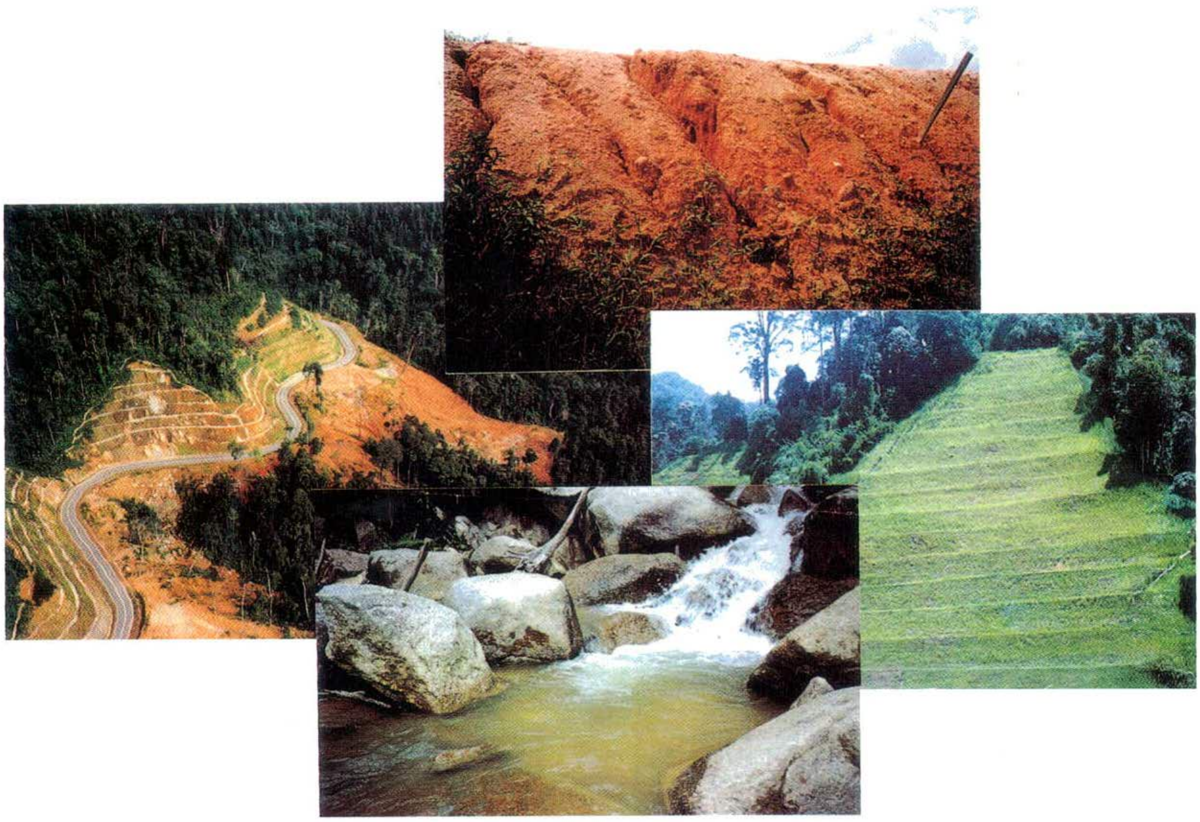
GUIDELINES FOR PREVENTION AND CONTROL OF SOIL EROSION AND SILTATION IN MALAYSIA



JABATAN ALAM SEKITAR
DEPARTMENT OF ENVIRONMENT
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GUIDELINES FOR PREVENTION AND CONTROL OF SOIL EROSION AND SILTATION IN MALAYSIA

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FOREWORD

Erosion and siltation has become a major problem in the face of the fast pace of development especially that related to land development. Policy planners, approving authorities, surveillance and monitoring agencies and implementors especially have difficulties in obtaining information and guidance to effect control.

This set of Guidelines is designed as an aid to Planners, Contractors, Developers, Consultants as well as staff in the numerous Regulatory Authorities, involved in land development and land development related activities. It outlines the principles for sound practices required to minimize soil erosion and sedimentation both during and after the land development process. It should be considered as a basis for the Regulatory Authorities and Developer to come to terms on the practicable measures necessary for the prevention of serious environmental degradation.

The completion of this set of Guidelines would not have been possible without the support and dedicated effort of the staff of the various Federal and State local authorities and agencies, land developers, consultants and Panel Members of the Steering Committee chaired by Department of Environment. I am expressly grateful to the group of experts who have answered my call to provide assistance and advice.

The Guidelines will henceforth be a specific requirement incorporated into conditions attached to approval given by DOE. It is my fervent hope that other authorities would adopt the same, so that the major environmental problems of siltation and erosion would be minimised in our route to sustainable development.

Ir. Tan Meng Leng, KMN
Director General of Environmental Quality
Malaysia

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1. INTRODUCTION

GUIDELINES FOR THE PREVENTION AND CONTROL OF SOIL EROSION AND SILTATION IN MALAYSIA

1. INTRODUCTION

1.1 Background

1.1.1 The effect of soil erosion and sedimentation on the environment has long been a subject of concern in Malaysia, particularly to the Department of Environment (DOE) which is entrusted with the task of ensuring a sustainable development. A review of the existing guidelines for the prevention and control of soil erosion and siltation is thus timely.

1.1.2 The first formal document to assist planners, practitioners and developers to control erosion was prepared by the DOE in 1978. Entitled "Guidelines for Prevention and Control of Erosion and Siltation" (referred to as ANNEX I), the publication was released four years after the enactment of the Environmental Quality Act 1974. The Guidelines were prepared to address widespread soil erosion problems arising from housing and infrastructural development activities. Sediment generated was transported into the river systems affecting water quality and in some instances causing flooding. Four categories of activities were identified as contributing substantially to erosion and sedimentation in the guidelines. These were:

Activities
Housing Development and Road Construction
Logging
Agriculture
Mining and Quarrying

1.1.3 The 1978 Guidelines also referred to various preventive measures, such as sediment traps and ponds, which could be applied to many types of activities. The Guidelines were widely used after 1st April 1988 which made environmental impact assessments mandatory for 19 prescribed activities under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987.

1.1.4 The fact that soil erosion and sedimentation continue to be an environmental problem of significant proportions in the country suggests that more definitive, and additional, guidelines may be necessary and that more stringent monitoring and enforcement is required.

1.1.5 In 1992, twenty-six Government Departments, agencies and academic institutions were called upon to identify activities that could cause substantial erosion and sedimentation and to recommend measures to check the erosion problem. The DOE Guidelines (1978) were reviewed and a new document entitled 'Guidelines for the Prevention and Control of Soil Erosion and Siltation' (known as ANNEX III) was produced. It contained most of the 1978 guidelines together with additional new methodologies for the prevention of erosion. It also included an index to facilitate retrieval of information.

1.1.6 Between 1994 and early 1996, the DOE produced guidelines relating to the preparation of environmental impact assessments (EIA) for each of the 19 prescribed activities listed in the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987. Each of these documents contain general guidelines pertaining to the control of erosion and sedimentation.

1.1.7 In addition to the above, many Government Departments and Agencies also have guidelines and regulations to control erosion and sedimentation. Among these are the Department of Irrigation and Drainage (DID), Public Works Department (JKR), Mines Department, Geological Survey Department, Town and Country Planning Department, Soil Section of the Department of Agriculture and Institut Kerja Raya Malaysia (IKRAM).

1.1.8 During the preparation of the Guidelines presented in this Report, the 1978 and 1992 Guidelines and the guidelines from other Departments and Agencies in Malaysia and overseas were reviewed. Relevant materials from all these guidelines have been incorporated in this Report to provide a range of information and methods for the assessment and control of soil erosion in Malaysia.

1.2 Aims of the Guidelines

1.2.1 The main purpose of the Guidelines is to provide a checklist of existing information pertaining to soil erosion and sedimentation so that developmental activities can be planned and executed in a judicious manner with minimum land degradation. The impact of development is being felt by every Local Councils, Municipalities and Districts in Malaysia. In particular, the construction phase entails major disturbance of the soil surface resulting in rates of erosion many times greater than that experienced from land covered with vegetation. A key aim is to ensure that there are relevant guidelines to control erosion from the range of developmental activities now taking place in the country. By applying the principles, procedures and methods of soil erosion and sedimentation prevention and control, it will be possible to plan development projects in a manner that will reduce both on-site and off-site environmental degradation.

1.2.2 Of equal importance is the aim to integrate and establish procedures and guidelines to assist in making environmentally sound and sensitive judgments for the implementation of erosion and sediment control measures during project development.

1.2.3 The Guidelines contained in this Report are not a substitute for professional experience, training and local knowledge. The techniques or methods recommended do not represent all the methods available nor do they relieve the practitioner or project proponent the responsibility to apply sound professional judgments to protect the environment.

1.3 Guidelines Usage

1.3.1 The proposed Guidelines contained in this Report, in whole or in part, are generic and can be applied to most types of development activities.

1.3.2 The proposed Guidelines have been prepared for a wide audience. They are intended for Federal and State Government Departmental and Agency staff who are engaged in land development planning, implementation and assessment; for private sector planners; for developers and for contractors and sub-contractors.

1.3.3 By using the Guidelines, it is hoped that planners and project proponents will be able to identify potential erosion risk areas in their project sites, based on an understanding of the processes which underlie the causes and effects of erosion and will then be able to plan and develop the site by avoiding such critical areas.

1.3.4 The Chapters are arranged in a logical sequence to explain the successive steps necessary to manage erosion and sedimentation problems. Erosion, siltation and sedimentation processes are briefly explained in Chapter 2, while Chapter 3 provides the procedural stages for carrying out an Erosion and Sediment Control

Plan (ESCP). Chapter 4 lists the guidelines for the prevention and control of soil erosion and sedimentation and Chapter 5 provides the common types of control measures. Costs of erosion control vary with locations and some indicative costs are provided in Chapter 6. Chapter 7 is a small sub-set manual explaining the use of the Guidelines in multimedia form.

1.3.5 Supplementary information is presented in the Appendices, which include a brief history of soil erosion in Malaysia, a number of case studies and details of relevant policies and legislation. It also incorporates trend analyses of suspended sediments of some major rivers in Malaysia.

1.3.6 It is stressed that the Guidelines in this Report are not meant to replace the existing departmental and agency guidelines, but to complement them. Where such guidelines are still relevant, they should be consulted.

1.3.7 The Guidelines do not contain technical geo-engineering, hydrological or hydraulic information *per se*. Where it is apparent that such information is required, the User should refer to relevant standard specialist texts or perhaps, more appropriately, consult with qualified practitioners.

2. EROSION AND SEDIMENTATION PROCESSES

2. EROSION AND SEDIMENTATION PROCESSES

2.1 Introduction

This Chapter presents a summary of the erosion and sedimentation processes that are found in Malaysia. The extent and magnitude of soil erosion in the country are documented in detail in Appendices A and B, based on literature reviews and indicative case studies.

2.2 Definition

The terms **erosion, siltation and sedimentation** are often used loosely and therefore definitions are necessary.

Terms	Definition
Soil	Soil is used here in the engineering sense of soil or overburden which includes organic material and weathered rock materials beneath.
Erosion	Any or all of the processes that loosen, entrain and remove earth or rock materials from their place of origin.
Sediment	Any size of earth or rock materials from fine clay to large boulders carried by an erosional agent, water or wind, and subsequently deposited.
Silt	Particles of soil or earth materials from 0.005 to 0.76 mm median diameter in size. Also used for the fine materials deposited in channels but only for materials less than 0.76 mm diameter.
Siltation	A process of deposition of soil or earth materials less than 0.76 mm diameter on land, in rivers or in the sea. The silting of the lower reaches of river channels often involves such fine materials but coarser sand deposition is frequently found further upstream.
Sedimentation	A process of deposition of any size of soil or earth materials on land, in rivers or in the sea. It is essentially a process of settling whereby the coarsest particles are deposited first and the finer particles remain in suspension longer.

Although the terms **siltation** and **sedimentation** are often used interchangeably and synonomously in many documents, in this Report the contrast in meaning will be emphasized and the use of the word siltation will be restricted to the deposition of the fine materials.

2.3 Sediment Classification

Sediment load is often classified on the basis of particle size as shown below.

Description	Nominal Diameter (mm)
Boulders	More than 200
Cobbles	200 - 60
Gravel	
Coarse	60 - 20
Medium	20 - 6
Fine	6 - 2
Sand	
Coarse	2 - 0.6
Medium	0.6 - 0.2
Fine	0.2 - 0.06
Silt	
Coarse	0.06 - 0.02
Medium	0.02 - 0.006
Fine	0.006 - 0.002
Clay	Less than 0.002

Note: To convert from mm to micron, multiply by 1000.
Source: Australian Standards 1289, 1977.

2.4 Soil Erosion Process

2.4.1 Soil erosion is the detachment, entrainment and transport of soil particles from their place of origin by the agents of erosion, such as water, wind and gravity. It is a form of land degradation and can be categorized as either geological or accelerated erosion. The former is part of the natural wearing down of the earth's land surface and occurs at rates ranging from virtually imperceptible soil creep to dramatic sudden landslides. The latter results from human activities exposing the soil surface and thus enabling erosive agents such as rain to wash away topsoil and the underlying weathered rock.

2.4.2 Dislodged soil particles are often stored within depressions in the land but may be dislodged during storm events. The amount of silt or sediment delivered into river systems through the processes of entrainment, transportation and deposition is a function of changes in surface drainage patterns, terrain roughness, vegetation and climatic conditions.

2.4.3 Water is the most significant agent of soil erosion. The removal of vegetative cover and the breakdown of soil structure through compaction and loss of organic matter often reduces infiltration and accelerates runoff and the entrainment of soil particles. The amount and sizes of soil particles transported increase as the volume and velocity of runoff increase. Hence, on project sites under development, drainage control is pre-requisite to erosion control. For a more detailed discussion of this, refer to Appendix B which provides a variety of examples of accelerated erosion due to changes in landuse.

2.4.4 The quantity of silt and sediment being carried by a river is known as sediment yield and can be estimated as the sum of both suspended load and bedload. Suspended loads are silt and sediments that move in suspension in water. Bedload consists of particles moving by rolling and saltating at or just above the bed of a channel. Fine sediment or silt particles are transported much longer distances than pebbles and coarse sands.

2.4.5 Sediments start to move once their threshold of motion is exceeded, that is, with increasing streamflow velocity. These particles may either move as bedload or in suspension, or interchangeably between the two during various times of streamflow.

2.4.6 While bedload is hard to measure, suspended load is easily sampled. Work overseas has shown that the proportion of bedload is generally between 1% to 25% of the total sediment load, depending upon the magnitude of the flood conditions (Simmons and Senturk, 1992, Wong, 1995). Bedload particles are generally coarser than those found in suspension. Under normal flow conditions, the finer sediments are generally transported as suspended load and there is very little bedload transport.

2.4.7 Sedimentation is the build-up (aggradation) of sediment on the channel bed. Sedimentation in river systems leads to the raising of river bed levels resulting in flash floods during heavy rainstorms. It is a dynamic process and is dependent upon the geomorphic and hydraulic characteristics of the river systems. The deposited sediment tends to remain in place for short periods of time, the next rain flushing the sediment downstream. Thus, sediment tends to be transported in pulses depending on the flow characteristics of the river systems.

2.4.8 Local research (Douglas, 1995) has shown that suspended loads rise during high flows and nearly half of the annual sediment transport may occur during the few biggest flows of the year. Suspended sediment is empirically one of the best indicators of sediment delivery into the river system from the land during land clearance and earthwork construction. It can be used to indicate the relative magnitude of soil loss from a project site.

2.5 Types of Erosion

Types	Description
Rainsplash Erosion	The force of falling raindrops can dislodge soil particles, which are then available for entrainment by slope runoff. Earth pillars a few millimetres high and often capped by small stones are evidence of rainsplash erosion (Figure 2.5.1). Bare soil surfaces in Malaysia are extremely susceptible to rainsplash erosion during high intensity rainstorms.
Sheet Erosion	Sheet erosion occurs when loose or detached soil is transported laterally in a uniform layer, with no discernible concentrated flow (Figure 2.5.2). The shallow layer of flowing water rolls many particles downslope, but fine particles may be carried in suspension. Sheet erosion occurs rapidly during heavy rain but is readily interrupted by vegetation. Where surface irregularities break the laminar sheet wash, turbulence may cause incision and the initiation of rill formation. The amount of soil loss depends on the depth and velocity of flow, soil structure and terrain. A serious consequence of sheet erosion is the very noticeable subsoil layer that is exposed at the surface after the topsoil is removed. Vegetation is particularly hard to re-establish in such layers.
Rill Erosion	Entrainment of soil particles over an exposed terrain causes rill formations (Figure 2.5.3). Rills are shallow channels usually no more than 30 cm deep but can be metres long. They may be widespread on compacted, exposed surfaces which are devoid of vegetation. Water flows more quickly in a rill because it is concentrated and this increases the detachment and transportation of soil particles. Vegetation plays an important role in dissipating runoff velocity and encourages deposition on-site.
Gully Erosion	Gullies are incised channels which often began as rills (Figure 2.5.4). The headwall of a gully tends to cut back upslope and the sidewalls to retreat through slumping associated with subsurface water altering the stability of the gully sides, or undercutting by surface water flowing over the head or sides of the gully. In deeply weathered rock material, gullies can be deep and narrow (depth twice the width). In exposed areas, runoff may enter a gully from the sides causing development of secondary gullies. When this occurs, erosion is categorized as severe. Gullies are highly effective conveyors of sediment to rivers and their density and depth are indicators of the severity of erosion.

Types	Description
Riverbank Erosion	Rivers constantly adjust the shapes of their channels and erode their banks under natural conditions. Much of the sediment carried by rivers in a natural rain forest state is derived from bank erosion. However, changes in runoff and sediment loads alter the stability of river channels and rapid bank erosion may occur as a consequence. The severity of bank erosion depends on the velocity of the stream, sediment loads carried from upstream and the channel shape. Vegetation on the banks helps reduce such erosion. Generally the outer edges of the river bends (concave side) are subjected to scouring, undercutting and erosion with the resultant sediments being deposited on the inner bends (convex side) (Figure 2.5.5).
Tunnel Erosion	Tunnel erosion frequently occurs in areas where the texture of the overburden or weathered rock and soil changes. Water moving readily through coarser materials may not be able to infiltrate into an underlying finer layer and thus moves laterally downslope. Such water tends to converge and develop a subsurface natural pipe which can enlarge as fine particles are carried away. Eventually the pipe may enlarge into a tunnel whose roof may collapse leaving a hole which develops into a surface gully. Increased infiltration accelerates tunnel erosion and gully development by tunnel collapse.
Landslides	Landslides are the sudden movement of soil and rocks downslope. They vary in size from a few metres in length and width and a metre or two deep to virtually whole hillsides (Figure 2.5.6). Landslides most frequently occur in steep mountainous terrain and may be triggered by high rainfall events. Some rock types are more susceptible to slipping than others and landslides are often found on steep roadside slopes, particularly where there is deep weathering of the rocks and drainage is inadequate.
Mass Movement	Highly weathered soils on unstable hillslopes represent another form of erosion that can contribute vast quantities of sediments into the river channels. Stabilizing steep slopes is often difficult and the best way to control mass soil movement is to prevent activities that cause it in the first place. Preventive treatment includes identifying hazard areas and avoiding or minimizing the disturbances on these areas such as road construction, logging etc.
Wind Erosion	Wind erosion occurs on dry surfaces, particularly where loose fine material is abundant. Although not usually a problem in Malaysia, it may be a nuisance where bare ground on construction sites dries out yielding dust which is blown onto neighbouring premises. Vegetation, which both

	breaks the force of the wind and protects the soil, could greatly reduce such erosion.

2.6 **Rates of Erosion**

Rates of erosion vary considerably over time and within an area, depending on terrain, geology, hydrogeology, soil types, climate and landuse (Appendix B). Examples of erosion rates for various landuses and terrain types in Malaysia are shown in Table 2.6.1.

As can be seen, rates of erosion under both natural and disturbed forest cover vary considerably with rock types such as between granitic areas in Peninsular Malaysia and the sandstone and shale formations of Sabah and Sarawak, while rates of erosion from construction sites and logging roads can be extremely high.

Table 2.6.1: Erosion Rates by Landuse and Rock Types

Landuse Type	**Geological Conditions/Rock Types**	**Rainfall Conditions (mm yr^{-1})**	**Rate of Erosion t km^{-2} yr^{-1}**
Undisturbed Lowland Rainforest	(a) Granite, P. Malaysia (b) Sandstone & Shale, Sabah & Sarawak	c 2000 2500 - 4000	19 - 75 20 - 312
Selective Logging Lowland Forest	(a) Granite, P. Malaysia (b) Sandstone & Shale, Sabah & Sarawak	c 2000 2500 - 4000	20 - 300 90 - 1,650
Selective Logging Steepland Forest	Granite, P. Malaysia	c 2500	1,120 - 2,850
Shifting Cultivation	Sandstone and Shale, Sarawak	c 3500	18 - 34
Logging Roads	Sandstone and Shale, Sabah	2500 - 4000	1,000 - 55,000
Temperate Vegetables, Highlands	(a) Granite, P. Malaysia (b) Sandstone & Shale, Kinabalu Highlands	2500 3000	200 - 250 1,000 - 1,050
Traditional Pepper Cultivation	Sandstone and Shale, Sarawak	3500	8,000 - 8,500
Conversion of Forest to Oil Palm	Sandstone and Shale, Pahang	2000	220 - 250

Construction Site	Granite, Selangor	2000	40,000 - 50,000
Streams affected by construction activity	Granite, Selangor and Pulau Pinang	2000	1200 - 10,000

2.7 Factors Affecting Erosion

2.7.1 In humid tropical countries like Malaysia, the potential susceptibility of an area to erosion can often be related to rainfall characteristics. Other factors being equal, the higher the annual rainfall, the higher the likely rate of erosion, particularly given the fact that the highest totals usually occur in steep mountainous terrain. The seasonal distribution of rainfall is also an important factor, especially where high rainfall totals are concentrated into relatively short time periods, as for example during the period of the north-east monsoon along the eastern side of Peninsular Malaysia.

2.7.2 Possibly of greater significance than annual or seasonal totals is the frequency of severe storm events, because measurements indicate that a very intense storm may evacuate 50% or more of a catchment's annual sediment yield.

2.7.3 Relief and slope are important factors affecting erosion. Soil losses can be expected to increase with slope length and steepness as a result of respective increases in volumes and velocities of surface runoff. Steep slopes are often susceptible to landslides even under natural forest conditions and such slopes become more susceptible to erosion once disturbed.

2.7.4 Erodibility of soils defines their resistance to both detachment and transport and is a function of their physical and organic properties. Large soil particles are more resistant to transport because of the greater force required to entrain them and fine particles are resistant to detachment because of their cohesiveness. Experiments undertaken by the Rubber Research Institute of Malaysia demonstrate considerable variations in erodibility between a number of commonly occurring soil series. As noted, some rock types are more susceptible to mass wasting and landslides than others.

2.7.5 Vegetation and the associated ground litter layer protect the ground surface from the erosive impact of rainfall and help to maintain soil infiltribility, thus reducing surface runoff. In some parts of the world, considerable protection from rainfall may be gained from a 40% vegetation cover, but in Malaysia with its high rainfall totals and storm intensities it is preferable to aim for complete cover. A critical part of the slope to protect is where surface and sub-surface flows converge in stream head hollows. Disturbance of the vegetation in these hollows can lead to rill and gully formation.

2.8 Erosional Effects

The serious consequences of soil erosion and sedimentation are frequently highlighted in the newspapers and are well documented in the scientific literature. Currently, the efficiency of mitigation measures in reducing the impact of soil erosion and sedimentation on the environment and receiving waters is little known. However, on-site and off-site effects of soil erosion, sediment transport, siltation and deposition are well-known and include:

Locations	Effects
On-site	• Loss of value, productivity and services from affected land. • Loss of topsoil and resulting costs to communities. • Undermining of roads and utilities. • Sediment and mud on roads with associated traffic problems and road safety issues. • Clogged drains and increased nuisance flooding. • Sedimentation and bank damage to construction sites. • Increased down-time on construction and building sites after storm events. • Unsightly appearance of construction works. • Sedimentation and loss of capacity in sediment basins. • High cost for reconstruction and maintenance.
Off-site	• Sedimentation in reservoirs and other storage structures, with resulting loss of water storage capacity. • Instability of stream channels caused by increased runoff and sediment loads: channel change and bank erosion may affect adjacent buildings and other infrastructure. • Siltation and sedimentation of rivers will cause a reduction in channel capacity leading to greater frequency of floods. • Proliferation of exotic weeds within watercourses due to the high nutrient content of silt and sediments. • Smothering of aquatic and marine flora and fauna: high turbidity in rivers excluding light penetration affecting fish life. • Land degradation caused by gully erosion and sediment deposition. • Increased pollution of rivers and streams. • Loss of navigable reaches of a river or water course. • Adverse ecological effects of high sediment loads, deposition and dredging and de-silting of waterways. • Decline or total loss of recreational and commercial fishing, particularly as a result of increased turbidity due to the sediment load. • Reduced recreational and aesthetic value of riverbanks and waterways.

Figure 2.5.1: Rainsplash Erosion

Figure 2.5.2: Sheet Erosion

Figure 2.5.3: Rill Erosion

Figure 2.5.4: Gully Erosion

Figure 2.5.5: Riverbank Erosion

Figure 2.5.6: Landslide

3. PROCEDURAL STAGES FOR EROSION AND SEDIMENT CONTROL

3. PROCEDURAL STAGES FOR EROSION AND SEDIMENT CONTROL

3.1 Introduction

Erosion and sediment control is an integral part of an environmental management system for a developmental activity. Its relationship to the generalized planning approval pathway is shown in Figure 3.1.1 and described sequentially below.

3.2 ISO 14000 Environmental Management Systems

3.2.1 An overall system embodying all environmental planning is the recently introduced ISO 14000 series on Environmental Management Systems. The ISO 14000 series is designed to provide guidelines for best environmental management practices. Such a system is essential to an organization's ability to anticipate and meet growing environmental performance expectations and to ensure ongoing compliance with national and/or international requirements. Responsible development organizations could consider certification to MS ISO/DIS 14000:1995 (P) and the responsible authority executing this is the Standards and Industrial Research Institute of Malaysia, now known as SIRIM Berhad.

3.2.2 The specification standard is still in its draft international status form but will in late 1996, adopt the ISO 14001 as the international standard for environmental management systems by the International Organization for Standardization (ISO). ISO 14004 will also be adopted as the guiding standard for developing and continuing environmental management systems.

3.2.3 The concept of protecting the environment is not new. The detection of substantial air, water and land pollution in the 1960's necessitate environmental laws to be passed in various countries (such as the United States of America and Sweden during the 1970's and 1980's).

3.2.4 Worldwide recognition of global pollution and hazardous waste problems eventually led to the International Conference on the Environment in Rio de Janeiro in 1992. It is not surprising therefore, that environmental policy legislations have received priority in Malaysia and many other countries.

3.2.5 In Malaysia, an Environmental Quality Act was passed as early as 1974 when it became evident that industrial processing of rubber, extraction of palm oil and mining and timber operations had already caused significant damage to the environment. Thus, in 1970's, many companies began incorporating environmental management systems in their operations.

3.2.6 In 1991, ISO formed the Strategic Action Group on the Environment (SAGE) to decide on an international environmental standard to accomplish three specific objectives:

- ENCOURAGE a common approach to environmental management;
- STRENGTHEN a company's ability to improve and measure its environmental performance; and
- REMOVE trade barriers and improve international trade.

The Group's research and study showed that such a standard would achieve these objectives, and the concept of the ISO 14000 series was born.

In 1992, the ISO formed Technical Committee (TC) 207 to draft the ISO 14000 series. Six international sub-committees and one working group made up this Committee.

3.2.7 There is no ISO 14000 *per se*. The original ISO 14000 has now become ISO 14004 and ISO 14000 has become the accepted term for the series in its entirety.

In practice, ISO 14001 and ISO 14004 provide the framework: the former specifies the minimum requirements for achieving certification, and the latter sets the guidelines for developing an environmental management system.

Other standards being considered are: ISO 14011-14015 for environmental auditing, ISO 14020-14024 for environmental labeling, ISO 14031 for environmental performance evaluation, ISO 14041-14044 for life-cycle analysis, and ISO 14060 for environmental aspects of product standards.

3.2.8 The immediate attention should be on ISO 14001 and 14004, as these will be the first to be adopted. ISO 14001 is the specification standard setting the minimum and basic provisions for an effective environmental management system. It will be used mainly for third-party certification.

ISO 14004 provides guidelines only, giving examples and descriptions for designing and implementing environmental management systems and principles.

3.2.9 ISO 14000 is still new and not as well-known in Malaysia as the ISO 9000 series for quality management systems. It is, however, a matter of time before Malaysian companies realize that their customers will demand certification under ISO 14000 as a requirement for a contract.

3.2.10 The rapid industrialization in Malaysia brings with it many side-effects such as toxic waste, air and water pollution, urbanization and loss of biodiversity. All these need to be checked and controlled and the government is considering effective steps such as, taxes and other incentives which are directed to help minimize wastes, conserve energy, increase recycling and utilize cleaner technologies. With the implementation of ISO 14000, it is expected that many companies and their employees will adopt a proactive approach towards protecting the environment. The ISO 14001 would certainly contribute to greener environment, especially so with regards to the pollution caused by industries and commerce. Thus, this Report recognizes the ISO 14000 series as the overall embodying environmental management and planning system.

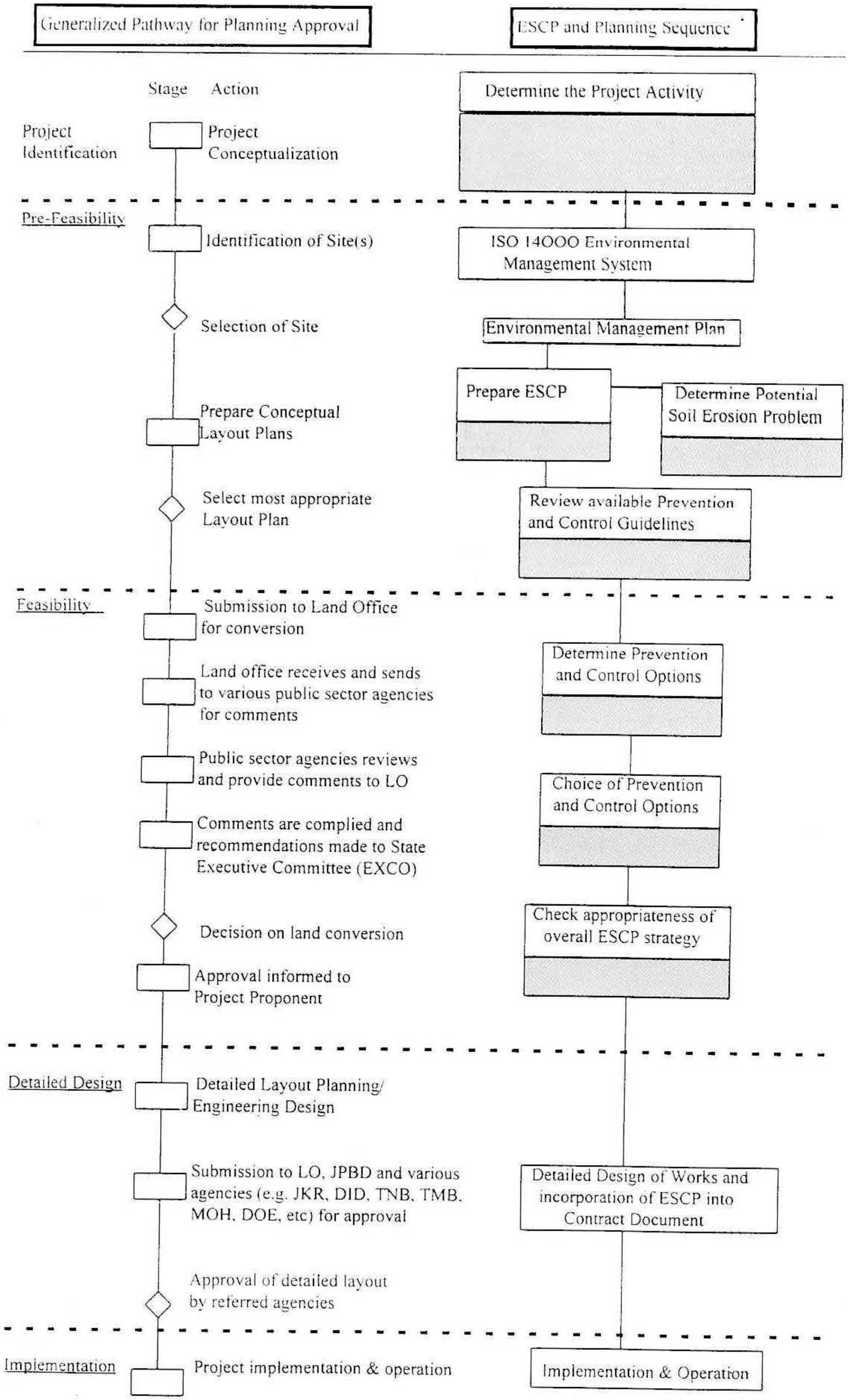
3.3 Environmental Management Plan

3.3.1 Within the ISO 14000 Series, there are provisions for the design of an Environmental Management Plan (EMP) which among other measures includes provisions for the management of soil erosion and river sedimentation during site clearing and earthworks. The components pertaining to erosion and sedimentation can be segregated out to form an **Erosion and Sediment Control Plan (ESCP)** which specifically aims to control erosion and siltation during the stages from land clearing to project completion.

3.3.2 Before a big developmental project can start, an EMP is required by DOE. An integral part of an EMP is an ESCP. The DOE generally requires an ESCP at the submission stage of an Environmental Impact Assessment (EIA) to enable it to assess the adequacy of the proposed mitigation measures for the control of erosion and sediment during earthworks and construction on-site. An ESCP can also be incorporated in the EMP if it is not already done in the EIA submitted earlier.

3.3.3 Systematic environmental site checks for compliance with standards carried out subsequently by DOE during construction and operation of a project are often based on comparative audits of information obtained during field surveys with the baseline information given in the EIA or in the ESCP and EMP. Thus, a well-documented ESCP is basic and meaningful for any project development.

Figure 3.1.1: ESCP and Planning Sequence



3.4 Erosion and Sediment Control Plan (ESCP)

3.4.1 General

The Erosion and Sediment Control Plan (ESCP) is the main document submitted to the DOE for the control of erosion and sedimentation, forming a component of a section in an EIA, outlining measures designed to mitigate environmental impacts. Until now, the 1978/1992 Guidelines have been widely adopted to help prepare the ESCP.

An ESCP should provide for temporary measures that can be adopted during the development phase and for mitigation measures that will remain in place once development is complete. The Plan is prepared by the project proponent or the proponent's consultants. A copy of this Plan is normally made available at the work site at all times as a reference.

3.4.2 Erosion and Sediment Control Strategy

The key objective in an erosion and sediment control strategy is to avoid causing additional erosion because an unpolluted environment is essential for sustainable development. In order to avoid or minimize erosion, it is necessary to delimit and interpret the natural constraints on a proposed development area prior to the start of the project. This could be carried out during the pre-feasibility stage (Figure 3.1.1).

The areas within the project site susceptible to erosion and sedimentation should be clearly defined and factors causing erosion be identified. Factors, such as, rainfall characteristics should be determined, the susceptibility of the soil types present ascertained, the distribution of steep slopes mapped, the theoretical potential erosion values for the area determined and the susceptibility of the area to landslides evaluated. This will enable site hazard maps to be prepared which will help determine site layout and will give an indication of the types of preventive measures required during and following development. It will also enable works to be scheduled to avoid likely periods of heavy storm rainfall.

An effective ESCP aims to prevent controllable erosion and to minimize the adverse effects of sediment transport from on-site to off-site areas. The plans may range from a simple plan for small sites (say <5 ha), to detailed comprehensive plans for a complex development on large sites (say >50 ha) or for areas of high ecological value. In general, an ESCP for a development project serves to provide:

(a)	Clear interpretation of the development's impact on the environment which in turn will improve the quality of evaluation and interpretation by the government authorities responsible for commenting on, approving and monitoring the project.
(b)	Clear interpretation of proposed erosion and sediment control measures, thus improving the quality of construction tender pricing.
(c)	A saving of time and costs because both the developer and approving authority agree on the implementation of the plan.
(d)	Clear interpretation of proposed erosion and sediment control measures by the project proponent, thus improving the efficiency and cost effectiveness of the control techniques.
(e)	The incorporation of a standard ESCP into engineering construction documentation is strongly recommended.

3.4.3 Preparation of ESCP: General Principles

The general principles with regards to the preparation of an ESCP are clearly related to the strategies mentioned above and the need for erosion control at the project site. The basic elements of an ESCP should form part of the engineering documents for the contractors and be part of the final engineering design drawings for documentation in the Schedule of Rates or Bill of Quantities.

- The first step in an ESCP preparation is to ensure that erosion and sediment control measures are fully integrated into the development sequence as shown in Figure 3.1.1. Erosion and sediment control can only be effective if construction and control practices are jointly planned during the pre-feasibility and feasibility stages and implemented simultaneously throughout the construction stage.

- The second step is to ensure that all control structures are maintained at all stages of the development, such as during earthwork preparation, piling and construction. Well maintained control structures may not overcome all erosional problems but will ensure that the extent of the problems are significantly reduced.

- The third step is to ensure that there is a system of continuous measurement of the parameters identified in the ESCP to control erosion throughout the development of the project.

- The fourth step is to prepare an Emergency Plan for immediate implementation if any of the erosion and sediment control measures fail due to unforeseen circumstances, such as severe rainstorms breaching sediment ponds.

3.4.4 Stages in Preparing an ESCP

The stages in preparing an ESCP are shown in Table 3.4.1. The checklist is most valuable when used in conjunction with pre-feasibility and feasibility stages for project development.

Table 3.4.1: Stages in an ESCP Process

Stages in Preparing an ESCP
• Developing goals and objectives • Identification of major issues and problems • Erosion risk analysis • Study alternatives and options • Select best management practices for a given site • Develop an Erosion and Sediment Control Programme • Implement and maintain programme • Monitor programme, and constantly review and implement best management practices

3.4.4.1 Developing Goals and Objectives

The goals and objectives of preparing an ESCP should be stated clearly and these should include as many as possible the following:

Goals and objectives
• Reduce erosion in the short-term • Reduce erosion in the long-term • Reduce sediment yield • Reduce turbidity of off-site runoff • Reduce long-term maintenance requirements • Maximize use of cost-effective techniques • Improve stability of slopes • Meeting regulations • Improve aesthetics • Decrease liability exposure • Maximize use of existing landscape features • Enhance existing environment

3.4.4.2 Identification of Major Issues and Problems

On-site and off-site erosional problems (Table 3.4.2) must be clearly defined in terms of:

Table 3.4.2: Checklist of Site Constraints

Issues	Identification and Plan of Action
Types of Erosion	• Determine the types of erosion on-site and off-site present prior to start of project after site investigation (refer to Chapter 2). • Plan the type of action required to prevent and reduce erosion (refer Chapter 4).
Spatial Coverage	Determine the spatial coverage of: • the project site • the erosion prone areas within the project site • the erosion prone areas off-site and the possible impacts of runoff and sediment on these areas
Site Constraints	Determine the site constraints from the following limitations.
(a) Geological and Hydrogeological Limitations	• Geology and rock types exert an important influence on the types of soils found in an area while the physical processes of soil formation are directly a consequence of the rate of weathering, terrain, biological and climatic conditions. Some rock types, such as exposed granites, are more susceptible to weathering and erosion than others because of their mineral composition. • Some steep terrain often have highly fractured rocks exposed which increase the susceptibility of the area to rockslides and landslides especially when heavy rains occur. • Fluctuating groundwater tables increase permeability of soils and loosening the soil particles thereby contributing to erosion.
(b) Soil Limitations: • High permeability	• Highly permeable soils rapidly transmit water through the soil profile but they are not necessarily well drained because they may be underlain by an impervious layer such as clay. • They are typically coarse textured sand or gravels and are likely to have low water retention capacity and require light but frequent watering during times of moisture stress. The soil particles are easily dislodged during heavy rainfall contributing to the overall supply of eroded sediments.
• Shallow soils	• Shallow soils normally occur in steeplands and are very often non-cohesive. • They tend to be subjected to erosion very easily. • They are often affected by soil creep and may slide when cleared of vegetation.

• Non-cohesive soils	• Non-cohesive soils are sometimes called unconsolidated soils. • Uncompacted fill materials and mechanically disturbed soils are also known as non-cohesive soils since the soil structure is disturbed. For this reason, it is desirable to minimize fill areas. • They are highly erodible.
• Acid sulphate soils • Soil Erodibility	• Acid sulphate soils are highly acidic and are found in areas of peat swamps which are often poorly drained. • Depending on the types of development in these areas, they can cause problems in terms of damage to aquatic life and prevent recreational and commercial use. • The soils are unconsolidated but they are not highly erodible unless disturbed. Areas with acid suphate soils are generally low-lying and they act as 'sinks' for sediment accumulation. • Their extreme acidity however prevents the growth of stabilizing vegetation. These areas are often excavated out and filled before structures are located on them. • Extra compaction and strengthened foundations are needed in such areas. • Soils vary in their resistance to erosion. Erodibility is the susceptibility of a soil to be detached and transported by the erosive agent. • It is a composite expression of those soil particle characteristics which affect the behaviour of a soil and the way it is able to resist erosive forces such as raindrop impact. • It is independent of the other factors influencing soil erosion such as topography, landuse, rainfall intensity and plant cover, but may be changed with soil management. • The qualitative categories used for soil erodibility are low, moderate, high, very high and extreme. • The most highly erodible soils are those most easily detached and transported by erosive agents. • High soil dispersibility is a good indicator of high soil erodibility. • Soil erodibility is an important component of USLE equation (refer to Section. 3.4.4.3). • Information on the relative erodibility of many Soil Series in Malaysia is available from the Rubber Research Institute of Malaysia.
(c) Topographic Limitations • Slopes	• Limitations vary according to length, shape, aspect and gradient of the slope. • Low slope gradients generally impose little or no limitations to development, while steep gradients may present severe problems due to increased runoff velocity and a greater requirement for cut and fill earthworks. • Steep gradients tend to increase the soil erosion hazard in an area. • The length of a slope influences the volume and velocity of runoff, while the shape of a slope can affect the location and time at which runoff is concentrated at any one point. The aspect of a slope can further influence the erosion potential through variations in vegetation covers and micro-climatic conditions.

• Terrain	• The slope factor is also one of the important components in the USLE (refer to Section 3.4.4.3). • The potential susceptibility of slopes to landslide is a crucial factor to be considered. • Terrain is related to slopes but it includes the dimension of appearance of landscape units. • In combination with slope gradient and soil data, the terrain unit can be used to identify unstable or erosion prone hazardous areas. • Commonly terrain units and corresponding limitations are given in Table 3.4.3 below.

Table 3.4.3: Terrain Units and their Common Physical Limitations

Terrain Unit	Limitations
Ridge crest	Shallow soil; rock outcrop; impeded soil drainage.
Sideslope	Slope gradient steep; mass movement including landslides; soil erosion hazard.
Footslope	Flooding from overland flow; seasonal water logging; soil erosion; deep soils.
Floodplain	Flooding; waterlogging; soil erosion.
Drainage line	Flooding; waterlogging; streambank erosion.
Swamp/wetlands	Flooding, waterlogging; organic soils.
Coastal plains	Flooding; waterlogging.
Sand dunes	Wind erosion; wave erosion; high permeability; unconsolidated soils.
Escarpment	Slope gradient; shallow soils; rock outcrop; mass movement; high erosion potential.

Source: J.S. Hunt, 1992

3.4.4.3 **Erosion Risk Analysis**

Erosion risk analysis is a planning tool to identify possible impacts on the environment when a project is undertaken at a particular site. There are various techniques to analyze erosion risk. These techniques are normally based on commonly used methodologies and models. However, the use of models for prediction should be exercised with care and prudence in view of their limitations taking into account the reliability of the data available for the prediction.

The most widely used mathematical model to estimate soil loss from an area is the Universal Soil Loss Equation (USLE). The USLE was developed by Wischmeier and Smith (1965) and is widely used for predicting soil loss from agricultural lands which have moderate slopes (less than 50%).

Another common model is the Modified Universal Soil Loss Equation (MSLE) which has been developed for wildland conditions (USDA Forest Service, 1980; Dissmeyer and Foster, 1985). It is now used for non-agricultural lands that exhibit a variety of vegetation types and on steeper and longer slopes.

An alternative to the USLE and MSLE is the Morgan, Morgan and Finney (MMF) Method that predicts long-term mean annual soil loss (Morgan, 1986).

Besides the above, there are computer models that can be utilized to predict erosion and soil loss. Most of these erosion models form part of a watershed models for representing the interactions among variables within the watershed or hydrological systems (Low, 1990). Some of the common models that have erosion components in them are:

- CREAMS Model which stands for *Chemical, Runoff and Erosion from Agricultural Management Systems*. Among its outputs are erosion and sedimentation and the model is applicable to land having single landuse, relatively homogenous soils, spatially uniform rainfall and single management practice.

- WEPP (*Water Erosion Prediction Project*) was developed by the U.S. Department of Agriculture to update and improve on the USLE. It includes a series of process based models of storm runoff, surface erosion and sediment yield, and is designed for application on agricultural areas, rangelands and disturbed forests including forest roads. The WEPP has three components: (a) a hillslope model which computes erosion and deposition along hillslopes, (b) a watershed version provides erosional sediment by channels, and, (c) a grid version which describes areas that do not conform to watershed boundaries. WEPP only takes into account sheet and rill erosion, while ignoring other forms of erosion such as gully, mass wasting and landslides.

- ANSWERS Model is a deterministic model developed by Beasley, Monke and Huggins (1977) for predicting runoff and erosion/sediment transport for different agricultural management systems. The erosion component of ANSWERS consists of modifications of the USLE. Two soil detachment processes are included, namely, rainfall and overland flow detachment of soil particles.

- EPIC (*Erosion Productivity Impact Calculator*) Model is often used to determine the relationship between soil erosion and soil productivity. Erosion by water is simulated with the MSLE and a sub-model takes into consideration plant growth with the uptake of plant nutrients such as nitrogen and phosphorus.

Besides the above, there are many other models in the market that basically have the same objectives. Every model has its own strengths and weaknesses and the choice is often dependent on the amount of data available for calibration of the model, the accuracy of prediction, time and cost. All these will affect the choice of using the models.

Universal Soil Loss Equation

Since 1971 onwards, USLE and MSLE had been used for predicting soil loss from construction sites and range and forest lands. In Malaysia, it is commonly used in Environmental Impact Assessments (EIA) for predicting erosion and soil loss from land development sites.

Care is necessary when using the Equation because it was developed in the United States of America (USA) through statistical analyses of erosion measurements on experimental plots on agricultural fields. Correlations are generally very good for sites in eastern USA but caution must be exercised when the Equation is applied in Malaysia because some of the relations do not always apply in a different environment. For example, the erodibility factor differs with the type of soil and therefore has to be adapted to local conditions. Also, the USLE requires complete data sets such as rainfall, for a number of years and detailed information on vegetation and soil conditions. The absence of some of these will render the outputs invalid. Even when sufficient data are available, some caution is needed because the Equation was not designed to estimate erosional losses from slopes of over 20^0 or longer than 70 m (150 feet).

The method described below is based mainly on the works of Wischmeier and Smith: Agriculture Handbook No 282 (1965).

The basic USLE is:

$$\mathbf{A = R\,K\,L\,S\,C\,P} \quad \text{.............}(1)$$

where,

A =	Computed soil loss per unit area,
R =	A rainfall factor converted to erosion index units (EI - units) for the period of consideration. The EI is a measure of the erosive force of a specific rain event.
K =	A soil erodibility factor depending on soil types. The erosion rate per unit of erosion index for a specific soil, on a plot of 9% slope and 22.1 m (72.6 ft) long.
L =	Slope length factor; the ratio of soil loss from the field slope length to that from 22.1 m length on the same soil type and gradient.
S =	Slope gradient factor; the ratio of soil loss from the field gradient to that from a 9% slope, on the same soil type and slope length.
C =	Cropping management factor; the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated.
P =	Erosion control practice factor; the ratio of soil loss with contouring, strip-cropping or terracing to that with straight row farming, up-and-down slope.

Predicting annual or rotational field soil loss (in agricultural areas)

In order to predict soil loss, the annual (or rotational) EI_{30}-value, the K-value, the LS-value, the annual (or rotational) C-value, and the P-value are evaluated and Equation (1) is solved.

Table 3.4.4 gives a list of some general equations for predicting soil loss in Malaysia.

Table 3.4.4: Some Equations for Predicting Soil Loss in Malaysia

Types	Formulae	Description	References
Empirical models	$Qs = aQw^b$ Qs = sediment discharge Qw = water discharge	Basic black box relationship between sediment and water discharge. Exponents a and b reflect catchment characteristics.	Jovanovic & Vukevic, 1958.
	$Qs = 27.12\ P^2/P - 475.4$ P^2 = mean rainfall of wettest month squared. P = mean annual	Basic equation for calculating order of magnitude of sediment yield for rivers in lowland areas of Peninsular Malaysia. Basic equation for	Morgan, 1986. Morgan, 1986.

	rainfall $Qs = 52.49P^2/P-513.2$	calculating order of magnitude of sediment yield for rivers in upland areas of Peninsular Malaysia.	
Morgan, Morgan & Finney Method.	A model with 15 input parameters and 6 operating functions.	Endeavours to retain the simplicity of the USLE while encompassing greater understanding of erosion processes. Has been applied to field plots in Malaysia.	Morgan, 1986.
Gulley Surface Growth	$G_a = R_1 A_t L_g L_w e^{\Delta p}$	Predicts gully surface growth (G_a) from an index of surface runoff (R_1), the terraced area of the watershed (A_t), the length of gully at the beginning of the period (L_g), the length from the end of the gully to the watershed divide (L_w), and 2.7183(e) raised to the exponent of $^{\Delta p}$ the deviation of rainfall from normal.	Mitchell and Bubenzer, 1980.
Gully Head Advance	$R = (5.25 \times 10^{-3})\ A^{0.46}\ p^{0.20}$	Gully head advance (R metres) is a function of drainage area above the gully head (A) and the total rainfall from 24-hour rains equal to or exceeding 12.7 mm (*p*).	Mitchell and Bubenzer, 1980.

Predicting field soil loss with X-year return period

The procedure to be followed is essentially the same as that for predicting average annual soil loss, with one exception; instead of the annual EI_{30}-value, the EI_{30}-value with an X-year return period needs to be calculated.

Predicting individual storm field loss

Because the relation adopted in the USLE represents statistical averages, predictions of individual storm losses are less accurate. However, valuable estimates can be obtained if the EI_{30}-value of the individual storm is known and if the C-value for the actual field conditions during the storm can be established.

Soil Loss Tolerance

Soil Loss Tolerance (T) is the maximum soil loss that can be tolerated in a particular place. It is sometimes referred to as permissible soil loss and for agricultural areas, it is the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.

The Soil Conservation Service of USA (1973) has established a value of 2.3 to 11.2 tonnes of soil loss/ha/year where food, feed and fibre plants are to be grown without affecting the plant nutrients and fertility. These values however are not applicable to construction sites or to other non-farm areas.

Unfortunately, there is hardly any research work being carried out on soil loss tolerance in Malaysia in order to establish the permissible soil loss limits. In the absence of this, the only indicators are the observable rates of cut and fill in construction sites and the compliance standards of suspended sediments in rivers.

Sediment Delivery Ratio

Less attention has been paid to the off-site tolerance of erosion and sedimentation. It is important to obtain information on sources of sediment to stream channels and to downstream points of concern, levels of channel erosion and amounts of sediment already in the channels because all these will affect the rates of sedimentation in stream channels. In many cases, these can be observed and sampled from various points within the project site. Locally determined relationships of sediment concentrations and erosion rates should be used wherever possible to calculate the sediment delivery ratios.

In most forms of land disturbance in Malaysia, the impacts on rivers and streams caused by silt and sediment tend to be severe unless erosion control measures are taken. Acceptable suspended sediment and turbidity levels for various uses are recommended in the Interim National Water Quality Standards.

Sensitive to:	Total Suspended Sediments (mg/l)	Turbidity (NTU)
Aquatic Lifeforms	< 50	< 50
Water Supply	<150	<150
Irrigation	<300	<300

3.4.4.4 Study Alternatives and Options

Alternatives should be evaluated by incorporating the goals and objectives of the project (as shown in Section 3.4.4.1), constraints (Section 3.4.4.2) and erosion risks (Section 3.4.4.3). Investigations into alternatives and options should among others include:

Alternatives and Options	Checklist
• Review the size of the proposed project to ascertain whether there are any alternatives to reduce the size if the project is big and located in erosion prone areas.	• Reduction in project size. • Relocation of project facilities in less erosion prone areas.
• Review the site layout vis-à-vis off-site landuse.	• Alter project layout to minimize land clearing and land shaping.
• Review where surface runoff will converge and whether the drainage to the off-site areas will affect them in terms of flooding and sedimentation. Review whether there are any alternatives.	• Establish temporary drainage channels prior to site construction. • Locate best outlets for the drainage channels to off-site areas.
• Review the proposed works schedule in terms of the exposure of the cleared areas, time of land clearing, cut and fill areas and dumping of overburden if there is excess of earth materials.	• Alter the phases of project development to allow for permanent stabilization of disturbed areas as soon as land shaping is complete. • Retain existing vegetation as buffers to act as effective sediment control zones. • Re-programme the works schedule to make best use of existing buffer zones and recently established stabilized areas.
• Investigating various drainage, erosion and sediment control techniques proposed in the engineering plans to ascertain their adequacy and suitability.	• Arrange the development so that most of the ground disturbance occur outside periods of the year when rainfall is highly erosive. • Check the plans for adequacy in erosion and sediment control for the erosion risks that have been analyzed for the project.

3.4.4.5 Selection of the Best Management Practices (BMP) for a Given Site

The wide range of projects being developed or planned in the Country involves many different site conditions, which require a variety of solutions to address erosion and sediment control both on-site and off-site. Best Management Practice is the judicious use of erosion preventive and control techniques to abate the erosional problems. The choice and use of the techniques, however, must be critically judged, based on the following criteria:

Criteria	Requirement for Application
• Cost-effectiveness	• Cost has always been a major problem in construction. The choice of techniques, however, must be based on their performance history and site conditions. The performance of techniques should be evaluated against costs for a number of items such as materials, installation and maintenance costs to be cost-effective in the long-term.
• Availability	• The materials used in various control measures must be readily available within a short timeframe.
• Feasibility	• The materials used for control measures must be relatively easy to apply under a wide range of field conditions.
• Durability	• The materials for control measures should be durable until vegetation (or other final surface condition) establishes effective erosion control.
• Compatibility	• The materials should be selected with due regard to environmental sensitivity of the area.
• Labour & Management	• Managers, supervisors and workers must all be aware of the aims and purpose of the works and carry out their duties and operations in a way that minimizes ground disturbance and the creation of routes for water to flow downslope and discharge off appropriately.

3.4.4.6 Develop an Erosion and Sediment Control Programme

An Erosion and Sediment Control Programme may be developed by implementing the principles of erosion and sediment control as specified in Sections 3.4.4.1 to 3.4.4.5 in this Guideline. A programme should be based on the following :

- Careful study of the development site
- Careful design of the project layout so that it fits the terrain, wherever possible
- Realistic recommendations for erosion control measures - these should be pragmatic, practical, easily understood and easily implemented
- Erosion control measures recommended should be cost-effective
- All erosion control measures must be flexible since the implementation of a project is often spread over many years.
- There should be open communication and dialogue between the Client, Contractors, Consultants and the Authorities regarding the effectiveness of the erosion control measures.
- Reports and instructions to the Contractors must be clear and simple with a specified time-frame for them to complete and maintain the erosion control measures.
- Timeframe for completion of erosion control measures and maintenance programmes must be specified

3.4.4.7 Implementation and Maintenance of ESCP

Implementation and maintenance of ESCP's should follow the procedures listed below:

Activity	Comments
• Supervision	• Supervision is needed during all stages of activity that are being implemented if erosion is to be controlled. Proper documentation must be kept on all the measures undertaken so that evaluation on their effectiveness can be undertaken later.
• Maintenance	• Maintenance is the upkeep of an area or system to a pre-determined standard. This will reduce degradation of the erosion control measures and the areas that they are protecting. All the erosion control measures should be inspected and maintained regularly to be effective. For example, silt traps have to be desilted at frequent intervals to prevent overflow. A regular maintenance programme should be in place to avoid unexpected and expensive repair work.
• Monitor	• Monitoring is the observation of the area and recording what is happening. It can take many forms including field observations or use of appropriate instruments. The aim of monitoring is to ensure that the erosion control measures undertaken are effective. Monitoring of all the measures must be properly documented for further analyses, such as, to establish trends in sediment outputs from the project site prior, during and after project development, or to establish whether the measures undertaken are sufficient and effective.
• Field training	• There must be a certain amount of field training for site workers, sub-contractors, lorry drivers, etc. relating to their responsibilities in minimizing erosion and transporting earth materials from the site. There should also be signs throughout the project site to remind them of the need to reduce erosion.

3.4.4.8 Monitor Programme and Constant Review

Monitoring the effectiveness of an ESCP is an integral component of site management and responsibility. Monitoring may consist of short-term and long-term monitoring.

- Short-term monitoring consists of daily, weekly or monthly standardized documentation on maintenance requirements such as the need for desilting, water sampling to determine suspended sediment concentrations and turbidity, inspection of control measures and checking for any failures.

- Long-term monitoring is carried out throughout the lifetime of the project and measures trends that are occurring over and above seasonal and short-term fluctuations. Data collected daily, weekly or monthly over a long period of time could be used for long-term trend analyses.

- Both short and long-term monitoring of environmentally sensitive areas is critical because environmental components such as rare or endemic flora and fauna may be affected by earthworks or heavy silt delivery in the river systems. Such flora and fauna should be properly preserved through various appropriate measures and the services of specialists should be sought. Through constant monitoring and review and dialogues with specialists, these elements of the natural heritage can be preserved.

- Monitoring should be carried over the entire project area. If the project area is very large, then it should be partitioned into smaller units such as sub-river basins or terrain units to ease observations and recording.

- The criteria selected for monitoring should be sensitive to changes, such as in suspended solids, turbidity, the relative areas of bare and vegetated ground, the build-up of sediment behind retaining structures and the amounts of material removed from sediment ponds. If degradation is occurring in the area that is being monitored, then it must be identified and measured. Feedback to management will help to ensure that the problem of erosion does not intensify or if it does intensify will help identify further abatement measures that need to be taken at the particular location.

Monitoring should also be carried out wherever possible beyond the project boundaries to include the types of landuse or development located upstream or downstream of the project site.

3.5 Environmental Baseline Information and Data Requirements

Environmental baseline information required for an ESCP include maps, landuse data, and details of vegetation, soils, and water resources. The extent of data collection necessary for a given project should be determined before the start of feasibility studies. Below are some of the information and data required.

Items	Comments
Site topographic maps	Malaysian Topographic Maps can be obtained at scales of 1:10,000, 1:63,360 and 1:50,000. The information will assist in the preparation of catchment maps depicting: • drainage boundaries • catchment area • contours • physical features • slopes • existing characteristics • overland flow path • watercourse slopes • lengths and typical terrain cross-sections.
Town plan zoning maps	These can be obtained from municipal structure plans and local plans.
Aerial photography	Aerial photographs are useful for delimiting possible on-site and off-site impacts. They also will provide very accurate information on landuse and terrain characteristics.
Landuse, vegetation and forestry maps	These will provide an indication of the types, coverage and location of vegetation in an area.
Cadastral maps	These will provide the lot numbers of the project site.
Geographical information	Geographical information is collected and collated to provide site characteristics. Such information includes: • soil types • vegetation • terrain • slope characteristics • climatic parameters • geology • geomorphology • water resources and water quality • pollutant sources • aquatic and terrestrial habitats • distribution species and population for both terrestrial and aquatic habitat

	• biodiversity of the site • change in vegetation cover over time • expansion of the bare soil areas over time Integrated geographical information maps are very useful for interpreting environmental impacts within and beyond project sites.

3.6 Statutory Compliance

Statutory compliance requirements with respect to erosion and sediment control in Malaysia can be found in various pieces of legislation listed below. The various statutes are administered by nominated agencies and departments. Detailed information is included in Appendix D.

- The Ninth Schedule of the Malaysian Constitution (Malaysia, 1995)
- Environmental Quality Act, 1974 (Laws of Malaysia Act 127)
- Natural Resources and Environment (Amendment) Ordinance, 1993 for Sarawak
- Natural Resources and Environment (Prescribed Activities) Order, 1994 for Sarawak
- Land Conservation Act, 1960 (Laws of Malaysia Act 395)
- National Forestry Act, 1984 (Laws of Malaysia Act 313)
- National Forestry (Amendment) Act 1993 (Act A864)
- State Mining Enactments
- The Street, Drainage and Building Act 1974 (Laws of Malaysia Act 133) and the Uniform Building By-laws, 1984
- Town and Country Planning Act 1976 (Laws of Malaysia Act 172); (Amendment) 1995, Act A933
- Local Government Act 1976 (Laws of Malaysia Act 171)
- Fisheries Act 1985 (Laws of Malaysia Act 317)
- Geological Survey Act 1974 (Laws of Malaysia Act 129)
- State Water Enactments
- Federal Territory of Kuala Lumpur, Earthworks by-Laws, 1988

3.7 Compliance to Water Quality Standards

3.7.1 Development activity often leads to increases in concentrated runoff which carries greatly increased quantities of sediment into adjoining river systems. This changes the characteristics and water quality of the rivers for considerable distances downstream.

3.7.2 The severity of silt and sediment contamination of rivers may be assessed by reference to designated water quality criteria and standards. The standards for five classes of beneficial water uses are contained in the **Proposed Interim National Water Quality Standards for Malaysia (INWQS)**. The indicators used in the standards to assess river sediment loads are total suspended solids (TSS) and turbidity.

3.7.3 Compliance levels for TSS and turbidity for a number of beneficial uses are shown in Table 3.7.1. These water quality limits suggest that a high level of erosion control is needed.

Table 3.7.1: Ambient Standards for TSS and Turbidity

Parameters	INWQS Classes					
	I	IIA	IIB	III	IV	V
TSS (mg/l)	25	50	50	150	300	300
Turbidity (NTU)	5	50	50	-	-	-

3.7.4 Compliance with these standards requires that water samples be taken when erosion is likely to occur, that is, during rainfall, especially during heavy rainstorms and during the period of rapid runoff immediately after rain.

3.7.5 Sampling should be a combination of regular, fixed interval sampling and rain-period sampling. Sampling should be taken from channels on the project site at least once a month, preferably within two hours of heavy rain (i.e a storm lasting 30 minutes and producing runoff). A standard reference on water quality monitoring that could be used is the GEMS Water Operational Guide (Global Environment Monitoring System, 1992). Rain event sampling is absolutely necessary to monitor sediment movement.

3.8 **Use of Monitoring and Water Quality Assessment to Determine Changing Erosion and Sedimentation Risk during Construction**

3.8.1 The effectiveness of mitigation measures such as sediment traps varies in different parts of a project site as development work progresses. The monitoring of water quality indicates the output of sediment from each particular drainage line or sediment retention system within the project. By assessing the water quality class (using Table 3.7.1) for any particular drainage line or sediment trap outlet, the erosion risk in that sector of the project can be assessed. Where the sediment concentration and turbidity are high, attention can be given to improving and upgrading the existing erosion control measures above the sampling point. Such reaction to monitoring is essential to prevent a development being halted for failing to meet statutory requirements. Monitoring and response to indications of severe erosion and sedimentation during construction and development operations will enable efficient deployment of labour and machinery to be made while ensuring that aggravated erosion and sedimentation problems do not occur.

3.8.2 A risk factor for a project can be assessed on the following basis:

Risk Factor	Effect
Low	• The construction of the project is having little effect on either the stream or river or the beneficial uses of the land or water. All reasonable precautions have been taken and the discharge will have silt and sediment content within the prescribed standards of Class I and II waters. • Full erosion and sediment control plans may not be required but runoff and drainage control plans are required.
Medium	• The construction activity may have a significant effect on the river and the beneficial uses of land or water. It will fall within the prescribed standards of Class III and IV waters and comprehensive and thorough precautions against all sediment discharges are required. • Re-assessment of the erosion and sediment control plan is required together with an improved runoff and drainage plan demarcating the areas where discharges are made, the types of mitigation measures required and maintenance of the area.
High	• The construction activity is having a major effect on the river or the beneficial uses of land and water. It exceeds the water quality standards for silt and sediment. • A detailed and careful re-assessment of existing mitigation measures must be made. The erosion and sediment control

	plans may have to be modified. Rapid action will be necessary to reduce the escape of sediment to the drainage line or silt trap outlet. Measures to control erosion upslope from the sampling site will have to be strengthened, especially when there are environmentally sensitive areas downstream.

3.9 Summary Checklist for ESCP Preparation

Below is a summary CHECKLIST for the preparation of an ESCP:

- Establish site layout
- Determine physical layout of works
- Ascertain physical limitations
- Identify erosion potential and risk
- Prepare erosion control programmes
- Prepare specifications and construction details for erosion control structures
- Apply erosion control techniques
- Develop management programmes
- Develop monitoring and evaluation programmes
- Respond to changes in erosion conditions during construction

4. GUIDELINES FOR THE PREVENTION AND CONTROL OF SOIL EROSION AND SEDIMENTATION

4. GUIDELINES FOR THE PREVENTION AND CONTROL OF SOIL EROSION AND SEDIMENTATION

4.1 Introduction

This Chapter presents the generic and specific Guidelines for twenty six (26) activities of which nineteen (19) are prescribed activities listed under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987 (Table 4.1.1). It has to be re-iterated here that all projects involving earthworks which result in soil movements and erosion need to consider the use of the Guidelines recommended in this Report although only 26 prevalent types of activities are listed. Guidelines for coastal erosion are not included in this Report because the processes operating in coastal areas are very different from those operating in terrestrial areas.

Table 4.1.1: List of Prescribed and New Activities

Number	Activity
1	Agriculture
2	Airport Projects
3	Drainage and Irrigation
4	Land Reclamation
5	Fisheries
6	Forestry
7	Housing
8	Industry
9	Infrastructure
10	Marine Ports
11	Mining
12	Petroleum Development
13	Power Generation and Transmission
14	Quarries
15	Railways
16	Transportation
17	Resort and Recreational Development
18	Waste Disposal and Sewerage
19	Water Supply
20	Land Conversion for Golf Course
21	Hill Slope Development
22	Development of Ecologically Sensitive Areas
23	Landfills
24	Development of Former Mining Lands
25	Cattle Ranching
26	Land Devastated by Forest Fires

4.2 Reference Codes for the Guidelines

4.2.1 All the recommended guidelines are grouped and coded into eight (8) main categories for easy reference and retrieval in Table 4.2.1. To gain access to a particular category of guidelines, the User has only to refer to the Reference Code. For example, if the User wants a reference on drainage controls, then **Code D1 - Drainage Control at Construction Sites,** should be referred to where all the drainage guidelines are listed.

4.2.2 The generic guidelines pertinent to each of the 26 activities are summarized in Table 4.2.2 and the User can check for the appropriate guidelines easily.

4.2.3 For specific guidelines for each activity, especially those relating to regulations, the User should refer to Codes 1 to 26. For example, **No 1 - Agriculture** - gives the specific planning guidelines as well as land clearing measures. Unfortunately, not all activities have planning guidelines and regulations governing land clearing measures and erosion. Hence, reference to the generic guidelines is recommended under such circumstances.

Table 4.2.1: Reference Codes for Erosion Prevention and Control Guidelines

Reference Code	Erosion Prevention and Control Categories
A 1	Minimizing Soil Erosion
B 1	Preserving the Topsoil and other Assets
C 1	Access Routes
D 1	Drainage Control at Construction Sites
E 1	Earthworks and Erosion Control
F 1	Sediment Prevention and Control
G 1	Slope Stabilization
H 1	Maintenance

Table 4.2.2: Guidelines for the Prevention and Control of Soil Erosion and Sedimentation

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
A1	**Minimizing Soil Erosion** Before development begins, preventive measures shall be put in place to minimize erosion through the preparation of :																										
	(a) A Preliminary Site Evaluation (PSE).	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	(b) An Erosion and Sediment Control Plan (ESCP).	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
A1.1	Reducing the working area: The working area for various facilities within a development site should be kept to less than twice the plinths of the building.		*						*	*	*		*	*			*	*	*	*							
A1.2	Regulate phases of development: Development schedule must be clearly defined. Completion date for each phase of development shall be indicated and all clearing, grading and stabilization operations shall be completed before moving onto the next phase.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
A1.3	Timing the development activities shall, wherever possible, be spread evenly over the development time-scale to ensure that the deleterious effects arising from development activities are minimized.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
A1.4 Development activities shall take into consideration the hydrological and climatic conditions experienced in the area, in particular, the rainfall and runoff patterns.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
A1.5 Existing vegetation shall be maintained as filters along contours to reduce velocity and improve water quality. When retained in development sites, they break up the length of long slopes and act as buffers to minimize erosion.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
A1.6 Stream buffers shall be retained. For rivers, the width of the buffers shall follow the DID regulations. For small streams within the development site, the following could be used as a guide:	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Watercourse Type	Average Grade of Basin	
	Undulating to moderate ($<15^0$)	Steep to very steep ($>15^0$)
Intermittent	10 m	20 m
Permanent	20 m	30 m

Source: SCA of Victoria, 1979, Guidelines for Minimizing Soil Erosion From Development Sites in Victoria.

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
B1	**Preserving the Topsoil and Other Assets**																										
B1.1	Sensitive ecological areas within a development site such as salt licks, natural springs, unusual rock outcrops, etc. shall be demarcated and preserved.	*	*	*				*	*	*		*	*	*		*	*	*	*	*	*	*	*			*	
B1.2	All known archaeological sites within the development site shall be demarcated and preserved. Advice from the Curator of Museum should be sought.	*	*	*				*	*	*		*	*	*		*	*	*	*	*	*	*	*			*	
B1.3	All known rare and endemic flora and fauna areas or niches within the development site shall be demarcated and preserved.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
B1.4	All excavated topsoil and nutrients shall be stockpiled and later used for revegetation. Topsoil should be stockpiled in areas where it will not contribute to erosion and sedimentation. Temporary stabilization is necessary for exposed stockpiles.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
B1.5	All trees that are rare shall be fenced and preserved or carefully uprooted and transferred to a nursery/ another site for replanting. Expert advice should be sought from the Department of Forestry or Forest Research Institute of Malaysia.	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	

	GUIDELINES	ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
C1	**Access Routes**																										
C1.1	All right-of-ways or access routes shall be shown on the ESCP and it shall be the responsibility of the Project Proponent to ensure that all vehicular traffic stays within the designated right-of-ways.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
C1.2	Access roads should be kept to a minimum with other areas off limit to traffic.		*	*	*		*	*	*	*	*		*	*		*	*	*	*	*	*	*	*		*	*	
C1.3	Roads and permanent storm drains should be installed as early as possible so that they can control runoff during development. However, they should be temporarily connected to the sediment basins until stabilization of graded areas is achieved.		*	*	*		*	*	*	*	*		*	*		*	*	*	*	*	*	*	*		*	*	*
C1.4	Road shoulders should be protected mechanically or vegetatively against erosion.		*	*	*			*	*	*	*		*	*		*	*	*	*	*	*	*	*		*	*	*
C1.5	Development of all new main and secondary timber extraction roads and any such access must be carried out with the written permission of the enforcement authority and in accordance with specifications laid down by the said authority. These accesses should, as far as possible, follow natural contours.						*											*			*	*				*	

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
C1.6 All movement of development vehicles over unsurfaced roads and areas should be kept to a minimum. Haul roads should be sprayed with water to reduce dust pollution during dry periods.		*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		
C1.7 All access roads to the site shall be paved for a distance of at least 10 metres from where these access roads join the existing paved roads.		*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		
C1.8 All vehicles should enter and leave the development site at a limited number of points. The exit points should provide for the washing of vehicles as they leave. The washing bay should be the full width at the exit.		*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
D1	**Drainage Control at Development Sites** Rates of soil erosion are often greatest where runoff water becomes concentrated along drainage lines and streams. Erosion control measures in these locations can have a major effect in reducing the risk of downstream sedimentation.																										
D1.1	The principles to be followed in establishing a drainage system in development sites are to direct runoff water so that it does not run across disturbed and unstable areas.		*	*				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
D1.2	Locate and study the hydraulic characteristics of the drainage system which include:																										
	D1.2.1 Overall drainage pattern	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	D1.2.2 Dimensions and flow of rivers and streams	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	D1.2.3 Springs and wells including flow and well logs	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	D1.2.4 Subsurface conditions including acquifer type and capacity, depth to water table and location of perched water table	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	D1.2.5 Salt water intrusion areas	*		*	*	*					*							*					*				

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
D1.2.6 Natural drainage depressions, basins and sinks	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
D1.2.7 Flood plains, both on-site and downstream, that will undergo change due to grading and development.	*	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
D1.3 Construct drainage routes and channels in such a way that the beds do not themselves degrade and so contribute to the sedimentation problems.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D1.4 Remove the sediment load accumulated in channels during the dry season to avoid downstream sedimentation.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D1.5 For hillside areas, slope drains must be constructed or extended as work progresses. Such drains include berm drains, cascading drains and sumps at the toes of the cascading drains to reduce the velocity. Diversion banks may be necessary to intercept runoff from higher areas and to divert it away from exposed areas. The longitudinal slope of the bank must not be excessive or the bank itself will erode.						*	*										*	*		*	*	*				
D1.6 In granular soil areas, a diversion drain may serve the same purpose as a diversion bank, but is more effective if	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			

GUIDELINES	ACTIVITIES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
it is lined with a geofabric material to filter silt.																										
D1.7 For unsealed roads, culverts and cross drains have to be constructed where the route of a road intercepts a stream, depression or natural drainage channels. The practice has been to lead the runoff from the table drains into the upstream end of the culverts. To reduce erosion, it is better to locate table drain culverts some 20 m - 30 m from the watercourse, so that it provides a natural filter for the runoff before it enters the stream.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D1.8 Temporary interceptor ditches and berms with filters at inlets should be constructed to direct runoff from the development area into the sediment basin.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
D1.9 The drainage and deviation of mainstreams and natural watercourses, including provisions of bunds and culverts shall be carried out wherever appropriate.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
D1.10 No watercourse or the reserves along the watercourse shall be disturbed until full plan details of the proposed works have been submitted to and approved by the DID. A system shall be maintained that water quality with respect to total sediment load at the		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*	*	*	*	*

	GUIDELINES	ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	downstream be maintained at the original or improved values subject to the satisfaction of the authorities concerned. The silt traps that are provided together with the drainage works shall be approved by the authorities concerned.																										
D1.11	Permanent drains when constructed shall have sediment or silt traps of adequate capacity and other conservation measures to be decided by the authorities concerned. The silt traps shall have the capacity to hold not less than 10 cm of silt at any time. The silt, in the silt traps, if removal is required, shall not be placed in such a way that it becomes a source of siltation of the drains downstream.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D1.12	Drains that are not mechanically stabilized shall be grassed and maintained.	*	*	*				*	*	*								*			*	*	*				
D1.13	In mining and quarry areas, no occupier shall allow effluent water from any mining area under his control containing solid matter in excess of the amount prescribed by rule to discharge into any river or natural watercourse or otherwise to pass beyond his control.											*			*										*		
D1.14	Ineffective drainage should be noted especially during wet weather and promptly corrected.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*		

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
E1	**Earthworks and Erosion Control** In general, earthworks should be stabilized as early as possible to minimize the rates of soil erosion. The following should be carried out where silt traps and sediment traps are not available and the soil is to remain exposed for more than a few months or where vegetation is difficult to establish.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	A topographic map defining the physical features and having a scale of 1 inch: 50 feet with contour intervals of 5 feet. The map shall extend beyond the site to be developed far enough so that any impact of erosion from the site and its deposition on adjacent properties can be assessed.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
E1.1	The development specifications shall clearly define the maximum length of time that a graded area will be left exposed and shall state what short term stabilization practices will be performed in the event of a lengthy delay (see E1.13).		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*	*	
E1.2	Earthworks to be carried out shall be phased in the order of proposal for such work as outlined in the development schedule submitted and approved by the authorities concerned		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*		

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	and no earthworks shall commence or continue to the next phase unless the engineer submitting the plans certifies in writing that the earthworks are not likely to cause nuisance or damage to the surrounding properties.																										
E1.3	Not withstanding the above, the authorities concerned may at any time before the earthworks may be continued to the next phase require adequate conservation measures as detailed below. The standards and specifications of such conservation measures shall be in accordance with the specifications of the Drainage and Irrigation Department (DID).	*	*	*				*	*	*	*		*	*		*	*	*	*	*	*	*	*	*	*		
E1.4	Extraneous runoff shall be directed away from the exposed soils by drains (See section D1.1 to D1.14).		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.5	Contour plough or deep-rip so as to leave a rough surface to increase infiltration.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.6	Provide protection covers such as vegetation and plastic sheets on exposed areas.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.7	Earthworks should be confined to periods of low expected precipitation.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.8	As small an area as practical should be exposed and graded at a time. The		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
size of the area will depend on the potential erodibility of the soil and the time required to stabilize the area after grading is completed.																										
E1.9 All earthworks exceeding 1.5 metres in height or depth shall not be cut or cleared until the site is ready to be worked.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.10 Clearing and grading should be done with care to protect and maintain the previously installed temporary control measures.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
E1.11 Fills should be placed in horizontal layers and the faces of the fill slopes should be maintained as filling progresses. The materials to be used and the degree of compaction shall be clearly specified.		*	*	*			*	*	*			*	*		*	*	*	*	*	*	*		*			
E1.12 Where it is intended that cleared ground is to be planted, then the area should be landscaped and the planting carried out as soon as possible even prior to the completion of the whole work.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*		
E1.13 Trees and other vegetation should not be cut or cleared until the earthwork site is ready to be worked. The cleared ground shall be revegetated (turfed) within three months after		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	commencement of earthworks during the dry season and within one month after commencement of earthworks during the wet season.																										
E1.14	Maximum gradient of cuts shall vary with soil texture. However, measures taken should ensure that slumping shall not occur.	*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*
E1.15	Land clearing and soil cultivation shall only take place in the dry season. Immediately after clearing, conservation measures shall be installed. This shall include silt traps and the maintenance and/ or establishment of a vegetative belt of at least 2 chains away from the edge of permanently flowing waterway. There shall be no obstruction whatsoever to flow of water by fallen timber or other debris.	*																									
E1.16	Unsuitable materials and surplus earth shall be disposed off in designated spoil tips. In the event additional disposal areas (spoil tips) are required, the contractor shall be responsible for identifying these disposal areas to be approved by the Site Officer.		*	*				*	*	*	*		*	*		*	*	*	*	*	*	*	*		*		
E1.17	On no account should cleared vegetation and debris be deposited or		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*			*	

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
pushed into watercourses, streams and rivers.																										
E1.18 Holes and cavities resulting from the clearing, grubbing, destumping and derooting shall be backfilled with acceptable materials and compacted to approximately densities of adjacent areas.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
E1.19 Batters or terraces represent a special and severe case of exposed surface after earthworks. While the surface may be protected by one of the methods described in Chapter 5, the resistance of the batter to erosion will be determined primarily by the engineering design. Batters must be designed to satisfy stability criteria. For stable soils, a batter slope of 2H:1V is recommended.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
F1	**Sediment Prevention and Control** Check dams, silt traps and sediment ponds are effective for trapping sediment and reduce flow velocities.																										
F1.1	Wherever feasible, sediment retention ponds, basins or sediment ponds shall be installed. They should be adequately sized and constructed prior to start of earthworks.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
F1.2	Small temporary silt traps operate by slowing or stopping runoff at some point on its route, so causing it to deposit its sediment load. These shall be constructed across drainage lines near the plinths of building. Allowance must be made for sediment removal and the sediment must be deposited in a suitable area in such a manner that it will not slide back into the traps.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
F1.3	Infiltration ponding basins and stormwater ponds can be temporarily used as sediment basins, provided they are satisfactorily maintained and cleaned out after development to ensure efficient operation as designed.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*		
F1.4	Silt traps and other temporary control measures should only be removed and dismantled when the permanent vegetative cover and control measures		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*		

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
are satisfactorily established.																										
F1.5 Where necessary, mitigatory measures such as silt traps, water bars and side drains shall be constructed in all hauling roads in order to reduce siltation into natural waterways.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
F1.6 For undulating agricultural lands (6^0 - 12^0), cover plants shall be established and erosion checks or silt traps shall be constructed along the contours with spacing of every two planting rows. The silt traps shall also serve to check runoff. Wherever a planting system permits, perennial crops shall be planted in rows following the contour.	*																									
F1.7 Annual crops shall normally be planted on level and undulating land (0^0 - 6^0). However on steeper terrain, they can be cultivated provided conservation measures acceptable to the authority concerned are instituted. Such conservation measures include terracing, bunding, erosion checks on silt traps, grass cover, runoff ponds, etc.	*																									

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
G1	**Slope Stabilization**																										
G1.1	All critical areas along streams must be marked on the ESCP and the recommended methods of stabilization indicated.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G1.2	Stream stabilization shall be scheduled during periods of dry weather flow whenever possible.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G1.3	The stabilization of all waterways shall be defined giving both temporary and permanent practices which state where and when sodding, temporary seeding and permanent seeding are to be used. The specifications shall include ground preparation, sod quality, seed type and quality, fertilization and mulching.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G1.4	In cases where permanent retaining structure or stabilization of slopes are exempted by the authorities concerned, be provided temporary retaining structures or stabilization of slopes during the continuance of such earthwork.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
G1.5	Slopes are protected against erosion.		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				
G1.6	Cut and fill slopes should be regularly irrigated and fertilized to encourage faster growth. Development should		*	*				*	*	*			*	*		*	*	*	*	*	*	*	*				

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	proceed with minimum disturbance of the planted areas and temporary control measures.																										
G1.7	Walls of cuts are to be protected with vegetation and/ or chemical stabilizers and/ or approved retention structures. Whenever necessary, non-permanent retention structures need to be maintained in order to ensure that erosion shall not aggravate. Vegetation, if used, shall establish complete cover.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G1.8	There shall be no obstruction or interference with the natural waterways. Where a road is to be cut across a river or stream, bridges and culverts as prescribed by the enforcement authority shall be constructed and maintained according to specifications.	*	*	*			*	*	*	*											*	*	*			*	
G1.9	For hilly land (12^0 and greater) terracing shall be done and maintained. Cover plants shall be established on the slopes of the platforms and walls of the terrace immediately after commencement of earthworks.	*																									
G1.10	No person shall employ any means of temporarily raising the top of any spillways without sanction of the authority concerned.											*			*										*		

GUIDELINES	ACTIVITIES																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
H1 Maintenance																										
H1.1 A maintenance programme for the control facilities shall be prepared that includes plans for the removal and disposal of materials from the control facilities in the project area.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
H1.2 All silt traps, sedimentation basins, erosion control measures must be constructed and maintained by the Contractor.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
H1.3 Water discharging from the silt traps/ sedimentation basins should have total suspended solids level of 150 mg/l and below. Water quality monitoring must be carried out on a regular basis with all results submitted to the State Offices of the Department of Environment.	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
H1.4 The Contractor shall provide all necessary temporary drainage for keeping the site and other areas free of standing water.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*	*	
H1.5 Mitigating measures must be put in place before site clearing and earthworks are carried out.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*		*	*	

GUIDELINES		ACTIVITIES																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
H1.6	Cleared vegetation and debris should be disposed off in designated spoil tips which must be approved by the S. O. The Contractor shall be responsible for identifying these disposal areas. The dump site/ disposal areas are to be finalized before any earthworks are allowed to be carried out on site.	*	*	*				*	*	*			*	*		*	*	*	*	*	*	*	*	*	*	*	

No 1	Agriculture

No	Guidelines	Source
1.	**Generic Guidelines**	
	• Lands with slopes >25° in Peninsular Malaysia or >30° in Sabah and Sarawak are not recommended for agriculture.	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• The Land Capability Classification (Peninsular Malaysia) should be consulted to obtain the overall perspective of the suitability of a piece of land for agriculture. The equivalent is used for Sarawak and Sabah.	Recommendations of the Workshop on the Preparation of Guidelines for Agricultural Activities on Steepland, 1993.
	• The Soil-Crop Suitability Classification of Peninsular Malaysia could also be used for determining types of agricultural landuse. However, all Class 5 lands (including steepland) designated as unsuitable for agricultural activities should not be used.	
	• Shifting cultivation is not encouraged as it tends to damage the environment. If it has to be practised, as in Sarawak and Sabah, annual crops should be cultivated only up to slopes of 12^0, and perennial crops up to 30^0.	
3.	**Land Clearing Measures**	
	• Clean felling will continue to be practised for most crops. However, selective felling is recommended for certain perennial crops, especially on lands that are steeply sloping.	
	• The method of clearing, namely, mechanical, will be dictated by crop types and terrain. For example, on hilly and steep terrain, manual clearing is recommended for the cultivation of vegetables and flowers as this method will minimize soil erosion.	
	• Destumping, whilst conventionally done in all land clearing operations, should be practised with more reservation in the future. On hilly to very steep terrain in the highlands, stumps and tree debris can effectively reduce soil erosion and are, therefore, best left on-site.	
	• Buffer zones for all natural waterways and water bodies should be left undisturbed. It is recommended that these buffer zones be gazetted if possible.	
	• In all land clearing operations, time is an important factor to reduce exposure of the land to degradational processes.	

4.	**Drainage, Erosion and Sediment Control Measures** • Drains and waterways should be an integral part of agricultural development. Structures such as bench terraces, silt pits, check dams etc. should be constructed wherever applicable to control soil erosion. The steeper the land, the greater the necessity for such structures.	The details of recommended structures and measures are given in Chapter 5 and in the attached Tables 1-1, 1-2 and 1-3 taken from the Recommendations of the Workshop on the Preparation of Guidelines for Agricultural Activities on Steepland, 1993.

Table 1-1: Recommended Land Clearing Measures for Various Crops and Land Slopes

<table>
<tr><th>Slope Range</th><th>0 - 2°</th><th>2 - 6°</th><th>6 -12°</th><th>12 - 20°</th><th>20 -25°</th><th>25 - 30°</th><th>> 30°</th></tr>
<tr><td colspan="8">IN LOWLANDS</td></tr>
<tr><td>Annual</td><td colspan="2">1, 2, 3, 4b, 6, 7, 8* ⟶</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Perennial</td><td colspan="5">1, 2/3, 4c, 5, 6, 7, 8 ⟶</td><td>- - - -></td><td></td></tr>
<tr><td>Grasses</td><td colspan="3">1, 2, 4c, 5, 6, 7, 8 ⟶</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Medium Term Crops</td><td colspan="3">1, 2/3, 4c, 5, 6, 7, 8 ⟶</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Aquaculture</td><td colspan="2">1, 2, 4c, 5, 6, 7, 8 ⟶</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">IN HIGHLANDS</td></tr>
<tr><td>Annual (Veg. Flowers)</td><td colspan="2">1, 2, 4c, 5, 6, 7, 8 ⟶</td><td colspan="3">1, 4a, 5, 6 ⟶</td><td>- - -></td><td></td></tr>
<tr><td>Perennial</td><td colspan="5">1, 2, 3, 4c, 5, 6, 8 ⟶</td><td>4a
- - -></td><td></td></tr>
</table>

Source: Recommendations of the Workshop on the Preparation of Guidelines for Agricultural Activities on Steepland, 1993.

* no burning or replanting

⟶ recommendation for Peninsular Malaysia, Sabah and Sarawak.

- - - - - - -> similar recommendation for Sabah and Sarawak only

LEGEND

1. In manageable stages
2. Clean felling
3. Selective felling
4. (a) Manual
   (b) Mechanical
   (c) Both
5. Buffer zone - wherever applicable
6. Timeliness
7. Destumping
8. Light burning

Table 1-2: Recommended Conservation Structures/ Measures for Various Crops and Land Slopes

Slope Range	$0 - 2^0$	$2 - 6^0$	$6 - 12^0$	$12 - 20^0$	$20 - 25^0$	$25 - 30^0$	$> 30^0$
IN LOWLANDS							
Annual	4	4, 6					
Perennial	4	4, 6	1/2, 5, 6, 7, 8 ——————►	——————►	——————►	2, 4 - - - ->	
Grasses	4	4, 6	4, 5, 6				
Medium Term Crops	4	4, 6	1/2, 4, 5, 6, 8				
Aquaculture	4	4, 5					
IN HIGHLANDS							
Annual (Veg. Flowers)	4	1, 4, 5, 6	1/3, 4, 5, 6, 8	1/3, 4, 5, 6, 8, 9, 10			
Perennial	4	4, 6	1/2, 4, 5, 6, 7,8 ——————►	——————►	——————►	2, 4 - - ->	

Source: Recommendations of the Workshop on the Preparation of Guidelines for Agricultural Activities on Steepland, 1993.

——————► recommendation for Peninsular Malaysia, Sabah and Sarawak

- - - - - - -> similar recommendation for Sabah and Sarawak only

<u>LEGEND</u>

1. Bench terrace
2. Platform/ Individual Basin
3. Plateau/ broad bench
4. Drain and waterways
5. Silt pits/ traps/ contour ditches
6. Hillside ditches
7. Orchard terrace
8. Check dams
9. Culverts
10. Stone wall/ retaining wall/ gabions

Table 1-3: Recommended Agronomic Measures for Various Crops and Land Slopes

<table>
<tr><th>Slope Range</th><th>0 - 2°</th><th>2 - 6°</th><th>6 -12°</th><th>12 - 20°</th><th>20 -25°</th><th>25 - 30°</th><th>> 30°</th></tr>
<tr><td colspan="8">IN LOWLANDS</td></tr>
<tr><td>Annual</td><td>3, 5, 6</td><td>2 to 10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Hill Paddy</td><td>3, 4, 5</td><td>7, 8</td><td colspan="3">1/2, 5, 6, 7, 8 ————►</td><td>4</td><td></td></tr>
<tr><td>Perennial</td><td>1, 3, 4, 5</td><td colspan="4">1, 2, 3, 4, 5, 7*, 8* ————►</td><td>- - -></td><td></td></tr>
<tr><td>Grasses</td><td colspan="3">4 ————►</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Medium Term Crops</td><td colspan="3">1, 3, 4, 5, 6, 7, 8, 10 ————►</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Aquaculture</td><td colspan="3">1 ————►</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">IN HIGHLANDS</td></tr>
<tr><td>Annual (Veg. Flowers)</td><td colspan="3">3, 5, 6, 7, 10 ————►</td><td colspan="2">- - - - - - - -></td><td></td><td></td></tr>
<tr><td>Perennial</td><td colspan="5">1, 2, 3, 4, 5, 7, 8, 9, 10 ————►</td><td></td><td></td></tr>
</table>

Source: Recommendations of the Workshop on the Preparation of Guidelines for Agricultural Activities on Steepland, 1993.

* Where applicable
————► recommendation for Peninsular Malaysia
- - - - - -> similar recommendation for Sabah and Sarawak only

LEGEND

1. Ground cover
2. Contour planting
3. Mulching
4. Minimum tillage
5. High density planting
6. Crop rotation
7. Intercropping
8. Alley cropping
9. Grass strips
10. Wind breakers

No 2	Airport Projects

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• The specific guidelines should refer to the construction period where the control of silt and sediments will be very important since a large area will be cleared for the runways and apron. Control of runoffs from runways and aprons is necessary to avoid on-site and off-site channel erosion and sedimentation. Large detention ponds will be required.	
	• Airports intruding on the coastal zone should follow regulations for coastal development.	
3.	**Land Clearing Measures**	
	• All land clearing should be restricted to those areas where earthwork is required and carried out just prior to grading and embankment operations. Long exposure of bare surfaces lead to unnecessary erosion.	Refer to Specifications for Civil Works (JKR, 1988)
	• The areas to be cleared should be delineated on the ground by the Contractor and clearing commence only after the Site Officer is satisfied that the areas delineated are the areas where such clearing is necessary.	
	• All spoil materials removed by clearing should be disposed of by removal to spoil areas within the property as approved or designated or to an approved landfill. Burning should be avoided and the Contractor should be responsible for compliance with all laws and regulations relating to fires on the Site. A contravention order will be necessary if burning is to occur.	
	• Any existing buildings, structures and superficial obstructions which are located in the way of or otherwise affected by the construction works should be demolished, broken up and removed and disposed of as directed.	
	• Existing turf which is required to be removed from construction area is to be cut into convenient sizes and transported to an area as directed, stacked and kept well watered until required for re-laying as directed.	
	• Turfs over areas which do not require regrading are to be preserved to the maximum extent and any damage beyond that considered by the Site Officer to be unavoidable is to be remedied at the expense of the Contractor.	

No 3	Drainage and Irrigation

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• The design process for drainage and irrigation construction should satisfy flooding criteria, and the morphology of any proposed river or channel improvement works, flood plains, flat plains etc.	
3.	**Land Clearing Measures**	
	• Construction of drainage and irrigation systems involves vegetation clearing and earthworks such as drain and channel excavation, bund construction, diversion of surface water, access roads construction and installation of culverts, weirs, pumping stations and many other structures. Appropriate drainage, erosion and sedimentation control measures must be put in place to control sediment generation and attendant water pollution and flooding.	All relevant DID Hydrological Procedures should be used. Environmental Impact Assessment Guidelines for Drainage and Irrigation Projects (DOE, 1995)
	• All drainage and irrigation works involving land clearing, drainage, erosion and sediment control measures in Chapter 5 should be applied.	

No 4	Land Reclamation

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Land reclamation projects are normally very large and inevitably involve transportation of earth to the fill areas. Care should be taken to ensure that the surface of the appropriate fill materials is compacted and surface runoff kept to a minimum with proper drainage and sediment control. • Care should be taken to ensure that the natural drainage of the area and beyond the reclamation site is not adversely affected. • Land reclamation of coastal areas are becoming very common. It involves filling of the sea to be reclaimed with rocks and fill materials. In many cases, the fill materials are dredged from the sea to fill the reclaimed land. A lot of41 • sediment movement is envisaged during such activities. Care should therefore be taken to ensure that the surrounding waters do not become highly turbid which could affect the marine lifeforms. • All land reclamation projects especially those near the coastal should follow the general and specific guidelines of DOE, DID and JKR.	All relevant DID Hydrological Procedures should be used. Environmental Impact Assessment Guidelines for Drainage and Irrigation Projects (DOE, 1995) can also be used. National Coastal Erosion Study (1985) Guidelines from National Committee on Mangrove (1986)

No 5	Fisheries

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** (a) Construction of Fishing Harbours Fishing harbour construction will result in erosion and sedimentation due to hydrologic changes caused by channel deepening and widening and shoreline development (construction of breakwaters, etc.). The impacts of dredging can be minimized by the adoption of sound operational procedures such as: • Avoidance of any unnecessary disturbance, destruction, impounding or any other impacts outside the necessary radius of activity. • Avoidance of sensitive areas or species at risk whenever possible. • Timing (tidal, diurnal and seasonal) of activities so as to work in harmony with natural or seasonal events. • The potential to restore degraded coastal land in the vicinity of the project to reduce or nullify net losses of areas such as mangroves.	Environmental Impact Assessment Guidelines for Fishing Harbours and/or Land-based Aquaculture Projects (DOE, 1995).
	(b) Aquaculture • The most significant adverse effects of aquaculture projects is the clearing of land (usually wetlands) and establishment of ponds. • Clearing of mangroves and other riparian vegetation should be kept to a minimum. • Effective drainage systems and sedimentation ponds need to be prepared prior to land clearing. Any outflow from the sedimentation ponds should not contain more than the stipulated total suspended solids by DOE. • The number of sedimentation ponds for each drainage line should be of a size and depth suitable for efficient entrapment of sediments. Sides of the sedimentation ponds should be non-porous with overflow facility and efficient filtration. • Tree felling and land clearance should be minimized and the removal of trees should be carried out in accordance to the Town and Country Planning Act (Amended) 1995. Forested areas surrounding the development must be preserved.	Guidelines from National Committee on Mangroves (1986)

	• A buffer zone of stipulated widths should be maintained along the coast between the pond site and the mean high water level of the sea. A bund of compacted materials may need to be constructed to reduce the outflow of sediments if the site is very near to the sea or river. • Construction roads need to be resurfaced before new pond excavations. • Adverse effects associated with flushing of both marine water from the sea to forested areas and draining of freshwater from the inland to the sea can be minimized by the construction of canals and the appropriate placement of culverts. • Earth slopes facing the remaining mangroves should be turfed with suitable materials to prevent excessive acid leaching. • Monitoring of water quality parameters at the origin and at the point where the water flows out of the mangroves should be carried out constantly.	

No 6	Forestry

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** The choice of forest management system to be used must take into consideration the requirements of biological diversity and soil conservation. Selective systems will be more compatible with soil conservation objectives than clear-felling or uniform systems. Reference to erosional control guidelines formulated are: • Patches of undisturbed forest must be left covering at least 5% of the logged area. These areas must be located so as to cover representative areas of all the forest types. • A Tree Harvesting Plan (THP) is to be prepared by the loggers prior to harvesting operations which specifies the location, harvesting machinery, forest roads, skid trails, landings, stream crossing, buffer zones and compartment boundaries in accordance with the plan format issued by the Forestry Department. • Buffer zones must be clearly demarcated and should not be less than 20 m width on each side of water course. Strictly, no logging is permitted in buffer strips. • Adherence to the cutting regimes imposed is essential and forest removal should be limited to less than 40% of the standing volume or approximately 30 m^3/ ha, whichever is lower. • Logging should not be encouraged or allowed above 500 m of elevation within a watershed. • In predominantly steep terrain with slopes greater than 60% (30^0 - 35^0), logging is not recommended. On such sites, careful cable logging may be permissable. • All climbers more than 2 cm diameter should be cut at least 3-6 months prior to logging. There should be no climber cutting in riparian reserves, stream or roadside buffers. • Skid trails design should minimize skidding distance to only 50m, avoiding steep slopes and stream crossing.	Guidelines on Logging Practices for the Hill Forest of Peninsular Malaysia, 1994. Harvesting Specifications, Forestry Department, Peninsular Malaysia. Garis Panduan Membalak di Kawasan Tadahan Air.

3.	**Road Construction and Skidding**	
	• Where road cuts are made, they should be at an angle of less than 20^0 which will give a stable slope and not lead to further sliding or slipping.	Guidelines on Logging Practices for the Hill Forest of Peninsular Malaysia, 1994.
	• Where possible, roads should be constructed against the sunlight in order to speed up the drying process of road surface after a heavy downpour.	Harvesting Specifications, Forestry Department, Peninsular Malaysia.
	• Any haulage tracks made to remove the trees should be blocked off by bulldozing temporary earth barriers across the roads at intervals. On slopes up to 30^0, one barrier every 20m should be sufficient.	Garis Panduan Membalak di Kawasan Tadahan Air.
	• Cross drains should be constructed on roads and skid trails at a spacing of 30m or less with a minimum slope angle of 30^0. It should be designed to disperse, rather than concentrate, runoff.	
	• Road gradient should be less than 10^0 and the road density (including skid roads) should be minimized to not more than 6% of working area.	
	• The gradient of skid trails should not exceed 20^0 except for short skidding. Blading is not permitted for skid trail construction on $<15^0$ slope.	
	• Skidding should not occur on slopes $>35^0$. Tractors should be used on a reverse down trail operation to avoid soil disturbance and tree damage.	
	• Landings (*matau*) are to be located on ridge or widened road areas, with slope of 2^0-3^0, size < 0.2 ha and minimum in number. The appropriate areal extent of landing should not be more than 4% of working areas.	
	• Areas adjoining or near to watercourses should be logged last.	
	• Skid tracks, log landings, logging camp sites and other bare areas should be revegetated as soon as possible after logging operations are completed.	
	• Earth bunds should be constructed along skid tracks after logging operations have been completed to retard surface runoff and erosion.	

No 7	Housing

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Guidelines with respect to erosion control in housing development areas are often associated with plans to beautify the area. The layout plans generally have information relating to: (i) measures for the protection and improvement of the physical environment; (ii) measures for the preservation of natural topography; (iii) landscape improvement measures; (iv) the preservation and planting of trees; (v) the location and species of trees with a girth exceeding 0.8 metre and other vegetation; (vi) provisions of open spaces; (vii) proposed earthworks, if any; and (viii) a description of works to be carried out. • Developers are prohibited from: (i) damaging the land, its physical environment, natural topography and landscape; (ii) removing or altering any of the natural features of the land; (iii) felling of trees of a certain size, age, type or species at any particular location unless it is to comply with any written instruction from the relevant authorities.	Akta Perancangan Bandar dan Desa (Pindaan) 1995
3.	**Land Clearing Measures** • Great care should be taken to ensure that slopes potentially prone to landslides are not developed unless appropriate precautionary measures are undertaken. • All cut and fill slopes and benches should be stabilized as rapidly as possible and suitable drainage installed. • Vegetation buffer should be maintained along watercourses for erosion control, recreational and aesthetic purposes. • Every attempt should be made to minimize runoff in order to avoid flash flooding and reduce erosion of adjoining watercourses.	Standard Specification for Road Works (JKR, 1988) Refer to DID guidelines on the protection of watercourses and limits of buffer zones

No 8	Industry

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Industrial projects will require lands to be cleared and therefore fall under erosion control guidelines similar to those for land clearance. • In addition to the above, some specific guidelines are: (a) Environmental Impact Assessment Guidelines for Industrial Estates (DOE, 1994). (b) Environmental Impact Assessment Guidelines for Industrial Projects (DOE, 1995). (c) Town and Country Planning Act (Amended) 1995 (d) Guidelines for the Siting and Zoning of Industries (DOE, 1996). • The first two (a) and (b) have guidelines for the control of erosion through installation of silt traps and sediment ponds during the construction stage while (c) has specific guidelines for environmental control and enhancement.	

No 9	Infrastructure

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Land Clearing Measures** Land clearing measures for any infrastructural projects are quite generic in nature and hence many of the measures adopted for land clearing operations for airport projects can be used. In particular: • Clearing should be restricted to those areas where earthwork is required to be executed. • Long exposure of bare surfaces lead to unnecessary erosion and should be avoided. • The areas to be cleared should be set out on the ground by the Contractor and clearing commences only after the Site Officer is satisfied that the areas delineated are the areas where clearing is necessary. • All spoil materials removed by clearing should be disposed of properly either within the property or in designated areas for such purposes. The Contractor shall be responsible for compliance with all laws and regulations relating to disposal. • Any existing buildings, structures and superficial obstructions which are located in the way of or otherwise affected by the construction work should be removed and disposed of as directed. • Existing turf which is required to be removed from construction area is advisable to be cut into convenient sizes and transported to an area as directed, stacked and kept well watered until required for re-laying. • Turfs over areas which do not require regrading are to be preserved to the maximum extent and any damage is to be remedied immediately.	Refer to No 2 - Airport Projects (pg 4-27).

No 10	Marine Ports

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** The specific guidelines are related to marine conservation with the aim of reducing the adverse effects of construction on the marine environment. These include: • Avoidance of adverse effects on the fish habitats and adjoining sensitive coastal foreshore areas. • Shore protection and sensitive coastal zone regulations to be followed. • Fisheries and rich fishing areas will require special protection from high turbidity. • Local policies and regulations on sensitive areas especially mangroves to be followed. • Plans should be designed to avoid creating acid sulphate soil problems in reclaimed areas. • Navigational Regulations to be followed and care must be taken to ensure that navigational requirements are not compromised. • Provisions should be made for the safe disposal of sludges and other wastes from ships.	Refer to DID Regulations on Shore Protection.
3.	**Land Clearing Measures** • Land clearing works should avoid impacting on natural coastal processes, particularly sand drift patterns. • Disposal of dredging wastes and excavated spoil should be dumped away from water courses or at an adequate distance off-shore in accordance with relevant regulations.	

No 11	Mining

No	Guidelines	Source
1	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** Management of mine and site drainage is a vital aspect of most mining operations. A comprehensive soil erosion and water management system requires the following: • Progressive rehabilitation measures should be built into a mining plan which involve sediment and erosion management by means of good design and operational practices, on-going stabilization, rehabilitation, collection and treatment. • The plan should include ways to minimize the volume of contaminated drainage, water recycle measures, dust control on- and off-site, tailings control and waste rock disposal and rehabilitation.	Environmental Impact Assessment Guidelines for Mines and Quarry (DOE, 1995)
3.	**Land Clearing Measures** Where clearing is required, the guidelines for land clearing should be followed. These recommended guidelines are: • Where the mine is in a Forest Reserve Area, permission and permits should be obtained from the state Forestry Department or other relevant authorities prior to entering or staying in Forest Reserve Areas. • During the preliminary stages of exploration where there is a need for some clearing of vegetation, good environmental practices can be initiated by using the following measures: (a) survey lines should be flagged. (b) rather than moving trees, flagging tape should be used at more frequent intervals to mark the line. (c) where larger clearing is required, as on sites for drilling, trenching, mine facilities, exploration camps etc. no trees should be left leaning onto the surrounding timber for safety reasons. (d) all bare areas should be covered wherever possible.	

	• During mining operations, the following are recommended with regards to soil erosion control: (a) The areas cleared should be kept small so as to limit the potential for soil erosion. (b) Environmental damage should be limited by clearing the area by phases as required when mining progresses. (c) Where extra clearing is required, the boundaries should follow the edge of natural openings and forest types. (d) All trees larger than 115 mm in diameter within 1.5 m from the edge of the road should only be felled when required. (e) Pre-logging should be done in consultation with the relevant government departments to ensure compliance with regulatory requirements. (f) In order to minimize the environmental impact of clearing operations, the regulations and guidelines from the relevant state forest departments should be followed. (g) No cutting should be undertaken on privately owned lands without consultation with the owner. (h) Clearing of vegetation should be kept to a minimum and if possible, land clearing on hill slopes greater than 15^0 should be avoided. (i) In order to reduce the effects of erosion, clearing activities should not be carried out during wet periods. (j) Branches of trees should be trimmed in preference to felling of trees. (k) Where trees have to be removed and in order to permit subsequent growth from the stump, they should be cut at the base rather than pulled out by the roots.	

No 12	Petroleum Development

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** Erosion, runoff and sedimentation are the major problems during the exploration and construction stage. Construction activities pertinent to petrochemical plant development projects include the following: site clearing, earthworks and site drainage, dredging, reclamation, construction of infrastructure and support facilities (roads, drainage, sewerage and wastewater treatment system, power cables and substation) and construction of plant structures. If the plant is sited near a coastal area, the following guidelines are recommended: • Identify the reach of the coastal area affected by the project, particularly the significant physical coastal processes at work within, upstream and downstream of the reach. These include currents, tides, winds and waves, coastal erosion and accretion. • Cite and use the Department of Irrigation and Drainage criteria and classification for coastal erosion. • Soils contaminated with chemicals that are extremely hazardous and very expensive to treat would require specialized treatment (e.g. bioremediation). Chemical waste streams therefore must not come in contact with soil or water. • Any jetties or moorings should be designed to avoid impacting on coastal processes and mangroves especially during the construction period.	Environmental Impact Assessment Guidelines for Petrochemical Industries (DOE, 1994) National Coastal Erosion Study (1985)
3.	**Land Clearing Measures** • The JKR has earthworks guidelines for land clearance and they should be followed strictly. • Spoil, sludges and other wastes should be appropriately disposed of and not allowed to enter watercourses. • Land clearance should be carried out with care and there should be adequate sediment traps to ensure that the sediments do not get into the river or coastal areas and affect the aquatic and marine life.	

No 13	Power Generation and Transmission

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** Where power generation and transmission involve the construction of dams and hydroelectric power schemes, guidelines relating to construction of dams and/or reservoirs, which also relate to sectors dealing with drainage and irrigation, and water supply, should be referred to. The construction of dams normally involves cutting and filling which inevitably cause erosion and high sediment yields. This, in turn adversely affects water quality by increasing turbidity and nutrient levels. Pertinent information for control of erosion and sedimentation include: • The incorporation of environmental controls within the plans for dam construction to strive for zero sediment discharge to surface water, achieved by designs which balance cut and fill (e.g. minimum cut to waste) and construction methods which incorporate slope protection, fill compaction, sediment control structures and buffer zones adjacent to water courses. • It is essential that dam projects be planned and managed in the context of overall river basin and regional development plans, including both the upland catchment areas above the dam and floodplain, and the watershed areas downstream. In practice, watershed protection requires watershed gazettal before any form of control can be implemented.	Local and State Governments planning guidelines on right-of -ways. Environmental Impact Assessment Guidelines for Petrochemical Industries (DOE, 1994). Specifications for earthworks and land clearance (JKR, 1988) Environmental Impact Assessment Guidelines for Thermal Power Generated and/or Transmission Projects (DOE< 1995)
3.	**Land Clearing Measures** • During land clearance, provisions should be made for the disposal of spoils from the desilting of reservoirs and for ash from thermal power stations. • Provisions should be made to ensure that spillway flows and flows from cooling water outfalls do not cause excessive downstream channel erosion. • Vegetated buffer zones should be retained along power line easements. • Appropriate erosion control measures should be installed along all power line access roads during land clearance and construction. • Temporary erosion and sediment control measures should be installed during excavations for underground power cables.	

No 14	Quarries

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** Management of dust and site drainage is a vital aspect of most quarry operations. A comprehensive soil erosion and water management system requires the following: • A progressive quarrying plan that includes sediment and erosion management by means of good design and operational practices, collection and treatment of site drainage and rehabilitation. • The plan should also include ways to minimize the volume of silted surface runoff and dust fallouts and controls on- and off-sites and waste residues disposal or rehabilitation.	 Environmental Impact Assessment Guidelines for Mines and Quarry (DOE, 1995)
3.	**Land Clearing Measures** • Land clearing measures should follow standard procedures, and provisions should be made for the disposal of spoils from the site. • Provisions should also be made for the proper drainage of surface runoff from the site which is heavily laden with silt and sediments to be channeled to a sediment trap prior to discharging into a stream or river.	

No 15	Railways

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** The guidelines are generally as for No. 9 - Infrastructure and No. 13 - Power Generation and Transmission. There are two types of development related to railways in Malaysia: (a) changes to the established railways system. (b) construction of new railways system. Under (a): • Clearing works for the railway corridor and other related infrastructure in railway reserves must be controlled to reduce erosion. • Ensure that existing old culverts and bridges are improved to cope with increased water and sediment loads from upstream and undercut them. • Care should be taken to ensure that all cut and fill slopes for railway embankments are appropriately compacted, drained and vegetated as soon as possible to reduce gully and sheet erosion. Under (b): • Clearing for the railway corridor and other infrastructure must be controlled and adhered strictly to the various regulations governing land clearance. • Clear the land phase by phase along the corridor as this will reduce erosion. • Provide adequate drainage and slope protection in cut areas. • Ensure compaction of fills and stabilize fill slopes through appropriate methods.	Refer to: JKR standards for earthworks and drainage controls. DID guidelines on the protection of slopes.

No 16	Transportation

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• It is important that thorough soil and geological surveys are undertaken prior to roads being designed.	
	• It is recommended that the JKR's *'Standard Specification for Road Works Chapter 2'* be used as a planning guide especially for the design and maintenance of cut and fill slopes and drainage works.	
	• Drainage and slope stabilization systems should be specifically designed to take into account the geology, soils and terrain of the affected areas.	
	• Required standards of compaction and vegetative protection must be adhered to.	
3.	**Land Clearing Measures**	
	• Drainage and maintenance of unsealed, laterite and gravel roads during clearing and also in rural, plantation and forestry areas must be given high priority as an erosion control measure.	Standard Specification for Road Works (JKR, 1988).
	• Clearing for highway and road construction should be done in manageable phases, clearing as little as practically possible at any one time.	Town and Country Planning Department's guidelines for urban and rural enhancement and beautification.
	• Tree planting should be undertaken as an important erosion control measure.	

No 17	Resort and Recreational Development

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Development of resort and hotel facilities involves site clearing and earthworks, construction of buildings and facilities, utilities, roads and drainage works which result in soil erosion and sedimentation.	
3.	**Land Clearing Measures** The construction stage of a resort development will have adverse impacts, particularly in terms of terrain and landforms disturbance. Erosion, runoff and sedimentation are the major problems during this stage. Appropriate drainage, erosion and sedimentation control measures must be adopted to control sedimentation generation, ecological damage and water pollution. Relevant measures include: • Careful planning of cut-and-fill slopes in hilly terrain to minimize erosion, including revegetation of exposed areas. Avoid site clearing during rainy monsoon periods. • Careful design and construction of drainage diversion channels and sediment traps or sedimentation basins to reduce sediments. • Buffer zones are recommended especially if the site is located in sensitive environments such as along the coast or hilly areas. • Provision of adequate silt traps to hold runoff as the resulting erosion can be very damaging to sensitive marine ecological habitats, beach and recreational areas.	Environmental Impact Assessment Guidelines for Resort/ Hotel in Hill Stations (DOE, 1995) Environmental Impact Assessment Guidelines for Development of Tourist and Recreational Facilities in National Parks (DOE, 1995)

No 18	Waste Disposal and Sewerage

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	(a) Sanitary Landfilling	
	Disposal of municipal solid waste through sanitary landfilling is the most common practice adopted by most local authorities. Development of the sites identified and acquired for sanitary landfilling will follow the guidelines for land clearance as follows:	Environmental Impact Assessment Guidelines for Municipal Solid Waste and Sewage Treatment and Disposal Projects (DOE, 1995).
	• During construction of access tracks to the site, minimize removal of terrestrial vegetation and extent of clearing.	
	• Solid waste on site to be buried and covered with sand daily. Minimize soil movements, cover the stockpile and shorten the excavation/ filling cycle.	
	• Limit the operating hours of vehicles to reduce dust dispersions and install wheelwash water troughs at exit points. The loads should be securely covered during transport of earth materials and moisten the surfaces of roads to reduce dust.	
	• To control erosion and sedimentation from the site, proper drainage channels, culverts and sedimentation traps should be installed.	
	• Minimize earthworks required by taking advantage of local topography.	
	(b) Municipal Sewage Wastewater Treatment	
	• The construction of a municipal sewage wastewater treatment plant involves excavation, trenching, tunneling, laying of conduits, filling and resurfacing and road diversion activities. Appropriate erosion and sedimentation control measures need to be instituted.	Sewage Services Act 508 (1993)
	• Do not route sewers into stream channels.	
	• Balance cuts and borrow pits.	

	(c) Marine Outfall A marine outfall makes use of the sea's oxidizing and dilution potential in disposal of treated municipal and industrial sewage. A marine outfall consists of a gravity line, an outfall pipe and diffuser head to maximize dispersion at the end of the outfall and supporting infrastructure. Changes in coastal processes and eventually coastal morphology may result from outfall structures (e.g. coastal erosion, accretion, littoral drift). The following guidelines are recommended: • Trenching and dredging operations will lead to seabed destruction, debris disturbance of aquatic and marine habitats. Work to minimize destruction to seabed should avoid alignment through hard strata which would require blasting and tunneling. • The potential siltation of the outfall trench and the risk and effect of burying the diffusers should be predicted and incorporated in the environmental plans for mitigation purposes. • If land reclamation is carried out, ensure maximum length of seawall is in place prior to operations to minimize the consequences of sedimentation and turbidity. Use of sediment curtains to prevent drift of fill outside reclamation area is recommended. • Identify the reach of the coastal area affected by the project, and the significant physical coastal processes at work within and beyond this reach. Physical coastal systems include currents, tides, wind and waves, coastal erosion and accretion, illuviation and alluviation. • Use the DID's criteria and classification for coastal erosion as a guide.	National Coastal Erosion Study (1985)

No 19	Water Supply

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** Guidelines relating to construction of dams and/or reservoirs should be referred to because they also relate to drainage, irrigation and water supply. The construction of dams normally involves cutting and filling which inevitably produces high sediment yields which in turn adversely affect surface water quality by increasing turbidity and nutrient levels. Pertinent guidelines for control of erosion and sedimentation include: • The goal for dam construction to strive for zero sediment discharge to surface water, achieved by designs which balance cut and fill (e.g. minimum cut to waste) and construction methods which incorporate slope protection, fill compaction, sediment control structures and buffer zones adjacent to watercourses. DOE normally require project proponents to limit sediment discharges to 50 mg/l suspended solids as a condition of EIA approval. • It is essential that dam projects be planned and managed in the context of overall river basin and regional development plans, including both the upland catchment areas above the dam and floodplain and watershed areas downstream. In practice, watershed protection requires watershed gazettal before any form of control can be implemented. • Access roads to intakes, control structures and particularly to pipeline should have appropriate erosion control measures. • Sludges from water treatment must be controlled and appropriately disposed of.	Environmental Impact Assessment Guidelines for Groundwater and/ for Surface Water Supply Projects (DOE, 1995) Environmental Impact Assessment Guidelines for Dams and/ or Reservoirs Projects (DOE, 1995)
3.	**Land Clearing Measures** • Catchment area protection regulations must be identified and adhered to. • Development should proceed according to phases. • Special attention should be given to erosion risk during excavations for pipeline corridor and related infrastructure.	

No 20	Land Conversion for Golf Course

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Golf course design should take advantage of the natural topography thus minimizing the need for earthworks and cut and fill slopes.	Environmental Impact Assessment Guidelines for Golf Course Development (DOE, 1994)
3.	**Land Clearing Measures** • Land should be cleared and developed in progressive stages. • Vegetation buffer strips should be retained along watercourses for erosion control, water quality amelioration, wildlife corridors and sanctuaries and for aesthetic reasons. • During the land clearance of vegetation and shaping of the golf course, silt and sediments are moved around causing very high sediment yields in the river systems. It is recommended that a good system of temporary drainage be laid during these stages to channel runoff laden with sediments to silt traps and sediment ponds. • Precautions should be taken to minimize the quantities of fertilizers entering drainage systems.	

No 21	Hill Slope Development

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• For extensive developments soil and geological surveys should be undertaken.	All relevant DID Hydrological Procedures should be used.
	• The development of slopes with high potential for landslides should be avoided.	Guidelines on Logging Practices for the Hill Forest of Peninsular Malaysia, 1994
	• All cut and fill slopes should be stabilized immediately after construction by means of appropriate drainage and vegetative cover.	
	• Road construction should be kept to a minimum.	
3.	**Land Clearing Measures**	
	• Logs should be removed in such a manner as to reduce erosion.	
	• Only relatively small areas should be cleared at any one time.	
	• Clearing should be scheduled to avoid likely periods of heavy rainfall.	
	• Buffer strips should be left along all waterways.	
	• All stream crossings should be protected.	
	• Steep slopes should be monitored regularly for any signs of erosion or mass movement and remedial measures implemented immediately if required.	

No 22	Development of Ecologically Sensitive Areas

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • It is essential that detailed flora, fauna and habitat surveys be undertaken at the outset to identify ecologically sensitive sites and areas and to identify any rare, vulnerable, endangered and protected plant and animal species. • Development plans must be designed to protect significant sites and species.	All relevant DID Hydrological Procedures should be used. Guidelines on Logging Practices for the Hill Forest of Peninsular Malaysia, 1994 DID Guidelines on the protection of watercourses and limits of buffer zones
3.	**Land Clearing Measures** • Vegetated buffer strips should be left along all watercourses and islands of vegetation should be left to provide wildlife sanctuaries. • Care should be taken to protect significant trees and other vegetation during the construction phase.	

No 23	Landfills

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• There are generally two main types of landfills, namely, sanitary landfills and unlined landfills. The former is nowadays used for domestic wastes and the guidelines are similar to No. 18 - Waste Disposal and Sewerage.	Environmental Impact Assessment Guidelines for Drainage and Irrigation Projects (DOE, 1995) can be used.
	• The latter is similar to land reclamation where depression areas are filled for development purposes such as for housing and other types of landuse.	DID guidelines on the protection of watercourses and limits of buffer zones
	• The control measures during filling of these depression areas will involve transportation of rock and earth materials to the site and this will churn up a lot of dust in the air and sediments in the rivers. Care should be taken when transporting the materials to the site.	Town and Country Planning guidelines for urban and rural enhancement and beautification
	• A bund should be constructed if the area to be filled is near to the river courses.	
	• Any vegetation near the fringes of the depression area should be left alone to act as a buffer to control erosion.	
	• If the depression area is filled with water, it should be slowly drained out into the water course by pumping near to the water surface. This will reduce the amounts of sediments being discharged into the rivers.	
	• The filled area should be vegetated as soon as possible to minimize dust and surface erosion.	

No 24	Development of Former Mining Lands

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • In Malaysia, there are extensive areas which were formerly mined but now abandoned and which have yet to be rehabilitated. These include lands formerly under tin, iron, gold and coal. Rehabilitation of these areas involves special management depending on the mining activities formerly carried out in the area. Environmental measures range from site remediation, chemical waste treatment to removal of all disused machinery. • In terms of erosion and sediment control, revegetation is one of the most important rehabilitation measures since most of the mined areas are often devoid of vegetation and could contribute large amounts of silt and sediment in the rivers. • In abandoned tin mines, the tailings are often unconsolidated and revegetation would be effective in controlling surface wash into the rivers. • Some types of tailings which involve chemical wastes should be removed to approved landfill sites to reduce contaminated runoff.	DID guidelines on the protection of watercourses and limits of buffer zones

No 25	Cattle Ranching

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines** • Cattle ranching is becoming an important landuse in the country. Large cattle ranching often involves large tracks of land being trampled by the cattle during grazing and roaming. Thus, although there is compaction of the soil, there is also degradation of the area through loss of vegetation covers with the bare areas contributing large amounts of sediments into the rivers. Measures should therefore be taken to ensure that there is a rotation of fields for the cattle to graze and leaving some of the degraded fields for furlough and the vegetation to recover. In addition, trees within the area should be retained for soil protection. • Cattle should not be allowed uninterrupted access to watercourses because they degrade the banks resulting in increased stream sediment loads. • All trampled muddy areas should be covered with grass or hay to reduce surface runoff and erosion during the wet seasons.	DID guidelines on the protection of watercourses and limits of buffer zones

No 26	Land Devastated by Forest Fire

No	Guidelines	Source
1.	**Generic Guidelines**	Refer to Guidelines in Table 4.2.2
2.	**Planning Guidelines**	
	• Forest fires are becoming very common during the dry seasons and large tracks of land are devoid of vegetation after the fire. The first rains after a forest fire will result in a considerable amount of debris and sediments in the rivers due to the friable nature of the topsoil after being subjected to the intense heat of the fire. Subsequent rains will result in more erosion and sediments because of the area being devoid of vegetation. Thus, bare areas and areas with sparse vegetation cover should be revegetated as soon as possible to minimize soil erosion. • Rehabilitation of the area after a forest fire is often difficult especially if the area is large and inaccessible. A very fast revegetation method is to sow legume seeds to cover the bare areas as soon as possible to reduce soil erosion. Aerial sowing is sometimes carried out in large and inaccessible but critical areas such as watershed areas reserved for water supply. • If the land is to be used for development purposes after the forest fire, then the development of the area should follow the appropriate guidelines for erosion and sediment control of the substituted landuse. • All land clearing measures for the new landuse will have to be incorporated into the development plans prior to development of the area. These should include earthworks and drainage controls on- and off-site of the project as outlined in Table 4.2.2.	All relevant guidelines pertaining to agriculture, housing, industries and infrastructure can be referred to if the area is being developed.

5. EROSION AND SEDIMENT PREVENTION AND CONTROL MEASURES

5. EROSION AND SEDIMENT PREVENTION AND CONTROL MEASURES

5.1 Introduction

Every land development site differs in geology, topography, soil types and the activity to be carried out. The best way to control the problems of erosion and sedimentation is to plan and implement control measures even before the start of the project. Measures for the prevention and control of soil erosion and sedimentation generally fall into three main categories: drainage controls - to control the flow of water by spreading and ponding; erosion control - to reduce the quantity of sediments generated; and, sediment control - to reduce the quantity of sediments leaving a construction site. Thus, the control measures in this Chapter are categorized into the above three main categories.

5.2 Choice of Techniques

The list of common control measures are provided below as an easy and quick reference for those faced with the problems of choosing the types of measures most suited to the development site. Each of the control measures has a reference code for retrieval. For example, **5A-5** refers to a photograph and a description of a **Berm Drain** and so on.

The list of control measures are by no means complete as there could be more techniques being developed. The final choice of control measures to be adopted will depend on the sensitivity of the area, terrain and cost.

The list gives the common measures that have been used with some degree of success at land development sites. It has to be reiterated here that the activity of putting in these measures must not in itself cause additional erosion on-site as have been commonly found. For example, the temporary access tracks used by tractors to construct bunds must be rapidly covered up with vegetation to minimize gully formation. Consulting Engineers, Site Supervisors and Environmental Consultants should decide on the most appropriate erosion and sediment control measures to be implemented for a land development site.

Control Measures	Measures	Reference Code
A: **Drainage Control** (Control of runoff from the construction sites).	• Catch Drain & Perimeter Bank • Diversion Channel • Rock Lined Channel • Concrete Lined Channel • Berm Drain • Cascading Drain • Roadside Catch Drain/Table Drain • Temporary Culvert Crossing • Check Dam (Loose-rock Dam) • Gabions • Temporary Diversion Dyke • Temporary Perimeter Dyke • Temporary Interceptor Dyke	• 5A-1 • 5A-2 • 5A-3 • 5A-4 • 5A-5 • 5A-6 • 5A-7 • 5A-8 • 5A-9 • 5A-10 • 5A-11 • 5A-12 • 5A-13
B: **Erosion Control** (Surface protection of exposed soils).	• Mulching • Revegetation (Turfing) • Spot-turfing and CloseTurfing • Fibromatting and Hydroseeding • Terracing/ benching • Cover Crops • Vetiver Grass • Interlocking Concrete Block • Crib Wall • Reinforced ConcreteWall • Reinforced Earth Wall • Reinforced Steel Anchor Wall • Rubble Wall • Rip-rap • Plastic Sheet • Bakau-fencing • Soil-cement Treatment • Sand Bund/Bag • Earth Bund • Geotextiles for Erosion Control • Road Base and Pavement	• 5B-1 • 5B-2 • 5B-3 • 5B-4 • 5B-5 • 5B-6 • 5B-7 • 5B-8 • 5B-9 • 5B-10 • 5B-11 • 5B-12 • 5B-13 • 5B-14 • 5B-15 • 5B-16 • 5B-17 • 5B-18 • 5B-19 • 5B-20 • 5B-21
C: **Sediment Control** (Trapping sediments within the sites).	• Sediment Retention Pond • Sediment Basin • Filter Dam and Sediment Weir • Sump • Sump Pit • Vegetative Buffer Strip • Shake-down Area	• 5C-1 • 5C-2 • 5C-3 • 5C-4 • 5C-5 • 5C-6 • 5C-7

DRAINAGE CONTROL MEASURES

5A-1	CATCH DRAIN and PERIMETER BANK

Description

- Catch drains, serving as temporary and permanent stormwater drainage, are usually excavated with a grader blade with the depth and width depending on the conditions of the development site. Excavated material is usually placed on the downstream side of the drain.
- A perimeter bank is a compacted ridge of soil with an upslope channel used to intercept and divert the flow of water. Perimeter banks should have a minimum height of compacted material.
- Bank slopes should not exceed 2(H):1(V).
- Usually significantly smaller than diversion channels.

Application/ Function

- Can be used to divert flow around disturbed areas or used within disturbed areas to direct contaminated flow to a sediment trap.
- Around stockpiles, perimeter banks are used to divert up-grade flow around the stockpile and to direct stormwater runoff from the stockpile to a suitable sediment trap.
- Catch drains at the base of partially completed landfill or cut slope are to carry sediment-laden flows to sediment traps.
- Usually do not require any formal design.
- Flow velocity is usually small enough to avoid special channel linings. However, concrete catch drains are used as permanent storm drains.
- Can cause sediment problems and flow concentration if over-topped during a heavy rain.
- Can restrict movement of equipment around the site and access to stockpiles.

5A-2	DIVERSION CHANNEL

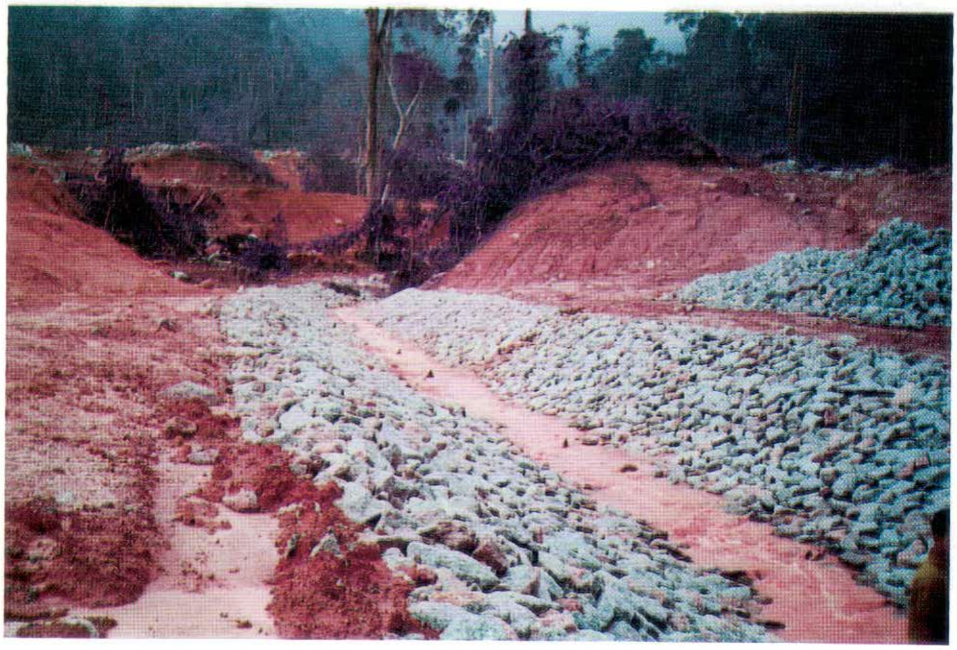
Description

- Formally designed temporary or permanent excavated channels often incorporating a diversion bank to intercept and divert large volumes of water.
- For large flows a bank of less than 2(H):1(V) is recommended.
- Typically used on catchment areas exceeding 1 to 2 ha.
- On larger catchments, the cost savings resulting from diversion of uncontaminated flow and the resulting reduction in erosion can be significant.

Application/ Function

- Used when the catchment area is large where the use of catch drains or perimeter banks would not likely be feasible.
- Normally constructed at the base of cut or fill slopes to direct sediment-laden flows to sediment traps.
- Can limit trafficable access to the site.
- Channels may be subject to erosive flows and thus require an expensive channel lining.
- Outlet flow is concentrated and may require energy dissipation and/or flow spreader.

5A-3	ROCK LINED CHANNEL

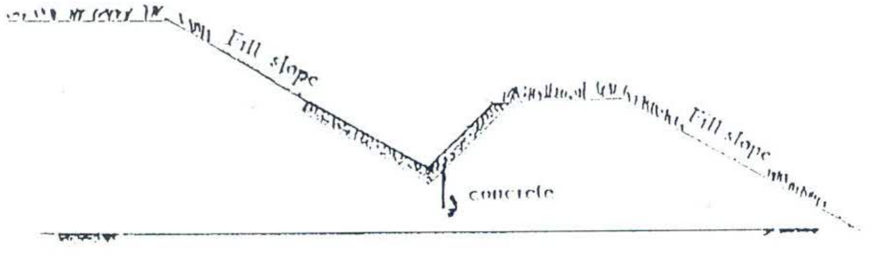


Description	Application/ Function
• Sized and graded rocks are placed along the bed and banks of a diversion channel, channel bend or spillways. • Rocks are generally placed over a geotextile or rock filter layer. • Rock lining of drains and channels is one of the simplest kinds of surface treatment. • It is particularly useful in critical sections of a channel such as bends and stormwater outlets. • One of the most common and inexpensive channel lining materials.	• The porous nature of riprap protects the channel from uplift or flotation concerns. • Does not require a well formed channel cross. • Problems of infestation by rodents and unsightly weeds. • Undersized rocks can migrate downstream and cause further erosion as they move along the channel bed during periods of flood. • Often difficult to desilt rock lined channels. • Side slopes of channel should not exceed 2(H):1(V). • Crushed rocks are generally more stable than rounded stones.

5A-4	CONCRETE LINED CHANNEL

Description	Application/ Function
• Concrete wall lined along the banks of a river or diversion channel. • Usually incorporated with culverts to drain water from nearby drains . • Typically used on bigger catchment areas exceeding 10 ha.	• Used when the catchment area is too large for the use of catch drains or perimeter banks. • Usually constructed in urban areas for diversion of concentrated outlet flow, especially during heavy rainfall.

5A-5	BERM DRAIN

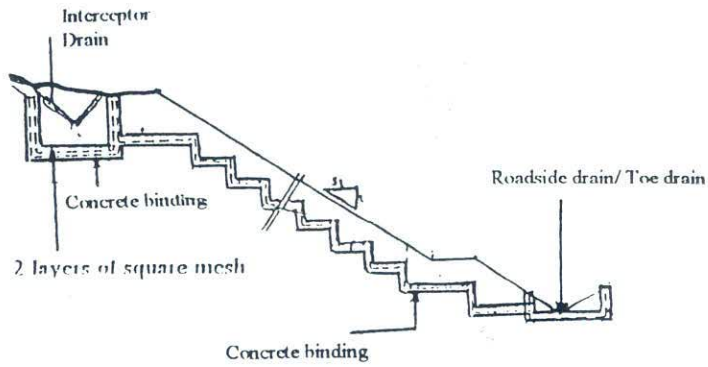


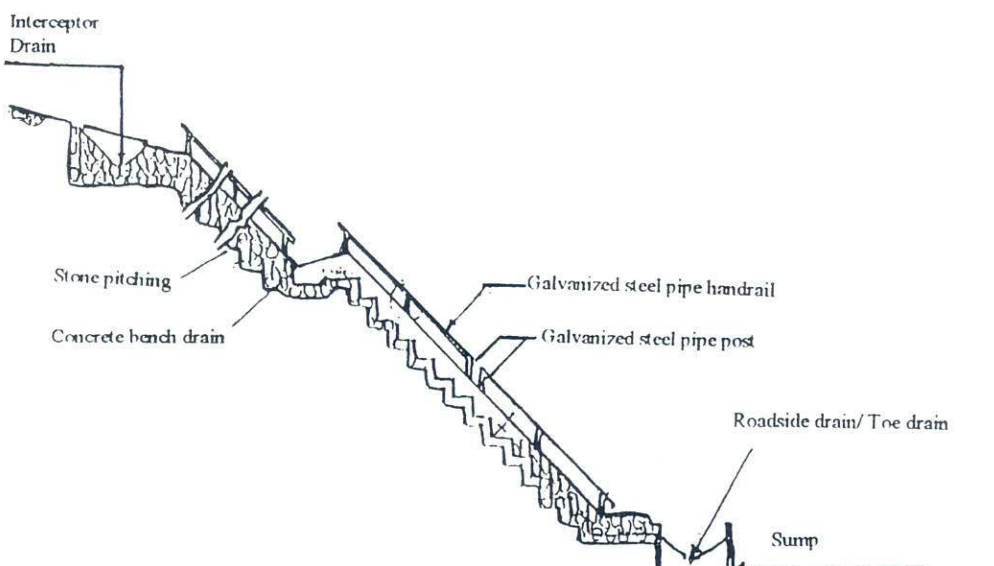
BERM DRAIN TYPE 1(BF 1)
CAST IN-SITU V DRAIN

Source: JKR, 1989

Description	Application/ Function
• These are horizontal concrete catch drains laid on the berms/terraces of steep hill slopes to channel flow collected from the slope surfaces to cascading drains down the slope and subsequently to catch drains at the base. • Berm drains are normally V-shaped.	• Catch drains across slopes (berm drains) are constructed to reduce slope length and to subdivide a partially completed area into manageable units. Berm drains are then channelled to cascading drains down the slope to base catch drains.

5A-6	CASCADING DRAIN





Source: JKR, 1989

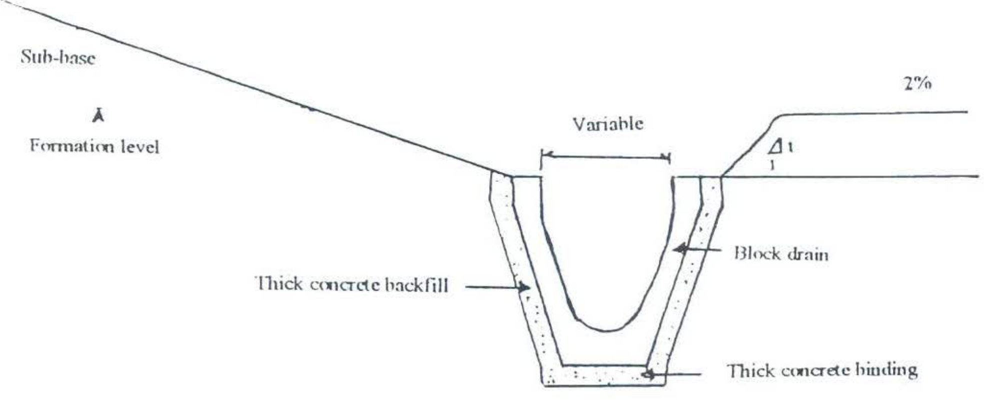
Description

- These are concrete stepped catch drains laid on the steep terraced slopes to guide flows from the berm drains down to catch drains at the base.

Application/ Function

- Cascading drains are effective in channeling concentrated flow down slopes thereby contributing to slope stability.
- For low slopes, cascading drains can be constructed directly down the slope.
- For medium to steep slopes, drains are recommended to follow the gradual terrain contours of the slopes.

5A-7	ROADSIDE CATCH DRAIN/TABLE DRAIN



ROADSIDE DRAIN TYPE 3 (RSD3)
PRECAST CONCRETE BLOCK DRAIN

Source: JKR, 1989

Description

- Formally designed permanent concrete catch drains at the base of slopes near road sides for channeling of storm runoffs to sumps/sediment traps.

Application/Function

- A drain running along the side of a road or track to collect runoff from the road/track surface.
- At the base of cut or fill slopes to direct sediment-laden flows to sediment traps.
- To prevent silt from overflowing to road surfaces, the bare earth strip between the drain and the road must be turfed to serve as a buffer strip.
- Low maintenance requirements.

5A-8	TEMPORARY CULVERT CROSSING

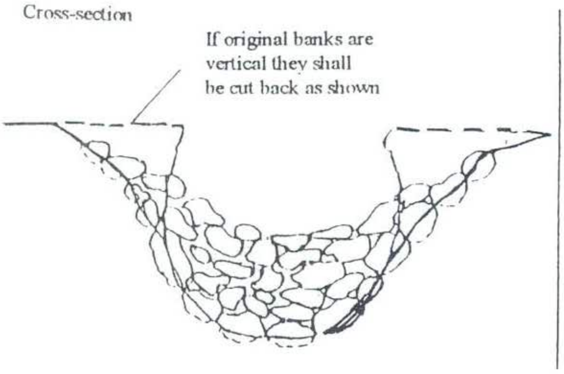
Description

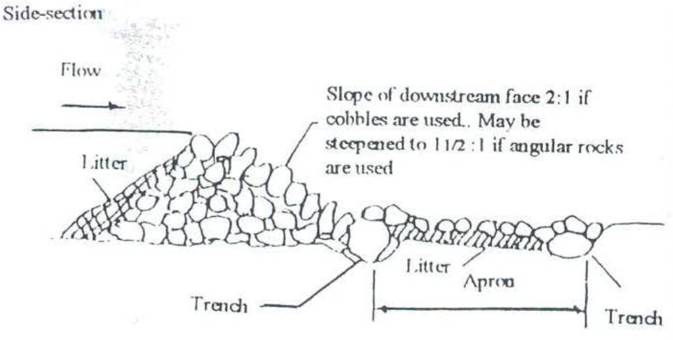
- A drain constructed across and below an accessway to intercept and divert runoff.
- A temporary access culvert may consist of one or more sections of pipes placed over filter cloth and covered with a suitably graded aggregate layer.
- Suitable for use in streams with deep cross sections.
- If the watercourse bed is solid, box culverts may be used.

Application/ Function

- A covered channel (usually a concrete pipe) used to carry water under the ground surface.
- Temporary culverts provide safe access for construction equipment with minimal disturbance to the watercourse.
- When the crossing is no longer needed, all materials including pipes, aggregate and filter cloth should be removed.
- Final clean up also includes restoration of the watercourse to the original channel cross section and stabilization of the bank.

5A-9	CHECK DAM (LOOSE - ROCK DAM)





Source: Morgan, 1986

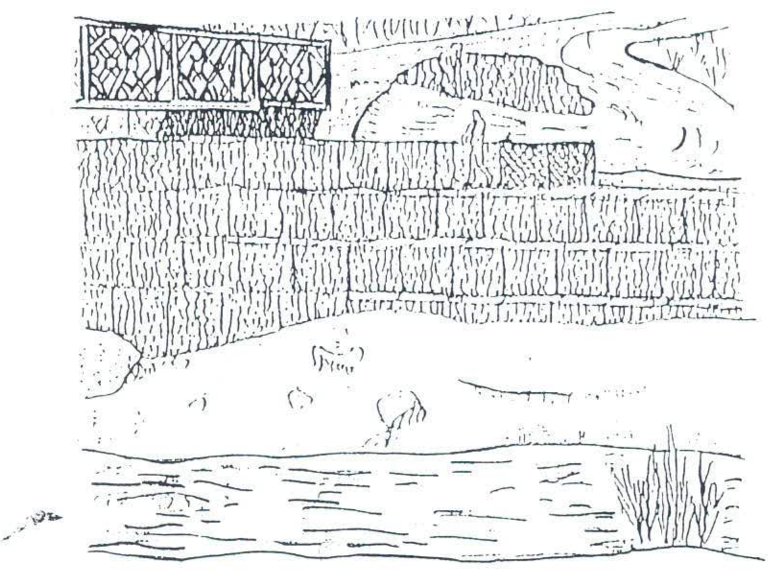
Description

- Check (Loose rock) dams are small dams, constructed from either semipervious or impervious materials including timber, rock, concrete, sheet piling, or sandbags, are built across gullies to trap sediment.
- Such dam should be limited in height to around 0.5 to 2.0 m.
- Construction begins by sloping back the tops of. the banks. A trench is then dug across the floor of the gully and into the banks into which large rocks are placed to form the toe of the structure.
- The catchment area is often limited to a few hectares.

Application/ Function

- To control minor gully erosion and serve as a simple silt trap.
- To control flow velocity in drainage channels, especially during the early stages of land development.
- Coarse aggregate wrapped in geotextile may be used for entrapment of sediment.
- Dams made of permeable materials will allow flow to pass through the structure and thus can be free draining.
- Care should be taken in their use since the check dams may cause downstream erosion if poorly designed or maintained, or if subjected to high flows.
- Should be located in straight sections of a watercourse or drain.

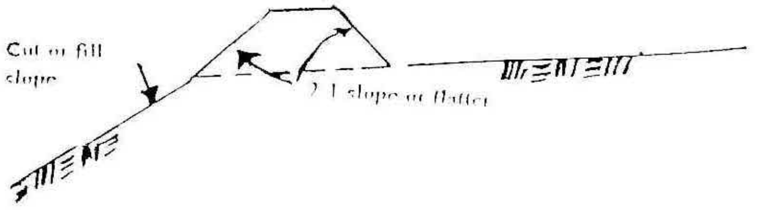
5A-10	GABION

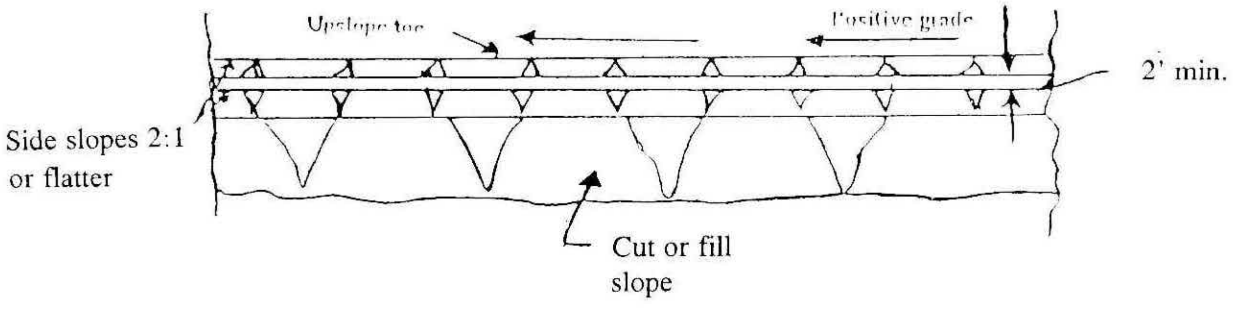


Source: Guidelines for Stabilizing Waterways, 1991

Description	Application/Function
• Rocks arranged in an interlocking manner in a rectangular box made from steel mesh. Gabions are assembled into many shapes (basic unit is 1m x 1m x 1m) for use as hydraulic structures to prevent slope failure in sloped areas undergoing land development.	• Used in erosion control structures. • Sometimes used to protect stream banks. • Low cost and easy construction. • Wire susceptible to breakage during maintenance. • Silt and organic matter can be trapped in the mesh.

5A-11	TEMPORARY DIVERSION DYKE





Source: Guidelines for Prevention and Control of Soil Erosion and Siltation, 1992.

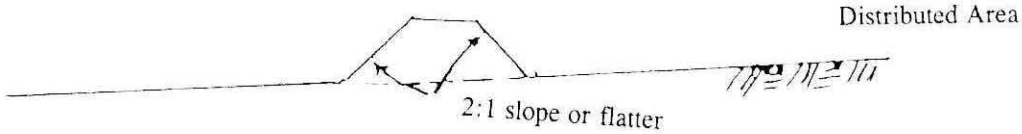
Description

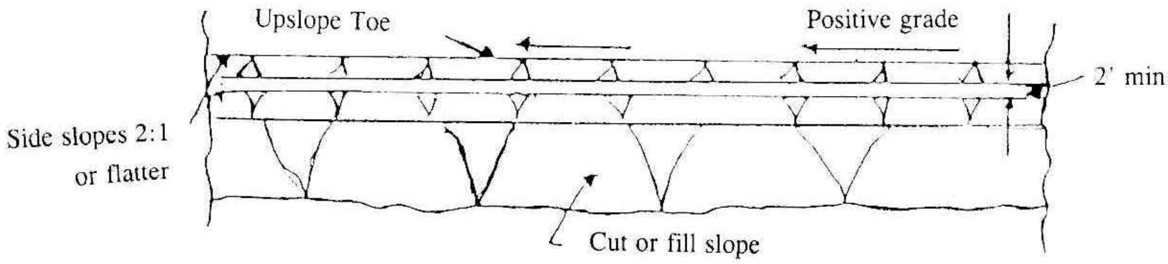
- A trapezoidal ridge of compacted soil with a general life expectancy of 1 year or less constructed immediately above cut or fill slopes.
- All dykes must be machine compacted.
- It is dependent upon topography, but must have positive drainage to the outlet.
- Diversion dykes must be seeded and mulched immediately after construction.

Application/Function

- To intercept storm runoff from small higher areas and to divert it away from exposed slopes to a stabilized outlet.
- Drainage areas must be small and preferably no larger than 3 to 4 ha..
- Diverted runoff must outlet directly onto an undisturbed stabilized area.

5A-12	TEMPORARY PERIMETER DYKE





Source: Guidelines for Prevention and Control of Soil Erosion and Siltation, 1992

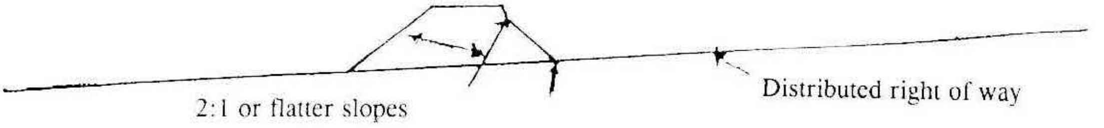
Description

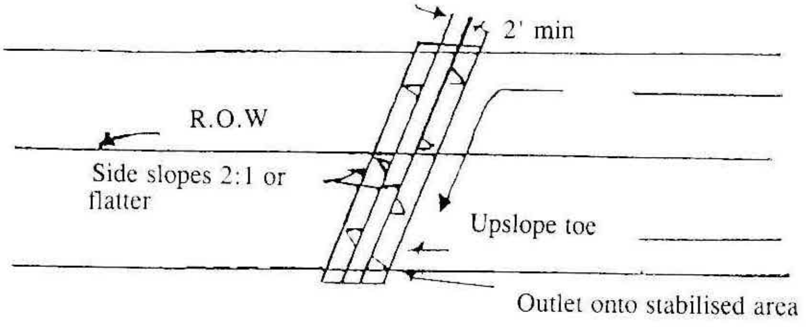
- A temporary perimeter dyke, which is a ridge of compacted soil, with a life expectancy of 1 year or less, constructed along the perimeter of the disturbed area.
- A formal design is not necessary.
- Dependent upon topography, but must have positive drainage to the outlet.
- Dykes must be seeded and mulched immediately after construction.

Application/ Function

- To divert sediment-laden storm runoff to on-site silt trap facilities.
- The dyke shall remain in place until the site is permanently stabilized.
- It may function as an elongated sediment dam. However, the capacity behind the dyke must be checked to assume good trap efficiency.
- The drainage area must be small and preferably no larger than 3 to 4 ha.

5A-13	TEMPORARY INTERCEPTOR DYKE





Source: Guidelines for Prevention and Control of Soil Erosion and Siltation, 1992

Description	Application/ Function
• A ridge of compacted soil or gravel, with a life expectancy of 1 year or less, constructed across disturbed rights-of-ways on sloping areas. • A formal design is not necessary.	• To shorten the length of exposed slopes, thereby reducing the potential for erosion by intercepting storm runoff and diverting it to stabilized outlets. • Diverted runoff must outlet directly onto an undisturbed stabilized area. • The dyke shall remain in place until the rights-of-ways are permanently stabilized.

EROSION CONTROL MEASURES

5B-1	MULCHING

Description	Application/Function
• Mulching is the use of plant residue, saw dust, straws or other suitable material to cover the soil surface. It provides a high degree of erosion control and improves moisture availability to establishing plants. • Mulch should be spread evenly with a maximum depth of 50 mm, thicker covering (75-100 mm) inhibits germination and can be used to control weed growth. • On steep slopes, mulch is normally kept in place by spraying with a bitumen emulsion, or by covering with a fine netting material. • Mulch should cover 70-75% of the soil surface to give adequate protection against erosion.	• Mulches should be applied on slopes that are steeper than 20% or where soil moisture is likely to be inadequate for successful plant establishment. • Hydroseeding or hydromulching is particularly useful in higher rainfall areas to protect against raindrop impact, restrict moisture loss, increase infiltration rate and minimize temperature fluctuations. • Associated bitumen-based fixers can release phosphorus to receiving waters. • May float away when subject to flooding or concentrated overland flow. • Application rate should be between 30,000-40,000 L/ha.

5B-2	REVEGETATION (TURFING)

Description

- Revegetation, through close turfing or grass sodding, is one of the most effective methods for surface soil erosion control where a rapid establishment of dense grass cover is required.
- In close turfing, clumps of grass are planted nearer to each other.
- In spot turfing, clumps of grass are planted in spots, usually on sites where the gradient is low.
- A 70% ground cover is required to provide satisfactory level of erosion control.
- Exposed steep roadside and land development site slopes can be turfed through hydroseeding.

Application/Function

- Soil surface protection and soil reinforcement.
- Used to protect critical slope areas, such as highway cuttings.
- In some cases, the turf is used to stabilize drainage lines.
- Environmentally sound and long term soil erosion control measure.
- Conflicts can exist between the choice of native and imported exotic grass species.
- The common grass used for spot/close-turfing is carpet grass.

5B-3	SPOT - TURFING and CLOSE - TURFING

Description

- Spot-turfing is a revegetation technique where clumps of grass are planted in spots on a bare earthworked or slope area. The clumps of well grown grass, about 150 mm diameter, are placed about 100 mm apart, compacted and left to grow, with frequent watering.
- Close-turfing is the same as spot-turfing except that the clumps of grass are placed nearer to each other and, in most instances, covering the entire exposed bare area or slope

Application/ Function

- Spot-turfing or close-turfing is an effective method for surface soil erosion control where a rapid establishment of dense grass cover is required.
- These forms of turfing are effective on bare level earthworked or sloped area where the gradient is low.
- A variety of grass types are used, such as *Axonopus compressus.*
- Spot-turfing or close-turfing is a very laborious revegetation technique and limited to use in critical areas. Hydroseeding would be recommended for large and/or sloped areas.

5B-4	FIBROMATTING and HYDROSEEDING

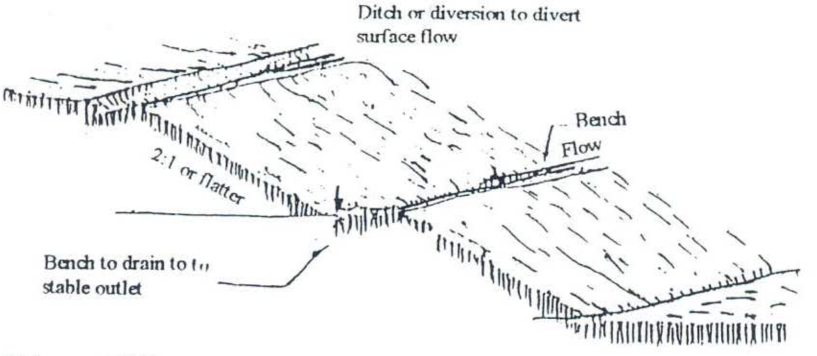
Description

- A fibromat is a large piece or layer of mat made from coconut husk/fibres (coco-matting) or jute for laying on hill slope to prevent soil erosion and to facilitate growth of grass seeds after hydroseeding.
- Hydroseeding involves the mixing of a slurry of selected grass seed varieties, fertiliser, paper or wood pulp (cellulose fibre) and water in a large tank. The slurry is then sprayed over the slope areas to be treated or turfed.

Application/ Function

- Well cut slopes are laid with the fibromat followed by hydroseeding with the selected seed variety.
- The mat provides a conducive medium and anchor for the germination of grass seeds on steep slopes after hydroseeding.
- An effective method for the quick establishment of vegetation or turfing of cut slopes if proper fertilisation and watering regimes are effected.
- The mat protects the seeds from being washed away during rain or from birds.
- With this technique, quite large areas can be treated at relatively low cost, compared to other specialised methods.

5B-5	TERRACING / BENCHING



Source: Morgan and Rickson, 1995

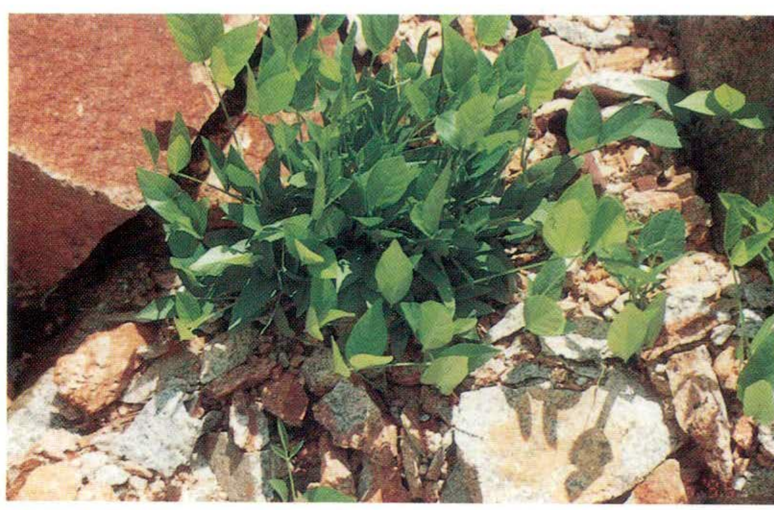
Description

- Slope terracing consists principally in transforming relatively steep land (20-50% slopes) into a series of level or nearly level strips, or steps, running across the slope. The strips are separated by almost vertical risers, which are of rock or earth, and covered by a heavy growth of vegetation.
- Terraces reduce erosion losses by shortening slope length and by conducting water across the slope at non-erosive velocities to protected outlets.

Application/ Function

- The use of bench terraces on steep slopes not only retards erosion losses but it also makes cropping operations on these slopes possible and safe.
- In areas of rubber and oil palm cultivation, terraces are constructed on sloping land to facilitate harvesting and as an erosion control measure. In rubber growing areas, terraces are recommended for slopes in excess of 8%.
- Excavated bench terraces and slopes must be stabilized by the planting of certain grasses or cover crops..
- Berm/cascading drains are effective in channelling runoff from terraced slopes.
- The cost of constructing bench terraces is normally high as heavy machineries have to be used.

5B-6	COVER CROPS



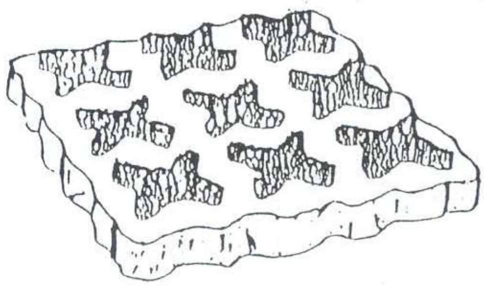
Description
- Cover crops have been extensively used to protect newly cleared land earmarked for planting rubber and oil palm. For the first 4 to 5 years leguminous cover crops are generally used.
- Legumes are preferred because they rapidly colonise bare areas inhibiting runoff and erosion and because they improve the nitrogen status of the soil which aids tree growth.
- After 4 to 5 years, rubber and oil palm trees start to shade out legumes necessitating the introduction of other cover species, such as shade tolerant grass and ferns.

Application/ Function
- Cover crops serve as an effective way of controlling soil erosion.
- The cover crops provide effective surface protection against raindrop impact, bind the underlying soil to resist detachment by surface flows, and improve and maintain the soil infiltration capacity.
- The costs of establishing cover crops is relatively high.
- However, cost associated with remedial erosion and siltation works are minimised.
- The most commonly used legumes are the creepers such as *Pueraria phaseoloides, Centrosema pubescens* and *Colopogonium mucunoides.*

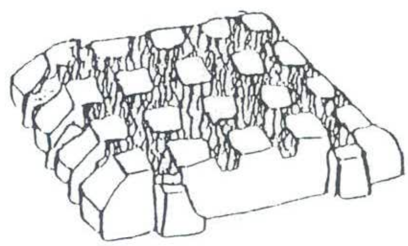
5B-7	VETIVER GRASS

Description	Application/ Function
• Vetiver grass is a coarse, tough bunch grass that grows up to 1 metre wide at its base. It can thrive on a range of soil and that no known pests or pathogens attack it. The grass has a tap-root system i.e. roots growing vertically. The roots hold firmly to soil particles and once established, it is very hard to uproot. It is grown manually.	• A commonly used grass for slope protection and streambank erosion control. • The grass is very hardy and a fast grower. • The grass needs to be cut periodically. • The grass does not reproduce by seeds and has to be replanted using its tillers. • The common variety used in the country is *Vertiveria zizanoides.*

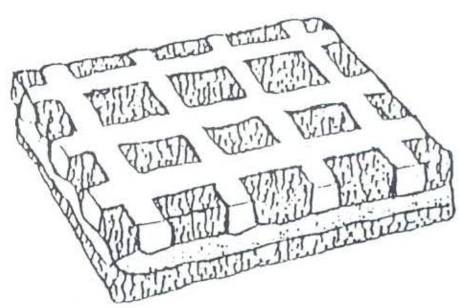
5B-8	INTERLOCKING CONCRETE BLOCK



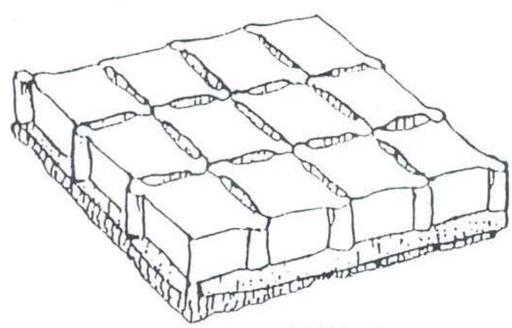
Powered-In-Place Slab



Castellated Unit



Lattice Unit



Modular Unit

Source Best Management Practice Handbook, 1993

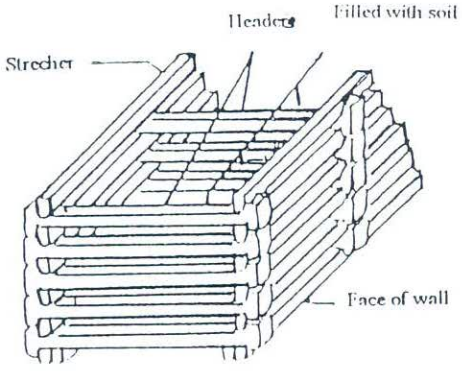
Description

- Geometrically-designed interlocking concrete blocks of various sizes and shapes used for paving roadsides, walkways and beaches prone to wave-based erosion.

Application/ Function

- Beaches which are prone to wave-based erosion can be protected and stabilised by laying such interlocking concrete blocks along the whole length of the beach.
- Aesthetic value of the beach front is further enhanced with proper landscaping of the surrounding area.

5B-9	CRIB WALL



Source: Bowles, 1988

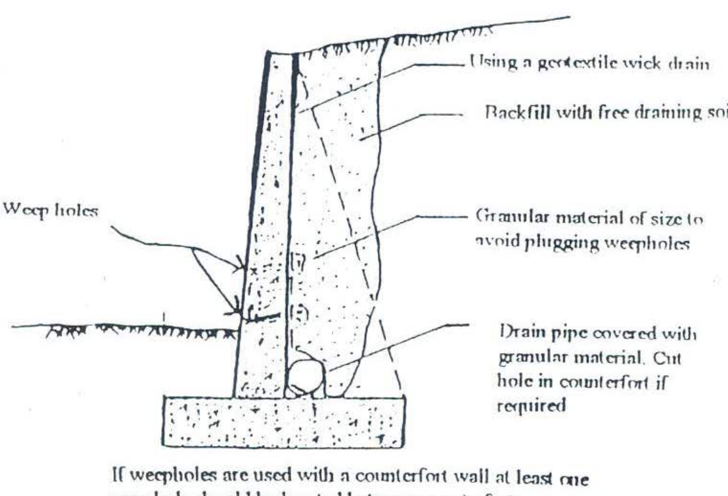
Description

- Blocks of ready-made concrete structures are stacked in an interlocking manner for slope stabilization and protection. A reinforced concrete base is prepared prior to laying of the blocks.
- The interlocking pattern of the blocks provides ample openings between blocks to facilitate drainage of trapped water behind the structure.
- Once the interlocking pattern has been established, stone aggregates and earth are backfilled to provide the structural integrity required for this type of wall structure.

Application/ Function

- A structurally sound wall for steep and high slopes, normally up to a height of about 10 metres.
- The wrong choice of aggregate size could result in such aggregates and backfilled earth materials being pushed out from the structural openings.
- Crib walls are commonly used for slope protection and stabilization in numerous highway and housing projects in the country.

5B-10	REINFORCED CONCRETE WALL



Source: Bowles, 1988

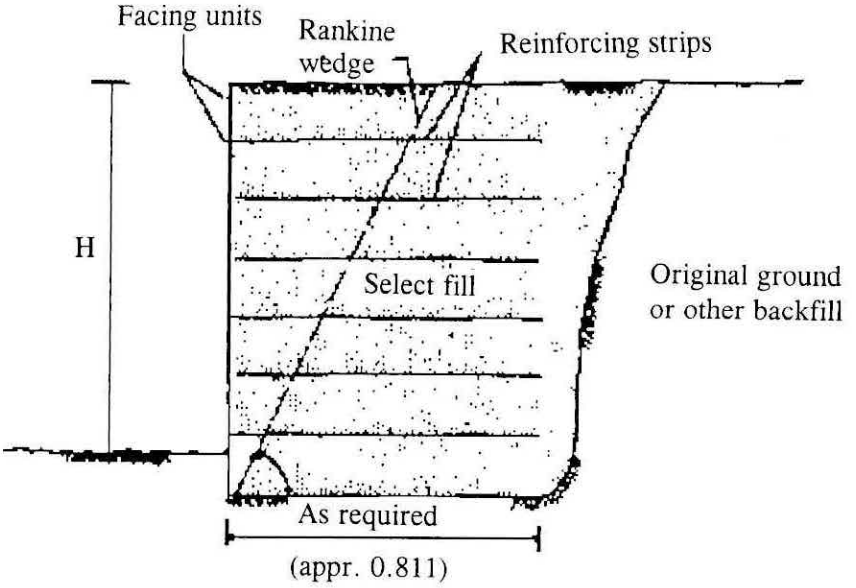
Description

- A type of wall of medium strength.
- Made of concrete and steel grating embedded into the concrete to give better strength.

Application/Function

- For stabilization of steep/vertical slopes.

5B-11	REINFORCED EARTH WALL



Line details of a reinforced earth wall in place

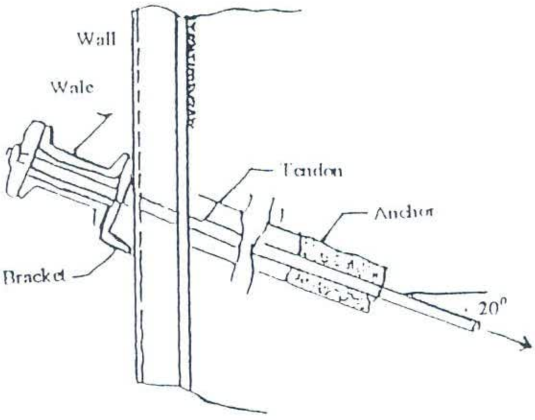
Description

- A type of wall where earth/soil is compacted between two concrete walls.
- The concrete wall is made of interlocking concrete blocks of various shapes and sizes.

Application/Function

- Prior to laying of concrete blocks, a proper foundation is constructed.
- When the concrete blocks are stacked, earth is filled and compacted simultaneously as the wall gets higher.
- A very durable and strong wall.
- Typically found in highway construction projects.

5B-12	REINFORCED STEEL ANCHOR WALL



Description

- A structural wall where steel pins are anchored into steep slope followed by surfacing of the slope surface with concrete.
- Sometimes known as concrete grouting, where small sections of steep slopes are grouted to prevent soil erosion.

Application/ Function

- Usually designed for steep slopes to prevent slope failure.
- Areas above such walls usually have sensitive structures such as electric transmission cable pillars.
- An expensive and complex structural wall.

5B-13 RUBBLE WALL

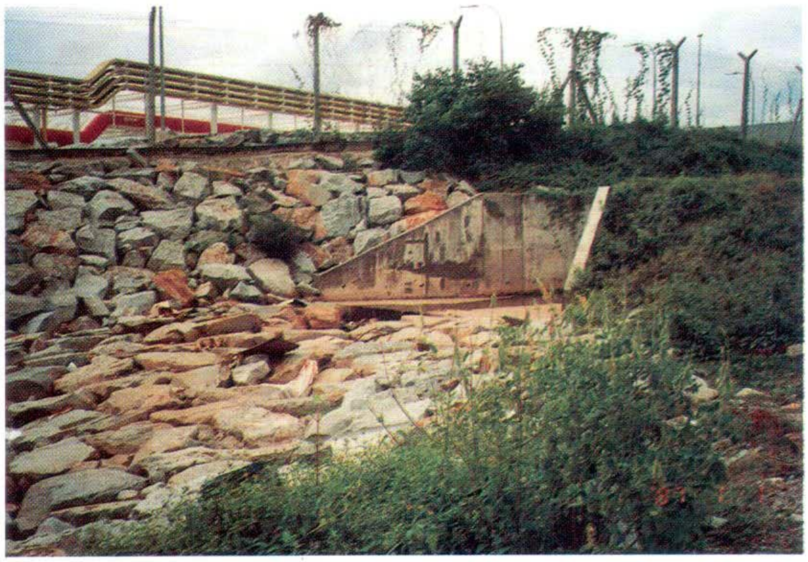
Description

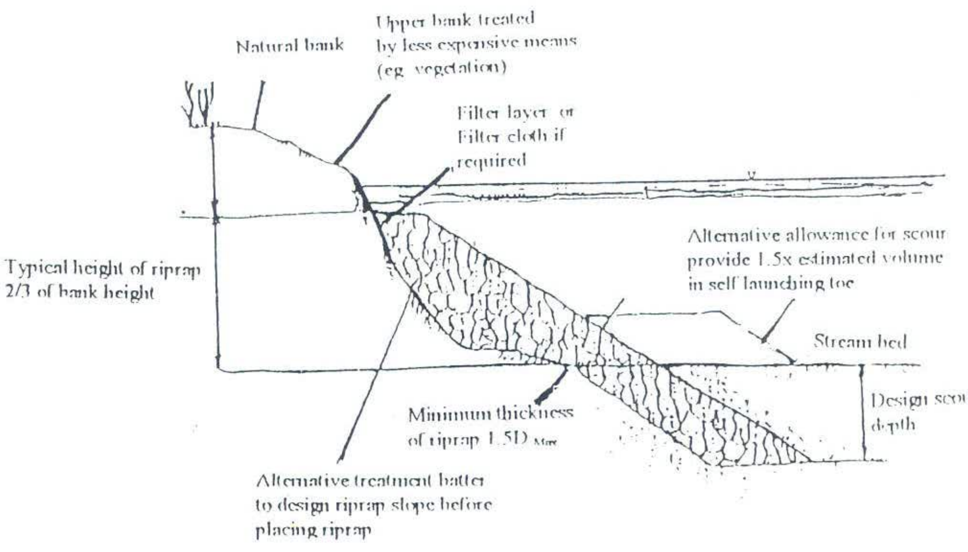
- A medium-strength structural wall for low slopes made of rocks cemented together in a neat orderly pattern.
- Circular pipes are embedded at various points in the wall for release of trapped water behind the wall.

Application/ Function

- Supported on a strong concrete base, such structural walls are effective in low slope stabilisation.
- Unless walls are properly designed and reinforced, failure could result which requires total demolition and reconstruction.

5B-14	RIP - RAP





Description

- Arrangement of rocks of various sizes in an interlocking manner for use as hydraulic structures to protect soil surface and prevent slope failure.

Application/ Function

- An application of such a hydraulic structure relates to the protection of sloped areas near beaches subjected to wave-based erosion.
- Unlike the commercially-produced interlocking concrete block system for protection of low-lying beach fronts, these rip-rap rock structures are used for protection of slopes near beach areas requiring certain structural attributes.

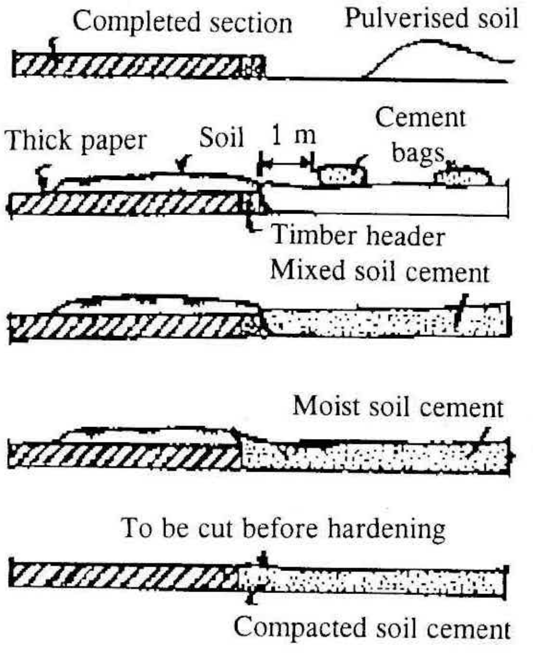
5B-15	PLASTIC SHEET

Description	Application/Function
• A plastic sheet of durable strength and specified thickness is used to cover bare areas. • Limited to small area and only for temporary surface protection. • For better protection, the plastic sheet should be embedded into the top part of the slope or topped with heavy rocks to keep it in place.	• Sheets of plastics are laid on bare slopes as temporary surface protection. • Very effective against raindrop impact. • Low cost, simple to implement. • After the plastic is taken away, the slope should be turfed as a permanent surface protection.

5B-16	BAKAU - FENCING

Description	Application/ Function
• Bakau poles positioned and arranged like a fence along river banks subjected to erosion by running stream.	• To protect/ strengthen river banks from erosion. • Usually used near rivermouth areas subject to seawater intrusion. • Bakau poles are very durable and strong and able to withstand saline water and will not rot easily.

5B-17 SOIL - CEMENT TREATMENT



Timber header to protect completed section during pulverisation

Thick paper to protext completed section before spreading cement

Soil and cement dry mixed, water added and remixed

Timber header removed, paper cut and folded up; mix spread uniformly

New section compacted about 5 cm above the end of completed section and cut offlater

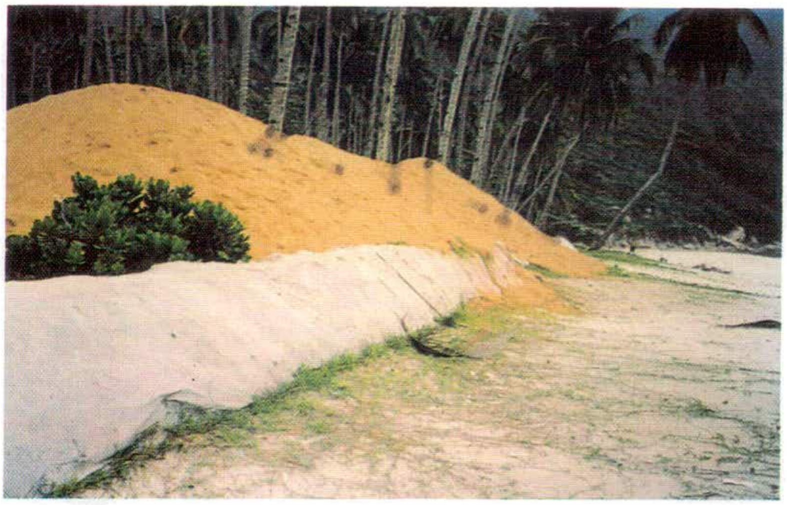
Description

- Soil-cement is a concrete product formed by the mixing of on-site soils with portland cement in-situ. The resulting mixture is a low-slump soil-cement concrete with a low compressive strength, frequently between 4 and 6 Mpa. A typical mixture contains about 6-12% cement and 8-12% moisture by weight.

Application/ Function

- Soil-cement has been used in the construction levees, channel bank protection, drop structures and merits consideration as a substitute for rip-rap protection in areas where rock is not economically available.
- Limited design information available.
- Limited interaction with vegetation.
- Low cost, durability and low permeability.
- Soil-cement linings tend to erode under rapidly changing water depths.

5B-18	SAND BUND / BAG



Description

- Bunds of sand or sand bags for lining areas that are prone to soil erosion and/or floods.
- Bunds of sand are often covered with plastic sheet to avoid the sand itself from being washed away.

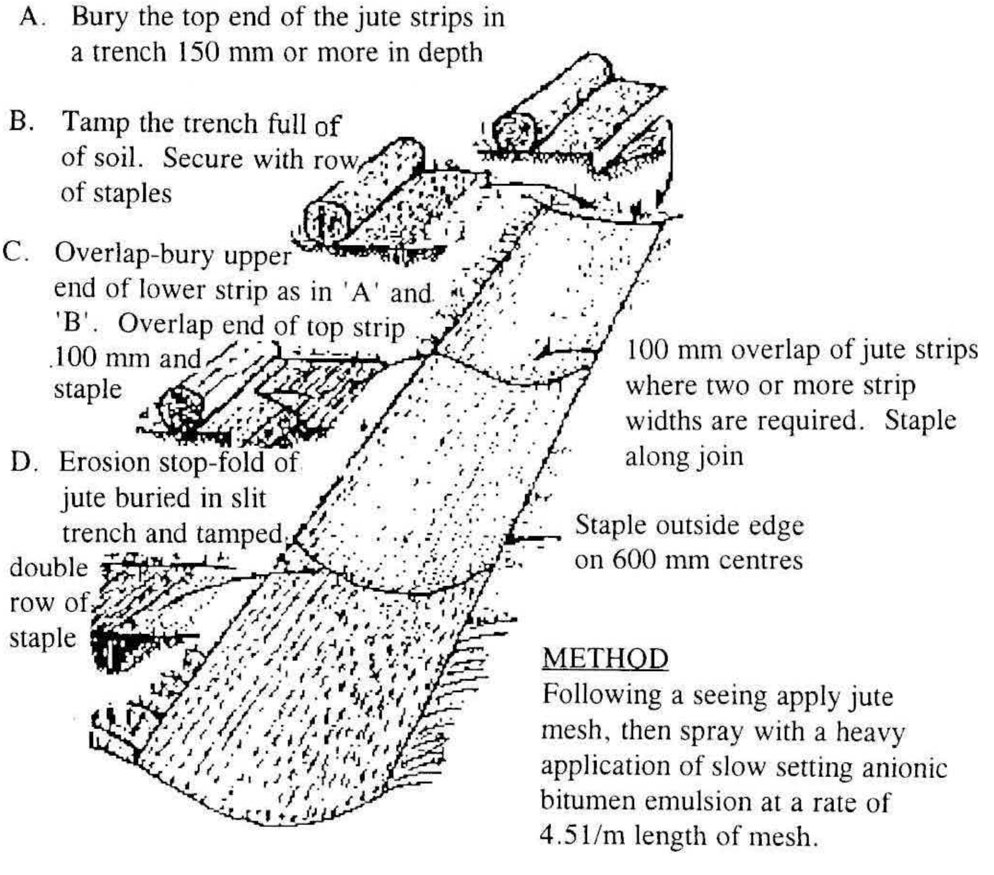
Application/Function

- Serves as a temporary measure to protect soils from being eroded or trap coarser sediment.
- Can also serve as a barrier for flood prevention.
- Plastic sheets on sand bunds can temporarily prevent soil from being washed away.

5B-19	EARTH BUND

Description	Application/Function
• Earth moulded into fence-like structure for soil erosion and/or flood control.	• As a temporary soil erosion and/or flood control measure structure. • Where necessary, earth bunds should be turfed to prevent soil erosion.

5B-20	GEOTEXTILES FOR EROSION CONTROL



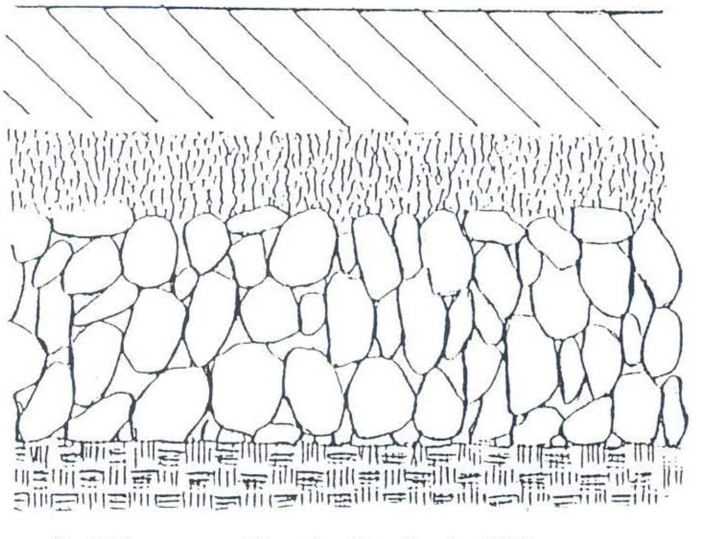
Description

- Several types of geotextiles (geofabric or filter cloth), netting woven from natural fibres such as jute or made from artificial fibres such as nylon, are now manufactured commercially for use in erosion control.
- They are supplied in rolls, unrolled over the hillslope from the top and anchored with large pins or stapled.

Application/Function

- Geotextiles are either surface-laid (slope surface) or buried (channel lining).
- They are designed to give temporary stability on roadsides and on steep slopes until such time as the vegetation cover grows.
- Are used to filter soil from water and prevent soil from being washed from under hydraulic structures.
- Minimal maintenance if properly designed.
- Some fabrics have a very limited life.
- Suitable for low velocity flows.

5B-21	ROAD BASE and PAVEMENT



Source: Best Management Practice Handbook, 1993

Description

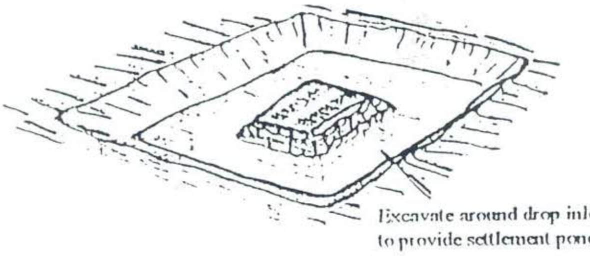
- The preliminary surface protection of tracks is the laying of roadbase consisting of aggregates of specified sizes and gradings.
- The aggregates protect the road surface from raindrop impact while allowing water to flow between them.
- The secondary and more permanent road protection is pavement with aggregates and bitumen.
- Locate tracks and roads in areas of well drained stable soils and minimal slope.
- Appropriate drainage must be included in the intial road design.

Application/Function

- Roadbase is only for temporary surface protection.
- For effective soil erosion control, roadside drainage (table drain) is laid along the lower side of the road to drain away excessive water.
- A grass buffer strip between the road and the table drain is recommended.
- Once the road is paved, it will be impermeable to rainwater, thus minimising erosion.

SEDIMENT CONTROL MEASURES

5C-1	SEDIMENT RETENTION POND



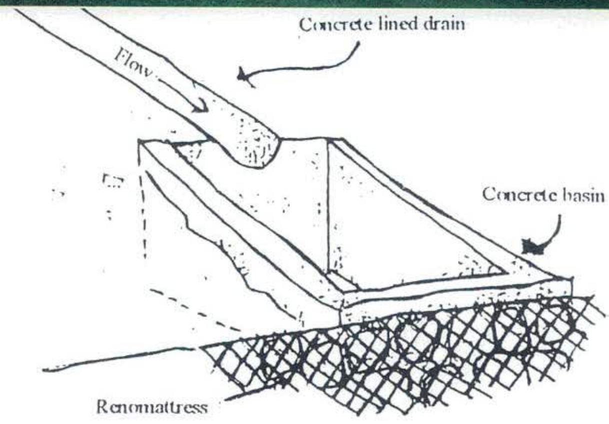
Description

- Sediment retention ponds are usually temporary structures which allow ponding and settlement of sediment-laden water from small land development sites.
- Usually an on-stream excavated pond with controlled flow entry point/s, low-flow filtered outlet and high-flow emergency spillway.
- Generally used in catchments less than 0.5 ha on steep catchments, 1 ha on medium slope catchments and 2 ha on low slope catchments.
- Generally based on a pond size of around 200 m^3/ha of effective drainage catchment; outlets and spillways require a formal design.
- Sediment ponds should be fenced if public safety is at risk.

Application/ Function

- A minimum capacity of 200 m^3 for each hectare of contributing catchment for operations of 2 years or more, or for sites with slopes 10% or greater in angle and/or 200 m in length. Sites less than this may have sediment retention ponds of 100 m^3 minimum capacity for each hectare of contributing catchment.
- Pond operation may incorporate chemical dosing to improve capture of fine sediment particles.
- Sediment basins are located upstream of water bodies and major stormwater systems.
- Very effective for coarse sediment removal.
- Ponds are difficult to relocate if the construction or drainage layout changes.
- Sediment pond and outlet structures should be inspected regularly.
- Sediment should be removed when 50% of the total storage is lost through sediment build-up.

5C-2	SEDIMENT BASIN



Source: Soil Conservation Handbook for Parks and Reserves in NT, 1993

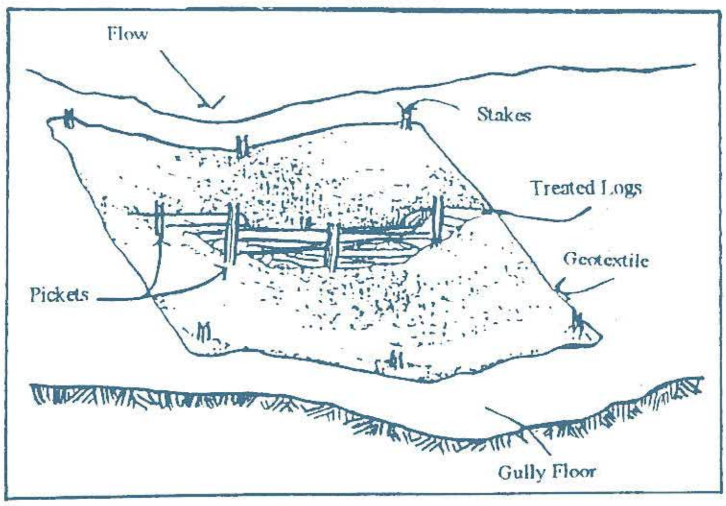
Description

- An excavated basin including controlled flow entry point/s, low flow filtered outlet and high flow emergency spillway.
- Sediment basins require a formal design based on the catchment hydrology, expected sediment transport rate and required level of performance.
- Sediment basins can be permanent or temporary structures which allow ponding and settlement of a significant proportion of the total runoff volume from a land development site.
- Sediment basins should be fenced if settled sediment depths exceed 300 mm at any point in the basin, or otherwise, if public safety is at risk.

Application/ Function

- Basin operation usually involves chemical dosing to improve capture of fine sediment particles.
- Sediment basins are located upstream of water bodies and major stormwater systems.
- Very effective for coarse sediment removal.
- Generally more effective than sediment ponds and other forms of sediment traps.
- Generally used in catchments greater than 1 ha.
- Basins are difficult to relocate if the construction or drainage layout changes.
- Sediment basin and outlet structures should be inspected regularly.
- Sediment should be removed in accordance to the maintainance schedule to remain effective.

5C-3	FILTER DAM and SEDIMENT WEIR



Source: Guidelines for Prevention and Control of Soil Erosion and Siltation, 1992

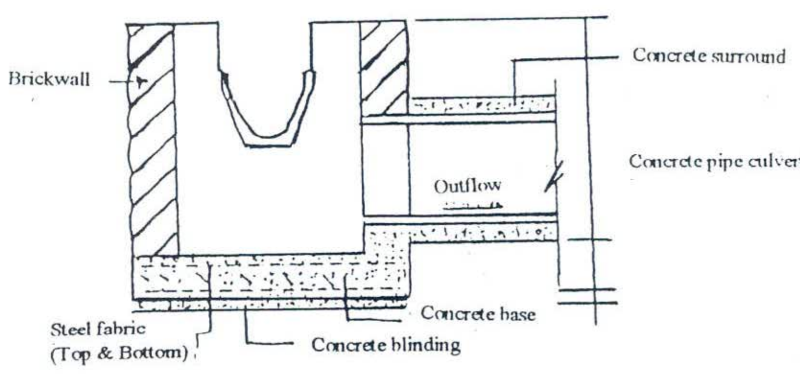
Description

- Filter dams may be constructed of pervious materials such as timber, washed stone or gravel filled bags or gabions. Geotextile filter fabric is normally used.
- Sediment weirs are constructed of steel posts and mesh walls filled with rip-rap.
- Filter dams are placed across minor drainage lines to trap sediment and are generally used to intercept concentrated flow rather than sheet flow. Can perform a similar function to check dams.
- Sediment weirs, however, allow concentrated flow to be filtered through the layers of rip-rap.

Application/Function

- These structures are very effective temporary or permanent sediment traps for perennial streams, and are particularly applicable where work is to be done in the stream itself. However, they have limited control over fine sediment particles.
- Excessive sediment should be removed from upstream of the dam.
- The filter dam should be reestablished when sediment begins to flow through the structure.

5C-4	SUMP



Source: JKR, 1989

Description

- A concrete pit or reservoir serving as a receptacle or as a drain for runoff from berm/ cascading/roadside drains, usually located at the bottom of sloped areas. Water from the sump is then channelled to bigger stormdrains.

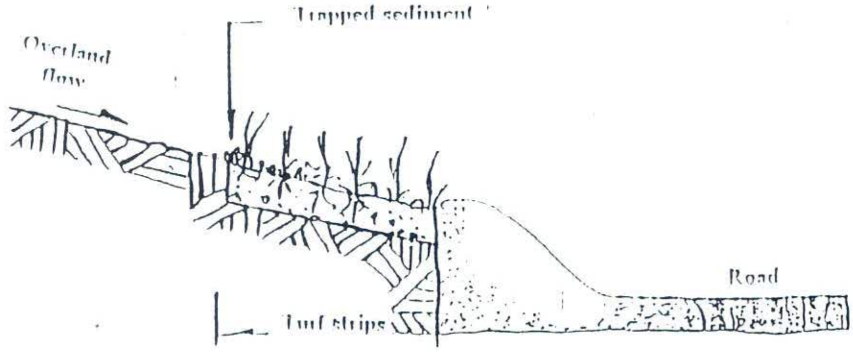
Application/ Function

- Desilting of and removal of vegetative debris from sumps need to be carried out periodically to avoid blockage of flow to stormdrains.

5C-5	SUMP PIT

Description	Application/ Function
• A perforated vertical stand corrugated or PVC pipe is placed in the centre of an excavated pit which is used to collect and filter contaminated runoff. The water is then pumped from the pipe to a suitable discharge point. A geotextile filter cloth and chicken wire may also be wrapped around the stand pipe. Once the stand pipe is installed the surrounding pit should be backfilled with aggregate.	• Sump pits are temporary structures built to trap and filter contaminated water before it is pumped to a suitable discharge point. • Sump pits can be used in areas where contaminated water cannot flow by gravity to sediment ponds. • Can be very effective for small catchments. • If the pit is being used for a long time, desilting may be required. Discharge quality should be monitored. • Requires a pump; not an automatic operation. • Can affect ground water level.

5C-6 VEGETATIVE BUFFER STRIP



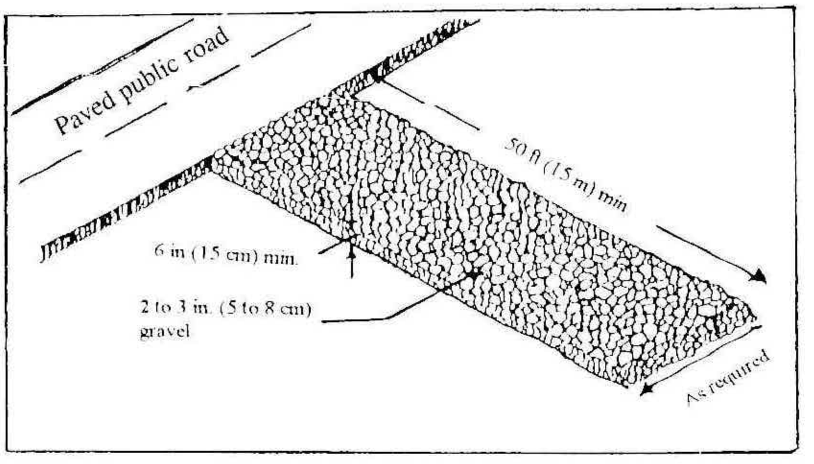
Description

- Buffer strips are corridors of vegetation which separate disturbed land from an adjacent watercourse or protected sensitive areas.
- Buffer strips can be areas of existing natural vegetation or specially prepared grassland. It is noted that the natural vegetation may itself require protection in which case it should not be used as a buffer strip.
- Wetlands, streams and rivers adjacent to land development sites should be protected by vegetated buffer strips whenever possible.
- Buffer strips can reduce the need for other types of erosion and sediment control measures.

Application/ Function

- To control and filter sediment from overland runoff from access roads, stockpiles or land development sites.
- Buffer strip performance increases as buffer width increases or as the buffer slope decreases.
- As a general rule, the width of the buffer strips in metres should be five times the percentage slope (i.e. 50 m buffer width on a 10% slope). Minimum width should be 10 m.
- Buffer strips generally only trap coarse sediments.
- Clay and fine silt particles will generally pass through a buffer strip during periods of heavy rain.
- Alternatives to buffer strips include sediment fences, catch drains and diversion channels directing flow to sediment basins.

5C-7 SHAKE-DOWN AREA



Description

- A temporary construction entrance structure or a stabilized pad located at any point where traffic will be entering or leaving a construction site to or from a public right-of-way, street, lane, footpath or parking area.
- The pad is constructed of coarse and well graded gravel, crushed rocks or cemented.
- The pad length should be at least 20 m or not less than the full width of all vehicular ingress or agress.
- Washed mud from the pad should drain into an approved sediment trap or sediment basin.

Application/ Function

- To reduce or eliminate the transport of mud from the construction area onto public right-of-ways by motor vehicles or by runoff.
- Wheels must be cleaned in the shake-down pad to remove mud prior to entrance onto public right-of ways.
- The entrance shall be maintained in a condition which will prevent tracking or flow of mud onto public right-of-ways.
- All materials spilled, dropped, washed or tracked from vehicles or site onto roadway or into storm drains must be removed immediately.

6. SOME INDICATIVE COSTINGS FOR EROSION AND SEDIMENT CONTROL

6. SOME INDICATIVE COSTINGS FOR EROSION AND SEDIMENT CONTROL

6.1 Introduction

This Chapter presents some indicative costs for: (a) surface protection of exposed soils, (b) control of runoff and (c) sediment trapping measures. These cost rates are only intended to be indicators of the cost to construct and maintain the various control measures. In a free market economy like Malaysia, these rates could fluctuate widely depending on location and supply and demand conditions.

The data were collected from several projects constructed between 1992 to 1996. To ensure confidentiality, the names and project proponents are not disclosed. The costings may not be representative of the industry as a whole as these are case studies. Nevertheless, they provide useful indicators of the range of costs for erosion and sediment control measures in the country.

6.2 Cost Definition and Classification

It is important to define the various cost definitions and classifications that are used in analyzing the various control measures.

Terms	Definitions
Cost	It is the cash or cash equivalent value sacrificed for goods and services that are expected to bring a current or future benefit to the project proponent.
Rate	It is the asking price by contractors for constructing control measures and incorporates both costs and profits.
Opportunity cost	It is the benefit given up or sacrificed when one alternative is chosen over another and is often a critical input for managerial decision-making.
Differential cost	It is the amount by which a cost differs between two alternatives.
Direct costs	These are those costs traceable to a cost object. A *cost object* is any item or activity, such as product, department, or project to which costs are assigned.
Indirect costs	These are those costs that are common to several cost objects.

6.3 Cost Items by Project Phase

Generally, the cost items of the various control measures can be classified according to the stage of construction of these measures. Three major phases of construction have been identified:

(a) preliminary and earthworks phase,
(b) construction phase, and,
(c) operation and maintenance phase.

The cost items vary slightly among the three categories of control measures and within the above three phases of development as shown in Sections 6.3.1, 6.3.2 and 6.3.3.

6.3.1 Cost Items in the Preliminary Phase

The preliminary phase involves mostly earthwork activities such as terracing, leveling, compacting, trenching, trimming and grading (Tables 6.3.1, 6.3.2, and 6.3.3). These are common earthwork activities required in constructing most control measures.

Terracing is commonly constructed on slopes to control erosion. Associated with this are other items such as, close turfing, hydroseeding, and construction of cascading drains and berm drains. On flat terrain, sediment control measures seldom require terracing but turfing and revegetation are often required.

Another cost item is leveling which is required for most drainage and sediment control measures. Leveling is carried out prior to the construction of cascading drains, berm drains, sump, roadside drains, check dam, culverts, gabion, rip rap, interlocking concrete block, roadbase and bitumen coating.

Compacting is also a cost item and is carried out for most erosion control measures with the exception of vetiver grass planting, and laying of plastic sheet. Similarly, it is also required for most drainage and sediment control works except bakau fencing and buffer zones.

Trenching is also sometimes required for some erosion, drainage, and sediment control measures while trimming and grading are essential for non-vegetation erosion control techniques.

Tables 6.3.1, 6.3.2, and 6.3.3 list the preliminary (earthworks) cost items for erosion control, drainage control, and sediment control techniques respectively.

Table 6.3.1: Cost Items for Erosion Control During Preliminary (Earthworks) Phase

Cost Items	Close Turf	Spot Turf	Vetiver Grass	Cover Crop	Hydroseed	Roadbase	Tar/Bituminous Surface	Interlocking Concrete Blocks	Rip-rap	Plastic Sheet	Fibromat
Terracing	/	/	-	-	/	-	-	-	-	-	/
Leveling	-	-	-	-	-	/	/	/	/	-	-
Compacting	/	/	-	/	/	/	/	/	/	-	/
Trenching	-	-	-	-	-	-	-	-	-	-	-
Trimming	-	-	-	-	-	/	/	/	/	-	/
Grading	-	-	-	-	-	/	/	/	/	-	/

Table 6.3.2: Cost Items for Drainage Control During Preliminary (Earthworks) Phase

Cost Items	Terraces	Cascade Drain	Berm Drain	Sump	Roadside Drain	Rocklined Stream Channel	Concrete Stream Channel	Weep Holes	Check Dam	Geosyntetic Lined Channel	Gabions	Temporary Culvert
Terracing	/	/	/	-	-	-	-	-	-	-	-	-
Leveling	/	/	/	/	/	-	-	-	/	-	/	/
Compacting	/	/	/	/	/	/	/	-	/	/	/	/
Trenching	-	/	/	/	/	/	/	-	/	/	-	/
Trimming	/	/	/	/	/	/	/	-	/	/	/	/
Grading	/	/	/	/	/	/	/	-	/	/	/	/

Table 6.3.3: Cost Items for Sediment Control During Preliminary (Earthworks) Phase

Cost Items	Buffer Zones	Filter Dams & Sediment Weir	Sediment Basins	Sediment Ponds	Earth/ Sand Bund	Bakau Fencing
Terracing	-	-	-	-	-	-
Leveling	-	/	/	/	/	-
Compacting	-	/	/	/	/	-
Trenching	-	/	/	/	-	/
Trimming	-	/	/	/	/	-

6.3.2 Cost Items in the Construction Phase

The bulk of the cost items in the construction phase consists of both direct costs of construction materials and direct labour. Depending on the types of control measures used, these construction materials would include among others grass seeds or seedlings, fertilizer, mulch, fibromat, concrete, aggregate, tar/ bitumen, weep-hole pipe, rock, sand, sandbags, gabions, concrete blocks, plastic sheets, bakau poles, wire mesh, culverts, and geosynthetic layers (Tables 6.3.4, 6.3.5, and 6.3.6).

The common direct labour costs incurred during construction phase include seeding, planting, fertilizing, spraying, mulching, concreting, layering, and fibromatting.

6.3.3 Cost Items during Operation and Maintenance Phase

The major cost items during the operation and maintenance phase for all three categories of control measures are pest control, clearing, 'desilting', replanting, repair and maintenance works (Tables 6.3.7, 6.3.8 and 6.3.9). Generally, it can be assumed that the bulk of these costs are maintenance and repairs.

6.3.4 Summary

To summarize, the cost items incurred vary with the project phases. During the preliminary phase, the major costs incurred are earthworks whereas during the construction phase, direct material and direct labour costs form the bulk of the total costs. During the operations phase, maintenance and repairs constitute the major costs.

Table 6.3.4: Cost Items for Erosion Control During Construction Phase

Cost Items	Close Turf	Spot Turf	Vetiver Grass	Cover Crop	Hydrosee d	Roadbas e	Tar/ Bituminous Surface	Interlocking Concrete Blocks	Rip-rap	Plastic Sheet	Fibromatting
Planting	/	/	/	/	-	-	-	-	-	-	-
Fertilizing	/	/	/	/	/	-	-	-	-	-	-
Watering	/	/	/	/	/	-	-	-	-	-	-
Spraying	-	-	-	/	/	-	-	-	-	-	-
Seeds*	-	-	-	/	/	-	-	-	-	-	-
Grass/ Seedlings*	/	/	/	-	-	-	-	-	-	-	-
Fertilizer*	/	/	/	/	/	-	-	-	-	-	-
Mulching	-	-	-	-	/	-	-	-	-	-	-
Mulch*	-	-	-	-	/	-	-	-	-	-	-
Fibromatting	-	-	-	-	/	-	-	-	-	-	*
Fibromat*	-	-	-	-	/	-	-	-	-	-	/
Concreting	-	-	-	-	-	-	-	-	-	-	-
Concrete*	-	-	-	-	-	-	-	-	-	-	-
Aggregates*	-	-	-	-	-	/	/	-	-	-	-
Layering	-	-	-	-	-	/	/	/	/	-	-
Tar/ Bitumen*	-	-	-	-	-	-	/	-	-	-	-
Culverts*	-	-	-	-	-	-	-	-	-	-	-
Rocks*	-	-	-	-	-	-	-	-	/	-	-
Weep hole pipes*	-	-	-	-	-	-	-	-	-	-	-
Sandbags*	-	-	-	-	-	-	-	-	-	-	-
Gabions*	-	-	-	-	-	-	-	-	-	-	-
Concrete blocks*	-	-	-	-	-	-	-	/	-	-	-
Geosyntetic layer*	-	-	-	-	-	-	-	-	-	-	-
Plastic sheet*	-	-	-	-	-	-	-	-	-	/	-
Bakau poles*	-	-	-	-	-	-	-	-	-	-	-
Sand*	-	-	-	-	-	-	-	/	-	-	-
Wire mesh*	-	-	-	-	-	-	-	-	-	-	-

* material item

Table 6.3.5: Cost Items for Drainage Control During Construction Phase

Cost Items	Terrace	Cascade Drain	Berm Drain	Sump	Roadside Drain	Rock Lined Channel	Concrete Stream Channel	Weep Holes	Check Dams	Geosyntetic Lined Channel	Gabions	Temporary Culverts
Planting	-	-	-	-	-	-	-	-	-	-	-	-
Fertilizing	-	-	-	-	-	-	-	-	-	-	-	-
Watering	-	-	-	-	-	-	-	-	-	-	-	-
Spraying	-	-	-	-	-	-	-	-	-	-	-	-
Seeds*	-	-	-	-	-	-	-	-	-	-	-	-
Grass/ Seedlings*	-	-	-	-	-	-	-	-	-	-	-	-
Fertilizer*	-	-	-	-	-	-	-	-	-	-	-	-
Mulching	-	-	-	-	-	-	-	-	-	-	-	-
Mulch*	-	-	-	-	-	-	-	-	-	-	-	-
Fibromatting	-	-	-	-	-	-	-	-	-	-	-	-
Fibromat*	-	-	-	-	-	-	-	-	-	-	-	-
Concreting	-	/	/	/	/	-	/	/	-	-	-	-
Concrete*	-	/	/	/	/	-	/	/	-	-	-	-
Aggregates*	-	/	/	/	/	/	/	-	-	-	-	-
Layering	-	/	/	/	/	/	/	-	/	/	/	-
Tar/ Bitumen*	-	-	-	-	-	-	-	-	-	-	-	-
Culverts*	-	-	-	/	/	-	-	-	-	-	-	/
Rocks*	-	-	-	-	-	/	-	-	/	-	/	-
Weep hole pipes*	-	-	-	-	-	-	-	/	-	-	-	-
Sandbags*	-	-	-	-	-	-	-	-	/	-	-	-
Gabions*	-	-	-	-	-	-	-	-	/	-	*	-
Concrete blocks*	-	-	-	-	-	-	-	-	-	-	-	-
Geosyntetic layer*	-	-	-	-	-	-	-	-	-	/	-	-
Plastic sheet*	-	-	-	-	-	-	-	-	-	-	-	-
Bakau poles*	-	-	-	-	-	-	-	-	-	-	-	-
Sand*	-	/	/	/	/	-	/	-	/	-	-	-
Wire mesh*	-	-	-	-	-	-	-	-	-	-	/	-

* material item

Table 6.3.6: Cost Items for Sediment Control During Construction Phase

Cost Items	Buffer Zones	Filter Dams & Sediment Weir	Sediment Basins	Sediment Pond	Earth/ Sand Bund	Bakau Fencing
Planting	-	-	-	-	-	-
Fertilizing	-	-	-	-	-	-
Watering	-	-	-	-	-	-
Spraying	-	-	-	-	-	-
Seeds*	-	-	-	-	-	-
Grass/ Seedlings*	-	-	-	-	-	-
Fertilizer*	-	-	-	-	-	-
Mulching	-	-	-	-	-	-
Mulch*	-	-	-	-	-	-
Fibromatting	-	-	-	-	-	-
Fibromat*	-	-	-	-	-	-
Concreting	-	-	/	/	-	-
Concrete*	-	-	/	/	-	-
Aggregates*	-	-	/	/	-	-
Layering	-	-	/	/	-	-
Tar/ Bitumen*	-	-	-	-	-	-
Culverts*	-	-	/	/	-	-
Rocks*	-	/	/	/	-	-
Weep hole pipes*	-	-	-	-	-	-
Sandbags*	-	/	/	/	/	-
Gabions*	-	/	/	/	-	-
Concrete blocks*	-	-	-	-	-	-
Geosyntetic layer*	-	/	/	-	-	-
Plastic sheet*	-	-	-	-	/	-
Bakau poles*	-	-	-	-	-	/
Sand*	-	-	/	/	/	-
Wire mesh*	-	-	-	-	-	-

* material item

Table 6.3.7: Cost Items for Erosion Measures During Operation and Maintenance Phase

Cost Items	Close Turf	Spot Turf	Vetiver Grass	Cover Crop	Hydroseed	Roadbase	Tar/ Bituminous Surface	Interlocking Concrete Blocks	Rip-rap	Plastic Sheet	Fibromat
Pest control	/	/	-	/	/	-	-	-	-	-	-
Pesticide*	/	/	-	/	/	-	-	-	-	-	-
Clearing	-	-	-	-	-	-	-	-	-	-	-
Desilting	-	-	-	-	-	-	-	-	-	-	-
Repair work	-	-	-	-	-	/	/	/	/	/	/
Replanting	/	/	/	/	-	-	-	-	-	-	-

Table 6.3.8: Cost Items for Drainage Control During Operation and Maintenance Phase

Cost Items	Terraces	Cascade Drain	Berm Drain	Sump	Roadside Drain	Rocklined Stream Channel	Concrete Stream Channel	Weep Holes	Check Dams	Geosyntetic Lined Channel	Gabions	Temporary Culvert Crossing
Pest control	-	-	-	-	-	-	-	-	-	-	-	-
Pesticide*	-	-	-	-	-	-	-	-	-	-	-	-
Clearing	-	/	/	/	/	/	/	-	-	/	-	-
Desilting	-	-	-	-	-	-	-	-	/	-	-	-
Repair work	/	/	/	/	/	/	/	/	/	/	/	/
Replanting	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.3.9: Cost Items for Sediment Control During Operations and Maintenance Phase

Cost Items	Buffer Zones	Filter Dams & Sediment Weir	Sediment Basins	Sediment Ponds	Earth/ Sand Bund	Bakau Fencing
Pest control	-	-	-	-	-	-
Pesticide*	-	-	-	-	-	-
Clearing	-	-	-	-	-	-
Desilting	-	/	/	/	-	-
Repair work	-	/	/	/	/	/
Replanting	/	-	-	-	-	-

6.4 Cost Classification by Function

The costs involved in the construction of erosion, drainage, and sediment control measures can be subdivided into two functional categories:

(a) construction costs, and,
(b) non-construction costs.

Construction costs are further divided into direct construction costs and indirect construction costs.

6.4.1 Direct Construction Costs

Direct construction costs are those costs that are directly traceable to the control measure being constructed. These costs consist of raw materials and the cost of labour required to convert the raw materials into a finished product (control measure).

(a) **Direct Material**

Raw materials are those materials that actually become part of the product (control measure), and are commonly referred to as direct materials. These materials are directly traceable to the various control techniques. Some examples of direct materials are grass seed, grass and plant seedlings, concrete, rocks, plastic sheet, fibronet, fibromat (coco-mat, geojute), wire mesh, geotextile, steel pin, soil, fertilizer, mulch, pebbles, sand and bitumen.

(b) **Direct Labour**

The cost of labour used to convert raw materials to a finished product is defined as the straight wages paid to those employees who actually combine materials and overheads into the product (straight wages excluding overtime). The labour cost, directly traceable to the finished product (control measure), is usually referred to as direct labour. In the construction of erosion, drainage, and sediment control structures, direct labour consists of excavating, leveling, compacting, laying, terracing of sites, etc. Direct labour activities convert the raw materials into finished product (control measure).

6.4.2 Indirect Construction Costs

All costs, other than direct materials and direct labour that are associated with the construction process are indirect construction costs. As indirect costs are common to all control techniques, they cannot be traced to any one control technique. Indirect construction costs consist of (a) construction overhead, (b) indirect material, and (c) indirect labour.

(a) **Construction Overhead**

Construction overhead is also known as indirect product cost. It consists of a wide variety of items and inputs, other than direct labour and direct material, that are needed to construct the control measures. All construction related indirect costs belong to the construction overhead category. Examples include depreciation on plant and equipment, maintenance, supplies (indirect materials), supervision, material handling and other indirect labour, utilities, and plant security.

(b) **Indirect Material**

Indirect materials are generally those materials necessary for construction that do not become part of the finished product (control measure). Lubricating oil for machinery used in the construction of control measures is an example of an indirect material. The oil is necessary to maintain the machinery but is not directly traceable to any control technique.

(c) **Indirect Labour**

Indirect labour is generally all construction labour other than those workers who actually transform the raw materials into the finished product (control technique). Examples include supervisors, supply clerks, and maintenance workers.

6.4.3 Non-Construction Costs

There are two categories of non-construction costs: (a) marketing costs and (b) administrative costs.

(a) **Marketing Costs**

Marketing costs are those costs necessary to market and distribute a product. Examples of marketing costs include items such as salaries and commission of sales personnel, warehousing, customer service and transportation.

(b) **Administrative Costs**

All costs associated with the general administration of the organization that cannot be reasonably assigned to either marketing or construction are administrative costs. Examples of administrative costs include the salary of executives, legal fee, printing reports and research and development costs.

6.5 Costs and Rates of Erosion Control Measures

As discussed earlier, erosion control measures can be categorized into two broad categories - revegetation and non-revegetation techniques. Revegetation technique consists of spot turfing, close turfing, vetiver grass, hydromulching, fibronetting and planting legume while non-revegetation techniques encompass rip-rap, plastic sheet cover, interlocking concrete blocks, mortar stone pitching, and concrete cut off wall.

6.5.1 Cost Items

The cost items for erosion control consist of four components - direct material, direct labour, construction overheads and marketing & administrative costs (Table 6.5.1).

Although direct labour cost items such as terracing, leveling and trimming are similar for most erosion control measures, the direct material cost items differ considerably. For example, the material cost items for revegetation techniques include grass seeds, grass seedlings, fertilizers, and pesticides while those for non-revegetation techniques are concrete, rock, sand, weep hole, tar, etc.

It should be noted that revegetation and non-revegetation techniques are not mutually exclusive. A combination of both techniques is not uncommon to suit the soil, terrain, or slope conditions. For example, in the case of steep slopes where surface runoff can be severe, revegetation technique alone may not be appropriate because the seeds can be washed off during heavy downpours. In such cases, non-vegetation techniques such as installing interlocking concrete blocks in certain stretches where vegetation technique proved to be inappropriate is needed.

Table 6.5.1: Cost Items for a Typical Erosion Control Measure

A.	**DIRECT MATERIALS** Grass Seed/Seedling Fertilizer Fibromat/Geojute Mulch Bitumen Sand Aggregate Other direct material
B.	**DIRECT LABOUR** Terracing Leveling Trimming Spreading/laying Compacting Planting Hydroseeding Other direct labour
C.	**CONSTRUCTION OVERHEAD** Indirect Labour Depreciation of Plant, Equipment, and Machinery Maintenance Rent Utilities
D.	**MARKETING AND ADMINISTRATIVE** Salaries of Office Executives and Staff Legal Fee Marketing and selling expense Warehousing Transportation Other non-construction expense

6.5.2 Indicative Rates for Revegetation Measures

Table 6.5.2 shows the indicative rates for selected revegetation measures used in a slope stabilization project in Pahang, 1995. As seen in the Table, revegetation techniques done manually such as close turfing, planting of legumes, are more expensive than non-manual techniques. The rates for these techniques average RM$3.50 per m^2. Non-manual control techniques such as hydromulching and hydroseeding cost between RM$1.30 and RM$1.85 per m^2 which are about 50% cheaper than manual methods.

Planting of vetiver grass costs between RM$15.00 to RM$18.00 per m^2 and is the most expensive revegetation measure. This is attributed to the high costs of grass seedlings and labour. The main advantage is that the vetiver grass has deep roots and hold the soil firmly.

The higher rates for the labour intensive manual methods are attributed to rising wage levels. Despite the higher cost, manual method is still used in situations where non-manual methods are inapplicable.

Table 6.5.2: Indicative Range of Cost Rates for Selected Revegetation Erosion Control Measures

Measures	Unit (m^2)	Rate (RM$)
(1) Hydromulching	1	1.30 - 1.45
(2) Hydroseeding	1	1.75 - 1.85
(3) Fibromatting	1	3.00 - 3.50
(4) Planting legumes seeds (manually)	1	3.00 - 4.00
(5) Planting legumes seeds (hydroseeding)	1	2.20 - 2.50
(6) Manual turfing (Cowgrass)	1	3.30 - 3.50
(7) Spot seeding with suitable species	1	1.20 - 1.40
(8) Planting of Vetiver Grass	1	15.00 - 18.00
(9)Supply and laying of fibronet including seeding.	1	3.50 - 4.00
(10) Close turfing	1	1.78 - 2.30
(11) Bituminous prime coating	1	1.00 - 1.50

Source: Resort Project, Pahang, 1995

6.5.2.1 Close Turfing

Among the manual methods, close turfing is popular. As indicated in Table 6.5.3, the rates for close turfing range from RM$1.78 to RM$2.30 per m^2. These costs exclude additional requirements such as erosion netting mesh which may be necessary in some sites with steep slopes. Meshes are placed under the turf and pegged to the soil to stabilize drainage lines. These rates also exclude post planting costs such as fertilizing and watering.

Table 6.5.3: Indicative Rates For Close Turfing

Contractor	Unit	Rate (RM$)	Project	Location
Contractor A	m^2	1.78	Construction of road and Transfer Tunnel, Access Road and Associated Works.	Negeri Sembilan
Contractor B	m^2	2.00		
Contractor C	m^2	2.15		
Contractor D	m^2	2.30		
Contractor E	m^2	1.95		
Contractor F	m^2	2.00		

Source: Transfer Tunnel Project, Negeri Sembilan, 1992

The cost for close turfing varies with location. In Shah Alam, for example, the rates for the six tender price quoted in 1992 vary between RM $3.00 to RM$5.00 per m^2 (Table 6.5.4), which is double that in Negeri Sembilan. For 1996 and subsequent years, this rate could be higher due to inflation and higher demand.

Table 6.5.4: Indicative Rates For Close Turfing Technique (5-Storey Flat Project, Shah Alam), 1995

Technique	unit	Con A (RM$)	Con B (RM$)	Con C (RM$)	Con D (RM$)	Con E (RM$)
Close Turfing	m^2	4.00	3.00	5.00	3.00	5.00

Source: Sepakat Setia Perunding (1995)

6.5.2.2 Spot Turfing

The rate for spot turfing is lower than close turfing. In the river catchment area project in Pahang in 1995, the average rate for spot turfing was RM$1.60 per m^2 which was less than 46% of the cost for close turfing for the same project.

6.5.3 Indicative rates for Non-Revegetation Control Measures

Table 6.5.5 indicates the rates for non-revegetation erosion control measures. It will be inaccurate to compare the rates of these measures because there is no common base for comparison. The unit of measurement may be similar, for example in terms of area, m^2, but the scope or size of the techniques may differ. Unless the specifications are common for all techniques, any comparison will not be meaningful. However, a comparison for the rates quoted by six contractors is indicative of the market rate for each of the techniques (with specified specifications) as listed in Table 6.5.5.

Table 6.5.5: Indicative Rates For Selected Non-Revegetation Erosion Control Measures

Control Measure	Unit	ConN A (RM$)	Con B (RM$)	Con C (RM$)	Con D (RM$)	Con E (RM$)	Con F (RM$)
Rip Rap (300 mm)	m^3	60	54	75	63	50	45
Mortar Stone Pitching (including weep holes)	m^2	90	32	53	35	45	49
Concrete Cut Off Wall (300 x 600) (1)	m^3	200	163	209	200	300	347
Crushed Aggregate Roadbase	m^3	65	45	35	52	53	65
SubBase With Gradation Limits A or B	m^3	25	30	28	52	50	38
Mortar Stone Pitching (2)	m^2	90	32	53	35	45	49

Source: Sepakat Setia Perunding (1992)

Notes:

(1) Concrete cut-off wall 300 x 600 grade 20/40 including excavation, backfilling and disposal of surplus materials. (Malacca, 1992).

(2) 300 mm thick mortar including weep holes.

As shown in Table 6.5.5, the range for the rates quoted is wide. For example, the rates for rip-rap (300 mm) ranged from RM$45 to RM$75 per m^3, mortar stone pitching from RM$32 to RM$90 per m^2, concrete cut off wall (300 mm x 600 mm) from RM$163 to RM$347 per m^3, crushed aggregate roadbase from RM$45 to RM$65 per m^3, and mortar stone pitching from RM$32 to RM$90 per m^2.

6.5.4 Bituminous Prime Coating

The rates for bituminous prime coating and binding are listed in Table 6.5.6. Prime coating spread costs RM$0.70 per m^2 while track coat spread cost was RM$0.40 per m^2 (Table 6.5.6).

Table 6.5.6: Indicative Rates of Bituminous Prime Coating and Binding

Control Measures	Unit (m^2)	Rate (RM$)
Bituminous prime coat spread (1)	1	0.70
Bituminous Track Coat spread (2)	1	0.40
Premix bituminous wearing course (3)	1	7.00
Premix bituminous binder course (4)	1	8.50
Premix bituminous binder course (5)	1	10.00
Premix bituminous wearing course (6)	1	12.60

Source: Project in Malacca, 1992

Notes:

(1) At rate of not less than 0.43 litre/m^2

(2) At rate of 0.25 to 0.55 litre/m^2

(3) Rolled to required chambers and gradients on binder course to carriageway 400 mm thick

(4) 50 mm thick, rolled to required chambers and gradients, on blinded crusher run roadbase to carpark

(5) 60 mm thick, rolled to required chambers and gradients, on blinded crusher run road base to carriage way

(6) 75 mm thick, rolled to required chambers and gradients on blinded crusher run roadbase to driveway

The rates for bituminous prime coating for a project in Negeri Sembilan is slightly higher than for a project in Malacca, varying between RM$1.00 to RM$1.55 per m^2 (Table 6.5.7).

Table 6.5.7: Indicative Rates For Bituminous Prime Coating

Contractor	Unit	Rate (RM $)	Project	Location
Contractor A	m^2	1.50	Construction of Transfer Tunnel, Access Road and Associated Works.	Negeri Sembilan
Contractor B	m^2	1.30		
Contractor C	m^2	1.20		
Contractor D	m^2	1.55		
Contractor E	m^2	1.00		
Contractor F	m^2	1.30		

Source: Project in Negeri Sembilan, 1992

6.5.5 Pavement up to Bituminous Surface

The rates for pavement up to bituminous surface are listed in Table 6.5.8. Excavating, trimming and leveling cost between RM$3.00 to RM$4.20 per m^3. Supplying, spreading, and compacting wet mixed crushed aggregate roadbase cost between RM$25 and RM$65.00 per m^3. Supplying, laying and compacting double bituminous dressing cost between RM$10.50 to RM$ 18.50.

Table 6.5.8: Indicative Rates For Pavement Up To Bituminous Surface

Cost Items	Unit	Con A (RM $)	Con B (RM $)
Excavate, trim and level the existing logger's track to formation level to receive the wet-mixed crushed aggregate roadbase.	m^3	3.00	4.20
Supply, spread and compact wet mixed crushed aggregate roadbase to lines, grades and specified thickness.	m^3	65.00	25.00
Supply, lay and compact double bituminous surface dressing on the prepared roadbase.	m^2	10.50	18.50

Source: Project in Negeri Sembilan, 1992

The above examples show a wide disparity between rates even within a project location and for the same project.

The excavation, trimming and leveling of an existing logger's track involved an area of approximately 12,500 m^3, approximately 2250 m^3 of wet mixed crushed aggregate had to be supplied, spread and compacted, and approximately 14,850 m^2 of double bituminous surface dressing were provided, laid and compacted. Based on the rates quoted, the breakdown of Contractor A's costs were RM$37,500 (excavating, trimming and leveling the existing logger's track), RM$146,250 (supplying, spreading and compacting wet mixed crushed aggregate roadbase) and RM$155,925 (supplying, laying and compacting double bituminous surface dressing). The total cost for Contractor A was RM$339,675.

The cost breakdown for Contractor B were RM$52,500 (excavating, trimming and leveling of existing logger's track to formation level), RM$56,250 (supplying, spreading and compacting wet crushed aggregate roadbase), and RM$274,725 (supplying, laying and compacting double bituminous surface dressing). The total cost for Contractor B was RM$383,475. Contractor B's cost was 12.9% higher than Contractor A's. Contractor B's rates for excavation, trimming and leveling, and supplying, laying and compacting double bituminous surface dressing works were RM$1.20 and RM$8.00 higher respectively than Contractor A's. However, Contractor B's rate for supplying, laying and compacting double bituminous surface dressing was RM$40 less than Contractor A's. There is thus a wide disparity between the two.

As indicated by the rates of the two contractors, the supplying, laying, and compacting of double bituminous surface dressing forms the bulk of the cost, ranging from 45.9% to 71.6%, followed by supplying, spreading and compacting wet mixed crushed aggregate roadbase (14.7% to 43.1%), and excavating, trimming and leveling the existing logger's track (11.1% to 13.7%). As a word of caution, the quantum of cost components vary not only with the rate but also the quantity or length of the component. In this illustration, the quantum of supply, laying and compacting of bituminous surface (14,850 m^2) dressing was substantially larger than the other cost items.

6.5.6 Comparative Rates - Revegetation and Non-Revegetation Techniques

Revegetation techniques are very much cheaper than non-revegetation techniques (Table 6.5.9).

Table 6.5.9: Comparative Rates: Revegetation and Non-Revegetation Measures (1992 prices)

Control Measures	Unit	Rate Per Unit (RM$)			Specifications
		Low	High	Average	
Hydroseeding	m^2	1.85	3.15	2.50	
Spot Turfing	m^2	0.80	1.30	1.05	
Close Turfing	m^2	1.68	2.86	2.07	
Manual Turfing	m^2	3.20	3.80	3.50	cow grass
Rip Rap	m^3	45.00	75.00	57.87	300 mm thick
Geotextile	m^2	2.26	10.00	4.44	Geotextile terram 1000
Bituminous Prime Coat	m^2	0.55	1.50	1.14	
Fibronetting	m^2	3.10	3.90	3.50	
Hydromulching	m^2	1.20	1.70	1.45	
Mortar Stone Pitching	m^2	32.40	90.00	50.75	300 mm including weep holes
Concrete Cut-Off Wall	m^3	79.00	150.0	92.06	300 x 600 mm

The average rate for revegetation techniques ranges from RM$1.20 per m^2 for spot turfing to RM$3.50 per m^2 for manual turfing with cow grass.

One of the most expensive non-vegetation techniques, mortar stone pitching, has an average rate of RM$50.75 per m^2, which is 14.5 times more expensive than manual turfing, the most expensive revegetation technique. Although rip-rap and concrete cut-off wall techniques cannot be compared laterally with revegetation techniques due to different units of measurement, they are more expensive than revegetation techniques.

6.6. Costs and Rates for Drainage Control Measures

Drainage control measures aim to control runoff and include catch drain and perimeter bank, check dam, diversion channel, geosynthetic lined channel, rock lined channel, gabion, temporary culvert crossing, cascade drain, berm drain, roadside drain, and unpaved drain. The cost items of drainage control are shown in Table 6.6.1.

Table 6.6.1: Cost Items for Drainage Control Measures

A.	**DIRECT MATERIALS**
	Concrete
	Rock
	Pre-cast drain
	Weep holes
	Culvert
	Other direct materials
B.	**DIRECT LABOUR**
	Excavation
	Terracing
	Laying
	Leveling
	Trimming
	Disposing
	Other direct labour
C.	**CONSTRUCTION OVERHEAD**
	Indirect labour
	Depreciation of plant, equipment and machinery
	Maintenance
	Rent
	Utilities
D.	**MARKETING AND ADMINISTRATIVE**
	Salaries of office executives and staff
	Legal fees
	Marketing and selling expenses
	Warehousing
	Transportation
	Other non-construction expenses

6.6.1 Comparative Rates for Selected Drainage Control Measures

Table 6.6.2 compares the rates for selected drainage control measures. The rates vary considerably and among the selected measures, cascading drains and grouted stone channel are among the expensive items compared to unpaved drains which are the cheapest.

Table 6.6.2: Comparative Costs of Drains and Grouted Stone Pitching

Control Measures	Unit	Rate Per Unit (RM$)			Specifications
		Low	High	Average	
Berm V-Drain (400 mm)	m	20.00	34.00	27.00	
Roadside Drain	m	40.00	55.00	47.50	
Interceptor Drain (500 mm)	m	60.00	38.00	49.00	
Embankment Toe-drain (450 mm)	m	32.00	67.00	29.50	
Cascade Drain	m	50.00	281.00(*)	165.50	
Unpaved Drain	m	5.00	15.00	10.00	
Grouted Stone Pitching	m^2	8.00	20.00	11.82	50 mm binding concrete grade 15/20.
Grouted Stone Pitching	m^2	32.00	93.60	56.43	225 mm thick grouted stone pitching.

Source: Sepakat Setia Perunding 1992, 1995

* Based on a sample of six projects. The higher value could include labour cost.

6.6.2 Comparative Rates for other Associated Structures

The rates for reinforced concrete sumps or catchpits are listed in Tables 6.6.3. For a concrete sump measuring 900mm and 750mm, the rates ranged from RM$900 to RM$1,500. For a brick wall sump with similar specifications, the rates are marginally cheaper, ranging from RM$750 to RM$1,200.

Table 6.6.3: Indicative Rates for Sumps

Drainage Control Measures	Unit	Con A (RM$)	Con B (RM$)	Con C (RM$)	Con D (RM$)	Con E (RM$)
Culvert (1)	m	300	300	550	250	250
Reinforced Concrete Sumps (2)	one	1500	1500	1500	900	1000
Brickwall Sumps (3)	one	1200	750	750	1000	800
Reinforced concrete drain (4)	m	400	350	600	450	800
Culvert (5)	m	600	450	650	320	350

Source: Project in Shah Alam Project, 1995

Notes:

(1) 600 mm class X
(2) 900 mm X 750 mm with galvanized m.s. grating
(3) 900 mm x 750 mm
(4) 300 mm thick crusher-run, 50 mm thick concrete blinding
(5) 900 mm class X

6.7 Costs and Rates of Sediment Control Measures

Sediment control measures include buffer zone, filter dam, sediment weir, sediment basin, sediment pond and sum pit. Cost items of sediment control are depicted in Table 6.7.1.

Table 6.7.1: Cost Items for Sediment Control Measures

A.	**DIRECT MATERIALS**
	Geotextile
	Concrete
	Rock
	Wire mesh
	Bakau poles
	Sand bags/plastic sheet
	Other direct materials
B.	**DIRECT LABOUR**
	Excavation
	Laying
	Leveling
	Trimming
	Disposing
	Other direct labour
C.	**CONSTRUCTION OVERHEAD**
	Indirect Labour
	Depreciation of Plant, Equipment, and Machinery
	Maintenance
	Rent
	Utilities
D.	**MARKETING AND ADMINISTRATIVE**
	Salaries of Office Executives and Staff
	Legal Fees
	Marketing and Selling expenses
	Warehousing
	Transportation
	Other non-construction expenses

6.7.1 **Sediment Traps**

The three major cost objects for the construction of sediment trap are excavation works, excavation and layering of geotextile for the sediment traps (Table 6.7.2). The rates for excavating, trimming and leveling existing stream range from RM$60.00 to RM$80.00 per m^3.

Table 6.7.2: Indicative Rates For Construction of Sediment Trap

Major Cost Component	Unit	Low (RM$)	High (RM$)
Excavate, trim and level existing areas to formation level to receive the gabions for sediment trap.	m^3	60.00	80.00
Construction of gabion	m^3	350.00	450.00
Provide a layer of geotextile for sediment trap.	m^2	10.00	15.00

Source: Sepakat Setia Perunding, 1995

The rates for construction of sediment traps differ with location. In Pahang, for example, the construction of the four gabion sediment traps and the provision of a layer of geotextile for each of the sediment trap amounted to RM$64 per m^3 each in 1995 compared to Negeri Sembilan which was RM$50 per m^3.

6.7.2 **'Desilting' Sediment Trap**

The cost data for 'desilting' of sediment trap was based on a river mitigation project in Pahang, 1995. Two contractors submitted quotations for the 'desilting' work, conducted fourteen times per month. Contractor A quoted RM$40,000 and Contractor B RM$140,000 for the project. The wide cost variation between the two costs imply an imperfect market situation due to locality.

6.8 Comparison of Costs between States

Nationwide comparison of costs of erosion control measures within and between States in the Country is very difficult. This is because of the varying costs of construction materials, labour and transport. Cost of construction materials such as stones, for example, could be cheap in a particular project, but the construction cost would be high because labour is costly. Transport cost also varies from State to State and within States. Thus, to provide an indicative cost for the various control measures would be extremely difficult.

6.9 Conclusion

This Chapter has analyzed the rates for some of the common erosion, drainage, and sediment control measures. It has also provided the average and range of rates which can serve as useful indicators on the cost of various control techniques. It should be stressed that the rates presented in the Chapter are meant to be indicators and are in no way representative of the entire industry. As pointed out earlier, in the absence of a nation-wide survey it is not possible to indicate the actual rates of these measures which are very much subject to market forces of supply and demand and other factors such as project locations, slope conditions and so forth. As a cautionary note, the rates are not to be quoted for tender purposes.

APPENDIX A

APPENDIX A

HISTORY OF SOIL EROSION AND SILTATION IN MALAYSIA

A1. Introduction

In recent years there has been increasing concern in Malaysia over soil erosion, siltation and the deterioration of water quality in many river systems. Ever increasing public environmental awareness, the all too frequent visual evidence of erosion and siltation as development extends into new areas and the increasing realisation that remedial works can be very expensive, have ensured that the topic remains on the national environmental agenda. Concern over soil erosion, however, is not entirely a phenomenon of recent times. A range of human activities in pre-independence times gave rise to soil losses and siltation necessitating the introduction of remedial and preventative measures, many of which are followed today.

A brief history of soil erosion in Malaysia is given below to put the present situation in perspective and to provide a context for current legislation, policies and preventative practices.

A1.1 Early Agricultural Practices

Recognition that the removal of the rain forest cover can result in accelerated soil loss and in hydrological changes dates back more than 150 years. Early colonial observers noted that clearings abandoned by Chinese pepper, gambier and tapioca growers in Penang, Singapore, Negeri Sembilan, Johor and Malacca were characterised by exhausted soils that were prone to erosion. As early as 1836, the use of 'binding grasses' on steep abandoned slopes in Penang was suggested and in 1848, Logan recommended that the Governor of Penang should prohibit the clearing of summit areas to ensure adequate streamflows during drought periods. It seems unlikely that soil losses from such sites, or from areas of traditional Malay shifting cultivation, were ever a serious problem given the relatively limited areal extent of such activities and because State governments gradually introduced regulations to curtail shifting cultivation in order to protect their forest resources and to prevent the spread of scrub forest (*belukar*) and lallang.

A1.2 Tin Mining

It was not agriculture but mining activities that first gave rise to severe soil erosion and siltation of a number of river systems in Peninsular Malaysia. Rich tin deposits were discovered in the Larut Valley in Perak in 1848 and in the following decades in the Kinta Valley of Perak and in parts of Selangor, Negeri Sembilan and Pahang. The main method of winning the tin in hill areas was to construct a water race along the contour of the hill, remove all the vegetation upslope and then push the soil and regolith containing the tin ore into the race. This technique, which was known as ground sluicing or *lampanning*, resulted in whole hillsides being stripped of vegetation and topsoil and exposed to the full force of the rain. Mining efficiency was greatly enhanced after 1892 with the introduction of high velocity water jets known as hydraulic monitors.

Vast quantities of silt entered the river systems draining the tin mining areas, including soils washed from 'mined' hillslopes and from surrounding hills from which timber had been removed to provide charcoal for the smelters and sand washed from the extensive tailings dumps. Siltation was extensive and at some localities dramatic. A contemporary mining expert estimated that between 1909 and 1939 some 16 million tonnes of sediment were added annually to the river systems of the Peninsula.

Agricultural land was rendered unproductive, river courses were choked, flooding exacerbated and expensive remedial measures were necessary. The situation was so severe along the Selangor River that the town of Kuala Kubu was frequently flooded necessitating the establishment of a new settlement, Kuala Kubu Bharu, on higher ground nearby. Expensive training works and dredging were required along many rivers including the Kinta, the Bentong in Pahang and the Klang River through Kuala Lumpur. Some 141,340 m^3 of silt were dredged from a 4 km stretch of the Klang River.

The severity of the problem forced the authorities to take action. Various Orders, Regulations, Enactments and Codes were introduced banning certain activities, requiring the containment of tailings and limiting sediment discharges to the river systems. The legislation proved to be generally effective but in some areas the legacy of past practices persists to the present day.

A1.3 Rubber Plantations

The first rubber seeds were planted at Kuala Kangsar in 1877 but it was not until after the turn of the century that rubber became a significant crop in Peninsular Malaysia. The area cultivated expanded from a mere 140 ha in 1897 to 405,000 ha by 1916 to 810,000 ha in 1921. It was initially concentrated on European and Chinese plantations but after 1910, Malay smallholders introduced the crop, accounting for some 40% of the area under cultivation by 1923.

The 'rubber boom' was accompanied by disconcerting human and environmental consequences. Malaria took its toll of the plantation labourers while soil losses from smallholdings, and particularly from estates, were widespread and often severe. For many years rubber estates were clean-weeded, with disastrous results. This imported European practice was obviously not suited to the Malayan environment with its high rainfall totals and storm intensities. Rubber trees and seedlings failed to flourish on denuded slopes, river systems were choked with sediment and sediment-laden flood waters ruined padi land. The severity of the problem can be gauged by examples given by the DID in its 1937 'Annual Report for the Federated Malay States and Straits Settlements'. The DID reported that some 7,000 acres of padi land in the Malacca River Valley had gone out of production, that dredging to remove 600,000 cubic yards of coarse silt and associated restoration works in the upper reaches of the river would cost RM$200,000 and that it was costing some RM$50,000 a year to keep the river mouth open for shipping.

The severity of the problem necessitated remedial and preventive measures. After the 1920s, the practice of clean-weeding was generally abandoned and on estates it became common practice to construct bunds and silt pits on sloping land.

During the 1930s, more and more planters introduced cover crops following successful demonstrations by the newly created Rubber Research Institute of Malaya. Although the potential benefits of terracing were recognised, their use did not become widespread or standard practice until after the Second World War when earth moving machinery became readily available. Most of the States introduced legislation aimed at controlling soil erosion but it would appear that enforcement was minimal.

By the time of the Japanese Occupation, excessive soil losses from rubber estates and small holdings were generally a thing of the past and the situation improved in the post-war years as terracing became standard practice. However, as will be discussed, soil losses from rubber growing areas remain far higher than from areas under forest cover.

A1.4 Logging

Although timber was extracted for commercial purposes from many forest areas in both East and Peninsular Malaysia prior to the Japanese Occupation, the techniques employed were relatively primitive and probably caused relatively little damage to the vegetation or to the ground surface. Trees were felled by axe and formed into planks at the stump or dragged short distances to saw mills or rivers. Buffalo, and in some areas, elephants were used to haul logs and in Johor, Pahang and North Borneo manpower was used to pull logs along wooden sledgeways. Areas of steep terrain were, naturally, generally avoided.

After the War, the availability of tractors and winch trucks and the advent of the chain saw meant that more distant and steeper areas could be logged and that environmental damage, including soil erosion, was more likely in such areas.

A1.5 Overview

During the 1950s and 1960s, soil erosion and siltation was not generally considered to be a problem in the Peninsular States or in Sarawak or North Borneo. The introduction of a range of preventive measures in the mining and rubber growing industries had all but eliminated the excessive rates of soil loss and siltation that had occurred during the nineteenth century and the early decades of the present century. Further, the pace of development was slow with more than 75% of the land area of both Peninsular and East Malaysia remaining under forest cover, although this situation was soon to change, particularly in the Peninsula.

But not all were complacent. During the late 1930s and the immediate post-war years, a number of colonial officers were of the opinion that continuing mismanagement of the land and further development would result in the deterioration of the country's river systems. One officer advocated that no land within 150 feet of designated rivers should be cleared and that occupants of river bank areas should be compelled to plant riparian strips to reduce bank erosion, while an officially appointed Commission, the Belgrave Commission, recommended that catchment boards should be appointed for each major river basin in the Peninsula, but the War and the 'Emergency' intervened and no action was taken until after the 1970s.

APPENDIX B

APPENDIX B

REVIEW OF CURRENT DISTRIBUTION AND CAUSES OF SOIL EROSION AND SILTATION IN MALAYSIA

B1. Introduction

Rates of soil erosion and transportation on undisturbed rain forest slopes and sediment concentrations in rain forest streams and rivers provide benchmarks against which changes following forest alterations or replacements can be evaluated. The erosion rates provided in the Sections below are based on various research studies carried out under different landuse, geological conditions and types of terrain and soil in Malaysia.

B1.1 Erosion under Undisturbed Rain Forest Cover

Many observations and measurements have clearly indicated that soil losses from rain forested slopes are seldom excessive. Patches of bare ground are uncommon and eroding rills and gullies rare. Close examination of the forest floor will, however, often locate ephemeral wash lines along which some sediment must be transported, eventually reaching stream courses. Contrary to common belief, litter does not often thickly blanket the forest floor, being typically only 1-3 cms deep and sometimes patchy (Leigh, 1982; Besler, 1987), and a direct relationship between the nature of the litter cover and volumes of surface wash and suspended sediment have been demonstrated in experimental studies (Peh, 1976, 1980; Leigh, 1982). In some rain forested areas in Malaysia, runoff and detached sediment may be washed into streams through pipes in the upper layers of the soil (Baillie, 1976; Brooks, Richards and Spencer, 1993).

The main source of sediment in rain forest streams and rivers is probably derived from eroding watercourse banks. Not unsurprisingly, it would appear that significant proportions of total river sediment loads are transported during severe storm events, which also detach and transport relatively high proportions of soil lost from hillslopes (Douglas *et al.* 1993). For example, 57% of the sediment transported from a natural forest plot in Sarawak over a 12-month period was removed in a single month (Hatch, 1981).

Care should therefore be taken in interpreting and using the limited amount of quantitative data that is available because the rain forest environment is far from uniform. Rates of soil erosion can be expected to be higher in areas of steep terrain, although slope angle may not be as important as previously thought (Douglas *et al.* 1993; Brooks, Richards and Spencer, 1993), and some rock types are more susceptible to erosion than others. It is also possible that rates of erosion vary under different rain forest types in relation to differences in rates of interception and the nature of the ground cover.

In addition, it would appear likely that many reported values for rates of sediment transport on slopes and in streams may have been underestimated because peak storm events were not recorded (Douglas *et al.* 1993).

From the information that is available, it is clearly apparent that rates of soil erosion and transportation are generally relatively low in rain forested areas in Malaysia which can be attributed to a number of factors:

- *the protective effect of the rain forest vegetation, measurements indicating that between 21.8% and 36.0% of annual rainfall is intercepted (Low, 1971; Manokaran, 1977);*
- *the protective nature of the litter cover;*
- *the general absence of areas of bare ground;*
- *the relatively high infiltrability of undisturbed forest soils;*
- *the vegetated nature of stream and river banks.*

As will be shown, modification of these attributes can result in accelerated soil losses and substantial increases in river sediment loads and siltation.

B1.2 Landslides in Undisturbed Rain Forest Areas

Landslides are a natural phenomenon on steep forested slopes throughout Malaysia. It would appear that slopes underlain by certain rock types are more susceptible to slipping than others and that landslides may be triggered by heavy rainfall events.

A large number of landslides occurred on the slopes of the Main Range of Peninsular Malaysia during the exceptionally heavy rainfall events of late December 1926 and January 1971 (Windstedt, 1927; Burgess, 1975), and Day (1980) considered heavy storms to have been the main trigger for a number of landslides observed in the Gunung Mulu National Park in Sarawak. Increases in pore water pressure during heavy storms or when drainage is impeded, cause failure. It is interesting to note that most of the slides observed in the Gunung Mulu National Park were situated on the lower slope sections although landslides are clearly associated with steep slopes. Of 21 landslides examined at Gunung Mulu, all are located on slopes in excess of 40° and 18 on slopes in excess of 50°.

Landslide distribution is also probably related to lithology. The weathered and fractured slaty shales of the Mulu Formation are clearly prone to slipping, with most of the slides occurring on slopes parallel to the dip of the rocks. In Peninsular Malaysia, landslides may be more common on slopes underlain by granitic rocks (Fitch, 1952).

Naturally occurring landslides may be more common than casual observation suggests. Some 120 major landslide scars have been recorded in the Gunung Mulu National Park, some multiple scars having a combined length of 250 m and width of 200 m. In the vicinity of Gunung Api, three slide scars covered 60,000 m^2 and another eight separate scars covered 70% of a slope area.

Clearly before roads are built in hill areas or before hill areas are developed it would be prudent to assess the susceptibility of an area to landslides by field survey and by closely examining aerial photographs.

B1.3 Logging, Forest Replacement and Erosion

Over the past two decades, extensive areas of forest in Peninsular Malaysia have been cleared for agricultural and other uses and large areas of the forest estates in both Peninsular and East Malaysia have been selectively logged. Both land development and selective logging will continue into the foreseeable future.

It has been clearly apparent for a number of years that logging and forest replacement are usually accompanied by erosion and increased sediment loads in nearby streams and rivers. Burgess (1971) noted that a 4 m deep gully remained on a logging track in the Ulu Sat hills in Kelantan some 18 months after it had been abandoned and Liew (1974) demonstrated how severe soil losses could be from selectively logged areas. Liew established two erosion plots on steep virtually bare slopes (32° and 35°) in the Tawau Hills Forest Reserve immediately after logging operations were completed. Net soil losses from the two plots over a 20-month period were the equivalent of 175 m^3 ha^{-1} and 266 m^3 ha^{-1} respectively.

More comprehensive information has been provided in recent years by a number of experimental studies. Results obtained by Lai and Samsuddin (1985) from two disturbed catchments in the Air Hitam Forest Reserve in Selangor demonstrated that suspended sediment concentrations were significantly higher in the more disturbed catchment. Sample concentrations in the less disturbed catchment ranged from 1 - 292 mg l^{-1} and from 2 - 1,305 mg l^{-1} in the more disturbed catchment. More extensive data with considerable implications for forest management have been obtained from a number of experimental studies that have been undertaken in Peninsular and East Malaysia. The results of these studies are briefly summarized in Section B2.0.

B1.4 Erosion from Agricultural Areas

Soil losses from agricultural land are higher than from forest areas. Actual losses are losely related to the character and maturity of different agricultural crops. The erosion risk will thus vary during the growing season or during the lifetime of a plantation.

Rates of sediment transport on terraced slopes planted with rubber at the University of Malaya campus in Kuala Lumpur were found to be 16 times higher than on rain forested slopes at Kepong in Selangor and at Pasoh in Negeri Sembilan (Aiken *et al.* 1982; Peh, 1976). There was no cover crop on the rubber covered slopes and the leaf litter provided a patchy cover. During heavy storms considerable quantities of sediment were moved downslope and some sediment was eroded from the bare terrace walls.

The effectiveness of leguminous and other cover crops has been demonstrated by a number of experiments (e.g. RRIM, 1974; Maene *et al.* 1975; Sungei Tekam Experimental Basin Project Study Group, 1983). An experiment undertaken by the RRIM clearly demonstrates the effectiveness of grass and ferns in reducing soil losses under stands of mature rubber trees. As can be seen from Table B1.1, ferns can be particularly effective in reducing rates of soil loss.

Table B1.1: Effect of Cover Crops on Erosion under Mature Rubber

Soil Series	Slope (°)	Rainfall (cm)	Amount of soil eroded (t/ha)		
			Bare	Grass	Ferns
Rengam	4 - 5	292	103	44	Negligible
Serdang	3 - 4	325	132	177	59

Source: Soong *et al.*, 1980, p.33

As Soong *et al* (1980) noted, cover crops reduce erosion in several ways:

- *By protecting the soil surface from erosion by falling rain drops.*
- *By offering resistance to flowing water.*
- *Through the roots helping to hold the soil in place.*
- *Through roots and crop residues improving soil structure making it more porous and better able to absorb rainfall.*

Studies at the Mardi research station 22 Km west Cukai in southern Terengganu (Hashim et. al., 1995) on terrain of 10 to 25^0 slopes found that lack of contact at ground level increased soil loss from 5 to 104 t ha^{-1} and that soil loss was substantially increased when large flow pathways were present. Information on soil losses from land under other crop types are limited. Soong *et al.* (1980) suggested that erosion from areas covered by oil palm was probably relatively low because this crop was usually planted on flat to gently undulating terrain. In contrast, rates of erosion from areas planted with some 'minor' crops would appear to be relatively high. Shallow (1956), from measurements of river sediment concentrations, estimated rates of sediment loss in the Cameron Highlands to be 336 kg ha^{-1} yr^{-1} from a forested area, 6,720 kg ha^{-1} yr^{-1} for an area planted with tea and 10,080 kg ha^{-1} yr^{-1} for an area planted with vegetables. High rates of soil loss have also been recorded from land under pepper and under hill padi cultivation in Sarawak (Hatch, 1983). Extrapolations from erosion plots gave annual losses ranging from 5,321 - 13,912 t km^{-2} for traditionally cultivated pepper, 68 - 1,155 t km^{-2} for terraced pepper, 29 - 143 t km^{-2} for terraced hill padi and a value of 18 t km^{-2} for traditionally cultivated hill padi. In contrast, rates from forested plots ranged from 4 - 14 t km^{-2} yr^{-1}. In the case of pepper cultivation, the effectiveness of terracing is clearly demonstrated.

B1.5 Urban Development and Erosion

Bare eroding slopes and drains choked with sediment can often be observed on building sites in urban areas throughout Malaysia. A number of measurements indicate that massive amounts are transported from development sites. Instantaneous stream suspended sediment concentrations in storm discharges of 15,343 mg l^{-1}, 19,000 mg l^{-1} and 81,230 mg l^{-1} have been recorded from three streams draining catchments undergoing development in Kuala Lumpur and Singapore (Douglas,1978; Leigh, 1982; Gupta, 1985). Total soil losses from two sites in Kuala Lumpur, one at Bukit Kiara and the other in Damansara, are estimated to have been in the order of 100,000 tonnes and 332,000 tonnes respectively. Sediment chokes urban waterways exacerbating flooding and often necessitating expensive river desilting and training works.

Urban development was particularly rapid in Kuala Lumpur and in the neighbouring urban centres of the Klang Valley in the late 1960s and 1970s. An untoward environmental effect of urban growth in the Kuala Lumpur area has been the frequent occurrence of excessive soil losses from construction sites and from sites cleared of vegetation but awaiting development. There has also been a deterioration in a number of water courses.

Investigations have been carried out to determine the magnitude of change in surface water characteristics and the environmental implications of these changes in the Kuala Lumpur area. The analysis of the data revealed that urbanisation in Kuala Lumpur caused an increase of peak flows by an average factor of 4.23. The runoff volumes increased by an average of 252%. A number of environmental consequences ensued. The most serious effect has been the occurrence of flash floods. The Kuala Lumpur metropolitan area has been hit by flash floods more frequently as urbanisation proceeded. Erosion by surface water is another important environmental implication. The river water quality in Kuala Lumpur was found to have deteriorated with increases in urbanisation. Other implications of change in surface water characteristics in Kuala Lumpur were also identified, such as health hazards posed by the frequent inundation of the low-lying areas (Ithnin, 1988).

Detailed investigations of urban sediment yields have been carried out in Kuala Lumpur and Penang, Malaysia (Table B1.2). Areas undergoing construction usually experience sediment yields 2 to 3 orders of magnitude greater than those under natural forest. In such catchments, the importance of extreme events is often more marked than under natural conditions, with between 35 and 80 percent of the annual load being carried in a single month at the Penang stations listed in Table B1.2.

Small bare areas such as urban construction sites on deeply weathered rocks, particularly granites, yield huge quantities of sediment in short periods of time. On a bare site at Mengkuang Heights in Ulu Kelang near Kuala Lumpur, Mykura (1989) calculated the rates of sediment yield as shown in Table B1.3.

Table B1.2: Results of Urban Catchment Studies in Peninsular Malaysia

Catchment	Land use	Area km^2	Rainfall mm	Sediment yield $t\ km^{-2}\ y^{-1}$	Source
Sg. Air Hitam, Penang	Tropical rainforest	4.75	2580	74.49	Wan Ruslan, 1995
Sg. Air Hitam, Penang	Tropical rainforest in upper part, stable urban area in lower	8.87	2580	376.59	Wan Ruslan, 1995
Sg. Relau, Penang	Disturbed forest and semi-urban	0.553	1830	911.09	Wan Ruslan, 1995
Sg. Relau, Penang	Rapidly urbansing , quarrying, construction	11.523	1830	3102.73	Wan Ruslan, 1995
Sg Jinjang (1)	Newly urbanising	10.3	2400	1056	Balamurugan, 1991
Sg. Jinjang (2)	Tin mining and urbanising	27.1	2300	2283	Balamurugan, 1991
Sg. Kelang (1)	Newly urbanising	14.2	2400	1480	Balamurugan, 1991
Sg. Kelang (2)	Newly urbanising and mature urban	29.0	2300	1372	Balamurugan, 1991
Sg. Keroh	Urban and industrial	35.9	2200	1759	Balamurugan, 1991
Sg. Batu	Forest and urban	145	2400	1265	Balamurugan, 1991
Mengkuang Heights	Bare, steep construction site	0.21	2400	330821	Mykura, 1989
Sg. Sering	27% bare construction site	6.50	2400	42076	Mykura, 1989
Sg. Gombak Jln Pekililing	forest and urban	140	2400	1157	Douglas, 1978

Table B1.3: Rates of Sediment Yields from Urban Granitic Areas

	Values in $t\ yr^{-1}$	Values in $t\ km^{-2}\ yr^{-1}$
Total	34 703	517 969
slope surface erosion	2 544	37 970
rill erosion	5 291	78 985
gully erosion	26 868	401 014

Commenting on these three sources of sediment, Mykura (1989) noted that surface erosion from slopes as measured at erosion plots can be expressed as an index which is the gradient term of the regression relationship of soil loss on erosive energy. Indices of particle size distribution, aggregate stability, and shear strength relate to soil erodibility and are important parameters. Shear strength (as measured by a hand shear vane) is the single soil parameter which provides the best indication of slope surface erosion. Soil microtopography and local characteristics such as lag-gravel armouring, crust formation and surface sealing affect raindrop impacts and infiltration and therefore influence soil losses.

Soil loss through rill development is largely controlled by slope angle. Soil shear strength plays a minor, but significant, role. Rills develop as local drainage routes and their presence or absence, position and density are largely dependent on surface roughness and micro topography, with features such as cracks caused by shrink-swell in clay soils (especially where the illite content is high) exploited by concentrated overland flow.

Gullies are the major sediment source on exposed construction sites. Gullies increase in size more rapidly on fill materials than on cut slopes. Downcutting is the dominant gully enlargement process in cut material, while sidewall retreat dominates on fill.

One of the major nuisances is when streams that have been diverted for highway or other forms of construction cause erosion in localities formerly considered safe. Frequent accounts of such bank erosion episodes occur in the South East Asian press. In June 1995, for example, a Malaysian newspaper reported the concern of a family at the way a diverted stream carrying extra runoff from a new highway had eroded laterally for 9 m and was threatening to undermine the family's house.

In an attempt to control the problem, the Federal Government introduced legislation enabling local authorities to exert greater control over the lay-out and management of construction sites and has published an urban drainage design standards and procedures manual for Peninsular Malaysian conditions. There is evidence to suggest that these measures have encouraged developers to take a more responsible approach to building site lay-out and management (Leigh, 1982).

B1.6 Mining and Siltation

The massive siltation of watercourses that accompanied tin mining activities during the latter half of the nineteenth century and the early decades of the present century is, fortunately, a thing of the past. From the limited evidence available, however, it would appear that rivers draining tin mining areas still carry relatively heavy suspended sediment loads.

It has been estimated that there are at present over 200,000 ha of tin mine tailings in Peninsular Malaysia, most of which remain unproductive (Mokhtaruddin et al.,1990). A study of the impact of past mining on the natural environment has estimated some 30,000 ha of mined land and tailings in the Kinta Catchment, together with a total area of over 16,000 ha in mining ponds (HSS

Integrated, 1993). The study noted that tin mining in the Kinta Catchment had resulted in total destruction of forest and other vegetational cover, with consequential heavy siltation of rivers and streams through the release of the mining effluent. In many instances, this form of mining activity was responsible for the heavy aggradation in the lower reaches of many rivers and streams which led to serious modification of the natural drainage system resulting in severe floodings in low lying areas.

The direct discharge of enormous loads of silt and sediment from the mining effluents into river systems raises the river beds through the accumulation of sediment. The 1938 Department of Irrigation and Drainage (DID) Report indicated that the annual recurrence of flooding in Ipoh and Kuala Lumpur at that time was attributed to the tin mining activity prevailing in these two traditional tin mining towns.

Even with the provision of settling ponds and statutory requirements for mine effluent quality standards, rivers continue to carry high sediment loads due to erosion from unvegetated old mining areas and from sediments stored in the river systems from past mining activities. Balamurugan (1991) observed that despite the cessation of mining activities in the Klang River Basin, rivers draining mining areas still carry high sediment loads. He reported that sediment yield increased by 3 to 6 times after the rivers passed through ex-mining land. Sediment from mining alters the runoff pattern and sediment characteristics of rivers, causes water quality to deteriorate and leads to siltation, which raises river beds and leads to more frequent overtopping of banks and flooding of adjacent areas. These factors seriously affect fish populations and change the structure, diversity and dynamics of the flora and benthic fauna of the rivers and streams of the area.

The National Water Resources Study (1982) estimated that the annual rate of soil erosion in Peninsular Malaysia ranges from about 0.3 $t\ ha^{-1}$ in natural forest to about 60 $t\ ha^{-1}$ from cleared land, as in the case of tin mining areas. The DOE maintains a number of water quality sampling points within the Kinta Catchment, and a range of physical and chemical attributes of the water courses have been recorded.

B1.7 Road Construction

A characteristic feature of roads in hill areas in Malaysia is the numerous cut slopes above the roadways, sometimes up to 100 m high. Such slopes are usually benched (berms) and protected by concrete crest and berm drains and by downslope cascading drains. The standard practice is to vegetate the bare surfaces through natural regeneration or by a variety of artificial techniques including turfing and hydroseeding.

There is often visual evidence of erosion on steep road-side slopes - rills, gullies and undermined drains, and sometimes landslides or slumps can be observed, particularly after heavy rain. Occasionally, whole slope faces slump posing a risk to human life and necessitating expensive remedial works. The potential risks associated with steep artificial slopes in areas of mountainous terrain are all too tragically illustrated by the massive earth slumps that occurred at Genting Sempah in July 1995 when 21 people were entombed in mud and debris (Sunday Star, 2 July, 1995). It would appear that the failed slope had not been benched.

A study of the Kuala Lumpur-Ipoh and Karak highways by Bayfield, Barker and Yah (1992) indicated that:

- *Slope failure is mainly related to lack of crest drains or horizontal drains.*
- *Erosion can result from cutting slopes too steep for the soil type present but is mainly related to inadequate vegetation cover.*
- *The predominant type of erosion varies with slope steepness: on 83° slopes, slumps were the only type of erosion recorded with collapses often occurring at discontinuities between variously weathered materials.*

- *On both roads, slumps increased in frequency with slope angle.*
- *Natural colonisation is most effective on gentle slopes.*
- *On the Kuala Lumpur -Karak Highway plant cover tends to decline with the size of the cut slope.*
- *Most cuttings that are more than 15 years old are reasonably well vegetated.*
- *Turfing and seeding tended to be more successful on east than west facing slopes due to the former drying out more rapidly.*
- *Hydroseeding failed for a number of reasons:*
  soil erosion prior to application
  inadequate soil moisture
  uneven spraying
  soil acidity
  infertile seed
  too much/too little/inappropriate fertiliser

B1.8 Resort Development in Upland Areas

The expansion of hill resorts, such as the Genting Highlands development and the construction of highways across upland areas have led to significant soil erosion and mass movement. The former increases downstream sedimentation, while the latter frequently results in disruptions of highway traffic (Khairi bin Mohd. et al, 1987). Steeplands are liable to landsliding even under natural forest conditions. Examination of aerial photographs for most parts of Malaysia reveals occasional landslide scars on steep slopes in natural forest areas, particularly close sandstone escarpments in Sabah and Sarawak. However, landsliding is more frequent in areas of human disturbance. An indication of the impact of human activities is provided by data from the City of Wellington in New Zealand where detailed analysis of 100 years of rainfall and landslide records showed that on natural slopes, landslides occurred when the 24 hour rainfall exceeded 200-250 mm, a value close to that of the 1 in 100 year recurrence interval storm (Crozier, 1984). However, the threshold for slip producing rainfall on artificially modified slopes in the urban area is 120 mm when soil moisture content is low and as little as 60 mm when the soil is saturated.

Most of the lowland forests of Malaysia have already been logged on one or more selective logging cycle and much of the lowland forest lands have been converted to plantation agriculture. New forest resources are thus generally restricted to steeplands and upland areas (Khairi bin Mohd. et al, 1987). Mechanical logging and road construction in these hilly areas have led to much soil erosion. The impact of logging in the steeplands of the Main Range has been discussed by Lai et al (1995). Accordingly, 52% of the steep Sg Batangsi Catchment in Ulu Langat, Selangor were being logged in 1987-89. The total sediment yield over the period of March 1987 to March 1989 was 5,424 t km^{-2}, 94.2% of which were transported in storm events. An average of four bulldozers and four winch lorries were used in the operations. The bulldozers were used to construct roads as well as to haul felled logs to landings, whence they were later transported to a local sawmill by the winch lorries. The mean road and snig track density was 6.1 km km^{-2} (Lai, 1992). Wet conditions caused operational difficulties in this steepland environment and timber harvesting stopped during severe rains. Poor road conditions were often reported by foresters overseeing these operations with erosion creating and enlarging rills on the road surface and roadside gullies which fed large quantities of weathered granitic sand and clay downslope and into the stream channels, which had a bed covered with coarse quartz sand.

B1.9 River and Marine Water Quality

Water which flows or is pumped from land disturbance sites can be contaminated by suspended, dissolved, flotable and settleable soil materials, oils, detergents, litter, fertilizers, alkaline cement materials and other chemicals.

Soil nutrients and chemical pollutants become attached to or are transported by sediment particles as a result of soil erosion, dewatering of trenches, washing of vehicles, cleaning of concrete supply equipment, careless waste disposal and other similar incidents. Heavy metals and disease organisms also become attached to, or protected by and transported on sediment particles. These pollutants reduce the usefulness and enjoyment of the water environment to people downstream and damage aquatic life in rivers, streams, lakes and estuaries.

Organic contaminants attached to particles sediment in streams lead to reduction in the dissolved oxygen in streams creating a sediment oxygen demand (SOD). Muddy sediment can smother stream beds where aquatic animals live, reproduce and obtain nourishment. Materials suspended in water can choke and abrade aquatic organisms and their eggs. Suspended materials can also reduce visibility and the ability of many fish and other organisms to capture prey. Suspended and coloured materials can block sunlight and prevent the growth of aquatic plants.

Silt and sediment can fill dams and block waterways and drains, thereby increasing removal or dredging costs. Sediment in drains which is exposed to the air between storm events becomes the growth medium for plants which then trap more sediments in storm flows and so gradually reduce the capacity of the drains. Siltation of streams can reduce their capacities to carry flood waters and increase the risk of flooding as a consequence. Muddy materials in water can also degrade its aesthetic appearance.

B1.9.1 Sediment Loads of Rivers

Data on suspended sediment concentrations collected by the Drainage and Irrigation Department of Sabah were used to calculate estimates of the sediment yields of the major rivers of Sabah (Murtedza, 1990). Comparison of these results with those calculated by the Department of the Environment (DOE, 1987) (Table B1.4) suggests that sediment yields in Sabah are considerably greater than those from major rivers in Peninsular Malaysia.

Table B1.4: Sediment Loads of Selected Rivers in Malaysia (after Murtedza, 1990)

River	Catchment area km^2	Annual mean discharge $m^{-3} s^{-1}$	Annual mean suspended sediment concentration $mg\ l^{-1}$	Mean Annual sediment load $10^3\ t\ y^{-1}$	Mean Annual sediment yield $t\ km^{-2}\ y^{-1}$
Peninsular Malaysia					
Pahang	25600	363	39	446	17
Muar	3130	35	38	42	22
Muda	3330	64	45	85	25
Perak	7770	170	106	568	73
Terengganu	3340	230	41	297	89
Golok	761	44	64	89	117
Langat	1240	32	147	148	119
Kelantan	11900	525	89	1474	124
Kelang	468	14	156	69	147
Bernam	1090	53	214	358	328
Sabah					
Padas	7718	187	194	1599	207
Labuk	3253	177	135	738	227
Segama	2450	89	382	1097	448
Kinabatangan	10800	527	451	7752	718
Sugut	2150	93	415	1181	549

The data in Table B1.4 rely on infrequent sampling for suspended sediment determinations across a range of discharges and on the establishment of rating curves of concentration against stream discharge. Their reliability depends on whether or not high discharges are sampled. Storm period sampling, which enables suspended sediment concentrations on the riding and the falling stages of the hydrograph to be determined is usually more reliable than interval sampling.

B2.0 Indicative Case Studies

Summary results from a number of experimental studies undertaken in Peninsular and East Malaysia are presented below. Cumulatively, a considerable amount of data on rates and processes of slope erosion and on river sediment loads has been collected, although notable gaps remain, particularly detailed information for hill and mountain areas where logging and development are becoming increasingly intense. Many of the results have significant implications for land development managers. What is required is to translate these implications into on-the-ground practices.

B2.1 Case Study 1: Rates of Soil Erosion in Sarawak

Soil erosion in Sarawak has been the subject of many comments by observers, but there are no detailed studies, apart from a long running set of plot experiments carried out by the Research Branch of the Department of Agriculture. Unfortunately, there has been little work on forest hydrology in Sarawak and no indicative measurements of the impact of logging on erosion rates and stream sedimentation are available. Subjective comments by foresters include the following:

"While floods in several basins in Sarawak have been attributed to extensive forest clearing, it is impossible to be sure of the exact role that clearing has played. However, in areas where the bush fallow period is not too short, shifting cultivation may not disrupt the hydrologic regime as much as recent arguments have suggested.......If a cleared area is left to be recolonized by secondary vegetation, peak streamflows and sediment yields gradually return to near natural levels. (The continuation of those effects in logging areas is due to the road system which remains after timber extraction has finished)" (Butt, 1983).

"Much of the damage is caused by logging roads and "skid trails". In rugged terrain, these roads must be carved into steep side slopes. The result is a wide corridor in which erosion is greatly accelerated. Above the road, the slope is undermined and becomes potentially unstable" (Butt, 1983).

Splash and slope wash are said to be the dominant processes on slopes of less than 25° while mass movement becomes more prominent on steeper slopes (Petch, 1985). Soil creep is a significant process and may be a forerunner of landslides (Eilers and Loi, 1982). Plot experiments, covering small areas of slope indicated that mean values of erosion under natural forests in Sarawak ranged from 10 to 23 t km^{-2} yr^{-1}, while those for unterraced pepper cultivation are 8,100 to 9,000 t km^{-2} yr^{-1} (Petch, 1985).

Under logging, fill or spoil heaps are a major source of material entering streams. Streams draining logging areas are often much more turbid than streams draining shifting cultivation areas (Petch, 1985). Hatch (1982) commented earlier that *"many of the logging operations in Sarawak are not carried out in a very responsible manner (from a soil erosion point of view) and it is obvious to even the casual observer that very serious erosion is caused during the construction of logging roads, landing sites and construction sites".*

Petch (1985) made the following conclusions about erosion in logging areas:

(a) Logging activities increase erosion rates far above natural rates under undisturbed forest.

(b) In at least some parts of the state, logging is a greater cause of erosion than hill padi cultivation.

(c) Erosion rates and processes are affected by soil disturbance as well as by removal of vegetative cover. For example, fill slopes seem to erode very quickly; road cuts on steep side slopes may induce landslips.

Petch (1985) also noted that in many parts of Sarawak, shifting cultivators are now entering recently logged areas, taking advantage of the access provided by logging roads. He observed a particularly erodible combination in such areas - disturbed soils, already with sparse regeneration, were cleared and burned. Padi (if planted) and weeds were slow to become established, so the soils were unprotected through at least one wet season.

In a study on the Semongkok Series soils, Ng and Teck (1992) noted, contrary to general belief, that the slash-and-burn system of growing hill padi and maize as a companion crop on hillslopes would incur severe soil and nutrient losses due to greater surface runoff and the very "open" soil surface. Their results suggested otherwise. Only 0.45 t ha^{-1} were lost in the first year after clearing. At Tebedau, Teck (1992) recorded 0.46 t ha^{-1} soil loss in the first year after clearance.

Earlier, Hatch (1982) had confidently said *"the rate of soil erosion under shifting cultivation gives no concern for alarm"*. However he warned that reduction in the fallow period was reported to have led to sheet erosion in some parts of Sarawak and that there may be a greater incidence of landslips in shifting cultivation fields than under natural forest. Field data from plot studies clearly supported this view (Table B2.1). Soil loss under shifting cultivation is of the same magnitude as that under natural forest, whereas once a cultivation system leaves bare ground between row crops, as in traditional pepper, erosion rates rise to 100 times that under natural forest.

Table B2.1: Data on Erosion Rates under Forest and Shifting Cultivation for Sarawak

Land Use	Location	Slope (degrees)	Period (years)	Soil loss t km^{-2} yr^{-1} mean	Soil loss t km^{-2} yr^{-1} range
PRIMARY FOREST	Niah F.R.	25-30	4	19	8.3-31
	Semongkok	25-30	11	24	7-77
SECONDARY FOREST					
b) with hill padi	Niah F.R.	25-30	4	23	11-36
c) 2 month old lallang and scrub	Semongkok	25-30	11	10	2-17
	Niah F.R.	33	3	1100	450-1800
HILL PADI/ SHIFTING CULTIVATION					
a) normal	Kg. Benuk	25-30	1	18	
b) terraced with cover	Semongkok	20	11	120	21-246
c) bush fallow	Semongkok	16-26	3	23.3	6-45
d) bush fallow	Tebedau	25	2	34	22-46
TRADITIONAL PEPPER	Semongkok	25-30	11	8944	5118-13912

Source: after Ng and Teck (1992) and Teck (1992).

B2.2 Case Study 2: Mendolong, Sabah

Studies of the effects of forest clearance in Malaysia are limited to the study of rain forest conversion to oil palm and cocoa plantation at Sungai Tekam in Pahang (DID, 1989) and to a study of rain forest conversion to forest plantation at Mendolong, Sabah (Malmer and Grip, 1993).

At Mendolong, five catchments were selected to study the impact of clear felling and plantation forestry on hydrology and soil properties. One investigation, utilising two catchments, 3.4 ha and 18.2 ha in size, examined the impact of mechanised and manual timber extraction on soil disturbance and loss of soil infiltrability (Malmer and Grip, 1990).

The two catchments lie on the slope of a ridge on the Miocene Maligan sedimentary formation which is largely made up of sandstones and siltstones with interbedded shales (Malmer, 1993). The vegetation of the two catchments was logged-over lowland dipterocarp rain forest. Slopes are moderately steep with some steeper segments. Two different soil types are present, one with a relatively high clay content and the other with a relatively high sand content.

Both catchments were selectively logged in 1981 using crawler tractors and many tracks were still visible in 1987 when the experiment commenced. The study involved clear-felling both catchments, one following standard commercial practice using crawler tractors and the other using the traditional manual 'kuda-kuda' method whereby logs are hauled on sleds by teams of men along wooden tracks to roadways or rivers.

Measurements indicated that there were considerable changes in the dry bulk density and infiltrability of the clay soils where tractors were used to extract timber and that there was practically no difference between the infiltrability of the new and six-year old tractor tracks. In contrast, there were no significant differences where manual extraction was practised.

Forest clearance led to increased runoff (Table B2.2). The burnt catchments and that in which tractors were used had the greatest increases in runoff. Similarly, the W5 stream had the highest post-treatment sediment yields. Single storms during timber extraction and immediately after burning exported high volumes of sediment. A storm on 14 December 1987 removed 28 kg ha^{-1} from W5 but only 7 kg ha^{-1} from W4. The second rain after burning at the W1 + 2 streams in March carried 56 kg ha^{-1}, 14% of the total load in a 5-month period. Natural forest streams did not yield more than 1 kg ha^{-1} in any rain event during that time. The suspended soil loss after treatment in these catchments was highest following the use of tractors for timber removal and soil loss over the first 18.5 months after treatment averaged 2.53 t ha^{-1} yr^{-1}.

There was a difference in the chemical character of the sediment eroded from gullies developed in tractor tracks and that released to streams after burning. Particles transported out after burning carried a high load of nutrients from the burned slash, while sediments eroded from deeper soils in gullies or on stream banks carried less plant nutrient materials. Gully erosion on tractor tracks produced much higher sediment yields of up to 547 t ha^{-1} yr^{-1} (Table B2.3).

Table B2.2: Increases in Runoff (mm) from different Catchments due to different Treatments in the Mendolong Experimental Catchments, Sabah, Malaysia.

Catchment	Year 1	Year 2	Year 3	Total 3 years
W1 + 2	397	522	89	1008
W4	197	170	80	447
W5	460	262	468	1190

Note: W1 + 2 involved cutting and burning of secondary vegetation, W4 was clear-felled, subject to manual log extraction and no burning, and W5 was clear-felled, had timber extraction by tractor and was burnt before being planted with fast-growing trees.

Table B2.3: Gully Development in terms of Soil Loss and Sediment Yield on 3 severely erodedTractorTracks 2 and 3 years after Timber Extraction at Mendolong, Sabah

				Dec 1987 - Dec 1989			Dec 1989- Dec 1990		
Track	Length	Slope	Texture	Volume	Weight	Yield	Volume	Weight	Yield
	m	degree		m^{-3}	t (dry)	t ha^{-1} yr^{-1}.	m^{-3}	t (dry)	t ha^{-1} yr^{-1}.
1	70	48	clay	16.4	17.2	244	2.6	2.7	77
2	60	18	loamy sand	17.6	26.7	547	nd	nd	nd
3	45	12	loamy sand	19.5	20.5	500	1.6	2.5	12.2

While most of the erosion on the tracks probably took place in the first six months after the tracks were brought into operation, erosion was still apparent in 1990, three years after disturbance. Erosion was least on Track 1, even though it was the longest, probably because the studied segment was nearer the top of the slope and had less on flow of eroding water than Tracks 2 and 3 (Table B2.4). This emphasises that long uninterrupted stretches of logging track running downslope are likely to have high rates of erosion and to supply large volumes of sediments to streams.

Table B2.4: Comparison of Estimates of Erosion Rates on Logging Tracks

Site	**Sediment yield from plot (t km^{-2})**
Danum immediately after logging	*19,050*
Danum one year after logging	*1,050*
Mendolong track 1	*24,400*
Mendolong track 2	*54,700*
Mendolong track 3	*50,000*

A comparable study of erosion in a bounded plot (5 x 1 m) on an abandoned logging track in Ulu Segama, Sabah showed a yield of 96 t ha^{-1} yr^{-1} in the period June 1989 - May 1990, 55% of which were eroded in the first two months after logging ceased. However, the bounded nature of the plot, which prevented water from upslope contributing to the erosion meant that deep gullying did not occur. Continuing studies in Ulu Segama showed that abandoned logging roads and tracks continued to yield sediment and to be subject to gullying, even where a vegetative canopy has developed over the bare soil, for at least five years after logging has ceased. Terrain conditions in Ulu Segama are not as steep as at Mendolong and the rocks tend to weather into more cohesive, clay-rich soils.

The results from Mendolong have considerable implications because reduction in infiltrability results in greater slope runoff and soil loss. At Mendolong, tractor tracks occupied a considerable proportion of area being logged; 24%, as against 4% for the catchment where manual extraction was practised.

Extensive soil disturbance by crawler tractors has been recorded elsewhere. Tractor paths were found to occupy 24.7% of a logging area in the Segaliud-Lohan area of Sabah, compared with 14% nine years earlier when lighter equipment was used, and there is a report of mechanised extraction laying bare or damaging 30% of the ground area at a site in East Kalimantan (Fox, 1969; Abdulhadi, Kartawinata and Sukardjo, 1981).

B2.3 Case Study 3: Erosion in Montane Environments

Information on soil erosion and river sediment loads in montane areas in Malaysia is, as might be expected, limited. Summarised below are the results of three studies undertaken in Cameron Highlands and in Kinabalu Highlands in Sabah.

B2.3.1 Kinabalu Highlands

Under natural conditions in the montane environment, landslides and debris slides are relatively common, but for the most part, erosion would appear to be limited in the montane forest ecosystem. This premise is suppoterd by the relatively low sediment yields recorded in the Sg Kalangaan in Kinabalu Park, Sabah. The annual suspended sediment yield of 15.5 t km^{-2} yr^{-1} is considerably less than loads from some undisturbed lowland steepland catchments (Table B2.5). For example, the yield of the Sg W8S5 at Danum Valley was 312 t km^{-2} yr^{-1}, approximately 20 times higher (Douglas *et al.*, 1992). In an area well to the south of Kinabalu Highlands, Malmer (1990) obtained sediment yields of 58.4 and 20.1 t km^{-2} yr^{-1} for two forested catchments, which are also significantly greater than that obtained for the Sg Kalangaan area. Outside Sabah, a study in an upland environment located at a lower altitude than the Sg Kalangaan, produced an annual yield of 53.7 t km^{-2} yr^{-1} for an undisturbed catchment, which is again much lower than that of the latter catchment (Table B2.5).

A separate study was undertaken within the Sg Kalangaan Catchment to examine soil losses from vegetable plots in vegetable gardens immediately adjacent to the Kinabalu National Park (Waidi Sinun, 1995). Two crops were selected based on their structure. One was a leafy vegetable (cabbage) while the other was stem-type vegetable (chili). The design was based on the fact that the effectiveness of vegetation in reducing or preventing erosion is dependent on the structure or characteristics of the vegetation cover (Stocking and Elwell, 1979; Evans, 1980; Morgan, 1986; Thornes, 1989).

The experiment was designed to investigate the effect of bed orientation on runoff and sediment production. During the first two phases of the monitoring, the beds were orientated parallel to the slope angle. In the latter two phases of the study, the beds were orientated perpendicular to the angle. Phases 1 and 3 saw the plots planted with cabbage and phases 2 and 4 saw the plots planted with chili. The results of the studies are shown in Table B2.6.

Table B2.5: Suspended Load of selected Catchments from Tropical Catchments

Catchments	Area (km^2)	Vegetation/ landuse	Sediment Yield ($t\ km^{-2}\ yr^{-1}$)	Methods	Comments
Malaysia					
1. Bukit Berembun					
C1	0.13	Unsupervised logging 40 % extraction	Before = 13.6 After = 27	Grab samples. Weighted sediment concentrations calculated with daily discharge.	Baharuddin (1988) Zulkifli *et al* (1990)
C2	0.04	Forests	Before = 20 After = 19		
C3	0.30	Supervised logging 33% extraction	Before = 13.7 After = 12		
2. Sg Tekam					
A	0.47	Forest to cocoa	Before = 22.5[a] After = 95[b]	USDH-48 and single-stage rising sampler. Sediment rating curve with mean daily discharge.	DID (1989); a-6 yr av.; b- 3 yr av.; c-9 yr av;
B[d]	0.96	Forests to oil plam	Before = 28[a] After = 225[b]		d-catchment nested below A
C	0.56	Forests control	Before = 29		
3. Sg Gombak	140	Various types of secondary vegeation.	178.3	Sediment flow duration curves. USDH-48 sampling at various discharges.	Douglas (1968); sediment production calculated using sp. gravity of 2.65
4. Hulu Langat and Sg Lalang Forest Reserve					
Sg Batangsi	19.8	Logging on going	2,826.2	Selected baseflow samples and samples collected during storms using an automatic sampler.	Lai (1992)
Sg Lawing (a) Aug 88 - Jul 89	4.7	100% upland Forest	53.7		Lai (1992)
Sg Lawing (b) Jan 93 - Dec 93	4.7	Logging started Jan 93	1129		Lai (1995b)
Sg Chongkak(a) Mar 87 - Jun 88	12.7	Logging until Apr 87	2,476		Lai (1992)
Sg Chongkak(b) Jul 88 - Oct 89	12.7	Post-logging recovery	1,335		Lai (1992)

Sg Lui	68.1	80% forested 20% rural area	89.7		Lai (1992)
5. Danum Valley Sabah					
Sg. W8S5	1.1	100% Lowland forest	312	Daily samples using 500 ml bottles and storm samples collected with Automatic Liquid sampler (ALS)	Douglas *et al* (1992)
Sg Steyshen Baru	0.56	Affected by loggings	1,600		
6. Lumaku Sepitang Sabah					
W1+W2	0.06	non-mechanised clearing, burning of slash and planting	71.4	Sampling at flume outlet. Autometic water samplers	SFI (1989) and Malmer (1990). 'Before' period average of 10 months data; 'after' period average of 18.5 months data
W3	0.19	Forest - control	58.4		
W4	0.03	Manual felling, manual extraction of logs - moving of slash into rows and planting. No burning.	142.7		
W5	0.10	Manual felling, extraction by crawler tractors, burning of slah and planting	253		
W6	0.04	Forest - control	20.1		
7. Cameron Highlands					
Sg Bertam	72.52	Forest-64% tea - 7% Vegetables - 7% Open areas - 8%	222	Winchester bottle lowered to 0.6 m stream depth. Sediment flow curves and duration curves.	Shallow (1956)
Sg Kial	21.37	Forests - 70% tea - 11% Vegetables - 19%	210		
Sg Telom	77.7	Forests - 94% Tea - 5% vegetables - 1%	27.4		

8. Kinabalu Highlands					
Sg Kalangaan	2.45	Unidisturbed Forest - 100%	15.5	Daily samples using 500 ml bottles and storm samples collected with Automatic Liquid sampler (ALS) set at 15 and 7.5 minutes sampling interval.	(Sinun, 1995)
Sg Silau Silau	1.91	Unidisturbed Forest - 95.6% Tourist development - 4.4%	108.9		
Sg Ayamut	0.91	Undisturbed Forest - 45% Vegetable Garden and Tourist Development - 45%	1076.4		

Table B2.6: **Estimated* Annual Sediment Yield of Experimental Plots (t km^{-2} yr^{-1})**

Stages	Phase 1 Cabbages Beds downslope	Phase 2 Chili Beds downslope	Phase 3 Cabbages Beds across slope	Phase 4 Chili Beds across slope
Period (days)	91	127	98	77
Plot A (t km^{-2} yr^{-1})	634.7	6,601.94	469.83	773.76
Plot B (t km^{-1} yr^{-1})	1,109.8	11,246.74	555.07	1,356.1

*Yield Calculation

Total Yield (t km^{-2})/No. of days analysed x 365.25 = Annual sediment Yield (t km^{-2} yr^{-1})

B2.3.2 Cameron Highlands

The classic study of catchment sediment yields in highlands in Malaysia is that carried out by Shallow (1956) in the Cameron Highlands. Shallow estimated a rate of soil loss of 27.4 t km^{-2} y^{-1} from the little disturbed Sg Telom Catchment (Forest = 94%, Tea = 5%, Vegetables = 1%), which is slightly higher than that recorded from the Kinabalu Highlands at similar altitude. Sediment yields for catchments where between 25 and 35% of the area had been converted to tea and vegetable cultivation were 257 to 277 t km^{-2} y^{-1} respectively.

A study 30 years later (Suki and Jaffar, 1990), estimated a soil loss of approximately 200 t km^{-2} y^{-1} for the whole of the 712 km^2 Cameron Highlands based on a few suspended sediment determinations. This study commented that due to the loss of top soil from the farmlands, farmers have cut into hitherto undisturbed hillsides to gain additional soil, thereby aggravating the erosion problem.

The similarity in sediment yields between Sg Kalangaan and Sg Telom Catchments reflects the special characteristics of highland forests, with their relatively low canopies, denser ground cover than lowland forests and frequent light, but steady rain.

B2.4 Case Study 4: Sungei Tekam Experimental Basin, Pahang

The Sungei Tekam Experimental Basin is located at the northern end of the Jengka Triangle land development area in Pahang. The natural vegetation of the area is Hill Dipterocarp Rain Forest. The study area had been previously logged, which was reflected in the structure and composition of the vegetation. Calibration commenced in July 1977 and monitoring continued until the end of 1986 (Sungei Tekam Experimental Basin Project Study Group, 1987). The programme was a very comprehensive collaborative effort undertaken by a number of government agencies and two universities.

The objectives of the programme were to monitor and evaluate:

- the effects of landuse changes on the hydrology of the basin, focussing particularly on the components of rainfall, streamflow and water balance;
- the effects on water quality of the various stages of agricultural development;
- the effects of landuse changes on soil fertility as affected by the return of organic matter to the soil, infiltration, soil erosion and chemical content; and
- the effectiveness of buffer strips and cover crops in soil and water conservation.

Two catchments were selected, one of which (Catchment C) remained under rain forest cover as the control. The other was divided into two sub-catchments with one being converted to cocoa (Catchment A) and the other to oil palm (Catchment B). The programme schedule is given in Table B2.7 below.

Table B2.7: Catchment Programme

Catchment	Calibration Period	Transition Period	Evaluation Period
C- Rain forest	Control catchment		
B- Oil palm	June 1977-June 1980	June 1980-June 1983	June 1983 onwards
A- Cocoa	June 1977-Sept. 1982	Oct. 1982-June 1986	June 1986 onwards

In addition, a number of erosion plots were established to determine the extent to which leguminous ground cover and riparian strips affected runoff and erosion and the impact of skid tracks on soil properties was also investigated.

Results and Management Implications

(a) **Stream Sediment Loads**

Predictably, clear felling and replacing the forest cover with cocoa and oil palm resulted in marked increases in stream sediment loads. In sub-catchment B, clear-felling was followed by an annual sediment load of 414 t km^{-2} in contrast with values of 20, 25 and 39 t km^{-2} for the three preceding years. Substantial increases were also recorded in catchment A, ranging from 10-35 t km^{-2} prior to logging but rising to 50 and 125 t km^{-2} following clear-felling.

Clear-felling was immediately followed by the planting of cocoa and oil palm in catchments A and B respectively. By the time the oil palms were two years old, sediment loads had returned to pre-development levels reflecting the effectiveness of the ground cover crop that was established, whereas sediment levels in the catchment planted with cocoa had not returned to near pre-development levels some three years after planting clearly indicating that the shade trees that were planted did not provide as effective a cover as do ground crops.

(b) **Erosion Plots**

A number of erosion plots were established to test the effectiveness of ground cover crops and streamside buffer strips in reducing rates of runoff and soil loss. Measurements demonstrated the effectiveness of both legumes and buffer strips in reducing runoff and erosion. Erosion from the bare plots was significantly higher than from the other plots.

The Project Team recommended that buffer strips and legume covers should be maintained as standard practices when opening up land for agriculture and that experiments should be conducted to establish the optimum widths for buffer strips. In addition, the Team recommended that access road networks should be carefully constructed to reduce sediment sources.

(c) **Impact of Skid Tracks**

The impact of crawler tractors on soil properties along skid trails was examined two years after logging operations ceased (Kamaruzaman Jusoff and Nik Muhamad Majid, 1986; Kamaruzaman Jusoff, 1988). Samples were taken from four positions:

- from the tracks
- from between the tracks where the logs are skidded
- from the berms pushed up by the side of the track
- from nearby undisturbed surfaces

Bulk soil densities were found to have increased on average in the top 15 cm of the soil by 54% on the tracks, by 37% between the tracks and 24% on the berms. Porosity was reduced by 20.4%, 13.4% and 8.8% respectively while resistance to penetration increased by 10% on the tracks. Available water holding capacity was similar on the skid tracks and undisturbed land.

A significant implication of these results is that reduced rates of percolation result in lower infiltration and increased runoff and therefore potentially greater rates of soil erosion. Further, the most compacted soils were found in track ruts where runoff would concentrate creating favourable conditions for the formation of rills and gullies.

Another implication relates to future productivity. Given the density of skid tracks at Sungei Tekam (0.02-0.06 km ha^{-1}), and the fact that many soil properties had not recovered to pre-logging levels some two years after operations had ceased, regeneration could be affected unless the tracks are treated.

The authors recommended that forest managers adopt four measures to reduce soil compaction during tractor logging:

- pre-plan and confine skidding to a low density network;
- winch logs to a trail instead of travelling to each log;
- locate skid trails on the driest soils and along contours,
- carry the load by lorries through confined tracks.

B2.5 Case Study 5: Bukit Berembun Forest Reserve

Between 1980 and 1988, the Forest Research Institute of Malaysia (FRIM) conducted an experiment to ascertain the impact of logging on stream sediment and turbidity levels and rates of recovery in an area of hill rain forest in the Bukit Berembun Forest Reserve in Negeri Sembilan. An area of hill forest was specifically chosen because logging operations would be increasingly concentrated in such areas (Baharuddin Kasran, 1988; Zulkifli Yusop and Anhar Suki, 1994). The study formed a component of a much broader study examining the impact of logging on forest hydrology.

Three small adjacent catchments (C1, C2 and C3) were selected. The catchments were underlain by homogenous granitic rocks and the vegetation was hill rain forest of the 'Red Meranti-Keruing' type. The catchments were calibrated for three years (1980-83). Catchments C1 and C3 were then selectively logged using winch lorries ('*san-tai-wong*') and crawler tractors or wheeled skidders. Catchment C2 was left untouched as a control. Selective logging in catchment C1 followed normal commercial practice but in C3, logging was more closely supervised and subject to a number of prescriptions:

- alignment of logging roads along contours
- proper drainage for road runoff
- construction of cross-drains at 45-60^{o} across logging roads
- installation of culverts or hollow logs at vehicular stream crossings
- no logging within 20 m-wide stream buffer strips

During the calibration period for the three catchments, suspended solid concentrations averaged 54 mg l^{-1} with a range from 4 to 360 mg l^{-1}. During the first year following logging, the mean for the unsupervised catchment (C1) 'leaped' to an average of 386 mg l^{-1} while the average for the supervised catchment (C3) was only 72 mg l^{-1} and for the control (C2) only 32 mg l^{-1}. Monthly means reverted to pre-logging levels in catchment C3 three years after logging but remained substantially higher in catchment C1. During the calibration and post calibration periods, concentrations were higher during the wetter months. Concentrations tended to remain low during times of baseflow even following logging.

The results from Bukit Berembun clearly indicate that if certain prescriptions are adhered to, rates of soil loss during selective logging operations can be significantly reduced and recovery times shortened. Although the effectiveness of the individual prescriptions was not monitored, it would appear that key factors were the presence of stream buffer strips, careful road construction and reducing the percent of the catchment covered by logging roads. The rapid revegetation of skid tracks aided recovery.

B2.6 Case Study 6: Danum Valley, Sabah

Extensive studies of the rain forest environment have been conducted since 1985 at the Danum Valley Field Centre at Ulu Segama in Sabah as part of the Royal Geographical Society's South-east Asian Rain Forest Research Programme (Marshall 1992). A component of the programme has been to investigate the impact of selective logging on stream hydrology, chemistry and sediment loads (Douglas *et al*. 1992, 1993).

Two forested catchments were selected; one which remained undisturbed as a conservation area and the other which was selectively logged. The forest is of the lowland dipterocarp type and the underlying lithology a mixture of sedimentary and volcanic rocks. Slopes typically range from 18^0 - 25^0 with steep 45^0 slopes on sandstone outcrops.

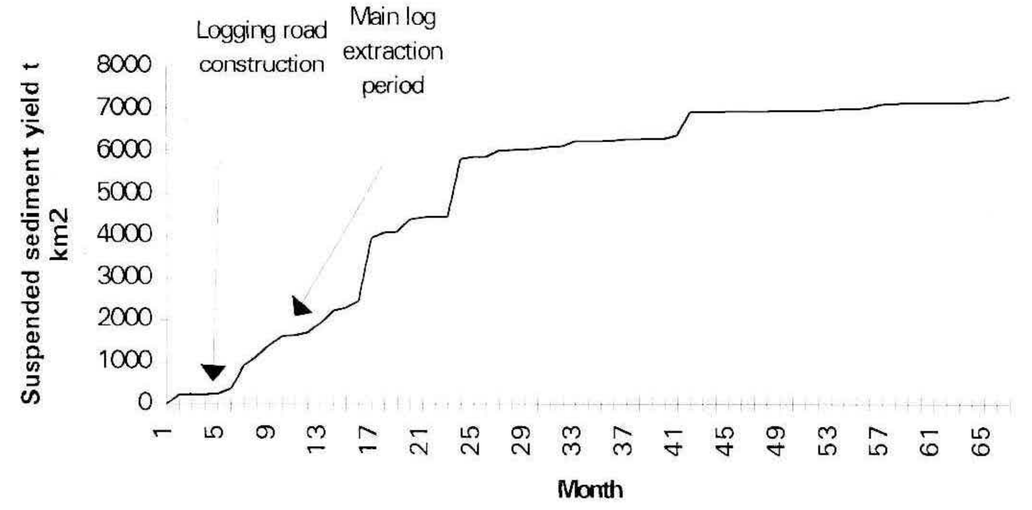
Logging road construction commenced in June 1988 and logging in January 1989.

The results showed that the ratio of monthly suspended sediment yield from the two catchments increased from 1:1 prior to disturbance, to 4:1 after a logging road had been built across the head of one catchment, to 5:1 after logging has taken place to within 37 m of the road, to 18:1 during the five months after logging within the rest of the catchment (Figure B2.1). A year after logging had ceased, the ratio reduced to 3.6:1 indicating a considerable degree of recovery.

Few data are available for the long-term sediment yield following biomass removal. Data for sediment yield following selective logging, with little disturbance of the catchment within 150 m of the gauging station are available for the Sg Steyshen Baru Catchment at Danum Valley in Sabah. High rates of erosion occurred for the first 24 months following logging (Figure B2.1), this period accounting for nearly 80% of the total sediment yield for the 67 months period shown in Figure B2.1. It is important to note that nearly 40% of the total yield came in only two months of the period when particularly large storms occurred.

If the figures from Steyshen Baru are compared with those for felling at Mendolong cited above, the peak annual load at Steyshen Baru (for the 12 months June 1989 to May 1990 immediately following the main logging activity) amounted to 4,118 t km^{-2} compared to 258 t km^{-2} for a catchment that was felled, burnt and replanted. The Mendolong study may have missed some storm peak sediment concentrations as sampling was restricted to 15 or 20 minute intervals during nine storms (Malmer, 1990). The Steyshen Baru Catchment is equipped with an automatic sampler which sampled storm flows at every 7.5 minutes for three hours and thus caught the rising and falling stages when sediment concentrations usually differed considerably.

Figure 2.1 Cumulative monthly sediment yield Sungai Steyshen Baru June 1988 - Dec 1993



The increased sediment loads were attributed to the reduction in opportunities for infiltration and to the exposure of areas of bare soil. Recovery after logging was rapid but was far from complete two years after logging operations had ceased. Some logging tracks continued to erode and sediment deposited on the narrow floodplain and within the river channel remained to be evacuated. It was suggested that gradually less and less sediment was evacuated by small and medium sized storms flows and eventually by the larger discharges.

In addition, to monitoring stream sediment loads, runoff and soil losses from plots on abandoned skid tracks were measured. On one track, a two-metre high earth bund was constructed on the upslope side of the plot to prevent inflow. Vegetation rapidly colonised this plot retarding soil losses whereas in contrast, uncompacted soil within the unbunded plot was rapidly removed and vegetation was slow to become established. It was recommended that earth barriers should be constructed along skid tracks as soon as logging operations cease.

B2.7 **Case Study 7: The Kinta Catchment**

The Sg Kinta has a series of important tributaries including the Sg Tumboh, Sg Raia, Sg Pinji, Sg Pari, Sg Cenderiang and Sg Kampar. Water is abstracted from Sg Kinta for public water supply and the upper reaches are also used for domestic and recreational purposes. A number of domestic sewage and industrial waste sources discharge into the river.

Canalisation along the main stream of the Sg Kinta was carried out through Ipoh in the 1920s and on downstream starting in the 1950s. There is evidence that water flow in these engineered sections of the river has been subsequently adversely affected by high sediment loads. It is likely that the primary source of sediment is the unvegetated old mine tailings rather than current mining activities.

Sediment levels of the Sg Kinta and tributaries are generally high and often exceed 100 mg l^{-1}. It is noteworthy that DOE sampling for suspended solids (SS) (mean value 1986-91) immediately below Ipoh City showed levels of 56 mg l^{-1}, even though the sampling station was located below the tributary inflow of the Sg Pari which was recorded as carrying a loading of 170 mg l^{-1}. The relatively clear Sg Kinta at this point diluted the very high SS loading it received to acceptable levels. The SS loadings of the tributaries of the Sg Kinta were in excess of 50 mg l^{-1}, and together they contributed excessive SS loads into the main Sg Kinta system. These high SS values are also reflective of the excessively high turbidity levels recorded in the tributary streams of the Sg Kinta. Turbidity levels of over 235 FTU have been recorded in the middle reaches of the Sg Kinta.

Suspended sediment levels above 50 mg l^{-1} and turbidity levels above 50 FTU denote Class III waters or worse (refer Proposed Interim Water Quality Standards for Malaysia) and which are unsuitable for recreational body contact sports and sensitive aquatic life. It is generally accepted that if sediment loadings are restricted to those that aquatic life will tolerate and thrive in, then the limits likely to be suitable for human and stock consumption will also have been achieved. For the maintenance of a vigorous aquatic flora and fauna in a water system, SS should ideally be kept to about 25 mg l^{-1}. However, even values of several thousands mg l^{-1} will not kill fish, provided exposure to these conditions is restricted to no more than a few days. Nevertheless, it is considered that at sustained concentrations in excess of 100 mg l^{-1}, aquatic life will be seriously compromised.

The time duration of high sediment loading and the magnitude of flow within the watercourse is also important in assessing water quality. High seasonal sediment loadings may not pose undue threats to aquatic life but could be critical at low flows.

The iron content in both the Sg Kinta and tributaries is of some concern. Very high levels of up to 3.77 mg l^{-1} (1990) had been recorded in Sg Pari at its confluence with Sg. Kinta. In most instances, the 5-year mean is approximately 2 mg l^{-1}. Any level in excess of about 0.3 mg l^{-1} will be detectable in taste and cause discolouration, deposits and growth of iron bacteria. Stock watering standards should be of the order of 1 mg l^{-1} or less.

Clearly, SS is the most critical pollutant in the Kinta Catchment and, with a SS Quality Index of less than 70, the river system will be considered 'very polluted' in DOE's classification.

B3.0 Summary and Conclusion

The observations and experimental results summarized above have a number of implications for land developers, project proponents and managers. The following facts are particularly pertinent:

- Standard commercial logging practices result in high sediment loads in adjoining streams and rivers mainly from the skid and haulage roads.
- Access roads and skidding tracks are significant sediment sources because of their bare nature and generally compacted state.
- Relatively high proportions of sediment are removed by severe storm events.
- Sediment loads decrease rapidly once logging operations have ceased but often do not return to pre-disturbance levels for many years because bare patches persist, particularly along skid tracks, and because accumulated sediment on floodplains and in watercourses is available for evacuation.
- Leguminous ground cover crops are effective in reducing runoff and soil losses from bare and clear-felled areas.
- Sediment from former mining areas contributes to the sediment loads of many Malaysian rivers.
- Soil losses from urban development sites can be excessively high if preventive measures are not taken.
- The retention of vegetated strips along watercourses reduces stream sediment loads.
- Stream sediment loads can be reduced if selective logging operations are carefully supervised and erosion prevention measures are prescribed.
- Improvements to logging machinery design may help to reduce erosion.
- Soil losses from vegetable growing areas can be high if conservation practices are not employed.
- Erosion from areas of shifting cultivation may not, contrary to popular opinion, be any higher than from undisturbed forest areas unless rotation periods are reduced and patches of bare soil exposed.
- Appropriate prescriptions are essential but are not by themselves enough. Managers and management agencies must provide leadership, motivation and supervision. It is interesting and relevant to note that with respect to logging in the Australian tropical rain forests. The key to reducing the impact of logging lies with the machinery drivers and operators. They commented that '*Developing programmes that enhance their sensibilities, skills, awareness and cooperation is perhaps one of the most important things rainforest managers can do*'.

APPENDIX C

APPENDIX C

ENVIRONMENTAL MANAGEMENT SYSTEMS

C1 Introduction

The International Standards Organization has prepared a set of draft standards relating to environmental management systems (EMS's). Five standards have been distributed for comment to member countries:

ISO/DIS 14001 - Environmental Management Systems Specification with Guidance for Use

ISO/DIS 14004 - Environmental Management Systems - General Guidelines on Principles, Systems and Supporting Techniques

ISO/DIS 14010 - Guidelines on Environmental Auditing - General Principles

ISO/DIS 14011 - Guidelines for Environmental Auditing - Audit Procedures - Auditing of Environmental Management Systems

ISO/DIS 14012 - Guidelines for Environmental Auditing - Qualification Criteria for Environmental Auditors

In January 1996, Malaysia officially adopted the draft standards for use as the 'Provisional Malaysian Environmental Management System and Environmental Auditing Standards'. The Standards and Industrial Research Institute of Malaysia (SIRIM) is the government agency responsible for the implementation of this scheme.

With respect to management principles, the standards have much in common with the widely accepted ISO 9000 series standards relating to business management and quality control.

C2 Environmental Management Systems

The two standards relating to Environmental Management Systems specify requirements that will enable an organization to formulate environmental policies and objectives taking into account legislative requirements and potential environmental impacts. An Environmental Management System applies only to those environmental aspects over which an organization can control or be expected to influence. It does not contain specific performance criteria.

An organization wishing to introduce an EMS requir[illegible]

- An environmental policy
- A planning framework
- Implementation and operational procedures
- Management and evaluation procedures
- Management review programmes

C3 Benefits

An EMS can help an organization provide confidence to interested parties that:

- a management system exists to ensure that environmental policies, objectives and targets are met;
- emphasis is placed on prevention rather than correction;
- evidence of reasonable care and regulatory compliance can be provided; and
- the systems design incorporates the process of continual improvement.

The benefits of an effective EMS to an organization include:

- assuring customers of commitment to demonstrable environmental management;
- maintaining good public/community relations;
- satisfying investor criteria and improving access to capital;
- obtaining insurance at reasonable cost;
- meeting vendor certification criteria;
- improving cost control;
- reducing incidents that result in liability;
- demonstrating reasonable care;
- conserving input materials and energy;
- facilitate obtaining permits and authorizations;
- fostering development and sharing environmental solutions; and
- improving industry-government relations.

APPENDIX D

APPENDIX D

STATUTORY CONTROLS

D1 Introduction

Current control measures fall into three main categories: statutory controls and requirements contained in various acts, regulations and by-laws; agency and other guidelines; and operating practices. In this Section, the statutory controls that relate both directly and indirectly to soil erosion and sedimentation control and prevention and the Federal Government Policy framework are briefly summarized.

D1.1 Statutory Controls

The Malaysian Constitution and Federal and State Government policies provide the framework for the Country's legislation. The Constitution stipulates the subjects on which the Federal and State Governments may legislate while government policies determine whether existing legislation will be retained or amended and whether new legislation will be introduced. The Sections below show how various pieces of legislation provide the framework for erosion and sedimentation control in the Country.

D1.1.1 The Malaysian Constitution

The distribution of legislative powers between the Federation and the States is for the most part contained in Articles 73-79, 95B-95E and the Ninth Schedule of the Malaysian Constitution (Malaysia, 1995).

The Ninth Schedule contains three 'Lists': a Federal List, a State List, and a Concurrent List. The Federal Government may make laws with respect to matters enumerated on the Federal and Concurrent lists and the State Governments with respect to matters enumerated on the State and Concurrent lists.

The Federal Parliament may, in addition, make laws for specific purposes as detailed in Article 76 of the Constitution with respect to matters on the State List. It may make laws 'for the purpose of promoting uniformity of the laws of two or more States'. Such legislation does not, however, become effective in the States until it is adopted by the State Legislatures and gazetted.

Article 95D stipulates that the above provision does not extend to Sabah and Sarawak.

Matters on the lists relating directly or indirectly to soil erosion, sedimentation and water quality are as follows:

Federal List	Ports and harbours; foreshores Federal works and power, including:- - public works for federal purposes - water supplies, rivers and canals, except those wholly within one State or regulated by an agreement between the States concerned.
State List	(a) Except with respect to the Federal Territories of Kuala Lumpur and Labuan; land including land tenure; colonization, land improvement and soil conservation and mining leases; (b) Except with respect to the Federal Territories of Kuala Lumpur and Labuan, agriculture and forestry; (c) Local government outside the Federal Territories of Kuala Lumpur and Labuan; (d) State works and water (including, subject to the Federal List, water supplies, rivers and canals), control of silt, riparian rights.
Concurrent List	(a) Town and country planning, except in the Federal Capital; (b) Drainage and irrigation, (c) Rehabilitation of mining land and land which has suffered soil erosion.

D1.1.2 Government Policies

Two key Federal Government policy documents, which are supported by all of the States, are the 'Second Outline Perspective Plan 1991-2000' and the 'Seventh Malaysia Plan 1996-2000'. Both documents confirm the Federal Government's commitment to sound environmental management.

The 'Second Outline Perspective' presents a 'New Development Policy' for the 1990s. One of the key components of the Policy is:

'ensuring that in the pursuit of economic development, adequate attention will be given to the protection of the environment and ecology so as to maintain the long-term sustainability of the country's development.'

In order to achieve this goal, it is stated that:

'Strategies for environmental protection will be incorporated into all development plans and programmes.

The implementation of such strategies will give priority to adopting environmentally sound practices.

Efforts will be taken to ensure effective and well-coordinated enforcement of such strategies and programmes by further upgrading the regulatory machinery at the State and Local Government levels.

The promotion of greater awareness, responsibility and participation of the public and private sectors as well as society in general in achieving a clean and healthy environment will be further intensified through mass media, education and training.'

In the 'Seventh Malaysia Plan', a whole chapter (Chapter 19) is devoted to environmental protection and management. It is stated in the Plan that 'Malaysia will continue to take appropriate action to ensure that development is sustainable and balanced.' and to achieve this 'environmental and conservation considerations will increasingly be integrated with development planning.

It is acknowledged in the Plan that indiscriminate clearing for development projects, unsound practices in a range of activities, inadequate legislation and lack of enforcement of legislation has resulted in soil erosion and water quality problems. During the Plan period the Government will:

- integrate soil conservation planning with physical development
- review current legislation and guidelines, and
- consider the need for a Soil Conservation and Sediment Control Act

D1.1.3 **Environmental Quality and Control**

The most significant piece of legislation in Malaysia relating to environmental quality and control is the Federal *Environmental Quality Act* 1974 (Laws of Malaysia Act 127). The Act applies to the Federal Territory and to all States except Sarawak. Sarawak has introduced its own legislation known as the *Natural Resources and Environment (Amendment) Ordinance,* 1993 and the *Natural Resources and Environment (Prescribed Activities) Order,* 1994.

The *Environmental Quality Act* 1974, which is described as '*An Act relating to the prevention, abatement, control of pollution and enhancement of the environment, and for purposes connected therewith'* provides for:

- The appointment of a Director-General of Environment and the establishment of a Department of the Environment (Section 3);
- The establishment of an Environmental Quality Council (Section 4);
- The issuing of licences for the emission or discharge of wastes (Part III);
- The licensing of prescribed premises (Part IV, Sections 18-20);
- The gazettement of 'any activity which may have significant environmental impact as a prescribed activity' (Section 34A); and,
- The preparation of a report prior to the carrying out of any prescribed activity which contains '*an assessment of the impact such activity will have or is likely to have on the environment and the proposed measures that shall be undertaken to prevent, reduce or control the adverse impact on the environment'*. Such reports are known as 'Environmental Impact Assessments' (EIA's) (Section 34A).

The most significant provisions of the Act with respect to soil erosion and sedimentation prevention and control are those relating to prescribed activities and the preparation of Environmental Impact Assessments. The prescribed activities are specified in the *Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order* 1987. In total some 19 activities are prescribed. For most of the prescribed activities, the Department of Environment has prepared 'Environmental Impact Assessment Guidelines', which contain some general recommendations relating to soil erosion and sedimentation prevention and control.

The list of prescribed activities are comprehensive and can be added as and when circumstances warrant. One criticism could be that for some activities, the minimum areas specified are too large. For example, land conversion from forest to agricultural production involving 500 ha or less and development of housing estates involving less than 50 ha do not require an EIA. In many instances, relatively small areas could be environmentally sensitive and can contribute large amounts of sediment to the river systems.

With respect to water quality, the following regulations passed under the Act are relevant:

- Environmental Quality (Sewage and Industrial) Regulations, 1979
- Environmental Quality (Prescribed Premises)(Raw Natural Rubber) Regulations, 1978
- Environmental Quality (Prescribed Premises)(Crude Palm-Oil) Regulations, 1977
- Environmental Quality (Scheduled Wastes) Regulations, 1989

D1.1.5 Land (Control of Erosion)

Legislation to control soil erosion, particularly from hill lands, has a long history in Malaysia dating back to the Silt Control Enactment of the Federated Malay States, the Hill Lands Ordinance, 1937 of the Straits Settlements, and similar enactments introduced in Kedah in 1940, and Kelantan and Pahang in 1951. The various pieces of legislation were amalgamated to form the Federal *Land Conservation Act* 1960 (Laws of Malaysia Act), which is described as '*An Act relating to the conservation of hill land and the protection of soil from erosion and the inroad of silt*'. It was subsequently adopted by all 11 Peninsular Malaysian states. Minor revisions, mainly relating to terminology, were introduced in 1989.

Part II of the Act - Control of Hill Land - provides for a State, by notification in the Gazette, to declare any area within the State to be hill land. No person is permitted to cultivate gazetted hill land or to clear or weed such land without a permit.

Part III of the Act - Control of Silt and Erosion - empowers State Land Administrators to serve notice on the owners or occupiers of any land when it appears:

(a) *that earth, mud, silt, gravel or stone from such land has caused or is likely to cause damage to other land, whether alienated or not, or to any water-course, whether natural or artificial, or has interfered or is likely to interfere with the due cultivation of other land, whether alienated or not; or*

(b) *that by reason of the steepness of the slope of such land, damage has been or is likely to be caused to such land by erosion or displacement of earth, mud, silt, gravel or stone upon or from such land.*

The owners or occupiers must comply with any instructions given with respect to halting or curtailing activities and undertaking remedial measures.

Potentially this is a very powerful Act but in practice it would appear to be generally ineffective because although areas have been declared to be 'hill lands' under the Act, few orders have been served to owners and occupiers, which is probably a direct consequence of the States not having assigned responsibility for the implementation of the Act to any department or agency.

D1.1.6 Forestry

Forests are a State matter but as noted, the Federal Government may introduce legislation for the purpose of achieving uniformity. Such legislation, however, has no legal standing in the States unless adopted by the State Legislatures and gazetted.

A National Forest Policy for Peninsular Malaysia was introduced in 1978 and was embodied in the *National Forestry Act* 1984 (Laws of Malaysia Act 313). Some provisions in the Act were amended under the *National Forestry (Amendment) Act* 1993 (Act A864).

The Act provides for classification of permanently reserved forests into 11categories of which only one category is intended for production forest where logging for timber under sustained yield will be allowed. The other 10 categories are essentially for protection forests which means that there should be no logging and soil disturbance will be minimal. These 10 categories include, 'soil protection forest', 'soil reclamation forest' and 'water catchment forest'.

There is no specific reference in the Act for the prevention of soil erosion but specific guidelines can be incorporated into the licence requirements. Section 20(b) of the Act requires licence applicants to prepare a forest management or harvesting plan and a reforestation plan in the manner specified by the Director. Requirements for soil prevention and control measures would normally be included.

In addition to the above, the Forestry Rules 1986, if followed, should ensure that provisions relating to soil protection will be carried out. The Rules require all logging plans, management plans and rehabilitation plans to be certified prior to the start of logging which should ensure that erosion and sedimentation issues are addressed.

D1.1.7 Mining

Mining is a matter on the State List. The Federated Malay States Mining Enactment (Cap 147) still applies in the States of Perak, Selangor, Pahang, Negeri Sembilan, Melaka, Penang, and the Federal Territory and similar legislation exists for the other states. The Federal Government has prepared no 'model' legislation.

The existing mining legislation contains only limited provisions relating to soil erosion and water quality including:

Section 64 of the FMS Enactment makes it an offence to 'alter or interfere with or permit any person to alter or interfere with the bank of any river, stream or water-course' unless permission has been obtained.

Section 74(I) makes it an offence to discharge waters containing chemicals deleterious to animal or vegetable life.

Section 74(ii) makes it an offence to discharge water from mining areas containing suspended solids in excess of the amount specified in any rule.

Section 83 gives Inspectors the power to give orders necessary to control the disposal 'all earth, sludge, dirt, tailings or other refuse matter'.

D1.1.8 Quarries

The *Perak Quarry Rules* 1992, passed pursuant to Section 14 of the *National Land Code*, requires quarry operators to 'take measures to ensure compliance with the law relating to environmental protection and pollution control' and may require operators to introdunce measures to control dust particles. It would appear that the other states have yet to introduce similar legislation.

D1.1.9 Rivers and Streams

Rivers and streams if located within a single State are State matters, but as noted in Section C1.1.3 above, a number of Federal Environmental Quality Regulations relate to water pollution.

The various State Water Enactments were primarily introduced to control waters for irrigation and for floodplain management purposes. The enactments make no reference to soil erosion or sedimentation but do contain a provision enabling the control of discharges to waterways that might be deleterious to public health and safety or to any beneficial uses.

D1.1.10 **Town Planning**

In 1974 and 1976, the Federal Government consolidated legislation relating to local government and town and country planning into three Acts:

The *Street, Drainage and Building Act* 1974 (Laws of Malaysia Act 133)

The *Local Government Act* 1976 (Laws of Malaysia Act 171)

The *Town and Country Planning Act* 1976 (Laws of Malaysia Act 172)

In 1984, Uniform Building By-Laws were introduced as provided for in the *Street, Drainage and Buildings Act* 1974.

These pieces of legislation, which were widely adopted by the States and local authorities, contain provisions relating to water quality and provisions enabling environmental matters, such as soil erosion and sedimentation, to be taken into account.

(a) **Local Government Act**

Sections 69-71 of the *Local Government Act* 1976 prohibit the deposition of trade wastes and refuse, solid or liquid sewage in or on the banks of any streams, drains or watercourses within a local authority area and empower local authorities to recover costs of any works that they undertake to rehabilitate watercourses.

(b) **Town and Country Planning Act**

Part II of the *Town and Country Planning Act* 1976 requires the setting up of a State Planning Committee to oversee the general policy with respect to planning of all lands within every local authority in the State. Section 4 states the functions of the Committee as follows:

(i) to promote in the State, within the framework of the national policy, the conservation, use and development of all lands in the State;

(ii) to advise the State Government, either on its own initiative or in response to a request by the State Government, on matters relating to the conservation, use and development of land in the State;

(iii) to undertake, assist in, and encourage the collection, maintenance, and publication of statistics, bulletins, and monographs, and other publications relating to town and country planning and its methodology.

Accordingly, Section 5(1) states that every local authority shall be the local planning authority for the area. Two very important functions of the local authority are found in Section 6(1) as follows:

(i) to regulate, control, and plan the development and use of all lands and buildings within its area;

(ii) to undertake, assist in, and encourage the collection, maintenance, and publication of statistics, bulletins and monographs and other publications relating to town and country planning and its methodology;

Part III of the Act requires the local authorities to prepare 'development' and 'structure' plans for their areas and 'local' plans for specified areas. Environmental consideration can be addressed in the plans. Environmental matters must be examined during the preparation of development plans and structure plans and local plans must contain a statement relating to 'measures for the physical improvement of the environmental'.

Part IV of the Act stipulates that no development can commence or be carried out without planning permission. In 1995, the Act was amended to include provisions relating to environmental protection (*Town and Country Planning (Amendment) Act* 1995 - Act A933).

The new section 21A(1) requires a proponent seeking planning approval to submit a development proposal containing:

(a) the development concept and justification;
(b) a location map and a site plan;
(c) particulars of land ownership and restriction, if any;
(d) (i) a description of the land including its physical environment, topography, landscape, geology, contours, drainage, water bodies and catchments and natural features thereon;
(i) a survey of the trees and all forms of vegetation; and
(ii) particulars of a building, which may be affected by a development;
(b) a landuse analysis and its effect on the adjoining land;
(c) layout plans, the details of which are specified in section 21B; and
(d) such other matters as may be prescribed by the local planning authority.

The amendment requires layout plans to be provided showing the proposed development and in particular:

(a) where the development is in respect of any land -
(i) measures for the protection and improvement of its physical environment;
(ii) measures for the preservation of its natural topography;
(iii) measures for the improvement of its landscape;
(iv) measures for the preservation and planting of trees thereon;
(v) the location and species of trees with a girth exceeding 0.8 metre and other vegetation thereon;
(vi) the making up of open spaces;
(vii) the proposed earthworks, if any;
(viii) a description of the works to be carried out.

The local authority may impose conditions on the applicant with respect to any of the above, thus potentially giving local authorities a vital role in preventing and controlling erosion on development sites throughout the country. In addition, section 35A of the Act enables a local authority to issue tree preservation orders for amenity protection. In certain locations rthe preservation of trees could help control erosion.

(c) Street, Drainage and Building Act

Section 70A of the Act stipulates that earthworks cannot be constructed without a permit from the local authority and allows a local authority to 'impose such conditions as it deems fit. In addition, a local authority is empowered to make by-laws relating to earthworks. These provisions give local authority the ability to require developers to undertake measures to prevent and control soil erosion from development sites where earthworks are in progress. The provisions do not apply to the Federal Governments, which would seem to be a weakness.

Section 50 of the Act allows a local authority 'to cause to be made and constructed and maintained surface and storm water drains, culverts, gutters and water-courses' and the power to construct and recover the costs thereof.

(d) Uniform Building By-Laws

As the name implies, these by-laws relate mainly to building standards and specifications. The only Section directly relating to soil erosion is Section 83 which stipulates that '*All air-wells and open spaces in and around buildings shall be suitably protected against soil erosion*'.

D1.1.11 Fisheries

Section 38 of the *Fisheries Act* 1985 (Laws of Malaysia Act 317) provides for State authorities and the Federal Minister to make rules on specified matters for the 'proper conservation, development, management and regulation of turtles and inland fisheries'. Rules can be made (Section 38 (1)(k)) '*for the purpose of the conservation of fish in riverine water, to regulate and control the construction of any slides, dams or other obstruction, or the removal of sand or gravel or other alteration to the natural environment or habitat of fish*'.

This provision could conceivably be used to control development activities that directly or indirectly adversely impact on watercourses.

D1.1.12 Geological Hazards

The Geological Survey Department of Malaysia operates under the *Geological Survey Act* 1974 *(Laws of Malaysia Act 129)*. The Act mainly relates to the structure of the organization, power and duties of officers, authority of Geological Survey and general obligations relating to Geological Survey. There are no clauses relating to geological hazards. Currently, the Department has only an advisory role in this area, and then only if requested. The Department's role is to identify the geological hazards and carry out hazard assessment which include among other location, area, intensity and magnitude of the hazards.

The Act is currently under review and sections relating to geological hazards will be introduced.

D1.2 Conclusions

There is a considerable body of legislation in Malaysia that can be used to help minimize and control soil erosion and sedimentation. The fact that erosion and sedimentation continue to be widespread, however, suggests that additional legislative controls are required and that existing legislation should be more effectively enforced.

The requirement under the provisions of the *Environmental Quality Act* 1974 that EIA's be prepared for 19 prescribed activities means that for most projects the issues of soil erosion and sedimentation will be addressed. A particular strength of the EIA process with respect to erosion and sedimentation is that monitoring can be required during the construction phases and for a number of years after the development has been completed. This Document has shown in Figure 3.1.1 how planning for erosion control can be strengthened within the framework of project planning and within the EIA process.

Clauses relating directly or indirectly to soil erosion, sedimentation and river water quality appear in a number of acts, by-laws and regulations but for the most part they are not particularly comprehensive or rely on appropriate provisions being included in licenses and permits.

It is encouraging to read in the 'Seventh Malaysia Plan' (Government of Malaysia, 1996) that the Federal Government intends to use legislation more effectively to help curb erosion associated with development activities. It will:

> Amend the Schedule of Works and Payment under the *Housing Developers Act* to include environmental considerations and a soil erosion standards for a range of activities;
>
> Amend the *Environment Quality Act* 1974, the *Town and Country Planning Act* 1976, the *Uniform Building By-laws* 1984 and the *Housing Developers (Control and Licensing) Regulations* 1989 to include provisions relating to erosion and sediment control;
>
> Explore whether the National Land Code can be used to prevent soil erosion and promote soil conservation; and
>
> Consider whether a Soil Conservation and Sediment Control Act is required.

It is recommended that when legislation is reviewed or amended, the opportunity is taken to include objectives relating to soil erosion and sedimentation prevention and control in addition to specific enabling measures.

APPENDIX E

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GLOSSARY

This glossary is by no means exhaustive, but should cover most of the terms used in this Document.

Terms	Definition
Accelerated erosion	Erosion which is taking place much more rapidly than would normally occur under natural conditions.
Basin	A hollow or depression within which water can be contained.
Batter	A sloping section of exposed soil or embankment, usually created through earthmoving and construction operations. It can be cut batter or a fill batter.
Buffer	An area, usually of vegetation, alongside to protect a feature such as a stream from damage or pollution.
Catchment	The area determined by landform within which falling rain will contribute to runoff at a particular point such as a stream or river. Often, it is used synonymously with basin or watershed.
Channel	The bed and banks within which water flows along a ditch, drain, stream or river. The bed and banks maybe sharply defined as for an eroded gully or transitional as for a gentle depression.
Cross drain	A drain constructed across an accessway to intercept and divert runoff. It includes inverts and floodways.
Culvert	A covered channel used to carry water under the ground surface or road.
Dispersible soils	Structurally unstable soils which break up easily in water.
Diversion bank	A bank used to intercept and divert volumes of water.
Drainage line	A location where flowing water concentrates in a channel.
Erosion	The detachment or wearing away of the earth's surface, particularly soil or loose materials, by flowing water, wind or other geological agents.
Erosion control structure	A structure designed to control erosion. It includes banks, culverts, inverts, sediment ponds, silt traps etc.

Erosion hazard	The susceptibility of a piece of land to the prevailing agents of erosion. It is dependent on climate, terrain, soil, landuse and land management.
Erosion risk	The intrinsic susceptibility of a piece of land to dislodged the soil materials by the prevailing agents of erosion. If land management factors are ignored, erosion risk is dependent on climate, terrain and soil factors.
Erosion and sediment control measures	A description of the methods that will be used to control erosion and sediment on-site and off-site.
Fill	Materials, usually excavated soil or rock, deposited on an area.
Gabion	A rectangular box made from steel or iron mesh and used to hold rocks. Gabions are assembled into many shapes for use to line channels to prevent erosion.
Geotextiles	A permeable membrane of woven, needle punched or loosely joined plastic filaments. Such membranes are used to filter soil from water, prevent soil being washed from under hydraulic structures and to increase the foundation stability of works such as roads.
Gradient	The slope or inclination of a surface. Gradients are usually expressed as a percentage of vertical rise divided by horizontal run or as degrees to the horizontal. They can also be expressed as the proportion x:1 where 'x' is the horizontal distance and '1' is the equivalent unit vertical distance.
Retaining wall	Solid wall used to support an embankment or vertical land face.
Runoff	The surface discharge or flow of water or from surface eroded soil.
Sediment	Mineral and organic materials that have been eroded and deposited. Suspended sediment is used in reference to soil which has become suspended in water.
Sedimentation	The deposition of sediment from suspension in water.
Silt	Soil particles between 0.005 mm and 0.76 mm in diameter. However, silt and sediments have often been used interchangeably although they are well defined in terms of particle size.
Siltation	Technically, it is the deposition of silt. Often it is used as an alternative to "Sedimentation".

APPENDIX F

APPENDIX F

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APPENDIX G

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