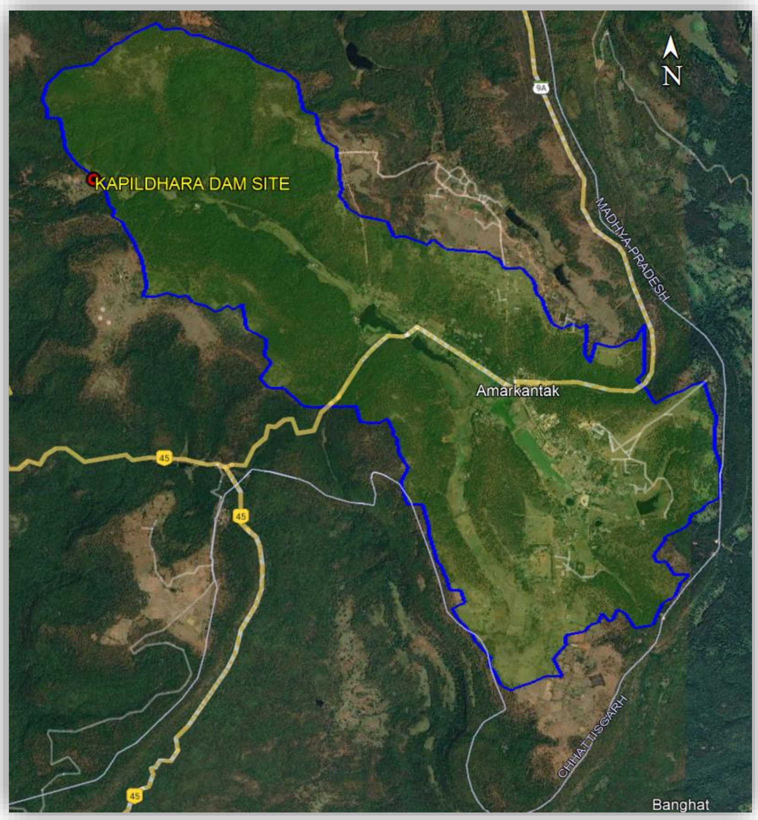
GOVERNMENT OF MADHYA PRADESH,

NAGAR PARISHAD AMARKANTAK

BARRAGE AT KAPILDHARA ON NARMADA RIVER

CATCHMENT AREA TREATMENT PLAN



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1. BACKGROUND OF THE KAPILDHARA PROJECT

The Proposed Kapildhara Project involves the construction of a dam across the Narmada River in the Upper Narmada Basin. The Narmada River originates from a small reservoir called Narmada Kund, situated in the sacred town of Amarkantak on the Amarkantak Plateau in the Anuppur District of Madhya Pradesh. This region is steeped in cultural and natural significance, with the river's course passing through picturesque landscapes and geological formations. After originating from Narmada Kund, the river descends from Amarkantak and forms the Kapildhara Waterfall, a breathtaking cascade with a vertical drop of about 100 feet, surrounded by mountains and dense forests. The river continues its journey through a meandering and tortuous path, crossing rocks and islands before reaching the historic ruins of Ramnagar. The Kapildhara Project is strategically located upstream of the Kapildhara Waterfall, near the parking area of the waterfall. It is a medium irrigation project aimed at harnessing the water resources of the Narmada River to support agricultural activities and enhance water availability in the region. In addition to its functional purpose, the project site is in close proximity to a location of immense natural beauty, underscoring the need for careful planning and sustainable development to balance ecological preservation with infrastructural development. This project represents a critical step toward regional development while acknowledging the ecological and cultural significance of its surroundings.

2. PURPOSE AND SCOPE OF THE CATCHMENT AREA TREATMENT PLAN

The Catchment Area Treatment (CAT) Plan is a vital component of sustainable watershed management, designed to address soil erosion and sedimentation issues that adversely impact the functionality and longevity of reservoirs. In the context of the proposed Kapildhara Dam Project, the CAT Plan aims to mitigate soil erosion, reduce sediment yield, and enhance land productivity in the catchment area. Erosion and sedimentation are critical concerns as they lead to the deposition of sediment in the reservoir, reducing its storage capacity and diminishing the availability of water for designated purposes such as irrigation and water supply.

The eroded sediment not only affects the reservoir but also settles on streambeds and banks, leading to the braiding of river channels, destabilization of riverbanks, and alteration of the natural flow regime. Additionally, the removal of the fertile topsoil due to erosion significantly reduces agricultural productivity, posing a challenge to the livelihoods of communities in the region. Grazing pressure, particularly in mountainous regions, exacerbates this problem, as continuous grazing by cattle, sheep, and goats depletes vegetative cover, leaving the soil exposed and vulnerable to runoff and erosion.

The CAT Plan is designed to counter these issues by comprehensively analysing the erosion characteristics of the catchment terrain and proposing remedial measures to reduce the erosion rate. It emphasizes the treatment of areas contributing directly to sediment load, including rivers, streams, tributaries, and erosion-prone zones. The associated costs of these measures are integrated into the project budget, ensuring a holistic approach to reservoir sustainability.

The sedimentation process in reservoirs involves erosion, entrainment, transportation, deposition, and compaction of sediment, which cumulatively reduces the reservoir's capacity and adversely affects its utility. The consequences of soil erosion include:

- Loss in agricultural production potential.
- Reduction in infiltration rates, diminishing groundwater recharge.
- Decreased water-holding capacity of the soil.
- Nutrient loss, leading to poor soil fertility.
- Increased costs for tillage operations.
- Diminished availability of water supply.

To combat these effects, the CAT Plan encompasses a management framework to treat erosion-prone areas using preventive and remedial measures. Soil erosion, defined as the detachment, transportation, and deposition of soil particles by agents such as water, air, or animals, is influenced by several factors, including rainfall intensity, runoff, slope gradient and length, soil erodibility, and vegetation cover. Addressing these factors through strategic interventions ensures the minimization of erosion and sedimentation.

This CAT Plan leverages freely available public domain data through advanced Remote Sensing and GIS techniques to identify and prioritize critical areas for intervention. By employing these cost-effective and precise methods, the CAT Plan proposes practical and sustainable solutions for soil conservation, water management, and ecological restoration.

In summary, the CAT Plan not only serves to mitigate the adverse impacts of soil erosion and sedimentation on the Kapildhara Dam Project but also contributes to the long-term environmental sustainability of the region. By reducing sediment influx, enhancing vegetative cover, and improving land productivity, the CAT Plan ensures that the project remains eco-friendly and aligns with the principles of sustainable development.

3. IMPORTANCE OF CATCHMENT AREA TREATMENT PLAN

The Catchment Area Treatment (CAT) Plan is an essential component of the proposed Kapildhara Dam Project, playing a pivotal role in ensuring the project's long-term sustainability and effectiveness. This plan addresses critical challenges related to soil erosion, sedimentation, and land degradation within the catchment area, which, if unmitigated, can severely impact the reservoir's functionality and the surrounding ecosystem.

One of the primary concerns in any dam project is sedimentation, which gradually reduces the reservoir's storage capacity, thereby limiting its ability to fulfil its intended purposes, such as irrigation, water supply, and hydropower generation. The sediment deposited in the reservoir originates from the erosion of topsoil within the catchment area, transported downstream by runoff during rainfall events. A well-implemented CAT Plan mitigates this issue by reducing soil erosion at the source, thereby prolonging the reservoir's lifespan and ensuring optimal water availability for its designated uses.

The proposed Kapildhara Dam Project is located in a region where mountainous terrain, steep slopes, and intense rainfall create conditions conducive to high rates of soil erosion. The problem is further exacerbated by insufficient vegetative cover and anthropogenic activities such as overgrazing, deforestation, and agricultural practices on marginal lands. These factors not only accelerate soil erosion but also degrade the fertility of agricultural land, impacting the livelihoods of local communities. The CAT Plan is critical in addressing these interconnected challenges by promoting soil conservation, restoring degraded land, and improving vegetative cover in the catchment. In the context of the Kapildhara Dam Project, the importance of the CAT Plan can be summarized as follows:

1. Reduction in Sedimentation:

The CAT Plan aims to minimize sediment inflow into the reservoir by implementing erosion control measures such as afforestation, check dams, contour bunding, and gully plugging. This reduction in sedimentation helps maintain the reservoir's storage capacity and extends its operational life.

2. Soil Conservation:

By preventing the loss of fertile topsoil, the CAT Plan safeguards the agricultural potential of the catchment area. Measures such as agroforestry and grassland development stabilize the soil, reduce surface runoff, and enhance land productivity.

3. Flood Mitigation:

Properly treated catchment areas reduce the intensity of surface runoff during heavy rainfall, thereby mitigating flash floods and stabilizing river channels. This contributes to safer downstream areas and reduced damage to infrastructure and agriculture.

4. Groundwater Recharge and Water Quality Improvement:

The CAT Plan promotes practices that enhance water infiltration into the soil, contributing to groundwater recharge. Additionally, reducing erosion improves water quality in streams and rivers by minimizing sediment and nutrient loads.

5. Biodiversity Conservation:

The plan focuses on restoring vegetation and natural habitats, which supports biodiversity conservation in the project area. This is especially significant given the ecological richness of the Kapildhara region, where forests and natural landscapes play a crucial role in maintaining ecological balance.

6. Sustainability of the Kapildhara Dam Project:

The success of the Kapildhara Dam Project relies heavily on the health of its catchment. A well-executed CAT Plan ensures that the dam functions efficiently over its intended lifespan by addressing sedimentation and erosion issues at their source.

7. Community Benefits:

By improving agricultural productivity, reducing land degradation, and creating opportunities for afforestation and sustainable grazing, the CAT Plan directly benefits local communities. It fosters a sense of ownership and participation among stakeholders, leading to better implementation and long-term maintenance of the proposed measures.

In summary, the Catchment Area Treatment Plan is not merely a technical requirement but a cornerstone of the Kapildhara Dam Project's success. It addresses key environmental, social, and economic challenges associated with soil erosion and sedimentation, ensuring that the project delivers its intended benefits while preserving the ecological integrity of the region. By integrating the CAT Plan into the project design, the Kapildhara Dam Project exemplifies a commitment to sustainable development and responsible water resource management.

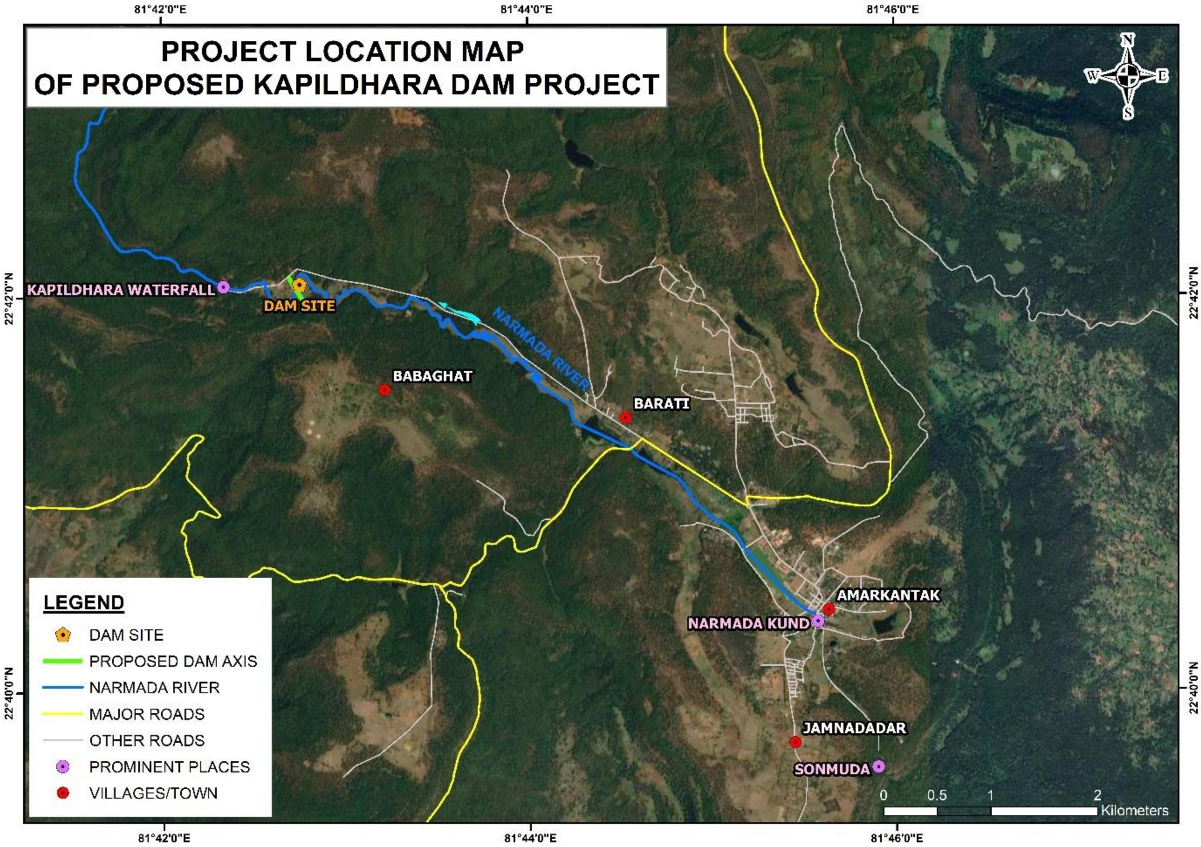
4. GEOGRAPHICAL LOCATION

The proposed Kapildhara Dam Project is strategically located in the Upper Narmada Basin near the town of Amarkantak, in the Anuppur District of Madhya Pradesh. Amarkantak, situated on the Amarkantak Plateau, is renowned as the origin point of the Narmada River, a sacred and historically significant river in India. The project site is positioned upstream of the Kapildhara Waterfall, adjacent to the parking area of this iconic natural attraction.

The Amarkantak Plateau, part of the Maikal Hills range, lies at the meeting point of the Vindhya and Satpura mountain ranges and forms part of the central Indian highlands. This region, characterized by rugged terrain and dense forests, serves as a critical ecological zone. The plateau rises to an average elevation of approximately 1,048 meters above mean sea level and is marked by steep slopes, rocky outcrops, and deep gorges, making it a significant source of major rivers, including the Narmada, Son, and Johila Rivers.

The Narmada River originates from a small, revered water body known as the Narmada Kund in Amarkantak. From its origin, the river flows through diverse landscapes, descending from Sonmuda and forming the Kapildhara Waterfall, where it plunges approximately 100 feet in a dramatic cascade surrounded by pristine forests and mountainous terrain. The river continues its journey through a meandering and tortuous course, navigating through rocky channels and islands before reaching the ruins of Ramnagar further downstream. A Project Location Map of the proposed Kapildhara Project is shown in **Figure 1** below.

Figure 1: Project Location Map of Proposed Kapildhara Project



The project site is situated in a region of exceptional scenic beauty, with dense forests, undulating hills, and rich biodiversity. The forests around the Kapildhara Waterfall are classified as tropical moist deciduous and dry deciduous forests, which host a variety of flora and fauna. This ecological richness underscores the need for careful planning and sustainable execution of the project to minimize environmental impacts. In terms of accessibility, Amarkantak is well-connected by road to nearby towns and cities, including Anuppur, Shahdol, and Jabalpur. The nearest railway station is in Anuppur, approximately 80 kilometres from the project site, while Jabalpur, a major city, provides the nearest airport, located about 240 kilometres away.

The geographical location of the Kapildhara Dam Project offers a combination of ecological, cultural, and hydrological significance. Its position upstream of the Kapildhara Waterfall allows for effective utilization of the Narmada River's flow for irrigation while preserving the natural beauty and ecological balance of the surrounding area. The unique topography and climatic conditions of the region, however, necessitate the implementation of robust measures, such as the Catchment Area Treatment Plan, to manage soil erosion, sedimentation, and environmental sustainability.

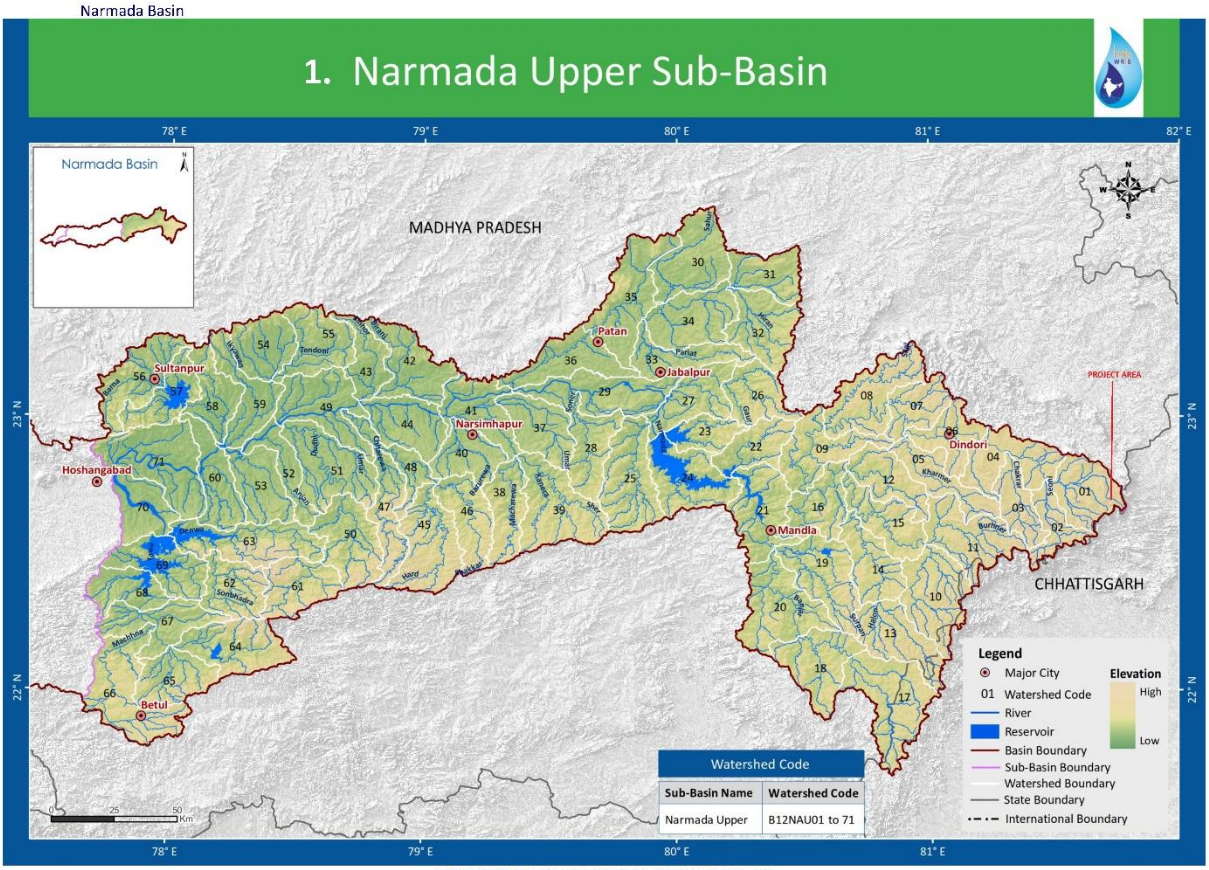
5. CATCHMENT AREA

The catchment area of the proposed Kapildhara Dam Project has been meticulously delineated and analysed using advanced geospatial techniques, resulting in a calculated catchment area of 16.41 sq km. This area has been determined utilizing the CartoDEM version-2.0, a high-resolution (30 m x 30 m) national digital elevation model developed from Cartosat-1 satellite data by NRSC/ISRO. The accuracy of the GIS-derived catchment area has been verified against Survey of India (SOI) toposheets, confirming the reliability of the analysis.

According to the Water Atlas of India, Second Edition 2012, the catchment under study is categorized under watershed code B12NAU01, a free-draining watershed within the Upper Narmada Basin. The specific area of interest for this project forms a sub-catchment of this watershed, contributing to the hydrology and sediment transport dynamics of the Narmada River.

Figure 2: Catchment Area of Proposed Kapildhara Project in the Narmada River Basin

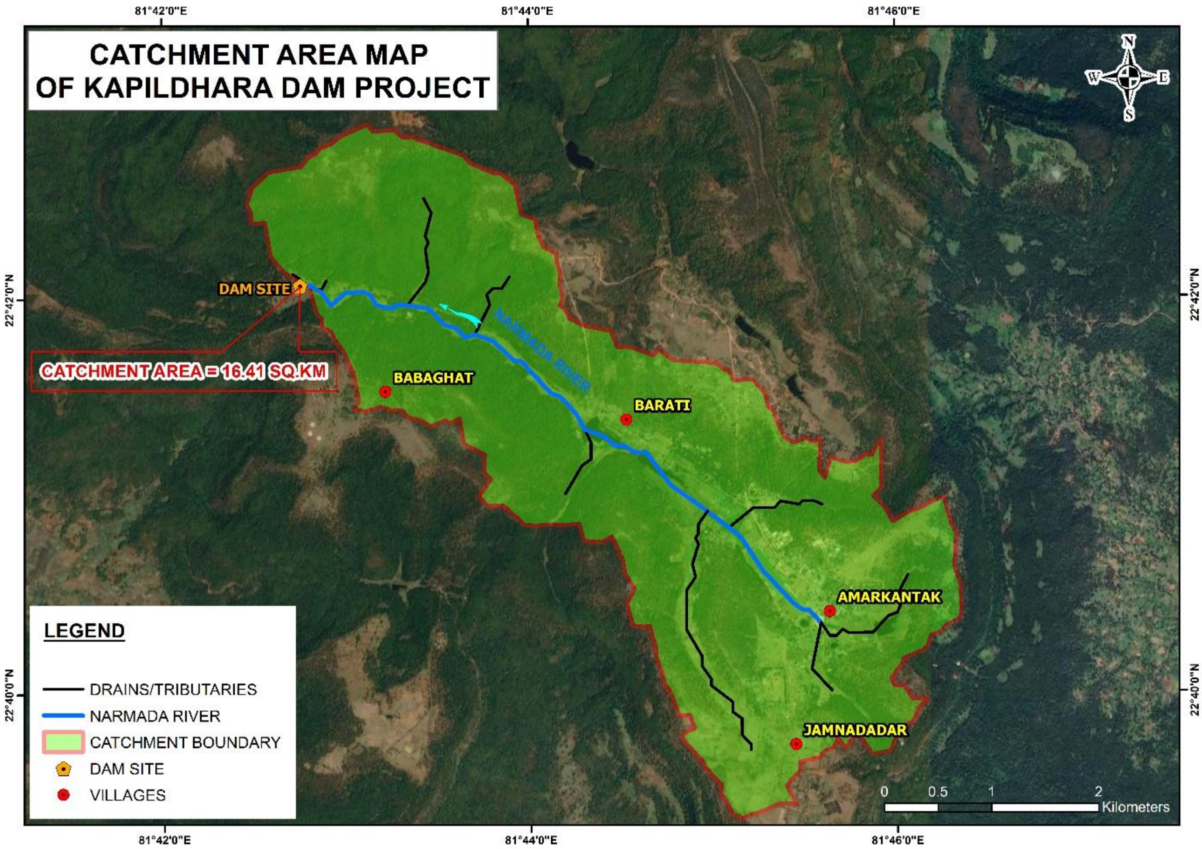
Narmada Basin



Map 13a. Narmada Upper Sub-basin and watersheds

The catchment map, generated using these geospatial tools, provides a detailed representation of the topography, drainage patterns, and boundaries, and is illustrated in **Figure 3** below. The catchment is characterized by its interception of four minor irrigation tanks, which are crucial for managing surface water resources within the region. Since the catchment is not intercepted by any other major or medium water resource project on upstream, the Catchment Area Treatment Plan shall be formulated for entire catchment (16.41 sq. km).

Figure 3: Free Draining Catchment Area Map of Proposed Kapildhara Project



Key Features of the Catchment Area:

1. Topography and Elevation:

- The elevation of the catchment ranges from approximately 930 meters to 1060 meters above mean sea level (MSL).
- The terrain is a mix of undulating hills and valleys, contributing to a varied runoff pattern and influencing soil erosion and sediment yield.

2. Drainage Network:

- The catchment is drained by the Narmada River, which traverses a length of approximately 6.3 kilometres up to the proposed dam site.
- The river's flow is augmented by contributions from minor streams and surface runoff within the catchment.

3. Land Use and Land Cover:

- The area comprises a mix of forested regions, agricultural land, and small water bodies (including the minor irrigation tanks).
- The vegetation cover is critical for soil conservation and runoff regulation, while the agricultural zones are vulnerable to erosion during intense rainfall.

4. Geological and Soil Characteristics:

- The catchment lies within the Maikal Hills region, characterized by rocky outcrops and loamy to fine silty soils.
- The soils in the catchment are moderately susceptible to erosion, necessitating effective management strategies under the Catchment Area Treatment Plan.

The delineation of the catchment area is instrumental in hydrological modelling, sediment yield analysis, and designing appropriate interventions for soil conservation and water management. The accurate mapping and verification of the catchment boundaries ensure a comprehensive understanding of the hydrological inputs and outputs at the proposed dam site. In summary, the catchment area of the Kapildhara Dam Project is a compact yet hydrologically significant region, whose effective management is essential for the sustainable operation of the dam. The integration of modern GIS tools with traditional cartographic validation underscores the precision of the analysis, making it a reliable foundation for further planning and implementation.

6. METHODOLOGY ADOPTED FOR THE STUDY

The preparation of the Catchment Area Treatment (CAT) Plan for the Kapildhara Dam Project involved a comprehensive and scientifically robust methodology. The primary objective was to model soil loss and sediment yield, which are critical for understanding erosion processes within the catchment and identifying areas requiring intervention. To achieve this, two well-established models, the Revised Universal Soil Loss Equation (RUSLE) and the Sediment Yield Index (SYI) model, are employed.

DEVELOPMENT OF SOIL LOSS MODEL USING RUSLE

The RUSLE model was utilized to estimate the annual average soil loss across the catchment. This empirical model has been widely applied in agricultural and forested watersheds due to its compatibility with Geographic Information Systems (GIS), moderate data requirements, and ease of implementation. RUSLE estimates soil erosion based on the interaction of five key factors:

Soil Loss (A) = R x K x LS x C x P

Where:

- A: Annual average soil loss (t ha^{-1} yr^{-1})
- R: Rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})
- K: Soil erodibility factor (t h MJ^{-1} mm^{-1})
- LS: Slope length and steepness factor (dimensionless)
- C: Land cover management factor (dimensionless, ranging from 0 to 1)
- P: Conservation support practice factor (dimensionless, ranging from 0 to 1)

Data Sources for RUSLE Input Factors:

- Rainfall Erosivity (R): Derived from regional rainfall data and calculated using rainfall intensity and distribution patterns.
- Soil Erodibility (K): Assessed based on soil type, texture, structure, and organic matter content, derived from soil maps and field surveys.
- Topography (LS): Calculated using slope and flow accumulation maps derived from CartoDEM Version 2.0 data at a 30 m spatial resolution.
- Land Cover Management (C): Determined using Land Use Land Cover (LULC) maps prepared from satellite imagery and classified into categories based on vegetation and human activities.
- Conservation Practice (P): Assigned based on existing conservation practices, such as terracing or contour farming, identified during field investigations.

The outputs of the RUSLE model are spatial soil loss maps, which provided a detailed depiction of erosion hotspots within the catchment area. These maps are instrumental in understanding the spatial variability of soil erosion and identifying critical zones requiring treatment.

SEDIMENT YIELD MODELING USING SYI

To complement the soil loss analysis, the SYI model was applied to prioritize areas within the catchment based on their sediment delivery potential. The SYI model, developed by the All India Soil and Land Use Survey, evaluates sediment yield using the following equation:

Sediment Yield Index = $(\Sigma (Ai \times Wi \times Di)/ Aw) \times 100$

Where:

- A_1: Area of the ith mapping unit (ha)
- W_1: Weightage assigned to the ith unit, based on erosion severity
- D_1: Delivery ratio assigned to the ith unit, representing the proportion of eroded soil reaching the river network
- A_e: Total area of the catchment (ha)

Data Processing in SYI:

- The soil loss map generated using the RUSLE model served as an input for assigning erosion severity weightages to each mapping unit (pixel).
- Delivery ratios (D_1) are calculated considering the terrain, proximity to streams, and sediment transport dynamics.
- Spatial data processing and analysis are conducted in a GIS environment, ensuring precise delineation of watershed and their sediment yield potential.

INTEGRATION AND ANALYSIS

- The sediment yield index values, combined with the soil loss map, enabled the categorization of the catchment into priority zones for treatment.
- High-priority zones, identified based on higher soil loss and sediment delivery potential, are earmarked for targeted interventions under the CAT plan.
- Proposed treatments included afforestation, check dams, contour bunding, and other soil conservation measures.

MAPPING AND VISUALIZATION

The outputs of the study are represented as spatial maps, including:

- Soil loss maps (RUSLE output) highlighting erosion-prone areas.
- Sediment yield index maps showing priority zones for intervention.

- Thematic maps for rainfall, soil, slope, and LULC factors, which are used as inputs.

SIGNIFICANCE OF THE METHODOLOGY

The combined application of RUSLE and SYI models ensures a holistic understanding of erosion and sedimentation processes. This approach allows for precise identification of vulnerable areas and the development of a targeted, cost-effective, and eco-friendly Catchment Area Treatment Plan. By utilizing high-resolution GIS data and proven empirical models, the methodology provides a robust framework for sustainable watershed management, ensuring the long-term viability of the Kapildhara Dam Project.

7. DATA ACQUISITION AND PREPARATION

The preparation of the Catchment Area Treatment (CAT) Plan for the Kapildhara Dam Project involved the acquisition and integration of diverse datasets from reliable sources, which were then processed and analysed using advanced Geographic Information System (GIS) and Remote Sensing (RS) techniques.

Rainfall data for the study area was sourced from the Hydrology Report of the Project. Since there are no dedicated rainfall monitoring stations within the catchment, data from nearby stations, spanning the last 30 years, were analysed to estimate the rainfall characteristics, including annual average rainfall and rainfall intensity patterns. This data served as a crucial input for calculating the Rainfall Erosivity Factor (R) in the Revised Universal Soil Loss Equation (RUSLE) model, which forms the basis for soil erosion assessment.

For soil data, the Madhya Pradesh Geoportal, developed by the Madhya Pradesh State Spatial Data Infrastructure (MPSSDI) along with Bhoomi Geoportal developed by NBSSLUP have been referred. The geoportal provided detailed information on soil texture, which is essential for understanding soil erodibility. However, since only soil texture data was available, a Soil Erodibility Factor Map (K-Factor Map) prepared by IIT Delhi for the entire country was used to supplement this information.

The Digital Elevation Model (DEM), critical for topographic analysis, was sourced from CartoDEM Version 2.0, a national elevation model derived from Cartosat-1 data provided by the National Remote Sensing Centre (NRSC), ISRO. With a spatial resolution of 30 m x 30 m, the DEM was used to derive the Slope Length and Steepness (LS) Factor, generate slope maps, analyse drainage patterns, and study flow accumulation characteristics within the catchment.

Land Use and Land Cover (LULC) analysis was performed using Landsat-9 satellite data with a spatial resolution of 30 m x 30 m. The LULC classification helped identify key land categories such as forest cover, agricultural land, barren land, and water bodies. This data was instrumental in deriving the Land Management Factor (C-Factor) for the RUSLE model and identifying erosion-prone zones based on land use practices.

Field verification and ground truthing is done to validate the remote sensing interpretations and cross-check soil properties, vegetation cover, and existing conservation measures on-site.

7.1 RAINFALL EROSIVITY (R) FACTOR

R factor is a function of the falling raindrop and rainfall intensity and is estimated as the product of the kinetic energy (E) of the raindrop and the maximum intensity of rainfall (I30) over duration of 30 min in a storm. The erosivity of rain is calculated for each storm, and these values are summed up for each year.

In this study, the storm wise rainfall data were not available for the computation of rainfall erosivity factor (R); therefore, the relationship between seasonal value of R and average rainfall has been used. The rainfall erosivity factor has been defined as $R = 81.5 + 0.38X$, where, R is the average seasonal erosivity factor (MJ mm/ha-1/h-1/year-1), and X is the annual average rainfall (mm).

For the estimation of rainfall erosivity in the free draining catchment area, average rainfall of 30 years has been taken from the Hydrology report of the Kapildhara Project. An Average Annual Rainfall for the catchment of the proposed Kapildhara Project as worked out in the Hydrology report is shown in **Table 1** below.

Table 1: Average Annual Rainfall in the Catchment of Kapildhara Project (From Hydrology Report)

S. No.	Year	Average Annual Rainfall (mm)
1	1981	880.4
2	1982	1064.3
3	1983	1175.7
4	1984	1347.2
5	1985	1260.6
6	1986	1278.1
7	1987	1051.7
8	1988	1065.2
9	1989	1016

10	1990	1204.6
11	1991	1067.5
12	1992	901
13	1993	971.1
14	1994	1840
15	1995	1164.4
16	1996	1268.7
17	1997	1334.5
18	1998	954.2
19	2001	1277
20	2002	742.8
21	2003	1513
22	2004	1088.1
23	2005	1323.2
24	2008	1138.4
25	2009	805.7
26	2010	857.8
27	2011	1375.3
28	2012	1109.5
29	2013	1222.5
30	2014	1242.6
Annual Average Rainfall (mm)		1151.37

Given the relatively small size of the catchment area and the availability of a single representative annual average rainfall value for the entire region, a uniform average annual rainfall value of 1151.37 mm was utilized for calculating the Rainfall Erosivity Factor (R-Factor). Based on this rainfall data, the R-Factor was computed to be 519.02 MJ mm ha^{-1} h^{-1} yr^{-1}. This calculated R-Factor was uniformly applied across the entire catchment area of the Kapildhara Project to ensure consistency in the soil erosion modelling process.

7.2 SOIL ERODIBILITY (K) FACTOR

The Soil Erodibility Factor (K-Factor) represents the inherent susceptibility of soil particles to detachment and transportation by rainfall and surface runoff under standardized conditions. It is primarily determined by key soil properties, including particle-size distribution, organic matter content, soil structure, and soil permeability. These properties collectively influence the soil's resistance to erosion processes and are essential for accurately assessing erosion potential within a catchment area.

In this study, the assessment of the K-Factor began with a detailed examination of soil maps available on recognized national geoportals. The Bhoomi Geoportal, published by the National Bureau of Soil Survey and Land Use Planning (NBSSLUP), indicates that the predominant soil type in the Kapildhara catchment area is Typic Ustochrepts. This soil type is characterized by moderately shallow to extremely shallow, extremely poorly drained, fine-loamy soils, typically found on moderately sloping plateaus, and exhibiting severe erosion vulnerability. Further validation was carried out using data from the Madhya Pradesh Geoportal, managed by the Madhya Pradesh State Spatial Data Infrastructure (MPSSDI). This geoportal identified the presence of Loamy, Loamy Skeletal, and Fine Silty Soils across the catchment area. These soil classifications suggest moderate to high susceptibility to erosion, depending on slope, land use, and hydrological factors. A soil classification and soil Depth map published in the Madhya Pradesh Geoportal is shown in **Figure 4 and 5** respectively.

Figure 4: Soil Classification Map of Kapildhara Project Free Draining Catchment Area by MPSSDI

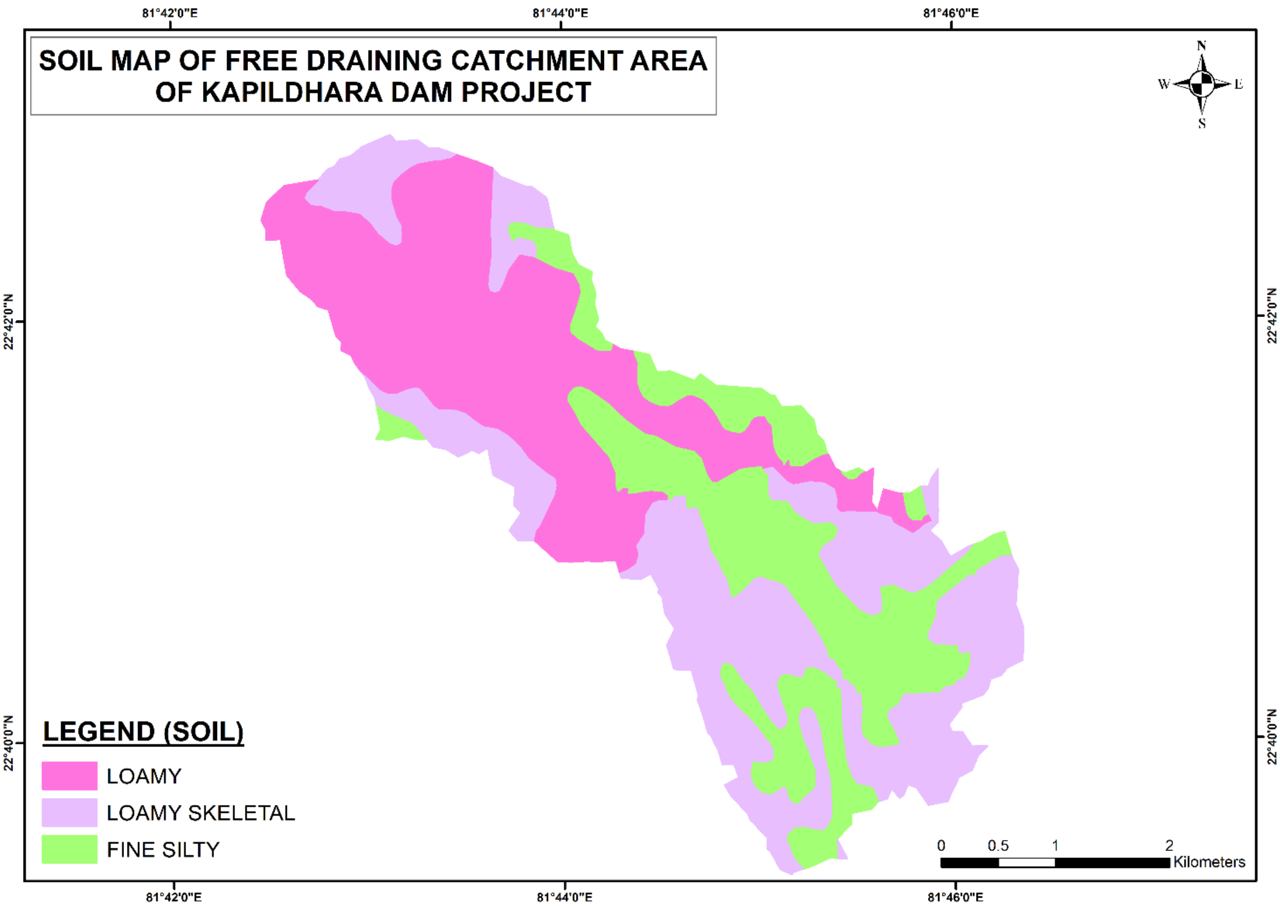
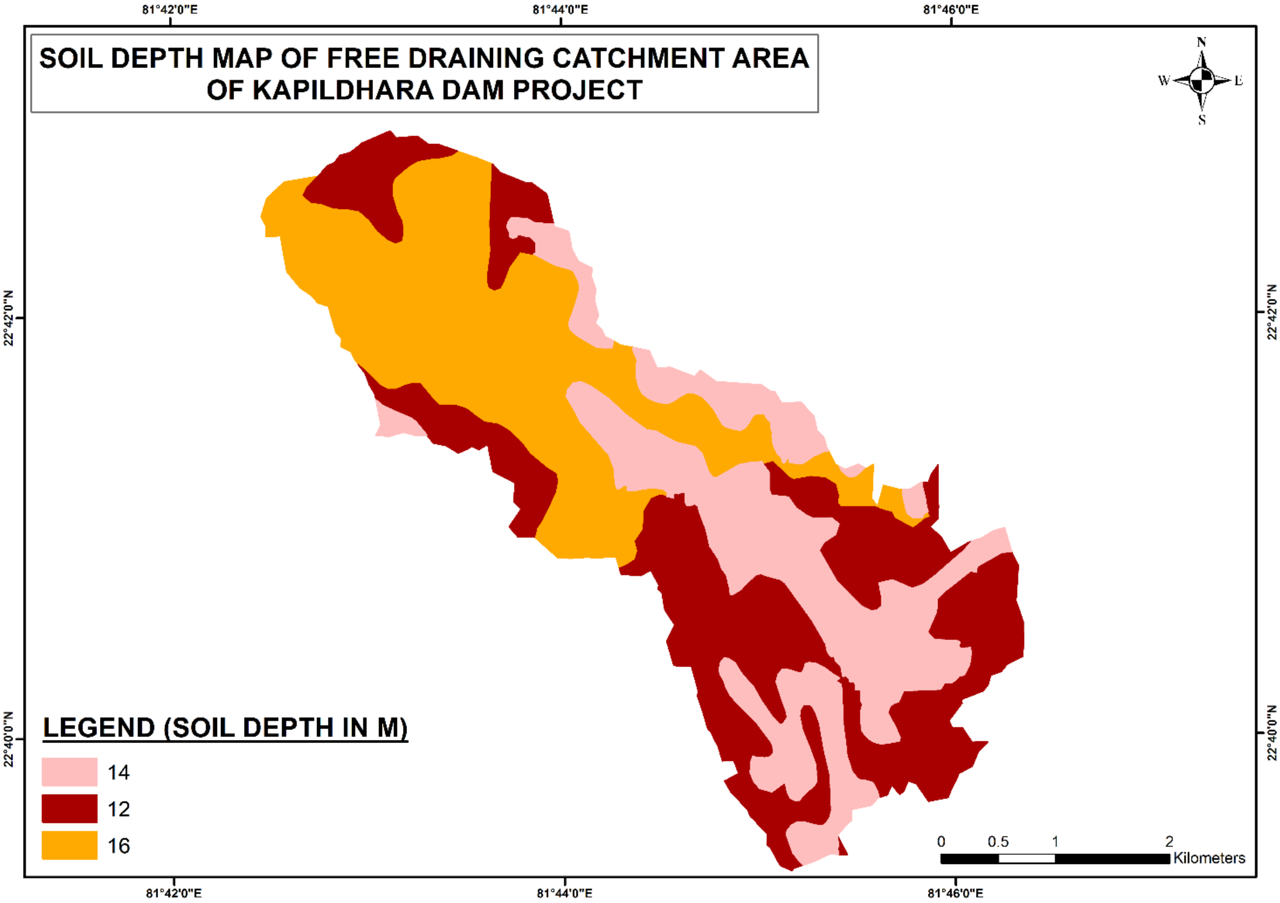


Figure 5: Soil Depth Map of Kapildhara Project Free Draining Catchment Area by MPSSDI



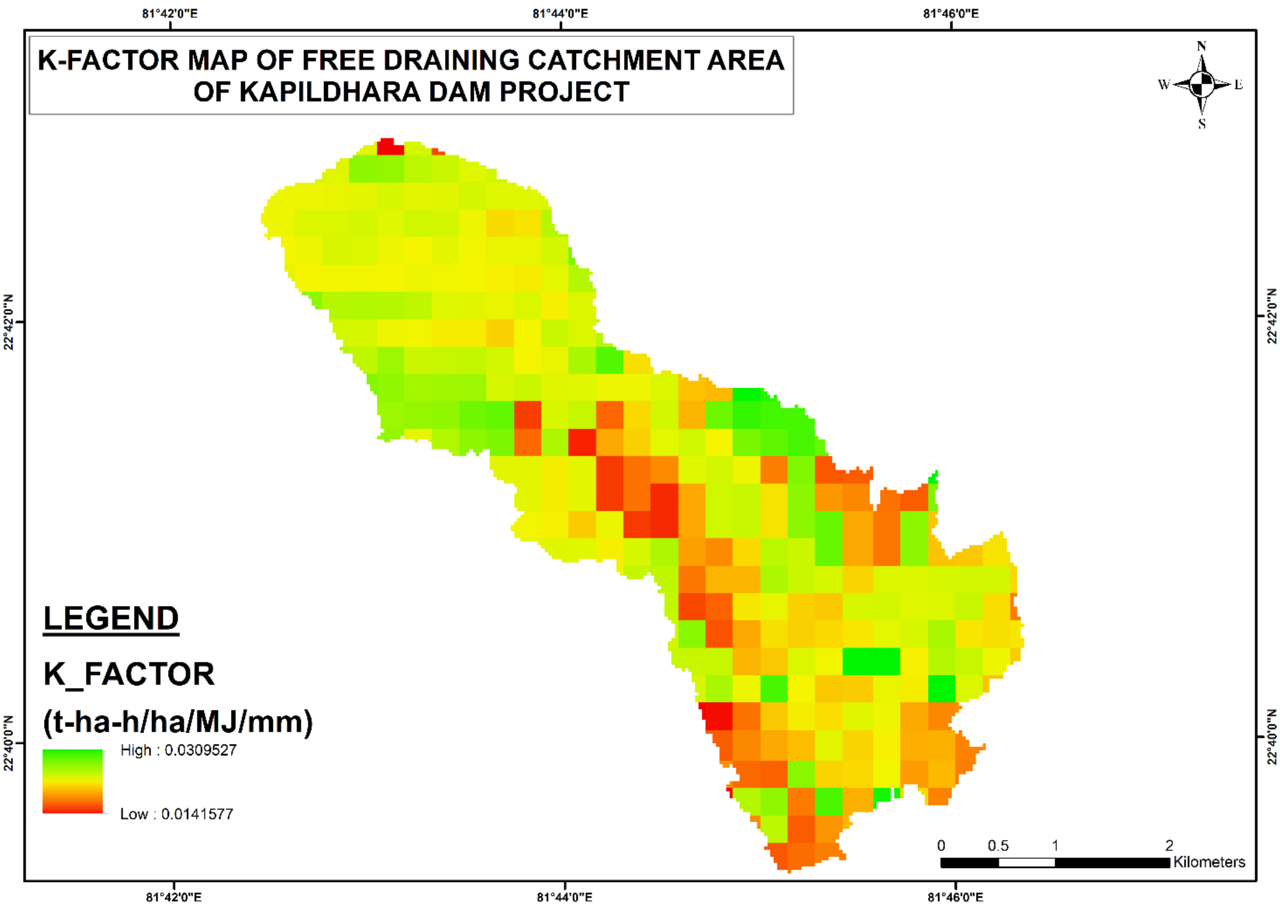
However, neither of these geoportals provided detailed quantitative data on critical soil parameters such as particle-size distribution, organic matter content, soil structure, and permeability. To address this data gap, a refined and nationally recognized dataset Indian Soil Erodibility Dataset (ISED) published by IIT Delhi was used. This dataset provides a scientifically validated Soil Erodibility Factor (K-Factor) raster map for the entire country, enabling more reliable erosion assessments at a regional scale.

The K-Factor raster data from the IIT Delhi dataset, originally available at a spatial resolution of 250 m x 250 m, was resampled to a resolution of 30 m x 30 m using advanced Geographic Information System (GIS) techniques. This resampling enhanced the spatial precision of the dataset, ensuring better alignment with other high-resolution datasets used in the study, such as CartoDEM Version 2.0 and Landsat-9 LULC data.

The resampled K-Factor raster dataset was then integrated into the Revised Universal Soil Loss Equation (RUSLE) model to quantify soil loss within the catchment. This refined K-Factor dataset provided an accurate representation of soil erodibility across the catchment and played a crucial role in identifying high-risk erosion-prone areas.

A K-Factor Map of the catchment area was prepared and analysed to visually represent the spatial distribution of soil erodibility across the terrain. The developed K-Factor map is shown in **Figure 6** below. This map serves as a critical input for designing targeted Catchment Area Treatment (CAT) measures, ensuring sustainable soil conservation and sediment control strategies for the Kapildhara Dam Project.

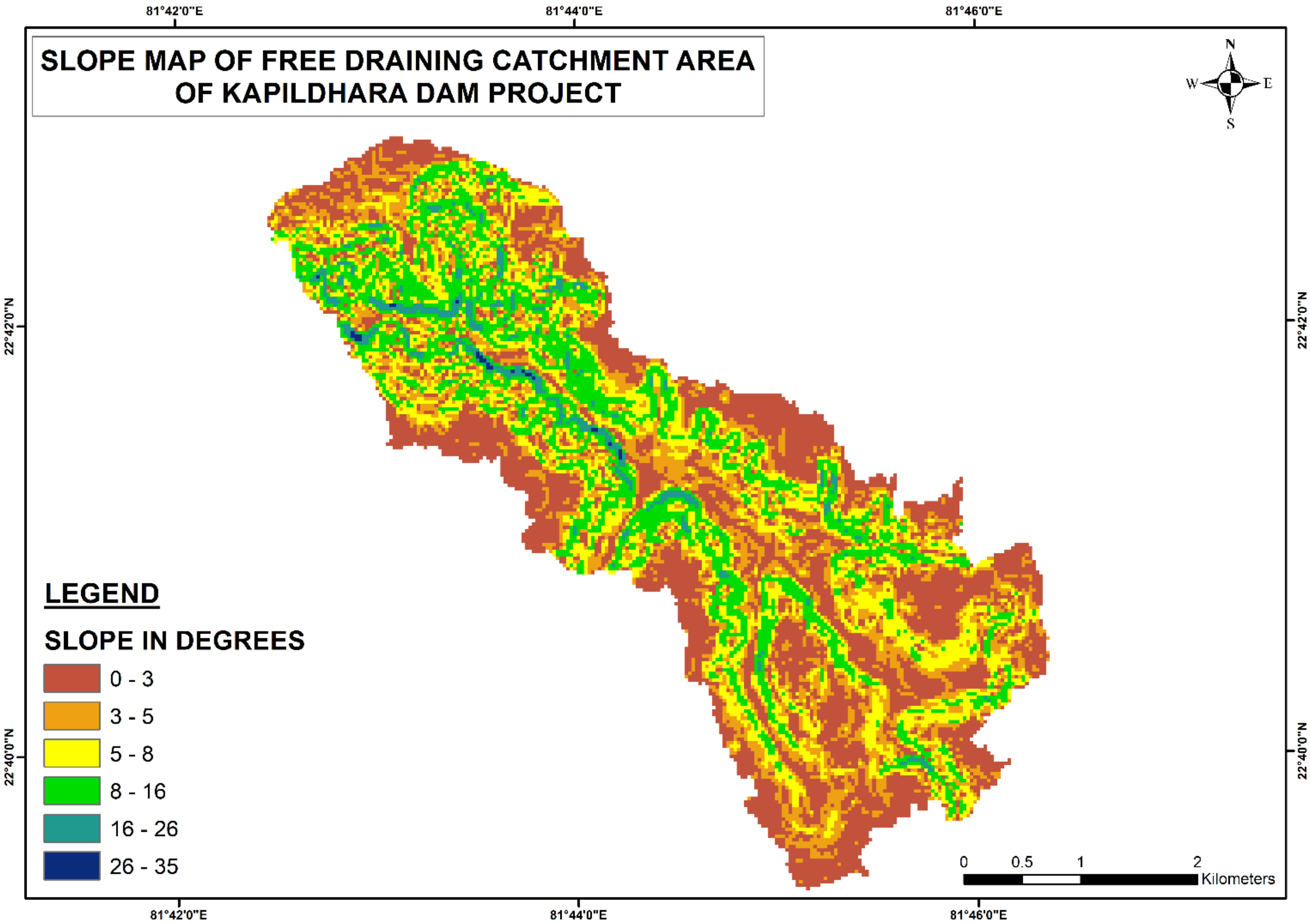
Figure 6: K Factor Map of Kapildhara Project Free Draining Catchment Area



7.3 TOPOGRAPHIC (LS) FACTOR

The Topographic Factor (LS-Factor) in the Revised Universal Soil Loss Equation (RUSLE) represents the combined effect of slope length (L) and slope steepness (S) on soil erosion. These two parameters play a crucial role in controlling the velocity and volume of surface runoff, which directly impacts soil detachment and transport. However, calculating the LS factor involves significant complexity and variability due to the existence of multiple empirical models and formulas, each offering distinct approaches for determining L and S values. The first step in calculating the LS factor is the development of slope map of the free draining catchment. The slope map of the free draining catchment of the proposed Kapildhara project have been worked out using the CartoDEM and is shown in **Figure 7** below. This soil map has served as a crucial inputs while estimating the LS factor of the catchment.

Figure 7: Slope Map of Kapildhara Project Free Draining Catchment Area



Slope Length Factor (L-Factor)

The L-Factor quantifies the influence of slope length on soil erosion, representing the distance over which runoff water accumulates and exerts erosive force on the soil surface. For this study, the formula proposed by Krishna et al. (2019) was adopted, as it has been found to produce more realistic values in field conditions. The L-Factor is calculated using the following equation:

$L = (\lambda_1 / 22.13)^m$;

$m = \beta / (1+\beta)$;

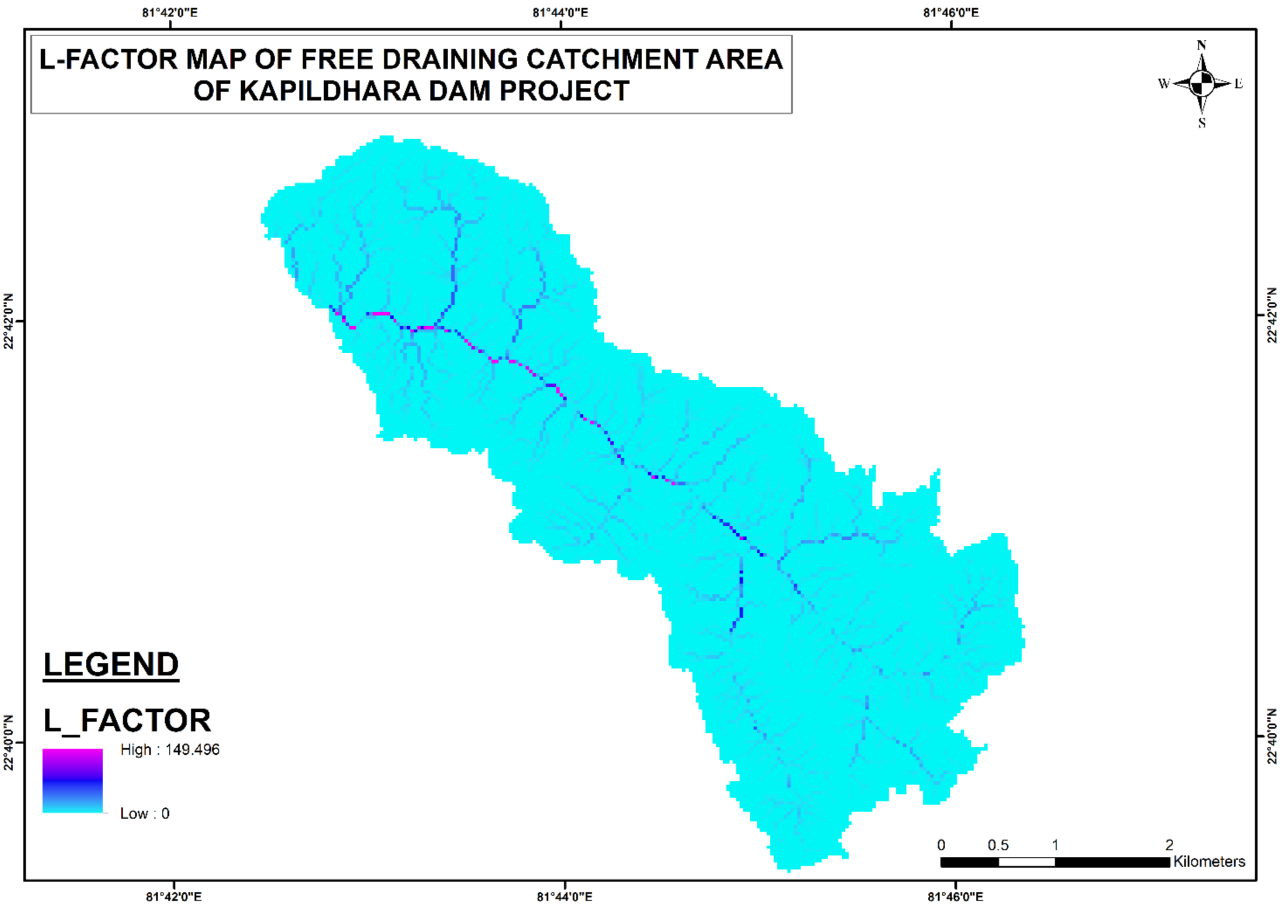
$\beta = (\sin\theta/0.089) / (3.0(\sin\theta)^{0.8}+0.56)$

Where:

- L is the slope length factor.
- λ_1 is the slope length derived from the Digital Elevation Model (DEM).
- m is the slope length exponent.
- β is a raster map derived from sinθ.
- θ is the slope angle derived from the DEM.

Using this formula, an L-Factor Map was generated for the catchment area of the Kapildhara Project and is shown in **Figure 8** below.

Figure 8: L Factor Map of Kapildhara Project Free Draining Catchment Area



Slope Steepness Factor (S-Factor)

The S-Factor represents the influence of slope gradient on soil erosion. Steeper slopes are more prone to erosion due to increased runoff velocity. Two widely recognized formulas were considered for calculating the S-Factor:

1. Liu et al. (2015) proposed the following equations:

- **For $\theta < 5°$:**
  $S = 10.8\sin\theta + 0.03$
- **For $5° \leq \theta \leq 14°$:**
  $S = 16.8\sin\theta - 0.05$
- **For $\theta > 14°$:**
  $S = 21.91\sin\theta - 0.96$

2. Boehner et al. (2006) proposed a generalized equation:

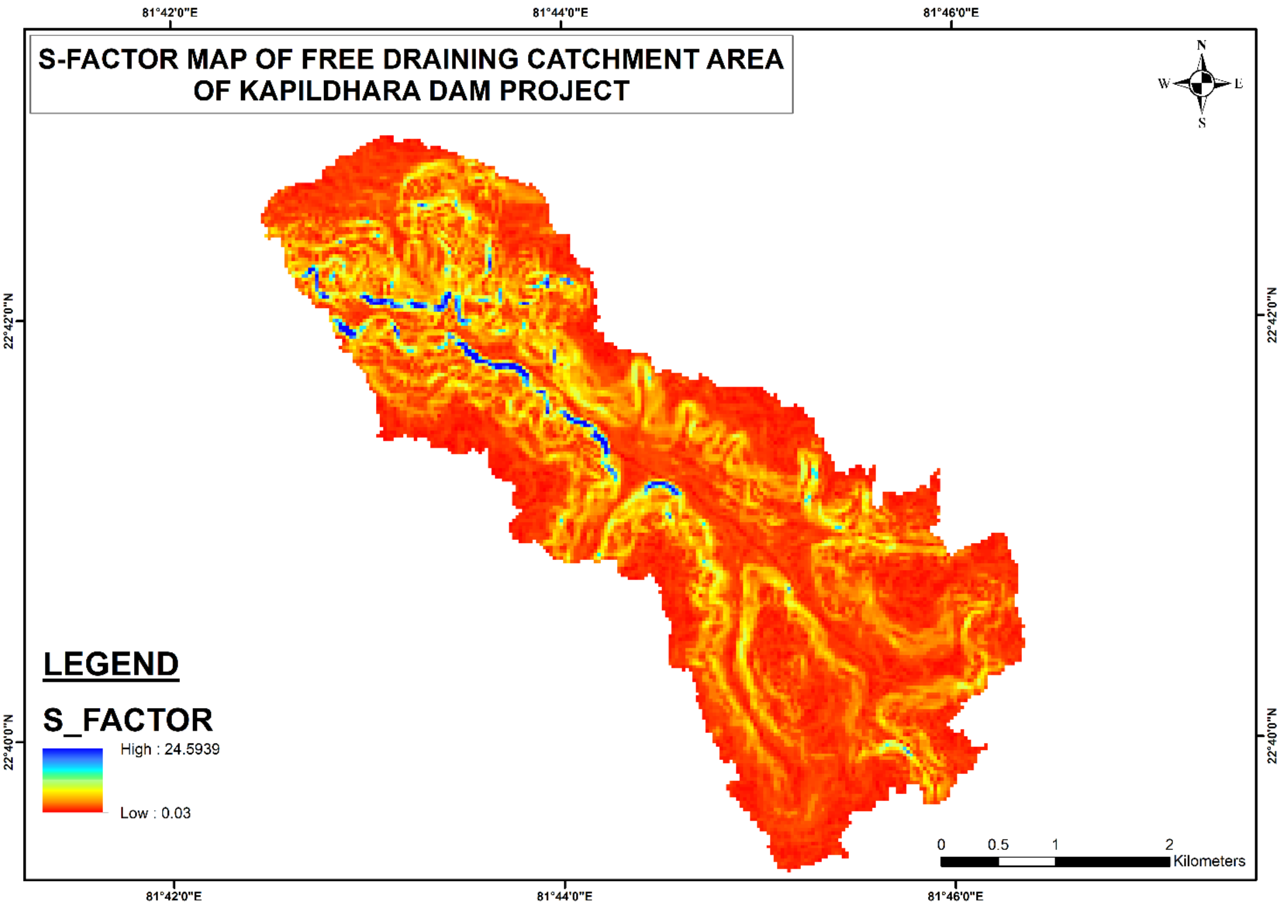
$$S = 65.41\sin^2(\alpha 0.01745) + 4.56\sin(\alpha 0.01745) + 0.065.$$

Where α is the slope in degrees.

Based on global best practices and crop planting suitability guidelines:
- Slopes less than 18°: The Liu et al. (2015) formula (S1) was applied.
- Slopes greater than 18°: The Boehner et al. (2006) formula (S2) was adopted.

This approach aligns with findings from Zhu and Zhu (2014) and Dai (2013), ensuring practical and context-specific modelling of slope steepness across varying terrain conditions. An S-Factor Map was prepared using these equations and is shown in **Figure 9** below.

Figure 9: S Factor Map of Kapildhara Project Free Draining Catchment Area

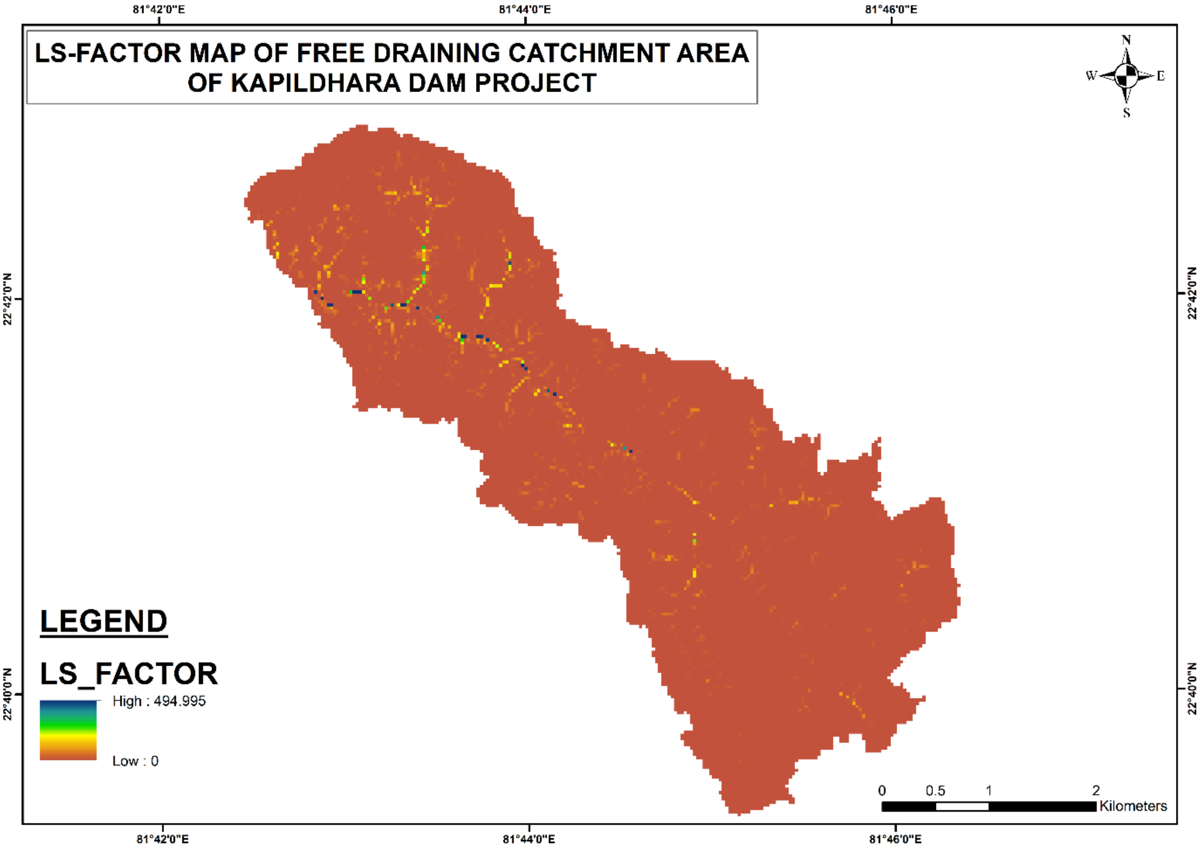


LS-Factor Map

Once the L-Factor and S-Factor were individually derived, the LS-Factor Map was generated by multiplying the two factors. The LS-Factor Map provides a spatial representation of erosion potential across the catchment area, highlighting regions most susceptible to soil erosion due to topographic influences.

The LS-Factor Map, along with the individual L-Factor Map and S-Factor Map, serves as a critical input for soil erosion modelling using the RUSLE model. These maps also guide the prioritization of erosion control measures under the Catchment Area Treatment (CAT) Plan for the Kapildhara Project, ensuring targeted interventions in high-risk zones. A LS factor Map developed for the free draining Catchment area of proposed Kapildhara Project is shown in **Figure 10** below.

Figure 10: LS Factor Map of Kapildhara Project Free Draining Catchment Area



7.4 CROP MANAGEMENT (C) FACTOR

The Crop Management (C) Factor in the Revised Universal Soil Loss Equation (RUSLE) represents the effect of land cover, vegetation, soil biomass, and soil-disturbing activities on soil erosion rates. It quantifies the protective effect of surface cover and vegetation against erosive forces such as rainfall and surface runoff. Higher vegetation cover and soil biomass contribute to lower C-Factor values, signifying reduced soil erosion potential, while barren or sparsely vegetated areas exhibit higher C-Factor values due to increased vulnerability to soil erosion.

Importance of the C-Factor

The C-Factor is a crucial parameter for estimating soil loss, as it directly reflects the degree of protection offered by vegetation and land use practices. Changes in crop cover, seasonal variations in vegetation density, and land management practices significantly influence the C-Factor. For instance:

- Dense forest cover or grasslands: Very low C-Factor values.
- Agricultural lands with seasonal crops: Moderate C-Factor values, varying across growing and non-growing seasons.

- Bare soil or barren lands: High C-Factor values, indicating maximum erosion susceptibility.

Approach for Estimation of the C-Factor

Traditionally, C-Factor values are assigned based on Land Use and Land Cover (LULC) maps by associating predefined empirical values with each LULC category. However, this approach has limitations, as it does not consider variations in soil properties, vegetation biomass, or the dynamic nature of land cover throughout the year. To address these shortcomings and ensure higher accuracy, a more refined approach was adopted in the current study using vegetation indices derived from satellite imagery.

The Normalized Difference Vegetation Index (NDVI), calculated from satellite data, serves as a robust indicator of vegetation health, density, and coverage. In the present study, the formula proposed by Van der Knijff, J. M., Jones, R. J. A., & Montanarella, L. (1999) was employed to estimate the C-Factor dynamically using NDVI data.

The formula is expressed as:

$$C = \exp\left(-\alpha\, NDVI / (\beta - NDVI)\right)$$

Where:

- C is the Crop Management Factor.
- α (alpha) and β (beta) are parameters that define the shape of the curve; standard values of 2 and 1, respectively, were used in the present study.
- NDVI is the Normalized Difference Vegetation Index, derived from remote sensing data.

Methodology for C-Factor Calculation

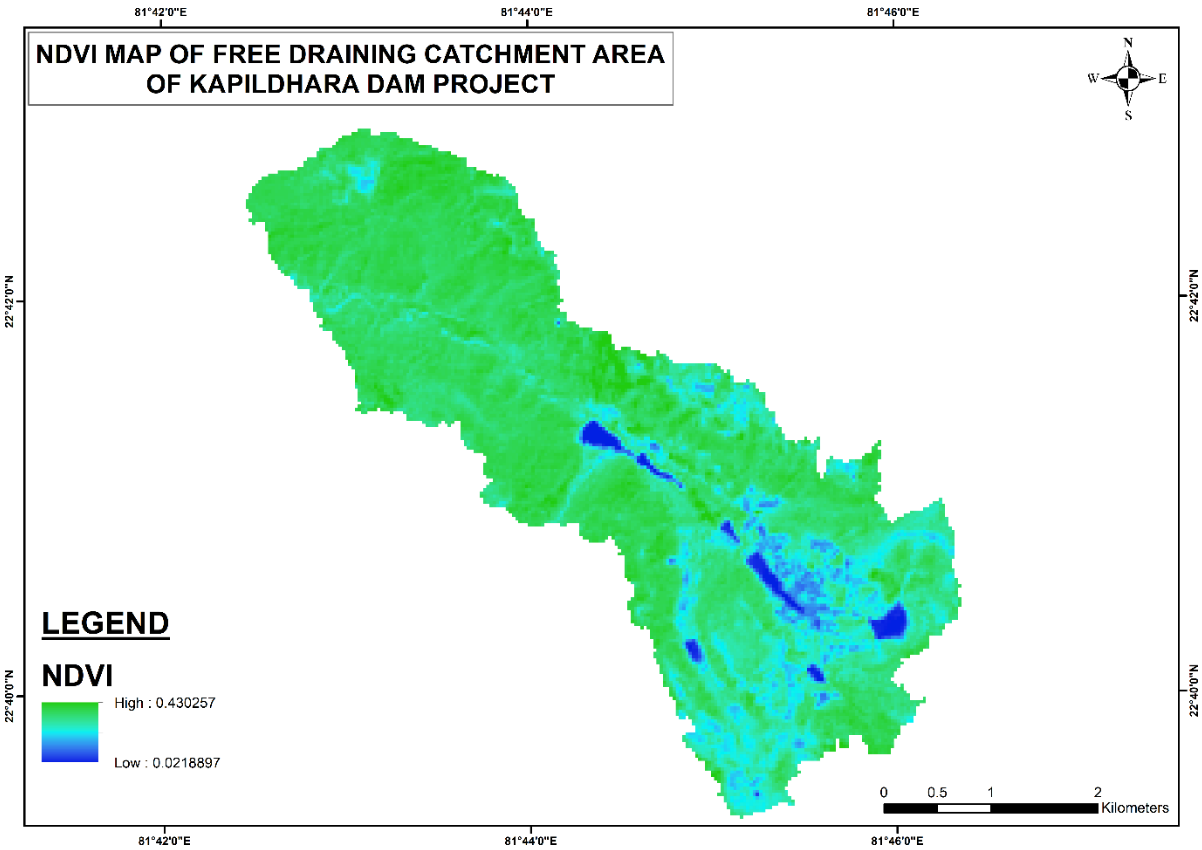
1. NDVI Map Generation:

- Satellite imagery (Landsat-9 data) was processed to generate the NDVI Map of the free-draining catchment area of the Kapildhara Project.
- NDVI values were computed using the formula:

$$NDVI = (NIR - Red) / (NIR + Red)$$

- Where NIR is the Near-Infrared band reflectance, and Red is the Red band reflectance from the satellite data. A NDVI Map prepared for the free draining Catchment area of proposed Kapildhara Project is shown in **Figure 11** below.

Figure 11: NDVI Map of Kapildhara Project Free Draining Catchment Area



2. Application of Van der Knijff Formula:

- The derived NDVI values were input into the Van der Knijff equation to calculate the C-Factor values for each pixel across the catchment area.

- The parameters α = 2 and β = 1 were applied to ensure accurate modelling of the relationship between NDVI and the C-Factor.

3. C-Factor Map Development:

- The calculated C-Factor values were spatially distributed to produce a C-Factor Map at a resolution of 30 m × 30 m using advanced GIS techniques.

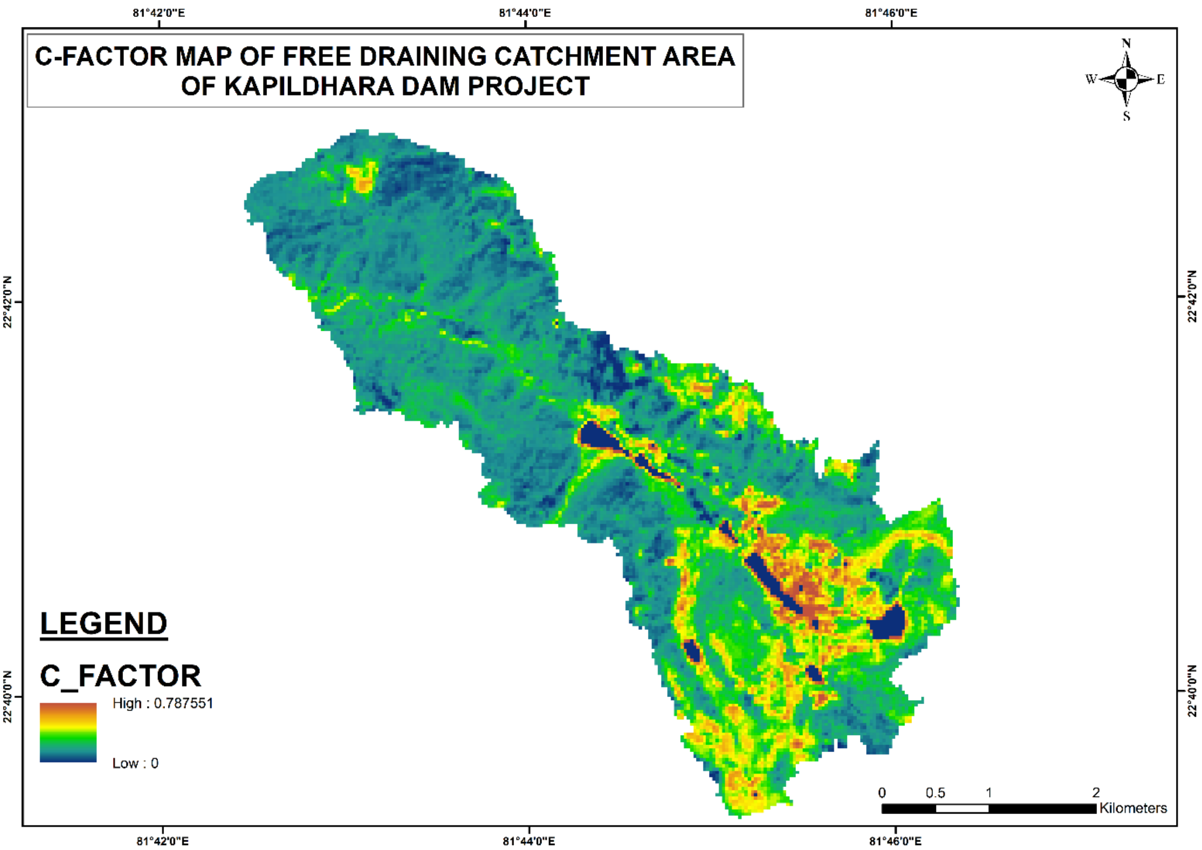
- The map provides a spatial representation of the crop management factor across the catchment, highlighting areas with varying degrees of soil protection based on vegetation cover.

Significance of the C-Factor Map

- The C-Factor Map serves as a critical input for the RUSLE Model, enabling precise estimation of soil erosion rates across the catchment area.
- Areas with high C-Factor values indicate zones prone to severe soil erosion and require immediate intervention, such as afforestation or adoption of soil conservation practices.
- Conversely, regions with low C-Factor values represent well-protected zones with dense vegetation cover and minimal erosion risk.

The integration of NDVI-derived C-Factor values ensures dynamic representation of crop management practices and vegetation cover, providing a more reliable basis for soil conservation planning under the Catchment Area Treatment (CAT) Plan for the Kapildhara Project. A C-Factor Map, developed using the methodology described above, is presented in **Figure 12**, offering a visual insight into soil erosion vulnerability across the catchment area.

Figure 12: C Factor Map of Kapildhara Project Free Draining Catchment Area



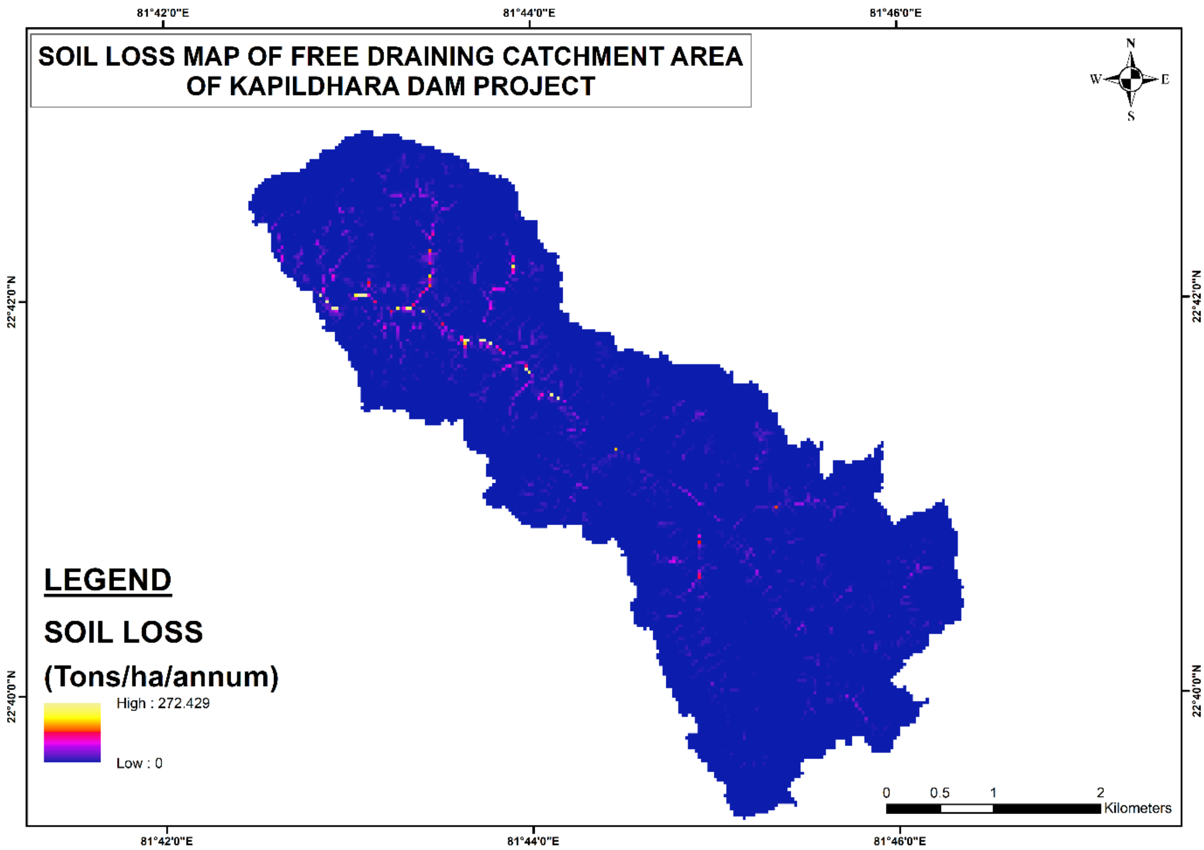
7.5 CONSERVATION SUPPORT PRACTICE (P) FACTOR

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of vegetation, and terracing, on soil loss at a particular site. It is the ratio of soil loss with specific support practice to the corresponding loss with up- or down-slope cultivation. The P factor is generally left out because it is felt that the effect of local conservation practices can be allowed for in the factor L or S within the topography or Erodibility K in the Soil System. Hence, in the present study, the P factor has been considered as 1.

8. ESTIMATION OF SOIL LOSS OF THE CATCHMENT (RUSLE METHOD)

A thematic map for soil loss of the free draining catchment area has been prepared using RUSLE model as discussed in the above section. The soil loss using the RUSLE method ranges upto 272.43 tonnes/ha/annum and a soil loss map of the catchment area of proposed Kapildhara Project is shown in **Figure 13** below.

Figure 13: Soil Loss Map of Kapildhara Project Free Draining Catchment Area



The free draining catchment area was then demarcated into different soil erosion intensity mapping units or classes based upon the extent of soil loss (see **Table 2 & Figure 14**). The free draining catchment area under different Erosion Intensity categories is given in **Table 3**. As can be seen from the figure and table, around 66.75% of the free draining catchment area is prone to less than 1 tons/ha/annum soil erosion, i.e. under negligible erosion intensity category. Almost negligible i.e. 0.37% of its area is prone to Severe and Very Severe soil erosion.

Table 2: Soil Loss Range and Erosion Intensity Categories

S. No.	Soil Loss in tons/hectare/annum	Erosion Intensity Category
1	<1	Negligible
2	1 to 5	Slight
3	5 to 10	Very Low
4	10 to 20	Low
5	20 to 40	Moderate
6	40 to 80	Severe
7	>80	Very Severe

Figure 14: Erosion Intensity Map of Free Draining Catchment Area of Kapildhara Project

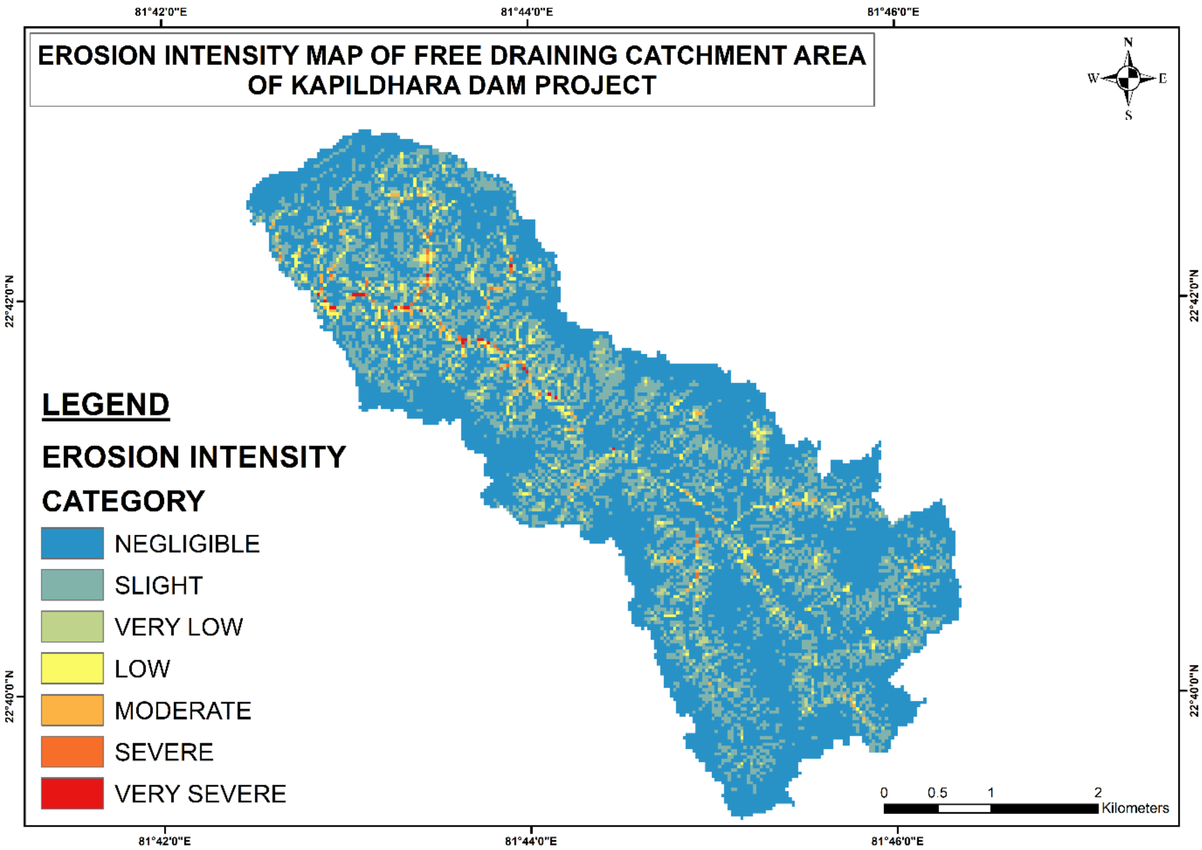


Table 3: Areas Falling under different Erosion Intensity Categories

S. No.	Soil Loss in tons/hectare/annum	Erosion Intensity Category	Area (Ha.)	Area (%)
1	<1	Negligible	1095.30	66.75%
2	1 to 5	Slight	413.10	25.17%
3	5 to 10	Very Low	78.03	4.76%
4	10 to 20	Low	34.92	2.13%
5	20 to 40	Moderate	13.59	0.83%
6	40 to 80	Severe	3.78	0.23%
7	>80	Very Severe	2.25	0.14%
TOTAL			**1640.97**	**100 %**

9. PRIORITIZATION OF WATERSHED USING SILT YIELD INDEX (SYI) METHOD

`Silt Yield Index' (SYI), method has been used for prioritization of areas in the catchment for treatment. The Silt Yield Index (SYI) is defined as the Yield per unit area and SYI value for hydrologic unit is obtained by taking the weighted arithmetic mean over the entire area of the hydrologic unit by using suitable empirical equation. The Silt Yield Index Model (SYI) considers sedimentation as product of erosivity, morphometry and delivery ratio of a particular watershed and was conceptualized by Soil and Land Use Survey of India (SLUSI) as early as 1969 and has been operational since then to meet the requirements of prioritization of smaller hydrologic units within river valley project catchment areas. Silt yield index (SYI) is calculated using following empirical formula:

Sediment Yield Index = $(\Sigma (A_i \times W_i \times D_i)/A_w) \times 100$

where,

A_i = Area of ith unit (EIMU)

W_i = Weightage value of ith mapping unit

n = No. of mapping units

A_w = Total area of watershed.

D_i = Delivery ratio

9.1 EROSION INTENSITY MAPPING UNIT

Erosion Intensity Mapping Units (EIMU) are demarcated and defined as per the soil erosion intensity map prepared above. Various EIMU categories, such as Very Severe, Severe, Moderate, Low, Very Low, and Negligible & Slight (clubbed together), were then used to calculate pixel wise SYI. Erosion Intensity

Mapping Units (EIMU) is a composite expression of physiography, land use, and conservation practices adopted. While computing soil erosion intensity in a catchment all the factors (physiography, land use, and conservation practices) are already taken into consideration. Therefore, EIMUs are assumed as per the soil erosion intensity in the area of the watershed.

9.2 WEIGHTAGE VALUE

Each erosion intensity unit is assigned a weightage value. When considered collectively, the weightage value represents approximately the 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. The weightage value assigned to erosion mapping unit in a watershed ranges from 11-20. A value of 11 is assigned to pixel showing negligible soil loss and a value of 20 is assigned to the pixels showing very severe soil loss and different K values have been assigned to each category on the basis of the soil loss observed in individual pixels. The K value adopted for each category is shown in **Table 4** below.

Table 4: Weightage (K) Value for each Category of Erosion Intensity Mapping Unit

S. No.	Soil Loss in tons/hectare/annum	Erosion Intensity Category	Weightage (K) Value
1	<1	Negligible	11
2	1 to 5	Slight	11.1
3	5 to 10	Very Low	11.4
4	10 to 20	Low	11.7
5	20 to 40	Moderate	12.5
6	40 to 80	Severe	14.1
7	>80	Very Severe	20

9.3 DELIVERY RATIO

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 reservoir or river/ stream. Delivery ratios are assigned to all erosion intensity units depending upon their distance from the nearest stream. The criteria adopted for assigning the delivery ratio are as follows:

Table 5: Criteria for assigning the delivery ratio

S. No.	Nearest Stream	Delivery Ratio
1	0 – 0.9 km	1.00
2	1.0 to 2.0 km	0.95
3	2.0 to 5.0 km	0.90
4	5.1 to 15.0 km	0.80
5	15.1 to 30.0 km	0.70

The catchment area under consideration is relatively small, resulting in a unique spatial characteristic where each erosion intensity mapping unit (pixel) is located in close proximity to an existing drainage channel. Detailed spatial analysis reveals that every pixel within the catchment lies within a maximum distance of 0.9 km from the nearest drain. This close proximity ensures minimal sediment deposition or retention within the catchment itself, as eroded materials are efficiently transported into the drainage network without significant losses along the way. Consequently, for the entire catchment, a sediment delivery ratio (SDR) of 1.0 has been assigned, indicating that nearly all eroded sediments are effectively delivered to the drainage outlet with negligible trapping or deposition in route.

9.4 SILT YIELD INDEX

The area of each of the mapping units is computed and silt yield indices of individual erosion intensity mapping unit (pixel) are calculated using the equations mentioned above. The SYI values for classification of various categories of erosion intensity rates are given in **Table 6** below.

Table 6: Calculation of SYI within the Free Draining Catchment Area of Proposed Kapildhara Project

EIMU	EIMU (Categorization)	EIMU Area (Ha.)	Weightage (K) Value	Silt Yield (SY) = EA * WF	Delivery Ratio	SYI = (SY*DR*100)/SA
1	Negligible	1095.30	11	12048.30	1.00	1100.00
2	Slight	413.10	11.1	4586.47	1.00	1110.26
3	Very Low	78.03	11.4	886.36	1.00	1135.90
4	Low	34.92	11.7	410.09	1.00	1174.36
5	Moderate	13.59	12.5	170.05	1.00	1251.28
6	Severe	3.78	14.1	53.11	1.00	1405.13
7	Very Severe	2.25	20	45.00	1.00	2000.00

9.5 PRIORITIZATION OF AREAS WITHIN CATCHMENT

The individual erosion intensity mapping unit (pixel) are subsequently rated into various categories corresponding to their respective SYI values. The criteria followed for priority categorization of areas within the watershed depending upon their SYI values is shown in **Table 7** below and the priority classification of areas within the watershed is given in **Table 8** and illustrated in **Figure 15**.

Table 7: Criteria for Priority Categorization

S. No.	Priority Categories	SYI Values
1	Very High	> 1300
2	High	1200 – 1299
3	Medium	1100 – 1199
4	Low	1000 – 1099
5	Very Low	<1000

Figure 15: Priority Classification Map of Free Draining Catchment Area of Kapildhara Project

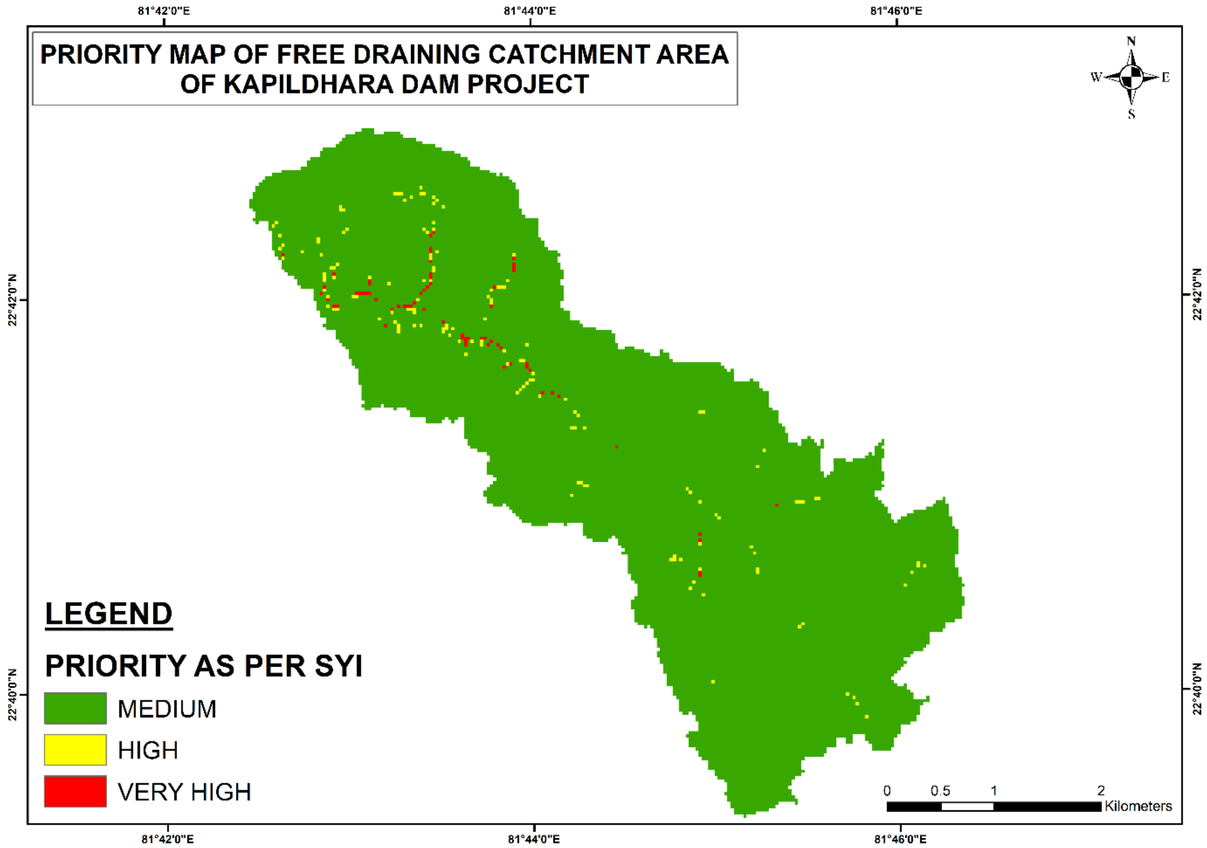


Table 8: Priority Area as per SYI Classification within the Catchment

S. No.	Priority Categories	SYI Values	EIMU Area (Ha.)	EIMU Area (%)
1	Very High	> 1300	6.03	0.37%
2	High	1200 – 1299	13.59	0.83%
3	Medium	1100 – 1199	1621.35	98.80%

10. TREATMENT PLAN

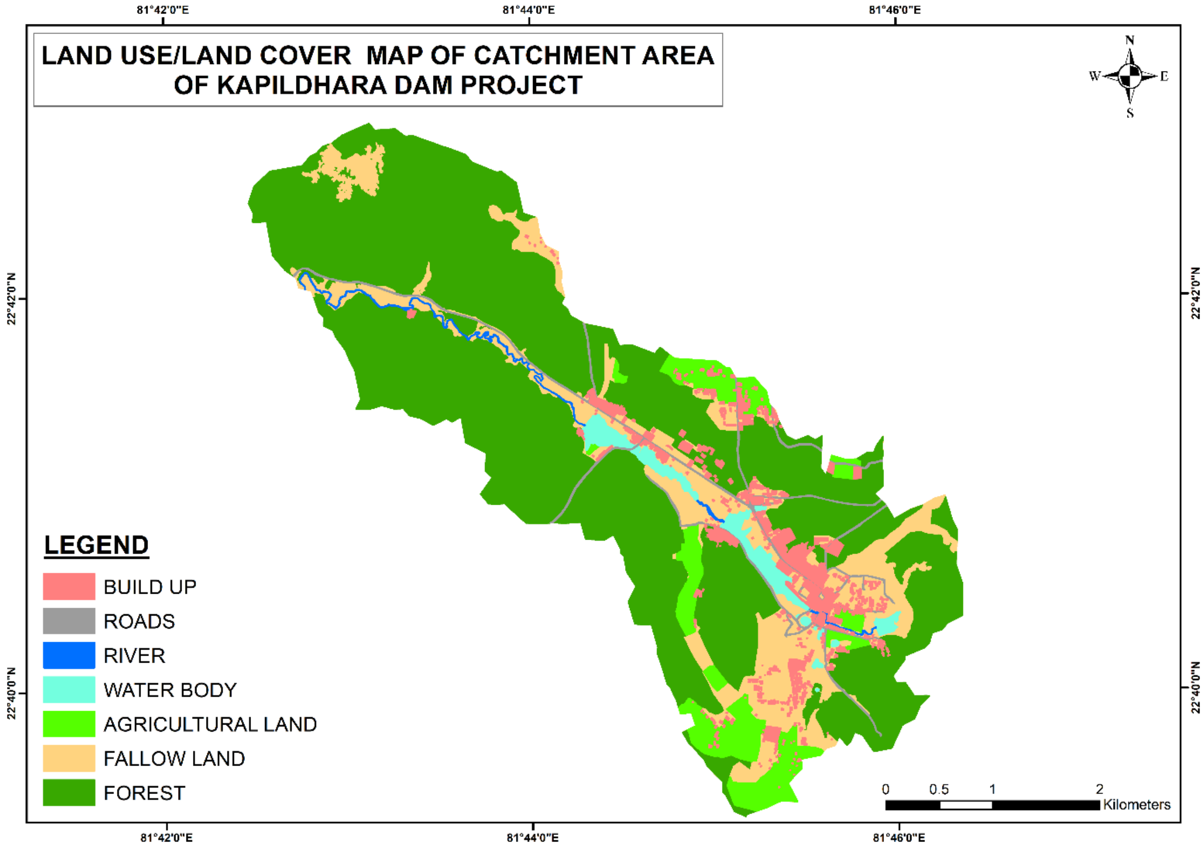
The Catchment Area Treatment (CAT) Plan for the proposed Kapildhara Medium Irrigation Project aims to address soil erosion, enhance water retention, and ensure the long-term sustainability of the reservoir by minimizing siltation and sediment deposition.

The primary objective of the CAT Plan is to stabilize vulnerable slopes, reduce sediment yield, and improve vegetation cover through a combination of structural and biological measures. These measures will include afforestation, contour trenching, gully plugging, check dams, and other soil and water conservation techniques tailored to the unique characteristics of the catchment. A comprehensive assessment using Remote Sensing (RS) and Geographic Information System (GIS) techniques has been carried out to identify critical areas requiring intervention. This includes mapping of watershed boundaries, land use and land cover (LULC), slope gradients, soil types, and erosion-prone zones. The treatment plan will be implemented in a phased manner, prioritizing highly erodible and ecologically sensitive zones to maximize impact and efficiency. Further details on specific treatment measures, their locations, and implementation strategies is elaborated in subsequent sections.

10.1 AREA TO BE TAKEN UP FOR TREATMENT

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 forestland 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 in a few places soil conservation measures are required. For treatment of catchment area, the areas that require treatment have been delineated from the Composite Erosion Intensity Unit Map. A Land use/Land Cover map developed through Landsat-9 Satellite image is shown in **Figure 16** below and the same has been used while detailing the area under treatment and for proposing appropriate mitigation measures.

Figure 16: Land Use/Land Cover Map of Kapildhara Project Free Draining Catchment Area



Area under very high priority category will be taken up for treatment at priority. To arrive at such an area, first of all area under very high priority category was extracted for each pixel, which comes out to be 6.03 ha. Thereafter, area under very severe erosion intensity category falling inside proposed submergence area was excluded. The area under very severe erosion intensity category falling outside proposed submergence area is only 3.06 ha. Lastly, area under very severe erosion intensity category (3.06 ha) falling under settlements and waterbody classes of land use/ land cover have been excluded as they are not being disturbed and 0.45 ha. of the area has found already treated at site. The area within the watershed and land use/ land cover wise area thus arrived at and considered as treatable area is 2.25 ha and is presented below in **Table 9**.

Table 9: Details of Area under Very High Erosion Category

S. No.	Description	Particular	Unit
1	Total Area under Very High Category	6.03	Ha.
2	Very High Category area under Submergence of Proposed Kapildhara Dam	2.97	Ha.
3	Very High Category area under existing Habitation and Water bodies	0.36	Ha.
4	Very High Category area already treated in the catchment	0.45	Ha.
5	Treatable Area	2.25	Ha.

Out of the total 2.25 ha to be treated, it is proposed to treat 1.17 ha by biological measures and the rest 1.08 ha by engineering measures. The details of the same is presented in **Table 10** below.

Table 10: Details of Treatable Area under Very High Erosion Category

S. No.	Description	Area	Unit
1	Area under Forest Land	0.36	Ha.
2	Area under Fallow/Shrub land	0.81	Ha.
3	Area along 2nd or 3rd order drain	1.08	Ha.
Total		**2.25**	**Ha.**

The period for implementing CAT plan interventions including maintenance has been taken as 7 years. It is proposed to establish administrative setup and implement other entry point activities in the first year itself. It is proposed to implement treatment measures in watershed falling under high priority in the second year, followed by Maintenance period of subsequent 5 years.

The area under High category is proposed to be taken up in the second year. The total area under high category works out to be 13.59 Ha. Out of which 2.43 ha. lies in the submergence area of the proposed Kapildhara dam, 1.71 ha. area lies in the existing habitation and water body zones, 1.89 ha. of the area has found already treated at site and around 3.06 Ha. of the area under high category has already been treated in the 1st year while treating the very high category zone. The total treatable area in the second phase works out to be 4.50 ha. The detail of the same is shown in **Table 11** below.

Table 11: Details of Area under High Erosion Category

S. No.	Description	Particular	Unit
1	Total Area under Very High Category	13.59	Ha.
2	High Category area under Submergence of Proposed Kapildhara Dam	2.43	Ha.
3	High Category area under existing Habitation and Water bodies	1.71	Ha.
4	High Category area already treated in the catchment	1.89	Ha.
5	High Category area treated under the 1 st year along with very high category area	3.06	Ha.
6	Treatable Area for second year	4.50	Ha.

Out of the total 4.50 ha to be treated, it is proposed to treat 4.05 ha by biological measures and the rest 0.45 ha by engineering measures. The details of the same is presented in **Table 12** below.

Table 12: Details of Treatable Area under High Erosion Category

S. No.	Description	Area	Unit
1	Area under Forest Land	2.97	Ha.
2	Area under Fallow/Shrub land	1.08	Ha.
3	Area along 2nd or 3rd order drain	0.45	Ha.
Total		**4.50**	**Ha.**

10.2 TREATMENT MEASURES

Watershed management is the optimal use of soil and water resources within a given geographical area so as to enable sustainable production. It implies changes in land use, vegetative cover, and other structural and non-structural action that are taken in a watershed to achieve specific watershed management objectives. The overall objectives of watershed management programme are to:

• increase infiltration into soil.

• control excessive runoff.

• manage & utilize runoff for useful purpose.

The basis of site selection for different engineering treatment measures under CAT are given in **Table 13** below.

Table 13: Basis for Selection of Catchment Area Treatment Measures

S. No.	Treatment Measure	Basis for Selection
1	Enrichment	Severe and Very Severe area falling under Forest Land
2	Energy Plantation	Very Severe area falling under Scrub Land/Barren Land/Riverbanks
3	Dry Stone Masonry Check Dams	In the streams of 2nd and 3rd order

10.2.1 BIOLOGICAL MEASURES

The biological measures would comprise of:

- Enrichment Plantation
- Energy Plantation

ENRICHMENT PLANTATION

Maintaining and enhancing existing forest cover reduces soil erosion to a great extent. It is therefore proposed to increase the vegetation cover of the existing forests. For this, patches of forest land falling under severe and very severe erosion intensity category shall be brought under enrichment plantation. 500 plants per hectare will be planted under this scheme. The plantation will be maintained for subsequent five years. RCC fence posts with 4 strand barbed wire fencing, interlaced with thorny bushes will be done in the plantation areas. The unit cost for enrichment plantation including maintenance cost for five years is estimated to be Rs. 1,50,000 per ha consisting of Rs. 1,14,440 for plantation and Rs. 35,560 for maintenance for five years. The detailed break-up of item-wise cost for enrichment plantation is furnished in **Table 14** below. The area to be brought under enrichment plantation and its unit rate is given at **Table 22**.

Table 14: Detailed break up of item-wise cost for Enrichment Plantation

Sl.No	Particular of Work	Qty	Total Mandays	Unit	Rate	Total Amount
First year preparation year						
A. Labour Oriented Works						
1	Survey and demarcation of plantation area (@0.45 mandays /ha)	1 ha	0.45	mandays /ha	424	190.8
2	Weeding of obnoxious weeds except lantana (@4 mandays /ha)	1 ha	4	mandays /ha	424	1696
3	Dag Belling with line for siting pits (@2.5 mandays/1000 no.)	500	1.25	mandays/1000 no.	424	530
4	Digging pits 45x45x45 cm (@5 mandays/100 no.)	500	25	mandays/100 no.	424	10600
5	Filling pits with FYM mix with soil and Pesticides (**@1.5 mandays/100 no.)**	500	7.5	mandays/100 no.	424	3180
6	Preparation of Path (@30 mandays/km)	240	7.2	30 mandays/km	424	3052.8
	Total Labour cost (A)					**19249.6**
B. Material Component						
1	Cost of FYM including carriage @ 10% of volume of pit i.e. 500(0.45x0.45x0.45) x0.1	4.56		Cum	1200	5472
2	Providing fertile soil including carriage @ 10% of volume of pit i.e. 500(0.45x0.45x0.45) x0.1	4.56		Cum	500	2280
3	Applying cost of Neem Cake @ 30g/pit	15		Kg	55	825
4	Cost of plant	550		Per Plant Per No.	13	7150
5	Cost of Service Pipe	100		Per RM	55	5500
6	Proportionate cost for providing irrigation implements like tank, pipe fittings & electric motor etc	1 job		L.S.	4200	4200
7	Proportionate cost for providing chowkidar hut	1 job		L.S.	2000	2000
	Total Material cost (B)					**27427**
C. Chain Link Fencing Work						
1(a)	Cost of 2m high RCC pole @ 2.5m c/c (145x1.1)/2.5=64	64		Per Number	296.3	18963.2
1(b)	GST @18% Rs	18963.2		0.18		3413.376
2(a)	Cost of barbed wire in five strands (141x5)/7=100	100		Per kg	90	9000
2(b)	GST @18% Rs	9000		0.18		1620
3(a)	Cost of U-nails	10		Per kg	90	900

3(b)	GST @18% Rs	900		0.18		162
4(a)	Cost of GI wire	3		Per kg	100	300
4(b)	GST @18% Rs	300		0.18		54
5	Cost of labour for stretching & fixing barbed wire and other miscellaneous work (@0.16 Mandays / RM)	145	6.56	Mandays / RM	424	2781.44
6	Excavation of pit for poles (@2.5 Mandays / 100 No.)	64	1.6	Mandays / 100 No.	424	678.4
7	Cost of fixing poles in pit with PCC 1:3:6 mix	2.32		Per Cum	3643	8451.76
8	Erection of poles	64		Per Pole	80	5120
	Total Fencing cost ('C')					**51444.18**
	Total Cost First year					**98120.78**
Second Year - Plantation Work						
A. Labour Oriented Works						
1	Carriage of plant raised in nursery over a distance of 45 Km	550		170/100 No.		935
2	Carriage of plants from road side to plantation site by manual labour up to 2 Km (@ 0.4 mandays /100 No.)	500	2	mandays /100 No.	466	932
3	Planting saplings in pits (@1.8 mandays /100 No.)	500	9	mandays /100 No.	466	4194
4	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	500	6.25	1.25 mandays /100 No.	466	2912.5
5	Carrying out second weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1 mandays /100 No.)	500	5	mandays /100 No.	466	2330
6	Spraying pesticides and insecticides (@0.6 mandays /100 No.)	500	3	mandays /100 No.	466	1398
7	Applying Irrigation	1	1	Job	1600	1600
8	Clearing of Fire lines (@2.25 mandays/km)	180	0.41	mandays/km	466	188.7
	Total Labour oriented Works cost (A)					**14490.23**
B. Material Component						
1	Cost of fertilizer (DAP/Urea) and Pesticides @ 40g and 10g / plant respectively	25		Per Kg	24	600

2	Cost of Diesel for Irrigation	1		Job	1000	1000
3	Contingency	1		Job	200	200
	Total Material cost (B)					**1800**
	Total Second year					**16290.230**
Third Year - Maintenance						
A. Labour Oriented Works						
1	Repair of fencing (@ 2 mandays /ha)	1 ha	2	mandays /ha	513	1026
2	Cost of replacing of dead plants (10% mortality) (@ Rs 15 / No.)	50	0	Per No.	15	750
3	Carriage of plant raised in nursery over a distance of 45 Km	50	0	170/100 No.	1.7	85
4	Carriage of plants from road side to plantation site by manual labourupto 2 Km (@0.4 mandays /100 No.)	50	0.2	mandays /100 No.	513	102.6
5	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	500	6.25	mandays/100 no.	513	3206.25
6	Carrying out second weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.0 mandays/100 no.)	500	5	mandays/100 no.	513	2565
7	Spraying pesticides and insecticides (@0.6 mandays/100 no.)	500	3	mandays/100 no.	513	1539
8	Applying Irrigation	1	1	Job	1600	1600
9	Clearing of Fire lines (@2.25 mandays/km)	180	0.41	mandays/km	513	207.765
	Total Labour oriented Works cost (A)					**11081.62**
B. Material Component						
1	Cost of fertilizer (DAP/Urea) and Pesticides @ 40g and 10g / plant respectively	25		Per Kg	24	600
2	Cost of Diesel for Irrigation	1		Job	1000	1000
3	Contingency	1		Job	200	200
	Total Material cost (B)					**1800**
	Total Third year					**12881.615**
Fourth Year - Second year of Maintenance						
A. Labour Oriented Works						

1	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	500	6.25	1.25 mandays /100 no.	564.3	3526.875
2	Applying Irrigation	1	1	Job	1950	1950
3	Watch and ward	1	1	Job	3000	3000
	Total Labour oriented Works cost (A)					**8476.875**
B. Material Component						
1	Cost of Diesel for Irrigation	1	1	Job	1100	1100
2	Contingency	1	1	Job	200	200
	Total Material cost (B)					**1300**
	Total Fourth Year					**9776.875**
Fifth Year - Third year of Maintenance						
A. Labour Oriented Works						
1	Fencing repair	1	2	mandays /ha	621	1242
2	Watch and ward	1	1	Job	3300	3300
	Total Labour oriented Works cost (A)					**4542**
B. Material Component						
1	Contingency	1	1	Job	220	220
	Total Material Component Cost (B)					**220**
	Total Fifth Year					**4762.000**
Sixth Year - Fourth year of Maintenance						
A. Labour Oriented Works						
1	Watch and ward	1	1	Job	3600	3600
	Total Labour oriented Works cost (A)					**3600**
B. Material Component						
1	Contingency	1	1	Job	240	240
	Total Material Component Cost (B)					**240**
	Total Sixth Year					**3840.000**
Seventh Year - Fifth year of Maintenance						
A. Labour Oriented Works						
1	Watch and ward	1	1	Job	4000	4000
	Total Labour oriented Works cost (A)					**4000**
B. Material Component						
1	Contingency	1	1	Job	300	300
	Total Material Component Cost (B)					**300**
	Total Seventh Year					**4300.000**
Abstract of Cost of Plantation and Maintenance						
	First year-preparation				98120.776	
	Second Year-Plantation				16290.230	

	Third year-First year of Maintenance	12881.615
	Fourth year-Second year of Maintenance	9776.875
	Fifth year-Third year of Maintenance	4762.000
	Sixth year-Fourth year of Maintenance	3840.000
	Seventh year-Fifth year of Maintenance	4300.000
	Total Cost	**149971.496**
		Say Rs 1.5 lakh /ha.

ENERGY PLANTATION

Energy plantation scheme is essential for a continuous supply of fuel and fodder. It can be easily carried out and it is economical to carry out. Agricultural land will not be used for energy plantation, instead, fallow land and scrub land falling under severe and very severe erosion intensity category will be used for energy plantation. 1600 plants per hectare will be planted under this scheme. The plantation will be maintained for subsequent three years. Wooden fence posts with 4 strand barbed wire fencing, interlaced with thorny bushes will be done in the plantation areas. The unit cost for energy plantation including maintenance cost for three years is estimated to be Rs. 2,70,000 per ha consisting of Rs. 2,07,000 for plantation and Rs. 63,000 for maintenance for three years. The detailed breakup of item-wise cost for energy plantation is furnished in **Table 15** below. The area to be brought under energy plantation and its unit rate is given at **Table 22**.

Table 15: Detailed break up of item-wise cost for Energy Plantation

Sl.No	Particular of Work	Qty	Total Mandays	Unit	Rate	Total Amount
First year preparation year						
A. Labour Oriented Works						
1	Survey and demarcation of plantation area (@0.45 mandays /ha)	1 ha	0.45	mandays /ha	424	190.8
2	Weeding of obnoxious weeds except lantana (@4 mandays /ha)	1 ha	4	mandays /ha	424	1696
3	Dag Belling with line for siting pits (@2.5 mandays/1000 no.)	1600	4	mandays/1000 no.	424	1696
4	Digging pits 45x45x45 cm (@5 mandays/100 no.)	1600	80	mandays/100 no.	424	33920
5	Filling pits with FYM mix with soil and Pesticides (**@1.5 mandays/100 no.)**	1600	24	mandays/100 no.	424	10176
6	Preparation of Path (@30 mandays/km)	240	7.2	30 mandays/km	424	3052.8
	Total Labour cost (A)					**50731.6**

B. Material Component						
1	Cost of FYM including carriage @ 10% of volume of pit i.e. 1600(0.45x0.45x0.45) x0.1	14.58		Cum	1200	17496
2	Providing fertile soil including carriage @ 10% of volume of pit i.e. 1600(0.45x0.45x0.45) x0.1	14.58		Cum	500	7290
3	Applying cost of Neem Cake @ 30g/pit	48		Kg	55	2640
4	Cost of plant	1760		Per Plant Per No.	13	22880
5	Cost of Service Pipe	100		Per RM	55	5500
6	Proportionate cost for providing irrigation implements like tank, pipe fittings & electric motor etc	1 job		L.S.	4200	4200
7	Proportionate cost for providing chowkidar hut	1 job		L.S.	2000	2000
	Total Material cost (B)					**62006**
C. Chain Link Fencing Work						
1(a)	Cost of 2m high RCC pole @ 2.5m c/c (145x1.1)/2.5=64	64		Per Number	296.3	18963.2
1(b)	GST @18% Rs	18963.2		0.18		3413.376
2(a)	Cost of barbed wire in five strands (141x5)/7=100	100		Per kg	90	9000
2(b)	GST @18% Rs	9000		0.18		1620
3(a)	Cost of U-nails	10		Per kg	90	900
3(b)	GST @18% Rs	900		0.18		162
4(a)	Cost of GI wire	3		Per kg	100	300
4(b)	GST @18% Rs	300		0.18		54
5	Cost of labour for stretching & fixing barbed wire and other miscellaneous work (@0.16 Mandays / RM)	141	6.56	Mandays / RM	424	2781.44
6	Excavation of pit for poles (@2.5 Mandays / 100 No.)	64	1.6	Mandays / 100 No.	424	678.4
7	Cost of fixing poles in pit with PCC 1:3:6 mix	2.32		Per Cum	3643	8451.76
8	Erection of poles	64		Per Pole	80	5120
	Total Fencing cost ('C')					**51444.18**
	Total Cost First year					**164181.78**
Second Year - Plantation Work						
A. Labour Oriented Works						

1	Carriage of plant raised in nursery over a distance of 45 Km	1760		170/100 No.		2992
2	Carriage of plants from road side to plantation site by manual labour up to 2 Km					
3	Planting saplings in pits (@1.8 mandays /100 No.)	1600	28.8	mandays /100 No.	466	13420.8
4	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	1600	20	1.25 mandays /100 No.	466	9320
5	Carrying out second weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1 mandays /100 No.)	1600	16	mandays /100 No.	466	7456
6	Spraying pesticides and insecticides (@0.6 mandays /100 No.)	1600	9.6	mandays /100 No.	466	4473.6
7	Applying Irrigation	1	1	Job	1600	1600
8	Clearing of Fire lines (@2.25 mandays/km)	180	0.41	mandays/km	466	188.7
	Total Labour oriented Works cost (A)					**39451.13**
B. Material Component						
1	Cost of fertilizer (DAP/Urea) and Pesticides @ 40g and 10g / plant respectively	80		Per Kg	24	1920
2	Cost of Diesel for Irrigation	1		Job	1000	1000
3	Contingency	1		Job	200	200
	Total Material cost (B)					**3120**
	Total Second year					**42571.13**
Third Year - Maintenance						
A. Labour Oriented Works						
1	Repair of fencing (@ 2 mandays /ha)	1 ha	2	mandays /ha	513	1026
2	Cost of replacing of dead plants (10% mortality) (@ Rs 15 / No.)	160	0	Per No.	15	2400
3	Carriage of plant raised in nursery over a distance of 45 Km	160	0	170/100 No.	1.7	272
4	Carriage of plants from road side to plantation site by manual labourupto 2 Km (@0.4 mandays /100 No.)	160	0.64	mandays /100 No.	513	328.32

5	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	1600	20	mandays/100 no.	513	10260
6	Carrying out second weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.0 mandays/100 no.)	1600	16	mandays/100 no.	513	8208
7	Spraying pesticides and insecticides (@0.6 mandays/100 no.)	1600	9.6	mandays/100 no.	513	4924.8
8	Applying Irrigation	1	1	Job	1600	1600
9	Clearing of Fire lines (@2.25 mandays/km)	180	0.41	mandays/km	513	207.765
	Total Labour oriented Works cost (A)					**29226.89**
B. Material Component						
1	Cost of fertilizer (DAP/Urea) and Pesticides @ 40g and 10g / plant respectively	80		Per Kg	24	1920
2	Cost of Diesel for Irrigation	1		Job	1000	1000
3	Contingency	1		Job	200	200
	Total Material cost (B)					**3120**
	Total Third year					**32346.885**
Fourth Year - Second year of Maintenance						
A. Labour Oriented Works						
1	Carrying out first weeding, nirai operations and application of fertilizer and pesticides including replacing of dead plants of previous year (@1.25 mandays /100 No.)	1600	20	1.25 mandays /100 no.	564.3	11286
2	Applying Irrigation	1	1	Job	1950	1950
3	Watch and ward	1	1	Job	3000	3000
	Total Labour oriented Works cost (A)					**16236**
B. Material Component						
1	Cost of Diesel for Irrigation	1	1	Job	1100	1100
2	Contingency	1	1	Job	200	200
	Total Material cost (B)					**1300**
	Total Fourth Year					**17536.000**
Fifth Year - Third year of Maintenance						
A. Labour Oriented Works						
1	Fencing repair	1	2	mandays /ha	621	1242

2	Watch and ward	1	1	Job	3300	3300
	Total Labour oriented Works cost (A)					**4542**
B. Material Component						
1	Contingency	1	1	Job	220	220
	Total Material Component Cost (B)					**220**
	Total Fifth Year					**4762.000**
Sixth Year - Fourth year of Maintenance						
A. Labour Oriented Works						
1	Watch and ward	1	1	Job	3600	3600
	Total Labour oriented Works cost (A)					**3600**
B. Material Component						
1	Contingency	1	1	Job	240	240
	Total Material Component Cost (B)					**240**
	Total Sixth Year					**3840.000**
Seventh Year - Fifth year of Maintenance						
A. Labour Oriented Works						
1	Watch and ward	1	1	Job	4000	4000
	Total Labour oriented Works cost (A)					**4000**
B. Material Component						
1	Contingency	1	1	Job	300	300
	Total Material Component Cost (B)					**300**
	Total Seventh Year					**4300.000**
Abstract of Cost of Plantation and Maintenance						
	First year-preparation				164181.776	
	Second Year-Plantation				42571.130	
	Third year-First year of Maintenance				32346.885	
	Fourth year-Second year of Maintenance				17536.000	
	Fifth year-Third year of Maintenance				4762.000	
	Sixth year-Fourth year of Maintenance				3840.000	
	Seventh year-Fifth year of Maintenance				4300.000	
	Total Cost				**269537.791**	
	Say Rs 2.7 lakh /ha.					

10.2.2 ENGINEERING MEASURES

The engineering treatment measures require less time to be put in place and can provide quick solutions. These would comprise of Dry stone masonry check dams.

DRY STONE MASONRY CHECK DAM

Dry stone masonry check dams can be made of boulder piled up across the gulley and along the banks if they are locally available. Such structures for damming a gulley or a stream to refine the flow velocity and to control bank erosion are called dry stone masonry/ loose bolder check dams. The detailed break-up of item-wise cost of all the proposed check dams is furnished from **Table 16 to Table 21** below. The total cost of dry-stone masonry check dams suggested is given at **Table 22**.

Table 16: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-1)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-1**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	20.00	1.50	0.40	12.00	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	20.00	3.00	0.30	18.00	Cum		
		TOTAL				**33.00**	**Cum**	281.5	9289.5
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	20.00	1.50	1.00	30.00	Cum		
	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	1.50	1.00	12.00	Cum		
	Floor Apron (In D/S Portion)	1	20.00	3.00	0.30	18.00	Cum		
		TOTAL				**66.00**	**Cum**	197.00	13002.00
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**66.00**	**Cum**	561.00	37026
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**66.00**	**Cum**	277.50	18315
	Total								77632.5
	Add 3 % Contingencies								2328.98
	Grand Total Rs.								79961.48
	Say Rs.								**₹ 80,000.00**

Table 17: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-2)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-2**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	8.00	2.00	0.40	6.40	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	8.00	3.00	0.30	7.20	Cum		
		TOTAL				**16.60**	**Cum**	281.5	4672.9
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	8.00	1.50	1.25	15.00	Cum		
	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	2.00	1.50	24.00	Cum		
	Floor Apron (In D/S Portion)	1	8.00	3.00	0.30	7.20	Cum		
		TOTAL				**52.20**	**Cum**	197.00	10283.40
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**52.20**	**Cum**	561.00	29284.2
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**52.20**	**Cum**	277.50	14485.5
	Total								58726
	Add 3 % Contingencies								1761.78
	Grand Total Rs.								60487.78
	Say Rs.								**₹ 61,000.00**

Table 18: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-3)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-3**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	12.50	2.00	0.40	10.00	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	12.50	3.00	0.30	11.25	Cum		
		TOTAL				**24.25**	**Cum**	281.5	6826.38
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	12.50	1.50	1.25	23.44	Cum		

	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	2.00	1.50	24.00	Cum		
	Floor Apron (In D/S Portion)	1	12.50	3.00	0.30	11.25	Cum		
		TOTAL				**64.69**	**Cum**	197.00	12743.44
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**64.69**	**Cum**	561.00	36289.69
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**64.69**	**Cum**	277.50	17950.78
	Total								73810.29
	Add 3 % Contingencies								2214.31
	Grand Total Rs.								76024.6
	Say Rs.								**₹ 77,000.00**

Table 19: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-4)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-4**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	16.00	2.00	0.40	12.80	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	16.00	3.00	0.30	14.40	Cum		
		TOTAL				**30.20**	**Cum**	281.5	8501.3
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	16.00	1.50	1.25	30.00	Cum		
	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	2.00	1.50	24.00	Cum		
	Floor Apron (In D/S Portion)	1	16.00	3.00	0.30	14.40	Cum		
		TOTAL				**74.40**	**Cum**	197.00	14656.80
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**74.40**	**Cum**	561.00	41738.4
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**74.40**	**Cum**	277.50	20646
	Total								85542.5
	Add 3 % Contingencies								2566.28
	Grand Total Rs.								88108.78
	Say Rs.								**₹ 89,000.00**

Table 20: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-5)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-5**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	12.00	2.00	0.40	9.60	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	12.00	3.00	0.30	10.80	Cum		
		TOTAL				**23.40**	**Cum**	281.5	6587.1
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	12.00	1.50	1.25	22.50	Cum		
	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	2.00	1.50	24.00	Cum		
	Floor Apron (In D/S Portion)	1	12.00	3.00	0.30	10.80	Cum		
		TOTAL				**63.30**	**Cum**	197.00	12470.10
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**63.30**	**Cum**	561.00	35511.3
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**63.30**	**Cum**	277.50	17565.75
	Total								72134.25
	Add 3 % Contingencies								2164.03
	Grand Total Rs.								74298.28
	Say Rs.								**₹ 75,000.00**

Table 21: Detailed break up of item-wise cost for Dry Stone Masonry Check Dam (CD-6)

Sl.No	Particular of Work	No.	Length	Width	Height	Quantity	Unit	Rates	Total Amount
1	**Dry Rubble Stone masonry (DRSM) Check Dam-6**								
(a)	Excavation in foundation with 50% soft rock & 50% E&B involving pick & jumper work								
	Gabion Wall (Crest Wall)	1	16.00	2.00	0.40	12.80	Cum		
	Wing Wall (In U/S Portion)	2	4.00	0.75	0.50	3.00	Cum		
	Floor Apron (In D/S Portion)	1	16.00	3.00	0.30	14.40	Cum		
		TOTAL				**30.20**	**Cum**	281.5	8501.3
(b)	Collection of boulders								
	Gabion Wall (Crest Wall)	1	16.00	1.50	1.25	30.00	Cum		

	Wing Wall (In U/S Portion) Step-1	2	4.00	0.75	1.00	6.00	Cum		
	Wing Wall (In U/S Portion) Step-2	2	4.00	2.00	1.50	24.00	Cum		
	Floor Apron (In D/S Portion)	1	16.00	3.00	0.30	14.40	Cum		
		TOTAL				**74.40**	**Cum**	197.00	14656.80
(c)	Carriage of boulder by manually beyond initial 100 m lead up to 1 Km					**74.40**	**Cum**	561.00	41738.4
(d)	Labour charges for dry stone masonry with outer face stone dressed & 100 m lead					**74.40**	**Cum**	277.50	20646
	Total								85542.5
	Add 3 % Contingencies								2566.28
	Grand Total Rs.								88108.78
	Say Rs.								**₹ 89,000.00**

10.2.3 SUMMARY OF TREATMENT MEASURES

The areas within the free draining catchment of Kapildhara dam project identified for treatment with different treatment measures for First Year in shown in **Figure 17** below and for Second Year is shown in **Figure 18** below.

Figure 17: Proposed Treatment Measures in First Year

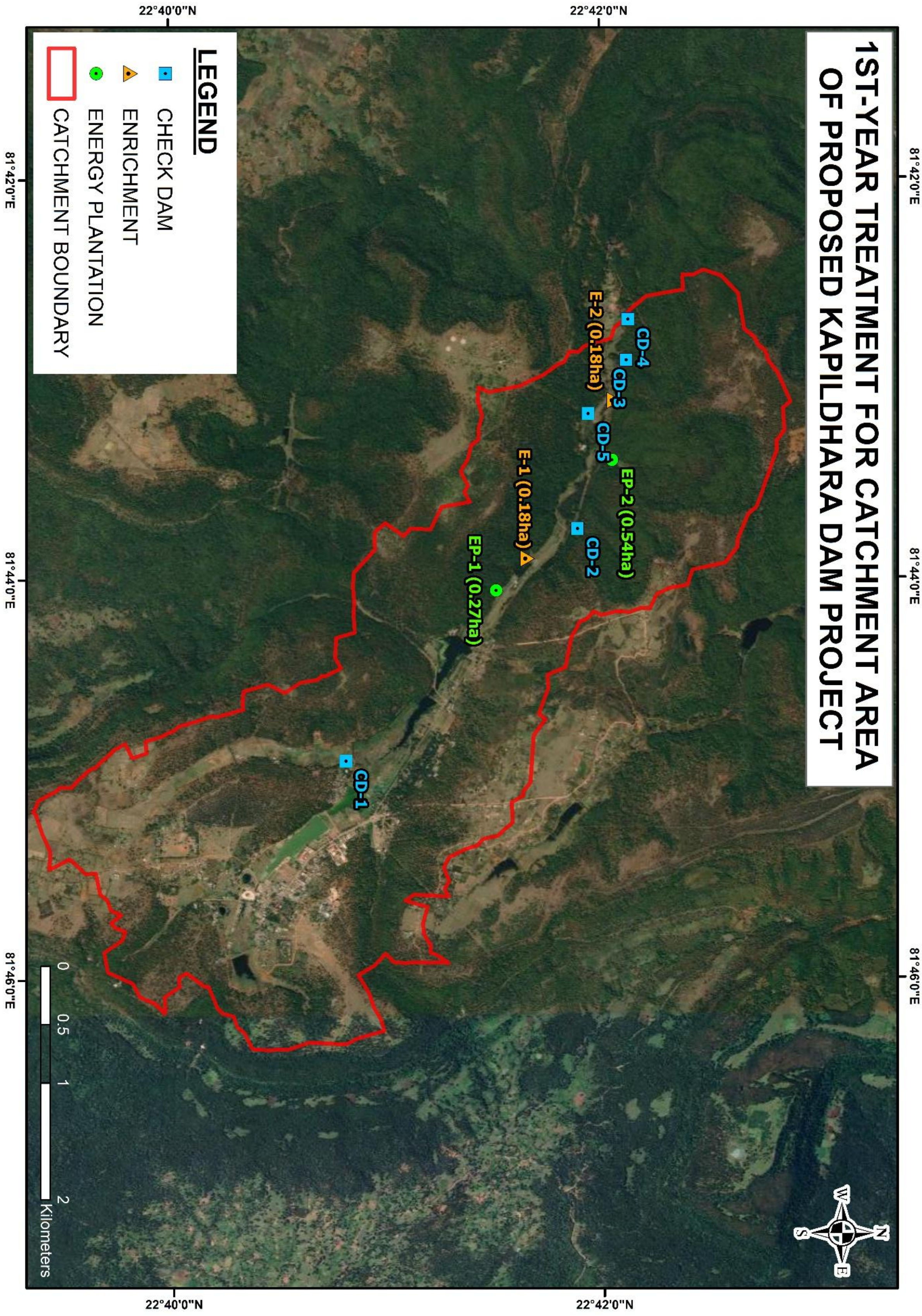
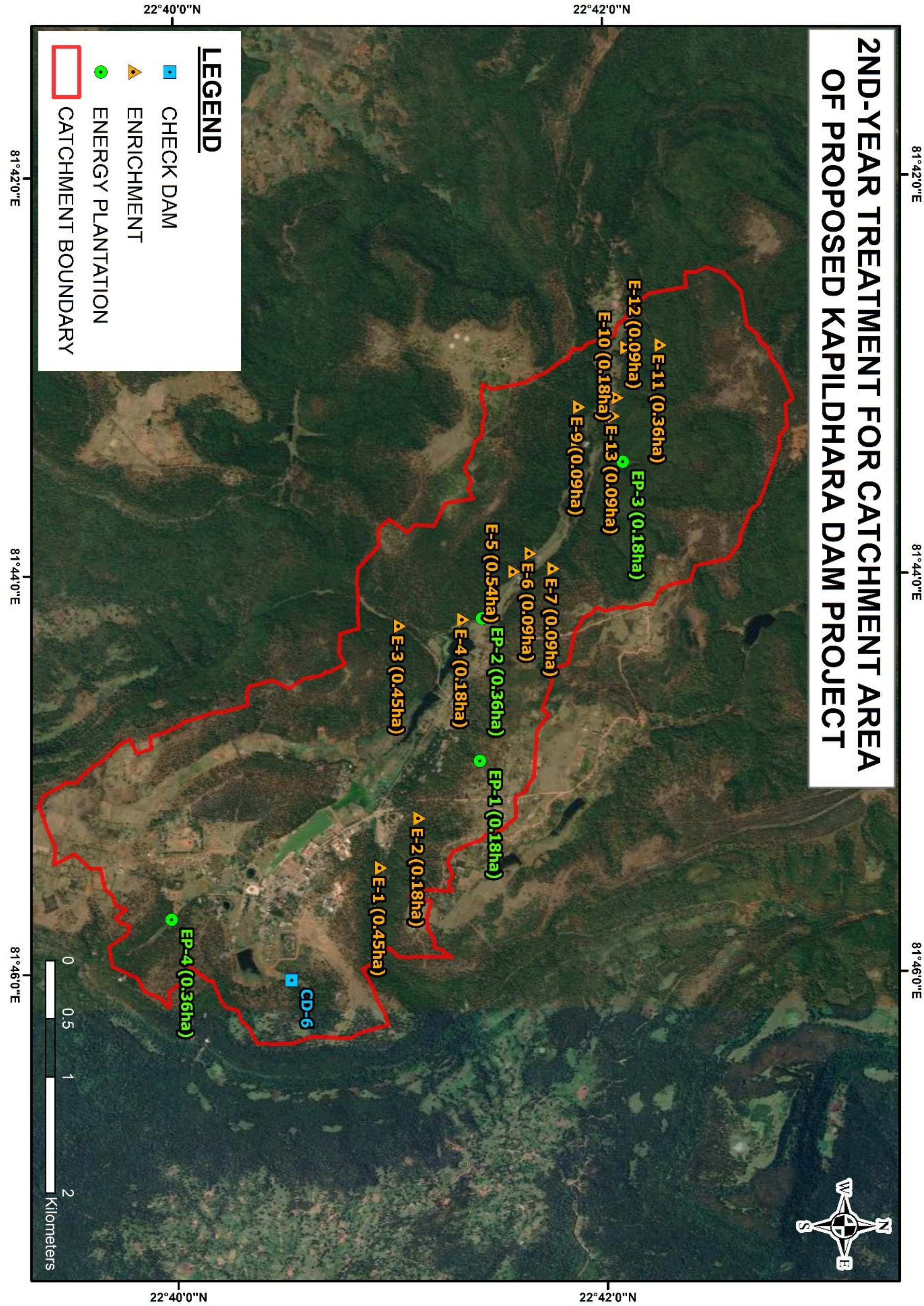


Figure 18: Proposed Treatment Measures in Second Year



The total cost required for treatment of 19.62 Ha. by means of different treatment measures in **Rs. 14.81 lakh**. The summary of treatment measures and their cost is given in **Table 22** below.

Table 22: Summary of Treatment Measures and their cost for CAT Plan

S. No.	Treatment Measure	Quantity	Unit	Unit Cost (Rs.)	Total Cost (Rs.)
First Year					
1	Enrichment	0.36	Ha.	1,50,000	54,000
2	Energy Plantation	0.81	Ha.	2,70,000	2,18,700
3	DRSM Check Dam-1	1	No.	80,000	80,000
4	DRSM Check Dam-2	1	No.	61,000	61,000
5	DRSM Check Dam-3	1	No.	77,000	77,000
6	DRSM Check Dam-4	1	No.	89,000	89,000
7	DRSM Check Dam-5	1	No.	75,000	75,000
Total for First Year					**6,54,700**
Second Year					
1	Enrichment	2.97	Ha.	1,50,000	4,45,500
2	Energy Plantation	1.08	Ha.	2,70,000	2,91,600
3	DRSM Check Dam-6	1	No.	89,000	89,000
Total for First Year					**8,26,100**
GRAND TOTAL					**14,80,800**

10.2.4 FIELD VALIDATION

Post conducting the erosion study as discussed above, a detailed site visit was conducted at Very High and High priority category areas to validate the results and was found to be satisfactory. Some photographs of the field visit are shown below.

Figure 19: Culvert approx..65m Downstream of proposed Check Dam (CD-1)

Figure 20: Culvert approx.115m Downstream of proposed Check Dam (CD-6)

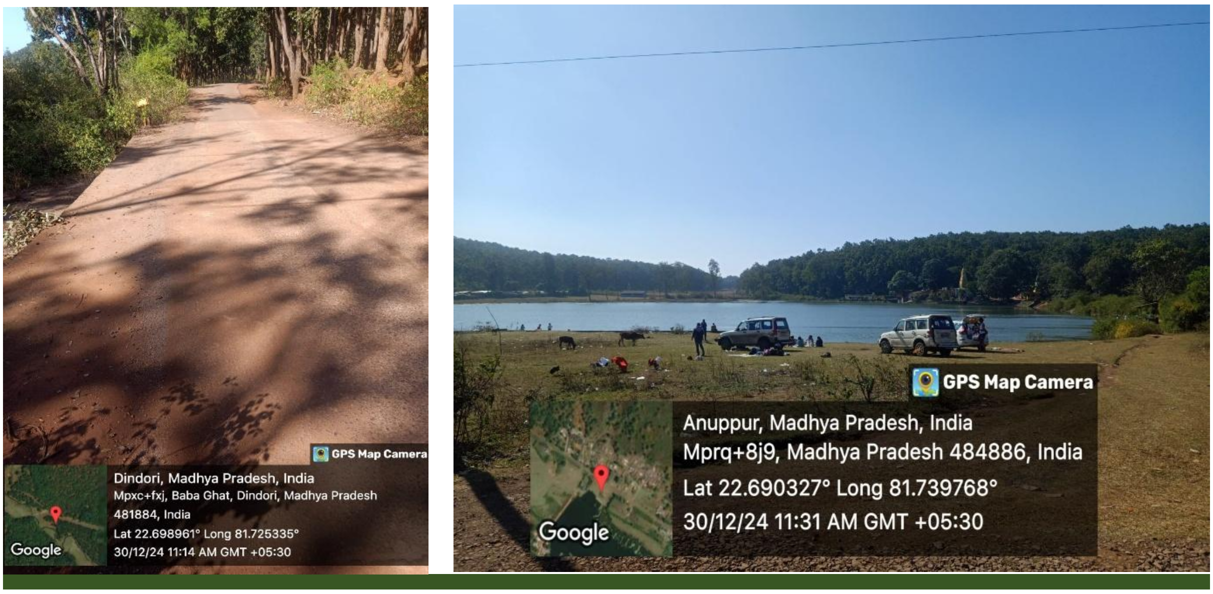
Figure 21: Site at Proposed Energy Plantation (EP-4) for 2nd Year treatment

Figure 22: Culvert approx.50m Downstream of proposed Check Dam (CD-3)

Figure 23: Site at Proposed Enrichment (E-10) for 2nd Year treatment

Figure 24: Ashram approx.250m right towards of proposed Check Dam (CD-5)

Figure 25: Some other photographs of areas in the Catchment




GPS Map Camera
Amarkantak, Madhya Pradesh, India
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Lat 22.678124° Long 81.752874°
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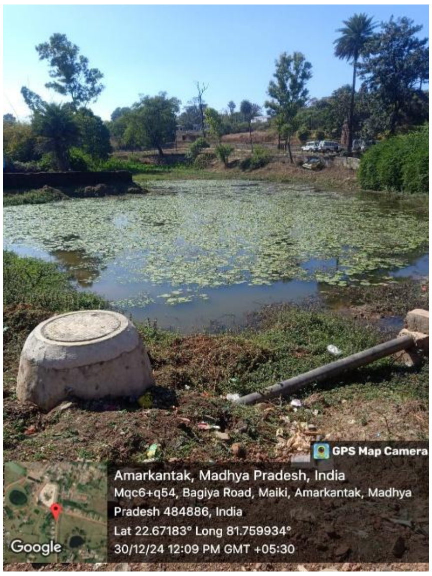
Google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11. OTHER COMPONENTS OF CAT PLAN

Apart from the biological and engineering treatment measures in the free draining catchment area there are other aspects of the CAT Plan to be addressed, and their cost included in the overall cost estimate of the plan. The charges for operational support, forest protection, social mobilization, documentation and publication, monitoring and evaluation and providing environmental services are some of the integral ingredients which must be considered and included while formulating the CAT plans.

11.1 ADMINISTRATIVE CHARGES

For an efficient management of forest resources, it is essential that operational support to the Forest Department is adequately developed. Similarly, in remote localities there are no places for shelter for the staff, people and trekkers. Therefore, a budgetary provision of **Rs 10.00 lakh** has been kept for this component.

11.2 DEVELOPMENT OF NURSERIES

Nursery is defined as an area where plants are raised for eventual planting out in the forest area or elsewhere selected for afforestation in field. Nursery should preferably be rectangular or square in shape with well laid out beds, separated by main paths, around the fence and within the Nursery for the movement of small machinery, wheelbarrows, etc. Nursery should be properly fenced; 5 to 7 strands barbed wire (with criss-cross barbed wire), with distance of strands closer below the ground and gradually increasing upwards. It should have gate for day-to-day labour movements. Nursery should have Mali's quarter, tool shade, store, and labour shed, with in nursery or just adjoining it for constant supervision and better success of the nursery. Water supply should have assured from perennial water sources/ springs/ streams throughout the year.

Some of the important points for nursery raising are:-
Nature of Nursery (Permanent or Temporary), Choice of site (Preferably Northern Aspect), Lay-out of nursery (Flat or Terraced), Dimensions of beds, Soil Preparations, Level & Edging, Inoculation with mycorrhiza (if required), Inputs in the soil (Forest Manure/ Farm Yard Manure), Pre-germination (Treatment), Method of Sowing (Line/ Broadcasting), Quality of Seed, Time of Sowing (Pre Monsoon/ Post Monsoon), Protection/ Covering the seed against birds & Rodents, Shading, Protection from Frost, Protection from rain & hail, Types of shade (Polythene/ Brush wood/ Grass), Hardening off

(Permeability/ Texture of soil), Watering and damping off (Drainage/ Aeration), Weeding & soil working, Herbicides for the nursery Hoeing/ weeding etc.

A provision of Rs. **10.00 lakh** has been made for establishment of a new nursery and Rs. **5.00 lakh** as maintenance cost for 5 subsequent years.

11.3 PROVISION FOR SILT MONITORING

For regular monitoring of silt load coming from nalas, one Silt Monitoring site have been suggested. This would ensure monitoring efficacy of implementation various treatments measures suggested as in CAT plan. Monitoring would be undertaken for a period of six years. A lumpsum cost Rs. **6.00 lakh** for establishment of monitoring site and **Rs. 4.00 lakh** as running and maintenance cost for silt observation has been made in the present CAT plan.

11.4 MONITORING AND EVALUATION

Monitoring and evaluation will be undertaken as a part of project management. A process of self-evaluation at specified intervals of time will ensure the field level verification of suggested treatment measures and efficacy of the CAT plan.

The spatial location of specific treatment to be carried out in the free draining catchment area would require extensive detailing during the implementation of CAT. Thereafter, annual work plan would be prepared well in advance after undertaking initial ground surveys during micro-planning, specifying physical and financial targets, sites, locations and beneficiaries of each component of the project activity. Month-wise work schedule 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. The monitoring committee shall be constituted at the project level for this purpose which too would monitor on a regular basis the quality and quantity of works being carried out under the CAT plan area.

A provision of 3% of the total cost of treatment measure amounting to **Rs 1.19 lakh** has been made for this component.

11.5 CONTINGENCIES

A provision of 10 % of the Treatment works amounting to Rs. **3.98 Lakhs** have been kept under this component for some leeway to adjust any unforeseen expenditure.

12. COST ESTIMATE

The estimated cost of implementation of CAT plan is **Rs. 54.98 lakh** and is given in **Table 23** below.

Table 23: Estimated Cost of CAT Plan

S. No.	Item	Rate (Rs)	Unit	Target	
				Physical	Financial (Rs)
I	**Biological Measures**				
1	Enrichment		ha		
	i) Creation	1,14,440		3.33	3,81,085.20
	ii) Maintenance for 5 years	35,560		3.33	1,18,414.80
2	Energy Plantation		ha		
	i) Creation	2,07,000		1.89	3,91,230.00
	ii) Maintenance for 3 years	63,000		1.89	1,19,070.00
3	Nursery Development				
	i) Creation	LS			10,00,000.00
	ii) Maintenance for 4 years	LS			5,00,000.00
Sub Total I (1+2+3)					**25,09,800.00**
II	**Engineering Measures**				
4	DRSM Check Dam-1	80,000	No	1	80,000.00
5	DRSM Check Dam-2	61,000	No	1	61,000.00
6	DRSM Check Dam-3	77,000	No	1	77,000.00
7	DRSM Check Dam-4	89,000	No	1	89,000.00
8	DRSM Check Dam-5	75,000	No	1	75,000.00
9	DRSM Check Dam-6	89,000	No	1	89,000.00
10	Silt Monitoring				
	i) Creation	LS			6,00,000.00
	ii) Maintenance for 4 years	LS			4,00,000.00
Sub Total II (4+5+6+7+8+9+10)					**14,71,000.00**
A	**Treatment Cost (Sub Total I + II)**				**39,80,800.00**
III	**Administrative Measures**				
11	Administrative Charges				10,00,000.00
12	Monitoring & Evaluation Cost @3% of Treatment Cost				1,19,424.00
13	Contingencies @10% of Treatment Cost				3,98,080.00
B	**Sub Total III**				**15,17,504.00**
Total CAT Plan Cost (A + B)					**54,98,304.00**