Catch Drains Part 5: Rock-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 13 – Rock lined catch drain

Photo 14 – Rock-lined catch drain

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*. The following design tables specifically address rock-lined catch drains of specific dimensions.

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

Rock-lined catch drains are often cut to the wrong dimensions (typically under-sized), and following placement of the rock the drains have insufficient available flow area to carry the design discharge.

Stormwater approaching the drain fails to enter the rock-lined section of the drain, but instead is deflected down the upper edge of the rock causing rill erosion (Figure 9). This problem most commonly occurs when the rock is placed such that is sits above the elevation of the surrounding ground. The problem can be avoided by ensuring that the drain is properly 'boxed out', and that the rocks sit flush with the surrounding soil (Figures 10 & 11).

Catch drains not discharging to a stable outlet either causing downstream erosion, or initiating erosion under the rock lining.

Special Requirements

The erodibility and 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 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 the required width and depth to achieve the desired hydraulic capacity.

Check that the rock is not reducing the drain's required hydraulic capacity.

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.

Check for displacement of rock or exposure of the underlying earth.

Check for placement of filter cloth under the rock. Note; filter cloth may not be specified if the spaces between the rock are filled with soil and planted (typical only for permanent drains in certain climates).

Materials

Rock:

- All rock must be hard, weather resistant, and durable against disintegration under conditions to be met in handling, placement and operation.

- All rock must have its greatest dimension not greater than 3 times its least dimensions.

- The rock used in formation of the drain must be evenly graded with 50% by weight larger than the specified nominal rock size and have sufficient small rock to fill the voids between the larger rock. Dirt, fines, and smaller rock must not exceed 5% by weight.

- 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.

- The colour of the riprap shall be [*insert*] and must be approved by the engineer. Once approved, the colour shall be kept consistent through the project.

Filter cloth:

- 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 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. Prior to placement, all rocks must be visually checked for size, elongation, cracks, deterioration and other visible. The degree and thoroughness of such checking must be appropriate for the potential consequences associated with failure of the structure or purpose for which the material will be used.

3. Clear the location for the catch drain, 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. Do not use debris to build the bank.

5. Remove all soft, yielding material; replace with suitable on-site material; compact to smooth firm surface.

6. Excavate the drain to the lines and grades shown on the approved plans. Over-cut the drain to a depth equal to the specified depth of rock placement such that the finished top surface will be at the elevation of the surrounding land. Placement of the rock lining must not reduce the drain's top width and depth as specified within the approved plans.

7. 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.

8. 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.

9. If the drain is cut into a dispersive (sodic) soil, then prior to placing filter cloth, the exposed dispersive soil must be covered with a minimum 200mm thick layer of non-dispersive soil prior to placement of filter cloth or rocks.

10. If a filter cloth underlay is specified, place the 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 secure anchor pins at minimum 1m spacing along the overlap.

11. Ensure the filter cloth 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.

12. 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.

13. Place rock lining to the extent and depth indicated within the approved plans.

14. Ensure the rock is placed in an appropriate manner to avoid displacing underlying materials or placing undue impact force on the bedding materials.

15. Ensure the rock is placed with a minimum thickness of 1.5 times the nominal rock size (d50).

16. Ensure materials that are d50 and larger are positioned flush with the top surface with faces and shapes matched to minimise voids.

17. Ensure projections above or depressions under the specified top surface are less than 20% of the rock layer thickness. The average surface plane of the finished rock is defined as the plane where 50% of the tops of rocks would contact.

18. Ensure the completed drain has sufficient deep (as specified for the type of drain) measured from the drain invert (average surface plane along channel invert) to the top of the embankment. The average surface plane of the finished rock is defined as the plane where 50% of the tops of rocks would contact.

19. To the maximum degree practicable, the material between larger rock must not be loose or easily displaced by the expected flow.

20. After placement of the rock lining, ensure the drain has a constant fall in the desired direction free of obstructions.

21. 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.

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. Closely inspect the outer edges of the rock protection. Ensure water entry into the rock-lined area is not causing erosion along the edge of the rock protection.

3. Carefully check the stability of the rock looking for indications of piping, scour holes, or bank failures.

4. Replace or reposition the surface rock such that the drain functions as required and the drain's required hydraulic capacity is not reduced.

5. Replace any displaced rock with rock of a significantly (minimum 110%) larger size than the displaced rock.

6. Ensure sediment is not partially blocking the drain. Where necessary, remove any deposited material to allow free drainage.

7. 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.
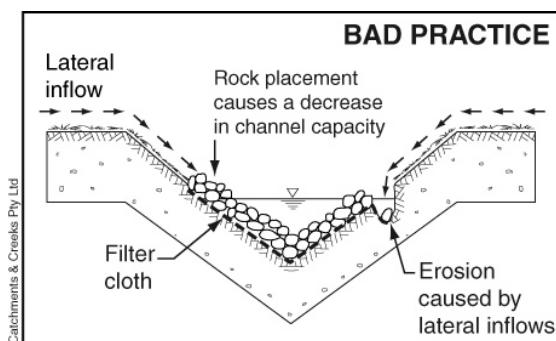

Figure 9 – Example of poor placement of rock
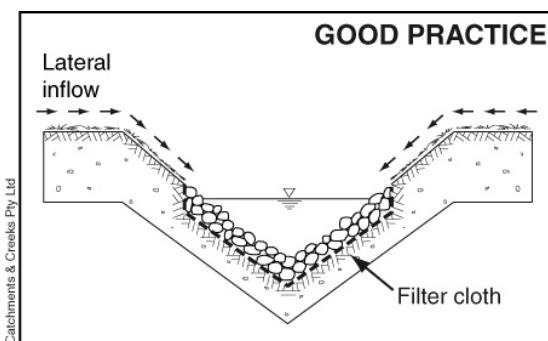
Figure 10 – Example of good placement of rock
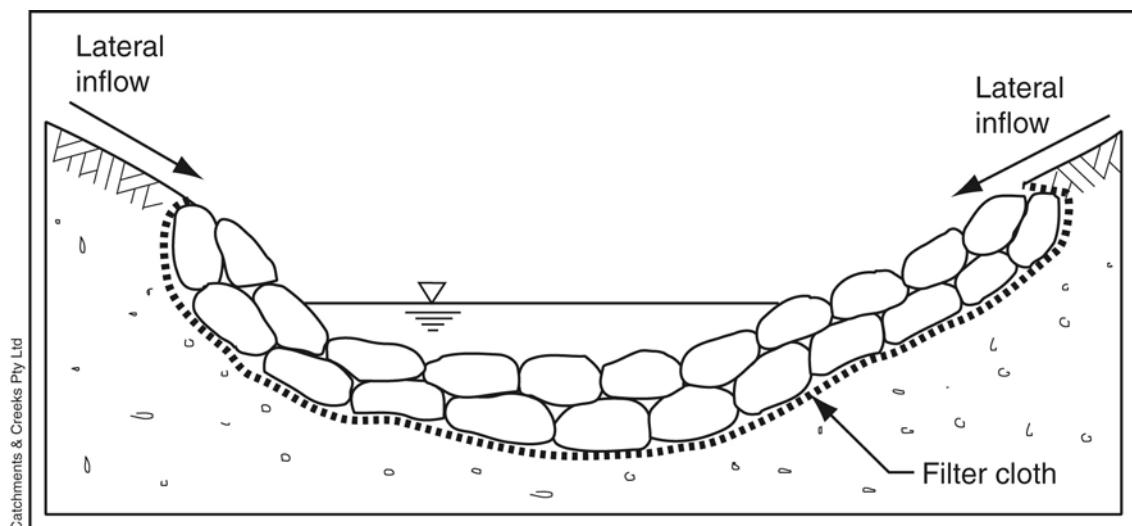
Figure 11 – Desired placement of rock within a catch drain such that lateral inflow has free entry into the drain

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

Step 1   Choose the preferred rock size of the catch drain. This may be governed by the rock size readily available on-site, or based on past experience.

Step 2   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. A triangular profile often best represents the profile of some table drains.

Step 3   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 4   Determine the appropriate *time of concentration* (t_c) for the catch drain (refer to Step 4 in IECA 2008, Appendix A, Section A2).

If the time of concentration is unknown, then a conservative approach is to adopt a time of 5 minutes, then review later is necessary.

Step 5   Given the design storm ARI, and duration (t_c), determine the *Average Rainfall Intensity* (I, mm/hr) 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 6   Determine the *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:

$$C = C_{10} . F_Y \le 1.0$$

Step 7   Determine the *unit catchment area* (A*) of the catch drain. The unit catchment area is equal to the actual catchment area (A) times the coefficient of discharge (C).

Thus: $A^* = A.C$ (hectares)

Step 8   Given the design discharge (Q), or the rainfall intensity (I) and the unit catchment area (A*), determine the desired drain size and slope, and mean rock size (d_{50}) from Tables 45 to 53, or Tables 56 to 64 depending on the chosen drain profile. *It is noted that information provided in these tables are based on the use of angular, fractured rock with a specific gravity (s_r) of 2.4.*

Noting that: $Q(m^3/s) = (C.I.A)/360$

It is noted that in some cases the drain slope will be defined by site conditions.

If the slope of the drain varies along its length (which is often the case for table drains), then the catchment area may need to be determined at various locations along the length of the drain.

Step 9   If it is necessary to further analyse the catch drain, the allowable flow velocity (V) and Manning's roughness (n) for the catch drain can be determined from Tables 44 or 55, depending on the chosen drain profile.

The maximum channel slope presented in these tables represents the gradient beyond which the maximum allowable discharge is governed by the maximum allowable flow velocity. At lower gradient the maximum discharge for the drain is governed by the maximum allowable flow depth (Y).

Step 10   If necessary, the maximum allowable horizontal spacing of the catch drains down the slope can be determined from Table 3 (*Catch Drain, Part 1 – General information*).

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:
$$Q = \frac{1}{n}.A.R^{2/3}.S^{1/2}$$
(Eqn 1)

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

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

$$Q = (C.I.A)/360$$
(Eqn 2)

$$A.C = 360(Q / I)$$
(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:
$$A* = 360(Q / I)$$
(Eqn 4)

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

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

For a given surface lining material we can determine the allowable flow velocity (V_{allow}). Therefore, 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 44 and 55. It is noted that at this channel slope, the maximum allowable flow velocity 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 45 to 53 for parabolic drains, and Tables 56 to 64 for drains with a triangular profile.

This means that Tables 45 to 53 and 56 to 64 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.

The allowable flow velocities (V_{allow}) presented in Tables 44 and 55 are based on the use of angular, fractured rock with a specific gravity (s_r) of 2.4. Therefore, the maximum unit catchment areas presented in Tables 45 to 53 and 56 to 64 are conservative for rock with a specific gravity greater than 2.4, but are not conservative if rounded rock is used.

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:
$$A = A*/C$$
(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 (S):

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

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.

For rock-lined channels the Manning's roughness can be determined from Equation 7.

$$n = \frac{(d_{90})^{1/6}}{26(1 - 0.3593^{(x)^{0.7}})} \qquad \text{(Eqn 7)}$$

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]

In 'natural' gravel-based streams the factor d_{50}/d_{90} is typically in the range 0.2 to 0.5, whereas in constructed channels in which imported graded rock is used, the ratio is more likely to be in the range 0.5 to 0.8. The results presented in Tables 44 to 53 and 55 to 64 are based on d_{50}/d_{90} = 0.67 which assumes that the maximum rock size is approximately equal to 1.5 times the mean rock size.

The allowable flow velocity for low gradient (i.e. S < 10%) rock-lined catch drains can be determined from Equation 8.

$$d_{50} = \frac{K_1 . V^2}{2.g.K^2(s_r - 1)} \qquad \text{(Eqn 8)}$$

where:
V = average flow velocity [m/s]
K_1 = 1.0 for angular (fractured) rock, or 1.36 for rounded rock
g = acceleration due to gravity [m/s^2]
K = 0.86 for highly turbulent flow as expected within a catch drain
s_r = specific gravity of the rock (refer to Table 42)

Table 42 – Typical values of the specific gravity of rock

Rock type	Specific gravity of rock (s_r)
Sandstone	2.1 to 2.4
Granite	2.5 to 3.1 (typically 2.6)
Limestone	2.6
Basalt	2.7 to 3.2

Adopting the values, K_1 = 1.0, K = 0.86 and s_r = 2.4, Equation 8 can simplified to Equation 9:

$$d_{50} = 0.05 \, V^2 \qquad \text{(Eqn 9)}$$

Note, Equations 8 and 9 are only applicable for small channels with a bed slope less than 10%.

Design example: Rock-lined catch drain

Design a long-term (> 24 months) rock-lined catch drain cut into a loam soil in Townsville with a catchment area of 2.0ha, and an average catchment land slope of 5%. 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 20 minutes.

Step 1   A rock-lined drain has been nominated. A review of site conditions indicated that rock of mean (d_{50}) size of 150mm is readily available, and is thus chosen.

Step 2   Choose a parabolic drain profile.

Step 3   Nominate a 1 in 10 year ARI design storm from Table 4.3.1 (Chapter 4).

Step 4   The catchment time of concentration (t_c) is given as 20 minutes.

Step 5   Determine the average rainfall intensity: I = 134mm/hr for Townsville from Table A11 (Appendix A) for ARI = 10-year, and t_c = 20 minutes.

Step 6   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 ($^1I_{10}$) is 91.9mm/hr, the 10-year coefficient of discharge, C_{10} = 0.70 from Table A5 (Appendix A – *Construction site hydrology and hydraulics*).

Thus: C = 0.7 ≤ 1.0 (OK)

also: Q_{10} = (C.I.A)/360 = (0.7 x 134 x 2.0)/360 = 0.521m³/s

Step 7   Calculate the unit catchment area (A*) for the catch drain:

A* = A.C = 2.0 x 0.7 = 1.4ha

Step 8   Given the design discharge (Q) of 0.521m³/s, a review Tables 45 to 50 indicates that it is unlikely that a Type-A or Type-B catch drain will have sufficient hydraulic capacity, thus a Type-C drain is chosen with dimensions: T = 3.0m, Y = 0.5m.

However, no design table is presented for a rock of size, d_{50} = 150mm. From Table 43 it can be determined that when flowing full (y = 0.5m), the hydraulic radius (R) is 0.310m, and the flow area (A) is 1.0m². Also, from Table 44 the Manning's roughness (n) is 0.048, and the maximum allowable flow velocity (V_{allow}) of 1.73m/s is achieved at a channel gradient of 3.35%. At this channel gradient the hydraulic capacity of the drain (Q) can be determined as:

Q_{max} = V_{allow} . A = 1.73 x 1.0 = 1.73m³/s >> Q = 0.521m³/s

Thus the drain has more than adequate hydraulic capacity at a gradient of 3.35%

Step 9   Given the above results, it will be possible to construct a Type-C drain at a gradient less than 3.35%. Manning's equation can be used to determine the minimum gradient (S_{min}) for the rock-lined catch drain.

$$Q = \frac{1}{n} A.R^{2/3} S^{1/2} = \frac{1}{0.048}(1.0)(0.310)^{2/3} S^{1/2} = 0.521$$

therefore; S_{min} = 0.00298 = 0.3%

Note, in the above equation, the term 'A' is the cross-sectional area of the catch drain at a depth of y = 0.5m (determined from Table 43), **not** the catchment area!

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 3.0m, and the flow depth (y) less than 0.5m. *(Note, the drain would still be constructed with the same standard overall physical dimensions specified for all Type-C catch drains.)*

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

$$y = 0.0556 (T)^2$$

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

$$A = 0.67(T.y) = 0.0371 T^3 = Q/V = 0.521/1.73 = 0.301 m^2$$

Therefore, the flow top width, $T = 2.011m$; the flow depth, $y = 0.225m$; and the hydraulic radius (R) can be determined from (Table A29b, Appendix A):

$$R = \frac{2T^2.y}{3T^2 + 8y^2} = \frac{2(2.011)^2 \times 0.225}{3(2.011)^2 + 8(0.225)^2} = 0.145m$$

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

$$S_{max} = 100 \times (V^2 . n^2)/R^{4/3} = 100 \times (1.73^2 \times 0.048^2)/0.145^{4/3} = 9.06\%$$

Therefore, the Type-C catch drain can be constructed at any longitudinal gradient between 0.3% (maximum flow depth) and 9% (maximum flow velocity), and still provide the required hydraulic capacity for the 1 in 10 year design storm. It is noted that constructing the drain at the steeper gradient will result in a construction site with maximum drainage capacity.

However, from the above analysis it was determined than a rock-lined drain with a gradient of 9% would achieve a flow of around 0.521m^3/s at a flow depth of 0.225m which is less than the maximum flow depth for a Type-B catch drain. This means that it now looks possible to construct a smaller Type-B catch drain rather than a Type-C drain.

Further analysis indicates that for a Type-B drain with dimensions (T = 1.8m, Y = 0.3m), mean rock size d_{50} = 150mm, and channel gradient of 9%, the following results can be achieved:

Manning's n = 0.061

Flow velocity = 1.60m/s < 1.73m/s OK

Peak discharge, Q_{max} = 0.577m^3/s < 0.521m^3/s OK

Thus a Type-B drain would be sufficient if a gradient of 9% can be achieved along its length, otherwise adopt a Type-C with a flatter channel gradient.

Table 43 – Dimensions of <u>standard</u> 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 44 – Hydraulic parameters of rock-lined, <u>parabolic</u> cross-section catch drains operating at maximum flow depth (Y)

Mean rock size, d_{50} (mm)	50	100	150	200	300
d_{90} (mm) [1]	75	150	225	300	450
Allowable flow velocity (m/s)	1.00	1.41	1.73	2.00	2.50
Type-A catch drain: width (T) = 1.0 m, depth (Y) = 0.15 m					
Manning's roughness 'n' [3]	0.042	0.066	0.088	0.108	0.148
Maximum channel slope (%)	4.09	[2]	[2]	[2]	[2]
Maximum channel slope (X:1)	24.4	[2]	[2]	[2]	[2]
Type-B catch drain: width (T) = 1.8 m, depth (Y) = 0.3 m					
Manning's roughness 'n' [3]	0.033	0.047	0.061	0.074	0.099
Maximum channel slope (%)	1.00	4.21	[2]	[2]	[2]
Maximum channel slope (X:1)	100.3	23.7	[2]	[2]	[2]
Type-C catch drain: width (T) = 3.0 m, depth (Y) = 0.5 m					
Manning's roughness 'n' [3]	0.029	0.039	0.048	0.058	0.075
Maximum channel slope (%)	0.39	1.43	3.35	6.32	[2]
Maximum channel slope (X:1)	258	70	30	15.8	[2]

[1]   Based on a rock size distribution defined by d_{50}/d_{90} = 0.67, and specific gravity of 2.4

[2]   Theoretical maximum channel slope exceeds 10% (1 in 10) for catch drain flowing at maximum allowable flow depth (Y).

[3]   Manning roughness values (n) are only applicable to the drain flowing full, i.e. depth = Y.
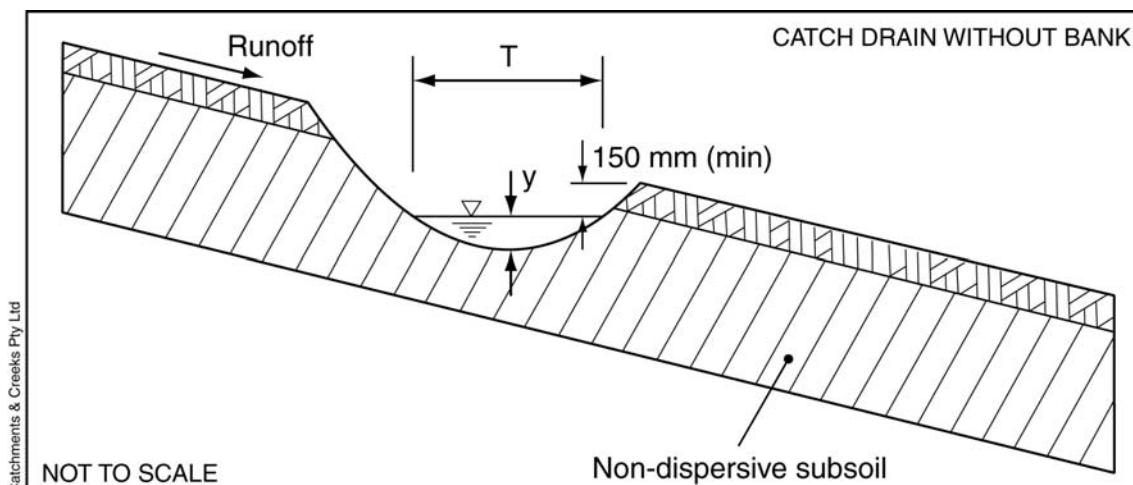
Figure 12(3) – Parabolic catch drain without bank

(Also refer to Part 1 of this fact sheet for diagram of parabolic catch drain with down-slope bank)

Table 45 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-A Catch Drain: Parabolic cross section

Mean rock size (d₅₀) = 100 mm and s_r = 2.4		Variation in rock size (d₅₀/d₉₀) = 0.67		

Mean rock size (d_{50}) = 100 mm and s_r = 2.4   Variation in rock size (d_{50}/d_{90}) = 0.67

Dimensions: Flow top width = 1.0 m   Flow depth = 0.15 m

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
20	0.569	0.804	0.985	1.137	1.271	1.393	1.504	1.608	1.706	1.798
25	0.455	0.643	0.788	0.910	1.017	1.114	1.204	1.287	1.365	1.438
30	0.379	0.536	0.657	0.758	0.848	0.929	1.003	1.072	1.137	1.199
35	0.325	0.460	0.563	0.650	0.727	0.796	0.860	0.919	0.975	1.027
40	0.284	0.402	0.492	0.569	0.636	0.696	0.752	0.804	0.853	0.899
45	0.253	0.357	0.438	0.505	0.565	0.619	0.669	0.715	0.758	0.799
50	0.227	0.322	0.394	0.455	0.509	0.557	0.602	0.643	0.682	0.719
55	0.207	0.292	0.358	0.414	0.462	0.506	0.547	0.585	0.620	0.654
60	0.190	0.268	0.328	0.379	0.424	0.464	0.501	0.536	0.569	0.599
65	0.175	0.247	0.303	0.350	0.391	0.429	0.463	0.495	0.525	0.553
70	0.162	0.230	0.281	0.325	0.363	0.398	0.430	0.460	0.487	0.514
75	0.152	0.214	0.263	0.303	0.339	0.371	0.401	0.429	0.455	0.479
80	0.142	0.201	0.246	0.284	0.318	0.348	0.376	0.402	0.426	0.450
85	0.134	0.189	0.232	0.268	0.299	0.328	0.354	0.378	0.401	0.423
90	0.126	0.179	0.219	0.253	0.283	0.310	0.334	0.357	0.379	0.400
95	0.120	0.169	0.207	0.239	0.268	0.293	0.317	0.339	0.359	0.379
100	0.114	0.161	0.197	0.227	0.254	0.279	0.301	0.322	0.341	0.360
105	0.108	0.153	0.188	0.217	0.242	0.265	0.287	0.306	0.325	0.342
110	0.103	0.146	0.179	0.207	0.231	0.253	0.274	0.292	0.310	0.327
115	0.099	0.140	0.171	0.198	0.221	0.242	0.262	0.280	0.297	0.313
120	0.095	0.134	0.164	0.190	0.212	0.232	0.251	0.268	0.284	0.300
125	0.091	0.129	0.158	0.182	0.203	0.223	0.241	0.257	0.273	0.288
130	0.087	0.124	0.152	0.175	0.196	0.214	0.231	0.247	0.262	0.277
135	0.084	0.119	0.146	0.168	0.188	0.206	0.223	0.238	0.253	0.266
140	0.081	0.115	0.141	0.162	0.182	0.199	0.215	0.230	0.244	0.257
145	0.078	0.111	0.136	0.157	0.175	0.192	0.208	0.222	0.235	0.248
150	0.076	0.107	0.131	0.152	0.170	0.186	0.201	0.214	0.227	0.240
155	0.073	0.104	0.127	0.147	0.164	0.180	0.194	0.208	0.220	0.232
160	0.071	0.101	0.123	0.142	0.159	0.174	0.188	0.201	0.213	0.225
165	0.069	0.097	0.119	0.138	0.154	0.169	0.182	0.195	0.207	0.218
170	0.067	0.095	0.116	0.134	0.150	0.164	0.177	0.189	0.201	0.212
175	0.065	0.092	0.113	0.130	0.145	0.159	0.172	0.184	0.195	0.205
180	0.063	0.089	0.109	0.126	0.141	0.155	0.167	0.179	0.190	0.200
185	0.061	0.087	0.106	0.123	0.137	0.151	0.163	0.174	0.184	0.194
190	0.060	0.085	0.104	0.120	0.134	0.147	0.158	0.169	0.180	0.189
200	0.057	0.080	0.098	0.114	0.127	0.139	0.150	0.161	0.171	0.180
210	0.054	0.077	0.094	0.108	0.121	0.133	0.143	0.153	0.162	0.171
220	0.052	0.073	0.090	0.103	0.116	0.127	0.137	0.146	0.155	0.163
230	0.049	0.070	0.086	0.099	0.111	0.121	0.131	0.140	0.148	0.156
240	0.047	0.067	0.082	0.095	0.106	0.116	0.125	0.134	0.142	0.150
250	0.045	0.064	0.079	0.091	0.102	0.111	0.120	0.129	0.136	0.144
Q (m³/s)	**0.032**	**0.045**	**0.055**	**0.063**	**0.071**	**0.077**	**0.084**	**0.089**	**0.095**	**0.100**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

<table>
<tr><th colspan="11">Table 46 – Maximum allowable unit catchment area (A*, hectares) [1]</th></tr>
<tr><td colspan="11">Type-A Catch Drain: Parabolic cross section</td></tr>
<tr><td colspan="4">Mean rock size (d$_{50}$) = 200 mm and s$_r$ = 2.4</td><td colspan="7">Variation in rock size (d$_{50}$/d$_{90}$) = 0.67</td></tr>
<tr><td colspan="3">Dimensions:</td><td colspan="4">Flow top width = 1.0 m</td><td colspan="4">Flow depth = 0.15 m</td></tr>
<tr><td rowspan="2">Rainfall intensity (mm/hr)</td><td colspan="10">Longitudinal slope of catch drain (%)</td></tr>
<tr><td>1.0</td><td>2.0</td><td>3.0</td><td>4.0</td><td>5.0</td><td>6.0</td><td>7.0</td><td>8.0</td><td>9.0</td><td>10.0</td></tr>
<tr><td>20</td><td>0.344</td><td>0.487</td><td>0.596</td><td>0.689</td><td>0.770</td><td>0.843</td><td>0.911</td><td>0.974</td><td>1.033</td><td>1.089</td></tr>
<tr><td>25</td><td>0.275</td><td>0.390</td><td>0.477</td><td>0.551</td><td>0.616</td><td>0.675</td><td>0.729</td><td>0.779</td><td>0.826</td><td>0.871</td></tr>
<tr><td>30</td><td>0.230</td><td>0.325</td><td>0.398</td><td>0.459</td><td>0.513</td><td>0.562</td><td>0.607</td><td>0.649</td><td>0.689</td><td>0.726</td></tr>
<tr><td>35</td><td>0.197</td><td>0.278</td><td>0.341</td><td>0.394</td><td>0.440</td><td>0.482</td><td>0.521</td><td>0.557</td><td>0.590</td><td>0.622</td></tr>
<tr><td>40</td><td>0.172</td><td>0.243</td><td>0.298</td><td>0.344</td><td>0.385</td><td>0.422</td><td>0.456</td><td>0.487</td><td>0.516</td><td>0.544</td></tr>
<tr><td>45</td><td>0.153</td><td>0.216</td><td>0.265</td><td>0.306</td><td>0.342</td><td>0.375</td><td>0.405</td><td>0.433</td><td>0.459</td><td>0.484</td></tr>
<tr><td>50</td><td>0.138</td><td>0.195</td><td>0.239</td><td>0.275</td><td>0.308</td><td>0.337</td><td>0.364</td><td>0.390</td><td>0.413</td><td>0.436</td></tr>
<tr><td>55</td><td>0.125</td><td>0.177</td><td>0.217</td><td>0.250</td><td>0.280</td><td>0.307</td><td>0.331</td><td>0.354</td><td>0.376</td><td>0.396</td></tr>
<tr><td>60</td><td>0.115</td><td>0.162</td><td>0.199</td><td>0.230</td><td>0.257</td><td>0.281</td><td>0.304</td><td>0.325</td><td>0.344</td><td>0.363</td></tr>
<tr><td>65</td><td>0.106</td><td>0.150</td><td>0.184</td><td>0.212</td><td>0.237</td><td>0.260</td><td>0.280</td><td>0.300</td><td>0.318</td><td>0.335</td></tr>
<tr><td>70</td><td>0.098</td><td>0.139</td><td>0.170</td><td>0.197</td><td>0.220</td><td>0.241</td><td>0.260</td><td>0.278</td><td>0.295</td><td>0.311</td></tr>
<tr><td>75</td><td>0.092</td><td>0.130</td><td>0.159</td><td>0.184</td><td>0.205</td><td>0.225</td><td>0.243</td><td>0.260</td><td>0.275</td><td>0.290</td></tr>
<tr><td>80</td><td>0.086</td><td>0.122</td><td>0.149</td><td>0.172</td><td>0.192</td><td>0.211</td><td>0.228</td><td>0.243</td><td>0.258</td><td>0.272</td></tr>
<tr><td>85</td><td>0.081</td><td>0.115</td><td>0.140</td><td>0.162</td><td>0.181</td><td>0.198</td><td>0.214</td><td>0.229</td><td>0.243</td><td>0.256</td></tr>
<tr><td>90</td><td>0.077</td><td>0.108</td><td>0.133</td><td>0.153</td><td>0.171</td><td>0.187</td><td>0.202</td><td>0.216</td><td>0.230</td><td>0.242</td></tr>
<tr><td>95</td><td>0.072</td><td>0.103</td><td>0.126</td><td>0.145</td><td>0.162</td><td>0.178</td><td>0.192</td><td>0.205</td><td>0.217</td><td>0.229</td></tr>
<tr><td>100</td><td>0.069</td><td>0.097</td><td>0.119</td><td>0.138</td><td>0.154</td><td>0.169</td><td>0.182</td><td>0.195</td><td>0.207</td><td>0.218</td></tr>
<tr><td>105</td><td>0.066</td><td>0.093</td><td>0.114</td><td>0.131</td><td>0.147</td><td>0.161</td><td>0.174</td><td>0.186</td><td>0.197</td><td>0.207</td></tr>
<tr><td>110</td><td>0.063</td><td>0.089</td><td>0.108</td><td>0.125</td><td>0.140</td><td>0.153</td><td>0.166</td><td>0.177</td><td>0.188</td><td>0.198</td></tr>
<tr><td>115</td><td>0.060</td><td>0.085</td><td>0.104</td><td>0.120</td><td>0.134</td><td>0.147</td><td>0.158</td><td>0.169</td><td>0.180</td><td>0.189</td></tr>
<tr><td>120</td><td>0.057</td><td>0.081</td><td>0.099</td><td>0.115</td><td>0.128</td><td>0.141</td><td>0.152</td><td>0.162</td><td>0.172</td><td>0.181</td></tr>
<tr><td>125</td><td>0.055</td><td>0.078</td><td>0.095</td><td>0.110</td><td>0.123</td><td>0.135</td><td>0.146</td><td>0.156</td><td>0.165</td><td>0.174</td></tr>
<tr><td>130</td><td>0.053</td><td>0.075</td><td>0.092</td><td>0.106</td><td>0.118</td><td>0.130</td><td>0.140</td><td>0.150</td><td>0.159</td><td>0.168</td></tr>
<tr><td>135</td><td>0.051</td><td>0.072</td><td>0.088</td><td>0.102</td><td>0.114</td><td>0.125</td><td>0.135</td><td>0.144</td><td>0.153</td><td>0.161</td></tr>
<tr><td>140</td><td>0.049</td><td>0.070</td><td>0.085</td><td>0.098</td><td>0.110</td><td>0.120</td><td>0.130</td><td>0.139</td><td>0.148</td><td>0.156</td></tr>
<tr><td>145</td><td>0.047</td><td>0.067</td><td>0.082</td><td>0.095</td><td>0.106</td><td>0.116</td><td>0.126</td><td>0.134</td><td>0.142</td><td>0.150</td></tr>
<tr><td>150</td><td>0.046</td><td>0.065</td><td>0.080</td><td>0.092</td><td>0.103</td><td>0.112</td><td>0.121</td><td>0.130</td><td>0.138</td><td>0.145</td></tr>
<tr><td>155</td><td>0.044</td><td>0.063</td><td>0.077</td><td>0.089</td><td>0.099</td><td>0.109</td><td>0.118</td><td>0.126</td><td>0.133</td><td>0.141</td></tr>
<tr><td>160</td><td>0.043</td><td>0.061</td><td>0.075</td><td>0.086</td><td>0.096</td><td>0.105</td><td>0.114</td><td>0.122</td><td>0.129</td><td>0.136</td></tr>
<tr><td>165</td><td>0.042</td><td>0.059</td><td>0.072</td><td>0.083</td><td>0.093</td><td>0.102</td><td>0.110</td><td>0.118</td><td>0.125</td><td>0.132</td></tr>
<tr><td>170</td><td>0.041</td><td>0.057</td><td>0.070</td><td>0.081</td><td>0.091</td><td>0.099</td><td>0.107</td><td>0.115</td><td>0.122</td><td>0.128</td></tr>
<tr><td>175</td><td>0.039</td><td>0.056</td><td>0.068</td><td>0.079</td><td>0.088</td><td>0.096</td><td>0.104</td><td>0.111</td><td>0.118</td><td>0.124</td></tr>
<tr><td>180</td><td>0.038</td><td>0.054</td><td>0.066</td><td>0.077</td><td>0.086</td><td>0.094</td><td>0.101</td><td>0.108</td><td>0.115</td><td>0.121</td></tr>
<tr><td>185</td><td>0.037</td><td>0.053</td><td>0.064</td><td>0.074</td><td>0.083</td><td>0.091</td><td>0.098</td><td>0.105</td><td>0.112</td><td>0.118</td></tr>
<tr><td>190</td><td>0.036</td><td>0.051</td><td>0.063</td><td>0.072</td><td>0.081</td><td>0.089</td><td>0.096</td><td>0.103</td><td>0.109</td><td>0.115</td></tr>
<tr><td>200</td><td>0.034</td><td>0.049</td><td>0.060</td><td>0.069</td><td>0.077</td><td>0.084</td><td>0.091</td><td>0.097</td><td>0.103</td><td>0.109</td></tr>
<tr><td>210</td><td>0.033</td><td>0.046</td><td>0.057</td><td>0.066</td><td>0.073</td><td>0.080</td><td>0.087</td><td>0.093</td><td>0.098</td><td>0.104</td></tr>
<tr><td>220</td><td>0.031</td><td>0.044</td><td>0.054</td><td>0.063</td><td>0.070</td><td>0.077</td><td>0.083</td><td>0.089</td><td>0.094</td><td>0.099</td></tr>
<tr><td>230</td><td>0.030</td><td>0.042</td><td>0.052</td><td>0.060</td><td>0.067</td><td>0.073</td><td>0.079</td><td>0.085</td><td>0.090</td><td>0.095</td></tr>
<tr><td>240</td><td>0.029</td><td>0.041</td><td>0.050</td><td>0.057</td><td>0.064</td><td>0.070</td><td>0.076</td><td>0.081</td><td>0.086</td><td>0.091</td></tr>
<tr><td>250</td><td>0.028</td><td>0.039</td><td>0.048</td><td>0.055</td><td>0.062</td><td>0.067</td><td>0.073</td><td>0.078</td><td>0.083</td><td>0.087</td></tr>
<tr><td>Q (m^3/s)</td><td>0.019</td><td>0.027</td><td>0.033</td><td>0.038</td><td>0.043</td><td>0.047</td><td>0.051</td><td>0.054</td><td>0.057</td><td>0.060</td></tr>
</table>

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 47 – Maximum allowable unit catchment area (A*, hectares) [1]										
Type-A Catch Drain: Parabolic cross section										
Mean rock size (d$_{50}$) = 300 mm and s$_r$ = 2.4			Variation in rock size (d$_{50}$/d$_{90}$) = 0.67							
Dimensions:			Flow top width = 1.0 m			Flow depth = 0.15 m				
Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
20	0.252	0.357	0.437	0.505	0.564	0.618	0.667	0.714	0.757	0.798
25	0.202	0.285	0.350	0.404	0.451	0.494	0.534	0.571	0.605	0.638
30	0.168	0.238	0.291	0.336	0.376	0.412	0.445	0.476	0.505	0.532
35	0.144	0.204	0.250	0.288	0.322	0.353	0.381	0.408	0.432	0.456
40	0.126	0.178	0.218	0.252	0.282	0.309	0.334	0.357	0.378	0.399
45	0.112	0.159	0.194	0.224	0.251	0.275	0.297	0.317	0.336	0.355
50	0.101	0.143	0.175	0.202	0.226	0.247	0.267	0.285	0.303	0.319
55	0.092	0.130	0.159	0.183	0.205	0.225	0.243	0.259	0.275	0.290
60	0.084	0.119	0.146	0.168	0.188	0.206	0.222	0.238	0.252	0.266
65	0.078	0.110	0.134	0.155	0.174	0.190	0.205	0.220	0.233	0.245
70	0.072	0.102	0.125	0.144	0.161	0.177	0.191	0.204	0.216	0.228
75	0.067	0.095	0.117	0.135	0.150	0.165	0.178	0.190	0.202	0.213
80	0.063	0.089	0.109	0.126	0.141	0.154	0.167	0.178	0.189	0.199
85	0.059	0.084	0.103	0.119	0.133	0.145	0.157	0.168	0.178	0.188
90	0.056	0.079	0.097	0.112	0.125	0.137	0.148	0.159	0.168	0.177
95	0.053	0.075	0.092	0.106	0.119	0.130	0.141	0.150	0.159	0.168
100	0.050	0.071	0.087	0.101	0.113	0.124	0.133	0.143	0.151	0.160
105	0.048	0.068	0.083	0.096	0.107	0.118	0.127	0.136	0.144	0.152
110	0.046	0.065	0.079	0.092	0.103	0.112	0.121	0.130	0.138	0.145
115	0.044	0.062	0.076	0.088	0.098	0.107	0.116	0.124	0.132	0.139
120	0.042	0.059	0.073	0.084	0.094	0.103	0.111	0.119	0.126	0.133
125	0.040	0.057	0.070	0.081	0.090	0.099	0.107	0.114	0.121	0.128
130	0.039	0.055	0.067	0.078	0.087	0.095	0.103	0.110	0.116	0.123
135	0.037	0.053	0.065	0.075	0.084	0.092	0.099	0.106	0.112	0.118
140	0.036	0.051	0.062	0.072	0.081	0.088	0.095	0.102	0.108	0.114
145	0.035	0.049	0.060	0.070	0.078	0.085	0.092	0.098	0.104	0.110
150	0.034	0.048	0.058	0.067	0.075	0.082	0.089	0.095	0.101	0.106
155	0.033	0.046	0.056	0.065	0.073	0.080	0.086	0.092	0.098	0.103
160	0.032	0.045	0.055	0.063	0.071	0.077	0.083	0.089	0.095	0.100
165	0.031	0.043	0.053	0.061	0.068	0.075	0.081	0.086	0.092	0.097
170	0.030	0.042	0.051	0.059	0.066	0.073	0.079	0.084	0.089	0.094
175	0.029	0.041	0.050	0.058	0.064	0.071	0.076	0.082	0.086	0.091
180	0.028	0.040	0.049	0.056	0.063	0.069	0.074	0.079	0.084	0.089
185	0.027	0.039	0.047	0.055	0.061	0.067	0.072	0.077	0.082	0.086
190	0.027	0.038	0.046	0.053	0.059	0.065	0.070	0.075	0.080	0.084
200	0.025	0.036	0.044	0.050	0.056	0.062	0.067	0.071	0.076	0.080
210	0.024	0.034	0.042	0.048	0.054	0.059	0.064	0.068	0.072	0.076
220	0.023	0.032	0.040	0.046	0.051	0.056	0.061	0.065	0.069	0.073
230	0.022	0.031	0.038	0.044	0.049	0.054	0.058	0.062	0.066	0.069
240	0.021	0.030	0.036	0.042	0.047	0.051	0.056	0.059	0.063	0.066
250	0.020	0.029	0.035	0.040	0.045	0.049	0.053	0.057	0.061	0.064
Q (m^3/s)	**0.014**	**0.020**	**0.024**	**0.028**	**0.031**	**0.034**	**0.037**	**0.040**	**0.042**	**0.044**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 48 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-B Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 100 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		Flow top width = 1.8 m			Flow depth = 0.3 m				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	5.953	8.418	10.310	11.905	Allowable unit catchment areas presented in the columns below are limited by the allowable flow velocity					
20	4.465	6.314	7.733	8.929						
25	3.572	5.051	6.186	7.143						
30	2.976	4.209	5.155	5.953	5.389	4.729	4.227	3.858	3.585	3.330
35	2.551	3.608	4.419	5.102	4.619	4.053	3.623	3.307	3.073	2.854
40	2.232	3.157	3.866	4.465	4.041	3.547	3.170	2.893	2.689	2.497
45	1.984	2.806	3.437	3.968	3.592	3.153	2.818	2.572	2.390	2.220
50	1.786	2.526	3.093	3.572	3.233	2.837	2.536	2.315	2.151	1.998
55	1.623	2.296	2.812	3.247	2.939	2.579	2.306	2.104	1.956	1.816
60	1.488	2.105	2.578	2.976	2.694	2.364	2.114	1.929	1.793	1.665
65	1.374	1.943	2.379	2.747	2.487	2.183	1.951	1.780	1.655	1.537
70	1.276	1.804	2.209	2.551	2.309	2.027	1.812	1.653	1.537	1.427
75	1.191	1.684	2.062	2.381	2.155	1.892	1.691	1.543	1.434	1.332
80	1.116	1.578	1.933	2.232	2.021	1.773	1.585	1.447	1.345	1.249
85	1.050	1.486	1.819	2.101	1.902	1.669	1.492	1.362	1.265	1.175
90	0.992	1.403	1.718	1.984	1.796	1.576	1.409	1.286	1.195	1.110
95	0.940	1.329	1.628	1.880	1.702	1.493	1.335	1.218	1.132	1.052
100	0.893	1.263	1.547	1.786	1.617	1.419	1.268	1.157	1.076	0.999
105	0.850	1.203	1.473	1.701	1.540	1.351	1.208	1.102	1.024	0.951
110	0.812	1.148	1.406	1.623	1.470	1.290	1.153	1.052	0.978	0.908
115	0.776	1.098	1.345	1.553	1.406	1.234	1.103	1.006	0.935	0.869
120	0.744	1.052	1.289	1.488	1.347	1.182	1.057	0.964	0.896	0.832
125	0.714	1.010	1.237	1.429	1.293	1.135	1.015	0.926	0.861	0.799
130	0.687	0.971	1.190	1.374	1.244	1.091	0.976	0.890	0.827	0.768
135	0.661	0.935	1.146	1.323	1.197	1.051	0.939	0.857	0.797	0.740
140	0.638	0.902	1.105	1.276	1.155	1.013	0.906	0.827	0.768	0.714
145	0.616	0.871	1.067	1.232	1.115	0.978	0.875	0.798	0.742	0.689
150	0.595	0.842	1.031	1.191	1.078	0.946	0.845	0.772	0.717	0.666
155	0.576	0.815	0.998	1.152	1.043	0.915	0.818	0.747	0.694	0.645
160	0.558	0.789	0.967	1.116	1.010	0.887	0.793	0.723	0.672	0.624
165	0.541	0.765	0.937	1.082	0.980	0.860	0.769	0.701	0.652	0.605
170	0.525	0.743	0.910	1.050	0.951	0.835	0.746	0.681	0.633	0.588
175	0.510	0.722	0.884	1.020	0.924	0.811	0.725	0.661	0.615	0.571
180	0.496	0.702	0.859	0.992	0.898	0.788	0.705	0.643	0.598	0.555
185	0.483	0.683	0.836	0.965	0.874	0.767	0.685	0.626	0.581	0.540
190	0.470	0.665	0.814	0.940	0.851	0.747	0.667	0.609	0.566	0.526
200	0.446	0.631	0.773	0.893	0.808	0.709	0.634	0.579	0.538	0.499
210	0.425	0.601	0.736	0.850	0.770	0.676	0.604	0.551	0.512	0.476
220	0.406	0.574	0.703	0.812	0.735	0.645	0.576	0.526	0.489	0.454
230	0.388	0.549	0.672	0.776	0.703	0.617	0.551	0.503	0.468	0.434
240	0.372	0.526	0.644	0.744	0.674	0.591	0.528	0.482	0.448	0.416
Q (m^3/s)	0.248	0.351	0.430	0.496	0.449	0.394	0.352	0.321	0.299	0.277

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 49 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-B Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 200 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67			

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

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
20	2.850	4.030	4.936	5.700	6.372	6.981	7.540	8.060	8.549	9.012
25	2.280	3.224	3.949	4.560	5.098	5.584	6.032	6.448	6.840	7.210
30	1.900	2.687	3.291	3.800	4.248	4.654	5.027	5.374	5.700	6.008
35	1.628	2.303	2.821	3.257	3.641	3.989	4.309	4.606	4.885	5.150
40	1.425	2.015	2.468	2.850	3.186	3.490	3.770	4.030	4.275	4.506
45	1.267	1.791	2.194	2.533	2.832	3.102	3.351	3.582	3.800	4.005
50	1.140	1.612	1.974	2.280	2.549	2.792	3.016	3.224	3.420	3.605
55	1.036	1.466	1.795	2.073	2.317	2.538	2.742	2.931	3.109	3.277
60	0.950	1.343	1.645	1.900	2.124	2.327	2.513	2.687	2.850	3.004
65	0.877	1.240	1.519	1.754	1.961	2.148	2.320	2.480	2.631	2.773
70	0.814	1.151	1.410	1.628	1.821	1.994	2.154	2.303	2.443	2.575
75	0.760	1.075	1.316	1.520	1.699	1.861	2.011	2.149	2.280	2.403
80	0.712	1.008	1.234	1.425	1.593	1.745	1.885	2.015	2.137	2.253
85	0.671	0.948	1.161	1.341	1.499	1.642	1.774	1.897	2.012	2.120
90	0.633	0.896	1.097	1.267	1.416	1.551	1.676	1.791	1.900	2.003
95	0.600	0.848	1.039	1.200	1.342	1.470	1.587	1.697	1.800	1.897
100	0.570	0.806	0.987	1.140	1.274	1.396	1.508	1.612	1.710	1.802
105	0.543	0.768	0.940	1.086	1.214	1.330	1.436	1.535	1.628	1.717
110	0.518	0.733	0.897	1.036	1.159	1.269	1.371	1.466	1.554	1.639
115	0.496	0.701	0.858	0.991	1.108	1.214	1.311	1.402	1.487	1.567
120	0.475	0.672	0.823	0.950	1.062	1.163	1.257	1.343	1.425	1.502
125	0.456	0.645	0.790	0.912	1.020	1.117	1.206	1.290	1.368	1.442
130	0.438	0.620	0.759	0.877	0.980	1.074	1.160	1.240	1.315	1.386
135	0.422	0.597	0.731	0.844	0.944	1.034	1.117	1.194	1.267	1.335
140	0.407	0.576	0.705	0.814	0.910	0.997	1.077	1.151	1.221	1.287
145	0.393	0.556	0.681	0.786	0.879	0.963	1.040	1.112	1.179	1.243
150	0.380	0.537	0.658	0.760	0.850	0.931	1.005	1.075	1.140	1.202
155	0.368	0.520	0.637	0.735	0.822	0.901	0.973	1.040	1.103	1.163
160	0.356	0.504	0.617	0.712	0.797	0.873	0.942	1.008	1.069	1.126
165	0.345	0.489	0.598	0.691	0.772	0.846	0.914	0.977	1.036	1.092
170	0.335	0.474	0.581	0.671	0.750	0.821	0.887	0.948	1.006	1.060
175	0.326	0.461	0.564	0.651	0.728	0.798	0.862	0.921	0.977	1.030
180	0.317	0.448	0.548	0.633	0.708	0.776	0.838	0.896	0.950	1.001
185	0.308	0.436	0.534	0.616	0.689	0.755	0.815	0.871	0.924	0.974
190	0.300	0.424	0.520	0.600	0.671	0.735	0.794	0.848	0.900	0.949
200	0.285	0.403	0.494	0.570	0.637	0.698	0.754	0.806	0.855	0.901
210	0.271	0.384	0.470	0.543	0.607	0.665	0.718	0.768	0.814	0.858
220	0.259	0.366	0.449	0.518	0.579	0.635	0.685	0.733	0.777	0.819
230	0.248	0.350	0.429	0.496	0.554	0.607	0.656	0.701	0.743	0.784
240	0.237	0.336	0.411	0.475	0.531	0.582	0.628	0.672	0.712	0.751
250	0.228	0.322	0.395	0.456	0.510	0.558	0.603	0.645	0.684	0.721
Q (m^3/s)	0.158	0.224	0.274	0.317	0.354	0.388	0.419	0.448	0.475	0.501

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 50 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-B Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 300 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		**Flow top width = 1.8 m**			**Flow depth = 0.3 m**				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
20	2.135	3.020	3.698	4.271	4.775	5.230	5.649	6.040	6.406	6.752
25	1.708	2.416	2.959	3.416	3.820	4.184	4.520	4.832	5.125	5.402
30	1.424	2.013	2.466	2.847	3.183	3.487	3.766	4.026	4.271	4.502
35	1.220	1.726	2.113	2.440	2.728	2.989	3.228	3.451	3.661	3.859
40	1.068	1.510	1.849	2.135	2.387	2.615	2.825	3.020	3.203	3.376
45	0.949	1.342	1.644	1.898	2.122	2.325	2.511	2.684	2.847	3.001
50	0.854	1.208	1.479	1.708	1.910	2.092	2.260	2.416	2.562	2.701
55	0.776	1.098	1.345	1.553	1.736	1.902	2.054	2.196	2.329	2.455
60	0.712	1.007	1.233	1.424	1.592	1.743	1.883	2.013	2.135	2.251
65	0.657	0.929	1.138	1.314	1.469	1.609	1.738	1.858	1.971	2.078
70	0.610	0.863	1.057	1.220	1.364	1.494	1.614	1.726	1.830	1.929
75	0.569	0.805	0.986	1.139	1.273	1.395	1.507	1.611	1.708	1.801
80	0.534	0.755	0.925	1.068	1.194	1.308	1.412	1.510	1.601	1.688
85	0.502	0.711	0.870	1.005	1.123	1.231	1.329	1.421	1.507	1.589
90	0.475	0.671	0.822	0.949	1.061	1.162	1.255	1.342	1.424	1.501
95	0.450	0.636	0.779	0.899	1.005	1.101	1.189	1.271	1.349	1.422
100	0.427	0.604	0.740	0.854	0.955	1.046	1.130	1.208	1.281	1.350
105	0.407	0.575	0.704	0.813	0.909	0.996	1.076	1.150	1.220	1.286
110	0.388	0.549	0.672	0.776	0.868	0.951	1.027	1.098	1.165	1.228
115	0.371	0.525	0.643	0.743	0.830	0.910	0.983	1.050	1.114	1.174
120	0.356	0.503	0.616	0.712	0.796	0.872	0.942	1.007	1.068	1.125
125	0.342	0.483	0.592	0.683	0.764	0.837	0.904	0.966	1.025	1.080
130	0.329	0.465	0.569	0.657	0.735	0.805	0.869	0.929	0.986	1.039
135	0.316	0.447	0.548	0.633	0.707	0.775	0.837	0.895	0.949	1.000
140	0.305	0.431	0.528	0.610	0.682	0.747	0.807	0.863	0.915	0.965
145	0.295	0.417	0.510	0.589	0.659	0.721	0.779	0.833	0.884	0.931
150	0.285	0.403	0.493	0.569	0.637	0.697	0.753	0.805	0.854	0.900
155	0.276	0.390	0.477	0.551	0.616	0.675	0.729	0.779	0.827	0.871
160	0.267	0.377	0.462	0.534	0.597	0.654	0.706	0.755	0.801	0.844
165	0.259	0.366	0.448	0.518	0.579	0.634	0.685	0.732	0.776	0.818
170	0.251	0.355	0.435	0.502	0.562	0.615	0.665	0.711	0.754	0.794
175	0.244	0.345	0.423	0.488	0.546	0.598	0.646	0.690	0.732	0.772
180	0.237	0.336	0.411	0.475	0.531	0.581	0.628	0.671	0.712	0.750
185	0.231	0.326	0.400	0.462	0.516	0.565	0.611	0.653	0.693	0.730
190	0.225	0.318	0.389	0.450	0.503	0.551	0.595	0.636	0.674	0.711
200	0.214	0.302	0.370	0.427	0.477	0.523	0.565	0.604	0.641	0.675
210	0.203	0.288	0.352	0.407	0.455	0.498	0.538	0.575	0.610	0.643
220	0.194	0.275	0.336	0.388	0.434	0.475	0.514	0.549	0.582	0.614
230	0.186	0.263	0.322	0.371	0.415	0.455	0.491	0.525	0.557	0.587
240	0.178	0.252	0.308	0.356	0.398	0.436	0.471	0.503	0.534	0.563
250	0.171	0.242	0.296	0.342	0.382	0.418	0.452	0.483	0.512	0.540
Q (m^3/s)	**0.119**	**0.168**	**0.205**	**0.237**	**0.265**	**0.291**	**0.314**	**0.336**	**0.356**	**0.375**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 51 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-C Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 100 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		Flow top width = 3.0 m			Flow depth = 0.5 m				
Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)								
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	28.36	Allowable unit catchment areas presented in the columns below are limited								
20	21.27	by the allowable flow velocity								
25	17.02	15.66	11.56	9.34	8.04	7.07	6.35	5.83	5.33	5.00
30	14.18	13.05	9.63	7.79	6.70	5.89	5.29	4.86	4.45	4.17
35	12.16	11.19	8.26	6.67	5.74	5.05	4.53	4.17	3.81	3.57
40	10.64	9.79	7.23	5.84	5.02	4.42	3.97	3.65	3.33	3.12
45	9.45	8.70	6.42	5.19	4.47	3.93	3.53	3.24	2.96	2.78
50	8.51	7.83	5.78	4.67	4.02	3.53	3.17	2.92	2.67	2.50
55	7.74	7.12	5.25	4.25	3.65	3.21	2.89	2.65	2.42	2.27
60	7.09	6.53	4.82	3.89	3.35	2.95	2.65	2.43	2.22	2.08
65	6.55	6.02	4.45	3.59	3.09	2.72	2.44	2.24	2.05	1.92
70	6.08	5.59	4.13	3.34	2.87	2.52	2.27	2.08	1.91	1.79
75	5.67	5.22	3.85	3.11	2.68	2.36	2.12	1.94	1.78	1.67
80	5.32	4.90	3.61	2.92	2.51	2.21	1.98	1.82	1.67	1.56
85	5.01	4.61	3.40	2.75	2.36	2.08	1.87	1.72	1.57	1.47
90	4.73	4.35	3.21	2.60	2.23	1.96	1.76	1.62	1.48	1.39
95	4.48	4.12	3.04	2.46	2.12	1.86	1.67	1.54	1.40	1.32
100	4.25	3.92	2.89	2.34	2.01	1.77	1.59	1.46	1.33	1.25
105	4.05	3.73	2.75	2.22	1.91	1.68	1.51	1.39	1.27	1.19
110	3.87	3.56	2.63	2.12	1.83	1.61	1.44	1.33	1.21	1.14
115	3.70	3.41	2.51	2.03	1.75	1.54	1.38	1.27	1.16	1.09
120	3.55	3.26	2.41	1.95	1.67	1.47	1.32	1.22	1.11	1.04
125	3.40	3.13	2.31	1.87	1.61	1.41	1.27	1.17	1.07	1.00
130	3.27	3.01	2.22	1.80	1.55	1.36	1.22	1.12	1.03	0.96
135	3.15	2.90	2.14	1.73	1.49	1.31	1.18	1.08	0.99	0.93
140	3.04	2.80	2.06	1.67	1.44	1.26	1.13	1.04	0.95	0.89
145	2.93	2.70	1.99	1.61	1.39	1.22	1.09	1.01	0.92	0.86
150	2.84	2.61	1.93	1.56	1.34	1.18	1.06	0.97	0.89	0.83
155	2.74	2.53	1.86	1.51	1.30	1.14	1.02	0.94	0.86	0.81
160	2.66	2.45	1.81	1.46	1.26	1.10	0.99	0.91	0.83	0.78
165	2.58	2.37	1.75	1.42	1.22	1.07	0.96	0.88	0.81	0.76
170	2.50	2.30	1.70	1.37	1.18	1.04	0.93	0.86	0.78	0.74
175	2.43	2.24	1.65	1.33	1.15	1.01	0.91	0.83	0.76	0.71
180	2.36	2.18	1.61	1.30	1.12	0.98	0.88	0.81	0.74	0.69
185	2.30	2.12	1.56	1.26	1.09	0.96	0.86	0.79	0.72	0.68
190	2.24	2.06	1.52	1.23	1.06	0.93	0.84	0.77	0.70	0.66
200	2.13	1.96	1.45	1.17	1.00	0.88	0.79	0.73	0.67	0.62
210	2.03	1.86	1.38	1.11	0.96	0.84	0.76	0.69	0.64	0.60
220	1.93	1.78	1.31	1.06	0.91	0.80	0.72	0.66	0.61	0.57
230	1.85	1.70	1.26	1.02	0.87	0.77	0.69	0.63	0.58	0.54
240	1.77	1.63	1.20	0.97	0.84	0.74	0.66	0.61	0.56	0.52
Q (m^3/s)	1.182	1.088	0.803	0.649	0.558	0.491	0.441	0.405	0.370	0.347

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 52 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-C Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 200 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		Flow top width = 3.0 m			Flow depth = 0.5 m				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	19.09	27.00	33.07	38.18	42.69	46.76	Allowable unit catchment areas presented in the columns below are limited by the allowable flow velocity			
20	14.32	20.25	24.80	28.64	32.02	35.07				
25	11.45	16.20	19.84	22.91	25.61	28.06				
30	9.55	13.50	16.53	19.09	21.34	23.38				
35	8.18	11.57	14.17	16.36	18.29	20.04	19.08	17.36	16.07	14.86
40	7.16	10.12	12.40	14.32	16.01	17.54	16.70	15.19	14.07	13.00
45	6.36	9.00	11.02	12.73	14.23	15.59	14.84	13.50	12.50	11.56
50	5.73	8.10	9.92	11.45	12.81	14.03	13.36	12.15	11.25	10.40
55	5.21	7.36	9.02	10.41	11.64	12.75	12.14	11.05	10.23	9.46
60	4.77	6.75	8.27	9.55	10.67	11.69	11.13	10.13	9.38	8.67
65	4.41	6.23	7.63	8.81	9.85	10.79	10.28	9.35	8.66	8.00
70	4.09	5.79	7.09	8.18	9.15	10.02	9.54	8.68	8.04	7.43
75	3.82	5.40	6.61	7.64	8.54	9.35	8.91	8.10	7.50	6.93
80	3.58	5.06	6.20	7.16	8.00	8.77	8.35	7.60	7.03	6.50
85	3.37	4.76	5.84	6.74	7.53	8.25	7.86	7.15	6.62	6.12
90	3.18	4.50	5.51	6.36	7.11	7.79	7.42	6.75	6.25	5.78
95	3.01	4.26	5.22	6.03	6.74	7.38	7.03	6.40	5.92	5.47
100	2.86	4.05	4.96	5.73	6.40	7.01	6.68	6.08	5.63	5.20
105	2.73	3.86	4.72	5.45	6.10	6.68	6.36	5.79	5.36	4.95
110	2.60	3.68	4.51	5.21	5.82	6.38	6.07	5.52	5.11	4.73
115	2.49	3.52	4.31	4.98	5.57	6.10	5.81	5.28	4.89	4.52
120	2.39	3.37	4.13	4.77	5.34	5.85	5.57	5.06	4.69	4.33
125	2.29	3.24	3.97	4.58	5.12	5.61	5.34	4.86	4.50	4.16
130	2.20	3.12	3.82	4.41	4.93	5.40	5.14	4.67	4.33	4.00
135	2.12	3.00	3.67	4.24	4.74	5.20	4.95	4.50	4.17	3.85
140	2.05	2.89	3.54	4.09	4.57	5.01	4.77	4.34	4.02	3.71
145	1.97	2.79	3.42	3.95	4.42	4.84	4.61	4.19	3.88	3.59
150	1.91	2.70	3.31	3.82	4.27	4.68	4.45	4.05	3.75	3.47
155	1.85	2.61	3.20	3.69	4.13	4.53	4.31	3.92	3.63	3.36
160	1.79	2.53	3.10	3.58	4.00	4.38	4.17	3.80	3.52	3.25
165	1.74	2.45	3.01	3.47	3.88	4.25	4.05	3.68	3.41	3.15
170	1.68	2.38	2.92	3.37	3.77	4.13	3.93	3.57	3.31	3.06
175	1.64	2.31	2.83	3.27	3.66	4.01	3.82	3.47	3.21	2.97
180	1.59	2.25	2.76	3.18	3.56	3.90	3.71	3.38	3.13	2.89
185	1.55	2.19	2.68	3.10	3.46	3.79	3.61	3.28	3.04	2.81
190	1.51	2.13	2.61	3.01	3.37	3.69	3.52	3.20	2.96	2.74
200	1.43	2.02	2.48	2.86	3.20	3.51	3.34	3.04	2.81	2.60
210	1.36	1.93	2.36	2.73	3.05	3.34	3.18	2.89	2.68	2.48
220	1.30	1.84	2.25	2.60	2.91	3.19	3.04	2.76	2.56	2.36
230	1.25	1.76	2.16	2.49	2.78	3.05	2.90	2.64	2.45	2.26
240	1.19	1.69	2.07	2.39	2.67	2.92	2.78	2.53	2.34	2.17
Q (m^3/s)	0.795	1.125	1.378	1.591	1.779	1.948	1.855	1.688	1.563	1.445

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 53 – Maximum allowable unit catchment area (A*, hectares)										

Type-C Catch Drain: Parabolic cross section

Mean rock size (d_{50}) = 300 mm and s_r = 2.4			Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:			Flow top width = 3.0 m			Flow depth = 0.5 m				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
20	10.98	15.53	19.03	21.97	24.56	26.91	29.06	31.07	32.95	34.74
25	8.79	12.43	15.22	17.58	19.65	21.53	23.25	24.86	26.36	27.79
30	7.32	10.36	12.68	14.65	16.38	17.94	19.38	20.71	21.97	23.16
35	6.28	8.88	10.87	12.55	14.04	15.38	16.61	17.75	18.83	19.85
40	5.49	7.77	9.51	10.98	12.28	13.45	14.53	15.53	16.48	17.37
45	4.88	6.90	8.46	9.76	10.92	11.96	12.92	13.81	14.65	15.44
50	4.39	6.21	7.61	8.79	9.83	10.76	11.63	12.43	13.18	13.89
55	3.99	5.65	6.92	7.99	8.93	9.78	10.57	11.30	11.98	12.63
60	3.66	5.18	6.34	7.32	8.19	8.97	9.69	10.36	10.98	11.58
65	3.38	4.78	5.85	6.76	7.56	8.28	8.94	9.56	10.14	10.69
70	3.14	4.44	5.44	6.28	7.02	7.69	8.30	8.88	9.42	9.92
75	2.93	4.14	5.07	5.86	6.55	7.18	7.75	8.29	8.79	9.26
80	2.75	3.88	4.76	5.49	6.14	6.73	7.27	7.77	8.24	8.68
85	2.58	3.66	4.48	5.17	5.78	6.33	6.84	7.31	7.75	8.17
90	2.44	3.45	4.23	4.88	5.46	5.98	6.46	6.90	7.32	7.72
95	2.31	3.27	4.01	4.63	5.17	5.66	6.12	6.54	6.94	7.31
100	2.20	3.11	3.81	4.39	4.91	5.38	5.81	6.21	6.59	6.95
105	2.09	2.96	3.62	4.18	4.68	5.13	5.54	5.92	6.28	6.62
110	2.00	2.82	3.46	3.99	4.47	4.89	5.28	5.65	5.99	6.32
115	1.91	2.70	3.31	3.82	4.27	4.68	5.05	5.40	5.73	6.04
120	1.83	2.59	3.17	3.66	4.09	4.48	4.84	5.18	5.49	5.79
125	1.76	2.49	3.04	3.52	3.93	4.31	4.65	4.97	5.27	5.56
130	1.69	2.39	2.93	3.38	3.78	4.14	4.47	4.78	5.07	5.34
135	1.63	2.30	2.82	3.25	3.64	3.99	4.31	4.60	4.88	5.15
140	1.57	2.22	2.72	3.14	3.51	3.84	4.15	4.44	4.71	4.96
145	1.52	2.14	2.62	3.03	3.39	3.71	4.01	4.29	4.55	4.79
150	1.46	2.07	2.54	2.93	3.28	3.59	3.88	4.14	4.39	4.63
155	1.42	2.00	2.45	2.83	3.17	3.47	3.75	4.01	4.25	4.48
160	1.37	1.94	2.38	2.75	3.07	3.36	3.63	3.88	4.12	4.34
165	1.33	1.88	2.31	2.66	2.98	3.26	3.52	3.77	3.99	4.21
170	1.29	1.83	2.24	2.58	2.89	3.17	3.42	3.66	3.88	4.09
175	1.26	1.78	2.17	2.51	2.81	3.08	3.32	3.55	3.77	3.97
180	1.22	1.73	2.11	2.44	2.73	2.99	3.23	3.45	3.66	3.86
185	1.19	1.68	2.06	2.38	2.66	2.91	3.14	3.36	3.56	3.76
190	1.16	1.64	2.00	2.31	2.59	2.83	3.06	3.27	3.47	3.66
200	1.10	1.55	1.90	2.20	2.46	2.69	2.91	3.11	3.30	3.47
210	1.05	1.48	1.81	2.09	2.34	2.56	2.77	2.96	3.14	3.31
220	1.00	1.41	1.73	2.00	2.23	2.45	2.64	2.82	3.00	3.16
230	0.96	1.35	1.65	1.91	2.14	2.34	2.53	2.70	2.87	3.02
240	0.92	1.29	1.59	1.83	2.05	2.24	2.42	2.59	2.75	2.89
250	0.88	1.24	1.52	1.76	1.97	2.15	2.33	2.49	2.64	2.78
Q (m^3/s)	0.610	0.863	1.057	1.221	1.365	1.495	1.615	1.726	1.831	1.930

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 44).

Table 54 – Dimensions of <u>standard</u> 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 55 – Hydraulic parameters of rock-lined, <u>V-drain</u> cross-section catch drains operating full, and at the maximum allowable channel slope

Mean rock size, d_{50} (mm)	50	100	150	200	300
d_{90} (mm) [1]	75	150	225	300	450
Allowable flow velocity (m/s)	1.00	1.41	1.73	2.00	2.45
Type-AV catch drain: width (T) = 1.0 m, depth (Y) = 0.15 m					
Manning's roughness 'n' [3]	0.047	0.076	0.102	0.127	0.175
Maximum channel slope (%)	7.53	[2]	[2]	[2]	[2]
Maximum channel slope (X:1)	13.3	[2]	[2]	[2]	[2]
Type-BV catch drain: width (T) = 1.8 m, depth (Y) = 0.3 m					
Manning's roughness 'n' [3]	0.036	0.053	0.070	0.086	0.116
Maximum channel slope (%)	1.71	7.69	[2]	[2]	[2]
Maximum channel slope (X:1)	58.5	13.0	[2]	[2]	[2]
Type-CV catch drain: width (T) = 3.0 m, depth (Y) = 0.5 m					
Manning's roughness 'n' [3]	0.030	0.043	0.054	0.066	0.087
Maximum channel slope (%)	0.63	2.50	6.06	[2]	[2]
Maximum channel slope (X:1)	159	40	16.5	[2]	[2]

[1] Based on a rock size distribution defined by d_{50}/d_{90} = 0.67, and specific gravity of 2.4

[2] Theoretical maximum channel slope exceeds 10% (1 in 10) for catch drain flowing at maximum allowable flow depth (Y).

[3] Manning roughness values (n) are only applicable to the drain flowing full, i.e. depth = Y.
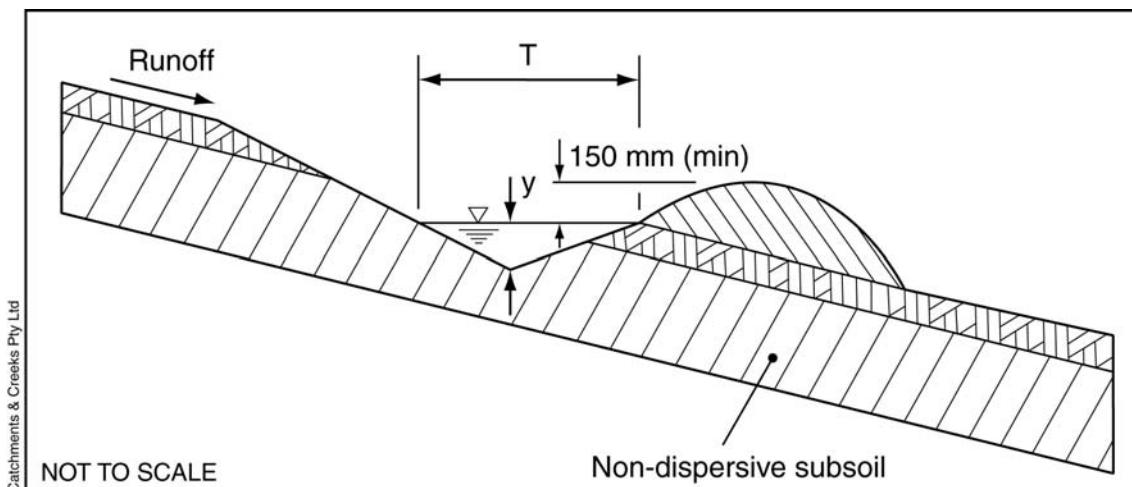
Figure 13(2) – Triangular V-drain with down-slope bank (from Part 1)

Table 56 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-AV Catch Drain: V-drain cross section

Mean rock size (d_{50}) = 100 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		**Flow top width = 1.0 m**			**Flow depth = 0.15 m**				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
15	0.410	0.579	0.709	0.819	0.916	1.003	1.084	1.158	1.229	1.295
20	0.307	0.434	0.532	0.614	0.687	0.752	0.813	0.869	0.922	0.971
25	0.246	0.348	0.426	0.491	0.549	0.602	0.650	0.695	0.737	0.777
30	0.205	0.290	0.355	0.410	0.458	0.502	0.542	0.579	0.614	0.648
35	0.176	0.248	0.304	0.351	0.392	0.430	0.464	0.496	0.527	0.555
40	0.154	0.217	0.266	0.307	0.343	0.376	0.406	0.434	0.461	0.486
45	0.137	0.193	0.236	0.273	0.305	0.334	0.361	0.386	0.410	0.432
50	0.123	0.174	0.213	0.246	0.275	0.301	0.325	0.348	0.369	0.389
55	0.112	0.158	0.193	0.223	0.250	0.274	0.296	0.316	0.335	0.353
60	0.102	0.145	0.177	0.205	0.229	0.251	0.271	0.290	0.307	0.324
65	0.095	0.134	0.164	0.189	0.211	0.232	0.250	0.267	0.284	0.299
70	0.088	0.124	0.152	0.176	0.196	0.215	0.232	0.248	0.263	0.278
75	0.082	0.116	0.142	0.164	0.183	0.201	0.217	0.232	0.246	0.259
80	0.077	0.109	0.133	0.154	0.172	0.188	0.203	0.217	0.230	0.243
85	0.072	0.102	0.125	0.145	0.162	0.177	0.191	0.204	0.217	0.229
90	0.068	0.097	0.118	0.137	0.153	0.167	0.181	0.193	0.205	0.216
95	0.065	0.091	0.112	0.129	0.145	0.158	0.171	0.183	0.194	0.204
100	0.061	0.087	0.106	0.123	0.137	0.150	0.163	0.174	0.184	0.194
105	0.059	0.083	0.101	0.117	0.131	0.143	0.155	0.165	0.176	0.185
110	0.056	0.079	0.097	0.112	0.125	0.137	0.148	0.158	0.168	0.177
115	0.053	0.076	0.093	0.107	0.119	0.131	0.141	0.151	0.160	0.169
120	0.051	0.072	0.089	0.102	0.114	0.125	0.135	0.145	0.154	0.162
125	0.049	0.070	0.085	0.098	0.110	0.120	0.130	0.139	0.147	0.155
130	0.047	0.067	0.082	0.095	0.106	0.116	0.125	0.134	0.142	0.149
135	0.046	0.064	0.079	0.091	0.102	0.111	0.120	0.129	0.137	0.144
140	0.044	0.062	0.076	0.088	0.098	0.107	0.116	0.124	0.132	0.139
145	0.042	0.060	0.073	0.085	0.095	0.104	0.112	0.120	0.127	0.134
150	0.041	0.058	0.071	0.082	0.092	0.100	0.108	0.116	0.123	0.130
155	0.040	0.056	0.069	0.079	0.089	0.097	0.105	0.112	0.119	0.125
160	0.038	0.054	0.067	0.077	0.086	0.094	0.102	0.109	0.115	0.121
165	0.037	0.053	0.064	0.074	0.083	0.091	0.099	0.105	0.112	0.118
170	0.036	0.051	0.063	0.072	0.081	0.089	0.096	0.102	0.108	0.114
175	0.035	0.050	0.061	0.070	0.078	0.086	0.093	0.099	0.105	0.111
180	0.034	0.048	0.059	0.068	0.076	0.084	0.090	0.097	0.102	0.108
185	0.033	0.047	0.058	0.066	0.074	0.081	0.088	0.094	0.100	0.105
190	0.032	0.046	0.056	0.065	0.072	0.079	0.086	0.091	0.097	0.102
200	0.031	0.043	0.053	0.061	0.069	0.075	0.081	0.087	0.092	0.097
210	0.029	0.041	0.051	0.059	0.065	0.072	0.077	0.083	0.088	0.093
220	0.028	0.039	0.048	0.056	0.062	0.068	0.074	0.079	0.084	0.088
230	0.027	0.038	0.046	0.053	0.060	0.065	0.071	0.076	0.080	0.084
240	0.026	0.036	0.044	0.051	0.057	0.063	0.068	0.072	0.077	0.081
Q (m³/s)	**0.017**	**0.024**	**0.030**	**0.034**	**0.038**	**0.042**	**0.045**	**0.048**	**0.051**	**0.054**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 57 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-AV Catch Drain: V-drain cross section

Mean rock size (d$_{50}$) = 200 mm and s$_r$ = 2.4		Variation in rock size (d$_{50}$/d$_{90}$) = 0.67							
Dimensions:		Flow top width = 1.0 m			Flow depth = 0.15 m				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	0.244	0.345	0.423	0.488	0.546	0.598	0.646	0.690	0.732	0.772
20	0.183	0.259	0.317	0.366	0.409	0.448	0.484	0.518	0.549	0.579
25	0.146	0.207	0.254	0.293	0.327	0.359	0.387	0.414	0.439	0.463
30	0.122	0.173	0.211	0.244	0.273	0.299	0.323	0.345	0.366	0.386
35	0.105	0.148	0.181	0.209	0.234	0.256	0.277	0.296	0.314	0.331
40	0.092	0.129	0.159	0.183	0.205	0.224	0.242	0.259	0.275	0.289
45	0.081	0.115	0.141	0.163	0.182	0.199	0.215	0.230	0.244	0.257
50	0.073	0.104	0.127	0.146	0.164	0.179	0.194	0.207	0.220	0.232
55	0.067	0.094	0.115	0.133	0.149	0.163	0.176	0.188	0.200	0.210
60	0.061	0.086	0.106	0.122	0.136	0.149	0.161	0.173	0.183	0.193
65	0.056	0.080	0.098	0.113	0.126	0.138	0.149	0.159	0.169	0.178
70	0.052	0.074	0.091	0.105	0.117	0.128	0.138	0.148	0.157	0.165
75	0.049	0.069	0.085	0.098	0.109	0.120	0.129	0.138	0.146	0.154
80	0.046	0.065	0.079	0.092	0.102	0.112	0.121	0.129	0.137	0.145
85	0.043	0.061	0.075	0.086	0.096	0.105	0.114	0.122	0.129	0.136
90	0.041	0.058	0.070	0.081	0.091	0.100	0.108	0.115	0.122	0.129
95	0.039	0.054	0.067	0.077	0.086	0.094	0.102	0.109	0.116	0.122
100	0.037	0.052	0.063	0.073	0.082	0.090	0.097	0.104	0.110	0.116
105	0.035	0.049	0.060	0.070	0.078	0.085	0.092	0.099	0.105	0.110
110	0.033	0.047	0.058	0.067	0.074	0.082	0.088	0.094	0.100	0.105
115	0.032	0.045	0.055	0.064	0.071	0.078	0.084	0.090	0.096	0.101
120	0.031	0.043	0.053	0.061	0.068	0.075	0.081	0.086	0.092	0.096
125	0.029	0.041	0.051	0.059	0.065	0.072	0.077	0.083	0.088	0.093
130	0.028	0.040	0.049	0.056	0.063	0.069	0.075	0.080	0.084	0.089
135	0.027	0.038	0.047	0.054	0.061	0.066	0.072	0.077	0.081	0.086
140	0.026	0.037	0.045	0.052	0.058	0.064	0.069	0.074	0.078	0.083
145	0.025	0.036	0.044	0.050	0.056	0.062	0.067	0.071	0.076	0.080
150	0.024	0.035	0.042	0.049	0.055	0.060	0.065	0.069	0.073	0.077
155	0.024	0.033	0.041	0.047	0.053	0.058	0.062	0.067	0.071	0.075
160	0.023	0.032	0.040	0.046	0.051	0.056	0.061	0.065	0.069	0.072
165	0.022	0.031	0.038	0.044	0.050	0.054	0.059	0.063	0.067	0.070
170	0.022	0.030	0.037	0.043	0.048	0.053	0.057	0.061	0.065	0.068
175	0.021	0.030	0.036	0.042	0.047	0.051	0.055	0.059	0.063	0.066
180	0.020	0.029	0.035	0.041	0.045	0.050	0.054	0.058	0.061	0.064
185	0.020	0.028	0.034	0.040	0.044	0.048	0.052	0.056	0.059	0.063
190	0.019	0.027	0.033	0.039	0.043	0.047	0.051	0.054	0.058	0.061
200	0.018	0.026	0.032	0.037	0.041	0.045	0.048	0.052	0.055	0.058
210	0.017	0.025	0.030	0.035	0.039	0.043	0.046	0.049	0.052	0.055
220	0.017	0.024	0.029	0.033	0.037	0.041	0.044	0.047	0.050	0.053
230	0.016	0.023	0.028	0.032	0.036	0.039	0.042	0.045	0.048	0.050
240	0.015	0.022	0.026	0.031	0.034	0.037	0.040	0.043	0.046	0.048
Q (m^3/s)	0.010	0.014	0.018	0.020	0.023	0.025	0.027	0.029	0.031	0.032

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 58 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-AV Catch Drain: V-drain cross section

Mean rock size (d_{50}) = 300 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		Flow top width = 1.0 m			Flow depth = 0.15 m				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	0.178	0.251	0.308	0.355	0.397	0.435	0.470	0.502	0.533	0.562
20	0.133	0.188	0.231	0.266	0.298	0.326	0.352	0.377	0.400	0.421
25	0.107	0.151	0.185	0.213	0.238	0.261	0.282	0.301	0.320	0.337
30	0.089	0.126	0.154	0.178	0.199	0.218	0.235	0.251	0.266	0.281
35	0.076	0.108	0.132	0.152	0.170	0.186	0.201	0.215	0.228	0.241
40	0.067	0.094	0.115	0.133	0.149	0.163	0.176	0.188	0.200	0.211
45	0.059	0.084	0.103	0.118	0.132	0.145	0.157	0.167	0.178	0.187
50	0.053	0.075	0.092	0.107	0.119	0.131	0.141	0.151	0.160	0.168
55	0.048	0.069	0.084	0.097	0.108	0.119	0.128	0.137	0.145	0.153
60	0.044	0.063	0.077	0.089	0.099	0.109	0.117	0.126	0.133	0.140
65	0.041	0.058	0.071	0.082	0.092	0.100	0.108	0.116	0.123	0.130
70	0.038	0.054	0.066	0.076	0.085	0.093	0.101	0.108	0.114	0.120
75	0.036	0.050	0.062	0.071	0.079	0.087	0.094	0.100	0.107	0.112
80	0.033	0.047	0.058	0.067	0.074	0.082	0.088	0.094	0.100	0.105
85	0.031	0.044	0.054	0.063	0.070	0.077	0.083	0.089	0.094	0.099
90	0.030	0.042	0.051	0.059	0.066	0.073	0.078	0.084	0.089	0.094
95	0.028	0.040	0.049	0.056	0.063	0.069	0.074	0.079	0.084	0.089
100	0.027	0.038	0.046	0.053	0.060	0.065	0.070	0.075	0.080	0.084
105	0.025	0.036	0.044	0.051	0.057	0.062	0.067	0.072	0.076	0.080
110	0.024	0.034	0.042	0.048	0.054	0.059	0.064	0.069	0.073	0.077
115	0.023	0.033	0.040	0.046	0.052	0.057	0.061	0.066	0.070	0.073
120	0.022	0.031	0.038	0.044	0.050	0.054	0.059	0.063	0.067	0.070
125	0.021	0.030	0.037	0.043	0.048	0.052	0.056	0.060	0.064	0.067
130	0.020	0.029	0.035	0.041	0.046	0.050	0.054	0.058	0.061	0.065
135	0.020	0.028	0.034	0.039	0.044	0.048	0.052	0.056	0.059	0.062
140	0.019	0.027	0.033	0.038	0.043	0.047	0.050	0.054	0.057	0.060
145	0.018	0.026	0.032	0.037	0.041	0.045	0.049	0.052	0.055	0.058
150	0.018	0.025	0.031	0.036	0.040	0.044	0.047	0.050	0.053	0.056
155	0.017	0.024	0.030	0.034	0.038	0.042	0.045	0.049	0.052	0.054
160	0.017	0.024	0.029	0.033	0.037	0.041	0.044	0.047	0.050	0.053
165	0.016	0.023	0.028	0.032	0.036	0.040	0.043	0.046	0.048	0.051
170	0.016	0.022	0.027	0.031	0.035	0.038	0.041	0.044	0.047	0.050
175	0.015	0.022	0.026	0.030	0.034	0.037	0.040	0.043	0.046	0.048
180	0.015	0.021	0.026	0.030	0.033	0.036	0.039	0.042	0.044	0.047
185	0.014	0.020	0.025	0.029	0.032	0.035	0.038	0.041	0.043	0.046
190	0.014	0.020	0.024	0.028	0.031	0.034	0.037	0.040	0.042	0.044
200	0.013	0.019	0.023	0.027	0.030	0.033	0.035	0.038	0.040	0.042
210	0.013	0.018	0.022	0.025	0.028	0.031	0.034	0.036	0.038	0.040
220	0.012	0.017	0.021	0.024	0.027	0.030	0.032	0.034	0.036	0.038
230	0.012	0.016	0.020	0.023	0.026	0.028	0.031	0.033	0.035	0.037
240	0.011	0.016	0.019	0.022	0.025	0.027	0.029	0.031	0.033	0.035
Q (m³/s)	0.007	0.010	0.013	0.015	0.017	0.018	0.020	0.021	0.022	0.023

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 59 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-BV Catch Drain: V-drain cross section

Mean rock size (d$_{50}$) = 100 mm and s$_r$ = 2.4		Variation in rock size (d$_{50}$/d$_{90}$) = 0.67		
Dimensions:		**Flow top width = 1.8 m**	**Flow depth = 0.30 m**	

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
15	3.304	4.673	5.723	6.609	7.389	8.094	8.742	Allowable unit catchment areas presented below are limited by the allowable flow velocity		
20	2.478	3.505	4.292	4.956	5.542	6.070	6.557			
25	1.983	2.804	3.434	3.965	4.433	4.856	5.245			
30	1.652	2.337	2.862	3.304	3.694	4.047	4.371			
35	1.416	2.003	2.453	2.832	3.167	3.469	3.747			
40	1.239	1.752	2.146	2.478	2.771	3.035	3.278	3.324	2.992	2.715
45	1.101	1.558	1.908	2.203	2.463	2.698	2.914	2.955	2.660	2.413
50	0.991	1.402	1.717	1.983	2.217	2.428	2.623	2.659	2.394	2.172
55	0.901	1.274	1.561	1.802	2.015	2.207	2.384	2.417	2.176	1.975
60	0.826	1.168	1.431	1.652	1.847	2.023	2.186	2.216	1.995	1.810
65	0.763	1.078	1.321	1.525	1.705	1.868	2.017	2.045	1.841	1.671
70	0.708	1.001	1.226	1.416	1.583	1.734	1.873	1.899	1.710	1.551
75	0.661	0.935	1.145	1.322	1.478	1.619	1.748	1.773	1.596	1.448
80	0.620	0.876	1.073	1.239	1.385	1.518	1.639	1.662	1.496	1.358
85	0.583	0.825	1.010	1.166	1.304	1.428	1.543	1.564	1.408	1.278
90	0.551	0.779	0.954	1.101	1.231	1.349	1.457	1.477	1.330	1.207
95	0.522	0.738	0.904	1.043	1.167	1.278	1.380	1.400	1.260	1.143
100	0.496	0.701	0.858	0.991	1.108	1.214	1.311	1.330	1.197	1.086
105	0.472	0.668	0.818	0.944	1.056	1.156	1.249	1.266	1.140	1.034
110	0.451	0.637	0.780	0.901	1.008	1.104	1.192	1.209	1.088	0.987
115	0.431	0.610	0.747	0.862	0.964	1.056	1.140	1.156	1.041	0.944
120	0.413	0.584	0.715	0.826	0.924	1.012	1.093	1.108	0.997	0.905
125	0.397	0.561	0.687	0.793	0.887	0.971	1.049	1.064	0.957	0.869
130	0.381	0.539	0.660	0.763	0.853	0.934	1.009	1.023	0.921	0.835
135	0.367	0.519	0.636	0.734	0.821	0.899	0.971	0.985	0.887	0.804
140	0.354	0.501	0.613	0.708	0.792	0.867	0.937	0.950	0.855	0.776
145	0.342	0.483	0.592	0.684	0.764	0.837	0.904	0.917	0.825	0.749
150	0.330	0.467	0.572	0.661	0.739	0.809	0.874	0.886	0.798	0.724
155	0.320	0.452	0.554	0.640	0.715	0.783	0.846	0.858	0.772	0.701
160	0.310	0.438	0.537	0.620	0.693	0.759	0.820	0.831	0.748	0.679
165	0.300	0.425	0.520	0.601	0.672	0.736	0.795	0.806	0.725	0.658
170	0.292	0.412	0.505	0.583	0.652	0.714	0.771	0.782	0.704	0.639
175	0.283	0.401	0.491	0.566	0.633	0.694	0.749	0.760	0.684	0.621
180	0.275	0.389	0.477	0.551	0.616	0.674	0.729	0.739	0.665	0.603
185	0.268	0.379	0.464	0.536	0.599	0.656	0.709	0.719	0.647	0.587
190	0.261	0.369	0.452	0.522	0.583	0.639	0.690	0.700	0.630	0.572
200	0.248	0.350	0.429	0.496	0.554	0.607	0.656	0.665	0.598	0.543
210	0.236	0.334	0.409	0.472	0.528	0.578	0.624	0.633	0.570	0.517
220	0.225	0.319	0.390	0.451	0.504	0.552	0.596	0.604	0.544	0.494
230	0.215	0.305	0.373	0.431	0.482	0.528	0.570	0.578	0.520	0.472
240	0.207	0.292	0.358	0.413	0.462	0.506	0.546	0.554	0.499	0.453
Q (m^3/s)	**0.138**	**0.195**	**0.238**	**0.275**	**0.308**	**0.337**	**0.364**	**0.369**	**0.332**	**0.302**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 60 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-BV Catch Drain: V-drain cross section

Mean rock size (d$_{50}$) = 200 mm and s$_r$ = 2.4			Variation in rock size (d$_{50}$/d$_{90}$) = 0.67						
Dimensions:			Flow top width = 1.8 m			Flow depth = 0.30 m			

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	2.061	2.915	3.570	4.122	4.608	5.048	5.453	5.829	6.183	6.517
20	1.546	2.186	2.677	3.091	3.456	3.786	4.090	4.372	4.637	4.888
25	1.237	1.749	2.142	2.473	2.765	3.029	3.272	3.498	3.710	3.910
30	1.030	1.457	1.785	2.061	2.304	2.524	2.726	2.915	3.091	3.259
35	0.883	1.249	1.530	1.767	1.975	2.164	2.337	2.498	2.650	2.793
40	0.773	1.093	1.339	1.546	1.728	1.893	2.045	2.186	2.319	2.444
45	0.687	0.972	1.190	1.374	1.536	1.683	1.818	1.943	2.061	2.172
50	0.618	0.874	1.071	1.237	1.383	1.514	1.636	1.749	1.855	1.955
55	0.562	0.795	0.974	1.124	1.257	1.377	1.487	1.590	1.686	1.777
60	0.515	0.729	0.892	1.030	1.152	1.262	1.363	1.457	1.546	1.629
65	0.476	0.673	0.824	0.951	1.063	1.165	1.258	1.345	1.427	1.504
70	0.442	0.625	0.765	0.883	0.988	1.082	1.168	1.249	1.325	1.397
75	0.412	0.583	0.714	0.824	0.922	1.010	1.091	1.166	1.237	1.303
80	0.386	0.546	0.669	0.773	0.864	0.947	1.022	1.093	1.159	1.222
85	0.364	0.514	0.630	0.727	0.813	0.891	0.962	1.029	1.091	1.150
90	0.343	0.486	0.595	0.687	0.768	0.841	0.909	0.972	1.030	1.086
95	0.325	0.460	0.564	0.651	0.728	0.797	0.861	0.920	0.976	1.029
100	0.309	0.437	0.535	0.618	0.691	0.757	0.818	0.874	0.927	0.978
105	0.294	0.416	0.510	0.589	0.658	0.721	0.779	0.833	0.883	0.931
110	0.281	0.397	0.487	0.562	0.628	0.688	0.744	0.795	0.843	0.889
115	0.269	0.380	0.466	0.538	0.601	0.658	0.711	0.760	0.806	0.850
120	0.258	0.364	0.446	0.515	0.576	0.631	0.682	0.729	0.773	0.815
125	0.247	0.350	0.428	0.495	0.553	0.606	0.654	0.700	0.742	0.782
130	0.238	0.336	0.412	0.476	0.532	0.582	0.629	0.673	0.713	0.752
135	0.229	0.324	0.397	0.458	0.512	0.561	0.606	0.648	0.687	0.724
140	0.221	0.312	0.382	0.442	0.494	0.541	0.584	0.625	0.662	0.698
145	0.213	0.302	0.369	0.426	0.477	0.522	0.564	0.603	0.640	0.674
150	0.206	0.291	0.357	0.412	0.461	0.505	0.545	0.583	0.618	0.652
155	0.199	0.282	0.345	0.399	0.446	0.489	0.528	0.564	0.598	0.631
160	0.193	0.273	0.335	0.386	0.432	0.473	0.511	0.546	0.580	0.611
165	0.187	0.265	0.325	0.375	0.419	0.459	0.496	0.530	0.562	0.592
170	0.182	0.257	0.315	0.364	0.407	0.445	0.481	0.514	0.546	0.575
175	0.177	0.250	0.306	0.353	0.395	0.433	0.467	0.500	0.530	0.559
180	0.172	0.243	0.297	0.343	0.384	0.421	0.454	0.486	0.515	0.543
185	0.167	0.236	0.289	0.334	0.374	0.409	0.442	0.473	0.501	0.528
190	0.163	0.230	0.282	0.325	0.364	0.399	0.430	0.460	0.488	0.515
200	0.155	0.219	0.268	0.309	0.346	0.379	0.409	0.437	0.464	0.489
210	0.147	0.208	0.255	0.294	0.329	0.361	0.389	0.416	0.442	0.466
220	0.141	0.199	0.243	0.281	0.314	0.344	0.372	0.397	0.422	0.444
230	0.134	0.190	0.233	0.269	0.301	0.329	0.356	0.380	0.403	0.425
240	0.129	0.182	0.223	0.258	0.288	0.316	0.341	0.364	0.386	0.407
Q (m^3/s)	0.086	0.121	0.149	0.172	0.192	0.210	0.227	0.243	0.258	0.272

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Type-BV Catch Drain: V-drain cross section

Mean rock size (d_{50}) = 300 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67			

Dimensions:		Flow top width = 1.8 m		Flow depth = 0.30 m	

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
15	1.529	2.162	2.648	3.058	3.419	3.745	4.045	4.324	4.587	4.835
20	1.147	1.622	1.986	2.293	2.564	2.809	3.034	3.243	3.440	3.626
25	0.917	1.297	1.589	1.835	2.051	2.247	2.427	2.595	2.752	2.901
30	0.764	1.081	1.324	1.529	1.709	1.872	2.022	2.162	2.293	2.417
35	0.655	0.927	1.135	1.310	1.465	1.605	1.734	1.853	1.966	2.072
40	0.573	0.811	0.993	1.147	1.282	1.404	1.517	1.622	1.720	1.813
45	0.510	0.721	0.883	1.019	1.140	1.248	1.348	1.441	1.529	1.612
50	0.459	0.649	0.794	0.917	1.026	1.123	1.213	1.297	1.376	1.450
55	0.417	0.590	0.722	0.834	0.932	1.021	1.103	1.179	1.251	1.319
60	0.382	0.541	0.662	0.764	0.855	0.936	1.011	1.081	1.147	1.209
65	0.353	0.499	0.611	0.706	0.789	0.864	0.933	0.998	1.058	1.116
70	0.328	0.463	0.567	0.655	0.733	0.802	0.867	0.927	0.983	1.036
75	0.306	0.432	0.530	0.612	0.684	0.749	0.809	0.865	0.917	0.967
80	0.287	0.405	0.497	0.573	0.641	0.702	0.758	0.811	0.860	0.907
85	0.270	0.382	0.467	0.540	0.603	0.661	0.714	0.763	0.809	0.853
90	0.255	0.360	0.441	0.510	0.570	0.624	0.674	0.721	0.764	0.806
95	0.241	0.341	0.418	0.483	0.540	0.591	0.639	0.683	0.724	0.763
100	0.229	0.324	0.397	0.459	0.513	0.562	0.607	0.649	0.688	0.725
105	0.218	0.309	0.378	0.437	0.488	0.535	0.578	0.618	0.655	0.691
110	0.208	0.295	0.361	0.417	0.466	0.511	0.552	0.590	0.625	0.659
115	0.199	0.282	0.345	0.399	0.446	0.488	0.528	0.564	0.598	0.631
120	0.191	0.270	0.331	0.382	0.427	0.468	0.506	0.541	0.573	0.604
125	0.183	0.259	0.318	0.367	0.410	0.449	0.485	0.519	0.550	0.580
130	0.176	0.249	0.306	0.353	0.394	0.432	0.467	0.499	0.529	0.558
135	0.170	0.240	0.294	0.340	0.380	0.416	0.449	0.480	0.510	0.537
140	0.164	0.232	0.284	0.328	0.366	0.401	0.433	0.463	0.491	0.518
145	0.158	0.224	0.274	0.316	0.354	0.387	0.418	0.447	0.474	0.500
150	0.153	0.216	0.265	0.306	0.342	0.374	0.404	0.432	0.459	0.483
155	0.148	0.209	0.256	0.296	0.331	0.362	0.391	0.418	0.444	0.468
160	0.143	0.203	0.248	0.287	0.320	0.351	0.379	0.405	0.430	0.453
165	0.139	0.197	0.241	0.278	0.311	0.340	0.368	0.393	0.417	0.440
170	0.135	0.191	0.234	0.270	0.302	0.330	0.357	0.382	0.405	0.427
175	0.131	0.185	0.227	0.262	0.293	0.321	0.347	0.371	0.393	0.414
180	0.127	0.180	0.221	0.255	0.285	0.312	0.337	0.360	0.382	0.403
185	0.124	0.175	0.215	0.248	0.277	0.304	0.328	0.351	0.372	0.392
190	0.121	0.171	0.209	0.241	0.270	0.296	0.319	0.341	0.362	0.382
200	0.115	0.162	0.199	0.229	0.256	0.281	0.303	0.324	0.344	0.363
210	0.109	0.154	0.189	0.218	0.244	0.267	0.289	0.309	0.328	0.345
220	0.104	0.147	0.181	0.208	0.233	0.255	0.276	0.295	0.313	0.330
230	0.100	0.141	0.173	0.199	0.223	0.244	0.264	0.282	0.299	0.315
240	0.096	0.135	0.166	0.191	0.214	0.234	0.253	0.270	0.287	0.302
Q (m^3/s)	0.064	0.090	0.110	0.127	0.142	0.156	0.169	0.180	0.191	0.201

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 62 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-CV Catch Drain: V-drain cross section

Mean rock size (d_{50}) = 100 mm and s_r = 2.4		Variation in rock size (d_{50}/d_{90}) = 0.67							
Dimensions:		**Flow top width = 3.0 m**			**Flow depth = 0.50 m**				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
15	16.10	22.77	Allowable unit catchment areas presented in the columns below are limited by the allowable flow velocity							
20	12.08	17.08								
25	9.66	13.66	12.87	9.80	8.04	6.86	5.93	5.32	4.79	4.34
30	8.05	11.39	10.72	8.16	6.70	5.72	4.94	4.43	3.99	3.62
35	6.90	9.76	9.19	7.00	5.74	4.90	4.24	3.80	3.42	3.10
40	6.04	8.54	8.04	6.12	5.03	4.29	3.71	3.32	2.99	2.72
45	5.37	7.59	7.15	5.44	4.47	3.81	3.29	2.95	2.66	2.41
50	4.83	6.83	6.43	4.90	4.02	3.43	2.97	2.66	2.39	2.17
55	4.39	6.21	5.85	4.45	3.66	3.12	2.70	2.42	2.18	1.97
60	4.03	5.69	5.36	4.08	3.35	2.86	2.47	2.22	1.99	1.81
65	3.72	5.26	4.95	3.77	3.09	2.64	2.28	2.05	1.84	1.67
70	3.45	4.88	4.60	3.50	2.87	2.45	2.12	1.90	1.71	1.55
75	3.22	4.55	4.29	3.27	2.68	2.29	1.98	1.77	1.60	1.45
80	3.02	4.27	4.02	3.06	2.51	2.14	1.85	1.66	1.50	1.36
85	2.84	4.02	3.79	2.88	2.37	2.02	1.74	1.56	1.41	1.28
90	2.68	3.80	3.57	2.72	2.23	1.91	1.65	1.48	1.33	1.21
95	2.54	3.60	3.39	2.58	2.12	1.80	1.56	1.40	1.26	1.14
100	2.42	3.42	3.22	2.45	2.01	1.71	1.48	1.33	1.20	1.09
105	2.30	3.25	3.06	2.33	1.91	1.63	1.41	1.27	1.14	1.03
110	2.20	3.11	2.92	2.23	1.83	1.56	1.35	1.21	1.09	0.99
115	2.10	2.97	2.80	2.13	1.75	1.49	1.29	1.16	1.04	0.94
120	2.01	2.85	2.68	2.04	1.68	1.43	1.24	1.11	1.00	0.91
125	1.93	2.73	2.57	1.96	1.61	1.37	1.19	1.06	0.96	0.87
130	1.86	2.63	2.47	1.88	1.55	1.32	1.14	1.02	0.92	0.84
135	1.79	2.53	2.38	1.81	1.49	1.27	1.10	0.98	0.89	0.80
140	1.73	2.44	2.30	1.75	1.44	1.22	1.06	0.95	0.85	0.78
145	1.67	2.36	2.22	1.69	1.39	1.18	1.02	0.92	0.83	0.75
150	1.61	2.28	2.14	1.63	1.34	1.14	0.99	0.89	0.80	0.72
155	1.56	2.20	2.08	1.58	1.30	1.11	0.96	0.86	0.77	0.70
160	1.51	2.13	2.01	1.53	1.26	1.07	0.93	0.83	0.75	0.68
165	1.46	2.07	1.95	1.48	1.22	1.04	0.90	0.81	0.73	0.66
170	1.42	2.01	1.89	1.44	1.18	1.01	0.87	0.78	0.70	0.64
175	1.38	1.95	1.84	1.40	1.15	0.98	0.85	0.76	0.68	0.62
180	1.34	1.90	1.79	1.36	1.12	0.95	0.82	0.74	0.66	0.60
185	1.31	1.85	1.74	1.32	1.09	0.93	0.80	0.72	0.65	0.59
190	1.27	1.80	1.69	1.29	1.06	0.90	0.78	0.70	0.63	0.57
200	1.21	1.71	1.61	1.22	1.01	0.86	0.74	0.66	0.60	0.54
210	1.15	1.63	1.53	1.17	0.96	0.82	0.71	0.63	0.57	0.52
220	1.10	1.55	1.46	1.11	0.91	0.78	0.67	0.60	0.54	0.49
230	1.05	1.49	1.40	1.06	0.87	0.75	0.64	0.58	0.52	0.47
240	1.01	1.42	1.34	1.02	0.84	0.71	0.62	0.55	0.50	0.45
Q (m^3/s)	**0.671**	**0.949**	**0.894**	**0.680**	**0.558**	**0.476**	**0.412**	**0.369**	**0.332**	**0.302**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 63 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-CV Catch Drain: V-drain cross section

Mean rock size (d$_{50}$) = 200 mm and s$_r$ = 2.4		Variation in rock size (d$_{50}$/d$_{90}$) = 0.67							
Dimensions:		**Flow top width = 3.0 m**			**Flow depth = 0.50 m**				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
15	10.52	14.88	18.23	21.05	23.53	25.78	27.84	29.77	31.57	33.28
20	7.89	11.16	13.67	15.79	17.65	19.33	20.88	22.32	23.68	24.96
25	6.31	8.93	10.94	12.63	14.12	15.47	16.71	17.86	18.94	19.97
30	5.26	7.44	9.11	10.52	11.77	12.89	13.92	14.88	15.79	16.64
35	4.51	6.38	7.81	9.02	10.09	11.05	11.93	12.76	13.53	14.26
40	3.95	5.58	6.84	7.89	8.82	9.67	10.44	11.16	11.84	12.48
45	3.51	4.96	6.08	7.02	7.84	8.59	9.28	9.92	10.52	11.09
50	3.16	4.46	5.47	6.31	7.06	7.73	8.35	8.93	9.47	9.98
55	2.87	4.06	4.97	5.74	6.42	7.03	7.59	8.12	8.61	9.08
60	2.63	3.72	4.56	5.26	5.88	6.44	6.96	7.44	7.89	8.32
65	2.43	3.43	4.21	4.86	5.43	5.95	6.43	6.87	7.29	7.68
70	2.26	3.19	3.91	4.51	5.04	5.52	5.97	6.38	6.77	7.13
75	2.10	2.98	3.65	4.21	4.71	5.16	5.57	5.95	6.31	6.66
80	1.97	2.79	3.42	3.95	4.41	4.83	5.22	5.58	5.92	6.24
85	1.86	2.63	3.22	3.71	4.15	4.55	4.91	5.25	5.57	5.87
90	1.75	2.48	3.04	3.51	3.92	4.30	4.64	4.96	5.26	5.55
95	1.66	2.35	2.88	3.32	3.72	4.07	4.40	4.70	4.99	5.25
100	1.58	2.23	2.73	3.16	3.53	3.87	4.18	4.46	4.74	4.99
105	1.50	2.13	2.60	3.01	3.36	3.68	3.98	4.25	4.51	4.75
110	1.44	2.03	2.49	2.87	3.21	3.52	3.80	4.06	4.31	4.54
115	1.37	1.94	2.38	2.75	3.07	3.36	3.63	3.88	4.12	4.34
120	1.32	1.86	2.28	2.63	2.94	3.22	3.48	3.72	3.95	4.16
125	1.26	1.79	2.19	2.53	2.82	3.09	3.34	3.57	3.79	3.99
130	1.21	1.72	2.10	2.43	2.72	2.97	3.21	3.43	3.64	3.84
135	1.17	1.65	2.03	2.34	2.61	2.86	3.09	3.31	3.51	3.70
140	1.13	1.59	1.95	2.26	2.52	2.76	2.98	3.19	3.38	3.57
145	1.09	1.54	1.89	2.18	2.43	2.67	2.88	3.08	3.27	3.44
150	1.05	1.49	1.82	2.10	2.35	2.58	2.78	2.98	3.16	3.33
155	1.02	1.44	1.76	2.04	2.28	2.49	2.69	2.88	3.06	3.22
160	0.99	1.40	1.71	1.97	2.21	2.42	2.61	2.79	2.96	3.12
165	0.96	1.35	1.66	1.91	2.14	2.34	2.53	2.71	2.87	3.03
170	0.93	1.31	1.61	1.86	2.08	2.27	2.46	2.63	2.79	2.94
175	0.90	1.28	1.56	1.80	2.02	2.21	2.39	2.55	2.71	2.85
180	0.88	1.24	1.52	1.75	1.96	2.15	2.32	2.48	2.63	2.77
185	0.85	1.21	1.48	1.71	1.91	2.09	2.26	2.41	2.56	2.70
190	0.83	1.17	1.44	1.66	1.86	2.04	2.20	2.35	2.49	2.63
200	0.79	1.12	1.37	1.58	1.76	1.93	2.09	2.23	2.37	2.50
210	0.75	1.06	1.30	1.50	1.68	1.84	1.99	2.13	2.26	2.38
220	0.72	1.01	1.24	1.44	1.60	1.76	1.90	2.03	2.15	2.27
230	0.69	0.97	1.19	1.37	1.53	1.68	1.82	1.94	2.06	2.17
240	0.66	0.93	1.14	1.32	1.47	1.61	1.74	1.86	1.97	2.08
Q (m^3/s)	**0.439**	**0.620**	**0.760**	**0.877**	**0.981**	**1.074**	**1.160**	**1.240**	**1.316**	**1.387**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).

Table 64 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-CV Catch Drain: V-drain cross section

Mean rock size (d$_{50}$) = 300 mm and s$_r$ = 2.4		Variation in rock size (d$_{50}$/d$_{90}$) = 0.67							
Dimensions:		**Flow top width = 3.0 m**			**Flow depth = 0.50 m**				

Rainfall intensity (mm/hr)	Longitudinal slope of catch drain (%)									
	1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
15	7.97	11.27	13.80	15.94	17.82	19.52	21.08	22.54	23.90	25.20
20	5.98	8.45	10.35	11.95	13.36	14.64	15.81	16.90	17.93	18.90
25	4.78	6.76	8.28	9.56	10.69	11.71	12.65	13.52	14.34	15.12
30	3.98	5.63	6.90	7.97	8.91	9.76	10.54	11.27	11.95	12.60
35	3.41	4.83	5.91	6.83	7.64	8.36	9.03	9.66	10.24	10.80
40	2.99	4.23	5.18	5.98	6.68	7.32	7.91	8.45	8.96	9.45
45	2.66	3.76	4.60	5.31	5.94	6.51	7.03	7.51	7.97	8.40
50	2.39	3.38	4.14	4.78	5.34	5.86	6.32	6.76	7.17	7.56
55	2.17	3.07	3.76	4.35	4.86	5.32	5.75	6.15	6.52	6.87
60	1.99	2.82	3.45	3.98	4.45	4.88	5.27	5.63	5.98	6.30
65	1.84	2.60	3.18	3.68	4.11	4.50	4.86	5.20	5.52	5.81
70	1.71	2.41	2.96	3.41	3.82	4.18	4.52	4.83	5.12	5.40
75	1.59	2.25	2.76	3.19	3.56	3.90	4.22	4.51	4.78	5.04
80	1.49	2.11	2.59	2.99	3.34	3.66	3.95	4.23	4.48	4.72
85	1.41	1.99	2.44	2.81	3.14	3.44	3.72	3.98	4.22	4.45
90	1.33	1.88	2.30	2.66	2.97	3.25	3.51	3.76	3.98	4.20
95	1.26	1.78	2.18	2.52	2.81	3.08	3.33	3.56	3.77	3.98
100	1.20	1.69	2.07	2.39	2.67	2.93	3.16	3.38	3.59	3.78
105	1.14	1.61	1.97	2.28	2.55	2.79	3.01	3.22	3.41	3.60
110	1.09	1.54	1.88	2.17	2.43	2.66	2.87	3.07	3.26	3.44
115	1.04	1.47	1.80	2.08	2.32	2.55	2.75	2.94	3.12	3.29
120	1.00	1.41	1.73	1.99	2.23	2.44	2.64	2.82	2.99	3.15
125	0.96	1.35	1.66	1.91	2.14	2.34	2.53	2.70	2.87	3.02
130	0.92	1.30	1.59	1.84	2.06	2.25	2.43	2.60	2.76	2.91
135	0.89	1.25	1.53	1.77	1.98	2.17	2.34	2.50	2.66	2.80
140	0.85	1.21	1.48	1.71	1.91	2.09	2.26	2.41	2.56	2.70
145	0.82	1.17	1.43	1.65	1.84	2.02	2.18	2.33	2.47	2.61
150	0.80	1.13	1.38	1.59	1.78	1.95	2.11	2.25	2.39	2.52
155	0.77	1.09	1.34	1.54	1.72	1.89	2.04	2.18	2.31	2.44
160	0.75	1.06	1.29	1.49	1.67	1.83	1.98	2.11	2.24	2.36
165	0.72	1.02	1.25	1.45	1.62	1.77	1.92	2.05	2.17	2.29
170	0.70	0.99	1.22	1.41	1.57	1.72	1.86	1.99	2.11	2.22
175	0.68	0.97	1.18	1.37	1.53	1.67	1.81	1.93	2.05	2.16
180	0.66	0.94	1.15	1.33	1.48	1.63	1.76	1.88	1.99	2.10
185	0.65	0.91	1.12	1.29	1.44	1.58	1.71	1.83	1.94	2.04
190	0.63	0.89	1.09	1.26	1.41	1.54	1.66	1.78	1.89	1.99
200	0.60	0.85	1.04	1.20	1.34	1.46	1.58	1.69	1.79	1.89
210	0.57	0.80	0.99	1.14	1.27	1.39	1.51	1.61	1.71	1.80
220	0.54	0.77	0.94	1.09	1.21	1.33	1.44	1.54	1.63	1.72
230	0.52	0.73	0.90	1.04	1.16	1.27	1.37	1.47	1.56	1.64
240	0.50	0.70	0.86	1.00	1.11	1.22	1.32	1.41	1.49	1.57
Q (m^3/s)	**0.332**	**0.470**	**0.575**	**0.664**	**0.742**	**0.813**	**0.878**	**0.939**	**0.996**	**1.050**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 55).