

Project completion report on
**International Training Workshop on Borehole Geophysics for
Groundwater**

By

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" YOGA KARMASU
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Submitted to

**WEST BENGAL ACCERATED DEVELOPMENT OF
MINOR IRRIGATION PROJECT (WBADMIP)**

November, 2014

INTRODUCTION

Groundwater provides the largest repository of fresh water in this planet, and our country, India, is the largest user of groundwater, globally, abstracting about 240 billion cubic meter of groundwater, every year. Hence the study of the science of groundwater from an applied perspective is the need of the day. However, unfortunately, in this country, groundwater science or hydrogeoscience, has not yet received the importance that it deserves among the geoscience community. Even the techniques of groundwater exploration, throughout the country (both government and private initiatives), have been mostly done through age-old, experienced-based “feeling” methods, rather than using modern, scientific, digital techniques. Thus states across India have limited hydrogeophysical potentiality, and for up-scaling the aquifer mapping programme country-wide it is essential to build the hydrogeophysical capacity of all the States. With this aim and objective, the World Bank initiated the formulation of International standard training programme on surface and borehole geophysics for groundwater with DFID funding. The Ministry Water Resources, River Development and Ganga Rejuvenation, Govt. of India and WBADMIP, Govt. of West Bengal also came forward to bridge the gap of knowledge by training the Govt. Scientists and Engineers throughout our country with the most modern groundwater exploration and study techniques, such as the application of borehole geophysics. Accordingly, the training on borehole geophysics was conducted at IIT, Kharagpur during Nov 11-21, 2014. The selection of IIT, Kharagpur in West Bengal was important in several aspects. It has a Geology and Geophysics department with a strong group of eminent academicians, it has a large campus, international standard class-rooms with a large number of computers and the internet facility, a standard guest house and the two boreholes drilled within the campus, represents the hydrogeological conditions in the eastern part of India. The invitation to USGS professional geophysicists and experts for the training-workshop was obvious as they are the most experienced experts, rather best in the field, with eminence in the field of modern geophysical logging of water wells, tackling a variety of exploration, contamination and rehabilitation issues in varied hydrogeological conditions similar to those found in India. The borehole geophysics training workshop provided the participants (*28 Government scientists and engineers from Central and State Government agencies and 5 IIT Kharagpur students*) with training on the use of digital borehole geophysical logging methods useful for groundwater-resources exploration, aquifer assessment and borehole integrity testing. Instruction on modern geophysical logging methods and tools were hired from professional hydrocarbon wirelog farm (Mitchel India) and also imported from the USA. These tools are used for advanced techniques in groundwater exploration to delineate geologic formations, estimate water quality, and optimize well completion and screen placement are being provided. The instruments include, caliper logs, gamma logs, electro-magnetic induction logs, acoustic tele-viewer etc. The hands-on, practical training was done in the two exploratory bore wells that were constructed up to a depth of 200 m in the barren land in front of VSRC ground. It was done by the USGS teachers, in association with the Mitchell India technical staffs and IIT Kharagpur organizing faculties. Instructor-led case studies and participant-collected data sets was used to illustrate the uses and limitations of different borehole geophysical methods and gain hands-on experience in the use of logging equipment and the performance of data analysis. Classroom exercises was conducted using PC-based well-log plotting and analysis software. The participants analyzed and interpreted the data collected during the field exercises. At the conclusion of the workshop, participants developed practical skills and the knowledge required to operate digital logging systems and

tools, and analyzed log data to solve a range of groundwater-resources exploration, aquifer assessment and borehole site selection and testing problem.

Trainers from U.S. Geological Survey

The program was led by an expert team with world-wide experience in hydrogeophysics and borehole geophysical logging: Dr. John W. Lane, John H. Williams, Dr. Fred Paillet, and J. Alton Anderson, Office of Groundwater, Branch of Geophysics, U.S. Geological Survey, USA; Consultants to the World Bank.

Organizers:

The program was being supervised and coordinated by Prof. Abhijit Mukherjee (Hydrogeologist) and Prof. Probal Sengupta (Geophysicist), both faculty at the Department of Geology and Geophysics at Indian Institute of Technology (IIT) Kharagpur.

In addition, the following personnel of IIT Kharagpur also provided support for the preparation and execution of the workshop:

- 1) Dr. D.K. Nanda, System Manager, Computer Informatics Centre.
- 2) Bankim Mondal, Junior Technical Superintendent
- 3) Biloy Jana, Technical Coordinator
- 4) P. Gangadhar, Job Assistant
- 5) Anindya Pradhan, Job Assistant
- 6) Joy Ram, Job Assistant
- 7) Palash Debnath, Research Scholar
- 8) Soumendra Bhanja, Research Scholar
- 9) Madhumita Chakraborty, Research Scholar
- 10) Mrinal Layek, Research Scholar
- 11) Shahab Anwar, Research Scholar
- 12) Ashok Shaw, Research Scholar

SPONSORS

- World Bank Group
- UKAID
- Ministry of Water Resources, Government of India
- United States Geological Survey
- WBADMIP, Government of West Bengal

VENUE

The class room teaching took place at the Computer and Informatics Center (CIC), Takshashila Building, Indian Institute of Technology, Kharagpur, West Bengal 721302. The course involved training of geophysical logging equipment in a field setting in a nearby field site, within the campus.

LOCAL HOSPITALITY

IIT Kharagpur has a self-contained residential campus. Lodging and sustenance (*breakfast, lunch and dinner*) for the participants were arranged in the IIT Technology Guest House. The IIT Kharagpur is situated about 120 km southwest of Kolkata. Kharagpur can be reached in about 2 hours by train from Howrah railway station of Kolkata or 3 hours by car from Kolkata Airport. Kharagpur is also connected by direct train services to most major cities of the country. The Institute is about 10 minutes drive from the Kharagpur railway station. Private taxi, auto-rickshaw, or cycle-rickshaw, can be hired to reach the Institute from the Railway Station. The participants had to reach the campus themselves.

TARGET GROUP AND SELECTED APPLICANTS

Such trainings are essential for hydrogeologist, hydrogeophysicists and water well drilling engineers in India to improve decision making, modernize the well assembly designing and construction procedure, reduce water well failures and maximize well yield economically. Thus, the training was designed to raise the skill of officers of Central and State Govt. agencies engaged in groundwater exploration related projects that involve aquifer assessment, well-siting, and drilling. In particular the training was intended for those who are engaged in the planning and implementation of borehole geophysical logging and data analysis programs. The registration was conducted by a web based portal that is hosted by the consultant:

<http://usgsworkshop.abhijitmukherjee.info>

There were 34 applicants from all over India been selected and invited to attend the course. Out of which 28 participants were finally successfully attended the course. In addition to that, 5 research students from the Department of Geology & Geophysics, IIT Kharagpur, had also attended the course.

The following personnel had selected and invited for the course:

No	Name	State	Organization	Position
1	NBV Reddy	Andhra Pradesh	Andhra Pradesh State Ground Water Department,	Assistant Geophysicist
2	Rajasekhra Reddy A	Andhra Pradesh	Ground Water Department	TAH
3	Sateesh Chandrapuri	Andhra Pradesh	National Geophysical Research Institute Hyderabad	Scientist
4	N.S.Dewangan	Chhattisgarh	Ground Water Survey, Water Resources Deptt. Chhattisgarh	Assistant Geohydrologist
5	Navinchandra	Gujarat	GWRDC Ltd., Gandhinagar (Gujarat	Junior

	Narsangbhai Chaudhari		Ground Water Agency)	Geologist
6	Shah Nikhil M.	Gujarat	GWRDC Gandhinagar (Gujarat Ground Water)	Jr. Geologist
7	Kuldeep Singh Mandhotra	Himachal Pradesh	Ground Water Organisation, I&PH Department Himachal Pradesh	Senior Hydrogeologist
No	Name	State	Organization	Position
8	Pawan Thakur	Himachal Pradesh	Ground Water Organisation, I&PH Department Himachal Pradesh	Senior Technical Assistant (Hydrogeology)
9	Rajesh Kumar	Jharkhand	Ground Water Directorate ,Water Resources Department, Govt. of Jharkhand	Deputy Director, Ground Water Directorate, Ranchi
10	Suganthi S	Tamil Nadu	Public Works Department, State Ground & Surface Water Resources Data Centre, Tharamani	Assistant Geologist
11	P. Srikanth	Telengana	Groundwater Dept	TAGP
12	Subash Chandra	Telengana	CSIR-National Geophysical Research Institute	Senior Scientist
13	Amuda Arjun	Telengana	Ground Water Department, Telangana State	Assistant Geophysicist
14	Virendra Kumar Upadhyay	Uttar Pradesh	U..P. Ground Water Department	Senior Geophysicist
15	Asish Tantubay	West Bengal	The State Water Investigation Directorate (SWID) Under The Water Resources Investigation & Development Department, Govt. Of West Bengal	Geologist
16	Dr. Malay Kanti Ghosh	West Bengal	State Water Investigation Directorate (SWID) Govt. Of West Bengal	Executive Engineer(Ai)
17	Rhitwik Chatterjee	West Bengal	State Water Investigation Directorate, Government Of West Bengal.	Geologist, Murshidabad.
18	Sunandan Sanyal	West Bengal	Water Resources Investigation & Development Department	Assistant Engineer

No	Name	State	Organization	Position
19	Chinmoyi Roy	West Bengal	State Water Investigation Directorate	Geologist
20	Anindita Lahiri	West Bengal	State Water Investigation Directorate	Geologist
21	Salil Bhattacharya	West Bengal	Water Resources Investigation & Development Department, Govt Of W.B	Executive Engineer(Agri-Irrigation)
22	Dr. Satyajit Biswas	West Bengal	State Water Investigation Directorate, WRI&DD, Govt. Of West Bengal	Senior Geophysicist
23	Soumyadip Das	West Bengal	State Water Investigation Directorate	Geological Assistant
24	Pratul Raychaudhuri	West Bengal	State Water Investigation Directorate, Water Resources Investigation & Development Department.	Superintending Engineer
25	Gopinath V S T	Tamil Nadu	Central Ground Water Board	Junior Geophysicist
26	B Venkateswarlu	Odisha	Central Ground Water Board	Scientist-B
27	Ajay Kumar Sinha	Chhattisgarh	Central Ground Water Board	Geophysicist
28	Basant Kumar Oraon	Chandigarh	Central Ground Water Board, NWR, Min. Of Water Resources ,	Scientist C (Senior Geophysicist)
29	Dr. Shyamal Kumar Adhikari	Bihar	Central Ground Water Board, Mer, Patna	Jr. Geophysicist
30	Smt. Mousumi Neogi Adhikari	West Bengal	State Water Investigation Directorate, WRI&DD	Geologist



Photo of the participants and students at the field



Photo of some of the participants and students at the workshop

PROGRAM CONTENTS AND SCHEDULE

The program is designed to develop an expertise in the acquisition and analysis of digital borehole logs. The modules that formed the content of the program include:

- ❖ Module 1: Review of conventional geophysical logging methods (I/s/n resistivity, EM induction, natural gamma, SP, SPR, fluid resistivity, fluid temperature)
- ❖ Module 2 : Introduction to digital log analysis using PC-based software
- ❖ Module 3 : Digital log acquisition and system operation
- ❖ Module 4 : Advanced logging methods (acoustic/optical televiewer, EM flowmeter)
- ❖ Module 5 : Image-log analysis using PC-based software
- ❖ Module 6 : Flowmeter logging and well-integrity testing
- ❖ Module 7 : Flowmeter log analysis using PC-based software

The following schedule had been fixed for the program:

Duration	Date	Week day	Schedule	Topics
Day 1	Nov-11-2014	Tuesday	10:30-11:30 13:00-17:00	Inauguration Intro to class, earth properties, geophysical logs, and caliper log lectures and WellCAD intro exercise
Day 2	Nov-12-2014	Wednesday	9:00-12:00 13:00-16:00 16:00-17:00	Nuclear, electric, and EM log lecture and exercises Nuclear, electric, and EM exercises cont. Field craft and site safety lecture and field demo day logistics and logging tools
Day 3	Nov-13-2014	Thursday	9:00-12:00 13:00-16:00 16:00-17:00	Group A & B field demo/Group C & D class project Group C & D field demo/Group A & B class project Field day wrap-up
Day 4	Nov-14-2014	Friday	9:00-12:00 13:00-16:00	Group A & B Display demo log /Group C & D field demo Group C & D Display demo log /Group A & B field demo
Day 5	Nov-15-2014	Saturday	9:00-10:00 10:00-12:00 13:00-15:00 15:00-17:00	Review class project Demo log header and analysis in WellCAD Neutron and gamma-gamma log lecture and exercises Sonic log lecture and exercises

Duration	Date	Week day	Schedule	Topics
Day 6	Nov-16-2014	Sunday		No class
Day 7	Nov-17-2014	Monday	9:00-12:00	Image log lecture and exercises
			13:00-17:00	Flow and fluid-property log lectures and exercises
Day 8	Nov-18-2014	Tuesday	9:00-12:00	Group A & B field demo/Group C& D class project
			13:00-16:00	Group C & D field demo/Group A & B demo data analysis
			16:00-17:00	Review/planning
Day 9	Nov-19-2014	Wednesday	9:00-12:00	Group A & B class project /Group C & D field demo
			13:00-14:00	Review/planning
			14:00-17:00	Group A & B field demo /Group C & D demo data analysis
Day 10	Nov-20-2014	Thursday	9:00-10:00	Review class project
			10:00-12:00	Field demo data processing and analysis
			13:00-17:00	Field demo data processing and analysis cont.
Day 11	Nov-21-2014	Friday	9:00-11:00	Final class project/examination
			11:00-12:00	Wrap-up and Valedictory Ceremony



Inaugural ceremony at Gargi Hall on 11 November 2014



Speeches of our esteemed guests at the inaugural ceremony.



Participants at the inaugural ceremony.

ARRANGEMENTS MADE:

- The organizers have coordinated and supported the training programme in collaboration with United States Geological Survey, USA and WBADMI Project at the campus of IIT Kharagpur
- The organizers have provided the space, training facilities, stationeries and other requisite support for successful completion of the course.
- The organizers have arranged the lodging and food for the participants, faculty and support members at the campus of IIT Kharagpur on twin sharing and single occupancy basis.
- The organizers have provided the local transport arrangement to the participants and trainers for the field work within the campus of the Institute.
- The organizers have supervised the drilling at two ~200 m deep boreholes with PVC casing drilled 60m apart in IIT, Kharagpur campus exclusively for the training.
- The organizers shall provide Instruments which are available to them as and when required for the demonstration purpose during the training course.
- All class work and field teaching during the course have been executed under the general technical observation and supervision of the organizers.
- According to the basic requirement of the course the organisers provided Class-room with pc for each trainee.

- The trainers provided soft copy of relevant books and lectures for individual trainee.
- Two modern digital logging machine were hired for the training in small groups of trainees.
- EM induction and EM flowmeter probes was also brought from USGS for the training.
- Arrangements were made for logging machine operation by each trainee.
- Arrangements were also made for field demonstration of logging by tools : electrical resistivity, electromagnetic induction, natural gamma radioactivity, neutron (porosity), gamma-gamma (density), temperature-fluid conductivity, electromagnetic flowmeter, sonic, magnetic susceptibility.
- The trainers also provided software on data processing and interpretation.
- The participants were also made to work on processing and interpretation of data collected from two boreholes in IIT campus.
- The organisers had arrangements for the evaluation of trainees and certificate on completion.

THE TWO BOREHOLES:

Location of the Site (IIT Khargapur Campus)

GPS & Geospatial data

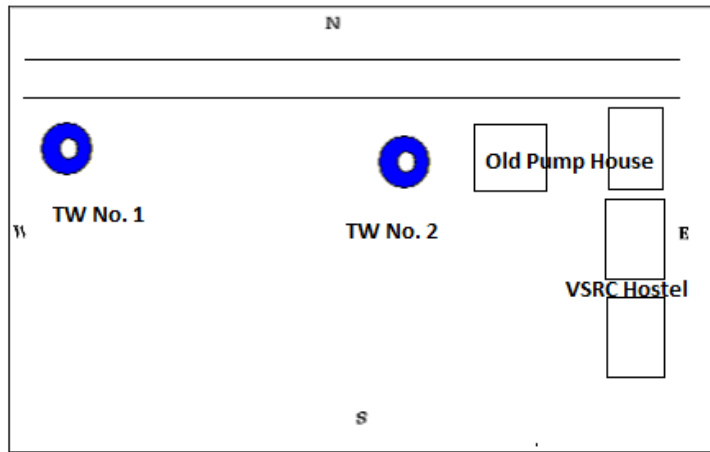
LOCATION

Latitude : 22.30961^o North

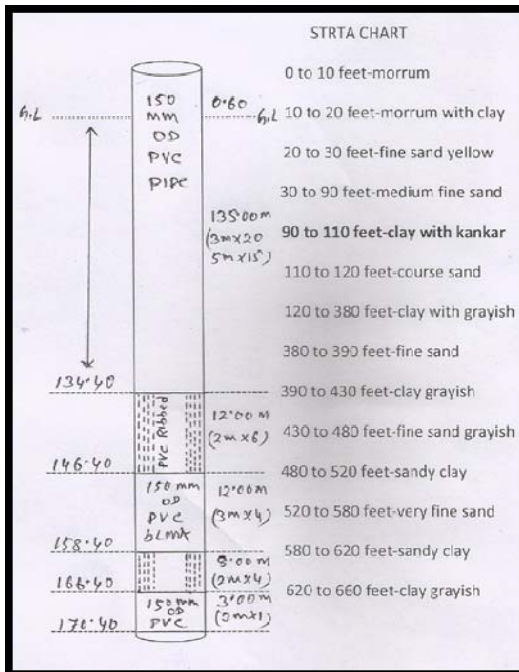
Longitude : 87.30804^o East

Height from MSL : 53 m

POSITIONAL DIAGRAM OF TUBEWELL POINT



Toposheet of Kharagpur Block Area



Drilling depth: Upto 175mts.

W1:

Drilling depth: Upto 200mts.

- 0'--10' Surface Sand & Moraine (Brown)
- 10'- 20' Moraine Sand (Red Brown)
- 20'- 30' Fine Sand (Yellow)
- 30' - 80' Medium Sand (Yellow)
- 80' - 90' Sandy Clay (Yellow)
- 90' - 120' Clay (Yellow Red)
- 120' - 130' Fine Sand (Yellow)
- 130' - 135' Clay (Yellow)

135' - 150' Medium Sand (Yellow)
150' - 220' Clay (Grey)
220' - 255' Fine Sand (Grey)
255' - 275' Clay (Yellow)
275' - 290' Coarse Sand (Grey white)
290' - 300' Fine Sand (Grey White)
300' - 310' Medium Sand (Grey White)
310' - 320' Clay (Grey)
320' - 335' Medium Sand (Grey White)
335' - 380' Clay (Grey)
380' - 390' Fine Sand (Grey Yellow)
390' - 430' Clay (Grey Yellow)
430' - 460' Fine Sand (Grey)
460' - 480' Clay (Grey)
480' - 490' Fine Sand (Grey)
490' - 560' Clay (Grey)



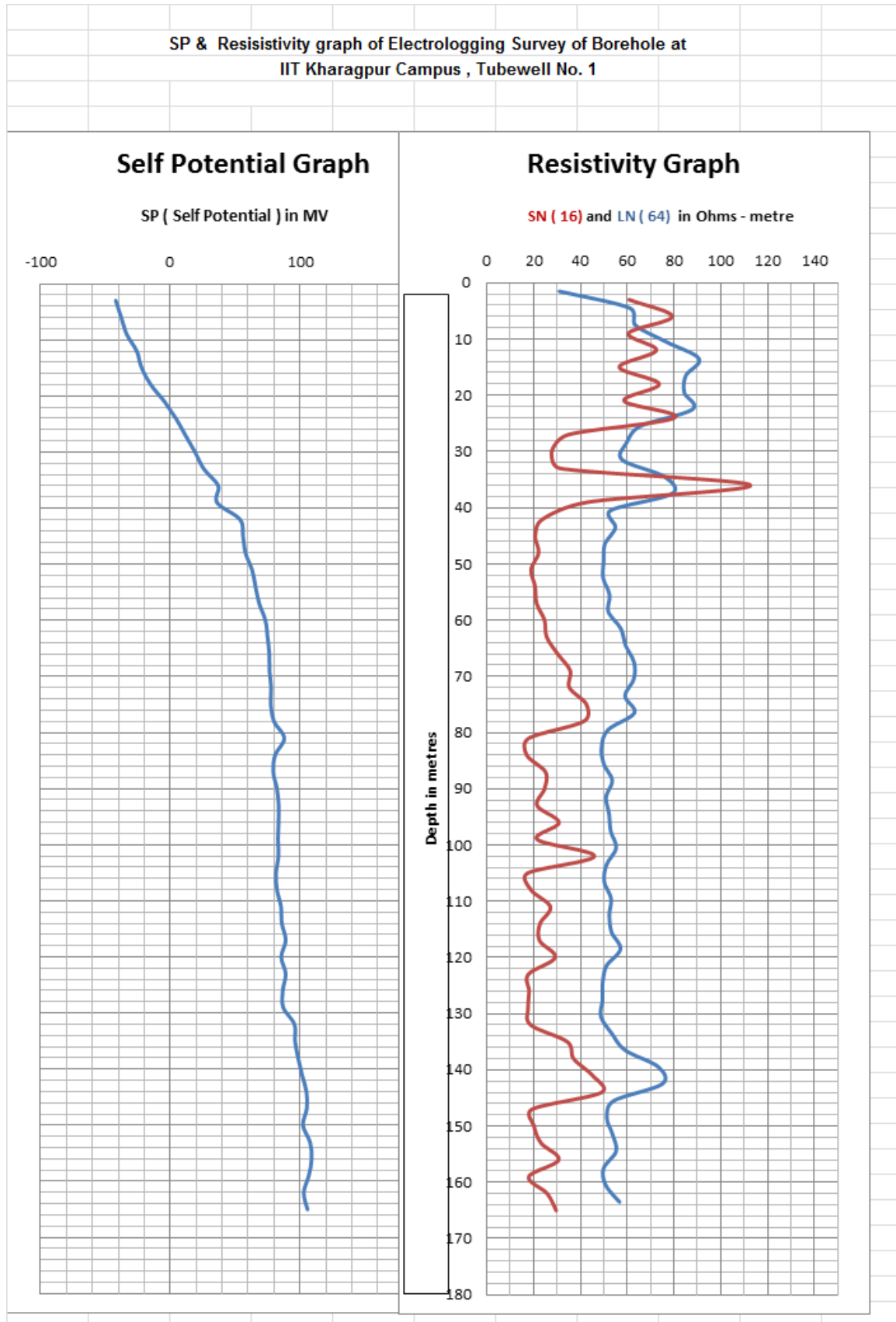
LITHOLOGS OF THE 200m BOREHOLE (TW2):

DEPTH (Ft)	Sediment	Oxic conditions	Images
10	LATERITIC GRANULES	OXIDISED	
20	LATERITIC DUST	OXIDISED	
30	MEDIUM GRAINED SAND	OXIDISED	
40	COARSE GRAINED SAND	OXIDISED	
50	COARSE GRAINED SAND	OXIDISED	
60	MEDIUM GRAINED SAND	OXIDISED	
70	MEDIUM GRAINED IRON	OXIDISED	
80	VERY COARSE GRAINED SAND	OXIDISED	
90	SILT	OXIDISED	
100	SILT	OXIDISED	
110	SILT	OXIDISED	
120	VERY COARSE GRAINED SAND	OXIDISED	
130	SILT	OXIDISED	
140	SILT	OXIDISED	
150	SILT	OXIDISED	
160	SILT	REDUCED	
170	CLAYEY SILT	REDUCED	
180	SILT	REDUCED	
190	CLAYEY SILT	REDUCED	
200	CLAYEY SILT	REDUCED	
210	SILT	REDUCED	
220	CLAYEY SILT	REDUCED	
230	SILT	REDUCED	

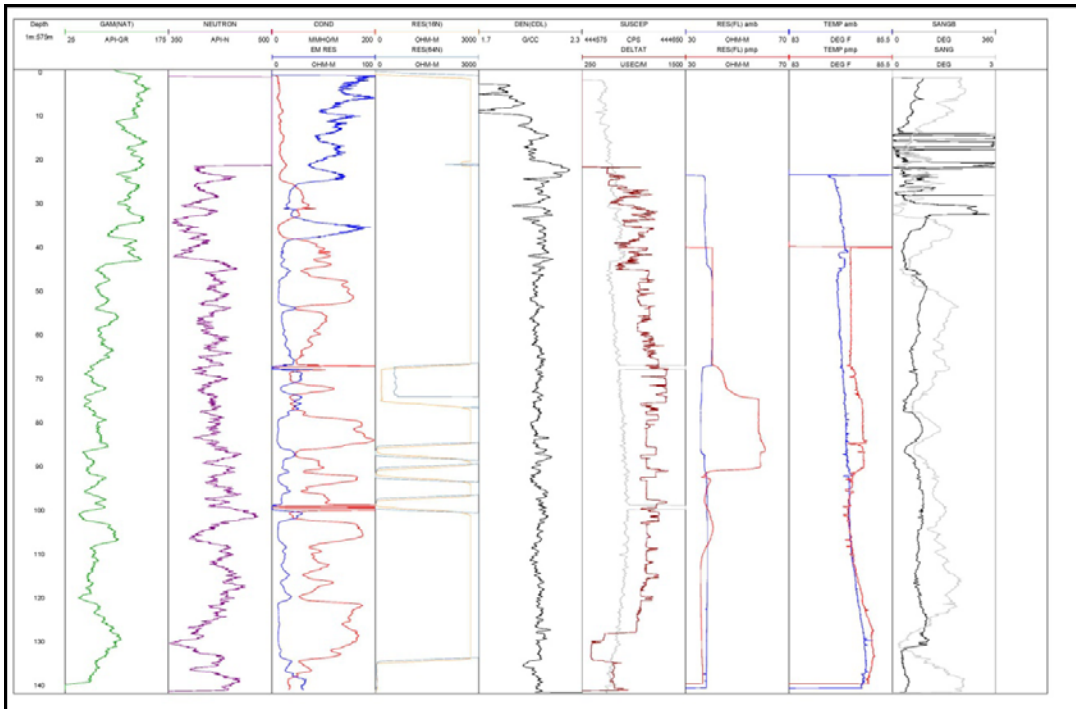
480 FINE SAND	REDUCED
490 SILTY CLAY	REDUCED
500 VERY FINE SAND	REDUCED
510 SILTY CLAY	REDUCED
520 CLAY	REDUCED
530 VERY FINE SAND	REDUCED
540 VERY FINE SAND	REDUCED
550 VERY FINE SAND	REDUCED
560 VERY FINE SAND	REDUCED
570 VERY FINE SAND	REDUCED
580 VERY FINE SAND	REDUCED
590 SILTY CLAY	REDUCED
600 MEDIUM SILT	REDUCED
610 FINE SILT	REDUCED
620 CLAYEY SILT	REDUCED
630 SILTY CLAY	REDUCED
640 CLAY	REDUCED
650 SILTY CLAY	REDUCED
660 SILTY CLAY	REDUCED



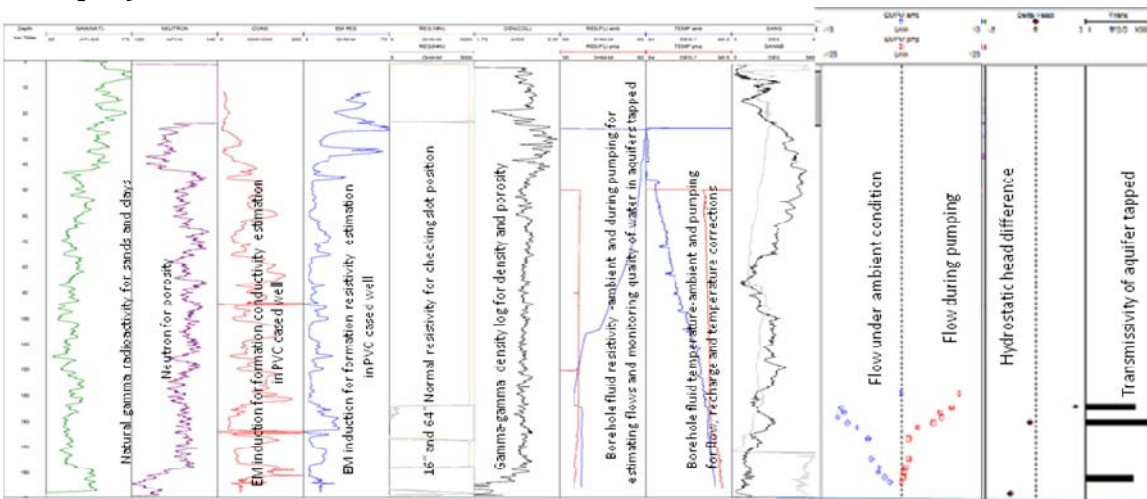
DATA GENERATED AT THE BOREHOLES DURING TRAINING:



Different types of log data generated by the trainees on BOREHOLE 1 (IIT, Kharagpur Campus)



Different types of log data generated by the trainees on BOREHOLE 2 (IIT, Kharagpur Campus)



Dr F Paillet from USGS making preparations for calibration of EM induction tool brought from USGS



Dr Lane making preparations for Neutron and Gamma-Gamma Logging at Borehole 1



Logging operation at Borehole 1. Logging technicians and crew from M/s MAPL, Asansol, West Bengal who supplied the Century make digital loggers are assisting the trainees.



Wire-logging at the field training site:



Some more photographs of the field work.













DATA ANALYSIS AND INTERPRETATION USING SOFTWARE:

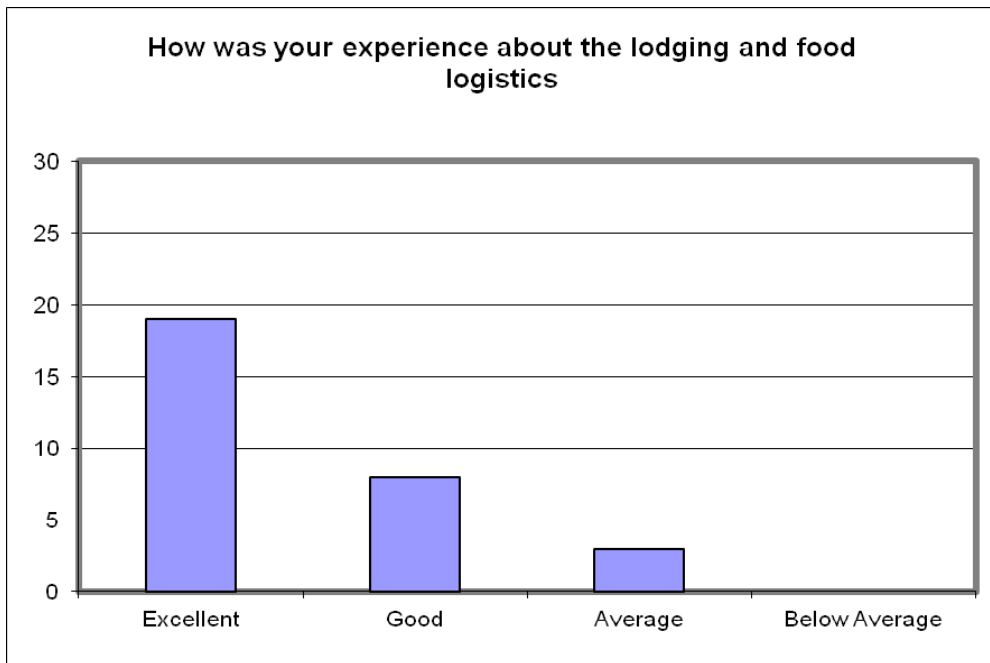
During the training extensive field demonstration of various geophysical logging tool operation was done. It was followed by the operation of the logging by individual trainee. The tools used and the parameters analyzed are given in the following table

Tools	Parameter	Remarks
Natural gamma radioactivity	Sand and clay content	Very useful in sedimentary area particularly coastal tracts for identifying aquifer zones
Neutron (active nuclear source)	Porosity	For quantitative analysis
EM induction	Formation resistivity in PVC cased well	Very useful in sedimentary area identifying fresh water aquifer zones in combination with natural gamma. Can be used in PVC cased wells and also for quality monitoring
Normal resistivity	Formation resistivity	Very useful for identifying sand and clay layers and fresh water aquifers in combination with natural gamma. In PVC cased wells slot position can be checked
Gamma-gamma density	Density/porosity	For quantitative analysis
Borehole fluid resistivity-temperature	Borehole fluid quality/temperature variations	Useful for aquifer water quality and monitoring
EM flow meter	Flow from aquifers tapped hydrostatic head and aquifer hydraulic parameter	Useful for individual aquifer yield and quantitative analysis
Magnetic susceptibility	Magnetic mineral content	Not essential
Sonic	Porosity/fractures	For quantitative analysis
The Acoustic Televiewer (ATV) could not be run due to its break down reported by the logging company		

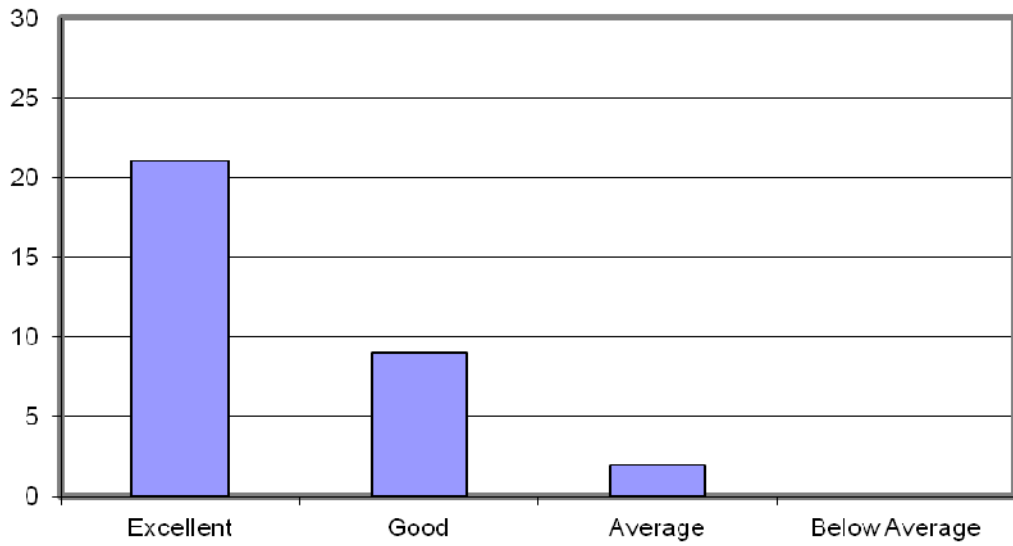
Feedback of the students:

A student's feedback programme has been conducted by a web based portal that is hosted by the consultant. The results of the same, are shared below:

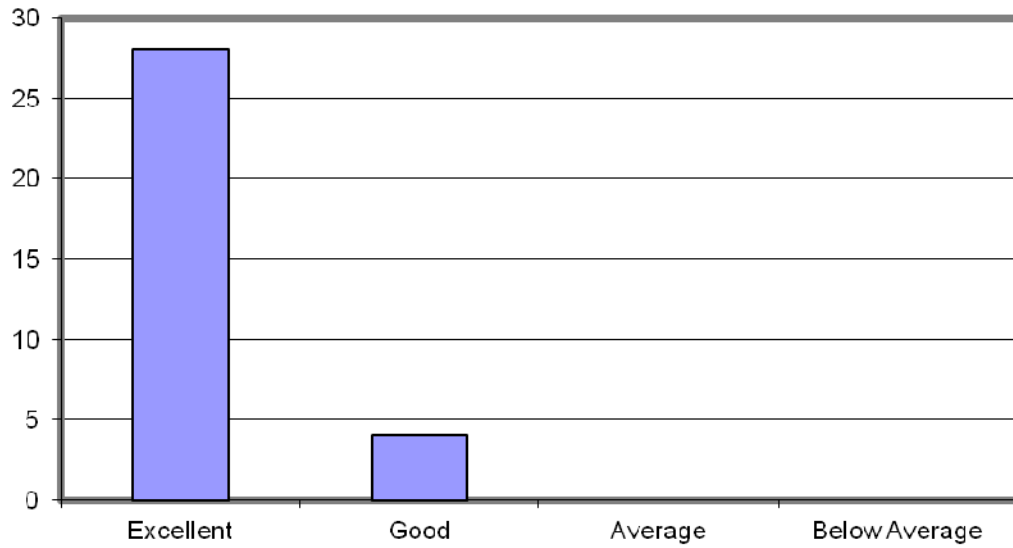
	Excellent	Good	Average	Below Average
How was your experience about the lodging and food logistics	19	8	3	0
How was your experience about the class room environment	21	9	2	0
How was your experience about the quality of the teachers	28	4	0	0
How was your experience about the field logistics	21	11	0	0
How was your experience about the organizer	22	8	2	0
How would you rate the overall experience	21	10	1	0



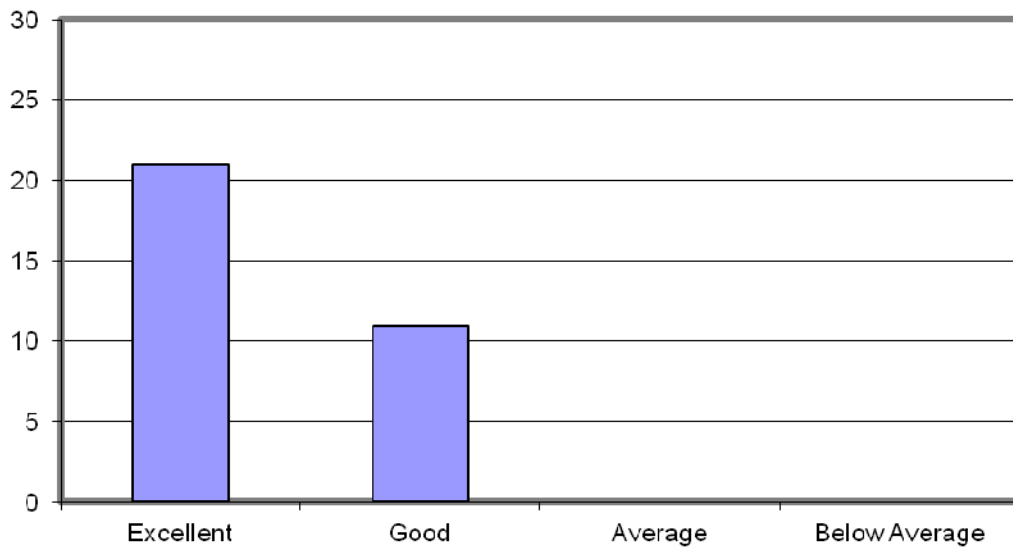
How was your experience about the class room environment



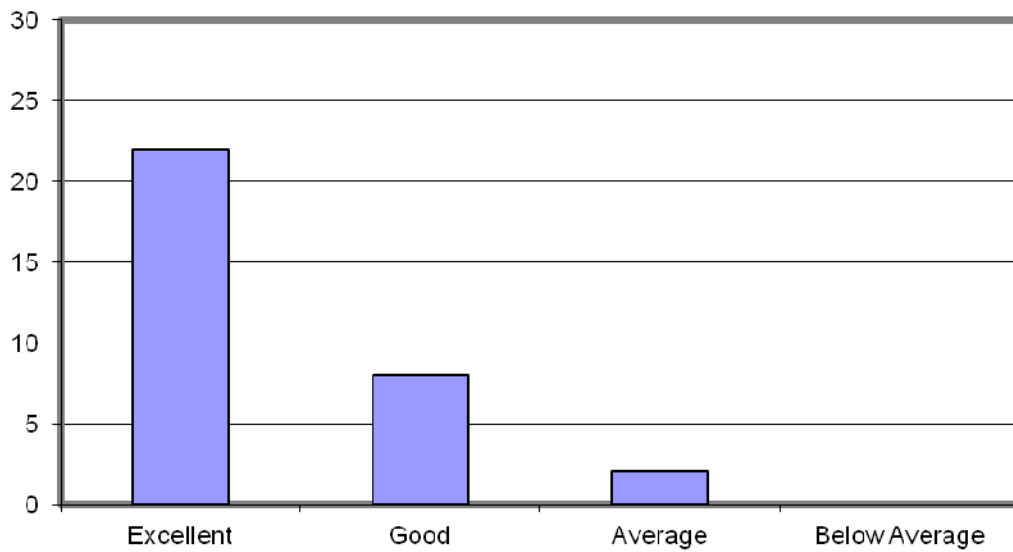
How was your experience about the quality of the teachers



How was your experience about the field logistics



How was your experience about the organizer





VALEDICTORY FUNCTION:







CONCLUSION:

The training-workshop on “Borehole Geophysics for Groundwater” is a timely, maiden, successful attempt by The World Bank towards hydrogeophysical capacity building of the States essentially required for sustainable development and management of groundwater in India and particularly for the active participation of the States in country-wide upscaling of aquifer mapping. It has given a rigorous and unique exposure to international standard borehole logging of water wells and bench-marking practices to be emulated and initiated a thought process amongst the geologists, geophysicists and engineers for a modern scientific outlook to the water well drilling and construction process. It has provided a vision to look ahead of the routine programme and get the maximum hydrogeological information out of a borehole drilled required to develop, exploit and manage the aquifers effectively. It has to be followed by the strengthening of hydrogeophysical infrastructure of the States in terms of professional resource and the technology to derive the best from the training course.

