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'NATIONAL PROJECT ON AQUIFER MANAGEMENT'

CONCEPT PAPER FOR DISCUSSION

GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL GROUND WATER BOARD
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National Project on Aquifer Management (NAQUIM)- Concept Paper for Discussion

Introduction

Groundwater is the backbone of India's agriculture and drinking water security. It is a common-pool resource, used by millions of farmers across the country and remains the only drinking water source in most of India's rural households. It also supports industrial water demand in many cases. The scarcity of water resources and ever increasing demands that are placed on the resource underline the importance of identifying, quantifying and management of groundwater to offset the problems of over-extraction and contamination and to obviate the consequent economic loss or environmental damage while balancing the demand for various uses. Revisiting aquifers by understanding them better through the aquifer mapping programme with a clear-cut forward link to participatory groundwater management is desired.

The Proposed programme is designed to make a significant step forward in groundwater resource management by identifying and mapping aquifers, quantifying the available groundwater resources potential and proposing plans appropriate to the scale of demand, aquifer characteristics and the institutional arrangements for management. This work will be systematically implemented in the country, by involving organisations / institutions across India. Considerable work and investigations have been carried out by Central and State Agencies, Universities & Research Institutions, NGOs etc. at different scales. Generally, various thematic maps related to ground water domain are available on 1:250,000 scale in the country. These maps have been used in limited way for regional planning and decision support to ground water development rather than management.

For the proposed project on aquifer mapping and creation of micro level aquifer information system, the activities are planned in such a way as to facilitate the formulation of the ground water management plan for individual aquifer units of optimal size in accordance with the nature of the aquifer, the stress on the resource and prevailing groundwater quality. In areas having adequate data base from completed studies, aquifer mapping at the scale of 1:50,000 scale will be prepared and aquifer information system will be created with minimal additional field data collection. In identified areas where ground water management issues are significant but existing data is not comprehensive, detailed mapping with integrated hydrogeological, geophysical, geochemical and remote sensing studies will be taken up and used for preparation of large scale aquifer map and aquifer information system for the entire country. At the other end of the spectrum some aquifer management units will require significant investment in detailed mapping with various scientific tools like remote sensing, conventional Hydrogeological, geophysical and hydrogeochemical studies etc. Aquifer mapping itself should lead to improved forms of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols must be the real derivatives of the aquifer mapping exercise and must find a place in the output (the map) and the outcome (changes in social behaviour of communities, reflecting these protocols). In fact, some important socio-economic information at the scale of wells and springs that will form the basic sample of groundwater information can be collected as part of the aquifer mapping effort.

The accelerated aquifer information data generation will require significant investment in organising the field work with required state of art advance techniques and latest equipments with a dedicated team by involving central, state agencies and creation of aquifer unit wise resource centre with local community participation in data collection and implementation of the aquifer management plan

This paper sets out, in greater detail, the background to the project proposal, objectives, the methodology that will be followed in aquifer investigations, creation of aquifer information system and preparation of management plans and the resources required, including resources for developing the tools and information systems required for implementation and delivery. It also deals with the detailed implementation strategy and the mechanism for participatory ground water management at the grass root level is an integral part of the scheme proposal to be implemented in XII (Plate-I) & XIII (Plate-II) five year plan period.

The rollout of India's 12th Five Year Plan includes aquifer mapping leading to development of participative strategies of groundwater management within the legislative framework that not only facilitates such management, but also emphasizes the protection of groundwater resources in various contexts of usage. The reasons for conducting such mapping are manifold. Considering the complex nature of groundwater resources, the numerous problems arising with regard to the resource and the countless dependents on this resource, India needs a standard methodology that ingrains the principles and practices of participatory groundwater management, the case for which is being made through various documents, including the mid-term appraisal by the Planning Commission. The rationale for a national programme on aquifer mapping and groundwater management can be summarised through the three points given below:

1. Recognising *aquifers* as the basic unit for understanding and managing groundwater, given the fact that millions depend upon this resource.
2. As with watersheds some 30 years ago, aquifer mapping can provide the basis for effective planning of groundwater use.
3. Although maps depicting *zones of recharge, discharge and potentialities* are useful in planning recharge and water harvesting, and in locating wells, they fall short of providing:
    a. An idea about the geometry of an aquifer – lateral and vertical boundaries.
    b. An estimate regarding the availability of groundwater.
    c. An idea about the distribution of geogenic and anthropogenic contaminants.

Aquifer mapping will lead to a toolkit for groundwater management, based on the principles of participatory management of groundwater. India's groundwater typology makes this exercise challenging, but necessary. The complex nature of groundwater and the diversity in groundwater conditions caused by hydrogeology, sociology, economy and ecology compel strategic thinking, design, planning and implementation of groundwater management, the first step being aquifer mapping. Aquifer mapping could lead the way towards improved systems of groundwater management and governance, and therefore, needs to be carefully designed and planned. It can be rolled out as a 5 year programme, as part of India's 12th Plan. The details of this plan are discussed in the following sections.

Background

The understanding of the natural resources, particularly water resources, is important in the sustainable and equitable management of such resources. The precipitation in the country is estimated at 4000 BCM by taking the annual normal rainfall of 1197 mm, which transforms into various surface, sub-surface and ground water sources. The surface water annual flow in the country is estimated at 1869.35 BCM and annual replenishable ground water is 431 BCM. As per the assessment of the ground water resources and categorization of assessment units in the country (as on March 31, 2009) out of the total of 5842 ground water assessment units, 802 units have been categorized as 'Over-exploited' , 169 as 'Critical' and 523 as 'Semi-Critical'.

The complexity of ground water flow in coastal aquifers due to sea level changes also needs better understanding to identify the potential threat due to sea water ingress. The ground water flow normally follows the ground slope and the actual discharge of ground water in sea is not studied in detail by any national agency. The hydrogeological conditions of the various aquifer systems in country have been studied in detail by CGWB under Ground water surveys and Exploration in the last 4 decades. The hydrogeological regime monitoring has been modernized under Hydrology project and protocol for water level and water quality monitoring is standardized in the country in association with various state and central agencies. The hydrological information system and decision support system to the various water users needs more scientific information of the aquifers in regional as well as village level potential and status of resource availability in terms of quantity and quality .

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. The detailed aquifer mapping of the country will help in providing protected water supply to all population and also ensuring its sustainability by water conservation and artificial recharge measures. Food security of the country can be achieved by modernizing the irrigation practices suiting the aquifer status prevailing in the area. The major zones of recharge and discharge and the best possible water management plan including the quality protection is feasible with aquifer mapping and hence a time bound aquifer mapping program of the country and making standards for scientific decision support system for identified water stress areas are proposed.

The report of the Expert Group on Groundwater Management and Governance of the Planning Commission (2007), states that, in 2004, 28% of India's blocks were showing high levels of groundwater use. The latest assessment carried out by CGWB in coordination with the states as on March, 2009 indicates about 30% of the assessment units are under Overexploited, critical and Semi-critical category. In addition to quantity related issues like inequitable distribution of ground water resources and overuse /underuse of the available potential in sustainable way, many parts of the country have reported *water quality* problems, causing drinking water shortage. This is a serious situation warranting immediate attention.

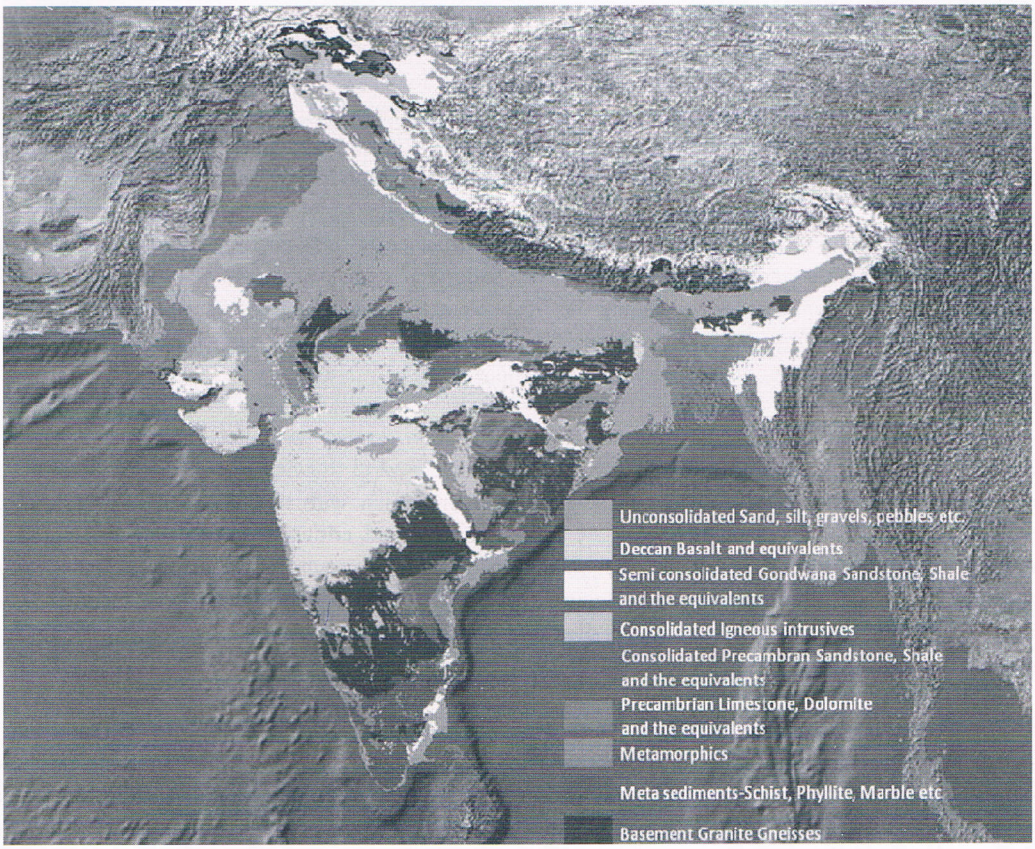
There has been a paradigm shift from "groundwater development" to "groundwater management". An accurate and comprehensive micro-level picture of groundwater in India through aquifer mapping in different hydrogeological settings will enable robust groundwater management plans at the appropriate scale to be devised and implemented for this common-pool resource. This will help 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 as well.

Aquifer system in India

The ground water condition of the country is compiled in block/district/state level by CGWB and other state agencies and academic institutions involved in the identified regions. The national level information is compiled by CGWB, MOWR. The generalized aquifer system of the country is shown in the map below which gives broad category of nine aquifers and same needs updating for the large scale maps as per the water stress in the area selected and the variations in Lithological units. The Geological maps prepared by GSI in 1:250,000 , 1:50,000 and 1:25,000 scale are used for grouping the geological units into aquifer units and give more details like water level, thickness of the aquifer, recharge-discharge area, water quality, areas of pollution etc. CGWB has prepared Hydrogeological Map of the country on 1:250,000 scale. On the basis of this, 15 Principal Aquifer Systems have been identified in the country.

Relevance and Benefit

The Detailed Aquifer Mapping Program will advance the knowledge of the regional hydrologic system. Depending upon the needs & requirements, it is envisaged to prepare hydrogeological maps on 1:50,000scale, and in certain cases, even on a still larger scale of 1:10,000 scale as ground water management needs to be taken up at Block and village level through participatory approach. The Aquifer management plans will be implemented through participatory management approach, and the entire exercise is aimed at providing information at local level to the stakeholders.



Sector institutions

Nationally, the Central Ground Water Board (CGWB) is the Apex national organization dealing with groundwater surveys and exploration and periodic assessment of resources. Besides CGWB, organisations like CWC and NIH also play a very important role in water resources investigation in the country. Organizations such as SOI, GSI, IMD, ISRO, CPCB, etc. play important roles at Central level in data collection, surveys and data base development in accordance with their mandates.
Besides the above, large number of research and academic Institutions like AMD, IITs, Universities, CSIR organisations like NGRI, NEERI etc. and Public Sector Organizations such as WAPCOS, CMPDI, MECL, ONGC, NMDC etc. also carry out exploration and ground water related studies.

Within the States and Union Territories there are Groundwater Departments, either with a certain degree of autonomy (like in the State of Maharashtra) or embedded within other Departments like the PWD,

Water Supply and Sewerage Board or the Mines and Geology Department and Irrigation Department, Public Health and Engineering Departments (PHED) etc. These departments play, within their administrative jurisdiction, a vital role along with the national institution on coordinated programmes of monitoring and investigation. At local level, groundwater development, protection and management is often effectively delivered through decentralised PRIs.

A key issue for effective implementation of the Aquifer mapping programme is the availability of skilled manpower resource for all stages of the programme. Existing national and state institutions may be constrained by their existing responsibilities and limits on recruitment. Hence, it is expected that many aspects of the work will be taken through out-sourcing to academic institutions, Public Sector, Private sector and Civil Societies. However, it will be important to recognise that the capacity of these sectors to address the tasks within the scope of the project is also important, and will be taken into consideration during implementation. The emphasis will be on partnerships and working on a mission mode, making it important to recognise the fact that integrating the work of a single parahydrogeologist on the ground with policy decisions taken at the central level is not only important, but requires collaboration on many fronts.

Knowledge base

There are significant resources of data and information that provide the basic knowledge on groundwater and aquifers, and from which it will be possible to develop Aquifer mapping programme in the regional scale at first and then upscale to village/cluster of village level. Beyond the basic topographic and administrative data provided by SOI, the Geological Survey of India provides geological and Lithological information. Using the satellite data, the NRSC prepares various layer such as Land use, Geomorphology and other thematic layers, similarly the soil maps are available with the NBSS. CGWB have produced comprehensive hydrogeological map at a scale of 1: 2 million and 1:250,000, complemented by regional studies and technical reports of state and districts including Hydrogeological Atlas and Ground Water User Maps. Groundwater Prospects Maps for selected areas have been prepared under the Rajiv Gandhi National Drinking Water Mission. In addition, there are several other organisations which have base-line information that shall be integrated under this programme. Especially in areas of extensive groundwater abstraction for urban water resources, industry or major irrigation schemes, comprehensive and detailed technical data, and management tools, including groundwater models may also exist. The State Ground Water Departments are also repository of large volume of State specific data collected over a period of time. Extensive data is also being collected by way of existing and new monitoring networks established under Hydrology Project.

Aquifer mapping – goal and objectives

The goal of the aquifer mapping programme must be linked to groundwater management actions that result in equitable, safe and sustainable management of India's groundwater resources through improved systems of resource mapping, utilization and governance, including improvements in energy use and pricing and legislative instruments of regulating groundwater overuse. The purpose of aquifer mapping in India has manifold dimensions. Firstly, it is the most scientific approach to understanding groundwater resources. Secondly, an aquifer-perspective will enable appropriate and accurate understanding of groundwater problems and therefore open up disaggregated assessment of groundwater resources in the country, leading to improved thinking, planning and implementation of response strategies. Therefore, the overall objective of aquifer mapping is to arrive at mapping of the complex geometry of different aquifer systems of the country, defined by hydrogeological settings, with a clear cut linkage to strategic actions on the ground (groundwater management strategies).

Aquifer mapping will enable improved responses to water management challenges that relate to the coherence between aquifers, watersheds, forests and administrative boundaries. Aquifer mapping refers to collection of information on the subsurface lithology in terms of their vertical and horizontal extension and water bearing properties including water quality. Even if estimates to the tune of 75% accuracy are available, groundwater management strategies relevant to aquifer conditions will emerge.

The primary objective of the Aquifer Mapping Project is to prepare micro-level aquifer information system with 1:50,000 or larger scale aquifer maps of 1:10,000 scale in identified stress areas and develop Aquifer Management Plans, which will allow institutions and stakeholders to effectively understand and manage groundwater resources at regional and local level.

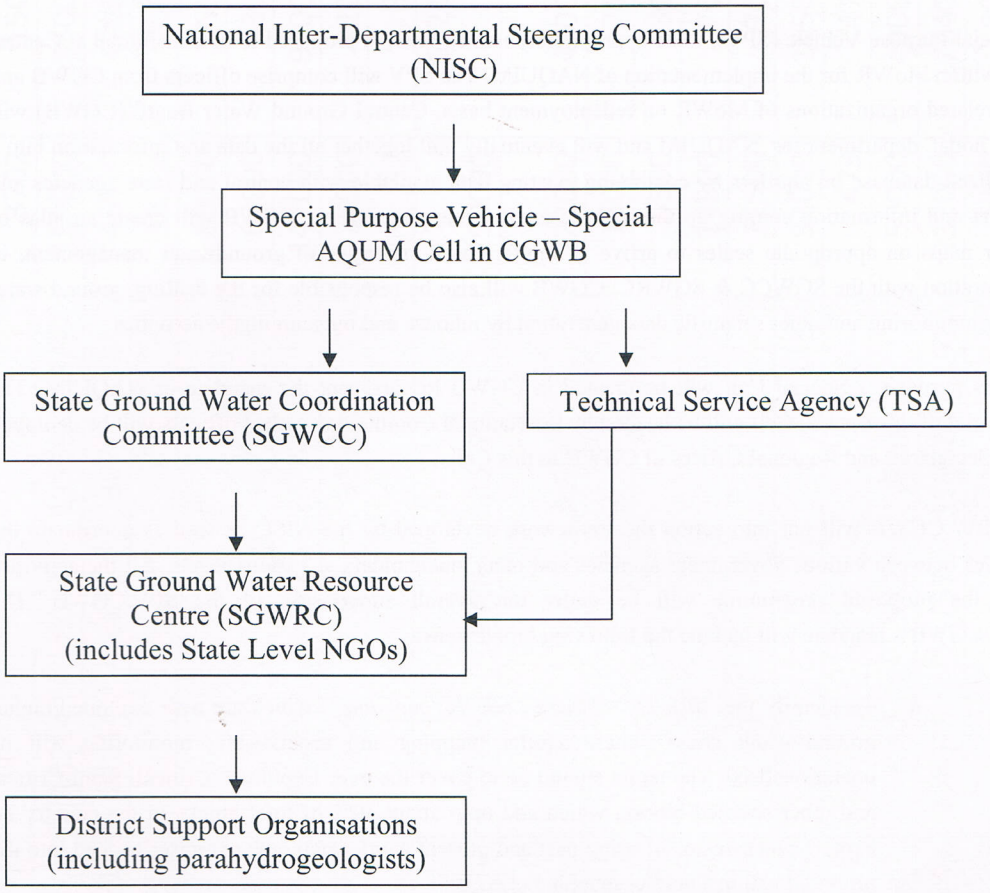
Implementation Strategy

There is a paradigm shift from "ground water development" to "ground water management". An accurate and comprehensive picture of groundwater through aquifer mapping in different hydro-geological settings will facilitate preparation of robust groundwater management plans that include systematic, participatory and even collective development of groundwater resources even in areas where groundwater resources need to be developed. This will help in achieving drinking water security, irrigation and sustainability in large parts of rural India, and many parts of urban India as well. Keeping this in consideration, MoWR is taking up the nationwide aquifer mapping as a 'flagship programme' National Project on Aquifer Management (NAQUIM) during the XII Plan.

A national level programme of this nature must be sufficiently decentralized. It will be taken up in a phased manner following a set of basic norms, criteria and training modules, but with sufficient opportunities for addressing local needs and the potential for subsequent up-scaling. The programme therefore needs to have a three tier institutional arrangement with a large base and a small apex. The major operational partners proposed are:

- National Inter-departmental Steering Committee (NISC) to provide overarching guidance to NAQUIM through the Special Purpose Vehicle (SPV).
- Special Purpose Vehicle (SPV) to lead NAQUIM.
- Technical Service Agency (TSA) to provide training and oversee the activities of State Level NGOs called State Implementation Partners (SIPs)
- State Groundwater Coordination Committee (SGWCC)
- State Groundwater Resource Centres (SGWRC), including SIPs
- District Support Organisation along with a team of para-hydrogeologists

The organogram for the National Project on Aquifer Management (NAQUIM) is as given below:



NATIONAL INTER-DEPARTMENTAL STEERING COMMITTEE (NISC)

The NISC will be constituted with the overall objective to provide guidance in the implementation of the Project at national level. Secretary, MoWR will be Chairman, with representatives from related ministries like Science & Technology, Earth Sciences, Rural Development, Drinking Water & Sanitation, etc. The Principal Secretaries of the States shall be members of the NISC. The NISC may also co-opt eminent hydrogeologists and sociologists/economists who have done work on groundwater and people with credibility of implementing groundwater demand-management on the ground.

The NISC shall be responsible to oversee the implementation of the National programme for Aquifer Mapping and Participatory Aquifer Management in the country, to coordinate with various organizations and to integrate various basin level programmes related to water sector with a view to promoting sustainable ground water management.

SPECIAL PURPOSE VEHICLE (SPV)

A Special Purpose Vehicle (SPV), to be appropriately named later, is proposed to be constituted at Central level within MoWR for the implementation of NAQUIM. The SPV will comprise officers from CGWB and other related organizations of MoWR on redeployment basis. Central Ground Water Board (CGWB) will be the nodal department for NAQUIM and will eventually pull together all the data and information into a centralized database on aquifers by combining existing data available with central and state agencies and the data and information coming up through the aquifer mapping effort . CGWB will create an atlas of aquifer maps on appropriate scales to arrive at aquifer-based strategies of groundwater management, in collaboration with the SGWCC & SGWRC. CGWB will also be responsible for the drilling, ground water regime monitoring and other scientific data generation by inhouse and outsourcingthe activities.

For this purpose, a Special Cell will be created in CGWB to carry out the mandate of NAQUIM. The Secretariat of this Special Cell will be headed by the National Coordinator. Select officers will be deployed in the Secretariat and Regional Offices of CGWB in this Cell.

The SPV/ CGWB will put into action the framework developed by the NISC as well as coordinate the activities between various government agencies and other stakeholders at various levels. All the activities under the proposed programme will be under the overall supervision of the SPV/CGWB. The SPV's/CGWB's mandate will include the following broad areas:

a. To identify the *districts – blocks / tehsils / mandals* – which are over exploited/higher ground water stress ,where aquifer mapping and groundwater monitoring will be operationalised. The target should be to cover the over Exploited, Critical, Semi-Critical and other stressed blocks, which add upto about 30% of total blocks in the country.To explore mechanisms of using past and present aquifer mapping exercises to feed into the proposed national aquifer mapping exercise
b. To finalise the 5 year programme suggested here by providing guidance in the design of and implementation of aquifer mapping in different hydrogeological settings in India, based on a basic design Action Plan laid down later in this document.
c. To suggest appropriate scales at which aquifer mapping will be done in each hydrogeological setting and outline detailed steps how these maps can be aggregated at a more regional scale for improved macro-level assessment and planning.
d. To create and maintain a data base for ground water resources in a digital form.
e. To explore how groundwater quality monitoring can be integrated with monitoring of quantity of water stored in aquifers, to generate a complete picture of water availability. The SPV/CGWB shall endeavour to upgrade water quality laboratories in CGWB through NABL accreditation.
f. To identify the specifications of various equipment, software etc, to be used for NAQUIM at different levels.
g. To decide on the numbers, distribution, and density of observation wells for monitoring groundwater quantity and quality.
h. To develop a way forward in how multiple organizations and agencies can come together to collect *primary data* on groundwater resources from as many wells and springs in the country as is possible, through a participative exercise, involving *paraprofessionals*.

i. To examine how various sources of geologic information, such as geological maps, remote sensing data and the primary data-sets emerging from the participatory exercise can be used to create three-dimensional images of the aquifer systems at relevant scales.

j. To identify and enter into MoUs with International as well as National consultants for implementation of NAQUIM

The SPV/CGWB will be responsible for coordination with, SGWCC, SGWRC for data collation, aggregation and capacity building / training requirements. The SPV/CGWB will assist the States in the preparation of Aquifer Maps, preparation of Aquifer Management Plans and in the development of plans for participatory management of ground water. The SPV/CGWB shall identify and prioritize the Aquifer Management Units (AMUs) in consultation with the SGWCC, and SGWRC. The SPV/CGWB shall identify partners/ consultants/ organizations/ institutions etc. to assist in project implementation and enter into agreements/ MoUs with the same, wherever specialised inputs are desired.

TECHNICAL SERVICE AGENCY (TSA)

A Technical Service Agency (TSA) is proposed to be constituted at Central level and will be identified by MoWR to lead the capacity building and participatory management exercise in the aquifer mapping programme. The TSA is proposed to comprise a consortium of National level NGOs with adequate experience in the field of ground water, capacity building and participatory management related activities.

The TSA shall be responsible for identification of State specific NGOs, called State Implementation Partners (SIPs), which will be involved in the implementation of the Project. The TSA shall also be responsible for imparting Training of Trainers (TOTs) of the SIPs, standardisation of training modules, oversee the activities of SIPs in organising participatory aquifer management programmes at Aquifer level, thereby monitoring the capacity building programme on behalf of MoWR. The TSA will, thus, be instrumental in evolving a model for participatory management of ground water

STATE GROUNDWATER CO-ORDINATION COMMITTEE (SGWCC)

The most crucial set of organizations will be at the level of each State. For this purpose, an SGCC is proposed to be constituted in each State/Union Territory with the overall objective of implementation of the Project at State level. It will be chaired by the Principal Secretary in-charge of ground water of the State Government with representatives from related departments like Ground Water, Irrigation, Drinking Water, Agriculture, Forests, etc. The SGWCC will also comprise representatives from SPV, TSA, NGOs/Academia and Collectors/ Members of Zila Panchayat on rotation basis. Concerned Regional Director, CGWB shall be the Member Secretary of SGWCC. The SGWCC shall identify the Nodal department which shall spear head the State Ground Water Resource Centre (SGWRC).

STATE GROUNDWATER RESOURCE CENTRE (SGWRC)

The State Ground Water Resource Centre (SGWRC) will be mainstay of SGWCC and shall comprise officers of the concerned departments dealing with water sector and also the representatives of the State Level NGOs called State Implementation Partners (SIPs) identified by the TSA in the State. The Nodal Officer of the Special Cell of CGWB in the concerned State shall be the Member Secretary of SGWRC.The SGWRC shall also be responsible for implementation of the Project through Line

departments of the State and the SIPs. The SGWRC will associate with SPV and chalk out a Working Plan for the Preparation of Aquifer Maps, preparation of Aquifer Management Plans and shall also be responsible for the implementation of participatory ground water management through SIPs.

The SGWRC, through DSOs is expected to undertake the following broad set of activities:

- Endeavour convergence of activities with MGNAREGA and other appropriate schemes
- Co-ordination and oversight to activities at the parahydrogeologist.
- Facilitate parahydrogeologists in collecting information of the right kind and at appropriate frequencies.
- Collation of data brought up from the DSOs.
- Fieldwork and analytical work, including lab testing (either in-house or outsourced) of groundwater quality to identify aquifers and develop first-cut strategies on groundwater management.
- Creation and maintenance of State level database on groundwater resources.

DISTRICT SUPPORT ORGANISATIONS (DSOs)

The SGWCC/SGWRC shall identify an institutional set up at District and Block level responsible for implementation of NAQUIM in the district through District Support Organisataions (DSOs) comprising the Panchayati Raj Institutions, NGOs, parahydrogeologists etc. A *district-level system is preferred* because technical back-up on groundwater is more readily available at the district-level (as compared to taluka / block level) today, in many States of the country. Each of these DSOs will be responsible for collating data from the parahydrogeologists in the District, linking up with State-level entities in order to move the database upward (to the State level system) and forward (adding their own value to the data and information). Each DSO is expected to undertake the following activities:

a. Co-ordinate the activities of parahydrogeologists.

b. Specifically organize extension of instrumentation available with the organization to parahydrogeologists – for instance, one time GPS measurements and in-situ water quality information.

c. Facilitate parahydrogeologists in collecting information of the right kind and at appropriate frequencies.

d. Collate information and data coming up from the villages, towns and cities.

e. Help in developing a database on groundwater and maintain databases under their scope and possibly integrate these into a district level database on groundwater.

Para-Hydrogeologists

There are some 640000 villages in India spread across nearly 6000 blocks / talukas. Even if we consider that the 12th Plan targets the 30% of the country – mainly overexploited blocks and blocks with major water quality issues in the country, one may consider about 250000 villages divided across 2000 blocks /

talukas spread across 214 odd districts spreading over 2.5 lakh villages. It is estimated that about 17000 parahydrogeologists in villages and about 3000 parahydrogeologists in urban areas would be required in this first phase of aquifer mapping. Each *parahydrogeologist* can be a village youth or college student, with the desire to learn and engage with the village-water problems.
Each parahydrogeologist will be responsible for the following activities:

a. One-time inventory: Creating a one-time well-inventory for the village – including names of owners of the wells, the dimensions of the structure (well/spring), pump and pumping system, etc. collected from the well-owner(s) / users of wells/springs, for all wells in the village.

b. Lithologs of wells / boreholes / tube wells – for a sample of about 15-20 wells per village: Observation-based description of rocks and rock types – some (the basis for which will be a *parahydrogeologist training programme* – see section below on Capacity Building), with these observations supporting the hydrogeological mapping exercise undertaken by specialized agencies – while conducting the one-time inventory.

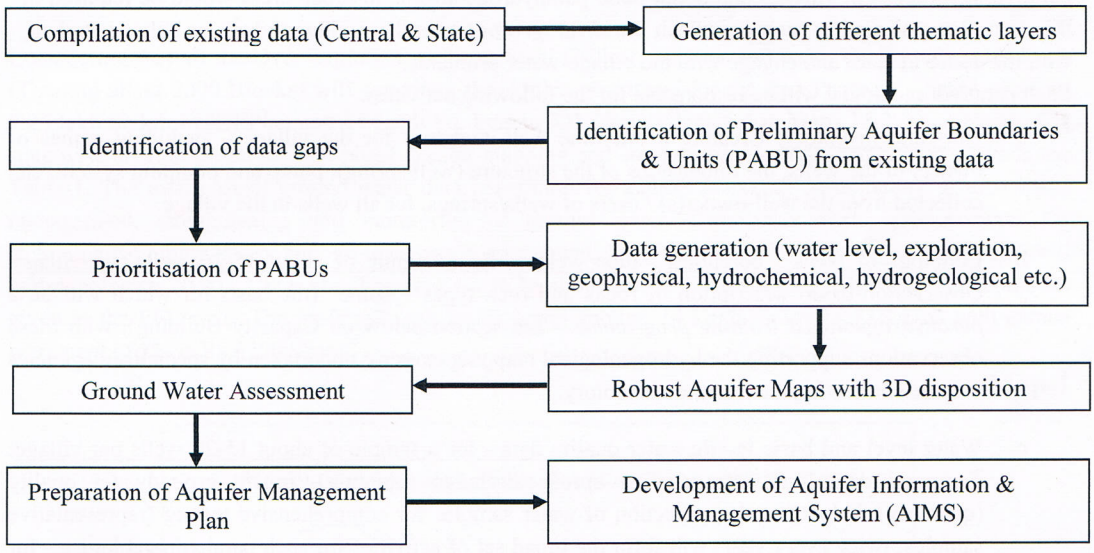
c. Water level and basic in-situ water quality data - for a sample of about 15-20 wells per village: Temporal data like water-levels / spring discharge (monthly), in-situ groundwater quality (quarterly), helping in the collection of water samples for comprehensive testing (representative samples, twice every year) will form the broad set of activities for each parahydrogeologist – for about 500 wells per parahydrogeologist/volunteer.

Methodology

It is worthwhile mentioning upfront that *aquifer mapping* is NOT simply a creation of aquifer maps. It is a process for visioning how India's groundwater resources will be managed not just in the next 5-10 years, but for the next 50 years, primarily through the active participation of its citizens. Aquifer mapping will lead to strategic plans for ensuring sustainable, equitable and efficient use of India's groundwater resources for many years to come. It will not only help understand aquifers but will use aquifers as units of measuring, monitoring, legislating and governing India's groundwater resources. Major reforms in data management, groundwater governance including the legislative framework and drinking water security will derive benefits from aquifer mapping through the development of strategic groundwater management plans. Hence, aquifers will form the units on which decisions are taken and actions performed with regard to groundwater resources. The methodology proposed is an amalgamation of both top-down and bottoms-up approach which suggests the use of latest technology as well as the process of participatory data collection and management of ground water.

Central Ground Water Board is implementing the **Pilot Project on Aquifer Mapping under the World Bank funded Hydrology Project** (HP-II). CGWB proposed to carry out advanced geophysical investigations and their interpretation for the Pilot Project under HP-II for aquifer delineation and its characterization through National Geophysical Research Institute (NGRI), which is a premier research organisation under CSIR (Ministry of Science and Technology). This information will, in turn, lead to an effective ground water management in a participatory approach involving various stake holders. The outcomes of the project are envisaged to establish the efficacy of various geophysical techniques under different hydrogeological conditions and to establish a protocol for geophysical investigations when aquifer mapping shall be up-scaled for the entire country.

The action plan for Aquifer mapping is as given below:



The detailed activities, sub –activities, tasks, deliverables, responsible Agencies and timelines are given in Annexure-I.

Five major steps have been identified for Aquifer mapping, namely:

1. Compilation of existing gfround water data and data gap analysis
2. Generation of additional ground water data
3. Preparation of Aquifer Maps
4. Preparation of Aquifer Management Plans
5. Participatory ground water management.

NAQUIM is expected to address the following issues, along with the timelines given as Appendix – I for various activities, in respect of each of the above mentioned steps as given below:

1. The existing data from all state and central agencies will be collected and processed to make a validated ground water data base. The specific parameters missing in the secondary data like co-ordinates and Reduced ground elevation etc will be collected and standard data base in GIS platform will be made.
2. The data generation to bring out validated ground information on aquifer geometry, its characteristics, status of development and stress acting in localised aquifer system like quality and scarcity, need for augmentation with suitable site and design and other factors controlling the ground water occurrence and movement in surface and sub-surface will be optimized. Specific scientific data required will be generated and used for better understanding of the total ground water system inclusinmg the interaction with surface water.

3. Preparation of Aquifer Maps

    a) Institutional and project management support – SPV, CGWB, State, District and Block level organisations.

b) Identification of Aquifer Management Units (AMU) and operationalisation at appropriate scales.
c) Prioritisation and work programmeon the basis of quantity, quality and stage of development of ground water and criticality of groundwater quality issues.
d) Investigation and data compilation for each / cluster of AMUs through participation of para-hydrogeologists, block and district level support and State Groundwater Co-ordination Committees.

4. Preparation of Aquifer Management Plans

    a) Facilitate State Government Organisations and other stakeholders in the Preparation of Aquifer Management Plan and supporting tools while taking into consideration the quantity and quality aspects of ground water.
    b) Development of Aquifer Information and Management System (AIMS).
    c) Articulate and share information across hydrological units for crop planning, drinking water security and urban water security, as the case may be. It is important to consider these three because some aquifers might transect rural-urban divides and may require an integrated management plan that includes both types of requirement.

5. Implementation of Aquifer management plan by Participatory ground water management.

    a. Demystify the science of ground water hydrology through capacity building and community level participation in real time data collection planning and development.
    b. Establishment of protocols for participatory ground water management through
        i. Suggesting mechanism for collection of required data / parameters for seasonal assessment of ground water resources and their regular updating at local level involving the end users.
        ii. Formulating appropriate strategies and methodology for strengthening local institutions and end users for ground water management and capacity building of stakeholders (staff / officials/PRIs/NGOs/CSOs etc.).
    c. Strengthen local institutions to address emerging ground water issues in respect of quantity and quality of ground water resources.
    d. Transform the perception of groundwater from private property to that of a "common good", where individual farmers take decisions for collective good.

I. Preparation of Aquifer Maps

Ia Institutional and project management support

The workflow of the project, envisaged for NAQUIM will be accomplished on a Project Mode with multi-disciplinary approach involving Central, State organisations along with PRIs, NGOs, CSOs, etc. This would require a skeletal framework given below, which will be further expanded on completion of benchmarking for the aquifer mapping based on the pilots in five areas.–

A. Institutional strengthening
    1. National Level: Besides NISC, an SPV with required administrative and financial power to take timely decisions for execution of the project and for proper co-ordination with different organisations, institutions, the State Governments etc.

2. State level: An SGWCC and an SGWRC for coordination and implementation.
3. Research and support Staff could be hired as per rules.

B. Capacity building to be taken up with the help of RGI, Institutions, National level NGOs, etc.
   1. Technical upgradation of Institutions
   2. Capacity building of personnel of SPV, SGWCC, SGWRC, SIPs, DSOs, through training and capacity building.
   3. Strengthening of para-hydrogeologists through National level and State level NGOs.

C. Monitoring mechanism
   1. National Level Inter-departmental Steering Committee (NISC)
   2. State Level Ground water Coordination Committees (SGWCC)
   3. Technical Support Agency (TSA)– an independent agency or a consortium of Agencies identified by MoWR

Ib Identification of Aquifer Unit

The major aquifer systems of India available in 1:2 Million scale gives the national level distribution of porous and fractured aquifers. There are number of sub-groups transgressing the states and basins and also the country, which maybe sub-divided on the lines of watersheds. The multi layered aquifers in porous formation also need to be classified on the basis of their extent and depths. Conventionally, geology and geomorphology plays key role in defining the aquifer units. It is proposed to demarcate the aquifers in the country in a scientific way from provinces to regions and local level to an optimal size management unit. Accordingly component of the project will include:-

- Lithological model, to include depth and thickness of major aquifers and aquicludes, significant structures, faults and lineaments.
- Surface area, particularly of phreatic aquifers.
- Lithologic and/or 'head' boundaries defined by the water table or potentiometric levels.
- Attribution of geological model with basic aquifer properties (storage, transmissivity).

Some information on all or some of these aspects exists with Central and State Agencie, Research Institutes and some NGOs working on groundwater-related issues. The aquifer mapping exercise envisages large-scale collection of basic information such as groundwater levels, groundwater quality and patterns of groundwater usage. Pre-existing and fresh information needs to be collated, filtered and layered onto existing 'centralised' information on aquifers and aquifer systems. An Aquifer Management Unit is the basic component of both planning and project implementation. Ideally an aquifer management unit will be defined on hydrogeological grounds, including their recharge areas and natural and anthropogenic discharge zones. This not only gives a simplistic premise for understanding but provided a good scope for beginning effective management of groundwater resources as a common pool. The identification of AMUs will be based on the boundaries of existing regional hydrogeological units, Watersheds and Administrative units.

Existing data from the central/state agencies will be compiled for each AU. The conceptual model developed from the compiled information will lead to better understanding of sources of recharge, interaction of surface and groundwater and their movement, abstraction and natural losses from the aquifer unit, ultimately leading to prioritisation of all AUs of the country.

Ic Prioritisation of Aquifer Units.

The prioritisation of AU, as well as the scale of mapping, shall be based on the evaluation of each AMU. The prioritisation will also indicate further investigations that may be required to fill in the data gaps for each AU. The Aquifer Management Plans will be accordingly prepared for the prioritised AUs.
Some of the important considerations for prioritisation of AUs could be:

- aquifer yield
- water quality
- demands and stress on the aquifer
- Status of ground water development (AUs with Overexploited/Critical/Semi-critical status will be a priority for mapping and data base creation)
- vulnerability of aquifer/environment degradation, viz. sea water ingress, pollution and condition of aquifer in terms of the degree of depletion.

Once prioritised, an investigative work plan will be drawn up for each AU. The prioritised AUs will be further classified on the basis of the data availability in these units into three categories:

i. Priority AUs with high data availability

ii. Priority AUs with moderate data availability

iii. Priority AUs with Low data availability.

The scope of work required in each AU is expected to vary across a spectrum, from AUs where there are sufficiently comprehensive data with which work can focus on digitisation and compilation of the outputs from data generated during previous studies to AUs where significant investments will be required in digitising detailed records and field data collection.

Id Investigation and data compilation for each AU

The Work plan for further investigation and analysis shall depend upon this categorisation.

a) The broad activities for data collection, analysis and reporting are as given below: Data Compilation from Primary & secondary data available

b) Additional Primary data generation:

Where significant data gaps are identified, additional hydrogeological, geological geophysical, geochemical data collection will be required to supplement existing reports and digital data.

II. Preparation of Aquifer Management Plan

Central ground Water Board shall assist the State Government in preparation of Aquifer Management Plans based on existing and data generated through the Parahydrogeologists, Block, District and State infrastructure and analysed through mechanisms such as simple simulations to advanced mathematical ground water models. For this, the State Government's machinery as specified in Item at Sl. No. Ia above is envisaged to play a vital role

The AMPs shall include, but not be limited to:

i. The AMPs should also talk about the sustainability of the resource; Sustainability should include reference to the reliability, resilience and the vulnerability of the resource. Reliability is the ability of system to meet demands; resilience is the measure of the ability of the system to recover from failure and vulnerability is the measure of loss/damage incurred because of failure. Sustainability,

in other words, is the capacity of an aquifer to provide safe and a projected quantity of water over the long run.

ii. The AMPs should address the issues of climate change and its impact on ground water resource availability.

iii. Feasible areas for ground water development along with yield potential, Type and Depth of drilling / safe yields etc.

iv. Feasible areas for rainwater harvesting and artificial recharge of groundwater vis a vis subsurface storage space and surplus non committed surface water runoff available for recharge.

v. Aquifer wise vulnerability map indicating ground water stress areas in terms of water availability and quality.

vi. The relevant Groundwater Management Protocol, which may range from management by municipal or governmental institutions where aquifers are primarily exploited for urban or industrial water supply, to participatory mechanisms that involve the community in agricultural and more rural areas and to explore funding options for the implementation of AMPs.

III. Participatory Groundwater Management

It is imperative to have the aquifer mapping activity with a road map for groundwater *management plan to ensure its transition into* a participatory groundwater management programme within the legislative framework for effective implementation of the Aquifer Management Plans (AMPs). This would require a coordinated effort involving government departments, research institutes, PRIs, civil society organizations and the stakeholders at the village level who would guide collective sharing and use of groundwater, based on a careful understanding of the storage and transmission characteristics of different aquifers in each of the hydrogeological settings. A National level identified consortium of NGOs is desirable for developing benchmark for this activity and facilitate its implementation.

As Aquifer Management Units (AMUs) vary in their scale, hydrogeology and the demands placed upon them, so groundwater management responses will vary. In urban areas, or where deep regional aquifers are subject to extensive exploitation by industrial or agricultural users, management is likely to be delivered by state or municipal institutions. In these instances it will be the responsibility of the relevant institution both to implement plans and to act as a focal point for other users with interests in the AMU. In the case of low intensity exploitation of shallow aquifers in rural areas a key deliverable from NAQUIM is the wide implementation of community focused participatory management.

The implementation of AMPs is possible only through collaborative approach amongst government departments, research institutes, PRIs, civil society organizations and the local community. The stakeholders would include farmers, landless farm workers with appropriate SC, ST and Women's representatives. Consensus-based decision making should be the goal of local water users association (WUA). Social audits should be inbuilt within the participatory ground water management. For separating implementation and monitoring processes, members not involved in the implementation process may conduct these audits. Gram Sabha can be the final arbiter in case of disputes and for establishing some basic regulatory norms under PRI system. A national level independent authority / agency / consortium has to be identified for evaluating the project. Serious endeavour should be made towards building capacity, skills and knowledge to ground water users. Further, identification of suitable youth, women etc. should be made so that they can be provided with advanced skills to act as facilitators, trainers and data managers.

Two major issues to be addressed are :–

1. Management of Groundwater
2. Monitoring leading to sustainability of Groundwater

Capacity building is a prerequisite for participatory ground water management. The capacity building will be required for the personnel from Central and State organisations, PRIs, NGOs, and Block level persons identified for this purpose (para-hydrogeologists)

Even though Aquifer mapping is a fairly complex exercise involving profound knowledge of Hydrogeology and other disciplines, the role of para-hydrogeologists (PHGs) cannot be understated. The PHGs shall be responsible for collection of basic hydrogeological data, periodic monitoring of identified key wells, and sensitization of the villagers regarding ground water trends, extensive usage and its ramification. Designated NGOs will identify and facilitate training to PHGs for the implementation of AMPs. The community should be able to generate resources for the payment of para-hydrogeologists in long run and initial funding from central govt for 3 years is proposed. The detailed note on participatory management of ground water is given in Appendix-II

Implementation time table

Successful delivery of Aquifer mapping programme will require considerable financial resources, but it is important to recognise that some of the preparatory and supplementary activities, although requiring relatively smaller investments, will be key to overall delivery. The schedule is appended in Appendix-I. The first step in this direction would be the constitution of the NISC and SPV/Special AQUM Cell in CGWB.

Constraints

NAQUIM is a time bound and multi disciplinary project with ambitious plan in its scope and requiring significant resourcing. This section seeks to identify key project risks that may impact on project success.

Risk

- Under par performance of institutions/organisations.
- Inadequate availability of dedicated and trained manpower, state of the art equipment etc.
- Insufficient availability of reliable data
- Slow decision making
- Complications in fund flow from Centre to States, NGOs, etc.

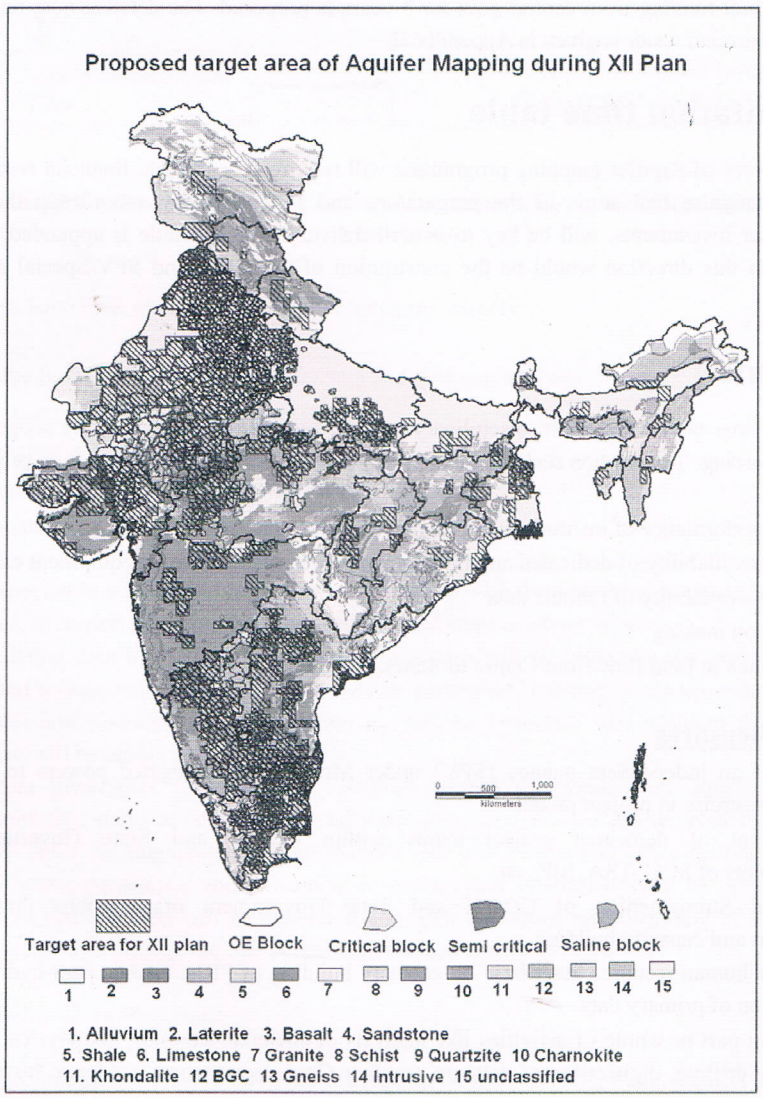
Mitigating measures

- Creation of an independent agency (SPV) under MoWR with delegated powers to undertake this mammoth exercise in project mode.
- Establishment of dedicated project teams within CGWB and State Governments through establishments of SCC, TSA, SIPs etc.
- Institutional Strengthening of Central and State Government organisations through technical upgradation and capacity building.
- Creation of human resource asset base by capacity building of PRIs, NGOs, para-hydrogeologists etc for collection of primary data.
- Outsourcing part or whole of activities like analysis of chemical samples, geophysical investigations, exploratory drilling, digitization of data etc. to other Govt departments, academic institutions and the private sector.

Cost Estimates and Financial Implications:

Considering that all the Over exploited, Critical, Semi-Critical, Salinity and water quality affected blocks (Totaling about 2000 Blocks) will constitute the AMUs prioritized for the first Phase in an area of about 9.25 lakh Sq.km in XII Plan and 14 Lakh Sq. kms in XII Plan as depicted in Maps 1&2 respectively. The state wise area proposed for first phase aquifer mapping and second phase aquifer mapping is given in the Table-1. The total cost of ground water data generation for aquifer mapping, participatory ground water management, strengthening and monitoring of ground water observation wells, procurements for technological upgradation and ground water assessment, including the cost for engagement of para-hydrogeologists NGOs, CSOs etc. is worked out to be about Rs 3250 Crore during XII Plan. The details are given in the EFC note. The projected cost for mapping another 14 Lakh Sq.km in XIII plan with annual increment of 7% is Rs 6700 Crore.

Map-1



Map-2

Proposed Target Area for Aquifer Mapping during XIIIth Plan

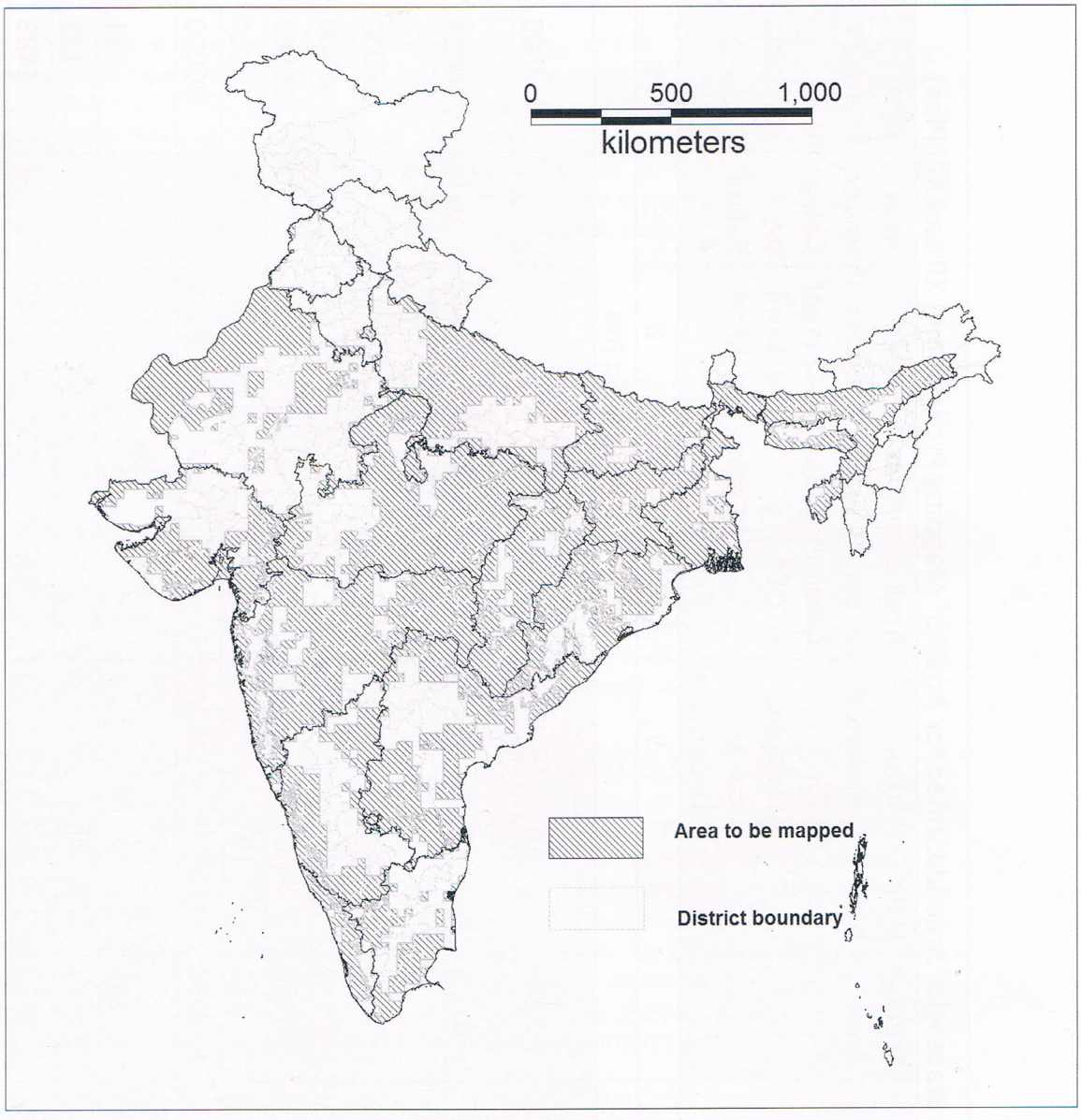


Table-1: State wise Area Identified for Aquifer Mapping Programme(XII and XIII Plan)											
S No	State/UT	Total Area	Hilly Area	Area excluded for mapping due to low thrust	Area under Category OE*	Area under Category Critical *	Area under Category Semi Critical *	Area under Category Saline *	Area identified for Mapping *	Target area for XII Plan	Target area for XIII Plan
1	2	3	4	5	6	7	8	9	10	11	12
		Area in Sq Km									
1	Andaman & Nicobar	8249	0	749					7500	1500	6000
2	Andhra Pradesh	275069	20240	44829	17863	9978	20019	3909	210000	100000	110000
3	Arunachal Pradesh	83743	36080	23663					24000	2027	21973
4	Assam	78438	7244	23194					48000	5600	42400
5	Bihar	94163	0	18663					75500	7400	68100
6	Chandigarh	114	0	0					114	114	0
7	Chhattisgarh	136034	14650	25384			8449		96000	11500	84500
8	Dadra NagarHaveli	491	0	0					491	491	0
9	Daman &Diu	112	0	0					112	112	0
10	Delhi	1483	0	0	972	381	59		1483	1483	0

11	Goa	3702		0					3702	1500	2202
12	Gujarat	196024	10020	36004	18214	9044	13559	13224	150000	83000	67000
13	Haryana	44212		712	24814	6856	3070		43500	42000	1500
14	Himachal Pradesh	55673	11390	11283					33000	7600	25400
15	Jammu & Kashmir	222236	42770	99466					80000	9656	70344
16	Jharkhand	79714	900	15814	1175	466	578		63000	6300	56700
17	Karnataka	191791	6427	38364	55083	10731	39202		147000	93000	54000
18	Kerala	38863	7703	3160	204	404	3286		28000	5200	22800
19	Lakshadweep	32	0	0					32	32	0
20	Madhya Pradesh	308000	20570	37430	17789	3488	53567		250000	69200	180800
21	Maharashtra	307713	27800	57913	6939		15299		222000	43000	179000
22	Manipur	22327	0	6327					16000	700	15300
23	Meghalaya	22429	9269	6660					6500	1800	4700
24	Mizoram	21081		6581					14500	700	13800
25	Nagaland	16579		5079					11500	700	10800
26	Orissa	155707	35870	27837				12335	92000	16500	75500
27	Pondicherry	479	0	0					479	479	0
28	Punjab	50362	0	362	37367	982	500		50000	49000	1000
29	Rajasthan	342239	29790	80449	208075	13757	11982	1919	232000	178400	53600
30	Sikkim	7096		1296					5800	800	5000

31	**TamilNadu**	130058	10210	25848	34338	8029	17512	3331	94000	68206	25794
32	**Tripura**	10492		2092					8400	3500	4900
33	**Uttaranchal**	53484	1184	11300	320		1813		41000	7700	33300
34	**Uttar Pradesh**	240928	0	46928	20870	8152	28576		194000	90800	103200
35	**West Bengal**	88752	0	13752		143	7409	9757	75000	15000	60000
	Total	3287869	292117	671139	444023	72411	224880	44475	2324613	**925000**	1399613
		32.88 lakh	**2.92 lakh**	**6.71lakh**	**7.86lakh**				**23.25lakh**	**9.25 lakh**	**14.00 lakh**

Priority is for OE, Critical and Coastal areas and Quality Problem areas

*Programme starting in year 1st will go upto 4th year and 2nd to 5th year and so on
Area identified for mapping in column 10 excludes hilly area and other areas where mapping is not possible

Appendix-II

ACTIVITIES AND TIME LINE FOR NATIONAL AQUIFER MAPPING PROGRAM-XII & XIII PLAN PERIOD

Sl. No	ACTIVITY	SUB ACTIVITY	TASK	Agency	XII Plan - 9.25 Lakh Sq.Kms					XIII Plan - 14.0 Lakh Sq.Kms				
					year-1	year-2	year-3	year-4	year-5	year-6	year-7	year-8	year-9	year-10
I	Compilation of Existing Data/ Identification of Principal Aquifer Units & Data Gap	1 A. Compilation of Existing ground water Data	Preparation of Base map and thematic layers	CGWB + SoI										
			Data base on Exploration wells	CGWB & through SRF/JRF, Institutions/ Agencies										
			Compilation of information of Geology, Geophysics, Hydrogeology, Geochemical, Hydrology											
			Delineation of principal aquifers (Vertical & Lateral)	CGWB										
			Compilation of Aquifer wise Water Level data	CGWB & through SRF/JRF, Institutions/ Agencies										
			Compilation of Aquifer wise Draft Data											
		1B Identificati	Data Gap in thematic layer	CGWB + States										

		on of Data Gap	Data gap in Sub-surface Information & aquifer parameters	CGWB + States										
			Data gap in information on Geology, Geophysics, Hydrogeology, Geochemical, Hydrology	CGWB + States + Partner organisations (e.g. NGRI etc.)										
			Data gap in delineation aquifers (Vertical & Lateral)	CGWB + States										
			Gap in Aquifer wise Water Level data	CGWB + States										
			Data gap in Aquifer wise Draft Data	CGWB + States										
II	Generation of Data	II A. Generation of Geological layers in1: 50,000 scale	Preparation of Geological Map in 1:50,000 scale	CGWB + GSI										
			Preparation of Sub-surface Geology	CGWB										
			Geomorphological Analysis	CGWB + NRSC + IIRS + MoDWSS										
			Analysis of Land use pattern											
		II.B.	Vertical Electrical	CGWB										

		Surface and sub-surface geoelectrical and gravity data generation	Sounding (VES)	+ Collaborative partners like NGRI											
			Bore Hole Logging												
			2-D Imaging												
			Advanced Geohysical Methods												
		II.C. Hydrological information	Preparation of Drainage Map	Survey of India + NRSC											
			Demarcation of water bodies												
			Soil Infiltration studies	CGWB + Agencies											
		II.D. Parameters on Ground water recharge	Rainfall data analysis	MoWR organisations + IMD + States											
			Canal flow, recharge structures etc												
		II-E. Preparation Hydrogeological maps in 1: 50,000 scale	Water Level Monitoring	CGWB/NGOs /Para hydrogeologists											
			Exploratory drilling	CGWB/ Drilling Agencies											
			Pumping tests												
			Well Inventory	CGWB/NGOs											

				/Parahydrogeologists									
		II.F. Generation of additional water quality parameters	Analysis of Groundwater for pesticide, Bacteriological contamination	CGWB/through NABL accredited labs, BARC, PRL etc.									
			As and F in groundwater										
III	Aquifer Map Preparation (1: 50,000 scale and For identified areas in 1:10,000 scale)	III.A. Analysis of data base and preparation of GIS layers III.B Preparation of Aquifer Maps	Integration of Hydrogeological, Geo-physical, Geological, Hydro-chemical data	CGWB/International and National Consultants engaged by MoWR									
IV	Aquifer Response Model/Aquifer Management Plan	IV A. Model Conceptualisation	Integration of Aquifer Geometry, Aquifer units, Aquifer parameters, Groundwater Draft	CGWB/International and National Consultants engaged by MoWR									

			& Recharge.												
		IV.B. Model Simulation	From field study, data from secondary sources (PWD & Local agencies)	CGWB/International and National Consultants engaged by MoWR											
		IV.C .Preparation of Aquifer Management Plan	Information of aquifer to public, villagers.	CGWB & through NGOs/ Parahydrogeologists											
V	IEC Activity & Implementation of Aquifer Management Plan	V.A. Capacity building V.B. Participatory Groundwater Management	Involvement of villagers, local administration, state government, farmers, women & NGO's	CGWB through State/ Para hydrogeologists											

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