5.1. CATCHMENT AREA TREATMENT PLAN

5.1.1 INTRODUCTION

Generally speaking, for the optimal functionality and longevity of a dam or reservoir of hydropower projects, it is essential to limit and minimize the sediment intake to minimum level. It is a well established fact that reservoirs formed by dams on rivers are subjected to sedimentation. The process of sedimentation embodies the sequential processes of erosion, entrainment, transportation, deposition and compaction of sediment. The study of erosion and sediment yield from catchments is of utmost importance as the deposition of sediment in reservoir reduces its capacity and thus affecting the water availability 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. Thus, a well designed catchment area treatment plan is essential to ameliorate the above mentioned adverse processes of soil erosion. In hilly area, as in the present case, erosion due to water is a common phenomenon and the same has been studied as a part of the Catchment Area treatment (CAT) plan. Hence, it is necessary to adopt corrective measures in the catchment area so as to reduce the sediment load. Therefore, Catchment Area Treatment (CAT) plan is an integral part of most of the hydropower development project that pertains to preparation of a management plan for treatment of erosion prone area of the catchment through biological and engineering measures. The main impact of soil erosion and its consequences are:

- loss in the production potential
- reduction in water holding capacity
- loss of nutrients
- reduction in water supply
- increase in tillage operation costs
- reduction in infiltration rates

In the catchment area of the proposed Tato-1 HE Project, there is a very large plain in the upstream part of the river, known as Mechuka Plain where both slope of the river bed (average of 0.26% over 16 km long stretch) and velocity of the water in the river (0.5 m/s to 2 m/s) are very low. Most of the silts get deposited there. Downstream of this plain and upstream of Heo H.E.

project, Pauk H.E. project is being developed by Velcan. The Arch Dam of Pauk H.E. Project creates a reservoir of 11.5 Mm^3 and 34 ha submergence area. The water velocity in the reservoir will fall down to less than 0.05 m/s, whereas the water velocity is never less than 0.2 m/s even in a desilting basin. Hence only desilted water is released by Heo H.E. Project tail race directly into Tato-I H. E. project intake. A very small part of the discharge comes from the catchment between Heo H.E. project dam and Tato-I intake. Hence the upstream Mechuka plain and Pauk Reservoir will be acting as a desilting basin for the Tato-1 H. E. project.

However, as a cautious practice, and even though Tato-I H.E. Proejct does not have a reservoir but only a very small pond (3 ha submergence including 1.8 ha river bed) CAT plan for the free-draining catchment area has been prepared with the main objective of arresting soil erosion. Based on the topographic factors, soil type, climate, land use and vegetation cover in the catchment area, various measures, both engineering / mechanical and biological are being proposed to be undertaken with the aim to check the soil erosion, prevent/check siltation of the pond and weir. The engineering measures will comprise construction of a number of check dams/walls, retaining walls, wire crates, etc. for gully control, stabilization of flood prone streams, landslides/slopes, river banks, roads, etc.

5.1.2 STUDY AREA AND STUDY APPROACH

The total area of free draining catchment of Tato-I HE Project from weir site upstream is around 7394.34 ha. The management plan is prepared for Yarjep catchment and its sub watersheds of Tato-I H. E. Project. Various spatial parameters like physiography, land use / land cover and soil class were studied before formulating a treatment plan for the catchment area of Tato-I HE Project. Various thematic maps have been used in preparation of the CAT plan. Geographic information system (GIS) was used as a common platform to analyze various spatial parameters, which is a computerized resource data base system. All the spatial data were Geo-referenced to geographic coordinate system of Yarjep catchment. GIS is a tool to store, analyze and display various spatial data. In addition, GIS has a capacity to perform numerous spatial functionalities with multi-thematic layers. It provides the capability to analyze large amount of data in relation to a set of established criteria. In order to ensure that latest and accurate data is used for the analysis. Besides remotely sensed satellite data has been used for deriving land use data complimented with ground truthing were also conducted.

The various steps covered in the study, are as follows:

1) Problem definition
2) Spatial database development and database acquisition
3) Erosion intensity assessment
4) Prioritization of sub watersheds for treatment
5) Activities to be undertaken (Biological measures and Engineering)
6) Period and Schedule of CAT plan implementation
7) Overall cost estimate of the CAT plan

The above mentioned steps are described in the following paragraphs.

5.1.3 PROBLEM DEFINITION

The requirements of the study were defined and the expected outputs were finalized, the various data layers of the catchment area to be used for the study are as follows:

- Drainage map
- Slope map
- Soil class and soil depth
- Land use classified map
- Soil erosion intensity mapping
- Area to be treated
- Treatment measures

5.1.4 SPATIAL DATABASE DEVELOPMENT AND DATA ACQUISITION

The data available from various sources has been collected. The contour maps, etc. were scanned, digitized and registered as per the requirement from the Survey of India (SOI) topographic sheets with a scale of 1:50,000. Data was prepared depending on the level of accuracy required. All the layers were geo-referenced and brought to common scale (real coordinates), so that overlay could be performed easily. A computer program using standard modeling techniques was used to estimate the soil loss. The formats of outputs from each layer were firmed up to match the formats of inputs in the program. The grid size to be used was also decided to match the level of accuracy required, the data availability and the software and time limitations. The format of output was finalized. Ground truthing and data collection was also included in the procedure. These data were collected, arranged and presented according to the standard methods used in the formulation of CAT

plan. These data were organized and presented in the form of a general drainage map of the catchment and its sub-watersheds (see **Figs. 5.1.1 & 5.1.2**). A slope model for entire catchment area was digitized from the contours of Survey of India topographical, where available, following a 40 m contour interval (see **Fig. 5.1.3**).

For the present study, IRS P6 LISS-III digital satellite data was used for interpretation and image classification. The data has been procured in raw digital format and has been geo-referenced using Survey of India Topographical sheets with the help of standard data preparation techniques in standard image processing software. The interpretation of geo-referenced satellite data has been done using standard enhancement technique and ground truthing. A detailed ground truth verification has been undertaken as a part of ecological survey to enrich the image classification process.

Soil map for the entire project area was prepared from the basic data/map of soil classification prepared by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, NBSS Publ. No. 57b, 1997), Indian Council of Agricultural Research (IARI). Soil classes and soil depth were acquired. This basic information was transferred to a GIS based map and was later used to designate/ classify areas of varying soil erosion proneness in combination with information on slope and forest cover.

From the thematic maps of slope, drainage, soil and land use a composite erosion intensity unit (CEIU) map was prepared on 1:50,000 scale. We used hierarchical querying to extract the various erosion intensity units. The composite erosion intensity unit map was then superimposed on the drainage map with sub-watershed boundaries, so that treatable land units could be obtained sub-watershedwise.

The areas in the different sub-watersheds of the Tato-I H.E. Project requiring treatment were 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 (combination of ArcGIS 9.1 & GeoMedia Professional 5.2). These queries included different attributes of parameters viz. slope, soil depth, 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 were undertaken for different slope categories ranging from gently sloping category to very steep 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. In all more than 150 such spatial queries were executed for the purpose for each and every sub-watershed separately. From these queries a thematic map of areas prone to erosion in the entire project 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 found inaccessible i.e. areas with more than 45º (50%) slope and above 3200 m elevation with natural ecosystems with little human interference and tree line were excluded to arrive at those areas where appropriate treatment measures can be undertaken. Such areas were extracted for each individual sub-watershed.

The treatment measures for arresting soil erosion in the catchment were basically classified into biological measures and engineering measures. These measures have been suggested as favored methods of treatment at various places/sites, depending on its location and geographic/geological condition.

Based on drainage network and topographical features, the catchment was delineated into 7 sub watersheds (Sk1-Sk7) (see **Fig. 5.1.2**). Further, based on the above methods on the database generation various spatial factors such as drainage, slopes, land use/ land cover, soil classes and soil depth were generated. Subsequently, using the spatial functionalities in the GIS tools soil erosion susceptible map was also generated. Furthermore, these erosion maps were used to assess the areas to be treated during the subsequent years of the project tenure. In this section various spatial features will be discussed accordingly to the sub watershed wise.

5.1.4.1 Drainage

In the free draining area most of the tributaries are flowing from the right bank of river Yarjep. Tributaries along the left bank are smaller and seasonal. Along the right bank of the Yarjep River two large tributaries are both called Sarak Korong (see **Fig. 5.1.1**).

Sarak Korong-a

Sarak Korong flows from the southern part of the free draining area for 7.9 km towards north and joins with Yarjep Chu near Lipusi village. It is a springfed stream which flows on the northern slopes of 2625 m peak, drains through a narrow gorge and joins Yargyap Chhu at 1320 m in the downstream of Lipusi. The tributaries of Sarak Korong are spread in five sub-watersheds (Sk1-Sk5) (see **Fig. 5.1.1**).

Un-named nala

Further the main river channel is joined by another tributary along the right bank. It flows from the southern part for 5 km northward and join Yarjep Chu downstream of Padusa village (see **Fig. 5.1.1**).

Sarak Korong-b

The next river is also called as Sarak Korong and it is the last river along the right bank. The catchment of this tributary is predominantly covered with dense forest. The river flows for 5.7 km towards north and drains into Yarjep upstream of the intake site (see **Fig. 5.1.1**).

5.1.4.2 Slope

In the free draining area the moderately steep class is prevalently spread in the southern part. It covers 67% of the total free draining area. Steep slope is the second predominant slope class in the free draining area covering an area of 1466.87 ha which is 20% of the total free draining area. It is followed by strongly sloping class with area coverage of 10.7% of the total free draining area. The remaining slope classes i.e., Gently sloping class, Moderately sloping and Very steep covers mere areas of 0.07%, 2% and 0.5% of free draining area (see **Fig. 5.1.3**).

Moderately steep class is the predominant slope class in the free draining area of Tato-I HE Project. It is largely spread in the sub-watershed of Sk7 with area coverage of 1198.22 ha of land. The remaining sub-watersheds have area coverage of 450 ha to 900 ha of land (see Table 5.1.1). Steep slope is largely spread in the Sk5, Sk6 and Sk7 covering an area of 567.35 ha, 317.22 ha and 433.03 ha respectively. Moreover it is more predominant on the left bank side of Yarjep Chhu (see **Fig. 5.1.3**).

Table 5.1.1 Slope classes along the sub watersheds (in ha)

Sub watershed	Gently Sloping	Moderately Sloping	Strongly Sloping	Moderately Steep	Steep	Very Steep	Total
SK1	0	16.71	102.12	552.24	51.63	0	**722.70**
SK2	0	24.47	155.2	767.26	44.61	0	**991.54**
Sk3	0	8.81	96.25	509.09	19.58	0	**633.73**
SK4	0.99	12.66	58.41	580.55	33.45	0	**686.06**
SK5	0.99	18.43	101.55	866.45	567.35	17.95	**1572.72**
SK6	1.95	17.39	43.95	479.61	317.22	2.45	**862.57**
SK7	1.08	46.99	230.91	1198.22	433.03	14.79	**1925.02**
Total	**5.01**	**145.46**	**788.39**	**4953.42**	**1466.87**	**35.19**	**7394.34**

5.1.4.3 Soil Types

In the free draining the S1 soil association is predominantly spread with an area of 67% of the free draining area. It is followed by S6 soil group with area coverage of 32% of free draining area. Soil associations S4 and S2 are accounts for small area coverage of 0.4% and 1% of free draining area (**Fig.5.1.4**). The soil categories are explained in the Soil chapter (3.2.3) of the EIA report.

S1 association is prevalently spread in the sub-watersheds of Sk5 and Sk7 with area coverage of 1450.13 ha and 1632.64 ha respectively. In the sub watersheds of Sk3 and Sk6 it is spread on area of 633.73 ha and 682.06 ha respectively. S6 association is more characterized in the southern and head water region of Sarak Korong. It is more prominent in the sub-watersheds of Sk1, Sk2 and Sk4 with area coverage of 639.38 ha, 703.17 ha and 442.01 ha respectively (see Table 5.1.2).

5.1.4.4 Soil Depth

Shallow and moderately shallow are the two soil depth classes in the free draining area. Besides the unclassified soil depth class is mapped as rocky mountain in the free draining area. Shallow class is the most predominant soil class in the free draining area. Shallow class covers an area of 67% of the free draining area. It is largely spread in the sub-watersheds of Sk5 and Sk7 with area coverage of 1450.13 ha and 1664.44 ha respectively. Other sub-watersheds Sk3 and Sk6 have area in the range of ~650 ha (see Table 5.1.3 & **Fig.5.1.5**).

Table 5.1.2 Soil class and its area (ha) along the sub watersheds in the free draining area

Sub watershed	S1	S2	S4	S6	Total
SK1	29.46	53.87	0	639.38	**722.71**
SK2	252.39	35.97	0	703.17	**991.53**
Sk3	633.73	0	0	0	**633.73**
SK4	244.05	0	0	442.01	**686.06**
SK5	1450.13	0	0	122.59	**1572.72**
SK6	682.06	0	0	180.51	**862.57**
SK7	1632.64	0	31.81	260.58	**1925.03**
Total	**4924.46**	**89.84**	**31.81**	**2348.24**	**7394.35**

Moderately shallow is spread in a mere area of 1.2% of the free draining area and it is devoid in most of the sub-watersheds, except in Sk1 and Sk2 with small area coverage of 53.87 ha and 35.97 ha, respectively.

Table 5.1.3 Soil depth area coverage in the catchment

Sub watershed	Shallow	Moderately Shallow	Rocky Mountain	Total
Sk1	29.46	53.87	639.38	**722.71**
Sk2	252.39	35.97	703.17	**991.53**
Sk3	633.73	0	0	**633.73**
Sk4	244.05	0	442.01	**686.06**
Sk5	1450.13	0	122.59	**1572.72**
Sk6	682.06	0	180.51	**862.57**
Sk7	1664.44	0	260.58	**1925.02**
Total	**4956.26**	**89.84**	**2348.24**	**7394.34**

5.1.4.5 Land Use/ Land Cover

The project area designated for the catchment area treatment plan covers 7394.33 ha. The recent land use/ land cover of this area was interpreted from the satellite images and confirmed by the field surveys. A false color composite (FCC) was generated for the entire free draining area as well as for all the 7 sub-watersheds (**Fig. 5.1.6**). The land use /land cover of the free draining area of the HE project area as well as of all the 7 sub-watersheds was classified under Dense Forest, Open Forest, Scrub, Degraded Forest, Cultivation, Moraines, Barren, River and Snow.

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 on CDROMs were procured from National Remote Sensing Agency, Hyderabad. Digital image processing of the satellite data and the analysis of interpreted maps were carried out at the Computer Centre at CISMHE using ERDAS Imagine 8.7. Several techniques and geo statistical approaches were used for the image processing of the Catchment. Such as supervised classification technique was used and later on a spatial statistic model (Maximum likelihood classifier) was applied for the sample set of the trained pixel were used to classify the satellite imagery. Unsupervised classification was also used in the procedure (Schowengerdt, 1997).

Digital data of IRS P6 LISS-3 and Landsat-7 full scene were used for image processing and thematic map preparation. For the secondary data, Survey of India toposheets on 1:50,000 and 1:25,000 were referred to for the preparation of base map and drainage map. With the objective of preparation of environment management plan and an action plan for watershed management and a catchment area treatment, the classification scheme adopted for the preparation of land use/ land cover maps and related thematic maps on 1:50,000 scale is as follows. 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 (agriculture) was also delineated for the calculation of erosion intensity classification. The non-forest land cover in the form of river, wetland and Jhum cultivation etc. was also delineated.

The base map, drainage map and land use/land cover map were prepared using the satellite data. Later it was digitized on computer 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 free draining area 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) techniques.

Table 5.1.4 Area (ha) under different land use/ land cover categories in different sub watersheds of Tato-I HE Project area

Sub watershed	Dense Forest	Open Forest	Scrub	Degraded Forest	Cultiva-tion	Moraines	Barren	River	Snow	Total
Sk1	239.13	1.37	258.34	0	0	38.95	99.59	0	85.32	**722.7**
Sk2	391.05	10.23	445.29	1.51	0	29.96	69.75	0	43.75	**991.54**
Sk3	338.23	156.06	122.69	16.74	0	0	0	0	0	**633.72**
Sk4	316.89	0.89	323.89	10.32	0	8.23	25.01	0	0.82	**686.05**
Sk5	616.27	433.75	251.68	255.23	5.13	0	0	10.67	0	**1572.73**
Sk6	432.9	94.52	258.33	70.89	0	0.8	5.12	0	0	**862.56**
Sk7	964.78	100.95	463.73	261.16	0.25	24.26	85.59	22.54	1.77	**1925.03**
Total	**3299.25**	**797.77**	**2123.95**	**615.85**	**5.38**	**102.2**	**285.06**	**33.21**	**131.66**	**7394.33**

Dense forest is prevalently spread in the free draining area of the Tato-I HE Project with area coverage of 44.6% of the total free draining area. It is followed by scrubs with area of 28.7% of the free draining area. Open forest is spread in an area of 10.8% and it is more prevalent in the northern part of the free draining area particularly along the right bank of Sarak Korong. Degraded forest is prevalent in the extreme north particularly on the left bank of the Yarjep Chhu. It has area coverage of 8.3% of the free draining area. Moraines and Barren land are more prevalent in the head water region of Sarak Korong, covering an area of 1.4% and 3.86% of the free draining area respectively. Snow accounts for 1.8% of the total free draining area (**Fig. 5.1.7**).

Dense forest is the most prevalent land cover in the free draining area. It is equally distributed in all the sub-watersheds. Sub-watershed Sk7 has area coverage of 964.78 ha of land under dense forest. The remaining sub-watersheds have area coverage in the range of ~230 ha to ~620 ha (see Table 5.1.4). Open forest is more prominent in the sub-watersheds along both the left banks of Sarak Korong. Therefore it is largely present in the sub-watershed of Sk5 with area under 433.75 ha of land. Sub-watersheds Sk3 and Sk7 have area coverage of 156.06 ha and 100.95 ha respectively. The remaining sub-watersheds have area less than 100 ha (see Table 5.1.4).

Scrub is the second predominant land cover in the free draining area. Scrub is largely spread in the sub-watershed of Sk2 & Sk7 with area coverage of 445.29 ha and 463.73 ha respectively. Most of the sub-watersheds have area in the range of ~250 ha - ~450 ha. Except sub-watershed Sk3 has area of 122.69 ha of land under scrub (see Table 5.1.4).

Degraded forest is more prominent in the sub-watersheds of Sk5 and Sk7, covering an area of 255.23 ha and 261.16 ha, respectively.

5.1.4.6 Erosion Intensity Assessment

Soil erosion intensity mapping was carried out using the above thematic layer. Soil erosion is mainly caused due to moving water and the gravity. It varies from place to place. Furthermore, it is intensified by human induced developmental projects. Within the Himalayan river basins water is the main agent of erosion. Erosion by water is most complex process and takes place due to rain splash, sheet wash or rill wash, channel erosion in rivers or gullies. The catchment area of the proposed Tato-I HE project experiences silt loads in the major river and its tributaries. In the present context, one of the significant negative impacts of soil erosion is reduction of the life of weir of a hydroelectric project. The increased silt in the rivers has severe adverse impacts on the micro- and macro-organisms, above and below ground as well as for the aquatic biodiversity including fishes. There are a number of factors in the Yarjep river basin which are responsible for extensive soil erosion and heavy silt load in the river. In the following section we have described on how to use soil erosion process on Silt Yield Index (SYI).

5.1.4.6.1 *Estimation of Soil Erosion in Catchment*

The entire catchment area has been delineated into 7 sub-watersheds. Detailed drainage map for the entire free draining as well as for each sub-watershed was prepared at 1:50,000 scale. All the rivers and streams have been delineated in each sub-watershed. The areas under different erosion intensities were calculated using GIS software. For the estimation of erosion intensity three spatial factors, soil depth, slope and land use, each with five to seven parameters, were considered during hierarchical querying. For soil depth, deep (score 1), moderately deep (score 2) and moderately shallow (score 3), were used. In case of slope, five parameters, Gently Sloping (score1) to Steep (score 5) were considered and similarly seven categories of Dense forest (score 1), Open Forest (score 2), Scrub (score 3), Degraded Forest (score 4), Cultivation (score 5), Settlements (score 6), moraines and Barren (score 7), was taken into account for calculating erosion in the catchment. After running the queries, an area with the final score of 12 or above was designated as having very severe erosion, the score 10 to 12 was designated as severe, 7 to 9 was classified as moderate erosion and score up to 6 was classified as having slight erosion. Areas under different erosion intensities were estimated for each sub-watershed as well as for entire free draining area and the results are presented

in Table 5.1.5. Around 66% of the total free draining area is found to be under moderate erosion class and nearly 24% area was classified under severe erosion (Table 5.1.5; **Fig. 5.1.8**). Severe erosion is spread in Sk2 and Sk5 with area coverage of 424.42 ha and 315.35 ha respectively. Very severe erosion accounts for 3% of the total free draining area and it is prevalently spread in the southern part i.e., sub-watersheds of Sk1, Sk2 and Sk7.

Table 5.1.5 Area under different intensity of erosion in the free draining of Tato-I H.E. project

Sub Water shed	Slight	Moderate	Severe	Very Severe	River	Snow	Total
SK1	1.67	225.35	304.59	105.78	85.32	0	**722.71**
SK2	12.06	454.47	424.42	56.84	0	43.75	**991.54**
SK3	60.67	567.15	5.9	0	0	0	**633.72**
SK4	9.96	406.92	251.58	16.77	0	0.82	**686.05**
SK5	69.29	1177.42	315.35	0	10.67	0	**1572.73**
SK6	18.58	640.42	200.55	3.02	0	0	**862.57**
Sk7	67.4	1467.42	313.53	52.37	22.55	1.77	**1925.04**
Total	**239.63**	**4939.15**	**1815.92**	**234.78**	**118.54**	**46.34**	**7394.36**

5.1.4.6.2 ***Sediment Yield Index***

To calculate sediment yield index, methodology developed by All India Soil & Land Use Survey (Department of Agriculture, Government of India) was followed, where each erosion intensity unit is assigned a weightage value. When considered collectively, the weightage value represents approximately the relative comparative erosion intensity. A basic factor of K = 10 was used in determining the weightage values. The value of 10 indicates a static condition of equilibrium between erosion and deposition. Any addition to the factor K (10+X) is suggestive of erosion in ascending order whereas subtraction, i.e. (10-X) is indicative of deposition possibilities.

Delivery ratios were adjusted for each of the erosion intensity unit. The delivery ratio suggests the percentage of eroded material that finally finds entry into dam/reservoir or river/stream. Area of each composite unit in each sub-watershed was then measured.

Sediment yield index (SYI) was calculated using following empirical formula (for SYI of individual sub-watersheds see Annexure-I).

$$SYI = \frac{\sum (A_{ei} \times W_{ei} \times DR)}{AW} \times 100$$

where,

SYI = Sediment yield index

A_{ei} = Area of composite erosion intensity unit

W_{ei} = Weightage of composite erosion intensity unit

DR = Delivery ratio

AW = Total area of the sub-watershed

5.1.4.6.3 *Erosion Intensity and Delivery Ratio*

Determination of erosion intensity unit is primarily based on the integrated information on soil characters, physiography, slope and land use/land cover. This is achieved through super-imposition of different thematic map overlays. Based on the ground-truth, carried out during the field work, weightage value and delivery ratio were assigned to each erosion intensity unit.

Delivery ratio, which depends on the type of material, soil erosion, relief length ratio, land cover conditions, etc. were assigned to all erosion intensity units depending on their distance from the nearest stream. The criteria adopted for assigning the delivery ratio are as follows:

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

5.1.5 PRIORITISATION OF SUB-WATERSHEDS FOR TREATMENT

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 (Table 5.1.6; see Annexure-I). The sub-watersheds would be treated on priority basis in the treatment scheme to be followed (Table 5.1.6). An index map showing treatment measures to be undertaken in different sub-watersheds was prepared according to their priority ranking for treatment and is given in **Fig. 5.1.9**.

Table 5.1.6 SYI for different sub-watersheds for Tato-I HE Project free draining catchment

Sub-watershed	Area (ha)	SYI	Treatment Area (ha)
Sk1	722.70	1379.19	20.49
Sk2	991.53	1422.71	26.48
Sk3	633.73	1246.43	5.90
Sk4	686.06	1290.80	9.99
Sk5	1572.72	1196.96	239.08
Sk6	862.57	1091.42	88.79
Sk7	1925.03	1163.30	188.18
Total	**7394.34**		**578.91**

The treatment area is the area subject to severe and very severe erosion that are accessible, i.e. less than 45° and below 3200 m elevation.

5.1.5.1 Year-wise Treatment of Watersheds

Silt yield index (SYI) has been calculated for all the 7 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and the sub-watersheds were accordingly prioritized for treatment (Table 5.1.7).

Table 5.1.7 Year-wise treatment of the sub-watersheds

Years	Sub-watershed Name	SYI	Priority Ranking	Treatment Area (ha)
Ist	Sk2	1422.71	1	26.48
	Sk1	1379.19	2	20.49
	Sk4	1290.80	3	9.99
	Sk3	1246.43	4	5.90
Total				**62.86**
IInd	Sk5	1196.96	5	**239.08**
IIIrd	Sk7	1163.30	6	**188.18**
IVth	Sk6	1091.42	7	**88.79**
Grand Total				**578.91**

5.1.6 ACTIVITIES TO BE UNDERTAKEN

For undertaking soil conservation measures in the Tato-I H.E. Project catchment area up to intake site various indirect or preventive measures like biological measures and direct or remedial measures like engineering measures have been discussed in the following paragraphs (see Table 5.1.8). Even though suggestions have been made regarding certain specific treatment measures to be undertaken in a particular sub-watershed, these measures, however, may require further micro-planning during the implementation stage.

5.1.6.1 Treatment Measures: Engineering Measures

Gully erosion is one of the concerned soil erosion in the slope and hilly areas. The gullys 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 stabilization of the slopes/area and prevention of further deepening of gullies and erosion. For controlling the gullys, 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.

In addition to the vegetative measures used for stabilization 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 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 gullies (see **Plate 5.1.1**). In all, 64 brushwood checkdams/ vegetative spurs would be constructed to check gully erosion, stream bank protection and slope stabilization works. An outlay of Rs. 20.67 Lakh @ Rs. 32,300 per checkdam has been made and shall be constructed in four years.

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 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, it is not of any use in small gullies 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, 65 DRSM checkdams would be constructed (see **Plate 5.1.2**). An outlay of Rs. 26.87 Lakh @ Rs. 41,345 per checkdam has been made and shall be constructed in four years.

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 many other 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 leveled fields. Thus, hazards of erosion are eliminated and manure and fertilisers applied are retained

in the leveled 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 80.25 ha will be covered under this plan. An outlay of Rs. 7.46 Lakh @ Rs. 9,300/ha has been made and shall be constructed in four years.

5.1.6.2 Preventive Biological Measures

It is always better to undertake preventive measures than to mitigate the factors that ultimately leads 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 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, Alangium chinense, Altingia excelsa, Bischofia javanica, Pterospermum acerifolium*, etc. would be undertaken. Afforestation measures would be taken up under catchment area treatment plan on 137.63 ha. An outlay of **Rs. 75.28 lakhs** has been provided to cover various areas under afforestation in different sub-watersheds.

Afforestation Programme

Different types of plantations would be undertaken under afforestation programme according to the methodology described below. The plantations that would be undertaken in the forest (scrub/degraded forest) would have a planting density of 1600 plants per ha and vegetative hedge in contour trenches. Contour planting conserves soil and enhances moisture regime and adverse effect of surface run off of rain water is reduced considerably. Trenches, pits and plants along the contour

reduce velocity of water, increase soil moisture and facilitate seepage of water in soil and reduce soil loss resulting in better growth of plants. Hence, soil working and planting along contours would be strictly followed in the project.

In the afforestation areas, the digging of trenches and pits would be along the contour. About 20 to 30 m long contour trenches would be dug leaving a space of 50 cm (septa) between the two consecutive trenches. Soil would be dug on the lower side of the trench and after removing pebbles and weeds, the trench to be half refilled with soil and remaining soil would be collected to form berm on lower side of trench. On the berm, seeds of shrubs/hedges like *Arenga saccharifera*, Calamus erectus, Bambusa tulda, *Debregeasia longifolia*, *Mussaenda roxburghii,* etc. would be sown to raise vegetative barrier. The size of pits would be 45 cm^3. The contour trenches would be at an interval of 5 m.

For digging 1600 pits per ha, pits would be dug 15 cm uphill side from the contour trenches. The spacing of pits along contour trench will not be closer than 1.25 m. In afforestation areas soil working would be started in October-November and would be completed by March. It is important that filling of pits and half filling of trenches is completed before the onset of monsoon, otherwise dug soil will be washed away by rains leaving only stones and pebbles near the pit. Extreme care would be taken in transporting the plants from nurseries to the plantation site to avoid any damage. Planting would be completed before the monsoon period is over. With a view to conserve not only soil and water but also for fuelwood production, it is important to raise the vegetative barrier of hedge plants. The seeds of hedges like Bambusa, *Debregeasia*, *Melocalamus*, *Pinanga,* etc. will be sown in contour trenches before the onset of monsoon. When the water of surface run-off reaches the line of hedges its speed is checked and silt is stopped by the hedge plants and only percolated water passes down slowly. Hedges spread and grow well in the silt left behind and form a natural terrace. The plants planted in the pits near contour trenches get more moisture and grow fast.

Choice of Species

The species for plantations would be selected after considering altitude, aspect, biotic pressures, soil depth, moisture, etc. As there is pressure of cattle grazing, non-fodder/ fuelwood species would also be planted in suitable proportion in between the fodder species. The tree species that would be planted under this programme are : *Actinodaphne obovata, Altingia excelsa* (Jutli),

Castanopsis indica (Hingori)*, Cinnamomum tamala* (Tej Pata)*, Ficus benjamina, Gynocardia odorata, Toona ciliata* (Poma), etc.

There are many shrubby plant species which are suitable for fodder/ fuelwood plantations, which are**:** *Bambusa tulda, B. pallida, Bauhinia variegata, Ficus auriculata* and *Morus alba.* The important legumes and grasses that would be planted are C*hrysopogon gryllus*, *Lolium perenne*, *Pennisetum purpureum*, *Thysanolaena latifolia* and *Themeda arundinacea* among grasses and White clover (*Trifolium repens*), Red clover (*Trifolium pratense*), Lucerene (*Medicago sativa*), Vetch (*Vicia villosa*), and Caucasian clover (*Trifolum ambiguum*) among legumes.

The plant species suitable for avenue and ornamental purposes are: *Altsonia scholaris, Bauhinia variegata*, *Cassia fistula*, *Delonix regia, Erythrina stricta*, *Exbuclandia poulnea*, *Hibisicus rosa-sinensis* and *Polyalthia longifolia*.

Fencing

Stone wall 120 cm high and 45 cm wide or 4 strand barbed wire fencing would be erected around the nursery and the plantation area during first year along with soil working. The cooperation of local villagers would be sought for the success of the plantation programmes.

Weeding and Mulching

Weeding, hoeing and mulching would be carried out during October-November. Weeding and loosening of soil by hoeing breaks the capillary action in soil and thus reduces the moisture loss. Mulching reduces evaporation and conserves soil moisture and adds humus to soil. Cut and uprooted weeds and grasses used as mulching material would be spread around the plant.

Watch and Ward and Fire Protection

Protection of plantation is the greatest challenge as some inhabitants and their livestock may damage the plantation before it is established. Hence the protection of plantation particularly in the juvenile stage is of paramount importance and watchmen/ chowkidars would be engaged from the nearby villages for the required job. Besides the above, other appropriate measures would be adopted to ward off these potential threats.

Table 5.1.8 Watershed-wise details of various activities

S.No.	Name of Sub-watershed	Component								
		Engineering Measures				Biological Measures				
		Gully Control			Bench Terracing	Afforestation	NTFP Regenera-tion/ Medi-cinal Plants Cultivation	Assisted Natural Regenera-tion	Pasture Improve-ment	Total
		Brushwood Check dams	DRSM checkdams	Contour Bunding						
		(Nos.)	(Nos.)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	
1.	Sk1	2	2	3.5	3.25	6.18	3.15	2.25	2.16	**20.49**
2.	Sk2	8	6	6.75	7.25	5.40	2.03	1.25	3.80	**26.48**
3.	Sk3	1	1	2	0	2.40	1	0	0.50	**5.90**
4.	Sk4	1	2	2	1.75	1.70	2	1	1.54	**9.99**
5.	Sk5	15	12	38	25.25	54.50	37.58	35.25	48.50	**239.08**
6.	Sk6	12	14	25.50	10.75	25.40	8.00	8.19	10.95	**88.79**
7.	Sk7	25	28	40	32	42.05	25.00	28.13	21.00	**188.18**
	Total	**64**	**65**	**117.75**	**80.25**	**137.63**	**78.76**	**76.07**	**88.45**	**578.91**

b) ***Assisted Natural regeneration in existing forest***

In some of the forest areas, conditions are conducive to natural regeneration provided that 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 plants or patches per hectare will be planted /sown to hasten the process of regeneration in the area uniformly. An outlay of **Rs. 11.35 lakhs** @ Rs 14,612 per ha for creation and Rs. 300 per ha for its maintenance has been made to cover 76.07 ha (see Annexure II).

c) ***NTFP Regeneration***

Arunachal Forest Division is rich in a variety of Non Timber Forest Produce (NTFP). 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 nurseries. An outlay of **Rs.42.54 lakhs** Rs @ Rs.45,422/- per ha has been suggested to cover about 78.76 ha for establishing (Rs.35.77 lakhs) and its maintenance (Rs.6.77 lakhs) of this facility for five years (see Annexure II).

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. 22.53 lakhs** @ Rs.24,765/- per ha has been earmarked for this purpose and it will cover about 88.45 ha of land for development at a cost of Rs.21.90 lakhs and its maintenance will cost Rs.0.63 lakhs for five years (See Annexure II).

5.1.6.3 Socio Economic Development for PAF's

Socio Economic Development for project affected families has been incorporated as per MoEF guidelines to be implemented by Van Panchayats or Joint Forest Management Committees. A lump sum amount of Rs. 45. 00 Lakhs has been allotted for this component.

5.1.7 *Administrative Setup*

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 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 the purpose during the project implementation period, i.e. for about four years.

Beside, several parallel activities should be undertaken to meet the various biological and engineering measure in process. These activities are Nursery development and forest infrastructure development. Other than that, some financial activities are also projected in the CAT plan. Activities such as Ecotourism can be promoted, Eco-restoration are formulated to meet the unemployment crisis at local level.

a) Baseline Survey and Study

An amount of Rs. 10.00 Lakh has been proposed for Baseline survey and study purpose.

b) ***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 the intake site and the proposed colony areas, preferably along the road side for easy accessibility. 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 lakh**. Development of nursery will start from the ignition year and will continue for 5 years (Table 5.1.9). During maintenance year (2 to 5 years) nursery will supply plants wherever required for the replacement.

Table 5.1.9 Cost for the Nursery Development

Amount (Rs. in lakhs)

Components	Development	Maintenance	Total
Shed House for raining saplings (one time grant)	0.80	0.80	1.60
Seeds collection procurement grant	1.70	-	1.70
Compost, soil, fertilizer and other materials	1.70	-	1.70
Shed House/ Chickhouse for maintaining and storing saplings (Nos 2)	1.70	0.8	2.50
Poly bags, pots, trays for raising saplings	1.70	-	1.70
Nursery Equipments	1.70	-	1.70
Glass wares and other laboratory wares	0.80	0.30	1.10
Chemicals, pesticides, and other plant growth regulators	0.80	0.30	1.10
Hand held trollies (Nos. 5) for transporting plant saplings	0.80	0.20	1.00
Mini-truck for transporting plants	1.70	1.70	3.40
Contingency grant for all recurring expenditure	1.70	-	1.70
Personnel/ staff	5.80	-	5.80
Total	**20.90**	**4.10**	**25.00**

c) ***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. 54.85 lakhs** is proposed for this purpose (Table 5.1.10).

Table 5.1.10 Budget for development of State Forest Department infrastructure

Amount (Rs. in lakhs)

S.No.	Components	Qty./Unit	Total
1.	Forest Office Establishment (one office)	-	12.85
2.	Forest Fire Fighting System	-	2.50
3.	Office Vehicle	1 No.	10.00
4.	Road and Foot Path Development	-	4.50
4.	Machinery & Equipment*	-	8.00
4.	W & W	8 Nos.	8.00

5.	Monitoring & Evaluation	-	3.00
6.	Adm. Cost	-	3.00
7.	Contingency	-	3.00
	Total		**54.85**

* Machinery & Equipment : Computers, Laptop, Photocopier, Digital Camera, etc.

5.1.8 *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 area development and employment generation are suggested and should be carried out through community welfare committees (CWC) 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.

1. Plantation in the degraded patches of community/civil/ forest land.
2. Water conservation and harvesting in the villages.
3. Soil conservation measures in village areas.
4. Improvement in agricultural and horticultural practices.
5. Technical and financial support for harnessing alternate energy sources such as micro-hydel and non-conventional energy (solar power and solar heating) to reduce pressure on the forest for fuel wood
6. Rural technology support programmes.
7. Awareness programmes for conservation of wildlife and natural resources.
8. Promotion of income generating schemes like ecotourism.

The total cost estimate for these activities is proposed as **Rs. 3.18 lakhs** (1% of total cost of treatment measures).

5.1.9 SCHEDULE OF TREATMENT PLAN

The total time scheduled for the execution of the planned CAT works has been kept at 4 years. Accordingly, areas from each sub-watershed have been prioritized for treatment and a year-wise plan has been assigned (**Fig.5.1.10**). Zero year has been kept for the development of nursery and raising sapling for plantation. Three to ten sub-watersheds have been suggested to be taken up for treatment in each year and accordingly area for treatment in each year is allotted. Maximum area

for treatment will be taken up in the second year and minimum will be taken up in the first year. In the first and second years the area taken up for treatment is 62.86 ha and 239.08 ha, respectively and in the fourth year the area to be taken up for treatment is 88.79 ha. One year time is given for the maintenance of the executed work in the catchment. Accordingly, a separate budget for the maintenance is given in Table 5.1.11.

5.1.9.1 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 to Divisional Forest Officer for its subsequent submission to 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 intake site in Yarjep River to evaluate the impact of the soil conservation measures. A sum of **Rs. 45 lakhs** has been provided for monitoring and evaluation.

5.1.10 PERIOD AND SCHEDULE OF IMPLEMENTATION

The execution of CAT plan in Tato-I -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 to be completed. However, the maintenance of plantations would continue for one year and accordingly CAT plan has been prepared for 5 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 Sk1, Sk2, Sk3, etc. (For details see Annexure-1).

The year-wise index map of schedule of implementation of different conservation measures under CAT plan has been given in **Fig.5.1.10**. Table 5.1.12 gives the year-wise physical details of various engineering and biological treatment measures to be undertaken.

5.1.11 COST ESTIMATES

The total estimated cost of catchment area treatment plan to be spent over a period of seven years is **Rs. 478.62 lakhs**. All the costs towards the administration during the implementation work have been included in the cost estimates of CAT.

Table 5.1.11 Component-wise cost estimate for catchment area treatment works

S. No.	Item of Work	Unit	Qty.	Rate (Rs.)	Amount (Rs. in lakhs)
A.	**Engineering Measures**				
1.	Gully Control				
	a) Brushwood checkdams	Nos.	64	32,300/-	20.67
	b) DRSM checkdams	Nos.	65	41,345/-	26.87
	c) Contour Bunding	ha	117.75	31,100/-	36.62
2.	Bench terracing	ha	80.25	9,300/-	7.46
	Total (1+2)				**91.62**
	Add 5% for maintenance of structures				4.58
	Sub-total (A)				**96.20**
B.	**Biological Measures**				
1.	Afforestation				
	i) Creation	ha	137.63	48,500/-	66.75
	ii) Maintenance			6,200/-	8.58
2.	Assisted natural regeneration in existing forests				
	i) Creation	ha	76.07	14,612/-	11.12
	ii) Maintenance (see Table 2.14)			300/-	0.23
3.	NTFP Regeneration				
	i) Creation	ha	78.76	45,422/-	35.77
	ii) Maintenance (see Table 2.15)			8,600/-	6.77
4.	Pasture development				
	i) Creation	ha	88.45	24.765/-	21.90
	ii) Maintenance			715/-	0.63

5.	Nurseries	25.00
	Sub-total (B)	**137.10**
C.	**Socio-Economic Activities**	**45.00**
	Sub-Total (A+B+C)	**317.90**
D.	**Micro-planning @ 3% of (A+B+C)**	**9.54**
E.	**Baseline Survey and Study**	**10.00**
F.	**Establishment Cost @ 7%**	**22.25**
G.	**Forest Infrastructure**	**54.85**
	Vehicles, machinery & equipment, paths, etc.	
H.	**Eco-restoration @ 1%**	**3.18**
I.	**Contingency @ 5%**	**15.90**
J.	**Monitoring and evaluation**	**45.00**
	Grand Total (A to H)	**478.62**

Table 5.1.10 Physical and Financial layout plan of Catchment Area Treatment for Tato-I H.E. Project — **Amount in lakhs**

S. No.	Item of Work	Unit	0th Year		I st 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 Control															
	a) Brushwood checkd	Nos.			12	3.88	15	4.85	25	8.08	12	3.88			64	20.67
	b) DRSM checkdams	Nos.			11	4.55	12	4.96	28	11.58	14	5.79			65	26.87
	c) Contour Bunding	ha			14.25	4.43	38	11.82	40	12.44	25.5	7.93			117.75	36.62
2	Bench terracing	ha			12.25	1.14	25.25	2.35	32	2.98	10.75	1.00			80.25	7.46
	Total (1+2)					**13.99**		**23.97**		**35.07**		**18.59**				91.62
	Add 5% for maintenance of structures					0.70		1.20		1.75		0.93				4.58
	Sub-total (A)					**14.69**		**25.17**		**36.82**		**19.52**				**96.20**
B.	**Biological Measures**															
1	Afforestation															
	i) Creation	ha			15.68	7.60	54.5	26.43	42.05	20.39	25.4	12.32			137.63	66.75
	ii) Maintenance					0.97		3.38		2.61		1.57				8.53
2	Assisted natural regeneration in existing forests															
	i) Creation	ha			4.50	0.66	35.25	5.15	28.13	4.11	8.19	1.20			76.07	11.12
	ii) Maintenance (see Table 2.14)					0.01		0.11		0.08		0.02				0.23
3	NTFP Regeneration															
	i) Creation	ha			8.18	3.72	37.58	17.07	25	11.36	8	3.63			78.76	35.77
	ii) Maintenance (see Table 2.15)					0.70		3.23		2.15		0.69				6.77
4	Pasture development															
	i) Creation	ha			8.00	1.98	48.5	12.01	21	5.20	10.95	2.71			88.45	21.90
	ii) Maintenance					0.06		0.35		0.15		0.08				0.63
5	Nurseries	ha		6.25		5.5		4.25		3.75		3		2.25		25.00
	Sub-total (B)			**6.25**		**21.21**		**71.98**		**49.80**		**25.23**		**2.25**		**176.70**
C.	**Socio - Economic Activities**					15		15		10		5				45.00
	Sub-Total (A+B+C)			**6.25**		**50.90**		**112.15**		**96.62**		**49.75**		**2.25**		**317.90**
D.	**Micro-planning @ 3% of (A+B+C)**			**0.19**		1.53		3.36		2.90		1.49		0.07		9.54
E.	**Baseline survey and study**					10										10.00
F.	**Establishment Cost @ 7%**			0.44		3.56		7.85		6.76		3.48		0.16		22.25
G.	**Forest Infrastructure**					20		15		10		9.85				54.85
	Vehicles, machinery & equipment, paths, etc.															
H.	**Eco-restoration @ 1%**			0.06		0.51		1.12		0.97		0.50		0.02		3.18
I.	**Contingency @ 5%**			0.31		2.55		5.61		4.83		2.49		0.11		15.90
J.	**Monitoring and evaluation**					15		12		10		8				45.00
	Grand Total (A to H)			**13.50**		**140.25**		**244.07**		**191.89**		**105.79**				**478.62**

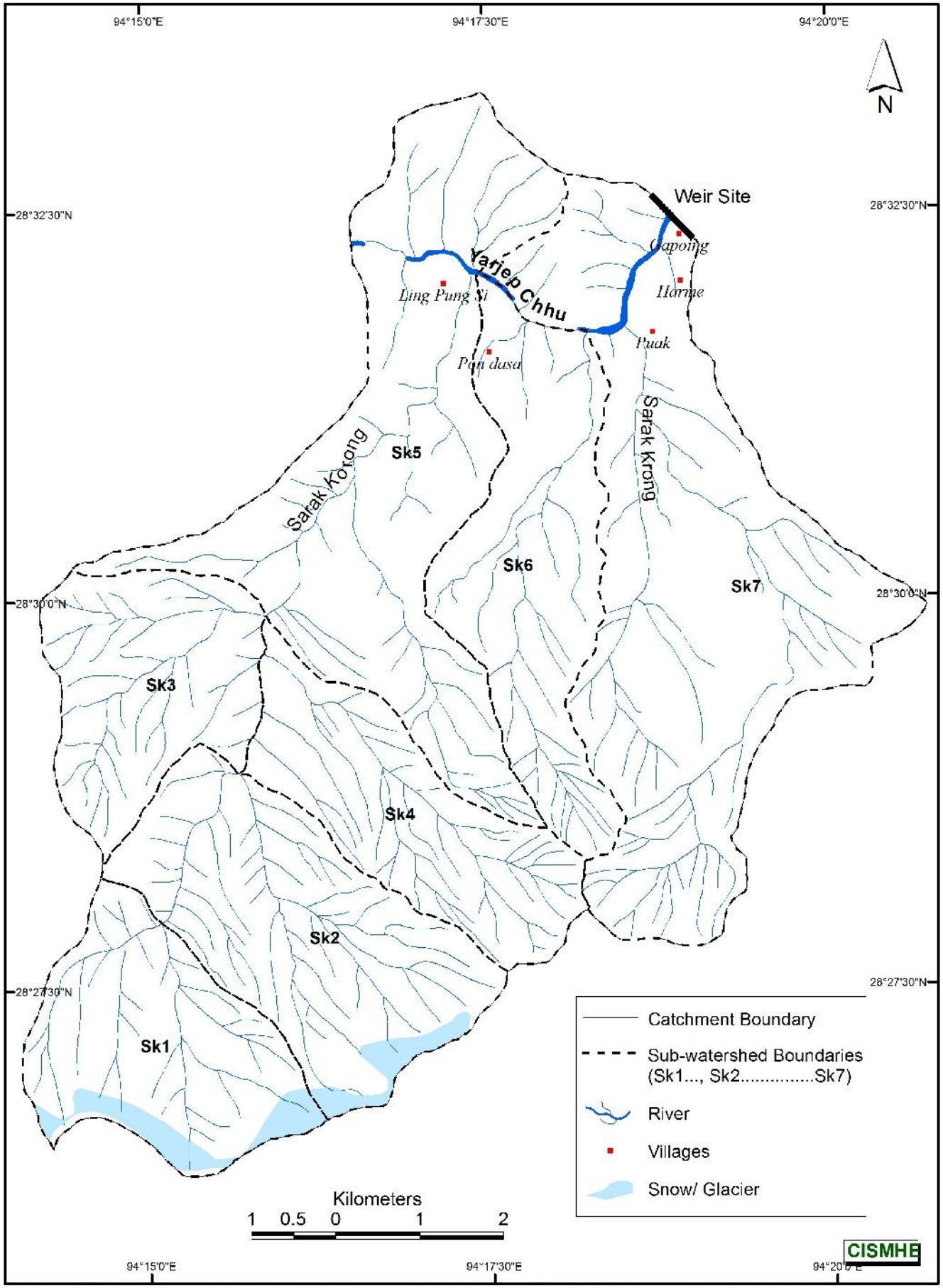


Fig.5.1.1 Index map showing drainage and subwatershed boundaries of Yarjep chhu in free-draining catchment of Tato-I H.E. project

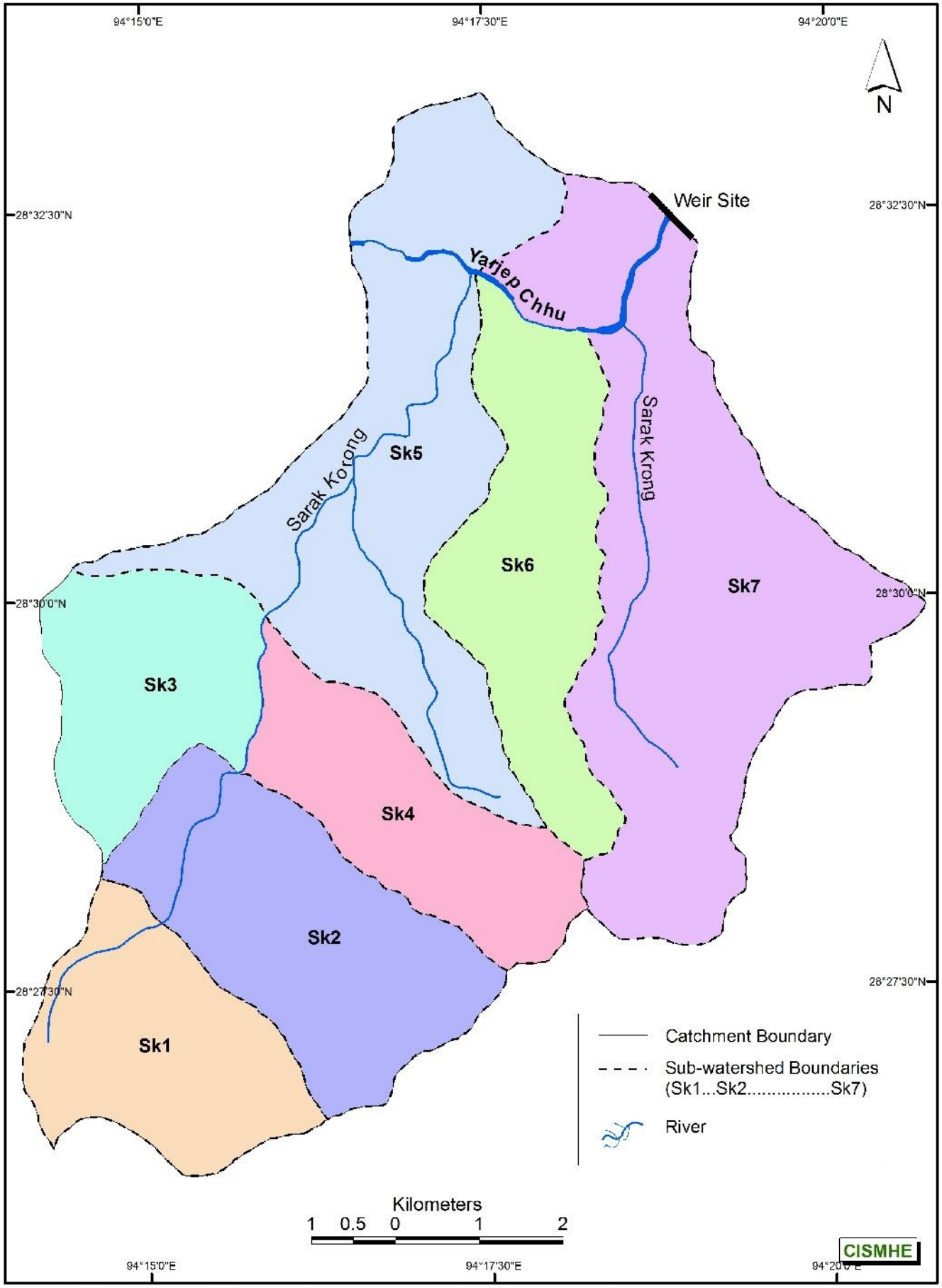


Fig.5.1.2 Index map of free-draining area of Tato-I H.E. project

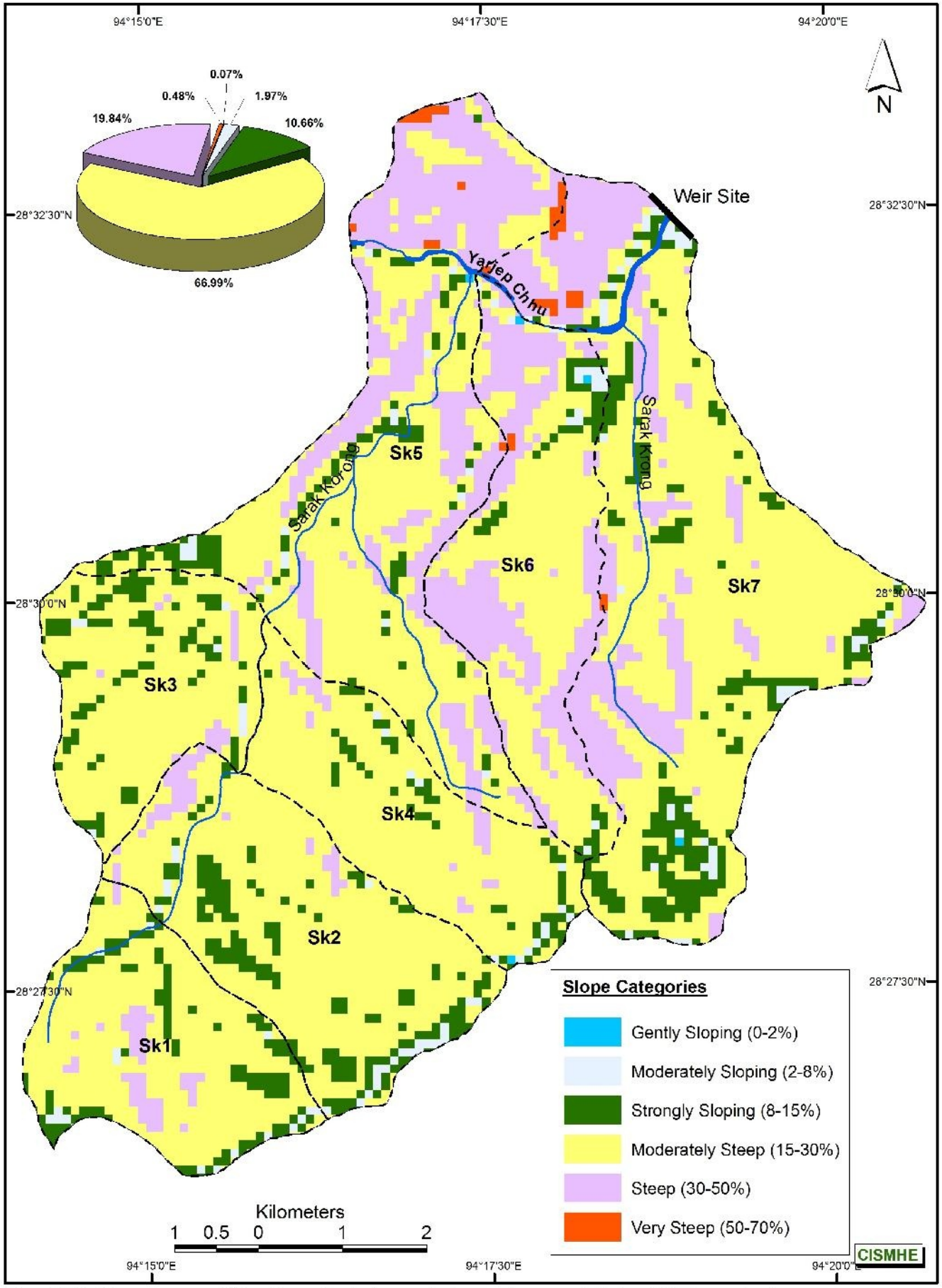


Fig.5.1.3 Slope map of the free-draining catchment area of Tato-I H.E. project

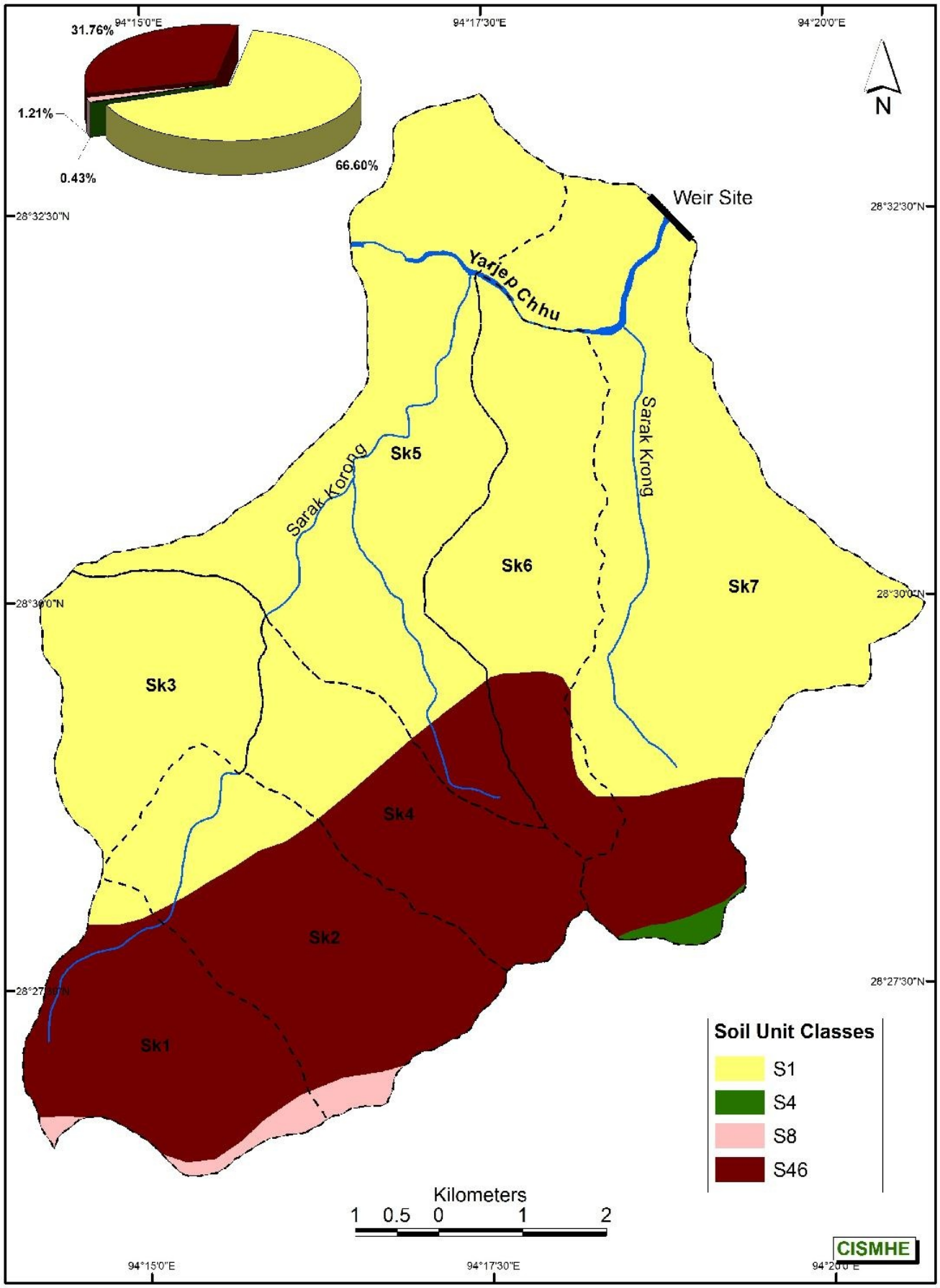


Fig.5.1.4 Soil map of the free-draining catchment of Tato- I H.E. project

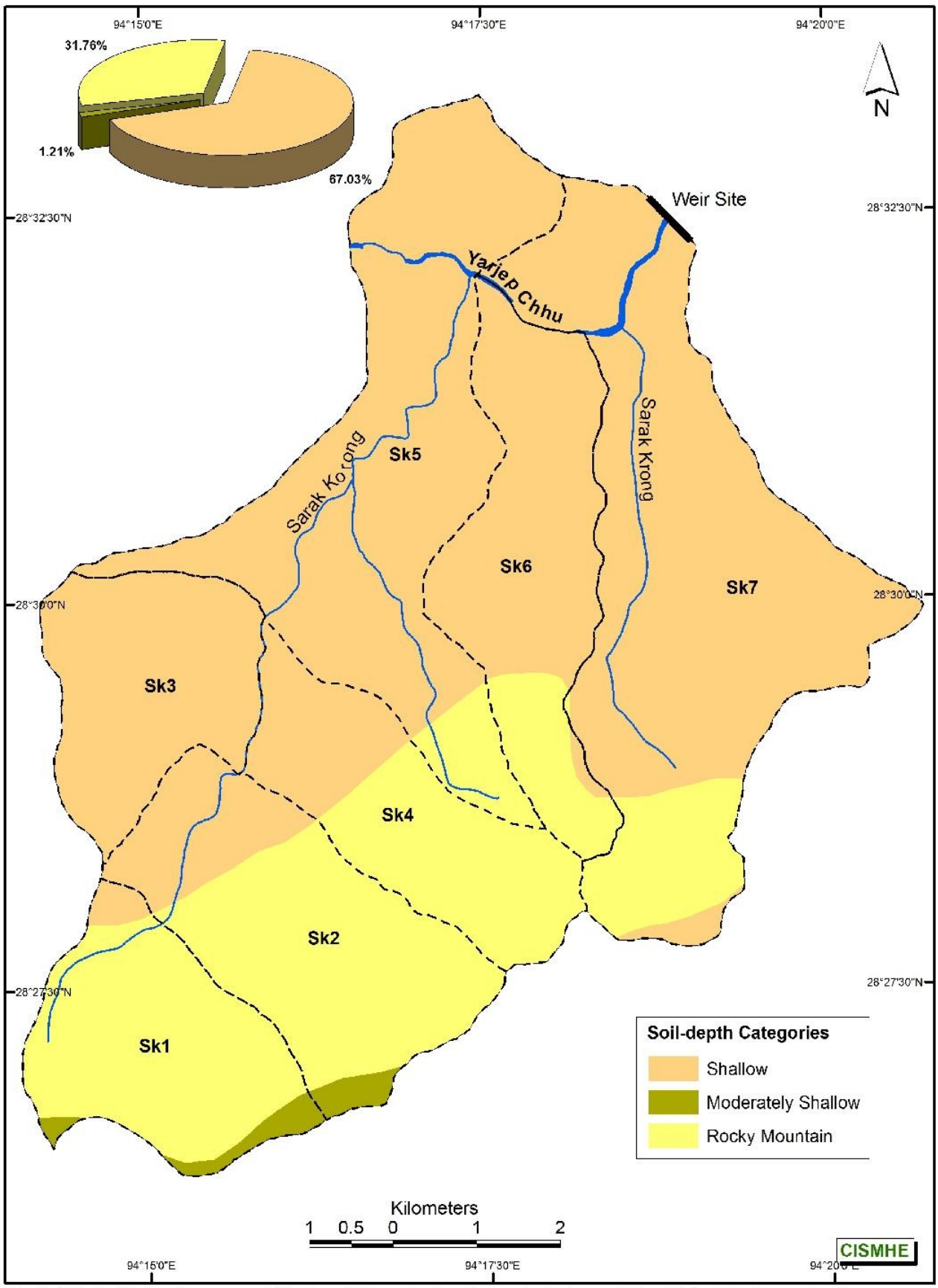


Fig.5.1.5 Soil-depth map of Yarjep Chhu in the free-draining of the Tato-I H.E. project up to the proposed dam site

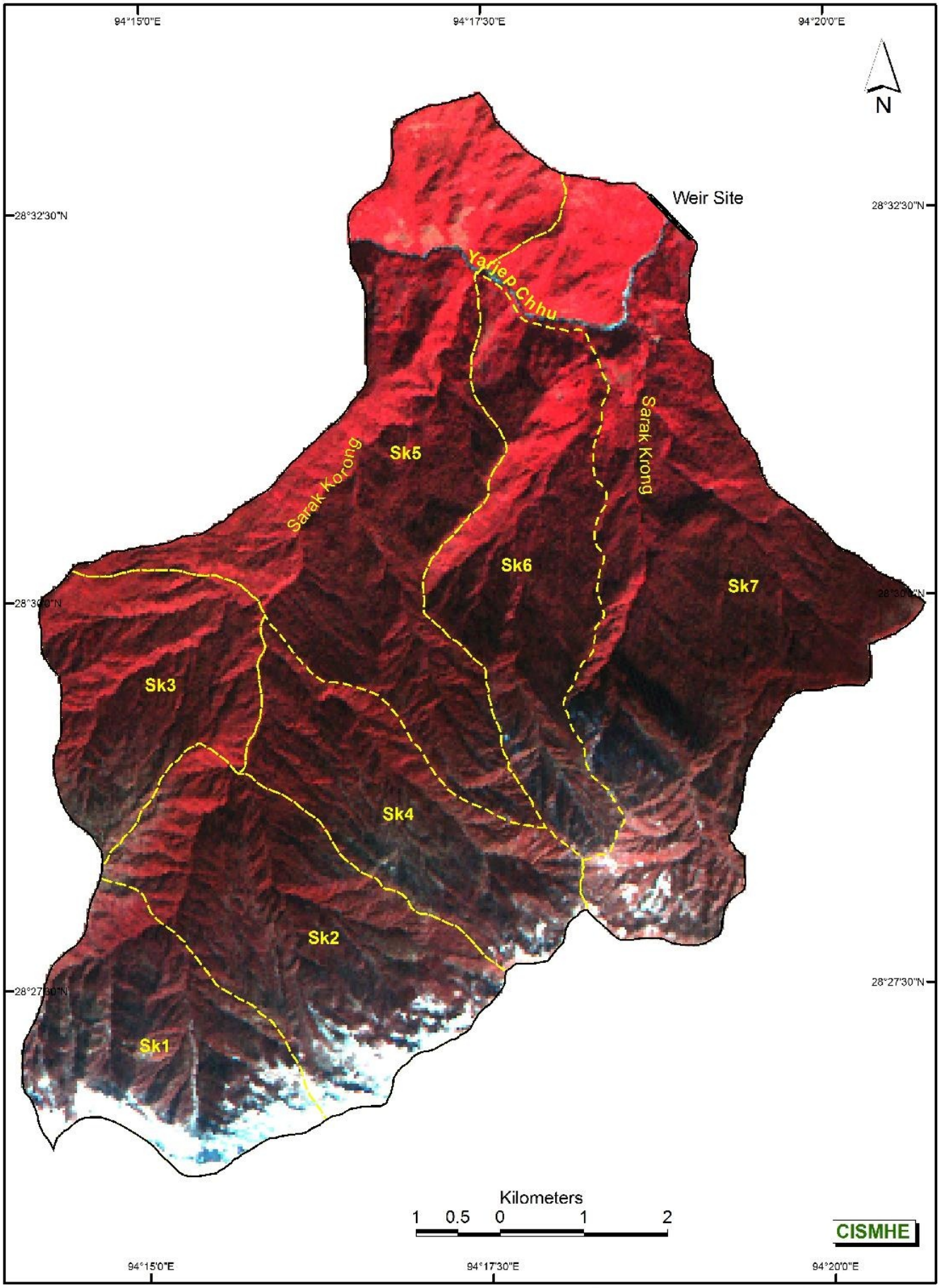


Fig.5.1.6 False Colour Composite (FCC) generated from IRS-P6 LISS-III, 2006 of the proposed Tato-I H.E. Project

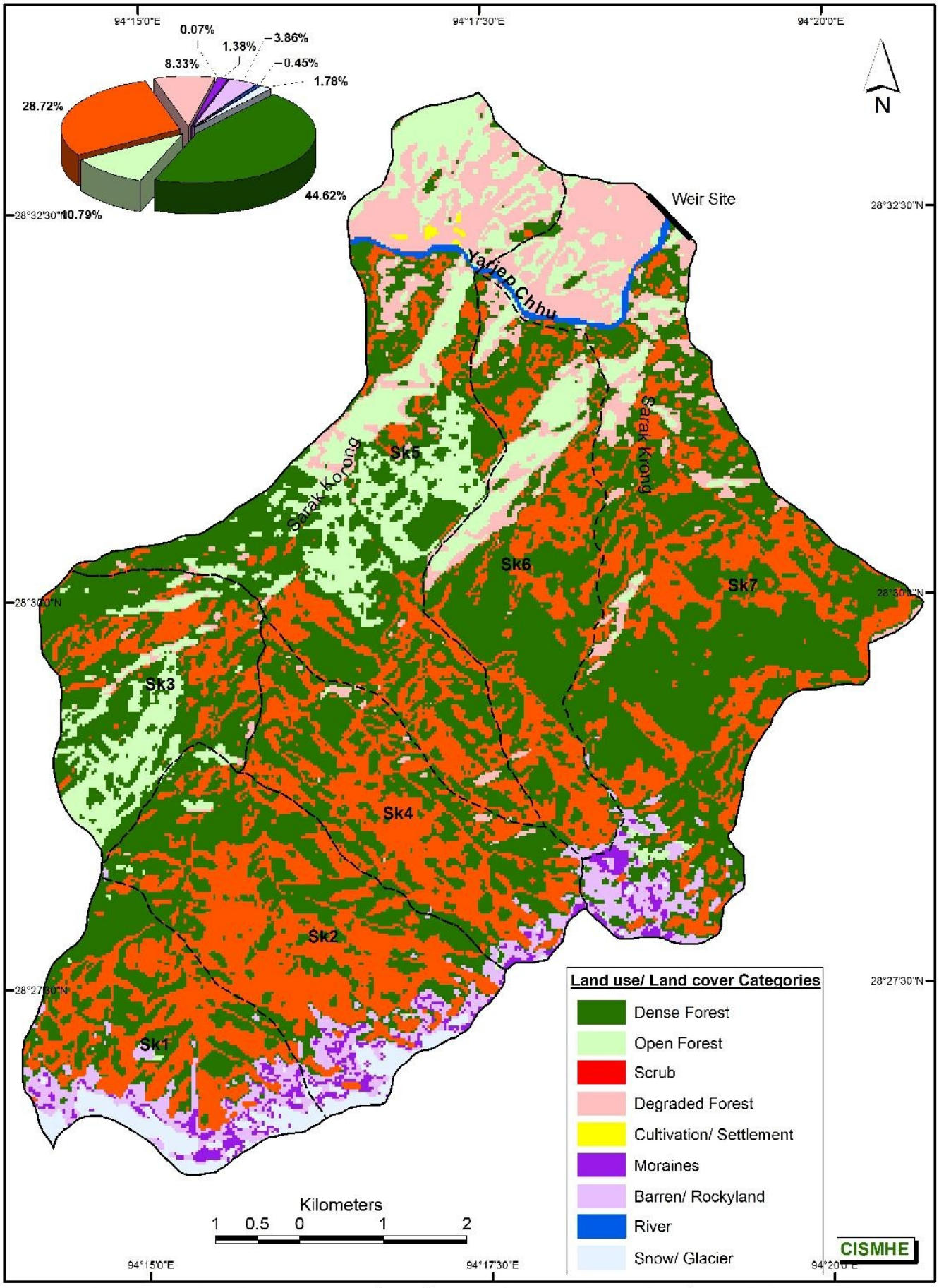


Fig.5.1.7 Land use/ land cover map of the free-draining catchmeht of Tato-I H.E. Project

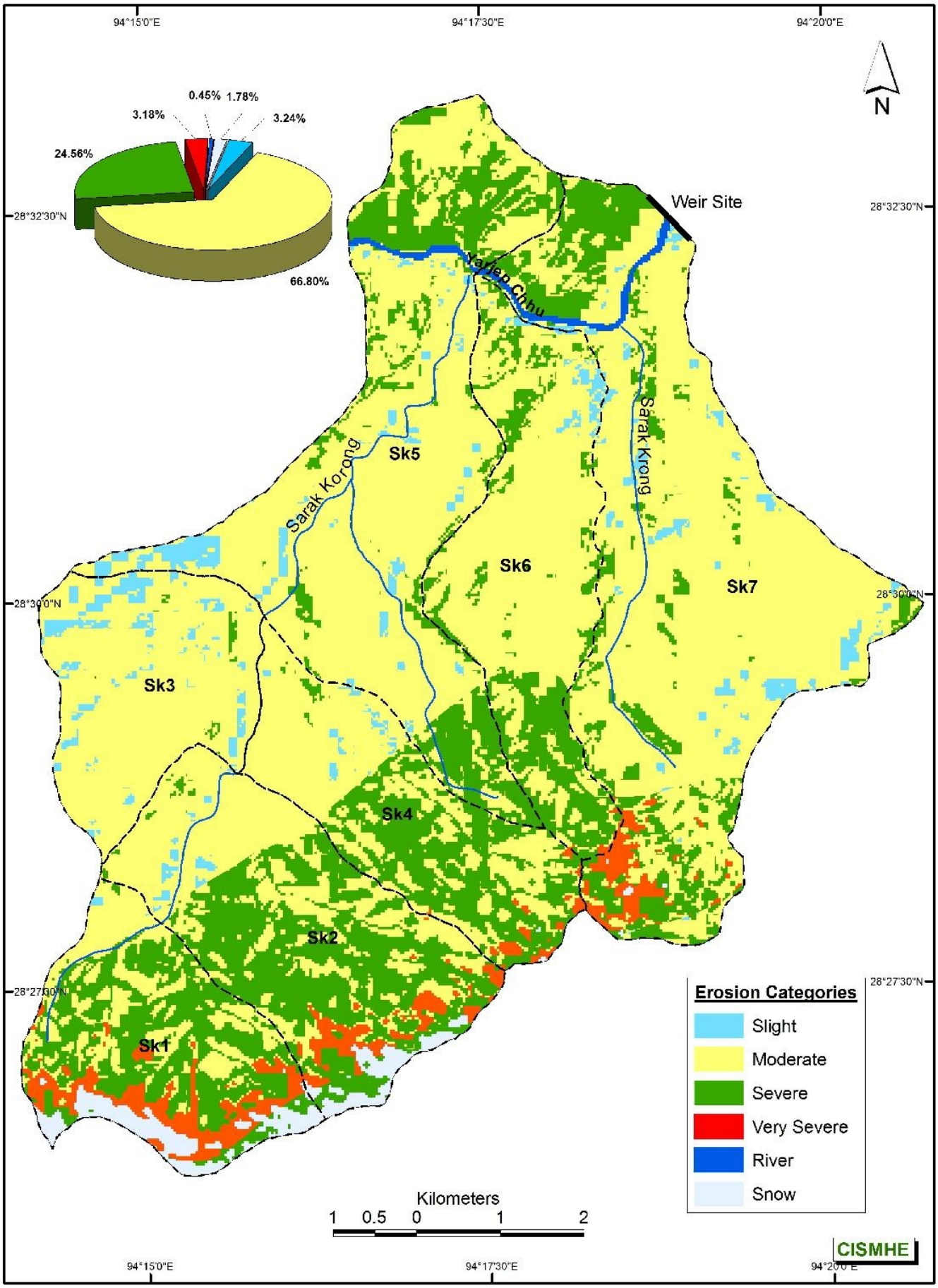


Fig.5.1.8 Erosion intensity map of free-draining catchment of Tato-I H.E. Project

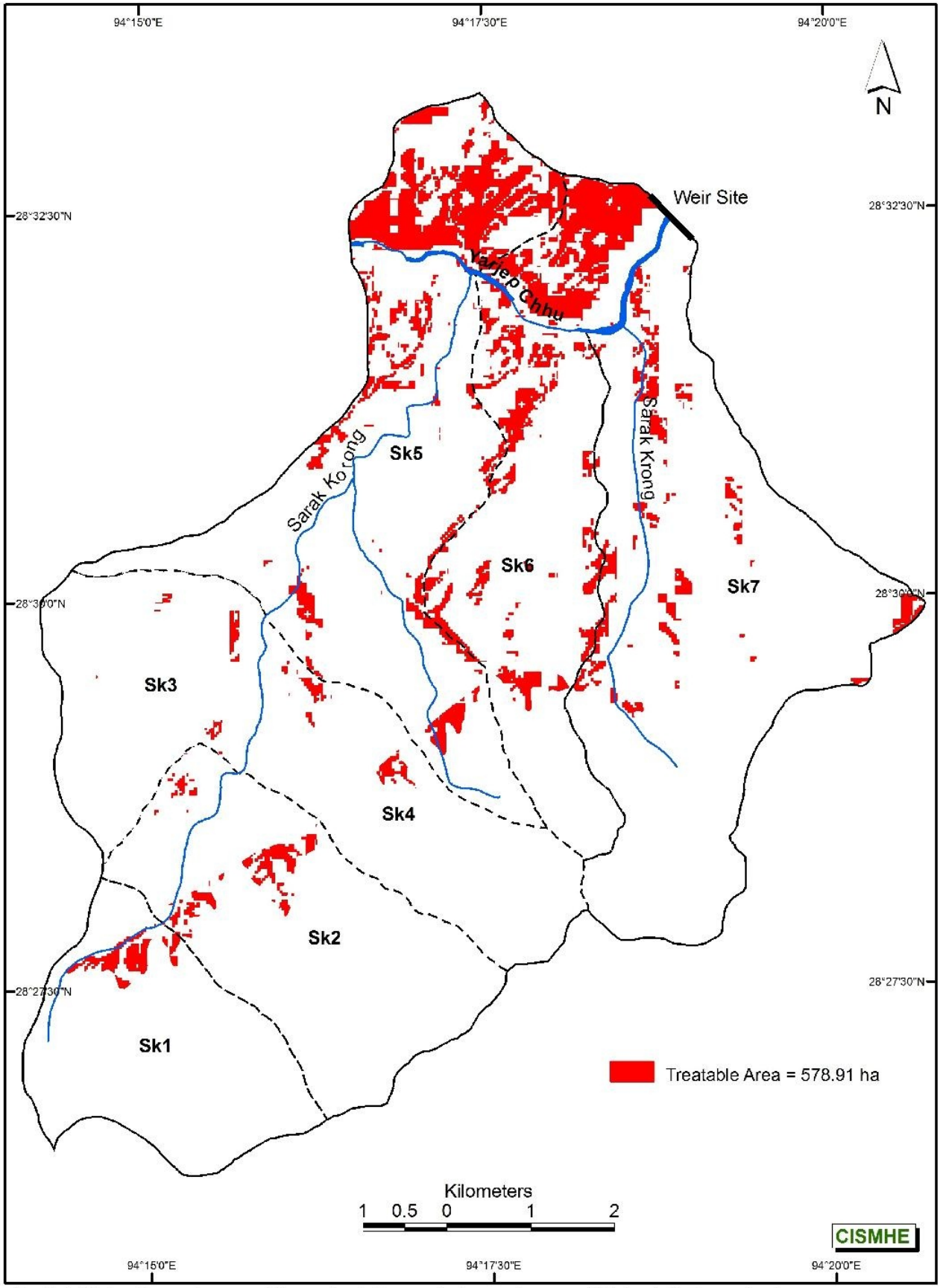


Fig.5.1.9 Treatment map of free-draining catchment area of Tato-I H.E. project

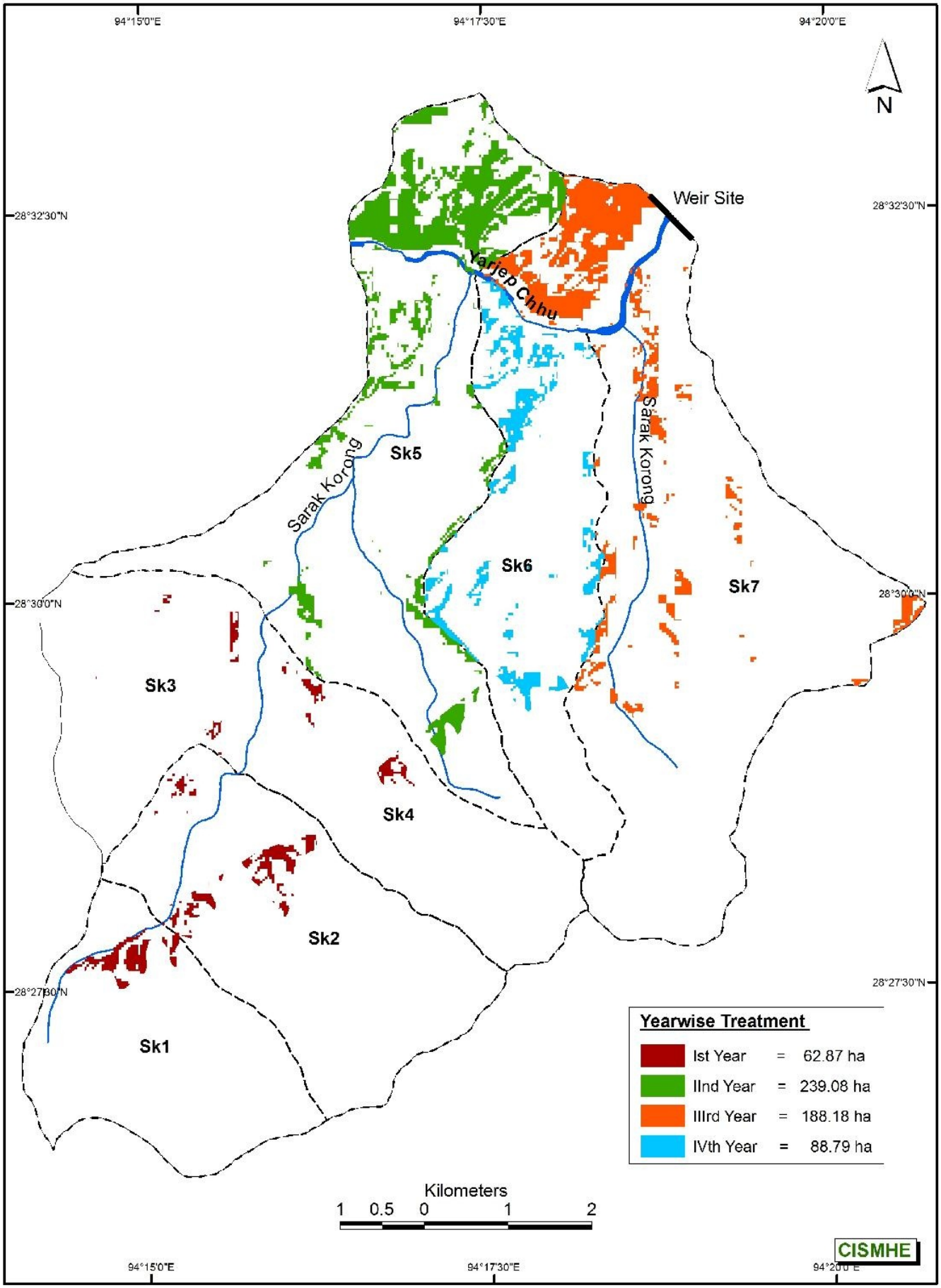
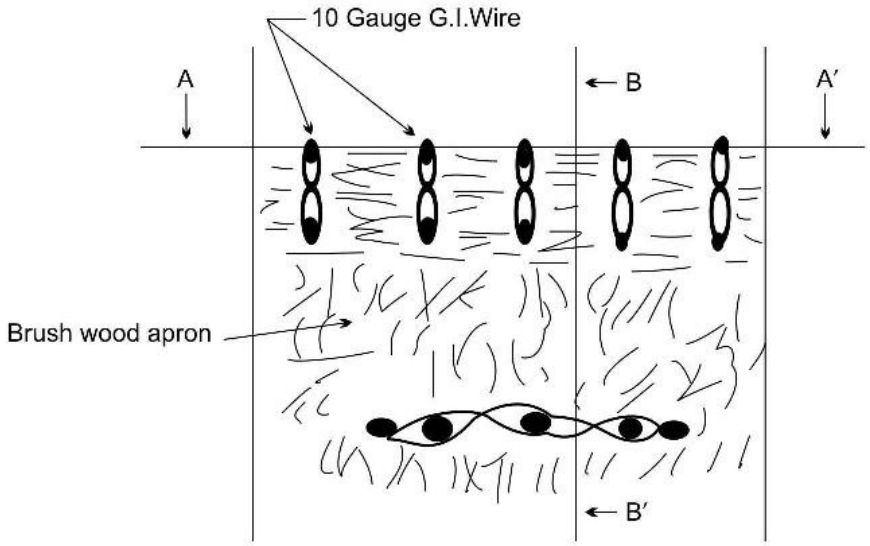
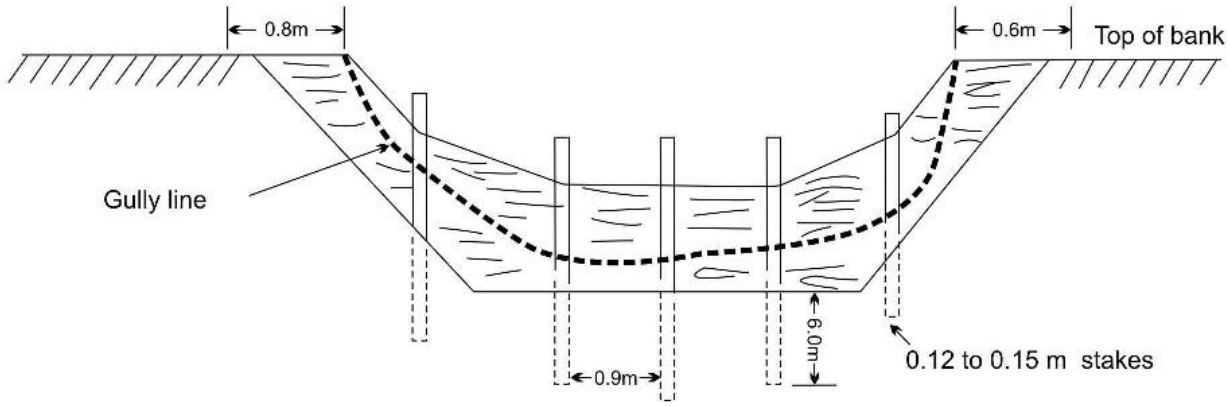


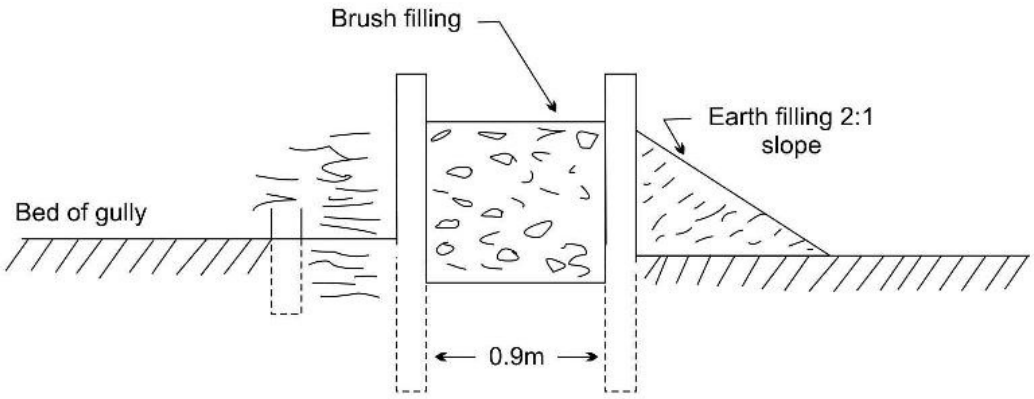
Fig.5.1.10 Yearwise treatment map of free-draining catchment area of Tato-I H.E. project



a) A double-row post brush dam

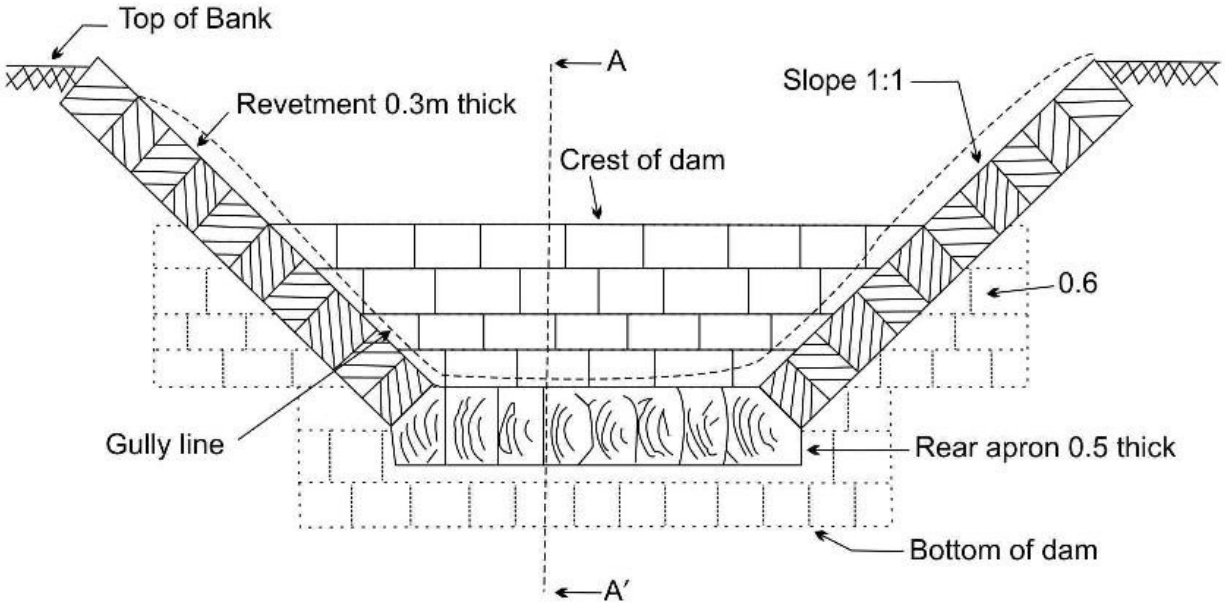


b) Section along A-A′

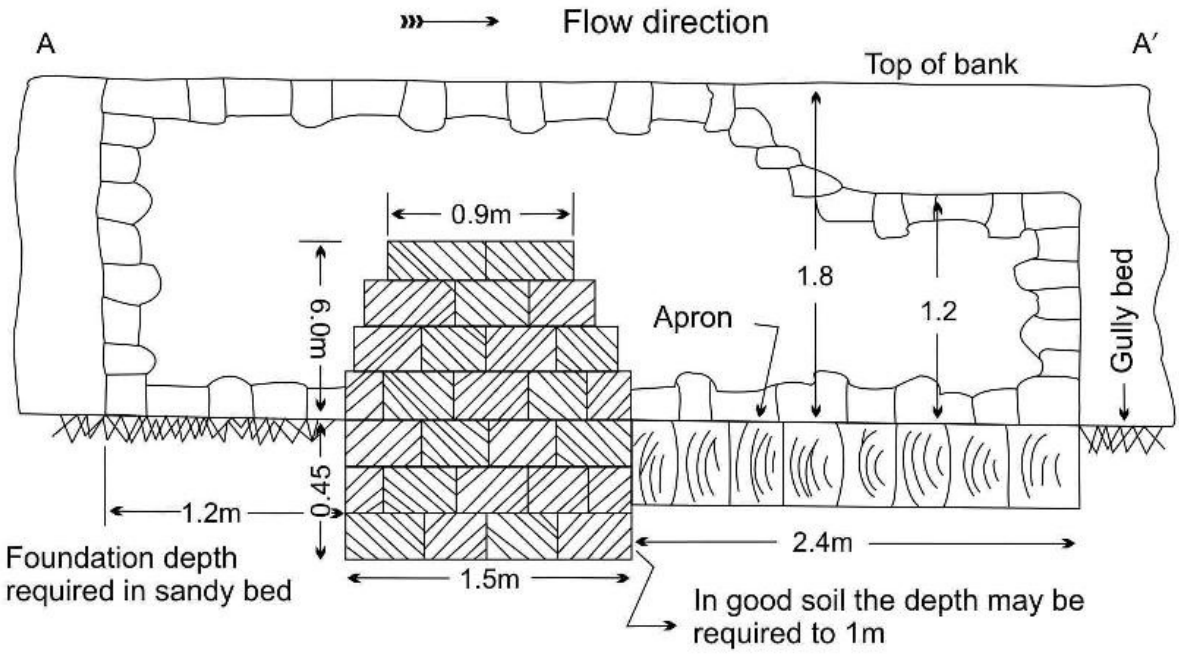


c) Section along BB′

Plate 5.1.1 A Schematic diagram of a double row brush wood check (a) and its cross section along the dam A-A′ (b) and across the dam (c).



a) Section of Dry rubble stone check dam along the structure



b) Section across the structure on A A′

Plate 5.1.2 A Schematic diagram of a Dry rubble stone check dam showing section along the dam looking up gully (a) and section along A-A′ on diagram(b) .

Annexure - I

Table for Computation of Silt Yield Index

Sub-watershed code	Erosion intensity	Area* (ha)	Weightage	Area x weight-age	Delivery ratio	Gross silt yield	Sediment yield index
Sk1	a	105.78	17	1798.26	0.95	1708	
	b	304.59	16	4873.44	0.9	4386	
	c	225.35	14	3154.9	0.85	2682	
	d	1.67	11	18.37	0.80	15	
Total		**637.39**				**8791**	**1379.19**
Sk2	a	56.84	19	1079.96	0.95	1026	
	b	424.42	17	7215.14	0.85	6133	
	c	454.47	16	7271.52	0.85	6181	
	d	12.06	15	180.9	0.8	145	
Total		**947.79**				**13484**	**1422.71**
Sk3	a	0.00	0	0	0.00	0	
	b	5.90	17	100.3	0.85	85	
	c	567.15	15	8507.25	0.85	7231	
	d	60.67	12	728.04	0.8	582	
Total		**633.72**				**7899**	**1246.43**
Sk4	a	16.77	18	301.86	0.90	272	
	b	251.58	17	4276.86	0.85	3635	
	c	406.92	14	5696.88	0.85	4842	
	d	9.96	12	119.52	0.8	96	
Total		**685.23**				**8845**	**1290.80**
Sk5	a	0.00	0	0	0.00	0.00	
	b	315.35	15	4730.25	0.85	4021	
	c	1177.42	14	16483.88	0.85	14011	
	d	69.29	12	831.48	0.8	665	
Total		**1562.06**				**18697**	**1196.96**
Sk6	a	3.02	17	51.34	0.85	44	
	b	200.55	15	3008.25	0.85	2557	
	c	640.42	13	8325.46	0.8	6660	
	d	18.58	11	204.38	0.75	153	
Total		**862.57**				**9414**	**1091.42**
Sk7	a	52.37	19	995.03	0.85	846	
	b	313.53	17	5330.01	0.8	4264	
	c	1467.42	14	20543.88	0.8	16435	
	d	67.40	12	808.8	0.7	566	
Total		**1900.72**				**22111**	**1163.30**

Annexure-II(a)

Afforestation cost/ ha of plantation

S. No.		Description	Cost
A.	**Execution**		
I.	**Wage Component**		
1.	Survey of plantation area and preparation of maps	@ Rs. 68.21	68.21
2.	Climbers cutting, removal of brushwood	@ Rs.292/ha	292.00
3.	Construction of inspections path 60cm 180Rmt	@ Rs.5.05/Rmt	909.00
4.	Fencing of area of barbed wire 4 strands horizontal and 2 strands diagonal (mp-5cm 400m/ha)	@ Rs. 27/running metres	10800.00
5	Digging of pits 45 cm^3	700 nos @ Rs.638.20/ 100	4467.96
6.	Digging of pits 30 cm^3	400 nos @ Rs. 318.20/100	1272.80
7	Filling of pits 45 cm^3	700 nos @ Rs. 182.28/100	1275.96
8.	Filling of pits 30 cm^3	400 nos @ Rs. 157.21/100	628.84
9.	Plantation of plants in pits	1100 nos @ Rs. 140.85/100	1549.35
10.	Cost of raising seedlings in nursery	@ Rs. 3.00/ plant	3300.00
	Total (A)		24564.12
11.	Add 18.93% increase		4649.99
	Total		**29214.11**
II.	**Cost of material**		
i)	Cost of materials for raising saplings	1100 nos @ Rs.4 / plan	4400.00
ii)	Cost of compost	Lump sum	2000.00
iii)	Filling of polybag and maintenance	Lump sum	200.00
	Total		**6600.00**
III.	**Maintenance of saplings planted saplings during execution period**		
11	Cost of protection (Lump sum)	@ Rs. 500.00	
12.	1st weeding during (July/August)	@ Rs. 850/500 san	1700.00
13.	2nd weeding during (Aug/Sep)	@ Rs. 850/1500 san	566.00
14.	Add 18.93% increase		428.95
	Total		**2694.95**
Total (A)			**38509.06**
			Say Rs. 39000/-
	Add escalation for 3 years (2014 to 2017) @ 7.5%/year = 48,850/-		**Say Rs. 48,500/-**
B.	**Maintenance cost**		**5000.00**
	Adding escalation for 3 years (2014 to 2017)		**6200.00**

Annexure-II(b)

Assisted Natural Regeneration Area (per ha)

S. No.		Description	Cost
A	**Execution**		
I.	**Wage Component**		
1.	Survey of Plantation area and preparation of maps	@ Rs. 66.85/ha	66.85
2.	Cleaning and un-saleable thinning (non commercial) in regeneration	@ Rs. 1158.22/ha	1158.22
3.	Bush cutting	@ Rs. 57.95/ha	57.95
4.	Digging of pits 45 cm^3	700 nos @ Rs.623.56/100	4364.92
5.	Filling of pits 45 cm^3	700 nos @ Rs. 178.64/100	1250.48
6.	Planting of Plants in pits	700 nos @ Rs. 87.25/100	610.75
7.	Carriage of Plants in polythene bags and nacked root plants at least 4½ km	700 nos @ Rs.12.00/100/km	378.00
8.	Moisture retention Intervention	@ Rs. 1500.00/ha	1500.00
9.	Cost protection	Lump sum	502.25
	Total		9889.42
	Add 18.93% increase		1872.49
	Total		**11,761.91**
	Add escalation for 3 years (2014 to 2017) @ 7.5%/year =		**Rs. 14,612**
B.	**Maintenance**		**247.64**
	Adding escalation for 3 years (2014 to 2017)		**Rs. 300.00**

Annexure-II(c)

NTFP REGENERATION / MEDICINAL PLANTS CULTIVATION

Planting norms	= 1500 patches /ha
2/3 (66.66%) patches are suitable for planting	= 1000 patches /ha
No. of plants to be planted per patch	= 15
Therefore No. of plants required per ha	= 15000

S.No.	Description	Cost (Rs.)
A.	**Execution**	
1.	Procuring planting materials (including planting out the patches)= 15000 Nos. @ Rs.2.016	30,240.00
	Add 18.93% increase	5724.43
2.	Fencing of individual plant sapling or patch of land	598.10
	Total	**36562.53**
	Adding escalation for 3 years (2014 to 2017)	**Rs. 45,422**
B.	**Maintenance**	**6894.74**
	Adding escalation for 3 years (2014 to 2017)	**Rs. 8,600**

Annexure-II(d)

Pasture Important

S. No.		Description	Cost
A.	**Execution**		
I.	**Wage Component**		
1.	Climber cutting/bush cutting in Plantation area ½ ha	@ Rs. 68.21	146.00
2	Survey of Plantation area and preparation of maps	@ Rs. 68.21/ha	68.21
3.	Digging of pits 45 cm^3	700 nos @ Rs. 936.25/100	6553.75
4.	Filling of pits 45cm^3	700 nos @ Rs. 482.28/100	3375.96
5.	Planting of Plants in pits for 45cm^3	700 nos @ Rs.233.85/100	1636.95
6	Carriage of Plants	700 nos @ Rs. 167.5/100/km	1172.5
7	Preparation of patches for	250 nos @ Rs. 266.85/100	667.12
8	Sowing of patches for grass sowing	250 nos @ Rs. 48.70/100	121.75
9	Cost of protection	Lump sum	400.00
10.	Collection of grass seed		97.00
	Total		**14239.24**
	Add 18.93% increase		2695.49
	Total (A)		**16934.73**
II.	**Cost of Material**		
	Cost of compost		3,000.00
	Grand Total (A+B)		**19934.73**
	Adding escalation for 3 years (2014 to 2017)		**Rs. 27,765**
B.	**Maintenance**		**607.41**
	Adding escalation for 3 years (2014 to 2017)		**Rs. 715**