4.3.4 Particular Structural Measures for Drainage in Low-lying Area

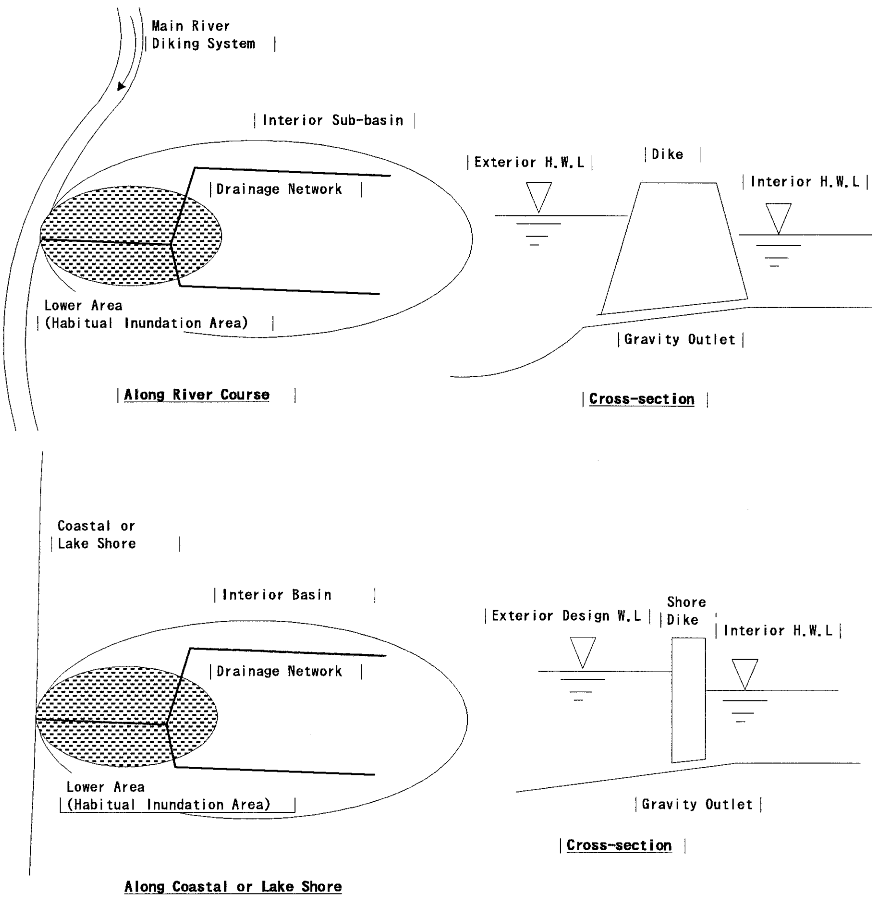
Particular drainage measures should be adopted to the low-lying drainage area where the water level of the exterior river and sea often exceeds the water level of the interior drainage channel.

Explanation:

When an interior drainage area is located in the low-lying area, the water stage of its connected external river and sea often exceeds the interior flood water level. Such low-lying drainage area needs to be protected by the dike, floodwall or seawall (called the line-of-protection), from flood water originating from the exterior river or sea.. However, the line-of-protection tends to cause difficulties in draining the stormwater from the interior drainage area toward the exterior river or sea.

Interior floodwaters are normally drained through the line-of-protection by gravity outlets when the interior water levels are higher than water levels of the exterior. On the other hand, when exterior stages are higher than the interior, floodwaters are stored and/or pumped over or through the line-of-protection. Fig. 4-9 illustrates the drainage conditions of the interior drainage area.

Fig.4.9 Typical Drainage Conditions of Low-lying Area



The possible structural measures are classified into the following three (3) types which contain various advantages and disadvantages according to topographic conditions*[4-10]. The suitable drainage plan should be formulated by combination of these measures taking these advantages and disadvantages into account.

(1) Gate/Pumping Drainage

The gate and/or pumping facilities are placed at the downstream end of the drainage channel. When the exterior water level is higher than the interior water level, the gate is closed and the stormwater is either stored in the interior drainage area or the pumped out to the exterior river or sea. The pumping facilities are one of the effective measures in the interior basin but they need higher operational cost. Prior to selection of pumping station, the possibility and viability of another type drainage should be properly studied.

(2) Separation of Flood Runoff Discharge from Upper Reaches

If the upper reaches of the objective low-lying area is hilly area with a ground level higher than the exterior design high water level, the runoff discharge from the upper reaches is either stored by the off-site type of detention pond or led to bypass channel so as to reduce the flood inflow discharge into the downstream low-lying area. This type of drainage measure is not applicable, if a substantial part of the drainage area has a flat topography. When the land development is located in such areas, the responsible agency should guide the developer to construction of on-site detention pond because the large collecting drain network could not necessary for this type. The open space between flats and park can be utilized for this kind of facilities.

(3) Drainage Channel Improvement

The entire bank level of the interior drainage channel is raised above the design high water level of the exterior river or sea in order to facilitate drainage of the stormwater through the drainage channel. This type aims at maximize the gravity drainage flow capacity and minimize the above structural size of the above gate and pumping facilities. However, This type is not applicable If a substantial part of the drainage area has a ground level below the exterior design high water level. Moreover, the type usually requires a wide space because of very gentle slope.

4.3.5 Erosion and Sediment Control

The suitable erosion and sediment control plan should be formulated in order to minimize the erosion and sediment runoff from the land development area and to maintain the design function of drainage facilities. .

Explanation:

A large part of surface in Malaysia is covered with the lateritic soil. The soil has a tendency to be loose and soft when they are wet, and therefore, easily eroded and flows out as the sediment runoff. Moreover, the erosion and sediment runoff are accelerated by the recent incentive urban development in Malaysia. The soil erosion and sediment runoff reduces the capacity of drainage facilities and deteriorates the environments at and around the drainage facilities. In order to retrieve such unfavorable conditions, suitable erosion and sediment control is required to the intensive land development area in particular.

The erosion and sediment runoff control involves various alternative measures, which are broadly classified into the following three (3) categories (refer to Fig. 4.10):

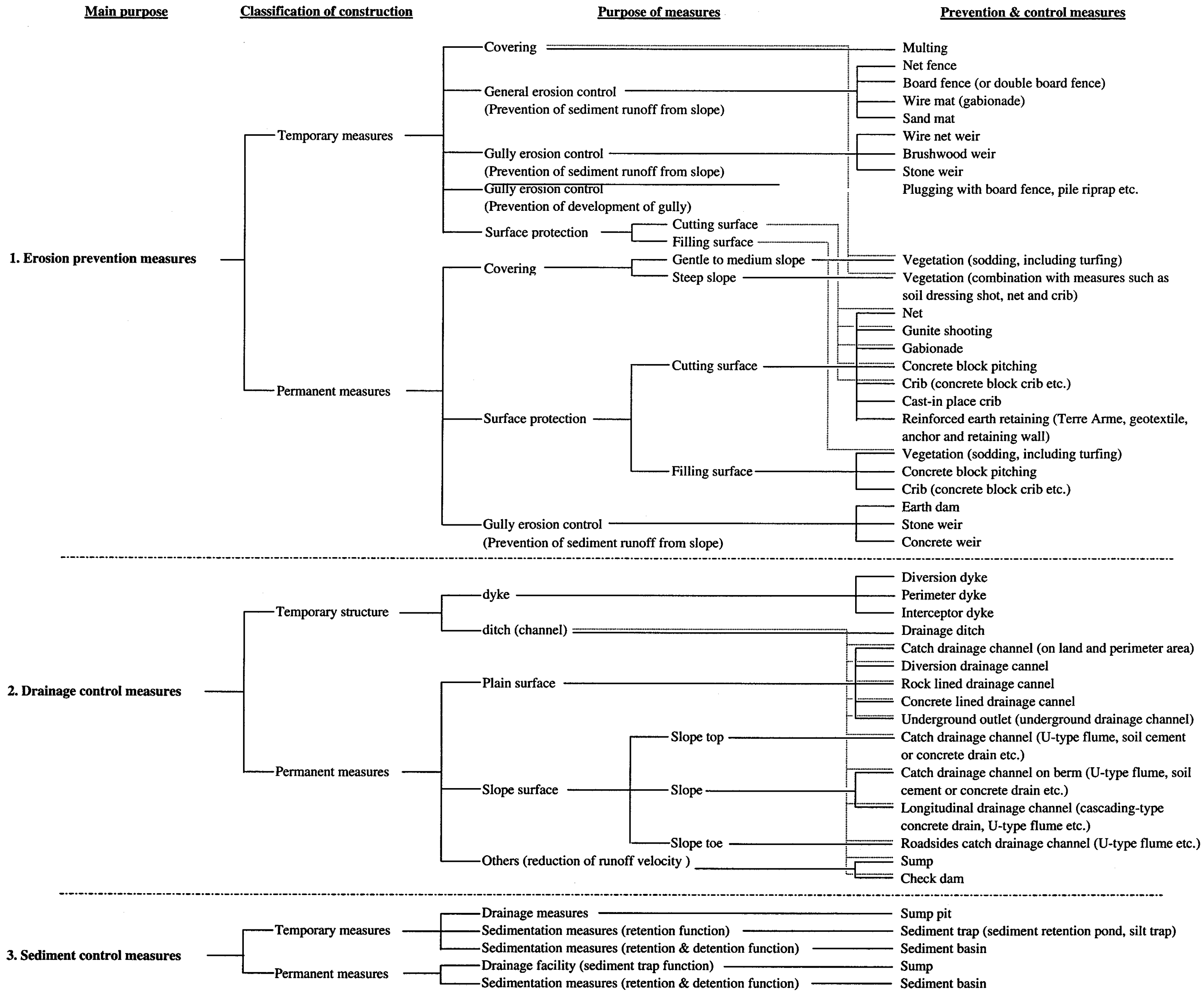
(a) Erosion control : Protection works on land slope to reduce quantity of erosion as the source of sediment runoff;

(b) Drainage control : Flood runoff control to spread and/or storage the flood runoff;

(c) Sediment control : Sediment runoff control to check the sediment runoff;

The above three (3) categories of control measure contain the temporary measure and the permanent measure in common. During construction stage for land development, the erosion frequently occurs from the surface of unpaved construction road and/or the exposed land surface causing large volume of sediment runoff. In order to control such erosion and sediment runoff, the temporary control measures should be taken during the land development works continue. After completion of land development works, the erosion and sediment runoff from the land development area could be remarkable reduced. Nevertheless, the erosion and sediment runoff would permanently continue from the land development area, and the permanent measure is required in order to reduce the regional total sediment runoff volume.

Fig. 4.10 Typical Measures for Erosion and Sediment Control



The land development involves different site conditions, which require a variety of erosion and sediment control measures. The optimum measure should be selected for each of development sites taking the following factors into account:

(a)	Cost-effectiveness	:	The measure should require less cost which includes material cost, installation cost and maintenance cost.
(b)	Availability	:	The materials used for measures should be available within a short timeframe
(c)	Technical viability	:	The measure should have the technical viability.
(d)	Durability	:	The structures by the measure should be durable for a target planning period.
(e)	Compatibility	:	The measure should be compatible with environment of the objective drainage area.
(f)	Management	:	The measure is subject to easy and sustainable maintenance.

The following are details of the alternative measures for erosion and sediment control (erosion control, drainage control sediment control):

(1) Erosion Control

Soil erosion, is classified in general into four (4) types, that is; (a) raindrop erosion, (b) sheet erosion, (b) rill erosion and (c) gully erosion. All of these types of erosion could occur everywhere in the land development sites.

(a) Gully Erosion Control

Among the types of soil erosion, the gully erosion tends to cause the largest volume of sediment runoff. The land development at Mengkuan Height in Ulu Kelang recorded the annual sediment runoff volume of about 518,000 ton/km^2, out of which about 80% was estimated to be by the gully erosion*[4-11]. Unless proper control measures are taken, the gully erosion could further develop into longer, deeper and border sizes accompanied with branch gullies, and lead to an non-restorable degradation on land within a short period. Therefore, gully erosion control is the most important issue of erosion control. The measures of gully control are classified into two types. First is to temporarily plug the gully erosion by board fence structure or pile riprap. Second measure is to check sediment runoff from gully erosion by construction of temporary and/or permanent weir.

(b) Control on Raindrop Erosion, Sheet Erosion and Rill Erosion

The raindrop erosion, sheet erosion and rill erosion tend to occur at the land slope (cutting slope and filling slope), and therefore, slope protection works should be made for the land slope, unless the slope surface consists of hard rocks. During construction stage for land development, the following temporary works should be taken in order to check the sediment runoff from the slope*[4-12]:

Table 4.8 Temporary Structural Measures for Control of Raindrop Erosion, Sheet Erosion and Rill Erosion

Location	Measures to be taken
1. Perimeter of site and around important facilities to be protected	Fence work
2. Slope, slope toe and inclined land	Fence work Gabion work

Note: The sand back works should be taken as the emergency measure everywhere in case of the excessive sediment expected.

After construction stage for land development, the sodding work (vegetation) and/or the permanent structural measures should be taken for slope protection.. The sodding work by the vegetation have effectiveness not only for erosion control but also for environmental improvement. This method is generally not costly and therefore popularly used to the applicable sites. However, in the case of poor soil conditions or steep slopes, the plants could hardly grow so that the sodding works should be reinforced by measures such as soil dressing shot, net and crib works.

The slope protection works by the permanent structure measures should be applied, when the sodding works are not suitable or not satisfactory for stable protection due to poor soil properties or steep slope gradients. The application of the permanent structural measures by soil type is summarized as below*[4-13]:

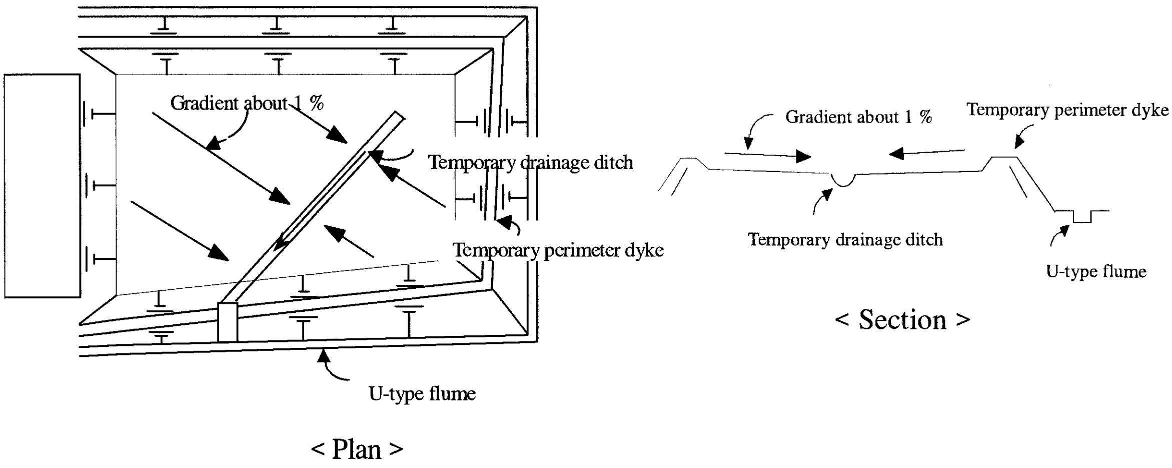
Table 4.9 Permanent Structural Measures for Control of Raindrop Erosion, Sheet Erosion and Rill Erosion

Slope Condition	Soil Type	Structure Works
Cutting slope	Hard clay, clay	Concrete block pitching works, crib works
	Hard dense gravely soil	Crib works
	Sand	Crib works, gabion works
	Weathered rock	Net works, crib works, concrete block pitching works
	Slightly weathered rocks	Net works, gunite shooting works, cast-in-place crib works
Filling slope	Sandy soil	Crib works
	Hard clayey soil	Concrete block pitching works, crib works
	Gravely soil	Concrete block pitching work, crib works

(2) Drainage Control

The drainage facilities should function both for drainage of storm runoff and control of erosion/sediment runoff. The erosion and sediment runoff occurs on the land slope during construction period of land development, in particular, and, therefore the proper temporary drainage facilities on the land slope should be provided as one of important erosion/sediment control measures. The temporary drainage facilities includes the drainage ditch, perimeter dyke, and U-type frame (refer to Fig. 4.11). In addition, installation of temporary silt trap and check dam (loose rock dam) will be required, if the excessive sediment runoff flows into the downstream.

Fig. 4.11 Sketch of Temporary Drainage Control Facilities



After construction stage of land development works, the permanent drainage channel network should be constructed for the sake of not only drainage of the stormwater but also for control of erosion and sediment runoff. When the drainage channel is constructed on the land slope, the channel should have a structure of watertightness to prevent penetration of channel flow into the land slope which causes serious erosion on the land slope.

(3) Sediment Control

Sediment control measures are installed for prevention of sediment runoff from the construction sites to off-site. The measures include sump and sump pit, sediment trap (in other words silt trap, sediment retention pond) and sediment basin.

(a) Sump

Sump is as a temporary facility to trap coarse sediment in sediment-laden flow in the drainage channel. The sump is usually placed at the inflection points of the channel where the sediment in sediment-laden flow is hardly transported by gravity flow of drainage channel, and tends to settle at the bottom of the channel. If the drainage channel has an extremely long length, the sediment also tends to settle at the bottom of the channel, and the sump is required on the way of channel. The sump pit is made by vertical corrugated stand or PVC pipe which is perforated at the bottom of the drainage channel and surrounded by geotextile filter and refilled by aggregates. The sump could not have a outlet facility for sediment deposits, and therefore periodical removal of sediment accumulated in the sump is required.

(b) Sediment Trap

Sediment trap, in other words sediment retention pond or silt trap, aims at allowing storage and settlement of sediment-laden water at the land development site. It is temporarily constructed by direct excavation of the ground but refilled when the land development works are completed producing less sediment runoff.

The sediment trap should be applied to the land development area of less than 2ha as specified in the existing guideline in Malaysia[*4-11]. However, the objective land development area has high soil erodibility, the sediment trap should be installed for the land development area of more than 2ha in order to reduce the sediment load flowing into the sediment basin and disperse risk of sediment runoff.

The design storage volume of sediment trap should be subject to the following minimum requirement as specified the existing guideline in Malaysia[*4-11] but finally decided on the basis of the contained soil type in the sediment-laden water, scale of the drainage area and required efficiency of sediment removal.

- 200 m^3/per hector of catchment area in the case of operation of more than 2year, or for a site with slopes of more than 10 %, and/or a length of more than 200 m;

- 100 m^3/ha in the case of a site less than the above

The spillway and outlet have to be also installed to the sediment trap. Removal of sediment is required when the sediment storage volume reaches to about a half of full volume of sediment trap.

(c) Sediment Basin

During the construction stage of large-scale land development of more than 2ha, sediment basin should be installed in order to retain or detain runoff of sediment-laden water and to settle excessive sediments from the land development site to offsite. Sediment basin is used as a temporary or permanent structure, which is installed by direct excavation or construction of embankment and usually accompanied with spillway and outlet.

The sediment basin also traps also flood runoff discharge in addition to the sediment runoff. After a storm rainfall ends and the sediment trapped by the sediment basin settles at the bottom of the basin , the flood water in the basin has a clear water layer at the upper portion. Such clear water layer should be drained out or pumped out in order to reserve a storage capacity for the next flood runoff. Determination on target water quality of discharged water to offsite should be based on the 'Proposed Interim National Water Quality Standard (INWQS) for Malaysia'.

Sediment basin should be placed as close as possible downstream of development sites for effective trap sediment-laden runoff. The design storage volume of a sediment basin is estimated by the following formula*[4-12 & 4-14]:

$V = Vf + Vs$ ....(Eq. 4.1)

Where; V : Design storage volume of sediment basin
Vf : Design storage volume for flood water
Vs : Design storage volume for sediment

The design storage volume for flood water "Vf" in the above formula (Eq. 4.1) could be estimated by the following formula:

$Vf = (r_i - r_c/2) \times ti \times fi \times A \times 1/360$ ....(Eq.4.2)

Where; Vf : Design storage volume for flood water (m^3)
r_i : Design peak rainfall intensity (refer to sub-sections 3.2) (mm/hr)
rc : Design outflow depth (mm/hr)
ti : Flood concentration time for "r_i" (refer to sub-section 3.3.4) (sec.)
fi : Saturated runoff rate (refer to sub-section 3.3.3)
A: : Catchment area (ha)

The design storage volume for sediment "Vs" in the above formula (Eq.4.1) is estimated on the basis of the period of land development work and interval for removal of sediment. That is, if sediments in the sediment basin are removed by dredging or excavation at intervals of N years, the design storage volume is determined as the sediment runoff volume for N years but subject to the lowest limit of volume for one year. In case that sediments are not removed, the design storage volume should correspond to the sediment runoff volume for a whole term of land development work. When some protection measures (or vegetation) for preventing of sediment runoff are performed at the sites, the design storage volume is estimated by the following formula on the premises that sediment runoff volume is reduced by half per year*[4-14].

$$Vs = Qs \times \{\sum_{i=0}^{N-1}(1/2)^i\} \times A \quad \text{.......(Eq.4.3)}$$

where,
- Vs : Design storage volume for sediment runoff (m^3)
- Qs : Design annual sediment runoff volume (m^3/ha/year)
- N : Sediment terms for design (years)
- A : Land development area (ha)

The design annual sediment runoff volume "Qs" in the above formula should be determined through either actual measurement or by theoretical model. In this guideline, the volume of 65m^3/ha/year which is prescribed in the existing guideline in Malaysia*[4-15] is provisionally recommended as the design annual sediment runoff volume. This design value was determined on the basis of the actual measurement, background of which is as described in the following "Reference".

Reference:

The actual sediment runoff volume has been measured in Kuala Lumpur and Penang*[4-15] (refer to Table. 4.10). The results of above actual measurement reveal that the natural reserved area yields 75 to 380 ton/km^2 of annual sediment runoff as shown in case of Sg. Air Hitam in Penang. On the other hand, the annual sediment runoff from the land development area increases to more than 900 ton/km^2/year. Mengkuang Height and Sg. Sering in particular yields a remarkably large sediment run-off of 42,000 to 330,000 ton/km^2/year. The geological conditions of these two areas are dominated by deeply weathered rocks, particularly granite, where cutting slope causes numerous gully erosions, leading to a large amount of sediment run-off.

As stated above, the sediment runoff volume varies according to the land use in the river basin, and the geological conditions (i.e., soil erodibility). Moreover, the sediment runoff volume could be also varied by rainfall intensity, slope length, slope gradient, and erosion control practice. Thus, the sediment runoff volume varies according to various factors, while the measurement record on the actual sediment runoff volume is limited.

Under such conditions, the "Urban Drainage Design Standards and Procedures for Peninsular Malaysia, DID, 1975" specifies 67 $yard^3$ /acre as the standard sediment runoff volume from land development area for a period of 18 months. This standard volume corresponds to 8,440 ton/km^2/year (or 65m^3/ha/year assuming 1.3ton/m^3 as the unit weight of sediment) which is larger than the aforesaid actual sediment runoff volume of 900 to 2,300 ton/km^2/year measured in the land development areas. In due consideration of variable unknown factors of the sediment runoff, the standard value of 8,440ton/km^2/year (= 65m^3/ha/year) could be provisionally applied as the design purpose for sediment basins for the following areas:

(a) If the intensive land development is made but any erosion control practice is not made to the area; and

(b) If the geological condition in the area is fare and not dominated by the deeply weathered rocks.

Table 4.10 Results of Actual Measurement of Sediment Runoff Volume

Catchment	Condition of Land Use	Area (km^2)	Rainfall (mm)	Sediment Run-off ($ton/km^2/year$)	Data Source
Sg. Air Hitam, Penang	Tropical rainforest	4.75	2,580	74.49	Wan Ruslan, 1995
Sg. Air Hitam, Penang	Tropical rainforest in upper part, stable urban area in lower	8.87	2,580	376.59	Wan Ruslan, 1995
Sg. Relau, Penang	Disturbed forest and semi-urban	0.553	1,830	911.09	Wan Ruslan, 1995
Sg. Relau, Penang	Rapidly urbanising, quarrying, construction	11.523	1,830	911.09	Wan Ruslan, 1995
Sg. Jinjang (1), Kuala Lumpur	Newly urbanising	10.3	2,400	1,056	Balamurugan, 1991
Sg. Jinjang (2), Kuala Lumpur	Tin mining and urbanising	27.1	2,300	2,283	Balamurugan, 1991
Sg. Kelang (1), Kuala Lumpur	Newly urbanising	14.2	2,400	1,480	Balamurugan, 1991
Sg. Kelang (2), Kuala Lumpur	Newly urbanising and mature urban	29.0	2,300	1,372	Balamurugan, 1991
Sg. Keroh, Kuala Lumpur	Urban and industrial	35.9	2,200	1,759	Balamurugan, 1991
Sg. Batu, Kuala Lumpur	Forest and urban	145	2,400	1,265	Balamurugan, 1991
Mengkuang Heights, Kuala Lumpur	Bare, steep construction site	0.21	2,400	330,821	Mykura, 1989
Sg. Sering, Kuala Lumpur	27% bare construction site	6.50	2,400	42,076	Mykura, 1989
Sg. Gombak, Jln Pekeliling, Kuala Lumpur	Forest and urban	140	2,400	1,157	Douglas, 1978