Catch Drains Part 2: Earth-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 7 – Earth-lined catch drain

Photo 8 – Large rural catch drain (channel-bank)

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 earth-lined (or unlined) 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) "Best Practice Erosion and Sediment Control", Appendix A – *Construction site hydrology and hydraulics*.

Common Problems

If earth-lined catch drains discharge to an unstable outlet, then erosion (rilling) can occur downstream of the outlet. This erosion often migrates up into the earth drain causing erosion (rilling) along the channel invert.

The above problem is commonly experienced when the catch drain is cut into dispersive soils.

Invert erosion is also common when the exposed soils are very sandy and lack the necessary qualities of clay to bind the soil.

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

Special Requirements

The erosion-resistance of the local subsoils should be investigated before planning or designing any unlined drains.

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

Unlined catch drains need to be appropriately compacted, possibly by running a grader's wheels along the drain.

Catch drain should drain to a suitable sediment trap if the diverted water is expected to contain sediment.

Unlined drains usually have a very mild gradient, but it is still important to ensure there is a positive gradient along its full length.

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 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 (invert) of the drain. Investigate the reasons for any erosion before recommending solutions. Bed 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 include:

- reduce effective catchment area;
- increase channel width;
- increase channel roughness;
- stabilise bed with turf, mats or rock;
- stabilise the outlet.

Installation (Earth-lined)

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 required 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. Specifically, 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. 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 temporary 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 site rehabilitation plan.

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

Step 1 Choose the preferred surface condition of the catch drain (in this case an unlined drain). Also, determine the appropriate Manning's roughness for the nominated surface condition using Table 5.

Step 2 Determine the allowable flow velocity (V_{allow}) from Table 6.

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 7 (parabolic drains), or Table 12 (triangular drains).

Ultimately this may require an iterative process where various drain sizes are tested for hydraulic capacity using the following design steps.

Step 5 Determine the required longitudinal gradient (S%) for the catch drain using Tables 8 or 13, depending on the chosen drain profile.

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 Appendix A (IECA, 2008) if no preferred local procedure exists.

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 9 to 11, or Tables 14 to 16 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 desired 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, that 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 8 and 13. 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 9 to 11 for parabolic drains, and Tables 14 to 16 for drains with a triangular profile.

This means Tables 9 to 11 and 14 to 16 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: Earth-lined catch drain

Design a temporary (< 6 months) catch drain in Townsville with a desired length of 50m across an open silty loam soil slope where the average land slope is 10%. The catch drain will be used to collect and transport 'dirty' water from a disturbed catchment (active construction site).

Step 1 Choose the preferred surface condition of the catch drain (in this case an earth-lined drain) and the associated Manning's (n) roughness. From Table 5 the expected surface condition is probably best represented by a Manning's n = 0.04.

Step 2 Nominate an allowable flow velocity (V_{allow}) of 0.6m/s from Table 6.

Step 3 Choose a parabolic drain profile.

Step 4 Initially try a Type-A catch drain with dimensions: T = 1.0m, Y = 0.15m.

Step 5 Determine the required longitudinal gradient (S) from Table 8 as S = 1.34% for an unlined parabolic drain with V_{allow} = 0.6m/s and n = 0.04.

Step 6 Nominate a 1 in 2 year ARI design storm from Table 4.3.1 (Chapter 4).

Step 7 Initially select a time of concentration (t_c) of 5 minutes.

This initial estimate of the time of concentration can be reviewed later after the spacing and length of the catch drain is finalised.

Step 8 Determine the average rainfall intensity: I = 148mm/hr for Townsville from Table A11 (Appendix A) for ARI = 2-year, and t_c = 5 minutes.

Step 9 Determine the maximum allowable unit catchment area as A* = 0.146ha from Table 9, given V = 0.6m/s, and I = 148mm/hr.

Step 10 Determine the coefficient of discharge (C_Y):

Given the catch drain's catchment area is open, disturbed soil with expected low permeability (due to soil compaction), 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 = 0.85 for the 1 in 2-year ARI storm from Table A7 (Appendix A of IECA, 2008).

Calculate the effective coefficient of discharge (C) for the 1 in 2-year event using Equation A4 (Appendix A):

$$C = C_2 = F_Y . C_{10} = 0.85 \times 0.70 = 0.60 \leq 1.0 \text{ (OK)}$$

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

$$A = (A^*)/C = 0.14/0.60 = 0.245\text{ha}$$

Step 12 Determine the maximum allowable spacing of the catch drains down the catchment slope to be 25m from Table 1 (*Catch Drain, Part 1: General information*) given the catchment slope of 10%.

Now, the question indicates that the desired length of the drain is 50m, this means the catchment area of the drain is 25 x 50 = 1250m^2, or 0.125ha (assuming a rectangular shape), which is less than the maximum allowable catchment area of 0.245ha determined in Step 11. Therefore, this area is OK.

Because the actual catchment area (0.125ha) is significantly less than the maximum allowable catchment area (0.245ha), this mean that the catch drain could be constructed at a longitudinal gradient slightly flatter or steeper than the 1.34% determined in Step 5.

Step 8a For demonstration purposes, a better estimate of the time of concentration may be determined as follows:

Using the Friend's equation (Equation A5 in Appendix A); choose a Horton's n of 0.028 for an open soil catchment slope, an overland flow path length (L) of 25m (i.e. the spacing between catch drains determined in Step 12), and a catchment slope (S) of 10%. (Note, this is not the same term (S) previously presented as the drain slope.) Thus, the travel time of the initial overland sheet flow is:

$$t = (107\,n\,L^{0.333})/S^{0.2} = (107 \times 0.028 \times 25^{0.333})/(10^{0.2}) = 5.5 \text{ minutes}$$

Based on an assumed flow velocity of 0.6m/s, the travel time of flow down the 50m long catch drain is (note, in this case L = length of the drain, **not** the length of the overland flow path):

$$t = L/(V \times 60) = 50/(0.6 \times 60) = 1.4 \text{ minutes}$$

Therefore, the total travel time from the top of the catchment area is:

$$t_c = 5.5 + 1.4 = 6.9 \text{ minutes (say, 7 minutes)}$$

Determine the effective average rainfall intensity for a 1 in 2-year, 7 minute storm in Townsville from Table A11 (Appendix A) as, I = 135mm/hr. This intensity would result in an allowable unit catchment area, A* = 0.160ha from Table 9, and a maximum catchment area, $A = A^*/C_Y = 0.160/0.56 = 0.286$ha > 0.125ha, OK

Step 5a 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} < 1.34%) limited by the maximum flow depth of 0.15m; or
- a steeper gradient (S_{max} > 1.34%) limited by the allowable velocity of 0.6m/s.

To determined **flattest** allowable gradient for this catch drain, first calculate the design 1 in 2-year flow rate at the end of the 50m long catch drain.

$$Q = C\,I\,A/360 = (0.6 \times 135 \times 0.125)/360 = 0.028\text{m}^3/\text{s}$$

The minimum channel gradient (S_{min}) can be determined from Manning's equation:

$$Q = 0.028 = (1/n).A.R^{2/3}.S^{1/2} = (1/0.04)(0.100)(0.094)^{2/3}.S^{1/2}$$

$$S_{min} = 0.29\%$$

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 1.0m, and the flow depth (y) less than 0.15m. *(Note, the drain would still be constructed with the same standard overall physical dimensions specified for all Type-A catch drains.)*

For a Type-A drain the numerical relationship between 'T' & 'y' is given in Table 4:

$$y = 0.15\,T^2$$

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

$$A = 0.67(T.y) = 0.1\,T^3 = Q/V = 0.028/0.6 = 0.0465\text{m}^2$$

Therefore, the flow top width, T = 0.775m; the flow depth, y = 0.090m; and the hydraulic radius (R) can be determined from (Table A29b, Appendix A):

$$R = \frac{2\,T^2.y}{3\,T^2 + 8\,y^2} = \frac{2(0.775)^2 \times 0.090}{3(0.775)^2 + 8(0.090)^2} = 0.058\text{m}$$

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

$$S_{max} = 100(V^2\,.\,n^2)/R^{4/3} = 100 \times (0.6^2 \times 0.04^2)/0.058^{4/3} = 2.57\%$$

Therefore, the Type-A catch drain can be constructed at any longitudinal gradient between 0.29% (maximum flow depth) and 2.57% (maximum flow velocity), and still provide the required hydraulic capacity for the 1 in 2 year design storm. It is noted that constructing the drain at the steeper gradient will result in a construction site with maximum drainage capacity.

Table 5 – Typical Manning's roughness for unlined, shallow catch drains [1]

Manning's n	Drain condition
0.02	• Smooth soil surface. • Surface of the drain is compacted to produce a firm, smooth surface using a hand-operated compactor. • There are few, if any, irregularities, sediment deposits or loose soil.
0.04	• Slightly irregular soil surface. • Surface of the drain is compacted to produce a firm smooth surface possibly by running a rubber wheel along the drain. • The drain has minor irregularities equivalent to that produced if an *Erosion Control Blanket* or jute mesh was pinned over the surface.
0.06	• Moderately irregular soil surface. • Surface of the drain is cut by a mechanical blade with little or no soil compaction. Alternatively the bed of the drain has been significantly disturbed by construction traffic. • The drain has irregularities equivalent to a recessed layer of 100mm rock, or the drain contains several clods of loose soil per metre length.

Note: [1] Shallow water drains with a flow depth less than 0.4 metres.

Table 6 – Allowable flow velocity for earth-lined drains

Type	Description	Allowable velocity	Comments
Open earth (unlined channels)	Extremely erodible soils	0.3m/s	• Dispersive clays are highly erodible even at low flow velocities and therefore must be either treated (e.g. with gypsum) or covered with a minimum 100mm of stable soil. • Highly erodible soils may include: Lithosols, Alluvials, Podzols, Siliceous sands, Soloths, Solodized solonetz, Grey podzolics, some Black earths, fine surface texture-contrast soils and Soil Groups ML and CL. • Moderately erodible soils may include: Red earths, Red or Yellow podzolics, some Black earths, Grey or Brown clays, Prarie soils and Soil Groups SW, SP, SM, SC. • Erosion-resistant soils may include: Xanthozem, Euchrozem, Krasnozems, some Red earth soils and Soil Groups GW, GP, GM, GC, MH and CH.
	Sandy soils	0.45m/s	
	Highly erodible soils	0.4 to 0.5m/s	
	Sandy loam soils	0.5m/s	
	Moderately erodible soils	0.6m/s	
	Silty loam soils	0.6m/s	
	Low erodible soils	0.7m/s	
	Firm loam soils	0.7m/s	
	Stiff clay very colloidal soils	1.1m/s	

Table 7 – 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 8 – Required longitudinal gradient (%) for unlined, parabolic catch drains

Manning's roughness (n)	Allowable flow velocity along catch drain (m/s)									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
	Type-A catch drain: flow top width (T) = 1.0 m and flow depth (Y) = 0.15 m									
Smooth soil n=0.02	0.084	0.15	0.23	0.34	0.46	0.75	0.93	1.34	2.10	3.73
Rough soil n=0.04	0.34	0.60	0.93	1.34	1.83	3.02	3.73	5.36	8.38	14.9
Very rough soil n=0.06	0.75	1.34	2.10	3.02	4.11	6.79	8.38	12.1	18.9	33.5
	Type-B catch drain: flow top width (T) = 1.8 m and flow depth (Y) = 0.3 m									
Smooth soil n=0.02	0.034	0.060	0.094	0.14	0.18	0.30	0.38	0.54	0.85	1.50
Rough soil n=0.04	0.14	0.24	0.38	0.54	0.74	1.22	1.50	2.17	3.39	6.02
Very rough soil n=0.06	0.30	0.54	0.85	1.22	1.66	2.74	3.39	4.88	7.62	13.5
	Type-C catch drain: flow top width (T) = 3.0 m and flow depth (Y) = 0.5 m									
Smooth soil n=0.02	0.017	0.030	0.048	0.069	0.093	0.15	0.19	0.27	0.43	0.76
Rough soil n=0.04	0.069	0.12	0.19	0.27	0.37	0.62	0.76	1.10	1.71	3.05
Very rough soil n=0.06	0.15	0.27	0.43	0.62	0.84	1.39	1.71	2.47	3.86	6.85

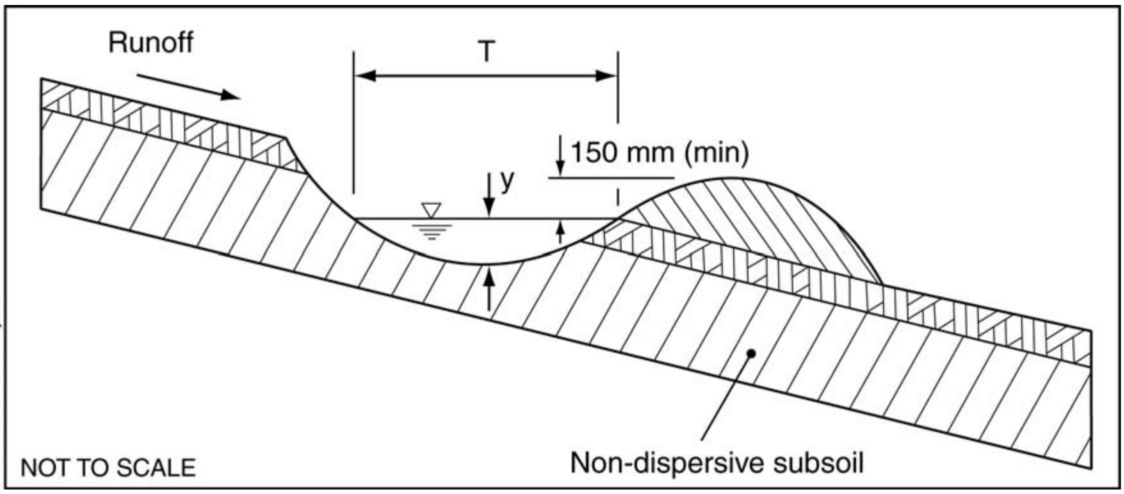

Figure 4(1) – Parabolic catch drain with bank

Table 9 – 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)**									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	0.720	0.960	1.200	1.440	1.680	1.920	2.160	2.400	3.600	4.800
20	0.540	0.720	0.900	1.080	1.260	1.440	1.620	1.800	2.700	3.600
25	0.432	0.576	0.720	0.864	1.008	1.152	1.296	1.440	2.160	2.880
30	0.360	0.480	0.600	0.720	0.840	0.960	1.080	1.200	1.800	2.400
35	0.309	0.411	0.514	0.617	0.720	0.823	0.926	1.029	1.543	2.057
40	0.270	0.360	0.450	0.540	0.630	0.720	0.810	0.900	1.350	1.800
45	0.240	0.320	0.400	0.480	0.560	0.640	0.720	0.800	1.200	1.600
50	0.216	0.288	0.360	0.432	0.504	0.576	0.648	0.720	1.080	1.440
55	0.196	0.262	0.327	0.393	0.458	0.524	0.589	0.655	0.982	1.309
60	0.180	0.240	0.300	0.360	0.420	0.480	0.540	0.600	0.900	1.200
65	0.166	0.222	0.277	0.332	0.388	0.443	0.498	0.554	0.831	1.108
70	0.154	0.206	0.257	0.309	0.360	0.411	0.463	0.514	0.771	1.029
75	0.144	0.192	0.240	0.288	0.336	0.384	0.432	0.480	0.720	0.960
80	0.135	0.180	0.225	0.270	0.315	0.360	0.405	0.450	0.675	0.900
85	0.127	0.169	0.212	0.254	0.296	0.339	0.381	0.424	0.635	0.847
90	0.120	0.160	0.200	0.240	0.280	0.320	0.360	0.400	0.600	0.800
95	0.114	0.152	0.189	0.227	0.265	0.303	0.341	0.379	0.568	0.758
100	0.108	0.144	0.180	0.216	0.252	0.288	0.324	0.360	0.540	0.720
105	0.103	0.137	0.171	0.206	0.240	0.274	0.309	0.343	0.514	0.686
110	0.098	0.131	0.164	0.196	0.229	0.262	0.295	0.327	0.491	0.655
115	0.094	0.125	0.157	0.188	0.219	0.250	0.282	0.313	0.470	0.626
120	0.090	0.120	0.150	0.180	0.210	0.240	0.270	0.300	0.450	0.600
125	0.086	0.115	0.144	0.173	0.202	0.230	0.259	0.288	0.432	0.576
130	0.083	0.111	0.138	0.166	0.194	0.222	0.249	0.277	0.415	0.554
135	0.080	0.107	0.133	0.160	0.187	0.213	0.240	0.267	0.400	0.533
140	0.077	0.103	0.129	0.154	0.180	0.206	0.231	0.257	0.386	0.514
145	0.074	0.099	0.124	0.149	0.174	0.199	0.223	0.248	0.372	0.497
150	0.072	0.096	0.120	0.144	0.168	0.192	0.216	0.240	0.360	0.480
155	0.070	0.093	0.116	0.139	0.163	0.186	0.209	0.232	0.348	0.465
160	0.068	0.090	0.113	0.135	0.158	0.180	0.203	0.225	0.338	0.450
165	0.065	0.087	0.109	0.131	0.153	0.175	0.196	0.218	0.327	0.436
170	0.064	0.085	0.106	0.127	0.148	0.169	0.191	0.212	0.318	0.424
175	0.062	0.082	0.103	0.123	0.144	0.165	0.185	0.206	0.309	0.411
180	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.300	0.400
185	0.058	0.078	0.097	0.117	0.136	0.156	0.175	0.195	0.292	0.389
190	0.057	0.076	0.095	0.114	0.133	0.152	0.171	0.189	0.284	0.379
200	0.054	0.072	0.090	0.108	0.126	0.144	0.162	0.180	0.270	0.360
210	0.051	0.069	0.086	0.103	0.120	0.137	0.154	0.171	0.257	0.343
220	0.049	0.065	0.082	0.098	0.115	0.131	0.147	0.164	0.245	0.327
230	0.047	0.063	0.078	0.094	0.110	0.125	0.141	0.157	0.235	0.313
240	0.045	0.060	0.075	0.090	0.105	0.120	0.135	0.150	0.225	0.300
250	0.043	0.058	0.072	0.086	0.101	0.115	0.130	0.144	0.216	0.288
Q (m^3/s)	**0.030**	**0.040**	**0.050**	**0.060**	**0.070**	**0.080**	**0.090**	**0.100**	**0.150**	**0.200**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 8).

Table 10 – 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)**									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	2.592	3.456	4.320	5.184	6.048	6.912	7.776	8.640	12.960	17.280
20	1.944	2.592	3.240	3.888	4.536	5.184	5.832	6.480	9.720	12.960
25	1.555	2.074	2.592	3.110	3.629	4.147	4.666	5.184	7.776	10.368
30	1.296	1.728	2.160	2.592	3.024	3.456	3.888	4.320	6.480	8.640
35	1.111	1.481	1.851	2.222	2.592	2.962	3.333	3.703	5.554	7.406
40	0.972	1.296	1.620	1.944	2.268	2.592	2.916	3.240	4.860	6.480
45	0.864	1.152	1.440	1.728	2.016	2.304	2.592	2.880	4.320	5.760
50	0.778	1.037	1.296	1.555	1.814	2.074	2.333	2.592	3.888	5.184
55	0.707	0.943	1.178	1.414	1.649	1.885	2.121	2.356	3.535	4.713
60	0.648	0.864	1.080	1.296	1.512	1.728	1.944	2.160	3.240	4.320
65	0.598	0.798	0.997	1.196	1.396	1.595	1.794	1.994	2.991	3.988
70	0.555	0.741	0.926	1.111	1.296	1.481	1.666	1.851	2.777	3.703
75	0.518	0.691	0.864	1.037	1.210	1.382	1.555	1.728	2.592	3.456
80	0.486	0.648	0.810	0.972	1.134	1.296	1.458	1.620	2.430	3.240
85	0.457	0.610	0.762	0.915	1.067	1.220	1.372	1.525	2.287	3.049
90	0.432	0.576	0.720	0.864	1.008	1.152	1.296	1.440	2.160	2.880
95	0.409	0.546	0.682	0.819	0.955	1.091	1.228	1.364	2.046	2.728
100	0.389	0.518	0.648	0.778	0.907	1.037	1.166	1.296	1.944	2.592
105	0.370	0.494	0.617	0.741	0.864	0.987	1.111	1.234	1.851	2.469
110	0.353	0.471	0.589	0.707	0.825	0.943	1.060	1.178	1.767	2.356
115	0.338	0.451	0.563	0.676	0.789	0.902	1.014	1.127	1.690	2.254
120	0.324	0.432	0.540	0.648	0.756	0.864	0.972	1.080	1.620	2.160
125	0.311	0.415	0.518	0.622	0.726	0.829	0.933	1.037	1.555	2.074
130	0.299	0.399	0.498	0.598	0.698	0.798	0.897	0.997	1.495	1.994
135	0.288	0.384	0.480	0.576	0.672	0.768	0.864	0.960	1.440	1.920
140	0.278	0.370	0.463	0.555	0.648	0.741	0.833	0.926	1.389	1.851
145	0.268	0.358	0.447	0.536	0.626	0.715	0.804	0.894	1.341	1.788
150	0.259	0.346	0.432	0.518	0.605	0.691	0.778	0.864	1.296	1.728
155	0.251	0.334	0.418	0.502	0.585	0.669	0.753	0.836	1.254	1.672
160	0.243	0.324	0.405	0.486	0.567	0.648	0.729	0.810	1.215	1.620
165	0.236	0.314	0.393	0.471	0.550	0.628	0.707	0.785	1.178	1.571
170	0.229	0.305	0.381	0.457	0.534	0.610	0.686	0.762	1.144	1.525
175	0.222	0.296	0.370	0.444	0.518	0.592	0.667	0.741	1.111	1.481
180	0.216	0.288	0.360	0.432	0.504	0.576	0.648	0.720	1.080	1.440
185	0.210	0.280	0.350	0.420	0.490	0.560	0.630	0.701	1.051	1.401
190	0.205	0.273	0.341	0.409	0.477	0.546	0.614	0.682	1.023	1.364
200	0.194	0.259	0.324	0.389	0.454	0.518	0.583	0.648	0.972	1.296
210	0.185	0.247	0.309	0.370	0.432	0.494	0.555	0.617	0.926	1.234
220	0.177	0.236	0.295	0.353	0.412	0.471	0.530	0.589	0.884	1.178
230	0.169	0.225	0.282	0.338	0.394	0.451	0.507	0.563	0.845	1.127
240	0.162	0.216	0.270	0.324	0.378	0.432	0.486	0.540	0.810	1.080
250	0.156	0.207	0.259	0.311	0.363	0.415	0.467	0.518	0.778	1.037
Q (m^3/s)	**0.108**	**0.144**	**0.180**	**0.216**	**0.252**	**0.288**	**0.324**	**0.360**	**0.540**	**0.720**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 8).

Table 11 – 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)									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	7.200	9.600	12.000	14.400	16.800	19.200	21.600	24.000	36.000	48.000
20	5.400	7.200	9.000	10.800	12.600	14.400	16.200	18.000	27.000	36.000
25	4.320	5.760	7.200	8.640	10.080	11.520	12.960	14.400	21.600	28.800
30	3.600	4.800	6.000	7.200	8.400	9.600	10.800	12.000	18.000	24.000
35	3.086	4.114	5.143	6.171	7.200	8.229	9.257	10.286	15.429	20.571
40	2.700	3.600	4.500	5.400	6.300	7.200	8.100	9.000	13.500	18.000
45	2.400	3.200	4.000	4.800	5.600	6.400	7.200	8.000	12.000	16.000
50	2.160	2.880	3.600	4.320	5.040	5.760	6.480	7.200	10.800	14.400
55	1.964	2.618	3.273	3.927	4.582	5.236	5.891	6.545	9.818	13.091
60	1.800	2.400	3.000	3.600	4.200	4.800	5.400	6.000	9.000	12.000
65	1.662	2.215	2.769	3.323	3.877	4.431	4.985	5.538	8.308	11.077
70	1.543	2.057	2.571	3.086	3.600	4.114	4.629	5.143	7.714	10.286
75	1.440	1.920	2.400	2.880	3.360	3.840	4.320	4.800	7.200	9.600
80	1.350	1.800	2.250	2.700	3.150	3.600	4.050	4.500	6.750	9.000
85	1.271	1.694	2.118	2.541	2.965	3.388	3.812	4.235	6.353	8.471
90	1.200	1.600	2.000	2.400	2.800	3.200	3.600	4.000	6.000	8.000
95	1.137	1.516	1.895	2.274	2.653	3.032	3.411	3.789	5.684	7.579
100	1.080	1.440	1.800	2.160	2.520	2.880	3.240	3.600	5.400	7.200
105	1.029	1.371	1.714	2.057	2.400	2.743	3.086	3.429	5.143	6.857
110	0.982	1.309	1.636	1.964	2.291	2.618	2.945	3.273	4.909	6.545
115	0.939	1.252	1.565	1.878	2.191	2.504	2.817	3.130	4.696	6.261
120	0.900	1.200	1.500	1.800	2.100	2.400	2.700	3.000	4.500	6.000
125	0.864	1.152	1.440	1.728	2.016	2.304	2.592	2.880	4.320	5.760
130	0.831	1.108	1.385	1.662	1.938	2.215	2.492	2.769	4.154	5.538
135	0.800	1.067	1.333	1.600	1.867	2.133	2.400	2.667	4.000	5.333
140	0.771	1.029	1.286	1.543	1.800	2.057	2.314	2.571	3.857	5.143
145	0.745	0.993	1.241	1.490	1.738	1.986	2.234	2.483	3.724	4.966
150	0.720	0.960	1.200	1.440	1.680	1.920	2.160	2.400	3.600	4.800
155	0.697	0.929	1.161	1.394	1.626	1.858	2.090	2.323	3.484	4.645
160	0.675	0.900	1.125	1.350	1.575	1.800	2.025	2.250	3.375	4.500
165	0.655	0.873	1.091	1.309	1.527	1.745	1.964	2.182	3.273	4.364
170	0.635	0.847	1.059	1.271	1.482	1.694	1.906	2.118	3.176	4.235
175	0.617	0.823	1.029	1.234	1.440	1.646	1.851	2.057	3.086	4.114
180	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	3.000	4.000
185	0.584	0.778	0.973	1.168	1.362	1.557	1.751	1.946	2.919	3.892
190	0.568	0.758	0.947	1.137	1.326	1.516	1.705	1.895	2.842	3.789
200	0.540	0.720	0.900	1.080	1.260	1.440	1.620	1.800	2.700	3.600
210	0.514	0.686	0.857	1.029	1.200	1.371	1.543	1.714	2.571	3.429
220	0.491	0.655	0.818	0.982	1.145	1.309	1.473	1.636	2.455	3.273
230	0.470	0.626	0.783	0.939	1.096	1.252	1.409	1.565	2.348	3.130
240	0.450	0.600	0.750	0.900	1.050	1.200	1.350	1.500	2.250	3.000
250	0.432	0.576	0.720	0.864	1.008	1.152	1.296	1.440	2.160	2.880
Q (m^3/s)	**0.300**	**0.400**	**0.500**	**0.600**	**0.700**	**0.800**	**0.900**	**1.000**	**1.500**	**2.000**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 8).

Table 12 – 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 13 – Required longitudinal gradient (%) for unlined, triangular cross-section V-drains

Manning's roughness (n)	Allowable flow velocity along catch drain (m/s)									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
	Type-AV catch drain: flow top width (T) = 1.0 m and flow depth (Y) = 0.15 m									
Smooth soil n=0.02	0.12	0.21	0.33	0.48	0.66	0.86	1.08	1.34	3.01	5.36
Rough soil n=0.04	0.48	0.86	1.34	1.93	2.63	3.43	4.34	5.36	12.1	21.4
Very rough soil n=0.06	1.08	1.93	3.01	4.34	5.91	7.72	9.76	12.1	27.1	48.2
	Type-BV catch drain: flow top width (T) = 1.8 m and flow depth (Y) = 0.3 m									
Smooth soil n=0.02	0.048	0.086	0.13	0.19	0.26	0.34	0.44	0.54	1.21	2.15
Rough soil n=0.04	0.19	0.34	0.54	0.78	1.06	1.38	1.74	2.15	4.85	8.61
Very rough soil n=0.06	0.44	0.78	1.21	1.74	2.37	3.10	3.92	4.85	10.9	19.4
	Type-CV catch drain: flow top width (T) = 3.0 m and flow depth (Y) = 0.5 m									
Smooth soil n=0.02	0.025	0.044	0.068	0.10	0.13	0.17	0.22	0.27	0.61	1.09
Rough soil n=0.04	0.10	0.17	0.27	0.39	0.53	0.70	0.88	1.09	2.45	4.36
Very rough soil n=0.06	0.22	0.39	0.61	0.88	1.20	1.57	1.99	2.45	5.52	9.81

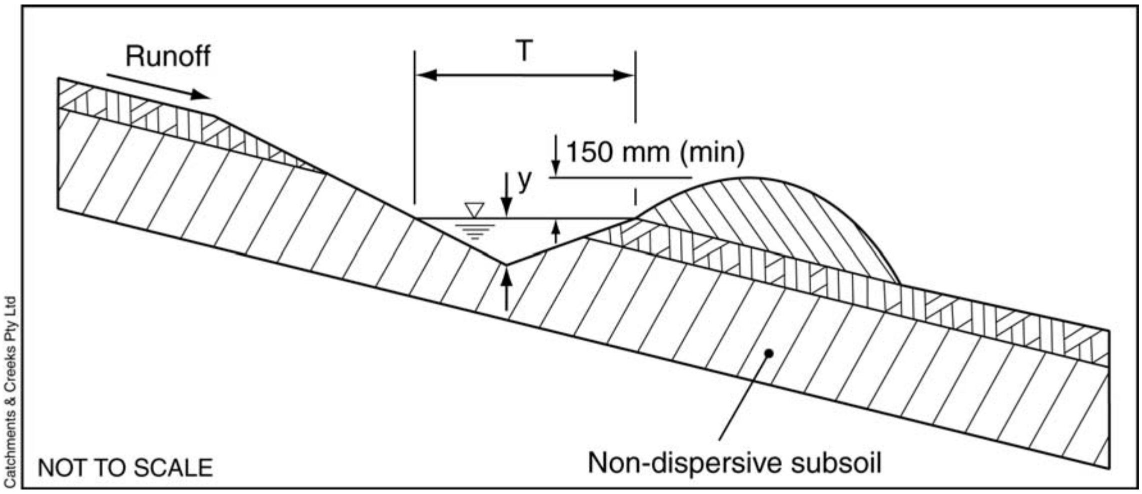

Figure 5(2) – Triangular V-drain with down-slope bank

Table 14 – 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)**									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	0.540	0.720	0.900	1.080	1.260	1.440	1.620	1.800	2.700	3.600
20	0.405	0.540	0.675	0.810	0.945	1.080	1.215	1.350	2.025	2.700
25	0.324	0.432	0.540	0.648	0.756	0.864	0.972	1.080	1.620	2.160
30	0.270	0.360	0.450	0.540	0.630	0.720	0.810	0.900	1.350	1.800
35	0.231	0.309	0.386	0.463	0.540	0.617	0.694	0.771	1.157	1.543
40	0.203	0.270	0.338	0.405	0.473	0.540	0.608	0.675	1.013	1.350
45	0.180	0.240	0.300	0.360	0.420	0.480	0.540	0.600	0.900	1.200
50	0.162	0.216	0.270	0.324	0.378	0.432	0.486	0.540	0.810	1.080
55	0.147	0.196	0.245	0.295	0.344	0.393	0.442	0.491	0.736	0.982
60	0.135	0.180	0.225	0.270	0.315	0.360	0.405	0.450	0.675	0.900
65	0.125	0.166	0.208	0.249	0.291	0.332	0.374	0.415	0.623	0.831
70	0.116	0.154	0.193	0.231	0.270	0.309	0.347	0.386	0.579	0.771
75	0.108	0.144	0.180	0.216	0.252	0.288	0.324	0.360	0.540	0.720
80	0.101	0.135	0.169	0.203	0.236	0.270	0.304	0.338	0.506	0.675
85	0.095	0.127	0.159	0.191	0.222	0.254	0.286	0.318	0.476	0.635
90	0.090	0.120	0.150	0.180	0.210	0.240	0.270	0.300	0.450	0.600
95	0.085	0.114	0.142	0.171	0.199	0.227	0.256	0.284	0.426	0.568
100	0.081	0.108	0.135	0.162	0.189	0.216	0.243	0.270	0.405	0.540
105	0.077	0.103	0.129	0.154	0.180	0.206	0.231	0.257	0.386	0.514
110	0.074	0.098	0.123	0.147	0.172	0.196	0.221	0.245	0.368	0.491
115	0.070	0.094	0.117	0.141	0.164	0.188	0.211	0.235	0.352	0.470
120	0.068	0.090	0.113	0.135	0.158	0.180	0.203	0.225	0.338	0.450
125	0.065	0.086	0.108	0.130	0.151	0.173	0.194	0.216	0.324	0.432
130	0.062	0.083	0.104	0.125	0.145	0.166	0.187	0.208	0.312	0.415
135	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.300	0.400
140	0.058	0.077	0.096	0.116	0.135	0.154	0.174	0.193	0.289	0.386
145	0.056	0.074	0.093	0.112	0.130	0.149	0.168	0.186	0.279	0.372
150	0.054	0.072	0.090	0.108	0.126	0.144	0.162	0.180	0.270	0.360
155	0.052	0.070	0.087	0.105	0.122	0.139	0.157	0.174	0.261	0.348
160	0.051	0.068	0.084	0.101	0.118	0.135	0.152	0.169	0.253	0.338
165	0.049	0.065	0.082	0.098	0.115	0.131	0.147	0.164	0.245	0.327
170	0.048	0.064	0.079	0.095	0.111	0.127	0.143	0.159	0.238	0.318
175	0.046	0.062	0.077	0.093	0.108	0.123	0.139	0.154	0.231	0.309
180	0.045	0.060	0.075	0.090	0.105	0.120	0.135	0.150	0.225	0.300
185	0.044	0.058	0.073	0.088	0.102	0.117	0.131	0.146	0.219	0.292
190	0.043	0.057	0.071	0.085	0.099	0.114	0.128	0.142	0.213	0.284
200	0.041	0.054	0.068	0.081	0.095	0.108	0.122	0.135	0.203	0.270
210	0.039	0.051	0.064	0.077	0.090	0.103	0.116	0.129	0.193	0.257
220	0.037	0.049	0.061	0.074	0.086	0.098	0.110	0.123	0.184	0.245
230	0.035	0.047	0.059	0.070	0.082	0.094	0.106	0.117	0.176	0.235
240	0.034	0.045	0.056	0.068	0.079	0.090	0.101	0.113	0.169	0.225
250	0.032	0.043	0.054	0.065	0.076	0.086	0.097	0.108	0.162	0.216
Q (m^3/s)	**0.023**	**0.030**	**0.038**	**0.045**	**0.053**	**0.060**	**0.068**	**0.075**	**0.113**	**0.150**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 13).

Table 15 – 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)**									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	1.944	2.592	3.240	3.888	4.536	5.184	5.832	6.480	9.720	12.960
20	1.458	1.944	2.430	2.916	3.402	3.888	4.374	4.860	7.290	9.720
25	1.166	1.555	1.944	2.333	2.722	3.110	3.499	3.888	5.832	7.776
30	0.972	1.296	1.620	1.944	2.268	2.592	2.916	3.240	4.860	6.480
35	0.833	1.111	1.389	1.666	1.944	2.222	2.499	2.777	4.166	5.554
40	0.729	0.972	1.215	1.458	1.701	1.944	2.187	2.430	3.645	4.860
45	0.648	0.864	1.080	1.296	1.512	1.728	1.944	2.160	3.240	4.320
50	0.583	0.778	0.972	1.166	1.361	1.555	1.750	1.944	2.916	3.888
55	0.530	0.707	0.884	1.060	1.237	1.414	1.591	1.767	2.651	3.535
60	0.486	0.648	0.810	0.972	1.134	1.296	1.458	1.620	2.430	3.240
65	0.449	0.598	0.748	0.897	1.047	1.196	1.346	1.495	2.243	2.991
70	0.417	0.555	0.694	0.833	0.972	1.111	1.250	1.389	2.083	2.777
75	0.389	0.518	0.648	0.778	0.907	1.037	1.166	1.296	1.944	2.592
80	0.365	0.486	0.608	0.729	0.851	0.972	1.094	1.215	1.823	2.430
85	0.343	0.457	0.572	0.686	0.800	0.915	1.029	1.144	1.715	2.287
90	0.324	0.432	0.540	0.648	0.756	0.864	0.972	1.080	1.620	2.160
95	0.307	0.409	0.512	0.614	0.716	0.819	0.921	1.023	1.535	2.046
100	0.292	0.389	0.486	0.583	0.680	0.778	0.875	0.972	1.458	1.944
105	0.278	0.370	0.463	0.555	0.648	0.741	0.833	0.926	1.389	1.851
110	0.265	0.353	0.442	0.530	0.619	0.707	0.795	0.884	1.325	1.767
115	0.254	0.338	0.423	0.507	0.592	0.676	0.761	0.845	1.268	1.690
120	0.243	0.324	0.405	0.486	0.567	0.648	0.729	0.810	1.215	1.620
125	0.233	0.311	0.389	0.467	0.544	0.622	0.700	0.778	1.166	1.555
130	0.224	0.299	0.374	0.449	0.523	0.598	0.673	0.748	1.122	1.495
135	0.216	0.288	0.360	0.432	0.504	0.576	0.648	0.720	1.080	1.440
140	0.208	0.278	0.347	0.417	0.486	0.555	0.625	0.694	1.041	1.389
145	0.201	0.268	0.335	0.402	0.469	0.536	0.603	0.670	1.006	1.341
150	0.194	0.259	0.324	0.389	0.454	0.518	0.583	0.648	0.972	1.296
155	0.188	0.251	0.314	0.376	0.439	0.502	0.564	0.627	0.941	1.254
160	0.182	0.243	0.304	0.365	0.425	0.486	0.547	0.608	0.911	1.215
165	0.177	0.236	0.295	0.353	0.412	0.471	0.530	0.589	0.884	1.178
170	0.172	0.229	0.286	0.343	0.400	0.457	0.515	0.572	0.858	1.144
175	0.167	0.222	0.278	0.333	0.389	0.444	0.500	0.555	0.833	1.111
180	0.162	0.216	0.270	0.324	0.378	0.432	0.486	0.540	0.810	1.080
185	0.158	0.210	0.263	0.315	0.368	0.420	0.473	0.525	0.788	1.051
190	0.153	0.205	0.256	0.307	0.358	0.409	0.460	0.512	0.767	1.023
200	0.146	0.194	0.243	0.292	0.340	0.389	0.437	0.486	0.729	0.972
210	0.139	0.185	0.231	0.278	0.324	0.370	0.417	0.463	0.694	0.926
220	0.133	0.177	0.221	0.265	0.309	0.353	0.398	0.442	0.663	0.884
230	0.127	0.169	0.211	0.254	0.296	0.338	0.380	0.423	0.634	0.845
240	0.122	0.162	0.203	0.243	0.284	0.324	0.365	0.405	0.608	0.810
250	0.117	0.156	0.194	0.233	0.272	0.311	0.350	0.389	0.583	0.778
Q (m^3/s)	**0.081**	**0.108**	**0.135**	**0.162**	**0.189**	**0.216**	**0.243**	**0.270**	**0.405**	**0.540**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 13).

Table 16 – 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)**									
	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.5**	**2.0**
15	5.400	7.200	9.000	10.800	12.600	14.400	16.200	18.000	27.000	36.000
20	4.050	5.400	6.750	8.100	9.450	10.800	12.150	13.500	20.250	27.000
25	3.240	4.320	5.400	6.480	7.560	8.640	9.720	10.800	16.200	21.600
30	2.700	3.600	4.500	5.400	6.300	7.200	8.100	9.000	13.500	18.000
35	2.314	3.086	3.857	4.629	5.400	6.171	6.943	7.714	11.571	15.429
40	2.025	2.700	3.375	4.050	4.725	5.400	6.075	6.750	10.125	13.500
45	1.800	2.400	3.000	3.600	4.200	4.800	5.400	6.000	9.000	12.000
50	1.620	2.160	2.700	3.240	3.780	4.320	4.860	5.400	8.100	10.800
55	1.473	1.964	2.455	2.945	3.436	3.927	4.418	4.909	7.364	9.818
60	1.350	1.800	2.250	2.700	3.150	3.600	4.050	4.500	6.750	9.000
65	1.246	1.662	2.077	2.492	2.908	3.323	3.738	4.154	6.231	8.308
70	1.157	1.543	1.929	2.314	2.700	3.086	3.471	3.857	5.786	7.714
75	1.080	1.440	1.800	2.160	2.520	2.880	3.240	3.600	5.400	7.200
80	1.013	1.350	1.688	2.025	2.363	2.700	3.038	3.375	5.063	6.750
85	0.953	1.271	1.588	1.906	2.224	2.541	2.859	3.176	4.765	6.353
90	0.900	1.200	1.500	1.800	2.100	2.400	2.700	3.000	4.500	6.000
95	0.853	1.137	1.421	1.705	1.989	2.274	2.558	2.842	4.263	5.684
100	0.810	1.080	1.350	1.620	1.890	2.160	2.430	2.700	4.050	5.400
105	0.771	1.029	1.286	1.543	1.800	2.057	2.314	2.571	3.857	5.143
110	0.736	0.982	1.227	1.473	1.718	1.964	2.209	2.455	3.682	4.909
115	0.704	0.939	1.174	1.409	1.643	1.878	2.113	2.348	3.522	4.696
120	0.675	0.900	1.125	1.350	1.575	1.800	2.025	2.250	3.375	4.500
125	0.648	0.864	1.080	1.296	1.512	1.728	1.944	2.160	3.240	4.320
130	0.623	0.831	1.038	1.246	1.454	1.662	1.869	2.077	3.115	4.154
135	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	3.000	4.000
140	0.579	0.771	0.964	1.157	1.350	1.543	1.736	1.929	2.893	3.857
145	0.559	0.745	0.931	1.117	1.303	1.490	1.676	1.862	2.793	3.724
150	0.540	0.720	0.900	1.080	1.260	1.440	1.620	1.800	2.700	3.600
155	0.523	0.697	0.871	1.045	1.219	1.394	1.568	1.742	2.613	3.484
160	0.506	0.675	0.844	1.013	1.181	1.350	1.519	1.688	2.531	3.375
165	0.491	0.655	0.818	0.982	1.145	1.309	1.473	1.636	2.455	3.273
170	0.476	0.635	0.794	0.953	1.112	1.271	1.429	1.588	2.382	3.176
175	0.463	0.617	0.771	0.926	1.080	1.234	1.389	1.543	2.314	3.086
180	0.450	0.600	0.750	0.900	1.050	1.200	1.350	1.500	2.250	3.000
185	0.438	0.584	0.730	0.876	1.022	1.168	1.314	1.459	2.189	2.919
190	0.426	0.568	0.711	0.853	0.995	1.137	1.279	1.421	2.132	2.842
200	0.405	0.540	0.675	0.810	0.945	1.080	1.215	1.350	2.025	2.700
210	0.386	0.514	0.643	0.771	0.900	1.029	1.157	1.286	1.929	2.571
220	0.368	0.491	0.614	0.736	0.859	0.982	1.105	1.227	1.841	2.455
230	0.352	0.470	0.587	0.704	0.822	0.939	1.057	1.174	1.761	2.348
240	0.338	0.450	0.563	0.675	0.788	0.900	1.013	1.125	1.688	2.250
250	0.324	0.432	0.540	0.648	0.756	0.864	0.972	1.080	1.620	2.160
Q (m^3/s)	**0.225**	**0.300**	**0.375**	**0.450**	**0.525**	**0.600**	**0.675**	**0.750**	**1.125**	**1.500**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 13).