Annexe 6

Designing a simple drainage system for stormwater

Designing a simple stormwater drainage system

In this annexe we present a method to estimate how much stormwater a catchment area will produce, and how a drain can be sized to remove this water.
This method can be used to design a simple drainage system, or to determine whether a proposed drainage system is realistic.

Materials needed:

- A map of the catchment area with gradient lines, or a study of the catchment area from which it is possible to calculate its gradients and boundaries
- Ruler
- Paper with gridlines
- A calculator with the option 'y to the power x' (y^x)
- Preferably the IDF-curves (intensity-duration-frequency curves) of the zone studied

Analysis of the catchment area

First the catchment area with its boundaries will have to be identified on the map. A catchment area is the entire surface that will discharge its stormwater to one point (the discharge point). As water always flows from high to low, it is possible to identify the catchment area on a map with the aid of the gradient lines. Once the catchment area is identified, its surface must be estimated. This can be done by transferring the contours of a catchment area on paper with gridlines, and counting the grids.

Now the average gradient in the catchment area has to be identified. This can be done on the map with the aid of the gradient lines and the horizontal distances. Figure A6.1 shows how to determine the gradient in a terrain. Usually the average gradient of the terrain can be taken.

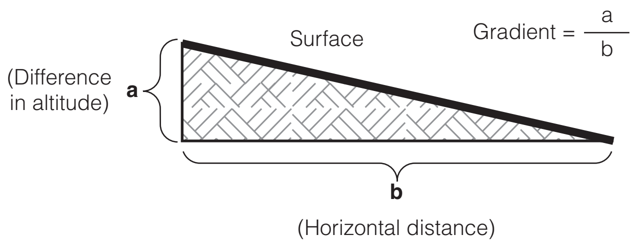

Figure A6.1. The gradient of a terrain

The next step is to assess the surface of the terrain. This information is needed to determine the runoff coefficient of the area. The runoff coefficient is that part of the rainwater which becomes stormwater; a runoff coefficient of 0.8 means that 80% of the rainfall will turn into stormwater. The runoff coefficient depends on the type of terrain, and its slope. Future changes in the terrain must be anticipated in the design of the drainage system to avoid problems at a later date. If no other values are available, the values from table A6.1 can be used.

Table A6.1. Runoff coefficients of different types of terrain (these values are approximate figures assuming a low soil permeability) (adapted from 49).

Terrain type	*Runoff coefficient*	
	Gradient < 0.05 (flat terrain)	*Gradient > 0.05 (steep terrain)*
Forest and pastures	0.4	0.6
Cultivated land	0.6	0.8
Residential areas and light industry	0.7	0.8
Dense construction and heavy industry	1.0	1.0

Determining the rainfall intensity for which the system is designed

If no local IDF-curves (intensity-duration-frequency curve) are available, a rainfall intensity of 100 mm per hour can be assumed (this value is for tropical countries, with catchment areas smaller than 150 ha) [17]. If no IDF curves can be found, the reader can skip directly to the section *Calculating the amount of water the catchment area will produce*

If the IDF curves of the area can be obtained, these should be used. IDF curves show the rainfall intensity (in mm per hour) against the duration of the rains (in minutes) for specific return periods. Several curves from different return periods may be presented in one graph. A curve with a return period of 1 year will show the worst storm that will on average occur every year, a curve with a return period of 2 years is the worst storm that can be expected in a 2 year period, and so on.

To know which value to take from the IDF curve, the time of concentration has to be calculated. The time of concentration is the time the water needs to flow from the furthest point in the catchment area to the point where it will leave the area (the discharge point). The time of concentration is determined with the formula [(49)]:

$$T_{con} = 0.02 \times (L_{max})^{0.77} \times (S_{av})^{-0.383}$$

T_{con} : the time of concentration (in minutes)
L_{max} : the maximum length of flow in the catchment (in metres)
S_{av}: the average gradient of the catchment area

If the furthest point of our catchment area is at a distance of 500 metres from the discharge point, and the difference in altitude between this point and the discharge point is 10 metres, than the time of concentration would be around ($0.02 \times (500)^{0.77} \times (10/500)^{-0.383}$ =) 11 minutes.

The curve with the appropriate return period is chosen (for residential areas often the curve with a 2 year return period [(39)]).

We look for the rainfall intensity on the chosen curve, at the duration of a storm equal to the time of concentration which we calculated.

Calculating the amount of water the catchment area will produce
The amount of stormwater the catchment will produce can be determined with the formula [(adapted from 49)]:

$$Q_{des} = 2.8 \times C \times i \times A$$

Q_{des} : the design peak runoff rate, or the maximum flow of stormwater the system will be designed for (in litres per second)
C : the runoff coefficient (see table F.1)
i : the rainfall intensity at the time of concentration read from the chosen IDF curve; if no IDF curves are available, a value of 100 mm/h can be taken (in mm/h)
A : the surface area of the catchment area (in ha (10,000 m^2))

Thus, if our catchment area would be a residential area, with a surface of 12 ha, a gradient of 0.02, and a rainfall intensity of 100 mm/h, than the design peak runoff rate would be around (2.8 x 0.7 x 100 x 12 =) 2350 litres per second.

It should be remembered that this figure is not a fixed value. Every once in a while storms will occur which produce more water than the drainage system can deal with (normally, on average, periods just above the return period). The larger the capacity of the system (the longer the return period the system is designed for) the less often it will overflow, and the higher its costs.

Sizing a drain to cope with the design peak runoff rate

With the design peak runoff rate known, we will have to plan where the drains will be installed. A drainage system must be planned together with other structures like roads and buildings to assure they are all adapted to one another.

Unlined drains are at risk of erosion, and should therefore have a relatively low gradient to control the velocity of the stormwater. Gradients in unlined drains should probably not exceed 0.005 (1 metre drop in 200 metres horizontal distance). In less stable soil unlined drains should be made with a slope less steep than 1/2 (see figure A6.2), in more cohesive material a steeper slope could be used [17].

The size of the drain can be calculated with the formula [17]:

$$Q = 1000 \times \left(\frac{A \times (R)^{0.67} \times (S)^{0.5}}{N} \right)$$

Q : the capacity of discharge of the drain (in l/s)
A : the cross section of the flow (in m^2)
R : the hydraulic radius of the drain (see figure F.3, in m)
S : the gradient of the drain
N : Manning's roughness coefficient: for earth drains, 0.025; brick drains,

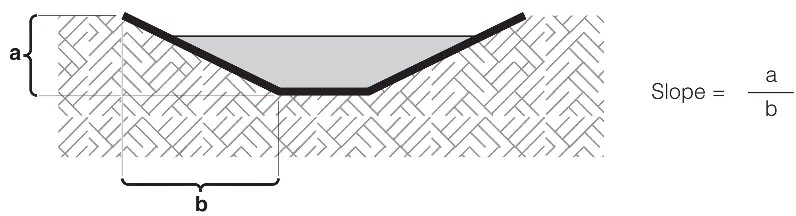

Figure A6.2. Section of an unlined drain in less stable soil

the hydraulic radius is the surface area of the cross section of the flow/the total length of the contact between water and drain;

Hydraulic radius = (a x b) / (a + b + c)

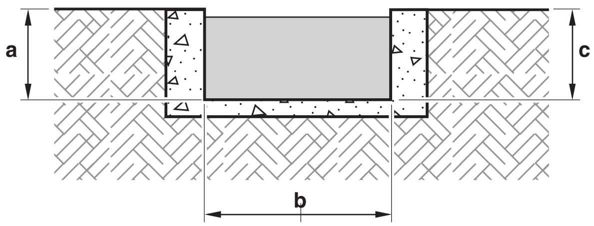

Figure A6.3. The hydraulic radius

A completely filled, rectangular, smooth concrete drain of 1.5 m by 0.7 m, with a gradient of 0.005, can in ideal circumstances discharge around $(1000 \times ((1.5 \times 0.7) \times ((1.5 \times 0.7/(1.5 + 0.7 + 0.7))^{0.67} \times (0.005)^{0.5}) / 0.015) = 2500$ litres per second.

This calculation will probably have to be repeated a number of times to find the adequate size of drain (17).

Some reserve will be needed so that the drain is not completely filled with water, and because the calculated discharge rate does not take into account deposited solids, and lack of maintenance, which will usually reduce the efficiency of the system (39).

Annexes

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