0.960	1.080	1.200	1.500	1.800	2.100	2.400
50	0.540	0.648	0.756	0.864	0.972	1.080	1.350	1.620	1.890	2.160
55	0.491	0.589	0.687	0.785	0.884	0.982	1.227	1.473	1.718	1.964
60	0.450	0.540	0.630	0.720	0.810	0.900	1.125	1.350	1.575	1.800
65	0.415	0.498	0.582	0.665	0.748	0.831	1.038	1.246	1.454	1.662
70	0.386	0.463	0.540	0.617	0.694	0.771	0.964	1.157	1.350	1.543
75	0.360	0.432	0.504	0.576	0.648	0.720	0.900	1.080	1.260	1.440
80	0.338	0.405	0.473	0.540	0.608	0.675	0.844	1.013	1.181	1.350
85	0.318	0.381	0.445	0.508	0.572	0.635	0.794	0.953	1.112	1.271
90	0.300	0.360	0.420	0.480	0.540	0.600	0.750	0.900	1.050	1.200
95	0.284	0.341	0.398	0.455	0.512	0.568	0.711	0.853	0.995	1.137
100	0.270	0.324	0.378	0.432	0.486	0.540	0.675	0.810	0.945	1.080
105	0.257	0.309	0.360	0.411	0.463	0.514	0.643	0.771	0.900	1.029
110	0.245	0.295	0.344	0.393	0.442	0.491	0.614	0.736	0.859	0.982
115	0.235	0.282	0.329	0.376	0.423	0.470	0.587	0.704	0.822	0.939
120	0.225	0.270	0.315	0.360	0.405	0.450	0.563	0.675	0.788	0.900
125	0.216	0.259	0.302	0.346	0.389	0.432	0.540	0.648	0.756	0.864
130	0.208	0.249	0.291	0.332	0.374	0.415	0.519	0.623	0.727	0.831
135	0.200	0.240	0.280	0.320	0.360	0.400	0.500	0.600	0.700	0.800
140	0.193	0.231	0.270	0.309	0.347	0.386	0.482	0.579	0.675	0.771
145	0.186	0.223	0.261	0.298	0.335	0.372	0.466	0.559	0.652	0.745
150	0.180	0.216	0.252	0.288	0.324	0.360	0.450	0.540	0.630	0.720
155	0.174	0.209	0.244	0.279	0.314	0.348	0.435	0.523	0.610	0.697
160	0.169	0.203	0.236	0.270	0.304	0.338	0.422	0.506	0.591	0.675
165	0.164	0.196	0.229	0.262	0.295	0.327	0.409	0.491	0.573	0.655
170	0.159	0.191	0.222	0.254	0.286	0.318	0.397	0.476	0.556	0.635
175	0.154	0.185	0.216	0.247	0.278	0.309	0.386	0.463	0.540	0.617
180	0.150	0.180	0.210	0.240	0.270	0.300	0.375	0.450	0.525	0.600
185	0.146	0.175	0.204	0.234	0.263	0.292	0.365	0.438	0.511	0.584
190	0.142	0.171	0.199	0.227	0.256	0.284	0.355	0.426	0.497	0.568
200	0.135	0.162	0.189	0.216	0.243	0.270	0.338	0.405	0.473	0.540
210	0.129	0.154	0.180	0.206	0.231	0.257	0.321	0.386	0.450	0.514
220	0.123	0.147	0.172	0.196	0.221	0.245	0.307	0.368	0.430	0.491
230	0.117	0.141	0.164	0.188	0.211	0.235	0.293	0.352	0.411	0.470
240	0.113	0.135	0.158	0.180	0.203	0.225	0.281	0.338	0.394	0.450
250	0.108	0.130	0.151	0.173	0.194	0.216	0.270	0.324	0.378	0.432
Q (m^3/s)	**0.075**	**0.090**	**0.105**	**0.120**	**0.135**	**0.150**	**0.188**	**0.225**	**0.263**	**0.300**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 38).

Table 40 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-BV Catch Drain: V-drain cross section

Dimensions:				Flow top width = 1.8 m				Flow depth = 0.3 m		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	6.480	7.776	9.072	10.368	11.664	12.960	16.200	19.440	22.680	25.920
20	4.860	5.832	6.804	7.776	8.748	9.720	12.150	14.580	17.010	19.440
25	3.888	4.666	5.443	6.221	6.998	7.776	9.720	11.664	13.608	15.552
30	3.240	3.888	4.536	5.184	5.832	6.480	8.100	9.720	11.340	12.960
35	2.777	3.333	3.888	4.443	4.999	5.554	6.943	8.331	9.720	11.109
40	2.430	2.916	3.402	3.888	4.374	4.860	6.075	7.290	8.505	9.720
45	2.160	2.592	3.024	3.456	3.888	4.320	5.400	6.480	7.560	8.640
50	1.944	2.333	2.722	3.110	3.499	3.888	4.860	5.832	6.804	7.776
55	1.767	2.121	2.474	2.828	3.181	3.535	4.418	5.302	6.185	7.069
60	1.620	1.944	2.268	2.592	2.916	3.240	4.050	4.860	5.670	6.480
65	1.495	1.794	2.094	2.393	2.692	2.991	3.738	4.486	5.234	5.982
70	1.389	1.666	1.944	2.222	2.499	2.777	3.471	4.166	4.860	5.554
75	1.296	1.555	1.814	2.074	2.333	2.592	3.240	3.888	4.536	5.184
80	1.215	1.458	1.701	1.944	2.187	2.430	3.038	3.645	4.253	4.860
85	1.144	1.372	1.601	1.830	2.058	2.287	2.859	3.431	4.002	4.574
90	1.080	1.296	1.512	1.728	1.944	2.160	2.700	3.240	3.780	4.320
95	1.023	1.228	1.432	1.637	1.842	2.046	2.558	3.069	3.581	4.093
100	0.972	1.166	1.361	1.555	1.750	1.944	2.430	2.916	3.402	3.888
105	0.926	1.111	1.296	1.481	1.666	1.851	2.314	2.777	3.240	3.703
110	0.884	1.060	1.237	1.414	1.591	1.767	2.209	2.651	3.093	3.535
115	0.845	1.014	1.183	1.352	1.521	1.690	2.113	2.536	2.958	3.381
120	0.810	0.972	1.134	1.296	1.458	1.620	2.025	2.430	2.835	3.240
125	0.778	0.933	1.089	1.244	1.400	1.555	1.944	2.333	2.722	3.110
130	0.748	0.897	1.047	1.196	1.346	1.495	1.869	2.243	2.617	2.991
135	0.720	0.864	1.008	1.152	1.296	1.440	1.800	2.160	2.520	2.880
140	0.694	0.833	0.972	1.111	1.250	1.389	1.736	2.083	2.430	2.777
145	0.670	0.804	0.938	1.073	1.207	1.341	1.676	2.011	2.346	2.681
150	0.648	0.778	0.907	1.037	1.166	1.296	1.620	1.944	2.268	2.592
155	0.627	0.753	0.878	1.003	1.129	1.254	1.568	1.881	2.195	2.508
160	0.608	0.729	0.851	0.972	1.094	1.215	1.519	1.823	2.126	2.430
165	0.589	0.707	0.825	0.943	1.060	1.178	1.473	1.767	2.062	2.356
170	0.572	0.686	0.800	0.915	1.029	1.144	1.429	1.715	2.001	2.287
175	0.555	0.667	0.778	0.889	1.000	1.111	1.389	1.666	1.944	2.222
180	0.540	0.648	0.756	0.864	0.972	1.080	1.350	1.620	1.890	2.160
185	0.525	0.630	0.736	0.841	0.946	1.051	1.314	1.576	1.839	2.102
190	0.512	0.614	0.716	0.819	0.921	1.023	1.279	1.535	1.791	2.046
200	0.486	0.583	0.680	0.778	0.875	0.972	1.215	1.458	1.701	1.944
210	0.463	0.555	0.648	0.741	0.833	0.926	1.157	1.389	1.620	1.851
220	0.442	0.530	0.619	0.707	0.795	0.884	1.105	1.325	1.546	1.767
230	0.423	0.507	0.592	0.676	0.761	0.845	1.057	1.268	1.479	1.690
240	0.405	0.486	0.567	0.648	0.729	0.810	1.013	1.215	1.418	1.620
250	0.389	0.467	0.544	0.622	0.700	0.778	0.972	1.166	1.361	1.555
Q (m^3/s)	**0.270**	**0.324**	**0.378**	**0.432**	**0.486**	**0.540**	**0.675**	**0.810**	**0.945**	**1.080**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 38).

Table 41 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-CV Catch Drain: V-drain cross section

Dimensions:					Flow top width = 3.0 m				Flow depth = 0.5 m
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
15	18.00	21.60	25.20	28.80	32.40	36.00	45.00	54.00	63.00	72.00
20	13.50	16.20	18.90	21.60	24.30	27.00	33.75	40.50	47.25	54.00
25	10.80	12.96	15.12	17.28	19.44	21.60	27.00	32.40	37.80	43.20
30	9.00	10.80	12.60	14.40	16.20	18.00	22.50	27.00	31.50	36.00
35	7.71	9.26	10.80	12.34	13.89	15.43	19.29	23.14	27.00	30.86
40	6.75	8.10	9.45	10.80	12.15	13.50	16.88	20.25	23.63	27.00
45	6.00	7.20	8.40	9.60	10.80	12.00	15.00	18.00	21.00	24.00
50	5.40	6.48	7.56	8.64	9.72	10.80	13.50	16.20	18.90	21.60
55	4.91	5.89	6.87	7.85	8.84	9.82	12.27	14.73	17.18	19.64
60	4.50	5.40	6.30	7.20	8.10	9.00	11.25	13.50	15.75	18.00
65	4.15	4.98	5.82	6.65	7.48	8.31	10.38	12.46	14.54	16.62
70	3.86	4.63	5.40	6.17	6.94	7.71	9.64	11.57	13.50	15.43
75	3.60	4.32	5.04	5.76	6.48	7.20	9.00	10.80	12.60	14.40
80	3.38	4.05	4.73	5.40	6.08	6.75	8.44	10.13	11.81	13.50
85	3.18	3.81	4.45	5.08	5.72	6.35	7.94	9.53	11.12	12.71
90	3.00	3.60	4.20	4.80	5.40	6.00	7.50	9.00	10.50	12.00
95	2.84	3.41	3.98	4.55	5.12	5.68	7.11	8.53	9.95	11.37
100	2.70	3.24	3.78	4.32	4.86	5.40	6.75	8.10	9.45	10.80
105	2.57	3.09	3.60	4.11	4.63	5.14	6.43	7.71	9.00	10.29
110	2.45	2.95	3.44	3.93	4.42	4.91	6.14	7.36	8.59	9.82
115	2.35	2.82	3.29	3.76	4.23	4.70	5.87	7.04	8.22	9.39
120	2.25	2.70	3.15	3.60	4.05	4.50	5.63	6.75	7.88	9.00
125	2.16	2.59	3.02	3.46	3.89	4.32	5.40	6.48	7.56	8.64
130	2.08	2.49	2.91	3.32	3.74	4.15	5.19	6.23	7.27	8.31
135	2.00	2.40	2.80	3.20	3.60	4.00	5.00	6.00	7.00	8.00
140	1.93	2.31	2.70	3.09	3.47	3.86	4.82	5.79	6.75	7.71
145	1.86	2.23	2.61	2.98	3.35	3.72	4.66	5.59	6.52	7.45
150	1.80	2.16	2.52	2.88	3.24	3.60	4.50	5.40	6.30	7.20
155	1.74	2.09	2.44	2.79	3.14	3.48	4.35	5.23	6.10	6.97
160	1.69	2.03	2.36	2.70	3.04	3.38	4.22	5.06	5.91	6.75
165	1.64	1.96	2.29	2.62	2.95	3.27	4.09	4.91	5.73	6.55
170	1.59	1.91	2.22	2.54	2.86	3.18	3.97	4.76	5.56	6.35
175	1.54	1.85	2.16	2.47	2.78	3.09	3.86	4.63	5.40	6.17
180	1.50	1.80	2.10	2.40	2.70	3.00	3.75	4.50	5.25	6.00
185	1.46	1.75	2.04	2.34	2.63	2.92	3.65	4.38	5.11	5.84
190	1.42	1.71	1.99	2.27	2.56	2.84	3.55	4.26	4.97	5.68
200	1.35	1.62	1.89	2.16	2.43	2.70	3.38	4.05	4.73	5.40
210	1.29	1.54	1.80	2.06	2.31	2.57	3.21	3.86	4.50	5.14
220	1.23	1.47	1.72	1.96	2.21	2.45	3.07	3.68	4.30	4.91
230	1.17	1.41	1.64	1.88	2.11	2.35	2.93	3.52	4.11	4.70
240	1.13	1.35	1.58	1.80	2.03	2.25	2.81	3.38	3.94	4.50
250	1.08	1.30	1.51	1.73	1.94	2.16	2.70	3.24	3.78	4.32
Q (m^3/s)	**0.750**	**0.900**	**1.050**	**1.200**	**1.350**	**1.500**	**1.875**	**2.250**	**2.625**	**3.000**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 38).