6. IMMEDIATE CATCHMENT AREA MANAGEMENT PLAN

6.1 GENERAL CONSIDERATIONS FOR MITIGATION PLANNING

Generally, moderate to steep slopes with fragile rocks or thick soil masses are prone to slope failure, especially during monsoon season. Various types of slope failures such as landslide, debris flow and embankment failures occur frequently along river banks and newly excavated project sites. In general, following points have been considered during planning and selection of the slope protection works.

- Selection of mitigation measures for slope failures are based on clear understanding of failure conditions like topography, geology, vegetation, failure type and its mechanism, scale of failure and others.
- Water management has been considered as an essential factor in controlling slope instability. Quick and effective drainage of surface and spring water and lowering of water table are the basic methods for stabilizing slopes.
- In most cases, earth work comprising of cutting unstable portion of a slope at crown and filling at the toe can stabilize the slope.
- Combination of water management and earthworks has been considered as primary control measures.
- Restrain measures such as retaining wall and structure like gabion wall and stone masonry are applicable when failure is small and or when the landslide movement is slow.
- As bioengineering techniques contributes to reduction of negative environmental impact its application has been considered in slope failures.

6.2 MITIGATION MEASURES PLANNING PROCEDURE

The slope protection planning procedure has been divided into five stages: Field Observation; Assessment of disaster for preliminary mitigation measures planning, Field investigation; Stability analysis and Selection of mitigation measures. A flow chart for mitigation, measures planning procedure is given in Figure 6-1.

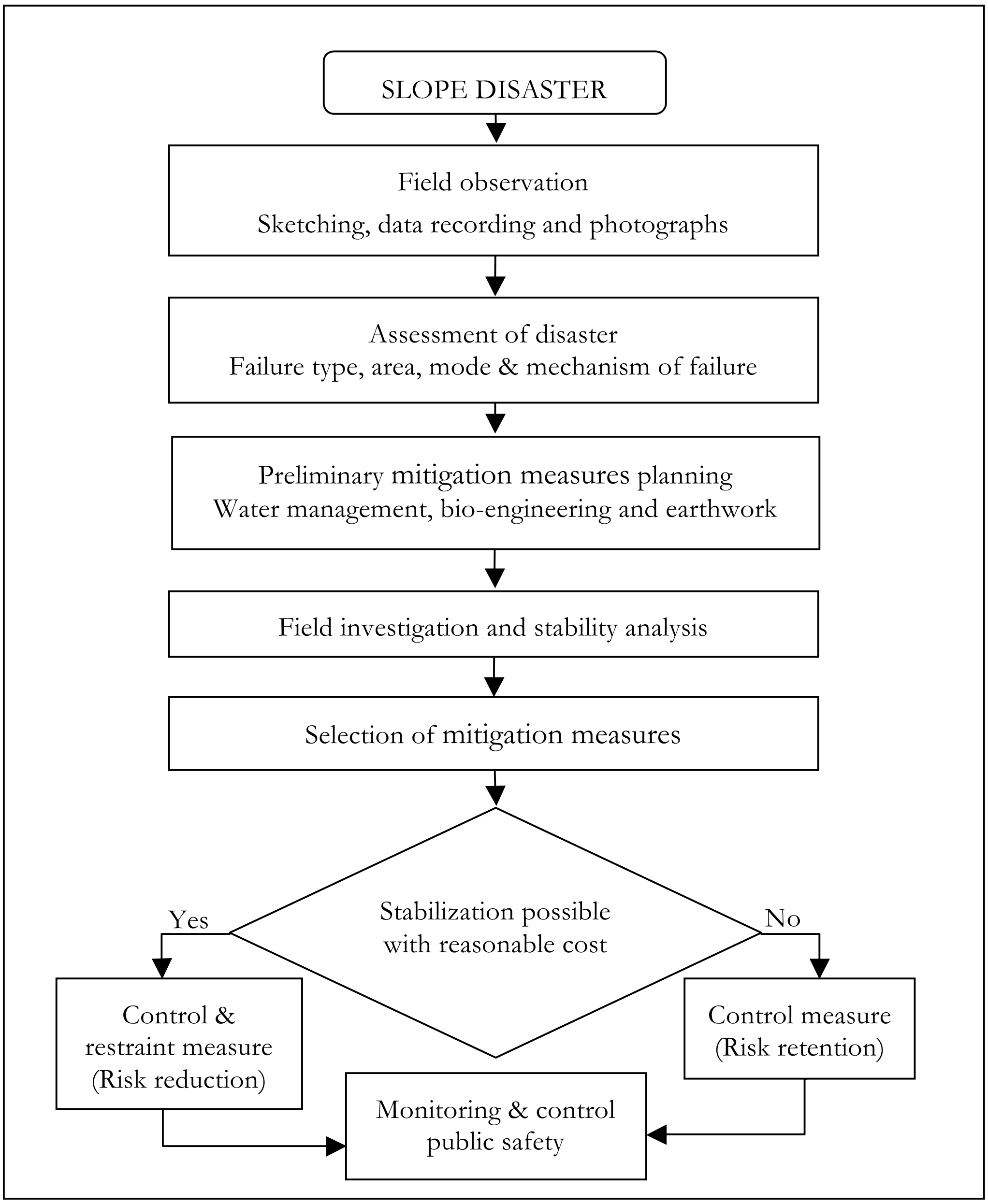

Figure 6-1: Flow chart, mitigation measures planning procedure

6.2.1 *Field Observation*

Field observations by an experienced geologist for assessment of types of slope failures, its mechanism and scale are required for planning initial mitigation measures. According to Japanese classification, slope failure are classified into the following six types considering their mode of failure and mechanism. Collapse (CL), Rock Fall (RF), Rock Mass Failure (RM), Landslide (LS), Debris Flow (DF) an Embankment Failure (EF).

Schematic illustration of types of slope failure with characteristic features is given in Appendix B. This adopted classification is also recommended for the study of slope failures in Nepal (GoN, 2003). At initial stages, landsat imagery is useful for understanding the general condition of the failures, especially for large scale landslides and debris flows.

6.2.2 *Disaster Assessment*

An understanding of conditions of disaster, its mechanism to be made by examining its failure type, nature, scales and deformation level at the site. At this stage, preliminary

mitigation measures planning carried out based on mechanism of disaster. Judgment of the destruction level and public safety should be analyzed.

6.2.3 Preliminary Mitigation Measures Planning

Preliminary mitigation measures planning should be based on field observation and early assessment of disaster and including study of surface drainage, earthworks and bioengineering. These are most important and effective to improve the stability of slope. They have been recommended for each studied landslides. Especially, draining out of surface, spring and groundwater are effective methods for stabilizing the slopes.

6.2.4 Field Investigation and Stability Analysis

For complex and large scale landslides detailed field investigations and stability analyses should be carried out to clarify the mechanism and scale of the land sliding. Reasonable restrain measures and rehabilitation plans can be made from these detailed investigations and stability analyses. In PMP area, six large and complex landslides have been identified. These landslides are: Bangabagar, Dethala, Gokuleshwor, Osap, Panjuniya (Jamari) and Chamtari. They all are large landslides and will endanger public assets, settlements, etc.

6.2.5 Selection of Mitigation Measures

Selection of mitigation measures have based on the following two approaches:

Risk Reduction

The risk reduction (restraint) measures shall be carried out to prevent the recurrence of the slope failure. The restraint works to include mainly retaining structures, anchoring, piling and other slope protection works.

Risk Retention

The risk retention (control) measure shall be carried out to improve the slope stability. It comprises execution of earth works, water management and bioengineering work. Earthworks and drainages are essential for improving slope stability.

6.3 MITIGATION MEASURES FOR STABILIZING EXISTING LANDSLIDES

Mitigation measures for slope failure are classified into two categories and seven groups depending upon its purpose and application. A suitable combination of these measures to be applied after assessment of slope failure and its mechanism, importance of the assets to be protected and the cost – effectiveness. General categories and groups of counter measures recommended for stabilization of slope failure are listed in the Table 6-1.

Table 6-1: Types of mitigation measures recommended for stabilization of slope failures

Category	Group
Mitigation measures	*Earthworks:* Cutting and filling *Bioengineering:* Various methods of vegetation and small scale engineering work in the slope and its vicinity *Water management:* Surface an sub-surface drainage
Restraint measures	*Slope work:* Stone pitching, frame work *Anchoring:* Rock bolt, Nailing and ground anchor *Walls and resisting structures:* Gabion, stone masonry, frame wall etc *Protection work:* Rock netting, check dam

All slopes are vulnerable for slope failure, that may be caused by gravity action, rise in pore water pressure during heavy rain and/or earthquake. Application of "Mitigation Measures" to be provide at the initial stages of slope failure. Restraint measures are considered as additional measures. General characteristic of civil engineering and bioengineering techniques commonly applied for slope stabilization are presented in Appendix B. Initial

mitigation measures have been worked out for all 35 studied landslides developed in Reservoir area. Sketches and photographs with mitigation measures are presented in Appendix B.

6.4 IMPACT RELATED MITIGATION MEASURES

Five major geological environmental impacts have been identified in the PHD. They are soil erosion in hill slopes, enhancement of sliding in existing landslide sites, occurrence of new slides in critical area, downstream river bank erosion and reservoir induced seismicity. In order to minimize the impacts, the followings mitigation measures have been planned corresponding to each impacts.

6.4.1 Soil Erosion in Hill Slopes

The project area experiences heavy precipitation (> 1,500 mm/year), which induces flash runoff along the fragile slopes, creates rill, gully and sheet erosion. These erosions will be enhanced by site clearance activities during construction of project facilities, access, haul and service roads. The following mitigation measures have been recommended to minimize the soil erosion in hill slopes:

- Vegetation clearance should be minimized;
- Off-site vegetation should be protected to control erosion;
- Barren area around the project site should be re-vegetated;
- Top soil should be stockpiled at a suitable place for reuse;
- During construction of access, haul and service roads cut and fill principle should be adopted;
- Road drainage plan should contain the side drain, cross drain and drainage outlet;
- Along the road corridor, up-slope, down slope and unstable areas should be protected;
- Spoil should not be stockpiled at construction sites, but transported to final disposal sites. Site – casting should be strictly prohibited;
- Cut and fill batters should be rehabilitated through bio-engineering and
- River and stream crossings of the road should be controlled by gabions, bank protection and bio-engineering.

6.4.2 Enhancement of Sliding in Existing Landslides

Recent visit to the project site reveals 34 active landslides along the river banks of Chameliya and the left bank of Mahakali River.

During construction activities like site clearance, drilling and blasting, formation of reservoir, the land sliding will be enhanced in these sites. Slope stabilization works are essential in all recorded slides, especially in six larger ones where nearby settlements are in danger. Depending on site conditions suitable combinations of civil engineering mitigation measures with bioengineering measures are essential for slope stabilization.

Drainage management of is often very important for control of landslides. So, the surface, near surface or deep sub-surface drainage is proposed to control the moisture content at the site. To improve shearing resistance of soil or rock mass retaining walls or anchor bolts/dowels to be applied. Slope modification to be made by trimming or cutting the heads and filling the toes as necessary. Surface erosion to be controlled by bioengineering. In addition to structural, drainage and bioengineering measures, certain bare soil surfaces within landslides needed immediate surface strengthening to prevent sheet, rill and gully erosion. In such areas, depending on supports availability, light surface non-structural measures like stone pitching; stone arches and riprap channels to be applied. Applicability of different mitigation measures to particular slope failure is given in control monitoring

Table 6-2: Applicability of mitigation measures in different types of slope failures

Category / group		Mitigation measures works		Slope failures					
				LS	CL	EF	DF	RF	RM
CONTROL MEASURES	Earthwork	Earthwork	Removable of top	O	O	×	O	O	O
			Rock cutting	O	O	×	O	O	O
			Soil cutting	O	O	×	O	×	×
			Filling at Toe	O	O	O	*	*	*
	Bioengineering	Vegetation	Re-vegetation	*	O	O	O	×	×
			Vegetative structure	*	O	O	O	×	×
	Water management	Surface drainage	Drain ditch	O	O	O	*	O	O
			Cascade	O	O	O	*	O	O
			Culverts	*	*	O	O	O	O
		Subsurface drainage	Horizontal drill hole drain	O	O	O	*	O	O
			Sub-surface drains	O	O	O	×	O	O
RESTRAINT MEASURES	Slope work	Shotcrete work	Shotcrete (Mortar)	×	O	×	O	O	O
			Shotcrete (Concrete)	×	O	×	O	O	O
		Frame work	Frame work (Precast/insitu)	*	*	O	×	O	*
		Pitching	Stone pitching	×	O	O	×	×	×
	Anchoring	Anchoring	Soil nail	*	O	O	*	×	×
			Rock bolt	O	O	×	*	×	O
			Ground anchor	O	O	×	*	×	O
	Wall and resisting structures	Retaining wall	Stone masonry wall	O	O	O	*	*	O
			Composite wall	O	O	O	*	O	O
			Frame wall	O	O	O	*	O	O
			Gabion wall	O	O	O	O	O	*
			Crib wall	O	O	O	O	×	×
		Series of retaining wall**	Gabion wall	O	×	O	*	*	*
			Stone masonry wall	O	×	O	*	*	*
			Composite wall	O	×	O	*	*	*
		Catch wall	Gabion wall	×	*	×	O	O	*
			Concrete wall	×	*	×	*	O	*
	Protection work	Protection work	Rock netting	×	*	×	×	O	×
		Check dam	Check dam (Sabo dam)	O	×	×	O	O	O

Note:

O:	Applicable	*:	Limited case	×:	Not Applicable
LS:	Landslide	CL:	Collapse	EF:	Embankment failure
DF:	Debris flow	RF:	Rock fall	RM:	Rock mass failure

** Series of retaining wall refers to multiple walls along cross section

6.4.3 Occurrences of New Landslides

In the zone of weak rock-masse or thick soil with steep to moderate slope, new landslides can occur due to drilling and blasting during construction and pit excavations at quarry and borrow sites. Also due to damming of Mahakali River, water table will rise at dam site and nearby reservoir areas. The water pressure will rise and saturate the soil and rock masses, consequently, reducing their shearing resistance and resulting in new landslides. So, regular monitoring of construction sites during construction phase and reservoir rim line during

operation phase is essential. Same mitigation measures as applied for stabilizing the existing landslides will be also applied for new landslides. To control shoreline erosion of reservoir, site brush layering fascines or other bioengineering techniques will be applied.

6.4.4 *Downstream Bank Erosion*

Fluctuation in peaking flows downstream of the dam site could cause riverbank erosion and bank failures. Depending on site conditions, different river bank protection works including gabion walls, retaining walls, revetments and spurs with the integration of bioengineering are recommended in order to control the riverbank erosion.

6.4.5 *Rise in Seismicity*

It is generally agreed that a reservoir is only triggering the release of natural tectonic strain and is not itself generating the principal seismic energy. Only when a perturbing phenomenon is introduced, such as a large reservoir, the breaking strength is locally exceeded. It has been suggested that the reservoir induced seismic events can be held to minimum if a reservoir is filled slowly and smoothly based on experience at Nurek Dam USSR (Clarence, 1982). So, it is generally recommended that some sort of seismographic network be established around new large deep reservoirs to clarify the following:

- Particularly for low magnitude earthquakes, only through instrumental recording it can be possible whether or not reservoir induced events have been preceded by numerous small ones.
- If reservoir induced earthquakes can be partly controlled by the manner in which the reservoir is filled, a reasonably sophisticated network is mandatory to plan operations and to monitor the progress in reservoir filling.
- The public living near and downstream from major dams will inevitably be concerned about earthquake in the vicinity, whether or not reservoir induced and a seismographic network is the only realistic means for providing prompt, forthright and accurate results.

6.5 CONTROL MONITORING

After implementation control measures, suitable monitoring plans should be made to secure the suitability of the mitigation measures. Attention should be paid during regular and bi-annual inspection of slope instability. The data used for design, records of field inspection, history of damages, repair works and stabilization works shall be complied and preserved for use in future design, maintenance and preventive works.

6.6 BIO-ENGINEERING TECHNIQUES

The bio-engineering techniques are relatively cheap to apply. The materials are locally available and cost less. According to Shrestha et al. (1998), the bio-engineering techniques appropriate for Nepal include: Planted grass lines: contour, down slope, diagonal and random; grass seeding; turfing; shrub and tree planting and seeding, large bamboo planting; brush layering; palisades; live check dams; fascines; vegetated stone pitching and jute netting in standard mesh or wide mesh. A brief description of bio-engineering mitigation techniques is given in Appendix E. Selection of individual bio-engineering techniques and their implementation should be made according to the principles and guidelines mentioned in the works of Geo-Environmental Units (1996, 1997) and Howell (1999), Department of Roads if not mentioned otherwise.

6.7 CIVIL ENGINEERING TECHNIQUES

The civil engineering structures are relatively expensive and will be applied in critical sites where protection is essential and bio-engineering techniques are less effective. The total cost of stabilization and mitigation of the nine medium-size and medium complex landslide

along Araniko Highway was about NRs 37 million (Adhikari, 2000). Standard Civil Engineering measures applicable for stabilization of slopes include:

1. Water management and drainage measures: catch drains, rip-rap channels; French drains and drilled horizontal drains;
2. Structural support measures: Retaining walls: Gabion, stone masonry; Anchored structures: Rock bolts, earth/rock anchors,
3. Surface treatment measures: stone pitching in addition to bio-engineering measures, thin gabion mattresses, stone arches, riprap channels, River bank protection: Revetments, spurs, launch aprons.
4. A brief description of standard civil engineering measures for stabilization of landslides is given in Appendix B. Before, designing the civil engineering measures at complex and large landslides, it is highly recommended to carry out detailed investigation including topographical survey, engineering geological survey, geophysical and geo-technical investigation and clearly understand the surface and sub-surface geological condition of the particular site.

A brief summary of impact related mitigation measures is given below in Table 6-3.

Table 6-3: Geological impacts and related mitigation measures

S N	Impacts	Mitigation measures
1	Soil erosion in hills slopes	• Control in de-vegetation along the hill slopes • No disturbances to stable slopes in critical areas • Application of engineering and bioengineering measures whenever required • Plantation in barren lands
2	Controlling of sliding in existing landslides	• No disturbances to stable slopes with dormant landslide • Control de-vegetation along the slopes • Regular monitoring of the existing landslides • Application of engineering and bioengineering measure to control the sliding
3	Reservoir rim instabilities	• Control de-vegetation along the reservoir rim • Prohibition of habitation near the rim area • Regular inspection of bank erosion(slope stability) along the rim area • Application of bioengineering and civil engineering works wherever required
4	Downstream river bank instabilities	• Regular observation of bank stability in down stream • Application of civil engineering or bioengineering measures wherever required • Control de-vegetation along the banks and adjoining hill slopes
5	Reservoir induced seismicity (RIS)	• Control rapid infilling of the reservoir • Control rapid fluctuation in water level of the reservoir • Application of comprehensive seismic monitoring program to investigate likely RIS after the impoundment of the reservoir

6.8 IMPLEMENTATION PLAN

The implementation of slope protection measures will be carried out during the project construction and operation phases. Most of the proposed mitigation measures are considered to be the civil engineering or bioengineering or both. At the very beginning of the construction phase, all the existing active landslides developed in reservoir rim area will be stabilized by applying site-specific civil engineering and bio-engineering mitigation measures. Plantation in barren lands will be completed to control the soil erosion. Regular

inspection of reservoir rim area, existing landslides, critical hill slopes, and construction sites will be made and site-specific mitigation measures will be undertaken. Reservoir induced Seismicity will be analyzed in relation to reservoir. Regular inspection will also continue in landslide prone areas and at critical hill slopes and found instabilities will be mitigated immediately. An implementation plan with the location, time, method, cost and implementing authority for the mitigation measures is presented in Table 6-4.

6.9 MONITORING

Monitoring programs are essential to ensure effectiveness of the proposed environmental mitigation measures which could be assessed by regular monitoring of the project activities.

In accordance with the national EMP guidelines of 2006, three types of monitoring has been proposed. They are baseline, compliance and impact monitoring. The monitoring plan and schedules are presented in Table 6-5.

6.9.1 Baseline Monitoring

According to the National Guidelines of Environmental Management Plan of Hydropower projects, 2006, if the anticipated time lapse between the EIA report approved and the commencement of project implementation is more than 5 years, in general, EIA report should suggest a baseline monitoring. The Lesser Himalayan Zone of Far-Western Nepal, where the Pancheshwar High Dam project is located lies within high seismic zone. Here, after each year's Monsoon rains, landslides occur at new locations. So, updating the base line information on slope stability and the overall environmental condition of the project implementation site/area is essential. The following baseline monitoring activities should be undertaken especially in reservoir area, main dam site and at others project associated structures and facilities:

- Observation and recording of Bank and Gulley erosions and Landslide/ slope failures in the catchment area during the construction phase of the project.
- Observation and recording of land use pattern acquired for the project.

The project authority will establish separate environmental monitory unit to monitor and update the baseline data. A data collection sheet for the study of land instabilities is given in Appendix B.

6.9.2 Compliance Monitoring

The compliance monitoring is essential in order to ensure that all conditions set-forth and commitments made in the environmental report and other applicable regulatory requirements and standards are well integrated with subsequent project documents e.g. Detail engineering design and tender documents etc, and they are actually fulfilled or complied with in practice. As such the Pancheshwar Multipurpose project will be implemented under the Pancheshwar Authority with representatives from both from Nepal and India, with the responsibility to ensure proposed mitigation measures are complied within the broad frame work of implementation plan of mitigation and enhancement measures. So, in order to control and enhance the land stabilities, the following recommendations have been made:

- Incorporation of landslide protection and soil erosion control measures in the detail design, contract document and tender documents applying suitable civil engineering and bio-engineering techniques.
- Allocation of cost for civil engineering and bio-engineering protection and control measures in tender documents.
- Allocation of adequate budget for establishment and operation of seismic network needed for monitoring likelihood of reservoir induced seismicity or else.

- Operation monitoring of all structural sites, disturbance to natural slope, slope protection measures, adequate drainage facility.
- Operation of quarry site and borrow area, quantity of extracted materials, excavated slope at designed angle and any damage in the vicinity.
- Regular supervision of spoil loading, transportation and dumping at designated site(s).
- Procedures for safe storage and use of explosives and toxic materials.
- Other conditions set-forth during the approval of the EIA/DEMP report, if any.

The project authority will establish separate Environmental Monitoring Units to monitor the compliance within the project area in Nepal and India. In order to guide and supervise the compliance monitoring, inter ministerial monitoring team can be established. This team will make necessary site visits to oversee the compliance monitoring.

6.9.3 Impact Monitoring

The impact monitoring will be carried out during project construction and operation phases to assess the sufficiency and effectiveness of the applied environment protection measures. It will focus each impact predicted and effectiveness of proposed mitigation measures. This will ensure that the actual impacts in the field are really within the manageable limit of the designed mitigation measures and may detect any unexpected damages and thereby provide early warning to the responsible agencies for undertaking corrective and additional measures to alert, if possible, or minimize the risks of such unanticipated impacts. In relation to geology, emphasis will be on stability of slopes, watershed condition and especially on reservoir induced seismicity.

6.10 MONITORING PARAMETERS/INDICATORS

During the construction and operational stages of the project following parameters/ indicators will be used for monitoring purposes in physical environment related to geological conditions:

Slope stability

Disturbance to natural slopes, slope protection measures, adequate drainage facility at all structural sites, reservoir shores, river or stream banks in catchment area.

Excavation and support installation procedure at construction site

Excavation and support installation as per approved drawings, adequacy of protection measures, working conditions and safety measures adopted by workers.

Operation of quarry and borrow sites

Quantity of extracted material and any damage in the vicinity

Spoil disposal

Spoil bank reclamation activities

Seismicity

Continuous recording and analysis of seismic events related to reservoir induced seismicity or else. A plan with monitoring parameters/indicators and their monitoring schedule with locations and methodology are given in Table 6-5.

Table 6-4: Plan for implementation of mitigation measures.

S N	Mitigating parameters	Location	Time	Methods	Cost estimation (NRs.)	Responsibility
1	Controlling of soil erosion	Project area and catchment area	Construction and operation phases	• Inspection of hill slopes for stability, de-vegetation • Plantation in barren lands • Application of bioengineering and engineering works where necessary	To be included in project cost	Consultant / Contractor
2	Controlling of sliding at existing landslides	Project area and catchment area	Construction and operation phases	• Regular inspection of existing landslides • Application of site-specific engineering and bioengineering works to control the sliding	To be included in project cost	Consultant / Contractor
3	Control in reservoir rim stability	Project area	Construction and operation phases	• Regular inspection of reservoir rim area • No settlement in reservoir rim area • Application of bioengineering or civil engineering works where necessary	To be included in project cost	Consultant / Contractor
4	Control of river bank erosion at downstream of dam site	Project area	Operation phases	• Regular inspection of the river banks • Application of site specific civil engineering or bioengineering work where necessary	To be included in project cost	Project authority, consultant and contractor
5	To investigate likely reservoir induced seismicity (RIS)	Reservoir area upstream and downstream	Operation phases	• Application of comprehensive seismic monitoring program	To be included in project cost	Project authority, consultant and contractor

Table 6-5: Monitoring plan and schedule

S N	Monitoring type	Parameters / Indicators	Methods	Locations	Schedule
1	Baseline	Soil erosion and landslides in catchment area	Observation	Reservoir area, along major tributaries in catchment area, Vicinity of Dam site	During construction and operation phase. Once a year.
		Distribution of land instabilities in project area including reservoir, dam site project structures and facilities		Reservoir, Dam site and other project's structural sites, camp and facilities areas.	
2	Compliance	Incorporation of EIA / DEMP recommendation into project documents	Review of design project specification and tender documents		Prior to construction starts
		Incorporation of environmental considerations in the tender documents and contract agreements.	Review of proposed work plan submitted by the contractor		During contract negotiation
		Integration of mitigation measures in the detailed design and contract documents	Reviewing	Project affected area	Prior to start of construction
3	Impact	Stabilization of river bank slopes and disturbed areas of major construction sites	Observation	Project affected area	During construction and operation phases
		Soil erosion and landslide control measures			
		Spoil handling and spoil tip management works	Observation	Spoil bank reclamation activities	Continuous during construction / Operation phase
		Clean up and reinstatement of the project area		Project affected area	At the end of construction phase
		Excavation at quarry and borrow sites	Observation	Slope stability at borrow and quarry sites	During construction
		Reservoir Induced Seismicity	Seismic net working	Reservoir area and its surroundings	During construction and operation phases

6.11 AUDITING

The environmental auditing assess the actual environmental impacts, the accuracy of prediction, the effectiveness of impact mitigation and enhancement measures and the functioning of monitoring mechanisms. According to the Environment Protection Rules (EPR) 1997, the Environmental Auditing has to be carried out after two years of the commencement of services in the project area. It is usually performed once for each project and should be carried out by MOEST as per Rule 14 of the EPR, 1997. But, in the case of PMP, the project completion period itself is too long i.e. 13.5 years and the cost incurred in environmental aspects would be substantial; therefore at least two auditing are essential.

6.11.1 Auditing Parameters

The audit requires the involvement of a multi-disciplinary team of experts including government officials, the proponent and the representative of the local people. The study team reviews the EIA / DEMP report and monitoring results and develops a work plan for the auditing work. Specially, the following activities related to geology need to be addressed during the planning of environmental audit:

- How have the distributions of landslides changed from the baseline conditions? Are there any changes in seismicity due to the formation of reservoir?
- Are there problems related to slope stability in the project area?
- Have slope stability and soil erosion control measures adopted by the project been effective in minimizing slope instability, soil erosion and landslide?
- Are there any bare or degraded areas around the project?
- What is the environmental condition of the quarry sites, borrow areas and spoil disposal areas?

6.12 ORGANIZATION AND STAFFING

Include one Environmental Geologist to the monitoring team and also add one Seismologist and two operators for the analysis and recording of seismic data.

6.13 FINANCIAL REQUIREMENT

As it has been discussed above, the construction and operation of Pancheshwar High Dam Project will have serious environmental impacts related to slope instabilities. The slope instability will occur as soil erosion in steep slopes and barren lands, debris flow, enhancement of sliding in existing landslides/slope failures, occurrences of new slides in reservoir rim areas, river bank toe cutting at downstream of the dam and rise in seismicity due to the formation of reservoir which will give rise to either bank erosion or landslide to failure. To minimize the impacts, several mitigation measures consisting Civil Engineering and Bio-Engineering techniques, commonly applied in slopes, have been planned.

The Civil Engineering measure include gabion wall, geotextile mattresses, stone pitching, rip-rap channels, retaining walls, anchor structures (rock bolts, earthen/rock anchors), river bank protection (revetments, spurs), earth works (slope modification, trimming of overhangs, filling at toe), stone masonry/ catch wall, check dam, concreting with or without wire mesh and construction of surface and subsurface drainage system.

The bio-engineering measures include Grass seeding, Grass/tree planting, Brush Layering, mulching/Brush matting, Brush work check dam and Joint planting. Depending on site conditions, a suitable combination of Civil engineering and Bio-engineering measures will be applied.

Due to changing nature of landslides in terms of its location, size with time, it is not possible to calculate the exact volume of individual measures that would be applied to stabilize the

existing landslides/slope failure. It will be carried out at the beginning of the construction phase of the project by making detailed topographic survey and other geological/ geotechnical surveys for each active landslides/slope failure. So, an overall cost for stabilization of a medium landslide in Nepal will be considered by estimating the budget for mitigation works. Similarly, at present it is not possible to predict the number of new slides that could occur in operation phase due to the formation of reservoir, bank erosion by water wave action and toe-cutting downstream of the dam site. So, for simplicity, same number of new slides as per existing (38) has been considered in making tentative budget estimation.

Considering the above mentioned conceptual background, the total estimated budget required for implementation, monitoring and auditing of mitigation measures would be NRs. 486 million refer (Table 6-6).

Table 6-6: The breakdown of the estimated cost for mitigation measures:

S N	Measures	Quantity	Rate	Amount
			(NRs. Million)	
1	Plantation in barren lands (Table-4.1, land use in PHD reservoirs)	(6 + 24) ha	0.5	15
2	Stabilization of existing slides	38	5*	190.0
3	Stabilization of future (predicted) slides in reservoir ad downstream of dam site(construction-operation period)	38	5	190.0
4	Establishment of Seismic net working	1	10	10.0
	Total			405
	Miscellaneous (20%)			81
	Grand total			486

Note * = Average cost for stabilizing a medium landslide varies up to NRs. 3 – 4 millions (Adhikari, 2000, CISMHE)

In addition to above mentioned, one engineering geologist will be engaged for the entire construction and operation phase of the project for supervision of implementation, monitoring and auditing of mitigation measures. One Seismologist and two operators will also be engaged for the analysis and recording of Seismic data.