Upgrading a conventional hydrological information system – an Indian example

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Abstract The existing hydrological information systems in many countries lack reliability, accessibility and timeliness. The main causes are sub-standard observation practice, manual processing, wide gap between the tools available and employed, and involvement of many agencies, often lacking integration. A comprehensive computerised hydrological-geographic database is key to efficient water management. An attempt to improve existing systems in nine peninsular states of India is underway through the Hydrology Project (HP). The prime objective of HP is to standardise data collection and processing and develop a Hydrological Information System (HIS). Infrastructure development, maintenance, and training of personnel are emphasized to ensure sustainability. The key features of HIS and experiences from revitalising the existing system over a region of about 1.7 million km^2 are highlighted.

Key words Hydrological information system; hydrological data; data processing; India.

INTRODUCTION

A necessary pre-requisite for wise water management is accurate, comprehensive, and timely hydrological data. Unfortunately, the systems for collecting and managing waterrelated data in many countries are inadequate and often deteriorating. Difficulties arise due to lack of funds, non-standard procedures for data collection and quality assurance, and outdated ways for data management and dissemination. To improve the existing Hydrological Information System (HIS) in India, a giant step has been taken by launching the ambitious Hydrology Project. HP aims at developing and improving the existing HIS of various government agencies in nine peninsular states of India: Andhra Pradesh, Chhattisgarh, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Kerala, Orissa and Tamil Nadu (Fig. 1). This will assist in gathering reliable and spatially intensive data on water quantity and quality and storage of this data in computerised databases. Special attention is being paid to standardisation of procedures for data observation and validation so that data is of acceptable quality and compatible across agencies. Infrastructure and human resources development aspects are being attended for sustainability of the system which should grow with developments in hydrology and allied technologies.

This paper highlights the salient features of the improved HIS. The HP is in advanced stage of implementation and the analysis has been made on the basis of the experience gained from this project. Also proposed are some plans as a follow up.

EXISTING HYDROLOGICAL INFORMATION SYSTEM IN INDIA

Hydrological data in India is primarily provided by various Central and State Government's meteorological, surface water (SW), and groundwater (GW) agencies. Information on SW is provided by the Central Water Commission (CWC) and state water resources departments; on GW by the Central Ground Water Board (CGWB) and respective state GW agencies. The responsibility for quality data lies with Central/ State Pollution Control Boards, Public Health Engineering Departments, CWC and CGWB.

Observation networks

Rainfall stations constitute the bulk of the hydro-meteorological network and are mainly owned by the state departments. The India Meteorological Department (IMD) collects and archives data from selected stations. The climate stations are mainly maintained by IMD. Unfortunately, most of the rainfall stations are quite old (ranging from 20 to 100 years) and many of these have not been maintained and upgraded adequately. Though the observation networks of the central and state agencies are expected to play complementary roles, the actual networks often have duplications and gaps.

River gauging stations have primarily been set up to collect water level, discharge and sediment data at important locations. CWC stations are located on the major rivers whereas those of the states are on tributaries and smaller rivers. CWC mainly gathers data on overall water resources of the country for planning major projects, to resolve interstate water sharing, and for flood forecasting. The networks of state agencies cover the basins more intensely and provide data to plan & design small and medium water resources projects. Coupled with an ever-reducing financial support, the shortage of trained observers has rendered many river gauging and meteorological stations non-operational. The observation process on most stations is manual though a few automatic equipments have been installed recently. The velocity measurement is mainly by current meters at CWC stations; the use of floats has been in vogue in many states.

The assessment of GW resources in India is based on annual recharge and discharge using water balance equation. Most GW observations have been at open dug wells that tap the upper unconfined aquifers; the measured water levels represent the piezometric head of the semi-confined/unconfined aquifers. However, the necessary well-aquifer hydraulic connection is not always confirmed. Usually, observations are taken four times in a year and are assumed to represent the troughs and peaks of the water table hydrograph. Clearly, four data points are too sparse to yield reliable conclusions. Limited monitoring of the piezometric head of the deeper confined/leaky confined aquifers has been carried out by some agencies.

Awareness about the need for collecting water quality data has grown only in the last decade, primarily due to deterioration of resources. Whereas the river gauging authorities take samples at the gauging stations, the pollution control boards undertake surveillance near industrial or urban centres. In the past, water quality labs were inadequate in terms of numbers, financial support and capabilities.

Data processing and dissemination

Computers are in use in India for hydrological data handling for quite some time with different levels of sophistication ranging from simple ASCII based files to more user friendly spreadsheet files and databases. However, there is a lack of uniformity in the formats and software in different agencies and even in different offices of the same agency. There have been sporadic efforts in past to improve the data processing systems but these were not designed to yield objective solutions.

SALIENT FEATURES OF NEW HIS

The prime objective of the HP is to develop a comprehensive, reliable, user-friendly, and sustainable HIS. A HIS comprises of physical infrastructure and human resources to collect, process, store, and disseminate water resources data. The primary role and scope of HIS is to provide reliable data for planning, design, and management of water resources and for research purposes. The new HIS is conceptualised and set-up through the following steps:

Review of observational networks

The existing observational networks have been thoroughly reviewed from three view points: (a) to open new stations in areas hitherto inadequately covered or to replace non-representative stations, (b) to avoid duplication of stations across agencies, and (c) to improve frequency and accuracy of observations through standard equipment and procedures. Old and defunct equipment have been replaced with standard ones. A comprehensive list of equipment is drawn and their detailed specifications made.

There were about 7200 rainfall and 640 climatic stations in the project area (HP 1995). Inspections revealed that improperly located stations, ill-maintained or defunct equipment, and sub-standard observation practices were quite common. A major improvement in the hydro-meteorological network has been the reactivation of these non-functional rainfall stations. Adding 500 new stations and upgrading another 1700 have revitalized the meteorological network. Many new climatic stations have also been set up.

The main improvements of river gauging stations have been the introduction of Digital Water Level Recorders (DWLRs) and replacing floats with current meters. About 265 existing stations have been upgraded and another 650 new stations have been established. Sophisticated techniques for discharge measurements like Acoustic Doppler Current Profilers (ADCPs) have also been employed, on experimental basis, at a few stations where gauging by conventional means is extremely difficult.

Previously, there were about 27,000 GW observation wells in the project area of which about 6% were tube wells while others were open dug wells. These were not properly maintained. The network has been strengthened by adding about 7,900 purpose-built, non-pumping observation wells to facilitate measurement of vertically averaged piezometric head of a selected single layer. These are also being used for water quality monitoring. The network has been optimised to give a good spatial and vertical coverage by integrating piezometers of different agencies. As many as 6400 piezometers have been equipped with DWLRs to enable measurement of head at the desired. The accurate and high frequency data will facilitate many new analyses.

An extensive network for monitoring of SW quality at about 675 locations and GW at about 29,000 locations has been established. Stations are categorised as “Baseline”, “Trend” and “Flux” stations based on the guidelines similar to that of the World Health Organisation (WHO 1992). The sampling frequency and water quality parameters to be analysed for each category of stations have been defined and documented (HP 2000a) for ensuring application of uniform monitoring procedures.

A comprehensive water quality laboratory development programme includes establishing/upgrading 290 laboratories under three categories: Level I, Level II, and Level II+. As many as 215 Level I labs cover six field parameters (colour, temperature, pH, dissolved oxygen, conductivity and turbidity). Another 50 Level II labs are for analysis of physico-chemical and microbiological parameters. Remaining 25 Level II+ labs undertake additional analysis of heavy metals and pesticides. Special instruments like UV-visible spectrophotometer, Atomic absorption spectrophotometer, and Gas chromatographs have been provided for identification of toxicants, trace metals, pesticides etc. The analysis procedures have been documented (HP 2000b) with illustrations and sample calculations.

An Analytical Quality Control programme ensures reliability and reproducibility of data across the labs.

Data processing, analysis and reporting

The existing manual system of data processing is being replaced by dedicated and user-friendly computerised systems. The raw data are in a variety of formats such as hand-written records, charts and digital records and contain gaps and inconsistencies. A hydrological data processing software HYMOS developed by Delft Hydraulics of The Netherlands, is employed by all SW. A comprehensive GW data processing software is also being prepared. Both softwares are modular and are being implemented with varying levels of sophistication. The primary module is dedicated for data entry and preliminary validation. The second module is focused on spatial consistency checks, data correction, compilation, and analyses. The highest-level setup has modules for hydrological validation and comprehensive reporting. Application of this system has, for the first time, enabled processing of all the hydrological data at a gigantic scale using uniform tools. Use of these tools in the field ensures immediate feed back to the stations in case of observational errors.

Management of historical data

A huge volume of historical data, mostly in manuscript or chart forms, is available. Often, these data are of variable or "unknown" quality since in many cases the recorded data were seldom scrutinised. For each agency, a comprehensive program of historical data entry and processing has been prepared. Such a mammoth organisation of hydrological data is being accomplished for the first time in the country. This provides an excellent opportunity to easily access and use historical hydrological information.

Data storage and dissemination

All historical and current data are proposed to be stored in well-defined computerised databases using industry standard relational database management systems. Both, raw and processed data will be stored to avoid loss of information. Typical features of data administration like security, protection from corruption, and controlled accessibility would be implemented. An efficient system aided with graphical visualisation on the maps for identifying the required data, also through Internet, is envisaged.

Assessing users' needs

Hydrological Data User Groups (HDUGs) consisting of a wide array of potential users have been constituted in each state and at the central level to ascertain the users' needs. The main aim of HDUGs is to review hydrological information needs, identify shortfalls and suggest improvements.

OVERALL STRUCTURE OF HIS

The structure of HIS at State/Regional/National levels, emphasising the distributed data processing, exchange, and dissemination is illustrated in Fig. 2. Each Data Processing Centre (DPC) has adequate communication links for exchange of data with other DPCs. From data observation to final storage, HIS operates at different levels in following way.

The observed field data are submitted to the Sub-divisional/District/Unit DPC (SDDPC/dDPC/UDPC) at the end of the month of observation. They are entered and preliminary validation is carried out within 10 days. The data are then passed on to the Divisional/Regional DPC (DDPC/rDPC). The WQ samples are regularly sent to designate water quality labs. Samples are analysed within the prescribed time frame. The results are entered in the computer and subjected to primary validation. At regular intervals, the laboratory passes the data to DDPC/rDPC.

Given their larger areal coverage under DDPC/rDPCs, data are organised in basin wise databases and secondary validation (spatial consistency checks) is completed within 15 days of receipt of data. The data are then transferred to the respective state/regional DPC (SDPC/RDPC). Main activity at SDPC/RDPC centres is the hydrological data validation, completion, analysis, and reporting. Inter-agency data validation exercises are scheduled twice a year: in February (for the data of monsoon months) and August (non-monsoon months). Next, the processed data are transferred to the respective State/Regional Data Storage Centres (SDSC/RDSCs).

Seven out of nine states have a common DSC for SW and GW data. Central agencies have separate DSC for each region. Each central agency also has a National DSC (NDSC) for an overall perspective of hydrological regime at the national level. All the SDSC/RDSCs store and administer the field (or raw) and processed (or authenticated) data and ensure smooth dissemination to the users. The DSCs function purely as a hydrological data library equipped with a catalogue of stored data. A strict distinction between the DPCs and the DSCs is emphasised for ensuring sustainability and maintenance of finalised databases for all future reference and use.

SUSTAINABILITY OF HIS

An extensive training program is being implemented to ensure skill building for the personnel involved in HIS. The subjects and activities covered include: (a) Observation practices for hydrological and allied data, (b) SW, GW, and WQ data entry and processing using dedicated softwares, (c) GIS and database management systems, (d) Water quality sampling and analysis, (e) Procurement and installation of equipment and other infrastructure facilities, and (f) Training and communication skills.

Most training courses have been institutionalised through designated research and academic institutions called the Central Training Institutes (CTIs). A three-pronged approach is being followed to impart training to a large number of trainees (about 10,000) by employing the concept of "training of trainers (ToT)". A core group of motivated officers are trained who in turn are expected to train the actual trainees. Trainees are further assisted at their work place by 'hands-on-sessions'. Comprehensive training documents including exercises and presentation material have been prepared to ensure uniformity and standardisation in delivery of training courses.

PROJECT IMPLEMENTATION

Implementation of any widespread project as the HP, involving more than 20 agencies, requires meticulous planning. The HP is being satisfactorily implemented by most of the agencies. However, a retrospective brooding brings out certain factors, which might have given better results, such as: (a) careful preparation of specifications of sophisticated equipment considering local conditions, (b) realistic accounting of time required for government procurement process, (c) ensuring availability of infrastructure facilities before delivery of equipment, (d) synchronising training with the availability of staff, computers, and readiness of observation stations, and (e) training of existing staff for specialised jobs rather then wait for recruitment of new staff.

The project is a unique experience of standardising equipment specifications, setting uniform and standard data collection procedures, providing structured training and implementing software for data processing and management at such a gigantic scale. Besides the successful implementation during the project period, it is also crucial to ensure sustenance of HIS activities in the future. Two major factors, which may impede this are the frequent transfers of officials and inadequate budgetary support.

CONCLUSIONS

A comprehensive, reliable, and easily accessible HIS is a pre-requisite for optimally utilising the available water resources. The Hydrology Project in India is a concerted effort to improve the existing system and provide a computerised HIS ensuring efficient dissemination of information. Augmentation and upgradation of various networks has provided fresh impetus to the (geo-)hydrological monitoring in the country. It has led to improved spatial and temporal coverage and data of better quality. The upgradation and augmentation of network may affect the homogeneity of data; this is to be ascertained when sufficient data become available. Data processing with decentralised hierarchical structure ensures a completely participatory approach. The system promotes greater interaction between different HIS agencies and also ensures uniformity of tools and procedures used. Such standardisation will help solve water disputes now and in the future. Improvements in infrastructure and institutional support are beginning to reflect in terms of availability of organised hydrological databases and timely availability of better quality data to the users. It would only be fitting that the improved system further grows and the experience gained is utilised for similar improvements elsewhere.

REFERENCES

HP (1995) Staff appraisal report. Unpublished Hydrology Project (India) document, New Delhi, India.

HP (2000a) Protocol for water quality monitoring. Unpublished Hydrology Project (India) document, New Delhi, India.

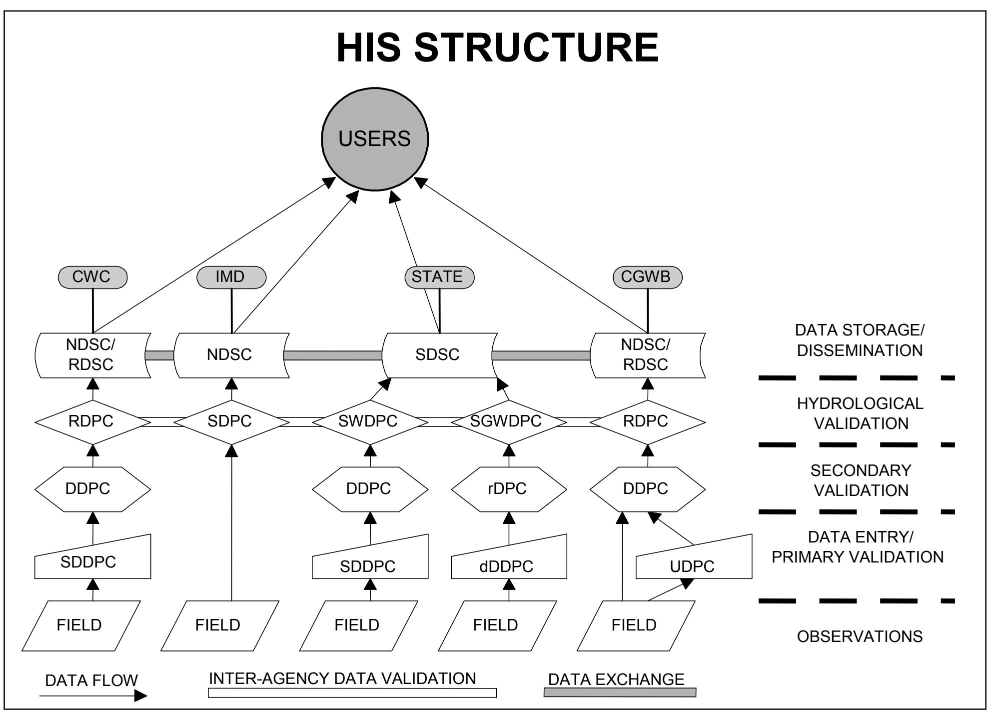
HP (2000b) Guidelines on standard analytical procedures for Water Analysis. Unpublished Hydrology Project (India) document, New Delhi, India.

WHO (1992) GEMS/WATER operational guide. Third edition, unpublished WHO document GEMS/W92.1, World Health Organisation, Geneva.

FIGURE CAPTIONS

Fig. 1: Hydrology Project area of nine Indian states

Fig. 2: HIS Structure at State/Regional/National levels



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Overview - 1

- **Hydrological Information System (HIS) in many countries is lacking in terms of:**
  - reliability
  - accessibility
  - timeliness

Overview - 2

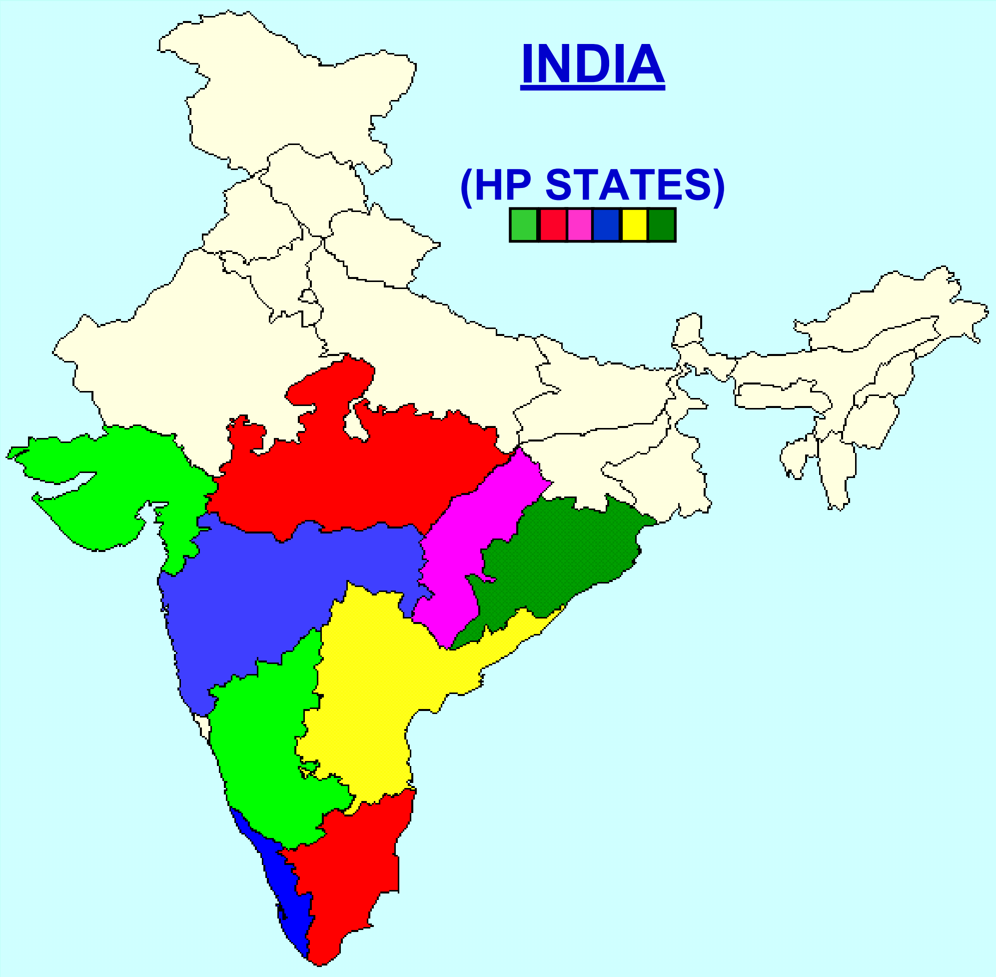
- **Main causes**
  - substandard observation practices
  - manual data processing
  - equipment with older technologies
  - lack of integration among agencies involved
  - lack of relialisation for need of good and adequate hydrological information
  - Inadequate financial resources for HIS

Overview - 3

- **HIS, in India too, needed improvements**

- **Hydrology Project (1996 - 2003) - India**
  - **a WB aided project is an attempt to bring about desired improvements**

Hydrology Project (HP) - India



- **Strengthening HIS in 9 peninsular states of the country (1.7 m sq. kms.)**

Overview - 4

- Objectives of HP
  - collection of reliable and spatially intensive data on SW / GW quantity and quality
  - standardised procedures for various activities
  - dedicated hydrological data processing software
  - storage of data in well-defined databases
  - efficient dissemination of information
  - institutional & human resources development
- First concerted effort at this scale for improving HIS in the country

Overview - 5

- **Outline**
  - about existing HIS
  - salient features of the new setup
  - experiences gained
  - conclusions

Features of existing HIS in India

- **Agencies involved**
- **Observational networks**
- **Data processing and dissemination**

Agencies involved - 1

- Central & States agencies
  - Surface Water agencies
  - Groundwater agencies
  - Meteorological agencies
  - Pollution Control Boards

Agencies involved - 2

- Complementary roles
  - Central : for regional level coverage on major rivers and geological setups
  - State : for more intensive coverage within the States
- Many instances of duplication in the network
- Virtually no exchange of information for purpose of data validation etc.

Observational networks

- Climatic stations
- River gauging stations
- Groundwater stations
- Water quality stations

Climatic stations

- **Rainfall stations**
  - mainly owned by State departments
  - 20 to 100 years old
    - many of these are not adequately maintained and upgraded in the past
- **Climatic stations**
  - mainly owned by India Meteorological Department (IMD)
  - State owned stations poorly maintained
- **Lot of duplication in State & IMD network**

River gauging stations

- **Networks of State & Central agencies**
  - * **Central agency: <u>C</u>entral <u>W</u>ater <u>C</u>ommission (CWC)**
    - **for overall assessment of WR of the country**
    - **to resolve interstate water sharing issues**
    - **for flood forecasting**
    - **stations maintained and institutional support stronger**
  - * **State agencies**
    - **for planning small & medium WR projects**
    - **ever-reducing financial support**
      - + **stations almost non-operational in many cases**
    - **primitive observation techniques - floats etc.**

Groundwater stations

- **Existing network**
  - mostly at open dug wells
    - * tapping upper unconfined aquifers
    - * well-aquifer hydraulic connection not always confirmed
    - * observations taken at 4 times a year only
      - assessment may have significant errors, at times
  - limited monitoring at deeper confined/leaky aquifers
- **Agencies**
  - Central & State
  - Cases of duplication not uncommon

Water quality stations

- Awareness about need to collect WQ data grew up only in last decade
  - * significant deterioration of water quality
  - * huge stress on availability of water
- Agencies
  - Pollution Control Boards (PCBs)
    - * orientation towards surveillance
    - * near industrial or urban centres
  - River gauging authorities
    - * not adequately mandated about WQ
- WQ laboratories
  - * very few and inadequately maintained

Data processing

- Computers in use for last few years in HIS offices but
  - there has been lack of planning on
    - * standard data processing procedures and formats
    - * use of some standard software at agency level
    - * preserving the computersied data for future use
  - no conscious planning and efforts to introduce standardisation and uniformity across various States and agencies

Data dissemination

- In most of the agencies
  - No proper catalogue about available data
  - No set policies for data dissemination
    - * pricing
    - * eligibility
    - * time frame for supply
  - Historical data largely as paper records
    - * inefficient dissemination and lot of duplication of efforts by various users in computerising the data and then using the same

New HIS strategy

- HP setup to develop/improve existing HIS
  - comprehensive, reliable, user-friendly, easily accessible and sustainable HIS
  - emphasis on
    - * better and latest tools
    - * standardisation of procedures
    - * adequate validation of data
    - * uniformity across various agencies
    - * training of personnel
    - * strengthening institutional framework

Salient features of New HIS

- Review of observational networks
- Data processing, analysis & reporting
- Management of historical data
- Data storage and dissemination

- Overall structure of HIS
- Sustainability of HIS

Review of observational networks

- **New stations**
  - in areas inadequately covered
  - to replace existing non-representative stations

- **Avoiding duplication of stations across agencies**

- **Improved frequency and accuracy of observations**
  - standard equipment and observational procedures

Meteorological network

- **Existing network**
  - 7200 rainfall & 640 climatic stations
  - Inspections revealed many stations
    - * improper exposure conditions
    - * ill-maintained
    - * with defunct equipment
    - * employing sub-standard observation procedures
- **Major improvements**
  - reactivation of all non-functional rainfall stations
  - 360 new rainfall stations and 100 new climatic stations

River gauging network

- **Existing network**
  - 800 stations in the project area
  - stations belonging to many States were found in almost non-functional condition
- **Major improvements**
  - 265 new and 650 existing stations upgraded
  - use of floats replaced by current meters
  - introduction of DWLRs
  - introduction of sophisticated equipment
    - * ADCPs for difficult gauging situations (on experimental basis)
    - * bathymetric survey equipment

Groundwater network

- **Existing network**
  - 27000 GW observation wells
    - * only 6% - tube wells; rest - open dug wells
    - * many-many wells ill-maintained or non-operational
- **Major improvements**
  - 7900 new purpose-built, non-pumping wells
  - 6400 wells equipped with DWLRs
  - network optimised for better spatial & vertical coverage
  - integration of network of different agencies

Water quality network

- Existing network
  - mainly with Central agencies
    - * with no clear mandate for monitoring WQ
- Major improvements
  - 675 river and 29 000 GW locations added
  - comprehensive WQ laboratory development programme (290 labs. New/upgraded)
    - * 215 Level I : field parameters
    - * 50 Level II : physico-chemical; micro-bio. para.
    - * 25 Level II+ : heavy metals & pesticides
    - * AQC - intra and inter-laboratory
  - WQAA established

Data processing, analysis & reporting

- **Dedicated & user-friendly SW/GW software**
  - uniformity achieved across all offices
    - * 200 SW data processing centres (DPCs)
    - * 180 GW data processing centres (DPCs)
  - first module
    - * easy data entry and preliminary validation
  - second module
    - * spatial consistency checks, data correction/completion, compilation & analysis
  - higher module
    - * hydrological validation and reporting

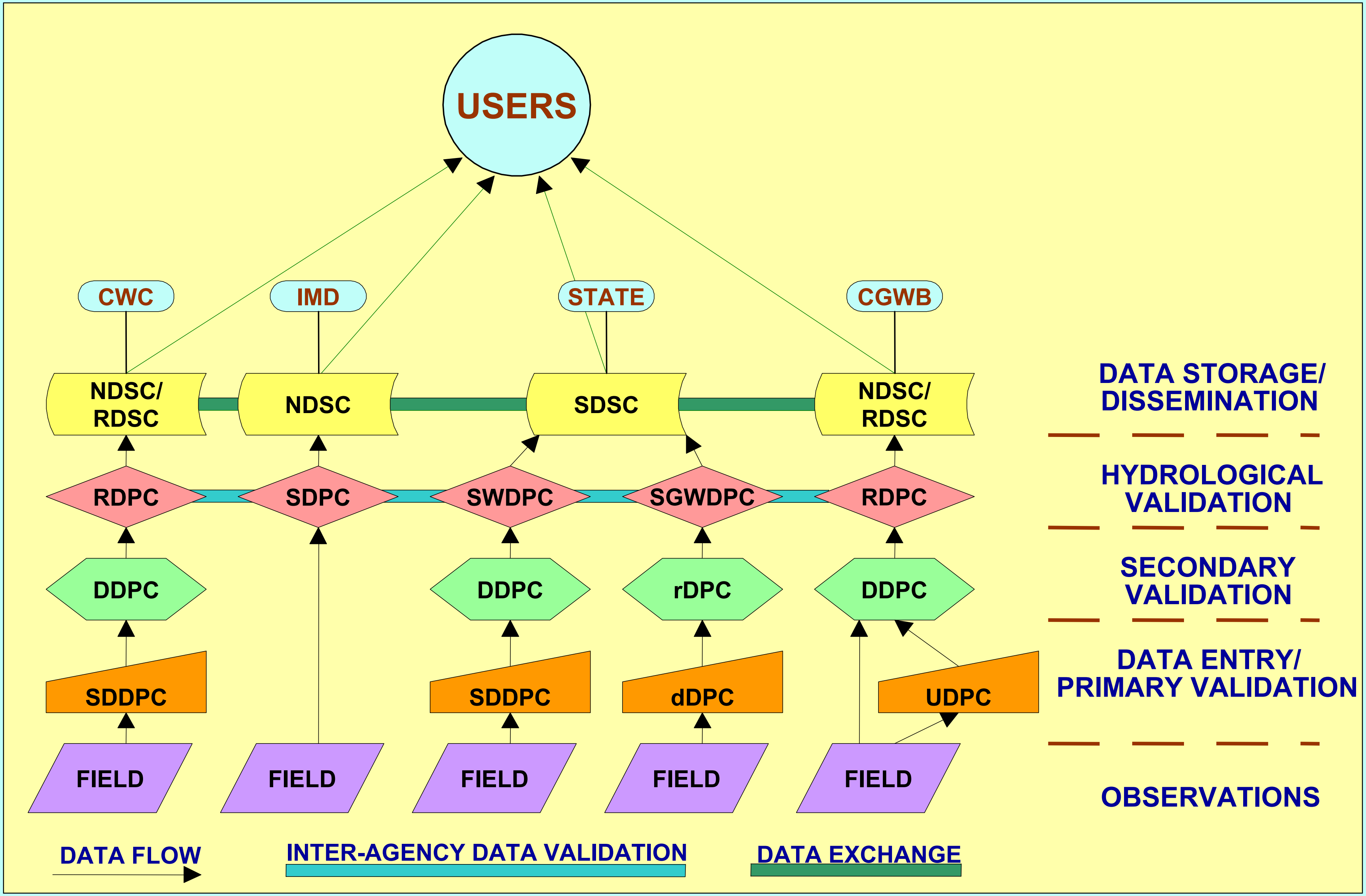
Management of historical data

- **Huge volumes of useful historical data**
  - mainly in manuscript & chart form
  - variable or “unknown” quality
    - * limited scrutiny in the past
- **Comprehensive programme of historical data entry & processing**
  - first time (was probably the last chance!!)
    - * 20 to more than 100 years of rainfall data
    - * 10 to 30 years of climate data
    - * 10 to 40 years of river gauging data
    - * 10 to 40 years of GW data
    - * 5 to 15 years of WQ data

Data storage and dissemination

- **All historical and current data**
  - in well-defined computerised databases
    - * relational database management system
      - easy and efficient data administration
  - both raw and processed data to be archived
  - comprehensive and widely circulated catalogue
    - * graphical visualisation on maps by data users for identifying/selecting required information
      - offline and web-based options
  - comfortable and faster data dissemination services

Overall structure of HIS



Sustainability of HIS

- **Extensive training programme**
    - observation procedures
    - SW / GW / WQ data entry & processing using dedicated software
    - GIS and database management systems
    - WQ sampling and analysis
    - procurement / installation / testing of equipment
    - training and communication skills
- **Central training institutions (CTIs)**
    - – standardised training documents & presentation material
    - – concept of ToTs (Training of trainers)
        - * core group of motivated officers trained
            - large number of training units (about 10 000) completed
            - assistance at place of work - “Hands on sessions”

Project implementation

- **Overall progress & achieving objectives**
  - * satisfactory for most of the agencies
- **Lessons learnt - crucial aspects**
  - * specifications for equipment and adequate testing before purchase
  - * realistic accounting of time for procurement
  - * synchronisation of training with availability of staff, computers, readiness of WQ labs. and equipment at observation stations
  - * option of training existing staff for specialised jobs rather then wait for new recruitment
  - – sustainability is to be ensured
    - * agencies to remain proactive for ensuring continuity in budgetary and staff support

Conclusions - 1

- **HP has significantly improved HIS in the project area**
  * **better equipment and standard observation practices**
  * **computerised data processing set up**
    - **uniformity across agencies**
    - **decentralised structure - participatory approach**
    - **comprehensive hydrological data libraries**
  * **efficient data dissemination facilities**
  * **integration of systems of different agencies**
  * **enhanced data exchange between agencies**
  * **improved in-house training capacity**

Conclusions - 2

- **HP has provided fresh impetus to**
  - * (geo-)hydrological / hydro-meteorological monitoring systems in the country
  - * better and timely data for
    - planning and design purposes
    - addressing problems of water sharing
    - optimum water utilization and poverty alleviation
- **Sustainability is most crucial**
  - * system has to continue and grow further
  - * continuous budgetary and staff support
    - more realisation about value of good HIS at Govt. level
- **Experience gained can be utilised**
  - * for similar improvements elsewhere, in India and abroad