DYNAMIC GROUNDWATER RESOURCES OF UNION TERRITORY OF PUDUCHERRY

(As on 31st March 2020)

Prepared by

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Government of Puducherry
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&

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CHAPTER - 1

1.0 BACKGROUND FOR RE-ESTIMATING THE GROUNDWATER RESOURCES OF THE STATE:

The groundwater is an important resource for meeting the water requirements for domestic, irrigation and industrial use. Groundwater is an annually replenishable resource but its availability is non-uniform in space and time. Hence, the sustainable development of groundwater resources warrants precise quantitative assessment based on reasonably valid scientific principles. The National Water Policy also insists the periodical assessment of groundwater resources on scientific basis. In view of this, the assessment of the potential of groundwater is undertaken as per the directions received by Ministry of Jal Shakti, Department of Water Resources, RD & GR. The groundwater potential was last assessed for the year ending March 2017. Now, the same has to be re-assessed and finalised for the year ending March 2020 as per GEC -15 methodology.

1.1 CONSTITUTION OF STATE-LEVEL COMMITTEE FOR GROUNDWATER RESOURCES ESTIMATION:

As per the guidelines issued by the Central Groundwater Board, groundwater resource assessment is to be carried out under the overall supervision of a “State Level Committee” headed by Secretary to Government, in charge of water resources, with heads of departments dealing with water, as member of the committee. In order to examine and approve the groundwater re-assessment report of the Union Territory of Pondicherry a State Level Committee has been constituted vide G.O.Ms.20/Ag, dt.21.09.2020 of Chief Secretariat (Agriculture), Puducherry. The constitution of the State Level Committee is as follows:-

Secretary to Government (Agriculture), Puducherry	Chairman
Regional Director, Central Groundwater Board, South Eastern Coastal Region, Ministry of Jal Shakti, Dept of Water Resources, RD & GR, Govt. of India, Chennai.	Member
Chief Engineer, Public Works Department, Puducherry	Member
Director of Agriculture and FW, Puducherry	Member
Member Secretary, Pondicherry Groundwater Authority, Pondicherry	Member
Member Secretary, Pondicherry Pollution Control Committee, Department of Science and Technology and Environment, Puducherry	Member
Hydrogeologist-I, State Ground Water Unit and Soil Conservation, Agriculture Department, Puducherry	Member Secretary

After the approval of the State Level Committee, the report will be referred to Central Ground Water Board, for placing the same to the National Level Committee.

1.2 BRIEF OUTLINE OF THE PROCEEDINGS OF THE RESOURCES ESTIMATION INCLUDING OUTCOME OF VARIOUS MEETINGS

During the course of time in re-estimating the groundwater potential of the Union Territory of Pondicherry, several sitting were held in the office of the Regional Director, Central Ground Water Board, South Eastern Coastal Region, Chennai. Discussions were held with Shri. Manoharan, Hydrogeologist, Government of Puducherry and scientists of Groundwater Resources Assessment Cell, comprising of Dr. N. Ramesh Kumar, Scientist B and Shri. J. Sivaramakrishnan, Scientist B. The data collected were computed and reassessed the groundwater potential of the Union Territory of Puducherry as on March 2020.

CHAPTER - 2

2.0 HYDROGEOLOGICAL CONDITIONS OF THE STATE

2.1 DESCRIPTION OF ROCK TYPES

The U.T. of Puducherry is underlain by the semi-consolidated and unconsolidated sedimentary formations ranging in age from lower Cretaceous to Recent, lying on Archaean basement. The generalised stratigraphic succession of the formations encountered in the four regions and their ground water potentials in brief are as follows:

2.1.1 PUDUCHERRY REGION

The region has a seaward dipping with increased thickness of strata consisting of unconsolidated and semi-consolidated formations lying on Archaean basement. The sediments are mainly clay, clay stone, silt, siltstone, marl, limestone, sand, sandstone and gravel. All these sediments occur as alternating strata. These sedimentary formations range in age from Cretaceous to Recent. The stratigraphic succession of the geological formations is presented in the following table:

Table 2.1 Stratigraphic succession of Geological Formations in Puducherry Region

Era	Period	Formations	Lithology
Quaternary	Recent	Alluvium, Laterite	Sands, Clays, silts, kankar and gravels, laterite.
	Mio-Pliocone	Cuddalore Formations	Pebbly and gravelly coarse grained sandstones with minor clays and siltstones with thin seams of lignite
--Unconformity----			
Tertiary		Manaveli formation	Yellow and yellowish brown, grey calcareous siltstone and claystone and shale with thin bands of limestone.
	Paleocene	Kadapperikuppam formation	Yellowish white to dirty white sandy, hard fossiliferous limestone calcareous sandstone and clays.
----Unconformity---			
		Turuvai limestone	Highly fossiliferous limestone, conglomerate at

Era	Period	Formations	Lithology
			places, calcareous sandstone and clays.
	Upper Cretaceous	Ottai clay stone	Greyish to greyish green claystones, silts with thin bands of sandy limestone and fine grained calcareous sandstone.
		Vanur sandstones	Quartzite sandstones, hard, coarse grained, occasionally feldspathic or calcareous with minor clays.
Mesozoic	Lower Cretaceous	Ramanathapuram formation (unexposed)	Black carbonaceous silty clays and fine to medium grained sands with bands of lignite and medium to coarse grained sandstones.
----Unconformity----			
Archaean		Eastern Ghat Complex	Charnockite and Biotite Hornblende Gneiss.

2.1.1.1 ARCHAEANS

The Archaean are represented by the rocks of Eastern Ghat complex comprising charnockites and gneisses. Coarse grained acid Charnockite is noticed in the low mounds along the bed of Varahanadhi, west of Tiruvakkarai. The biotite-hornblende gneiss is exposed north-west of Puducherry region associated with the charnockites. The Eastern Ghat complex forms the basement for Cretaceous-Tertiary sediments in the region. The yield of wells drilled in these formations in general is meagre.

2.1.1.2 CRETACEOUS (MESOZOIC) SEDIMENTS

The oldest sedimentary formations are the Cretaceous sediments of Mesozoic era and are exposed in the north-western part of the Region and north of Varahanadhi river. The trend of these formations is NE-SW. Four stratigraphic units were identified by the ONGC namely the Ramanathapuram, Vanur, Ottai and Turuvai formations.

2.1.1.3 RAMANATHAPURAM FORMATIONS

The Ramanathapuram formations representing the Lower Cretaceous age are not exposed anywhere. They were encountered only in boreholes drilled north of Varahanadhi river and also between Ponnaiyar and Varahanadhi on the western part of the region. At Ramanathapuram, they are unconformably overlain by younger Cuddalore formations, whereas in the rest of the area drilled, they are overlain by Vanur sandstones. They comprise alternate layers of sands, sandstone and carbonaceous-claystone with thin seams of lignite. The thickness of this formation ranges between 55 and 250m.

2.1.1.4 VANUR SANDSTONE

The Vanur sandstones represent the oldest unit of the upper Cretaceous formations. These formations comprise coarse-grained friable, greyish white, pebbly sandstones, felspathic at places with veins of aragonite and with thin intercalations of dark grey to greenish grey shales. These sandstones are also encountered in the boreholes drilled north of Varahanadhi and in the eastern part of the region between Ponnaiyar and Varahanadhi. The thickness of this formation is 152m at Vanur whereas it is only 52 m at Katterikuppam.

2.1.1.5 OTTAI CLAYSTONES

The Ottai formations consist of black to greenish grey claystone with bands of limestone and calcareous and micaceous silts and siltstones. These are exposed in comparatively larger area covering part of Valudhavur, Ottai and Pulichappallam villages (north of Gingee river). These formations are encountered in the boreholes drilled to the north of Varahanadhi river and in the deeper boreholes drilled south of Varahanadhi river in the western half of the region. The outcrops of this formation are commonly yellowish grey in colour. The thickness of this formation is about 139 m at Karasar, over 231 m at Lake Estate and about 88 m at Kalapettai. This formation thins towards northeast at Auroville and Kalapettai.

2.1.1.6 TURUVAI LIMESTONES

The uppermost of the upper Cretaceous formation know at Turuvai limestones are exposed as a narrow strip in NE-SW direction, extending from Mettuveli in the south to Abirampattu of Tamil Nadu in the north. The Turuvais comprise fossiliferous, cement grey limestone with a few bands of sandstones. These are highly conglomeratic with pebbles of quartz at places as seen in the dug well section at Royapudupakkam. But, this formation is limited in thickness.

2.1.1.7 PALEOCENE (TERTIARY) FORMATIONS

The Paleocene formations of lower Tertiary are represented by the Kadapperikuppam and Manaveli formations in the region.

2.1.1.8 KADAPPERIKUPPAM FORMATIONS

The Kadapperikuppam formations are exposed near Pillaiyarkuppam, Sedarapattu, Kadapperikuppam and Alankuppam. These formations are essentially calcareous sandstones, yellowish grey to dirty white in colour with thin lenses of clay and shale and bands of shell limestone.

2.1.1.9 MANAVELI FORMATIONS

The Manaveli formations belong to upper Paleocene age and formations comprise yellowish brown calcareous sandy clay and shales with pieces of thin shell and limestone bands. The upper contact with Cuddalore sandstone is unconformable and is marked by laterite. These formations occur in a small stretch covering the villages Manaveli, Thiruchitrambalam, Kottakkarai and east of Alankuppam. These are encountered in the boreholes drilled in the area north and south of Varahanadhi river towards east.

2.1.1.10 CUDDALORE FORMATIONS

The upper Tertiary sediments in the area are represented by Cuddalore formations are Mio-Pliocene age. The Cuddalores are composed of thick succession of pebbly and gravelly, coarse-grained sandstones with minor clays rarely with seams of lignite. Silicified wood has been noticed at places in the outcrops and well sections. They occur as two widely separated outcrops of ferruginous laterite high ground, one on the north-western margin known as Tiruvakkarai ridge, the other in the north-eastern portion along the coast. All other older formations are cropped out in between these two patches. In the north-western margin, the Cuddalore overlie Vanur sandstones, which is underlain by the Ramanathapuram formations. In the north-eastern portion they overlie the Manaveli formations. The thickness of these formations varies from 30 to 130 m at outcrop area and maximum thickness of 450 m is observed at Mnapattu along the coast in the south-eastern side.

2.1.1.11 RECENT (QUATERNARY) FORMATIONS

The Recent (Quaternary) formations in the Region are represented by laterites and alluvium. Laterite occurs as thin cap over the Cuddalore formations. Thick alluvial deposits are built-up along the course of Ponnaiyar and Gingee rivers covering three fourths of Puducherry region. It occurs in the interstream area and also north of Gingee River in the area extending from Puducherry town on the east to Usteri tank on the west. The alluvium in the area is composed of sands, clays, silts, gravels and kankar. The thickness of alluvium varies from 10 to 55 m at different places with a maximum of 55 m at Satyamangalam.

2.1.2 KARAIKAL REGION

The region is chiefly occupied by unconsolidated to semi-consolidated sediments ranging in age Tertiary to Quaternary. The Quaternary formations occupy the entire area and are underlain by older Tertiary formations. The unconsolidated sediments of Quaternary age comprise alluvium of fluvial origin consisting of sands clays, gravels and blown sands (Aeolian). The alluvium is underlain by the Karaikal beds (Pliocene) and Cuddalore sandstone (Miocene). Aeolian sands occur along the coast in the east.

The generalised stratigraphic succession of the formations encountered in Karaikal region is as follows (Table-3.2)

Table 2.2 : Stratigraphic Sequence of Geological Formations in Karaikal Region

Era	Period	Formation	Lithology
Quaternary	Recent and sub-Recent	Blown sands, alluvium	Sands, gravel, silt and clay.
	Pliocene	Karaikal beds	Gravelly sands, argillaceous sandstones, conglomerates and fossil beds.
Tertiary	Miocene	Cuddalore sandstones	Coarse-grained Calcareous sandstones, shales and claystones occasionally with lignite.

The Mio-Pliocene sediments do not outcrop anywhere in the Karaikal region and its environs. The studies carried out by GSI and ONGC in the area enabled deciphering the geology and structure of the Region. The area lies in the Thanjavur sub-basin, which is characterised by the presence of minor basement highs and lows. One such basement high near Karaikal is known as “Karaikal High”, which is a relatively small feature mostly lying in the off-shore with an ENE-WSW alignment. Exploratory drilling on the basement high by ONGC in their search for oil had revealed the thickness of sediments to vary from 1700 m in the ENE to 2400 m in the WSW. Most of the sediments are of Tertiary age and the Cretaceous sediments are generally either thin or absent in the central part of the high.

The exploratory boreholes drilled by the CGWB range in depth between 300 and 451 m in the Region piercing the Alluvium (Recent), Karaikal beds (Pliocene) and Cuddalore sandstones (Miocene and Eocene). The various geological formations occurring in the Region are briefly described in the following paragraphs.

2.1.2.1 MIO-PLIOCENE (TERTIARY) FORMATIONS

CUDDALORE SANDSTONES

The oldest formations encountered so far in drilling in the Region are Cuddalores (Tertiaries). Cuddalore sandstones underlie the Karaikal beds separated by a thick clay bed of thickness ranging between 3 and 71 m. The Cuddalores comprises brownish or greyish, medium to coarse grained sandstones tending to be calcareous at places and intercalated with black or greyish shales, clays and claystones and occasionally with thin lignite seams. The thickness of these formations ranges from 194 to 374 m. These formations seem to be deposited under marine environment towards east as revealed by fossil content. The arenaceous facies seem to change to calcareous facies as evidenced by the occurrence of limestones in the south-eastern part of Polagam. These calcareous facies represented by limestones, which are equivalent to arenaceous (Tittacherry) formation and are termed as Madanam limestones by ONGC. The Cuddalore sandstone formations of this group are arenaceous in the western part and become argillaceous in the east and northeast. Due to transition of the depositional environment to marine in the east, the ground water of moderate quality in the west changes to saline in the east.

KARAIKAL BEDS

The Karaikal beds overlie the Cuddalore sandstone (Miocene) and lie beneath the Alluvium (Quaternary). It consists of alternating layers of sand and clay with gravel and pebbles at places. Thin bands of sandstone, argillaceous and conglomeratic at places are also noticed. The fossiliferous section met within the bottom horizon yielding a variety of rich molluscous faunas with Gastropoda domination suggest the marine sedimentation. The thickness of this formation ranges from 54 m in the west of Mathur to about 77 m in the east at Kottucherry.

2.1.2.2RECENT (QUATERNARY) FORMATIONS

ALLUVIUM

The Alluvial formations of fluvial origin occupy a major part of the Region. In addition, coastal sands and aeolean sands occur along the coast on the east. The Alluvium consists mainly of clays and sands. The alluvial thickness ranges between 40 m in the west to 60 m in the east of which sands constitute 40 to 90 percent of the total thickness of the alluvium. A prominent granular zone ranging in thickness between 9 m in the east occurs beneath a clay bed. There is a general increase in clay content towards east that is the coast wards occurring as lenses.

2.1.3 MAHE REGION

The coastal area of Mahe region is covered by Quaternary alluvium. Rest of the area is occupied by Precambrian metamorphic rocks, represented by hornblende-biotite gneiss, outcrops of which are seen right on the coast. The gneisses are traversed by quartz veins and granitic bodies and are intruded by dolerite dykes. Both the Crystalline rocks and dolerite dykes. The crystallines are lateritised to a thickness up to 10m.

2.2 HYDROMETEOROLOGY:

Union Territory of Pondicherry comprises of four regions, namely Pondicherry, Karaikal, Mahe and Yanam, of which Pondicherry, Karaikal and Yanam regions are located on the coromandal coast where as Mahe is situated on the Malabar coast. Therefore, the hydrometerological conditions are quite different.

2.2.1 PONDICHERRY REGION

The normal annual rainfall is 1323.06 mm which is precipitated in four seasons. The maximum rainfall is during north-east monsoon (Oct to Dec), which brings about 65% of the total annual rainfall, which accounts for about 660 mm. The Southwest monsoon rainfall, which precipitates between June and September, brings about 350mm rainfall. The rainfall in winter period (Jan & Feb) and hot weather period (March to May) is collectively accounts about 200 mm.

The climate of Pondicherry region is tropical. Both winter and summer are not very severe. The temperature ranges from a minimum of 17^0C to a maximum of 42^0C. The humidity is comparatively higher, becoming as high as 83% at times.

2.2.2 KARAIKAL REGION

Karaikal region receives the rainfall under the influence of both Southwest and Northeast monsoon. Most of the precipitation occurs in the form of cyclonic storms caused due to the depression in Bay of Bengal, chiefly during northeast monsoon period. The normal annual rainfall is 1435.65 mm of which the northeast monsoon contributes 69% and the southeast monsoon contributes 21%.

The region enjoys a humid and tropical climate. The monthly temperature varies between 31.8^0C (May) and 21.7^0C (March). The relative humidity is generally high above 70% during August to April and minimum varying from 60 to 65% during the month of June and about 80% during October to April.

2.2.3 MAHE REGION

The normal annual rainfall in Mahe region is about 3344.08 mm. As it is situated on the West Coast, the bulk of the rainfall (77%) is received during June to September under the influence of south-west monsoon. 13% of the annual rainfall comes from North-east monsoon and the balance 10% occurs in winter and hot-weather periods.

2.2.4 YANAM REGION

The normal annual rainfall in Yanam is of the order of 1214.27 mm, out of which 691.3mm is received during southwest monsoon, 450.3mm is received during northeast monsoon and rest during non monsoon period. Yanam experiences a comparatively hotter climate with temperature varying between 15^0C and 40^0C.

2.3 DESCRIPTION OF HYDROGEOLOGICAL UNITS

2.3.1 PUDUCHERRY REGION

The Puducherry region consists of three major aquifer systems, namely, (a) unconsolidated quaternary alluvial deposits of recent period covering 90% area of the region with a thickness ranging from 10 to 55 mts (b) Unconsolidated to semi-consolidated Tertiary Cuddalore sandstone formation of Mio-Pliocene period, covering about 65% area of the region with a thickness ranging from 50mts to 450mts and (c) semi consolidated Mesozoic Vanur and Ramanathapuram sandstone formation of the Upper to Lower cretaceous period covering about 25% area of the region with a thickness ranging from 75mt to 150mt. The Kadapperikuppam formation of the Palaeocene period constitutes the major aquifer to be reached by shallow tube wells in a part of the north-central portion, where the Cuddalore sandstone formation is either absent or badly eroded.

Among the various water bearing formation of Cretaceous age, the Ramanathapuram and Vanur formation form potential aquifers. They occur in the north-western part of Pondicherry. The aquifers of the above formation include sands and calcareous sandstones. They are coarse grained in the western part and grade into finer facies towards east and northeast. The yields of the tube wells with depths between 65 and 400 m, tapping these aquifers between 800 and 1500 lpm. The Transmissivity of Cretaceous aquifer is in the range of 100-2000 m^2/day with the storativity 2.93×10^{-5} to1.36×10^{-4}.

The most potential Cuddalore sandstone of Mio-Pliocene age comprises of sandstone, sands and gravels. Ground water occurs in this aquifers mainly under confined conditions and is developed by means of tube wells ranging in depth between 27mts and 220 mts. The yield of the tube wells shall range from 200 and 3000 lpm. The Transmissivity of the aquifer is in the range of 1000 – 2000 m^2/day with storativity 9.583×10^{-5} and 8.9×10^{-4}.

The alluvial aquifer comprises of sands and grovels and this formation occupies nearly three forth of the region. These aquifers form the most potential shallow aquifer system in the area. The thickness of these aquifers ranges from 5 mts to 40 mts and groundwater occurs in this aquifer under water table condition. The Transmissivity of alluvial aquifer is in the range of 275 to 770m^2/day with the specific yield of 6 – 15%.

2.3.2 KARAIKAL REGION

Groundwater occurs under both phreatic and confined condition in all the three major group of geological formation viz. Cuddalore Sandstone, Karaikal formation and alluvial formation. Occurrence and movement of groundwater in the said geological formation are controlled by the primary porosities of the sediments. Shallow alluvial aquifers and the medium to coarse grained Cuddalore sandstones constitute the major potential aquifer system in the region. The eastern part of the region is characterized by saline groundwater and hence there is no development.

The medium and coarse grained Cuddalore sandstone constitute the potential aquifer. The Cuddalore, which underlie the Karaikal beds, are separated from the later by an aquiclude with a thickness of 3 to 71 mts. The granular zone of Cuddalore sandstone occurring beneath the aquiclude is intercalated with clay beds. Groundwater occurs under confined condition in the groundwater zones of these formations. The yield of the tube well ranges from 8 to 44 lps. The specific capacity of the wells piercing the aquifer ranges from 21049 to 32908 lpm/m of drawdown. The permeability of the groundwater zones is fairly high ranging from 16.01 to 34.16 m/day in the Western part as against the low values ranging from 0.90 to 12.17 m/day in the eastern and northeaster part. The Transmissivity of this aquifer is 1100-2640 m^2/day with the storativity of $1.21x10^{-4}$ and $1.02x10^{-3}$.

The Karaikal beds occur in between Quaternary and Tertiary formations in the region. The Karaikal beds vary in thickness from 54m in the west to 77m in the east. The sands and sandstones of the formation are water bearing zones whose thickness varies between 11 and 40m. But as groundwater is saline in nature, it is found unsuitable for all purposes.

The sands of alluvial formation form the potential aquifer with thickness ranging from 9 to 40 mts. Groundwater occurs under water table conditions and in semi confined to confined conditions in the granular zones, which are encountered between 26 and 43m bgl. The Transmissivity of alluvial aquifer is in the range of 200-400 m^2/day.

2.3.3 MAHE REGION

Groundwater occurs under water table conditions in the coastal alluvium, laterite and crystalline rocks around Mahe. The dug wells located in the valleys are yielding around 30 to 50 KL per day whereas the wells on the hills and mounds become dry during summer.

2.4 GROUNDWATER LEVEL CONDITIONS

2.4.1 PUDUCHERRY REGION

State Ground Water Unit of Agriculture Department, Puducherry has constructed about 100 observation tube wells, piercing different aquifer system and the water level data are periodically collected from these observation tube wells. While perusal of the water level data, it is observed that the water level in the alluvial aquifer ranges from 5 to 20 mts bgl. In Cuddalore sandstone formation, the water level is in the range of 15m to 27 mts bgl whereas in cretaceous aquifer, the water level is 25 to 45 mts bgl.

Declining trend is noticed from the water level data collected. On an average, there is a drop in water level by 1 m to 1.5 m per year, in spite of sufficient rain and rainwater harvesting technologies are widely adopted. This is because of the reason that the groundwater is the only sources of water for all purpose.

2.4.2 KARAIKAL REGION

There are observation tube wells constructed in the region to facilitate to collect water level data. It is observed from the water level data that is not much fall in water level noticed.

2.5 GROUND WATER QUALITY

2.5.1 PUDUCHERRY REGION

The groundwater of alluvial aquifer is almost neutral to alkaline in nature with pH values ranging from 7 to 8.5. The water is generally bicarbonate chloride type, the bicarbonate is predominating over chloride. Carbonate is generally absent or occurs in traces. Chloride content is generally below the permissible limit except in few places along the coast. The electrical conductivity ranges from 1500 to 2000 micromhos/cm at 25^{0}C.

The quality of groundwater being tapped from Tertiary aquifer is alkaline with pH ranging from 7.4 to 8.5. Carbonate is almost nil and the groundwater is generally calcium – Magnesium – bicarbonate type.

The quality of groundwater in the Cretaceous aquifer is slightly alkaline with pH ranging from 7.7 to 8.5. The concentration of chloride is generally within 150ppm. The electrical conductivity values are less than 1500 micromhos/cm at 25^{0}C.

Groundwater from all the aquifer system is, in general, suitable for both domestic and irrigational purpose. However, water with high salinity and medium sodium hazard are reported from both alluvial and Tertiary aquifers in the coastal areas of Pondicherry region. Vary high salinity and high sodium are reported along the coast due to sea water intrusion.

2.5.2 KARAIKAL REGION

The quality of groundwater from shallow alluvial aquifers is almost neutral in nature with pH values ranging from 6.7 to 7.8. The water is generally sodium – bicarbonate – chloride type, the bicarbonate predominating over chloride. The electrical conductivity values are between 1400 to 3000 micromhos/cm at 25^{0}C.

In deeper Tertiary aquifer, the quality of groundwater is alkaline with pH ranges from 7.6 to 8.8. The quality of groundwater in the eastern part is poor and unfit for both domestic and industrial purpose. The groundwater in the western part of the region is comparatively better with EC values generally ranging around 1500 micromhos/cm at 25^{0}C. The chloride concentration is within 500 ppm.

The water from both shallow alluvial aquifer and deeper Cuddalore aquifers in western part of the region is fit for domestic purpose. It is generally unsuitable for irrigational purpose due to higher concentration of sodium in water. Therefore, the groundwater is conjunctively used with surface water for irrigation.

Chapter-III

3.0 GROUND WATER RESOURCES ESTIMATION METHODOLOGY

Ground water resource as on 2020 has 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 both the Groundwater resources components, i.e., Replenishable ground water resources or Dynamic GroundWater Resources and In-storage Resources or Static Resources. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas down to the depth of bed rock or 300 m, whichever is less. In caseof hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, if it is known that groundwater extraction is being done from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer have to be estimated. Until aquifer geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/mandals/ firkas in soft rock areas may be continued.

It is also pertinent to add that as it is advisable to restrict the groundwater development as far as possible to annual replenishable resources, the categorization also takes into account the relation between the annual replenishment and groundwater development. An area devoid of ground water potential may not be considered for development and may remain safe whereas an area with good groundwater potential may be developed and may become over exploited over a period of time. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

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 replenishedon 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.

3.1.1. 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 –

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

Equation (1) can be further elaborated as –

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

Where,

ΔS	-	Change is storage
R_{RF}	-	Rainfall recharge
R_{STR}	-	Recharge from stream channels
R_C	-	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 flow across the aquifer system
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. Due to lack of data for all the components in most of the assessment units, it is proposed that at present the water budget may be restricted to the major components only, taking into consideration certain reasonable assumptions. The estimation is to be carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

3.1.1.1. Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum periodof 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of waterlevel data, two water level readings, during pre and post monsoon seasons, are the minimum requirement. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

3.1.1.1.1. 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 in non-command areas is given by

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

Where,

ΔS - Change is storage R_{RF} - Rainfall recharge
R_{STR} - Recharge from stream channels
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 flow across the aquifer system
LF - Lateral flow along the aquifer system (through flow)
GE - Ground water extraction
T - Transpiration
E - Evaporation
B - Base flow

Whereas the water balance equation in command area will have another term i.e., Recharge due tocanals (R_C) and the equation will be as follows:

$$\Delta S = RRF + RSTR + RC + RSWI + RGWI + RTP + RWCS \pm VF \pm LF - GE - T - E - B \ldots\ldots \quad (4)$$

A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth from which ground water is being extracted should be considered. One should consider only the draft from the same aquifer for which the resource is being estimated.
The change in storage can be estimated using the following equation:

$$\Delta S = \Delta h \times A \times SY \ldots\ldots\ldots\ldots \quad \textbf{(5)}$$

Where
, ΔS - Change is storage
Δh - rise in water level in the monsoon seasonA - Area for computation of recharge
S_Y - Specific Yield

Substituting the expression in equation (5) for storage increase ΔS in terms of water level fluctuationand specific yield, the equations (3) & (4) becomes (6) & (7) for non-command and command sub- units,

$$R = \Delta h \times A \times S_Y - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots\ldots\ldots(6)$$

$$R = \Delta h \times A \times S_Y - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots(7)$$

Where base flow/ recharge to/from streams have not been estimated, the same is assumed to be zero. The rainfall recharge obtained by using equation (6) and (7) provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalized for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let R_i be the rainfall recharge and r_i 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, R_i is obtained as per equation (6) & equation (7) depending on the sub-unit for which the normalization is being done.

After the pairs of data on R_i and r_i have been obtained as described above, a 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

$$R = ar \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots.(8)$$

Where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

The computational procedure to be followed in the first method is as given below:

$$R_{RF}(normal) = \frac{\sum_{i=1}^{N} [R_i \frac{r(normal)}{r_i}]}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots..(9)$$

Where,

R_{RF}(normal) - Normalized Rainfall Recharge in the monsoon season

R_i - Rainfall Recharge in the monsoon season for the i[th] year

r(normal) - Normal monsoon season rainfall

r_i - Rainfall in the monsoon season for the i[th] year

N - No. of years for which data is available

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

$$R_{RF}(normal) = a \times r(normal) + b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (10)$$

Where,

R_{RF}(normal) - Normalized Rainfall Recharge in the monsoon season

r(normal) - Normal monsoon season rainfall

a and b - constants.

The two constants 'a' and 'b' in the above equation are obtained through a linear regression analysis. The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where,

$$b = \frac{S_2 - aS_1}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (12)$$

$$S_1 = \sum_{i=1}^{N} r_i \ , \ S_2 = \sum_{i=1}^{N} R_i \ , \ S_3 = \sum_{i=1}^{N} r_i^2 \ , \ _4 = \sum_{i=1}^{N} R_i r_i$$

3.1.1.1.2. Rainfall Infiltration Factor Method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However, the ground waterextraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from water level fluctuation approach with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

$$R_{RF} = RFIF \times A \times \frac{(R - a)}{1000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (13)$$

Where,

R_{RF} - Rainfall recharge in hamA - Area in hectares

RFIF - Rainfall Infiltration FactorR - 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. The minimum threshold limit is in accordance with the relation shown in equation (13) and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rain is too high to contribute to infiltration and they will only contribute to surface runoff. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is tobe deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. 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. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data.

3.1.1.1.3. 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

$$PD = \frac{R_R(normal, wtfm) - R_{RF}(normal, rifm)}{R_{RF}\ (normal, rifm)} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

R_R (normal, wtfm) = Rainfall recharge for normal monsoon season rainfall estimated bythe ground water level fluctuation method

R_{RF} (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 givenbelow:

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

3.1.1.2. 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. The methods of estimation of recharge from different sources are as follows.

Sl. No.	Source	Estimation Formula	Parameters
1	Recharge fromCanals	$RC = WA \times SF \times Days$	R_C = Recharge from CanalsWA = Wetted Area SF = Seepage Factor Days = Number of Canal Running Days
2	Recharge from Surface Water Irrigation	$RSWI = AD \times Days \times RFF$	R_{SWI} = Recharge due to applied surface waterirrigation AD = Average Discharge Days = Number of days water is discharged tothe Fields RFF = Return Flow Factor
3	Recharge from Ground Water Irrigation	$RGWI = GEIRR \times RFF$	R_{GWI} = Recharge due to applied ground waterirrigation GE_{IRR} = Ground Water Extraction for IrrigationRFF = Return Flow Factor

Sl. No.	Source	Estimation Formula	Parameters
4	Recharge dueto Tanks & Ponds	$R_{TP} = AWSA \times N \times RF$	R_{TP} = Recharge due to Tanks & PondsAWSA = Average Water Spread Area N = Number of days Water is available in theTank/Pond RF = Recharge Factor
5	Recharge dueto Water ConservationStructures	$R_{WCS} = GS \times RF$	RWCS = Recharge due to Water ConservationStructures GS = Gross Storage = Storage Capacitymultiplied by number of fillings. RF = Recharge Factor

3.1.1.3. Lateral Flow Along the Aquifer System (Through Flow)

In equations 6 & 7, if the area under consideration is a watershed, the lateral flow across boundaries can be considered as zero in case such estimates are not available. 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. These calculations are most conveniently done in a computer model. It is recommended to initiate regional scale modelling with well-defined flow boundaries. Once the modelling is complete, the lateral throughflows (LF) across boundaries for any assessment unit can be obtained from the model. In case Lateral Flow is calculated using computer model, the same should be included in the water balance equation.

3.1.1.4. 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. Any other information on local-level base flows such as those collected by research centers, educational institutes or NGOs may also be used to improve the estimates on base flows.

Base flow separation methods can be divided into two main types: non-tracer-based and tracer- based separation methods. Non-tracer methods include Stream hydrograph analysis, water balance method and numerical ground water modelling techniques. Digital filters are available for separatingbase flow component of the stream hydrograph.

Hydro-chemical tracers and environmental isotope methods also use hydrograph separation techniques based on mass balance approach. Stream recharge can be computed either using modelling techniques or simply by applying the Darcy Law.

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.

3.1.1.5. 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. Ground water flow modelling is an important tool to estimate such flows. As envisaged in this report regional scale modelling studies will help in refining vertical inter aquifer flow estimates.

3.1.1.6. 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 1.0mbgl, evaporation can be estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0mbgl, 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 than3.5m bgl, the transpiration should be taken as zero.

For estimating evapotranspiration, field tools like Lysimeters can be used to estimate actual evapotranspiration. Usually agricultural universities and IMD carry out lysimeter experiments and archive the evapotranspiration data. Remote sensing based techniques like SEBAL (Surface Energy Balance Algorithm for Land) can be used for estimation of actual evapotranspiration. Assessing offices may apply available lysimeter data or other techniques for estimation of evapotranspiration. In case where such data is not available, evapotranspiration losses can be empirically estimated fromPET data provided by IMD.

3.1.1.7. Recharge During Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows during monsoon seasonis 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.

3.1.1.8. Recharge 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. Thesum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows 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.

3.1.1.9. 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.

3.1.1.10. Annual Extractable Ground Water Resource (EGR)

The Annual Extractable Ground Water Resource (EGR) is computed by deducting the Total Annual Natural Discharge from Total Annual Ground Water Recharge.

The 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 determinedin 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 assumptionis to be followed.

In the water level fluctuation method, a significant portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice (GEC 1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. 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).

3.1.1.11. Estimation of Ground Water Extraction

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

$$GE_{ALL} = GE_{IRR} + GE_{DO} + GE_{IND} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

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 methods for estimation of ground water extraction are as follows.

***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.

***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 Tehsil office, Agriculture Census and also by using Remote Sensing techniques.

***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 ofpower consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

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

There are several methods for estimation of extraction for domestic use(GEDOM). Some of the commonly adopted methods are described here.

***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.

***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.

$$GE_D = Population \times Consumptive\ Requirement \times L_g \text{......................} (16)$$

Where,

L_g = 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.

3.1.1.11.2. Ground Water Extraction for Industrial Use (GE_{IND})

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

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.

Consumptive Use Pattern Method: – In this method, water consumption of different industrial units is determined. Numbers of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

$$GE_{IND} = Number\ of\ Industrial\ Units \times Unit\ Water\ Consumption \times L_g \text{...} (17)$$

Where,

L_g = 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.

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. The storage depletion during a season, where other recharges are negligible can betaken as ground water extraction during that particular period.

3.1.1.12. Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$Stage\ of\ GW\ Extraction = \frac{Existing\ Gross\ GW\ Extraction\ for\ all\ Uses}{Annual\ Extractable\ GW\ Resources} \times 100 \text{...} (18)$$

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 shouldbe obtained separately for command areas, non-command areas and poor ground water quality areas.

3.1.1.13. Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. In view ofthis, 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 prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. If the ground water resource assessment and the trend of long- t e r m 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.

SOGWE	Ground Water Level Trend	Remarks
≤ 70%	Significant decline 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

3.1.1.14. Categorization of Assessment Unit

As emphasized in the National Water Policy, 2012, a convergence of Quantity and Quality of ground water resources is required while assessing the ground water status in an assessment unit. Therefore, it is recommended to separate estimation of resources where water quality is beyond permissible limits for the parameter salinity.

3.1.1.14.1. Categorization of Assessment Unit Based on Quantity

The categorization based on status of ground water quantity is defined by Stage of Ground Water Extraction as given below:

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

3.1.1.14.2. Categorization of Assessment Unit Based on Quality

As it is not possible to categorize the assessment units in terms of the extent of quality hazard, basedon the available water quality monitoring mechanism and database on ground water quality, the Committee recommends that each assessment unit, in addition to the Quantity based categorization (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit may be tagged with the particular Quality hazard.

3.1.1.15. Allocation of Ground Water Resource for Utilization

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. In situations where adequate data is not available to make this estimate, the following empirical relation is recommended.

Where, $Alloc = 22 \times N \times L_g$ ……………………….……………………….(19)

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 (19), 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 cannever be less than the present day extraction as it is unrealistic.

3.1.1.16. 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 availabilityfor 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.

3.1.1.17. Additional Potential Resources under Specific Conditions 2.1.1.17.1. Potential Resource Due to Spring Discharge

Spring discharge occurs at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus, Spring Discharge is a form of 'Annual Extractable Ground Water Recharge'. It is a renewable resource, though not to be used for Categorization. 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.

$$Potential\ ground\ water\ resource\ due\ to\ springs = Q \times No.\ of\ days \quad ..(20)$$

Where,

Q = Spring Discharge

No of days = No of days spring yields.

3.1.1.17.2. 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. The computation of potential resource to ground water reservoir in shallow water table areas can be done by adopting the following equation:

$$Potential\ ground\ water\ resource\ in\ shallow\ water\ table\ areas = (5 - D) \times A \times SY \ldots (21)$$

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

3.1.1.17.3. Potential Resource in Flood Prone Areas

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

3.1.1.17.3.1. Areal extent of flood plain
3.1.1.17.3.2. Retention period of flood
3.1.1.17.3.3. Type of sub-soil strata and silt charge in the river water which gets deposited and controlsseepage

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.

$$Potential\ ground\ water\ resource\ in\ Flood\ Prone\ Areas = 1.4 \times N \times \frac{A}{1000} \ldots \quad (22)$$

Where,

N = No. of Days Water is Retained in the
AreaA = Flood Prone Area

3.1.1.18. Apportioning of Ground Water Assessment from Watershed to Development Unit

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/taluka/mandal/firka. This may be done as follows.

A block may comprise of one or more watersheds, in part or full. First, the ground water assessment in the subareas, command, non-command and poor ground water quality areas of the watershed may be converted into depth unit (mm), by dividing the annual recharge by the respective area. The contribution of this subarea of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub-area. This procedure must be followed to calculate the contribution from the sub-areas of all watersheds occurring in the block, to work out the total ground water resource of the block.

The total ground water resource of the block should be presented separately for each type of sub- area, namely for command areas, non-command areas and poor ground water quality areas, as inthe case of the individual watersheds.

3.1.2. Assessment of In-Storage Ground Water Resources or Static Ground Water Resources

The computation of the static or in-storage ground water resources may be done after delineating the aquifer thickness and specific yield of the aquifer material. The computations can be done as follows: -

$$SGWR = A \times (Z_2 - Z_1) \times S_Y \text{ ....(23)}$$

Where

,

SGWR = Static or in-storage ground water resources
A = Area of the assessment unit
Z_2= Bottom of unconfined aquifer
Z_1 = Pre-monsoon water level
S_Y = Specific yield in the in-storage zone

3.1.3. Assessment of Total Ground Water Availability in Unconfined Aquifer

The sum of Annual Exploitable Ground Water Resource and the In-storage Ground Water Resources of an unconfined aquifer is the Total Ground Water Availability of that aquifer.

3.2. GROUND WATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

The assessment of the ground water resources of the confined aquifers is done by following ground water storage approach. If the areal extent of the confined aquifer is "A" then the total quantity of water added to or released from the entire aquifer is

$$O = S \times A \times \Delta h \text{ ....(24)}$$

Where,

Q = Quantity of water confined aquifer can release (m^3)S = Storativity
A = Areal extent of the confined aquifer (m^2)
Δh = Change in Piezometric head (m)

Once the piezometric head reaches below the top confining bed, it behaves like an unconfined aquifer and directly dewaters the aquifer and there is a possibility of damage to the aquifer as wellas topography. The quantity of water released in confined aquifer due to change in pressure can be computed between piezometric head (ht) at any given time 't' and the bottom of the top confining layer (ho) by using the following equation.

$$Q_P = S \times A \times \Delta h = S \times A \times (h_t - h_0) \text{ .... } \mathbf{(25)}$$

Where,

Q_P = Ground Water Potential of Confined Aquifer
S = Storativity
A = Areal extent of the confined aquifer
Δh = Change in Piezometric head
h_t = Piezometric head at any particular time
h_0 = Bottom of the top Confining Layer

If any development activity is started in the confined aquifer, the assessment is done for both thedynamic as well as in-storage resources of the confined aquifer.

3.2.1. Dynamic Ground Water Resources of Confined Aquifer

To assess the dynamic ground water resources of the confined aquifer the following equation can beused with the pre and post monsoon piezometric heads of the particular aquifer.

$$Q_D = S \times A \times \Delta h = S \times A \times (h_{POST} - h_{PRE}) \text{ .... } \mathbf{(26)}$$

Where,

Q_D = Dynamic Ground Water Resource of Confined Aquifer (m^3)
S = Storativity
A = Areal extent of the confined aquifer (m^2)
Δh = Change in piezometric head (m)
h_{POST} = Piezometric head during post-monsoon period (m amsl)
h_{PRE} = Piezometric head during pre-monsoon period (m amsl)

3.2.2. In-storage Ground Water Resources of Confined Aquifer

For assessing the in- storage ground water potential of a confined aquifer, one has to compute the resources between the pre-monsoon piezometric head and bottom of the top confining layer. That can be assessed using the following formula:

$$\mathbf{O} = S \times A \times \Delta h = S \times A \times (h_{PRE} - h_0) \text{ ....}\mathbf{(27)}$$

Where,

Q_I =In-storage Ground Water Resource of Confined Aquifer (m^3)
S = Storativity
A = Areal extent of the confined aquifer (m^2)
Δh = Change in piezometric head (m)
h_0 = Bottom level of the top confining layer (m amsl)
h_{PRE}= Piezometric head during pre-monsoon period (m amsl)

If the confined aquifer is not being exploited for any purpose, the dynamic and static resources of the confined aquifer need not be estimated separately. Instead the in-storage ground water resource of the aquifer can be computed using the following formula.

$$\mathbf{O}_P = \times A \times \Delta h = S \times A \times (h_{POST} - h_0) \text{ ....}\mathbf{(28)}$$

Where,

Q_P = In-storage Ground Water Resource of Confined Aquifer or the quantity of water underpressure (m^3)
S = Storativity
A = Areal extent of the confined aquifer (m^2)
Δh = Change in piezometric head (m)
h_0 = Bottom level of the top confining layer (m amsl)
h_{POST} = Piezometric head during post-monsoon period (m amsl)

The calculated resource includes small amount of dynamic resource of the confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the static or in-storage resource of the confined aquifer.

3.2.3. Assessment of Total Ground Water Availability of Confined Aquifer

If the confined aquifer is being exploited, the Total Ground Water Availability of the confined aquiferis the sum of Dynamic Ground Water Resources and the In-storage Ground Water Resources of that confined aquifer whereas if it is not being exploited, the Total Ground Water Availability of the confined aquifer comprises of only one component i.e. the In-storage Ground Water Resources of that confined aquifer.

3.3. GROUND WATER ASSESSMENT OF SEMI-CONFINED AQUIFER SYSTEM

The Assessment of Ground Water Resources of a semi-confined aquifer has some more complications. Unless and until, it is well studied that the recharge to this is not computed either in the over lying unconfined aquifer or underlying/overlying semi confined aquifers, it should not be assessed separately. If it is assessed separately, there is a possibility of duplication of estimating the same resource by direct computation in one aquifer and as leakage in the other aquifer. As it is advisable to under estimate rather than to overestimate the resources, it is recommended not to assess these resources separately as long as there is no study indicating its non-estimation. If it is found through field studies that the resources are not assessed in any of the aquifers in the area, these resources are to be assessed following the methodology similar to that used in assessing the resources of Confined aquifers.

3.4. TOTAL GROUND WATER AVAILABILITY OF AN AREA

The Total Ground Water Availability in any area is the sum of dynamic and static/in-storage ground water resources in the unconfined aquifer and the dynamic and In-storage ground water resources of the Confined aquifers and semi-confined aquifers in the area.

3.5. GROUND WATER ASSESSMENT IN URBAN AREAS

The Assessment of Ground Water Resources in urban areas is similar to that of rural areas. Because of the availability of draft data and slightly different infiltration process and recharge due to other sources, the following few points are to be considered.

- Even though the data on existing ground water abstraction structures are available, accuracyis somewhat doubtful and individuals cannot even enumerate the well census in urban areas. Hence it is recommended to use the difference of the actual demand and the supply by surface water sources as the withdrawal from the ground water resources.
- The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, it is proposed to use 30% of the rainfall infiltration factor proposed for urban areas as an adhoc arrangement till field studies in these areas are done and documented field studies are available.

- Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component is also to be included in the other resources and the recharge may be estimated. The percent losses may be collected from the individual water supply agencies, 50% of whichcan be taken as recharge to the ground water system.

- In the urban areas in India, normally, there is no separate channels either open or sub surface for the drainage and flash floods. These channels also recharge to some extent the ground water reservoir. As on today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the ground water resources with nitrate also contribute to the quantity of resources and hence same percent as in the case of water supply pipes may be taken as norm for the recharge on the quantityof sewerage when there is sub surface drainage system. If estimated flash flood data is available the same percent can be used on the quantum of flash floods to estimate the recharge from the flash floods. Even when the drainage system is open channels, till further documented field studies are done same procedure may be followed.

- It is proposed to have a separate ground water assessment for urban areas with population more than 10 lakhs.

3.6. GROUND WATER ASSESSMENT IN COASTAL AREAS

The assessment of ground water resources in coastal areas is similar to that of other areas. Because of the nature of hydraulic equilibrium of ground water with sea water, care should be taken in assessing the ground water resources of this area. While assessing the resources in these areas, following few points are to be considered.

- The ground water resources assessment in coastal areas includes the areas where the influence of sea water has an effect on the existence of fresh water in the area. It can be demarcated from the Coastal Regulatory zone or the Geomorphological maps or from the maps where sea water influences are demarcated.

- Wherever, the pre monsoon and post monsoon water levels are above mean sea level the dynamic component of the estimation will be same as other areas.

- If both these water levels are below sea level, the dynamic component should be taken as zero.

- Wherever, the post monsoon water table is above sea level and pre monsoon water table is below sea level the pre monsoon water table should be taken as at sea level and fluctuation is to be computed.

- The static or in storage resources are to be restricted to the minimum of 40 times the pre monsoon water table or the bottom of the aquifer.

3.7. GROUND WATER ASSESSMENT IN WATER LEVEL DEPLETION ZONES

There may be areas where ground water level shows a decline even in the monsoon season. The reasons for this may be any one of the following: (a) There is a genuine depletion in the ground water regime, with ground water extraction and natural ground water discharge in the monsoon season (outflow from the region and base flow) exceeding the recharge. (b) There may be an error in water level data due to inadequacy of observation wells.

If it is concluded that the water level data is erroneous, recharge assessment may be made based on rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the ground water level fluctuation method may be applied for recharge estimation. As ΔS in equation 3&4 is negative, the estimated recharge will be less than the gross ground water extraction in the monsoon season. It must be noted that this recharge is the gross recharge minus the natural discharges in the monsoon season. The immediate conclusion from such an assessment in water depletion zones will be that the area falls under the over-exploited category which requires micro level study.

3.8. MICRO LEVEL STUDY FOR NOTIFIED AREAS

In all areas which are 'Notified' for ground water regulation by the Central and/ or State Ground Water Authorities, it is necessary to increase the density of observation wells for carrying out micro- level studies to reassess the ground water recharge and draft. Following approach may be adopted:

- The area may be sub-divided into different hydrogeological sub-areas and into rechargearea, discharge area and transition zone and also on quality terms.

- The number of observation wells should be increased to represent each such sub-areas with at least one observation well with continuous monitoring of water levels.

- Hydrological and hydrogeological parameters particularly the specific yield should be collected for different formations in each sub-area.

- Details regarding other parameters like seepage factor from canals and other surface water projects should be collected after field studies, instead of adopting recommended norms. Base flow should be estimated based on stream gauge measurement.

- The data of number of existing structures and unit draft should be reassessed after fresh surveys and should match with the actual irrigation pattern in the sub-area.

- All data available with Central Ground Water Board, State Ground Water Departments and other agencies including research institutions and universities etc. should be collected forthe watershed/sub-areas and utilized for reassessment.

- Ground water assessment for each sub-area may be computed adopting the recommended methodology and freshly collected values of different parameters. The assessment may be made separately for monsoon and non-monsoon period as well as for command, non-command and poor ground water quality areas.

- The ground water potential so worked out may be cross-checked with behaviour of ground water levels in the observation wells and both should match. If it does not, the factor that causes such an anomaly should be identified and the revised assessment should be re- examined.

- Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be classified adopting norms for categorization as recommended elsewhere in the methodology.

3.9. NORMS TO BE USED IN THE ASSESSMENT

The committee recommends that the state agencies should be encouraged to conduct field studies and use these computed norms in the assessment. For conducting field studies, it is recommended to follow the field-tested procedures for computing the norms. There is the possibility of error creeping in at various levels in the field study and hence the committee is of the opinion to give a maximum and minimum values for all the norms used in the estimation. The committee can foresee the handicap of the state agencies which are not able to compute the norms by their own field study. In such cases, it suggests an average of the range of norms to be used as the recommended value for the norm.

3.9.1. Specific Yield

Recently under Aquifer Mapping Project, Central Ground Water Board has classified all the aquifers into 16 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The values recommended in the **Table 2.1** may be followed in the future assessments. The Major aquifer map can be obtained from Regional officesof Central Ground Water Board.

The recommended Specific Yield values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values. The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table 3.1: Norms Recommended for Specific Yield

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareousconcretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular orJointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic toCenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coalbeds	Upper Palaeozoic to Cenozoic	3	1	5

16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerat e	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	Karstified Miliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered ,Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2

40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex -Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoi c	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries / Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoi c	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic toCenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic toCenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic toCenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic toCenozoic	0.35	0.2	0.5

3.9.2. Rainfall Infiltration Factor

It is recommended that to assign Rainfall Infiltration Factor values to all the aquifer units recently classified by the Central Ground Water Board. The values recommended in **Table 2.2** may be followed in the future assessments. The recommended Rainfall Infiltration Factor values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values.

An additional 2% of rainfall recharge factor may be used in such areas or parts of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage,only provisional, and will need revision based on pilot studies.

The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table 3.2: Norms Recommended for Rainfall Infiltration Factor

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareousconcretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly	Mesozoic to Cenozoic	2	1	3

			Jointed				
13	Sandstone	ST01	Sandstone/Conglomera te	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomera te	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quarternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered ,Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5

42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex -Massive, Poorly Fractured	Azoic	2	1	3
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoi c	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries / Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoi c	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
62	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

3.9.3. Norms for Canal Recharge

Unlike other norms, the Recharge factor for calculating recharge due to canals is given in two units viz. ham/million m^2 of wetted area/day and cumecs per million m^2 of wetted area. As all other norms are in ham, the committee recommends the norm in ham/million m^2 of wetted area for computing the recharge due to canals.

There is a wide variation in the values of the recharge norms proposed by GEC 1997.The Canal seepage norm is approximately 150 times the other recharge norms. In the absence of any field studies to refine the norms it is decided by the committee to continue with the same norms. The committee strongly recommends that each state agency must conduct one field study at least one in each district before completing the first assessment using this methodology. The committee also suggests a recommended value and minimum and maximum values as in the case of other norms. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

The Norms suggested in **Table 3.3** below are nothing but the rationalization and redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Table 3.3: Norms Recommended for Recharge due to Canals

Formation	Canal Seepage factor ham/day/million square meters of wetted area		
	Recommended	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

3.9.4. Norms for Recharge Due to Irrigation

The Norms Suggested by GEC-1997 gives for only three ranges of water levels and it creates a problem in the boundary conditions. For instance, as a result of the variation in water level from 24.9 to 25.1m bgl in the adjoining blocks, change occurs in the return flow from irrigation in the range of 10% to 15%. Hence to reduce the discrepancy it is recommended to have linearrelationship of the norms in between 10m bgl water level and 25m bgl water level. It is proposed to have the same norm of 10m bgl zone for all the water levels less than 10m. Similarly, the norm recommended for 25m may be used for the water levels more than 25m as well. The Recommended Norms are presented in Table 2.4.

For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

Table 3.4: Norms Recommended for Recharge from Irrigation

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
≤ 10	45.0	25.0	50.0	30.0
11	43.3	23.7	48.3	28.7
12	40.4	22.1	45.1	26.8
13	37.7	20.6	42.1	25.0
14	35.2	19.2	39.3	23.3
15	32.9	17.9	36.7	21.7
16	30.7	16.7	34.3	20.3
17	28.7	15.6	32.0	18.9
18	26.8	14.6	29.9	17.6
19	25.0	13.6	27.9	16.4
20	23.3	12.7	26.0	15.3
21	21.7	11.9	24.3	14.3
22	20.3	11.1	22.7	13.3
23	18.9	10.4	21.2	12.4
24	17.6	9.7	19.8	11.6
≥ 25	20.0	5.0	25.0	10.0

3.9.5. Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997 in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

3.9.6. Norms for Recharge due to Water Conservation Structures

Even though the data on the field studies for computing recharge from Water Conservation Structures are very limited, it is recommended that the Recharge from the water conservation structures is 40% of the Gross Storage based on the field studies by Non-Government Organizations. Hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is 40% of gross storage during a year which means 20% during monsoon season and 20% during non- monsoon Season.

3.9.7. Norm for Per Capita Requirement

As the option is given to use the actual requirement for domestic needs, the Requirement Norm recommended by the committee is 60 lpcd for domestic needs. This can be modified if the actual requirement is known.

3.9.8. Norm for Natural Discharges

The Discharge Norm used in computing Unaccounted Natural Discharge is 5% if water table fluctuation method is used or 10% if rainfall infiltration factor method is used for assessing the Rainfall recharge. This committee recommends to compute the base flow for each assessment unit. Wherever, there is no assessment of base flow, earlier norms recommended by GEC 1997 i.e. 5% or 10% of the Total Annual Ground Water Recharge as the Natural Discharges may be continued.

3.9.9. Unit Draft

GEC-1997 methodology recommends to use well census method for computing the ground water draft. The norm used for computing ground water draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structure and calculating the discharge from that particular type of structure and collecting the information onhow many hours of pumping is being done in various seasons and number of such days during each season. The Unit Draft during a particular season can be computed using the following equation:

$$Unit\ Draft = Discharge\ in\ m^3/hr \times No.\ of\ pumping\ hours\ in\ a\ day \times No.\ of\ days \ldots\ldots\ldots \quad (29)$$

One basic drawback in the methodology of computing unit draft is that there is no normalization procedure for the same. As per GEC-1997 guidelines, the recharge from rainfall is normalized for a normal rainfall. It means that even though the resources are estimated in a surplus rainfall year or in a deficit rainfall year, the assessment is normalized for a normal rainfall which is required for planning. For recharge from other sources, average figures/ values are taken. If the average figures are not available for any reason, 60% of the design figures are taken. This procedure is very much essential as the planning should be for average resources rather than for the recharge due to excess rainfall or deficit rainfall. But the procedure that is being followed for computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from ground water will be less. Similarly, if the year of the computation of unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which can be followed. If the unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 31 is to be followed or else the first method shown in equation 30 may be used.

$$Normalised\ Unit\ Draft = \frac{Unit\ Draft \times Rainfall\ for\ the\ year}{Normal\ Rainfall} \ldots\ldots \quad (30)$$

$$Normalised\ Unit\ Draft = \frac{\sum_{i=1}^{n} Unit\ Draft_i}{Number\ of\ Years} \ldots\ldots \quad (31)$$

Although GEC-1997 methodology recommends a default value for the unit drafts, each State is using its own values, generally after conducting field studies, even though without a documentation. Hence, it is felt that this norm may be computed by the state agency, which is going to assess the norms before commencement of the assessment. But it is strongly recommended that the field studies should be documented and submitted along with the results of the assessment.

3.10. INDIA -GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)

“INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad. It will provide common and standardized platform for Ground Water Resource Estimation for the entire country and its pan- India operationalization (Central and State Governments). The system will take ‘Data Input’ through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categoriesfor all the assessment units (AU) of the country. The Ground Water Resources thus assessed can be viewed from the **URL of IN-GRES** http://ingres.iith.ac.in

CHAPTER 4

4.0 PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT INCLUDING ASSUMPTION

In the present re-assessment of groundwater, various data, viz., water level, rainfall total cropped area, surface storage, tube well population of agriculture, domestic and industrial purposes, and their draft for the period 2015-2020 were taken for computation. Various parameters and data could not be compiled at watershed level and due to smallness of the area, computations have been done directly for region wise. Further, data also could not be segregated into command and non-command and hence it has been carried out combined. In short, the computations have been carried out directly at the level of region. No additional tube wells were permitted during the re-assessment period and about 5% reduction of tube wells in agriculture such as the agricultural land was converted into residential plots. At the same time, due to increase in demand for domestic purposes, Public Works Dept. additionally constructed tube wells. No other changes in the guidelines or norms have been made in the present re-assessment for all the regions in the UT of Puducherry.

State Ground Water Unit of Agriculture Department and Central Ground Water Board, SECR maintain monitoring wells and water level data are regularly collected from these tube wells and therefore the said data were taken for computations. Rainfall particulars, maintained by Meteorological Department, Pondicherry were utilised in the computations. Further, the data on area under groundwater irrigation, and total cropped area were collected from the Department of Economics and Statistics, Puducherry. Surface water particulars were collected from the Irrigation Division of Public Works Department, Puducherry. The groundwater draft from irrigation tube wells was computed after random verification and computed in the calculation. The domestic water requirement was collected from Public Health Division of Public Works Department, which is dealing with domestic water supply and the industrial water requirement was collected from Pondicherry Ground Water Authority. No changes in the guidelines or norms have been made in the present re-assessment for all the regions in UT of Puducherry and the dynamic resources have been computed for each region, using the norms, prescribed in the GEC-2015 methodology.

CHAPTER 5

COMPUTATION OF GROUNDWATER RESOURCES ESTIMATION IN THE STATE:

5.1 SALIENT FEATURE OF THE ASSESSMENT

In UT of Puducherry, the assessment unit is region and there are four regions in the Union Territory of Puducherry comprising of Puducherry, Karaikal, Mahe & Yanam.

5.2 COMPUTATION OF RAINFALL RECHARGE

The rainfall recharge has been estimated using rainfall infiltration factor in Puducherry & Mahe regions while in Karikal region, water level fluctuation approach is used. The details of recharge computed during monsoon and non-monsoon recharge is provided in Annexure D1.

5.3 SALIENT FEATURES OF ASSESSMNET OF THE STATE

Ground water resources assessment was taken up as per the guidelines issued in the norms of GEC-2015 methodology and dynamic resources have been computed for each region separately.

The Dynamic ground water resources for UT of Puducherry have been assessed Region wise i.e Karaikal, Mahe, Puducherry & Yanam. The Annual Ground Water Recharge of the UT of Puducherry has been assessed as 0.22 bcm, Annual Extractable Ground Water Resources is 0.2 bcm and the Annual Ground Water Extraction is 0.15 bcm. The overall Stage of Ground Water Extraction of UT of Puducherry is 74.27 %. Out of 4 regions, 1 region (Puducherry) has been categorized as 'Critical', 2 Regions (Karaikal & Mahe) as 'Safe' and 1 Region (Yanam) as 'Saline'.

5.4 COMPARISSON WITH THE PREVIOUS ESTIMATE

As compared to 2017 assessment, there is no significant change in Annual Ground Water Recharge & Ground Water Extraction. Only Puducherry Region improved from 'Over-exploited' category to 'Critical' Category.

However, the stage of development has come down in Puducherry region from 102% to 98.81%. The stage of development for Kariakal region has marginally increased from 16% to 21.21 % and for Mahe from 69% to 69.55%. The reduction in the change of stage of development in Puducherry region is due to the refinement in database and groundwater augmentation measures taken up by the Government of U.T of Puducherry under various schemes are the reasons for bringing in the increase in recharge and decrease in ground water extraction & stage of groundwater extraction. However, there is no significant change in overall ground water resources of U.T. of Puducherry.

Besides, groundwater draft is regulated by Puducherry Groundwater Authority under the provisions of " The Pondicherry Groundwater (Control & Regulation) Act & Rules". Further, subsidy is extended to farmer to adopt water conservation devices namely sprinkler and drip and laying underground pipe lines. Farmers are encouraged to adopt precision farming which has become very popular and successful. Rain water harvesting structures are constructed in full swing. Besides, Govt of Puducherry has constructed number of bed dams across the rivers, with which has increased water spread area, facilitating effective recharge. Under Tank Rehabilitation programme, an externally aided project, all the major tank have been revived to increase the water holding capacity. In Karaikal region also, tail end regulators have been constructed to arrest the run off Cauvery water into the sea and also entry of back water during high tide seasons.

Region	Stage of Development (%) (2017)	Categorization (as on March 2017)	Stage of Development (%) (2020)	Categorization (as on March 2020)
Puducherry	102	Over Exploited	98.81	Critical
Karaikal	16	Safe	21.21	Safe
Mahe	69	Safe	69.55	Safe
Yanam	-	Saline	-	Saline

5.5 ADDITIONAL POTENTIAL RECHARGE

The additional potential recharge in UT of Puducherry is nil

Contributors' page

Department of Agriculture Government of Puducherry Puducherry	Central Ground Water Board South Eastern Coastal Region Ministry of Water Resources, RD & GR Government of India Chennai
Shri. Manoharan, Hydrogeologist	**Guidance & Supervision** **Dr. S. Subramanian,** Scientist-D (HG) & H.O.O **Principal Contributors** **Dr. N. Ramesh Kumar**, Scientist-B (HG) **Shri. J. Sivaramakrishnan,** Scientist-B (HG)

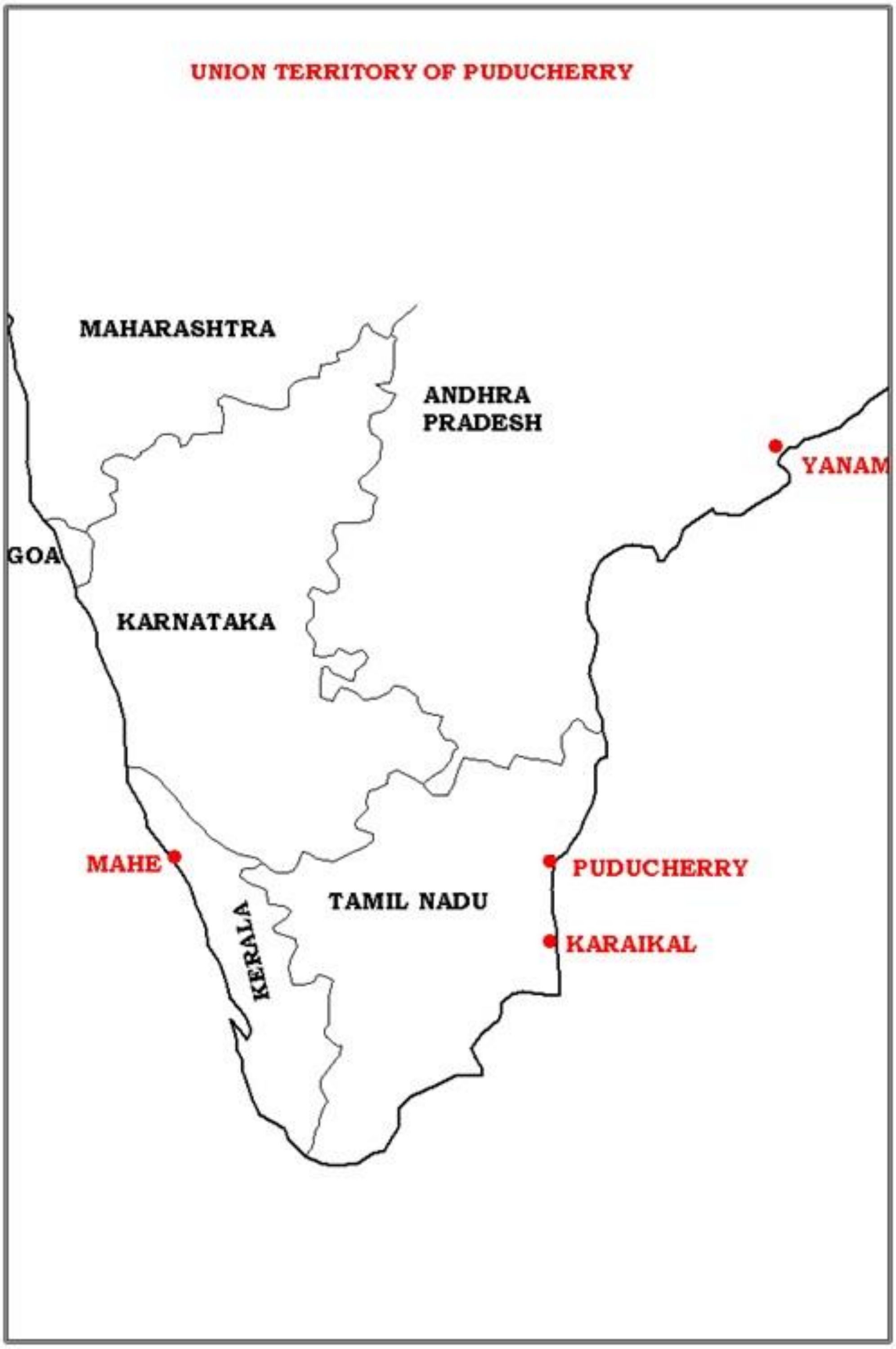


Figure.1 Location Map of U.T. of Puducherry

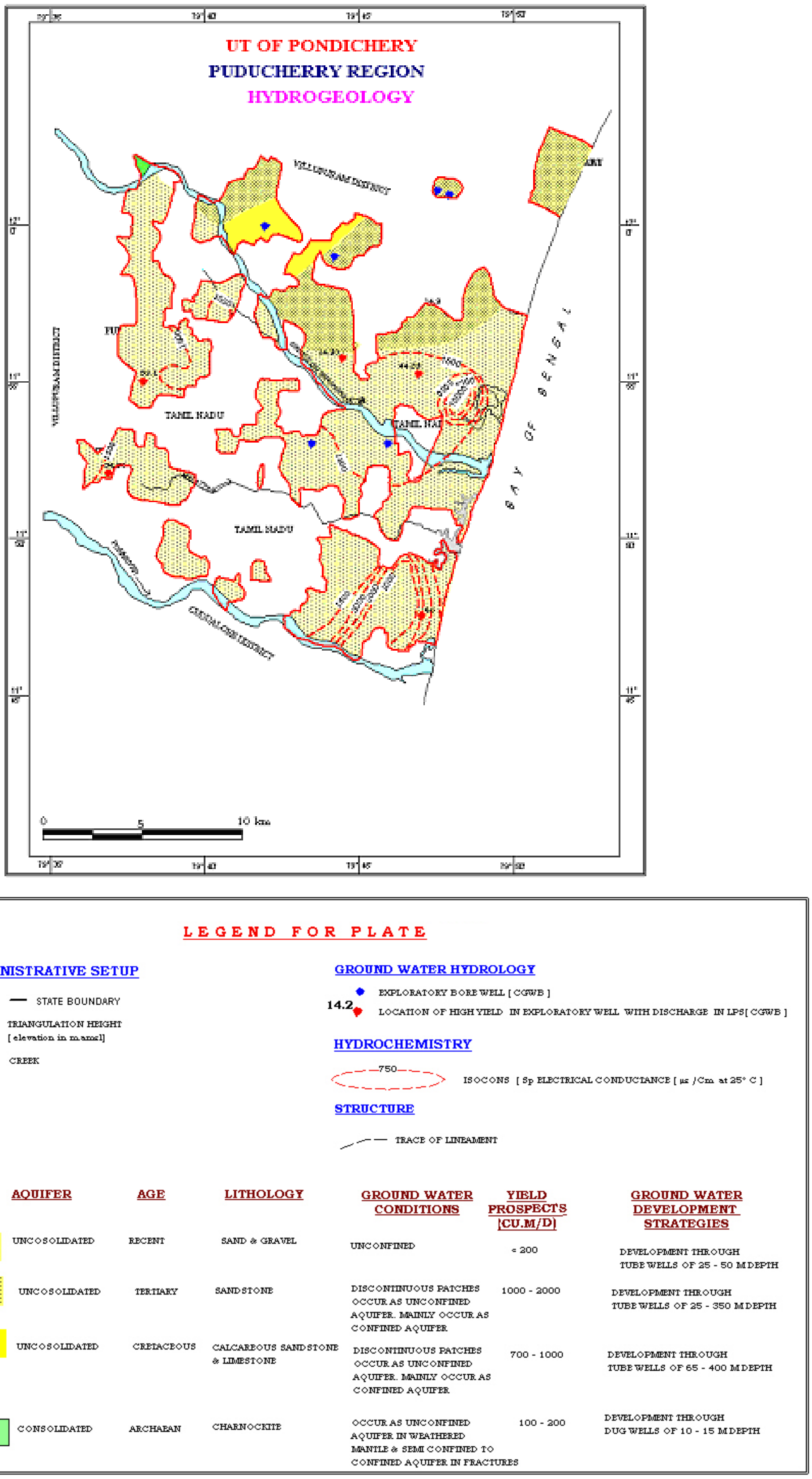
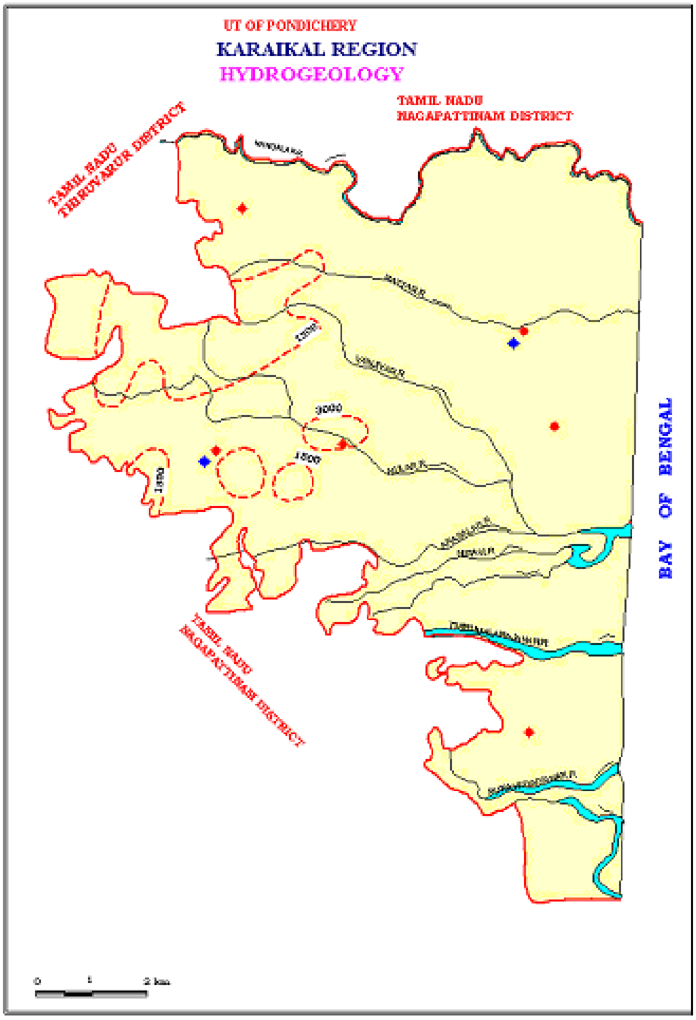


Figure 2. Hydrogeology Puducherry Region, U.T. of Puducherry.



LEGEND FOR PLATE VI

ADMINISTRATIVE SETUP

STATE BOUNDARY

RIVER WITH FLOW DIRECTION

TRIANGULATION HEIGHT [elevation in m.amsl]

CREEK

GROUND WATER HYDROLOGY

EXPLORATORY BORE WELL [CGWB]

LOCATION OF HIGH YIELDINGEXPLORATORY WELLS WITH DISCHARGE IN LPS [CGWB]

HYDROCHEMISTRY

ISOCONS [Sp ELECTRICAL CONDUCTANCE [μs /Cm at 25° C]

AQUIFER	AGE	LITHOLOGY	GROUND WATER CONDITIONS	YIELD PROSPECTS [CU.M/D]	GROUND WATER DEVELOPMENT STRATEGIES
UNCOSOLIDATED	RECENT	RIVER ALLUVIUM, FLOOD PLAIN-DEPOSITS	DISCONTINUOUS, THIN, UNCONFINED TO SEMI CONFINED	> 200	DEVELOPMENT THROUGH LARGE DIAMETER DUG WELLS AND SHALLOW TUBE WELLS.
	TERTIARY	SANDSTONE	DISCONTINUOUS. CONFINED AQUIFER	1000 - 2000	DEVELOPMENT THROUGH TUBE WELLS OF 150 - 350 M DEPTH

Figure 3. Hydrogeology, Karikal Region, U.T. of Puducherry.

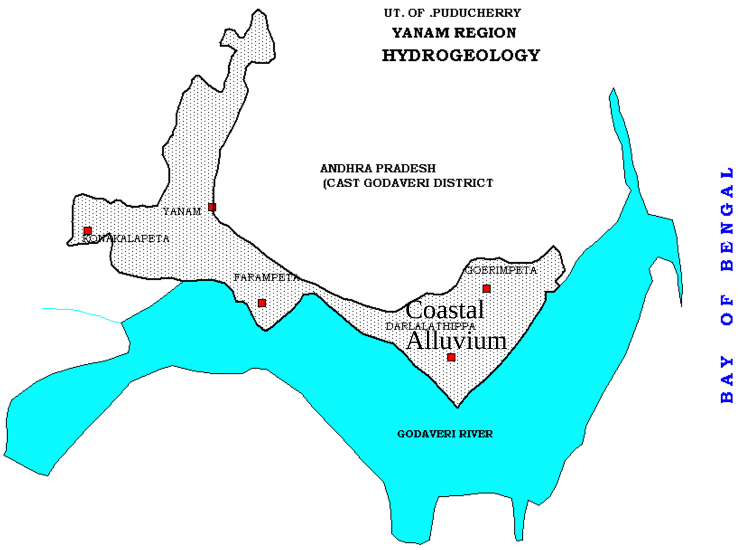


Figure 4. Hydrogeology Yanam Region, U.T. of Puducherry.

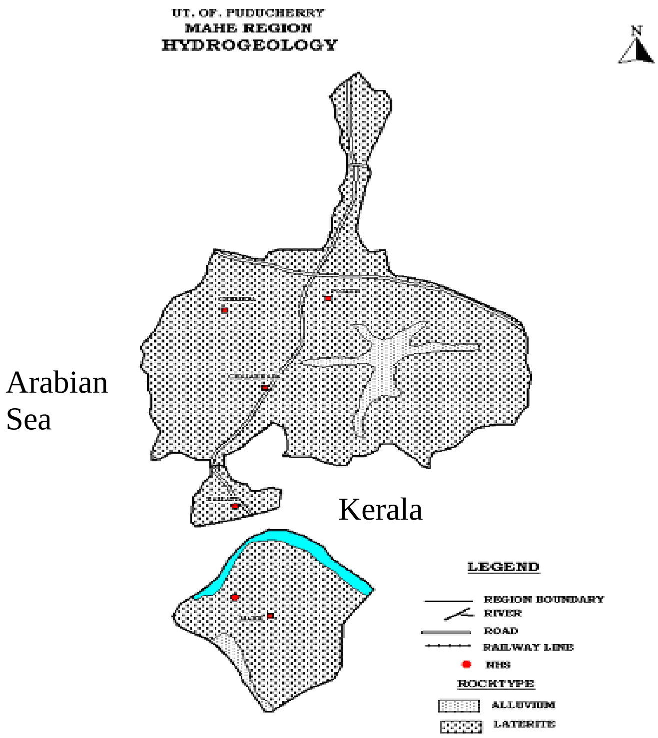


Figure 5. Hydrogeology Mahe, U.T. of Puducherry.

UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES AVAILABILITY - 2020

Sl. No	State/UT	District/Region	Assessment Unit Name/Region	Assessment Unit Type	Total Area of Assessment Unit (Ha)	Recharge Worthy Area(Ha)	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources-Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources- Non Monsoon Season	Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	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 Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-ExploitedE/Critical/Semicritical/Safe/Saline)
1	U.T of Puducherry	Karaikal	Karaikal	Region	16100	16100	1542.26	3936.85	20.98	1481.15	6981.24	698.12	6283.12	786.98	17	528.71	1332.69	973.37	4895.12	21.21	Safe
2	U.T of Puducherry	Mahe	Mahe	Region	900	900	218.7	0	2.79	0	221.49	22.15	199.34	0	0	138.65	138.65	149.84	49.04	69.55	Safe
3	U.T of Puducherry	Puducherry	Puducherry	Region	29300	29300	4270.18	6135.05	1445.95	3280.02	15131.2	1513.12	13618.08	8983.5	631.5	3841.42	13456.42	4338.92	161.67	98.81	Critical
4	U.T of Puducherry	Yanam	Yanam	Region	2000	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Salinity
Total					48300	48300	6031.14	10071.9	1469.72	4761.17	22333.93	2233.39	20100.54	9770.48	648.5	4508.78	14927.76	5462.13	5105.83	74.27	

UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES AVAILABILITY, 2020															
															(in bcm)
S. No.	States / Union Territories	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge			Irrigation	Industrial	Domestic	Total			
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	U.T of Puducherry	0.060	0.101	0.015	0.048	0.223	0.022	0.201	0.098	0.006	0.045	0.149	0.055	0.051	74.27

DYNAMIC GROUND WATER RESOURCES OF UNION TERRITORY OF PUDUCHERRY, 2020 (in Ham)															
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020															
S. No.	Name of District/Region	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-monsoon Season		Total Annual Ground Water Recharge			Irrigation	Industrial	Domestic	Total			
		Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Karaikal	1542.26	3936.85	20.98	1481.15	6981.24	698.12	6283.12	786.98	17	528.71	1332.69	973.37	4895.12	21.21
2	Mahe	218.7	0	2.79	0	221.49	22.15	199.34	0	0	138.65	138.65	149.84	49.04	69.55
3	Puducherry	4270.18	6135.05	1445.95	3280.02	15131.2	1513.12	13618.08	8983.5	631.5	3841.42	13456.42	4338.92	161.67	98.81
4	Yanam	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total (Ham)	6031.14	10071.9	1469.72	4761.17	22333.93	2233.39	20100.54	9770.48	648.5	4508.78	14927.76	5462.13	5105.83	74.27

CATEGORIZATION OF BLOCKS/ MANDALS/ TALUKAS IN INDIA (2020)											
Union Territory of Puducherry											
S.No.	Total No. of Assessed Units	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
		Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
1	4	2	50	0	0	1	25	0	0	1	25

NOTE- Assesment Unit Type-Region

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2020													
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020													
S.No	Name of District/Region	Total No. Of Assessed Units	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			No.	%	No.	%	No.	%	No.	%	No.	%
1	Karaikal	1	1	100								
2	Mahe	1	1	100								
3	Puducherry	1					1	100				
4	Yanam	1									1	100

ANNUAL EXTRACTABLE/REPLENISHABLE RESOURCE OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN INDIA(2020)												
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020												
S.No.	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline		
		Total Annual Extractable Ground Water Resource (in mcm)	%	Total Annual Extractable Ground Water Resource (in mcm)	%	Total Annual Extractable Ground Water Resource (in mcm)	%	Total Annual Extractable Ground Water Resource (in mcm)	%	Total Annual Extractable Ground Water Resource (in mcm)	%	
1	201.01	64.82	32.25	0	0	136.18	67.75	0	0	0	0	

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2020												
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020												
S.No	Name of District/Region	Total Annual Extractable Ground Water Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%	Annual Extractable Ground Water Resource (in mcm)	%
1	Karaikal	62.83	62.83	100	0	0	0.00	0	0	0	0	0
2	Mahe	1.99	1.99	100	0	0	0.00	0	0	0	0	0
3	Puducherry	136.18	0.00	0	0	0	136.18	100	0	0	0	0
4	Yanam	0.00	0.00	0	0	0	0.00	0	0	0	0	0

AREA OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN INDIA (2020)												
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020												
S.No.	**Total Recharge Worthy Area of Assessed Units (in sq.km)**	**Safe**		**Semi-Critical**		**Critical**		**Over-Exploited**		**Saline**		
		Recharge Worthy Area (in sq.km)	**%**	**Recharge Worthy Area (in sq.km)**	**%**	**Recharge Worthy Area (in sq.km)**	**%**	**Recharge Worthy Area (in sq.km)**	**%**	**Recharge Worthy Area (in sq.km)**	**%**	
1	483	108.6		0	0	293		0	0	81.4	16.85	

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2020													
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020													
S.No	Name of District	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%
1	Karaikal	161	99.6	61.86	0	0	0	0	0	0	61.4	38.14
2	Mahe	9	9	100	0	0	0	0	0	0	0	0
3	Puducherry	293	0	0	0	0	293	100	0	0	0	0
4	Yanam	20	0	0	0	0	0	0	0	0	20	100

CATEGORIZATION of ASSESSMENT UNITS, 2020							
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020							
S. No	Name of District/Region	S. No	Name of Semi-Critical Assessment Unit	S. No	Name of Critical Assessment Unit	S. No	Name of Over-Exploited Assessment Unit
1	Puducherry			1	Puducherry		
ABSTRACT							
Total No. of Assessed Units		Number of Semicritical		Number of Critical Assessment Unit		Number of Over Exploited Assessment	
3		0		1		0	

QUALITY PROBLEMS IN ASSESSMENT UNITS, 2020							
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020							
S. No	Name of District/ Region	S. No	Name of Assessment Unit affected by Fluoride	S. No	Name of Assessment Unit affected by Arsenic	S. No	Name of Assessment Unit affected by Salinity
1	Yanam					1	Yanam
ABSTRACT							
Total No. of Assessed Units		Number of Assessment Unit affected by Fluoride		Number of Assessment Unit affected by Arsenic		Number of Assessment Unit affected by Salinity	
1						1	

STATE-WISE SUMMARY OF ASSESSMET UNITS IMPROVED AND DETERIORATED FROM 2017 TO 2020 ASSESSMENT				
S. No.	**Name of States / Union Territories**	**Number of Assessment Units Improved**	**Number of Assessment Units Deteriorated**	**Number of Assessment Units With No Change**
1	**U.T of Puducherry**	**1**	**0**	**3**

COMPARISON OF CATEGORIZATION OF ASSESSMENT UNITS (2020 AND 2017)									
UNION TERRITORY OF PUDUCHERRY GROUND WATER RESOURCES, 2020									
S. No	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) in 2017	Categorization in 2017	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) in 2020	Categorization in 2020	Remark
Improved									
1	Puducherry	Puducherry	102	Over-Exploited	Puducherry	Puducherry	98.81	Critical	Improved
COMPARISON OF CATEGORIZATION OF ASSESSMENT UNITS (2020 AND 2017)									
STATE/UT NAME									
S. No	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) 2017	Categorization 2017	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) in 2020	Categorization 2020	Remark
Deteriorated									
1									Deteriorated

GOVERNMENT OF PUDUCHERRY

ABSTRACT

Constitution of State Level Committee for re-assessment of Ground Water Resources for UT of Puducherry as on 31st March, 2020 – Orders – Issued.

CHIEF SECRETARIAT (AGRICULTURE)

G.O. Ms.20 /Ag   Puducherry, dt.21.09.2020

READ: Lr. No.T-13014/1/2019-GW Section-MOWR dt. 4th August 2020 of Govt. of India, Ministry of Jal Shakti, Dept. of Water Resources, River Development & Ganga Rejuvenation, New Delhi.

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ORDER:

Citing the National Water Policy 2012, which recommends for re-assessment of Ground Water Resources periodically, the Ministry of Jal Shakti in their letter read above have asked the State / UT Governments to constitute a State Level Committee to re-assess Ground Water Resources for the year 2019-20.

2. Accordingly, the State Level Committee for re-assessment of Ground Water Resources for UT of Puducherry is constituted with the following composition.

i.	Secretary (Agriculture)	- Chairman
ii.	Regional Director, Central Ground Water Board, Chennai	- Member
iii.	The Chief Engineer, PWD, Puducherry	- Member
iv.	Director of Agriculture & FW, Puducherry	- Member
v.	Member Secretary, PGWA, Puducherry	- Member
vi.	Member Secretary, Pondicherry Pollution Control Committee, Dept. of Science & Technology, & Environment, Puducherry	- Member
vii.	Hydrogeologist-I, SGWU&SC, Agriculture Dept, Puducherry	- Member Secretary

3. The functions of the State Level Committee among others are as follows:

(i) To re-assess annual ground water recharge of the state in accordance with the Ground Water Resources Estimation Methodology-2015.

(ii) To estimate the status of utilization of the annual extractable ground water resources.

(iii) To review measures outlined in the UT Water Policy-2016 pertaining to Ground Water.

4. The State Level Committee constituted in para 2 above will be in force until re-constituted and will attend to the re-assessment work periodically as and when the Ministry issues directions for re-assessment in future.

//BY ORDER//

(S. MURUGESAN)
UNDER SECRETARY TO GOVERNMENT (AGRICULTURE)

To
The Officers Concerned.

Copy to:

1. The Director of Agriculture & FW, Puducherry.
2. The Chief Engineer, PWD, Puducherry.
3. The Deputy Director (AE), SGWU&SC, Agriculture Dept, Puducherry.
4. The Member Secretary, PGWA, Puducherry.
5. The Hydrogeologist-I, SGWU&SC, Dept. of Agrculture & FW, Puducherry.
6. The OSD to Hon'ble Chief Minister, Puducherry.
7. The OSD to Hon'ble Agriculture Minister, Puducherry.
8. The Central Record Branch, Puducherry.
9. G.O/ Spare.

Minutes of the meeting of State Level committee on Re- assessment of dynamic ground water resources of U.T Puducherry as on March 2020 held on 26.03.2021 in the Conference hall of Directorate of Agriculture and Farmers Welfare

Present:
Tvl:

1. **Dr.B. Ramakichenin@ Balagandhi, Director of Agriculture &FW - Member**
2. **Dr. S. Subramanian, Scientist D, CGWB, SECR, Chennai - Member**
3. **Dr. N. Ramesh kumar, Scientist B, CGWB, SECR, Chennai - Special Invitee**
4. **A. Ravichandiran, Executive Engineer, PWD, Puducherry - Member**
5. **R.Sahaya Alfred, SSo, DSTE&E, Puducherry - Member**
6. **Dr. S.Pethaperumal, Member Secretary, PGWA, Puducherry - Member**
7. **J. Sivaramakrishnan, Scientist B, CGWB, SECR, Chennai – Special Invitee**
8. **S. Manohar, Hydrogeologist, SGWU, Dept. of Agriculture - Member Secretary.**

At the outset the Member Secretary of the State Level Committee, welcomed the Director of Agriculture and Farmers Welfare and other members of the State Level Committee, the scientist from CGWB, Chennai and explained the objective of the meeting i.e. the Dynamic Ground Water Resources as on March 2020 for the Union Territory of Puducherry.

The Member Secretary explained and presented the Dynamic Ground Water Resources of the U.T. of Puducherry to the Committee members in guidance with the Scientist of CGWB, Chennai. The Dynamic Ground water resources of the U.T. of Puducherry as on March 2020 is as follows:

The present ground water report as on March 2020 reveals that the Ground Water Resources Re-Assessment, the Puducherry Region is categorized as critical (98.72%), Karaikal Region as Safe (20.5%) Mahe Region as safe (62.6%) and Yanam Region as Saline. During the discussion, the representative from PWD asked the reason for the reduce in stage of development of ground water in Puducherry region. The Member Secretary of this committee appraised that, out of 6813 total numbers of tube wells in Puducherry region, 5230 number of shallow tube wells were changed over into deeper aquifer due to poor quality and the gradual decrease in the stage of development over the years is attributed to increase in recharge, measures taken up by the State Government to improve the ground water resource by artificial recharge measures viz., renovation of tanks, village ponds with recharge shafts, construction of check dams with recharge shafts and construction roof top of rain water harvesting structures in Government, industrial, institutional and Commercial buildings and also due to the reduction in extraction of water from agricultural tube wells due to urbanization.

After detailed discussion, the State Level Committee approved the "Dynamic Ground Water Resources Re-assessment as on March 2020" of the U.T. of Puducherry unanimously. The ground water re-assessment was prepared and jointly assessed by CGWB, Government of India, South Eastern Coastal Region, Chennai and State Ground Water Unit, Department of Agriculture & Farmers Welfare, U.T. of Puducherry.

The Executive Engineer, PWD, Puducherry, representative of Chief Engineer, PWD, Puducherry and the representative from the Department of Science and Technology and Environment, Puducherry, has expressed that their department does not allow water based industries in Puducherry and the department has also implemented the water management works under Climate Change Programme to desilt the tanks and village ponds and also told that the discharge from the industries are constantly monitored to prevent ground water pollution and the industries are issued license with one of the condition that to use the recycled water for gardening and toilet flush.

At the conclusion of the meeting the Member Secretary put forth the following recommendations for better water resource management.

- The farmers may be advised to use the water available in the tanks for irrigation activities to minimize the drawal of water from the tube wells during monsoon seasons while the water available in the tanks. It will reduce the load on ground water.
- The farmers may be advised to switch over the alternate crops other than the water intensive crops such as pulses during summer seasons.
- The Public Works Department prepare a master plan for setting up of surface water pumping stations on the major tanks to provide drinking water supply to the nearby villages during monsoon seasons when water available in the tanks.
- To control and regulate the extraction of Groundwater "The Pondicherry Groundwater (Control and Regulation) Act 2004 should be strictly enforced.
- To conserve water, subsidy assistance is extended to farmers for laying of underground pipeline to convey irrigation water without any loss and also for installation of drip/sprinkler irrigation systems should be continued.
- More Rainwater harvesting structures are provided in most of the Government buildings and instruction were given to industries and educational institutions to construct RWH structures and made it mandatory.
- The scheme of desilting of Village ponds and tanks to increase the water holding capacity and providing recharge shafts should be continued.
- To conserve water Precision farming scheme should be continued
- Bed dams across the rivers, effectively impound runoff water may be increased in numbers.
- Tail end regulators have been constructed in Karaikal region across the rivers which have effectively arrested the high tide water and recharging ground water may be explored further.

The committee unanimously agreed with the above recommendations and the members suggested that the above recommendations may be referred to the line departments for effective implementation.

The Member Secretary thanked the Committee members and Special invitees on participation, deliberations and effective suggestions.

A.S.P.S.RAVIPRAKASH, I.A.S.
SECRETARY TO GOVT.(AGRI.)
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CHAIRMAN- STATE LEVEL COMMITTEE