ANNEXURE 10

SMEC

CHAPTER – 1

CATCHMENT AREA TREATMENT PLAN

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1 CATCHMENT AREA TREATMENT PLAN

1.1 INTRODUCTION

The study of erosion and sediment yield from catchment is of utmost importance as the deposition of sediment in reservoir reduces its capacity, thus affecting the water available for the designated use. The eroded sediment from catchment when deposited on streambeds and banks causes braiding of river reach. The removal of top fertile soil from catchment adversely affects the agricultural production and silt laden water affect the turbine blades truly affect the hydro-power production. Another important factor that adds to the sediment load is due to grazing by animals. A large number of cattle, sheep, and goats graze the pastures continuously for about six months in a mountainous region.

The lack of proper vegetal cover is a factor which causes degradation and thereby results in severe run off/soil erosion, resulting in premature siltation of the reservoir. Thus, a well-designed Catchment Area Treatment (CAT) Plan is essential to ameliorate the above including process of soil erosion. The catchment area treatment involves the understanding of the erosion characteristics of the terrain and identifying / suggesting remedial measures to reduce the erosion rate. For this reason the catchment area responsible for directly draining rivers, streams, tributaries, etc. are treated and the cost is included in the project cost.

The 80,500 ha area free draining catchment of "New Melling HEP" consists of 10 sub-watersheds. The pre-requisite for a watershed management is the collection of multipronged data like geology, geomorphology, topography, soil, land use/ land cover, climate, hydrology, drainage pattern, etc. The multi-pronged data generated from various published sources and actual data collected from these watersheds on the above-mentioned parameters are the basis of the Action Plan for Catchment Area Treatment.

CAT plans for the free draining catchment area of the proposed project has been prepared for areas with moderately soil erosion intensity, which targets toward overall improvement in the environmental conditions of the region. All the activities are aimed at treating the degraded and potential areas with severe soil erosion. The plan provides benefits due to biological and engineering measures and its utility in maintaining the ecosystem health. The plan with objectives addresses issues such as prevention of gully erosion, enhancing the forest cover for increasing soil holding capacity; and arresting total sediment flow in the reservoir and flowing waters.

Although the proposed project is not expected to have any significant negative impacts on the environment, measures to minimize the entry of silt in to its reservoir and enhance its life as well as for conservation of the ecosystem, are described in the following paragraphs.

1.2 OBJECTIVES

The main aim of the CAT is to rejuvenate various potential and degraded ecosystems in the catchment area. The action plan has been prepared for this purpose with the following objectives:

- To facilitate the hydrological functioning of the catchment and to augment the quality of water of the river and its tributaries
- Conservation of soil cover and to arrest the soil erosion, floods and siltation of the river and its tributaries and consequent reduction of siltation in the reservoir of the project
- Demarcation of the priority of sub watersheds of treatment on the basis of soil erosion intensity in the catchment area
- Rehabilitation of degraded forest through afforestation
- Mitigation of landslide landslip and rock falls
- Soil conservation through biological and engineering measures to reduce sediment load in river and tributaries, thus improving the quality of water
- Ecosystem conservation resulting from increased vegetative cover and water retaining properties of soil
- Employment generation through community participation and conservation

1.3 CATCHMENT SCENARIO AND DRAINAGE

Mago Chu originates at an EL 6500 m and travels southwest before joining Nyukcharong Chu River. It has a length of 48 km before its confluence with Nyukcharong Chu and and the river after confluence is called as Tawang Chu. Tawang Chu flows to Bhutan after traversing approx. 45 km in India. It is a tributary of Brahmputra River. Mago Chu is joined by major tributaries of Gorang Chu and Dungma Chu on its right bank.

The Dungma Chu originates from the springs fed by melting snow at about 5530 m. The river flows in EW direction and traverse about 23 km to meet with Mago Chu at 3455 m near Mago village.

Gorang Chu originates from snow-clad mountain having elevation range of 5000-5200 m and travels about 25.85 km from east to west direction and meet at 3360 m on the right bank of Mago Chu. It has many perennial and non-perennial nalas on the both banks. Some nalas have been originated from the lakes.

The area of the free-draining catchment of the New Melling H.E. project is 80500 ha and covered with perennial and non-perennial streams on both the banks of Mago Chu river (**Figure 1-1**).

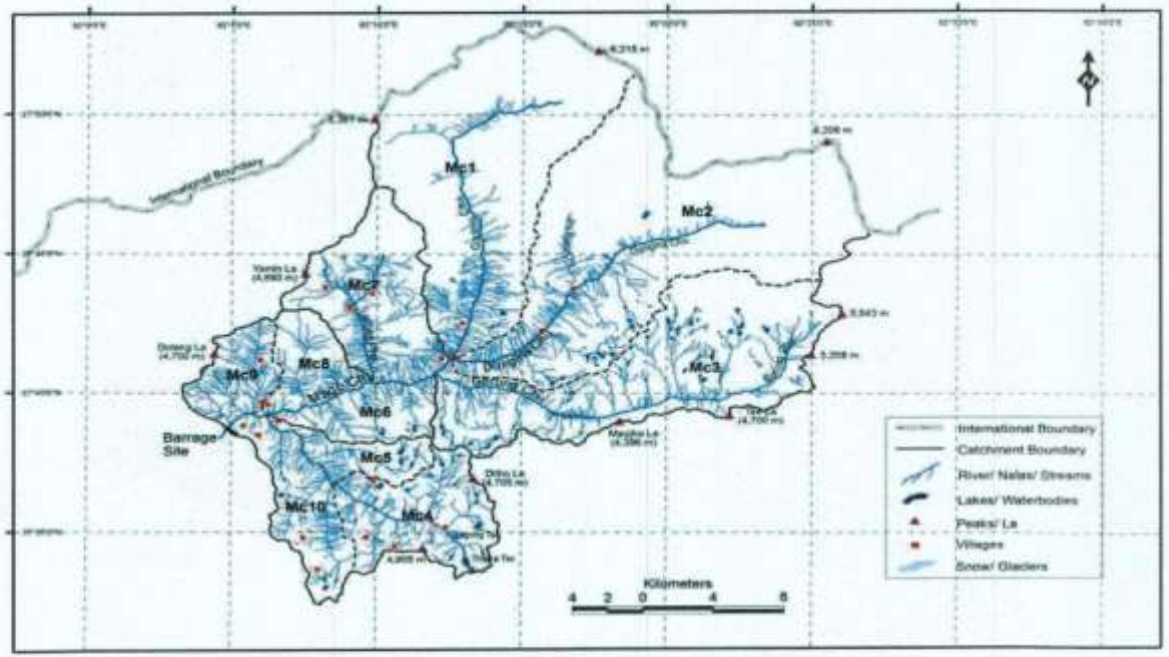

Figure 1-1: Drainage Map of Free Draining Catchment

1.3.1 DELINEATION OF WATERSHEDS AND SUB-WATERSHEDS (FREE DRAINING CATCHMENT)

For the demarcation of sub-watersheds, hierarchical delineation system developed by AIS & LUS (AIS&LUS Technical Bulletin 9) was followed. The codification system as given in Watershed Atlas of India (AIS&LUS) was followed for Tawang River watershed on 1:50,000 Survey of India toposheets. Tawang Chu 3A2D2 watershed comprises a part of Tawang (3A2D) sub-catchment of Tawang catchment (3A2). The catchment treatment plan has been limited to free-draining catchment of New Melling HEP. The free draining catchment area has been delineated into 10 sub-watersheds, viz. MC1 – MC10 (**Figure 1-2**). The area of each sub-watershed is given below:

Table 1-1: Area of Different Sub-Watersheds

Codification No.	Sub-watershed Name	Area (ha)
3A2D2	Mc1	18346.13
	Mc2	21957.52
	Mc3	14080.00
	Mc4	5426.17
	Mc5	1988.66
	Mc6	2714.79
	Mc7	6934.56
	Mc8	2637.66
	Mc9	2550.54
	Mc10	3863.97
	Total	80500.00

Figure 1-2: Index map of different sub- watersheds of free draining catchment

1.4 SOIL CLASS SOIL DEPTH

Soil erosion in the Himalayan region is a major problem, which results in loss of soil fertility and increased sediment load in the rivers. Apparently, increase in sediment load has direct influences on the conditions of a hydroelectric project. Therefore to ensure proper maintenance of soil functions and its health the project proponents propose a number of management interventions in the relevant watershed. Arunachal Pradesh has rich forest resources partly due to presence and results of various soils types. A total of five soil series belonging to various soil groups are identified in New Melling H.E. Project. In this region with soft weathering rocks covered with a thin layer of soil is highly susceptible and sensitive to landslides. However, in Arunachal Pradesh, magnitude of man induced activities is low rather than other Himalayan states. Arunachal Pradesh is biggest Himalayan states having dense forest, low population density and poor in basic amenities and developmental activities.

In the present study the NBSS Soil Bulletin 57 on Arunachal Pradesh was used to prepare soil-based thematic maps and also to collect other attributes such as soil type and soil depth of the region (catchment area). In the proposed New Melling H.E. Project, a catchment area treatment plan is being prepared, which considers various attributes related to soil, such as soil depth, texture, drainage, pH of the soil, etc. Some of the parameters are extremely important to deduce the erosion intensity and developing a susceptible erosion model in a particular region and accordingly to plan various treatment measures and to protect it from soil erosion.

Soil and soil depth types in the free-draining catchment were delineated from the soil map of Arunachal Pradesh. This source has identified single soil series in the catchment area. Soil units S46 (37.98%) followed by S1 (28.64%), S2 (23.50%) and others covers an entire area of the free-draining catchment as well as in soil depth class. The soil unit S2 has deep soil on moderately steeply sloping having loamy surface with severe erosion hazard and moderate stoniness associated with moderately shallow excessively drained, sandy skeletal soils (Refer **Figure 1-3 and Figure 1-4**).

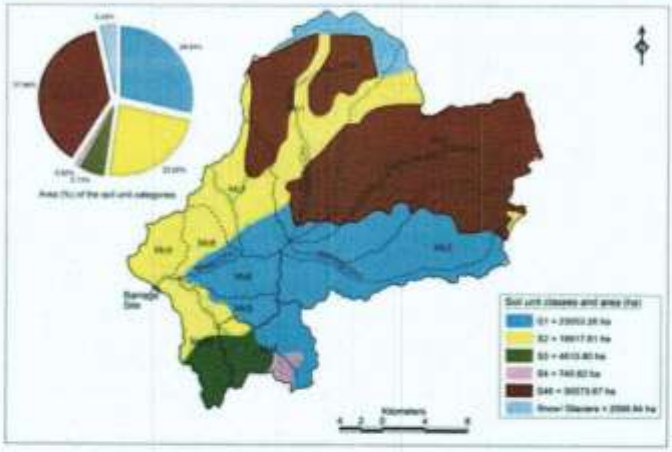

Figure 1-3: Soil Map of Free-Draining Catchment Area

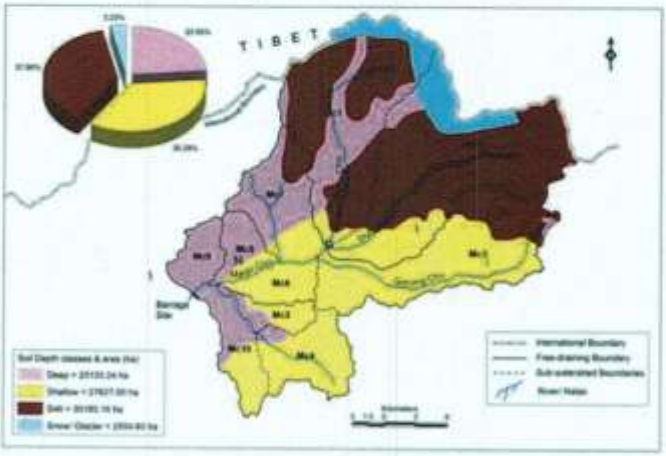

Figure 1-4: Soil Depth Map of Free-Draining Catchment Area

1.5 LAND USE

1.5.1 LAND USE/ LAND COVER

A land use/ land cover thematic map depicts the land composition, using land cover classification technique, which is one of the most common applications of remote sensing. New Melling free draining area depicts a land cover, predominantly with dense forest and scrub followed by open forest. Land use and land cover mapping was carried out by standard methods of analysis of remotely sensed data followed by ground truth collection and interpretation of satellite data. Digital data was procured from National Remote Sensing Agency, Hyderabad. Digital image processing of the satellite data and the analysis of interpreted maps were carried out using ERDAS Imagine 8.7. False colour composite (FCC) was generated from the procured digital data. The details of the satellite data used in this study are as follows:

Satellite	Sensor	Path/Row	Date	Data type & Bands
IRS P6	LISS-IV	110/51	06-11-2006	Digital (2, 3, 4, 5)

1.5.2 IMAGE PROCESSING SCHEME

Land use/ Land cover map was prepared on 1:50,000 scale with the objective of preparation of environment management plan and an action plan for watershed management and a catchment area treatment. Two forest density classes were interpreted for the forest cover mapping. The forests with >40% canopy cover were delineated as dense forests and between 10% and 40% crown density as open forest. Furthermore, degraded forests (with <10% canopy cover) and scrubs were also delineated for the purpose of erosion mapping. The cropland (Cultivation) was also delineated for the calculation of erosion intensity classification. Alpine meadow was also delineated. The non-forest land cover in the form of glaciers, barren land, water bodies (lakes and river), moraines, etc. was also delineated.

Density Class	Forest Type
Dense forest (Crown density > 40%)	• Tropical semi-evergreen • Sub-tropical wet hill forest • Wet-temperate broadleaved forest
Open forest (Crown density 10 - 40%)	• Sub-tropical pine forest • Temperate dry coniferous forest • Secondary moist bamboo bracks
Scrub	• Temperate scrub • Alpine scrub/ meadow Slope grassland
Non-forest	• Agriculture • Barren/ rockyland
Snow/ Glaciers	

The base map, drainage map and land use/land cover map prepared using the satellite data were digitized for further processing and analysis using combination of ArcGIS

9.0 and GeoMedia Professional 5.2. The sub-watershed boundaries were then overlaid on the drainage map and land use map of the Mago Chu river watershed up to New Melling Barrage site in order to extract the drainage and land use of the sub-watersheds, which were further used for overlay analysis by Geographic Information System (GIS) functionalities and techniques.

In this free-draining catchment of the New Melling HEP, snow/ glacier covers major part of the area with 63.20% (50875.47 ha) followed by moraines (10.43%) and barren land (9.69%). About 13.35% of the free-draining area up to the proposed barrage site is covered with dense forest (12.70%) and open forest (0.65%) (**Figure 1-5**). Major part of the catchment along the river on the left bank covered an area. Dense forest forms predominant class belonging mainly to tropical forest types. Subsequently scrub /alpine scrub accounts for mere area coverage of 1.47% of the free-draining area. Some patches of degraded forest with alpine meadows were found for only 1.19% of the total catchment area. Water bodies (River and lakes) accounts for 0.67% of the free draining area.

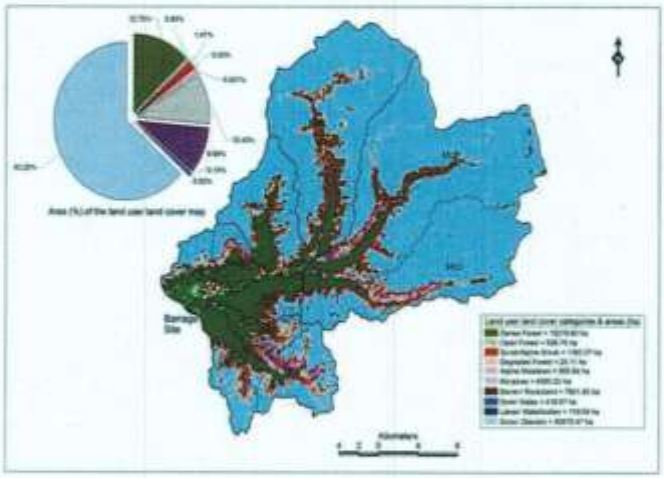

Figure 1-5: Land use Map of Free Draining Catchment Area

1.5.3 SLOPE

Slope has major influence on the loss of soil and water from the watershed and thereby influences the land use capability. The slope percentage determines the

erosion susceptibility of the soil depending on its nature and class. This helps in classifying various land suitability classes, which enables us to formulate suitable conservation measures for the prevention of soil erosion. The following slope classes (**Table 1-2**) and ranges are recommended by All India Soil & Land Use Survey (AIS&LUS).

Table 1-2: Slope Range Classification

Slope class	Slope range	Description
A	0 - 5%	Gently sloping
B	5 - 8%	Moderately sloping
C	8 - 15%	Strongly sloping
D	15 - 30%	Moderately steep
E	30 - 50%	Steep
F	50 - 70%	Very steep
G	Above 70%	Escarpment

The slope model for the proposed New Melling H.E. Project area was generated from the contours of Survey of India (SOI) toposheets at 1:50,000 scale following at 40 m interval using ArcGIS 9.0. Analysis through the slope model reveals that the Strongly sloping and Moderately sloping are predominantly distributed in the free draining catchment with area coverage of 36.85% and 37.48% respectively of the total area. Subsequently, Gently sloping and Moderately steep slope covers 15.99% and 10.00% respectively. While Steep and Very steep are covers each less than 1% of the area in free draining catchment (Refer **Table 1.3 and Figure 1-6.**).

Table 1-3: Slope Class with Area in Hectares

Slope Class	Area (ha)	Percentage
Gently Sloping	12872.38	15.99
Moderately Sloping	29368.54	36.48
Strongly Sloping	29665.43	36.85
Moderately Steep	8046.78	10.00
Steep	543.98	0.68
Very Steep	2.89	0.004
Total	**80500**	

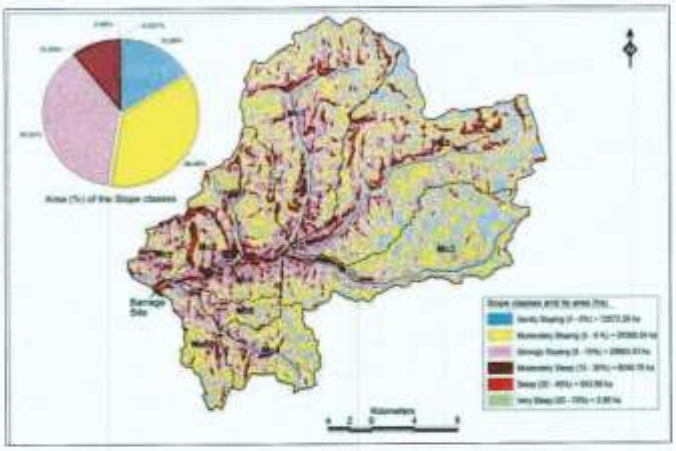

Figure 1-6: Slope Map of Free Draining Catchment

1.6 METHODOLOGY USED FOR THE STUDY

Superimposing topography, slope, soil and land use data/maps, a tentative estimation of erosion prone areas and landslides area in the catchment have been made. The vulnerable and problematic areas were identified in different physiographic zones.

These data sets were used for preparation of the thematic maps, calculation of sediment yield index and Erosion Intensity Units.

1.6.1 SOIL LOSS USING SILT YIELD INDEX (SYI) METHOD

The Silt Yield Index Model (SYI), considering sedimentation as product of erosivity, erodibility and aerial extent was conceptualized in the All India Soil and Land Use Survey (AIS&LUS) as early as 1969 and has been in operational use since then to meet the requirements of prioritization of smaller hydrologic units within river valley project catchment areas.

Methodology for the calculation of sediment yield index developed by All India Soil & Land Use Survey (Development of Agriculture, Govt. of India) was followed in this study.

(i) Erosion Intensity and Delivery Ratio

Determination of erosion intensity unit is primarily based upon the integrated information on soil characters, physiography, slope, land-use/land-cover, lithology

and structure. This is achieved through super-imposition of different thematic map overlays. Based upon the field data collected during the field survey and published data, weightage value and delivery ratio were assigned to each erosion intensity unit. The composite map for delineating different erosion intensity units was prepared through superimposition of the maps showing soil types, slope and land-use/land-cover. This thematic mapping of erosion intensity for entire catchment was done using the overlay and union techniques. Based on ground truth verification conducted during fieldwork and published data, weightage and delivery ratio was assigned to each erosion intensity units. The composite erosion intensity map was then superimposed on the drainage map with sub-watershed boundaries to evolve CEIU for individual sub-watershed.

Each element of erosion intensity unit is assigned a weightage value. The cumulative weightage values of the erosion intensity units represent approximately the relative comparative erosion intensity within the watersheds. A basic factor of K=10 was used in determining the cumulative weightage values. The value of 10 indicated an equilibrium condition between erosion and deposition. Any value of K (10+X) is suggestive of erosion intensity in an ascending order whereas the value of K (10-X) is suggestive of deposition intensity in descending order.

The delivery ratio is calculated for each composite erosion intensity unit, which suggests the percentage of eroded material that finally finds entry into the reservoir or river/ stream. Total area of different erosion intensity classes (composite erosion intensity unit) in each watershed was then calculated. The delivery ratio is generally governed by the type of material, soil erosion, relief length ratio, cover conditions, distance from the nearest stream, etc. However, in the present study the delivery ratio to the erosion intensity units were assigned upon their distance from the nearest stream (being the most important factor responsible for delivery of the sediments) according to the following scheme. The delivery ratio criteria adopted for the study is presented in **Table 1-4.**

Table 1-4: Delivery Ratio (DR) Criteria Adopted

Nearest Stream	Delivery ratio
0 - 0.9 km	1.00
1.0 - 2.0 km	0.95
2.1 - 5.0 km	0.90
5.1 - 15.0 km	0.80
15.1 - 30.0 km	0.70

(ii) Sediment Yield Index & Prioritization of Sub-Watersheds

The erosivity determinates are the climatic factors and soil and land attributes that have direct or reciprocal bearing on the units of the detached soil material. The

relationship can be expressed as:

Soil erosivity = f (Climate, physiography, slope, soil parameters land use/land cover, soil management)

The Silt Yield Index (SYI) is defined as the Yield per unit area and SYI value for hydrologic unit is obtained by taking the weightage arithmetic mean of the products of the weightage value and delivery ratio over the entire area of the hydrologic unit by using suitable empirical equation.

Prioritization of smaller hydrological units within the vast catchments is based on the SYI of the smaller units. The boundary values of range of SYI values for different priority categories are arrived at by studying the frequency distribution of SYI values and locating the suitable breaking point. The watershed/ sub-watersheds are subsequently rated into various categories corresponding to their respective SYI values.

The application of SYI model for prioritization of sub-watersheds in the catchment areas involves the evaluation of:

- Climatic factors comprising total precipitation, its frequency and intensity
- Geomorphic factors comprising land forms, physiography, slope and drainage characteristics
- Surface cover factors governing the flow hydraulics
- Management factors.

The data on climatic factors can be obtained for different locations in the catchment area from the meteorological stations whereas the field investigations are required for estimating the other attributes.

The various steps involved in the application of model are:

- Preparation of a framework of sub-watershed through systematic delineation
- Rapid reconnaissance surveys on 1:50,000 scale leading to the generation of a map indicating erosion-intensity mapping units.
- Assignment of weightage values to various mapping units based on relative silt-yield potential.
- Computing Silt Yield Index for individual watersheds/sub watersheds.
- Grading of watersheds/sub-watersheds into very high, high medium, low and very low priority categories.

The area of each of the mapping units is computed and silt yield indices of individual sub-watersheds are calculated using the following equations:

Silt Yield Index
SYI = (Ai x Wi x Di) x 100/Aw; where I = 1 to n

Where
Ai = Area of ith (EIMU)
Wi = Weightage value of ith mapping unit
Di = Delivery ratio
n = No. of mapping units
Aw = Total area of sub-watershed

The SYI values for classification of various categories of erosion intensity rates were taken for the present study as follows:

Priority Category	SYI Values
1. Very High	>1300
2. High	1200-1299
3. Medium	1100-1199
4. Low	1000-1099
5. Very low	<1000

The areas that require treatment have been delineated from the Composite Erosion Intensity Unit Map. The sum of weightages was reclassified as per the **Table 1-5** to further subdivide the area as per the erosion intensity classes. The weightages for Land use, Slope & Soil were summed to get the Erosion Intensity Classes.

Table 1-5: Legend for Composite Erosion Intensity Unit (CEIU) & Weightages

Erosion	Slope Intensity	Land use/ Land cover	Soil depth	Weightage/ DR Unit
Very Severe	Very steep	Open forest,	Shallow	20/0.95
(a)	>50%	scrub forest		
Severe	Steep to very	Open forest,	Moderately	18/0.90
(b)	steep 25 -50%	scrub, cultivation	shallow	
Moderate to	Strongly sloping	Dense forest,	Moderately	13-15/0.90
Slight	to moderately	open forest,	deep	
(c)	steep 10-25%	cultivation		
Slight to	Gently sloping	Dense forest,	Deep	11/0.85
Negligible	to moderately	open forest		
(d)	sloping 5-10%			

Accordingly, after excluding the area under permanent snow/glaciers from the total geographical area of sub-watershed, the Sediment Yield Index has been calculated for 10 sub-watersheds, computation of SYI for each MWS is presented in **Table 1-6.**

Table 1-6: SYI & Ranking for Sub-watersheds

Sub-watershed code	Erosion intensity	Area* (ha)	Weightage	Area x weightage	Delivery ratio	Gross silt yield	Sediment yield index
Mc1	a	0.00	0	0	0	0	
	b	1488.61	17	25306.37	0.90	22776	
	c	627.89	15	9418.35	0.85	8006	
	d	4.65	13	60.45	0.8	48	
Total		**2121.15**				**30830**	**1453.44**
Mc2	a	8.21	18	147.78	0.90	133	
	b	906.93	16	14510.88	0.90	13060	
	c	823.66	15	12354.9	0.8	9884	
	d	10.82	13	140.66	0.75	105	
Total		**1749.62**				**23049**	**1317.38**
Mc3	a	0.00	0	0	0.00	0	
	b	1800.30	18	32405.4	0.95	30785	
	c	1207.24	15	18108.6	0.85	15392	
	d	43.12	13	560.56	0.7	392	
Total		**3050.66**				**46570**	**1526.55**
Mc4	a	-	-	-	-	-	
	b	1581.09	18	28459.62	0.90	25614	
	c	967.13	17	16441.21	0.8	13153	
	d	52.03	15	780.45	0.7	546	
Total		**2600.25**				**39313**	**1511.89**
Mc5	a	0.15	19	2.85	0.90	3	
	b	633.11	17	10762.87	0.85	9148	
	c	817.79	15	12266.85	0.75	9200	
	d	6.74	13	87.62	0.75	66	
Total		**1457.79**				**18414**	**1263.16**
Mc6	a	1.20	19	22.8	0.95	22	
	b	328.80	18	5918.4	0.95	5622	
	c	1884.47	16	30151.52	0.85	25629	
	d	18.51	14	259.14	0.85	220	
Total		**2232.98**				**31472**	**1409.40**
Mc7	a	16.11	18	289.98	0.90	261	
	b	1035.93	16	16574.88	0.85	14089	
	c	1444.25	14	20219.5	0.85	17187	
	d	228.65	12	2743.8	0.7	1921	
Total		**2724.94**				**33196**	**1218.22**
Mc8	a	3.49	19	66.31	0.95	63	
	b	568.37	18	10230.66	0.90	9208	
	c	1123.87	16	17981.92	0.85	15285	

Sub-watershed code	Erosion intensity	Area* (ha)	Weightage	Area x weightage	Delivery ratio	Gross silt yield	Sediment yield index
	d	161.98	15	2429.7	0.75	1822	
Total		**1857.71**				**26315**	**1416.50**
Mc9	a	-	-	-	-	-	
	b	455.54	19	8655.26	0.80	6924	
	c	946.62	17	16092.54	0.8	12874	
	d	224.86	16	3597.76	0.75	2698	
Total		**1627.02**				**22497**	**1382.68**
Mc10	a	1.23	18	22.14	0.90	20	
	b	784.17	17	13330.89	0.85	11331	
	c	1215.15	15	18227.25	0.75	13670	
	d	347.09	14	4859.26	0.7	3401	
Total		**2347.64**				**28403**	**1209.86**

Based on the Sediment Yield Index (SYI), sub-watersheds that require treatment measures were prioritized using the simple rule that the sub-watersheds with a higher SYI were ranked higher in priority for treatment. The sub-watersheds would be treated on priority basis in the treatment scheme to be followed (**Table 1-7**). An index map giving physical targets of the year-wise treatment measures to be undertaken in different sub-watersheds prepared according to their priority ranking for treatment was prepared.

Table 1-7: SYI &Ranking for Sub-watersheds

Sub watersheds	Area (ha)	SYI	Ranking	Treatable Area (ha)	Priority category
Mc3*	14080.00	1526.55	1	–	Very High
Mc4*	5426.17	1511.89	2	–	Very High
Mc1*	18346.13	1453.44	3	–	Very High
Mc8	2637.66	1416.50	4	20.59	Very High
Mc6	2714.79	1409.40	5	11.18	Very High
Mc9	2550.54	1382.68	6	16.29	Very High
Mc2*	21957.52	1317.38	7	–	Very High
Mc5	1988.66	1263.16	8	9.37	High
Mc7*	6934.56	1218.22	9	–	High
Mc10	3863.97	1209.86	10	15.21	High
Total	**80500**			**72.64**	

** no treatable area*

1.7 CATCHMENT AREA TREATMENT PLAN

It is known that there are mainly five categories of Land uses for which a proper treatment plan should be developed. First is the Agricultural Land as this activity can never be eliminated, because the faulty practice results in heavy loss of fertile soil.

Second, being open forest land for obvious conservation reasons. Third is scrub or degraded land, which contributes heavily to the silt load and possibilities exist to bring this area under pastures and other plantation to meet the local demand of fuel and fodder and thus decreasing the biotic pressure on the forests and leading to environment friendly approach of sustainable development. The fourth and most important category is Barren land because with practically no vegetal cover, the area produces huge amount of silt load. The fifth is dense forest land, where soil conservation measures are required at few places.

Considering the topographic factors, soil type, climate, land-use/land-cover in the catchment area, engineering and biological measures have been proposed to be undertaken with the aim to check soil erosion, prevent/check siltation of reservoir and to maintain its storage capacity in long run.

The Erosion Intensity Map of the free draining catchment has been generated on the basis of SYI data and is presented in **Figure 1-7**.

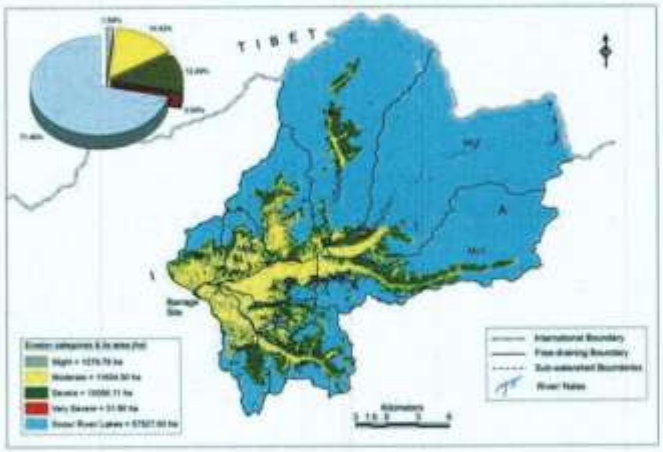

Figure 1-7: Erosion Intensity Map of Free Draining Catchment Area

In this free draining, about 12.49% of the area was found to be under severe erosion. While 14.42% (11604.30 ha) of free draining area is classified under moderate erosion whereas slight erosion accounts for 1.59 per cent and very severe erosion covers only 0.04%. Rest of the area falls under snow/ glaciers and river/ water body (71.46%) in the free-draining catchment of the proposed New Melling H.E. project.

Erosion intensity for each of the erosion classes in the sub-watersheds are described in the section.

After exclusion of rocks and inaccessible terrain, only those areas which fall under severe erosion intensity category would be taken up for conservation treatment measures in very high priority category micro-watersheds, whereas in the rest of micro-watersheds belonging to other priority categories.

1.8 TREATABLE AREA FOR SOIL CONSERVATION MEASURES

The prioritized areas in the different sub-watersheds of the free-draining of New Melling H.E. Project that require treatment were delineated and their areas calculated from the composite erosion intensity unit map. For this, a number of simple as well as complex spatial queries were run in a step-wise manner using GIS software (ArcGIS 9.0). These queries included different attributes of parameters that have been defined earlier in the chapters, viz. slope, soil depth and land use. For executing these queries all the thematic maps of different attributes and parameters were geo-referenced to maintain the accuracy of the resultant outputs. In case of slope, the spatial queries were undertaken for different slope categories ranging from gently sloping category to escarpments with different soil classes like shallow soils, deep soils, etc. The subsequent queries were executed with resultant outputs from the first level queries with different attributes of land use/ land cover. From these queries a thematic map of areas susceptible to erosion in the entire free-draining catchment area was prepared. From the thematic map of erosion intensity, areas that require treatment measures were extracted with the help of further spatial queries. Areas which were classified as inaccessible, i.e. areas with more than 45° (100%) slope and areas above 3,200 m with natural ecosystems having little human interference were excluded from the treatment measures even though these areas may have ranked high in prioritization for treatment. After taking out the areas where it is not feasible to carry out treatment, the total area that will require treatment under this CAT plan is of the order of 72.64 ha (**Table 1-8**). The total area earmarked for the treatment comprises more than 0.09% of the free-draining catchment area, and about 0.72% of the total area under severe and very severe erosion intensity category requiring for treatment measures.

1.8.1 YEAR-WISE TREATMENT OF SUB-WATERSHEDS

Silt yield index (SYI) has been calculated for all the 5 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and accordingly prioritized for treatment. Maximum area of 48.06 ha (around 66.16% of the total treatment area) has been taken in the Ist (31.77 ha) and IInd (16.29 ha) year for treatment and minimum treatment area in the IIIrd year is around 9.37 ha (12.90% of the total treatment area). The maximum estimated SYI value of 1526.55 is recorded for Mc3 sub-watershed and the minimum value of 1209.86 is in Mc10 sub-watershed (the Mc1, Mc2, Mc3, Mc4, Mc7, sub-watershed are not considered for treatment in the plan).

An area of 31.77 ha with 2 sub-watersheds will be taken for treatment in the first year according to the prioritization of SYI (**Table 1-8**). In the fourth year, 15.21 ha will be treated with one sub-watershed (**Figure 1-8**).

Silt yield index (SYI) has been calculated for all the 10 sub-watersheds, following the

Table 1-8: Year- wise treatment of the sub-watersheds

Sub-watersheds	Area	Treatable Area	Year wise
Mc6	2734.79	11.18	Ist Year
Mc8	2637.66	20.59	
		31.77	
Mc9	2550.54	16.29	IInd Year
		16.29	
Mc5	1988.66	9.37	IIIrd Year
		9.37	
Mc10	3863.97	15.21	IVth Year
		15.21	
Total		**72.64**	

Treatment area under different sub-watershed of free draining catchment of New Melling HEP is given in **Figure 1-8** and the Year wise Treatment Index map showing schedule of implementation of different measures in **Figure 1-9.**

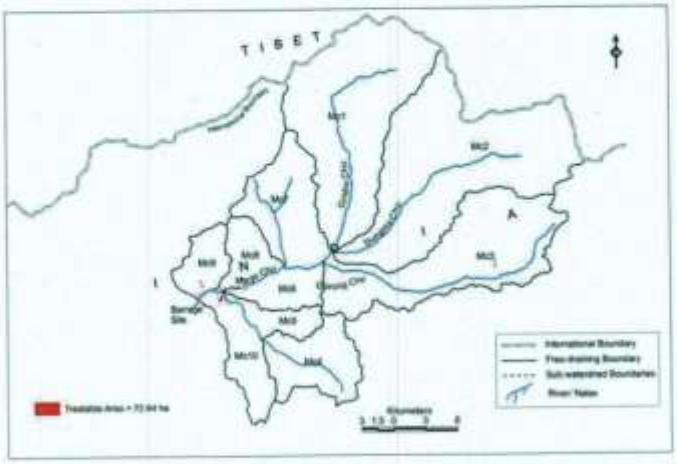

Figure 1-8: Treatment Area of New Melling free draining catchment

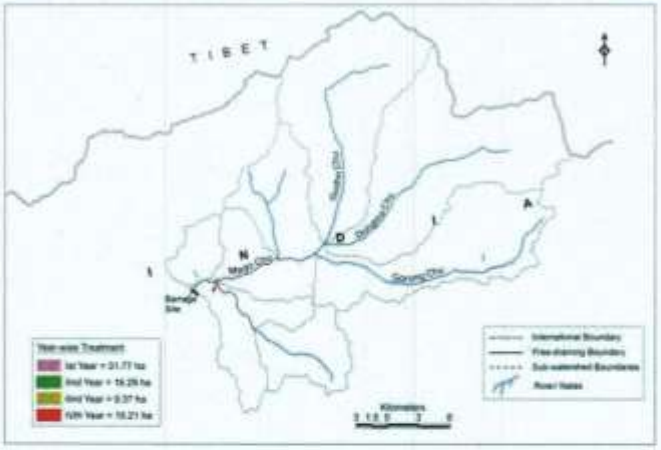

Figure 1-9: Year wise Treatment Index map for free draining catchment showing schedule of implementation measures

1.9 TREATMENT OF INDIVIDUAL SUB-WATERSHED

The area and type of treatment to be undertaken is based upon the stream drainage pattern, extent of forest cover, accessibility of the area, land-use, soil profile and slope. The erosion area is mostly concentrated in areas under land use class, glacier melts/moraine, glacier and water bodies, degraded forest, open forest, barren land and agricultural settlement. Based on computation of SYI, seven sub-watersheds have been classified as Very High and three sub-watersheds as High. The area of slope, land use and erosion of all the 10 sub water sheds has been detailed in following section.

1.9.1 MC1 SUB-WATERSHED

This sub-watershed is located in the valley of Goshu Chu river and having area of 18346.13 ha covers in the free-draining catchment of the New Melling H.E. project. The slope terrain of the sub-watershed ranging from 0.42-42.12% i.e. strongly sloping coverage an area of 42.12% followed by moderately sloping (35.20%) and moderately steep covers 11.60% of the area. Other slope classes are covered an area 10.66% (Gently sloping) and 0.42% (Steep). More than 72% of sub-watershed area comes under snow and glacier while 12.43% of the area is barren land followed by moraines (10.19%). Few patches of the forest (dense 4.27% & open 0.20%) found at the lower elevation in the region. Severe erosion class is predominantly in the area with coverage

an area of 1562.10 ha (8.51%). The severe erosion was analysed for treatment. (Refer Table 1-9 and Figure 1-10)

Table 1-9 Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc1 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	1955.20	Dense forest	783.96	Slight	4.91
Moderately sloping	6458.28	Open forest	36.26	Moderate	658.89
Strongly sloping	7726.95	Scrub/ Alpine scrub	9.10	Severe	1562.10
Moderately steep	2128.83	Degraded Forest	5.70	River/ water bodies	16120.23
Steep	76.87	Alpine Meadows	53.39	Snow	
		Moraines	1869.06		
		Barren/ rocky land	2279.97		
		River/ Nalas	4.97		
		Lakes/ Water bodies	20.51		
		Snow/ Glaciers	13283.22		
Total	**18346.13**	**Total**	**18346.13**	**Total**	**18346.13**

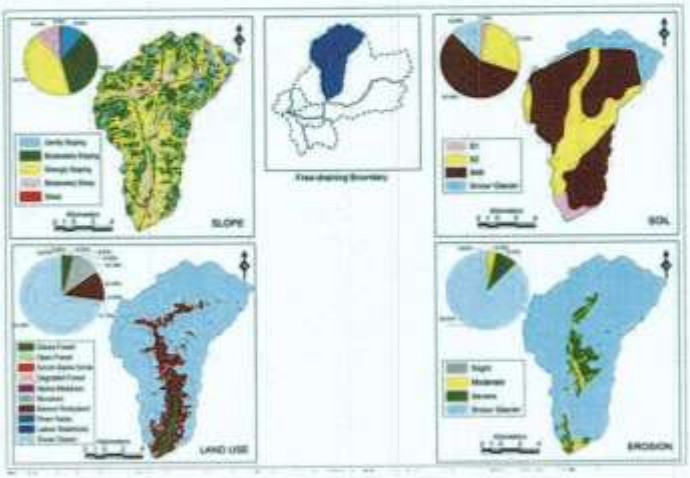

Figure 1-10: Map showing slope, soil, erosion & land use of sub-watershed MC1

1.9.2 MC2 SUB-WATERSHED

This sub-watershed is located in the valley of Dongma Chu of the proposed New Melling H.E. project with coverage an area of 21957.52 ha and covers major part of the area under snow (77.47%) on the higher elevation of the region. Most of the area falls under strongly (32.13%) and moderately (35.39%) sloping. Few patches of the steep slope is found in the region with coverage an area of 0.77%. Gently sloping covers 22.26% followed by moderately steep (9.45%). Dense forest covers an area 4.37% of the sub-watershed Mc2 while 8.37% of the area falls under rockyland. Few pockets of scrub were seen on left bank of the river Dongma chu with coverage an area of 0.70% (154.37 ha). About 4.33% is prone to severe erosion in the region (Refer **Table 1-10 and Figure 1-11**)

Table 1-10: Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc2 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	4888.44	Dense forest	960.24	Slight	11.34
Moderately sloping	7769.89	Open forest	45.62	Moderate	864.38
Strongly sloping	7055.14	Scrub/ Alpine scrub	154.37	Severe	951.68
Moderately steep	2075.55	Degraded Forest	4.25	Very Severe	8.62
Steep	168.51	Alpine Meadows	233.70	Snow/ river/	20121.50
		Moraines	1628.47	Water body	
		Barren/ rocky land	1836.79		
		River/ Nalas	44.64		
		Lakes/ Water body	38.70		
		Snow/ glaciers	17010.75		
Total	**21957.52**	**Total**	**21957.52**	**Total**	**21957.52**

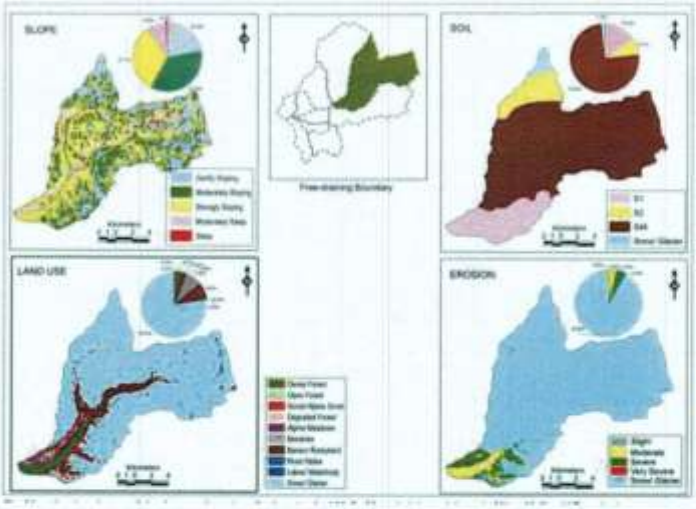

Figure 1-11: Map showing slope, soil, erosion & land use of sub-watershed MC2

1.9.3 MC3 SUB-WATERSHED

The area of this sub-watershed is having 13417.26 ha and located on the Gorong Chu valley with some perennial and non-perennial streams/nalas. Moderately sloping is predominantly with coverage of an area 42.82% in the region followed by 24% and 29.33% of the area falls under strongly and Gently sloping respectively. Few patches of moderately steep and steep were found in this sub-watershed. More than 76% of the area covers under snow/ glaciers in this sub-watershed. Small patches of forest (dense & open), moraines, barren rocks and river were found respectively. This sub-watershed has few area covers under severe erosion (13.42%) on the higher elevation. So this sub-watershed is not considered for the treatment. (Refer **Table No. 1-11** and **Figure 1-12**)

Table 1-11: Area (ha) of different classes of slope, land use and erosion of sub watershed Mc3 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	4130.08	Dense forest	826.49	Slight	45.25
Moderately sloping	6029.70	Open forest	31.15	Moderate	1266.87

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Strongly sloping	3378.67	Scrub/ Alpine Scrub	288.16	Severe	1889.23
Moderately steep	539.45	Alpine Meadows	164.43	Snow/ River/	10878.65
Steep	2.10	Moraines	1233.49	Water body	
		Barren/ Rocky land	711.97		
		River/ Nalas	65.72		
		Lakes/ Water body	13.59		
		Snow/ Glaciers	10745.00		
Total	14080.00	Total	14080.01	Total	14080.00

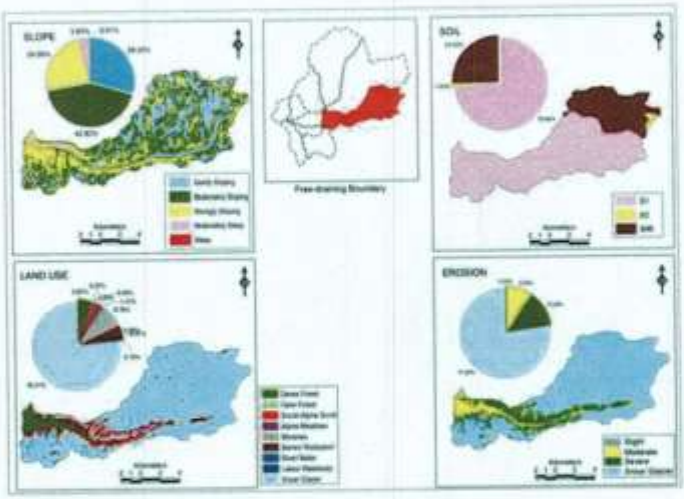

Figure 1-12: Map showing slope, soil, erosion& land use of sub-watershed MC3

1.9.4 MC4 SUB-WATERSHED

This sub-watershed in the region having an area of 5426.17 ha and with many lakes on the higher altitude. About 46% of the area comes under moderately sloping in the entire region followed by strongly sloping coverage an area of 34.17%. 5-13% slope category are Moderately steep and Gently steep in the region. Few pockets of steep slope cover 0.06% of the area. About 47.80% of the region comes under snow/ glaciers with small patches of forest (10.04%). While moraines covers 22.81% of the area while Alpine scrub covers an area of 5.58% followed barren rocks (8.59%). Severe erosion intensity

class is predominantly covering an area of the region with 30.58% followed by moderate erosion. (Refer Table No. 1-12 and Figure 1-13)

Table 1-12: Area (ha) of different classes of slope, land use and erosion intensity of sub-watershed Mc4 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	739.24	Dense forest	485.50	Slight	54.60
Moderately sloping	2509.75	Open forest	5.06	Moderate	1014.90
Strongly sloping	1854.09	Scrub/ Alpine scrub	231.93	Severe	1659.19
Moderately steep	319.68	Alpine meadows	302.59	River/ water body	2697.48
Steep	3.41	Moraines	1237.47	Snow/ glaciers	
		Barren/ rocky land	466.13		
		River/ nalas	92.85		
		Lakes/ water bodies	10.68		
		Snow/ glaciers	2593.96		
Total	**5426.17**	**Total**	**5426.17**	**Total**	**5426.17**

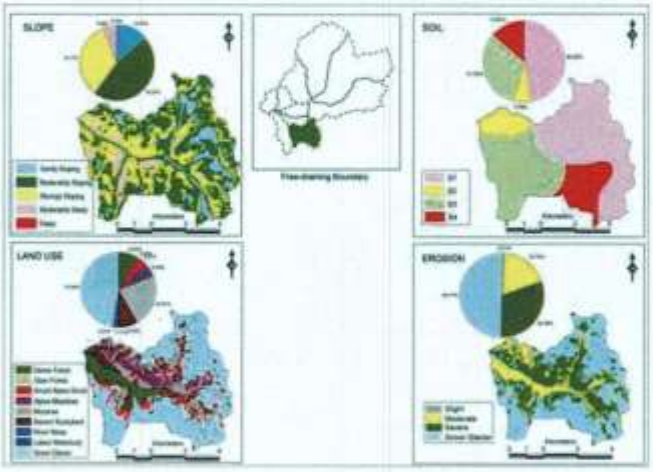

Figure 1-13: Map showing slope, soil, erosion& land use of sub-watershed MC4

1.9.5 MC5 SUB-WATERSHED

This is the smallest sub-watershed in the region having area of 1988.66 ha covers in the free-draining catchment of the New Melling H.E. project. The slope terrain of the sub-watershed ranging from 1-43% i.e. strongly sloping coverage an area of 42.33% followed by moderately sloping (39.26%) and moderately steep covers 8.69% of the area. Other slope classes are covered an area 9.67% (Gently sloping) and 0.98% (Steep). This sub-watershed has good forest covers 37.76% comes under dense and open forests while 19.97% of the area is moraines followed by barren (19.27%). Few patches of the degraded forest (0.03%) and alpine meadows (0.34%) found in the region. Severe erosion class is predominantly in the area with coverage an area of 664.38 ha (33.41%) with moderate erosion (43.15%). The severe erosion is considered for treatment. (Refer **Figure 1-14** and **Table 1-13**)

Table 1-13: Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc5 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	197.27	Dense forest	732.46	Slight	134.11
Moderately sloping	780.81	Open forest	18.56	Moderate	858.19
Strongly sloping	841.80	Scrub/ Alpine scrub	118.00	Severe	664.38
Moderately steep	172.75	Degraded Forest	0.61	Very severe	0.16
Steep	1.03	Alpine Meadows	6.75	Snow/River/ water body	331.82
		Moraines	397.21		
		Barren/ rocky land	383.25		
		River/ Nalas	35.44		
		Lakes/ Water bodies	7.90		
		Snow/ Glaciers	288.48		
Total	**1988.66**	**Total**	**1988.66**	**Total**	**1988.66**

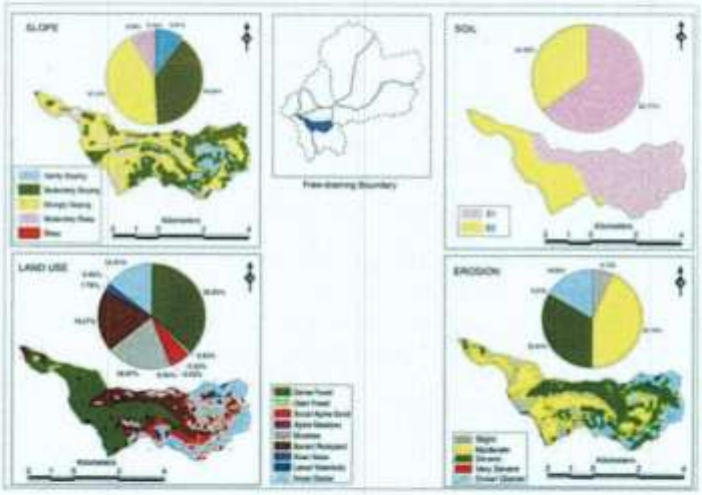

Figure 1-14: Map showing slope, soil, erosion& land use of sub-watershed MC5

1.9.6 MC6 SUB-WATERSHED

This sub-watershed is located along the Mago Chu on the left bank of the proposed New Melling H.E. project with coverage an area of 2714.79 ha. Most of the area falls under strongly sloping (55.77%) and moderately sloping (23.75%). While moderately steep slope covers 16.25% of the area followed Gently sloping (3.52%). Major of the region covers dense forest with an area of 71.40% of the sub-watershed while 11.14% of the area falls under snow/glaciers. Few pockets of other categories of landuse/ landcover were seen in the sub-watershed. About 12.71% and 0.05% is prone to severe and very severe erosions respectively for treatment in the region. (Refer **Table 1-14** and **Figure 1-15**).

Table 1-14 Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc6 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	95.55	Dense forest	1938.48	Slight	19.42
Moderately sloping	644.75	Open forest	7.44	Moderate	1977.55
Strongly sloping	1514.16	Scrub/ Alpine scrub	123.41	Severe	345.04
Moderately steep	441.10	Degraded Forest	0.48	Very Severe	1.26
Steep	19.24	Alpine Meadows	3.64	Snow/ river/	371.52

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
		Moraines	129.23	Water body	
		Barren/ rocky land	140.60		
		River/ Nalas	65.28		
		Lakes/ Water body	3.85		
		Snow/ glaciers	302.37		
Total	2714.79	Total	2714.79	Total	2714.79

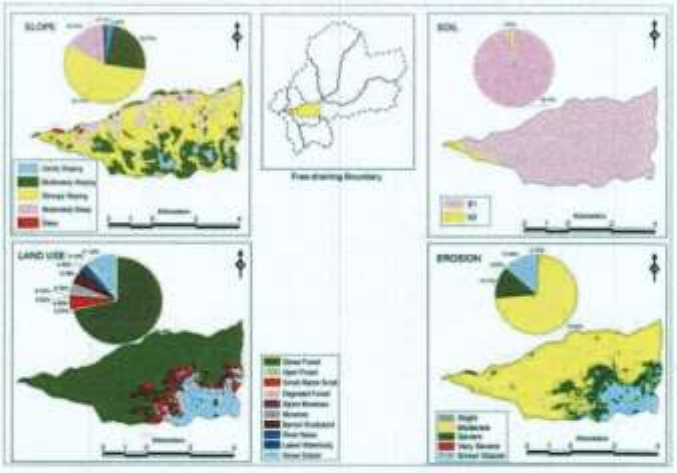

Figure 1-15: Map showing slope, soil, erosion& land use of sub-watershed MC6

1.9.7 MC7 SUB-WATERSHED

The area of this sub-watershed is having 6934.56 ha and located on the right bank of Mago Chu with some perennial and non-perennial streams/ nalas. Strongly sloping is predominant (42.90%) followed by moderately sloping (34.97%) and Moderately steep (14.39%). Few patches of steep slope were found in this sub-watershed. More than 54.68% of the area covers under snow/ glaciers in this sub-watershed. About 18.42% of the region is covered with dense forest and few pockets of open forest (1.42%) are also found. This sub-watershed has few area covers under severe erosion (15.68%) on the higher elevation. Therefore, this sub-watershed is not considered for the treatment. (Refer **Table No. 15** and **Figure 1-16**)

Table 1-15: Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc7 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	415.86	Dense forest	1277.37	Slight	239.94
Moderately sloping	2424.75	Open forest	98.17	Moderate	1515.59
Strongly sloping	2974.90	Scrub/ Alpine Scrub	97.38	Severe	1087.10
Moderately steep	998.08	Degraded Forest	8.77	Very severe	16.91
Steep	120.96	Alpine Meadows	66.01	Snow/ river/	4075.02
		Moraines	697.93	Water body	
		Barren/ Rocky land	834.86		
		River/ Nalas	42.88		
		Lakes/ Water body	19.41		
		Snow/ Glaciers	3791.78		
Total	6934.56	Total	6934.56	Total	6934.56

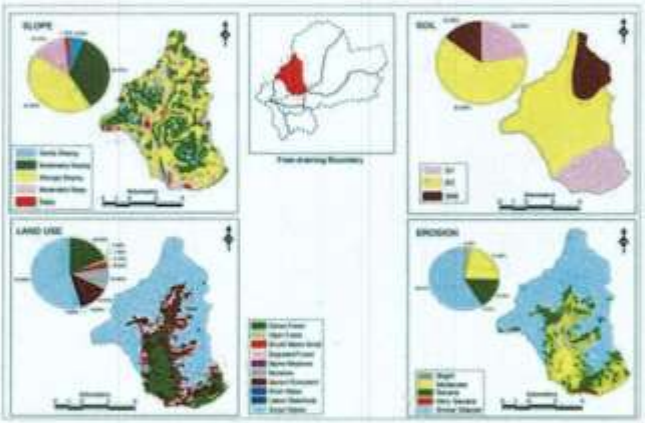

Figure 1-16: Map showing slope, soil, erosion& land use of sub-watershed MC7

1.9.8 MC8 SUB-WATERSHED

This sub-watershed in the region having an area of 2637.66 ha on the right bank of Mago chu. About 45% of the area comes under strongly sloping in the entire region followed by moderately steep area (24.87%), moderately sloping area (23.13%). This sub-watershed has good forest under dense (37.81%) and open (4.59%). About 25.06% of the region comes under snow/ glaciers with small patches of barren (17.34%) while

moraines covers 11.28%. Severe erosion intensity class is predominant (22.61%) for treatment with very severe erosion. (Refer **Table No. 1-16** and **Figure 1-17**)

Table 1-16: Area (ha) of different classes of slope, land use and erosion intensity of sub-watershed Mc8 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	62.80	Dense forest	997.30	Slight	169.98
Moderately sloping	609.98	Open forest	121.01	Moderate	1179.38
Strongly sloping	1185.80	Scrub/ Alpine scrub	22.83	Severe	569.44
Moderately steep	656.07	Degraded forest	1.55	Very severe	3.66
Steep	120.12	Alpine meadows	51.89	Snow/ river/	688.19
Very steep	2.89	Moraines	297.42	Water body	
		Barren/ rocky land	457.45		
		River/ nalas	23.53		
		Lakes/ water bodies	3.64		
		Snow/ glaciers	661.03		
Total	**2637.66**	**Total**	**2637.66**	**Total**	**2637.66**

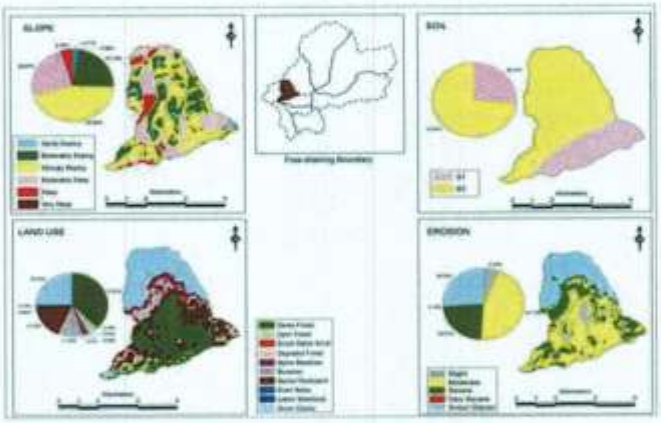

Figure 1-17: Map showing slope, soil, erosion& land use of sub-watershed MC8

1.9.9 MC9 SUB-WATERSHED

This sub-watershed is located on the right bank of Mago chu at the mouth of barrage axis with having an area of 2550.54 ha with small streams/nalas. Strongly sloping is

predominant with coverage of an area 57.13% in the sub-watershed followed by moderately sloping area (24.68%). This sub-watershed has a very good forest at the lower elevation near project area covers an area of 35.03% followed by snow/ glaciers (32.46%). About 12.74% of the region is covered with moraines. This sub-watershed has 38.95% area covers under moderate erosion on the lower elevation and severe erosion (18.74%) is considered for treatment. (Refer **Table No.1-17** and **Figure 1-18**).

Table 1-17: Area (ha) of different classes of slope, land use and erosion of sub-watershed Mc9 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	75.55	Dense forest	893.42	Slight	235.97
Moderately sloping	629.38	Open forest	144.22	Moderate	993.38
Strongly sloping	1457.24	Scrub/ Alpine Scrub	7.18	Severe	478.04
Moderately steep	369.26	Degraded Forest	3.74	Snow/ river/	843.16
Steep	19.11	Alpine Meadows	34.76	Water body	
		Moraines	324.84		
		Barren/ Rocky land	299.23		
		River/ Nalas	14.35		
		Lakes/ Water body	0.82		
		Snow/ Glaciers	827.99		
Total	2550.54	Total	2550.54	Total	2550.54

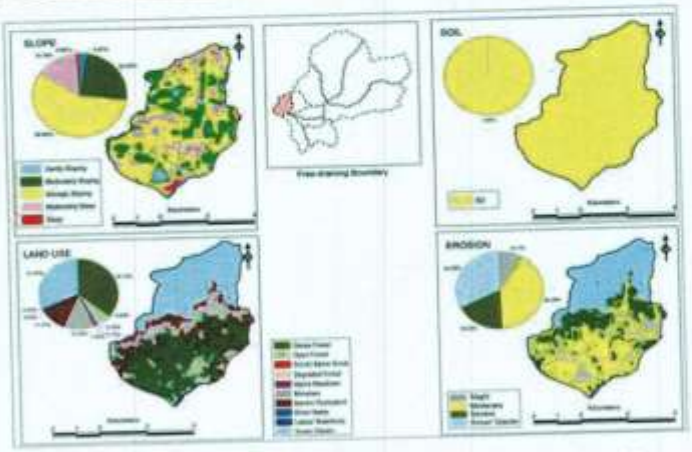

Figure 1-18: Map showing slope, soil, erosion& land use of sub-watershed MC9

1.9.10 MC10 SUB-WATERSHED

The location of the sub-watershed Mc10 is on the right bank of Mago chu at barrage axis in the region with having an area of 3863.97. About 43.39% of the area falls under strongly sloping, followed by moderately sloping (39.11%). This sub-watershed has good forest under dense (34.26%). About 35.48% of the sub-watershed falls under snow/ glaciers with small patches of moraines (15.01%) while barren covers 10.14% of the area. Severe and very severe erosion intensity classes are predominantly covering an area of the region with 21.33% for treatment. (Refer **Table No. 1-18** and **Figure 1-19**)

Table 1-18: Area (ha) of different classes of slope, land use and erosion intensity of sub-watershed Mc8 of the free-draining catchment area

Slope class	Area (ha)	Land use class	Area (ha)	Erosion	Area (ha)
Gently sloping	317.40	Dense forest	1323.79	Slight	364.23
Moderately sloping	1511.25	Open forest	19.22	Moderate	1275.17
Strongly sloping	1676.69	Scrub/ Alpine scrub	129.71	Severe	822.90
Moderately steep	346.01	Degraded forest	0.61	Very severe	1.29
Steep	12.62	Alpine meadows	18.68	Snow/ river/	1400.37
		Moraines	579.91	Water body	
		Barren/ rocky land	391.68		
		River/ nalas	29.01		
		Lakes/ water bodies	0.48		
		Snow/ glaciers	1370.89		
Total	3863.97	Total	3863.97	Total	3863.97

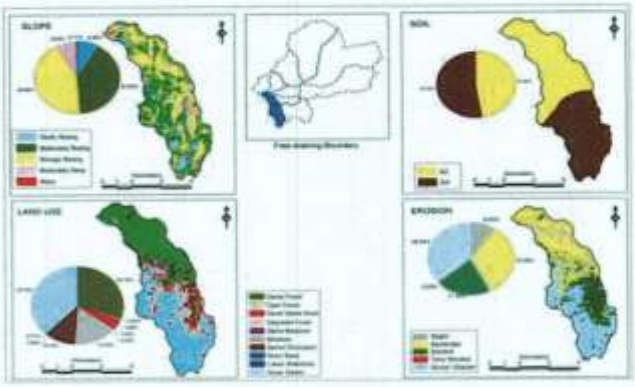

Figure 1-19: Map showing slope, soil, erosion& land use of sub-watershed MC10

1.10 ACTIVITIES TO BE UNDERTAKEN (TREATMENT MEASURES)

Details of treatment measures viz. engineering measures as well as biological measures to be undertaken are described in the following paragraphs. Watershed-wise details of various activities to be undertaken are provided in **Table 1-19**.

1.10.1 ENGINEERING MEASURES

Gully Control: The gully(s) would be treated with the help of engineering/ mechanical as well as vegetative methods. Check dams would be constructed in some of the areas to promote growth of vegetation that will consequently lead to the stabilisation of the slopes/area and prevention of further deepening of gully(s) and erosion. For controlling the gully(s), the erosive velocities are reduced by flattening out the steep gradient of the gully. This is achieved by constructing a series of check dams which transform the longitudinal gradient into a series of steps with low risers and long flat treads. Different types of check dams would be required for different conditions comprising different materials depending upon the site conditions and the easy availability of material at local level.

The following types are recommended for this area:

i. Brushwood checkdam
ii. DRSM (Dry Rubble Stone Masonry) - Check dams with stones available at the site
iii. Combination of DRSM and crate works. For moderate to deep gullys with stones available at the sites
iv. Contour Bunding
v. Slope modification by Stepping/ Bench Terracing

In addition to the vegetative measures used for stabilisation of gullys, temporary or permanent mechanical measures will be used as supplementary measures to prevent the washing away of young plantations by large volume of runoff. The gullys get stabilised over a period of time with the establishment and growth of vegetation cover. With the passage of time mechanical structures weaken and vegetative measures get strengthened.

Table 1-19: Watershed-wise details of various activities

Name of Sub-watershed	Engineering Measures				Biological Measures				
	Gully Control			Bench Terracing	Afforestation	NTFP Regeneration	Assisted Natural Regeneration	Pasture Development	Total Area
	Headwall/ Check dams	DRSM check dams	Contour Bunding						
	No.	No.	Ha	Ha	Ha	Ha	Ha	Ha	Ha
Mu7	4	8	1.25	1.7	2.25	1.35	1.05	1.37	9.37
Mu8	3	5	2.5	1.85	1.7	2.55	1.4	1.18	11.18
Mu8	9	12	9.25	8.5	2.75	1	1	1.00	20.39
Mu9	3	4	3.75	4.5	2	3.04	1	2	16.29
Mu10	4	6	2.85	3.75	2.25	4.25	1.85	0.46	15.21
Total	27	35	19.6	17.5	10.95	11.99	6.7	6.1	72.44

For engineering measures following types of checkdams are suggested.

a. Brushwood checkdams

The main advantage of brushwood checkdams is that they are quick and easy to construct and are inexpensive as they are constructed by using readily available materials at the site. In brushwood check dams, small branches preferably of coppiceable species are fixed in two parallel rows across the gully or nala and packed with brushwood between the rows of these vertical stakes. The vertical stakes are tied down with wires or fastened with sticks across the top. The important consideration in erecting brushwood check dams is to pack the brushwood as tightly as possible and to secure it firmly. This type of check dam is generally constructed over small gullys or at the starting stretch of gullys. In all, 27 brushwood checkdams/ vegetative spurs would be constructed to check gully erosion, stream bank protection and slope stabilisation works with an estimated budget of **Rs. 7.02 lakhs**.

b. Dry Rubble Stone Masonry (DRSM) checkdams

The site where DRSM check dams are to be constructed is cleared and the sides are sloped 1:1. The bed of gully is excavated for foundation to a uniform depth of 0.45 m to 0.60 m and dry stones are packed from that level. Over the foundation, DRSM super structure of check dam is constructed. The stones are dressed and properly set in with wedges and chips. The width of check dam at the base should be approximately equal to maximum height and successive courses are narrower so the section is roughly a trapezium. It is common to find upstream face of check dams vertical with all slopes on the downstream face but while there is sound engineering reason for this in case of large check dams but it is not of any consequence in small gully control dams. In the centre of the dam portion sufficient waterway is allowed to discharge the maximum run off. The dry stone work should go up to 0.30m to 0.60m in the stable portion of the gully side to prevent end-cutting. Sufficient apron is provided to prevent scouring of the structure. The thickness of the apron packing would be about 0.45 m and gully sides above the apron have to be protected with packing to a height of at least 0.30 m above the anticipated maximum water level to prevent side scour being formed by the falling water. For gully control measures, 35 DRSM check dams would be constructed with an estimated budget of **Rs. 11.65 lakhs**.

c. Slope modification by Stepping/ Bench Terracing

Bench terracing is one of the most popular mechanical soil conservation practices adopted by farmers in India and other many countries. It is constructed in the form of step like fields along contours by half cutting and half filling and would result in the conversion of the original slope into levelled fields. Thus, hazards of erosion are eliminated and manure and fertilisers applied are retained in the levelled fields. The sloping fields in the valley need to be bench terraced by cutting and filling with the

latter supported by retaining stone wall. While making bench terraces, care will be taken not to disturb the top soil by spreading earth from the lower terraces to higher terraces. The vertical intervals between the terraces will not be more than 1.5 m and cutting depth would be kept at 50 cm. The minimum average width of the terrace would be 4 to 5 m to enable the usage of prolong hinge. The shoulder bunds of 30 x 15 cm would also be provided. The excess water from the terraces will be drained off by staggered channels. An area of 17.30 ha will be covered under this plan with an estimated budget of **Rs. 1.30 lakhs.**

1.10.2 BIOLOGICAL MEASURES/PREVENTIVE MEASURES

The Biological Measures/Preventive Measures suggested are:

A. Afforestation
B. Assisted Natural Regeneration (ANR)
C. Non Timber Forest Produce (NTFP) Regeneration
D. Pasture Development

It is always betterto undertake preventive measures than to mitigate the factors that ultimately lead to soil erosion. Such preventive measures will indirectly help to conserve soil in the long run, keeping in view the importance of integrating eco-restoration strategy with socio-economic needs of the local community wherein both ecology and economics are developed. The preventive measures that are suggested for the project area have been discussed below.

A. Afforestation

In the upland region like this project area, the trees and vegetation cover play an important role in the conservation of soil and ecology. Afforestation programme would be taken up in such forest areas that contain large patches of barren grassy slopes and are generally devoid of trees and are honey-combed by cultivation. In critically degraded areas, plantation of locally useful, diverse and indigenous plant species such as *Alnus nepalensis, Albizia Oodaratissima, Castanea Sativa, Cinnamomum pauciflorum, Quercus glauca, Schima wallichi,* etc. would be undertaken. Afforestation measures would be taken up under catchment area treatment plan.

An outlay of **Rs. 6.69** lakhs (Rs. 4.27 lakhs for creation and Rs. 2.42 lakhs for its maintenance) for 10.95 ha has been provided to cover various areas under afforestation in different sub-watersheds.

The tree species that would be planted under this programme are : *Alangium chinense, Castanea sativ, Erythrina arborescus, Phykkanthus emblica, Pinus roxburghi, etc. The important shrubs are Bambusa pallida, Coriaria nepalensis and Zanthoxylum*

acanthopodium. The root species Agare sisulana, Chrysopogon gryllus, Cybopogon flexuosus, Penninetum, purpureum, Themeda arundinaca, etc.

B. Assisted Natural Regeneration in Existing Forest

In some of the forest areas, conditions are conducive to natural regeneration provided some sort of assistance is provided. Such areas shall be taken up under this component. The areas shall be closed to exclude biotic interference. Forest floor will be cleared of slash; debris and felling refuse to afford a clean seedbed to the falling seed. At certain places some soil raking may also have to be done to facilitate germination of seeds. Where natural regeneration is found deficient, it will be supplemented by artificial planting. Patch sowing in suitable areas may also be done. Bush cutting & cleaning operations are done depending on necessity. Up to 800 plant or patches per hectare will be planted /sown to hasten the process of regeneration in the area uniformly. An outlay of **Rs. 1.54 lakh** including its creation (Rs. 0.79) and maintenance (Rs. 0.75) has been made to cover 6.70 ha.

C. Non Timber Forest Produce (NTFP) Regeneration

Arunachal Pradesh Forest Division is rich in a variety of non-timber forest produce. However, because of over-exploitation of NTFP in the past there has been depletion of this valuable resource. Therefore, in order to augment natural stock of NTFP in the forests, it is proposed to take up planting of NTFP and establishing nursery. An outlay of **Rs. 6.97 lakhs** per ha has been suggested to cover about 11.99 ha for establishing (Rs. 4.38 lakhs) and its maintenance (Rs. 2.59 lakhs) of this facility.

D. Grazing Land/ Pasture Improvement

The livestock owned by the local communities exert significant pressure on the natural habitats. In order to improve the grazing areas/pastures and to make these sustainable, the degraded areas, particularly among community lands will be taken up for treatment under silvi-pastoral model. An outlay of **Rs. 1.90 lakhs** has been earmarked for this purpose and it will cover about 6.10 ha of land for development at a cost of Rs. 1.22 lakhs and its maintenance will cost Rs. 0.68 lakhs.

1.10.3 COST OF OTHER COMPONENTS OF CAT PLAN

Apart from the Forestry works and the drainage line treatment in the catchment area there are other aspects of the CAT plan to be addressed and their cost to be included in the overall plan. The eco-restoration works, livelihood support works, social mobilization, documentation and publication, monitoring and evaluation are some of the integral ingredients which have to be considered and included while formulating the CAT plans as per suggestions made from time to time by the MOEF.

1.10.3.1 Administrative Set up

The catchment area treatment (CAT) project involves intensive and highly technical operations, which require the expertise of technical personnel. It is, therefore, recommended that the existing forest staff of Arunachal Pradesh Forest Division in the area will look after all the works to be carried out under the CAT plan including plantation and maintenance as all the areas to be covered under CAT plan fall under these divisions. However, temporary staff may be engaged for this purpose during the project implementation period.

1.10.3.2 Establishment works related to area development

There is urgent need to reduce the dependency of local population on the forest and other natural resources which are under severe pressure. The establishment works related to area development is suggested and should be carried out through Community Welfare Committees (CWC) of local villages in free draining catchment area of New Melling HEP. This should include the following measures, which would help in rejuvenating the ecosystems and in reducing the soil erosion in the region.

1. Establishment of a committee for plantation
2. Avenue plantation using fuel wood trees with suitable fencing in the villages
3. Technical and financial support for using alternate energy sources such as non-conventional energy (solar heating) to reduce pressure on the forest (tree cutting) for fuel wood
4. Maintenance of hygiene in the villages
5. Establishment of Training, Awareness programmes, etc. for water conservation and harvesting in the villages, Soil conservation measures in village areas, Improvement in agricultural and horticultural practices, etc.
6. Establishing a rural technology support programmes
7. Awareness programmes for conservation of wildlife and natural resources

1.10.3.3 Micro-planning

An estimated cost of **Rs. 3.41 lakhs** (5% costs of total Engineering and biological measures) has been proposed for micro-planning (**Table 1-18**).

1.10.3.4 Forest Infrastructure Development

The works of the catchment area treatment plan will be executed by the Forest Department, Government of Arunachal Pradesh. These works will be an added responsibility for the Forest Department that may not have adequate facilities and infrastructure to execute the work as suggested in the plan. Provision has, therefore, been made in the CAT plan to develop the infrastructure of Forest Department in the region and accordingly a budget of **Rs. 44.00 lakh** is proposed for this purpose.

Table 1-20: Budget for Development of State Forest Department Infrastructure

Amount (Rs. in lakhs)

Components	Establishment	Running Cost	Amount (Rs. Lakhs)
Forest Fire Fighting System	5.00		5.00
Road and Foot Path Development	8.00		8.00
Office Vehicle	10.00	6.00	16.00
Contingency	15.00		15.00
Total	**38.00**	**6.00**	**44.00**

1.10.3.5 ECO-RESTORATION

There is urgent need to reduce the dependency of local population on the forest and other natural resources which are under severe pressure. The eco-restoration works and other activities related to income generation are suggested and should be carried out through Community Welfare Committees of local villages. These should include the following measures, which would help in rejuvenating the ecosystems and in reducing the soil erosion in the region.

- Plantation in the degraded patches of community/civil/ forest land
- Water conservation and harvesting in the villages
- Soil conservation measures in village areas
- Improvement in agricultural and horticultural practices
- Rural technology support programmes
- Awareness programmes for conservation of wildlife and natural resources
- Promotion of income generating schemes like ecotourism

There is no need to consider the cost for eco-restoration as the cost for this aspect has already been considered in Mago Chu HEP (another project of SEW).

1.10.3.6 MONITORING AND EVALUATION

Monitoring and evaluation will be developed as in built part of the project management. Thus, a process of self-evaluation at specified intervals of time will ensure the field worthiness and efficacy of the CAT plan.

Annual work plan for each sub-watershed would be prepared well in advance specifying physical and financial targets, sites, locations and beneficiaries of each component of the project activity. Month-wise work scheme of various items of each component for the financial year would also be prepared in advance and its timely implementation would be ensured. Monthly progress report on all activities would be submitted by the Range Officers to Divisional Forest Officer for its subsequent submission to the project authorities and Ministry of Environment & Forests, Government of India. The monitoring committee appointed for this purpose would also monitor on a regular basis the quality and quantity of works carried out in the area.

For monitoring, reference points of silt load observation in the river are suggested to install silt-recording station upstream of barrage site on Mago Chu to evaluate the impact of the soil conservation measures. A sum of **Rs. 50.00 lakhs** has been provided for monitoring and evaluation.

1.10.4 INSTITUTIONAL MECHANISM

1) Role of Project Proponent

The forest department would implement the Catchment Area Treatment plan. A joint inspection group would be formalized which would include officers from State Forest Department and Official from the Environment Cell of the project proponent. The management will have liaison with the forest officials as far as the financial disbursement would evolve employment opportunities. Thus, people's participation should be encouraged and would involve mobilization of manpower for such activities. Experts and professionals competent enough in operating the plan need to be consulted from time to time.

2) CAT Implementation

Environmental Officer or Manager (Environment) of project proponent would coordinate with the forest department for the implementation of the proposed Plan. The Environment Officer would evaluate/monitor financial aspects at Site Office. The modalities of financial disbursement every quarter in a year need to be taken care of. The implementing agency shall submit completion certificate in the light of guidelines fixed by CAMPA. The implementation of CAT Plan should have enough flexibility and should be subject to changes as per requirements and periodic gains. A monitoring committee as per the MOEF guidelines should be instituted for the project for administrative guidance and smooth realization of targets.

3) Period and schedule of implementation

The execution of CAT plan in New Melling H.E. Project area would require extensive efforts on the part of executing agencies. Keeping in view the local topography and climate, it is being estimated that the entire treatable area would require at least 4 years for creation and 1 year for maintenance to complete. However, CAT plan has been prepared for five years. All these works would have to start with the pre-construction activities especially the studies in respect of micro-planning for each sub-watershed, which would require further detailed investigations. Based on the silt yield index of the sub-watersheds, the conservation measures would be first taken up in sub-watershed Mc6 and Mc8. (Refer **Table 1-6**). The year-wise index map of schedule of implementation of different conservation measures under CAT plan has been given in **Figure 1-9**. **Table 1-21** gives the year-wise physical details of various engineering and biological treatment measures to be undertaken.

Table 1-21: Physical and Financial layout plan of Catchment Area Treatment for New Melling HEP

Amount in lakhs

Sl. No.	Item	Unit	0 Year		1st Year		II nd Year		III rd Year		IV th Year		V th Year		Total	
			Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin
A	**ENGINEERING MEASURES**															
1	Gully Plugging															
a)	Brushwood checkdams	Nos	-	-	13	3.12	6	1.56	4	1.04	5	1.30	-	-	27	7.02
b)	DRSM checkdams	Nos	-	-	13	4.90	8	2.60	5	1.60	7	2.33	-	-	38	11.43
c)	Contour Bunding	ha	-	-	8.62	2.16	4.31	1.13	2.55	0.64	3.92	0.98	-	-	19.6	4.90
2	Bench Terracing	ha	-	-	7.61	0.57	3.98	0.30	2.25	0.17	3.46	0.26	-	-	17.3	1.30
	Sub-total (1+2)		-	-									-	-		24.87
	Add: 5% for maintenance structure		-	-									-	-		1.24
	TOTAL (A)												-	-		26.11
B	**BIOLOGICAL MEASURES**		-	-									-	-		
a)	Afforestation	ha	-	-	4.82	1.68	2.82	0.98	1.62	0.55	2.19	0.85	-	-	10.95	4.27
	Maintenance		-	-	-	-	-	1.07		0.56		0.71		0.48		2.42
b)	NTFP Regeneration	ha	-	-	5.27	1.93	2.96	1.01	1.86	0.57	2.40	0.88	-	-	11.99	4.38
	Maintenance		-	-	-	-	-	1.14		0.60		0.34		0.52		2.59
c)	Pasture Improvement	ha	-	-	2.68	0.54	1.4	0.28	0.79	0.16	1.23	0.25			6.10	1.22
	Maintenance		-	-	-	-	-	0.30		0.16		0.09		0.14		0.68
d)	Assisted natural regeneration in existing forests	ha	-	-	3.95	0.35	1.54	0.18	0.83	0.10	1.34	0.16	-	-	6.70	0.79
	Maintenance		-	-	-	-	-	0.33		0.17		0.10		0.15		0.75
e)	Wire Barbed fencing		-	-	-	11	-	5.75	-	3.25	-	2.5	-	2.5	-	25
	Sub-total (a+b+c+d+e)															42.11
	TOTAL (A + B)															68.21
C	**Micro-planning @ 5% of (A+B)**		-	-	-	1.50	-	0.78	-	0.44	-	0.34	-	0.34	-	3.41
D	**Establishment Cost @ 7% of (A + B)**		-	-	-	2.10	-	1.10	-	0.62	-	0.48	-	0.48	-	4.77
E	**Forest Infrastructure Development**		-	-	-	19.30	-	10.12	-	5.73	-	4.40	-	4.40	-	44
F	**Contingency @ 5% of (A + B)**		-	-	-	1.50	-	0.78	-	0.44	-	0.34	-	0.34	-	3.41
G	**Monitoring and Evaluation for 5 Years**		-	-	-	22.00	-	11.50	-	6.50	-	5.00	-	5.00	-	50
	GRAND TOTAL															173.81

4) Project Monitoring and Reporting Procedures

Meetings would be held every three months to resolve logistic problems in plan implementation. A Joint committee would be formed with the Environment Cell of project proponent and State Forest Department team members to ensure the implementation and monitoring of the CAT works and review the progress from time to time. Quarterly progress reports and completion certificates would be submitted to project proponent, for evaluation and disbursement of finance. In addition, the work done should be published through public awareness campaigns. Visual and print media need to be used to embark on maximum benefit by direct and indirect beneficiaries. Such efforts would resolve conflicts which otherwise are potential sources for project gestation.

1.10.5 COST ESTIMATE OF CAT PLAN

The total estimated cost of catchment area treatment plan to be spent over a period of five years **Rs. 173.81 lakhs**. The details of cost estimates and physical work schedule as well as phasing of expenditure are given as follows in **Tables 1-22**. All the costs towards the administration during the implementation work have been included in the cost estimates of CAT.

Table 1-22: Component-wise cost Estimate for Catchment Area Treatment Plan

Sl. No.	Item of Work	Unit	Qty.	Rate (Rs)	Amount (Rs. lakhs)
A.	ENGINEERING MEASURES				
1	Gully Control				
	a) Brushwood checkdams	Nos.	27	26,000	7.02
	b) DRSM checkdams	Nos.	35	33,281	11.65
	d) Contour Bunding	ha	19.6	25,000	4.90
2	Bench terracing	ha	17.3	7,500	1.30
	Sub-Total (1+2)				**24.87**
	Add 5% for maintenance of structures				1.24
	Sub-total (A)				**26.11**
B.	BIOLOGICAL MEASURES				
1	Afforestation				
	i) Creation	ha	10.95	39,000	4.27
	ii) Maintenance			22135	2.42
2	Assisted natural regeneration in existing forests				
	i) Creation	ha	6.7	11,760	0.79
	ii) Maintenance			11254	0.75
3	NTFP Regeneration				

Sl. No.	Item of Work		Unit	Qty.	Rate (Rs)	Amount (Rs. lakhs)
	i)	Creation	ha	11.99	36,563	4.38
	ii)	Maintenance			21,569	2.59
4	Pasture development					
	i)	Creation	ha	6.1	20,000	1.22
	ii)	Maintenance			11,128	0.68
5	Wire/Barbed fencing					25.00
	Sub-total (B)					**42.11**
	Total (A+B)					**68.21**
C.	**Micro-planning @ 5% of (A+B)**					**3.41**
D.	**Establishment Cost @ 7%**					**4.77**
E.	**Forest Infrastructure**					
	i	Forest Fire Fighting System				5.00
	ii	Road and Foot Path Development				12.00
	iii	Instrument cost, office furniture & vehicle				20.00
	iv	Contingency				7.00
	Sub-total (F)					**44.00**
F.	**Contingency @ 5%**					**3.41**
G.	**Monitoring and evaluation for 5 years**					**50**
	GRAND TOTAL (A TO H)					**173.81**

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Date
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