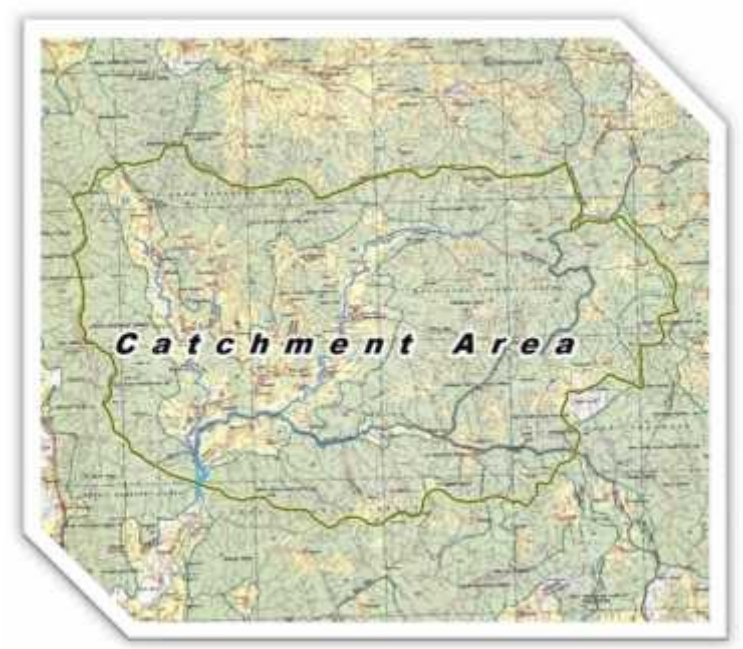
GOVERNMENT OF ODISHA
DEPARTMENT OF WATER RESOURCES

CATCHMENT AREA TREATMENT (CAT)

FOR

KALA BARRAGE PROJECT



DIST: DEOGARH, ODISHA

Sundargarh
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1. Introduction

The Catchment Area Treatment (CAT) targets overall improvement in the environmental conditions of the region. All the activities are aimed at treating the degraded and potential areas of severe soil erosion. The plan provides benefits due to biological and engineering measures.

The CAT Plan would cover the following aspects:

- Identification of free draining catchment
- Assessment of Land Use, Soil, Slope in the catchment based on Remote Sensing (RS) /Geographic Information System (GIS) and Validation through field survey
- Erosion levels the watershed and prioritization of water sheds will be done by appropriate methods.
- As per the requirement of Ministry of Environment & Forests and Climate Change (MoEF& CC), Government of India, the treatment measures will be proposed for the area falling higher priority erosion categories. Both Engineering measures as well as Biological treatment measures will be proposed in the CAT plan.
- The cost of the administrative set up and meditative measures will include recommendation from State Forest Department and other lines department.

2. Need

Pondage formed by barrage on rivers are subject to sedimentation. The process of sedimentation embodies the sequential processes of erosion, entertainment, 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 pondage 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 threading of river reach. The removal of top fertile soil form catchment adversely affects the agricultural production. Thus, a well-designed catchment area treatment plan is essential to ameliorate the above -mentioned adverse process of soil erosion.

The CAT plan highlights the management techniques to control erosion in the catchment area of a water resource project. The life span of a reservoir is greatly reduced due to erosion in the catchment area. Adequate preventive measures are thus needed for the treatment of catchment for its stabilization against future erosion.

Quantifying soil erosion and reservoir sedimentation is necessary for prioritizing catchments for treatment and development of a suitable treatment mix. It is, therefore, also required that the effect of various treatments on controlling soil erosion are quantitatively known. River gauging data are the best information source for undertaking the above activities. As such data are not available for this catchment, so estimation procedure is adopted. At the present level of data availability and also based on the past experience, **Sedimentation (Silt) Yield Index (SYI)** appears to be an acceptable parameter for use in catchment prioritization work.

SYI is calculated using an empirical formula. Based on the numerical value of SYI, catchments are categorized into five priority classes from Very High (SYI>1300) priority to Very Low (SYI<1000) priority. The method was proposed by **All India Soil Survey and Land Use Planning (AISSLUP)** currently known as **Soil and Land Use Survey of India (SLUSI)** based on several studies. The method has been used to prioritize catchments in India totaling in area of millions of hectares. It is reported that, the SYI procedure is fairly reliable for determining priority watersheds. The empiricism in this method is manifest in the selection of unit area (mapping unit) and assigning an appropriate value of delivery ratio to it. SYI method is widely used because of the fact that it is easy to use and lesser data requirement. Moreover, it can applied to larger areas like sub watersheds etc.

3. Methodology adopted

Database on natural resources, terrain conditions, soil type of the catchment area is a pre-requisite to prepare CAT plan. Various thematic maps were prepared and used in preparation of the CAT plan, in Geographic Information System (GIS) platform.

The methodology adopted for development of CAT plan for the project is as under:

- Catchment boundary delineation from Survey of India Topo sheets
- Watershed boundary form watershed Atlas of India of Soil and Land Use Survey of India (SLUSI) and the micro watershed boundary collected from Watershed Mission of Odisha
- Land use/Land cover map preparation from recent 5.8m resolution LISS-IV Multi Spectral Satellite image
- Contour digitization from Survey of India OSMtopo sheet and generation of slope map
- Soil map preparation from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)
- Assigning weightage value of mapping units based on slope, land use and soil texture and Delivery ratio based on distance from nearest stream

- Estimation of Soil Loss using Silt Yield Index
- Watershed Prioritization
- Selection of locations of treatment and Catchment Treatment (CAT) Plan
- Cost Estimate

Thematic data integration and erosion index modeling was done using relevant map layers in GIS.

Silt Yield Index (SYI) of various Sub watersheds within the free catchment was estimated. Watershed management approach were proposed for optimal use of soil and water resources within the catchment with the broad objective of

- increasing infiltration into soil
- control excessive runoff
- manage & utilize runoff for useful purpose

4. Salient feature of Kala Barrage Catchments

The scheme envisages construction of a barrage at village Kaliapal in Barkote Block of Deogarh District across Kala Nallah. Kala Nallah originates from DeogarhPahada in Deogarh District and merges with Rengali Reservoir i.e. River Brahmani. The catchment area of the project at the site is 185 Km^2. The project has planned to irrigate 4050 ha of C.C.A. with 89% intensity during Khariff. The catchment map of Kala Barrage Project is enclosed at ***Plate-1.***

5. Thematic Map Generation

As mentioned in the methodology, various thematic layers like catchment, watershed, drainage, contour, slope, land use, soil were prepared in Geographic Information System (GIS) platform using satellite image, OSMSoITopo Sheet and other secondary source data. For seamless integration of different thematic layers and interactive spatial analysis, the themes were generated UTM (Universal Transverse Mercator) projection system. This projection system is used in the recent publication Open Series Map (OSM) of SoI and is also suggested in National Map Policy. Datum used for the projection is WGS 1984 and Zone is UTM 45 North.

5.1. Catchment and Watershed map

The catchment boundary of Kala Barrage was delineated from SoItopo sheets F45-N2 looking at the contours and drainage. The contour and drainage map of the project is enclosed at ***Plate-2***. The entire catchment is a part of the Watershed 4H1C2 as per the Watershed Atlas of India published by SLUSI. Since the catchment is very small (185 km^2), it was decided to prepare the CAT plan at Mini Watershed level instead of Watershed level. The mini watersheds are prepared using the information available in Watershed Atlas of India published by Soil and Land Use Survey of India (SLUSI) and the micro watershed boundary collected from Watershed Mission of Odisha. The Miniwatershed map is enclosed at ***Plate-3***.

Table-1: Area falling under different slope category

SL	Mini Watershed Code	Area (Km^2)
1	04080103020101	28.08
2	04080103020201	17.36
3	04080103020202	15.66
4	04080103020302	16.29
5	04080103020401	15.97
6	04080103020402	16.39
7	04080103022101	18.08
8	04080103022102	22.33
9	04080103020301	14.9
10	04080103020102	19.94
	Total	185.00

5.2. Slope Map

The Slope map was derived from contours shown on SoITopo sheet. After marking the catchment area, all the contours and spot heights shown on the topographical maps were mapped with 'Z' value (height above MSL in m) the contour map is enclosed at ***Plate-4***. Since the area is mostly flat and contours are wide spaced, the spot heights collected in DGPS (differential GPS) during ground truthing of land use were also used as input.

A surface was created using the elevation values stored in the form of contours or points. A Digital Terrain Model (DTM) of the area was then prepared, which was used to derive a slope map. The slope was divided in classes of slope percentages. The areas falling under various standard slope categories have been tabulated in **Table-1** and the slope map is enclosed at ***Plate-5***.

Table-1: Area falling under different slope category

Slope Category	Slope (%)	Area in %	Area in Km^2
Gently Slopping	0-15	21.35	39.5
Moderately sloping	15-30	2.76	5.11
Strongly sloping	30-45	23.1	42.74
Steeply sloping	45-60	52.65	97.39
Very steeply sloping	60-75	0.14	0.26
Extremely sloping	>75		
Total		**100**	**185**

5.3. Land Use/ Land Cover Map

Land Use map was prepared from recent 5.8m resolution LISS-IV Multi Spectral Satellite Image collected from National Data Centre of National Remote Sensing Centre (NRSC), Hyderabad. Details of Satellite Image are given bellow.

Satellite: IRS-P6

Sensor: LISS-IV MX (Multi Spectral)

Date of Pass: 1st February 2017

Path: 105

Row: 057

The image was geo-referenced using the common Ground Control Points (GCP) of Survey of India topographical sheets and satellite image with the help of feature registration techniques in standard image processing software. The satellite image map is enclosed at ***Plate-6***. As the catchment area is very small, visual interpretation of the geo-referenced satellite data was done by qualified professionals using standard enhancement techniques followed by detail ground truthing to enhance the quality of image interpretation. The classified land use map of the catchment area is depicted in ***Table-2*** and the map is enclosed at ***Plate-7***.

Table-2: Area falling under different Land Use

Description	Area in Km^2	Area in %
Moderate Dense Forest	137.71	74.44
Open Forest	3.02	1.63
Scrub	0.96	0.52
Grooves & Orchards	0.68	0.36
Cultivation	39.72	21.47
River/Water Body	1.05	0.57
Settlement	1.87	1.01
Total	185	100.00

5.4. Soil Map

Soil map was prepared by digitizing the soil map collected from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) for Odisha. The soil map is depicted at ***Plate-8*** and catchment area coming under different soil category is depicted in ***Table-3***.

Table-3: Area falling under different soil category

Code	Description	Texture	Area in km^2	Area in %
1	Moderately deep, well drained, coarse-loamy soils on gently sloping denuded hills with loamy surface and severe erosion, associated with; Deep, well drained, fine-loamy soils with loamy surface, moderate erosion and moderate stoniness	Coarse-loamy	22.7	12.27
2	Deep, imperfectly drained, fine soils on very gently sloping inter hill basin with loamy surface and slight erosion; associated with; Moderately shallow, well drained, gravelly loamy soils with loamy surface and moderate erosion.	Fine	118.8	64.21
3	Moderately shallow, moderately well drained, fine-loamy soils on very gently sloping undulating upland with sandy surface and slight erosion, associated with; Deep, moderately well drained fine-loamy soils with loamy surface and slight erosion.	Fine-loamy	16.48	8.91
4	Moderately deep, moderately well drained, fine-loamy soils on very gently sloping upland with loamy surface and slight erosion; associated with; Very deep, well drained, fine-loamy soils with loamy surface and moderate erosion.	Fine-loamy	27.02	14.61
	Total		**185**	**100.00**

6. Estimate of Soil Loss intensity using Silt Yield Index (SYI) method

The Sedimentation (Silt) Yield Index Model (SYI), considering sedimentation as product of erosivity, erodibility and arial extent was conceptualized in the AISLUS, as early as 1969 and has been in operational use since then to meet the requirements of prioritization of smaller hydrologic units. The erosivity determinants are the climatic factors and soil and land attributes that have direct or reciprocal bearing on the unit of the detached soil material.

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.

In SYI methodology, each Erosion Intensity Unit (EIU) is assigned a weightage value. When considered collectively, the weightage value represents approximately the relative comparative erosion intensity. The slope, soil and land use theme of the catchment were combined using union tool in GIS and EIU were formed using different combination of soil, slope and land use categories.

SYI was calculated using following empirical formula:

$$SYI = \frac{\sum (Ai \times Wi) \times Di \times 100}{Aw} \quad [\text{where } i = 1 \text{ to } n \text{ (n is the No. of EIU)}]$$

Ai = Area of i^{th} unit (EIU)

Wi = Weightage value of the i^{th} unit EIU

Di = Delivery Ratio of the i^{th} unit EIU

Aw = Total area of Sub-watershed

Weightage Value (W)

Weightage Value is a combination of two factors K and X. 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. Solicited

Delivery Ratio (D)

Delivery ratios were assigned for each of the erosion intensity unit. The delivery ratio suggests the percentage of eroded material that finally finds entry into reservoir. Area of each EIU in each Sub watershed was then estimated.

Delivery ratios were 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-4: Delivery Ratio

Nearest Stream	Delivery Ratio
0 - 0.99 km	1.00
1.01 - 2.0 km	0.95
2.01 - 5.0 km	0.90
5.01 - 15.0 km	0.80
15.01 - 30.0 km	0.70

1.0 km, 2.0 km, 5.0 km, 15.0 km and 30.0 km buffers were created around the main stream and reservoir using GIS. EIUs falling in different buffer zone were assigned the Delivery ratio of the respective buffer zone.

7. Prioritization of Sub Watershed based on SYI findings

The objective of the SYI method is to prioritize sub watershed in a catchment area for treatment. For prioratizing the sub watersheds, these are to be divided in to different categories based on their SYI. The SYI values for classification of various categories of erosion intensity rates are depicted below

Table-5: Priority based on SYI

Priority categories	SYI Values
Very high	> 1300
High	1200-1299
Medium	1100-1199
Low	1000-1099
Very Low	<1000

The sub watershed wise SYI and category of erosion is depicted in ***Table-4*** and ***Plate-9***

Table-6: Soil Erosion Priority Category of Sub Watersheds

SL	SWS Code	SYI	Priority
1	04080103020202	**1205**	High
2	04080103020401	**1160**	Medium
3	04080103020301	**1153**	Medium
4	04080103022102	1146	Medium
5	04080103020402	1139	Medium
6	04080103020102	1131	Medium
7	04080103020101	1128	Medium
8	04080103020302	1083	Low
9	04080103020201	1064	Low
10	04080103022101	1042	Low

As referred from the above table, there isn't any watershed of very high category; therefore the area under high erosion categories is proposed to be treated at the project. A base map showing land use, Reserve Forest boundary, slope, major drains and priority watershed is enclosed at ***Plate-10*** for micro planning of the catchment area treatment plan. As the steep areas are more prone to soil erosion, looking at the land use and topography and SYI value 04080103020202, 04080103020401 and 04080103020301 Mini-watershed (Area 46.53 km2) were finally selected for catchment area treatment plan which is directly draining to the rivers.

The topographic map, drainage and contour map and land use and slope map of the sub watershed is enclosed at **Plate11.a, 11.b and 11.c** respectively.

7.1. Demography of the watershed

The village map of the sub watershed is enclosed at ***Plate-12***. The demography of the villages as per Census 2011 is depicted below.

Table-7: Demography as per Census 2011

Sl	Name	Population	Male	Female	SC	ST
1	Badachuan	519	249	270	0	506
2	Budhakhaman	326	154	172	0	326
3	Daleisara	1121	651	470	0	1084
4	Jagati	358	185	173	0	318
5	Jinakela	384	202	182	2	224
6	Kumudi	908	444	464	109	558
7	Kunu	85	38	47	0	83
8	Lunga	542	274	268	6	515
9	Mahulapada	469	226	243	149	267
10	Rengali	656	351	305	33	290
11	Tasada	263	139	124	0	254

8. Catchment Area Treatment (CAT) Plan

Following Engineering and Biological measures are planned for the catchment area treatment depending upon the requirement and suitability:

a. Biological measures
   - Assisted Natural Regeneration
   - Block Plantation/Afforestation
   - Fodder land development

b. Engineering measures
   - Loose boulder wall-gully plugging in small hilly streams
   - Stone masonry check dams - in major drains

As the area under agriculture is (21.47%),awareness campaign will be done for farm management (negatives of burning farm residuals, adoption of proper cropping pattern etc.), digging of farm pond, controlled grazing in graze land, etc.

8.1. Assisted Natural Regeneration

Assisted Natural regeneration is suggested in the 100ha of open forest available within the Reserve Forests. The sites to be treated are depicted in ***Plate-13.***The detail estimate is depicted at***Annexure-1.***

8.2. Block Plantation/Afforestation

The village wise revenue forest and govt. land is depicted in the table below.

Table-8: Availability of Govt. And revenue forest land

All areas are in Ha

Sl.	Village	Govt.	Forest	Total
1	Badachuan	51.890	10.020	61.91
2	Budhakhaman	1746.130	333.610	2079.74
3	Daleisara	849.600	455.480	1305.08
4	Jagati	225.460	151.280	376.74
5	Jinakela	801.360	134.680	936.04
6	Kumudi	171.540	32.310	203.85
7	Kunu	750.940	110.670	861.61
8	Lunga	587.600	138.680	726.28
9	Mahulapada	2283.660	39.150	2322.81
10	Rengali	3200.350	40.000	3240.35
11	Tasada	532.330	269.620	801.95

As 455.48 ha and 33.61 ha of forest land is available in Daleisara village and Budhakhaman village respectively, it is proposed to block plantation of 50 ha each in these villages. The detailed estimate is enclosed at ***Annexure-2***

8.3. Fodder land development

To minimize the pressure on forest for grazing, it is suggested to develop fodder land in the watershed.

Table-9: Availability of Gochar Land

Sl.	Village	Gochhar (Ha)	Population
1	Badachuan	8.400	519
2	Budhakhaman	96.900	326
3	Daleisara	48.930	1121
4	Jagati	18.720	358
5	Jinakela	15.270	384
6	Kumudi	17.590	908
7	Kunu	43.700	85
8	Lunga	31.730	542
9	Mahulapada	0.000	469
10	Rengali	0.000	656
11	Tasada	37.130	263

Looking at the availability of Gochar land and population it is proposed to develop 1 blocks (of 10 ha each) of fodder land development in Daleisara, Lunga and Kumudi. The detail estimate is given at ***Annexure-3***.

8.4. Loose boulder wall-gully plugging in small hilly streams

Gully erosion, including ephemeral gully erosion, refers to the cutting of narrow channels resulting from concentration of sheet and rill flow of runoff water. Ephemeral gullies are small channels of approximately 3 to 12 inches deep. Gullies may be one to several feet deep. Gully erosion occurs when rill erosion is neglected. The tiny grooves develop into wider and deeper channels, which may assume a huge size. This state is called “gully” erosion. Gullies are the most spectacular evidence of the destruction of soil. The gullies usually deepen and widen with every heavy rainfall. They cut up large fields into small fragments and, in course of time, make them out of shape for cultivation.

Gully plugging work is required for reduction of runoff velocities within permissible limits and for controlling gully erosion of micro-watersheds. Appropriate gully plugging works would be selected from brush wood check dams, gabion structures, sunken pits, etc. A provision is kept for 100 gully plugging in the hilly streams. The typical Estimate of Gully Plugging is depicted at ***Annexure-4.***

8.5. Stone masonry check dams - in major drains

Check dams range in size, shape and cost. It is possible to build them out of easily available materials and even at a very little cost. Decision of building such a dam depends on its location. Essentially a check dam has an earthen dam and masonry spillway.

It cuts the velocity and reduces erosive activity The stored water improves soil moisture of the adjoining area and allows percolation to recharge the aquifers Spacing between the check dams should be such that water spread of one should be beyond the water spread of the other Height depends on the bank height, varies from 1 metre to 3 metre and length varies from less than 3m to 10m.

The typical Estimate of earthen check dam with concrete core is depicted at ***Annexure-5***

The locations of proposals for all treatments other than ANR activities are depicted in ***Plate-14*** **.**The detail year wise cash flow estimate is depicted at***Annexure-6.***

9. Cost Estimate

SL	Item	Rate in Rs.	Unit	Physical	Financial (Rs, in Lakh)
Biological Measure					
1	ANR: Enrichment of Plantation/Re-densification	44,745	Ha	100	44.75
2	Block Plantation Afforestation including maintenance	1,73,879	Ha	100	173.88
3	Grass land (Fodder land) development including grass reserves over 50.0ha (10 ha one unit)	13,00,000	Ha	30	39.00
Engineering Measure**(Water Harvesting Structures)**					
4	Loose Boulder wall gully plugging	4771.53	No	100	4.77
5	Earthen Check dam with Concrete Core	2,47,253	No	5	12.36
Others					
6	Awareness campaign for farm management, control grazing etc.	-	-	-	5.00
7	Drinking water facility to villagers	-	-	-	5.00
	Total				**284.75**

Total cost of Biological, Engineering measure and silt observation at site =		Rs. 284.75lakh
Cost for supply of gas connection/solar cooker to the project affected families @5%	=	Rs. 14.24 lakh
Sub Total	=	**Rs. 298.99lakh**
Contingency cost @ 5%	=	Rs 14.95 Lakh
Sub Total	=	**Rs. 313.94 lakh**
Administrative Expenditure @5%	=	Rs. 15.70 Lakh
Total	=	**Rs. 329.64 lakh**

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