केन्द्रीय भूमिजल बोर्ड

जल शक्ति मंत्रालय, जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

भारत सरकार

Central Ground Water Board

Ministry of Jal Shakti,
Department of Water Resources, River Development
and Ganga Rejuvenation
Government of India

Report on

AQUIFER MAPPING AND MANAGEMENT PLAN

Karkala Taluk, Udupi District, Karnataka

दक्षिण पश्चिमी क्षेत्र, बेंगलुरु

South Western Region, Bengaluru

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Government of India
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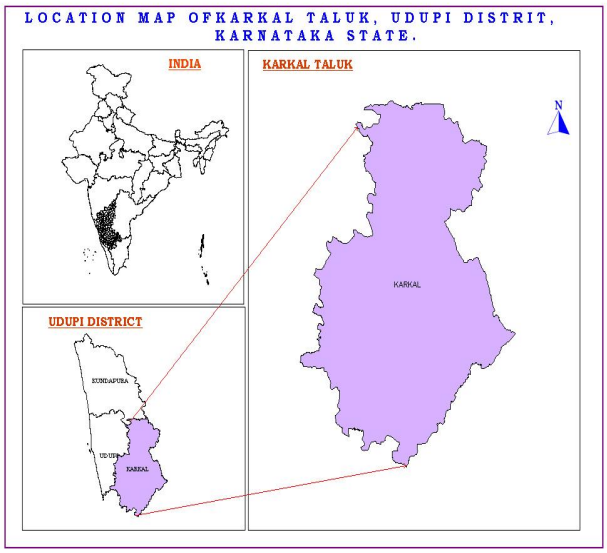
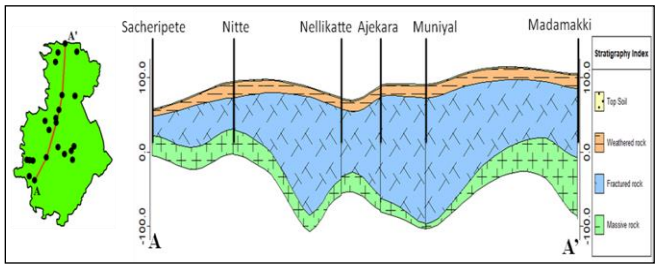
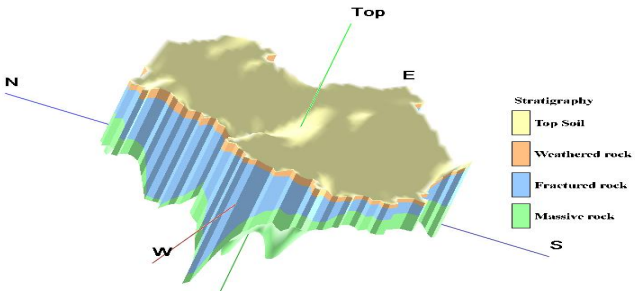
AQUIFER MAPS AND MANAGEMENT PLAN, KARKALA TALUK, UDUPI DISTRICT, KARNATAKA STATE

(AAP: – 2022-2023)







By

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MAY 2023

AQUIFER MAPS AND MANAGEMENT PLAN, KARKALA TALUK, UDUPI DISTRICT, KARNATAKA STATE

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AQUIFER MANAGEMENT PLAN FOR KARKALA TALUK, UDUPI DISTRICT, KARNATAKA STATE

1. INTRODUCTION

National Project on Aquifer Mapping (NAQUIM) initiated by Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India with a vision to identify and map the aquifers at the micro level with their characteristics, to quantify the available groundwater resources, to propose plans appropriate to the scale of demand and institutional arrangements for participatory management in order to formulate a viable strategy for the sustainable development and management of the precious resource which is subjected to depletion and contamination due to indiscriminate development in the recent past.

Groundwater is being increasingly recognized as a dependable source of supply to meet the demands of domestic, irrigation and industrial sectors of the country. The development activities over the years have adversely affected the groundwater regime in many parts of the country. Hence, there is a need for scientific planning in development of groundwater under different hydrogeological situations and to evolve effective management practices with the involvement of community for better groundwater governance.

Aquifer Mapping has been taken up in Karkala taluk, Dakshina Kannada district with a view to formulate strategies for sustainable management plan for the aquifer system in accordance with the nature of the aquifer, the stress on the groundwater resource and prevailing groundwater quality which will help in drinking water security and improved irrigation facility. It will also result in better management of vulnerable areas.

1.1 Objectives

The objectives of the aquifer mapping can broadly be stated as:

- To define the aquifer geometry, type of aquifers and their lateral and vertical extent
- To determine the groundwater regime scenario
- To determine the hydrogeochemical characteristics of the aquifer units
- To define 2D and 3-D dispositions of the aquifer units
- To estimate the availability of groundwater resources in the aquifer system
- To develop a sustainable groundwater management plan for the aquifer system

1.2 Scope of the Study

The important aspect of the aquifer mapping programme is the synthesis of the large volume of data already generated during specific studies carried out by **Central Ground Water Board (CGWB)** and various Government organizations with a new data set generated that broadly describe the aquifer system. The available generated data are assembled, analyzed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is to be converted into computer based GIS data sets.

Data gaps have been identified after proper synthesis and analysis of the available data collected from different state organizations like GWD, Watershed Department, etc. In order to bridge the data gap, data generation programme has been formulated in an organized way in the study area. Exploration work has been carried out in different segments of the regions and aquifer parameters have been estimated. Groundwater monitoring regime has been strengthened by establishing/adding State agencies additional monitoring wells. 2D and 3D sections have been prepared to bring out more realistic as the data points are more closure to the field.

1.3 Ground water Issues in the study area

The main issues pertaining to the Karkala taluk is as follows

- About 80% dependency on groundwater for irrigated agriculture
- Lack of surface water resources as alternate water sources
- Source Sustainability for drinking and irrigation, especially in lean periods
- Declining groundwater level trends in wells analyzed tapping phreatic aquifer during pre monsoon period.
- Contamination of Urban areas with municipal waste and sewage

1.4 Approach & Methodology

Integrated multi-disciplinary approach involving geological, geophysical, hydrological, hydrogeological and hydrogeochemical components were taken up in 1:50000 scale to meet the objectives of study. Geological map of the study area has been generated based on the GSI maps, geophysical data have been generated through vertical electrical soundings and geoelectrical layers with different resistivity have been interpreted in corroboration with the litho-stratigraphy of the observation wells and exploratory wells down to depths of 250 mbgl. Hydrological and Hydrometeorological data have been collected from Statistical department, Govt of Karnataka. Drainage, Soil and Geomorphology of the taluk were prepared based on the satellite data interpreted by KSRSAC.

Based on the data gap analysis, data generation process has been scheduled through establishing key observation wells, integrating Ground Water Directorate (GWD) observation wells, pinpointing exploratory sites for drilling through in-house, collecting geochemical samples in order to study groundwater regime, geometry of the aquifer and aquifer parameters and quality of the groundwater respectively. Groundwater recharge and draft have been computed based on approved guidelines and method to estimate the ground water resources of the aquifer system.

Based on the above studies Management strategies both on the supply side through augmentation of groundwater through artificial recharge and water conservation and on demand side through change in irrigation pattern have been formulated for sustainable management of the groundwater resource.

2. SALIENT FEATURES

Name of the Taluk	: Karkala
District	: Udupi
State	: Karnataka
Area	: 1091 sq.km
Population (Census 2011)	: 216091
Normal annual rainfall	: 4828 mm

2.1 Study area

Aquifer mapping studies have been carried out in Karkala taluk, Dakshina kannada district, Karnataka State under National Aquifer Mapping Project. Karkala covering an area of 1375 sq.km and situated between latitudes 13°5'13”N - 13°24'18”N and longitudes 74°49'04”E - 75°13'06”E. The area is bounded on the north by Hebri taluk, on the south by Dakshina Kannada district, on the east by Chikmagalur district and on the west by Udupi and Kapu taluks. The taluk has 02 hoblis, 34 Gram Panchayaths and 49 villages. Karkala is the taluk headquarters.

The location map of the taluk is presented in **Fig-1**.

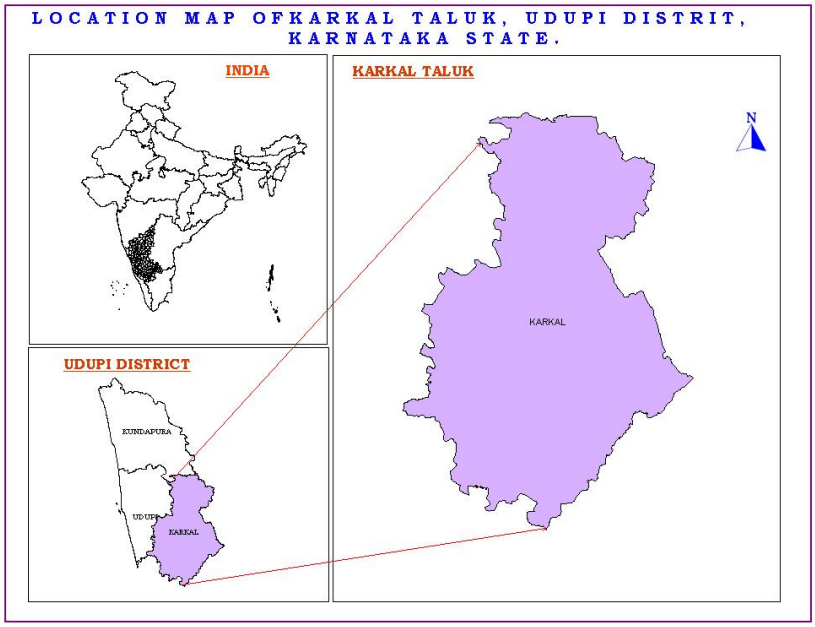

Fig 1: Location Map

2.2 Population

According to 2011 census, the human population in Karkala taluk is 216091 out of which 15% constitutes the urban population and 85% constitutes the rural population. The taluk has an overall population density of 157 persons per sq.km. In the taluk, the decadal variation in population from 2001-2011 is 5.1%. The population details are given in **Table-1.**

Table-1: Population details

Total	Male	Female	Share of the district population	Rural population	Urban population	Decadal change in population	Decadal change in rural population	Decadal change in urban population
216091	103591	112500	1.93	183410	32681	5.1	1.62	30.12

Source: District at a glance 2015-16, Govt. of Karnataka

2.3 Rainfall and Climate

Karkala taluk experiences semi-arid climate. The area falls under Coastal agro-climatic zone of Karnataka state and is categorized as drought prone in rabi season. The climate of the study area is quite agreeable and free from extremes. The year is usually divided into four seasons namely summer from March to May; rainy season or south-west monsoon season from June to September, post-monsoon season covering the months of October and November and dry or winter Season from December to February. Normal annual rainfall in the Taluk for the period 1951 to 1990 is 4828 mm. The rainfall data from 2017 to 2022 of the taluk is given in **Table.2.**

Table 2: Rainfall Data (2017 to 2022)

Year	Pre Monsoon														
	Jan			Feb			March			April			May		
	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP
2017	2.2	0.7	-67	0.7	0.0	-100	6.6	0.3	-96	40.3	17.2	-57	181.8	135.4	-26
2018	2.2	0.0	-100	0.7	0.4	-42.9	7	62	833	40	73	81	182	420	131
2019	2	0	-100	1	0	-47	7	3	-57	40	31	-24	182	24	-87
2020	3	0	-97	1	0	-80	7	46	570	37	76	107	174	177	1
2021	3.3	168.5	5006	1.0	16.6	1560	6.9	25.0	262	36.5	155.4	326	174.2	441.4	153
2022	3.3	0.9	-73	1.0	0.0	-100	6.9	36.6	430	36.5	89.5	145	174	344	97

Year	South West Monsoon											
	June			July			August			September		
	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP
2017	1166	1217	4	1632	1030	-37	1181	1060	-10	438	378	-14
2018	1166	1237	6	1632	1411	-14	1181	1444	22	438	79	-82
2019	1166	618	-47	1632	1379	-15	1181	1587	34	438	873	99
2020	1049	882	-16	1503	1099	-27	1143	1340	17	422	1058	151
2021	1048.6	816.0	-22	1502.8	1087.2	-28	1143	703	-39	422	511	21
2022	1048.6	571.9	-45	1502.8	1817.2	21	1143.4	962.1	-16	421.9	397.7	-6

Year	North East Monsoon									Annual Rainfall Pattern		
	October			November			December			(1st January to 31st December)		
	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP	Normal (mm)	Actual (mm)	%DEP
2017	278	329	18	104	31	-70	21	14	-32	5051	4213	-17
2018	278	284	2	104	39	-62	21	10	-54	5051	5058	0
2019	278	658	136	104	113	8	21	28	38	5051	5313	5
2020	289	368	28	125	43	-66	24	17	-31	4777	5107	7
2021	289	385	33	125	403	223	24	23	-4	4777	4736	-1
2022	288.9	194.7	-33	125.0	103.7	-17	24	23	-6	4776.6	4540.4	-5

2.4 Agriculture & Irrigation

Agriculture is the main occupation in Karkala taluk. Major Kharif crop is Paddy. Important crops of Rabi season are vegetables and oilseeds **(Table-3)**. Oil seeds grown in 0.1% of total crop area in the taluk. Pulses are grown in 1.5% of the total area. Fruits grown in 38.5% and short duration crop vegetable are grown in 312 Ha (1.7%) of the crop area which requires ground water during post monsoon season especially during summer.

Table-3: Cropping pattern 2017-2018 (Ha)

Crop	Paddy	Maize	Bajra	Jowar	Pulses	Fruits	Vege tables	Oil seeds	Sugar cane	Cotton	Coconuts	Total crop
Area(ha)	10409	0	0	0	261	6873	312	20	0	0	0	17875
Area %	58.2	0	0	0	1.5	38.5	1.7	0.1	0	0	0	100

Source: District at a glance 2015-16, Govt. of Karnataka

About 30.5% of the geographical area is covered by forest. It is observed that net sown area accounts for 22.3% and area sown more than once is 2.9% of total geographical area in Karkala taluk. Area not available for cultivation, the other uncultivable land and fallow land cover are 8.7%, 33.7% and 4.8% respectively of total geographical area. About 71.3% of net area irrigated is from wells, 7.5% are from bore/tube wells and 1.2% from tanks constituting 1.2% of irrigation is from surface water and 80% from ground water. Thus major source of irrigation is groundwater **(Fig.-2)**. The details of land use and the details of Irrigation are given in **Table 4 and 5** respectively. The land use pattern is given in **Fig.-3**.

Table-4: Details of land use 2017-2018 (Ha)

Total Geographical Area	Area under Forest	Area not available for cultivation	Other uncultivable land	Fallow land	Net sown area	Area sown more than once	Gross sown area
107586	32812	9342	36223	5144	24006	3159	27165
% of the area	30.5	8.7	33.7	4.8	22.3	2.9	25.2

Source: District at a glance 2015-16, Govt. of Karnataka

Table-5: Details of Irrigation

Source of Irrigation	Length in Km/No of structures	Gross area Irrigated (Ha)	Net area Irrigated (Ha.)	% of area
Canals	0	0	0	0
Tanks	104	96	96	1.2
Wells	6535	6535	6036	71.3
Bore/Tube wells	639	639	639	7.5
Lift Irrigation	1011	1011	1011	12
Other Sources		874	684	8
Total			8466	100

Source: District at a glance 2015-16, Govt. of Karnataka

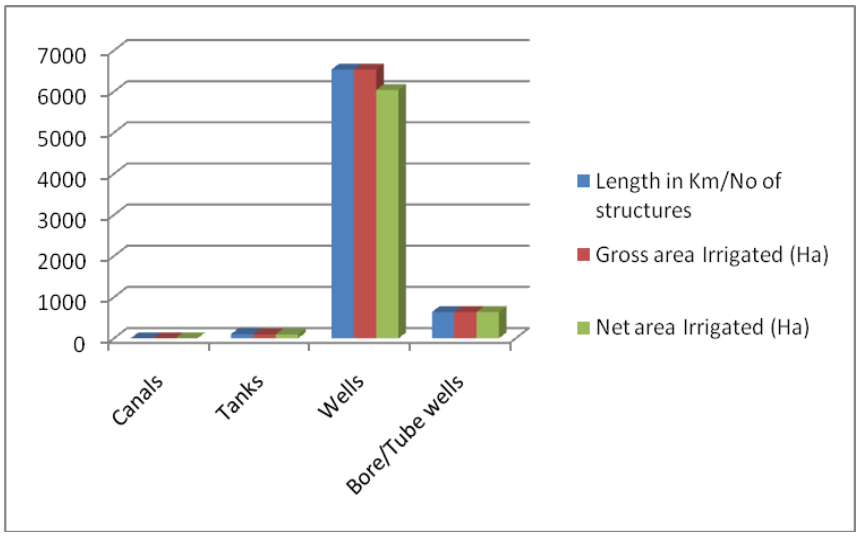

Fig 2-Sources of Irrigation

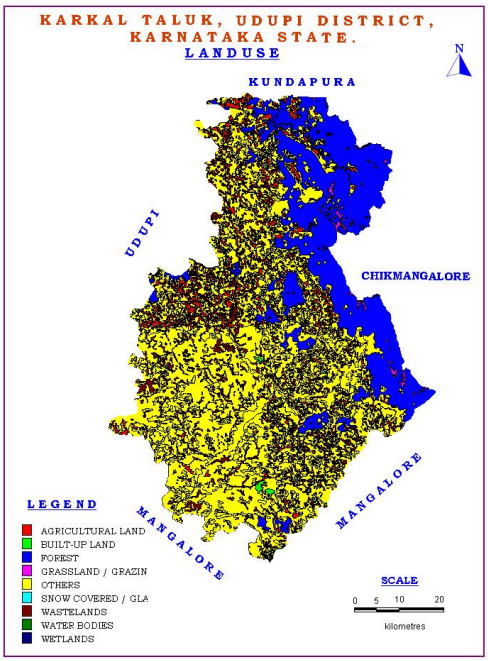

Fig. 3: Land use/land cover map

2.5 Geomorphology, Physiography & Drainage

The Taluk is categorised as Upland Pediplain **(Fig.4).** Physiographically, it can be divided into three physiographic units viz., hills and plateau, piedmont zones and pediplains. The eastern part of the Taluk is hilly with thick forest cover which forms part of the Western Ghats. The hills of the area range in elevation from 1200 to 1500 m above mean sea level. The ground surface is flat, gently sloping forming broad valleys and flat-topped hills. Drainage pattern is dendritic to semi-dendritic **(Fig.5).**

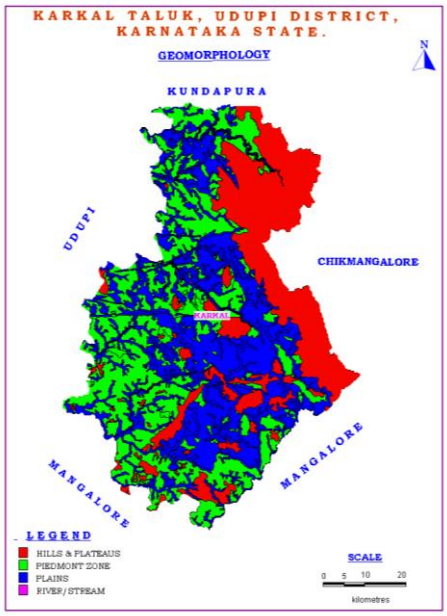

Fig. 4: Geomorphology map

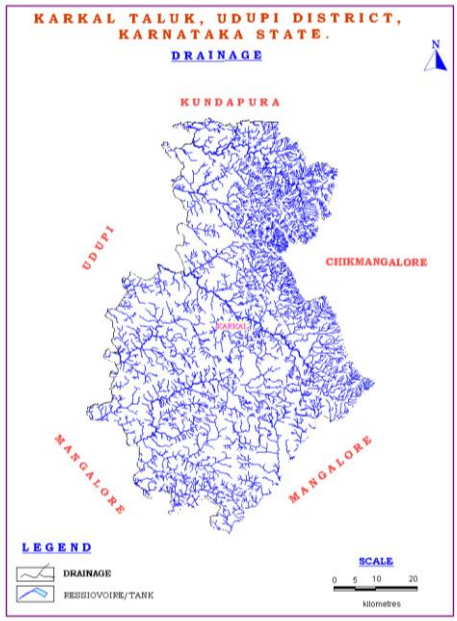

Fig. 5: Drainage map

2.6 Soil

Soil plays a major role in hydrologic control of the infiltrating water. Soils are generally classified by taking their color, texture, fertilities and chemical combinations includes salts, minerals and the solution effect over them. Most of the area consists of Clayey Skeletal soil. Clayey skeletal soil is noticed in all over the parts of the taluk. Clayey soil, Sandy Loamy soil occurrence is very minimum in North-Eastern part and in Western part of the taluk **(Fig.6).**

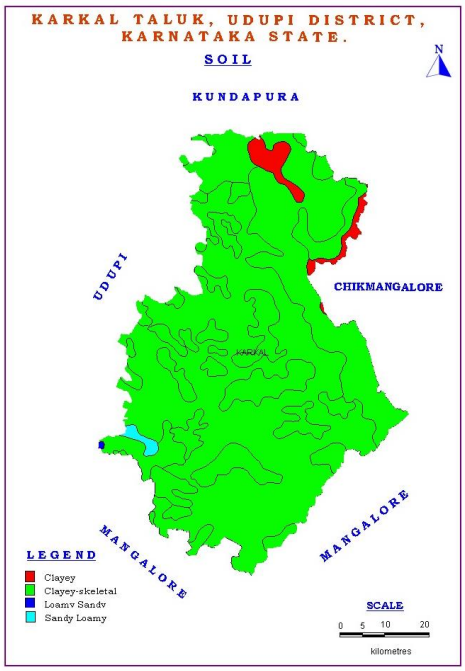

Fig. 6: Soil map

2.7 Ground water resource availability and extraction

As per the ground water resource estimation 2017 & 2020 (**Table 6**), the data on ground water resources shows that the net annual ground water availability is 14249 & 24056 ham respectively. The existing gross groundwater for irrigation is 3426 and 3976 ham. The stage of groundwater development is 37% & 24% and falling under 'Safe' category.

Table.6 Dynamic Ground Water Resource, (2017 & 2020,in Ham)

Year	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for Irrigation	Existing Gross GW Draft for Domestic and Industrial Water Supply	Existing Gross Ground Water Draft for All Uses	Allocation For Domestic and Industrial Use for Next 25 Years	Net Ground Water Availability for Future Irrigation Develop-ment	Existing Stage of Ground Water Development	Category
2017	14249	3426	1905	5331	2050	8774	37	Safe
2020	24055.96	3975.55	1700.98	5676.53	1798.37	18282.04	23.60	Safe

2.8 Existing and future water demands (as per GWRA-2017, 2020 and 2022)

As per the GWRA 2017 and 2020, the net ground water availability is 14249 & 24056 ham and the total ground water draft for all uses is 5331 & 5677 ham with stage of development at 37% & 23.6% and the taluk falls in Safe category. There is a scope for future irrigation development @ 18282 ham (2020). The domestic (Industrial sector) demand for next 25 years is estimated at 2050 & 1798 ham.

The details of dynamic ground water resources as on 2022 is shown in **Table-7**. It is observed that the stage of ground water extraction increases in the taluk from 23.6% (2020) to 36.6% (2022) with the net ground water availability of 13775 ham (2022).

Table.7 Detail of Dynamic Ground Water resource (as on 2022)

Annual Extractable GW Resource (Ham)	GW Extraction for Irrigation Use (Ham)	GW Extraction for Industrial Use (Ham)	GW Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net GW Availability for future use (Ham)	Stage of GW Extraction (%)	Categorization (Over-Exploited/ Critical/ Semi-critical/ Safe/Saline)
13775.02	4688.66	8.9155	343.6362	5041.21	354.06	8723.39	36.6	Safe

2.9 Water level behavior

The water level data have been monitored from the representative dug wells and borewells under NHS monitoring programme for both pre and post monsoon seasons during 2022 in Aquifer I and Aquifer II. The depth to water level data is shown in **Table.8 (CGWB)** and **Table. 9 (SGWD)** for both Aquifer-I (Phreatic) and Aquifer-II (Fractured) respectively.

(a) Depth to water level :-

Aquifer I:

The water level data pertaining to the period of May 2022 (pre monsoon) and November 2022 (Postmonsoon) was used for the preparation of depth to water level map of the taluk.

The depth to water level during May 2022 is varied from 4.62 to 12.05 mbgl **(Fig.7)**. Major part of the taluk shows water level in the range of 5 to 10 mbgl. Small patch recorded water level in the range of 2 to 5 mbgl and found in north western portion of the taluk. Water level ranging 10 to 20 mbgl is observed in 15% area of the taluk.

The depth to water level during November 2022 is varied from 5.3 to 11.03 mbgl **(Fig.8).** Majority of the taluk shows water level in the range of 5 to 10 mbgl of about 90% and 10% area shows water level in the range of 10 to 20 mbgl in the central eastern part of the taluk.

Aquifer II:

The depth to water level during May 2022 is varied from 6.9 to 17.46 mbgl **(Fig.14)**. Major part of the taluk shows water level in the range of 10 to 20 mbgl in the eastern part of the taluk. Water level ranges 5-10 mbgl in western part of the taluk.

The depth to water level during November 2022 is varied from 5.5 to 24.05 mbgl **(Fig.15).** Majority of the taluk shows water level in the range of 5-10 mbgl in the western part of the taluk, 10-20 mbgl in the central part of the taluk of about 35% and 20 to 30 mbgl in eastern part of about 30% area of the taluk.

(b) Seasonal water level fluctuation:-

Aquifer I:

The seasonal water level fluctuation is the difference of pre and post monsoon water level data of wells. The rise in water level ranges from 0.18 to 3.05 mbgl **(Fig.9).** The fall in water level ranges from -1.2 to -0.48.

Aquifer II:

The rise in water level ranges from 0 to 4.3 mbgl **(Fig.16).** There is no fall in water level and majority of the taluk shows rises in the range of 0 to 2 mbgl in the southern part of the taluk.

(c) Decadal water level and fluctuation:

During premonsoon, the decadal average water level ranges from 6.1 to 12.05 mbgl **(Fig.10)** and majority of the taluk shows water level in the range of 5 to 10 mbgl in all over the taluk & 10% of the taluks shows in the range of 10 to 20 mbgl in the central western part of the taluk. The fluctuation map **(Fig.12)** shows the rise in water level ranges from 0.3 to 2.78 mbgl & the fall in the range of -2.5 to -1.17 mbgl.

During postmonsoon it varies from 3.25 to 7.07 mbgl **(Fig.11)** and majority of the taluk shows water level in the range of 2 to 5 mbgl & 15% of the taluks shows in the range of 5 to 10 mbgl in the central western part of the taluk. The fluctuation map **(Fig.13)** shows the rise in water level ranges from 0.27 to 0.51 mbgl & the fall ranges from -2.1 to -1.56 mbgl.

Table 8: Depth to Water Level Data Pre-monsoon & Post-Monsoon,CGWB,SWR, Bangalore

Sl. No	Village	Type of Well	Depth of the Well (mbgl)	Pre-monsoon Depth to water Level (May 2022) (mbgl)	Post-monsoon Depth to water Level (November 2022) (mbgl)	Seasonal Depth to Water level Fluctuation (meter)
Aquifer-I (Phreatic Aquifer)						
1	Jodu Katte Guddeanngadi	Dug Well	15.0	11.75	8.70	3.05
2	Ajekar	Dug Well	7.4	4.62	5.30	-0.68
3	Bailur	Dug Well	11.2	6.36	7.00	-0.64
4	Bajegoli	Dug Well	13.8	12.05	11.03	1.02
5	Hebri	Dug Well	10.6	8.88	8.50	0.38
6	Hosmar	Dug Well	9.2	6.60	7.31	-0.71
7	Kukundur	Dug Well	9.4	5.25	6.53	-1.28
8	Maathbettu-Maniyala	Dug Well	11.2	7.42	5.62	1.80
9	Miyar	Dug Well	12.5	6.53	7.05	-0.52
10	Mudubidri A	Dug Well	15.4	6.87	7.35	-0.48
11	Mundargi	Dug Well	12.9	8.53	8.25	0.28
12	Nitte	Dug Well	9.8	6.38	6.20	0.18
13	Samplge	Dug Well	12.9	9.43	8.62	0.81
14	Someswar	Dug Well	12.5	8.61	7.13	1.48
15	Thodaaru	Dug Well	15.2	10.37	10.10	0.27
Aquifer-II (Fractured Aquifer)						
16	Ajekar	Borewell	50	11.98	10	1.98

Table 9: Depth to Water Level Data Pre-Monsoon & Post-Monsoon, SGWD, Bangalore

Sl. No	Village	Type of Well	Depth of the Well (mbgl)	Pre-monsoon Depth to water Level (May 2022) (mbgl)	Post-monsoon Depth to water (November 2022) (mbgl)	Seasonal Water level Fluctuation (meter)
Aquifer-I						
1	Guddeyangadi	Dug Well	10.35	8.30	4.75	3.55
2	Hirgana	Dug Well	10.40	8.62	5.35	3.27
3	Kukunduru	Dug Well	10.80	9.50	7.95	1.55
4	Mundkuru	Dug Well	5.35	4.00	3.20	0.80
5	Hebri	Dug Well	13.10	7.90	5.60	2.30
6	Kelajadvu	Dug Well	6.20	2.73	1.58	1.15
7	varanga	Dug Well	10.40	6.92	6.02	0.90
8	Belve	Dug Well	10.75	5.82	3.82	2.00
Aquifer-II						
9	Hirgana	Borewell	90.0	8.03	6.08	1.95
10	Kukunduru	Borewell	78.0	10.00	9.21	0.79
11	Hebri	Borewell	78.0	7.05	6.11	0.94
12	varanga	Borewell	78.0	17.46	13.15	4.31
13	Belve	Borewell	90.0	6.90	5.55	1.35

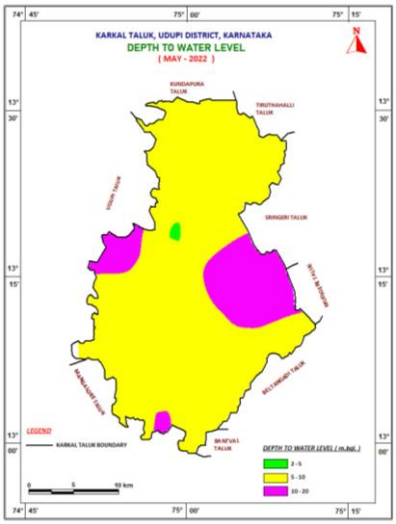

Fig.7: Pre-monsoon Depth to Water Level (Phreatic Aquifer)

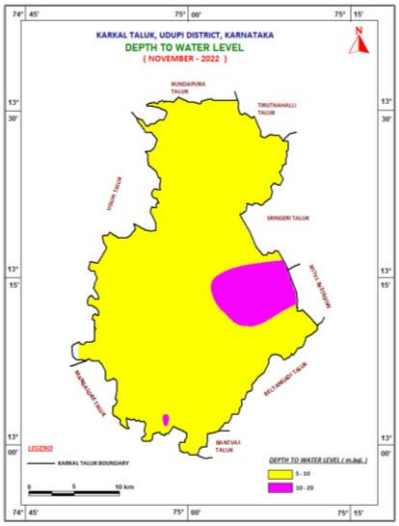

Fig.8: Post-monsoon Depth to Water Level (Phreatic Aquifer)

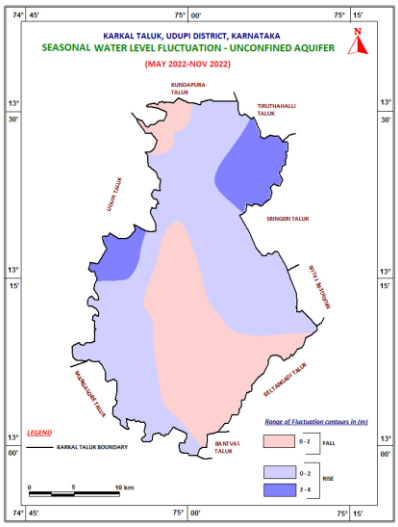

Fig.9: Seasonal Water Level Fluctuation (Phreatic Aquifer)

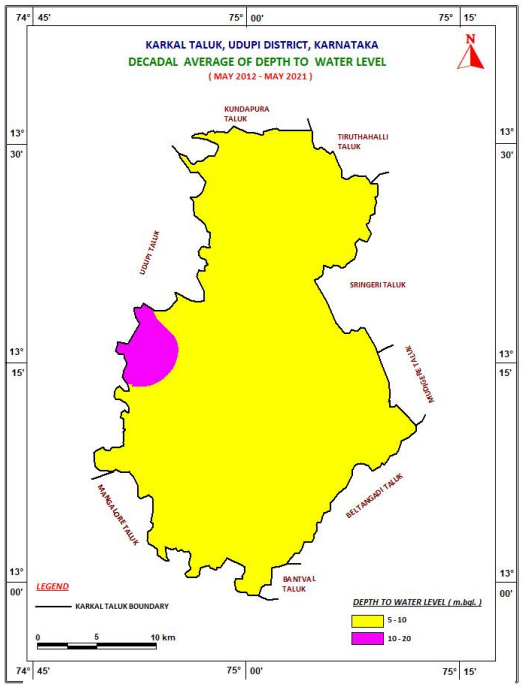

Fig.10: Decadal avg water level (Pre) (Phreatic Aquifer)

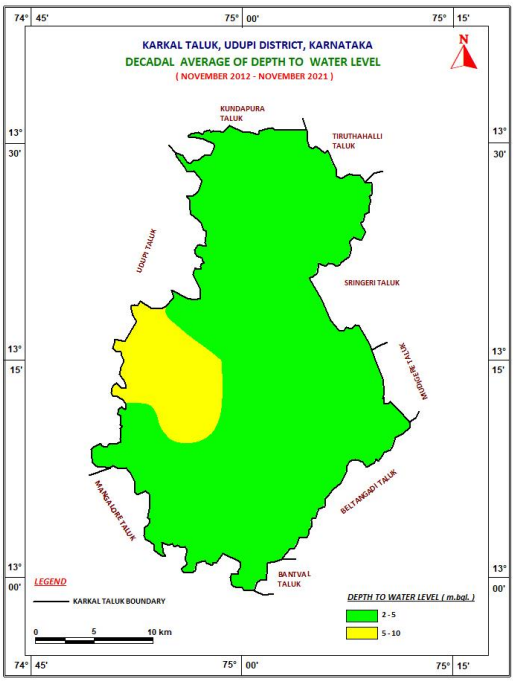

Fig.11: Decadal avg water level (Post) (Phreatic Aquifer)

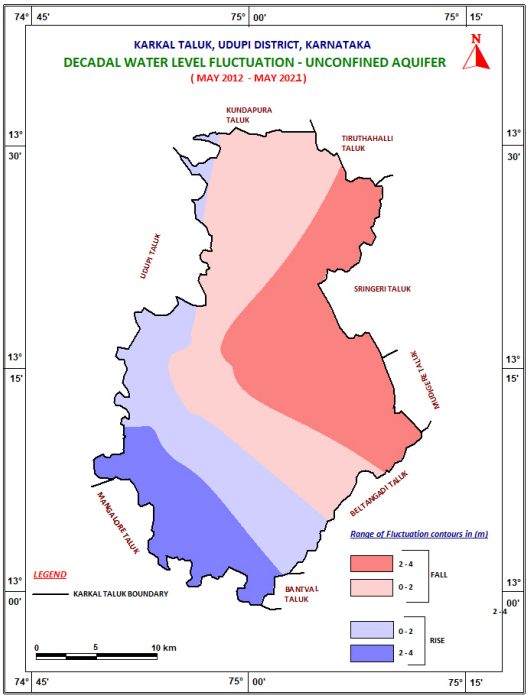

Fig.12: Decadal avg water level fluc (Pre) (Phreatic Aquifer)

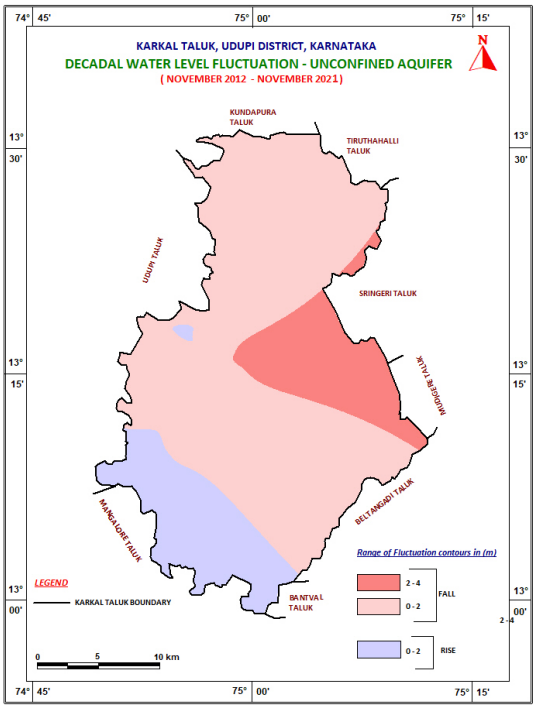

Fig.13: Decadal avg water level fluc (Post) (Phreatic Aquifer)

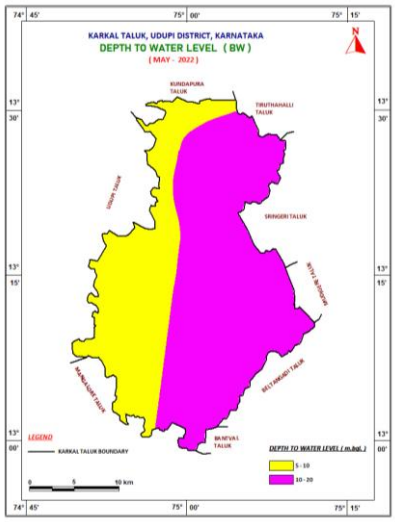

Fig.14: Pre-monsoon Depth to Water Level (Fractured Aquifer)

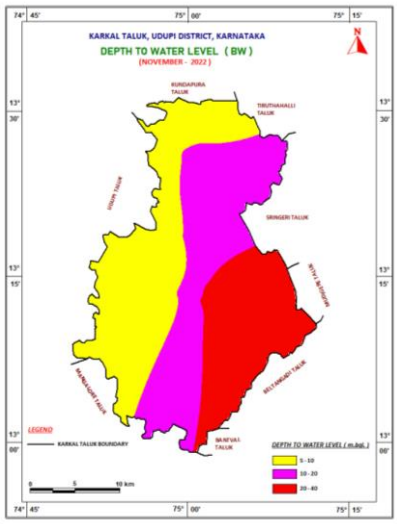

Fig.15: Post-monsoon Depth to Water Level (Fractured Aquifer)

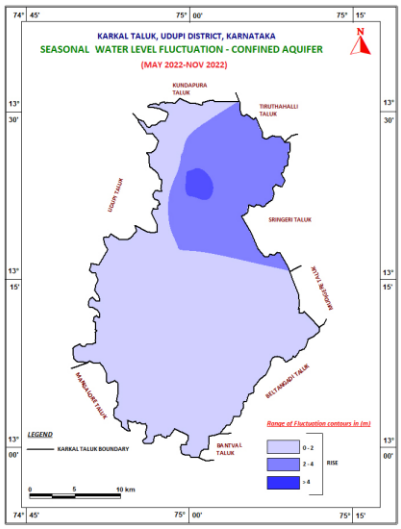

Fig.16: Seasonal wl fluctuation (Fractured Aquifer)

3. AQUIFER DISPOSITION

The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifers in the area are Banded Gneissic Complex and Schist and the occurrence and movement of ground water in these rocks is controlled by various factors and it primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and weathering in the hard rock.

3.1 Aquifer Types

In Karkala Taluk, there are mainly two types of aquifer systems

i. **Aquifer-I (Phreatic aquifer)** comprising Weathered Banded Gneissic Complex / Schist

ii. **Aquifer-II (Fractured aquifer)** comprising Fractured Banded Gneissic Complex / Schist

In the taluk, Banded gneissic complex occupies major part of the taluk area and Schist & Laterite formation noticed as an isolated pocket (**Figure-17)**. Ground water occurs within the weathered and fractured gneisses and schist under water table condition and semi-confined condition. In the Taluk, bore wells were drilled from a minimum depth of 26 mbgl to a maximum of 300 mbgl. Depth of weathered zone (Aquifer-I) ranges from 2 mbgl to 20 mbgl. Ground water exploration reveals that aquifer-II fractured formation was encountered between the depths of 26 to 303 mbgl. Fractured gneissic complex is the major water bearing formation **(Fig-18).** The yield of this aquifer unit II ranges from 0.13 to 5.9 lps. In general ground water in fractured aquifer is potable.

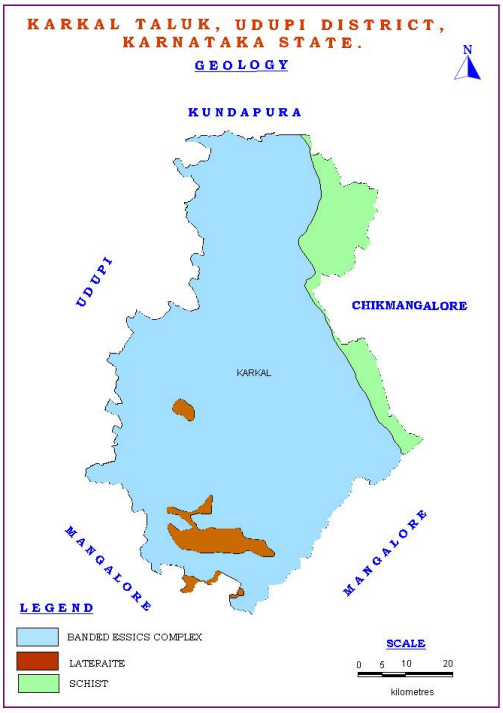

Fig.17: Geology map

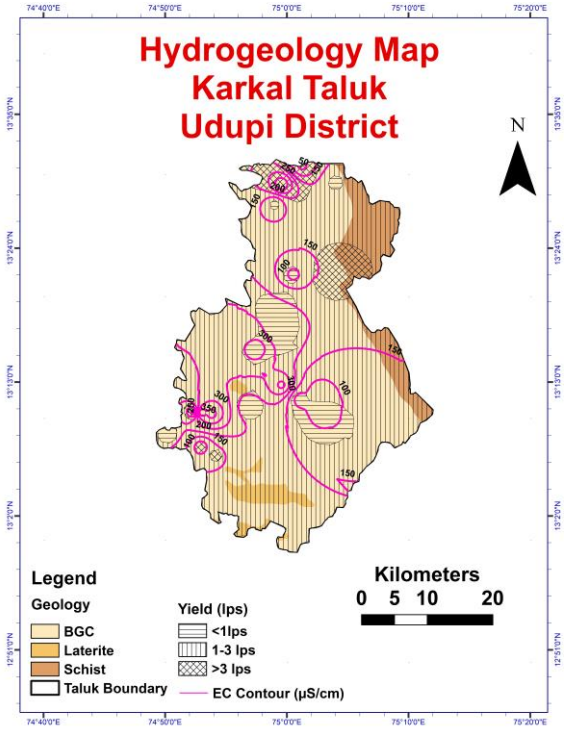

Fig.18: Hydrogeology map

3.1.1 Depth wise Aquifer System

The data generated from ground water monitoring wells, micro level hydrogeological inventories, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. In the Taluk, if we consider the vertical distribution of aquifer, two types of aquifer system are observed i.e., Aquifer – I which is a shallow phreatic aquifer and Aquifer – II which constitutes the deeper fractured aquifer.

a) Aquifer-I (Shallow Phreatic aquifer)

Aquifer – I comprises of Laterite, schist and weathered Banded Gneissic Complex. The spatial distribution of depth of occurrence and aquifer thickness of Aquifer-I is depicted in **Fig. 19a**. It indicates that the depth of occurrence of aquifer – I ranges from 5 to 32 m bgl. However, it mainly occurs in the depth range of 10 to 15 m bgl covering 60% of the area in southern parts and Northern part of the Taluk. The depth of occurrence of 5 to 10 m bgl is observed in about 15% of area throughout the taluk. 15 to 20 m bgl is observed in 20% of the area in northern and western parts of the Taluk. The depth of occurrence of 20 to 25 m bgl is observed in about 3% of the area in north-eastern and south-western part. The deeper depth of occurrence of 25 to 32 m bgl is observed in about 2% of the area in north-eastern part of the taluk. The perusal of the map for aquifer thickness indicates that

it ranges from 0.4 to 9 m, however aquifer thickness of 0.4 to 2.5 m is observed in 15% of the area covering north-eastern, south-western and central parts of the taluk. The aquifer thickness of 2.5 to 5 m is observed in about 55% of the area covering northern and southern parts. The thickness of 5 to 7.5 m is observed in 25% of the area covering south-western and northern parts of the taluk and the thickness of 7.5 to 9 m is observed in 5% of the area in north-eastern part of the taluk.

b) Aquifer-II (Deeper Fractured aquifer)

It comprises of fractured Banded Gneissic Complex and Schistose rock. The spatial distribution of depth of occurrence and aquifer thickness of Aquifer-II is depicted in **Fig. 19b**. It indicates that the depth of occurrence of aquifer – II ranges from 25 to 274 m bgl. However, it mainly occurs in the depth range of 75 to 125 m bgl covering 50% of the area mainly in northern and central parts of the taluk. The depth of occurrence of 25 to 75 m bgl is observed in about 20% of area in southern, central and north-eastern parts. The depth of occurrence of 125 to 175 m bgl is observed in 15% in northern & central-western parts of the taluk. The deeper depth of occurrence of 175-225 & 225-274 m bgl is observed in about 10% & 5% of area respectively in north-eastern & central-western parts of the taluk. The perusal of the map for fractured aquifer thickness indicates that it ranges from 2 to 14 m, however aquifer thickness of 2 to 5 m is observed in 40% of the area covering southern and north-eastern parts of the taluk. The aquifer thickness of 5 to 10 m is observed in 50% of the area covering northern & central-western parts. 10 to 14 m thickness is observed in 10% of the area in northern & central-western parts of the taluk.

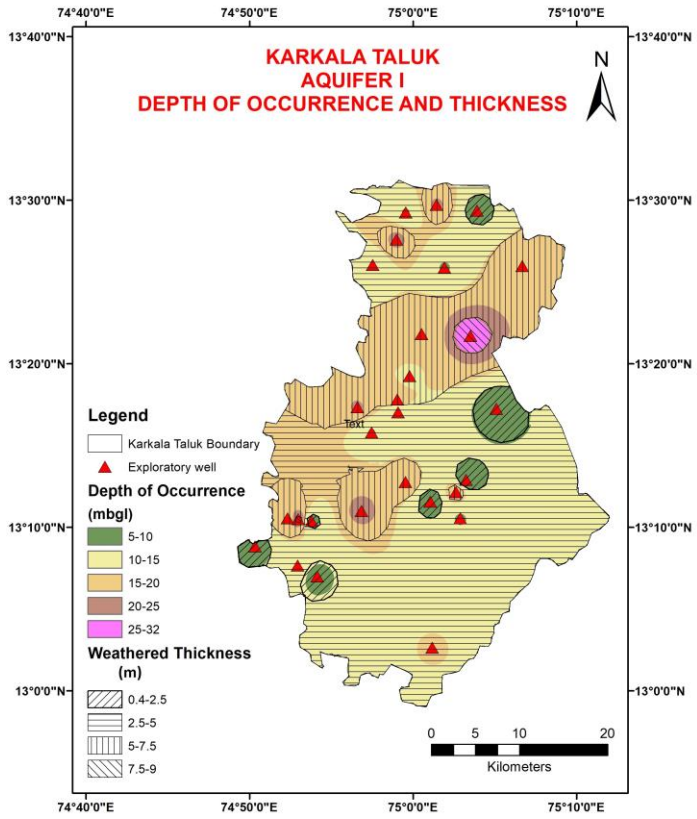

Fig.19a: Depth of Occurrence & Thickness map (Aq-I)

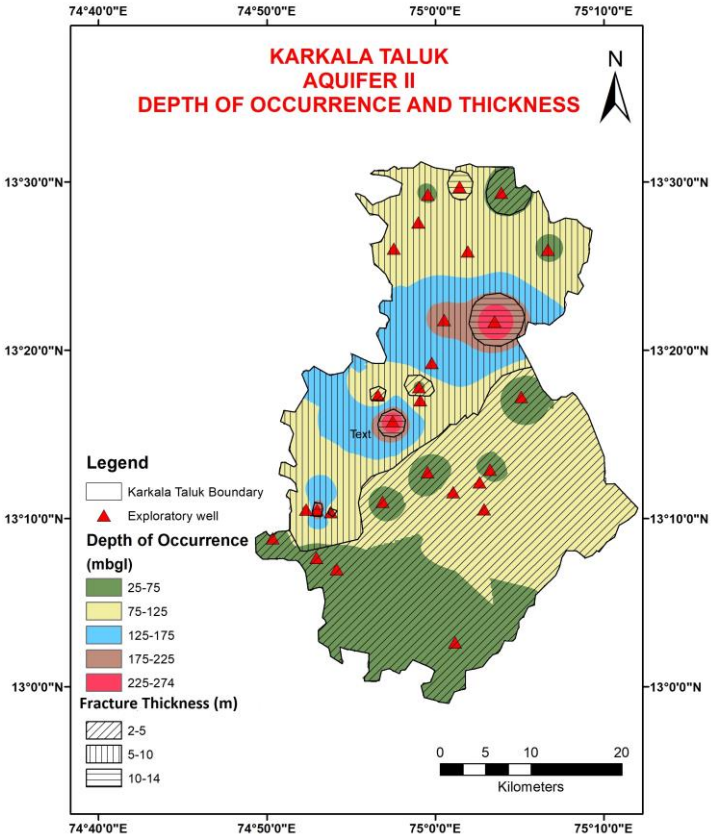

Fig.19b: Depth of Occurrence & Thickness map (Aq-II)

Table.10a: Details of Groundwater Exploration

Sl. No	Location	Long	Lat	Depth	Casing	SWL (mbgl)	Q (lps)
1	Airody EW	74.7097	13.4569	26		3.1	4
2	Airody OW	74.7097	13.4569	26		3.2	3.2
3	Belman EW	74.8833	13.1750	303.28	28	24.7	0.3
4	Belman OW	74.9833	13.0092	78.8	16	7.2	
5	Hunsmukhi EW	74.7903	13.5833	94	11	3.9	6.1
6	Hunsmukhi OW	74.7903	13.5833	94.57	10	4.4	11.2
7	Inna EW	74.8392	13.1472	51.5	6	6.54	0.5
8	Mala EW	75.1097	13.3333	42.8	5	8.8	
9	Mutalpadiandar EW	75.0589	13.3617	183	12	9	6.4
10	Mutalpadiandar OW	75.0589	13.3617	300	32	6.8	0.7
11	Mutalpadiandar Pz	75.0589	13.3617	195.24	25	10.9	5.5
12	Nallar EW	75.1333	13.5917	77.7	20	10.8	3.7

Table 10b: Well Inventory Data

Sl.No	Location	Long	Lat	Depth	Casing	Q (lps)	WL
1	Gandhi Maidana	74.9927	13.2127	79	21	2.1	6.3
2	Jodukatte	75.0180	13.1929	92	6	0.78	5.9
3	Miyyaru	75.0442	13.2025	107	22	1.4	6.1
4	Bajagole	75.0545	13.2150	76	5	2.1	7.4
5	Nalluru	75.0484	13.1758	168	10	0.13	6.8
6	Nitte	74.9479	13.1834	92	24	0.43	8.3
7	Kedinje	74.8967	13.1731	122	7	2.1	9.7
8	Belman	74.8722	13.1757	107	17	4.4	6.4
9	Sacheripete	74.9028	13.1165	57	8	3.1	7.2
10	Mundkuru	74.8825	13.1277	55	13	3.16	6.8
11	Kukkundoor	74.9580	13.2631	290	10	0.78	9.2
12	Yerlapady	74.9435	13.2890	150	22	1.4	8.4
13	Nellikatte	74.9852	13.2838	122	13	0.78	9.6
14	Yennehole	74.9843	13.2970	98	18	0.43	10.3
15	Ajekara	74.9968	13.3208	183	15	0.78	11.8
16	Muniyal	75.0089	13.3636	199	18	0.78	9.9
17	Hebri	74.9834	13.4601	141	23	0.78	6.1
18	Kucchuru	74.9928	13.4877	125	10	5.9	6.8
19	Madamakki	75.0206	13.5133	208	22	4.4	7.8
20	Someshwara	75.0656	13.4896	61	8	0.78	7.6

3.2. 3 D aquifer disposition and Cross-Sections

2D & 3D aquifer disposition models of the aquifer system have been deciphered by using ROCKWORKSsoftware and 2D cross section have been generated along different directions of Karkala taluk. All such 2D cross sections were verified and the model was calibrated to bring out the 3D aquifer disposition of the aquifer system. The type cross sections generated in different direction of the aquifer system are presented in **Fig.20, Fig.21** and 3D aquifer disposition fence diagram **in Fig.22.**

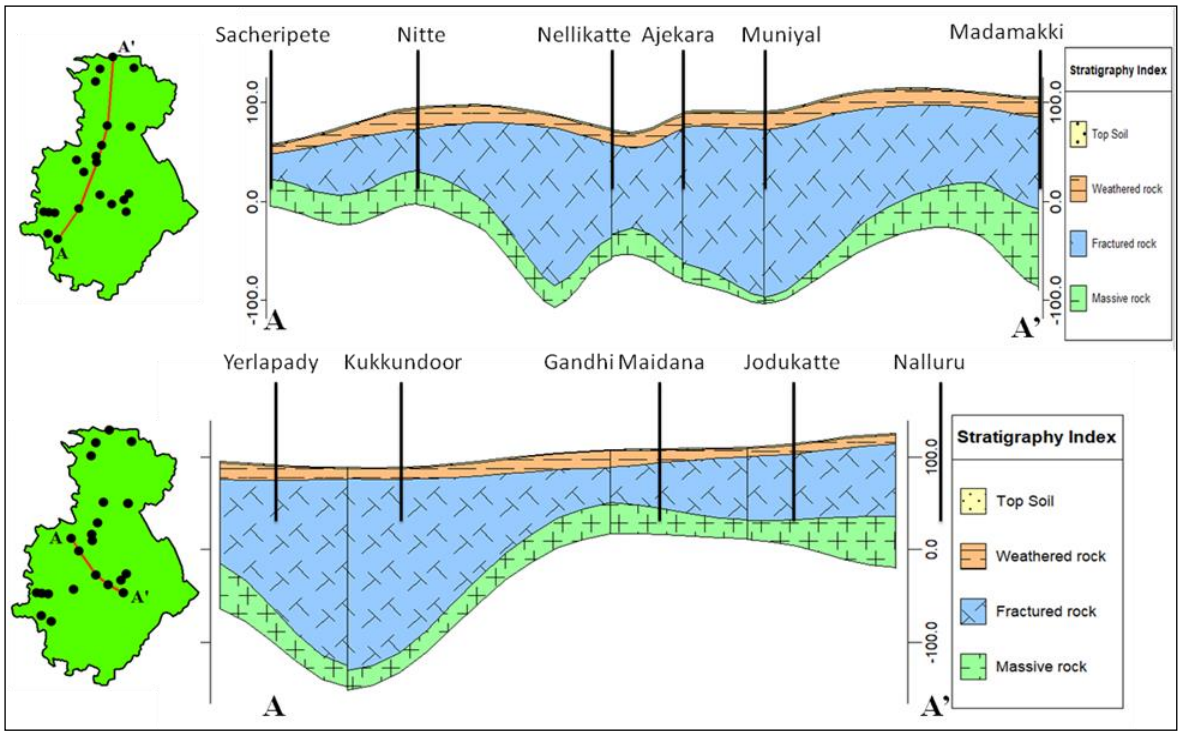

Fig.20: 2D Aquifer Cross Section

Hydrogeological cross section A-A' (Fig.-20) represents south-north direction and data of 7 exploratory wells has been utilised. It can be clearly seen from the south to central part i.e., from Sacheripete to Nellikatte, the thickness of Aquifer-II (deeper aquifer) is increasing and gradually decreases towards northern part and again starts increasing at Muniyal and again the thickness starts decreasing towards extreme part of northern part at Madamakki. The maximum depth of Aquifer-II is attained at Nellikatte and Muniyal. On the contrary, the thickness of Aquifer-I (shallow aquifer) is constant from southern to northern part. In the next cross section, it represents the NW-SE direction and data of 5 exploratory wells has been utilised. From NW part the thickness of Aquifer-II starts increasing from Yerlapady to Kukkundoor and it gradually decreases towards SE part at Gandhi Maidana and again starts increasing towards extreme SE part till Nalluru.

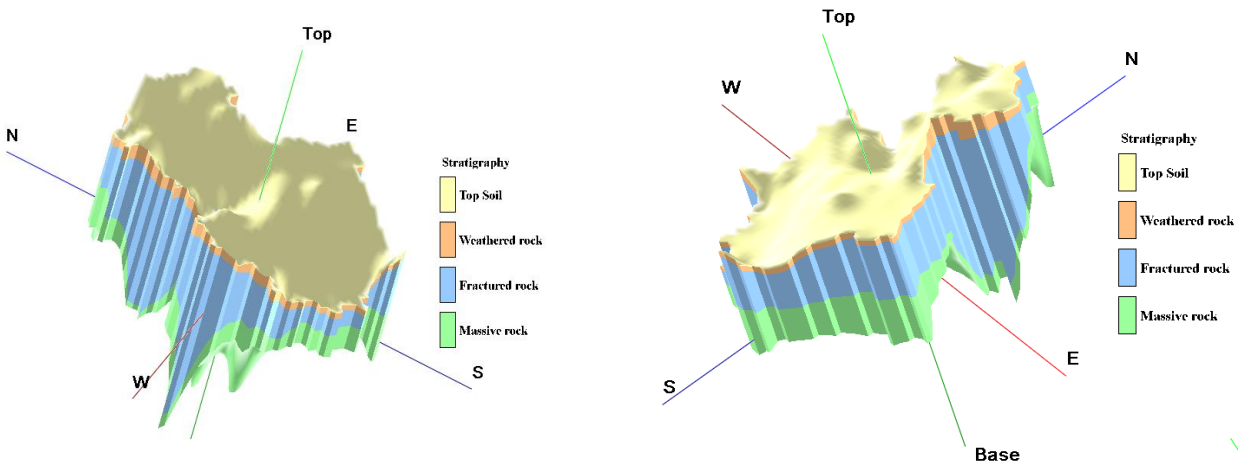

Fig.21: 3D Aquifer Disposition

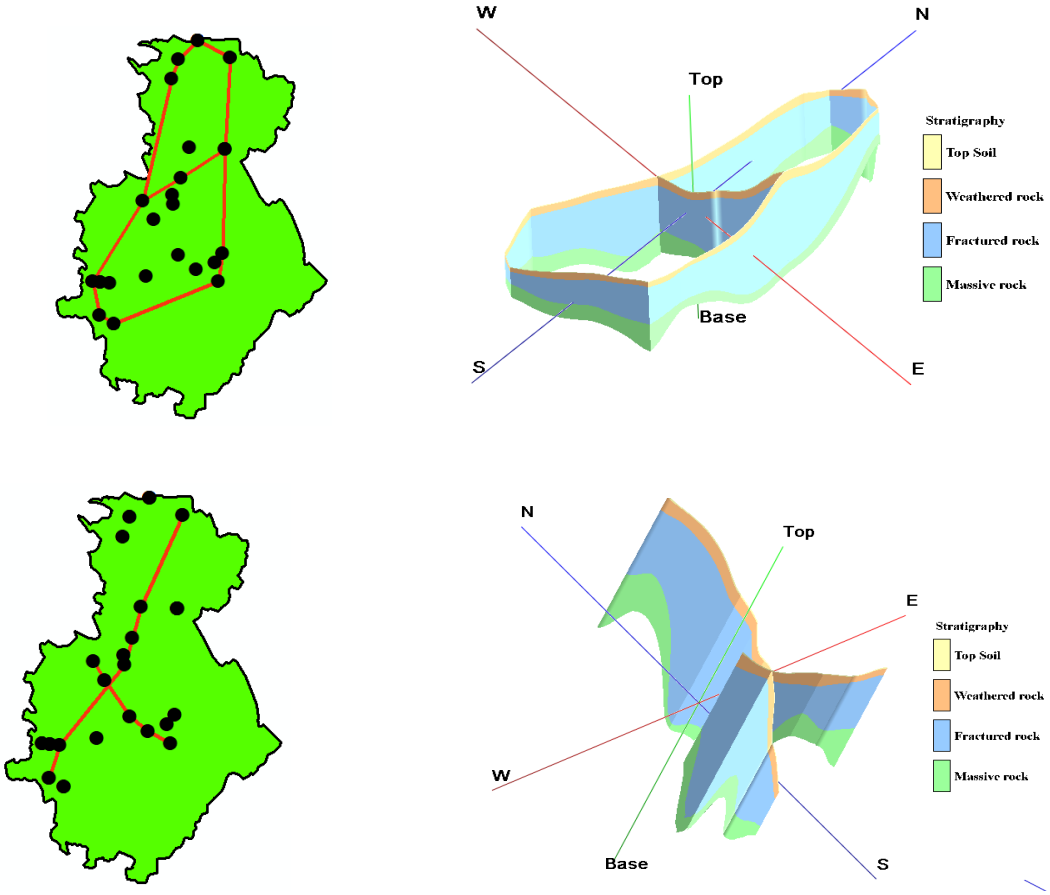

Fig.22: 3D Aquifer Fence diagram

4. GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES

The main ground water issues are over exploitation, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, deeper water levels especially in Aquifer II, declining water level trend which are all inter-related or inter dependent.

4.1 Comparison of Ground Water Resource and Extraction

The Dynamic Ground Water Resource 2017, 2020 and as on 2022 have already been summarised above and are shown in **Table 11**. It is observed that the stage of GW development in 2022 is same as 2017 but goes down in 2020. It is attributable to the improvement in the irrigation practice, influence of command area and also due to the water conservation / recharge activities carried out in the taluk by various state govt. and other agencies.

Table 11: Comparison of groundwater availability and draft scenario (in ham)

Taluk	2017			2020			2022		
Karkala	GW availability	GW Extraction	Stage of GW development	GW availability	GW Extraction	Stage of GW development	GW availability	GW Extraction	Stage of GW development
	14249	5331	37	24056	5677	24	13775	5041	37

4.2 Chemical quality of ground water and contamination

The quality of shallow ground water has been evaluated from CGWB monitoring wells and water quality of fractured aquifer in Karkala taluk has been evaluated by sampling and analysis of water sample collected from wells inventoried during field work as monitoring wells of CGWB. The water in phreatic aquifer zones is found in potable form. The well wise chemical analysis data of the samples are given in the **Table 12a** (Dug wells collected in May 2022) and water quality analysis of wells inventory made in Karkala taluk is given in **Table 12b.**

Electrical conductivity (EC), Chloride (Cl), Nitrate (NO3), and Fluoride (F) parameters are observed to be in the range of desirable limit as per BIS, 2012.

In dug wells, the value of pH ranges from 6.57 to 7.86. EC value is in the range of 75 to 300 m/mhos/cm at 25^{o}C. Cl ranges from 7 mg/l to 32 mg/l. The value of NO_3 ranges from 1 to 24 mg/l. Fluoride ranges from 0.01 to 0.12 mg/l.

In bore wells, the value of pH ranges from 5.61 to 7.74. EC value is in the range of 40 to 370 m/mhos/cm at 25^{o}C. Cl ranges from 7 mg/l to 18 mg/l. The value of NO_3 ranges from 0 to 16 mg/l. Fluoride ranges from 0.08 to 0.43 mg/l.

Table 12a: Ground water quality (2022) – Dug wells

Sl. No	Location	Type of well	pH (6.5-8.5)	EC in m S/cm	TH (600)	Ca (200)	Mg (100)	Na	K	HCO_3	Cl (1000)	SO_4 (400)	NO_3 (45)	SiO2	F (1.5)	TDS (2000)	TA (600)
					<.....mg/L.....>												
1	Arsakatte	DW	7.86	150	35	10	2	15	2.8	37	21	3	3	8	0.02	84	30
2	Hosmar	DW	6.97	140	25	8	1	13	9.6	37	14	10	3	2	0.12	79	30
3	Modabidri	DW	6.57	95	20	4	2	11	1.0	18	14	2	8	2	0.02	54	15
4	Sampige	DW	6.89	75	25	8	1	5	0.7	18	7	8	2	1	0.04	42	15
5	Thodur	DW	7.28	150	45	14	2	14	0.5	55	14	4	1	7	0.02	84	45
6	Jodukatte Guddeangadi	DW	6.73	145	30	8	2	16	2.1	37	18	3	7	7	0.02	81	30
7	Someshwar	DW	6.92	140	45	12	4	10	1.4	31	7	24	3	5	0.01	81	25
8	Hebbri	DW	6.87	160	50	14	4	11	1.2	24	14	25	5	13	0.01	99	20
9	Mudardi	DW	7.32	270	65	18	5	29	4.9	73	18	33	8	5	0.10	157	60
10	Mata bettu Maniyala	DW	7.03	205	35	10	2	30	1.1	37	18	24	15	11	0.02	129	30
11	Ajekar	DW	6.87	160	30	8	2	21	1.2	37	14	18	6	15	0.02	104	30
12	Yenni Hole	DW	7.07	155	40	10	4	17	1.0	37	14	21	1	13	0.01	99	30
13	Nitte	DW	6.76	160	35	10	2	19	0.5	31	11	22	11	9	0.01	100	25
14	Kukandaur	DW	6.94	195	45	12	4	22	1.9	37	18	26	8	6	0.01	115	30
15	Bailur	DW	7.13	300	65	16	6	34	5.4	55	32	29	24	5	0.02	178	45
16	Badami katte	DW	6.69	160	35	10	2	19	1.3	24	21	22	1	12	0.02	101	20
17	Miyar	DW	6.61	190	40	12	2	23	0.9	24	28	22	2	6	0.01	109	20
18	Bajgoli	DW	7.36	135	45	10	5	8	1.1	24	11	8	18	5	0.01	78	20

Table 12b: Ground water quality (2022) – Bore wells

Sl. No.	Location	Type of well	pH (6.5-8.5)	EC in m S/cm	TH (600)	Ca (200)	Mg (100)	Na	K	HCO_3	Cl (1000)	SO_4 (400)	NO_3 (45)	Si O2	PO4	F (1.5)	TDS (2000)	TA (600)
					<.....mg/L.....>													
1	Gandhi Maidana, Karkala	BW	7.50	310	105	34	5	15	3.5	140	18	7	0	86	0.04	0.25	254	115
2	Jodukatte	BW	6.54	80	25	8	1	6	0.9	24	11	4	0	20	0.00	0.09	66	20
3	Miyyaru	BW	5.61	60	25	4	4	5	0.5	18	11	3	0	21	0.00	0.09	59	15
4	Bajagole	BW	5.91	100	40	10	4	9	1.5	43	11	10	0	26	0.00	0.10	97	35
5	Nalluru	BW	5.90	70	25	6	2	6	0.8	24	11	2	0	90	0.00	0.09	132	20
6	Nitte	BW	6.52	170	65	20	4	13	3.4	85	11	3	0	79	0.00	0.20	184	70
7	Kedinje	BW	7.59	370	110	32	7	28	4.6	183	18	4	0	91	0.03	0.25	296	150
8	Belman	BW	6.02	80	35	8	4	5	1.1	31	11	2	0	9	0.00	0.10	58	25
9	Sacheripete	BW	6.55	140	50	12	5	10	3.1	61	14	4	0	72	0.00	0.13	157	50
10	Mundkuru	BW	6.28	70	20	6	1	7	3.1	18	14	3	0	18	0.00	0.10	64	15
11	Kukkundoor	BW	7.74	340	85	26	5	31	1.4	159	14	8	0	84	0.02	0.40	266	130

12	Yerlapady	BW	7.67	270	100	30	6	12	3.5	128	14	2	2	49	0.03	0.29	197	105
13	Nellikatte	BW	7.13	230	85	30	2	11	4.2	92	14	4	6	42	0.01	0.35	170	75
14	Yennehole	BW	7.50	250	100	28	7	12	2.6	122	11	4	0	76	0.03	0.43	215	100
15	Ajekara	BW	6.70	200	75	18	7	11	5.0	85	14	21	0	49	0.00	0.35	177	70
16	Muniyal	BW	5.80	90	30	8	2	5	3.7	31	11	6	0	11	0.00	0.10	65	25
17	Hebri	BW	6.20	110	40	12	2	7	3.8	55	7	2	0	57	0.04	0.11	125	45
18	Kucchuru	BW	7.50	330	140	46	6	11	3.0	159	14	8	0	81	0.02	0.40	266	130
19	Madamakki	BW	6.21	40	20	4	2	4	0.3	12	7	2	9	20	0.00	0.08	56	10
20	Someshwara	BW	6.84	180	75	20	6	11	6.1	79	14	3	16	66	0.01	0.32	191	65

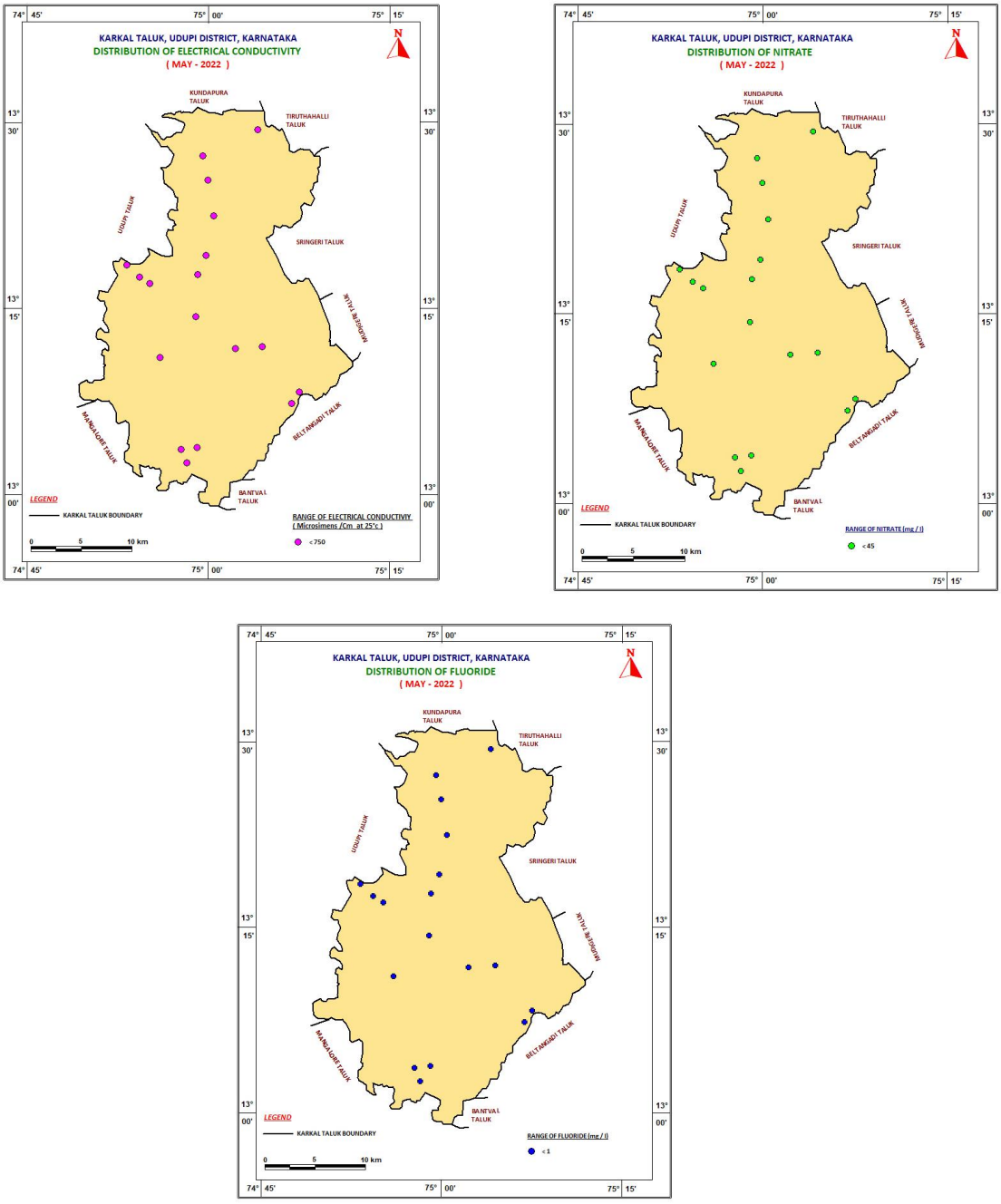

Fig.23: Ground water quality maps

5. GROUNDWATER RESOURCE ENHANCEMENT

5 .1 Resource Enhancement by Supply Side Interventions

The Master Plan for Artificial recharge to ground water prepared by CGWB (2020) recommended to replenish the desaturated aquifer system, both phreatic & deeper **(Aquifer I & II)** in the taluk through construction of artificial recharge structures, viz; check dams, percolation tanks & Sub surface dykes (**Table.13**). The choice of recharge structures should be site specific and such structures need to be constructed in areas already identified as feasible for artificial recharge. Scientific site selection of AR structures is a prerequisite to improve the efficacy of Managed Aquifer Recharge.

Table-13: Details of Proposed AR structures

Geographical area	1091
Area feasible for AR	1033
Non committed monsoon runoff available (MCM)	76.971
Number of Check Dams	339
Number of Percolation Tanks	69
Number of Subsurface dykes	2
Tentative total cost of the project (Rs. in lakhs)	4811.675
Excepted recharge (MCM)	25.26
Additional irrigation Potential (Lakh hectares)	0.07

The area feasible for artificial recharge structures in Karkala taluk is shown in **Fig.24.** The tentative location of the recharge structures in Dharwad taluk is shown in **Fig.25.** The tentative list of the proposed Percolation tanks and Check dams are listed in **Annexure 1.**

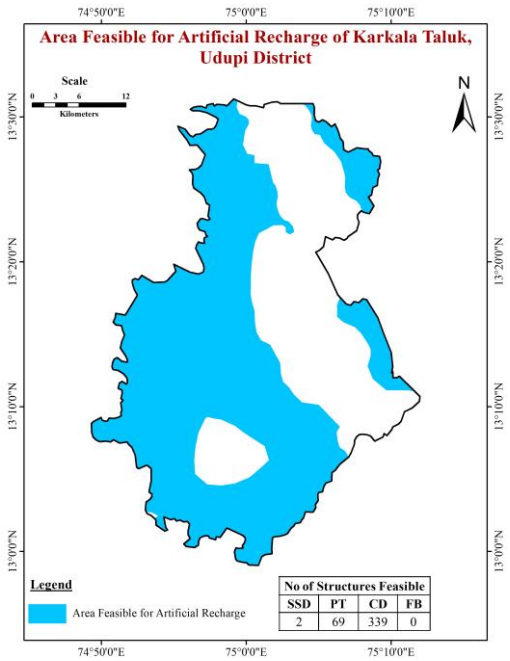

Fig.24: Tentative Locations of AR Structures

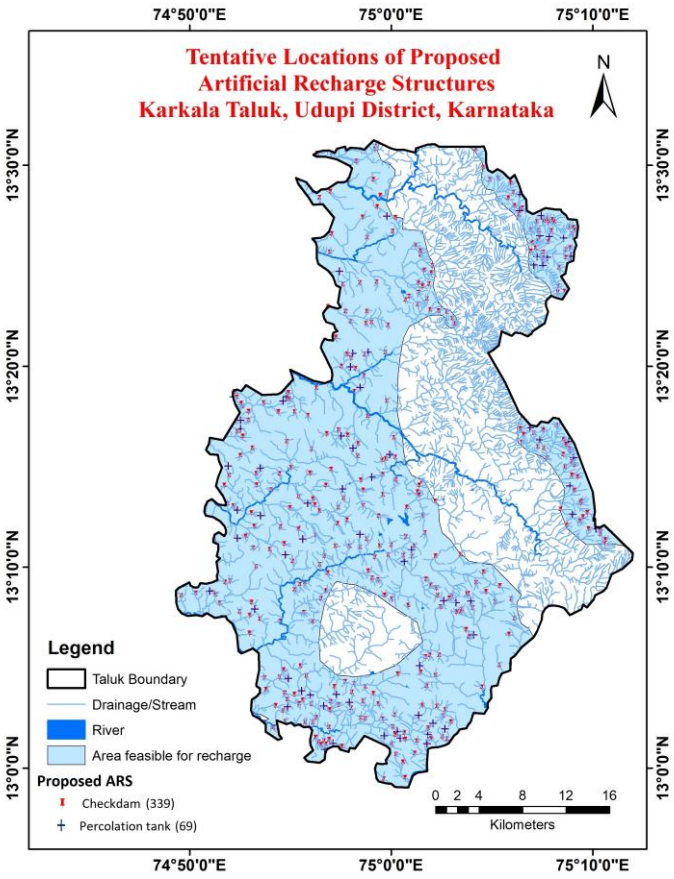

Fig.25: Tentative Locations of AR Structures

After implementation of Artificial Recharge structures for GW recharge, the annual ground water availability will increase from 13775 to 16301 ham and the expected improvement in stage of extraction is 6.1% from 37% to 30.9%. **(Table 14)**

Table 14: Improvement in GW availability (GWRA 2022) due to Recharge

Taluk	Net annual ground water availability	Existing Ground Water extraction for all uses	Existing Stage of Ground water extraction	Expected recharge from proposed artificial recharge structures	Cumulative annual ground water availability after implementation of AR structures	Expected improvement in stage of ground water extraction after the implementation of the project	Expected improvement in stage of ground water extraction
	HAM	HAM	%	HAM	HAM	%	%
Karkala	13775	5041	37	2526	16301	6.1	30.9

5.2 Resource Savings by Demand Side Interventions

The important crops grown are Paddy, pulses, fruits, vegetables etc. Ground water is the major source for irrigation. In view of this, Water Use Efficiency (**WUE**) practices like Drip needs to be strengthened to save irrigation water by way of precision farming mechanism. This ultimately enhances the area under irrigation potential.

Efficient irrigation practices like Drip irrigation and sprinkler have to be adopted by the farmers in the existing 8466 ha of net irrigated area. It is proposed to adopt micro irrigation (drip) techniques in paddy (10409 ha), fruits and vegetables (7185 ha). It is assumed that 25% of paddy area i.e., 2602 ha and 50% of fruits and vegetables i.e., 3592 ha is irrigated by ground water. Implementation of efficient irrigation techniques will contribute in saving ground water by 1750 ham. The details of the resource enhancement through artificial recharge in the taluk and through Water Efficiency practices in Irrigation are shown in **Table.15.**

Table.15: Improvement in GW availability due to Recharge and WUE

Sl. No.	**Resource Details**	**As per 2022 Estimation**
1	Net Ground Water Availability in Ham	13775
2	Existing ground water draft for all uses in Ham	5041
3	Existing Stage of Ground Water Development in percentage %	36.6%
4	Expected Recharge from Artificial Recharge sources in Ham	2526
5	Cumulative Ground water availability in Ham	16301
6	Expected improvement in stage of ground water development %	31%
8	Saving due to adopting Water Use Efficiency in Ham	1750
9	Ground water availability after AR & WUE in Ham	18051
10	Expected improvement in stage of ground water development after implementation of AR & WUE %	**27.9%**

5.3 Ground Water Development Plan

In Karkala taluk, the present stage of ground water extraction (2022) is 36.6 % with net ground water availability for future use is 8723 ham and total extraction is 5041 ham (2022). The ground water draft for irrigation purpose is 4689 ham, thus indicating that ground water irrigation needs to be encouraged in the area after considering the “Safe” level of extraction of 36.6%, which can be implemented in scientific manner. The implementation of the plan needs to be based on site

specific detailed hydrogeological, geophysical and scientific surveys for pinpointing the sites for construction of dug wells and bore wells.

As per the conservative estimate and after considering the average unit draft figure for the taluk, about 3260 dug wells (15-30 m depth; 3 to 5 m diameter) are recommended to be constructed in feasible areas. Further as per the estimate about 290 bore wells (40 to 100 m depth; 150 mm dia) are also recommended to be drilled in feasible areas so as to maintain the safe category of the taluk. The likely additional irrigation potential which can be created considering prevailing crop water requirement for the area is will be 4959 ha.

Table – 16 a: Feasibility of Additional GW abstraction structures based on GWRA 2022 availability

Annual Extractable GW Resource (Ham)	Net GW Availability for future use (Ham)	Stage of GW Extraction (%)	GWR required to take SOE to 60%	Total Extrac-tion / Draft	Balance GWR available to enhance SOE 60%	No. of DW feasible considering 82% of balance GWR with unit draft of 0.9 ham	No. of BWs feasible considering 18% of balance GWR with unit draft of 1 ham
13775	8723	36.6	8265	5041	3224	3260	290

Table – 16 b: Ground Water Resource Development Plan as per GWRA 2022 availability

Items	**Proposed Structures**		**Total**
Present GW Availability is 13775 MCM Present Gross Annual Extraction is 5041 MCM Present Stage of GW Development is 36.6%	**Dug wells – 3260** Depth: 15 to 30 m Dia: 3 to 5 m Av. Annual Gross draft – 0.9 ham	**Bore well - 290** Depth: 40 to 100 m Dia – 150 mm Av. Annual Gross draft – 1 ham	**3550**
Additional irrigation potential created considering crop water requirement of 0.65 m (Ha)	**4513**	**446**	**4959**

Note- Hydrogeological and scientific intervention is needed for pinpointing the sites for construction of dugwells and Borewells

5.4 Regulation and Control

As per the resource estimation – 2022, Karkala taluk falls under "**Safe"** category with the stage of ground water extraction of 36.6**%**. However, the mandatory guidelines like rainwater harvesting and artificial recharge issued by Karnataka Ground Water Authority needs to be strictly implemented in the taluk, so that quality of ground water will improve in due course of time.

5.5 Other interventions proposed

- Karkala Taluk receives high amount of rainfall during monsoon. There is good availability of seepage water during post monsoon period.
- There is extensive scope for seepage and rain water harvesting through construction of percolation tank, and farm ponds.
- Moisture and water use efficiency is possible to boost up agricultural production and to solve drinking water problem (District Irrigation Plan, Pradhan Mantri Krishi Sinchai Yojana, Udupi district).
- Periodical maintenance of artificial recharge structures should also be incorporated in the Recharge Plan.

6. SUMMARY AND RECOMMENDATIONS

The main ground water issues are Low Ground Water Development, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, Deeper Water Levels particularly in Aquifer-II in some parts of areas which are all inter-related or inter dependent. The summary of ground water management plan of the taluk is given in **Table-17.**

Table 17: Summary of Management plan

Stage of GW Extraction and Category (2022)	36.6 %, Safe
Annual Extractable GW Resource (Ham)	13775
Total Extraction (Ham)	5041
Ground Water Draft for Irrigation (Ham)	4689
Ground Water Resource Enhancement by Supply side Interventions	
No of Proposed AR structures SSD PT CD	 2 69 339
Expected Additional Recharge to GW due to AR (Ham)	2526
Additional Irrigation Potential that can be created (lakh Ha)	0.07
Total Estimated Expenditure (Rs. in Cr.)	48.11
Change in Stage of GW Extraction (%)	36.6 to 30.9%
Ground Water Resource Savings by Demand side Interventions	
Expected Saving due to adopting WUE measures (Ham)	1750
Change in Stage of GW development (%) [Both supply & demand side interventions]	36.6 to 27.9
Ground Water Resource Development Plan	

Balance GWR available to enhance SOE 60% (Ham)	3223.8
No. of wells proposed **DW** – Depth: 15 to 30 m, Dia: 3 to 5 m, Unit Cost –Rs. 3.00 lakh, Av. Annual Gross draft – 4.8 ham **BW** – Depth: 40 to 100 m, Dia: 150 mm, Unit Cost – Rs. 2.00 lakh, Av. Annual Gross draft – 22.1 ham	3260 290
Additional irrigation potential created considering crop water requirement of 0.65 m (Ha)	4959
Total Estimated Expenditure (Rs. in Cr.)	103.59
Increase in Stage of GW Extraction (%)	36.6 to 60

As per the resource estimation – 2022, Karkala taluk falls under Safe category with the stage of ground water extraction is 36.6 %. However, there is need to formulate management strategy to tackle the water scarcity related issues in the taluk in the coming days to avoid water crisis in the future. It is suggested to adopt a scientific and multi-pronged ground water management strategy covering supply side interventions, demand side interventions, ground water development interventions and ground water quality protection aspects as mentioned in the management plan suggested above

- **Ground water resource enhancement by supply side interventions**: Quantity of surface water available through non-committed surface run-off is estimated to be 76.97 MCM. This can be used to recharge the aquifer mainly through percolation tanks (69), check dams (339) and sub surface dyke structures (2). The volume of water expected to be recharged is 2526 ham through these AR structures. The approximate cost estimate for construction of these AR structures is Rs. 48.11 Cr. The additional area which can be brought under assured ground water irrigation will be about 0.07 Lakh hectares.
- **Ground water resource enhancement by demand side interventions**: At present about 80 % of irrigation is by wells and bore wells (groundwater). The micro irrigation practices like drip and sprinkler irrigation are comparatively less practiced in comparison with traditional surface flooding mode of irrigation. Efficient irrigation practices like Drip irrigation and sprinkler has to be adopted by the farmers in the existing 8466 ha of net irrigated area. It is proposed to adopt micro irrigation (drip) techniques in paddy (10409 ha), fruits and vegetables (7185 ha). It is assumed that 25% of paddy area i.e., 2602 ha and 50% of fruits and vegetables i.e., 3592 ha is irrigated by ground water. Implementation of efficient irrigation techniques will contribute in saving ground water by 1750 ham. However, in long run the practice of efficient irrigation techniques will add to the ground water resource in large extent.

- **Ground Water Resource Development Plan:** The present stage of ground water extraction (2022) is merely 36.6 % with net ground water availability of 13775 ham and total extraction of 5041 ham. The ground water draft for irrigation purpose is @ 4689 ham, thus indicating that ground water irrigation needs to be encouraged in the area. To overcome the low ground water development, it is imperative to have a robust ground water resource development plan for the area, which can be implemented in scientific manner. The implementation of the plan needs to based on site specific detailed hydrogeological, geophysical and scientific surveys for pinpointing the sites for construction of dugwells and Borewells.
- In view of above, the focus of proposed ground water development plan is to up the ante of ground water development from the present 37% to 60% in a systematic way by adopting scientific approach. About 3260 dugwells (15-30 m depth; 3 to 5 m diameter @ Rs. 3.00 lakh/dugwell) are recommended to be constructed in feasible areas. Further 290 borewells (40-100 m depth; 150 mm dia @ Rs. 2.00 lakh/borewell) are also recommended to be drilled in feasible areas. Additional irrigation potential which can be created considering crop water requirement of 0.65 m (Ha) will be 4959 ha. The total expenditure proposed to be incurred is Rs. 103.59 Cr.
- **Regulation and control:** Taluk is categorized as **"Safe".** However, the mandatory guidelines like rainwater harvesting and artificial recharge issued by Karnataka Ground Water Authority needs to be strictly implemented in the taluk so that quality of ground water will improve in due course of time.
- **Participatory management:** Awareness programmes and practice of participatory approach needs to be strengthened with the involvement of all the stake holders for sustainable management.

Annexure 1:

A) Tentative Locations of Proposed Percolation Tanks, Karkala taluk

Sl.No	Long	Lat
1	75.1062	13.4624
2	75.1064	13.4759
3	75.1241	13.4584
4	75.1231	13.4416
5	75.1307	13.4409
6	75.1208	13.4241
7	75.1255	13.4170
8	75.1292	13.4238
9	75.1181	13.4174
10	75.1487	13.4244
11	75.1427	13.4397
12	74.9965	13.4579
13	74.9571	13.4121
14	74.9663	13.3328
15	74.9809	13.3450
16	74.9682	13.3441
17	74.9743	13.3156
18	74.9133	13.3081
19	74.9107	13.3045
20	74.8695	13.3080
21	74.8754	13.2885
22	74.8754	13.2885
23	74.8756	13.2814
24	74.8651	13.2506
25	74.8917	13.2487
26	74.8728	13.2141
27	74.8728	13.1909
28	74.9125	13.1771
29	74.8919	13.2096
30	74.9269	13.1900
31	74.8498	13.1470
32	74.8871	13.1321
33	74.9150	13.0745
34	74.9143	13.0509
35	74.9548	13.0612
36	74.9443	13.0517
37	74.9258	13.0642
38	74.9330	13.0607
39	74.9654	13.0547
40	74.9519	13.0207
41	74.9451	13.0156
42	74.9941	13.0270

43	75.0074	13.0248
44	75.0052	13.0304
45	75.0296	13.0204
46	75.0444	13.0327
47	75.0348	13.0371
48	75.0302	13.0280
49	75.0229	13.0439
50	75.0238	13.0850
51	75.0682	13.1105
52	75.0435	13.1388
53	75.0536	13.1372
54	75.0660	13.1386
55	75.0109	13.1716
56	75.0168	13.1811
57	74.9840	13.2415
58	74.9598	13.2316
59	74.9742	13.1939
60	74.9310	13.2198
61	74.9684	13.2656
62	74.9587	13.2754
63	74.9988	13.2602
64	75.1149	13.2823
65	75.1231	13.2723
66	75.1510	13.2574
67	75.1468	13.2710
68	75.1479	13.2341
69	75.1500	13.2106

(Source: Master Plan, CGWB, 2020. It is likely that the number of structures proposed may vary depending upon the ground truth verification and feasibility criteria)

B) Tentative Locations of Proposed Check dams, Karkala taluk

Sl.No	Long	Lat
1	75.0760	13.4978
2	75.0818	13.4878
3	75.0888	13.4886
4	75.0991	13.4847
5	75.0704	13.5133
6	75.1011	13.4775
7	75.0969	13.4724
8	75.1021	13.4660
9	75.1054	13.4585
10	75.1087	13.4639
11	75.1207	13.4527
12	75.1263	13.4532
13	75.1284	13.4547
14	75.1309	13.4530
15	75.1339	13.4545
16	75.1349	13.4525
17	75.1478	13.4478
18	75.1506	13.4479
19	75.1516	13.4456
20	75.1497	13.4428
21	75.1323	13.4453
22	75.1214	13.4455
23	75.1159	13.4459
24	75.1164	13.4355
25	75.1215	13.4369
26	75.1294	13.4361
27	75.1446	13.4295
28	75.1446	13.4230
29	75.1388	13.4145
30	75.1251	13.4223
31	75.1381	13.3996
32	75.1067	13.2811
33	75.1096	13.2763
34	75.1179	13.2774
35	75.1079	13.2697
36	75.1259	13.2801
37	75.1370	13.2838
38	75.1426	13.2726
39	75.1479	13.2644
40	75.1496	13.2535
41	75.1541	13.2413
42	75.1516	13.2300
43	75.1569	13.2192

44	75.1773	13.1890
45	75.1732	13.1937
46	75.1587	13.2079
47	75.1633	13.1982
48	75.1564	13.2044
49	75.1450	13.2011
50	75.1263	13.2650
51	75.1425	13.2598
52	74.9713	13.5028
53	74.9881	13.5179
54	74.9867	13.5131
55	74.9647	13.4874
56	74.9853	13.4878
57	74.9909	13.4744
58	74.9886	13.4651
59	74.9765	13.4564
60	75.0035	13.4562
61	75.0014	13.4448
62	74.9497	13.4776
63	74.9406	13.4727
64	74.9507	13.4428
65	74.9492	13.4273
66	74.9800	13.4396
67	74.9601	13.4008
68	74.9742	13.4021
69	74.9879	13.4027
70	74.9477	13.3821
71	74.9623	13.3783
72	74.9800	13.3784
73	74.9665	13.3702
74	74.9794	13.3686
75	74.9836	13.3693
76	74.9971	13.3669
77	75.0203	13.4333
78	75.0242	13.4291
79	75.0344	13.4162
80	75.0270	13.4125
81	75.0332	13.4102
82	75.0313	13.4011
83	75.0260	13.3993
84	75.0223	13.4020
85	75.0227	13.3941
86	75.0297	13.3889
87	75.0151	13.3909
88	75.0219	13.3842
89	75.0118	13.3880

90	75.0392	13.3788
91	75.0460	13.3779
92	75.0528	13.3680
93	74.9542	13.3568
94	74.9587	13.3328
95	74.9636	13.3429
96	74.9666	13.3397
97	74.9706	13.3310
98	74.9781	13.3428
99	74.9951	13.3443
100	74.9698	13.3117
101	74.9773	13.3250
102	74.9966	13.3040
103	74.9151	13.3108
104	74.9157	13.3057
105	74.9383	13.3149
106	74.9202	13.2951
107	74.9309	13.2919
108	74.9067	13.2950
109	74.8946	13.3025
110	74.8705	13.3118
111	74.8725	13.3073
112	74.8759	13.3021
113	74.8770	13.3000
114	74.8822	13.2953
115	74.8820	13.2880
116	74.8727	13.2786
117	74.8774	13.2748
118	74.8852	13.2650
119	74.8752	13.2587
120	74.8658	13.2423
121	74.8620	13.2342
122	74.8647	13.2189
123	74.8694	13.2171
124	74.8887	13.2344
125	74.8884	13.2439
126	74.9007	13.2302
127	74.9077	13.2438
128	74.9173	13.2491
129	74.9137	13.2706
130	74.9342	13.2642
131	74.9467	13.2769
132	74.9565	13.2801
133	74.9728	13.2686
134	74.9641	13.2757
135	74.9723	13.2581

136	74.9808	13.2916
137	75.0024	13.2737
138	75.0033	13.2574
139	74.9956	13.2560
140	74.9925	13.2549
141	74.9748	13.2386
142	74.9931	13.2431
143	75.0038	13.2387
144	74.9933	13.2263
145	74.9769	13.2300
146	74.9769	13.2173
147	74.9505	13.2473
148	74.9328	13.2443
149	74.9234	13.2249
150	74.9353	13.2230
151	74.9407	13.2129
152	74.9370	13.2179
153	75.0255	13.2380
154	75.0231	13.2343
155	75.0219	13.2287
156	75.0231	13.2259
157	75.0364	13.2209
158	75.0262	13.2092
159	75.0130	13.2159
160	75.0279	13.1946
161	74.9459	13.2341
162	74.9607	13.2235
163	74.9564	13.2156
164	74.9634	13.2054
165	74.9555	13.2024
166	74.9163	13.2154
167	74.9082	13.1997
168	74.9234	13.1980
169	74.9374	13.1925
170	74.8843	13.2113
171	74.8867	13.2002
172	74.8797	13.1918
173	74.8535	13.1883
174	74.8859	13.1821
175	74.8997	13.1809
176	74.9116	13.1858
177	74.8627	13.1538
178	74.8667	13.1546
179	74.8881	13.1668
180	74.8546	13.1436
181	74.8263	13.1425

182	74.8382	13.1446
183	74.8584	13.1364
184	74.8745	13.1292
185	74.8829	13.1263
186	74.8847	13.1371
187	74.8826	13.1115
188	74.8915	13.1235
189	74.9083	13.1214
190	74.9185	13.1711
191	74.9407	13.1683
192	74.9449	13.1754
193	74.9540	13.1836
194	74.9658	13.1836
195	74.9743	13.1828
196	74.9799	13.1897
197	74.9906	13.1840
198	75.0000	13.1846
199	75.0123	13.1915
200	75.0194	13.1838
201	75.0172	13.1751
202	75.0101	13.1759
203	74.9897	13.2085
204	75.0368	13.1754
205	75.0575	13.1766
206	75.0764	13.1622
207	75.0899	13.1507
208	75.0994	13.1398
209	75.1020	13.1237
210	75.0975	13.1105
211	75.0895	13.0850
212	74.9976	13.1763
213	74.9865	13.1745
214	74.9809	13.1632
215	74.9893	13.1559
216	74.9842	13.1572
217	74.9477	13.1615
218	74.9463	13.1467
219	74.9286	13.1535
220	74.9243	13.1520
221	74.9200	13.1477
222	74.9278	13.1287
223	74.9352	13.1210
224	74.9111	13.0810
225	74.9077	13.0749
226	74.9142	13.0564
227	74.9121	13.0619

228	74.9044	13.0515
229	74.9125	13.0382
230	74.9107	13.0473
231	74.9289	13.0378
232	74.8965	13.0648
233	74.8953	13.0746
234	74.9249	13.0844
235	74.9298	13.0761
236	74.9532	13.0671
237	74.9199	13.0608
238	74.9269	13.0560
239	74.9498	13.0550
240	74.9492	13.0481
241	74.9380	13.0416
242	74.9485	13.0333
243	74.9354	13.0375
244	74.9239	13.0531
245	74.9342	13.0529
246	74.9564	13.0522
247	74.9668	13.0494
248	74.9675	13.0626
249	74.9619	13.0714
250	74.9696	13.0695
251	74.9786	13.0671
252	74.9770	13.0550
253	74.9853	13.0615
254	75.0054	13.0778
255	75.0246	13.0791
256	75.0285	13.0919
257	75.0319	13.0933
258	75.0397	13.0933
259	75.0367	13.0764
260	75.0621	13.1145
261	75.0371	13.1490
262	75.0328	13.1514
263	75.0289	13.1562
264	75.0386	13.1427
265	75.0409	13.1333
266	75.0482	13.1405
267	75.0502	13.1422
268	75.0637	13.1443
269	75.0627	13.1441
270	75.0703	13.1534
271	75.0785	13.1460
272	75.0676	13.1324
273	75.0586	13.1311

274	75.0568	13.1293
275	75.0542	13.1292
276	75.0861	13.1375
277	75.0648	13.1082
278	75.0142	13.1345
279	75.0005	13.1399
280	74.9947	13.1430
281	74.9938	12.9906
282	75.0117	12.9918
283	75.0098	13.0046
284	75.0040	13.0109
285	75.0196	13.0119
286	75.0006	13.0195
287	75.0214	13.0221
288	75.0119	13.0235
289	75.0108	13.0289
290	75.0016	13.0339
291	75.0034	13.0273
292	75.0329	13.0241
293	75.0306	13.0328
294	75.0463	13.0239
295	75.0423	13.0256
296	75.0494	13.0379
297	75.0431	13.0430
298	75.0450	13.0479
299	75.0382	13.0510
300	75.0260	13.0515
301	75.0751	13.0666
302	75.0293	13.0676
303	74.9932	13.0403
304	75.0029	13.0438
305	74.9785	13.0406
306	74.9748	13.0411
307	74.9894	13.0529
308	74.9376	13.0250
309	74.9402	13.0213
310	74.9422	13.0192
311	74.9444	13.0225
312	74.9460	13.0194
313	74.9487	13.0234
314	74.9593	13.0176
315	74.9026	13.0336
316	74.9420	13.1402
317	75.1196	13.4308
318	75.1156	13.4283
319	75.1257	13.4275

320	75.1484	13.4311
321	75.1379	13.3942
322	75.1436	13.3949
323	75.1214	13.2661
324	75.1445	13.2678
325	75.1286	13.2568
326	75.1515	13.2510
327	75.1497	13.2425
328	75.1441	13.2495
329	75.1484	13.2624
330	75.1571	13.2210
331	75.1767	13.1861
332	75.1736	13.1982
333	75.1623	13.2116
334	75.1403	13.2144
335	75.0241	13.4255
336	74.9390	13.5095
337	74.9509	13.5097
338	75.0325	13.3796
339	75.0506	13.3727

(Source: Master Plan, CGWB, 2020. It is likely that the number of structures proposed may vary depending upon the ground truth verification and feasibility criteria)