REPORT OF THE
GROUND WATER RESOURCE ESTIMATION COMMITTEE
(GEC-2015)

METHODOLOGY

Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India

NEW DELHI
October, 2017

FOREWORD

Ground water is an important source to meet the water requirements of various sectors like irrigation, domestic and industries. Groundwater usage if left unregulated may lead to serious inter-sectoral conflicts. Hence growth in both agriculture and industry is impingent on how India is able to manage her groundwater resources, particularly the aquifers in different parts of the country. The sustainable development of ground water resource requires precise quantitative assessment based on reasonably valid scientific principles. The fundamental basis for good ground water management is a clear understanding of aquifers, and the status of ground water accumulation and movement in these aquifers. The Ground Water Estimation Committee- 1997 has been the basis of ground water assessment in the country for last two decades. The ground water development programme implemented in the country was also guided by ground water resource availability worked out using this methodology. The experience gained in last more than one decade of employing this methodology supplemented by a number of research and pilot project studies has brought to focus the need to update this methodology of ground water resource assessment. The National Water Policy also enunciates periodic assessment of ground water potential on scientific basis. The Ministry of Water Resources, Govt. of India, therefore, constituted a committee consisting of experts in the field of ground water to recommend a revised methodology. This report is the final outcome of the recommendations of the Committee. The revised methodology as recommended has incorporated number of changes compared to the recommendations of Ground Water Estimation Committee - 1997.

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment to which demarcation of lateral as well as vertical extent and disposition of different aquifers is pre-requisite. However, it is recommended that ground water resources may be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

It also recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. Keeping in view of the rapid change in ground water extraction, GEC-2015 recommends resources estimation once in every three years. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride and arsenic.

In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for ‘ground water resources’ in hilly areas.

This report is the ultimate culmination of the efforts of the members of the committee and other experts in the field of ground water who have made significant contribution in revising this methodology. The group to draft the report of this committee has done a laudable job in not only preparing the draft report for discussions of the committee members but has also finalised the same after modifications as desired by them. I would like to express my appreciation to Shri G.C. Pati, Member Secretary and Member, Central Ground Water Board who with his untiring efforts and significant contributions has ably assisted the committee in preparing this report. It is hoped that the recommendations of the committee would be followed by different states for reassessing the ground water resources on realistic basis.

30/4/2012

Akhil Kumar

Joint Secretary (A & GW), MoWR, RD & GR &

Chairman, Central Ground Water Board

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INTRODUCTION

1.1 PREAMBLE

Ground Water is the backbone of India's agriculture and drinking water security in urban and rural areas. Nearly 90% of rural domestic water use is based on groundwater while 70% of water used in agriculture is pumped from aquifers. Increasing evidence points to the fact that 50% of urban water usage is groundwater. Groundwater is also important for the industrial sector in a large measure and if left unregulated may lead to serious inter-sectoral conflicts. Hence growth in both agriculture and industry is impingent on how India is able to manage her groundwater resources, particularly the aquifers in different parts of the country. A serious groundwater crisis prevails currently in India due to excessive over-extraction and groundwater contamination covering nearly 60 percent of all districts in India and posing a risk to drinking water security of the population. In addition to over-extraction and biological and chemical contamination, excess groundwater and water logging is also a serious problem in many regions, impacting livelihood security of large sections of society. The acute problems relating to groundwater warrant a change in both the perspective on our aquifers as well as the approach in the use and management of groundwater resources. It is necessary to acknowledge the hydrogeological characteristics of groundwater and its integral link to land, vegetation and surface water resources and perceive it as a 'resource' rather than a 'source'.

Acknowledging the ubiquity of groundwater usage and its importance to all sections of society, it is necessary to recognize it as a common pool resource and adopt an aquifer-based approach to its management. The existing legal framework derived from common law principles and judicial interpretation that recognises private property rights over water is inappropriate for the emerging status, conflicts and dynamics of groundwater. It is imperative to recognise groundwater as a natural resource vital to life, livelihood and environment, and to change the existing legal status of groundwater. Respect for established fundamental rights and application of accepted norms and principles of environmental law is another key change needed to respond to the contemporary challenges. Most importantly, regulation and improvement of groundwater is inevitable to ensure safe and adequate drinking water for everyone and thereby for the realisation of the right to water. Given the highly decentralised way in which groundwater is being used, the regulatory and institutional framework need to apply the principle of decentralisation and participation effectively by replacing the existing centralised licensing mechanism. However, first and foremost, it is important to back the above-mentioned reforms in India's approach to managing aquifers with a more robust groundwater assessment methodology that is backed not only by data at finer granularity, but also by improved analysis and synthesis that will enable decisions that are in tune with the tenets of equitable, efficient and sustainable management of our aquifers.

The primary basis for classification of assessment units (largely administrative units – blocks/talukas/mandals/ firkas, and in some cases hydrological units - watersheds) into safe, semi-critical, critical and overexploited categories is the relationship between pumping and annual replenishment. However, the status of ground water resources in India, presents only a part of a more complete picture. This is because the problems surrounding ground water overuse are not just a matter of the share of pumping to the annual replenishment. The relationship between these two important parameters is complex and depends upon the "aquifers" from which ground water is tapped by wells, tube wells and bore wells; and, in many cases, which supply water to springs. The fundamental basis for good ground water management is a clear understanding of aquifers, and the status of ground water accumulation and movement in these aquifers.

Understanding aquifers is primarily based on a proper understanding of the geology of an area– rock types and rock structure (the hydrogeological setting). The geological diversity in India makes understanding aquifers challenging, but all the more important because local conditions are important in determining approaches to managing ground water resources. Moreover, these local conditions also define the implications of ground water overuse, droughts, floods etc. on how drinking water security is endangered, both in the short and the long terms. Much of the purpose of the ground water assessment in the country has revolved around the estimation of potential of ground water resources. Given the seriousness of ground water related problems, the estimation of ground water potential is no longer restricted to finding ground water but it also involves understanding aquifers. Many of the states have moved forward in formulating and legislating Ground water Acts. Proactive implementation of such legislation, in combination with community-based, participatory forms of management would require more accurate assessment of ground water resources. The revision of methodology will enable integration of ground water legislation and participatory ground water management.

Shift from a ground water assessment to an 'aquifer' based ground water assessment has many advantages. First and foremost, it is linked to the National Aquifer Mapping Programme (NAQUIM) taken up by Central Ground Water Board during XII Five Year Plan. Though, achieving an aquifer-wise assessment for the entire country in the next few assessments is difficult, but keeping that as a goal will enable significant improvement in the current assessment. Improvement is envisaged on the following counts:

- Data and data-base used for the assessment
- Estimation methods, including the use of simple algorithms and models
- Comprehensiveness and granularity of data used in the assessment

1.2 COMPOSITION OF THE COMMITTEE

With the above background in view, the Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India, constituted a committee headed by Chairman, CGWB to review and revise the Ground Water Resource Estimation Methodology 1997 (GEC-97) and to look into related issues (Annexure I). The committee consisted of the following members and special invitees:

1	The Chairman, Central Ground Water Board	Chairman
2	The Joint Secretary (WSM), Ministry of Rural Development, Government of India, New Delhi.	Member
3	The General Manager, National Bank for Agriculture, & Rural Development(NABARD), Sterling Centre, Shivsagar Estate, Dr. Annie Besant Road, PostBoxNo.6552,Mumbai-400018	Member
4	The Dy. Director General, Geological Survey of India, CGPB Secretariat, Geological Survey of India, Pushpa Bhawan, A-Block, 2nd Floor, Madangir Road, New Delhi – 110062.	Member
5	The Director, State Water Investigation Directorate, Government of West Bengal, Sech. Bhawan (3rd Floor),Salt Lake, Kolkata – 700 091.	Member
6	The Chief Engineer (PWD), State Ground and Surface Water Resources Data Centre, Water, Government of Tamil Nadu,IWS Campus, Tharamani, Chennai – 600 113.	Member
7	Superintending Geohydrologist, Government of Madhya Pradesh, Ground Water Survey Circle, Bhopal(MP).	Member
8	The Managing Director, Gujarat Water Resources Development Corporation Ltd., Government of Gujarat, Sector-10 A, Near BijBhawan, Gandhinagar – 382043.	Member
9	The Director, State Ground Water Department, Government of Andhra Pradesh, B.R.K.R. complex, 7th and 8th Floor, B-Block, Tank Bund Road, Hyderabad – 500063.	Member
10	The Director, Groundwater Survey and Development Agency, Government of Maharashtra, Bhujal Bhawan, Shivaji Nagar, Pune – 411 005.	Member

11	The Director, Water Resources & Environment Directorate, Government of Punjab, SCO- 32-34, Sector-17C Chandigarh.- 160017	Member
12	The Director, UP Ground Water Department, Government of Uttar Pradesh,9th Floor, Indira Bhavan, Ashok Marg, Lucknow – 226 001.	Member
13	Member(TT&WQ), CGWB, NH-IV, Faridabad	Member Secretary

Special Invitees:

1	The Commissioner (SP), Government of India, Ministry of Water Resources, Krishi Bhawan, NewDelhi-110001.	Member
2	The Head, Ground Water Hydrology Division, National Institute of Hydrology, Jalvigyan Bhawan, Roorkee - 247667	Member
3	Professor Dr. N. J. Raju, School of Environmental Sciences, Jawahalal University, New Delhi	Member
4	Prof.Dr. A.K. Gosain, Department of Civil Engineering, IIT Delhi	Member
5	Dr. S. K. Srivastav, IIRS, Dept. of Space, Govt. of India 4, Kalidas Road, Dehradun - 248 001 (India)	Member
6	Dr. Himanshu Kulkarni, Advanced Centre for Water resources Development And Management, Pune, Maharashtra	Member
7	The Member(SAM), Central Ground Water Board, NH-IV, Faridabad	Member
4	The Member (SM&L) and Member Secretary, CGWA, R.K. Puram, New Delhi	Member

Shri Rana Chatterjee, Scientist D will assist the committee

1.3 TERMS OF REFERENCE

The terms of reference of this Committee are as follows:

1. Firming up/updating various parameters and their values currently used in the assessment of ground water resources based on the scientific work carried out by various organizations.
2. To look into the details of the methodology recommended by Ground Water Estimation Committee (1997) and to suggest aspects which call for a revision. The Committee may, if consider necessary, update the existing or recommend a new methodology for the assessment of ground water resources in different hydrogeological situations and climatic zones.
3. To recommend the smallest assessment unit for assessment of ground water resources based on hydrogeological/hydrological and/or administrative division.
4. To recommend a methodology for assessment of ground water resource in urban areas/specific areas.
5. Suggest alternative approaches for real time assessment of ground water resources.
6. Committee should suggest modality and methodology for incorporating quality consideration in assessment of ground water resources.

7. Review and recommend methodology for assessment of Total Ground Water Availability.
8. Any other aspects relevant to the terms referred to above.

1.4 PROCEEDINGS OF THE COMMITTEE

After the constitution of the Committee, views on ground water estimation methodology were sought from the State Ground water Departments, Scientific and research organizations dealing with ground water, Universities, NABARD, and Ground water experts. Based on these views an Approach Paper on "Revision of Ground Water Estimation Methodology" was prepared for consideration of the Committee. The first meeting of the Committee was held on 10.02.2015 under the Chairmanship of Shri K.C.Naik, Member (TT & WQ), CGWB. Minutes of the meeting are enclosed in **Annexure II**. After reviewing the Approach Paper, the Committee decided to constitute three sub groups each headed by a Convenor and assisted by a Resource Person to facilitate working of the committee and timely completion of the terms of references of the committee. The deliverables of the subgroups are as follows:

(i) Sub-Group I - Refinement in the Ground Water Assessment Methodology

(ii) Sub-Group II - Database used for Ground Water Resources Estimation

(iii) Sub-Group-III - Alternative approach for Assessment Involving Advanced Technology

The sub committees consisted of the following members:

Sub-Group I - Refinement in the Ground Water Assessment Methodology

Dr. Himanshu Kulkarni, Director, Advanced Center for Water Resources Development and Management (ACWADAM), Pune	Convener
Sh. E. Sampath Kumar, Member (SM&L), CGWB, New Delhi	Member
DR. N.J. Raju, Professor, School of Environmental Science, JNU, New Delhi	Member
Dr. K. Venugopal, Director, AP Ground Water Department	Member
Sh. P.S. Bhogal, Director, Water Resources, Punjab	Member
Sh. S.K. Sahni, Joint Director, Ground Water Department, UP	Member
Sh. Rana Chatterjee, Scientist D, CGWB, New Delhi	Resource Person

Sub-Group II - Database used for Ground Water Resources Estimation

Dr. A.R. Khan, Deputy General Manager, NABARD	Convener
Dr. Dipankar Saha, Member(RGI), CGWB	Member
Dr. S.K. Srivastava, Group Head, Remote Sensing & Geoinformatics Group, IIRS, Dehradun	Member
DDG & National Mission Head II, Geological Survey of India, Maharashtra	Member
Shri Vimal Chaurasia, SE, Ground Water Survey Circle, Madhya Pradesh, Bhopal	Member
Dr S. Suresh, Scientist D, CGWB, Faridabad	Member

Shri A.V.S.S. Anand, Scientist C, RGNGWTRI, CGWB, Raipur.	Resource Person

Sub-Group-III - Alternative approach for Assessment Involving Advanced Technology

Dr. A.K. Gosain, Professor, IIT, Delhi	Convener
Shri. K.C. Naik, Member (SAM), CGWB, Faridabad	Member
Dr. N.C. Ghosh, Scientist 'G' and Head, Groundwater hydrology division, NIH, Roorkee	Member
Shri. Vivek Kapadia, MD, GWRDC, Govt. of Gujarat	Member
Shri. V. Shanmugan, Chief Engineer, SG&SWRDC, Tamil Nadu	Member
Shri. S. K. Sinha, Scientist 'D', CGWB, Faridabad	Member
Shri. R.K. Ray, Scientist 'C', CGWB, Faridabad	Resource Person

The second meeting exclusively for the sub group members was convened on 03.07.2015 under the Chairmanship of Shri K.B.Biswas Chairman, CGWB, Minutes of the meeting are enclosed in **Annexure III**. During the meeting, the reports submitted by the three Sub Groups were discussed and a few modifications were suggested. Another meeting of the committee to review and revise GEC 97 Methodology was convened on 18.09.2015. During the meeting final reports of the Sub Groups were approved. A drafting committee headed by Shri G.C. Pati, Member (TT & WQ), CGWB was constituted for compilation of the final report. The Drafting Committee consisted of the following members:

Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad

Dr.B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad

Shri A.V.S.S. Anand, Scientist-D, Central Ground Water Board, NGWTRI, Raipur.

Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.

Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

The group finalised its report and the draft report was circulated to all the members of the Committee for their views. During the fourth meeting of the committee, held on 03-12-2015 under the Chairmanship of Shri K.B. Biswas, Chairman, CGWB, the draft report of "Ground Water Resource Estimation Committee - 2015 (GEC 2015) was discussed in detail. The views expressed by the members for revised methodology were considered and necessary modifications were made and report of the Committee was finalised. The minutes of the meeting are enclosed as Annexure IV.

As decided in the meeting held on 09.02.2016 at New Delhi on Revision of Ground water estimation Methodology-97, a workshop on "Ground Water Resource Estimation Methodology - 2015" was held on 24th January 2017 at CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag. The recommendations have been suitably incorporated in the present report.

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2

NATIONAL SCENARIO OF GROUND WATER

2.1 HYDROGEOLOGICAL SETUP

India is a vast country with varied hydrogeological situations resulting from diversified geological, climatological and topographic setups. The rock formations, ranging in age from Archaean to Recent, control occurrence and movement of ground water, widely vary in composition and structure. Physiography varies from rugged mountainous terrains of Himalayas, Eastern and Western Ghats and Deccan plateau to the flat alluvial plains of the river valleys and coastal tracts, and the aeolian deserts in western part.

Based on ground water bearing properties the geological formations of the country are broadly classified into following two categories.

1. **Porous rock formations**

(a) Unconsolidated formations.

(b) Semi - consolidated formations.

2. **Hard rock/consolidated formations**

2.2 AQUIFER SYSTEMS OF INDIA

The various rock formations with distinctive hydrogeological characteristics act as different aquifer systems of various dimensions. The various major rock formations of India can be broadly categorized in to 14 Principal aquifer Systems based on their broad hydrogeological properties. A brief account of the Principal Aquifer Systems is discussed in the following paragraphs. The principal Aquifer systems as identified by Central Ground Water Board are shown in **Fig 1.**The Principal Aquifers are further divided into 42 Major Aquifers(**Fig 2)**depending on their distinctive hydrological characteristics and their spatial distribution.The details are given as **Table 1.**

2.2.1 Alluvial Aquifers

The unconsolidated Quaternary sediments comprising Recent Alluvium, Older Alluvium, Aeolian and Coastal Alluvium along the eastern coast of India, by and large forms the major Alluvial Aquifers. These sediments are essentially composed of clays, silts, sands, pebbles, Kankar etc.

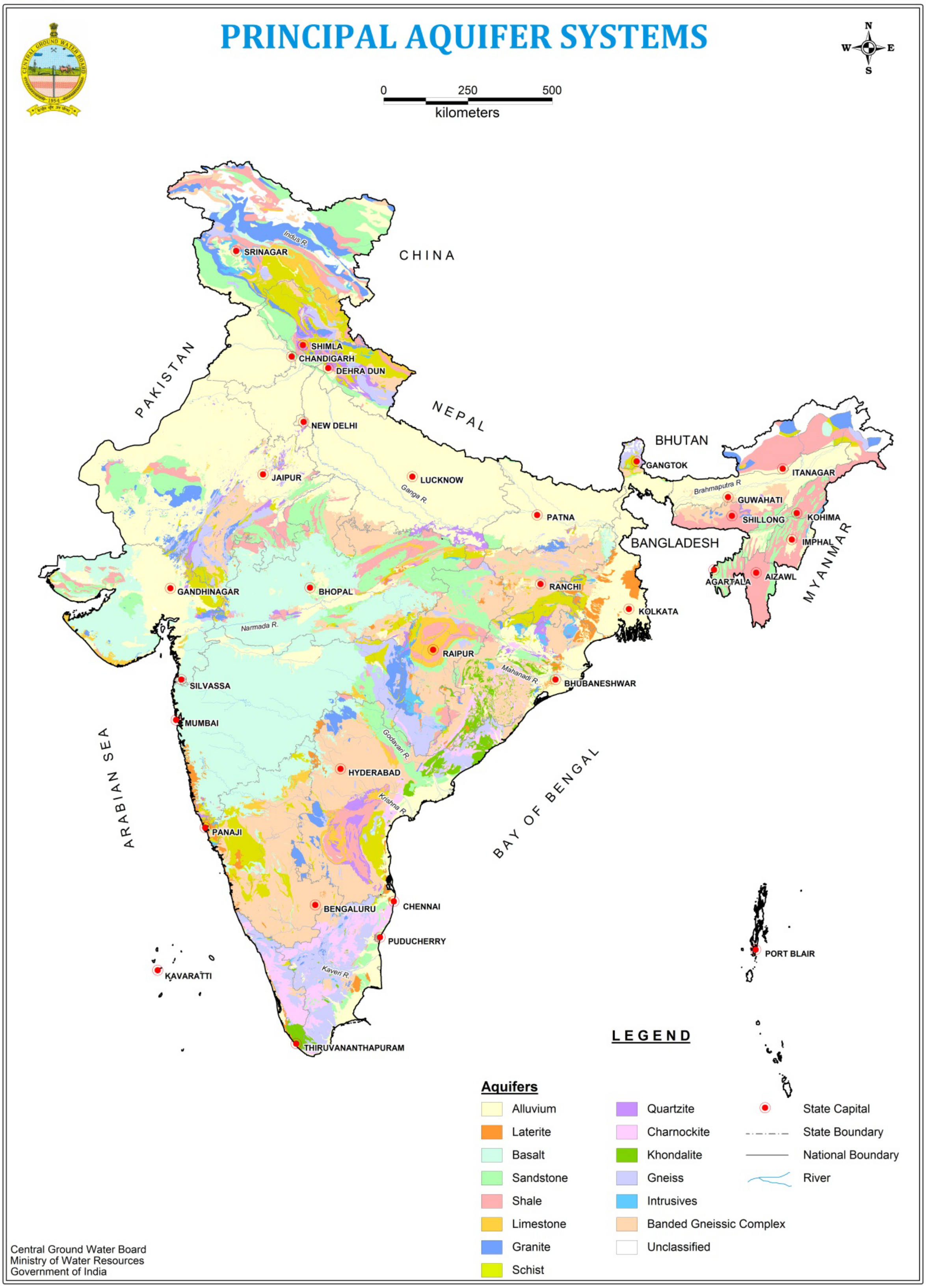

Fig 1. Principal Aquifer Systems of India

Alluvial Aquifers are the most significant ground water reservoirs which support large scale and extensive development of the country. The Indo-Ganga-Brahmaputra basin having distinctive hydrogeological environment and ground water regime conditions have enormous fresh ground water potential. Bestowed with high incidence of rainfall and underlain by a thick sequence of porous sediments, the alluvial aquifers in Indo-Ganga-Brahmaputra basin get replenished every year and are being used extensively. In addition to the Annual Replenishable Ground Water Resources in the zone of Water Level Fluctuation (Dynamic Ground Water Resource), a huge ground water reserve occurs below the zone of fluctuation in unconfined aquifers and as well as in the deeper confined aquifers. The coastal aquifers though have replenishable ground water resources show wide variation in the water quality, both laterally and vertically, thus imposing quality constraints for ground water development.

2.2.2 Laterite Aquifer

Laterites are formed due toleaching (chemical weathering) of parent sedimentary rocks (sandstones, clays, limestones); metamorphic rocks (schists, gneisses, migmatites) and igneous rocks (granites, basalts, gabbros, peridotites) under hot and humid climatic conditions. Laterites rich in iron and aluminium contents are the most wide spread and extensively developed aquifer especially in the peninsular states of India. Laterite forms potential aquifers along valleys and topographic lows where thick saturated zone sustain large diameter open wells for domestic and irrigation use.

2.2.3 Sand Stone, Shale Aquifer

The sand stone and shale generally belong to the group of rocks ranging in age from Carboniferous to Mio-Pliocene forms this aquifer. The terrestrial freshwater deposits belonging to Gondwana System and the Tertiary deposits along the west and east coast of the peninsular region are included under this category. The Gondwana sandstones form highly potential aquifers, locally. Elsewhere, they have moderate potential and in places they yield meagre supplies. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers.

2.2.4 Limestone Aquifer

The consolidated sedimentary rocks include carbonate rocks such as limestone, dolomite and marble. Limestone is the dominating rock type among the carbonate rocks, which is widely distributed in the country. In the carbonate rocks the secondary porosity like fractures and solution cavities form the aquifer. Consolidated sedimentary rocks of Cuddapah and Vindhyan subgroups and their equivalents consist of limestone/dolomites apart from other major litho-units such as conglomerates, sandstones, shale, slates and quartzite form this principal aquifer.

2.2.5 Basalt aquifers

Basalt is the basic volcanic rock which forms alternate layers of compact and vesicular beds of lava flows as seen in the Deccan trap area. The ground water occurrence in the basalts are controlled by nature and extent of weathering, presence of vesicles and lava tubes, thickness, number of flows and the nature of inter-trappean layers . The basalts have usually medium to low permeability. Ground water occurrence in the Deccan Traps is controlled by the contrasting water bearing properties of different flow units, thus, resulted in multiple aquifer system, at places. The water bearing zones are the weathered and fractured zones.

2.2.6 Crystalline Aquifers

The crystalline hard rock aquifers such as granite, gneisses and high grade metamorphic rocks viz. charnockite and khondalite constitute moderate to good repository of ground water. Hard rocks generally neither receive nor transmit water, due to negligible or limited primary porosity. However, these may form good aquifers if weathered and/or have good secondary porosity in the form of faults, fractures, joints and bedding planes The crystalline rocks also form the aquifers with weathered zone or the fracture system. The weathered mantle cover and associated secondary porosity do not occur uniformly, but are rather localised phenomena. The weathered zone is underlain by semi-weathered saprolite zone followed by fractured and massive rock.

In these aquifers, ground water occurs under phreatic condition in the weathered mantle cover and under semi-confined to confined state in underlying fissured, fractured, and jointed hard rock. The volume of ground water stored under semi-confined condition within the body of the hard rock is much lower than the storage in the overlying phreatic aquifer which is often much greater. Hydraulically connected fissures and fractures underlying weathered mantle cover generally serves as a permeable conduit feeding the deeper wells. Ground water flow rarely occurs across the topographical water divides so far as the unconfined aquifer is concerned and each basin or sub-basin can be treated as a separate hydro geological unit for planning the development of ground water resources.

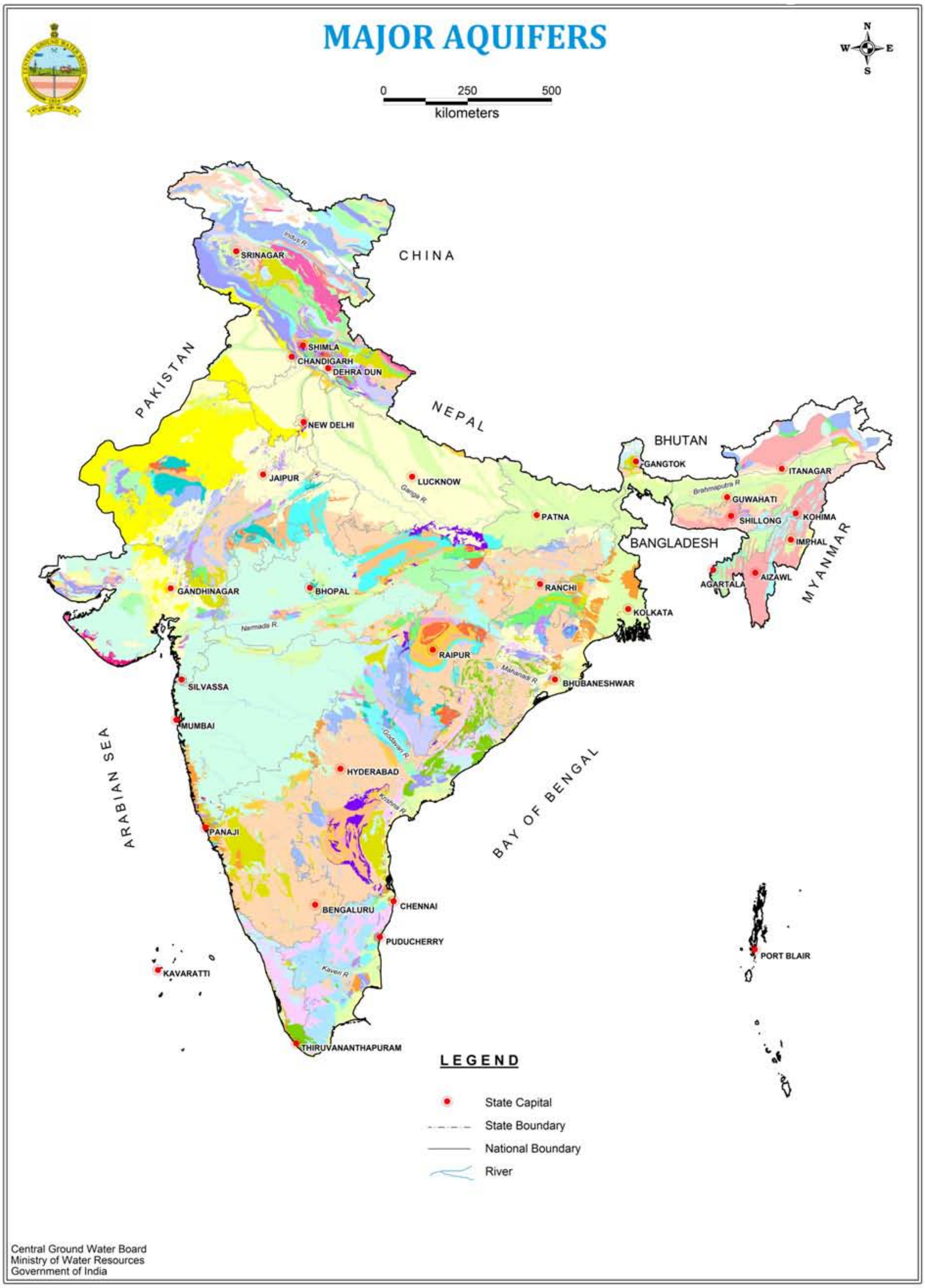

Fig 2. Major Aquifer Systems of India

Table 1. Description of Major Aquifer Systems of India

S. No	Principal Aquifer Systems		Yield (m3/ day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
1	AL	Alluvium (945753 sq km) (29.82 %)	10-6500	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	339298	Quaternary
2				AL02	Pebble / Gravel/ Bazada/ Kandi	5203	Quaternary
3				AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	407490	Quaternary
4				AL04	Aeolian Alluvium (Silt/ Sand)	149208	Quaternary
5				AL05	Coastal Alluvium (Sand/Silt/Clay)	40661	Quaternary
6				AL06	Valley Fills	3864	Quaternary
7				AL07	Glacial Deposits	31	Quaternary
8	LT	Laterite (40925 sq km) (1.29 %)	5 - 6000	LT01	Laterite / Ferruginous concretions	40926	Quaternary
9	BS	Basalt (512302 sq km) (16.15 %)	1-480	BS01	Basic Rocks (Basalt)	512290	Mesozoic to Cenozoic
10				BS02	Ultra-Basic	12	Mesozoic to Cenozoic
11	ST	Sandstone (260415 sqkm) (8.21 %)	5 - 3700	ST01	Sandstone/Conglomerate	50026	Upper Palaeozoic to Cenozoic
12				ST02	Sandstone with Shale	75355	Upper Palaeozoic to Cenozoic
13				ST03	Sandstone with Shale/ Coal beds	37720	Upper Palaeozoic to Cenozoic
14				ST04	Sandstone with Clay	21540	Upper Palaeozoic to Cenozoic
15				ST05	Sandstone/Conglomerate	56354	Proterozoic to Cenozoic
16				ST06	Sandstone with Shale	19420	Proterozoic to Cenozoic
17	SH	Shale (225397 sqkm) (7.11 %)	8 -2900	SH01	Shale with Limestone	3784	Upper Palaeozoic to Cenozoic
18				SH02	Shale with Sandstone	87771	Upper Palaeozoic to Cenozoic
19				SH03	Shale, Limestone and Sandstone	45539	Upper Palaeozoic to Cenozoic
20				SH04	Shale	5938	Upper Palaeozoic to Cenozoic
21				SH05	Shale/Shale with Sandstone	64265	Proterozoic to Cenozoic

S. No	Principal Aquifer Systems		Yield (m3/ day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
22				SH06	Shale with Limestone	18100	Proterozoic to Cenozoic
23	LS	Limestone (62898 sqkm) (1.98 %)	4 - 2100	LS01	Miliolitic Limestone	2946	Quaternary
24				LS02	Limestone / Dolomite	19747	Upper Palaeozoic to Cenozoic
25				LS03	Limestone/Dolomite	34708	Proterozoic
26				LS04	Limestone with Shale	5499	Proterozoic
27				LS05	Marble	995	Azoic to Proterozoic
28	GR	Granite (100991 sqkm) (3.18 %)	10-1440	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)	133	Mesozoic to Cenozoic
29				GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.)	100858	Proterozoic to Cenozoic
30	SC	Schist (140934.90 sqkm) (4.44%)	3-550	SC01	Schist	93026	Azoic to Proterozoic
31				SC02	Phyllite	31589	Azoic to Proterozoic
32				SC03	Slate	16321	Azoic to Proterozoic
33	QZ	Quartzite (46904 sqkm) (1.48%)	2 - 400	QZ01	Quartzite	20830	Proterozoic to Cenozoic
34				QZ02	Quartzite	26074	Azoic to Proterozoic
35	CK	Charnockite (76359 sq km) (2.41%)	1 - 3000	CK01	Charnockite	76360	Azoic
36	KH	Khondalite (32913 sq km) (1.04 %)	20-1500	KH01	Khondalite, Granulite	32914	Azoic
37	BG	Banded Gneissic Complex (478382 sq km) (15.09 %)	2 - 3600	BG01	Banded Gneissic Complex	478383	Azoic
38	GN	Gneiss (158753 sq km) (5.01 %)	10 - 2500	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic	59260	Azoic to Proterozoic
39				GN02	Gneiss	43266	Azoic to Proterozoic
40				GN03	Migmatitic Gneiss	56228	Azoic
41	IN	Intrusive (19895 sqkm) (0.63 %)	Low Yield	IN01	Basic Rocks (Dolerite, Anorthosite etc.)	11167	Proterozoic to Cenozoic
42				IN02	Ultra-Basics (Epidiorite, Granophyre etc.)	8729	Proterozoic to Cenozoic

2.3 GROUND WATER QUALITY

Ground water quality data generated in various scientific studies and the data of National Quality Monitoring Stations of Central Ground Water Board indicate that the ground water in major part of the country is potable.However,some parts of various states arecontaminated by inland & coastal Salinity, Arsenic, Fluoride, Iron and Nitrate.Higher concentration of arsenic in ground water is generally geogenic and partlyoccur due to anthropogenic activities like application of fertilizers, burning of coal, leaching from coal-ash tailings and from mining activity.Arsenicin ground water beyond the permissible limit of 10 ppb has been reported from 10 states namely West Bengal, Bihar, Uttar Pradesh, Assam, Manipur, Jharkhand, Punjab, Haryana, Chhattisgarh and Karnataka. Mostly the Indo-Gangetic alluvium and the Brahmaputra alluvium have higher concentration of arsenic in localized pockets. Fluoride contamination (more than 1.5 mg/l)in ground water is widely prevalent in different parts of India mostly in the states of Telangana, Andhra Pradesh, Rajasthan, Maharashtra, Madhya Pradesh, West Bengal, Bihar, Odisha, Punjab, Haryana, Tamil Nadu, Uttar Pradesh, Karnataka and Gujarat. Some parts of Chhattisgarh, Delhi and Kerala are also affected by Fluoride contamination. Salinity in ground water is found mainly in western, north western and southern parts of India. Salinity has been observed in all major aquifer systems. Inland salinity caused by high sulphate in ground water has also been reported from some parts of the country. Besides salinity originated from saline water intrusion in coastal areas due to over pumping of ground water in various scales has been reported in the states of Tamil Nadu, West Bengal, Odisha, Gujarat and Andhra Pradesh.

High levels of iron in ground water (more than 1 mg/l) have been reported from many states. Pollution due to human and animal wastes and fertilizer application has resulted in higher levels of nitrate and potassium in ground water in some parts of the country. Ground water pollution due to indiscriminate disposal of industrial effluents has been observed as localised contamination in major industrial zones.

2.4 GROUND WATER RESOURCE POTENTIAL

The dynamic ground water resources are also known as the Annual Replenishable Ground Water Resources since it gets replenished/ recharged every year. The Annual Replenishable Ground Water Resource for the entire country has been assessed as 433 billion cubic meter (bcm). The major source of ground water recharge is the monsoon rainfall. About 58% of the annual replenishable resources i.e. 253 bcm are contributed by monsoon rainfall recharge. The overall contribution of rainfall to country’s Annual Replenishable Ground

Water Resource is 68% and the share of other sources viz. canal seepage, return flow from irrigation, recharge from tanks, ponds, and water conservations structures taken together is 32%. The contribution from other sources such as canal seepage , return flow from irrigation, seepage from water bodies etc. in Annual Replenishable Ground Water Resource is more than of 33% in the states of Andhra Pradesh, Delhi, Haryana, Gujarat, Goa, Jammu & Kashmir, Karnataka and Punjab,

In spite of the national scenario that the availability of ground water being favourable, there are pockets in certain areas in the country that face scarcity of water. This may happen due to non-uniform ground water development, being quite intensive in some areas resulting in over-exploitation leading to fall in water levels and even salinity ingress in coastal areas. The declining water levels have resulted in failure of wells or deepening of extraction structures leading to additional burden on the farmers.

Out of 6607 number of assessed administrative units (Blocks/ Taluks/ Mandals/ Districts), 1071 units are Over-exploited, 217 units are Critical, 697 units are Semi-critical, and 4530 units are Safe(Ground Water Assessment, 2011). Apart from these, there are 92 assessment units which are completely saline. Number of Over-exploited and Critical administrative units are significantly higher (more than 15% of the total assessed units) in Delhi, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan,Tamil Nadu and Uttar Pradesh and also the Union Territories of Daman& Diu and Puducherry.

2.5 GROUND WATER DEVELOPMENT SCENARIO

During the past four-five decades, there has been a phenomenal increase in the growth of ground water abstraction structures due to implementation of technically viable schemes for development of the resource, backed by liberal funding from institutional finance agencies, improvement in availability of electric power and diesel, good quality seeds, fertilisers, government subsidies, etc. The net irrigated area tripled from 21 million hectares in 1950–51 to 63 million hectares in 2008–09; the share of ground water irrigation through wells rose substantially from 28 per cent to 61 per cent. The main contribution in this came from rapid growth in tube well irrigation, the share of which rose from zero in 1950–51 to over 41 per cent by 2008–09. This shows that ground water irrigation with the advent of tube well irrigation technology has made a huge contribution to irrigation growth in India. This could also be assessed from the facts that during the period 1951-92, the number of dug wells increased from 3.86 million to 10.12 million that of shallow tube wells from 3000 to 5.38 million and public bore/tube wells from negligible to 68000. The number of electric pump sets has increased from negligible to 9.34 million and the diesel pump sets from 66,000 to about 4.59 million. Such a magnitude of ground water development requires realistic assessment of ground water resources to avoid any deleterious effects on ground water regime and to provide sustainability to the ground water development process.

2.6 NATIONAL WATER POLICY

The 'National Water Policy (2012) adopted by the Government of India regards water as a scarce natural resource, fundamental to life, livelihood, food security and sustainable development. It emphasizes that the efforts to develop, conserve, utilise and manage this resource have to be guided by national perspective. The concerns related to water are generally the skewed accessibility to safe water for drinking and other domestic needs, general perception that ground water is an individual's property rather than community resource, encroachment of river channels, blockage of recharge zones and inter regional disputes in sharing water etc. Safe water for drinking and sanitation should be considered as pre-emptive needs, followed by high priority allocation for other basic domestic needs including needs of animals, achieving food security, supporting sustenance agriculture and minimum eco-system needs. The National Water Policy enunciates the following guidelines for ground water in particular.

- The availability of water resources and its use by various sectors in various basins and states in the country need to be assessed scientifically and reviewed at periodic intervals, say every five years.
- Water is essential for sustenance of eco-system and therefore, minimum ecological needs should be given due consideration.
- The anticipated increase in variability in availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely soil moisture, ponds, ground water, small and large reservoirs and their combination.
- There is a need to map the aquifers so as to know the quantum and quality of ground water resources replenishable as well as non replenishable in the country.
- Quality conservation and improvement is very important for ground water since cleaning of it is very difficult.
- Declining ground water levels in over exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community based management of aquifers.

- Watershed development activities with ground water perspectives need to be taken up in a comprehensive manner to increase soil moisture, reduce sediment yield and increase overall land& water productivity.

The present action of revising the ground water estimation methodology is a sequel to the tenets of the National Water Policy for periodic reassessment of ground water potential on scientific basis.

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3

RECOMMENDATIONS OF THE EXISTINGMETHODOLOGY (GEC 1997)

3.1 REVIEW OF GROUND WATER RESOURCE ASSESSMENT METHODOLOGIES

Attempts have been made from time to time byvarious Working Groups/Committees/Task Force, constituted by Government of India to estimate the ground water resources of the country based on status of available data and in response to developmental needs. But, due to paucity of scientific data and incomplete understanding of the parameters involved in recharge and discharge processes, all these early estimations were tentative and at best approximation.In 1972, guidelines for an approximate evaluation of ground water potential was circulated by the Ministry of Agriculture, Government of India to all the State Governments and financial institutions. The guidelines recommended norms for ground water recharge from rainfall and from other sources.

The first attempt to estimate the ground water resources on a scientific basis was made in 1979. A High Level Committee, known as Ground Water Over Exploitation Committee was constituted by the then Agriculture Refinance and Development Corporation (ARDC). The committee was headed by the Chairman, CGWB and representatives from the state ground water organizations and financial institutionswere included as its members. This Committee recommended definite norms for ground water resources computations.

In the year 1982, Government of India constituted “Ground Water Estimation Committee” (GEC) with the members drawn from various organizations engaged in hydrogeological studies and ground water development. In 1984 this Committee, after reviewing the data collected by central and state agencies, research organisations, universities, etc. recommended the methods for ground water recharge estimation. This is popularly known as GEC 1984.This was the first methodology which dealt with the subject exhaustively and assessed the resources on a fool proof methodology. This methodology was in practice for next 12 years.

In the year 1996, Government of India again constituted "Ground Water Estimation Committee" (GEC) with the members taken from various organizations engaged in hydrogeological studies and ground water development. In 1997 this Committee, after reviewing the data collected by central and state agencies, research organisations, universities, etc. recommended the methods for ground water recharge estimation. This is popularly known as GEC 1997. The recommendations of this Committee are summarised in this chapter.

3.2 RECOMMENDATIONS OF GEC 1997

Two basic approaches recommended by the GEC - 1984,namely ground water level fluctuation method and rainfall infiltration factor method, still form the basis for ground water assessment. In GEC 1997 methodology, distinctions such as hard rock areas and alluvial areas, canal command areas and non-command areas and recharge in monsoon season and non-monsoon season, are kept in view. The resources are estimated based on the Ground water balance equation.

3.2.1 Unit for Ground Water Recharge Assessment

Watershed with well-defined hydrological boundaries is an appropriate hydrological unit for ground water resource estimation. In hard rock areas, the hydrogeological and hydrological units normally coincide, which may not be the case in alluvial areas where the aquifers traverse the basin boundaries. In hard rock areas which occupy about 2/3rd area of the country, assessment of ground water resources on watershed as a unit is more desirable. In many states where the development unit is either a block, taluka or a mandal, the ground water resources worked out on watershed as a unit, may be apportioned and presented finally on block/taluka/mandal-wise basis, for planning of development programmes. In case of alluvial areas where it is difficult to identify watershed considering the trans-boundary aquifer system, assessment of ground water potential on block/taluka/mandal-wise basis may prevail.

3.2.2 Delineation of Subareas in the Assessment Unit

GEC - 1997 recommends identifying hilly areas where slope is more than 20% as these areas are likely to contribute more to run off than to ground water recharge. Such hilly areas should be subtracted from the total geographical area of the unit. The areas where the quality of ground water is beyond the usable limits, should also be identified and handled separately.The remaining area need to be re-delineated as (a) Non-command areas which do not come under major/medium surface water irrigation schemes and (b) Command areas which come under major/medium surface water irrigation schemes.

3.2.3 Season-Wise Assessment of Ground Water Resources

Ground water recharge assessment is to be made separately for the non-command, command areas and poor ground water quality areas in the assessment unit. For each of these subareas, recharge in the monsoon season and non-monsoon season is to be estimated separately. For most parts of the country receiving the main rainfall from South west monsoon, the monsoon season would pertain to *kharif*period of cultivation. In areas, such as Tamil Nadu, where the primary monsoon season is the North east monsoon, the period of monsoon season should be suitably modified. For the purposes of recharge assessment using water level fluctuation method, the monsoon season may be taken as May/June to October/November for all areas, except those where the predominant rainfall is due to the North east monsoon. In areas where the predominant rainfall is due to North east monsoon, the period for recharge assessment may be based on pre-monsoon (October) to post monsoon (February) water level fluctuations.

3.2.4 Estimation of Ground Water Draft

Ground water draft is estimated for all the ground water uses viz. Domestic, Irrigation and Industrial. Domestic draft can be estimated based on well census method or requirement method. Irrigation draft can be estimated using well census method, cropping pattern method or power consumption method. Industrial draft can be estimated using well census method, power consumption method or requirement method. Sum of all these drafts is the Gross ground water draft.

3.2.5 Estimation of Ground Water Recharges

Ground water recharge due to rainfall is to be estimated using ground water level fluctuation method and rainfall infiltration factor method.

3.2.5.1 Ground water level fluctuation method

The water level fluctuation method is applied for the monsoon season to estimate the recharge using ground water balance equation. The ground water balance equation for the monsoon season is expressed as,

$$R_G - D_G - B + I_S + I = \Delta S$$

Where

R_G = gross recharge due to rainfall and other sources including recycled water

D_G = gross ground water draft

B = base flow into streams from the area

I_S = recharge from streams into ground water body

I = net ground water inflow into the area across the boundary (inflow - outflow)

ΔS = increase in ground water storage

In the above equation, if the area under consideration is a watershed, the net ground water inflow (I) may be taken as zero. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections. For the present ground water assessment as prescribed in these recommendations, the net inflow may be dropped. There are similar difficulties in estimating the base flow and recharge from streams in the above equation. Hence, it is recommended that the base flow and recharge from stream in the above equation may also be dropped.After deleting net inflow and base flow the equation is now rewritten as,

$$R = \Delta S + D_G = h \times Sy \times A + D_G$$

Where

R= Possible recharge, which is gross recharge minus the natural discharges in the area in the monsoon season (R_G - B + I +I_S)

h = rise in water level in the monsoon season

A = area for computation of recharge

S_y = specific yield

ΔS = increase in ground water storage

D_G = gross ground water draft

The recharge calculated from the above equation gives the available recharge from rainfall and other sources for the particular monsoon season. For non-command areas, the recharge from other sources may be recharge from recycled water from ground water irrigation, recharge from tanks and ponds and recharge from water conservation structures, The recharge from rainfall is given by,

$$R_{rf} = R - R_{gw} - R_{wc} - R_t = hxS_y \times A + D_G - R_{gw} - R_t - R_{wc}$$

Where

R_{rf} = recharge from rainfall

R_{gw} = recharge from ground water irrigation in the area

R_{wc} = recharge from water conservation structures

R_t = Recharge from tanks and ponds

In command areas there are two more components in recharge due to other sources viz. recharge due to canals and return flow from surface water irrigation. Hence the rainfall recharge can be estimated using the following formula.

$R_{rf} = h \times S_y \times A + D_G - R_c - R_{sw} - R_{gw} - R_t - R_{wc}$

Where,

R_{rf}= rainfall recharge

h = rise in water level in the monsoon season

S_y= specific yield

A = area for computation of recharge

D_G= gross ground water draft in the monsoon season

R_c= recharge due to seepage from canals

R_{sw}= recharge from surface water irrigation

R_{gw} = recharge from ground water irrigation

R_t= recharge from tanks and ponds

R_{wc} = recharge from water conservation structures

3.2.5.2. Estimation of normal rainfall recharge during monsoon season

The rainfall recharge obtained by using above equations provide the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall which in turn is obtained as the average of the monsoon season rainfall for the recent 30 to 50 years. The normalisation procedure requires that, a set of pairs of data on recharge and associated rainfall are first obtained. To eliminate the effects of drought or surplus years, it is recommended that the rainfall recharge during monsoon season is estimated not only for the current year for which assessment is being made, but also for at least four more preceding years.

Two possible methods are recommended for the normalisation procedure. The first method is based on a linear relationship between recharge and rainfall of the form,

R = a r

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:

$$R_{rf}(\text{normal}) = \frac{\sum_{i=1}^{N}\left[R_i \times \frac{r(\text{normal})}{r_i}\right]}{N}$$

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

R = ar + b

Where,

R = rainfall recharge

r = 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:

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2}$$

$$b = \frac{S_2 - aS_1}{N}$$

Where

N= No. of datasets and

$$S_1 = \sum_{i=1}^{N} r_i \quad S_2 = \sum_{i=1}^{N} R_i \quad S_3 = \sum_{i=1}^{N} r_i^2 \quad S_4 = \sum_{i=1}^{N} r_i R_i$$

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

R_{rf} (normal) = a x r(normal) + b

3.2.5.3 Rainfall Infiltration Factor Method

Recharge from rainfall in monsoon season can also be estimated based on the Rainfall Infiltration Factor method and is estimated using the following equation

R_{rf} = f x A x Normal rainfall in monsoon season

Where

f = rainfall infiltration factor

A = area for computation of recharge

3.2.5.4 Percent Deviation

After the estimation of rainfall recharge for normal monsoon season rainfall using the water table fluctuation method and rainfall infiltration factor method, Percent Deviation(PD) which is the difference between the two methods expressed as a percentage of the latter is computed as,

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

Where,

R_{rf} (normal, wtfm) = Rainfall recharge for normal monsoon season rainfall estimated by the water table 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 criteria given below:

If PD is greater than or equal to -20%, and less than or equal to +20%, Rrf (normal) is taken as the value estimated by the water table fluctuation method.

If PD is less than -20%, R_{rf} (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.

If PD is greater than +20%,R_{rf} (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

3.2.5.5 Recharge due to Other Sources

Recharge due to other sources constitute recharges from Canals, Applied Surface Water irrigation, Applied Ground Water Irrigation, Tanks& Ponds and Water Conservation Structures in Command areas. Whereas in Non-command areas only the recharge due to Applied Ground Water Irrigation, Tanks & Ponds and Water Conservation Structures are possible.

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

$$\mathbf{R_C = WA * SF * Days}$$

Where:

R_C= Recharge Due to Canals

WA=Wetted Area

SF= Seepage Factor

Days= Number of Canal Running Days.

3.2.5.5.2 Recharge due to Applied Surface Water Irrigation: Recharge due to applied surface water irrigation is estimated based on the following formula:

$$\mathbf{R_{SWI} = AD*Days*RFF}$$

Where:

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

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

3.2.5.5.3 Recharge due to Applied Ground Water Irrigation: Recharge due to applied ground water irrigation is estimated based on the following formula:

$$\mathbf{R_{GWI} = GD_I*RFF}$$

Where:

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

GD_I= Gross Ground Water Draft For Irrigation

RFF= Return Flow Factor

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

$$\mathbf{R_{TP} = AWSA*R \;\; *RF}$$

Where:

R_{TP} = Recharge due to Tanks & Ponds

AWSA= Average Water Spread Area

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

RF= Recharge Factor

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

$$\mathbf{R_{WCS} = GS*RF}$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage= Storage Capacity X No. of Fillings.

RF= Recharge Factor

3.2.5.6 Recharge during Monsoon Season

The sum of Normalized Monsoon Rainfall Recharge and the recharge due to other sources during monsoon season is the total recharge during Monsoon season.

3.2.5.7 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. The sum of Non-Monsoon Rainfall Recharge and the recharge due to other sources during non monsoon season is the total recharge during Non-Monsoon season.

3.2.5.8 Total Annual Ground Water Recharge

The sum of the recharge during monsoon season and Non monsoon season is the Total Annual Ground Water Recharge.

3.2.6 Unaccounted Natural Discharges

The Unaccounted Natural Discharges are estimated based on the method with which rainfall recharge is estimated during monsoon season. If the rainfall recharge is computed using water table fluctuation method,5% of the Total Annual Ground Water Recharge is taken as unaccounted Natural discharges else it is 10%of the Total Annual Ground Water Recharge.

3.2.7 Net Annual Ground Water Availability

The difference between total annual ground water recharge and the unaccounted natural discharges is the net annual ground water availability.

3.2.8 Stage of Ground Water Development

Stage of Ground Water Development is to be computed using the following formula.

$$Stage\ of\ Ground\ Water\ Development = \frac{\text{Existing gross ground water draft for all uses}}{\text{Net annual ground water availability}} \times 100$$

3.2.9 Ground Water Level Trends

GEC 1997Methodology links the categorization to Dual criteria: one is the Stage of Ground Water Development and the other is Ground water level trends. For each assessment sub unit the long term ground water level trends are to be determined for categorizing the assessment sub unit.

3.2.10 Categorization

Based on the dual criteria shown in the Table below the assessment sub unit is categorized. The original categorization provided by GEC 1997 is not complete hence GEC 2004 has modified the categorization and provided the following Table 2.

Table 2. CATEGORIZATION OF ASSESSMENT SUB UNITS AS PER GEC-2004.

Stage	Declining Pre-Monsoon Trend	Declining Post-Monsoon Trend	Category
<=70%	No	No	Safe
<=70%	No	Yes	To Be Reassessed
<=70%	Yes	No	To Be Reassessed
<=70%	Yes	Yes	To Be Reassessed
>70% and <=90%	No	No	Safe
>70% and <=90%	No	Yes	Semi-Critical
>70% and <=90%	Yes	No	Semi-Critical
>70% and <=90%	Yes	Yes	To Be Reassessed
>90% and <=100%	No	No	To Be Reassessed
>90% and <=100%	No	Yes	Semi-Critical
>90% and <=100%	Yes	No	Semi-Critical
>90% and <=100%	Yes	Yes	Critical
>100%	No	No	To Be Reassessed
>100%	No	Yes	Over-Exploited
>100%	Yes	No	Over-Exploited
>100%	Yes	Yes	Over-Exploited

3.2.11 Allocation for Future Domestic and Industrial Needs

Allocation is estimated based on the following formula for the future domestic and Industrial needs. $\mathbf{A = 22 * N * L_g}$

Where

A = Allocation for domestic and Industrial water Requirement in mm/year.

N = Projected Population density of the sub unit in thousands per square kilometer.

L_g= Fractional Load on ground water for domestic and industrial water supply (≤ 1.0)

3.2.12 Net Annual Ground Water Availability for Future Irrigation Use

The net Annual Ground Water availability for future irrigation use is computed by subtracting current Gross Ground Water draft for Irrigation and Future Allocation for Domestic and Industrial Needs from the Net Ground Water Availability.

3.2.13 Potential Resource Due to Shallow Water Table Areas

Potential Resource Due to Shallow Water Table areas is a onetime resource which is available in the aquifers above 5.0m bgl. This can be computed using the following formula.

$$\mathbf{PRWL = (5-DTW) * A * S_Y}$$

Where

PRWL = Potential Resource in Water Logged and Shallow Water Table Areas

DTW = Average Depth to Water Level

A = Area of the Water logged Zone

S_Y = Specific Yield in the zone upto 5.0m bgl.

3.2.14 Potential Resource in the Flood Prone Area

Potential Resource in the Flood Prone Area is a onetime resource which is available in the Flood Prone Areas only. This can be computed using the following formula.

$$\mathbf{PRFL = 1.4 * N * A/1000}$$

Where

PRFL = Potential Recharge in Flood Prone Areas

N = No of Days Water is Retained in the Area

A = Flood Prone Area

3.2.15 Static Ground Water Resources

Static Ground Water Resources of an area are the resources which remain available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. This can be computed using the following formula.

$$\mathbf{SGWR = A * (Z2 - Z_1) * S_Y}$$

Where

SGWR = Static Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Maximum extension of Zone of Water Table Fluctuation

S_Y = Specific Yield in the Zone of static ground water resources

3.2.16 Apportioning

Wherever the resources are computed hydrological unit wise. This should be apportioned to development units i.e. block, so that management plans can easily be developed. Hence GEC 1997 recommends to apportion all these resources to development units.

3.2.17 Confined Aquifer

There are two types of situations of occurrence of confined aquifers. In hard rock areas, the upper water table aquifer in the weathered zone is connected to the deeper fracture zone, which is semi-confined. In such situations, the assessment procedure already given for unconfined aquifer accounts for the full recharge, and hence no separate assessment is to be made for the confined aquifer.

In specific alluvial areas, resource from a deep confined aquifer may be important. If the confined aquifer is hydraulically connected to the overlying shallow water table aquifer, it is a semi-confined aquifer, and not strictly a confined aquifer. If there is no hydraulic connection to the overlying water table aquifer, the resource may have to be estimated by specific detailed investigations, taking care to avoid duplication of resource assessment from the upper unconfined aquifers.

3.3 NORMS RECOMMENDED BY GEC 1997

3.3.1 Norms for specific yield

The norms for Specific yield as recommended by GEC 1997 are given in Table 3.

Table 3. NORMS FOR SPECIFIC YIELDAS RECOMMENDED BY GEC 1997

S.No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Sandy alluvium	**16.0**	12.0	20.0
	Silty alluvium	**10.0**	8.0	12.0
	Clayey alluvium	**6.0**	4.0	8.0
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	**3.0**	2.0	4.0
	Weathered granite, gneiss and schist with significant clay content	**1.5**	1.0	2.0
	Weathered or vesicular, jointed basalt	**2.0**	1.0	3.0
	Laterite	**2.5**	2.0	3.0
	Sandstone	**3.0**	1.0	5.0
	Quartzite	**1.5**	1.0	2.0
	Limestone	**2.0**	1.0	3.0
	Karstified limestone	**8.0**	5.0	15.0
	Phyllites, Shales	**1.5**	1.0	2.0
	Massive poorly fractured rock	**0.3**	0.2	0.5

Note : Usually the recommended values should be used for assessment, unless sufficient data based on field study is available to justify the minimum, maximum or other intermediate values.

3.3.2 Norms for Rainfall Infiltration Factor

The norms for Rainfall Infiltration factor as recommended by GEC 1997 are given below in Table 4.

Table 4. NORMS FOR RAINFALL INFILTRATION FACTOR AS RECOMMENDED BY GEC 1997

S.No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Indo-Gangetic and inland areas	22	20	25
	East coast	16	14	18
	West coast	10	8	12
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	11	10	12
	Weathered granite, gneiss and schist with significant clay content	8	5	9
	Granulite facies like charnockite etc.	5	4	6
	Vesicular and jointed basalt	13	12	14
	Weathered basalt	7	6	8
	Laterite	7	6	8
	Semi-consolidated sandstone	12	10	14
	Consolidated sandstone, quartzite ,limestone (except cavernous limestone)	6	5	7
	Phyllites, shales	4	3	5
	Massive poorly fractured rock	1	1	3

Note:1. Usually, the recommended values should be used for assessment, unless sufficient information is available to justify the use of minimum, maximum or other intermediate values.

2. An additional 2% of rainfall recharge factor may be used in such areas or part 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.

3.3.3 Norms for Recharge due to seepage from canals

The norms for Recharge due to seepage from canals as recommended by GEC 1997 are given below in Table 5.

Table 5. NORMS FOR RECHARGE DUE TO SEEPAGE FROM CANALS AS RECOMMENDED BY GEC 1997

(a) Unlined canals in normal soils with some clay content along with sand	1.8 to 2.5 cumecs per million sq m of wetted area (or) 15 to 20 ham/day/million sq m of wetted area
(b) Unlined canals in sandy soil with some silt content	3.0 to 3.5 cumecs per million sq m of wetted area (or) 25 to 30 ham/day/million sq m of wetted area
(c) Lined canals and canals in hard rock area	20% of above values for unlined canals

Notes:

1. The above values are valid if the water table is relatively deep. In shallow water table and waterlogged areas, the recharge from canal seepage may be suitably reduced.
2. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

3.3.4 Norms for Return flow from irrigation

The recharge due to return flow from irrigation may be estimated, based on the source of irrigation (ground water or surface water), the type of crop (paddy, non-paddy) and the depth of water table below ground level. The norms for Return flow from irrigation as recommended by GEC 1997 are given below in Table 6.

Table 6. NORMS FOR RETURN FLOW FROM IRRIGATION AS RECOMMENDED BY GEC 1997

Source of irrigation	**Type of crop**	**Water table below ground level**		
		<10m	**10-25 m**	**>25m**
Ground water	Non-paddy	25	15	5
Surface water	Non-paddy	30	20	10
Ground water	Paddy	45	35	20
Surface water	Paddy	50	40	25

Notes:

1. 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.
2. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used.
3. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

3.3.5 Recharge from Storage Tanks and Ponds

1.4 mm/day for the period in which the tank has water, based on the average area of water spread. If data on the average area of water spread is not available, 60% of the maximum water spread area may be used instead of average area of the water spread.

3.3.6 Recharge from Percolation Tanks

50% of gross storage, considering the number of fillings, with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

3.3.7 Recharge due to Check Dams and Nala Bunds

50% of gross storage (assuming annual de-silting maintenance exists) with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

* * *

4

REVIEW OF GROUND WATER ESTIMATIONMETHODOLOGY (1997) AND RECENT CASESTUDIES

4.1 INTRODUCTION

Ground water estimation methodology, 1997 is based on water balance theory. Various input and output components of ground water balance are computed to estimate the Ground Water Recharge. The Ground Water Draft is estimated and assessment unit is also categorised based on the percentage of ground water draft with respect to ground water recharge. The methodology is robust and is reflective of field conditions. However, with time, the ground water scenario of the country has changed significantly. The extraction of ground water resources has increased manifold. As a consequence, the storage of ground water resources have depleted in over-exploited areas. National Water Policy, 2012 suggests that assessment of ground water resource should take into consideration the base flow as well as other elements of water cycle. Assessment of the ground water resources should also include information on quality of ground water along with its quantity which should be based on the knowledge of aquifer disposition and characteristics in different hydrogeological settings of the country.

Improvement in the existing methodology requires a relook on the concepts and details of the methodology applied as well as evaluation and incorporation of the findings of the case studies of ground water assessment carried out in recent years in different parts of the country. While going through such a review process, one may also keep in view the status of current data available for ground water resource evaluation. The methodology as recommended by the GEC - 1997 is reviewed here both on its merits and limitations. The chapter also provides a review of recent case studies on ground water assessment in various parts of the country and the type of data that is available, both from routine observations and from special studies.

4.2 MERITS OF EXISTING METHODOLOGY

The existing methodology outlined in Chapter 3 has many basic merits. This methodology is conceptually best suited to the situation of the day taking into account the limitations of the data available with the State and Central Government Organizations. Even though conceptual thoroughness was categorically mentioned in the methodology, some components were ignored depending on the complexities of the estimation procedure. This has many improvements over earlier methodology like deciding on the hydrogeological assessment unit for hard rock areas, dividing the unit into sub units and assessing the resources for monsoon and non monsoon seasons etc.

4.2.1 Unit for Ground Water Resource Assessment

Even though an administrative unit is convenient for assessing the resources from development angle, GEC 1997 recommends watershed as an assessment unit in hard rock areas. In contrast to hard rock areas where surface and subsurface water divides coincide, in alluvial areas, there may be ground water flow across watershed boundaries also. Hence, it is recommended to continue with the administrative unit (block/Taluka/ Mandal) as an assessment unit in alluvial areas..

4.2.2 Delineation of Areas within an Assessment Unit

The estimation of ground water recharge as per GEC-1997 has basically two components: (a) recharge from rainfall (b) recharge from other sources. Among these, the recharge from rainfall is the only component which is available in a distributed way over the entire block or taluka. Recharge from other sources viz. recharge from canals and recharge due to applied surface water irrigation are mainly relevant only to canal command areas. Hence GEC1997 methodology recommends separate assessment for command areas and non command areas. To some extent assessment based on quality of ground water is also considered in this methodology by way of separating quality affected area as Poor Ground Water Quality area.

4.2.3 Season-wise Assessment of Ground Water Resources

The water availability in any area is not uniform. It depends on time.GEC 1997 recommends the assessment of ground water resources in two annual seasons viz. monsoon season and non monsoon season.

4.2.4 Ground Water Resource Estimation in Confined Aquifer

GEC -1997 has made a brief mention regarding ground water resource estimation in confined aquifers based on Darcy’s law where it is proven that the resources are not duplicated in semi-confined aquifers where part of the recharge is contributed from the unconfined aquifer as leakage.

4.2.5 Estimation of Specific Yield

The ground water level fluctuation method requires the use of specific yield value as a key input for assessment of ground water recharge. The specific yield determined by the pumping test is for the aquifer material which occurs within the cone of depression created during the pumping test. It may introduce an error in computation unless and until there are sufficient number of pumping tests conducted in the assessment sub unit. Secondly, pumping tests are more useful for estimating transmissivity value than specific yield value. Small duration pumping tests on dug wells are not suitable for the estimation of specific yield. Thirdly, an estimation of parameters (including specific yield) from long duration pumping tests in hard rock areas, requires the use of fairly sophisticated modelling techniques. Simplified estimates based on Theis curve (or some other simple models) may result in wrong assessment of specific yield. Hence, GEC 1997 recommends using dry season ground water balance method for estimating specific yield which represents entire area of the assessment sub unit.

4.2.6 Ground Water Draft Estimation

Ground water draft refers to the quantity of ground water that is being withdrawn from the aquifer. Ground water draft is a key input in ground water resource estimation. Hence, accurate estimation of ground water draft is highly essential to calculate the actual ground water balance available. The following three methods are normally used in the country for ground water draft estimation.

(a) Based on well census data: In this method, the ground water draft is estimated by multiplying the number of wells of different types available in the area with the unit draft fixed for each type of abstraction structure in that area. This method is being widely practiced in the country.

(b) Based on electrical power consumption: In this method, the ground water draft estimation is done by multiplying the number of units of power consumed for agricultural pump sets with that of the quantity of water pumped for unit power.

(c) Based on the ground water irrigated area statistics: In this method, the ground water draft is estimated by multiplying the acreage of different irrigated crops (cultivated using ground water) with that of the crop water requirement for each crop.

4.2.7 Return flow from ground water Irrigation

Unlike the earlier methodology, GEC-1997 recommends to separately estimate return flow from ground water irrigation. In the earlier methodology, it was suggested to use a resulting term of gross draft and return flow from ground water irrigation as net ground water draft.

4.2.8 Separating Potential Resources from Normal Assessment

In the earlier methodologies, the computation of potential resource because of shallow water table and flood prone areas were linked to the normal ground water resources and even categorization of the area. This methodology explained that the availability of potential resources is not regular. The potential resource in shallow water table areas is only one time resource and even the potential resource in the flood prone areas is also not regular and is not available every year. Hence, GEC 1997 recommended separating the estimation of the potential resource from the regular assessment and emphasized that it should not be used in the categorization.

4.2.9 Detailed Guidelines for the Estimation

The GEC 1997 methodology provides detailed guidelines; even though it is not part of the final recommendations. The methodology provides the procedures to be followed. The computational complexities were explained in detail and the recommended formats were also provided in the report. This makes the implementation of the methodology easy without any difficulty in the country.

4.2.10 Constitution of R&D Advisory Committee

Based on the recommendations of the GEC 1997 and supported by GEC 2004, an R&D Advisory committee was constituted with the ultimate powers in modifying the methodology without waiting for the constitution of another estimation committee. This is a permanent body, which will solve the day to day problems in the assessment by studying the merits of the proposal without affecting the overall purpose of the estimation.

4.3 LIMITATIONS OF EXISTING METHODOLOGY

Even though this methodology was built on a robust concept, strong theoretical base and with the support of detailed guidelines, there are certain issues which need to be modified with the advent of fast computing systems and availability of data. The limitations of the existing methodology are summarised as follows.

4.3.1 Quality Based Assessment

GEC 1997 methodology recommends assessing the resources for poor ground water quality sub units separately. But it doesn’t provide any clarity as to what is meant by poor ground water quality. It is left for the states to decide on this. Presently this assessment is carried out only for areas where electrical conductivity is more than 3000μS/cm at 25°C. Though, the poor ground water quality area can be an area where Fluoride and Arsenic are also not within the permissible limits. Present methodology recommends not to categorize these areas as there is no extraction for these waters. But as on now, there are users even for brines and hence the categorization of these sub units is also important.

4.3.2 No Importance to the Aquifer wise Assessment

GEC 1997 methodology mentions about the resources of confined aquifers. However, it has not stressed upon the aquifer wise resource estimation. Central Ground Water Board has taken up country wide programme for aquifer mapping which will provide hydrogeological information on major aquifer systems of the country. Assessing ground water resources aquifer wise may become a reality in near future.

4.3.3 Spring Discharges are Ignored

GEC 1997 Methodology recommends to remove hilly area from the assessed areas where the runoff will be more than the infiltration. In most of the hilly areas there occurs isolated aquifers which occasionally manifest in the form of springs. These springs can sustain the water needs of the inhabitants for the time being or forever. There is no provision in the existing methodology to account for this resource.

4.3.4 Base Flows are not Estimated

GEC 1997 Methodology recommends to ignore the base flow component as it is difficult to assess. Even though one can use the data if available, however, the same has not been used in the present studies undertaken for resource assessment. Though GEC 1997 methodology recommends having at least one stream gauge station at the mouth of the watershed, it has never been practiced.

4.3.5 Directly Linking Trends to Categorization

GEC 1997 Methodology recommends to categorize the assessment sub unit on dual criteria viz. Stage of ground water development and Ground water level trends. There are serious objections on this.

- If there is no observation well in the sub unit, at least for another 10 years, one cannot assess the resources and categorize.

- If the percent deviation of rainfall recharge computed using water level fluctuation method and rainfall infiltration factor method is more that 20% or less than -20%, finally one has to depend on the estimate made using rainfall infiltration factor method. However the trend of the same wells is used for categorization.
- In case of command areas where rejected recharge is more and hence the percent deviation is within the required range, the trends of these wells are also not truly reflecting the situation.

4.3.6 No Direct Reflection of Ground Water Mining

The ground water resources of the country have been assessed three times using this methodology during the years 2003-2004, 2008-2009 and 2010-2011 and 2012-2013. The ground water resources of the country are always estimated around 430bcm. Common man cannot understand why the resources are constant even though there is over exploitation in certain parts of the country. The reason being normalised rainfall data is used for resource estimation which does not change annually. The normal rainfall data gets affected in a span of 20-30 years, even though the annual rainfall figures are different. The effect of annual rainfall is not reflected in resources computed on normalised rainfall data. Even though the water levels are declining day by day in over exploited areas, it is difficult to explain the effects of ground water mining in these areas because of the lacuna in this methodology. Unless and until the availability of total ground water resources i.e. dynamic and in storage/ static resources of confined and unconfined aquifers in an area is estimated, this cannot be answered.

4.3.7 No Database Structure

Even though the guidelines have provided very good procedural details, it has not mentioned about the type of data and its precision and how it is to be stored in computer compatible format.

4.3.8 Detailed Methodology for Estimating the Resources in Confined Aquifer

Even though GEC 1997 methodology indicates that the resources of the confined aquifer are to be assessed using flow concept, it has not provided any compulsions or detailed procedures to compute the resources in the confined aquifer.

4.4 IMPROVEMENTS IN THE EXISTING METHODOLOGY

After due consideration of the limitations discussed above, several improvements are proposed in the existing methodology. These are as follows.

- The frequency of assessment is proposed to be increased from once in every five years as proposed in GEC 1997 to once in every three years.
- Estimation of base flow in the ground water balance equation wherever possible.
- Estimation of lateral flow or through flow wherever possible.
- Estimation of Aquifer-wise Exploitable GW Resources and In-storage Resources wherever Aquifer Geometry have been established. Till such time general guidelines are provided for assessing the resources up to a certain predetermined depth.
- Recommends to compute Potential Resource due to springs in hilly areas wherever possible.
- Ground Water Level Trends are proposed to be used as Validation of the exercise instead of one of the criterion for categorization.
- Categorisation of Assessment units is based on ground water quantity and there will be ground water quality tag wherever the ground water is of poor quality i.e. effected by salinity, arsenic or fluoride.
- Proposed to assess Total Ground Water Availability which can reflect Ground Water Mining
- Database Structure is proposed which is to be followed.
- Detailed Methodology for Estimating the Resources in Confined Aquifers is also provided.
- Refinement of Norms of parameters used in computation of ground water resources. It is proposed to have some field studies before conducting periodical assessment. The data of the field studies should be maintained with proper documentation for future reference.

4.5 REVISION OF NORMS FOR GROUND WATER ASSESSMENT

As stated earlier, there is a need to apply the recommended norms for recharge assessment in situations where adequate field data is not available. However, these norms need to be revised periodically on basis of the results and observations of ground water assessment studies carried out in various parts of the country by a number of central and state government agencies, research institutions, universities, non-government organisations etc. These studies are varied in nature; consultation and analysis of these require considerable time. In the limited time available for the committee, only some of these studies could be consulted.

While it is reasonable to adopt a specific standardised methodology of ground water assessment, it is necessary to update the norms on regular basis, considering the results of case studies. For this, it is recommended that the R& D Advisory committee may be revived and strengthened with additional members and supporting staff. This committee may be authorised to revise the norms periodically and circulate it to the different states. The present committee has made a limited review of case studies of ground water assessment in the last 10 to 15 years, in order to revise the norms for ground water assessment.

4.5.1 Case Studies of Ground Water Assessment

The studies carried out on ground water assessment in recent years can be broadly categorised as follows:

(a) Ground water assessment by State Ground Water Agencies and Central Ground Water Board, based on the recommendations of the GEC - 1997.

(b) Pilot Aquifer Mapping by Central Ground Water Board

(c) Ground water assessment through modelling as part of the pilot studies referred above or otherwise.

(d) Special Studies carried out by Central Ground Water Board and State Ground Water Departments.

The committee recommends that all the agencies involved in Ground Water Resource Estimation should be encouraged to conduct field studies and use the norms thus computed in the assessment. Even though every user agency follows the methodology suggested, there is a possibility of error cropping in at various levels in the field study and hence the committee is of the opinion that maximum and minimum values for all the norms be suggested which can be used in the estimation. If the agency has not computed the norms through their own field studies, the norms suggested and values given in chapter 5 may be used for the assessment of resources.

* * *

5

PROPOSED METHODOLOGY

5.1 APPROACH OF GEC-2015

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and In-storage resources or Static resources.GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. 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 up to the depth of bed rock or 300m whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100m. In case of confined aquifers, if it is known that ground water extraction is being taken place 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 has to be estimated

5.2 PERIODICITY OF ASSESSMENT

Keeping in view of the rapid change in ground water extraction, the committee recommends more frequent estimation of ground water resources. The committee observes that the comprehensive assessment of ground water resources is a time intensive exercise. Hence as a trade-off, it recommends that the resources should be assessed once in every three years. As per the present practice, there is a considerable time lag between assessment and publication of the results. Hence the committee recommends to make all out efforts to reduce the time lag and the results may be reported within the successive water year.

5.3 GROUND WATER ASSESSMENT UNIT

This methodology recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than alluvium. Ground water resources worked out on watershed as a unit, may be apportioned and presented on administrative units (block/taluka/mandal/ firka). This would facilitate local administration in planning of ground water management programmes. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and demarcation of watershed boundaries may be difficult in such areas. Even if the demarcation is done, this may lead to trans boundary movement of ground water because of excessive pumping in one of the watersheds. 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.

5.4 GROUND WATER ASSESSMENT SUB-UNITS

It is recommended that ground water recharge may be estimated for the entire assessment unit. Out of the total geographical area of the unit, hilly areas wherever slope is greater than 20%,are to be identified and subtracted as these areas have more runoff than infiltration. The hilly areas wherever slope is more than 20% may be demarcated using DEM data and geomorphological maps. This would allow the valleys, terraces, plateaus occurring within >20% slope zone to be considered for recharge computations. It is quite likely that with hilly areas, densely forested area may also be excluded; this may affect to some extent ground water losses caused due to transpiration by deep rooted trees in the area of assessment. Apart from this it is also important that the areas where the quality of ground water is beyond the usable limits (for drinking water in particular) in terms of salinity is to be identified and handled separately. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride and arsenic.

In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'ground water resources' in hilly areas. The assessment of spring discharge would constitute the 'replenishable potential ground water resource' but it will not be accounted for in the categorisation of ground water assessment, at least not in the near future.

The ground water resource beyond the permissible quality limits in terms of the salinity has to be computed separately. The remaining area after excluding the area with poor ground water quality is to be delineated as follows:

(a) Non-command areas which do not come under major/medium surface water irrigation schemes. (command area <100 Ha in the assessment unit should be ignored)

(b) Command areas which come under major/medium surface water irrigation schemes which are actually supplying water (>100 Ha of command area in the assessment unit.)

It is proposed to have all these areas of an assessment unit in integer hectares to make it national database with uniform precision.

5.5 GROUND WATER RESOURCES OF AN ASSESSMENT UNIT

The ground water resources of any assessment unit is the sum of the total ground water availability in the principal aquifer (mostly unconfined aquifer) and the total ground water availability of semi-confined and confined aquifers existing in that assessment unit. The total ground water availability of any aquifer is the sum of dynamic ground water resources and the in-storage or static resources of the aquifer.

5.6GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

As mentioned earlier, assessment of ground water includes assessment of dynamic and in-storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

5.6.1 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 –

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

Equation 1 can be further elaborated as -

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

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 inter aquifer flow

LF- Lateral flow along the aquifer system (throughflow)

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. The present status of database available with government and non-government agencies is not adequate to carry out detailed ground water budgeting in most of the assessment units. Therefore, 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.

5.6.1.1 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 period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of water level 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.

5.6.1.1.1 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

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

Where,

ΔS – Change is storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

R_{SWI} – Recharge from surface water irrigation (Lift Irrigation)

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from tanks& ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical inter aquifer flow

LF- Lateral flow along the aquifer system (throughflow)

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 to canals (R_C) and the equation will be as follows:

$$\Delta S= R_{RF}+R_{STR}+R_C+R_{SWI}+R_{GWI}+R_{TP}+R_{WCS} \pm VF \pm LF - GE - T - E - B \qquad 4$$

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:

$$\Delta S= \Delta h * A * S_Y \qquad 5$$

Where

ΔS – Change is storage

Δh - rise in water level in the monsoon season

A - area for computation of recharge

Sy - Specific Yield

Substituting the expression in equation 5 for increase in storage i.e. ΔS in terms of water level fluctuation and specific yield, the equations 3 &4 becomes,

$$\mathbf{R_{RF} = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \qquad \mathbf{6}$$

$$\mathbf{R_{RF} = h \times Sy \times A - R_{STR} - R_{C} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \qquad \mathbf{7}$$

The recharge calculated from equation 6 in case of non-command sub units and equation 7 in case of command sub units and poor ground water quality sub units gives the rainfall recharge for the particular monsoon season. However, it may be noted that in case base flow/ recharge from stream and through flow have not been estimated, the same may be assumed to be zero.

The rainfall recharge obtained by using equation 6 & equation 7 provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let Ri be the rainfall recharge and ri be the associated rainfall. The subscript i takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, Ri is obtained as per equation 6 & equation 7 depending on the sub unit for which the normalization is being done.

$$\mathbf{R_i = h_i \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \qquad \mathbf{8}$$

$$\mathbf{R_i = h_i \times Sy \times A - R_{STR} - R_{C} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \qquad \mathbf{9}$$

where,

Ri = Rainfall recharge estimated in the monsoon season for the i^{th} particular year

h_i = Rise in ground water level in the monsoon season for the i^{th} particular year

Sy =Specific yield

A = Area for computation of recharge

R_{STR} = Recharge from stream channels in the monsoon season for i^{th} particular year

R_C = Recharge from canals in the monsoon season for i^{th} particular year

R_{SWI} = Recharge from surface water irrigation including lift irrigation in the monsoon season for the ith particular year

R_{GWI}= Recharge from ground water irrigation in the monsoon season for the ith particular year

R_{TP}= Recharge from tanks and ponds in the monsoon season for the ith particular year

R_{WCS} =Recharge from water conservation structures in the monsoon season for the ith particular year

LF = Recharge through Lateral flow/ Through flow across assessment unit boundary in the monsoon season for the ith particular year

VF – Vertical inter aquifer flow in the monsoon seasonfor the ith particular year

T- Transpiration in the monsoon season for the ith particular year

E- Evaporation in the monsoon season for the ith particular year

GE = Ground water extraction in monsoon season for the ith particular year

B = Base flow the monsoon season for the ith particular year

After the pairs of data on Ri and ri 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

$$\mathbf{R = ar} \qquad \mathbf{10}$$

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:

$$Rrf(normal) = \frac{\sum_{i=1}^{N}\left[R_i \times \frac{r(normal)}{r_i}\right]}{N} \qquad \mathbf{11}$$

Where,

$Rrf(normal)$ - Normalized Rainfall Recharge in the monsoon season.

R_i - Rainfall Recharge in the monsoon season for the ith 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, this linear relationship is of the form,

$$R = ar+b \qquad 12$$

where,

R = Rainfall recharge during monsoon season

r = 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:

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \qquad 13$$

$$b = \frac{S_2 - aS_1}{N} \qquad 14$$

Where

$$S_1 = \sum_{i=1}^{N} r_i \quad S_2 = \sum_{i=1}^{N} R_i \quad S_3 = \sum_{i=1}^{N} r_i^2 \quad S_4 = \sum_{i=1}^{N} r_i R_i$$

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

$$\mathbf{R_{rf}\ (normal) = a \times r(normal) + b} \qquad 15$$

5.6.1.1.2 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 water extraction 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 -

$$\mathbf{R_{rf} = RFIF * A* (R - a)/1000} \qquad 16$$

Where,

R_{rf}= Rainfall recharge in ham

A = Area in Hectares

RFIF = Rainfall Infiltration Factor

R = Rainfall in mm

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

The relationship between rainfall and ground water recharge is a complex phenomenon depending on several factors like runoff coefficient, moisture balance, hydraulic conductivity and Storativity/Specific yield of the aquifer etc. In this report, certain assumptions have been adopted for computation of Rainfall recharge factor. These assumptions may be replaced with actual data in case such area specific studies are available. At the same time, it is important to bring in elements of rainfall distribution and variability into sharpening the estimates of precipitation. Average rainfall data from nearby rain gauge stations may be considered for the ground water assessment unit and the average rainfall may be estimated by the Theisen polygon or isohyet method. Alternatively, other advanced methods may also be used.

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 16 and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rains 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 to be 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.

5.6.1.1.3 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

$$PD = \frac{R_{rf}(normal, wtfm) - R_{rf}(normal, rifm)}{R_{rf}(normal, rifm)} \times 100 \qquad \mathbf{17}$$

where,

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

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

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

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

5.6.1.2 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 are possible.

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

$$\mathbf{R_C = WA * SF * Days} \quad \mathbf{18}$$

Where:

R_C= Recharge from Canals

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

SF= Seepage Factor

Days= Number of Canal Running Days.

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

$$\mathbf{R_{SWI} = AD*Days*RFF} \quad \mathbf{19}$$

Where:

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

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

5.6.1.2.3 Recharge from Ground Water Irrigation: Recharge due to applied ground water irrigation isto be estimated based on the following formula:

$$\mathbf{R_{GWI} = GE_{IRR} * RFF} \qquad \mathbf{20}$$

Where:

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

GE_{IRR}= Ground Water Extraction for Irrigation

RFF= Return Flow Factor

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

$$\mathbf{R_{TP} = AWSA * N * RF} \qquad \mathbf{21}$$

Where:

R_{TP} = Recharge due to Tanks & Ponds

AWSA= Average Water Spread Area

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

RF= Recharge Factor

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

$$\mathbf{R_{WCS} = GS * RF} \qquad \mathbf{22}$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

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

RF= Recharge Factor

5.6.1.3. Lateral flow along the aquifer system (Throughflow)

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.

5.6.1.4Baseflow 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 centres, 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 separating base 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.

5.6.1.5 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.

5.6.1.6 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 within3.5m 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 from PET data provided by IMD.

5.6.1.7 Recharge/ Accumulations 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 season is the total recharge/ accumulation during monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

5.6.1.8 Recharge/ Accumulations during Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using rainfall infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & 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.

5.6.1.9 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.

5.6.1.10 Annual Extractable Ground Water Resource (EGR)

The Total Annual Ground Water Recharge cannot be utilised for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined.

The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore, ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. 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).

5.6.1.11 Estimation of Ground Water Extraction

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

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \qquad \textbf{23}$$

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

5.6.1.11.1 Ground Water Extraction for Irrigation(GE_{IRR}): The single largest component of the ground water balance equation in large regions of India is the ground water extraction and the precise estimation of ground water extraction is riddled with uncertainties. Therefore it is recommended that at least two of the three methods for estimation of ground water extraction maybe employed in each assessment sub unit. 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. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tehsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

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

Direct metering of ground water draft in select irrigation and domestic wells and in all wells established for industrial purpose may be initiated. Enforcing fitting of water meters and recording draft in all govt. funded wells could also be a feasible option. The unit drafts obtained from these sample surveys can be used to assess ground water extraction. In addition to metering, dedicated field sample surveys (instantaneous discharge measurements) can also be taken up.

5.6.1.11.2Ground Water Extraction for Domestic Use(GE_{DOM}): There are several methods for estimation of extraction for domestic use(GE_{DOM}). Some of the commonly adopted methods are described here.

***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_{DOM}= Population X Consumptive Requirement X Lg **24**

Where,

Lg = Fractional Load on Ground Water for Domestic Water Supply

The Load on Ground water can be obtained from the Information based on Civic water supply agencies in urban areas.

5.6.1.11.3Ground 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. Number of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

GE_{IND}= Number of industrial units X Unit Water Consumption X Lg **25**

Where,

Lg = Fractional load on ground water for industrial water supply

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

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered. The storage depletion during a season, where other recharges are negligible can be taken as ground water extraction during that particular period.

5.6.1.12 Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$Stage\ of\ Ground\ Water\ Extraction(\%) = \frac{\text{Existing gross ground water extraction for all uses}}{\text{Annual Extractable Ground water Resources}} \times 100 \qquad \textbf{26}$$

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

5.6.1.13 Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. The estimation of ground water extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from ground water. The denominator in equation 26, namely Annual Extractable Ground Water Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels.

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

In interpreting the long-term trend of ground water levels, the following points may be kept in view. If the pre and post monsoon water levels show a fairly stable trend, it does not necessarily mean that there is no scope for further ground water development. Such a trend indicates that there is a balance between recharge, extraction and natural discharge in the unit. However, further ground water development may be possible, which may result in a new stable trend at a lower ground water level with associated reduced natural discharge.

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

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

In case, the category does not match with the water level trend given above, a ‘reassessment’ should be attempted. If the mismatch persists even after reassessment, the sub unit may be categorized based on Stage of Ground Water Extraction of the reassessment. However, the sub unit should be flagged for strengthening of observation well network and parameter estimation.

5.6.1.14 Categorisation of Assessment Units

As emphasised 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.

5.6.1.14.1 Categorisation of Assessment Units Based on Quantity: The categorisation based on status of ground water quantity is defined by Stage of Ground Water Extractionas given below:

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

5.6.1.14.2 Categorisation of Assessment Units Based on Quality

GEC 1997 proposed categorisation of assessment units based on ground water extraction only. To adequately inform management decisions, quality of ground water is also an essential criterion. The committee deliberated upon the possible ways of categorizing the assessment units based on ground water quality in the assessment units. It was realised that based on the available water quality monitoring mechanism and available database on ground water quality it may not be possible to categorise the assessment units in terms of the extent of quality hazard. As a trade-off, the committee recommends that each assessment unit, in addition to the quantity based categorisation (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. Such quality hazards are to be based on available ground water monitoring data of State Ground Water Departments and/or Central Ground Water Board. 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.

5.6.1.15 Allocation of Ground Water Resource for Utilisation

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

$$\mathbf{Alloc = 22 \ X \ N \ X \ L_g \ \ mm\ per\ year} \qquad \mathbf{27}$$

Where

Alloc=Allocation for domestic water requirement

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

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

In deriving equation 27, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present day extraction. It can never be less than the present day extraction as it is unrealistic.

5.6.1.16 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 availability for future use. The Net annual ground water availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

5.6.1.17 Additional Potential Resources under Specific Conditions

5.6.1.17.1 Potential Resource Due to Spring Discharge: Spring discharge constitutes an additional source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. 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 Categorisation. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season. The committee recommends that in hilly areas with substantial potential of spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential ground water resource due to springs = Q x No of days **28**

Where

Q= Spring Discharge

No of days= No of days spring yields.

5.6.1.17.2 Potential Resource in Waterlogged and Shallow Water Table Areas: The quantum of water available for development is usually restricted to long term average recharge or in other words "Dynamic Resources". But the resource calculated by water level fluctuation approach is likely to lead to under-estimation of recharge in areas with shallow water table, particularly in discharge areas of sub-basin/watershed/block/taluka/ Firka and waterlogged areas. In such cases rejected recharge may be substantial and water level fluctuations are subdued resulting in under-estimation of recharge component. It is therefore, desirable that the ground water reservoir should be drawn to optimum limit before the onset of monsoon, to provide adequate scope for its recharge during the following monsoon period.

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. It is therefore recommended that in such areas, ground water resources may be estimated up to 5m bgl only assuming that where water level is less than 5m bgl, the same could be depressed by pumping to create space to receive recharge from natural resources. It is further evident that this potential recharge would be available mostly in the shallow water table areas which would have to be demarcated in each sub-basin/watershed/block/taluka/ mandal/ Firka.The computation of potential resource of the ground water reservoir can be done by adopting the following equation:

Potential ground water resource in shallow water table areas = (5-D) x A x S_Y **29**

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

The planning of future minor irrigation works in the waterlogged and shallow water table areas as indicated above should be done in such a way that there should be no long term adverse effects of lowering of water table up to 5m and the water level does not decline much below 5m in such areas. The behaviour of water table in the adjoining area which is not water logged should be taken as a bench mark for development purposes.

This potential resource of ground water is available only after depression of water level up to 5m bgl. This is not an annual resource and should be recommended for development on a very cautious approach so that it does not adversely affect the ground water potentials in the overall area.

5.6.1.17.3 Potential Resource in Flood Prone Areas: Ground water recharge from a flood plain is mainly the function of the following parameters-

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

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

Potential ground water resource in Flood Prone Areas = 1.4 x N x A/1000 **30**

Where

N = No of Days Water is Retained in the Area

A = Flood Prone Area

5.6.1.18 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 in the case of the individual watersheds.

5.6.2 Assessment of In-Storage Ground Water Resources or Static Ground Water Resources

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. While water table hydrograph could be an indicator to distinguish dynamic resources, at times it is difficult when water tables are deep. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

Assessment of In-storage ground water resources has assumed greater significance in the present context, when an estimation of Storage Depletion needs to be carried out in Over-exploited areas. Recently Remote Sensing techniques have been used in GRACE studies, to estimate the depletion of Ground Water Resources in North West India. Such estimation presents larger scale scenario. More precise estimation of ground water depletion in the over-exploited area based on actual field data can be obtained by estimating the Change in In-storage during successive assessments. Thus In-storage computation is necessary not only for estimation of emergency storage available for utilisation in case of natural extremities (like drought) but also for an assessment of storage depletion in over-exploited areas for sensitising stakeholders about the damage done to the environment.

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: -

$$\mathbf{SGWR = A * (Z_2 - Z_1) * S_Y} \qquad \mathbf{31}$$

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

5.6.3 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.

5.7 GROUND WATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to its specific yield. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred metre and subsidence of land surface posing serious geotectonical problems.

It is recommended to use ground water storage approach to assess the ground water resources of the confined aquifers. The co-efficient of storage or storativity of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the aquifer (ΔV) can be calculated as follows

$$\Delta V = S \, \Delta h \qquad (32)$$

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

$$Q = A \, \Delta V = SA\Delta h \qquad (33)$$

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)

Most of the storage in confined aquifer is associated with compressibility of the aquifer matrix and compressibility of water. 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 well as topography. Hence ground water potential of a confined aquifer is nothing but the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential. The quantity of water released in confined aquifer due to change in pressure can be computed between piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$$Q_P = SA\Delta h = SA\,(h_t - h_0) \qquad \textbf{34}$$

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, then there is a need to assess the dynamic as well as in storage resources of the confined aquifer. To assess the ground water resources of the confined aquifer, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed.

5.7.1 Dynamic Ground Water Resources of Confined Aquifer

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

$$Q_D = SA\Delta h = SA\,(h_{POST} - h_{PRE}) \qquad \textbf{35}$$

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)

5.7.2 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:

$$Q_I = SA\Delta h = SA\,(h_{PRE} - h_0) \qquad \textbf{36}$$

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 of the aquifer can be computed using the following formula.

$$Q_P = SA\Delta h = SA\,(h_{POST} - h_0) \qquad \textbf{37}$$

Where

Q_p = In -storage Ground Water Resource of the confined aquifer or the Quantity of water under pressure (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_0 = Bottom of the Top Confining Layer (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.

5.7.3 Assessment of Total Ground Water Availability of Confined Aquifer

If the confined aquifer is being exploited, the Total Ground Water Availability of the confined aquifer is 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 of that confined aquifer.

5.8 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.

5.9TOTAL GROUND WATER AVAILABILITY OF AN AREA

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

5.10 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, accuracy is 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 which can 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 quantity of 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.

5.11 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 include 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.

5.12 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.

5.13 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:

1. The area may be sub-divided into different hydrogeological sub-areas and into recharge area, discharge area and transition zone and also on quality terms.
2. 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.
3. Hydrological and hydrogeological parameters particularly the specific yield should be collected for different formations in each sub-area.
4. 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.

5. 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.
6. All data available with Central Ground Water Board, State Ground Water Departments and other agencies including research institutions and universities etc. should be collected for the watershed/sub-areas and utilised for reassessment.
7. 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.
8. 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.
9. Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be classified adopting norms for categorisation as recommended elsewhere in the methodology.

5.14 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. This has been further clarified in the following paragraphs.

5.14.1 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 7 may be followed in the future assessments. The Major aquifer map can be obtained from Regional offices of 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 7: NORMS RECOMMENDED FOR THE SPECIFIC YIELD

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	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 or Jointed	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 to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	KarstifiedLimestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	KarstifiedLimestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	KarstifiedLimestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	KarstifiedMarble	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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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 Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	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 to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

5.14.2 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 8 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 8: NORMS RECOMMENDED FOR THE RAINFALL INFILTRATION FACTOR

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	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 Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	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/Conglomerate	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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	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

5.14.3 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 150times 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 filed 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 9below 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.

TABLE9: NORMS RECOMMENDED FOR THE 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

5.14.4 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 linear relationship 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 10.

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.

TABLE10: NORMS RECOMMENDED FOR THE RECHARGE FROM IRRIGATION

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non Paddy	Paddy	Non Paddy
<=10	45	25	50	30
11	43.3	23.7	48.3	28.7
12	41.7	22.3	46.7	27.3
13	40	21	45	26

14	38.3	19.7	43.3	24.7
15	36.7	18.3	41.7	23.3
16	35	17	40	22
17	33.3	15.7	38.3	20.7
18	31.7	14.3	36.7	19.3
19	30	13	35	18
20	28.3	11.7	33.3	16.7
21	26.7	10.3	31.7	15.3
22	25	9	30	14
23	23.3	7.7	28.3	12.7
24	21.7	6.3	26.7	11.3
>=25	20	5	25	10

5.14.5 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 1997in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

5.14.6 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 is40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season.

5.14.7 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.

5.14.8 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 1997ie. 5% or 10% of the Total Annual Ground Water Recharge as the Natural Discharges may be continued.

5.14.9 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 on how 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:

$$Unit\ Draft = Discharge\ in\ m^3/hr \times No.\ of\ \ Pumping\ hrs\ in\ a\ day \times No.\ of\ \ days \qquad 38$$

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 normalised 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 40 is to be followed or else the first method shown in equation 39 may be used.

$$Normalized\ Unit\ Draft = \frac{Unit\ Draft \times Rainfall\ \ for\ the\ Year}{Normal\ Rainfall} \qquad \mathbf{39}$$

$$Normalized\ Unit\ Draft = \frac{\sum_{i=1}^{n} Unit\ Draft_i}{Number\ of\ Years} \qquad \mathbf{40}$$

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.

5.15 SUMMARY REPORT OF GROUND WATER ASSESSMENT

A summary for each unit adopted for ground water assessment is to be presented in the formats given in the following tables. These tables should also be accompanied by one graphical plot showing the ground water level trend during pre monsoon and post monsoon seasons for each of the sub unit assessed. The committee also recommends that there should be two reports for each state one with the results of the Dynamic Ground Water Resources which can be used for planning for future ground water management. Whereas the other report should contain the Total Availability of the resources which will indicate the ground water mining taking place in the country for sensitizing stakeholders about the damage being done to the environment and for planning the remedial measures there upon for rectifying the damage.

TABLE 11: SUMMARY REPORT IN RESPECT OF THE DYNAMIC GROUND WATER RESOURCES OF EACH GROUND WATER ASSESSMENT UNIT

A. Dynamic Ground Water Resources of Unconfined Aquifer:

1. Command and Non - command Areas

S. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season				
2	Recharge from 'Other Sources' during monsoon season				
3	Resultant Ground Water Inflow during monsoon season				
4	Recharge from 'Rainfall' during non - monsoon season				
5	Recharge from 'Other Sources' during non - monsoon season				
6	Resultant Ground Water Inflow during non-monsoon season				
7	Annual ground water recharge [(1) + (2) + (3) + (4)+(5)+(6)]				
8	Estimated Base Flow Restricted to ecological Flow				
9	If Base flow is estimated separately, Estimated Evapotranspiration Losses				
10	If Base flow is not estimated separately Unaccounted annual natural discharges				
11	Total Natural Discharges [(8)+(9)) or (10)				
12	Annual Extractable Ground Water Resource [(7) - (11)]				
13	Current annual gross ground water extraction for 'All Uses'				
14	Current annual gross ground water extraction for 'Domestic				

S. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
	Use’				
15	Current annual gross ground water extraction for ‘Irrigation’				
16	Current annual gross ground water extraction for ‘Industrial use'’				
17	Annual ground water allocation for domestic water supply as on 20 25.				
18	Net annual ground water availability for ‘Future Use’ [(12) - (15) - (16) -(17)]				

S. No.	Description of item	Non - command area	Command area
19	Stage of ground water Extraction as a percentage [((13) / (12)) * 100]		
20	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical / Over exploited)		
21	Quality Tagging (if any)		
22	Does the water table during pre and post monsoon seasons show a significant falling trend (Yes / No)		
23	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed)		

2. Poor Ground Water Quality Area

S. No.	Description of item	in hectare metres	in mm
1	Recharge from ‘Rainfall’ during monsoon season		
2	Recharge from ‘Other Sources’ during monsoon season		
3	Resultant Ground Water Inflow during monsoon season		
4	Recharge from ‘Rainfall’ during non - monsoon season		
5	Recharge from ‘Other Sources’		

S. No.	Description of item	in hectare metres	in mm
	during non - mon4soon season		
6	Resultant Ground Water Inflow during non-monsoon season		
7	Annual ground water recharge [(1) + (2) + (3) + (4) +(5)+(6)]		
8	Estimated Base Flow Restricted to Ecological Flow		
9	If Base flow is estimated separately, Estimated Evapotranspiration Losses		
10	If Base flow is not estimated separately Unaccounted annual natural discharges		
11	Total Natural Discharges [(8)+(9)) or (10)]		
12	Annual Extractable ground water Resource [(7) - (11)]		
13	Current annual gross ground water extraction for 'All Uses'		
14	Current annual gross ground water extraction for 'Domestic Use'		
15	Current annual gross ground water extraction for 'Irrigation'		
16	Current annual gross ground water extraction for 'Industrial use''		
17	Annual ground water allocation for domestic water supply as on 20 25.		
18	Net annual ground water availability for 'Future Use' [(12) - (15) - (16) -(17)]		

S. No	Description of item	Poor Ground Water Quality Area
19	Stage of ground water Extraction as a percentage [((13) / (2) * 100]	
20	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical /	

S. No	Description of item	Poor Ground Water Quality Area
	Over exploited)	
21	Quality Tagging	
22	Does the water table during pre and post monsoon interval show a significant falling trend (Yes / No)	
23	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed)	

3. Potential Resources (If any)in Ground Water Assessment Unit

a.	Potential resource due to Springs in hectare meters	=	
b.	Potential resource in waterlogged and shallow water table areas in hectare metres	=	
c.	Potential resource in flood prone area in hectare metres	=	
d.	Total potential recharge in hectare metres [(a) + (b) + (c)]	=	

B. Dynamic Ground Water Resources of Confined/ Semi-Confined Aquifers: (If the aquifer is being exploited)

S.No	Aquifer Number & Name	Type	Dynamic Ground Water Resources in ham
1			
2			
3			

TABLE 12: SUMMARY REPORT IN RESPECT OF THE TOTAL GROUND WATER AVAILABILITY OF EACH GROUND WATER ASSESSMENT UNIT

A. In storage Ground Water Resources of Unconfined Aquifer in Ground Water Assessment Unit

a.	In storage / Static ground water resource in hectare metres	=	

B. In storage Ground Water Resources of Confined/ Semi-Confined Aquifers:

S.No	Aquifer Number & Name	Type	In storage Ground Water Resources in ham
1			
2			
3			

C. Total Extractable Ground Water Availability in the Assessment Unit

S.No	Aquifer Number & Name	Type	Extractable Ground Water Resources in ham
1			
2			
3			

(Note: For Unconfined Aquifer - it is Annual Extractable Ground Water Resources and for other aquifers it is the dynamic resources computed)

D. Total Ground Water Availability in the Assessment Unit

1	Total Extractable Ground Water Resources in ham	:	
2	Total In storage Ground Water Resources in ham	:	
3	Total Ground Water Availability in ham	:	

Apart from this, it is recommended to create a GIS based village wise database of all primary information and data related to estimation of ground water resources. The final output is recommended to be depicted on maps and should be accessible using web based interactive tools.

* * *

6

PROPOSED DATABASE FOR THE ESTIMATION

The database for ground water resource assessment has two components which are equally important viz., data elements like water level, rainfall etc. and the norms like specific yield, rainfall infiltration factor etc. The committee studied the database maintained by the various states. Most of the states maintain their database either in MS-Excel or in MS-Access format. The database capabilities of MS-Excel are limited for handling such a huge database especially for a State or country. Hence it is recommended to use MS-Access for future Ground Water Resources Estimation exercise in all levels from an assessment unit to the country.

6.1 DATA ELEMENTS USED IN THE ASSESSMENT

The detailed guidelines published as an annexure to the GEC 1997 report has meticulously described each of the data element used in the methodology. This helped to clarify the concept behind the computations. However the document failed to specify the structure of data elements and their required precision. There is no common structure of the data elements in GEC 1997 report. Hence it is difficult to combine the data sets to make it a national dataset. The central level expert group during 2009 assessment suggested certain annexure for making a unified database, still the required level of uniformity in the data elements could not be achieved. There is a need to devise the data structure of all the elements with its name, type of data and its precision. The broad data elements used in the ground water resource estimation are given in Table 13:

TABLE 13.BROAD DATA ELEMENTS USED IN THE GROUND WATER RESOURCES ESTIMATION

Component	Parameter	Unit	Data type	Source
Assessment Sub Units	Total Geographic Area	Hectares	Integer	Revenue Census
	Hilly Area	Hectares	Integer	DEM/ Geomorphological Maps
	Poor Ground Water Quality	Hectares	Integer	SGWD

Component	Parameter	Unit	Data type	Source
	Area			
	Command Area	Hectares	Integer	Irrigation Department
	Non Command Area	Hectares	Integer	Irrigation Department
Ground Water Extraction	Well Census	Number	Integer	MI Census
	Number of days	Number	Integer	Field Studies
	Cropping Pattern	Acres	Float(7,2)	Agriculture Department/ Block Office
	Power Consumed	Kilo Watt Hours	Integer	Electricity Department
Base Flow & Recharge From Streams	River Stage	Meters	Float(7,2)	Central Water Commission & Irrigation Department
	River Discharge	Cumecs	Float(7,2)	Central Water Commission & Irrigation Department
	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Transmissivity	Square meters/day	Float(7,2)	CGWB/SGWD
Lateral Flows	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Transmissivity	Square meters/day	Float(7,2)	CGWB/SGWD
	Width of the Seepage Face	Meters	Integer	Field Studies
Vertical Flows	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Hydrualic Conductivity of the Aquitard	meters/day	Float(7,2)	CGWB/SGWD
	Thickness of the Aquitard	Meters	Float(7,2)	Field Studies
Evaporation	Evaporating Area	Hectares	Integer	Field Studies
	Evaporation rate	mm/day	Float(6,2)	IMD
Transpiration	Transpiring Area	Hectares	Integer	Field Studies
	Transpiration rate	mm/day	Float(6,2)	IMD/ Agricultural Universities
Canal Seepage	Reach Length	Meters	Integer	Irrigation Department
	Full Supply Depth	Meters	Float(5,2)	Irrigation Department
	Side Angle	Degrees	Float(5,2)	Irrigation Department
	Base Width	Meters	Float(5,2)	Irrigation Department
	Number of Days	No	Integer	Irrigation Department
Recharge Due	Cropping	Acres	Float(7,2)	Agriculture

Component	Parameter	Unit	Data type	Source
to Ground Water Irrigation	Pattern			Department / Block Office
Recharge Due to Surface Water Irrigation	Design Discharge of the Outlet	Cumecs	Float(6,2)	Irrigation Department
	Number of Days	Number	Integer	Irrigation Department
	Cropping Pattern	Acres	Float(7,2)	Irrigation Department/ Agriculture Department / Block Office
Recharge Due to Tanks/Ponds	Water Spread Area	Hectares	Float(7,2)	Irrigation Department/Remote Sensing
	Number of Days	Number	Integer	Irrigation Department/Remote Sensing
Recharge Due to Water Conservation Structures	Gross Storage	Hectare meters	Float(7,2)	Irrigation Department/Watershed Management
	Number of Refills	Number	Float(3,1)	Irrigation Department/Watershed Management/ Field Studies
Rainfall Infiltration Factor Method	Rainfall	millimeter	Float(5,1)	IMD/Revenue Department
Water Table Fluctuation Method	Water Level	Meter	Float(6,2)	CGWB/SGWD
Allocation	Population as on base year	Number	Integer	Population census
	Population Growth rate	Percent	Float(5,2)	Population census
	Dependency on Ground Water	Ratio	Float(5,2)	Water Supply Departments
Ground Water Level Trend	Water Level	Meters	Float(6,2)	CGWB/SGWD
Apportioning	Block areas	Hectares	Integer	SGWD
In Storage Resources of Unconfined Aquifer	Area	Hectares	Integer	CGWB/SGWD
	Bottom of Dynamic Zone	Meters above MSL	Float(7,2)	CGWB/SGWD
	Bottom of unconfined Aquifer	Meters above MSL	Float(7,2)	CGWB/SGWD
Dynamic Resources of Confined/ semi	Area	Hectares	Integer	CGWB/SGWD
	Pre monsoon Piezometric	Meters above	Float(7,2)	CGWB/SGWD

Component	Parameter	Unit	Data type	Source
confined Aquifer	head.	MSL		
	Post monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
In storage Resources of Confined/ semi confined Aquifer	Area	Hectares	Integer	CGWB/SGWD
	Pre monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
	Post monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
	Bottom of Top Confining Layer	Meters above MSL	Float(7,2)	CGWB/SGWD

Note: The number in the bracket indicates total number of digits and number of required decimals.

6.2 STANDARDIZATION OF DATA ELEMENTS USED IN THE GROUND WATER RESOURCES ESTIMATION

Considering the existing limitations, the committee recommends the following standards and precisions for data elements. This standardization is envisaged to maintain uniformity in reporting and improve comparability of the assessment figures.

6.2.1 Region Specific Data Elements (Chapter - I)

S.No	Parameter	Type	Size	Decimals
1	Predominant Rock Terrain	Text	30	
2	Predominant Monsoon	Text	30	
3	Type of Assessment Unit	Text	10	
4	Ground Water Year	Text	20	
5	Monsoon Season	Text	20	
6	Non Monsoon Season	Text	20	
7	Pre-Monsoon Monitoring Month	Text	10	
8	Post-Monsoon Monitoring Month	Text	10	

6.2.2 Data Elements Pertaining To Sub Units (Chapter - II)

S.No	Parameter	Type	Size	Decimals
1	Toposheet Numbers	Text	50	
2	Starting Latitude	Text	10	
3	Ending Latitude	Text	10	
4	Starting Longitude	Text	10	
5	Ending Longitude	Text	10	
6	Total Area	Number	7	0
7	Hilly Area	Number	7	0
8	Recharge Worthy Area	Number	7	0
9	Poor Ground Water Quality Area	Number	7	0
10	Command Area	Number	7	0
11	Non Command Area	Number	7	0

6.2.3 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Unit DraftMethod (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Type of Structure	Text	50	
2	Assessment Sub Unit	Text	20	
3	Draft Per day	Number	3	0
4	Monsoon Days	Number	3	0
5	Non Monsoon Days	Number	3	0
6	Monsoon Unit Draft	Number	5	2
7	Non Monsoon Unit Draft	Number	5	2
8	Annual Unit Draft	Number	5	2
9	Extraction Type	Text	10	0
10	Total No. of Structures	Number	5	0
11	Total No. of Structures in Use	Number	5	0
12	Total Structure Monsoon Extraction	Number	7	2
13	Total Structure Non Monsoon Extraction	Number	7	2
14	Total Structure Annual Extraction	Number	7	2
15	Total Sub Unit Monsoon Extraction	Number	7	0
16	Total Sub Unit Non Monsoon Extraction	Number	7	0
17	Total Sub Unit Annual Extraction	Number	7	0
18	Total Sub Unit Domestic Monsoon Extraction	Number	7	0
19	Total Sub Unit Domestic Non Monsoon Extraction	Number	7	0
20	Total Sub Unit Domestic Annual Extraction	Number	7	0
21	Total Sub Unit Irrigation Monsoon Extraction	Number	7	0
22	Total Sub Unit Irrigation Non Monsoon Extraction	Number	7	0
20	Total Sub Unit Irrigation Annual Extraction	Number	7	0
21	Total Sub Unit Industrial Monsoon Extraction	Number	7	0
22	Total Sub Unit Industrial Non Monsoon Extraction	Number	7	0
23	Total Sub Unit Industrial Annual Extraction	Number	7	0
24	Total Sub Unit All Uses Monsoon Extraction	Number	8	0
25	Total Sub Unit All Uses Non Monsoon Extraction	Number	8	0
26	Total Sub Unit All Uses Annual Extraction	Number	8	0
27	Total Sub Unit All Uses Monsoon Extraction m	Number	5	3
28	Total Sub Unit All Uses Non Monsoon Extraction m	Number	5	3
29	Total Sub Unit All Uses Annual Extraction m	Number	5	3

6.2.4 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Crop Water Requirement Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Crop Type	Text	10	
3	Crop Name	Text	20	
4	Crop Season	Text	10	
5	Crop Acreage	Number	8	2
6	Crop Water Requirement	Number	6	2
7	Extraction for the Crop During Monsoon	Number	7	2
8	Extraction for the Crop During Non Monsoon Season	Number	7	2
9	Annual Extraction for the Crop	Number	7	2

S.No	Parameter	Type	Size	Decimals
10	Draft Type	Text	10	0
11	Total Sub Unit Extraction During Monsoon	Number	8	0
12	Total Sub Unit Extraction During Non Monsoon	Number	8	0
13	Total Sub Unit Annual Extraction	Number	8	0

6.2.5 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Power Consumption Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Domestic Power consumption in Monsoon Season	Number	8	0
3	Domestic Power Consumption in Non Monsoon Season	Number	8	0
4	Annual Domestic Power Consumption	Number	8	0
5	Irrigation Power consumption in Monsoon Season	Number	8	0
6	Irrigation Power Consumption in Non Monsoon Season	Number	8	0
7	Irrigation Domestic Power Consumption	Number	8	0
8	Domestic Extraction For Unit Power Consumption During Monsoon Season	Number	7	2
9	Domestic Extraction For Unit Power Consumption DuringNon MonsoonSeason	Number	7	2
10	Irrigation Extraction For Unit Power Consumption During Monsoon Season	Number	7	2
11	Irrigation Extraction For Unit Power Consumption DuringNon MonsoonSeason	Number	7	2
12	Domestic Extraction using Power Consumption During Monsoon	Number	8	0
13	Domestic Extraction using Power Consumption During Non Monsoon	Number	8	0
14	Irrigation Extraction using Power Consumption During Monsoon	Number	8	0
15	Irrigation Extraction using Power Consumption During Non Monsoon	Number	8	0

6.2.6 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population as on base year	Number	6	0
3	Growth Rate of Population per year	Number	5	0
4	Population as the Assessment Year	Number	6	0
5	Per capita daily requirement for Domestic Needs	Number	3	0
6	Fractional Load on Ground Water	Number	4	2
7	Domestic extraction During Monsoon Season	Number	8	0
8	Domestic extraction During Non Monsoon Season	Number	8	0
9	Annual Domestic extraction	Number	8	0

6.2.7 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Pattern Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	

S.No	Parameter	Type	Size	Decimals
2	Type of Industry	Text	20	
3	No of Such Units	Number	4	0
4	Ground Water Requirement of the Industry During Monsoon	Number	6	0
5	Ground Water Requirement of the Industry During Non Monsoon	Number	6	0
6	Annual Ground Water Requirement of the Industry	Number	6	0
7	Fractional Load on Ground Water	Number	4	2
8	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
9	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
10	Annual Industrial Extraction For the Type of Industry	Number	8	0
11	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
12	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
13	Annual Industrial Extraction For the Sub Unit	Number	8	0

6.2.8 Data Elements Pertaining to Estimation of Recharge from Canals (Chapter - IV)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Canal Segment	Text	50	
3	Type of Canal	Text	10	
4	Canal Length	Number	6	0
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Full Supply Depth	Number	5	2
10	Base Width	Number	5	2
11	Side Slope	Number	4	1
12	Wetted Perimeter	Number	6	2
13	Wetted Area million sq m	Number	8	5
14	Lining	Text	10	
15	Soil Type	Text	10	
16	Canal Seepage factor	Number	4	1
17	Monsoon Days	Number	3	0
18	Non Monsoon Days	Number	3	0
19	Monsoon Canal Recharge	Number	7	2
20	Non Monsoon Canal Recharge	Number	7	2
21	Total Sub Unit Monsoon Canal Recharge	Number	7	0
22	Total Sub Unit Non Monsoon Canal Recharge	Number	7	0
23	Total Sub Unit Annual Canal Recharge	Number	7	0

6.2.9 Data Elements Pertaining to the Estimation of Recharge from Surface Water Irrigation (Chapter - V)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Outlet	Text	50	
3	Name of the Canal	Text	50	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Design Discharge	Number	6	3
7	Monsoon Days	Number	3	0
8	Non Monsoon Days	Number	3	0
9	Monsoon Water Released	Number	7	2
10	Non Monsoon Water released	Number	7	2
11	Total Sub Unit Monsoon Water Released	Number	7	0
12	Total Sub Unit Non Monsoon Water Released	Number	7	0
13	Total Sub Unit Annual Water Released	Number	7	0
14	Name of the Observation Well	Text	50	
15	Previous Post Monsoon Water level	Number	6	2
16	Current Pre Monsoon Water level	Number	6	2
17	Current Post Monsoon Water level	Number	6	2
18	Average Previous Post Monsoon Water level	Number	6	2
19	Average Current Pre Monsoon Water level	Number	6	2
20	Average Current Post Monsoon Water level	Number	6	2
21	Water level During Monsoon	Number	6	2
22	Water level During Non Monsoon	Number	6	2
23	Name of the Crop	Text	20	
24	Area of Crop Monsoon	Number	7	2
25	Area of Crop Non Monsoon	Number	7	2
26	Total Area of Paddy Monsoon	Number	8	2
27	Total Area of Paddy Non Monsoon	Number	8	2
28	Total Area of Non Paddy Monsoon	Number	8	2
29	Total Area of Non Paddy Non Monsoon	Number	8	2
30	Type of Irrigation Water Monsoon	Text	10	
31	Return Flow Factor Paddy Monsoon	Number	5	2
32	Return Flow Factor Non Paddy Monsoon	Number	5	2
33	Weighted Average Return Flow Factor Monsoon	Number	5	2
34	Type of Irrigation Water Non Monsoon	Text	10	
35	Return Flow Factor Paddy Non Monsoon	Number	5	2
36	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
37	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
38	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
39	Total Sub Unit Non Monsoon Recharge due to SWI	Number	7	0
40	Total Sub Unit Annual Recharge due to SWI	Number	7	0

6.2.10 Data Elements Pertaining to the Estimation of Recharge from Ground Water Irrigation (Chapter - VI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Ground Water Applied Monsoon	Number	7	2
3	Ground Water Applied Non Monsoon	Number	7	2
4	Name of the Observation Well	Text	50	
5	Previous Post Monsoon Water level	Number	6	2
6	Current Pre Monsoon Water level	Number	6	2
7	Current Post Monsoon Water level	Number	6	2
8	Average Previous Post Monsoon Water level	Number	6	2
9	Average Current Pre Monsoon Water level	Number	6	2
10	Average Current Post Monsoon Water level	Number	6	2
11	Water level During Monsoon	Number	6	2
12	Water level During Non Monsoon	Number	6	2
13	Name of the Crop	Text	20	
14	Area of Crop Monsoon	Number	7	2
15	Area of Crop Non Monsoon	Number	7	2
16	Total Area of Paddy Monsoon	Number	8	2
17	Total Area of Paddy Non Monsoon	Number	8	2
18	Return Flow Factor Paddy Monsoon	Number	5	2
19	Return Flow Factor Non Paddy Monsoon	Number	5	2
20	Weighted Average Return Flow Factor Monsoon	Number	5	2
21	Return Flow Factor Paddy Non Monsoon	Number	5	2
22	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
23	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
24	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
25	Total Sub Unit Non Monsoon Recharge due to GWI	Number	7	0
26	Total Sub Unit Annual Recharge due to GWI	Number	7	0

6.2.11 Data Elements Pertaining to the Estimation of Recharge from Tanks & Ponds (Chapter - VII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Tank	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	Year of Construction	Text	9	
6	Monsoon Water Spread Area	Number	5	0
7	Non Monsoon Water Spread Area	Number	5	0
8	Monsoon Days	Number	3	0
9	Non Monsoon Days	Number	3	0
9	Monsoon Recharge TP	Number	7	2
10	Non Monsoon Recharge TP	Number	7	2
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0

6.2.12 Data Elements Pertaining to the Estimation of Recharge from Water Conservation Structures (Chapter - VIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Water Conservation Structure	Text	50	
3	Type of Water Conservation Structure	Text	20	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Year of Construction	Text	9	
7	Storage Capacity	Number	5	0
8	No Fillings	Number	3	1
9	Gross Storage	Number	6	0
10	Monsoon Recharge WCS	Number	7	2
11	Non Monsoon Recharge WCS	Number	7	2
12	Total Sub Unit Monsoon Recharge WCS	Number	7	0
13	Total Sub Unit Non Monsoon Recharge WCS	Number	7	0
14	Total Sub Unit Annual Recharge WCS	Number	7	0

6.2.13 Data Elements Pertaining to the Estimation of Recharge from Other Sources (Chapter - IX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Canal Recharge	Number	7	0
3	Total Sub Unit Non Monsoon Canal Recharge	Number	7	0
4	Total Sub Unit Annual Canal Recharge	Number	7	0
5	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
6	Total Sub Unit Non Monsoon Recharge due to SWI	Number	7	0
7	Total Sub Unit Annual Recharge due to SWI	Number	7	0
8	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
9	Total Sub Unit Non Monsoon Recharge due to GWI	Number	7	0
10	Total Sub Unit Annual Recharge due to GWI	Number	7	0
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0
14	Total Sub Unit Monsoon Recharge WCS	Number	7	0
15	Total Sub Unit Non Monsoon Recharge WCS	Number	7	0
16	Total Sub Unit Annual Recharge WCS	Number	7	0
17	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
18	Total Sub Unit Non Monsoon Recharge Other Sources	Number	8	0
19	Total Sub Unit Annual Recharge Other Sources	Number	8	0

6.2.14 Data Elements Pertaining to Estimation of Lateral Flow (Chapter - X)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Through Flow section ID	Text	20	
3	Average Hydraulic gradient Through seepage face During monsoon Season	Number	7	2
4	Average Hydraulic gradient Through seepage face During Non-Monsoon Season	Number	7	2

5	Transmissivity of the Aquifer	Number	8	2
6	Length of Seepage Section	Number	8	2
7	Through flow During Monsoon Season	Number	8	0
8	Through flow During Non-Monsoon Season	Number	8	0
9	Sub Unit Resultant Through flow During Monsoon Season	Number	8	0
10	Sub Unit Resultant Through flow During Non-Monsoon Season	Number	8	0

6.2.15 Data Elements Pertaining to Estimation of Vertical Flow (Chapter -XI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Leakage section ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Head in the Top/Bottom Aquifer During Monsoon Season	Number	7	2
6	Average Head in the Top/Bottom Aquifer During Non-Monsoon Season	Number	7	2
7	Hydraulic Conductivity of the Aquitard	Number	8	2
8	Thickness of the Aquitard	Number	8	2
9	Seepage Effected Area	Number	7	0
10	Vertical flow During Monsoon Season	Number	8	0
11	Vertical flow During Non-Monsoon Season	Number	8	0
12	Sub Unit Resultant Vertical flow During Monsoon Season	Number	8	0
13	Sub Unit Resultant Vertical flow During Non-Monsoon Season	Number	8	0

6.2.16 Data Elements Pertaining to Estimation of Base Flow(Chapter - XII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	River Segment ID	Text	20	
3	Stream Flow	Number	8	2
4	Base Flow	Number	8	2
5	Total Base flow During Monsoon Season	Number	9	2
6	Total Base flow During Monsoon Season	Number	9	2
7	Sub Unit Base flow During Monsoon Season	Number	9	2
8	Sub Unit Base flow During Non Monsoon Season	Number	9	2

6.2.17 Data Elements Pertaining to Estimation of Recharge from Streams (Chapter - XIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Flow section ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Stage in the Stream During Monsoon Season	Number	7	2
6	Average Stage in the Stream During Non-Monsoon Season	Number	7	2
7	Transmissivity of the Aquifer	Number	8	2

8	Length of Recharge Section During Monsoon Season	Number	8	2
9	Length of Recharge Section During Non-Monsoon Season	Number	8	2
10	Recharge Due to Streams During Monsoon Season	Number	8	0
11	Recharge Due to Streams During Non-Monsoon Season	Number	8	0
12	Sub Unit Resultant Recharge Due to Streams During Monsoon Season	Number	8	0
13	Sub Unit Resultant Recharge Due to Streams During Non-Monsoon Season	Number	8	0

6.2.18 Data Elements Pertaining to Evaporation & Transpiration (Chapter - XIV)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Evaporating Area During Monsoon Season	Number	7	0
3	Evaporating Area During Non Monsoon Season	Number	7	0
4	Evaporation Rate During Monsoon Season	Number	7	2
5	Evaporation Rate During Non Monsoon Season	Number	7	2
6	Sub Unit Evaporation During Monsoon Season	Number	8	0
7	Sub Unit Evaporation During Monsoon Season	Number	8	0
8	Transpiring Area During Monsoon Season	Number	7	0
9	Transpiring Area During Non Monsoon Season	Number	7	0
10	Transpiration Rate During Monsoon Season	Number	7	2
11	Transpiration Rate During Non Monsoon Season	Number	7	2
12	Sub Unit Transpiration During Monsoon Season	Number	8	0
13	Sub Unit Transpiration During Non Monsoon Season	Number	8	0

6.2.19 Data Elements Pertaining to the Estimation of Rainfall Recharge By Rainfall Infiltration Factor Method (Chapter - XV)

S.No	**Parameter**	**Type**	**Size**	**Decimals**
1	Assessment Sub Unit	Text	20	
2	Name of Raingauge	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No. of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Normal Monsoon Rainfall	Number	7	2
9	Normal Non Monsoon Rainfall	Number	7	2
10	Normal Annual Rainfall	Number	7	2
11	Average Normal Monsoon Rainfall	Number	7	2
12	Average Normal Non Monsoon Rainfall	Number	7	2
13	Average Normal Annual Rainfall	Number	7	2
14	Percentage of Non Monsoon rainfall	Number	5	2
15	Predominant Rock Terrain	Text	30	
16	Geographic location	Text	20	
17	Hard rock type	Text	30	
18	Watershed Development Activity Present	Logical		
19	Rainfall Infiltration Factor	Number	5	2
20	Area	Number	7	0
11	Total Sub Unit Monsoon RF Recharge RFIF	Number	8	0
12	Total Sub Unit Non Monsoon RF Recharge RFIF	Number	8	0

S.No	Parameter	Type	Size	Decimals
13	Total Sub Unit Annual RF Recharge RFIF	Number	8	0
14	Total Sub Unit Monsoon RF Recharge RFIF m	Number	7	3
15	Total Sub Unit Non Monsoon RF Recharge RFIF m	Number	7	3
16	Total Sub Unit Annual RF Recharge RFIF m	Number	7	3

6.2.20 Data Elements Pertaining to the Estimation of Rainfall Recharge by Ground Water Level Fluctuation Method (Chapter - XVI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Raingauge	Text	50	
3	Current year Monsoon Rainfall	Number	7	2
4	Average Current Year Monsoon Rainfall	Number	7	2
5	Name of Observation well	Text	50	
6	Current year Pre Monsoon WL	Number	6	2
7	Current year Post Monsoon WL	Number	6	2
8	Average Current Year Pre Monsoon WL	Number	6	2
9	Average Current Year Post Monsoon WL	Number	6	2
10	Average Current Year WL Fluctuation	Number	6	2
11	Predominant Rock Terrain	Text	30	
12	Soil Type	Text	20	
13	Hard rock type	Text	30	
14	Specific Yield	Number	5	2
15	Area	Number	7	0
16	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
17	Total Sub Unit All Uses Monsoon Draft	Number	8	0
18	Total Sub Unit Monsoon Change in GW Storage	Number	8	0
19	Total Sub Unit Monsoon RF Recharge WTFM	Number	8	0
20	Ground Water year	Number	4	0
21	Monsoon Rainfall m	Number	7	3
22	Corresponding Monsoon RF Recharge WTFM THam	Number	7	3
23	Deviation Monsoon RF with Normal	Number	5	2
24	Normal RF RechargeY=mX	Number	7	3
25	Average Normal RF RechargeY=mX	Number	7	3
26	Rainfall Square	Number	7	3
27	Product of Rainfall and Recharge	Number	7	3
28	Sum Rainfall	Number	7	3
29	Sum Recharge	Number	7	3
30	Sum Rainfall Square	Number	7	3
31	Sum Product	Number	7	3
32	Number of Data Points	Number	2	0
33	Slope	Number	7	3
34	Intercept	Number	7	3
35	Normal RF RechargeY=mX+C	Number	7	3
36	Percent Difference	Number	6	2
37	Noramlized RF Recharge	Number	7	0
38	Final RF Recharge Monsoon	Number	7	0
39	Final RF Recharge Monsoon m	Number	7	3
40	Final RF Recharge Non Monsoon	Number	7	0
41	Final RF Recharge Non Monsoon m	Number	7	3
42	Final RF Recharge Annual	Number	7	0
43	Final RF Recharge Annual m	Number	7	3

6.2.21 Data Elements Pertaining to the Estimation of Annual Extractable Ground Water Resources (Chapter - XVII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
3	Total Sub Unit Non Monsoon Recharge Other Sources	Number	8	0
4	Total Sub Unit Annual Recharge Other Sources	Number	8	0
5	Total Sub Unit Resultant Inflows During Monsoon Season	Number	8	0
6	Total Sub Unit Resultant Inflows During Non Monsoon Season	Number	8	0
7	Final RF Recharge Monsoon	Number	7	0
8	Final RF Recharge Non Monsoon	Number	7	0
9	Final RF Recharge Annual	Number	7	0
10	Total Annual Ground Water recharge	Number	8	0
11	Base Flows restricting to Ecological Flows	Number	8	0
12	Unaccounted Natural Discharges	Number	8	0
13	Annual Extractable Ground Water Resources	Number	8	0
11	Area	Number	7	0
12	Annual Extractable Ground Water Resources	Number	8	0

6.2.22 Data Elements Pertaining to the Estimation of Stage of Ground Water Extraction (Chapter - XVIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	Total Sub Unit All Uses Annual Extraction	Number	8	0
4	Stage of Ground Water Extraction	Number	6	2

6.2.23 Data Elements Pertaining to the Estimation of Ground Water Level Trends (Chapter - XIX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Observation Well	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Year	Number	4	0
9	Pre-Monsoon Water Level	Number	6	2
10	Post-Monsoon Water Level	Number	6	2
11	Year X	Number	2	0
12	WL	Number	6	2
13	Year X Square	Number	4	0
14	Product of Year and WL	Number	7	3
15	Sum Year X	Number	7	3
16	Sum WL	Number	7	3
17	Sum Year X Square	Number	7	3

18	Sum Product	Number	7	3
19	Number of Data Points	Number	2	0
20	Slope	Number	7	3
21	Intercept	Number	7	3
22	Trend	Text	20	
23	Stage of Ground Water extraction	Number	6	2
24	Validity	Text	10	

6.2.24 Data Elements Pertaining to the Categorization (Chapter - XX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Stage of Ground Water Extraction	Number	6	2
3	Validity	Text	10	
4	Quantity Category	Text	20	
5	Quality Tag	Text	10	

6.2.25Data Elements Pertaining to the Allocation (Chapter - XXI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population	Number	7	0
3	Year of Census	Number	4	0
4	Growth Rate	Number	5	2
5	Projected Population	Number	7	0
6	Dependency on GW	Number	3	2
7	Percapita requirement	Number	3	0
8	Annual Allocation	Number	8	0
9	Area	Number	7	0
10	Annual Allocation m	Number	7	3

6.2.26 Data Elements Pertaining to the Estimation of Net Ground Water Availability for Future Use (Chapter - XXII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Area	Number	7	0
3	Annual Extractable Ground Water Resource	Number	8	0
4	Total Sub Unit Irrigation Annual Extraction	Number	7	0
5	Total Sub Unit Industrial Annual Extraction	Number	7	0
5	Annual Allocation for Domestic needs	Number	8	0
6	Net Ground Water Availability For Future Use	Number	8	0
7	Net Ground Water Availability For Future Use m	Number	7	3

6.2.27 Data Elements Pertaining to the Estimation of Additional Potential Resources (Chapter - XXIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Unit	Text	20	
2	Spring discharge During Monsoon	Number	5	2
3	Spring Discharge During Non Monsoon	Number	5	2

4	Average Monsoon Days Spring Yields in the unit	Number	3	0
5	Average Non Monsoon Days Spring Yields in the unit	Number	3	0
6	Annual Spring Discharge in the Unit	Number	5	2
7	No of Such Springs in the Unit	Number	4	0
8	Potential resource Due to Spring Discharges	Number	8	0
9	Water Logged Area	Number	7	0
10	Average Depth to Water level	Number	6	2
11	Specific Yield	Number	5	2
12	Potential Resources Shallow WT	Number	8	0
13	Flood Prone Area	Number	7	0
14	No of Days Area is Submerged	Number	3	0
15	Potential Resources in Flood Prone Areas	Number	8	0
16	Total Potential Resources	Number	8	0

6.2.28 Data Elements Pertaining to the Dynamic Ground Water Resources of Confined/ Semi-Confined Aquifer (Chapter - XXIV)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Total Dynamic Resource of Confined Aquifer	Number	8	0

6.2.29 Data Elements Pertaining to the Preparation of Summary Report (Chapter - XXV)

S.No	**Parameter**	**Type**	**Size**	**Decimals**
1	State	Text	50	
2	Assessment Unit	Text	20	
3	Type of Assessment Unit	Text	20	
4	Predominant Rock Terrain	Text	30	
5	Total Area	Number	7	0
6	Poor Ground Water Quality Area	Number	7	0
7	Command Area	Number	7	0
8	Non Command Area	Number	7	0
9	Ground Water Assessment year	Text	9	0
10	Final Monsoon Recharge Other Sources NC	Number	8	0
11	Final Non Monsoon Recharge Other Sources NC	Number	8	0
12	Base Flow During Monsoon NC	Number	8	0
13	Recharge Due to Streams Monsoon NC	Number	8	0
14	Lateral Flows During Monsoon NC	Number	8	0
15	Vertical Flows During Monsoon NC	Number	8	0
16	Evaporation During Monsoon NC	Number	8	0
17	Transpiration During Monsoon NC	Number	8	0
18	Recharge Due to Streams Non Monsoon NC	Number	8	0
19	Lateral Flows During Non Monsoon NC	Number	8	0
20	Vertical Flows During Non Monsoon NC	Number	8	0
21	Evaporation During Non MonsoonNC	Number	8	0
22	Transpiration During Non MonsoonNC	Number	8	0
23	Final RF Recharge Monsoon NC	Number	7	0

S.No	Parameter	Type	Size	Decimals
24	Final RF Recharge Non Monsoon NC	Number	7	0
25	Total Annual Ground Water recharge NC	Number	8	0
26	Unaccounted Natural Discharges NC	Number	8	0
27	Annual Extractable Ground Water Recharge NC	Number	8	0
28	Total Sub Unit All Uses Annual Extraction NC	Number	8	0
29	Stage of Ground Water Extraction NC	Number	6	2
30	Total Sub Unit Irrigation Annual Extraction NC	Number	8	0
31	Total Sub Unit Industrial Annual Extraction NC	Number	8	0
32	Annual Allocation NC	Number	8	0
33	Net Ground Water Availability For Future Use NC	Number	8	0
34	Final Monsoon Recharge Other Sources C	Number	8	0
35	Final Non Monsoon Recharge Other Sources C	Number	8	0
36	Recharge Due to Streams Monsoon C	Number	8	0
37	Lateral Flows During Monsoon C	Number	8	0
38	Vertical Flows During Monsoon C	Number	8	0
39	Evaporation During Monsoon C	Number	8	0
40	Transpiration During Monsoon C	Number	8	0
41	Recharge Due to Streams Non Monsoon C	Number	8	0
42	Lateral Flows During Non Monsoon C	Number	8	0
43	Vertical Flows During Non Monsoon C	Number	8	0
44	Evaporation During Non Monsoon C	Number	8	0
45	Transpiration During Non Monsoon C	Number	8	0
46	Final RF Recharge Monsoon C	Number	8	0
47	Final RF Recharge Non Monsoon C	Number	8	0
48	Total Annual Ground Water recharge C	Number	8	0
49	Unaccounted Natural Discharges C	Number	8	0
50	Annual Extractable Ground Water Recharge C	Number	8	0
51	Total Sub Unit All Uses Annual Extraction C	Number	8	0
52	Stage of Ground Water Extraction C	Number	6	2
53	Total Sub Unit Irrigation Annual Extraction C	Number	8	0
54	Total Sub Unit Industrial Annual Extraction C	Number	8	0
55	Annual Allocation C	Number	8	0
56	Net Ground Water Availability For Future Use C	Number	8	0
57	WTFM Used NC	Logical	1	
58	WTFM Used C	Logical	1	
59	Method For SY Determination NC	Text	20	
60	Method For SY Determination C	Text	20	
61	Declining Pre and Post WL NC	Logical		
62	Category NC	Text	15	
63	Validity NC	Text	10	
64	Declining Pre and Post WL C	Logical		
65	Category C	Text	15	
66	Validity C	Text	10	
67	Final Monsoon Recharge Other Sources PQ	Number	8	0
68	Final Non Monsoon Recharge Other Sources PQ	Number	8	0
69	Recharge Due to Streams Monsoon PQ	Number	8	0
70	Lateral Flows During Monsoon PQ	Number	8	0
71	Vertical Flows During Monsoon PQ	Number	8	0
72	Evaporation During Monsoon PQ	Number	8	0
73	Transpiration During Monsoon PQ	Number	8	0
74	Recharge Due to Streams Non Monsoon PQ	Number	8	0
75	Lateral Flows During Non Monsoon PQ	Number	8	0
76	Vertical Flows During Non Monsoon PQ	Number	8	0

S.No	Parameter	Type	Size	Decimals
77	Evaporation During Non Monsoon PQ	Number	8	0
78	Transpiration During Non Monsoon PQ	Number	8	0
79	Final RF Recharge Monsoon PQ	Number	7	0
80	Final RF Recharge Non Monsoon PQ	Number	7	0
81	Total Annual Ground Water Recharge PQ	Number	8	0
82	Unaccounted Natural Discharges PQ	Number	8	0
83	Annual Extractable Ground Water Recharge PQ	Number	8	0
84	Total Sub Unit Irrigation Annual Extraction PQ	Number	8	0
85	Total Sub Unit Industrial Annual Extraction PQ	Number	8	0
86	Net Ground Water Availability For Future Use PQ	Number	8	0
87	WTFM Used PQ	Logical	1	
88	Method For SY Determination PQ	Text	20	
89	Declining Pre and Post WL PQ	Logical		
90	Category PQ	Text	15	
91	Validity PQ	Text	10	
92	Potential Resources Due to Spring Discharges	Number	8	0
93	Potential Resources Due to Shallow WT	Number	8	0
94	Potential Resources Due to Flood Prone Area	Number	8	0
95	Total Potential Resources	Number	8	0

6.230. Data Elements Pertaining to the Apportioning (Chapter - XXVI)

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Administrative Unit	Text	20	
3	Type of Administrative Unit	Text	20	
4	Toposheet Numbers	Text	50	
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Total Area	Number	7	0
10	Hilly Area	Number	7	0
11	Recharge Worthy Area	Number	7	0
12	Poor Ground Water Quality Area	Number	7	0
13	Command Area	Number	7	0
14	Non Command Area	Number	7	0
15	Name of the Assessment Unit	Text	20	
16	Annual Extractable Ground Water Recharge NC	Number	8	0
17	Area of Assessment Sub Unit in the Admin Unit NC	Number	7	0
18	Annual Extractable Ground Water Recharge in Admin NC	Number	8	0
19	Total Area of Assessment Unit in the Admin Unit NC	Number	7	0
20	Total Annual Extractable Ground Water Recharge in Admin NC	Number	8	0
21	Total Annual Extractable Ground Water Recharge in Admin NC m	Number	8	3
22	Sub Unit All Uses Annual Extraction NC	Number	8	0
23	Sub Unit All Uses Annual Extraction in Admin NC	Number	8	0
24	Total Sub Unit All Uses Annual Extraction Admin NC	Number	8	0
25	Total Sub Unit All Uses Annual Extraction Admin NC m	Number	8	3
26	Sub Unit Irrigation Annual Extraction NC	Number	8	0
27	Sub Unit Irrigation Annual Extraction in Admin NC	Number	8	0
28	Total Sub Unit Irrigation Annual Extraction Admin NC	Number	8	0

S.No	Parameter	Type	Size	Decimals
29	Total Sub Unit Irrigation Annual Extraction Admin NC m	Number	8	3
30	Sub Unit Industrial Annual Extraction NC	Number	8	0
31	Sub Unit Industrial Annual Extraction in Admin NC	Number	8	0
32	Total Sub Unit Industrial Annual Extraction Admin NC	Number	8	0
33	Total Sub Unit Industrial Annual Extraction Admin NC m	Number	8	3
34	Sub Unit Allocation NC	Number	8	0
35	Sub Unit Allocation in Admin NC	Number	8	0
36	Total Sub Unit Allocation Admin NC	Number	8	0
37	Total Sub Unit Allocation Admin NC m	Number	8	3
38	Sub Unit Pretrend NC	Number	8	0
39	Sub Unit Pretrend in Admin NC	Number	8	0
40	Total Sub Unit Pretrend Admin NC	Number	8	0
41	Sub Unit Posttrend NC	Number	8	0
42	Sub Unit Pretrend in Admin NC	Number	8	0
43	Total Sub Unit Posttrend Admin NC	Number	8	0
44	Stage of Ground Water Extraction NC	Number	6	2
45	Annual Extractable Ground Water Resource C	Number	8	0
46	Area of Assessment Sub Unit in the Admin Unit C	Number	7	0
47	Annual Extractable Ground Water Resourcein Admin C	Number	8	0
48	Total Area of Assessment Unit in the Admin Unit C	Number	7	0
49	Total Annual Extractable Ground Water Resource in Admin C	Number	8	0
50	Total Annual Extractable Ground Water Resource in Admin C m	Number	8	3
51	Sub Unit All Uses Annual Extraction C	Number	8	0
52	Sub Unit All Uses Annual Extraction in Admin C	Number	8	0
53	Total Sub Unit All Uses Annual Extraction Admin C	Number	8	0
54	Total Sub Unit All Uses Annual Extraction Admin C m	Number	8	3
55	Sub Unit Irrigation Annual Extraction C	Number	8	0
56	Sub Unit Irrigation Annual Extraction in Admin C	Number	8	0
57	Total Sub Unit Irrigation Annual Extraction Admin C	Number	8	0
58	Total Sub Unit Irrigation Annual Extraction Admin C m	Number	8	3
59	Sub Unit Industrial Annual Extraction C	Number	8	0
60	Sub Unit Industrial Annual Extraction in Admin C	Number	8	0
61	Total Sub Unit Industrial Annual Extraction Admin C	Number	8	0
62	Total Sub Unit Industrial Annual Extraction Admin C m	Number	8	3
63	Sub Unit Allocation C	Number	8	0
64	Sub Unit Allocation in Admin C	Number	8	0
65	Total Sub Unit Allocation Admin C	Number	8	0
66	Total Sub Unit Allocation Admin C m	Number	8	3
67	Sub Unit Pretrend C	Number	8	0
68	Sub Unit Pretrend in Admin C	Number	8	0
69	Total Sub Unit Pretrend Admin C	Number	8	0
70	Sub Unit Posttrend C	Number	8	0
71	Sub Unit Pretrend in Admin C	Number	8	0
72	Total Sub Unit Posttrend Admin C	Number	8	0
73	Stage of Ground Water Extraction C	Number	6	2
74	Annual Extractable Ground Water Resource PQ	Number	8	0
75	Area of Assessment Sub Unit in the Admin Unit PQ	Number	7	0
76	Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
77	Total Area of Assessment Unit in the Admin Unit PQ	Number	7	0

S.No	Parameter	Type	Size	Decimals
78	Total Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
79	Total Annual Extractable Ground Water Resource in Admin PQ m	Number	8	3
80	Sub Unit All Uses Annual Extraction PQ	Number	8	0
81	Sub Unit All Uses Annual Extraction in Admin PQ	Number	8	0
82	Total Sub Unit All Uses Annual Extraction Admin PQ	Number	8	0
83	Total Sub Unit All Uses Annual Extraction Admin PQ m	Number	8	3
84	Sub Unit Irrigation Annual Extraction PQ	Number	8	0
85	Sub Unit Irrigation Annual Extraction in Admin PQ	Number	8	0
86	Total Sub Unit Irrigation Annual Extraction Admin PQ	Number	8	0
87	Total Sub Unit Irrigation Annual Extraction Admin PQ m	Number	8	3
88	Sub Unit Industrial Annual Extraction PQ	Number	8	0
89	Sub Unit Industrial Annual Extraction in Admin PQ	Number	8	0
90	Total Sub Unit Industrial Annual Extraction Admin PQ	Number	8	0
91	Total Sub Unit Industrial Annual Extraction Admin PQ m	Number	8	3
92	Sub Unit Allocation PQ	Number	8	0
93	Sub Unit Allocation in Admin PQ	Number	8	0
94	Total Sub Unit Allocation Admin PQ	Number	8	0
95	Total Sub Unit Allocation Admin PQ m	Number	8	3
96	Sub Unit Pre trend PQ	Number	8	0
97	Sub Unit Pre trend in Admin PQ	Number	8	0
98	Total Sub Unit Pre trend Admin PQ	Number	8	0
99	Sub Unit Post trend PQ	Number	8	0
100	Sub Unit Pre trend in Admin PQ	Number	8	0
101	Total Sub Unit Post trend Admin PQ	Number	8	0
102	Stage of Ground Water Extraction PQ	Number	6	2

6.2.31 Data Elements Pertaining to the Static/ In Storage Ground Water Resources of Unconfined Aquifer (Chapter - XXVII)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Static Resources Area	Number	7	0
3	Average Depth of Fluctuation	Number	6	2
4	Bottom of Aquifer	Number	7	2
5	Bottom of Aquifer for Computation	Number	7	2
6	Specific Yield	Number	5	2
7	Total Static Resources Unconfined	Number	8	0

6.2.32 Data Elements Pertaining to the In storage Ground Water Resources of Confined/ Semi-Confined Aquifer (Chapter - XXVIII)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2

S.No	Parameter	Type	Size	Decimals
6	Bottom of Top Confined Layer	Number	7	2
6	Total In Storage Resource of Confined Aquifer	Number	8	0

6.2.33 Data Elements Pertaining to the Total Ground Water Availability (Chapter - XXIX)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	In storage Ground Water Resources of Unconfined Aquifer	Number	8	0
4	Total Ground Water Availability of Unconfined Aquifer	Number	8	0
5	Dynamic Ground Water Resources of Confined Aquifers	Number	8	0
6	In storage Ground Water Resources of Confined Aquifers	Number	8	0
7	Total Ground Water Availability of Confined Aquifers	Number	8	0
8	Dynamic Ground Water Resources of Semi-Confined Aquifers	Number	8	0
9	In storage Ground Water Resources of Semi-Confined Aquifers	Number	8	0
10	Total Ground Water Availability of Semi-Confined Aquifers	Number	8	0
11	Total Ground Water Availability of the Assessment Unit	Number	8	0

6.3 NORMS USED IN THE RESOURCE ESTIMATION

In assessing the ground water resources five categories of norms are being used as recommended by the current methodology. These are Storage Norms, Infiltration Norms, Abstraction Norms, Requirement Norms and Discharge Norms. The storage norm is represented as specific yield, which is expressed as a fraction or percent. The requirement norm for the domestic and industrial water requirement is expressed in litres per capita per day (lpcd). The abstraction norm is expressed in hectare metres (ham). The discharge norm is expressed as a percentage. The Infiltration norms which make a major chunk of the norms are expressed as percent as in the case of Rainfall Infiltration Factor, Return Flow Factor for irrigation and Seepage Factor for water conservation structures. In the case of Return Flow Factor for tanks and ponds it is expressed as mm/day and as ham/day/million m^2 of wetted area for the Canal Seepage Factor. The different norms proposed for ground water resource estimation is given in Table 14.

TABLE14. TYPES OF NORMS USED IN THE GROUND WATER RESOURCE ESTIMATION USING GEC-2015.

Type Of Norm	Parameter	Unit
Storage Norm	Specific Yield	Percent
Infiltration Norms	Rainfall Infiltration Factor	Percent
	Canal Seepage	Ham/day/10^6m^2 of wetted area
	Return Flow Factor For Irrigation	Percent
	Infiltration Factor For Tanks & Ponds	mm/day
	Seepage Factor For Water Conservation Structures	Percent
Requirement Norms	Per capita Requirement For Domestic and Industrial Needs	lpcd
Abstraction Norm	Unit Draft	Ham
Discharge Norm	Unaccounted Natural Discharges	Percent

* * *

7

FUTURE STRATEGIES

7.1 REFINEMENTS TO THE RECOMMENDED METHODOLOGY

7.1.1 Introduction

The methodology for ground water resource estimation as described in Chapter 5 is based on relatively sound scientific basis. It also meets the practical requirements for formulating rational ground water development strategies. This methodology commensurate with available human resources, their level of technical skills and infrastructure facilities available with the state level ground water organisations for formulating rational ground water development strategies. However, the methodology still has considerable scope for refinement and improvement which can be planned and achieved in a time bound and phased manner for future assessments. Some of these essential refinements are briefly described below.

7.1.2 Aquifer wise Assessment

One of the major recommendations in the present (GEC-2015) methodology is to assess the ground water resources aquifer wise. The major issues are estimating recharge for shallow aquifer, extraction for the deeper aquifer and categorization of assessment units based on the results so obtained. It is recommended that ground water resources may be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

7.1.3 Switching Over to Watershed as an assessment unit in areas other than alluvium

As per the recommendations of GEC-97, watershed should be taken as the assessment unit in areas other than alluvium. However, even now many states dominated by hard rock areas are still assessing the resources administrative unit wise. Hence, GEC 2015 also recommends a switch over to watershed as the unit for resource assessment in the areas dominated by lithology other than Alluvium.

7.1.4 Employing Remote Sensing Techniques

Remote sensing techniques can be profitably employed for quantifying various components of the methodology described in Chapter 5. The Digital Elevation Models (DEM) DEM data can be utilized for delineating hilly areas where slope is more than 20%. If the temporal data of the area is available, these techniques can also be used for delineating the water spread area of tanks & ponds and the number of days water is available in such structures. Similarly the technique can also be used for assessing the cropped area and the mode of irrigation (either ground water or surface water) predominantly employed.

7.1.5 Computerization of the Ground Water Resource Estimation Methodology

In most states, the application of the methodology for ground water resource estimation is predominantly carried out using MS-Excel or MS-Access. Even though automated system like GWA Module in GEMS is available, it is not utilized to the fullest due to lack of basic knowledge of the system in a client-server environment and Oracle database. Hence, there is a need to develop a simple, user friendly application that can be used even in the basic models of personal computers.

7.1.6 Data monitoring

The availability of adequate data is the key to the successful application of GEC-2015 methodology of ground water resource estimation as given in Chapter 5. This will be achieved when a switch over is made to an aquifer wise assessment and all the components in the ground water balance equation are utilized. Following are the prerequisites:

- Aquifer mapping to establish aquifer geometry and aquifer parameters.
- Establishment of appropriate grid of observation wells for monitoring water table fluctuations and quality.
- Establishment of at least one rain gauge station in each assessment unit for monitoring daily rainfall.
- Establishment of at least one pan evaporimeter in each assessment unit for evaporation measurements.
- Establishment of one stream gauge at the mouth of the watershed with emphasis on base flow measurements.
- Adequate number of field level experiments are to be conducted for measurement of aquifer parameters, seepage losses, infiltration rates and other norms used in the estimation.

7.1.7 Norms for the Estimation of Recharge

Norms for Ground water resource estimation provided in section 5.14may be used in situations where field studies could not be conducted. An attempt has been made in Chapter 5 to specify these norms in as realistic manner as possible most of which are the redistribution of the norms suggested by GEC 1997 methodology. It is however, necessary that a proper mechanism be evolved through which these norms can be periodically evaluated and refined based on field level studies.

7.1.8 Distributed Parameter Modelling

The methodology described in Chapter 5 is essentially a lumped parameter system approach. Although the physical ground water unit has been categorised into a few distinct and relevant sub-units but spatial variations are not adequately represented. A need therefore arises to consciously employ computer based distributed parameter system approach using techniques like finite difference, finite element and boundary integral equation methods. Such application for a few selected hydrogeologic units should be undertaken in a phased and time bound manner.

7.2 ALTERNATIVE METHODOLOGY

The methodology described in Chapter 5 for ground water resource estimation for the unconfined aquifer is essentially a water balance approach in which:

- The physical system for which the water balance is carried out is a lumped system representing the ground water regime (below the water table). It has a number of input and output components. This is true even in aquifer wise resource estimation,
- Only one of the input components i.e. recharge from rainfall is considered to be unknown. All other components can be either directly estimated individually, or ignored due to some reasonably valid factor or accounted for in some indirect manner.
- The algebraic sum of all input and output components is equated to the change in storage within the ground water regime as reflected by the water table fluctuation. This in turn results in estimating the single unknown component i.e. recharge from rainfall.

There is a genuine need for an alternative methodology for computing the recharge from rainfall which does not make use of the water table fluctuation. This need has also been emphasised in the GEC 1997 methodology and the approach paper on the Hydrology Project. One direct advantage of the application of such an alternative methodology is that the recharge from rainfall thus estimated can be used to corroborate the estimate obtained by the water table fluctuation method and thereby gain confidence in the validity of the estimate. In case there is a discrepancy in the two estimates, it is also advantageous in the sense that it can motivate practicing hydrogeologists to look more closely into the discrepancies and seek scientific explanations. This, in turn, can considerably enhance their understanding on all issues related to ground water resource estimation.

7.2.1Soil Water Balance Method

The soil water balance method has been widely applied in many watersheds in North America, Europe and Israel. The main characteristics of the soil-water-balance method are briefly mentioned below:

a) It is essentially a water balance approach similar to the methodology presented in Chapter 5. However, it significantly differs in the sense that the physical system for which the water balance is applied comprises of the zone above the water table. This system is again divided into two sub-units- an upper zone representing the vegetative surfaces, leaf litter and ground surface and a lower zone representing the vertical soil profile above the water table.

b) The sub-system representing the upper zone has a number of input and output components. The algebraic sum of these components is equated to the change in soil moisture. Given a rainfall input P in mm/day and potential evapotranspiration E_p in mm/day, the output component of excess rainfall, PM in mm/day is obtained. PM contributes to surface runoff Q in mm/day and to replenishment to the lower zone, PEM in mm/day. Determination of Q requires the use of a suitable method such as SCS method.

c) The lower zone also has a number of input and output components. The algebraic sum of these components is equated to the change in soil moisture within the lower zone. Given the value of PEM in mm/day, and the evaporation, $E_a$in mm/day, the output component of natural replenishment to the ground water system below, GW in mm/day is finally obtained. GW represents the recharge from rainfall to the ground water regime.

d) The application of the method yields reliable results only if the water balance is carried out over a number of very small discrete time periods. The recommended time duration is one day. On the other hand, the methodology presented in Chapter 5 allows much larger duration of time period in which the water balance is carried out. For instance, one year has been divided into only two discrete time durations.

e) The method also requires calibration of the water budget model with actual field data before it is applied.

The alternative methodology described above has significant advantages. However, given the limitations of lack of data on meteorological, hydrologic and soil characteristics on a watershed basis obtained through a comprehensive system of field level instrumentation, it is probably not practical to immediately apply the method on a very wide scale. The state level ground water organisations may also not have the required infrastructure facilities. Under these circumstances, it is recommended that this method can be used as a validating process rather than the method for estimation.

7.3 R & D Studies

Norms given in the Chapter 5 may be used in the estimations of ground water resources for situations as GEC-2015 has made an attempt to specify the norms used for estimation of ground water resources in as realistic manner as possible. The norms can be used for situations where data from field studies is not available. To strengthen and to refine various parameters used for the ground water resources estimation special R & D studies must be carried out. Some of these broad areas where special R&D studies are to be done on priority include:

- Return flow from irrigation/ micro irrigation.
- Seepage from canals
- Flows across Command and non-command areas.
- Spring discharge and spring hydrology.
- Aquifers in waterlogged areas.
- Aquifers and soil water balance
- Confined aquifer systems.
- Coastal studies in different hydrogeological settings.
- Urban ground water balance.
- Aquifers of arid regions.

Urban Ground Water Balance Studies may be taken up in Lucknow and Hyderabad and study of spring discharge and spring hydrology may be taken up in the state of Sikkim.

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ANNEXURE I

(TO BE PUBLISHED IN THE GAZETTE OF INDIA PART-I, SECTION -I)

File No. T-13014/4/2014-GW –M

Government of India

Ministry of Water Resources, River Development & Ganga Rejuvenation

(Ground Water Desk)

****

Shram Shakti Bhawan, Rafi Marg

New Delhi- 110 001

Dated: 6th January, 2015 7th

RESOLUTION

Sub: Constitution of Ground water estimation Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97).

The ground water resources assessment of the country is being carried out jointly by Central Ground Water Board and State Ground Water Departments based on methodology recommended by "Ground Water Estimation Committee 1997" (GEC 1997) at regular interval with the objective to identify and prioritize the areas for ground water management interventions. The ground water assessments in 2004, 2009 and 2011 were done as per GEC-97.

2) The Central Ground Water Board, State Ground Water Organisation, Universities and other organisations have carried out number of studies on assessment of ground water resources since the GEC-97 was adopted. Results of the studies were presented and deliberated in various consultative meetings and workshops. A need was felt to review and revise the GEC-1997 methodology to incorporate new advancements/practices/tools like ground water modelling and also refining the various parameters being used in assessment.

3) Composition of the Committee:

In the view of above, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India hereby constitutes a committee to review and revise the Ground water Estimation Methodology (GEC-97) and look into related issues. The Committee will consist of following Members:

1.	Chairman, Central Ground Water Board	Chairman
2.	Joint Secretary (WSM), Ministry of Rural Development, Government of India, New Delhi.	Member
3.	General Manager, National Bank for Agriculture, & Rural Development (NABARD), Sterling Centre, Shiv Sagar Estate, Dr. Annie Besant Road, Post Box No. 6552, Mumbai - 400 018	Member
4.	Dy. Director General, Geological Survey of India, CGPB Secretariat, Geological Survey of India, Pushpa Bhawan, A-Block, 2nd Floor, Madangir Road, New Delhi – 110062.	Member
5.	Director, State Water Investigation Directorate, Government of West Bengal, Sectt. Bhawan (3rd Floor), Salt Lake, Kolkata – 700 091.	Member
6.	Chief Engineer (PWD), State Ground and Surface Water Resources Data Centre, Water, Government of Tamil Nadu, IWS Campus, Tharamani, Chennai – 600 113.	Member
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11.	Director, Water Resources & Environment Directorate, Government of Punjab, SCO- 32-34, Sector-17C Chandigarh.- 160017	Member
12.	Director, UP Ground Water Department, Government of Uttar Pradesh, 9th Floor, Indira Bhavan, Ashok Marg, Lucknow – 226 001.	Member
13.	Member(TT&WQ), CGWB, NH-IV, Faridabad	*Member Secretary*

3.1) Special Invitees:-

1.	Commissioner (SP), Government of India, MOWR,RD&GR, Shram Shakti Bhawan, New Delhi - 110 001.
2.	Head, Ground Water Hydrology Division, National Institute of Hydrology, Jalvigyan Bhawan, Roorkee – 247667
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8.	Member (SML) and Member Secretary, CGWA, R.K. Puram, New Delhi

3.2) Sh. Rana Chatterjee, Scientist-D, CGWB, will assist the Committee.

3.3) The committee may co-opt any other Member(s), if necessary.

4) Terms of reference

The terms of reference of the Committee are as follows:

1. Firming up / updating various parameters and their values currently used in the assessment of ground water resources based on the scientific work carried out by various organizations.
2. To look into the details of the methodology recommended by Ground Water Estimation Committee (1997) and to suggest aspects which call for a revision. The Committee may, if considered necessary, update the existing or recommend a new methodology for the assessment of ground water resources in different hydrogeological situations and climatic zones.
3. To recommend the smallest assessment unit for assessment of ground water resources based on hydrogeological/hydrological and/or administrative division.
4. To recommend a methodology for assessment of ground water resource in urban areas/specific areas.
5. Suggest alternative approaches for real time assessment of ground water resources.

Contd..3..

6. Committee should suggest modality and methodology for incorporating quality consideration in assessment of ground water resources.
7. Review and recommend methodology for assessment of Total Ground Water Availability.
8. Any other aspects relevant to the terms referred to above.

5) Time frame:
The Committee may submit its report within 6 month from the date of issue of resolution.

6) Expenditure
Expenditure on account of TA/DA to official Members of the Committee will be met from the source from which they draw their salaries and that of non-official Members (if any), will be borne by the Central Ground Water Board, subject to the directions indicated in MoF OM No. 19030/3/2008-E.IV dated 23.09.2008 and directions issued by MoF from time to time in relation to austerity, travel restrictions etc.

This issues with the approval of the Hon'ble Minister (WR,RD&GR).

(R.K. Gupta)
Director (GW)

ORDER

Ordered that the above RESOLUTION be published in the Gazette of India for general information.

Ordered also that a copy of the Resolution published be communicated to this Ministry.

(R.K. Gupta)
Director (GW)

To

The Manager,
Government of India Press,
Faridabad (Haryana).

Copy to:
1. PS to Minister(WR,RD&GR)
2. PS to MoS (WR,RD&GR)
3. Sr. PPS to Secretary (WR,RD&GR).
4. PS to Additional Secretary (WR,RD&GR).
5. All Wing Heads, Ministry of Water Resources, New Delhi
6. All Organization Heads of Ministry of Water Resources, New Delhi
7. Chairman, Central Ground Water Board, Faridabad.
8. All concerned Committee members.

Copy also to:
NIC for uploading on the Ministry's website.

(R.K. Gupta)
Director (GW)

ANNEXURE II

No 40/CGWB/M(TT &WQ)/RES/2014- 1819
Govt. of India
Ministry of Water Resources, RD & GR
Central Ground Water Board
Bhujal Bhawan
Faridabad
Haryana
0129-2477108
Date: 04/03/2015

05 MAR 2015

To,

As per addresses overleaf

Subject: Constitution of Sub-Groups to review and revise the ground water resources estimation methodology

Sir,

Kindly refer to the minutes of the first meeting (copy enclosed for ready reference) of the Ground Water Estimation Committee to review and revise the ground water estimation methodology 1997 (GEC-97) held on 10.02.2015 at CGWB, Jamnagar House, New Delhi. As decided in the meeting, in order to facilitate the working of the Committee and to ensure timely completion of the Terms of References of the Committee, the deliverables of the committee have been divided into three sub-heads: i) Refinement of ground water resource assessment methodology, ii) Database used for estimation of ground water resources and iii) Alternative approach for assessment involving advanced technologies. Accordingly the following three sub-groups have been formed. The Groups would be spearheaded by a Convener and would be assisted by a Resource Person. Sub-Group wise broad scope of deliverables are proposed as follows

- **Sub-Group I** (Refinement of ground water resource assessment methodology): Refinement in ground water assessment methodology incorporating the concept of sustainable yield (NWP, 2012), small assessment unit, quality consideration, assessment in urban/ specific areas, total groundwater availability. Framing of Standard Operational Procedure for Groundwater Assessment including – Institutional involvement and Protocol for collection and validation of data, Detailed Guidelines on ground water resources assessment

- **Sub-Group II** (Database used for estimation of ground water resources): Database used in resources estimation – Preparation of a comprehensive data bank on information pertaining to parameters to be made use of in ground water resource estimation obtained from all ground water assessment studies / research studies made by government agencies, research institutions, universities, non-governmental organisations etc.; Guidelines on methodologies for estimation of various parameters; and Benchmarking of the data elements to be used for Ground Water Resources Assessment

- **Sub-Group III** (Alternative approach for assessment involving advanced technologies): Alternate approach for real time assessment of ground water resources using advanced tools like remote sensing, ground water flow modelling. Application of advance techniques in validation of database, parameter estimation and ground water recharge and discharge estimation etc. used in ground water resources estimation.

Sub-Group I (*Refinement of ground water resource assessment methodology*)	**Sub-Group II** (*Database used for estimation of ground water resources*)	**Sub-Group III** (*Alternative approach for assessment involving advanced technologies*)
Dr. Himanshu Kulkarni Director, Advanced Centre for Water resources Development and Management - Convener	Dr. A.R. Khan, Dy General Manager, NABARD – Convener	Dr. A.K. Gosain, Professor, IIT, Delhi - Convener
Member (SM&L), CGWB, Faridabad	Member (RGI), CGWB, Faridabad	Member (SAM), CGWB, Faridabad
Dr. N.J. Raju, Professor, School of Environmental Sciences, JNU	Dr. S.K. Srivastava, Head Geoinformatics Department, IIRS, Dehradun	Dr. N.C. Ghosh, Scientist 'G' and head groundwater hydrology division, NIH, Roorkee.
Dr. K. Venugopal, Director, AP Ground Water Department	DDG and National Mission Head II, Geological Survey of India Maharashtra	Sh. Vivek P. Kapadia, MD, GWRDC, Govt. of Gujarat
Sh. P. S. Bhogal, Director, Water Resources, Punjab	Sh. Vimal Chaurasia, SE, Ground Water Survey Circle, Bhopal	Er. V. Shanmugam, Chief Engineer, SG&SWRDC, Tamil Nadu
Sh. S.K. Sahni, Joint Director, Ground Water Department, UP	Dr. S. Suresh, Scientist-D CGWB, Faridabad	Shri S.K. Sinha, Scientist-D CGWB, Faridabad
Resource Person: Sh. Rana Chatterjee, Scientist 'D', Central Ground Water Board, Jaipur	Resource Person: Sh. A.V.S.S. Anand, Scientist 'C', RGNGWTRI, Raipur	Resource Person: Sh. Ranjan Kumar Ray, Scientist 'C', Central Ground Water Board, Faridabad

Each Sub-Group will submit its recommendations to the Chairman of the Committee within two months from issue of this letter for finalization of consolidated report of the Committee.

This issues with approval of the Chairman.

Yours faithfully

4.3.15

(G.C. Pati)
Member (TT&WQ)

ANNEXURE III

No. 40/CGWB/M (TT&WQ) RES/2014-
Central Ground Water Board
Ministry of Water Resources,
River Development & Ganga Rejuvenation
Government of India
Bhujal Bhawan, NH-IV
Faridabad-121001, Haryana
Email: mtt-cgwb@nic.in

Subject: Minutes of 1st meeting of Ground Water estimation Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) held on 10th February, 2015 at Jamnagar House, New Delhi-reg.

With reference to the above cited subject, please find enclosed herewith minutes of 1st meeting of Committee held on 10th February, 2015 at Jamnagar House, New Delhi for further necessary action.

This issues with approval of Chairman, CGWB

Yours faithfully
24.2.15
(G.C. Pati)
Member (TT&WQ)

To

1. All Members/ Special invitees of Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97).
2. TS to Chairman, CGWB, Bhujal Bhawan, NH-IV, Faridabad
3. TS to Member (SAM), CGWB, Bhujal Bhawan, NH-IV, Faridabad
4. TS to Member (SML), CGWA, R.K. Puram, New Delhi
5. All Regional Directors, CGWB
6. Special invitees/participants

Minutes of the 1st meeting of Experts to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) held on 10.02.2015 at Jamnagar House, New Delhi

The meeting of members of Committee, constituted by Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) was held under the chairmanship of Shri K. C. Naik, Member (TT&WQ), Central Ground Water Board at 1100hrs on 10/02/2015 at CGWB, Jamnagar House, New Delhi. At the onset, Chairman welcomed all the members of the Committee and other invitees. He apprised the members that assessment of Ground Water Resources of India is being carried out at an interval of two years with the objective to identify and prioritize the areas for ground water management interventions. However there is need to review and revise the GEC-1997 methodology to incorporate new advancements/practices/tools like ground water modelling and also refining the various parameters being used in assessment.

Shri Rana Chatterjee, Scientist-D, CGWB made a presentation wherein various aspects of the present assessment using GEC-97 were described including its strengths and weaknesses. The best international practices followed worldwide were touched upon and the key issues to be considered by the committee were highlighted. He pointed out that the bottom-line of the entire exercise would be to develop a robust but executable solution which is scientific and simple & easy to understand for common people.

Dr. K. Venugopal, Director Ground Water Department, Government of Andhra Pradesh opined that the declining water levels are not always the best indicator of the depletion of ground water resources and safe blocks not necessarily indicate good potential. So it is necessary to change nomenclature of safe. He recommended that measuring yield of the wells/aquifer should be introduced in resource assessment along with measurement of ground water level. Effect of micro irrigation on ground water draft needs to be also considered and the parameter which is used for weathered / hard rock i.e Specific Yield or Storativity needs to be defined clearly.

Dr. A.R. Khan, Deputy General Manager, NABARD, Mumbai emphasized that unit draft of ground water structures should be measured accurately. He also stated that the results of Micro level studies may be incorporated in Ground water resources assessment. A quality consideration is necessary in resource assessment. There should be interlinking of assessment and management and state specific/region specific parameters. He also stressed that software should be developed to keep updating data regarding parameters/database that is being used.

Climate change issues need to be considered as water is the most vulnerable sector. Dr. Khan also suggested that if in the next meeting the results of some of the micro level studies is presented, then it will be very informative.

Er. P. S. Bhogal, Director, Water Resources & Environment Directorate, Government of Punjab pointed out that in Punjab in some cases adjoining blocks show significant differences in stage of ground water development though they have similar hydrogeological charasteristics. He opined that the vertical variation in hydrogeological properties should be accounted for in recharge estimation. Methodology should be region wise as there is huge variation in geology for alluvial areas and hard rock areas. There should be clear demarcation between dynamic and static ground water resources. Depth of dynamic ground water resources should be fixed to some extent region wise. Water level be the criterion for categorization of assessment units. He also stated that instead of stage of ground water development, it should be stage of ground water withdrawal for convenience of common man.

Shri Vivek P. Kapadia, Managing Director, Gujarat Water Resources and Development Corporation Limited, Government of Gujarat stressed that quality consideration should be taken into account for assessment of ground water resources. He also suggested that the monitoring stations should be increased.

Shri S. K. Sahani, Joint Director, Ground Water Department, Uttar Pradesh stated that assessment unit should be Nyaya Panchayat particularly for over-exploited areas.

Sri V Shanmugam , Chief Engineer ,SG & SWRDC Ground water Department, Tamil Nadu opined that specific yield and rainfall recharge factors need to be revised. Actual field tests need to be carried out to estimate region wise parameters.

Dr. A K Gosain, Professor, IIT Delhi felt that the for resource assessment, macro picture has to be in place before micro level studies are undertaken. He stressed the need for a plan for using advanced techniques and for real time assessment.

Dr. N C Ghosh, Head, Hydrology Division ,NIH Roorkee stressed that management needs to be incorporated ,parameters should be revised and modeling studies may be incorporated which can be carried out by Central Agencies/Research institutes like IIT/NIH .There is also need for capacity building on advanced techniques.

Dr S K Srivastava ,Scientist , Indian Institute of Remote Sensing, Dehradun felt that GEC needs to be strengthened with improved data base and geomorphological factors may also be incorporated. Alternate methodologies of resource estimation need to be used. Ground water flow modeling and GEC'97 should be done simultaneously for some areas.

Dr. N. Janardhana Raju, Prof. from JNU, New Delhi, emphasized the need to incorporate ground water quality considerations in the methodology.

On the suggestion from Er. P. S. Bhogal, Director, Water Resources & Environment Directorate, Punjab that the 2013 estimation should based on new methodology instead of GEC'97 methodology, Sri S.K.Sinha, Scientist 'D' ,CGWB clarified that 2013 estimation cannot be postponed. The states may refine the parameters to bring out a more realistic picture.

After the deliberations, it was decided that three subgroups namely for (i) Refinement of ground water resource assessment methodology (ii) database used in resource assessment and (iii)alternative approach for assessment involving advanced technologies would be constituted to facilitate the working of the committee and to ensure timely completion of the Terms of Reference. The Sub-Groups members would be from the members and special invitees of the Committee. It would be spearheaded by a convener and assisted by a resource person from CGWB.

The meeting ended with the vote of thanks.

ANNEXURE IV

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 16.07.2015

To

(As per the list)

Sub: Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 3rd July, 2015 at 12.00 hrs

Kindly find enclosed herewith a the Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 3rd July, 2015 at 12.00 hrs.

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON "REVISION OF GEC-97 METHODOLOGY" HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHI ON 3rd JULY, 2015 AT 12.00 HRS

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee and informed that the revised GEC Methodology needs to be very precise taking into consideration the public information and ground water regulation. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the three subgroups constituted to facilitate the working and timely completion of terms of references of the committeeto review and revise the GEC-97 Methodology were supposed to submit their report by 06.07.2015. The meeting was called to discuss upon the progress of work done by the subgroups and what new parameter/factors can be used for refinement of GEC-97 methodology.

With the permission of the Chair, Dr.Himanshu Kulkarni, Executive Director, ACWADAM, and convener of the Sub Group-I, AVSS Anand, Scientist C RGNGWT & RI and Resource Person for Subgroup-II and Ranjan K Ray, Scientist C and Resource Person for Subgroup III made presentations on work done for the revision of the GEC Methodology.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. The subgroups will submit a base report on their recommendation for revision of GEC-97 Methodology to the Chairman within one month from the date of issue of the minutes of the meeting.

2. Another meeting may be held to discuss and finalize the Base Report.

3. Pilot studies may be taken up to test the implementation of the recommendations of the three subgroups.

4. After finalization of the methodology, the detailed guidelines for implementation of the methodology will be prepared.

Meeting ended with vote of thanks.

List of Participants

Sl.No	Participants
1.	Chairman, Central Ground Water Board, CHQ, Faridabad
2.	Member (SAM), Central Ground Water Board, CHQ, Faridabad
3.	Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4.	Member (RGI), Central Ground Water Board, CHQ, Faridabad.
5.	Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6.	Dr.Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7.	Dr.A.R.Khan, Dy. General Manager, NABARD
8.	Dr. A.K. Gosain, Professor, IIT Delhi.
9.	Shri. A.K. Madhukar, Superintending Geophysicist, Central Ground Water Board, CHQ, Faridabad.
10.	Dr. S. Suresh, Scientist D, Central Ground Water Board, CHQ, Faridabad.
11.	Shri S.K. Sinha, Scientist D, Central Ground Water Board, CHQ, Faridabad.
12.	Shri. Rana Chatterjee, Scientist D, Central Ground Water Board, Jamnagar House, New Delhi
13.	Dr. B.C. Joshi, Scientist D, Central Ground Water Board, CHQ, Faridabad
14.	Shri AVSS Anand, Scientist C, Central Ground Water Board, RGNGWTRI, Raipur.
15.	Shri. Ranjan Kumar Ray, Scientist C, Central Ground Water Board, CHQ, Faridabad.
16.	Ms. Rumi Mukherjee, Scientist C, Central Ground Water Board, CHQ, Faridabad.
17.	Ms. Parveen Kaur, Scientist B, Central Ground Water Board, CHQ, Faridabad

ANNEXURE V

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 22.09.2015

To

(As per the list)

Sub: Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 18th Sept, 2015 at 2.30 P.M

Kindly find enclosed herewith the Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 18th Sept, 2015 at 2.30 P.M

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON "REVISION OF GEC-97 METHODOLOGY" HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHION 18TH SEPT, 2015 AT 2.30 P.M

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee and sought recommendation from the three subgroups. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the report of the committee to review and revise the GEC-97 Methodology will be finalized on the basis of the recommendation of the three subgroups constituted to facilitate the timely completion of terms of references of the committee.

Dr.Himanshu Kulkarni, Executive Director, ACWADAM, and convener of the Sub Group-I, AVSS Anand, Scientist C RGNGWT & RI and Resource Person for Subgroup-II and Ranjan K Ray, Scientist C and Resource Person for Subgroup III made presentations on recommendations of the respective subgroups.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. As per the recommendations of the Subgroup I, the term Ground water development may be exchanged with Ground water exploitation.

2. Ground water resources assessment may be done once in 5 years.

3. Resource assessment is done quantitatively but simultaneously quality may also be added. It was decided to consider Stage of Ground water Exploitation for categorization of assessment units. Categorization of Assessment units which are affected by Arsenic or fluoride, the term respective Hazard Areas may be used. The assessment of for salinity affected areas in practice may continue.

4. Committee members agreed upon the recommendations of the subgroup II that Pilot studies need to be conducted to determine base flow factor in the proposed methodology.

5. Digital Elevation Models (DEM) may be used for determining the hilly area over a region which is considered not suitable for ground water recharge.

6. Recommendations of all the Subgroups were deliberated upon during the meeting and there was a broad agreement over these recommendations.

7. A committee is constituted to prepare the final report on the Revised GEC-Methodology and detailed Guidelines for calculation of Ground water Resources Assessment.

Following are the Member of the Committee:

Sl. No	Members
1	Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
2	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
3	Shri AVSS Anand, Scientist-C, Central Ground Water Board, RGNGWTRI, Raipur.
4	Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
5	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

Meeting ended with vote of thanks.

List of participants:

Sl.No	Participants
1	Shri. K.B. Biswas, Chairman,Central Ground Water Board, CHQ, Faridabad
2	Shri. K.C. Naik, Member (SAM), Central Ground Water Board, CHQ, Faridabad
3	Shri G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4	Dr.DipankarSaha, Member (RGI), Central Ground Water Board, CHQ, Faridabad.
5	Dr. E. Sampath Kumar, Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6	Dr.Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7	Dr. A.R.Khan, Dy. General Manager, NABARD
8	Dr. A.K. Gosain, Professor, IIT Delhi.
9	Dr.J.S.Mehta, Director, Geological Survey India, New Delhi.
10	Shri. A.K. Madhukar, Superintending Geophysicist, Central Ground Water Board, CHQ, Faridabad.
11	Dr. S.K. Srivastava, Head, Geoinformatics Department, IIRS, Dehradun
12	Shri. BimalJeet Bhandari, Executive Engineer (Agronomist), Director, Water Resources, Punjab, Sector-68, Mohali, Punjab
13	Shri. Rana Chatterjee, Scientist-D, Central Ground Water Board, Jamnagar House, New Delhi
14	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
15	Shri AVSS Anand, Scientist-C, Central Ground Water Board, RGNGWTRI, Raipur.
16	Dr.Jyoti P. Patil, Scientist C, NIH, Roorkee
17	Shri. Ranjan Kumar Ray, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
18	Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
19	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

ANNEXURE VI

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 10.12.2015

To

(As per the list)

Sub: Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 3rd Dec, 2015 at 11.30 A.M

Kindly find enclosed herewith the Minutes of the Meeting on "Revision of GEC-97 Methodology" held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 3rdDec, 2015 at 11.30 A.M

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON "REVISION OF GEC-97 METHODOLOGY" HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHI ON 3rd DEC, 2015 AT 11.30 A.M

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the drafting committee has prepared the final draft report on GEC-2015. Shri AVSS Anand, Scientist D RGNGWT & RI and Resource Person for Subgroup-II made presentation on highlights of the final draft report for discussion.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. As per the recommendations of the committee, the term 'Ground water development' will be replaced with the term 'Ground water extraction'.

2. The GEC-2015 recommends aquifer wise ground water resource assessment of both Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources for all aquifers after a period of 3 years. However, the presently used assessment units may continue till the aquifers are fully deciphered. Only the report on Dynamic Ground Water Resources assessment will be shared with the States or with public.

3. The Ground water resources worked out Aquifer wise may be apportioned and presented on administrative units such as block/taluka/mandal/ firka as well as higher administrative units like Districts/State.

4. Water year is to be considered as the base for ground water resources assessment.

5. The GEC-2015 recommends classification of assessment units into 4 categories i.e. Safe, Semi-Critical, Critical, Over-Exploited on the basis of Stage of Ground water extraction. The criteria for categorization of Assessment units will be: 0 to <= 65 Safe; >65 to <=85 Semi-critical; >85 to <= 100 Critical and >100 Over Exploited. The results will be validated using the Long term ground water level trends.

6. The Quality aspect of Ground water will also be considered during the resources assessment and assessment units with poor ground water quality will be tagged for salinity, Fluoride and Arsenic Hazard.

7. Special studies need to be taken up for refinement of norms on various factors such as return flow from irrigation taking into account the micro irrigation, seepage from canal, spring discharge, aquifer and soil water balance. Immediate studies may be taken up in Lucknow, Sikkim and Hyderabad for different hydrogeological terrains.

Over all there was a broad consensus on the recommendations of the report on GEC-2015. It was deliberated that there is a need to conduct R & D studies for refinement of various parameters used for resource assessment.

List of participants:

Sl.No	Participants
1.	Shri. K.B. Biswas, Chairman, Central Ground Water Board, CHQ, Faridabad
2.	Shri. K.C. Naik, Member (RGI), Central Ground Water Board, CHQ, Faridabad
3.	Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4.	Dr. Dipankar Saha, Member (SAM), Central Ground Water Board, CHQ, Faridabad.
5.	Dr. E. Sampath Kumar, Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6.	Dr. Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7.	Dr. A.R. Khan, Dy. General Manager, National Bank for Agriculture, & Rural Development(NABARD),
8.	Dr. Nandakumaran. P., Regional Director, Central Ground Water Board, CHQ, Faridabad.
9.	Shri. Sanjay Marwaha, Regional Director, Central Ground Water Board, CHQ, Faridabad.
10.	Professor N.J. Raju School of Environmental Sciences, Jawaharlal University, New Delhi.
11.	Dr. S.K. Srivastava, Head, Geoinformatics Department, IIRS, Dehradun
12.	Shri. S.K. Sinha, Central Ground Water Board, CHQ, Faridabad.
13.	Dr. S. Suresh, Scientist D, Central Ground Water Board, CHQ, Faridabad
14.	Shri. Ravi Kant Singh, Senior Hydrogeologist, Ground water Department, Uttar Pradesh.
15.	Shri. Dharamveer Singh Rathore, Directorate (Lucknow), A.E. (Mechanical), Ground water Department, Uttar Pradesh

16.	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
17.	Shri AVSS Anand, Scientist-D Central Ground Water Board, RGNGWTRI, Raipur.
18.	Shri. Ranjan Kumar Ray, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
19.	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad