

# **Evaluation of Scheme of Ground Water Management & Regulation (2012-17)**

Report prepared for  
Central Ground Water Board  
Ministry of Water Resources, River Development &  
Ganga Rejuvenation, Govt. of India

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## **Executive summary**

CGWB has implemented Groundwater Management & Regulation (GWMR) Scheme, which is a Central Sector Scheme of Ministry of Water Resources, River Development & Ganga Rejuvenation during 12th plan (2012-17). The purpose of this evaluation is to carry out a comprehensive and critical review of the activities carried out by CGWB under the scheme of GWMR during the period 2012-17 and provide recommendations for continuation of the scheme during the remaining period of 14th Finance Commission (2017-2020). The evaluation of the scheme was based on the relevance of objectives & design of activities and achievement of the objectives based on the outcomes.

The scheme has four components which are (a) Aquifer Mapping; (b) Participatory Ground Water Management; (c) Technological up-gradation; and (d) Ground Water Monitoring, Assessment, Regulation, Publication, Seminars, Awards, technical assistance to states, etc. The mammoth new data generated including revisiting the data generated in the past for the 8.9 lakh km<sup>2</sup> for developing 3-D aquifer disposition in the form of aquifer mapping as part of the National Aquifer Mapping & Management Programme (NAQUIM) project has made a valuable scientific contribution to better understanding of groundwater resources and the hydrogeological system. The NAQUIM programme is well conceived & being implemented with an innovative approach. The aquifer maps being developed under the NAQUIM program are based on proper design and found to be an extremely useful and desired contribution to developing groundwater management plans. The NAQUIM project in the 12th plan (2012-17) catalysed innovative approaches to developing the aquifer characterization in three dimensions both in hard rock and alluvium areas of the country and resulted a better understanding of groundwater resources and for improved management in an aquifer specific environment. Some of the important achievements of the scheme are:

(a) Analysis and integration of borehole lithologs and subsurface geophysical information for delineation and preparation of block diagrams showing disposition of the aquifers in 3-D;

(b) Bringing out aquifer specific hydrogeological properties, water levels and ground water availabilities and identification and quantification of aquifer wise ground water issues; resource availability, yield of well & sustainability of production wells;

(d) Development of aquifer management plans for an area of 6.3 lakh km<sup>2</sup> including suggestions for supply and demand side management;

e) Ground Water Regime monitoring (four times in a years) across the country including one time water quality analysis;

f) Assessment of Dynamic ground water resources for the entire country as on 2011 & 2013 for 6607 assessment units/blocks/mandals/firkas and categorisation on the basis of level of ground water development;

g) Regulation of Ground Water withdrawal in respect of new and existing industries. Issuing advises for conservations of water & artificial recharge of ground water;

h) Publication of 70 state ground water reports, 115 ground water year books (incorporating water levels & quality of hydrograph stations) and 642 District ground water brochures.

Based on the individual ratings of the various components, the composite rating for the scheme is **Satisfactory**. The recommendation is that the NAQUIM project and other proposed components of the GWMR scheme should be continued and the proposed plans should be supported during 2017-2020 (14th Finance Commission). One of the components, i.e participatory ground water management envisaged in EFC 2012-17 should be taken as a separate scheme or merged with any other scheme with commensurate objectives during 2017-2020. The recommendations cover various suggestions to the scheme, which may bring improved outcomes.

## **Glossary of Terms**

1. **MOWR, RD & GR**- Ministry of Water Resources, River Development & Ganga Rejuvenation
2. **GWMR**- Ground Water Management & Regulation
3. **EFC**- Expenditure Finance Committee
4. **NAQUIM**- National Aquifer Mapping & Management Programme
5. **VES**- Vertical Electrical soundings
6. **TEM**-Trans-electromagnetic
7. **ERT**-Electrical Resistivity Tomography
8. **NHS**- National Hydrograph Station

## 1. Introduction

CGWB has implemented Groundwater Management & Regulation (GWMR) Scheme, which is a Central Sector Scheme of Ministry of Water Resources, River Development & Ganga Rejuvenation during 12th plan (2012-17). The scheme has four components which are (i) Aquifer Mapping (ii) Participatory Ground Water Management (iii) Technological up-gradation (iv) Ground Water Monitoring, Assessment, Regulation, Publication, Seminars, Awards, technical assistance to states, etc. As per MOA signed between CGWB & IISC, Bangalore, on 27<sup>th</sup> June 2017, an independent third party evaluation of the scheme of GWM&R during the period 2012-17 was assigned to IISc, Bangalore. The purpose of this evaluation is to carry out a comprehensive and critical review of the activities carried out by CGWB under the scheme of GWMR during the period 2012-17 and provide recommendations for continuation of the scheme during the period 2017-20. The scope of the work is

- i) Comprehensive review of activities taken up under the scheme of Ground Water Management and Regulation;
- ii) Critical appraisal of the various works carried out under the scheme;
- iii) Evaluate the project design and outputs/outcome of the scheme;
- iv) Suggestions/Recommendations for further improvements of the scheme.

In the evaluation report that will follow, the above items were reviewed on two separate criteria - the relevance of objectives and design of activities and achievement of the objectives (efficacy) and each of these are rated based on the outcomes as per the rating scale presented in Table A.1 in Appendix A. In summary, the overall scheme's outcome rating, which is a composite rating of the above individual ratings is given along with recommendations.

## 2. Scheme Details

### 2.1 Background

There has been a paradigm shift from “groundwater development” to “groundwater management”. An accurate and comprehensive micro-level picture of ground water in India through aquifer mapping in different hydrogeological settings will enable preparation and implementation of robust ground water management plans at the appropriate scale. This, in turn, will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India and many parts of urban India. It will also result in better management of ground water in vulnerable areas.

Keeping in view the existing and future challenges in ground water sector in the country, the scheme on ‘**Ground Water Management and Regulation**’ during XII plan period has been designed for National Project on Aquifer Management with an overall objective of proper assessment and management to ensure sustainability of ground water resources. The scheme has been implemented by Ministry of Water Resources through Central Ground Water Board with four components viz. (i) Aquifer Mapping, (ii) Participatory Ground Water Management, (iii) Technological up-gradation, and (iv) Ground Water Monitoring, Assessment, Regulation, Publication, Seminars, Awards, technical assistance to states, etc.

### 2.2. Objectives of the scheme

The following were the objectives of the scheme:

- Aquifer Mapping for Delineation of Aquifer disposition in 3-D along with their characterization on 1:50,000 scale in 8.89 lakh sq.km. falling in the Over-Exploited, Critical and Semi-critical categories of Assessment units as well as water quality and other problem/ vulnerable areas;
- Quantify water availability and water quality parameters to formulate Aquifer Management Plan for facilitating sustainable management of ground water

resources at regional and local level through participatory management approach with involvement of community and stakeholders;

- Regulate and control the development and management of ground water resources;
- Upgradation of technological capabilities and infrastructure of the Central Ground Water Board to meet the upcoming challenges in ground water field with best international practices;
- To increase capacity building in all aspects of ground water development and management through information dissemination, education, awareness and training;
- Periodic long term monitoring of ground water regime for creation of time series of data for updating ground water resource estimation at aquifer unit level.

### 2.3 12<sup>th</sup> Plan Approved outlay

The approved outlay of the scheme of GWMR for 12<sup>th</sup> plan was Rs 3319 Crore. The component wise break-up of the approved outlay of the scheme is as given below:

<b>SI No</b>	<b>Scheme Components</b>	<b>Approved Outlay (Rs in Crore)</b>
1	Aquifer Mapping	2051
2	Participatory Ground Water Management	575
3	Procurements for technological Upgradation	305
4	Groundwater Regime Monitoring, Assessment, Regulation, Publication, Seminars, Awards etc	388
	<b>Total</b>	<b>3319</b>

## **2.4 Identified Components of the scheme**

### **(a) Aquifer Mapping**

Aquifer Mapping is a multidisciplinary scientific process wherein a combination of geologic, geophysical, hydrogeologic, hydrologic, and water quality data are integrated to characterize the quantity, quality, and distribution of ground water in aquifers. Following are the various components of Aquifer Mapping,

- Compilation and Integration of existing data;
- Assessment of the data gaps;
- Scientific data generation through hydro-geological investigations; hydro-meteorological studies; geophysical investigations, geochemical analysis and exploratory drilling;
- Preparation of Aquifer maps on 1:50,000 scale by depicting aquifer geometry in 2D/3D;
- Formulation of Aquifer Management Plans.

### **(b) Participatory Groundwater Management**

This component was envisaged to enable the community and stake holders to monitor and manage the ground water as common pool resources themselves through coordinated effort involving government departments, research institutes, PRIs, civil society organizations and the stakeholders at the village level.

. The sub-components are

- Ground Water Management Programme Facilitation;
- Participatory Outreach programme for end users.

### **(c) Technological Upgradation**

This component aimed to upgrade the institutional, infrastructural and human resource capabilities and bring CGWB at par with international standards for better management of ground water resources in the country.



**(d) Ongoing Regular Activities (groundwater monitoring, assessment, regulation, publication etc.)**

This component comprises of the following

- Ground Water regime monitoring( four times in a year during April/May, August, November, January) across India including water quality analysis;
- Assessment of dynamic ground water resources for 6607 assessment units in the country once in 2 years;
- Regulation of Ground Water withdrawal in respect of new and existing industries;
- Publication of Scientific Reports like state groundwater reports, groundwater year book and district groundwater brochures etc.

## **2.5 Physical and Financial Progress**

The physical and financial progress of the scheme during 2012-17 is presented in Table B.1 of Appendix B.

## **3. Evaluation**

### **3.1 Relevance of Objectives and Design of the Activities**

(a) Relevance of objectives

National Project on Aquifer Management (NAQUIM), is an important programme of Ministry of Water Resources, River Development and Ganga Rejuvenation being implemented by Central Ground Water Board. Under NAQUIM, it was proposed to cover around 23.25 lakh Km<sup>2</sup> mappable areas distributed over several States and Union Territories of the country. During the XII Plan an area of 8.89 lakh Km<sup>2</sup> was proposed to be covered under this project and remaining would be taken up later on .during XIII Plan period. The aim was to delineate aquifer disposition in 3-D along with their characterization on 1:50,000 scale in 8.89 lakh Km<sup>2</sup> falling in the over-exploited, critical and semi-critical categories of assessment units as well as water quality and other problem/ vulnerable areas.

Further, it was envisaged to also quantify water availability and water quality parameters to formulate Aquifer Management Plan for facilitating sustainable management of ground water resources at regional and local levels through participatory management approach with involvement of community and stakeholders. The other activities that were planned under the GWMR scheme in addition to NAQUIM were: (i) pilot project on aquifer mapping, (ii) ground water exploration and construction of high yielding wells, (iii) geophysical studies, (iv) chemical studies, (v) water supply investigations, (vi) ground water regime monitoring, (vii) spill over items of demonstrative artificial recharge studies, (viii) regulation of ground water development (Central Ground Water Authority), (ix) re-estimation of ground water resource and (x) publication of reports, maps and dissemination of information.

The pilot projects on aquifer mapping (NAQUIM) focused on six different hydrogeological terrains (alluvial plains, alluvium overlying hard rocks, basaltic traps, crystalline rocks, coastal sediments, desert terrain) covering parts of states of Bihar, Rajasthan, Maharashtra, Karnataka and Tamil Nadu applying for the first time in the country the Heliborne Transient Electromagnetic technique in addition to other state of art geophysical surveys using VES, TEM, ERT and combined with existing borehole information to derive precise characterisation of shallow and deep aquifers with their geometry at 1:50000 scale. These pilot projects on aquifer mapping were designed to cover an area of approximately 350-675 Km<sup>2</sup> at each of these sites and with a total coverage of 3000 Km<sup>2</sup> across the country. Figure 1 presents the locations of the pilot project sites for aquifer mapping using heliborne geophysical method. The task of conducting the Heliborne Transient Electromagnetic Method (HeliTEM) and the concurrent measurements of the magnetic field (HeliMAG) surveys was entrusted to the CSIR-NGRI who entered into a scientific collaboration with the Aarhus University, Denmark for employing the state of the art high resolution SkyTEM system developed by the Aarhus University. These pilot experiments were meant to understand the spatial behavior of the multiple layers below the ground surface in these differed geological regions and capture the hydrogeological conditions (e.g. subsurface lineaments, dykes, fracture density and direction) in these layers through heliborne geophysical maps and then evaluate the correlations

of these features on bore well yield using exploration wells. To examine these aspects, some of the reports prepared in Karnataka and Maharashtra under NAQUIM project were reviewed. Clearly, this kind of detail studies were not feasible to cover the proposed 23.25 lakh Km<sup>2</sup> area of the country for aquifer mapping. Hence a secondary goal was to evaluate the role of classical geophysical surveys as well as recently developed techniques in capturing these subsurface layers and features obtained from high intensity studies in these pilot sites so that the large volumes of in-house data of exploration wells and geophysical surveys gathered over the years by CGWB to put to use for developing protocol for geophysical surveys & order aquifer maps for the 23.25 lakh Km<sup>2</sup> of the country.

Further proposed activities under the GWMR scheme were:

(i) To perform exploratory drilling operations to enable demarcation of aquifers both in lateral and vertical extensions and conducting pumping tests for evaluation of various aquifer parameters, designing of suitable structures and assessment of their yield potential in various hydrogeological settings.

(ii) To carry out surface electrical resistivity technique for source detection These surveys are undertaken to support, supplement and corroborate the hydrogeological surveys, ground water exploration and short-term water supply investigations. Besides, geophysical surveys are performed undertaken for demarcating saline-fresh water interface, Coastal aquifer management studies, estimation of overburden thickness and bedrock configuration, identifying favourable sites for artificial recharge structures as well as snow harvesting sites in Himachal Pradesh, flood plain studies and in farmer distress villages etc.

(iii) To perform water quality studies (i.e. analysis of major and minor inorganic constituents in water samples) through the 16 regional chemical laboratories. Analysis of Ground Water samples during 2012-17 (including ~15,000 ground water samples collected by CGWB once in a year from the water level monitoring stations) to demarcate critical areas where there is water quality deterioration for taking necessary action for management of ground water resources.

(iv) To provide assistance to defence and government agencies / establishments to solve their immediate water supply problems by selecting suitable sites for construction of ground water abstraction structures

(v) To perform groundwater monitoring in 20 thousand plus monitoring wells in the country four times a year to record the response of ground water regime to various stresses, establish its long-term behaviour and creation of time series of data for updating ground water resource estimation.

(vi) To carry out groundwater resource assessment across all states with state groundwater departments once in two years for categorization of assessment units for ground water regulation and assessing ground water resource improvement/deterioration.

(vii) Ground water regulation and notification of areas as per the policy decisions. Awareness campaign, workshop, seminars, impact studies in notified areas were also envisaged.

(viii) Publication of Reports including district Ground Water brochures, ground water year books and state ground water reports etc for Information/knowledge dissemination on plethora of issues related to groundwater to audience ranging from specialized researchers and academicians/ planners/administrators to common people

(ix) Organize national ground water congress, workshops, seminars etc.; carry out awareness for ground water conservation & rainwater harvesting etc.

**Rating: Satisfactory**

(b) Relevance of design

The major activities under the NAQUIM were the aquifer mapping at the country scale was to combine the past extensive data sets of aquifer characteristics already available from analysis of exploratory wells, geological & geophysical observations data being generated through inhouse & outsourcing activities combined with groundwater monitoring data sets leading to a first assessment of the aquifer maps and management plans. In the next step these aquifer maps to be improved in a

leap-frog manner with additional exploration wells, geophysical studies and numerical modeling studies. This design approach was to take into account phase-wise improvement of the aquifer maps while filling the gaps, granularity in terms of vertical and lateral resolution. Moreover, the aquifer maps were targeted in the phase-1 for the 5.26 lakh Km<sup>2</sup> falling in the over-exploited and critical areas in terms of groundwater withdrawals and quality affected for effectively using them for developing the aquifer management plans in these areas. The aquifer mapping project is supported by inputs from different premier institutes like NRSC, GSI, SOI, NIH through MOU. The geological maps are provided by GSI, lithogemophic maps are provided by NRSC, toposheets by SOI, isotope analysis by NIH, etc. . Additional data was generated through in-house studies through exploratory drilling including well yield test, pumping tests, vertical electrical sounding( VES), hydrochemical analysis, water level monitoring, and micro level sub-surface hydrogeological data from existing wells. Apart from this, data generation for Aquifer Mapping in about 0.36 lakh km<sup>2</sup> area in NCR, parts of Bundelkhand and Arsenic affected area of U.P were done through outsourcing. In addition, the NAQUIM project combined innovatively the pilot studies using heliborne geophysical methods in different hydrogeological regions to generate first order aquifer maps at the country scale.

**Rating: Satisfactory**

### **3.2. Comments on project cost and dates**

The total budget outlay for the GWMR scheme initially was Rs. 3319 Crore during 2012-2017 (XII Plan) based on the proposal by the MoWR and amount actually agreed to by the Planning Commission. Further, based on the expenditure pattern and availability of funds in MoWR the budgetary estimate for plan was 1315.38 Crore and this estimate was further revised to 741.77 Crore. Non-procurement of major equipments and since services couldn't be outsourced, the actual utilisation for plan was Rs. 580.93 Crore. Appendix C presents the Tables C.1 and C.2 showing the budget details for each of the years for the XII plan and also the expenditure for the sub-components of the GWMR scheme.

### **3.3 Achievement of Objectives (Efficacy)**

#### **(a) Objective 1**

**Delineation of aquifer disposition in 3-D along with their characterization on 1:50,000 scale in 5.26 lakh km<sup>2</sup> (reprioritised) falling in priority areas.**

Outcome:

The activities that were taken up in phased manner have been divided into various components of data compilation and generation of additional data. Under the data procurement, digital toposheets were procured. Database for exploratory wells was compiled, and data pertaining to hydrogeology, geophysics, geochemical and hydrology was completed. Further, data gap analysis was done which will form the basis to generate data sets for the gap area. The aquifer maps developed using this design provided an insight of the aquifers & hydrogeology at the scale of 1:50,000 which is ideal for undertaking aquifer maps and aquifer management plans. Table D.1 in Appendix D presents the aquifer mapped areas achieved in different states and UTs, which covered an area of 6.3 lakh km<sup>2</sup> against the reprioritised target area of 5.26 lakh km<sup>2</sup>. In addition, even though the aquifer maps were generated for 6.3 lakh km<sup>2</sup> (4.47 lakh km<sup>2</sup> from prioritised area and remaining 1.83 lakh km<sup>2</sup> from remaining other critical areas of the country) several other items pertaining to aquifer mapping have been completed for the initial proposed area of 8.89 lakh km<sup>2</sup> as given in Table B.1. Figure 2 presents the spatial coverage of the completed aquifer mapped regions in the country for the 2012-17. The achieved aquifer maps in the first phase covered importantly the over exploited, critical and other selected areas using innovatively the inhouse data sets combined with data generated in the gap areas. The aquifer maps generated using this design were also benefitted to a greater extent on generating the critical featured based on the detailed pilot studies using heliborne geophysical methods implemented in parallel covering the mapped regions. More than 4000 exploratory well drillings were carried out through in-house support and outsourcing while nearly 14000 geophysical investigations (VES) were performed. These helped in the aquifer mapping program for delineating the aquifers and characterising the hydrogeological parameters.

The preparation of aquifer maps and management plans in 6.3 lakh km<sup>2</sup> area has resulted in generation of hydrogeological and related scientific data base, delineation of the aquifers for their quality and quantity, their lateral and vertical extents up to a depth of 200 m in hard rocks and 300 m in soft rocks as far as possible, identification of ground water recharge worthy areas, delineation of protected aquifers in recharge areas, suggesting suitable supply side and demand side ground water management interventions for increasing ground water sustainability and management.

The pilot projects were undertaken for producing state-of-the-art aquifer maps in approximately 3000 Km<sup>2</sup> area in six different hydrogeological regions in the country by using heliborne transient electromagnetic surveys along with geophysical surveys using VES, TEM, ERT and combined with existing borehole information, which yielded precise characterisation of shallow and deep aquifers with their geometry at 1:50000 scale. The knowledge accrued through these pilot projects have helped in understanding the multi-aquifers in the vertical resolution and to characterise the deeper aquifers that are under exploitation and the sustainability of these aquifers.

It is expected that the aquifer maps of 13.70 lakh km<sup>2</sup> that are proposed to be produced in the next phase (2017-2020) and the improvements that will be made to the already generated 6.3 lakh km<sup>2</sup> will be immensely benefited from the inputs of the pilot aquifer mapping studies.

### **Rating: Highly Satisfactory**

(b) Objective 2

**Preparation of aquifer management plans for facilitating sustainable management of ground water resources at regional and local level through participatory management approach with involvement of community and stakeholders.**

Outcome: The extensive groundwater monitoring network combined with the aquifer mapping program facilitated in preparing near precise aquifer management plans especially in the over-exploited and critical categorised regions in the country. These were combined with approximately 140,000 water quality investigations, which helped in preparing improved management plans. The management Plans are fit to

be used by the communities through participatory approach. Though the original programme envisaged in EFC on participatory ground water management could not be takeoff, however though various activities of CGWB like training programme organised by NGI, Workshops in state level & Bhujal Manthan, the information on Aquifer Maps and management plans were dissemination to a great extent. However the participatory management programme through involving communities should be taken as separate programme.

**Rating: Moderately Satisfactory**

(c) Objective 3

**Upgradation of technological capabilities and infrastructure of the Central Ground Water Board to meet the upcoming challenges in ground water field.**

Outcome: 17 drilling rigs of various capacity in addition to state-of-art hydrogeological, chemical, geophysical equipments and scientific software were procured. These will aid in further explorations, analysis and modeling, which will feed to the generation of phase-2 aquifer maps.

**Rating: Satisfactory**

(d) Objective 4

**Periodic long term monitoring of ground water regime for creation of time series of data for updating ground water resource estimation at aquifer unit level. Regulate and control the development and management of ground water resources. Capacity building in all aspects of ground water development and management through information dissemination, education, awareness and training.**

Outcome: Groundwater level monitoring in more than 20000 stations for four times in a year were carried out, which was used in conjunction with the state water level data for groundwater resource estimation for the entire country once in two years. Strengthening of Ground Water Monitoring network has helped **for fine tuning the response of the aquifers to various stress conditions.**



The spatial spread of these stations in various states and UTs is presented in Table E.1 given in Appendix E. In addition this network data was used for developing aquifer management plans based on the categorization of units. Moreover, this data base was also used for the NAQUIM project and groundwater modeling studies.

**Re-estimation of ground water resources has categorized the assessment units for ground water regulation and helps in assessing ground water resource improvement/ deterioration.**

Other achievements were:

- 720 NOCs were issued for regulation of ground water withdrawal through CGWA in respect of new and existing industries; Besides directions/advisories were issued controlling ground water over-exploitation & water harvesting/artificial recharge adaptation
- 70 state ground water reports, 115 ground water year books, and 642 district ground water brochures were published. **The reports are widely shared with stakeholders. It has helped in Information/knowledge dissemination on plethora of issues related to groundwater to audience ranging from specialized researchers and academicians/ planners/ administrators to common people.**
- 133 demonstrative artificial recharge projects as spill over items of 11<sup>th</sup> plan were undertaken in 22 states, which involved conceptualising and installing about 799 structures (i.e. percolation tanks, recharge shafts, recharge wells, gabion, check dams, RTRWH, subsurface dykes).

**Rating: Satisfactory**

### **3.4 Reasons for Shortfall**

The shortfall has been observed in following three group of activities

- Data Generation through outsourcing (Reasons- Outsourcing proposal couldn't be finalised)

- Procurement of machinery & equipments (Reasons- non-procurement of Major equipments and machinery due to various constrains)
- Non-Take off of activities under PGWM (Reasons- no prior experience of CGWB in executing the Participatory Ground Water Management)

### **3.5 Positive Points**

Prior to 2012, CGWB has been undertaking hydrogeological investigation/survey bringing out groundwater reports in different states and districts. However, after catalysing the NAQUIM project in the GWMR scheme in the 2012-17 period, resulted in innovative approaches to developing the aquifer characterization in three dimensions both in hard rock and alluvium areas of the country towards a better understanding of groundwater resources and for improved management in an aquifer specific environment. The following are the list of improvements achieved in this direction.

(i) Analysis and integration of borehole lithologs and subsurface geophysical information for delineation and preparation of block diagrams showing disposition of the aquifers and aquitards in 3-D;

(ii) Bringing out aquifer specific hydrogeological properties and ground water availabilities;

(iii) Identification and quantification of aquifer wise ground water issues; resource availability, yield of well & sustainability of production wells;

(iv) Development of aquifer wise management plans including suggestions for supply and demand side management. The management plans included in the reports are more exhaustive including quantification of each component. The management plans are being prepared in consultation with experts from allied fields like agriculture;

(v) In some cases, attempts have been made to integrate flow modeling studies for refinement of aquifer parameters, more accurate quantification of stresses and prediction of scenarios. Similar studies are being extended to other areas also. Further, collaboration with premier institutes like IISc and IITs have been initiated for modeling studies;

(vi) A three tier evaluation process has been put in place to ensure quality of outputs; Firstly it is presented in the Region office, then presented to the concerned members at head quarter, finally in front of the National Expert committees at Delhi.

(vii) State Ground Water Coordination Committees (SGWCC) headed by the respective Principal Secretaries have been constituted in the States for effective sharing of findings of aquifer mapping studies.

viii) The outcomes of Aquifer Mapping have been used by various state and central agencies to develop water supply schemes, exploitation of aquifers and framing up of recharge schemes. One such scheme that merits mention is the ***Tapi Mega Recharge Scheme*** which has been cleared by the task force constituted by the MOWR, RD & GR on the basis of findings of Aquifer Mapping.

### **3.6 Drawbacks**

- Since the quantity of data to be generated was substantial and inhouse capacity available with CGWB was not adequate, a large part of the data generation work was envisaged to be completed through outsourcing. CGWB had no prior experience of managing outsourcing work of such magnitude and it only evolved during the implementation of GWMR in subsequent years.
- There was no prior experience of executing the Participatory Ground Water Management envisaged in scheme. Further the core expertise of CGWB lies in hydrogeological investigations which are predominantly scientific/technical in nature where as PGWM requires expertise in socio-economic domain.

## **4. Conclusions & Recommendations**

The mammoth new data generated including revisiting the data generated in the early years in 8.9 lakh km<sup>2</sup> for developing 3-D aquifer disposition in the form of aquifer mapping as part of the NAQUIM project has made a valuable scientific contribution to better understanding of groundwater resources and the hydrogeological system. Apart from Aquifer Mapping, the achievement in respect of report preparation and publication for dissemination of information at district and State levels was also found satisfactory. The exercise of ground water resource

assessment completed at two years interval has helped in categorisation of assessment unit on the basis of level of ground water extraction which forms the basis for regulatory interventions.

Recommendations based on the evaluation of the scheme are listed in this section. The purpose of these recommendations is to add value to the ongoing aquifer mapping exercise and the future attempts to cover the remaining 17.35 lakh km<sup>2</sup> in the next few years. Based on the individual ratings of the components, the composite rating for the scheme is **Satisfactory**.

The following are the recommendations to bring in relevant future changes in the design of the scheme:

- i. The NAQUIM programme is well conceived & being implemented with an innovative approach. The aquifer maps being developed under the NAQUIM program are based on proper design and found to be extremely useful in developing groundwater management plans. These should be sustained and the mapping of the remaining target area of ~17lakh km<sup>2</sup> should be achieved in the next four to five years. It is proposed to achieve this in additional two phases, i.e. 13.70 lakh km<sup>2</sup> during 2017-2020 (14<sup>th</sup> Finance commission) and the remaining area in subsequent years. These efforts are to be continued and the proposed plans should be supported. It must be kept in mind that the management plans developed cannot be static and final as the ground water resource utilisation is a dynamic phenomena. The aquifer maps developed in the over-exploited and critical ground water assessment regions of the country in the phase-1 should be improved by combining modeling studies to improve the aquifer maps and also the management plans. Following this, the entire country should be covered by this iterative approach to make periodic improvements to the aquifer mapping, which would bring in more details within the mapping data sets as well as improved resolution of information both laterally and vertically in the aquifer units.
- ii. Relatively few modeling studies were undertaken in the NAQUIM project and GMWR scheme even though great strides were made on the aquifer mapping with innovative approaches for 6.3 lakh Km<sup>2</sup> including very detailed heliborne

geophysics for aquifer mapping for 3000 km<sup>2</sup> through pilot studies. By suitably fusing the high density aquifer mapping information with modeling tools, these efforts should be taken forward to address issues (i) on how to develop conjunctive use policies in canal command areas to prevent waterlogging, (ii) on how we may project the future scenarios of GW use and balance components under climate change, (iii) on whether the urban groundwater system dynamics can be developed, and (iv) on how the knowledge can be extrapolated to store flood waters in different types of aquifers etc. Most of these may not be possible by CGWB in-house, and hence collaboration with academic and research institutes are desired to make these possible.

- iii. State-of-the-art numerical modeling studies need to be taken up combining the huge monitoring data gathered each year with the aquifer maps from the NAQUIM program for forecasting future groundwater storage and level changes in over-exploited and critical assessment units in the country to enable improved management plans with realistic groundwater use scenarios. Moreover, studies related to demand side (i.e. groundwater use) in important aquifer units or blocks have to be taken up, which would require characterizing crop and ground water irrigation.
- iv. The current groundwater monitoring program should be strengthened with more temporal and higher spatial resolution in some critical and over-exploited units. Outsourcing and participatory approaches towards this aspect need to be considered for bringing this additional data set. Strengthening of the data base for groundwater monitoring should also be envisaged through automatic sensors in important blocks or for urban areas.
- v. The exploration wells planned in the next few years through in-house rigs and outsourcing activities are critical for achieving the remaining aquifer mapping target area of ~17 lakh km<sup>2</sup>. These exploration wells are also important in certain areas to improve the phase-1 aquifer maps in the completed 6.3 lakh Km<sup>2</sup> area. Moreover, efforts should be made to improve the aquifer maps generated with the available technologies for any possible

extrapolation/generalisation possible innovative modelling, remote sensing, satellite data assimilation, newer technologies etc.

- vi. Efforts should be made to regulate exploitation of ground water for irrigation which accounts for 85 % of ground water utilisation, especially in over-exploited and critical areas through innovative groundwater management plans formulated by combining aquifer maps with groundwater models.
- vii. The outcome of the scheme may be judged on the basis of the area covered under Aquifer Mapping and number of districts/states for which aquifer maps and management plans are shared with state agencies. A mechanism may be evolved in future to evaluate the scheme outcome on the basis of adoption of the management plans by the concerned state agencies.
- viii. The fund allocation should be made in commensuration with targets proposed in 2017-20 and considering the experiences gained by CGWB in limited outsourcing activities undertaken during 2012-17.
- ix. As there is a scope for substantial activities to be undertaken through outsourcing to cover 13.70 lakh km<sup>2</sup> under Aquifer Mapping, an effective monitoring mechanism supported by adequate manpower strengthening is required both at HQ & Regional Level.
- x. Considering the importance of involvement of communities in ground water resource management it is emphasised that the participatory ground water management envisaged in EFC 2012-17 should be taken as a separate scheme or merged with any other scheme.
- xi. The GWMR scheme is unique as it is the only scheme with a dedicated component for Aquifer Mapping in particular and ground water in general. Considering the above facts, continuation of the GWMR Scheme with all the three components as proposed for 2017-20 is recommended in view of the extensive dependence of the nation on ground water resources and the pressing need to understand the aquifer system and ground water regime in its entirety.

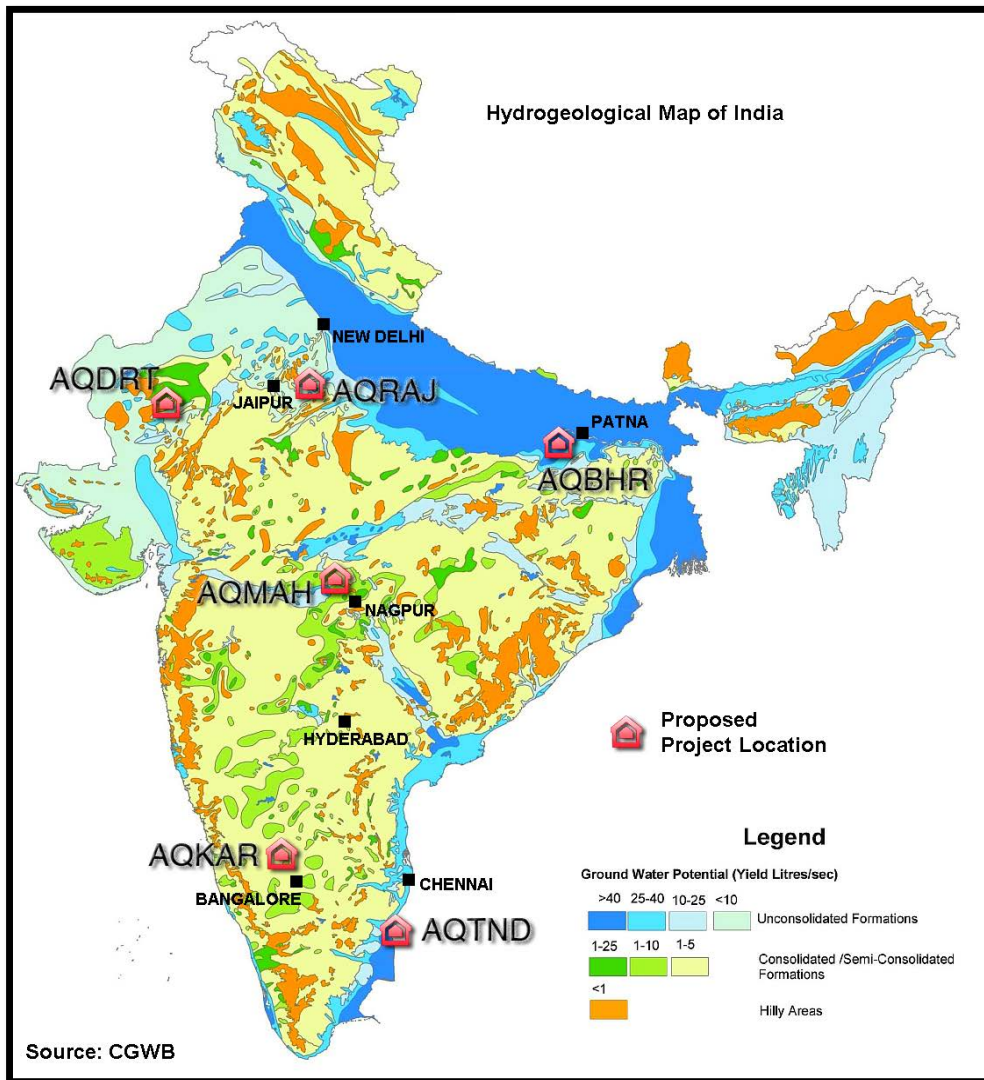


Figure 1 The location of the pilot sites selected for aquifer mapping using heliborne geophysical method.

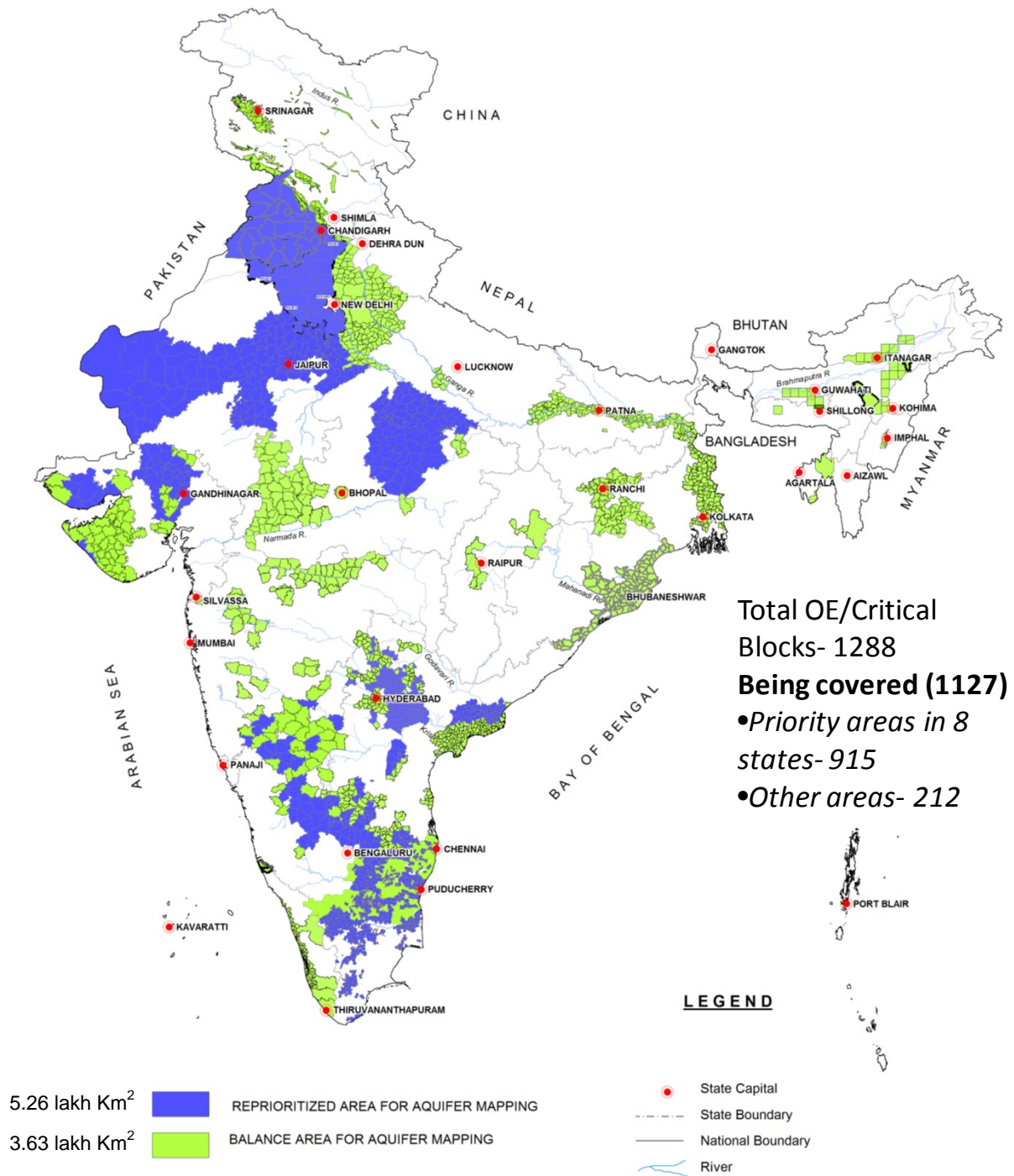


Figure 2 Areas covered under the aquifer mapping (NAQUIM project) across the country for 2012-17 period (Reprioritized target area 5.26 lakh Km<sup>2</sup> and achieved 5.9 lakh Km<sup>2</sup>)



## APPENDIX A

Table A.1 Rating scale used and related basis of outcomes.

Sl. No.	Rating	Outcome basis
1.	Highly Satisfactory	There were <b>no</b> shortcomings in the task's achievement of its objectives, in its efficiency, or in its relevance.
2.	Satisfactory	There were <b>minor</b> shortcomings in the task's achievement of its objectives, in its efficiency, or in its relevance.
3.	Moderately Satisfactory	There were <b>moderate</b> shortcomings in the task's achievement of its objectives, in its efficiency, or in its relevance.
4.	Moderately Unsatisfactory	There were <b>significant</b> shortcomings in the task's achievement of its objectives, in its efficiency, or in its relevance.
5.	Unsatisfactory	There were <b>major</b> shortcomings in the task's achievement of its objectives, in its efficiency, or in its relevance.

**APPENDIX B Table B.1 Physical and Financial Achievements of Scheme of GWMR ( 2012-17)**

S. No.	Component	Activity	Physical		Financial ( Rs in Crores)		
			Target	Achievement	Target	Achievement	
1	Aquifer Mapping	1. Collection and Compilation of existing data ( <i>lakh Sq Km</i> )	8.89	8.89	2439 ( EFC Outlay) 1071.72 ( BE) 597.19 ( RE)	503.42  (Combined Financial Achievement for Components 1 and 32)	
		2. Identification of Data Gap ( <i>lakh Sq Km</i> )	8.89	8.89			
		3. Data Generation					
		i) Exploratory Drilling ( <i>No of Wells</i> )	Inhouse: 3784 Outsourcing: 6721 Total: 10505	Inhouse: 3602 Outsourcing: 585 Total: 4187			
		ii) Geophysical Investigation ( <i>VES</i> )	Inhouse: 10073 Outsourcing: 22750 Total: 32823	Inhouse: 12807 Outsourcing: 1003 Total: 13810			
		iii) Chemical Quality	Inhouse: 101939 Outsourcing: 214665 Total: 316604	Inhouse: 134004 Outsourcing: 3746 Total: 137750			
		4. Aquifer Maps and Management Plans ( <i>lakh Sq Km area</i> )	8.89 (The target upon reprioritisation of the area was revised to 5.26 lakh Sq Km)	6.3 Lakh Sq Km			
			25				

2	<b>Groundwater Monitoring, Assessment, Resource</b>	Ground Water Regime Monitoring	Monitoring of ground water observation wells 4 times in a year	Achieved					
		Ground Water Resource Estimation	To be done once every 2 years	Completed for base year 2011 and 2013					
		Ground Water Regulation	Regulation of Ground Water withdrawal in respect of new and existing industries	No of new NOC issued	No of Renewal NOC issued				
				1145	222				
		<b>Publication of Reports</b>							
		State Ground Water Reports (Hydrogeological/ Chemical/Gephysical/ Exploration)	70	70					
		Ground Water Year Book	115	115					
		District Ground Water Brochures	625	642					
3	<b>Technological Up-gradation</b>	Procurement of drilling equipments, scientific instruments and software	Procurement of drilling equipments, scientific instruments and software	Procured 17 Rigs , various scientific software and minor equipments		305( EFC Outlay)	312.76( BE)	144.58 ( RE)	77.51
4	<b>Participatory Ground Water management</b>	i) Ground Water Management Programme facilitation ii) Participatory Outreach Programme for end users				575 ( EFC outlay)	Nil		

## APPENDIX C

Table C.1 Budget estimates, revised estimates and actual expenditure for the years 2012-13, 2013-14, 2014-15, 2015-16 and 2016-17 for GWMR scheme showing separately plan and non-plan expenditure

				<b>Rs in Crores</b>
<b>Year</b>	<b>EFC Outlay</b>	<b>Budget Estimates</b>	<b>Revised Estimates</b>	<b>Actual Expenditure</b>
2012-13	117	318.00	180.00	118.64
2013-14	274	275.00	140.00	84.18
2014-15	475	325.00	143.00	124.89
2015-16	784	163.00	164.02	140.84
2016-17	1669	303.48	114.75	112.38
<b>Total</b>	<b>3319</b>	<b>1384.48</b>	<b>741.77</b>	<b>580.93</b>

Table C.2 Budget utilisation for sub-components of the GWMR scheme ( 2012-17)

					<b>Rs in Crores</b>
<b>S.I. No</b>	<b>Component</b>	<b>EFC Outlay</b>	<b>Budgetary Estimate of Plan component</b>	<b>Revised Estimate of Plan component</b>	<b>Actual Expenditure of Plan component</b>
1	Aquifer mapping				
2	Ground Water Monitoring, Assessment and Regulation etc	2439	1071.72	597.19	503.42
3	Technological Upgradation	305	312.76	144.58	77.51
4	Participatory Ground Water Management	575	-	-	-
<b>Total</b>		<b>3319</b>	<b>1384.48</b>	<b>741.77</b>	<b>580.93</b>

## APPENDIX D

Table D.1 Aquifer maps in different states and UTs targeted under NAQUIM project (2012-17) with reprioritized target and finally achieved by March 2017

<b>Aquifer Mapping Area during 2012-17- State wise Targets and Achievement ( Area in Sq Kms)</b>			
<b>States/UTS</b>	<b>Targets As per EFC 2012-17</b>	<b>Reprioritized Target*</b>	<b>Achievement by March 2017</b>
Andaman & Nicobar	1500		0
Andhra Pradesh	100000	28379	39141
Telngana		26429	22328
Arunachal Pradesh	2027		1965
Assam	5600		6179
Bihar	7400	521	9607
Chandigarh	114		0
Chhattisgarh	11500		10619
Dadra NagarHaveli	491		490
Daman & Diu	112		0
Delhi	1483	1483	1483
Goa	1500		0
Gujarat	83000	34768	31522
Haryana	42000	44179	44179
Himachal Pradesh	7600		0
Jammu & Kashmir	9656		8220
Jharkhand	6300		17693
Karnataka	93000	48669	48311
Kerala	5200		5200
Lakshadweep	32		32
Madhya Pradesh	69200	36794	45430
Maharashtra	43000	360	31418
Manipur	700		155
Meghalaya	1800		1627
Mizoram	700		0
Nagaland	700		400
Orissa	16500		10193
Pondicherry	479		293
Punjab	49000	50362	50368
Rajasthan	142400	168223	143275
Sikkim	800		0
TamilNadu	68206	46204	44573
Tripura	3500		559
Uttaranchal	7700		2811
Uttar Pradesh	90800	40199	45339

West Bengal	15000		8008
<b>Grand Total</b>	<b>889000</b>	<b>526570</b>	<b>631418</b>

**\* As per National Inter-Departmental Steering Committee (NISC) decision to focus on ground water stressed and ground water quality affected area in 8 States and Bundelkhand Region of U.P and M.P**

## APPENDIX E

Table E.1 Status of groundwater monitoring stations in various states and UTs

SI No	Name of the State/UTs	Number of GW Monitoring Stations (March 2017)		
		DW	PZ	Total
1	Andhra Pradesh	742	113	855
2	Arunachal Pradesh	30	0	30
3	Assam	422	39	461
4	Bihar	715	33	748
5	Chhattisgarh	1054	268	1322
6	Delhi	24	103	127
7	Goa	102	49	151
8	Gujarat	844	404	1248
9	Haryana	527	661	1188
10	Himachal Pradesh	128	0	128
11	Jammu & Kashmir	266	11	277
12	Jharkhand	453	22	475
13	Karnataka	1490	383	1873
14	Kerala	1402	266	1668
15	Madhya Pradesh	1204	325	1529
16	Maharashtra	1641	192	1833
17	Manipur	0	0	0
18	Meghalaya	68	12	80
19	Nagaland	22	12	34
20	Odisha	1606	89	1695
21	Punjab	170	794	964
22	Rajasthan	724	446	1170
23	Tamil Nadu	847	531	1378
24	Telangana	344	445	789
25	Tripura	69	8	77
26	Uttar Pradesh	804	247	1051

SI No	Name of the State/UTs	Number of GW Monitoring Stations (March 2017)		
		DW	PZ	Total
27	Uttarakhand	41	126	167
28	West Bengal	813	805	1618
	<b>UTs</b>			
1	Andaman & Nicobar	110	2	112
2	Chandigarh	1	24	25
3	Dadra & Nagar Haveli	16	0	16
4	Daman & Diu	14	5	19
5	Pondicherry	10	7	17
	<b>TOTAL</b>	<b>16703</b>	<b>6422</b>	<b>23125</b>