
47 HILLSIDE DRAINAGE

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47.1 INTRODUCTION

Hillside development has been rapid in the last two decades in Malaysia and has resulted in acute environmental problems in many locations such as Penang, Klang Valley and other strong growth areas. Apart from urban expansion, development has also occurred in inland hilly areas as well as near coastlines and on islands for resort purposes. Planning and achieving sustainable development in such environment is particularly important in regard to drainage, flash flood, erosion and sediment and slope stability management. Some residential areas or settlements in hilly areas are also prone to frequent water supply shortage due to severely low water pressure. Malaysia is subject to high intensity and more frequent rainstorms than most developed countries and it thus requires more stringent control measures, structural and/or non-structural, to deal with the problems.

47.1.1 Objectives

This chapter aims to provide designers and users with additional and specific requirements for planning, design and implementation of drainage/stormwater management facilities in hillside development project based on the criteria already described in Chapter 4. The primary goals of the design are:

1. to attenuate and control surface runoff quantity while enhancing total/smooth conveyance of the reduced flow from developed areas
2. to reduce infiltration, erosion/sedimentation and subsequently enhance slope stability

47.1.2 Requirements

To achieve the prescribed goals the followings are among the requirements/measures that shall be observed:

(a) Structural Methods

1. More or larger detention facilities (lined) are required
2. Runoff infiltration facilities are not permitted
3. Conveyance facilities are fully lined
4. Encourage integration of efficient subsoil drainage
5. Biofiltration and infiltration trench are not allowed except over large (plateau) areas
6. Wet sediment basin and wet pond are not permitted unless they are fully lined
7. Enhance bioengineering stabilisation techniques

(b) Planning and Non-structural Methods

1. Water cycle changes and consequences due to the development should be thoroughly understood
2. Development should be properly scheduled and earthworks only undertaken in drier periods

3. Strengthening administrative/legal framework and local authority requirements
4. Submission of special earthwork/construction activity plan, ESCP plan, and drainage plan
5. Subsurface/vadose zone drainage plan shall also be submitted and approved along with the surface drainage plans
6. Percent (%) imperviousness and landuse types should be carefully planned in an effort to reduce increased runoff quantity
7. Proximity of hillside development area to receiving waters, lake/reservoir, river, estuary and sea requires further design criteria for runoff control measures
8. Surface/subsurface soil and geological investigation should be thoroughly planned and carried out and be critically assessed and approved by the authority concerned
9. Cut and fill slopes must not be steeper than the gradient of original/natural slope and platform must be graded unless protected by retaining walls

47.2 CURRENT PRACTICES

Housing and resort related developments are common activities on hillsides and their components include buildings, roads, car parks and open space. The existing practices for hillside development in relation to drainage are discussed below.

Local standard practice often fails to take into account the natural features of the landscape. Hillside land offers greater opportunities than flat land for imaginative design and landscape planning. Despite this and the fact that hillside lots are highly valued in most societies, developers too often fail to take advantage of the site or destroy it by taking inappropriate planning decisions.

There must be a 'fit' between the site and the nature of the development proposed. For example, hillside land is rarely appropriate for large buildings, which would be better located on flat land that has easy access and requires less earthworks. The hillside land would be more suitable for dispersed housing.

47.2.1 Increased Surface Runoff and Impacts

For the same imperviousness area and rainstorm magnitude a hillside zone normally generates higher flood peaks than a flat area due to its shorter time of concentration. Thus development over hillsides usually causes more severe flash flooding impacts to downstream settlements and receiving waters. The increased runoff rates can lead to increased flooding, erosion and soil loss.

The common feature in this process is that the residents of the river lowlands are affected by flooding and water quality problems caused by development in upstream

areas. This is a form of social inequity, and has been recognised as such in many overseas countries, where it is dealt with by planning, economic and social mechanisms.

Erosion and sediment control practices during construction are rarely up to the standard required. Because of the high intensity of rainfalls in Malaysia, erosion and sediment control is particularly important to prevent the loss of topsoil and siltation of rivers. This is even more so in hillside areas because the steep slopes create potential for rapid soil loss and mass movement during construction.

47.2.2 Increased Runoff Infiltration and Impacts

Of all the techniques considered for the correction or prevention of slope instability on hillside development, proper drainage is recognised as the most important element. Proper drainage reduces soil moisture content and the destabilising hydrostatic and seepage forces on a slope, as well as the risk of surface erosion and piping. Poor site planning and design in a hillside development area causes large quantities of rainwater collected in the drainage system and from direct rainfall, to infiltrate into the ground.

As a long-term solution it has not always been effective, because the drains must be properly designed and maintained if they are to continue to function. In the current practice, often, the design has made the maintenance difficult. Whether this is so or not, proper maintenance is rarely planned and even more rarely practised.

(a) Earthworks Problems

In local standard practice, grading of a hillside development area is done with a combination of cutting or filling the terrain with slopes to achieve the intended platform (refer Figure 47.1).

In cases where the factor of safety is not achieved, a retaining structure is built. Although this is a common practice, cutting and filling to create a flat land platform actually produces a poor overland water flow. Due to the flat area, stormwater does not run off the site but ponds on the platform and starts to infiltrate into the soil, causing seepage and eventually slope instability problems.

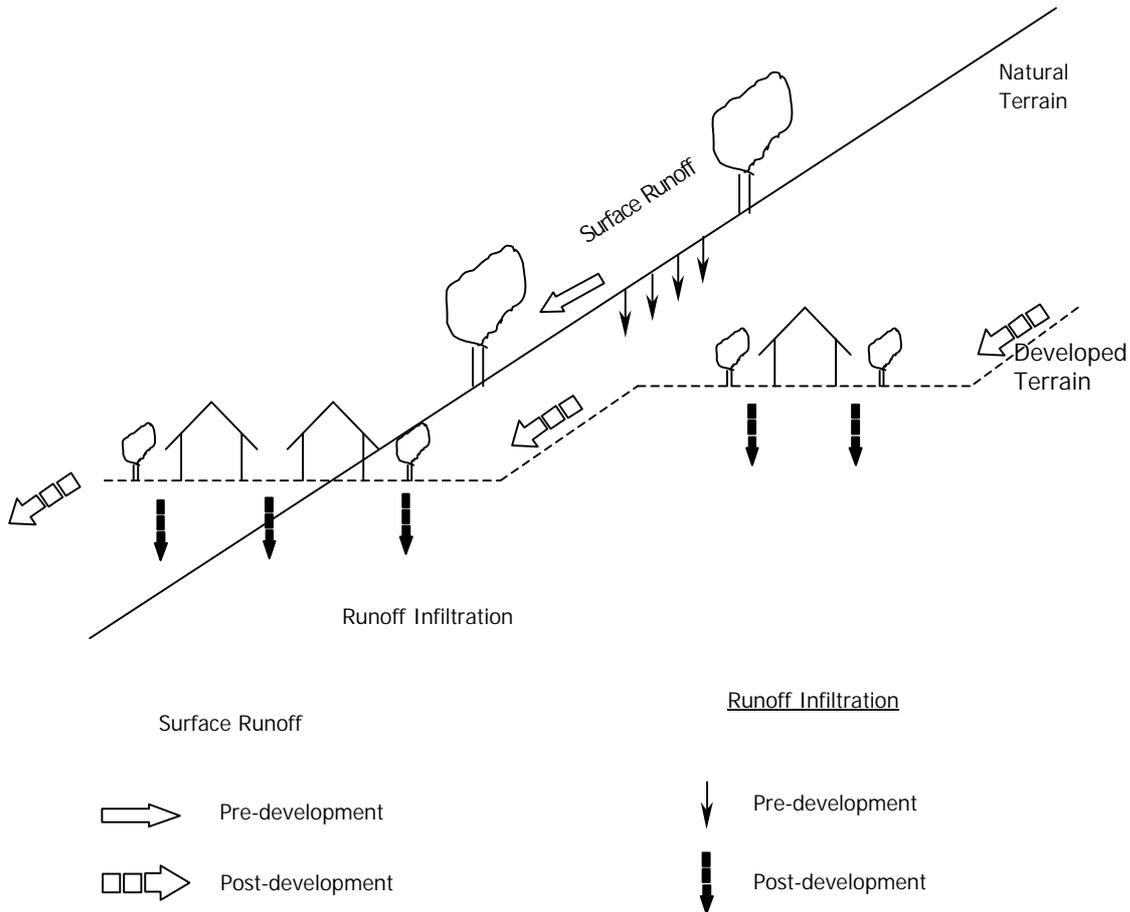


Figure 47.1 Typical Hillside Development Impacts on Runoff

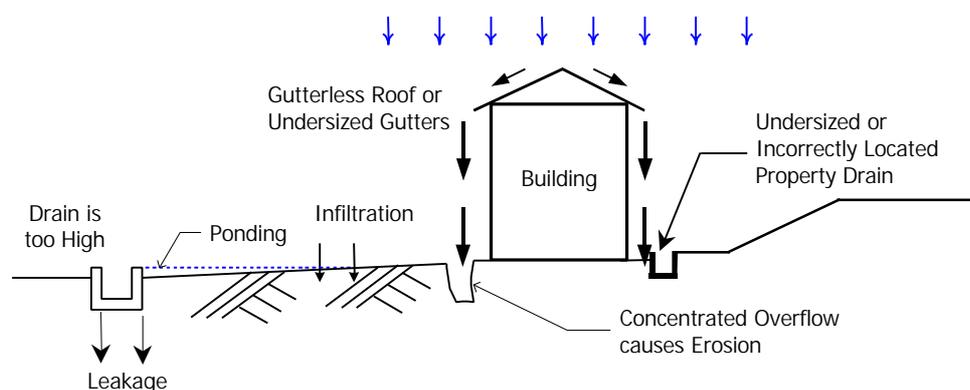


Figure 47.2 Typical Roof and Property Drainage Problems

For cases involving retaining structures, drainage is not properly maintained even if the structure has been properly designed. Granular materials are seldom used for backfill behind the retaining wall. Due to this, weep holes are easily clogged with the backfill material. With the weep holes not functioning, pore water pressure builds up (from infiltration) behind the structure, eventually resulting in failure.

(b) Roof and Property Drainage Problems

In common practice, although the roofs of buildings are designed to collect stormwater, there is no provision to effectively drain them to the perimeter drain surrounding the buildings. The concentrated runoff from the roof eaves is sometimes much higher than the direct impact due to rainwater. This can cause ground erosion (Figure 47.2).

(c) Public Drainage Problems

Public drainage system here refers to all types of surface drainage outside of the individual properties. While flooding in the commonly understood sense is usually not a problem, many other types of problems do occur with the public drainage system in hillside areas.

In some cases surface drains are installed in such a way that the wall of the drain is much higher than the surrounding platform itself (refer Figure 47.2). This prevents lateral surface runoff from entering the drains, causing ponding and infiltration into the ground. Furthermore some of the drainage systems leak or crack, allowing infiltration to take place. This affects the stability of slopes due to the downward spreading of infiltrated water.

In the normal practice pavements are built with some gradient and are designed to be impermeable. Due to the poor supervision during construction, and high traffic loads, the pavement starts to crack and becomes permeable with time. Concrete and asphalt pavements are

supported by a subbase of sand or stone to provide the structural stability and drainage for the total structure. However, a significant amount of stormwater can infiltrate to this subbase course and creating water path or gullies below the structures, eventually increasing problems to the pavements. It also creates stability problems to the surrounding area due to increased moisture content in the vadose zone.

In some cases, a good amount of stormwater is usually collected beneath the pavement and is designed to channel out from the pavement by means of a sub-soil drainage system. But again due to poor maintenance, the outlets may become clogged and ponding starts and is followed by infiltration. For pavements without sub-surface drainage system the scenario becomes worst where gullies will be created and eventually ponding can induce infiltration.

(d) Slope Stability

The infiltration actually creates the wetting front such that the unsaturated zone (vadose zone) becomes saturated resulting in superficial failure and finally the overall slope fails by the same phenomena in a retrogressive process (Figure 47.3). This phenomenon normally takes place within the vadose zone in urban slopes where the water table is quite low.

47.3 RECOMMENDED PRACTICES

47.3.1 Design and Planning Requirements

Further and/or specific design considerations applicable for hillside development are given below. Relevant information on these recommendations will be found in other Chapters of this Manual, as listed.

The standards set out in this section are mandatory for the development of all land that has a natural slope of 20% (12.5°) or greater.

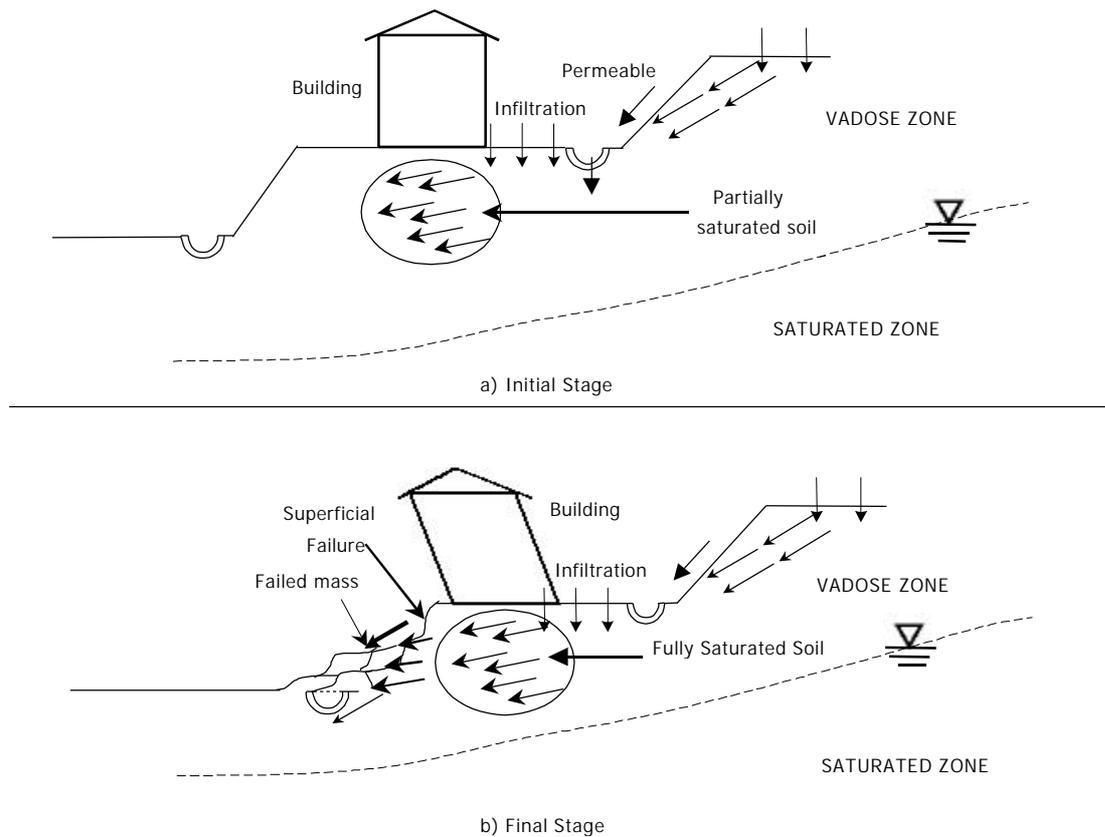


Figure 47.3 Typical Slope Failure due to Infiltration

Local Authorities may choose to apply the provisions for land that has a flatter natural slope, such as 15%, if local geological, climatic or other conditions justify this application.

(a) Design Standards

(i) Design Rainfall Intensities

The designer is alerted to the possibility that design rainfall intensities in hillside areas, particularly those at the foot of mountain ranges, could be higher than on adjacent flat land. This effect is well recognised in certain overseas countries where rainfall is dominated by orographic influences.

It is not possible at present to quantify this effect in Malaysia, due to lack of data. Most rainfall here comes from convective thunderstorms, which may possibly be less influenced by orographic effects. More data collection including the placing of pluviometers in hilly areas, is

needed to allow further research. It is considered that in the interim, the higher design standards recommended in this chapter will provide some allowance for this effect.

(ii) Roof and Property Drainage

Buildings in which roof gutters are omitted, shall not be permitted in hillside areas. This type of roof drainage would have unacceptable consequences in terms of the erosion impact and infiltration of rainfall, on potentially unstable hill slopes.

The 20 year ARI standard for roof eaves gutters (Table 23.1) should be increased to 50 year ARI in hillside areas. The standard for box gutters is governed by other factors, and does not change.

(iii) Public Drainage System

Cut-off drains (see Chapter 26, section 26.5) shall be installed on the uphill side of all developments on land

where the total uphill catchment is greater than 0.4 hectare. The purpose of these drains is to ensure that runoff from the surrounding hillsides does not flow into the development.

The use of swales, infiltration basins and on-site retention is generally not permitted in hillside areas because of the risk of increasing soil saturation and instability. On-site detention, if required, should use underground or above ground storage tanks as described in Section 47.3.2. Sloping sites will generally preclude the use of on-ground detention storage.

(b) Site Planning

As a general principle, the less the amount (volume) of earthworks on hillside land, the lesser the problems will be. Consider whether a cut-and-filled platform is really necessary or whether a better result can be achieved by terracing or other means.

A qualified geotechnical consultant, taking account of the site conditions should check the extent of cut and fill.

Developers should be aware that proper site planning will be in their own long-term interests. It will reduce costs (such as earthworks costs), increase the market value of the development and eliminate risk and maintenance cost associated with slope failure.

47.3.2 Surface Runoff Control

The runoff hydrograph from a hillside development is likely to be very 'peaky' due to the steep slopes causing a short time of concentration. For this reason, every effort should be made to incorporate detention storage in the development. The aim of this OSD is to make the post development peak discharge lower than the predevelopment peak discharge such that the risk of downstream flooding or soil erosion is reduced.

On-site detention (OSD) facilities (Chapter 19), at roof tops, ground floor, below ground tank, pipe jacket, basement parking etc, are required at lot or property levels with a design standard corresponding to that of the minor drainage system. The *storage design storm* shall be 10 year ARI.

Where it is not practicable, because of land constraints, to include detention storage within the development the developer should pay a suitable contribution towards the cost of constructing detention storage further downstream. OSD using green park/lawn is not permitted. OSD can also be incorporated together with stormwater/rainwater reuse facilities.

At community/public levels detention facilities are required to be designed at 100 year ARI. This applies to tennis court (highly paved), wet basin (lined), park pond (over

clay and with network of subsurface collection pipes) and football field (over clay and with network of subsurface collection pipes). For detention pond and sediment pond (with lining and subsurface collector pipes) overflows are allowed only under rarer events (200 year ARI). Proximity of these ponds to downstream slope depends on slope steepness, pond size/volume and local soil characteristics. Advice of a geotechnical consultant should be obtained before proceeding to such installation.

47.3.3 Minimising Erosion, Infiltration and Slope Failures

(a) Erosion and Sediment Control

The provisions of Part H of this Manual dealing with Erosion and Sediment Control, apply to all land development. However, it is pointed out that erosion and sediment control is particularly important for hillside areas due to the higher flow velocities and potential instability of the ground.

Cut-off channels shall be installed at the construction stage before significant earthworks are carried out on the development site. These cut-off channels should be included in the overall ESCP for the development because they will considerably assist in reducing stormwater flow across the disturbed areas.

The construction schedule should aim to minimise the amount of exposed earthworks at any given time. Ideally, a section of works should be completed and revegetated before the next section is commenced.

(b) Earthworks

In a hillside development area where cutting or filling is undertaken, the platform should be graded at between 1% and 2% to permit runoff and minimise infiltration that may lead to instability. Planting should be used to stabilise the slope by the binding action of plant roots.

(c) Retaining Walls

For cases where a retaining structure is needed due to stability, the retaining structures must be designed to allow passage of groundwater without endangering the integrity and performance of the structure. Permeable material such as sand or aggregate should be placed behind the retaining structure to cater the infiltration and seepage. A perforated subsurface drain should be placed at the toe of retaining structure to collect the infiltrated water to the proper channel without endangering the slopes. A surface drain can also be introduced on the uphill side of the retaining structure to cater the surface runoff (Figure 47.4).

In cases where the water table is high, horizontal drains should be installed to reduce the seepage pressure.

Geotechnical specialists should undertake the design of these drains. Water collected from the horizontal drains is to be conveyed down the slope to berm drains using lined slope drains to prevent erosion.

(d) Roof and Property Drainage

Properly designed gutters must be provided to collect stormwater from the roof and convey it to the formal property drainage system, either open drains or pipes. As a general principle, it is desirable to directly connect all significant impervious areas to the lined drainage system.

Property drainage shall be installed at or below ground level, to maximise the interception of surface runoff. The creation of ponding areas due to poor grading of property drainage is not permitted.

Slopes within the development that are greater than 20% (12.5°) must be protected from excessive surface flow, which would cause rill or gully erosion. A practicable means of protection is to install open cut-off channels close to the top of the slope (see Figure 47.5) to intercept runoff from higher areas.

Slopes should also have intermediate berm drains. Erosion protection can be installed on slopes in addition to the above measures. All open drains and berm drains must be connected to the formal stormwater drainage system by cascading drains or drops. See also the description of drainage control measures in the DOE "Guidelines for Prevention and Control of Soil Erosion and Siltation in Malaysia" (1996).

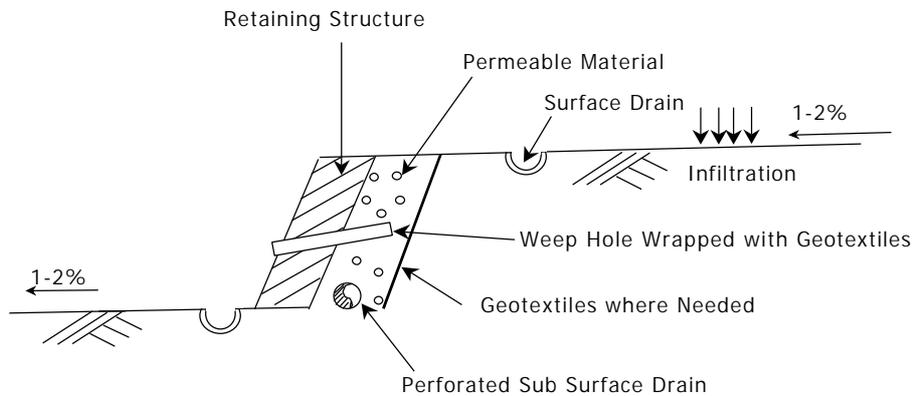


Figure 47.4 Retaining Walls

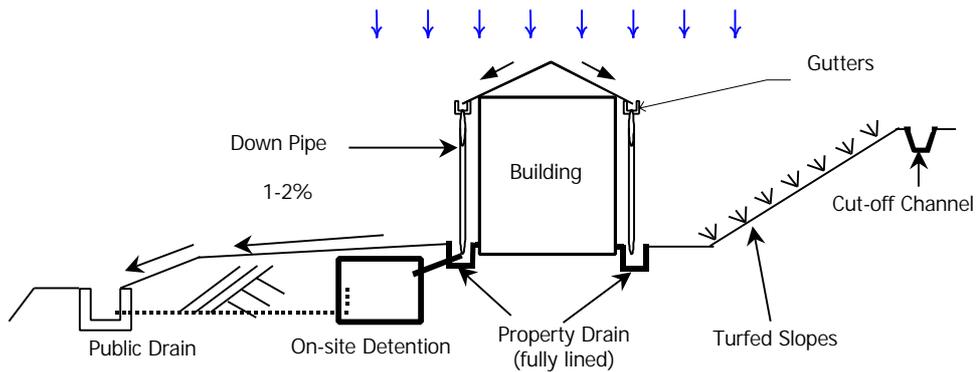


Figure 47.5 Recommended Property Drainage System

(e) Public Drainage/Conveyance System

A drainage system should be designed to drain the rainwater collected from roofs and properties and attenuated through detention to a stable discharge point where it will not cause overflow, surcharge and erosion.

The drainage system that collects the rain and convey reduced stormwater flows must be designed to be fully lined to prevent infiltration to the ground. In addition, the collected stormwater from detention facilities must be conveyed safely down slope. The public drainage system in hillside areas will usually need to incorporate devices such as drop structures, cascading drains or energy dissipators in order to avoid excessive velocities. Alternatively, a pipe system can be successfully used especially on smaller developments, with the head loss being taken up in drop pits and similar structures.

Only impervious pavement systems are suitable for hillside development areas. Road construction disturbs the natural hillslopes and the resulting instability could be aggravated if infiltration is encouraged. Stormwater runoff from the road pavement, as well as any sub-soil drains, should be captured and disposed of by lined stormwater drains or pipes. Quality control during construction is one of the major elements needed to achieve an impervious pavement. Regular maintenance, including patching of potholes, is essential. Overloading by heavy vehicles must be avoided as it could lead to stressing and premature failure of the pavement.

Hillside open space should be disturbed as little as possible. The area should preferably be left in its natural state. Adequate number of inlet/pits shall be constructed with collector drain network across open areas for efficient runoff collection. Cut-off channels should be constructed around the upper edge of development on hillsides, to intercept runoff from the open space before it reaches the developed areas. Stormwater flow from the cut-off channels should be conveyed to the nearest formal drainage system. Drop structures and/or energy dissipators may be needed in these channels in order to reduce flow velocities.

(f) Subsoil Drainage

Large open areas within a hillside development should be equipped with subsoil drainage in order to minimise infiltration and the possible effects on slope stability. Details of subsoil drainage systems are discussed in Chapter 44.

The subsoil drainage system should be designed for minimum maintenance. Flow collected in the subsoil drains must be conveyed to the main drainage system in either pipes or open drains, and then conveyed away from the development to a suitable discharge area.

(g) Geotechnical Analysis

In cases where the project concerned is large and more complicated, relevant software should be used to study the impact of infiltration on the overall stability of the site. This shall be based on the unsaturated-saturated groundwater modelling (refer Chapter 12).

(h) Maintenance and Construction

Drainage inspection and maintenance is particularly important in hillside areas. Neglect of routine maintenance can lead to infiltration and slope failures in hillside developments, with potentially devastating consequences.

It is essential that the responsibility for future maintenance is clearly established and formal arrangements should be drawn up for regular inspection and maintenance. Funding should be agreed, staff allocated and the duties and responsibilities confirmed in writing. The frequency and requirements for inspection will vary depending on local conditions and should be reviewed periodically (say every two to three years) in the light of conditions experienced on site.

To achieve the construction standard, it is important that the works are supervised on site by an appropriately trained drainage engineer/supervisor who will be responsible for ensuring that the works are built in accordance with the plans. To do so, he or she should be knowledgeable about the intent of the design as well as the construction methods.

47.3.4 Water Quality Facilities

Implementation of water quality treatment devices (refer to Part G of the manual) does not require special or additional design criteria for hillside development. However, the higher flow velocities and absence of flat land generally make hillside locations unsuitable.

Those devices that involve infiltration methods, such as swales, vegetative filter, trench, basin, porous pavement and wet ponds are not allowed except over a relatively large platform areas where a network of subsoil collecting pipes are introduced. Wet ponds, wetlands, sediment trap and wet sediment basin are to be lined to prevent infiltration especially closed to downstream slope.