Oxfam

Low cost drainage for emergencies

Effective drainage is important in emergencies when there is a risk of flooding or there is a risk of poor environmental health conditions developing from standing water, muddy conditions, or erosion. It would not usually be the first priority in the initial stages of an emergency, but should be considered after the immediate water, sanitation and hygiene needs have been met. Sites which have natural slopes and drainage may not require additional work except in localised areas, such as providing cut off drains to prevent water from flowing into latrines or shelters.

This Technical Brief provides an overview of the general principles of good drainage design and introduces a range of construction options for simple drainage channels, erosion control and road crossings. It focusses only on surface water drainage and does not cover the disposal of sullage or sewage. It has drawn heavily on early work by UNCHS (Habitat) and by the ILO in the area of labour intensive construction and low cost drainage.

Purpose of drainage

The purpose of surface water drainage is:

1. To remove water safely and effectively from living areas and hence improving the living environment.

2. To prevent standing water, flooding and erosion.

3. To ensure that vehicular and pedestrian access is possible at all times, particularly for access in medical emergencies.

In turn effective drainage can prolong the life of simple structures, reduce breeding grounds for mosquitoes and reduce the build up of muddy stagnant pools. These can harbour dangerous pathogens which can cause a range of faecal oral related diseases, from which children playing around them can be particularly susceptible. They can also become breeding grounds for mosquitoes.

Attention to drainage is particularly necessary, but also most challenging, where the ground is either very steeply sloping (in the form of erosion control), or very flat.

Simple earth drains being constructed to reduce the muddy conditions around the tents in Jabba tented village, IDP camp in Pakistan
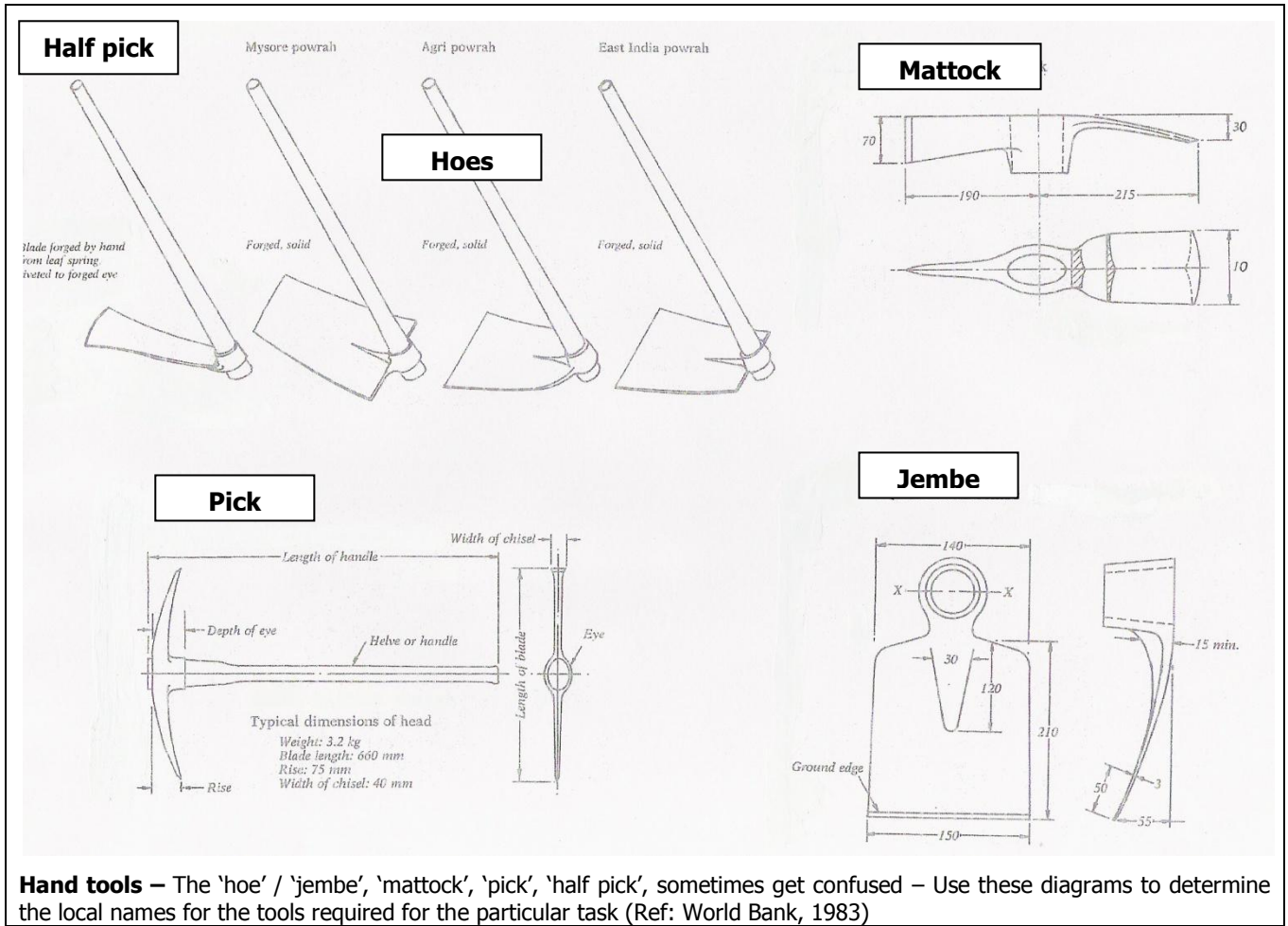
During emergencies there may be particular needs for drainage in camp situations and in urban environments. In urban environments, it is possible that the work

required will be limited to unblocking or repairing existing drainage networks, but in poor peri-urban environments, existing drainage may be non-existent.
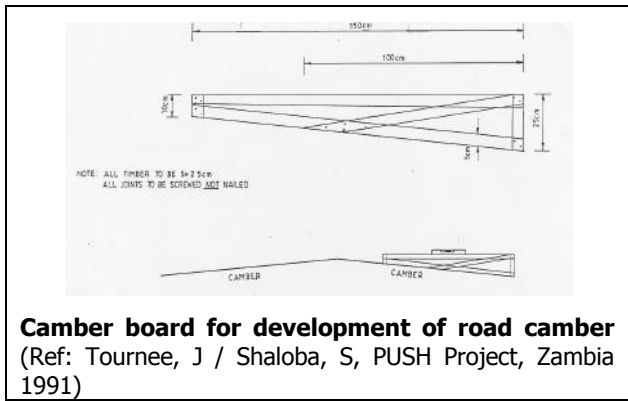
Principles of good drainage design

1. Drainage design starts from the receiving water body or outfall. Drain inverts will need to be designed backwards from this point and wherever possible follow the natural fall of the ground surface.

2. Secondary drainage feeds into larger interceptor drains which connect into the receiving water body or outfall.

3. Water should always be kept flowing and should not stop when reaching a crossing point. Drainage must allow water to pass effectively across all roads (over or under) and road junctions, whilst also allowing vehicular and safe pedestrian access.

4. Water should ideally flow fast enough that the solids it is carrying will not be deposited in the drain. Drains with sloping sides and narrow bases help to maintain a steady flow.

5. When the fall along the bottom of the drain is steeper than 1% (falls greater than 1 unit in 100 units distance), protection against scouring effects will be needed, either by lining or providing protection at particularly vulnerable points along the network.

6. Ground which slopes greater than 5% can be considered a steep slope. Drainage will require design features to reduce the speed of the flow, such as turn-out-drains, constructing drainage along the contours, or including steps or check-walls into the drain profiles.

7. Effective drainage construction and operation and maintenance are activities which benefit from the involvement of the local communities and / or the affected populations.

Tools for drainage construction

Half pick

Mysore powrah   Agri powrah   East India powrah

Hoes

Mattock

Blade forged by hand from leaf spring riveted to forged eye

Forged, solid   Forged, solid   Forged, solid

70   190   215   30   10

Pick

Jembe

Width of chisel

Length of handle

Depth of eye   Helve or handle   Eye

Length of blade

Typical dimensions of head
Weight: 3.2 kg
Blade length: 660 mm
Rise: 75 mm
Width of chisel: 40 mm

Rise

140   X   X   30   120   210   15 min.   50   3   55   Ground edge   150

Hand tools – The 'hoe' / 'jembe', 'mattock', 'pick', 'half pick', sometimes get confused – Use these diagrams to determine the local names for the tools required for the particular task (Ref: World Bank, 1983)

150 cm   100 cm   NOTE: ALL TIMBER TO BE 5×7.5cm   ALL JOINTS TO BE SCREWED NOT NAILED   CAMBER   CAMBER

Camber board for development of road camber (Ref: Tournee, J / Shaloba, S, PUSH Project, Zambia 1991)

The selection of hand tools, appropriate to the local users, is important for drainage construction. The pickaxe, mattock, hoe and shovel or spade are the tools which will be required in greatest numbers. Communities usually have a preference for the type of tool they feel most comfortable working with and local names can vary. The pictures at the top of this page have been provided so that they can be used when discussing the purchase of tools for drainage construction.

As with any tools for labour intensive work, care must be taken to ensure that the tools are sharpened on a regular basis and the handles are securely fixed into the heads without additional wood being fitted into the gaps. Loose heads or blunt tools can lead to accidents. A stock of spare handles for the key tools is also useful (if heavy

use is expected then purchase an additional 10% of handles when placing initial orders).

Other tools which may be required include: sledge hammers and crowbars for breaking rock, a tape measure for measuring distances and drain widths, string, pegs and lump hammer or lime powder for marking out the line of the drain, and a spirit level or **'line level'** (a spirit level which is hung on a line) to help determine the slope of the drain.

Shovel   Hoe   Pick   Mattock   Camber board   Drain profile
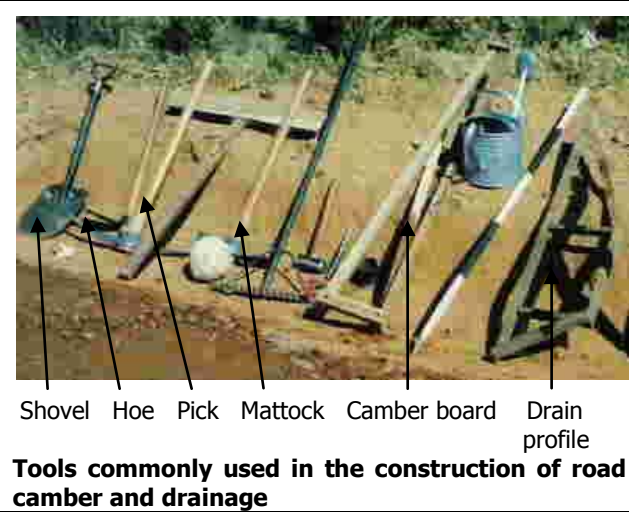
Tools commonly used in the construction of road camber and drainage

Men and women may prefer different tools. For example, women sometimes prefer head-pans for earthmoving whilst men may prefer wheelbarrows. Wherever possible consult the users as to their preferred tools, particularly for extensive drainage works.

A **'camber board'** is a triangular board which can be used to form the slope or **'camber'** of a road surface or a drain slope. It is used in conjunction with a spirit level which makes sure the camber board is held level. A **'ditch or drain profile'** is a shape of the cross section of the drain which can be used as template during excavation.

Large rocks which can not be removed by digging around them or by hitting them with a sledge hammer can be removed using the **'fire and water method'**. A fire is burnt on the rock and then when it is very hot, cold water is poured onto the rock. The heating and cooling process results in cracks in the rock which can then be forced apart using a crow bar. This method however is both time-consuming and expensive and can use up a large quantity of wood. Any work involving smashing rock with a sledge hammer must be undertaken with appropriate clothing and in particular with goggles to protect the workers eyes from flying pieces of rock.

Simple drainage channel designs
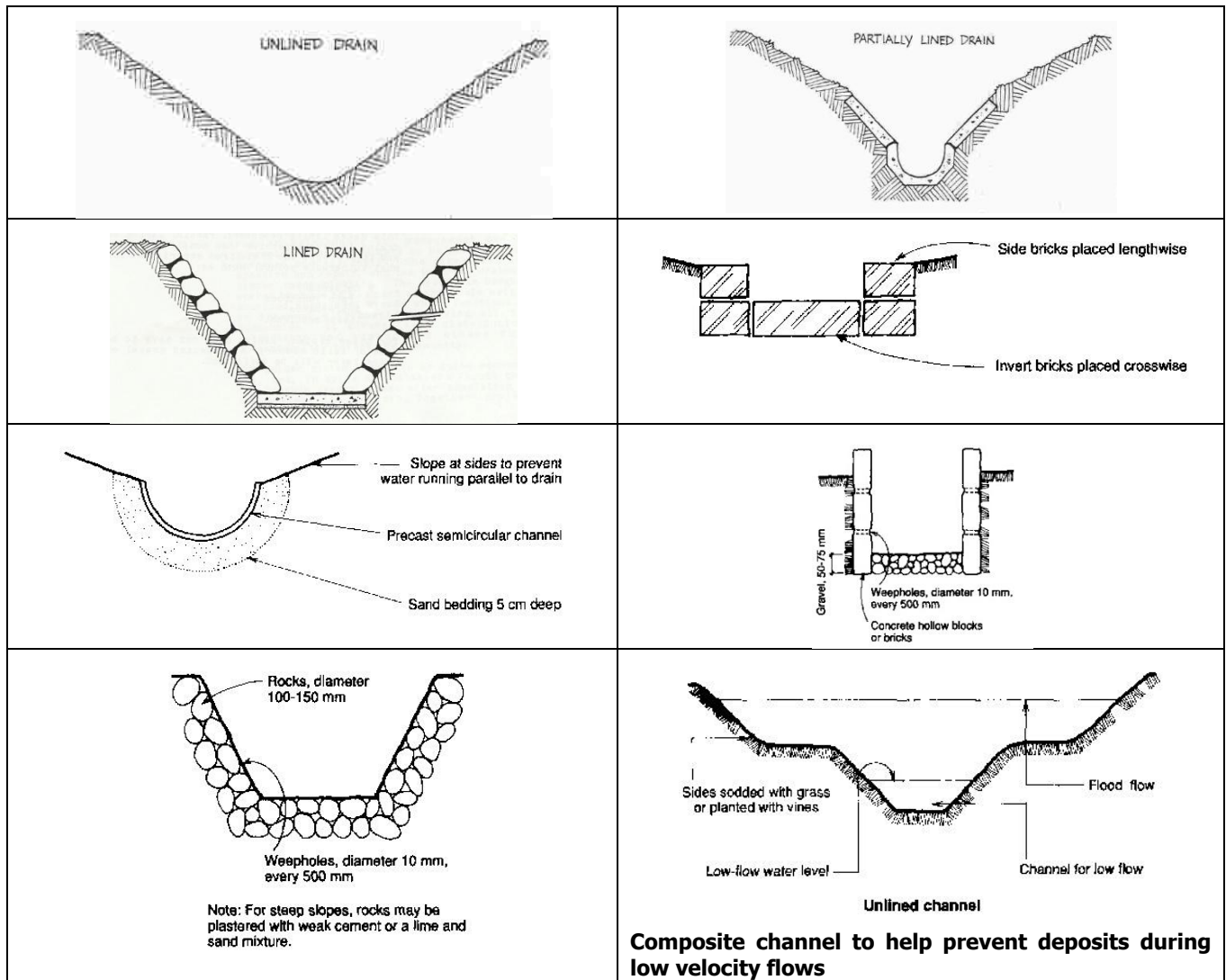
Variations in simple drainage cross-sections (Refs: taken directly from UNCHS (Habitat), 1986; WHO, 1991)

A range of different low-cost drain cross sections are shown above. The choice of shape, size and lining of the drainage channels will depend on a number of factors. For example, it would not be appropriate to construct expensive lined drains in an IDP camp which is expected to only be in place for a short period of time and hence simple earth unlined drains may be adequate. However, if the site is on a steeply sloping where there is a risk of gulleys forming and damage to living areas, then simple unlined drains may not be appropriate on their own. Where there is limited space, a drain with vertical sides

may be the only design possible, but unless the drainage is only required for a short period of time, the sides should ideally be lined to prevent erosion.

The **'composite channel'** is a small drain within a drain and is designed for areas where there are likely to be a wide variation in flows and particularly where there may be sullage thrown into the drain as well as the drain collecting storm water. Without the smaller channel in the middle, the sullage water will deposit its solids as it

would have a low velocity in the large channel. This could then pose an environmental hazard.

For large or complex areas, for example in peri-urban environments where there are going to be many road crossings, detailed design of the drainage network will be required (see the final section below). But for a small area where it is clear in which direction the water will naturally flow, it may be appropriate to simply design the lines, sizes and fall of the drains by eye on site. Watching the flow of the water and any particular problem areas during a heavy rainfall can be a useful tool in determining the required routes of the drains.

Self-cleansing flow

'Roughly speaking, a channel of 10-15cm wide will need a minimum slope of about 1% to achieve a self-cleansing speed of flow. A channel twice the size needs roughly half the slope' (WHO, 1991). Such gradients will not always be possible however, so a regular drain cleaning regime will be required to prevent the drains from filling.

## Erosion protection

Drainage on steep slopes

Slopes of ground above 5% can be considered steep slopes and will require additional features to reduce the speed of the water and prevent erosion. These features can include:

1. Constructing **'turn-out-drains'**, which take the water away from the main drainage route and direct it into fields to soak away. These are usually only possible in rural environments or where there is open space in urban areas.

2. Constructing the drainage along the contours of the land.

3. Construct **'check-walls'** or **'erosion checks'** at regular intervals down a slope. These effectively form small walls across the drain and can be constructed of stone, wooden poles, or masonry, or for large drains from gabions (large baskets of wire with large stones placed inside). As the water passes down the drain it stops behind each check-wall and deposits its solid load. After a while the solids build up until a stepped effect is produced which reduces the effective slope of the drain (see the diagrams opposite).

4. In areas with a moderate drain slope (4-10%), the drains can also be lined with concrete masonry or vegetation.

Stone pitching for erosion protection alongside a road culvert and at the join of two drains

For unlined drains, erosion protection may still be needed at particularly vulnerable locations where sour effects may be strongest, for example at bends, or at outlets to drifts or culverts, or where one drain feeds into another drain. Stone masonry known as **'stone pitching',** uses stones of approximately 15cm thick and cement mortar to bind the stones together (see the photo above).
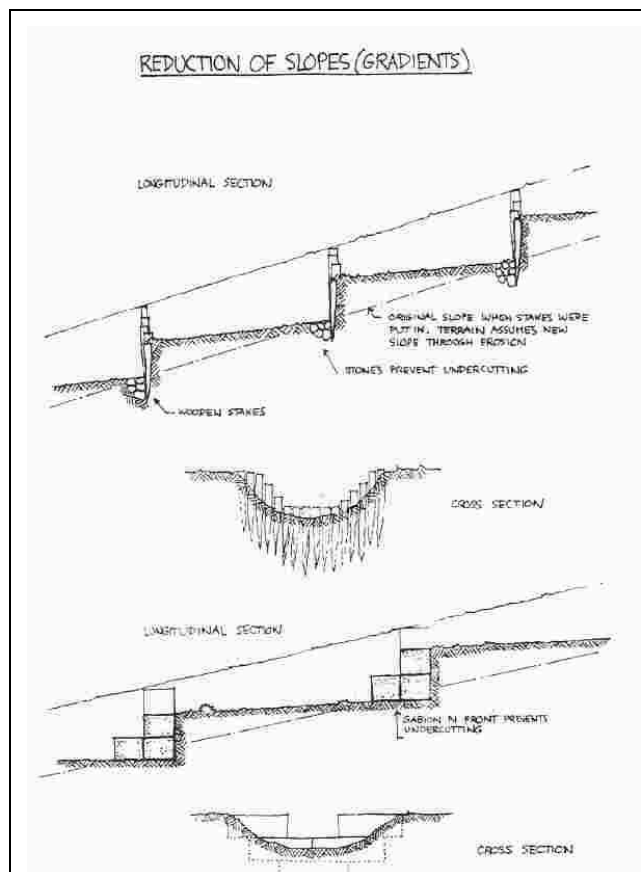
Steepness	Gradient	Spacing of erosion checks
Very steep hill	More than 10%	5m spacing
Steep hill	Between 5-10%	10m spacing
Gentle hill	Between 3-5%	20m spacing
Almost flat	Up to 3%	Checks are not required

(Ref: Antoniou, J et al, 1990)

Roads and drainage

Roads are important to ensure access at all time. This is particularly important for medical related emergencies where vehicle access may be needed to take somebody to hospital. **Drainage is the most important part of a road** and if the drainage is correct and the road surface material reasonable, then the road should be passable for most of the year.

Road surfaces

The best surface for a simple road is compacted **'road gravel'**, which consists of approximately 50% stone, 40% sand and 10% clay. Its strength comes from the various sizes of stone locking together on compaction with water.

Drainage for roads includes:

- A **'catch water drain'** catches the water flowing from above the road, before it reaches the road and directs it away from the road surface.

- The slope, **'camber'** or **'cross-fall'** of the road surface which allows the water to drain from the road.

- The roadside drain(s) which collect the water from the road surface.

- The **'interceptor drains'** or **'turn out drains'** which take the water away from the roadside drains to disposal.

- The road crossings or **'cross-drainage'**, which allow the water in the drains to cross over or under the road and allow drains to cross over or under road junctions. These are often the most difficult part of drainage construction.

Road camber or crossfall

1. For earth and gravel (laterite) roads (those which are not covered in tarmac nor have a concrete surface), the cross fall or camber should be between 5 – 7% (i.e. it rises by 7 units for every 100 units in length). (Ref: Antoniou, J et al, 1991).

2. Where there is a fall in one direction this is called a **'cross-fall'**. Where the slopes form a roof shape and falls in two directions from the centre of the road down to drain on either side this is called a **'camber'**.

3. When the road turns around a corner, the camber of the road should change to form a single cross-fall, from the outer edge falling down towards the inner edge of the turn.

4. The camber can be formed using a number of methods, but the use of a camber board with spirit level is one of the simplest methods.

Road crossings or 'cross drainage'

Three types of road crossings are discussed below – drifts, culverts and vented fords.
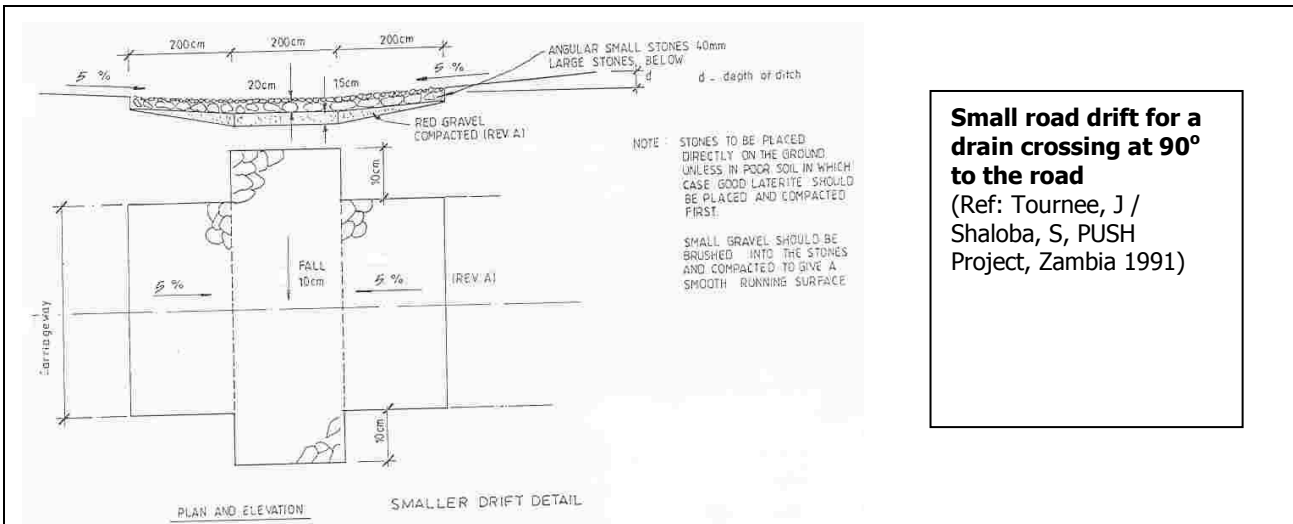
Small road drift for a drain crossing at 90° to the road
(Ref: Tournee, J / Shaloba, S, PUSH Project, Zambia 1991)
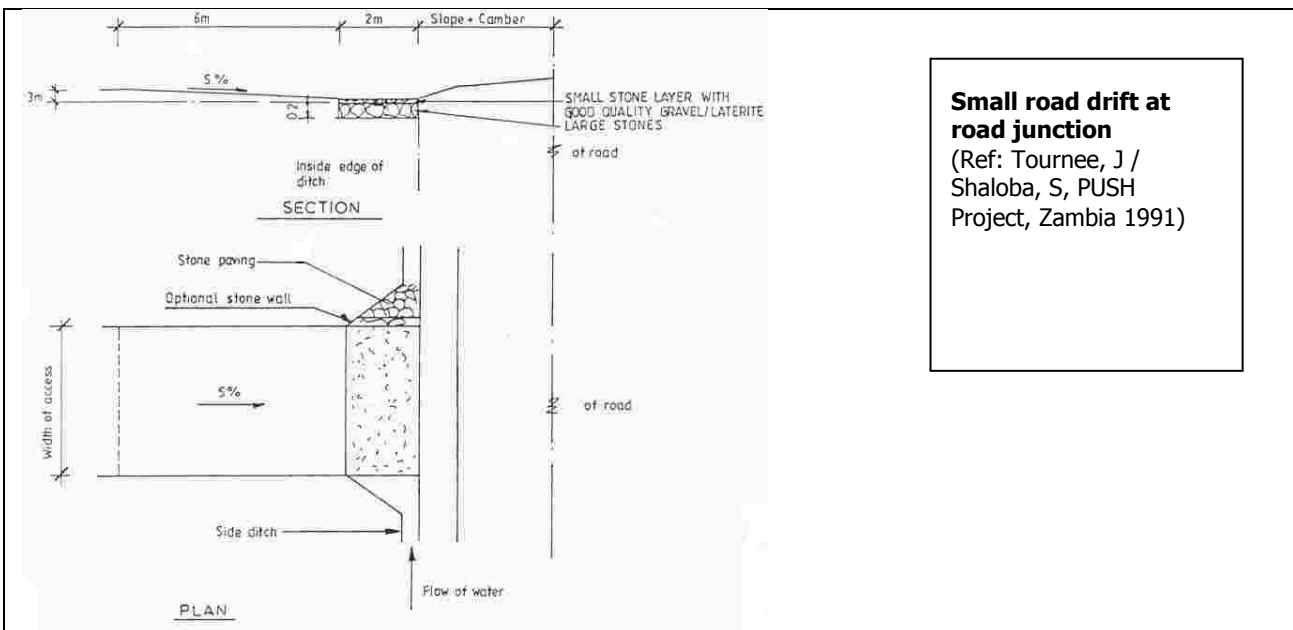
Small road drift at road junction
(Ref: Tournee, J / Shaloba, S, PUSH Project, Zambia 1991)

In many instances, a **'drift'** will be preferable to a pipe. Pipes block easier than drifts and unless they are of large enough diameters, they will be difficult to unblock. Two small drift designs are shown above, but numerous variations are possible.

Drifts

'Drifts' can be constructed of a range of sizes, and can be constructed with large stones, well graded road gravel and small chippings, or can have a surface of concrete with weld mesh or reinforcement bars on top of a stone foundation. They are usually used for drain crossings where there are reasonably small flows.

The entrance and exit slopes of the road should have a maximum 5% slope to ensure that vehicles can pass over them easily without hitting the underside of the vehicle on the ground.

The most important design considerations for a drift are:

1. There should be a fall across the drift and there should be a clear outlet for the water, so that the water will not stop and pond on the drift.

2. The base of the drift and the approaches should be firm enough that they will not deform significantly when there are vehicle movements when the ground is wet.

**Road drift as an alternative to culverts**

Culverts

Pipes / culverts of 600mm in diameter are the recommended minimum size for road crossings, as smaller pipes than this block easily and are more difficult to clean. However, to use 600mm pipes the drains need to be deep, which is not always possible. The culverts should have headwalls to provide a visible indication of the edge of the road for vehicles and pedestrians. Pipes / culverts however should be avoided wherever possible due to the difficulty in their maintenance.
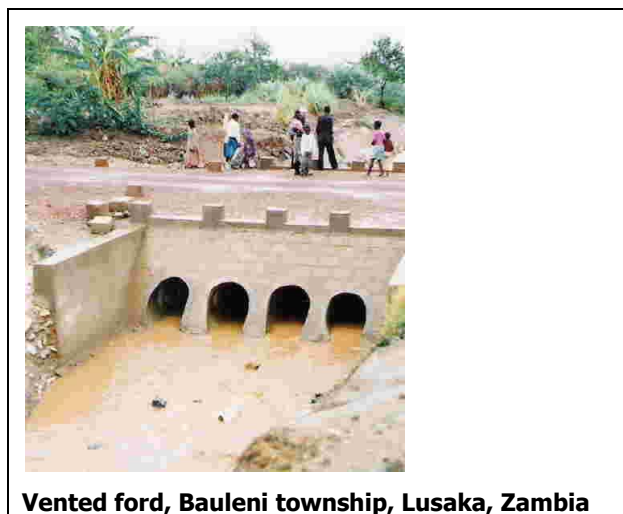
Vented fords

Vented fords are a cross between a pipe culvert and a drift. They allow for the water to pass through the pipes under a road during normal flows and then for the water to pass over the road surface when there are exceptional flows. They allow the number of pipes to be minimised and hence reduce the cost of the road

crossing. Care must be taken to ensure that the surface of the vented ford is lower than the surrounding ground area and the rest of the road, so that the flood waters remain in the channel and do not damage the surrounding road surface.

A vented ford would be considered when a major drain crosses a road.
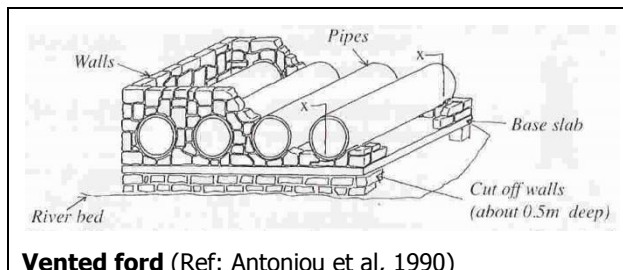
Vented ford (Ref: Antoniou et al, 1990)

Vented ford, Bauleni township, Lusaka, Zambia

Maintenance of drainage systems

The design of a maintenance system for drainage will depend on the context. In an emergency camp setting, occasional clearing of the drainage system can be undertaken on a cash-for-work basis. In peri-urban communities, a community based scheme for long term maintenance could be considered.

In both instances, people will require appropriate tools to be able to clean the drainage and remove the deposited material from the sides of the drains, so that it doesn't just wash back in again during the next rains. The people responsible will need long handled hoes, shovels or scoops, buckets or headpans, wheelbarrows, gloves, waterproof boots and overalls if the work is particularly dirty. Minor repairs may also be needed at the end of each rainy season to ensure that stone pitching and constructed drifts and culverts retain their integrity.

Simple drainage design

Terms used in storm water drainage design
(Ref: UNCHS, 1986, WHO, 1991 and Cotton & Franceys, 1991):

1. **'Rainfall intensity' (i)** is usually measured in mm/hour. This is the depth of water which would cover an area of flat ground after one hour of rainfall if there was no infiltration into the ground.

2. The volume of water also depends on the intensity of rainfall. The more severe rainfalls occur less regularly. The probability of a certain intensity of rainfall occurring is called the **'return period'**. A rainfall with a return period of 1 in 20 years is called a '20 year storm'. In the design a balance has to be made between the damage that could be done designing for shorter return periods and the extra cost of designing larger drains. A 5 year return period is often used to design primary drainage systems in tropical cities, but 1 to 3 year return periods are sometimes used for the smaller drains through residential areas.

3. The proportion of water which runs over the ground and needs collecting in drains (i.e. does not evaporate or infiltrate) is called the **'run-off coefficient'**. It varies with different types of ground surfaces – soil types, terrain and land use. Run-off coefficients are higher in clay soil or rock, steep slopes and densely built up areas with little vegetation. For a run off coefficient of 1, all water runs of off it, and for a coefficient of 0, all water infiltrates and hence there is no run-off. If there are periods of intense rain which lasts for a long time, the ground can be saturated and the run-off coefficient will increase to 1.

4. The correct duration of rainfall to use in designing a drain is the **'concentration time'** of the catchment area which it serves, which is the time for water falling from the furthest edge of the catchment area to travel over the ground and through drains to the point which is being designed.

Steps in designing a storm water drainage network

1. Decide on the appropriate return period and concentration time.

2. Find the maximum rainfall intensity for those conditions (I, mm/hr). This can usually be obtained from the department of hydrogeology or water resources. Some examples are shown in the chart on the following page.

3. Locate or draw a map of the area with key features and distances identified.

4. Decide how dense the drainage network will need to be to cope with the surface water. Draw the lines of the drains on a map as much as possible following the contours. Artificially cut the land up around each of the drains to indicate which areas of land which will feed into each drain which is **'the catchment area' (A)**.

5. The rational method assumes that the storm duration which is appropriate for a particular drainage catchment equals the total time it takes for rain falling on the most distant part of the catchment to flow down to the outfall point of that catchment.

'The Rational Method'

'Time of Concentration' = **'Time of Entry'** for the water to reach the drain + **'Time of Flow'** in the drainage system to reach that point.

- Time of Entry can be taken as 3 minutes for urban housing

- Time of Concentration can be taken as 15 mins for areas of up to 20 ha with slopes <0.5%, or for flatter areas up to 4 ha

$$\textbf{'Time of Flow'} = \frac{\text{Length of drain}}{\text{Velocity in the drain}}$$

- Assume the velocity in the drain to be 0.7m/s for the first estimate

- The duration of the storm appropriate to the catchment is equal to the time of concentration, and hence the rainfall intensity can be determined

- If there is no rainfall data then assume a rainfall intensity of 100 mm/hr for tropical climates for areas less than 150 ha

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6. Estimate the **runoff coefficient for the catchment (C.)**

7. Calculate the **'peak flow'** or the **volume of water to be drained into each drain per second (Q)**.

'The rational method'

Q (l/s) = 2.78 x C x A (hectares) x I (mm/hr)

(1 hectare = 10,000 m^3; 10m x 10m area = 0.01 ha)

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8. Determine the drain size which can carry the required flow either using Mannings Formula or by using the chart on the following page with adjustments for channel shape and surface material (using the Mannings Roughness Coefficient).

Mannings roughness coefficient:

Earth – 0.025

Brick – unrendered – 0.018

Brick – smooth rendered – 0.015

Concrete – smooth finish – 0.015

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9. Check the expected water velocities to reduce deposits and limit scour and select types of drain and lining appropriately.

10. Modify the drain sizes and repeat the calculations in an iterative manner, until the velocity is finally acceptable.

Built up areas	Run off Coefficients (C.)		
	Commercial and industrial	High density residential	Low density residential
	0.75 – 1.0	0.5 – 0.6	0.3 – 0.4

Humid regions	Soil permeability			
Average ground slope	Very low (rock and clay)	Low (clay loam)	Medium (sandy loam)	High (sand and gravel)
Flat: 0-1%	0.55	0.40	0.2	0.05
Gentle: 1-4%	0.75	0.55	0.35	0.20
Medium: 4 – 10%	0.85	0.65	0.45	0.30
Steep: >10%	0.95	0.75	0.55	0.40

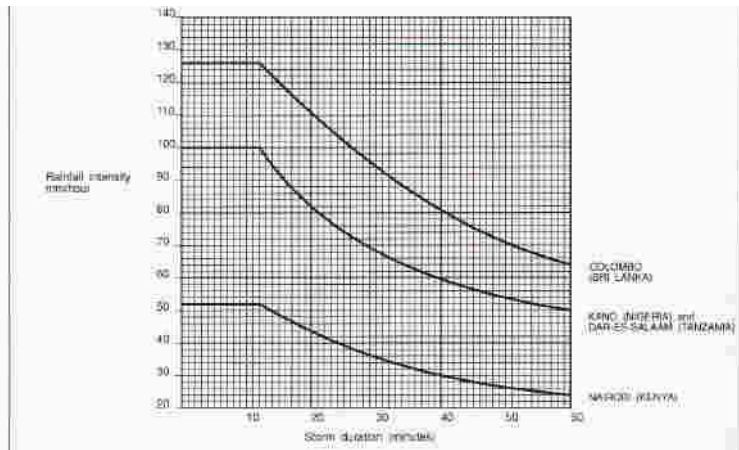| Semi-arid regions	Soil permeability			
Average ground slope	Very low (rock and clay)	Low (clay loam)	Medium (sandy loam)	High (sand and gravel)
Flat: 0-1%	0.75	0.40	0.05	0.00
Gentle: 1-4%	0.85	0.55	0.20	0.00
Medium: 4 – 10%	0.95	0.70	0.30	0.00
Steep: >10%	1.00	0.80	0.50	0.05

Figure 3.14: Examples of rainfall intensity for once in one year design storms at various locations

Run-off coefficients
(Ref: WHO, 1991 and UNCHS, 1986)

Rainfall intensity charts
(Ref: Cotton & Franceys, 1991)

Flow chart vs slope and channel depth and alternative cross sections
(WHO, 1991)
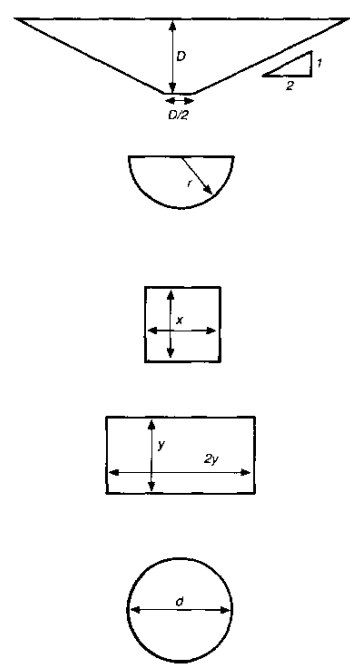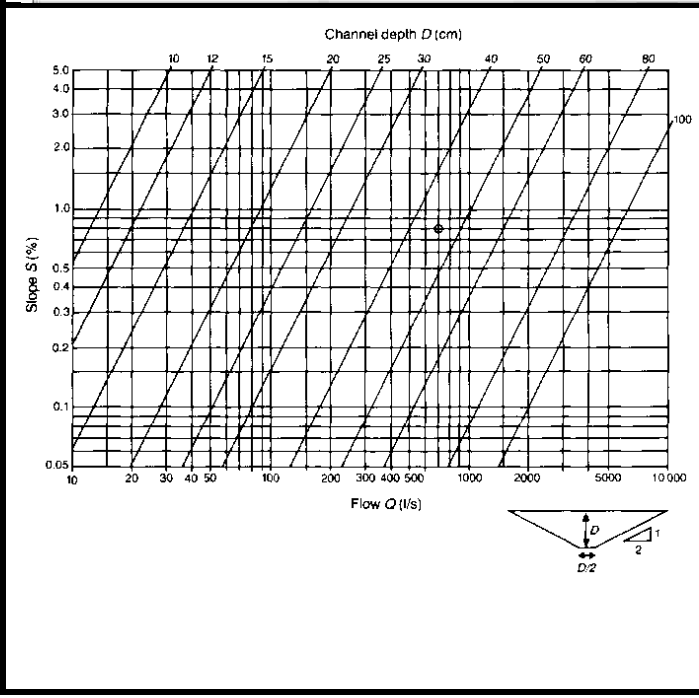
(a) Trapezoidal channel
Base width = $\frac{D}{2}$
Side slope = 1 in 2
Find D from Fig. A2.3.

(b) Semicircular channel
Radius r = 1.2 D
Find D from Fig. A2.3.
Then multiply by 1.2 (i.e., add 20%) to find r

(c) Square channel
Side x = 1.56 D
Find D from Fig. A2.3.
Then multiply by 1.56 (i.e., add 56%) to find x.

(d) Rectangular channel
Depth y, width 2y
y = 1.1 D
Find D from Fig. A2.3.
Then multiply by 1.1 (i.e., add 10%) to find y

(e) Closed circular pipe, flowing full
Diameter d = 1.34 D
Find D from Fig. A2.3.
Then multiply by 1.34 (i.e., add 34%) to find d.

Further information

Antoniou, J, Guthrie, P, De Veen, J (1990) Building roads by hand, An introduction to labour-based road construction, ILO , published by Longman Group (UK) Ltd

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