CHAPTER 1 ROAD SLOPE DISASTER MANAGEMENT

1.1 CONCEPT OF ROAD SLOPE DISASTER MANAGEMENT

1.1.1 Objective

The total road network in Nepal is around 16,000 km at present. Out of the total road network about 5,000 km length is strategic road network, which forms important infrastructure for social and economical activities in Nepal. These roads are prone to frequent traffic blockade due to slope disasters induced by harsh natural conditions such as steep topography, fragile geology, heavy rainfall, river floods and earthquakes. The road slope disaster management can play vital role in delivering efficient and effective transport services to road users. Objectives of the road slope disaster management are as follows:

1) tomaintain the traffic operation
2) to secure the traffic safety
3) to reduce the environmental degradation
4) tominimize the traffic operation cost

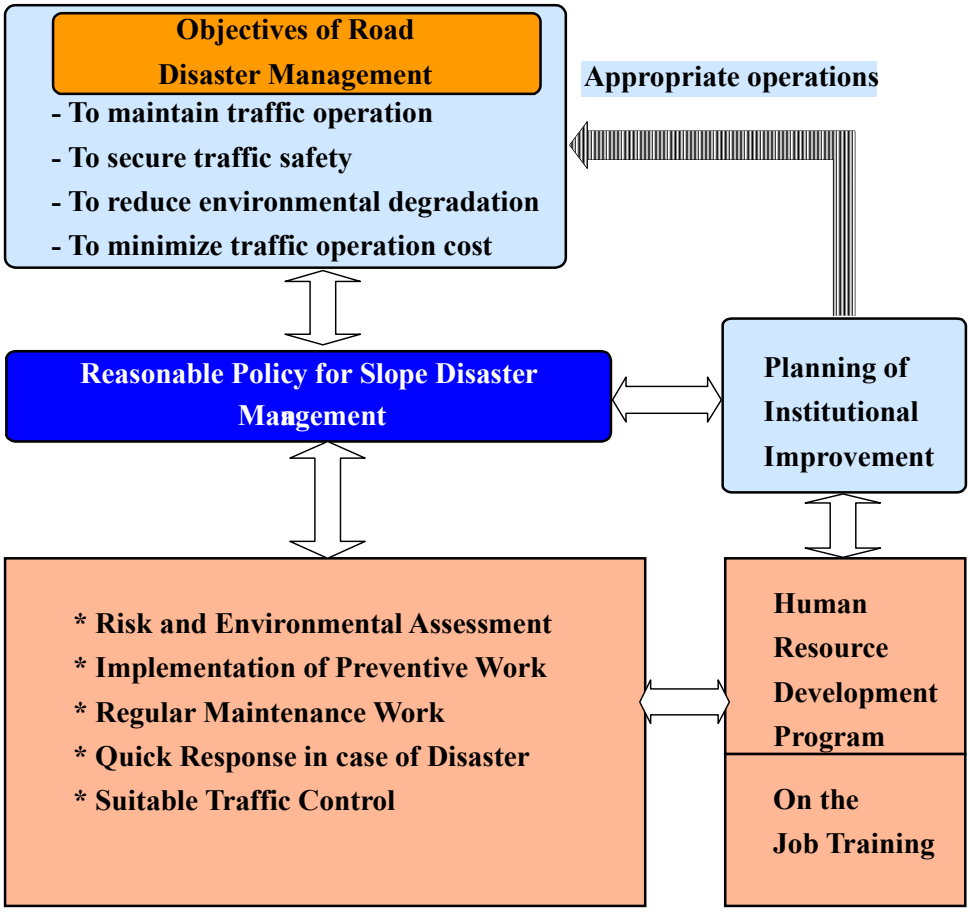

Figure 1.1: Concept of Road Slope Disaster Management

To achieve the objectives, following tasks are required.

1) Understand the conditions of Strategic Roads on disaster probability and environmental impacts (Risk and Environmental Assessment)
2) Formulate Reasonable Standard Policy and Plan for Slope Disaster Prevention
3) Implement Preventive Works
4) Continue Regular Maintenance Works to keep the slope and other road structures in good condition
5) Response quickly in case of Disaster
6) Manage Traffic Operation in case of Disaster
7) Develop Human Resources
8) Strengthen the Road Maintenance Organisation

1.1.2 System for Road Slope Disaster Management

Proposed system for Road Slope Disaster Management in Nepal is shown below.

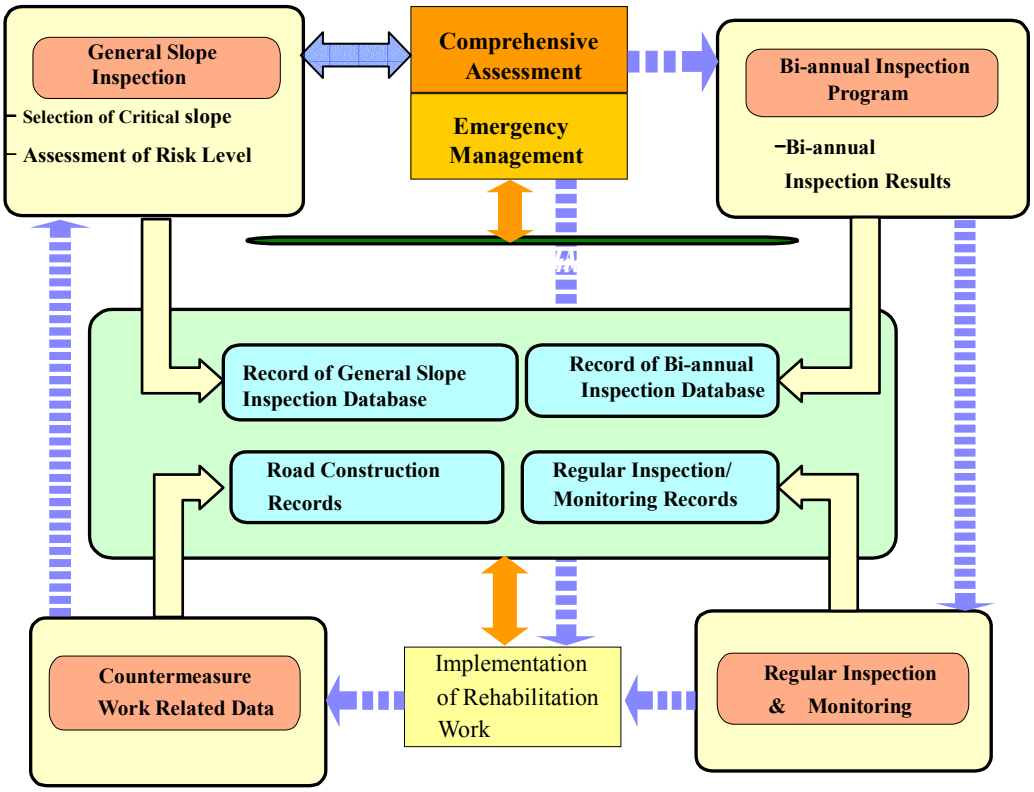

Figure 1.2 Proposed System of Road Slope Disaster Management

Basic components for Road Slope Disaster Managementare listed in the Table below.

Table 1.1: Basic Components of Road Disaster Management

Basic Component	Description
General Slope Inspection: Carried out jointly by Geo-Environment Unit (GEU), DOR and Division Road Office (DRO) (for first time)	- Selection of Critical Slope Section - Assessment of the Slope Failure Hazard - Assessment of Consequence of the Slope Failure - Assessment of Risk Level of the Slope Failure - Annual Implementation Planning of Countermeasure Works (with Priority) - Formulation of Short, Medium, and Long- Term Plan
Comprehensive Risk Assessment: Evaluated by Maintenance Branch (MB) & Design and Planning Branch/GEU in DOR	- Prioritisation of Critical Slopes - Planning Improvement of Organisation for Disaster Management
Emergency (or Crisis) Management: Coordinated by DOR Head Office, Regional Directorate and executed by DRO with support from Heavy Equipment Division (HED)	- Emergency Response Plan - Crisis Management Organisation - Reporting/ Communication System - Co-ordination/ Cooperation with Other Related Agency - Logistics for Emergency Road Opening Work - Training for Emergency Management - Traffic Management - Information to Road Users
Regular Inspection and Monitoring Data kept in DRO	- Regular Inspection to Check Road Condition - Monitoring for Critical Slope - Execution of Routine Maintenance
Bi-annual Inspection Carried out by DRO and Data Forwarded to MB	- Update the Slope Record - Re- evaluate the Risk Level - Plan Countermeasure Works
Implementation of Rehabilitation Work Data of Implemented Countermeasure Works Forwarded to MB	- Site Investigation and Design of Countermeasure Works - Implementation of Countermeasure Works - Records of implemented Countermeasure
Data Base of Road Disaster Management Preparedby DRO and MB	- Record of General Inspection - Record of Bi-annual Inspection - Record of Regular Inspection - Record of Road Construction / Rehabilitation - Record of Historical Disasters

1.2 General Slope Inspection

General Slope Inspection consists of following three stages, which are discussed below.

1.2.1 Selection of Critical Slope Section

The DRO selects critical slope sections on the basis of followings;

a) High frequency of disaster (every year)
b) Active deformations on the slopes/ roads
c) High probability of slope disaster (geological setting of the slope)

Selected critical slopes shall be recorded in the inspection sheet indicating the location in available topographical map (1:25,000).

1.2.2 General Inspection of Critical Slopes

General Inspection of selected critical slopes shall be carried out and details are filled in the following record sheets and a copy of which shall be forwarded to the Maintenance Branch, DOR.

a) General Information of the Road Section with Location on topographical map (1:25,000); Form A
b) General Sketch of the Road Section; Form B
c) Photograph; Form C
d) Slope Feature, Form D
e) Slope Hazard Assessment; Form E
f) Consequence/ Risk Level Assessment; Form F

The above mentioned standard forms are given in the Appendix.

1.2.3 Implementation Planning

The Maintenance Branch finalizes the implementation plan on the basis of information provided by DRO through the General Inspection.

Table 1.2: Framework of Implementation Plan

Time Frame	Time Period	Slope Criteria	Note
a) Emergency Plan	To be implemented urgently (from budget for Emergency works)	Evaluated as Risk Level I on highly important road sections	To be treated as urgent repair work
b) Short term Plan	Within 1 to 2 years	Rated as Risk Level I on important road	Budget & improvement of organisation should be planned
c) Medium-term Plan	Within 3 to 5 years	Master Plan for Strategic Road Network	
d) Long-term Plan	Within 6 to 10 years		

1.3 RISK ASSESSMENT

1.3.1 General Flow of Risk Assessment

Figure 1.3 shows the workflow for road slope disaster management, which consists of three stages as mentioned in the section 1.2

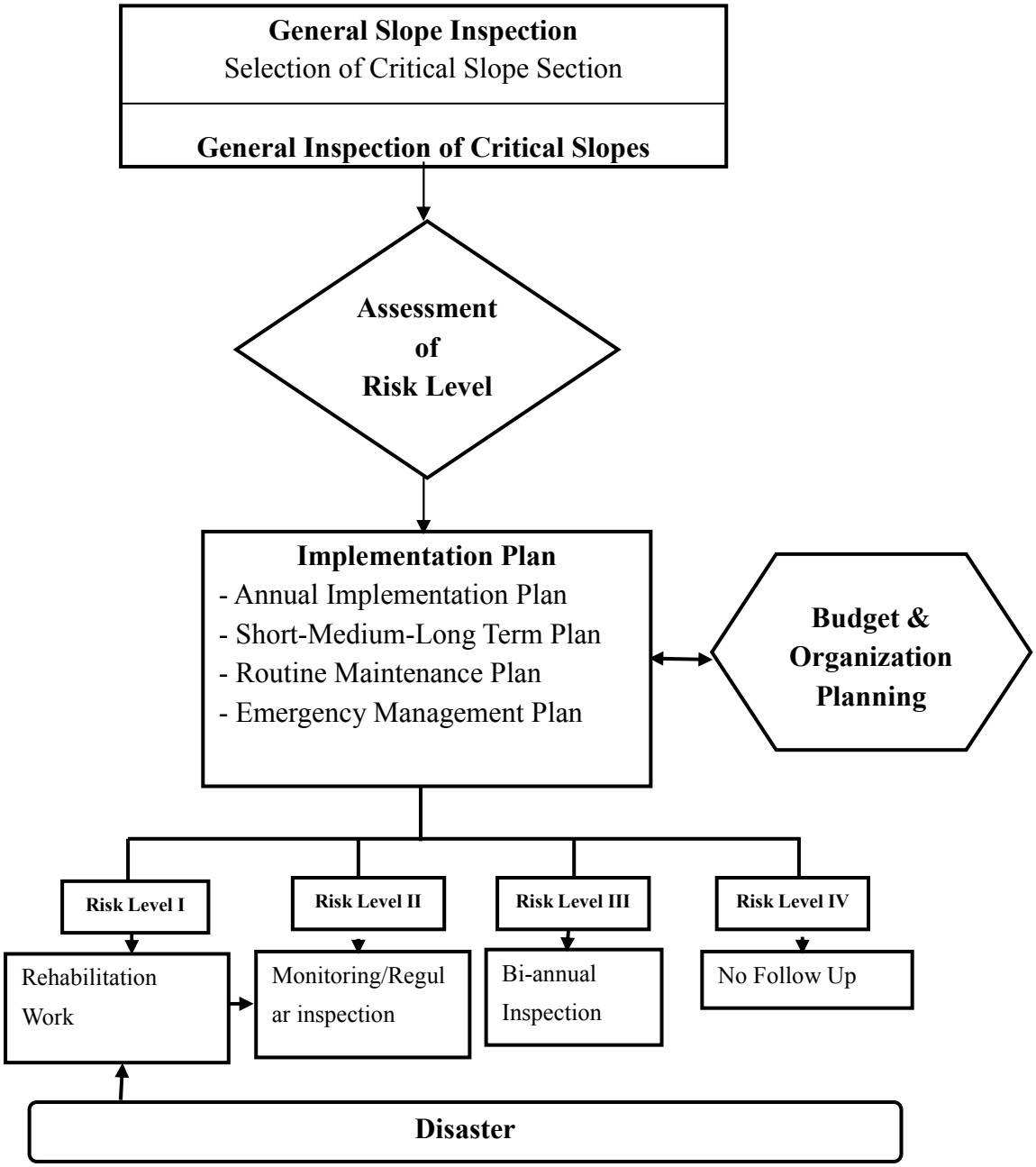

Figure 1.3: General Flow of Risk Assessment

1.3.2 Slope Hazard Assessment

The assessment of Landslides, Debris Flow and Embankment Failure is carried out considering the hazard level and topographic conditions. Hazard levels are defined as A, B and C to reflect its level from highest to lowest.

(1) Landslide

Hazard Level	Conditions
High (A)	- A large number of clear deformations such as scarps, bulges, side cracks, and - Visible movements of cracks, subsidence, upheaval, and toe erosion.
Medium (B)	- Obvious landslidetopography such as bulge, stepped land, but - No visible movement is found
Low (C)	- Suspicious landslide topography , but no evidence of deformation at present

(2) Debris Flow

Hazard Level	Conditions
High (A)	Frequent Occurrence: Within every two years
Medium (B)	Periodical Occurrences: Over five years
Low (C)	Traces of collapses are in the source area, but Debris flow occurrence is rare

(3) Embankment Failure

Hazard Level	Conditions
High (A)	- Frequent occurrence of slope failures disturbing traffic operation - Visible deformations such as tension crack and settlement
Medium (B)	- Periodical occurrence but traffic operation is normal - Visible deformations such as tension crack or settlement
Low (C)	- No repair work is required in structures, drainages, and vegetation - No deformations in the slope

1.33 Assessment of Consequence of Slope Failure

Consequence of the Road Slope Failure is assessed on the basis of criteria mentioned in the table below. Consequence effects are also categorized in three different levels as High, Medium and Low depending upon the consequence of slope failures on mainly four criteria. In case of different consequences levels in different criteria the highest shall govern for assessing the risk level. Criteria for assessment of consequence of slope failures are not limited but may vary for different road sections depending upon their importance.

Table1.3: Assessment of Consequences

Criteria \ Consequences	High a	Medium b	Low c
1) AADT (A)	A≧800	150≦A ＜800	A＜150
2) Public Asset	Very Important	Important	Less Important
3) Number of Private House (H)	H≧10	3＜H≦10	H＜3
4) Time for Reopening (P-days)	P≧3	1＜P≦3	P＜1

1.3.4 Assessment of Risk Level

Slope Hazard of the road sections and its consequence shall be evaluated by means of qualitative and semi-quantitative criteria. Risk Levels are classified into four levels; Level-I, Level-II, Level-III and Level-IV as shown in the Table 1.4 . The risk level assessment is proposed to be evaluated on the basis of the combination of the slope hazard level and its consequences as shown in the Table 1.5.

Table 1.4: Assessment of Risk Level

Risk Assessment		Consequence of the Slope Failure		
		a	b	c
Slope Hazard Level	A	I	I	II
	B	I	II	III
	C	II	III	IV

Table 1.5: Risk Level and Suggested Actions

Risk Level	Combination	Action
I	Aa, Ab, Ba	Implementation of Countermeasures (1st Priority)
II	Ac, Bb, Ca	Monitoring (monitoring by measurement of landmass movement and/or regular inspection)
III	Bc, Cb	Bi-annual Inspection (before and after monsoon)
IV	Cc	No more follow-up until some changes occur

Proposed combination of Slope Hazard and its Consequence to determine the Risk Level is flexible and could be changed depending upon available resources and strategy.

14 Road Slope Inspection

Road Slope Inspection is defined as the normal inspection carried out by DROs focussing on slope stability. Following three types of slope inspection are proposed;

(1) Regular Slope Inspection,
(2) Bi-annual Slope Inspection, and
(3) Emergency Slope Inspection.

Slope inspection shall include the filling in new or updating of Road Slope Inspection Sheets as well as recording of the following Slope Inspection Record Forms.

a) Inspection Record; Form R-A
b) Disaster Record; Form R-B
c) Countermeasure Record; Form R-C
d) Inspection Summary: Form R-D
e) Disaster Summary; Form R-E
f) Countermeasure Summary: Form R-F
g) Road Closure Record; Form R- E

The above mentioned standard recording forms are given in the Appendix.

1.4.1 Regular Slope Inspection

The frequency of Regular Slope Inspection is recommended minimum once a month, in general. It may be adjusted in accordance with slope conditions, traffic volume, important structures and social conditions. This Inspection is carried out in order to assess the slope stability and to initiate suitable action for prevention of slope failure disasters. The scope of Regular Slope Inspection is as follows;

1) To check the road conditions for smooth traffic operation (risk of possible traffic obstruction, particularly by stones/rock fragments or debris from hill slope)
2) To check the condition of road structures, pavements, shoulders, drainage, walls, and vegetation works.
3) To check condition on the road or in the adjacent area which are likely to affect the road traffic or slope stability.
4) To take necessary emergency action, in case any urgent event is identified
5) When any damage or unusual state is found with road structure during inspection, it should be carefully observed and recorded for reporting and further follow-up.

14.2 Bi-annual Slope Inspection

The scope of Bi-annual Slope Inspection shall include:

1) The interval of Bi-annual Slope Inspection is recommended two times in a year (before and after monsoon season).
2) The purpose of Bi-annual Slope Inspection is to check the slope conditions in detail (before monsoon) and to assess the damage and deterioration of each road structures (after monsoon).
3) When the Inspector finds indication of hazard in a slope, it shall be recorded and reported to DRO and Maintenance Branch in DOR and concerned agencies.
4) Bi-annual Slope Inspection shall focus mainly;
   a) The slopes identified as of Risk Level I, II and III during the General Inspection

b) Inspection shall be made basically by visual observation of the slope, as well as other road features including vegetation, slope surface works, drainage (on-slope), wall and fence at toe, and
c) Pavement, drainage (roadside), shoulders, culvert, which are located adjacent to the slope as well as riverside structures.

5) During the inspection, careful attention should be paid to the Deformation/ Settlement/ Erosion / Scouring/ Rock Fall/ Debris/ Cracks/ Pavement and Road Structures.
6) Generally, inspection shall be made on foot covering the slope area.
7) The Standard Slope Inspection Forms shall be filled and recorded as a part of slope database.
8) Engineers and technicians of the respective DRO shall carry out the inspection and prepare the slope data records

1.4.3 Emergency Slope Inspection

Emergency Slope Inspection shall be carried out after the event of Disaster or very high intensity rainfall in the vicinity. The objective of this inspection is to make proper planning and decision for disaster prevention as well as restoration of traffic operation. Inspection shall be made basically on the following locations.

a) Sections which are prone to recurrent disaster
b) Selected slopes evaluated as Risk Level I and II. Advance planning for Disaster Management is advised for highly risky road sections.

Information on the slopes that collected during Emergency Slope Inspection shall be immediately reported to the DRO and Maintenance Branch in DOR. Necessary emergency action should be taken without delay depending upon the extent of Slope Failure/ Disaster.

14.4 Points to be Considered for Slope Inspection

The following points should be considered while preparing for slope inspection and reporting in order to carry out effective management of a slope disaster.

1) Engineers and Technicians involved in the slope inspection should thoroughly check the general slope inspection and its updated reports. During the inspection they should also carry the copy of past records.
2) Location and Status of critical slopeswith Risk Level I & II should be given higher priority.
3) Any indication of slope failure that observed during inspection are to be immediately reported to concerned agencies.
4) Standard slope inspection forms with the following information should be prepared for reporting;
   a) Location Map

b) Sketches of the Site (plan & sections)
c) Photographs
d) Concept of Proposed Repair or Rehabilitation Works

Points to be considered for General, Regular, Bi-annual and Emergency slope inspection are also presented in Table 1.6.

Table 1.6: Points for Observation and Recording

Position	Structure	Points for Observation and Recording
On-Road	Pavement	Depression, longitudinal or transversal cracks or any defects? (New or progressing?)
		Fallen rocks or debris on the road from hill slope?
	Shoulder	Depression, opened cracks or any defects? (New or progressing?)
Road Side	Drain & Culvert	Drainage obstruction due to blockade or broken by fallen rocks, debris and/or any defects?
	Wall	Fallen material in pocket, breakage, deformation, cracks, tilting, depression, inadequate interlocking, or any defects?
On- Slope	Slope	Rock fall or slope failure: (new or progressing?)
		Depression, swelling, opened cracks, or any defects? (new or progressing?)
		Marked erosion of Gully type (new or progressing ?)
		Spring water or running water on slope or in drains:(any change in discharge and turbidity?)
		Fallen tree or tilting trees on the slope (new or progressing?)
	Slope Works	Breaking, deformation, cracks, tilting, depression, or any defects? (new or progressing?)
River Side	River Protection	River scouring (new or progressing?) Protection works (in sound conditions?)

Training programs shall be arranged in advance for the inspection procedure and recording the slope data.

15 Recording System of Slope Inspection and Maintenance

1.5.1 Importance of Records

Recording and reporting on the slope inspection and maintenance work is an essential procedure in the slope disaster management. The importance of which are;

1) The information collected during Slope Inspection and Maintenance is useful in identifying on-coming slope failure in the near future. In such a situation, suitable action could be taken as soon as possible in order to prevent occurrence of slope disaster that may cause damage to the road traffic and facilities
2) Records and information on the condition of slopes and applied countermeasures are useful to successor staff in DROs for continuity of maintenance activities.
3) Historical records of disaster occurrences and countermeasure implementation provide useful information to prepare further effective and efficient slope management plan.

15.2 Slope Related Database

For planning of Slope Disaster Management the slope related database such as records on slope inspection, disaster occurrences, and countermeasure implementation to be collected and updated by the DROs as well as Maintenance Branch, DOR as shown in Table 1.7

Table 1.7: Slope Related Database

Description of Database		Responsible Organization
Slope Inspection Record	General Slope Inspection	DRO and Maintenance Branch, DOR
	Regular Inspection Record	Once a month in general; Relevant Standard Forms can be used.(DRO)
	Bi-annual Inspection Record	Two times in a year; before & after Monsoon (DRO)
	Emergency Slope Inspection Record	At the time of emergency Relevant Standard Forms shall be used (DRO)
Monitoring Record	Rainfall data	Annual Rainfall data, Rainfall data related with big scale disasters, (DRO)
	Instrument measurement data of mass movement	Any kind of monitoring records for slope (DRO)
Relevant Slope Management Records	Topographical Maps Soil Investigation Report Countermeasure Works	(DRO)

15.3 Format for Slope Recording Sheet

The Standard formats of recording and summary sheet for slope inspection and maintenance are listed in Table 1.8 and attached in the Appendix.

Table 18: Standard Formats

Description of Standard Formats		Note
Recording Sheet	**Slope Inspection Record**	Distinct findings thatlikely to lead slope instability shall be recorded.
	Slope Disaster Record	Slope failures affecting road/ traffic operation shall be recorded.
	Slope Countermeasure Record	All types of countermeasures that applied in slopes shall be recorded.
Summary Sheet	**Slope Inspection Summary**	Lists of all inspected slopes shall be recorded.
	Slope Disaster Summary	List of Slope disasters shall be recorded.
	Slope Countermeasure Summary	List of all slope countermeasures shall be recorded.

16 Road Maintenance

Road maintenance is a continuous process to keep the road in safe and in good conditions. Following three **"R"** are most important practices to observe

a) Record correctly on the Regular Inspection
b) Report quickly to DRO and Maintenance Branch in DOR when found any abnormality
c) Respondimmediately to the matters to be treated

The following activities are important for road maintenance purpose. The details on maintenance of On-Road, Road Side Support and Bridges according to their types such as Routine, Recurrent and Preventive maintenance are described in the DOR Manual **"Road Maintenance Manual for Engineers and Overseers, 2055"** which covers mainly;

1. Materials on the Roads
   If fallen material from hillside slope such as soil, boulder and trees are found, they shall be removed to suitable disposal place.

2. Maintenance of Drainage System
   It is required that the drainage systems on roadside as well as off-road drains shall be kept functioning. If the drainage system is found damaged or clogged, it shall be repaired or cleaned at earliest possible time.

3. Retaining Walls
   Masonry and concrete retaining walls have weep holes for water drain. In some cases, plants grow in the weep holes and block the drainage function of the wall. These weep holes shall be cleaned from time to time.

4. Gabion Wall

   As life of wire is considered to be 15-20years in general, it is necessary to check the condition of the wire. In case of failure of gabion wall suitable repair measures and or structures shall be considered.

5. Gully Erosion

   To prevent the gully erosion, following measures can be applied depending upon the site condition.
   - Construction of catch-drain
   - Construction of channel drain at embankment
   - Turfing
   - Stone riprap
   - Channel drain at outer boundary of shoulder

6. Bio- Engineering

   Maintenance of Bio –engineering works includes;
   - Thinning trees and shrubs
   - Pruning plants
   - Repair vegetative structures such as Palisades, Facine, Brush Layering and Turf
   - Vegetation enrichment
   - Removal of following trees;
     - Unwanted shrubs and trees,
     - Dead trees or those trees, which may fall down themselves,
     - Tree obstructing the traffic or driver's line of sight,
     - Trees surcharging the steep slope,
     - Trees thatneeded to be removed for widening of road.

If season is appropriate and land is fertile, grass seeding can be done to protect the slope surface erosion. Turfing and plantation of suitable species of grass, shrubs, trees, bamboo and other vegetation can be used to control the surface erosion as well as protection of slopes. Growth of Grass, Tree and Bamboos used in bioengineering may also result in obstruction for road traffic and driver's line of sight leading to traffic accidents. Therefore, it is necessary to prune the trees and mow the grasses in regular basis as maintenance work.

Selection of suitable species of plants, grasses, grass seeds, and plantation season with details of maintenance activities are described in "Road Side Bio- Engineering Reference Manual , "Road Side Bio-Engineering Site Hand Book and other relevant documents published by Geo-Environment Unit, DOR.

7. River Bank Protection
   It is important to check the effectiveness of structures in river control and bank protection works. If damages are found it should be immediately reported for the necessary remedial action.

8) Small scale landslides to be treated by;
   - Reshaping to decrease the slope angle
   - Removing the soil mass and dumping it at appropriate place
   - Implementing suitable drainage and retaining structures such as Dry Stone Masonry, Gabion, Cement Masonry and Cribwork.

1.6.1 Road Slope Maintenance

Protection and maintenance work in road corridor and its vicinity are called "Road Side Support Maintenance . Under this category, the protection and maintenance work for road slopes and structures are such as culverts, retaining walls, drain systems, vegetation and river control works.

Road slope maintenance plays important role in the overall road maintenance works. Routine slope maintenance and implementation of preventive countermeasures are most effective for avoiding the possible slope disasters. However, implementation of preventive countermeasures demands much budgetary funding to meet all the requirements. Thus the significance of routine slope maintenance work should be given highest priority.

16.2 Necessity for Slope Maintenance

Slopes differ from road structures that are made of artificial material, soil, concrete, or bitumen. Slopes consist of natural materials, soil and rocks, which have many uncontrollable factors. Slope stability is subject to many factors such as, topography, geological structure, type of rocks and soils, grade of weathering, surface and ground water conditions, effectiveness of protection work, rainfall, and earthquakes. In due course of time various natural and artificial factors contribute to road slope instability despite of proper design and implementation during construction stage. Major natural and artificial factors are;

1) Weathering effect
   Weathering effect is the deterioration of strength and other properties of rocks, soils, and slope protection works in due course of time after completion of construction. Even after several years of road construction and its successful operation, slope failures could occur due to weathering effect due to factors, which may not have been possible to foresee during the construction phase.

2) Effect of Rainfall

High intensity rainfall is most influential for slope instability in this country. Similarly prolonged rainfall during monsoon period weakens the shear resistance of soil, increases pore water pressure at the slip surface and weight of the groundmass resulting in slope failures.

3) Artificial Factors

Road Encroachment, Irrigation System, De-forestation, Uncontrolled Quarrying and Construction of Access Roads are among the major artificial factors contributing instabilities in the road slopes.

As many Natural and Artificial factors influence change in the road slope stability conditions, it is very difficult to predict and assess the stability of slope at the time of its design and construction. A continuous monitoring of road slopes and their timely maintenance are therefore indispensable.