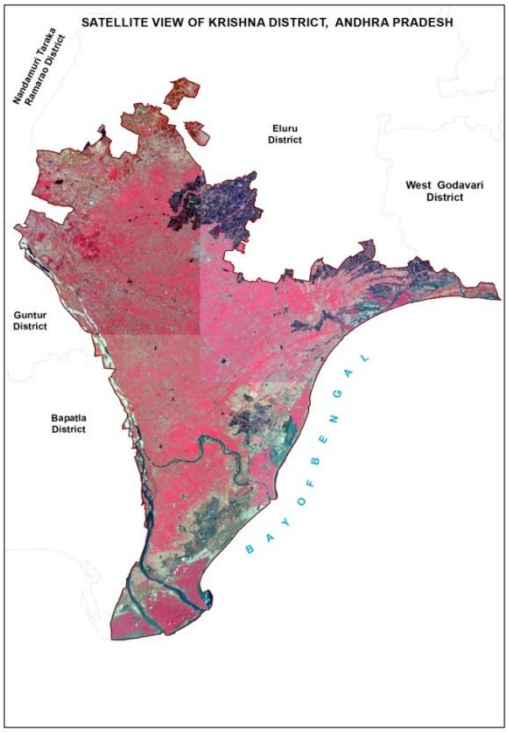
DISTRICT SURVEY REPORT
FOR
SAND AND OTHER MINOR MINERALS
KRISHNA DISTRICT

(FOR THE DEPARTMENT OF MINES AND GEOLOGY, GOVT. OF AP)

As per Notification No. S.O. 141 (E), 15.01.2016, S.O. 3611(E), 25.07.2018, & Enforcement & Monitoring Guidelines for Sand Mining 2020 of MOEF&CC, GoI



Prepared by

ANDHRA PRADESH SPACE APPLICATIONS CENTRE (APSAC)
ITE&C Department, Govt. of Andhra Pradesh

Submitted to

DEPARTMENT OF MINES AND GEOLOGY
Government of Andhra Pradesh

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Report Scrutiny Mechanism

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PREFACE

The Natural resource inventory is the assessment of the status of a given natural resource of an area at a given point in time. Population pressure results in over- exploitation of resources. The baseline information on the resources would help the administration for better planning and decision making. The main purpose of the report is to disseminate data on the natural resource up to the lowest administrative functionary to facilitate micro level planning and development. The efforts have been made to assess and document the information on land use/land cover, crop, surface water resource, soils, slope, groundwater prospects, groundwater quality, geological information, and minerals resources in Krishna district, Andhra Pradesh, based on the satellite remote sensing data and socioeconomic information.

The Department of Mines and Geology (DMG), Government of Andhra Pradesh (AP) requested the Andhra Pradesh Space Applications Center (APSAC) to update the district survey reports with availability of sand mineral information, major and minor mineral details, and river morphology for all the districts in the State. The District Survey report emphasizes and updated the major and minor minerals in the districts of AP. The District Survey reports are updated following the "Sustainable Sand Mining guidelines" issued in 2016 and 2020 and SO 741 of 2016 of the Ministry of Environment, Forests and Climate Change provided by the DMG. The comments received from the public, if found fit, shall be incorporated in the report. A list of leases in the district will be provided by the concerned Assistant Directors of Mines and Geology.

The report is an outcome of the efforts of the Scientists and Project Associates at APSAC. I heartily congratulate the team for compiling the report.

(Dr.Sundar Balakrishna, IFS)
Vice-Chairman
APSAC

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Our sincere gratitude to **Sri Gopal Krishna Dwivedi, IAS**, **Principal Secretary,** Department of Mines and Geology, Govt. of Andhra Pradesh for whole-hearted support.

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We are grateful to the **Sri. V.G. Venkata Reddy**, **Director**, Department of Mines and Geology, Govt. of Andhra Pradesh for entrusting the work for the preparation of District Survey Reports of Andhra Pradesh.

We owe a great deal to **Sri. P Raja Babu, Joint Director,** Department of Mines and Geology for his overall support and guidance during the execution of this work.

We are very much thankful to **Dr.M.J.Ratnakanth Babu, Royalty Inspector (Head Office**) Mines and Geology for his support to complete the work successfully.

We are also thankful to the **District Mines and Geology Officer,** Krishna District for their support in providing information

Our sincere thanks are due to the scientific staff of APSAC who has generated all the thematic maps for District Survey Reports.

APSAC

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List of Abbreviations

APSAC	: Andhra Pradesh Space Applications Centre
APMMC	: Andhra Pradesh Minor Mineral Concession
AMSL	: Above Mean Sea Level
AWiFS	: Advanced Wide Field Sensor
APWALTA	: Andhra Pradesh State Water, Land and Trees Authority
APMDC	: Andhra Pradesh Mineral Development Corporation
Bgl	: Below ground level
BT Road	: Bituminous Road
Cl	: Chlorine
CC Road	: Cement concrete
CRZ	: Coastal Regulatory Zone
CPSU	: Central Public Sector Undertaking
CGWB	: Central Ground Water Board
cu.m/day	: Cubic meter per day
DSR	: District Survey Report
DMF	: District Mineral Fund
DMG	: Directorate of Mines and Geology
DM&GO	: District Mines and Geology Officer
DES	: Directorate of Economics and Statistics
DEM	: Digital Elevation Model
dS/m	: Decisiemens per meter
EIA/EMP	: Environmental Impact Assessment
F	: Fluorine
FAC	: Full Additional Charge
FASAL	: Forecasting Agricultural output using Space, Agrometeorology and Land-based observations
Fe	: Iron
Ft	: feet
GD	: Geosciences Division
GIS	: Geographical Information System
GSI	: Geological Survey of India
Ha	: Hectare
Km	: Kilometre
IRS	: Indian Remote Sensing Satellite
ITE and C	: Information Technology Electronics and Communications
LISS	: Linear Imaging Self Scanning
LULC	: Land Use / Land Cover
Lps	: Litres per second

M	: meter
Mi	: mile
mm	: millimetre
MT	: Million Tonne
MoEF	: Ministry of Environment and Forests
MERIT	: Mineral Exploration Research Innovation Trust Fund
MSL	: Mean Sea Level
NIRD	: National Institute of Rural Development
NH	: National Highway
$NaNO_3$	: Sodium nitrate
NRSA	: National Remote Sensing Agency
NRSC	: National Remote Sensing Centre
PESA	: Panchayats Extension to Scheduled Areas
pH	: Power of hydrogen
PSD	: Performance Security Deposit
PSU	: Public sector Undertakings
R2	: ResourceSat-2
RGNDWM	: Rajiv Gandhi National Drinking Water Mission
RWS and S	: Rural Water Supply and Sanitation
SAR	: Synthetic Aperture Radar
SEB	: Special Enforcement Bureau
SO_4	: Sulphate
Sq.Km	: Square Kilometre
Sq.m	: Square metre
TA	: Tantalum
TIN	: Triangular Irregular Network
TGA	: Total Geographical Area
TIS	: Tank Information System
TTD	: Tirumala Tirupati Devasthanams
WBM	: Water Bound Macadam

Chapter I – Introduction &General Profile

1.1 Administrative Setup

Krishna district is a part of the coastal Andhra region. The administrative headquarters of the district is Machilipatnam.
Geographically, Krishna district is bounded on north by Eluru & NTR districts, on the south by Bay of Bengal, on the west by Guntur & Bapatla districts and on the east by Eluru and Krishna districts. Total geographical area of the district is 3,775 Sq.km. It is covered with 3 Revenue divisions namely Gudivada, Machilipatnam and Vuyyuru. The district comprising of 25 Revenue mandals and 505 Revenue villages. Pedana mandal is having maximum number of villages (32) and Avanigadda mandal is having minimum number of villages (7). Out of 25 mandals of the district, the maximum extent of area (413 Sq.km) is occupied by Nagayalanka Mandal and minimum area in Avanigadda Mandal (74 Sq.km). `

The mandals covered in each Revenue division are shown in Table-1 and its spatial distribution is shown in Figure-1. Satellite view of the district is shown in Figure-2.

Table 1 List of mandals covered in each Revenue division

Sl.No	Gudivada Division	Sl.No	Machilipatnam Division	Sl.No	Vuyyuru Division
1	Bapulapadu	9	Avanigadda	19	Ghantasala
2	Gannavaram	10	Bantumilli	20	Kankipadu
3	Gudivada	11	Challapalle	21	Movva
4	Gudlavalleru	12	Guduru	22	Pamidimukkala
5	Nandivada	13	Koduru	23	Penamaluru
6	Pamarru	14	Kruthivennu	24	Thotlavalluru
7	Pedaparupudi	15	Machilipatnam	25	Vuyyuru
8	Unguturu	16	Mopidevi		
		17	Nagayalanka		
		18	Pedana		

Data Source: APSAC, Vijayawada.

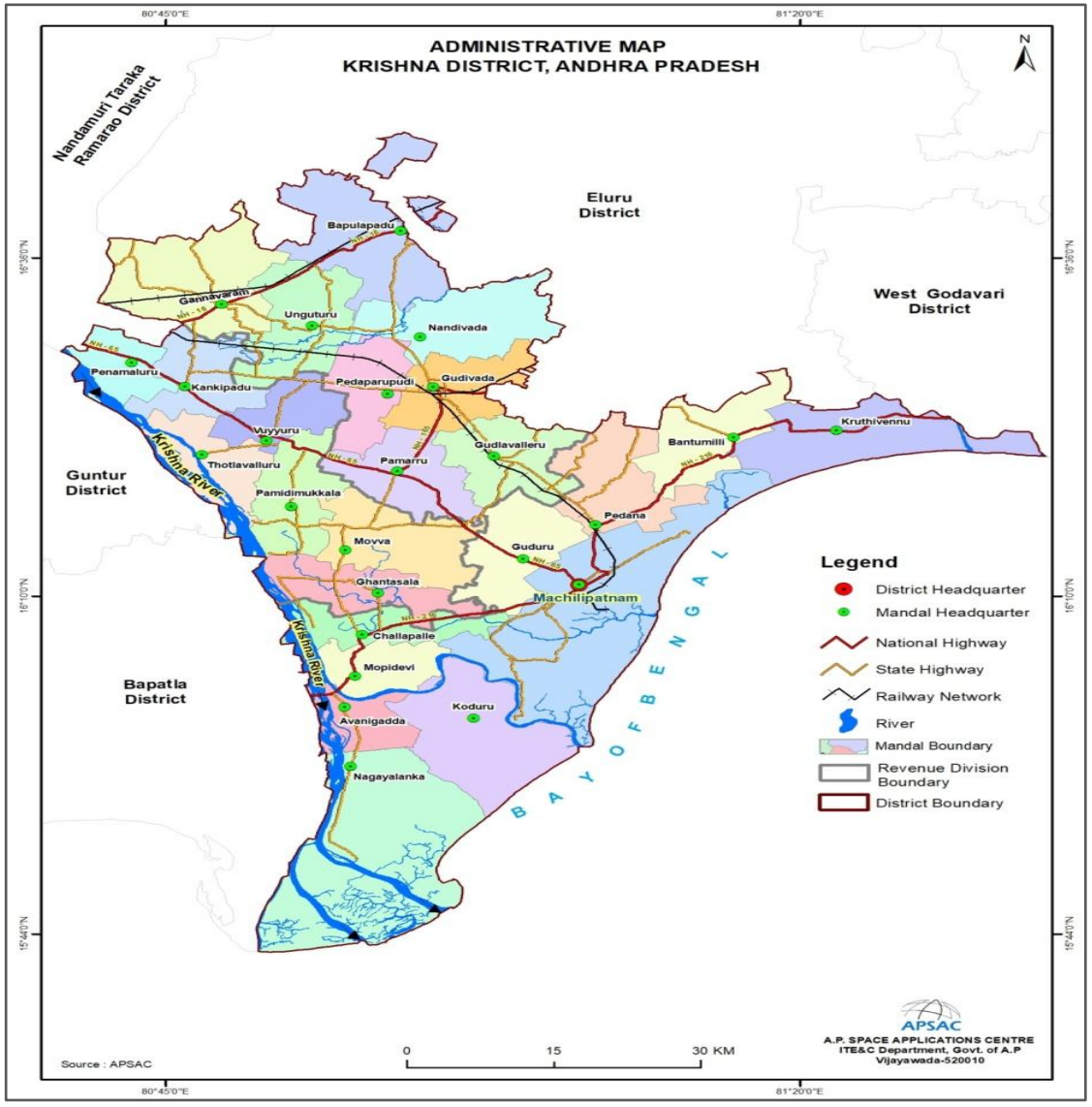


Figure-1: Administrative Map of Krishna district, Andhra Pradesh

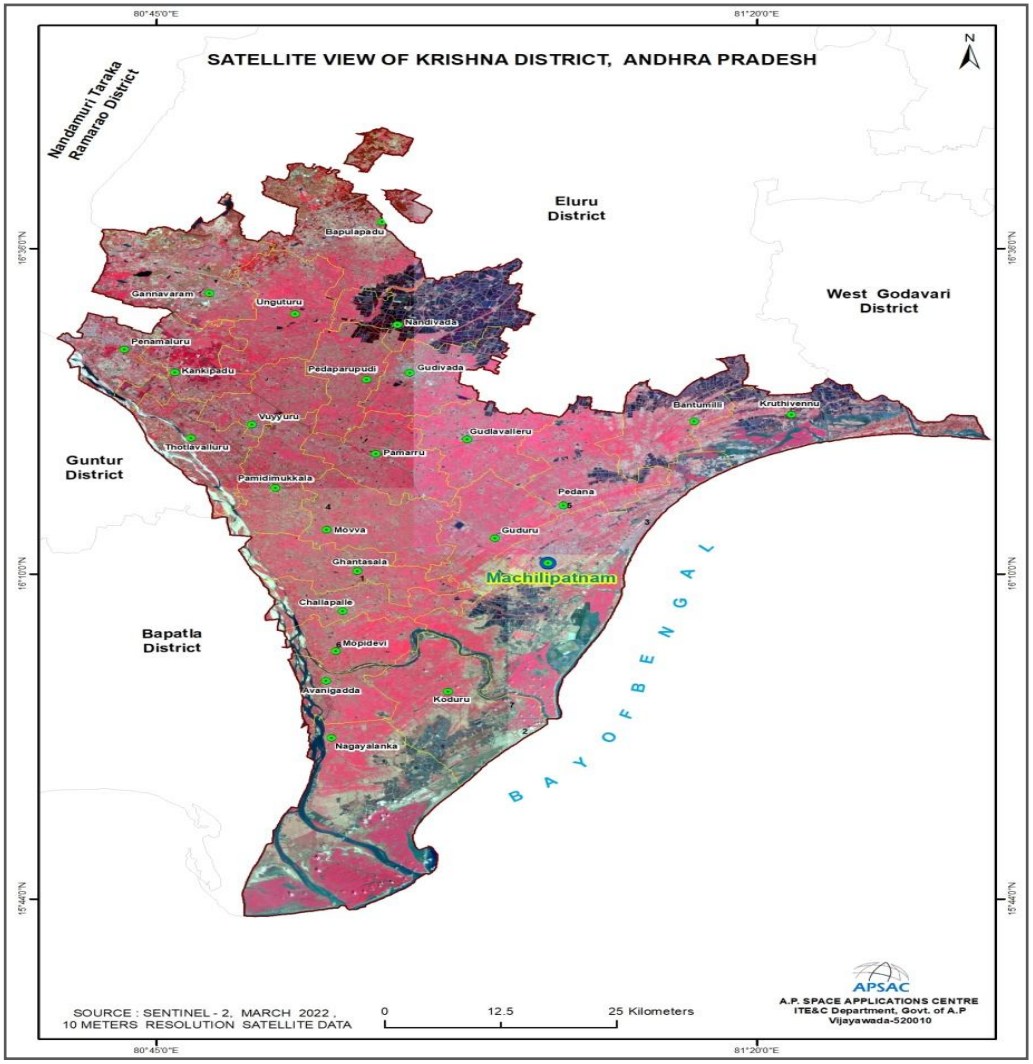


Figure-2: Satellite View of Krishna District

1.2 Physiography

1.2.1 Physiography

Physiographically, Krishna District is typically a deltaic region composed of nearly level plain lands. A few patches of highly steeping slopes can be found in the north- north western part of the district.

1.2.2 Relief

As per the guidelines of the All India Soil and Land Use Planning (AIS & LUP) soil survey manual, the slope distribution clearly shows that the district terrain is plain, and the slope varies from nearly level to very steep slopes (Figure-3). More than 79% of the district is under nearly level sloping areas (0-1%) and is found in deltaic areas along with very gently sloping (1-3%) areas, which are found along the streams and 18.66% of the land is under very gently slopes. The remaining slope categories are found along the scrubs and forest areas. Very steep slopes (>35%) are observed at the peak of the hills and are concentrated more in the northern parts of the district.

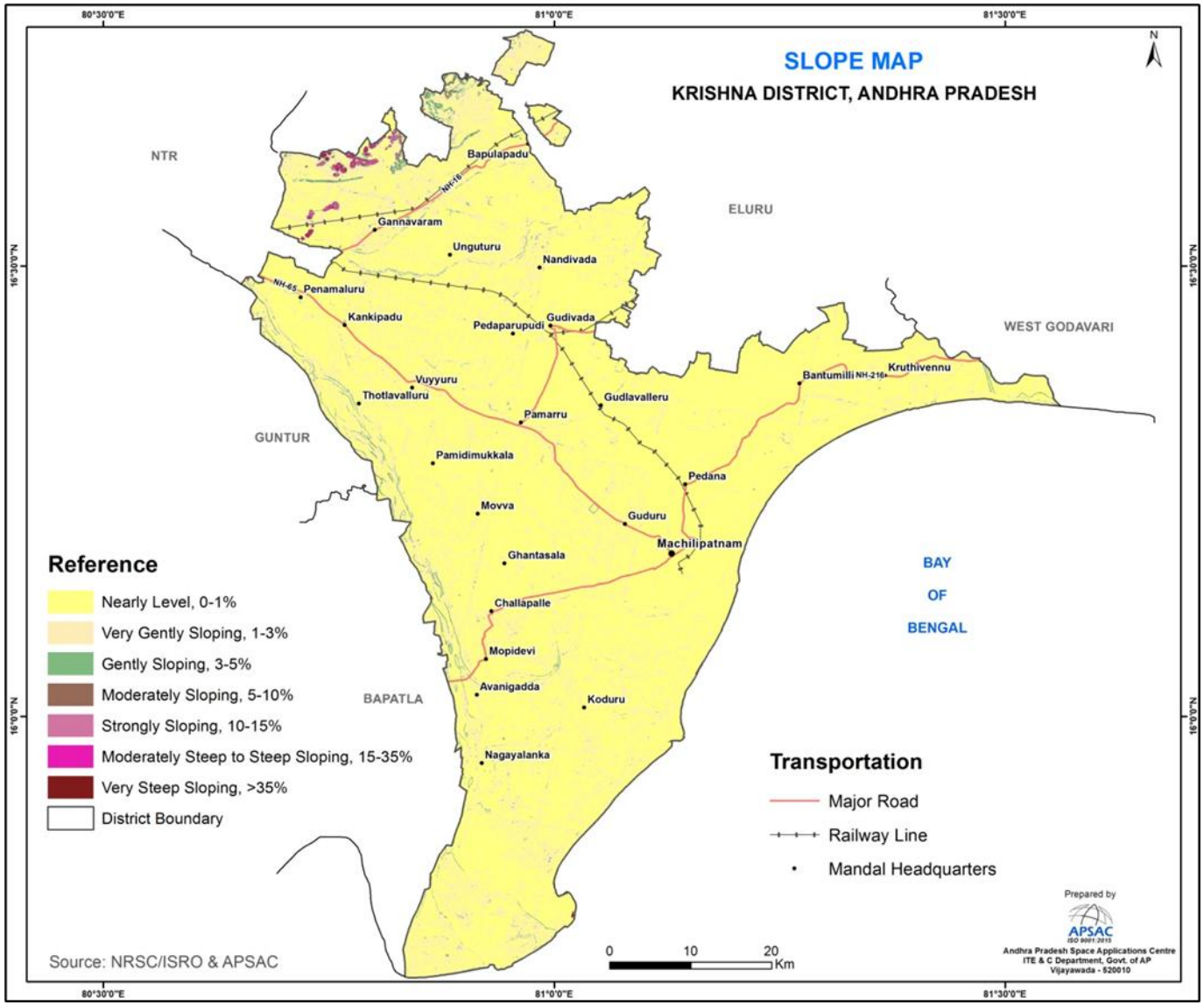


Figure-3: Slope Map of Krishna District

1.2.3 Climate & Rainfall

1.2.3.1. Climate:

Tropical climate conditions with extremely hot summer and cold winter prevail in this District. During the months of April to June is the hottest period with the high temperature in May. The climate of the district is moderate and characterized by a tropical rainy climate with aggressive summer. The period from December to the middle of February month is generally the season of fine weather. The area experiences dry, sub-humid, mega thermal climate with oppressive summer and good seasonal rainfall. The southwest monsoon sets in the second week of June and lasts till September end. October and November receive rainfall from northeast monsoon. The winter starts from December and lasts till mid February followed by summer season up to early June. The mean minimum and maximum temperatures recorded in the district are 21.6° C in the months of January and 36° C in May respectively. The average rainfall for the last 25 years data used for the analysis. The locations of Automatic Weather Stations (AWS) in Krishna District shown in Figure-4.

1.2.3.2. Rainfall:

The study of long term rainfall pattern from the rain gauge at Machilipatnam shows that the long term normal is 1052 mm and 55% of the years in this period the area received normal rainfall and 17 % of years the area received excess rainfall where and 28% of the years received deficit rainfall. Most of the rainfall (68%) occurs during the southwest monsoon season. The average annual rainfall of the district is 1023.45 mm, of which 665.81 mm falls as South-West (June-September) and 263.55 mm as North-East (October-December) monsoon. The mean minimum and maximum temperatures recorded in the district are 21.6° C in January and 36° C in May, respectively. The average rainfall for the last 25 years is used for the analysis. The average annual rainfall is shown in Figure-5 and details are given in Table-2.

Table 2 Average Annual Rainfall (mm) in the district, during the year 1997-2021

S.No	Month	Average Annual Rainfall (mm)
1	January	7.38
2	February	11.42
3	March	11.32

4	April	13.09
5	May	50.88
6	June	127.03
7	July	189.63
8	August	184.08
9	September	165.08
10	October	162.12
11	November	81.80
12	December	19.63
	Total	**1023.45**

Data source: AWS & APSDPS, Vijayawada

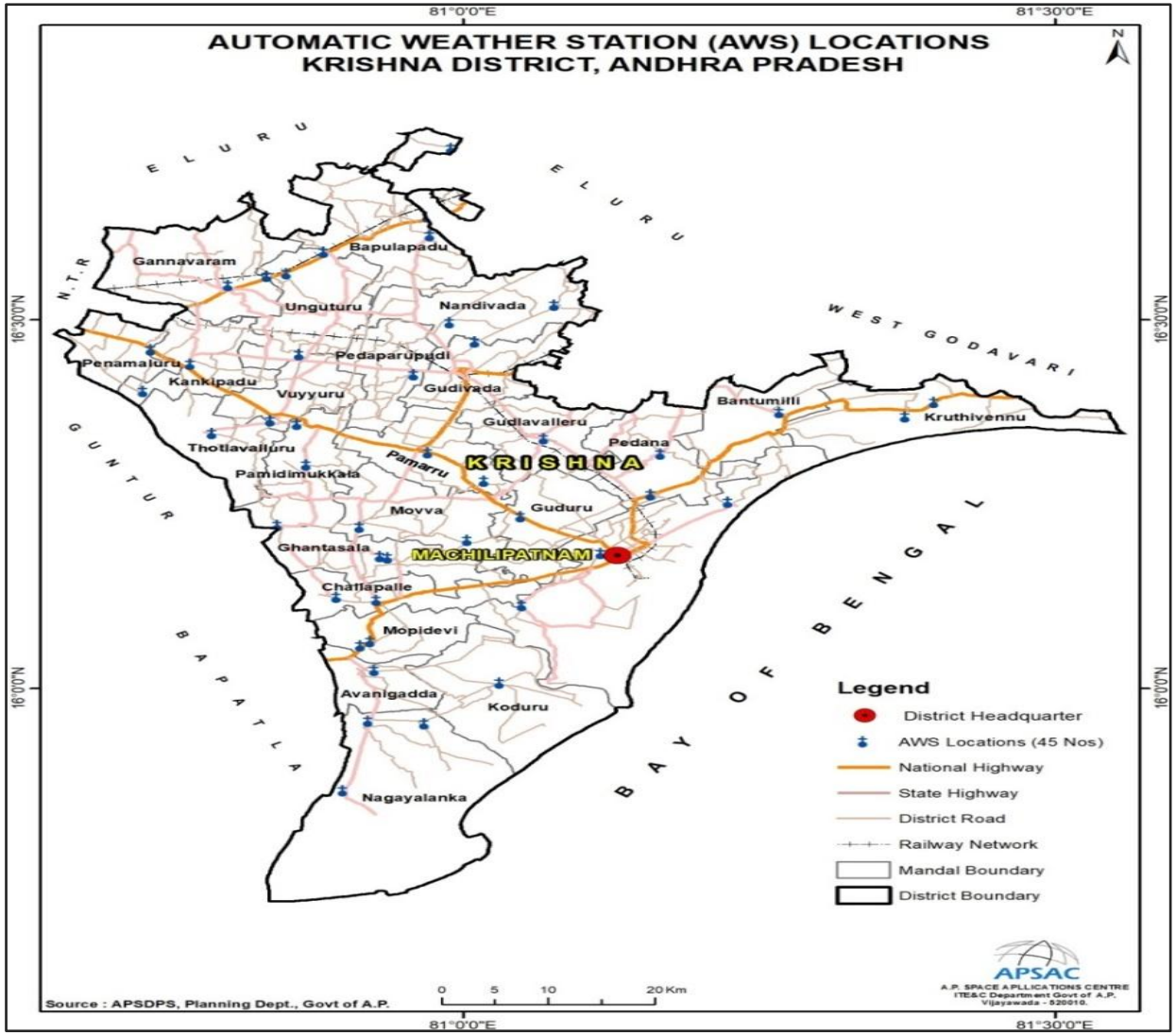


Figure-4: Locations of Automatic Weather Stations (AWS) in Krishna District

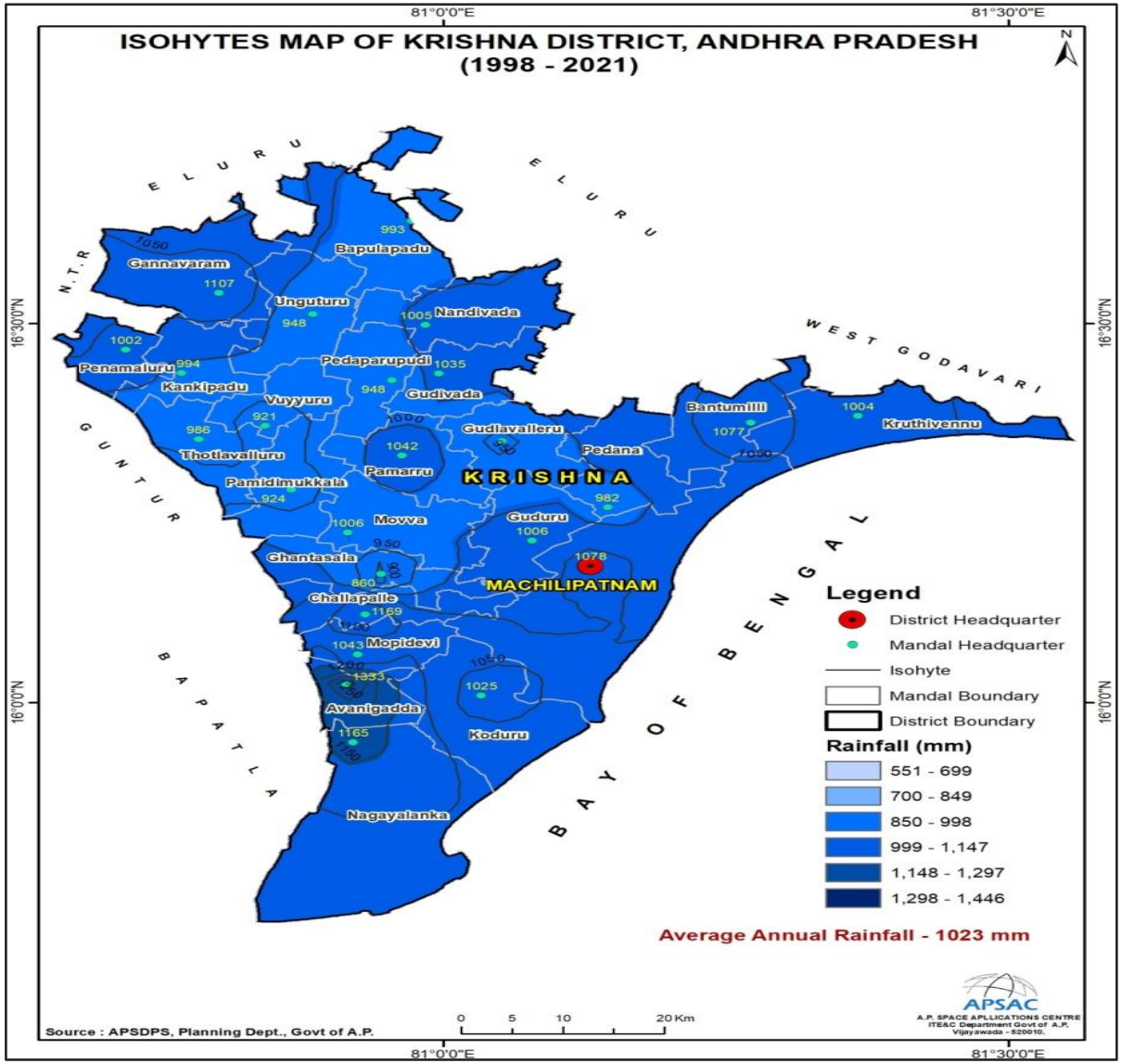


Figure-5: Rainfall distribution in Krishna District

1.2.4 Drainage

The district is named as Krishna District after the holy River Krishna and which is situated between15°43'-00" & 17°10'-00" Northern latitude and 80° 00'-00" & 81° 33'-00" in Eastern latitude. Krishna District lies in the Krishna River basin (45%), Budameru basin (2.67%) Thammileru Basin (3.3%) and Ramileru Basin(2.67%).The District is bordered by Khammam District on North, Bay of Bengal on South, Bay of Bengal and West Godavari District on East, and River Krishna, Guntur and Nalgonda District on West. The river Krishna which skirts the western boundary of the district provides irrigation facilities in the Krishna District.

1.3 Population and Literacy

1.3.1. Population:

The total population of the district is 17,35,079 (as per the 2011 census of India); of which male and female are 8,69,215 and 8,65,864 respectively. Among all the mandals, Machilipatnam Mandal is having maximum population of 2,38,962; whereas Pedaparupudi Mandal is having minimum population of 31,348.

The total schedule caste(SC) population in the district is 3,46,989; of which male and female are 1,72,677 and 1,74,312 respectively. The schedule tribe (ST) population is 37,716; of which male and female are 18,881 and 18,835 respectively. The mandal wise population is shown in Table-3. The mandal wise spatial distribution of population is depicted in Figure-6.

1.3.2. Literacy:

The total literacy in the district is 11,83,966; of which male and female are 6,21,172 and 5,62,794 respectively. The total illiterates are 5,51,113; of which male and female are 2,48,043 and 3,03,070 respectively. The mandal wise Literacy is shown in Table-4.

1.3.3. Details of the Occupational Health issues in the District (Last five-year data of number of patients of Silicosis): No cases were reported during last 5 years due to mining activity.

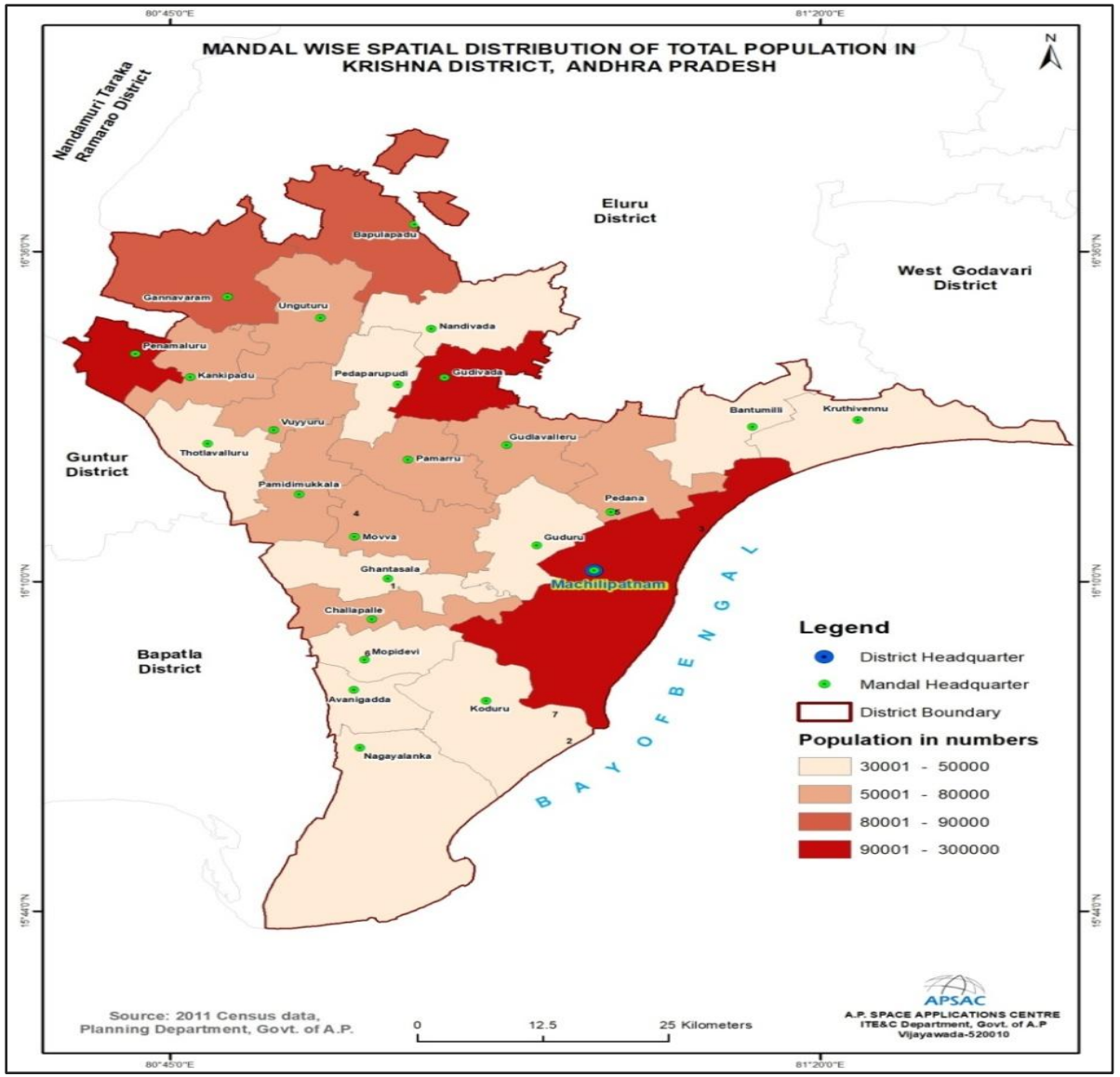


Figure-6: Mandal wise Spatial Distribution of Population in Krishna district, Andhra Pradesh

Table 3 mandal wise Population Statistics

S.No	Mandal Name	No. of House Holds	Total Population	Total Male Population	Total Female Population	Total SC Population	Male SC Population	Female SC Population	Total ST Population	Male ST Population	Female ST Population
1	Avanigadda	11954	40986	20966	20020	6588	3384	3204	1193	614	579
2	Bantumilli	13335	46370	23116	23254	6638	3277	3361	898	425	473
3	Bapulapadu	24036	84922	42406	42516	21375	10648	10727	2036	1035	1001
4	Challapalle	16430	53540	26593	26947	11963	5838	6125	1448	713	735
5	Gannavaram	23409	87027	43172	43855	22562	11123	11439	1960	1004	956
6	Ghantasala	12946	40098	20182	19916	14693	7393	7300	1155	585	570
7	Gudivada	43430	161453	80752	80701	31644	15531	16113	1895	950	945
8	Gudlavalleru	14821	51753	25711	26042	14944	7417	7527	1208	596	612
9	Guduru	14310	49228	24823	24405	6946	3542	3404	698	352	346
10	Kankipadu	18719	69562	36178	33384	19841	9881	9960	1491	774	717
11	Koduru	13684	45281	22924	22357	5858	2919	2939	722	365	357
12	Kruthivennu	13830	48892	24405	24487	2303	1124	1179	1034	521	513
13	Machilipatnam	66191	238962	118820	120142	21052	10672	10380	4429	2193	2236
14	Mopidevi	10761	35967	18447	17520	9050	4538	4512	969	481	488
15	Movva	16108	52974	26666	26308	15523	7908	7615	1504	753	751
16	Nagayalanka	14680	47899	25076	22823	6160	3186	2974	1310	699	611
17	Nandivada	11247	36924	18491	18433	12408	6234	6174	694	343	351
18	Pamarru	16256	54634	26847	27787	17243	8474	8769	1809	907	902
19	Pamidimukkala	16330	53913	26835	27078	13722	6804	6918	1018	499	519
20	Pedana	18916	65657	32831	32826	7436	3705	3731	848	430	418
21	Pedaparupudi	9625	31348	15474	15874	10745	5379	5366	747	372	375
22	Penamaluru	42789	168022	84485	83537	22057	10913	11144	4561	2229	2332
23	Thotlavalluru	11781	38641	19118	19523	11830	5836	5994	799	398	401
24	Unguturu	15839	54323	26660	27663	16428	8015	8413	1271	649	622
25	Vuyyuru	21682	76703	38237	38466	17980	8936	9044	2019	994	1025
	Grand Total	**493109**	**1735079**	**869215**	**865864**	**346989**	**172677**	**174312**	**37716**	**18881**	**18835**

Data Source: 2011 Census data, Planning Department & DES.

Table 4 Mandal wise Literacy statistics

S.No	Mandal Name	Total Literacy	Male Literacy	Female Literacy	Total Illiterates	Male Illiterates	Female Illiterates
1	Avanigadda	29070	15383	13687	11916	5583	6333
2	Bantumilli	28439	14986	13453	17931	8130	9801
3	Bapulapadu	55236	28807	26429	29686	13599	16087
4	Challapalle	36439	18794	17645	17101	7799	9302
5	Gannavaram	58379	30457	27922	28648	12715	15933
6	Ghantasala	27212	14319	12893	12886	5863	7023
7	Gudivada	116556	61050	55506	44897	19702	25195
8	Gudlavalleru	35443	18400	17043	16310	7311	8999
9	Guduru	32523	17302	15221	16705	7521	9184
10	Kankipadu	48387	26841	21546	21175	9337	11838
11	Koduru	28143	14924	13219	17138	8000	9138
12	Kruthivennu	29119	15360	13759	19773	9045	10728
13	Machilipatnam	171144	88632	82512	67818	30188	37630
14	Mopidevi	23113	12553	10560	12854	5894	6960
15	Movva	35933	19157	16776	17041	7509	9532
16	Nagayalanka	29995	16525	13470	17904	8551	9353
17	Nandivada	24673	12895	11778	12251	5596	6655
18	Pamarru	37818	19317	18501	16816	7530	9286
19	Pamidimukkala	35136	18430	16706	18777	8405	10372
20	Pedana	40380	21554	18826	25277	11277	14000
21	Pedaparupudi	21766	11148	10618	9582	4326	5256
22	Penamaluru	122471	63888	58583	45551	20597	24954
23	Thotlavalluru	25094	12984	12110	13547	6134	7413
24	Unguturu	35641	18480	17161	18682	8180	10502
25	Vuyyuru	55856	28986	26870	20847	9251	11596
	Grand Total	**1183966**	**621172**	**562794**	**551113**	**248043**	**303070**

Data Source: 2011 Census data, Planning Department & DES

1.4 Land Utilization Pattern

1.4.1 Land Use / Land Cover

The Land Use / Land Cover (LULC) pattern of any region is an outcome of various physical and cultural factors and their utilization by man in time and space. Land use refers to the type of utilization to which man has put the land. It also refers to the evaluation of the land with respect to various natural characteristics. But land cover describes the vegetal attributes of the land. Land use/land cover data is essential for planners, decision-makers, and those concerned with land resource management. For a proper understanding of the influence of the various human-induced land-use practices with regard to environmental change, it is essential to help simulate the land-use changes. Remote sensing technology is considered the most effective as it provides timely and authentic information about the spatial distribution of land use/land cover, while the Geographical Information System (GIS) provides a flexible digital environment for collecting, storing, visualizing, and analyzing spatial data. Remote sensing as a vital tool helps for rapid assessment and monitoring of a natural resource. When combined with GIS, it makes it possible to map land use/ land cover phenomena in detail for further planning, development, and decision-making, which is essential for meeting the increasing demands and welfare of the ever-growing population.

1.4.2 Spatial Distribution of Land Use / Land Cover

Using on-screen interpretation techniques, the major common LULC categories such as built-up (240.77 sq. km), agriculture (2926.69 sq. km), forest (170.90 sq. km), wastelands (34.48 sq. km), wetlands (179.36 sq. km), and water bodies (222.79 sq. km) were identified and delineated. The study area has been mapped into 31 level-III LULC classes (NRSC, 2006). The predominant category is agricultural land followed by built-up. About 78% of the land is under the agriculture category spread over the district. The spatial distribution of land use/land cover map of Krishna district is presented in Figure-7 and the area statistics are shown in Table-5.

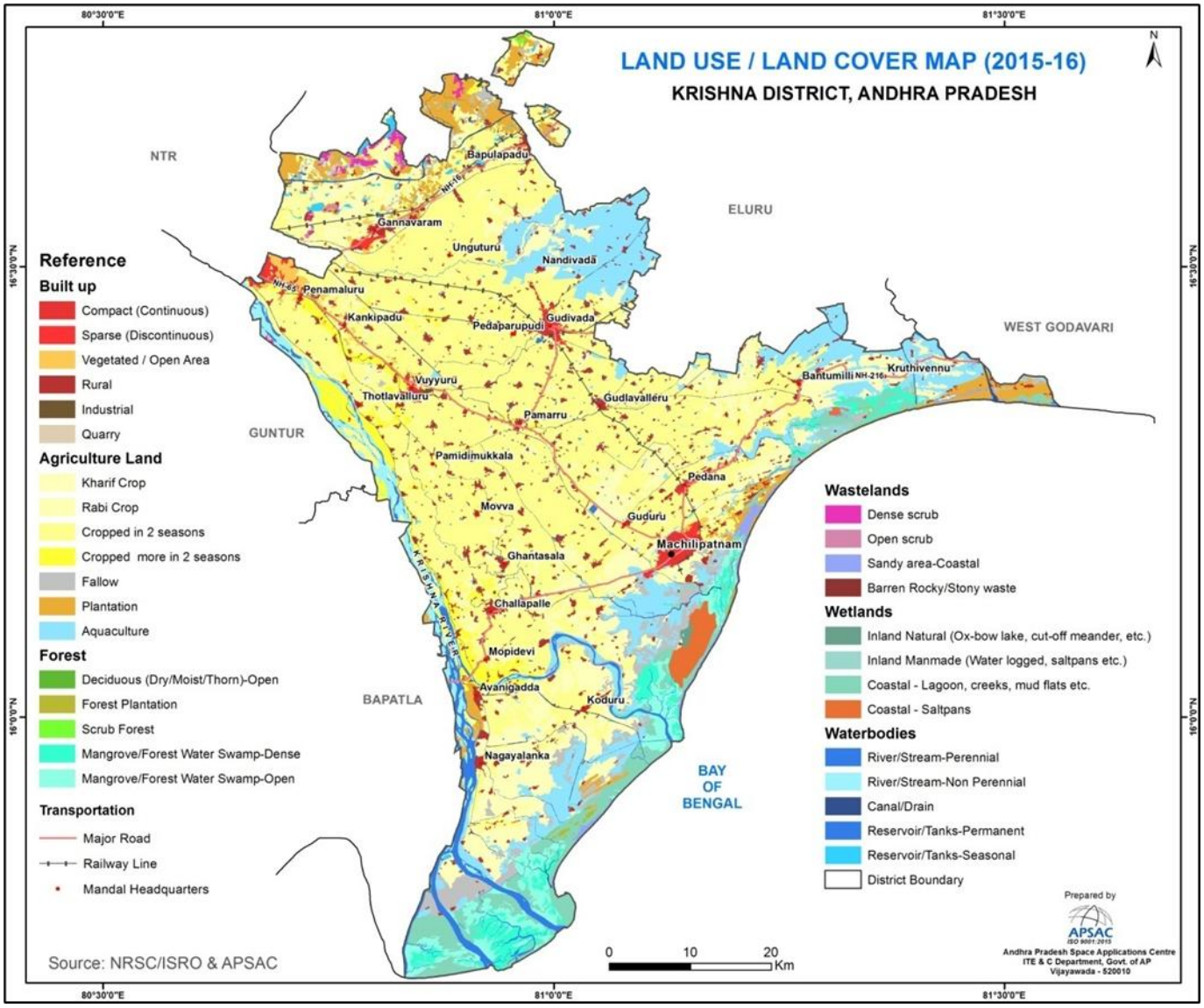


Figure-7: Land use / land cover map of Krishna District 2015-16

Table 5 Category-wise distributions of Land Use/Land Cover during 2015-16

S. No	LULC categories	Area in sq. km	% to total
Built Up		**240.77**	**6.38**
1	Compact (Continuous)	31.95	0.85
2	Sparse (Discontinuous)	13.92	0.37
3	Vegetated / Open Area	26.58	0.70
4	Rural	161.38	4.28
5	Industrial	6.06	0.16
6	Quarry	0.88	0.02
Agricultural Land		**2926.69**	**77.53**
7	Kharif Crop	582.64	15.43
8	Rabi Crop	15.27	0.40
9	Cropped more in 2 seasons	1616.92	42.83
10	Cropped in 2 seasons	96.50	2.56
11	Fallow	109.71	2.91
12	Plantation	129.39	3.43
13	Aquaculture	376.26	9.97
Forest		**170.90**	**4.53**
14	Deciduous (Dry/Moist/Thorn)-Open/Closed	0.05	0.00
15	Forest Plantation	4.34	0.11
16	Scrub Forest	1.17	0.03
17	Swamp Forest (Mangrove)-Dense	70.67	1.87
18	Swamp Forest (Mangrove)-Open	94.68	2.51
Wastelands		**34.48**	**0.91**
19	Dense scrub	11.32	0.30
20	Open scrub	3.67	0.10
21	Coastal Sand	19.39	0.51
22	Barren Rocky/Stony waste	0.10	0.00
Wetlands		**179.36**	**4.75**
23	Inland Natural	3.07	0.08
24	Inland Manmade (Water logged, saltpans etc.)	12.66	0.34
25	Coastal - Lagoon, creeks, mud flats etc.	136.90	3.63
26	Coastal - Saltpans	26.73	0.71
Water bodies		**222.79**	**5.90**
27	River/Stream-Perennial	86.97	2.30
28	River/Stream-Non Perennial	63.81	1.69
29	Canal/Drain	41.66	1.10
30	Reservoir/Tanks-Permanent	13.04	0.35
31	Reservoir/Tanks-Seasonal	17.30	0.46
Total		**3775.00**	**100.00**

Data source: NR Census 3rd cycle mapping, NRSC/ISRO & APSAC, GoAP

1.4.2.1. Built-up

These are the areas where people live and are supported by infrastructure such as buildings, roads, and other modes of transportation, as well as utilities connected to water, vegetation, and open spaces. It consists of built-up (Compact and Sparse), Vegetated / Open Area, Rural, Industrial, and Mining/Quarry. It occupies an area of 240.77 sq. km, which is about 6.38% of the total geographical area of the district. The built-up category includes district headquarters, some mandal headquarters, industrial areas, and rural settlement areas based on size and population. Many vacant lands with layouts and fencing are being developed for real estate development on the outskirts of the major Machilipatnam, Gudivada, and Tadigadapa towns.

1.4.2.2. Built-up - Compact (Continuous)

Most of the land is covered by buildings, roads, and artificially surfaced areas and covers almost all the ground. The built-up-compact class is assigned where the impermeable surfaces such as the transportation network and urban structures take up more than 80% of the surface area. This category occupied 31.95 sq. km, which are found in Machilipatnam, Gudivada, and Tadigadapa towns.

1.4.2.3. Built-up - Sparse (Discontinuous)

Most of the land is covered by structures like buildings, roads, and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces. Between 30 to 80 % of the total surface should be impermeable. Scattered blocks of residential flats, hamlets, and small villages are delineated under this category. It contributes an area of 13.92 sq. km, which is found in peri-urban areas.

1.4.2.4. Vegetated / Open Area

These are vegetated areas within the urban agglomeration (situated within or in contact with urban areas). The vegetation cover of trees, shrubs, and herbs covers the surface area, and it has been delineated. Open areas used as Parks, sports and leisure facilities, camping grounds, sports grounds, leisure parks, golf courses, race courses, including formal parks, etc are considered in this category. This category occupies an area of 26.58 sq. km and is found in and around Machilipatnam, Gudivada, and Tadigadapa towns.

1.4.2.5. Built-up – Rural

These are the lands used for human settlement of size comparatively less than the urban settlements of which more than 80% of the people are involved in the primary activity of agriculture and associated with non-commercial and allied classes are identified as a built-up (rural) category.

The rural built-up area is the predominant category among the built-up category and is spread over the district. It contributed an area of 161.38 sq. km (4.282%).

1.4.2.6. Industrial

Non-linear impervious surfaces are included in this class which is related to trade, manufacturing, distribution, and commerce. These are areas where human activity is observed in the form of manufacturing along with other supporting establishments for maintenance. The industrial area occupies an area of 6.06 sq. km, which is observed in and around towns.

1.4.2.7. Quarry

These are manifestations of surface mining operations wherein small-scale excavation of the land surface of sand, gravel, granite, quartzite quarries, etc., are taking place. They are mostly characterized by their nearness to urban areas. It contributes an area of 0.88 sq. km of the district's total area.

1.4.2.8. Agricultural Land

Agriculture land is primarily used for the production of food, fiber, and other commercial and horticultural crops. It includes land under crops namely cropland, fallow land, agricultural plantation, and aquaculture. The district's economy is primarily based on agriculture, which was found to account for 2926.69 sq. km (77.53%) of its total area during the period. It is also found that the double-cropped area accounts for about 77.53% of the district total. The major agricultural products are Rice, Maize, Jowar, Cotton, Sugarcane, Groundnuts, Pulses, Chillies, Mango, Guava, Oil Palm, Coconut, Cashew, Lemon, etc. Similarly, vegetables grown in the district include Cucumber, Gaurds, Bhendi, Brinjal, Tomato, Cabbage, Cauliflower and leafy vegetables.

1.4.2.9. Kharif Crop

The agricultural area cultivated between June/July to September/October coinciding with the southwest monsoon season is considered Kharif crop. It is associated with rain-fed crops under dry land farming with limited or no irrigation and areas of rain-fed paddy and other dry crops. Kharif cropland is the second-largest agricultural category, covering 582.64 sq. km (15.43%).

1.4.2.10. Rabi Crop

These areas are cultivated between November/December to February/March. It is associated with areas under assured irrigation irrespective of the source of irrigation. However, Rabi-cropped areas also occur in rain-fed regions, under residual soil moisture conditions especially in black soil areas with high rainfall during the Kharif season. Mainly irrigated crops like rice, sugarcane and chillies are grown during the Rabi season by utilizing canals,

tanks and groundwater resources. In some places, lift irrigation is also practiced in the district. Rabi cropland occupied an area of 15.27 sq. km (0.40%) during the year 2015-16.

1.4.2.11. Cropped in two seasons

These are the areas that are cropped during two cropping seasons that are often seen associated with irrigated areas. Three combinations are possible in this category viz., - Kharif + Rabi, Kharif + Zaid, and Rabi + Zaid. Areas under crop during any two seasons are mapped under cropped in 2 season's category and it occupies an area of 96.50 sq. km (2.56%). These can be found all over the district, with reliable irrigation facilities provided by canals, tanks, and groundwater.

1.4.2.12. Cropped in more than two seasons

These are the areas that are cropped in more than two cropping seasons. It includes triple-cropped areas (Kharif, Rabi, and Zaid), and areas under multiple cropping. Long-duration crops like sugarcane, cotton, banana, and tobacco are considered under this category. This category accounts for 1616.92 sq. km (42.83%) of the district's total geographical area.

1.4.2.13. Fallow land

The agricultural land which is being used for cultivation, but is temporarily allowed to rest or un-cropped for one or more seasons, but not less than a year and for not more than five years is referred to as fallow land. The fallow land covers an area of 109.71 sq. km and is devoid of crops during both cropping seasons for various reasons.

1.4.2.14. Agricultural Plantation

These are the areas under agricultural tree crops planted adopting agricultural management techniques. These also include the areas of land use systems and practices wherein the cultivation of herbs, shrubs, and vegetable crops are deliberately integrated with crops mostly in irrigated conditions for ecological and economic reasons. These areas are separable from cropland, especially with the data acquired during the Rabi/Zaid season. Plantations appear in dark-red to red tones of different sizes with regular and sharp edges indicating the presence of a fence around it. Plantations such as banana, mango, guava, oil palm, coconut, lemon, teak, and others are grown throughout the district. The plantations category occupies an area of 129.39 sq. km (3.43%) of the total geographical area of the district.

1.4.2.15. Aquaculture

These are the areas where fish and shrimp are bred and reared for commercial purposes. Aquaculture ponds are located mostly along the coast or in lakes, rivers, and estuaries. This also includes Breeding and rearing of freshwater or marine fish in captivity. The aquaculture category occupies an area of 376.26 sq. km. It is found in and around Kolleru Lake and along with Krishna and Upputeru rivers.

1.4.2.16. Forest

The term forest is used to refer to land with a tree canopy cover of more than 30 percent and an area of more than 0.5 ha. Forest is determined both by the presence of trees and the absence of other predominant land uses within the notified forest boundaries. The trees should be able to reach a minimum height of 5 m within the notified forest boundaries. The forest area occupies an area of 170.90 sq. km (4.53%) and is found in the north and east of the district where several forest species grow.

1.4.2.17. Deciduous (Dry/Moist/Thorn)-Open

This category is predominantly composed of species, which shed their leaves once a year, especially during summer. These are mostly broad-leaved tropical forests with a tendency to shed their leaves annually. This category includes all the forest areas where the canopy cover/density ranges between 10% - 40%. In addition to timber, these forests also contain a large variety of fauna like tigers, leopards, wolves, bears, etc. An area of 0.05 sq. km is attributed to this category.

1.4.2.18. Forest Plantation

These are the locations where important tree species for forestry are grown and managed, particularly in notified forest areas. The majority of these are found in uplands and coastal regions. Many of these can be identified based on the sharp boundaries exhibited by them. Forest plantations, mainly teak, bamboo, casuarinas, etc have been delineated with an area of 4.34 sq. km during the period.

1.4.2.19. Scrub Forest

These are the forest areas that are generally seen on the fringes of dense forest cover and settlements, where there is biotic and abiotic interference. Most times they are located closer to habitations. Forest blanks which are the openings amidst forest areas, devoid of tree cover, observed as openings of assorted sizes and shapes as manifested in the imagery are also included in this category. The scrub forests accounted for 1.17 sq. km (0.03%),

which is generally prone to the conversion of forest plantations and other development activities within the notified forest.

1.4.2.20. Swamp Forest (Mangrove)-Dense

These are the areas with plants evergreen in nature, halophytic, dense or woody in nature, occurring along tidal waters/creeks, estuaries, and along the delta in coastal areas. They are densely colonized in coastal areas on tidal flats, estuaries salt marshes, etc. This category includes all the areas where the canopy cover/density is more than 40%. This category is found along the coastal areas with an account of 70.67 sq. km (1.87%) in the district.

1.4.2.21. Swamp Forest (Mangrove)-Open

These are the areas with plants evergreen in nature, halophytic, dense, or woody in nature, occurring along tidal waters/creeks, estuaries, and along the delta in coastal areas. They are densely colonized in coastal areas on tidal flats, estuaries salt marshes, etc. This category includes all the forest areas where the canopy cover/density ranges between 10% - 40%. It is found that 94.68 sq. km (2.51%) area is under this category in the district.

1.4.2.22. Wasteland

Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating due to lack of appropriate water and soil management or on account of natural causes. Wastelands can result from inherent/imposed disabilities such as location, environment, chemical and physical properties of the soil, or financial or management constraints. During the study, the area under the wasteland category was mapped at 34.48 sq. km (0.91%), which includes the subcategories of dense scrub, open scrub, and barren rocky/stony waste.

1.4.2.23. Dense scrub

The scrub is usually confined to topographically elevated areas, on the hill slopes generally surrounded by agricultural lands. These areas possess shallow and skeletal soils, at times chemically degraded, extremes of slopes, severely eroded, and lands subjected to excessive aridity with scrubs dominating the landscape. It is found with varying sizes of small to large areas having a contiguous or dispersed pattern. The dense scrub areas can be found on hills with moderate slopes. The area was mapped at 11.32 sq. km during the period.

1.4.2.24. Open scrub

This category has a similar description as mentioned in the dense scrub except that they possess sparse vegetation or are devoid of scrub and have a thin soil cover. The open scrub areas are found at the foothills and moderate to gentle slopping areas are surrounded by agricultural lands. The area mapped under this category is about 3.67 sq. km.

1.4.2.25. Coastal Sand

Coastal sands are the sands that are accumulated as a strip along the sea coast. Very high reflectance exhibited by this category, especially in the near-infrared region of the spectrum enables their separation with the salt-affected land. It is found in along the coast and occupies an area of 19.39 sq. km (0.51%).

1.4.2.26. Barren Rocky/Stony waste

The barren rock exposures are especially confined to hilly terrain with down slopes with rock outcrops, stony waste, and fragments. Barren rocky areas have been observed as rocky outcrops in the forest and scrubland. It is found that most of the barren rocky areas are being quarried for various construction activities in the district. The area under this category is 0.10 sq. km.

1.4.2.27. Wetlands

All submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic which necessarily have a land-water interface, are defined as wetlands. Hence, the portions of the water body (partial or full) having emergent vegetation or observable submerged vegetation is placed in the Wetlands category. The wetland category contributes 179.36 sq. km and is found along the coastal areas.

1.4.2.28. Inland Natural

These are the areas that include ox-bow lakes, cut-off meanders, playas, swamps, marsh, peat bogs, etc (with vegetation). This category contributes to 3.07 sq. km of the district's total geographical area.

1.4.2.29. Coastal - Lagoon, creeks, and mud flats etc.

These are the areas which are submerged by high tides at some stage of the annual tidal cycle. Non-wooded areas are tidally, seasonally or permanently waterlogged with brackish or saline water. These include estuaries, lagoons, creeks, backwaters, bay tidal flat/mud flat, mangrove, salt marsh/marsh with vegetation and other hydrophytes vegetation. These are found in coastal areas of the district with an area of 136.90 sq. km.

1.4.2.30. Inland Manmade (Water logged, saltpans etc.)

For the majority of the year, these are the areas flooded or prone to flooding by fresh, brackish, or standing water, with specific vegetation coverage consisting of low shrub, semi-ligneous, or herbaceous species. Waterlogged areas (seasonal and perennial) are formed as a result of the negative effects of human management practices and are vegetated. The saltpans are flat expanses of salt-covered land, usually white under the Sum. Saltpans are manmade saline ecosystems from which crude salt is extracted during summer. These are un-drained, usually small and shallow, natural depressions or hollows in which brackish water accumulates and evaporates leaving behind salt deposits. About 12.66 sq. km is occupied by this category in the district.

1.4.2.31. Coastal – Saltpans

The saltpans are flat expanses of salt-covered land, usually white under the Sum. Saltpans are manmade saline ecosystems from which crude salt is extracted during summer. These are un-drained, usually small and shallow, natural depressions or hollows in which brackish water accumulates and evaporates leaving behind salt deposits. About 26.73 sq. km of area is occupied by this category in the district along the coast.

1.4.2.32. Water Bodies

This category comprises areas with surface water, either impounded in the form of ponds, lakes, and reservoirs or flowing as streams, rivers, canals, etc are delineated. These are seen clearly in the satellite image in blue to dark blue or cyan colour depending on the depth of water. This category comprises rivers, streams, canals, lakes, ponds, reservoirs, and tanks. The water bodies which include all the sub-categories are about 222.79 sq. km (5.90%).

1.4.2.33. River/Stream-Perennial

Rivers/streams are the natural course of water flowing on the land surface along a definite channel/slope regularly or intermittently towards a sea in most cases or a lake or an inland basin in desert areas or a marsh or another river. The rivers/streams that flow continuously throughout the year are considered as perennial. It contributes an area of 86.97 sq. km. The Krishna River flows through the district in a west-south direction.

1.4.2.34. River/Stream-Non Perennial

When the water covers the surface for less than nine months each year, it is considered non-perennial. This also includes the dry part of the river generally characterized by the presence of sand or exposed rocks. It is found

most of the rivers/streams are under the non-perennial category and it contributes an area of 63.81 sq. km.

1.4.2.35. Canal/Drain

Canals and drains are artificial watercourses constructed for irrigation, navigation or to drain out excess water from agricultural lands. It is found mostly in the coastal plains with an area of 41.66 sq. km.

1.4.2.36. Reservoir/Tanks-Permanent

The reservoir is an artificial lake created by the construction of a dam across the river specifically for hydel power generation, irrigation, and water supply for domestic/ industrial needs, and flood control, either singly or in combination. Tanks are small lakes of impounded waterways constructed on land surfaces for irrigation. They are associated with croplands, lowlands, and reservoirs surrounded by hills without vegetation. This includes all reservoirs/tanks with water spread seen at least during one season in a year is considered under the permanent category. The reservoir/tanks-permanent category was delineated with an area of 13.04 sq. km. These are one of the sources of irrigation and spread over the district.

1.4.2.37. Reservoir/Tanks-Seasonal

Dry reservoirs/tanks are those which do not have water spread throughout the year and are considered seasonal. During the mapping period, where the water spread not found in the three seasons, those areas are mapped in this category. Many of the tanks are found to be seasonal, with a total area of 17.30 sq. km.

1.4.3 Forest Cover Distribution

The forest cover maps were prepared based on the interpretation of multi-source topographical maps and IRS R2 LISS III satellite data. The term forest is used to refer to land with a tree canopy cover of more than 10 percent and an area of more than 0.5 ha. Forest is determined both by the presence of trees and the absence of other predominant land uses within the notified forest boundaries. The trees should be able to reach a minimum height of 5 m within the notified forest boundaries. The district's forest cover is primarily found along the coast and in a few isolated locations on the north. The predominant categories are dense mangroves and open mangroves, which contribute 70.67 sq. km and 94.68 sq. km, respectively. These are mostly concentrated along the coast. Forest plantations covering an area of 4.34 sq. km have been mapped. The scrub forest category covers an area of 1.17 sq. km of the district. The spatial distribution of forest cover

and its statistics are presented in Figure-8 and Table-6. As per the Forest Department, Government of Andhra Pradesh the Forest boundary map is presented in Figure-9 and Wildlife Sanctuary boundary map of Krishna District showed in Figure-9A.

Table 6 Forest cover distribution in Krishna District

S. No	Type of Forest	Area in sq. km	% to district total
1	Deciduous (Dry/Moist/Thorn)-Open/Closed	0.05	0.00
2	Forest Plantation	4.34	0.11
3	Scrub Forest	1.17	0.03
4	Swamp Forest (Mangrove)-Dense	70.67	1.87
5	Swamp Forest (Mangrove)-Open	94.68	2.51
	Total	**170.90**	**4.53**

Data source: NR Census 3rd cycle mapping, NRSC/ISRO & APSAC, GoAP

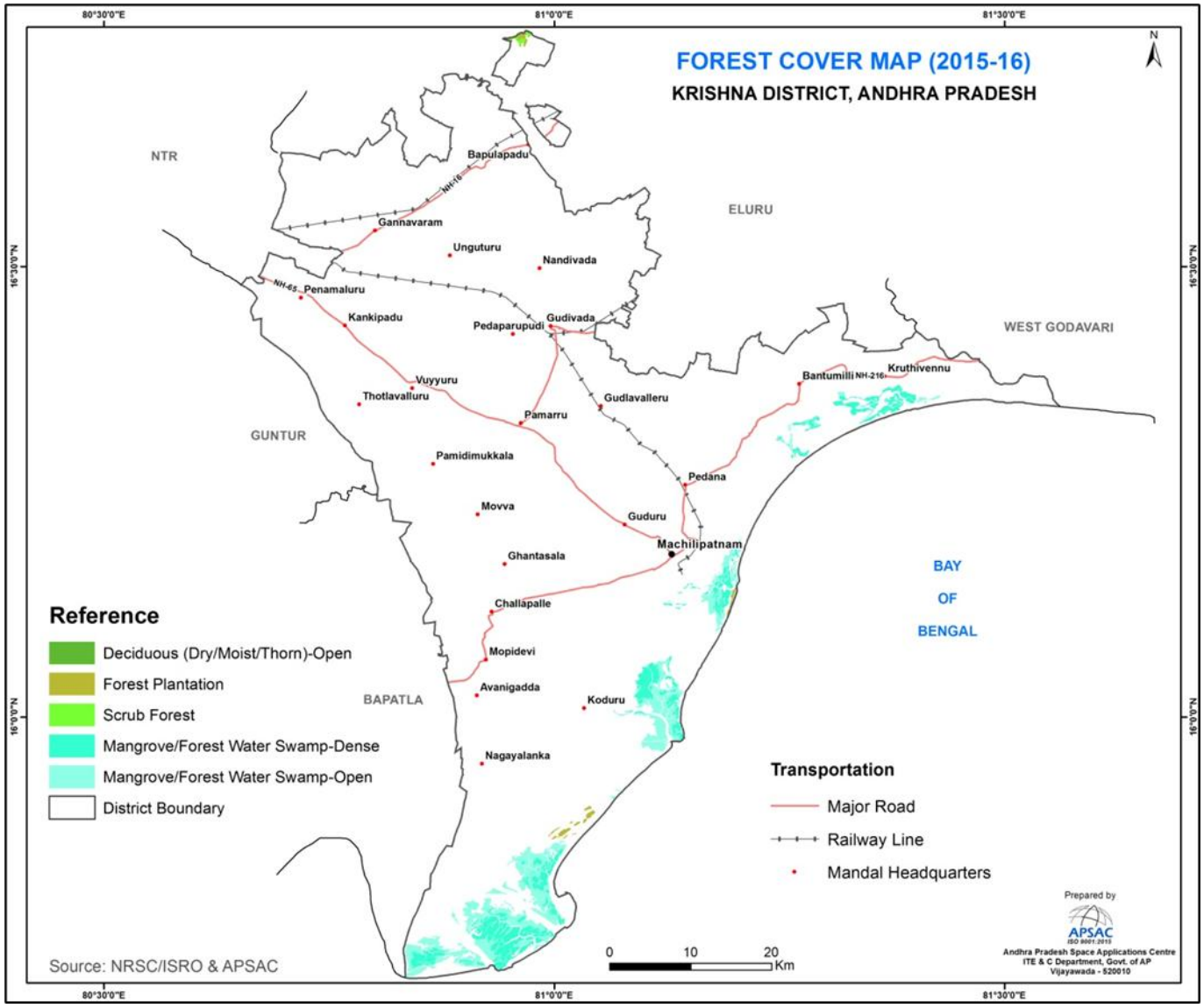


Figure-8: Forest cover map of Krishna District

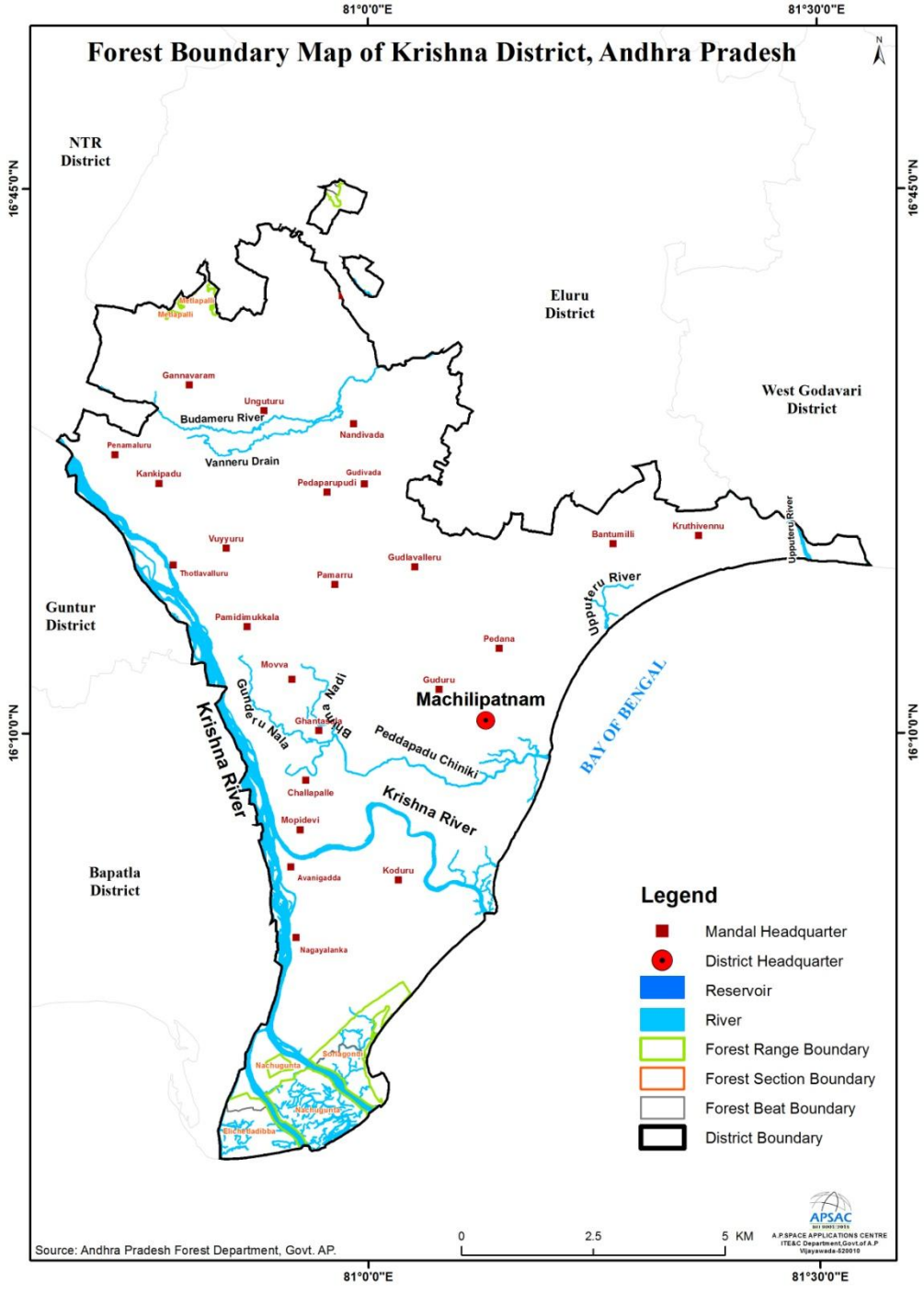


Figure-9: Forest boundary map of Krishna District

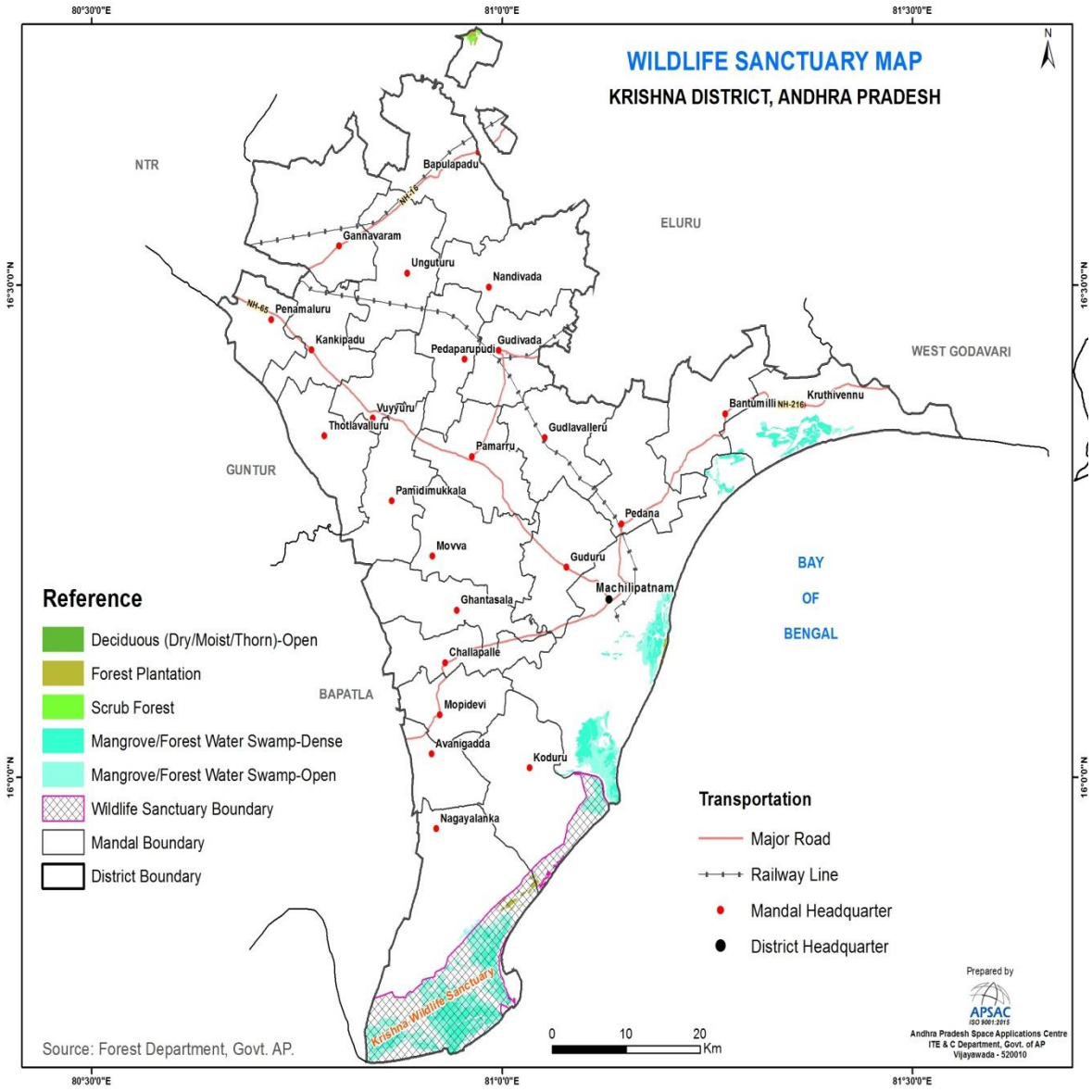


Figure-9A: Wildlife Sanctuary boundary map of Krishna District

1.4.4 Agricultural Resources in Krishna District

Over the past two decades, APSAC has effectively employed remote sensing technology in agriculture, encompassing both spatial and temporal dimensions across various projects. The continuous evolution of satellite remote sensing technology has facilitated systematic monitoring of crop conditions and vigor across extensive regions. Within the realm of spectral vegetation indices derived from remote sensing data, the Normalized Difference Vegetation Index (NDVI) stands out as the most widely utilized for operational drought assessment. Its popularity stems from its straightforward calculation, ease of interpretation, and the capacity to mitigate the impacts of atmospheric conditions, illumination geometry, and other variables.

APSAC conducted in-season crop condition assessments at the Mandal level in Andhra Pradesh. This initiative aimed to provide administrators and planners with crucial insights for strategic decision-making regarding drought management, import-export policies, and trade negotiations. The NDVI is calculated using the formula (NIR–Red)/(NIR+Red), where NIR and Red represent the reflectance in the visible and near-infrared channels, respectively. Water, clouds, and snow exhibit higher reflectance in the visible region, causing NDVI to assume negative values for these features. Bare soil and rocks, with similar reflectance in both visible and near-infrared regions, yield index values close to zero. NDVI values for vegetation typically range from 0.2 to 0.6, with higher values associated with greater green leaf area and biomass. The Shortwave Infrared (SWIR) band is sensitive to soil and crop canopy moisture. Early in the cropping season, when soil background dominates, SWIR is sensitive to top 12 cm soil moisture. As crop growth progresses, SWIR becomes sensitive to leaf moisture content, providing surface wetness information.

The Normalized Difference Wetness Index (NDWI), computed using SWIR data, complements NDVI for drought assessment, especially in the early cropping season. NDWI is derived as follows: NDWI=(NIR-SWIR)/(NIR+SWIR), where NIR and SWIR represent reflected radiation in the Near-Infrared and Shortwave Infrared channels. Higher NDWI values indicate increased surface wetness.

For satellite-based crop condition anomalies indicating agricultural drought, the Vegetation Condition Index (VCI) of both NDVI and NDWI can be computed. When combining VCI values of NDVI and NDWI, the minimum of the two can be considered. For instance, if at least one is categorized as severe, the overall category is considered severe. If at least one is moderate, the overall category is taken as moderate. The vegetation conditions and corresponding ranges are detailed in Table-7.

Table 7 Vegetation condition and range in percentage

VCI range (%)	Vegetation Condition	Description
60-100	Normal	Crop condition is Normal
40-60	Moderate	Crop condition is Moderate
0-40	Severe	Crop condition is Severe

1.4.4.1 Kharif Crop Condition Assessment

Andhra Pradesh Space Applications Centre (APSAC) conducted a crop condition assessment in Krishna district during Kharif 2022-23 utilizing MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data. The assessment revealed that out of the total mandals in the district, 17 were categorized as having a normal crop condition, 05 were classified as moderate, and 03 were identified as severe. Notably, urban and forest cover mandals were excluded from the vegetation condition assessment. This comprehensive evaluation provides valuable insights into the agricultural landscape of Krishna district, aiding in targeted interventions and resource allocation to mitigate the impacts of varying crop conditions.

1.4.4.2 Rabi Crop Condition Assessment

During Rabi 2022-23, the assessment identified 05 mandals with normal crop conditions, 05 mandals categorized as moderate, and 15 were identified as severe. Notably, mandals predominantly covered by urban or forest areas were excluded from the vegetation condition assessment. This evaluation provides valuable insights into the agricultural status of Krishna district during the Rabi season, facilitating informed decision-making and resource allocation to support agricultural sustainability and productivity.

1.4.5 Soil Resources of the Krishna District

In the Krishna district of Andhra Pradesh, a variety of soil types contributes to its diverse terrain. The predominant soil types in the district include deep black clayey soils, covering 1653.32 sq.km (45.05%), followed by moderately deep calcareous black soils at 970.24 sq.km (26.44%). Additionally, clayey to gravelly clayey moderately deep dark brown soils span 291.44 sq.km (7.94%), while loamy to clayey skeletal deep reddish brown soils occupy 215.95 sq.km (5.88%). Moderately deep calcareous moist clayey soils cover 184.86 sq.km (5.04%), with shallow gravelly red soils extending over 112.68 sq.km (3.07%). Light gray deep sandy soils are found across 97.19 sq.km (2.65%), while very dark brown moderately deep wet silty soils encompass 82.18 sq.km (2.24%). Lastly, dark grayish brown moderately deep stratified loamy soils are present in an area of 62.13 sq.km (1.69%). The soil resource map of the district is shown in Figure-10 and the soil category with area is shown in Table-8.

Table 8 Soil classes in Krishna district

S.No	Classification	Area in Sq.km	Percentage (%)
1	Clayey to gravelly clayey moderately deep dark brown soils	291.44	7.94
2	Dark grayish brown moderately deep stratified loamy soils	62.13	1.69
3	Deep black clayey soils	1653.32	45.05
4	Light gray deep sandy soils	97.19	2.65
5	Loamy to clayey skeletal deep reddish brown soils	215.95	5.88
6	Moderately deep calcareous black soils	970.24	26.44
7	Moderately deep calcareous moist clayey soils	184.86	5.04
8	Shallow gravelly red soils	112.68	3.07
9	Very dark brown moderately deep wet silty soils	82.18	2.24
	Total[#]	3669.99	100.00

[#]Excluding the Urban and Water bodies area, Data Source: APSAC, Vijayawada

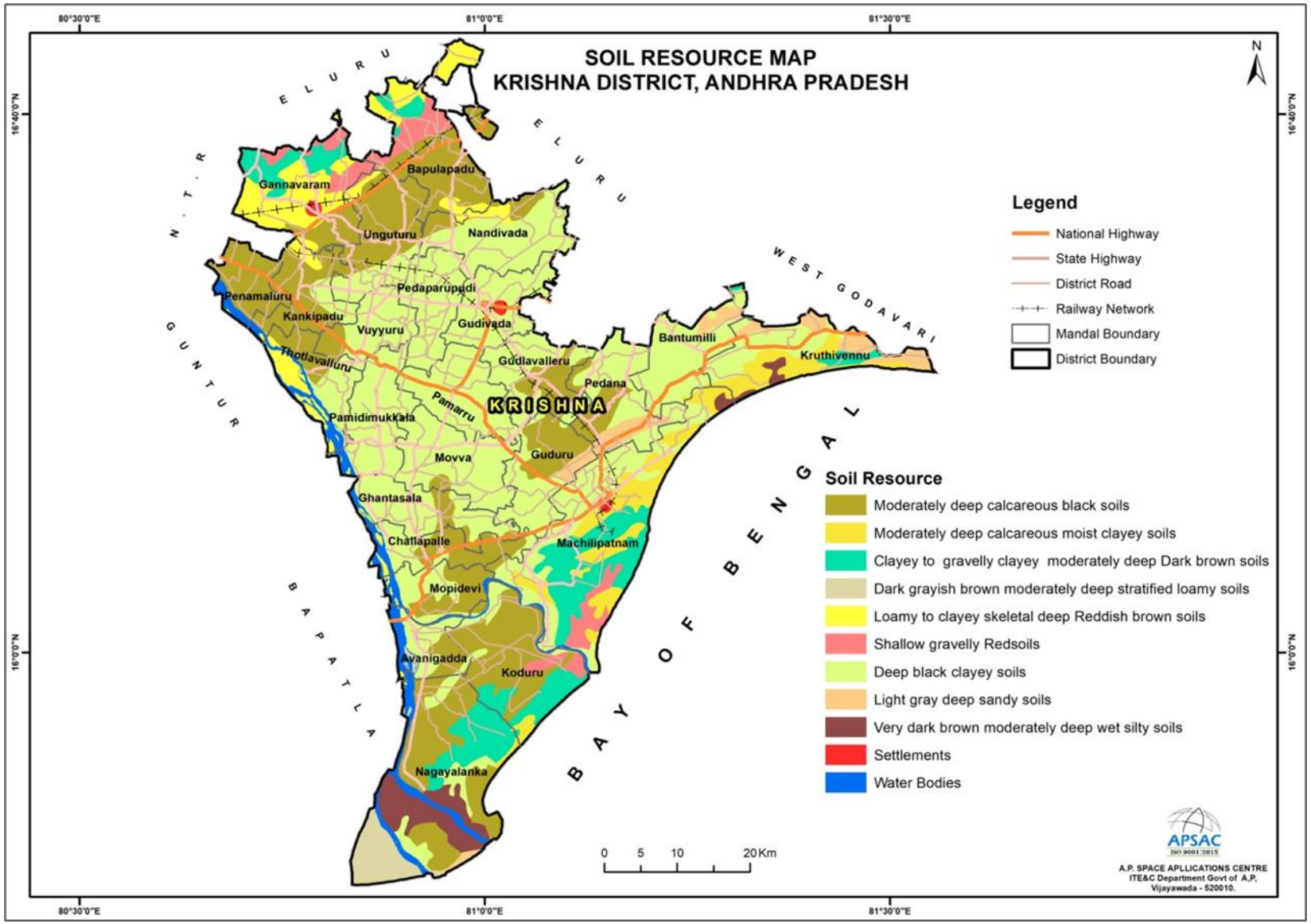


Figure-10: Soil resource map of Krishna District

1.4.6 Horticulture

Horticulture is a science, as well as, an art of production, utilization and improvement of horticultural crops, such as fruits and vegetables, spices, ornamental, plantation, medicinal and aromatic plants. It also includes plant conservation, landscape restoration, landscape, garden design, construction, maintenance, arboriculture, ornamental trees and lawns.
In the Krishna district, Oil Palm is the major horticulture crop, cultivated in an area of 137.97 ha. followed by Mango plantations (10.17 ha.), Date Palm (5 ha.), and Coconut (2.93 ha.). The total area under horticulture crops is 160.77ha. The horticulture crop-wise detail is shown in the Table-9.

Table 9 Area of horticultural crops in Krishna district

S.No	Crop	Area in ha
1	Banana	2.10
2	Mangoes	10.17
3	Coconut	2.93
4	Coconut & Cocoa	2.60
5	Date Palm	5.00
6	Oil Palm	137.97
Total Area		**160.77**

Source: Government of Andhra Pradesh Rashtriya Krishi Vikas Yojana-2022-23.

1.4.7 Coastal Resources and Aqua Culture of Krishna District

1.4.7.1 Shoreline Change Status of Krishna District

The shoreline change estimation was conducted for the entire Krishna coast, spanning approximately 122.07 km in length. In this study, shorelines were extracted from satellite images for the years 1989, 1999, 2005, 2010, and 2012 through visual interpretation. The coastline rate of change was calculated using Digital Shoreline Analysis Software (DSAS) and two different statistical techniques: End Point Rate (EPR) and Linear Regression Rate-of-Change (LLR). Baselines were constructed seaward and parallel to the general trend of the shorelines. Transects were spaced 200m apart using DSAS, and rates of shoreline change were calculated at each transect using linear regression. The most significant changes were observed along the Krishna Coast. Summary statistics for the rate of change are provided in

Table-10. Shoreline changes are presented with an emphasis on shoreline erosion, as it represents a significant natural coastal risk along coastal wetlands. Table-10 summarizes rates of shoreline change as averages of all changes, including both erosion and accretion. Coastal land loss primarily arises due to natural changes in the coastal system and human activities such as agriculture, irrigation, reclamation, and fisheries (Figure-11).

Table 10 Shoreline Characteristics and statistics for Krishna Coast

Classification of Coast	Extent (km)	Percentage of Coast (%)	Cumulative (%)
Length of coastline Including River Mouth and Ports	122.07		
High Erosion	42.27	34.63	
Moderate Erosion	12.03	9.85	
Low Erosion	8.26	6.76	*51.24
Stable	10.06	8.24	8.24
Low Accretion	9.13	7.48	
Moderate Accretion	16.24	13.31	
High Accretion	24.08	19.72	$40.51
Number of port/Harbour	1		
Number of Breakwater / Groyne /Seawall	0		

** (Sum of High Erosion% + Sum of Medium Erosion%+ Sum of Low Erosion %)*
$(Sum of High accretion% + Sum of Medium Accretion%+Sum of Low Accretion %)
Source: APSAC, Vijayawada

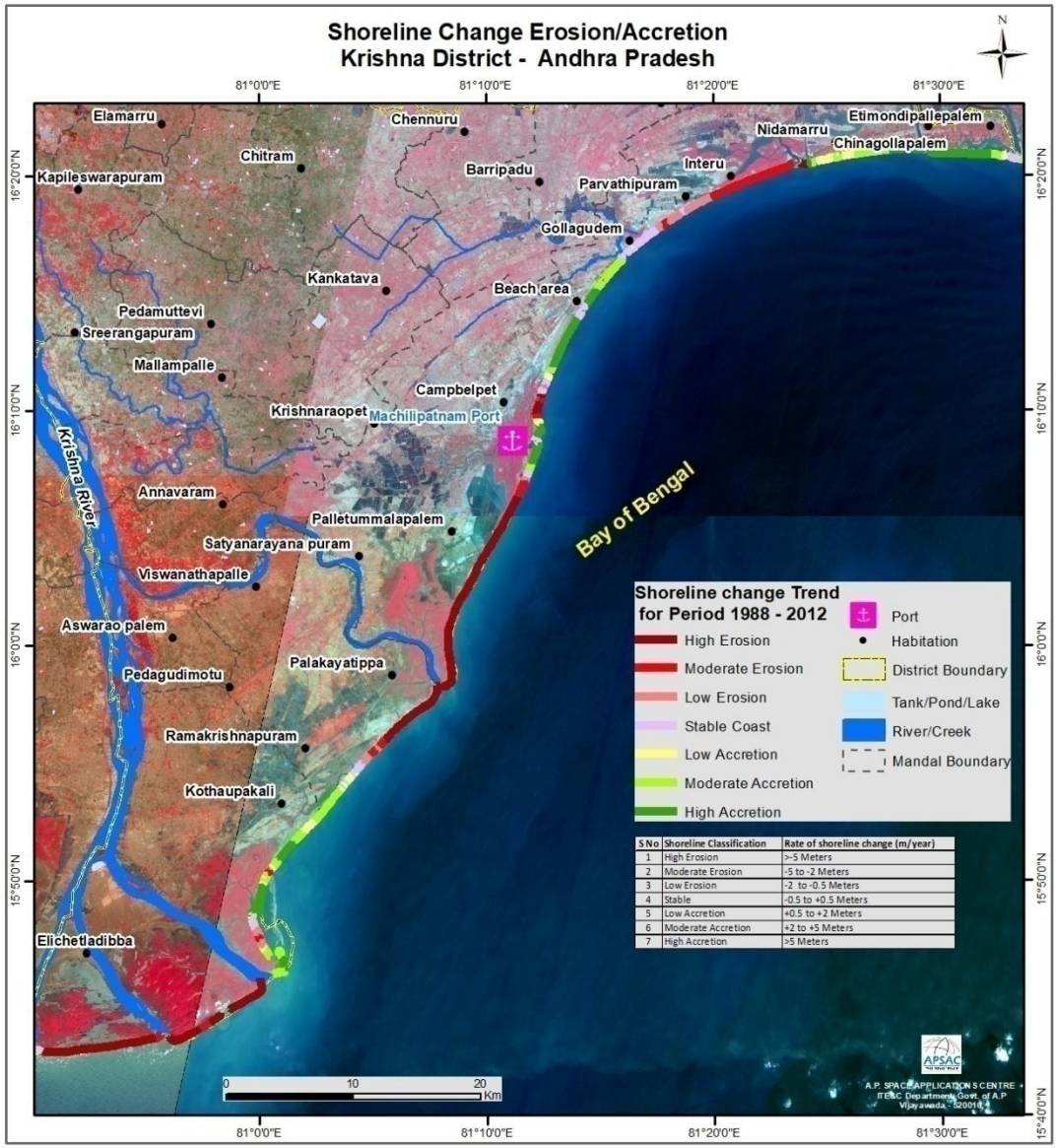


Figure-11: shoreline changes along the coastline of Krishna district

1.4.7.2 Aquaculture in Krishna District

Using high resolution satellite data coupled with ground survey existing aquaculture sites, potential areas for aquaculture development and abandoned aquaculture regions are mapped in the Krishna district and mandal wise/ village wise area statistics are generated and shown in the following Table-11.

The spatial distribution of the aquaculture is shown in Figure-12

Table 11 Mandal - wise Aquaculture in Krishna District (Area in Ha)

SNo	Mandal Name	Aquaculture (Hectares)	Dry/ Abandoned/ Potential (Hectares)	Saltpans (Hectares)	Total (Hectares)
1	Avanigadda	25.17	51.66		76.82
2	Bantumilli	3447.71	167.88		3615.60
3	Bapulapadu	1002.69	36.77		1039.45
4	Challapalle	56.53			56.53
5	Ghantasala	35.60			35.60
6	Gudivada	714.22	1.87		716.09
7	Gudlavalleru	275.87			275.87
8	Guduru	0.00			0.00
9	Koduru	2187.77	2763.80		4951.57
10	Kruthivennu	5269.64	1749.36	137.24	7156.23
11	Machilipatnam	4374.15	6062.92	559.93	10997.00
12	Mopidevi	109.47	36.28		145.75
13	Nagayalanka	2262.65	2465.04		4727.70
14	Nandivada	8407.08	397.97		8805.06
15	Pedana	752.28	145.37		897.65
16	Pedaparupudi	286.12	8.99		295.11
17	Unguturu	13.27			13.27
	Total	**29220.24**	**13887.90**	**697.17**	**43805.31**

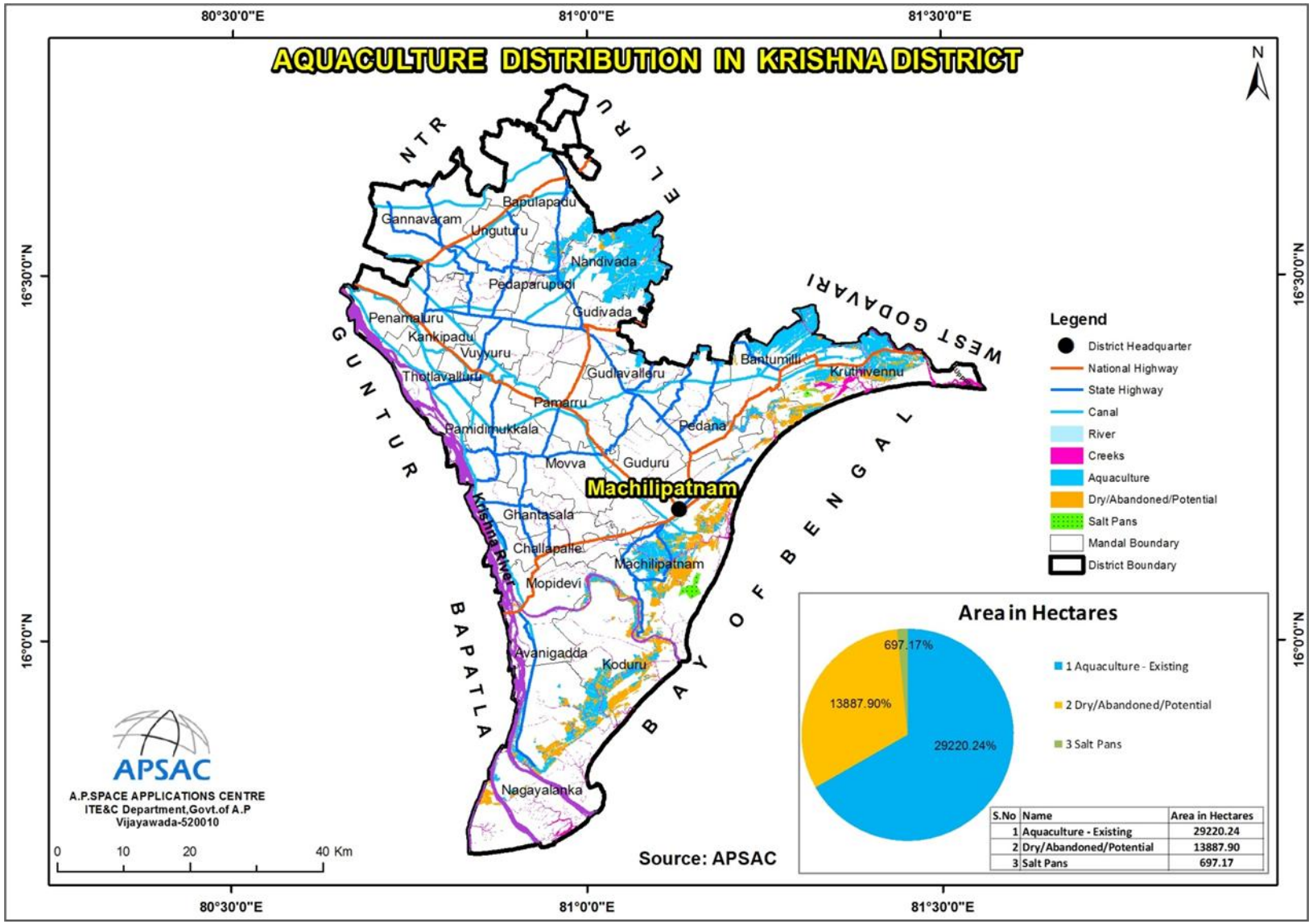


Figure-12: Area of Aquaculture Distribution in Krishna District

1.5 Ground Water Prospects in the District:

Groundwater occurs in almost all geological formations, and its potential depends on the nature of geological formations, geographical setup, and the incidence of rainfall, recharge, and other hydrogeological characteristics of the aquifer. In consolidated formations, groundwater occurs under unconfined to semi-confined conditions. Groundwater is developed in these formations by dug wells, dug-cum-bore wells, and bore wells tapping weathered and fractured zones, with yields ranging from 20 to 70 m^3/day. Fractures in crystalline formations are typically limited to depths of 30 to 40 m below ground level (bgl), occasionally extending to 70 - 100 m bgl. Bore wells constructed in crystalline formations generally tap weathered and fractured zones, with yields ranging from 80 to 400 m^3/day. Higher yields are constrained by the available thickness of fractured and jointed zones. In meta sediments, yields are very limited, ranging from 10 to 80 m^3/day, with higher yields occurring in limestone formations.

Groundwater in semi-consolidated formations occurs under unconfined to confined conditions. Groundwater is developed in these formations by dug-cum-tube wells and tube wells. These formations are potential aquifers, with yields of dug-cum-tube wells ranging from 30 to 45 m^3/day. The granularity of the sandstone bed is the determining factor of yield potential, with higher yields recorded in the Rajahmundry sandstones tapping coarse sandstone beds. Yields of tube wells in Gollapalli sandstones and Rajahmundry sandstones range from 60 to 200 m^3/day and 600 to 1500 m^3/day, respectively.

The deltaic area is underlain by alluvium of recent age consisting of varying proportions of clay, silt, sand, and gravel. The thickness of alluvium ranges from a few meters to about 600 m, followed by tertiary formations. In deltaic areas, groundwater occurrence is controlled by landforms, leading to significant heterogeneity in hydrogeological conditions both spatially and vertically.

Freshwater is generally limited to shallow to moderate depths only, whereas in the southern part of the delta, it occurs as pockets and lenses. Deep aquifers are generally saline. Paleochannels are favourable locations for freshwater aquifers. Groundwater occurs under phreatic to confined conditions and is developed through shallow dug wells, filter point wells,

and shallow tube wells. The depth of dug wells ranges from about 2 to 7 m, while the depth of filter point wells varies from 5 to 13 m, and the depth of tube wells varies from 40 to 80 m. Yields generally range in this aquifer between 250 to 400 m^3/day. Occasionally, high yields of up to 15 litters per second (lps) exist in the paleochannels. The transmissivity value of the aquifer in the semi and unconsolidated formations varies from 2.5 to 5560 m^3/day.

Water Level Scenario: During the pre-monsoon season (May 2012), the depth of water levels in the district ranges between 2 and 10 m bgl. Water levels of more than 5 m bgl occur in parts of Gannavaram, Jaggayyapet, Reddygudem, Vissannapeta, and Tiruvuru mandals, whereas water levels less than 2 m bgl occur in parts of Kalidindi and Ibrahimpatnam mandals. During the post-monsoon season (Nov 2012), in general, the depth to water level is less than 2 m bgl, whereas in parts of Jaggayyapeta, Vijayawada, and Musunuru, water levels are more than 2 m bgl (CGWB, 2013). The groundwater prospects map of the Krishna district is shown in Figure-13.

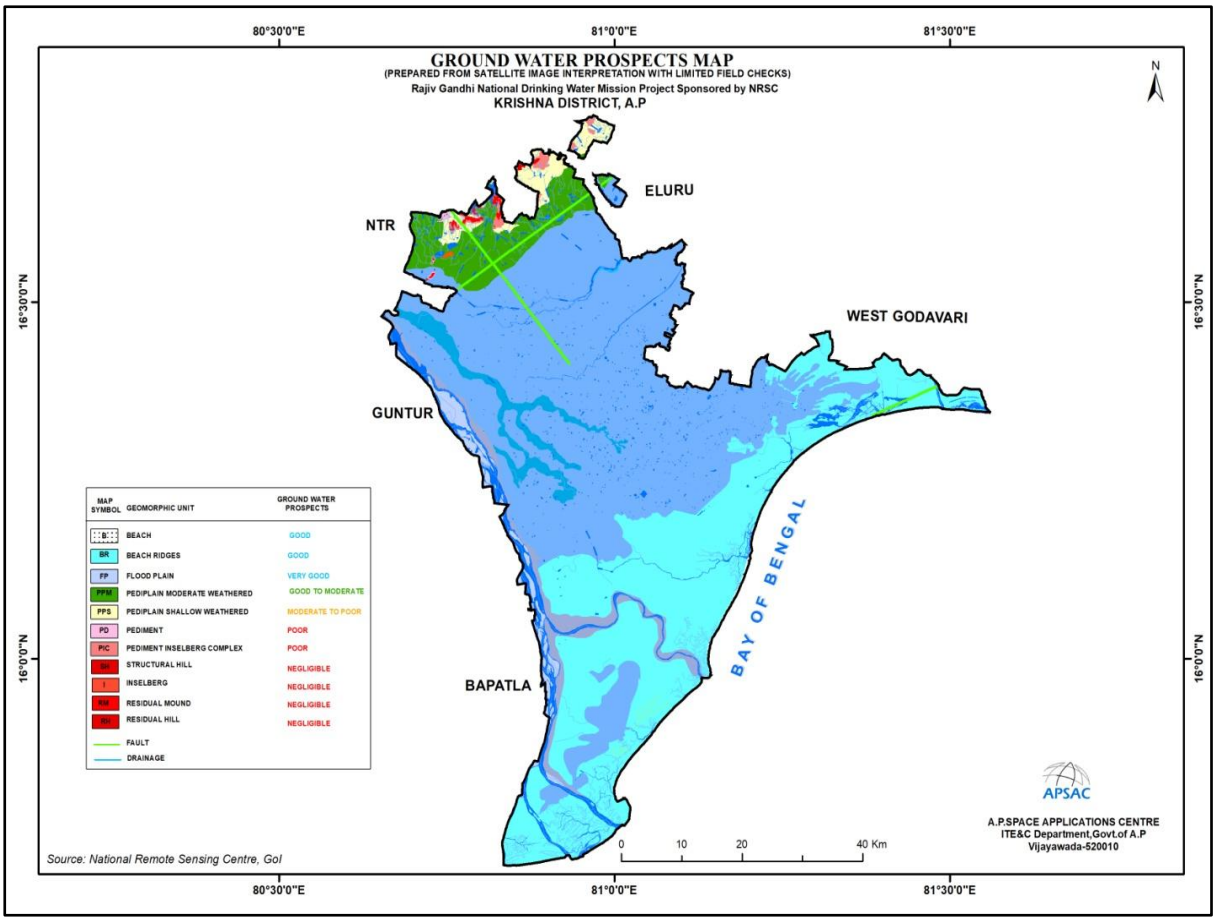


Figure-13: Ground Water prospects in Krishna District, Andhra Pradesh

1.6 Infrastructure

1.6.1 Transport Network

Krishna district has a well-connected by various modes of transportation such as Road, Rail, Air and Sea. The connectivity of each category is also depicted in Figure-14. The details of each transport network distribution in the district are given below.

1.6.1.1. Road Transport: The road network of the district has been delineated by using high resolution satellite data under Space Based Information Support for Decentralized Planning (SIS-DP) project and arrived the lengths of the each type of road network. It can be observed that Krishna district has a well-developed road network that facilitates connectivity to all towns within the district, and to other major cities and towns of nearby districts. The major road network includes National Highways (NH), State Highways (SH), and District Roads (DR). The rural

areas of the district also good connectivity by Panchayat Raj roads / village roads.

The total length of the road network in the district is about 7288.52 Km. of which, the length of the National Highways is about 204.64 km, State Highways is having a length of about 418.16 km. The district roads connecting all towns and mandals are having a length of 1206.38 km. The length of each road category covered in the district is shown in Table-12.

Table 12 Road Category wise Lengths.

S.No	Road Type	Length in Km
1	National Highway	204.64
2	State Highway	418.16
3	District Road	1206.38
4	Village Road	3724.37
5	Cart Track	391.53
6	Foot Path	1090.72
7	City Road	252.72
Total Length		**7288.52**

Data Source: R&B Department & APSAC, Vijayawada.

Krishna district is traversed by Four National Highways. The traverse and description of each highway is as given below:

1.6.1.1.1.National Highway 216(NH216): The former highways of NH 214 and 214A were merged and renumbered as NH 216 in the state of Andhra Pradesh. This highway starts from NH 16 junction at Kathipudi in Kakinada district and Enters at Kruthivennu in Krishna district passes through Bantumilli, Pedana, Machilipatnam, Challapalle and Mopidevi Mandal headquarters in Krishna district and connects NH 16 at Ongole in Prakasam district.

1.6.1.1.2.National Highway 16 (NH16): The NH16 is a major National Highway in India that runs along east coast of West Bengal, Odisha, Andhra Pradesh and Tamil Nadu states. It is a part of the Golden Quadrilateral project to connect India's major cities.

The NH starts at Odisha border which passes through the coastal districts in Andhra Pradesh. It traverse through Gannavaram mandal in Krishna district, The Highway enters at Ichchapuram Mandal in Srikakulam district and passes through Vizianagaram, Visakhapatnam, Anakapalli, Kakinada, East Godavari, Eluru, Krishna, Guntur, Palnadu, Bapatla, Prakasam, S.P.S.Nellore and Tirupati districts and connects to Tamil Nadu Border at Tada in Tirupati district.

1.6.1.1.3. National Highway 165(NH216A): National Highway 165, Pamarru and Palacole road is a National Highway in the state of Andhra Pradesh. It starts NH 65 at Pamarru mandal headquarter in the district and passes through Gudivada mandal and connects NH 216 at Narasapuram in Krishna district.

1.6.1.1.4. National Highway 65 (NH 65): National Highway 65 runs along the states of Maharashtra, Karnataka, Telangana and Andhra Pradesh. It starts at Pune and ends at Machilipatnam. Major cities on this route are Pune, Solapur, Hyderabad, Suryapet, Vijayawada and Machilipatnam. It enters at Penamaluru in the district and passes through Kankipadu, Vuyyuru, Pamarru, Guduru and ends at Machilipatnam in Krishna district.

Some important State Highway segments are covered in the district is given below:

Machilipatnam – Nuzvid – Kalluru road (SH028)
Gudivada – Challapalli – Kothapalem road (SH328)
Telaprolu - Vuyyuru - Valluru road (SH280)
Kowthavaram – Nidamolu – Iluru road (SH253)
Ramanagaram – Nadakuduru road (SH267)
Gudivada – Kankipadu road (SH243)
Machillipatnam - Kammavaricheruvu road (via) Chinnapuram (SH338)

1.6.1.2. Railways : Krishna district is traversed by a significant railway line that connects various parts of the district and provides connectivity to neighbouring regions. Howrah-Chennai Main Line which is a major trunk route that connects Howrah (Kolkata) in West Bengal to Chennai in Tamil Nadu and also facilitating passenger and freight transportation across the region. It passes through Krishna district, serving important railway

station Nuzvid and train stations such as Veeravalli, Telaprolu, Pedda Avutapalle, Gannavaram and Mustabada. Vijayawada-Machilipatnam Line connects Vijayawada to the coastal town of Machilipatnam serving important railway stations such as Tarigoppula, Gudivada Junction, Gudlavalleru, Kavutaram, Pedana, Chilakalapudi and Machilipatnam.

The Indian Railway line traversing from northeast in Krishna district covering the various stations to cater the transportation needs of the people. The length of Rail network in the district is about 115.70 km covering 22 railway stations. Among these, the important railway stations in the district are Chilakalapudi, Gudivada Junction, Gudlavalleru, Kavutaram, Machilipatnam, Nuzvid, Pedana and Tarigoppula; and the Train stations are Dosapadu, Gannavaram, Guntakonduru, Indupalli, Moturu, Mustabada, Nujella, Pedda Avutapale, Telaprolu, Tenneru, Uppaluru, Vadlamannadu, Veeravalli and Ventrapragada.
In addition to the main line, there are various branch lines and spur lines namely Gudivada Junction - Bhimavaram Town that extend from the main line to connect specific towns with in Krishna district. These lines provide local connectivity and transportation services to different parts of the district.

1.6.1.3. Air Transport: Vijayawada Airport, is an international airport serving the city of Vijayawada, Andhra Pradesh, India. The airport is located at Gannavaram where National Highway16 connecting Chennai to Kolkata . The Government of India granted international status to the airport on 3 May 2017. The airport is internationally connected to the Middle Eastern countries of United Arab Emirates, Oman and Kuwait.

1.6.1.4. Seaport: Machilipatnam Port is a proposed deep sea port on the coast of Bay of Bengal. It is located at Machilipatnam, the District headquarters of Krishna district in the Indian state of Andhra Pradesh at a distance of about 12 km. The port was originally expected to begin its operations by 2021. There is a proposal to develop a mega thermal power plant near Machilipatnam during 11th Five Year Plan. It is proposed to construct of 2 Nos. General cargo berth and 1 OSV berth in Phase 1 Depth of the Channel: 12.80 Mt with ship handled capacity is 65000 DWT and port anticipated handling capacity.

1.6.2 Irrigation

1.6.2.1. Major and Medium Irrigation Projects in Krishna district:

Irrigation has assumed an increasing significance in agriculture in the context of new technology, where high yielding varieties and multiple cropping are being practiced. The main reasons for low yields are inadequate rainfall, uneven and uncertain rains during the period of crop growth. It is generally found that the introduction of irrigation is associated with changes in the cropping pattern. The shift from a traditional cropping pattern to the most advantageous cropping pattern is possible only in the presence of irrigation facilities. The new agricultural technology is highly based on sufficient moisture conditions. Thus, the development of irrigation is crucial for increasing agricultural production. The irrigation projects are classified as major, medium and minor irrigation details are shown in Table-13 and Figure-15.

1.6.2.1.1. Major Irrigation Projects:

In Krishna district there are two major irrigation projects i.e., Krishna Delta System (KDS-Eastern Delta) and Polavaram Right Main Canal. The ayacut details of Krishna Delta System covered in the combined district was an extent of 6,79,498 Ac and the Polavaram Right Main Canal is diversion of 80 TMC of Godavari waters into the Krishna River and Irrigation facilities to an extent of 62,000 Ac (Combined district) and stabilize ayacut of 13.08 lakh acres in Krishna Delta.

1.6.2.1.2. Medium Irrigation Projects:

The Water Resources Department 28Nos of minor irrigation tanks covered in the district an ayacut extent of 9,594 Ac. And also, 73Nos of minor irrigation tanks (bellow 100 Ac ayacut) covered in the district an extent of 3,250 Ac.

Table 13 Major and Medium Irrigation Projects in Krishna District

S.No	Project Type	Name of the Project	Status	Ayacut in Ac
1	Major	Krishna Delta System (KDS) **(Combined District)**	Completed	6,79,498
2		Polavaram RMC (80 TMC of water diversion to Krishna River and Stabilize ayacut of 13.08 lakh acres Krishna Delta **(Combined**	Ongoing	62,000

		District)		
3	Minor	Minor Irrigation Tanks - 28Nos (Ayacut above 100 Acres)	Completed	9,594
4	Minor	Minor Irrigation Tanks - 73Nos (Ayacut bellow 100 Acres)		3,250
Total				**7,54,342**

Data source: WRD, APWRIMS, Govt. of A.P.

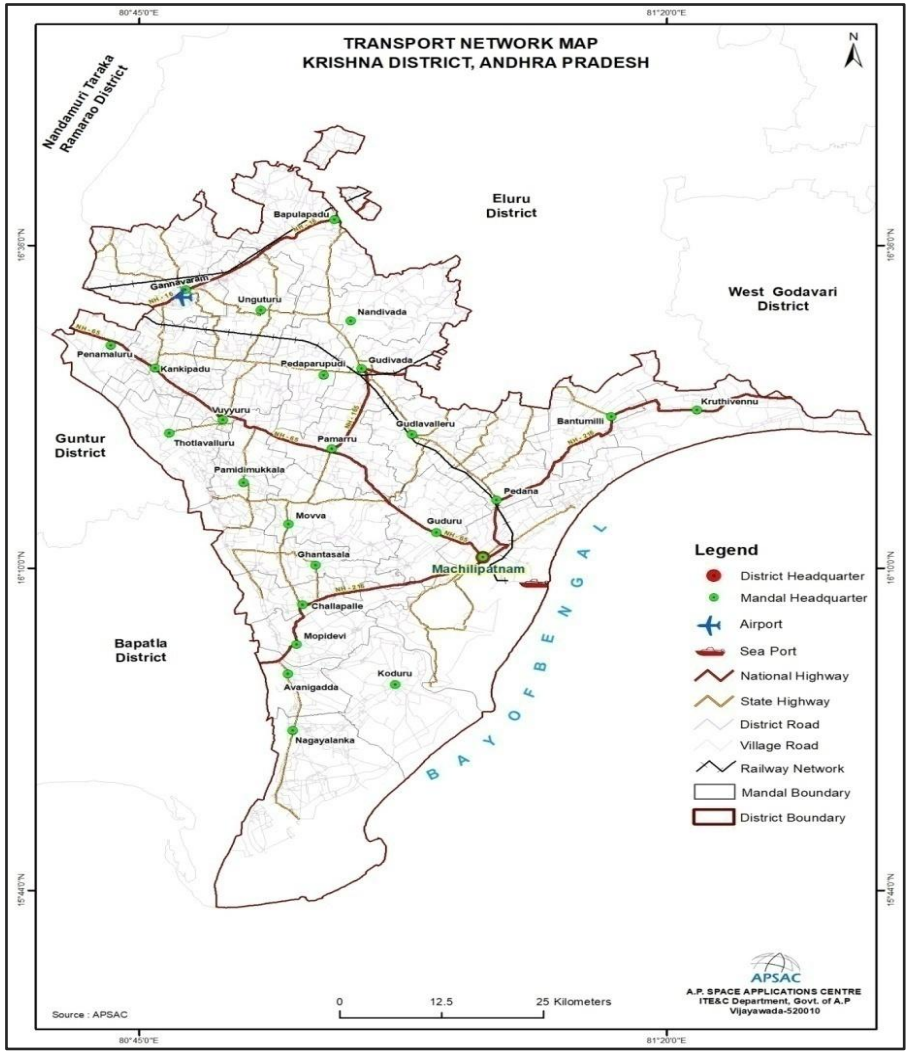


Figure-14: Transport Network of Krishna District, Andhra Pradesh.

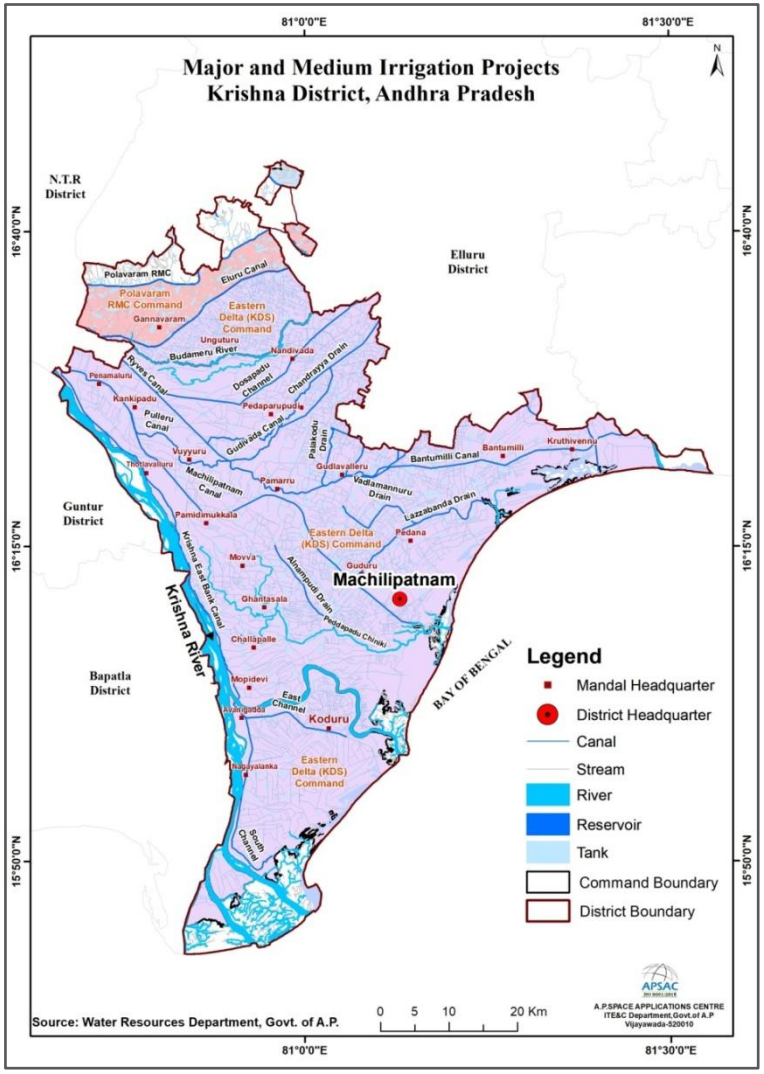


Figure-15: Major and Medium Irrigation Projects of Krishna District

1.6.2.2. Tank Information System

As per the information of Water Resources Departmental portal, Andhra Pradesh Water Resources Information & Management System (APWRIMS) and the URL:https://apwrims.ap.gov.in/ in Krishna district have 98 minor irrigation tanks. The Designed Storage Capacity of minor irrigation tanks in Krishna district 2,350.6 mcft and Current Storage Capacity is 1,777.44 mcft. The major part the district is irrigated with the Krishna Delta System (KDS-Eastern Delta) Canals and Channels. The ponds and canal water used for drinking and irrigation purposes. The mandal wise minor irrigation tanks details of Krishna district are shown in Table-14.

Table 14 Mandal wise Minor Irrigation Tanks details of Krishna district

S.No	Mandal	No. of MI Tanks	Designed Storage Capacity (mcft)	Current Storage Capacity (mcft)
1	BAPULAPAD	50	444.89	318.33
2	GANNAVARAM	40	1,799.84	1,379.71
3	MACHILIPATNAM	2	19.71	14.78
4	UNGUTURU	6	86.17	64.62
TOTAL		**98**	**2,350.6**	**1,777.44**

Data source: WRD, APWRIMS, Govt. of A.P.

1.6.3 Eco-sensitive and Important places

Krishna district is blessed with several tourist attractions that offer a mix of historical, cultural, and natural wonders. The important popular tourist, religious and cultural places to visit in the Krishna district are shown in the Table-15 and the geographical location of each place is depicted in Figure-16.

Table 15 Important places of Tourism in Krishna district.

S.No	Name	Village	Mandal
1	Ghantasala Buddhist Museum	Ghantasala	Ghantasala
2	Hamsaladeevi Beach	Ullipalem	Koduru
3	Manginapudi Beach	Manginapudi	Machilipatnam
4	Pedana Kalamkari	Pedana (M)	Pedana
5	Subramanya Swamy Temple	Mopidevi	Mopidevi
6	Venugopala Swamy Temple	Ullipalem	Koduru

Data Source: Tourism Department, Government of Andhra Pradesh.

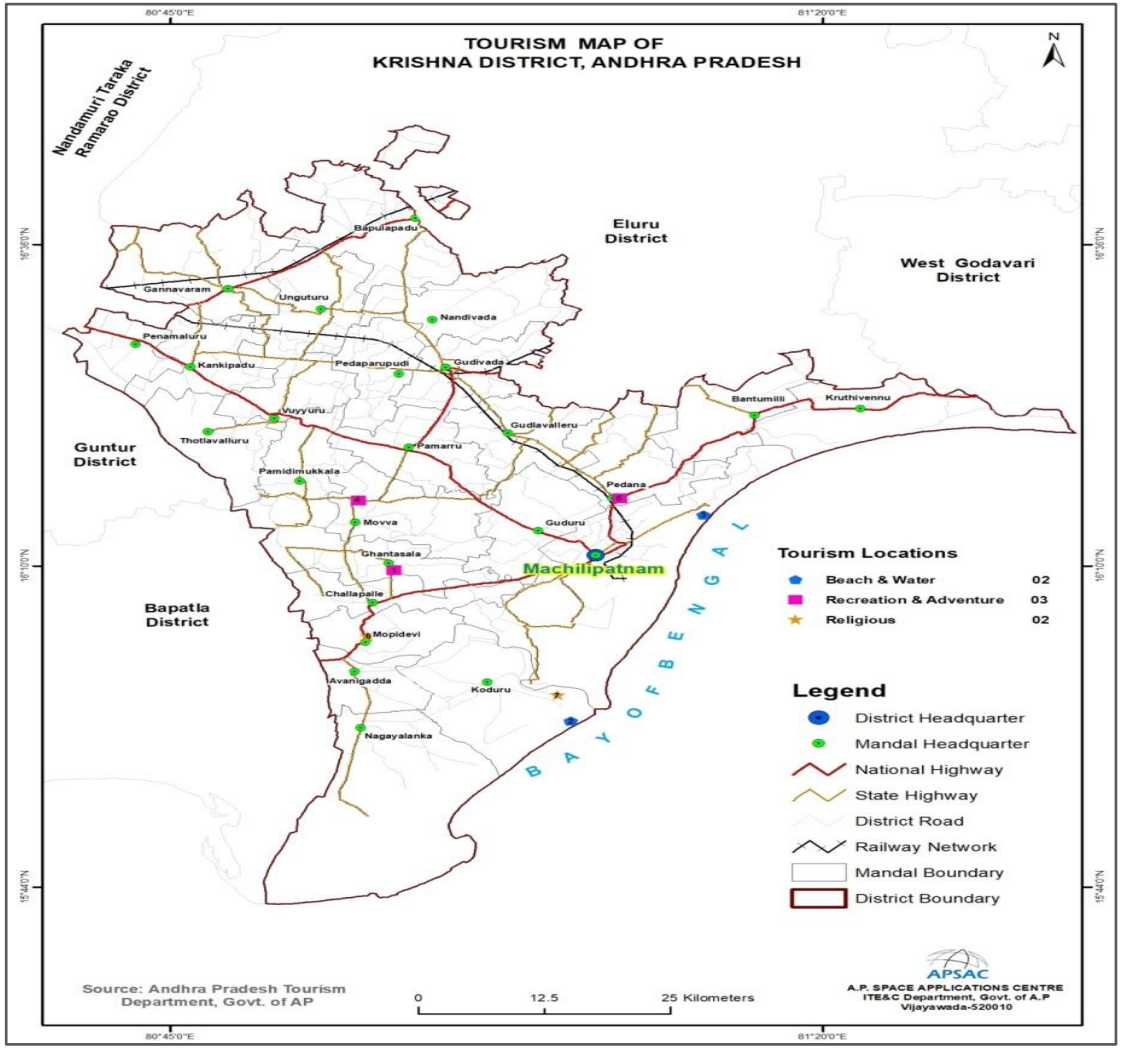


Figure-16: Tourist Map of Krishna District, Andhra Pradesh

1.6.3.1. Kuchipudi: Kuchipudi is located at about 35 km from the district headquarter Machilipatnam. It is a pre-eminent Indian classical dance form counted among ten leading classical dance forms of India. It is a dance-drama performance art that originated in a village of Krishna district of Andhra Pradesh, India. Like all leading Indian classical dance forms, Kuchipudi too evolved as a religious art rooting back to the age-old Hindu Sanskrit text 'Natya Shastra' and connects traditionally with temples, spiritual faiths and travelling bards.

1.6.3.2. Manginapudi Beach: Manginapudi Beach is located at about 15 km from the district headquarter Machilipatnam. It has a glorious historical background and is famous for the Dutch memories associated with the area. The Manginapudi Beach serves as the gateway for commercial activities in India and is also a natural harbor in India. The surroundings of this place are unique and offer exclusive view to the visitors. Manginapudi Beach is also a place for the relaxation of the tired souls and offers relief from the turmoil of daily existence.

1.6.3.3. Pedana Kalamkari: Pedana is located at about 10 km from the district headquarter Machilipatnam. Pedana Kalamkari also known as Machilipatnam style of Kalamkari work which involves vegetable dyed block-painting of a fabric. It is produced at Pedana a nearby town of Machilipatnam in Krishna district of the Indian state of Andhra Pradesh. It was registered as one of the geographical indication from Andhra Pradesh under handicraft goods by Geographical Indications of Goods.

1.6.3.4. Ghantasala Buddhist Museum: Ghantasala Buddhist Museum is located at about 27 km from the district headquarter Machilipatnam. It is a rare and reputed centre for Buddhist sculptures. It is Known as Katakasila in ancient times, Ghantasala was once a renowned Buddhist centre. Rooted in history, it invites history-lovers and archaeologists for its rich heritage.

1.6.3.5. Hamsaladeevi: Hamsaladeevi is located at about 32 km from the district headquarter Machilipatnam. It is a village in Diviseema, Koduru Mandal, Krishna District of the Indian state of Andhra Pradesh. In the regional language it translated as "Swans Island". In this place Krishna River converges into the Bay of Bengal**.** The Krishna River meets the Bay of Bengal outside the village of Hamsaladeevi.

1.6.4 Places of Religious and Cultural importance

1.6.4.1. Panduranga Swamy Temple: Panduranga Swamy Temple is located at about 3.6 km from the district headquarter Machilipatnam. It is devoted to Lord Panduranga Vithal. The idol of the god measures around 3 feet in height and he shares similarity with the childhood appearance of Lord Krishna. The Panduranga Swamy temple is flanked by a prakaram on all its three sides, which feature the images of the disciples of Sri Panduranga Vithal. Just beside the entrance of the temple, there is another temple that houses the images of Rukmini, Radha and Satyabhama.

1.6.4.2. Venugopala Swamy Temple: Venugopala Swamy Temple is located at about 30 km from the district headquarter Machilipatnam. Sri Movva Venugopala Swamy Temple is the place where Kshetrayya is said to have composed his famous lyrics. The Kshetrayya Kala Samithi at Movva now teaches music and dance to students.

1.6.4.3. Sri Subrahmanyeswara Swamivari Devasthanam: Sri Subrahmanyeswara Swamy Vari Devasthanam or Mopidevi Temple is in the village of Mopidevi, Krishna district in Andhra Pradesh. It is located at about 70 km from the district headquarter Machilipatnam. Here, Sri Subrahmanya Swamy is in the form of lingam (Shiva Lingam).

1.6.4.4. Andhra Mahavishnu: Andhra Mahavishnu is located at about 37 km from the district headquarter Machilipatnam. There is a temple of Andhra Mahavishnu, who must have been a noble royal sage. It is said that Sri Krishna Deva Raya worshipped at this temple and a dream was asked by the Deity to compose a poem on him.

1.7 Drainage Pattern

1.7.1 Drainage

The principal rivers flowing in the district are the Krishna, Budameru, Peddapadu Chiniki (Gunderu Nala) and Upputeru Rivers. The borders of the district Krishna River in the east side and Upputeru River in the west side. The major part the district is irrigated with the Krishna Delta System (KDS-Eastern Delta) Canals and Channels. The Krishna River originates in the Western Ghats, Mahabaleswar hills, Sattar District in Maharashtra State and enters into the district near Enamalakuduru. The river flows towards south direction 55 km and bifurcates into Ballaleru, Nadimi Eru, Krishna River at Edurumondi, Nagayalanka mandal in Krishna district. The Krishna River flows towards south direction 16 km and Joining to Bay of Bengal near Lankavanidibba in Krishna district. The Budameru River rises in the Chimalapadu RF, A.Konduru mandal in NTR dsitrict and flows towards southeast direction and joining to Kolleru Lake near Immanivanigudem in Krishna district. The Upputeru River rises near Kolleru Lake, flows towards south direction and joining to Bay of Bengal near Perupalem village in Mogalthur mandal in Krishna district. Five major drains are covered in the district; they are Chandrayya Drain, Lazzabanda Drain, Ainampudi Drain, Polaraju Drain and Pedalanka Drain. The Kolleru Lake is one of the largest freshwater lakes in the country located east side part of the district and located between the Krishna and Godavari deltas. The Budameru, Tammileru, Ramileru and Gunderu rivers are rises in NTR and Eluru districts, these rivers are flows towards south direction and joining to Kolleru lake Figure-17 Illustrates the drainage system and the surface water bodies.

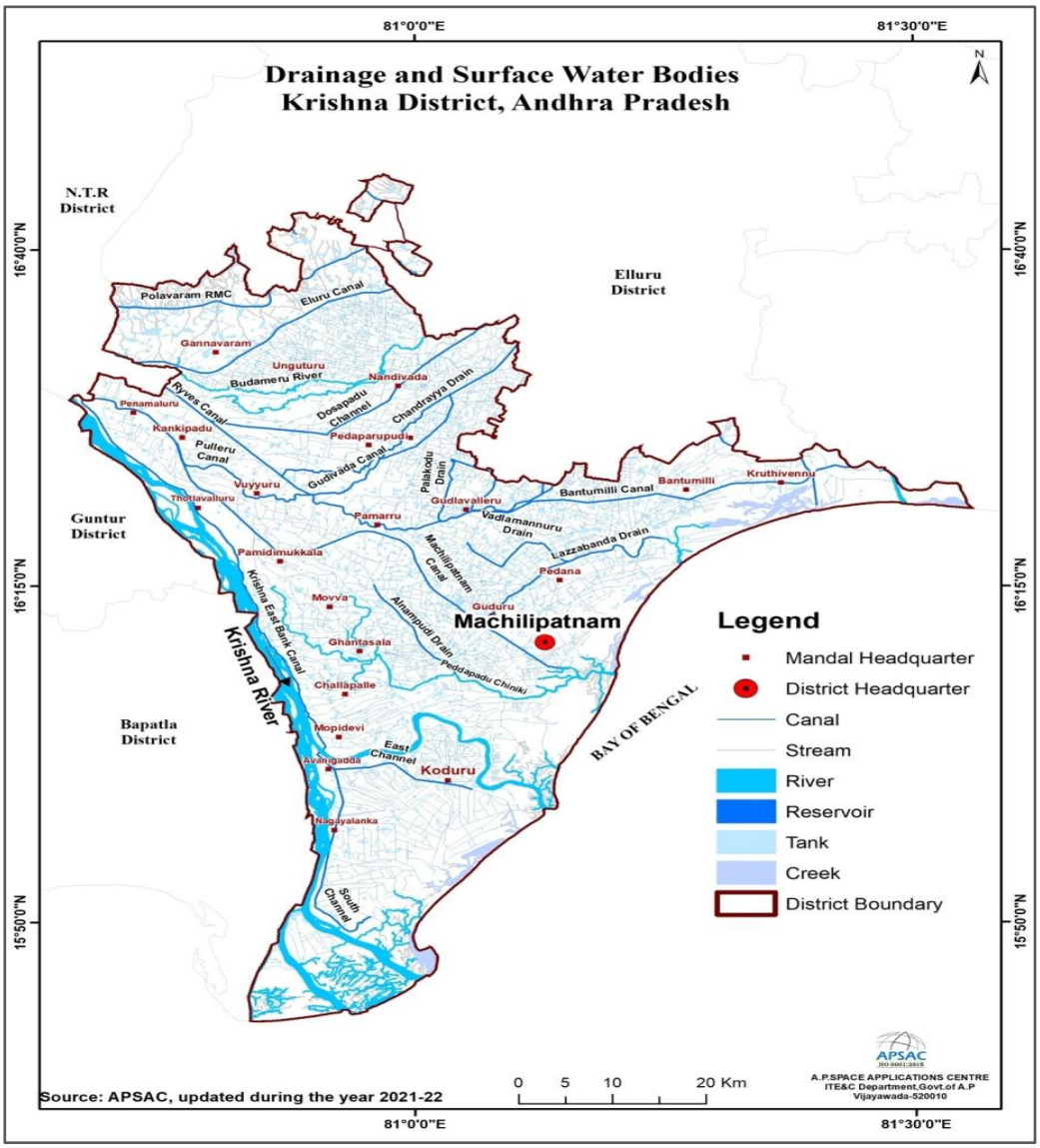


Figure - 17: Drainage Network and Surface Water Bodies of the Krishna *District*

1.7.2 Geomorphology of the District:

Using IRS satellite data and GIS, a detailed geomorphological and structural map of Krishna District was generated in accordance with the guidelines of the Rajiv Gandhi National Drinking Water Mission (RGNDWM) on a 1:50,000 scale. The objective of this mapping is to map lithology, geomorphology, and structural characteristics of an area at a 1:50,000 scale and integrate the same to locate potential groundwater prospect zones and recommend suitable structures for groundwater recharge. Various hydrogeomorphic units are delineated, and suitable recharge structures are proposed for villages affected by drinking water scarcity under this project. The geomorphology map of Krishna district is shown in Figure-18.

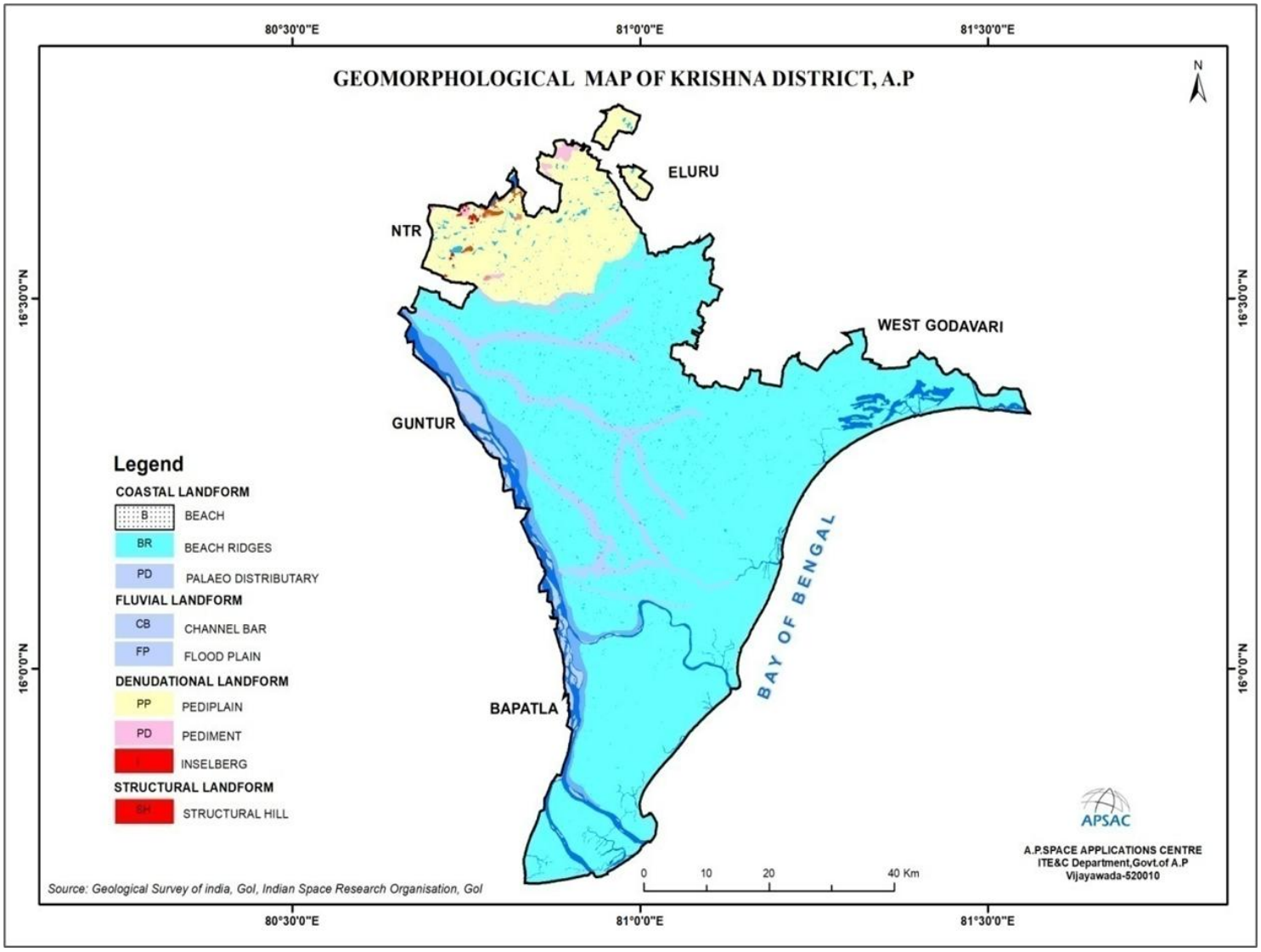


Figure 18: Geomorphology of Krishna District, Andhra Pradesh

1.7.3 Landforms of Fluvial origin

In earth science, the term "fluvial" refers to processes and landforms created by running water. Similar to other surficial processes, running water can either erode material from the Earth's landscape or deposit layers of sediment. The resulting landforms can be classified as either erosional or depositional. The immense power of running water in shaping various erosional and depositional landforms is well recognized. Although the quantity of water in a stream may be small at certain times of the year, large volumes of water move through the channel, constituting a crucial component of the hydrological cycle. The fluvial dissection of the landscape comprises valleys and their associated channels organized into a drainage network. Drainage networks exhibit various types of quantitative regularities that are useful in analyzing both fluvial systems and the terrains they dissect (NRSA, 2007).

Floodplain: The surface or strip of relatively smooth land adjacent to a river channel is constructed (or in the process of being constructed) by the present river in its existing regimen. It is covered with water when the river overflows its banks during times of high water. The floodplain is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current.

Delta: The low, nearly flat, alluvial tract of land is deposited near the mouth of a river. It commonly forms a triangular or fan-shaped plain of considerable area enclosed and crossed by many distributaries of the main river. It may extend beyond the general trend of the coast, resulting from the accumulation in a wider body of water (usually a sea) of sediment supplied by a river in such quantities that it is not removed by tides, waves, and currents.

1.7.4 Landforms of Coastal origins

Coasts are the sites of a unique assemblage of erosional and depositional processes. Various landforms of coastal areas are almost exclusively the result of the action of ocean waves. Wave action creates some of the world's most spectacular erosional landforms. Where wave energy is reduced, depositional landforms like beaches are created. The source of energy for coastal erosion and sediment transport is wave action. A wave possesses potential energy as a result of its position above the wave trough and kinetic energy caused by the motion of the water within the wave. This wave energy is generated by the frictional effect of winds moving over the ocean surface. The higher the wind speed and the longer

the fetch, or distance of open water across which the wind blows and waves travel, the larger the waves and the more energy they possess. Long open ocean waves or swells travel faster than short, locally generated sea waves. They also have longer wave periods, distinguishing them from the short sea waves upon reaching the coast. Long swells, which have travelled hundreds of kilometres, may have wave periods of up to 20 seconds, while smaller sea waves have wave periods of 5 to 8 seconds. When ocean depths exceed the length of the waves, wave motion does not extend to the ocean floor and remains unaffected by the bottom. As the ocean depth falls below half the wavelength, the bottom increasingly affects wave motion. As the water depth decreases, wave height increases rapidly, and wavelength decreases rapidly. Thus, the wave becomes more peaked as it approaches the shore, finally curling over as a breaker and breaking on the shore. As the wave breaks, its potential energy is converted into kinetic energy, providing a large amount of energy for the wave to work along the shoreline. Transportation by waves and currents is necessary to move rock particles eroded from one part of a coastline to a place of deposition elsewhere.

One of the most important transport mechanisms results from wave refraction. Since waves rarely break onto a shore at right angles, the upward movement of water onto the beach (swash) occurs at an oblique angle. However, the return of water (backwash) is at right angles to the beach, resulting in the net movement of beach material laterally. This movement is known as beach drift. The endless cycle of swash and backwash and resulting beach drift can be observed on all beaches. Frequently, backwash and rip currents cannot remove water from the shore zone as fast as it is piled up there by waves. As a result, there is a build-up of water that results in the lateral movement of water and sediment just offshore in a direction with the waves. The currents produced by the lateral movement of water are known as longshore currents. The movement of sediment is known as longshore drift, which is distinct from the beach drift described earlier, operating on land at the beach. The combined movement of sediment via longshore drift and beach drift is known as littoral drift. Tidal currents along coasts can also be effective in moving eroded material. While incoming and outgoing tides produce currents in opposite directions daily, the current in one direction is usually stronger than the other, resulting in a net one-way transport of sediment. Longshore drift, longshore currents, and tidal currents in combination determine the net direction of sediment transport and areas of deposition. Using multi-temporal satellite data can reveal the dynamics of the coast (NRSA, 2007).

1.7.4.1. Beach: A gently sloping zone, typically with a concave profile, of unconsolidated material that extends landward from the low-water line to the place where there is a definite change in material or physiographic form (such as a cliff) or to the line of permanent vegetation (usually the effective limit of the highest storm waves).

1.7.4.2. Beach ridge: A low, essentially continuous mound of beach or beach and dune material (sand, gravel, shingle) heaped up by the action of waves and currents on the backshore of a beach beyond the present limit of storm waves or the reach of ordinary tides. They occur singly or as one of a series of approximately parallel deposits. The ridges are roughly parallel to the shoreline and represent successive positions of an advancing shoreline.

1.7.4.3. Tidal flat: An extensive, nearly horizontal, marshy or barren tract of land that is alternately covered and uncovered by the rise and fall of the tide. It consists of unconsolidated sediment (mostly mud and sand) and may form the top surface of a deltaic deposit.

1.7.5 Landforms of Structural Origin

Landforms of structural origin are related to the structural aspects of the area. Most of the landforms in this class have genesis related to the underlying structure. Structure plays an important role in reducing the resistance of rock, which manifests itself in different geomorphic forms. Some variations are minor, while others are on a mega-scale. Mega-scale forms have a dramatic effect on the genesis of landforms, and mapping such forms indirectly indicates the structural setup of the area. Mega-scale structural features like faults and folds, depending on their type, play an important role in the genesis of structural landforms. The influence of geologic structures on the development and appearance of landscapes is prominent. This influence ranges from large features that exert a dominant influence on the form of an entire landscape to small features that affect individual landforms and the geomorphic processes operating on them. Structural control could be active structures whose form is directly impressed on the modern landscape or ancient structural features whose influence on a modern landscape is primarily due to differential erosion (NRSA, 2007).

1.7.5.1. Structural Hills: Hills and valleys originating from tectonic processes and highly dissected by drainage lines. This classification can

further be categorized as highly, moderately, and lowly dissected depending on the density of joints and drainage. Mostly interpreted from planimetric satellite data, this classification is highly subjective.

1.7.5.2. Dyke Ridge: Intrusive features emplaced within pre-existing fractures or where the fluid pressure is sufficient to form fractures during emplacement. They are discordant bodies.

1.7.6 Landforms of denudational origins

The landforms of denudational origin are formed where the denudation process dominates over other processes. Most landforms resulting from this process are the combined effect of mechanical and chemical weathering. Denudation is the process of material removal by erosion and weathering, which directly influences the relief of the area, especially in reducing relief to the base level. The agents primarily involved are water, ice, and wind. The major factors affecting denudation are geology, climate, tectonics, and anthropogenic effects. All rocks and minerals at or near the surface are subject to physical and chemical processes. The effects of these processes vary due to rocks' varying resistance to change. Consequently, weathering and erosion yield several landforms with typical shapes and forms. Weathering is an essential part of the rock cycle. The parent material or rock undergoes weathering, disaggregating to form smaller fragments, and some minerals dissolve and are removed by agents such as water. This material removal is erosion and is accomplished by running water, wind, glaciers, etc. Weathering provides the raw material for sedimentary rock and soil (NRSA, 2007).

1.7.6.1. Denudational Hill: A highly dissected hill with obliterated structures.

1.7.6.2. Inselberg: A prominent, isolated, steep-sided, usually smoothed and rounded residual knob, hill, or small mountain of circumdenudation rising abruptly and surrounded by an extensive and nearly level, lowland erosion surface in a hot, dry region (as in the deserts of southern Africa or Arabia). Generally bare and rocky, though partly buried by debris derived from and overlapping its slopes, it is characteristic of an arid or semiarid landscape in a late stage of the erosion cycle.

1.7.6.3. Pediment: A broad, flat, or gently sloping rock-floored erosion surface or plain of low relief, typically developed by sub aerial agents

(including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment. Underlain by bedrock (occasionally by older alluvial deposits), it may be bare but more often partly mantled with a discontinuous veneer of alluvium derived from upland masses and in transit across the surface.

1.7.6.4. Pediplain: An extensive, multi-concave, rock-cut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes, representing the result (the "peneplain") of the mature stage of the erosion cycle. Based on the thickness of weathering, they are further classified as shallow, moderate, and deep pediplains.

1.7.7 Structural Features of Krishna District

Krishna District has consolidated formations, including crystallines (Khondalites, Charnockites, and Granitic Gneisses), and meta-sediments (Dolomites, Shales, Phyllites, and Quartzites) from the Archaean and Pre-Cambrian periods, respectively. The Khondalite Group of rocks is prominent as hill ranges (strike ridges) south of Vijayawada, extending towards the north and northeast. The rocks of Khondalite, Charnockite groups, and the layered complex show foliation trending dominantly North-South, with local swerves to the northeast (NE)-southwest (SW) and northwest (NW)-southeast (SE) (GSI, 2000). Semi-consolidated formations are represented by Tertiary formations (Rajahmundry and Gollapalli sandstones), while unconsolidated formations comprise deltaic alluvial deposits from the Quaternary period (CGWB, 2013).

Semi-consolidated formations occur in the northeastern part of the district, with their extension limited to a small area, namely parts of Bapulapadu and Gannavaram mandals. These consolidated formations, part of the Eastern Ghats mobile belt, are highly disturbed, and with the semi-consolidated rocks also affected by tectonic activity. Unconsolidated formations occur in the southern part of the district, particularly in the delta area, where lineaments cannot be deciphered due to alluvial cover. Prominent lineaments trend in the northeast (NE)-southwest (SW), northwest (NW)-southeast (SE), and north-northeast (NNE)-south-southwest (SSW) directions in the district (CGWB, 2013). The structural map of Krishna District is shown in Figure-19.

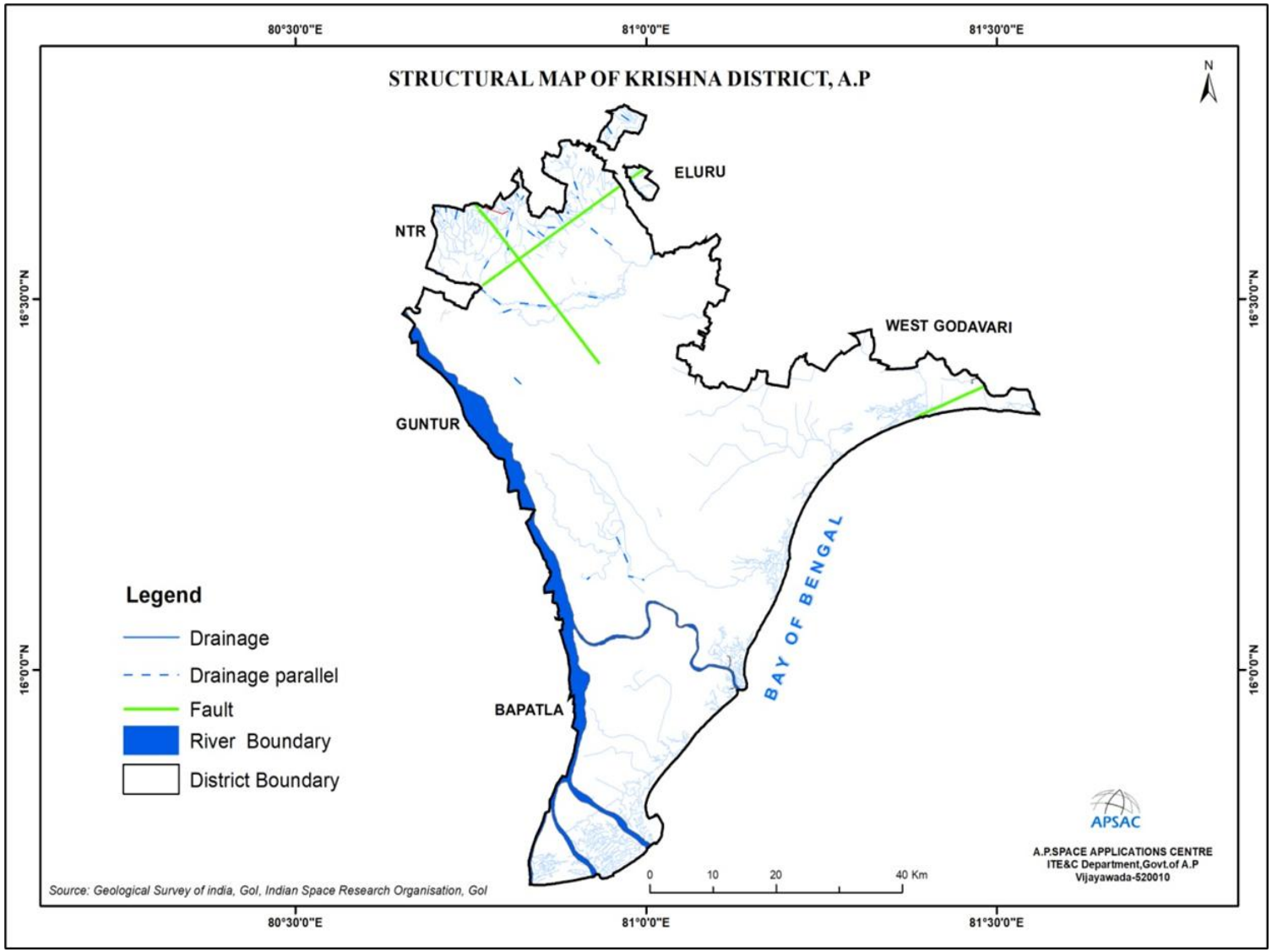


Figure-19 : Structural Map of Krishna District, Andhra Pradesh

1.7.8 Ground Water Quality in Krishna District

The groundwater quality laboratory analyzed physicochemical parameters such as Total Dissolved Solids, Total Hardness, Chlorides, Nitrate, pH, Fluoride, Iron, Alkalinity, and Sulphate using standard techniques. Groundwater quality samples were collected for two seasons, i.e., post-monsoon and pre-monsoon, from the Rural Water Supply and Sanitation Department (RWS and S) from December 2017 to June 2019. These samples were compared with the Bureau of Indian Standards, 2015 Groundwater Quality standards, categorized as desirable, permissible, and non-potable classes. Blue, yellow, and red colours indicate pre-monsoon quality, and + and - symbols indicate post-monsoon quality for desirable, permissible, and non-potable classes, respectively. The Groundwater quality map of the Krishna district is shown in Figure-20.

From the analysis, it has been observed that groundwater is polluted in both pre-monsoon and post-monsoon seasons, with about 5% of the area falling under the non-potable category due to high concentrations of Total Dissolved Solids, Fluoride, and Total Hardness (APSAC, 2017b). Furthermore, approximately 85% of the area falls under the potable category, while the remaining 10% of the area is covered with hills and water bodies throughout the district. The occurrence and movement of groundwater in an area are governed by several factors, such as topography, lithology, geological structure, depth of weathering, extent of fractures, drainage pattern, and climate conditions, and the interrelationship between these factors (APSAC, 2017b)

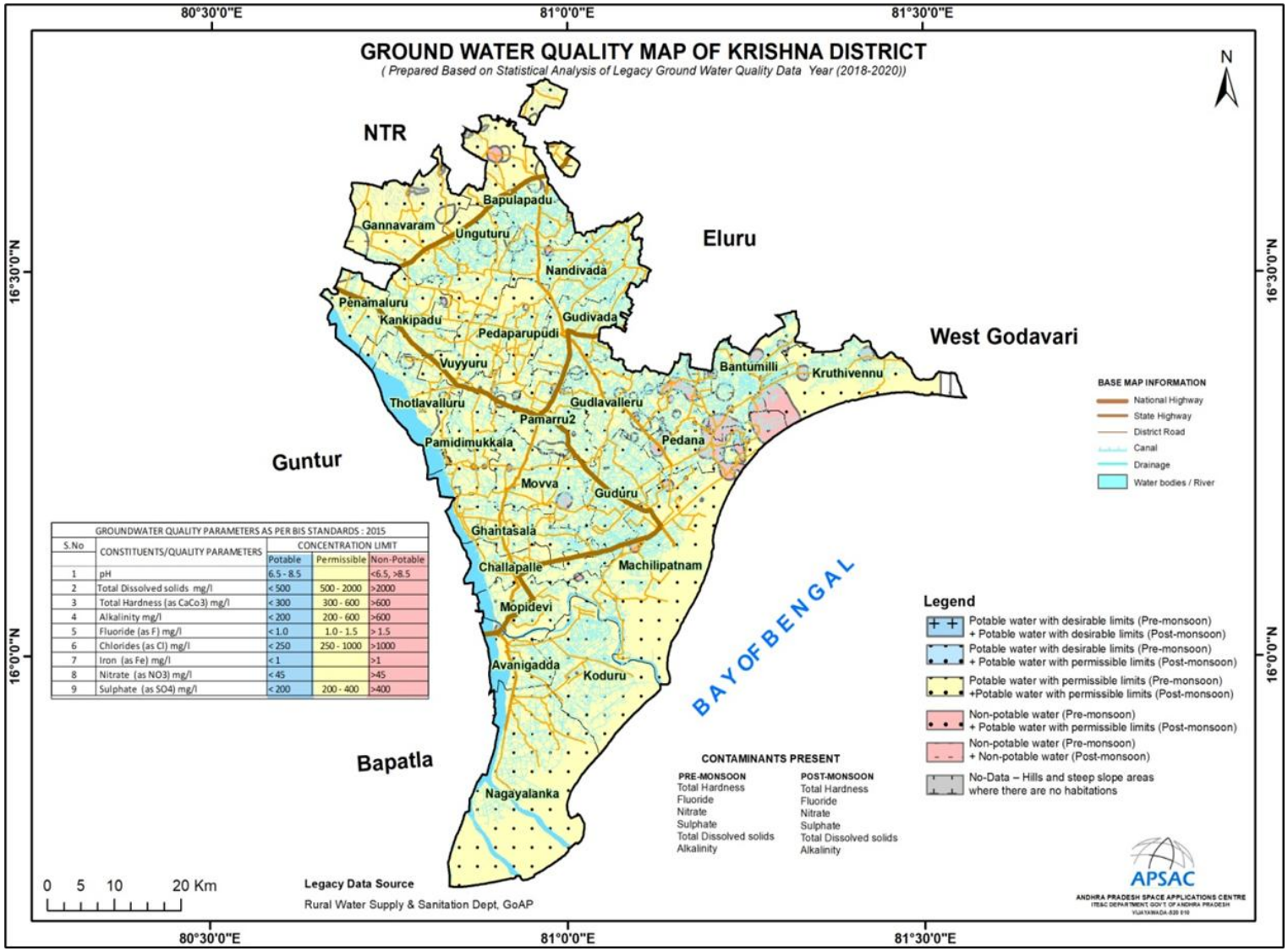


Figure-20: Ground Water Quality Map of Krishna District

Chapter – II Minor Minerals

2.1 Overview of Mining Activity

The following leases exist in this Krishna office jurisdiction. Mineral Regulatory, the important functioning of this office in these aspects is:-

i. Achievement of Targets of Mineral Revenue collections being fixed to this office annually
ii. Receiving and processing of the Mineral Concession Applications duly conducting the technical inspection, Survey and demarcation of the Mineral bearing applied areas
iii. Execution and Regulation of the operations of the Mining / Quarry leases in accordance with the Acts and Rules
iv. Issuing of dispatch permits duly collecting the Advance Royalty / Seig.fee from the lease holders on the minerals produced and intend to dispatch from their leased areas through online permit system
v. Controlling the illegal Mining / Quarrying and transportation by conducting the periodical inspections of the Mines and Quarries and also conducting the surprise vehicular checking and imposing the penalties
vi. Finalisation of Demand, Collection and Balance statements of the leases on annual basis

Krishna District is one of the chief minor minerals producing districts in the state and endowed with rich & varied minor mineral resources such as gravel and ordinary earth.

It is estimated that during the year 2022-23,2,38,864 Cum of Gravel and 27,212Cum of Ordinary earth are produced

2.2 Geology of the District

Genaralized Litho-stratigraphic Succession of Andhra Pradesh

Geological Time (a)	Supergroup (b)	Group (c)	Formation (d)
Holocene	-	-	Alluvium, river terraces, beach sands and soils
Pleistocene	-	-	Laterite and Gravel
Mio-Pilocene	-	-	Rajahmundry Fm.
Late Cretaceous Eocene	-	-	Deccan Trap with infra-and inter-trappeans

Lower Cretaceous to Upper Carboniferous	Gondwana	Upper Gondwana	Godavari Valley (Fluviatile) Chikiala Fm. Gangapur Fm.	Coastal Area (Fluvio-marine) Tirupati Fm. (Vejendla Fm) Raghavapuram Fm. (Vemavaram), Kandukuru, Sriperambadur Fms)
		Lower Gondwana	Kota Fm. Maleri Fm.	Gollapalle Fm. (Satyavedu Fm.) Kamthi Fm. Barren Measures, Barakar Fm. Talchir Fm.
			Cuddapah Basin	**Pakhal Basin**
				Sullavai Sandstone
Middle to Upper Proterzoic (980-500 m.y)		Kurnool	Nandyala Shale Koilakuntla Limestone Panyam Quarzite Owk Shale Narji Limestone Banaganapalli Quartzite	Putnur Limestone Penganga Group Takalapalle Arkose

			Srisailam Quartzite	**Alabaka Sandstone**
		Nallamalai	Cumbum Fm.	Lankavaram Shale Pattipalle Quartzite
			Mulug Group	Polavaram Fm. Jakaram Arkose
Middle Proterozoic (1600-1300 m.y.)	Cuddapah	Chitravathi	Bairankonda Quartzite Gandikota Quartzite	Pandikunta Shale
			Tadipatri Fm.	Gunjeda Dolomite
			Pulivendula Quartzite Mallampalli Group	
		Papaghni	Vempalle Fm. Gulcheru Quartzite	Bayyaram Quartzite Bolapalle Fm.
EPARCHAEAN INTERVAL				
Middle Proterozoic to Late Archean (2600-970 m.y)	Eastern Ghats		Charnockite	Charnockite with megacrystic k-feldspar charnockite
			Khondalites	Two pyrozene granulite / amphibolite Calc-silicate / granulite, Garnet-sillimanite-quartz-graphite gneiss (biotite-k-feldspar (Khondalite) Quartzite (gernet, sillimanite)
Late Archaean (2700 m.y)	Dharwar	Ramagiri-Penakacherla, Kolar, Kadiri, Gadwal-Narayanpet, Jonnagiri, Veligallu		Pyroclastic Rocks, local conglomerate / event conglomerate Metabasalt (Pillowed), Acid volcanics, minor andesite, dacite, rhyodacite, amphibolites, metaultramafics, minor

		Peddavuru Schist Belts & W.Part of Nellore Belt.	quartzite, calcsilicates, phyllites, intrusives of basic rocks and granites, rare lamprophyres.
Middle Archaean (3100-2900 y.m)	Older Supracrustals (Sargur)	Eastern and Southern parts of Nellore.	High Grade schists include include garnet, staurolite, kyanite, sillimanite, cordierite (rarely sapphirine-kornuropine as in Karimnagar) Mica schists, calcilicate rocks, crystalline limestone (minor). BIF, fuchsite quartzite, hornblende granulite, amphibolite, migmatite streaky biotite gneiss.
Gneissic Complex			Banded Tonalite-Trondhjemite Gneiss.

Geologically, the State of Andhra Pradesh forms a part of peninsular India and is one of the most ancient land masses. The geological formations of Andhra Pradesh range from the oldest to the recent.

The Sargur Supracrustals are the oldest rocks in Southern India, mostly present as enclaves within the migmatitic gneiss. These supracrustals are exposed in the eastern and southern parts of the Nellore schist belt. The lithology of Sargur mostly comprises garnet, staurolite, kyanite schists, BIFs, quartzites, granulites, and amphibolites. The gneissic complex comprises banded tonalite trondhjemite gneiss, which is the basement rock of the study area, along with migmatitic gneiss and biotite granite gneiss. TTGs are sodic, quartz-bearing granitic (plutonic) rocks with plagioclase as the most common feldspar, and K-feldspar ranging from subordinate to nearly absent.

The Dharwarian rocks in Andhra Pradesh are exposed in the western part of the Nellore belt and in many other areas like Anantapur, Ramagiri-Penakacherla, Kolar, Kadiri, Gadwal-Narayanpet, Jonnagiri, Veligallu Peddavuru Schist Belts & the western part of the Nellore Belt. The lithology mostly comprises metabasalt (pillowed), acid volcanics, minor andesite, dacite, rhyodacite, amphibolites, metaultramafics, minor

quartzite, calcsilicates, phyllites, intrusives of basic rocks and granites, rare lamprophyres, and some pyroclastic rocks and local conglomerates/event conglomerates defining hiatus in stratigraphy observed in the study area. Rocks of the middle Proterozoic to late Archaean are exposed in the Eastern Ghats mobile belt, characterized by extremely high-grade metamorphism falling under the granulite metamorphic facies. They mostly include khondalites and charnockites. The metamorphic facies of rocks of the Eastern Ghats goes up to granulite facies, with occurrences of charnockite with megacrystic K-feldspar, two pyroxene granulite/amphibolite, calc-silicate/granulite, and garnet-sillimanite-quartz-graphite gneiss (biotite-K-feldspar). Quartzite (garnet, sillimanite) is exposed in most of the state.

The Cuddapah basin is a part of the Dharwar craton and is the second-largest purana basin of Peninsular India, marking the profound unconformity known as the Eparchaean unconformity in early literature. The Cuddapah basin formation exposes rocks from the late Proterozoic to upper Proterozoic. It is divided into four groups: Nallamalai, Chitravathi, Papaghni, and Kurnool. Papaghni comprises dolomite and limestones, Chitravathi comprises shale, dolomite, and quartzites, Nallamalai comprises shale, quartzites, and arkosic sandstones, while Kurnool comprises shales, quartzites, and limestones. The Cuddapah basin is characterized by a rhythmic pattern of quartzite-shale-carbonate cycles. Uraniferous limestone is also reported from the Cuddapah basin. The major exposures of purana rock formations are in Prakasam, Kurnool, Cuddapah, Chittoor, and Nellore. The Deccan traps are found in East and West Godavari districts, with exposures near Rajahmundry. Outcrops of tertiary formations are found in East and West Godavari and Visakhapatnam districts, while quaternary sediments occur as thick blankets of alluvium in river valleys, deltas, and along the East coast.

Krishna district is underlain by a variety of geological formations spanning from the oldest Archaeans to Recent Alluvium. Hydrogeologically, these formations are classified as consolidated (Hard), semi-consolidated (Soft), and unconsolidated (Soft) formations. The consolidated formations include crystallines (Khondalites, Charnockites, and Granitic Gneisses) and metasediments (Dolomites, Shales, Phyllites, and Quartzites) of the Archaean and Pre-Cambrian periods, respectively. The semi-consolidated formations are represented by Tertiary formations (Rajahmundry and Gollapalli sandstones), while unconsolidated formations comprise deltaic

alluvial deposits of the Quaternary period (CGWB, 2013). Semi-consolidated formations occur in the northeastern part of the district, extending to a small area in parts of Bapulapadu and Gannavaram mandals. Unconsolidated formations occur in the southern part of the district, specifically in the delta area.

The Geological Survey of India (GSI, 2000) provided a detailed account of the geology/lithology of the district with a map on a 1:250,000 scale shown in Figure-23. An elaborate legend with stratigraphic sequence description is provided by GSI as follows: The Eastern Ghats Super Group, comprising Khondalite and Charnockite Groups, is exposed in the central part of the upland area. They consist of quartz, K-feldspar, garnet, sillimanite, and graphite, with or without corundum. In the northeastern part, many calc granulite and quartzite bands are present within Khondalite. Acid and intermediate varieties of Charnockite, with patches of pyroxene granulite Metagabbro (north of Krishna River in the Kondapalli hill ranges) and minor magnetite-hypersthene-quartz granulite, extend southwest of the Kondavidu hill ranges. Layered igneous rocks comprising anorthosite, gabbroic noritic Anorthosite, Leuco gabbro noritic gabbro, and pyroxenite, associated with chromite ore, occur as feeble bands within Charnockites (GSI, 2000).

The rocks of the Peninsular Gneissic Complex are mostly in the form of Migmatized gneisses with enclaves of older metamorphic rocks, such as amphibolite, pyroxene granulite, and actinolite schist. The grey granite gneiss, mostly confined to the western part, is always well-banded, with bands alternately light and dark in colour. The gneissic rocks are intruded by dykes of dolerite, pegmatite, and aplite. The rocks of Archaean age are overlain by Proterozoic cover sequences of the Cuddapah Super Group and Kurnool Group. The contact between the older crystallines and the younger sediments is marked by a pronounced unconformity known as the Eparchaean Unconformity. The Cuddapah Super Group is represented in the area by the Cumbum Formation (Shale, phyllite, dolomite, limestone, quartzite). The Kurnool Group comprises Banganapalle Conglomerate Quartzite and Narji Limestone. Micaceous quartzite of Mulug Group of Pakhal Super Group occurs as discontinuous outcrops east of Nandigama. The Pakhal Super Group is considered to be the time equivalent of the Cuddapah Super Group.

Rocks of the Upper Gondwana Group of the Gondwana Super Group, comprising Tirupati Sandstone, Gollapalle, Chintalapudi Sandstone, and Kamthi Sandstone, are exposed north, northwest, and east of Nuzvid. These rocks trend northeast (NE)-southwest (SW) with a 20° dip towards the southeast. Unconformably overlying the Gondwana rocks is a small patch of Rajahmundry Sandstone, occurring northeast of Nuzvid. The sandstone is brick-red and contains nodules of clay. The Krishna River built up its delta south of Vijayawada. It flows southwards up to Avanigadda, where it bifurcates into two channels, with the main channel continuing to flow southwards up to its confluence with the sea near Nagayalanka, and the branch at Avanigadda flowing eastwards up to its confluence with the sea near Hamsaldeevi.

The Geological Survey of India (GSI, 2000) provided a detailed account of the geology/lithology of the district with a map on a 1:250,000 scale (Figure-21) and an elaborate legend with a stratigraphic sequence as described above.

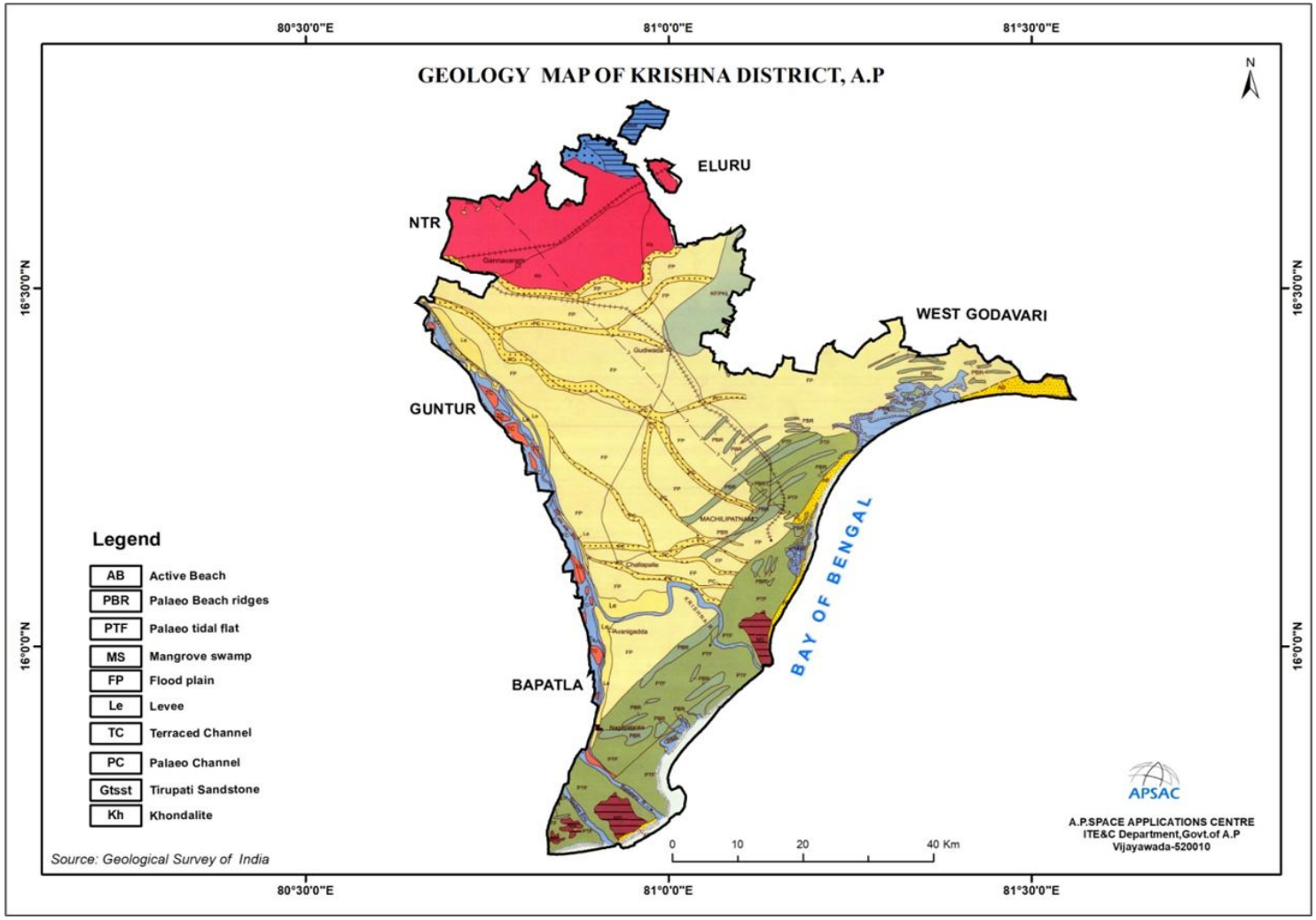
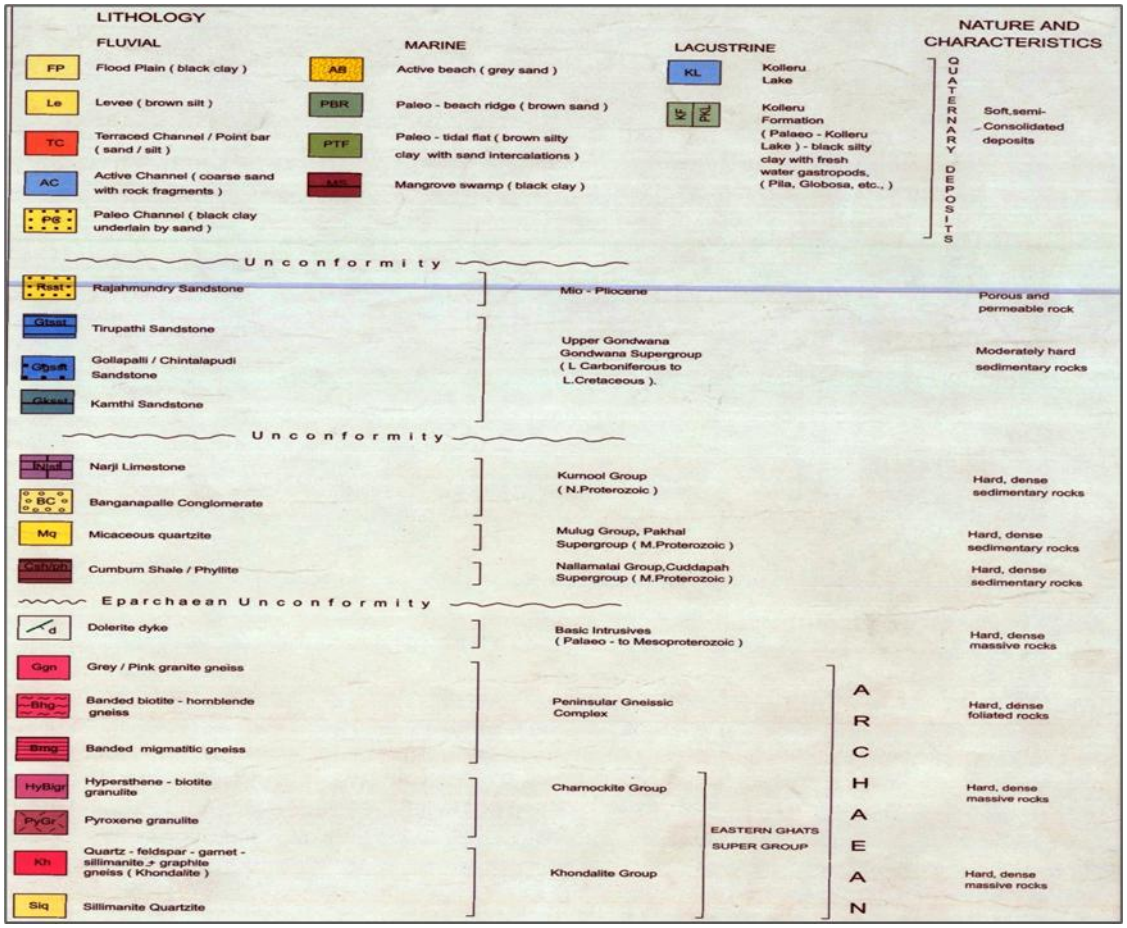


Figure 21: Geology of Krishna District, Andhra Pradesh (Source: GSI, 2000)



Detailed Legend with Stratigraphic Sequence of Krishna District

2.3 Minor Mineral Resources of Krishna District:

2.3.1. Building Stone: Utilized for construction purposes and available in Vedurupavuluru in Gannavaram Mandal.

2.3.2. Gravel: Used for the formation of kacha roads and filling low-level areas, available in Vedurupavuluru, Gopavarapugudem, and Gollanapalle, Gannavaram Mandal, and Mallavilli in Bapulapadu Mandal. The Mineral Resources Map of Krishna District is shown in Figure-22.

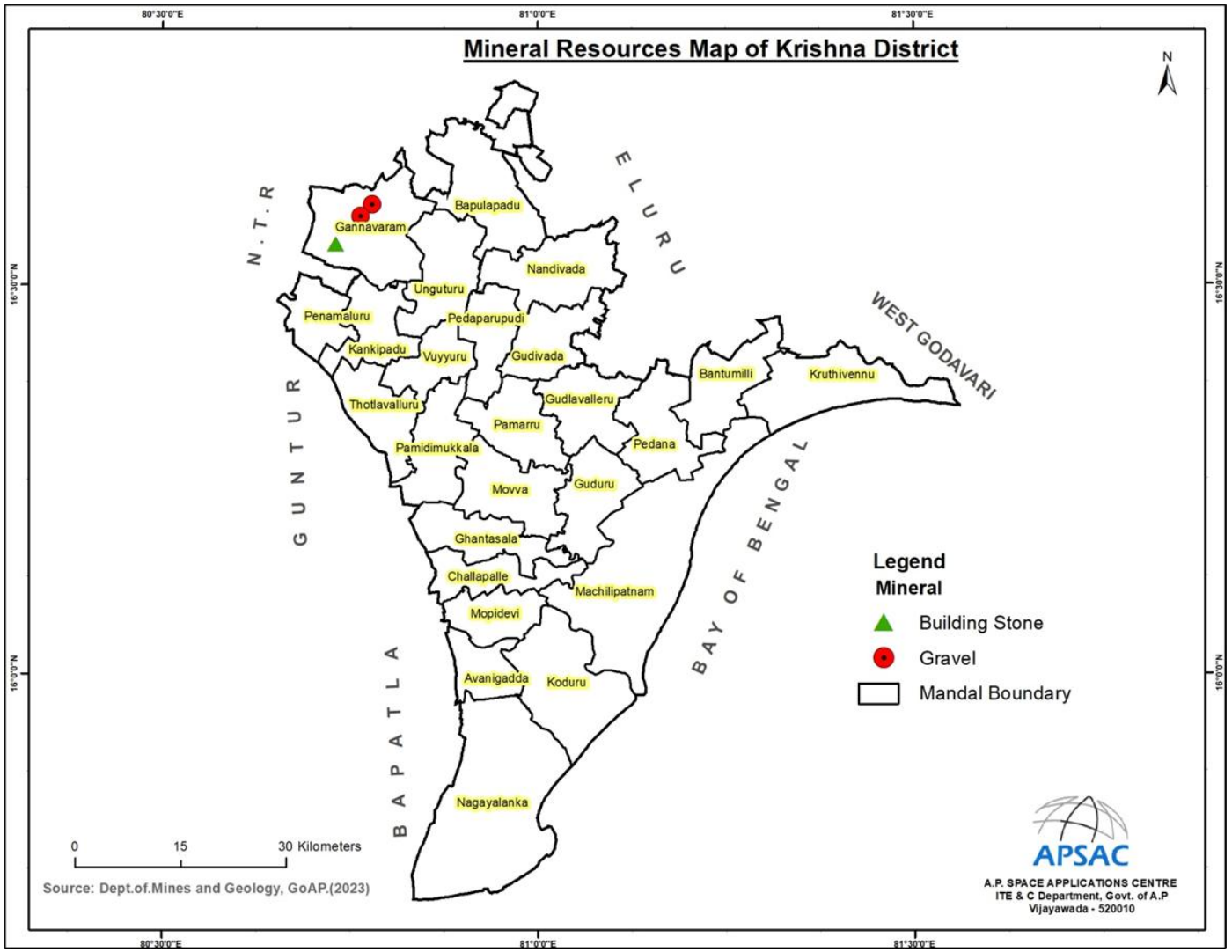


Figure-22: Mineral Resurce Map of Krishna District

The Detailed List of statement showing the Leases of Major and Minor Minerals in the distrct is in Table-16.

Table 16 List of Leases for Minor Minerals

S.NO	Name of the Mineral	Name of the Lessee	Address & Contact No. of the Lessee	Quarry Lease Grant Order No. & Date	Quarry lease location	Period of Quarry Lease (Initial)		Period of Quarry Lease (1st & 2nd …renewal)		Date of commencement of Quarry Operation	Status (Working/ non-working/Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude & Longitude)	Method of Mining (Opencast/Underground)
						From	To	From	To						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Gravel	G.Koteswari	9848125029	Proc.3985/Q3/2018, dt.02.08.2019 of DDM&G, Vijayawada	Extent 2.546ha, Sy.No. 9/1 & 4P of Gopavarapu gudem Village, Gannavaram Mandal, Krishna District	7/8/2019	6/8/2024	-	-	7/8/2019	Working	Non captive	SEIAA/AP/KRI/MIN/04/2019/929-490, dt.29.06.2019 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No: a 16° 36'52.79012" 80° 45' 17.031224"; b 16° 36'51.22125" 80° 45' 20.39982"; c 16° 36'46.82967" 80° 45' 17.65124"; d 16° 36'45.57221" 80° 45' 19.17372"; e 16°36'44.83304" 80° 45' 17.28771"; f 16° 36'42.29078" 80° 45' 14.8001"; g 16° 36'40.97404" 80° 45' 14.93816"; H 16° 36'40.99309" 80° 45' 14.22964"; I 16° 36'41.32822" 80° 45' 13.30114"; j 16° 36'46.84926" 80° 45' 15.59102"	Open Cast
2	Gravel	Sri Lavu Dora Babu	9133030975	Proc.346/Q3/2020, dt.12.03.2021 of DDM&G, Vijayawada	Extent 1.157 Ha, Sy.No.20/4(P), 20/5, 20/6, 12(198), Gopavarapu gudem Village, Gannavaram Mandal, Krishna Disrtrict	7/5/2021	6/5/2026	-	-	7/5/2021	Working	Non captive	SEIAA/AP/KRI/MIN/06/2020/1970/552, dt26.11.2020 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No: a 16° 36' 23.77431" 80° 45' 45.54211"; b 16° 36' 23.69427" 80° 45' 46.31820"; c 16° 36' 20.93257" 80° 45' 47.97704"; d 16° 36' 20.11863" 80° 45' 47.53720"; e 16° 36' 19.63648" 80° 45' 44.71546"; f 16° 36' 22.16304" 80° 45' 44.96389"; g 16° 36' 22.17901" 80° 45' 40.04128"; h 16° 36' 21.60690" 80° 45' 44.07287"; i 16° 36' 21.56932" 80° 45' 42.65207"; j 16° 36' 22.09588" 80° 45' 42.52739"; k 16° 36' 23.63850" 80° 45' 43.96102"	Open Cast
3	Gravel	Polavarapu Srinivas	9705348888	Proc.347/Q3/2020, dt.12.03.2021 of DDM&G, Vijayawad	Extent 1.019 Ha, Sy.No.39/4, 39/5 Gopavarapu gudem	7/5/2021	6/5/2026	-	-	7/5/2021	Working	Non captive	SEIAA/AP/KRI/MIN/06/2020/1969/550, dt26.11.2020 of Member Secrertary,	Sl.N: a 16° 36' 2118.520" 80° 45' 20.86289"; b 16° 36' 2158.568" 80° 45' 19.58496"; c 16° 36' 18.45445" 80° 45' 18.89949"; d 16° 36'17.94609" 80° 45' 15.53158"; e 16° 36' 19.12745" 80° 45' 15.7158; f 16° 36'17.30047" 80° 45' 15.80740"	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address & Contact No. of the Lessee	Quarry Lease Grant Order No. & Date	Quarry lease location	Period of Quarry Lease (Initial)		Period of Quarry Lease (1st & 2nd …renewal)		Date of commencement of Quarry Operation	Status (Working/ non-working/Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude & Longitude)	Method of Mining (Opencast/Underground)
				a	Village, Gannavaram Mandal, Krishna Disrtrict								SEIAA, AndhraPradesh	g 16° 36' 16.89510" 80° 45' 17.23981" H 16° 36'16.58752" 80° 45' 19.98877" I 16° 36' 18.14896" 80° 45' 20.22095" j 16° 36' 18.26503" 80° 45' 19.798563"	
4	Gravel	Smt Lavu Prashanti	9440819667	Proc.736/Q3/2020, dt.12.03.2021 of DDM&G, Vijayawada	Extent 2.031 Ha, Sy.No.31 Gopavarapu gudem Village, Gannavaram Mandal, Krishna Disrtrict	7/5/2021	6/5/2026	-	-	7/5/2021	Working	Non captive	SEIAA/AP/VSP/MIN/07/2020/2021-719, dt.08.12.2020 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E a 16° 36'06.70017" 80° 45'18.39697" b 16° 36'07.00477" 80° 45'15.42643" c 16° 36' 08.35815" 80° 45' 16.13360" d 16° 36' 09.46628" 80° 45'17.53935" e 16° 36' 11.18933" 80° 45'18.93603" f 16° 36'11.58383" 80° 45'20.29419" g 16° 36' 12.57217" 80° 45' 21.69414" H 16° 36' 12.12140" 80° 45' 23.65680" I 16° 36' 11.02699" 80° 45' 25.23435" j 16° 36' 10.02934" 80° 45'25.12293" K 16° 36' 10.24681" 80° 45' 22.19417" L 16° 36' 08.30044" 80° 45' 19.21012"	Open Cast
5	Gravel	Sri Moram Bhavana Rushi	9393511320	Proc.No.28/Q3/2018, dt.11.09.2020	Extent 4.611 Ha, Sy.No.27P Gopavarapu gudem Village, Gannavaram Mandal, Krishna Disrtrict	7/10/2020	6/10/2025	-	-	7/10/2020	Non Working	Non captive	SEIAA/AP/KRI/MIN/05/2019/1006-716, dt.06.08.2019 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E 1 16° 36'08.50027" 80° 45' 21.22624" 2 16° 36'06.65277" 80° 45' 26.83625" 3 16° 36' 07.09300" 80° 45' 31.87814" 4 16° 36' 10.55199" 80° 45' 33.06985" 5 16° 36' 08.38792" 80° 45' 35.85636 " 6 16° 36' 07.28712" 80° 45' 37.34160" 7 16° 36' 05.24000" 80° 45' 36.47658" 8 16° 36' 04.01580" 80° 45' 33.62821" 9 16° 36' 03.91247" 80° 45' 28.06696" 10 16° 36' 05.91829" 80° 45' 21.57889"	Open Cast
6	Gravel	Sri D. Venkata Siva Rama Rao	8985325378	Proc.849/Q3/2019, dt.23.11.2020 of DDM&G, Vijayawada	Extent 2 Ha, Sy.No. 121/3B(P), 122/3,4 Gollanapalle Village, Gannavaram Mandal, Krishna Disrtrict	28/11/2020	27/11/2025	-	-	28/11/2020	Working	Non captive	SEIAA/AP/KRI/MIN/01/2020/1606/448, dt.24.09.2020 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E a 16° 36'36.12424" 80° 47' 04.35640" b 16° 36'36.71162" 80° 47' 02.40009" c 16° 36' 38.92448" 80° 47' 02.86818" d 16° 36' 38.33261" 80°47' 04.69002" e 16° 36' 38.97704" 80° 47' 04.68803 " f 16° 36' 41.48088" 80° 47' 05.04128" G 16° 36' 40.66310" 80° 47' 08.35841" H 16° 36' 39.84548" 80° 47' 08.18331" I 16° 36' 38.48471" 80° 47' 07.91170" J 16° 36' 35.06879" 80° 47' 06.83939"	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address & Contact No. of the Lessee	Quarry Lease Grant Order No. & Date	Quarry lease location	Period of Quarry Lease (Initial)		Period of Quarry Lease (1st & 2nd …renewal)		Date of commencement of Quarry Operation	Status (Working/ non-working/Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude & Longitude)	Method of Mining (Opencast/Underground)
														k: 16⁰ 36’ 34.78122” / 80⁰ 47’ 06.25201” L: 16⁰ 36’ 35.05705” / 80⁰ 47’ 05.89811” m: 16⁰ 36’ 35.87383” / 80⁰ 47’ 05.50002”	
7	Gravel	G Ramesh Kumar	9381032293	Proc.231/Q3/2021, dt.27.04.2022 of DDM&G, Vijayawada	Extent 2.024 Ha, Sy.No.189 Gollanapalle Village, Gannavaram Mandal, Krishna Disrtrict	10/10/2022	9/10/2027	-	-	10/10/2022	Non Working	Non captive	SEIAA/AP/KRI/MIN/06/2021/3271/168.53/165.42, dt22.11.2021 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E a: 16⁰ 36’ 33.24292” / 80⁰ 45’ 05.03201” b: 16⁰ 36’ 32.73978” / 80⁰ 45’ 06.61563” c: 16⁰ 36’ 30.26014” / 80⁰ 45’ 06.64010” d: 16⁰ 36’ 25.85687” / 80⁰ 45’ 04.84329” e: 16⁰ 36’ 26.82620” / 80⁰ 45’ 01.29041	Open Cast
8	Gravel	SRI PRATHIPATI RAM PRASAD	9491211122	Proc.No.4052/Q3/2018, dt.02.07.2020 of the DDMG, Vijayawada	Extent 1.235 Ha, Sy.No.860 Vedurupavuluru Village, Gannavaram Mandal, Krishna Disrtrict	6/8/2020	5/8/2030	-	-	6/8/2020	Non Working	Non captive	SEIAA/AP/KRI/MIN/03/2019/864-332, dt.31.05.2019 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E 1: 16⁰ 33’55.42” / 80⁰ 45’ 9.40” 2: 16⁰ 33’51.29” / 80⁰ 45’ 17.20 3: 16⁰ 33’50.57” / 80⁰ 45’ 11.63” 4: 16⁰ 33’51.94” / 80⁰ 45’ 11.36”	Open Cast
9	Gravel	Gummadi Sesha Talpa Sai	9866254439	Proc.830/Q3/2021, dt.23.03.2022 of DDM&G, Vijayawada	Extent 2.632 Ha, Sy.No.437/3 Mallavilli Village, Bapulapadu Mandal, Krishna Disrtrict	11/5/2022	10/5/2027	-	-	11/5/2022	Non Working	Non captive	SEIAA/AP/KRI/MIN/8/2021/3409/168.47/165.39, dt22.11.2021 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E a: 16⁰ 40 43.78931” / 80⁰ 52’ 00.94389” b: 16⁰ 40 43.32372” / 80⁰ 52’ 07.34081” c: 16⁰ 40 38.82430” / 80⁰ 52’ 06.59801” d: 16⁰ 40 39.23069” / 80⁰52’00.53520”	Open Cast
10	Gravel	Sk Tanesha	8712292929	Proc.10/Q3/2021, dt.01.04.2022 of DDM&G, Vijayawada	Extent 0.688 Ha, Sy.No.458, 502/2A Mallavilli Village, Bapulapadu Mandal, Krishna	6/6/2022	5/6/2027	-	-	6/6/2022	Non Working	Non captive	SEIAA/AP/KRI/MIN/02/2021/2850/163.60&160.51/602, dt.26.08.2021 of Member Secrertary, SEIAA, AndhraPradesh	Sl.No / Latitude-N / Longitude-E 1: 16⁰ 39’ 56.94678” / 80⁰ 52’10.34831” 2: 16⁰39’ 57.12082” / 80⁰ 52’09.60692” 3: 16⁰ 39’ 56.87841” / 80⁰ 52’09.46178” 4: 16⁰ 39’ 56.81308” / 80⁰ 52’07.74133” 5: 16⁰ 39’ 57.11333” / 80⁰ 52’05.74711” 6: 16⁰ 39’57.71862” / 80⁰ 52’03.21748” 7: 16⁰ 39’ 55.44489” / 80⁰ 52’02.30891” 8: 16⁰39’ 55.89462” / 80⁰ 52’05.65910”	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address & Contact No. of the Lessee	Quarry Lease Grant Order No. & Date	Quarry lease location	Period of Quarry Lease (Initial)		Period of Quarry Lease (1st & 2nd ...renewal)		Date of commencement of Quarry Operation	Status (Working/ non-working/Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude & Longitude)	Method of Mining (Opencast/Underground)
					Disrtrict										

Data Source: Assistant Director of Mines and Geology, Krishna District, Andhra Pradesh

Table 17: List of Letter of Intent (LOI) Holders in the District along with its validity as per the following format

Sl. No.	Name of the Mineral	Name of the Lessee	Address & Contact No. of Letter of Intent Holder	Letter of Intent Grant Order No. & date	Area of Mining Lease to be allotted				Validity of LoI	Use (Captive/ Non-Captive)	Location of the Mining Lease (Latitude & Longitude)
1	2	3	4	5	Survey Nos.	Village	Mandal	Extent in Hect	7	8	9
					6						
	G rave I	Sri. Narra Venkateswara Rao	Sri.Narra Venkateswara Rao S/o Sitaramaiah Chintalapeta Village, Ga nnavara m mandal, Krishna Dist 9440151518	LOI Notice No r4s/Q3/2027 Dated 24.3.202L	16.00 Hects				1 year	NON captive	160 36', 58.76642" N 800 46',39.57504"E 160 36', 56.16510"N 800 46', 38.96713"8 160 36' 53.91945"N 8oo 46' 33.74809"E 160 36' 40.29419" N800 46' 27.45982"E t6a 36' 3g.3o7oz" N 800 46' 32.08951"E L6o 36' 43.72855" N 800 46' 36.43670" E L6a 36' ss.L57o" N 80046' 44.78699" E
NIL											

Data Source: Assistant Director of Mines and Geology, Krishna District, Andhra Pradesh

2.4 Details of Royalty in last 3 years

The royalty of last three years in the district detailed list is given in Table-18.

Table 18 Details of Royalty in last 3 years

Royalty for 2022-23

S. No.	Mineral	Royalty (in Rs. Lakhs)	Consideration Amt. (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Gravel	107.607	107.607	32.282	2.152
2	Ordinary Earth	14.136	14.136	4.241	0.283
Total		**122**	**122**	**37**	**2.4**

Royalty for 2021-22

S. No.	Mineral	Royalty (in Rs. Lakhs)	Consideration Amt. (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Gravel	291.477	145.73	87.433	5.830
2	Ordinary Earth	53.07	26.53	15.921	1.061
Total		**345**	**172**	**103**	**7**

Royalty for 2020-21

S. No.	Mineral	Royalty (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Gravel	248.328	74.498	4.967
2	Ordinary Earth	61.598	18.479	1.232

S. No.	Mineral	Royalty (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
Total		**310**	**93**	**6**

Data Source: District Mines and Geology Officer, Krishna District

2.5 Details of Production in last 3 years

Production of last three years in the Eluru district details is given in Table-19.

Table 19 Details of Production in last 3 years

Production for 2022-23

S. No.	Mineral	Unit	Production (in MT)
1	Gravel	Cubic Meter	2,38,864
2	Ordinary Earth	Cubic Meter	27,212

Production for 2021-22

S. No.	Mineral	Unit	Production (in MT)
1	Gravel	Cubic Meter	6,37,711
2	Ordinary Earth	Cubic Meter	1,17,934

Production for 2020-21

S. No.	Mineral	Unit	Production (in MT)
1	Gravel	Cubic Meter	5,34,997
2	Ordinary Earth	Cubic Meter	1,35,827

Data Source: District Mines and Geology Officer, Krishna District

2.6 Impact on environment

The extraction and utilization of minor minerals have become integral to our modern way of life, fueling infrastructure development, construction, and various industries. However, the impact of these activities on the environment cannot be underestimated. Minor minerals, which include granite, road metal, gravel, clay, and more, play a significant role in shaping the natural landscape and ecosystems. The various environmental consequences associated with the extraction and uses of minor minerals are:

2.6.1. Habitat Destruction: The mining of minor minerals often entails the removal of topsoil and vegetation, leading to habitat destruction. This can disrupt ecosystems, displace wildlife, and threaten the survival of numerous species. Loss of biodiversity is a significant concern in regions with extensive mining operations.

2.6.2. Land Degradation: Mining activities can lead to land degradation, including soil erosion and compaction. This not only reduces the land's fertility but also affects its ability to support agriculture and vegetation growth. Moreover, land degradation can contribute to increased vulnerability to natural disasters like floods.

2.6.3. Water Pollution: Mining operations can contaminate nearby water bodies through the discharge of sediments, chemicals, and heavy metals. This pollution can have detrimental effects on aquatic life, disrupt local hydrology, and compromise the quality of water available for human consumption.

2.6.4. Air Quality: Dust emissions from mining sites can deteriorate air quality in surrounding areas. The fine particles and pollutants released during excavation and transportation of minor minerals can pose health risks to both workers and nearby communities.

2.6.5. Regulatory Challenges: Enforcing regulations and monitoring mining activities in remote or unregulated areas can be challenging, allowing illegal and unsustainable practices to persist.

The extraction and utilization of minor minerals are essential for economic development, but they come at a cost to the

environment. Recognizing the environmental impacts of these activities is crucial for sustainable resource management.

2.7 Remedial Measures

The provision of Rule 12 (1) and Rule 12 (5) and of Andhra Pradesh Minor Mineral Concession Rules, 1966 allows the State Government to issue the Letters of Intent with the stipulated conditions to submit Approved Mining Plan (AMP), Environment Clearance (EC) and Consent for Establishment (CFE) for grant of lease.

Mine Plan stipulate the maximum permissible annual production of the mineral from the designated lease area and also includes estimated quantum of solid waste generation and its method of disposal, etc. Based on the Approved Mine Plan projections, Environment Management Plan shall be prepared and SEIAA makes the decision to grant the EC based on the EMP.

Leaseholders commit to all the remedial measures in the Mining Plan and the State Environment Impact Assessment Authority (SEIAA) ensures the remedial measures are being adhered to during the tenure of the Environmental Clearance.

Leaseholders in the district have adopted various remedial measures to mitigate the impact of mining on the environment. These measures aim to reduce the environmental footprint of mining operations and address the associated challenges. Some common practices include:

2.7.1. Environmental Impact Assessments (EIAs): Leaseholders conduct comprehensive EIAs to evaluate the potential environmental consequences of mining projects. They shall use this information to develop mitigation strategies.

2.7.2. Reclamation and Rehabilitation: Leaseholders work to restore mined areas by recontouring landscapes, replanting native vegetation, and stabilizing soils to promote ecosystem recovery.

2.7.3. Water Management: Proper management of water resources is crucial. Leaseholders use techniques like sedimentation ponds, water

recycling, and water treatment facilities to minimize water pollution and ensure responsible water use.

The following preventive measures are being followed for minimizing adverse effects on water regime:

- Small Gully checks, gully check dams, silt settling tanks, silt traps, etc. shall be constructed.
- Along all discharge points leaving the mining lease, into the surrounding area, suitable number of filter walls of sufficient lengths shall be erected across the flow, at intervals, all along the length to prevent suspended solids entering the surrounding streams/ drains/ water courses, to confine the discharge water quality to the permissible limits.
- Regular monitoring may be carried out and further remedial steps as may be necessary may be taken.

2.7.4. Waste Management: Effective management of mining waste, such as tailings and slag, involves containment in secure facilities to prevent soil and water contamination. Advances in waste disposal technologies are also being explored.

Steps being followed for effective waste management:

- Implementation of practices to minimize waste generation at the source. This involves optimizing extraction techniques, reducing overburden removal, and improving resource utilization.
- Encouraging recycling and reuse of waste materials wherever possible within the mining operation.
- Selection of an appropriate disposal methods based on waste characteristics and environmental considerations. Common methods include landfilling, controlled dumping, and backfilling.
- Treatment of contaminated water and effluents using appropriate technologies before discharge.

2.7.5. Afforestation: Leaseholders carry out a year-wise afforestation plan for the initial years with detailed costing of each plant, its maintenance per piece, etc.

While these measures represent positive steps toward mitigating environmental impact, it's important to note that the effectiveness of these practices can vary widely depending on factors such as the location, scale, and specific mineral being mined. Continuous improvement and adaptation are essential in the mining industry's ongoing efforts

2.8 Reclamation Measures

As per Rule 7A (ii) of Andhra Pradesh Minor Mineral Concession Rules, 1966, Mine Closure Plan shall be submitted by the leaseholder before 6 months of expiry of the lease in the proforma as prescribed by the Director. The Deputy Director concerned shall approve the mine closure plan and ensure compliance of conditions of the approved mine closure plan before expiry of the lease period.

Financial assurance of Rs.50,000/-(Rupees Fifty Thousand) for the quarry lease granted below five(5) hectares and Rs.10,000/- (Rupees Ten Thousand) per Hectare or part thereof for the quarry lease granted five (5) hectares and above, shall be submitted in the form of deposit. If the leaseholder does not reclamate the area as mentioned in the Mine Closure Plan, the deposit shall be forfeited and the Department of Mines & Geology ensure the proper implementation of the Mine Closure Plan.

2.9 Risk Assessment & Disaster Management Plan

Leaseholders conduct comprehensive risk assessment, prepare a model disaster management plan and submit in the Mining Plan.

The leaseholders maintain and arrange following resources at the mine site:

a) Fire fighting equipment

b) Ambulance services with location

c) List of volunteer organizations

d) List of Civil, Police and other authorities to be informed in case of an accident

e) Last of mobile crane operators (Government, Public Sector, and Private Sector).

f) List of mines, contacts, facility available nearby

g) List of first aiders and contacts.

h) List of Officers of DGMS to be informed in case of serious accidents Concerned DGMS officers concerned is displayed at the mine head.

The leaseholders shall monitor the total execution of the disaster management plan. The resources of all departments including men and material are being promptly made available. They are also conducting regular mock rehearsals with their staff to update the risk register and accordingly, disaster management plan

2.9.1. Mineral Regulatory:

The important functioning of District Mines and geology Officer, Krishna are:-

- Achievement of Targets of Mineral Revenue collections being fixed to this office annually
- Receiving and processing of the Mineral Concession Applications duly conducting the Technical inspection, Survey and demarcation of the Mineral bearing applied areas
- Execution and Regulation of the operations of the Mining / Quarry leases in accordance with the Acts and Rules
- Issuing of dispatch permits duly collecting the Advance Royalty / Seig.fee from the lease holders on the minerals produced and intend to dispatch from their leased areas through online permit system
- Controlling the illegal Mining / Quarrying and transportation by conducting the periodical inspections of the Mines and Quarries and also conducting the surprise vehicular checking and imposing the penalties
- Finalisation of Demand, Collection and Balance statements of the leases on annual basis

2.10 Plantation & Green Belt Development

Leaseholders are complying with the plantation and green belt development programmes as committed in their Mining Plans.

CHAPTER III: SAND

3.1 Sand Mineral Resources of Krishna District

3.1.1 General Sand Mineral Details Krishna District

(Prepared as per Sustainable Sand Mining Management Guidelines 2016 & 2020) *(Data Source: Assistant Director of Mines and Geology, Krishna District, Andhra Pradesh)*

In Krishna District, four rivers flow: Krishna, Budameru, Peddapadu Chiniki (Gunderu Nala), and Upputeru Rivers, covering a total length of 55 km, 22.72 km, 50.74 km, and 46.87 km, respectively. These rivers are major contributors to sand deposits and are mostly seasonal, flowing primarily during the rainy season. The Prakasam Barrage, mentioned above, is located across the Krishna River. Details of the Production of Sand in the last three years are listed in Table-20.

Table 20 Details of Production of Sand in Last three years in the District

Year	Production (In MTs)	Revenue Generated (in Rs)
2020-21	--	--
2021-22	731390	6,43,62,320
2022-23	179684	1,58,12,192

Data Source: District Mines and Geology Officer, Krishna District

3.1.2 River Basins in Krishna District

The Krishna major river basin is covered 80% area of the district and Budameru, partially covered with Ramileru, Tammileru river basins in the district. The Krishna Basin extends over Andhra Pradesh, Maharashtra and Karnataka having a total area of 2,58,948 Sq.km which is nearly 8% of the total geographical area of the country. The Krishna River enters the district near Enamalakuduru and Joining to Bay of Bengal near Lankavanidibba in Krishna district (*Figure-23)*.

The catchment area of each river basin is delineated by using master plan records and updated with survey of India topo sheets (1:50K). The Krishna River basin and Budameru river basin areas are 3,096.19 Sq.km and 680.18 Sq.km in the district. The district having total number of tanks including ponds and minor irrigation tanks 3,009. The Hydrological

units of Krishna district is shown in Table-21, Drainage system with description of main rivers is shown in Table-22,rivers lengths of Krishna district is shown in Table-23.Salient features and altitudes origin of rivers is shown in Table-24.

Table 21 Hydrological units of Krishna District

S.No	Major Basin	Minor Basin	Catchment Area (Sq.km)	No of. Tanks
1	Krishna	Branches of River Krishna Joining Sea	1718.98	895
2		Minor Drainages in Krishna Delta Joining Sea in Krishna District	1377.21	1605
3	Budameru	Budameru	680.18	483
4	Tammileru	Tammileru	12.67	5
5	Ramileru	Ramileru	33.09	21
		Total	**3822.13**	**3,009**

Data source: APSAC, Vijayawada

Table 22 Drainage System with Description of main rivers

S.No	Name of the River	Area Drained (Sq.Km)	% of Area Drained in the District
1	Budameru	680.53	17.80
2	Branches of River Krishna Joining Sea	1718.98	44.97
3	Minor Drainages in Krishna Delta Joining Sea in Krishna District	1377.11	36.03
4	Ramileru	32.20	0.84
5	Tammileru	13.21	0.35

Data source: APSAC, Vijayawada

Table 23 River Lengths in Krishna District

S.No	Name of the Major Basin	Name of the Minor Basin	Name of the River	River Length in Km
1	Budameru	Budameru	Budameru River	1.94
2			Chimala Vagu	1.95
3			Vanneru Drain	30.50
4	Krishna	Branches of River Krishna Joining Sea	Bhima Nadi	18.04
5			Gaddigondi Kaluva	13.75
6			Gollavani Kaluva	84.19
7			Gunda Kaluva	20.79
8			Gunderu Nala	35.81
9			Krishna River	166.21
10			Mala Kaluva	6.38
11			Mangaleru Drain	15.16

12			Peddapadu Chiniki	58.36
13			Raju Kalava	4.26
14		Minor Drainages in Krishna Delta Joining Sea in Krishna District	Upputeru River	15.18
			Total	**472.52**

Data source: APSAC, Vijayawada

Table 24 Salient Features of Important Rivers in Krishna District

S.No	Name of the River	Place of Origin	Altitude at Origin (m)
1	Krishna	Western Ghats, Mahabaleswar hills, Sattar District, Maharashtra State	1,400
2	Budameru	Chimalapadu RF, A.Konduru mandal in NTR dsitrict	415
3	Ramileru	Annaravupeta RF, Vissannapet mandal in NTR dsitrict	428
4	Tammileru	Tirumal Kunta RF, Lankalapalli in Telangana State	423

Data source: APSAC, Vijayawada

3.1.2.1. The Krishna River: After the Ganga, Godavari, and Brahmaputra, the Krishna River is the fourth-largest river in terms of watercourses and river basin in India. The river, also called Krishnaveni, is around 1,288 kilometers (800 miles) long. In India's Maharashtra, Karnataka, Telangana, and Andhra Pradesh, it is a significant source of irrigation. Krishna River enters into north east part of the district near Chilumuru village, Kolluru mandal and joining to Bay of Bengal near Gangadipalem village, Nizampatnam mandal in Bapatla district.

3.1.2.2. Budameru Riverin Krishna district which originates in the hills surrounding Mylavaram and empties itself into Kolleru Lake. Budameru is also known as The Sorrow of Vijayawada. In order to control the floods, the river was dammed at Velagaleru village and a diversion channel named, Budameru Diversion Channel (BDC) was constructed from Velagaleru to join Krishna River upstream of Prakasam Barrage. This is the first water diversion to the main Krishna river from another river basin

3.1.2.3. Tammileru River is a medium river which forms the boundary between Krishna district and Eluru district of Andhra Pradesh state. It is an area that is often affected by floods. The river drains into the Kolleru lake. Tammileru dam was constructed in the year 1980 to irrigate 3,720 hectares of land.

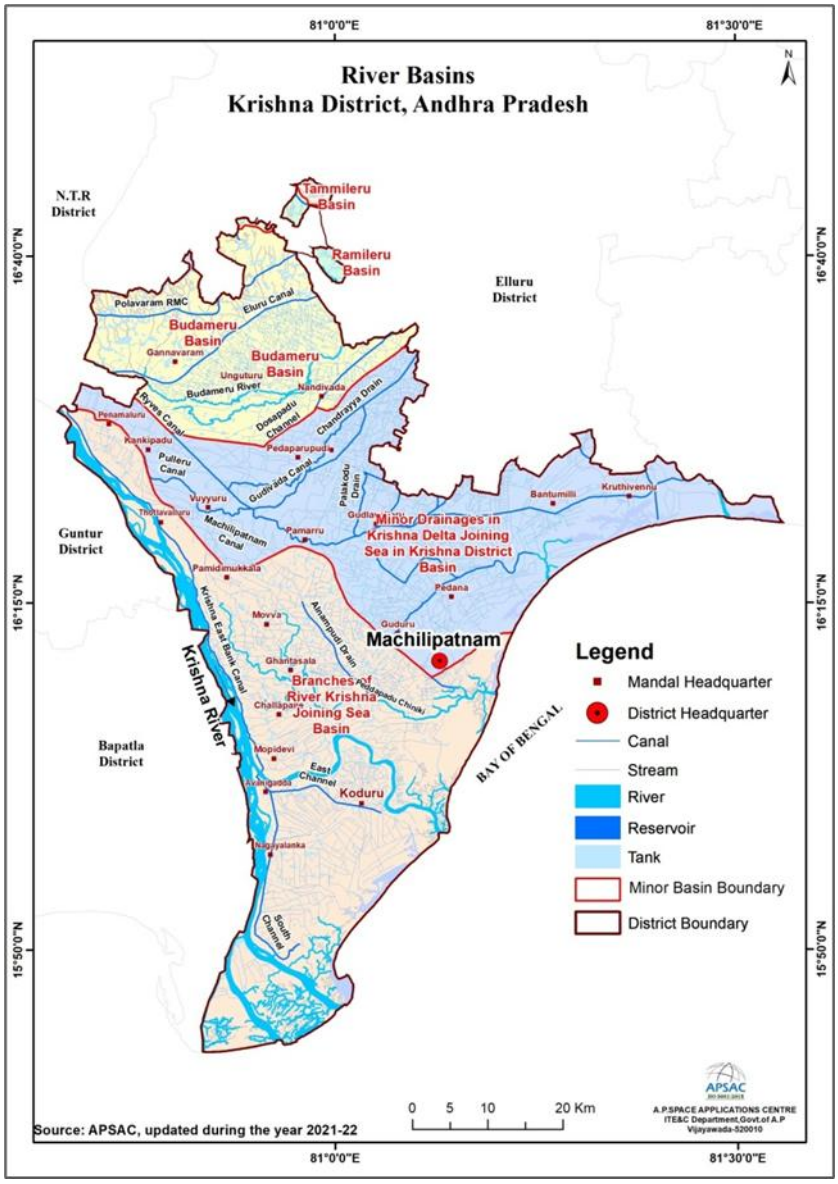


Figure 23 -Major and Minor River basin boundaries in Krishna District

3.1.3 Process of Deposition of Sediments in the Rivers of the District

Sediment transport is a natural process, and many have argued that the point of rivers is to move sediment downstream. However, with land use changes, e.g., deforestation and construction; agricultural practices; and development activities, accelerated erosion rates are ubiquitous. Sediment in the water column reduces transparency and can be deposited downstream and exacerbate flooding. Three principal sources of sediment are the following:

Sediment transport is the movement of organic and inorganic particles by water. In general, the greater the flow, the more sediment that will be conveyed. Water flow can be strong enough to suspend particles in the water column as they move downstream, or simply push them along the bottom of a waterway. Transported sediment may include mineral matter, chemicals and pollutants, and organic material. Another name for sediment transport is sediment load. The total load includes all particles moving as bedload, suspended load, and wash load.

3.1.3.1. Bedload

As the name suggests, this element of sediment movement consists of loose, granular particles at the sediment-water interface (such as a stream bed or tidal flat). Air or water that moves across the bed will being to move grains if the flow velocity is great enough to overcome the force of gravity and any resistance at grain contacts. This is the **threshold velocity (Figure-24)**.

The bedload contains two main components:

- the **traction load**, or traction carpet, and
- the **saltation loads**.

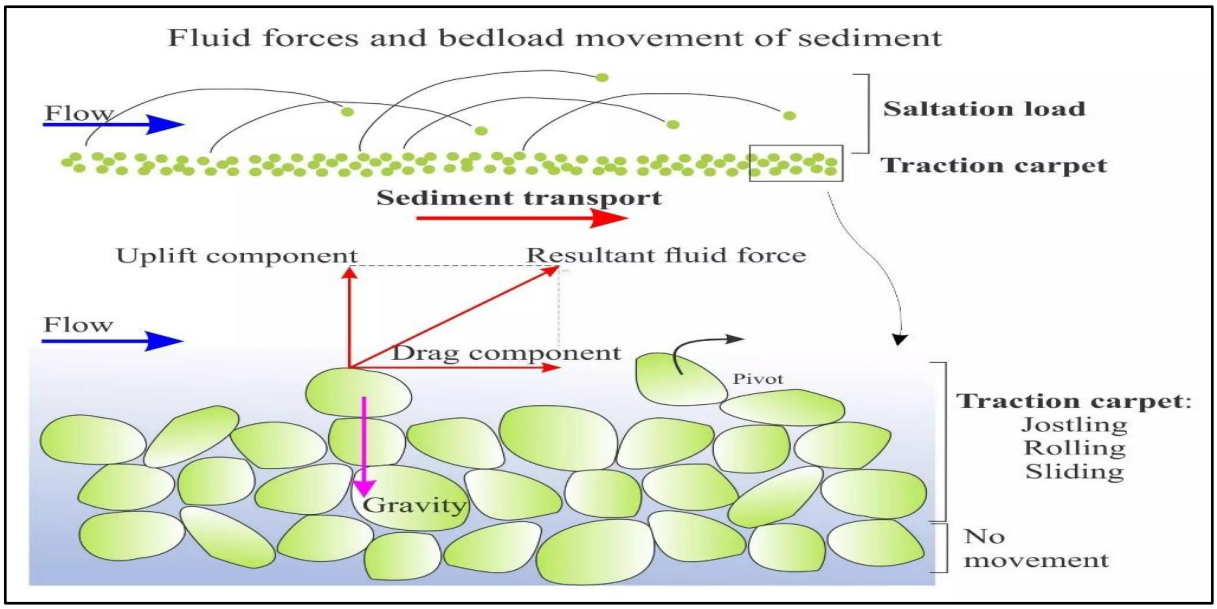


Figure-24: Bedload Movement of Sediment

The various components of force involved in initiation of grain movement are shown above. Here, fluid flowing over a sediment bed produces shear stresses that can be resolved into a component of drag (parallel to the bed) and a lift component normal to the bed. At the threshold velocity when the resultant fluid force on grains is greater than gravity, grains begin to roll, slide and jostle along the bed like a moving carpet – the **traction carpet**.

3.1.3.2. Suspended Load Most natural flows in rivers, shallow marine settings and air are turbulent. Even at low-flow velocities, the speed and trajectories of flow can vary considerably – witness the eddies and boils in seemingly tranquil streams. Very fine particulate sediment (particularly clays) can be kept in suspension for long periods by turbulence; the stresses generated by turbulent flow balance or overcome the gravitational force acting on the particles.

If turbulence decreases significantly, for example when a river empties into a lake, then most particles will gradually settle to the sediment bed. The rate at which a particle settles out of suspension is called the **settling velocity**, where the force of gravity (downwards) exceeds the combined effects of upward-directed **buoyancy forces** acting on a grain and the drag on a particle caused by **fluid (viscous) resistance**. Thus, the rate of settling depends on the size, shape and density of particles, and the viscosity of the fluid. In general, settling through air is much more rapid than through water.

Both bedload and suspension load are important processes in the generation of sedimentary structures. In particular, bedload transport of loose sand is the critical process for growth of bedforms and their internal cross-stratification (crossbedding). The description of **bedforms** (crossbeds) and the flow conditions (**flow regime**) under which they form have been described in other posts (*Figure-25)*.

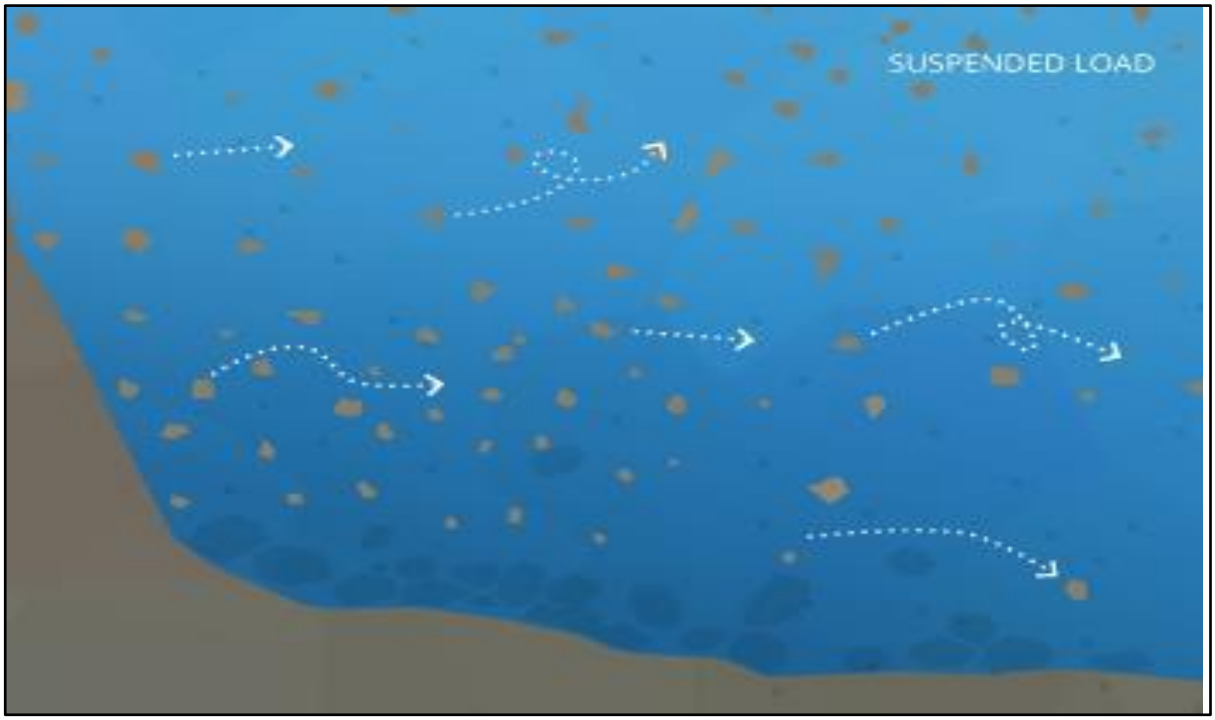


Figure-25: Sediment Load

3.1.3.3. Wash Load

The wash load is the portion of sediment that will remain suspended even when there is no water flow. The wash load is a subset of the suspended load. This load is comprised of the finest suspended sediment (typically less than 0.00195 mm in diameter). The wash load is differentiated from the suspended load because it will not settle to the bottom of a waterway during a low or no flow period. Instead, these particles remain in permanent suspension as they are small enough to bounce off water molecules and stay afloat. However, during flow periods, the wash load and suspended load are indistinguishable. Turbidity in lakes and slow-moving rivers is typically due the wash load 8. When the flow rate increases (increasing the suspended load and overall sediment transport), turbidity also increases. While turbidity cannot be used to estimate sediment transport, it can approximate suspended sediment concentrations at a specific location (*Figure-26)*.

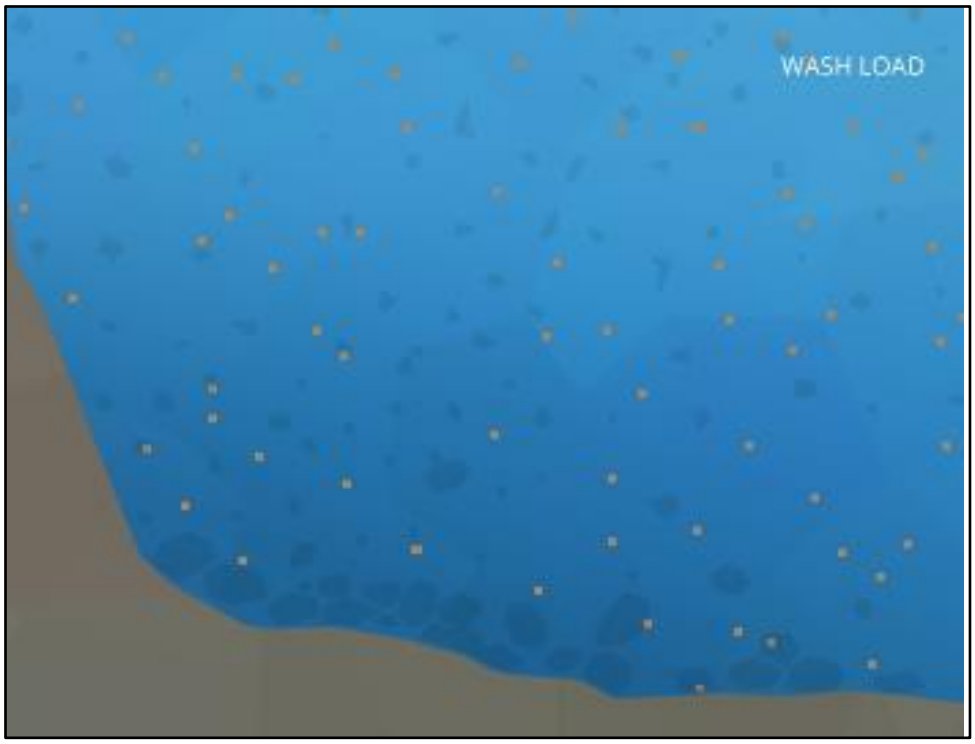


Figure-26: Wash Load

3.1.3.4. Settleable Solids

The suspended particles that fall to the bottom of a water body are called settleable solids. As they are found in riverbeds and streambeds, these settled solids are also known as bedded sediment. The size of settleable solids will vary by water system – in high flow areas, larger, gravel-sized sediment will settle out first. Finer particles, including silt and clay, can be carried all the way out to an estuary or delta (*Figure-27)*.

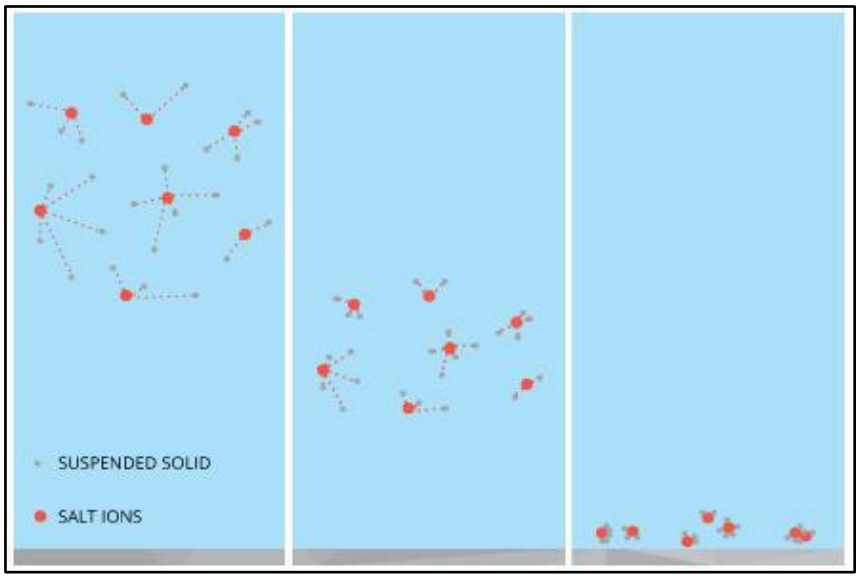


Figure-27: Settleable Solids

3.1.3.5. Sediment Deposition

Sediment is necessary to the development of aquatic ecosystems through nutrient replenishment and the creation of benthic habitat and spawning areas. These benefits occur due to sediment deposition – when suspended particles settle down to the bottom of a body of water. This settling often occurs when water flow slows down or stops and heavy particles can no longer be supported by the bed turbulence. Sediment deposition can be found anywhere in a water system, from high mountain streams, to rivers, lakes, deltas and floodplains. However, it should be noted that while sediment is important for aquatic habitat growth, it can cause environmental issues if the deposition rates are too high, or too low. Sediment transportation and Deposition depends upon various factors like Slope of the Area, Annual Rainfall, Lithology, and flow intensity of River, Geomorphology, Soil, Geology and Land use.

In sediment transport a distinction is generally made between fine and coarse sediment, because the transport mechanisms differ. Coarse sediment (grain size >63 μm) tends to be characterised by particles that remain separate and are chemically inert; fine sediments (<63 μm) on the other hand tend to come together as flocculated populations (flocs) and have the tendency to attract organic material and contaminants to their surface. A great deal has been researched and written about the break up and flocculation of these primary particles under turbulence and subsequent settling (e.g., Uncles et al., 2010). These differences imply important variations in the rate of transport and settling characteristics for the same flow conditions for different sediments. The nature of the physical environment also has an important bearing on this, in that fine sediment tend to be found in sheltered environments (shallow, enclosed estuarine systems), while beaches on open coasts are characterised by coarser materials. This reflects the energy of the water in which the particles become suspended and their subsequent fate.

Rates of transport of material are generally expressed in terms of a flux, as kg/s for example, where this figure is generally obtained by considering the product of the flow rate (in m^3/s) and the concentration of material in suspension (kg/m^3). This does not necessarily imply a requirement for the material to be suspended; it is equally possible to express a bed load using the same units, for example, but it does imply that to obtain an estimate of the sediment flux it is necessary to know both the concentration and the flow rate over a given cross section. Both

these quantities can be measured and there are a variety of techniques available to do this, using insitu collection or sampling, in situ optical or acoustic methods, or remote sensing from aircraft or satellites (Uncles and Mitchell, 2017) (*Figure-28)*

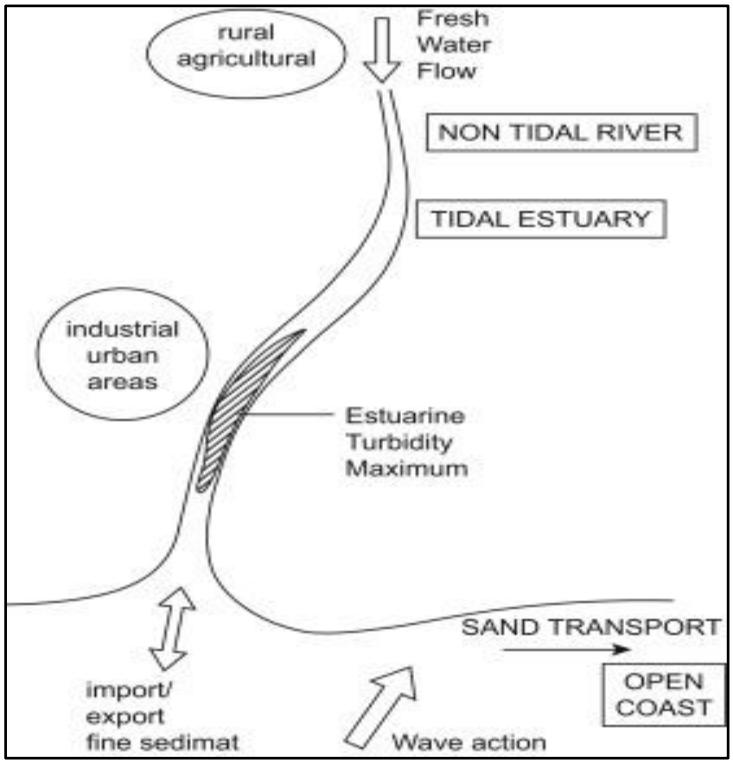


Figure-28: Sediment Deposition Process

Process of Deposition of Sediments in the Rivers of the District Sand is deposited because of the following reasons: (a) Floods: The surface or strip of relatively smooth land adjacent to a river channel constructed (or in the process of being constructed) by the present river in its existing regimen and covered with water when the river overflows its banks at times of high water. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current (b) Valley fill: The unconsolidated sediment deposited by any agent so as to fill or partly fill a valley.

3.1.4 Replenishment Study

A replenishment study for riverbed sand is required in order to nullify the adverse impacts arising due to excessive sand extraction. Mining within or near the riverbed has direct impact on the stream's physical characteristics, such as channel geometry, bed elevation, substratum composition and stability, in-stream roughness of the bed, flow velocity, discharge capacity, sediment transport capacity etc. For sustainable river

sand mining, it is necessary that the mine pits formed as a result of sand excavation are refilled with sand by the natural process of replenishment in a reasonable period so that the area is again available for mining. The rate of gross erosion is dependent upon many physical factors like climatic conditions, the nature of the soil, the slope of the area, topography and land use. The effect of any of these variables may vary greatly from one geographic location to another, and the relative importance of controlling factors often varies within a given land resource area (Dendy, 1976).

There is no denial of the fact that bed load changes from hour to hour, day to day, and year to year; estimating annual bed load rates is a dynamic process involving careful examination. Therefore, proper care has been taken before applying the empirical model to calculate the sediment yield from the watershed.

The estimation of sand replenishment is based on empirical and analytical approaches. There are many sediment transport equations as well as models which are suitable for use in the prediction of the replenishment rate of rivers/watersheds. The sedimentation models include SWAT, HEC-HMS etc. These models are developed based on the fundamental hydrological and sediment logical processes. They may provide detailed temporal and spatial simulation but usually require extensive data input. Hourly/daily input values of meteorological and radiation variables are required for continuous simulations. Some of the empirical equations for estimating sediment transport are as follows.

Annual Replenishment Rate for sand for Major Sand Resource Area is determined using emperial mathematical expression Dendy Bolton Equation and reproduced below:

- Einstein (1950)
- Laursen (1958)
- Bagnold (1966)
- Engelund-Hansen equation (1967)
- Yang equations (1973)
- Dendy- Bolton equation (1976)
- Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt (1977)
- Van Rijn (1984)
- Zanke (1987)

To estimate the transport capacity or the sediment load being conveyed by a water stream, one of the many transport equations that are available in the literature is frequently used. Einstein (1950) introduced statistical

methods to represent the turbulent behaviour of the flow. Bagnold (1966) introduced an energy concept and related the sediment transport rate to work done by the fluid. Engelund and Hansen (1967) presented a simple and reliable formula for the total load transport in rivers. The Yang equation makes use of the total bedhydraulic radius, and studies show that it is good for estimating the sediment transport in the channel for the condition of dunes on the bed. MUSLE includes only one type of sediment yield (sheet and rill Erosion). Van Rijn (1984) solved the equations of motions of an individual bed-load particle and computed the saltation characteristics and the particle velocity as a function of the flow conditions and the particle diameter for plane bedconditions. The equations of Zanke and Van Rijn seem to be only moderately satisfactory in estimating the sediment transport in the channel for the condition of dunes on the bed. However, it appears that no single equation could provide reliable estimates of a total load of sediment transport for all of the bed forms that could occur sequentially or randomly in alluvial channels or natural water courses. The comparison of the equations for estimating sediment rate is given below Table- 25–

Table 25: Types of Sediment Transport Equation

Sl.No.	**Sediment Transport Equation**	**Remarks**
1	Einstein (1950)	Bed load function was determined for many but not all types of stream channels
2	Laursen (1958)	Laursen equation outperforms other transport equations in the silt range
3	Bagnold (1966)	Bagnold related the sediment transport rate to work done by the fluid
4	Engelund-Hansen equation (1967)	The original Engelund-Hansen relation (OEH) is based on a single characteristic grain size, which limits its applicability in sand-bed rivers with a wide GSD
5	Yang equations (1973)	It makes use of a total bed hydraulic radius

Sl.No.	Sediment Transport Equation	Remarks
6	Dendy- Bolton equation (1976)	It uses both drainage area and means annual runoff for estimation of sediment yield. It calculates all types of sediment yield like sheet and rill erosion, gully erosion, channel bed and bank erosion and mass movement
7	Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt (1977)	MUSLE includes only one type of sediment yield (sheet and rill Erosion)
8	Van Rijn (1984)	Calculated equations of motions of an individual bed-load particle for plane bed conditions
9	Zanke (1987)	Zanke was found to be moderately satisfactory for the condition of the dunes on the bed.

In this study, the rate of gross silt production in the watershed and the ability of the stream system to transport the eroded material in a river have been carried out by the Dendy-Bolton equation. Dendy-Bolton formula is often used to calculate the sedimentation yield as it uses both drainage area and mean annual runoff as key parameters to give a yield value. Also, Dendy-Bolton equation calculates all types of sediment yield like sheet and rill erosion, gully erosion, channel bed and bank erosion and mass movement.

The drainage area of Krishna River in Krishna district is situated downstream of the Prakasam Barrage. The Water Resource Department of Andhra Pradesh records the surplus discharge from the Prakasam Barrage, which is considered as the downstream run-off the river Krishna. For calculation of sediment yield, the total surplus discharge of the Prakasam Barrage for water year 2022-23 (June 2022 to May 2023) of 1330 TMC is taken as run-off.

Annual Replenishment Rate for sand for Major Sand Resource Area is determined using emperial mathematical expression Dendy Bolton Equation and reproduced below:

For Average Annual Run-off less than 2"

$S = 1280 \times Q0.46 [1.43 - 0.26 \log (A)]$ Formula.....(A)

For Average Annual Run-off move than 2"

$S = 1965 \times (e^{-0.055 \times Q}) [1.43 - 0.26 \log (A)]$ Formula.....(B)

Q = Mean Annual Run-off in mm

A = Net drainage Area in Sq. km

S = Sediment yield (tons/Sq. km/yr)

The sedimentation yield for Krishna River in Krishna District is arrived based on the above Dendy Bolton Equation or Formula (B). The ssedimentation yield in Kakinada District is shown in Table -26

Table 26 Sedimentation yield for Krishna River in Krishna District

Name of the River	Area Drained (sq. km)	Mean Annual Run-off (in mm)	Rate of Annual Deposition in the River (tons / sq. km /year)	Annual Deposition (tonne)
Krishna	3096.09	33.33	320.01	9,90,151*

In this report, the sediment yield was calculated using the standard records of Department of Water Resources. To ensure systematic and scientific studies, Department of Mines & Geology is in the process of selection of NABET Accredited agency for conducting detailed & regular replenishment studies for potential sand bearing areas.

***Note**: The sedimentation yield was calculated manually by APSAC and the value is **10,90,914 Tones/ year**. The details are provided as an Annexure at page number 113.

3.1.5 Details of Sand Mining Leases:

The river Krishna is the main source of sand in the district flowing in the eastern side of the Krishna district through following mandals

Sl.No	Mandals
1	Penamauru
2	Kankipau
3	Thotlavaluru
4	Ghantasala
5	Challapalli
6	Mopidevi
7	Avanigadda
8	Nagayalanka

Proposed potential Sand Mining Leasesin Krishna district shown in Table-27.

Table 27 The detail of Potential Sand Mining Leases

Reach Name	Quantity (in MTs)	Geo-Coordinates	Remarks
Northvalluru -2	73500	1.16°19'36.52"N, 80°45'28.94"E 2.16°19'36.67"N, 80°45'36.19"E 3.16°19'29.58"N, 80°45'39.25"E 4.16°19'27.49"N, 80°45'30.70"E 5.16°19'33.46"N, 80°45'32.43"E	Proposed
Northvalluru -3	66750	1.16°19'13.78"N, 80°45'54.35"E 2.16°19'08.75"N, 80°45'57.89"E 3.16°19'06.47"N, 80°45'49.58"E 4.16°19'11.91"N, 80°45'46.69"E	Proposed
Northvalluru -6	72600	1.16°19'46.33"N, 80°45'01.19"E 2.16°19'52.71"N, 80°45'07.35"E 3.16°19'43.72"N, 80°45'08.66"E 4.16°19'39.01"N, 80°45'06.03"E	Proposed
Royyuru -1	73500	1.16°22'16.87"N, 80°43'48.94"E 2.16°22'22.32"N, 80°43'52.30"E 3.16°22'13.16"N, 80°43'57.91"E 4.16°22'10.57"N, 80°43'52.00"E	Proposed
Royyuru -5	67500	1.16°21'53.70"N, 80°43'59.53"E 2.16°21'56.17"N, 80°44'04.17"E 3.16°21'48.11"N, 80°44'10.27"E 4.16°21'45.94"N, 80°44'06.22"E	Proposed
Srikakulam -2	30000	1.16°11'58.67"N, 80°50'04.08"E 2.16°12'02.08"N, 80°50'03.04"E 3.16°11'59.28"N, 80°45'39.25"E	Proposed

Reach Name	Quantity (in MTs)	Geo-Coordinates	Remarks
		4.16°11'55.80"N, 80°49'59.85"E	
Srikakulam -3	73500	1.16°10'54.76"N, 80°50'32.57"E 2.16°11'00.71"N, 80°50'29.95"E 3.16°11'08.94"N, 80°50'28.17"E 4.16°11'02.79"N, 80°50'24.68"E 5.16°10'53.24"N, 80°50'28.84"E	Proposed
Srikakulam -5	73500	1.16°11'29.98"N, 80°50'17.91"E 2.16°11'28.80"N, 80°50'16.27"E 3.16°11'40.29"N, 80°50'11.63"E 4.16°11'43.37"N, 80°50'10.94"E 5.16°11'43.54"N, 80°50'14.19"E 6.16°11'37.24"N, 80°50'17.65"E 7.16°11'33.66"N, 80°50'17.98"E 8.16°11'33.10"N, 80°50'18.16"E	Proposed
Madduru -2	39000	1.16°23'00.75"N, 80°43'24.16"E 2.16°23'03.49"N, 80°43'21.40"E 3.16°23'09.93"N, 80°43'19.25"E 4.16°23'10.26"N, 80°43'23.96"E	Proposed
Madduru -3	74250	1.16°23'53.54"N, 80°42'32.79"E 2.16°23'44.86"N, 80°42'38.98"E 3.16°23'57.63"N, 80°42'37.99"E 4.16°23'49.66"N, 80°42'41.56"E	Proposed
Chowdavaram - 4	73500	1.16°24'12.71"N, 80°42'08.29"E 2.16°24'19.78"N, 80°42'13.51"E 3.16°24'23.67"N, 80°42'08.60"E 4.16°24'17.28"N, 80°42'03.53"E	Proposed
Chowdavaram - 6	69150	1.16°24'35.18"N, 80°41'55.63"E 2.16°24'28.60"N, 80°41'51.06"E 3.16°24'33.79"N, 80°41'47.21"E 4.16°24'40.65"N, 80°41'51.64"E	Proposed
Northvalluru - 1	59100	1.16°19'27.46"N, 80°45'30.61"E 2.16°19'33.48"N, 80°45'32.43"E 3.16°19'37.64"N, 80°45'27.70"E 4.16°19'30.54"N, 80°45'25.07"E	Proposed
Northvalluru - 4	66750	1)16°19'21.24"N80°45'12.72"E 2)16°19'33.02"N80°45'17.23"E 3)16°19'30.58"N80°45'20.68"E 4)16°19'18.34"N80°45'16.22"E	Proposed
Northvalluru - 5	73500	1)16°19'36.28"N, 80°45'14.22"E 2)16°19'28.32"N, 80°45'09.78"E 3)16°19'21.24"N, 80°45'12.72"E 4)16°19'33.02"N, 80°45'17.23"E	Proposed
Royyuru - 2	72000	1)16°22'11.80"N, 80°43'41.60"E 2)16°22'14.39"N, 80°43'47.53"E 3)16°22'12.05"N, 80°43'48.64"E 4)16°22'08.57"N, 80°43'51.85"E	Proposed
Royyuru - 3	73500	1)16°22'04.40"N, 80°43'45.89"E 2)16°22'08.57"N, 80°43'51.85"E	Proposed

Reach Name	Quantity (in MTs)	Geo-Coordinates	Remarks
		3)16°22'02.42"N, 80°43'56.85"E 4)16°22'58.68"N, 80°43'51.22"E	
Royyuru - 4	72000	1)16°21'58.68"N, 80°43'51.22"E 2)16°22'02.42"N, 80°43'56.85"E 3)16°21'54.74"N, 80°44'01.55"E 4)16°21'52.27"N, 80°43'56.91"E	Proposed
Srikakulam - 1	73500	1)16°11'03.57"N, 80°50'39.00"E 2)16°10'58.82"N, 80°50'40.57"E 3)16°10'54.76"N, 80°50'32.57"E 4)16°11'00.71"N, 80°50'29.95"E	Proposed
Srikakulam - 4	73500	1)16°11'08.94"N, 80°50'28.17"E 2)16°11'12.28"N, 80°50'31.20"E 3)16°11'06.56"N, 80°50'33.09"E 4)16°11'07.56"N, 80°50'35.92"E 5)16°11'03.02"N, 80°50'36.81"E	Proposed
Chowdavaram - 1	74850	1)16°24'03.61"N, 80°42'19.31"E 2)16°24'03.82"N, 80°42'21.68"E 3)16°24'09.85"N, 80°42'28.47"E 4)16°24'13.95"N, 80°42'23.05"E 5)16°24'05.11"N, 80°42'17.39"E	Proposed
Chowdavaram - 2	73500	1)16°24'13.95"N, 80°42'23.05"E 2)16°24'05.11"N, 80°42'17.39"E 3)16°24'08.32"N, 80°42'12.98"E 4)16°24'17.88"N, 80°42'16.20"E	Proposed
Chowdavaram - 4	73500	1) 16°24'08.32"N, 80°42'12.98"E 2)16°24'17.88"N, 80°42'16.20"E 3)16°24'12.71"N, 80°42'08.29"E 4)16°24'19.78"N, 80°42'13.51"E	Proposed

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

Probable Sand bearing areas in Krishna district is shown in Table-28. The name of the sand bearing index are given from North to South direction. The Probable Sand bearing areas were identified through field survey with the help of hand held GPS (Global Positional System) and the help of existing literature. The map of the probable sand bearing areas is shown in Figure-34.

Table 28: Probable sand bearing areas in the Krishna District

S.No	Name of the River	Sand Bearing Area	Central Coordinates		Area in Ha.
			Latitude	Longitude	
1	Krishna River	A	16° 27' 14.126" N	80° 40' 22.127" E	39.89
2	Krishna River	B	16° 19' 27.688" N	80° 45' 36.456" E	22.13

3	Krishna River	C	16° 16' 9.396" N	80° 48' 26.113" E	47.15
4	Krishna River	D	16° 13' 44.801" N	80° 49' 42.726" E	58.04
5	Krishna River	E	16° 9' 34.305" N	80° 51' 29.858" E	70.75
6	Krishna River	F	16° 4' 31.099" N	80° 53' 29.502" E	42.48

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.6 Details of De-Siltation Location: (Lakes/Ponds/Dams etc.)

The details of the potential de-siltation locations in the Krishna Distinct are shown in Table-29.

Table 29 List of Potential De-Siltation Location: (Lakes/Ponds/Dams etc.) (Existing and proposed)

Name of the Reservoir/Dams	Maintain/ Controlled by State Govt./PSU etc.	Location	District	Tehsil	Size (Ha)	Quantity MT/Year	Existing/ Proposed
NIL							

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.7 Details of Patta Lands in the District:

The details of Patta Lands in the Krishna distinct are shown in Table-30.

Table 30 Details of Patta Lands.

Owner	Sy. No.	Area (Ha)	District	Tehsil	Village	Total Reserve (MT)	Total Mineral to be mined (MT)	Existing/ Proposed
NIL								

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.8 Details of M-Sand Plants in the District:

The details list of Manufacturing Sand in Krishna district shown in Table-31.

Table 31 Shown Details of Details of M-Sand Plants

Plant Name	Owner	District	Tehsil	Village	Geo-location	Quantity Tonnes/Annum
NIL There are no existing M - Sand units under this Krishna office jurisdiction						

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.9 Details of Cluster of Sand Mining Leases

The area of Cluster of Mining Leases in Krishna jurisdiction is shown in Table-32.

Table 32 Details Cluster of Mining Leases in Krishna District

Sl.No	Name of the Cluster	Location (Latitude and Longitude)	Extent (in Ha)	Total No. of Mining Leases in the Cluster	No.of Leases working	Extent of the working leases (in Ha)
NIL						

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.10 Details of Contiguous Clusters

The area of Contiguous Cluster of Sand Reaches in Krishna jurisdiction is shown in Table-33.

Table 33 Details of Contiguous Cluster of Sand Reaches in Krishna District

Sl.No	Name of the Cluster	Location (Latitude and Longitude)	Extent (in Ha)	Total No. of Mining Leases in the Cluster	No.of Leases working	Extent of the working leases (in Ha)
NIL						

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh

3.1.11 Sand Reaches Details in Krishna District

The Department of Mines and Geology has already identified sand reach points in Krishna district. The locations details of the sand reach points are provided by the District Mines and Geology Officer, Krishna district. Based on these location details, the sand reach points are shown in Figure-29, Figure-30, and Figure-31. Figure-32 and Figure-33 display the pre- and post-monsoon sand reach points at C and D, respectively. The probable sand-bearing areas are depicted in Figure-34.

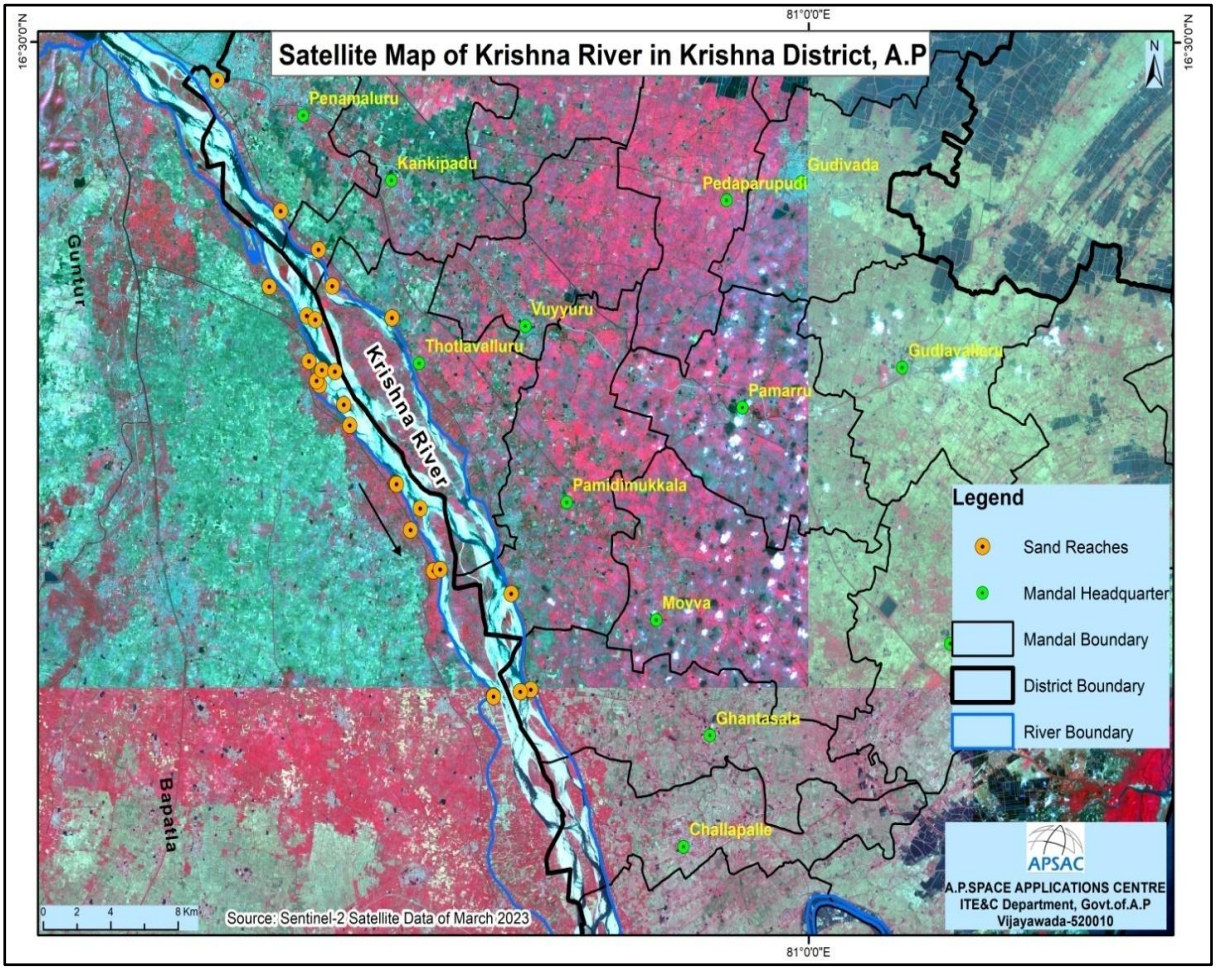


Figure-29: Satellite View of Krishna River map in Krishna District.

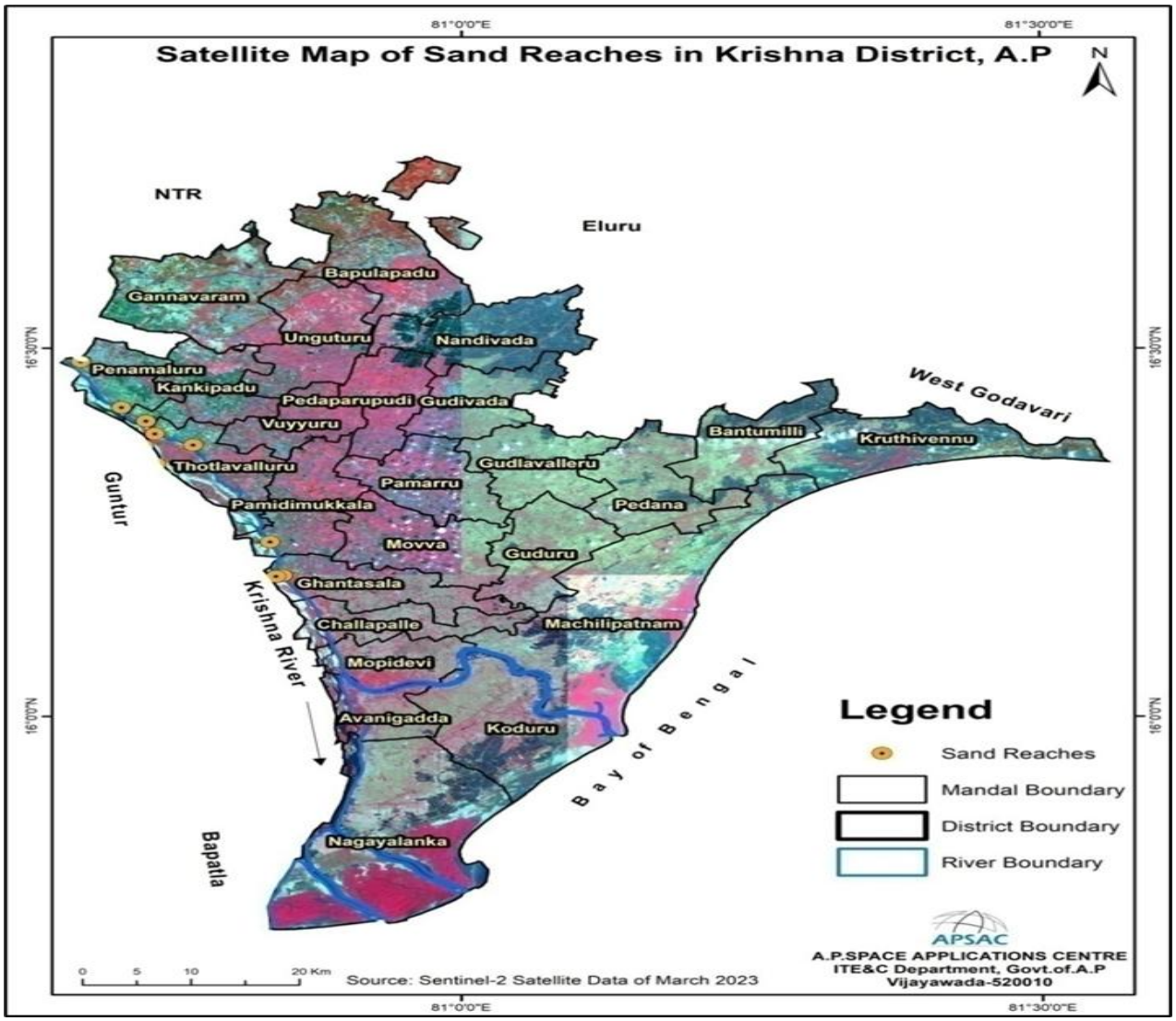


Figure-30: Satellite Map of Sand reaches in Krishna District

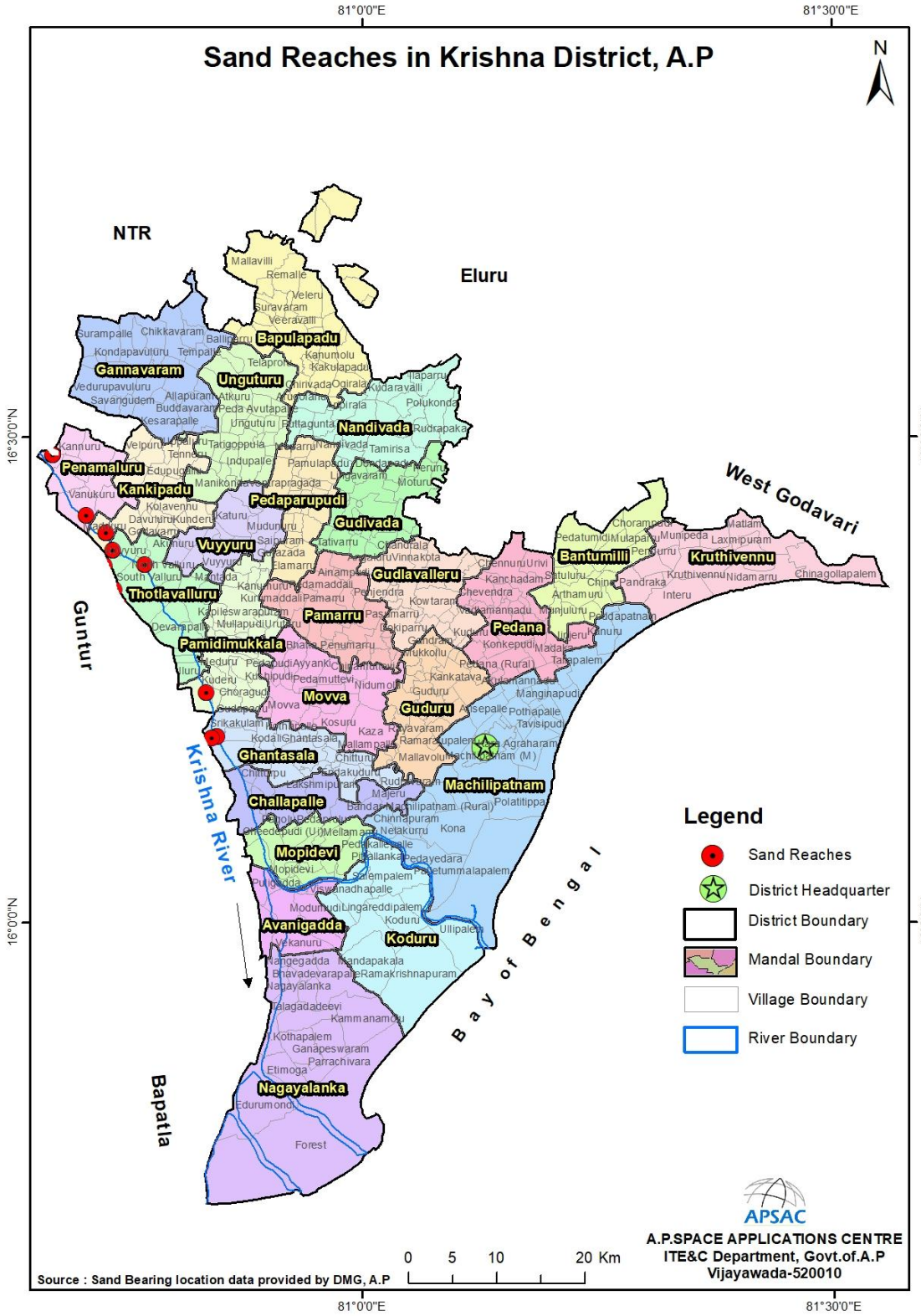


Figure-31: Mandal wise Sand Reaches map in Krishna District

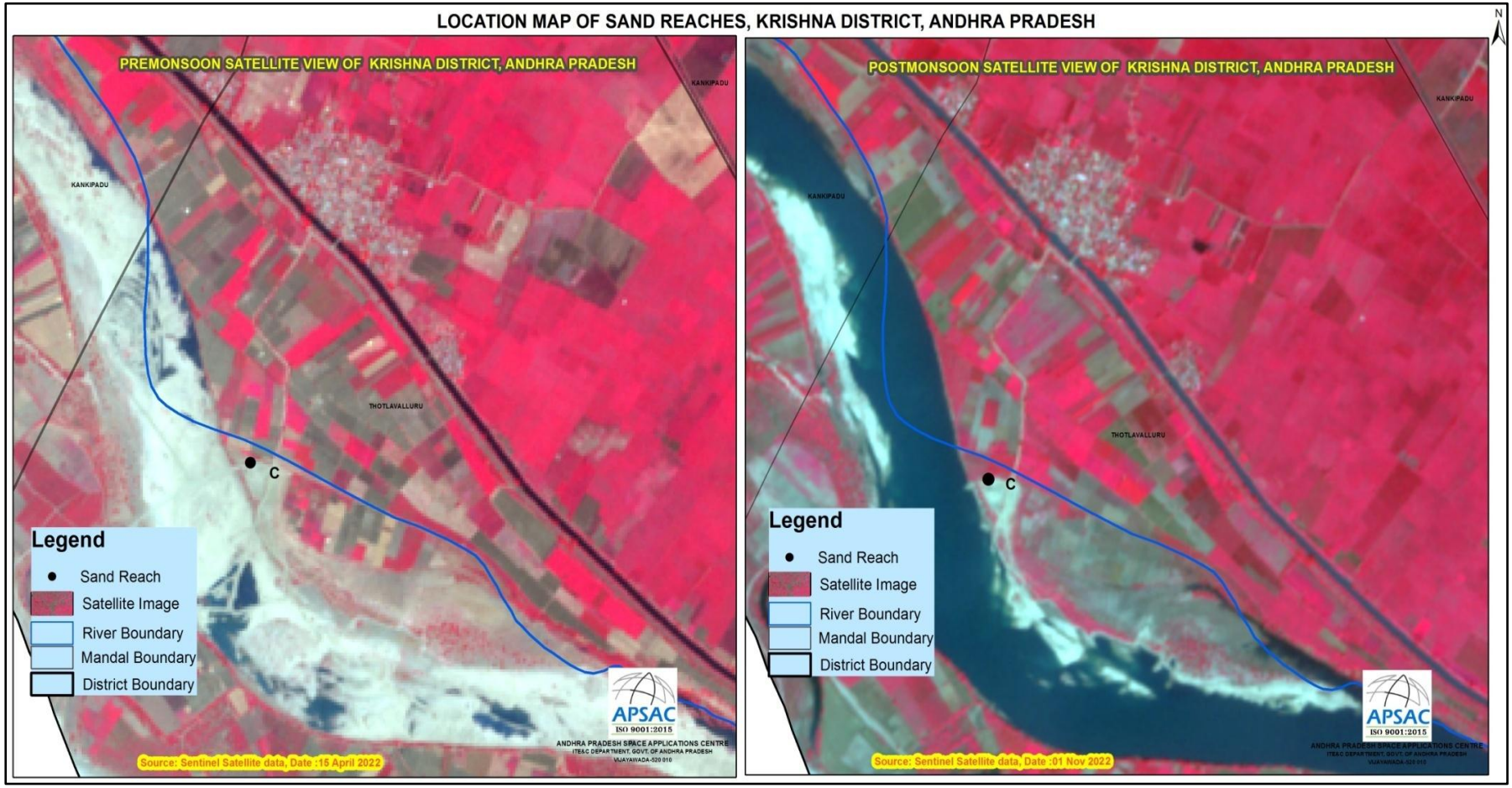


Figure-32: Pre and Post Monsoon Sand Reach Point - C

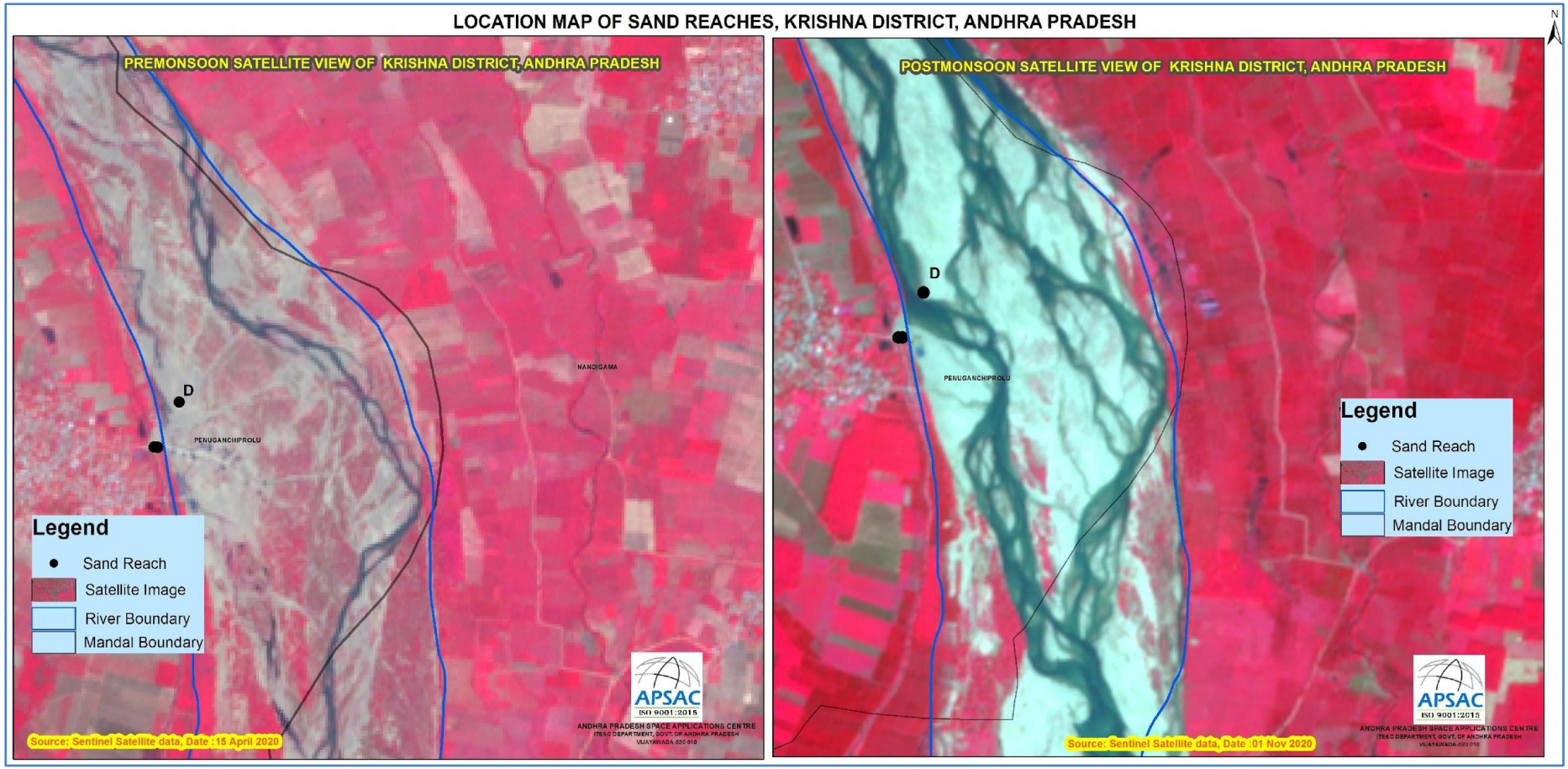


Figure-33: Pre and Post Monsoon Sand Reach Point-D

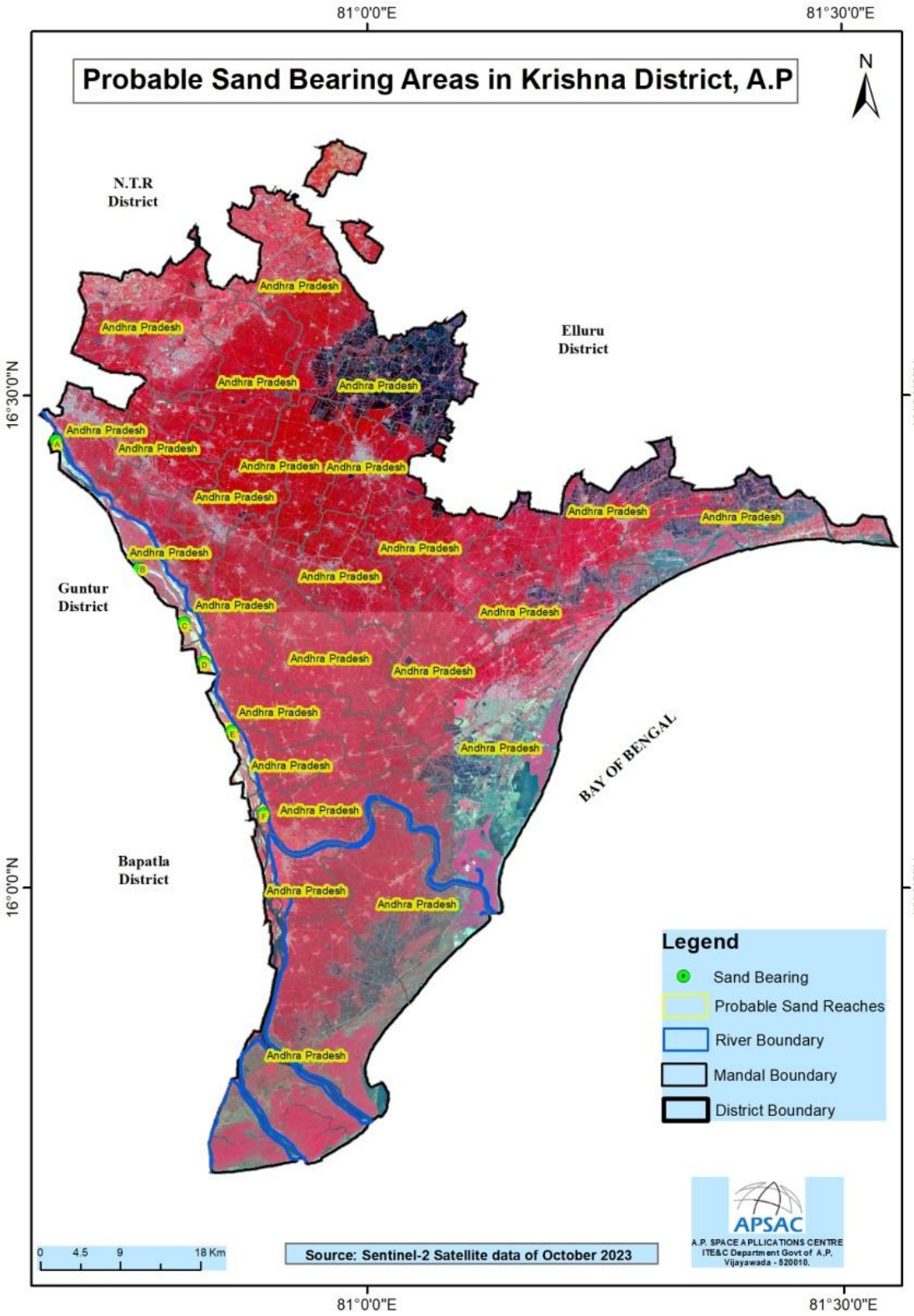


Figure-34: Probable Sand Mining reaches in the Krishna District

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ANNEXURE

As the average annual run-off is less than 2" in the Krishna District, the sedimentation yield in Krishna River in Krishna District was manually arrived by the APSAC based on the Dendy Bolton Equation or Formula and is given below.

$$S = 1280 \times Q^{0.46} [1.43 - 0.26 \log (A)]$$

Q = Mean Annual Run-off in mm
A = Net drainage Area in Sq. km
S = Sediment yield (tons/Sq. km/yr)

Sedimentation yield for the Krishna River in Krishna District

Name of the River	Area Drained (sq. km)	Mean Annual Run-off (in mm)
Krishna	3096.09	33.33

Data Source: District Mines and Geology Officer, Krishna District, Andhra Pradesh and APSAC, Vijayawada

The given drained area value converted from Sq.Km to Sq.mile and the mean annual run-off converted from mm to inches for the calculations.

$$S = 1280 \times Q^{0.46} [1.43 - 0.26 \log (A)]$$ **Tons/sq.mile/year**

Drainage Area (A) = 3096.09 sq. Km (1 Sq.km = 0.386 Sq.mile)
= 3096.09 x 0.386
A = 1195.091 Sq.mile ----------(1)

Mean Annual Run-off (Q) = 33.33 mm (1 mm = 0.0393 inches)
= 33.33 x 0.0393
Q = 1.309869 inches ----------(2)

$$S = 1280 \times Q^{0.46} [1.43 - 0.26 \log (A)]$$ **Tons/sq.mile/year**

$S = 1280 \times (1.309869^{0.46}) [1.43 - 0.26 \log (1195.091)]$

Log 11 of 9 = 0.0755
0.5 = 19
As per base, the value = 3.0000
(+)
Log 1195.091=3.0774 ----------(3)

$= 1280 \times (1.309869^{0.46}) [1.43 - 0.26 \times 3.0774]$
$= 1280 \times (1.309869^{0.46}) [1.43 - 0.800124]$
$= 1280 \times (1.309869^{0.46}) [0.629876]$
$= 1280 \times 1.132204 \times 0.629876$
$= 912.8295$
S = 912.8295 **Tons/sq.mile/year** ----------(4)

For total district Sedimentation Yield =
Per Sq.mile Sedimentation Yield (4) x Total Drainage Area (1)

912.8295 x 1195.091 = 10,90,914

As the Sedimentation yield calculated manually,
The sedimentation in the total River in the Krishna District = **10,90,914 Tons/ year**