ANNEXURE 10

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 thereby 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 68.085 sq. km area free draining catchment of "Nyukcharong Chu HEP" consists of five 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 for the longevity of the reservoir storage capacity. 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

Nyukcharong Chu originates in Tibet in the Himalayas at an elevation of 6500 m and travels for about 74 km in Tibet and enters Indian Territory. Total length of Nyukcharong Chu stream is approx. 92 km up to the confluence of Mago Chu.

Nyukcharong Chu joins Mago Chu upstream of CWC Murga Bridge G & D site 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 Brahmaputra River

The drainage network is mostly dendritic. Major part of the catchment area is occupied by snow and glaciers on the higher altitude and at lower altitude covered by mixed forest. Free-draining catchment of the proposed Nyukcharong Chu HEP is 6808.46 ha. For planning, management and implementation of the catchment area treatment plan the entire catchment was delineated into five (5) sub-watersheds.

A description of the major perennial/ non-perennial tributaries joining the Nyukcharong Chu in the project free-draining catchment area has been described in the EIA report. Index map showing different sub-watersheds and drainage map of the free draining catchment are shown in **Figure 1-1** and **Figure 1-2** respectively.

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 Chu River watershed on 1:50,000 Survey of India toposheets. Nyukcharong Chu- 3A2D2 watershed comprises a part of Tawang (3A2D) sub-catchment of Tawang Chu catchment (3A2) as per the AISLUS, watershed Atlas of India. The catchment area treatment plan has been limited to free-draining catchment of Nyukcharong Chu project. Therefore, for the preparation of CAT plan, part of Tawang Chu watershed (3A2D2 as per AISLUS) comprising the free draining catchment area has been delineated into 5 sub-watersheds (Nr1, Nr2, Nr3, Nr4, Nr5) on Nyukcharong Chu (3A2D2-Nr) watershed as per the Watershed Atlas of India as cited earlier, shown in **Figure 1.3.** The area of each sub-watershed is given in **Table 1-1.**

Table 1-1: Characteristics of Different Sub-Watersheds

Watershed Name	Sub-watershed Name	Area (ha)
3A2D2-Nr	Nr1	509.44
	Nr2	665.66
	Nr3	1359.18
	Nr4	1879.03
	Nr5	2395.13
Total		**6808.45**

1.3.2 TOPOGRAPHY

The free draining catchment area lies in North East Himalayas. At the project site, the river flows in a Valley having mean elevation of 2450 msl. The river bed at barrage site is about 152 m wide and the abutments are steep sloping on the left bank at angles of about 60 degree to 65 degree and on the right bank slope is 40 degree up to the proposed barrage top. The elevation of the study area varies from El. 2450 masl at barrage site to El. 4970 masl in the free draining catchment area. The topography of the free draining catchment is shown in **Figure 1-2.**

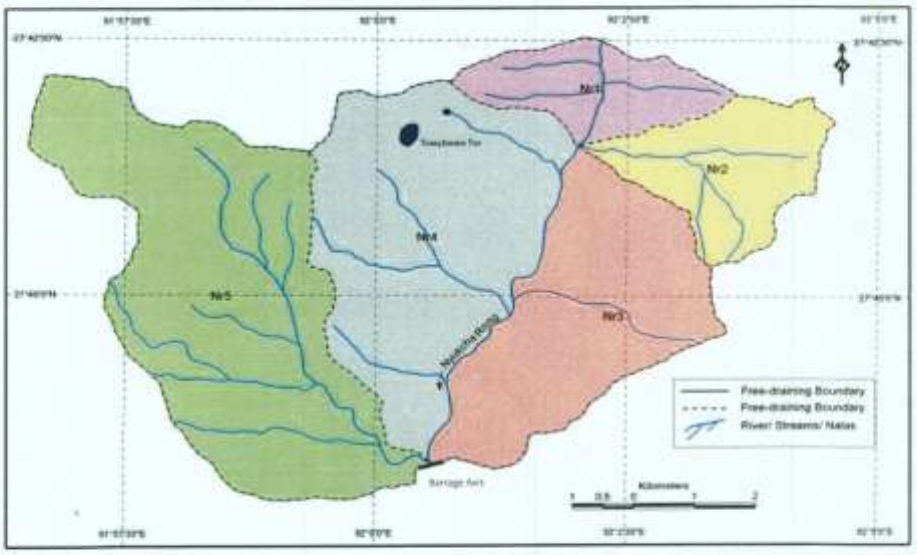

Figure 1-1: Index map of different sub- watersheds of free draining catchment

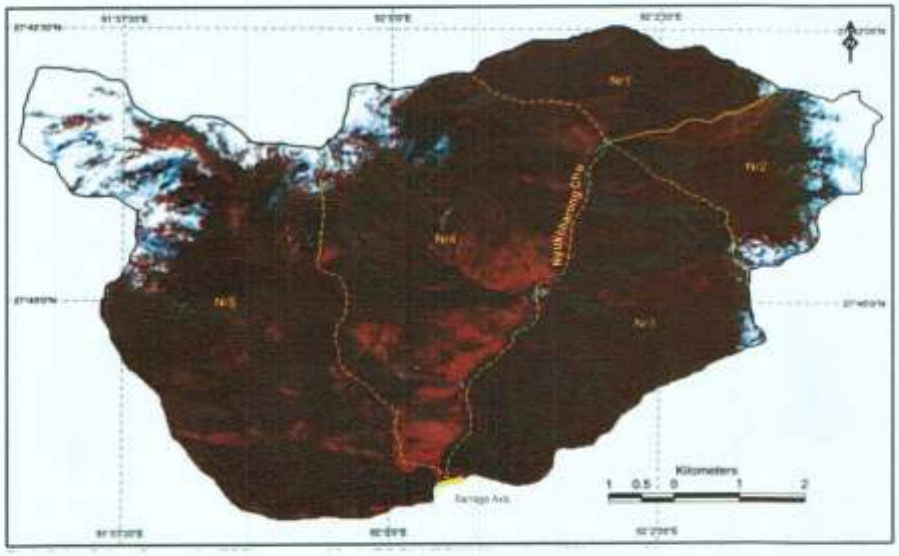

Figure 1-2: Satellite Imagery of Free Draining Catchment and Topography of the Area

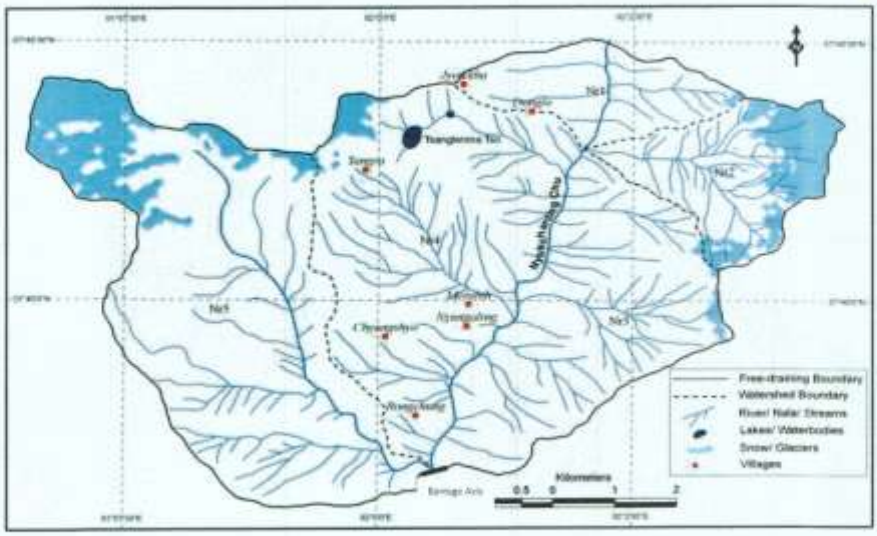

Figure 1-3: Drainage Map of Free Draining Catchment

1.4 SOIL

1.4.1 SOIL CLASS

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, it is required 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 two soil series belonging to various soil groups are identified in the 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 present study the NBSS Soil Bulletin 57 on Arunachal Pradesh was used for preparing 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 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.

Total free-draining of the proposed project has covered an area of 6808.46 ha. Soil types in the catchment were delineated from the soil map of Arunachal Pradesh. Soil classes were extracted along the five sub-watersheds of Nyukcharong Chu (Nr1-Nr5).

Soil pedon is the smallest unit of the soil classification, pedon has two association types, namely Soil association type I and Soil association type II. Association type I is usually dominated by 2/3 of the total soil representation. For example, in case of S1 type with two soil associations Lithicudrothents and Typic Udorthents. Lithic udorthents represented by 2/3rd of the total association of S1 type whereas Typic Udorthents represent by 1/3rd of the S1 type. Three soil association types were identified in the free-draining area, shown in **Figure 1-4**. Soil type S2 (Loamy skeletal – Sandy skeletal) forms the prevalent soil association type in the free draining catchment of Nyukcharong with 68.82% of total area coverage. The second dominant soil association type is S1 (Lithic Udorthents : Typic Udorthents) with 21.39 % with total area coverage of the land. Rest of the area is covered by snow/glaciers (9.79%).

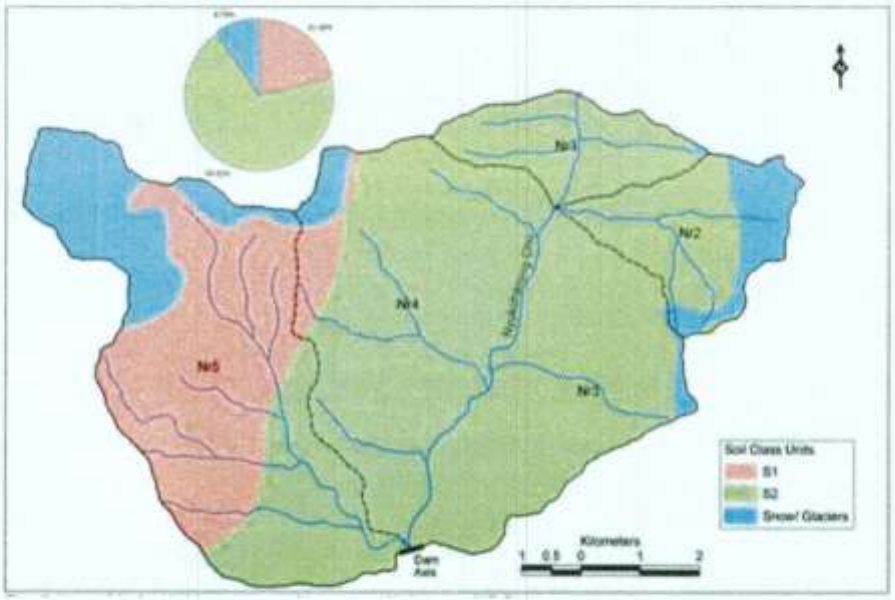

Figure 1-4: Soil Map of Free-Draining Catchment Area

Table 1-2 below provides the Area (ha) with percentage of different soil classes of free-draining area of the proposed project. Soil group with their characteristics of the project is given in **Table 1-3**.

Table 1-2: Area (ha) with Percentage of Different Soil Classes

Soil Class	Area (ha)	(%)
S 1	1456.27	21.39
S 2	4685.66	68.82
Snow/ Glacier	666.52	9.79
Total	**6808.45**	**100.00**

Table 1-3 Soil Groups and their Characteristics

Soil Group	Soil Type	Soil Characteristics
S1	Loamy-skeletal, Lithic Udorthents	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard and moderate stoniness: associated with
	Loamy-skeletal, Typic Udorthents	Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes with severe erosion hazard and moderate stoniness.

Soil Group	Soil Type	Soil Characteristics
S2	Loamy-skeletal, Entic Haplumbrepts	Deep, somewhat excessively drained, loamy- skeletal soils on moderately steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness; associated with;
	Sandy-skeletal, Typic Udorthents	Moderately shallow, excessively drained, sandy-skeletal soils on steeply sloping summits with very severe erosion hazard and slight stoniness.

1.4.2 SOIL DEPTH

Soil depth is an important factor to determine the susceptibility to erosion. In the free draining catchment of proposed project, soil depth is divided into two classes; shallow class and deep class covered with snow/ glaciers. Deep class is more susceptible to soil erosion rather than shallow soil. Both the soil classes (shallow and deep) are proportionately spread in the free draining area. Deep class accounts for 4685.66 ha (68.82%) of the free draining area where as shallow class accounts for 21.39% of the free draining area and rest of the area is covered by snow/ glacier (9.79%). The spatial distribution of the soil depth classes is described along sub watersheds (Table 1-4).

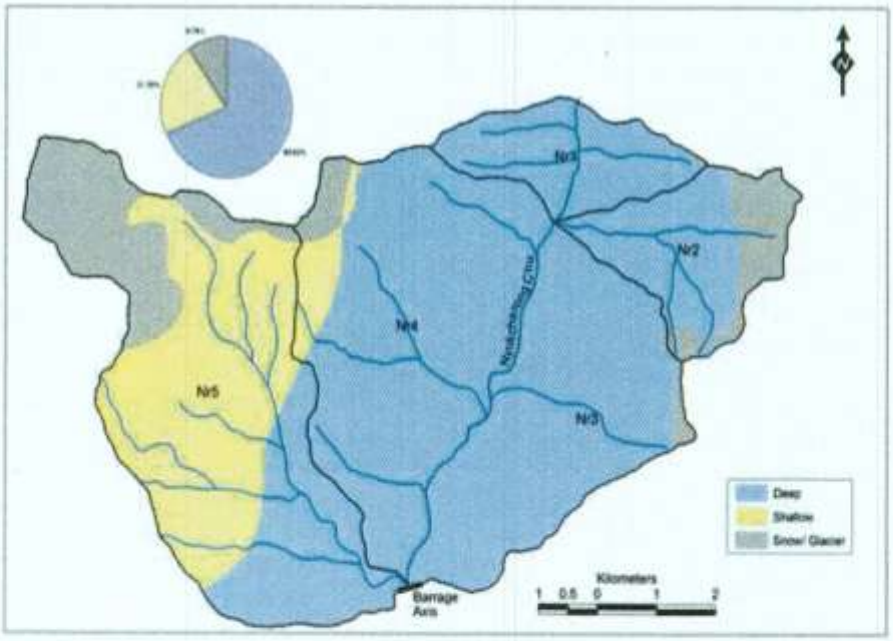

Figure 1-5: Soil Depth Map of Free-Draining Catchment Area

Table 1-4: Area (ha) and Percentage of Soil Depth of Free-Draining Catchment Area

Soil Depth Classes	Area (ha)	Percentage
Deep	4685.66	68.82
Shallow	1456.27	21.39
Snow/ Glacier	666.52	9.79
Total	6808.45	100.00

1.5 LAND USE

1.5.1 LAND USE/ LAND COVER

A Land cover thematic map depicts the land composition, using land cover classification technique that is one of the most common applications of remote sensing. Nyukcharong Chu free draining area depicts a land cover, predominantly with dense forest and open forest, followed by barren land. 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. For this purpose digital data of IRS P6 was procured from National Remote Sensing Agency (NRSA), Hyderabad. Digital image processing of the satellite data and the analysis of interpreted maps were using ERDAS Imagine 8.7. The project area was extracted from the full scenes (**Figure 1-2**) above. The details of the satellite data used in this study are as follows:

Satellite	Bands	Sensor	Path/Row	Date	Data type
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 canopy cover >40% 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

Density Class	Forest Type
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/ rocky-land
Snow/ Glaciers	

The base map, drainage map and land use/land cover map prepared using the satellite data were digitized on computer for further processing and analysis using combination of ArcGIS 9.0. The sub-watershed boundaries were then overlaid on the drainage map and land use map of the Nyukcharong Chu watershed up to 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.

Nyukcharong Chu free-draining catchment has a good forest cover. About 9.79% of the free-draining area is covered with snow and glaciers (**Table 1-5, Figure 1-6**). Dense forests forms second predominant class belongs mainly to Sub-tropical forest and Semi evergreen forest types. It covers 52.45% of the total free draining area. Subsequently, Open forest and Degraded forest accounts for area coverage of mere 7.14% and 0.14% of the area. Other classes, such as Moraines and barren classes account for 12.15% and 12% of the free draining area. The Scrub/ Alpine scrub and Alpine Meadow land classes accounts for 2.36% and 2.80% of the free draining area respectively. In the free draining catchment, cultivation and settlement accounts for only 0.02% of the total project area. Lakes/ Water bodies and River/ Nallas account for 0.15% of the free draining area.

Table 1-5: Area (ha) of different Land use/ Land cover

Land use/ Land cover	Area (ha)	%
Dense Forest	3570.85	52.45
Open Forest	486.43	7.142
Scrub/ Alpine Scrub	160.78	2.36
Degraded Forest	9.59	0.14
Alpine Meadows	190.79	2.80
Cultivation/ Settlements	1.14	0.02
Moraines	827.17	12.15
Barren/ Rocky-land	817.10	12.00
River/ Nalas	68.57	1.01

Land use/ Land cover	Area (ha)	%
Lakes/ Water bodies	9.51	0.14
Snow/ Glaciers	666.52	9.79
Total	**6808.45**	**100.00**

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 lands suitability classes, which enables us to formulate suitable conservation measures for the prevention of soil erosion. The following slope classes (**Table 1-6**) and ranges are recommended by All India Soil & Land Use Survey (AIS&LUS).

Table 1-6: 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 project area was generated from the contours of Survey of India (SOI) toposheets at 1:50,000 scale following a 40 m contour interval. The contours were digitized using ArcGIS 9.1 and wherever SOI toposheets not available, Analysis through the slope model reveals that strongly sloping is predominantly distributed in the free draining area with area coverage of 38.99% of total area coverage followed by moderately sloping (35.90%). Subsequently, moderately steep slope and gently sloping covers 16.28% and 7.73% respectively. The Steep and Very Steep are scarcely spread in the free draining area, these classes covers an area of 1.09% and 0.001% (**Table 1-8** and **Figure 1-7**).

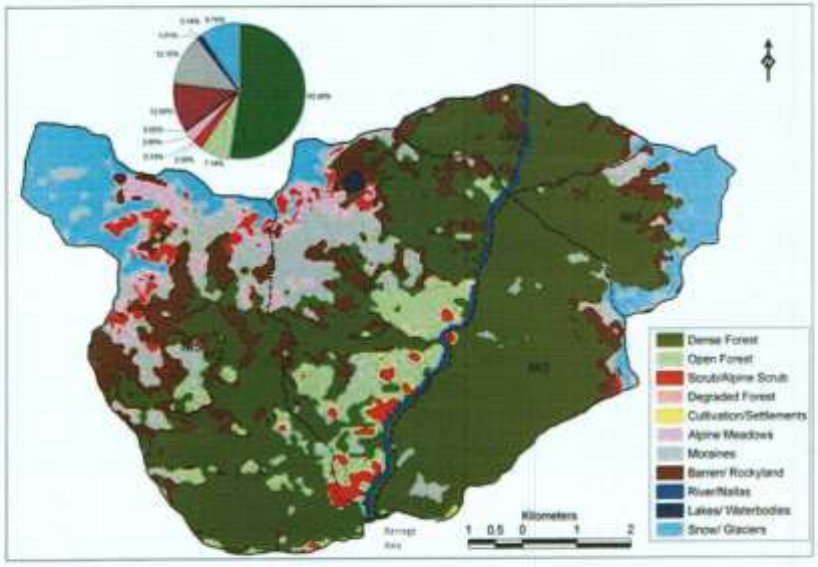

Figure 1-6: Land use Map of Free Draining Catchment Area

Table 1-7: Land use/ land cover for different sub-watersheds

Sub-watersheds	Different types of Land use										
	Dense Forest	Open Forest	Scrub/ Alpine Scrub	Degraded Forest	Alpine Meadows	Cultivation/ Settlements	Barren/ Rocky-Land	Moraines	River/ Nallas	Lakes/ Water bodies	Snow/ Glaciers
Nr1	402.53	2.99	0.11	-	0.16	-	74.94	9.06	15.31	-	4.35
Nr2	316.41	2.38	-	-	4.73	-	66.12	53.85	-	-	222.13
Nr3	1208.85	5.17	4.59	-	0.58	1.14	44.07	73.46	1.72	0.01	19.58
Nr4	690.45	363.79	82.84	8.55	64.07	-	251.79	310.16	49.29	9.48	48.59
Nr5	952.60	112.19	72.16	1.04	121.21	-	380.17	380.64	2.25	-	371.87
Total	3570.85	486.43	160.78	9.59	190.79	1.14	817.10	827.17	68.57	9.51	666.52

Table 1-8: Slope Class with Area in Hectares

Slope Class	Area (ha)	Percentage
Gently Sloping	408.24	6.09
Moderately Sloping	2318.20	34.05
Strongly Sloping	2984.66	43.84
Moderately Steep	1027.59	15.09
Steep	69.27	1.02
Very Steep	0.50	0.01
Total	6808.46	

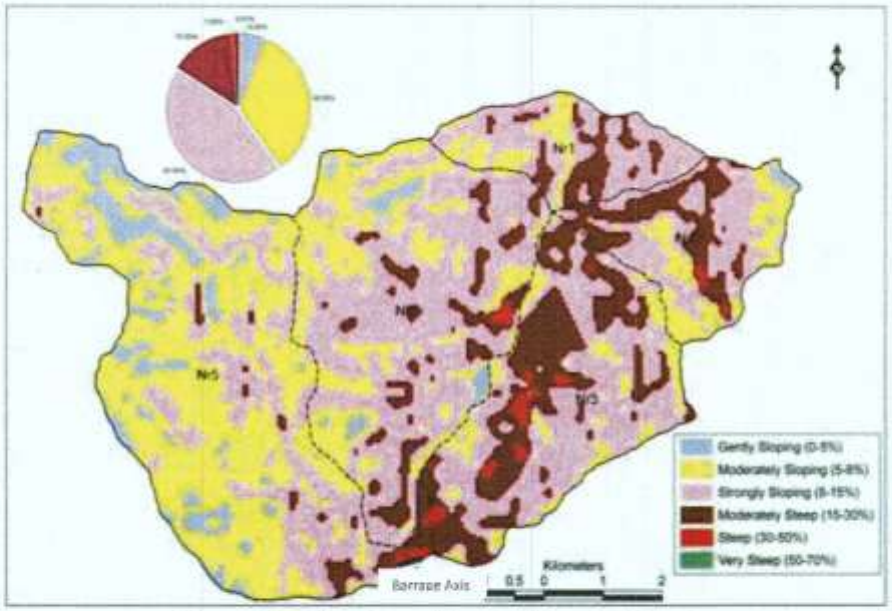

Figure 1-7: Slope Map of Free Draining Catchment

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 has been made. The vulnerable and problematic areas have been identified in different physiographic zones. These data sets have been 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 AIS&LUS (Development of Agriculture, Govt. of India) has been followed.

(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 has been assigned to each erosion intensity unit. The composite map for delineating different erosion intensity units has been prepared through superimposition of the maps showing soil types, slope and land-use/land-cover. This thematic mapping of erosion intensity for entire catchment has been done using the overlay and union techniques. Based on ground truth, verification conducted during fieldwork and published data, weightage and delivery ratio has been assigned to each erosion intensity units. The composite erosion intensity map has 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 has been 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 has been calculated for each composite erosion intensity unit. The delivery ratio 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 has 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 ration to the erosion intensity units have been 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 1-9**.

Table 1-9: 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 i^{th} (EIMU)
Wi	=	Weightage value of i^{th} 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 1-10**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 1-10: 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 5 sub-watersheds, computation of SYI for each MWS is presented in **Table 1-11.**

Table 1-11: SYI & Ranking for Sub-watersheds

Sub-watershed code	Erosion Intensity	Area* (ha)	Weightage	Area x weightage	Delivery ratio	Gross silt yield	Sediment Yield Index (SYI)
Nr1	a	0.00	0	0	0	0	
	b	57.68	16	922.88	0.95	877	

Sub-watershed code	Erosion intensity	Area* (ha)	Weightage	Area x weightage	Delivery ratio	Gross silt yield	Sediment Yield Index (SYI)
	c	365.63	15	5484.45	0.85	4662	
	d	66.47	12	797.64	0.85	678	
Total		**489.78**				**6217**	**1269.25**
Nr2	a	-	-	-	-	-	
	b	106.87	17	1816.79	0.90	1635	
	c	283.75	14	3972.5	0.85	3377	
	d	52.91	13	687.83	0.7	481	
Total		**443.53**				**5493**	**1238.52**
Nr3	a	0.00	0	0	0.00	0	
	b	101.59	17	1727.03	0.85	1468	
	c	1108.60	13	14411.8	0.85	12250	
	d	127.66	12	1531.92	0.7	1072	
Total		**1337.85**				**14790**	**1105.53**
Nr4	a	-	-	-	-	-	
	b	469.78	18	8456.04	0.85	7188	
	c	1105.34	17	18790.78	0.8	15033	
	d	196.55	14	2751.7	0.75	2064	
Total		**1771.67**				**24284**	**1370.69**
Nr5	a	-	-	-	-	-	
	b	696.74	17	11844.58	0.85	10068	
	c	1037.26	15	15558.9	0.75	11669	
	d	287.02	12	3444.24	0.7	2411	
Total		**2021.02**				**24148**	**1194.84**

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 1-12**). 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 1-12: SYI &Ranking for Sub-watersheds

Sub watersheds	Area (ha)	SYI	Ranking	Priority category
Nr1	509.44	1269.25	2	High
Nr2	665.67	1238.52	3	High

Sub watersheds	Area (ha)	SYI	Ranking	Priority category
Nr3	1359.19	1105.53	5	Medium
Nr4	1879.03	1370.69	1	Very High
Nr5	2395.13	1194.84	4	Medium
Total	**6808.46**			

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 1-8** and the statistics are presented in **Table 1-13**.

Table1-13: Area (ha) Different Erosion Categories

Erosion categories	Area (ha)	%
Slight	730.61	10.73
Moderate	3900.59	57.29
Severe	1432.65	21.04
River/ Nallas	68.57	1.01
Lakes/ Water bodies	9.51	0.14
Snow/ Glaciers	666.52	9.79
Total	**6808.45**	**100.00**

Around 21.04% of the total free draining area is found to be under severe erosion. A large area 57.29% of free draining area is classified under moderate erosion whereas slight erosion accounts for 10.73 per cent. Rest of the area falls under the water bodies and snow/ glaciers.

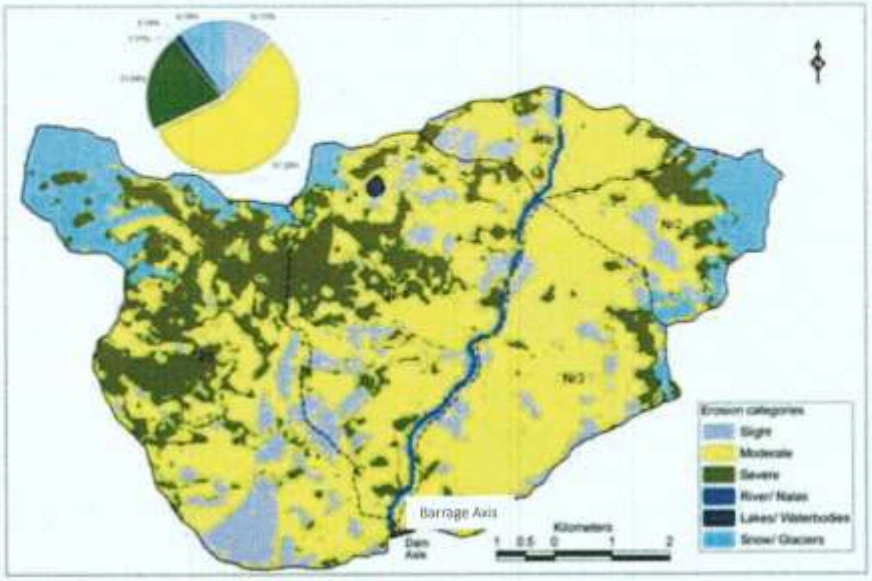

Figure 1-8: Erosion Intensity Map of Free Draining Catchment Area

After exclusion of rocks and inaccessible terrain, only those areas which fall under very severe and 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, the area falling under very severe erosion intensity class shall be taken for treatment with biological and engineering measures under the CAT Plan.

1.8 TREATABLE AREA FOR SOIL CONSERVATION MEASURES

The prioritized areas in the different sub-watersheds of the free-draining of Nyukcharong Chu 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 have been run in a step-wise manner using GIS software (ArcGIS 9.2 & GeoMedia Professional 5.2). These queries included different attributes of parameters that have been defined earlier in the chapters, viz. slope, soil, land use, etc. 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 have been 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 have been 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 has been prepared. From the thematic map of erosion intensity, areas that require treatment measures have been extracted with the help of further spatial queries. Areas classified as inaccessible, i.e. areas with more than 45^0 (100%) slope and areas above 3,200 m with natural ecosystems having little human interference have been excluded from the treatment measures even though these areas may have ranked high in prioritization for treatment (i.e. Nr2). The total area that require treatment under this CAT plan (76.78 ha) has been calculated after excluding the areas where it is not feasible to carry out treatment. (**Figure 1-9**). The total area earmarked for the treatment comprises more than 1.13% of the free-draining catchment area, and 21.04% of the total area under severe erosion intensity categories requiring for treatment measures. The total treatable area is 5.36% to be considered for treatment of the total severe erosion category.

1.8.1 YEAR-WISE TREATMENT OF SUB-WATERSHEDS

Silt yield index (SYI) has been calculated for all the 4 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and accordingly prioritized for treatment. Maximum area of 51.95 ha (around 67.66% of the total treatment area) has been taken in the first year for treatment and in the third year minimum treatment area is around 4.75 ha (6.19% of the total treatment area). The maximum estimated SYI value of 1370.69 is recorded for Nr4 sub-watershed and the minimum value of 1105.53 is in Nr3 sub-watershed.

An area of 51.95 ha will be taken for treatment in the first year according to the prioritization of SYI (**Table 9**). In the second and third year, 9.54 ha and 4.75 ha respectively and in the fourth year 10.54 ha of land will be treated in Nr3 sub watershed (**Figure 10**).

Table 1-14: Year-wise treatment of the sub-watersheds

Sub-watersheds	Area	Treatable Area (ha)	Year wise
Nr4	1879.03	51.95	Ist Year
Nr1	509.44	9.54	IInd Year
Nr5	2395.14	4.75	IIIrd Year
Nr3	1359.15	10.54	IVth Year
Total		**76.78**	

Note: In the sub-watershed Nr2, no treatment activities will be taken because this sub-watershed is located on higher altitude with most of the area covered with rocks with perpetual snow and glaciers

Treatment area under different sub-watershed of free draining catchment of Nyukcharong Chu HEP is given in **Figure 1-9** and Year wise Treatment Index map in **Figure 1-10.**

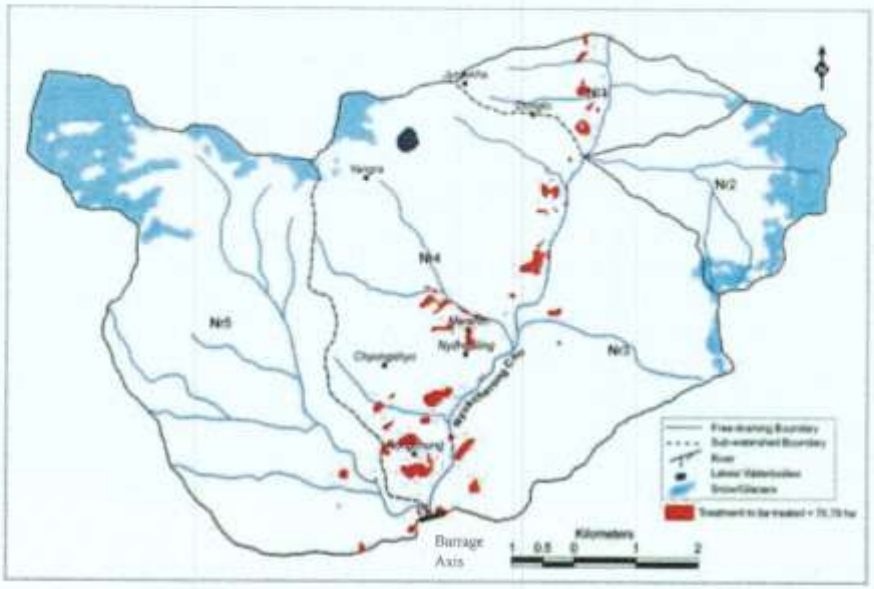

Figure 1-9: Treatment Area of Nyukcharong Chu free draining catchment

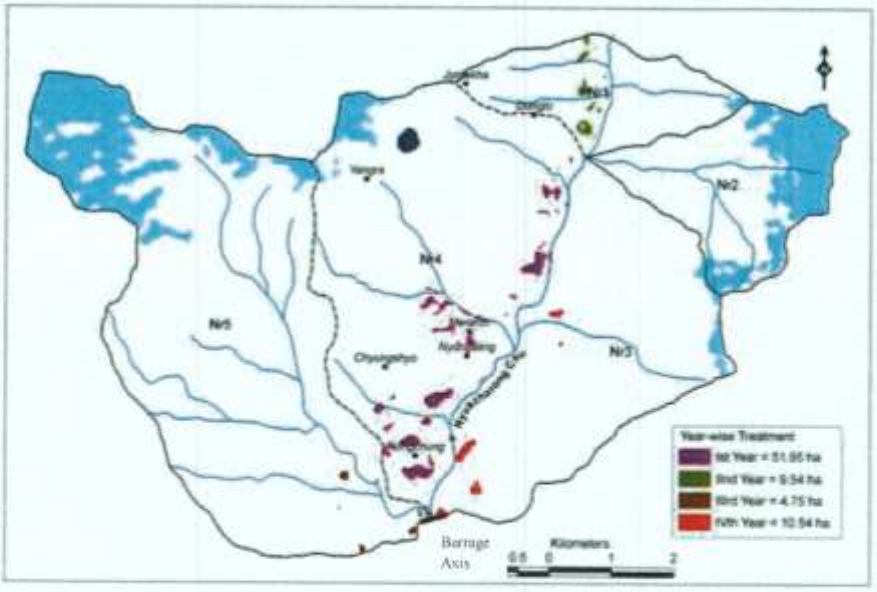

Figure 1-10: Year wise Treatment Index map for free draining catchment

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 areas with very severe erosion intensity having very steep slopes and which are inaccessible would be left alone of natural rejuvenation category also have been earmarked for treatment owing to local conditions and degradation factors.

The erosion area is mostly concentrated in areas under land use class, glacier melts/ moraine, degraded forest, open forest, barren land and agricultural settlement. Based on computation of SYI, two sub-watersheds have been classified as High erosion category, two sub-watersheds as Medium erosion category and one sub-watershed as High erosion category. Area under different slope, soil, erosion and land use categories have been classified and detailed in **Table 1-15, Table 1-16, Table 1-17** and **Table 1-18** respectively.

Table 1-15: Area (ha) of the different slope categories for the sub-watersheds

Sub-watersheds	Slope Categories						
	Gently Sloping	Moderately Sloping	Strongly Sloping	Moderately Steep	Steep	Very Steep	Total
Nr1	0.01	100.96	299.83	108.65	-	-	509.45
Nr2	12.98	163.51	303.06	179.36	6.75	-	665.66
Nr3	2.31	161.95	672.8	474.82	46.81	0.5	1359.19
Nr4	63.39	511.19	1085.86	207.52	11.06	-	1879.02
Nr5	329.56	1380.58	623.1	57.24	4.65	-	2395.13
Total	**408.25**	**2318.19**	**2984.65**	**1027.59**	**69.27**	**0.5**	**6808.46**

Table 1-16: Area (ha) of the different soil categories for sub-watersheds

Sub-watersheds	Soil categories		
	S1	S2	Snow/ Glaciers
Nr1	-	505.1	4.35
Nr2	-	443.53	222.13
Nr3	-	1339.61	19.58
Nr4	125.26	1705.17	48.59
Nr5	1331.01	692.25	371.87
Total	**1456.27**	**4685.66**	**666.52**

Table 1-17: Area (ha) of the different erosion categories for sub-watersheds

Sub-watersheds	Erosion categories					
	Slight	Moderate	Severe	River	Lakes/ Waterbodies	Snow/Glaciers
Nr1	66.47	365.63	57.68	15.31	-	4.35
Nr2	52.91	283.75	106.87	-	-	222.13
Nr3	127.66	1108.61	101.59	1.72	0.03	19.58
Nr4	196.55	1105.34	469.78	49.29	9.48	48.59
Nr5	287.02	1037.25	696.74	2.25	-	371.87
Total	**730.61**	**3900.59**	**1432.65**	**68.57**	**9.51**	**666.52**

Table 1-18: Areas (ha) of the different land use/ land cover for sub-watersheds

Sub-water sheds	Land use/ Land cover categories										
	Dense Forest	Open Forest	Scrub/ Alpine Scrub	Degraded Forest	Alpine Meadows	Cultivation / Settlements	Barren/ Rocky Land	Moraines	River/ Nalas	Lakes/ Water-Bodies	Snow/ Glaciers
Nr1	402.53	2.99	0.11	-	0.16	-	74.94	0.06	15.31	-	4.35
Nr2	316.41	2.38	-	-	4.77	-	66.12	53.85	-	-	222.13
Nr3	1208.85	5.17	4.59	-	0.58	1.14	44.07	73.46	1.72	0.03	19.58
Nr4	690.45	363.7	82.94	8.55	64.07	-	251.79	310.16	49.29	9.48	48.59
Nr5	952.6	112.19	73.16	1.04	121.21	-	380.17	380.64	2.25	-	371.87
Total	**3570.85**	**486.43**	**160.78**	**9.59**	**190.79**	**1.14**	**817.1**	**827.17**	**68.57**	**9.51**	**666.52**

1.9.1 NR1 SUB-WATERSHED

This sub-watershed is located at the north-east of the free-draining catchment with small tributaries on both the banks of the Nyukcharong Chu with an area of 509.44 ha. This sub-watershed has strongly sloping area with 299.83 ha (58.85%) followed by moderately steep (108.65 ha) **(Table 1-15).** Above 99% of the catchment area is covered by S2 (Deep – loamy skeletal/ entichaplumbrepts with sandy skeletal) **(Table 1-16).** This sub-watershed is covered with dense forest (78%) followed by patches of barren/ rocky land (14.71%) on the ridges **(Table 1-17).** About 72% of the free-draining catchment area is predominantly covered by moderate erosion **(Table 1-18** and **Figure 1-11).**

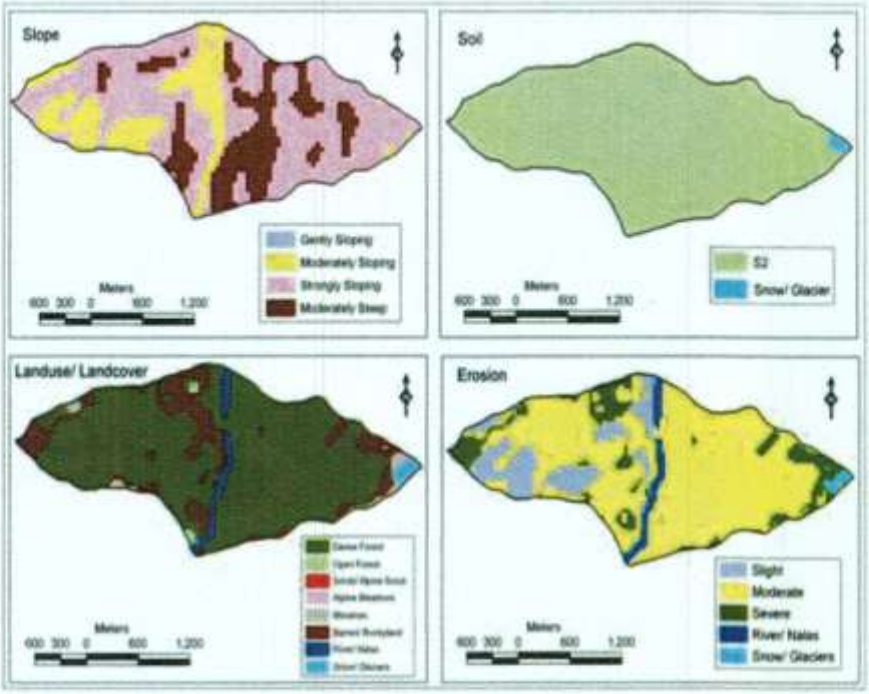

Figure 1-51: Map showing slope, soil, erosion& land use land cover of sub-watershed Nr1

1.9.2 NR2 SUB-WATERSHED

This Nr2 sub-watersheds having an area of 665.67 ha and is located on the east of the catchmentwith glacier fed rivers joins with Nyukcharong Chu on its left bank. In this sub-watershed, the strongly (8-15%) sloping (45.53%) is predominantly covered the

land with moderately (15-30%) steep and moderately (5-8%) sloping **(Table 1-15).** The soil in this sub-watershed is S2 (Deep – loamy skeletal/ entichaplumbrepts with sandy skeletal) covered the land with 443.53 ha area **(Table 1-16).** More than 47% of the land in this sub-watershed is under dense forest followed by snow/ glaciers. The patches of barren (9.93%) and moraines (8.09%) are also seen **(Table 1-17).** About 16% of the sub-watershed is prone to severe erosion **(Table 1-18**and **Figure 1-12).**

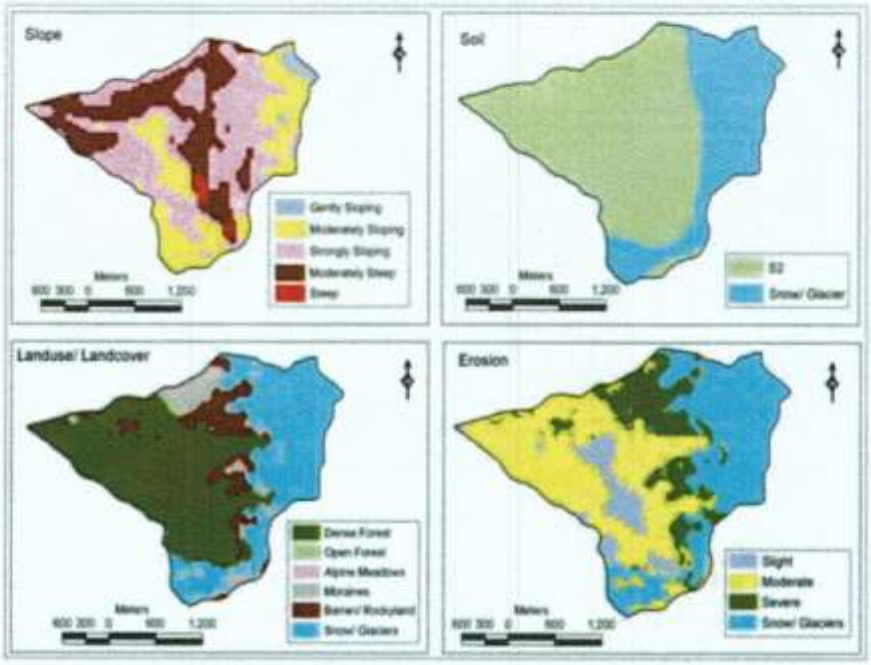

Figure 1-62: Map showing slope, soil, erosion& land use land cover of sub-watershed Nr2

1.9.3 NR3 SUB-WATERSHED

This sub-watershed is located on the left bank of the Nyukcharong Chu having an area of 1359.19. Major tributary of this sub-watershed is glacier fed with small nallas, with slopes varying from 162 to 673 ha covering moderately sloping, strongly sloping and moderately steep **(Table 1-15).** The soil of this sub-watershed is belonging to S2 soil unit category. About 89% of the Nr3 sub-watershed is having dense forest with moraines and barren (5.40% and 3.24% respectively) patches with a very little area of 1.14 ha in the sub-watershed is covered under cultivation/ settlement. The ridge is covered with snow/ glaciers **(Table 1-17)** and the sub-watershed is predominantly covered with moderate erosion **(Table 1-18**and **Figure 1-13).**

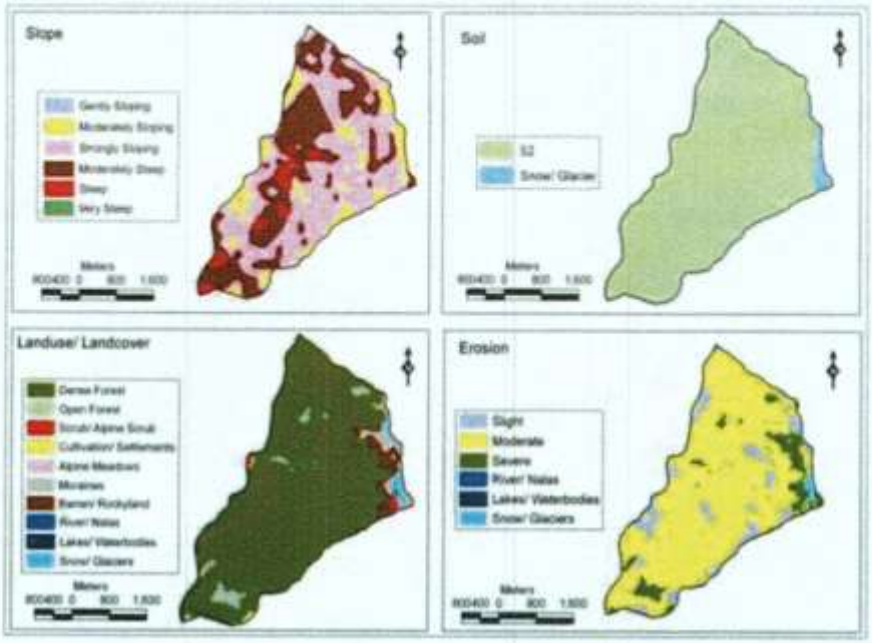

Figure 1-73: Map showing slope, soil, erosion& land use land cover of sub-watershed Nr3

1.9.4 NR4 SUB-WATERSHED

The Nr4 sub-watershed is having an area of 1879.03 ha and is located on the right bank of the Nyukcharong Chu with a large Tsanglenma Tso lake (water body) on the higher elevation with an area of approx. 9.51 ha. This sub-watershed is having perennial and non-perennial streams on the right bank of Nyukcharong Chu. Major part of the sub-watershed is lying under strongly slope with an area of 1085.86 ha (57.79%) followed by moderately sloping (27.21%) (**Table 1-15**). S1 and S2 soil units are lying in this sub-watershed with an area of 125.26 ha and 1705.17 ha respectively while snow patches are also found on the ridge of the sub-watershed (**Table 1-16**). About 1054.15 ha are covered with forest of the sub-watershed (36.75% of the dense forest and 19.36% of the open forest). Barren and moraines are covered the land of the Nr4 sub-watershed while 4.87% of the land is lying under scrub/alpine scrub and degraded forest (**Table 1-17**). The soil erosion of the land is predominantly covered by moderate while severe erosion covers 469.78 ha and prone for treatment (**Table 1-18** and **Figure 1-14**).

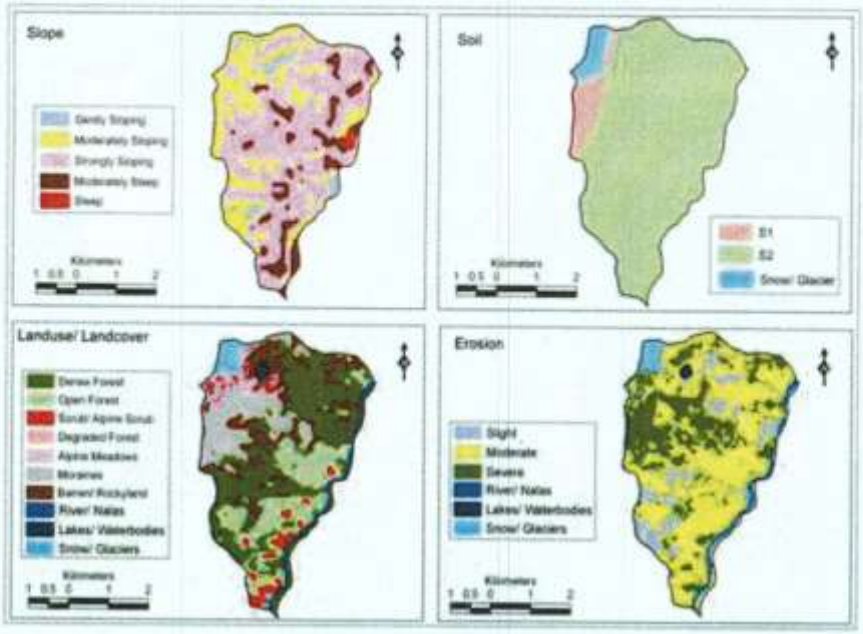

Figure 1-84: Map showing slope, soil, erosion& land use land cover of sub-watershed Nr4

1.9.5 NR5 SUB-WATERSHED

This is the largest sub-watershed in the free-draining catchment of the Nyukcharong Chu HEP and located at the west of sub-watershed with having an area of 2395.13 ha and having a major glacier fed tributary with small nallas on its both banks joins the Nyukcharong Chu at the proposed dam site location. In this sub-watershed the slope area is ranging from 4 ha to 1381 ha (steep to moderately sloping) (**Table 1-15**). Shallow (loamy skeletal with lithic udorthents) and deep (loamy skeletal entichaplumbrepts with sandy skeletal) are covered under the land of the sub-watershed with patches of snow/glaciers on the higher elevations (**Table 1-16**). Major part of the land is covered by forest (dense and open forest) with an area of 1064.79 ha). While barren and moraines are covered almost the same area of the land with approximately 380 ha. The snow/ glacier is also covered the higher elevations of the sub-watershed with 371.87 ha area (**Table 1-17**). More than 43% of the land is covered by moderately erosion while treatment of the area is prone under severe erosion (**Table 1-18** and **Figure 1-15**).

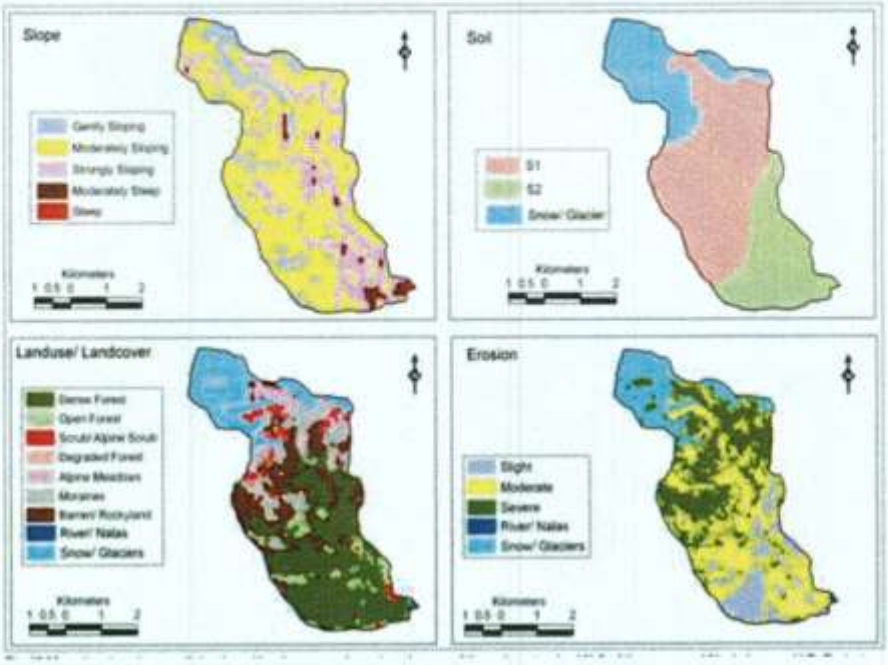

Figure 1-5: Map showing slope, soil, erosion& land use land cover of sub-watershed Nr5

1.10 ACTIVITIES TO BE UNDERTAKEN (TREATMENT MEASURES)

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 checks 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:

a. Brushwood checkdam
b. DRSM (Dry Rubble Stone Masonry) - Check dams with stones
c. Contour Bunding

d. 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.

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 checkdams, small branches preferably of coppice able species are fixed in two parallel rows across the gully or nalla 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 checkdams is to pack the brushwood as tightly as possible and to secure it firmly. This type of checkdam is generally constructed over small gully or at the starting stretch of gully. In all, 15 brushwood checkdams/ vegetative spurs would be constructed to check gully erosion, stream bank protection and slope stabilisation works.

b. Dry Rubble Stone Masonry (DRSM) check dams

The site where DRSM checkdams 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 checkdam 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 checkdams vertical with all slopes on the downstream face but while there is sound engineering reason for this in case of large checkdams 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, 23 DRSM checkdams would be constructed.

c. Contour Bunding

Contour bunding is one of the simple methods of soil and water conservation. It plays an important role in soil and water conservation in the field with medium slope. Along bunds trees which fix nitrogen into the soil are planted with grass along the bunds. Contour bonding helps in soil and water conservation. When there is rainfall, contour bund acts as a barrier to the water flow and checks the velocity. This reduces chances of soil erosion. When water starts flowing along the fields, bund becomes obstruction for it. Due to the obstruction, velocity reduces and water percolates behind the bunds. This allows infiltration of water into the soil. A total area of 16.00 ha will be used for contour bonding with an estimate budget of **Rs. 4.00 lakhs**.

d. 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. The sloping fields in the valley need to be bench terraced by cutting and filling with the later 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 9.75 ha will be covered under this plan with an estimated budget of **Rs. 0.73 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
E. Nursery development

It is always better to 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 *Acer sikkimensis, Alangiumalpinum, Alnusnepalensis, Betulaalnoides, Brassiopsisglomerulata, Pinusroxburghii,Pinuswallichiana, Quercuslamellose, Quercussemicarpifolia, Rhododendron maddenii, Rhododendron campanulatum, Taxusbaccata, Berberisaristrata, Daphnaepapyracea, Lindernieesiana, Zanthoxylumoxyphyllum,Anaphalismargaritacea, Aster trinervius, Cyathulacapitata, Ophiopogonintermedius, Plantago major, Trifoliumrepens,* etc. would be undertaken. Afforestation measures would be taken up under CAT plan. An outlay of **Rs.9.78 lakhs** (Rs. 6.24 lakhs for creation and Rs. 3.54 lakhs for its maintenance) for 16.00 ha has been provided to cover various areas under afforestation in different sub-watersheds.

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 operationsare 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. 1.53 lakhs** including its creation and maintenance has been made to cover 6.65 ha.

B. 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 valuable resources. 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.2.24 lakhs**has been suggested to cover about 3.85 ha for establishing (Rs. 1.41 lakhs) and its maintenance (Rs.0.83 lakhs) of this facility.

C. 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. 2.11 lakhs** has been earmarked for this purpose and it will cover about 6.78 ha of land for development at a cost of Rs.1.36 lakhs and its maintenance will cost Rs.0.75 lakhs.

D. Nursery Development

Proper development of nursery and allied services, like drip irrigation or micro-irrigation, will be crucial for successful execution of CAT plan. It will be important to prepare a stock of plant material for the supply of saplings for afforestation programme and various other activities. Main nursery may be developed near dam site, proposed colony areas, preferably along the road side for easy accessibility. The nurseries may be developed around colony area because of its proximity to both the upstream and downstream part of the CAT plan area as it lies in the middle of catchment. Besides, this area possesses necessary infrastructure and various raw materials for nursery development can be easily made available. In addition, provision will also be made for two green-houses/chick houses for maintaining plant saplings. The estimated cost for the development of nursery and greenhouses will be around **Rs. 25 lakhs**. Development of nursery will start from the zero year and will continue for 5 years with its maintenance (**Table 1-19**). During maintenance, nursery will supply plants wherever required for the replacement. The Estimated Cost for the development of Nursery is given in **Table 1-19.**

Table 1-19: Estimated Cost for the Nursery Development

Components	Development	Maintenance	Total Amount (Lakhs)
Shed House for raining saplings (one time grant)	0.65	0.15	0.80
Seeds collection procurement grant	3.00	-	3.00
Compost, soil, fertilizer and other materials	2.00	-	2.00
Shed House/ Chick house for maintaining and storing saplings (Nos 2)	2.00	1.00	3.00
Poly bags, pots, trays for raising saplings	2.00	-	2.00
Nursery Equipments	2.00	-	2.00
Glass wares and other laboratory wares	1.00	0.25	1.25
Chemicals, pesticides, and other plant growth regulators	1.00	0.25	1.25
Hand held trollies (Nos. 10) for transporting plant saplings	0.50	0.15	0.65
Mini-truck for transporting plants	3.50	0.55	4.05
Contingency grant for all recurring expenditure	2.00	-	2.00
Personnel/ staff	3.00	-	3.00
Total	**22.65**	**2.35**	**25.00**

Watershed-wise details of various activities are detailed in **Table 1-20**.

1.10.3 COST OF OTHER COMPONENTS OF CAT PLAN

Apart from the Forestry works 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 CAT plan involves intensive and highly technical operations, which require the expertise of technical personnel. It is therefore, recommended that the existing forest staff of Tawang Forest Division 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 the divisions. However, temporary staff may be engaged for this purpose during the project implementation period.

Schedule of Rates adopted is inclusive of 10% overhead charges as per indication at 3.1 (page-1) of PWD Schedule of rates.

Table 1-20: 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
	Brushwood Check dams	DRSM check dams	Mulching	Contour Bunding						
	No.	No.	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha
Nr1	3.00	2.00	0.75	1.50	1.50	2.35	1.35	1.40	0.69	**9.54**
Nr3	1.00	2.00	2.00	1.00	1.00	1.20	0.00	2.50	2.84	**10.54**
Nr4	10.00	18.00	15.00	12.50	6.75	11.45	2.00	2.00	2.25	**51.95**
Nr5	1.00	1.00	0.00	1.00	0.50	1.00	0.50	0.75	1.00	**4.75**
Total	**15.00**	**23.00**	**17.75**	**16.00**	**9.75**	**16.00**	**3.85**	**6.65**	**6.78**	**76.78**

Note: In the sub-watershed Nr2, no treatment activities will be taken because this sub-watershed is located on higher altitude with most of the area covered with rocks with perpetual snow and glaciers

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 Nyukcharong Chu 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. 1.75 lakhs** (3% costs of total Engineering and biological measures) has been proposed for micro-planning (**Table 1-23**).

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. Therefore, provision has been made under CAT plan to develop infrastructure of Forest Department in the region and accordingly a budget of **Rs. 98.15 lakhs** has been proposed (**Table 1-21**).

Table1-21: Budget for Development of State Forest Department Infrastructure

Components	Establishment	Running Cost	Total Amount (Lakhs)
1. Forest Office Establishment	20.00	6.00	26.00
2. Forest Fire Fighting System	5.00	-	5.00
3. Road and Foot Path Development	6.00	-	6.00
4. Office Equipment and Stationery	10.95	-	10.95

Components	Establishment	Running Cost	Total Amount (Lakhs)
5. Office Vehicle	25.00	10.20	35.20
6. Contingency	15.00	-	15.00
Total	**81.95**	**16.20**	**98.15**

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.

The total cost estimate for these activities works out to be **Rs. 44.25** lakhs, including maintenance for 5 years, started from 2nd year onwards after creation of the measures (refer **Table 1-21**). The Summary of cost is given in **Table 1-22.**

Table 1-22: Budget for Eco-restoration

Sub-Components	Amount (Rs. Lakhs)
Plantation of avenue trees in the villages and towns	5.00
Energy conservation measures	6.00
Maintenance of hygiene in the villages and towns	7.25
Training, awareness, extension and other activities	8.00
Income generating schemes	6.00
Contingency	12.00
Total	**44.25**

1.10.3.6 MONITORING AND EVALUATION

Monitoring and evaluation will be developed as a part of the project management. Thus, a process of self-evaluation at specific 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 MoEF, GoI. The monitoring committee appointed for this purpose would also monitor the quality and quantity of works carried out in the area on a regular basis.

Installation of silt recording station upstream of barrage site on Nyukcharong Chu is suggested to monitor the silt load and impact on soil conservation measures. A sum of **Rs. 30.00 lakhs** has been provided for monitoring and evaluation (**Table 1-23**).

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 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.

Table 1-23: Physical and Financial layout plan of Catchment Area Treatment for Nyukcharong Chu HEP

Sl. No.	Item	Unit	0 Year		Ist Year		IInd Year		IIIrd Year		IVth Year		Vth Year		Total Amount in lakhs	
			Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin
A	**ENGINEERING MEASURES**															
1	Gully Plugging															
a)	Brushwood check dams	Nos.	-	-	10	2.60	2	0.52	1	0.26	2	0.52	-	-	15	3.90
b)	DRSM check dams	Nos.	-	-	16	5.32	3	1.00	1	0.33	3	1.00	-	-	23	7.65
c)	Mulching	ha	-	-	12.07	0.48	2.13	0.09	1.07	0.04	2.48	0.10	-	-	17.75	0.71
d)	Contour Bunding	ha	-	-	10.88	2.72	1.92	0.48	0.96	0.24	2.24	0.56	-	-	16	4.00
2	Bench Terracing	ha	-	-	6.63	0.50	1.17	0.09	0.59	0.04	1.36	0.10	-	-	9.75	0.73
	Sub-total (1+2)		-	-									-	-		17.00
	Add: 5% for maintenance structures		-	-		**0.58**		**0.11**		**0.05**		**0.11**	-	-		0.85
	Total (A)					**12.21**		**2.28**		**0.97**		**2.39**	-	-		17.85
B	**BIOLOGICAL MEASURES**		-	-									-	-		
a)	Afforestation	ha	-	-	10.88	4.24	1.92	0.75	0.96	0.37	2.24	0.87	-	-	16	6.24
	Maintenance		-	-	-	-	-	2.41	-	0.42	-	0.21	-	0.50	-	3.54
b)	Assisted Natural Regeneration	ha	-	-	4.52	0.53	0.8	0.09	0.4	0.05	0.9	0.11	-	-	6.62	0.78
	Maintenance		-	-	-	-	-	0.51	-	0.09		0.05	-	0.10	-	0.75
c)	NTFP Regeneration	ha	-	-	2.62	0.96	0.46	0.17	0.23	0.08	0.54	0.20	-	-	3.85	1.41
	Maintenance		-	-	-	-	-	0.57	-	0.10	-	0.05	-	0.12	-	0.83
d)	Pasture Improvement	ha	-	-	4.61	0.92	0.81	0.16	0.41	0.08	0.95	0.19			6.78	1.36
	Maintenance		-	-	-	-	-	0.51	-	0.09	-	0.05	-	0.11	-	0.75
e)	Nursery Development		-	15.4	-	2.72	-	1.36	-	2.27	-	0.9	-	-	-	22.65
	Maintenance		-	-	-	-	-	1.6	-	0.28	-	0.14	-	0.33	-	2.35
	Sub-total B (a+b+c+d+e)			**15.4**		**9.37**		**8.13**		**3.84**		**2.76**		**1.15**		40.65
	Total (A + B)			**15.4**		**21.58**		**10.41**		**4.81**		**5.15**		**1.15**		58.51
C.	**Micro-planning @ 3% of A+B**		-		-	1.10	-	0.21	-	0.11	-	0.18	-	0.07	-	1.75
D.	**Eco-restoration**		-	-	-	30.09	-	5.31	-	2.66	-	4.43	-	1.77	-	44.25
E.	**Establishment Cost @ 7% of A + B**		-		-	2.78	-	0.49	-	0.25	-	0.41	-	0.16	-	4.09
F.	**Forest Infrastructure Development**		-	-	-	66.74	-	11.78	-	5.89	-	9.82	-	3.93	-	98.15
G.	**Contingency @ 5% of A + B**		-		-	1.99	-	0.35	-	0.18	-	0.29	-	0.12	-	2.92
H.	**Monitoring and Evaluation**		-	-	-	20.4	-	3.60	-	1.80	-	3.00	-	1.2	-	30
	GRAND TOTAL															239.68

3) 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 ten years is **Rs. 239.68 lakhs**. The details of cost estimates and physical work schedule as well as phasing of expenditure are given as follows in **Table 1-24**. All the costs towards the administration during the implementation work have been included in the cost estimates of CAT plan.

Table 1-24: Component-wise cost Estimate for Catchment Area Treatment Plan

No.	Item of Work	Unit	Qty.	Rate (Rs)	Amount (Rs. in lakhs)
A.	**ENGINEERING MEASURES**				
1	Gully Control				
	a) Brushwood check dams	Nos.	15	26,000	3.90
	b) DRSM check dams	Nos.	23	33,281	7.65
	c) Mulching	ha	17.75	4,000	0.71
	d) Contour Bunding	ha	16	25,000	4.00
2	Bench terracing	ha	9.75	7,500	0.73
	Sub-Total (1+2)				**17.00**
	Add 5% for maintenance of structures				0.85
	Sub-total (A)				**17.85**
B.	**BIOLOGICAL MEASURES**				
1	Afforestation				
	i) Creation	ha	16	39,000	6.24
	ii) Maintenance			22,135	3.54
2	Assisted natural regeneration in existing forests				
	i) Creation	ha	6.65	11,760	0.78
	ii) Maintenance			11,254	0.75
3	NTFP Regeneration				

No.	Item of Work	Unit	Qty.	Rate (Rs)	Amount (Rs. in lakhs)
	i) Creation	ha	3.85	36,563	1.41
	ii) Maintenance			21,569	0.83
4	Pasture development				
	i) Creation	ha	6.78	20,000	1.36
	ii) Maintenance			11,128	0.75
5	Nurseries				25.00
	Sub-total B (1+2+3+4+5)				**40.66**
	Total (A+B)				**58.51**
C.	**Establishment Cost @ 7% of (A+B)**				**4.09**
D.	**Micro-planning @ 3% of (A+B)**				1.75
E.	**Forest Infrastructure Development**				98.15
F.	**Eco-restoration**				44.25
G.	**Contingency @ 5% of (A+B)**				2.93
H.	**Monitoring and evaluation**				30.00
	GRAND TOTAL				**239.68**

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