PROJECT COMPLETION REPORT

HYDROLOGY PROJECT PHASE-II

(IBRD-47490)

Government of India

Ministry of Water Resources, River Development & Ganga Rejuvenation

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Project Completion Report of Hydrology Project Phase II

Contents

1 INTRODUCTION

1.1 Background

The first phase of the Hydrology Project was implemented from 1996 to 2003. Its objectives were to:

- Improve organisational arrangements for hydrological, hydro-meteorological and water quality data measurements, validation, analysis and storage;
- Strengthen institutional and technical capabilities of Implementing Agencies
- Improve physical facilities and services for hydrological, hydro-meteorological and water quality data measurement, validation and analysis, and
- Improve the use of hydrological, hydro-meteorological and water quality data.

The project was jointly funded by the World Bank, the Government of the Netherlands (who provided Grant Aid to support consultancy services) and the Government of India. Participating agencies included nine States (Andhra Pradesh, Chhattisgarh, Gujarat, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu), and six central agencies (Ministry of Water Resources, Central Water Commission, Central Groundwater Board, National Institute of Hydrology, Central Water and Power Research Station andIndia Meteorological Department).

Activities undertaken included:

- Procurement of equipment for hydrological, hydro-meteorological and water quality measurements;
- Development of State Data Centres for collation and processing of data;
- Development and procurement of software for
    - data entry for surface water (SWDES),
    - data entry for groundwater (GWDES)
    - data entry for water quality (WQDES)
    - data processing software for surface water (HYMOS)
    - data processing software for groundwater (GEMS)
    - data storage software (WISDOM).
- Institutional strengthening

1.2 Hydrology Project Phase 2

The second phase of the hydrology project was formulated in order to build on the achievements of the first phase, and extend the project into promotion and use of Hydrological Information System. The Project Appraisal Document of the World Bank (July 2004) describes the project formulation in detail. For project implementation, the Project Implementation Plan prepared by the Ministry of Water Resources (May 2004) provides detail of activities to be undertaken by the various implementing agencies.

The total number of Implementing Agencies under HP-II was 28 as given below:

1. The HP1 States, mostly with two agencies (surface water and groundwater) except Tamil Nadu which has a combined single implementing agency. Total 17 Agencies.
2. Four new States, each having a single agency for surface water and groundwater. Total 4 Agencies.

3. The Central Agencies: Ministry of Water Resources, Central Water Commission, Central Groundwater Board, National Institute of Hydrology, Central Water and Power Research Station, Central Pollution Control Board and the Bhakra Beas Management Board. The India Meteorological Department withdrew at an early stage leaving 7 Agencies.

The second phase of the Hydrology Project provides for three components:

(a) Institutional strengthening

(b) Vertical extension, covering activities relating to consolidation of the work in the first phase of the project within the agencies that participated in the first phase of the project, and

(c) Horizontal extension, covering expansion of the network of implementing agencies to include four new States (Goa, Himachal Pradesh, Puducherry andPunjab) and two new central agencies (Central Pollution Control Board andBhakra Beas Management Board)

(a) The institutional strengthening component comprises:

- Consolidation of first phase activities
- Institutional support for awareness raising, dissemination and knowledge-sharing
- Implementation support for activities of the implementing agencies (IAs).

Consolidation of first phase activities includes providing training and support for the software processes used by the IAs, as well as training in the use of non-standard equipment.Awareness raising and information dissemination activities will include reviewing software and web-sites for increasing the profile of hydrological activities, and improving the interface between data providers and data users.Support activities for project implementation include a wide range of activities to assist procurement, financial management and management information systems to support smooth running of the project.

(b) Vertical extension of project activities includes enhancement of the data processing software to provide increased functionality for the end-users, including a range of purpose-driven studies to develop and demonstrate new capabilities of the system.

(c) Horizontal extension is to work with new IAs to implement activities of basic improvements to data systems, including upgrading of data collection networks, improvement of data processing systems, and staff training.

The components of the Hydrology Project II, as per the Project Appraisal Document (PAD) are shown in Table 1.1.

Table 1.1: Components of the Hydrology Project Phase II

Component Activity		**Budget Allocation (US $ million)**	**% of project allocation**
Component I: Institutional Strengthening			
I.A	HP I Consolidation	6.63	5.7
I.B	Awareness, dissemination and knowledge sharing	9.10	7.8
I.C	Implementation Support	27.36	23.4
Component II Vertical Extension			
II.A	Hydrological Design Aids	3.86	3.3
II.B	Decision Support Systems	36.10	30.9
II.C	Purpose-driven Studies	11.03	9.4

Component III: Horizontal Expansion		
III.A Upgrading of data collection	11.07	9.5
III.B Upgrading of data processing and management	9.31	8.0
III.C Purpose-driven studies (for horizontal expansion)	1.85	1.6
III.D Training (for horizontal expansion)	0.49	0.4
TOTAL BASE COST	116.80	100
Physical Contingencies	7.71	
Price Contingencies	10.54	
GRAND TOTAL	135.05	
LOAN COMPONENT (as per Loan Document)	**104.98**	

The Loan Agreement between the World Bank and the Government of India was signed on 19 January 2006. The Project started in April 2006, and was to run to the end of June, 2012.

The IMD withdrew from the project in early 2009, citing low level of interest in undertaking the proposed programmes of work. They continued support to other Implementing Agencies through training and data validation, without using loan funds.

Following a request from the Government of India, the World Bank agreed to an extension of the loan agreement to 31 May 2014 vide letter dated 3 April 2012.

1.3 Key Events in the Project

World Bank missions to the Project were held on:

Mission	Date
March 2008	3 to 18 March 2008
July 2009	
Mid-term Review Mission	1 to 14 October 2009
March 2010	4 to 16 March 2010
December 2010	30 November to 7 December 2010
January 2012	16 to 25 January 2012
June 2012	25 to 28 June 2012
October 2012	01 to 5 October 2012
October 2013	30 September to 11 October 2013
May 2014	Completion Mission

The scope of work of the project was reviewed and revised on a number of occasions.

The Mid Term Review in October 2009 led to a significant revision, with all Agencies reviewing the work they wished to undertake. A major change introduced at this time was the inclusion of a Real Time -Decision Support System(RT-DSS) for Maharashtra Surface Water Agency. Another major change was the inclusion of the Pilot Project on Aquifer Mapping in six study areas for Central Ground Water Board.

Subsequent reviews were undertaken in March 2011, July 2012 and October 2013.

2 Project Objectives

2.1 Objectives set out in the Project document

The main objective of the Hydrology Project II was to promote the sustained and effective use of the Hydrological Information System (HIS) developed under HP-I by all potential users concerned with water resources planning and management, both public and private. This was to be achieved by:

(a) strengthening the capacity of water resources departments (surface water and groundwater) to develop and sustain the use of the HIS for hydrological designs and decision tools;

(b) improving the capabilities of implementing agencies at State/Central level in using HIS for efficient water resource planning and management to facilitate the country's poverty reduction objectives;

(c) establishing and enhancing HIS as user-friendly, demand responsive and easily-accessible HIS and

(d) improving access to the HIS by public agencies, civil society organizations and the private sector by supporting outreach services.

2.2 Measures of Success in Achieving Objectives

It is not a simple task to measure success in achieving project objectives as thesemostly intangibles, and there is no simple yard stick to indicate success. However, most of the Project Development Objectives have been achieved, and even exceeded on several accounts. Very few of the Project Development Objectives have been only partially achieved. Overall, the Hydrology Project Phase-II can be surely classified as successfully completed and its success can be highlighted by the fact that most of the States have requested for the third phase of the Project and for that the Bank has also given its consent.

The strengthening of the capacity to sustain the HIS has been demonstrated by most Implementing Agencies in the course of the project, through qualitative assessment of performance. For the HP1 Agencies, the performance during the DSS (Planning) work indicated very significant increase in capacity to understand water resources issues for planning and management as well as improvement in ability to use models for this purpose.

The development of the HIS as a user-friendly and accessible source of hydrological data has somehow been weighed down by delay in completion of key softwares – the eSWIS package for surface water data management and dissemination, and eGEMS for groundwater. The completion of the software(s)integration with the functioning of the Implementing Agencies and guidance & training to the users will also help in achieving the objectives.

3 Project Implementation

3.1 Project Coordination

The Project was established with a National Level Steering Committee (NLSC) chaired by Secretary, Ministry of Water Resources, with three sub-committees of the NLSC termed "Hydrological Information System Management Group" (HISMG) committees:

- Technical (HISMG-Tech)
- Institutional Strengthening and Training (HISMG-IS&T)
- Data Dissemination (HISMG-DD)

To support these committees a Project Coordination Secretariat was set up under Commissioner (B&B), Ministry of Water Resources..

A Specifications Committee was also constituted, which undertook review and approval of technical specifications for equipment to be procured under the project.

3.2 Institutional Strengthening

3.2.1 Consolidation of HP1

(i) Overview

The consolidation of the Hydrology ProjectI was aimed at providing resources for the HP1 States[1] and the HP1 Central Agencies[2]to consolidate the monitoring networks and data processing systems established during the first phase of the Hydrology Project (HP1).

Work done by the Implementing Agencies for consolidation included:

- upgradation of computers in data centres; Replacement of laboratory equipment supplied under HP1 that had outlived its useful life or else was non-functional for various reasons; Replacement or upgradation of monitoring equipment: CWC, for example, introduced acoustic Doppler current profiles (ADCP). A number of Agencies replaced non-functional equipment in climate stations, or added automatic weather stations (AWS) to their network;
- Extension of monitoring networks; Orissa Ground Water agency added 148 observation wells to their network and Gujarat added 228 piezometers.

(ii) Real time Networks

During the Mid Term Review of the Project, Implementing Agencies were urged to consider the further development of their monitoring networks by introducing real-time reporting equipment that would allow transmission of data directly from the observation site to the Data Centre. One pre-condition applied to this was that the Agency would ensurethat the real-time data would be made available to data users through their web-site.

States/Implementing Agencies that used this provision are:

- Andhra Pradesh Ground Water: added 120 Digital Water Level Recorders (DWLR) with telemetry;Gujarat Surface Water: retro-fitted telemetry equipment to 60 Automatic Water Level Recorders (AWLR) in their networkand procured 50 Automatic Weather Stations (AWS) with telemetry;
- Madhya Pradesh Surface Water: procured a comprehensive Real Time Data Acquisition System (RT-DAS) for the Wainganga Basin;

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[1] The HP1 States are Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu`

[2] The HP1 Central Agencies are Ministry of Water Resources, Central Water Commission, Central Groundwater Board, Central Water and Power Research Station, India Meteorological Department and National Institute of Hydrology

- Orissa Ground Water procured 20 DWLR with telemetry;
- Orissa Surface Water procured a RT-DAS system for the whole State;
- Karnataka Surface Water procured AWLR and AWS with telemetry to augment a novel system used for entering daily-read rainfall data from over 1,000 stations in near-real time;
- Tamil Nadu procured raingauges and AWS with telemetry;
- CPCB and CWC established/procured ten and three real time water quality monitoring stations, respectively, for the Ganga basin, which measureand report ten water quality parameters

In addition, the New States in HP2 have adopted the use of telemetry to obtain data instantaneously:

- Himachal Pradesh using telemetry extensively for groundwater data, rain-gauge data and weather stations;
- Goa using telemetry for rain-gauges, weather stations and groundwater data;
- Punjab using telemetry for groundwater, rain-gauges and surface water level data;
- Puducherry using telemetry for weather stations and groundwater data;.

There were other Agencies with plans for real time systems that could not be bought to fruition due to delays and administrative hurdles – these included AP SW, Karnataka GW, Tamil Nadu (SW system) Kerala SW and CGWB.

3.2.2 Awareness Raising and Data Dissemination

All Implementing Agencieshave conducted programmesto publicise availability of hydrological data, and to improvefrom the feedback of data users.

- Procure Audio visual equipment and upgrading of conference rooms in data centres;
- hold workshops and meetings with stakeholders to raise awareness;
- Upgrade technical and managerial skill of key staff through International training programmes; procure web-GIS data management system for all water quality data throughout India by CPCB for improved data access;
- Fund training courses held at the CWC's National Water Academy (NWA)

3.2.3 Implementation Support

Implementation support was used by some HP2 States as well as the HP1 States to fund work to consolidate their infrastructure for Hydrology Information System (HIS). Examples are:

- Additional office building: Andhra Pradesh Ground Water constructed a new State Data Centre (not having done this under HP1). Karnataka constructed a new regional office / training centre in Bellary. Kerala Ground Water constructed a building in Erakulum. CWC constructed additional facilities at the NWA.
- Building work to improve facilities ;procurement of additional vehicles;
- Procurement of Office equipment;
- The CPCB hired a consultancy to advice on water quality assessment;
- The Technical Assistance and Management Consultancy, supporting the Project Coordination Secretariat were funded under this head.

3.3 Vertical Extension

3.3.1 Hydrological Design Aids

The Hydrological Design Aid (HDA) programme was originally envisaged to include three components:

- Surface water design aids
- Groundwater design aids
- Water quality design aids

However, while formulating the detailed terms of reference for the groundwater and water quality HDA,it emerged that no consensus could be arrived at for inclusion of various aspects and eventually it was decided that it would not be useful to pursue these aspects of the project. For groundwater, many of the facilities that were believed to be useful were incorporated into the design of the database software (eGEMS).

The Surface Water HDA contract was awarded by CWC to Consulting Engineering Services (India) Private Limited (CES).

In addition, a minor funding line was provided to State Agencies under this head, and this was sometimes used to procure computer hardware and software.

The CWC have given commitment for completion of this work after the end of the World Bank loan. It is understood that the HDA will become a fundamental part of core activity of CWC and hence there is little perceived risk that the HDA, as specified, will eventually be delivered and used extensively. At the end of the project the development of the surface water HDA is still continuing, with around 75% of the task completed. The constraints, inter-alia, have been provision of making the software 'licence free' for the user and enormity of the task. Although, some of the constraints have now been easedbut efforts are being made to complete the remaining works of development of software by CWC with CES as per the scheduled target.

3.3.2 Decision Support Systems

In the Project Implementation Plan, two major Decision Support Systems (DSS) were to be developed:

- DSS (Planning), led by NIH, to develop a system for supporting planning decisions in a variety of pilot basins across all HP1 States
- Real Time DSS, for BBMB, to support operation of reservoirs, barrages and water transfer systems of the BBMB using information in real time to improve operational efficiency.

Both of these contracts were awarded to M/s DHI Water and Environment Denmark. The RT-DSS was to be supported by an extensive data collection and real-time reporting (RT-DAS) system procured separately – a contract awarded to M/s Essel Shyam of Delhi.

Later, considering the expected benefits from the RT-DSS of BBMB, Maharashtra Surface Waterrequested to develop a similar system to support operation of their reservoirs in the Upper Bhima and Upper Krishna basins. This was agreed at Mid Term Review, and subsequently the contract for providing the DSS was also awarded to M/sDHI, with M/s Mechatronics receiving the contract for supply of the RT-DAS.

The DSS (Planning) was successfully completed by August 2013, with a significant up gradation of the DHI software being made in early 2014 which is in the process of being rolled out. There has also been a requirement identified to have additional support from DHI in development applications and providing advice and guidance on extended models. It is expected that an AMC will be signed by NIH and DHI from September 2014 to cover these aspects.

The Real Time DSS for BBMB has been effectively completed in May 2014. Delay has been largely due to late completion of the RT-DAS which subsequently resulted indelays in calibrating the models in the DSS. The system was partly tested in year 2013 (with only partial information from the RT-DAS) and has been more thoroughly tested in the monsoon season of year2014. The RT-DSS will be continued to be supported by DHI through their warranty. A contract for additional support for the DSS is being prepared by BBMB to augment their in-house staff skills for immediate post-completion period. Early indications are that the DSS has been fully embraced by operations staff of BBMB and it will be used extensively in planning reservoir operations, irrigation releases and flood management.

The Maharashtra real time DSS has also been completed, but final model calibration has been held up as data from the RT-DAS is not available to allow the models to be thoroughly tested and calibrated. Again, the final testing of the system has been done during themonsoon period of 2014 and will be supported by the developer.

3.3.3 Purpose-driven Studies

The HP1 Agencies had budget lines for funding studies intended to demonstrate the use of data collected through the HIS.

Studies were proposed by nearly all Agencies, and reviewed by the key central agencies (the CWC for surface water studies, and the CGWB for groundwater studies) and when cleared, they were put up for review by the HIS-MG Tech[3] committee.

41 Purpose-driven Studies (PDS) were approved which are summarised in Annexure 3.

Expenditure made on the PDS included:

- Consultancy: Many Agencies did not have the resources to carry out their own PDS without external support, and so used consultancy services for this purpose. Under World Bank procurement procedures, obtaining small-value consultancies is administratively challenging and this contributed tosome delays in implementation. Finally, mostconsultancies obtained were from academic sources.
- Equipment (and civil works) for additional monitoring for key data needed for the Study, or for construction of trial facilities so the impact of such facilities can be monitored
- Office, IT equipment and software to support those carrying out the studies. This includes additional laboratory equipment in some cases.
- A late addition to the programme was the Aquifer Mapping Pilot Programme of CGWB. This was an ambitious programme to trial methods of delineating and mapping aquifers throughout India, and developing community based groundwater management practices. The 12 Five Year Plan contained a requirement to undertake this work nationally, but a pilot programme was needed to establish appropriate methodology. The Hydrology Project was asked to provide this vehicle, and it was agreed to include the pilot programme under the PDS programme, with a budget of some 20 crore rupees.

[3] Hydrological Information System Management Group Technical

A number of workshops have been held during the project to review and discuss progress being made, seeking peer review from other Principal Investigators and the HISMG-Tech committee members. These have proved useful in "raising the bar" and challenging those undertaking the studies to set themselves additional targets and seeking to improve the relevance of the results of the studies for potential beneficiaries.

The outcome from this programme has been very successful. Papers in have been printed in several International and national journals. Although, some papers were limited in scope but this has generally meant that the staff of IAs have improved their technical knowledge. In particular, the contribution of NIH to this programme deserves special mention.

Annexure 7 contains a summary of the work undertaken under the PDS programme.The Final PDS reports are being published through the Project web-site.

3.4 Horizontal Expansion

3.4.1 Upgrading of Data Networks

The Horizontal Expansion element of the programme is for the four new States[4]. Under upgrading the networks the work undertaken has included:

- Installation ofrain gauges and climate stations
- Providing water level records and discharge measuring equipment for surface water discharge and water level measurement
- Construction of new observation boreholes / piezometers for groundwater monitoring, including installation of DWLRs at some locations.
- A number of the measurement devices have been equipped with telemetry so all new States are receiving some data in real time.

The CGWB also had a budget line for construction of piezometers to increase their networks within the new States. However, they could not construct Piezometers in the State of Himachal Pradesh.

3.4.2 Upgrading of Data Processing and Data Management

The four new States have constructed new State Data Centres (SDC) under this budget line. The SDC for Punjab had procurement issues to get architectural services for the design of the centre, making the programme to build the centre very late. It is expected the SDC will be readyby the end of 2014.

Additionally, all new States have invested in IT hardware and software, constructed sub-divisional and subsidiary offices. Goa has also procured GIS data-sets.

3.4.3 Purpose-driven Studies

The new States have had a limited programme of PDS with Goa and Puducherry undertaking one study each, and Punjab no studies. Himachal had three studies approved, but dropped one and completed the other two. The PDSs are listed in Annexure 3.

[4] The New States being Himachal Pradesh, Goa, Puducherry and Punjab

3.5 Training

The Ministry of Water Resources (MoWR) endorsed a number of international short training courses put on by the University of UNESCO-IHE, Delft Netherlands; the London School of Economics and the University Of Newcastle upon Tyne, UK. This assisted the approval of such international training under the project. Additional opportunities for international training came from study tours (under international consultancy contracts to support development of officers engaged within the development programme) and other international exchange missions. A list of those benefitting from International training is given in Annexure 4.

Training was also provided within the country. TAMC developed annual training programmes through engagement of the Implementing Agencies (identifying training needs) and the partners providing training opportunities (such as the CWC/NWA, the CGWB through their Rajiv Gandhi Training Institute, the CPCB and NIH). The IMD also provided observer and technician training for meteorological observation and data processing. In addition, many HP1 Agencies had trained trainers, and were providing in-house training courses for their own staff to ensure sustainability in skills to manage the HIS despite staff postings.An example of the training developed is shown in Annexure 8, where the training programme for 2013-14 is reproduced.

Funds were also available for in-country study tours which were encouraged so that officers and staff could learn by sharing experiences.

3.6 Recurrent Expenditure

Much of the HP2 expenditure has been as recurrent expenditure. This covers:

- Incremental staff costs (salary and related expenses for staff working on the project)
- Incremental building maintenance costs
- Incremental vehicle hire and running costs
- Incremental operation and maintenance costs for networks and IT systems

3.7 Instrumentation

While instrumentation recommendations were based on the instruments used in HP1, there were a number of significant developments made in technology (especially in the real-time transmission of data) and so there was significant evolution of choice of instrumentation used.

The specifications used for the procurement of equipment were again based on the HP1 documents – but thoroughly reviewed and updated where needed by TAMC experts. Interaction with equipment suppliers in pre-bid meetings also highlighted areas for review within the specifications, and a number of changes were made to make sure they were inclusive as well as demanding an appropriately high standard for reliability and ease of maintenance.

A summary of the changes in instrumentation choice is contained in the following sections.

3.7.1 Care and Maintenance of Equipment

The earlier HP1 project had some issues with procurement of equipment which subsequently became unreliable, and some thought went into arrangements to avoid such issues. A commonly-adopted solution in HP2 was the use of extended warranty periods (2 years being standard) and compulsory three years of comprehensive Annual Maintenance Contract (AMC) following the warranty period – and costed at the time of bidding for the supply of the equipment, with the cost being included in the overall evaluation for the supply contracts.

3.7.2 Use of Real-time Data transmission

The development of the use of real-time data networks started with the requirement for a system of collection of comprehensive parameters of weather and stream flow in real time for the BBMB Real Time Decision Support System (RT-DSS). The plan for a suitable Data Acquisition System (RT-DAS) to drive the models of the DSS was in-built in Project Planning, and the DSS Consultants provided inputs from an equipment specialist to select and specify a suitable network of stations and their technical requirements.

As understanding of the possibilities and potential of such systems spread, the World Bank supervisory team encouraged other Implementing Agencies to also develop real-time systems based on mobile phone networks (GSM systems) because of their low cost. A requirement to put information obtained in real time on Agency web-sites was a pre-condition for use of World Bank loan for such procurements – but the offer was taken up by most implementing agencies.

Networks require reliable communication in times of extreme weather (for flood warnings), most of the real time systems procured used the GSM networks established for mobile phones as these were simpler (lower power needs, no special Government permissions) and cheaper over the satellite transmission systems.

Power provision for real-time systems is an issue for remote sites, and usually independence was sought either through use of replaceable batteries (where power consumption is low) or the use of solar panels and rechargeable batteries. With remote locations with solar panels and (typically) vehicle batteries there was concern about theft of the equipment. But this has not yet proved to be a significant problem.

Specifications developed for this type of equipment were largely based on the work done for BBMB.

Karnataka Surface Water developed proposals for an SMS-based reporting of daily rainfall. This was supported by TAMC, who assisted the development of specifications and software to collate the incoming SMS messages automatically. This proved to be a successful and low-cost way of getting up-to-date information on rainfall centrally.

3.7.3 Rainfall and Climate Measurement

While there was procurement of the traditional, daily-read storage raingauges, there was increasing procurement of tipping bucket gauges that also measure rainfall intensity – sometimes with real-time telemetry and sometimes as downloadable data during a site visit.

For HP2 there were few "full climate stations" procured (with separate, manually-read climate instruments), with most agencies opting for automatic weather stations (AWS). These are digital weather stations, with regular measurements centrally recorded in a data-logger. These data are either down-loaded during site visits – or transmitted through telemetry to a base station off-site.

3.7.4 Water Level Recording

A number of alternative methods of measuring water levels in rivers and reservoirs have been adopted under HP2, with TAMC supporting development of specifications for:

- Radar water level records
- Bubbler systems
- Pressure-sensors
- Shaft-encoders

There was use of gauge-boards for newly-established gauging locations, but nearly all sites had automatic water level recorders. These were chosen for accuracy, and for more comprehensive and frequent recording of data.

Water level recording using stilling wells (construction of sumps beside rivers with links into the river bed at its lowest point so the water level in the sump is the same as that in the river) is the traditional method of allowing recording of water levels as a float-driven, chart recorder could be used to monitor water levels. The stilling wells are prone to silt up (lose connection with the river) and need constant attention to make sure it is functioning properly. Additional challenges in India are the seasonal rivers (with the dry season being a problem for maintenance) and river bed disturbance due to sand mining in the river bed. Therefore the use of shaft encoders (a simple digital equivalent of the chart recorder) was not encouraged despite being a simple and accurate device.

Water level recorders that do not rely in stilling wells are the pressure sensor, the bubbler system and the radar water level recorder. Pressure sensors are simply a vented pressure sensor immersed in the river recording the pressure of water above the sensor. Accuracy is good, but it can suffer from silt accumulation at the tip (recoding false high water levels due to the pressure of silt) and is vulnerable to site interference unless carefully buried. They can also be washed away in times of flood. The bubbler system works by using a pressure line where gas (usually air) passes to an outlet located in the water and the gas pressure needed to expel bubbles is used as a measure of the depth of water above the outlet. This has similar problems to the pressure sensor, but has the advantage that if it gets washed away during floods, the bubble tube is the only vulnerable part of the system and this is inexpensive to replace. Bubblers are the currently most popular system for recording water levels in India.

The radar water level recorder used a mounting vertically above the water surface to bounce radar waves from a source in the instrument back to a recorder in the instrument. The depth to the water surface is computed from the return signal, and acceptable accuracy can be obtained with sufficient number of measurements – and the averaging is performed within the instrument. These instruments are more expensive than the other water level recorders, but are much simpler to install if bridges are available. In Goa (where land ownership of the river banks is a big problem) radar water level recorders were the preferred method of measurement.

3.7.5 River Discharge Measurement

The method used in India to estimate flows in rivers before HP2 was predominantly use of cup-type current meters, which require frequent re-calibration. Changes encouraged by TAMC included:

- Use of current metering to establish rating curves , and using water level measurements to estimate discharges at a number of times each day
- Use of Acoustic Doppler current profilers (ADCP) for integrated measurement of the total flow in a river

During HP2 it was established that the current meters supplied under HP1 were being regularly re-calibrated at the CWPRS facility (and at other facilities around India – such as that of the Anna University in Chennai) with minor adjustments required to the calibration of the current meter being typically needed on recalibration.

The “standard” approach in India to the estimation of river flow has been to use a daily (or twice-daily) series of current meter measurements to physically measure the river flow. Normal international practice is to use current metering to define a relationship between river water level and flow rate, and to use the relationship to calculate discharge. This has two main advantages:

- Current metering as measurement of river flow has certain inaccuracies that arise from a number of sources. Many of these inaccuracies can be “averaged out” with repeated observations. The relationship between water level and flow does this averaging, and so becomes a more accurate method for estimating flow than the physical measurement by current meter.
- Developing a relationship between water level and flow allows water levels obtained more frequently to be used to estimate flow when it is changing quickly and this provide a better estimate of total flow in a day. It also allows extrapolation of behaviour on days when no flow measurement is possible due to high flow velocities.

The use of ADCP for more comprehensive and accurate monitoring of river discharges is considered a major advancement with the CWC and States/Agencies like Punjab, Maharashtra, BBMB, Orissa, Goa and Karnataka having procured many of these instruments. While these instruments are expensive to procure, they function very efficiently and can provide a wealth of useful data. Goa has also procured special vehicles to work with the ADCP to allow them to be used on a daily basis on several sites.

3.7.6 Groundwater monitoring

The use of Digital Water Level Recorders (DWLR) for groundwater monitoring was an area of particular concern in the latter part of HP1, with particularly poor performance of the equipment supplied. However, in the intervening years the technology has improved, and the specification was carefully revised to try to ensure good performance in HP2. Large numbers of DWLR were purchased by some States, but some HP1 States were reluctant to invest again in the equipment.

Many States wanted a core network of real-time reporting DWLR for up-to-date information on the status of the groundwater for drought forecasting and planning of groundwater use.

TAMC advised that significant improvements had been made in technologies used in the DWLR since the HP1 procurement, and advised in developing of new specifications to obtain the improved instruments. The value of high-frequency groundwater level data over the periodic (four times a year, six times a year or 12 times a year according to Agency) measurements include:

- A complete record of groundwater levels, allowing more precise definition of ppre-monsoon and post-monsoon water levels, amongst many other things
- Allowing closer analysis of recharge processes to groundwater as the rate of response was well as total water level recovery during the monsoon could be analysed
- Removing uncertainties about local factors in recorded groundwater levels. Where observation points are affected by groundwater abstractions in surrounding wells (which can have a large influence on measured water levels) this can be seen from the high-frequency data, and the influence of pumping can be removed from the data.

While it is not recommended that all observation points are equipped with DWLR, perhaps 10% to 20% would be a reasonable target in general, with higher densities of DWLR needed where aquifers are particularly responsive or there were particular requirements of additional data for management groundwater.

Real time telemetry of groundwater data was also an area where HP2 made significant progress, with many Agencies looking at the possibility of fielding such equipment. While groundwater levels change relatively slowly there is not an immediately obvious need for fast transmission of data to a central control centre. However, there are circumstances where prompt access to up-to-date data is very valuable – especially for drought management and seasonal planning of groundwater use (establishing appropriate planting areas for crops irrigated from groundwater as a function of estimated groundwater resource for the irrigation season, for example).

A particular problem with DWLR procurement for HP2 was the flurry of complaints about procurement process made by DWLR manufacturers and their agents. Due to this the procurement process for some of the ~~all~~ large DWLR contracts was also affected.In some instances it also led to the abandonment of the procurement process late in the cycle (including procurement by AP, Karnataka, and CGWB). While none of the complaints was upheld at any level, which was filed often through proxies seemingly in an effort to prevent rivals winning contracts, the uncertainties led to derailment of the process. There also seemed to be no sanction against those raising complaints (often through proxies).

3.7.7 Direct Water Quality Monitoring – in Real Time

The introduction of modern real time water quality monitoring equipment to India for the first time was a significant contribution of HP2 to the evolution of water resources monitoring in the country. The new technology installations were procured by CPCB (ten number) and CWC (three number) for use in the Ganga basin and have proven very effective with each installation being able to monitor ten parameters. This pilot testing of the technology under HP2 was to support the upcoming World Bank Ganga project which would require an extensive network of such stations. TAMC supported World Bank experts and the CPCB in development of specification, the bidding process and management of contract.

3.7.8 Laboratory Equipment for Determination of Water Quality

The HP1 used three different levels of laboratory in a structure defining the number of parameters able to be analysed. These were:

- Level I. Field measurement of parameters – mostly those that will change on the way for laboratory analysis such as temperature, pH, Eh and dissolved oxygen.
- Level II. Regional level laboratories in the State that can carry out basic major ion analysis and similar straightforward measurements.
- Level II+. State level laboratories with equipment for COD analysis, plus gas chromatograph and atomic absorption spectrophotometer for more detailed analysis on minor ions and other pollutants.

HP1 had provided detailed specifications for all laboratory equipment. For most simple equipment these remained valid – but changes were needed for the more complex Level II+ laboratories.

There has been a continuing problem in getting the full spectrum of 29 parameters being analysed as recommended under HP1 for water quality monitoring. The regular reporting of Agency performance during HP2 showed that many of the Agencies could maintain laboratories to measure 13 or 14 parameters, with continued operation of the AAS and GC equipment in the level II+ laboratories (providing most of the missing analyses) being a particular problem. This is discussed in Section 4.4.

Evolution of technical specifications for the more expensive laboratory equipment to seek to address issues of reliability and simplicity to use (as well as changes in computer technology) has been an on-going task of TAMC under the project. The derived specifications need continuing review, as it has been developed to avoid limiting the number of suppliers able to deliver while trying to keep a reasonable basic quality to avoid similar low cost and low quality kit available within the mass market in India developed for medical sample analysis without the required accuracy.

The support of CPCB experts in this process has been very valuable.

3.7.9 Management of Laboratories and Water Quality Data within HIS

Water quality laboratories face many of the same issues of staff recruitment and retention that have affected other HP project disciplines. In too many cases there is shortage of qualified staff within the agencies, which in turn are unable to attract qualified Water Quality staff from the open market. For existing staff there is often little scope for career progression or promotion for the laboratory staff. Some have been in the same post for many years; others have been seconded to the laboratories as part of a departmental rotation, but regarded it as a poor-status posting.

It is evident that the best HP laboratories are associated with good managers. Good management provides a clear agenda, sets an expectation of high standards, and motivates staff to achieve those standards.

Unfortunately it seems that the laboratories are operating in isolation from each other, and this is impacting on the quality of their work. Advances made during HP1 in introducing Analytical Quality Control protocols in the HP laboratories have been largely forgotten. This is a major weakness and prevents the laboratories in (a) understanding the limitations of their own data (e.g. uncertainty, bias) and, ultimately, (b) being able to demonstrate the integrity of their data if necessary. This may lead to the suspicion that many laboratories are not achieving good analytical performance.

3.7.10 Appreciating High Frequency Data

While HP1 introduced water level recorders, rainfall recorders and automatic weather stations with short-time interval recording of data, there has been little application and analysis of such data. There are also challenges to access such data as the “standard” data management modules of HP1 (SWDES and GWDES) have not been used to archive this information. This is a major drawback, which has resulted in loss of value.

It is noted that CGWB, for example, has run courses in its training institute (RGI) on analysis of high frequency groundwater data – which is a good first step, but does not appear to have fully addressed these issues. TAMC have been urging:

- New data management systems (eSWIS and eGEMS) to properly interface with the high-frequency data)
- The management of NWA and RGI to consider extending learning opportunities to make wider use of the opportunities for analysis presented by high frequency data

3.7.11 Process for Development of Specifications

The HP1 specifications provided an excellent start for the specification of equipment for HP2.

Prior to the start of TAMC consultancy, a committee had been established drawing on technical skills and experience of the central HP2 agencies, plus Bureau of Indian Standards (BIS), to periodically review the specifications and suggest improvements. The TAMC experts also contributed to this process, and provided revised specifications for consideration by the committee from time to time. While the committee met regularly in the first half of the project, in the second half the reduced need to improve specifications resulted in meetings being less frequent.

While specifications "approved" by the committee were available for use by all implementing agencies (and available for download through the web-site) a number of agencies, on a number of occasions, chose to modify the standard specification for use for a specific procurement application. Mostly such changes were reviewed by TAMC and were provided with a "no objection" message prior to their use in bidding documents.

As technical specifications of equipment available in the market change, so the specifications for procurement of such equipment might also need to adapt. Manufacturers have been maintaining contact with TAMC to suggest modifications to specifications, and this has sometimes led to changes recommended to the committee in order to prevent unnecessary exclusion of equipment that is understood to meet or exceed required standards, and has a history of good performance.

Despite all efforts, there are continuing needs to update and revise specifications. The intention is to leave the latest specifications as HP2 "legacy" available for download, and a further round of revision is planned for the final days of the project to allow these specifications to be a complete as possible.

3.8 Improvements in Data Management

3.8.1 Overview

Under HP1 several data management tools were introduced to manage the collection, collation and dissemination of surface water and groundwater data.

In the early stages of HP1 relatively simple software packages (SWDES, GWDES and WQDES) were developed for data entry and reporting. These were essentially stand-alone desktop packages. Later in the project these were supplemented by commercial packages for data analysis, and by centralised server based software designed to allow data to be shared within and between institutions. These included the GEMS software for groundwater data management, the commercial HYMOS package for analysing surface water data, and WISDOM, which was designed to handle surface water data and was also meant to provide web tools for data dissemination.

These HP1 data management tools improved operational management of hydrological data, but proved to be hard to maintain once the project ended. There were several reasons for this, but the principal issue has proven to be limited institutional capacity for software support especially within the state implementing agencies. For GEMS and WISDOM this meant that many of the Implementing Agencies reverted to the earlier SWDES and GWDES packages, and there have been only limited updates and revisions to the main packages since 2005.

At the start of HP2 there was a considerable stress on identifying areas where improvements were required to the existing data management software. The rapid development of IT over the years since the HP1 software was developed provided both challenges and opportunities to introduce new technology. Through a series of visits to IAs, and extensive discussions with the two main central agencies, CWC and CGWB, the specifications for two new software packages; eGEMS for groundwater data and eSWIS for surface water data were developed. In both cases the aim has been to improve the maintainability of the software by holding data and applications on central servers, accessed via the Internet.

The process of specifying, procuring, developing, adapting and rolling out the new software has not proven easy. There were considerable delays in the procurement process and development only started late in the project. Ambitious time frames for development have given little leeway for inevitable problems encountered during development to be addressed. This has meant that all software remains to be finalised at the end of the project, and fine tuning is held over to maintenance periods in the main – although with software with greater problems, actual finalisation of the development is still on-going and alternative funding has to be found to complete the task. As the central Agencies are fully committed to the software completion there is little perceived risk of non-completion. The risk is the lack of full roll-out and training in the use of software to ensure all Agencies fully embrace the new technology and the advantages it delivers.

The software packages developed under HP2 include:

- eSWIS – a web-based data storage and management software for surface water (replacing the SWDES, WISDOM and HYMOS packages of HP1) being managed by CWC
- eGEMS – a web-based data storage and management software for groundwater (replacing GWDES, GEMS developed under HP1) being managed by CGWB
- eWQIS, a web-based GIS database for water quality data being developed for CPCB.
- The Surface Water Hydrological Design Aids (HDA). While these are not primarily data management tools, they contain a lot of data quality review tools that can contribute to effective data management. Being managed by CWC.
- Tools within the DSS (Planning) that include data quality control tools that can be used as part of a comprehensive data management process. Being managed by NIH.

These software tools sit within a wider context of Hydrological Information at Institutional and National level within India. Both within States and within other agencies there are initiatives for agency websites and information systems. The Ministry of Water Resources has invested in the development of the Water Resource Information System (WRIS), aimed at disseminating information on water resources to a wide community, including the public. The Aquifer Management programme conceived as part of the 12th Five Year Plan will generate large quantities of hydrogeological and spatial data. The primary role for data management software development within HP2, in this context, is to provide a system for ensuring the efficient, basic, recording and analysis of field data and laboratory measurement capable of providing future initiatives with prompt access to quality assured and reliable data.

3.8.2 Surface Water Data - eSWIS

The objective of the e-SWIS system of CWC is to create a web-based hydrological information system (HIS), which can be easily accessed by multiple agencies through the internet, without future licensing and maintenance issues. The system replicates functionalities of previouslyadopted systems, which were not kept fully operational due to software maintenance issues. As a server based system, the central data base system WISDOM (developed under HP-I) had to be run on specialised hardware and required specialised and expensive IT support staffbeyond the resources available within most State IAs.

There was also considerable debate over the most appropriate form of contracting the new software, with a decision taken to use the World Bank Single Stage IT Procurement methodology, in preference to the conventional Consultancy that had been used in HP1 and for other HP2 software procurement.

The system under development – eSWIS – incorporates the initial design aims, although it is assumed that users will shift almost immediately from SWDES to a web interface, and hence the analytical functions will only be available to users of the Internet version of the software. The database and application are hosted on commercial cloud servers, with all IA data held in a single database, but with access controls and permissions retained by the original measuring/data collecting agency. Each IA will be able to set policies for access to detailed data as they require, although it is expected that all users will be able to access at least basic station metadata, and where appropriate open access may be given to summary data or detailed reports. Ensuring that IAs perceive their data to be secure is key to their acceptance of this approach.

The use of a centralised system, with users interacting via the Internet brings major benefits, in that IAs are relieved of the requirement to purchase, maintain and support their own software and hardware. This has an added benefit in that it will allow eSWIS to be used by states and agencies outside HP2 with minimal added costs. The developer has been required to use Open Source software, which should also contribute to future modifications and expansion of functionality. The key risks are its reliance on broadband Internet connections in all participating IA offices and the need for CWC and other agencies to maintain ownership and control of the system; the long term benefits of an open source system may be lost with an over reliance on support from the system developers.

3.8.3 Groundwater Data – eGEMS

The objective of the web-based e-GEMS system of CGWB is to create an internet based central repository and data processing tool for groundwater related data (such as water level, water quality, exploration, geophysics and GIS data) in multiple servers at CGWB in Faridabad. It replicates the functionalities of the previous GWDES and GEMS systems, under a much enhanced and integrated system design, and incorporating six years of experience with the previous systems.A main issue with the previous GEMS system was that it required specialised hardware and software support beyond the resources of most State GW departments, while licensing costs also formed a major obstacle for its use outside CGWB. Users in State and Regional agencies will be able to enter and process data on-line, within their own virtual data repositories.

A set of meetings were held between CGWB, IAs and TAMC to refine and develop the requirements for eGEMS. While it was always conceived of as storing data centrally, with user interaction over the Internet it was felt that retaining a basic ability for users to enter data in ‘offline’’ mode would be important. Other areas of concern were whether there was functionality within GEMS that was used so rarely that it wasn’t worth retaining, the most cost effective approach for providing users with map production capability, and how best to procure the required hardware

Development of eGEMS commenced in 2013, after a protracted tendering exercise. The system under development retains the Oracle database system but migrates the GIS functionality from MapInfo, which was used in GEMS, to ESRI’s ArcGIS. According to latest proposals, the database and application will be hosted on servers leased from BSNL (a state-owned telecommunications company).

As with eSWIS, the introduction of eGEMS will simplify operations, removing the burden of hardware and software procurement from IAs, and allowing its use by agencies outside HP2. The system does use proprietary software, and while the contract include a comprehensive agreement for maintenance and support, CGWB will need to expand its own capabilities to ensure that users, especially outside CGWB, feel fully supported in their use of the system, and that future upgrades or replacement are effectively managed.

3.9 Awareness Raising and Engagement with Data Users

Interaction between the data provider and the data user has been recognised as important within Hydrology Project and the key mechanism for this has been the Hydrological Data Users Group (HDUG).

Activation of HDUGs as a preferred practice to promote user engagement was aggressively promoted during HP 1 and to some extent this approach was successful. However, it became unsustainable once HP-1 ended, without any active external help. Revival of HDUGs in HP 2 did not enthuse many agencies and users alike for a range of reasons. For the new states this was an uncharted path and the project unwittingly missed an opportunity to show case the success of HDUGs during HP1. The inherent lack of user orientation among HIS producers and the inability of HIS outputs to connect directly with end user needs without the intermediate interpretative assistance of technical experts (SW, GW and WQ) were two major factors. The Hydrology Information System Management Group (Technical) was constituted under the project to suggest policy interventions for the promotion of HIS. However, the scope of the group was eventually narrowed down to review the status of Purpose Driven Studies and accelerate their completion.

A series of HIS awareness raising workshops were conducted on a regional basis and a manual was developed and shared with all agencies to take the HIS promotion activities forward. As a follow on activity, some specific visual tools (posters, brochures, pamphlets) were designed and shared with all agencies for reproduction and distribution. While some agencies (AP-GW, Maharashtra-GW, and Gujarat) took full advantage of these tools, most agencies showed lack of enthusiasm, despite some aggressive follow up

3.10 Benefits Derived from the Project

The quantification of the benefits of an improved HIS is a problem, as many of the key benefits are not directly tangible. The immediately tangible – the revenue from the sale of data – is insignificant and a distraction.

Reliable, representative and accurate hydrological data is enormously important for the accurate design and management of water resources development projects, and for understanding the environmental impact of such projects. This is where the value of the HIS lies – both now and in the future when a long time-series of data will be invaluable for improved management and allocation of water resources.

The Agencies with mostly complete regular reporting of data are the AP GW and Gujarat GW. This reflects the greater emphasis within the groundwater divisions on routine reporting, with surface water agencies seemingly limited to year books as a format for printed dissemination of HIS information.

The range of groundwater reports produced has included:

- Groundwater estimation reports. These summarise the analysis of groundwater level, groundwater use and groundwater recharge data to determine groundwater balances and the level of exploitation on a block by block basis. State reports are prepared periodically (and three rounds of assessment have occurred during HP2), district reportst have also been prepared in AP.
- Annual groundwater yearbooks
- Monthly reports on piezometry (produced in AP: they have produced 1656 such reports during HP2)
- Pre and post-monsoon water quality reports

- District monthly water level scenario reports (produced in AP)
- Forecasts of water levels in districts (for future planning for drinking water – used in AP)

These reports all have value – otherwise the efforts to prepare them would not be regularly repeated. The value of the groundwater estimation reports are well understood in India – the primary mechanism for regulation of groundwater overdevelopment is to identify overdeveloped blocks and restrict access of farmers in those blocks to loans for sinking of new wells. A large amount of effort goes into the groundwater assessment process.

Groundwater status reports are used by administration officials as a monitor of groundwater resources for drought monitoring and for advice on planting for farmers.

Groundwater quality information routine reporting is sometimes used for monitoring spread of water quality issues – increasing salinization of groundwater bodies, or presence of significant levels of fluoride in drinking water for example. But these are only indicators of issues – more detailed studies would be needed to quantify such problems and these require more extensive data.

The surface water yearbooks are relatively rudimentary still, and do not appear to develop wide interest. One of the objectives of year books historically is to archive data and allow multiple copies of data for data security purposes. In the computer age this is no longer needed. The yearbooks should be taken as an opportunity to have a critical review of information obtained through the HIS, and flag potential water management issues. This has not yet been developed within the yearbooks seen to date.

In general, the value of hydrological data lies in the increasing efficiency of design or operation of water resources projects that can be achieved with good data.

For example, if a long time series of river flow data is available in a catchment, then design of a reservoir or water allocation system can be made in detail and with confidence because the reliable flows and the extreme flows are relatively well defined. Without such direct data, estimates will be made using proxy data (or short time series of data that are not necessarily representative) and key parameters will be estimated with less accuracy, leading to inefficient design. For example, reservoirs might be sized incorrectly, spillways over-sized (expensive) or undersized (insufficient protection against overtopping). Similarly, without a good understanding of the characteristics of dry years and wet years, reservoir operating rule curves will not be accurate and could well result in emptying of reservoirs or failure to fill reservoirs in appropriate seasons.

The loss of efficiency in scheme design or operation cannot be easily quantified. However, if assumptions are made, it is possible to approximate to the value of hydrological data. For example, if the efficiency of a scheme designed with good hydrological data makes increased use of water compared to a scheme designed using poor data, the value of the data lies in the increased water that can be delivered by a well-designed project. If this is only 1%, then the value of the data becomes 1% of the overall scheme cost, for example. Similarly, if increased knowledge of inflow patterns through having good data improves operational efficiency of a scheme by 5%, then 5% of the benefits derived from the project are attributable to the good data.

The benefits of the HIS are not only felt today, but will also be felt in the future. In decades to come, pressure on water resources will be much more severe, and there will be absolute necessity to manage water resources efficiently and equitably. For this, there will be need for long time series of accurate and representative data, and this will only be possible if the networks at present are continued to be invested in, and data collected rigorously and effectively. In the future there will also be more pointed debate on the likely impact of climate change, and the water needs of the environment. We need to be collecting appropriate baseline data now for these important future scientific needs.

3.11 Summary of Major Achievements under Hydrology project-II:

The major achievements under HP-II can be summed up as:

- Moved From Manual Data Collection to Real Time Data Acquisition System
- From Desktop Data Management to Web-based Data Management
- Collating Data into Analyzed Information for Decision Making through Decision Support System (DSS) Planning, Hydrological Design Aids (HDA), Purpose Driven Studies (PDS) etc.
- Up gradation to real time flood forecasting and reservoir operation systems through development of Real Time DSS (RTDSS), Real-Time Stream Flow (RTSF) & Reservoir Operation System (ROS).

A. Upgradation/ strengthening of Hydrological Information System (HIS)

➢ Construction of Data Centres

S. No.	Description	Total Number
1	State Data Centre	4
2	Divisional data centre	4
3	Sub Divisional data centre	12
4	Training centre	5
5	Site offices / site stores etc.	64

➢ Strengthening of meteorological stations

Sl No.	Description	Total Number
1	Manual FCS, Raingauges and SRRG	679
2	Digital Raingauges and AWS without telemetry	56
3	Automatic Weather Station (AWS) with telemetry	132
4	Digital Rain Gauges (DRG) with telemetry	318

- Strengthening of hydrological stations

Sl No.	Description	Total Number
1	Establishment / upgradation of river/ reservoir water level measurement stations	245
2	Gauge and discharge sites	195
3	Gauge plates / staff gauge	224
4	Automatic water level recorder - shaft encoder type/Bubbler/RADAR	114
5	Current Meter	387
6	ADCP	36

- Strengthening of Groundwater Monitoring

Sl No.	Description	Total Number
1	DWLR without telemetry	136
2	DWLR with telemetry	265
3	Installation of Piezometers without DWLR	2540
4	Installation of Piezometers with DWLR	196

- Strengthening of Water Quality stations

Sl No.	Water Quality monitoring stations	Total Number
1	Real time Water quality Stations in Ganga and Yamuna by CPCB (10 Parameters)	10
2	Real time Water quality Stations by CWC (6 parameters)	3
	Construction & establishment of Laboratories	
3	Level 2+	3
4	Level 2	3
5	Level 1	12

➢ Development of Web-based Data Management System

- e-SWISS - for data entry, storage validation and Dissemination
- e-GEMS - Groundwater estimation and Management system
- Water Quality: GIS based Water Quality Web Portal

B. River Basin Planning and Management Tools

➢ Decision Support System (DSS) for Water Resources Planning and Management

- DSS framework set-up in 13 river basins across 9 states
- Modules includes:
  - i. Surface water planning
  - ii. Integrated operation of reservoirs
  - iii. Conjunctive water use planning
  - iv. Drought monitoring and management
  - v. Water quality management

The DSS-P has been successfully developed for these basins and is found to be very useful for decision making on the above mentioned aspects. Government of Kerala has already initiated replication of the DSS-P for the entire State of Kerala. Further, nearly all the States under HP-II have requested for extension of DSS for other river basins during HP-III.

➢ Hydrological Design Aids (HDA)

- The tool facilitates and expedites the hydrological design of infrastructure
- Modules developed so far:
  - i. Assessment of water resources potential availability/ yield assessment.
  - ii. Estimates of Design Flood
  - iii. Sedimentation rate estimation

The HDA tools also provide (for the first time in the country) the basis for uniform approaches amongst states and between states and central agencies for estimation of design floods, assessment of water resources and estimation of sedimentation rate.

➢ Flood Management and Reservoir Management Tools

(i) Development of RTDSS in BBMB involves:

a. Commissioning of a Real-time Data Acquisition System (RTDAS) including 91 real-time monitoring stations and 9 snow stations,

b. Cross-section surveys of the major rivers and tributaries, and

c. Development of a flood forecasting and reservoir operation modelling system.

The RT-DSS developed by BBMB is very helpful in increasing the lead time for flood forecasting. The Real Time data acquisition System installed for the DSS helped BBMB tremendously in averting major damage during the floods of 2013.

(ii) Real Time Flood Streamflow Forecasting and Reservoir Operation System (RTSF & ROS) – Krishna & Bhima Basins

a. The system is designed to reduce future flood damages and dry season water supply through improved reservoir management based on daily/hourly flood forecasting.

b. The RTDAS is operational with 237 real-time reporting monitoring stations.

The RT-DSS developed by Maharashtra is remarkable in the sense that the area covered under this DSS was very prone to Floods. With this DSS, Maharashtra Water Resources Department is managing a series of Dams/reservoirs within the basin for optimal utilisation of water resources.

C. <u>Groundwater Management (Aquifer Mapping)</u>

Six (6) pilot projects of aquifer mapping were carried out to develop the framework for large scale mapping.

The projects included the organization of existing database, hydro-geological modeling and conducting field tests, geophysical investigations and exploratory drilling. Heli-borne geophysical survey was carried out for the first time in the country for delineation of aquifers on a pilot scale. The Pilot Project is envisaged as a precursor for the Nation-wide aquifer mapping programme.

The advanced geophysical techniques used for aquifer delineation have shown efficacy of these techniques in various hydrogeological terrains. Prima facie, the results are very encouraging especially in desert areas of Rajasthan and in the coastal areas where saline and fresh water interface exist.

4 Financial Performance

Slow disbursement of funds was an on-going issue in the project. The reasons behind this were many, but included:

- Late appointment of advisory consultants. : While, it was envisaged that the TAMC team were to be active from month 3 of the project, the consultancy did not start until February 2009 (month 34). Without the central technical advice, implementing agencies were uncertain of the procurement process.
- Poor understanding of World Bank procurement procedures, and so need for significant revision of documents and extended explanations of reasons that changes had to be made. While extensive training in World Bank procedures was provided, those made responsible for procurement were not necessarily those who had received training in procedures.

- Challenges of the World Bank procurement procedures themselves in some cases. Particular issues included:
  - Extended procedures needed for recruiting consultants, even for the very minor assignments for the PDS programme
  - Need to obtain multiple quotations for supply of vehicles, for example when vehicle distributors generally only source of a specific vehicle in a territory and the suppliers refused to provide the necessary bidding documents and bidding guarantees (this issue was resolved by allowing purchase through DGS&D[5] system)
- Challenges to the bid evaluation process made by unsuccessful bidders. This was particularly a problem for the procurement of DWLR where repeated appeals and protests had major impacts on procurement of these devices for a number of Agencies.
- Slow decision-making, and extended routes for decision taking for procurement. Reluctance to take decisive responsibility for procurement resulted in extensive internal review of procurement decisions and long timelines.

The Project used a system of financial management reporting (FMR) that was a web-based system for data entry and processing developed by CWC. This required all transactions to be entered by the appropriate financial officer at source, and accorded appropriate codes to indicate the type of expenditure and the category. These data were consolidated by the software into a series of reports viewable within the Agency and by supervisors and the Bank. Data had to be "confirmed" by the appropriate nodal officer before consolidation in higher level reports.

The system worked effectively enough, but the officers inputting the data lacked the discipline to regularly update the information, and to also make sure the "FMR" data was consistent with other project accounts presented for audit. This led to a number of problems with audit and account reconciliation.

5 Lessons Learned

5.1 Key Positives

The Hydrology Project is a challenging project administratively with 28 active Agencies to be managed. This did produce a sense of "community" in project implementation enhanced through relatively frequent coordination meetings and extended contact between specialists during training (particularly for the DSS planning implementation).

The key positives for lessons learned are:

[5] The Government's Directorate General Supplies and Disposals of the Ministry of Commerce has centrally-negotiated rates for the supply of a number of items at rates accepted by the World Bank as commercially competitive.

- The DSS(P) development pushed selected staff into a programme of demanding data review and appreciation, modelling skills, database development and applied water resources management problem solving. This was seen to have a significant positive impact on the skills of key persons in the State Data Centres, and significant enhancement of the institutional abilities to “add value” within the HIS
- The most successful Agencies were those with continuity in the project. Most Agencies had key staff trained under HP1 and making active contribution to HP2 with their earlier experience and appreciation of what was to be done. The new agencies also had significant continuity through the project and these key staff held the project together.
- The consolidation of the HP1 networks was enthused by the development of real time systems. This was a late addition to the programme, and warmly received. This produced a sea change in the information available to users, and the benefits of such data were being explored enthusiastically and much appreciated.
- The New States made great strides to developing effective HIS, with support from the extended community within the project and also warmly embracing the opportunity to move directly into extensive “real time” networks and data provision.
- Within the central agencies, the project presented a range of opportunities to develop. BBMB focused on their DSS which is expected to a major improvement to their operational systems, and the CPCB delivered effective real-time water quality monitoring and the web GIS for data dissemination marking key large steps forward for them. The CWC and CGWB consolidated their networks, data management systems and in the HDA will develop a tool that should fundamentally improve one of their key institutional procedures. NIH had the opportunity of considerable enhancement of modelling exposure, DSS development as well as the resources for undertaking a wide range of PDS.
- The new data management software (eSWIS and eGEMS) have the scope to be of considerable benefit and a revitaliser for all Agencies if appropriate steps are taken in training and support for induction of each Agency in the post-project period.
- The change in policy for data dissemination by the MoWR recently, having a “default” position for unclassified data available through free download is a very significant development and should make a fundamental change in the availability of data to those who need to use it. It is hoped this policy will be adopted by the States as well.

5.2 Problem Areas

A number of factors contributed to challenges in project implementation. These included:

- Management of international consultancy contracts and software development
- DWLR procurement
- Consultancy for PDS
- Indecision concerning contract award

For the real time DSS developed by DHI, although these contracts started relatively promptly in the project, delays with related contracts (particularly the RT-DAS system procurement and installation) were delayed, meaning the data for model calibration and system finalisation was not available till very late.For DSS (Planning) delays arose over review, revision and acceptance of progress reports.

For the database systems, the scope of work grew beyond simple database requirements, with extended “add on” facilities required by the Client organisations CWC and CGWB. Discussion of specification and the requirements of the bidding documents caused many months delays, and the complications of the final requirements also led to delays in the schedule for delivery by the contractors. The computational requirements for the CGWB’s eGEMS developed problems and delays in the procurement of the hardware and software needed to host the developed software.

For the HDA (SW) contract, the selected contractor proved to be very slow in his approach, and acceptance of milestone reports was delayed due to quality and content issues. Once these had been resolved, the software development proved to be very slow, and a major re-write and re-start was needed to improve the overall structure of the software. There is still a long way to go before completion.

For the CPCB web-GIS development considerable delay was experienced in the formulation and bidding phases, but also in negotiating with the preferred bidder. This led to a very late start for the contractor.

The procurement of DWLR had extensive issues hanging over from HP1, where there were major problems with the technical quality of the DWLR procured and extensive early failures of the equipment. Procurement during HP2 was cautious, and extensive discussions over the specification of the equipment continued to improve the quality of the procured instruments. Having overcome all this, the bidding and contract award processes for many of the procurements were disrupted by complaints about bid evaluation. In the end, a number of planned procurements could not be realised as the process was derailed by a variety of circumstances. Large procurements that were started but not completed included:

- 1262 DWLR for AP GW
- 175 DWLR with telemetry for Karnataka GW
- 222 DWLR for CGWB

5.3 Management of Multiple Implementing Agencies

The number of implementation agencies created a number of distinct administrative problems. These included:

- Procurement. The number of Agencies trying to understand and comply with World Bank procurement rules was large, and meant that any training and support in these areas was considerably diluted. So procurement support remained a big challenge. Post-project audits were also a challenge to organise, and responding to matters raised in such audits was also a problem for PCS.
- Monitoring the project progress. While monitoring systems were developed, they mostly added to ad-hoc requirements to submit information to the Project Coordination Secretariat (PCS) or reminders to complete web-based data entry processes so that the PCS could compile the data. Feedback to the Agencies concerning performance was also less than direct, except where PCS decided performance was poor enough to require official written communication to the Agency Project Coordinator. Monitoring reports were compiled six-monthly (the Semi Annual Progress Report) but this was mostly intended for the World Bank rather than as a feedback mechanism to the Implementing Agencies.

- Financial Management. Financial progress was reported through the "Financial Management Reporting (FMR)" system developed by CWC, which required all financial activity to be entered by the concerned accounts officer at source, and verified and consolidated. This provided capacity for supervisors to review financial progress by agency and sub-head, but often data were not up-to-date and were inconsistent with audited accounts, requiring much work to reconcile accounts. Arranging for audits of project accounts was also a challenge, and for some agencies (such as CGWB with expenditure in centres all around the country) this required multiple audits of unit accounts and then a consolidated certificate.

How could this be improved? The key first step is to have stronger points of contact in each Implementing Agency with appropriate authority and resources to be an active "partner" to PCS with dedication to the project and with the resources to be able to deploy staff to assemble the information required promptly, and with authority to send off the information directly and not involve their own internal administrative chain. This would greatly simplify the PCS role. Also critical is that staff are appropriately trained in procedures to be followed (the project trained many persons in the financial management and World Bank procurement methods) but that also the trained staff are assigned the tasks for which the training has been provided (it was also found that Agencies with many staff trained in World Bank procurement actually asked the procurement to be managed by people who were not aware that there were World Bank procurement guidelines.

5.4 Potential Problem Solutions for Similar Project in Future

The HP2 experience has suggested that there are a number of steps that might be taken to improve project performance if a similar project is to be implemented:

- Delegation of appropriate powers to Project Implementation Unit. Many procurement issues and implementation delays stemmed from the need to get clearance and approvals from authorities above those persons directly involved in the Project. It is understood that the original Project design for HP2 had a full-time Commissioner heading PCS and it is believed that this is appropriate. In addition, the Commissioner should be delegated appropriate powers to approve proposals, upto a certain threshold value, so that the implementation unit would need to seek clearances only for very large proposals.
- The implementation unit in the Ministry would also require a full time senior finance and accounts officer to assist the Commissioner in matters relating to procurement and also matters of account reconciliation and audit.
- Monitoring and evaluation systems must be simplified, established early in the project and become routine for those working in the project for data entry such that the provision of information for such a system becomes considerable less onerous to enter and compile. Early establishment of the MIS would mean greater opportunity to explain and train users of the system, and time to get data entry established as integral to the administrative process.
- Internal travel should be made easier for project officers. Appropriate budgets and travel arrangements are required to facilitate attendance at meetings and training and inter-agency visits as shared experience also become a key way of learning. Some State's have very restrictive policies on limits of expenditure for per diems and not allowing use of air travel (meaning a need to book well in advance for train travel)

6 Sustainability Post-project

6.1 Introduction

The Hydrology Project has encouraged participating agencies to invest in their HIS and provided key guidance in how this can be done. Networks have been improved, and the data management side of the HIS has been developed through software and hardware delivery. Efforts have been made to increase awareness of the importance of good, reliable, accurate and representative hydrological data, and key staff have been trained to improve efficiency and effectiveness of the HIS.

Can this be sustained? Main challenges are:

- Funding. Can the Agencies maintain sufficient funding to continue activities, support the financial requirements for the Annual Maintenance Contracts (AMCs) entered into as part of the procurement of key equipment, the field travel needed to maintain networks and the salaries / payments to observers and field supervisors?
- Knowledge. Can the Agencies keep the trained staff in post for sufficient time that the replacements can be trained and that the knowledge imparted under HP2 is not lost?
- Willingness to share data, and promote data use. Will the momentum of increasing openness with data and willingness to readily share data (freely given or after payment) continue?
- Roles of Central Agencies. Will the Central Agencies continue to nurture and assist the State Agencies to develop, and increase their role in data validation to allow the Central Agencies to recognise the data collected by the State Agencies?

6.2 Funding

The availability of budget funds is not a major problem these days;however “funding momentum” means that maintaining budgets similar to previous years is an administrative challenge. So it is expected that funding will continue for many of the activities. However, the shortage of staff and funds over a period of time may lead to neglect of the facilities created under HP-I and HP-II. Some Central Agencies, such as the CGWB, have drastically increased budgets to carry out increasing scope of work. However, if and when the next phase of Hydrology project rolls out, the funding for the sustainability of the facilities created under HP-I and HP-II should be considered to be brought into the proposal.

6.3 Spill-over Work

There are a number of key activities that could not be completed before the Loan Closing Date of 31 May 2014. Some activities (such as annual maintenance contracts for equipment procured) were always known to over-run the project period, and Implementing Agencies knew to ensure sufficient budget from their own funds for these. Where the spill-over was result of delays in implementation there have been checks to make sure appropriate management and provision is made to ensure work completion after the loan closing date.

Some of the key procurements affected are:

- Development of HDA and eSWIS by CWC. There is strong internal senior management commitment to these tasks, and funds are assured and work will be completed.
- Development of eGEMS, procurement of hardware and software for eGEMS, completion of the Aquifer Mapping pilot programme by CGWB. Again, institutional and senior management commitment is there, and work is expected to be completed satisfactorily.

- Completion of the web-GIS development of CPCB.
- Payments for RT-DSS, RT-DAS and software by BBMB. Matters been largely resolved and the balance work and AMC for operation of the system is under consideration by BBMB authorities.
- Procurement of the State Data Centre, Punjab, and the fitting out of the building. While the construction will be largely complete by the end of 2014, there will be a need to finalise the construction and the equipping of the building using other funds. These have not yet been confirmed.

6.4 Knowledge and Staffing

The custom of moving Government staff between posts every two or three years is still strong, and so it is inevitable that most of those trained under HP2 will move away from the core positions for maintenance and management of the HIS. Under HP2 there was less emphasis on training trainers than in HP1, and so this is potentially a problem for sustainability.

What is key for maintaining appropriate levels of skill for maintaining the HIS is training and guidance provided by Central Agencies where their staff have more focused experience on key HIS skills, and where established high levels of competence exist. Training at the NWA by CWC officers, and the RGI by CGWB officers remains the key and it is very important that the training opportunities are recognised and used by the States.

A re-organisation of the HP1 training resources and guidance manuals has been made under HP2, to improve their accessibility in the hope that this will increase use of these valuable resources by all those involved in the HIS of all Agencies. These resources will be available to all through the internet, but again it must become established procedure that all are in the know of the existence and usefulness of such guides and staff in all Agencies actively seek to use resources of training and guidance to assist them to achieve excellence in their work.

6.5 Willingness to Share Data

The Ministry of Water Resources have a Hydro-meteorological Data Dissemination Policy (2013) that provides data freely for all but specific classified categories. The policy spells out that data will be downloadable from the CWC (the WRIS web-site) and the CGWB (the GWIS web-site). In addition, the CPCB has developed a web-site hosting all water quality data.

This policy will greatly increase availability of data, and set the benchmark for sharing data.

In the past, while observation networks within States was developed jointly by Central and State Agencies (to avoid duplication of locations for observations) there was no automatic exchange of data, and both State and Central Agencies did not have the data collected from the other part of the observation network. This was clearly wrong. Some exchange of data occurred to facilitate the process of secondary data validation developed under HP1 (whereby some 25% or so of the data collected by State Agencies were sent to Central Agencies for quality control checks). However, feedback from the validation process was reported to be inadequate, and there was no automatic transfer of data from Central Agencies to State, or recognition by the Central Agencies that the State Agencies collected data and these data should be incorporated into Central databases for use in the advanced hydrological analyses periodically undertaken within the Central Agencies. The Hydrological Design Aids for CWC have been developed without recourse to any State data.

The sharing of groundwater data between State and CGWB for the Groundwater Assessment process is the main exception to this lack of cooperative exchange of information.

New procedures and guidance developed under HP2 are intended to address these issues and create a much more interactive data validation process and a standard procedure whereby data is automatically shared between Centre and State and should lead to Central Agencies increasing their recognition for the State data. The eSWIS database system is designed to make data-sharing like this a formality that should happen automatically through appropriate "permissions" in the data management structure.

6.6 Roles of Central Agencies

The Central Agencies hold the skills and expertise to drive the HIS forward. The States have the local focus and resources. The synergy should be that the Central Agencies seek to actively support the State Agencies through training, mentorship and development of the database through appropriate data validation and checking processes.

The long history of inter-State water disputes creates a level of distrust between States and between State and the Centre. This is recognised, but it is necessary that all work to overcome this, and develop mutual respect for the work of other parties and seek to resolve differences through scientific mediation and expert discussion. Openness in sharing data, improved data validation tools through eSWIS, HDA and the dashboard of the DSS (Planning) system will provide tools that can greatly assist the resolving of such difficulties. It is appropriate that Central Agencies (particularly CWC, NIH and CWPRS) work proactively to improve the hydrological understanding of flow regimesand the effective use of the new tool-set in routine evaluation of data collected.

7 Principal Gains and Conclusions

7.1 Gains for the HP1 Agencies

For the State HP1 Agencies the principal gains from HP2 are:

- The chance to replace equipment that had failed since the HP1 project conclusion, including the wholesale upgrade of IT equipment
- The chance to invest in real-time equipment, meaning they had the opportunity to get data to data-centres quickly, and could develop uses for such information to address operational and disaster-warning applications for the data
- Opportunities to invest in other "new technology" equipment such as ADCPs[6], AWS,[7]
- Additional buildings, or renovation of buildings, for the HIS
- New data management software, for storing, quality control / verification of data, and data dissemination
- New software for key applications, such as analysis for the Detailed Project Reports (DPR) needed for clearance of new or renovated water resources management projects
- New software and processes for project planning through the Decision Support System development and use in pilot basins
- Examples of the application of data from the HIS for practical solutions to a variety of problems through the Purpose-driven Studies programme
- Training opportunities for key staff

[6] "Acoustic Doppler current profiler" equipment to accurately measure streamflow
[7] "automatic weather stations" that digitally record a wide range of climatological parameters

For the Central Agencies, HP2 represented opportunities to develop new technologies through software and expertise sharing, upgrade of equipment resources and training facilities, and opportunities for overseas training. This has led to:

- Deployment of ADCP and automatic water quality monitoring stations for CWC, plus the software tools within the HDA and eSWIS to transform the way CWC processes and disseminates data, and how the DPR submitted for review are processed. They have also substantially upgraded their National Water Academy.
- CGWB have substantially upgraded their data management system and processes through development of eGEMS, and the work of the Aquifer Mapping Pilot Studies have had a major impact on their ability to review and quantify aquifers and groundwater resources.
- For IMD, early withdrawal from the project means there has been no impact of the project on the IMD
- For CPWRS low levels of involvement in the Project means that the impact on the organisation has also been minor
- For the NIH the extensive work with DHI on the development of the DSS (Planning) has exposed a large number of staff to advanced river basin modelling, and provided important tools to help understand and resolve a wide range of water management issues. The PDS programme has also provided opportunities for a significant number of NIH staff to undertake demanding investigations and produce good results allowing their scientific development.

7.2 Gains for the new HP2 Agencies

For the new States, there has been significant extension of their monitoring networks for climate, streamflow and groundwater. They have added buildings to accommodate HIS staff, and the computers, network servers and laboratories needed for their improved systems. Staffs have been extensively trained and they have developed professional resources for monitoring and dissemination of data.

Because the new States are (mostly) small, they have been able to build quickly and effectively using support from HP1 States, they have rapidly progressed in matching the HP1 Agencies for their ability to manage their HIS. Punjab is a little behind in this process but expected to be able to build post-project with support of regional offices of CWC, CGWB and the BBMB.

For CPCB the renovation of water laboratories in their head office and development of the web-GIS data management and reporting system will have lasting impacts. The successful development and deployment of real time water quality monitoring stations in the Ganga Basin is revealing a major impact of such information for river basin management.

For the BBMB, a major transformation has been possible. The comprehensive real-time data monitoring networks, the software of the RT-DSS and the development of procedures and processes to utilise the RT-DSS data in the management of the reservoirs, water transfer systems and the irrigation water distribution systems should greatly improve overall efficiency of the BBMB.

7.3 Key Areas for Further Support

A key disappointment for HP-II has been the late completion of the key data management software, eGEMS and eSWIS. Ideally, these should have two years post-completion within the project to make sure training was delivered and cascaded through all levels of users, and the new processes are fully embedded within the HIS. So this is a key area for further support.

In the development of applications for DSS(P) a lot of focus was on real-time operation of water resources (something the DSS(P) was not prepared for and relatively ill-equipped to deal with). Therefore there is a need for developing assistance in such information and operational advice. The applications would be focused on both flood management and the water resources allocation and irrigation planting issues associated with the management of both groundwater resources and reservoir / pond storage.

Effective data validation and quality assurance of data is another key area for further support for the State agencies (it being generally accepted that the Central Agency data is adequately quality-controlled). In HP2 it was apparent that Central Agencies still do not recognise State data, and any programme to develop quality assurance should also seek to encourage full recognition of the value of /state collected data within national databases and scientific analysis.

Under HP-II, Central and State organisations procured State of the Art equipment, tools and technology. Following key items/ applications have been developed for the first time in the country:

i) Real-time Hydro-meterological Data Acquisition Systems were procured and installed in several parts of the country, which provide data through means like satellites, telephony or V-SAT.

ii) Real-Time Decision Support System (RT-DSS) has been developed for flood control and reservoirs operations in Bhakra Beas Management Board and in Maharashtra.

iii) Decision Support Systems- Planning (DSS-P) for surface & ground water planning, irrigation management, drought monitoring management and conjunctive use of surface water & ground water etc. have also been developed

iv) Real-time Water Quality equipment has also been successfully installed at 10 different locations on river Ganga and measures upto 10 parameters.

v) The Pilot Phase of the Aquifer Mapping Programme of MoWR has seen the application of Heliborne survey for aquifer mapping for the first time in the country. This technique is just a few years old and India joins the league of few nations like USA, Netherlands, Denmark, Canada, Australia etc.

While much of India has been covered in Phases I and II of the project, there are large northern States that have not yet been involved. These include the States in the Ganga and Brahmaputra Basins (including much of Madhya Pradesh).Several States/Central organisations have now proposed that the applications developed under the HP-II needed to be upscaled for the entire country, including those States which have not been covered under Hydrology Projects. Many of these States, viz. North-eastern States, West Bengal, Haryana, U.P., Jharkhand etc. have conveyed their keenness to participate in the Phase III of the Project. The States/Central organisations were of the view that the HIS and their consequent applications like DSS etc. developed under HP-II need to be replicated throughout the country, so as to bring the entire nation at par.

Any new phase of Hydrology Project should be closely aligned with National Water Policy, Five Year Plans etc. The National Water Policy (2012) has identified basic principles for water resources management in India. These include management within national perspectives, equity and social justice to inform use and allocation of water, sustainability of water use, managed as a community resource, efficient water use, recognition of environmental needs and recognising interlinking of water quality and water quantity. All these point to a need to develop Integrated Water Resources Management (IWRM) within a river basin unit. Hydrology Project Phase III would also take into account these principles with the Project Development Objectives (PDO).There are a number of areas where a further project might have a role to support:

- Development of HIS in non-Hydrology Project States
- Continued support for development of HIS in Hydrology Project States
- Introduction of new techniques and technologies to participating Agencies
- Continued support for central agencies.

Continued support for the existing Hydrology Project Agencies is needed, as sustainability without external support has not yet been firmly established in many of the States. Some of the developments within HP-II (such as the Hydrological Design Aids; the Decision Support System for Planning; the surface water and groundwater database systems) are areas where continued support would prove to be very important to guarantee and consolidate improvements made under HP-II.

For sustainability, it seems appropriate to concentrate on development of the capacity and focus of central agencies to provide technical support to the State Agencies – through training programmes, advice on matters relating to observations (networks, equipment, Standard Operating Procedures etc.) and data management, and also to advise regarding appropriate solutions to water resources management issues. Further, cross learning from participating States would not only benefit the new States, but would also help the Old States to consolidate their gains.

7.4 Conclusions

Ministry of Water Resources, Government of India, with the help of the State and Central organisations has successfully implemented the Hydrology Project Phase – II during the period April 5, 2006 to May 31, 2014. Several new activities like development of Decision Support Systems for Planning (DSS-P) and Decision Support Systems for Flood Forecasting were successfully developed for the first time in the country. Installation of Real-Time Data Acquisition Systems has transformed the outlook and speed of data interpretation and analysis in the organisations where HP-II has been implemented. India has joined the league of the few nations by using advanced Geophysical Techniques like Heliborne Dual Moment Transient Electro-Magnetic (TEM) for aquifer Mapping in six pilot project areas. Implementation of these activities has laid the foundation of the management of water resources in the future. The Hydrology Project has done much to improve the hydrological information systems of the thirteen States involved and the central agencies. Networks have been developed and used to generate information on water resources that should be invaluable in years to come. Applications have been developed in the DSS programme and the PDS programme showing how HIS data can be used to address a wide range of water resources issues. Institutions have been developed and a large number of persons trained in the process of management of the HIS, and applying the data collected to the solution of water management problems.

The challenge faced during the Implementation of HP-II was that as many as 28 Implementing Agencies (IAs) were involved. Further, a major challenge faced by the IAs was following of the World Bank’s procurement guidelines and documents, which were altogether new for them. MoWR and the Implementing Agencies, however, have been able to successfully overcome these initial delays and impedances with the result that Hydrology Project Phase-II has been completed successfully with several achievements.

In years to come, India will face increasing problems with the management of scarce water resources, and competition for use of these resources. To improve water management, a solid historical database of hydrological and hydrogeological information is going to be of enormous value. Hydrology Project is contributing in a great way to the development of the database that is going to be needed.

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A.1 Purpose-driven Studies

Approved PDS:

Ref Nr.	Title	Tech Group
SW-AP-1	Reservoir sedimentation studies in AP	Reservoir / sediment
SW-BBMB-1	Assessment of effects of sedimentation on the capacity/life of Bhakra Reservoir (Gobind Sagar) on rivers Satlej and Pong Reservoir on river Beas	Reservoir / sediment
SW-CH-1	Study of reservoir sedimentation, impact assessment and development of catchment area treatment plan for Kodar reservoir	Reservoir / sediment
SW-CH-2	Water availability study and supply-demand analysis in Seonath sub-basin	River quantity
SW-GJ-1	Crop water requirement of central province of Gujarat for optimum utilisation of irrigation water	Crop water needs
SW-GJ-2	Study of WQ fluctuation in river Vishwamitri	Water Quality
SW-GJ-3	Study of trend in WQ of locations identified as hot spots	Water Quality
SW-GJ-4	Monitoring of WQ fluctuations in river Sabarmati	Water Quality
SW-HP-1	Study of impact of river/Khad Bed on water sources (water winning structures) and evolution of policy and guidelines to prevent adverse impact	Water Quality river ecology
SW-KN-1	Study of water samples at various sites in southern Karnataka	Water Quality
SW-KL-1	Comprehensive assessment of WQ in Kerala State by Kerala State Irrigation Dept, GW Dept and Hard Rock Regional Centre NIH, Belgaum	Water Quality
SW-MP-1	The effect of contaminated Shahpura Lake basin on ground water environment, Bhopal, MP	Water Quality
SW-MH-1	Optimisation of G&D stations network of Maharashtra	monitoring network
SW-MH-2	Effect of changing water allocation in Nathsagar project, Jayakawadi Dam, Paithon, District Aurangabad	Surface water
SW-NIH-1	Integrated approach for snowmelt runoff studies and effect of anthropogenic activities in Beas Basin (BBMB)	Surface water
SW-NIH-2	Impact of sewage effluent of drinking water sources of Shimla city and suggested ameliorative measures (H.P.)	Water Quality
SW-NIH-3	Hydrological assessment of ungauged catchments (small catchments) Mahanadi sub-basin (Orissa)	Surface water
SW-NIH-4	Urban hydrology for Chennai city (Tamil Nadu)	stormwater management
SW-OR-1	WQ monitoring and modelling of Taldanda Canal, Orissa	Water Quality
SW-OR-2	Modelling of sediment yield and distribution in Hirakund Reservoir	Reservoir / sediment

GW-AP-1	R&D Studies on Urban Hydrology, GW Quality, Pollution & Management of Hussain Sagar Micro Basin (In & around twin cities Hyderabad and Secunderabad) Musi sub basin, Krishna basin	Water Quality
GW-AP-2	Participatory geo-ecological management in Tettuvanka basin, Rishi valley, Kurbalakota Mandal, Gittoor District	Groundwater management
GW-GJ-1	Ground Water Management in Water logged area of Dharoi Project Command (RBC) and Strategy to maintain harmony on water levels of Perched Aquifer with Deep Aquifer	Groundwater management
GW-CGWB-1	Study of GW dynamics and installation of real-time GW monitoring system in NCT, Delhi	Groundwater quantity
GW-CGWB-2	Specific yield studies for planning and designing artificial recharge structures in sub-urban areas of Chennai	Groundwater management
GW-CGWB-3	Aquifer mapping	Groundwater management
GW-Goa-1	Evaluation of downstream consequences of well pumping at Verna Plateau & working out Water Resource Management strategy	Groundwater management
GW-KN-1	Urban Ground Water Hydrology & Ground Water Quality in and around Bangalore city	Water Quality
GW-MP-1	Applying Aquifer modification techniques like Hydrofraking, bore blasting in existing GW abstraction structures built on various Hydro geological units of Dhasan Basin	Groundwater management
GW-MP-2	Ground Water Quality in Jabalpur urban areas with emphasis on transport of pathogenic pollutants	Water Quality
GW-MH-1	Techno Economic Feasibility of Artificial Recharge of aquifer as a mitigatory measures in Fluoride affected area, Distt. Yavatmal	Groundwater management
GW-MH-2	Study of Ground Water Dynamics in the Earthquake affected area of Manjar sub-basin, Watershed no. MR-35, mini watershed No.2/5 Distt. Lattur.	Groundwater management
GW-MH-3	Effects of sea water intrusion on Ground Water quality in & around Kelwa- Mahim village, Distt. Thane, Konkan Region	Groundwater management
GW-NIH-1	Study of coastal Ground Water Dynamics and Management in the Saurashtra region, Gujarat	Groundwater management
GW-NIH-3	Groundwater Management in Over Exploited of Chitradurga & Tumkur Districts of Karnataka	Groundwater management
GW-NIH-4	Groundwater dynamics of Bist Doab area, Punjab, using isotopes.	Groundwater management
GW-OR-1	Application of remote sensing technique for mapping waterlogged and salt affected areas in coastal tract, Orissa	Groundwater management
GW-OR-2	Planning for optimal development of GW in coastal sand pockets of Orissa	Groundwater management
GW-PU-1	To improve the GW potential of drastically affected deep seated cretaceous aquifer (Vanur sandstone) in northern parts of Pundicherry through appropriate recharge techniques	Groundwater management

An appreciative summary of the PDS programme is enclosed as Annexure 7.

A.2 ANNEXURE 4 TRAINING

INTERNATIONAL TRAINING COMPLETED

Date	Location	Name	Designation	Course Title
23-28 May 2010	Brazil: Study Tour	Narinder Chauhan	Princ. Sec Gov. Himachal Pradesh	Study Tour
		Narender Kumar	Commissioner (B&B), MoWR	
		Raajiv Yaduvanshi	Sec., Govt. Goa	
		M Moorthy	Chief Eng., Govt Tamil Nadu	
		Avanish Kant	Snr Geol., MoWR	
6-23 April, 2010	UNESCO-IHE, Delft Netherlands	Sushant Kumar Samal	Ex. Eng., CWC	Short course: Hydrological Data Collection & Processing
		Naveen Kumar	Asst. Director, CWC	
		Hari Prakash Chaurasia	Asst. Director-II, CWC	
		Rishi Srivastava	Director, CWC	Short Course: River Basin Modelling
		Diwakar M Raipure	Director, CWC	
		Anup Kumar Srivastava	Dep. Director, CWC	
		Y S Varshney	Dep. Director, CWC	
		Aditya Sharma	Super. Eng. CWC	Short Course: Water Resources Planning
		D S Chaskar	Director, CWC	
		M M Kshirsagar	Snr. Res. Officer, CWPRS	
		C Paul Prabhakar	Sci. D CGWB	
20-27 September 2010	UK and Egypt	C M Pandit	Chief. Eng. CWC	Study Tour under HDA
		Rajesh Kumar	Chief. Eng. CWC	
		Bhopal Singh	Director, CWC	
		R K Sharma	Eng in Chief, IPH Dept., Govt Himachal Pradesh	
		S T Nadkarni	Chief Eng., WRD, Govt. Goa	
8-12 November 2010	South Africa and Denmark	A K Bajaj	Chairman, CWC	Study Tour under DSS(P)
		Sushil Gupta	Member, CGWB	
		Rakesh Kumar	Sci. F., NIH	
		Ramesh Grover	Snr Jt Comm., MoWR	
		P Lathika	Chief Eng., Govt of Kerala	
22-28 October, 2010	Denmark, Slovenia, France	M L Gupta	Director, BBMB	Study Tour under DSS-RT
		R K Garg	Director, BBMB	
2 August to 10 September 2010	DHI, Denmark	9 officers from States plus 1 officer from CPCB		Course under DSS(P)
25 October to 12 November 2010	DHI, Denmark	Dr D S Rathore	Scientist E2, NIH	Course under DSS(P)
		Dr M K Goel	Scientist E2, NIH	
		Dr A K Lohani	Scientist E1, NIH	
		Dr Vijay Kumar	Scientist E1, NIH	

Date	Location	Name	Designation	Course Title
		Dr R P Pandey	Scientist E1, NIH	
		Dr Surjeet Singh,	Scientist C, NIH	
		Dr Sanjay Kumar	Scientist C, NIH	
13 September to 22 October, 2010	DHI, Denmark	Rajiv Bansal	Exec. Eng, BBMB	Course under DSS(RT)
		Arvind Sharma	Exec. Eng, BBMB	
		Anil Vyas	ADE, BBMB	
		G S Virk	ADE, BBMB	
		Anil Dhawan	ADE, BBMB	
		Maanek Ahlawat	ADE, BBMB	
		J P Singh	ADE, BBMB	
		Bhuvnesh Nauhria	Dpty Sec, Power, BBMB	
7 to 25 February 2011	UNESCO-IHE, Delft Netherlands	P K Mehrotra	Director MoWR	Short Course: Water Quality Assessment
		O R K Reddy	Exec. Eng CWC	
		M K Sharma	Scientist C, NIH	
28 March to 15 April 2011	UNESCO-IHE, Delft Netherlands	Rajesh Chandra	Sc-C, CGWB	Short Course: Environmental Monitoring and Modelling
		Sushil Kumar	Director, CWC	
		Rajeev Kumar	Director, MoWR	Short Course: Financial Management of Water Organisation
		S K Swaroop	Scientist B, CGWB	
		Asit Chaturvedi	Dty Comm MoWR	Short Course: Hydrological Data Collection and Processing
		K V Prasad	Ex. Eng., CWC	
		G Rambabu	Ex. Eng., CWC	
		Sanjeev Kaul	Ex Eng., IPD, Govt Himachal Pradesh	
		R B Ghanti	Ex Eng., WRD, Govt of Goa	
26 April to 13 May 2011	UNESCO-IHE, Delft Netherlands	N Mukherjee	Snr Jt Comm., MoWR	Short Course: Water and Environmental Law
		P K Bhunya	Sci. E-1, NIH	Short Course: Introduction to River Flood Modelling
		Anupam Prasad	Director, CWC	
		Vijay Saran	Director, CWC	
		Anil Mehta	Ex Eng., IPD, Govt Himachal Pradesh	
		Shailesh K Naik	Tech Asst., WRD, Govt of Goa	
25 to 29 April, 2011	London School of Economics, UK	D K Jena	DC, B&B, MoWR	Executive Training Programme
		S Kunar	Member, CGWB	
		Ratnakar Jha	Projects Administrator, WB Projects, Govt MP	
14 June to 01 July 2011	UNESCO-IHE, Delft Netherlands	Narendra Kumar	Commissioner (B&B), MoWR	Short Course: Flood Risk Management
		Pankaj K Sharma	Dy Director, CWC	
		Jaiveer Tyagi	Sci E2, NIH	
		Hemant Puri	Asst Eng., IPD, Govt Himachal Pradesh	
		D A Bagade	Ex Eng., Gov Maharashtra	
		Bhupinder Singh	Snr Jt Comm MoWR	Short Course: Managing Water Organisations
		Sudhir Garg	Jt Sec., MoWR	
		Rakesh Kumar	Sci F, NIH	
		R K Rajak	Asst Geohydrol., MP	
		Avanish Kant	Sr Geol., MoWR	Short Course: Applied Groundwater Modelling
		M S Rao	Sci C., NIH	
		Sunil Kumar	Super. Hydrogeol., CGWB	

Date	Location	Name	Designation	Course Title
		S K Sinha	Sci D CGWB	
		Pratul Saxena	Sci C CGWB	
		Kishor N Deshmukh	Asst Geol. Govt Maharashtra	
		Sajeev Soni	Asst Eng., IPD, Govt Himachal Pradesh	
		Pradeep Mishra	Geol. Asst., MP	
4 July to 22 July 2011	UNESCO-IHE, Delft Netherlands	Ramesh Grover	Snr Jt Comm., MoWR	Short Course: Watershed and River Basin Management
		Paramesham	Super Eng.,CWC	
		Yogesh Paithankar	Director, CWC	
		Anuradha Madhukar Bhokre	Dpty Director, GSDA, Govt Maharashtra	
		Ananya Ray	Jt Sec & FA, MoWR	Short Course: Public-private Partnership in Water Sector
		Rajesh Yadav	Dty Comm., MoWR	
		Manish Singh	Add Secy., Govt MP	
19 September to 7 October 2011	DHI, Denmark	B Venkatesh	Sci E2, NIH	Course under DSS(P)
		Ravi Galkate	Sci E1, NIH	
		Dr Anupma Sharma	Sci C, NIH	
		Dr P C Nayak	Sci C, NIH	
		Ram Jeet Verma	Dty Director, CWC	
		H S Sengar	Director, MoWR	
		Dr C Ramesh	Res Officer, CWPRS	
		Shiva Kumar	Sci C, CGWB	
		Thomas Mathew	Dpty Director, Kerala	
		Ajith Kumar	Snr Hydrologist Kerala	
		K S Chandrashekar	Asst Eng., Karnataka	
14 to 18 November 2011	Newcastle University, UK	Kannan S	ARO, CWPRS	Short Course: Climate Change
		P Nandkumar	Super Hydrgeol CGWB	
		L N Thakural	Sci B, NIH	
12 to 16 December 2011	Newcastle University, UK	Rana Chatterjee	Sci D CGWB	Groundwater assessment
		AVSS Anand	Sci C CGWB	
		Shivaji Tulshiram Padmane	Snr Geol Govt Maharashtra	
June, 2013	Study Tour to USGS	G Mohan Kumar	Special Secretary MoWR	Visit to USGS
		Sushil Gupta	Chairman, CGWB	
		Avanish Kant	Sr Hydrgeologist, MoWR	
Sept 2013	London School of Economics, UK	Narendra Kumar	Commissioner, B&B, MoWR	Executive Training Programme
		Sunil Kohli	JS&FA, MoWR	

A.3 An Appreciation of the PDS Programme

The PDS work has covered a wide range of environments and technical areas, ranging from basically simple monitoring programmes to complex state-of-the-art investigations of some aspects of hydrology.

In this appreciation the review has tried to present in simple terms key achievements of each Study.

Modelling reservoir sedimentation

Deposition of sediment in reservoirs can reduce their storage capacity and reduce their useful operational life. Reservoir management may be assisted by greater understanding of sediment inflow rate and by improved knowledge of where within the live and dead storage

To assess the effects of sedimentation on the capacity of two reservoirs, the Bhakra and Pong,on the Sutluj and Beas rivers respectively, sediment inflow rates for the reservoirs were measured, and compared with hydrographic surveys, remote sensing studies and with theoretical calculations from catchment models.

It was found that the results from different methods were comparable, but remote sensing techniques can't be used to estimate sediment loads in areas permanently under water. The theoretical calculations required a large amount of field data, and even then tended to underestimate the actual amount of sedimentation.

Hydrographic surveys are expensive and time consuming, so it may be possible to combine occasional surveys with regular remote sensing. The modelling techniques are valuable for predicting future trends.

PDS carried out by the National Institute of Hydrology, Roorkee and BBMB

SW-BBMB-1

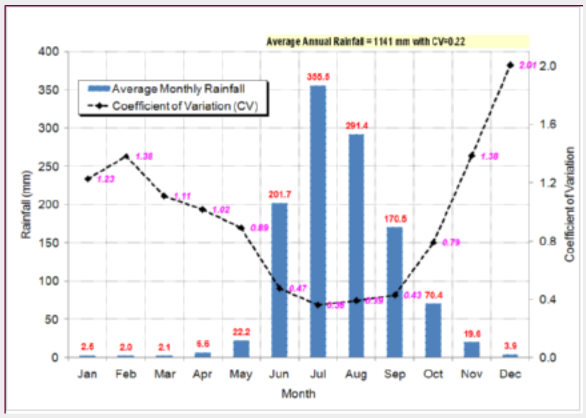
Optimisation of stream gauge and rain gauge networks

Observational networks need continual review to make sure that they are fit for purpose.

An existing network in the Upper Bhima basin of Mahrashta has a catchment area of 14,000 km^{2}., with 44 existing rain gauges and 14 sites were river flow is measured.

A mixture of statistical and empirical methods were used to assess the operation of individual stations and of the networks as as a whole.

The optimisation of the rainfall network recommended abandoning 14 existing sites, and adding 5 new stations.



Several of the stream gauges were found to be poorly sited, and affected by dams downstream, or were sited where the data could be as easily provided from operational monitoring of the reservoirs.

By re-siting some gauges, better measurements of surface water could be obtained with 2 fewer stations.

A careful network review can improve data quality while making savings in recurrent expenditure.

PDS carried out by Central Water and Power Research Station, Pune

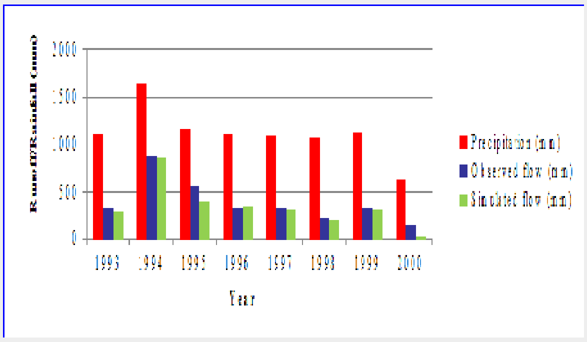
SW-MH-1

Modelling water availability

Pressures on surface water resources are growing throughout India due to increasing demands for irrigation, industry and domestic water supply. As these demands are expected to grow there will be more frequent water deficits.

A computer model of surface water flows in the Kharun basin, Chattisgar was developed to investigate possible solutions.

The model was used to extend the length of the records of river flow using historical rainfall data, and to study the likelihood of droughts. It was shown that rainfall droughts (more than 25% deficiency in annual rainfall) might occur every 5 years.



The investigation highlighted that while surface water resources in the Kharun basin could be adequate, with runoff considerably exceeding demand, the lack of reservoir storage leads to a shortfall during the dry months of January to May, despite existing inter-basin transfers.

The model was used to study how existing surface water sources were able to meet the various industrial demands as well as that of Raipur city, and was then used to test different configurations of storage that could meet dry season needs.

PDS carried out by National Institute of Hydrology, Bhopal and Water Resource Department,Raipur, Chhattisgarh

SW-CH-2

Participatory monitoring

Monitoring doesn't have to be carried out by professional hydrologists and hydrogeologists. In many cases communities can monitor their own resources.

Research that linked hydrogeology, ecology and land management practices in the Tettuvanka Basin of Andhra Pradesh demonstrates the value of farmers monitoring the resource that they themselves use.

As in many other parts of India the basin has experienced marked falls in groundwater levels due to over-exploitation.

The background characteristics of the area were established by making an inventory of boreholes and wells, and measuring their characteristics.

Local farmers were trained to monitor groundwater levels on a regular basis. This not only provided basic data for the study but also empowers farmers to identify early signs of over pumping.

Changes in water availability have forced farmers to change their cropping patterns, with paddy rice cultivation giving way to fodder crops. The expansion of dairy has given farmers new sources of income.

PDS carried out by the Groundwater Department, Government of Andhra Pradesh

GW-AP-2

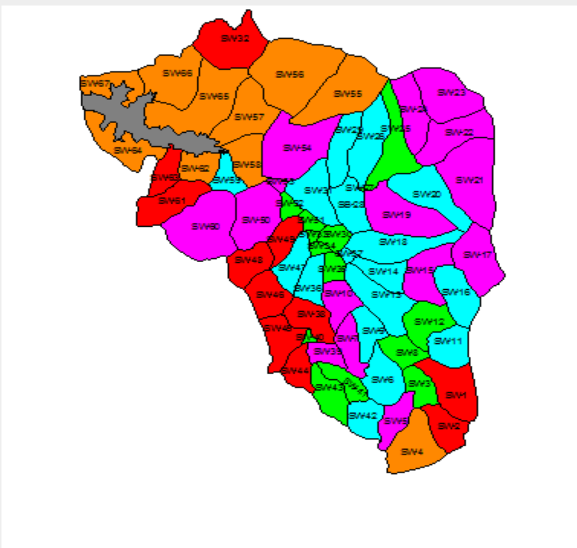
Reducing sediment inflows

Sedimentation of reservoirs can reduce their storage capacity and reduce their useful operational life.

Remote sensing shows that the Kodar Reservoir in Chattisgarh has lost 43% of its dead storage and 17% of its live storage capacity to sedimentation over the past 32 years (1976-77 to 2008-09).

A model of the reservoir's catchment, combining information on soil and land use with records of rainfall was used to prepare maps showing where erosion is greatest.

This mapping was used to develop a catchment management plan, testing the impact of various modifications that might be made in the catchment and identifying priority areas where action would be most effective.



Improved agricultural practices, e.g. contour farming, boulder bunds, reforestation combined with channel modifications such as gully and nulla plugs plus larger check dams could produce significant reductions in sediment inputs to the reservoir.

PDS carried out by the National Institute of Hydrology, Bhopal and Water Resource Department, Raipur, Chhattisgarh

SW-CH-1

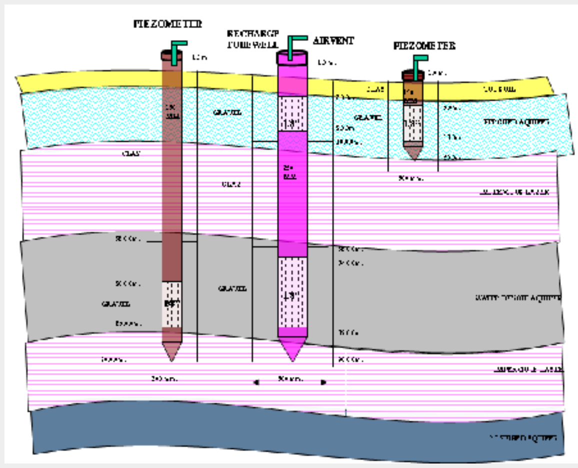
Water-logging

In many irrigation schemes water-logging of low lying areas is a serious issue. The over-application of irrigation water and poor drainage leads to high water tables, reducing productivity and eventually leading to saline soils as shallow water is evaporated.

In the Dharoi Project Command in Gujarat the irrigated areas are underlain by clay and a shallow aquifer is extensively water-logged. At the same time a deeper aquifer is over-exploited. If water can be transferred from the shallow to the deep aquifer it will benefit both.

To test the effectiveness of the proposed scheme two approaches were used.

Experimental recharge structures were designed and installed at three sites, and their performance evaluated.



At the same time a large amount of data on the behaviour of the different aquifer layers was gathered together and used to set up a model of the aquifers, calibrated with historical observations of rainfall and abstraction.

The model can be used to test how the aquifers would respond to a full scale scheme.

PDS carried out by the Gujarat Water Resources Development Corporation, Gandhinagar

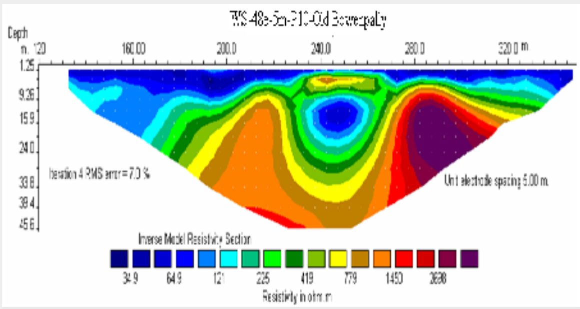
GW-GJ-1

Using geophysics to map urban groundwater

Hussain Sagar is a lake located between the twin cities of Hyderabad and Secunderbad. It was constructed initially as a source of drinking water although now merely an ornamental lake because it has become polluted by domestic sewage and industrial effluents.

A survey was commissioned to gain a better understanding of the present status of groundwater resources within the lake basin and of the extent of pollution in groundwater.

As part of the survey of the aquifer resistivity surveys were undertaken. These surveys, in favourable conditions, allow a 3-dimensional picture of shallow aquifers to be constructed.



This helped hydrogeologists analyse where pollution was reaching the aquifer. If all efforts are concentrated on preventing polluted surface water runoff to the lake, it is possible that polluted groundwater would still reach it.

A long term solution to the pollution issue will require the construction of new sewerage treatment plants and sewerage networks. Detention basins will have a dual role; improving quality and reducing flood risk. Matching measures for groundwater protection will include enhancing recharge by encouraging water harvesting in both existing and new constructions.

PDS carried out by the Groundwater Department, Government of Andhra Pradesh

GW-AP-1

Coastal water-logging

When groundwater is found within 2 metres of the land surface an area is considered to be waterlogged. Water-logging can be permanent, or seasonal. In low lying coastal areas the possibility of tidal inundation is added to the risk of waterlogging from irrigation

In the Cuttack & Jagatsinghpur coastal districts of Orissa, highly productive deltaic alluvial aquifers are present. Boreholes can have yields of over 50 l/s, with thick lenses of fresh water, but saline water at depth.

The topography of the district is generally very flat. The higher land elevations are located along the river banks which dissect the delta, leaving lower ground between the rivers that is prone to water-logging.

Monitoring of groundwater, including measurements of groundwater level and water quality has been used to help understand the aquifer system. Satellite imagery can be used to map the water-logged areas, especially where sea water or high rates of evaporation have created saline soils.

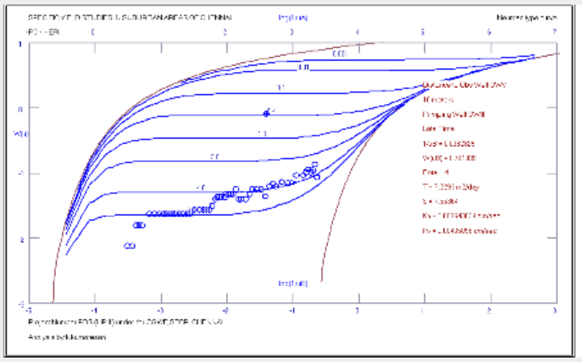
PDS carried out by Directorate of Ground Water Survey & Investigation,
W. R. Department, Government Of Orissa

GW-OR-1

Pumping tests

Measuring water level in a borehole under natural conditions is used to map depthh to the water table, and where groundwater is flowing. To understand how an aquifer behaves under stress we can carry out a pumping test.

This involves pumping at a controlled rate and measuring the response of the water in the pumped well and in nearby wells, By analysing pumping tests the long term sustainable yield of an aquifer can be inferred.



The rapidly growing city of Chennai, Tamil Nadu, relies on groundwater for much of its public supply. The groundwater is pumped from well fields outside the city. The aquifers are complex, with interlayered sands, gravels and silts. The highest yields are found where thick gravels allow water to flow freely.

To help understand where these gravels can be found, a series of boreholes were drilled and tested. The aim was to relate the yield of the boreholes to mapped hydrogeological characteristics. This will help site new well fields for an expanding demand. It will also aid location of artificial recharge structures to make the greatest contribution to maintaining aquifer productivity.

PDS carried out by the Central Groundwater Board, Southeastern Coastal Region, Chennai

GW-CGWB-2

Urban Lakes

Lakes in urban areas can be an important civic amenity, as areas for recreation, as wildlife habitats and as reservoirs that can play their role in flood protection and maintaining public water supply.

Unfortunately all too often uncontrolled discharge of sewage and industrial effluent can convert a lake from amenity to problem.

The Shahpura Lake in Bhopal, Madhya Pradesh is an example. Water from the lake is highly polluted, and although public supply in its environs is mostly groundwater, the polluted lake waters are infiltrating and degrading groundwater quality.

To address this a long-term monitoring mechanism for water quality was put in place.

The monitoring confirmed that groundwater quality was being affected by the linkages between lake water and groundwater.

It also demonstrated the impact of contaminants on biological diversity and tropic status of the lake

Native fish species were found to be declining in the lake because of the poor water quality yet introduced Tilapia, which can tolerate poorer water were thriving.

PDS carried out by the Water Resources Department , Government of Madhya Pradesh

GWMP-3

Fluoride

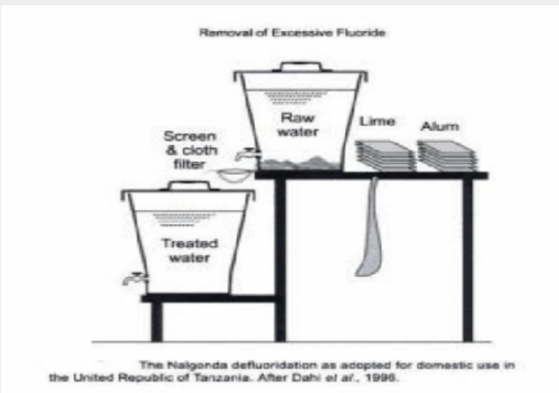
Groundwater is usually considered a good quality source of drinking water, as the natural filtration processes in aquifers remove contaminants and bacteria. If groundwater passes through rocks that contain dangerous elements, such as Arsenic or Fluoride, problems can arise.

High Fluoride levels occur in a number of dug wells and boreholes in the Deccan trap basalts of the Yavatmal District, Maharashtra. Fluoride concentrations in deep boreholes are typically 2 to 4ppm whilst the permissible limit is 1.5ppm. In dug wells water quality was slightly better.

Observation wells were drilled, and samples taken at different depths to study the relationship between hydrogeology and mineralogy. The Fluoride is associated with mineralisation, especially in contact zones between basalt flows.

The observation wells, and existing village supply wells, were sampled over several years to see how Fluoride concentration changes as monsoon water recharges the aquifer. As one would expect, post-monsoon concentrations are lower than pre-monsoon values due to dilution.

While treatment technologies are available, the monitoring results suggest that artificial recharge, to further dilute high fluoride waters,may be effective.



PDS carried out by the Groundwater Surveys and Development Agency, Maharashta

GW-MH-1

Springs

Springs represent the natural discharge point of an aquifer, and when boreholes are used to pump water the flow to springs may be reduced or cut off.

Many of the industries in Goa are located on narrow plateaus where they obtain
water supplies from boreholes into underlying aquifers.

Groundwater resources are becoming stretched due to industrial and population growth and there are concerns amongst villagers and farmers living in the surrounding plains that local wells, springs and tanks are being affected by this industrial pumping.

One such area is about 22km south of Panaji on the Verna Plateau with an industrial hub covering some $7km^2$. The springs in the area are considered tourist attractions.

Using DWLR it was possible to show that drinking water wells in surrounding villages were not affected by industrial groundwater abstractions, the plateau aquifers are perched and not hydraulically connected to coastal aquifers

Nevertheless pumping was affecting spring flows, and village supplies were impacted by land use change and water export’ to neighbouring industries.

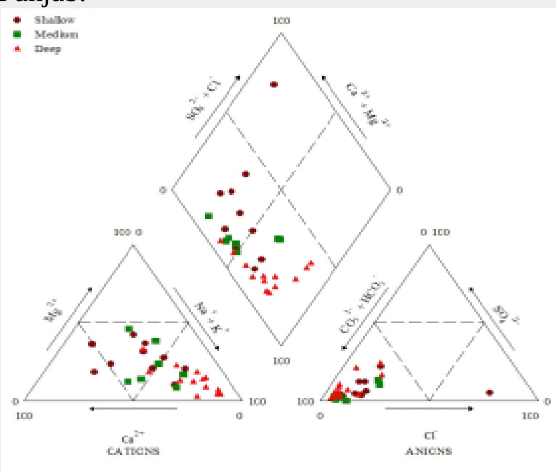
PDS carried out by the Water Resources Department, Government of Goa

GW-GOA-1

Isotopes

It is tempting to think that one molecule of water, H_2O, is the same as any other molecule of water. In fact there are subtle differences in the isotopic composition of water. Water derived from melting snow can be distinguished from water that fell as rain at lower altitudes.

Isotopes, and other chemical analyses have been used to study groundwater dynamics in the Bist-Doab area, Punjab.



Groundwater in Punjab is seriously overexploited – demand is 4.38 Mha m whereas the total supply from surface water canals and recharge is only 3.13 Mha m. It is therefore really important to understand the relationship between groundwater and the rivers and irrigation canals that cris- cross the plain.

The isotopic analysis, and other chemical data identified, an upper and lower layer with limited connectivity, with much of the recharge coming from irrigation canals and from cultivated areas.

But the pattern of recharge is complicated with local variations in the aquifer controlling which areas receive recharge from canals ('young' water) and which only receive recharge from rainfall.

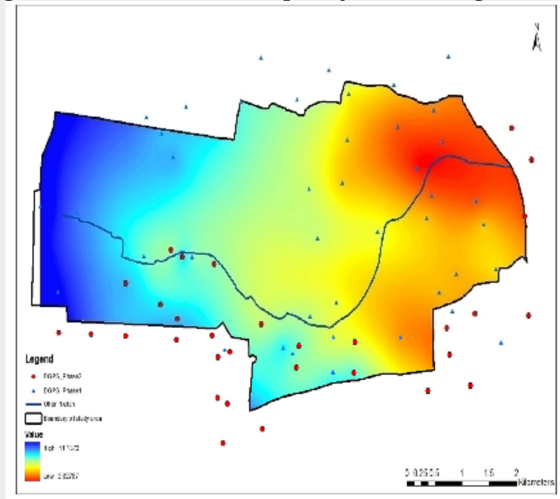
PDS carried out by the National Institute of Hydrology, Roorkee and CGWB(NWR)

GW-NIH-4

Storm water drainage

Many urban areas experience flooding after heavy rainfall when storm water drains are under sized. The Otteri Nullah sub-basin in Chennai is no exception.

Models of surface water flows can be integrated with information on rainfall and accurate data on the ground elevation and capacity of existing drains.



For accuracy these models need to know rainfall intensity and 30-years of hourly rainfall from the IMD raingauge at Nungambakkam were analysed to produce storm inputs to the model.

The model was then used to test the relative effectiveness of a number of possible new channel and storm drain configurations

One of the most promising was to adjust the profile of the Nullah. At present Otteri Nullah produces a flood hydrograph with high flows lasting almost 20 hours. With the re-shaped channel, the storm rainfall evacuates the runoff much more efficiently, and the peak is passed within 4-5 hours.

PDS carried out by the Chennai Corporation, Chennai, Tamil Nadu
National Institute of Hydrology, Belgaum

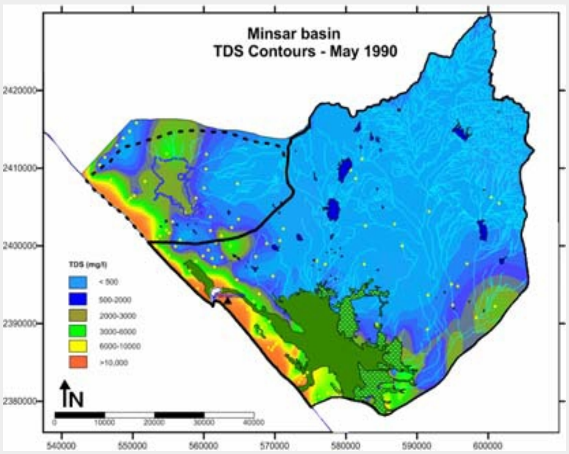
SW-NIH-4

Coastal groundwater

Water resources in coastal regions are often under serious pressure.

Groundwater may be an important local water source, especially where flat coastal lands and arid climates limit the opportunity to build reservoirs to store surface waters, and it is becoming more and more depleted as demands from irrigation, a growing population and industry take more and more from aquifers.

When a coastal aquifer in the Saurashtra region of Gujarat was reported to be becoming saline, a study was initiated to characterise the various hydrological components and establish their quantitative inter-relationships, and identify the causes of increased salinity in groundwater.



Water levels and chemistry were collected from 114 monitoring points every two months, from open wells, piezometers and from streams, lakes and the sea.

Historical data was used to establish trends in salinity, which was shown to be inked to sea water intrusion.

It may be possible to mix saline and non- saline waters to improve overall availability..

PDS carried out by the National Institute of Hydrology, Roorkee in collaboration with Gujarat Water Resource Development Corporation

GW-NIH-1

Water quality surveys

Comprehensive surveys of water quality across wide regions, integrating data on surface water and groundwater, are an important tool for managers and regulators of water resources.

The Government of Kerala recognised that surface and ground water resources throughout the state were becoming polluted.

Samples were taken at 477 monitoring points across the state, and analysed for 20 chemical and biological parameters. The survey was repeated on five occasions, pre and post-monsoon 2008, pre-monsoon 2009, and pre and post-monsoon 2010.

The samples were collected from rivers, lakes, ponds, wells and boreholes. Water quality in the headwaters of most rivers and streams is good but generally deteriorates further downstream. This can be simulated with simple models.

The major water quality problem in Kerala rivers is bacteriological pollution, often the result of bad sanitation practices, dumping of solid wastes, bathing and discharge of effluents.

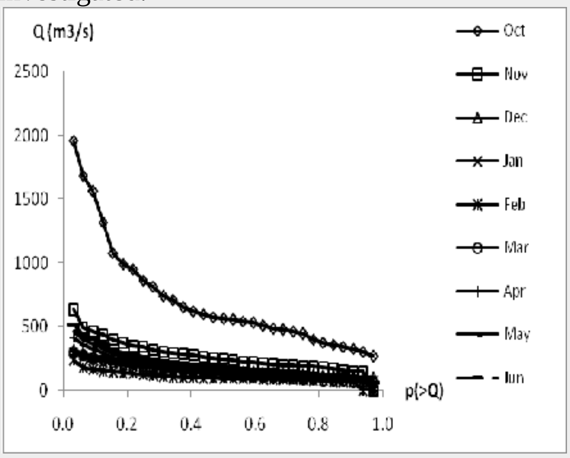
PDS carried out by the Kerala State Irrigation Department, Kerala State Groundwater Department and National Institute of Hydrology, Belgaum

SW-KL-1

Un-gauged catchments

Surface water runoff is often only monitored over the long-term on larger rivers. When planners or engineers need to estimate flows on smaller rivers, to design bridges, dams, embankments or similar structures they can use relationships between rainfall and the catchment size and shape.

There are various standard methods recommended by researchers and regulators. Using the Mahanadi and Rushikula basins in Orissa for reference, the effectiveness of different calculations was investigated.



The tools investigated enable estimation of different flow parameters, for instance the flood peak at any required return period or the flow duration curve.

The input data required are fairly simple and universally available measurements such as catchment area, slope, stream length, and regional rainfall statistics.

These sorts of calculations can be done quickly, but care is needed to understand uncertainties in the estimated values , and the implications of those uncertainties on designs.

PDS carried out by the National Institute of Hydrology, Roorkee

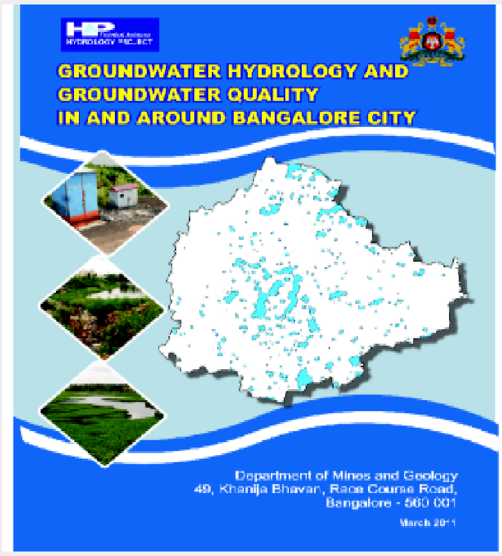
SW-NIH-3

Urban water quality

The population in urban areas of India is growing rapidly. In Bangalore it has almost doubled between 1990 and 2010, and water supply and sanitation facilities have not kept pace.

Previous studies in the city had shown that groundwater, which much of the population use for regular supply was polluted. This is mainly because untreated sewage infiltrates the aquifer.

A very comprehensive groundwater sampling programme was undertaken with over 3,000 samples taken and analysed from the 800km^2 study area.



Detailed maps of overall groundwater quality were produced along with spatial analyses of specific problem areas affected by particular pollutants, such as a cluster of oil and grease problems beneath petrol bunkers in the west of the city.

In addition to the water quality issues, almost uncontrolled borehole drilling is lowering the water table. In the 12 months from February 2009 to January 2010 almost 14,500 new boreholes were drilled within the study area, a growth rate of 14.9%.

PDS carried out by the Department of Mines and Geology, Bangalore

GW-KN-1

Improving well yield

In hard rock aquifers the yield of boreholes and wells may be very low. Most of the water in these aquifers is found in fractures, and though aerial photography and geophysics can be used to target locations for drilling, a borehole may fail to intercept enough fractures for success.

In part of the Rohani watershed of Dhasan basin, in Madhya Pradesh, hand dug wells in are dry during the summer months. Farmers have drilled deeper boreholes into a weathered granitic aquifer. When these boreholes had low yield, their owners used explosives to try and enhance yields. However as often as not they just succeeded in destroying the borehole.

A safer technique is 'hydrofracking'. A small section of the borehole, where fractures are thought to occur, is sealed off and water is pumped in at high pressure to crack the aquifer.

Trials were carried out at 15 sites, with variable results. Some, but not all, boreholes showed significantly increased yields. The main outcome appears to be that the greatest benefits come from low-yielding boreholes (yields of less that 10-15 l/min).

The costs were estimated as 33% the cost of a new borehole, and in about 50% of the trials hydrofrakking was the most economical option for increasing yields.

PDS carried out by the Water Resources Department, Government of Madhya Pradesh

GW-MP-1

Tides

Tidal variations in the ocean can be used as a tool to study coastal aquifers. If the aquifer is connected to the sea it should be possible to detect tides in observation boreholes.

Over pumping of groundwater in the Kelwa-Mahim coastal area of Maharashtra led to a belief that saline water was being drawn into the aquifer. In 1984 the Government of Maharashtra imposed a ban on construction of any new wells in the area, but there has been increasing conversion of hand pumps to electrical pumps and groundwater levels have continued to fall.

Measuring groundwater levels with a DWLR suggest that there is limited evidence of tidal influence on groundwater levels.

This suggests that local salinity issues cannot be explained by simple horizontal movement of a saline intrusion front from the sea; the dominant problem is vertical migration of saline waters from deeper aquifers and leaching downwards of saline water from salt pans in the area.

Isotope studies showed that shallow groundwaters are, as expected, modern but that the deeper groundwater is almost stagnant which explains why saline waters have not been flushed and why over-pumping and reduced groundwater levels have caused problems.

PDS carried out by the Groundwater Surveys & Development Agency, Government of Maharshtra

GW-MH-3

Polluted drinking water

Inadequate sewage systems can,often pose direct threats to human health, as untreated effluent reaches the aquifers and streams used for water supply.

In a city like Shimla in Himachal Pradesh, the spread of the city up and down precipitous hills has made it hard to install sewers. Drinking waters in Shimla have been contaminated by a variety of pollutants, particularly from human waste.

Sampling, survey and analysis showed that the source waters to the Ashwani water treatment works were being contaminated by human defecation in the open, by leakage from faulty sewers and by dumping of solid waste in stream channels.

The Ashwani plant was not designed to cope with organics and pathogens, and will need to be upgraded to cope with the poor quality raw water entering the plant.

Long term routine monitoring of the organic quality of surface waters is important to detect potential threats to human health.

PDS carried out by the National Institute of Hydrology, Roorkee

GW-NIH-2

Analysing river waters

Where pollution is expected sampling can be targeted upstream and downstream of concentrations of population and industry. This sampling strategy makes it easier to quantify man's impacts on the river.

Measurements were made on the Vishwamitri River in Gujarat upstream and downstream of Varodra.

Major pollution from untreated or partially treated domestic sewage was found below the urban area. The river water has high nutrient loads and hence high BOD demands. Many sites had very high TDS values (greater than 5,000 to 10,000mg/l) due to industrial pollution.

The river is important ecologically, with unique crocodile species and other reptiles threatened by the pollution,

The Gujarat Pollution Control Board has taken legal action against a number of industries and all large and medium industries are being forced to build suitable treatment plants for their effluent.

PDS carried out by the Gujarat Engineering Research Laboratory, Narmada Water Resources, Water Supply and Kalpasar Department

SW-GJ-2

Pollution hotspots

Monitoring for pollution can take two forms - routine surveillance monitoring across a district to measure background levels of pollution, and hopefully provide early warning of problems – or targeted analysis of 'hotspots' where pollution is known to occur.

A study of water quality and pollution in rivers at eight specific 'hot spots' within the Vadodara-Anlkelshwar-Vapi industrial belt in Gujarat collected a large amount of data

All the hot spots are shown to be affected by industrial effluents.

Industrial pollution is probably a greater issue that that of human waste at these hotspots although the former cannot be ignored.

Several sites had heavy metal concentrations above permissible limits. These come from chemical plants, metal industries and dye works.

While measures are put in place to ensure that industries area allowed to discharge treated effluent, continued monitoring and surveillance is required to ensure compliance, and detect any new threats to water quality.

PDS carried out by the Gujarat Engineering Research Laboratory, Narmada Water Resources, Water Supply and Kalpasar Department

SW-GJ-3

Depth of reservoirs

Before a reservoir is constructed the ground upstream will be carefully surveyed so that the volume of water in the reservoir can be calculated from the depth of the water, which is usually measured at the dam wall or main off-take.

With time erosion in the catchment area washes material into the reservoir, depositing silt and lowering its capacity. Bathymetric surveys use boats equipped with echo sounders to create maps of the reservoir that can be compared with the original surveys to quantify the loss f storage, and plan remedial actions.

A boat mounted bathymetric system has been used to survey major reservoirs in Andhra Pradesh.

The extent of the siltation problem is illustrated by the Priyadarshini Jurala reservoir on the Krishna River.

Since it first started impounding in 1996, 19.1% of its capacity has been lost due to sedimentation; 12.1% of the dead storage capacity and 7% of the live storage capacity.
This is a rate of siltation equivalent to 0.49 ha-m/100km^2/year.

PDS carried out by the Andhra Pradesh Engineering Research Laboratory

Quality Baselines

The monitoring of stretches of river thought to be relatively unpolluted is as important as targeting known areas of pollution.

This surveillance monitoring builds up a database of water quality that can be used to understand the processes within a river that maintain good quality and sustain ecological functioning.

In Southern Karnataka many rivers have relatively good water quality. To develop the baseline water quality profiles data was obtained from 14 sites on 11 rivers with monthly sampling from December 2009 to December 2011.

Samples were analysed for 27 parameters, both major ions and indicators of organic pollution. A series of water quality indices were computed..

In general the rivers were relatively unpolluted although all rivers contained Faecal Coliform indicating human waste is entering the rivers. Faecal Coliform levels in the Taraka, Suvarnavathi and Lokapavani Rivers were consistently high.

PDS carried out by the Karnataka Engineering Research Station, Krishnarajasagara

SW-KN-1

Adapting to scarcity

Water resources are, inevitably, finite. As agriculture, industry and cities develop so the way in which rivers, reservoirs and groundwater resources are allocated has to change.

All too often these changes in allocation are unplanned, as almost always public water supply and industrial demand are prioritised over irrigation.

The Jayakawadi reservoir, in Maharashtra was constructed primarily to supply water for irrigation to the Nathsagar area. However, with catchment area development and new demands for water for domestic supply and industry are causing problems.

Hydrologists reviewed a large number of earlier reports, documenting the changing understanding of available water resources and the impacts of upstream developments on water resources.

Farmers have adapted to the reduced reliability of water supply from the reservoir because of abstractions by other users, that were not part of the original scheme, by changing their cropping practices.

Overall there had been significant benefits from the scheme even if water was now being used in ways very different to those originally planned.

PDS carried out by the C.E. Hydrology Project, Nasik, Maharshtra

SW-MH-2

Snow melt

In Northern India the headwater catchments of major rivers may be in the Himalayas, and snow melt provides an important contribution to their flow.

Snow and glacier melt provide key inputs to Pandoh dam in the Beas basin, an important source of hydroelectric power.

Snow gauges can be used to directly measure snow pack thickness, but in mountainous regions it is hard to install comprehensive networks.

Remote sensing and models can be used to supplement the direct measurement, as can analysis of stable isotopes in the winter snow, summer rain, ice core and meltwater.

Snowmelt provides about 52% of Pandoh dam inflow, rainfall about 6-7% and glacier
melt about 42% although these figures vary from month to month.

Knowing where inflow comes from allows more accurate analysis of the potential effects of climate change on reservoir operation.

PDS carried out by the National Institute of Hydrology, Roorkee in collaboration with
Bhakra Beas Management Board

SW-NIH-1

Earthquake!

The Latur District of Maharashtra was affected by a 6.4 magnitude earthquake in September 1993 which was believed to have affected groundwater in the basalt aquifer.

To quantify the effect, if any, on the aquifer there is a need for consistent long term monitoring. Unfortunately there is only limited groundwater information on aquifer conditions prior to the1993 earthquake.

Without continuous records it is hard to say that change happened because of the earthquake.

Monitoring would show changes in the lateral and vertical movement of groundwater following the earthquake; as well as changes in the chemical quality of the groundwater.

What data there is shows some changes in groundwater level, and a shift from flood irrigation to drip irrigation over the past decade and changes in cropping patterns. However, it is unclear whether this was driven by the earthquake or by other factors.

PDS carried out by the Ground Water Surveys and Development Agency, Latur (M.S.)

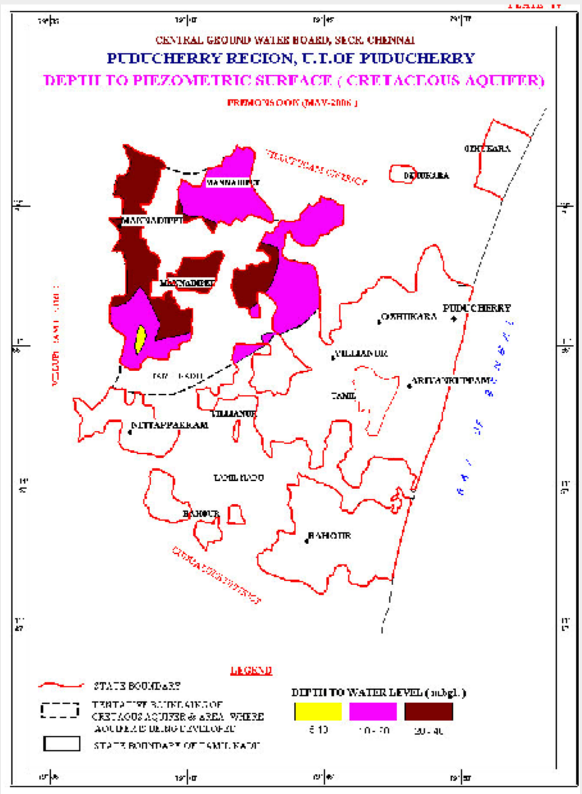
GW-MH-2

Recharging aquifers

If an aquifer is overexploited and excess surface water is available, one option is artificial recharge.

Historically Pundicherry relied on surface water from a system of tanks. However these tanks have not been maintained and people now rely on groundwater., much of it pumped from the deep seated Cretaceous Vanur sandstone aquifer.

Groundwater levels have fallen dramatically due to over-pumping and quality has deteriorated in recent years . CGWB estimate that pumping is 179% of the figure sustainable by recharge.



Surface water tanks might be used to recharge the aquifer in the areas worst affected by over-extraction, although identifying tanks that are underlain by appropriate geology and have sufficient storage proved difficult.

PDS carried out by the State Groundwater Unit , Government of Pudicherry

Gw-PU-1

Canals and rivers

Irrigation canals and rivers can have complex relationships. The impoundments for canals can starve a river of its natural flow., but flow from canals can also add to a rivers discharge.

Measurements of river flow may need to be 'naturalised' to account for the effects of dams and other abstractions,

The upper reaches of the Sabarmati River in Gujarat have good quality water due to inputs from the Narmada system

However, the river becomes heavily polluted after Gandihinagar due to discharges of domestic, agricultural and industrial waste rendering river water unfit for human consumption or irrigation.

Where there are inputs of canal waters from the Narmada canal they dilute pollutants in the river and improve water quality.

To observe this effect samples were collected and analysed from 11 river sampling points and 9 groundwater points.

Groundwater along the river is generally of reasonable quantity because of recharge from good quality Narmada main canal water.

PDS carried out by the Gujarat Engineering Research Laboratory, Narmada Water Resources, Water Supply and Kalpasar Department

SW-GJ-4

Protecting coastal groundwater

When groundwater is exploited close to the coast there is always a risk that salt water will be drawn from the sea into the aquifer.

In many areas fresh water only exists as a lens, floating on top of deeper saline water. Uncontrolled pumping will draw up the saline water and so careful management is required. Long term monitoring of quality is required to make sure that these valuable aquifers, and the ecosystems that depend on them containing fresh water, are protected.

In sand dunes pockets along the coastal tract of Odisha, remote sensing has helped study the aquifers.

Ground water samples were taken to assess water quality across the dunes and to study the trend of concentration of different parameters in the project area.

At the moment the aquifers contain fresh water, and to ensure that this continues the effectiveness of different artificial recharge measures was studied.

PDS carried out by Directorate of Ground Water Survey & Investigation,
W. R. Department, Government Of Orissa

GW-OR-2