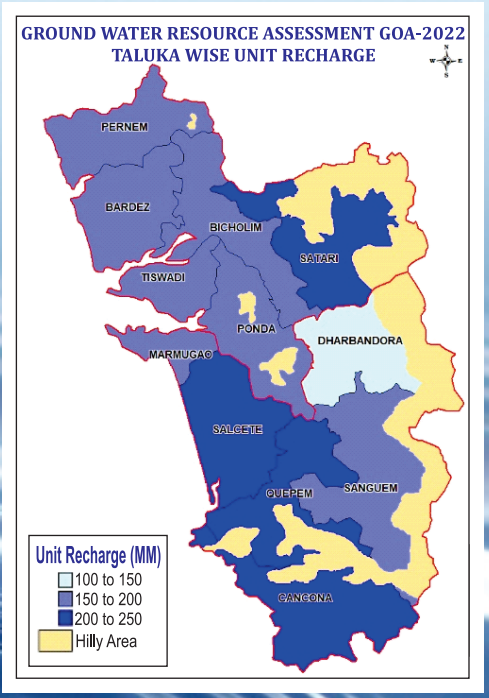
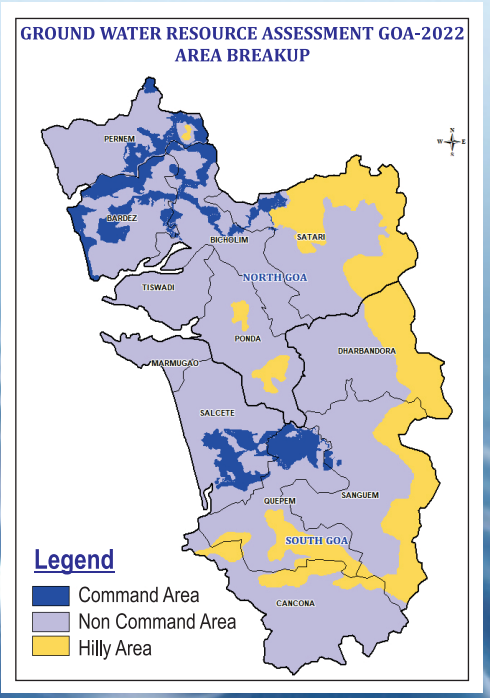
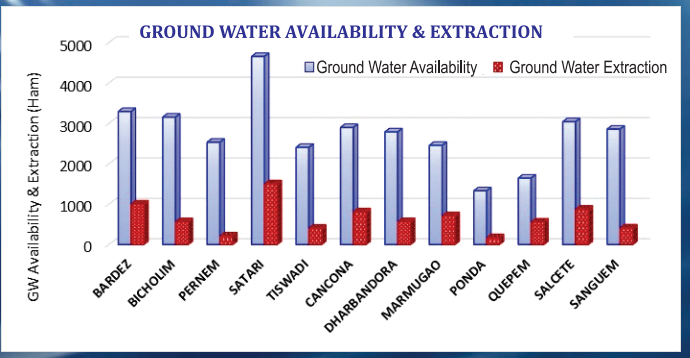
DYNAMIC GROUND WATER RESOURCES OF GOA - 2022







Water Resource Department
Government of Goa

Central Ground Water Board
South Western Region
Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti,
Government of India

DYNAMIC GROUND WATER RESOURCES OF GOA 2022

Water Resource Department
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&
Central Ground Water Board,
South Western Region
Department of Water Resources, River Development &
Ganga Rejuvenation, Ministry of Jal Shakti,
Government of India

FOREWORD

I consider it my privilege to write this foreword for the Report on Ground Water Resources of Goa - 2022. Groundwater is a natural resource with both ecological and economic value and is of vital importance for sustaining life, health and integrity of ecosystems. Scarcity and misuse of groundwater pose a serious threat to sustainable development and livelihood.

Goa is one of the most well-endowed States in the country in respect of rainfall. Goa's reserve of water resources is generally considered bountiful. However, even amidst the plenitude of its water resources, scarcity is faced in some parts during the lean period, creating a paradox of sorts Hitherto, the State's main activities in water resources development have focused on surface water resources. With an ever-increasing demand for water to meet various requirements like domestic, industrial and irrigation, the importance of groundwater in supplementing and augmenting supply, especially in remote and far-flung areas through piped water is all too apparent. Goa realized the importance of groundwater early on and has been one of the pioneering states in enacting legislation for groundwater regulation through scientific process and conservation measures.

The ground water resource assessment is being carried out periodically based on the protocols and guidelines issued from time to time by Central Ground Water Board, New Delhi. The current Ground Water Resource Assessment – 2022 (GWRA-2022) had been done jointly by Water Resources Department, Government of Goa and Central Ground Water Board, South Western Region, Bangalore as per the Ground Water Estimation Methodology 2015 on administrative unit basis. As per the GWRA 2022, the annual extractable ground water resources in the State of Goa are 33071 ham, whereas the total extraction is 7815 ham, thus the stage of ground water extraction is 23.63%.

I am confident that the report will be of immense use to all the State Government agencies involved in ground water planning and development as well as the educational institutional, research organization, stake holders and end users. I take this opportunity to compliment the officers Central Ground Water Board and the Water Resources Department for their efforts in preparation of the report.

Subhash Chandra, IAS
Secretary, Water Resources, Govt. of Goa
Place: Alto – Porvorium – Goa

FOREWORD

Most of the ancient civilization, cities and towns were developed along river banks as water is the most essential natural resource required for sustaining any form of life. The previous ground resource assessment studies had indicated that Goa State is blessed with plentiful of ground water resources and it is one of the State's most important natural resources. It provides drinking water to rural as well as urban community, supports irrigation & industry, sustains the flow of streams & rivers and maintains wetland ecosystem.

Water Resources Department, Government of Goa in association with Central Ground Water Board has been making all efforts to improve the quality of ground water estimation since last ten years. Of late, the ground water has gained more importance due to scarcity of surface water and frequent fluctuations in supply of water to the various consumers. Keeping this in view, the Government of Goa has enacted Goa Ground Water Regulation Act 2002; wherein various measures have been adapted to regulate over extraction of ground water. At present the entire commercial establishment throughout Goa has been covered by computerized metering and billing.

The Water Resources Department, Government of Goa and Central Ground Water Board, South Western Region, Bangalore had jointly assessed the ground water resources of State of Goa for 2022 as per the Ground Water Estimation Methodology 2015 on administrative unit basis. The precision of groundwater resource estimation is mainly dependent on the quality of the basic data. This assessment is carried out with the help of the secondary data. Despite the limitations of the secondary data, WRD has taken efforts and has tried to collect more accurate irrigation well census, crop and surface irrigation data, data on water conservations structures, tanks & ponds data etc. As per the GWRA 2022, the annual extractable ground water resources in the State of Goa are 33071 ham, whereas the total extraction is 7815 ham, thus the stage of ground water extraction is 23.63%. On contrary to other States, the domestic draft is on higher side @ 61% as compared to other uses reflecting the non-agrarian nature of the State.

This report will serve as a ready reckoner for the water sector planning by administrators, technocrats, industries and other water related professionals. I earnestly hope that the report will be able to guide the future course of ground water development in the State of Goa thereby benefitting / further uplifting the socio-economic situation of Goa State.

Pramod B. Badami
Chief Engineer (WRD)
Govt. of Goa
Place: Alto – Porvorium – Goa

सत्यमेव जयते

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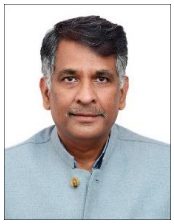
Ministry of Jal Shakti



PREFACE

Central Ground Water Board, under Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India (GoI) is the National Apex Organisation for Scientific and Sustainable development and management of Ground Water Resources. The CGWB in association with the respective State Ground Water Departments/UTs has been periodically assessing ground water resources of all the States and Union Territories of the country over the last three decades based on the norms recommended by the Government of India. The precise and reliable estimation of ground water is necessary for its optimal and sustainable development.

It is necessary to acknowledge the hydrogeological characteristics of groundwater and its integral link to land, vegetation and surface water resources and perceive it as a 'resource' rather than a 'source'. Acknowledging the ubiquity of groundwater usage and its importance to all sections of society, it is necessary to recognize it as a common pool resource and adopt an aquifer-based approach to its management.

Here a fruitful attempt has been made by Central Ground Water Board, Bangalore and Water Resources Department, Goa to assess the dynamic ground water resources of the State of Goa for 2022 as per the groundwater estimation committee methodology-2015 on administrative unit basis. At the outset, the basic data needed for the assessment viz; geographical area, forest area, rainfall, details of canal and command area, net irrigated area, irrigation well census, data on WCS, tanks and ponds etc. were provided WRD, Goa. For the three basic parameters viz., water level, specific yield and unit draft, the CGWB data has been used. The support provided by Shri P.B. Badami, CE, Shri S.B. Ghantkar, EO, Shri Rajan Kamble, Ex. Engg. & Sr. Hydrogeologist and Shri Sudesh G. Parulekar, AE from WRD, Goa is duly acknowledged in GWRA-2022. The present report is outcome of the untiring efforts made by Shri Rahul R. Shende, Scientist-C, Dr. Lubna Kouser, Scientist-C and Shri Sushant S. Navarat, AHG of SWR, CGWB, Bangalore and SUO, Belgaum and it is highly appreciable.

The ground water assessment of Goa State will be very much useful to the planners, policy makers and other stake holders for effective and proper management of precious ground water resources. I hope that the people of Goa State get benefitted due to the resource estimation as it is the main input for deciding many ground water related Central Govt. aided schemes.

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Regional Director

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Principal Contributions by

Water Resources Department **Government of Goa, Alto – Porvorium – Goa**	**Central Ground Water Board** **South Western Region, Bengaluru**
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Shri Rajan Kamble, Senior Hydrogeologist	Dr. Lubna Kouser, Scientist-C
Shri Sudesh G. Parulekar, Assistant Engineer	Shri Sushant S. Navarat, AHG

DYNAMIC GROUND WATER RESOURCES OF GOA STATE - 2022

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1 INTRODUCTION

Goa state having a total geographical area of 3702 sq.km and is administratively divided into 2 districts and 12 taluks (**Fig.-1**). Ground water resources of the state of Goa were assessed on administrative unit (Taluk) wise, based on Groundwater Estimation Committee (GEC) 2015 Methodology. The assessment was done using the Ground Water database as on March 2022 validated by Water Resources Department (WRD), Govt. of Goa and Central Ground Water Board (CGWB), SWR, Bengaluru using INGRES software developed by Vassar Labs. GEC 2015 methodology recognises that it has considerable scope for refinements and improvements, which can be achieved in a phased manner, as per the guidance of the R&D advisory committee on Groundwater Estimation.

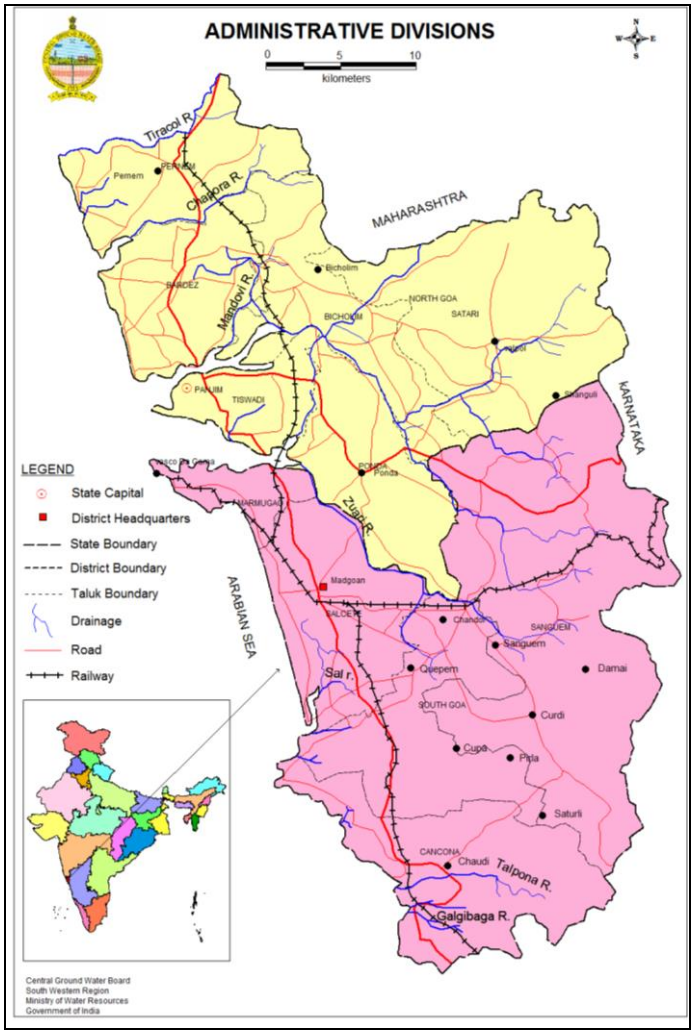

Fig.-1: Index Map

1.1 Background

In the State of Goa, groundwater has emerged as an important source to meet the water requirements of various sectors especially tourism, domestic and industrial sectors. Demands

for groundwater resources are ever increasing and competition amongst users has intensified. The sustainable development of groundwater requires precise quantitative assessment based on reasonably valid scientific principles. The occurrence, movement and storage of groundwater are quite complex, being governed by several factors like meteorology, geomorphology, geology, hydrogeology, and above all the human activities. All these factors make the precise assessment of groundwater very difficult and there is no direct technique available for precise assessment. Hence the methods applied for groundwater resource estimation are all indirect. There are several techniques and methodologies *in vogue* for estimation of groundwater resources. Quantification of groundwater resources is often critical and no single comprehensive technique is yet identified which is capable of estimating accurate groundwater potential. Since groundwater is a dynamic and replenishable resource, its proper and economic development on a sustainable basis, requires its realistic assessment. The estimation must be seen as an interactive procedure. Initial estimation are revised and refined by comparing these results with the results obtained by adopting alternative methods and third party studies.

The Ministry of Jal Shakti, Dept. of Water Resources, River Development & Ganga Rejuvenation, Govt. of India desires to reassess the Ground Water Resources for the entire country once in two years and hence the current re-estimation of resources as in March 2022 has been taken up in view of the changes that are observed in the ground water scenario. The data provided by the state agencies have been used in the present ground water assessment. During 2020 assessment, a software named INDIA – Groundwater Resource Estimation System "INGRES" has been introduced for assessing the ground water resources of India and the same is used for current assessment. The data collected were compiled as per format in INGRES and was uploaded in the software and the results generated were validated with the manual calculations for few sample assessment units to ensure the error-free functioning of software.

1.2 Constitution of State Level Committee

A State Level Committee for Ground Water Resources Assessment (GWRA) was constituted under the chairmanship of Secretary, Water Resources, Govt. of Goa vide U.O. No. 4/9/CE-CPO/WRD/2021-22/610 dated 03/03/2022 (Annexure I) with Regional Director, Central Ground Water Board, Bangalore being the Member Secretary. The composition of the Committee is as follows:

Secretary, Water Resources	Chairman
Chief Engineer, Water Resource Department	Member
Chief Engineer, (Water Supply & Sanitation Dept.) PWD	Member
Director, Department of Agriculture	Member
Director, Department of Industries	Member
Director, Department of Planning, Statistics & Evaluation	Member
General Manager, NABARD	Member
Superintending Engineer, CPO, WRD	Member
Superintending Engineer, Circle I, WRD	Member
Senior Hydrogeologist, WRD	Member
Regional Director, Central Ground Water Board, Bangalore	Member Secretary

As per the protocol, a GWRA cell comprising of the officers of the CGWB and WRD was also formed for resource evaluation. The members of the group had several meetings and

discussions for data authentication, monitoring the progress and address the constraints in resource evaluation. Various departments were requested to provide data required for the purpose.

1.3 Brief Outline of the Proceedings of the Committee

The first meeting of the State level Committee (SLC) for Ground Water Resources Assessment - 2022 of Goa State was held on 24.05.2022 at 11.00 hrs, Conference Room, Water Resource Department, Alto-Porvorim, Goa. Shri. Pramod B. Badami, Chief Engineer, chaired the meeting. Shri. Rahul R Shende, Scientist – B, CGWB, presented the 2015 methodology to be adopted in resource assessment of 2022 with the final results of previous assessment of 2020. He informed the committee that, the resources in Goa were assessed Taluka-wise which were further sub-divided into command and non-command units. Further details of the data required for the present 2022 resource assessment was briefed to the committee member with the details of time line to be followed was also discussed. Based on the agenda and discussions held during the meeting, it was decided by the committee to consider the 12 taluks as assessment units. It was also decided that ground water draft data based on actual number of wells and industries which have been granted NOC by WRD will be considered for resource estimation. Shri. Pramod B. Badami, Chief Engineer, WRD, Goa, suggested that that the mining projects wherein the mine pits are present and are continuously filled with water may also be considered as the recharge sources for estimation of recharge due to tanks and ponds. The minutes of the meeting are attached as ***Annexure-II.***

The second meeting of the SLC was held on 28.08.2022 at 10.30 hrs through online mode. Shri. Pramod B. Badami, Chief Engineer, chaired the meeting. Shri N. Jyothi Kumar, Regional Director, CGWB, SWR, Bangalore & Member Secretary welcomed the Chairman, Members & Invitees to the State Level Committee Meeting. He appreciated the efforts put in by the officers of GWRA cells of CGWB and WRD in providing the data required for the resource assessment and carrying out the important task. Shri. Rahul R Shende, Scientist – B, CGWB, presented the draft results and findings of GWRA 2022.

Shri. Pramod B. Badami, Chief Engineer, WRD, Goa appreciated the work done by CGWB and WRD and the findings arrived in GWRA 2022. He stressed that the ground water extraction is increasing since 2011 as per the presentation and domestic draft is on higher side @ 61% as compared to other uses. Thus, efforts need to be concentrated towards reducing the load on domestic use of ground water by increasing the supplementary surface water supply through various schemes. He also suggested that the stage of extraction is more than 30% for Marmugao, Bardez and Salcette taluks and any one of these 3 taluks needs to be taken as sample taluk for detailed assessment in the next assessment, since Goa state is having only small area and there are only 12 assessment units/taluks. It was agreed to take one sample taluk in the next assessment for detailed survey/data collection in association with WRD. Based on the detailed discussions held during the meeting, the GWRA 2022 were approved by all the committee members unanimously. The minutes of the meeting are attached as Annexure-III.

2 HYDROGEOLOGICAL CONDITIONS OF GOA STATE

2.1 Climate and Rainfall

The state has a tropical-maritime monsoonal type climate with distinct aerographic influence. January is the coolest month with mean daily temperature of about 23°C. The temperature is highest (around 33°C) in pre monsoon months of April and May and again in post monsoon months of November and January. Due to the maritime climate the diurnal variation in temperature is not much. Due to proximity to the Arabian Sea humidity throughout the year is more than 60% and it ranges from 80 to 90% during monsoon period.

Rain occurs during the South West monsoon period from June to September. Over 90 percent of annual rainfall occurs during monsoon period. The balance of 10 percent occurs during the pre-monsoon period from March to May and post monsoon period from October to December. The distribution of normal annual rainfall is depicted in **Fig.-2** and it indicates that rainfall is increasing from 2902.80 mm (Tiswadi taluk) in the west to 4217.70 mm (Satari taluk) in the east. As a result of orographic influence rainfall increases towards the Western Ghats from the coast. Similarly, rainfall decreases from south to north along the coast as well as interiors. While the normal annual rainfall in the North Goa district averages to 3389.74 mm it is 3352.23 mm in the South Goa district, whereas for entire Goa State it is 3367.86 mm. June and July are the wettest months with around 1000 mm rainfall each month. Rainfall during the months of January and February is negligible.

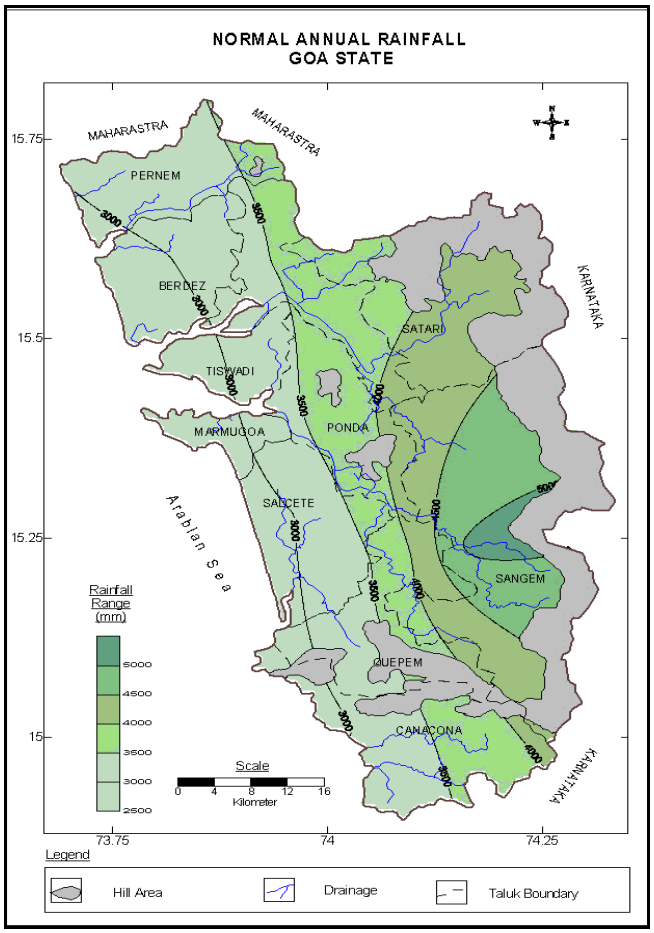

Fig.-2: Distribution of Normal Annual Rainfall Map

2.2 Geomorphology

Geomorphologically, Goa state is divided into four morphological units namely, the 1. Coastal plains with dominant marine land forms on the west, followed successively towards the east by the 2 .Vast etch plain, 3. Low dissected denudational hills and table land and 4. Deeply dissected high Western Ghats with denudational hills occurring all along the eastern part of Goa rising to a maximum of 832 meters above mean sea level (mamsl). The fluvial landforms are limited in aerial extent.

Goa state forms part of coastal tract of the west coast of India. The principal perennial rivers are Terekhol, Chapora, Mandovi, Zuavari and Galjibagh, whereas Baga, Sal, Saleri and Talpona are ephemeral rivers. Kumbharaja canal is an important feature of natural drainage of Goa and it links Mandovi River with Zuavari River about 20 km east of the coast and it provides natural link connecting two major rivers of Goa.

2.3 Soils

Soils of the state can be grouped into 5 classes whose aerial distribution and brief descriptions are as under.

2.3.1 Lateritic Soils

These are highly porous and permeable and constitute 2150 km^2 of the state area. These are slightly acidic with low pH values, low in organic matter, Ca and P.

2.3.2 Alluvial Soils

They are reddish brown to yellowish coarse grained and confined to narrow valleys of rivers and are well drained. These soils are acidic with low pH and organic content. These occupy an area of 80 km^2 in the state.

2.3.3 Hilly Area Soil

These soils occupy an area of 705 km^2. They are rich in humus content and retain good soil moistures. However, the thickness of the same is very limited.

2.3.4 Saline Soils

Saline soils occupy flood plains of Zuari and Mandovi rivers in Tiswadi, Ponda and Bardez taluks and also occur in Cancona, Pernem taluks. These Soils are deep, poorly drained and less permeable. Saline soils are saline, high in pH and contain humus and organic matter and occupy an area of 430 km^2 in the state

2.3.5 Marshy Soils

Marshy soils occur in low lying water logged and tidal affected areas confined to patches in Salcete, Canacona and Marmugao taluks. These soils occupy an area of 119 km^2 in the state

2.4 Geology

Goa state is dominantly covered by the formations of the Goa group belonging to Dharwad Super Group of Archaean to Proterozoic age, except for a narrow strip along the north eastern corner occupied by Deccan Trap of Upper Cretaceous to Lower Eocene age. The Goa group is consisting of green schist facies of the metamorphic rocks and is divided in to Barcem, Sanvordem, Bicholim and Vageri formations in the ascending order of super position.

The Goa groups of rocks have been intruded by granite gneiss, feldspathic gneiss, hornblende gneiss and porphyritic granite, followed by basic intrusive. During The Sub-Recent and Recent times the rocks have been subjected to lateritisation of varying thickness. Coastal alluvium occurring along the coastal planes consists of fine to coarse sands with intercalations of sandy loam, silt and clay. The general geological succession of Goa is as follows.

Table- 1: Geological Succession of Goa State

AGE	GROUP	FORMATION	ROCK TYPE
Quaternary		Alluvium	Beach Sand
Cenozoic			Laterites
Upper Cretaceous to Eocene	Deccan Trap		Basalt
Lower Proterozoic	Clospet Granite		Granite
		Peridotite, Gabbro, Norite	Pyroxenite, Periditite, Serpentinite, Gabbro
Archaean to Lower Proterozoic	Goa Group	Vageri Formation	Carbonate-quartz-chlorite schist with Greywacke
		Bicholim Formation	Dolomitic limestone
			Quartz- Sericite schist
			Banded iron formation
			Chert and quartzite
			Quartz-chlorite-biotite schist with layers of chert, iron oxide, carbonate, metabasalt and meta gabbro
		Sanvordem Formation	Greywacke with conglomerate
			Quartzite
		Barcem Formation	Quartz-chlorite schist
			Meta-acid volcanics
			Metabasalt
			Ortho-quartzite
Archaean	Peninsular Gneissic complex		Granite Gneiss, Migmatites and Granites

The Goa group of rocks is disposed in a general NW-SE direction throughout the territory except in south western part where they have WNW-ESE trend. The rock types indicate three cycles of folding. The straight coastal line suggests the major fault along the west coast. Associated with this fault a number of weak planes have developed. Along these weak planes Terekhol, Chapora, Mandovi and Zuari rivers flow to meet the Arabian Sea. Western Ghats which extends in NS to NNW-SSE direction represent a prominent fault zone. Even though the rock types of Goa group have suffered considerable faulting, all the faults are not exposed on surface owing to the extensive cover of laterite. During the sub- recent to recent times, the rocks have been subjected to lateritisation resulting in cover of laterite of varying thickness.

2.5 Ground Water Conditions

Ground water bearing formations in Goa state are alluvium, laterite, granite and granite gneiss, meta-volcanics and sedimentaries. The major aquifer system in Goa is presented in **Fig.-3**.

2.5.1 Alluvium

The thickness of the coastal alluvium varies from 5 m to 22 m. Fine to coarse sands with intercalations of sandy loam, silt and clay occurring at depth range of 1.42 to 8.0 meters below ground level (mbgl) is tapped by dug wells. Depth to water levels in these formations varies from 1.4 to 5.85 m bgl. Specific capacity ranges between 72 and 297.85 m^3/day/m. Exploratory tube wells constructed in alluvium vary in depth from 15.5 to 22 m. The thickness of sand and gravel bed varies from 3 to 3.5 m occurring at depth range of 10 and 20 mbgl. The recorded discharges are between 1.88 and 3 liters per second (lps). The specific capacities vary between 27.1 and 200.78 m^3/day/m and transmissivity varies from 25.44 to 177.5 m^2/day.

2.5.2 Laterites

The laterites are the important water bearing formations in the state. Laterites are of two type's viz. as in-situ in plateau areas or of detrital origin generally occupying valley portions. Besides inherent porosity the laterites are highly jointed and fractured which control their water bearing capacity. The topographic settings of laterites control its ground water potential. The thickness of laterites extends up to 40 m. Irrigation dug wells tapping laterite range in depth from 2.85 m 20.38 m and depth to water level varies from 1.3 to 19.0 mbgl. Ground water occurs under phreatic condition. Specific capacities vary from 1.73 to 3205 m^3/day/m. Promising areas for groundwater development are located near Malpem and Tuem in Prename taluk, Advalpal and Mayem in Bicholim taluk, Kirlapal in Sanguem taluk and Arlen in Salcete taluk.

2.5.3 Granites and Granite Gneisses

Ground water occurs under unconfined, semi-confined and confined conditions in the weathered and fractured zones of granite and granitic gneiss. Depth to water level in these formations in open wells varies from 3.8 to 6.25 mbgl and specific capacities between 14.4 and 77.3 m^3/day/m. Exploratory boreholes drilled in granite and granite gneiss are in the depth range of 70.7 to 124m bgl with discharges ranging from 0.77 to 8.8 lps. Specific capacities in exploratory wells vary from 2.27 to 43 m^3/day/m and transmissivity from 0.87 to 34.6 m^2/day.

2.5.4 Meta-volcanics

The aquifer characteristics of the meta-volcanics and meta-sedimentaries vary widely. Irrigation dug wells are tapping the weathered zones up to 9.25 mbgl. The diameter of dug wells vary from 2.2 to 6.1 m and depth to water varied from 1.48 to 6.26 mbgl. Specific capacity varies from 10.6 to 228.7m^3/day/m. Exploratory wells and deposit wells drilled in this formation range in depth from 37.2 to 200.75 m and recorded discharges ranging from 0.18 to 25 lps. Productive zones were encountered down to 119 mbgl. The specific capacities of the boreholes tested varied from 0.46 to 988.47 m^3/day/m and transmissivity values from 0.25 to 346.1 m^2/day. Studies have indicated that boreholes drilled in meta-volcanics and meta-

sedimentaries with thick lateritic cover in the plateau areas and close to lineaments have yields ranging between 2 to 5 lps. Artesian wells with free flow of 2.8 lps with head of 4.61 m agl was encountered within the meta-greywacke at depths of 38.2 and 65 m bgl at Honda in Satari taluk and free flow of 0.2 lps with head of 0.6 m bgl in quartzite within phyllite was encountered at 67.70 and 112-113.5 mbgl depths at Virnoda in Pernem taluk.

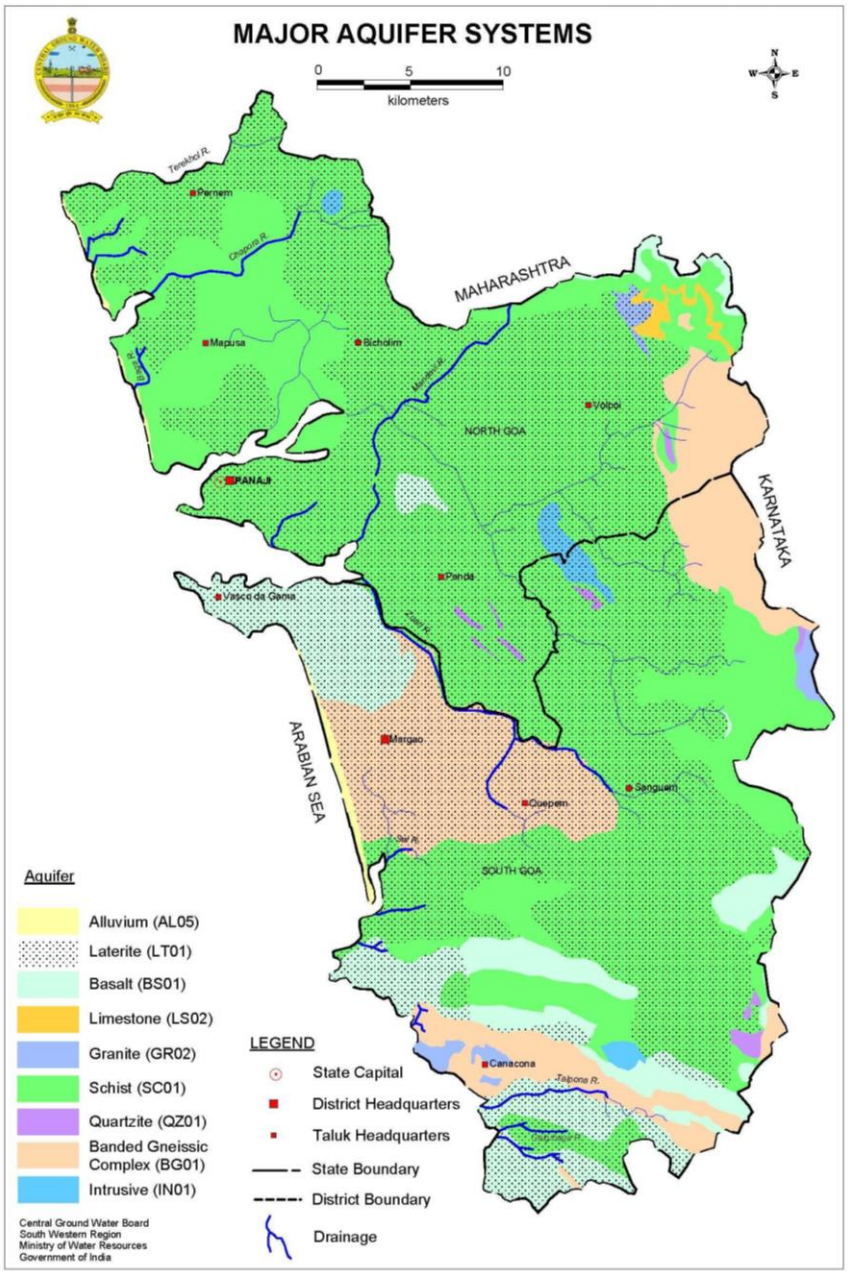

Fig.-3: Major Aquifer System Map

2.5.5 Depth to Water Level

CGWB is maintaining 96 dug wells and 45 piezometers under National Hydrograph Network Monitoring Stations in the state of Goa. The hydrograph stations are spread over different lithological and administrative units of the state. They represent the general groundwater conditions under varying geomorphic as well as geologic units of the assessment unit. Data from these stations were used for assessing the pre monsoon and post monsoon water levels, fluctuation and decal trends. The water levels could not be monitored during May

2020, Nov. 2020, May 2021. Hence average of pre and post monsoon water levels were considered for the assessment purpose.

2.5.6 Pre monsoon Depth to Water Level (May 2019)

The depth to water level recorded in the State of Goa during May 2019 ranged from 1.71 mbgl to 14.95 mbgl. It is seen that out of 78 ground water monitoring wells analyzed during the month, 5% wells have water level less than 2 mbgl, 44% wells have 2 to 5 mbgl water level, 39% wells have 5 to 10 mbgl water level, 12% wells have 10 to 20 mbgl water level. Water level in the range of less than 2 mbgl is observed in some parts of Bardez, Ponda, Quepem and Salcete taluks and 2 to 5 mbgl is observed in almost all taluks of Goa State. Water level in the range of 5 to 10 mbgl is observed in almost all taluks of Goa State except in Mormugao and more than 10 mbgl is observed as isolated pockets in Berdez, Cancona, Salcete, Sanguem and Satari taluks (**Fig.-4**).

2.5.7 Post Monsoon Depth to Water Level (November 2019)

The depth to water level recorded in the State of Goa during November 2019 ranged from 0.04 mbgl to 14.67 mbgl. It is seen that out of 81 stations analysed during the month, 23% wells have water level less than 2 mbgl, 47% wells have 2 to 5 mbgl water level, 23% wells have 5 to 10 mbgl water level, 6% wells have 10 to 20 mbgl water level. The depth to water level map (**Fig.-5**) shows that the water level in the range of 2 to 5 and 5 to 10 mbgl is the general water level in the State.

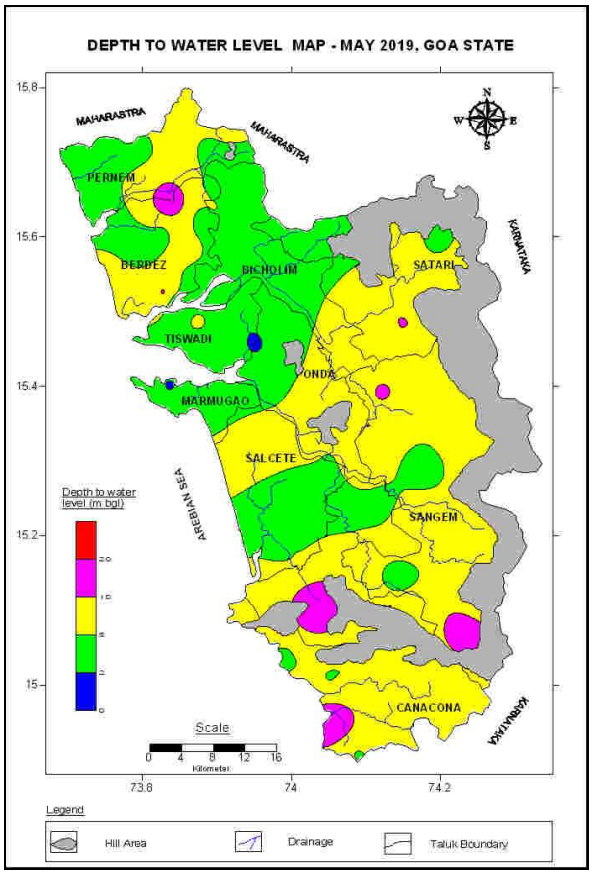

Fig.-4: Pre monsoon Depth to Water Level Map (May 2019)

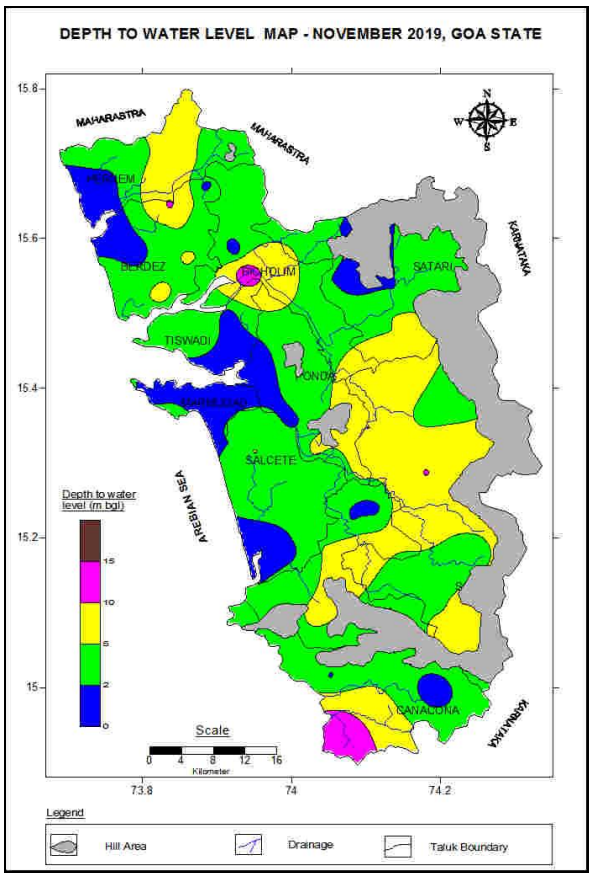

Fig.-5: Post monsoon Depth to Water Level Map (Nov. 2019)

Less than 2 mbgl of water level is observed in almost all taluks except in Mormugao and Sanguem taluks. Water level more than 10 mbgl is observed as patches in of Bardez, Bicholim, Sanguem and Cancona taluks.

2.6 Ground Water Quality

Water samples from the NHS are collected once a year during the month of May and CGWB is continuously monitoring the ground water quality throughout the state. The assessment of chemical quality of ground water samples from Ground Water Monitoring Stations (GWMS) of Goa State for the year 2019 is presented in the following sections.

The water samples from 71 monitoring stations of shallow aquifers from 2 districts were collected during the month of May 2019. These samples were analyzed in the Regional Chemical Laboratory for 13 parameters (EC, pH, major cations, major anions (Cl, HCO_3, SO_4) and also Nitrate and Fluoride) by employing Standard methods. Based on the hydro-chemical data, the potability of these samples has been assessed as per the standards prescribed by the Bureau of Indian Standards and classified into 'Desirable', 'Permissible' and 'Unsuitable' classes.

2.6.1 pH

In the shallow groundwater of the state, the pH ranged between 6.72 and 9.73. Analysis of the data shows that a major part of state has pH 7 to 8.3. Based on the NHS 2019 data, in about 8% of the area the groundwater pH is between 8.3 and 9.60. The occurrence of pH <7 are sporadic and is insignificant. No pattern of spatial variation is observed with respect to the distribution of pH. In recharge areas, where fresh rainwater gets recharged, groundwater without much dissolution is characterized by low EC values. It increases along groundwater flow path, because of the utilization of H^+ ions for mineral dissolution leading to the formation of bicarbonate ions with increase of alkalinity.

2.6.2 Electrical Conductivity

Electrical conductivity ranged between 121 and 930 µs/cm at 25°C with an average of 317 µs/cm at 25°C during May 2019. In general, the groundwater quality in the state is fresh in about 98.5 % of the Groundwater Monitoring wells as indicated by the EC value less than 750 µs/cm at 25°C. In about 1.5 % of the Groundwater Monitoring wells, the EC is between 751-2250 µs/cm at 25°C indicating that the groundwater is of moderate quality.

2.6.3 Chloride

Chloride is one of the major anions in groundwater. The high mobility of the ion and the high solubility of chloride salts make the chloride ions present in waters. Moreover, chloride ions do not take part in any of the geochemical (or) biochemical reactions, hence it can be used as a good indicator of groundwater pollution. Over 500 mg/L it imports saline taste to drinking water. BIS specified 250 mg/L as the desirable and 1000 mg/L as the permissible limit in the

absence of alternate sources for drinking water. Chloride concentration ranged between 11 and 99 mg/l with an average concentration of 24 mg/l during May 2019. The chloride content is less than the desirable limit of 250 mg/L in the entire sample analyzed.

2.6.4 Nitrate

Nitrate concentration ranged between 0 and 122 mg/l with an average concentration of 9 mg/L during May 2019. The Nitrate content is less than 45mg/L in about 93 % of the sample analyzed and 7 % of sample shows more than 45 mg/L which are from North Goa district.

2.6.5 Fluoride

Fluoride concentration ranged between 0.01 and 0.88 mg/L with an average concentration of 0.51 mg/L during May 2019. The Fluoride content is less than 1.5 mg/L in all the 71 samples collected from National Hydrograph stations.

3 GROUND WATER RESOURCES ASSESSMENT METHODOLOGY

Ground water resource as in 2022 have been estimated following the guidelines mentioned in the GEC 2015 methodology using appropriate assumptions depending on data availability. The principal attributes of GEC 2015 methodology are given below: The methodology recommends aquifer wise ground water resource assessment of the Groundwater resources components, i.e., Replenishable ground water resources or Dynamic Ground Water Resources.

3.1 Ground Water Assessment of Unconfined Aquifer

Though the assessment of ground water resources includes assessment of dynamic and in-storage resources, the development planning should mainly focus on dynamic resource as it gets replenished on an annual basis. Changes in static or in-storage resources normally reflect long-term impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper planning for augmentation in the succeeding excess rainfall years.

3.2 Assessment of Annually Replenishable or Dynamic Ground Water Resources

The methodology for ground water resources estimation is based on the principle of water balance as given below –

$$Inflow - Outflow = Change in Storage\ (of an aquifer) \quad \textbf{(1)}$$

Equation 1 can be further elaborated as –

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \quad \textbf{(2)}$$

Where,

ΔS – Change is storage
R_{RF} – Rainfall recharge
R_{STR}- Recharge from stream channels
Rc – Recharge from canals
R_{SWI} – Recharge from surface water irrigation
R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from Tanks & Ponds
R_{WCS} – Recharge from water conservation structures
VF – Vertical inter aquifer flow
LF- Lateral flow along the aquifer system (through flow)
GE-Ground Water Extraction
T- Transpiration
E- Evaporation
B-Base flow

It is preferred that all the components of water balance equation should be estimated in an assessment unit.

3.2.1 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation method and rainfall infiltration factor method during monsoon season and the rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

3.2.1.1 Ground water level fluctuation method

The ground water level fluctuation method is to be used for assessment of rainfall recharge in the monsoon season. The ground water balance equation is given by

$$\Delta S = R_{RF}+R_{STR}+ R_C+R_{SWI}+R_{GWI}+R_{TP}+R_{WCS}\pm VF \pm LF - GE - T - E - B \quad (3)$$

Where,

ΔS – Change is storage
R_{RF} – Rainfall recharge
R_{STR}- Recharge from stream channels
R_C – Recharge due to Canals
R_{SWI} – Recharge from surface water irrigation (Lift Irrigation)
R_{GWI}- Recharge from ground water irrigation
R_{TP}- Recharge from tanks & ponds
R_{WCS} – Recharge from water conservation structures
VF – Vertical inter aquifer flow
LF- Lateral flow along the aquifer system (through flow)
GE-Ground water Extraction
T- Transpiration
E- Evaporation
B-Base flow

This change in storage can be estimated using the following equation:

$$\Delta S = \Delta h * A * SY \quad (4)$$

Where

ΔS – Change is storage
Δh - rise in water level in the monsoon season
A - Area for computation of recharge
Sy - Specific Yield

Substituting the expression in equation 4 for increase in storage i.e.ΔS in terms of water level fluctuation and specific yield, the equations 3 becomes,

$$R_{RF} = h \times Sy \times A - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \quad (5)$$

The recharge calculated from equation 5 gives the rainfall recharge for the particular monsoon season. This rainfall recharge is specific to a particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall as per the procedure indicated below.

3.2.1.2 Normalization of Rainfall Recharge

Let Ri be the rainfall recharge and ri be the associated rainfall. The subscript i takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, Ri is obtained as per equation 5 for which the normalization is to be done using any of the following two procedures. This normalisation procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained as the average of recent 30 to 50 years of monsoon season rainfall.Two methods are possible for the normalisation procedure.

The first method is based on a linear relationship between recharge and rainfall of the form

$$R = ar \quad (6)$$

Where,

R = Rainfall recharge during monsoon season
r = Monsoon season rainfall
a = constant

The second method is also based on a linear relation between recharge and rainfall. However, this linear relationship is of the form,

$$R = ar + b \quad (7)$$

Where,

R = Rainfall recharge during monsoon season
r = Monsoon season rainfall
a and b = constants.

The rainfall recharge during monsoon season for normal monsoon rainfall condition is computed as below:

$$R_{rf}(normal) = axr\ (normal) \quad (8)$$

Or

$$R_{rf}(normal) = axr(normal) + b \quad (9)$$

3.2.1.3 Rainfall Infiltration Factor method

Recharge from rainfall is estimated by using the following relationship –

$$R_{rf} = RFIF * A * (R - a)/1000 \quad (10)$$

Where,

R_{rf} = Rainfall recharge in ham
A = Area in Hactares
RFIF = Rainfall Infiltration Factor

R = Rainfall in mm

a = Minimum threshold value above which rainfall induces ground water recharge in mm

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating ground water recharge using rainfall infiltration factor method. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall.

3.2.2 Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the ground water level fluctuation method and rainfall infiltration factor method these two estimates have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as

$$PD = \frac{R_{rf}(normal, wtfm) - R_{rf}(normal, rifm)}{R_{rf}(normal, rifm)} \times 100$$

Where,

Rrf (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the ground water level fluctuation method

Rrf (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

- If PD is greater than or equal to -20%, and less than or equal to +20%,Rrf (normal) is taken as the value estimated by the ground water level fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

3.2.3 Recharge from other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures in command areas where as in non-command areas it constitutes the recharge due to surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures.

3.2.3.1 Recharge from Canals

Recharge due to canals is to be estimated based on the following formula:

$$R_C = WA * SF * Days \quad (12)$$

Where:

R_C= Recharge from Canals

WA=Wetted Area = Wetted Perimeter X Length of Canal Reach.

SF= Seepage Factor

Days= Number of Canal Running Days.

3.2.3.2 Recharge from Surface Water Irrigation

Recharge due to applied surface water irrigation, either by means of canal outlets or by lift irrigation schemes is to be estimated based on the following formula:

$$R_{SWI} = AD * Days * RFF \quad (13)$$

Where:

R_{SWI} = Recharge due to applied surface water irrigation

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

3.2.3.3 Recharge from Ground Water Irrigation

Recharge due to applied ground water irrigation is to be estimated based on the following formula:

$$R_{GWI} = GE_{IRR} * RFF \quad (14)$$

Where:

R_{GWI} = Recharge due to applied ground water irrigation

GE_{IRR}= Ground Water Extraction for Irrigation

RFF= Return Flow Factor

3.2.3.4 Recharge due to Tanks & Ponds

Recharge due to Tanks & Ponds is to be estimated based on the following formula:

$$R_{TP} = AWSA * N * RF \quad (15)$$

Where:

R_{TP} = Recharge due to Tanks & Ponds

AWSA= Average Water Spread Area

N=Number of days Water is available in the Tank/Pond

RF= Recharge Factor

3.2.3.5 Recharge due to Water Conservation Structures

Recharge due to Water Conservation Structures is to be estimated based on the following formula:

$$R_{WCS} = GS * RF \quad \mathbf{(16)}$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage = Storage Capacity multiplied by number of fillings.

RF= Recharge Factor

3.2.3.6 Lateral flow along the aquifer system (Through flow)

If the area under consideration is a watershed, the lateral flow across boundaries can be considered as zero. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections.

3.2.3.7 Base flow and Stream Recharge

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using Stream Hydrograph Separation method, Numerical Modelling and Analytical solutions. If the assessment unit is a watershed, a single stream monitoring station at the mouth of the watershed can provide the required data for the calculation of base flow.

Base flow assessment and Stream recharge should be carried out in consultation with Central Water Commission in order to avoid any duplicity in the estimation of total water availability in a river basin.

3.2.3.8 Vertical Inter Aquifer Flow

This can be estimated provided aquifer geometry and aquifer parameters are known. This can be calculated using the Darcy's law if the hydraulic heads in both aquifers and the hydraulic conductivity and thickness of the aquitard separating both the aquifers are known.

3.2.3.9 Evaporation and Transpiration

Evaporation can be estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. It is recommended to compute the evaporation through field studies. If field studies are not possible, for areas with water levels within 1.0 mbgl, evaporation can be estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0m bgl, the evaporation losses from the aquifer should be taken as zero.

Transpiration through vegetation can be estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. It is recommended to compute the transpiration through field studies. Even though it varies from place to place depending on type of soil & vegetation, in the absence of field studies the following estimation can be followed. If water levels are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

3.2.4 Recharge/ Accumulations during Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during monsoon season is the total recharge/ accumulation during monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.2.5 Recharge/ Accumulations during Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using rainfall infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during non-monsoon season is the total recharge/ accumulation during non-monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.2.6 Total Annual Ground Water Recharge

The sum of the recharge/ accumulations during monsoon and non-monsoon seasons is the total annual ground water recharge/ accumulations for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.3 Annual Extractable Ground Water Resource (EGR)

The Total Annual Ground Water Recharge cannot be utilised for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined. The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore, ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Ground Water Resources (EGR).

3.4 Estimation of Ground Water Extraction

Ground water draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \quad (17)$$

Where,

GE_{ALL}=Ground water extraction for all uses

GE_{IRR}=Ground water extraction for irrigation

GE_{DOM} =Ground water extraction for domestic uses

GE_{IND} = Ground water extraction for industrial uses

The single largest component of the ground water balance equation in large regions of India is the ground water extraction and the precise estimation of ground water extraction is riddled with uncertainties.

3.4.1 Ground Water Extraction for Irrigation (GE_{IRR})

The Ground Water Extraction for Irrigation is to be assessed employing at least two of the three methods recommended for estimation of ground water extraction for irrigation. The methods for estimation of ground water extraction are as follows.

3.4.1.1 Unit Draft Method

In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tahsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

3.4.1.2 Crop Water Requirement Method

For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by ground water abstraction structures. The database on crop area is obtained from Revenue records in Tahsil office, Agriculture Census and also by using Remote Sensing techniques.

3.4.1.3 Power Consumption Method

Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

3.4.2 Ground Water Extraction for Domestic Use (GE_{DOM})

There are several methods for estimation of extraction for domestic use (GE_{DOM}). Some of the commonly adopted methods are described here.

3.4.2.1 Unit Draft Method

In this method, unit draft of each type of well is multiplied by the number of wells used for domestic purpose to obtain the domestic ground water extraction.

3.4.2.2 Consumptive Use Method

In this method, population is multiplied with per capita consumption usually expressed in litre per capita per day (lpcd). It can be expressed using following equation.

$$GE_{DOM} = \text{Population X Consumptive Requirement X Lg} \quad (18)$$

Where,

Lg = Fractional Load on Ground Water for Domestic Water Supply

The load on ground water can be obtained from the Information based on civic water supply agencies in urban areas.

3.4.3 Ground water Extraction for Industrial use (GE_{IND})

The commonly adopted methods for estimating the extraction for industrial use are as below:

3.4.3.1 Unit Draft Method

In this method, unit draft of each type of well is multiplied by the number of wells used for industrial purpose to obtain the industrial ground water extraction.

3.4.3.2 Consumptive Use Pattern Method

In this method, water consumption of different industrial units is determined. Number of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

$$GE_{IND} = \text{Number of industrial units X Unit Water Consumption X Lg}$$

Where,

Lg = Fractional load on ground water for industrial water supply

The load on ground water for industrial water supply can be obtained from water supply agencies in the Industrial belt. Other important sources of data on ground water extraction for industrial uses are - Central Ground Water Authority, State Ground Water Authority, National Green Tribunal and other Environmental Regulatory Authorities.

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered.

3.5 Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$\text{StageofGroundWaterExtraction}(\%) = \frac{\text{ExistingGrossGroundWaterExtracrtionofalluses}}{\text{AnnualExtractableGroundWaterResources}} \times 100 \quad (20)$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes. The stage of ground water extraction should be obtained separately for command areas, non-command areas and poor ground water quality areas.

3.5.1 Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. The estimation of ground water extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from ground water. The denominator in equation 20, namely Annual Extractable Ground Water Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels.

Long term water level trends are to be prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. The water level trend would be average water level trend as obtained from the different observation wells in the area.

If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below in **Table-2**.

Table-2: Stage of GW Extraction and Trend Mismatch

SOGWE	Ground Water Level Trend	Remarks
≤70%	Significant decline in trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

3.6 Categorization of Assessment Units Based on Quantity:

The categorization based on status of ground water quantity is defined by Stage of Ground Water Extraction as given below in **Table-3**.

Table-3: Stage of GW Extraction and Category

Stage of Ground Water Extraction	Category
≤70%	Safe
> 70%and ≤90%	Semi-Critical
> 90% and ≤100%	Critical
> 100%	Over Exploited

3.7 Quality Tag

If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units on 1:50000 scale, the assessment sub unit may be tagged with the particular quality hazard.

3.8 Allocation of Ground Water Resource for Utilisation

The Annual Extractable Ground Water Resources are to be apportioned between domestic, industrial and irrigation uses. Among these, as per the National Water Policy, requirement for domestic water supply is to be accorded priority. This requirement has to be based on population as projected to the year 2025, per capita requirement of water for domestic use, and relative load on ground water for urban and rural water supply. The estimate of allocation for domestic water requirement may vary from one sub unit to the other in different states. In situations where adequate data is not available to make this estimate, the following empirical relation is recommended.

$$Alloc = 22 \text{ X } N \text{ X } L_g \text{ mm per year} \qquad (21)$$

Where,

Alloc= Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.

L_g = fractional load on ground water for domestic water supply (≤ 1.0)

In deriving equation 21, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present-day extraction. It can never be less than the present-day extraction as it is unrealistic.

3.9 Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The Net annual ground water availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

3.10 Additional Potential Resources Under Specific Conditions

3.10.1.1 Potential Resource Due to Spring Discharge

Spring discharge constitutes an additional source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. Even though, the Spring Discharge is a form of 'Annual Extractable Ground Water Recharge', It is a considered as a potential resource because of the limited data available as on today. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season. The committee recommends that in hilly areas with substantial potential of spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential ground water resource due to springs = Q x No of days (22)

Where,

Q = Spring Discharge

No of days= No of days spring yields.

3.10.1.2 Potential Resource in Waterlogged and Shallow Water Table Areas

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. It is therefore recommended that in such areas, ground water resources may be estimated up to 5m bgl only assuming that where water level is less than 5m bgl, the same could be depressed by pumping to create space to receive recharge from natural resources. It is further evident that this potential recharge would be available mostly in the shallow water table areas which would

have to be demarcated in each sub-basin/ watershed/ block/ taluka/ mandal/ Firka. The computation of potential resource of the ground water reservoir can be done by adopting the following equation:

Potential ground water resource in shallow water table areas = (5-D) x A x S_Y (23)

Where,

D= Depth to water table below ground surface in pre-monsoon period in shallow aquifers.

A= Area of shallow water table zone.

S_Y = Specific Yield

3.10.1.3 Potential Resource in Flood Prone Areas

Ground water recharge from a flood plain is mainly the function of the following parameters-

- Areal extent of flood plain
- Retention period of flood
- Type of sub-soil strata and silt charge in the river water which gets deposited and controls seepage

Since collection of data on all these factors is time taking and difficult, in the meantime, the potential resource from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has to be calculated over the water spread area and only for the retention period using the following formula.

Potential ground water resource in Flood Prone Areas = 1.4 x N x A/1000 (24)

Where,

N = No of Days Water is Retained in the Area

A = Flood Prone Area

4 PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT 2022

4.1 Data Source

For assessment, data from multiple agencies involved in water sector is required like Water Resources Dept. (WRD), Minor Irrigation Dept., Agriculture Dept., Industries Dept., Statistics Dept. etc. The data compilation and validation in itself a huge task. The various data inputs required and used for the assessment are discussed below.

4.1.1 Area

In Goa State, taluks is being used as a unit of assessment in the State irrespective of the Methodology. The areas of the taluk have been computed by from shape files and revenue dept. data. The command areas of the Irrigation Project as per the command area map of NWIC, GoI and Water Resources Department, GoK have been used in this assessment. No poor-quality areas were considered in the current assessment. This data base was used for sub-dividing the assessment unit into command and non-command area.

4.1.2 Well Census

For estimation of ground water extraction for Irrigation purpose, the minor irrigation well census data as well as the data from district administration provided by WRD was considered. Both the irrigation dugwells and borewells have been considered for the draft purpose.

For estimation of ground water extraction for domestic purpose, consumptive method based on population (2011) was used.

For estimation of ground water extraction for industrial purpose, the data on number of wells being used by industries and their annual requirement was considered to arrive at unit draft. This data was acquired from WRD as they are the nodal dept. for ground water regulation in the State.

4.1.3 Canals, Tanks & Ponds

The data base related to canals, command area, number of rotations, and volume of water released into the canals etc have been collected at taluk/circle level from the Water Resources Dept. The taluk level data on tanks and ponds was also provided WRD. The data is as of the year 2021-22.

4.1.4 Water Conservation Structures

The data base related to WCS was at taluk level was also provided WRD. The data is as of the year 2021-22.

4.1.5 Cropping Pattern

The taluk wise crop data and irrigated agriculture data, as on 2021-22 season, collected from district offices of the State Agriculture Department by WRD have been used for the computations of irrigation return flow.

4.1.6 Rainfall

The rainfall data has been sourced from Indian Meteorological Dept. (IMD), Goa. The normal as well as yearly actual monsoon and non-monsoon rainfall measured at various stations within the assessment unit upto 2021 has been used.

4.1.7 Ground Water Levels

The CGWB is monitoring the ground water levels in the State on quarterly basis i.e., in January, March, May and November. There are about 141 observation wells, which consists of 96 dug wells and 45 borewells/piezometers. The water levels could not be monitored during May 2020, Nov. 2020, May 2021. Hence average of pre and post monsoon water levels were considered for the assessment purpose.

4.1.8 Population

The 2011 census data has been used in the computations for estimation of ground water extraction for domestic purpose based on consumptive method.

4.2 Various Norms Used

4.2.1 Assessment area

Out of the total geographical area, the hilly area (slope > 20%), hill tops and rocky waste land were identified and subtracted and the remaining area is considered as recharge worthy or assessment area.

4.2.2 Specific Yield

The specific yield value recommended as per prescribed norms of GEC-2015 methodology were taken.

4.2.3 Rainfall infiltration factor

In all the watersheds, the coefficients for RIF are as per the recommended values of GEC-2015 methodology norms.

4.2.4 Recharge due to canal seepage

The prescribed norms of GEC-2015 methodology i.e., 3.5 Ham per day/million sq. m wetted area for all canals in hard rock have been considered.

4.2.5 Recharge from Tanks and Ponds

The prescribed norms of GEC-2015 methodology i.e., Average water spread area (60% of total water spread area) * No. of days * **0.00144** meters per day per Ha, has been considered.

4.2.6 Recharge from water conservation structure

The recharge considered due to water conservation structures was considered as 50% instead of 40% (per norms) of the gross storage capacity of the water conservation structure. The number of fillings considered are ranging from 1 or 6 depending on the local conditions.

4.2.7 Unit Draft or Extraction

The unit draft computed for different abstraction structures representing typical geological formations has been used for the estimation. The unit draft for irrigation dug well fitted with electric pump was considered as 0.27 ham/annum. For irrigation bore wells (with electric pump), the unit draft considered was 0.54 ham/ annum. For irrigation Dug cum bore wells, the unit draft considered was 0.45 ham/ annum. The unit draft considered for the various types of abstraction structures is given below in **Table – 4**.

Table-4: GW abstraction structure wise unit draft values for Irrigation draft

STRUCTURE	UNIT DRAFT (HAM/ANNUM)
DUG WELL	0.27
BORE WELL	0.54
DUG CUM BOREWELLS	0.45

For Industrial dug wells (with electric pump), the unit draft considered ranges from 0.05 to 0.97 ham/ annum, whereas for Industrial bore wells, the unit draft considered ranges from 0.14 to 1.62 ham/annum and is given below in **Table – 5**.

Table-5: GW abstraction structure wise unit draft values for Industrial draft

STRUCTURE	UNIT DRAFT (HAM/ANNUM)
DUG WELL	0. 05 – 0.97
BORE WELL	0. 14 – 1.62

4.2.8 Return flow from irrigation

The prescribed norms of GEC-2015 methodology have been adopted for estimation of recharge due to return flow from surface water and ground water irrigation.

4.3 Stage of Ground water Extraction and Categorization

The norms of GEC-2015 methodology have been used for the computation of the Stage of Ground water Extraction and Categorization.

Stage of Ground Water Extraction	Category
≤70%	Safe
> 70%and ≤90%	Semi-Critical
> 90% and ≤100%	Critical
> 100%	Over Exploited

5 COMPUTATION OF DYNAMIC GROUND WATER RESOURCES, 2022

There are many components viz., recharge, extraction, stage of extraction, categorization, domestic allocation and future irrigation availability which were assessed for Goa State. The salient features of the dynamic ground water resources are as under:

5.1 Resources assessment unit and Area

Taluk is the type of ground water assessment unit which was used in the State for the purpose of groundwater estimation and evaluation. There were 12 assessment units in the State. Out of these 12 taluks, 2 taluks come under only non-command area, whereas in remaining 10 taluks both command and non-command units are present. However, no taluks are considered under poor-quality area.

Out of the total area (370198 ha) of the taluka the non-worthy area (hilly area – 149239 ha) is deducted and only the recharge worthy area (220959 ha) is considered for this assessment. The recharge worthy area is further sub-divided into command (28715 ha) and non-command areas (192244 ha) and their percentages for the State are 13% & 87% respectively. The taluka wise details of these areas along with the rainfall are given in ***Annexure IV*** and the State area break up is shown in **Fig.-6.** The recharge is estimated for the groundwater worthy area of all the sub-units.

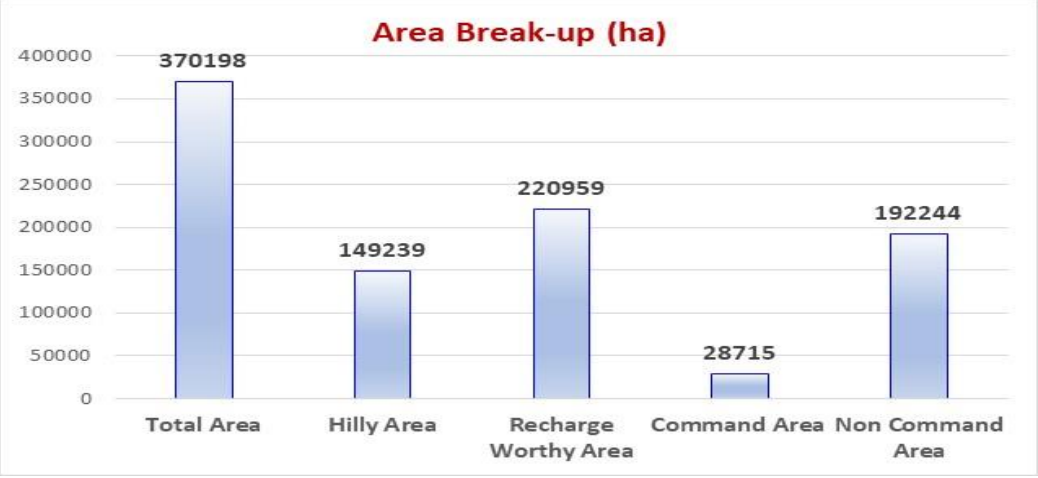

Fig.-6: Areas under different categories

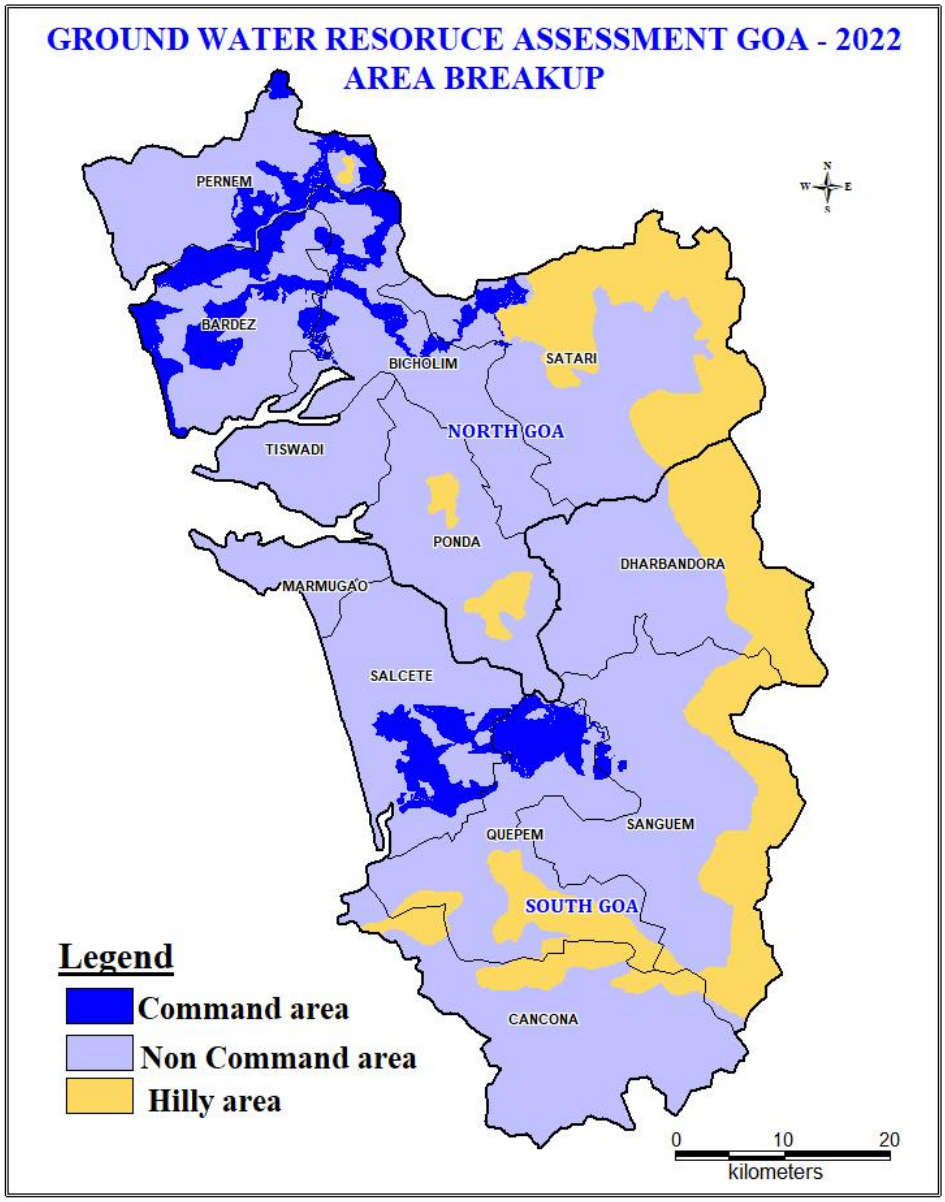

Fig.-6: Area Break-up Map

5.2 Base year of data

The rainfall and water levels data for the past 5 years year 2017 to 2021 has been considered in the computations. Based on this database the sub-unit wise average pre-monsoon and post-monsoon groundwater levels and fluctuations are calculated and used in the assessment. The canal, tanks, ponds and water conservation structures data of the year 2021-22 was utilised. The 2011 census data with annual growth rate has been used in the computations for estimation of ground water extraction for domestic purpose based on consumptive method.

5.3 Total Annual Ground Water Recharge

Recharge to ground water from different sources was computed based on the GEC 2015 methodology. As per assessment it was observed that the total recharge from all sources is 41338.33 ham and the recharge due to rainfall is the major contributor with 35190.42 ham, followed by recharge due to return flow from surface water irrigation and recharge due to water conservation structures @ 3255.50 ham and 1349.25 ham. The recharge due to seepage

from canals, return flow from ground water irrigation and tanks & ponds and is pegged at 746.35 ham, 593.15 ham and 203.66 ham respectively as shown in **Fig.-7**.

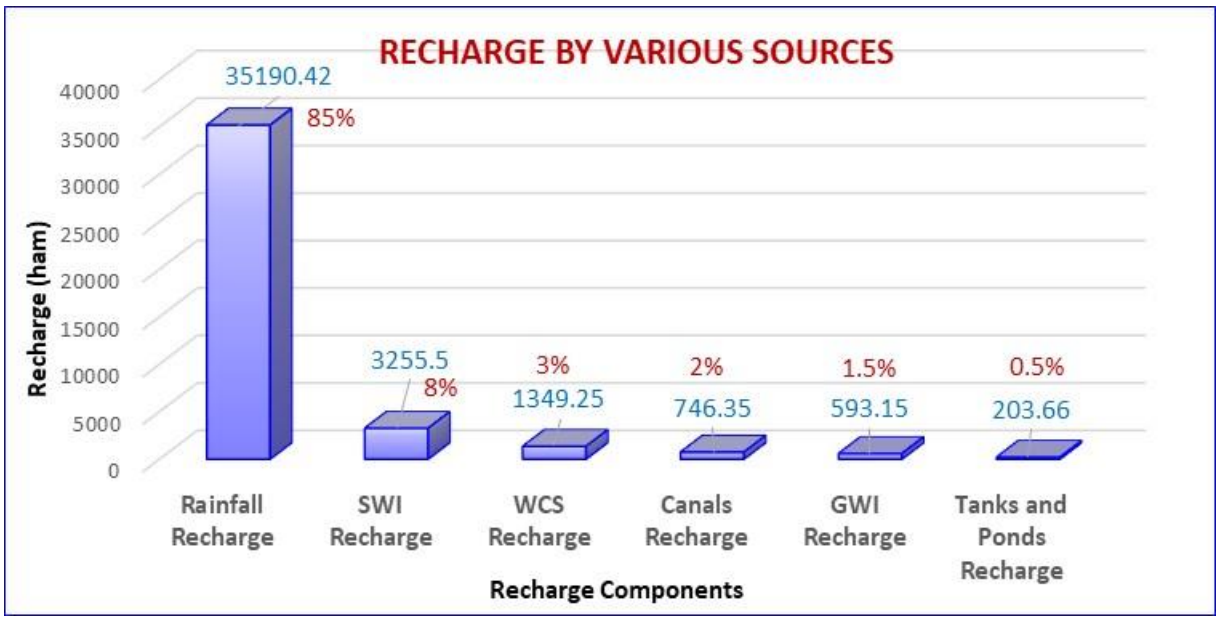

Fig.-7: Recharge by Different Sources

The taluk wise recharge is also presented in **Fig.-8** and it indicates that maximum recharge is taking place in Salcete taluk (5822.59 ham) and minimum recharge is taking place in Dharbondara taluk (1664.62 ham). In all the districts, rainfall recharge is the major contributor. The assessment unit wise ground water resources 2022 (recharge component) is presented in ***Annexure-VA***.

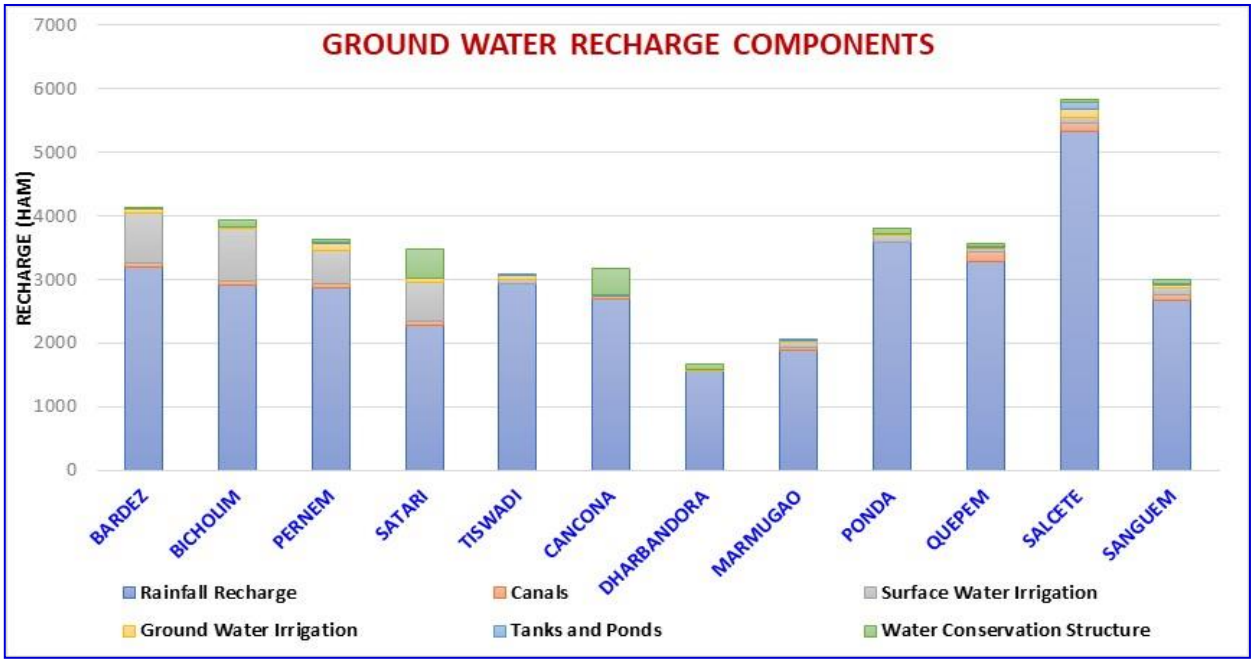

Fig.-8: Taluk Wise Recharge by Different Sources

5.4 Annual Extractable Groundwater Resources

The entire quantum of ground water recharge cannot be considered for extraction since ecological commitments need to be fulfilled, before the extractable resources is defined. To cater to the ecological requirements, some percentage of ground water recharge is subtracted from

annual ground water recharge based on the GEC 2015 guidelines. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance accounts for Annual Extractable Ground Water Resources (EGR). As per assessment data, the annual extractable ground water resources for the State are 33070.68 ham and it ranges from 1331.70 ham at Dharbandora taluk to 4658.08 ham in Salcete taluk.

5.5 Ground Water Extraction

The ground water extraction for various uses viz., irrigation, domestic and industrial has also been assessed as shown in **Fig.-9** and it indicates that major extraction about 62% is for domestic @ 4811 ham, whereas 33% is for irrigation @ 2599 ham and 5% for industrial purpose @ 405 ham. The assessment unit wise ground water resources 2022 is presented in ***Annexure-VB***.

The taluk wise ground water extraction for various uses has also been assessed as shown in **Fig.-10** and it indicated that ground water extraction for domestic, irrigation and industrial uses is highest in Salcete taluk, whereas it is lowest in Dharbondara taluk.

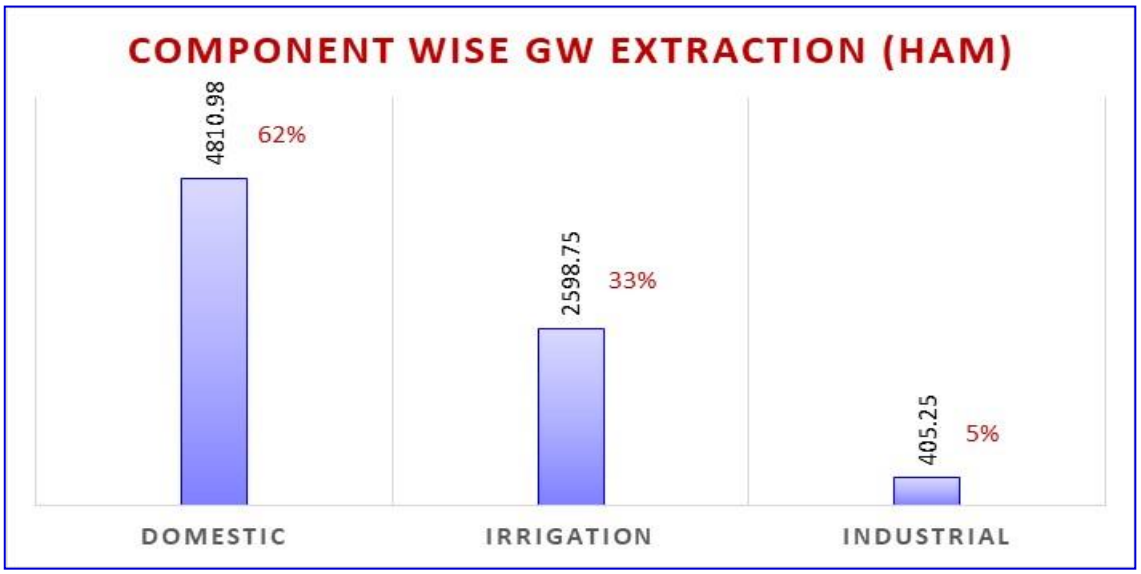

Fig.-9: Ground Water Extraction for Various Uses

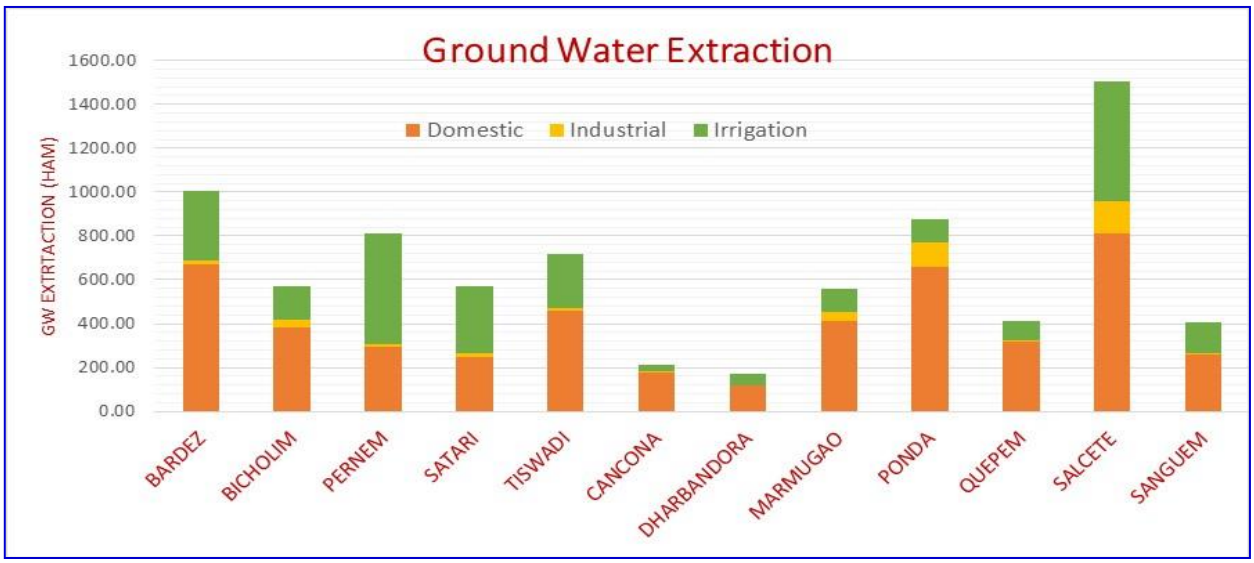

Fig.-10: District Wise Ground Water Extraction for Various Uses

5.6 Ground Water Availability and Extraction

The ground water availability and extraction should be balanced and in Goa State, in all the 12 taluks, the availability is more than extraction (**Fig.-11**), thus the situation is more skewed towards huge availability of resources. The district wise ground water resources 2022 is presented in ***Annexure-VI***.

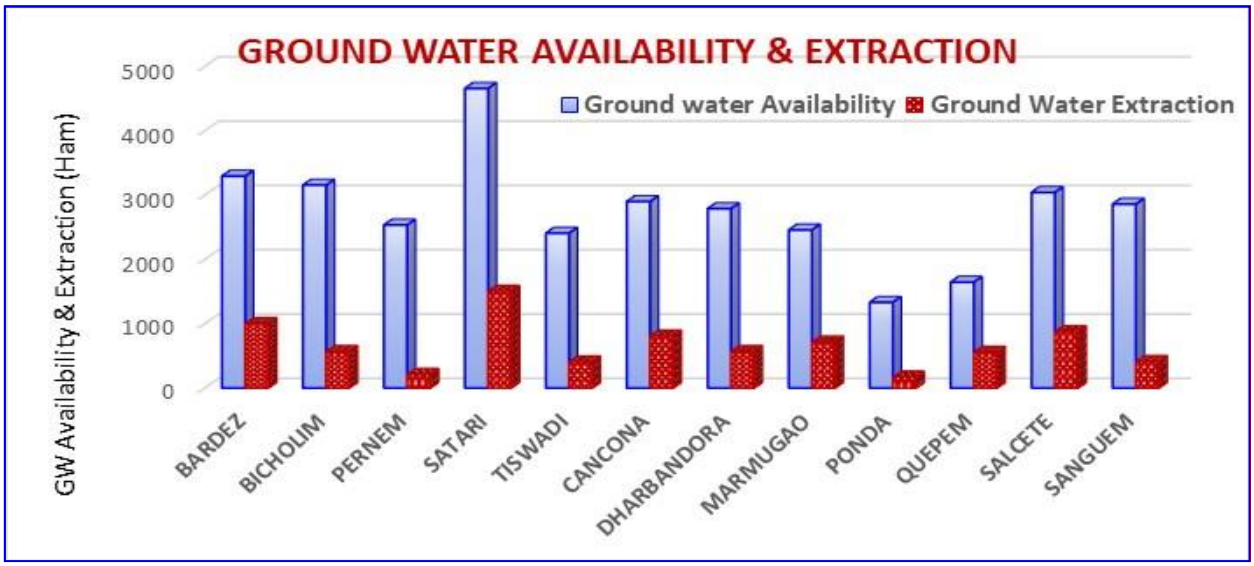

Fig.-11: Taluk Wise Ground Water Availability and Extraction

5.7 Categorization of Talukas

The categorization of talukas is done as per the norms mentioned in GEC-2015 methodology. Based on these computations, it is observed that all 12 talukas are falling in Safe category. Taluka wise categorization are given in ***Annexure V B***. The categorization of talukas is also shown in **Fig.12.**

5.8 Future Allocations for Domestic Use

The Future Domestic & Industrial Allocations is more than the existing domestic draft. The future allocation for domestic use for projected year 2025 ranges from 126.42 ham at Dharbondara taluk, South Goa district to 861.09 ham at Salcete taluk in South Goa district.

5.9 Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The ground water availability for future use for Goa State is 24959 ham and it ranges from 1062.40 ham at Mamugao taluk, South Goa district to 3103.78 ham at Salcete taluk in South Goa district.

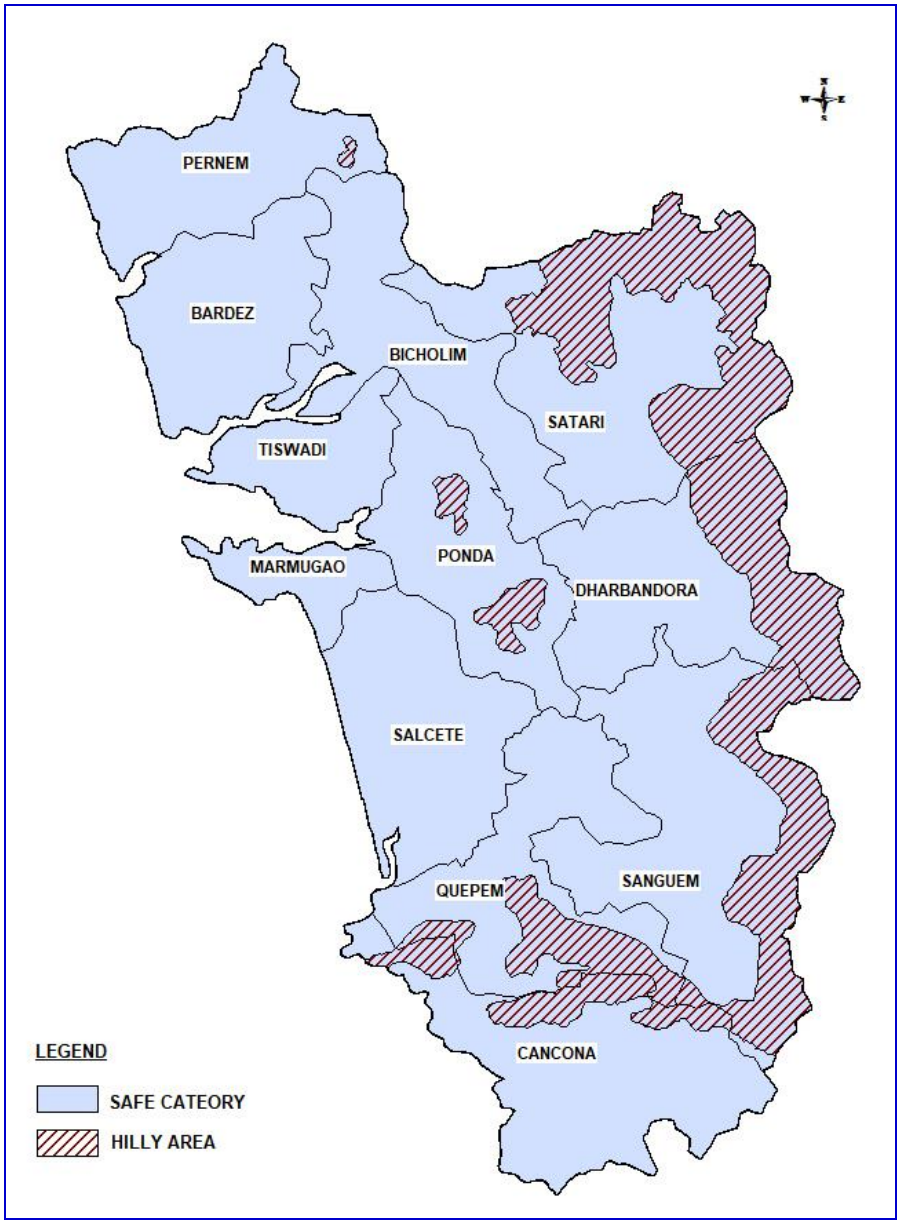

Fig.-12: Taluk wise Categorisation Map

5.10 Taluk wise Unit Recharge

The ground water recharge is a function of rainfall, geomorphology and geology. The State is having heterogeneity in all these parameters. Hence the recharge to groundwater is not uniform in all the talukas. Based on the total Annual Groundwater Recharge and the Area of Assessment Unit, the taluk wise annual groundwater resources (in mts) had been computed. One taluka (8%) has annual recharge up between 100 to 150 mm, 7 taluks (59%) between 150 and 200 mm and 4 taluks have annual recharge of 200 to 250 mm. These details have been shown in the **Table -6** and taluka map of the State (**Fig.-13**).

Table- 6: Distribution of Assessment Units as per Unit Recharge

Unit GW Recharge (mm)	No. of Assessment Units	% of Assessment Units
100 to 150	1	8
150 to 200	7	59
200 to 250	4	33

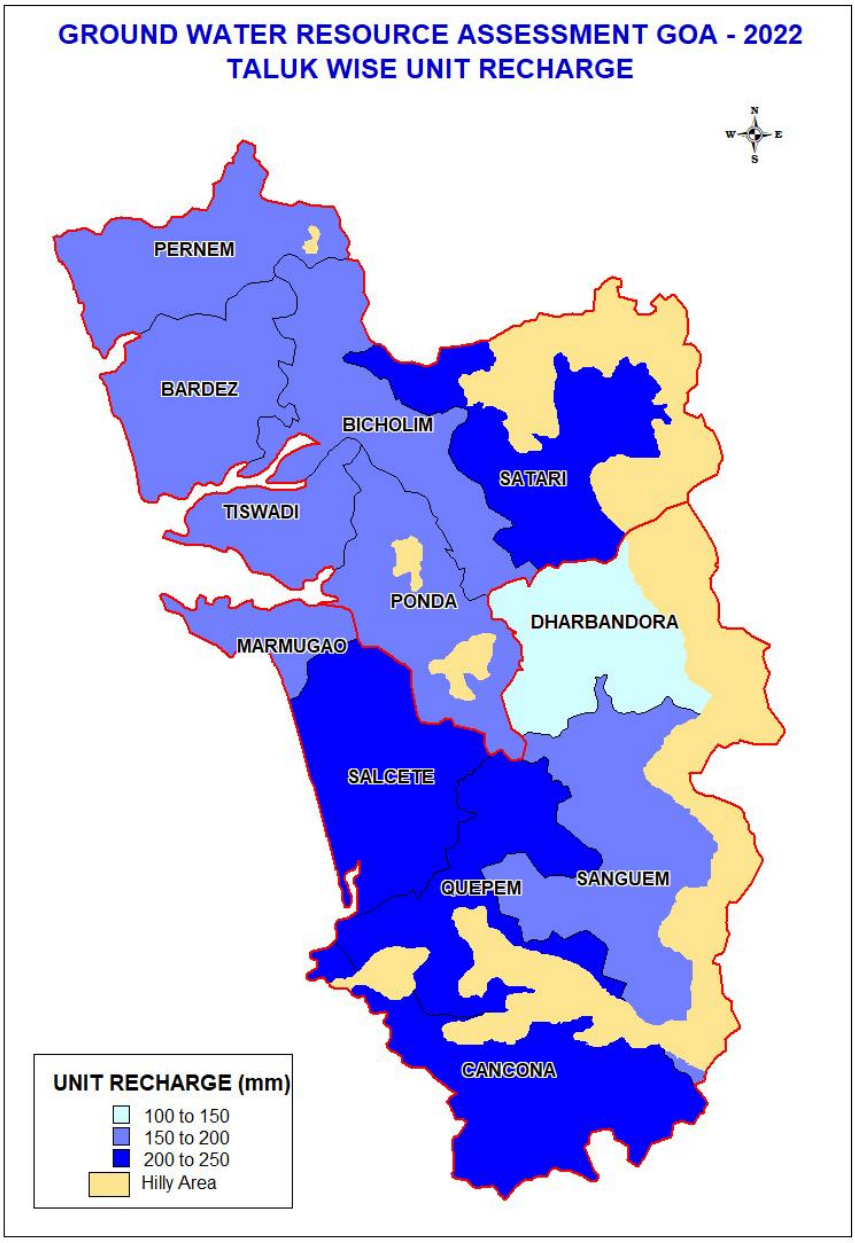

Fig.-13: Taluk wise Unit Recharge

The perusal of the map indicates that in South Goa, the unit recharge is more in the range of 200 to 250 mm as compared to North Goa where it is mostly in the range of 150 to 200 mm. Dharbondara taluk in South Goa also has the lowest unit recharge value @ 139 mm.

5.11 Dynamic Ground Water Resources – at a glance

The groundwater estimation is carried out for 12 taluks of Goa State. As per the protocol the groundwater availability and use has been computed for the taluk wise assessment-units, and the categorization has been done for the Taluk. The State abstract showing details of Dynamic Groundwater Resources 2022 is given in **Table 7**.

As per the assessment, the total rechargeable fresh groundwater resources in the State are computed as 41338.33 and the Annual Extractable Ground Water Resource is to the tune of 33070.68 ham. The Total Extraction is 7814.99 ham. The Stage of groundwater development for the State, as whole, is 23.63%. This indicates that on an average 23.63% of yearly replenishable groundwater is being used in the State.

Considering the domestic and industrial requirement the annual ground water allocation for domestic water supply as on March 2025 is 5107.44 ham. Leaving this allocation, the net groundwater availability for future use development is around 24959.23 ham. All the taluks had been categorised as Safe.

Table-7: Ground Water Resources – At a Glance

Description	GWRA 2022
Total No. of Assessment Units in the State	12
Rainfall Recharge	35190.42
Recharge due to Other Sources	6147.91
Annual Groundwater Recharge (ham)	41338.33
Total Natural Discharges (ham)	8267.65
Annual Extractable Ground Water Recharge (ham)	33070.68
Groundwater Irrigation Extraction (ham)	2598.75
Groundwater Extraction Domestic (ham)	4810.98
Groundwater Extraction Industrial (ham)	405.24
Total Annual Extraction (Draft) (ham)	7814.99
Allocation of Ground Water Resource for Domestic Utilisation upto 2025 (ham)	5107.44
Net Annual Ground Water Availability for Future Use (ham)	24959.23
Stage of Ground Water Extraction (%)	23.63
Categorization	Safe
No. of Over Exploited / Critical / Semi Critical Assessment Units	Nil

5.12 Comparison with Earlier Assessments

5.12.1 Ground Water Recharge

Compared to 2020 there is increase in annual ground water recharge by Water Conservation Structures (WCS) from 1213 to 1349 ham an increase of 10%, recharge due to return flow from ground water irrigation has increased from 262 ham to 593 ham an increase of

56%, whereas in case of Tanks & Ponds it has increased from 57 ham to 204 ham an increase of 72% as depicted in **Fig. 14**. The increase in recharge due to GWI is most probably due to the increase in ground water irrigation draft and area. The recharge due to WCS has also increased by 10% due to the increased number of WCS structures constructed under the various water conservation schemes taken by State Govt., as well as de-silting of structures taken up by State Govt. under various district levels schemes including MGNREGA. The increase in recharge from tanks and ponds could be possible due to increase in number of tanks from 381 to 1352. The recharge due to return flow from surface water irrigation has remained the same.

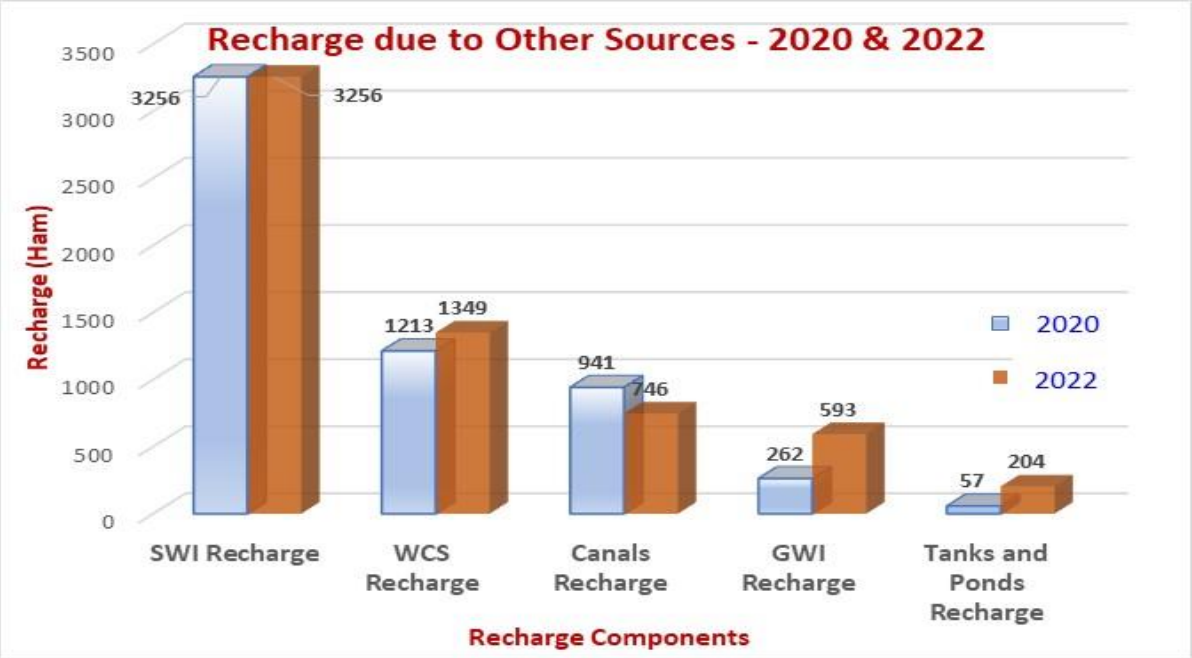

Fig.-14: Comparisonof Recharge due to Other Source (2020 and 2022).

The past good rainfall years supported by the development of new surface irrigation systems, increase in number of water conservation structures, tanks & ponds has replenished the ground water in the non-monsoon period also. The initiatives taken up by the Govt. of Goa and community in developing and maintaining the water conservation structures, tanks & ponds, canal network is being reflected in the increased recharge due to other sources as compared to 2020 assessment.

The comparison of historical recharge due to rainfall and other sources has also been carried out for the ground water resource assessments from 2011 to 2022 and is presented in **Fig. 15**. It indicates that the recharge due to rainfall has increased continuously from 16315 ham in 2011 to 35190 ham in 2022, whereas recharge due to other sources has decreased from 7923 ham in 2011 to 5729 ham in 2020 and increased in 2022 to 6148 ham.

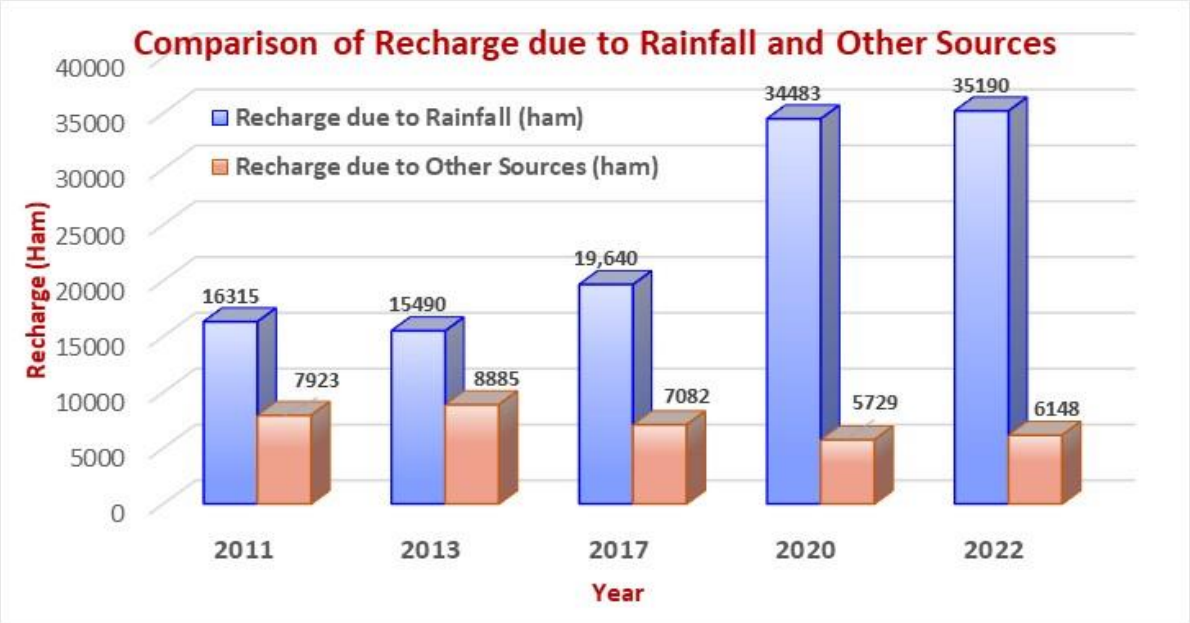

Fig.-15: Comparison of Recharge due to Rainfall and Other Sources (2011 to 2022)

5.12.2 Ground Water Extraction / Draft

The importance of ground water resource for domestic, irrigation and other purposes is critical as major share of these is met from ground water sources. A comparison of ground water extraction / draft since 2011 to 2022 presented in **Fig. 16** also re-iterates this fact. It indicates that extraction/draft has increased from 4114 ham in 2011 to 7815 ham in 2022 an increase of about 90% in last 12 years. This is probably due to increase in number of abstraction structures in the last decade or so.

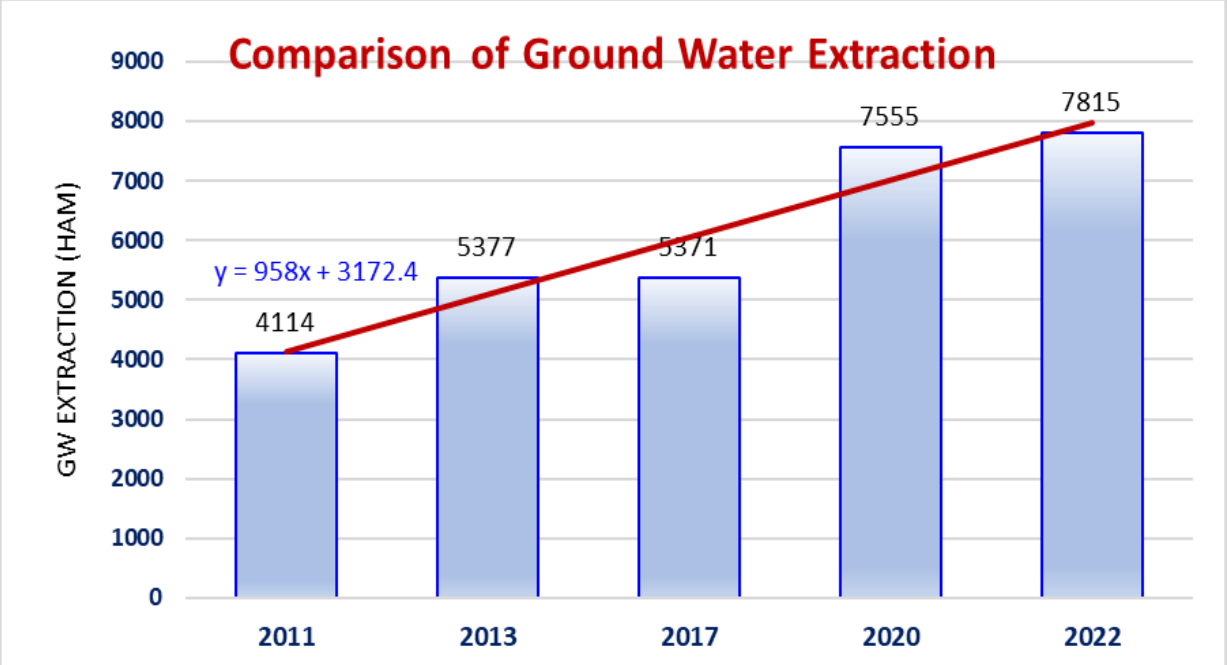

Fig.-16: Comparison of Ground Water Extraction (2011 to 2022)

5.12.3 Comparison of Ground Water Resources 2020 and 2022

The comparison of ground water resources for 2020 and 2022 is also done and presented in **Table – 8**. It indicates that the rainfall recharge has increased by 2.05%, whereas recharge due

to other sources has increased by 7.32%. The total annual ground water extraction has increased by 3.44% and stage of extraction has increased by 0.64%.

Table – 8: Comparison of Ground Water Resource Assessment 2022 with 2022

Description	2020	2022	Increase / Decrease in %
Total No. of Assessment Units in the State	12	12	No Change
Rainfall Recharge	34483.3	35190.42	2.05
Recharge due to Other Sources	5728.77	6147.91	7.32
Annual Groundwater Recharge (ham)	40212.07	41338.33	7.86
Total Natural Discharges (ham)	8042.41	8267.65	2.80
Annual Extractable Ground Water Recharge (ham)	32169.66	33070.68	2.80
Groundwater Irrigation Extraction (ham)	2425.14	2598.75	7.16
Groundwater Extraction Domestic (ham)	4744.194	4810.982	1.41
Groundwater Extraction Industrial (ham)	385.3828	405.2482	5.15
Total Annual Extraction (Draft) (ham)	7554.75	7814.99	3.44
Allocation for Domestic Utilisation for 2025 (ham)	5168.79	5107.44	-1.19
Net Annual Availability for Future Use (ham)	24190.33	24959.23	3.18
Stage of Ground Water Extraction (%)	23.48	23.63	0.64
Categorization	Safe	Safe	
No. of Over Exploited / Critical / Semi Critical Assessment Units	Nil	Nil	

ANNEXURE-I: GOVERNMENT ORDER REG. CONSTITUTION OF STATE LEVEL COMMITTEE

No. 4/9/ CE-CPO/WRD/2021-22/ 610
Office of the Chief Engineer,
Water Resources Department,
Sinchai Bhawan, Alto Porvorim
Bardez Goa.
Dated: -03/03/2022.

O R D E R

Sub: Constitution of State Level Committee for Re-assessment of Ground Water Resources of Goa (as on March 2022)

Approval of the Government is hereby conveyed to constitute the State Level Committee for Assessment of Ground Water Resources of Goa State (as on March 2022) with the following composition:

1.	Secretary, Water Resources	Chairman
2.	Chief Engineer, Water Resources Department	Member
3.	Chief Engineer, Water supply & sanitation Dept.)PWD	Member
4.	Director, Department of Agriculture	Member
5.	Director, Department of Industries	Member
6.	Director, Department of Planning, Statistics & Evaluation	Member
7.	General Manager NABARD	Member
8.	Superintending Engineer, CPO,WRD	Member
9.	Superintending Engineer, Circle I, WRD	Member
10.	Sr. Hydrogeologist, WRD	Member
11.	Regional Director, CGWB, Bangalore	Member Secretary

The committee may co-opt any other member(s)/ special invitee(s), if necessary.

1. Terms of reference: The broad terms of the reference of the committee would be as follows:
   (i) To estimate annual replenishable ground water resources of the state in accordance with the Ground Water Resources Estimation Methodology.
   (ii) To estimate the status of utilization of the annual replenishable ground water resources.
2. Time frame: The committee will submit its report within six months from the date of its constitution
3. Expenditure: Expenditure on account of TA/DA to the official members of the committee will be met from the source from which their salaries are drawn and that of non official members, will be borne by the Water Resources Department, Government of Goa.

This order issues with the approval of Government conveyed under U.O. No Secy (WRD) 305/F dated 16-02-2022

By order and in the name of the
Governor of Goa

(P.B.Badami) 3/3/22
Chief Engineer (WR) &
Ex-Officio Additional Secretary to
Government of Goa

Copy to:
The concerned

ANNEXURE-II: MINUTES OF 1st STATE LEVEL COMMITTEE MEETING

MINUTES OF THE 1st STATE LEVEL COMMITTEE MEETING FOR GROUND WATER RESOURCES ASSESSMENT – 2022 OF GOA STATE

The meeting of the 1st State level Committee (SLC) for Ground Water Resources Assessment - 2022 of Goa State was held on 24.05.2022 at 11.00 hrs in the Conference Room, Water Resource Department, Alto-Porvorim, Goa. Shri. Pramod B. Badami, Chief Engineer, chaired the meeting. The State Level committee headed by the Secretary, Water Resource Department, Porvorim, Goa was constituted by the Government of Goa vide Government Order no. 4/9/CE-CPO/WRD/2021-22–610 dated 03.03.2022. The meeting was attended by various committee members or their representatives as per the attached list.

Shri. Rahul R. Shende, Sci-B, CGWB, SWR, Bangalore welcomed the Chairman, Members & Invitees to the State Level Committee Meeting. He stressed that the Ground Water Resources Assessment is the time bound process and re-assessed periodically every two years as per the GEC-2015 methodology.

Shri. Pramod B. Badami, Chief Engineer, WRD, Goa welcomed all the members and informed that Ground Water Resources Assessment should reflect the improvement in resources due to various recharge and water conservation works taken up by the State Govt. He stressed that although the resource assessment is an estimation based on norms, it should reflect the actual groundwater situation prevalent in the state.

He suggested that Goa state is different from other states as the groundwater draft for irrigation is on the lower side as compared to domestic draft. He also stressed at the number of industries present in the state and their corresponding groundwater draft needs to be updated as per the present conditions. He further stated that there are numerous mining industries with mining pits whose recharge should also get reflected in the resource assessment. He requested the committee members to speed up the data collection process.

Shri. S. B. Ghantkar, Engineering Officer, WRD, Porvorim, Goa enquired about the recharge which may take place due to river water. He also enquired about the methodology to arrive at area considered for resource estimation. In reply to this, Shri. Rahul Shende informed that the recharge due to rainfall take into consideration the Rainfall Infiltration Factor (RIF), Area and Rainfall and thus, the runoff in the streams is not considered for recharge. He also informed that, the recharge worthy area is demarcated after deducting the hilly area.

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Shri. Rajan Kamble, Executive Engineer, WRD Works Division XIII, Porvorim, Goa suggested that cropping pattern data and crop water requirement can be used for estimation of groundwater draft for irrigation. In reply to this, Shri. Sanjeev A. Mayekar, Deputy Director, Department of Agriculture, Goa informed that the Agriculture Department has not conducted any specific study to assess the water requirement of different crops and if needed ICAR may be approached for conducting specific study.

Ms. Neumani M. Rodrigues, Deputy Director, Department of Planning and Statistics, Goa informed that many of data requirements are available on the website in the form of e-publications, however, the recent data as required may not be available. Shri. Rahul R Shende informed that CGWB is also proposing to include the GWRA data in district / state wise statistical handbook released by Department of Planning and Statistics, Goa.

Shri. Rahul R Shende, Scientist – B, CGWB, presented the 2015 methodology to be adopted in resource assessment of 2022 with the final results of previous assessment of 2020. He informed the committee that, the resources in Goa were assessed Taluka-wise which were further sub-divided into command and non-command units. Further details of the data required for the present 2022 resource assessment was briefed to the committee member with the details of time line to be followed was also discussed. He also explained in details the various recharge and draft aspects involved in the methodology with special reference to the tanks/ponds, water conservation structures and recharge due to various other sources.

Based on the agenda and discussions held during the meeting, following decisions were taken.

1. **Finalisation of assessment units** - Regarding the finalisation of the assessment units, it is decided by the committee to consider the 12 taluks as assessment units for the Groundwater Resource assessment of 2022.

2. **Data requirement from various Agencies/Departments** – As per the timelines, the committee was of the opinion that the data compilation was to be completed by 30th April 2022. However, the same is yet to be completed, thus the WRD will direct its field/taluk level offices to fast track the data collection and compilation from concerned State Govt. offices. The concerned State Govt. Departments especially Minor Irrigation, Agriculture, WRDO, RWS will provide information to WRD officials on priority.

3. **Industrial Data** - Ground water draft data based on actual number of wells and industries which have been granted NOC by WRD will be

considered for resource estimation. The WRD will provide the data regarding the same in the desired format.

4. **Recharge due to Mining pits** – It was decided that the mining projects wherein the mine pits are present and are continuously filled with water will also be considered as the recharge sources for estimation of recharge due to tanks and ponds. The WRD will provide the data regarding the same in the desired format.

5. **Time lines to be followed** – The representatives of CGWB & WRD stressed to follow the timelines for GWRA and requested all the line departments to provide the necessary data for the same. They also stressed on the pro-active role to be adopted by WRD and CGWB for its timely completion. It was decided that the data compilation/collection sheets will be completed by 30/06/2022 by W.R.D. and submitted to CGWB for future computation in INGRS software.

6. **Any other item** – Nil.

The meeting ended with thanks to the Chair proposed by Shri. Sushant S. Navarat, Assistant Hydrogeologist, CGWB, SUO, Belagavi.

(Shri. Pramod B. Badami)
Chief Engineer,
Water Resource Department
Porvorim, Goa

Members attending the State Level Committee meeting for Ground Water Resource Assessment of Goa - 2022 on 23.05.2022 in Conference Room, Chief Engineer Office, WRD, Porvorim, Goa

S. No.	Name	Designation	Department	Contact No.	Email id	Signature
1.	Sh. P.B. Badami	Chief Engg.	WRD	9422063064	ce-wrd.goa@nic.in	
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3.	Shri Santosh Mhapre	Chief Engineer I	PWD	9822123230	santoshmhapre@gmail.com	24/5/22
4.	SMT. Ashwini A. Gaunekar Desai	Dy. Director Industries	DITC	9923765534	dir-indu.goa@nic.in	24/5/22
5.	Ms. Neumani M. Rodrigues	Representative DPSE Dy. Director	Dte. of Planning & statistics	9822389036	cord-dpse.goa@nic.in	24/05/22
6.	Sanjeev A. Mayekar	Dy Director Agriculture	Agriculture	9422545283	dir-agri.goa@nic.in	
7.	Sonali Bhogle Bandekar	Assistant General Manager	NABARD	9029244006	panaji@nabard.org	24/5
8.	Rahul R. Shende	Sc-B	CGWB	9850393338	sdsw-cgwb@nic.in	
9.	Sushant S. Kavarat	Asst. Hydrogeologist	CGWB	9763975339	sushant-cgwb@nic.in	
10.	Sh. S.B. Ghantkar	Engineering officer, WRD	WRD	9420690037	eo-wrd.goa@nic.in	

ANNEXURE-III: MINUTES OF 2ND STATE LEVEL COMMITTEE MEETING

MINUTES OF THE 2nd STATE LEVEL COMMITTEE MEETING FOR GROUND WATER RESOURCES ASSESSMENT – 2022 OF GOA STATE HELD ON 28.08.2022 IN VC MODE

The meeting of the 2nd State level Committee (SLC) for Ground Water Resources Assessment - 2022 of Goa State was held on 28.08.2022 at 10.30 hrs through online mode. Shri. Pramod B. Badami, Chief Engineer, Water Resource Dept., Govt. of Goa chaired the meeting. The meeting was convened to discuss the results and findings of the GWRA 2022 and to approve the GWRA 2022. The meeting was attended by various committee members or their representatives as per the attached list.

Shri N. Jyothi Kumar, Regional Director, CGWB, SWR, Bangalore and Member Secretary of SLC welcomed Chairman, Members & Invitees to the State Level Committee Meeting. He also appreciated the efforts put in by the various State Govt. Dept.'s, GWRA cells of CGWB and WRD in providing the data required for the resource assessment.

Shri. Rahul R. Shende, Sc-B, CGWB, SWR, Bangalore presented the findings/results of the GWRA 2022. He informed the committee that, the resources in Goa were assessed Taluka-wise which were further sub-divided into command and non-command units. He explained the various basic, recharge, extraction data used for GWRA 2022. He also presented in details the various recharge and draft components estimated and the taluk wise results. He informed that the recharge due to rainfall (35190.42 ham) is the major source of recharge followed by recharge due to other sources (6147.91 ham). Whereas in case of extraction, domestic extraction is the major user @ 4810.98 ham, followed by irrigation extraction @ 2598.75 ham and industry sector accounting for 405.24 ham. The stage of extraction for the entire state is 23.63%.

Shri. Pramod B. Badami, Chief Engineer, WRD, Goa appreciated the work done by CGWB and WRD and the findings arrived in GWRA 2022. He stressed that the ground water extraction is increasing since 2011 as per the presentation and domestic draft is on higher side @ 61% as compared to other uses. Thus, efforts need to be concentrated towards reducing the load on domestic use of ground water by increasing the supplementary surface water supply through various schemes. He also suggested that the stage of extraction is more than 30% for Mormugao, Bardez and Salcete taluks and any one of these 3 taluks needs to be taken as sample taluk for detailed assessment in the next assessment, since Goa state is having only small area and there are only 12 assessment units/taluks. He stressed that such detailed study may also lead to further refinement in the resource assessment which can be replicated by other states at national level. He also indicated that during the covid pandemic, many of the rural population have shifted to agriculture activity and thus the irrigation draft should also increase.

Replying to these, Shri N. Jyothi Kumar informed that, this year CGWB has already taken a detailed study on sea water ingress in part of Goa state. He also agreed to take one sample taluk in the next assessment for detailed survey/data collection in association with WRD.

Replying to the above observation, Shri. Rahul R. Shende informed that the domestic ground water draft is estimated by consumptive method by taking into account the population, per capita water requirement and load on ground water. The load on ground water was considered separately for rural and urban populations. He also informed that the irrigation draft has increased by about 7% for the State.

Shri. Rajan Kamble, Executive Engineer, WRD Works Division XIII, Porvorim, Goa enquired whether roof top rain water harvesting structures constructed by industries have been considered for computing the recharge. It was replied that, since these are very small structures which are primarily used of storage and reuse and their number will be very few and the data was also not available it was not included. However, if data is provided, then those can also be used for estimation of recharge component.

Shri Sandip PalDesai, Agriculture Dept., Goa informed that forest dept. is taking up water and soil conservation activities in hilly areas whereas in resource assessment, the hilly areas are excluded. Replying to this, it was conveyed that hilly areas with more than 20% slope is excluded from resource assessment as per the GEC 2015 methodology, whereas other hilly areas are considered.

Based on the detailed discussions held during the meeting, the GWRA 2022 were approved by all the committee members unanimously. The gist/brief findings of the approved GWRA 2022 are given below.

Description	GWRA 2022
Total No. of Assessment Units in the State	12
Rainfall Recharge (ham)	35190.42
Recharge due to Other Sources (ham)	6147.91
Annual Groundwater Recharge (ham)	41338.33
Total Natural Discharges (ham)	8267.65
Annual Extractable Ground Water Recharge (ham)	33070.68
Groundwater Irrigation Extraction (ham)	2598.75
Groundwater Extraction Domestic (ham)	4810.982
Groundwater Extraction Industrial (ham)	405.2482
Gross Annual Extraction (Draft) (ham)	7814.99
Allocation of Ground Water Resource for Domestic Utilisation upto 2025 (ham)	5107.44
Net Annual Ground Water Availability for Future Use (ham)	24959.23
Stage of Ground Water Extraction (%)	23.63
Categorization	Safe
No. of Over Exploited / Critical / Semi Critical Assessment Units	Nil

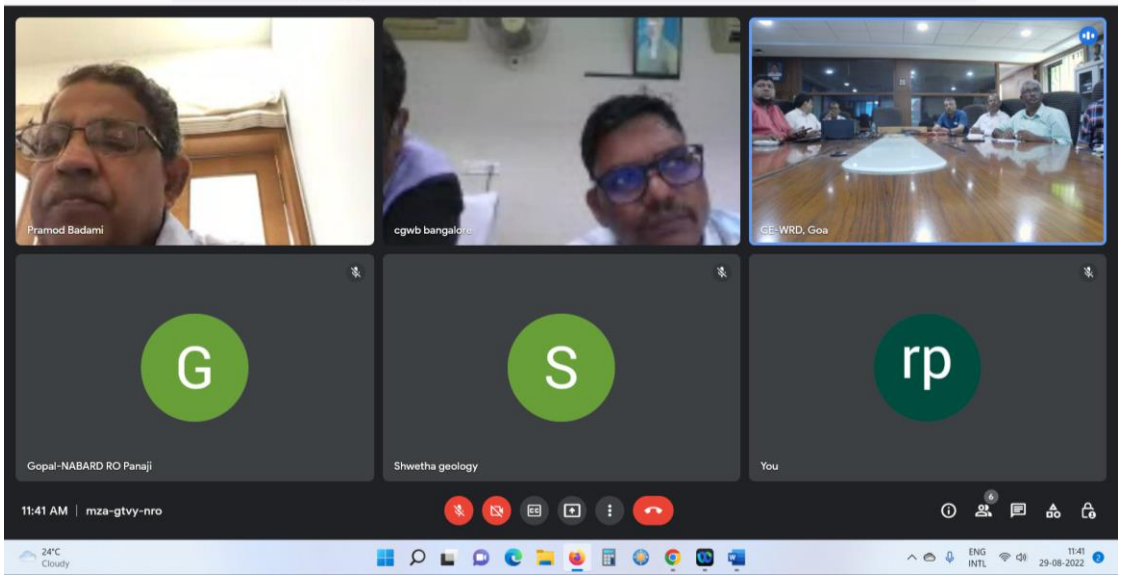
The meeting ended with the vote of thanks to the Chair and Committee proposed by Shri. Rahul R. Shende.

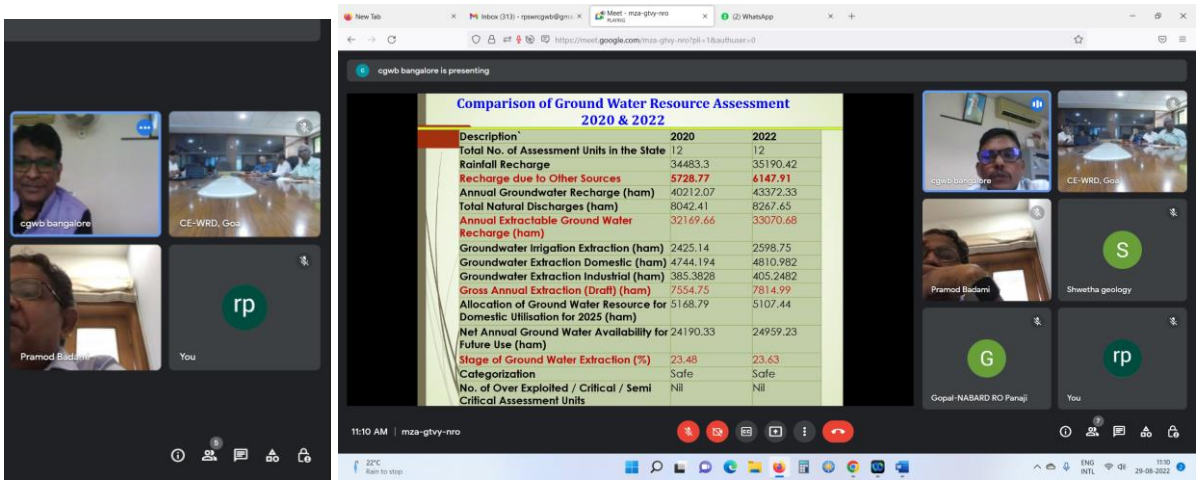
Badami

(Shri. Pramod B. Badami) 12/9/22
Chief Engineer,
Water Resource Department
Porvorim, Goa

Participants List – Online 2nd SLC Meeting

S. No.	Name and Designation	Department
1.	Shri. Pramod B. Badami, Chief Engineer	Water Resource Dept., Govt. of Goa
2.	Shri N. Jyothi Kumar, Regional Director	CGWB, SWR, Bangalore and Member Secretary
3.	Ms. D. Dhyamalar, Scientist-E	CGWB, SWR, Bangalore
4.	Shri. Rajan Kamble, Executive Engineer	WRD Works Division XIII, Porvorim, Goa
5.	Shri. Nazresh Vaz, Executive Engineer	WRD, Works Division I, Porvorim, Goa
6.	Shri Bhanudas R. Naik, Surveyor of Works	WRD, Porvorim, Goa
7.	Shri Sandip Pal Desai, Dy Director	Directorate of Agriculture, Goa
8.	Sanjay Shirodkar, Agriculture Officer	Directorate of Agriculture, Goa
9.	Ms. Neumani Rodrigues, Dy. Director	Dept. of Planning & Statistics, Goa
10.	Shri Gopal Sarkate, Assistant Manager	NABARD – Goa Regional Office, Panaji, Goa
11.	Shri Rahul R. Shende, Scientist-B	CGWB, SWR, Bangalore
12.	Ms. Suchetna Biswas, Scientist-B	CGWB, SWR, Bangalore
13.	Dr. Lubna Kouser, Assistant Hydrologist	CGWB, SWR, Bangalore





Annexure IV: GENERAL DESCRIPTION OF THE GROUND WATER ASSESSMENT UNITS OF GOA STATE 2022

District	Taluk	Rainfall (mm)			Total Geographical Area (ha)				
					Recharge Worthy Area (ha)			Hilly Area	Total
		C	NC	Total	C	NC	Total		
GOA NORTH	BARDEZ	2983.7	2983.7	2983.7	5171	18040	23211	3189	26400
GOA NORTH	BICHOLIM	3601.6	3601.5	3601.53	6235	14646	20881	2999	23880
GOA NORTH	PERNEM	3243.8	3243.8	3243.8	4348	14572	18920	6250	25170
GOA NORTH	SATARI	4216.8	4216.9	4216.887	2100	14480	16580	32930	49510
GOA NORTH	TISWADI	2902.8	2902.8	2902.8	0	19395	19395	1955	21350
SOUTH GOA	CANCONA	3000.2	3000.2	3000.2	550	13466	14016	21186	35202
SOUTH GOA	DHARBANDORA	3362.9	3362.9	3362.9	100	11842	11942	24755.2	36697.2
SOUTH GOA	MARMUGAO	3050.3	3050.1	3050.107	375	10368	10743	169	10912
SOUTH GOA	PONDA	3362.9	3362.9	3362.9	0	23711	23711	5569	29280
SOUTH GOA	QUEPEM	3878.2	3878.1	3878.12	3508	13825	17333	14492	31825
SOUTH GOA	SALCETE	3119.3	3119.4	3119.381	5288	22447	27735	1559	29294
SOUTH GOA	SANGUEM	3691.9	3691.9	3691.9	1040	15452	16492	34185.5	50677.5
		3409.836	**3347.159**	**3355.304**	**28715**	**192244**	**220959**	**149238.7**	**370197.7**

Annexure VA: ASSESSMENT OF DYNAMIC GROUND WATER RESOURCES OF GOA STATE *(RECHARGE COMPONENT) – GWRA 2022*

District	Taluk	Recharge from Rainfall - Monsoon (Ham)	Recharge from Other Sources - Monsoon (Ham)	Recharge from Rainfall - Non Monsoon (Ham)	Recharge from Other Sources - Non Monsoon (Ham)	Total Recharge from Rainfall (Ham)	Total Recharge from Other Sources (Ham)	Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
GOA NORTH	BARDEZ	3189.40	312.46	0.00	616.26	3189.40	928.72	4118.12	823.62	3294.50
GOA NORTH	BICHOLIM	2908.19	379.43	0.00	655.72	2908.19	1035.15	3943.34	788.67	3154.67
GOA NORTH	PERNEM	2860.71	278.93	0.00	484.44	2860.71	763.37	3624.08	724.82	2899.26
GOA NORTH	SATARI	2216.81	235.28	53.52	980.00	2270.33	1215.28	3485.61	697.12	2788.49
GOA NORTH	TISWADI	2939.62	0.86	0.00	130.61	2939.62	131.47	3071.09	614.22	2456.87
SOUTH GOA	CANCONA	2703.51	228.08	0.00	236.31	2703.51	464.39	3167.90	633.58	2534.32
SOUTH GOA	DHARBANDORA	1553.62	13.29	0.00	97.71	1553.62	111.00	1664.62	332.92	1331.70
SOUTH GOA	MARMUGAO	1884.21	21.73	0.00	151.15	1884.21	172.88	2057.09	411.42	1645.67
SOUTH GOA	PONDA	3585.10	70.15	0.00	146.20	3585.10	216.35	3801.45	760.29	3041.16
SOUTH GOA	QUEPEM	2995.14	2.42	287.17	289.44	3282.31	291.86	3574.17	714.83	2859.34
SOUTH GOA	SALCETE	5341.72	126.70	0.00	354.17	5341.72	480.87	5822.59	1164.51	4658.08
SOUTH GOA	SANGUEM	2671.70	49.69	0.00	286.88	2671.70	336.57	3008.27	601.65	2406.62
	Total State	**34849.73**	**1719.02**	**340.69**	**4428.89**	**35190.42**	**6147.91**	**41338.33**	**8267.65**	**33070.68**

ANNEXURE - V B: ASSESSMENT OF DYNAMIC GROUND WATER RESOURCES OF GOA STATE – GWRA 2022

District	Assessment Unit Name	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Ground Water Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future Use (Ham)	Stage of Ground Water Extraction (%)	Categorization
GOA NORTH	BARDEZ	3294.50	315.90	20.62	667.73	1004.25	708.88	2249.10	30.48	Safe
GOA NORTH	BICHOLIM	3154.67	150.12	34.34	383.36	567.83	406.98	2563.22	18.00	Safe
GOA NORTH	PERNEM	2899.26	507.33	6.96	296.78	811.07	315.06	2069.91	27.98	Safe
GOA NORTH	SATARI	2788.49	304.83	15.68	250.19	570.70	265.61	2202.37	20.47	Safe
GOA NORTH	TISWADI	2456.87	245.70	14.24	457.10	717.04	485.27	1711.66	29.19	Safe
SOUTH GOA	CANCONA	2534.32	29.16	6.13	178.36	213.66	189.35	2309.67	8.43	Safe
SOUTH GOA	DHARBANDORA	1331.70	51.30	0.92	119.08	171.31	126.42	1153.05	12.86	Safe
SOUTH GOA	MARMUGAO	1645.67	106.65	39.17	412.06	557.87	437.46	1062.40	33.90	Safe
SOUTH GOA	PONDA	3041.16	105.30	113.57	658.63	877.50	699.22	2123.07	28.85	Safe
SOUTH GOA	QUEPEM	2859.34	89.64	4.18	318.74	412.56	338.37	2427.15	14.43	Safe
SOUTH GOA	SALCETE	4658.08	548.10	145.11	811.11	1504.32	861.09	3103.78	32.29	Safe
SOUTH GOA	SANGUEM	2406.62	144.72	4.32	257.84	406.88	273.73	1983.85	16.91	Safe
	State Total	**33070.68**	**2598.75**	**405.25**	**4810.98**	**7814.99**	**5107.44**	**24959.23**	**23.63**	**Safe**

ANNEXURE - VI: DISTRICT WISE GROUND WATER RESOURCE ASSESSMENT OF GOA STATE - GWRA 2022

District	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Ground Water Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future Use (Ham)	Stage of Ground Water Extraction (%)
GOA NORTH	14593.79	1523.88	91.83112	2055.164894	3670.89	2181.8	10796.26	25.15
SOUTH GOA	18476.89	1074.87	313.41705	2755.816941	4144.1	2925.64	14162.97	22.42
State Total	**33070.68**	**2598.75**	**405.25**	**4810.98**	**7814.99**	**5107.44**	**24959.23**	**23.63**

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