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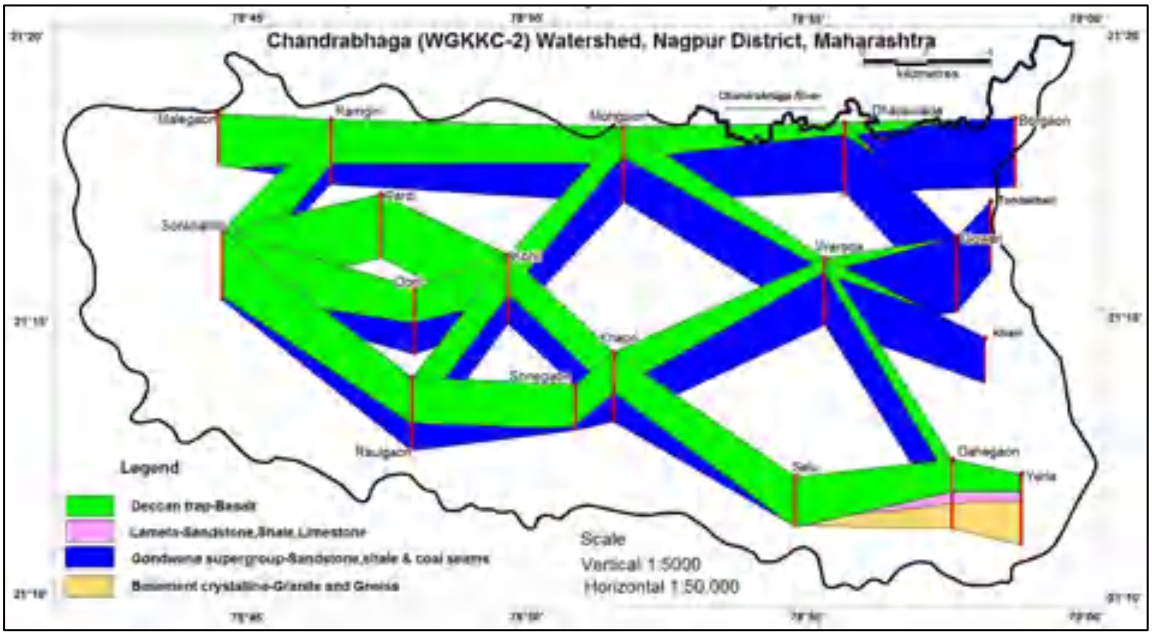
GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES,
RIVER DEVELOPMENT AND GANGA REJUVENATION

CENTRAL GROUND WATER BOARD



प्रायोगिक जलभृत मानचित्रण परियोजना का प्रतिवेदन
चंद्रभागा वाटरशेड (डबल्यूजीकेकेसी-2) नागपुर जिला, महाराष्ट्र

REPORT ON PILOT PROJECT ON AQUIFER MAPPING IN CHANDRABHAGA WATERSHED (WGKKC-2), NAGPUR DISTRICT, MAHARASHTRA

मध्य क्षेत्र, नागपुर CENTRAL REGION, NAGPUR

दिसंबर-2015 December-2015

K. B. Biswas
Chairman

सत्यमेव जयते

केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास
एवं गंगा संरक्षण मंत्रालय
भारत सरकार
नई दिल्ली

Central Ground Water Board
Ministry of Water Resources,
River Development and Ganga Rejuvenation
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FOREWORD

Increasing development of ground water to meet the requirements of various segments has resulted in the over-exploitation of this vital natural resource in parts of the country and consequent adverse environmental impacts include, deepening water levels and drying up of shallow wells, reduction in sustainability of wells and seawater ingress in coastal freshwater aquifers. Contamination of ground water due to natural and anthropogenic causes has also increased substantially in the recent decades. The anticipated impact of global warming and climate change are also considered to add to further complicate the issues plaguing the water resources sector in India in the not so distant future. Sustainable development of ground water through judicious management interventions becomes very important to ensure the water security of the future generations.

It is in this context that the Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India decided to take up the National Aquifer Mapping and Management (NAQUIM) Programme, aimed at detailed and systematic study of the major aquifer systems in the country and formulation of management plans for sustainable development of their ground water resources. The Programme envisaged various activities such as compilation of all available data, analysis of data gaps and generation of additional data to fill them, preparation of detailed aquifer maps and formulation of management plans. Various conventional and modern techniques of field data generation, data processing and analysis including integration of data on a GIS platform and numerical groundwater modelling were expected to be used for the programme.

With a view to understand the applicability and efficacy of the above-mentioned techniques in different hydrogeological settings, pilot projects on aquifer mapping were taken up in Six different Hydrogeological terrains in the states of Bihar, Rajasthan, Maharashtra, Karnataka and Tamil Nadu.CSIR-NGRI was engaged as a consultant by CGWB to facilitate use of advanced geophysical techniques in the programme. During the course of the study, groundwater issues have been identified by CGWB specific to the area. With inputs from aquifer mapping studies, aquifer response models have been formulated and various strategies have been tested to arrive at optimal aquifer management plan for sustainable management of precious resources.

This is one among the six reports being brought out based on the studies taken up in the pilot projects. The findings are brought out in the report very coherently and I would like to place on record my appreciation for the excellent work done by the team. I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the area.

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PREFACE

Around 92% of areas of Maharashtra and entire area of UT of Dadra and Nagar Haveli are occupied by hard rocks. The uneven distribution of groundwater in the State can be mainly attributed by highly heterogeneous lithology and variability and regional variation of rainfall. The basic characteristics of hard rock aquifer coupled with variability physiography and rainfall place the limitations on the availability of groundwater. Therefore, the scientific understanding and management of groundwater is essential for optimal and sustainable use of this limited and precious natural resource to fulfil the agricultural, industrial and domestic need of the state in terms of quality and quantity. In order to address the upcoming challenges, it has become imperative to delineate the aquifers and formulate Aquifer Management Plan to establish the priorities of ground water use with community involvement at various levels of implementation.

Central Ground Water Board, Central Region, Nagpur has been engaged in collection of hydrogeological data and preparation of reports since last 50 years on various aspects of groundwater. In the recent past the focus has shifted from development to management of ground water. The various aquifer systems, which are repository of groundwater, shall have to be developed scientifically. This warrants that the management of the ground water has to be focused on the aquifer and incidentally these are not evenly distributed throughout the Country/State. Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols are the real derivatives of the aquifer mapping exercise and will find a place in the output (the map) and the outcome (changes within social behaviour that reflects these protocols). Some important socio-economic information at the scale of well have been form the basic sample of groundwater information and are collected as part of the aquifer mapping effort to define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000 scale. Thus, the project was undertaken with broad objectives of the pilot project and the aquifer geometry is defined with precise lateral and vertical demarcation including hydraulic characteristics of both shallow and deeper aquifers down to the depth of 200 m. Followed by, preparation of Aquifer Maps indicating dispositions of aquifers along with their characterization for formulation of the Aquifer Management Plans for sustainable development and management of ground water resources.

During the project, apart from the hydrogeological and traditional geophysical surveys by CGWB, the Electrical Resistivity Tomography (ERT), Ground Transient Electromagnetic (TEM) and SkyTEM (Time-domain heli-borne electromagnetic system) methods have also been applied first time in basaltic terrain to delineate the aquifer system up to 200 m depth. These advanced geophysical investigations and their interpretation has been carried out through National Geophysical Research Institute (NGRI), which is a premier research organisation under CSIR (Ministry of Science and Technology).

This report has clearly brought out the precise mapping of aquifers on 1:50,000 scale for studying of aquifer-based activities. One of the main objective of the Pilot Project on Aquifer Mapping was also to upscale the aquifer mapping activity across entire length and breadth of the Maharashtra State and UT of Dadra & Nagar Haveli. Based on the experiences of Pilot Project, the National Aquifer Mapping (NAQUIM) was also initiated in the 12th five year Plan (2012-17) and so far the water stressed areas of about 18,000 sq.km has been completed under NAQUIM.

The data requirements for compiling the report were met earnestly and efficiently by the respective departments especially, CGWB, CSIR-NGRI, GSDA, GSI, MRSAC. I will also like to place on record, the whole hearted efforts put in by all the contributors in carrying out the field work and compiling this report especially Dr. P.K. Jain, Superintending Hydrogeologist and Nodal officer, Sh. S. D. Waghmare, Assistant Hydrogeologist, Sh. P. Narendra, Sc-D (GP), Dr. Bhushan R. Lamsoge, Senior Hydrogeologist, from CGWB, CR, Nagpur. Sh. M. K. Rafiuddin, Sc-D, CGWB, SR, Hyderabad, Dr. V. Arulprakasam, Sc- D (GP), SECR, Chennai, and Dr. N. C. Nayak, Sc-D, SER, Bhubaneshwar. My sincere thanks are also due towards Sh. Avanish Kant, Senior hydrogeologist, MoWR, RD & GR for his constant follow up and the World Bank and their representatives for their strategic inputs.

Sh. K. B. Biswas, Chairman, Dr. Dipankar Saha, Member (SAM), have been the moving spirit for preparation of this report. Dr. S. C. Dhiman and Sh. Sushil Gupta and Dr. R. C. Jain, Chairman then CGWB have been the constant source of guidance and inspiration. Their efforts to arrange for timely approvals of financial inputs has provided much needed support for implementation of the project. The officers at CHQ, CGWB, Faridabad in HP and pilot project cell have time to time provided necessary inputs for successful completion of the project.

I am sure that this report will provide better insight into the groundwater regime with its all ramifications and a foundation for evolving scientific and viable strategies for efficient management of aquifers with sustainability for the benefit of policy makers and stake holders.

Regional Director

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Abbreviations

CGWB	Central Ground Water Board
GSI	Geological Survey of India
GSDA	Groundwater Surveys and Development Agency
ET	Evapotranspiration
K	Hydraulic Conductivity
T	Transmissivity
Sy	Specific Yield
S	Storativity
EC	Electrical Conductivity
µS/Cm	Micro Siemens/Centimeter
MCM	Million Cubic Meters
GHB	General Head Boundary
msl	Mean Sea Level
bgl	Below Ground Level
a msl	above mean sea level
m bgl	Meters below ground level
m agl	Meters above ground level
RMSE	Root Mean Square Error
EW	Exploratory Well
OW	Observation Well
KOW	Key Observation Well
DTWL	Depth to Water Level
TCG	Trap Covered Gondwana
BG contact	Basalt-Gondwana contact

Executive Summary

Aquifer mapping is a multi-disciplinary holistic scientific approach for *aquifer characterization* and it leads to comprehensive *aquifer-based groundwater management plans.* The pilot project on aquifer mapping representing a type locality of hard rock Basalt i.e., Chandrabhaga watershed (WGKKC-2) has been selected, occupying an area of 360 sq. km., and situated in the north western part of Nagpur district covering about 60 villages in parts of Nagpur (rural), Kalmeshwar and Katol talukas. The major part is occupied by Deccan trap basalt (313 sq. km) of Upper Cretaceous to Eocene age. A small part (47 sq.km.) is occupied by Gondwana formation of Permian age and exposed in the NE part and also a small linear stretch south of area. The outcomes of the project are envisaged to establish the efficacy of various hydrogeological and geophysical techniques considering different hydrogeological conditions and to establish a protocol for hydrogeological and geophysical investigations when aquifer mapping shall be up-scaled for the entire country in general and for basaltic terrain in specific. The erratic rainfall pattern; limited aquifer thickness of unconfined aquifer (up to 15-20 m bgl); drying up of aquifer after January; existence of unknown and unpredictable deeper aquifer systems of basalt, failure of dug wells/bore wells due to unscientific selection and delineation of boundary between Deccan Trap basalt and Gondwana sandstone, were the major issues tackled during the project.

During the project period 2011-2014, data gap analysis has been carried out and then the data has been generated with systematic planning. The ground water exploration and advance geophysical survey has been outsourced while rest of the activities viz, micro-level hydrogeological survey, ground water regime monitoring, infiltration tests, pumping tests on dug wells, water quality analysis, geophysical survey for VES, VLF, GRP etc., has been carried out by the team of hydrogeologist and geophysicists of CGWB, CR, Nagpur.

Physiographically, Chandrabhaga watershed forms the Moderately Dissected Plateau (MDB) of Deccan trap (basaltic terrain) where four sets of lineaments are interpreted, which trending in NE-SW, NW-SE, N-S and E-W directions.

The area is drained by the ephemeral Chandrabhaga River and its tributaries are Saptadhara River, Mortham Nala. The drainage is dendritic and the flow direction of main stream i.e., Chandrabhaga is from west to east and its tributary from south to north, the main stream ultimately joins the Kolar river outside the watershed.

Major part of the watershed is occupied by clayey soil known as Black Cotton Soil followed by clayey loam observed along the northern fringe of the watershed. The soil infiltration rate ranges

from 4 mm/hr at Tondakhiri for the sandy loam to clay loam soil type to 40.02 mm/hr at Dhapewada for clay loam soil type.

The normal annual rainfall at Kalmeshwar and Katol is 985.4 mm and 973 mm respectively.

Major part of the watershed is having depth of weathering in the range of 3 to 6 m bgl, followed by < 3 m bgl and 6 to 9 mbgl depth range, which increases from west to east and towards the north-eastern part it is maximum near to the confluence of Chandrabhaga river with local tributary.

Agricultural activity especially orange cultivation is prominent followed by pulses and cotton. The wasteland, notified and un-notified forests are mostly observed in the western part of the watershed, which is mostly hilly.

14 exploratory and two observation wells upto 200 m depth have been constructed, in addition to existing 9 wells in the Chandrabhaga watershed to decipher the lateral and vertical disposition of the aquifer system prevailing in the area and ground water potential of Gondwana formation occurring below Basalt.

The north-eastern part of the watershed is extensively covered by rocks of Gondwana Supergroup comprises of Kamthi Sandstone and Shales. The central part is consisting of Trap Covered Gondwana Formation where the thickness of traps ranges from 62.00 m bgl (Waroda) to 195.00 mbgl (Sonkhamb). Towards extreme south-eastern part, Archaean gneisses occur below the traps (Dahegaon), whereas towards the extreme western part of the watershed thickness of the Deccan trap is observed more than 200 mbgl.

Extensive study of the ground water exploration indicated that there are three aquifer system exist in the pilot project area, and are.

a. *Aquifer I* - Unconfined aquifer. Occurring in major part of the area occupied by basaltic formation and Gondwana Supergroup in the northeastern part. This aquifer generally occurs to the depth of 20 to 30 m bgl and mostly tapped by the shallow dug wells.
b. *Aquifer II* – Semi-confined to confined aquifer. Generally occurs below 30 mbgl Deccan trap basalt occupied by major parts and Gondwana Supergroup in the notheastern part. The thickness of aquifer varies from 0.50 cm to 6 meters in Basaltic formation and 3m to 34 m in Gondwana formation and are mostly tapped by the deep bore/tube wells.
c. *Aquifer III* - It is mostly 'Trap Covered Gondwanas in major parts and Trap Covered Gneisses' (TCG) in southeastern part. Generally occurs as semi-confined to confined conditions at places, they also exhibit unconfined condition and occur at

shallow depth where the thickness of basalt is less, and are tapped by the dug wells. Otherwise, tapped by deep bore/tube wells in the major parts of the area covered by basaltic formation at the top.

Pumping tests were conducted on seven exploratory wells to determine the parameters of deeper aquifers. The drawdown ranges between 6.34 and 36.97 m and recorded Transmissivity (T) of aquifer in basalts is 30 m^2/day (Sonkhamb) whereas in Gondwana sandstone transmissivity varies from 15 m^2/day (Khairi Lakhmaji) to 173 m^2/day (Kohli). The storativity (S) 0.001 is estimated at Dhapewada. In addition, 21 pumping tests have been conducted on open dug wells to determine the parameters of the shallow aquifer. The analytical results of the tests indicated the transmissivity (T) for basaltic aquifer ranges between 1.04 and 72.56 m^2/day whereas the transmissivity (T) for sandstone aquifer ranges between 3.64 and 11.37 m^2/day.

Advanced geophysical techniques viz., Electrical Resistivity Tomography (ERT), Ground Transient Electromagnetic (TEM) and SkyTEM (Time-domain heli-borne electromagnetic system) methods have also been applied to delineate the aquifer system up to 200m depth. National Geophysical Research Institute (NGRI), Hyderabad a premier research organisation under CSIR (Ministry of Science and Technology) has provided the technical consultancy to carry out the advance geophysical investigations. These techniques have been used first time in basaltic terrain which are rapid, time saving, and found very effective for covering larger and inaccessible area with closed spaced data.

Application of ERT shows significant signatures of structural controls like lineaments and to delineate layered nature of flows but the results are not effective enough to distinguish between two successive lava flows. The findings from TEM and VES are found complementing each other, and are further validated by available borehole lithologs. However, TEM provides significant information of shallow depth up to 90 m bgl. Ground TEM data have not shown good result/information in basaltic terrain especially for shallow aquifers.

Heliborne or SkyTEM investigation has revealed fascinating results on the aquifer systems and its spatial characteristics covering Gondwana, Trap covered Gondwana and Trap covered Gneiss formations present in the study area. The results, in general, helped in mapping the litho-units in 3-Dimension. Besides, it helped in reconstructing the concealed subsurface spatial disposition of structures controlling the groundwater dynamics. SkyTEM survey is useful to demark the different litho-units having significant difference in conductance of the material.

The integration of Heli-TEM data with ground geophysical survey and inputs from borehole lithologs has been to derive the precise basaltic flow thickness and various layers of Gondwana formation. However, the SkyTEM data fails to identify or demarcate red/grey/green bole layer of significant thickness. Aquifer disposition could not be made precisely, especially the fracture in basaltic terrain saturated with ground water.

In Aquifer-I, shallow ground water levels (3 to 6 m bgl) are observed as isolated patches in southwestern and northern parts whereas the moderate ground water levels of 6 to 9 mbgl are observed in major parts of the watershed. Deeper ground water levels 9 to 12 and more than 12 mbgl are observed in north eastern and eastern parts of the watershed in a area occupying by Gondwana formation.

The ground water level in Aquifer-II and III in major central part range from 50 to 73 m bgl. The eastern and western part of the watershed shows gradual decrease in ground water level i.e., up to 20 m bgl while in the Sandstone (Aquifer-II) ground water level is observed shallow i.e., up to 7 m bgl. The deeper ground water levels are due to the potential zones encountered at depth between 45 and 197 m bgl.

The ground water resources (2011) indicate that the stage of ground water development is about 80%. Compared with 2004, the recharge has been increased by about 5% and draft has increased by about 22%. The ground water is mainly used for irrigation purpose (about 5368 ham) out of total draft of 5545 ham.

Ground water in Aquifer-I is affected by nitrate contamination as about 79% of samples show higher nitrate concentration (more than 45 mg/L) while the nitrate in deeper Aquifer-II has been found beyond permissible limit at few places only. In Aquifer-II, fluoride occur below MPL of 1.5 mg/l. Heavy metal analysis indicted that Aquifer-I is more contaminated as compared to deeper ground water Aquifer-II where the presence of Fe and Pb noticed. However, ground water from Aquifer – I and II is good and potable for drinking, domestic and irrigation purpose, except at one or two locations, where nitrate contamination is observed and at places the salinity hazard due to excess of magnesium is recorded.

A two layer *ground water flow model* has been generated using Visual MODFLOW software to resolve the issues/problems in the Chandrabhaga watershed. Four boundary conditions i.e., Constant Head Boundary, Linear Gradient River Boundary and No Flow Boundary and Drain have been assigned to the model area at different parts as per requirement and suitable values of different parameters are assigned considering the local hydrogeological conditions. The unit draft as deciphered from the field observation is considered. A uniform rate of pumping is assigned to the region for the whole non-monsoon season of 215 days (November to May).

For transient state calibration ground water level data from June-2012 to October-2014 of 52 observation wells has been used. The approximate water table data as deciphered from the pre-monsoon depth to water level map is considered as initial head values for running the transient model. Multiple stress periods were included into the model and data for each stress period was entered separately. After entering all the input parameters for each stress period, the model was run for the transient state calibration. With the convergence of the transient model, scenario of different stress period is generated for 30, 60, 90, 120, 150, 165, 190, 215, 265, 315 and 365 days. The normalized root mean square error is calculated for each stress period and found to be between 6.8% to 8.78%. Transient calibration shows a good agreement to the actual field condition. The sensitivity analysis indicates that it is less sensitive to specific yield and gives only slight change in head value. The model is found to be quite sensitive to changes in hydraulic conductivity. The parameters determined during transient calibration and verification is used to predict the response of the system to future events by running the model for predictive simulation. Considering issues/problems in the Chandrabhaga watershed, and to achieve the objectives, two scenarios were suggested for shallow unconfined Aquifer-I.

The Aquifer Management Plan, thus, generated has been found more realistic for the Aquifer-I comprising of Basalt and Sandstone,

Scenario-1: construction of check dam on Chandrabhaga river- This will raise the ground water level in the area. The total improvement will be around 289273 m^3, which is 9 % of the total recharge from the river to the aquifer before construction of the structures. The Chandrabhaga watershed (WGKCC-2) has a heavy ground water withdrawal for agriculture especially for orange cultivation, this will of immense help during the dry seasons.

Scenario-2: Construction of recharge wells to enhance ground water recharge and dilution of pollution - The specially designed recharge wells tapping the full thickness of the aquifer (20-30 meters) to obtain maximum transmissivity so as to accept maximum amount of harvested water. 25 recharge wells can be added on the river grids with a recharge rate of 300 m^3/day for the full rainy season and zero recharge rate for the rest of the period. This will enhance the ground water resources of the area by 1125000 m^3 annually.

Site-specific ground water management plans has been suggested for ground water stress area. Unconventional measures like fracture seal cementation (FSC), Hydro-fracturing, Well jacketing (WJ), Borewell Blasting Technique (BBT) etc.; soil and water conservation methods such as gabion structures, farm ponding, nala widening and bunding, Under Ground *Bandhara* (UGB) etc., along with rooftop rain water harvesting are also recommended to enhance the water quantity. Besides this adoption of modern irrigation practices like drip irrigation, sprinkler etc., in place of traditional irrigation will further reduce the groundwater draft up to 30 % to 40 %. Change the cropping pattern by low water intensive crop would also help in ground water management.

Considering the local physiographical and hydrogeological set up and source water availability to augment the ground water the following artificial recharge methods are suggested for individual villages

a. Construction of Percolation tanks and check dams on 2nd and 3rd order stream
b. Construction of KT weir and UGB at mini and micro-watershed level and
c. Periodic maintenance by repair and desilting of existing water conservation structures before onset of monsoon is also proposed

The major quality vulnerable area is restricted to industrial area of Kalmeshwar town. The suggested Aquifer Management plan is if the area would be recharged with fresh water through 25 recharge wells, then it could be possible to dilute the ground water pollution. This will, in turn, reduces the contamination and also enhance the ground water level in the area. However, there is need to enforced to regulatory measures to stop the untreated/semi-treated disposal of industrial effluent to the ground water system.

The experiences gained from the pilot project on aquifer mapping (AQMAH) in Chandrabhaga watershed helps to develop a protocol for upscaling the various activities of the NAQUIM area of Maharashtra and UT of Dadra and Nagar Haveli. Following are the protocols for aquifer mapping in the State as well as in the Country may be adopted

STEP 1 **:** Acquiring Heli TEM and Heli MAG through Advance geophysical survey

STEP 2 **:** Validation by ground geophysical, hydrogeological studies and exploratory drilling.

STEP 3 **:** Data integration and interpretation for 3D aquifer model and characteristics

1 INTRODUCTION

The Working Group on 'Sustainable Groundwater Management' constituted by the Planning Commission to prepare the 12th Five Year Plan has recommended that the *'Aquifer Mapping'* shall be taken up as a co-ordinated effort for sustainable management of ground water. The primary objective of the Aquifer Mapping Exercise is "*Know your Aquifer, Manage your Aquifer"*. As per the recommendations of the Working Group, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose". This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. In short, Aquifer mapping is a multi-disciplinary holistic scientific approach for *aquifer characterization* and it leads to comprehensive *aquifer-based groundwater management plans*. As a first step, the need for precise mapping of aquifers on 1:50,000 scale should be initiated for studying of aquifer-based activities at a large scale to develop a strategy for improved and sustainable management of groundwater.

In pursuance of the above, the CGWB has launched the National Project on Aquifer Mapping & Management (NAQUIM) in its 12th Plan for mapping and managing the entire aquifer systems in the country. To establish a methodology for the National Project on Aquifer Management, the CGWB has undertaken a pilot study of six areas in different hydrogeological terrains. The pilot project areas are in the States of Bihar (AQBHR), Karnataka (AQKAR), Maharashtra (AQMAH), Rajasthan (AQRAJ & AQDRT), and Tamil Nadu (AQTND). Groundwater over-exploited areas and water quality vulnerable areas are being given priority in the NAQUIM.

The pilot project envisages revisiting aquifers by understanding them better through the aquifer mapping programme with a clear-cut forward link to participatory groundwater management. Comprehensive plan for participatory groundwater management based on the understanding and outcome of aquifer mapping shall be taken up. Stakeholders should be motivated through appropriate mechanisms by exploring the possibility of a dedicated programme on groundwater or implementation through other appropriate programmes.

The pilot project of Aquifer mapping programme in the State of Maharashtra (AQMAH) is been taken up in the Chandrabhaga Watershed (WGKKC-2) of Nagpur district, Maharashtra. As per CGWB and GSDA's watershed, in nomenclature of ***WGKKC-2***, 'WG' stands for Wainganga river, 'K' for Kanhan river, again 'K' for Kolar river and 'C' for Chandrabhaga river. The Pilot Project has been taken up to study the complex aquifer system of the basalt which occupies more than 82% of the state area and also the various other formations exposed or occur above and below basalt. Thus, the experience gained from multidisciplinary micro-level aquifer mapping on pilot basis shall be utilized to map the aquifers in the whole country.

1.1 Objectives and Scope

The objectives of the pilot project are

i. To define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000 scale.

ii. Intervention of new geophysical techniques and establishing the utility, efficacy and suitability of these techniques in different hydrogeological setup.

iii. Finalizing the approach and methodology on which National Aquifer mapping programme of the entire country can be implemented.

iv. The experiences gained can be utilized to upscale the activities to prepare micro level aquifer mapping.

1.1.1 Scope

The activities of the Pilot Project on Aquifer Mapping can be envisaged as follows

1. **Data Compilation & Data Gap Analysis**: One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets. On the basis of available data, Data Gaps were identified.

2. **Data Generation**: There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys. CSIR-NGRI has been hired as consultant to carry out geophysical studies including advance Heliborne Transient Electro Magnetic Method (Heli-TEM) to delineate

multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

3. **Aquifer Map Preparation**: On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference aquifer extremities, quality, ground water level, potential and vulnerability (quality & quantity).

4. **Aquifer Response Model**: On the basis of aquifer characterization, issues pertaining to sustainable aquifer management in the area have been identified. Initially, a conceptual model has been developed for the pilot area and subsequently, a mathematical model has been formulated simulating the field situation, which was calibrated and validated with the field data. Various scenarios have been tested in the model to study the response of the aquifer to various stress conditions and predictive simulations have been carried out up to the year 2025.

5. **Aquifer Management Plan Formulation**: Aquifer response Model has been utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

Aquifer mapping is a multidisciplinary study wherein a combination of geological, geophysical, hydrological, hydrogeological, meteorological and hydro-chemical information is integrated to characterize the spatial and temporal variation of quantity and quality of the aquifer system. In the pilot project area of Chandrabhaga Watershed (WGKKC-2) of Nagpur district, the following are the main issues and challenges.

- Paucity of rains with long dry spells
- Limited aquifer thickness of unconfined aquifer
- Drying up of aquifer
- Failure of dugwells/borewells due to unscientific selection
- Industrial & agriculture pollution

To resolve such issues and also to firm up the approach and methodology for National Aquifer Mapping Programme, the pilot study for aquifer mapping has been taken up in Chandrabhaga Watershed (WGKKC-2) with following broad objectives

- ➢ To define the aquifer geometry with precise lateral and vertical demarcation.
- ➢ To define Ground water regime behaviour in time and space.
- ➢ To study the hydraulic characteristics of both shallow and deeper aquifer.
- ➢ To study the Geochemistry of aquifer systems down to the depth of 200 m.

- To assess the efficacy and efficiency of advanced geophysical techniques like ERT, SKY-TEM etc., for type area.
- To prepare Aquifer Maps indicating three dimensional dispositions of aquifers along with their characterization.
- To develop the Aquifer Response Model.
- To formulate the Aquifer Management Plans for sustainable management of ground water resources.
- To upscale the activities to the other similar parts of the country.

1.2 Approch

Geologically, the major parts of the State of Maharashtra is occupied by the rock of basaltic lava flows (Deccan Traps), which covers an area of about 2,49,934 sq km (81.2 % of the geographical area of State). It is present in almost all the districts of the State except Bhandara and Gadchiroli. Other major geological formations are Archaeans occupying an area of about 32,235 sq km (10.5 %), Precambrian (Purana) formations occurring over an area of 6,217 sq km (2 %), Gondwanas over an area of 4,800 sq. km (1.6 %), and Alluvium covers over an area of about 14,526 sq. km (4.7 %) in the state. Nagpur district of Maharashtra state known for its orange orchards is located in eastern part of the state. The main occupation is agriculture and major part of the district is covered by hard rocks having limited availability of ground water due to heterogeneity of formation. Thus, the demand of water for its various requirements put the ground water resources under tremendous pressure resulting in decline of ground water level in many parts of the district. Therefore, it was envisaged to formulate a proactive “Aquifer Management Plan”. The Chandrabhaga watershed of Godavari basin in Nagpur District was chosen as the area for the pilot project on “Micro Level Aquifer Mapping and Management”. The major parts of the Chandrabhaga Watershed (WGKKC-2 is represented by the Deccan Trap Basaltic terrain where the Basalt is followed by the Sandstone (Gondwana Supergroup) forming a regional aquifer system. To study the spatio-temporal behaviour of aquifers of Deccan Trap Basalt as well as Gondwana Sandstone where the multiple aquifer systems exist, the approach of the management of aquifer is challenging.

1.3 Location

Chandrabhaga Watershed (WGKKC-2), occupy an area of 360 sq. km. is situated in the north western part of Nagpur district covering about 60 villages in parts of Nagpur (rural), Kalmeshwar and Katol talukas. It lies between north latitudes 21°10’ and 21°10’ and east longitudes 78°42′ and 78°59′ and falls in parts of Survey of India toposheets 55 K-11, 12, 15 & 16. The watershed is well connected by all season motorable roads (Fig.1).

Fig. 1.1: Administrative and location map of Chandrabhaga Watershed (WGKKC-2)

2 DATA AVAILABILITY AND DATA GAP ANALYSIS

2.1 Climate and Rainfall

The climate of the watershed is characterized by a hot summer and general dryness throughout the year, except during the south-west monsoon season, i.e., June to September. The mean minimum temperature is around 12°C and mean maximum temperature is more than 45°C. There are two rain gauge stations located at Tahsil Offices at Kalmeshwar and Katol taluka headquarters. The rainfall data for last 17 years was available with the State Government. The analysis of rainfall data for Kalmeshwar and Katol rain gauge stations is presented in Fig. 1.2a, 1.2b, 1.2c and 1.2d. The normal annual rainfall recorded at Kalmeshwar and Katol rain gauge is 985.4 mm and 973 mm respectively. The rainfall trend for Katol is falling significantly @ -43.26 mm/year during 2005-2014, and marginally @ -13.13 mm/year during 1998-2014. Likewise, it has been observed that, the rainfall trend for Kalmeshwar is significantly rising @ +34.88 mm/year during 2005-2014, and falling marginally @ -14.83 mm/year during 1998-2014.

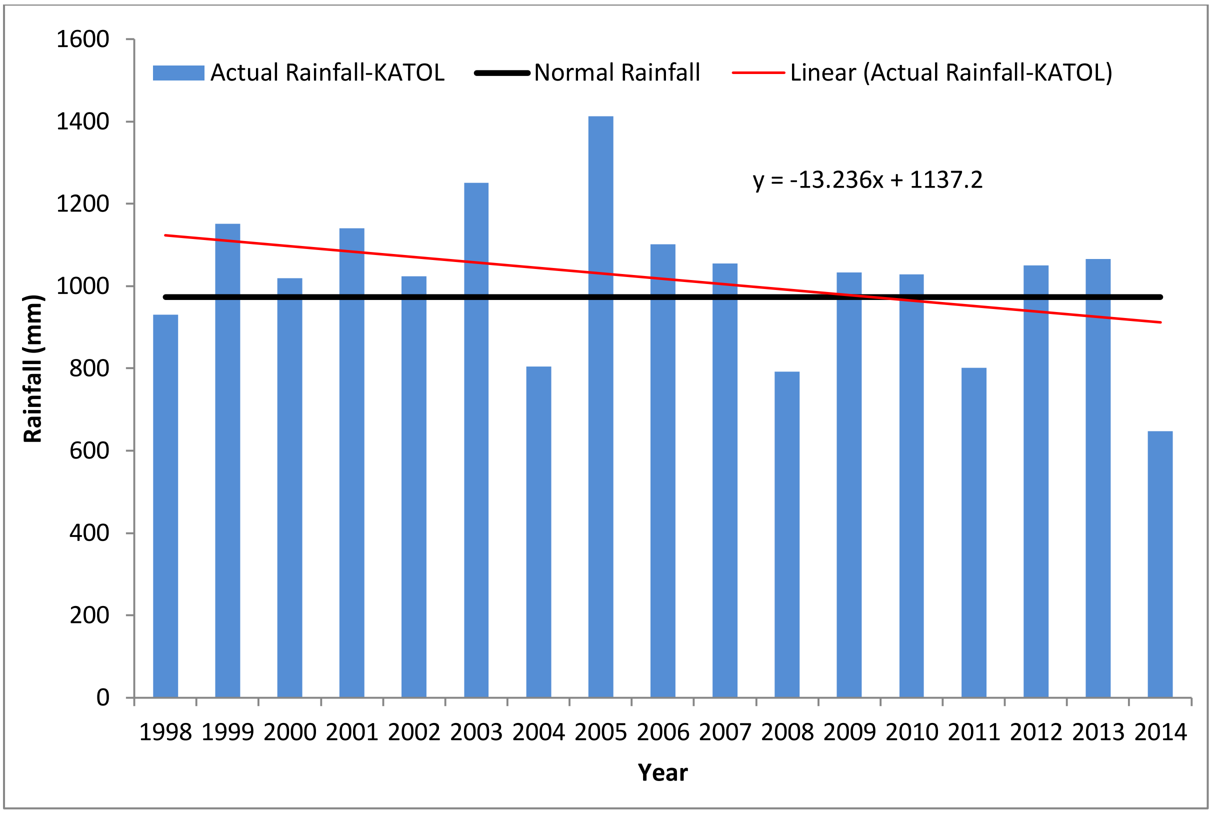


Fig. 2.1 a: Rainfall trend (1998-2014) at Katol, Chandrabhaga Watershed (WGKKC-2)

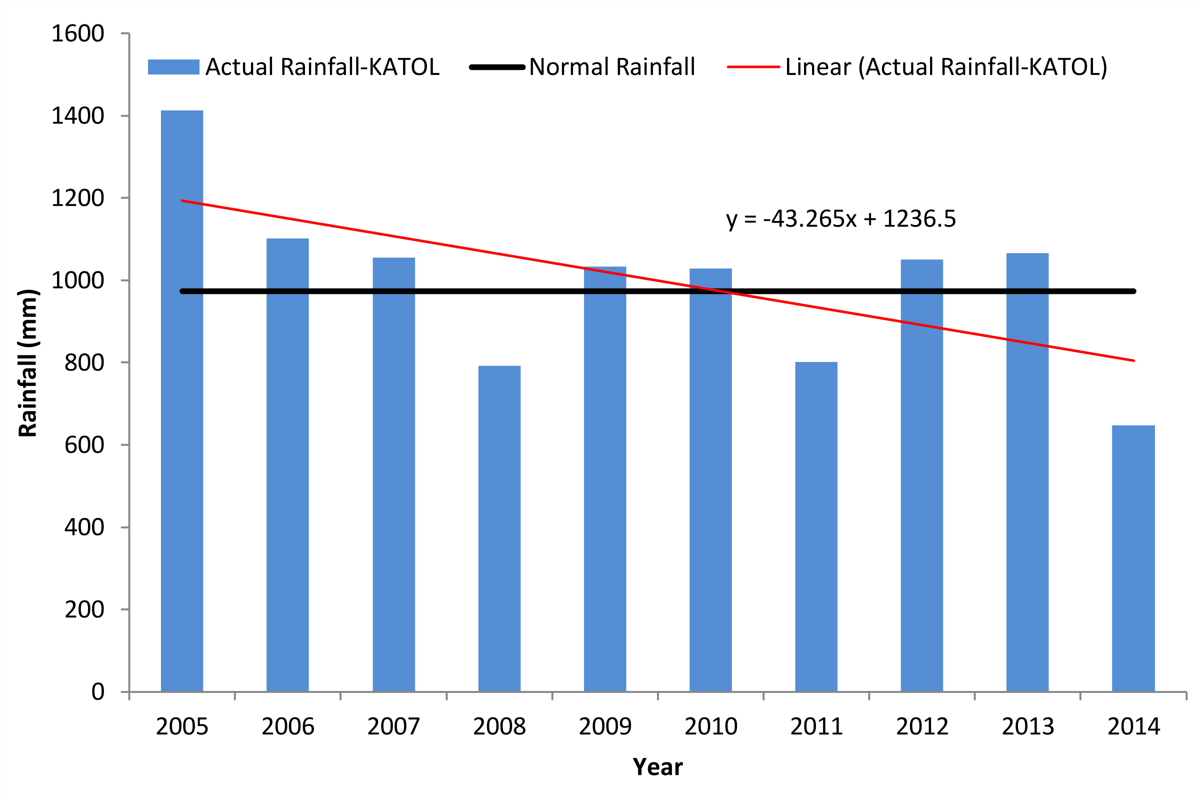


Fig. 2.1b: Rainfall trend (2005-2014) at Katol, Chandrabhaga Watershed (WGKKC-2)

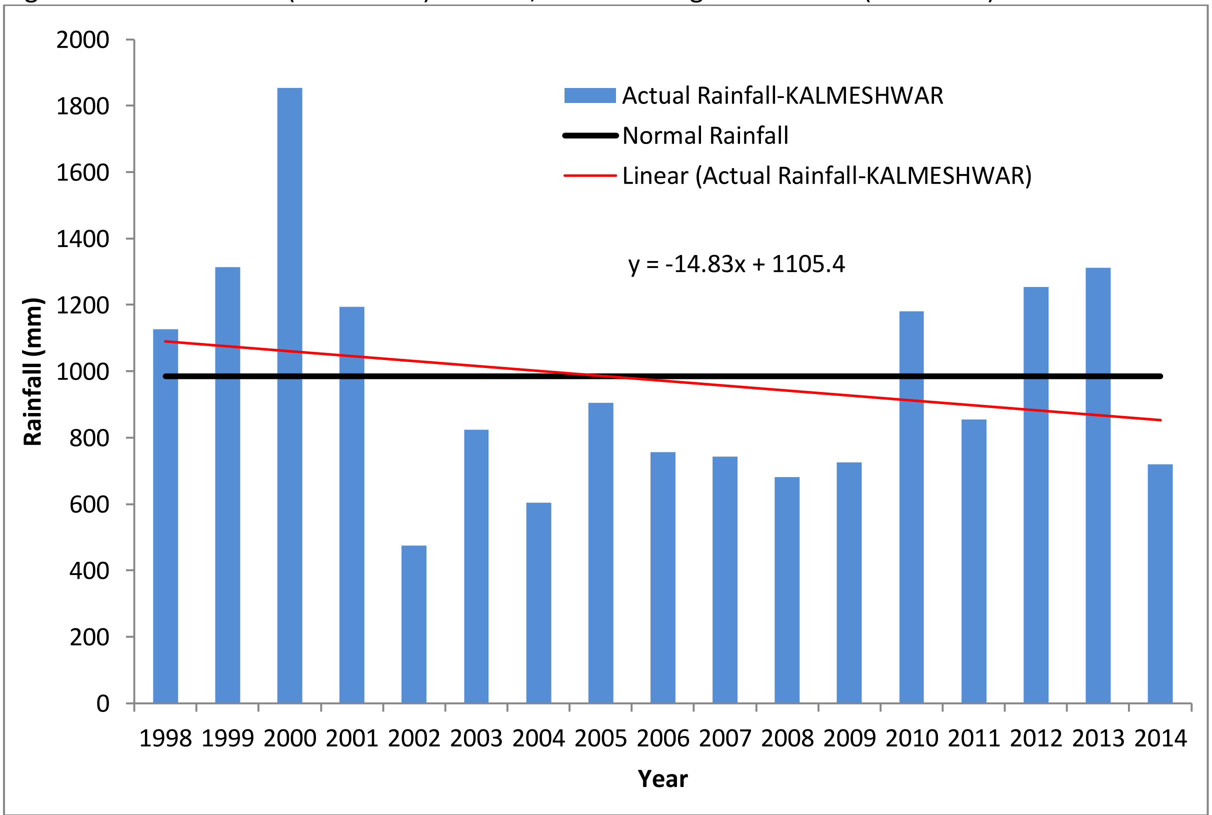


Fig. 2.1c: Rainfall trend (1998-2014) at Kalmeshwar, Chandrabhaga Watershed (WGKKC-2)

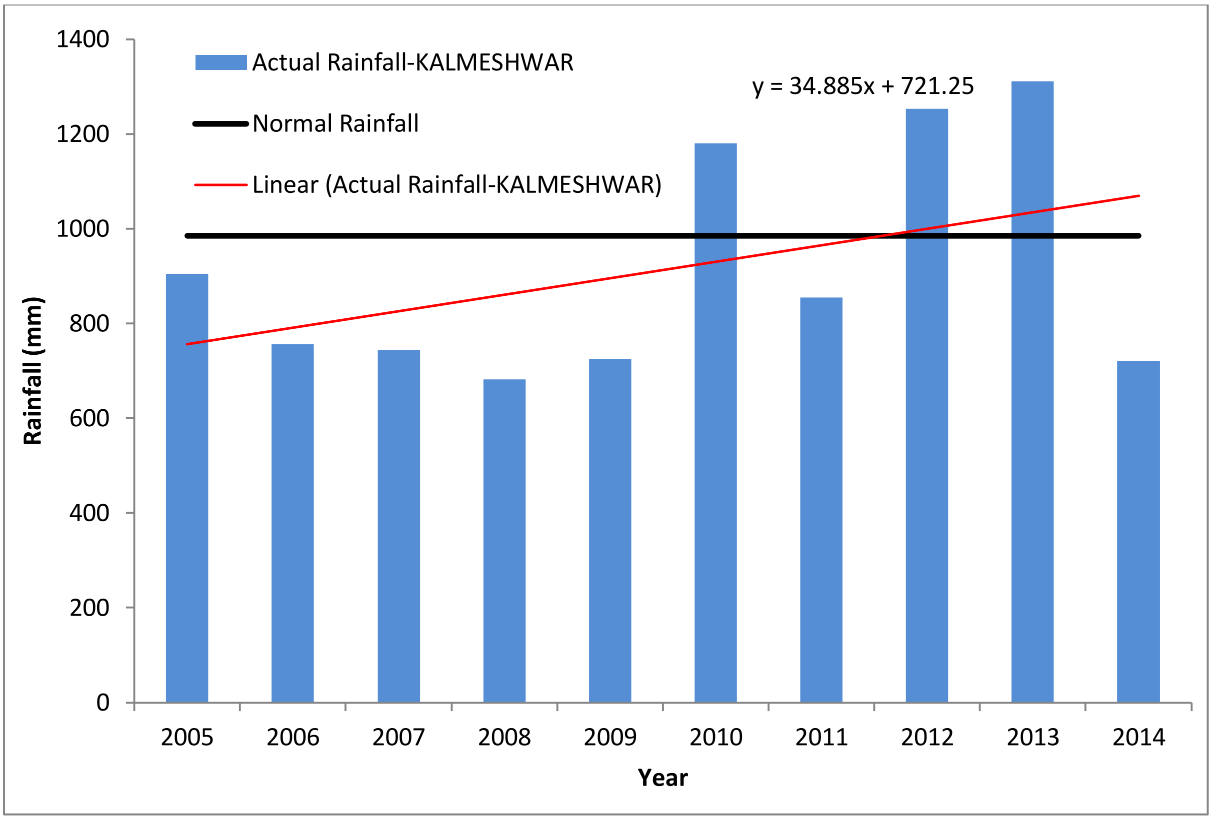


Fig. 2.1d: Rainfall trend (2005-2014) at Kalmeshwar, Chandrabhaga Watershed (WGKKC-2)

2.2 Soil

The soil data and the thematic map of the pilot study area available with the GSDA, Nagpur has been collected and studied on GIS platform. It has been observed that the major part of the watershed is occupied by clayey soil followed by clayey loam observed along the northern fringe of the watershed. The small portion of the area in eastern and southern part is occupied by sandy loam to sandy clay type of soil whereas sandy loam also occurs in very small patch in western boundary of the area. The thematic map on the soil distribution in the study area is shown in Fig.2.3

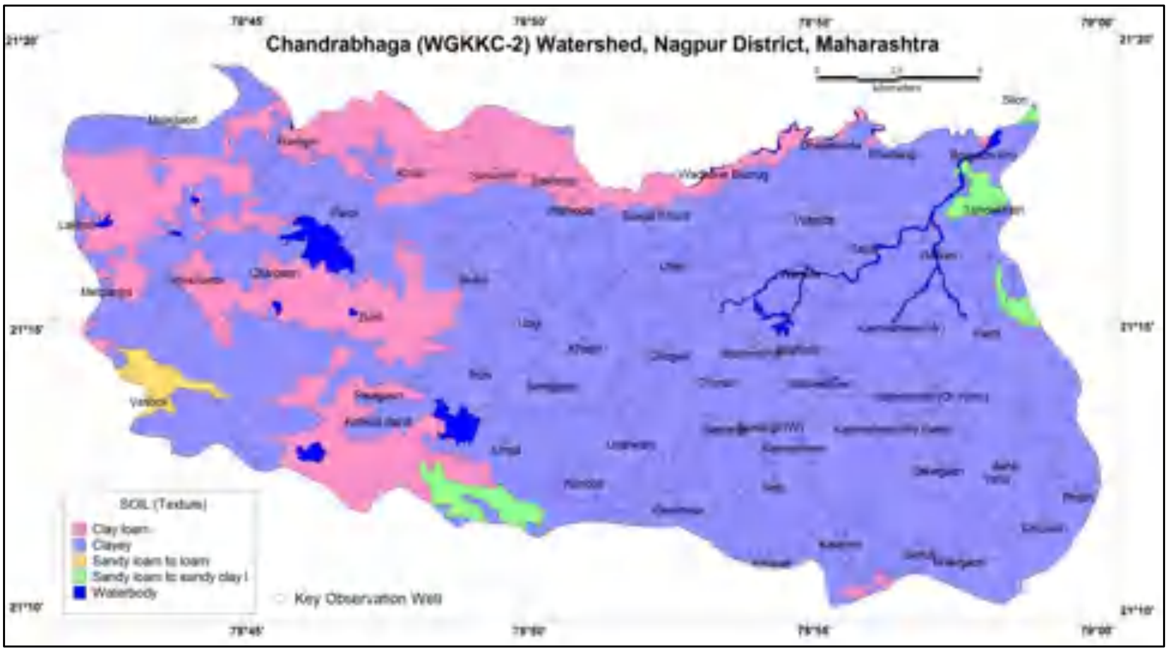


Fig. 2.3: Soil, Chandrabhaga Watershed (WGKKC-2)

2.3 Land use

The landuse details and the thematic map available with the GSDA, Nagpur has been collected and analysed with reference to the present agricultural practices, various land use etc. It has been observed that the major parts of the area are covered by agricultural land. The wasteland, notified and un-notified forests are mostly observed in the western part of the watershed. The built up area is reflected wherever settlements have come up. The thematic map on land use/land cover is shown in Fig 2.4.

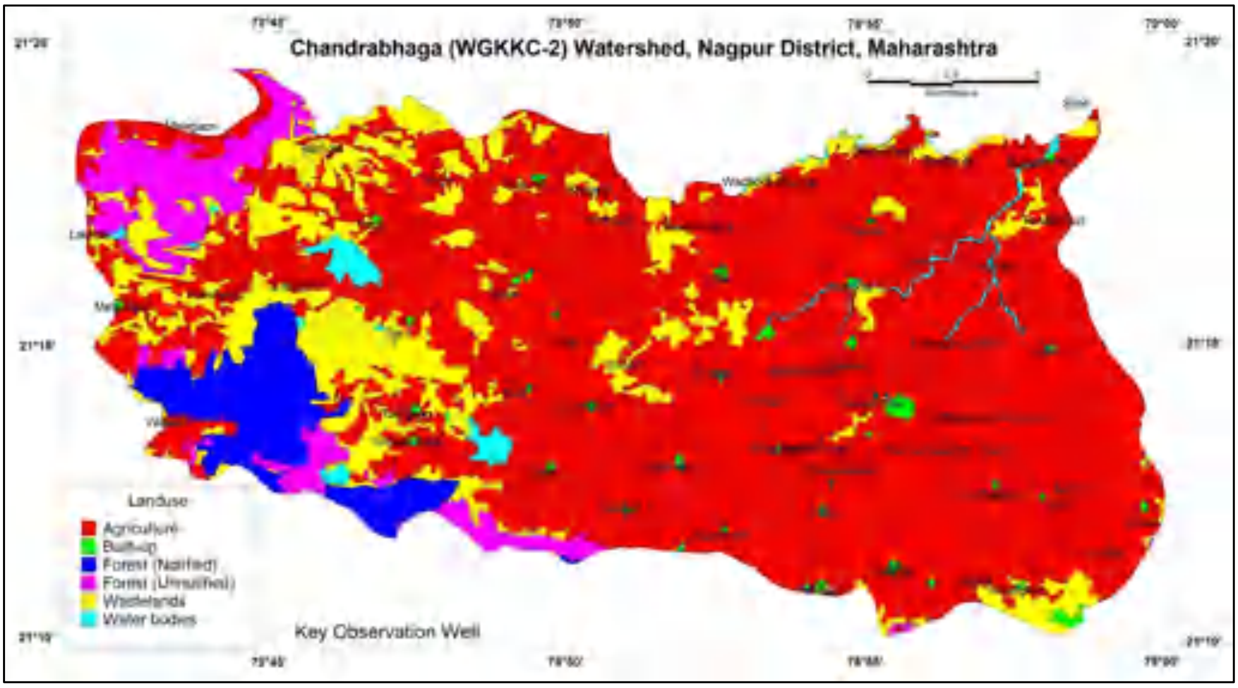


Fig.2.4: Land use, Chandrabhaga Watershed (WGKKC-2)

2.4 Geomorphology and Drainage

The relief and slope studies were carried out by compiling the topographical maps of the study area and the downloaded SRTM data of study area available on website of United States Geological Survey (http:// dds.cr.usgs.gov/ SRTM / Version2_1/ SRTM3/ Eurasia/) on GIS platform. The area has an undulating terrain with highest elevation around 509 m amsl in the north-western part and the lowest about 310 m amsl in the north eastern part (Fig.2.5).

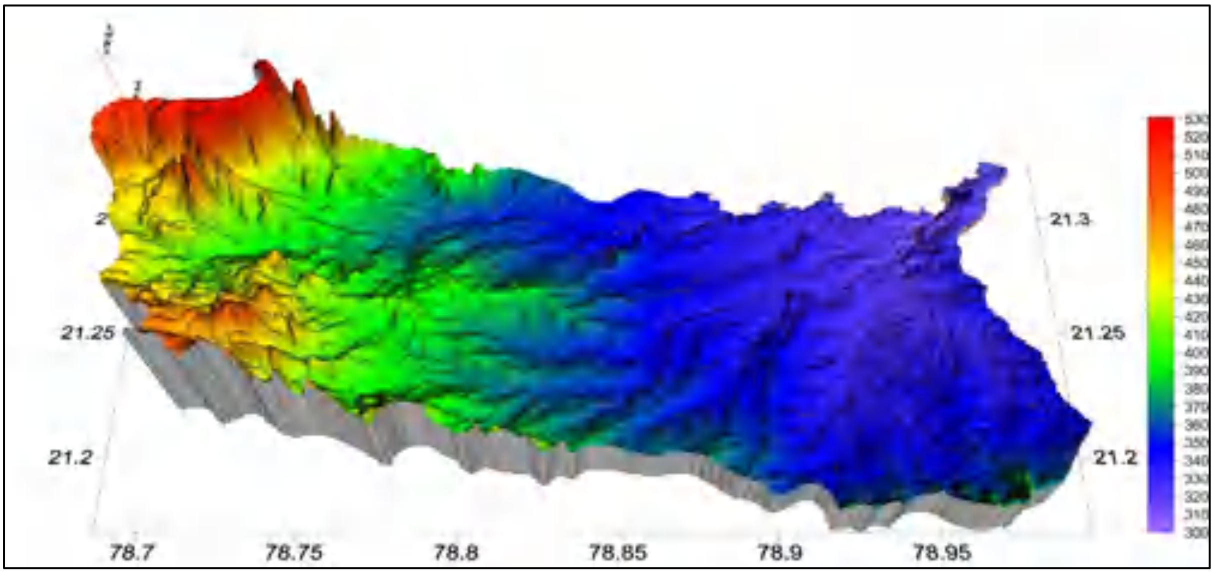


Fig. 2.5: Digital Elevation Model, Chandrabhaga Watershed (WGKKC-2)

The analysis of geomorphological data and thematic map collected from GSDA, Nagpur reveals that almost entire area of watershed forms the Moderately Dissected Plateau (MDB), which can be broadly divided in to three units depending on extent of weathering and thickness of soil cover viz. 1) MDP-a, in north central and north eastern part of the area having very thick soil cover. 2) MDP-b, occupying central and southern parts of the area with moderate soil cover and 3) MDP-c, mostly occurs in western and north western part of the area with very thin soli cover and exposure of rocks. Whereas a small portion in North West and south western parts of the area is occupied by outer fringes of upper plateau (denudational hills). The north eastern part of the area forms the moderately weathered and moderately buried pediplains of Kamthis. The geomorphology of the area is shown in Fig. 2.6

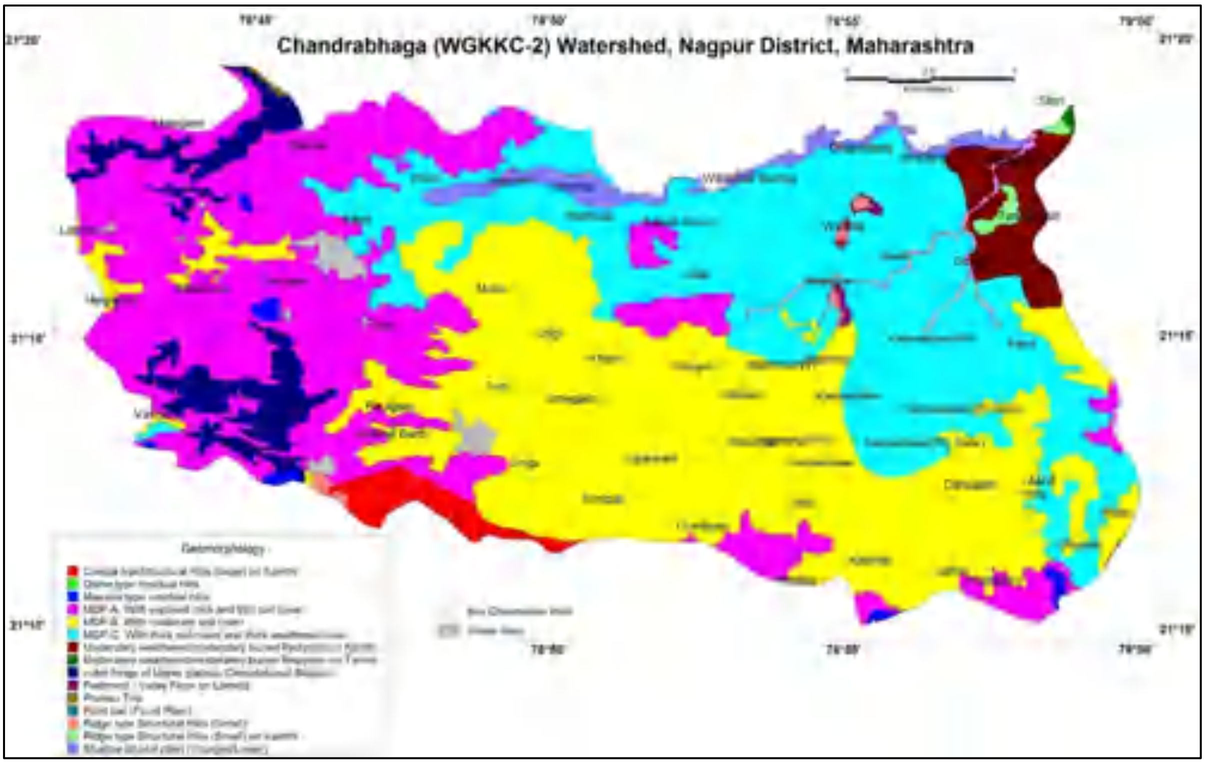


Fig. 2.6: Geomorphology, Chandrabhaga Watershed (WGKKC-2)

The ephemeral Chandrabhaga River is flowing from a height of 334.333 m above MSL at village Wadhona (Bk) to 299.69 m above MSL at village Sillori. It has a course of about 20.74 km and forms northern boundary of the watershed. The area is also drained by tributaries of the Chandrabhaga river viz., Saptadhara River, Mortham Nala. The drainage is dendritic and the flow direction of main stream i.e., Chandrabhaga is from west to east and its tributary from south to north, the main stream ultimately joins the Kolar river outside the watershed in the eastern part. The drainage map is shown in Fig. 2.7.

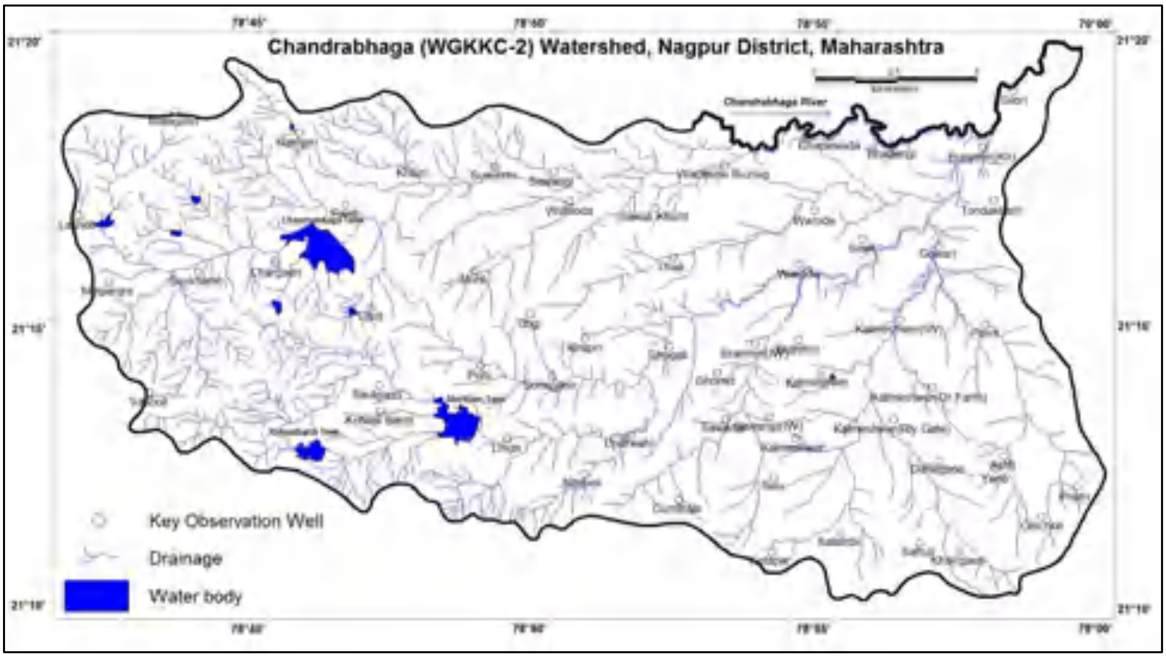


Fig. 2.7: Drainage, Chandrabhaga Watershed (WGKKC-2)

2.5 Geology and Lineaments

Major part of the area (about 313 sq. km) is occupied by Basaltic lava flows of Upper Cretaceous to Eocene age. A total of 12 basaltic flows above ground level have been mapped/ identified in the area by Geological Survey of India (GSI). The area is dotted with small isolated patches of outcrops of basaltic residual ridges often attaining a height of 2 to 3 meters above ground level. The Gondwana formation of Permian age occupy an area of 47 sq.km and it is mainly exposed in the north-eastern part and also occur as a small linear patch south of Kotwalbardi and Linga villages along the southern boundary. In Gondwanas, the major litho-unit is Kamthi formation which is followed by Barakars. The Kamthi is a ferruginous, reddish yellow to buff colored, medium to coarse grained hard and compact sandstone with shale. The geology and lineament map is shown in 2.8. The general geological succession of the area is given in Table 2.1.

Table 2.1: General geological succession of Chandrabhaga Watershed (WGKKC-2)

Formation	Age
Soil/ Alluvium	Recent
Deccan basaltic lava flows with associated Inter-trappean sediments	Lower Eocene to Upper Cretaceous
Lameta beds	Cretaceous
Gondwana Supergroup Kamthi Stage Barakar Stage	Permian to Carboniferous
Granitic gneisses, Sausar and Sakoli Series of metasediments	Archean

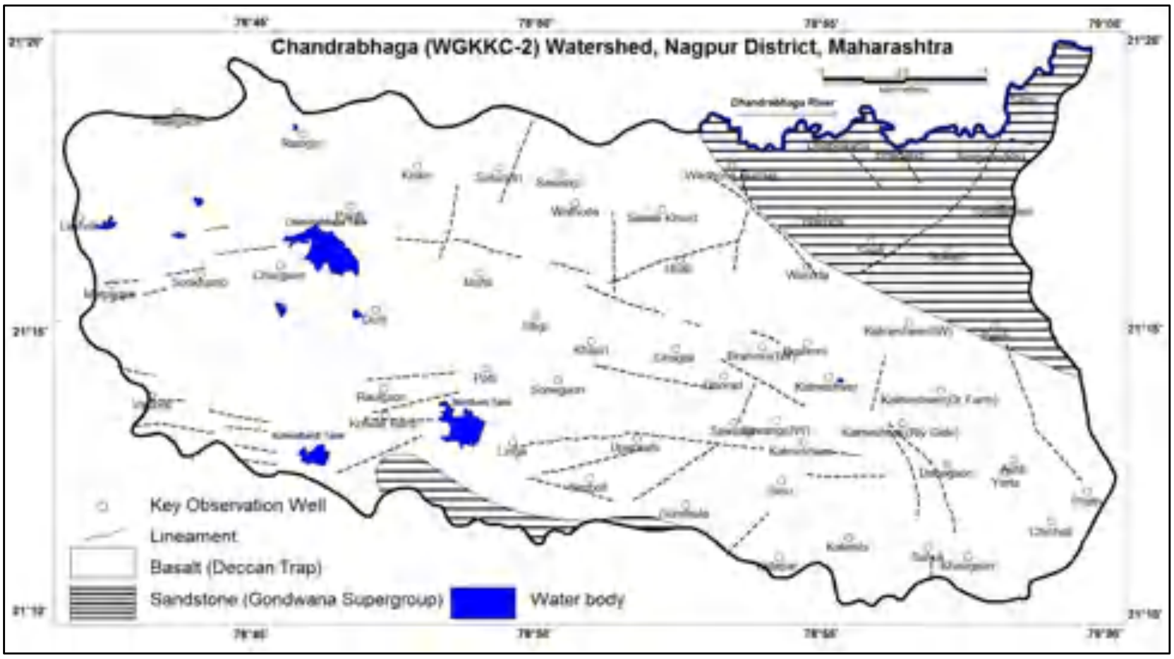


Fig.2.8: Geology and lineament, Chandrabhaga Watershed (WGKKC-2)

The primary data of lineament has been taken from the old CGWB reports and the lineament map is prepared for the study area and shown in Fig.2.8. In the study area, four sets of lineaments are interpreted which trends in NE-SW, NW-SE, N-S and E-W directions. The E-W trending lineament is predominantly seen in the southern part of the study area.

2.6 Geophysics

Prior to the commencement of the pilot project in Chandrabhaga watershed, CGWB has carried out 19 VES to decipher the vertical and horizontal extensions of basaltic aquifer (Fig. 2.9). Beside this, NGRI/NEERI has also carried out geophysical investigations in parts of the study area. The interpreted results published in various scientific journals are discussed below:

The 2D inverse models of resistivity variation with depth suggest that the potential aquifers mostly occur in weathered/fractured zones within the traps or below it. The interpreted results have been verified by a bore well drilled at a site near Ghogali village. A potential water-bearing aquifer was struck at a depth of 35 m, which was in good agreement with the interpreted results (Ratna Kumari et al, 2012). The Electrical Resistivity Tomography (ERT) survey has proved the occurrence of groundwater potential zones in hard rock (a heterogeneous environment). Resistivity models have ascertain presence or potential groundwater zones at several sites in this top alluvium and weathered mantle which can be explored for groundwater. Similarly, resistivity models have also deciphered groundwater potential zones at deeper level within and below traps in the Lameta/Gondwana formations (Ratna Kumari et al, 2012).

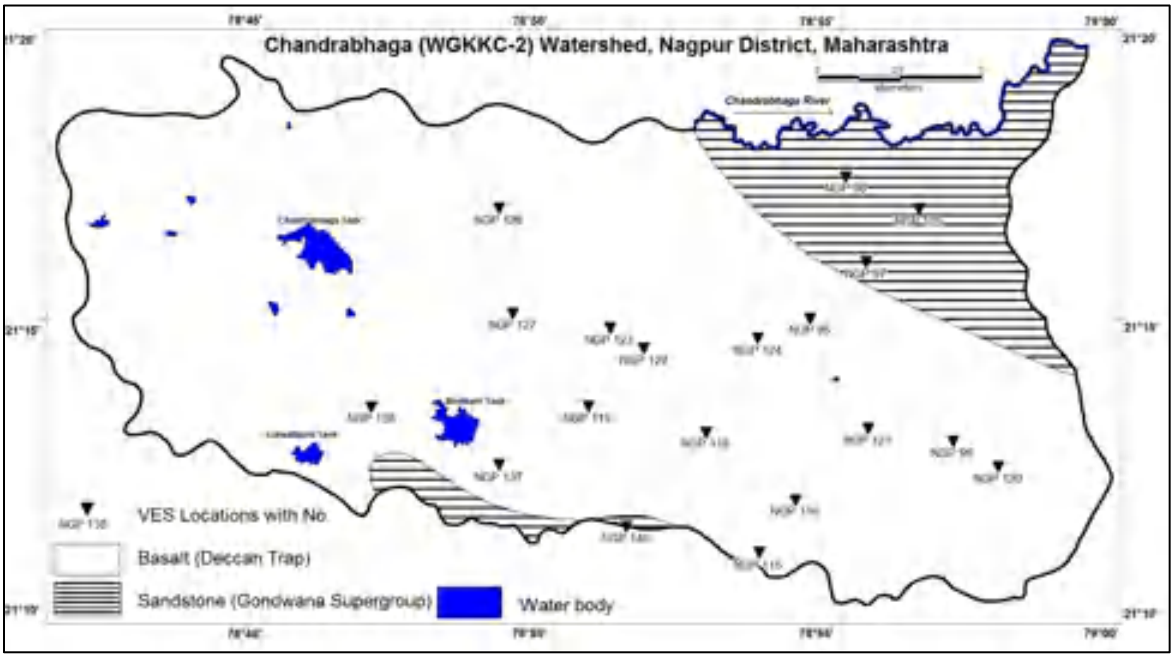


Fig.2.9: Data availability, VES by CGWB, Chandrabhaga Watershed (WGKKC-2)

The gravity maps prepared by GSI based on gravity survey carried out in parts of study area prior to the pilot project indicate that the positive contours southeast of Kalmeshwar in the residual Gravity map (Fig. 2.10 and 2.11) infer that the high-density granitic basement is shallow and the Gondwanas are absent in this area (T.S. Ramakrishna, et al, 1990).

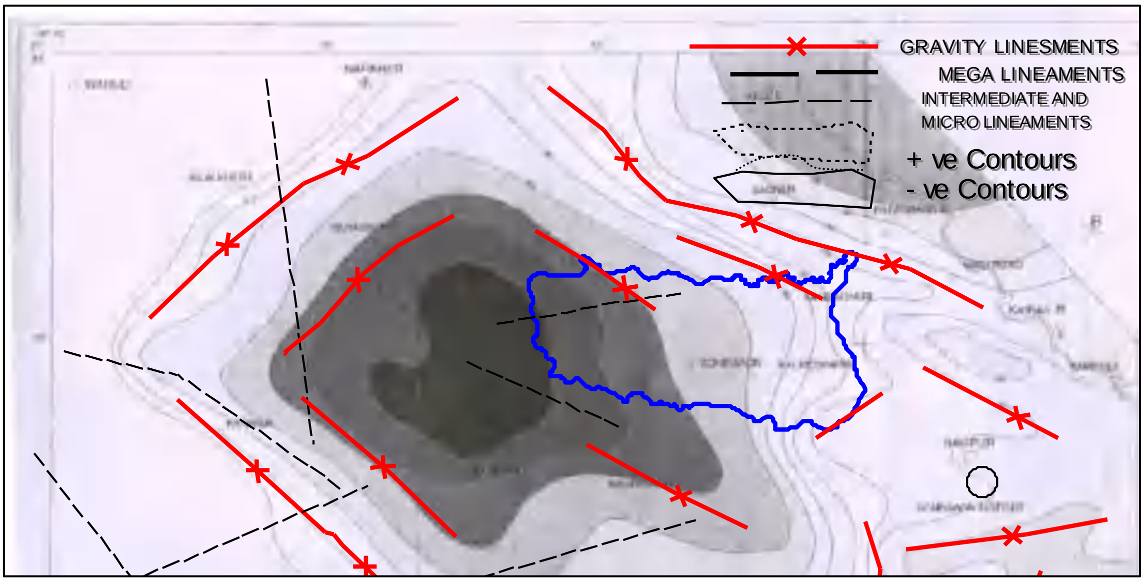


Fig.2.10: Bouguer gravity anomaly map (part of the map after T.S. Ramakrishna, et al, 1990)

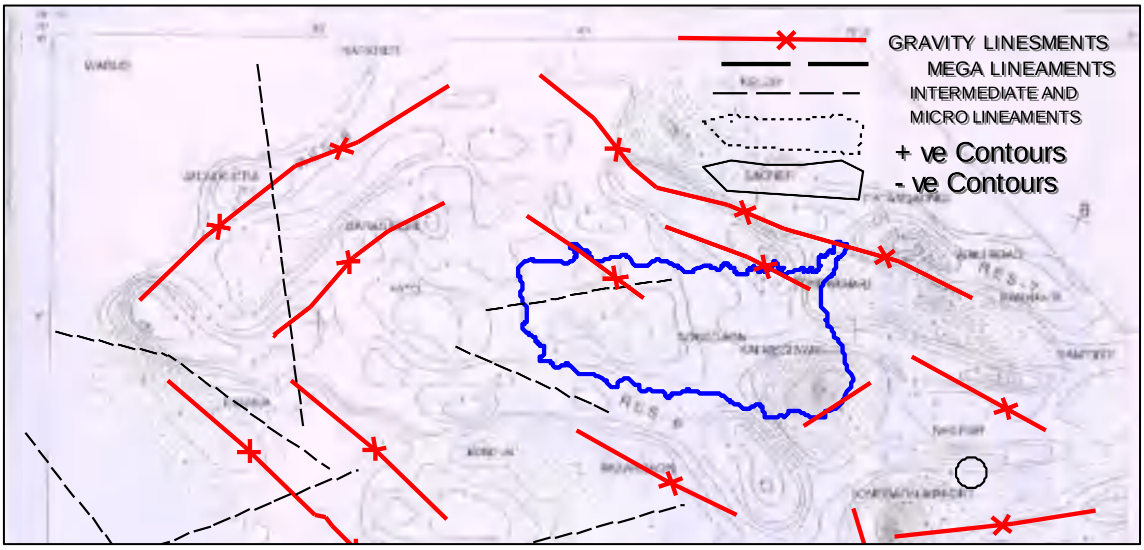


Fig.2.11: Residual gravity anomaly map (part of the map after T.S. Ramakrishna, et al, 1990)

2.7 Sub Surface Lithological Information

Prior to pilot study, CGWB has drilled 6 exploratory wells (EW), 1 observation well (OW) and 3 piezometers in the watershed (Fig. 2.12). The details of the wells drilled are presented in Table 2.2. The depth of the wells ranged from 40 to 202m bgl, the water bearing zones were encountered in the depth range of 7-15m bgl and 183.5-186.5m bgl. The discharge of the wells ranged from negligible to 13.96 lps. The ground water quality is good except nitrate, which is found above permissible limits of 45 mg/L.

The study of lithologs of the exploratory and observation wells indicate that Gondwana sandstone was encountered at 123 and 111m bgl respectively at Dorli in the western part of the watershed. Whereas the same sandstone was encountered at very shallow depth i.e., 27m bgl in eastern part of the watershed at Jhunki (Shindi), and at Borgaon (Khurd). Whereas, at Pardi piezometers site located at eastern corner, the Gondwana sandstone is exposed at ground level. Thus it inferred that the thickness of Basalt is increasing from east to west. The lithology of EW drilled at Yerla shows that the basalts underlain by Lameta beds which is then followed by Archaean Gneisses below 59 m bgl.

Table 2.2: Details of ground water exploration (by CGWB, Nagpur), Chandrabhaga Watershed (WGKKC-2)

S. No.	Location	Latitude Longitude	Depth Drilled (m bgl)	Zones Tapped/ Encountered (m bgl)	Discharge (lps)	Transmissivity (m^2/day)	Storativity	Basalt-Gondwana contact (m bgl)
1.	Dorli EW	21°18’00”; 78°58’00”	153.50	30.50 – 33.50, 115.50 – 125.00, 131.10–140.30	13.96	7.11	5.50x 10^{-5}	123.00
1a	Dorli OW	-do-	125.00	36.60 –39.60 88.40 – 100.60	1.37	-	-	111.00

S. No.	Location	Latitude Longitude	Depth Drilled (m bgl)	Zones Tapped/ Encountered (m bgl)	Discharge (lps)	Transmissivity (m^2/day)	Storativity	Basalt-Gondwana contact (m bgl)
2.	Metpanjara EW	21°15'30"; 78°42'00"	122.00	**Abandoned**	-	-	-	-
3.	Jhunki (Shindi) EW	21°16'00" 78°55'45"	132.00	7-15, 36-52, 71-75	1.37	5.55		27.00
4.	Tondakhairi EW	21°16'50" 78°57'47"	201.80	93-99, 104-107, 111-113, 118-124, 128-136, 156.5-159.5, 162.5-164.5, 167.5-173.5, 183.5-186.5	1.37	3.14	-	Entire formation-sandstone
5.	Selu EW	21°12'00" 78°54'00"	140.30	-	-	-	-	137.20 Abandoned
6.	Yerla EW	21°13'00" 78°58'00"	159.45	29.75, 55.00	4.45	-	-	Basalt down to 59 m followed by Lameta and Gr. Gneiss
7.	Borgaon Khurd Pz	21°17'58" 78°57'55"	127.00	24-29, 45-51, 70-74, 91-94	3.75	21.80	-	Entire formation-sandstone
8.	Pardi Pz	21°14'46" 78°57'48"	101.36	22-26, 38-46, 55-60	0.14	-	-	Entire formation-sandstone
9.	Fetri Pz*	21°12'21" 78°59'17"	40.00	11.50	Negligible	-	-	Entire formation-Basalt

Note-* Constructed through outsourcing (pre-project).

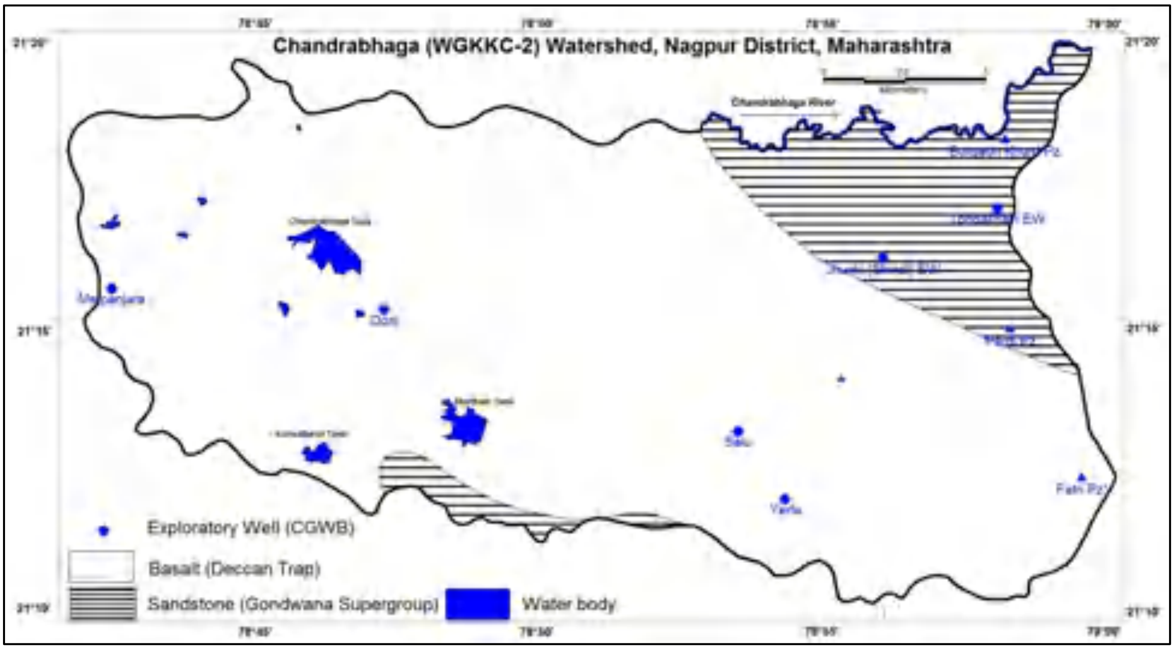


Fig.2.12: Ground water exploration (CGWB), Chandrabhaga Watershed (WGKKC-2)

2.8 Hydrogeology

The major part of the area is occupied by Deccan trap basalt (313 sq. km) of Upper Cretaceous to Eocene age. A small part of the watershed (47 sq.km.) is occupied by Gondwana formation of Permian age and exposed in the NE part and also a small linear stretch south of Kotwal Bardi, Linga and Nimboli villages. The area occupied by basaltic terrain is followed by Gondwana formation at different depths. Ground water occurs under phreatic conditions in the exposed lava flows and in semi-confined to confined state in the subsurface flows. Ground water is present in interconnected pore spaces of vesicular unit and in the jointed and fractured portions of massive unit of each flow. However, secondary porosity and permeability that developed on account of weathering, fracturing and joints play a very important role in storage and movement of ground water and constitute the important water bearing formations (aquifer) in hard rock of basalt. Weathering not only produces granular materials but also widens the fractures, joint and shear zones. In Deccan Trap Basalt, the depth of the phreatic aquifer ranges from 6.25 to 21.3 m bgl. The thickness of the weathered mantle ranges between 0.80 and 12.7 mbgl. In Gondwana Sandstone, the thickness of the weathered part ranges between 3.00 and 10.40 mbgl. The depth of the phreatic aquifer has been recorded between 8.5 and 19.1 m bgl. Hydrogeological map of the area is shown in Fig.2.13.

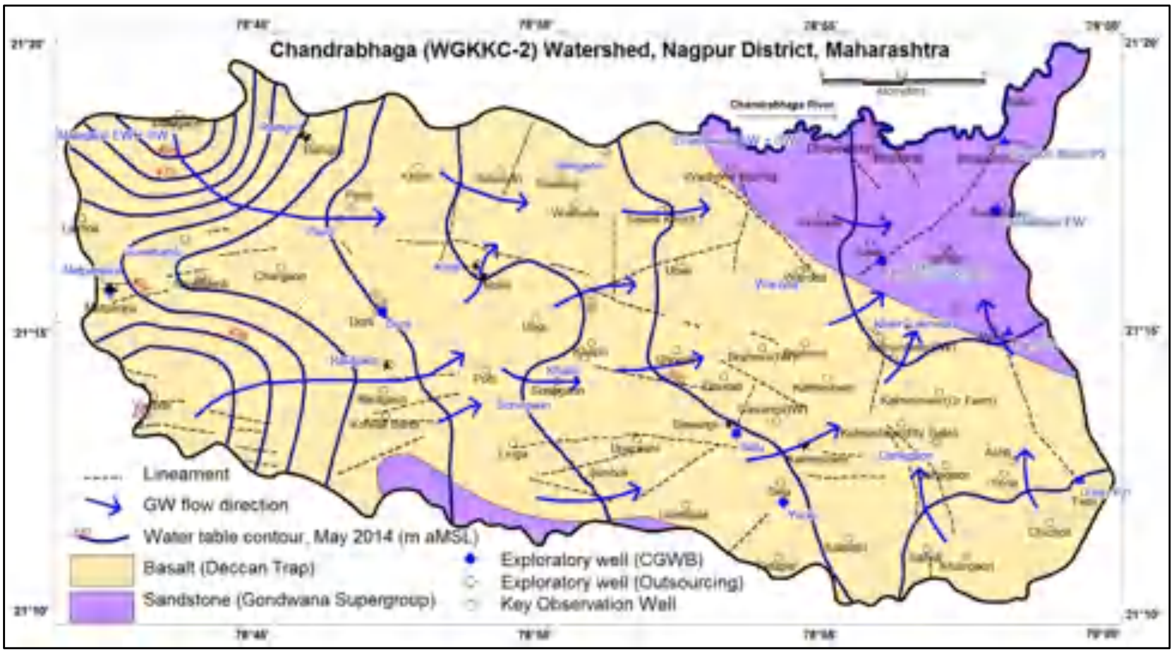


Fig.2.13: Hydrogeology, Chandrabhaga Watershed (WGKKC-2)

Among the Gondwana group of formation, the Barakars and Kamthis generally consist of medium to coarse-grained friable sandstone. These granular rocks constitute the important water bearing formations in the watershed. Ground water occurs under both phreatic and confined conditions. Sandstone is usually friable and possesses primary porosity due to its granular nature. However, the storage and movement of ground water in this formation depend upon the size and shape of grains, there arrangements and degree of cementation. But when these formations are subjected to other tectonic activity, secondary porosity develops and its ground water potential increases substantially. The occurrence of sufficient thickness of shale and other impervious unit above and below the sandstone simulate the confining condition in the sandstone aquifer.

2.9 Aquifer Disposition

Based on the historical data on ground water exploration, three types of aquifer systems are deciphered:

1. *Aquifer I* - Unconfined aquifer. Occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. This aquifer generally occurs to the depth of 20 to 30m bgl and mostly tapped by the shallow dug wells in area occupied by basaltic and sandstone terrain.
2. *Aquifer II* – Semi-confined to confined aquifer. Generally occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. The thickness of aquifer varies from 0.50 cm to 6 meters in Basaltic formation and 3m to 34 m in Gondwana formation and mostly tapped by the deep bore/tube wells in area occupied by basaltic and sandstone terrain.
3. *Aquifer III* - It is mostly 'Trap Covered Gondwanas or Gneisses' (TCG). Generally occurs as semi-confined to confined conditions but at places, they exhibit unconfined condition and occur where the thickness of basalt is less, and tapped by the shallow dug wells or deep bore/tube wells in area occupied by basaltic and sandstone terrain.

The detailed study of the data indicates that the major parts of the area are occupied by trap covered Gondwana formation. The thickness of the Basalt increases from east to west i.e. from ground level near village Gowari in the northeast to 110.0m bgl around Dorli in the west. At western boundary near Metpanjra, the thickness of Trap is observed down to 122.0 m bgl. As none of the well tapped the Gondwana formation occurring below basalt in the area, the ground water potential of trap covered Gondwana was not ascertained based on existing data. Hence, drilling and construction equally distributed exploratory bore/tube well tapping basaltic aquifer, sandstone aquifer and aquifer occurring below basalt was proposed.

2.10 Ground Water Level

Two Ground Water Monitoring Wells (GWMW) located at Kalmeshwar and Chargaon were studied for the analysis of long-term water level. Since 1982 these wells were monitored four times a year. Both the GWMW are representing the unconfined basaltic aquifer. There is no GWMW in Gondwana formation; hence the ground water scenario in the area occupied by Sandstone formation was not available. The ground water level data of existing wells were analyzed and it has been observed that it is not reflecting the true ground water scenario of entire watershed. Hence, establishment of more observation wells were proposed.

The long-term (1982-2012) hydrograph analysis indicates the rise in ground water level during both pre monsoon and post monsoon seasons. The GWMS located at Kalmeshwar shows rise of 0.12 m/year in pre monsoon season, whereas in post monsoon it shows rise of 0.05 m/year (Fig. 2.14a). Whereas, the decadal trend analysis (2001-2010) indicates negligible rise during post monsoon while moderate rise of 0.10 m/year has been recorded (Fig. 2.14b).

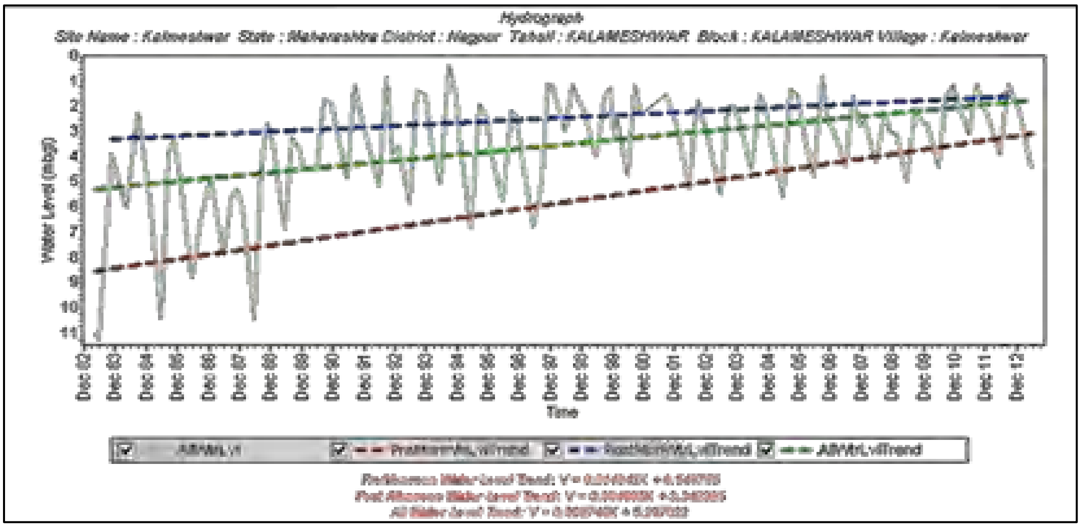


Fig.2.14a: Hydrograph of GWMW located at Kalmeshwar(1982-2012), Chandrabhaga Watershed (WGKKC-2)

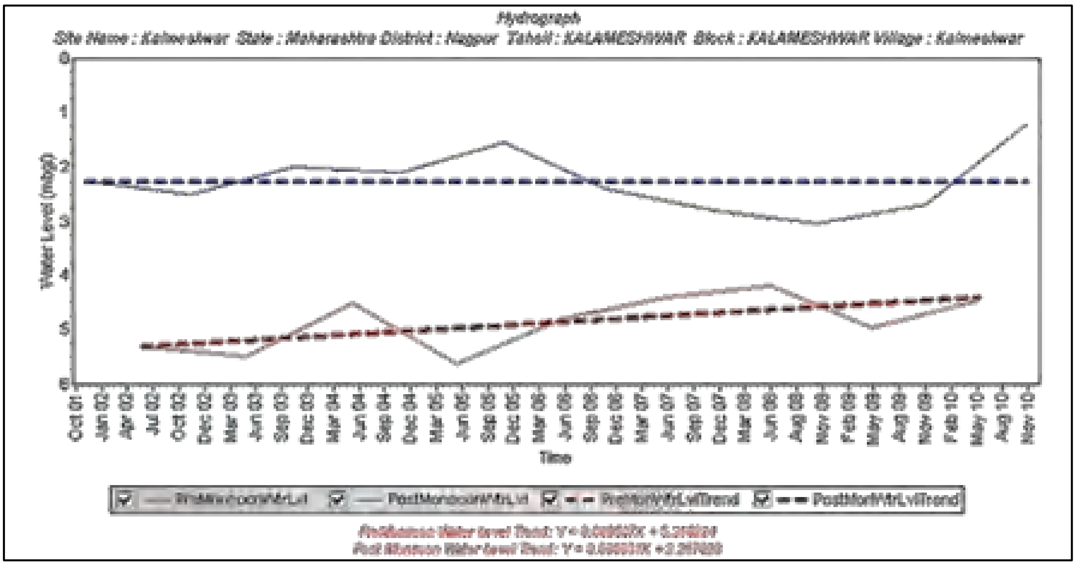


Fig.2.14b: Hydrograph of GWMW located at Kalmeshwar(2001-2010), Chandrabhaga Watershed (WGKKC-2)

The log-term ground water level trend (1982-2012) at GWMW located at Chargaon shows negligible rise in pre monsoon season, whereas in post monsoon it shows rise of 0.012 m/year (Fig. 12a). Whereas, the decadal ground water level trend (2001-2010) indicates appreciable rise of 0.096 m/year (Fig. 12b) during post monsoon while moderate rise of 0.14 m/year has been observed.

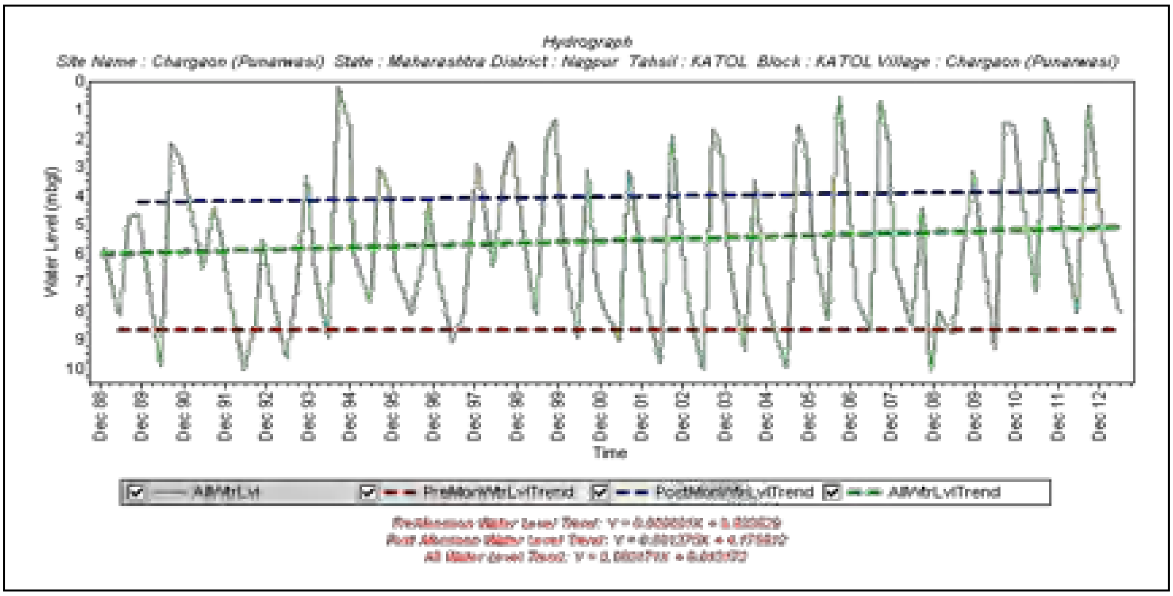


Fig.2.15a: Hydrograph of GWMW located at Chargaon (1988-2012), Chandrabhaga Watershed (WGKKC-2)

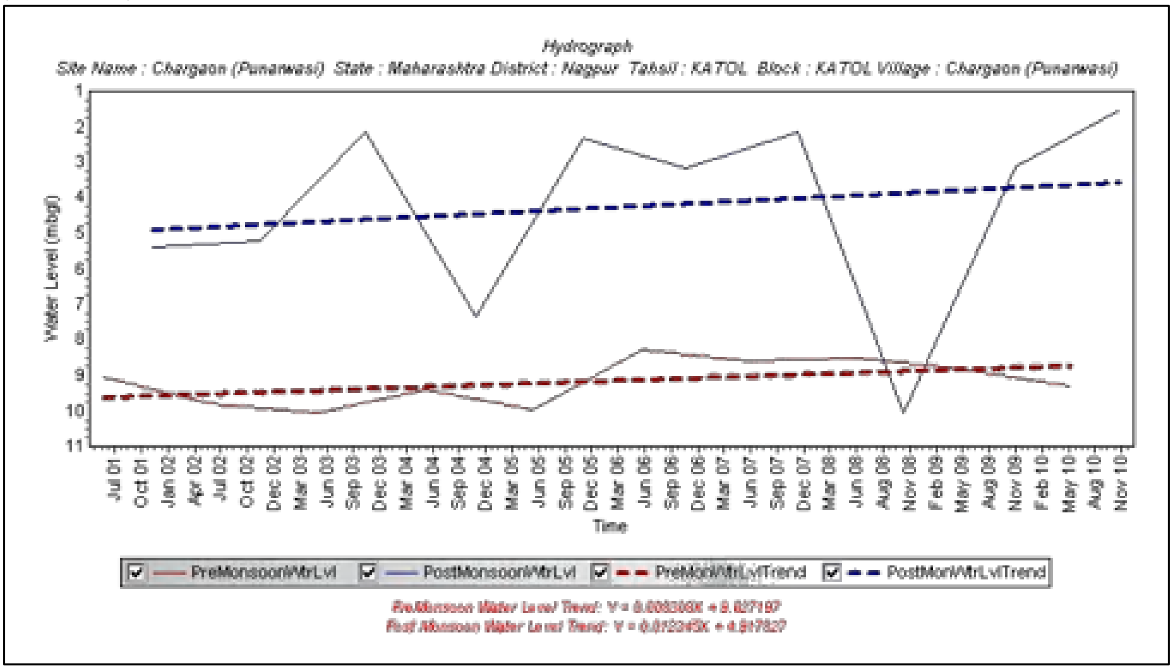


Fig.2.15b: Hydrograph of GWMW located at Chargaon (2001-2010), Chandrabhaga Watershed (WGKKC-2)

2.11 Water Quality

The water quality data from GWMW located at Kalmeshwar and Chargaon were studied for the analysis of long-term water quality. The chemical analysis of the water sample collected from GWMW (representing shallow aquifer) during the year 2013 is presented as Table 2.3. The parameters like Nitrate, Fluoride, Electrical Conductivity, TDS and Total Hardness have been studied for the period 1989 to 2013 and for last decade i.e., 2000 to 2010 (Fig. 13a & b, 14 a & b).

Table 2.3: Chemical analysis of GWMW located at Kalmeshwar and Chargaon, 2013

GWMW location	pH	EC µS/cm	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F	SAR	RSC
Kalmeshwar	8.2	899	584	430	168	2	6	0.3	0	293	135	6	9	1.59	0.04	-3.8
Chargaon	8.0	359	233	185	46	17	2	0.0	0	214	21	2	BDL	0.09	0.02	-0.2

All are in mg/l except pH & EC

A perusal of the above table indicates that the overall quality of ground water is potable and fit for both irrigation and domestic purpose. However, the analysis data from Kalmeshwar GWMW shows the presence of Fluoride above MPL i.e., 1.59 mg/l.

Beside this, the long-term trends for Nitrate, Fluoride, Electrical Conductivity, TDS and Total Hardness indicate that the EC and TDS shows significant rise since year 2000 at GWMW located at Kalmeshwar. The area around monitoring well at Kalmeshwar is prone for ground water pollution as it is located in the heart of city and surrounded by the industrial belt. The long-term trend analysis indicated the rise in EC @ 21.13 µS/cm per year; rise in TDS @ 34.21 mg/l and rise in Nitrate 0.63 mg/l since year 2000. It seems that the anthropogenic activity in and around the monitoring well may be responsible for rise in EC, TDS and nitrate. Thus, the analysis of long-term trend on ground water quality gives the indications of contamination due to various factors like urbanization, industrialization etc., on ground water quality.

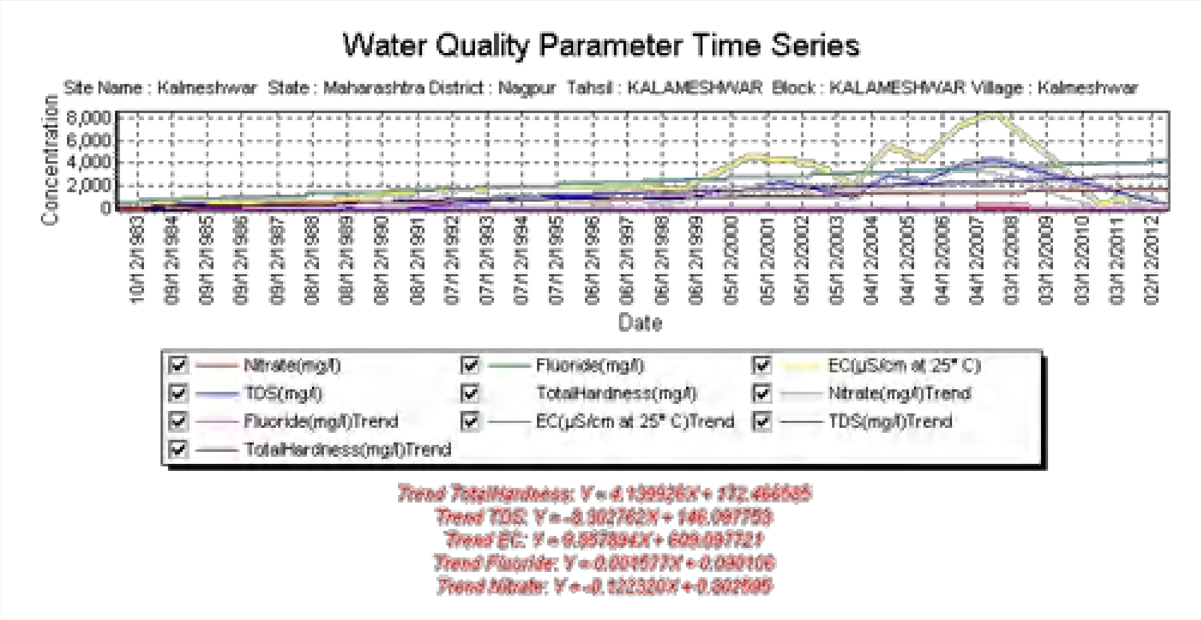


Fig.2.16a: Time series plot for Water Quality (NO_3, F, EC, TDS & TH) of GWMW located at Kalmeshwar (1982-2013), Chandrabhaga Watershed (WGKKC-2)

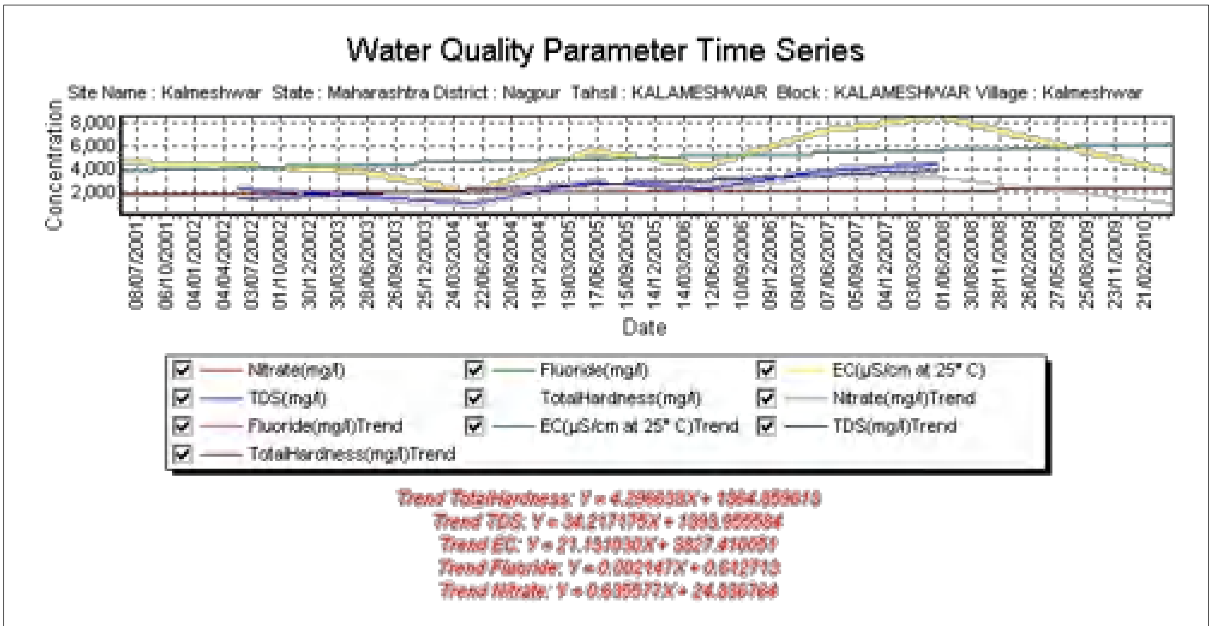


Fig.2.16b: Time series plot for Water Quality (NO_3, F, EC, TDS & TH) of GWMW located at Kalmeshwar (2000-2010), Chandrabhaga Watershed (WGKKC-2)

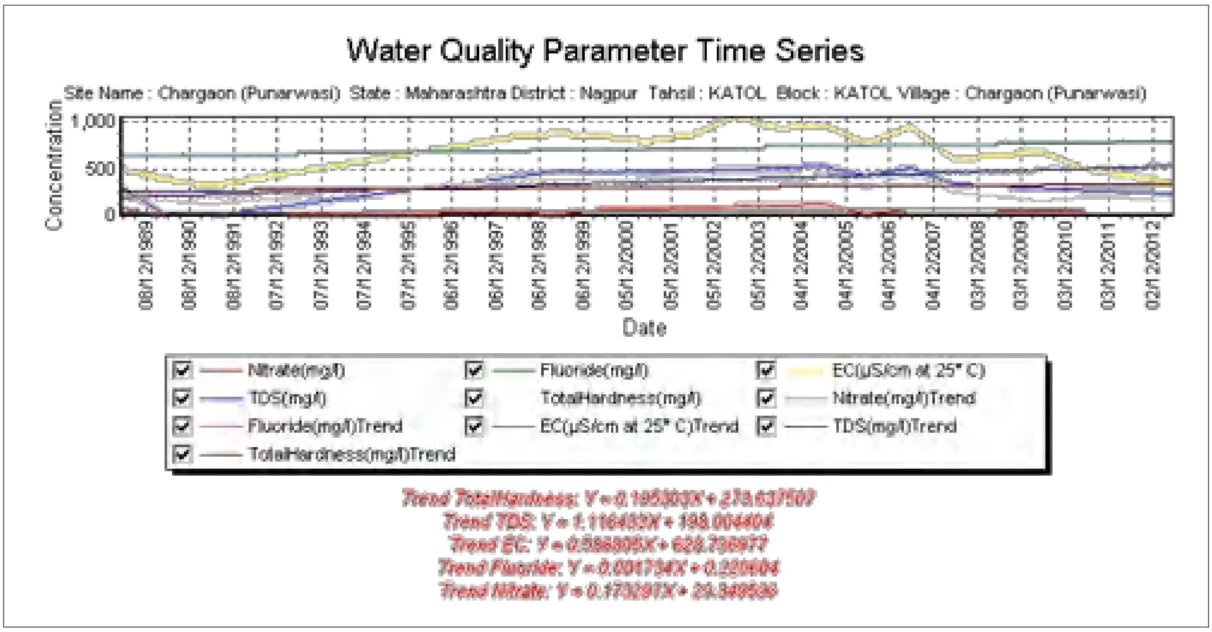


Fig.2.17a: Time series plot for Water Quality (NO_3, F, EC, TDS & TH) of GWMW located at Chargaon (1989-2013), Chandrabhaga Watershed (WGKKC-2)

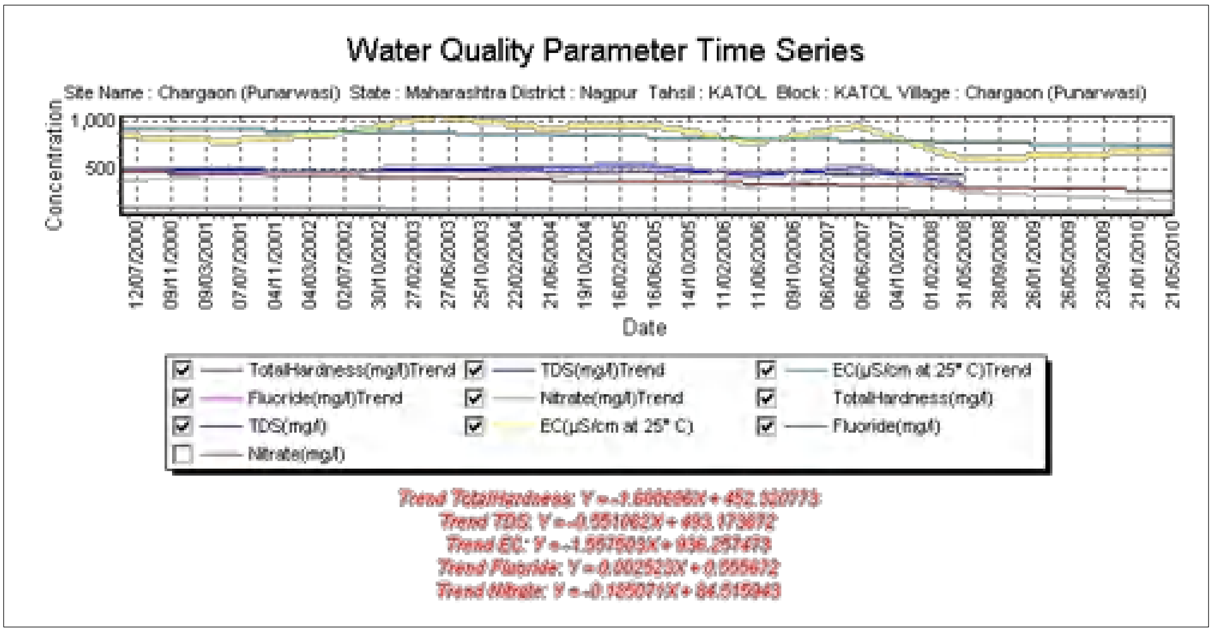


Fig.2.17b: Time series plot for Water Quality (NO_3, F, EC, TDS & TH) of GWMW located at Chargaon (2000-2010), Chandrabhaga Watershed (WGKKC-2)

2.12 Ground Water Resources, Recharge Parameters and Discharge Parameters

The ground water resource assessment of the Chandrabhaga watershed has been computed jointly by the CGWB, CR, Nagpur and GSDA, GOM, Pune (Table 2.4). The ground water resources for the year 2004 indicate that the stage of ground water development is about 80%.

However, the long-term ground water level trend was raising thus the watershed was categorised as "Safe". As such, it becomes more pertinent to develop a sustainable water resource management plan for the watershed, which is one of the objectives of the project.

Table 2.4. Ground water resources (2004), Chandrabhaga Watershed (WGKKC-2)

S. No.	Particulars	Command	Non-Command
1	Area (sq. kms)	37.26	284.25
2	Annual Ground Water Recharge (ham)	623.80	5585.12
3	Net Ground Water Availability (ham)	592.61	5305.86
4	Total Gross Draft (ham)	494.04	4047.46
5	Domestic + Industrial Allocation (ham)	464.83	
6	Net Ground Water Available for Irrigation (ham)	686.83	
7	State of Ground Water Development (%)	80.48	
8	Category of Watershed	Safe	

No separate study was carried out earlier for the estimation of recharge and discharge parameters in Chandrabhaga watershed. However, the State Govt. agency i.e., GSDA has computed the resources based on the ground data of the respective year.

Estimation of In-Storage Ground Water Resources

In the state of Maharashtra in-storage groundwater resources computation is limited to unconfined aquifer only and annually replenishable aquifer has been considered. The decline in groundwater level on long-term basis in many parts of the state clearly indicates that the development has gone beyond the extent of annual replenishable resources and excessive withdrawal is from in-storage groundwater resources. Based on the guidelines issued by GoI following formula has been used in the computation of the in-storage groundwater resources.

Thickness of Aquifer
(Granular/ productive zone) X Specific Yield X Area
below zone of WTF

In the State, heterogeneous hard rock constitutes predominant aquifer and hence fracture porosity plays a very vital role in the aquifer geometry. Based on the data and the field experience of the hydro-geologists from GSDA and CGWB both the depth and the thickness of the shallow aquifer have been taken up for computation. However, in the WGKKC-2 watershed there is no granular zones exist below the pre-monsoon depth to water level. Hence, the in-storage ground water resources have not been estimated.

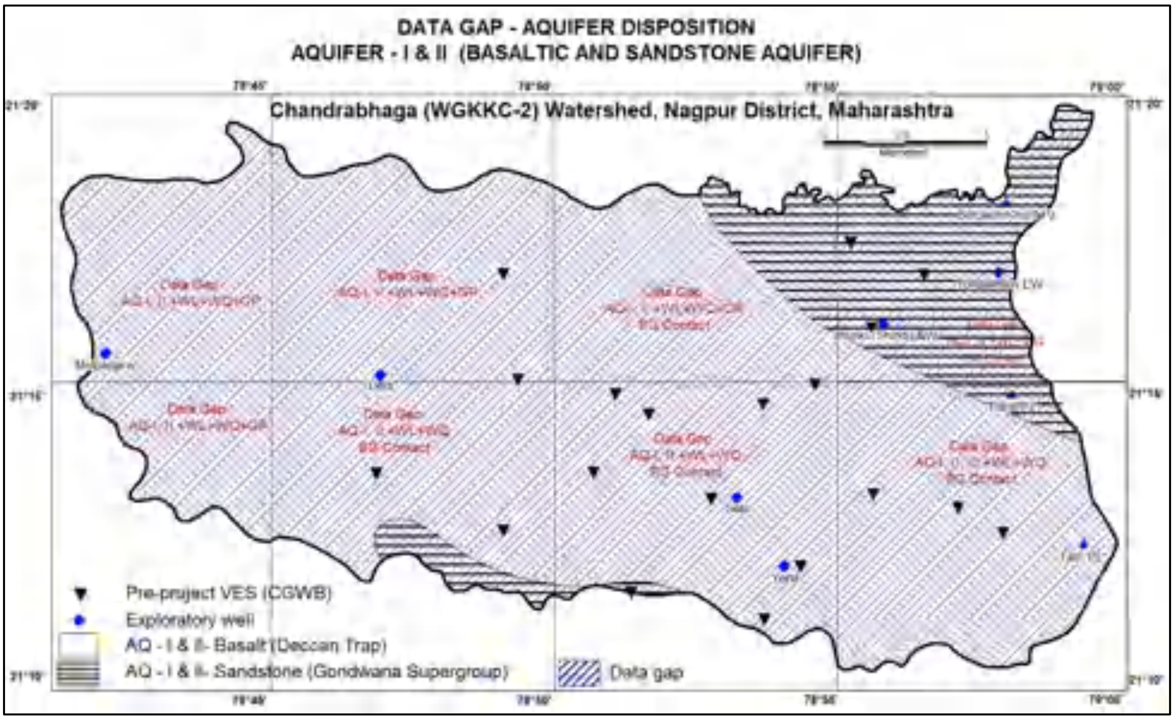
2.13 Data gap analysis

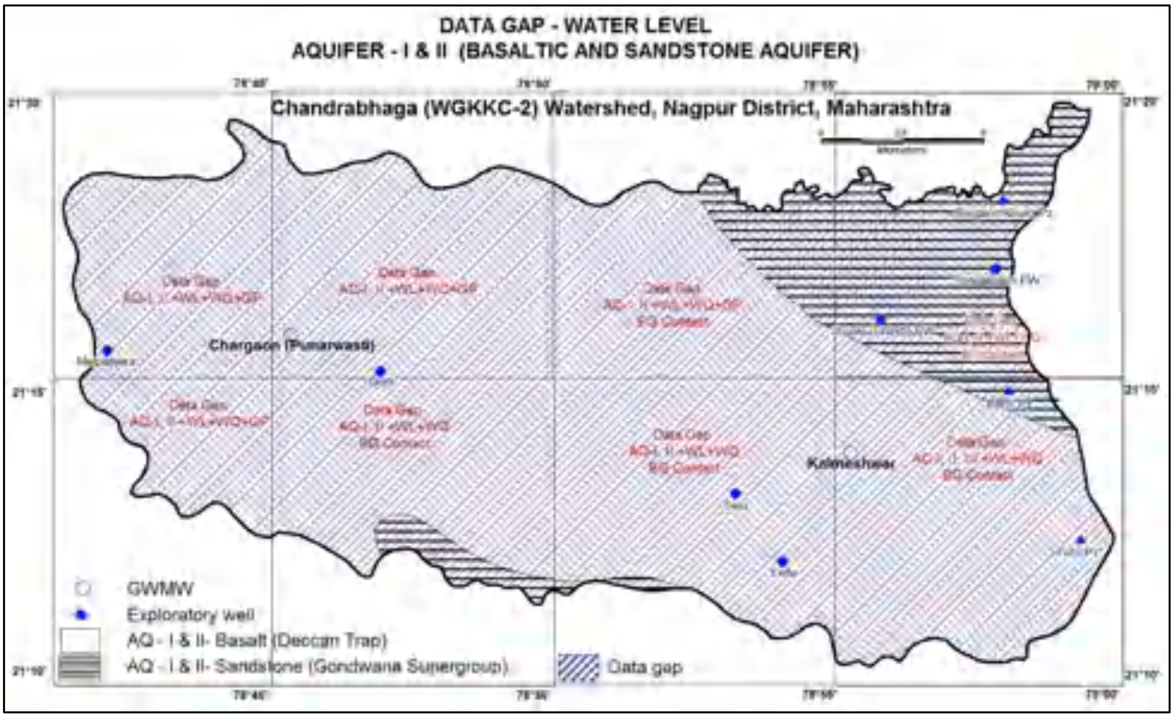
The careful study of all the available data, as discussed above, indicated that the data on aquifer disposition in all aquifers; ground water level both for unconfined and semi-/confined aquifers of Basalt and Sandstone; water quality for all the aquifers; sub-surface lithological information and aquifer parameters are very sparse. Therefore, after plotting all the available data on 1:50,000 scales, the aquifer wise, grid wise data gaps have been identified for the entire watershed (Table 2.5 and Fig. 2.18). Accordingly, the data generation plan considering the objective of the project has been prepared. Point wise details on data generation are discussed successive chapter.

Table 2.5: Data gap analysis, Chandrabhaga Watershed (WGKKC-2)

Sl. No.	**Items**	**Data available**			**Data required / Data gap identified**			**Data generation**		
		AQ-I	**AQ-II**	**Total**	**AQ-I**	**AQ-II**	**Total**	**AQ-I**	**AQ-II**	**Total**
1	Aquifer Disposition (GW exploration)	5	4	9 Basalt =4 EW+2 Pz Sandstone =2 EW+1 Pz	63/58	20/16	74	58 KOW	16 wells (outsourced)	Out of 16, Basalt= 5EW+1OW Sst= 4EW+1 OW TCG= 5EW Total= 74
2	Ground water monitoring	2	NA	2	60/58	16	74	58 KOW	16 wells	74
3	Ground water quality	2	NA	2	60/58	20/16	74	58 KOW	16 wells	74
4	Geophysical survey (In-house)	19 VES with DOI 160 m bgl			Substantial micro level data upto 200 m bgl depth is necessary to decipher the 3D aquifer geometry of complex hydrogeological system exists in the study area.			137 VES with DOI 200 m bgl 1 GRP (300 line m) with DOI 40 m bgl 5 VLF with DOI 30 to 40 m bgl		
	Geophysical survey Out sourced (carried out by NGRI, Hyderabad)	NIL						21 VES with DOI 99 GTEM with DOI upto 32 to 250 m 19 ERT (17.6 LKM) with DOI upto 90 m bgl SkyTEM (954 LKM) with DOI 30 to 50 m bgl (shallow depth) DOI 200 m upto 300 m bgl (deeper depth)		
5	Infiltration test	NA	NA	NA	9	--	9	9	--	9
6	Pumping test	NA	4	4	20	10/6	26	21 on DW	7 on EW	28
7	Landuse/Land cover	NA			Required for entire study area			GIS output acquired from GSDA, Govt. of Maharashtra		
8	Geomorphology									
9	Climate	No Data Gap			Not required			No Data Gap		

NA=Not available


DATA GAP - AQUIFER DISPOSITION
AQUIFER - I & II (BASALTIC AND SANDSTONE AQUIFER)
Chandrabhaga (WGKKC-2) Watershed, Nagpur District, Maharashtra
Pre-project VES (CGWB)
Exploratory well
AQ - I & II- Basalt (Deccan Trap)
AQ - I & II- Sandstone (Gondwana Supergroup)
Data gap


DATA GAP - WATER LEVEL
AQUIFER - I & II (BASALTIC AND SANDSTONE AQUIFER)
Chandrabhaga (WGKKC-2) Watershed, Nagpur District, Maharashtra
Chargaon (Punarwasti)
Kalmeshwar
GWMW
Exploratory well
AQ - I & II- Basalt (Deccan Trap)
AQ - I & II- Sandstone (Gondwana Supergroup)
Data gap

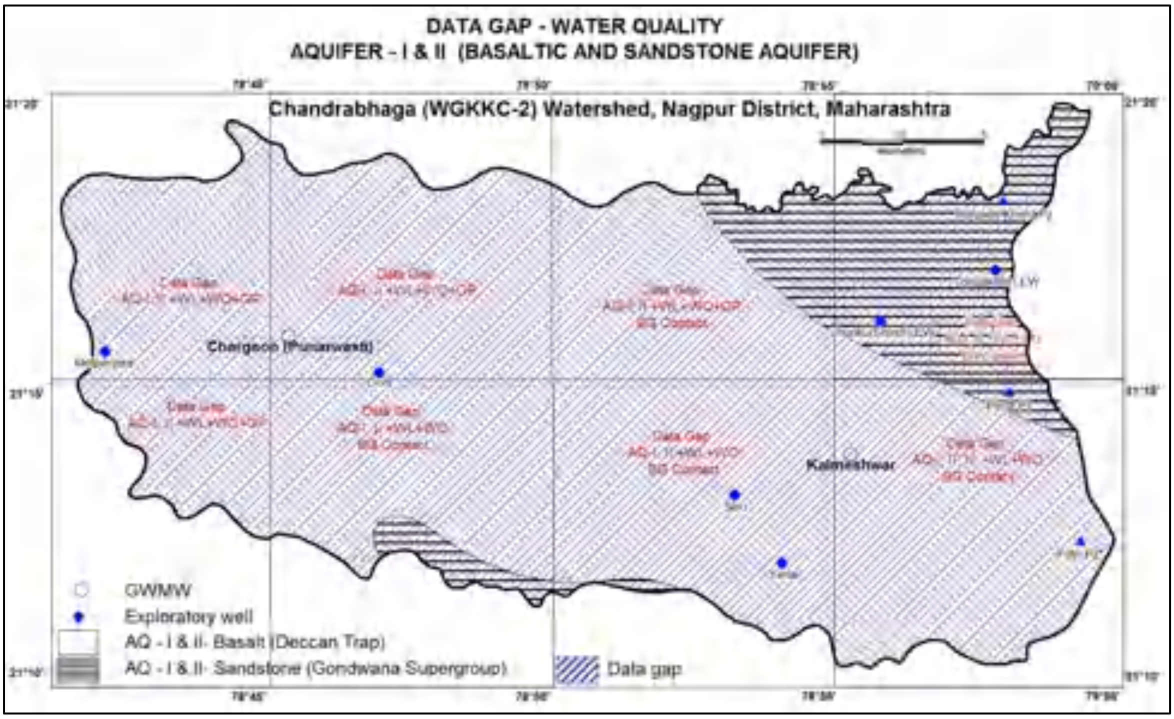


Fig.2.18: Aquifer wise data gap analysis for aquifer disposition, ground water level and water quality, Chandrabhaga Watershed (WGKKC-2)

3 DATA GENERATION

3.1 Geomorphology

The lineaments demarcated earlier on map have been verified based on the visual interpretation of IRS-ID, LISS-III satellite data and the lineament map were modified. These lineaments are surface manifestation of underlying structural features like fractures, joints, faults and dykes. Lineaments are also seen as straight alignment of drainage and vegetation. A perusal of the lineament map indicates that there are four sets of lineaments exist in the watershed trending NE-SW, NW-SE, N-S and E-W directions. E-W trending lineaments are predominant in the southern parts of the study area.

3.2 Geophysics Geophysical Survey by CGWB (In-House)

The study of the terrain below the earth's surface can be possible only by integration of the data obtained from the borehole or mining. Geophysical investigations provide the basis for the extension of such knowledge in the unknown area. Surface Geophysical methods are very useful tools for constructing a subsurface picture of the geological/ structural/ hydrogeological condition of the virgin area or the area where very little subsurface borehole data are available. Thus, the prime objective of geophysical investigation is to unravel the hidden sub-surface hydrogeological information to save money and time, which would otherwise have been spent on drilling of test boreholes.

The major objectives of surface geophysical investigation in the pilot project area are as follows:

I. Delineation of aquifer geometry, water bearing horizons and fracture/fault zones and precise demarcation of trap cover Gondwana/Archaean boundary up to 200 m below ground level,
II. Application of modern geophysical techniques to offer precise data with reduced uncertainty and ambiguity about shallow and deep aquifers with their geometry,
III. Establishment of efficacy of various geophysical techniques under different hydrogeological conditions,
IV. Formulation of a protocol for geophysical investigations to be taken up as an aid to aquifer mapping,
V. Toning up the capacity of CGWB, state authorities and stakeholders in advance geophysical techniques and modelling through outreach programs.

In addition to the surface geophysical investigations, subsurface borehole logging was also carried out in the bore wells drilled in the area and the primary objectives of subsurface geophysical logging are:

i. For validation of geophysical parameters derived from the data acquired from various advanced surface and airborne geophysical techniques,
ii. To identify distinct boundaries between different hydrogeological units,
iii. To select the proper setting of the screen depths against productive aquifers and casing against the collapsible formations and also sealing bad quality of water bearing formation,
iv. To determine and delineate the aquifer geometry and its framework in space and time.
v. To differentiate the different lava flows in Basaltic rock formation

For estimation of the ground water potential, it is necessary to have an accurate delineation of the aquifer disposition, their extension and thickness; and this can be assessed only through generation of the micro-level data from the field. Thus, in order to draw the precise picture of the aquifer geometry in the area, heliborne geophysical investigations (SKYTEM) were taken up with the following objectives

1. To delineate aquifers, understand the dispositions of the lava flows separated by red boles and depth to Gondwanas and/or Archaeans up to 250 m depth in the context of the occurrence of aquifers,
2. To generate a new and comprehensive three-dimensional picture of the subsurface clearly indicating the aquifer disposition and to form the best possible basis for the subsequent hydrogeological and geological modeling with distinct demarcation of Basalt-Gondwana margin and individual basaltic flows.

A systematic electrical resistivity survey was carried out by ABEM SAS 300C Terrameter by employing Schlumberger configuration with maximum current electrode separation (AB) of 600 m depending on the available spread length. A total of 138 VES including 52 VES for exploratory drilling (Fig.3.1) (Annexure-I) were carried out to estimate the thickness of the top basaltic formation or depth of Gondwana formations. In addition to this, 300 line meters of Gradient Resistivity Profiling and 610 line meters of Very Low Frequency (VLF) electromagnetic profiling were also carried out to locate the fractures/lineaments in Chandrabhaga Watershed. The VES data acquired was interpreted by IPi2Win software and analyzed to infer the subsurface geo-electric layers. The same are presented as Annexure-II.

The VES results were standardized based on the local Geology, Hydrogeology and existing borehole data (Table3.1). Each geo-electric layer obtained from the investigations is not exactly the response from the individual litho-units, but it is the equivalent resistivity or the weighted average of the two or more numbers of the subsurface layers.

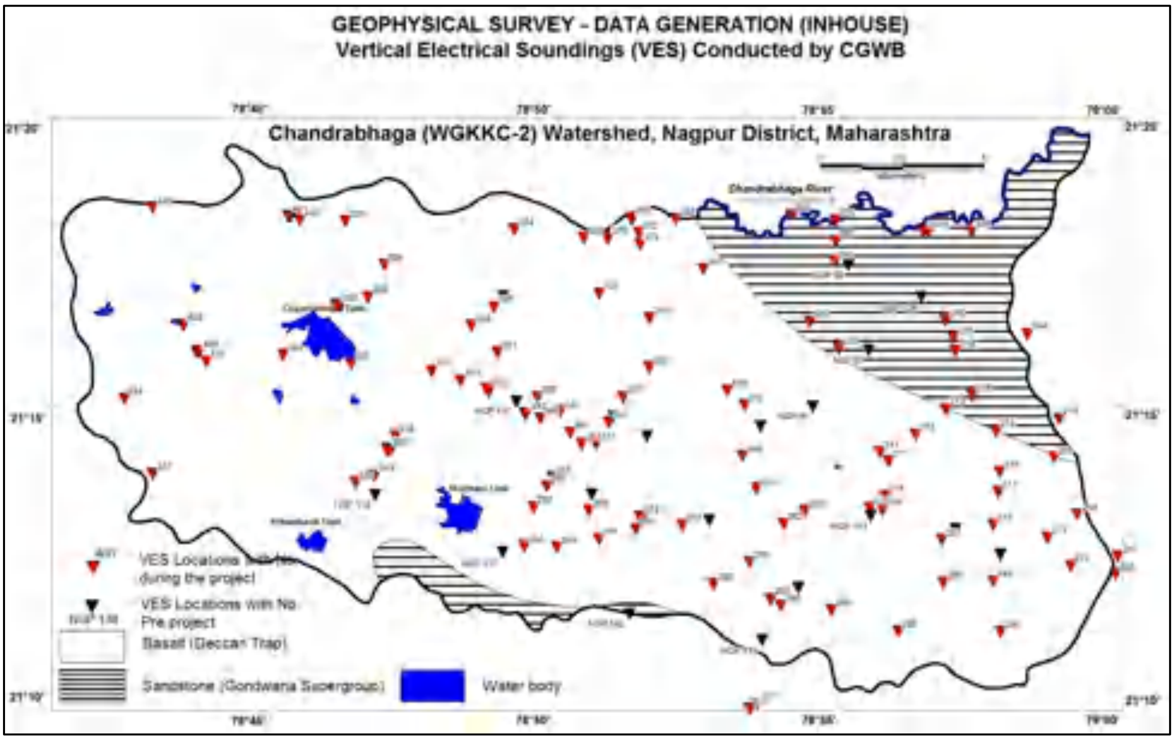


Fig 3.1: Locations of VES conducted by CGWB Chandrabhaga Watershed (WGKKC-2)

Table 3.1: Resistivity ranges and inferred lithology, Chandrabhaga Watershed (WGKKC-2)

Resistivity range (Ohm.m)		**Lithology**	**Thickness range (m)**	
3.2	181	Top Soil	0.2	2
1	6	Clay	1.1	27.7
1.8	5	Shale	1.1	82.9
6	9	Sandy Clay	3	11.3
11	34	Sand	4.3	11.3
10	14	Sandstone + Shale	2.3	114
16	87	Sandstone	3.5	79.3
152	1343	Compact sandstone	0.9	84
3.5	35	Weathered Basalt	0.6	39.5
30	43	Moderately Weathered	3.5	8.6

Resistivity range (Ohm.m)		Lithology	Thickness range (m)	
		Basalt		
40.5	58	Vesicular Basalt	1.1	125
6.7	40	Fractured Basalt	1.3	144
More than 60		Massive Basalt	1.1	102
12		Fracture Granitic Gneiss	Bottom most layer	
More than 554		Massive Granitic Gneiss	Bottom most layer	
10		Lameta bed	Limited data from literature	5

It is inferred from VES data that the thickness of the basalt is increasing from east to west. It is measured around 60m at village Yerla in the eastern part, around 108 m at village Dorli, and more than 150 m in the western and northern part of the watershed. However, Gondwanas are seen at shallow depths, approximately 30 to 40m depths around village Raulgaon. Occurrence of Gondwana at shallow level could be attributed to reverse faulting (?) at this place or the extension of Gondwana of southern part. All the data generated using various geophysical surveys conducted in the watershed were utilized to generate various 2D, 3D sections and maps of the basins and the results of the same are discussed below.

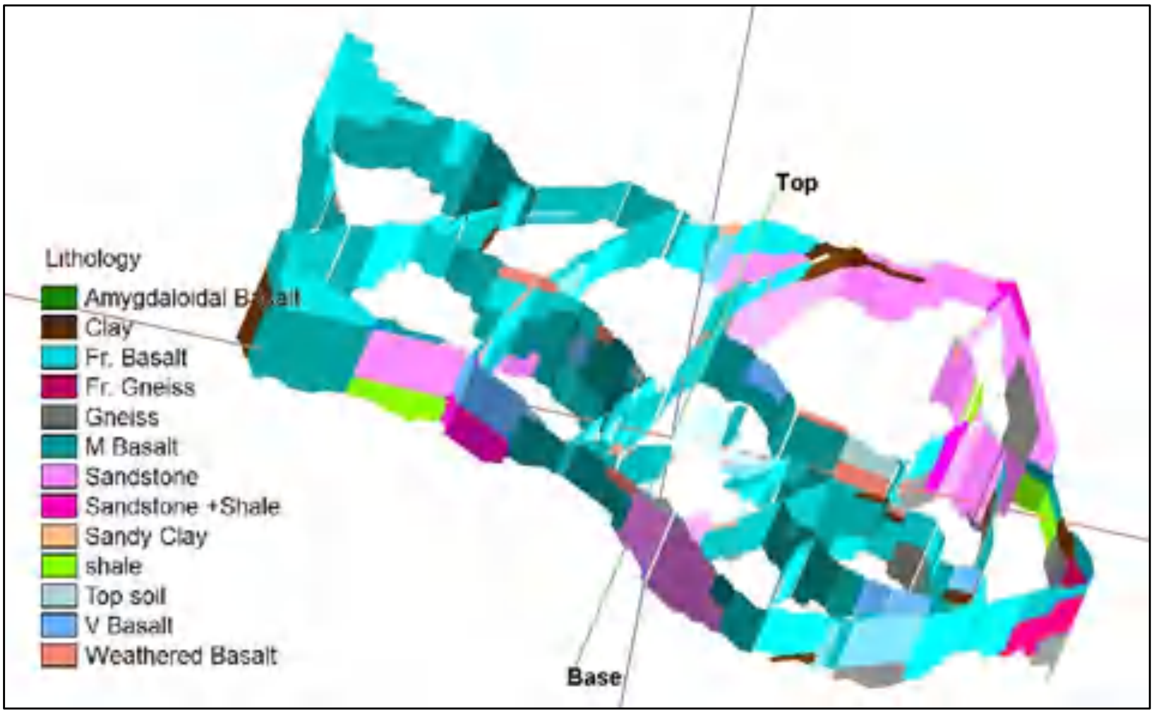


Fig.3.2: Generation of Subsurface disposition, geoelectrical layers translated to lithological layers using Rockworks, Chandrabhaga Watershed (WGKKC-2)

The Gondwana formations are extending more than 150m depth in the NE part of the area. The Gondwanas are absent in the SE part of the area and it was confirmed from the existing borehole data at Yerla. In this area, the Archaeans are encountered below basaltic formation at depths around 60 mbgl. In the northern and western parts of the area, the thickness of the top basaltic formation is more than 150m but in the SW part of the area around Raulgaon, the Gondwana formation occur at shallow depths. The various contour maps, 2D, 3D figures generated based on VES results and geophysical logs are discussed below.

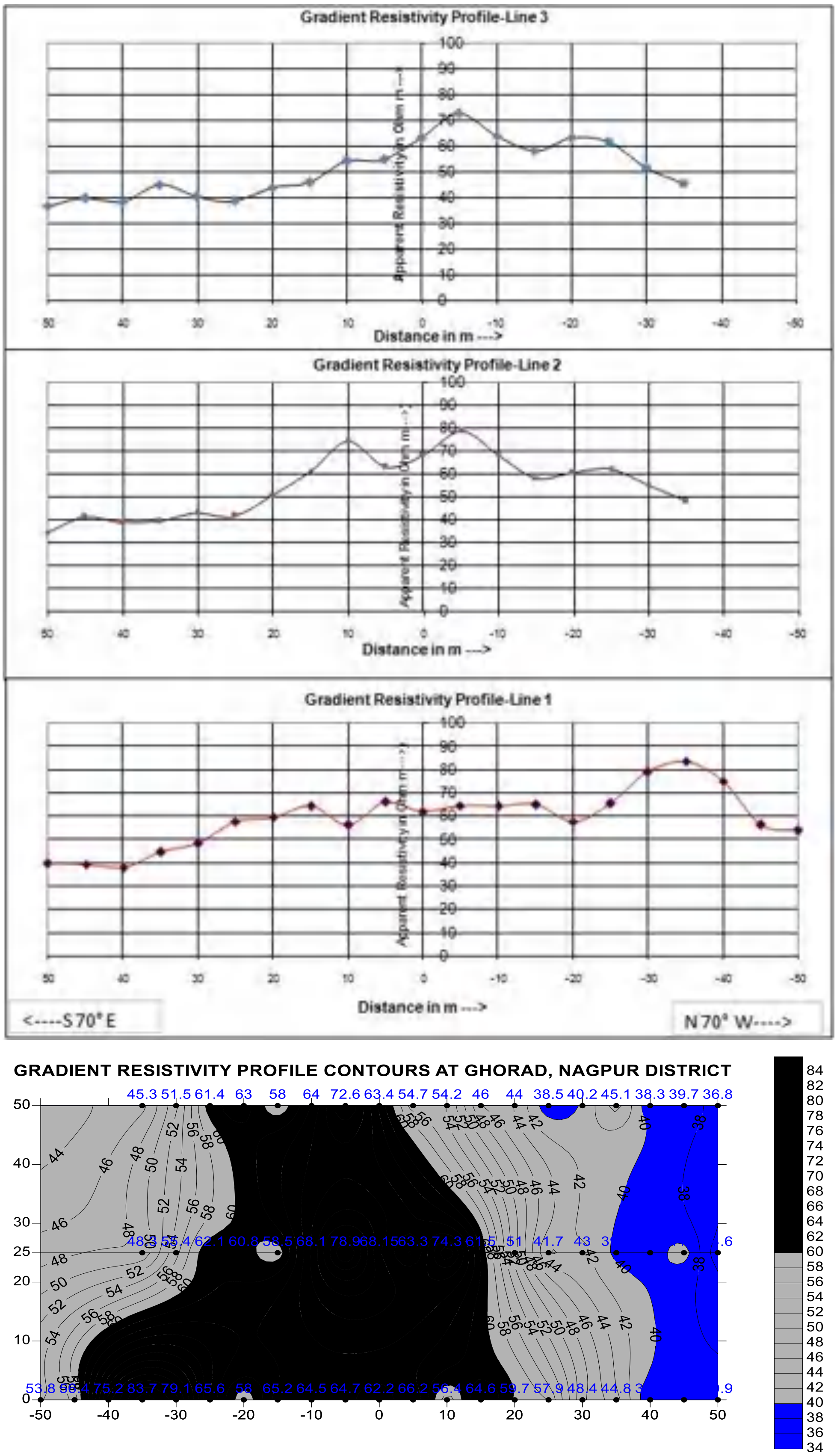
3.2.1.1 Gradient Resistivity Profiling:

Three parallel gradient resistivity profiles – Line 1, Line 2 and Line 3 were carried out in S 70° E – N 70° W direction at village Ghorad for exploratory drilling and the apparent resistivity values are plotted on linear scale against the distance from the central point of the profiles. The length taken for GRP at Line 1 is about 100 m, whereas for Lines 2 and 3 are about 85 m each. Apparent resistivity contours were also generated using SURFER software based on the GRP data. The results of analysis indicates that in the SE Side, the apparent resistivity values are moderate, ranging from 40-60 Ωm, in the central part, the apparent resistivity values are high, ranging from 60-80 Ωm and in the NW part, the apparent resistivity values are low, less than 40 Ωm. In the NW part of the profile, the low apparent resistivities may indicate fracture zone (Fig. 3.3).

In the Gradient Resistivity Profiles, the apparent resistivities in the NW part were recorded low, despite the locations of the apparent resistivity measuring of points nearer to the current electrodes of the profiles. The comparative analysis of the GRP and VLF profiles, infer that the fractures in the NW part of the profiles are productive.

One GRP on the VLF profile 3, at 60 m from the starting point of the VLF profile was also carried out. The VES results of earlier surveys in the same site indicate that the top geo-electric layer of 70 Ωm resistivity and 0.9 m thickness represents top soil. The second geo-electric layer of 24 Ωm resistivity and 1.0 m thickness represents weathered basalt, the third and fourth geo-electric layers of 13 and 6 Ωm resistivities up to 8.8 m depth represents fractured basalt, the fifth layer with 46 Ωm resistivity up to 40 m depth may represent moderately fractured or vesicular basalt. The bottom most layer with 216 Ωm resistivity represents massive basalt.

The low apparent resistivities values obtained from GRP Line 1, low apparent resistivity contours generated from parallel GRP of less than 40 Ωm apparent resistivity and high Fraser derivative values infer potential fracture zone in NW part of the area surveyed.



<----S 70° E N 70° W---->

Fig.3.3: Gradient Resistivity Profiles & contours at Ghorad, Chandrabhaga watershed (WGKKC-2)

3.2.1.2 Very Low Frequency (VLF) Electromagnetic Profiling

Five parallel VLF profiles, Line 1, Line 2, Line 3, Line 4 and Line 5 were carried out in N85°E-S85°W direction at village Ghorad for exploratory drilling. Line 1 is of 110 m length, Line 2, 4 and 5 are of 125 m length and line 3 is of 120 m length had been taken. The data on Tilt and ellipticity were plotted on linear scale against distance from the starting point of the profile. Fraser derivatives of the Tilt were also computed and plotted along with Tilt on linear scale against distance from the starting point of the profile. Contour maps were also generated for Tilt, Ellipticity and Fraser Derivatives (Fig. 3.4).

On the tilt angle profile, a maximum followed by a minimum separated by an inflection point located above the top of the conductive body. In the present case, the conductive body is a potential ground water bearing fracture zone. In order to give an easier correlation between the anomaly and the structure, Fraser derivatives of tilt angles were used. The expression for the Fraser Derivative is (a+b) - (c+d) where a, b, c, and d, are the rough values of the tilt angle measured at four successive stations separated by the same spacing. The values of the Fraser Derivatives are plotted at the middle of the stations b and c. In the case of a fracture, the maximum of this Fraser curve is located just above the position of the fracture.

The ellipticity used to distinguish highly conductive structures (the ellipticity value is less than the tilt value and has an opposite sign) from poorly conductive structures or geological contacts (the ellipticity value is of the same order as the tilt value and has an same sign). As per the thumb rule of the method to determine the top of the conductive body, the depth is approximately half the distance between the positions of the minimum and the maximum on the rough value of tilt curve.

Contour maps for Fraser derivatives, Tilt angle and Ellipticity were generated. Tilt angle and Ellipticity curves are highly fluctuating, 3 point moving average has been computed for them. VLF Profiling data are presented as graphs of variation of tilt, ellipticity and Fraser derivatives plotted against distance from the starting point of each profile and along 5 profiles. The tilt and ellipticity are highly fluctuating, may be due to noise. The maximum of this Fraser curve is located just above the position of the fracture and these points are joined to get the orientation of the fracture. Five fractures (Fr.1, Fr.2, Fr.3, Fr.4 and Fr.5) were delineated from combined analysis of the VLF profiles and they are oriented in approximately N - S direction.

The tilt, ellipticity and Fraser derivative values are plotted against distance at all points in the area and then contour lines are drawn by using SURFER 9 software. From the combined analysis of the VLF profiles (Fig. 3.4) and the contour maps (Fig. 3.5) of the Fraser derivatives, five fractures (Fr.1, Fr.2, Fr.3, Fr.4 and Fr.5) were delineated and found that they are oriented in approximately N - S direction.

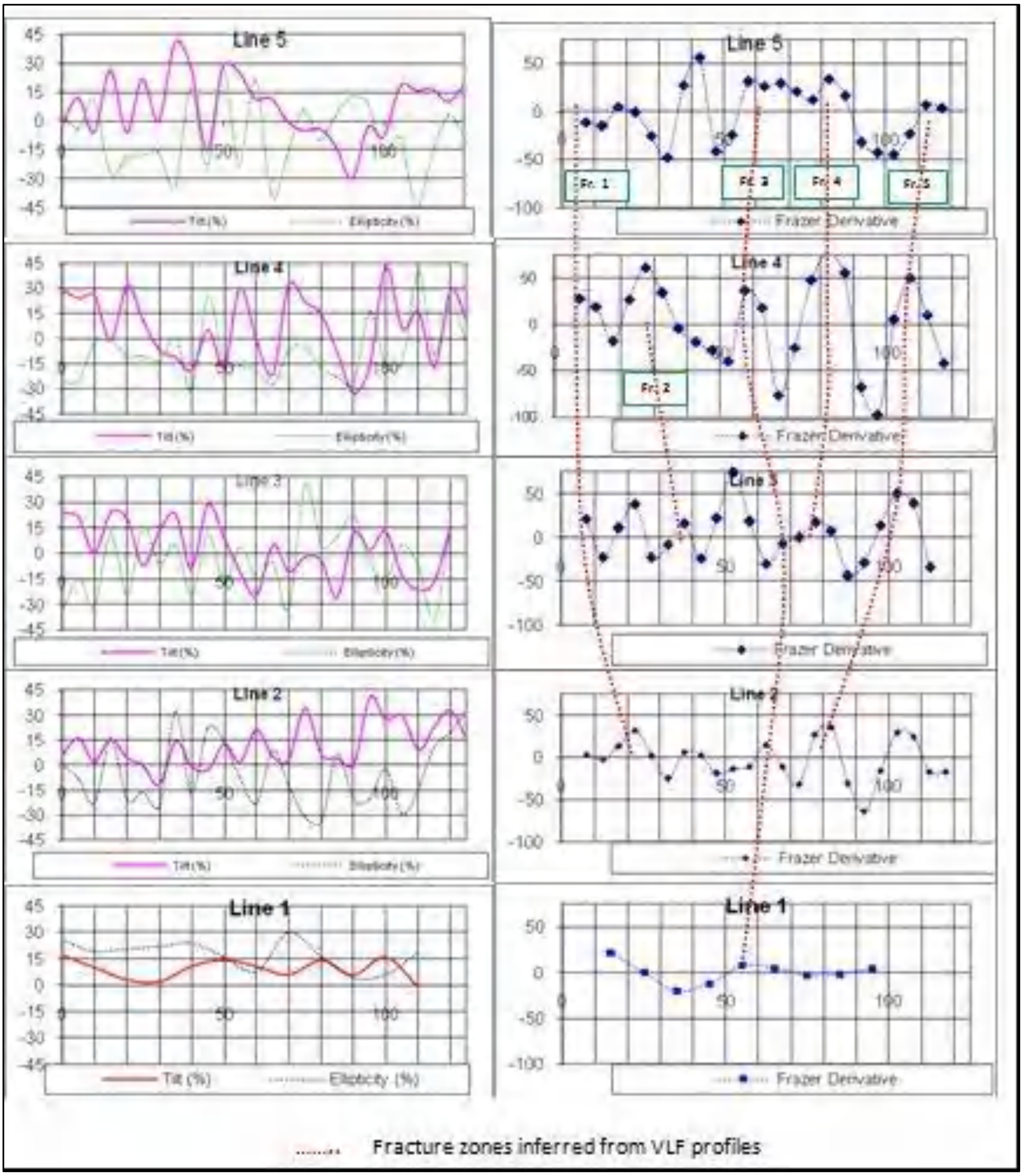


Fig.3.4. VLF profiles at Ghorad, Chandrabhaga Watershed (WGKKC-2)

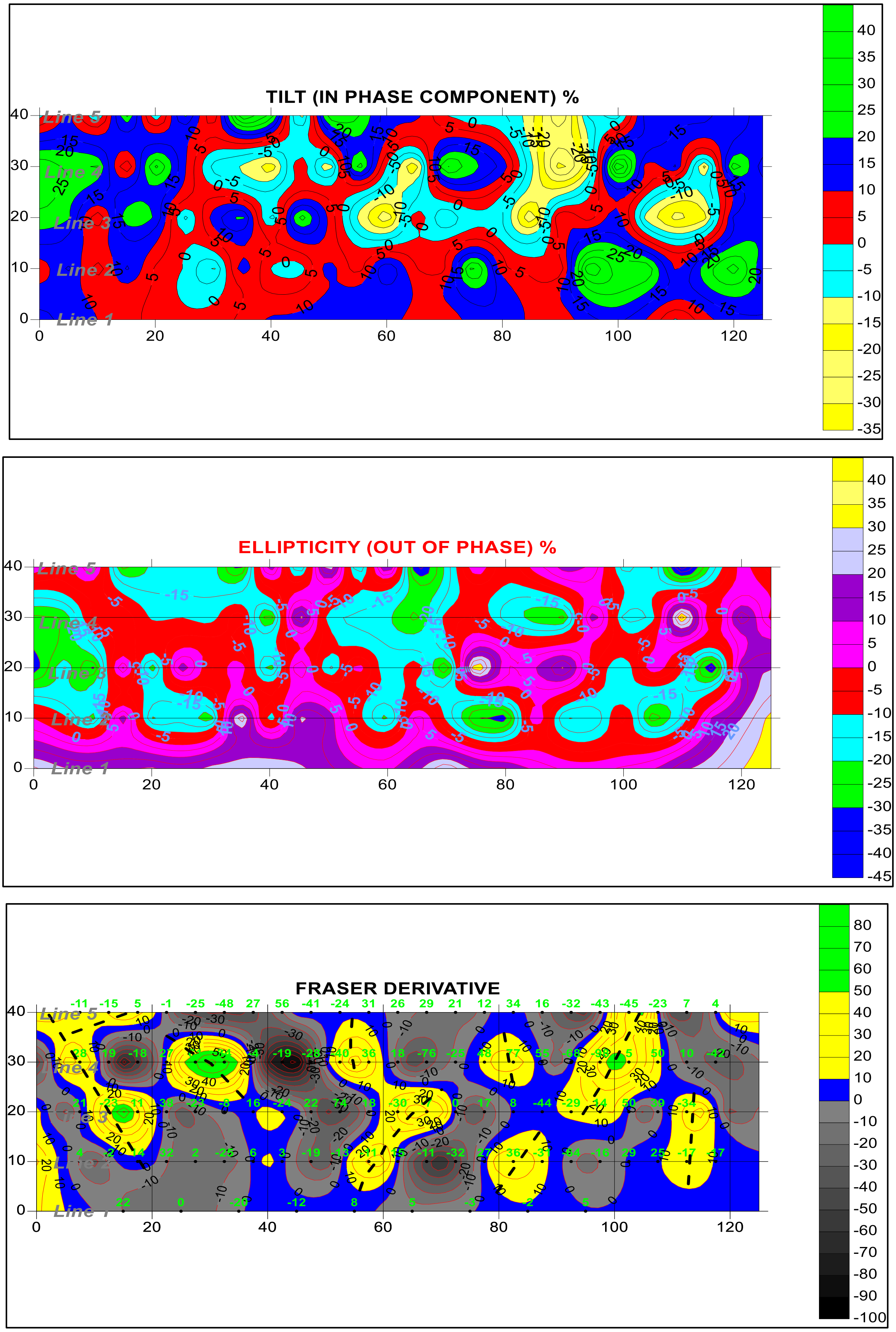


Fig.3.5 Contour Maps generated based on Parallel VLF Profiles at Ghorad, Chandrabhaga Watershed (WGKKC-2)

3.2.1.3 Spatial distribution of resistivities with depth

Using resistivity data top layer resistivity contour maps was prepared and presented as Fig. 3.6. It is inferred from this Figure that the high resistivities between 40 and 60 Ohm m in the western and in some isolated patches in the watershed area may represent vesicular basaltic formation whereas the resistivities more than 60 Ohm m represents massive basaltic formation. The moderately low resistivities between 20 and 40 Ohm m are seen from central to eastern part of the area along the river/ stream courses represent alluvial soil. However, the same resistivities in the western part of the area represent weathered basaltic formation. The low resistivities ranging between 5 and 20 Ohm m in the northern, southern, north-eastern, south-eastern and small portions of the eastern, north western, south-western and west central parts of the area represent highly weathered basaltic formation.

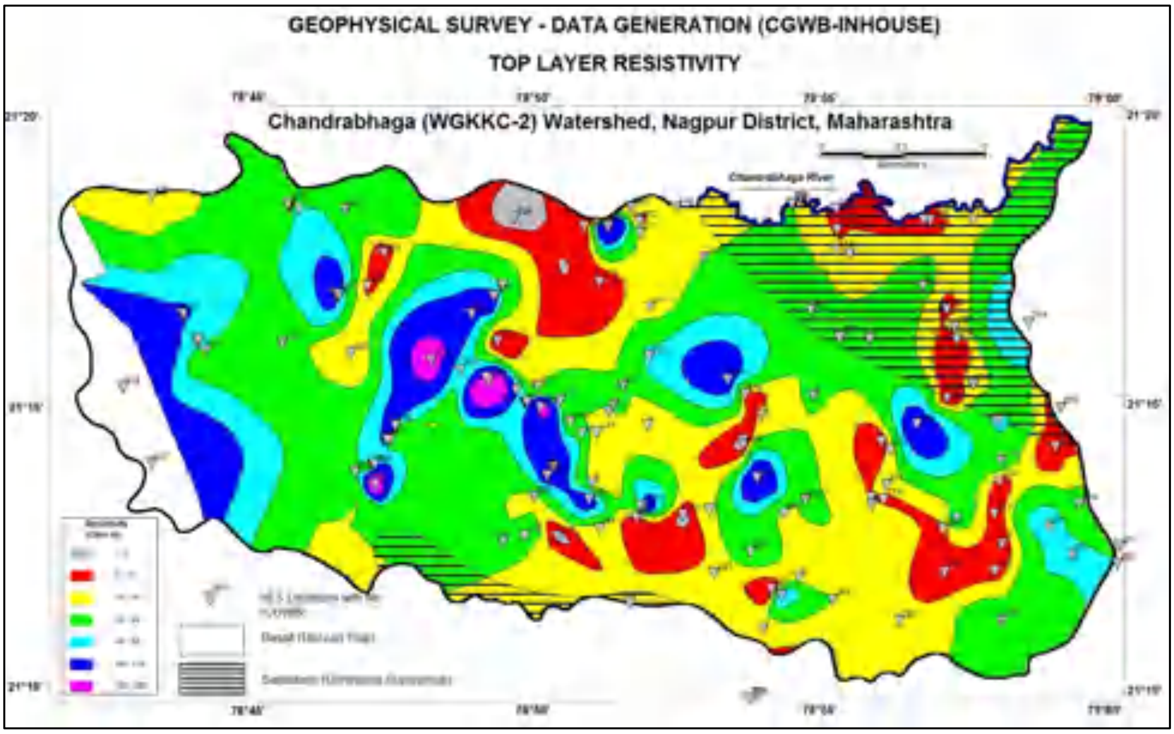


Fig. 3.6: Spatial Distribution of Top Layer Resistivity, Chandrabhaga Watershed (WGKCC-2)

Elevations at the VES locations were recorded through GPS and checked from the Toposheets. Depth slicing has been done by generating the contour maps for resistivity values at different elevations based on the VES results. These depth slice are ranging from 400 m amsl to 150 m amsl at every 50 m interval. The western part of the area is highly elevated with 400 to 500 m amsl

The perusal of Fig. 3.7 indicates that the high resistivity values more than 200 Ωm in the eastern part of the study area at 150m amsl could be attributed to Granitic Gneiss (specifically in SE parts) and by Gondwana sandstones in other areas. The resistivities less than 200 Ωm represent Gondwana formation with different degrees of compactness and saturation. The higher resistivities represent compactness of the formation. It is seen from the Fig. 3.7 that from central to western part of the area, the VES results could not give the information below 150 m amsl because of the limited spread length (current electrode separation AB) available for carrying out VES. The resistivities with > 200 Ωm in the central part of the area represent massive basaltic formations of different nature. The elongation of the resistivity contours in N-S direction with resistivities < 200 Ωm may be due to the influence of the lineament in the same direction and the low resistivities < 40 Ohm m represents the fractures extending in the same direction. The small isolated patches of low resistivities of < 5 Ohm m in the central and southern parts of the area represent clay or Lameta bed.

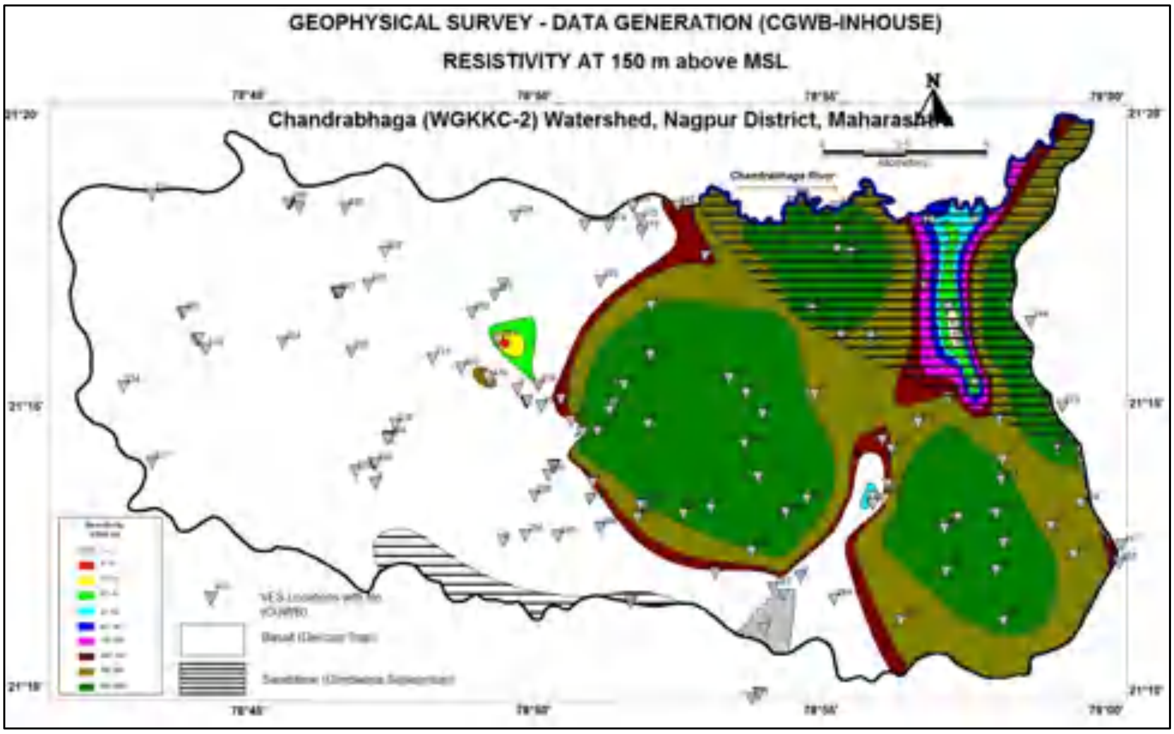


Fig. 3.7: Resistivity variation at 150 m amsl, Chandrabhaga Watershed (WGKCC-2)

The resistivity values at 200m amsl (Fig.3.8), indicate that the south-eastern part of the study area, the high resistivities more than 200 Ωm represent Granitic Gneiss. The resistivities less than 200 Ωm in the north eastern part represent Gondwana formation with different degrees of compactness and saturation. The northeast elongation of the contours in this region represents influence of the lineament in the same direction. The same resistivities in the south eastern part represent fractured gneiss with different degrees of fracturing. In the central and southwestern parts of the area, the high resistivities more than 200 Ωm represent massive basaltic formations. The low resistivities < 200 Ωm in the central and north western parts of the area represent basaltic formations of different nature may correspond to different flow. The elongation of the contours with resistivities less than 40 Ωm in the western part south of Sonkhamb in EW direction, in the central part south of Dorli in NE-SW direction represents lineament-controlled areas in this direction. The elongation of the contours in NW-SE direction with resistivities less than 40 Ωm in the central part of the area may represent highly weathered / fractured basaltic formation.

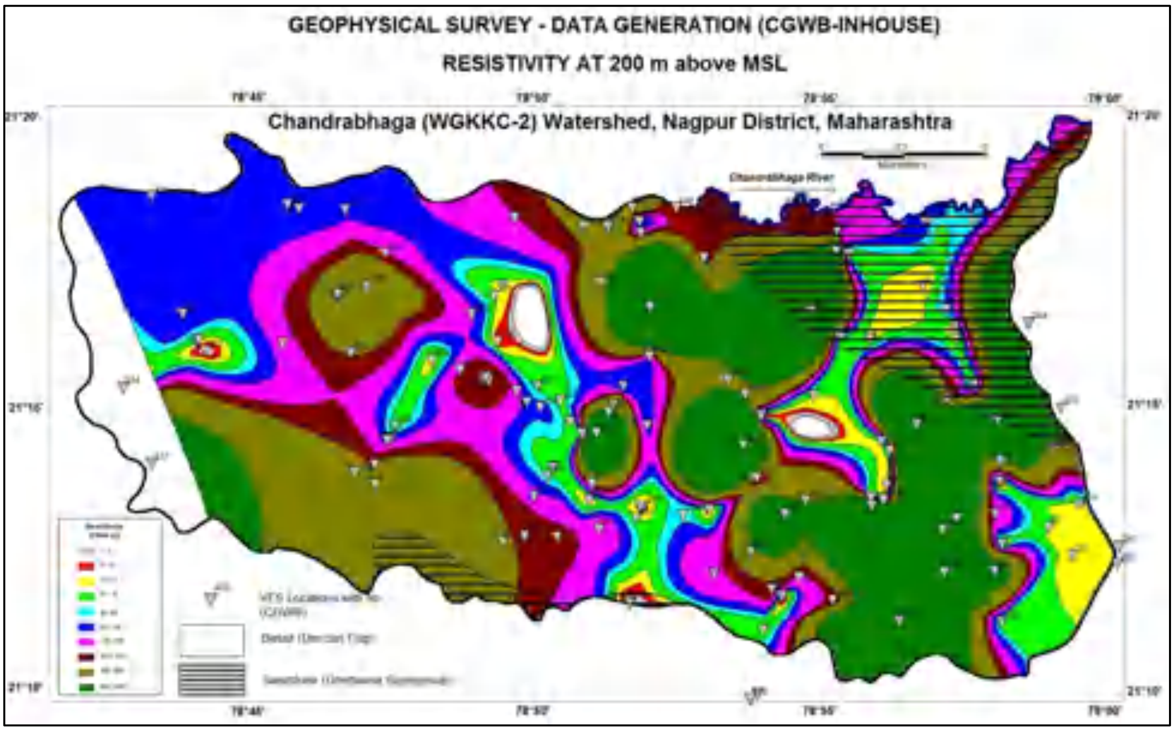


Fig.3.8: Resistivity variation at 200 m amsl, Chandrabhaga Watershed (WGKCC-2)

The resistivity values at 250 m amsl (Fig.3.9) indicate that the south eastern part of the study area, the high resistivities more than 200 Ωm represent Granitic Gneiss whereas the same resistivities in the north eastern part of the area represent compact sandstone. The resistivities less than 200 Ωm in the south eastern part of the study area represent fractured gneiss with different degrees of fracturing. The direction of the elongation of the contours (NW-SE and NE-SW) represents the orientation of the lineament / fracture system in the respective directions. These directions are matching with the directions of the lineaments mapped and presented in the lineament map. The area from central to western part, the high resistivities > 60 Ωm represent massive basaltic formation. However, the distribution of the resistivities < 200 Ωm from central to north western part may represent the basaltic formation of different flow. The horizontal extent of this flow is increasing as the elevation increases (5-8 km at 200 m amsl and l6-10 km at 250 m amsl). In the central to western part of the area, the resistivities between 40 and 60 Ωm represent vesicular/ Amygdaloidal basalts and the resistivities between 10 and 40 Ωm represent weathered/ fractured basalts. The isolated patch of low resistivities < 5 Ωm in the central portion of the area represent associated clayey layers. The ENE-WSW orientation of the resistivity contours between 5 and 40 Ωm resistivity west of Dorli, represents the orientation of the system of Lineaments/fractures in the same direction and it is matching with the lineament map. The NW-SE orientation of the resistivity contours of same range northeast of Dorli, represent the orientation of the system of Lineaments/fractures in the same direction. The E-W orientation of the resistivity contours of same resistivity range southeast of Dorli, represent the orientation of the system of Lineaments/fractures in the same direction. The NE-SW orientation of the resistivity contours of same resistivity range south of Dorli, represent the orientation of the system of Lineaments/ fractures in the same direction. The contact between basalt with gneisses and Gondwanas is clearly predicted by the contour maps extending from east of Selu in NE-SW direction through Kalmeshwar.

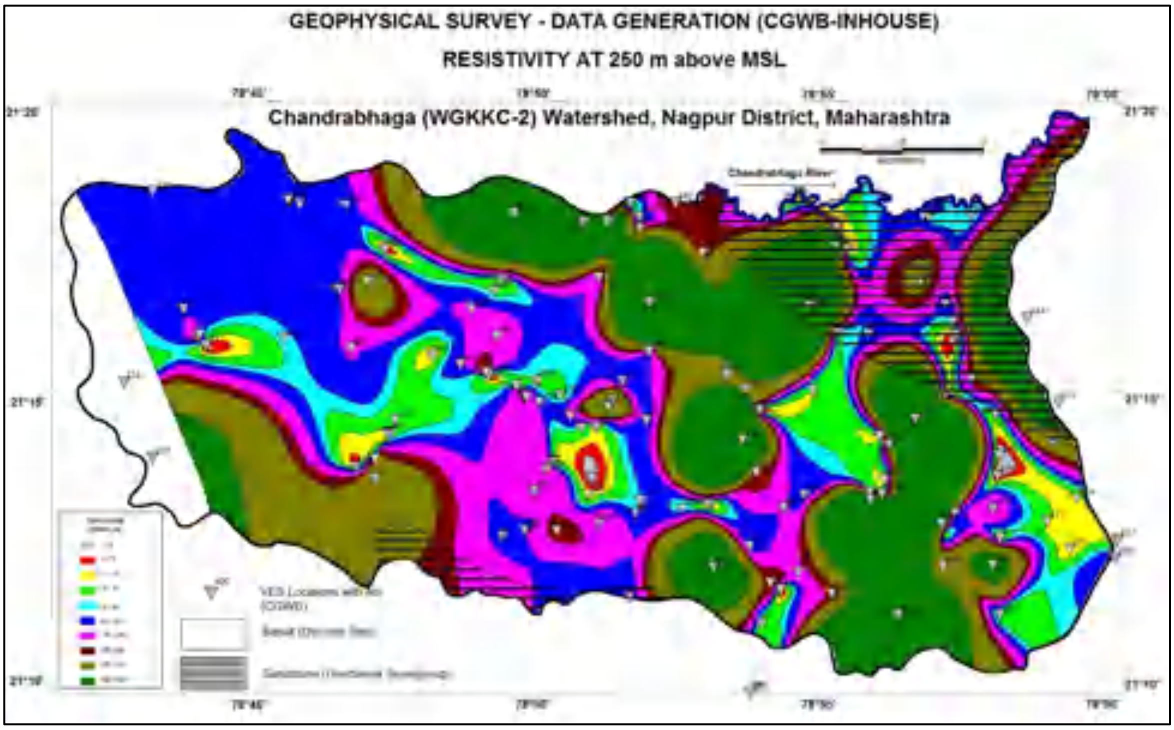


Fig3.9: Resistivity variation at 250 m amsl, Chandrabhaga Watershed (WGKCC-2)

The resistivity values at 300 m amsl (Fig.3.10) indicate that the south eastern, central and western parts of the study area, the high resistivities more than 60 Ωm represent massive basaltic formation. The boreholes drilled by CGWB at Yerla up to 159.45m bgl, at Selu up to 140.3m bgl and Dorli up to 153.5 m bgl encountered Gneisses at a depth of 59m at Yerla, clay at 140.3 m depth at Selu and Gondwanas at 123m depth at Dorli, (CGWB, 2001). However, the distribution of the resistivities < 200 Ωm from central to north western part may represent the basaltic formation of different flow. The horizontal thickness of this flow (5 to 16 km) is increasing as the elevation increases. In the southwestern and western parts of the area, the low resistivities ranging from 20 to 40 Ωm represent weathered / fractured basaltic formation. In the western part, the elongation of the contours in NE-SW direction around Rawalgaon and Kotwalbardi, represent Lineament (s) extending in the same direction. Whereas in the northeast part of the area, the resistivities more than 200 Ωm may represent compact sandstone, the resistivities between 10 and 200 Ωm may represent sand stone with different degrees of saturation and compactness. However, the resistivities ranging from 10 to 20 Ωm along the river courses in this part of the area represent river alluvium. The resistivities between 5 and 10 Ωm may represent sandstone with shale intercalations.

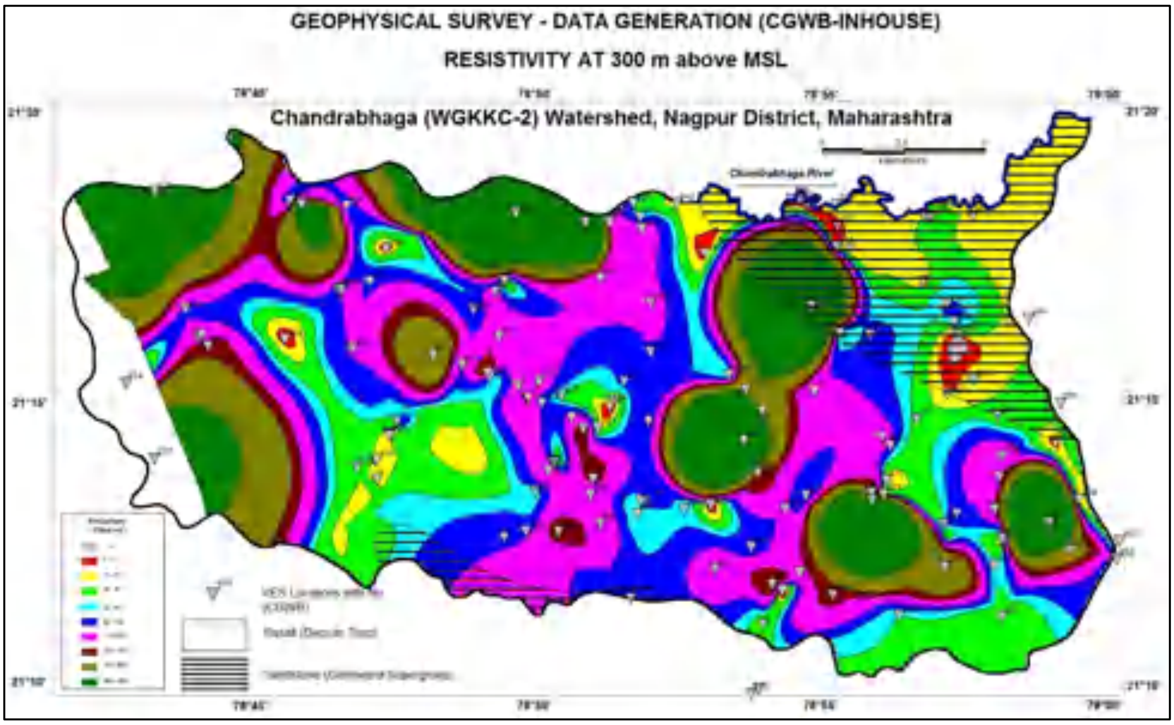


Fig. 3.10: Resistivity variation at 300 m amsl, Chandrabhaga Watershed (WGKCC-2)

The resistivity values at 350 m amsl (Fig 3.11) indicate that the resistivity information is available only from the central to western part of the study area, since the elevations are less than 350m amsl in this area. The high resistivities more than 200 Ωm in the NW part of the area represent massive basaltic formation. The low resistivities less than 200 Ohm m in the southern and central parts of the area may correspond to basaltic flow of different nature. The low resistivities ranging between 20 and 40 Ohm m in the west central part of the area may represent fractured basaltic formation. In the southern part of the area, the resistivities ranging from 5 to 20 Ohm m may represent weathered/ fractured formation. The very low resistivities less than 5 Ohm m in this area represent clay. Based on the borehole data Gondwana formation is encountered at 336 and 351 m amsl at Rawalgaon and Kotwlbardi (NGRI 2011) respectively. Correlating this borehole data with VES results it is inferred that in this area, the resistivities ranging from 60 to 300 Ωm represent Gondwana formation.

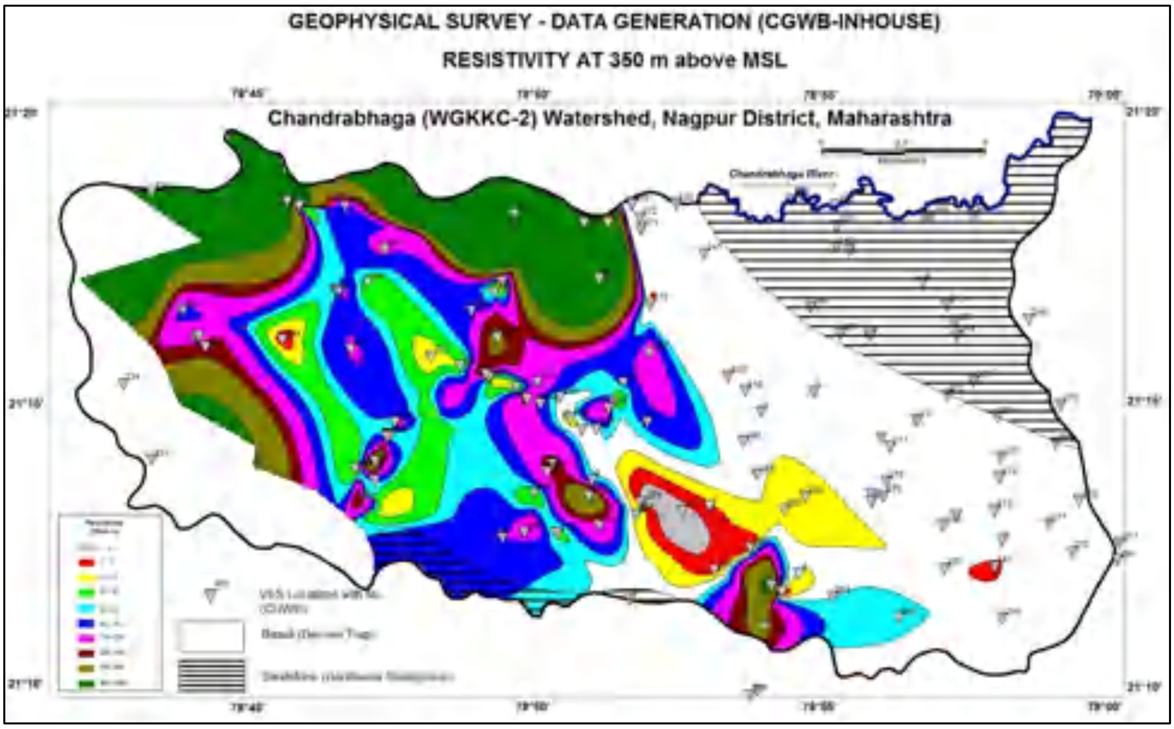


Fig. 3.11: Resistivity variation at 350 m amsl, Chandrabhaga Watershed (WGKCC-2)

The western part of the watershed is highly elevated land. The high resistivities more than 60 Ohm m around Dorli, Sonkhamb and Metpanjra villages, represent massive basaltic formation, the resistivities ranging between 40 and 60 Ohm m around Chargaon and Pardi Deshmukh may represent vesicular basalt and the low resistivities ranging between 20 and 40 Ohm m around Rawalgaon, Wasbodi, Malegaon, and Ramgiri may represent fractured basaltic formation (Fig.3.12).

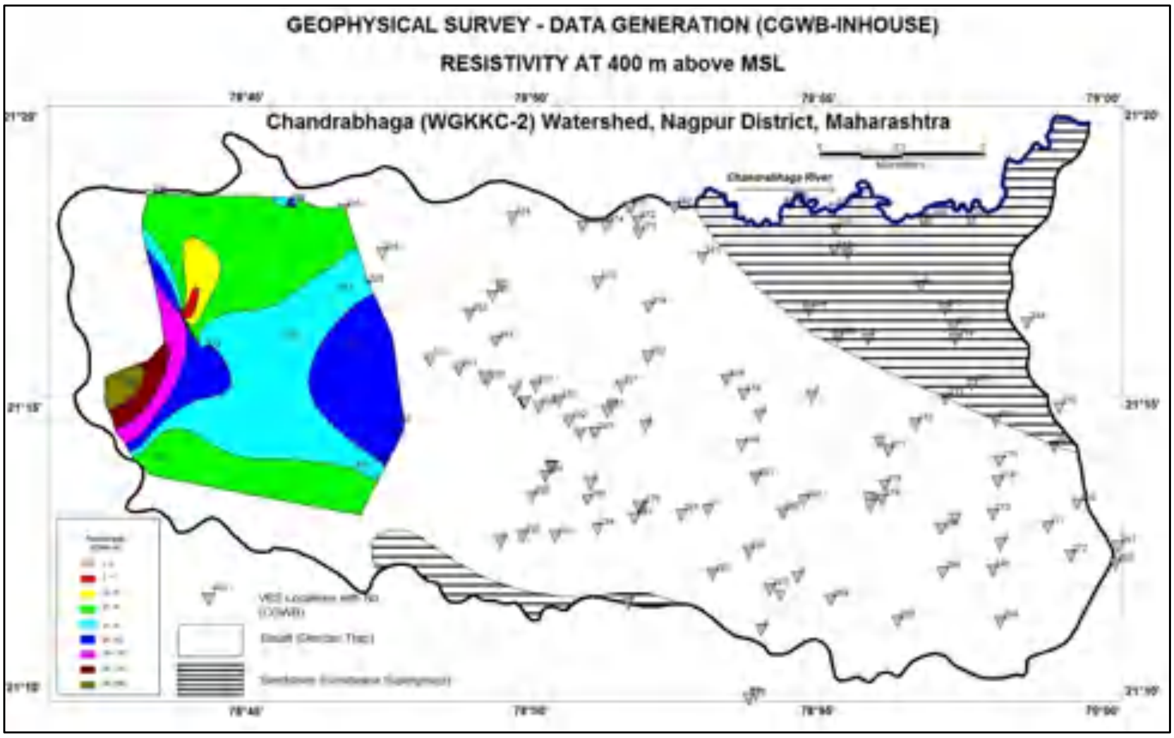


Fig. 3.12: Resistivity variation at 400 m amsl, Chandrabhaga Watershed (WGKCC-2)

Pseudo Depth and Resistivity cross sections (Fig. 3.13) were generated using IPI2Win software along Section 1-1' of 5.7 Km length, passing through the villages Kohli, Mohli, (VES No. Ngp 331, 303, 360, 330, 127), Ubgi (NGP 390, 358), Khapri (NGP 302, 357, 347). The low resistivity zone with less than 30 Ohm m resistivity in the pseudo Depth section may correspond to a system of lineaments or fractures at pseudo depths (AB/2) ranging from 5 to 100 m.

The resistivity cross section (Fig. 3.13) also depicts fractures at VES No. NGP303, 360, 127, 390, 358, 357 and 347. Whereas the low resistivity of 4.6 Ωm at VES no. NGP 330 may correspond to the bole bed below 284 m amsl or 94 m bgl. The Gamma log in the borehole drilled in Kohli village shows relatively a rise in gamma at this depth.

Along Section 2-2' also Pseudo Depth and Resistivity cross sections (Fig. 3.13) were generated using IPI2Win software of 8.3 Km length, passing through the villages Gowari (VES No. NGP 315,356,314), Khairi (NGP 356), Pardi (NGP 276), Ashti (NGP 275,274), Yerla (NGP 270,120,345). The low resistive layer with resistivities below 20 Ohm m in the Pseudo Depth section north of VES 356 i.e. N of Gowari corresponds to the Gondwana group of formations. Whereas the same resistivity range in southern part of the section beyond Gowari village correspond to the weathered/ fractured basaltic formation. The higher order of the resistivities N of the Gowari village correspond to Sandstone and the south of this village (VES 356) may correspond to the Archaeans.

In the resistivity cross section 2-2'(Fig. 3.13) the resistivity ranges between 60 and 70 Ohm m North of Gowari Village (VES 356) correspond to the Sandstone formation. The low resistivity layer of 9.6 Ωm at VES 356 corresponds to the alternate layers of sandstones and shale/clay layers. This has been confirmed with the geophysical log and litholog of the borehole drilled in Gowari village. The resistivity log shows high resistivities up to 80m depth (240m amsl) indicating the sandstones with a thin clay layer between 40 and 45 m depths (280 and 285m amsl). The very low resistive layer South of the Gowari village may correspond to the clay layer. The low resistive layer of 1.8 Ohm m at VES No. NGP 314 may correspond to the clay. At VES 355 near Khairi village, the layer with 12 Ωm from 8.9 to 30 m depth (314 to 293m amsl) and the layer with 13.6 Ωm resistivity below 77 m depth (246 mamsl) to the fractured Sandstone. The low resistive layer of less than 2 Ωm resistivity at NGP 275 and 274 below 55 and 44 m depths respectively near Asta village correspond to the clay / lameta bed which is lying above the Archaean formation and below the Deccan Trap formation. At VES 273 near Yerla Village the contact of the Basalt and the Archaean formations could not be delineated may be due to the minimal resistivity contrast. However the litholog of the borehole drilled during the pre-project period in Yerla village shows basaltic formation up to a depth of 59m bgl followed by lametas and granitic gneisses. The low resistivity of 14 Ωm below 48 m depth (294m amsl) at NGP 120 corresponds to the fractures gneiss. The high resistivity layers overlying this layer correspond to the compact basaltic formations.

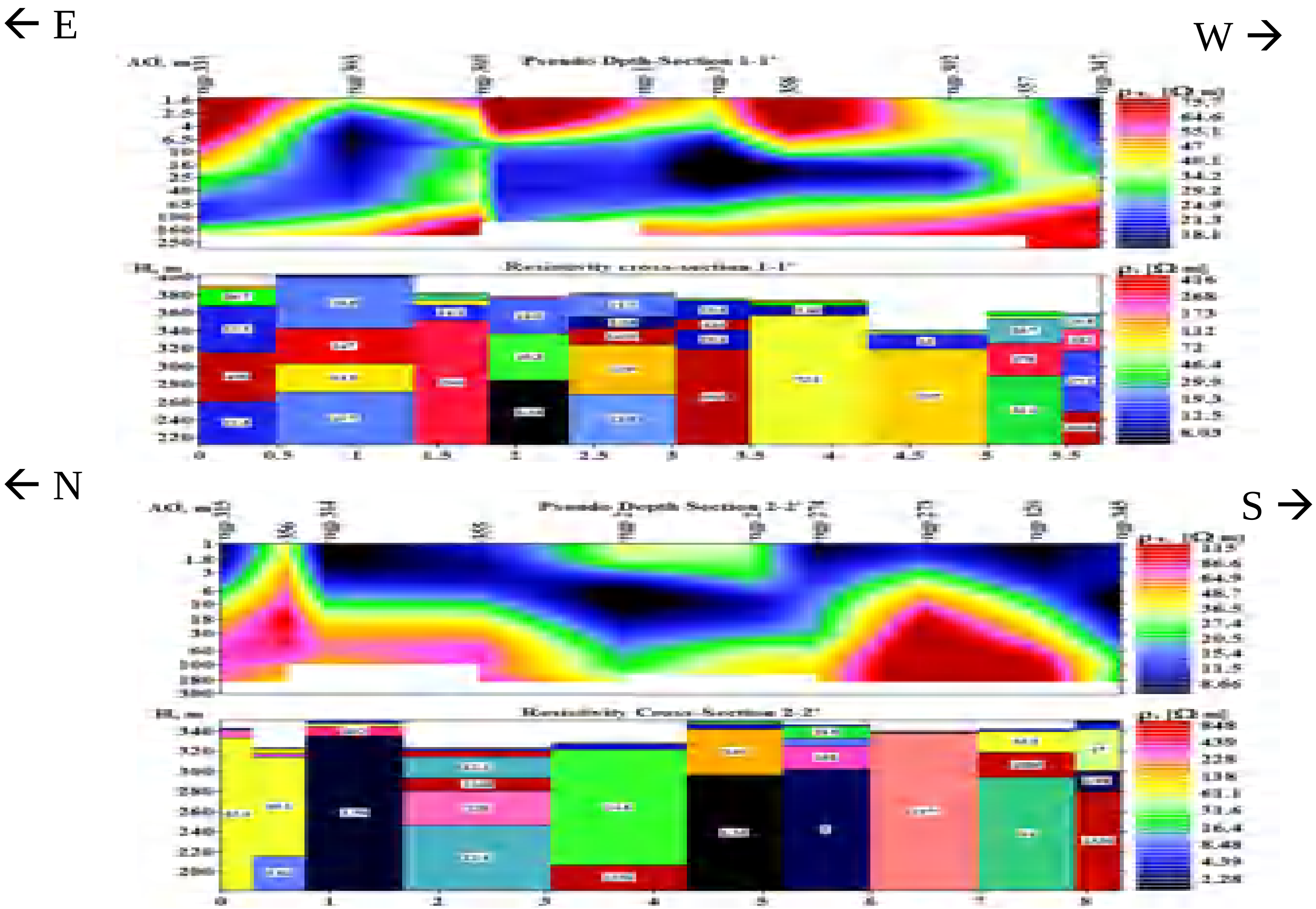


Fig. 3.13: Pseudo Depth Section and Resistivity Cross Sections along Section 1-1', Chandrabhaga Watershed (WGKCC-2)

An attempt has been made to generate the geo-electric 3D maps (Fig. 3.14) based on VES conducted. The resistivities at different elevations have been use to generate these maps. The resistivities at ground level, 150 m amsl, 200 m amsl, 250 m amsl, 300 m amsl and 350m m amsl elevation have been used. The sliced 3D geo-electrical maps, thus, generated has been found near to the actual lithological units and the aquifer exist in the area.

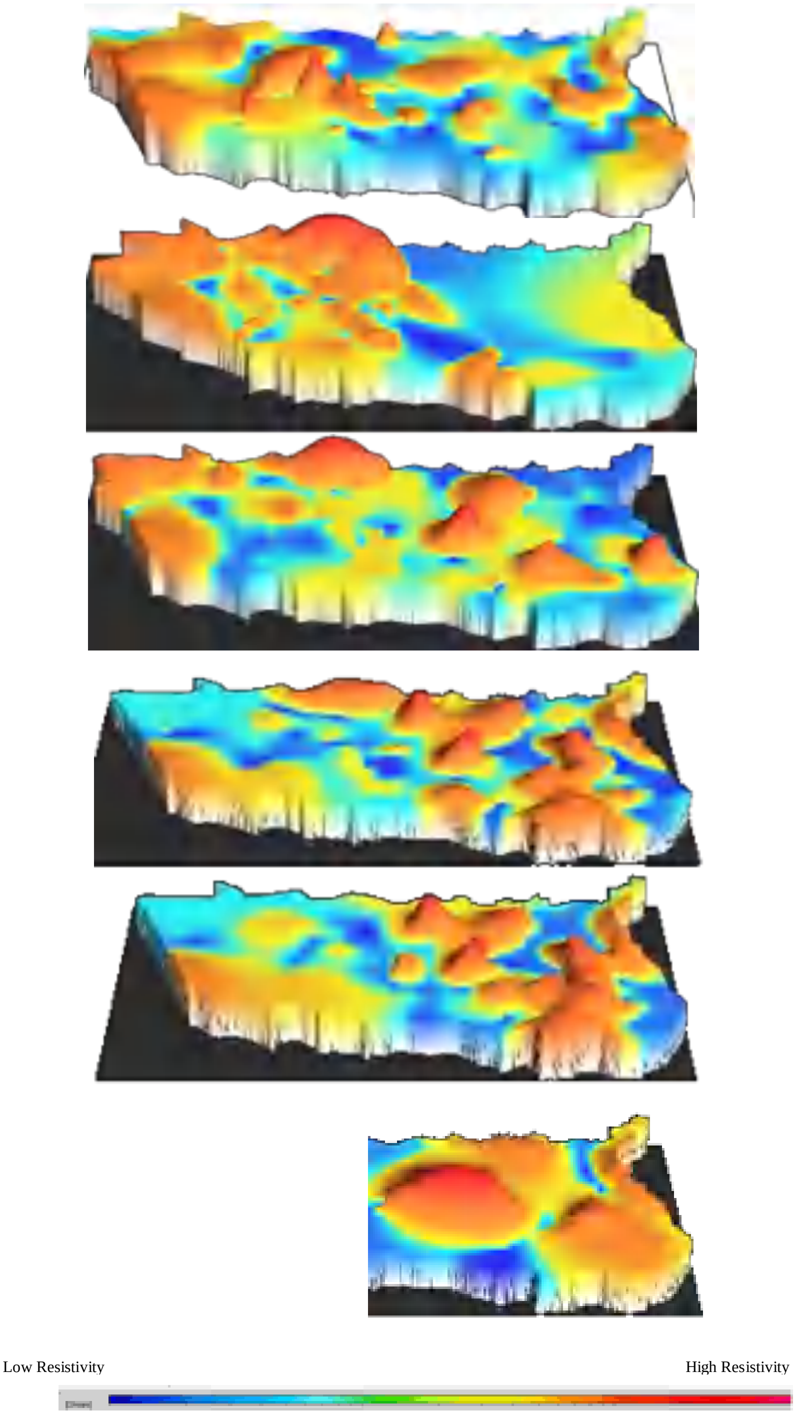


Fig. 3.14. 3D view of the resistivity images at different elevations generated based on VES.

3.2.1.4 Inferences from Electrical Resistivity survey

1. Based on the VES results, it is inferred that the thickness of the basalt is increasing from east to west. In the eastern part of the area, approximately 60 m around Yerla where as in the mid-western part it is 108 m around Dorli, and more than 150 m northern and extreme western parts. However, Gondwanas are inferred at shallow depths, approximately 30 to 40m depths around Raulgaon in the SW prt of the area. This result predicts the undulating nature of the paleo-topography on which Deccan lavas were poured out.
2. Interpreted VES results infer that the Gondwana formations are extending more than 150m depth in the NE part of the area. The Gondwanas are absent in the SE part of the area and was conformed from the existing borehole data at Yerla. In this area, Achaeans are encountered below basaltic formation at depths around 60m bgl. In the northern and western parts of the area, the thickness of the top basaltic formation is more than 150m but in the SW part of the area around Raulgaon, the Gondwana formation occur at shallow depths.

The VLF and GRP were carried out to infer the location and orientation of the fractures/ lineaments in the area. Based on combine results of various geophysical surveys carried out in the area 15 sites were selected and recommended for exploratory drilling. The details of recommended sites are given below.

1. Khairi or Gowari and Dhapewada in the area occupied by Gondwanas
2. Kohli-Mohli, Ubgi, Pardi Deshmukh, Ramgiri and Ghorad in the area occupied by basalts and
3. Rawalgaon, Sonegan and Uperwahi in the Trap Covered Gondwana area.

3.2.1.5 Geophysical Logging

During the previous surveys CGWB has carried out geophysical logging in borewells/tubewells drilled at Borgaon, Junkishindi, Tondakhairi, Pardi, Yerla and Dorli Villages. Since only the point resistance log was carried out earlier in Dorli, a SP, Short and Long Normal resistivity loggings were carried out by ABEM Terrameter with SAS 200 Attachment in July 2012 down to a depth of 151.4m. Since the ground water level was 54 mbgl, electrical logging could be done from 54.4 mbgl only. Electrical logging at Dorli (Fig. 3.15) infers that the thickness of the top basaltic formation upto 108m. This basaltic formation is underlain by a clay layer of 4 m thickness followed by Gondwana formation.

Village: DORLI Depth drilled:155.5 m Depth Logged: 151.4 m
Instrument: ABEM Terrameter with SAS 200 attachment
Date: 19-07-2012 Logged by: Shri P. Narendra, Sc- 'C' & Vijesh V K , Sc-'B'

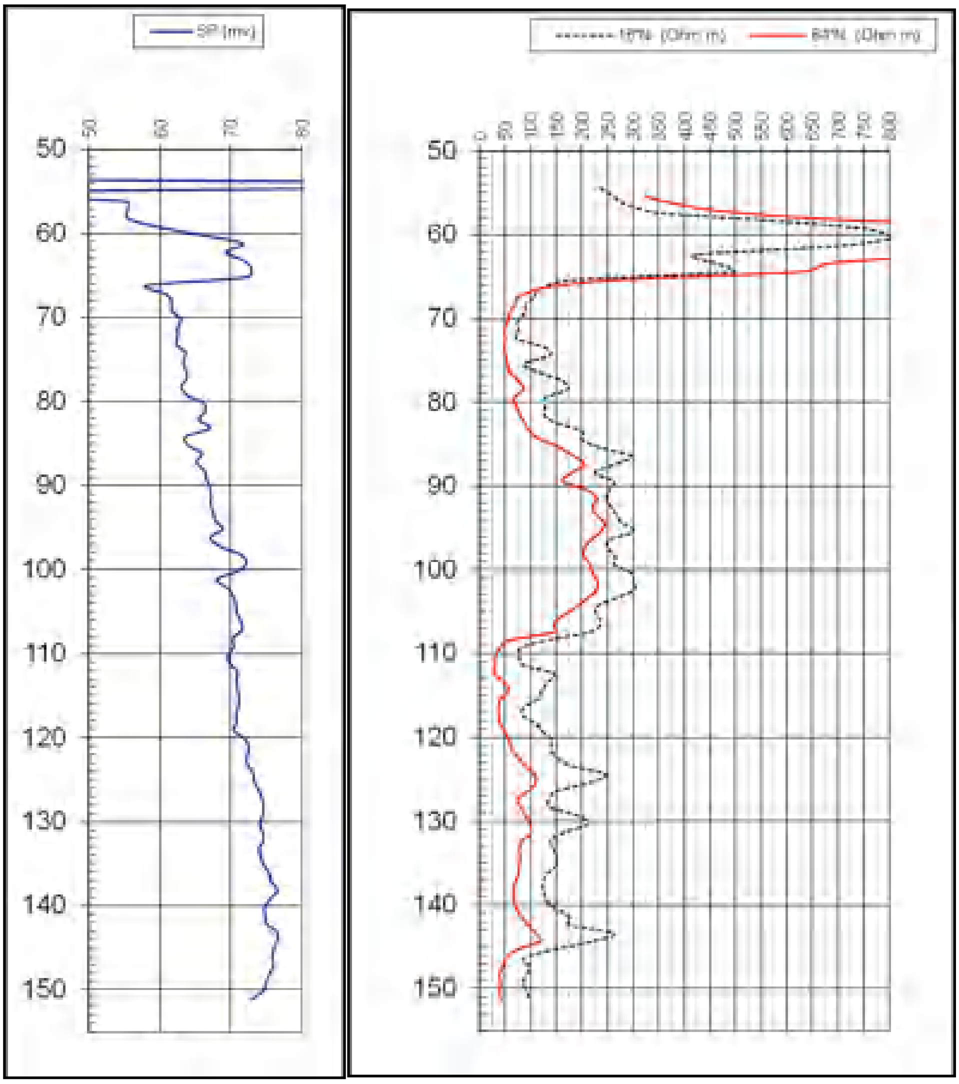
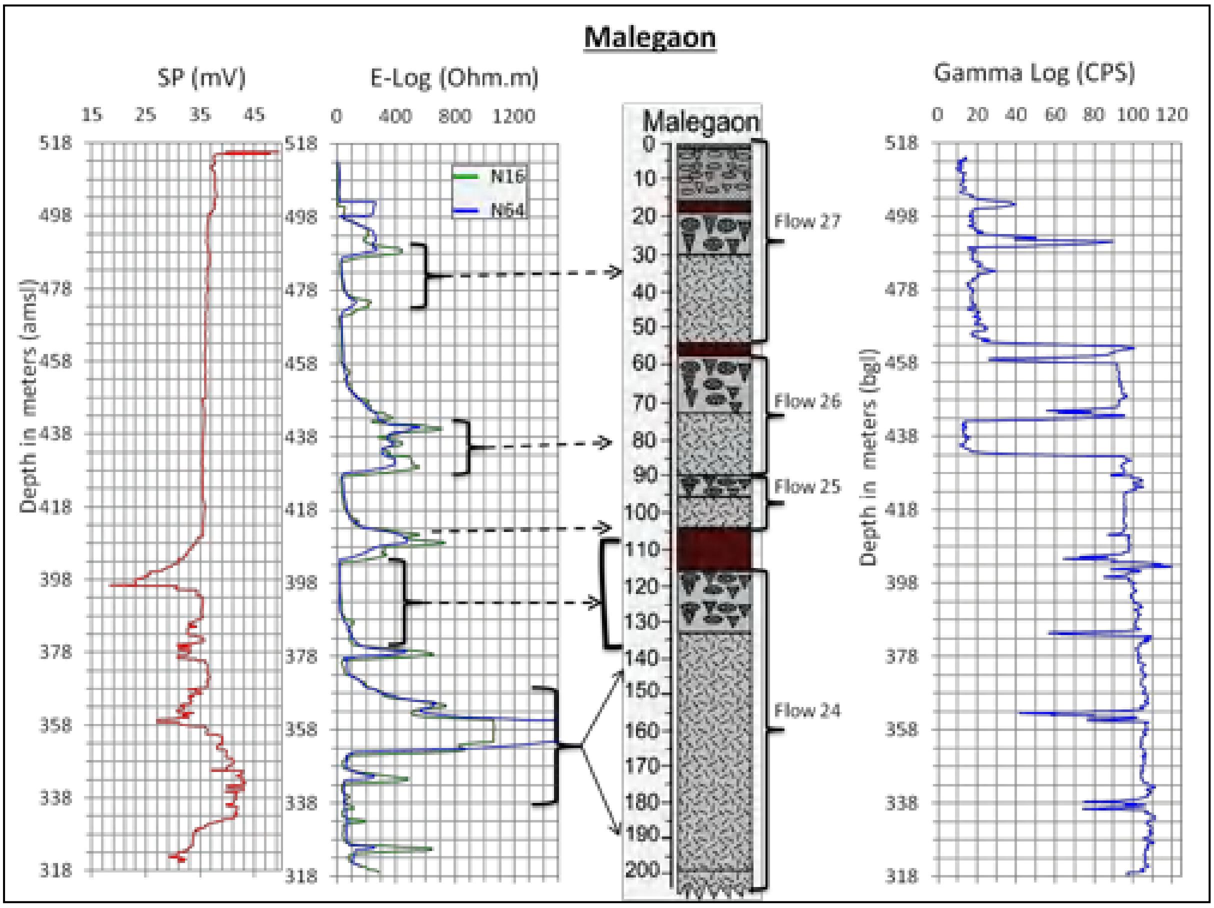


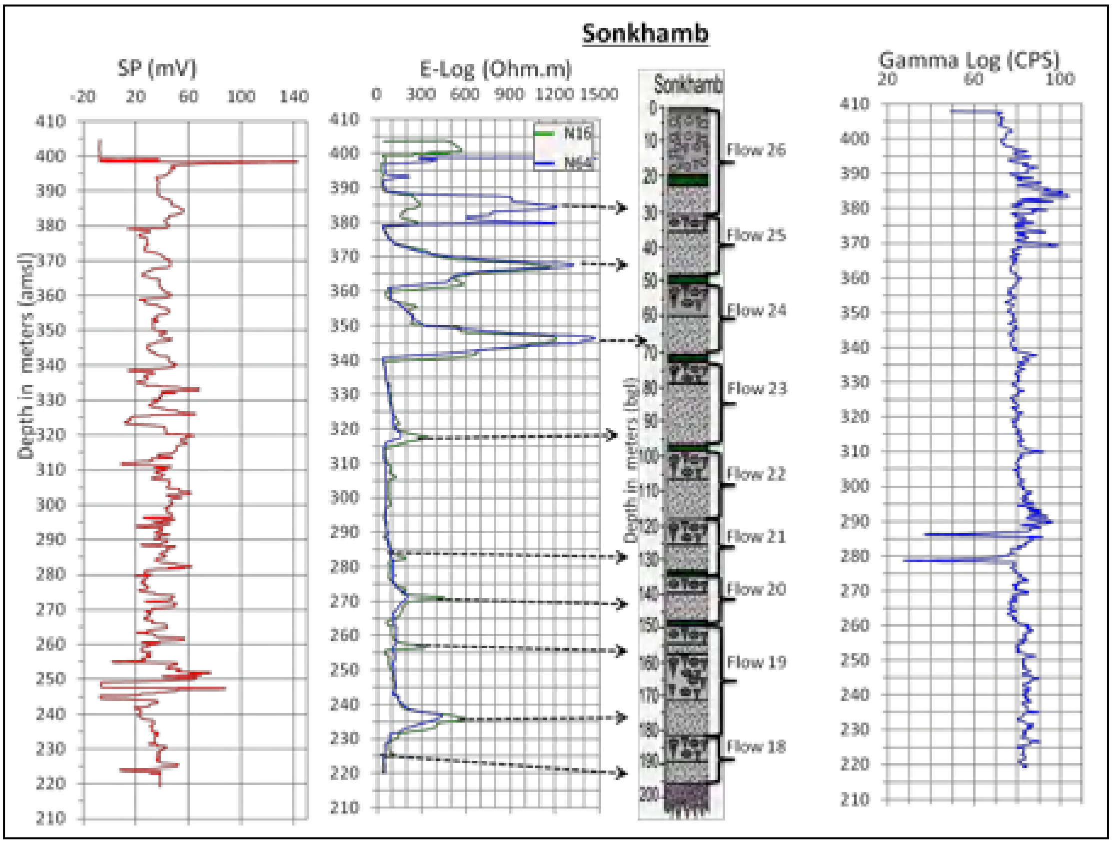
Fig. 3.15: Electrical Log at Dorli, Chandrabhaga Watershed (WGKCC-2)

During the project period 16 exploratory wells were drilled. These 16 boreholes, including observation wells were geophysically logged by UPTRON Logger. Geophysical logging carried out includes Electrical, SP, and Gamma. The logging depth varies from 65 m to 199 m bgl. At couple of places, the geophysical logging has been restricted up to shallow depth due to the collapse of the drilled wells prior to the logging.

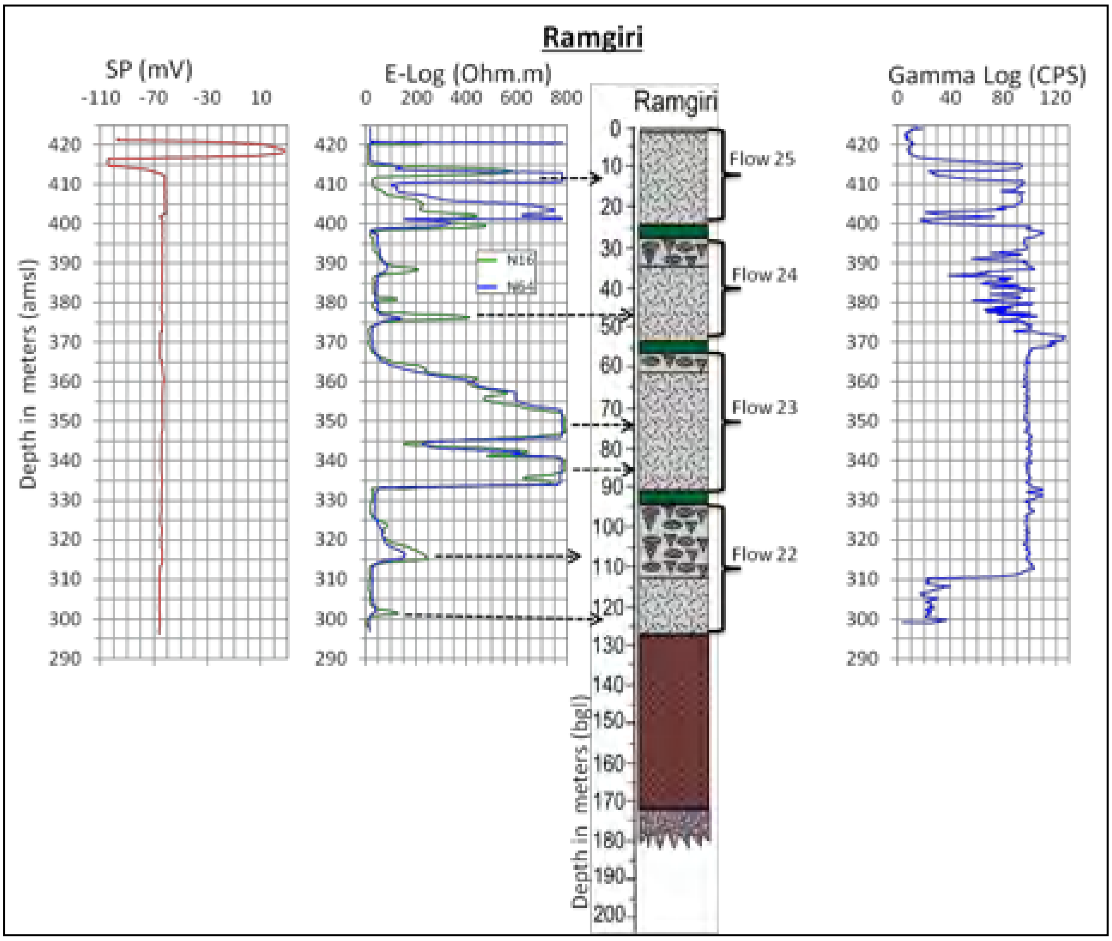
NGRI, Hyderabad has digitized the geophysical log sheets and matched with the drilling lithologs of the corresponding well. The correlative study of the lithology and geophysical logs indicates that the resistivity signatures in E-logs corresponds to the basaltic flows as shown in the below images (Fig. 3.16 and 3.17)



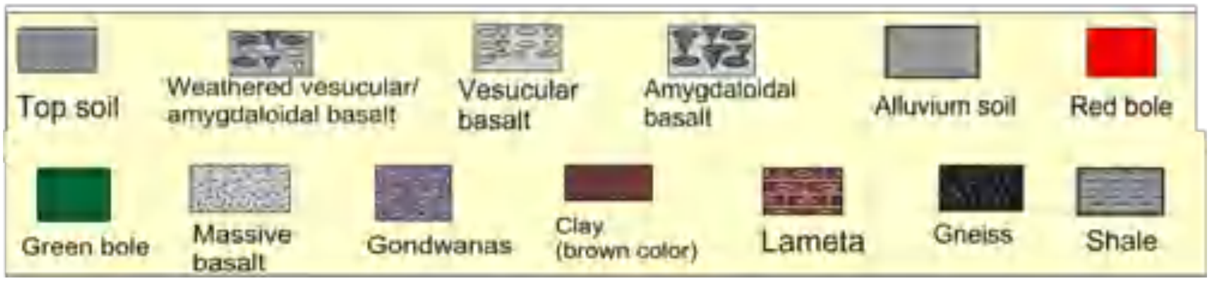
Litho-symbols

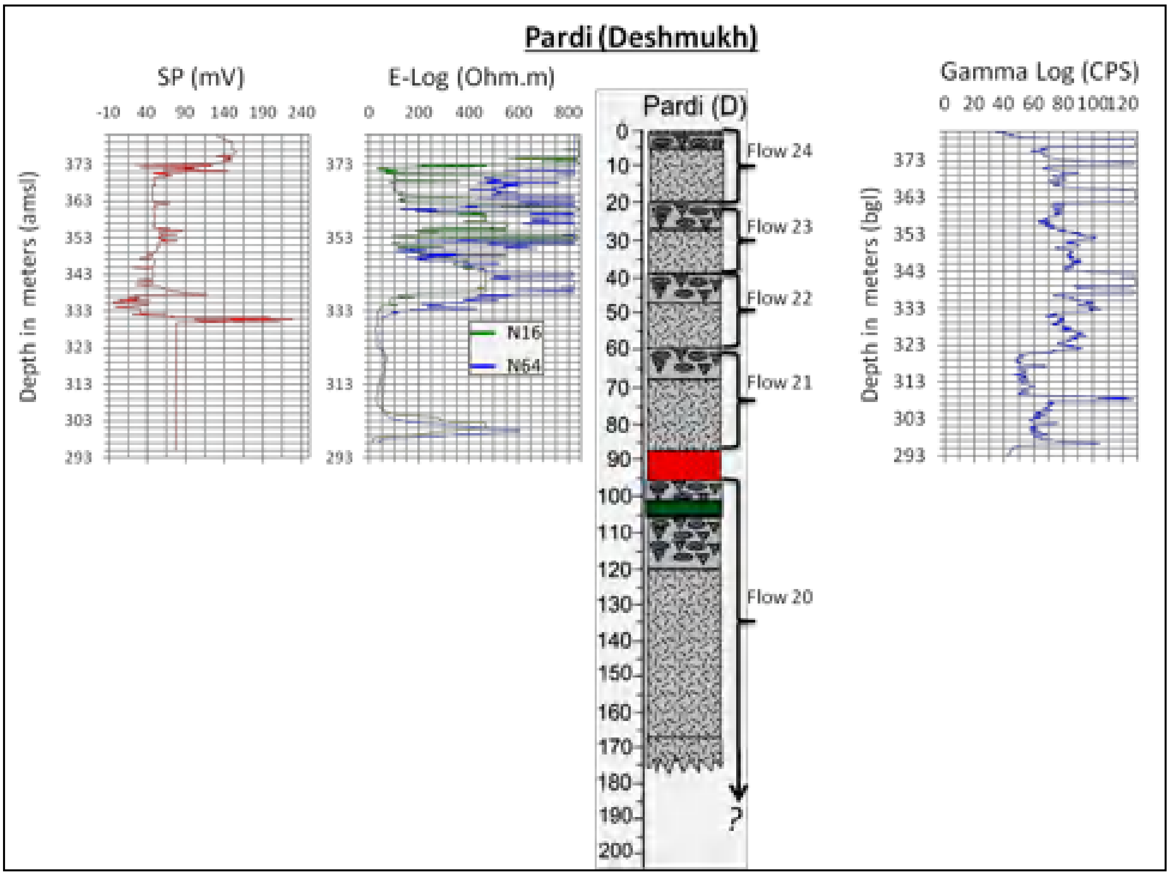


Litho-symbols

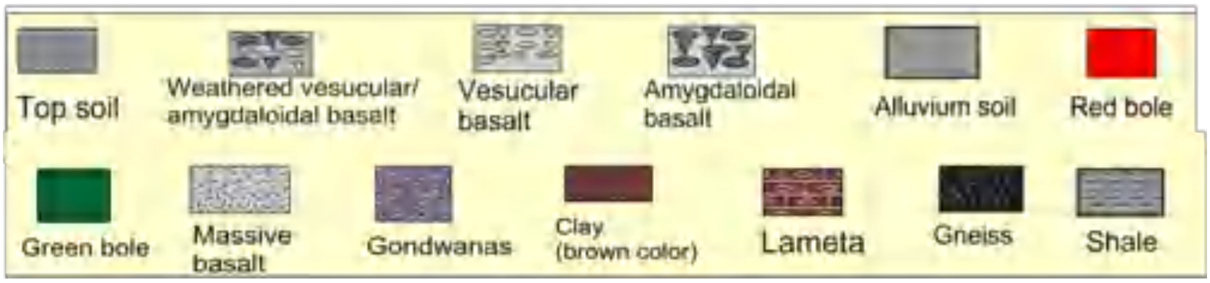


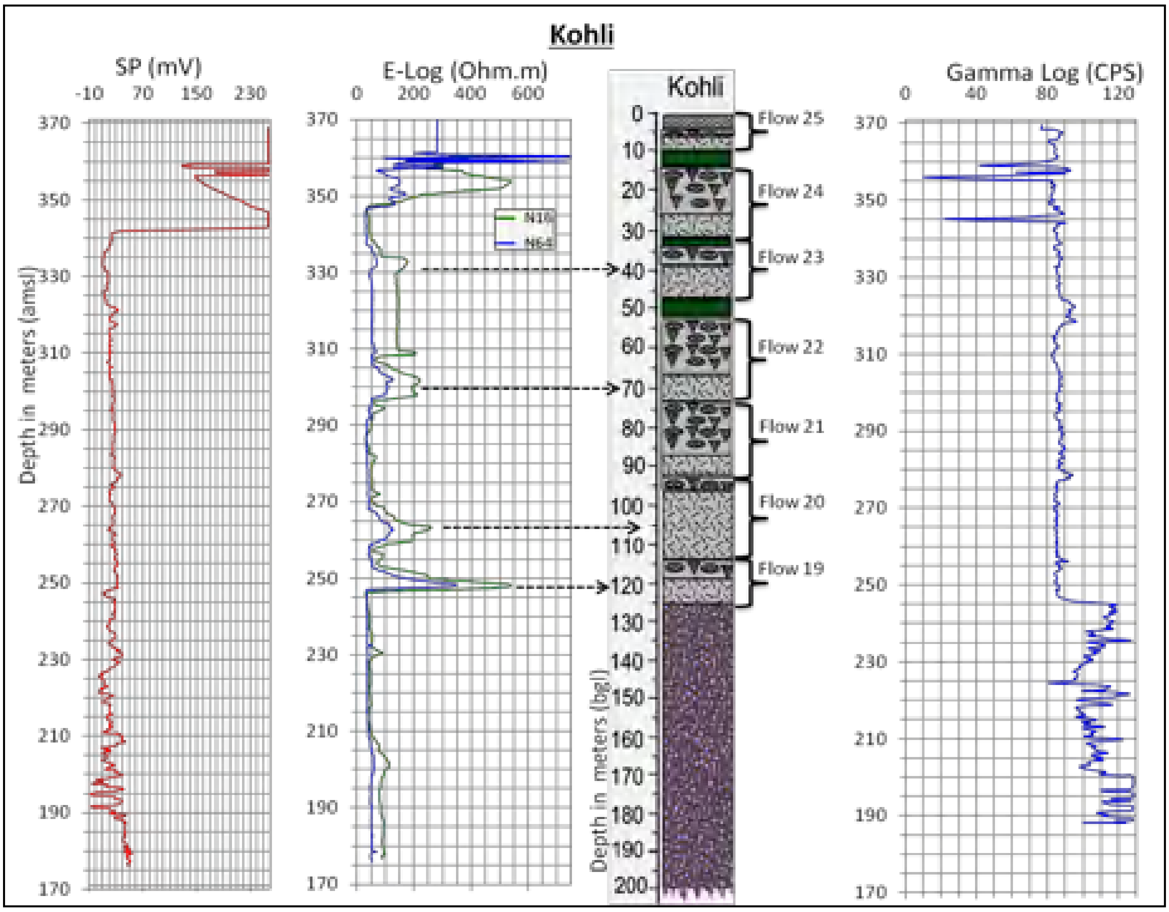
Litho-symbols

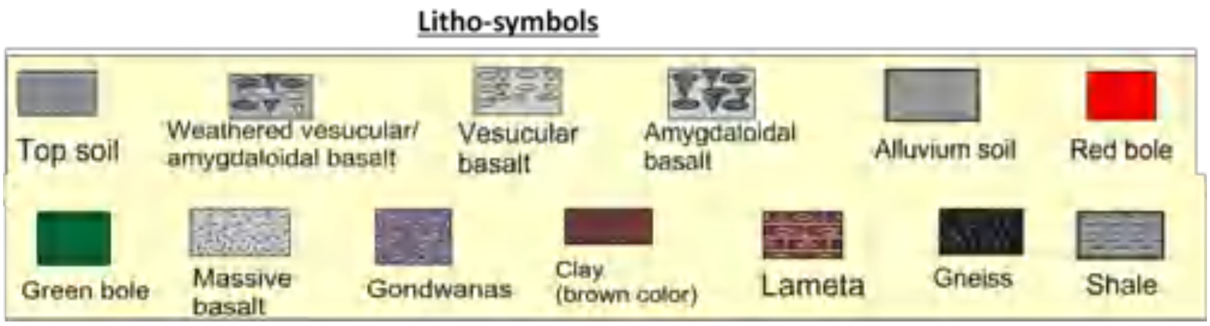


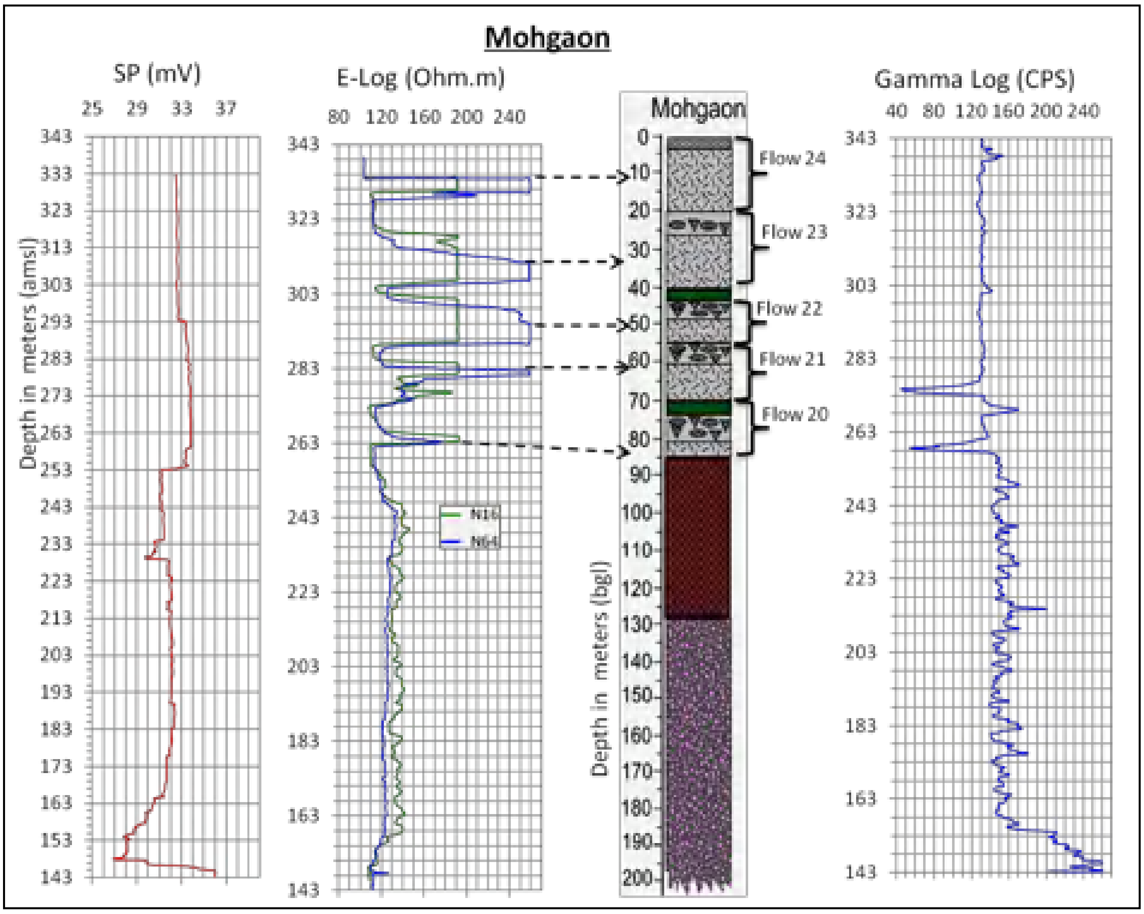


Litho-symbols

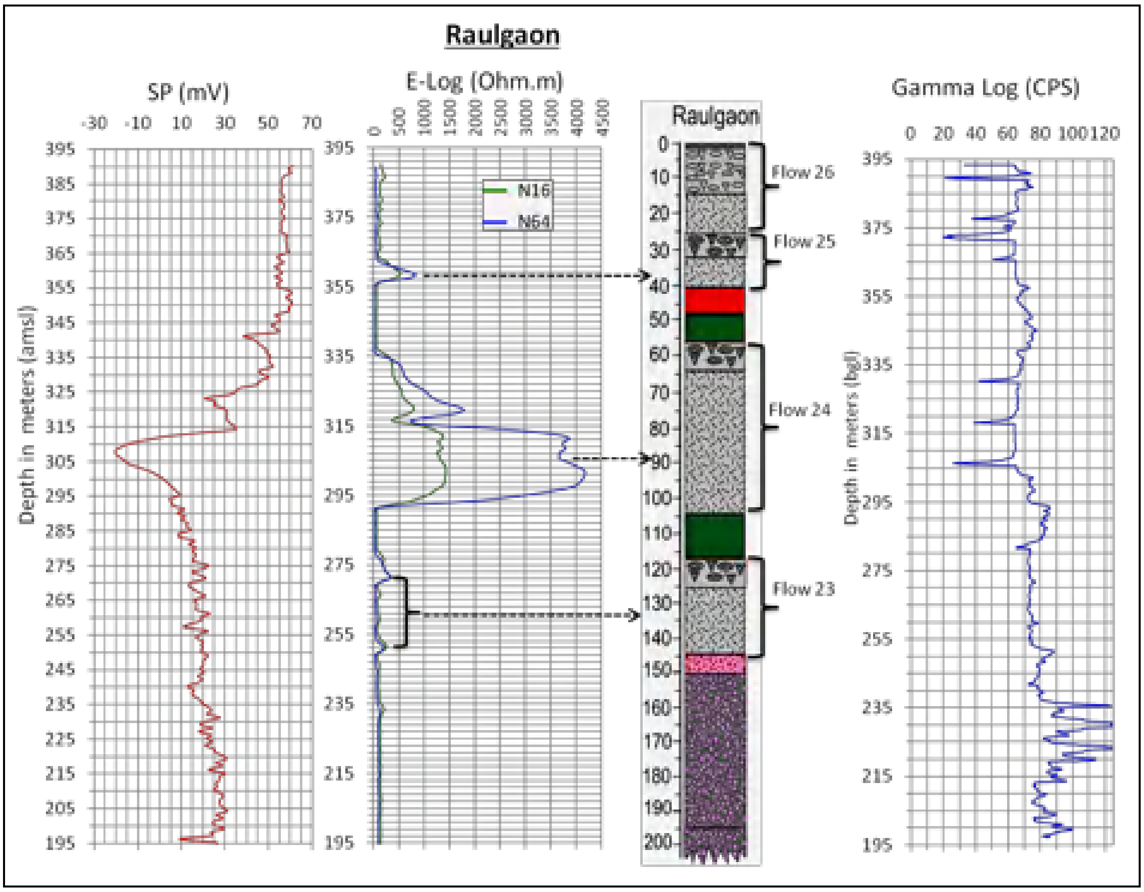



Kohli
SP (mV)
E-Log (Ohm.m)
Kohli
Gamma Log (CPS)
Depth in meters (amsl)
Depth in meters (bgl)
N16
N64
Flow 25
Flow 24
Flow 23
Flow 22
Flow 21
Flow 20
Flow 19

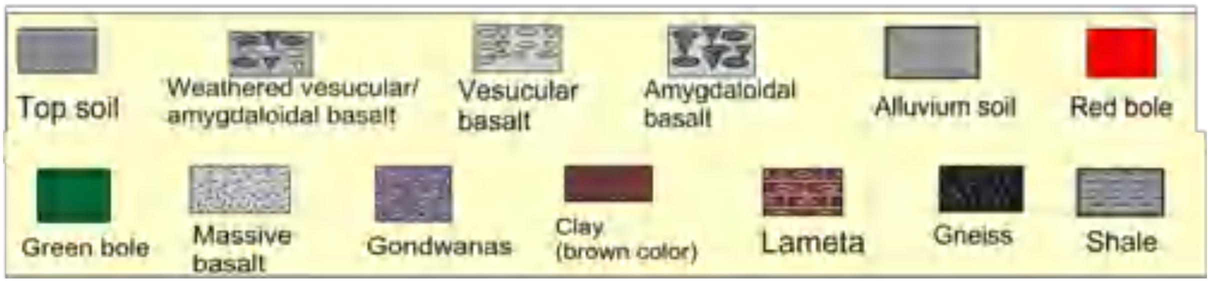

Litho-symbols
Top soil
Weathered vesucular/ amygdaloidal basalt
Vesucular basalt
Amygdaloidal basalt
Alluvium soil
Red bole
Green bole
Massive basalt
Gondwanas
Clay (brown color)
Lameta
Gneiss
Shale

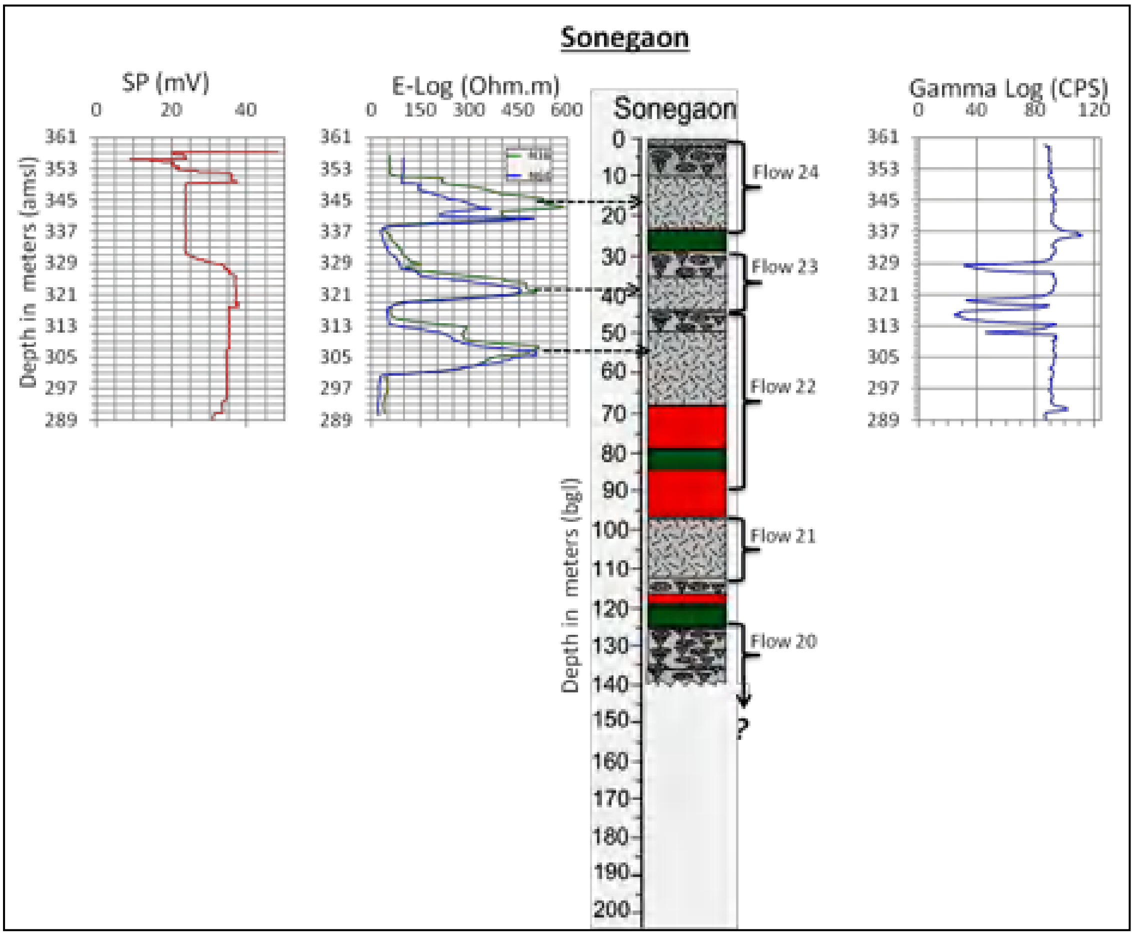


Litho-symbols

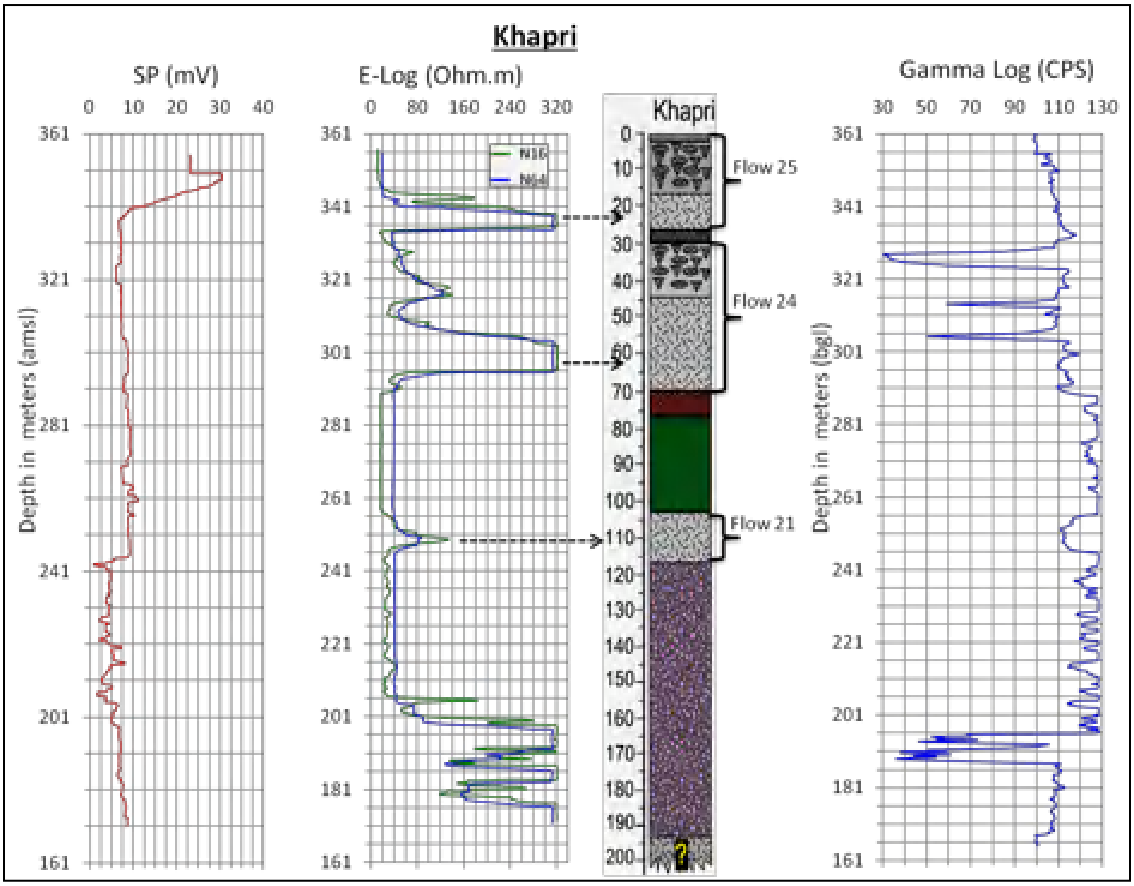


Litho-symbols

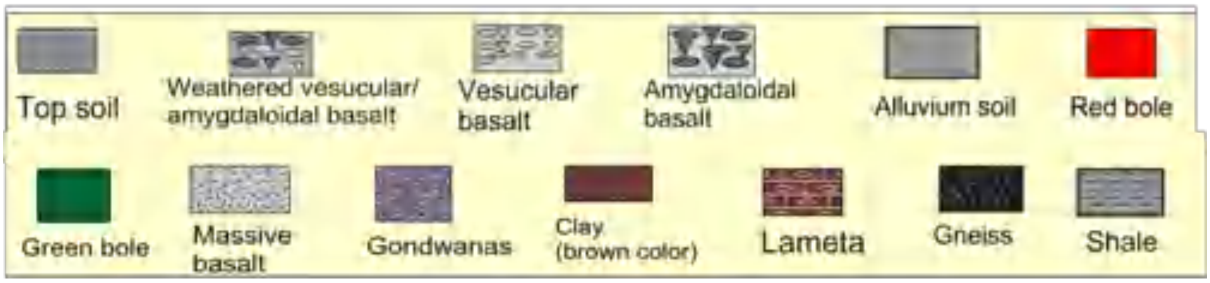


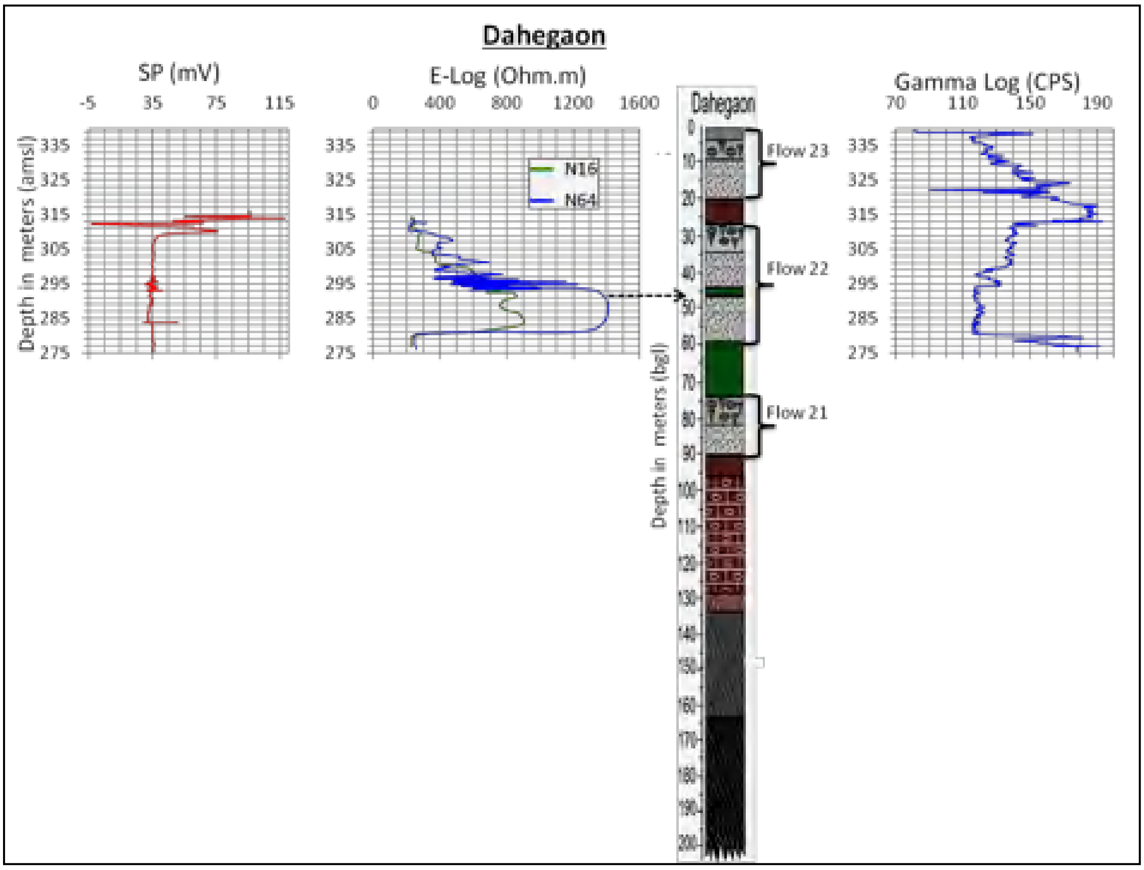


Litho-symbols

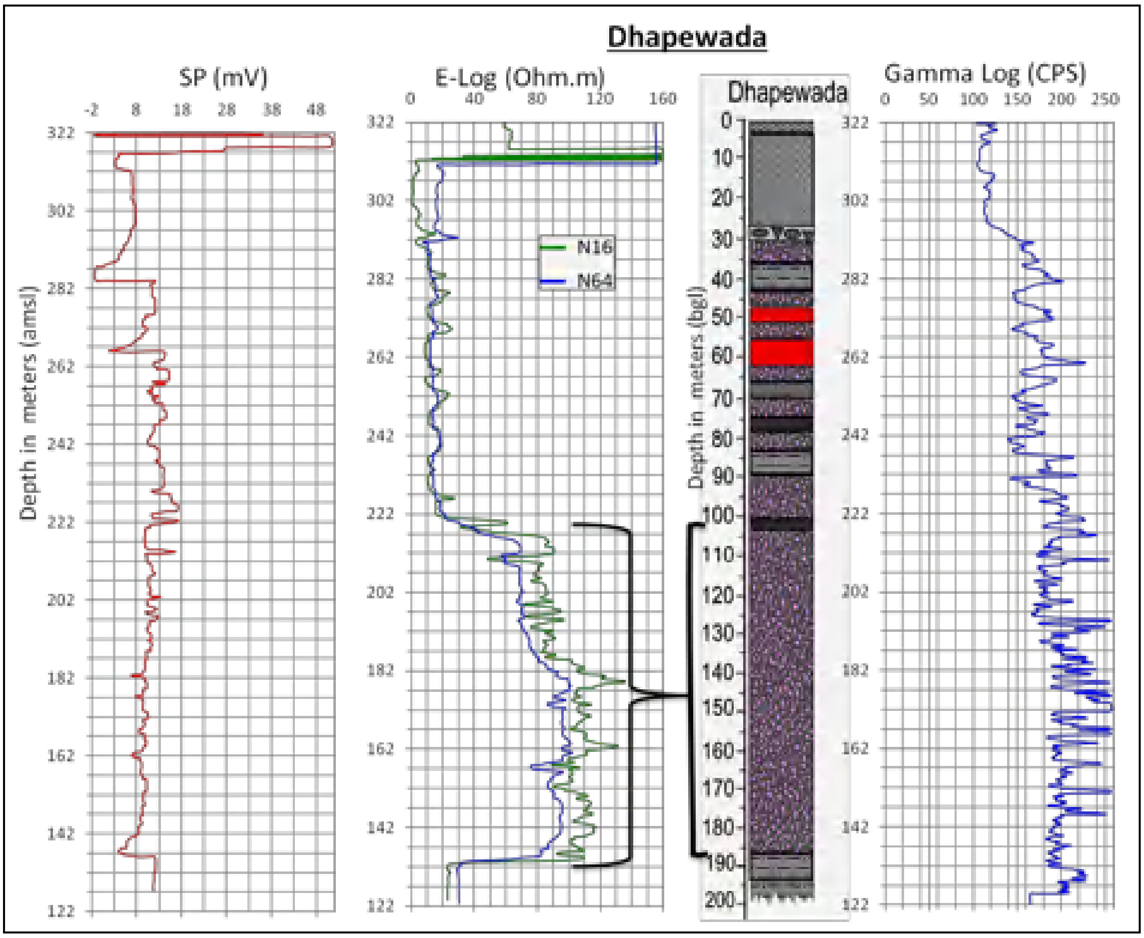


Litho-symbols

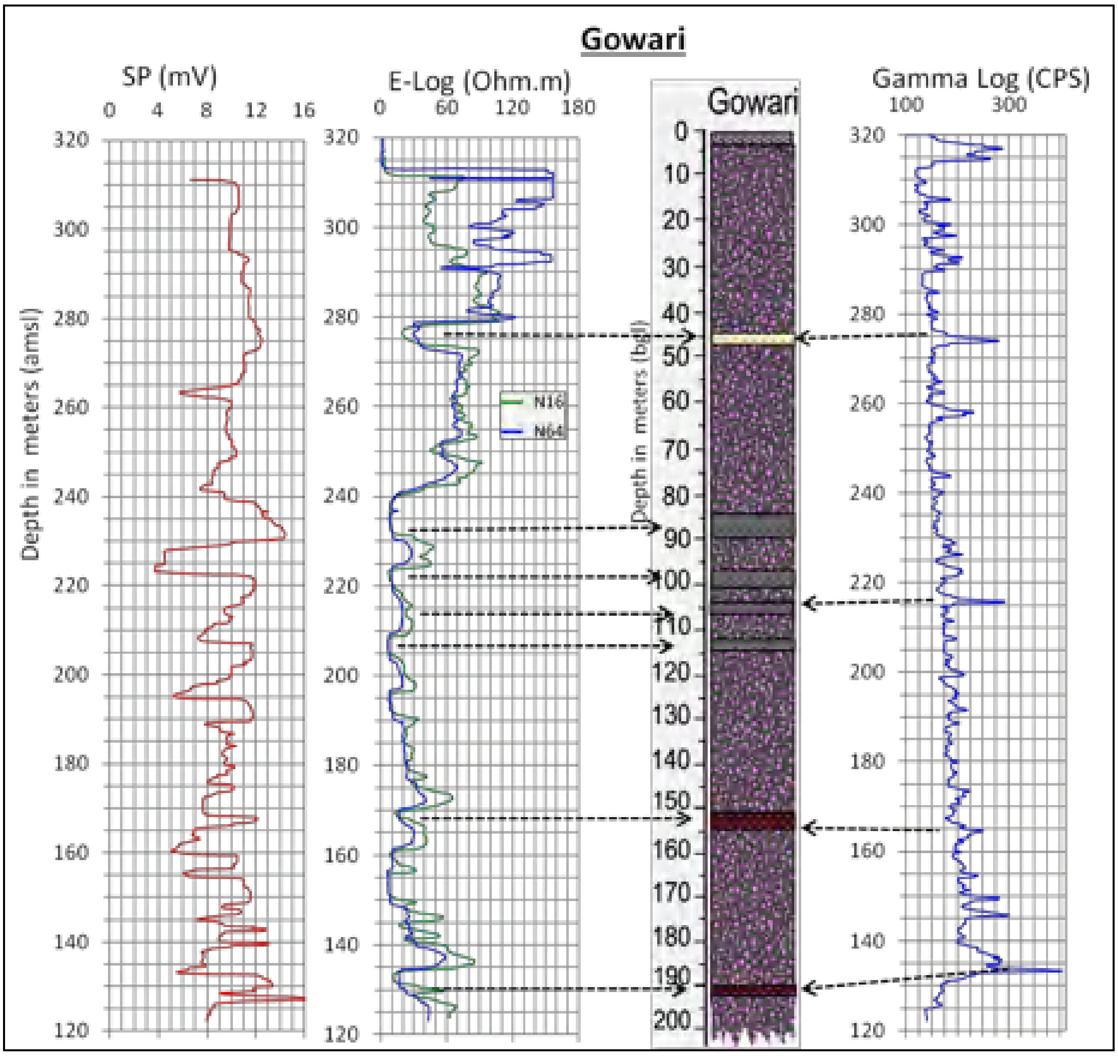


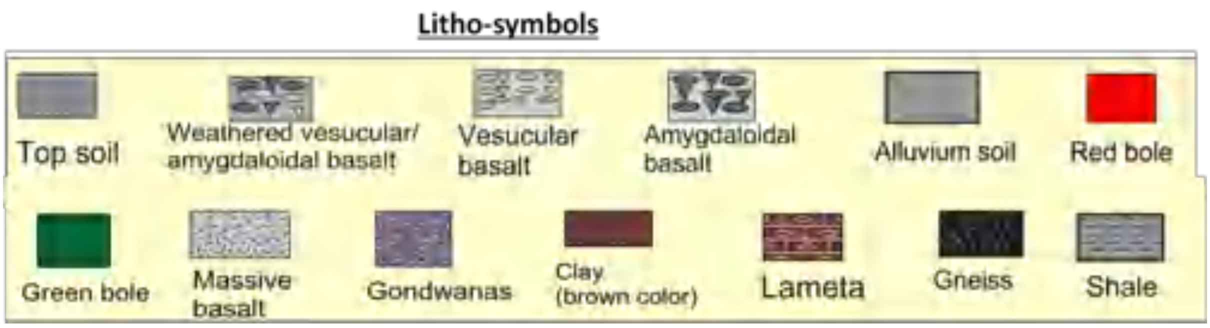


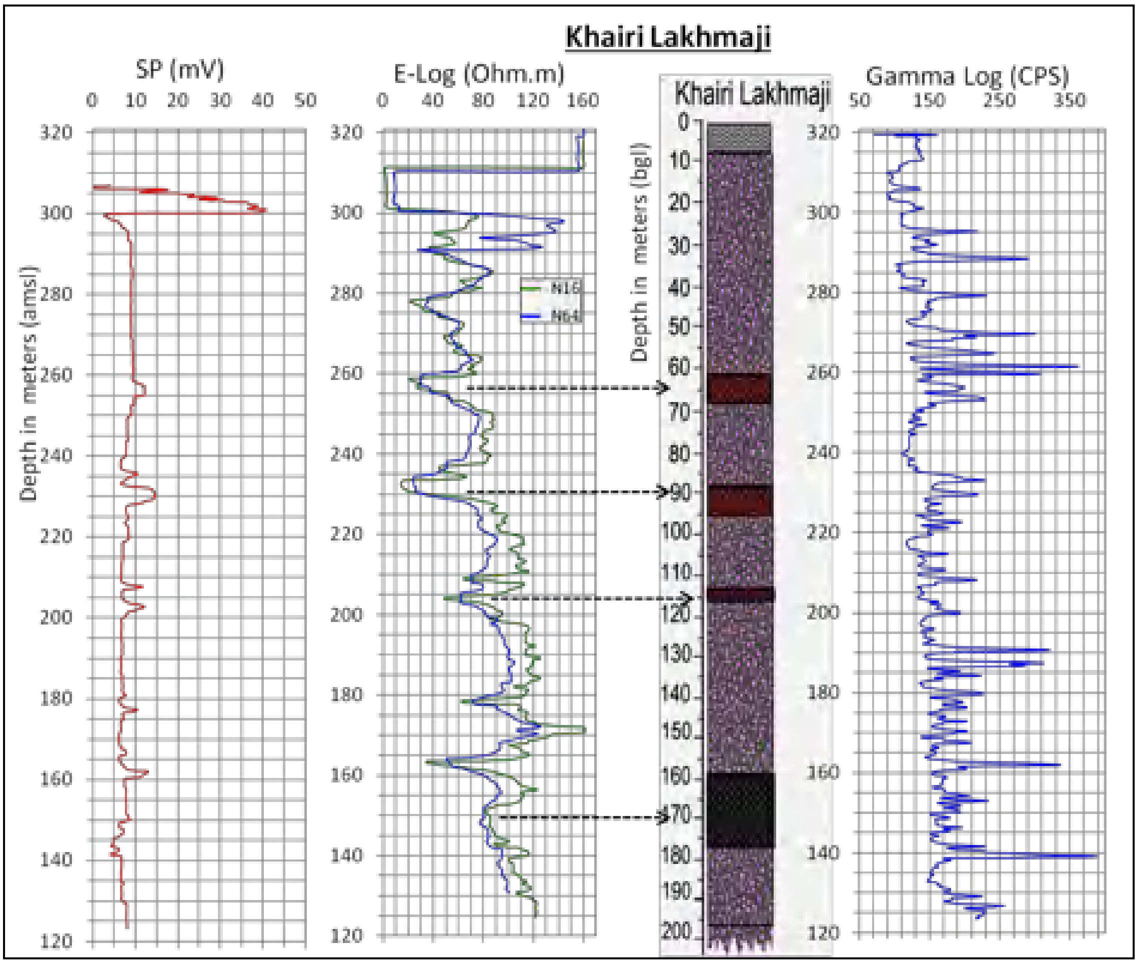
Litho-symbols



Litho-symbols


Gowari
SP (mV)
E-Log (Ohm.m)
Gowari
Gamma Log (CPS)
Depth in meters (amsl)
Depth in meters (bgl)
N16
N64


Litho-symbols
Top soil
Weathered vesucular/ amygdaloidal basalt
Vesucular basalt
Amygdaloidal basalt
Alluvium soil
Red bole
Green bole
Massive basalt
Gondwanas
Clay (brown color)
Lameta
Gneiss
Shale



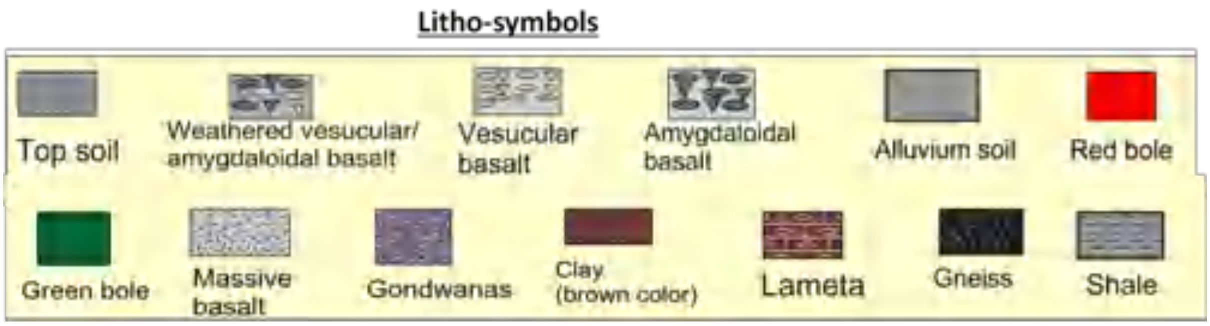


Fig. 3.16: Geophysical logs with drilling lithologs, Chandrabhaga Watershed (WGKCC-2)

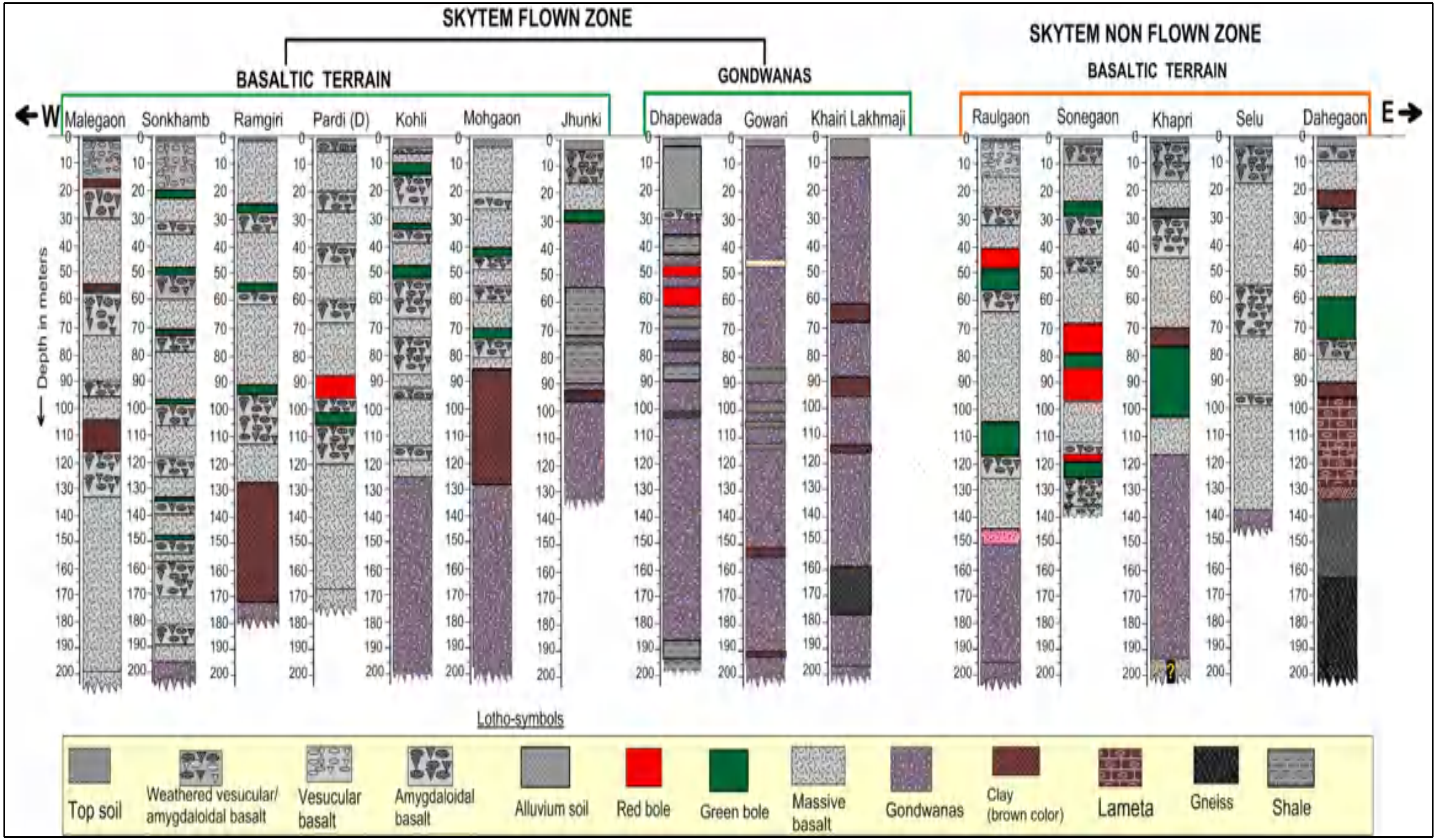


Fig. 3.17**:** Consolidated lithology of CGWB drilled wells, Chandrabhaga Watershed (WGKCC-2)

3.2.2 Geophysical Survey by NGRI

The geophysical survey work has been carried out by CSIR-NGRI, Hyderabad to establish the protocol of geophysical methods for delineating the aquifer disposition in terms of geo-electric layers. During the project period, the NGRI has carried out geophysical survey including data acquisition, processing and interpretation by Resistivity survey (VES, 2D Resistivity Imaging survey), Ground Electromagnetic survey (G-TEM), Heliborne TEM (SkyTEM) and geophysical logging of bore-holes drilled for precisely delineating the potential aquifer zones along with its continuity both vertically and laterally to an extent of ~200 m in hard rock areas. The details of geophysical investigations carried out is presented in Fig.3.18 while the data acquisition with brief remark on instrument used and system parameters is presented as Table 3.2.

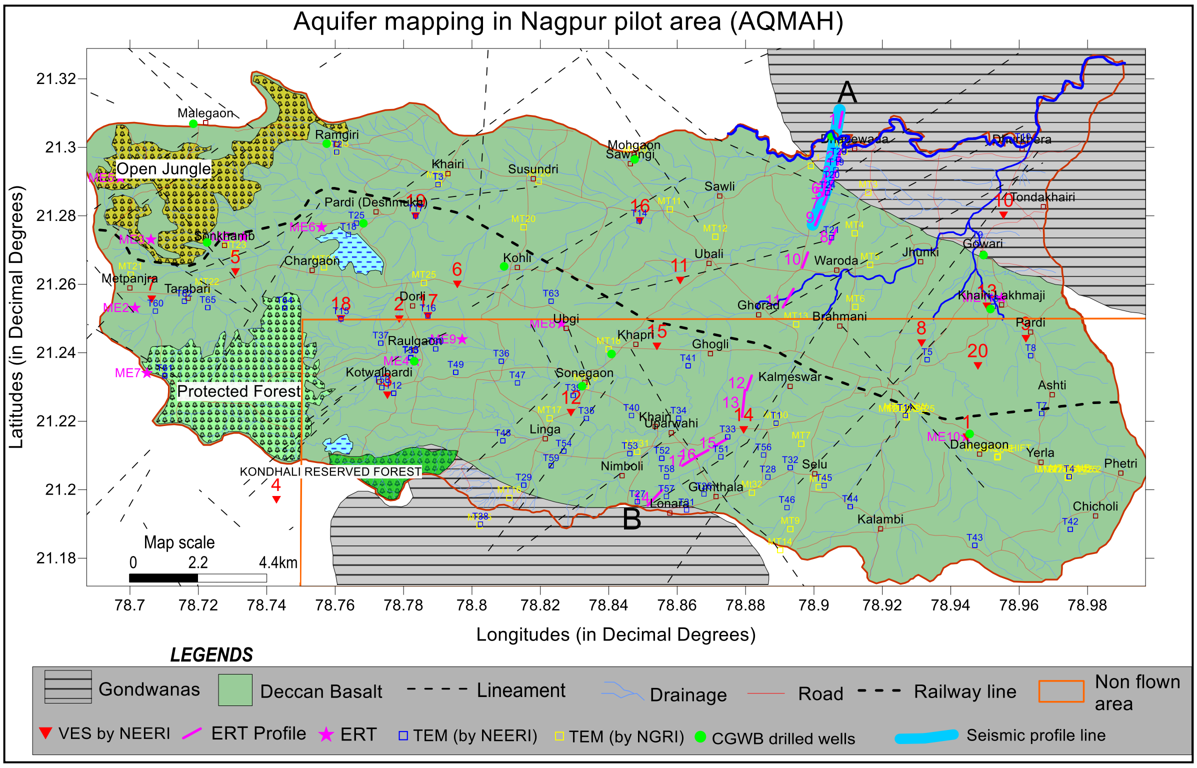


Fig. 3.18: Geophysical investigations by NGRI, Chandrabhaga Watershed (WGKKC-2)

Table 3.2: Data acquired in AQMAH pilot area by NGRI (NGRI, 2015)

Data summary at Chandrabhaga watershed (WKCC-2), AQMAH area, Nagpur (Maharashtra)							
Name of Activity		**Target**	**pre SkyTEM**	**SkyTEM**	**Post SkyTEM**	**Total**	**Remarks**
1-D GEOPHYSICS	VES (no.)	100	21		-	21	Syscal (IRIS)
	TEM (no.)	20	42		57	99	TEM fast 48 HPC system & TerraTEM with 40m x 40m loop size, 1 and 4 A current were used
2-D GEOPHYSICS	ERT (LKM)	20	17.6			17.6	Syscal (IRIS)
	HRSS (LKM)	-	6		-	6	
Borehole Logging	Wells (No.0	0	0		0	0	-
HeliTEM	SkyTEM (LKM)			954		954	TEM and Magnetic data using Line/Tie line spacing : 200/2000 ms

The helicopter borne transient electromagnetic measurement method, SkyTEM is the leading geophysical methods for ground water mapping. The target of altitude in open terrain is approximate 30 m with fluctuations ranging from 25 to 45 m. The altitude will increase by the height of the objects over flown. The Heliborne SkyTEM investigation has been carried out in areas approved by MoD from 13/11/2013 to 16/11/2013 covered by 946 line km.'s (Fig. 3.19)

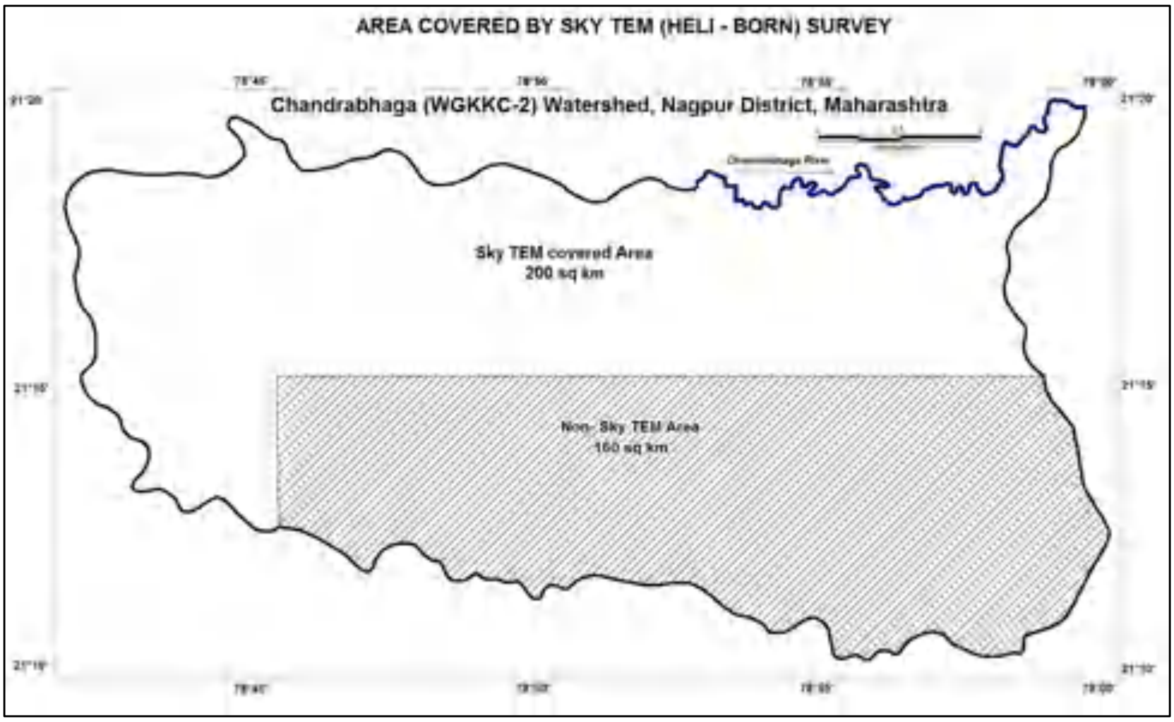


Fig. 3.19: Area covered under Heliborne Sky-TEM geophysical survey, Chandrabhaga Watershed (WGKKC-2)

3.2.2.1 Vertical Electrical Sounding (VES)

The objective of the VES is to decipher the disposition of the aquifer system in the study area. In the central portion of the study area, the objective is to decipher the contacts between the flow units as well as the contact between the Basalts and the underlying Gondwanas. VES have been carried out at different locations in the study area. Attempt has been made to cover the maximum Current Electrode (AB) spacing. In view of the field limitations, the maximum AB/2 which could be attained in the field was 500m. The VES data were collected using the SSR-MPA AT Resistivity meter (IGIS-Hyderabad make). To ensure QA/QC of the data, the equipment was tested against known resistance in a resistance box before the initiation of the survey. The repeatability of the measurements was also tested in the field. The field observations like the well cuttings and ground water level were noted to strengthen the geophysical interpretation. The resistivity data were interpreted using the IX-1D software (Version 2.06). The VES curves were presented in the **Annexure-III** and the VES results are presented in Table 3.3.

Table 3.3: Geo-electrical parameters of VES in Chandrabhaga Watershed (WGKKC-2) (NGRI, 2014)
[ρ = resistivity (Ωm), h = thickness of layer (m) & H=total thickness (m)]

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
1	VES -1	Dahegaon	78°56'41.8" 21°12'5.4"	343	400	Basalt	I	4.35	0.49	0.49	Soil	
							II	2.11	2.64	3.13	Weathered	
							III	22.33	3.1	6.23	Clay/Vesicular	
							IV	226.47	8.59	14.82	Compact basalt	
							V	12.03	24.86	39.68	Clay/Vesicular	
							VI	130.36	51.45	91.13	Compact basalt	
							VII	3758.6			Granitic Gneiss	
2	VES -2	Dorli	78°46'43.4" 21°14'59.5"	398	300	Basalt	I	30.68	0.31	0.31	Soil	In view of the limited AB, no conclusive evidence can be cited for the bottom most layer.
							II	333.2	6.91	7.22	Compact basalt	
							III	574.26	12.31	19.53	Compact basalt	
							IV	68.89	11.81	31.34	Vesicular Basalt	
							V	135	68.49	99.83	Compact basalt	
							VI	39.29				
3	VES -3	Raulgaon	78°46'31.3" 21°13'39.5"	402	300	Basalt	I	110	1	1	Vesicular and Massive Basalts	
							II	150	3	4		
							III	400	7	11		
							IV	200	5	16		
							V	130	10	26		
							VI	20	45	71	Bole bed	
							VII	80	72	143	Compact basalt	
							VIII	10			Gondwana	
4	VES -4	Murli	78°44'34.2" 21°11'49.6"	407	250	Gondwana	I	18.91	3.44	3.44	Soil + Sand	
							II	9.86	3.2	6.64	Clay	
							III	165.86	2.65	9.29	Compact Sst	
							IV	72.18	6.27	15.56	Sandstone with different nature, texture and saturation	
							V	43.74	99.76	115.32		
							VI	43.18	1.39	116.71		
							VII	27.48				

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
5	VES -5	Sonkhamb	78°43'51.8" 21°15'49.1"		400	Basalt	I	18.64	5.24	5.24	Soil	Gondwana encountered in Sonkhumb village at 195m depth.
							II	497.98	9.54	14.78	Compact basalt	
							III	133.68	108.36	123.14		
							IV	31.7			Fractured Basalt	
6	VES -6	Kohli	78°47'44.6" 21°15'36.0"	387	400	Basal	I	49.66	1.83	1.83	Soil	EW drilled at Kohli (approx. 1.5 km from VES 6) encountered bole bed at 10m depth and Gondwana encountered at 125 m depth
							II	221.9	3.87	5.7	Compact basalt	
							III	3.67	6.69	12.39	Clay / Bole bed	
							IV	17.71	72.36	84.75	Weathered / fractured basalt	
							V	380.32	88.12	172.87	Compact basalt	
							VI	20.53			Gondwana	
7	VES -7	Tarabodi	78°42' 22.9" 21°15'20.4"	412	125	Basalt	I	64.28	0.38	0.38	Soil	
							II	59.68	1.04	1.42	Weathered Basalt	
							III	699.73	2.44	3.86	Compact basalt	
							IV	23.69	4.75	8.61	Fractured Basalt	
							V	126.27	3.53	12.14	Compact basalt	
							VI	140.25				
8	VES -8	Kalmeshwar	78°55'53.3" 21°14'34.3"	321	500	Basalt	I	5.27	3.51	3.51	Soil	This site is locatedNE of the Kalmeswar Village and S of the contact between Deccan Traps and
							II	4.39	3.84	7.35	Clay	
							III	3.95	3.48	10.83		
							IV	294.99	24.43	35.26	Compact basalt	
							V	32.5	40.18	75.44	Sandstone	
							VI	9.1			Clay	

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
												Gondwanas
9	VES -9	Pardi	78°57'43.1" 21°14'38.9"	327	300	Gondwana	I	13.74	0.9	0.9	Soil	This site is located close to Pardi village, in the vicinity of the contact between the Basalts and Gondwanas.
							II	4.76	7.4	8.3	Clay	
							III	4.18	1.72	10.02		
							IV	74.45	3.74	13.76	Compact basalt	
							V	108.13	2.88	16.64		
							VI	12.29	36.3	52.94	Clay	
							VII	62.01				
10	VES -10	Tondakairi	78°57'19.5" 21°16'48.6"	318	500	Gondwana	I	469.18	0.88	0.88	Soil	This site is close to Tondakhairi Village falling on the Gondwana formations.
							II	68.97	3.72	4.6	Sandstone with different nature, texture and saturation	
							III	27.74	2.69	7.29		
							IV	47.44	23.43	30.72		
							V	413.02	44.71	75.43	Compact Sandstone	
							VI	20.75	109.05	184.48	Sandstone	
							VII	17.32				
11	VES -11	Ubali	78°51'39.2" 21°15'40.1"	344	500	Basalt	I	107.42	0.4	0.4	Soil	This site is falling in the Basaltic terrain
							II	90.65	2.61	3.01	Compact basalt	
							III	293.8	2.71	5.72		
							IV	13.46	4.22	9.94	Clay	
							V	77.27	116.25	126.19	Compact basalt	
							VI	223.97	69.16	195.35		
							VII	14.64			Gondwana ?	
12	VES -12	Sonegaon	78°49'44.2" 21°13'21.2"	362	500	Basalt	I	53.91	0.25	0.25	Soil	This site is at the Saonegaon village falling in the basaltic formations.
							II	41.66	6.87	7.12	Weathered / vesicular basalt	
							III	331.36	3.76	10.88	Compact basalt	
							IV	29.23	2.13	13.01	Fractured Basalt	
							V	72.02	40.22	53.23	Basalt	
							VI	48.44	43.39	96.62	Basalt+Bole	
							VII	41.66			Basalt	

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
13	VES -13	Khari Lakhanji	78°57'2" 21°15'13"	323	250	Gondwana	I	5.58	1.43	1.43	Soil	This site is near Khairi Lakmaji Village falling in Gondwana formations as per the borehole data at this village.
							II	8.98	2.55	3.98	Clay	
							III	2.18	8.17	12.15		
							IV	22.67			Sand	
14	VES -14	Linga	78°52'46" 21°13'3"	338	300	Basalt	I	43.42	0.37	0.37	Soil	
							II	4.6	0.47	0.84	Clay	
							III	23.27	10.09	10.93	Vesicular Basalt	
							IV	447.86	19.24	30.17	Compact Basalt	
							V	25.82	20.76	50.93	Fractured Basalt	
							VI	37.28			Gondwana ?	
15	VES -15	Ghogli	78°51'14.8" 21°14'30.8"	401	200	Basalt	I	18.81	0.68	0.68	Soil	
							II	9.77	4.52	5.2	Weathered Basalt	
							III	29.86	21.76	26.96	Fractured Basalt	
							IV	75.2	22.32	49.28	Amy. Basalt	
							V	184.4	24.14	73.42	Compact Basalt	
							VI	11.27			Clay / Bole bed	
16	VES -16	Wathoda,	78°50'56.8" 21°16'42.7"	416	200	Basalt	I	4.15	0.48	0.48	Soil	North of this village, Gondwana encountered at 85m in Mohgaon and at 116 m at Khapri which is S. Of the village
							II	8.25	1.09	1.57	Weathered Basalt	
							III	146.8	27.61	29.18	Compact Basalt	
							IV	33.55	47.25	76.43	Vesicular Basalt	
							V	278.29	42.53	118.96	Compact Basalt	
							VI	18.7			Gondwana	

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
17	VES -17	Dorli	78°47'13.6" 21°15'2.8"	397	200	Basalt	I	39.51	1.34	1.34	Soil	This site is nearer to Dorli Village where Gondwanas are encountered at 125m Depth
							II	15.1	3.92	5.26	Weathered Basalt	
							III	241.67	12.83	18.09	Compact Basalt	
							IV	33.2	29.38	47.47	Vesicular Basalt	
							V	298.35	43.15	90.62	Compact Basalt	
							VI	17.75			Clay/Gondwana	
18	VES -18	Dorli to Tadabori	78°45'42.0" 21°14'59.7"	410	200	Basalt	I	64.39	0.55	0.55	Soil	This site is nearer to Dorli Village where Gondwanas are encountered at 125m Depth
							II	526.36	30.51	31.06	Compact Basalt	
							III	47.15	31.96	63.02	Vesicular Basalt	
							IV	258.92	38.57	101.59	Compact Basalt	
							V	18.65			Gondwana	
19	VES -19	Pardi	78°47'0.6" 21°16'47.8"	361	200	Basalt	I	31.28	2.63	2.63	Soil	Redbole encountered at 87m depth in Pardi Deshmukh village
							II	96.1	33.54	36.17	Compact Basalt	
							III	18.35	35.59	71.76	Fractured Basalt	
							IV	369.18	30.16	101.92	Compact Basalt	
							V	25.59			Bole Bed	
20	VES -20	Deshmukh Badduji Dorli	78°56'52.6" 21°14'10.3"	341	200	Basalt	I	6.74	4.79	4.79	Soil	
							II	475.38	22.61	27.4	Compact Basalt	
							III	6.1	19.31	46.71	Clay	
							IV	13.27	40.67	87.38	Weathered/Fractured Basalt	
							V	143.16	12.2	99.58	Compact Basalt	
							VI	13.1			Clay / Bole bed	
21	VES -21	Waroda	78°54'19.7" 21°16'25.6"	341	300	Basalt	I	5.4	0.59	0.59	Soil	This site is almost lying
							II	71.31	2.53	3.12	Compact Basalt	

Sl. No.	ID	Village /Location	Lat/long	Elevation (m a MSL)	AB/2 (m)	Terrain	Layer No	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology	Remarks
							III	5.32	7.2	10.32	Weathered/ Vesicular Basalt	on the ERT8 profile. It was done to cross check the data and the subsequent interpretation
							IV	103.33	29.8	40.12	Compact Basalt	
							V	3.5	29.89	70.01	Clay/Bole + Vesicular/jointed Basalt	
							VI	36.68			Gondwana	

3.2.2.2 Electrical Resistivity Tomography (ERT)

The central objective of the ERT is to decipher the disposition of the intertrappeans, and vertical contact of basalts and underlain Gondwana formation, which are thought to be potential aquifer zone. To meet the objective of the proposal, a joint inversion includes High Resolution Seismic (HRS) and Electrical Resistivity Tomography has been planned to cover a common profile of about 15 km in North-South direction (Fig. 3.20a, and 3.20b).

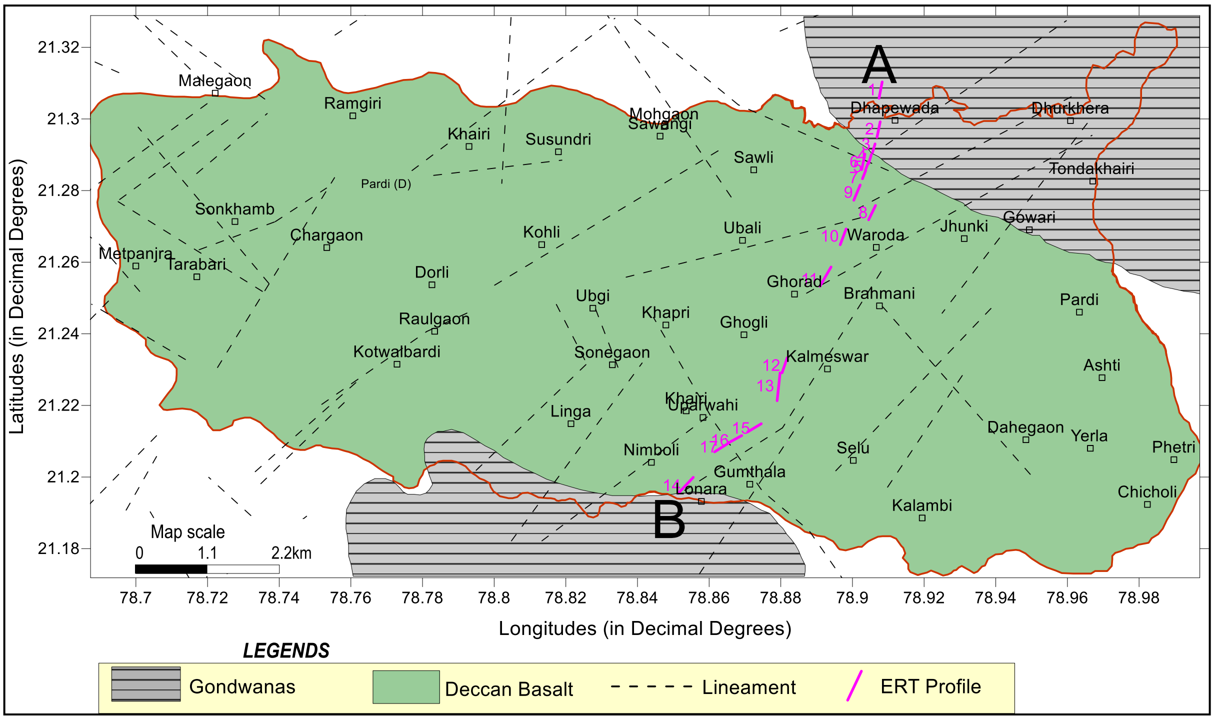


Fig.3.20a. Joint inversion profile orientation (A-B) in Chandarbhaga Watershed (WGKKC-2)

Fig.3.20b. Fixing of end points 'A' (north) and 'B' (south) for proposed line in the presence of NGRI, CGWB and NEERI staff at Nagpur study area

The field survey plan to cover the profile A-B (Fig.3.20a) of about 15 km line was finalized by NGRI Scientists in the presence of CGWB, Central Region, Nagpur officials (Fig.3.20b). ERT points (Table 3.4) have been followed the proposed line with maximum possible extent. Few windows between the ERT profiles were left due to the inaccessibility or transport lines such as roads, railway tracks etc.

Table 3.4: Locations of ERT with their geo references and type of geology, in Chandrabhaga Watershed (WGKKC-2).

ERT No.	**Longitudes**	**Latitudes**	**Terrain**
'A' Point	78.90956	21.30989	Gondwana
ERT1	78.90797	21.30811	Gondwana
ERT2	78.90729	21.29717	Gondwana
ERT3	78.9063	21.29285	Gondwana
ERT4	78.9052	21.28977	Gondwana
ERT5	78.90393	21.28667	Basalts
ERT6	78.90302	21.288	Basalts
ERT7	78.90289	21.28356	Basalts
ERT8	78.9055	21.27381	Basalts
ERT9	78.90137	21.27947	Basalts
ERT10	78.89746	21.26725	Basalts
ERT11	78.892	21.25522	Basalts
ERT12	78.8811	21.23115	Basalts
ERT13	78.8794	21.22542	Basalts
ERT14	78.85337	21.19761	Basalts
ERT15	78.87264	21.2136	Basalts
ERT16	78.86678	21.21023	Basalts
ERT17M	78.8637	21.20835	Basalts
'B' Point	78.85136	21.19556	Gondwana

The field geology along the proposed line shows basaltic terrain with Gondwana formation exposed to surface as patches in the north and south of the study area. In the basaltic terrain the black cotton soil admixed with calcret (lime) and chert (silica) were observed. Based on the dug well cuttings existing along the proposed line A-B, the sequence of the soil profile from top to bottom as > top soil > weathered basalt > vesicular basalt (mostly amygdaloidal silica filled) > massive basalt > intertrappeans with white clay. Vesicles in the basalts are filled with well-developed crystal form of silica called as Geoids.

The field environmental condition shows dry top soil, post harvested agriculture lands, tractor ploughed lands, patches of orange and sugar cane forms, barren land. Mostly flat topography was found with gentle slope towards north. The average atmospheric temperature is noted 47^{o} C. During the fieldwork, the geological and hydrological evidences such as rock sample collection from well cuttings and groundwater water table measurements were noted to enhance the precision of geophysical data interpretation.

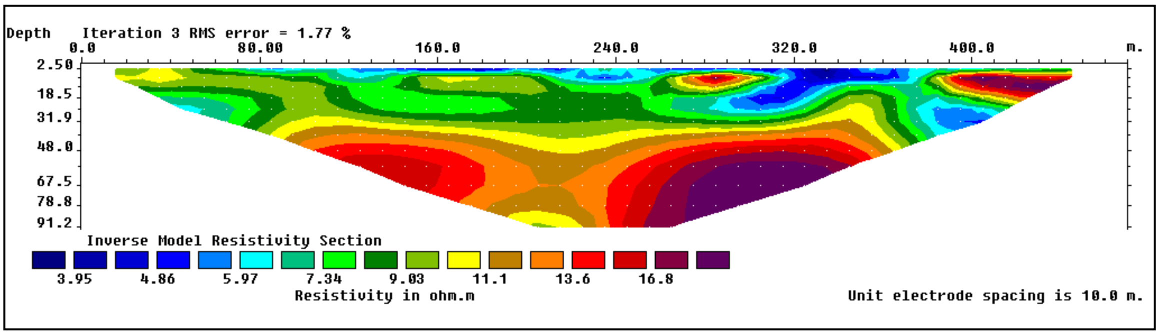
A total of 17 ERT profiles have been carried out using Wenner Schlumberger configuration with the help of Syscol Jr Switch 48 Meter (France make). The ERT profiles were performed in N-S orientation where 1st electrode at north and 48th at south is followed. The accuracy of the instrument was verified with other instruments of Super Sting and IGIS which matched closely, hence it is proceeded the data acquisition to accomplish the target. The geo coordinates were noted for each electrode of field lay out. The details of the each ERT profile is discussed as below.

ERT 1 & 2

This ERT 1 is carried out in the north at 'A' point, located 600 m north of the Dhapewada village and north of the Chandrabhaga River. The orientation of profile is as 1st electrode at south and 48th at north. Geologically this area belongs to Gondwana formation (Sandstone). Flat topography, loose dry surface with ploughed land post harvested open farm land. Black cotton soil (clay) mixed with coarse sand. Dug well cutting (5m east of 12th electrode) indicates ground water level 8m bgl. ERT 2 is carried out in the south of the Dhapewada village (south of Chandrabhaga River) belong to Gondwana formation. The area shows flat topography, black cotton soil, dry loose surface, post harvested farmland and orange farm. Depth to water level is noted 20 m bgl.

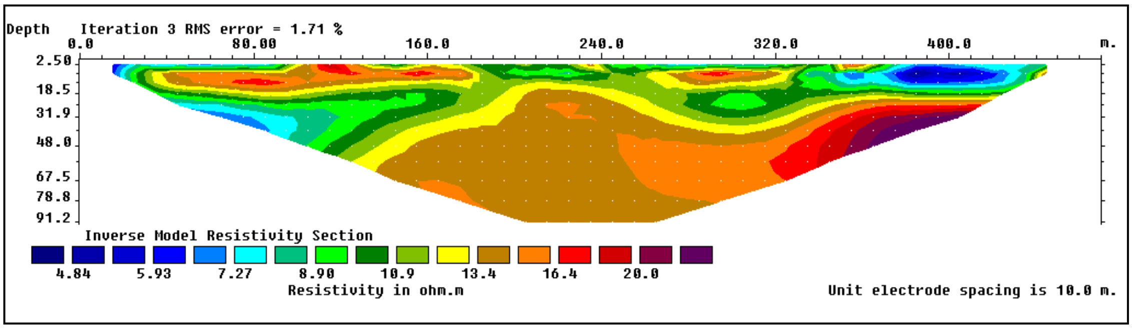
ERT 3

The profile is performed in the south of Dhapewada village. Gondwana formation, black cotton soil were found. Ground water level was recorded 18 m bgl.



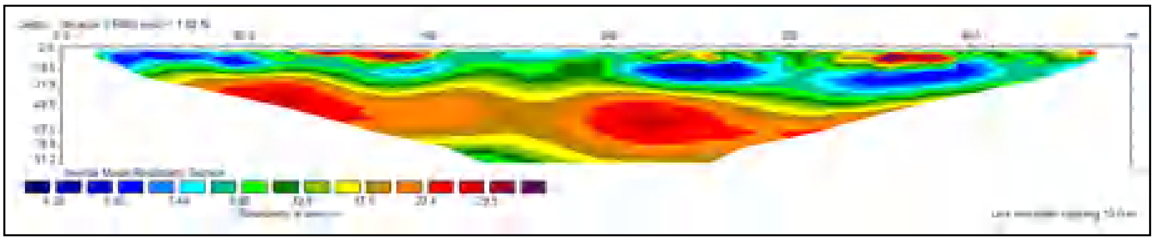
ERT 4

It is carried out in the Gondwana formation. This profile's 1-12 electrodes overlaps 37-48 electrodes of ERT 3. Top soil as black cotton soil, loose dry soil with ploughed land, flat topography is found in the area. Dug well found at 40m in the east from 40th electrode. Water level in dug well is found 12m depth, even long duration of pumping no change in ground water level variation was found indicates potentiality of the well.



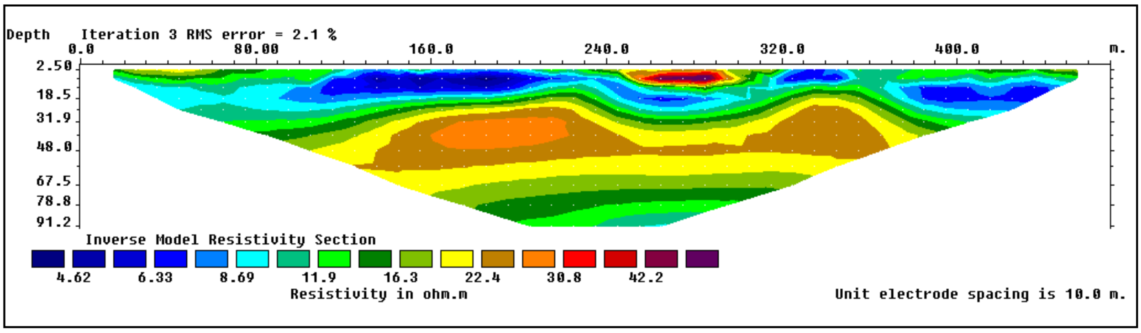
ERT 5

The area belongs to basaltic terrain. Dug well cuttings (40m in the west from 30th electrode) shows basaltic traps with two different flows separated with intertrappeans (white clay material). Probably the top flow is composed of compact massive basalt up to 10m depth followed by 30-60cm intertrappeans. Ground water level in the dug well is found 13.4 m bgl. As per farmer's information the well get empty within two hours using 3HP pump.



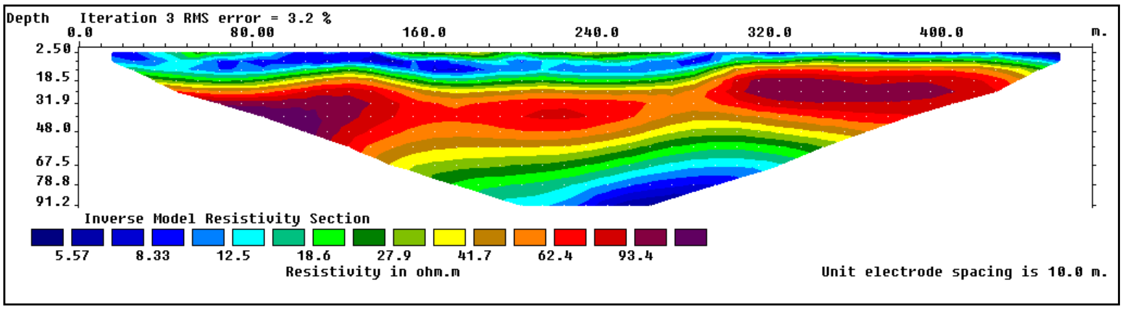
ERT 6

It is carried out parallel to ERT 5, 80m in the western side close to the dug well south of Dhapewada village. This area belong to basaltic terrain as dug well cutting of shows top black cotton soil with calcret up to 1.5 m depth followed by massive basalt up to 10 m depth. Below massive basalt a thin layer of intertrappeans (~1m thick) with white greyish mostly clay is noted below which weathered vesicular basalt and amygdaloidal filled with mostly silicate and occasionally calcite is recorded in the dug well cutting. Ground water level is 13.4m bgl in the dug well.



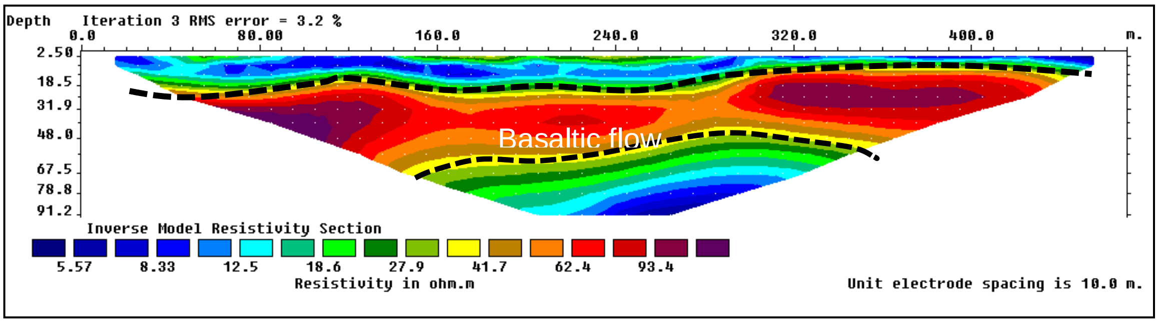
ERT 7

It is performed in the south of Dhapewad village. The survey land is post irrigated, dry loose soil with calcret belong to basaltic terrain. This profile's 1-12 electrodes are overlapping the 37-48 electrodes of ERT 5. A Dug well is observed at 4 m west from 20th electrode. The dug well cutting shows top loose soil, lined up to 2.5 m depth below which weathered and semi weathered basalt is noted. Ground water level in the dug well is recorded 13m bgl but as per farmer's information 7HP pump runs 4 hours then then the well recovers within two hours. Well casing is up to 7m bgl. The Weathered basalt is further noted below 7m depth.



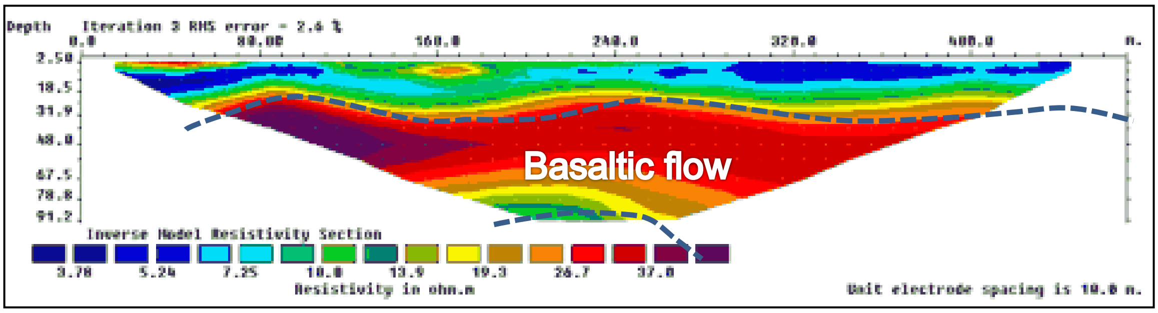
ERT 8

This profile is carried out in the north of Waroda village. The ERT point is performed over the Dr. S. N. Rai's P7 ERT profile (Current Sc. Jour) in the same orientation. The area belongs to basaltic terrain with black cotton soil, dry loose soil admixed with clacrete particles. The ERT 8 profile is ~800m shifted towards east hence not falling in the A-B proposed line of survey. Dug well (4m west of 5th electrode) cutting shows up to 30m depth (total depth) compact basalts. Below 30m occurrence of intertrappeans is recorded. Excavated well material shows vesicular and compact basalt. Ground water level in the well is noted 10m bgl. As per farmer's information, 3 HP pump will empty the well within one hour 3 hour well recovers in 3 hours. To get lateral connectivity the well has been horizontal drilling to 3 directions in the well to increase the well yield. The trend in the P7 image of S. N. Rai is approximately matched with the ERT 8 but resistivity range is noted low in ERT 8 (Wenner Schlumber array) in comparison with P7 (Wenner array). Hence, it is also assured that the Syscol instrument is functioning.



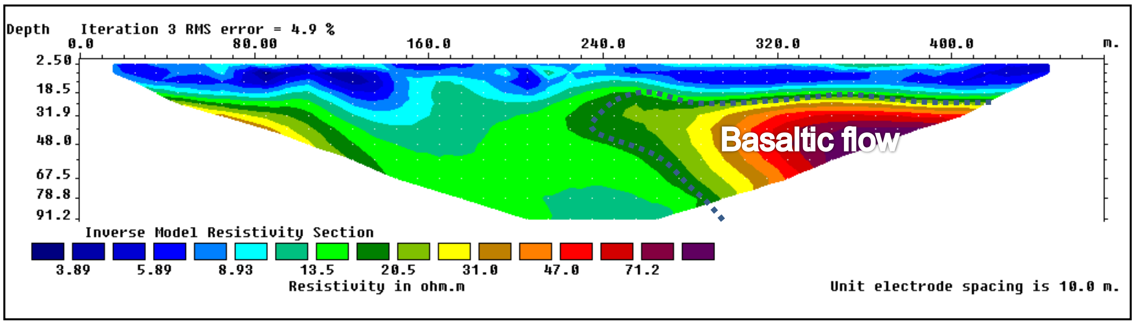
ERT 9

This profile is carried out in the south of Dhapewada village and continuation of proposed line of survey from ERT 7. The area belong to basaltic terrain with black cotton soil admixture with calcret and chert. Flat topography, dry loose surface, post harvested farm land with tractor ploughed. Dug well (20 m west of 48th electode) cutting shows Quaternary medium up to 10m depth due to the reverine/alluvium deposit of Saptadhara River passing (W-E) nearby 30 m south of the 48th electrode. Weathered basalt is noted below 10m depth. Ground water level in the dug well is noted 13m bgl. Saptadhara River is found close to mature stage since it shows 10-15m thick sediments deposited over the banks. It might have spread up to 50-30m either side. Hence the resistiviy is noted low up to 15m bgl in ERT 9 image.



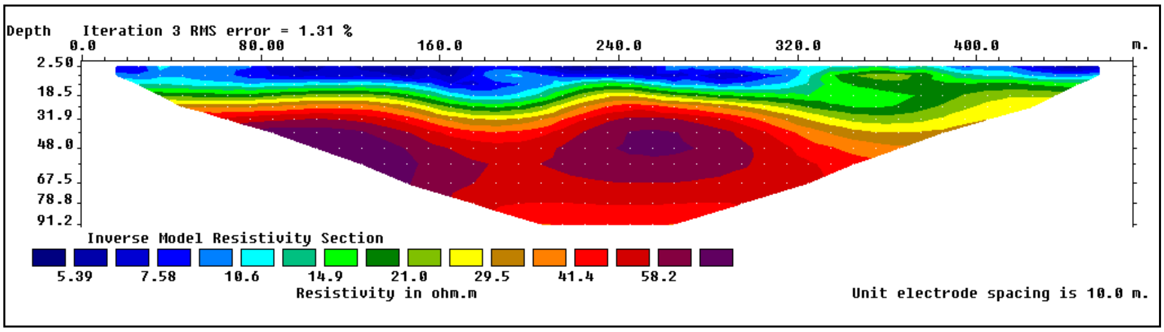
ERT 10

This profile is done in the west of Waroda village belong to basaltic terrain with black cotton soil on top. Flat topography, post harvested farm land with tractor ploughed. Black cotton soil admixed with calcret. Electrode from 16-18 are grounded in the wet (veg. farm) surface. As per farmers information the water striking depth in this area is 17-20m bgl.



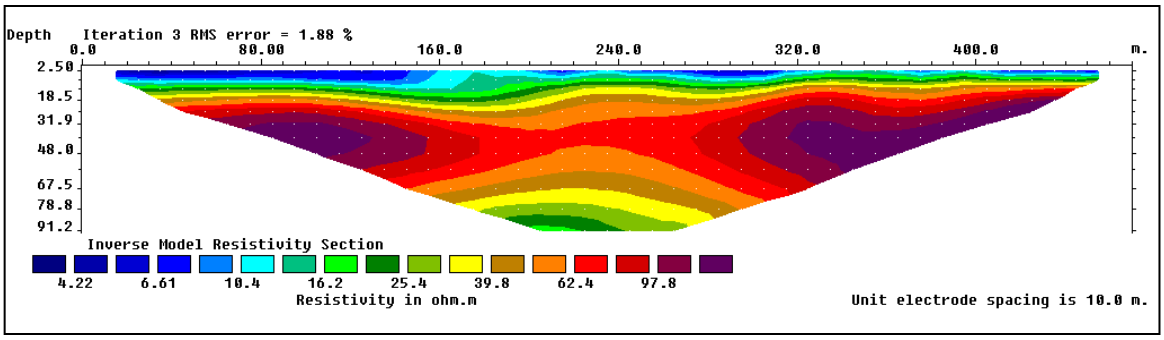
ERT 11

The profile is at north of Ghorad village belong to basaltic terrain. Dug well (3m south of 26 electrode) show ground water level 8m bgl. Weathered basalt up to 10 m depth followed by vesicular and massive basalt observed in the well cuttings excavated material.



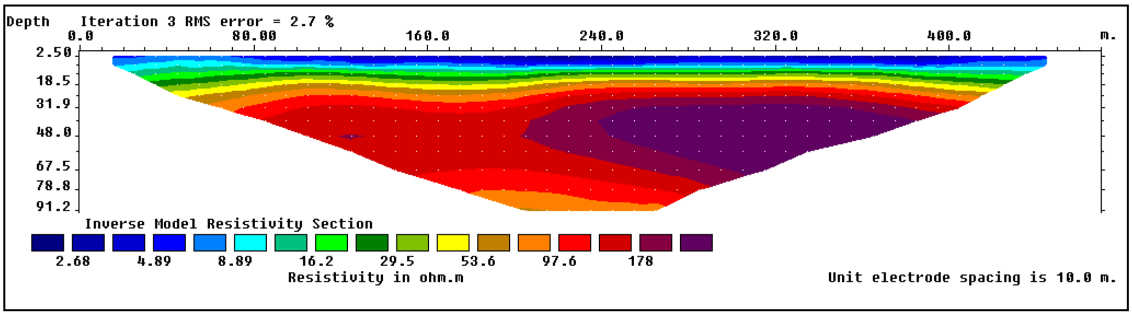
ERT 12

It is carried out in the southwest of Kalmeshwar town belong to basaltic terrain. Massive basalt start at 4-5m depth. Above massive basalt, vesicular basalt with well-developed crystallized Geo is noted in vesicles.



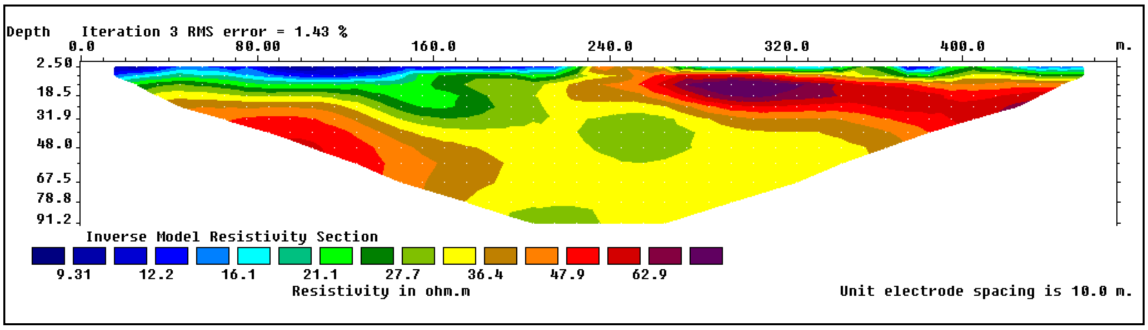
ERT 13

It is carried out at Sawangi village belong to basaltic terrain. Dug well 10m from east from 11 electrode shows ground water level 5m bgl. Weathered formation up to 3-4 m followed by vesicular basalt underlying the massive basalt. The area is rich in black cotton soil with calcrete ($CaCO_3$), ploughed farmland.



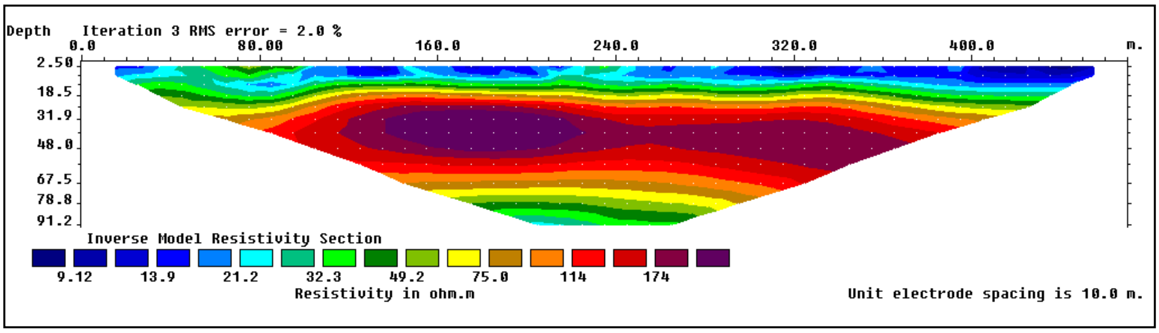
ERT 14

It is performed in the west of Sawangi village, extreme south 'B' point belong to Gondwana formation (Sandstone) (Plate 2A). Well-developed compact sandstone with laminated, bedding planes are clearly visible. The cementing material siliceous. Ground water level in dug well (30 m east of 36 electrodes) is 6 m bgl.



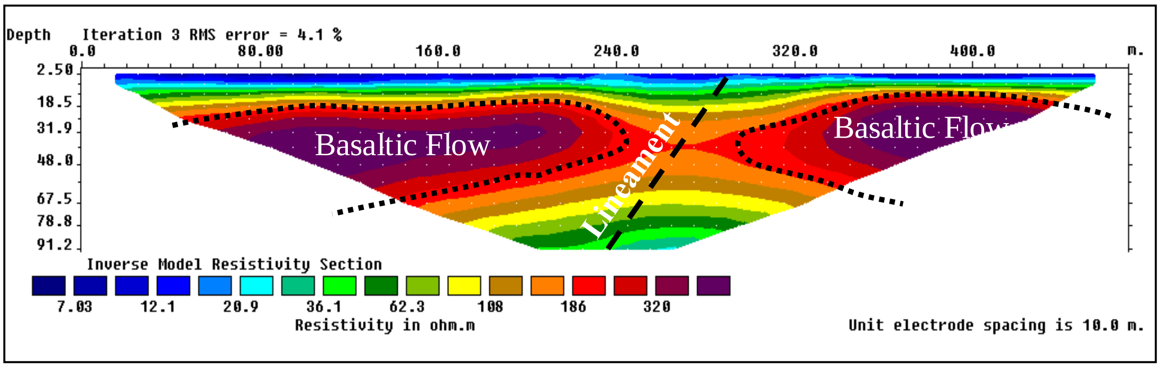
ERT 15

The location of the profile is at west of Gumthala village belong to basaltic terrain. The black cotton soil is dominated with calcrete. Ground water level in the dug well (50m east of 36 electrode) is 3m bgl. Weathered basalt is found up to 4 m depth. Flat topography, dry loose surface with calcrete.



ERT 16

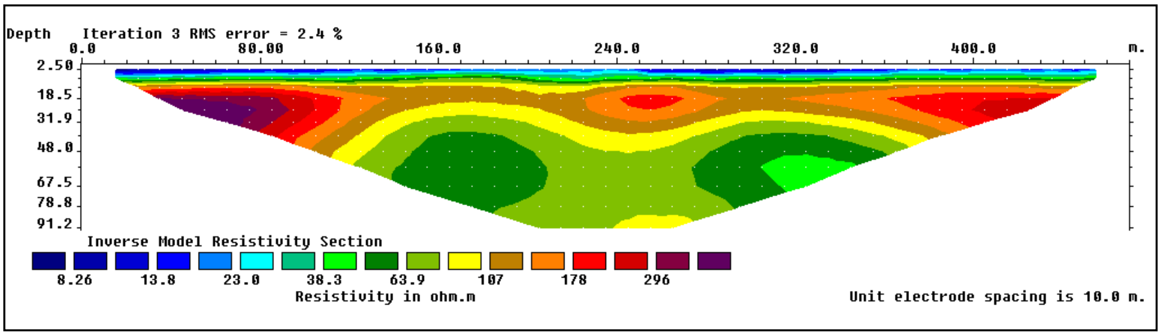
The ERT profile is carried out in the western side of Gumthala village belong to basaltic terrain continuation of ERT. Ground water level nearby dug well (15m SE 3electrode) is 3.5m bgl. It is indicating the fringe zone of basalt and sandstone of lateral variations. It indicates the fringe zone between lateral contact of Gondwana and basalts, shows potential for groundwater. Excavated material of dug well shows top soil + Morrum followed by intertrappeans underlying massive basalt with Geod.



ERT 17

This profile is continuation of ERT 16 belong to basaltic terrain. This profile's 1-12th electrodes overlaps the 36-48th electrodes of ERT16. The excavation material of shows top soil

(1m thick) followed by intertrappeans (white clay) followed by weathered basalt. Black cotton soil mixed with calcrete and chert is found at the survey point. Maximum current sent by the resistivity is noted 400 volts.



The ERT ME 3 and 4 show low resistivity up to 20 Ωm indicating Gondwana sediments that was verified by dug well rock cuttings. Investigated resistivity is found varying in range of 5 to 20 Ωm. However ME14 that falls on other side of the profile reveals completely different resistivity range varying from 10 to70 Ωm. Such differences are a clear indication of either different mineralogical compositions or different hydrogeological set up. Looking at the megascopic hand specimens it is evident that the northern part of Gondwanas consists of mainly coarse grained Ferruginous sandstone. The low order of resistivity might be the result of Fe elements, water contents, water quality, etc. which needs to be further verified. The Motur Gondwana in south is composed of fine to coarse grained sandstone with inclusion of mudstone as seen in the rock cutting in a dug wells. Higher order of resistivity in this portion still need to be understood by more investigations and would be important from the point of groundwater dynamics.

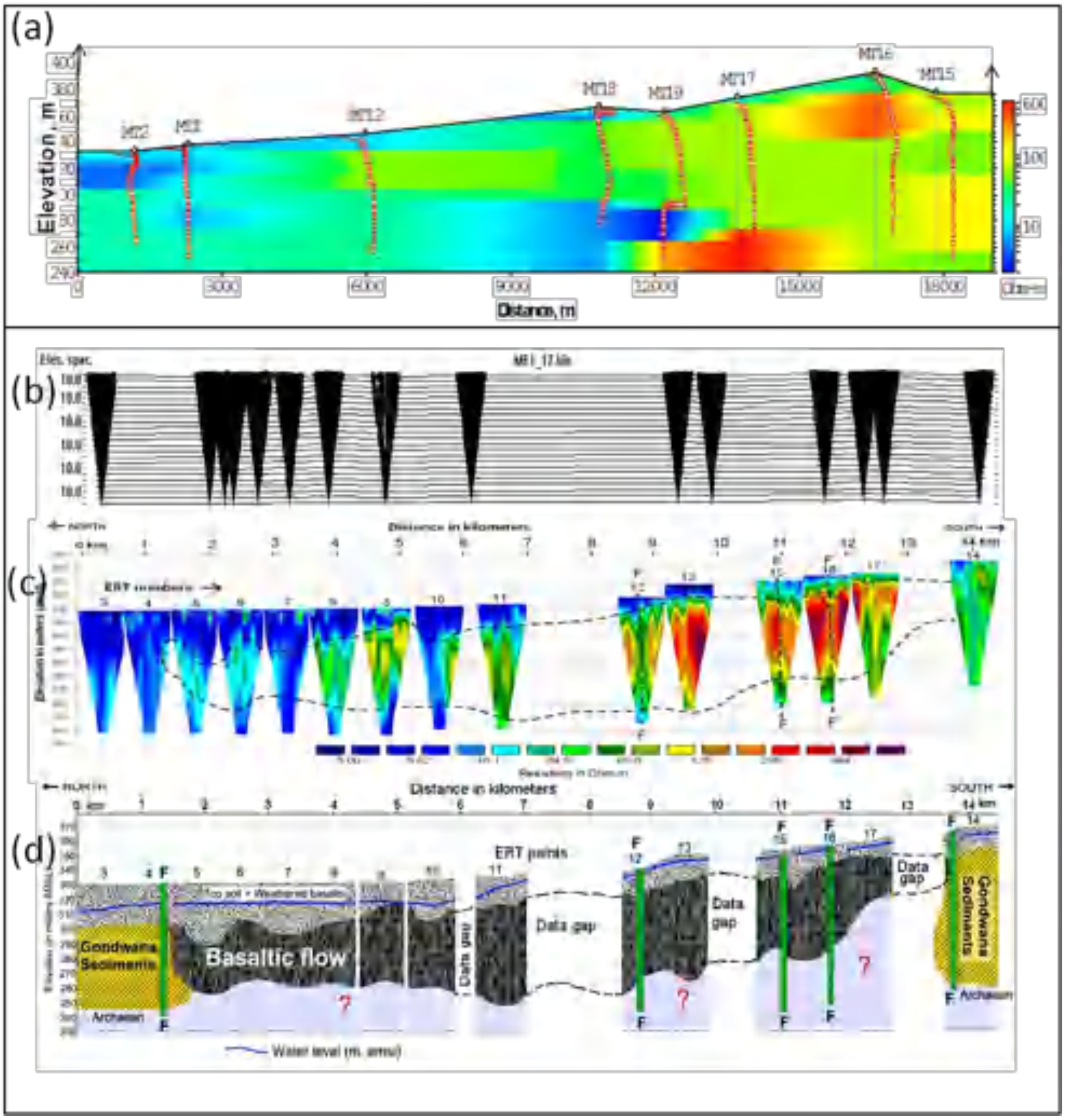


Fig. 3.21 (a) Resistivity image with altitude from TEM; (b) ERT data pattern; (c) ERT image and (d) derived hydrogeological map from showing basaltic flow of N-S profile along AB line

The ERT images, further in south from ERT 5 onward, exhibits basaltic flow pattern as marked by dotted lines lying roughly between 30-80 m depths (ERT 5). Resistivity range, though observed low, indicates increasing trend towards south and reaches up 400 Ωm. theoretically such flow is expected to be continuous. However, observed low resistivity breaks within the ERT profile over basaltic terrain could be inferred as weak zone as an indicative of lineament. Occurrence of such lineaments could be taken as associated potential groundwater bearing zones. The inferred lineaments are marked in the respective ERTs.

3.2.2.3 Ground Transient Electromagnetic (TEM) methods

Transient Electromagnetics, (also Time-Domain Electromagnetics / TDEM), is a geophysical exploration technique in which electric and magnetic fields are induced by transient pulses of electric current and the subsequent decay response measured. TEM / TDEM methods are generally able to determine subsurface electrical properties, but are also sensitive to subsurface magnetic properties. TEM/TDEM surveys area very common surface EM technique for mineral exploration, groundwater exploration, and for environmental mapping, used throughout the world in both onshore and offshore applications. Two fundamental electromagnetic principles are required to derive the physics behind TEM surveys: Faraday's law of induction and Lenz's Law. A loop of wire is generally energized by a direct current. At some time (t_0) the current is cut off as quickly as possible. Faraday's law dictates that a nearly identical current is induced in the subsurface to preserve the magnetic field produced by the original current (eddy currents). Due to ohmic losses, the induced surface currents dissipate this causes a change in the magnetic field, which induces subsequent eddy currents. The net result is a downward and outward diffusion of currents in the subsurface which appear as an expanding smoke ring (Nabighian, 1979) when the current density is contoured (Nabighian and Macnae, 1991). These currents produce a magnetic field by Faraday's law. At the surface, the change in magnetic field (flux) with time is measured. The way the currents diffuse in the subsurface is related to the conductivity distribution in the ground (McNeill, 1980). When conductive bodies are present, the diffusion of the transients is changed. In addition, transients are induced in the conductive bodies as well (NGRI, 2014).

NGRI has carried 99 Ground TEM using TEM fast 48 HPC system & TerraTEM with 40m x 40m loop size, 1 and 4 A current. The representative TEM plots generated have been presented in **Annexure-IV**.

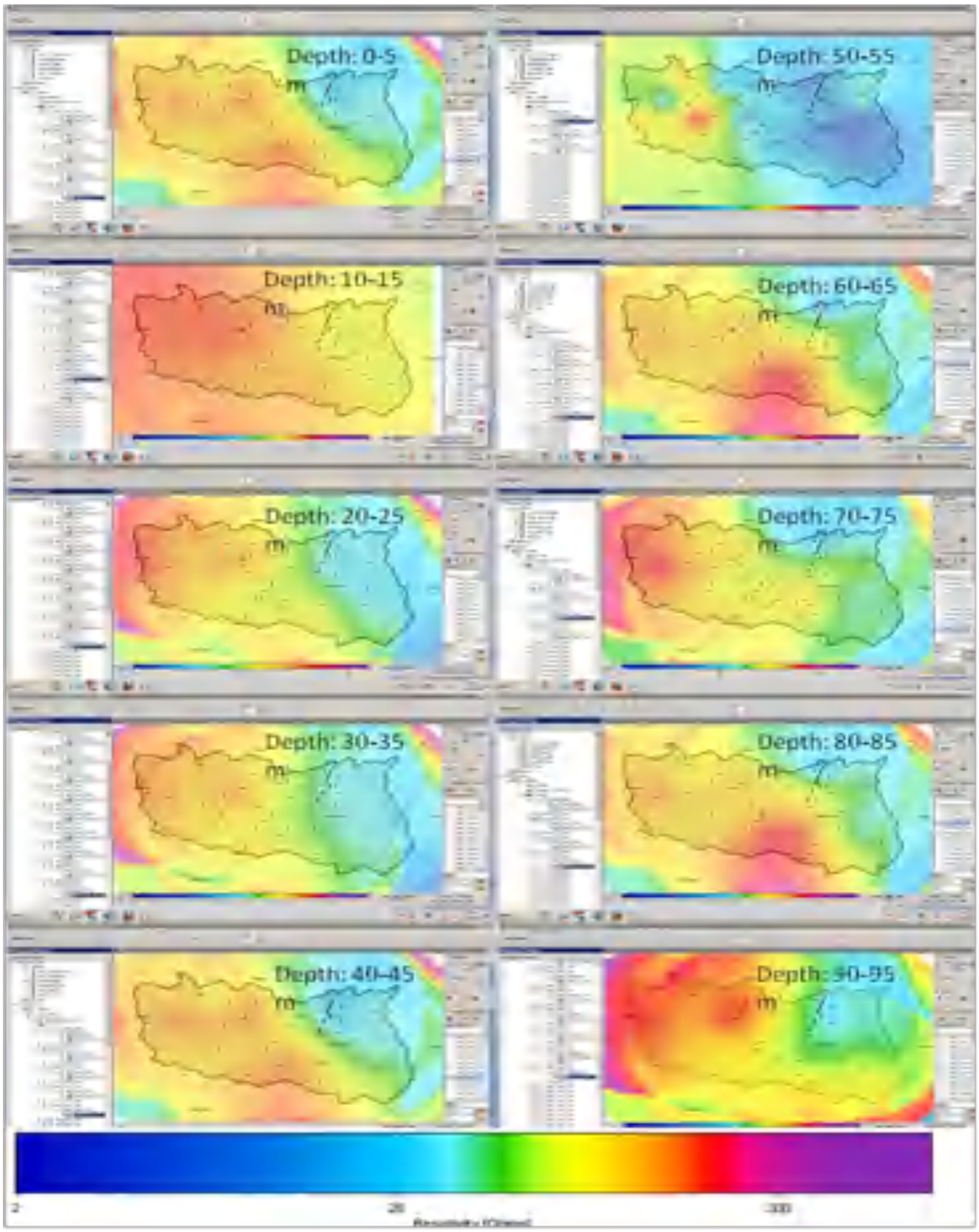


Fig. 3.22: Mean resistivity maps at different depth, Chandrabhaga Watershed (WGKCC-2)

Hydro-geophysical thematic maps are prepared representing mean resistivity distribution for depth interval 0-5 m, 10-15 m, 20-25 m and so on upto 80-90 m depths (Fig. 3.22). This shows the change in the resistivity pattern as an effect of lithological /hydrogeological changes. The Gondwana in the NE appears to be of low resistivity compared to Basaltic terrain. Even within the NE zone resistivity varies with depth e.g. resistivity around 25 Ωm at 0-5 m depth changed to around 80 Ωm at 10-15 m depth and reaches back to 25 Ωm at 20-25 m giving a layered model. It is important to note that the above themes are prepared with the sparse data network for demonstration purpose only. Its full utilization will be done after SkyTEM survey to clearly demarcate the lithological and hydrogeological interfaces and units etc precisely.

3.2.2.4 Geophysical Inferences by NGRI

Geophysical investigations VES, ERT and TEM have been carried out in the study area covering the northern Gondwana (Kampthi), Trap covered Gondwana and southern Gondwana (Motur).

In northern Gondwana, VES technique is able to delineate between different Gondwana litho-units like compact sandstone (~400 Ω-m) and shale (~20 Ω-m). ERT investigations showing single layer of low resistivity but failed to delineate between shale and sandstone. TEM is able to delineate various litho-units up to shallow depth (~90 m) which is further correlating with electrical logs.

In the trap covered Gondwana VES method has successfully distinguished the Trap-Gondwana contact, however, it is unable to distinguish between successive lava flows separated by bole beds. ERT shows significant signatures of structural controls like lineaments and also layered nature of flows could be delineated. But difficult distinguish between two successive lava flows. TEM provides significant information of shallow depth up to 50 m bgl. Gondwana occurring in southern part (Motur) shows high resistive values as compared to Gondwanas found in NE part which is observed in ERT and VES surveys. The reasons for high resistivity formation could be due to the mineralogical composition and grain size. ERT fails to delineate between the different litho units of Gondwana.

The ERT investigation shows that in basaltic terrain the low resistivity up to 60 Ω-m is attributed to the vesicular basalt followed by massive basalt with resistivity range 60-125 Ω-m. But in Gondwana formation the resistivity of saturated sandstone falls in the range of 18-35 Ω-m.

A) Comparative analysis of Litholog vs. VES, TEM, ERT

Correlation of TEM with the Geophysical log and Litholog at Dhapewada

TEM sounding has been varied out using a 40 m × 40 m loop close to Dhapewada (Fig. 3.23). The layered inversion indicates top layer (soil) of 2.3 m thickness having approximate resistivity of 567 ohm-m. Further below a low resistivity formations (<8 ohm-m) up to a depth of 35 m was noted. The resistivity and depth are well resolved. Subsequently, we have resistivity increasing up to 35 ohm-m at a depth of 133 m. The thin red bole (5 m and more) beds at a depth > 50 m are not reflected distinctly in the TEM model. However, the low resistive formations (typical Gondwana, bole beds) throughout the 90 m depth (bgl) in the litholog are in agreement with the TEM response. The E-log at the site also indicates almost uniform response of 10-20 ohm-m throughout the 100 m depth (bgl) and the TEM is in agreement with the E-log response. A comparison of the TEM response, E-log and litholog at the site indicates that E-log and TEM response are indicating low resistivity formations upto 90 m and it is reflected in the litholog (Fig. 3.24). Beyond 90 m, the TEM response indicates resistivity of 35 ohm-m and it is not resolved fully. It needs to be mentioned that with the 40 m by 40 m loop, the depth of investigation will be typically 80 m – 120 m and hence the resolution suffers at greater depth.

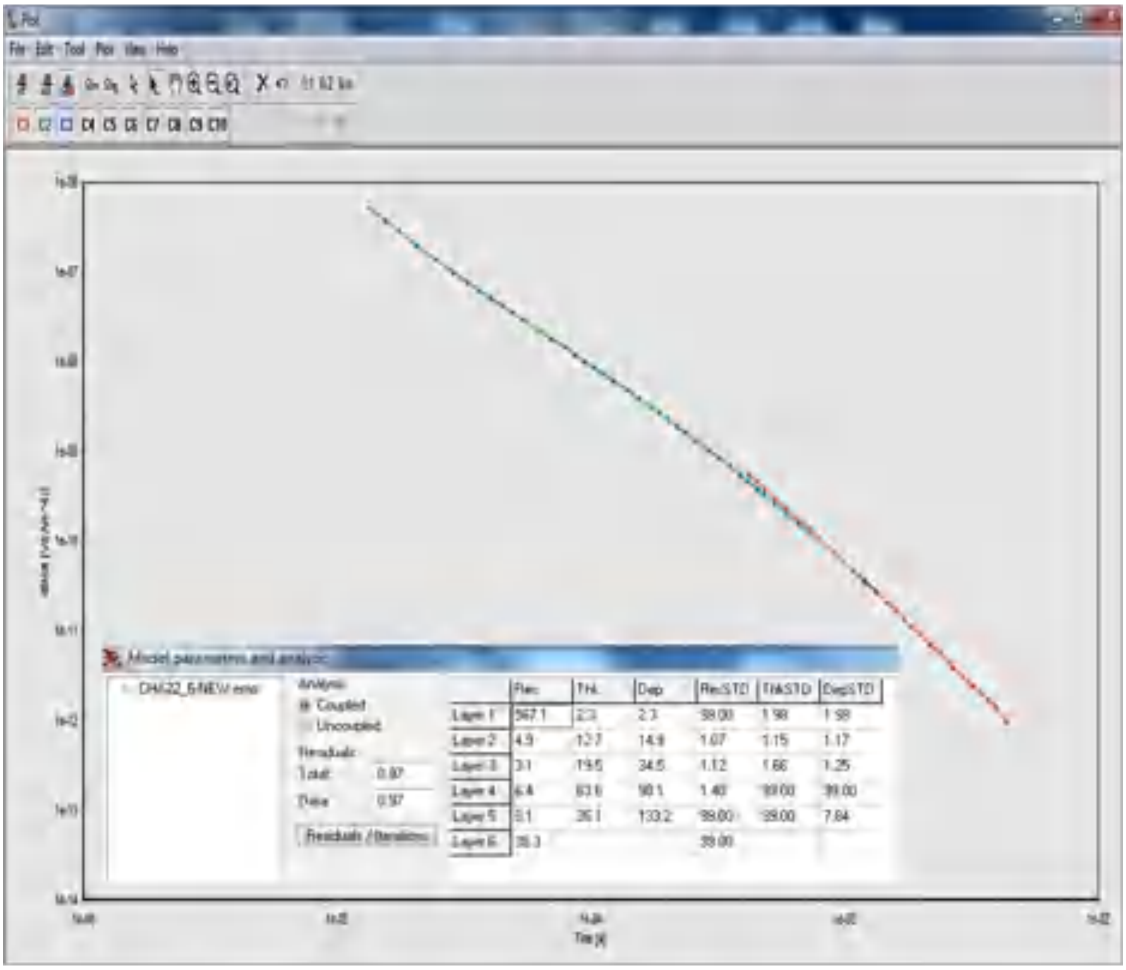


Fig. 3.23**:** Decay curve of TEM and inverted layers at Dhapewada, Chandrabhaga Watershed (WGKCC-2)

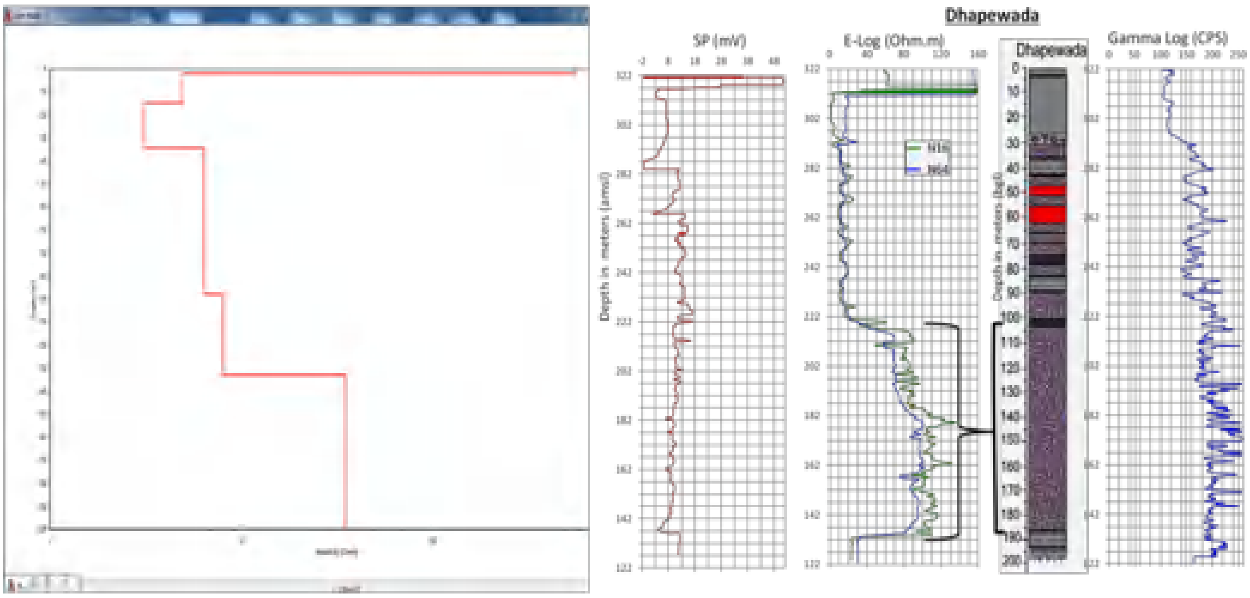


Fig. 3.24**:** Layered model from Dhapewada, Geophysical log and Litholog, Chandrabhaga Watershed (WGKCC-2)

Correlative study at Raulgaon:

At Raulgaon the 1D investigations (VES 3) has shown the top layer resistivity ranges from 110 to 400 Ω-m attributed to various litho units of vesicular and massive basalts up to a depth of about 26 m bgl. Further below, the low resistivity 20 Ω-m for considerable thickness indicates the bole bed of about 25 m and weathered vesicular basalt of 8 m up to a depth of 71 m bgl. A thick layers of 72 m bearing the resistivity of about 80 Ω-m can be attributed to massive basalt and bole bed up to a depth of 135 m bgl (Fig. 3.25). Beneath 135 m bgl, the resistivity drops to 10 Ω-m corresponding to Gondwana rocks.

The correlation of ID sounding with drilling lithologs reveals that the VES is able to decipher the Trap-Gondwana contact. It is also observed that VES tool is unable to distinguish the two consecutive lava flows separated by bole beds. It could be due to the equivalence problem where different layers having different resistivity generate same electrical field on the surface.

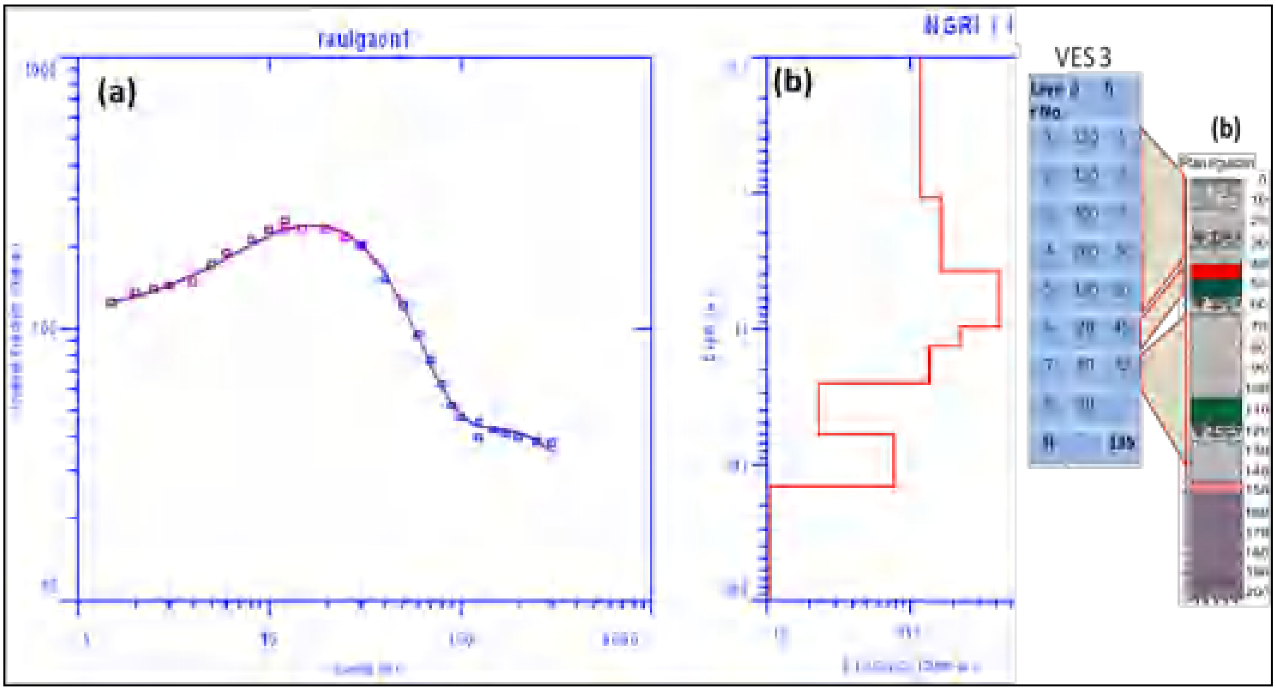


Fig. 3.25:**(a)** VES 3 curve, and **(b)** Drilling lithologs at Raulgaon village, Chandrabhaga Watershed (WGKCC-2)

Correlative study at Waroda:

A typical sounding undertaken at a Waroda village where ERT is also undertaken (ERT8) is presented here for a comparison. The sounding data has been collected with AB/2 spacing of 300m. The data has been stacked 4 times to check the repeatability. The data has been interpreted using the IX1D software (version 2.08). The sounding location is in the area characterized by basalts. The interpreted geolectrical model (Fig. 3.26) indicates 100 ohm-m varying from 10m to approximately 50m, which is followed by lower resistivity 5 ohm-m (extending up to 100m). The non-availability of litholog near the sounding location makes a direct comparison with the sounding date difficult. However, the high resistivity zone of approximately 100 ohm-m (10m to 50m) approximately matches the high resistivity zone, which can correspond to the basalt flow. As in the ERT8, the high resistivity zone is underlain by lesser resistivity continuing from 50m to 100m. Unlike the ERT8, the VES not able to completely resolve the low resistivity vescicular formations from the massive basalts.

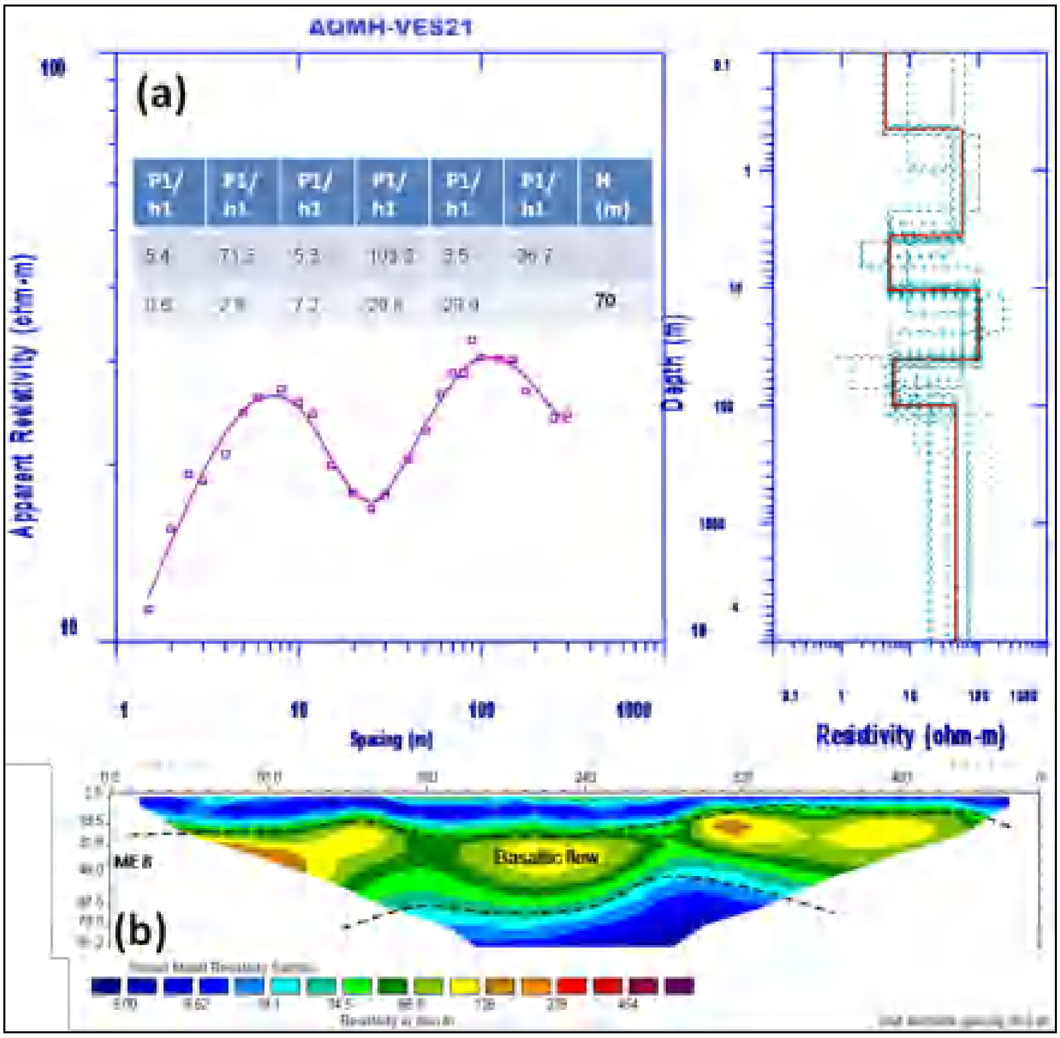


Fig. 3.26: Integration of **(a)** 1D sounding (VES-21) and **(b)** 2D profiling (ERT 8) at Waroda village, Chandrabhaga Watershed (WGKCC-2)

Table 3.5: Location details of TEM in Chandrabhaga watershed (WGKKC-2)

Longitude	Latitude	TEM ID	Sample code	Village Name	Elevation (m)	Soil type	location details
78.88892	21.21944	T1	CHA1	Sawangi	345	Black cotton till 2 and half Feet, Well is having ground water level is 20 to 22 feet	RHS on the road at ramgiri
78.76044	21.29864	T2	CHA2	Ramgiri	420	Red colour with bold like basalt ont surface till 1 and half feet soil layer, Weathered and massive black basalt in well	After railway line about 1.2 km RHS on the road
78.79008	21.28914	T3	CHA3	Khairi Deshmukh	368	Black cotton soil, in orange farm	Behind mishra poultry food farm fetari
78.97464	21.20383	T4	CHA4	Fetari	346	Black cotton soil	Near kalmeshwar town
78.93308	21.238	T5	CHA5	Kalmeshwar town	330	Black cotton soil	Pehkar farm RHS of the road
78.95244	21.25361	T6	CHA6	Khairi Lakhamaji	319	Black cotton soil	In front of Bhavance school
78.96658	21.22228	T7	CHA7	Dahegaon	330	Black cotton soil	Backside of fire engineering college
78.96336	21.23917	T8	CHA8	Dorli (Bhodji)	331	Black cotton soil	Gondwana region near gowari village
78.94783	21.27222	T9	CHA9	Gowari	314	Black cotton soil	Conflict point of Chandrabhaga and saptadhara river
78.96108	21.30083	T10	CHA10	Borgaon	314	Black cotton soil	LHS of Kalmeshwar bypass
78.92672	21.22172	T11	CHA11	Kalmeshwar bypass	332	Black cotton soil	Near Raulgaon old basti on the way to Kotwalbardi, infront of temple LHS to kotwalbardi
78.77711	21.22819	T12	CHA12	Kotwalbardi area	403	Black cotton soil	Near raulgaon new basti CGWB point no 384.
78.78211	21.23867	T13	CHA13	Raulgaon New basti	403	Barren land hill slope	Wathoda village, Sonali area and VES location centre is same
78.84889	21.2785	T14	CHA14	Wathoda	353	Black cotton soil, in orange, chili, Mango farm	1.62 km from LHS of NH248 highway after dorli village turning unpaved road at hill side
78.76169	21.24994	T15	CHA15	Dorli	410	Barren land, Red colour with bold like basalt on surface Weathered and massive black basalt in well	LHS - 900 m from dorli village back side
78.78711	21.25078	T16	CHA16	Behind dorli village	397	Barren land, Red colour with bold like basalt on surface Weathered and massive black basalt in well	Wheat farm, pardi deshmukh to khari road RHS from road 400 m inside
78.78353	21.27997	T17	CHA 17	Dorli and tadabori village road	361	Black cotton soil	Lake side NH 248 to way to pardi deshmukh turning

Longitude	Latitude	TEM ID	Sample code	Village Name	Elevation (m)	Soil type	location details
8.76386	21.27458	T18	CHA 18	Pardi deshmukh lake side	377	Lake side bold like basalt on surface very less sand on bank	
78.90642	21.29342	T19	CHA 19		334		
78.90514	21.28972	T20	CHA 20		335		
78.90514	21.27364	T21	CHA 21		342		
78.90881	21.29919	T22	CHA 22		340		
78.90722	21.29653	T23	CHA 23		337		
78.90397	21.28672	T24	CHA 24		337		
78.76622	21.27789	T25	CHA 25	Padri Deshmukh	365		
78.86783	21.19878	T26	CHA 26	Gumthala Village	370		
78.84836	21.19653	T27	CHA 27		363		
78.88653	21.20372	T28	CHA 28		369		Towards linga village LHS of the road just adjesent to Mr. Agrawal tike wood farm about 300 acre No power lines till 300 m
78.81514	21.20136	T29	CHA 29	Linga before hill area	376	Before boundry line of Gondwana trap Barren land, bold like basalt on surface Weathered with yellow colur soil	Approx 400 to 450 m away from high tention line on barren land, and approx 110 to 140 m away from the domestic electric line
78.78939	21.24114	T30	CHA 30	Rahulgaon barren land LHS before village T point	406	Barren land, Red colour with bold like basalt on surface Weathered and massive black basalt in well	In cotton farm, from loop approx 500 + m away from high tention line and approx 100 m away from the domestic electric line
78.86275	21.19411	T31	CHA 31	Lonara village near poltry farm	359	black cotton soil	No electric as well as high tenshition line near by. On the way to gumthala RHS before nala
78.89306	21.20647	T32	CHA 32	selu after the village towards gumtala - lonara road end RHS	351	black cotton soil near nala	After sawangi village LHS of the road approx 200 m in side from main road, 100 + m electric pole near orange farm
78.87478	21.21544	T33	CHA 33	Sawangi before jagdamba mil	345	Black cotton soil	Cotton farm Mr. vastant sakhare, nala is near by approx 50 m away from loop, no electric poles near by
78.86042	21.22089	T34	CHA 34	Uparwahi after village near kabrasthan	348	black cotton soil	Mr. Bhimrao Khandekar farm, cotton and soyabean farming, approx 2 km from khari to sonegaon road, 300 m no electric line and any vihiculer movment
78.83344	21.22083	T35	CHA 35	mid of linga and sonegaon LHS 300 m	368	black cotton soil with bolt	Near camp of rajasthani people near by dargaha, approx 600 m barren land no electric poles near by 200 m

Longitude	Latitude	TEM ID	Sample code	Village Name	Elevation (m)	Soil type	location details
				away from road side			
78.80858	21.23756	T36	CHA 36	Pohi gond Khairi	375	Barren land, Red colour with bold like basalt on surface Weathered	after dorlli village beside school on RHS of very long exposed black besalt rock terren, approx 700 m from dorlli village and approx 500 m away from high tenstion line
78.77333	21.24283	T37	CHA 37	Dorlli RHS Mukund baba road	401	Barren land with bold like basalt hill slope	Orange farm, approx 100 m away from electric pole, no electricity that time, well containg till 6 m bolted shape loose rock formation, near by nala having rade yahoow colour kampthi sand stone approx 200 m from loop
78.80247	21.18997	T38	CHA 38	Linga before nala orange farm	374	bolted shape of white colour rock of gondwana	near weat farm before sonegaon village electric poles 100 +m away from loop
78.82961	21.22756	T39	CHA 39	Sonegaon after linga village approx 876 m	366	black cotton soil	approx 200 m away from electric pole, from khari to sonegaon on RHS. Near orange farm
78.84664	21.22169	T40	CHA 40	khari and sonegaon mid CHA 34 and CHA 35	364	black cotton soil and litil bit bolt of black besalt	approx 100 m away from electric line, toward paper mill after orange farm very small unpaved local road, before cotton farm and orange farm survey has done
78.86322	21.23622	T41	CHA 41	Ghogli village	351	Black cotton soil	Approx 150 m away from DP box, and approx 500 m from high tenstion line of Fetri village. In side the Mr. Thakur farm, no culivation seens 2 year, before that cotton farming had done
78.97494	21.18844	T42	CHA 42	Chicholi village after fetri to wadi outer road LHS	363	black cotton soil	near by Stone crusher, in front of exposed besalt rock on hill side
78.94703	21.18378	T43	CHA 43	Sahuli village from fetri to ketapar road	360	black cotton soil	Near CMPDI drilling site where Gondwana stuck at 90m.
78.91061	21.19508	T44	CHA 44	Kalambi Village	351m	black cotton soil	In barren land on LHS road towards Kalambi from Selu. Electric pole 100m and above . Open well near the site.
78.90294	21.20125	T45	CHA 45	Selu village	357m	Barrel land	In barren land On RHS road towards Khapri, Behind the factory
78.89211	21.19481	T46	CHA 46	Sellu Village	352m	Barren land	
78.81331	21.23122	T47	CHA 47	Pohi gond Khairi Village	359m		
78.80903	21.21431	T48	CHA 48	Linga Village	374m		approx 200m from transformer
78.79525	21.23431	T49	CHA 49	Near Raulgoan	381m		In farm near cricket ground, electric pole is approx 100 m and above
78.77364	21.22986	T50	CHA 50	Near Raulgoan	406m	Black Cottan soil	In Orange farm, approx 100m away from electric pole on south. Small cements stacks (without wire loop) on all side of farm.
78.87278	21.20961	T51	CHA51	Uparwahi, Kothari Farm	352m	Black Cotton Soil	In Orange farm on road towards Lonara from Uparwahi. approx 100m away from

Longitude	**Latitude**	**TEM ID**	**Sample code**	**Village Name**	**Elevation (m)**	**Soil type**	**location details**
							electric pole on south.
78.8555	21.20919	T52	CHA52	Uparwahi, Badage Farm	365m	Black Cotton Soil	Paytode farm on RHS road towards Niboli village. Behind farm house, nearby electric pole is approx 100m from site.
78.84617	21.21056	T53	CHA53	Nimboli (Gadkari), Paytode farm house	350m	Black Cotton Soil	An orange farm on LHS of road towards Linga from Kalmeshwar. Nearby electric pole is approx 150m above
78.82686	21.21128	T54	CHA54	Linga Village	362m	Black Cotton Soil	An barren land beside new basti of raulgoan. Electric pole on approx 150m above
78.78203	21.23847	T55	CHA55	Raulgoan New Basti	400m	barren land	A farm on RHS of Road to sawangi from Selu. Electric pole is on north side approx 100m.
78.88525	21.21017	T56	CHA56	Sawangi Village	355m	Black Cotton Soil	A farm on LHS road towards uparvahi from Lonara. Near Lonara village Electric pole on North side approx 150m and above.
78.85686	21.19806	T57	CHA57	lonara village Surendra Mahalle farm	365m	Barren Land of farm	Barran land on RHS on Lonara - Uparwahi unpaved road. Electric pole is approx 150m and above.
78.85689	21.20383	T58	CHA58	Lonara Village	359m	Barren Land with black cotton soil	Barren land of village on east side of linga village after canal. High tention line on south approx 250m and above.
78.82314	21.20703	T59	CHA59	Linga Village	378m	Barren Land	In barren land on LHS road towards Vajbodi village. High tention line on south approx 500m and above
78.70744	21.25219	T60	CHA60	Metpanjara village	424m	Barren land	An barren forest land on LHS road towards Vajboldi village.
78.71019	21.23331	T61	CHA61	Near Vajbodi village	487m	Forrest Land	On barren land behind Tarabodi village. High tention line and on south around 500m. Ston
78.71592	21.25508	T62	CHA62	Tarabodi Village	408m	Barren Land,	In farm on LHS of Ashok baba peer road from Chargaon.
78.82314	21.25508	T63	CHA63	chargoan Village, Ashok baba peer road	422m	Yellow color soil	On forest land after Ashok baba peer near chargoan village
78.74525	21.25308	T64	CHA64	chargoan Village, Ashok baba peer	450m	Barren land of forest	On barren land after Ganesh thakre farm. An unpaved road towards forest from Tarabodi village.
78.72275	21.25322	T65	CHA65	Tarabodi Village	413m	Barren land with exosure of black basalt rock	LHS of the road in front of Tantra Vidyalaya sawangi, the place is belongs to Tantra Vidyalaya sawangi

3.3 Sub Surface Information

3.3.1 Ground Water Exploration

Ground water exploration down to the depth of 200 m bgl in the parts of Chandrabhaga watershed (WGKKC-2) has been taken up in the area where the data gap exists and accordingly 16 exploratory wells have been constructed. The major objective of ground water exploration in the study area was

I. To understand aquifer geometry of the area.

II. Precise demarcation of Basalt (Hard rock) Gondwana (Soft rock) contact and lateral & vertical disposition of various aquifer layers existing below the surface.

III. Estimation of various aquifer parameters required for ground water modelling and formulation the aquifer management plan.

IV. Assessment of ground water quality in various aquifers system occurring up to 200 m depth for ensuring its suitability for various uses.

V. Estimation of different geophysical parameters by conducting various subsurface loggings for data integration with surface geophysics applied in the area and,

VI. To draw 3D cross section of the area.

Pinpointing of Sites:

In general, the process of ground water exploration commences with selection of sites in identified data gap for drilling and construction of exploratory wells. As the study area has complex hydrogeological setup thus, 3 exploratory wells in area tapping entire thickness of basalt, 3 exploratory wells in area tapping entire thickness of Gondwana and 7 exploratory wells in area tapping trap (basalt) cover Gondwana and 1 exploratory well in basalt tapping gneissic formation have been drilled and constructed. Beside this 2 observation well have also been constructed at Malegaon and Dhapewara villages for estimation of aquifer parameters of basaltic formation and Gondwana sandstone respectively. Sites for drilling are selected in consultation with the team of geophycist from CGWB and NGRI for ensuring its suitability from data integration point of view. Beside this the drilling operator has also been involved for insuring placement of rig unit considering the accessibility of the site and capacity of rig for drilling and testing operations. The explorative drilling sites/village locations are shown in Fig. 3.27. The detail of ground water exploration is presented in Table 3.6. The well wise drilling details are presented as **Annexure-V**.

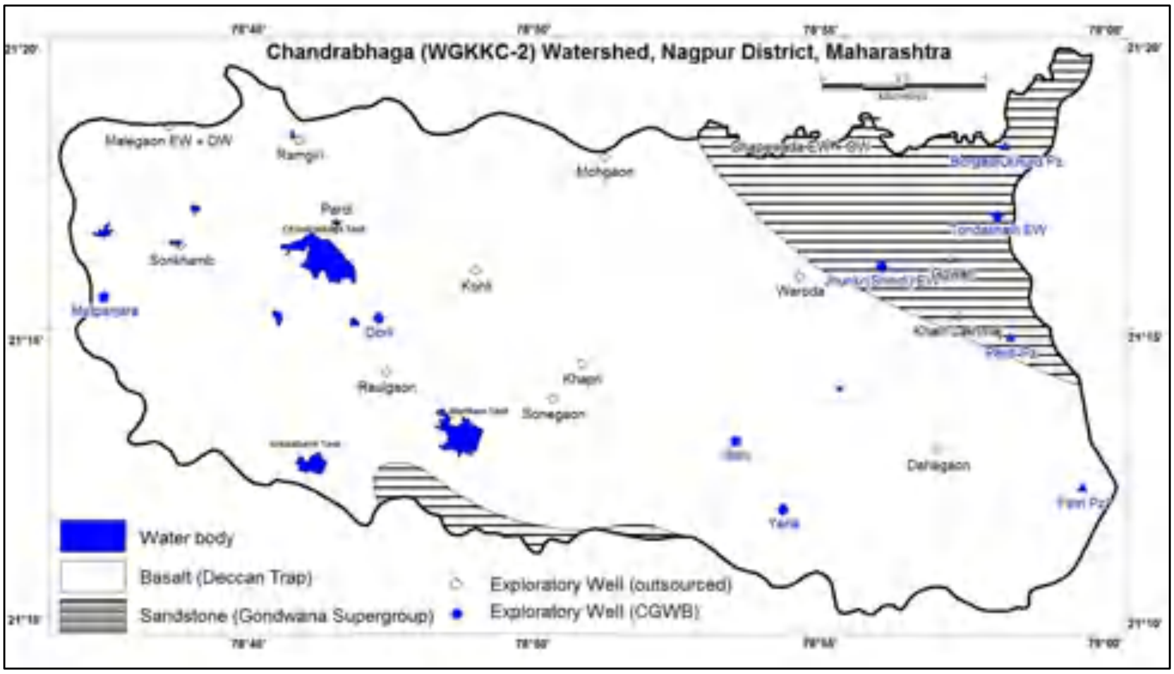


Fig.3.27: Ground water exploration (CGWB and Outsourced), Chandrabhaga Watershed (WGKKC-2)

In Deccan Trap Basaltic formation 6 wells (5 EW & 1 OW) are drilled down to the depth varies from 135 mbgl (Sonegaon) to 200 mbgl (Malegaon). The depth of casing in these wells ranges from 6.00 m bgl to 29.80 m bgl. The ground water potential zones encountered in these wells ranges from 11.10 -11.20 to 160.00 - 161.00 mbgl. The Static Water Level varies from 11.27 mbgl (Sonkhamb) to more than 100 mbgl (Malegaon OW) and the discharge measured ranges from 0.14 to 4.30 lps.

The fractured jointed vesicular basalt and massive basalt when overlain by red or green bole beds of considerable thickness develops semi-confined to confined conditions. Hence, the red or green bole beds acts as a confining layer in basaltic terrain. The bole beds, being clayey in nature, acts as a barrier for downward movement of groundwater. The collapsable red bole occurred at several locations in the watershed i.e. at Pardi (Deshmukh) it was encountered at depth from 87 to 96 & 101 to 104 m bgl, in Ramgiri collapsable red boles occurs at 127 m bgl, while in Sonegaon collapsable red boles and green boles occurs at various depths.

The Gondwana sandstone due to its granular nature constitutes potential aquifer and when it is subjected to tectonic disturbances, the fracture and joints developed increases the yield of well substantially. Four wells (3 EW & 1 OW) are drilled in Gondwana formation down to the depth of 200 mbgl and the maximum discharge measured is 14.88 lps at Gowri. The construction depth of exploratory wells ranges from 149.17 m bgl (Gowri) to 190.63 m bgl

(Khairi lakhmaji). The Static Water Level recorded in exploratory well is varies from 6.01 m bgl (Khairi Lakhmaji) to 12.42 mbgl (Dhapewada OW). The ground water potential zones are ranges from 33.00-39.05 to 174.69 - 186.85 mbgl.

In Trap Covered Gondwana formation 5 wells have been drilled upto the depth of 200 mbgl. The depth of exploratory wells ranges from 151.00 m bgl (Khapri) to 200.00 m bgl (Mohgaon). The Gondwanas were encountered at 133 m bgl in Khapri and at 90.40 m bgl in Mohgaon. The Static Water Level varies from 14.90 mbgl (Waroda) to 78.12 mbgl (Kohli). The discharge ranges from 1.05 lps (Khapri) to 5.94 lps (Mohgaon). The ground water potential zones are ranges from 120.49 - 126.55 to 195.72 - 198.72 mbgl.

The area is traversed by large number of faults. The Basalt-Sandstone contact is observed at various depths varying in the range of 62 mbgl (Waroda) to 195.10 mbgl (Sonkhamb) from east to west of the watershed. Towards eastern part of the watershed the Gondwana sandstone is exposed on the surface, as we moves from east to west the thickness of traps is increasing in the range of 90.40 m bgl (Mohgaon) to 144.00 m bgl (Raulgaon). The deepest Basalt- Gondwana contact is reported at Sonkhamb i e 195.10 m bgl. The contact between Basalt -Achaean Gneiss is reported in the southeastern part of the watershed i.e. at Dahegaon at the depth of 129.95 mbgl.

To estimate the deeper aquifer parameters pumping tests were conducted on seven exploratory wells drilled in the Chandrabhaga watershed. The drawdown recorded during pumping test ranges between 6.34 and 36.97 m, whereas aquifer parameters viz Transmissivity (T) ranging from aquifer in basalts is 30 m^2/day (Sonkhamb) and in Gondwana sandstone 15 m^2/day (khairi Lakhmaji) to 173 m^2/day (Kohli). The storativity (S) of 0.001 is measured at Dhapewada. The site wise plot depicting RDD Vs T/T' are presented graphs as **Annexure-VI**.

Table 3.6: Salient features of Ground Water Exploration through Outsourcing, Chandrabhaga Watershed (WGKKC-2)

Sr. No	Location	Type of Well	Latitude Longitude	RL (m A MSL)	Drilling Depth (m bgl)	Well completion depth (m bgl)	Casing (m bgl)	Zones (mbgl)	Aquifer	SWL (m bgl)	Discharge (lps)	Draw down (m)	T (m^2 / day)	S	Basalt-Gondwana Contact
1	Pardi (Deshmukh)	EW	21°16'40.2" 78°46'05.7"	381	173	173	6.00	152.00 - 152.55, 160.00 - 161.00	FMB	Filled Up	4.30	_	_	_	_
2	Sonkhamb	EW	21°16'20.1" 78°43'21.1"	411	197.75	197.75	11.20	11.10 - 11.20, 22.60 - 23.00, 76.45 - 79.10, 195.1-197.75	WB & FMB	11.27	5.15	15.43	30.00	_	195.10
3	Sonegaon	EW	21°13'49.0" 78°49'56.0"	358	135	135	12.00	6.00 - 7.00, 14.30 - 15.00	WB & FMB	Filled Up	0.14	_	_	_	_
4	Ramgiri	EW	21°18'04.0" 78°45'27.1"	416	179	179	11.53	7.00 - 8.00	FWB	Filled Up	0.78	_	_	_	172.50
5	Malegaon	EW	21°18'24.9" 78°43'06.7"	518	200	200	17.64	7.00 - 8.00, 127.30 - 129.95	FAB	11.74	1.37	_	_	_	Entire Basalt
6	Malegaon	OW	21°18'25.4" 78°43'06.7"	518	200	200	21.00	7.00 - 8.00, 79.10 - 82.10, 139.00 - 140.00	WB & FMB	> 100	Traces	_	_	_	Entire Basalt
7	Raulgaon	EW	21°14'15.2" 78°46'59.3"	394	200	199.8	59.37	150.34 - 162.45, 174.55 - 198.80	sst	36.52	3.00	12.55	42.83	_	144.00
8	Mohgaon	EW	21°17'47.4" 78°50'51.2"	343	200	200	59.50	144.23 - 162.38, 180.53 - 186.60, 195.72 - 198.72	sst	63.00	5.94	_	_	_	90.40
9	Khapri	EW	21°14'22.8" 78°50'26.9"	359	200	151	60.00	120.49 - 126.55, 134.60 - 140.66, 144.60 - 150.72	WB & FMB	68.00	1.05	_	_	_	133.00
10	Dahegaon#	EW	21°12'58.8" 78°56'43.9"	340	200	200	29.80	14.30 - 16.95, 22.60 - 25.60, 62.15 - 65.15, 116.00 - 118.65	FWB	Filled Up	0.38	_	_	_	# Basalt-Gneiss contact-129.95

Sr. No	Location	Type of Well	Latitude Longitude	RL (m A MSL)	Drilling Depth (m bgl)	Well completion depth (m bgl)	Casing (m bgl)	Zones (mbgl)	Aquifer	SWL (m bgl)	Discharge (lps)	Draw down (m)	T (m^2 / day)	S	Basalt-Gondwana Contact
11	Dhapewada	EW	21°18'11.9" 78°54'18.4"	323	200	187.3	78.00	78.00 - 84.05, 114.30 - 120.30, 138.42 - 144.48, 153.53 - 161.58, 173.71 - 185.80	sst	11.47	7.76	15.62	64.82	_	Entire Sandstone
12	Dhapewada	OW	21°18'11.6" 78°54'18.3"	322	200	188.35	78.02	78.02 - 84.07, 114.33 - 120.38, 138.54 - 144.59, 156.52 - 162.60, 174.69 - 186.85	sst	12.42	9.84	6.64	69.60	0.001	Entire Sandstone
13	Gowri	EW	21°16'06.8" 78°56'58.5"	322	200	149.17	33.00	33.00-39.05, 48.10-60.20, 72.28-78.33, 117.63-123.68, 135.67-147.67	sst	7.90	14.88	7.71	119		Entire Sandstone
14	Khairi Lakhmaji	EW	21°15'10.1" 78°57'05.8"	320	200	190.63	72.00	72.00-84.29, 98.29-110.44, 128.44-140.56	sst	6.01	5.94	36.97	15.00	_	Entire Sandstone
15	Kohli	EW	21°15'54.9" 78°48'33.8"	371	200	193.37	96.56	127.64-145.28, 153.28-169.28, 185.28-191.37	FMB & sst	78.12	2.16	6.34	173.00	_	122.00
16	Waroda	EW	21°15'48.8" 78°54'17.4"	349	200	188	98.37	62.00-68.00, 99.00-117.00, 126.00-138.00, 164.00-186.00	sst	14.9	2.16	_	_	_	62

Here- FMB- Fracture Massive Basalt, WB-Weathered Basalt, FWB-Fractured Weathered Basalt, FAB-Fractured Amygdular Basalt sst-Sandstone

3.3.2 Ground water level

To ascertain the long-term behaviour of ground water level in the area, long-term ground water level analysis of CGWB's GWMW located (Fig. 2.7 and 2.18) in the area were conducted.

The hydrograph analysis of GWMW located at Kalmeshwar shows that there is moderate rise of ground water level @ 0.12 m/year and 0.50 m/year for both pre and post monsoon season respectively for the period between 2004 and 2014 (Fig.3.28). While GWMW located at Chargaon shows that there is insignificant to moderate rise of ground water level @ 0.19 m/year and 0.01 m/ for both pre and post monsoon season respectively for the period between 2004 and 2014 (Fig.3.29). However, the shallow piezometer drilled at Fetri in the year 2011 shows insignificant fall in ground water level @ 0.05 m/year in pre-monsoon and significant fall in ground water level @ 0.26 m/year during post-monsoon for the period 2011 to 2014 (Fig.3.30). Hence, to study the ground water level scenario of the area and its long-term behaviour, 58 Key Observation Wells have been established for monthly measurement of ground water levels. The details of well inventory are presented as **Annexure-VII**.

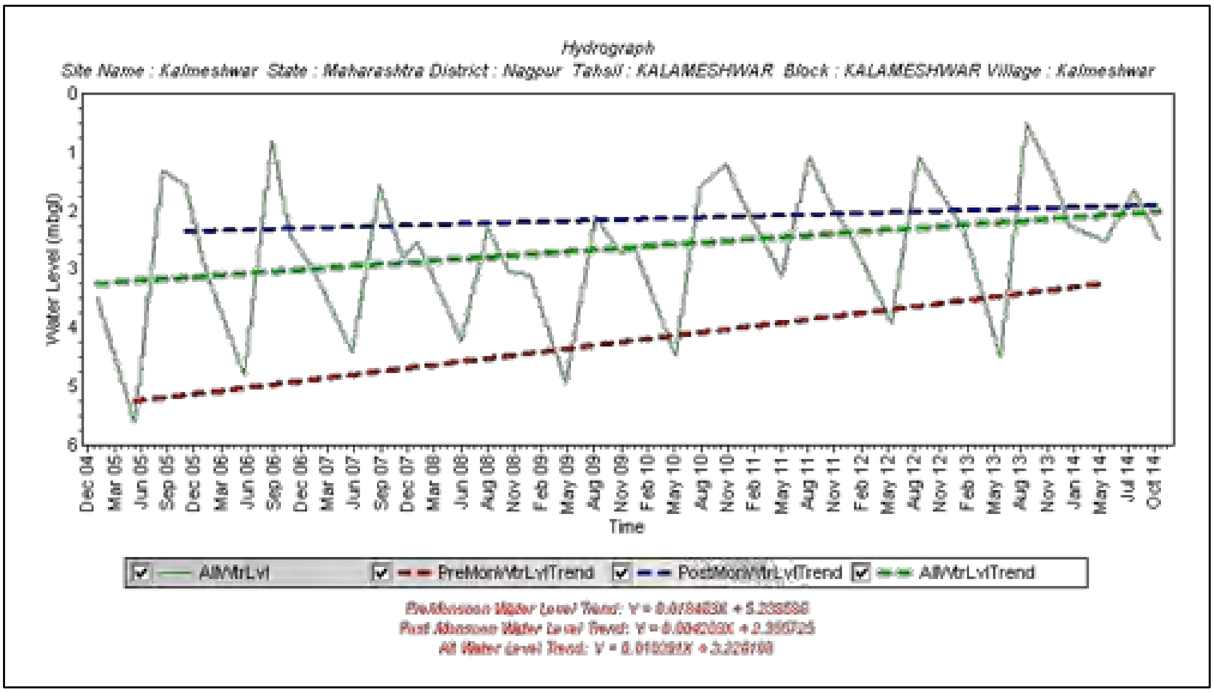


Fig.3.28: Hydrograph of GWMW located at Kalmeshwar (2004-2014), Chandrabhaga Watershed (WGKKC-2)

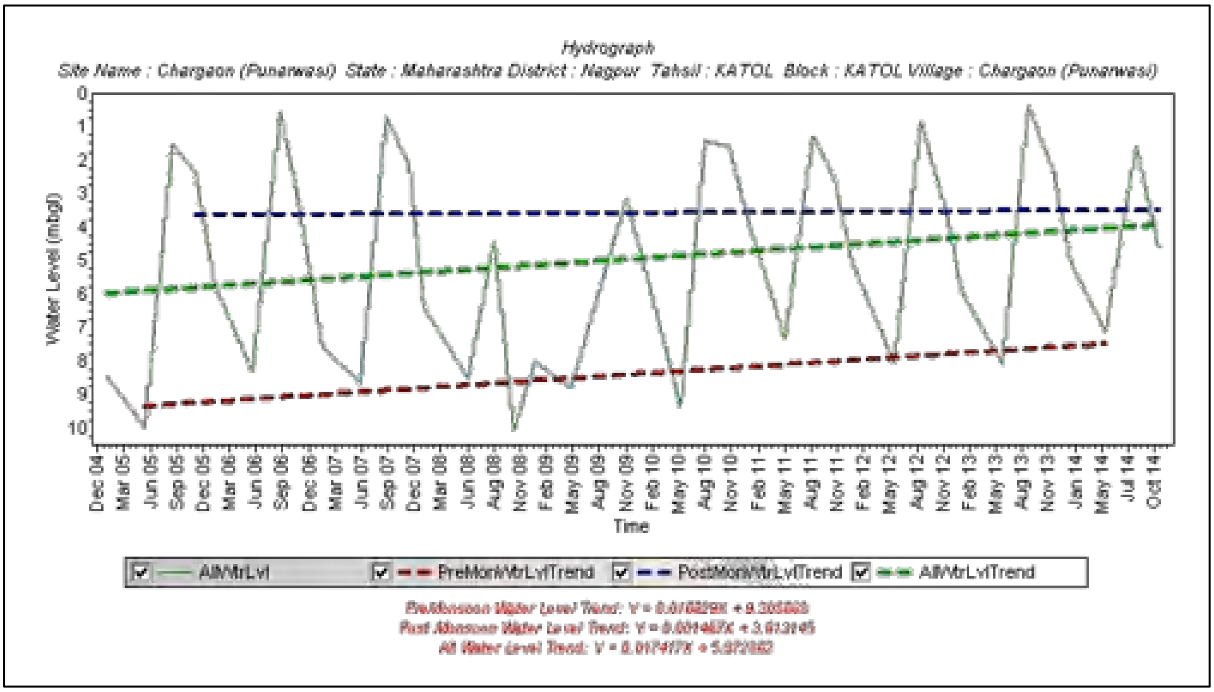


Fig.3.29: Hydrograph of GWMW located at Chargaon (2004-2014), Chandrabhaga Watershed (WGKKC-2)

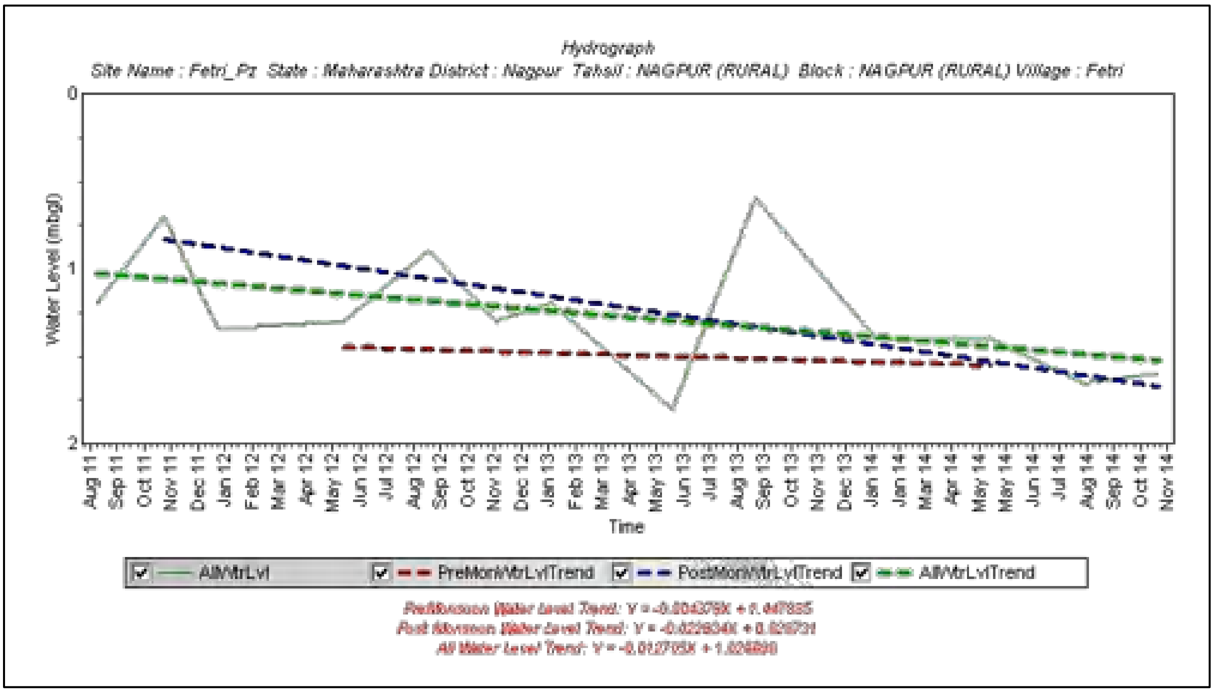


Fig.3.30: Hydrograph of GWMW located at Fetri (2011-2014), Chandrabhaga Watershed (WGKKC-2)

3.3.2.1 Key Well Inventory

As a part of hydrogeological investigation, a total of 120 dugwells were inventoried tapping the unconfined aquifer and all the possible data by measurement and discussion with owner/ user have been recorded in well inventory form for its detailed analysis for various purposes. During well inventory 112 wells tapping Deccan Trap (Basalt) and 8 wells tapping Gondwana group of rocks have been inventoried. The analysis of well inventory data indicates that Basalt and Gondwana sandstone is forming the phreatic aquifer in the study area as described below. The details of well inventory are presented as Annexure-VIII.

1. Deccan Trap Basalt: The depth of the wells in Basaltic aquifer ranges from 6.50 to 21.90 m bgl. The weathered and fractured basalt is forming the phreatic aquifer which is normally encountered between 5 and 20 m bgl. In most of the cases the aquifer is tapped between 8 and 14 m bgl with the thickness of 1.00 to 11.00 m, but in majority of wells the aquifer thickness varies between 4 and 6 m. The ground water level in phreatic aquifer ranges from 0.50 to 15.60 m bgl. The yield ranges between 10.80 and 23.40 m^3/hr, however in majority of wells it is ranging from 12 to 18 m^3/hr.
2. Gondwana Group of Rocks: Weathered and fractured feldspathic sandstone of Kamthi and Barakar sub-groups forming the major aquifers in the area covered by soft rocks of Gondwana. The depth of the wells in these area ranges from 10.20 to 22.00 m bgl. The main aquifer is encountered between 3 and 16 m bgl and the thickness of the aquifer ranges from 2.50 to 13 m. The ground water level in these aquifesr ranges from 3.80 to 15.70 m bgl. The yield of this aquifer ranges from 16.20 to 21.60 m^3/hr.

3.3.2.2 Weathered Thickness

Based on the well inventory data, depth of weathering map has been prepared and presented in Fig. 3.31. A perusal of Fig. 3.31 Indicates that the depth of weathering increases from west to east and towards the northeastern part it is maximum near to the confluence of Chandrabhaga river with local tributary. Major part of the watershed is having depth of weathering in the range of 3 to 6 m bgl, followed by < 3 m bgl and 6 to 9 mbgl depth range. The weathered thickness contour generated is shown in Fig.3.31.

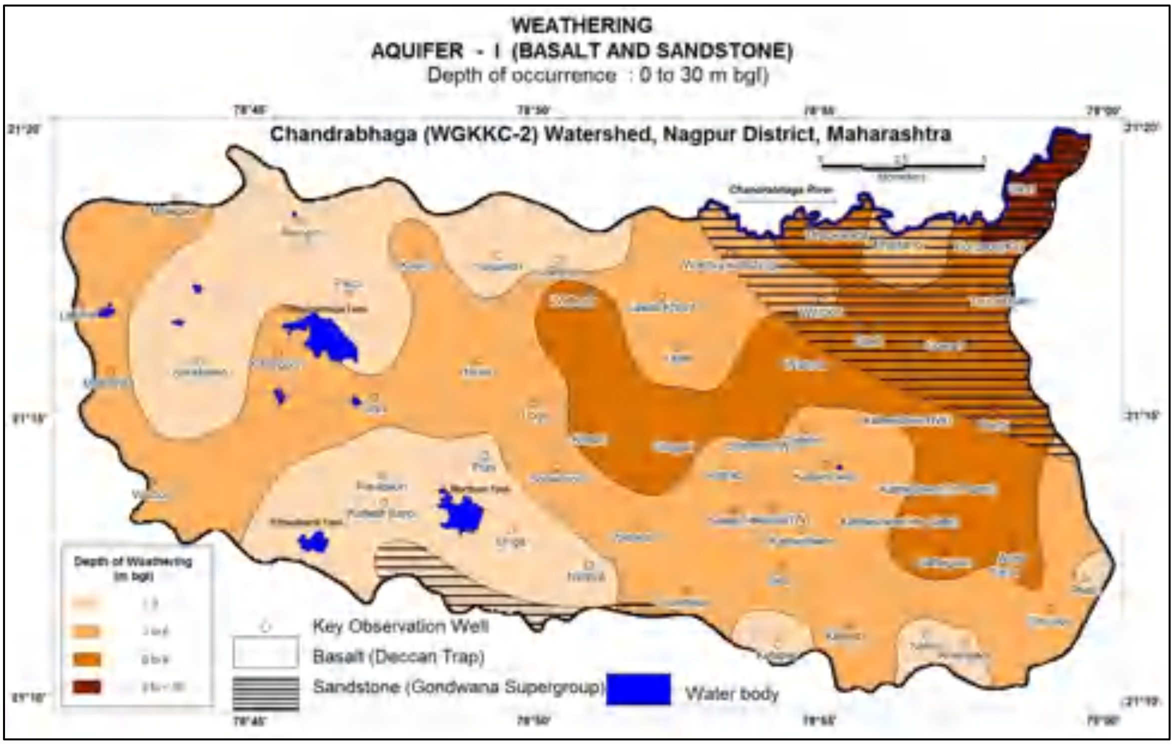


Fig.3.31: Depth of weathering, Aquifer – I (Basalt & Sandstone), Chandrabhaga watershed (WGKKC-2)

3.3.2.3 Ground water level Monitoring

To decipher the ground water level scenario in both time and space, 58 Key Observation Wells (KOW) have been established in the area tapping the unconfined aquifer (Aquifer-I) for monthly monitoring of ground water levels (Annexure-IX). The DTWL of KOW has been analysed for pre-monsoon (May) and post- monsoon for the year 20111, 2012, 2013 and 2014. However, the ground water level of Aquifer – II (Deeper Basaltic and Sandstone aquifer) was available from May-2014 onwards (Annexure-X). Hence, the ground water level of deeper aquifers have been analysed for the year 2014.

3.3.2.3.1 Pre monsoon Depth to Water Level (May) in Aquifer-I

Rocks of both basalt and Gondwana formation are forming the phreatic aquifer in the area, hence the DTWL data for both the aquifers have been analysed. The depth to water levels (DTWL) during May ranges between 5.25 (Gowari) and 16.75 mbgl (Tondakhairi) in the Gondwana formation whereas in the basaltic terrain, it is ranging between 1.7 (Kotwalbardi) and 14.8 m bgl (Kalmeshwar). The perusal of the Fig.3.32a, b, c, d and Fig. 3.33a, b, c, d indicates that in shallow ground water levels in the range of 3 to 6 m bgl are observed as isolated patches in southwestern and northern parts of the watershed. The moderate ground water levels ranging from 6 to 9 mbgl are observed in major parts of the watershed occupying south eastern fringe areas, central and western parts.

Whereas deeper ground water levels in the range of 9 to 12 m bgl and more than 12 mbgl are observed in north eastern and eastern parts of the watershed.

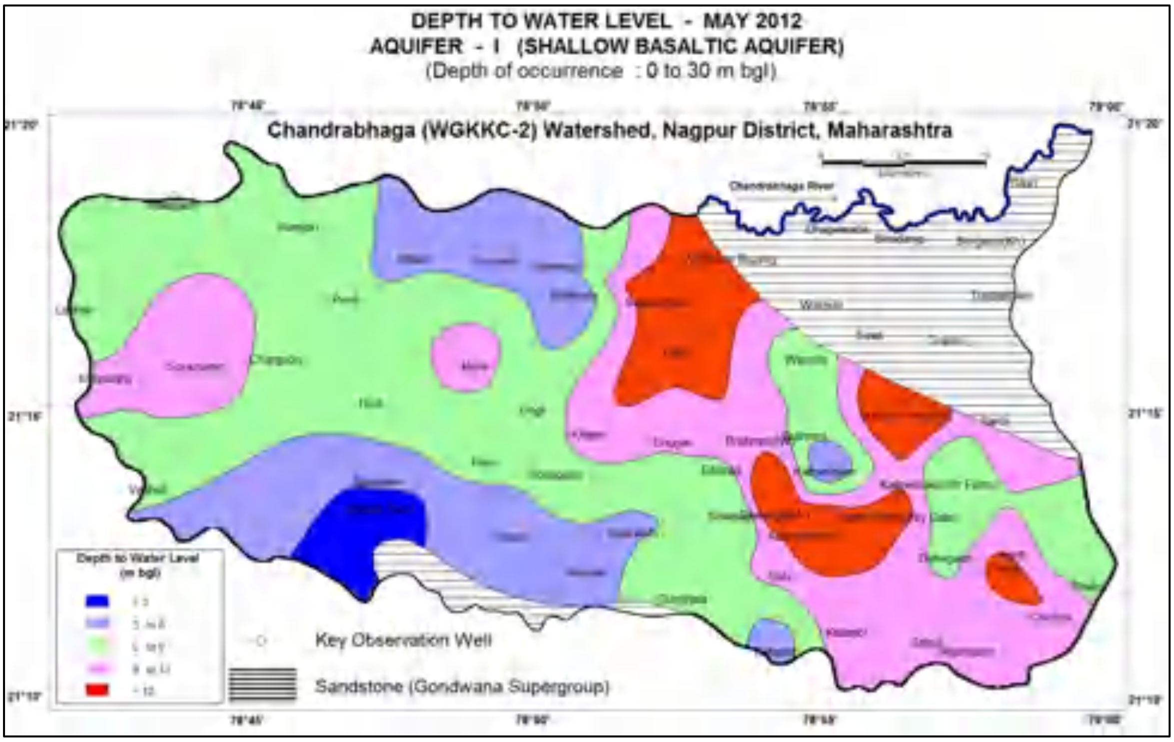


Fig. 3.32a: Pre monsoon Depth to Water Level – BASALT (Aquifer – I), May - 2012

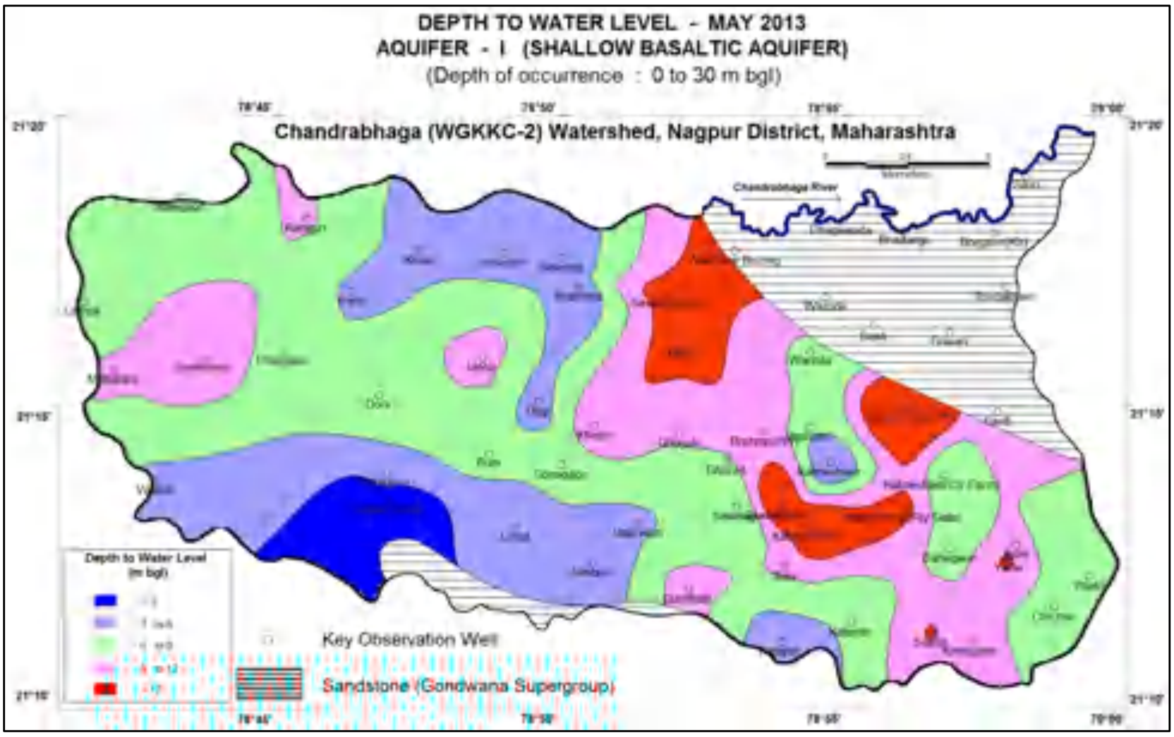


Fig. 3.32b: Pre monsoon Depth to Water Level – BASALT (Aquifer – I), May - 2013

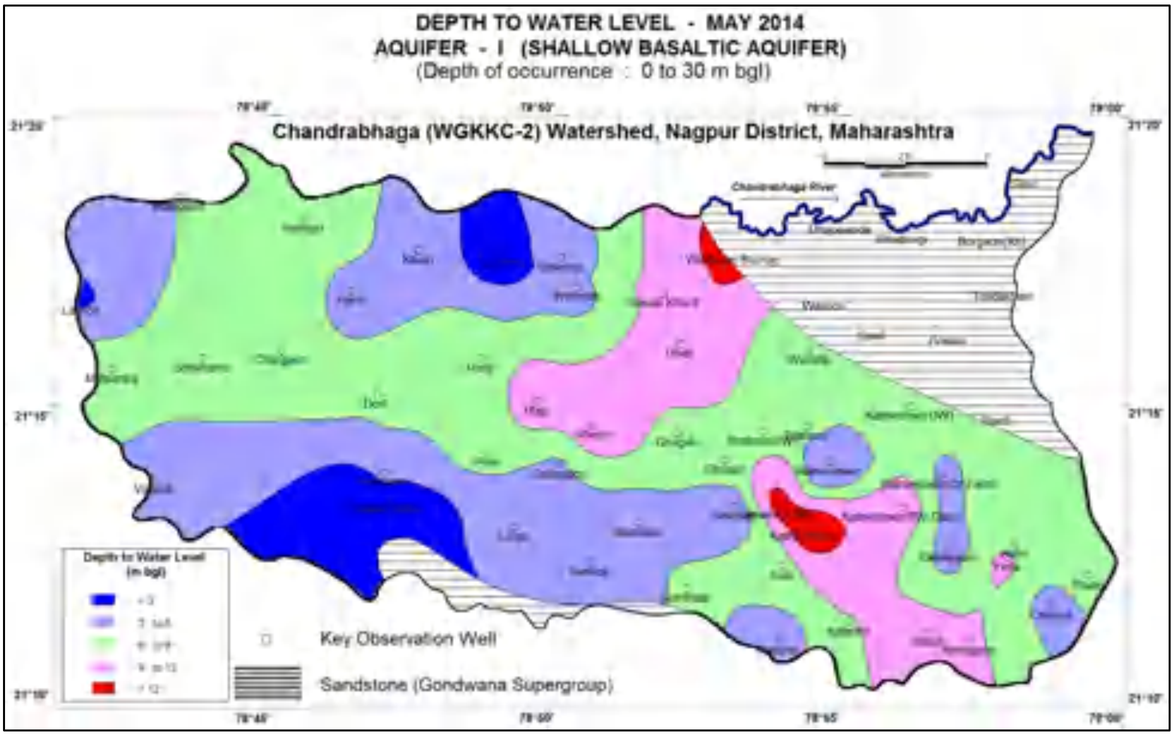


Fig. 3.32c: Pre monsoon Depth to Water Level – BASALT (Aquifer – I), May - 2014

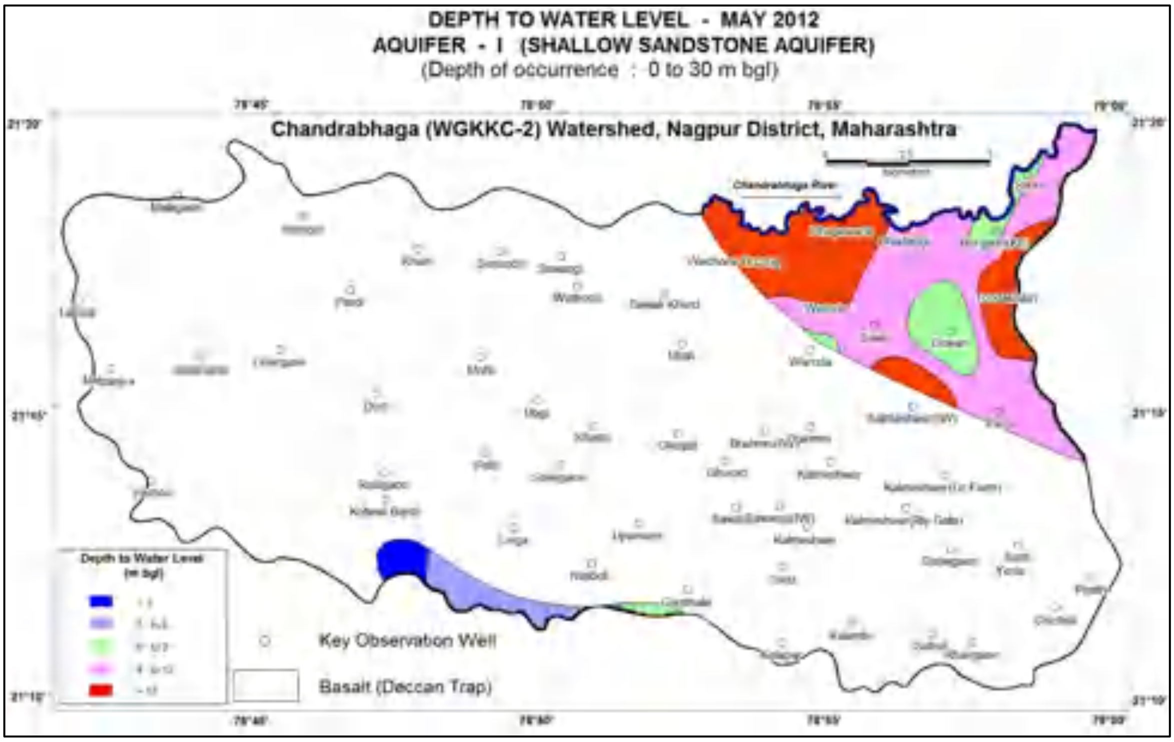


Fig. 3.33a: Pre monsoon Depth to Water Level – SANDSTONE (Aquifer – I), May - 2012

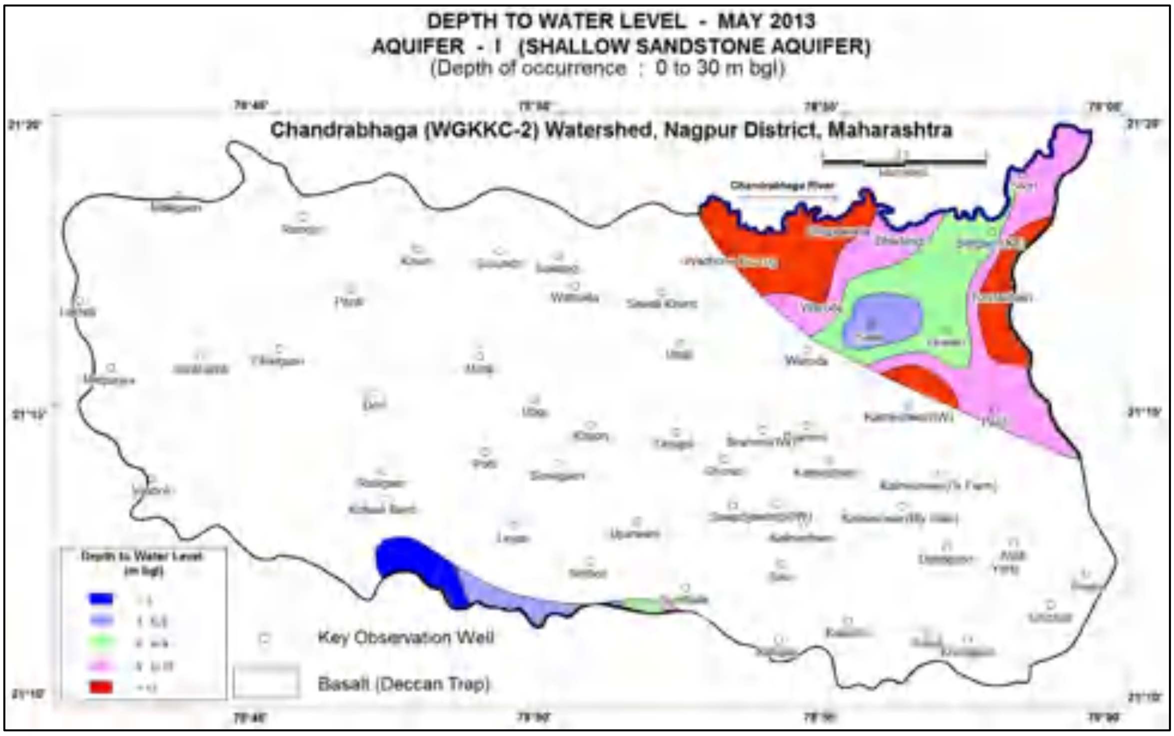


Fig. 3.33b: Pre monsoon Depth to Water Level – SANDSTONE (Aquifer – I), May - 2013

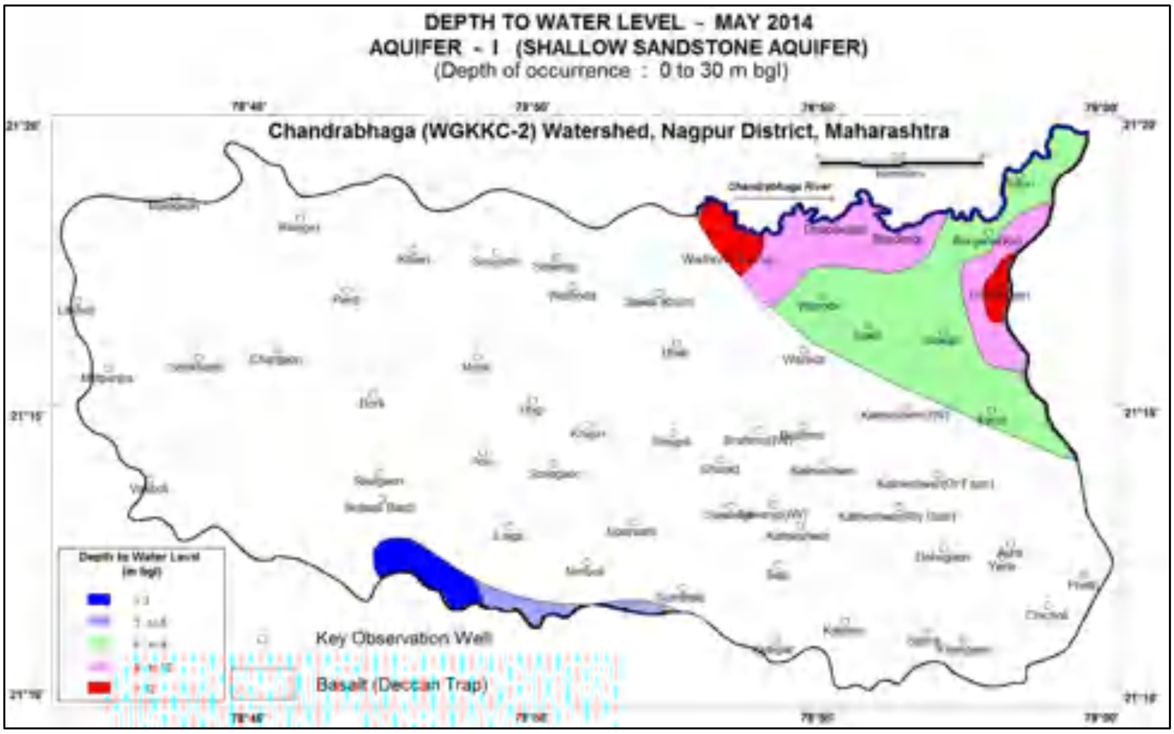


Fig. 3.33c: Pre monsoon Depth to Water Level – SANDSTONE (Aquifer – I), May - 2014

3.3.2.3.2 Post monsoon Depth to Water Level (November) in Aquifer-I

The depth to water levels during November ranges between GL (Dahegaon) and 14.3 mbgl (Tondakhairi) in the Gondwana formation whereas in the basaltic terrain it is ranging between 0.60 – (Vasboli) and 15.7 mbgl (Brahmni). The perusal of the Fig.3.34a, b, c, d and 3.35a, b, c, d indicates that in southern, western and central part of the watershed the ground water levels are shallow and ranging from 0 to 6 mbgl. The ground water level in the range of 6 to 9 m bgl is observed in the north eastern part of the watershed, whereas the deeper ground water levels 9 to 10 m bgl has been recorded in village Wadhone BK, Ghorad, Brahmni in central part of the area.

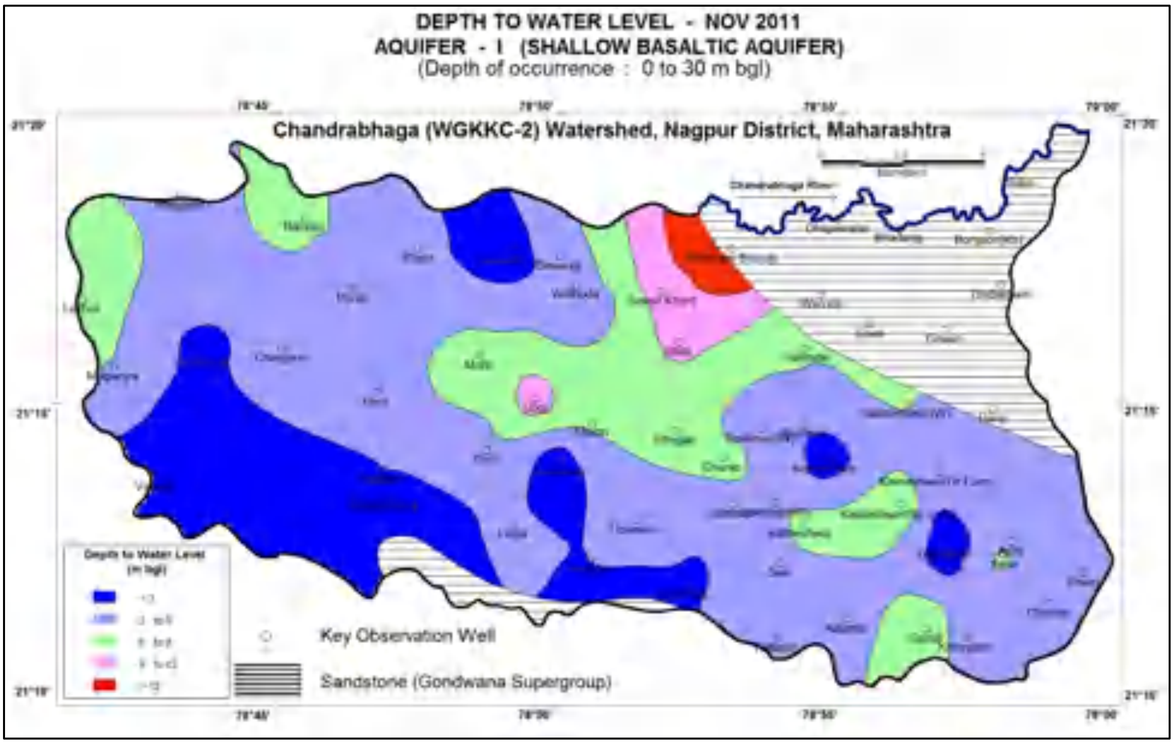


Fig. 3.34a: Post monsoon Depth to Water Level - BASALT (Aquifer – I), November-2011,

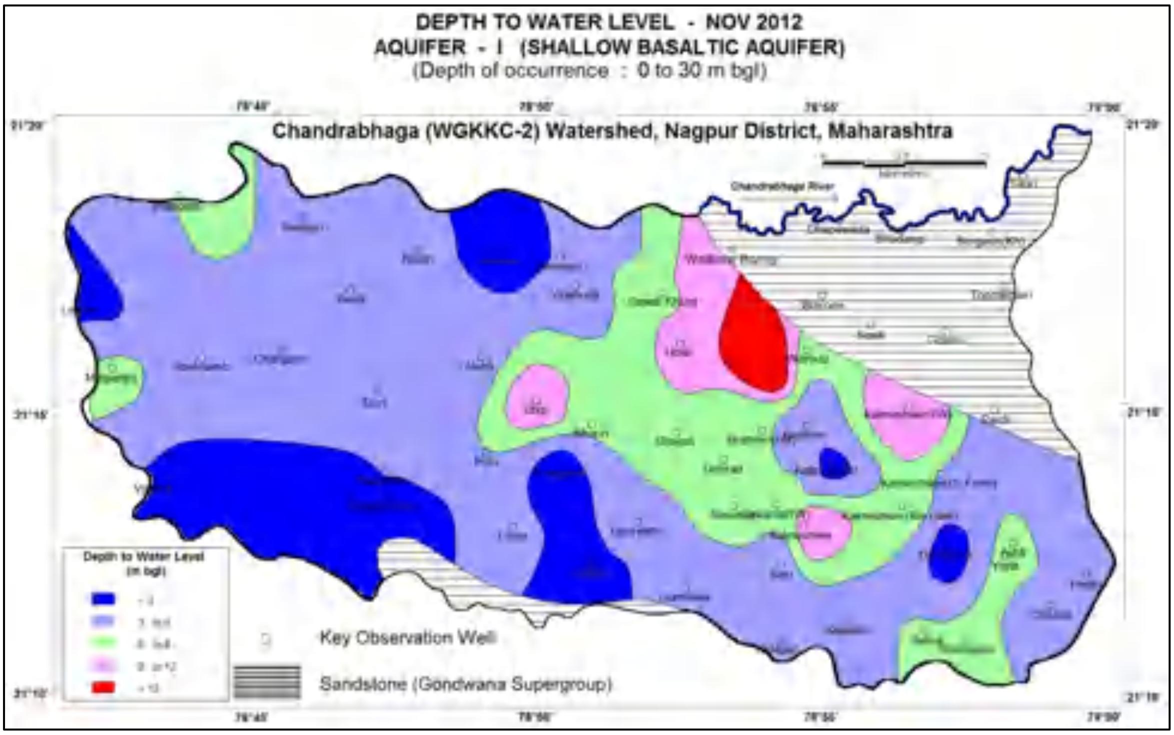


Fig. 3.34b: Post monsoon Depth to Water Level - BASALT (Aquifer – I), November- 2012

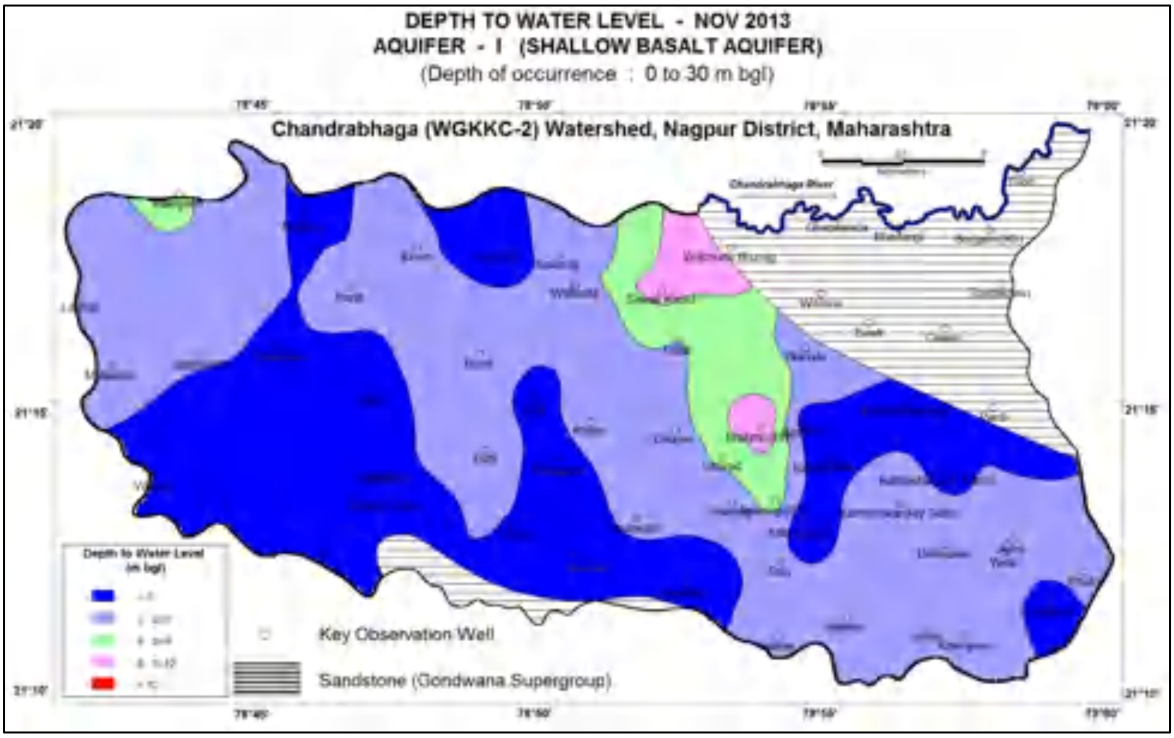


Fig. 3.34c: Post monsoon Depth to Water Level - BASALT (Aquifer – I), November-2013

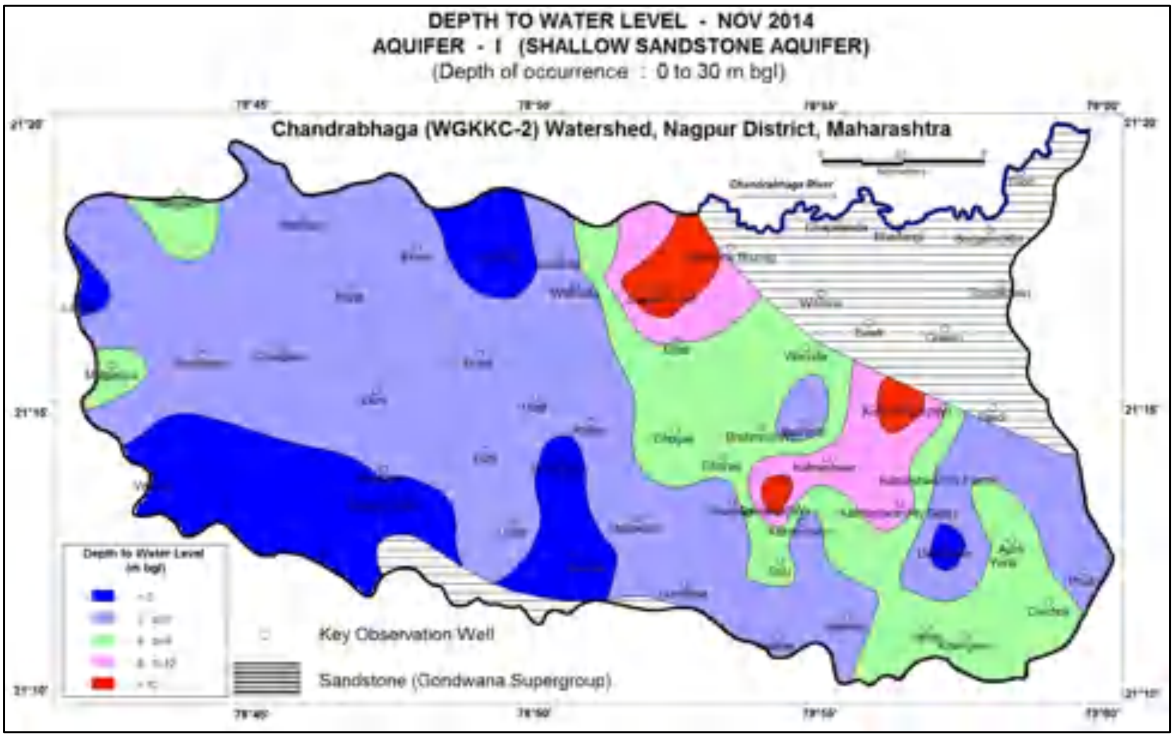


Fig. 3.34d: Post monsoon Depth to Water Level - BASALT (Aquifer – I), November-2014

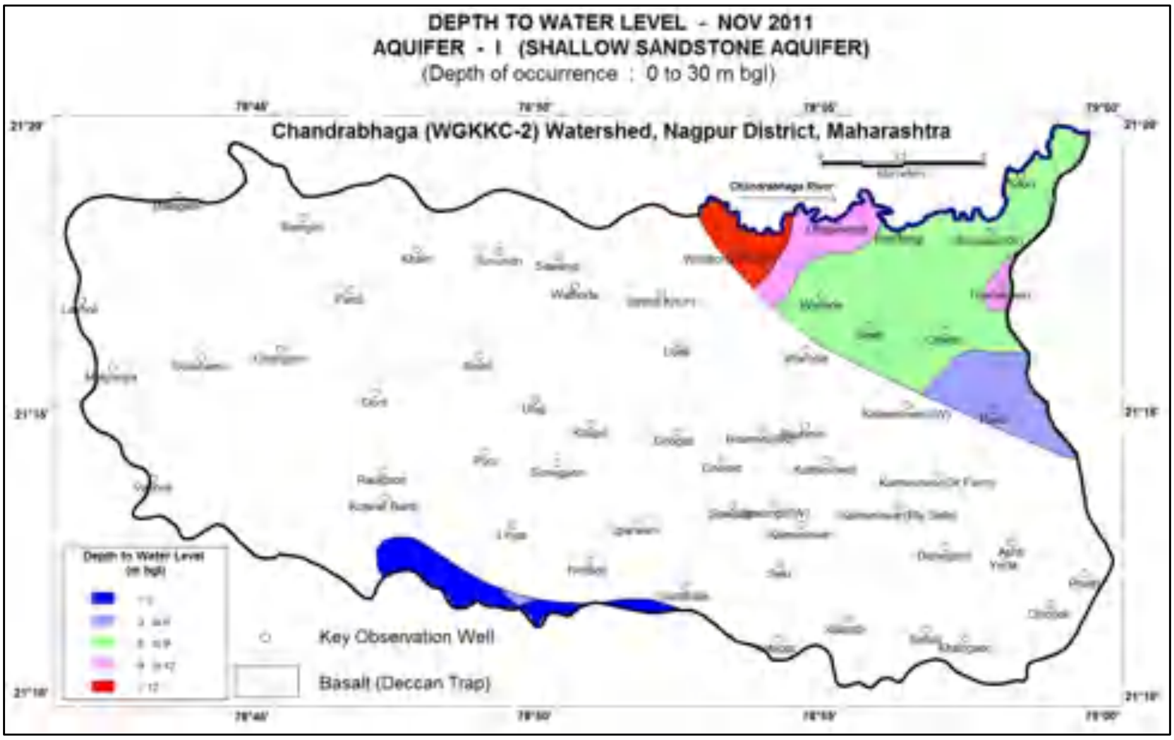


Fig. 3.35a: Post monsoon Depth to Water Level - SANDSTONE (Aquifer – I), November-2011

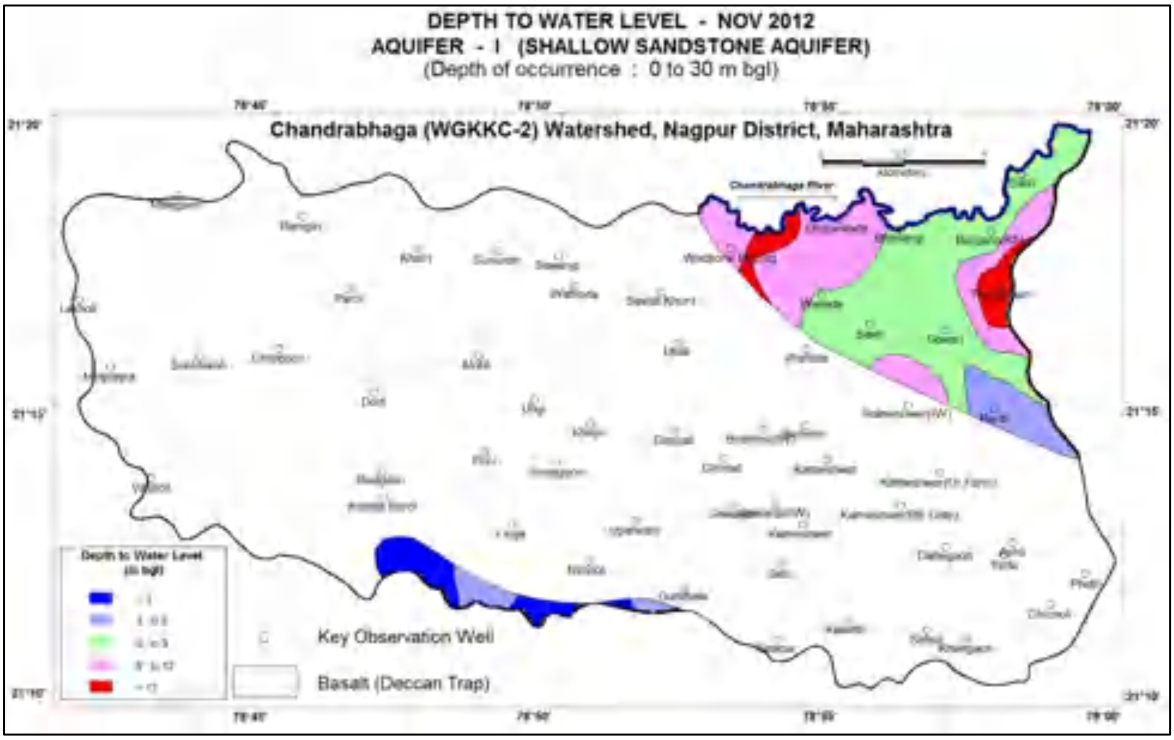


Fig. 3.35b: Post monsoon Depth to Water Level - SANDSTONE (Aquifer – I), November-2012

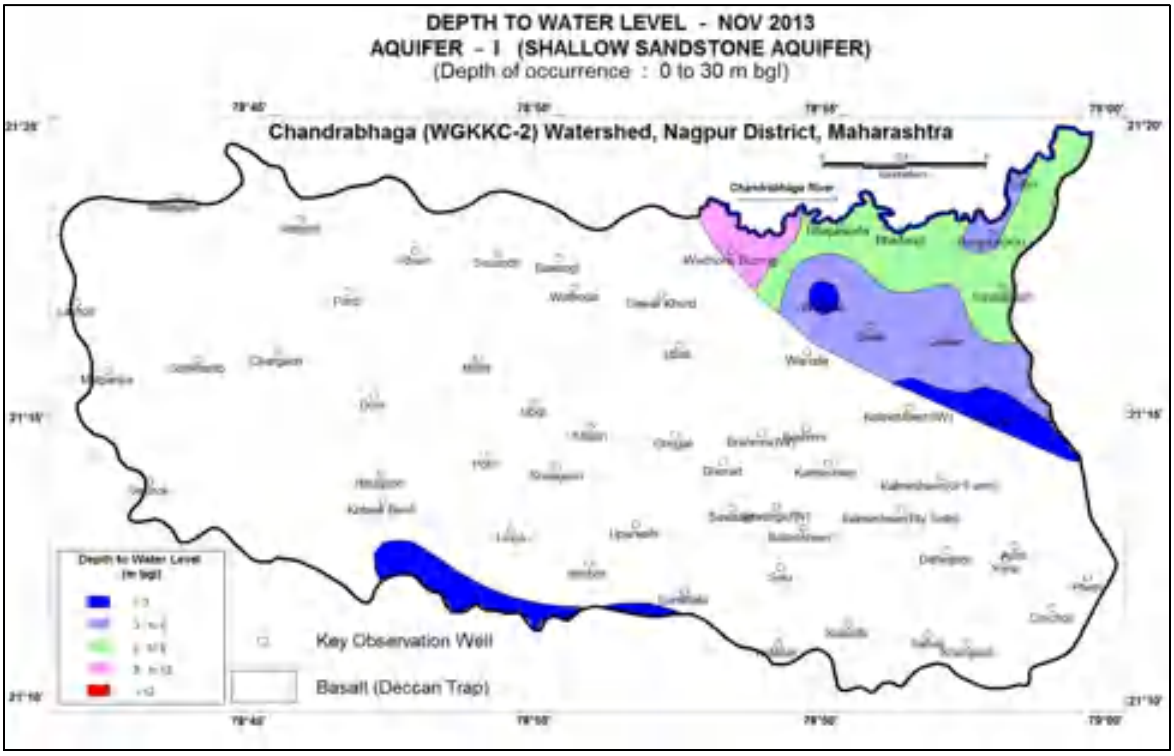


Fig. 3.35c: Post monsoon Depth to Water Level - SANDSTONE (Aquifer – I), November-2013

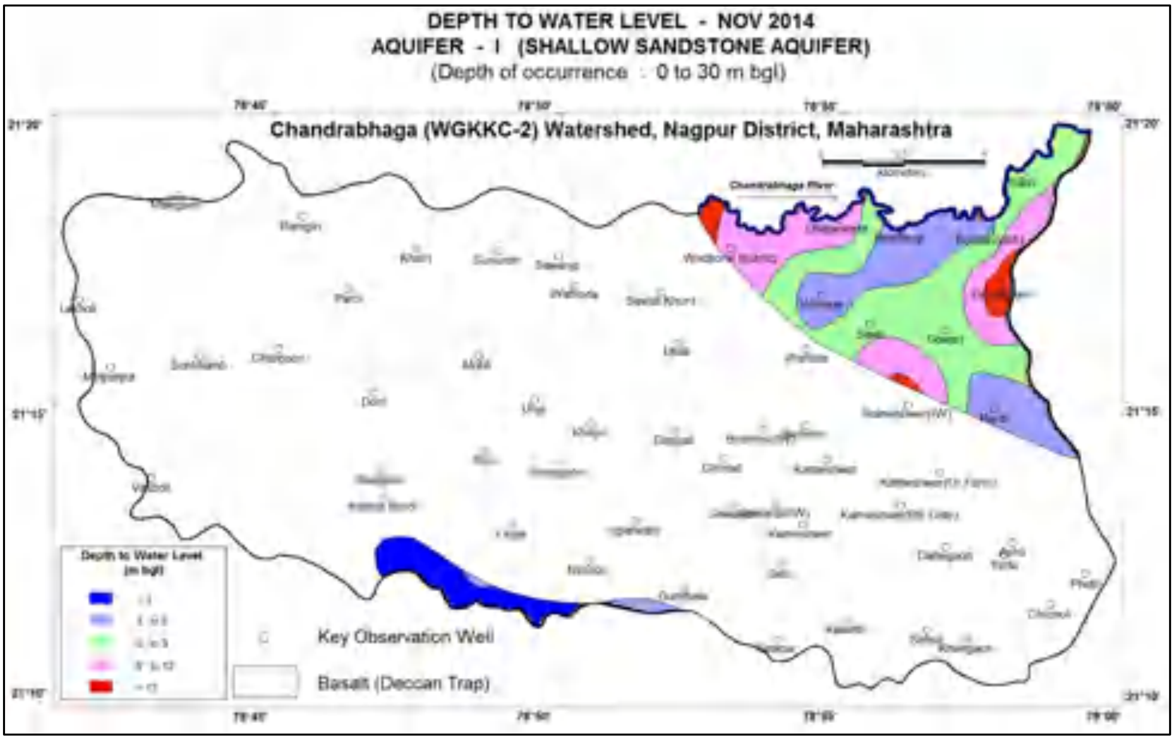


Fig. 3.35d: Post monsoon Depth to Water Level - SANDSTONE (Aquifer – I), November-2014

3.3.2.3.3 Short term ground water level trend (2011 to 2014) Aquifer – I

To study the long-term behaviour of ground water level in the basin monthly ground water level data collected from 58 KOW's has been analysed. However, the DTWL of Aquifer – I is available for 3 years only i.e., from October 2011 to November- 2014. The same has been analysed and short term DTWL trend has been work out (Table 3.7). It has been observed from analysis that almost all wells except two KOW in the Chandrabhaga watershed are showing rise in ground water level trend, ranging from 0.005 m/month to 0.28 m/month (Fig.3.36). Fall in ground water level trend ranging from -0.01 m/month (Wathoda) to -0.03 m/month (Kalmeshwar) are seen at two KOW's. However, the rise in ground water level observed in the watershed is insignificant but it is matching with long-term trend of CGWB's GWMW.

Table 3.7: Short-term ground water level trend (2011 to 2014) Aquifer-I

Sl. No.	Well No.	Village	WL Trend (m/month)	Rise/Fall
1	DW1	Phetri	0.0503	Rise
2	DW2	Khairgaon	0.0552	Rise
3	DW3	Kalambi	0.0214	Rise
4	DW4	Selu	0.0636	Rise
5	DW5	Kalmeshwer (RH)	-0.0113	FALL
6	DW6	Dahegaon	0.0644	Rise
7	DW7	Ashti	0.0349	Rise
8	DW8	Pardi	0.0723	Rise
9	DW9	Gowari	0.0134	Rise
10	DW10	Tondakhairi	0.0511	Rise
11	DW11	Borgaon(Kh)	0.2802	Rise
12	DW12	Silori	0.0404	Rise
13	DW13	Dhapewada	0.0674	Rise
14	DW14	Bhadangi	0.0853	Rise
15	DW15	Warode(IW)	0.1368	Rise
16	DW16	Brahmni	0.0199	Rise
17	DW17	Sawli	0.1025	Rise
18	DW18	Ketapar	0.0187	Rise
19	DW19	Sahuli	0.0839	Rise
20	DW20	Gumthala	0.0196	Rise
21	DW21	Sawangi (IW)	0.0204	Rise
22	DW22	Uparwahi	0.0058	Rise
23	DW23	Nimboli	0.0125	Rise
24	DW24	Linga	0.0226	Rise
25	DW25	Sonegaon	0.0514	Rise
26	DW26	Khapri	0.0455	Rise
27	DW27	Ghogali	0.0201	Rise
28	DW28	Brahmni(IW)	0.0151	Rise
29	DW29	Ghorad	0.0319	Rise
30	DW30	Ubali	0.0893	Rise
31	DW31	Wadhone Buzrug	0.0619	Rise
32	DW32	Sawali Khurd	0.0517	Rise
33	DW33	Wathoda	-0.0305	FALL
34	DW34	Sawangi (Anganwadi)	0.0093	Rise
35	DW35	Susundri	0.0413	Rise
36	DW36	Khairi	0.0222	Rise
37	DW37	Pardi	0.0247	Rise

Sl. No.	Well No.	Village	WL Trend (m/month)	Rise/Fall
38	DW38	Ramgiri	0.0674	Rise
39	DW39	Dorli	0.0430	Rise
40	DW40	Ubgi	0.0558	Rise
41	DW41	Kohli	0.0486	Rise
42	DW42	Kotwali Bardi	0.0343	Rise
43	DW43	Raulgaon	0.0228	Rise
44	DW44	Chargaon	0.0312	Rise
45	DW45	Sonkhamb	0.0912	Rise
46	DW46	Metpanjra	0.0410	Rise
47	DW47	Malegaon	0.0195	Rise
48	DW48	Vasboli	0.0393	Rise
49	DW49	Pohi	0.0245	Rise
50	DW50	Yerla	0.0997	Rise
51	DW51	Chicholi	0.0754	Rise
52	DW52	Kalmeshwer (NE of Selu)	0.1307	Rise
53	DW53	Sawangi (SW of Kalmeshwar)	0.0392	Rise
54	DW54	Kalmeshwer (South of Gowari)	0.1068	Rise
55	DW55	Kalmeshwer (Ashti Road	0.0430	Rise
56	DW56	Waroda	0.0226	Rise
57	DW57	Lakholi	0.0768	Rise
58	DW58	Kalmeshwar(Rly Gate)	0.0953	Rise

-ve values indicate fall in ground water level trend.

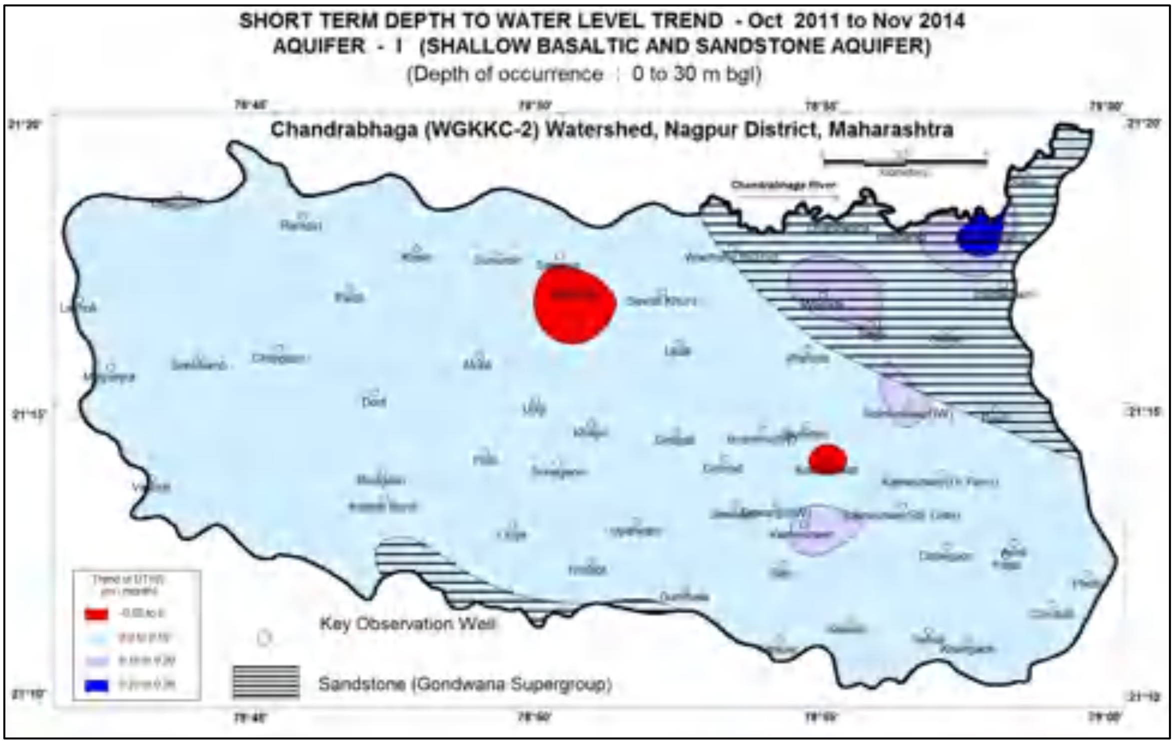


Fig.3.36: Short-term DTWL trend (Oct 2011 to Nov 2014), Aquifer – I

3.3.2.3.4 Pre monsoon Depth to Water Level (May-2014) in Aquifer-II

The ground water level data of Aquifer – II is available from May-2014, hence, the ground water level maps have been prepared for the year 2014. The close study of pre monsoon ground water level map of deeper aquifer in Basaltic terrain reveals that major central part of the watershed indicates the ground water level range from 50 to 73 m bgl. The eastern and western part of the watershed shows gradual decrease in ground water level i.e., up to 20 m bgl while in the Sandstone (Aquifer-II) ground water level is observed shallow ie up to 7 m bgl (Fig.3.37 a and b). The deeper ground water levels are due to the potential zones encountered at depth more than 45 m bgl upto 197 m bgl.

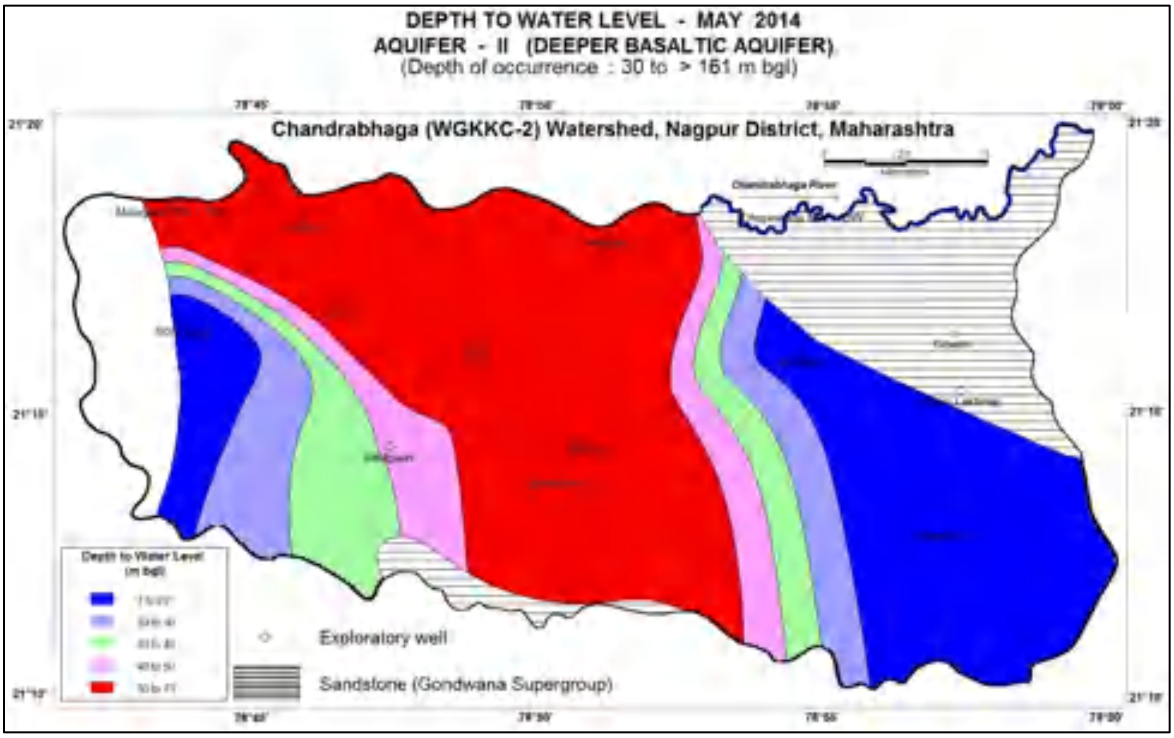


Fig. 3.37a: Pre monsoon Depth to Water Level (Aquifer –II), Basalt, May-2014

3.3.2.3.5 Post monsoon Depth to Water Level (November-2014) in Aquifer-II

The close study of post monsoon ground water level map of deeper aquifer indicates the post monsoon ground water level does not show much variation as compare pre monsoon scenario. Ground water level map of deeper aquifer in Basaltic terrain reveals that major central part of the watershed indicates the ground water level range from 50 mbgl to 79 m bgl. However, the area occupied by deeper ground water level is much less as compare to pre monsoon. This indicates that the Aquifer – and II in basaltic terrain are interconnected and getting recharge from Aquifer I. The eastern and western part of the watershed shows gradual decrease in ground water level i.e., upto 20 m bgl while in the Sandstone (Aquifer-II) ground water level is observed shallow i.e., up to 6 m bgl l which is almost similar to pre monsoon scenario (Fig.3.38).

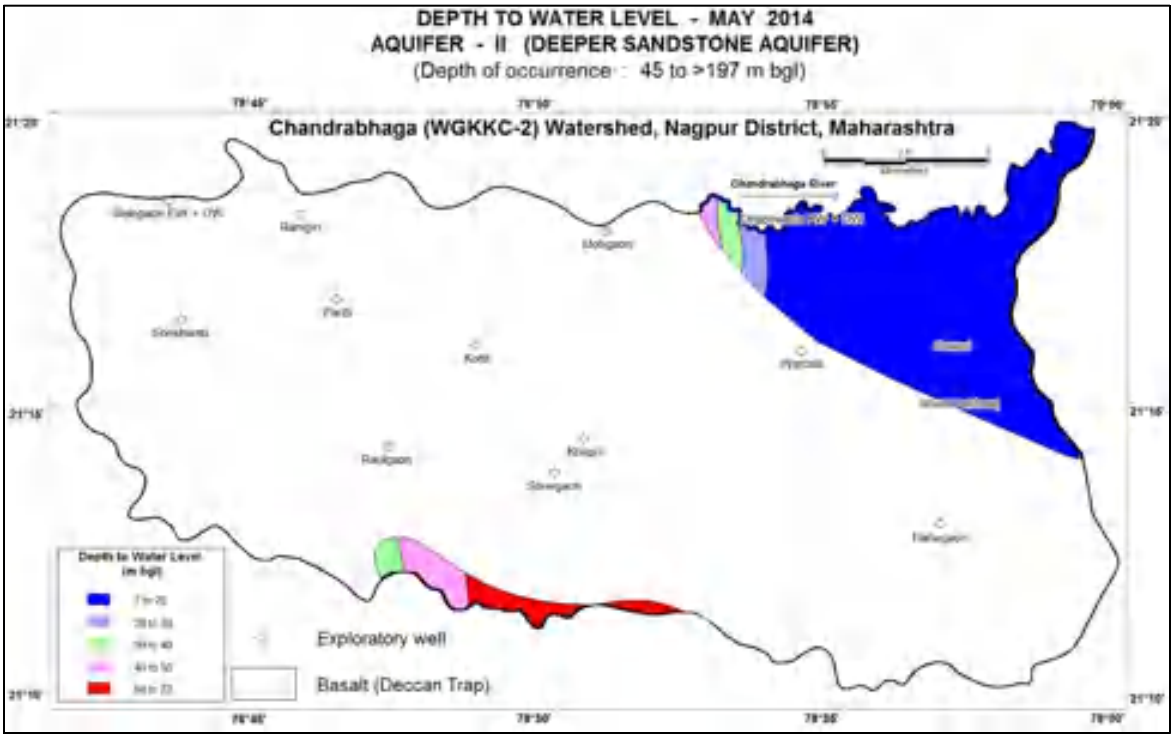


Fig. 3.37b: Pre monsoon Depth to Water Level (Aquifer –II), Sandstone, May-2014

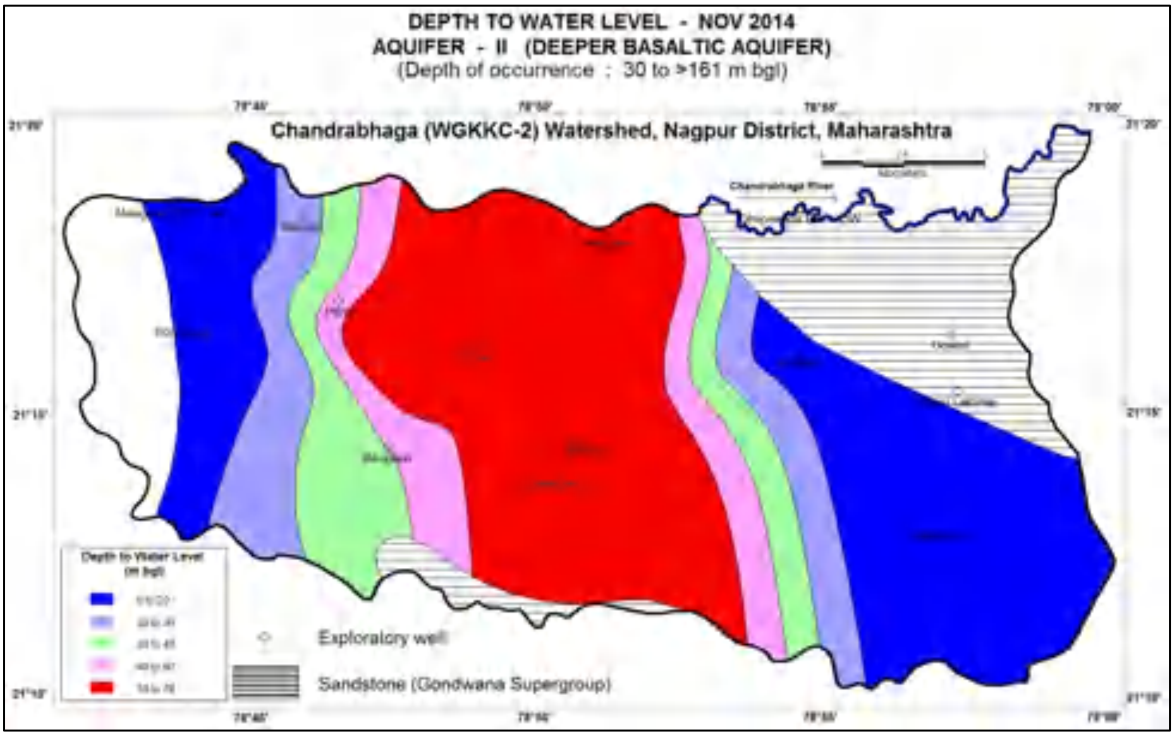


Fig. 3.38a: Post monsoon Depth to Water Level (Aquifer – II), Basalt, November-2014

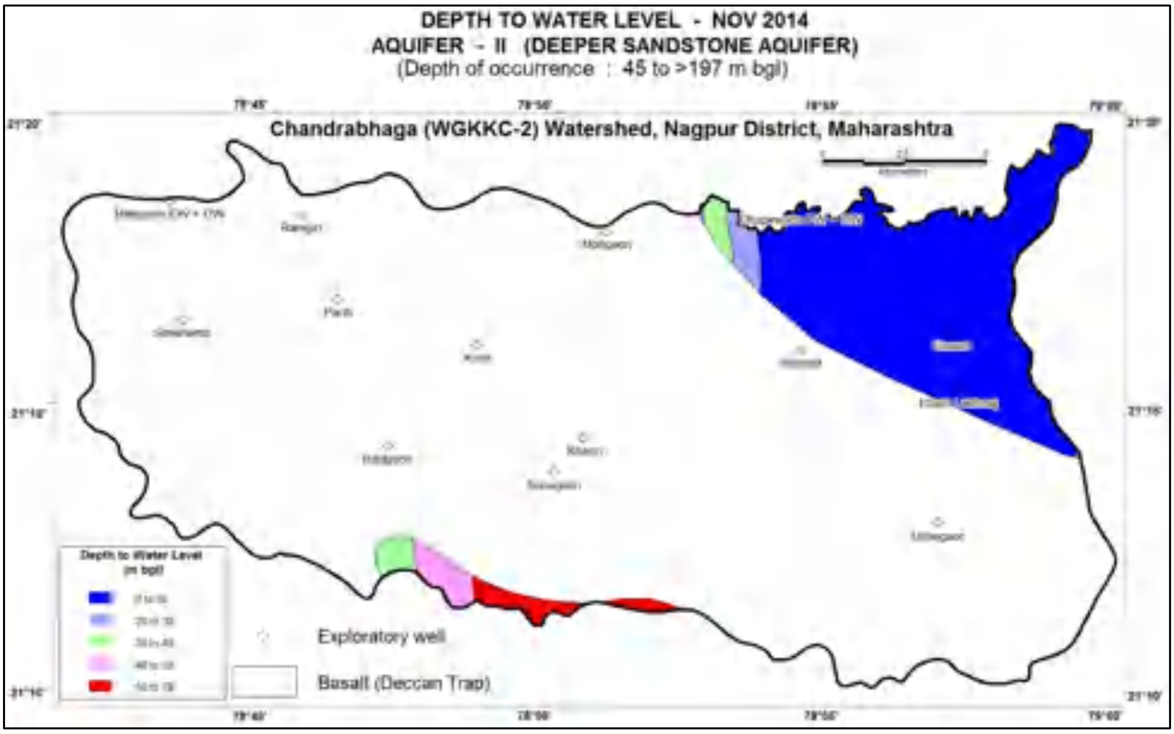


Fig. 3.38b: Post monsoon Depth to Water Level (Aquifer – II), Sandstone, November-2014

3.3.2.4 Ground Water Table

In order to decipher, the ground water flow direction in the watershed water table contour map for Aquifer-I and II during the pre and post-monsoon period (2014) has been prepared using the reduced levels (RL) of the wells and presented as Fig. 3.39, 3.40, 3.41 and 3.42. A perusal of ground water contour map reveals that

1) The pre-monsoon water table (May-2014) in Chandrabhaga watershed ranging from 295.030 m above MSL at Sillori in northeast end of the watershed to 511.080 m above MSL at Malgaon in the northwest corner of the watershed. While the post-monsoon water table (May-2014) ranging from 294.530 m above MSL at Sillori in northeast end of the watershed to 510.22 m above MSL at Malegaon in the northwest corner of the watershed. Overall, average minimum water table elevation is 294 m above MSL while average maximum water table elevation is 511 m above MSL.
2) The movement of groundwater is from southwest to northeast direction, which ultimately converges with the Chandrabhaga River. This indicates that the ground water flow in the watershed fallow the topographic control.
3) Comparatively close water table contours in the elevated areas reveal low permeability of the water bearing formations for example, hilly area located at northwest and southwest of watershed.

4) The groundwater divides, marked by the divergence of flow lines, almost coincide with the topographic divides, indicating the importance of the geomorphic features in demarcating the areas of groundwater development and management.

5) The areas marked by total convergence of flow lines are indicative of higher transmissibility and thus form 'hydraulic troughs' in the area. The ground water levels in these areas are relatively deeper (>9 m)

6) The areas marked by divergent flow lines are indicative of poor transmissibility. The ground water level in this area is relatively shallower (< 9 m).

7) The convergence of flow lines indicates zone of higher transmissivity while the areas of flow line divergence show zones of poor transmissivity.

8) The ephemeral Chandrabhaga River is flowing from a height of 334.333 m above MSL at village Wadhona (Bk) to 299.69 m above MSL at village Sillori. The Chandrabhaga river is gaining water from ground water in its upper reaches in-and-around villages Wadhona (Bk)-Dhapewada-Bhadangi and acts as a *Effluent River*. While in lower reaches, it is losing water to the groundwater and acts as a *Influent River* in-and-around Bhadangi – Borgaon (Kh) – Sillori villages. Thus, Chandrabhga river is ephemeral effluent as well as influent river.

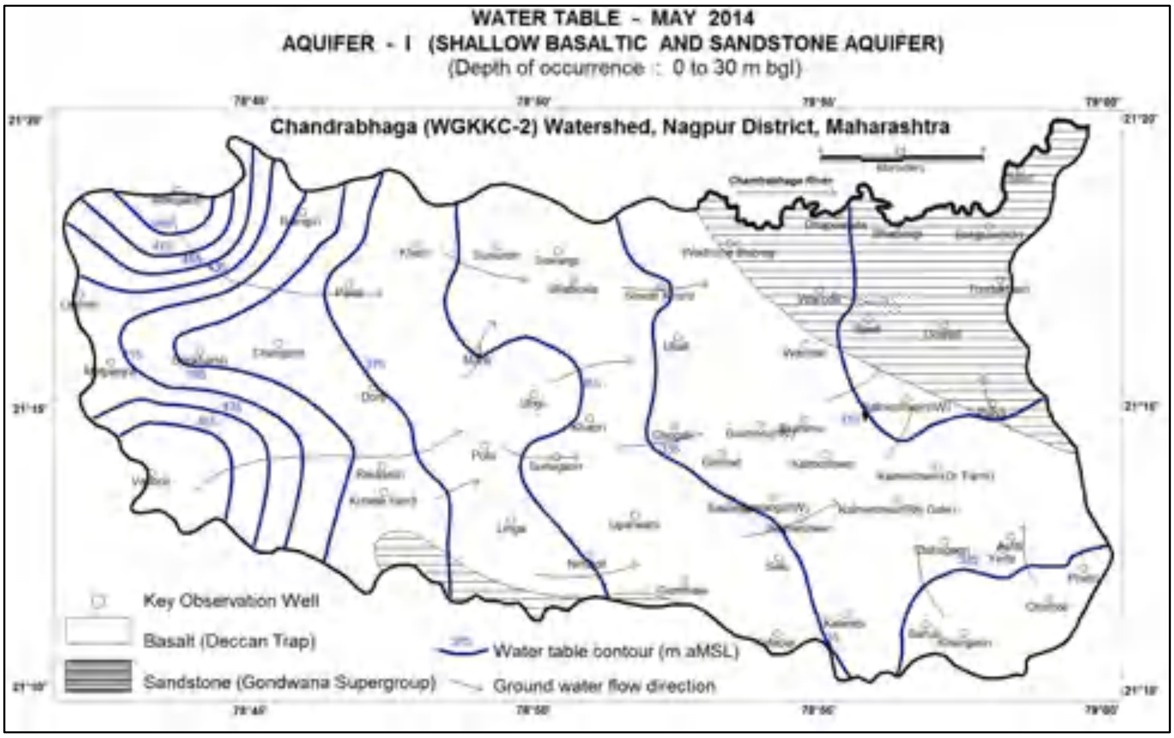


Fig. 3.39: Pre monsoon Water Table (Aquifer – I), May-2014

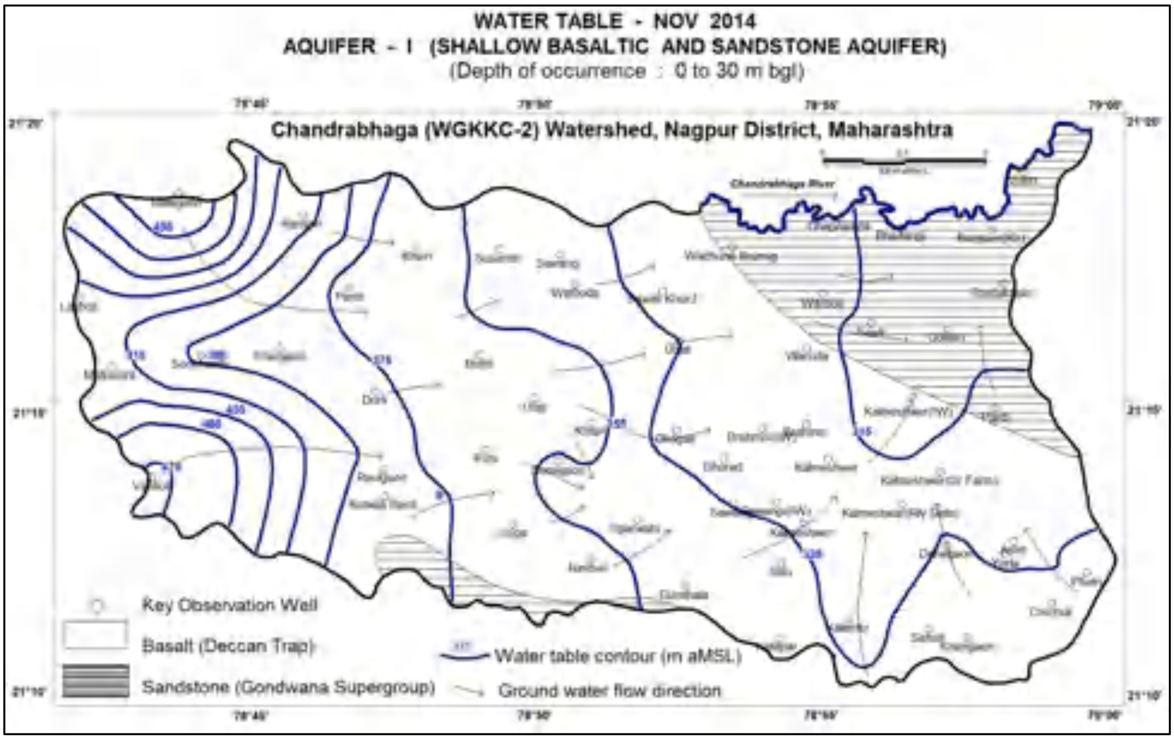


Fig. 3.40 Post- monsoon Water Table (Aquifer – I), Nov-2014

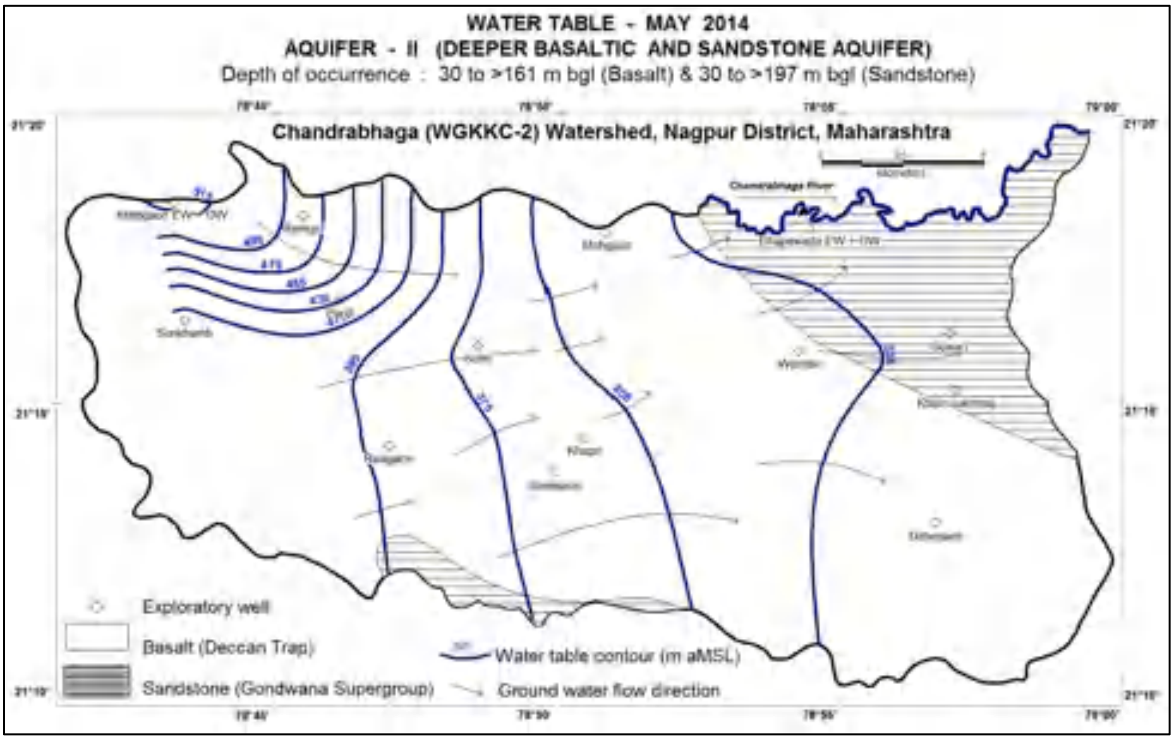


Fig. 3.41: Pre monsoon Water Table (Aquifer –II), May-2014

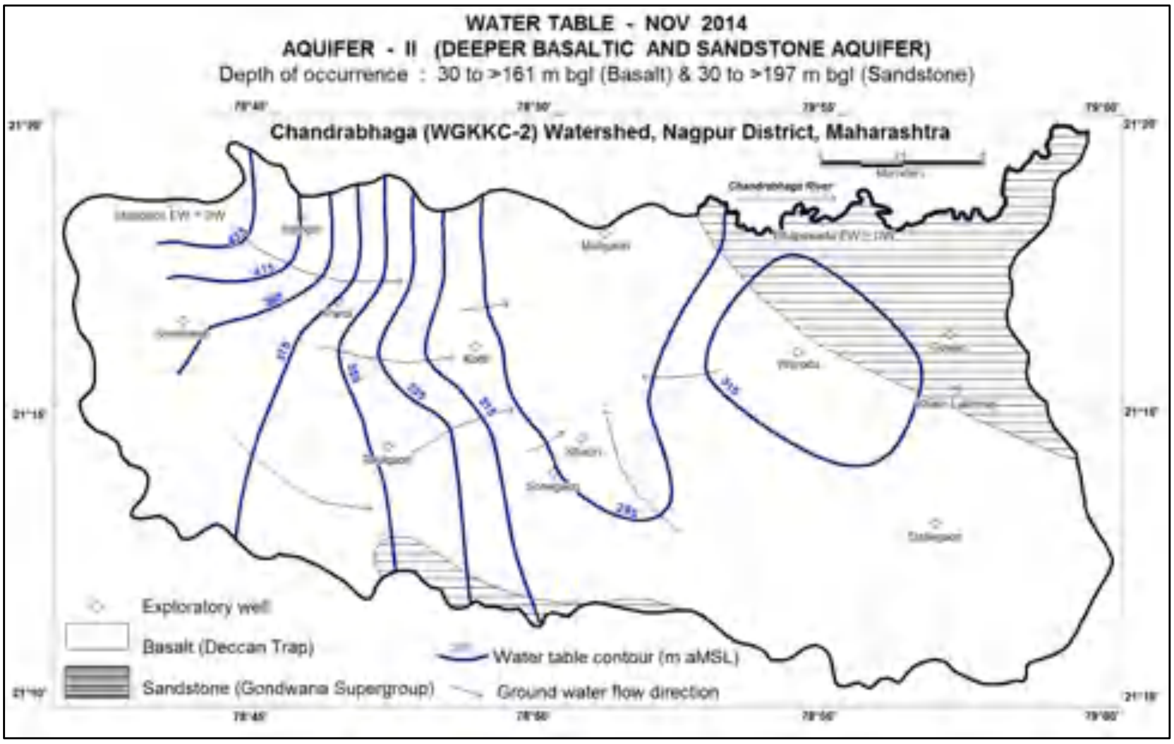


Fig. 3.42: Post- monsoon Water Table (Aquifer – II), Nov-2014

3.3.3 Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. The standards proposed by the Bureau of Indian Standards (BIS-2012) were used to decide the suitability of ground water for various purposes. For estimation of the quality of ground water, ground water samples from 57 KOW's (shallow dug wells representing phreatic aquifer) have been collected during pre-monsoon and post monsoon season. Similarly for deeper Aquifer – II representing basalt and sandstone, the ground water samples were collected during the drilling and pumping test activities of 16 exploratory constructed in the watershed. The ground water samples were analysed for major chemical constituents and analytical results are presented in Annexure-XI and Annexure-XII for Aquifer-I and Aquifer-II respectively. The aquifer wise ranges of different chemical constituents present in ground water are given in Table 3.8.

The study area of Chandrabhaga watershed, basalt is the main water bearing formation. The basaltic rock is usually composed of chain silicates, pyroxene (partly amphibole) and the feldspars group of minerals. The dissolution of these minerals mainly yields Ca, Mg and Na ions to the groundwater. The concentration of HCO_3 ion in groundwater is mainly influenced by the amount of CO_2 dissolved in water from atmosphere and decay of organic matter. The concentration of K^+ in groundwater of basaltic aquifer is generally very low. It is liberated with great difficulty from K-feldspars, which are the main sources of potassium in the basalt, and has a strong tendency to be reincorporated into the solid weathering product. The K-feldspars are very resistant to the attack by water. In basalts, there is no apparent source of Cl, SO_4 and NO_3. The groundwater in basaltic terrain of the study area which is rich in these ions is indicative of anthropogenic contamination.

Table 3.8: Aquifer wise ranges of different constituents in ground water, Chandrabhaga watershed (WGKKC-2), Nagpur

Sl. No.	Constituents	Aquifer - I				Aquifer - II			
		Basalt		Sandstone		Basalt		Sandstone	
		Min	Max	Min	Max	Min	Max	Min	Max
1	pH	7.30	9.00	7.40	8.10	7.90	8.50	7.20	8.60
2	EC µmhos/cm	420.00	2353.00	710.00	2532.00	445.00	857.00	470.00	2211.00
3	TDS as ppm	252.00	1412.00	426.00	1519.00	--	--	--	--
4	TA	83.61	531.97	151.64	540.16	55.00	300.00	60.00	290.00

Sl. No.	Constituents	Aquifer - I				Aquifer - II			
		Basalt		Sandstone		Basalt		Sandstone	
		Min	Max	Min	Max	Min	Max	Min	Max
5	TH (as $CaCO_3$) ppm	96.00	768.00	256.00	792.00	205.00	400.00	110.00	960.00
6	Calcium ppm	16.00	138.00	35.00	130.00	8.02	52.10	12.02	246.49
7	Magnesium ppm	13.00	149.00	22.00	114.00	26.73	81.42	31.60	140.96
8	Sodium ppm	18.00	178.00	35.00	247.00	3.73	16.27	2.39	26.07
9	Potassium ppm	0.00	112.00	1.00	135.00	0.07	0.41	0.04	17.94
10	Carbonate ppm	0.00	12.00	0.00	0.00	0.00	12.00	0.00	15.00
11	Bicarbonate ppm	102.00	649.00	185.00	659.00	67.10	366.00	73.20	353.80
12	Chloride ppm	16.00	340.00	40.00	782.00	24.82	159.53	39.00	556.57
13	Sulphate ppm	11.00	236.00	4.00	145.00	3.30	189.00	4.50	340.00
14	Nitrate ppm	7.00	320.00	14.00	271.00	1.60	65.00	0.75	47.00
15	Fluoride ppm	0.11	0.65	0.16	0.53	0.28	1.40	0.12	1.46

The chemical constitution of ground water is controlled by various factors like composition and frequency of precipitation, lithology, soil composition, resident time and prevailing physicochemical conditions. The samples representing the Aquifer-I and II comprises of Basalt and Sandstone have been classified on the basis of piper diagram/plot.

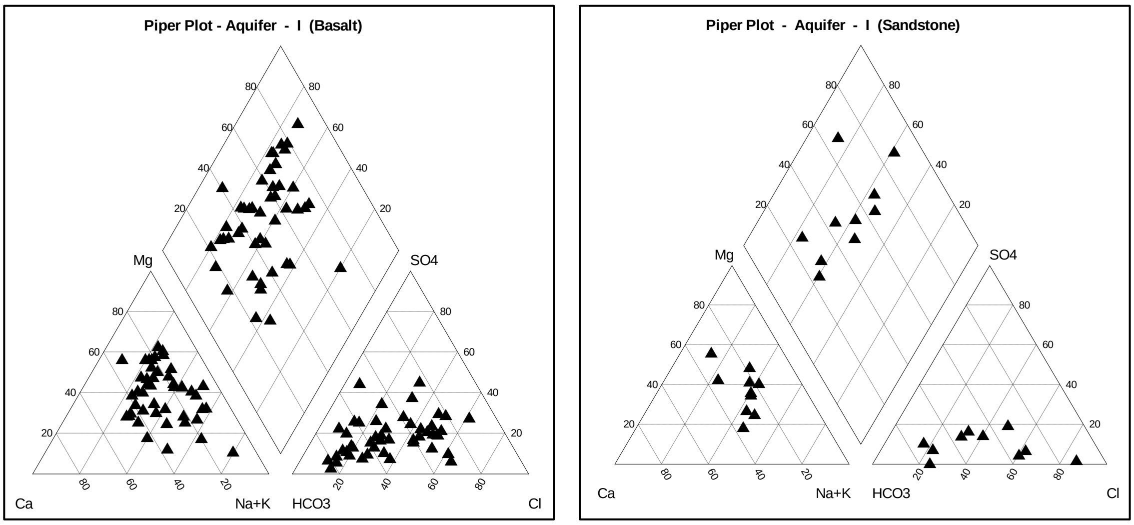


Fig. 3.43: Chemical classification of ground water samples from dugwells, Aquifer-I

Piper plot (Fig. 3.43) for ground water samples from Aquifer-I (shallow aquifer) shows that the alkaline earths (Ca+Mg) exceed alkalis (Na+K) and weak acids (CO_3+HCO_3) exceed strong acids (Cl+SO_4+NO_3) in majority of groundwater samples. The groundwater is predominately of Ca-Mg-

HCO_3 type and represents the water from basaltic aquifer. Only few samples were found to have fallen in the category of mixed type of water. This change in the type of water in the groundwater samples of the study area may be attributed to the influence of surface activities. The percolation of waste/wastewater, from the surface, rich in alkalis and strong acids might have caused such changes in groundwater.

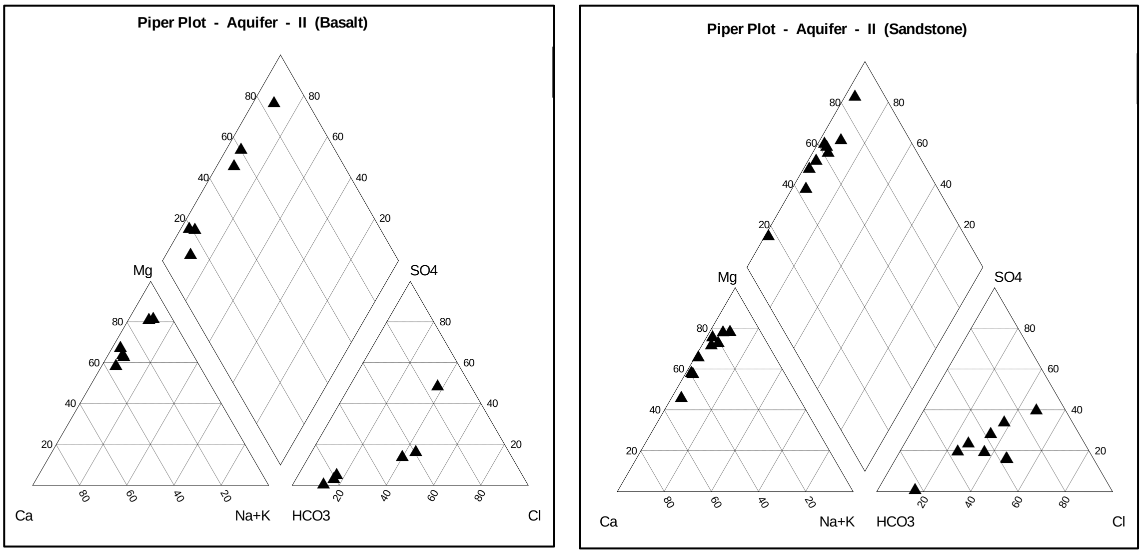


Fig. 3.44: Chemical classification of ground water samples from bore wells, Aquifer-II

Piper plot (Fig. 3.44b) for ground water samples from Aquifer-II (deeper aquifer) shows that the groundwater in deeper aquifer is also dominated by alkaline earths (Ca + Mg) over alkalis (Na+K) and weak acids (CO_3+HCO_3) over strong acids (Cl+SO_4). The groundwater spends more time in deeper aquifer leading to exchange of Ca and Na ion in groundwater. However, the change in water type is indicating that either the water is not regularly getting recharged or the strong percolation of any effluent has taken place from the surface activities.

3.3.3.1 Suitability of ground water for drinking and domestic purposes

The physical and chemical quality of groundwater is important in deciding its suitability for drinking purposes. As such, the suitability of groundwater for potable uses with regard to its chemical quality has to be deciphered and defined based on some vital characteristics of the water. On this basis of Bureau of Indian Standards (BIS) classification, the natural groundwater of India has been categorized as desirable, permissible and unfit for human consumption considering the drinking and domestic use of water. In the present study, the groundwater quality assessment for drinking purpose was carried out based on the drinking water standards, prescribed by Bureau of Indian Standards (BIS, 2012). The aquifer wise ground water quality for drinking and domestic purpose is presented as Table 3.9.

Table 3.9: Aquifer wise ground water quality for drinking purpose and ionic concentration range (BIS: 2012)

Parameters	DL in ppm	PL in ppm	Undesirable effect outside limit	No. of Samples >PL			
				Aquifer-I		Aquifer-II	
				Basalt (47 sample)	Sandstone (10 sample)	Basalt (12 sample)	Sandstone (23 sample)
Calcium	75	200	Encrustation in water supply structure and adverse effects on domestic use.	0	0	0	1
Magnesium	30	100	Encrustation in water supply structure and adverse effects on domestic use.	7	1	0	5
Chloride	250	1000	Taste, Corrosion palatability are affected	0	0	0	0
Sulphate	200	400	May cause gastro intestinal problems	0	0	0	0
Hardness (as CO_3)	300	600	Encrustation in water supply structure and adverse effects on domestic use.	0	0	0	0
Total dissolved Solids	500	2000	Palatability decrease and may cause gastro intestinal problems	0	0	-	-
Nitrate	45	No Relaxation	May cause Methanoglobineimia	41	6	1	3
pH	6.5-8.5	No Relaxation	The water will affect the mucous membrane and water supply system.	7	0	0	1
Fluoride	<1.5	>1.5	Excessive fluoride causes mottling of tooth enamel and skeletal deformation	0	0	0	0

Here, DL- Desirable Limit, PL – Permissible Limit

A perusal of above table and piper plots reveals that the ground water quality in the Aquifer-I comprises of Basalt and Sandstone is mainly affected by nitrate contamination as most of samples show higher nitrate concentration (more than 45 mg/L) (Fig. 3.45). The field observations during the study have indicated that the anthropogenic activities in the vicinity of groundwater sampling source like open unlined sewers, improper disposal of cow dung for manure, excessive use of fertilizer in the agriculture field for orange cultivation etc. are the main reasons for the nitrate contamination in the ground water of the study area. At some places problem of hard water has been observed where the Magnesium at 13 locations where found beyond permissible limit. However, the ground water from Aquifer – I and II in the study area is suitable for drinking and domestic purpose, except at few places where nitrate is beyond permissible limit.

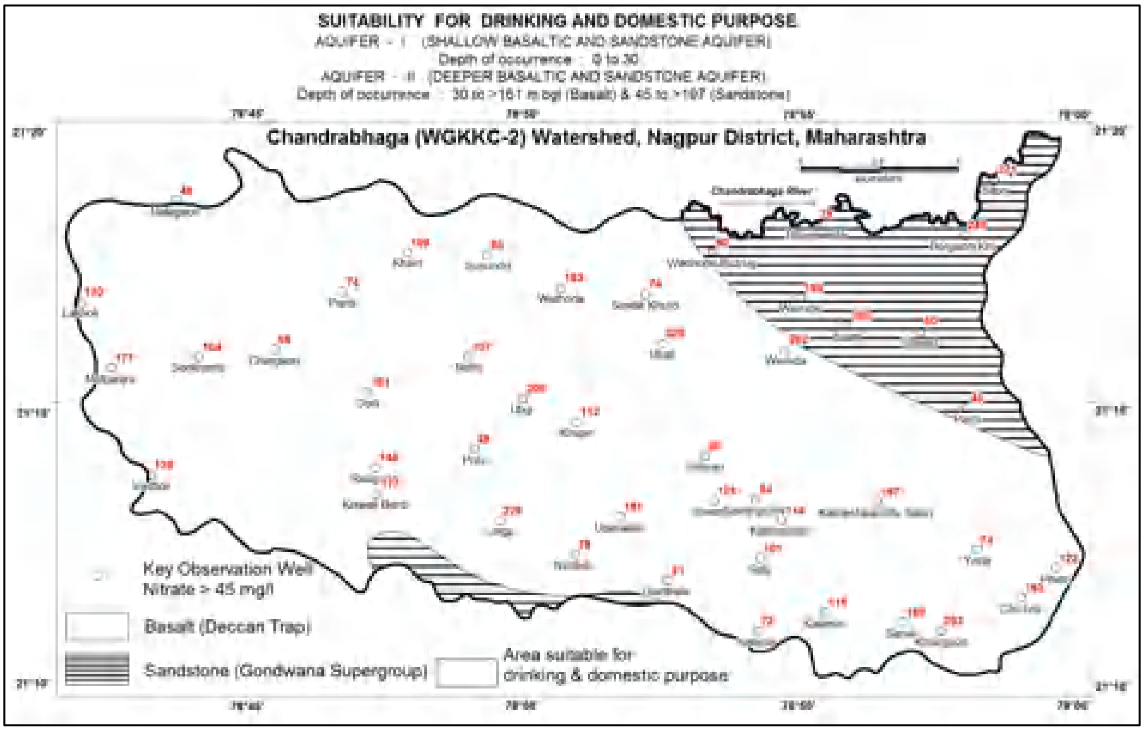


Fig. 3.45: Suitability for Drinking and Domestic purpose with spatial distribution of nitrate, Nov-2011, Aquifer – I and II (Basalt and Sandstone)

3.3.3.2 Suitability of ground water for irrigation purpose

In the present study, Salinity hazard, sodium hazard as Soluble Sodium Percentage (SSP) and Percent Sodium (%Na), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium Ratio (MR) and Kelly's ratio (KR), are discussed to determine the quality of groundwater for irrigation purpose while Corrosivity ratio (CR) is used to find suitability of water for transportation through metallic pipes (Table 3.10) (**Annexure-XIII** and **Annexure-XIV** for Aquifer-I and Aquifer-II respectively). In addition to this the spatial distribution of electrical conductance for Aquifer – I and II has been prepared and presented as Fig. 3.46, 3.47 and 3.48. The level of salinity hazard based on EC and sodium hazard based on SAR value was assessed using U.S. Salinity diagram(Wilcox diagram) (Fig. 3.49 and 3.50).

Ratio/Parameter	Formulae	Significance
Percent Sodium (%Na)	$\%Na = \left[\frac{Na}{Ca + Mg + Na + k}\right] x100$	suitability for irrigation , as Na reduces permeability

Ratio/Parameter	Formulae	Significance
Sodium Absorption Ratio (SAR)	$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$	Relative proportion of Na to Ca & Mg
Soluble Sodium Percentage (SSP)	$SSP = \frac{Na^{+} \times 100}{Ca^{++} + Mg^{++} + Na^{+}}$	Na replaces Ca & lowers soil permeability
Residual Sodium Carbonate (RSC)	$RSC = (HCO_3^{-} + CO_3^{--}) - (Ca^{++} + Mg^{++})$	Excess HCO3, NA, Ca, Mg affects the yield of crops
Kelly's Ratio (KR)	$KR = \frac{Na^{+}}{Ca^{++} + Mg^{++}}$	The level of sodium measured against calcium and magnesium
Magnesium Ratio (MR)	$MR = \frac{Mg^{++} \times 100}{Ca^{++} + Mg^{++}}$	excess amount of magnesium over calcium and magnesium
Corrosivity Ratio (CR)	$CR = \frac{(Cl^{-}/35.5) + 2(SO_4^{--}/96)}{2(HCO_3^{-} + CO_3^{-}/100)}$	to know whether the water can be transported in metallic pipes or not

Table 3.10: Classification of groundwater samples from Aquifer I and II based on %Na, SAR, SSP, RSC, EC, KR, MR and CR ratio

Ratio	Range (meq/L)	Category	Aquifer-I (Basalt)		Aquifer-I (Sandstone)		Aquifer-II (Basalt)		Aquifer-II (Sandstone)	
			No. of Samples	Percentage	No. of Samples	Percentage	No. of Samples	Percentage	No. of Samples	Percentage
%Na	< 20	Excellent	2	4	2	4	12	100	23	100
	20-40	Good	38	81	38	81	0	0	0	0
	40-60	Permissible	7	15	7	15	0	0	0	0
	60-80	Doubtful	0	0	0	0	0	0	0	0
	> 80	Unsuitable	0	0	0	0	0	0	0	0
SAR	< 10	Excellent	47	100	47	100	12	100	23	100
	10-18	Good	0	0	0	0	0	0	0	0
	18-26	Fair	0	0	0	0	0	0	0	0
	> 26	Unsuitable	0	0	0	0	0	0	0	0
SSP	< 50	Good	44	94	44	94	12	100	23	100
	> 50	Unsuitabl	3	6	3	6	0	0	0	0

Ratio	Range (meq/L)	Category	Aquifer-I (Basalt)		Aquifer-I (Sandstone)		Aquifer-II (Basalt)		Aquifer-II (Sandstone)	
			No. of Samples	Percentage	No. of Samples	Percentage	No. of Samples	Percentage	No. of Samples	Percentage
		e								
RSC	< 1.25	Safe	45	96	45	96	12	100	23	100
	1.25-2.5	Suitable	2	4	2	4	0	0	0	0
	> .5	Unsuitable	0	0	0	0	0	0	0	0
EC	<250	Excellent	0	0	0	0	0	0	0	0
	250-750	Good	5	11	5	11	8	67	9	39
	750-2000	Permissible	40	85	40	85	4	33	13	57
	2000-3000	Doubtful	2	4	2	4	0	0	1	4
	>3000	Unsuitable	0	0	0	0	0	0	0	0
KR	< 1	Good	44	94	44	94	12	100	23	100
	> 1	Unsuitable	3	6	3	6	0	0	0	0
MR	< 50	Suitable	11	23	11	23	0	0	2	9
	> 50	Unsuitable	36	77	36	77	12	100	21	91
CR	< 1	Good	5	11	5	11	3	25	0	0
	> 1	Unsuitable	42	89	42	89	9	75	23	100

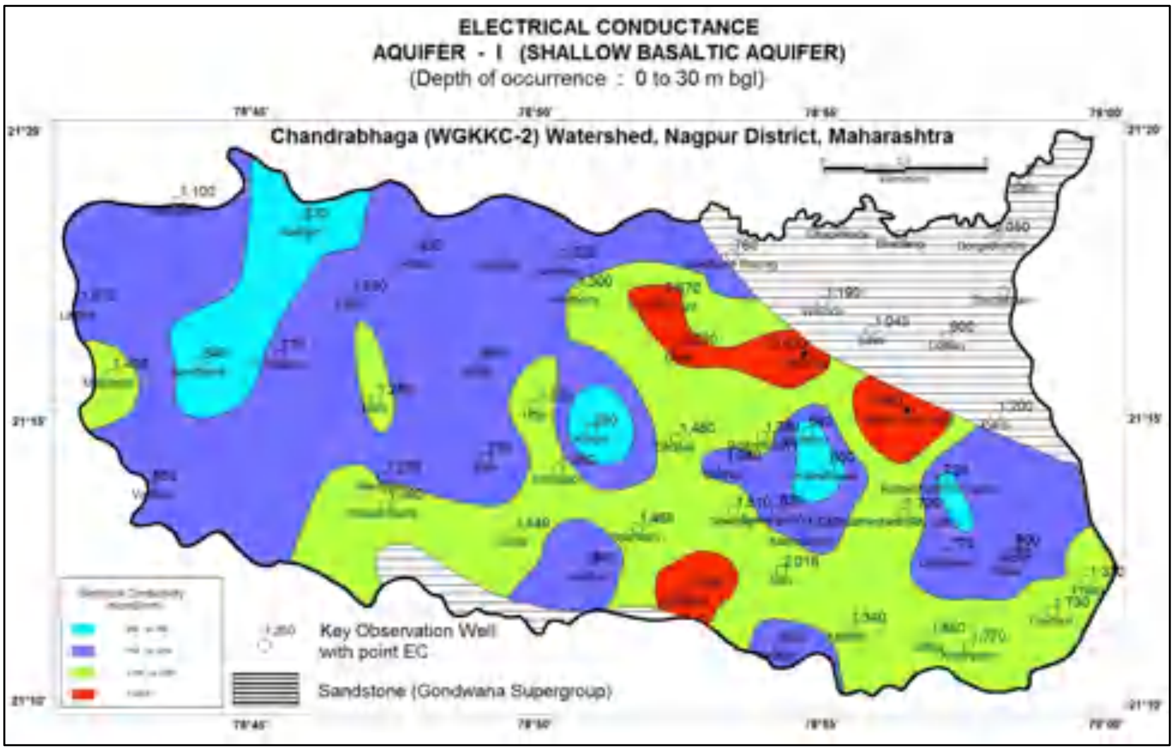


Fig. 3.46: Spatial Distribution of Electrical Conductance, May-2014, Aquifer – I (Basalt)

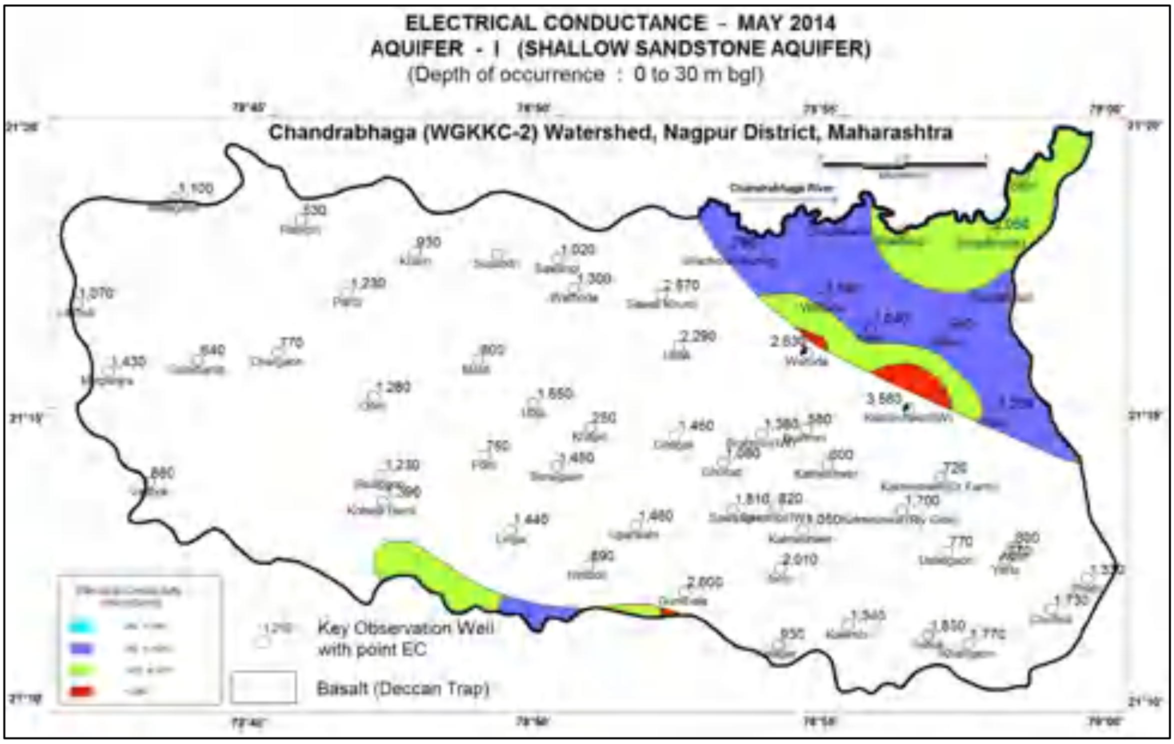


Fig.3.47: Spatial Distribution of Electrical Conductance, May-2014, Aquifer – I (Sandstone)

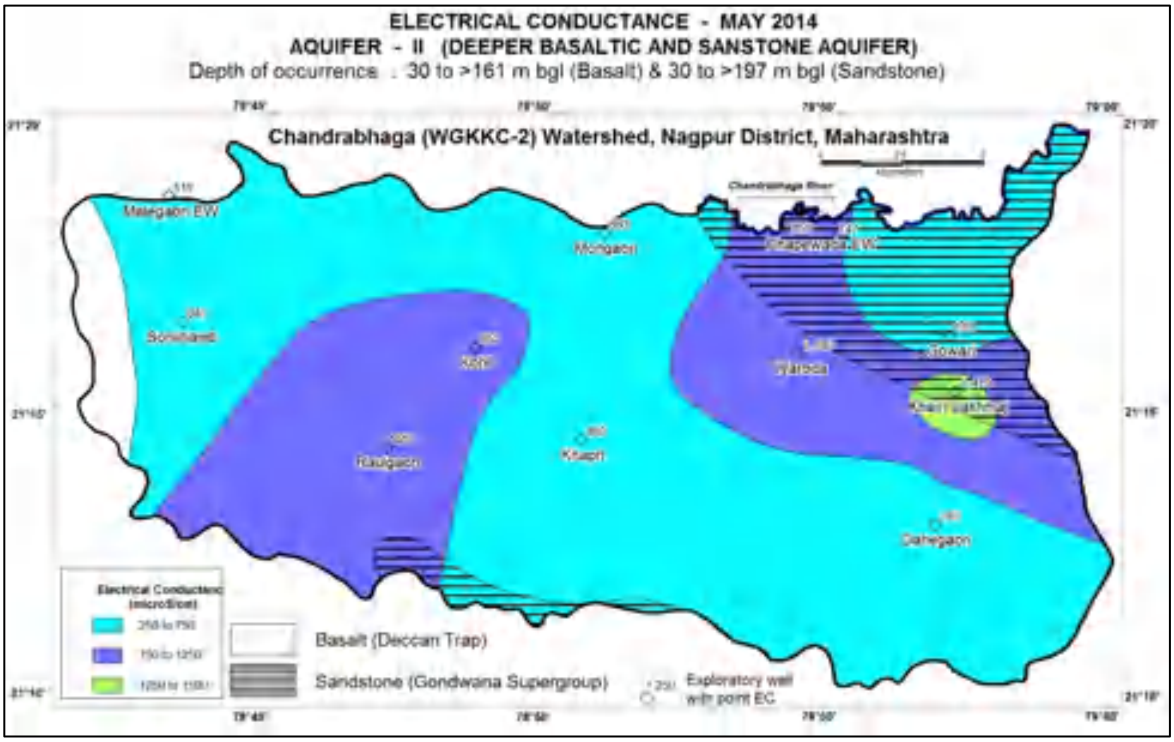


Fig. 3.48: Spatial Distribution of Electrical Conductance, May-2014, Aquifer – II based on ground water exploration

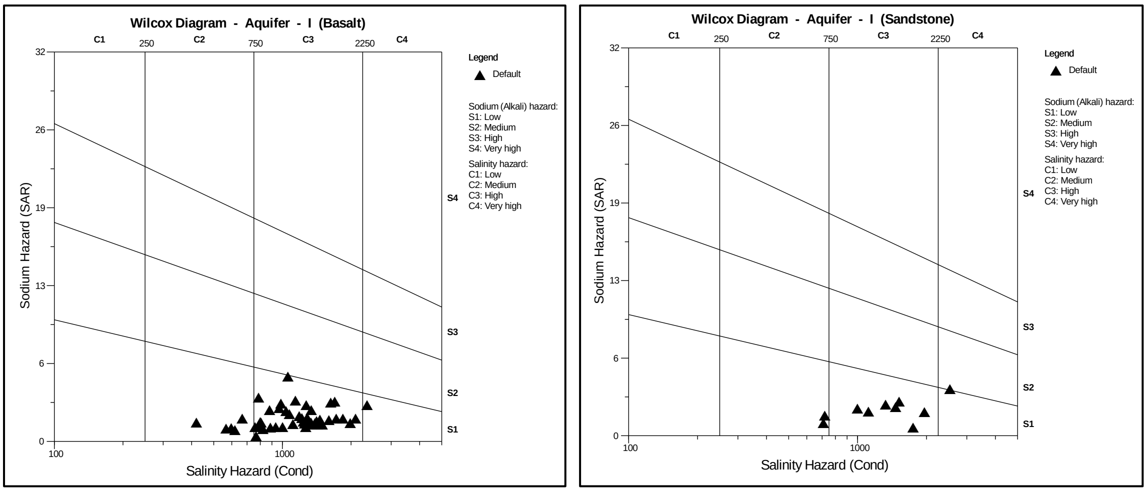


Fig. 3.49: SAR *vs.* conductivity plot of ground water samples from Aquifer-I (shallow aquifer)

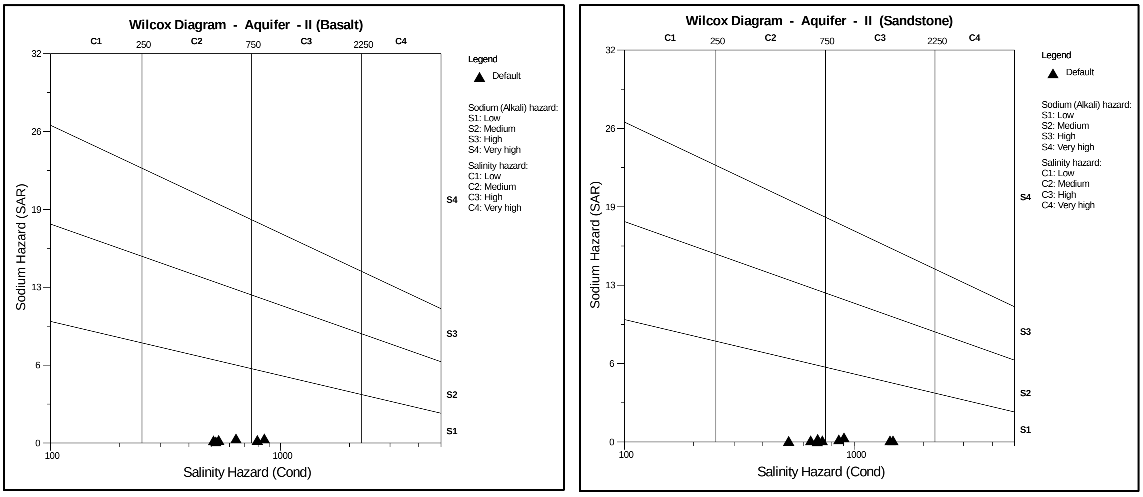


Fig. 3.50: SAR *vs.* conductivity plot of ground water samples from Aquifer-II (Deeper aquifer)

The analysis of various ratios, maps and plots indicates that

1. In Aquifer-II, the fluoride ranges from 1.23 to 1.46 mg/l i.e., marginally high but below MPL of 1.5 mg/l and has been observed in Sonkhamb (22.60-23m), Raulgaon (127.3-129.95m), Raulgaon (135.6-138.6m), Khapri (48.2-50.85m), and Dhapewada (Zone-I).
2. Likewise in Aquifer-II, the nitrate has been found beyond permissible limit at Ramgiri (65 mg/l), Gowri (47 mg/l) and Raulgaon (46 mg/l).
3. From the analysis of salinity hazard, sodium hazard as Soluble Sodium Percentage (SSP) and Percent Sodium (%Na), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium Ratio (MR), Kelly's ratio (KR), indicates that except high Magnesium Ratio all the ratios are found suitable category.
4. The Corrosivity Ratio (CR) indicates that the ground water from all Aquifer- I and II should not be transported in metallic pipes due its corrosive nature. It is suggested that the metal

pipes should be avoided for water transportation especially for irrigation and industrial purposes.

5. The perusal of spatial distribution of Electrical Conductivity (EC) map indicates that major part of the area is having EC in the range between 750 and 1250 μmhos/cm. The presence of high EC is observed mainly around Kalmeshwar town, which is probably due to industrial pollution. EC is ranging from 250 to 750 μS/cm in major parts except in south-western and south-eastern part of the watershed were it observed in the range of 750 to 1250 μS/cm. The deeper sandstone Aquifer-II, it shows gradual zonation from 1250 to 750 to 250 towards north east end of watershed.
6. The Wilcox diagram for Aquifer-I and II indicates that the possibility of sodium hazard to the soil is low (S1) as the SAR values of the ground water samples from Aquifer-I and II are less than 10 (Fig. 3.49 and 3.50). However, EC values of most of the samples fall under the category of medium (C2) and high (C3) salinity hazard zone indicating that special crop and water management practices are required for utilizing such water for irrigation purpose (Fig. 3.49 and 3.50).

Overall, the ground water quality of Aquifer- I and II is good and suitable for irrigation purpose (Fig. 3.51) except at few places of salinity hazard to soil.

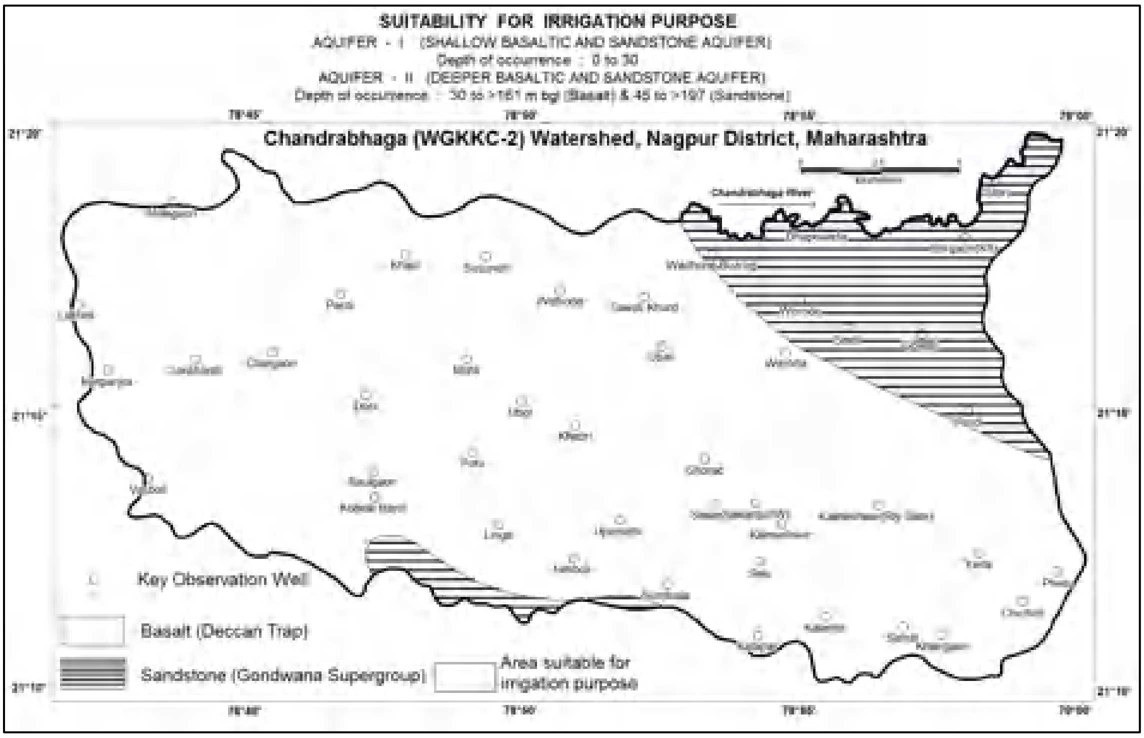


Fig. 3.51: Suitability for irrigation purpose, Aquifer – I and II (Basalt and Sandstone)

3.3.3.2.1 Analysis of Trace Elements

Trace elements in natural or contaminated ground water with the exception of Iron almost invariably occur at concentrations well below 1 mg/l. Concentrations are low because of constraints imposed by solubility of minerals or amorphous substances and adsorption on clay minerals or on hydrous oxide of iron and magnesium. Isomorphous substitution or co-precipitation with minerals or amorphous substitution or co-precipitation with minerals or amorphous solids can also be important as far as the occurrence of trace elements in natural water is concerned. The solubility of cationic trace elements increases as pH decreases particularly at pH < 5. In the area under investigation, 25 water samples were analysed for trace elements like Mn Pb, Cu, Zn and Fe and the analysis results (Table 3.11) reveals that ground water contamination may occurred due to the presence of lead. The results of the analysis of trace elements are discussed below.

Manganese (Mn): The major forms of Manganese in nature are oxides, silicates and carbonates. It is widely distributed in soil and an essential plant micronutrient element in plant metabolism and is expected that the organic circulation of Manganese can influence its occurrence in natural water. The sugarcane plant, which is used as raw material in sugar industry, may be possible source of Mn in ground water as the effluent generated from sugar and allied industries contains high amount of Mn. The desirable limit of Mn in drinking water is 0.1 mg/L and max. permissible limit is 0.3 mg/L as per BIS standard for drinking water. The concentration of Manganese found in the ground water of study area are in the range of 0.001 to 0.098 ppm. In deeper water the concentration of Manganese found in the range of 0.001to 0.06 ppm.

Iron (Fe): Iron in ground water generally exists as Fe (II) but may oxidised to Fe (III) when ground water is under aerobic condition. On land, major sources of Iron are the effluents of industries related with the manufacture of Iron or Steel and units in which Iron is one of the raw materials. Inspite of heavy discharge of Iron in the atmosphere and land, solubility controls restrict migration of the Iron to the saturated zone. In the study area of WGKKC-2 watershed, the iron content in content in the samples of ground water is in the range of 0.034 to 7.69 mg/l. In surface water the concentration of Iron found in the range of BDL to 1.733 mg/l.

Lead (Pb): The natural lead content of lake and river water worldwide is in the range of 0.001 to 0.01. Lead content of ground water is generally low due to solubility control and capacity of soils to absorb lead. The higher values of lead have been found where the contamination has occurred particularly from industrial sources. The chemical analysis results of ground water from WGKKC-2 watershed indicate that the lead content is in the range of BDL to 0.061 mg/l. In surface water the concentration of Lead found in the range of 0.031 to 0.089 mg/l.

Copper (Cu): The copper found in ground water of WGKKC-2 watershed varies from BDL to 0.064 mg/L and in surface water, it is observed below detectable limit. This is also essential micronutrient and very likely to come through the spent wash of distillery or other industrial effluents.

Zinc (Zn): The zinc content in WGKKC-2 watershed varies from BDL to 0.0712mg/L. However, in surface water samples zinc concentration observed below the desirable limit of BIS (5 mg/L).

Selenium (Se): The selenium content in WGKKC-2 watershed found <0.1 mg/L in all the ground water as well as surface water samples collected.

Chromium (Cr): The Chromium content in WGKKC-2 watershed varies from <0.004 to 0.009mg/L in all the ground water as well as surface water samples collected.

Arsenic (As): The Arsenic content in WGKKC-2 watershed varies from <0.001 to 0.005 mg/L in all the ground water as well as surface water samples collected.

Cadmium (Cd): The Cadmium content in WGKKC-2 watershed varies from 0.0001 to 0.0006 mg/L in all the ground water as well as surface water samples collected.

The analysis of water samples for trace elements indicates that

1. The ground water samples collected from dugwells representing shallow Aquifer- I indicate that Lead contaminated ground water has been observed in and around Kalmeshwar town while iron contamination is seen in Ubgi and around Kalmeshwar town.
2. Analysis of water samples collected from bore well and hand pump representing the deeper Aquifer – I and II indicates that iron has been found more than Permissible Limit (MPL) in and around Ubgi, Sonkhamb and Kalmeshwar area while lead has been observed in Kalmeshwar area.

Based on BIS standards for drinking water it has been observed that shallow ground water Aquifer-I is more contaminated as compare to deeper ground water Aquifer-II in respect of heavy metals iron and lead. Except at one or two locations, ground water from shallow as well as form deeper aquifer is good and potable for drinking and domestic purpose

Table 3.11: Heavy metal analysis of water sample, Chandrabhaga Watershed (WGKKC-2), Aquifer –I and II

Sample No	Site Name	Type of Well	Cr	Fe	Zn	Se	Pb	Mn	Cu	As	Cd
1	Khairgaon	Dug Well	0.005	0.14	0.02	<0.1	<0.0005	0.001	0.002	0.001	0.0006
2		Hand Pump	0.005	0.27	0.22	<0.1	0.001	0.018	0.006	0.002	0.0004
3	Kalambi	Dug Well	0.009	0.18	0.01	<0.1	<0.0005	0.098	0.003	0.002	0.0001
4		Bore Well	0.005	0.12	0.03	<0.1	0.001	0.003	0.002	0.002	0.0002
5	Kalmeshwar	Dug Well	<0.004	0.16	0.12	<0.1	0.008	0.011	0.005	0.001	0.0003
6	Ubali	Dug Well	0.007	0.27	0.01	<0.1	0.001	0.001	0.002	0.003	0.0003
7		Hand Pump	<0.004	0.21	0.01	<0.1	<0.0005	0.001	0.001	0.002	0.0001
8	Ubgi	Dug Well	<0.004	0.37	0.20	<0.1	0.007	0.020	0.007	0.002	0.0002
9		Hand Pump	<0.004	0.43	0.21	<0.1	0.003	0.013	0.006	0.002	0.0001
10	Sonkhamb	Dug Well	<0.004	0.19	0.02	<0.1	0.002	0.009	0.002	<0.001	0.0003
11		Hand Pump	<0.004	1.07	0.75	<0.1	0.002	0.051	0.007	<0.001	0.0003
12	Kalmeshwar(Sawangi)	Dug Well	<0.004	0.22	0.06	<0.1	0.005	0.010	0.003	<0.001	0.0005
13	Kalmeshwar (S of Gowri)	Dug Well	<0.004	0.23	0.09	<0.1	0.005	0.017	0.005	0.005	0.0004
14	Kalmeshwar (Eastern Rlygate)	Dug Well	<0.004	0.26	0.47	<0.1	0.012	0.098	0.011	0.001	0.0002
15		Hand Pump	<0.004	1.17	0.01	<0.1	0.030	0.060	0.015	<0.001	0.0003
16	Kalmeshwar (Western Rly gate)	Dug Well	<0.004	0.23	0.02	<0.1	0.002	0.030	0.004	0.004	0.0001
17		Hand Pump	<0.004	0.28	0.33	<0.1	0.002	0.010	0.005	0.004	0.0002
18	Kalmeshwar (Gajanan Maharaj Devshtan)	Dug Well	<0.004	0.41	0.17	<0.1	0.005	<0.0005	0.005	0.003	0.0002
19		Hand Pump	<0.004	0.46	0.01	<0.1	0.004	0.013	0.003	0.003	0.0001
20	Kalmeshwar (Zenda Chowck)	Dug Well	<0.004	0.33	0.22	<0.1	0.012	<0.0005	0.019	0.002	0.0001
21		Hand Pump	<0.004	0.46	0.22	<0.1	0.001	<0.0005	0.002	0.002	0.0001
22	Kalmeshwar (Agri Farm on Gowri Rd)	Dug Well	<0.004	0.47	0.60	<0.1	0.002	0.018	0.003	<0.001	0.0001
23	Brahmni (W)	Dug Well	<0.004	0.12	0.01	<0.1	0.001	0.018	0.002	0.002	0.0002
24	Kalmeshwar (Chilla Darbar)	Dug Well	<0.004	0.93	0.16	<0.1	0.003	0.062	0.013	0.001	0.0002
25	Kalmeshwar (market yard)	Dug Well	<0.004	0.40	0.14	<0.1	0.004	0.020	0.004	0.002	0.0001

All values in ppm

3.3.4 Ground Water Resources, Recharge Parameters and Discharge Parameters

The ground water resources for the year 2011 had been finalized and salient feature is presented as Table 3.12. As compared to 2004 scenario the recharge has increased by about 5% and draft has increased by about 22%. The ground water is mainly used for irrigation purpose i.e., about 5368 ham out of total draft of 5545 ham.

Table-3.12: Ground water resources (2011), Chandrabhaga Watershed (WGKKC-2)

S. No.	Particulars	Command	Non-Command
1	Area (Sq. km.)	37.26	284.25
2	Annual Ground Water recharge (ham)	1234	5316
3	Net Ground Water Availability (ham)	1172	5050
4	Domestic & Industrial Draft (ham)	76	101
5	Irrigation Draft (ham)	2589	2779
6	Total Gross Draft (ham)	2665	2880
7	Domestic + Industrial Allocation (ham)	354	
8	Net Ground Water Available for Irrigation (ham)	500	
9	State of Ground Water Development (%)	89.2	
10	Category of Watershed	Safe	

3.3.5 Infiltration tests

To estimate the actual rate of infiltration of various soil cover and their impact on recharge to ground water, 9 infiltration tests have been conducted on various soil types (Fig. 3.52 and 3.53). The data has been analyzed and the salient features of the infiltration tests are presented in Table 3.13. The duration of the test was 30 min, the cumulative time of the test ranges from 150 min to 245 min. The final infiltered water depth varies from 0.20 cm to 2.01 cms. The final infiltration rate in the area ranges from 4 mm/hr at Tondakhiri for the sandy loam to clay loam soil type to 40.02 mm/hr at Dhapewada for clay loam soil type.

Fig.3.52: Field infiltration test, Chandrabhaga Watershed (WGKKC-2)

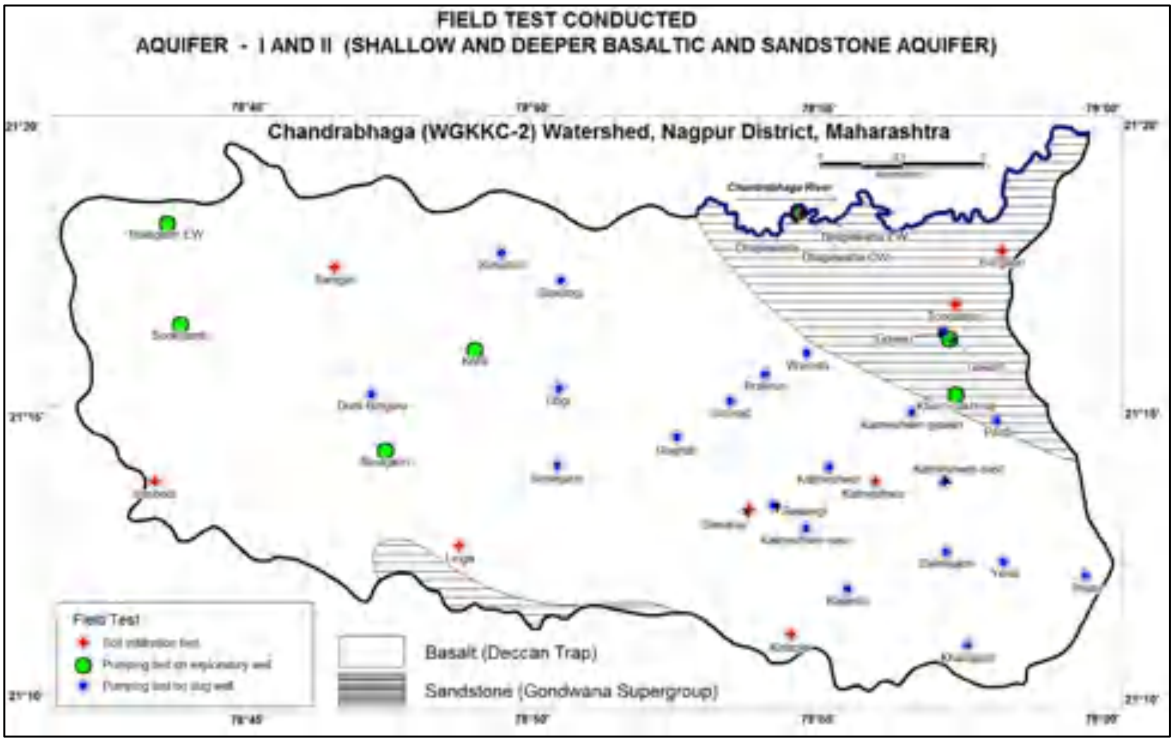


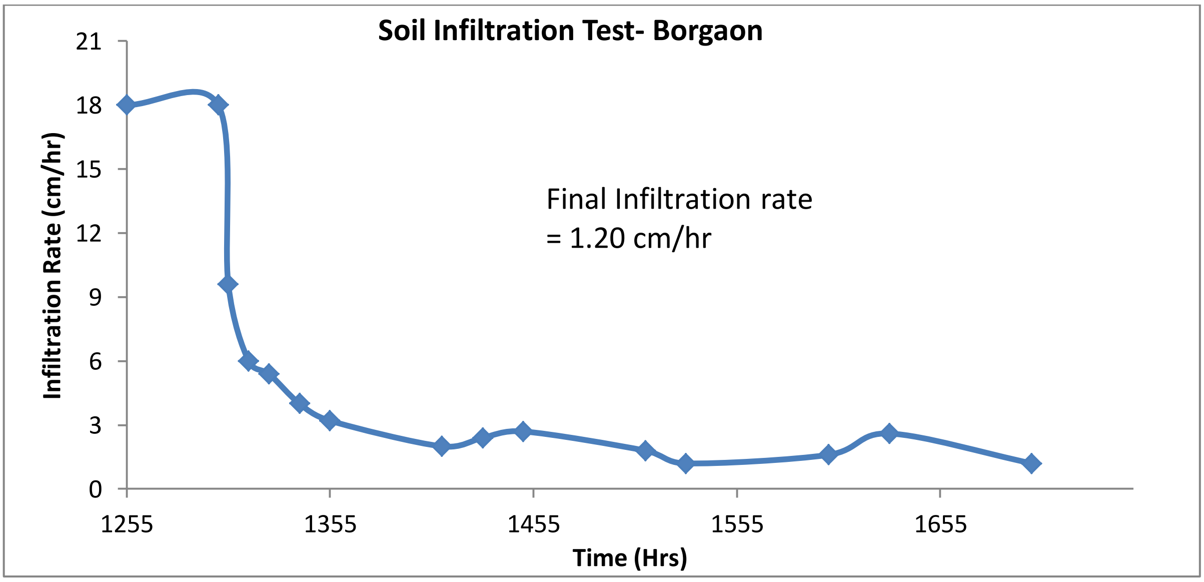
Fig.3.53: Site locations of field test conducted i.e., Soil Infiltration Test, Pumping test (dug well and exploratory well)

Table 3.13: Salient Features of infiltration tests, Chandrabhaga Watershed (WGKKC-2)

SL. No.	Village	Geology	Soil Type	Duration	Cumulative Time	Ground water level	Final Infiltered Water Depth	Final Infiltration Rate
				(min)	(min)	(cm agl)	(cm)	mm/hr
1	Borgaon	Sandstone	Sandy Loam to sandy clay	30	245	11	0.60	12.0
2	Dhapewada	TCG	Clayey Loam	30	245	11	2.01	40.2
3	Kalmeshwar	Basalt	Clayey	30	150	10	1.60	40.0
4	Ketapar	Basalt	Clayey	30	185	7	1.93	38.6
5	Linga	Basalt	Clayey	20	152	3	1.30	39.0
6	Sawangi	Basalt	Clayey	30	175	11	1.90	38.0
7	Tondakhairi	Sandstone	Sandy loam to clayey loam	30	235	11	0.20	4.0
8	Vasboli	Basalt	Sandy Loam to loam	30	235	12	0.40	8.0
9	Ramgiri	Basalt	Clayey Loam	30	165	12	1.10	40.0

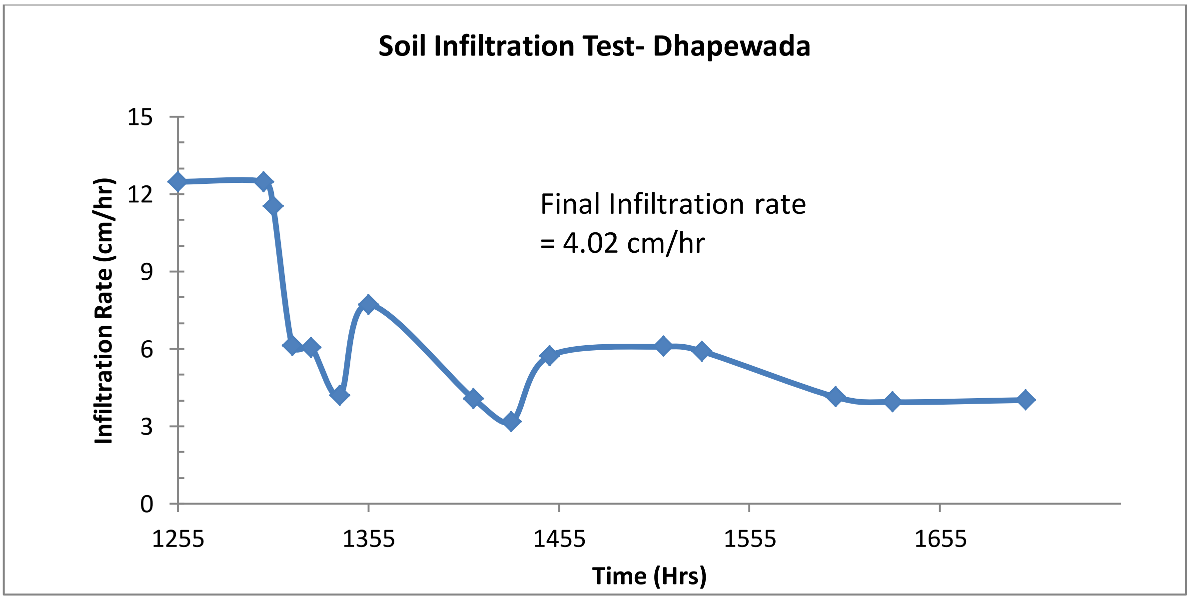
Site	:	Borgaon
Location	:	In the field of Sanjay Annaji Wagh
Coordinates & Elevation	:	$21^{0}17''32.2''$ & $78^{0}57''55.1''$; 330 m amsl
Date	:	30/04/2013
Initial Ground water level	:	11.00 cm
Geology	:	Gondwana Sandstone
Soil type	:	Sandy clayey

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	12.55	0	0	11.00	0.00	0.00	
2	13.00	5	5	12.50	1.50	18.00	
3	13.05	5	10	13.30	0.80	9.60	
4	13.15	10	20	14.30	1.00	6.00	
5	13.25	10	30	15.20	0.90	5.40	
6	13.40	15	45	16.20	1.00	4.00	
7	13.55	15	60	17.00	0.80	3.20	
8	14.10	15	75	17.50	0.50	2.00	
9	14.30	20	95	18.30	0.80	2.40	
10	14.50	20	115	19.20	0.90	2.70	
11	15.10	20	135	19.80	0.60	1.80	
12	15.30	20	155	20.20	0.40	1.20	
13	16.00	30	185	21.00	0.80	1.60	
14	16.30	30	215	16.30	1.30	2.60	filled upto 15 cm
15	17.00	30	245	16.90	0.60	1.20	



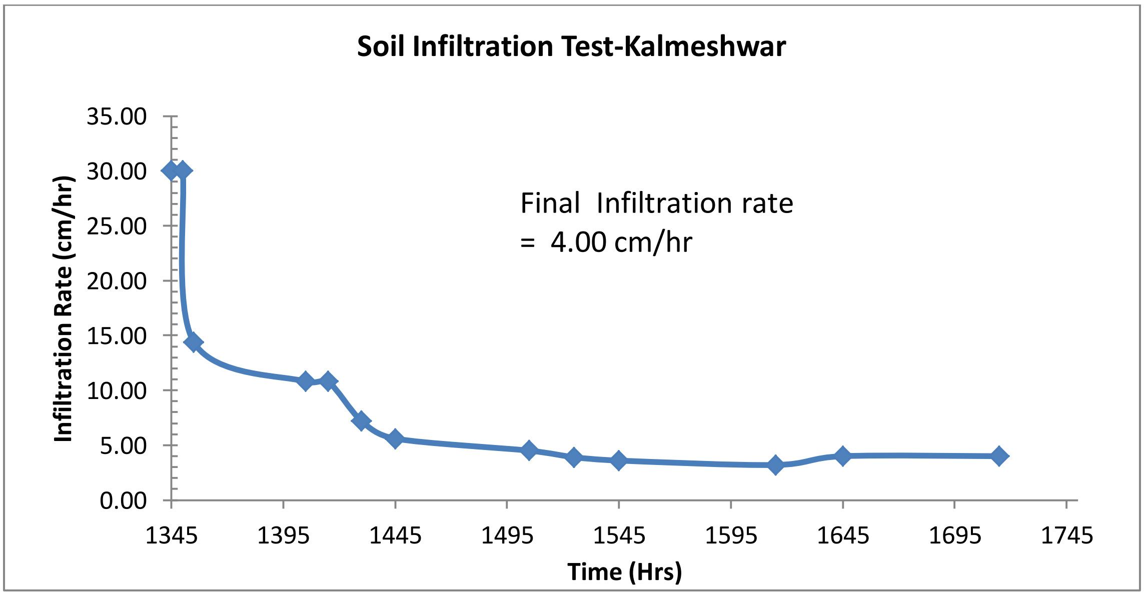
Site	:	Dhapewada
Location	:	In the premises of Kolbaswami School.
Coordinates & Elevation	:	$21^0$18’20” & $78^0$54’00” , 324m amsl
Date	:	11/03/2013
Initial Ground water level	:	11.00 cm
Geology	:	Gondwana Sandstone
Soil type	:	clayey Loamy

Sl.No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate cm/hr)	Remarks
1	1255	0		11.00	0		
2	1300	5	5	12.04	1.04	12.48	
3	1305	5	10	13.00	0.96	11.52	
4	1315	10	20	14.02	1.02	6.12	
5	1325	10	30	15.03	1.01	6.06	
6	1340	15	45	16.08	1.05	4.2	
7	1355	15	60	18.01	1.93	7.72	
8	1410	15	75	19.03	1.02	4.08	
9	1430	20	95	20.09	1.06	3.18	
10	1450	20	105	22.00	1.91	5.73	
11	1510	20	135	13.03	2.03	6.09	
12	1530	20	155	15.00	1.97	5.91	
13	1600	30	185	17.07	2.07	4.14	
14	1630	30	215	19.04	1.97	3.94	
15	1700	30	245	21.05	2.01	4.02	



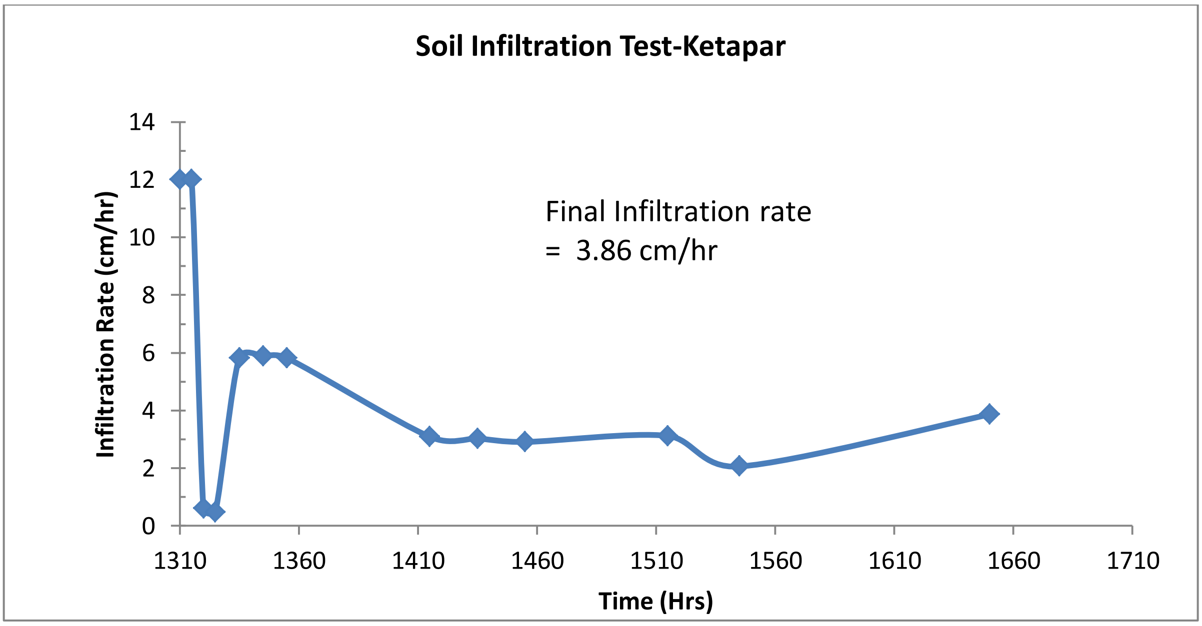
Site	:	Kalmeshwar
Location	:	In the premises of PWD Rest House.
Coordinates & Elevation	:	$21^0174''01''$ & $78^057''55.1''$, 338 m amsl
Date	:	11/03/2013
Initial Ground water level	:	11.00 cm
Geology	:	Gondwana Sandstone
Soil type	:	clayey

Sl.No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate cm/hr)	Remarks
1	13.45	0	0	10.00	0.00		
2	13.50	5	5	12.50	2.50	30.00	
3	13.55	5	10	13.70	1.20	14.40	
4	14.05	10	20	15.50	1.80	10.80	
5	14.15	10	30	16.70	1.80	10.80	
6	14.30	15	45	18.50	1.80	7.20	
7	14.45	15	60	19.90	1.40	5.60	
8	15.05	20	80	21.40	1.50	4.50	
9	15.25	20	100	22.70	1.30	3.90	
10	15.45	20	120	23.90	1.20	3.60	
11	16.15	30	150	25.50	1.60	3.20	
12	16.45	30	180		2.00	4.00	
13	17.15	30	210		2.00	4.00	



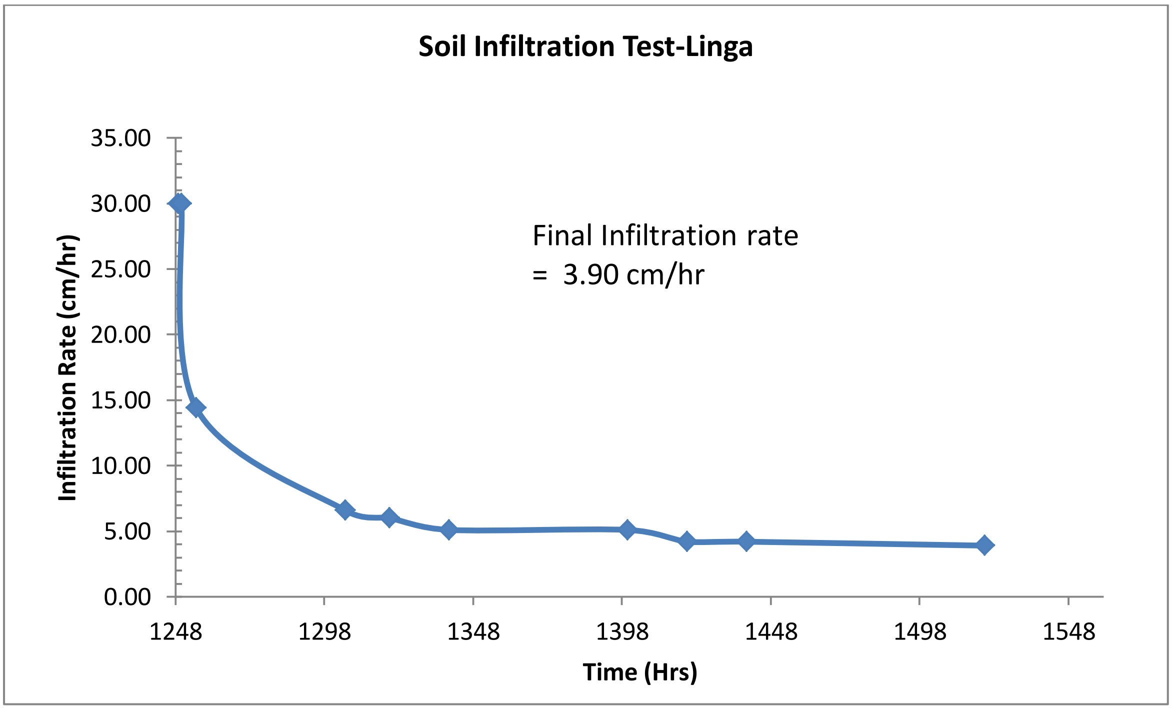
Site	:	Ketapar
Location	:	In the field of Pilaji Asole
Coordinates & Elevation	:	21^{0}11'1.5"& 78^{0}53'00"' , 363m amsl
Date	:	26/04/13
Initial Ground water level	:	11.00 cm
Geology	:	Gondwana Sandstone
Soil type	:	clayey

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	13.10	0	0	7.00	0		
2	13.15	5	5	8.00	1	12	
3	13.20	5	10	8.05	0.05	0.6	
4	1325.00	5	15	8.09	0.04	0.48	
5	13.35	10	25	9.06	0.97	5.82	
6	13.45	10	35	10.04	0.98	5.88	
7	13.55	10	45	11.01	0.97	5.82	
8	14.15	20	65	12.04	1.03	3.09	
9	14.35	20	85	13.05	1.01	3.03	
10	14.55	20	105	14.02	0.97	2.91	
11	15.15	20	125	15.06	1.04	3.12	
12	1545.00	30	155	16.09	1.03	2.06	
13	16.15	30	185	18.02	1.93	3.86	



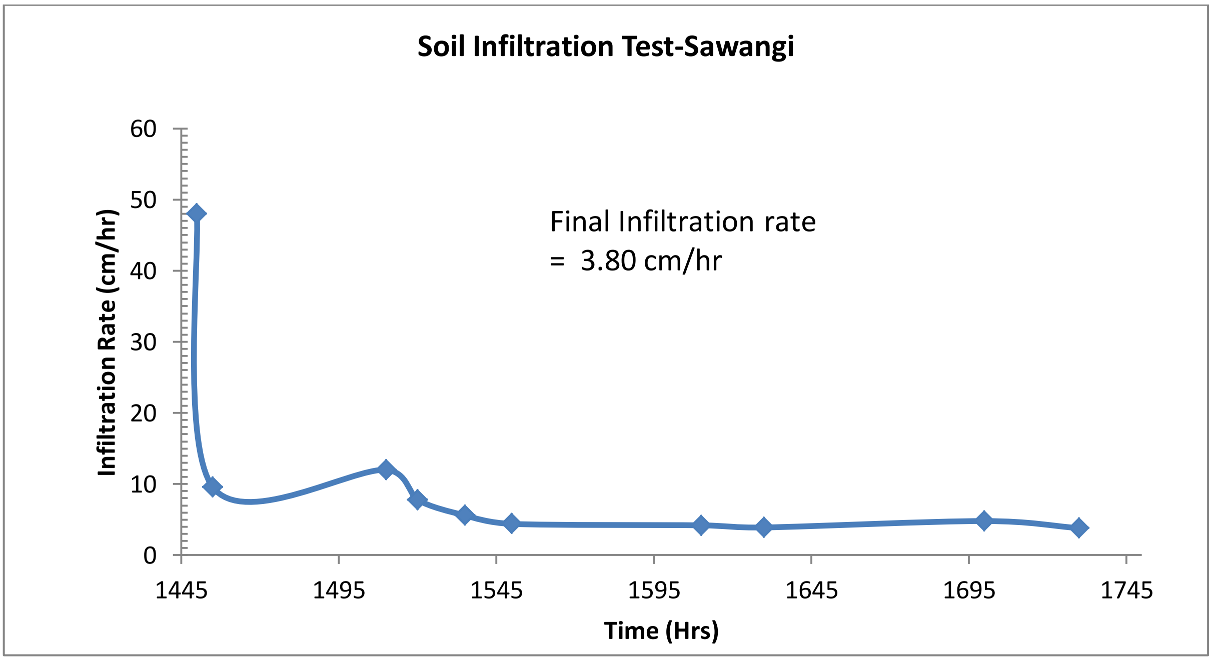
Location	:	Linga
Coordinates	:	21^0 12' 39.3" N; 78^0 48' 18" E: Ele:374 m amsl
Date	:	11/3/2013
Initial Ground water level	:	3.00 cm agl
Geology	:	Gondwana Sandstone
Soil type	:	Clay

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	1248	0	0	3	3	0.00	
2	1249	1	1	3.5	0.5	30.00	
3	1250	1	2	3	0.5	30.00	
4	1255	5	7	4.2	1.2	14.40	
5	1305	10	17	4.1	1.1	6.60	
6	1320	15	32	4.5	1.5	6.00	
7	1340	20	52	4.7	1.7	5.10	
8	1400	20	72	4.7	1.7	5.10	
9	1420	20	92	4.4	1.4	4.20	
10	1440	20	112	4.4	1.4	4.20	
11	1520	20	152	4.3	1.3	3.90	



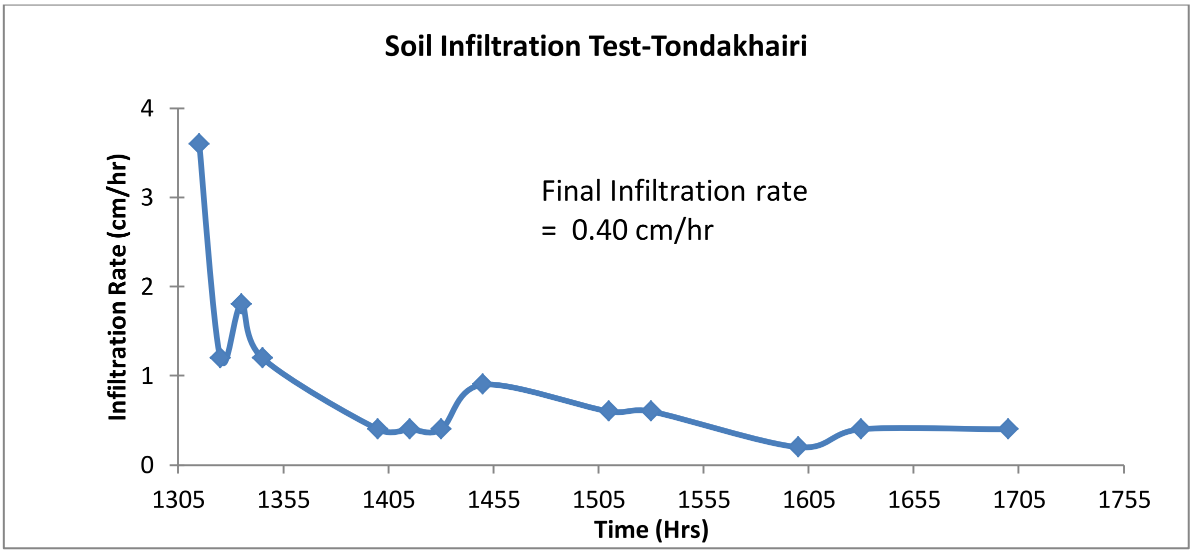
Site	:	Sawangi
Location	:	Near the house of Yeshu Sitaram Dabre
Coordinates & Elevation	:	21^{0}16'00" & 78^{0}51'00", 360 m amsl
Date	:	03/05/2013
Initial Ground water level	:	11.00 cm
Geology	:	Basalt
Soil type	:	Loamy Sandy

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	14.45	0	0	11.00	0.00	0.00	
2	14.50	5	5	15.00	4.00	48	
3	14.55	5	10	15.80	0.80	9.6	
4	15.10	10	20	17.80	2.00	12	
5	15.20	10	30	19.10	1.30	7.8	
6	15.35	15	45	20.50	1.40	5.6	
7	15.50	15	60	21.60	1.10	4.4	
8	16.10	20	80	23.00	1.40	4.2	
9	16.30	20	100	24.30	1.30	3.9	
10	17.00	30	140	17.40	2.40	4.8	filled upto 15 cm
11	17.30	30	175	19.30	1.90	3.8	



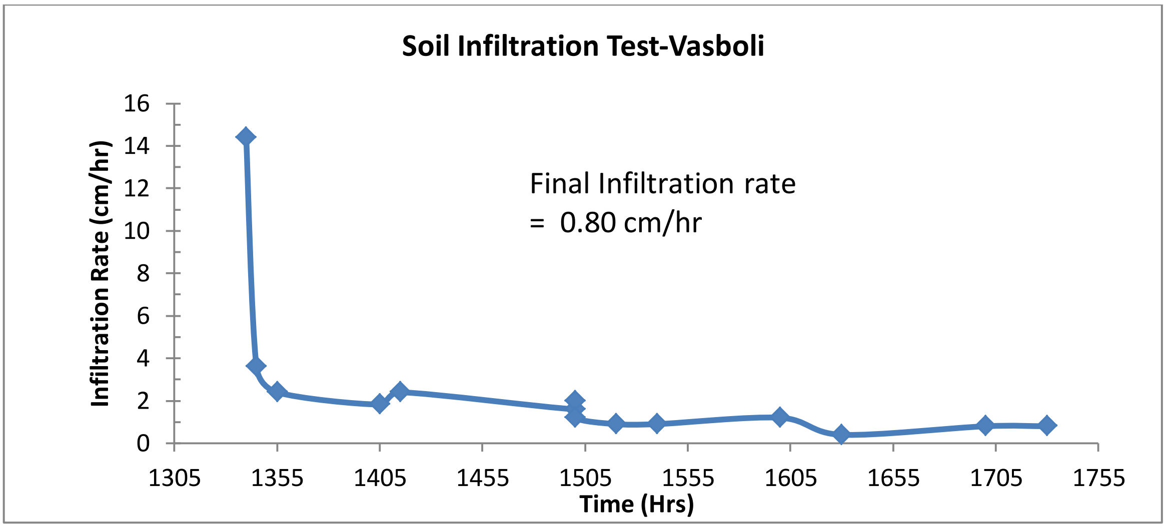
Site	:	Tondakhairi
Location	:	Near Water Supply tank in open land
Coordinates & Elevation	:	$21^0$16''38.7" & $78^0$57''05.5", 311 m amsl
Date	:	02/05/2013
Initial Ground water level	:	11 cm agl
Geology	:	Gondwana Sandstone
Soil type	:	Sandyclay

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)
1	13.05	0	0	11.00	0	0
2	13.10	5	5	11.05	1.5	18
3	13.15	5	10	11.80	0.3	3.6
4	13.25	10	20	12.00	0.2	1.2
5	13.35	10	30	12.30	0.3	1.8
6	13.45	10	40	12.50	0.2	1.2
7	14.00	15	55	12.60	0.1	0.4
8	14.15	15	70	12.70	0.1	0.4
9	14.30	15	85	12.80	0.1	0.4
10	14.50	20	105	13.10	0.3	0.9
11	15.10	20	125	13.30	0.2	0.6
12	15.30	20	145	13.50	0.2	0.6
13	16.00	30	175	13.60	0.1	0.2
14	16.30	30	205	13.80	0.2	0.4
15	17.00	30	235	14.00	0.2	0.4



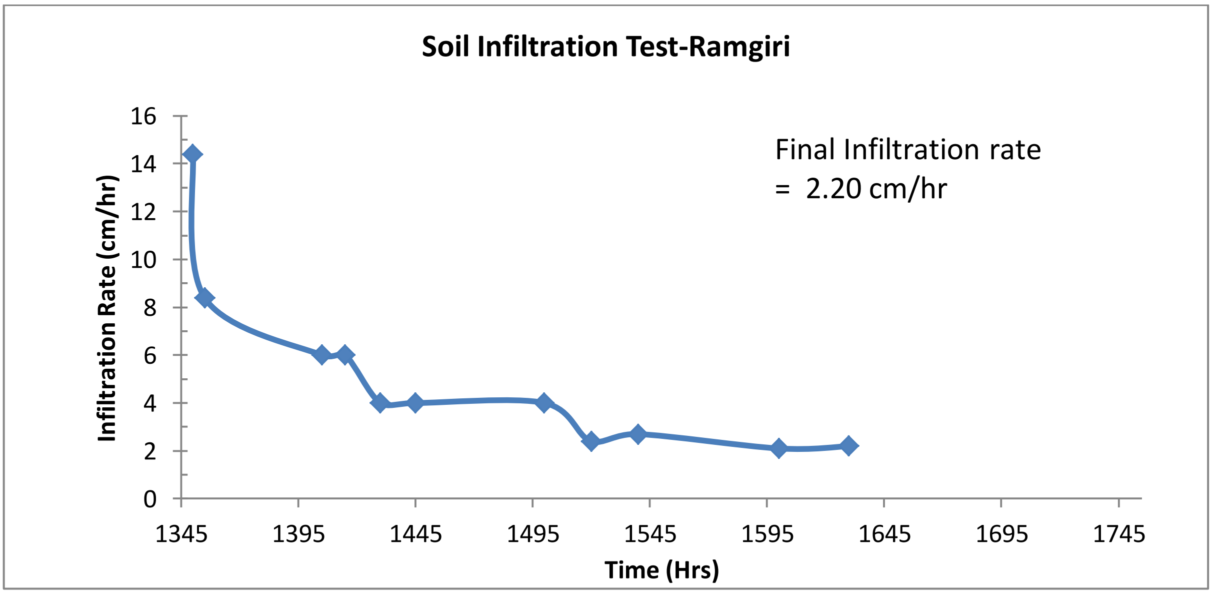
Site	:	Vasboli
Location	:	In open space 15 m west of Vasboli KOW.
Coordinates & Elevation	:	21^{0}13''45" & 78^{0}42''45.6" , 320 m amsl
Date	:	8/05/2013
Initial Ground water level	:	11.00 cm
Geology	:	Deccan Trap
Soil type	:	Sandy loamy to Loamy

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	13.35	0	0	12.00	0.00		
2	13.40	5	5	13.20	1.20	14.4	
3	13.45	5	10	13.50	0.30	3.6	
4	13.55	10	20	13.90	0.40	2.4	
5	14.05	10	30	14.20	0.30	1.824	
6	14.15	10	40	14.60	0.40	2.4	
7	15.00	15	55	15.00	0.40	1.6	
8	15.00	15	70	15.50	0.50	2	
9	15.00	15	85	15.80	0.30	1.2	
10	15.20	20	105	16.10	0.30	0.9	
11	15.40	20	125	16.40	0.30	0.9	
12	16.00	20	145	16.80	0.40	1.2	
13	16.30	30	175	17.00	0.20	0.4	
14	17.00	30	205	17.40	0.40	0.8	
15	17.30	30	235	17.80	0.40	0.8	



Site	:	Ramgiri
Location	:	In the field of Sh Sashikant Shrikhande.
Coordinates	:	21^0 17'15.7" & 78^0 46'5"
Date	:	7/05/2013
Initial Ground water level	:	11.00 cm
Geology	:	Basalt
Soil type	:	Clayey Loamy

Sl. No.	Clock time	Duration (m)	Cumulative Time (m)	Water level (cm)	Infiltrated water Depth (cm)	Infiltration rate (cm/hr)	Remarks
1	13.45	0	0	12.00	0.00		
2	13.50	5	5	12.80	0.80	9.6	
3	13.55	5	10	13.50	0.70	8.4	
4	14.05	10	20	14.50	1.00	6	
5	14.15	10	30	15.50	1.00	6	
6	14.30	15	45	16.50	1.00	4	
7	14.45	15	60	17.50	1.00	4	
8	15.00	15	75	18.50	1.00	4	
9	15.20	20	95	19.30	0.80	2.4	
10	15.40	20	115	20.20	0.90	2.7	
11	16.00	20	135	20.90	0.70	2.1	
12	16.30	30	165	22.00	1.10	2.2	



3.3.6 Pumping Tests

To estimate the aquifer parameters of shallow aquifer system in the watershed 21 pumping tests on open dug wells have been conducted (Fig3.54a to 3.54u). The data has been analyzed by various methods, the salient features of pumping tests are given in Table 3.14.

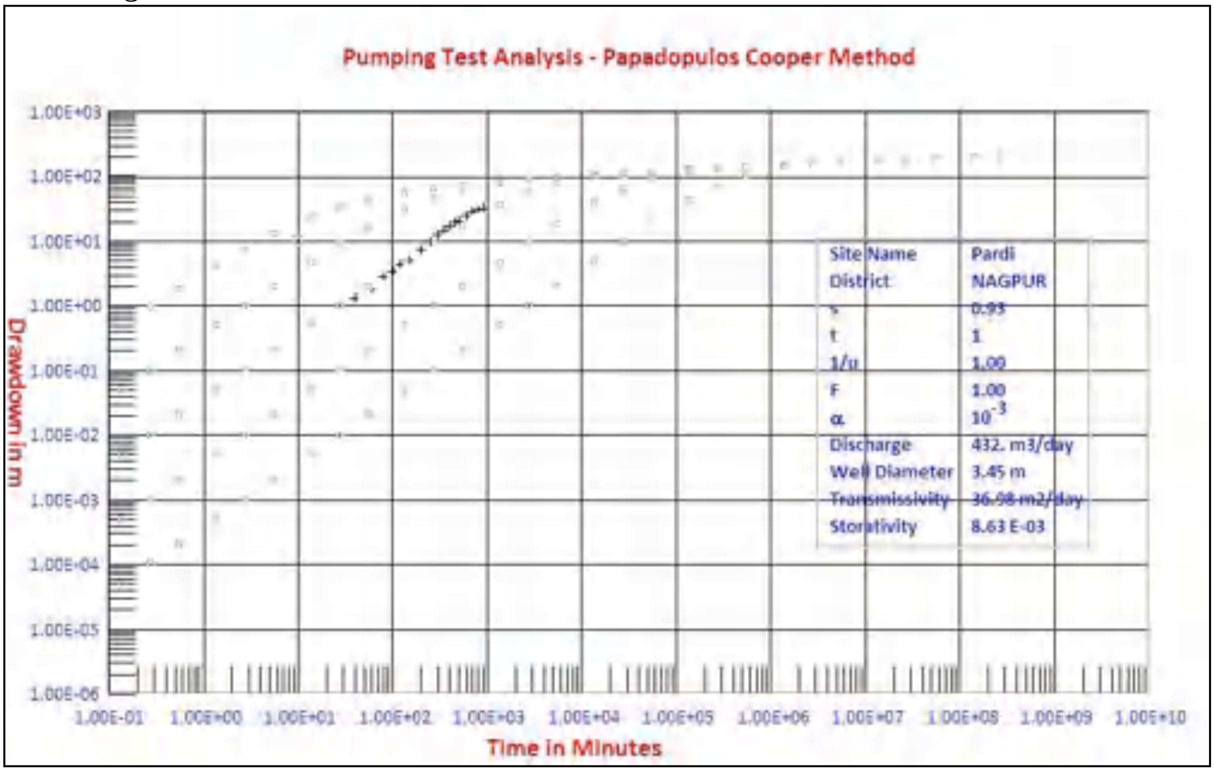
Table 3.14: Salient features of pumping tests – shallow aquifer (dug well) using Popadopulous and Cooper method

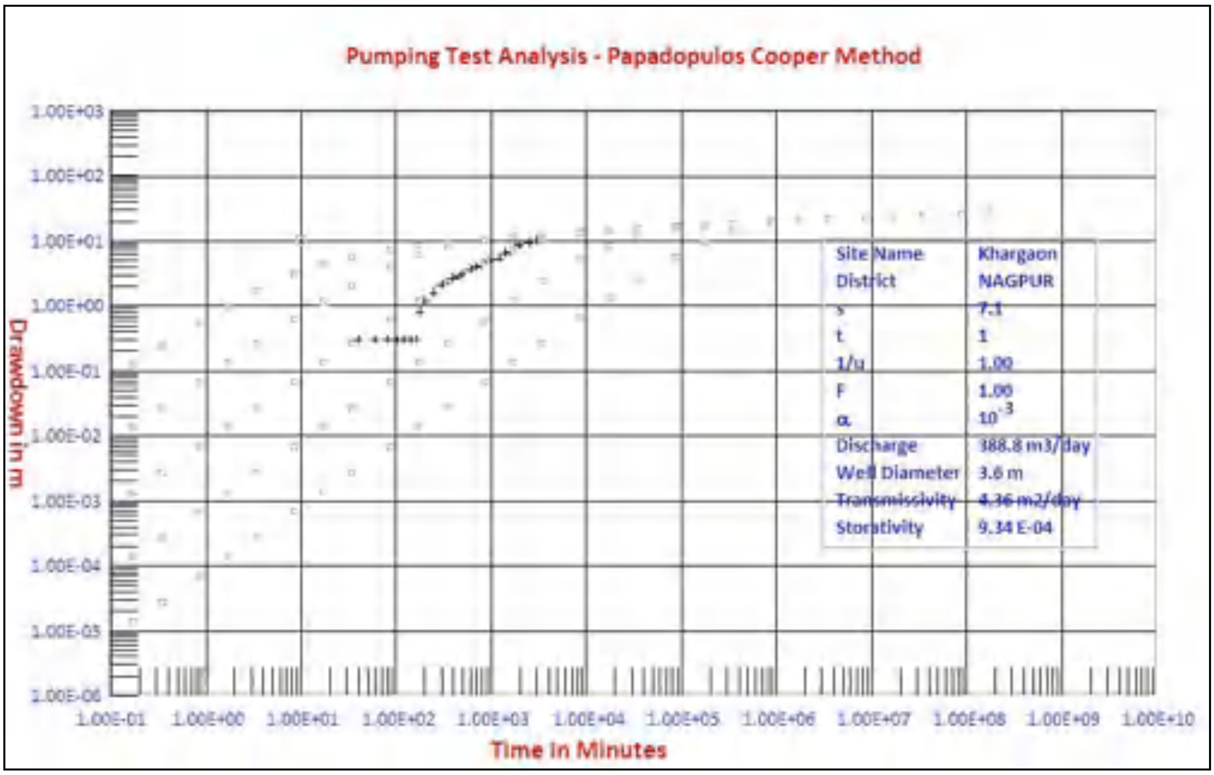
S. No.	Village	Aquifer	Dia (m)	Depth (m bgl)	SWL (m bgl)	Q (LPM)	Pt (min)	Rt (min)	D/D (m)	RDD (m)	T m^2/day)	S
1	Pardi	Basalt	3.45	12.8	9.47	300	90	300	3.2	2.09	36.98	8.63×10^{-3}
2	Khargaon	Basalt	3.6	17.2	11.43	270	300	60	1.01	0.25	4.36	$9.34x10^{-4}$
3	Dahegaon	Basalt	4.3	17.1	15.75	240	30	300	1.05	0.59	5.99	$9.01x10^{-5}$
4	Kalmeshwer	Basalt	2.65	14.3	5.27	396	130	200	1.59	0.07	13.88	$5.49x10^{-2}$
5	Kalmeshwer-east	Basalt	2.6	14	9.4	360	90	300	4.4	3.55	26.12	$1.07x10^{-3}$
6	Phetri	Basalt	2.21	13.67	10.55	300	200	130	1.78	1.49	12.20	$6.94x10^{-3}$
7	Yerla	Basalt	7.68	9.7	7.9	300	200	200	1.3	1.01	7.87	$3.71x10^{-5}$
8	Kalmeshwer gowari	Basalt	3.8	13.44	10.67	280.8	200	200	1.89	0.88	11.42	$2.20x10^{-3}$
9	Kalambi	Basalt	3.3	19.25	9.58	321	200	200	2.97	1.72	18.31	$4.67x10^{-3}$
10	Kalmeshwer selu	Basalt	3.9	13.1	9.5	240	200	200	2	1.35	11.28	$2.06x10^{-3}$
11	Sawangi	Basalt	4.55	15	11.55	316.8	70	160	1.44	1.1	10.0	$1.35x10^{-4}$
12	Ubgi	Basalt	4.7	14.3	6.66	324	130	160	3.08	2.56	16.73	$2.10x10^{-3}$
13	Brahmni	Basalt	4.65	14.6	12.52	78	240	130	0.51	0.36	1.04	$1.33x10^{-5}$
14	Gowari	Sandstone	5	20.3	14.23	132	200	200	1.46	1.01	3.64	$4.04x10^{-4}$
15	Waroda	Basalt	2.75	15.9	11.1	283.8	90	180	2.33	0.59	10.46	$3.84x10^{-3}$
16	Ghorad	Sandstone	3.4	25	17.05	308.4	60	200	1.93	0.05	11.37	$2.73x10^{-4}$
17	Goghali	Basalt	3.35	17.2	6.08	462	180	200	8.73	6.67	72.56	$1.80x10^{-2}$
18	Sonegaon	Basalt	5.24	14.4	9.38	348	180	180	2.58	1.32	14.61	$1.48x10^{-3}$
19	Dorli-Bingare	Basalt	3.35	13.05	8.82	858.6	180	180	2.44	0.08	36.59	$9.06x10^{-2}$
20	Susundri	Basalt	3.25	13	7.78	327	110	180	4.27	1.07	20.60	$5.42x10^{-3}$
21	Sawangi	Basalt	5.8	11.25	7.69	392.4	180	180	1.63	0.41	18.44	$1.52x10^{-2}$

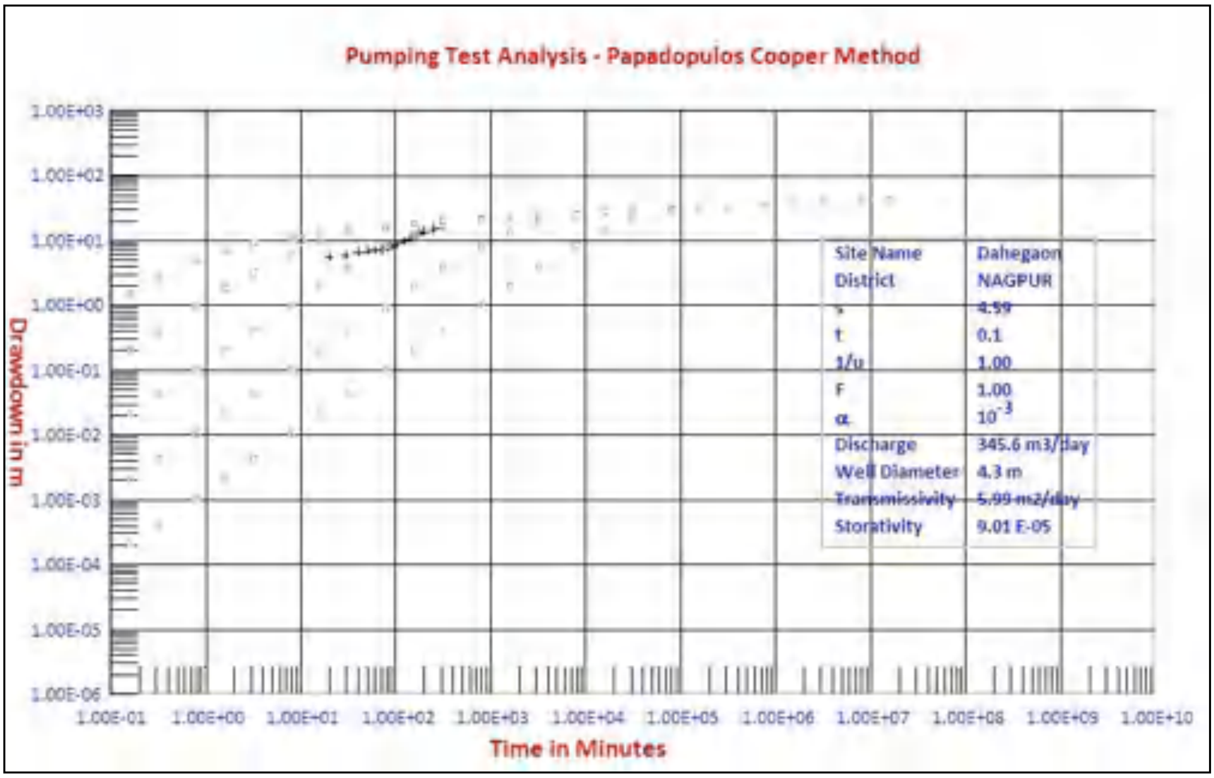
Here, Q=Discharge in liter per minute (LPM), Pt=Pumping duration in Minutes, Rt= Recovery duration in Minutes

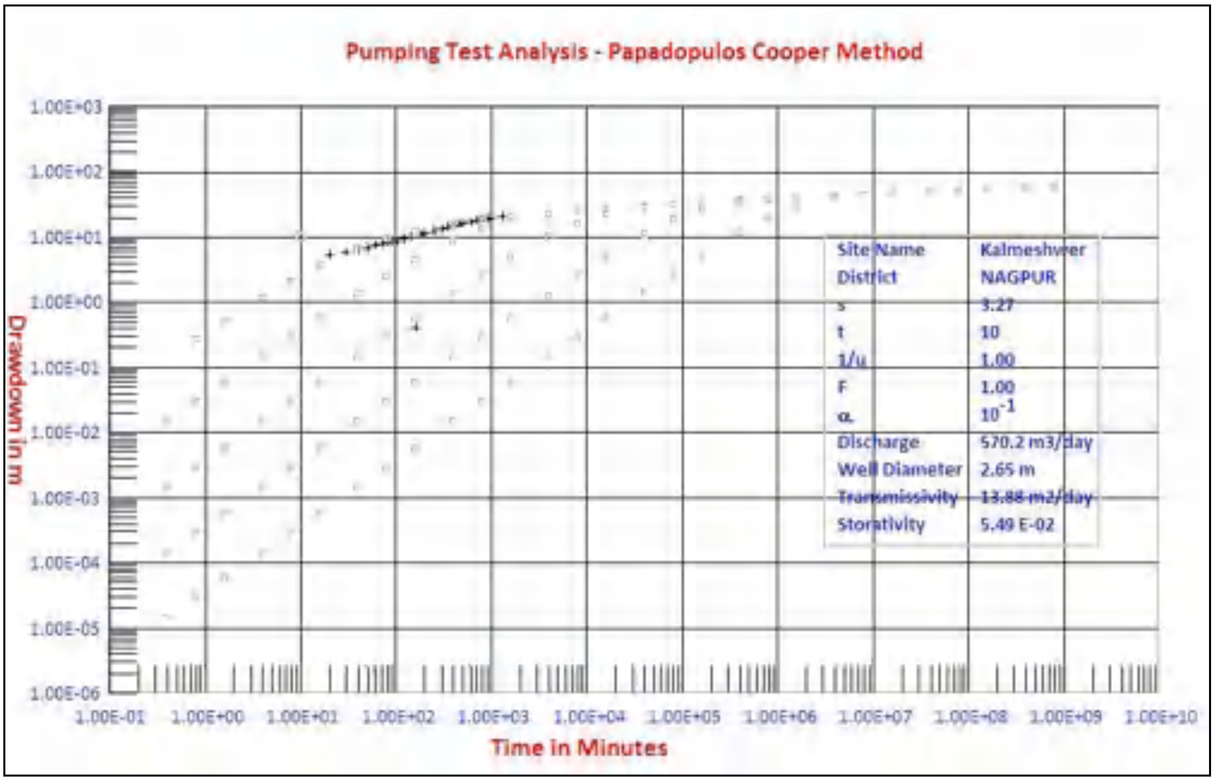
It is to note that all the pumping tests were conducted on medium to high discharge dug wells, as no dug wells having low discharge were found fitted with power pump to conduct such test. It has been observed from analytical data that the transmissivity (T) for basaltic aquifer varies from 1.04 to 72.56 m^2/day whereas for sandstone aquifer it varies from 3.64 to 11.37 m^2/day. The graphs depicting the calculus part of Popadopulous and cooper method are presented below. The aquifer parameters derived from the pumping test of large diameter wells are used for ground water modelling.

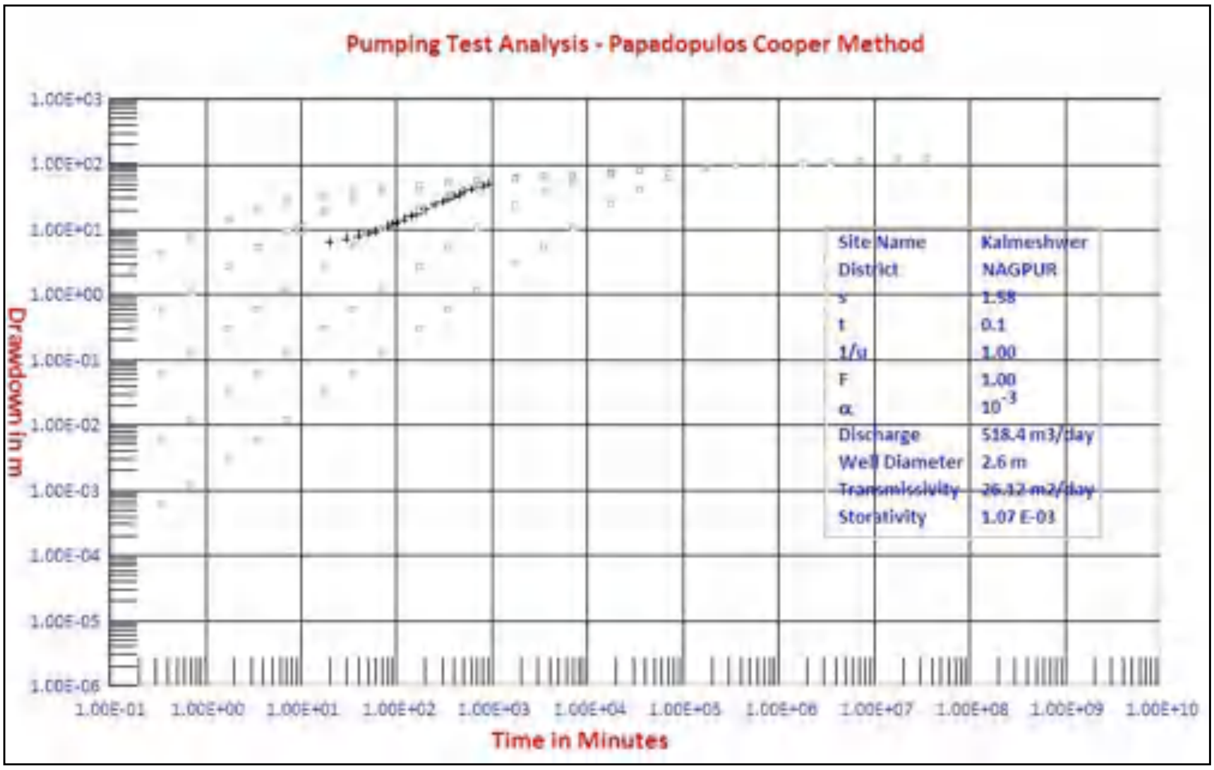
Fig. 3.54a to 3.54u

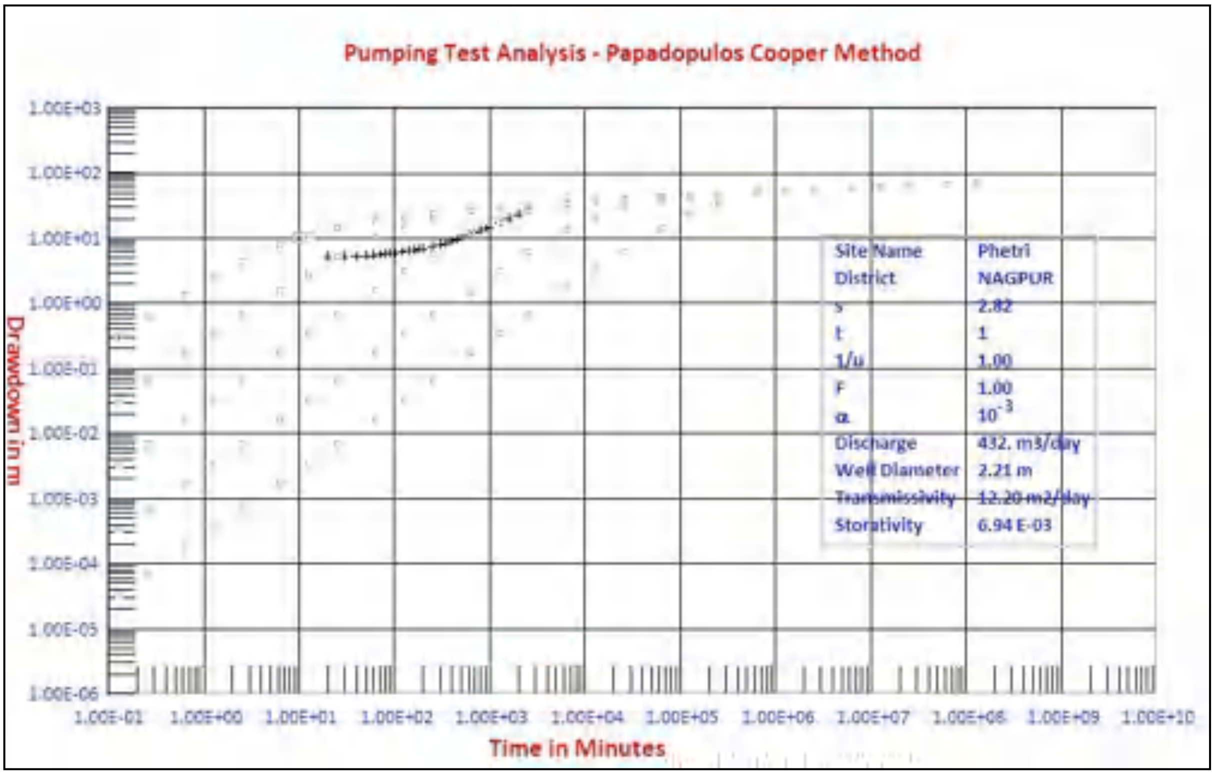


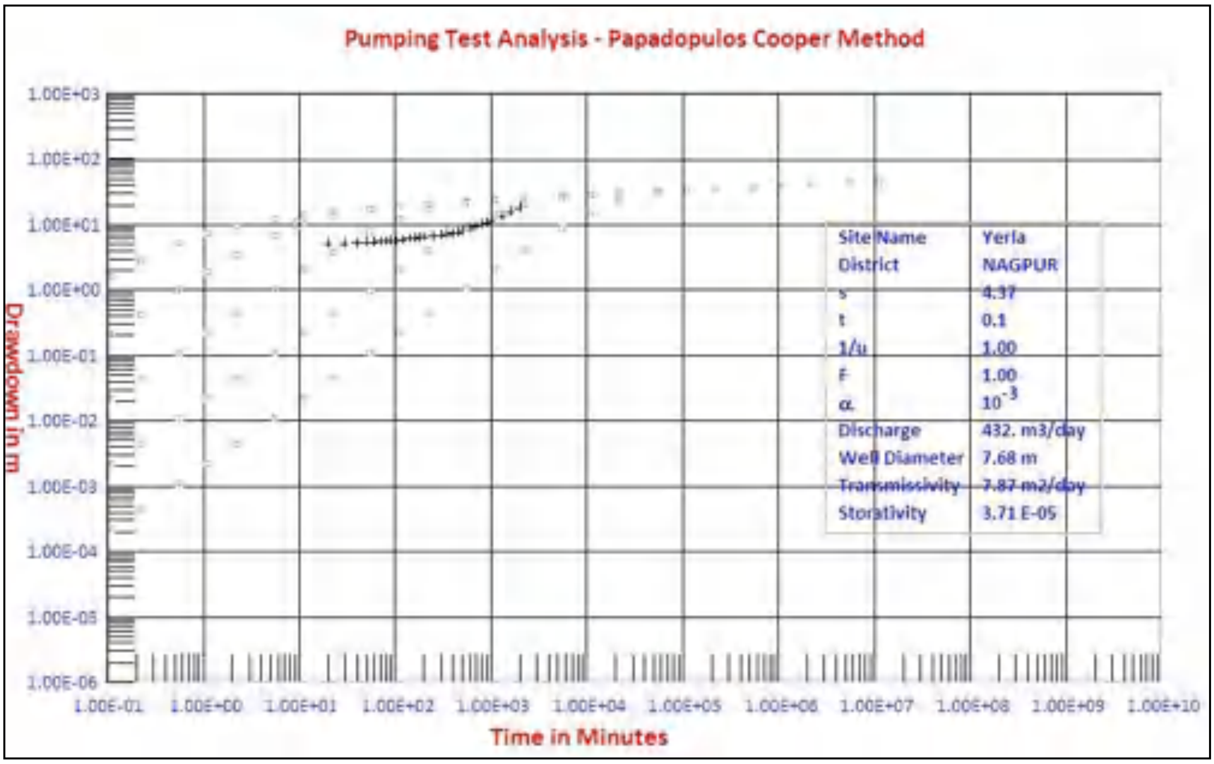


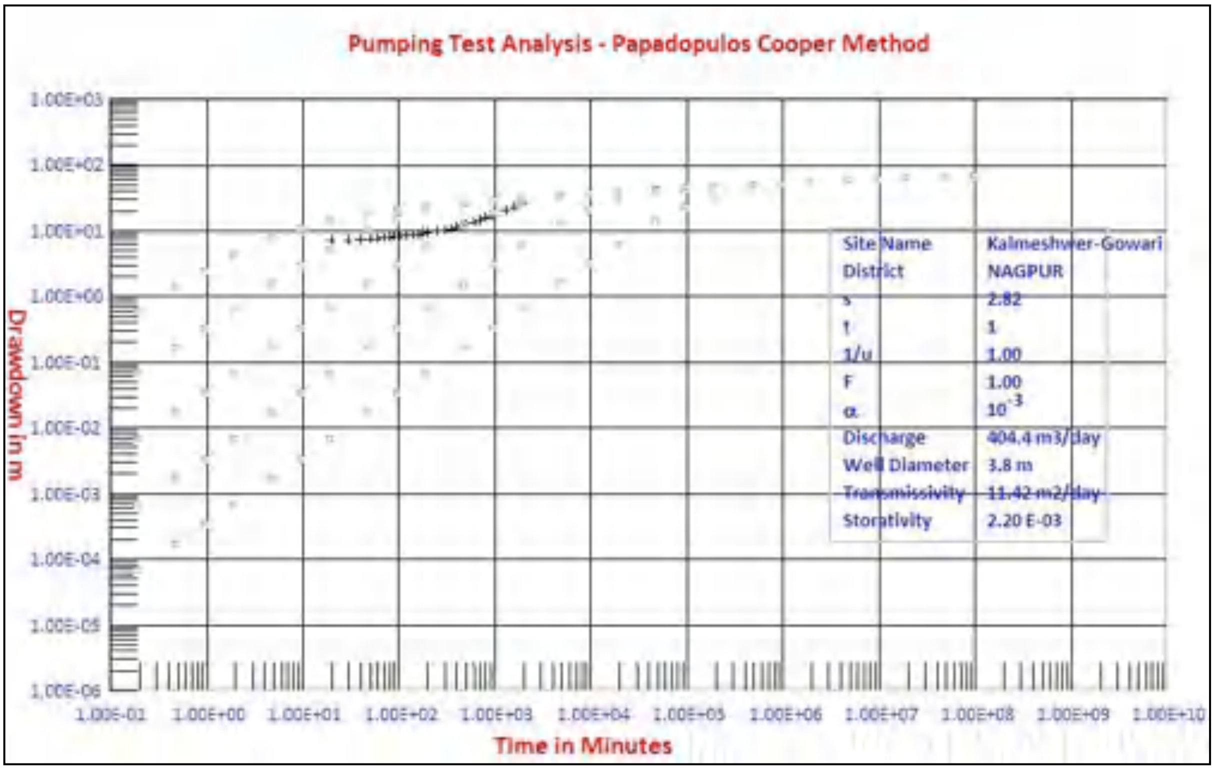

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name | Dahegaon
District | NAGPUR
s | 4.59
t | 0.1
1/u | 1.00
F | 1.00
α | 10-3
Discharge | 345.6 m3/day
Well Diameter | 4.3 m
Transmissivity | 5.99 m2/day
Storativity | 9.01 E-05

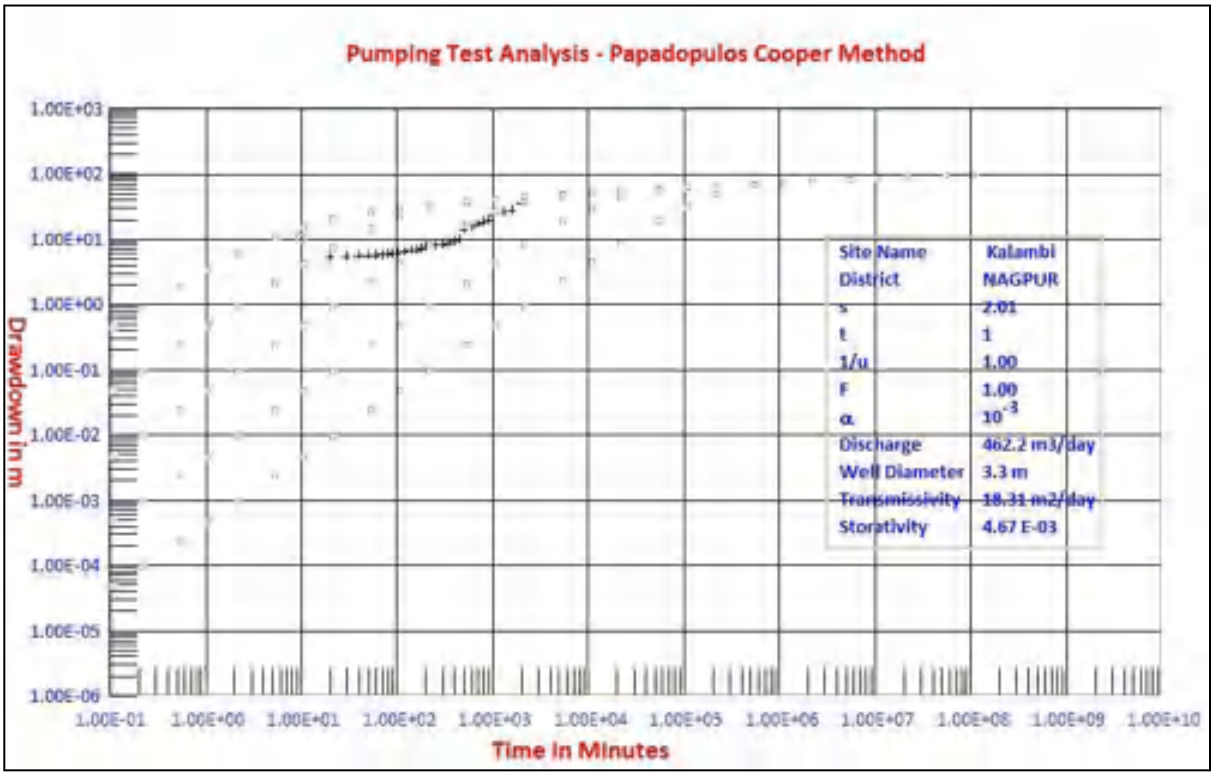

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name | Kalmeshwer
District | NAGPUR
s | 3.27
t | 10
1/u | 1.00
F | 1.00
α | 10-1
Discharge | 570.2 m3/day
Well Diameter | 2.65 m
Transmissivity | 13.88 m2/day
Storativity | 5.49 E-02

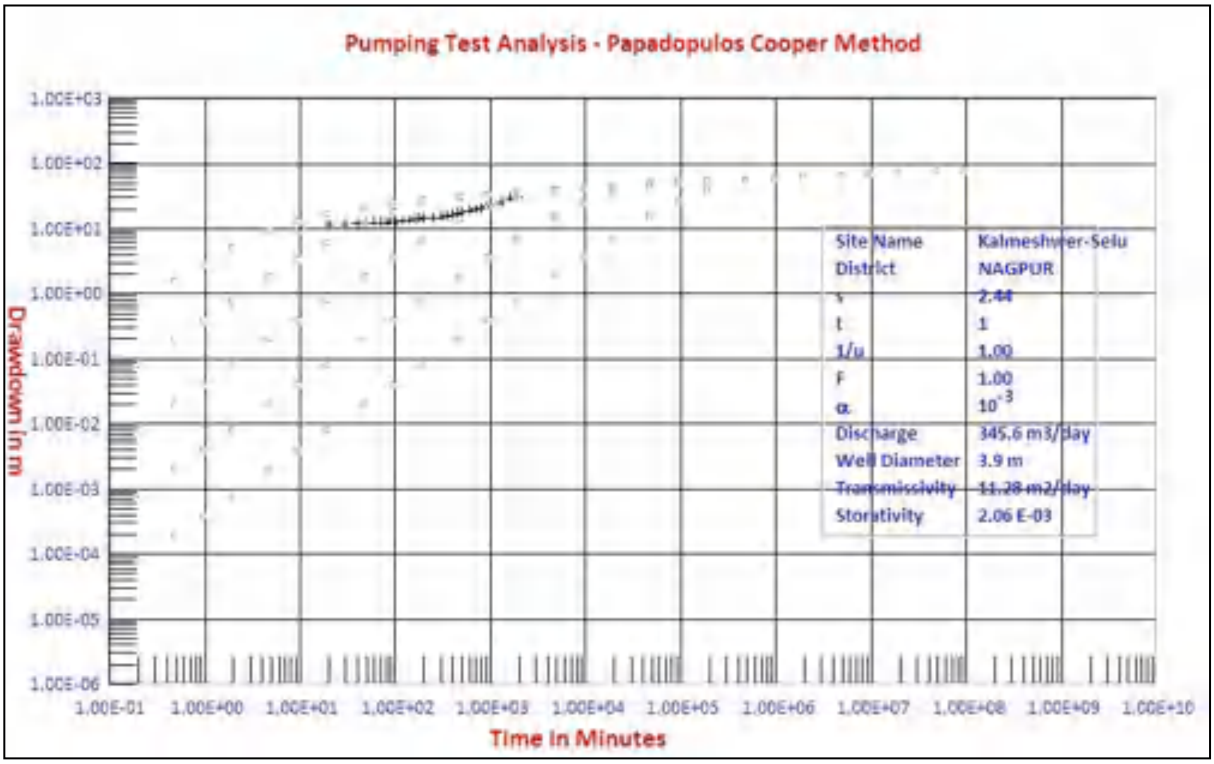

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name | Kalmeshwer
District | NAGPUR
s | 1.58
t | 0.1
1/u | 1.00
F | 1.00
α | 10^-3
Discharge | 518.4 m3/day
Well Diameter | 2.6 m
Transmissivity | 26.12 m2/day
Storativity | 1.07 E-03

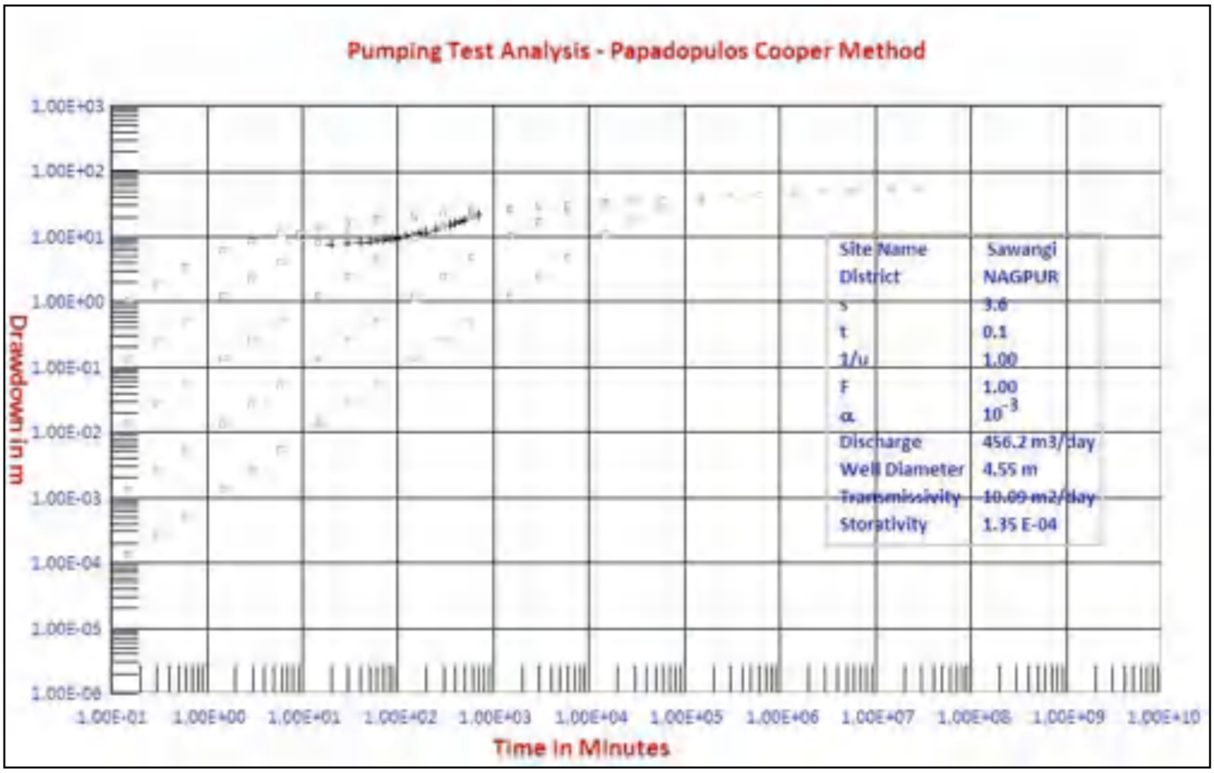

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name | Phetri
District | NAGPUR
s | 2.82
t | 1
1/u | 1.00
F | 1.00
α | 10^-3
Discharge | 432. m3/day
Well Diameter | 2.21 m
Transmissivity | 12.20 m2/day
Storativity | 6.94 E-03

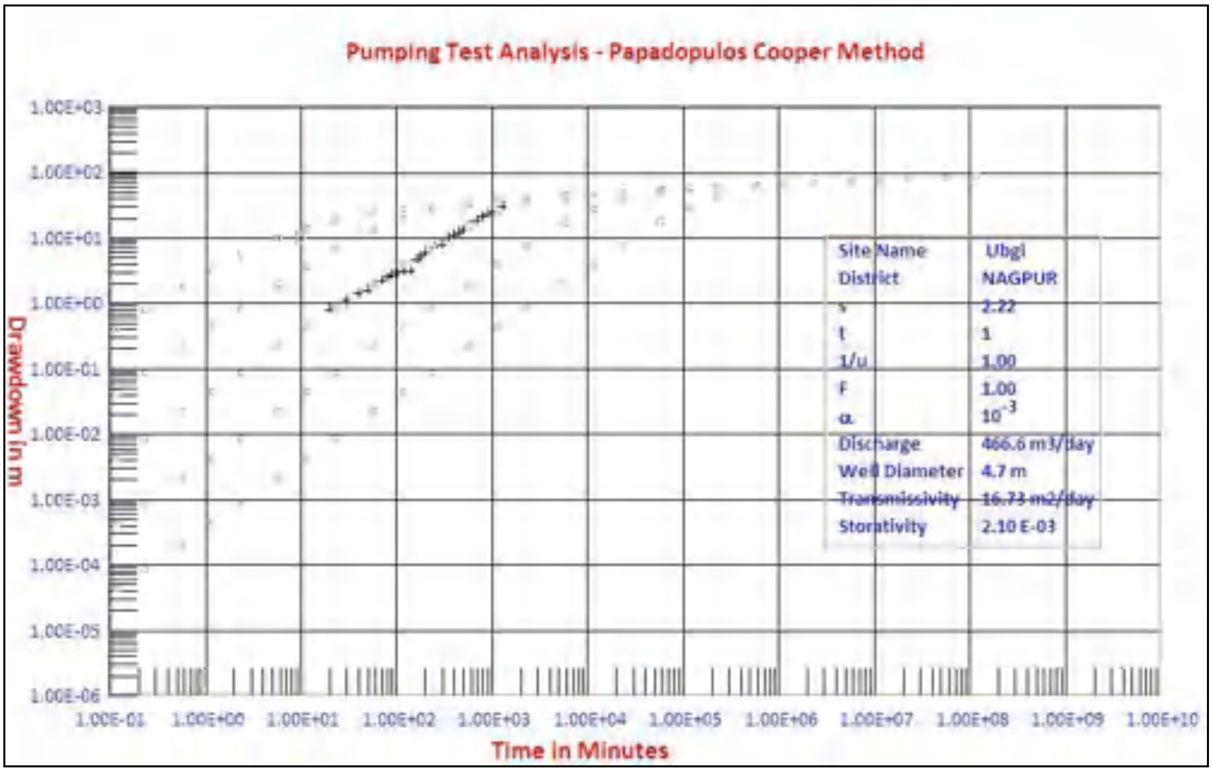

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Yerla
District NAGPUR
s 4.37
t 0.1
1/u 1.00
F 1.00
α 10-3
Discharge 432. m3/day
Well Diameter 7.68 m
Transmissivity 7.87 m2/day
Storativity 3.71 E-05


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Kalmeshwer-Gowari
District NAGPUR
s 2.82
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 404.4 m3/day
Well Diameter 3.8 m
Transmissivity 11.42 m2/day
Storativity 2.20 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name Kalambi
District NAGPUR
s 2.01
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 462.2 m3/day
Well Diameter 3.3 m
Transmissivity 18.31 m2/day
Storativity 4.67 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name Kalmeshwer-Selu
District NAGPUR
s 2.44
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 345.6 m3/day
Well Diameter 3.9 m
Transmissivity 11.28 m2/day
Storativity 2.06 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Sawangi
District NAGPUR
s 3.6
t 0.1
1/u 1.00
F 1.00
α 10-3
Discharge 456.2 m3/day
Well Diameter 4.55 m
Transmissivity 10.09 m2/day
Storativity 1.35 E-04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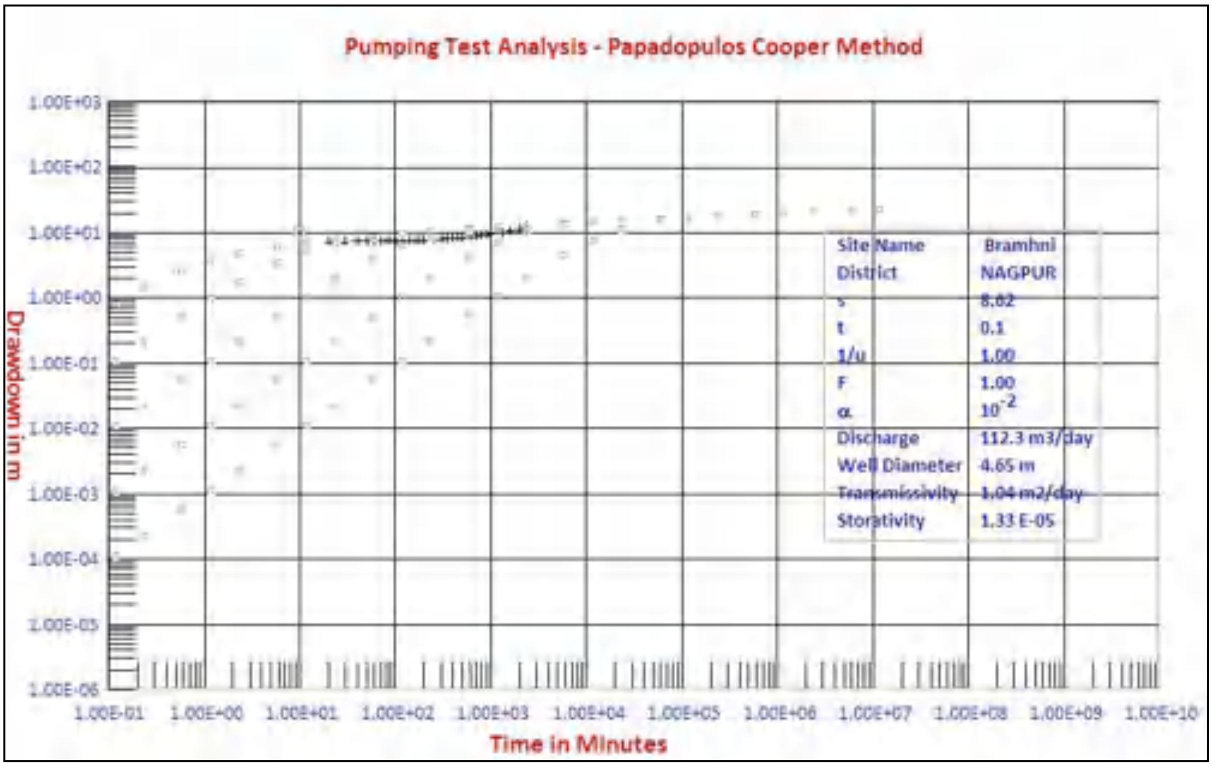
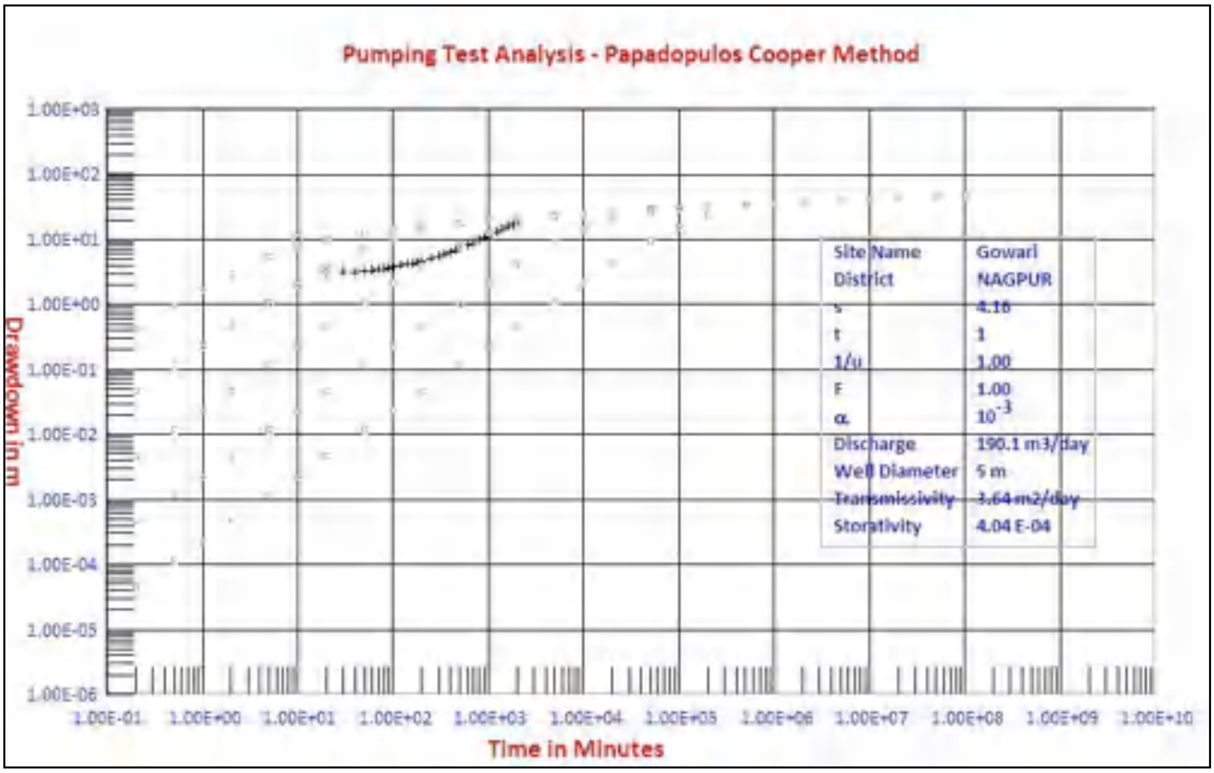
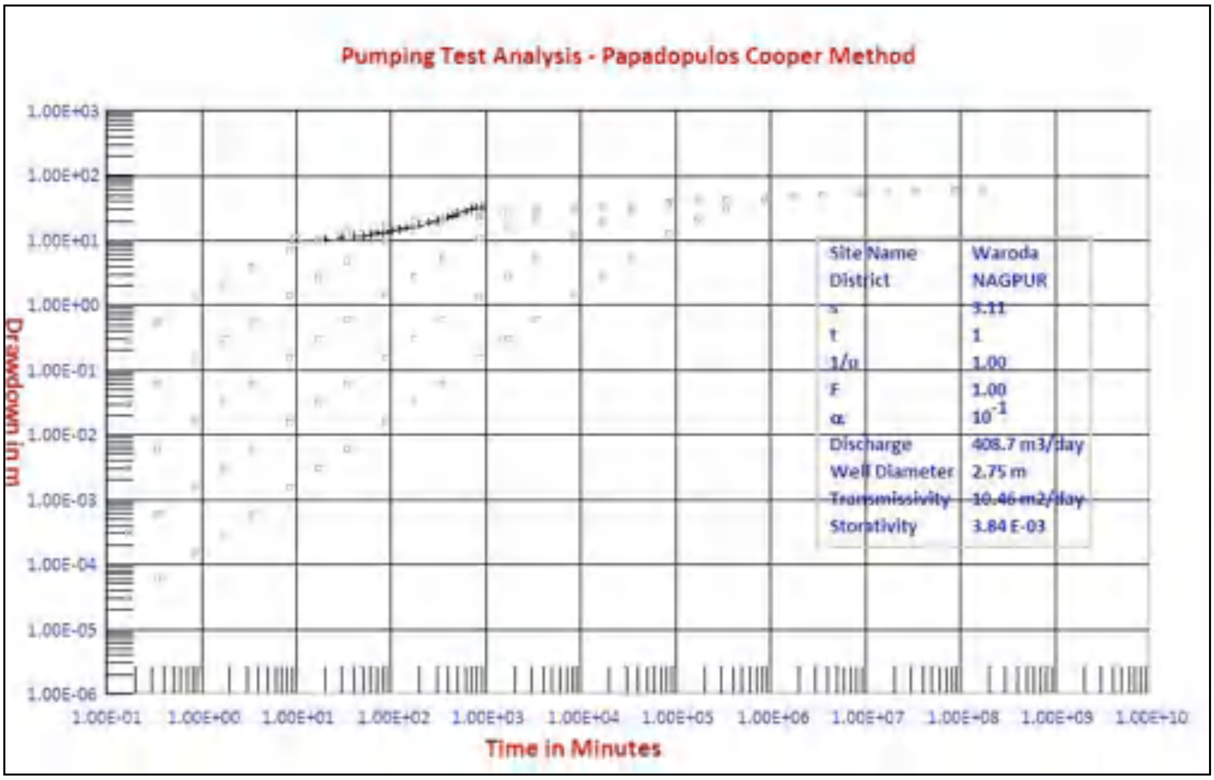
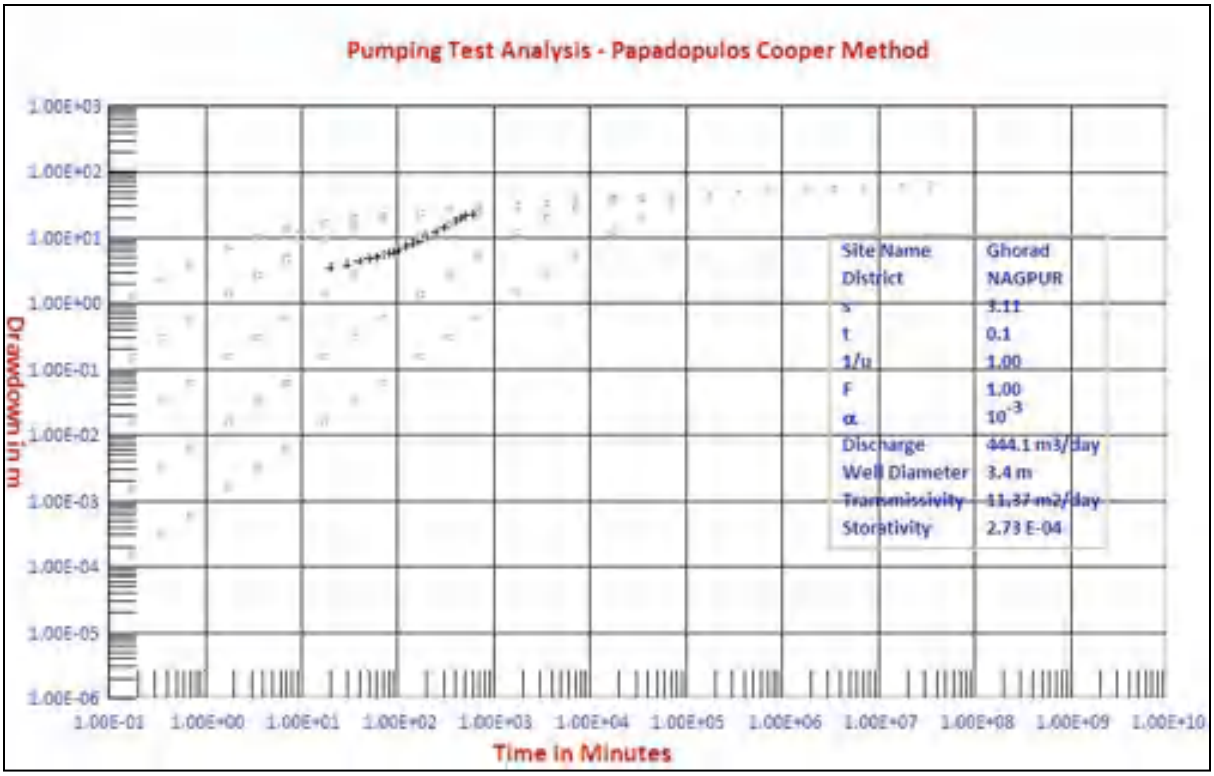
Drawdown in m
Time in Minutes
Site Name Ubgi
District NAGPUR
s 2.22
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 466.6 m3/day
Well Diameter 4.7 m
Transmissivity 16.73 m2/day
Storativity 2.10 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Bramhni
District NAGPUR
s 8.02
t 0.1
1/u 1.00
F 1.00
α 10^-2
Discharge 112.3 m3/day
Well Diameter 4.65 m
Transmissivity 1.04 m2/day
Storativity 1.33 E-05

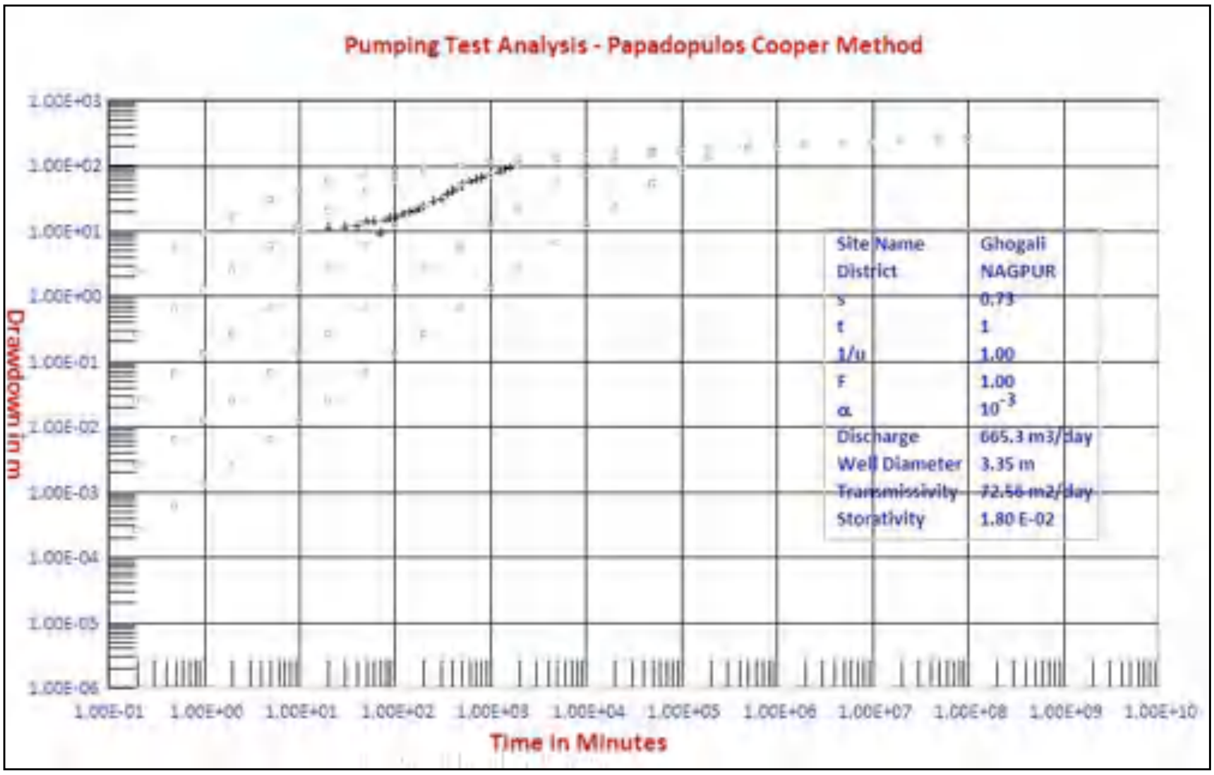

Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Gowari
District NAGPUR
s 4.16
t 1
1/u 1.00
F 1.00
α 10^-3
Discharge 190.1 m3/day
Well Diameter 5 m
Transmissivity 3.64 m2/day
Storativity 4.04 E-04

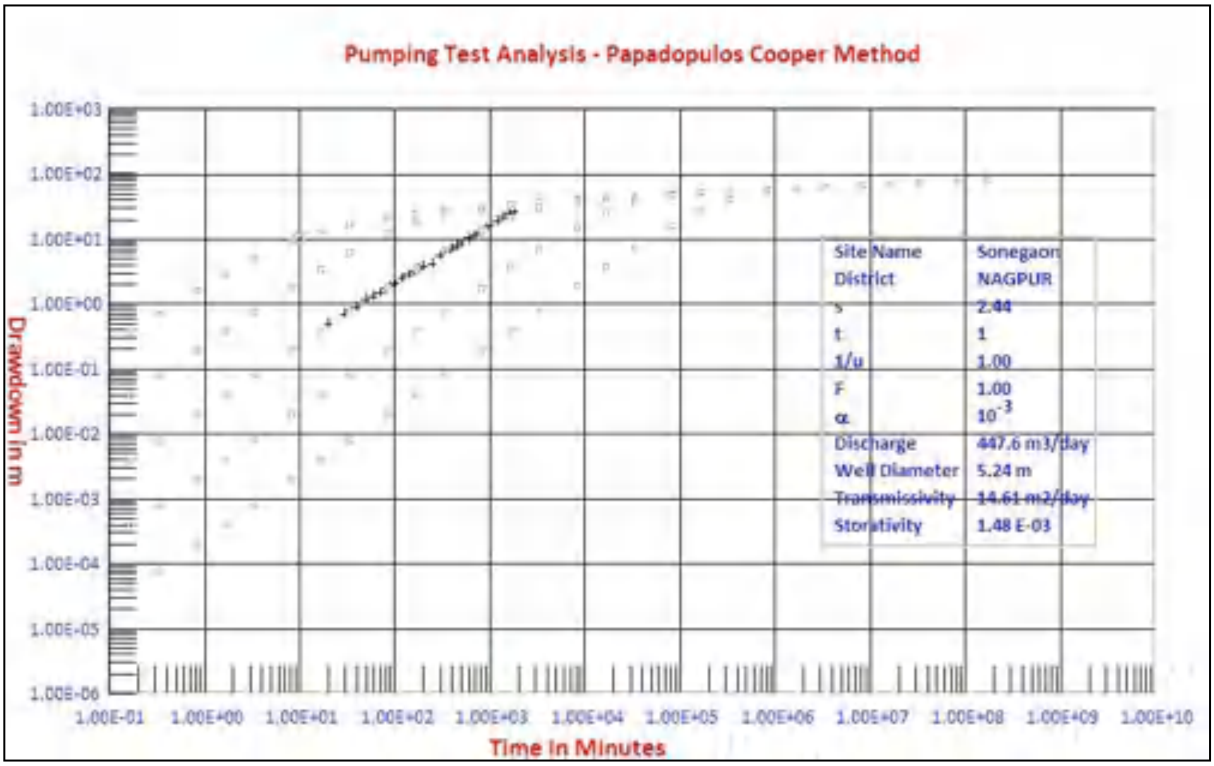


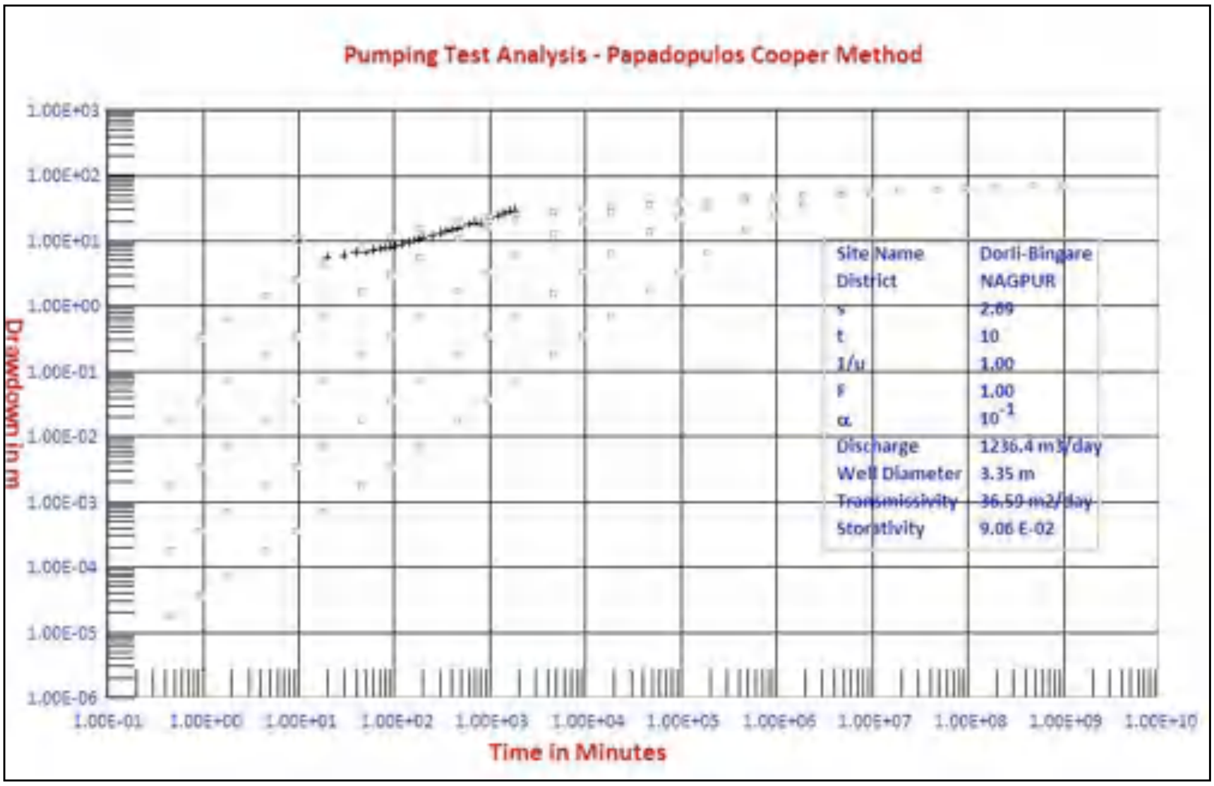
Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name Waroda
District NAGPUR
s 3.11
t 1
1/u 1.00
F 1.00
α 10-1
Discharge 408.7 m3/day
Well Diameter 2.75 m
Transmissivity 10.46 m2/day
Storativity 3.84 E-03

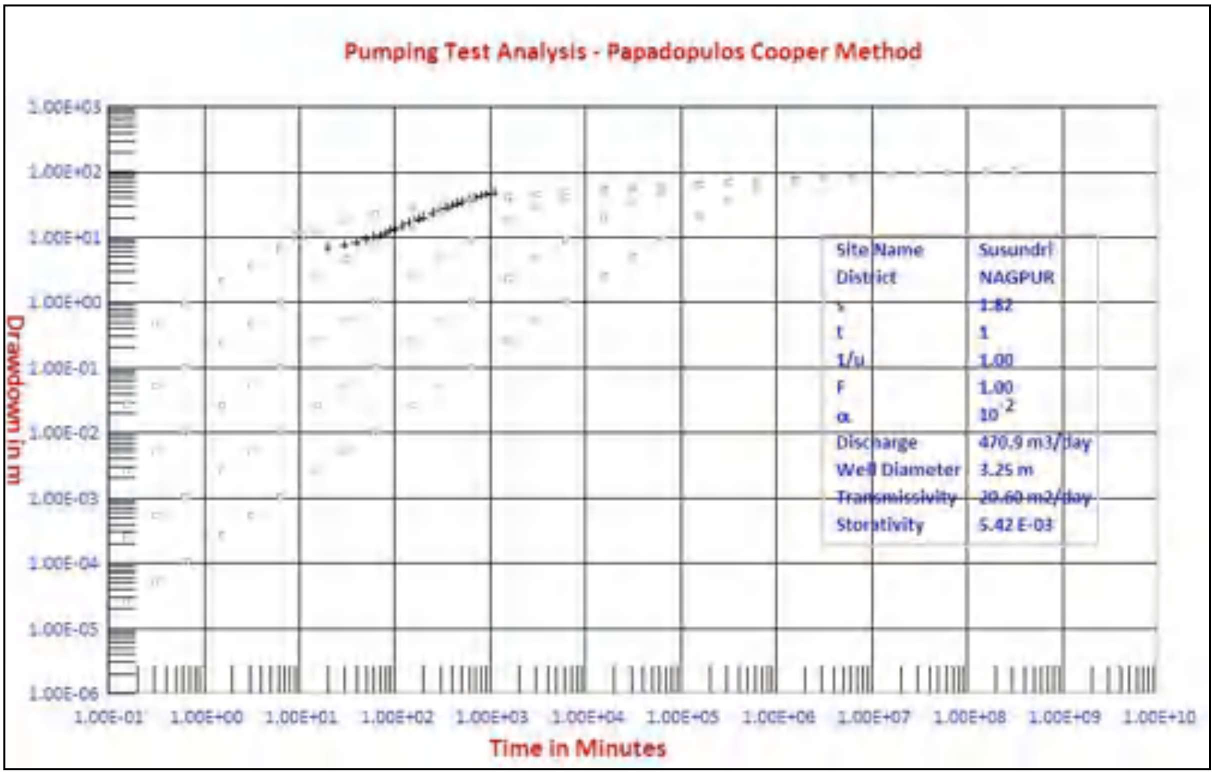


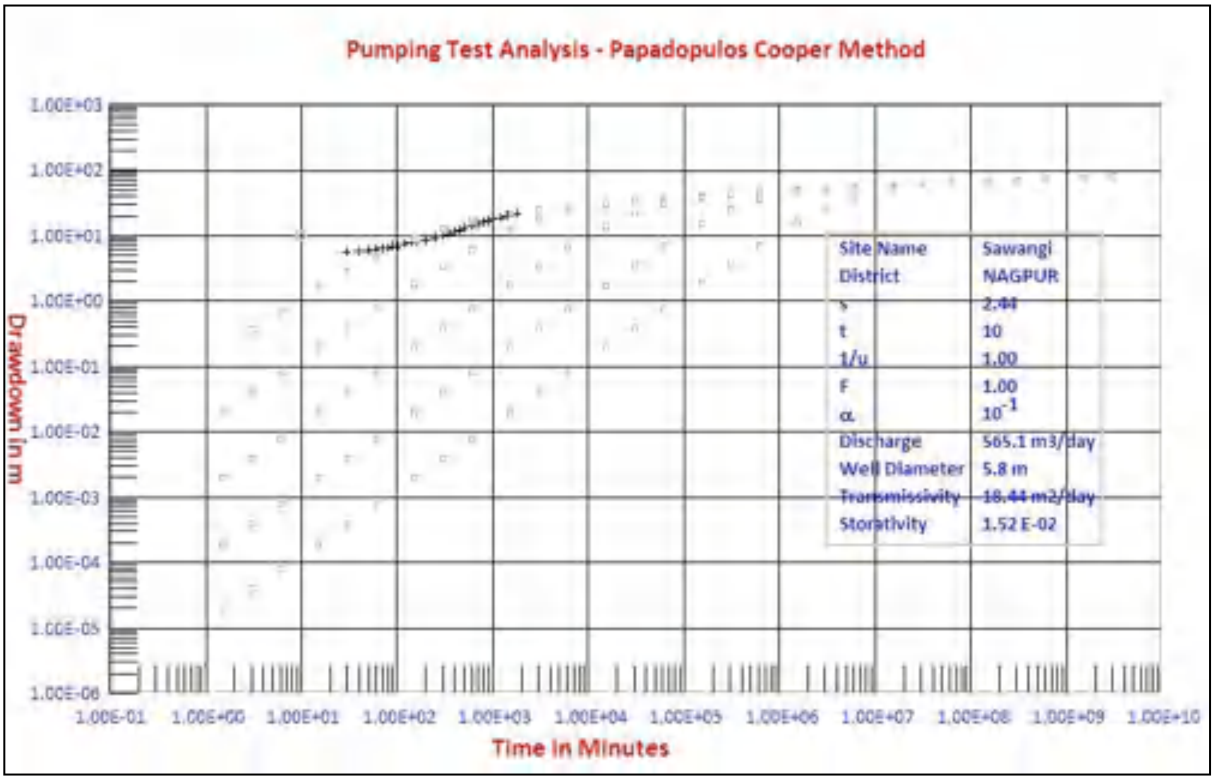
Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Site Name Ghorad
District NAGPUR
s 3.11
t 0.1
1/u 1.00
F 1.00
α 10-3
Discharge 444.1 m3/day
Well Diameter 3.4 m
Transmissivity 11.37 m2/day
Storativity 2.73 E-04


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Ghogali
District NAGPUR
s 0.73
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 665.3 m3/day
Well Diameter 3.35 m
Transmissivity 72.56 m2/day
Storativity 1.80 E-02


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
Site Name Sonegaon
District NAGPUR
s 2.44
t 1
1/u 1.00
F 1.00
α 10-3
Discharge 447.6 m3/day
Well Diameter 5.24 m
Transmissivity 14.61 m2/day
Storativity 1.48 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01 1.00E+00 1.00E+01 1.00E+02 1.00E+03 1.00E+04 1.00E+05 1.00E+06 1.00E+07 1.00E+08 1.00E+09 1.00E+10
Site Name Dorli-Bingare
District NAGPUR
s 2.89
t 10
1/u 1.00
F 1.00
α 10-1
Discharge 1236.4 m3/day
Well Diameter 3.35 m
Transmissivity 36.59 m2/day
Storativity 9.06 E-02


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
Time in Minutes
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01 1.00E+00 1.00E+01 1.00E+02 1.00E+03 1.00E+04 1.00E+05 1.00E+06 1.00E+07 1.00E+08 1.00E+09 1.00E+10
Site Name Susundri
District NAGPUR
s 1.82
t 1
1/u 1.00
F 1.00
α 10-2
Discharge 470.9 m3/day
Well Diameter 3.25 m
Transmissivity 20.60 m2/day
Storativity 5.42 E-03


Pumping Test Analysis - Papadopulos Cooper Method
Drawdown in m
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
1.00E+07
1.00E+08
1.00E+09
1.00E+10
Time in Minutes
Site Name Sawangi
District NAGPUR
s 2.44
t 10
1/u 1.00
F 1.00
α 10-1
Discharge 565.1 m3/day
Well Diameter 5.8 m
Transmissivity 18.44 m2/day
Storativity 1.52 E-02

4 DATA INTEGRATION

To cover the entire area of Chandrabhaga Watershed (WGKKC-2) through geophysical surveys, the survey work has been outsourced to NGRI, Hyderabad. Modern state of art Heliborne Geophysics, the major component of the AQUIM project, has been done by NGRI, Hyderabad in collaboration with Aarhus University, Denmark using dual moment SkyTEM system developed at Aarhus University, operated, and owned by SkyTEM Survey Aps, Denmark. Dual moment ensures high-resolution information from top to deeper level by means of low and high moments. Originally, it was planned to carry out SkyTEM surveys first and followed by its ground truth by ground-based investigation. However, due to too tight time schedule and complicated and lengthy administrative procedures; it could be flown during month of November 2013 over Chandrabhaga Watershed (WGKKC-2) Nagpur area. Focus of the survey is to map the principal aquifers within intertrappeans, fractured vesicular/ amygdaloidal basalt and transition zone of Basalt-Gondwanas up to maximum 200 m depth. The result of this project is also aimed to set the road map by establishing efficient, cost effective, and fast methodology for high-resolution aquifer mapping that could be up scaled to nationwide aquifer mapping programme (NAQUIM) (NGRI, 2015).

Overview of the SkyTEM system

SkyTEM is a time-domain helicopter borne electromagnetic system designed for hydro-geophysical, environmental and mineral investigations. The following contains a general introduction to the SkyTEM system. The SkyTEM system with the hexagonal frame below the helicopter. The lengths of the frame sides are approximately 11 m. The transmitter loop is mounted on the frame in an octagonal polygon configuration. The receiver loop is placed approximately 2 m above the frame in what is roughly a central loop configuration with a vertical offset. Two lasers placed on the frame measure the distance to terrain continuously while flying, and two inclinometers measure the tilt of the frame. Power is supplied by a generator placed between the helicopter and the frame. The positions of the different devices on the frame (Fig. 4.1). The configuration of the system is customized for each survey. Measurements are carried out with one or two transmitter moments, depending on the target geology. The standard configuration uses a low and a high transmitter moment applied sequentially. Each sequence has between 100 and 200 individual transient measurements. Background noise is measured for each 20 sec.

The flight altitude is depending on flight speed, topography, etc. A typical nominal flight altitude is 30-50 m. Over forested areas, the altitude is increased to maintain a necessary safety distance to the treetops. The operating speed is customized to the survey area and target. A typical nominal flight speed is 45-90 km/h, depending on the target. Apart from GPS-, altitude- and TEM data, a number of instrument parameters are monitored and stored digitally in order to be used for quality control when the data are processed. The penetration depth for the SkyTEM system depends on the moment, the geological conditions, the level of the background noise and the speed and altitude of the frame. The influence of the latter is important, and in order to achieve good data, the altitude should normally be less than 50 m. A penetration depth of approximately 200-250 m can normally be achieved in hard rock geology. During the inversion a depth of investigation is estimated for each resistivity model (NGRI, 2015).

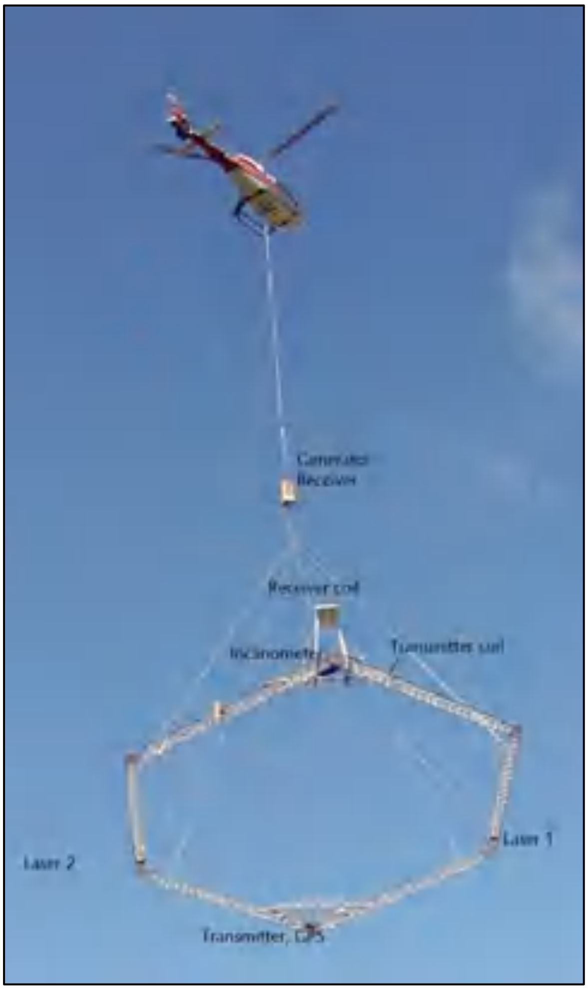


Fig. 4.1: The airborne SkyTEM system (NGRI, 2015)

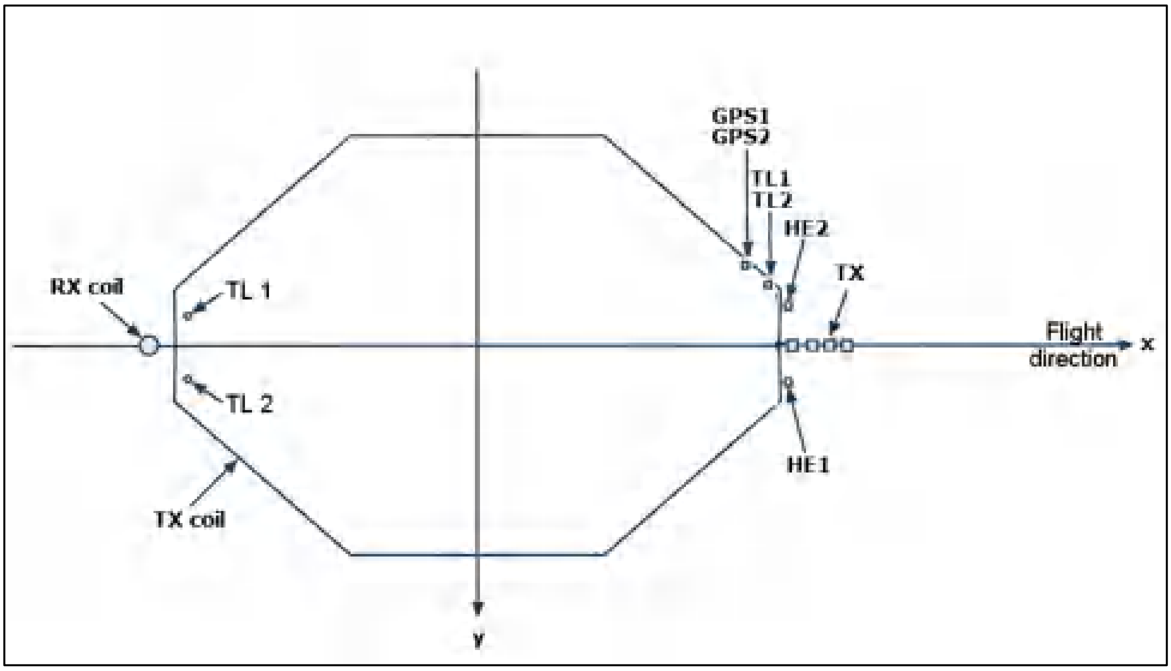


Fig. 4.2: Instrument setup for the SkyTEM system used. HE 1 and 2 is laser altimeters, TL 1 and 2 inclinometer, GPS 1 and 2 GPS sensors, Tx the transmitter (NGRI, 2015).

Survey was influenced by Nagpur airport and permission was not given for 171 km2 (48%) to fly during flights landing or take off from Nagpur airport. Hence, only 189 km2 (52%) area was covered among total study area of 360 km2. The actual field survey took place from the November 10th to 18th, 2013 for nine days; where in total 954-line km of data were acquired. The details of nine days heliborne survey are: total survey days are seven, non-flown/off days are one and test flown days are one while the total flying time is 28 Hrs 17 min. The individual flight lines were closely spaced with only 200 m of separation and the average flight speed of the helicopter was 17 m/s with an average flight altitude (frame height) of 35 m above the ground. Even though the survey area is influenced by man-made installations, the general data quality of the acquired data is good (NGRI, 2015).

The collected SkyTEM data were subsequently processed with state of the art processing schemes to remove couplings arising from roads and man-made installations such as iron pipes, buried cables and possibly also closed iron sheep fences. Afterwards the data were inverted with preliminary inversion to make sure all the coupled and noisy data had been removed, and furthermore to establish a suitable starting model for the entire survey area. The preliminary inversions thus suits as a quality check of the previous processing. Finally the data were inverted with a smooth model using the spatially constrained inversion (SCI) approach (NGRI, 2015).

4.1 Integration of data from Conventional and Advanced Techniques

The geophysical methods adapted in the AQMAH pilot area, i.e., Chandrabhaga watershed (WGKKC-2) have been described in the Table 4.1. The ground based and air borne geophysical methods have been validated and integrated to acquire the data gaps. The integration has assisted in deciphering the disposition of geological formations and their extension on lateral scale. The demarcation of geological formation such as individual flows separated by intertrappeans has been useful information in delineating the aquifer systems. Thus the geophysical data base has been transformed into lithological model and subsequently in to hydrogeological model. The geophysical methods employed in the pilot area have been shown in Table 4.1 (NGRI, 2015).

Table 4.1: Geophysical methods/ Techniques employed in Chandrabhaga watershed (WGKKC-2) (NGRI, 2015)

Methods			Techniques	Geophysical parameters	Applications
Air-borne		Electromagnetic (Time Domain)		layer conductivity (inverse of resistivity) and thickness	Almost continuous information on Aquifer geometry in 3D
Surface	**1-D Geophysics**	Resistivity,	Vertical electrical soundings	layer resistivity and thickness	Aquifer/aquitard characteristics and thickness
		Transient Electromagnetic	sounding	layer conductivity and thickness	Aquifer/aquitard characteristics and thickness
	2-D Geophysics	Resistivity	Electrical resistivity tomography	Spatial distribution of resistivity and thickness	Aquifer geometry
		Seismic	High Resolution Seismic	Formation velocity	Depth of basement
Sub-surface		Borehole Logging	Short Normal, Long Normal, Lateral, SP and natural Gamma	In-situ physical property measurements	Precise delineation of aquifer and well design

At the outset, it was planned (Fig. 4.3) to carry out the heliborne geophysical data acquisition just after the compilation of existing data in the area and conceptualization of the existing aquifer system. Followed by its validating by ground based measurements such as VES, TEM, ERT, drilling, borehole logs, etc., and then integration and inversion of all the data depending on their sensitivity leading into realistic aquifer models and their characteristics. However, management and time constraints forced to modify the original plan broadly in three phases i.e. pre-SkyTEM, SkyTEM and post-SkyTEM. SkyTEM survey took place in the month of Sept-Oct., 2013. Detailed activity vs. time chart is given in Figure 4.3 and Table 4.1.

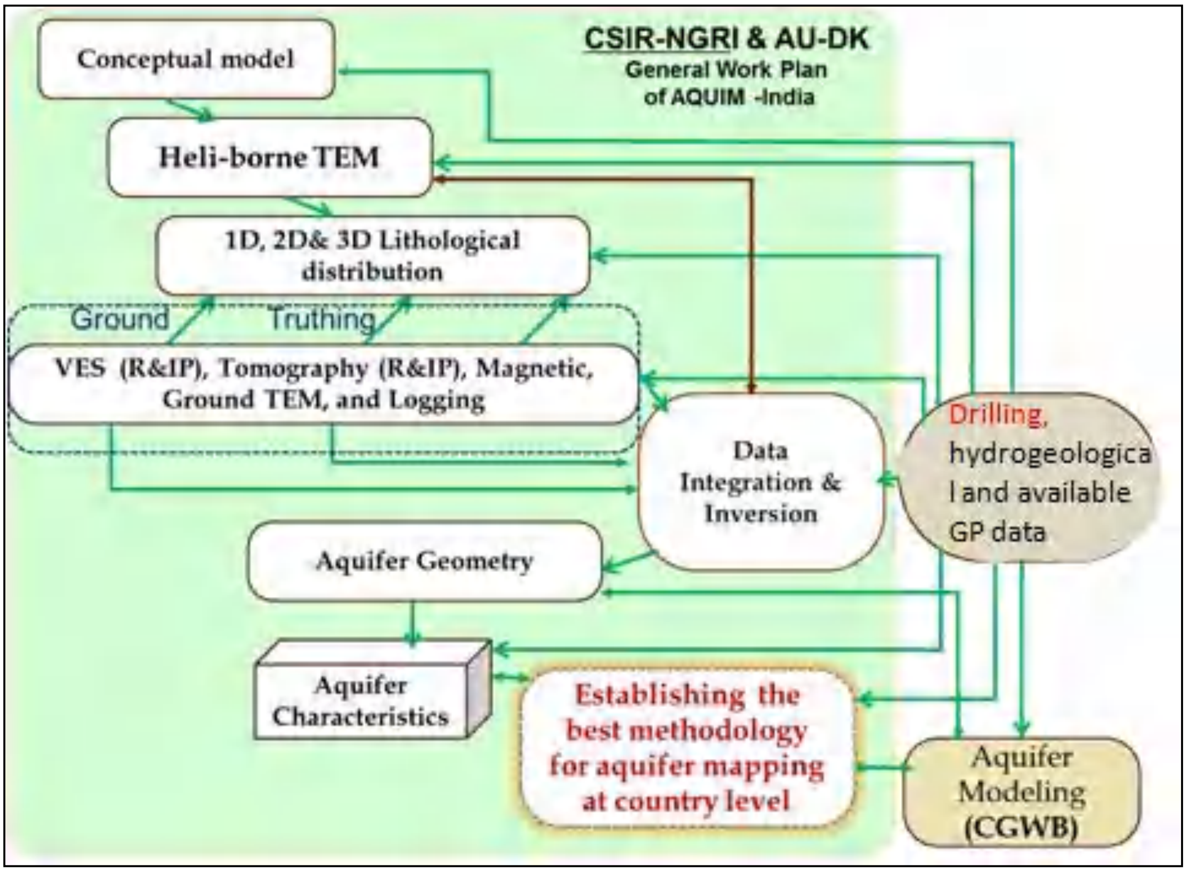


Fig. 4.3: Original work plan conceived at start of the project, Chandrabhaga watershed (WGKKC-2) (NGRI, 2015)

Table 4.2: Details of SkyTEM survey AQMAH 2013, Chandrabhaga watershed (WGKKC-2) (NGRI, 2015)

Locality	Chandrabhaga watershed (WGKKC-2), AQMAH, India
Field Period	November 10th - 18th, 2013
Line km planned	954 km
Line km acquired	954 km
Flight Line separation	200 m
Tie Line separation	2000 m
Average flight speed	~17 m/s
Average flight altitude (frame height)	35 m above the ground

In order to achieve one of the main objectives of mapping the aquifers, an approach has been established to translate the geophysical results into the hydrogeological models through the steps as follows:

a. SkyTEM results are calibrated against the drilling lithologs, ground and borehole geophysical results and then integrated lithological log at each borehole are prepared.
b. Equivalent litho-units of the integrated logs are converted into principal litho-units as proxy of principal aquifer and aquitard.
c. The principal lithologs are imported to the Arhus Workbench and incorporated with the individual sections prepared at each 2 km x 2 km grid line.
d. The principal litho-facies are interpolated and extrapolated along the SkyTEM sections using the calibrated resistivity values.
e. The principle lithological units are finally attributed into principal aquifers, confining layers and Basalt-Gondwana interface.

Lithological layer boundaries are prepared for all possible SCI model separated ~25 m from each other along the grid lines. This is followed by gridding using the kriging interpolation scheme. Of course, the interpolation has averaged out some of the sharp anomalies indicating smooth variation. In order to retain the small-scale variation, it is desired to do the digitization and demarcation of lithological boundaries for all the flight lines (NGRI, 2015).

The HeliTEM survey was carried out in the period November 10th - 18th, 2013. The survey area is located near to city Nagpur city in central India (Fig. 4.4). The full survey holds 954-line km and covers an area of 189 km2. The line spacing is 200 m. The average flight speed was approximately 17 m/s with an average flight altitude of 30 m (frame height) (NGRI, 2015).

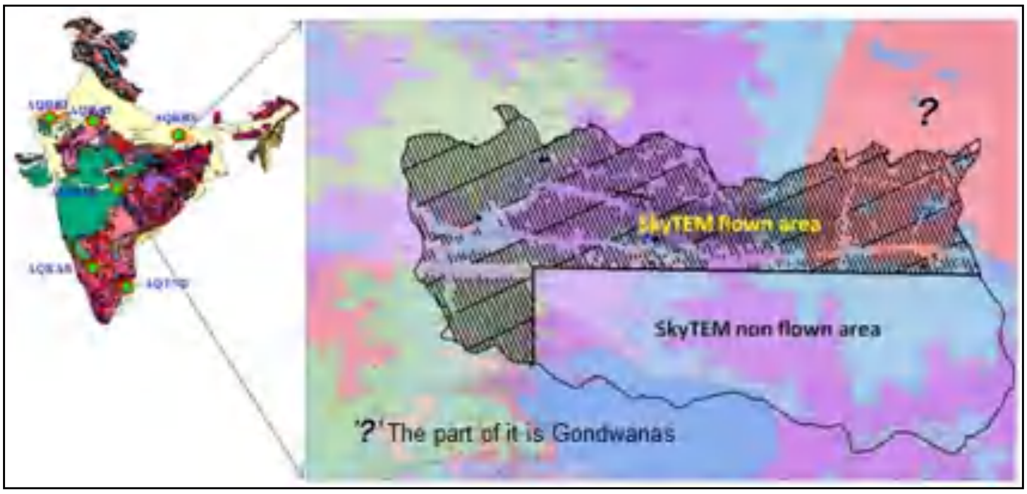


Fig. 4.4. The survey area, the flight lines and tie are shown as black lines (NGRI, 2015)

Ground geophysical data (i.e. VES, ERT, G-TEM, and borehole) collection was done during pre and post SkyTEM phases. The locations of the geophysical investigations have been shown in Figure 4.5.

Calibration of remotely sensed resistivity sections with the collateral (ground truth) information has been imperative in order to understand the subsurface geological features and enhance the precision. Heliborne survey has been taken up in the Nagpur pilot area applying transient electromagnetic parameters to cover an area of 189 km^2. The heliborne survey is therefore adapted for its rapid and large areal coverage with high density data focusing aquifer exploration and characterizing saturated formations for about 200 m depth in basaltic traps underlain by Gondwanas (NGRI, 2015).

4.1.1 validation by ground based results and refinement

To understand and calibrate the SkyTEM generated subsurface maps, various profile sections covering exploratory wells (logs) have been chosen within the SkyTEM flown region of Nagpur pilot area (Fig. 4.5). A total of six profile sections with different directions and geo-referenced elevation have been selected for calibration with collateral data. The HeliTEM derived resistivity sections were calibrated /compared with the borehole lithology, e-logs and gamma logs of exploratory wells, considering lineaments and ground geophysics such as VES. Efforts have been put to characterize the saturated and unsaturated zones by means of resistivity parameters and also to decipher the resistivity range for aquifers within basalts, transition zone of Basalt-Gondwanas and within Gondwanas (NGRI, 2015).

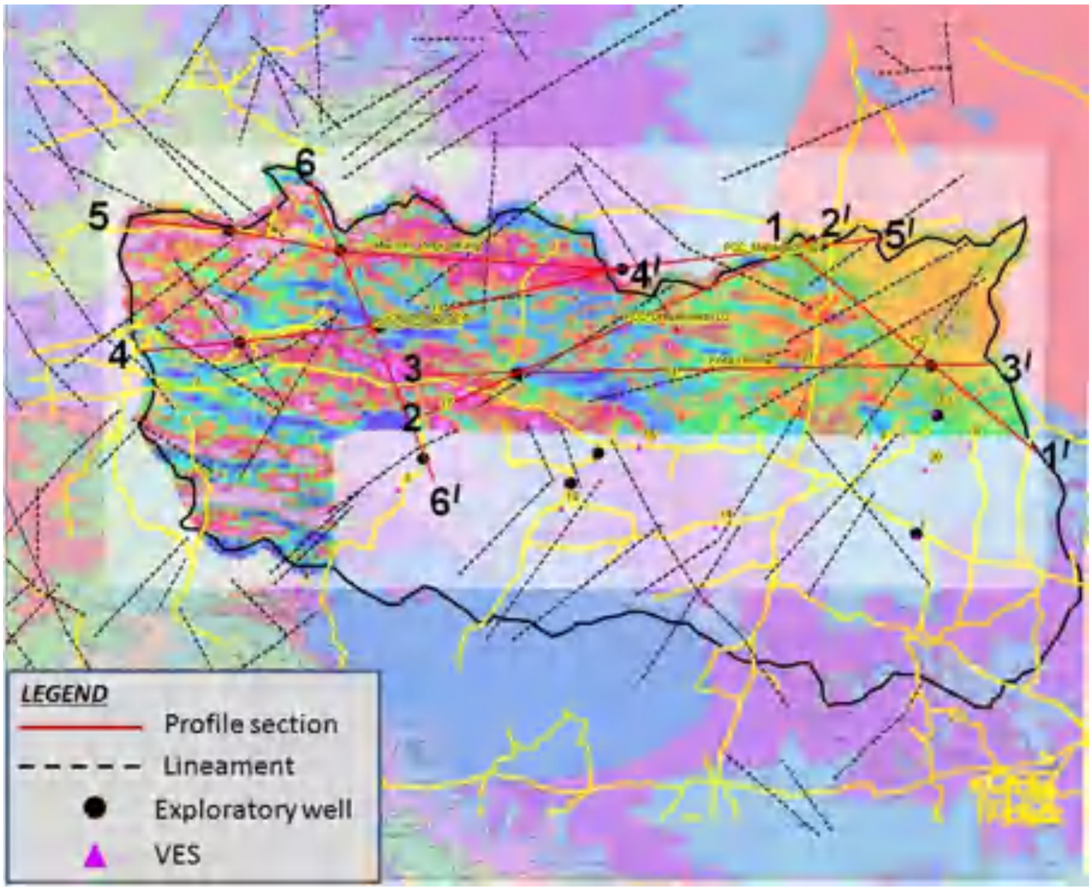


Fig. 4.5: Location of SkyTEM sections in different orientations in the AQMAH pilot area (NGRI, 2015).

4.1.1.1 Section wise validation of SkyTEM data

1. Section 1-1/ (Dhapewada to Gowari villages)

This section extends for 10.5 LKM in NW-SE orientation in the NE part of the study area covering the area between exploratory wells Dhapewada to Gowari (Fig. 4.5 & 4.6). This section is traversed by four lineaments trending NE-SW orientation and near perpendicular to the section. The section at Dhapewada exploratory well shows resistivity 5-15 Ω-m up to 27 m bgl corresponds to thick pile of alluvium soil admixture with kankar, sand and clay. Groundwater struck (Aq1) in this zone from 22.6 to 25.6 m, bgl with discharge 0.14 lps reflects in resistivity profile with 10-12 Ω-m (Fig. 4.6). Basalts has been noted between depth zone 27.0-30.5 m bgl followed by alternate layers of sandstone, shale and sandy clay which extends up to 104 m, bgl. The second aquifer zone (Aq2) with discharge 2.16 lps has been found between 62.15-65.15 m, bgl with resistivity 20-25 Ω-m between clay underlain by sandstone. Third aquifer zone (Aq3) was noticed in the fractured sandstone at 116.0-118.6 m, bgl with discharge 4.43 lps corresponds to resistivity 5-8 Ω-m. The alternate layers of dipping bands designated with resistivity 10-20 Ω-m and 30-100 Ω-m from 4 km onwards could be attributed to textural and digenetic variations in the sandstone. The exploratory well at Gowari shows sandstone up to 200 m drilled depth with thin bands of 2-5 m clay lens between 85-105 m depth zone (Fig. 4.6). The compact sandstone up to 85 m depth is well reflected with resistivity range 50-80 Ω-m followed by clay layers with of resistivity 10-12 Ω-m. The general observation in this section is that the resistivity of various litho-units in sandstones of Gondwans has been well resolved up to 200 m depth and aquifer zones at different depth are deciphered. Apart from, the four lineaments traversing the Dhapewada-Gowari profile are well reflected in the Heli TEM section where significant distributions in litho-disposition were noticed in the hydrogeological nature of the aquifer system.

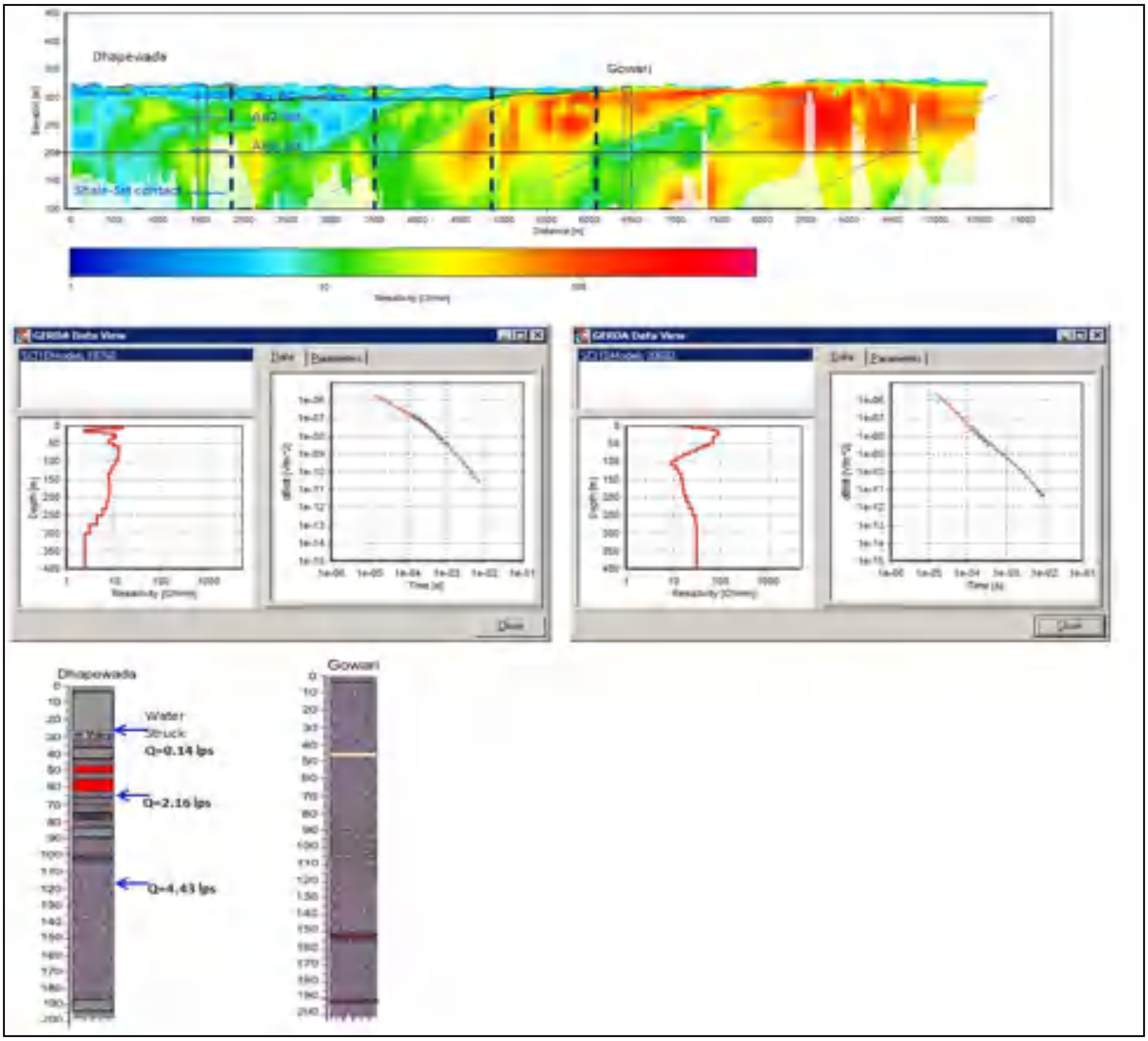


Fig. 4.6:Heli TEM section 1-1′ in NW-SE orientation covering exploratory well at Dhapewada and Gowari villages (NGRI, 2015)

2. Section 2-2/ (Kohli to Dhapewada villages)

This section trends in SW-NE orientation and covers exploratory well at Kohli and Dhapewada extending up to 14.5 line kilometres (Fig. 4.5 & 4.7). The bore hole lithologs of exploratory well at Kohli shows various flows having alternate vesicular and massive basalts extended up to 125 m bgl designated with resistivity range 30-40 Ω-m. Gondwana sandstone characterized with fine to medium grains, and rich in ferruginous and quartz material, was struck at 125 m, depth corresponds litho resistivity range 110-120 Ω-m (Fig. 4.7). In this section the vertical contact between basalt and Gondwanas has been deciphered with the resistivity contrast. However, it is unable to detect the aquifer zones tapped at depths 127.6-145.3 m, 153.3-169.3 m, and 185.3-191.4 m within the fractured Gondwanas. In this profile the horizontal bands of the lava flows and lineaments are clearly deciphered (Fig. 4.7). The lateral contact between basalts and Gondwanas are clearly demarcated with the resistivity contrast.

3. Section 3-3/ (Kohli to Gowari villages)

The section trends W-E direction covering a distance of 19.0 LKM (Fig. 4.5). The exploratory wells located at Kohli and Gowari villages (Fig. 4.8). Four lineaments traverse across this section at various locations. These NE-SW lineaments which could be the areas for groundwater recharge in basaltic flow and sandstone of probably of Motur stage are well reflected along the section. The Basalt-Gondwanas contact with resistivity variations as evidenced from the drilling lithologs was traced (Fig. 4.8). The Gondwanas hold thick (~100 m) compact sandstone underlain by clay/shale in the western and central parts of the section. In the eastern part Deccan Traps thin out near Gowari (Fig. 4.8). There is a lateral facies change in the Gondwanas from west to east. The Gondwanas hold low (4-5 Ω-m) resistivity sediments in the east central part.

The bore hole lithology of Kolhi and Gowari matches satisfactorily with the Heli TEM section. The VES 11 and VES 21 fall between Kohli and Gowari exploratory wells also matches satisfactorily with the Heli TEM section. The Deccan Trap is about 150m thick in the western part and it tappers towards east-central part of the section. The massive basalt (Flow Nos. 24 & 23) is up to a depth of 100 m followed by a thick (30 m) vesicular, amygdaloidal, fractured basalts. The extent of the Gondwanas in east central part is probably controlled by the two parallel NE-SW lineaments resulting into horst type of faulting system (Fig. 4.8). The inferred line of Basalt- Gondwana contact has been overlaid on this section based on the controlled point of exploratory well at Kohli.

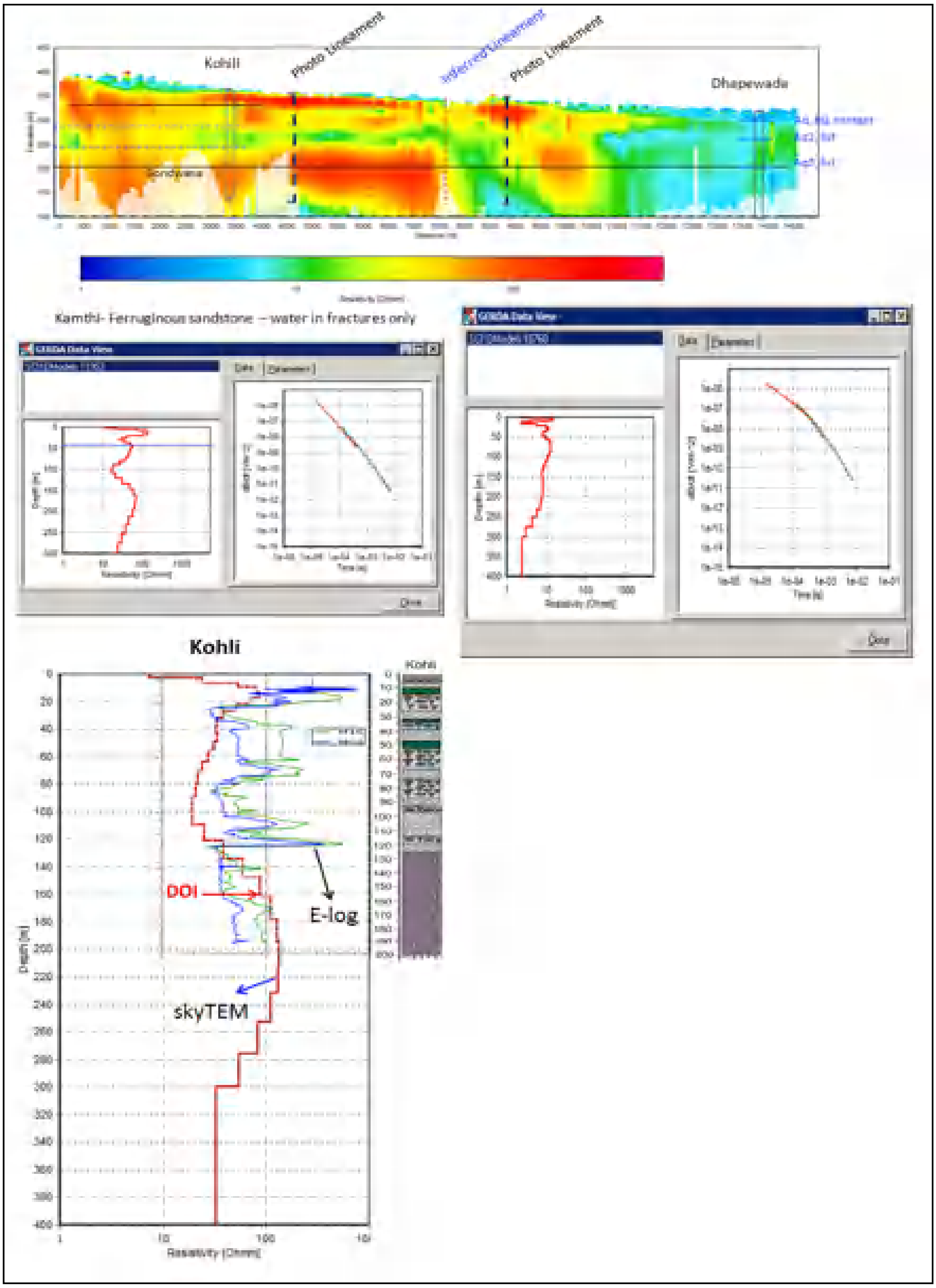


Fig. 4.7: Heli TEM section 2-2/ in SW- NE orientation covering exploratory well at kohli and Dhapewada villages (NGRI, 2015).

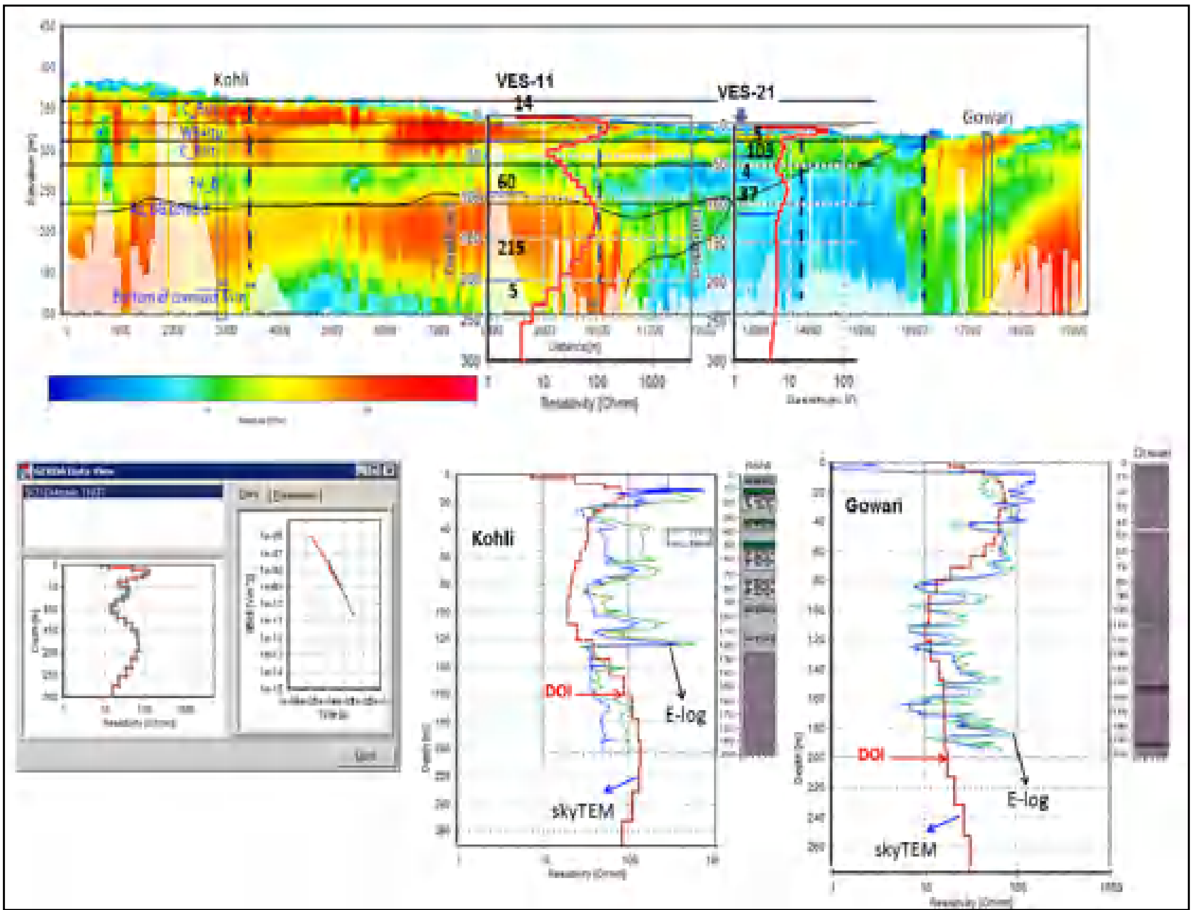


Fig. 4.8: Heli TEM section 3-3/ in E-W orientation covering exploratory well at Kohli and Gowari villages (NGRI, 2015)

4. Section 4-4/ (Sonkhamb, Pardi Deshmukh and Mohagaon)

The orientation of the section is W-E which covers the exploratory wells at Sonkhamb, Pardi Deshmukh and Mohagaon (Fig. 4.5 & 4.9). Five lineaments with NW-SE and NE-SW orientation are cutting across in the section (Fig. 4.9). It is possible to delineate the different flows with vesicular and massive basalts units. The bore hole lithology at Sonkhamb depicts first aquifer (Aq1) struck at 22 m bgl corresponding the resistivity 10-15 Ω-m with Q=0.78 lps followed by second aquifer (Aq2) at 50-60 m bgl in fractured amygdaloidal basalt increased the yield to Q= 1.73 lps holding corresponding resistivity range 35-40 Ω-m in the section (Fig.4. 9). The third aquifer (Aq3) zone was met at the Basalt-Gondwana contact at 195 m bgl with ultimate yield of 5.15 lps. The resistivity of the high yielding aquifer zone in Heli TEM was noted between 15-20 Ω-m (Fig. 4.9). The contact of Basalt-Gondwanas has been clearly delineated over this section using the bore hole control points and TEM signatures. Similarly at Pardi exploratory well, the lithology indicates alternate layers of different flows up to 87 m bgl which are satisfactorily matching with the Heli TEM section on broad way. A thick bole bed from 87-105 m bgl has been reflected in the section with resistivity range 20-25 Ω-m followed by amygdaloidal basalt up to 120 m depth (Fig. 4.9). Two aquifer zones between152.0-152.55 m (Aq1, Q=0.8 lps) and 160-161 m (Aq2) depth with Q=4.3 lps were recorded within thick pile of massive basalts with fracture. The corresponding resistivity of these two aquifers were noted 25-30 Ω-m.

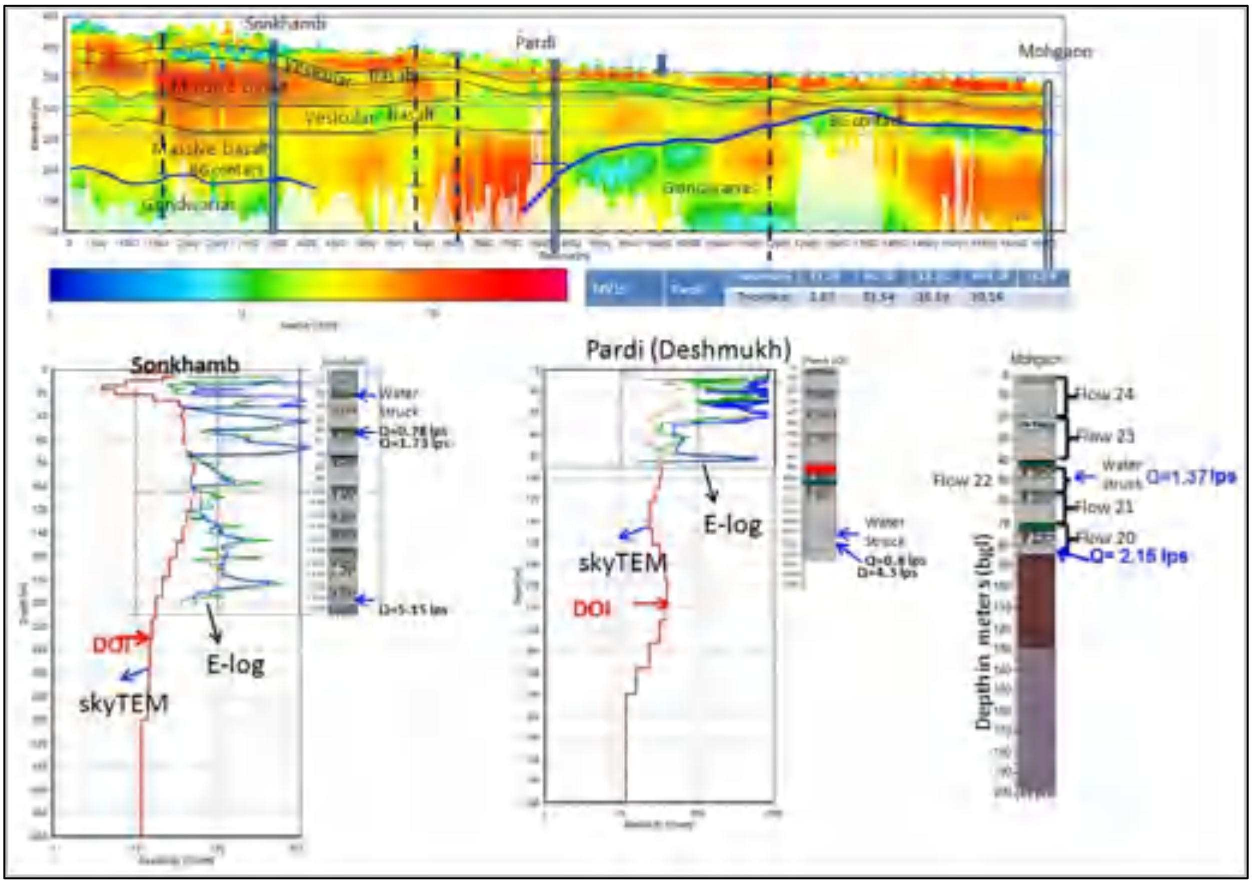


Fig. 4.9: Heli TEM section 4-4/ in NW-SE and NE-SW orientation covering exploratory well at Sonkhamb, Pardi Deshmukh and Mohagaon (NGRI, 2015).

At Mohagaon the drilling lithology shows alternate layers of different flows with two potential aquifers which is satisfying the corresponding resistivity in the Heli TEM section. The first aquifer (Aq1) zone is found within fractured vesicular filled with secondary minerals at 42-45 m, depth with Q=1.37 lps and falls in resistivity range 25-30 Ω-m (Fig. 4.9). The second aquifer (Aq2) zone is noted at basalt-Gondwana contact at 82-85 m depth with Q= 2.16 lps with corresponding resistivity range of 20-30 Ω-m (Fig. 4.9). Based on the Heli TEM section and bore hole lithology, the Gondwana formation has been characterized with the resistivity parameter which in turn helped in inferring the Basalt-Gondwana contact in this section. The lineaments, which are the potential aquifers, have clearly been visualized from the Heli TEM results.

5. Section 5-5/ (Malegaon, Ramgiri and Mohgaon villages)

The section trends W-E orientation for 16.5 LKM covering the exploratory wells at Malegaon, Ramgiri and Mohgaon villages (Fig. 4.5 & 4.10). Five lineaments (NE-SW & N-S) traverse across the section. The exploratory well at Malegaon village indicates, top weathered vesicular soil up to 16 m depth with water struck of Aq1 with yield Q = 0.38 lps at 10 m depth followed by red bole, weathered amygdaloidal basalt and massive basalt up to 55 m depth which constitutes a single flow (Flow No. 27) (Fig. 4.10). The resistivity parameters of Occum inversion (TEM) and bore hole e-logs varies but follows the trend. The second aquifer (Aq2) with Q = 1.37 lps yield met at 126 m, depth in amygdaloidal basalt zone corresponds the resistivity 10-20 Ω-m in TEM section. The extension of these two aquifers (Aq1 & Aq2) was observed further in the west to Malegaon village with the resistivity 10-20 Ω-m (Fig. 4.10). The lineament at the western end of the Flow no. 27 has been clearly demarcated in the TEM section. The Basalt-Gondwana contact at this well was not noted up to a drilled depth of 200 m bgl (Fig. 4.10).

Further, at Ramgiri exploratory site, the two aquifers were noted at 10 m (Aq1) and 175 m (Aq2) depth with yield Q = 0.78 lps and 6.18 lps, respectively. The Aq1 struck in the fractured basalt with corresponding resistivity in TEM 30-50 Ω-m. The Aq2 was met at Basalt-Gondwana contact at 175 m depth with noted resistivity 10-15 Ω-m in TEM section (Fig. 4.10).

The Basalt-Gondwana contact and its extension towards east up to Mohgaon village with elevation variations have been clearly identified in the TEM section (Fig. 4.10). This Basalt-Gondwana contact could be the potential aquifer (Aq2) in hydrogeological point of view. The rapid change in elevation of the Basalt-Gondwana contact at 11-12.5 km distance of the section has been by the two lineaments traverse through the section. Similarly, Mohgaon village the exploratory well lithologs indicates two potential aquifers at 42-48 m depth (Aq1) in the vesicular basalt and 82-85 m depth (Aq2) at the Basalt-Gondwana contact zone (Fig. 4.10). The Aq1 with yield Q = 1.37 lps corresponds the resistivity 20-30 Ω-m in the TEM section and this aquifer zone extension was noted clearly towards east (Fig. 10). The Aq2 is noted at the Basalt-Gondwana contact holding the resistivity 15-25 Ω-m with the yield Q = 2.16 lps. Its extension is noted fairly continuing towards east up to Ramgiri village except at two lineaments (Fig. 4.10) where vertical displacement took place.

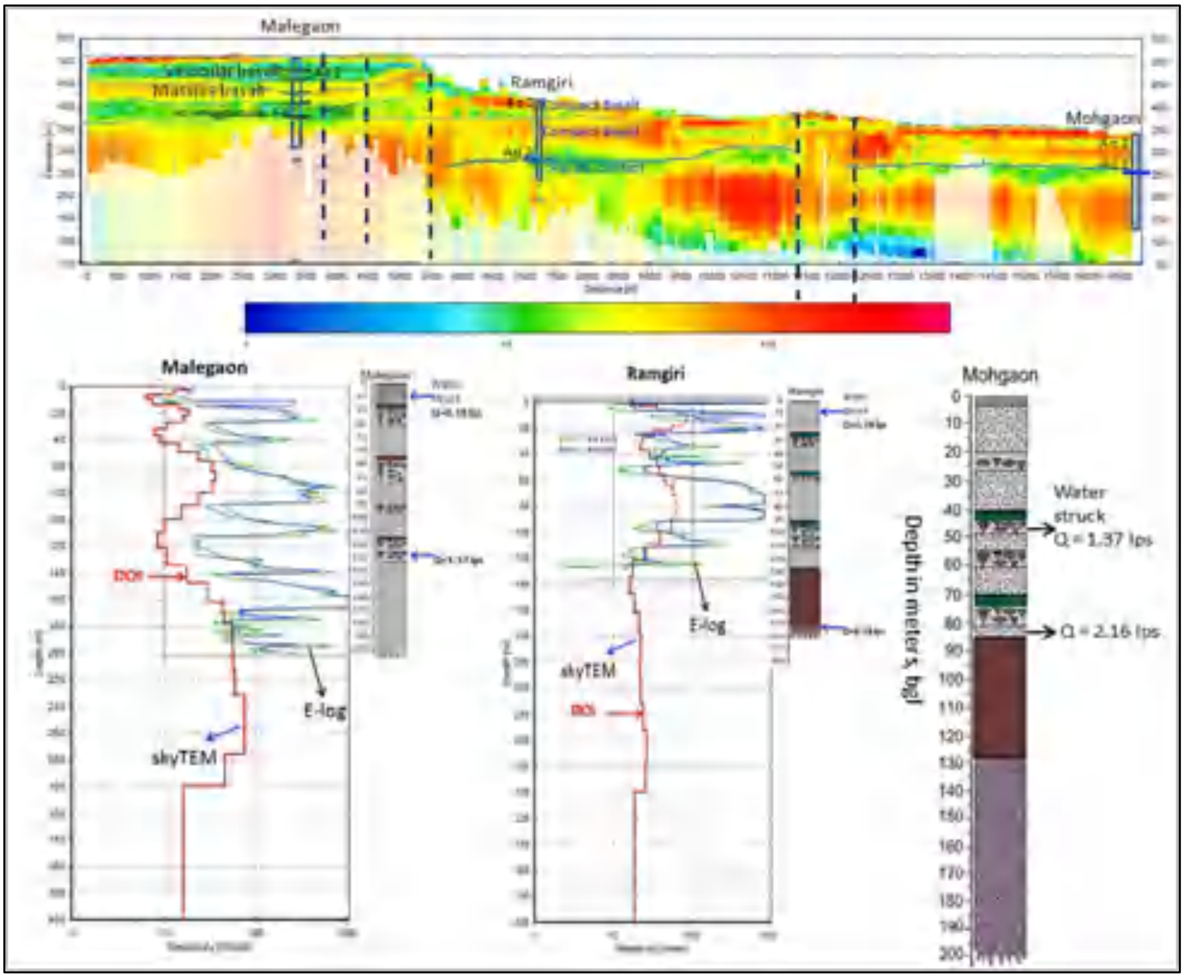


Figure 4.10: Heli TEM section 5-5/ in W-E orientation covering exploratory well at Malegaon, Ramgiri and Mohgaon villages (NGRI, 2015).

6. Section 6-6/ (Ramgiri, Pardi (Deshmukh) and Raulgaon villages)

The section trends in NW-SE orientation for 11 LKM covering the exploratory wells at Ramgiri, Pardi and Raulgaon villages (Fig. 4.5 & 4.11). Raulgaon falls in non-flown zone of Heli TEM (Fig.4.5) therefore to fill the data gaps ground geophysics such as TEM and VES have been carried out at this location. In this Heli TEM section a significant topographic elevation variations has been observed in the west of Ramgiri village where Flow Nos 27 & 26 ends there itself (Fig. 4.5). Ramgiri village situated over Flow no. 25 wherein the first aquifer (Aq1) is struck in fractured basalt at 7-8 m depth with yield Q = 0.78 lps holding the resistivity 25-35 Ω-m in Heli TEM section (Fig. 4.11). The second aquifer (Aq2) was met at Basalt-Gondwana contact between 172-179 m depth with yield Q = 6.18 lps which holds resistivity range 10-15 Ω-m (Fig. 4.11). The extension of the B-G contact towards east has not been observed, it could be due to the lineaments traversing across the section. Based on the resistivity range obtained by the Heli TEM for of B-G contact, the predicted B-G contact is demarcated about 200 m below surface from the distance 3 LKM of the section up to 7.8 LKM in the section covering Pardi village (Fig. 4.11). The bore hole lithology at Pardi village show two aquifers in fractured basalts. The first aquifer (Aq1) met at 152 m depth and second aquifer (Aq2) at 160 m depth with yield Q is 0.8 lps and 4.30 lps, respectively. The resistivity range for both the aquifers falls within the range of 25-35 Ω-m in Heli TEM section (Fig. 4.11). The Aq2 is probably continued towards east since the resistivity band of the 25-35 Ω-m show its extension in the east ward.

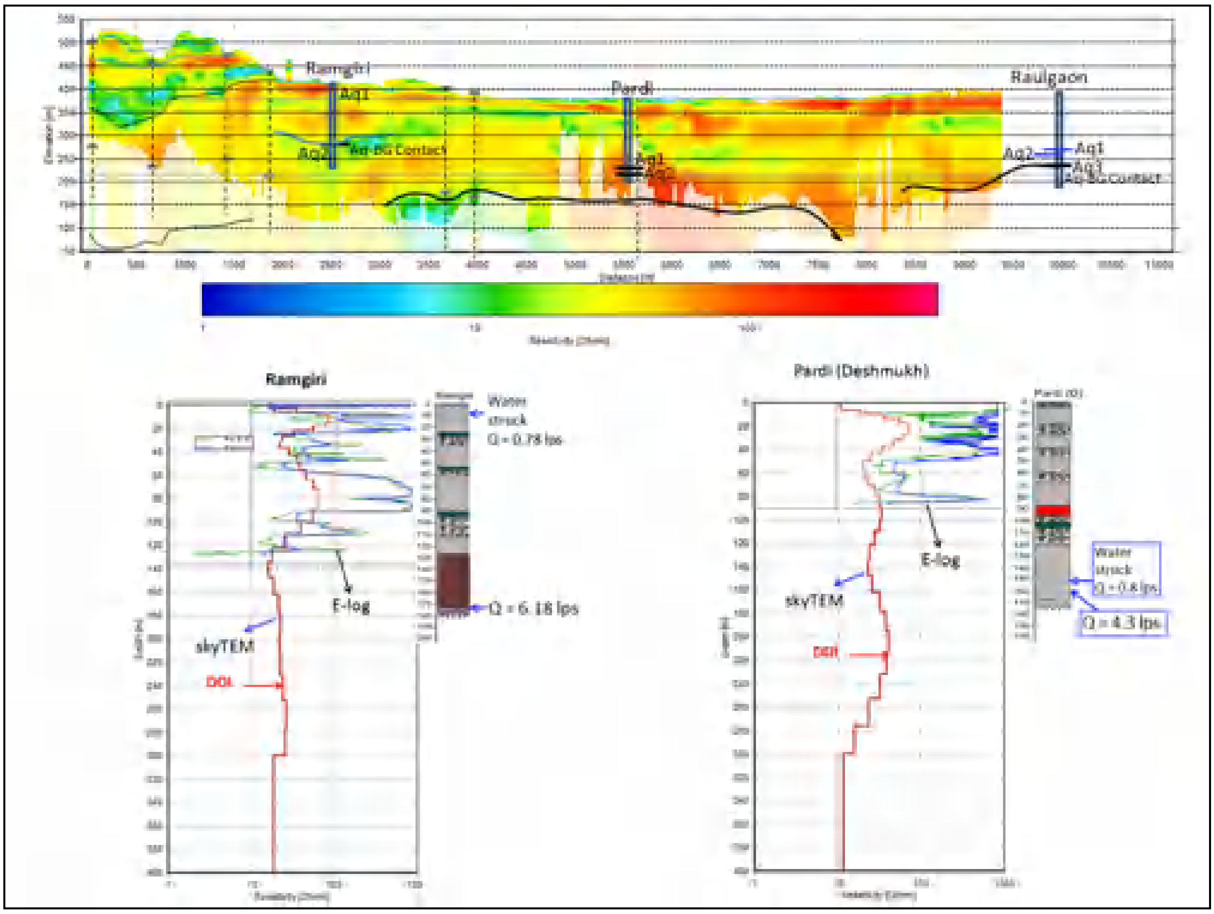


Fig. 4.11: Heli TEM section 6-6/ in W-E orientation covering exploratory well at Ramgiri and Pardi (D) villages, and VES 3 curve at Raulgaon village (NGRI, 2015).

4.1.1.2 Validation of SkyTEM data by resistivity sections in grid fashion

The study area has been studied by establishing grids of size 2000 m x 2000 m in SW-NE and NW-SE orientations. The orientation of SW-NE is therefore chosen to avoid the sharp changes in topographic variations and to cover the various basaltic flows. The reason for choosing NW-SE orientation is that the flight lines of Heli TEM survey falls in this orientation. Since, the dipping of northern part Gondwanas are towards SW direction and the strike in NW-SE direction, the resistivity section of NW-SE grids would be useful in understanding the dispositions of subsurface geological formations. The grid map of size 2 km x 2 km has been shown in Figure 4.12. A total of 12 Heli TEM resistivity sections in SW-NE grids have been coded with I – IX (X-XII non flown zone), similarly 14 Heli TEM resistivity sections shown in NW-SE are indicated with 1 – 14 (**Annexure- XV**).

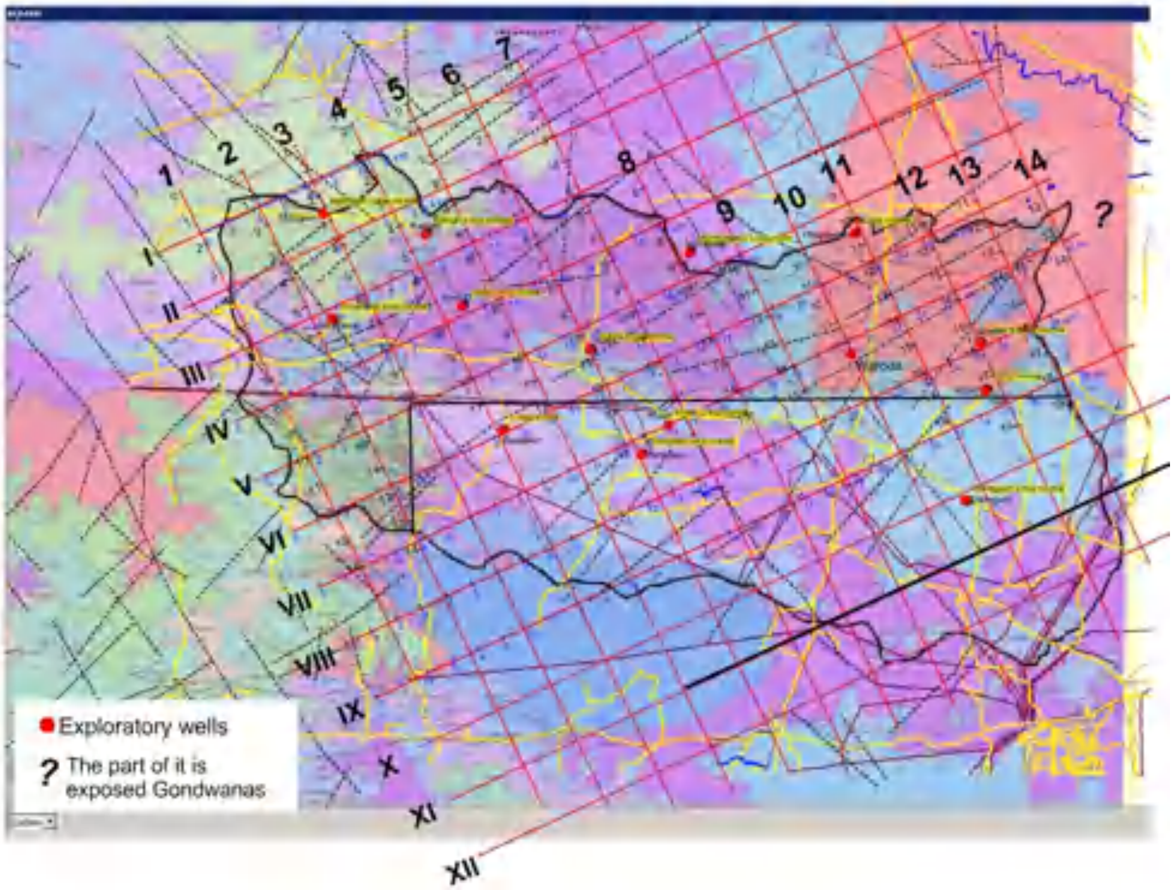


Fig. 4.12: Heli TEM resistivity sections in grid fashion in SW-NE and NW-SE Orientation (NGRI, 2015).

Heli TEM section – III:

A patch of resistivity section **III** has been interpreted calibrating with the lithologs of Sonkhamb village exploratory well. Figure 13 shows a patch of Heli TEM resistivity section between 1700 m to 5400 m distances. In this section, the control point of Sonkhamb village exploratory well lithologs is at 4600 m distance. There are two lineaments fall at 3200 m and 4600 m distances. This sections falls on the Basaltic Flow Nos. 26, 25 and 27 (Source: GSI) from SW to NE direction (Fig. 4.12). The aquifers can be mapped precisely by transforming the resistivity parameter into lithological model and subsequently into aquifer zones with geological perception. To accomplish the mapping of aquifer zones, a series of inter related maps such as Heli TEM derived resistivity model and lithological model have been generated using control points.

In the litho profile of Sonkhamb village site, a total of nine flows from flow no. 26 -16 in sequence have been recorded. The top flow up to a depth of 30 m bgl have been identified with the resistivity range 8-40 Ω-m (Fig. 13). It includes topsoil, weathered vesicular basalt followed by massive basalt. Saturated zones noted at 11 m and 22 m could be the reasons of resistivity below 20 Ω-m in the top weathered zone. The top flow extends horizontally towards SW and NE directions till the lineaments where an uplift in the zone is noted. The signatures of lineaments have been clearly identified in this section. The second flow with resistivity 40-50 Ω-m and 50-60 Ω-m corresponds to the vesicular and massive basalt. Similar resistivity trend is observed for the rest of the subsequent flows. It is noted that the gradual increase in resistivity ranges for basaltic flow as the depth increases. It could be due to the massive basalt and reduction in vesicles. Another aquifer is recorded in the saturated fracture of amygdaloidal basalt between 76-79 m bgl with resistivity range 60-70 Ω-m. A potential aquifer recorded at Basalt-Gondwana (B-G) contact with resistivity range 25-40 Ω-m. The resistivity of Gondwana sandstone is noted in the range of 15-25 Ω-m.

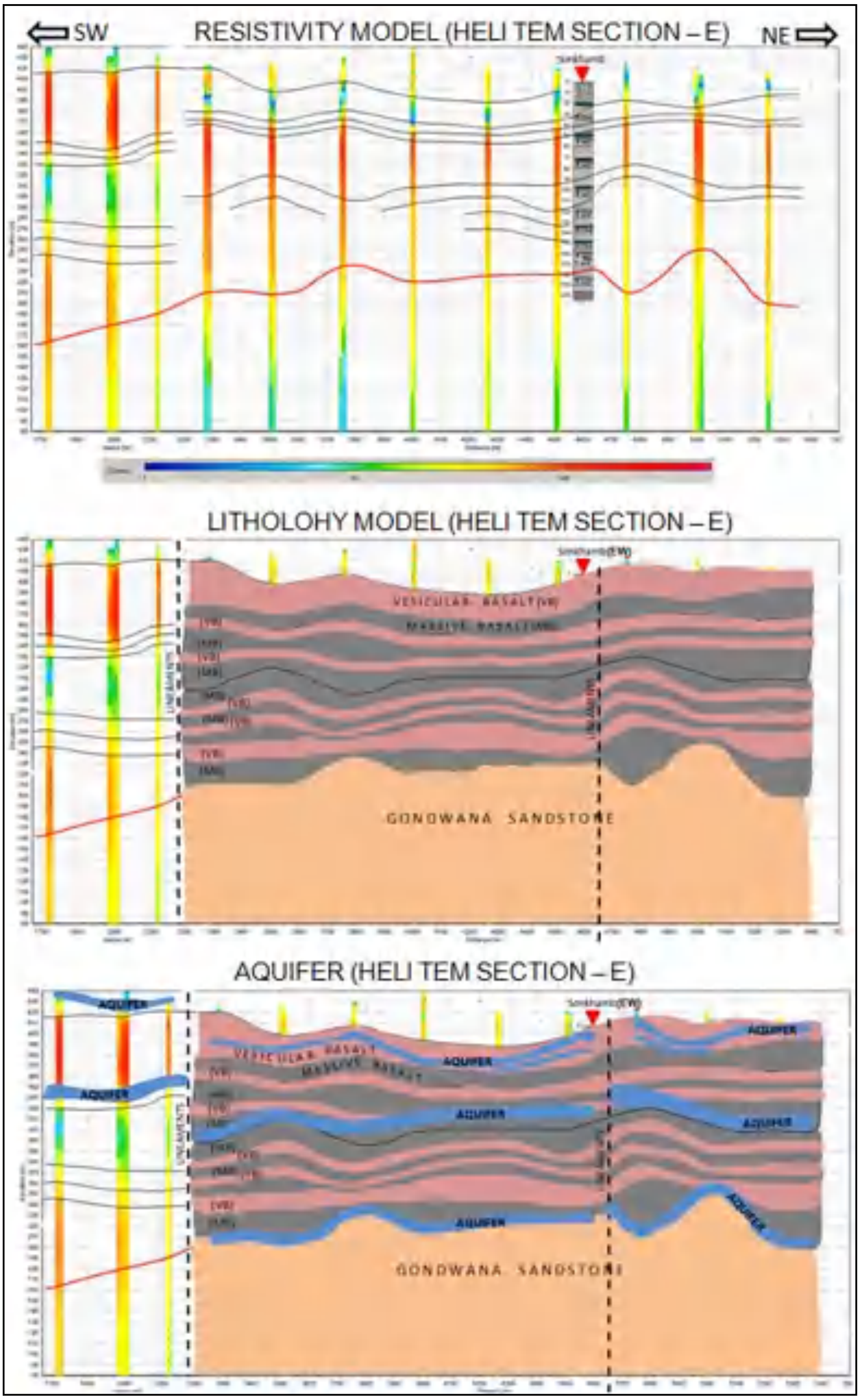


Fig. 4.13: Resistivity model, lithological model and aquifer zones derived from Heli TEM resistivity section of HeliTEM section-III (NGRI, 2015).

4.2 Value Addition from Geophysical Studies

4.2.1 Estimation of Basalt thickness and Gondwana topography

The integration of HeliTEM data base with ground geophysics and controlled points such as bore hole lithologs has been useful to derive the basaltic trap thickness and Gondwana topography. To derive these thematic maps the study area have been made into grids of 2 km x 2 km size, then the vertical information available at the node of the grid has been considered for the interpolation. Figure 4.14 indicates the variations in thickness of lava flows (~400 m) in the NW part and its thinning towards SE of the study area. The NW-SE part of the study area indicates the valley of Gondwanas as evidenced by the 3D map of Gondwana topography (Fig. 4.16). Further, in the SE part the basaltic traps are underlain by Archaean base as confirmed from the bore hole lithologs (at Dahegaon village) and higher order of resistivity at 90 m below ground level (Fig. 4.15). In addition to the basaltic aquifer, the interface of Basalt-Gondwana can be considered as potential aquifer. The elevated topography can be found in the NE and southern part of the study area and also documented by the filed verifications.

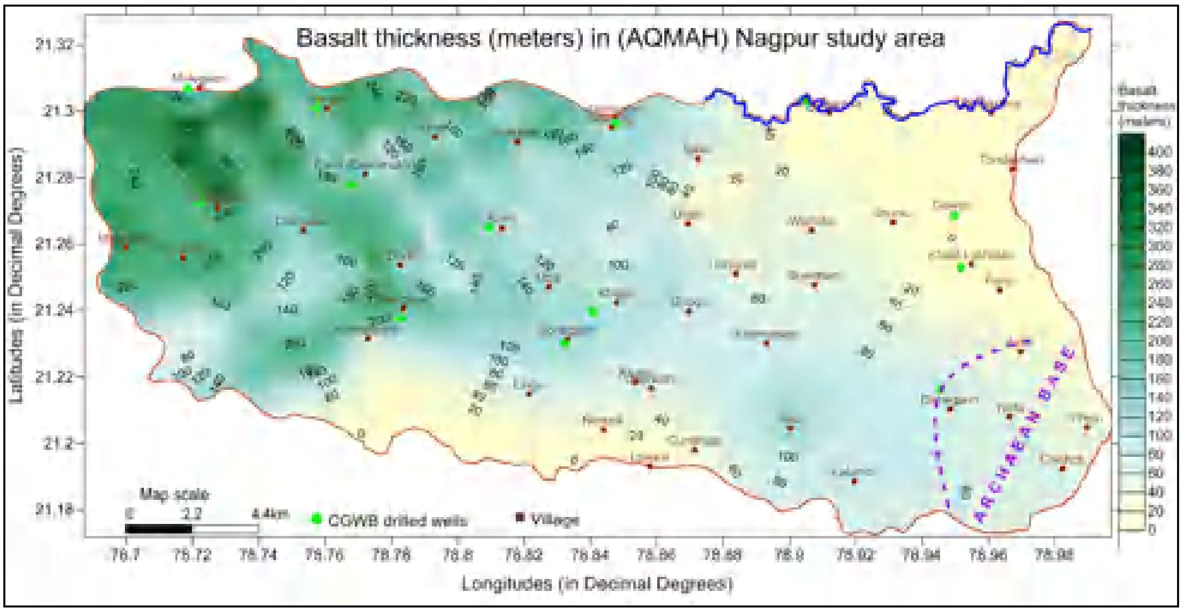


Fig. 4.14: Estimated basalt thickness derived from the HeliTEM and ground geophysical methods (NGRI, 2015)

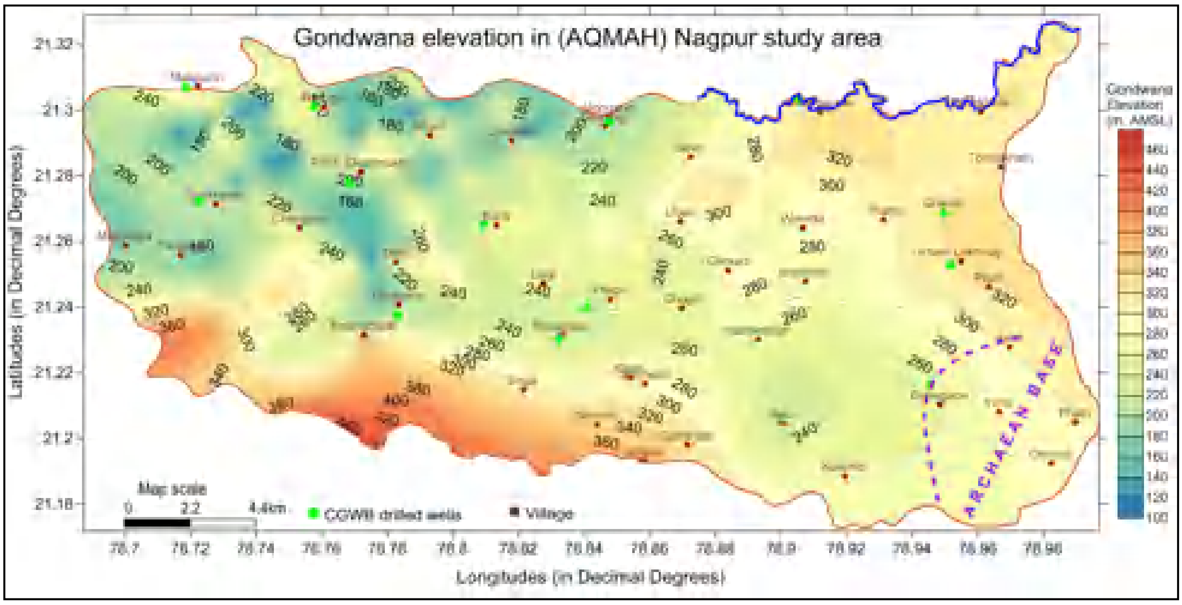


Fig. 4.15: Estimated Gondwana elevation (m, AMSL) drived from the HeliTEM and ground geophysical methods (NGRI, 2015)

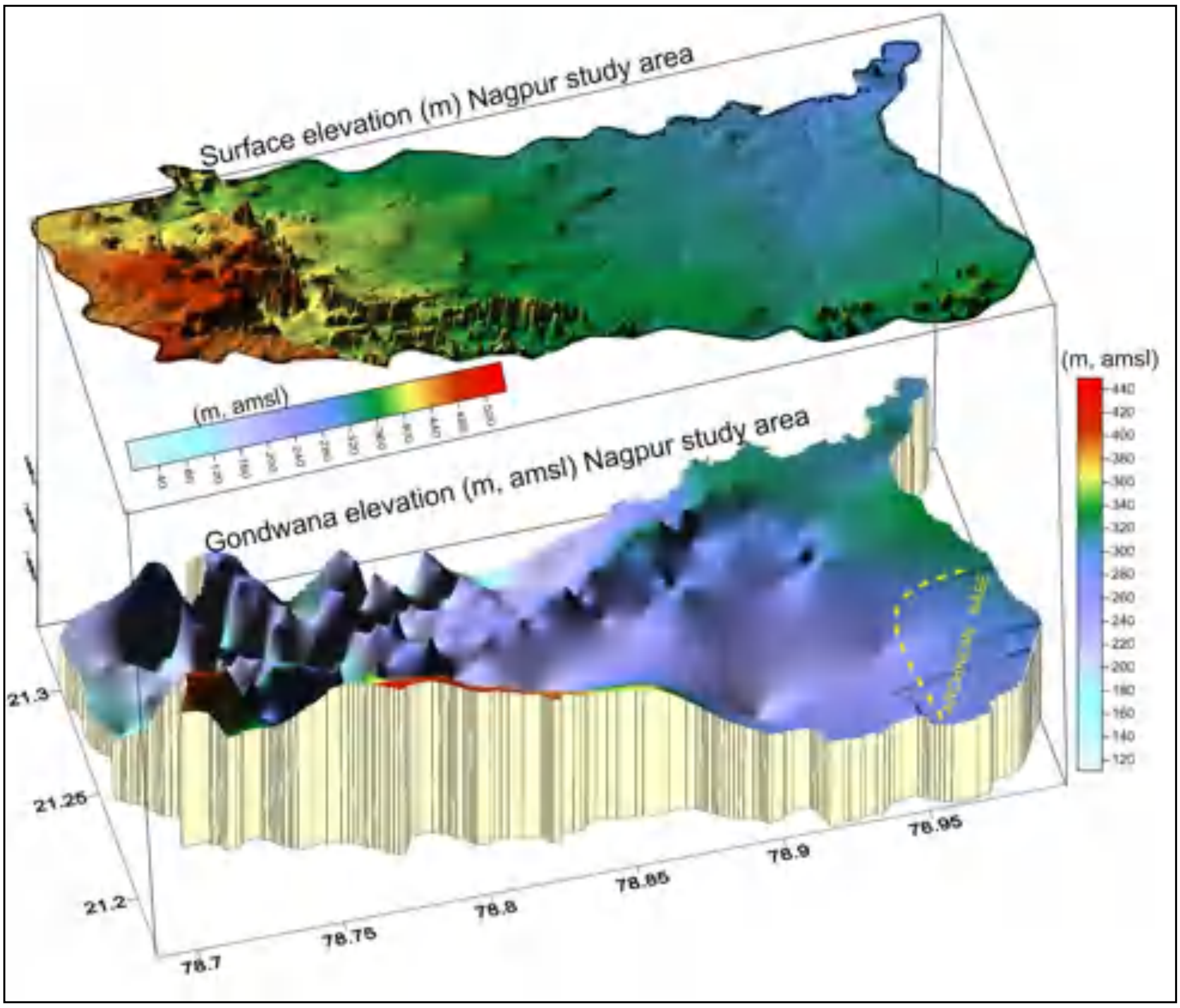


Fig. 4.16: 3D map showing the estimated Gondwana paleo topography (m , AMSL) (NGRI, 2015)

4.2.2 HeliMag results

HeliMag survey was carried out along with HeliTEM using Geometrix Caesium vapour type having sensitivity 0.1 nT. Magnetic sensor was synchronized with TEM measurements. The position of the magnetometer sensor is placed at the front panel. There is another base station used for continuous magnetic measurement to record the temporal changes, which is applied for correcting the magnetic data recorded by the by main magnetometer attached with HeliTEM transmitter. Final processing of the magnetic data involved the application of traditional corrections to compensate for diurnal variation and heading effects prior to gridding. Advanced full processing of magnetic data was implemented in Geosoft's Oasis Montaj software as follows:

- Processing of static magnetic data acquired on magnetic base station
- Pre-processing of airborne magnetic data
- Stacking of data to 10 Hz in SkyLab (SkyTEM in-house software).
- Moving positions to the center of the sensor in SkyLab.
- Processing and filtering of airborne magnetic data
- Standard corrections to compensate the diurnal variation and heading effect
- IGRF correction
- Statistical and full levelling
- Micro levelling
- Gridding

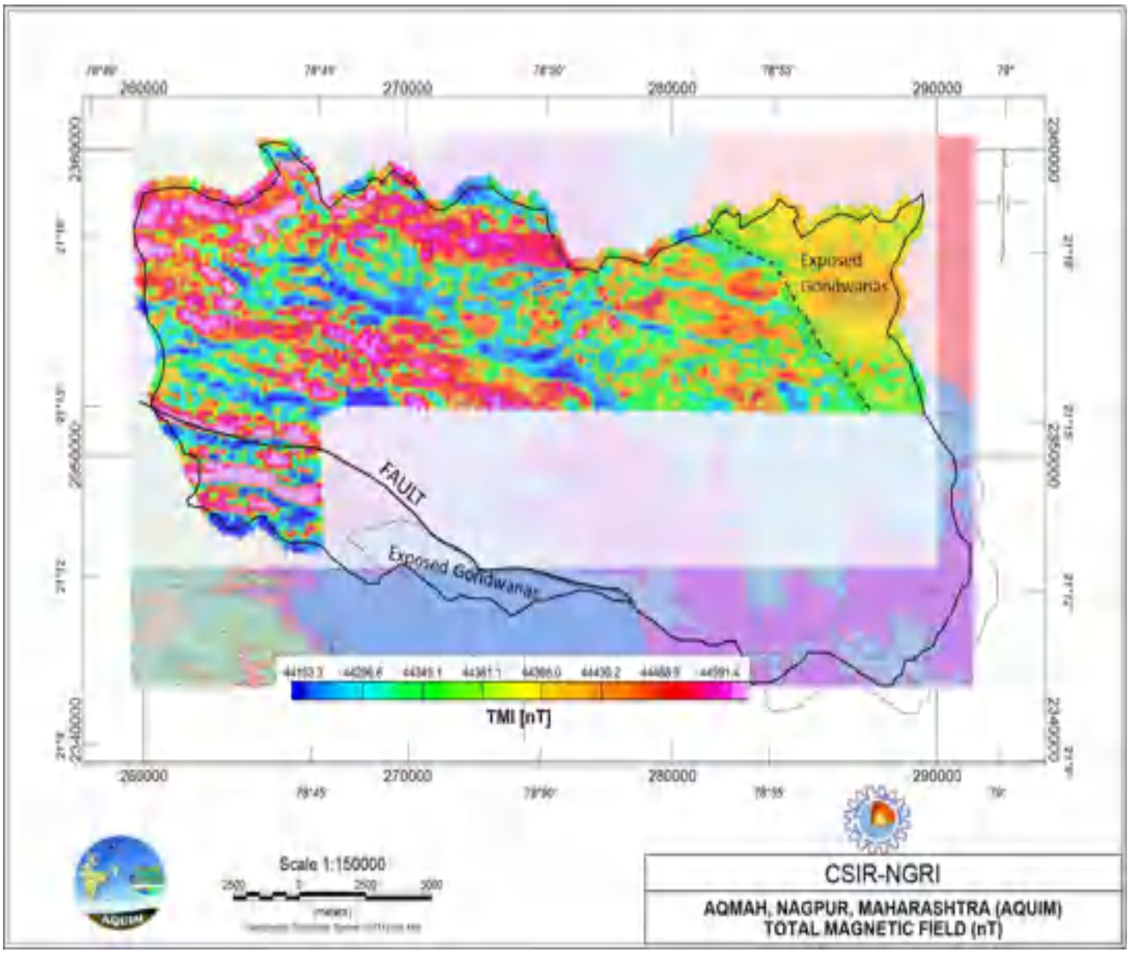


Fig. 4.17: HeliMAG map of the AQMAH pilot area (NGRI, 2015)

Finally, total magnetic field intensity map has been prepared after all correction and data levelling (Fig.4.17). Magnetic data is found varying from 44153 nT to 44591 nT. The high magnetic field intensity corresponds with the followings observations

- The lateral contact between Deccan Traps-Gondwanas exposed in the north east has been very clearly demarcated.
- Overall the average magnetic field intensity (nT) is found relatively low magnitude over Gondwana compared to the traps
- It is also found very effective in delineating the structural feature such as fault which is reflected as low resistivity band elongated in WNW-ESE. Such band is also aligned with the strike of the Gondwana palaeo-topography referred from the literature study. The fault and Gondwanas are also reflected in the mean resistivity maps provided in **Annexure-XVI**.

4.2.3 Geophysical Parameters Characterization

Geophysical parameter characterization is imperative in view of understanding the subsurface geological formations as well as their geometry. It is therefore essential to place the multiple geophysical parameters obtained through various investigations at a particular point, on single platform. Comparative study of various parameters such as ground based VES, TEM, ERT, electric log, gamma logs, SP logs, bore hole lithologs, drilling time, penetration rate, and remote sensed electromagnetic (EM) surveys such as Heli TEM and Heli MAG investigations are significant to standardize the geophysical parameters for a particular geological formation. WellCAD is a PC based composite log package, which combines comprehensive graphic editing mechanisms and data processing tools and handles a wide range of geophysical data with advanced depth matching tools. All data are numerical and can be edited in a separate spread sheet view. Hence the geophysical data acquired at exploratory wells at AQMAH study area have been integrated and interpreted on WellCAD platform. To represent the study area, two cases at Trap covered Gondwanas and exposed Gondwanas have been explained in detail on WellCAD software. The similar interpretation approach can be applied for the rest of the cases.

4.2.3.1 Integration at Ramgiri village (Trap covered Gondwanas)

The main objective to select Ramgiri site as a typical example for integration of geophysical parameters is that, the basalts underlain by Gondwanas separated by Infratrappeans. The exploratory well lithologs at Ramgiri village shows basaltic flows with Flow No. 25 to 22 from top with green earth layers of 2-3 meters. Gondwana sandstone struck at 172.5 m depth below ground level (bgl). The geophysical parameters such as SP logs, E-logs, gamma logs, resistivity from Heli TEM, gradient of Heli TEM resistivity and VES, and drilling time and penetration rate have been studied in comparative and integrated manner validating with ground truth information such as bore hole lithologs (Fig. 4.18). The integrated interpretation reveals that the top basaltic flow (no. 25) extends up to 25.6 m bgl (390.4 m, amsl) with saturated fractures, shows the resistivity range 25-50 Ω-m obtained in Heli TEM with negative gradient. The same resistivity range is well correlated with resistivity peaks in e-logs and CGWB VES (No. 402), and low gamma. This flow is underlain by a thin layer (2.4 m) of Green Bole and well resolved by low resistivity in Heli TEM and e-logs, and high gamma counts. The transition zone between flow no. 25 and Green Bole is clearly indicated by the positive gradient in Heli TEM resistivity. The second flow (Flow no. 24) occurs between 388 to 363 m, amsl consisting fractured amygdaloidal basalt and massive basalt bearing the resistivity range 20-40 Ω-m in Heli TEM with positive gradient (Table 4.4). Low resistivity and moderately high gamma with no deflections in SP are noted for fractured amygdaloidal basalt. Similar trend has been observed for the subsequent basaltic flows. A thick (45.5 m) pile of red sticky clay below 127 m depth bgl (289-243 m, amsl) is falling in the resistivity range of 20-30 Ω-m in Heli TEM survey. This clay with friable chips could be the lametas. Further, the Gondwana sandstone encountered at 172.5 m bgl (243.5 m, amsl) is reflected with the resistivity range 20-40 Ω-m in Heli TEM.

Overall in the basaltic flows, it is observed that the Heli TEM acquired resistivity for amygdaloidal basalt varies between 20-30 Ω-m, whereas the resistivity range 20-70 Ω-m corresponds to massive basalt. Further, the resistivity gradient of Heli TEM was found to be supportive to demarcate the vertical variations in litho-units. Thus, the integrated interpretation of various geophysical parameters clearly indicates the relative efficacy of Heli TEM survey with more resolution in demarcating the fractures in amygdaloidal and massive basalts, intertrappeans, and Basalt-Gondwana vertical boundary which are the potential aquifers.

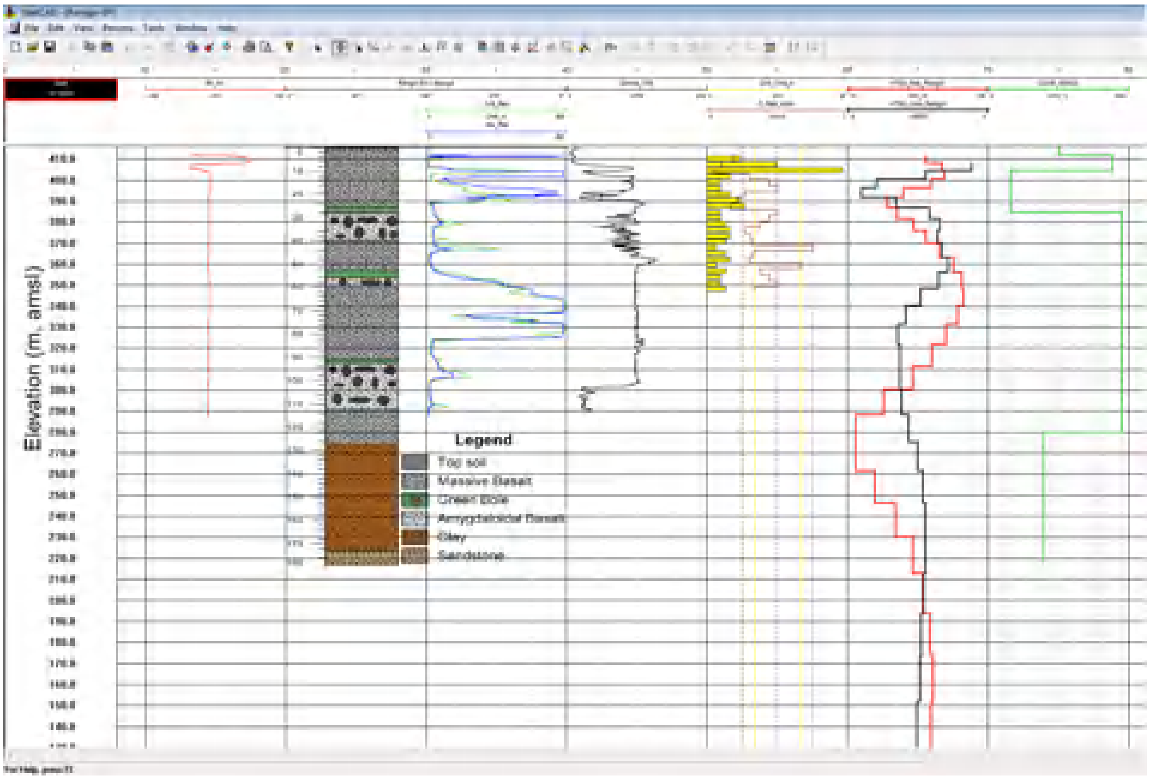


Fig. 4.18. Geophysical parameters characterization by integration method (usingn WellCAD software) in Trap covered Gondwanas at Ramgiri village (NGRI, 2015).

Table 4.4: Integration of Integration of geophysical parameters in Trap covered Gondwanas at Ramgiri village (NGRI, 2015).

Depth (m, amsl)		Lithology	Heli TEM Resistivity Ω-m	HeliTEM Res gradient	Flow No.	CGWB VES-402 Resistivity Ω-m	Remarks
From	To						
419	391	Basalt: Fractured and massive	25-50	-ve	25	50-100	Top soil up to 0.5m, water zone 408-409 m (amsl)
391	388	Green bole:	20	+ve	-	9	Low resistivity , High Gamma, no significant SP
388	382	Basalt: Fractured Amygdaloidal	20-30	+ve	24	9	Moderately high Gamma, Low resistivity, no SP deflection
382	364	Basalt: Fractured massive	20-40	+ve	24	9	Significant gamma fluctuations
364	360	Green bole:	50-60	+ve	-	9	Significant high gamma, low resistivity
360	356	Basalt: Fractured Amygdaloidal	60	-ve	23	9	Moderate-high gamma
356	325	Basalt: Fractured and massive	70	-ve	23	9 And 2200	337-333 high fracture indicated by resis-log, No variation in gamma.
325	322	Green bole:	50	-ve	-	2200	High gamma, low resis.
322	300	Basalt: Fractured Amygdaloidal	30	Normal	22	2200	High gamma, low resis.
300	289	Basalt: Massive & Fractured	18	+ve	22	2200	Low gamma with fluctuations
289	262	Clay	20-30	+ve	--	46	VES Resis reduces from 2200 to 46 @ 250 m amsl
262	172	Sandstone	20	+ve	--		

4.2.3.2 Integration at Khairi Lakhmaji village (Exposed Gondwanas)

The exploratory well located at Khairi Lakhmaji village beset on Gondwana formation has been selected in order to represent the Gondwana terrain of the study area (Fig. 4.12). At this site, the litho profile consists top soil mixed with clay up to a depth of 8 m bgl (312 m, amsl) with the corresponding low order of resistivity range 3-8 Ω-m in Heli TEM, 5 -10 Ω-m in ground TEM and 2-9 Ω-m in VES by NGRI (VES No. 13) (Fig. 4.19 and Table 4.5). The relative low resistivity could be due to the soil composed clay materials. This clay is also reflected by the corresponding gamma peaks. The top soil is followed by the Sandstone of fine to medium grain and extends to a depth of 62 m, bgl (258 m, amsl). The Heli TEM resistivity range 5-8 Ω-m up 20 m bgl (300 m, amsl) with positive gradient and high gamma peaks correspond to the fine grain with intercalation. Whereas, it shows the relative high order of resistivity range 6-38 Ω-m for the medium to coarse grain sandstone in the same zone from 20 to 62 m bgl. The high gamma peaks matching with low resistivity in e-logs at 289 m, 269 m, & 259 m amsl depth could be due to clay intercalations. Sandy clay layer of 5 m thick lies between 62-67 m bgl (258-253) is reflected by the Heli TEM resistivity about 38 Ω-m with high gamma counts and SP peak. Similar trend has been observed for the sandstone below 67-200 m bgl separated by the clay/shale layers at various depth. Based on the Heli TEM observation in the Gondwana terrain in the entire study area, the ranges of resistivity varies due to the compositional variations in the Gondwanas sediments. The cementing matrix such as calcite, ferruginous and siliceous which binds the sediments during the diagenesis process also alters the resistivity of greater magnitudes. However, the signatures attributed to clay/shale layers in the Gondwana formations has been noted with distinct resolution in the Heli TEM resistivity surveys.

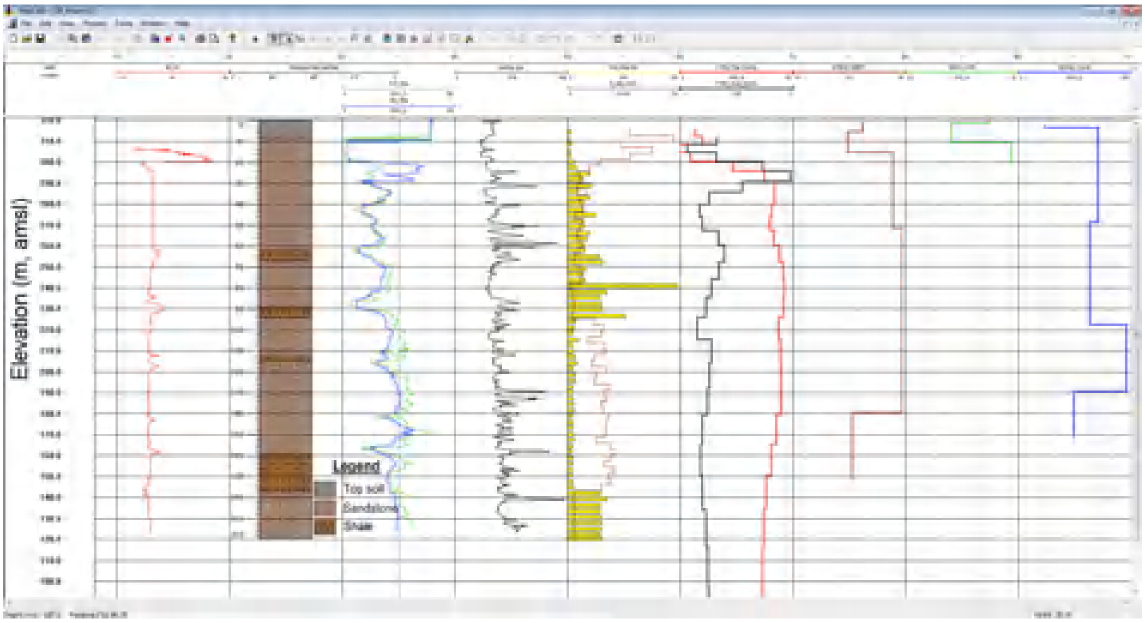


Fig. 4.19: Geophysical parameters characterization by integration method (using WellCAD software) in exposed Gondwanas at Khairi Lakhmaji village (NGRI, 2015).

Table 4.5. Integration of geophysical parameters in exposed Gondwanas at Khairi Lakhmaji village (NGRI, 2015).

Depth (m)		Litholog	HTEM Resistivity (Ω-m)	HTEM Resistivity Gradient	GTEM (Res)	VES13_NGRI Resistivity (Ω-m)	VES371_CGWB Resistivity (Ω-m)	Remarks
From	To							
320	312	Top soil	3-8	-ve	5-10	2-9	6-52	Top soil mixed with clay is reflecting by low resistivity ranges and gamma peak corresponds to clay
312	300	Sandstone	5-8	+ve	5-36	2-22	52	Gamma peaks at 306-300 m (amsl) could be due to fine grain with clay intercalations.
300	258	Sandstone	6-38	+ve to -ve	36-51	22	37-52	High gamma peaks matching with low resistivity in e-logs at 289m, 279m, 269m, & 259m (amsl) depth could be due to clay intercalations.
258	253	Sandy Clay	38	normal	51	No information	37	High gamma and SP peak could be the reasons for sandy clay
253	231	Sandstone	38-41	-ve	51	No information	37	Low gamma and high resistivity corresponds to medium to coarse grain with quartz nad clay intercalcations are reflected by gamma peaks and low resistivity at 234-230m (amsl)
231	226	Clay/Shale	37-41	-ve	51	No information	37	Shale/clay is reflected by gamma peaks
226	207	Sandstone	37-41	-ve	51	No information	37-168	Sandstone fine to coarse grain corresponds to high resistivity peaks in e-logs
207	205	Clay/Shale	37-41	-ve	51	No information	168	Gamma peaks, SP deflection and low resistivity peaks in e-logs could be due to Clay/Shale
205	161	Sandstone	36-38	-ve	9-51	No information	168-20	High gamma fluctuations could be due to the shale intercalations also reflected in SP deflections
161	143	Clay	29-32	+ve	7	No information	No information	Clay lens are indicated by gamma peaks and SP fluctuations, and with low resistivity in e-logs
143	120	Sandstone	25-28 (Below DOC)	+ve	No information	No information	No information	The progress in the resistivity value in e-logs are the signatures of sandstone. The high gamma at 137-140m (amsl) could be due to changing litho units form clay to sandstone

4.2.4 Three-dimensional resistivity section

The main aim to present the 3D maps of Heli TEM sections has been to understand the basaltic flows directions and their extension on vertical and lateral scale. The Figure 20 has been generated using the Heli TEM sections in W_E and SW-NE orientation. The W-E section shows individual flows in the west and their extension towards east their ending. Further, on the same section the vertical contact of between Basalt-Gondwana (B-G) has been clearly demarcated with distinct variations in the resistivity. The B-G contact can also be seen its smooth merging with the SW-NE Heli TEM section. The aquifer systems in basalts and Gondwanas and their extensions are also clearly demarcated in the 3D map (Fig. 4.20)

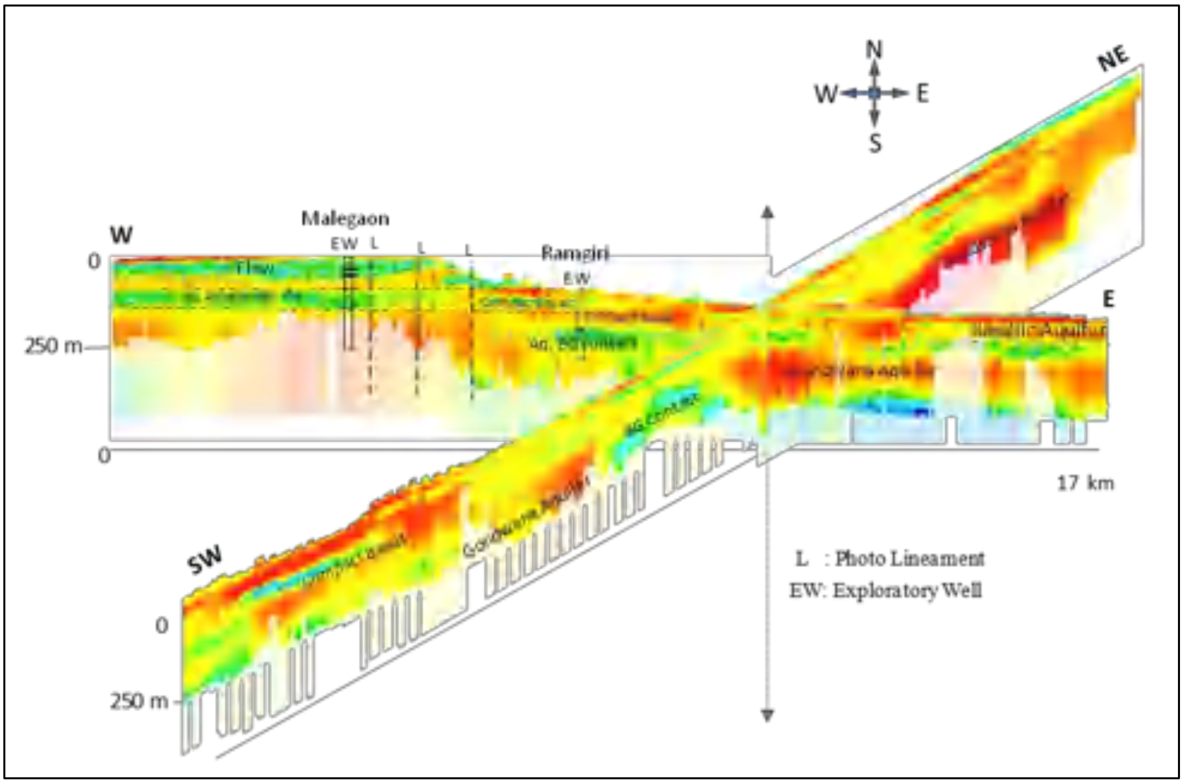


Fig. 4. 20: 3D map showing the Heli TEM sections of the AQMAH study area, Nagpur, (NGRI, 2015b).

Thus, data generated has been integrated and georeferenced. Georeferenced elevation of the principal hydrogeological layers at each node of the grids of the AQMAH study area is presented in **Annexure-XVII** (NGRI, 2015b).

4.3 Efficacy of various Geophysical Techniques for different Hydrogeological terrain

The present pilot project on aquifer mapping (AQMAH), in Chandrabhaga watershed (WGKKC-2) is a prestigious project where the advance geophysical techniques have been used first time in the country. Also it is a pilot project to establish the methodology for various divergent geological and hydrogeological settings of the country, additional conclusion both scientific and managerial have to be discussed and used for replicating them in up-scaling. Two important aspects viz., the degree of performance of various methods in a particular case as well as the cost-effectiveness of the employed methodology have been discussed based on the present experiences (NGRI, 2015a).

The performance matrix of various geophysical methods applied in Pilot Aquifer mapping (AQMAH) in Chandrabhaga Watershed (WGKKC-2) is presented in Table 4.6. Also, the cost effectiveness considering ground vs airborne geophysical survey has been carried out and presented in Table 4.7 (NGRI, 2015a).

Table 4.6: Performance Matrix of various geophysical methods applied in Pilot Aquifer mapping (AQMAH) in Chandrabhaga Watershed (WGKKC-2) (NGRI, 2015a)

Sl. No.	Hydrogeological Objective	Geophysical Objective	Performance of Geophysical Method used					
			Surface			Heliborne		Borehole logging
			VES	GRP	TEM	TEM	MAG	
1	Aquifers in weathered zone	Moderately resistivity layers	1	NA	1	1	NA	1
2	Aquifers in vesicular and fractured zone	Moderately resistive layer underlying highly resistive (massive basalt) layer	4	NA	3	2	NA	1
3		Geological structures	5	NA	5	3	1	NA
4	Basalt-Gondwana contact	deeper moderately resistive (Gondwana sandstone) layer	3	NA	4	3	NA	1
5	(maximum depth 200m)		Depth of investigation depends on			NA	NA	NA

Sl. No.	Hydrogeological Objective	Geophysical Objective	Performance of Geophysical Method used					
			Surface			Heliborne		Borehole logging
			VES	GRP	TEM	TEM	MAG	
			subsurface resistivity distribution					
Where Index on 5-point Scale is 1: Excellent, 2: Very Good, 3: Good, 4: Fair, 5: Poor, NA: Not Applicable								

Table 4.7: The cost effectiveness considering ground vs airborne geophysical survey (NGRI, 2015a)

COST EFFECTIVENESS

Economic Evaluation: Ground vs. Airborne Geophysics

Area	Size sq.km	SkyTEM Flight Line(LKM)	SkyTEM Charges (INR)	SkyTEM Models / Soundings	SkyTEM model/sq.km	SkyTEM Rate (INR)	VES Rate (INR)	G-TEM Rate (INR)
AQRAJ	598	3499	25356910	80602	135	315		
AQDRT	600	3400	24639467	94492	157	261		
AQMAH	216	954	6913544	25673	119	269		
AQBHR	150	766	5551127	18307	122	303		
AQKAR	376	2843	20602942	—	—	—		
AQTND	234	2337	16936010	—	—	—		
Cost including survey, processing and interpretation and resolution of results					Average	287	13287	11780
					Cost Ratio	Ground/air	46	41

✧ Measurement density AEM : ~500 measurements/ sq km

✧ Measurement Time : ~300 measurement per hour

It is difficult to indicate an optimal area but with general perception it can be understood that large is the area, more cost-effective will be heliborne survey. It depends on the objectives of the project. If high-resolution regional picture of the aquifer is required, obviously the heliborne geophysical survey will be many folds less expensive and faster. If a detailed investigation on local scale is required, ground survey will be cost-effective. Overall for up-scaling the heliborne geophysical survey including processing and interpretation, the cost will be several ten times less than the classical methods of ground geophysical survey, which is about 46 times less than a VES and 41 times less than one ground TEM(Table 4.7) (NGRI, 2015a).

4.4 Protocol for Geophysical Investigations in Aquifer Mapping

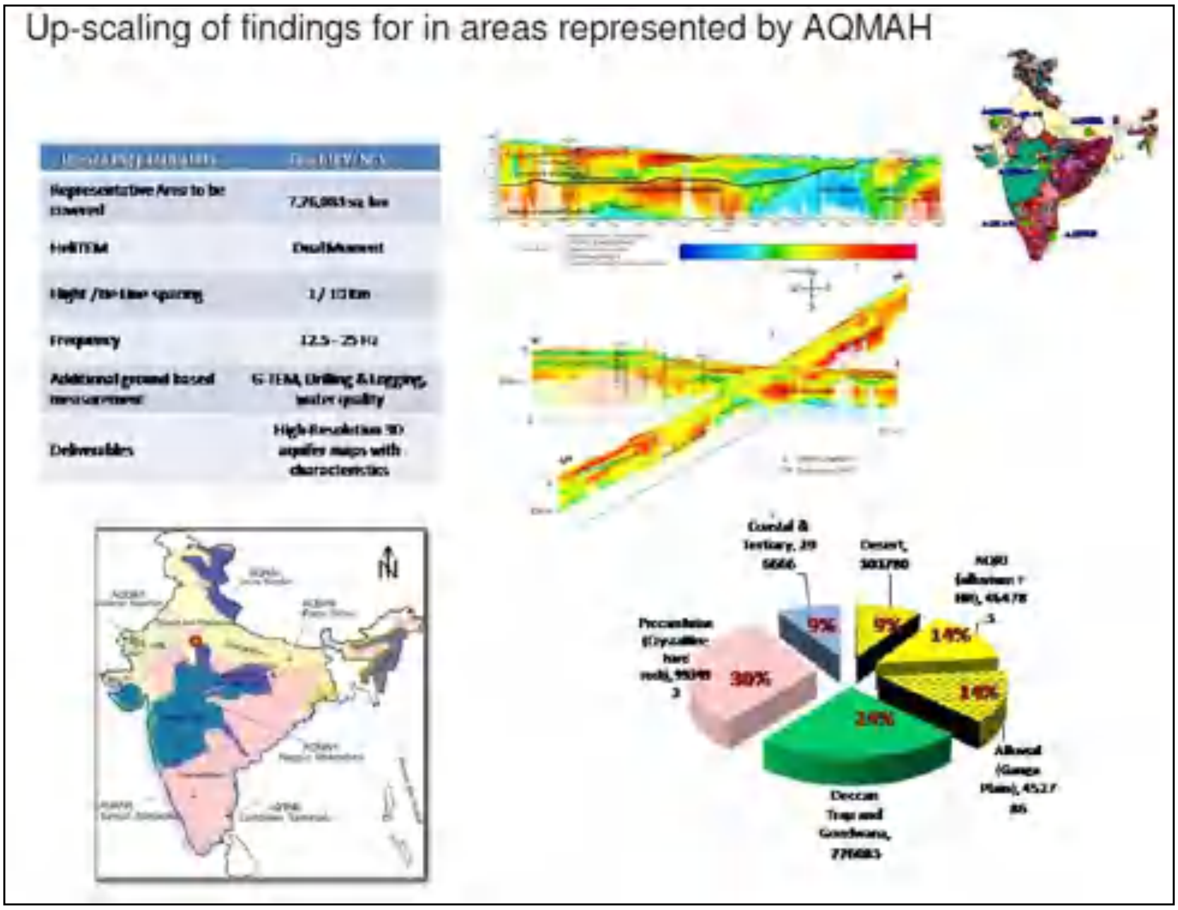


Fig.4.21. Upscaling of findings of geophysical surveys (SkyTEM) to Deccan Trap Basaltic Terrain (NGRI, 2015a)

An area of about 7,76,083 sq. km. in central India is represented by Deccan trap Basaltic terrain. NGRI, Hyderabad suggested that, the heliborne (HTEM & HMAG) survey could be carried out with the above mentioned parameters. In addition, following ground survey could complete the task in this terrain (NGRI, 2015a).

1. A few G-TEM to cover the non-flown area as well as supplement the HTEM survey.
2. A few traverses of HRSS clearly delineate boundaries of various flows.
3. Selected drilling for validation and calibration of heliborne survey.
4. Water quality measurement to apply suitable corrections.

NGRI, 2015a has suggested the following protocol for covering entire area of aquifer mapping in the State as well as in the Country.

STEP 1

Heli TEM and Heli MAG

STEP 2

Validation by ground geophysical, hydrogeological studies and exploratory drilling.

STEP 3

Data integration and interpretation for 3D aquifer model and characteristics.

CGWB agreed with the protocol suggested by NGRI, Hyderabad for covering entire area of aquifer mapping in the State. However, the cost component may vary based on the actual ground situation at the time of implementation.

5 GENERATION OF AQUIFER MAPS

5.1 Aquifer Disposition

Basalt is the main rock type of the area and comprises two distinct units viz, upper vesicular unit and lower massive unit. The massive basalt is hard, compact and does not have primary porosity and hence impermeable. Weathering, jointing and fracturing induces secondary porosity in massive unit of basalt. In vesicular basalt, when vesicles are interconnected constitutes good primary porosity and when the vesicles are filled/ partly filled the porosity is limited. Ground water occurs under phreatic/ unconfined to semi-confined conditions in basalts.

Based on extensive analysis of historical data, micro level hydrogeological survey data generated and ground water exploration carried out during project study, the following three types of aquifers can be demarcated in the Chandrabhaga watershed as detailed below:

1. *Aquifer I* - Unconfined aquifer. Occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. This aquifer generally occurs to the depth of 20 to 30m bgl and mostly tapped by the shallow dug wells in area occupied by basaltic and sandstone terrain.
2. *Aquifer II* – Semi-confined to confined aquifer. Generally occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. The thickness of aquifer varies from 0.50 cm to 6 meters in Basaltic formation and 3m to 34 m in Gondwana formation and mostly tapped by the deep bore/tube wells in area occupied by basaltic and sandstone terrain.
3. *Aquifer III* - It is mostly 'Trap Covered Gondwanas or Gneisses' (TCG). Generally occurs as semi-confined to confined conditions but at places, they exhibit unconfined condition and occur where the thickness of basalt is less, and tapped by the shallow dug wells or deep bore/tube wells in area occupied by basaltic and sandstone terrain.

The Aquifer-I in the area predominantly consist of weathered, fractured and jointed basalt and sandstone in north east part of the watershed. The data collected during detailed well inventory have been used to understand the thickness of Aquifer-I i.e., unconfined shallow basaltic and sandstone aquifer. Isopach of Aquifer-I reveals that the thickness of basaltic Aquifer-I ranges from 0 to 2 m. In the southeast part of the watershed at isolated patches, the aquifer thickness upto 4m has been observed especially in and, around villages Kalmeshwar, Khairgaon, Dahegaon and Phetri. However, in NE part of the watershed thickness of sandstone aquifer encountered from 2 to 4 and up to 6m, having thick aquifer zones (Fig. 5.1).

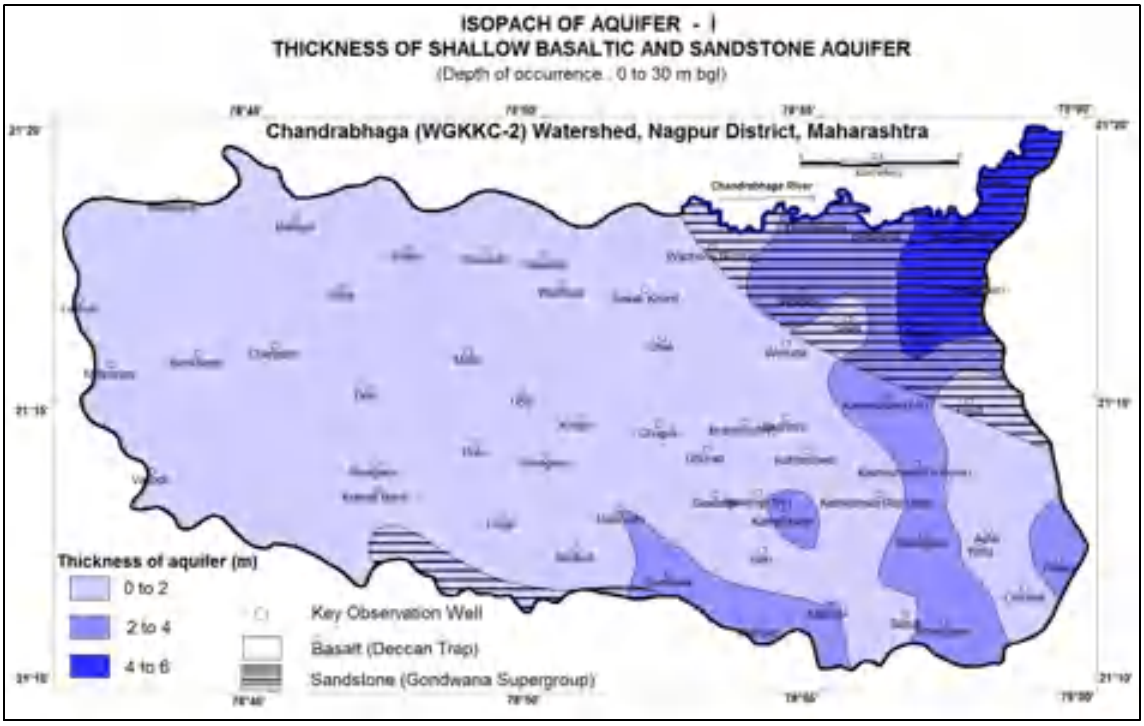


Fig.5.1: Isopach of Aquifer – I (Thickness of Shallow Basaltic & Sandstone Aquifer)

Similarly, using the historical data of CGWB on ground water exploration and data generated during drilling and construction of exploratory wells in the project area, an attempt has been made to decipher the deeper aquifer disposition in WGKCC-2 watershed. Isopach map of Aquifer-II and Aquifer-III both for basalt and Sandstone has been prepared based on the zones encountered during the drilling of ground water wells (Fig. 5.2, 5.3 and 5.4).

The study of lithological logs generated during ground water exploration indicates the existence of Gondwana formation at various depths below basaltic terrain in major parts of the area. The ground water in basaltic terrain occurs under phreatic conditions in the exposed lava flows and in semi-confined to confined state in the subsurface flows. Ground water is present in pore spaces in the vesicular unit of each flow and in the jointed and fractured portions of massive unit. However, secondary porosity and permeability that has been developed because of weathering, fracturing and joints play a very important role in the storage and movement of ground water. Weathering not only produces granular materials but also widens the fractures, joint and shear zones and constitute ground water potential aquifers in the area.

The Basaltic aquifer-II has been observed between the depth range of 30 m to >161 m bgl (Fig. 5.2). The south west part of the area and small part around village Pardi has Basaltic aquifer thickness upto 2m. The central part, around village Khapri, has aquifer thickness 4m to 6m while most of the area has Basaltic aquifer thickness ranges from 2m to 3m.

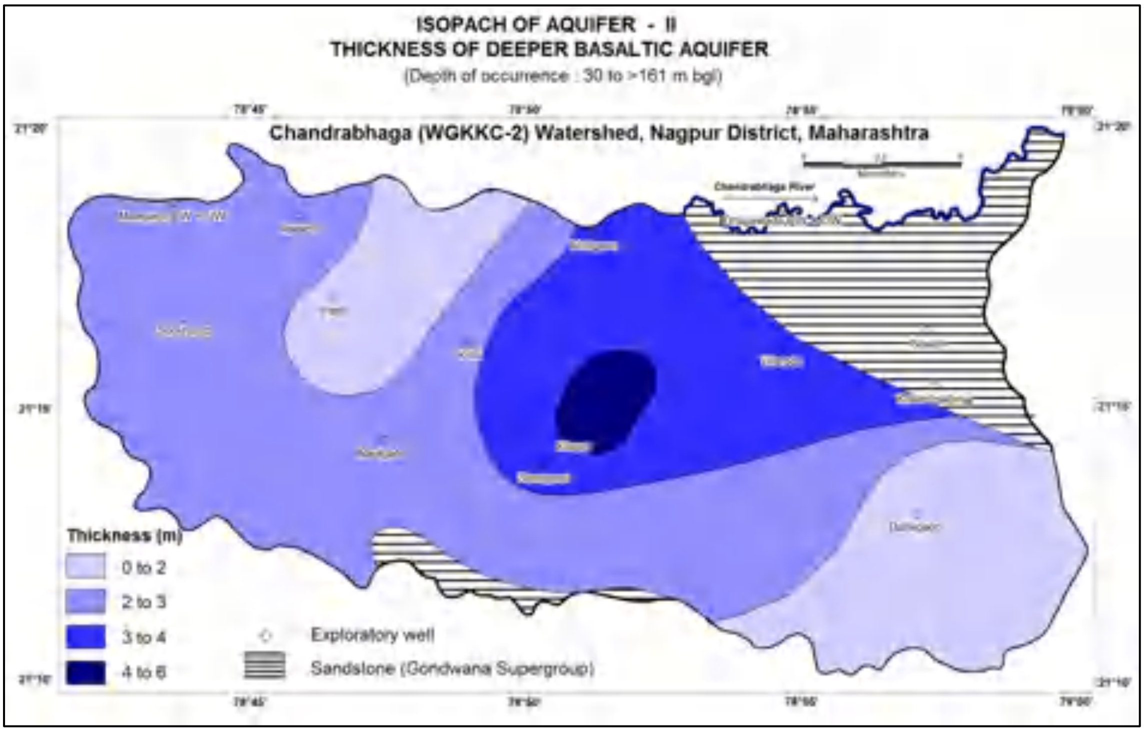


Fig.5.2: Isopach of Aquifer – II (Thickness of Deeper Basaltic Aquifer)

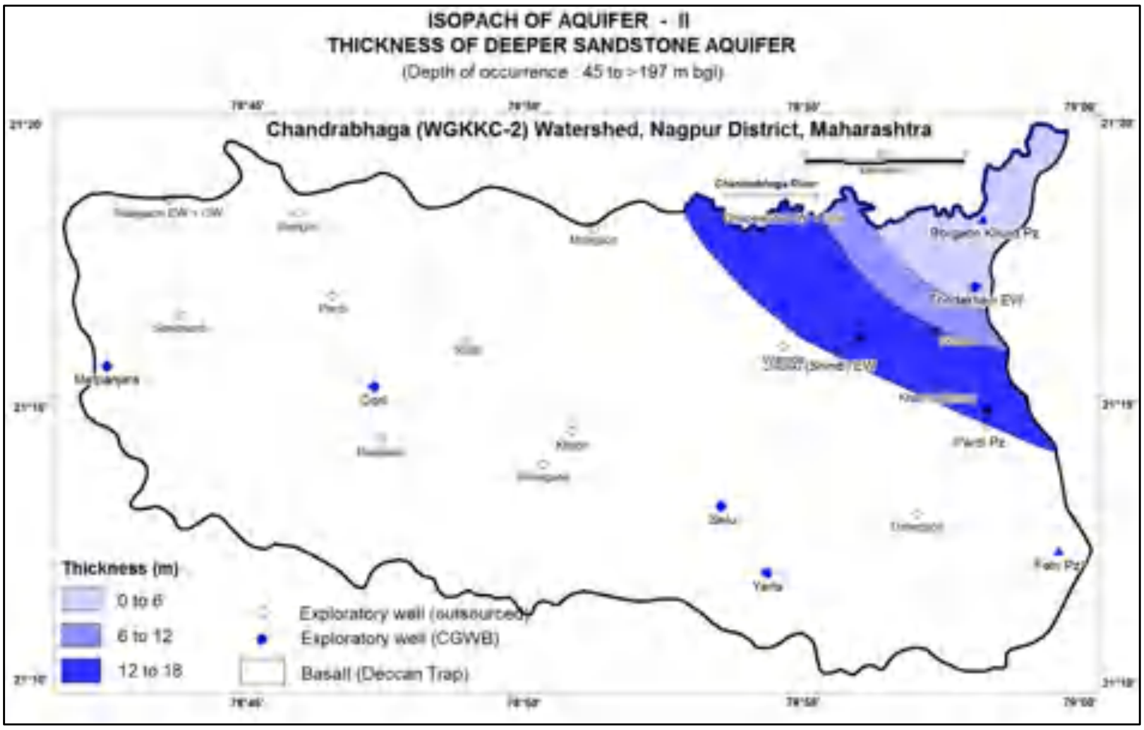


Fig.5.3: Isopach of Aquifer – II (Thickness of Deeper Sandstone Aquifer)

North eastern part of the watershed is covered by rocks of Gondwana Supergroup and consists mainly of Kamthi Sandstone and Shales. In this area, the outcrops of sandstone formation are prominently exposed. The Sandstone Aquifer-II has been encountered at a depth 45m bgl to > 197 m bgl (Fig. 5.3). The maximum thickness of aquifer ranges from 12m to 16m which is gradually reduces to 0m to 6m towards north-eastern end of the watershed.

The Trap covered Gondwana form Aquifer-III and widely distributed over the area (Fig. 5.4). It has been observed that the Sandstone Aquifer-III, covered with Basaltic flows, has maximum thickness upto 24m. It observed at isolated patches in and around villages Mohgaon, Waroda and Raulgaon. The central part of Trap Covered Gondwana formation has aquifer thickness ranges from 18 to 22m, while overall thickness is ranges from 12 to 18m. Towards extreme southeastern part, gneissic formation occur below the traps (Dahegaon), (Fig.5.2).

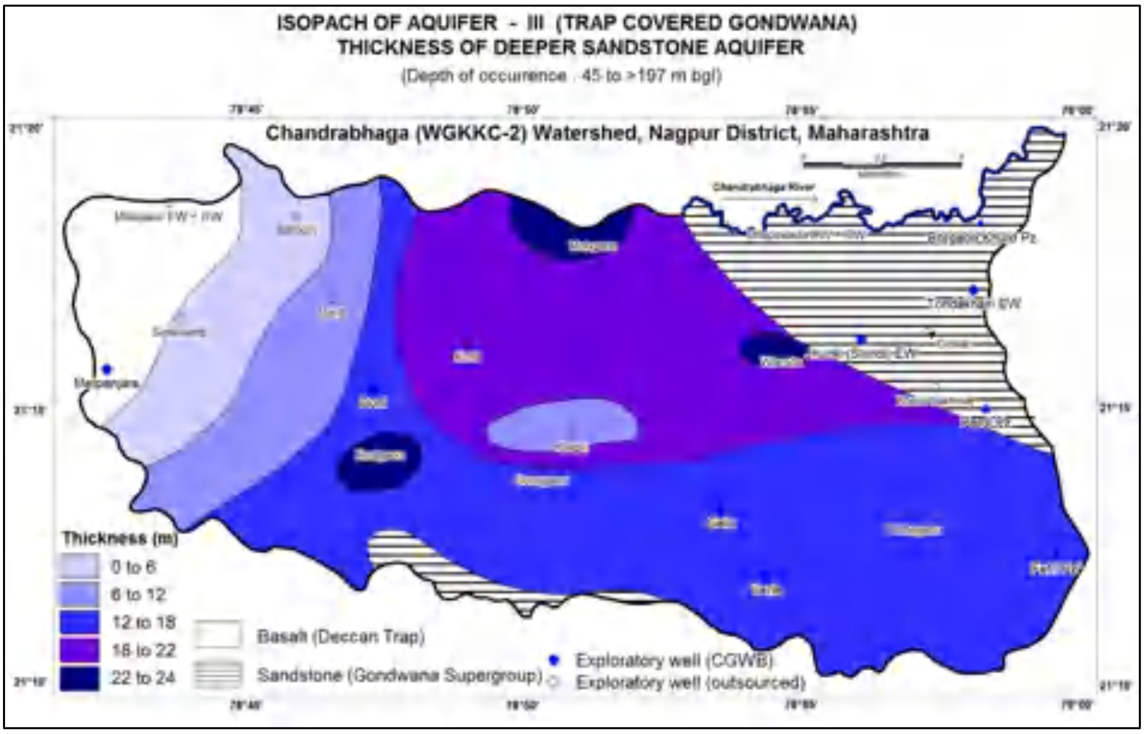


Fig.5.4: Isopach of Aquifer – III (Thickness of Deeper Sandstone Aquifer) Trap covered Gondwana (TCG)

5.1.1 3D Aquifer Maps

The well inventory data for phreatic aquifer was analysed using Rockworks software and 3D disposition of phreatic aquifer was generated (Fig.5.5). It has been observed that the basaltic terrain has typical lithological sequence in Aquifer-I, as top soil followed by highly weathered to moderately weathered basalt, fractured basalt and massive basalt. The unconfined basaltic aquifer-I is mostly restricted to fractured basalt and moderately weathered basalt.

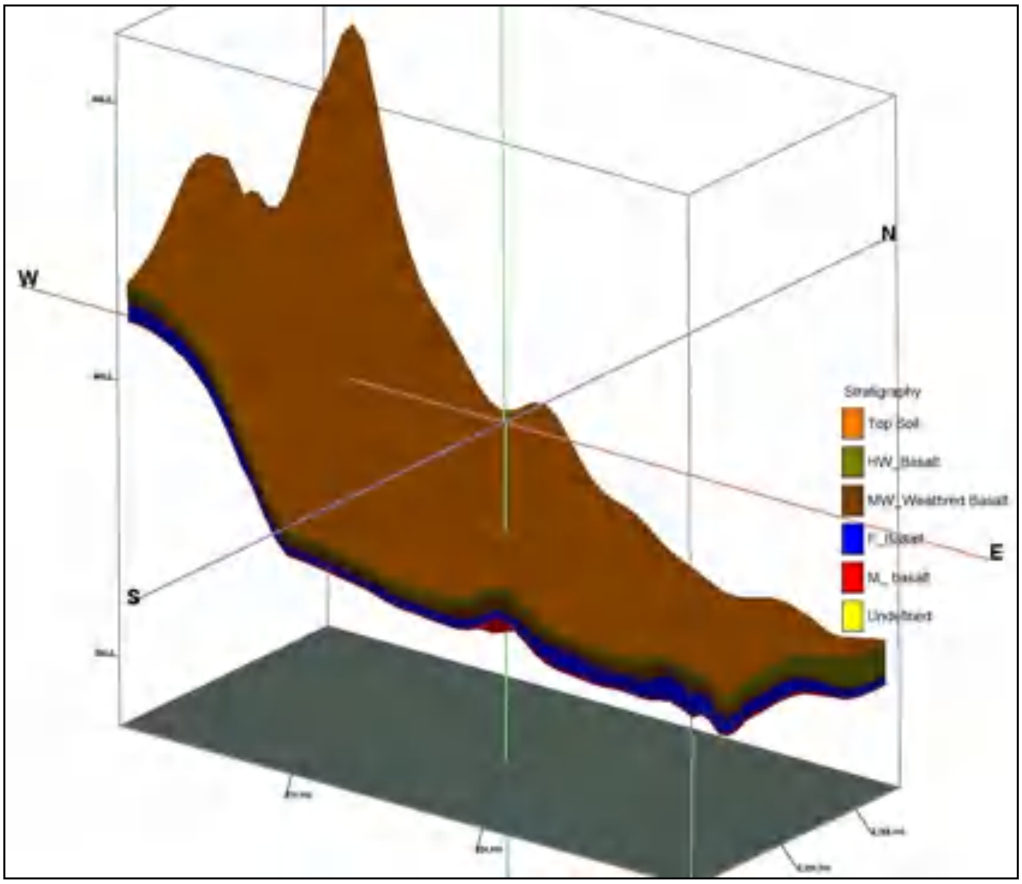


Fig. 5.5: 3D Disposition of Basaltic Aquifer-I (Shallow, unconfined)

Likewise, for Aquifer –II, the ground water exploration data has been used to generate the 3D disposition of deeper basaltic and sandstone aquifers. Using Rockworks software, a composite 3D aquifer system of the area has been generated and presented as Fig. 5.6. It comprises of all existing litho-units and the zones tapped during the ground water exploration, forming an aquifer. However, it has been observed that the true picture of the subsurface aquifer system could not be generated due to lack of data, hence the litho-units and the aquifer has been extrapolated in the model. The marker horizons like red/green and grey boles were not truly representing the subsurface disposition.

Based on the ground water exploration and micro-level hydrogeological survey lithological Fence diagram has been generated (Fig. 5.7). The Gondwana sandstone is exposed in the NE part of the watershed while the basaltic lava flows covers the rest of the watershed. The thickness of the basaltic lava flows decreases from SW to NE. It could be concluded that the central part of the watershed has Trap covered Gondwana formation, while the western part has entire Basalt and on the eastern part entire Sandstone is encountered. The SE part of the watershed has trap covered Archaean formation i.e. Gneisses.

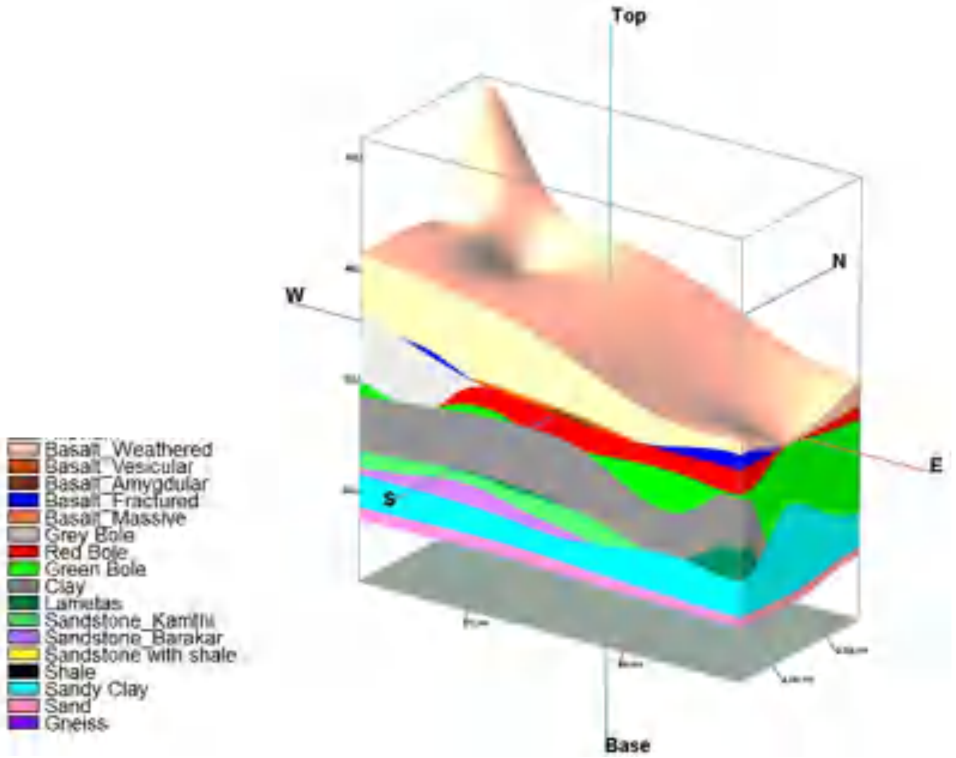


Fig. 5.6: 3D Disposition of Aquifer-II (deeper, unconfined)

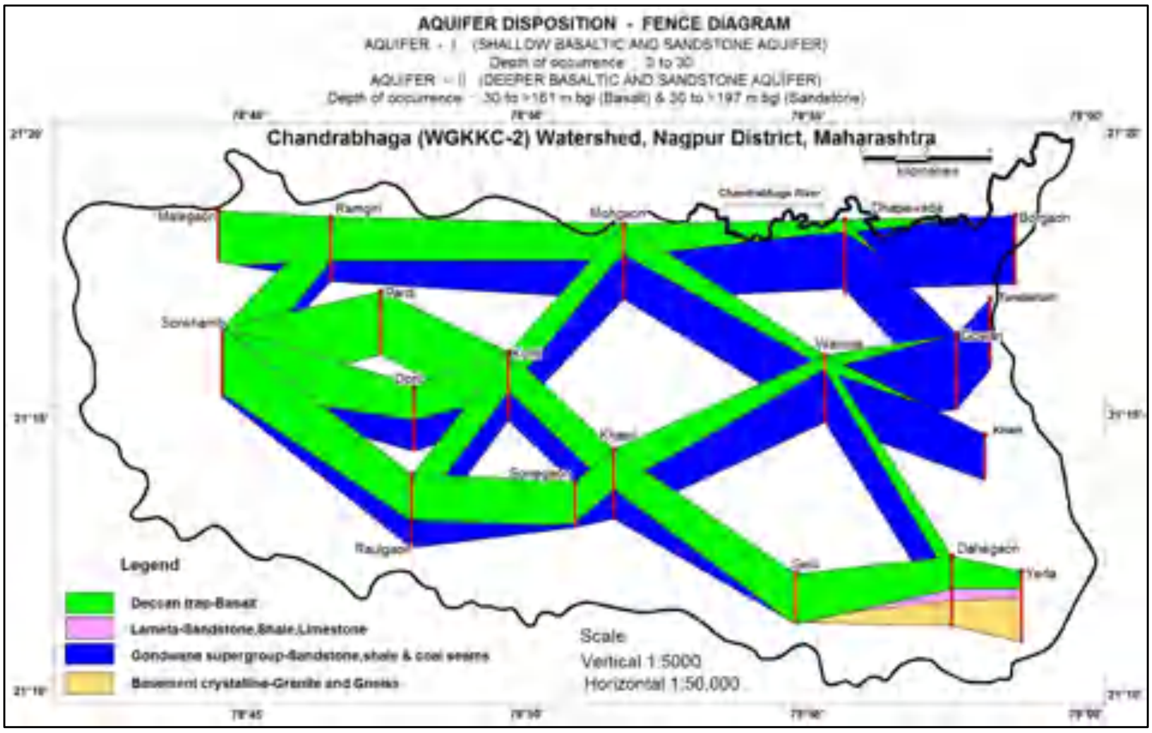


Fig. 5.7: Aquifer disposition with lithological fence diagram of the area based on ground water exploration

5.2 Aquifer Characterisation

The primary aquifer system in the Chandrabhaga watershed is unconfined Basaltic Aquifers and classified as Aquifer-I. It occurs in entire area except in northeastern part of the area where the Sandstone of Gondwana formation constituting the unconfined aquifer. The rest two aquifers i.e., Aquifer II and Aquifer –III, are semi-confined to confined in nature and spread all over the area. Based on the ground water exploration, the yield potential of these aquifers has been generated and presented as Fig. 5.8. Thus, based on hydro-geological and geophysical surveys the characteristics of aquifers in Chandrabhaga watershed has been generated and presented as **Annexure XI**.

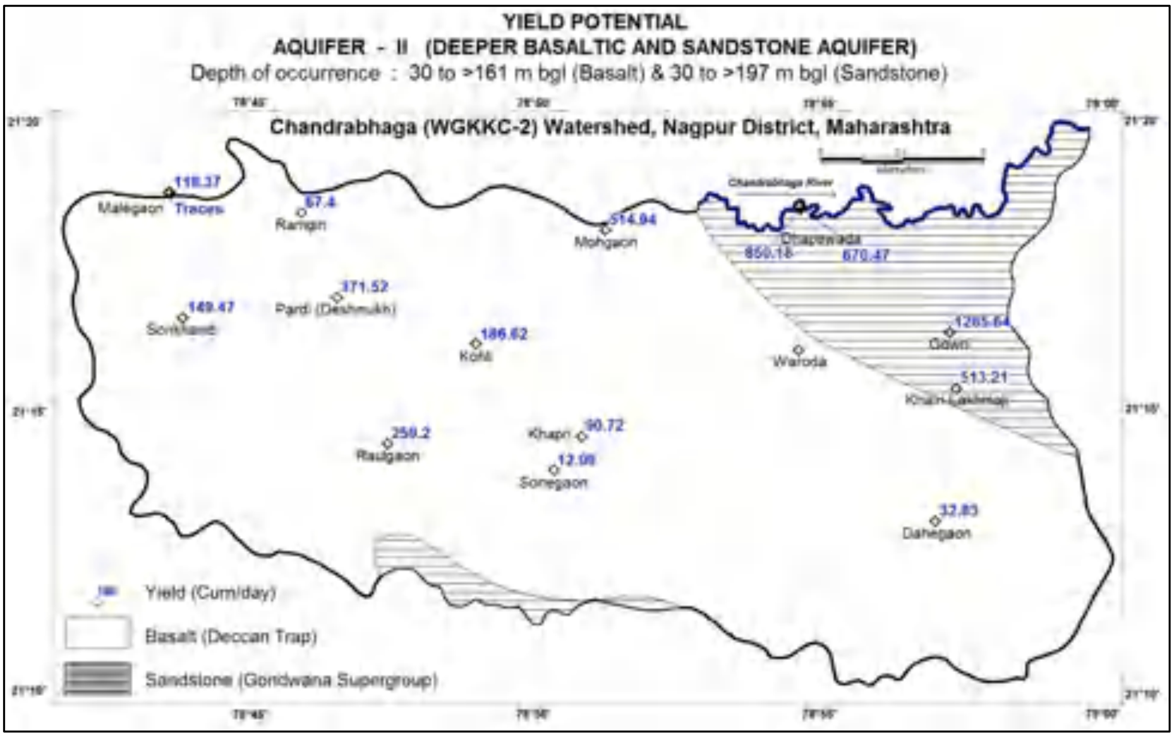


Fig.5.8: Aquifer wise yield potential, Chandrabhaga Watershed (WGKKC-2)

The Aquifer-I in area occupied by Basalt is comprises of typical lithological sequence, top soil followed by highly weathered to moderately weathered basalt, fractured basalt and massive basalt. The unconfined basaltic aquifer-I is mostly confined to fractured basalt and moderately weathered basalt. The weathering of basaltic flows exposed at surface plays a key role in recharging of the Aquifer-I. It is observed that more the depth of weathering, more will be the chances of getting shallow ground water level and vice versa. The north-western part of the watershed is hilly and hence less susceptible to weathering as compared to central and northern part. Another controlling factor for occurrence and movement of ground water is fractures in basalt as well as in sandstone. These fractures/joints are of secondary origin. The density of fractures encountered varies place to place and controls the discharge of the wells. It has been observed that in Basaltic flows the fracture in vesicular basalt helps to connect pore spaces, which ultimately creates more space for storage of ground water in unconfined aquifer. However, in massive Basalt, the width of the fracture plays a key role. The more widen the fracture more will be yield of the aquifer. Besides this, length, orientation, and width of the fracture also plays vital role in occurrence and movement of ground water when these fractures are exposed to surface, facilitate the recharge to deeper aquifer.

The Aquifer-I (Sandstone) is mainly characterised by the interconnected voids/pore spaces, cementing material and secondary fracture and joints. It is observed that the Aquifer-I in the study area is represented by the Sandstone of Gondwana formation. The weathering thickness is recorded more than 6m to 9m in the area. The presence of weathered Sandstone, its thickness, and areal extent are playing main role in recharging of the Aquifer –I (sandstone).

The pre-monsoon depth to water level of Aquifer –I (Basalt) is varying from 3 to 9 m bgl almost uniformly distributed in the watershed, except central and central eastern part where the deeper ground water level upto 12 m bgl has been observed. In Sandstone formation, the DTWL is vary from 6 to 12 m bgl.

The Aquifer-II consists of Basalt and Sandstone are characterised by Semi-confined nature. The area occupied by Basalt Aquifer-II of mostly confined to western and Southwestern, and north-western part of the watershed. Whereas in the areas occupied by Sandstone Aquifer-II is restricted in northeast part of the watershed. The sandstone of Gondwana formation is found to be most yield potential formation in the Aquifer-II followed by the jointed, fractured massive basalt. The discharge of exploratory wells constructed at Sandstone was 5 lps to maximum upto 14.88 lps. The ground water potential zones encountered at 33.00- 39.05 to 174.69 -186.85 m bgl. This indicates that though the potential zones are less in occurrence but the yield of the Sandstone formation is more. In Basaltic Aquifer-II, the ground water potential zones encountered at 11.10 -11.20 to 160.00 - 161.00 m bgl and the discharge is ranges from 0.14 to 4.30 lps.

The occurrence of bole beds is one of the major issues of Aquifer-II (Basalt). If the bole beds of sufficient thickness is encountered then it is not possible to drill the well further due to its collapsible nature by DTH drilling rig. The collapsable red bole occur at several locations in the watershed, for instance at Pardi (Deshmukh) it occurs at 87 to 96 & 101 to 104 m bgl, at

Ramgiri collapsable red boles occurs at 127 m bgl, and at Sonegaon collapsable red boles and green boles occur at various depths. As a result construction of wells in these area restricted above red bole beds only.

The third aquifer type, Aquifer-III, observed in the Chandrabhaga watershed is Trap covered Gondwana and Archaean Gneisses formations (TCG). The trap covered Archaean Gneisses exist only in the south-eastern part of the watershed near Yerla and Dahegaon. The Aquifer-III are characterised by the thin/thick cover of Basaltic flows having thickness from 27 m to 195.10 m. Most of the area of the Chandrabhaga watershed falls in Aquifer-III, covering central, southern central part of the watershed. However, the trap covered Archaean Gneiss is seen in the southeastern part of the watershed i.e., at Dahegaon at the depth of 129.95 mbgl. The construction of tube wells in such terrains is always a challenging task.

The upper hard formation (Basalt) is followed by the soft formation (Sandstone), which is a reversal of the formation in terms of ground water well construction. Due to which most of the people in the Chandrabhaga watershed have difficulties to tap the potential of Sandstone aquifer occupying below Basalt as it is very costly to construct tube well penetrating huge pile of hard rock. During the ground water exploration, it has been observed that the thickness of hard basalt encountered from 59.50 m bgl (Mohgaon), 62 m bgl (Waroda), 96.56 m bgl (Kohli) to 195.1 m bgl (Sonkhamb) while the ground water potential zones encountered 62-68 m bgl to 195.72 - 198.72 mbgl. The deeper ground water level is another issue of Aquifer-III. The ground water level in these tube wells is observed from 11.27 mbgl (Sonkhamb) to 78.12 mbgl (Kohli). The yield of the Aquifer-III is recorded moderate to high and the discharge recorded ranges from 1.05 lps (Khapri) to 5.94 lps (Mohgaon).

6 AQUIFER RESPONSE MODEL AND AQUIFER MANAGEMENT PLAN FORMULATION

6.1 AQUIFER RESPONSE MODEL-AQMAH

6.1.1 Introduction

Groundwater is an important resource so it must be managed prudently. However, there are several difficulties associated with understanding a groundwater system. Its invisibility and highly heterogeneity nature has made it very difficult to accurately characterize the media in which the groundwater is stored. One way of improving our understanding of these highly complex systems is to build and experiment with models which replicate them.

Fetter (1988) defines a model as “any representation of a real system”. Bedient et al (1997) stated that “a ground water model is a tool designed to represent a simplified version of a real field site”. Anderson and Woessner (2002) agree, defining a model as “any device that represents an approximation of a field situation”. The overriding concept is that a model enables the user to use limited field data to find the (approximate) answers to questions posed.

There are two principle drivers behind most modeling exercises. First, to gain an understanding of why a system behaves as it does and second to predict future behaviour (Fetter, 1988; Anderson and Woessner, 2002). Anderson and Woessner (2002) add a third dimension as a tool to provide solution and regulatory guidelines for improvements and corrective measures. Models can help the designer to understand a system’s behaviour through the iterative process by which the model is modified until the results generated match field results (known as calibration, see later).

It is important to clearly establish the purpose of the model. Anderson and Woessner (2002) recommend that the following questions must be asked constructing a model:

- What do you want to learn from the model?
- What questions do you want the model to answer?
- Is a modelling exercise the best way to answer the question(s)?”

Addressing these questions helps the modeller to decide if a model is needed, what type of model is appropriate, and what the data requirements might be.

6.1.2 Scope and Objective of Ground Water Modeling

The watershed is characterized by high ground water withdrawal for agricultural and industrial uses with the stage of ground water development touching 89%. No declining trend is observed in the well hydrographs of the region. However if ground water withdrawal goes abated at this pace then, the ground water condition in the watershed will become critical in near future. Thus, the purpose of this study is

1. to understand the behavior of the aquifer system in the watershed
2. to evaluate the effects of the Chandrabhaga river flowing along the northern border of the watershed

For improving the ground water resource position, possible scenarios like

1. The effect of raising the river stage by the construction of two to four check weirs on River Chandrabhaga on the ground water regime and quantifying the benefits accrued out of it.
2. Improving the recharge in the highly stressed aquifers underlying the Kalmeshwar Industrial Area by series of check dams and recharge wells and quantifying the increase in recharge

6.1.3 Numerical model Design

Developing a model concept is the initial and the most important part of every modeling effort. It requires a thorough understanding of hydrogeology, hydrology and dynamics of groundwater flow in and around the area of interest. A computerized data base and simplified maps and cross sections are being used in the model design. A model that simulates groundwater flow is the simplified representation of the aquifer system, which may be used to predict aquifer response to various input/ output stresses.

Mathematical models use equations to represent the processes occurring in a field situation and include analytical, numerical and stochastic models (Fetter, 1988). Numerical models are exact solutions but can be used in simple cases with homogeneous condition and simplified boundary condition. However numerical solutions for complex solutions are not available. Numerical models are based on a computer program approximating the controlling partial differential equations as simultaneous equations expressed in matrix form. The power of numerical modeling reflects the efficiency of computers in solving large numbers of simultaneous equations.

Numerical models all start with the equation of flow. At its most basic, this can be represented as the Laplace equation shown below (Fetter, 1988):

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = 0$$

for steady state condition where *h* represents head

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = \frac{S}{T}\frac{\partial h}{\partial t}$$

for transient or unsteady state condition.

Anderson and Woessner (2002) give a more general form:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t} - R*$$

Where *K* is the hydraulic conductivity, S_s is the specific storage and *R** is a source/sink term. This version of the governing equation allows for temporal variation of head.

The above equation, when combined with boundary and initial conditions, describes the groundwater flow under non-equilibrium conditions in a heterogeneous and anisotropic medium, provided the principle axis of hydraulic conductivity is aligned with the x-y Cartesian co-ordinate axes. Generally, numerical methods are used to solve the groundwater flow equations. The groundwater flow process solves above equation using the finite-difference method in which the groundwater flow system is divided into a grid of cells. For each cell, there is a single point, called a node, at which head is calculated. The set of computer commands used to solve these governing equations on a computer forms the computer program or code. The code is generic, where as a model includes a set of boundary and initial conditions as well as site specific nodal grids and site specific parameter values and hydrologic stresses. A code is written once but a model can be designed for each modeling applications. (McDonald and Harbaugh, 1984; 1988). The finite-difference computer code MODFLOW developed by McDonald and Harbaugh 1988, embedded in the VISUAL MODFLOW Package is used to simulate the groundwater flow in the study area.

6.1.3.1 Methodology

Groundwater modeling for the hard rock area of Deccan Trap Basalt is always a challenging task as it is very difficult to run the model because of the heterogeneity in the aquifer parameters and unpredictable basaltic aquifer geometry. For successful groundwater modeling, there are some modeling protocols have to be followed. A protocol for modeling includes model design, calibration, sensitivity analysis and finally prediction as presented in flow chart for modeling process (Fig. 6.1) (Aderson and Woessner 1992).

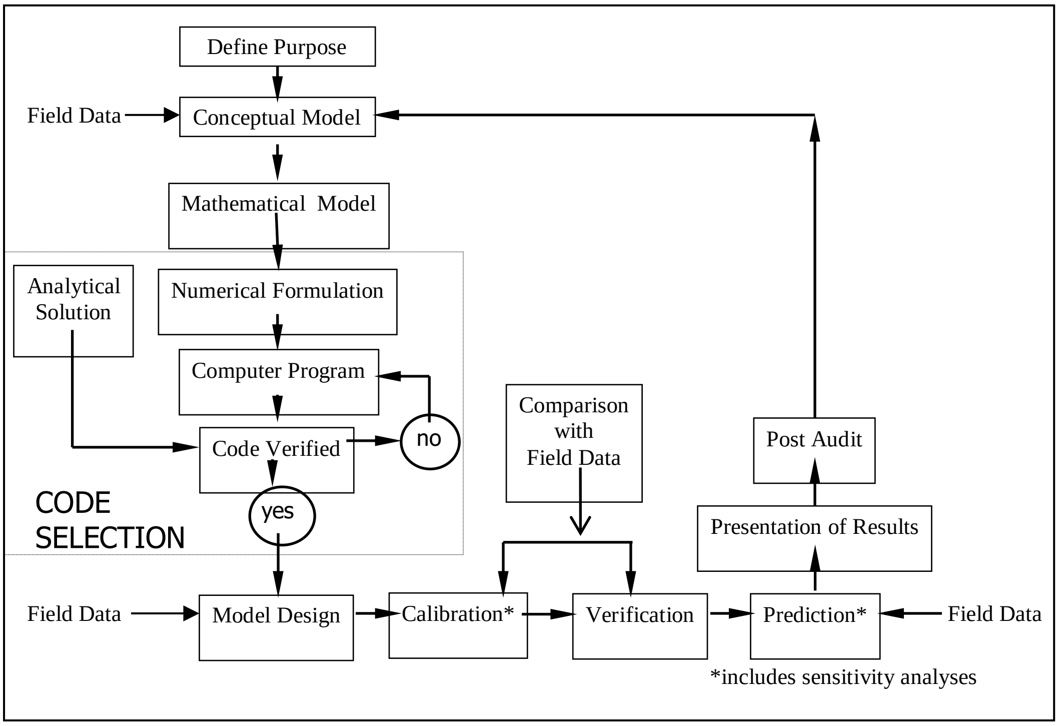


Fig. 6.1: Flow chart for modeling process (after Aderson and Woessner, 1992)

First of all the **purpose** of the model must be defined as discussed in the earlier section. This can consist of a list of questions for the model to answer.

A **conceptual model** is developed in any situation involving groundwater. It describes the best understanding of what is present under the ground from the available data. It can consist of text and/or diagrams, but usually includes a plan view and a cross-section.

The “**mathematical model**” box on the flowchart indicates choosing the relevant governing equation. The governing equation of flow in a porous media was discussed earlier but other governing equations may be required for other modeling purposes, e.g. solute transport for the migration of a contaminant plume.

A published computer **code** will usually have been used by other modelers (unless it is very new). Successful use of a computer code indicates that most bugs have been corrected and the code gives reasonable and reliable results. The more a code has been used by other modelers and shown to work, the greater the trust that will be put into new models built using the same code. It is therefore usual to use a well-established computer code.

The computer model is **designed** using information from the conceptual model. Usually a map is uploaded and features such as aquifers, aquitards and surface water bodies are added with their properties specified according to the conceptual model.

Calibration is the process by which the properties of features in the model are adjusted until the model produces heads and flows which match those measured in the field. A sensitivity analysis is carried out to assess the effect of uncertainties in the data. In some cases properties in the calibrated model (e.g. hydraulic conductivities) may be different to those measured in the field (Hill and Tiedeman, 2007) and it is necessary to make a professional judgment about whether this is appropriate. For example, hydraulic conductivity cannot be accurately measured so if the modeled hydraulic conductivity is within half an order of magnitude of the field value this is usually considered acceptable.

Verification can be confused with calibration but it is a separate stage. The calibrated model is run and should reproduce a set of field data which was not used in the calibration process. This is a "final check". (Note: the term "verification" is also used to refer to the process of checking the computer code works correctly. To avoid confusion, the term "validation" is used elsewhere in this report to refer to the process of running a calibrated model with a new set of data.)

The model is then used to make the **predictions** required. A sensitivity analysis should also be performed at this stage to estimate the uncertainties associated with the answers generated by the model.

Models which are kept for a long time, such as those developed for aquifer management can undergo a process called "**post audit**". The model was used to make predictions, for example ten years, into the future. In ten years' time, the field data measured over the intervening period can be compared to the predictions made by the model and used to assess the model's performance. Discrepancies can be used to inform changes to the model.

During the project period, available data pertains to study area was complied, data gap analysis was carried out and data generated to fill these gaps. The various thematic maps like drainage, soil, geomorphology, landuse/landcover, hydrology, lineaments, geology etc. prepared based on data available using software like Arcmap, Mapinfo discover, Rockworks etc. Extensive hydrogeological surveys have been carried out. A total 16 exploratory wells were constructed through outsourcing to decipher the aquifer geometry, its lateral and vertical extend and determination of deeper aquifer parameters. All the boreholes were logged upto drilled depth through gamma logging to get the accurate disposition of fracture geometry. The entire data has been used to formulate the ground water flow model using MODFLOW code.

6.1.4 About Visual Modflow

Over the last few decades, U.S. Geological Survey's modular finite-difference groundwater flow model, which is commonly known as MODFLOW, is significantly used for the description and prediction of the behaviour of groundwater systems. The original version of MODFLOW-88 or MODFLOW-96 can simulate the effects of wells, rivers, drains, head-dependent boundaries, recharge and evapo-transpiration. MODFLOW can simulate underground flow under steady and unsteady conditions in anisotropic and non-homogeneous porous media. It is designed to simulate aquifer systems in which saturated flow conditions exists, Darcy's Law applies, density of groundwater remains constant and the principal directions of horizontal hydraulic conductivity or transmissivity do not vary within the system (McDonald and Harbaugh, 1984 and 1988). In MODFLOW, an aquifer system is replaced by a discretized domain consisting of an array of nodes and associated finite difference blocks. Groundwater simulation modeling is a powerful management tool to study such problematic areas. At present, the most investigations related to groundwater modeling are carried out by MODFLOW (Anderson and Woessner, 1992). Many new capabilities have been added to the original model. MODFLOW-2005 is the most current release of MODFLOW. MODFLOW-2005 (Harbaugh, 2005) simulates steady and non-steady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined.

Presently, Visual MODFLOW is the most complete, and user-friendly, modeling environment for practical applications in three-dimensional groundwater flow and contaminant transport simulation. Visual MODFLOW Premium is a three-dimensional groundwater flow and contaminant transport modeling application that integrates MODFLOW-2005, SEAWAT, MODPATH, MT3DMS, MT3D99, RT3D, VMOD 3D-Explorer, WinPEST, Stream Routing Package, Zone Budget, MGO, SAMG, and PHT3D. Applications include well head capture zone delineation, pumping well optimization, aquifer storage and recovery, groundwater remediation design, simulating natural attenuation, and saltwater intrusion Flow from external stresses, such as flow to wells, areal recharge, evapotranspiration, flow to drains, and flow through river beds, can be simulated.

6.1.5 Conceptual Model

The field survey, ground water exploration study and geophysical surveys in the study area has been used to conceptualized model area based on geology (Fig. 6.2a), based on major lithounit (Fig. 6.2b) and based on aquifer type (Fig. 6.2c). In the present study, conceptual models were developed assuming different boundary conditions specially for hilly area in western end and river boundary in northeast of the study area (Bredehoeft J., 2005).

Weathered and fractured residuum underlain by massive basaltic flow serves as the main aquifer system in the area. Ground water occurs under unconfined condition and the head is reflected as ground water level in the dug wells. Though the dug wells are of 10 to 15 meters of depth, they have not fully tapped the phreatic aquifer. Hence, the thickness of the aquifer is taken as 20 to 35 meter as deciphered from the geophysical and well inventoried data and is considered as first layer in the model. Similarly, the top weathered and fractured zone on the Gondwana sandstone present in the north eastern part is also included in the first layer of the model. The aquifer characteristics and ground water level data is available for this layer. Ground water exploration carried down to depth of 200 m, shows number of basaltic flows with ground water contribution mainly from fractures and contact of different flows. Similar is the condition in the Gondwana sandstone and thus a second layer comprising of basalt, Gondwana sandstone and trap covered sandstone is conceptualized to the depth of 200 meter with very low permeability value unless until good fractures are encountered. However due to paucity of data the second layer is not being modeled. There is a scope for refinement of model as per the requirement of aquifer management plan.

Conceptual model I

Parameters	Layer-I	Layer-II
Formation	Zone-I Hilly Basalt (Deccan Trap) Zone-II Basalt(Deccan Trap) & Sandstone (Gondwana)	As per availability of data in future
Layer Type	Unconfined, Type-1	Semi-confined to Confined, Type-2
Layer thickness (m)	Varying (GL to 20 to 35m)	145-180(20 mbgl to 200 m bgl)
Grid size	1000m x 1000m	1000m x 1000m

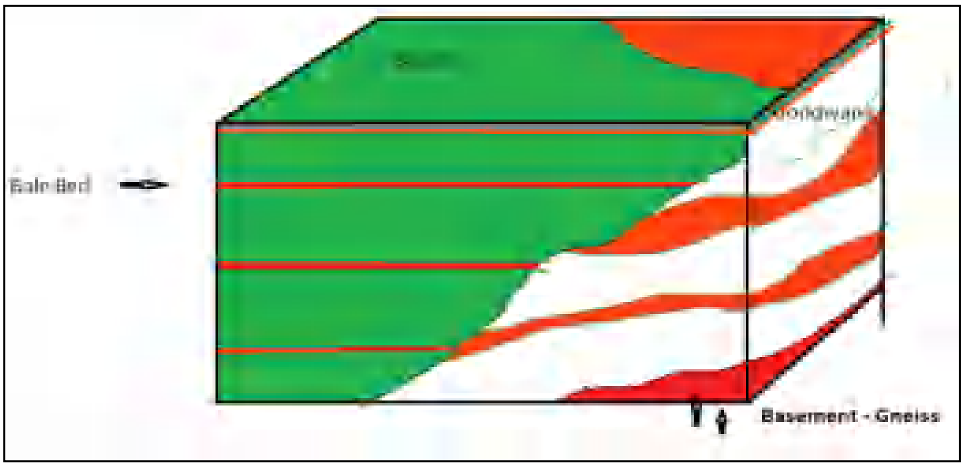


Fig. 6.2a. Conceptualization of area based on geology

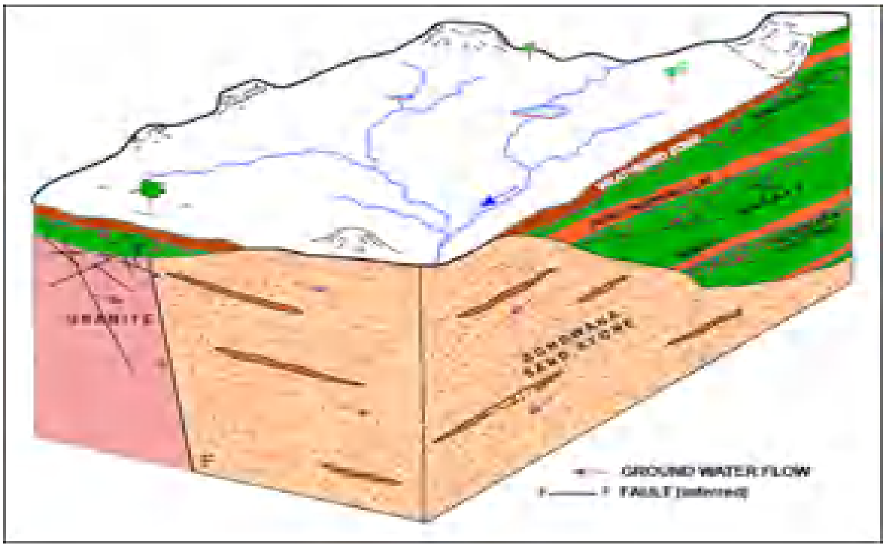


Fig. 6.2b. Conceptualization of area based on major litho-unit

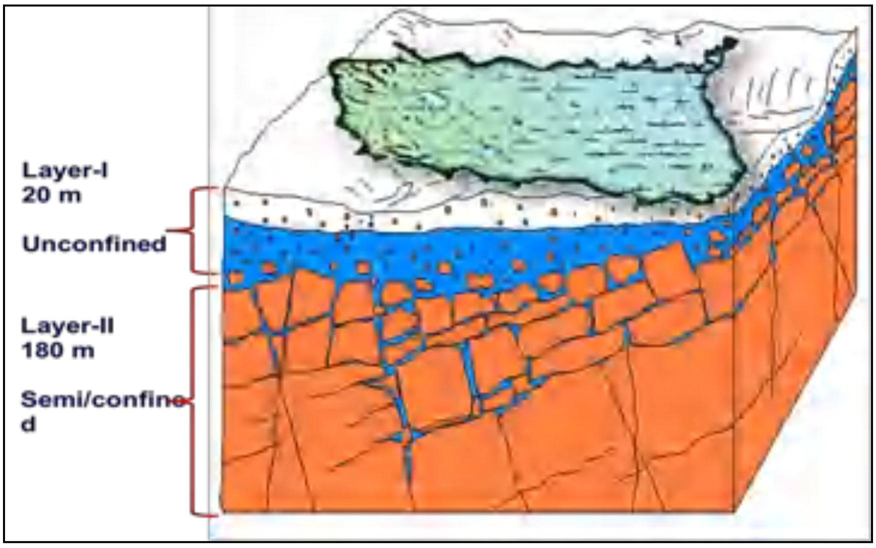


Fig. 6.2c. Conceptualization of area based on aquifer type

6.1.6 Grid Design

Under this backdrop, a two layer model is generated for the watershed. Based on the available data, a coarse uniform grid of 1000 ×1000 m is designed and the layer top elevation of the model is imported from the SRTM data after refining to accommodate to the model grid size. A perusal of the well depth and geophysical data hints the depth of the phreatic aquifer varies from 20 to 35 meter below ground level. Thus, the thickness of the phreatic aquifer is taken from well depth data by contouring and calculating the depth at each grid and adding another 15 meter to that value. The 2nd layer bottom is taken as the layer top elevation minus 70 meter.

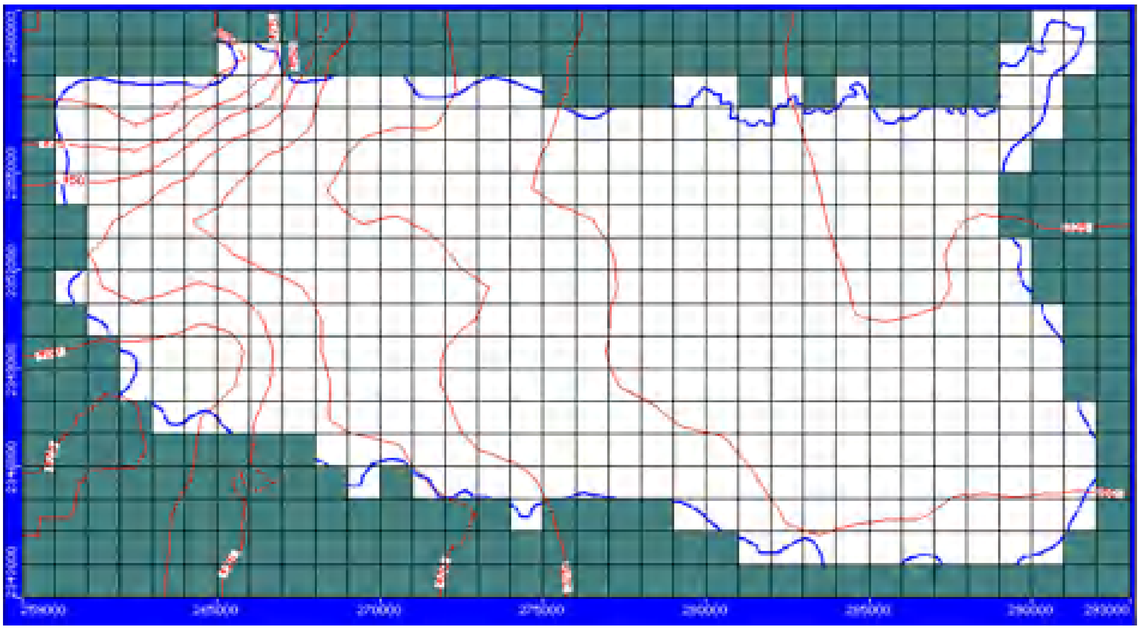


Fig.6.3: Model grids with active (white) and inactive (green) cells and land elevation contours superimposed

6.1.7 Assumptions Used in the Conceptual Model

To translate the aquifer system in the area into mathematical model, the following assumptions are made;

1. Most part of the watershed boundary serves as hydrological boundary for the modeled area and thus contributes negligible flow to or from the modeled area.
2. The river Chandrabhaga flowing along the northern part of the study area contains good amount of surface water in the form of flow so that it can be treated as a source of water at least for part of its course.
3. Rainfall is the only source of recharge for the top phreatic aquifer. Recharge due to the return flow from irrigation is not considered.
4. The ground water flow system in the western hilly area is local and is confined to small valleys interspersed in hills and is nothing to do with the regional flow system depicted in the model. Hence ground water draft from these areas is not considered in the model.
5. Due to the limited size and extent of the river flowing through the watershed, its contribution to the model is limited to a drain.

6.1.8 Geometry and Boundary Conditions

Based on geologic information including geologic maps, The Lithological data, cross sections, well logs, VES data the horizontal and vertical disposition of aquifers in the study area to a depth of 70 m bgl is translated into the model. The boundary as assumed in the earlier section is also discretised in the model. The planar and sectional view is shown in the Figure (Fig. 6.4a & 6.4b).

Assigning Boundary

The area is discretized into 612 grids of 1000 × 1000 meter grid size. A total 18 rows and 34 columns were considered. Out of 612 grids, 392 grids are kept active following the watershed boundary. By making the rest of the grids inactive, the no flow boundary is created at the watershed boundary.

The river flowing along the north-eastern part is modeled as a linear gradient river assigning river stage of 332 to 305 m amsl at the western and eastern part respectively. The width of the river is 20 meter in the western part and widened to 30 meter in the eastern part. The permeability of the river bottom is high compared to the aquifer and hence is taken as 2 m/day with its thickness below the river bottom as 1 meter.

To simulate the large reservoirs present in the eastern part of the watershed, a constant head boundary is assigned to the cells underlain by reservoirs. Three big reservoirs are considered for the purpose. To simulate the river draining the watershed, a drain boundary is revoked so that it will imitate an ephemeral stream. All these boundaries are shown in the Figure 6.4a & b.

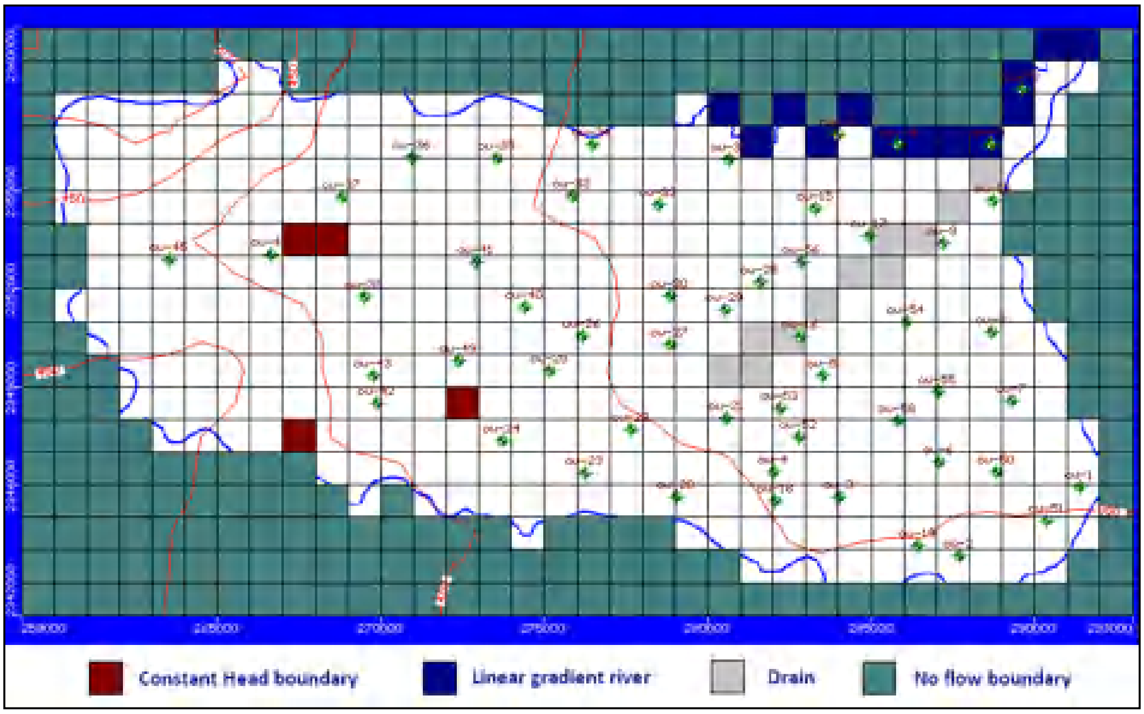


Fig. 6.4a: The conceptual model Layer -1 plan view, the surface elevation contour with an interval of 25 meter is shown as red line. The green points are monitoring well locations.

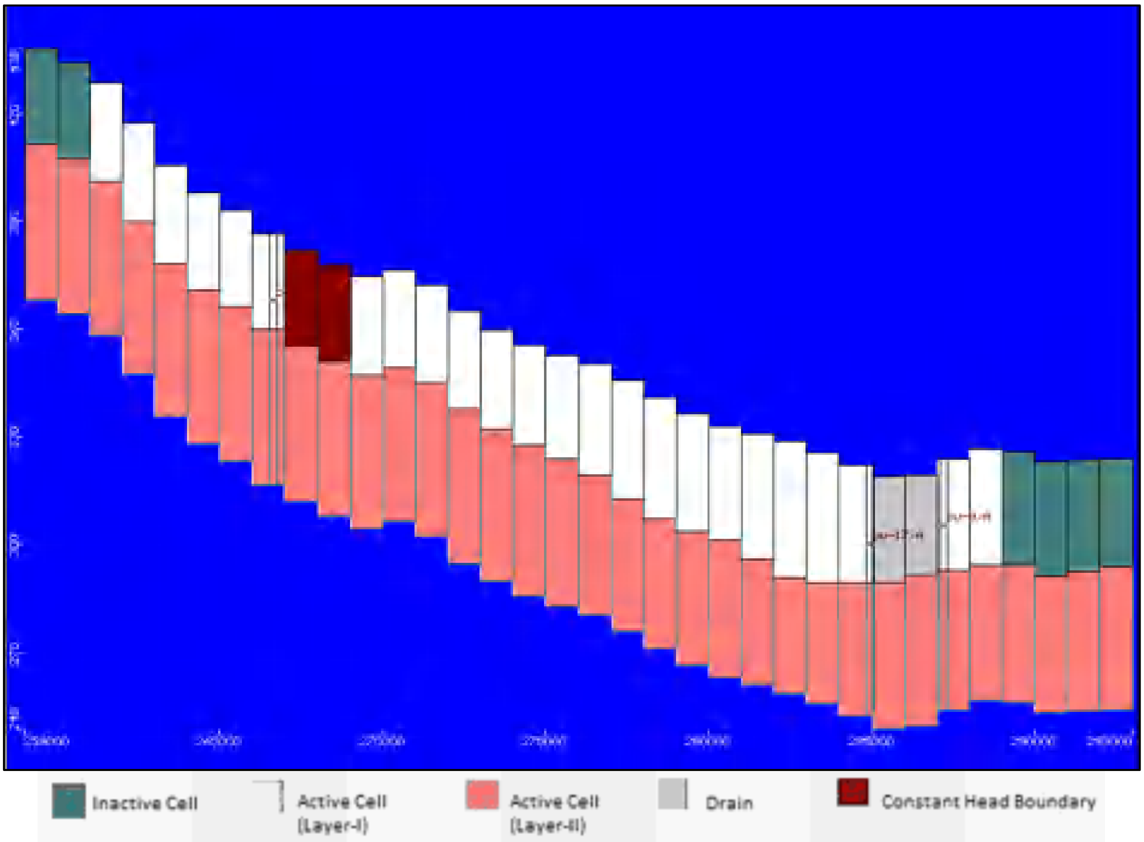


Fig.6.4b: The conceptual model sectional view on row 7.

6.1.9 Distribution of Conductivity Values

Pumping tests in 21 numbers of dug well are conducted to know the permeability of the phreatic aquifer. The range of hydraulic conductivity for this layer varies from 6 to 100 meter/day. Thus, conductivity of around 12 m/day was considered for most part of the phreatic aquifer. Vertical hydraulic conductivity has been taken as 10% of the horizontal hydraulic conductivity. From geophysical data, massive basaltic horizons underlain by fractured basalt are found in the top aquifer at some localized patches. Since the same fractured aquifer is considered foe modelling, same permeability value is assigned to the local changes in the aquifer. The hilly area in the western part is highly sloping and is not practically considered for modeling purpose. Thus, to simulate the area in the model, a very low permeability value of 0.01 m/day is assigned. The 2nd layer is also considered to be massive and non-productive and hence conductivity value of 0.0001m/day is assigned.

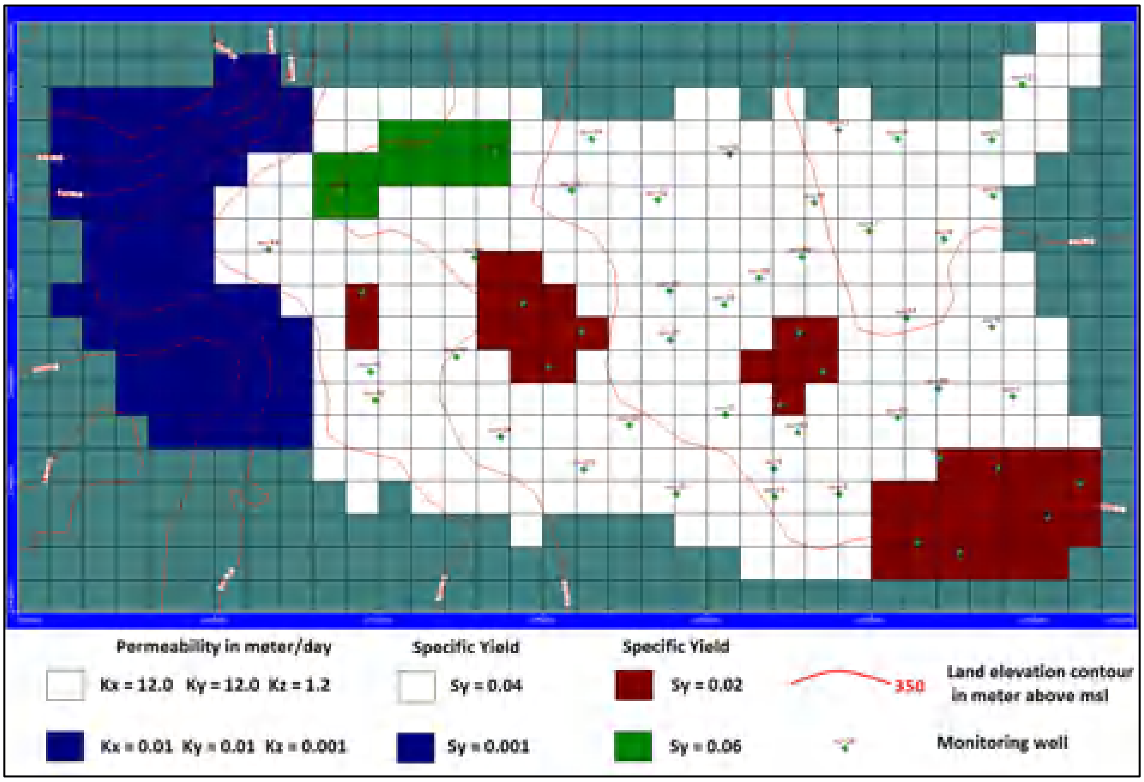


Fig. 6.5: Zone wise distribution of hydraulic conductivity and storage in the modeled area

6.1.10 Distribution of Storage parameters

Since the weathered and fractured zone is very productive and devoid of much clay content, a specific yield value of 0.04 is considered for the major part of the model area. Though the range of specific yield value for fractured basalt varies between 0.02 – 0.03 as per GEC-1997 recommendations; however in local parlance it may be higher than that. Presence of good yielding dug wells sustaining to long duration of pumping indirectly indicates high conductivity and storage value of the phreatic aquifer. However the storage value of massive basaltic horizons underlain by fractured basalt as deciphered from geophysical investigation is low and is taken as 0.02. The hilly area present in the western part is underlain by massive basalt and hence a very low storage value of 0.0001 is assigned to this zone.

6.1.11 Recharge

The recharge to the watershed is only from precipitation and thus vertical recharge is the only source of ground water in the basin. The actual rainfall data of Kalmeshwar rain gauge station of 2012, 2013 & 2014 is used whereas the normal monsoonal rainfall is considered for predicted period. Studied conducted in the Sina & Man basin during 1982 shows a recharge value of around 23.7% and 18.5% for Sina & Man basin respectively. However due to more rainfall in the watershed under study, a low recharge value of around 16% is considered for most part of the study area. The western hilly area is assigned a very low recharge value of only 1% (Fig. 13). A somewhat lower recharge of 13% is assigned to the valley area since they fall under ground water discharge zone at least during peak monsoon season. A less recharge of 8% is assigned to the north-western part which is characterized by undulating hills and valleys.

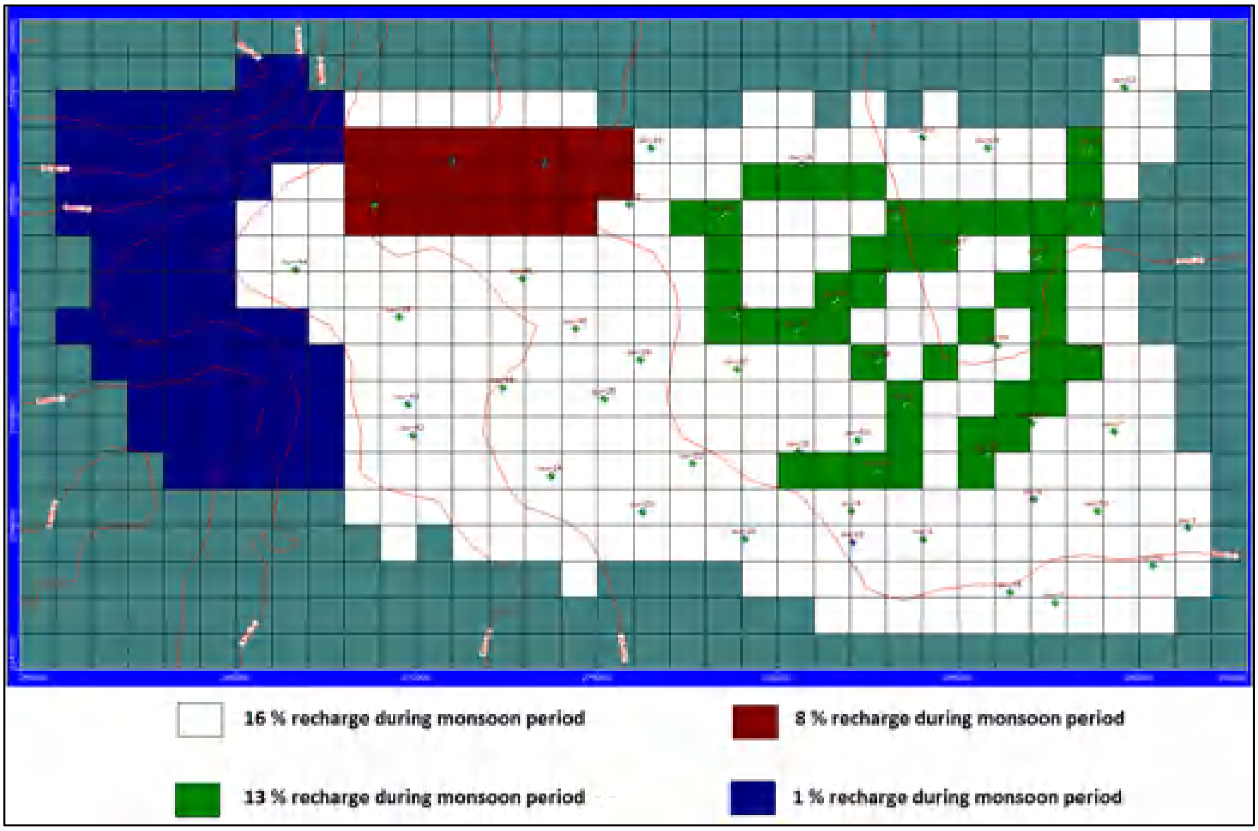


Fig. 6.6: Zone wise distribution of recharge rates in the modeled area

6.1.12 Discharge Data

Generally pumping from the aquifer occurs during the Rabi season and hence ground water draft is considered after November. The village wise well census data is first distributed grid wise to arrive at the numbers of wells falling in each grid. The unit draft as deciphered from the field observation is considered as 50 m^3/day. Though the pumping varies during the different period of the crop growth, a uniform rate of pumping is assigned to the region for the whole non-monsoon season of 215 days (November to May). Thus, pumping rate equivalent to the number of wells multiplied by unit draft is inserted into the respective grids to simulate draft from the grids. Since the annual increase in draft is 3%, for predictive calculations 3% draft is increased every year in the withdrawal. As the ground water flow in the hilly area is local, so localized pumping has nothing to do with the regional aquifer system. Hence, ground water withdrawal from these cells falling under the hilly region is not used in the model.

6.1.13 Model Calibration

Calibration of a flow model refers to a demonstration that the model is capable of producing field measured head and flows, which are the calibration values. Calibration is accomplished by finding a set of parameters, boundary conditions, and stress that produce simulated heads and fluxes that matches field measured values within a pre-established range of errors (Aderson and Woessner, 1992). During the study, the strategy for calibration of model applied is 'vary the best-known parameters as little as possible, and vary the poorly known or unknown values the most'. It is done by sequential adjustment of the model parameters until the closed match found between the observed and the calculated heads (Anderson and Woessner, 1992).

6.1.13.1 Steady State Calibration

Groundwater flow is said to be under steady state when the magnitude and direction of specific discharge remain constant with time. Steady state flow implies that the position of potentiometric surface and the hydraulic gradient remains unchanged. There is no addition or withdrawal from the storage of the aquifer and equilibrium conditions have been reached between recharge and discharge (Karanth, 1999). The steady state condition is existed in the aquifer before any development had occurred. Matching the initial heads observed for the aquifer with the hydraulic heads simulated by MODFLOW is called steady state calibration (Anderson and Woessner, 1992).

As recharge and ground water withdrawal occurs at different periods, the steady state condition is not applicable for the present study. Hence, it is imperative to design a transient model to accommodate different periods of recharge and discharge and to get the ground water scenario and budget at different stress periods.

6.1.13.2 Transient State Calibration

The groundwater flow is said to be transient or unsteady or in non-equilibrium state when the magnitudes or direction of specific discharge changes with time. Change in the storage of the aquifer is involved in non-steady flow. Transient state flow is described with respect to boundary and initial conditions (Karanth, 1999). Successful transient calibration depends mainly on the good estimation of hydraulic conductivities and boundary conditions obtained from the steady state calibration. Generally, specific yield for unconfined aquifers and storage coefficient for confined aquifers are the main parameters that are changed during the transient calibration (Anderson and Woessner, 1992).

For the purpose of calibration 52 observation wells out of 58 established wells were selected excluding wells in hilly areas. The ground water level data of these well is available from October 2011 onwards on monthly basis. Hence, for transient state calibration ground water level data from June-2012 to October-2014 has been used. The approximate water table data as deciphered from the pre-monsoon depth to water level map is considered as initial head values for running the transient model and the computed head for the pre-monsoon period is taken as initial head for successive model run. Multiple stress periods were included into the model and data for each stress period was entered separately. After entering all the input parameters for each stress period, the model was run for the transient state calibration. Then the parameter values were adjusted judiciously in order to obtain a good match between the observed and calibrated head. With the convergence of the transient model, scenario of different stress period is generated for 30, 60, 90, 120, 150, 165, 190, 215, 265, 315 and 365 days.

The head condition calculated by the model is to be tested against the monitoring data for different stress periods is an essential part of model calibration. This is done by plotting head potential contours and water table contours in the map and visually interpreting the goodness of matching. Figure 6.7 and 6.8 shows the goodness of matching for the month of June and November 2012.

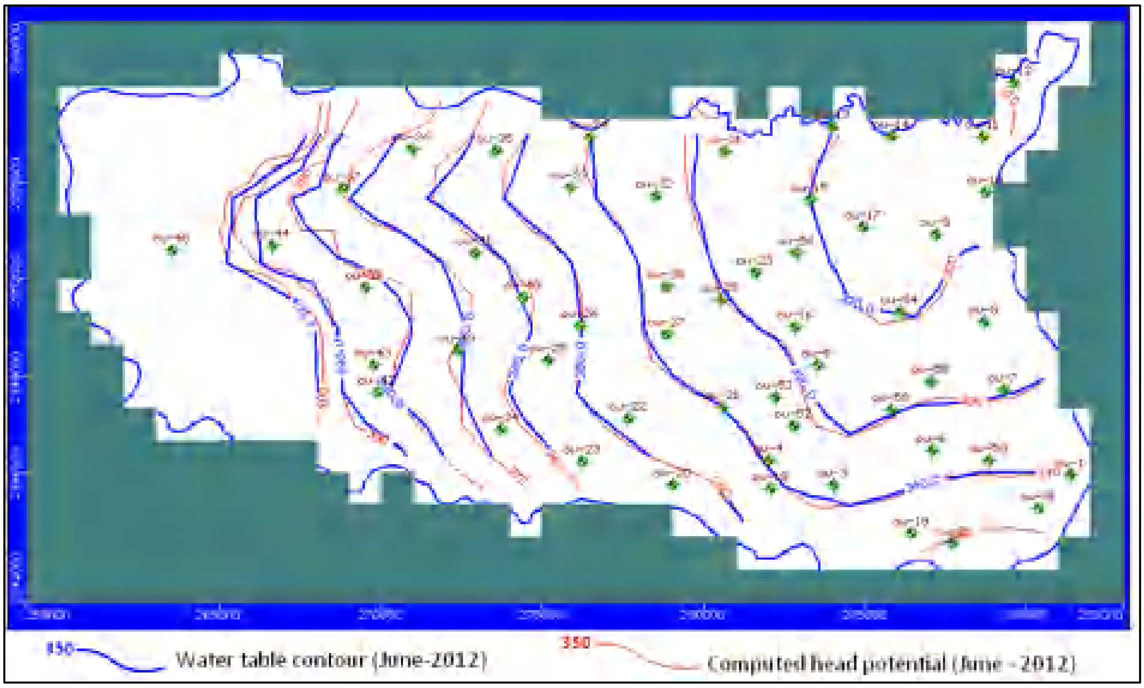


Fig. 6.7: Goodness of fit of water table contours and computed head potential for June

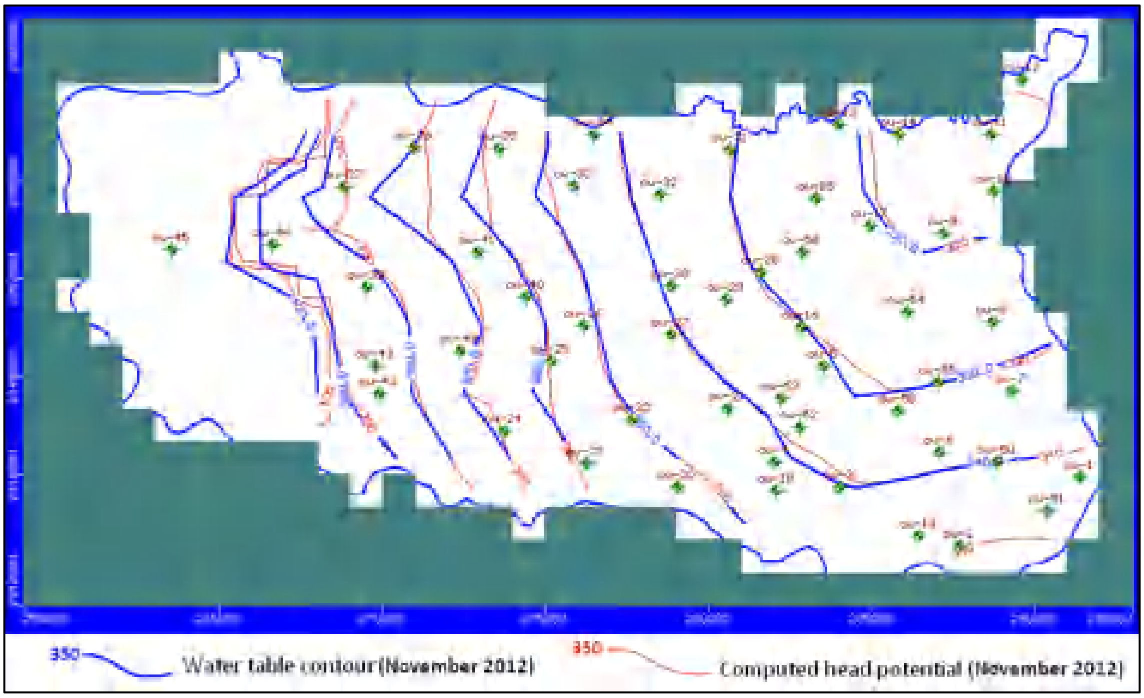


Fig. 6.8: Goodness of fit of water table contours and computed head potential for November

However, statistical fitting of observed and computed heads gives a quantitative approach to the calibration. The root mean square error which is a computation of departure of data can be taken as a measure of fitting between both the heads. However, root mean square divided by the range of data expressed in percentage also known as normalized RMS is a better tool for measuring the goodness of fit and departure. The normalized root mean square error is calculated for each stress period and found to be between 6.8% and 8.78% (Fig. 6.9. and 6.10). Thus, transient calibration shows a good agreement to the actual field condition. Generally, good matching is observed during June & July while the calibration is poor during September & October. This can be explained by the fact that the aquifer is saturated upto the maximum level during August and hence is not taking much recharge as expected by the model. During December to February the assumed ground water withdrawal from the aquifer for the standing Rabi crop satisfies with the field condition, hence the good match between observed and calculated head.

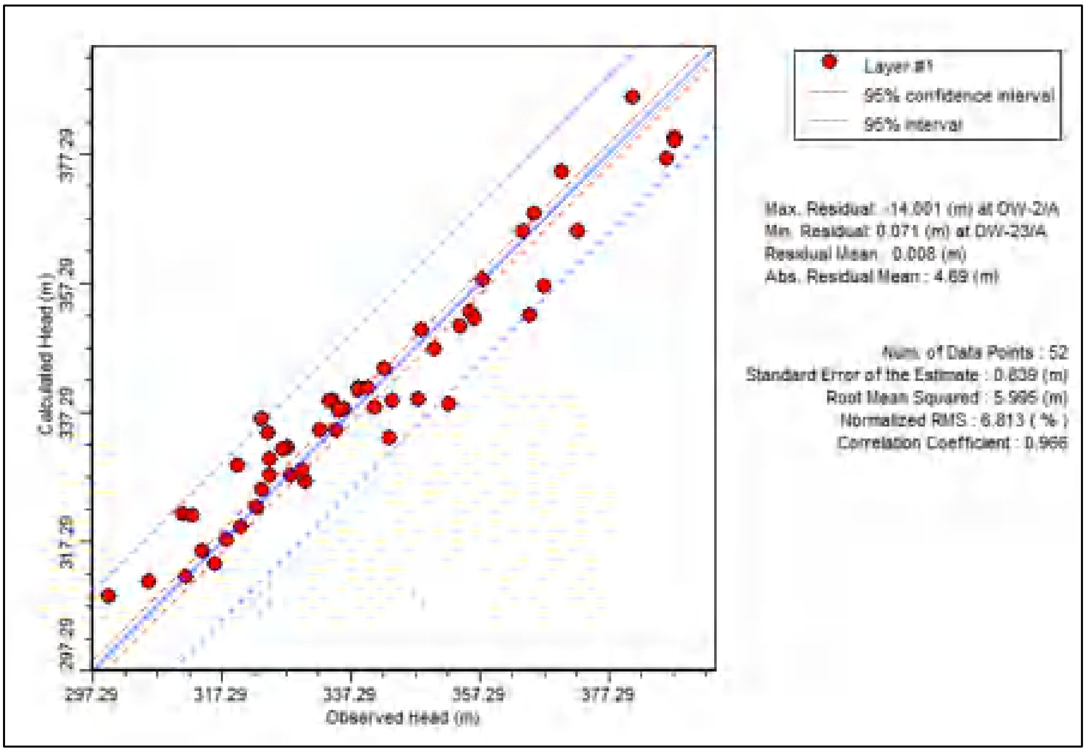


Fig. 6.9: Goodness of fit of calibrated vs observed head for pre-monsoon (June)

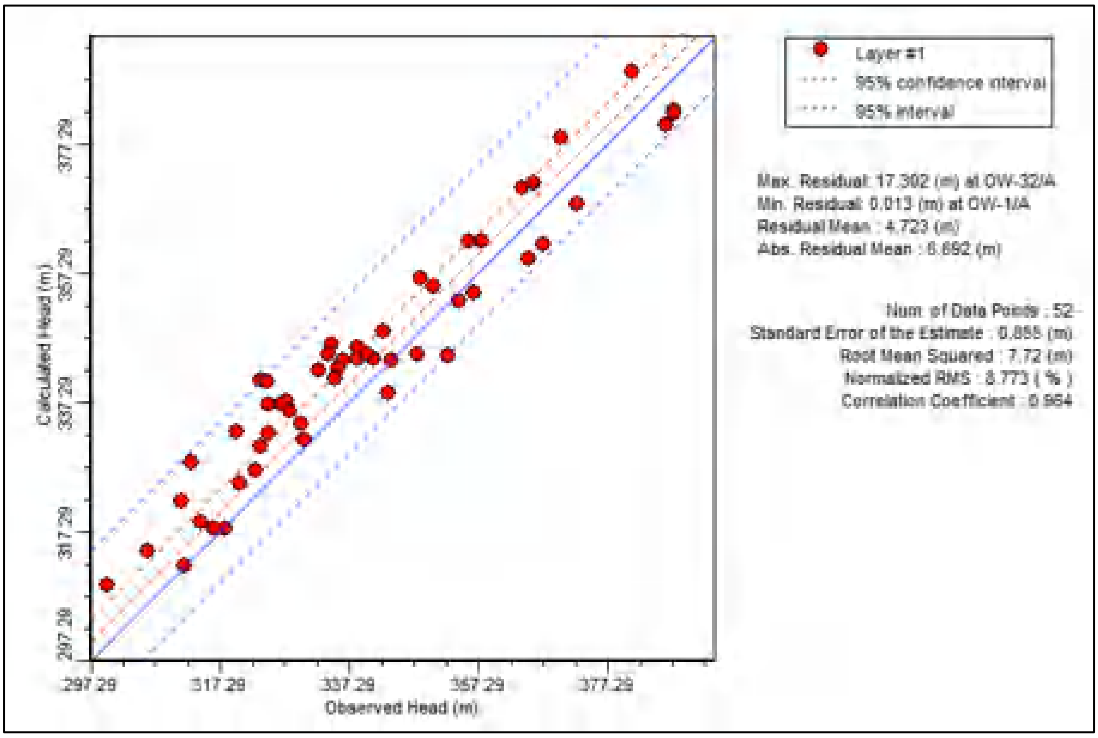


Fig. 6.10: Goodness of fit of calibrated vs observed head for post-monsoon (November)

Most of the calibrated wells generally show more or less similar trends of recharge and ground water withdrawal. However, peak water table is not matching with the modeled one (Fig. 6.12) due to the fact that most of the phreatic aquifers get full recharge and water table reaches its peak at the end of August in humid tropical regions of India. Most of the ill calibrated plots have high calculated head as compared to that of the observed head and shows a constant head during the whole year. These head observation wells are adjacent to the river and falling in the river grids and since river is assigned a constant head for the full year, the calculated head at grid containing the river as well as the head observation well remains constant and is much above the observed water level in the aquifer.

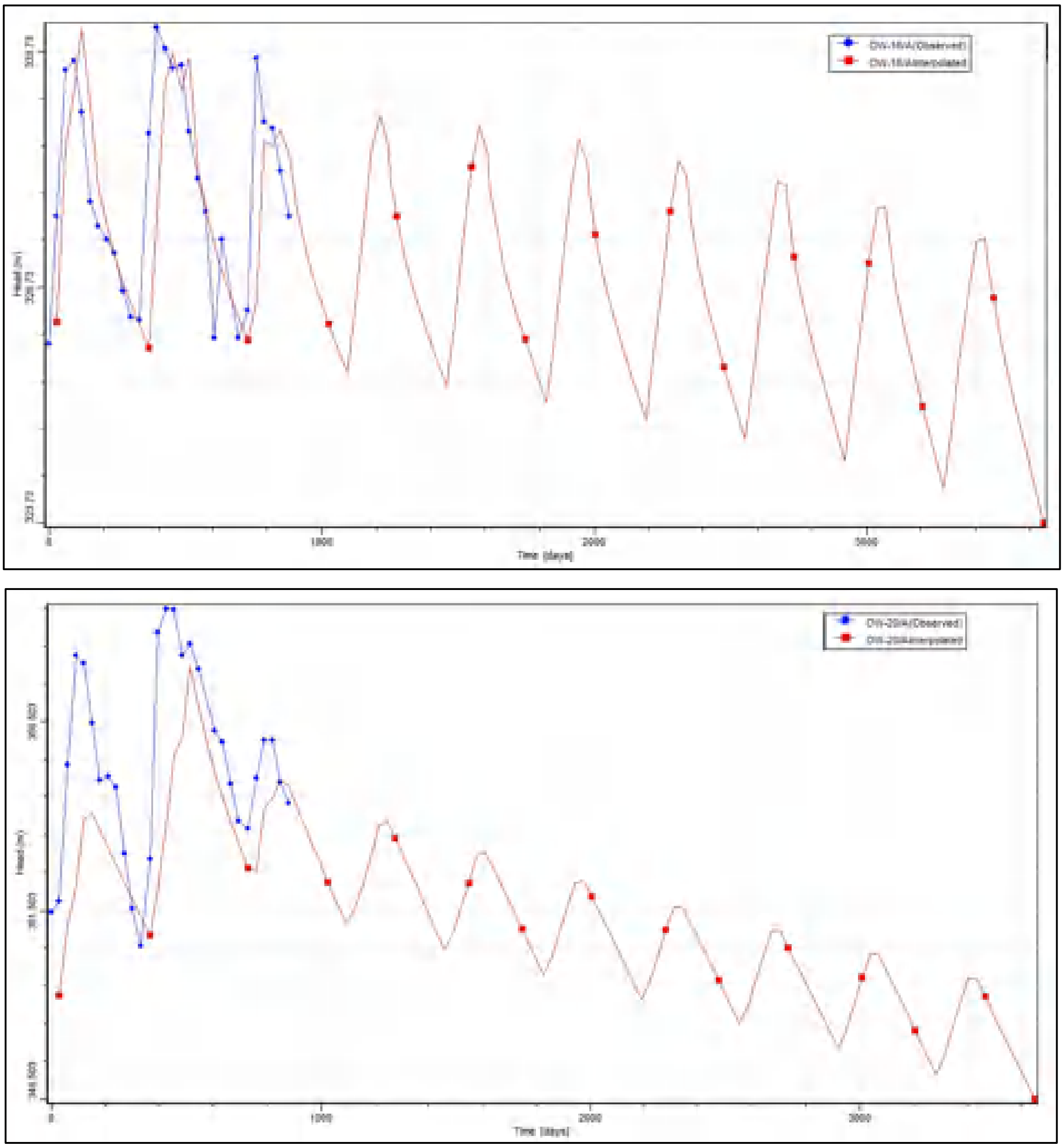
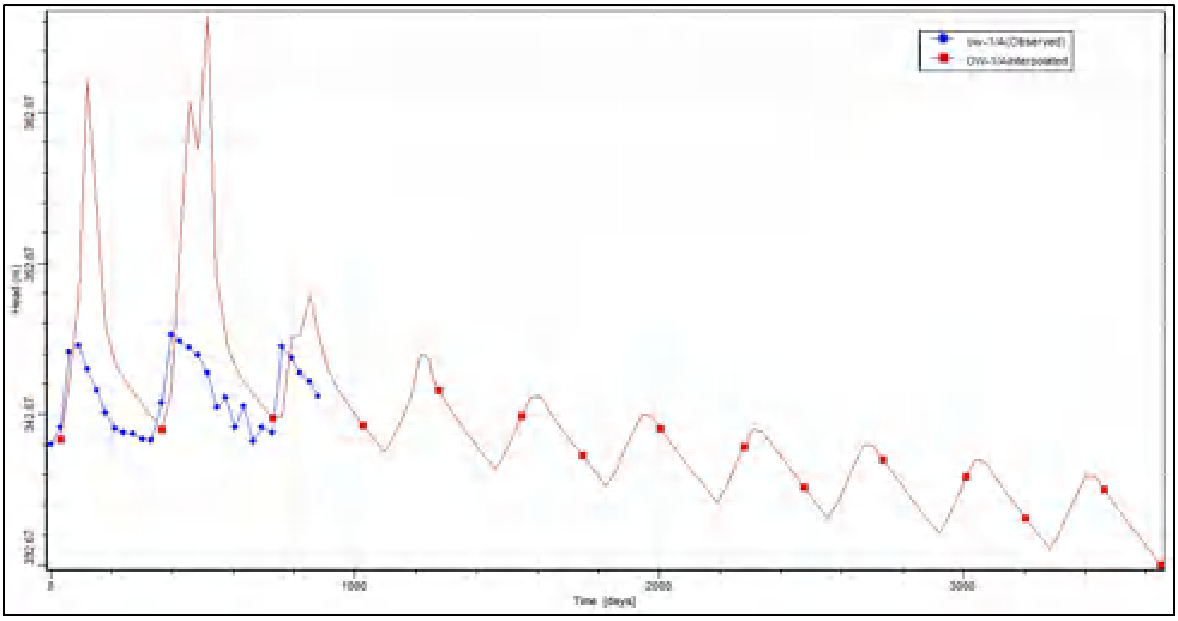


Fig. 6.11: Time series plots of some of the well calibrated monitoring stations (well – 16 & 20)



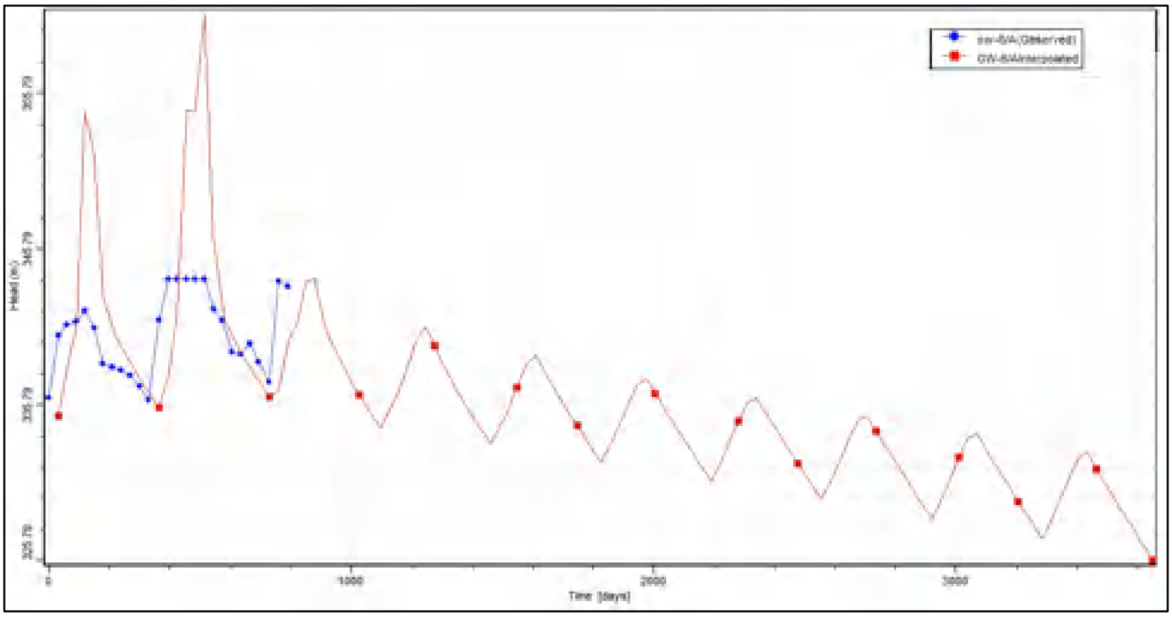


Fig. 6.12: Time series plots of some of the well calibrated monitoring stations (well – 1 & 6)

From the hydrographs it is clear that most of the area experiences of a rise of around 5 to 6 meter in ground water level during August month and matches well with the predicted recharge (Figure-11). However, the mismatch of peaks of hydrographs shown in figure-6.12 is due to less storage space in the aquifer attributed by the low specific yield as shown in figure - 6.5. Since draft is increasing at a rate of 3% annually, decline in ground water level is observed in the hydrograph. However as there was 20 % excess rainfall during 2012 & 2013, a rise in ground water level is observed in both actual and model calculated hydrograph.

6.1.13.3 Cumulative Budget

In the study area recharge is observed from June to October (0-150 days) and is shown as an illustration in the Fig. 6.13. Part of the constant head cells and river are both working as source and sink in different reaches.

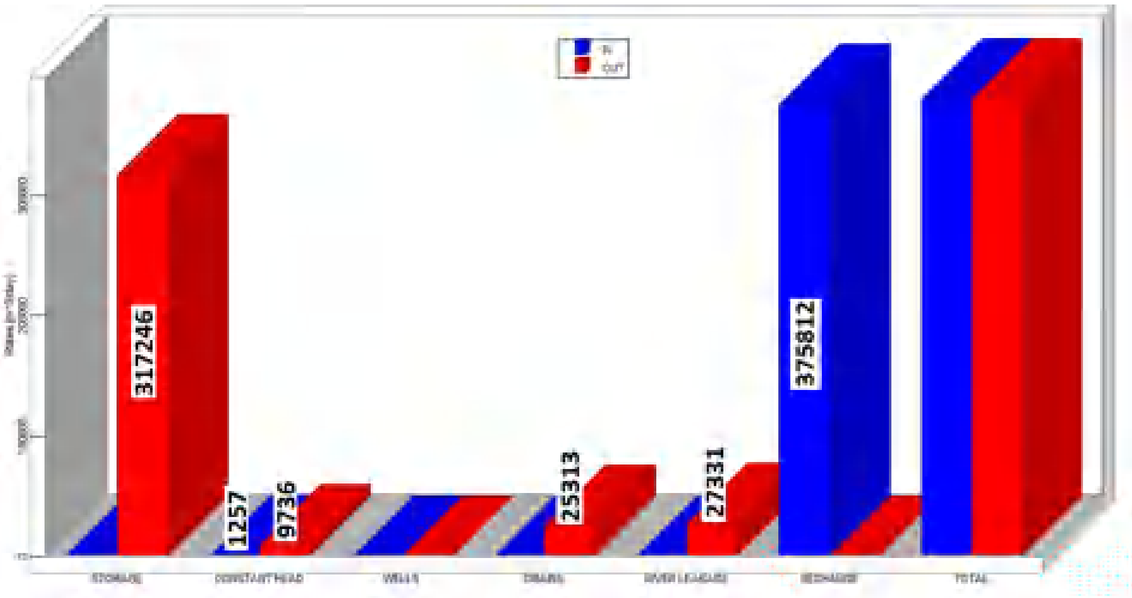


Fig. 6.13: Ground water budget for August

Once rain subsides, pumping generally starts in the area. Though rate of pumping varies with the different period of crop growth, however for simplicity, a uniform withdrawal rate for individual grids derived from village well census data is inserted into the model for the whole summer period (150-365 days). The following is the water budget for middle of November (Fig. 6.14). It is interesting to note that the well withdrawal is more compared to the contribution from ground water during peak summer and thus river plays a great role in alleviating the water demand of the area in an indirect way.

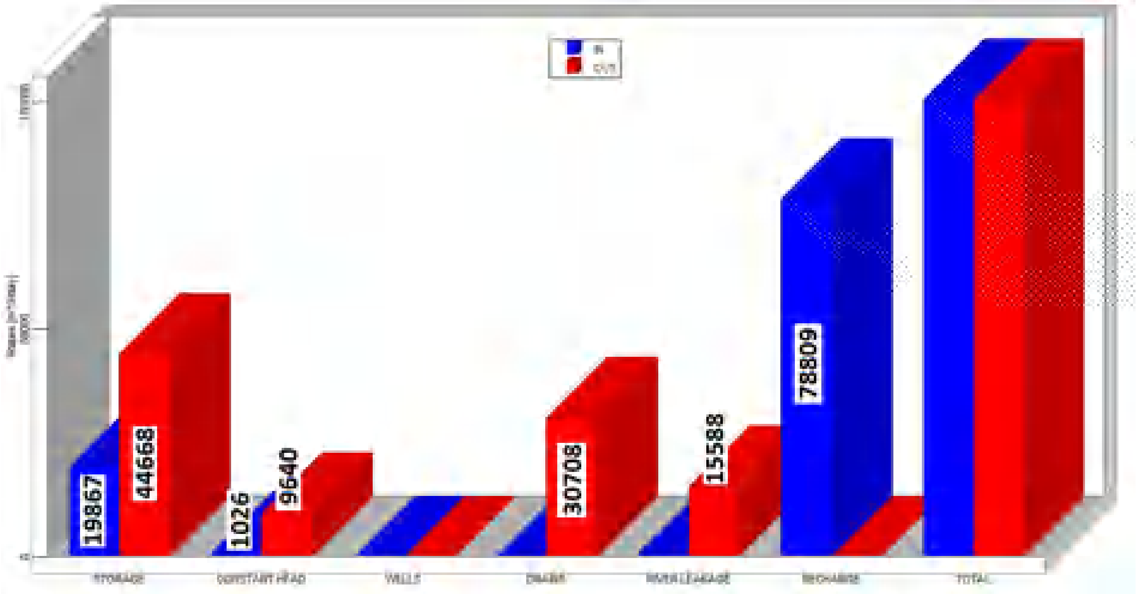


Fig. 6.14: Ground water budget for Early November

As ground water head declines with time after November, the contribution of aquifer towards draft is reduced and is compensated by the river which is flowing in the north-eastern part of the watershed. The summer month ground water level (stage) of the river if maintained by creating a check dam/weir, then it will prove very helpful in maintaining the water balance in the area (Fig. 6.15).

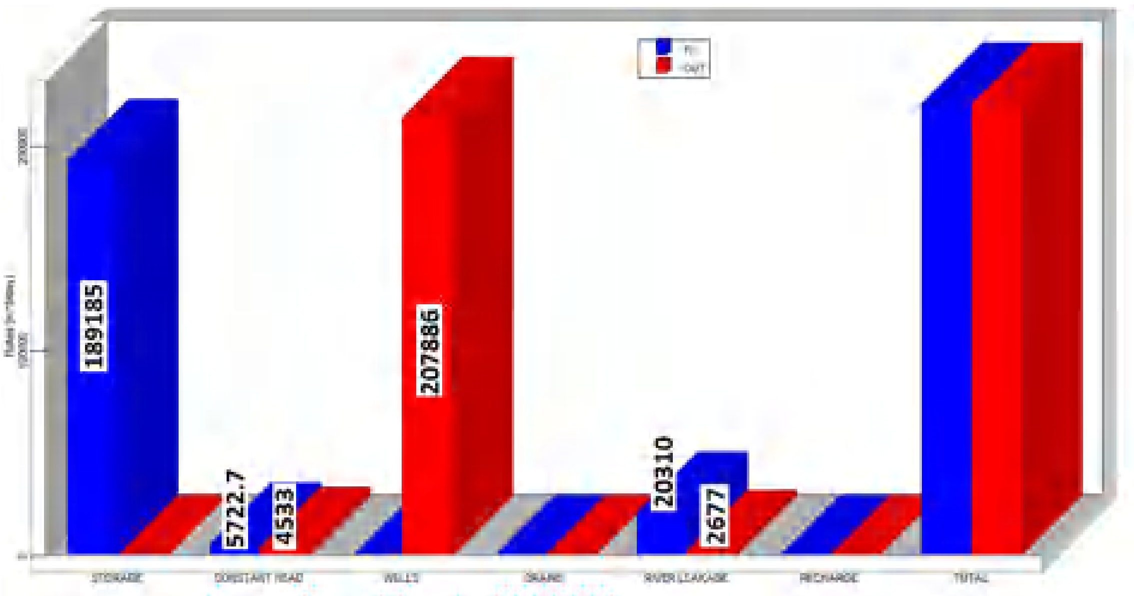


Fig. 6.15: Ground water budget for May

The drain package is invoked for the small stream flowing through the area. Sufficient amount of ground water releases through this stream during peak recharge as shown in figure-

6.14. However due to moderately deep water table condition during post monsoon seasons, the ground water leakage to the drain is virtually nil beyond January month.

Table 6.1: The detailed ground water budget, Chandrabhaga Watershed (WGKKC-2)

Items	Stress Period (Days) June to May									
	30	**60**	**90**	**120**	**150**	**180**	**210**	**255**	**320**	**365**
Storage in	2720	2612	2585	2583	19867	220690	210862	202957	196554	193704
Storage out	269365	338970	317246	258005	44668	58	38	36	36	35
Const. Head in	3816	2324	1257	325	1027	3326	4008	4691	5592	6133
Const. Head out	6000	7794	9736	11196	9640	7457	6668	5700	4706	4181
Well in	0	0	0	0	0	0	0	0	0	0
Well out	0	0	0	0	0	214112	214112	214112	214112	214112
River Leak. In	2806	249	0	0	867	11117	13490	16065	19248	21176
River Leak. out	12652	21880	27331	30230	15588	4751	3761	2834	2674	2640
Recharge in	280915	374113	375812	334523	78810	0	0	0	0	0
Recharge out	0	0	0	0		0	0	0	0	0
Drain out	2213	10640	25313	37966	30708	8753	3828	985	0	0

Note: Values are given in meter^3/day

6.1.13.4 Sensitivity Analysis

The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stress, and boundary conditions. A sensitivity analysis is an essential step in all modeling applications. During the sensitivity analysis, calibrated values of hydraulic conductivity, storage parameters, recharge and boundary conditions are systematically changed, one parameter value at a time, within the previously established plausible range (Aderson and Woessner, 1992). Sensitivity Analysis was used to identify the input parameters that have maximum influence on the output for both the historical and predictive simulations. Model verification will help to establish greater confidence in the calibration. It is often impossible to verify a model because usually only one set of field data is available (Aderson and Woessner, 1992).

To carry out the sensitivity analysis of the model under study, hydraulic conductivity value has been changed and the errors obtained in each calibration are plotted for all the stress periods. It is found to be quite sensitive (Fig.6.16) to changes in hydraulic conductivity as per the expected line. With a permeability value of 14 m/day, the model is not at all converging.

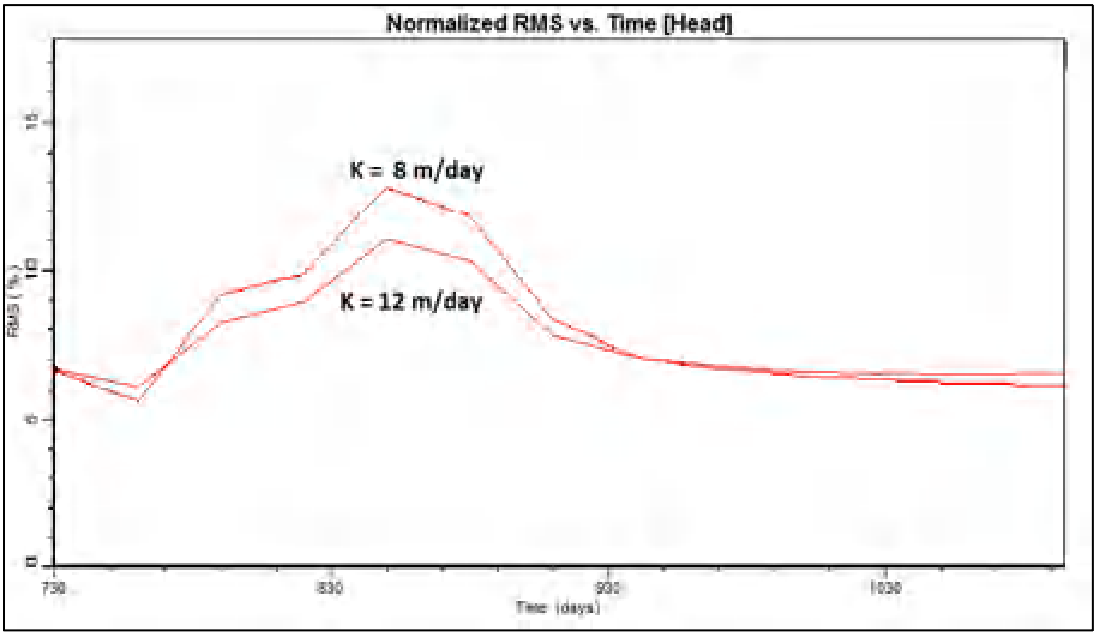


Fig.6.16: Sensitivity analysis for hydraulic conductivity

Similarly, the process is repeated for specific yield and is shown in Fig.6.17. The model is found to less sensitive to specific yield and gives only slight change in head value.

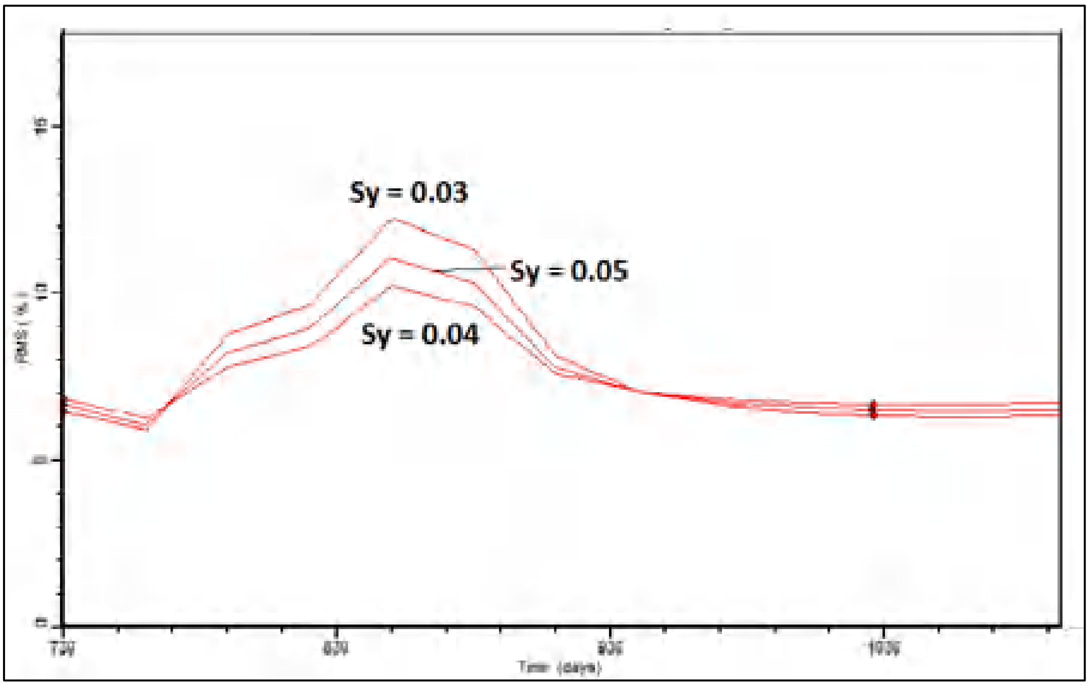


Fig.6.17: Sensitivity analysis for Specific yield

6.1.13.5 Model Verification

This is done by observing the response of heavy rainfall or heavy ground water withdrawal in a time period in the aquifer system and verifying that in the model. It is often impossible to verify a model because usually only one set of field data used to be available

(Aderson and Woessner, 1992). However, model verification will help to establish greater confidence in the calibration. Since monitoring is going on for the year of 2015, model verification will be tried utilizing these data.

6.2 AQUIFER MANAGEMENT PLAN FORMULATION

EVOLVING MANAGEMENT STRATEGIES AS PREDICTIVE SCENARIOS

In predictive simulation, the parameters determined during calibration and verification is used to predict the response of the system to future events. An important task in predictive modeling is to determine the length of time for which the model will accurately predict the future (Aderson and Woessner, 1992). A predictive simulation should not to be extended for more than twice the period for which calibration data is available. During the present modeling exercise, one set of data for the period 2012-2014 was collected and being used. The model in present form can be a helpful for prediction of future groundwater scenario, as transient state calibration had an appreciable result.

6.2.1 Predictive Model Results (Management Strategies)

The primary objective of this work was to study the present stress on aquifers and action to be taken for the sustainability of the aquifer system present in the area. Though, presently the watershed falls under safe category with stage of ground water development is about 89 % and categorized as 'safe' watershed, however, there is very limited groundwater availability for irrigation & other activities after April of every year. As compared to 2004 scenario, the recharge has increased by about 5% and draft has increased by about 22%. Thus, the stress on the phreatic aquifer needs to be analysed and proper groundwater management plan is to be advocated.

Considering the above-mentioned facts, the calibrated model has been used to assess the impact of recharge improvement and enhancement on the aquifer system so that the aquifer can sustain to the ever increase in ground water demand for agriculture and industries situated in the watershed.

The following two hypothetical scenarios have been generated for the watershed;

Scenario -1: Construction of check dam/weirs on Chandrabhaga river at selected locations to raise the river stage so as to reduce base flow and to increase recharge to the aquifer.

Scenario - 2: Construction of check dams and recharge wells along the ephemeral river and its tributaries draining through the watershed to enhance ground water recharge

6.2.1.1 Scenario 1- Construction of check dam on Chandrabhaga river

Management strategy-1: The Chandrabhaga river plays a major role in supplying water to the underneath aquifer and thus if its stage is improved at certain conducive locations by means of the construction of suitable check weirs, then recharge to the aquifer will improve and the aquifer contribution to the river will be reduced. This concept is tried to be replicated in the model by increasing the river stage by 1.5 meters at grids where during post monsoon season the river is out flowing or else is contributing very little recharge. The model was re-run and the improvement in the grids is tabulated below (Table 6.2):

Table 6.2: Change in recharge rate, November scenario, Chandrabhaga Watershed (WGKKC-2)

River Reach	Row	Column	Original River Stage (m amsl)	Recharge Rate m^3/day	Modified River Stage (m amsl)	Recharge Rate m^3/day
1	3	22	332.0	-1939	*333.5*	-1954
2	4	23	328.8	-1966	328.8	-1947
3	3	24	325.5	-618	*327*	-632
4	4	25	323.2	-198	323.2	-258
5	3	26	320.9	-444	320.9	-461
6	4	27	318.6	-422	318.6	-1697
7	4	28	316.0	-1132	*317.5*	1595
8	4	29	314.0	-825	314.0	-3271
9	4	30	312.0	-2596	*313.5*	181
10	3	31	310.5	867	310.5	-1096
11	2	31	308.0	-2294	*309.5*	-454
12	1	32	306.6	-124	306.6	-1958
13	1	33	305.0	-3031	*306.5*	-1483

*The underlined values are the improvement of river stage at suitable location

Reduction of ground water seepage to the river is reduced to the tune of 1288 m^3/day during November season by raising the river stage with the construction of 4 check dams. Moreover, during peak summer around 559 m^3/day of ground water recharge will take place and will support the summer draft adjacent to the river.

There will be little change in the contours when compared with the earlier, as there is no overall change in the modeled area except near to the river. However, discernible change in ground water scenario is observed in the water budget with the overall improvement in the river leakage as observed in the Table 6.3 below:

Table 6.3: Improvement in the river leakage, Scenario 1, Chandrabhaga Watershed (WGKKC-2)

Parameters	**Days**									
	30	**60**	**90**	**120**	**150**	**180**	**210**	**256**	**320**	**365**
River Leak. In	2806	248	0	0	867	11117	13490	16065	19248	21176
River Leak. out	12652	21880	27331	30230	15588	4751	3761	2834	2674	2640
<u>River Leak. In</u>	<u>3440</u>	<u>767</u>	<u>441</u>	<u>370</u>	<u>1776</u>	<u>11764</u>	<u>14132</u>	<u>16734</u>	<u>19474</u>	<u>21109</u>
<u>River Leak. out</u>	<u>13090</u>	<u>21892</u>	<u>27237</u>	<u>29742</u>	<u>15209</u>	<u>3850</u>	<u>3069</u>	<u>2541</u>	<u>2196</u>	<u>2014</u>
Ground water Improvement	634	19	441	370	909	647	642	669	226	-67
	-438	-12	94	488	379	901	692	293	478	626
Overall improvement	196	7	535	858	1288	1548	1334	962	704	559

Nb: 1. Values are given in meter^3/day
2. The underlined values are the predicted values for the management strategy-1 as compared to the existing scenario given in the row above

The total improvement will be around 289273 m^3, which is 9 % of the total recharge from the river to the aquifer before construction of the structures. Though the improvement seems to be quite low, but as the area is falling in a heavy ground water withdrawal zone, this will of immense help during the dry seasons. However, more perfect calculation using the actual river stage data at each grid is necessary prior to the field implementation of this management strategy.

6.2.1.2 Scenario 2- Construction of recharge wells

Management strategy-2: The river draining the watershed is ephemeral in nature and flow exists till the end of monsoon season. Hence, a second strategy can be adopted by harvesting the run off generated during the rainy season with the construction of check dams/weirs at suitable locations and to divert the harvested water to the phreatic aquifer by means of recharge wells. The specially designed recharge wells are to be gravel packed tapping the full thickness of the aquifer (20-30 meters) to obtain maximum transmissivity so as to accept maximum amount of harvested water. 25 recharge wells can be added on the river grids with a recharge rate of 300 m^3/day for the full rainy season and zero recharge rate for the rest of the period (Fig. 6.18). This will enhance the ground water resources of the area by 1125000 m^3 annually.

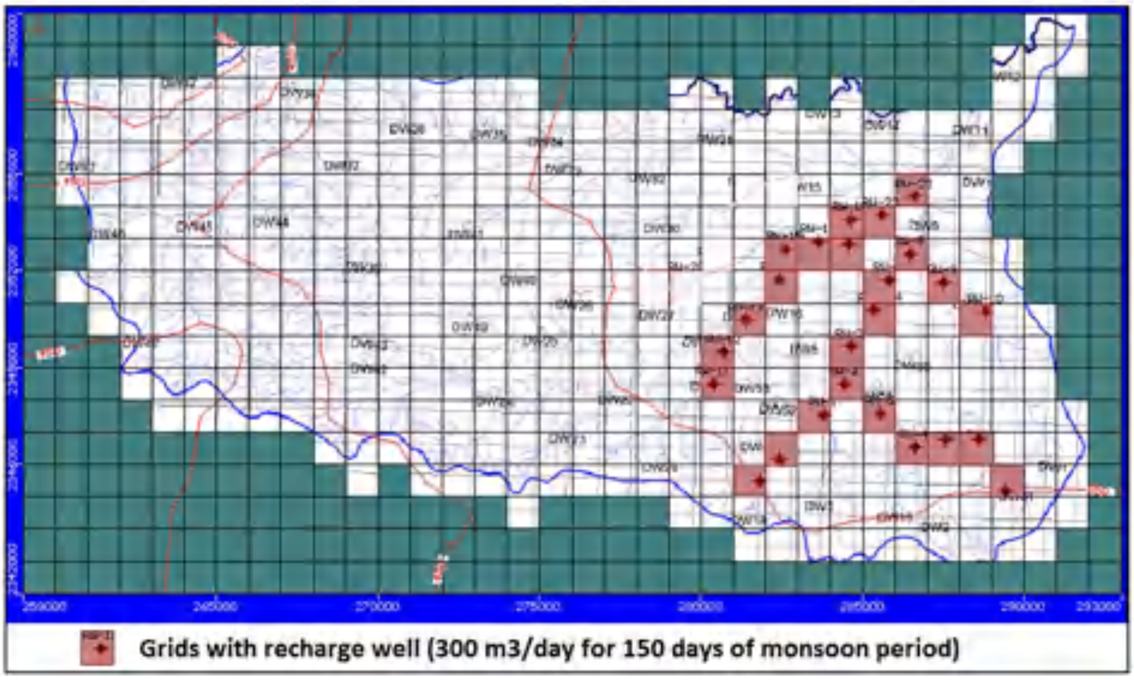


Fig. 6.18: Location of proposed recharge wells (25 recharge wells)

The impact of the improved recharge on the predicted water table of November and June is shown in the Fig. 6.19 and 6.20. Appreciable change is not observed in the overall pattern; however slight down gradient movement of 320 & 330 meter water table contours indicates the improvement of water table by the extra recharge.

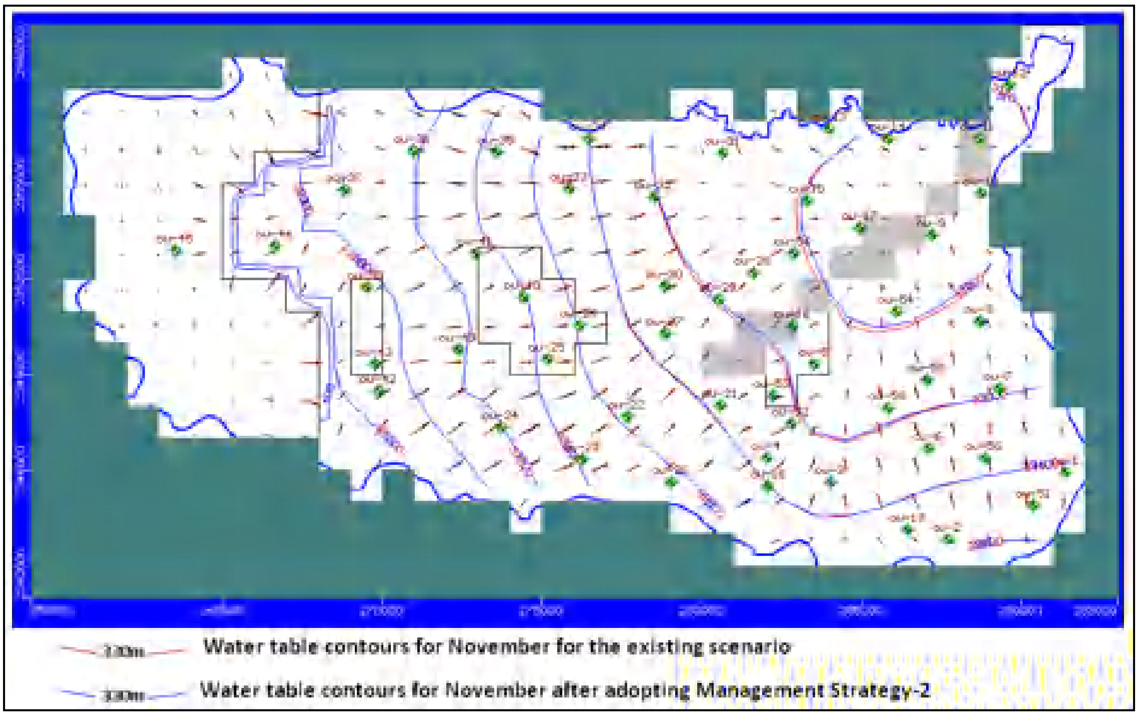


Fig. 6.19: Impact of the improved recharge on the predicted water table of November

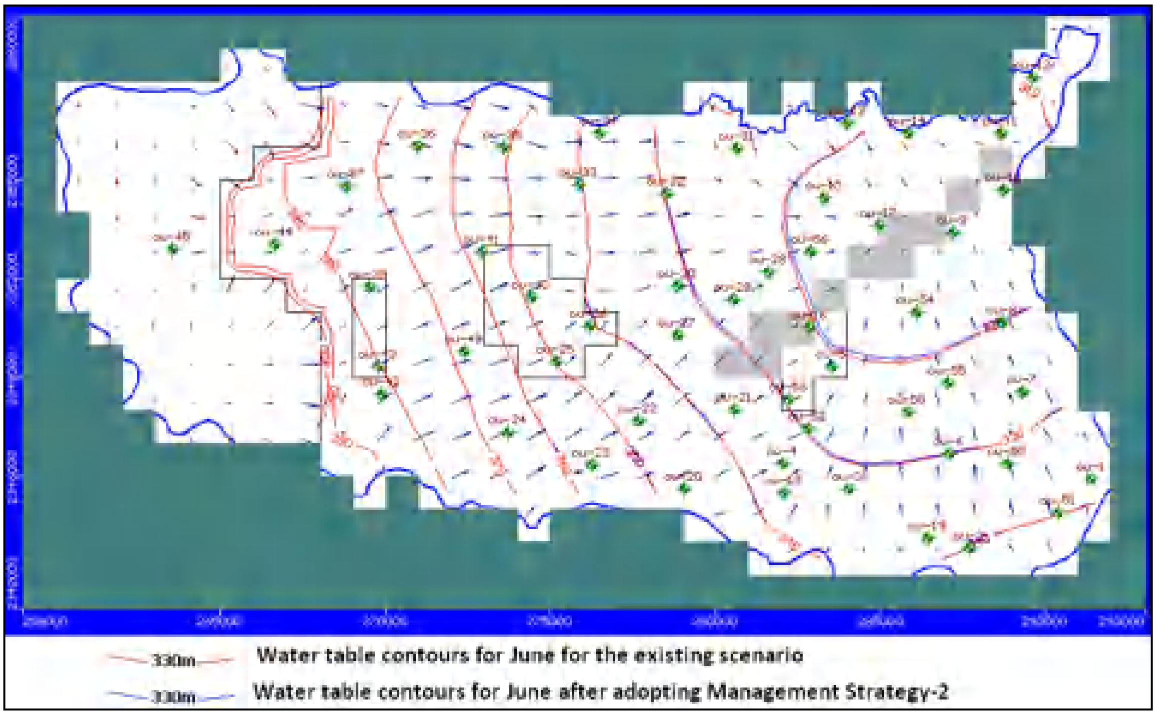


Fig. 6.20: Impact of the improved recharge on the predicted water table of June

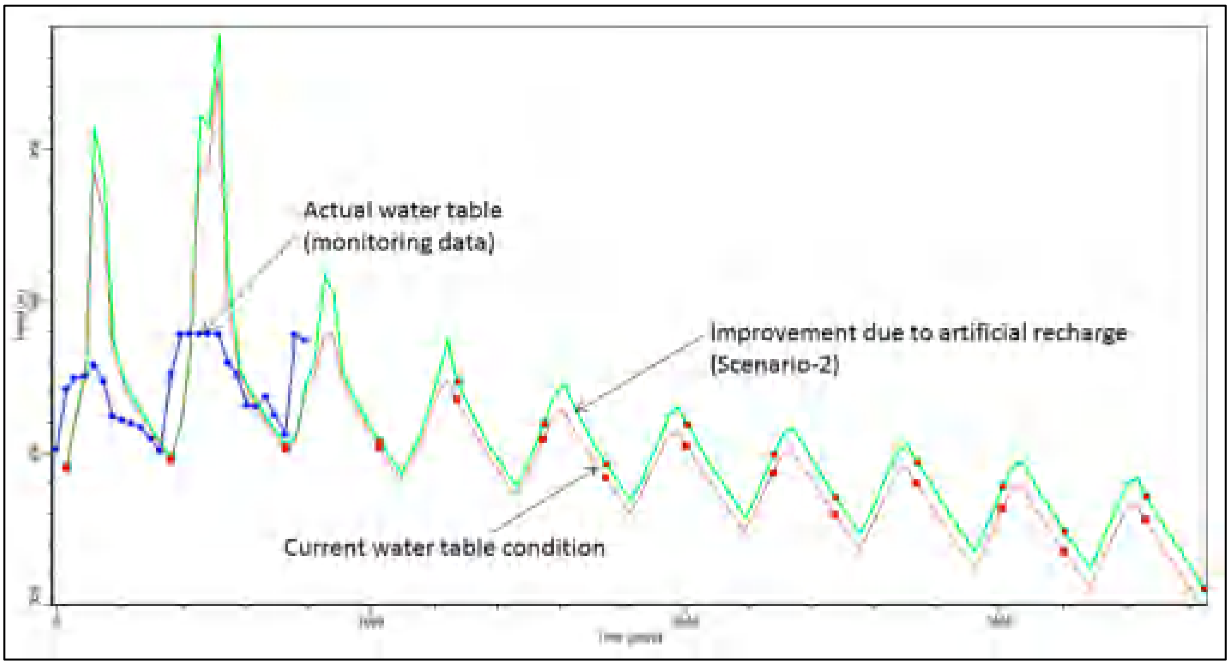


Fig. 6.21: Impact of the improved recharge on the predicted water table of well-6

However, a significant change in ground water level is observed as shown in figure 6.21. Though the decline trend in ground water level is not reversed, but its slope has been improved. Since this is an area with heavy ground water draft, more and more recharge structures can be created subject to the availability of surface water so that the ground water regime can be improved.

7 IMPLEMENTATION PLAN AND RECOMMENDATIONS

The Pilot study for aquifer mapping has been taken up with certain objectives which were already listed out in Chapter 1, however, it was conceptualized to develop a common implementation plan for all similarly problematic areas of Basaltic terrain of Maharashtra. In the Chandrabhaga watershed (WGKCC-2), the following issues were considered for formulation of management plan to effectively understand and manage groundwater resources at regional and local level.

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

During the study, a mammoth data has been collected, generated and analysed to know the root of the problems and some of the data is being collected/generated considering the future ground water necessities. All these data has been analysed on GIS platform and various thematic maps were prepared. After careful study of the all available thematic layers and data generated during the hydrogeological investigation, the area vulnerable for ground water pollution, stress area and area identified for artificial recharge area have been demarcated (Fig. 7.1). Before formulation of management plan these areas were considered. The detailed Aquifer wise maps, its disposition, management plan are produced as final output. The aquifer wise details are tabulated and presented as **Annexure-XVIII**. The major aspects are discussed below.

7.1 Area vulnerable for ground water quantity / Ground water stress area

These areas were demarcated based on local hydrogeological, physiographical setup, prevailing summer water scarcity situations and low yielding capacity of aquifers down to 80 m depth (Fig.7.1). The areas are as under,

a. Area around villages located in north western boundary of the watershed, i.e., Malegaon, Chendkapur, Ramgiri, Khursapar, Mhasepur, Mohpa

b. Area around village Metpanjra which is severely affected by water scarcity during summer.

c. Area around Upparwahi village in southern-central parts of the watershed also experience stress during major part of the year.

d. Falling short-term DTWL trend in-and-around Wathoda and Kalmeshwar villages has been recorded indicating the future ground water scarcity areas.

e. Deeper DTWL (>12 m bgl) during post-monsoon season in-and-around Wadhona and Sawangi villages in Basaltic Aquifer-I and Tondakhairi in Sandstone Aquifer-I.

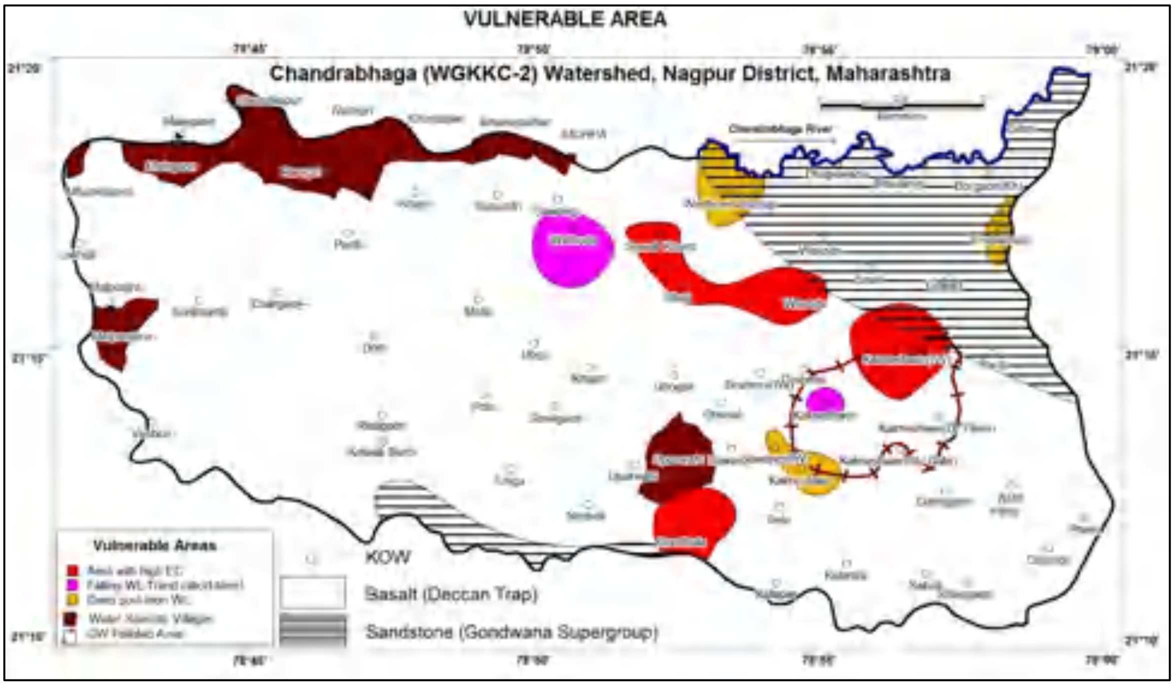


Fig.7.1: Area vulnerable for ground water quantity / Ground water stress area, Chandrabhaga watershed (WGKCC-2)

7.1.1 Suggested Management Plan for Ground water stress area

The ground water modeling has suggested the remedial measures to tackle these issues by construction of check dam across Chandrabhaga river and construction of 25 recharge wells as shown in the Fig.6.19 and 6.20. This will be enhancing the ground water levels of the unconfined Aquifer-I as shown in Fig. 6.20 and 6.21. However, considering the local hydro-geological and physiographical setup site-specific solutions has been suggested. Unconventional measures like fracture seal cementation (FSC), Hydro-fracturing, Well jacketing (WJ), Borewell Blasting Technique (BBT) etc., which are commonly practiced in the basaltic terrain of

Maharashtra are the most appropriate techniques to enhance the yield properties of the aquifer. The soil and water conservation methods such as gabion structures, form ponding, nala widening and bunding, Under Ground *Bandhara* (UGB) etc., along with rooftop rain water harvesting in these villages are also recommended to improve the water availability and to tackle the summer water scarcity (Fig. 7.2).

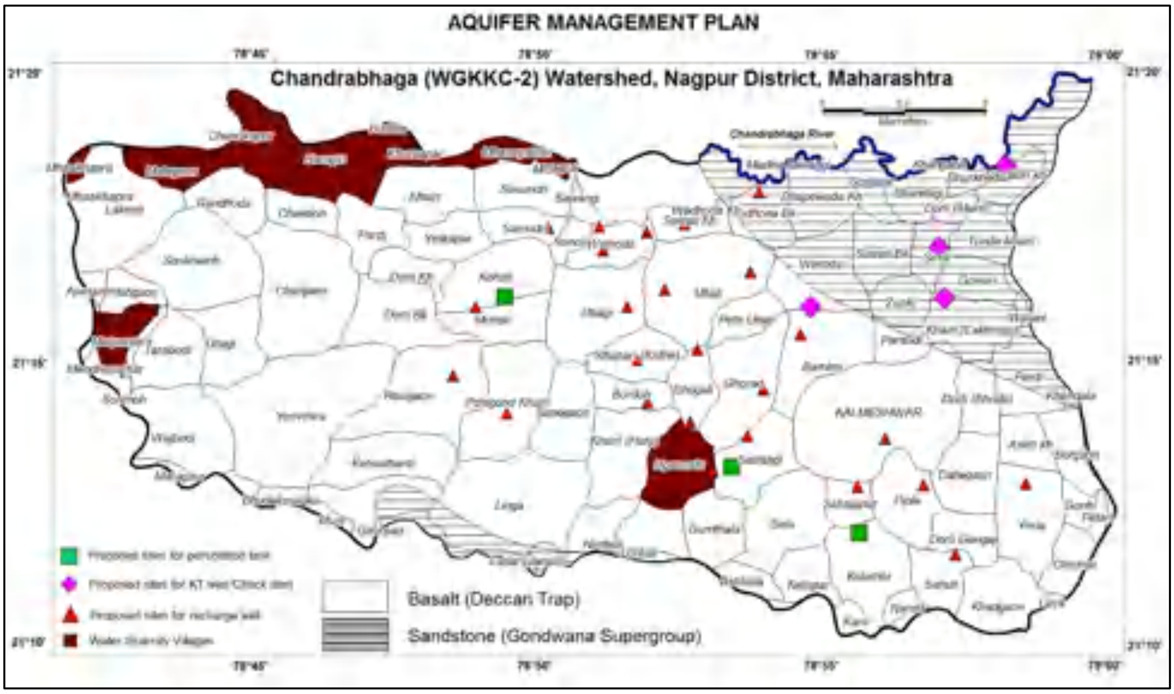


Fig.7.2: Aquifer management plan, Chandrabhaga watershed (WGKCC-2)

7.2 Area vulnerable for ground water quality

The Kalmeshwar town has industrial area under the policy of 'Maharashtra Industrial and Development Corporation (MIDC)'. The Kalmeshwar town and its surrounding area has been contaminated with the industrial pollution specially in high EC, Chlorides, Calcium, Magnesium, Trace metal, Lead and low pH (CGWB, 1999). Thus, the major quality vulnerable area is restricted to industrial area of Kalmeshwar town. In addition to this, it has been observed that area in-and around Sawali khurd, Ubali, Waroda villages in central part of the watershed and Gumthala village in southern part of the watershed has ground water salinity problem where the electrical conductance (EC) encountered more than 2000 µS/cm.

7.2.1 Suggested Management Plan for area vulnerable for ground water quality

To overcome the deterioration to aquifer system due to industrial pollution, the restoration of aquifer is most feasible option by using artificial recharge practices in the area. The result of ground water flow modeling (Fig. 6.20, 6.21 and 6.22) shows that if the area would be recharged with fresh water through 25 recharge shafts/wells, then it could be possible to dilute the ground water pollution. This will, in turn, reduces the contamination and also enhance the ground water level in the area (Fig. 7.2). However, there is need to enforced to regulatory measures to stop the untreated/semi-treated disposal of industrial effluent to the ground water system. It is also recommended that the industrial effluent must be treated before it released to the *nalas*. All the industries should follow the norm set by the CPCB and MPCB for effluents.

7.3 Site specific management plan and recommendations

The concept of Integrated Water Resources Management (IWRM) is widely debated and an unambiguous and unanimously agreed definition but yet to be finalised. However, the 'technical advisory committee of global water partnership' has adopted the following definition that 'IWRM is a process, which promotes the co-ordinate development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (Kjelds et al., 2010). The highly diversified occurrence and considerable variations in the availability and utilization of groundwater in India makes its management a challenging task. Scientific development and management strategy for groundwater has become imperative to avert the looming water crisis. In this regard, various issues such as, prioritization of areas for development of groundwater resources vis-a-vis its availability, augmentation of groundwater through rainwater harvesting and artificial recharge, pricing and sectoral allocation of resources and participation of the stakeholders must be considered. The community based groundwater management, for example, initiatives in Andhra Pradesh and Maharashtra, offers tremendous scope for sustainable management of groundwater resources of India, especially, in hard rock areas (Bansal, 2010). Moreover, Govt. of India has formulated Common Guidelines for Watershed Development Projects in coordination with the Planning Commission (2008), in order to have a unified perspective by all Ministries to make all the watershed development programme more participatory, sustainable and equitable. These guidelines are therefore applicable to all watershed development projects in all Departments / Ministries of Govt. of India.

In view of the above, the present pilot study area of Chandrabhaga watershed (WGKCC-2) emphasizes to adopt a systematic, economically sound and politically feasible framework for groundwater management. However, technical, institutional, and socio-economic factors that govern the occurrence, availability, development and management of groundwater resources make the process of groundwater management relatively complex.

Considering the local physiographical and hydrogeological set up and source water availability to augment the ground water the following artificial recharge methods are suggested for individual villages (Fig. 7.2).

- Construction of Percolation tanks and check dams on 2nd and 3rd order stream
- Construction of KT weir and UGB at mini and micro-watershed level

These should be clubbed with the desilting of existing water conservation structures.

Apart from this, it is suggested to adopt groundwater management strategies, particularly for irrigation sector. The demand side intervention should also be encouraged by adopting modern irrigation techniques. During the fieldwork, it was observed that most of groundwater is being utilized for irrigating orange orchard by using traditional water spread method. If modern irrigation practices like drip irrigation, sprinkler etc. will be use, in place of traditional, then it is possible to reduce the groundwater draft up to 30 % to 40 % (PKV, 2009). Also, there is urgent need to change the cropping pattern by adopting crops from heavy water requirement types such as orange, banana, rice etc. to low water requirement types, such as cotton, oil seeds, pulses, vegetables etc., so that the groundwater draft could be reduced, without any financial losses to the farmers. Stakeholders, people, administrators should come forward for the above-referred interventions by strengthening collaboration and increasing confidence amongst them, before the system deteriorates. It is strongly recommended that the archive of groundwater model should be prepared for similarly problematic areas in Maharashtra State covering Deccan trap basalt. This will helpful to solve the critical problems of these areas before worsening the conditions by updating the groundwater models regularly.

8 CONCLUSIONS

1. The pilot study area of aquifer mapping i.e., Chandrabhaga watershed (WGKKC-2) is a type locality of hard rock Basalt. The basaltic hydrogeology has peculiar behaviour, as the different basaltic lava flows co-exist and acts as multi-aquifer system aquifer or as single aquifer only when fracture/ joints are connected to each other. The major part is occupied by Deccan trap basalt (313 sq. km) of Upper Cretaceous to Eocene age. A small part (47 sq.km.) is occupied by Gondwana formation of Permian age and exposed in the NE part and also a small linear stretch south of Kotwal Bardi, Linga and Nimboli villages.
2. The achievement against the objectives of the pilot project are tabulated below:

Objectives	Achievement during the project
To define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000 scale.	Based on the ground water exploration and geophysical surveys the aquifer geometry have been defined, and existing aquifers are categorized into shallow and deeper aquifer in Basaltic formation, Sandstone (Gondwana) formation and in Trap covered Sandstone (Gondwana) [TCG] formation (AQ-I, II and III). The ground water regime behaviour, aquifer parameter and geochemistry of respective aquifers have been deduced and the aquifer maps on 1:50,000 scale have been generated on GIS environment.
Intervention of new geophysical techniques and establishing the utility, efficacy and suitability of these techniques in different hydrogeological setup.	Besides the traditional geophysical techniques, advanced geophysical techniques viz., Electrical Resistivity Tomography (ERT), Ground Transient Electromagnetic (TEM) and SkyTEM (Time-domain heli-borne electromagnetic system) methods have also been applied to delineate the aquifer system up to 200m depth. These techniques have been used first time in basaltic terrain. These new techniques are rapid, time saving, and found very effective for covering larger and inaccessible area with closed spaced data, but unable to delineate the various basaltic flows occurring below the ground level.

Objectives	Achievement during the project
Finalizing the approach and methodology on which 'National Aquifer Mapping programme' of the entire country can be implemented. The experiences gained can be utilized to upscale the activities to prepare micro level aquifer mapping.	The experience gained during the project is very useful for upscaling the target oriented approach and methodology for 'National Aquifer mapping programme' particularly for Deccan trap basaltic terrain. It has been observed that the intensive hydrogeological data acquisition, ground water exploration along with geophysical investigations are suitable for Deccan trap basaltic terrain. However, for inaccessible areas Sky TEM survey is suitable technique. However, before its application the clearance from various authorities must be ensured.

3. There are three aquifer system in the pilot project area exist i.e., Aquifer-I represented by shallow unconfined; Aquifer-II and III represented by deeper semi-confined to confined aquifers occur in Deccan trap basaltic area and Sandstone of Gondwana formation. Apart from these challenging hydrogeological aspects, the occurrence of Gondwana sandstone and Archaean gneisses below basaltic trap is again a controlling factor in the watershed. The analysis of ground water exploration data also infers the existence of three types of aquifer in the area.
    a. *Aquifer I* - Unconfined aquifer. Occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. This aquifer generally occurs to the depth of 20 to 30m bgl and mostly tapped by the shallow dug wells in area occupied by basaltic and sandstone terrain.
    b. *Aquifer II* – Semi-confined to confined aquifer. Generally occurs in Deccan trap basalt which is exposed in major parts and Gondwana Supergroup in the NE part. The thickness of aquifer varies from 0.50 cm to 6 meters in Basaltic formation and 3m to 34 m in Gondwana formation and mostly tapped by the deep bore/tube wells in area occupied by basaltic and sandstone terrain.
    c. *Aquifer III* - It is mostly 'Trap Covered Gondwanas or Gneisses' (TCG). Generally occurs as semi-confined to confined conditions but at places, they exhibit unconfined condition and occur where the thickness of basalt is less, and tapped by the shallow dug wells or deep bore/tube wells in area occupied by basaltic and sandstone terrain.

4. The erratic rainfall pattern; limited aquifer thickness of unconfined aquifer (up to 15-20 m bgl); drying up of aquifer after January; existence of unknown and unpredictable deeper aquifer systems of basalt, failure of dugwells/borewells due to unscientific selection and delineation of boundary between Deccan Trap basalt and Gondwana sandstone, were the major issues tried to tackled during the project.

5. The only source of recharge to ground water level in the area is the south-west monsoon rainfall. The normal annual rainfall recorded at Kalmeshwar and Katol rain gauge is 985.4 mm and 973 mm respectively. The rainfall trend for Katol is falling significantly @ -43.26 mm/year during 2005-2014, and marginally @ -13.13 mm/year during 1998-2014. Likewise, it has been observed that, the rainfall trend for Kalmeshwar is significantly raising @ +34.88 mm/year during 2005-2014, and indicating falling trend marginally @ -14.83 mm/year during 1998-2014.

6. Chandrabhaga watershed forms the Moderately Dissected Plateau (MDB) of Deccan trap (basaltic terrain) where four sets of lineaments are interpreted, which trending in NE-SW, NW-SE, N-S and E-W directions. The E-W trending lineament is predominantly observed in the southern part of the watershed. Major part of the watershed is having depth of weathering in the range of 3 to 6 m bgl, followed by < 3 m bgl and 6 to 9 mbgl depth range, which increases from west to east and towards the north-eastern part it is maximum near to the confluence of Chandrabhaga river with local tributary. Major part of the watershed is occupied by clayey soil known as Black Cotton Soil followed by clayey loam observed along the northern fringe of the watershed. The land use is indicates most of the area falls in agricultural land where orange cultivation is prominent followed by pulses and cotton. The wasteland, notified and un-notified forests are mostly observed in the western part of the watershed, which is mostly hilly.

7. The area is drained by the ephemeral Chandrabhaga River and its tributaries Saptadhara River, Mortham Nala. The drainage is dendritic and the flow direction of main stream i.e., Chandrabhaga is from west to east and its tributary from south to north, the main stream ultimately joins the Kolar river outside the watershed.

8. During the project period, data gap analysis has been carried out and then the data has been generated with systematic planning. The ground water exploration and geophysical survey has been outsourced while rest of the activities viz, micro-level hydrogeological survey, ground water regime monitoring, infiltration tests, pumping tests on dug wells, water quality analysis, geophysical survey for VES, VLF, GRP etc., has been carried out by the team of hydrogeologist and geophysicists of CGWB, CR, Nagpur.

9. To decipher the lateral and vertical disposition of the aquifer system prevailing in the area and ground water potential of Gondwana formation occurring below Basalt, 14 exploratory and two observation wells upto 200 m depth have been constructed through outsourcing in four different geological formations. Out of which 6 wells are drilled in Deccan Trap basaltic formation, 5 wells in Trap covered Gondwana Formation, 4 wells in Gondwana formation and one well in Trap covered Gneissic formation. These wells were constructed in addition to existing 9 wells in the Chandrabhaga watershed.

10. North-eastern part of the watershed is extensively covered by rocks of Gondwana Supergroup comprises of Kamthi Sandstone and Shales. The central part is consisting of Trap Covered Gondwana Formation where the thickness of traps ranges from 62.00 m bgl (Waroda) to 195.00 mbgl (Sonkhamb). Towards extreme south-eastern part, Archaean gneisses occur below the traps (Dahegaon), whereas towards the extreme western part of the watershed thickness of the Deccan trap is observed more than 200 mbgl.

11. To determine the parameters of deeper aquifers, pumping tests were conducted on 7 exploratory wells. During the tests, the drawdown ranges from 6.34 to 36.97 m and recorded Transmissivity (T) of aquifer in basalts is 30 m^2/day (Sonkhamb) whereas in Gondwana sandstone transmissivity varies from 15 m^2/day (Khairi Lakhmaji) to 173 m^2/day (Kohli). The storativity (S) 0.001 is estimated at Dhapewada.

12. In addition, to determine the parameters of the shallow aquifer, 21 pumping tests has been conducted on open dug wells. It has been observed that the transmissivity (T) for basaltic aquifer ranges between 1.04 and 72.56 m^2/day whereas for sandstone aquifer it ranges between 3.64 and 11.37 m^2/day.

13. The results of infiltration test conducted at 9 different soil types revealed the infiltration rate in the area ranges from 4 mm/hr at Tondakhiri for the sandy loam to clay loam soil type to 40.02 mm/hr at Dhapewada for clay loam soil type.

14. The In-House geophysical survey comprising 138 VES including 52 VES for exploratory drilling were carried out to estimate the thickness of the top basaltic formation and depth of Gondwana formations. In addition to this, 300 line meters Gradient Resistivity Profiling and 610 line meters Very Low Frequency (VLF) electromagnetic profiling were carried out.

15. Based on the VES results, it is inferred that the resistivities ranging from 16 to 87 Ωm represent the aquifer zone in the Gondwana formations, whereas the resistivities ranging from 7 to 40 Ωm represent the aquifer zone in the Deccan Trap formations. However, in the Archaean formations, the fractured Gneiss has been delineated with 12 Ωm resistivity, at only one VES location.
    a. Interpretation of VES in Chandrabhaga watershed area infers that the Gondwana formations are extending more than 150m depth in the NE part of the area. They are absent in the SE part of the area and was conformed from the existing borehole data at Yerla. In this area, the Achaeans are encountered below basaltic formation at depths around 60m bgl. The thickness of the basalt is increasing from east to west. In the eastern part of the area, approximately 60 m around Yerla whereas in the western part, it is 195m around Sonkhamb in the western part. However, it varies from 80 m at Mohgaon to 127m at Ramgiri in the northern part of the study area. In the SW part of the area Gondwanas are inferred at shallow depths, approximately 30 to 40m depths around Raulgaon. Occurrence of Gondwana at shallow level could be attributed to reverse faulting (?) at this place or the extension of Gondwana of southern part. This infers the undulating nature of the paleo-topography of Gondwana over which basaltic lavas were poured out. The VES results could not demarcate the individual basaltic flow tops since the resistivity contrast between two flows is minimal. This is one of the limitations of the 1D resistivity survey.
    b. The VLF and GRP were carried out to infer the location and orientation of the fractures/ lineaments in the area and also based on the VES carried out in the

area. 15 sites were selected for exploratory drilling. The details of sites are given below.

i. Khairi or Gowari and Dhapewada in the area occupied by Gondwanas
ii. Kohli-Mohli, Ubgi, Pardi Deshmukh, Ramgiri and Ghorad in the area occupied by basalts and
iii. Raualgaon, Sonegan and Uperwahi in the Trap Covered Gondwana area.

c. Geophysical logging infers that the thickness of the top basaltic formation is increasing from east (59 m at the village Yerla, as per the CGWB data acquired before Pilot Project) to west (145m at Raulgaon in the SW of the study area and 127 m at Ramgiri in the NW of the study area). The Trap-Gondwana contact and Trap-Gneiss contact were clearly demarcated in the Fence diagram generated based on the consolidated lithologs prepared from the integration of the geophysical log and litholog prepared from drilling samples. Very thin layers of clay/bole beds and fractured zones were resolved with high accuracy from Gamma Log.

d. ERT shows significant signatures of structural controls like lineaments and layered nature of flows could be delineated but difficult to distinguish between two successive lava flows. The ERT investigation shows that in basaltic terrain the low resistivity up to 60 Ω-m is attributed to the vesicular basalt followed by massive basalt with resistivity range 60-125 Ω-m. However, in Gondwana formation the resistivity of saturated sandstone range from 18 to 35 Ω-m. Thus, *ERT fails to delineate between the different litho units of Gondwana.*

e. The findings from TEM and VES are found complementing each other, which are further validated by available borehole lithologs. TEM is able to resolve the relatively conductive Gondwanas at 50-60m depth with a loop size 40m x 40m. Based on the interpretation the estimated depth to Gondwana from TEM and VES are closer to the borehole information at Raulgaon and Kotwalbardi. At Raulgaon the 1D investigation have shown the highly conductive layer (2.3 Ωm) at ~50m depth obtained from TEM data and the conductive layer (20 Ωm) at ~ 44m depth obtained from VES data. The borehole information at Raulgaon indicates the presence of Gondwana at 45.7m depth strengthening and validating the TEM and VES results and its suitability for aquifer mapping. Similarly, at Kotwalbardi village, the layer with resistivity 21.3 Ωm at ~50.6m depth was obtained from TEM data and layer with resistivity 27 Ωm at 29 m depth was acquired from VES data. The borehole litholog indicated the presence of Gondwana at 47.2m validating the TEM and VES data at Kotwalbardi.

f. The resistivity sections generated based on the 8 TEM soundings corrected for elevation and geological cross section aligned in NS following the same alignment as ERT. The individual ERT images found well corroborating with TEM results. Since both the measurement is limited within 100 m depth of investigation, thus the basaltic flow at deeper level could not be mapped. However, both the measurements indicated relatively low order of resistivity at the extremities responding to Gondwanas and alternate layering of low, high and low resistivity due to basaltic flows, associated with alterations and the intertrappeans. *However, TEM provides significant information of shallow depth up to 90 m bgl*.

g. Heliborne Transient Electromagnetic investigation has revealed fascinating results on the aquifer systems and its spatial characteristics covering Gondwana, Trap covered Gondwana and Trap covered Gneiss formations present in the study area. The results, in general, helped in mapping the lithounits in 3-Dimension. Besides, it helped reconstructing the concealed subsurface spatial disposition of structures controlling the groundwater dynamics. The main advantages of the heliborne geophysical surveys are that they are fast (~2000 measurements/hour), highly dense data, precise and economical. Moreover, they can be carried out in remote and inaccessible areas. It helped getting a clear insight into the prevailing hydrogeological conditions; identify the aquifers and also delineating the subsurface structures. The unique advantage of such investigation is that it doesn't suffer from the uncertainty of interpolation. Concurrent measurements of the magnetic field (HeliMAG) provide valuable information on the geological structures that control the occurrence of the groundwater.

h. The integration of Heli-TEM data with ground geophysics and controlled points such as borehole lithologs has been useful to derive the basaltic trap thickness and Gondwana topography. The lateral contact between Trap-Gondwanas exposed in the north east has been very clearly demarcated in the Heli-MAG map. It is also found very effective in delineating the structural feature such as fault, which is reflected as low resistivity band elongated in WNW-ESE. The integrated interpretation of various geophysical parameters clearly indicates the relative efficacy of Heli-TEM survey with more resolution in demarcating the fractures in amygdaloidal and massive basalts, inter-trappean and Basalt-Gondwana vertical boundary which are the potential aquifers.

i. The SkyTEM data gives a new and comprehensive three-dimensional picture of the subsurface. This method incorporates the unique feature of using dual (low and high) moments for the transmitter. The low moment data ensured the high resolution mapping of near surface and high moment data to the deeper level. Thus, the dual moment provided high resolution mapping of subsurface from top to ~ 250 m depths. The results revealed a clear contrast between the Basalt-Gondwana (B-G) zone bearing the resistivity range 10-15 Ωm with groundwater yield 6-8 lps. It is also noted that, deeper (> 150 m) the Basalt-Gondwana contact greater is the groundwater yield (> 6 lps) and relative low resistivity range. The resistivity of aquifers in vesicular basalt ranges from 20-25 Ωm, wherein fractured vesicular basalts it ranges from 15-25 Ωm. Apart, the lava flows separated by intertrappeans layers are clearly demarcated by the SkyTEM sections. The potential aquifer zones such as intertrappeans, fractures in vesicular basalts and Basalt-Gondwana contact are mapped in the resistivity section of SkyTEM. The regional fault (potential aquifer) which is abutting in the SW part with its orientation SE-NW is successfully delineated in the mean resistivity maps of below 486 m amsl with corresponding resistivity range 8-10 Ωm. The aquifer systems in basalts and Gondwanas and their extensions are also clearly demarcated on the 3D map using HeliTEM data. The HeliMAG maps was useful in delineating, i) the lateral contact between Deccan Traps-Gondwanas exposed in the north east, and ii) the structural feature such as fault which is reflected as low resistivity band elongated in WNW-ESE. The integration on WellCAD has been fruitful for the geophysical parameter characterization, where resistivity gradient as first derivative provided sharp contacts on vertical scale. The spatial maps of mean resistivity of 10 m interval on vertical scale would help in understanding the depth of the fractures and faults. Grid wise vertical information was generated to assist the groundwater modeling and further groundwater management aspects.

j. The interpretation of mean resistivity maps denotes that the flow no. 27 and 26 in the western part extends up to 50 m depth, which covered in mean resistivity maps of 476-526 m, amsl. Similarly, the subsequent flows are also identified with each flow thickness range 20-40 m. The depth wise mean resistivity maps also follow the step like topography on regional scale sloping towards north-east. Moreover, the exposed Gondwanas in the north-east of study area is clearly demarcated from its lateral basalt contact with the relative low resistivity obtained on the mean resistivity maps of 306-326 m, amsl. This elevation is also well correlates with the topographic elevation of surface Gondwanas in the N-E part.

k. The regional fault which is abutting in the SW part with its orientation SE-NW is successfully delineated in the mean resistivity maps of below 486 m. amsl. The relative high resistivity anomaly trending in NW-SE direction in the central part has been observed at the depth of 216-116 m, amsl which is also matching with the maps of gravity and magnetic anomalies has to be resolved. The depth wise spatial variations acquired in the mean resistivity maps have been imperative in view of mapping aquifer zones which corresponds the relative low resistivity.

l. The SkyTEM data fails to identify or demarcate red/grey/green bole layer of significant thickness.

i. It has been observed that 1.5 m thick clay at a depth of 11.5 m depth and 1m clay bed at depth of 31.5 m are not revealed by SkyTEM at KOHLI EW site

ii. Similarly, the 8.3 m thick red bole at a depth of 87.75m is not detectable by SkyTEM at Pardi (Deshmukh).

iii. Aquifer disposition could not be made precisely especially the fracture in basaltic terrain saturated with ground water are not shown in SkyTEm results.

16. Ground TEM data have not shown good result/information in basaltic terrain especially for shallow aquifers.

17. To monitor shallow aquifer ground water levels 58 KOW were established tapping the unconfined aquifer (Aquifer-I) and monitored periodically including 2 existing GWMW at Kalmeshwar and Chargaon. While for deeper aquifer 16 exploratory wells tapping the semi-confined/confined aquifers (Aquifer-II and III) monitored periodically. The aquifer wise ground water levels have been analysed. It has been observed that in aquifer I, shallow ground water levels in the range of 3 to 6 m bgl are observed as isolated

patches in southwestern and northern parts of the watershed. The moderate ground water levels ranging from 6 to 9 mbgl are observed in major parts of the watershed occupying south eastern fringe areas, central and western parts. Whereas deeper ground water levels in the range of 9 to 12 m bgl and more than 12 mbgl were observed in north eastern and eastern parts of the watershed.

18. However, ground water level in Aquifer-II and III reveals that major central part of the watershed observed in the range from 50 to 73 m bgl. The eastern and western part of the watershed shows gradual decrease in ground water level i.e., up to 20 m bgl while in the Sandstone (Aquifer-II) ground water level is observed shallow i.e., up to 7 m bgl. The deeper ground water levels are due to the potential zones encountered at depth more than 45 m bgl upto 197 m bgl.

19. Aquifer-I is affected by nitrate contamination as about 79% of samples show higher nitrate concentration (more than 45 mg/L) while the nitrate in deeper Aquifer-II has been found beyond permissible limit at Ramgiri (65 mg/l), Gowri (47 mg/l) and Raulgaon (46 mg/l). In Aquifer-II, fluoride occur in the range from 1.23 to 1.46 mg/l i.e., marginally high but below MPL of 1.5 mg/l has been observed in Sonkhamb (22.60-23m), Raulgaon (127.3-129.95m; 135.6-138.6m), Khapri (48.2-50.85m), and Dhapewada (Zone-I). Heavy metal analysis indicted that Aquifer-I is more contaminated as compared to deeper ground water Aquifer-II where the presence of Fe and Pb noticed.

20. However, ground water from Aquifer – I and II is good and potable for drinking, domestic and irrigation purpose, except at one or two locations, where nitrate contamination is observed and at places the salinity hazard due to excess of magnesium is recorded.

21. The movement of groundwater is from southwest to northeast direction, which ultimately converges with the Chandrabhaga River. This indicates that the ground water flow in the watershed fallow the topographic control. Overall, average minimum water table elevation is 294 m above MSL while average maximum water table elevation is 511 m above MSL. The groundwater divides, marked by the divergence of flow lines, almost coincide with the topographic divides, indicating the importance of the

geomorphic features in demarcating the areas of groundwater development and management.

22. The Chandrabhaga river is gaining water from ground water in its upper reaches in-and-around villages Wadhona (Bk)-Dhapewada-Bhadangi and acts as a *Effluent River*. While in lower reaches, it is losing water to the groundwater and acts as an *Influent River* in-and-around Bhadangi – Borgaon (Kh) – Sillori villages. Thus, Chandrabhaga river is ephemeral effluent as well as influent river.

23. The ground water resources (2011) indicate that the stage of ground water development is about 80%. As compared to 2004 scenario the recharge has been increased by about 5% and draft has increased by about 22%. The ground water is mainly used for irrigation purpose i.e., about 5368 ham out of total draft of 5545 ham.

24. All the data thus generated has been used to generate a *ground water flow model* to resolve the issues/problems in the Chandrabhaga watershed. The data for Aquifer-I, i.e., shallow/unconfined phreatic aquifer is available and hence used. However, there is very less data available for 2nd layer, i.e., for Aquifer-II and III, deeper semi/confined aquifer. A two layer model is generated for the watershed. Based on the available data, the area is discretized into 612 grids (392 active grids) of 1000 × 1000 meter grid size. A total 18 rows and 34 columns were considered. Four boundary conditions i.e., Constant Head Boundary, Linear Gradient River Boundary and No Flow Boundary and Drain have been assigned to the model area at different parts as per requirement.

    a. Conductivity of around 12 m/day was considered for most part while at places 7.5 m/day considering local hydrogeological conditions and for hilly area 0.01 m/day has been considered.
    b. The Specific yield value of 0.04 is considered for most of the area and for hilly area 0.001 value has been considered. Like conductivity, specific yield of 0.02 and 0.06 is assigned to isolated areas considering the local hydrogeological conditions.
    c. A low recharge value of around 16% of actual rainfall is considered for most part of the study area. The western hilly area is assigned a very low recharge value of only 1%. A somewhat lower recharge of 13% is assigned to the valley

area since they fall under ground water discharge zone at least during peak monsoon season. A less recharge of 8% is assigned to the north-western part which is characterized by undulating hills and valleys.

d. The unit draft as deciphered from the field observation is considered as 50 m^3/day. Though the pumping varies during the different period of the crop growth, a uniform rate of pumping is assigned to the region for the whole non-monsoon season of 215 days (November to May).

e. For transient state calibration ground water level data from June-2012 to October-2014 of 52 observation wells has been used. The approximate water table data as deciphered from the pre-monsoon depth to water level map is considered as initial head values for running the transient model. Multiple stress periods were included into the model and data for each stress period was entered separately. After entering all the input parameters for each stress period, the model was run for the transient state calibration.

f. With the convergence of the transient model, scenario of different stress period is generated for 30, 60, 90, 120, 150, 165, 190, 215, 265, 315 and 365 days. The normalized root mean square error is calculated for each stress period and found to be between 6.8% to 8.78%. Thus, transient calibration shows a good agreement to the actual field condition.

g. The sensitivity analysis indicates that it is less sensitive to specific yield and gives only slight change in head value. However, the model is found to be quite sensitive to changes in hydraulic conductivity, as it is not at all converging after changing the hydraulic conductivity.

h. Thus, the parameters determined during transient calibration and verification is used to predict the response of the system to future events and model was run for predictive simulation. Considering issues/problems in the Chandrabhaga watershed, and to achieve the objectives, two scenarios were suggested for shallow unconfined Aquifer-I.

i. The Aquifer Management Plan, thus, generated has been found more realistic for the Aquifer-I comprising of Basalt and Sandstone, as under

Scenario-1: construction of check dam on Chandrabhaga river

This will raise the ground water level in the area. The total improvement will be around 289273 m^3, which is 9 % of the total recharge from the river to the aquifer before construction of the structures. The Chandrabhaga watershed (WGKCC-2) has a heavy ground water withdrawal for agriculture especially for orange cultivation, this will of immense help during the dry seasons.

Scenario-2: Construction of recharge wells to enhance ground water recharge and dilution of pollution

The specially designed recharge wells tapping the full thickness of the aquifer (20-30 meters) to obtain maximum transmissivity so as to accept maximum amount of harvested water. 25 recharge wells can be added on the river grids with a recharge rate of 300 m^3/day for the full rainy season and zero recharge rate for the rest of the period. This will enhance the ground water resources of the area by 1125000 m^3 annually.

25. Area vulnerable for ground water quantity / Ground water stress area has been identified and site-specific ground water management plans has been suggested. Unconventional measures like fracture seal cementation (FSC), Hydro-fracturing, Well jacketing (WJ), Borewell Blasting Technique (BBT) etc.; soil and water conservation methods such as gabion structures, form ponding, nala widening and bunding, Under Ground *Bandhara* (UGB) etc., along with rooftop rain water harvesting are recommended. Also, modern irrigation practices like drip irrigation, sprinkler etc. will be use, in place of traditional, then it is possible to reduce the groundwater draft up to 30 % to 40 %. Also, there is urgent need to change the cropping pattern by low water intensive crop.
26. Considering the local physiographical and hydrogeological set up and source water availability to augment the ground water the following artificial recharge methods are suggested for individual villages
    a. Construction of Percolation tanks and check dams on 2nd and 3rd order stream
    b. Construction of KT weir and UGB at mini and micro-watershed level
    c. Besides this periodic desilting of existing water conservation structures before onset of monsoon is also proposed
27. Area vulnerable for ground water quality / Ground water stress area have been identified and it has been observed that the major quality vulnerable area is restricted to industrial area of Kalmeshwar town. The suggested Aquifer Management plan is if the area would be recharged with fresh water through 25 recharge wells, then it could be possible to dilute the ground water pollution. This will, in turn, reduces the

contamination and also enhance the ground water level in the area. However, there is need to enforced to regulatory measures to stop the untreated/semi-treated disposal of industrial effluent to the ground water system. It is also recommended that the industrial effluent must be treated before it released to the nalas. All the industries should follow the norm set by the CPCB and MPCB for effluents discharge.

28. Apart from this, it is also suggested to adopt groundwater management strategies, particularly for irrigation sector as the main activity of the people in the Chandrabhaga watershed (WGKKC-2) is agriculture.
29. The experiences gained from the pilot project on aquifer mapping (AQMAH) in Chandrabhaga watershed helps to develop a protocol to be adopted in rest of the NAQUIM area of Maharashtra and UT of Dadra and Nagar Haveli. It is suggested that following protocol for aquifer mapping in the State as well as in the Country may be adopted

    STEP 1 : Acquiring Heli TEM and Heli MAG through Advance geophysical survey

    STEP 2 : Validation by ground geophysical, hydrogeological studies and exploratory drilling.

    STEP 3 : Data integration and interpretation for 3D aquifer model and characteristics.

30. It is recommended that the ground water monitoring of wells (DW and EW/Pz) should be continued in future to test the various strategies of the modeling.
31. The ground water modeling is very important tool to precisely assess the problem related to quantity and quality issues. It also helps to suggest the appropriate plan to address the issues. However, it requires herculean task of collecting data on micro level for all the hydrogeological parameters with high level of accuracy to run the model. In order to accomplish the task, it is suggested that site specific/problematic area for modeling may be taken up.

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ANNEXURES

ANNEXURE-I: VES Results in Chandrabhaga Watershed WGKKC-2, Nagpur District

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
1	Brahmani/NGP 96	336	400	**I**	21	0.5	0.5	335.5	Top Soil	>160m Basalt
				II	43	3.5	4	332	Mod. weathered basalt	
				III	33	26.6	30.6	305.4	Fr. Basalt	
				IV	115	32	62.6	273.4	M Basalt	
				V	20	88	150.6	185.4	Fr. basalt	
				VI	58	8.1	158.7	177.3	V basalt	
				VII	595				M basalt	
2	1/2 Km W of Junki / NGP 97	322	400	**I**	27	2	2	320	Top Soil	21 m Basalt, below more than 2oo m Gondwana
				II	3.7	2.4	4.4	317.6	Clay	
				III	11.8	16.5	20.9	301.1	W basalt	
				IV	64	79.3	100.2	221.8	Sandstone	
				V	19					
3	2Km from Dhapewada on Kalmeshwar road / NGP 98	323	400	**I**	12	2.5	2.5	320.5	Top Soil	Up to 81m Gondwana, below 81m gneiss
				II	22	7.2	9.7	313.3	Sandstone	
				III	2.6	4.7	14.4	308.6	Shale	
				IV	14	66.1	80.5	242.5	Sandstone	
				V	31				Fr. Gneiss	
4	On Kalmeshwar-Nagpur Road, 200 m E of Rly gate / NGP 99	342	400	**I**	26	0.6	0.6	341.4	Top Soil	>125m basalt
				II	37	0.6	1.2	340.8	W basalt	
				III	9	1.3	2.5	339.5	Fr. basalt	
				IV	55	2.8	5.3	336.7	V basalt	
				V	10	5.8	11.1	330.9	Fr. basalt	
				VI	91				M basalt	
5	Ketapar on Kalmeshwar-Gondkhairi road / NGP 115	361	400	**I**	13	0.9	0.9	360.1	Top Soil	Up To 48 m basalt, 48 to approx. 125 m Gondwana
				II	30	8.6	9.5	351.5	Mod.weathered basalt	
				III	353	38	47.5	313.5	M basalt	
				IV	28				Sandstone	
6	Selu, On Selu-Kalambe Road / NGP 116	347	400	**I**	18	0.9	0.9	346.1	Top Soil	More than 125m Basalt
				II	43	3.4	4.3	342.7	V Basalt	
				III	155	16.5	20.8	326.2	M basalt	
				IV	63	24.8	45.6	301.4		
				V	189					
7	Sawangi, On Sawangi-Linga Road / NGP 118	349	400	**I**	18	0.9	0.9	348.1	Top Soil	More than 150m Basalt
				II	14	3.4	4.3	344.7	W Basalt	
				III	53	16.5	20.8	328.2	V basalt	
				IV	450	24.8	45.6	303.4	M basalt	
				V	6.7				Fra. Basalt	
8	Kinga, On Linga-Uparwadi Road / NGP 119	361	400	**I**	13	0.9	0.9	360.1	Top Soil	Up To 46 m Basalt, 46 to approx. 125 m Clay (Gondwana ?)
				II	9.6	3.4	4.3	356.7	W Basalt	
				III	23	5.2	9.5	351.5		
				IV	57	11.3	20.8	340.2	V basalt	
				V	394	24.8	45.6	315.4	M basalt	
				VI	1.7				Clay	
9	On Nagpur-katol Road / NGP 120	342	400	**I**	6.4	2	2	340	Top Soil	Up to 50m Basalt, Below 50 m Gneiss
				II	66	21.5	23.5	318.5	M basalt	
				III	1885	24.8	48.3	293.7		
				IV	14				Fra.Basalt	
10	On Kalmeshwar bypass road / NGP 121	330	400	**I**	19	0.7	0.7	329.3	Top Soil	More Than 150m Basalt
				II	4	5.3	6	324	Clay	
				III	1.5	9.3	15.3	314.7		
				IV	4136				M Basalt	
11	Ghogali, Kalmeshwar-Katol Road / NGP 122	347	400	**I**	13	2.7	2.7	344.3	Top Soil	Up to 70 m Basalt, below 70 m Gondwana
				II	43	2.9	5.6	341.4	V Basalt	
				III	9.4	5	10.6	336.4	W.Basalt	
				IV	83				M Basalt	
12	Khapri, on Rly gate road / NGP 123	355	400	**I**	31	2.1	2.1	352.9	Top Soil	Up to 88 m Basalt, More than 88 m
				II	8.9	2.5	4.6	350.4	W.Basalt	
				III	222	20.4	25	330	M Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
				IV	13.4	63.2	88.2	266.8	Fra. Basalt	Gneiss ?
				V	817				M Basalt	
13	On Kalmeshwar-Mohpa Road / NGP 124	334	400	**I**	12	0.9	0.9	333.1	Top Soil	> 150m basalt
				II	8	1.1	2	332	W Basalt	
				III	21	19	21	313		
				IV	281	83	104	230	M Basalt	
				V	9				Fra. Basalt	
14	Ubali, on Ubali-Mohpa Road, 1 Km from Ubali / NGP 125	317	400	**I**	25	0.9	0.9	316.1	Top Soil	>150m Gondwana
				II	50	3.5	4.4	312.6	Sandstone	
				III	8.7	5.2	9.6	307.4	Sandy clay	
				IV	18	11.3	20.9	296.1	Sandstone	
				V	356	84	104.9	212.1	Compact Sandstone	
				VI	11				Sandstone + Shale	
15	Mohpa, On Mohpa-Katol Road / NGP 126	356	400	**I**	31	2.2	2.2	353.8	Top Soil	> 150m basalt ?
				II	3.3	4.4	6.6	349.4	Clay	
				III	9873	5.4	12	344	M Basalt	
				IV	18				Fr.Basalt	
16	Near Moholi-Koholi, On Katol-Nagpur road / NGP 127	382	400	**I**	59	1.6	1.6	380.4	Top Soil	> 150m basalt ?
				II	21	25.4	27	355	W. Basalt	
				III	8	12.5	39.5	342.5		
				IV	1430	18.3	57.8	324.2	M basalt	
				V	119	55.7	113.5	268.5		
				VI	24				Fr. basalt	
17	Linga, On Linga-Bazargaon Road / NGP 137	371	400	**I**	20.8	0.9	0.9	370.1	Top Soil	>150m Basalt
				II	60.7	3.43	4.33	366.67	M basalt	
				III	12.7	5.16	9.49	361.51	Fr. basalt	
				IV	90.6				M. basalt	
18	In between Rawalgaon & Kotwalbardi / NGP 138	396	400	**I**	157	1.3	1.3	369.7	Top Soil	Up to 84m basalt, 84 to 138m Gondwana, below 138 m Gneiss
				II	366	4.4	5.7	365.3	M Basalt	
				III	54	78.4	84.1	286.9	V Basalt	
				IV	11	53.9	137.9	233.1	SST +Shale(Gondwana)	
				V	554				Massive Basalt	
19	Lonara / NGP 140	366	400	**I**	11	1.9	1.9	364.1	Top Soil	> 150m Gondwna
				II	308	0.9	2.9	363.1	Compact Sandstone	
				III	30	42.0	44.9	321.1	Sandstone	
				IV	66	75.2	120.1	245.9		
				V	2				Shale	
20	Phetri / NGP 266	344	400	**I**	44	1.0	1.0	343.0	Top Soil	Up to 70m basalt, Below 70 m Gneiss ? (Curve break)
				II	513	8.7	9.7	334.3	M Basalt	
				III	86					
21	Phetri / NGP 267	351	400	**I**	30	3.5	3.5	347.5	Top Soil	Up to 158m basalt, Below 158m gneiss
				II	142	26.4	29.9	321.1	M basalt	
				III	16	128	157.9	193.1	Fr. basalt	
				IV	269				Gneiss	
22	E. of Borgaon / NGP 268	350	400	**I**	22	0.9	0.9	349.1	Top Soil	Up to 150m Basalt
				II	17	3.2	4.1	345.9	W. basalt	
				III	501	14.3	18.4	331.6	M basalt	
				IV	3	22.4	40.8	372.4	Fr. basalt	
				V	93				M. basalt	
23	N of Borgaon / NGP 269	342	400	**I**	5	2.4	2.4	339.6	Top Soil	Up to 22 m Basalt
				II	425	20	22.4	319.6	M basalt	
				III	8				SST + Shale	
24	SW of Khandala / NGP 270	338	400	**I**	5	0.9	0.9	337.1	Top Soil	Up to 150m Gondwana
				II	42	1.1	2	336	Sandstone	
				III	4	2.5	4.5	333.5	Shale	
				IV	1343	5.5	10	328	Compact Sandstone	
				V	37				Sandstone	
25	N. of Shri Asharam Bapu	348	400	**I**	50	0.8	0.8	347.2	Top Soil	Up to 33m Basalt , Below
				II	208	19.1	19.9	328.9	M Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
	Ashram / NGP 271			**III**	18	13.1	33	315	Fr. basalt	33m Gneiss
				IV	6651				Gneiss	
26	Gondni / NGP 272	351	400	**I**	44	0.45	0.45	350.55	Top Soil	Up to 53m Basalt, below 53m fra. Gneiss
				II	3.7	6.5	6.95	344.05	Clay	
				III	374	45.9	52.85	298.15	M Basalt	
				IV	12				Fra. Gneiss	
27	N of Yerla / NGP 273	340	400	**I**	7	0.9	0.9	339.1	Top Soil	Up to 150m Basalt
				II	4200	1.1	2	338	M Basalt	
				III	197					
28	Ashti / NGP 274	346	400	**I**	6	0.8	0.8	345.2	Top Soil	Up to 74 m Basalt Below 74m Clay(Gondwana) ?
				II	18	26.6	27.4	318.6	W Basalt	
				III	176	46.9	74.3	271.7	M Basalt	
				IV	2				Clay (Gondwana)	
29	Between Ashti & pardi / NGP 275	350	400	**I**	31	1.9	1.9	348.1	Top Soil	Up to 54 m Basalt Below 74m Clay (Gondwana) ?
				II	13	2	3.9	346.1	W Basalt	
				III	3	4.3	8.2	341.8	Clay	
				IV	149	45.8	54	296	M Basalt	
				V	1.35				Clay (Gondwana)	
30	Pardi / NGP 276	329	400	**I**	42	1.2	1.2	327.8	Top Soil	Up to 122m SST, Below 122m Gneiss
				II	4.3	6.3	7.5	321.5	Clay	
				III	25	115	122.5	206.5	Sandstone	
				IV	2330				Gneiss	
31	Kalmeshwar / NGP 277	338	400	**I**	14	0.9	0.9	337.1	Top Soil	Up to 82m Basalt, Below 82 m Gneiss
				II	40.5	10	10.9	327.1	V.Basalt	
				III	350	71	81.9	256.1	M basalt	
				IV	38				Fr. Gneiss	
32	1.2 Km SE of Kalmeshwar on Kalmeawar-Nagpur road / NGP 278	334	400	**I**	17	1	1	333	Top Soil	Up to 125m Basalt
				II	3	3.4	4.4	329.6	Clay	
				III	3190	7.5	11.9	322.1	M basalt	
				IV	12				Fr. basalt	
33	Kalmeshwar / NGP 279	322	400	**I**	5	5.7	5.7	316.3	Top Soil	Up to 125m Basalt
				II	37	5.2	10.9	311.1	W Basalt	
				III	3.4	10	20.9	301.1	Clay	
				IV	37				Fra Basalt	
34	Kalmeshwar / NGP 280	337	400	**I**	21	1.7	1.7	335.3	Top Soil	Up to 111m Basalt, Below 111m Gneiss
				II	88	2.5	4.2	332.8	M basalt	
				III	7	5.1	9.3	327.7	W Basalt	
				IV	77	102	111.3	225.7	M basalt	
				V	885				Gneiss	
35	Kalmeshwar / NGP 281	341	400	**I**	83	1	1	340	Top Soil	Up to 150m Basalt
				II	3	3	4	337	Clay	
				III	520	4.4	8.4	332.6	M basalt	
				IV	19	31.8	40.2	300.8	Fr. basalt	
				V	251				M basalt	
36	Kalmeshwar / NGP 282	354	400	**I**	18	0.8	0.8	353.2	Top Soil	Up to 106m Basalt, elow 106m Gneiss
				II	14	17	17.8	336.2	W.Basalt	
				III	104	88.5	106.3	247.7	M Basalt	
				IV	1862				Gneiss	
37	Selu / NGP 283	361	400	**I**	5	0.9	0.9	360.1	Top Soil	Up to 125m Basalt
				II	12	3.5	4.4	356.6	W.Basalt	
				III	777	5.2	9.6	351.4	M Basalt	
				IV	31	37.1	46.7	314.3	Fr. basalt	
				V	271				M Basalt	
38	Khargaon / NGP 284	352	400	**I**	28	0.7	0.7	351.3	Top Soil	Up to 125m Basalt
				II	3	0.8	1.5	350.5	Clay	
				III	1121	5.2	6.7	345.3	M basalt	
				IV	24				Fr. basalt	
39	Dahegaon / NGP 285	341	400	**I**	5	1.3	1.3	339.7	Top Soil	Up to 116m Basalt, Below 116m Gneiss
				II	574	115	116.3	224.7	M Basalt	
				III	5916				Gneiss	
40	Dahegaon / NGP 286	340	400	**I**	3.2	0.6	0.6	339.4	Top Soil	Up to 139m Basalt, Below 139m Gneiss
				II	13	1.9	2.5	337.5	W Basalt	
				III	107	136	138.5	201.5	M Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
				IV	5278				Gneiss	
41	Phetri / NGP 287	327	400	I	4.5	0.9	0.9	326.1	Top Soil	Up To 42m Basalt, Below 42m Clay/ Fr.Gneiss ?
				II	31	3.2	4.1	322.9	W Basalt	
				III	55	4.7	8.8	318.2	V basalt	
				IV	92				M Basalt	
42	E. of Kalambi / NGP 288	344	400	I	14	1.1	1.1	342.9	Top Soil	Up to 89m Basalt, Below 89m Gneiss
				II	48	6.7	7.8	336.2	V basalt	
				III	820	10.7	18.5	325.5	M basalt	
				IV	40	70.8	89.3	254.7	V basalt	
				V	3666				Gneiss	
43	W. of Kalambi / NGP 289	342	400	I	20	0.9	0.9	341.1	Top Soil	> 100m Basalt
				II	699	1.1	2	340	M basalt	
				III	184	18.8	20.8	321.2		
				IV	218					
44	Selu / NGP 290	362	400	I	29	0.3	0.3	361.7	Top Soil	> 100m Basalt
				II	7	7.3	7.6	354.4	W. basalt	
				III	80				M basalt	
45	Sawangi / NGP 291	372	400	I	15	1	1	371	Top Soil	Up to 83m Basalt, Below 83m Gneiss
				II	63	0.5	1.5	370.5	M basalt	
				III	4.2	1	2.5	369.5	W Basalt	
				IV	73	2.7	5.2	366.8	M basalt	
				V	7	5	10.2	361.8	Fra. Basalt	
				VI	77	73.3	83.5	288.5	M basalt	
				VII	4254				Gneiss	
47	Sawangi / NGP 292	344	400	I	6.2	2.3	2.3	341.7	Top Soil	> 125m Basalt
				II	7.5	8.8	11.1	332.9	W Basalt	
				III	180				M basalt	
48	W of Sawangi / NGP 293	360	400	I	4.1	4.2	4.2	355.8	Top Soil	> 125m Basalt
				II	7.4	12.9	17.1	342.9	W Basalt	
				III	55				V basalt	
49	3Km E of Linga / NGP 294	375	400	I	18	1.2	1.2	373.8	Top Soil	> 125m Basalt
				II	3.6	5.8	7	368	Clay	
				III	165				M basalt	
50	3Km E of Linga / NGP 295	382	400	I	4	3.9	3.9	378.1	Top Soil	> 125m Basalt
				II	34	25.8	29.7	352.3	W basalt	
				III	230				M basalt	
51	1Km E of Linga / NGP 296	388	400	I	38	0.9	0.9	387.1	Top Soil	> 125m Basalt
				II	142	0.8	1.7	386.3	M basalt	
				III	17	12.8	14.5	373.5	W. basalt	
				IV	213	22.6	37.1	350.9	M basalt	
				V	72					
52	Uperwahi / NGP 297	357	200	I	7	0.9	0.9	356.1	Top Soil	> 70m basalt
				II	12	1.1	2	355	W basalt	
				III	6	2.5	4.5	352.5	Clay	
				IV	15	5.5	10	347	Fr. basalt	
				V	162	12.4	22.4	334.6	M basalt	
				VI	41				V basalt	
53	SW of Sonegaon on Linga-Sonegaon Road / NGP 298	370	200	I	17.4	0.9	0.9	369.1	Top Soil	> 70m basalt
				II	10.4	1.1	2	368	W basalt	
				III	23.3	20.5	22.5	347.5	Fr. basalt	
				IV	50.5				V basalt	
54	Sonegaon / NGP 299	367	400	I	70	4.8	4.8	362.2	Top Soil	Up to 125m Basalt
				II	488	5	9.8	357.2	M basalt	
				III	34	12.1	21.9	345.1	Fr. basalt	
				IV	127	69.1	91	276	M basalt	
				V	11				Fr. basalt	
55	S of Sonegaon / NGP 300	361	300	I	71	0.9	0.9	360.1	Top Soil	Up to 100m Basalt, Below 100m Gneiss
				II	199	3	3.9	357.1	M basalt	
				III	16.1	4.3	8.2	352.8	Fr. basalt	
				IV	194				M basalt	
56	Khapri, 1Km E of the Village / NGP 301	323	200	I	14.5	0.8	0.8	322.2	Top Soil	> 70m basalt
				II	11.1	8.7	9.5	313.5	W Basalt	
				III	213	42.1	51.6	271.4	M basalt	
				IV	5.7				Fr. basalt	
57	Khapri, 1Km W of the Village /	340	400	I	27	0.9	0.9	339.1	Top Soil	Up to 100 m Basalt, below
				II	49	3.4	4.3	335.7	M basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
	NGP 302			**III**	13	16.5	20.8	319.2	Fr. basalt	100m Gneiss (curve break)
				IV	107				M basalt	
58	Mohli / NGP 303	402	400	**I**	48	1	1	401	Top Soil	Up to 131m Basalt, below 131m Gondwana
				II	12.5	2.6	3.6	398.4	W Basalt	
				III	20	55.8	59.4	342.6	Fr. basalt	
				IV	347	40	99.4	302.6	M basalt	
				V	95	31.6	131	271		
				VI	20				Sandstone	
59	Chargaon / NGP 304	427	300	**I**	23	0.2	0.2	426.8	Top Soil	> 100m Basalt
				II	52	3.7	3.9	423.1	V basalt	
				III	7.3	6	9.9	417.1	W Basalt	
				IV	96	17.6	27.5	399.5	M basalt	
				V	6.7				Fr. basalt	
60	Dorli, SW of the Lake / NGP 305	415	400	**I**	10	1.7	1.7	413.3	Top Soil	Up to 130m Basalt
				II	15	2.1	3.8	411.2	W Basalt	
				III	7	4.8	8.6	406.4		
				IV	102				M basalt	
61	Waroda / NGP 306	325	400	**I**	28	7.9	7.9	317.1	Top Soil	up to 20m Gondwana, below 20 m Gneiss
				II	8	11.2	19.1	305.9	W Basalt	
				III	4485				Gneiss	
62	Dhapewada / NGP 307	323	400	**I**	9	1	1	322	Top Soil	> 150 m Gondwana
				II	1.6	0.9	1.9	321.1	Clay	
				III	5.8	25.7	27.6	295.4		
				IV	60	15.4	43	280	Sandstone	
				V	5	50	93	230	Shale	
				VI	203				Compact Sandstone	
63	Bhadangi / NGP 308	354	400	**I**	5	1.2	1.2	352.8	Top Soil	>150m Gondwana
				II	20	2.4	3.6	350.4	Sandstone	
				III	4	3.3	6.9	347.1	Shale	
				IV	41				Sandstone	
64	Borgaon / NGP 309	340	400	**I**	18	0.6	0.6	339.4	Top Soil	>150m Gondwana
				II	3.9	1.7	2.3	337.7	Clay	
				III	14	21	23.3	316.7	Sandstone+Shale	
				IV	45				Sandstone	
65	Bhadangi / NGP 310	349	400	**I**	8.2	0.9	0.9	348.1	Top Soil	>150m Gondwana
				II	3.4	1.1	2	347	Clay	
				III	10.7	7.5	9.5	339.5	Sandy clay	
				IV	19.9	36.1	45.6	303.4	Sandstone	
				V	87					
66	Kalmeshwar / NGP 311	278	400	**I**	6	4.8	4.8	273.2	Top Soil	Up to 80m Basalt, below 80m Gneiss ? (Curve break)
				II	10	8.8	13.6	264.4	W Basalt	
				III	123	30	43.6	234.4	M Basalt	
				IV	18.5				Fr. basalt	
67	Kalmeshwar / NGP 312	343	400	**I**	80	0.4	0.4	342.6	Top Soil	Up to 68m Basalt, below 68m Gneiss
				II	7	6.7	7.1	335.9	W Basalt	
				III	35	60.6	67.7	275.3	Fr.Basalt	
				IV	6923				Gneiss	
68	Khairi / NGP 313	352	400	**I**	5	1.6	1.6	350.4	Top Soil	Up to 123m Gondwana, below 123m Gneiss
				II	2.3	7.5	9.1	342.9	Clay	
				III	10	114	123.1	228.9	Sandstone+Shale	
				IV	311				Gneiss	
69	Gowari / NGP 314	350	200	**I**	6	2	2	348	Top Soil	> 100m Gondwana
				II	50	3.8	5.8	344.2	Sandstone	
				III	432	9.3	15.1	334.9	Compact Sandstone	
				IV	1.8				Shale	
70	Gowari / NGP 315	343	400	**I**	7	2	2	341	Top Soil	>150m Gondwana
				II	257	7.6	9.6	333.4	Compact Sandstone	
				III	62				Sandstone	
71	Khapri / NGP 316	370	200	**I**	9	3.5	3.5	366.5	Top Soil	> 100m Basalt
				II	87	4	7.5	362.5	M Basalt	
				III	19				Fr. basalt	
72	Khapri / NGP 317	370	200	**I**	3.4	0.7	0.7	369.3	Top Soil	Up to 78m Basalt below
				II	11	2.9	3.6	366.4	W Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
				III	103	3.5	7.1	362.9	M Basalt	78m Gondwana
				IV	25	71	78.1	291.9	Fr. basalt	
				V	1				Clay/Shale	
73	Gharad / NGP 318	330	400	**I**	7	1.5	1.5	328.5	Top Soil	> 100 m Basalt
				II	16	7.6	9.1	320.9	W basalt	
				III	872				M Basalt	
74	Ubali / NGP 319	359	400	**I**	15	0.6	0.6	358.4	Top Soil	Up to 74 m Basalt, below 74m Gneiss
				II	48	1.8	2.4	356.6	V basalt	
				III	9.7	10.9	13.3	345.7	W.basalt	
				IV	112	60.8	74.1	284.9	M basalt	
				V	8304				Gneiss	
75	Mohgaon / NGP 320	400	300	**I**	7	0.7	0.7	399.3	Top Soil	> 100 m Basalt
				II	1	0.9	1.6	398.4	Clay	
				III	490	1.4	3	397	M Basalt	
				IV	8	5.9	8.9	391.1	Fr. Basalt	
				V	4851				M Basalt	
76	Khapri / NGP 321	353	400	**I**	20	0.9	0.9	352.1	Top Soil	Up to 80m basalt, Below 80m Gneiss
				II	55	1.1	2	351	V Basalt	
				III	5	2.4	4.4	348.6	Fr.Basalt	
				IV	64				M Basalt	
77	Ubali / NGP 322	364	400	**I**	44	0.9	0.9	363.1	Top Soil	> 125m Basalt
				II	131	8.6	9.5	354.5	M Basalt	
				III	34	11.3	20.8	343.2	Fr. basalt	
				IV	98				M Basalt	
78	Wathoda / NGP 323	357	400	**I**	6.7	0.9	0.9	356.1	Top Soil	Up to 103 m Basalt, below 103m Gneiss ?
				II	3.6	1.1	2	355	Clay	
				III	8.6	2.4	4.4	352.6	Sandy clay	
				IV	3.4	5.2	9.6	347.4	Clay	
				V	109	103.5	113.1	243.9	M Basalt	
				VI	573				Gneiss	
79	Susundri / NGP 324	388	200	**I**	4	0.9	0.9	387.1	Top Soil	> 80m basalt
				II	7	8.7	9.6	378.4	W Basalt	
				III	6904				M basalt	
80	Kohli / NGP 325	378	240	**I**	85	1.9	1.9	376.1	Top Soil	> 80m basalt
				II	262	2.4	4.3	373.7	M Basalt	
				III	41	11.9	16.2	361.8	V Basalt	
				IV	167				M Basalt	
81	Waroda / NGP 326	313	300	**I**	30	1	1	312	Top Soil	Up to 134 m Gondwana, below 134m Gneiss
				II	8	10.6	11.6	301.4	Sandy clay	
				III	37	122	133.6	179.4	Sandstone	
				IV	860				Gneiss	
82	Pardi / NGP 328	383	400	**I**	9	0.9	0.9	382.1	Top Soil	Up to 101 m basalt, below 101m Gondwana ?
				II	5	1.1	2	381	Clay	
				III	14	7.6	9.6	373.4	W basalt	
				IV	27	11.3	20.9	362.1	Fr.Basalt	
				V	95	80.5	101.4	281.6	M Basalt	
				VI	465				Compact Sandstone	
83	Khairi / NGP 329	378	300	**I**	6.5	0.6	0.6	377.4	Top Soil	Up to 141m Basalt, Below 141m Clay (Gondwana)
				II	3.2	4.1	4.7	373.3	Clay	
				III	165	21.5	26.2	351.8	M Basalt	
				IV	31	115	141.2	236.8	Fr.Basalt	
				V	5				Clay	
84	Mohli / NGP 330	378	240	**I**	181	1.9	1.9	376.1	Top Soil	Up to 94 m Basalt, below 94 m Gondwana
				II	19	39.5	41.4	336.6	Fr. basalt	
				III	40	52.5	93.9	284.1	V Basalt	
				IV	4.6				Clay	
85	Kohli / NGP 331	390	600	**I**	113	3.2	3.2	386.8	Top Soil	Up to 130 m Basalt, below 130m Gondwana
				II	37	19.2	22.4	367.6	W Basalt	
				III	13	52.2	74.6	315.4	Fr. basalt	
				IV	495	55.1	129.7	260.3	M basalt	
				V	13				Sandstone+Shale	
86	Kalmeshwar / NGP 332	331	600	**I**	6.7	0.8	0.8	330.2	Top Soil	Up to 159 m Basalt, below 159m Gneiss
				II	3.6	10.1	10.9	320.1	Clay	
				III	82	3.3	14.2	316.8	M Basalt	
				IV	10	8.9	23.1	307.9	Fr. Basalt	

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				V	575	16.2	39.3	291.7	M Basalt	
				VI	11	32.5	71.8	259.2	Fr. Basalt	
				VII	361				M Basalt	
87	Sonkhamb / NGP 333	409	600	I	31	1.4	1.4	407.6	Top Soil	Up to 135 m Basalt, below 135m Gondwana
				II	64	34.7	36.1	372.9	M Basalt	
				III	271	98.8	134.9	274.1		
				IV	2.8				Clay (Gndwana)	
88	Metpanjra / NGP 334	421	600	I	107	0.9	0.9	420.1	Top Soil	Up to 72 m Basalt, below 72m Gondwana ?
				II	31	0.9	1.8	419.2	W Basalt	
				III	496	5.6	7.4	413.6	M Basalt	
				IV	20	7.6	15	406	Fr. basalt	
				V	322	56.6	71.6	349.4	M Basalt	
				VI	1.3				Clay	
89	Ramgiri / NGP 335	401	600	I	34	1.9	1.9	399.1	Top Soil	> 150m Basalt
				II	3224	2	3.9	397.1	M Basalt	
				III	89				M Basalt	
90	Malegaon / NGP 336	518	600	I	13	0.8	0.8	517.2	Top Soil	Up to 154m Basalt, Below 154m Gneiss ?
				II	119	4	4.8	513.2	M Basalt	
				III	775	5.3	10.1	507.9		
				IV	27	144	154.1	363.9	Fr. basalt	
				V	2411				Gneiss ?	
91	Wasbodi / NGP 337	472	600	I	88	1	1	471	Top Soil	Up to 300m Basalt
				II	779	0.7	1.7	470.3	M Basalt	
				III	48	1.7	3.4	468.6	V basalt	
				IV	930	5	8.4	463.6	M Basalt	
				V	6.4	4.6	13	459	Fr. basalt	
				VI	393	18.1	31.1	440.9	M Basalt	
				VII	21	62.2	93.3	378.7	Fr.Basalt	
				VIII	1424				M Basalt	
92	Dorli / NGP 338	399	600	I	92	2.9	2.9	396.1	Top Soil	Up to 130m Basalt, Below 130 m Gondwana (Curve break and Borehole information
				II	1412	6.1	9	390	M Basalt	
				III	33				Fr. basalt	
93	Kotwalbordi / NGP 339	402	600	I	39	2.9	2.9	399.1	Top Soil	Up to 24m Basalt, below 24 m Gondwana
				II	154	21.3	24.2	377.8	M Basalt	
				III	27	79.5	103.7	298.3	Sandstone	
				IV	8.6	82.9	186.6	215.4	Shale	
				V	366				Compact SSt	
94	Uibgi / NGP 340	374	600	I	38	3	3	371	Top Soil	Up to 200m Basalt, below 200m Sandstone
				II	2.6	1.6	4.6	369.4	Clay	
				III	110	3.3	7.9	366.1	M basalt	
				IV	4.4	6.3	14.2	359.8	Clay	
				V	33	209	223.2	150.8	Fr.Basalt	
				VI	269				Compact Sandstone	
95	Wadhona Bz / NGP 341	332	600	I	20	0.5	0.5	331.5	Top Soil	Up to 36 m Basalt, below 36m Gondwana
				II	166	0.9	1.4	330.6	M basalt	
				III	7.8	34.9	36.3	295.7	Fr. basalt	
				IV	279				Compact SST	
96	Pipla / NGP 342	340	600	I	11	1.2	1.2	338.8	Top Soil	Up to 57m Basalt, below 57m Gondwana
				II	47	2.2	3.4	336.6	V basalt	
				III	6	2.4	5.8	334.2	W basalt	
				IV	18	50.7	56.5	283.5	Fr. basalt	
				V	265				Compact SST	
97	Dhapewada / NGP 343	326	600	I	14	1.7	1.7	324.3	Top Soil	Up yo 72 m Gondwa Below 72m Gneiss ?
				II	31	5.1	6.8	319.2	Sandstone	
				III	7.3	65.6	72.4	253.6	Sandstone+Shale	
				IV	1940				Compact SSt/Gneiss	
98	Valni / NGP 344	339	600	I	57	0.7	0.7	338.3	Top Soil	Up yo 43 m Gondwa Below 43m Gneiss ?
				II	13	2.3	3	336	Sandstone+Shale	
				III	5.4	5.9	8.9	330.1	Clay	
				IV	152	7.7	16.6	322.4	Compact SSt	

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				V	16	25.9	42.5	296.5	Sandstone	
				VI	3097				Gneiss	
99	Yerla / NGP 345	350	600	**I**	7.7	0.8	0.8	349.2	Top Soil	Up to 50m Basalt, Below 71m Gneiss
				II	30	0.6	1.4	348.6	W Basalt	
				III	3.8	6.6	8	342	Clay	
				IV	47	41.7	49.7	300.3	V Basalt	
				V	2	21	70.7	279.3	Clay	
				VI	1339				Gneiss	
100	Selu / NGP 346	356	600	**I**	56	0.9	0.9	355.1	Top Soil	Up to 150 m Basalt, below 150m Gondwana (curve break, Inverse slope and borehole data)
				II	20	3	3.9	352.1	W basalt	
				III	6.6	4.2	8.1	347.9	Fr. Basalt	
				IV	604	26.7	34.8	321.2	M Basalt	
				V	11				Fr. basalt	
101	Khapri / NGP 347	359	600	**I**	11	0.9	0.9	358.1	Top Soil	Up to 110m Basalt, below 110m Gneiss
				II	26	16.87	17.77	341.23	W basalt	
				III	252	24	41.77	317.23	M Basalt	
				IV	17	68.3	110.07	248.93	Fr. basalt	
				V	3008				Gneiss	
102	Kalmeshwar / NGP 348	339	600	**I**	4.2	1.5	1.5	337.5	Top Soil	Up to 200m Hard rock (Basalt/Gneiss)
				II	12	13	14.5	324.5	W basalt	
				III	8583				M.Basalt	
103	Khairi/NGP 355	323	600	**I**	13	0.74	0.74	322.26	Top Soil	Approx. upto 200m Sandstone
				II	6	2.28	3.02	319.98	Clay	
				III	820	5.9	8.92	314.08	Compact/dry Sst	
				IV	12	21.1	30.02	292.98	Sandstone	
				V	2238	12.6	42.62	280.38	Compact/dry Sst	
				VI	228	34.1	76.72	246.28		
				VII	14				Sandstone	
104	Gowari/NGP 356	323	400	**I**	20	0.4	0.4	322.6	Top Soil	Approx. upto 130m Sandstone
				II	74	5.1	5.5	317.5	Sandstone	
				III	314	3	8.5	314.5	Compact/dry Sst	
				IV	69	99.1	107.6	215.4	Sandstone	
				V	9.6				Sandstone	
105	Bordo(Khapri)/ NGP 357	361	600	**I**	35	3.9	3.9	357.1	Top Soil	Approx. upto 200m Basalt
				II	51	4.2	8.1	352.9	V basalt	
				III	27	26.8	34.9	326.1	F.Basalt	
				IV	275	37.4	72.3	288.7	M Basalt	
				V	33				F.Basalt	
106	Ubigi/NGP 358	374	600	**I**	115	2.5	2.5	371.5	Top Soil	Upto 150 m Basalt
				II	35	3.5	6	368	W.Basalt	
				III	9.4	11	17	357		
				IV	72				M Basalt	
107	Ubigi/NGP 359	379	900	**I**	18	0.8	0.8	378.2	Top Soil	
				II	6.3	3.4	4.2	374.8	W.Basalt	
				III	107	2.8	7	372	M Basalt	
				IV	8.4	16.9	23.9	355.1	F.Basalt	
				V	142	75.2	99.1	279.9	M Basalt	
				VI	38				F.Basalt	
108	Kohli-Mohli/NGP 360	382	600	**I**	79	0.9	0.9	381.1	Top Soil	Approx. upto 130m Basalt
				II	30	8.2	9.1	372.9	W.Basalt	
				III	57	8.9	18	364	V.Basalt	
				IV	11	12.5	30.5	351.5	F.Basalt	
				V	311				M Basalt	
109	Kohli-Mohli/NGP 361	364	600	**I**	5	0.9	0.9	381.1	Top Soil	
				II	70	7.4	8.3	373.7	M Basalt	
				III	324	8.7	17	365		
				IV	27	18	35	347	F.Basalt	
				V	174	115	150	232	M Basalt	
				VI	7				F.Basalt	
110	Kohli-Mohli/NGP 362	367	600	**I**	67	1.3	1.3	365.7	Top Soil	
				II	212	4.1	5.4	361.6	M Basalt	
				III	92	16.1	21.5	345.5	M Basalt	
				IV	57	63	84.5	282.5	V.Basalt	

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				V	110				M.Basalt	
111	Sonogaon / NGP 363	358	600	**I**	69	0.9	0.9	357.1	Top Soil	Approx. upto 150m Basalt
				II	217	3.2	4.1	353.9	M.Basalt	
				III	13	4.2	8.3	349.7	W.Basalt	
				IV	261	39.4	47.7	310.3	M.Basalt	
				V	40				V.Basalt	
112	Sonogaon / NGP 364	358	600	**I**	81	1.9	1.9	356.1	Top Soil	
				II	270	2	3.9	354.1	M.Basalt	
				III	7.4	4.2	8.1	349.9	W.Basalt	
				IV	185	38.4	46.5	311.5	M.Basalt	
				V	20				F.Basalt	
113	Sonogaon / NGP 365	358	300	**I**	95	1.5	1.5	356.5	Top Soil	Approx. upto 150m Basalt
				II	468	1.8	3.3	354.7	M.Basalt	
				III	12	4.1	7.4	350.6	W.Basalt	
				IV	661	21.5	28.9	329.1	M.Basalt	
				V	3				F.Basalt	
114	Mohgaon / NGP 366	347	400	**I**	9.4	0.9	0.9	346.1	Top Soil	Approx. upto 200m Basalt
				II	5.2	3.4	4.3	342.7	W.Basalt	
				III	3.5	5.2	9.5	337.5		
				IV	34	11.3	20.8	326.2	F.Basalt	
				V	14	84.8	105.6	241.4		
				VI	688				Comp.Sst	
115	Mohgaon / NGP 367	347	400	**I**	10	1.1	1.1	345.9	Top Soil	
				II	4	1.9	3	344	W.Basalt	
				III	7.5	12	15	332		
				IV	34				Fr.Basalt	
116	Mohgaon / NGP 368	347	300	**I**	16	0.8	0.8	346.2	Top Soil	
				II	7	3.6	4.4	342.6	W.Basalt	
				III	10	12.2	16.6	330.4		
				IV	41	125	141.6	205.4	V.Basalt	
				V	472				Comp.Sst	
117	Dhapewade / NGP 369	324	300	**I**	20	0.9	0.9	323.1	Top Soil (Alluvium)	Approx. upto 200m Gondwana
				II	6.4	3	3.9	320.1	Sandy Clay(Alluvium)	
				III	19	4.3	8.2	315.8	Sand	
				IV	4.4	27.7	35.9	288.1	Clay	
				V	16				Sandstone	
118	Dhapewade / NGP 370	324	200	**I**	9	2	2	322	Top Soil	
				II	11	8.1	10.1	313.9	Sand	
				III	2	12.4	22.5	301.5	Clay	
				IV	18				Sandstone	
119	Dhapewade / NGP 371	324	300	**I**	14	3.4	3.4	320.6	Top Soil	
				II	34	7.9	11.3	312.7	Sand	
				III	2	14.7	26	298	Clay	
				IV	18				Sandstone	
120	Mohgaon / NGP 372	343	300	**I**	8	1.7	1.7	341.3	Top Soil	Approx. upto 200m Basalt
				II	17	27	28.7	314.3	W.Basalt	
				III	51				V.Basalt	
121	Mohgaon / NGP 373	343	200	**I**	19	0.8	0.8	342.2	Top Soil	
				II	4.3	0.8	1.6	341.4	W.Basalt	
				III	12	35.7	37.3	305.7	F.Basalt	
				IV	121				M.Basalt	
122	Mohgaon / NGP 374	343	300	**I**	89	0.8	0.8	342.2	Top Soil	
				II	37	2	2.8	340.2	W.Basalt	
				III	195	43.4	46.2	296.8	M.Basalt	
				IV	40	30	76.2	266.8	V.Basalt	
				V	3491				M.Basalt	
123	Mohgaon / NGP 375	343	200	**I**	119	2.2	2.2	340.8	Top Soil	
				II	21	1.5	3.7	339.3	W.Basalt	
				III	276	2.6	6.3	336.7	M.Basalt	
				IV	28.5				F.Basalt	
124	Uperwadi / NGP 376	353	300	**I**	78	0.4	0.4	352.6	Top Soil	Approx. upto 125m Basalt
				II	3	3.3	3.7	349.3	W.Basalt	
				III	73				M.Basalt	
12	Uperwadi /	35	300	**I**	33	1.9	1.9	351.1	Top Soil	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
5	NGP 377	3		**II**	8	2.1	4	349	W.Basalt	
				III	66				M.Basalt	
126	Uperwadi / NGP 378	353	300	**I**	37	0.8	0.8	352.2	Top Soil	Approx. upto 125m Basalt
				II	11	7.1	7.9	345.1	W.Basalt	
				III	67	121	128.9	224.1	M.Basalt	
				IV	7.5				F.Basalt	
127	Uperwadi / NGP 379	353	300	**I**	21	1.9	1.9	351.1	Top Soil	
				II	7	2.1	4	349	W.Basalt	
				III	29	13.5	17.5	335.5		
				IV	451	19	36.5	316.5	M.Basalt	
				V	3.2				F.Basalt	
128	Rawalgaon / NGP 380	395	200	**I**	29	1.5	1.5	393.5	Top Soil	Upto 45 m Basalt
				II	50	6.5	8	387	V.Basalt	
				III	2.2	18.5	26.5	368.5	F.Basalt	
				IV	640				M.Basalt	
129	Rawalgaon / NGP 381	394	160	**I**	30	1.9	1.9	392.1	Top Soil	
				II	54	6.9	8.8	385.2	V.Basalt	
				III	1.3	10	18.8	375.2	clay	
				IV	468				M.Basalt	
130	Rawalgaon / NGP 382	394	200	**I**	35	2.5	2.5	391.5	Top Soil	
				II	44	6.4	8.9	385.1	V.Basalt	
				III	1.4	11.8	20.7	373.3	clay	
				IV	682				M.Basalt	
131	Rawalgaon / NGP 383	395	180	**I**	47	0.9	0.9	394.1	Top Soil	
				II	17	3.5	4.4	390.6	W.Basalt	
				III	32	16.3	20.7	374.3	F.Basalt	
				IV	3.9	24.4	45.1	349.9	Clay	
				V	848				Comp.Sst	
132	Rawalgaon / NGP 384	395	400	**I**	47	1.9	1.9	393.1	Top Soil	
				II	846	2.6	4.5	390.5	M.Basalt	
				III	40	40	44.5	350.5	V.Basalt	
				IV	20				Sandstone	
133	Rawalgaon / NGP 385	394	400	**I**	63	1.1	1.1	392.9	Top Soil	
				II	494	3.3	4.4	389.6	M.Basalt	
				III	124	29.2	33.6	360.4		
				IV	28				Sandstone	
134	Rawalgaon / NGP 386	394	400	**I**	46	0.8	0.8	393.2	Top Soil	
				II	1071	1.6	2.4	391.6	M.Basalt	
				III	92	41.4	43.8	350.2		
				IV	23				Sandstone	
135	Rawalgaon / NGP 387	394	400	**I**	97	0.8	0.8	393.2	Top Soil	
				II	61	0.8	1.6	392.4	V.Basalt	
				III	1046	2.4	4	390	M.Basalt	
				IV	13	4.9	8.9	385.1	F.Basalt	
				V	138	13.7	22.6	371.4	M.Basalt	
				VI	47	15.2	37.8	356.2	V.Basalt	
				VII	13				Sandstone+Shale	
136	Rawalgaon / NGP 388	394	400	**I**	61	0.8	0.8	393.2	Top Soil	
				II	156	6.4	7.2	386.8	M.Basalt	
				III	64	41.8	49	345		
				IV	9.2				Sandstone+Shale	
137	Ubgi / NGP 389	376	400	**I**	12	0.6	0.6	375.4	Top Soil	Upto 150 m Basalt
				II	119	1	1.6	374.4	M.Basalt	
				III	1.4	3.1	4.7	371.3	Clay	
				IV	65.2				M.Basalt	
138	Ubgi / NGP 390	376	400	**I**	42	2.4	2.4	373.6	Top Soil	
				II	11	21.8	24.2	351.8	W.Basalt	
				III	434	10.9	35.1	340.9	M.Basalt	
				IV	10	22.5	57.6	318.4	F.Basalt	
				V	565				M.Basalt	
139	Ubgi / NGP 391	376	400	**I**	141	0.9	0.9	375.1	Top Soil	Upto 150 m Basalt
				II	38	2.5	3.4	372.6	W.Basalt	
				III	8.3	12	15.4	360.6		
				IV	71				M.Basalt	
140	Ubgi / NGP 392	376	600	**I**	10	1.5	1.5	374.5	Top Soil	
				II	45	2.1	3.6	372.4	V.Basalt	

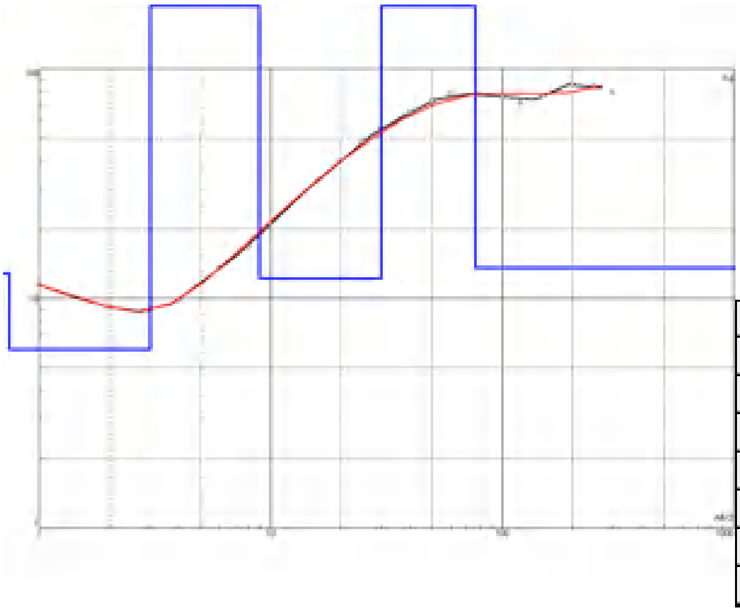
Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
				III	3	4.4	8	368	W.Basalt	
				IV	80				M.Basalt	
142	Pari Deshmukh / NGP 393	379	400	**I**	63	0.9	0.9	378.1	Top Soil	Approx.200m basalt
				II	85	7.3	8.2	370.8	M.Basalt	
				III	41	28.2	36.4	342.6	V.Basalt	
				IV	93				M.Basalt	
143	Pari Deshmukh / NGP 394	379	240	**I**	65	0.9	0.9	378.1	Top Soil	
				II	105	10.4	11.3	367.7	M.Basalt	
				III	22	14.7	26	353	F.Basalt	
				IV	87				M.Basalt	
144	Pari Deshmukh / NGP 395	378	200	**I**	82	2.1	2.1	375.9	Top Soil	
				II	319	2.7	4.8	373.2	M.Basalt	
				III	29	23.2	28	350	F.Basalt	
				IV	76				M.Basalt	
145	Pari Deshmukh / NGP 396	377	200	**I**	48	0.8	0.8	376.2	Top Soil	
				II	121	7.6	8.4	368.6	M.Basalt	
				III	11	8.7	17.1	359.9	F.Basalt	
				IV	124				M.Basalt	
146	Pari Deshmukh / NGP 397	377	160	**I**	42	1.9	1.9	375.1	Top Soil	
				II	392	2.2	4.1	372.9	M.Basalt	
				III	4.4	4.7	8.8	368.2	W.Basalt	
				IV	113				M.Basalt	
147	Ramgiri / NGP 398	419	400	**I**	35	0.8	0.8	418.2	Top Soil	Approx. 200m basalt
				II	216	7	7.8	411.2	M.Basalt	
				III	1972	5.3	13.1	405.9		
				IV	111					
148	Ramgiri / NGP 399	419	400	**I**	29	1	1	418	Top Soil	
				II	610	8.5	9.5	409.5	M.Basalt	
				III	134	76.8	86.3	332.7		
				IV	37				F.Basalt	
149	Ramgiri / NGP 400	419	300	**I**	32	1.4	1.4	417.6	Top Soil	
				II	3605	2.2	3.6	415.4	M.Basalt	
				III	71					
150	Ramgiri / NGP 401	419	300	**I**	45	0.9	0.9	418.1	Top Soil	
				II	178	3	3.9	415.1	M.Basalt	
				III	764	14.3	18.2	400.8		
				IV	10	18.7	36.9	382.1	F.Basalt	
				V	3927				M.Basalt	
151	Ramgiri / NGP 402	419	300	**I**	47	0.9	0.9	418.1	Top Soil	
				II	54	1	1.9	417.1	V.Basalt	
				III	78	2.1	4	415	M.Basalt	
				IV	237	4.3	8.3	410.7		
				V	926	9	17.3	401.7		
				VI	25	59.8	77.1	341.9	F.Basalt	
				VII	2321				M.Basalt	
152	Sonkhamb / NGP 403	400	400	**I**	84	2.1	2.1	397.9	Top Soil	appox.200m basalt
				II	1834	2.7	4.8	395.2	M.Basalt	
				III	92	22.3	27.1	372.9		
				IV	192					
153	Sonkhamb / NGP 404	401	400	**I**	49	1.2	1.2	399.8	Top Soil	appox.200m basalt
				II	2075	1.1	2.3	398.7	M.Basalt	
				III	36	3.3	5.6	395.4	W.Basalt	
				IV	1243	4.7	10.3	390.7	M.Basalt	
				V	93				M.Basalt	
154	Sonkhamb / NGP 405	401	400	**I**	20	1.3	1.3	399.7	Top Soil	
				II	1330	3.5	4.8	396.2	M.Basalt	
				III	13	5.7	10.5	390.5	W.Basalt	
				IV	114				M.Basalt	
155	Sonkhamb / NGP 406	411	600	**I**	52	2.5	2.5	408.5	Top Soil	
				II	155	9.8	12.3	398.7	M.Basalt	
				III	15	39.2	51.5	359.5	F.Basalt	
				IV	109				M.Basalt	
156	Sonkhamb / NGP 407	409	600	**I**	51	1.9	1.9	407.1	Top Soil	
				II	132	11.5	13.4	395.6	M.Basalt	
				III	5.8	15.2	28.6	380.4	W.Basalt	
				IV	83				M.Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
157	Sonkhamb / NGP 408	409	600	**I**	81	0.7	0.7	408.3	Top Soil	
				II	18	0.8	1.5	407.5	W.Basalt	
				III	725	2.1	3.6	405.4	M.Basalt	
				IV	5.3	15.3	18.9	390.1	F.Basalt	
				V	84				M.Basalt	
158	Ghoard / NGP 409	335	160	**I**	70	0.9	0.9	334.1	Top Soil	appox.200m basalt
				II	24	1	1.9	333.1	W.Basalt	
				III	13	2.2	4.1	330.9	M.Basalt	
				IV	6.4	4.7	8.8	326.2	W.Basalt	
				V	46	31.3	40.1	294.9	V.Basalt	
				VI	216				M.Basalt	
159	Kotwalbardi / N 1	399		**I**	18	1.5	1.5	397.5	Top Soil	Up to 58 m Basalt, below 58m Gondwana
				II	119	22.9	24.4	374.6	M.Basalt	
				III	58	33.1	57.5	341.5	V.Basalt	
				IV	19				Sandstone	
160	Kotwalbardi / N 2	401		**I**	20	1.6	1.6	399.4	Top Soil	Up to 70 m Basalt, below 70m Lameta bed
				II	66	34.8	36.4	364.6	V.Basalt	
				III	257	23.7	60.1	340.9	M.Basalt	
				IV	105	9.5	69.6	331.4	M.Basalt	
				V	10				Lameta bed	
161	Kotwalbardi / N 3	397		**I**	37	1.6	1.6	395.4	Top Soil	Up to 40 m Basalt, below 70m Lameta bed
				II	8	4.4	6	391	W.Basalt	
				III	138	34.6	40.6	356.4	M.Basalt	
				IV	10	5	45.6	351.4	Lameta bed	
				V	31				Sandstone	
162	Kotwalbardi / N 4	395		**I**	113	0.4	0.4	394.6	Top Soil	Up to 62.5 m basalt, below that Gondwana
				II	328	4.4	4.8	390.2	M.Basalt	
				III	59	57.7	62.5	332.5	V.Basalt	
				IV	31				Sandstone	
163	Raulgaon / N 5	388		**I**	30	8	8	380	Top Soil	Upto 45 m Basalt
				II	15	3.1	11.1	376.9	W.Basalt	
				III	42	22.4	33.5	354.5	V.Basalt	
				IV	13	5.7	39.2	348.8	F.Basalt	
				V	46				V.Basalt/Sandstone	
164	Raulgaon / N 6	391		**I**	11	0.6	0.6	390.4	Top Soil	
				II	271	1.8	2.4	388.6	M.Basalt	
				III	65	50.6	53	338	V.Basalt	
				IV	15.6				Sandstone	
165	Raulgaon / N 7	397		**I**	33	1	1	396	Top Soil	Upto 45 m Basalt
				II	330	7.4	8.4	388.6	M.Basalt	
				III	633	12.4	20.8	376.2		
				IV	182	13.6	34.4	362.6		
				V	116	20.4	54.8	342.2		
				VI	75					
166	Raukgaon / N 8	403		**I**	66	1.5	1.5	401.5	Top Soil	
				II	235	31.2	32.7	370.3	M.Basalt	
				III	103	12.6	45.3	357.7		
				IV	68	44	89.3	313.7	V.Basalt	
				V	54					
167	Raukgaon / N 9	384		**I**	19	1.3	1.3	382.7	Top Soil	
				II	54	3.5	4.8	379.2	W.Basalt	
				III	192	10.7	15.5	368.5	M.Basalt	
				IV	75	3.7	19.2	364.8		
				V	117	5.2	24.4	359.6		
				VI	30				F.Basalt	
168	Raukgaon / N 10	383		**I**	34	0.6	0.6	382.4	Top Soil	
				II	121	6.4	7	376	M.Basalt	
				III	78	2	9	374		
				IV	191	23.7	32.7	350.3		
				V	18	4.4	37.1	345.9	F.Basalt	
				VI	200	8.6	45.7	337.3	M.Basalt	
				VII	23				Sandstone	
169	Raukgaon / N 11	382		**I**	26.8	1.1	1.1	380.9	Top Soil	
				II	52	3	4.1	377.9	V.Basalt	
				III	122	7.2	11.3	370.7	M.Basalt	

Sl. No	Village / VES No.	RL	Max. Current Electrode separation (m)	Layer No.	Resistivity (Ohm m)	Thickness (m)	Depth (m)	Elevation to the bottom of the Layer	Anticipated Lithology	Consolidated thickness of the Litho-unit
				IV	94	45.7	57	325		
				V	37				Sandstone	
170	Pohi / N 12	391		**I**	30	2.2	2.2	388.8	Top Soil	Upto 45 m Basalt
				II	90	11.8	14	377	M.Basalt	
				III	44	34.5	48.5	342.5	V.Basalt	
				IV	16				Sandstone	

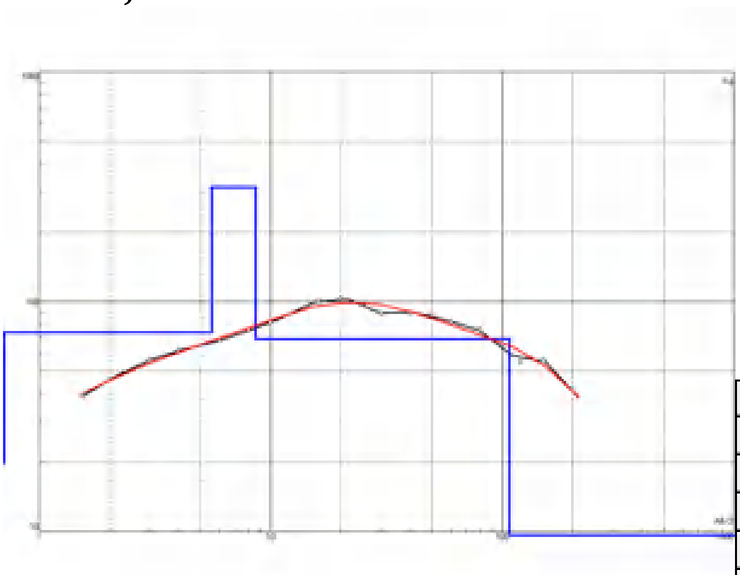
ANNEXURE-II: VES Curvrs, obtained after Geophysiacl Survey by CGWB, Chandrabhaga Watershed (WGKKC-2), Nagpur District

NG 355, Khairi – In the Play Ground



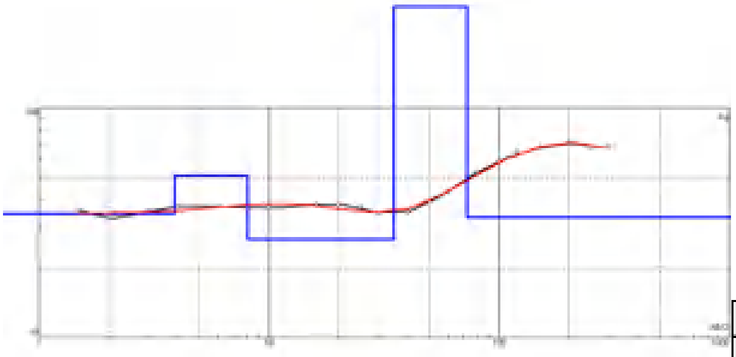
N	ρ	h	d
1	12.9	0.74	0.74
2	5.99	2.28	3.02
3	820	5.87	8.89
4	12.2	21.1	30
5	2238	12.6	42.6
6	228	34.1	76.7
7	13.6		

NG 356, Gowari – Backside of the School



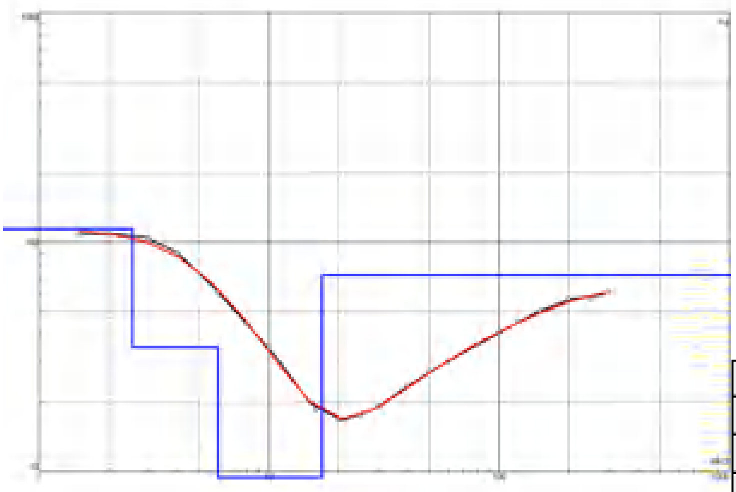
N	ρ	h	d
1	19.7	0.44	0.44
2	73.5	5.1	5.54
3	314	3.05	8.59
4	69.1	99.1	108
5	9.64		

NG 357,Khapri (Bordo) Near Jal Swaraj Project well



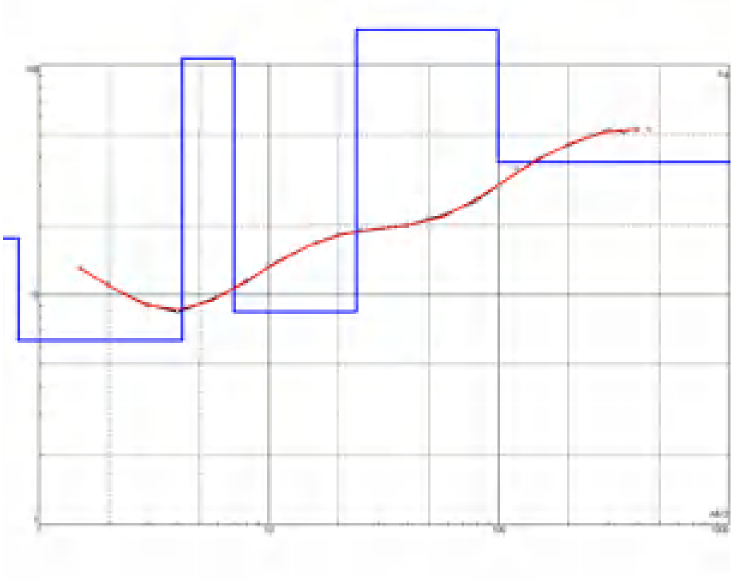
N	ρ	h	d
1	34.6	3.88	3.88
2	50.7	4.18	8.06
3	26.7	26.8	34.9
4	275	37.4	72.3
5	33.4		

NG 358 Ubgi (Near Pajhar Talav)



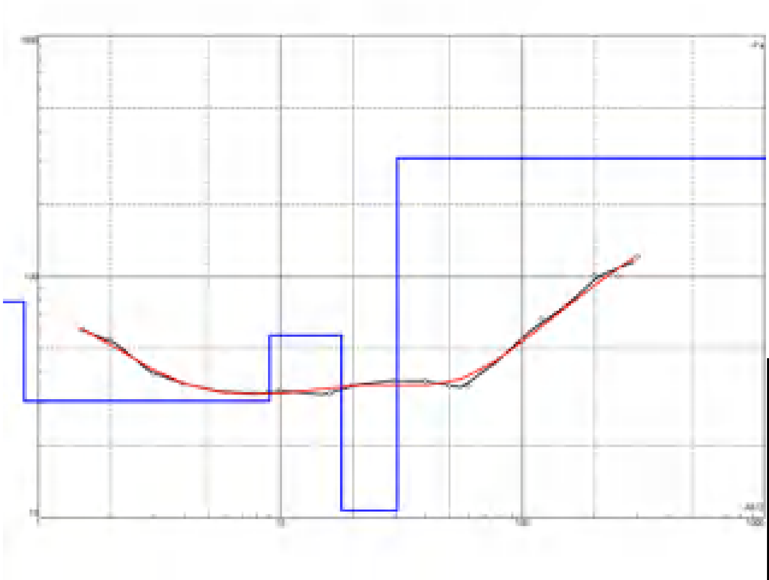
N	ρ	h	d
1	115	2.54	2.54
2	34.9	3.46	6
3	9.43	11	17
4	72.1		

NG 359, Ubgi (In front of Primary School)



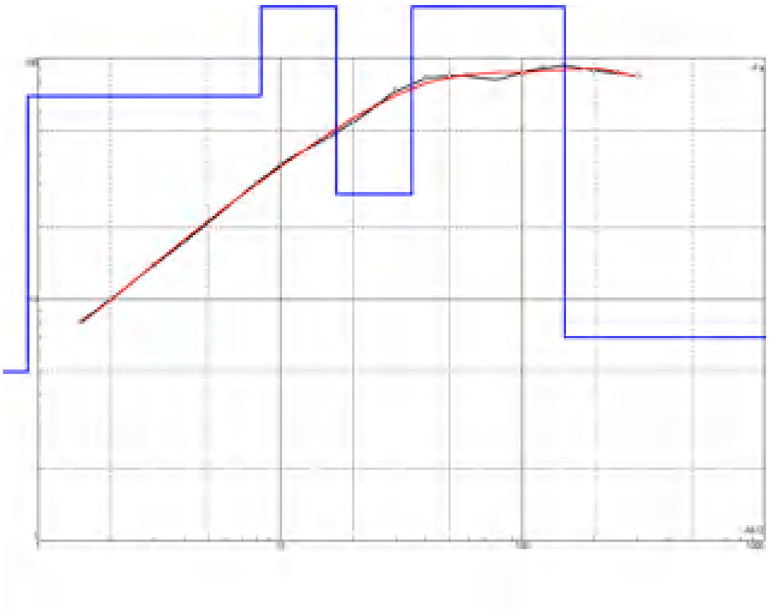
N	ρ	h	d
1	17.66	0.8112	0.8112
2	6.334	3.379	4.19
3	106.7	2.847	7.037
4	8.396	16.89	23.93
5	142	75.22	99.15
6	37.77		

NG 360, Kohli-Mohli (Near Burrial Ground Shed)



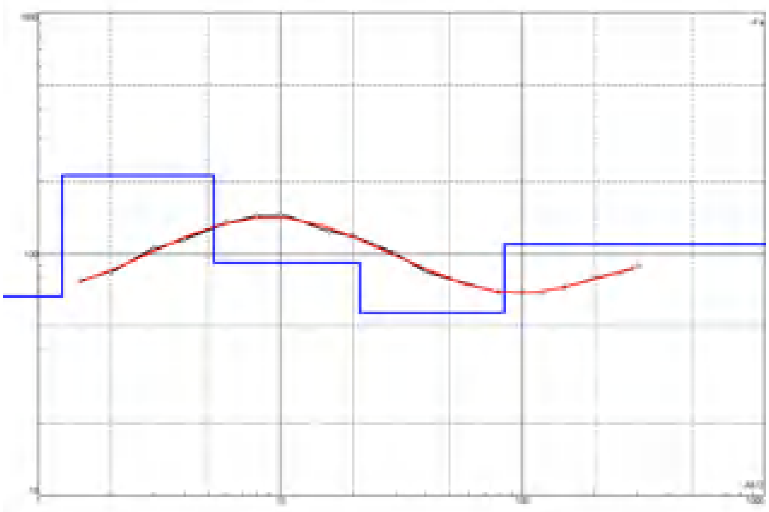
N	ρ	h	d
1	78.8	0.873	0.873
2	30.4	8.18	9.05
3	57.2	8.88	17.9
4	10.7	12.5	30.4
5	311		

NG 361, Kohli-Mohli (Near Dug Well)



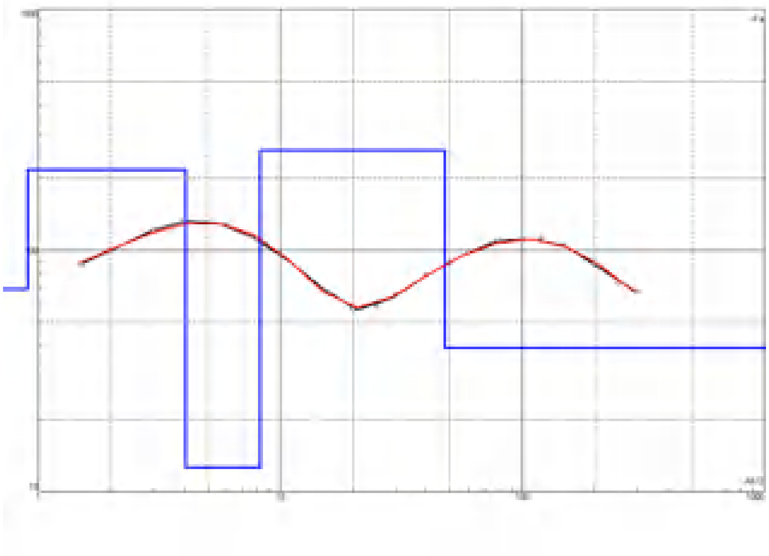
N	ρ	h	d
1	5.02	0.9	0.9
2	69.8	7.42	8.32
3	324	8.68	17
4	27.3	18	35
5	174	115	150

NG 362Kohli-Mohli (Railway colony backside)



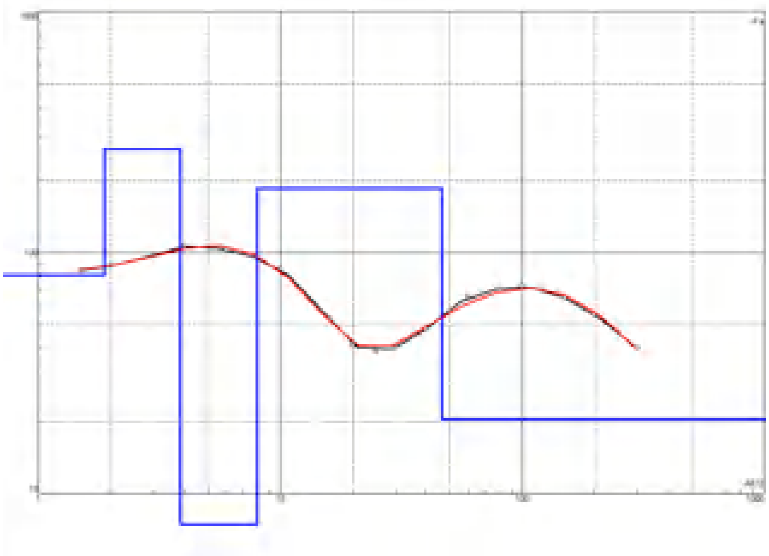
N	ρ	h	d
1	66.91	1.25	1.25
2	212.4	4.055	5.305
3	92.4	16.07	21.38
4	57.27	63.02	84.4
5	110.1		

NG 363, Sonegaon (Near Burrial Ground)



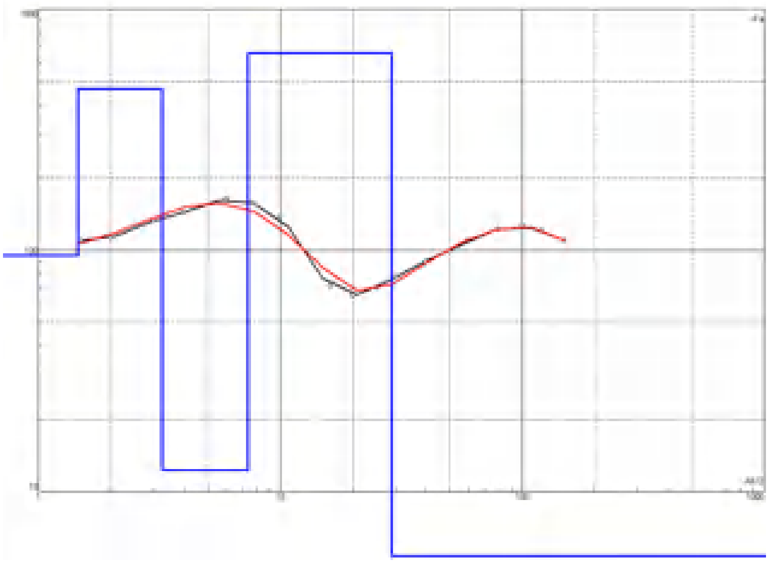
N	ρ	h	d
1	68.97	0.9	0.9
2	216.8	3.156	4.056
3	12.64	4.18	8.236
4	260.7	39.44	47.68
5	39.45		

NG 364, Sonegaon (Near Burrial Ground)



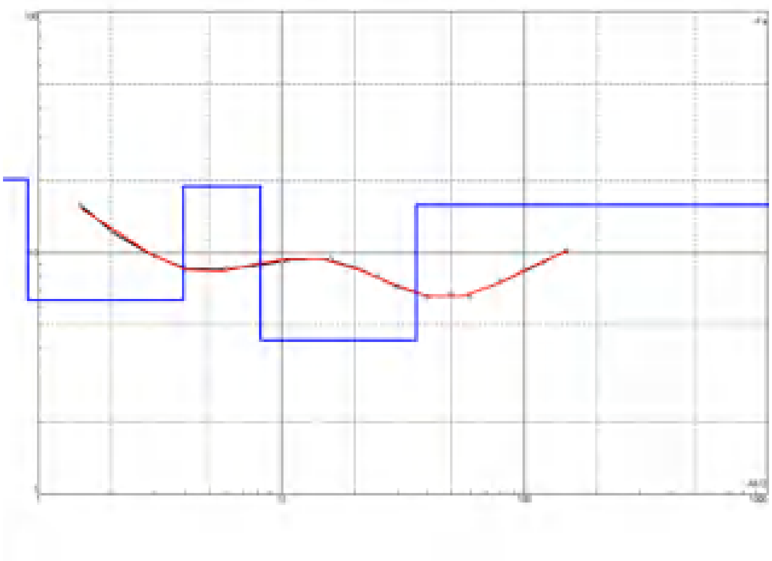
N	ρ	h	d
1	80.8	1.87	1.87
2	270	2.01	3.88
3	7.44	4.18	8.06
4	185	38.4	46.5
5	20.3		

NG365, Sonegaon (Near Burrial Ground)



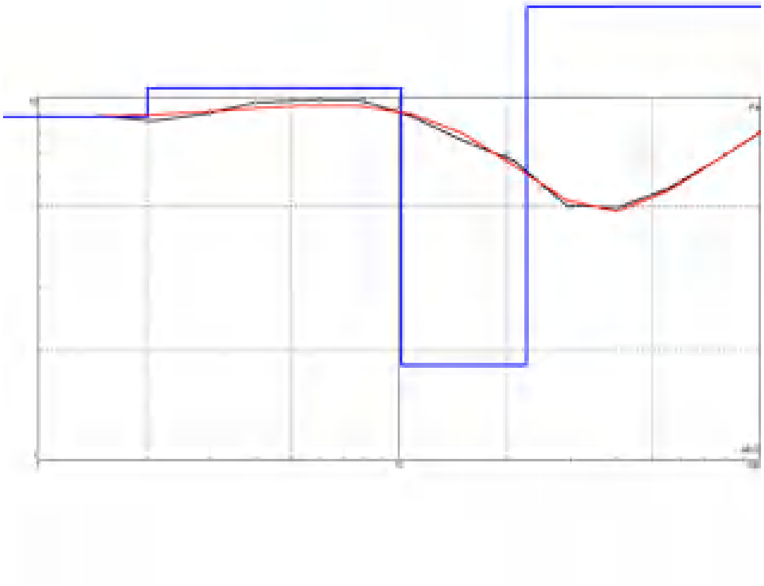
N	ρ	h	d
1	95.4	1.46	1.46
2	468	1.77	3.23
3	12.3	4.14	7.37
4	661	21.5	28.9
5	3.01		

NG 369, Dhapewada, by the side of Chandrabhaga River



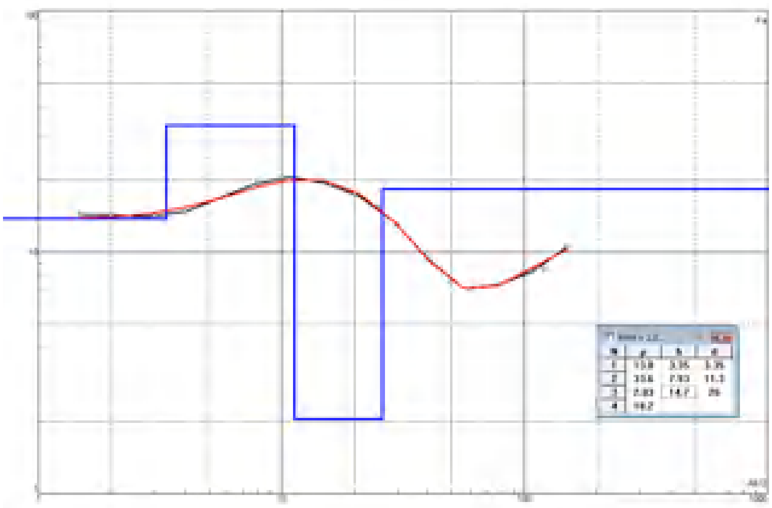
N	ρ	h	d
1	20.25	0.9	0.9
2	6.358	3.042	3.942
3	18.92	4.285	8.227
4	4.352	27.69	35.92
5	15.81		

NG 370, Dhapewada, by the side of Chandrabhaga River, near Shamshan Bhumi, Near Kolba Swami Vidyalay



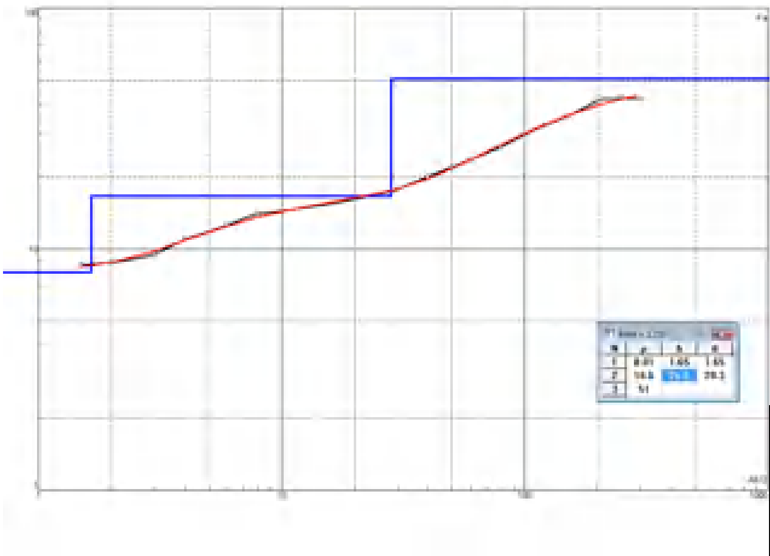
N	ρ	h	d
1	8.83	2.01	2.01
2	10.6	8.13	10.1
3	1.82	12.4	22.5
4	17.8		

NG 371, Dhapewada, Shamshan Ghat, Near Kande Farm, Backside of ITGA



N	ρ	h	d
1	13.8	3.35	3.35
2	33.6	7.93	11.3
3	2.03	14.7	26
4	18.2		

NG 372, Mohgaon, Site I, Gaonthan Area, Near Santra Garden, 1km E of Mohgaon

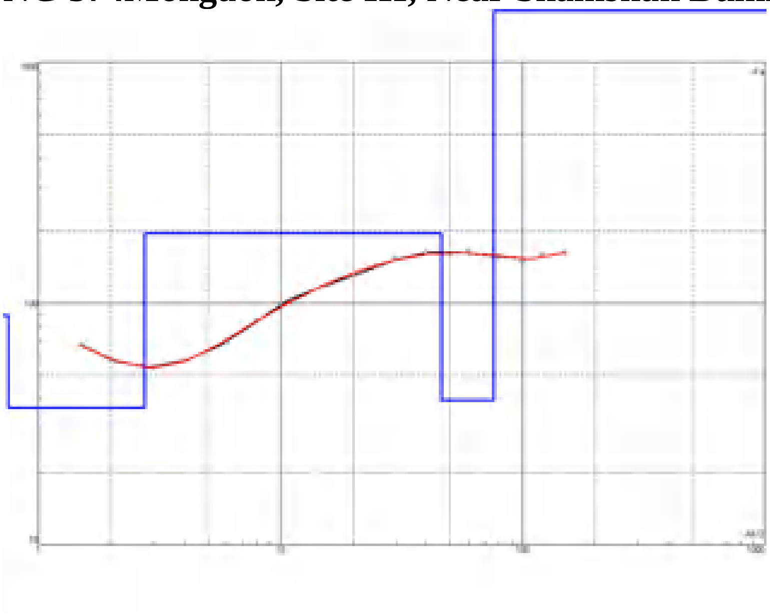


N	ρ	h	d
1	8.01	1.65	1.65
2	16.6	26.6	28.3
3	51		

NG 373, Mohgaon, Site II, Gaonthan Area,

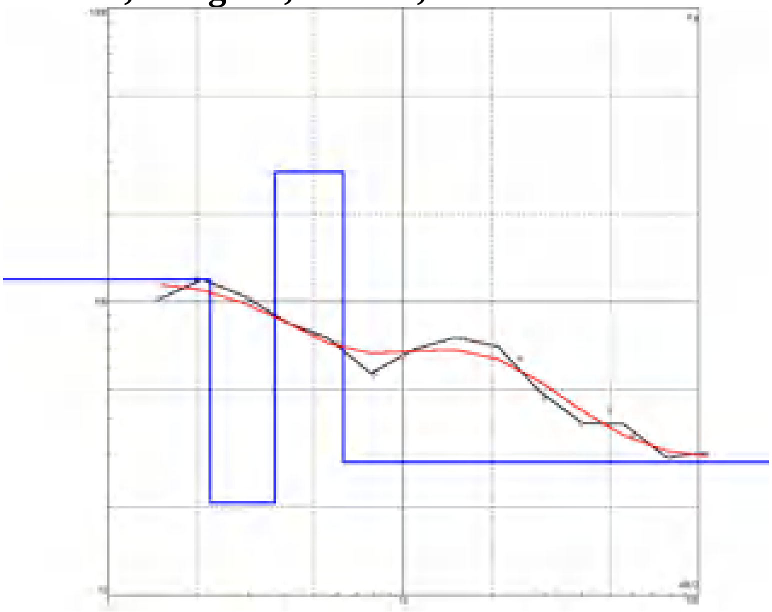
N	ρ	h	d
1	19.01	0.75	0.75
2	4.304	0.8321	1.582
3	11.56	35.69	37.27
4	120.5		

NG 374Mohgaon, Site III, Near Shamshan Bumi



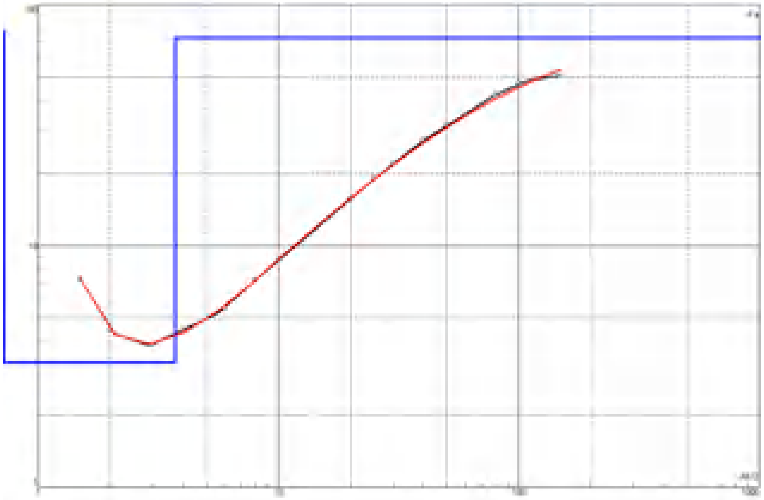
N	ρ	h	d
1	88.91	0.75	0.75
2	36.99	1.994	2.744
3	195.1	43.37	46.11
4	39.82	29.89	76
5	3491		

NG 375,Mohgaon, Site III, Near Shamshan Bumi, Inside River Bed



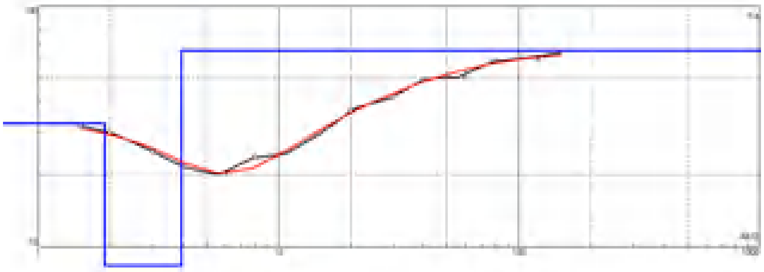
N	ρ	h	d
1	119	2.22	2.22
2	20.6	1.47	3.69
3	276	2.59	6.28
4	28.5		

NG376, UPERWAHI, Near Shamshan Ghat



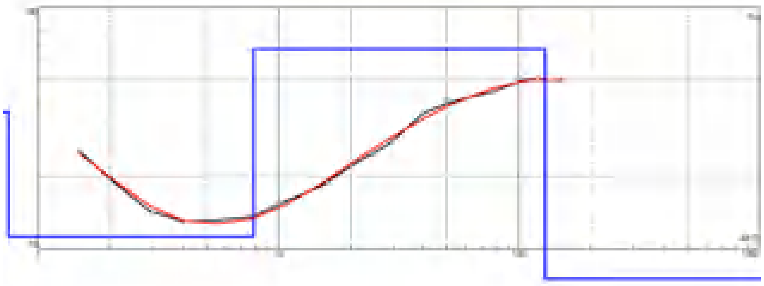
N	ρ	h	d
1	78.3	0.361	0.361
2	3.28	3.34	3.7
3	73.2		

NG 377, UPERWAHI, By the side of Ropewatika



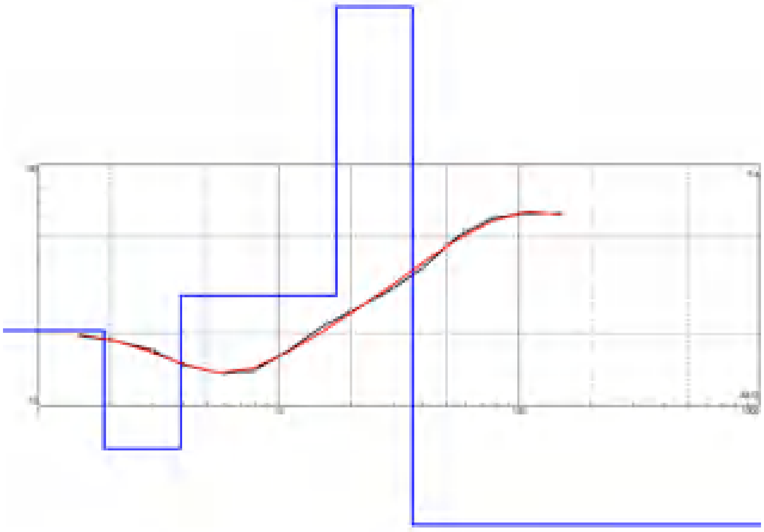
N	ρ	h	d
1	32.6	1.89	1.89
2	8.38	2.05	3.94
3	65.5		

Fig-24, NG 378, UPERWAHI, 20m from VES 377, by the side of Rope watika



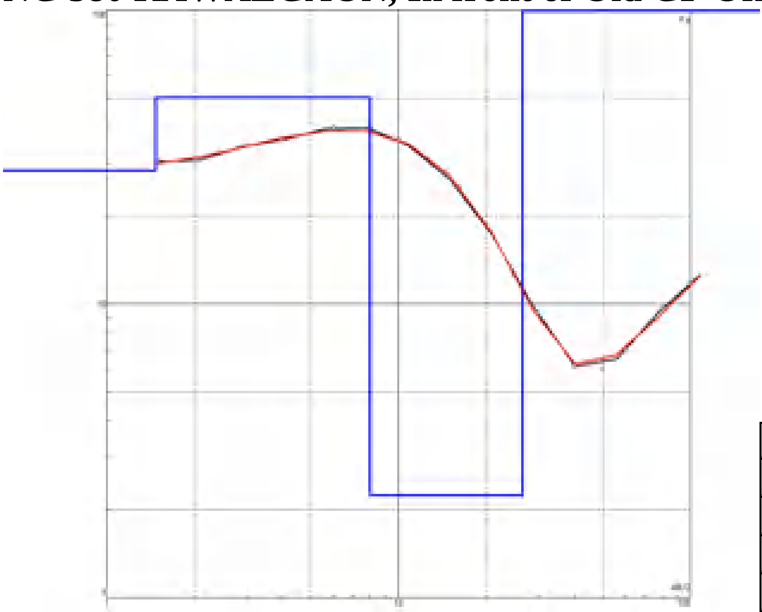
N	ρ	h	d
1	36.9	0.75	0.75
2	11.2	7.13	7.88
3	67.2	121	129
4	7.53		

NG 379, UPERWAHI, 20m from VES 377, inside Rope watika



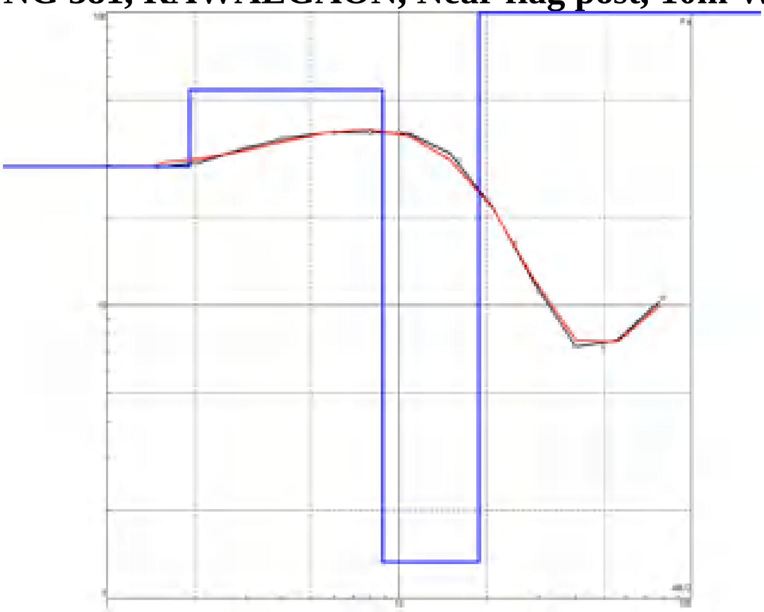
N	ρ	h	d
1	20.5	1.88	1.88
2	6.63	2.05	3.93
3	28.7	13.5	17.4
4	451	18.7	36.1
5	3.21		

NG 380 RAWALGAON, In front of Old GP Office



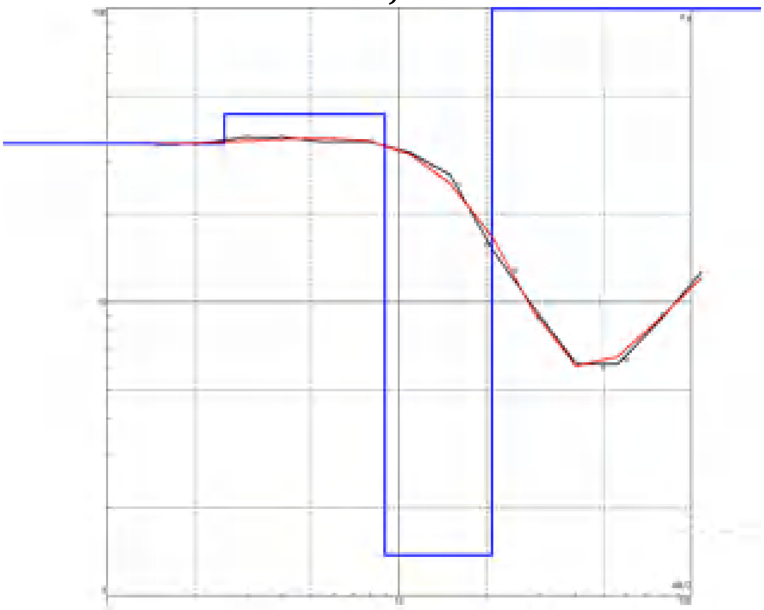
N	ρ	h	d
1	28.5	1.47	1.47
2	50.4	6.53	8
3	2.23	18.5	26.5
4	640		

NG 381, RAWALGAON, Near flag post, 10m W of VES 380



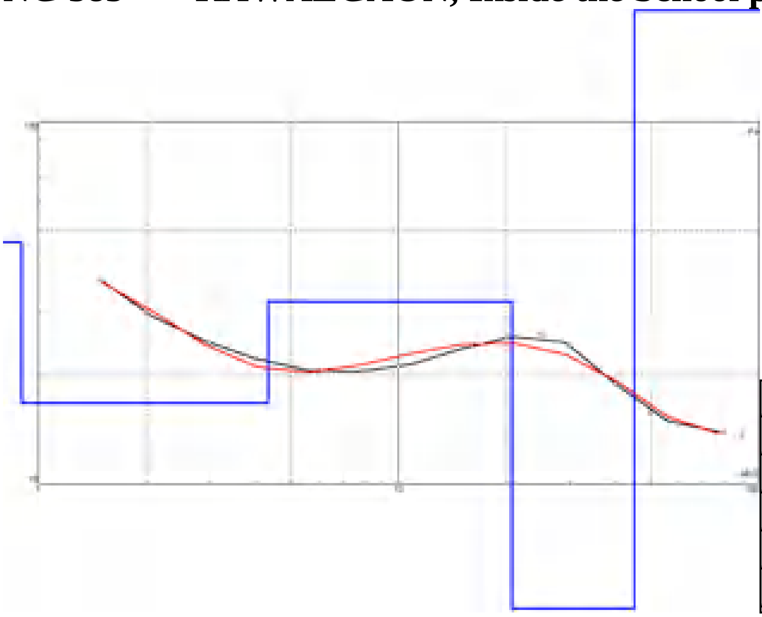
N	ρ	h	d
1	29.7	1.92	1.92
2	54.3	6.88	8.8
3	1.33	9.96	18.8
4	468		

NG 382 RAWALGAON, 10m E of VES 380



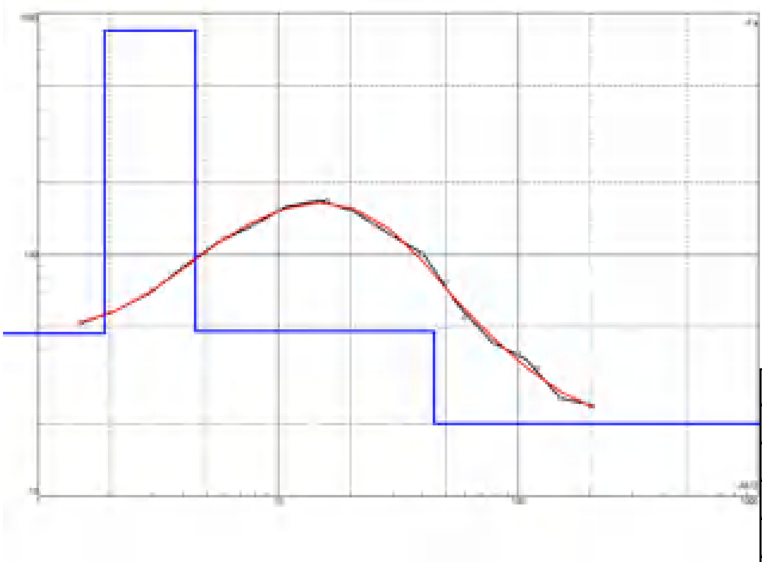
N	ρ	h	d
1	34.5	2.53	2.53
2	43.5	6.39	8.92
3	1.38	11.8	20.7
4	682		

NG 383 RAWALGAON, Inside the School premises



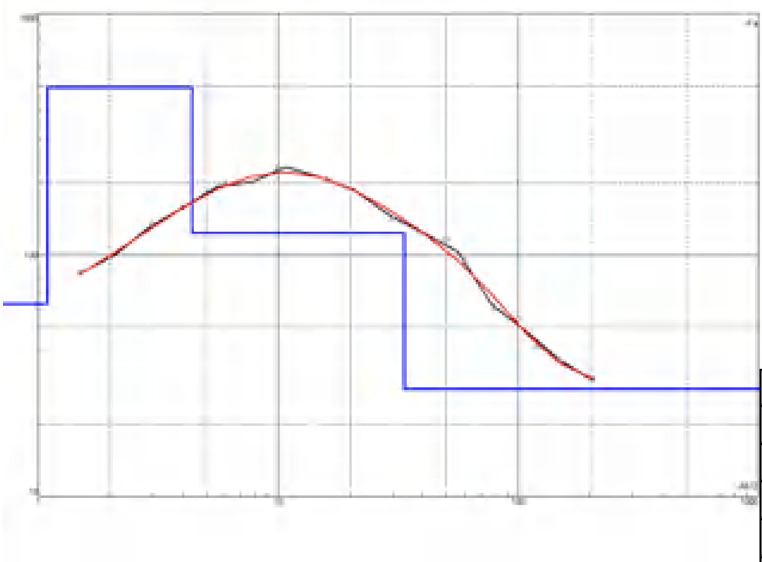
N	ρ	h	d
1	46.5	0.9	0.9
2	16.7	3.45	4.35
3	31.9	16.3	20.6
4	3.92	24.4	45
5	848		

NG 384 RAWALGAON, Jhopadpatti Area , In front of Godam Gate, 10m S60°W of Electric pole



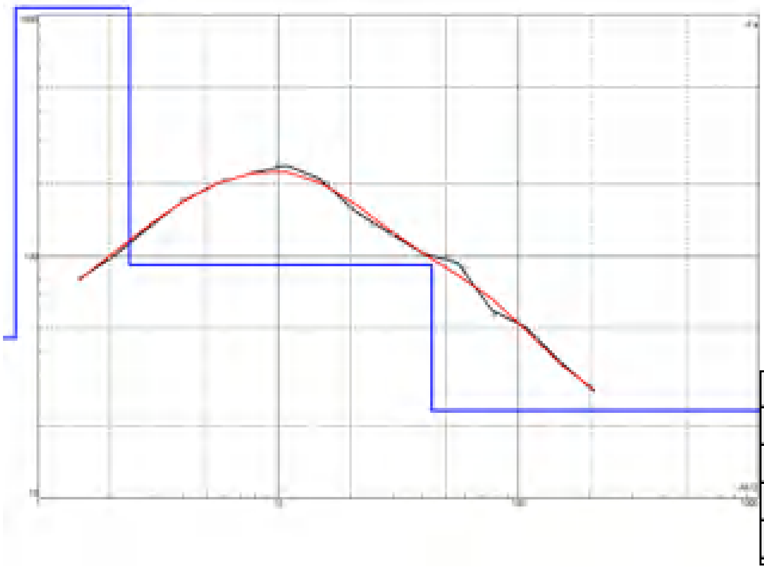
N	ρ	h	d
1	47.3	1.89	1.89
2	846	2.63	4.52
3	48.2	40	44.5
4	19.9		

NG 385 RAWALGAON, Jhopadpatti Area , 10m S of VES 384



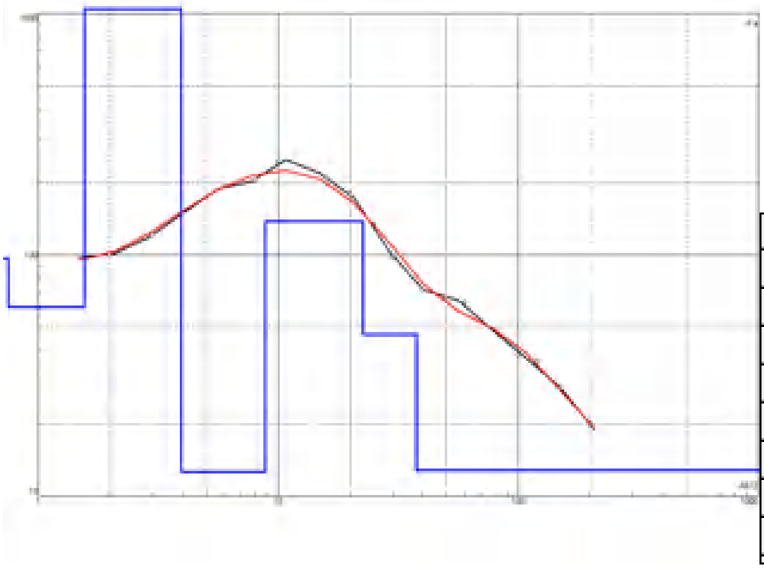
N	ρ	h	d
1	62.7	1.09	1.09
2	494	3.28	4.37
3	124	29.2	33.6
4	27.9		

NG 386 RAWALGAON, Jhopadpatti Area , 20m S of VES 384



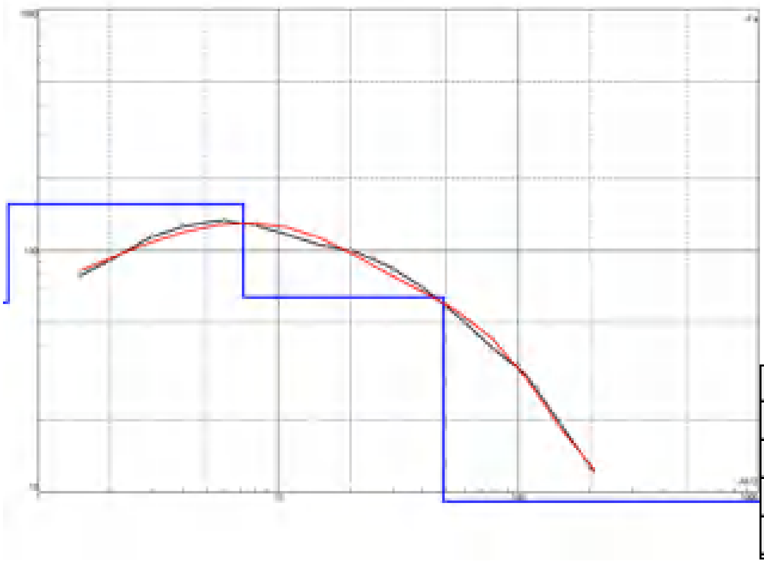
N	ρ	h	d
1	45.9	0.805	0.805
2	1071	1.59	2.39
3	92.4	41.4	43.8
4	23		

NG 387 RAWALGAON, Jhopadpatti Area , 35m S of VES 384



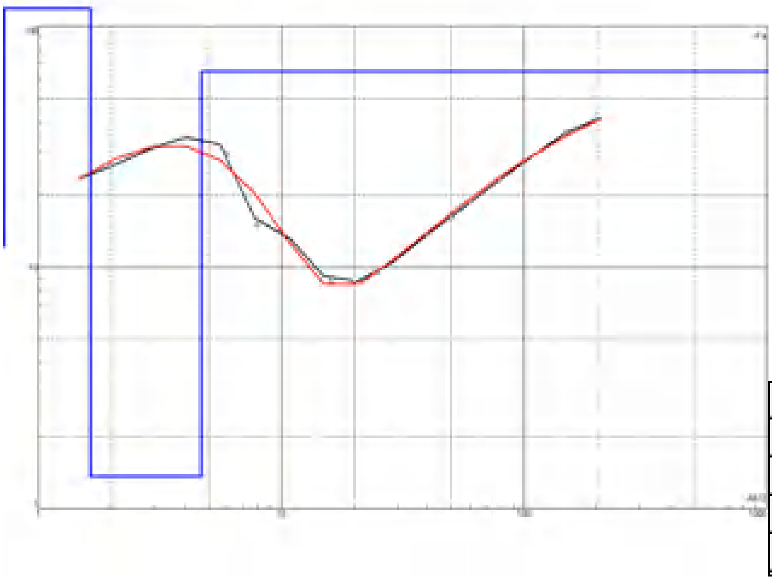
N	ρ	h	d
1	96.5	0.75	0.75
2	60.6	0.806	1.56
3	1046	2.39	3.95
4	12.6	4.87	8.82
5	138	13.7	22.5
6	46.8	15.2	37.7
7	12.8		

NG 388 RAWALGAON, Jhopadpatti Area , 50m S of VES 384



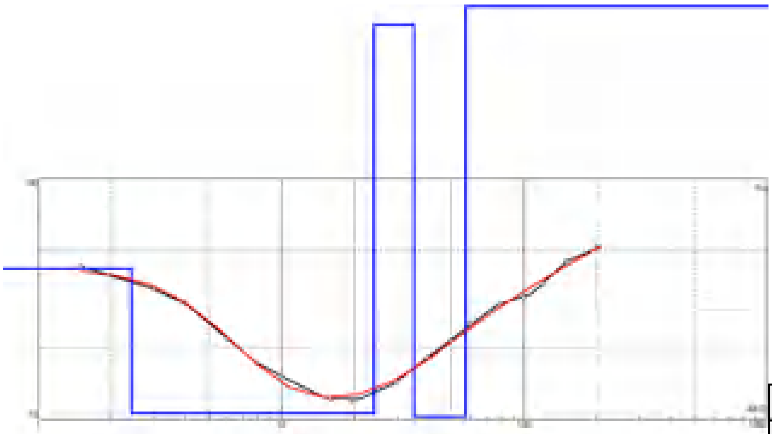
N	ρ	h	d
1	61.1	0.75	0.75
2	156	6.39	7.14
3	64	41.8	48.9
4	9.15		

NG 389 UBGI, W of Pajhar Tlav (Percolation Tank), Ubgi-Sonegaon Border



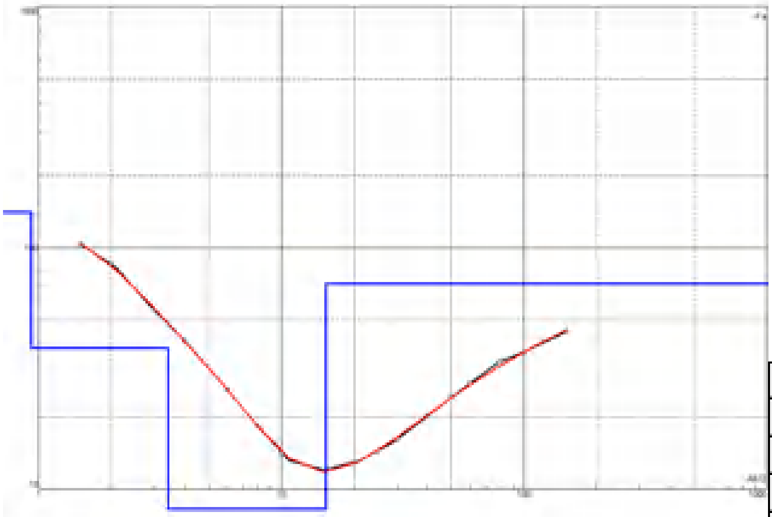
N	ρ	h	d
1	12.2	0.595	0.595
2	119	1.04	1.63
3	1.36	3.06	4.69
4	65.2		

NG 390 UBGI, W of Pajhar Tlav (Percolation Tank), 20m N75°E of VES 389



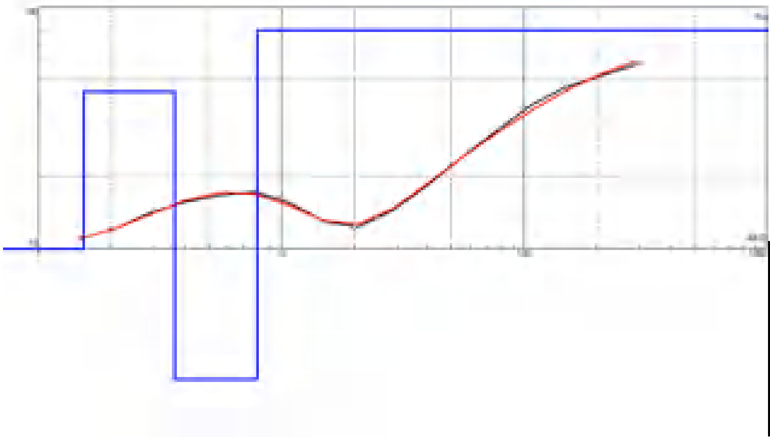
N	ρ	h	d
1	42.4	2.41	2.41
2	10.6	21.8	24.2
3	434	10.9	35.1
4	10.3	22.5	57.6
5	565		

NG 391 UBGI, W of Pajhar Tlav (Percolation Tank), 40m N75°E of VES 389



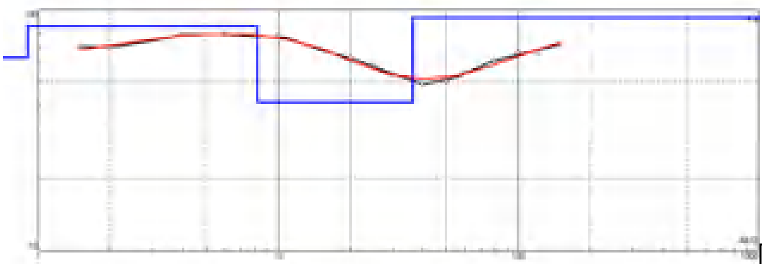
N	ρ	h	d
1	140.8	0.932	0.932
2	38.32	2.483	3.415
3	8.271	11.89	15.31
4	70.9		

NG 392 UBGI, W of Pajhar Tlav (Percolation Tank), 60m N75°E of VES 389



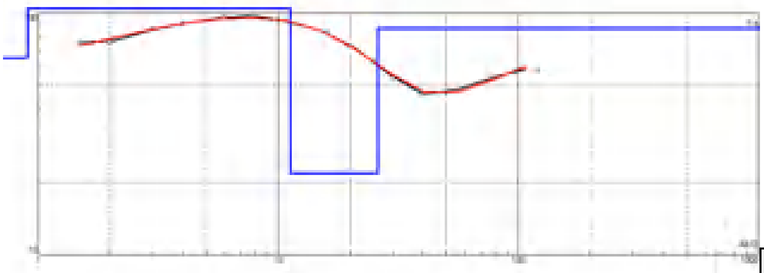
N	ρ	h	d
1	9.95	1.54	1.54
2	44.8	2.09	3.63
3	2.86	4.37	8
4	80.2		

NG 393 PARDI DESHMUKH , Near Water Tank



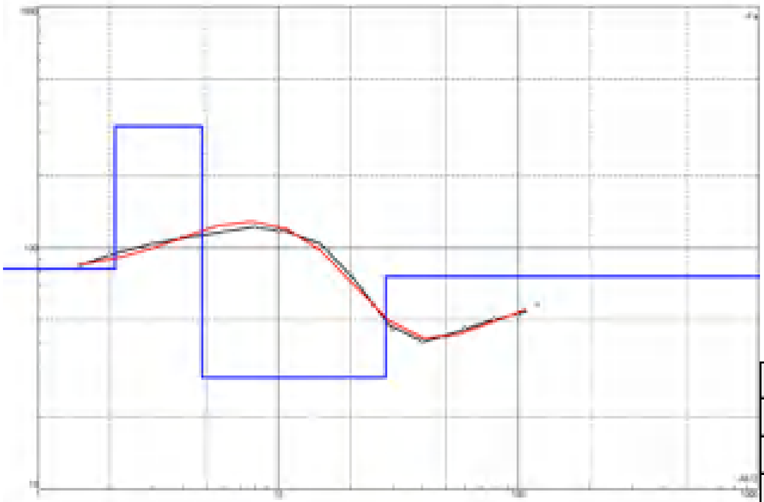
N	ρ	h	d
1	63.4	0.9	0.9
2	85.2	7.32	8.22
3	41.3	28.2	36.4
4	93		

NG 394 PARDI DESHMUKH , Near Water Tank, 6m from VES 393



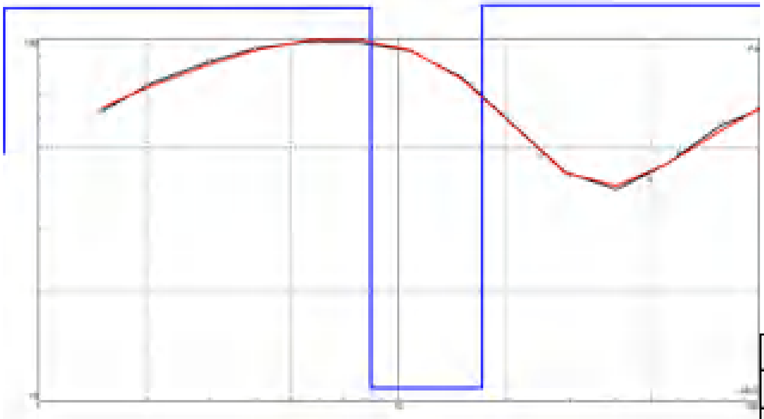
N	ρ	h	d
1	65.34	0.9	0.9
2	104.8	10.36	11.26
3	21.78	14.72	25.98
4	86.59		

NG 395 PARDI DESHMUKH , Near Water Tank, 14m from VES 393, 20m from VES 394



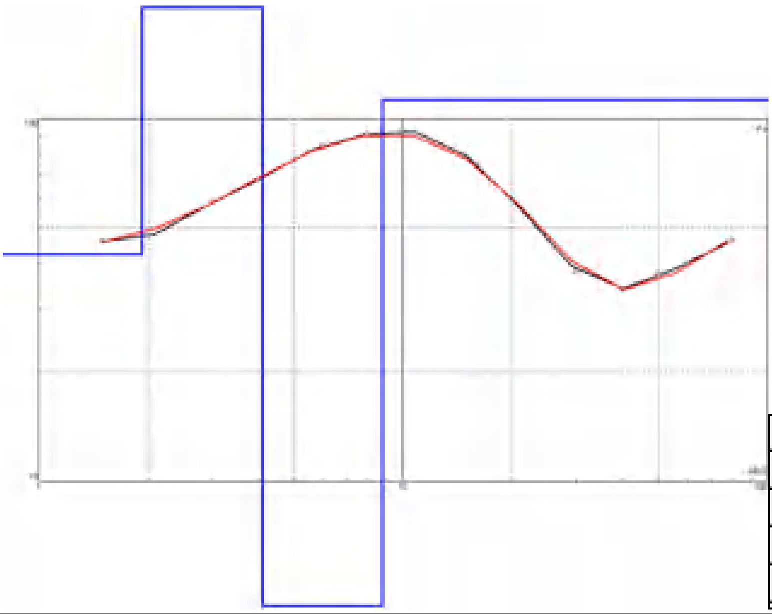
N	ρ	h	d
1	81.9	2.09	2.09
2	319	2.74	4.83
3	29.1	23.2	28
4	75.9		

NG 396 PARDI DESHMUKH , Near Water Tank, 100m E of Road



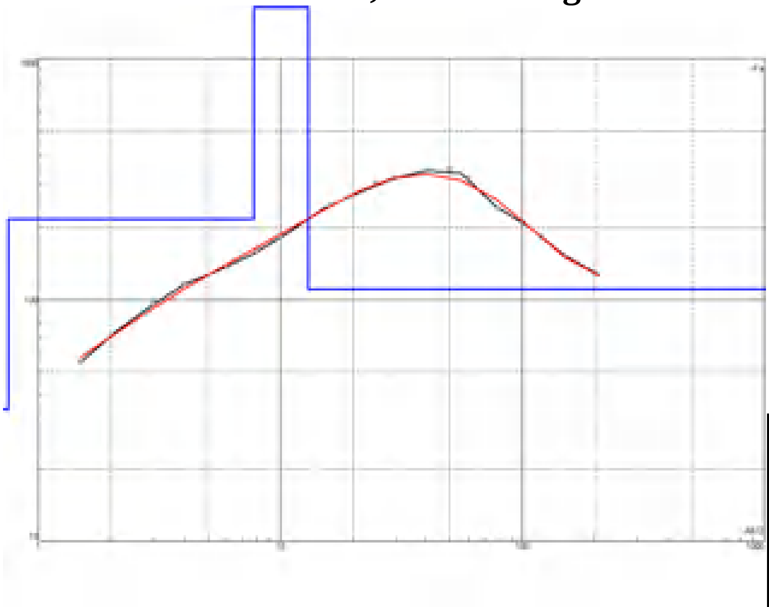
N	ρ	h	d
1	48.21	0.75	0.75
2	121.4	7.619	8.369
3	10.84	8.695	17.06
4	124		

NG 397 PARDI DESHMUKH , Near Water Tank, 20m W of VES 396



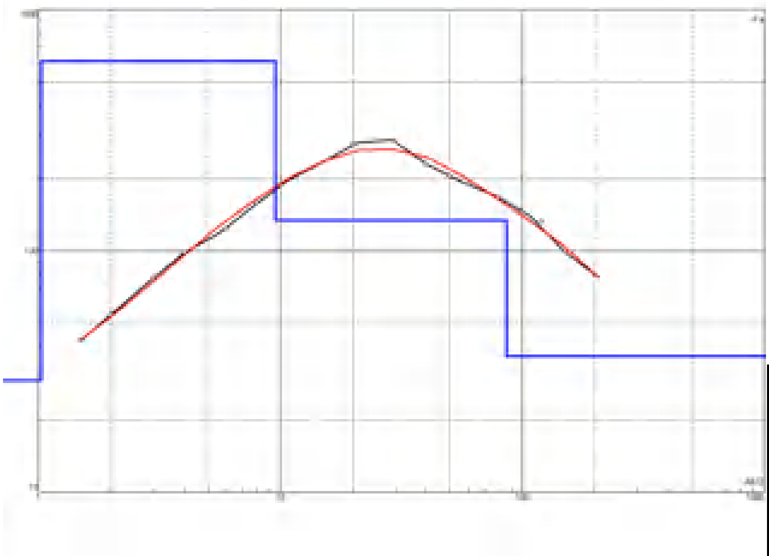
N	ρ	h	d
1	42.29	1.926	1.926
2	392.3	2.183	4.109
3	4.43	4.663	8.772
4	113.1		

NG 398 RAMGIRI, Near Storage Tank



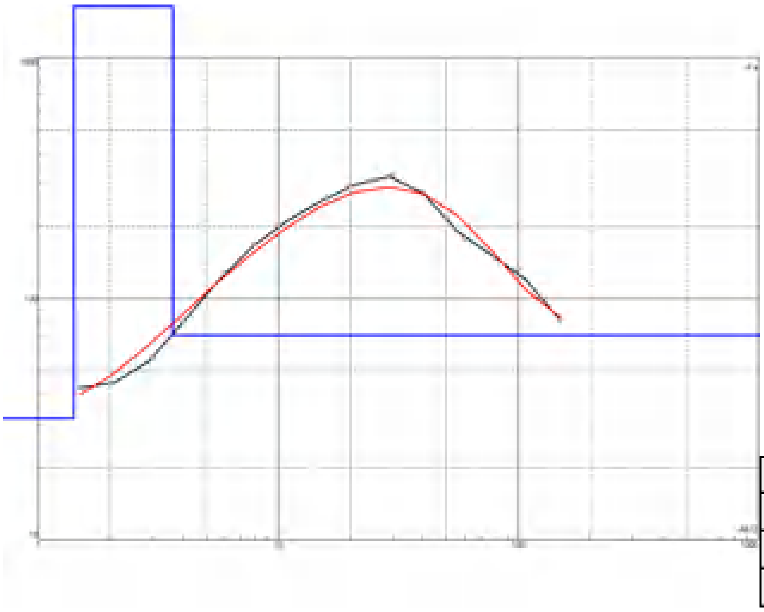
N	ρ	h	d
1	35.2	0.75	0.75
2	216	7.03	7.78
3	1972	5.29	13.1
4	111		

NG 399 RAMGIRI, Near Storage Tank, 20m S50°W of VES 398



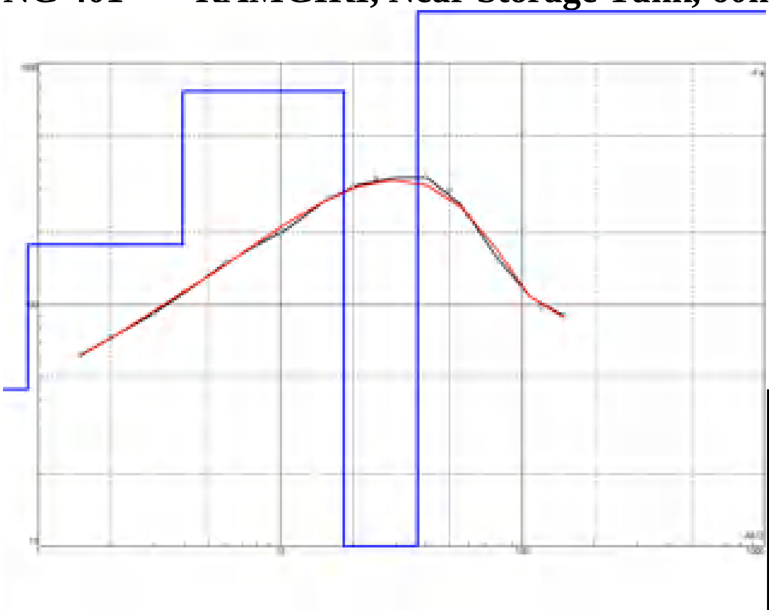
N	ρ	h	d
1	29.1	1.03	1.03
2	610	8.48	9.51
3	134	76.8	86.3
4	36.7		

NG 400 RAMGIRI, Near Storage Tank, 40m S50°W of VES 398



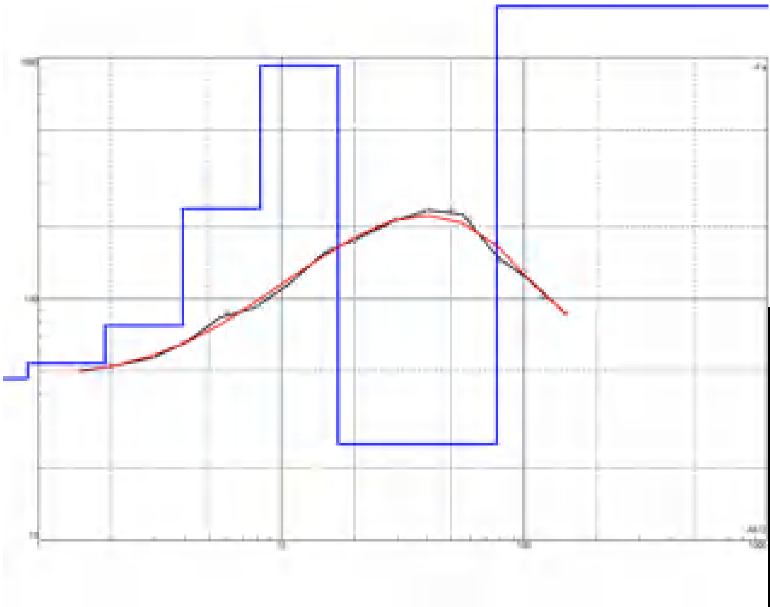
N	ρ	h	d
1	32	1.41	1.41
2	3605	2.22	3.63
3	70.7		

NG 401 RAMGIRI, Near Storage Tank, 60m S50°W of VES 398



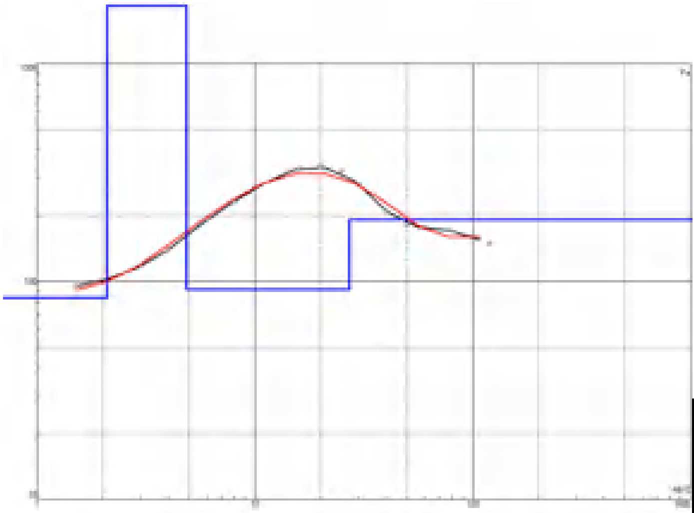
N	ρ	h	d
1	44.6	0.9	0.9
2	178	3.04	3.94
3	764	14.3	18.2
4	9.98	18.7	36.9
5	3927		

NG 402 RAMGIRI, Near Water Supply Well, By the Side of the Road



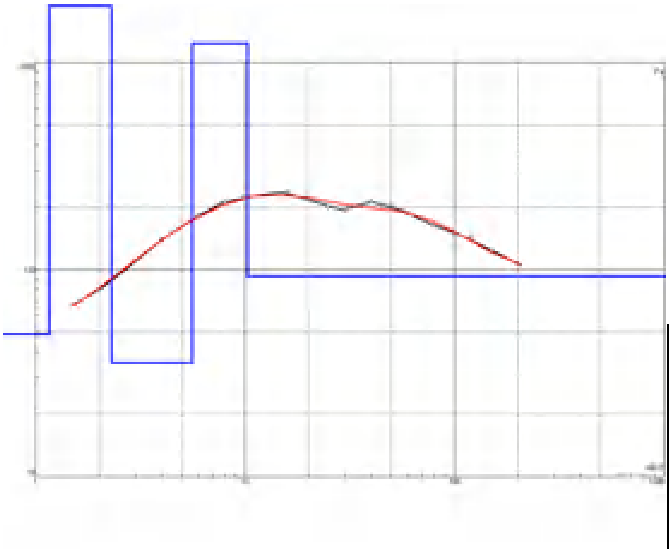
N	ρ	h	d
1	47	0.9	0.9
2	53.9	0.981	1.88
3	77.9	2.05	3.93
4	237	4.28	8.21
5	926	8.95	17.2
6	25	59.8	77
7	2321		

NG NG 403 Sonkhumb, Jhopadpatti area and 15 m west electrical pole in front of the house of Shri. Ramesh shivnate



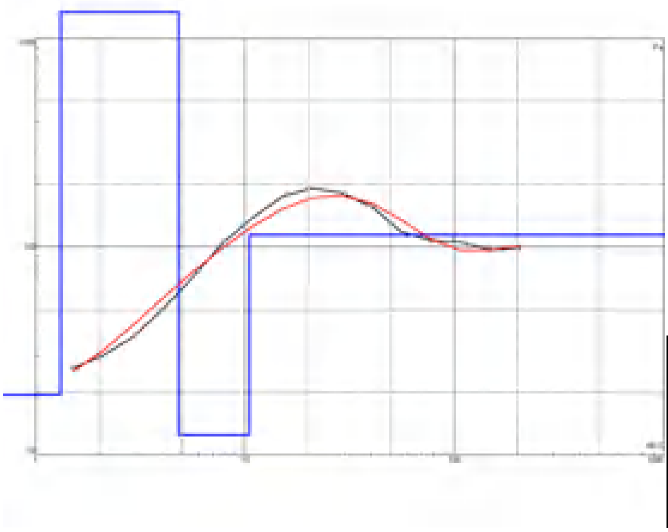
N	ρ	h	d	Alt
1	84.2	2.1	2.1	-2.1
2	1834	2.74	4.84	-4.84
3	91.6	22.3	27.1	-27.14
4	192			

NG 404 Sonkhumb, Jhopadpatti area and 50 m East of VES 403



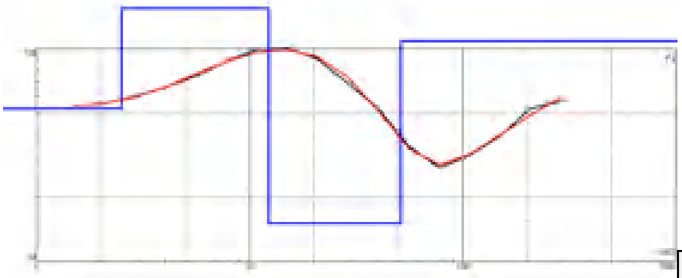
N	ρ	h	d	Alt
1	48.8	1.16	1.16	-1.16
2	2075	1.13	2.29	-2.29
3	35.6	3.29	5.58	-5.58
4	1243	4.74	10.3	-10.32
5	92.9			

NG 405 Sonkhumb, Jhopadpatti area and 30 m East of VES 404



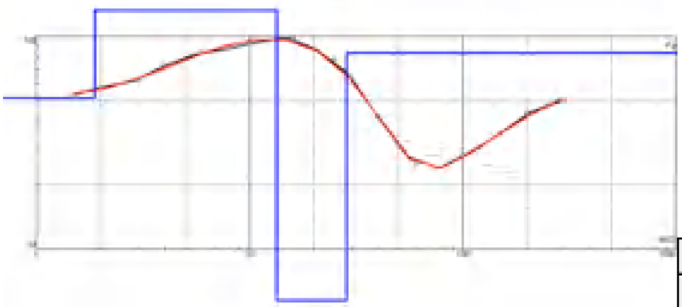
N	ρ	h	d	Alt
1	19.5	1.31	1.31	-1.31
2	1330	3.5	4.81	-4.81
3	12.5	5.71	10.5	-10.52
4	114			

NG 406 Sonkhumb, 21.8m North 20°West of Railway Building near Railway Gate



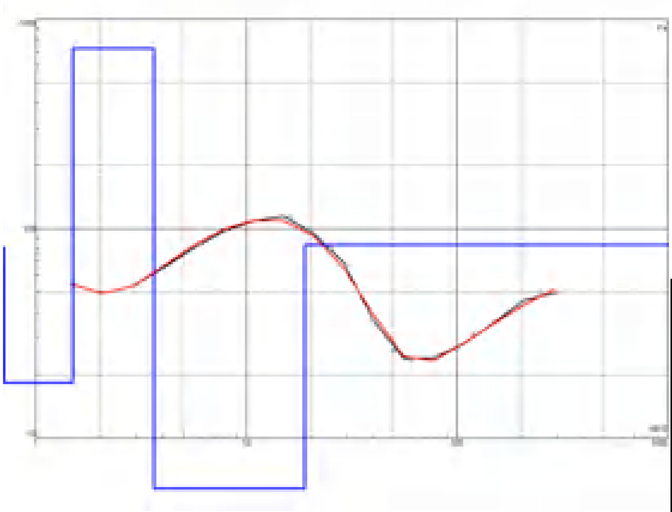
N	ρ	h	d	Alt
1	52.3	2.5	2.5	-2.5
2	155	9.79	12.3	-12.29
3	15.2	39.2	51.5	-51.49
4	109			

NG 407 Sonkhumb, Near Railway Gate and 16 m North 50°East of VES 406



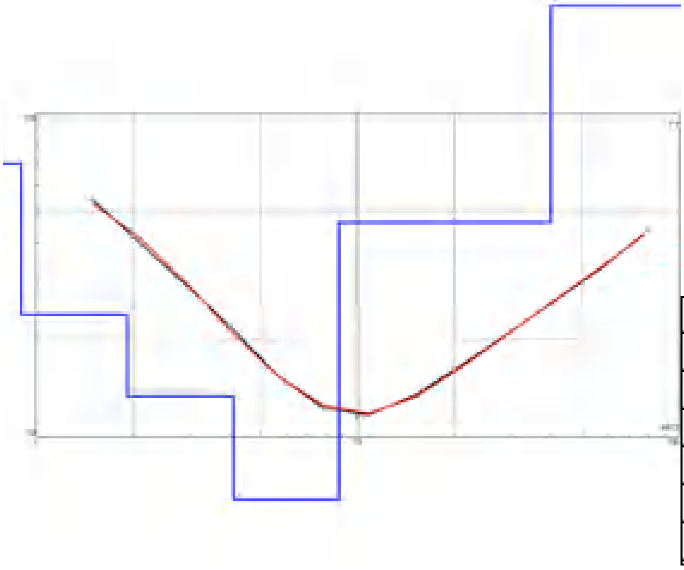
N	ρ	h	d	Alt
1	51.4	1.88	1.88	-1.88
2	132	11.5	13.4	-13.38
3	5.76	15.2	28.6	-28.58
4	83.3			

NG 408 Sonkhumb, Near Railway Gate and 16 m North 50° East of VES 407



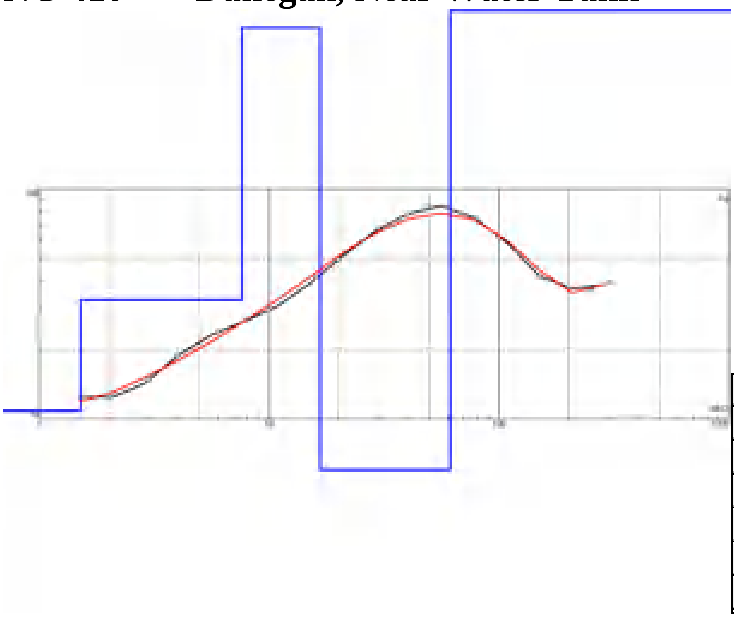
N	ρ	h	d	Alt
1	81.2	0.692	0.692	-0.692
2	18.4	0.799	1.49	-1.491
3	725	2.14	3.63	-3.631
4	5.75	15.3	18.9	-18.93
5	83.7			

NG 409 Ghorad, 14.5 m from Parallel bars and back side of the school and 9.20m from Valley ball court rod



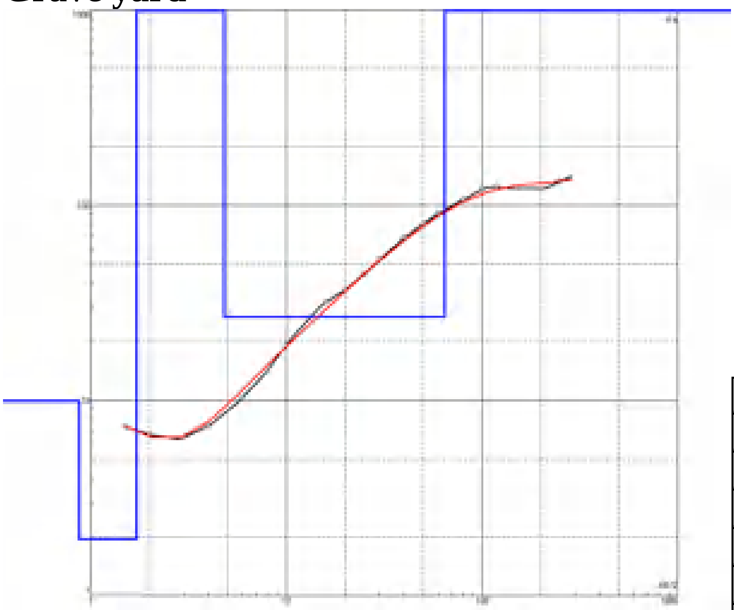
N	ρ	h	d	Alt
1	70.24	0.9	0.9	-0.9
2	23.98	1.022	1.922	-1.922
3	13.37	2.183	4.105	-4.105
4	6.423	4.663	8.768	-8.768
5	46.08	31.26	40.03	-40.028
6	216.2			

NG 410 Dahegan, Near Water Tank



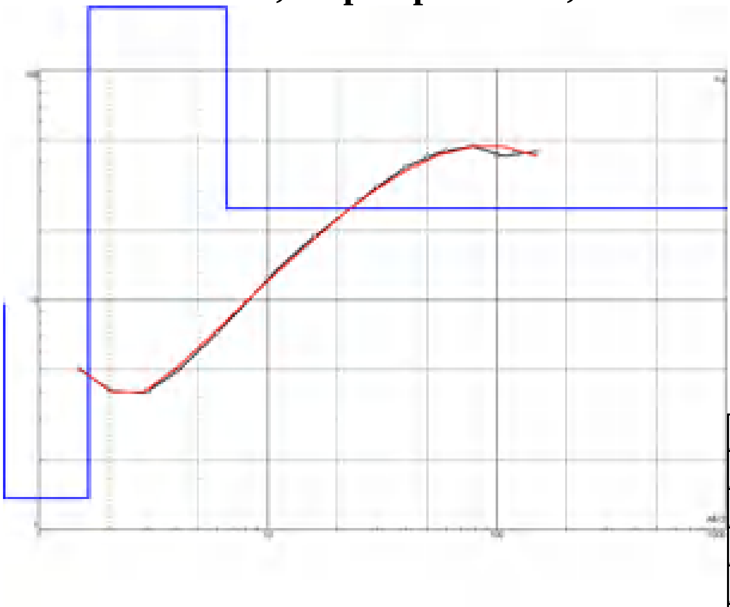
N	ρ	h	d	Alt
1	10.8	1.52	1.52	-1.52
2	32.9	6.11	7.63	-7.63
3	504	9.01	16.6	-16.64
4	6.03	44.7	61.3	-61.34
5	2665			

NG 411 Dahegan, Near Grave Yard/N 15° W of dug well, N 30° E of Grave yard



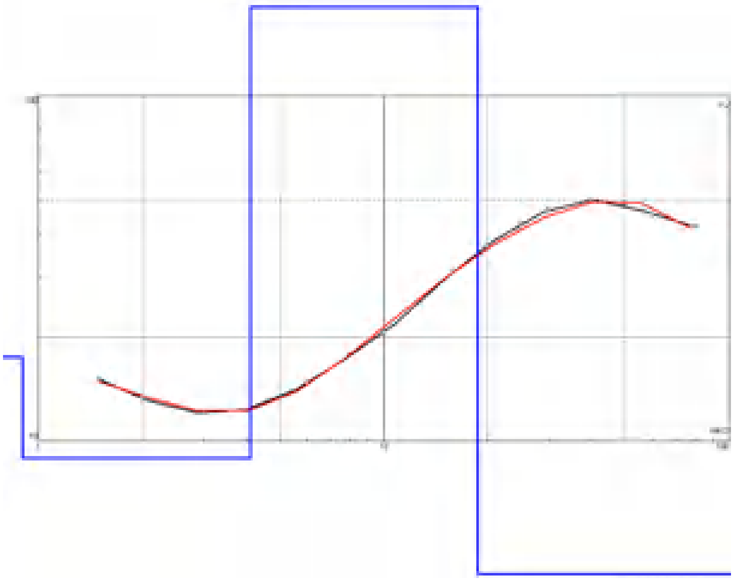
N	ρ	h	d
1	9.93	0.872	0.872
2	1.95	0.847	1.72
3	4816	3.07	4.79
4	26.9	59.8	64.6
5	4388		

NG 412 Dahegan, Near Flag Post, Near the corner of thye Fence with barbed wire,Jhopad patti area, Phokatnagar



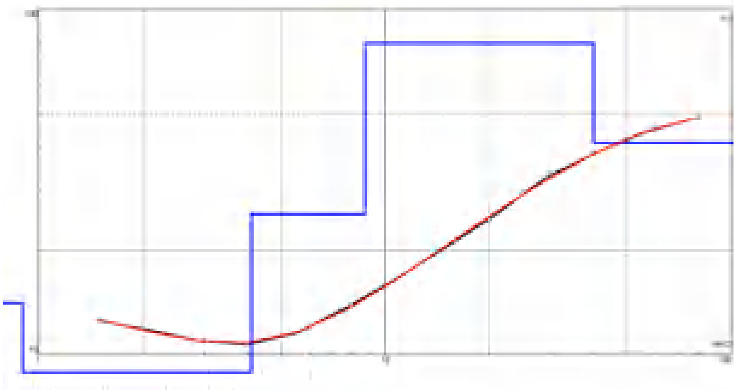
N	ρ	h	d
1	9.48	0.663	0.663
2	1.37	0.984	1.65
3	591	4.94	6.59
4	25		

NG 413 Khair, Near Mango Tree and Tamirind Tree/ 20m from the electric pole by the side3 of kacha road to Ramgiri



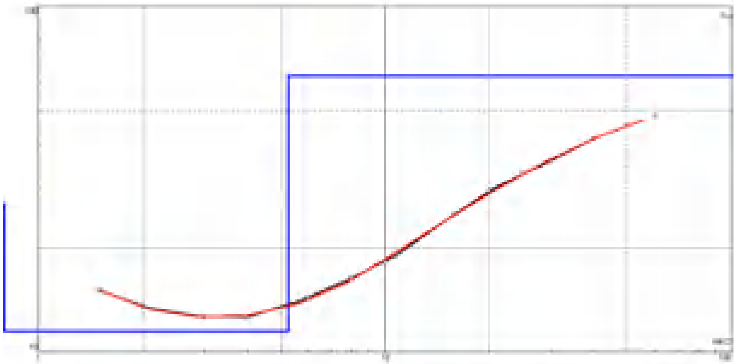
N	ρ	h	d
1	17.5	0.9	0.9
2	8.9	3.21	4.11
3	181	14.6	18.7
4	2.54		

NG 414 Khairi, Back side of the school, in the cultivating land



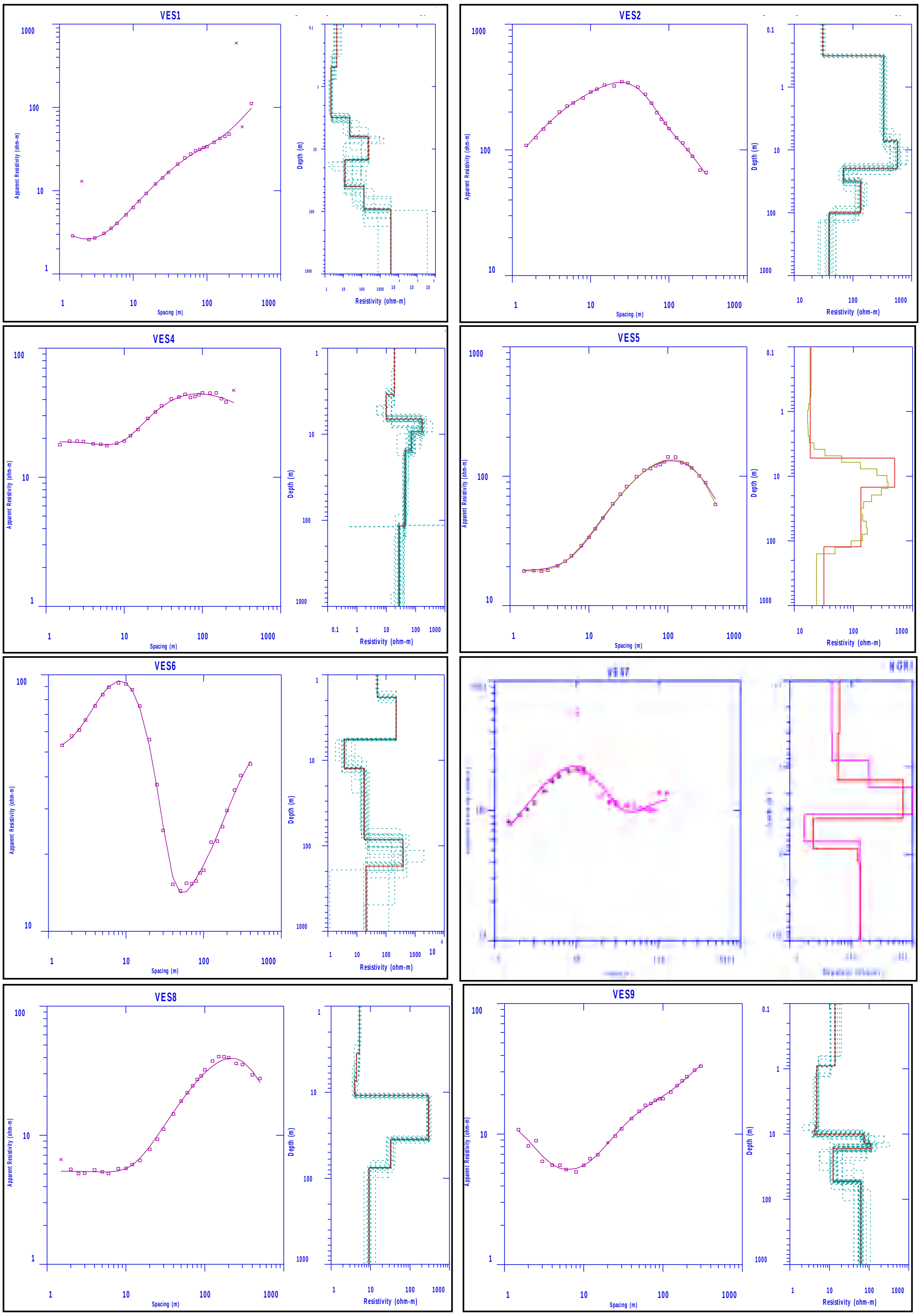
N	ρ	h	d
1	14.1	0.9	0.9
2	8.855	3.206	4.106
3	25.53	4.663	8.769
4	79.92	31.24	40.01
5	41.14		

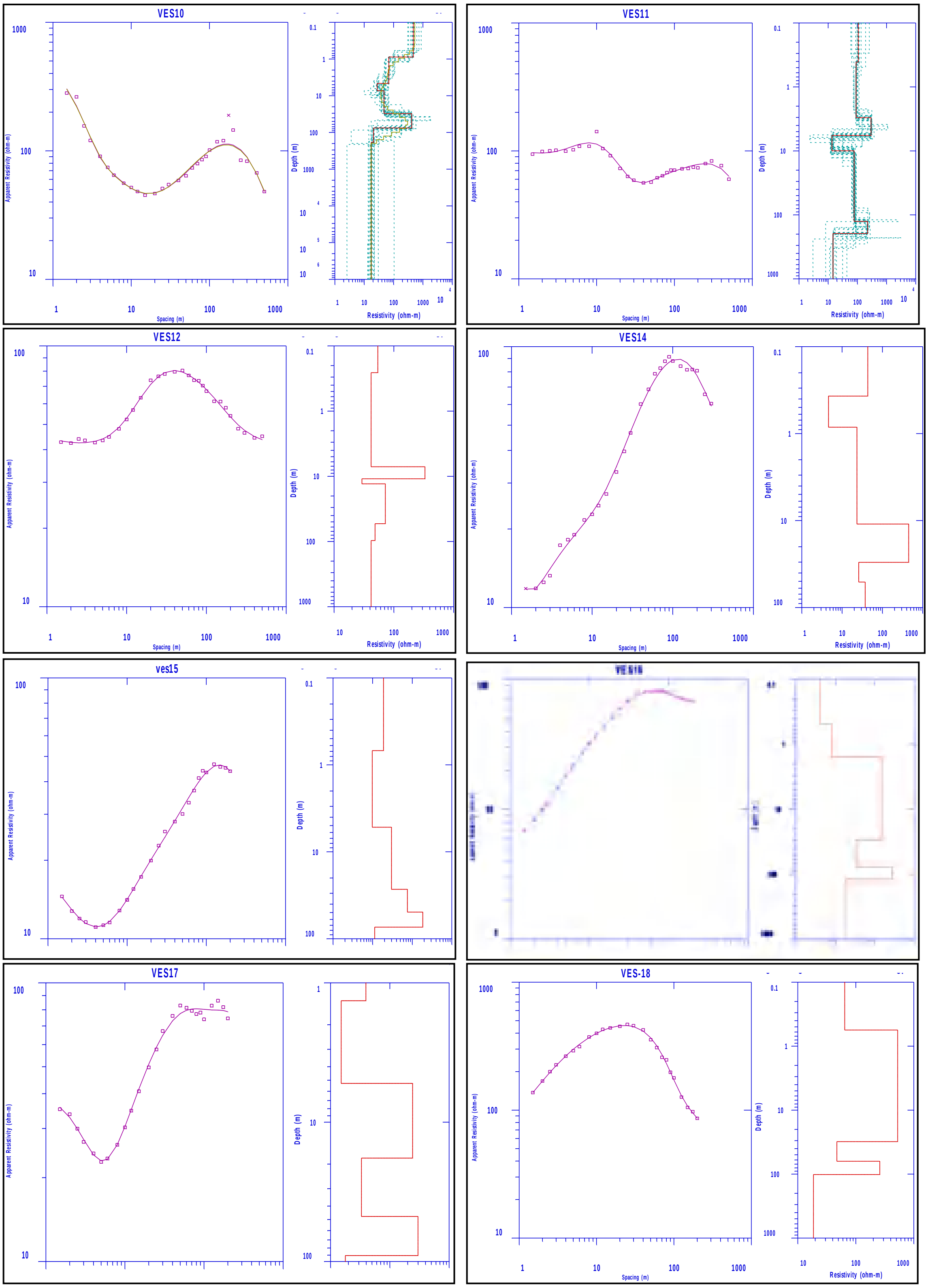
NG 415 Khairi, Back side of the school, in the cultivating land, 20m from NG 414

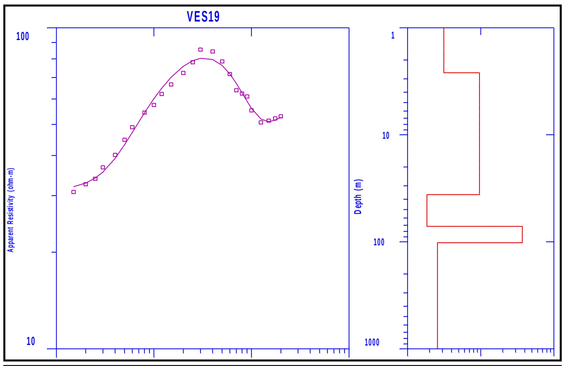


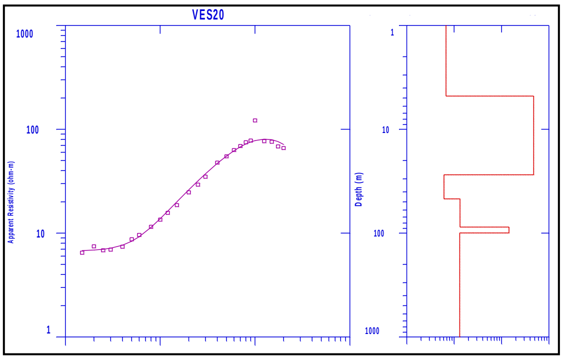
N	ρ	h	d
1	26.87	0.4389	0.4389
2	11.49	4.814	5.253
3	62.92		

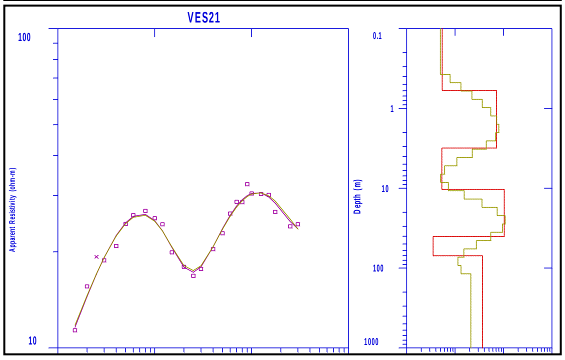
ANNEXURE-III: VES Curvrs, obtained after Geophysiacl Survey by NGRI, Chandrabhaga Watershed (WGKKC-2), Nagpur District




VES10
VES11
VES12
VES14
ves15
VES17
VES-18
Apparent Resistivity (ohm-m)
Spacing (m)
Depth (m)
Resistivity (ohm-m)


VES19
100
10
Apparent Resistivity (ohm-m)
1
10
100
1000
Depth (m)


VES20
1000
100
10
1
Apparent Resistivity (ohm-m)
1
10
100
1000
Depth (m)

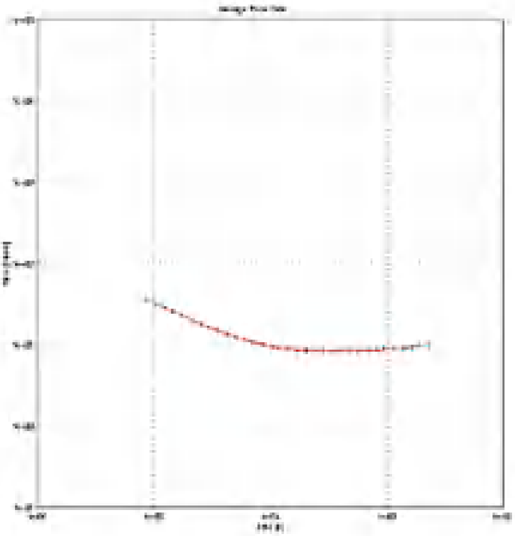

VES21
100
10
Apparent Resistivity (ohm-m)
0.1
1
10
100
1000
Depth (m)

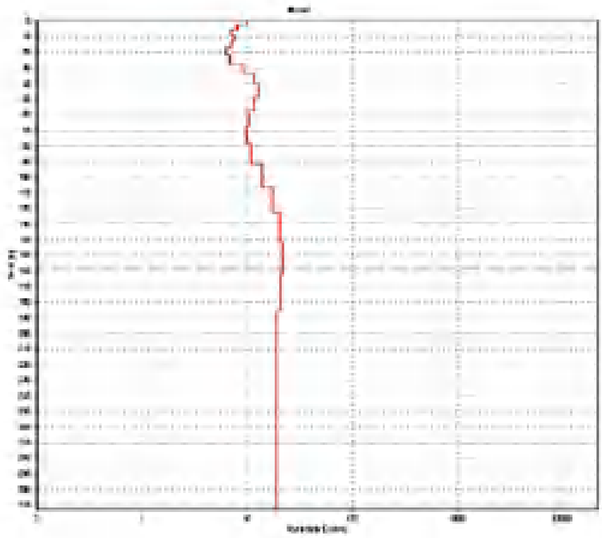
ANNEXURE-IV: TEM Plot, Chandrabhaga watershed (WGKKC-2), (NGRI, 2015a)

MT_1

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	282051
UTMY:	2356208
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	7.652E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	157m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	10	1.22	2.65	1.001	2.65	1.001
2	8.11	1.34	2.99	1.001	5.64	1.001
3	7.14	1.28	3.37	1.001	9.01	1.001
4	7.48	1.32	3.81	1.001	12.8	1.000
5	7.14	1.32	4.3	1.001	17.1	1.000
6	6.37	1.32	4.86	1.001	22	1.000
7	6.98	1.35	5.48	1.001	27.5	1.000
8	9.28	1.41	6.19	1.001	33.6	1.000
9	11.1	1.47	6.99	1.001	40.6	1.000
10	12.7	1.48	7.89	1.001	48.5	1.000
11	11.8	1.44	8.9	1.001	57.4	1.000
12	10.4	1.46	10.1	1.001	67.5	1.000
13	9.82	1.41	11.4	1.001	78.8	1.000
14	10.9	1.34	12.8	1.001	91.6	1.000
15	13.8	1.39	14.5	1.001	106	1.000
16	17.6	1.27	16.3	1.001	122	1.000
17	20.9	99.00	18.4	1.001	141	1.000
18	22.2	99.00	20.8	1.001	162	1.000
19	21.5	99.00	23.5	1.001	185	1.000
20	19.4	99.00				

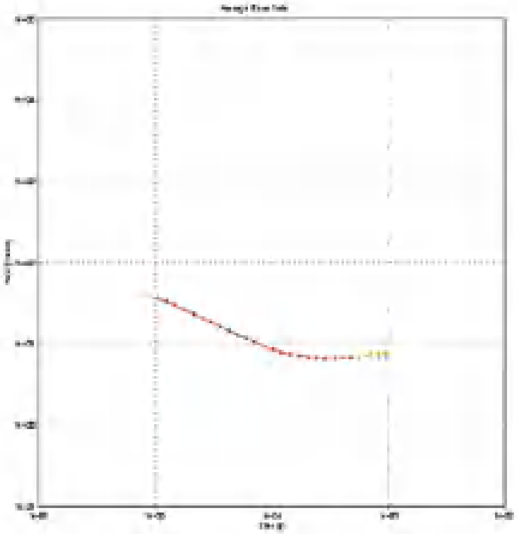


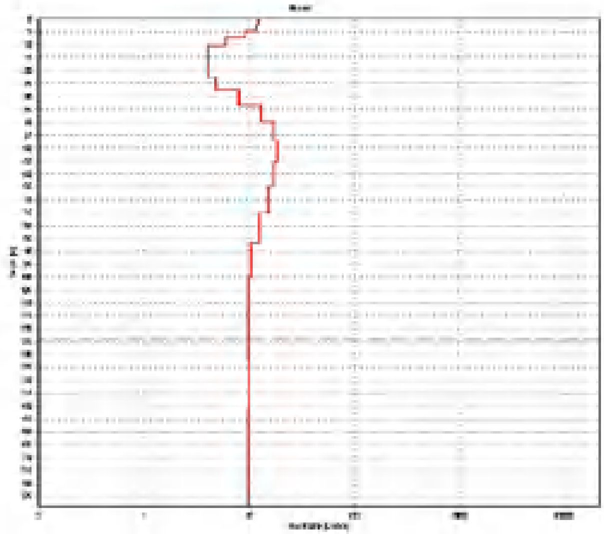


MT_2

Print Date: 02.05.2014
Database Name: AQMAH.gdb
UTMX: 283071
UTMY: 2356645
EPSG: 32644=UTM Zone 44N (WGS 84)
Number of Data Points: 0 points in use
First Gate: 4.060E-06 sec
Last Gate: 7.652E-03 sec
Data Residual: 0.2
No. of Layers: 20
DOI: 124m
Program: ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	12.3	1.32	2.17	1.001	2.17	1.001
2	11.6	1.39	2.45	1.001	4.61	1.001
3	9.29	1.36	2.76	1.001	7.38	1.001
4	6.04	1.28	3.12	1.001	10.5	1.000
5	4.07	1.25	3.52	1.001	14	1.000
6	4.08	1.27	3.97	1.001	18	1.000
7	4.08	1.29	4.49	1.001	22.5	1.000
8	4.61	1.33	5.07	1.001	27.5	1.000
9	8.14	1.44	5.72	1.001	33.3	1.000
10	13.1	1.53	6.46	1.001	39.7	1.000
11	17.4	1.59	7.29	1.001	47	1.000
12	19.1	1.63	8.23	1.001	55.2	1.000
13	17.9	1.64	9.29	1.001	64.5	1.000
14	15.1	1.62	10.5	1.001	75	1.000
15	12.4	1.59	11.8	1.001	86.9	1.000
16	10.6	1.81	13.4	1.001	100	1.000
17	9.91	2.64	15.1	1.001	115	1.000
18	9.9	3.29	17	1.001	132	1.000
19	10.1	3.97	19.2	1.001	152	1.000
20	9.81	4.08				

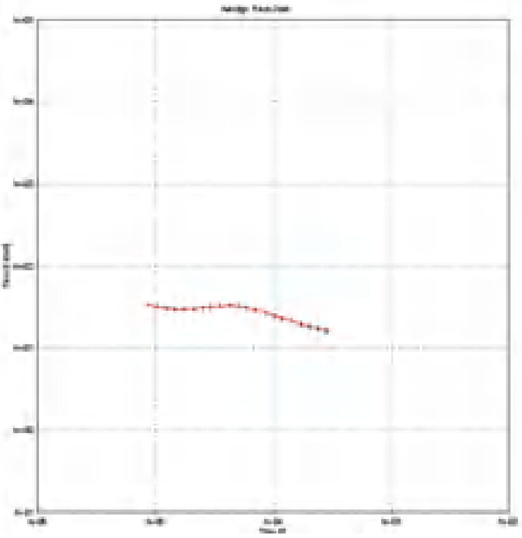


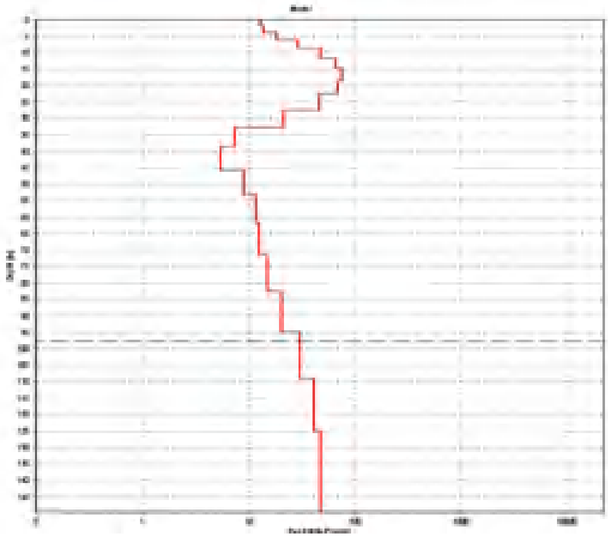


MT_3

Print Date: 02.05.2014
Database Name: AQMAH.gdb
UTMX: 283783
UTMY: 2355315
EPSG: 32644–UTM Zone 44N (WGS 84)
Number of Data Points: 0 points in use
First Gate: 4.060E-06 sec
Last Gate: 3.826E-03 sec
Data Residual: 0.3
No. of Layers: 20
DOI: 98m
Program: ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	12.7	99.00	1.78	1.001	1.78	1.001
2	15.7	1.40	2.01	1.001	3.79	1.001
3	18.6	1.48	2.27	1.001	6.07	1.001
4	29.6	1.50	2.57	1.001	8.65	1.000
5	47	1.60	2.9	1.001	11.5	1.000
6	65.7	1.69	3.27	1.001	14.8	1.000
7	75.4	1.72	3.69	1.001	18.5	1.000
8	68.8	1.68	4.17	1.001	22.7	1.000
9	46.3	1.58	4.7	1.001	27.4	1.000
10	21.5	1.45	5.31	1.001	32.7	1.000
11	7.35	1.27	6	1.001	38.7	1.000
12	5.43	1.21	6.77	1.001	45.4	1.000
13	8.94	1.36	7.64	1.001	53.1	1.000
14	11.6	1.37	8.63	1.001	61.7	1.000
15	12.6	1.48	9.74	1.001	71.5	1.000
16	14.9	99.00	11	1.001	82.5	1.000
17	20.8	99.00	12.4	1.001	94.9	1.000
18	30.7	99.00	14	1.001	109	1.000
19	41.9	99.00	15.8	1.001	125	1.000
20	47.9	99.00				

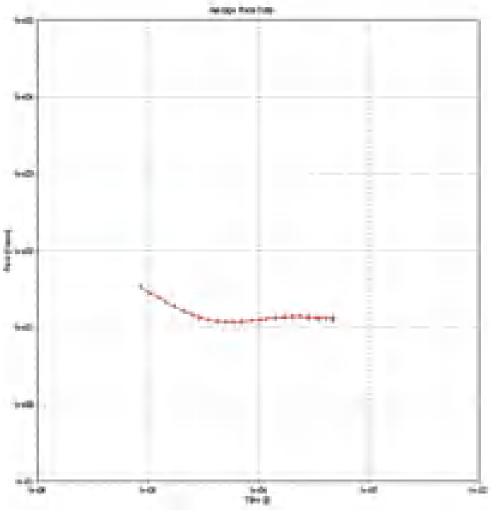


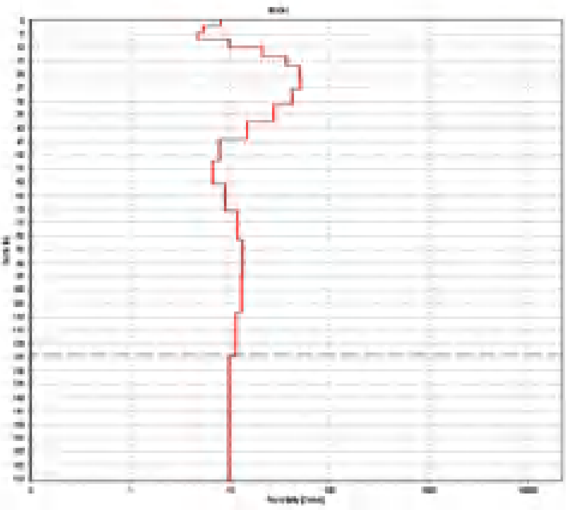


MT_4

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	283352
UTMY:	2354007
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.530E-02 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	124m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	8.07	99.00	2.04	1.001	2.04	1.001
2	5.40	1.34	2.3	1.001	4.34	1.001
3	4.8	1.28	2.6	1.001	6.93	1.001
4	9.83	1.41	2.93	1.001	9.86	1.000
5	21.6	1.61	3.31	1.001	13.2	1.000
6	37.5	1.90	3.74	1.001	16.9	1.000
7	50.1	1.97	4.22	1.001	21.1	1.000
8	32.2	1.39	4.76	1.001	25.9	1.000
9	42.9	1.34	5.38	1.001	31.3	1.000
10	27.8	2.44	6.07	1.001	37.3	1.000
11	14.8	4.01	6.85	1.001	44.2	1.000
12	7.84	3.82	7.74	1.001	51.9	1.000
13	6.71	1.40	8.73	1.001	60.7	1.000
14	8.95	3.02	9.86	1.001	70.5	1.000
15	11.9	3.09	11.1	1.001	81.7	1.000
16	13.5	99.00	12.6	1.001	94.2	1.000
17	13.1	99.00	14.2	1.001	108	1.000
18	11.5	99.00	16	1.001	124	1.000
19	9.89	4.06	18.1	1.001	142	1.000
20	9.89	2.90				

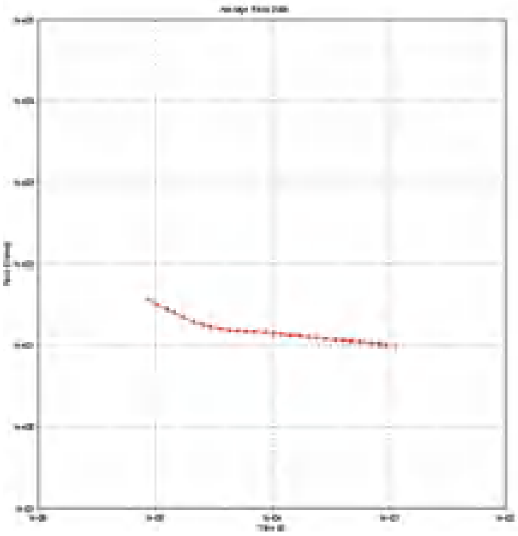


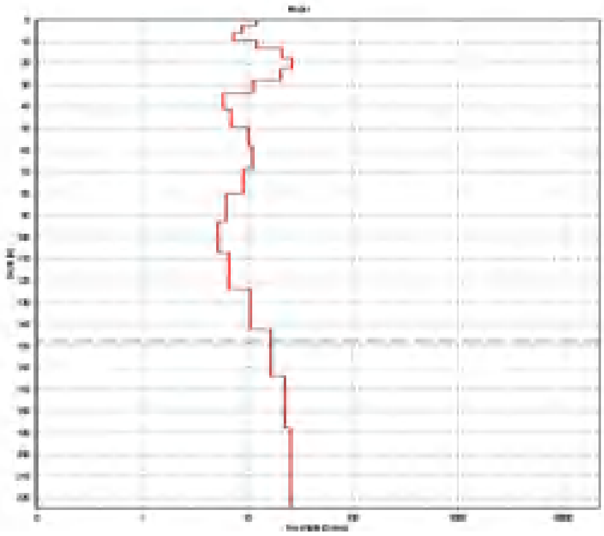


MT_5

Print Date: 02.05.2014
Database Name: AQMAH.gdb
UTMX: 283804
UTMY: 2352982
EPSG: 32644=UTM Zone 44N (WGS 84)
Number of Data Points: 0 points in use
First Gate: 4.060E-06 sec
Last Gate: 3.826E-03 sec
Data Residual: 0.3
No. of Layers: 20
DOI: 148m
Program: ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	12.1	99.00	2.68	1.001	2.68	1.001
2	8.96	1.34	3.02	1.001	5.7	1.001
3	7.44	1.23	3.41	1.001	9.11	1.001
4	12.2	1.36	3.85	1.001	13	1.000
5	21.5	1.44	4.35	1.001	17.3	1.000
6	20.7	1.50	4.91	1.001	22.2	1.000
7	21.2	1.49	5.54	1.001	27.8	1.000
8	11.2	1.40	6.26	1.001	34	1.000
9	5.9	1.28	7.07	1.001	41.1	1.000
10	7.05	1.35	7.98	1.001	49.1	1.000
11	10.5	1.80	9.01	1.001	58.1	1.000
12	11.9	2.10	10.2	1.001	68.2	1.000
13	9.19	1.90	11.5	1.001	79.7	1.000
14	6.41	1.39	13	1.001	92.7	1.000
15	5.37	1.33	14.6	1.001	107	1.000
16	6.85	7.14	16.5	1.001	124	1.000
17	10.8	99.00	18.6	1.001	142	1.000
18	16.8	99.00	21.1	1.001	164	1.000
19	23	3.45	23.8	1.001	187	1.000
20	28.1	2.00				

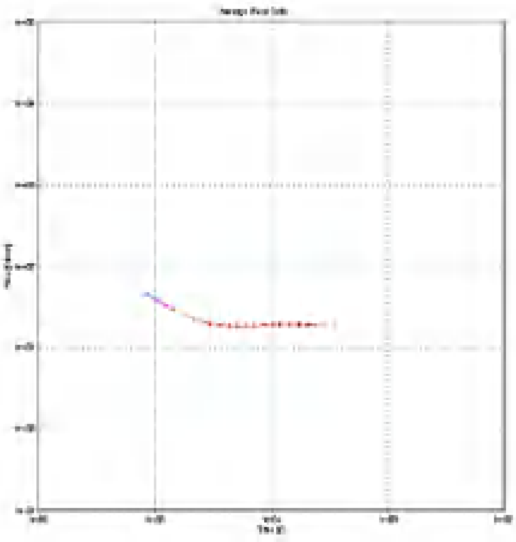


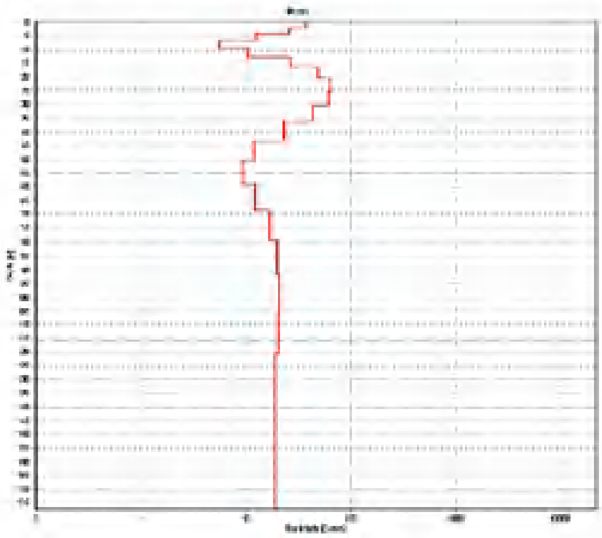


MT_6

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	283342
UTMY:	2351624
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.2
No. of Layers:	20
DOI:	116m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res STD	Thk	Thk STD	Dep	Dep STD
1	17.9	99.00	1.98	1.001	1.98	1.001
2	26.3	1.43	2.23	1.001	4.21	1.001
3	12.6	1.42	2.52	1.001	6.73	1.001
4	5.6	1.24	2.85	1.001	9.58	1.000
5	10.5	1.39	3.21	1.001	12.8	1.000
6	27.1	1.54	3.65	1.001	16.4	1.000
7	49.9	1.64	4.1	1.001	20.5	1.000
8	64.7	1.70	4.65	1.001	25.1	1.000
9	60.2	1.70	5.22	1.001	30.4	1.000
10	43.4	1.80	5.89	1.001	36.3	1.000
11	23.8	1.40	6.66	1.001	42.9	1.000
12	12	1.25	7.51	1.001	50.4	1.000
13	9.34	1.35	8.48	1.001	58.9	1.000
14	12.3	1.21	9.58	1.001	68.5	1.000
15	16.9	1.55	10.8	1.001	79.3	1.000
16	20.2	99.00	12.2	1.001	91.5	1.000
17	22.1	99.00	13.8	1.001	105	1.000
18	20.5	99.00	15.6	1.001	121	1.000
19	20.3	99.00	17.6	1.001	138	1.000
20	20.3	99.00				

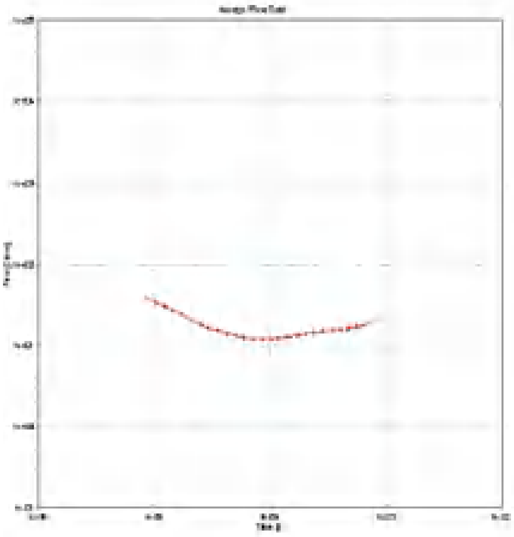


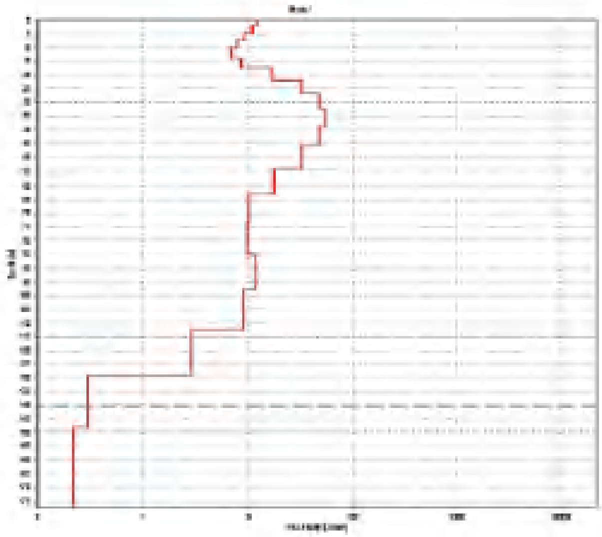


MT_7

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	281641
UTMY:	2347222
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.5
No. of Layers:	20
DOI:	141m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	Rho STD	Thk	Thk STD	Dep	Dep STD
1	12.1	99.00	2.11	1.000	2.11	1.000
2	10.9	1.28	2.39	1.000	4.5	1.000
3	9.3	1.34	2.69	1.000	7.2	1.000
4	7.06	1.32	3.04	1.000	10.2	1.000
5	6.05	1.29	3.43	1.000	13.7	1.000
6	8.55	1.32	3.88	1.000	17.6	1.000
7	17	1.42	4.38	1.000	21.9	1.000
8	33.5	1.59	4.94	1.000	26.9	1.000
9	48.7	1.63	5.58	1.000	32.5	1.000
10	55.5	1.47	6.3	1.000	38.8	1.000
11	48.4	99.00	7.11	1.000	45.9	1.000
12	32.7	99.00	8.03	1.000	53.9	1.000
13	18	1.26	9.07	1.000	63	1.000
14	10.3	99.00	10.2	1.000	73.2	1.000
15	9.79	99.00	11.6	1.000	84.8	1.000
16	11.6	1.46	13	1.000	97.8	1.000
17	9.07	99.00	14.7	1.000	113	1.000
18	2.9	2.00	16.6	1.000	129	1.000
19	0.301	2.47	18.8	1.000	148	1.000
20	0.221	3.32				

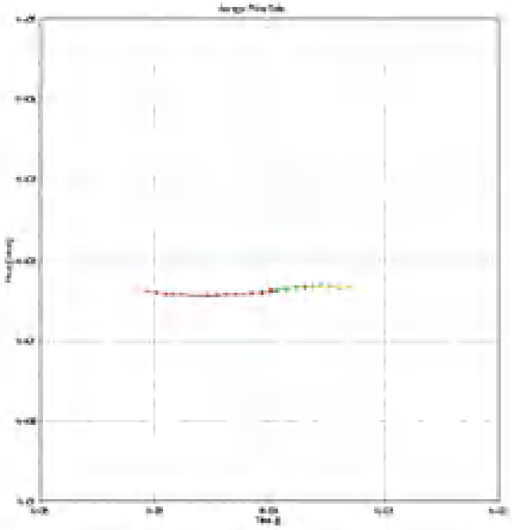


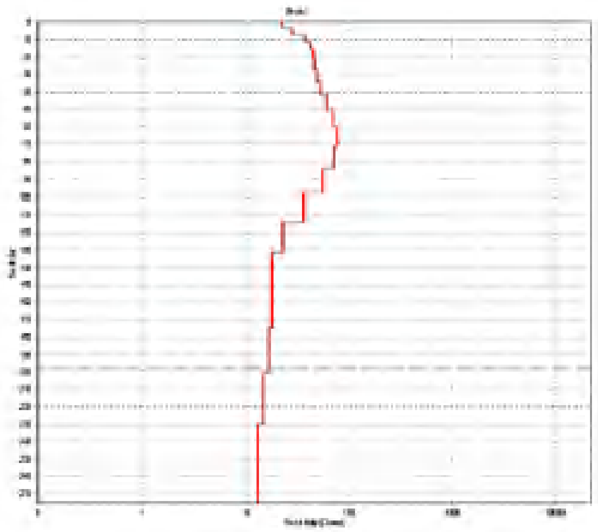


MT_8

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	282152
UTMY:	2345809
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	197m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	22.4	99.00	3.28	1.001	3.28	1.000
2	28.7	1.41	3.7	1.001	6.99	1.001
3	37	1.41	4.18	1.001	11.2	1.001
4	42.7	1.41	4.72	1.001	15.9	1.000
5	45.3	1.45	5.33	1.001	21.2	1.000
6	46.8	1.45	6.02	1.001	27.2	1.000
7	48.8	1.45	6.8	1.001	34	1.000
8	52.7	1.45	7.67	1.001	41.7	1.000
9	59.9	1.47	8.66	1.001	50.4	1.000
10	69.7	1.51	9.78	1.001	60.1	1.000
11	78.3	1.55	11	1.001	71.2	1.000
12	72.4	1.56	12.5	1.001	83.6	1.000
13	56.6	1.52	14.1	1.001	97.7	1.000
14	34.7	1.45	15.9	1.001	114	1.000
15	22.4	1.38	17.9	1.001	132	1.000
16	18.3	1.76	20.2	1.001	152	1.000
17	18.1	2.19	22.8	1.001	175	1.000
18	16.5	2.06	25.8	1.001	200	1.000
19	14.3	2.07	29.1	1.001	230	1.000
20	13.3	2.32				

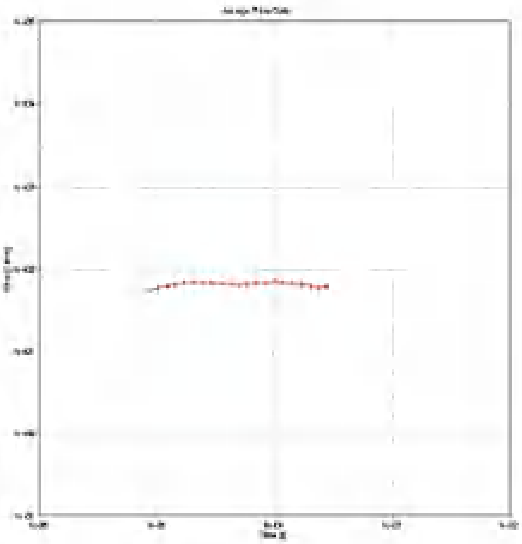


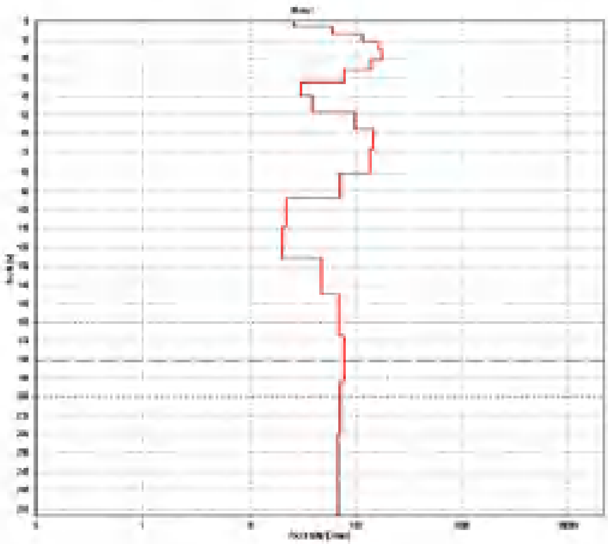


MT_9

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	281270
UTMY:	2344470
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	7.652E-03 sec
Data Residual:	0.7
No. of Layers:	20
DOI:	181m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	RhoSTD	Thk	ThkSTD	Dep	DepSTD
1	26.2	99.00	3.14	1.001	3.14	1.001
2	79.7	1.49	3.55	1.001	6.69	1.001
3	116	1.59	4.01	1.001	10.7	1.001
4	166	1.60	4.52	1.001	15.2	1.000
5	181	1.61	5.11	1.001	20.3	1.000
6	144	1.59	5.78	1.001	26.1	1.000
7	77.1	1.50	6.53	1.001	32.6	1.000
8	30.7	1.29	7.35	1.001	39.9	1.000
9	38.6	1.37	8.29	1.001	48.2	1.000
10	97.4	1.50	9.36	1.001	57.6	1.000
11	153	1.82	10.6	1.001	68.2	1.000
12	140	2.27	11.9	1.001	80.1	1.000
13	71.5	2.81	13.5	1.001	93.6	1.000
14	22.6	1.41	15.2	1.001	109	1.000
15	20.7	1.85	17.2	1.001	126	1.000
16	47.1	5.17	19.4	1.001	145	1.000
17	70.5	99.00	21.9	1.001	167	1.000
18	76.8	99.00	24.7	1.001	192	1.000
19	71.5	3.25	27.9	1.001	220	1.000
20	69.2	2.00				

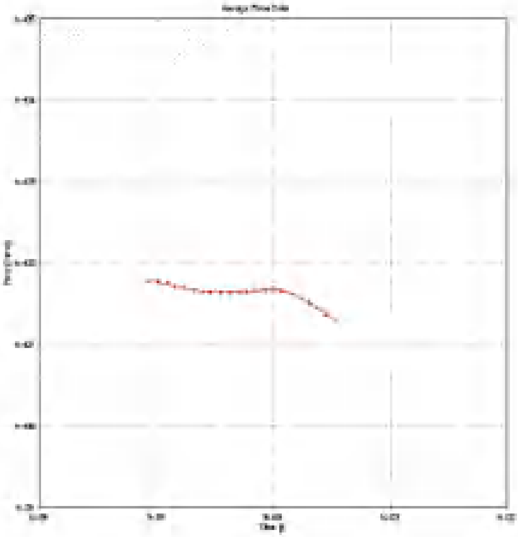


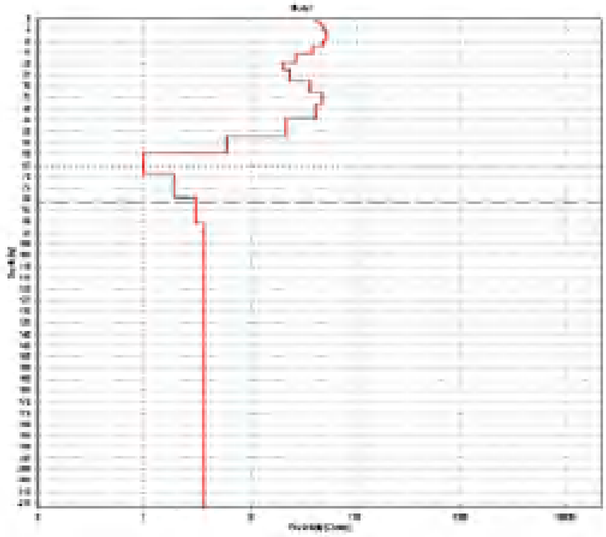


MT_10

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	276720
UTMY:	2356534
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	7.652E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	82m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	44.5	99.00	1.49	1.001	1.49	1.001
2	40.9	1.58	1.68	1.001	3.17	1.001
3	50.8	1.58	1.9	1.001	5.07	1.001
4	34.1	1.69	2.14	1.001	7.21	1.000
5	34.5	1.75	2.42	1.001	9.63	1.000
6	49.7	1.69	2.75	1.001	12.4	1.000
7	39.5	1.57	3.08	1.001	15.4	1.000
8	27.9	1.49	3.48	1.001	18.9	1.000
9	20.9	1.41	3.95	1.001	22.9	1.000
10	28.3	1.45	4.44	1.001	27.3	1.000
11	37.3	1.60	5.01	1.001	32.3	1.000
12	48.4	1.60	5.66	1.001	38	1.000
13	42.6	1.94	6.39	1.001	44.4	1.000
14	22.6	3.45	7.21	1.001	51.6	1.000
15	6.13	6.04	8.14	1.001	59.7	1.000
16	1.01	1.62	9.19	1.001	68.9	1.000
17	1.91	4.16	10.4	1.001	79.3	1.000
18	3.07	2.00	11.7	1.001	91	1.000
19	3.67	2.67	13.2	1.001	104	1.000
20	3.67	3.32				

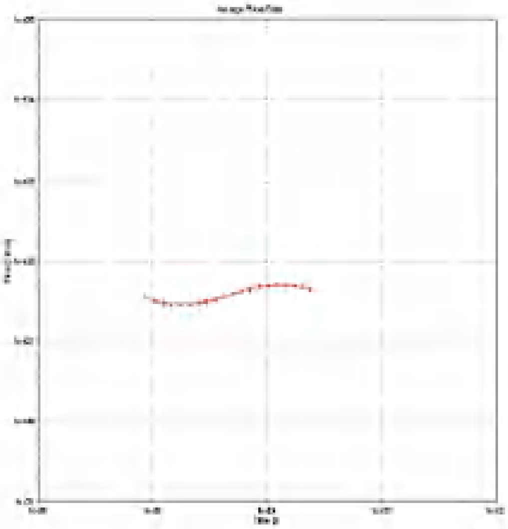


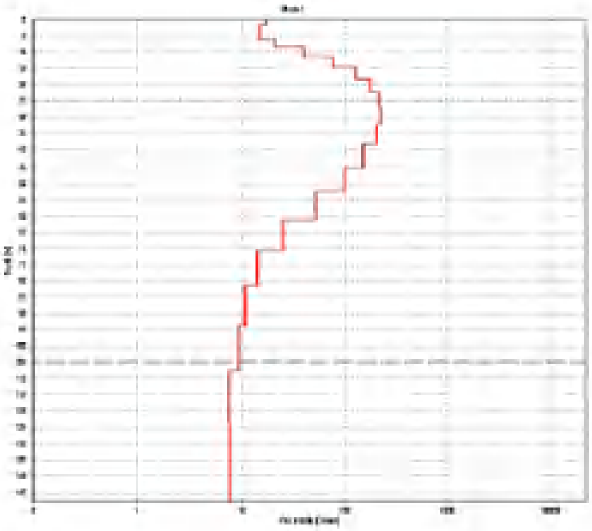


MT_11

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	277753
UTMY:	2354855
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	104m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	RhoSTD	Thk	ThkSTD	Dep	DepSTD
1	17.4	99.00	1.76	1.000	1.76	1.000
2	15	1.39	1.99	1.000	3.75	1.001
3	14.8	1.76	2.24	1.000	5.99	1.001
4	21.7	1.82	2.53	1.000	8.52	1.000
5	41	1.58	2.86	1.000	11.4	1.000
6	78.6	2.16	3.23	1.000	14.6	1.000
7	126	3.60	3.66	1.000	18.3	1.000
8	179	5.67	4.11	1.000	22.4	1.000
9	218	7.78	4.65	1.000	27	1.000
10	228	8.88	5.24	1.000	32.3	1.000
11	205	8.08	5.92	1.000	38.2	1.000
12	155	5.56	6.68	1.000	44.9	1.000
13	99	2.77	7.55	1.000	52.4	1.000
14	53	1.75	8.52	1.000	60.9	1.000
15	25.6	3.55	9.62	1.000	70.6	1.000
16	14.1	3.93	10.9	1.000	81.4	1.000
17	10.9	99.00	12.3	1.000	93.7	1.000
18	9.4	3.93	13.8	1.000	108	1.000
19	7.36	2.09	15.6	1.000	123	1.000
20	7.09	2.67				

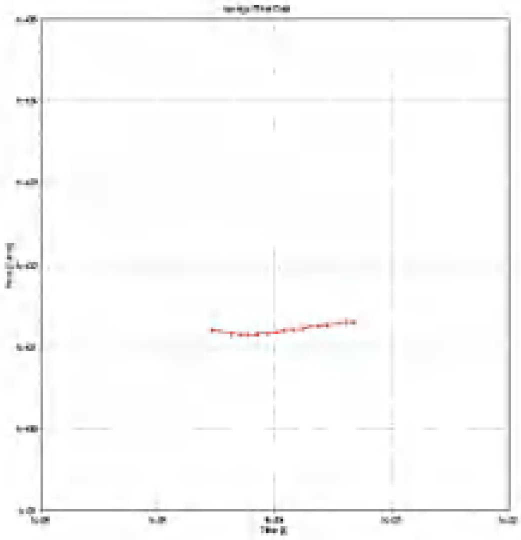


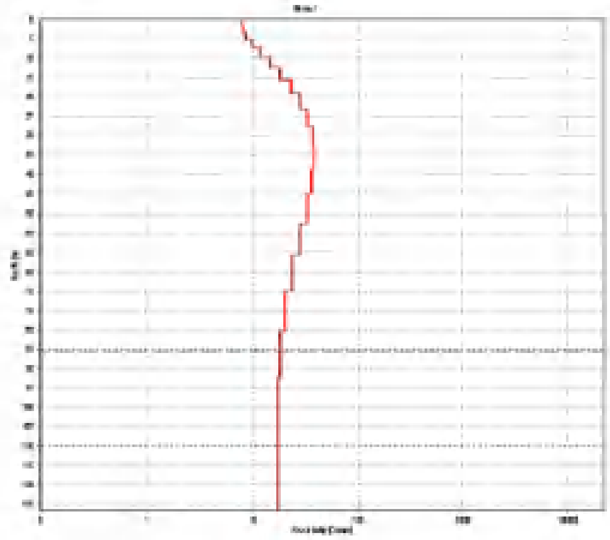


MT_12

Print Date:	02.05.2014
Database Name:	A\QMAH.gdb
UTMX:	279121
UTMY:	2353953
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	4.781E-04 sec
Data Residual:	0.1
No. of Layers:	20
DOI:	85m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	7.95	1.76	1.51	1.001	1.51	1.001
2	8.16	1.50	1.71	1.001	3.22	1.001
3	8.71	1.56	1.92	1.001	5.14	1.001
4	9.8	1.66	2.17	1.001	7.31	1.000
5	11.7	1.68	2.45	1.001	9.77	1.000
6	14.5	1.65	2.77	1.001	12.5	1.000
7	18.4	1.65	3.13	1.001	15.7	1.000
8	23.4	1.70	3.53	1.001	19.2	1.000
9	28.7	1.75	3.99	1.001	23.2	1.000
10	33.7	1.78	4.5	1.001	27.7	1.000
11	37.1	1.78	5.08	1.001	32.8	1.000
12	38.2	1.77	5.74	1.001	38.5	1.000
13	36.8	1.74	6.48	1.001	45	1.000
14	33.1	1.68	7.31	1.001	52.3	1.000
15	28.5	1.61	8.26	1.001	60.5	1.000
16	24	1.57	9.32	1.001	69.9	1.000
17	20.6	1.68	10.5	1.001	80.4	1.000
18	18.6	2.00	11.9	1.001	92.3	1.000
19	17.9	2.47	13.4	1.001	106	1.000
20	17.5	3.32				

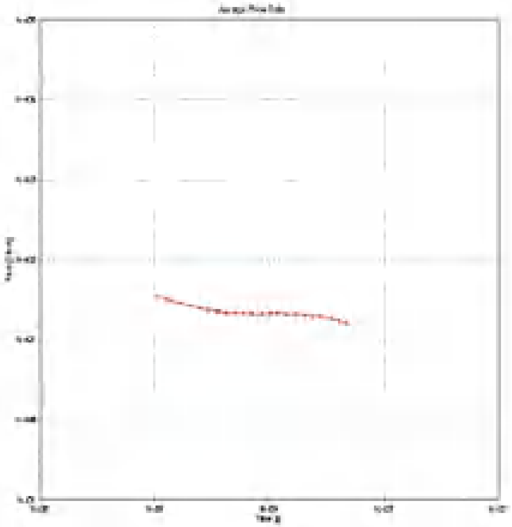


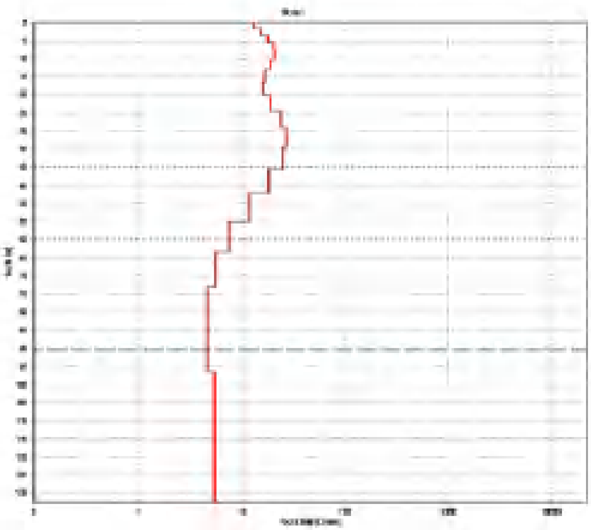


MT_13

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	281533
UTMY:	2351087
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	4.781E-04 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	91m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	Rho STD	Thk	Thk STD	Dep	Dep STD
1	13.2	99.00	1.50	1.001	1.50	1.000
2	15.3	1.41	1.76	1.001	3.26	1.000
3	18.3	1.70	2.01	1.001	5.27	1.000
4	20.7	1.62	2.27	1.001	7.54	1.000
5	21	1.54	2.57	1.001	10.1	1.000
6	19	1.50	2.9	1.001	13.1	1.000
7	16.4	1.49	3.27	1.001	16.4	1.000
8	16	1.46	3.68	1.001	20.1	1.000
9	19.1	1.49	4.17	1.001	24.2	1.000
10	24.2	1.35	4.7	1.001	28.9	1.000
11	27.3	1.30	5.31	1.001	34.2	1.000
12	25.1	1.29	6	1.001	40.2	1.000
13	18.6	1.15	6.77	1.001	47	1.000
14	11.8	1.41	7.64	1.001	54.7	1.000
15	7.59	99.00	8.63	1.001	63.3	1.000
16	5.62	1.30	9.74	1.001	73	1.000
17	4.71	99.00	11	1.001	84	1.000
18	4.71	99.00	12.4	1.001	96.4	1.000
19	5.42	2.00	14	1.001	110	1.000
20	5.4	2.07				

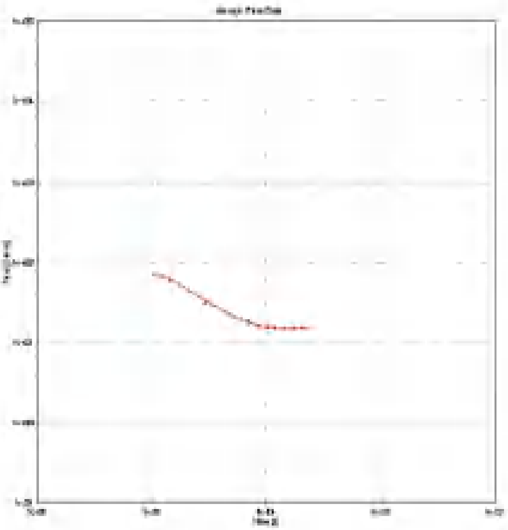


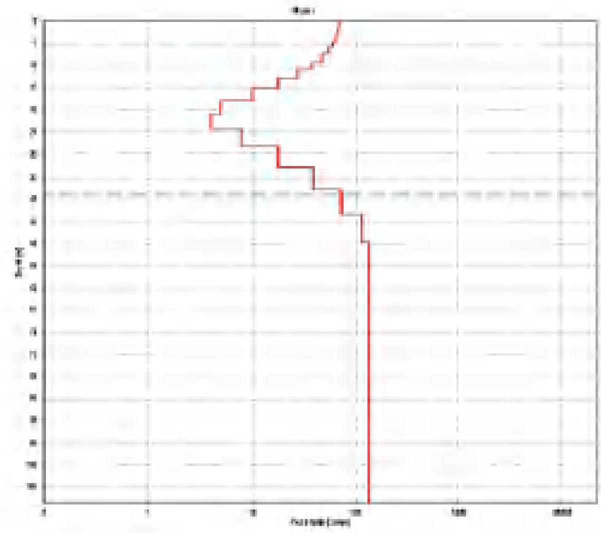


MT_14

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	280953
UTMY:	2343792
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	2.388E-04 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	39m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	70.3	99.00	0.707	1.001	0.707	1.001
2	69.5	2.76	0.758	1.001	1.5	1.001
3	69	2.36	0.903	1.001	2.41	1.001
4	67.4	2.08	1.02	1.001	3.42	1.001
5	64.6	1.92	1.15	1.001	4.57	1.001
6	60.4	1.86	1.3	1.001	5.87	1.001
7	54.7	1.86	1.46	1.001	7.33	1.001
8	47.2	1.89	1.65	1.001	8.98	1.001
9	38.2	1.86	1.87	1.001	10.9	1.001
10	28.2	1.76	2.11	1.001	13	1.001
11	18.3	1.59	2.38	1.001	15.3	1.001
12	10.1	1.42	2.68	1.001	18	1.001
13	5.01	1.33	3.03	1.001	21	1.001
14	4.03	1.23	3.42	1.001	24.5	1.001
15	7.88	1.28	3.86	1.001	28.3	1.001
16	18	1.22	4.36	1.001	32.7	1.001
17	38.9	99.00	4.93	1.001	37.6	1.001
18	74	99.00	5.56	1.001	43.2	1.001
19	117	99.00	6.28	1.001	49.5	1.001
20	140	99.00				

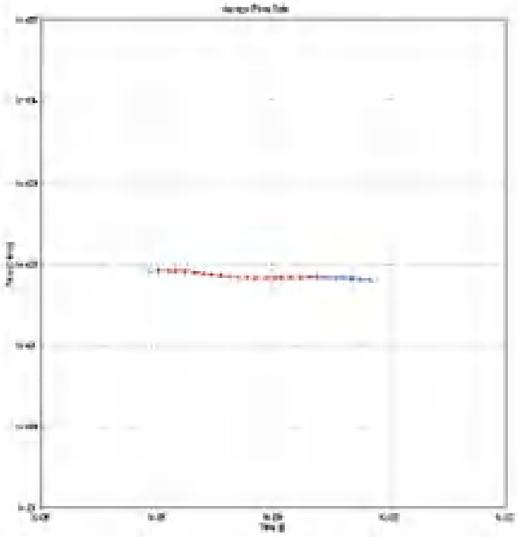


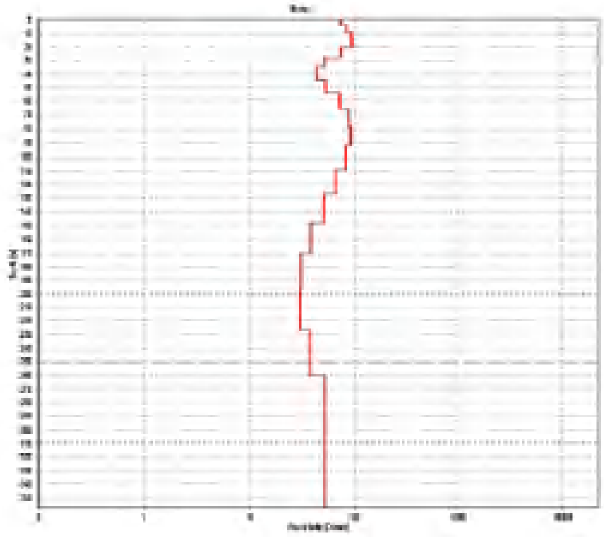


MT_15

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	271837
UTMY:	2344706
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	250m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	75.7	99.00	4.25	1.000	4.25	1.000
2	85.2	1.43	4.8	1.001	9.06	1.001
3	95.9	1.53	5.43	1.000	14.5	1.001
4	94.4	1.43	6.12	1.001	20.6	1.000
5	75.3	1.38	6.91	1.000	27.5	1.000
6	52.7	1.33	7.8	1.001	35.3	1.000
7	44.8	1.29	8.82	1.000	44.1	1.000
8	54.4	1.34	9.96	1.001	54.1	1.000
9	72.9	1.40	11.2	1.000	65.3	1.000
10	88.9	1.45	12.7	1.000	78	1.000
11	93.7	1.46	14.3	1.000	92.3	1.000
12	82.4	1.49	16.2	1.000	108	1.000
13	67.4	1.53	18.2	1.001	127	1.000
14	51.7	1.43	20.6	1.000	147	1.000
15	39.2	1.45	23.2	1.001	170	1.000
16	31.4	1.40	26.3	1.000	197	1.000
17	30.4	2.37	29.6	1.000	226	1.000
18	38.2	2.00	33.5	1.000	260	1.000
19	53.4	2.67	37.8	1.001	298	1.000
20	53.4	3.02				

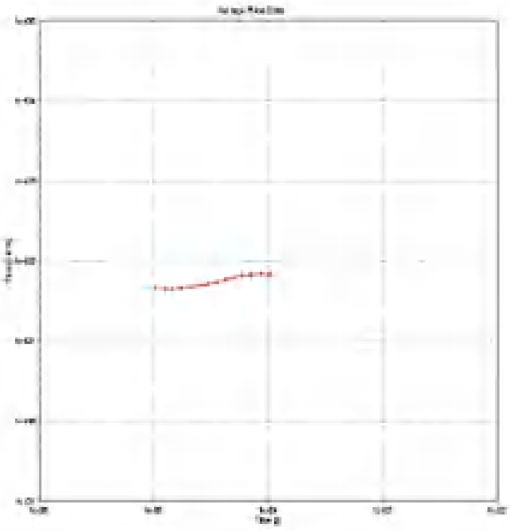


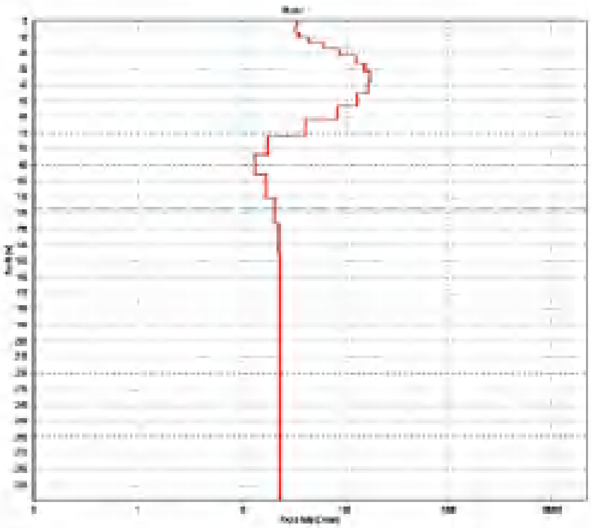


MT_16

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	272753
UTMY:	2345587
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.2
No. of Layers:	20
DOI:	117m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	RhoSTD	Thk	ThkSTD	Dep	DepSTD
1	35.1	99.00	2.08	1.001	2.08	1.001
2	36	1.41	2.34	1.004	4.42	1.001
3	33.4	1.32	2.64	1.001	7.06	1.001
4	30	1.32	2.99	1.004	10	1.000
5	44.5	1.48	3.37	1.001	13.4	1.000
6	62.1	1.56	3.82	1.001	17.2	1.000
7	90.1	1.63	4.3	1.004	21.5	1.000
8	126	1.69	4.85	1.001	26.4	1.000
9	159	1.73	5.48	1.004	31.9	1.000
10	177	1.79	6.18	1.001	38	1.000
11	167	1.84	6.98	1.001	45	1.000
12	131	1.88	7.88	1.001	52.9	1.000
13	82.8	1.88	8.9	1.001	61.8	1.000
14	41.2	1.82	10	1.001	71.8	1.000
15	18.3	1.82	11.3	1.001	83.2	1.000
16	13.4	2.48	12.8	1.001	96	1.000
17	17	4.11	14.5	1.001	110	1.000
18	21.2	2.00	16.3	1.001	127	1.000
19	27	2.67	18.4	1.001	147	1.000
20	23.6	3.32				

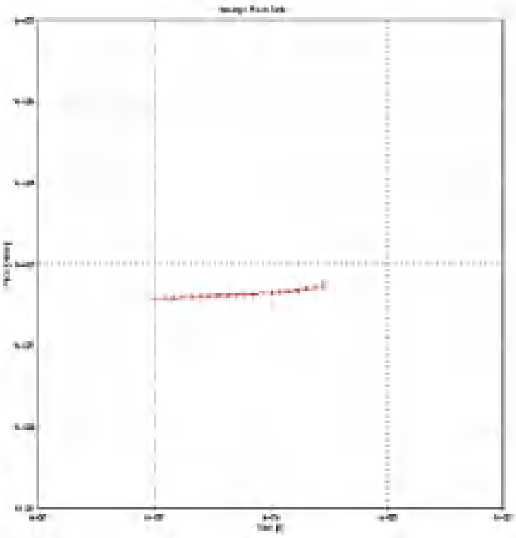


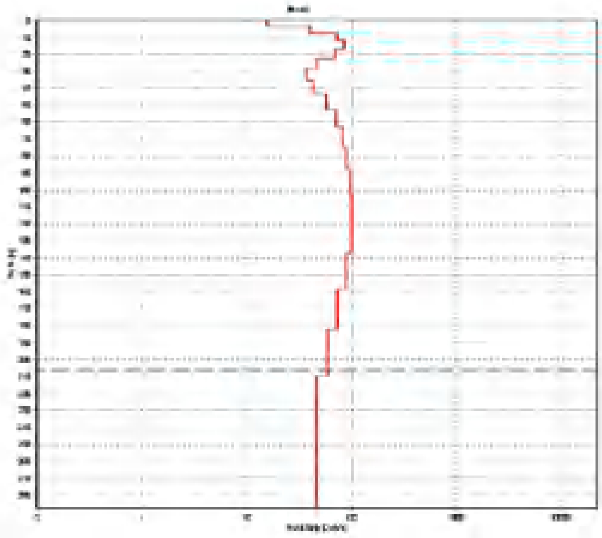


MT_17

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	274010
UTMY:	2348148
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.2
No. of Layers:	20
DOI:	206m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	13.5	99.00	3.43	1.001	3.43	1.001
2	40.2	1.46	3.87	1.001	7.3	1.001
3	73.4	1.48	4.37	1.001	11.7	1.001
4	85.6	1.50	4.93	1.001	16.6	1.000
5	89.8	1.51	5.57	1.001	22.2	1.000
6	47.8	1.44	6.29	1.001	28.5	1.000
7	37.1	1.38	7.1	1.001	35.6	1.000
8	45	1.39	8.02	1.001	43.6	1.000
9	58.3	1.43	9.05	1.001	52.6	1.000
10	72.1	1.53	10.2	1.001	62.8	1.000
11	82.2	1.54	11.5	1.001	74.4	1.000
12	89.8	1.56	13	1.001	87.4	1.000
13	96.5	1.64	14.7	1.001	102	1.000
14	101	1.66	16.6	1.001	119	1.000
15	98.6	1.68	18.7	1.001	137	1.000
16	88.9	1.76	21.2	1.001	159	1.000
17	73.8	8.48	23.9	1.001	182	1.000
18	58.7	9.41	27	1.001	209	1.000
19	48.8	10.45	30.4	1.001	240	1.000
20	48.8	99.00				

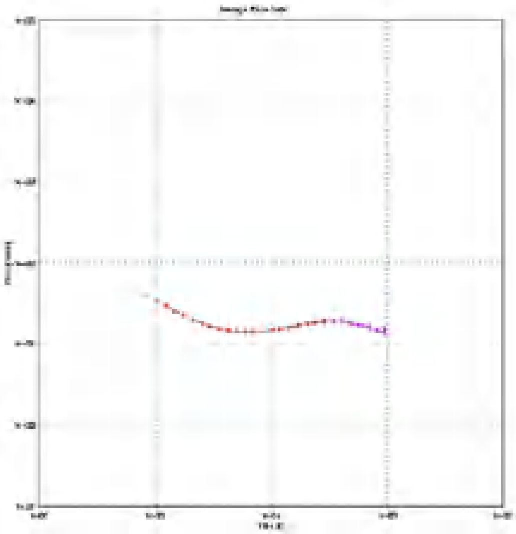


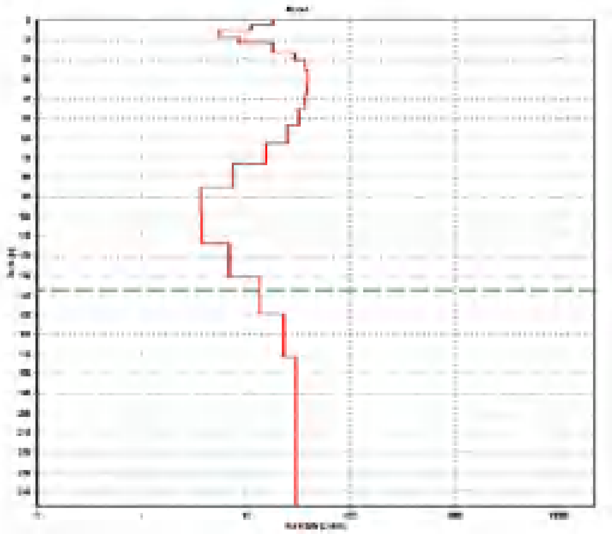


MT_18

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	275833
UTMY:	2350355
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	137m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	18.7	99.00	2.46	1.001	2.46	1.001
2	11.1	1.34	2.77	1.001	5.23	1.001
3	5.63	1.23	3.13	1.001	8.36	1.001
4	4.71	1.34	3.53	1.001	11.9	1.000
5	18.5	1.46	3.99	1.001	15.9	1.000
6	29.9	1.53	4.5	1.001	20.4	1.000
7	37.1	1.58	5.08	1.001	25.5	1.000
8	39.6	1.59	5.74	1.001	31.2	1.000
9	39.1	1.59	6.48	1.001	37.7	1.000
10	37.3	1.59	7.32	1.001	45	1.000
11	31	1.59	8.26	1.001	53.3	1.000
12	21.1	1.59	9.33	1.001	62.6	1.000
13	11.4	1.60	10.5	1.001	73.1	1.000
14	7.53	1.50	11.9	1.001	85	1.000
15	3.77	1.28	13.4	1.001	98.4	1.000
16	3.86	1.36	15.2	1.001	114	1.000
17	4.98	3.81	17.1	1.001	131	1.000
18	12.7	2.00	19.3	1.001	150	1.000
19	23.4	2.67	21.8	1.001	172	1.000
20	30.5	3.32				

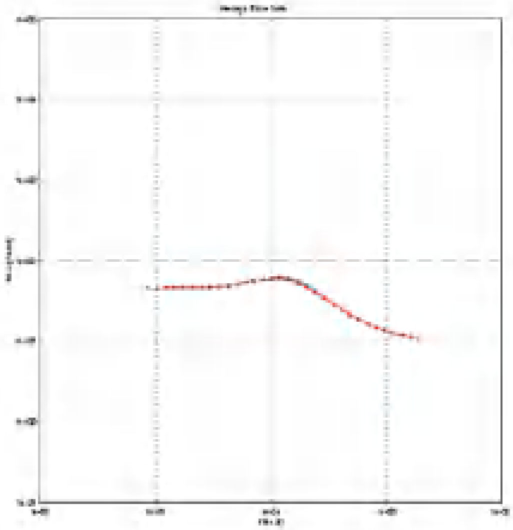


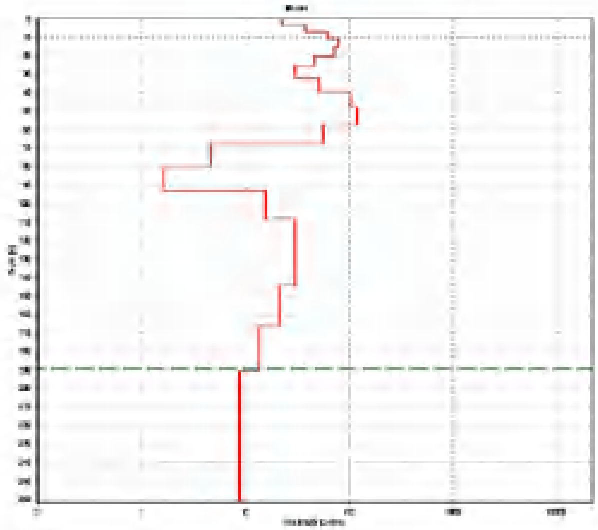


MT_19

Print Date: 02.05.2014
Database Name: AQMAH.gdb
UTMX: 275121
UTMY: 2349180
EPSG: 32644=UTM Zone 44N (WGS 84)
Number of Data Points: 0 points in use
First Gate: 4.060E-06 sec
Last Gate: 1.913E-03 sec
Data Residual: 0.4
No. of Layers: 20
DOI: 189m
Program: ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	28.1	1.53	3.12	1.001	3.12	1.001
2	38	1.44	3.52	1.001	6.64	1.001
3	61.8	1.51	3.88	1.001	10.5	1.001
4	78.4	1.50	4.49	1.001	15.1	1.000
5	71.1	1.50	5.07	1.001	20.2	1.000
6	40.4	1.43	5.72	1.001	25.9	1.000
7	30.8	1.31	6.46	1.001	32.4	1.000
8	52.2	1.42	7.29	1.001	39.7	1.000
9	103	1.55	8.23	1.001	47.9	1.000
10	118	1.61	9.3	1.001	57.2	1.000
11	36.4	1.54	10.5	1.001	67.7	1.000
12	4.71	1.10	11.9	1.001	79.5	1.000
13	1.63	1.05	13.4	1.001	92.9	1.000
14	15.6	1.53	15.1	1.001	108	1.000
15	30.8	1.62	17.1	1.001	125	1.000
16	30.5	1.91	19.3	1.001	144	1.000
17	21.4	2.78	21.7	1.001	166	1.000
18	13.7	3.42	24.5	1.001	191	1.000
19	8.86	4.10	27.7	1.001	218	1.000
20	8.86	4.82				

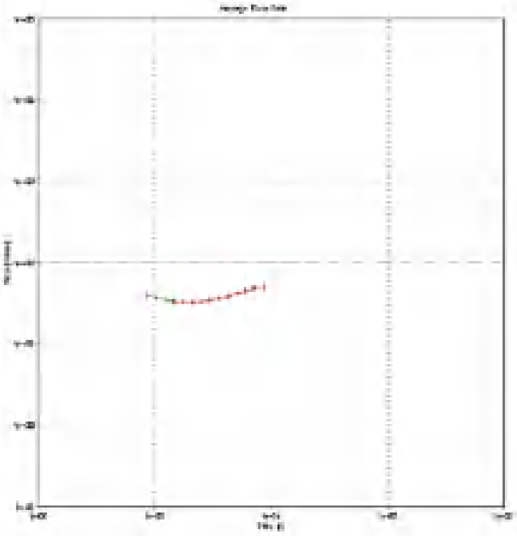


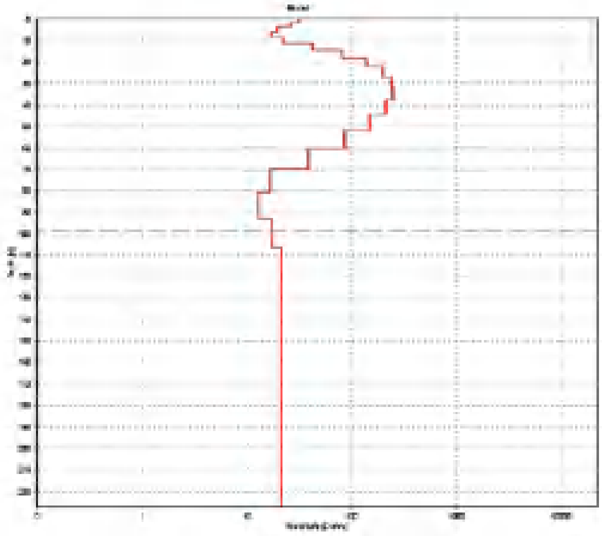


MT_20

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	273305
UTMY:	2354340
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.5
No. of Layers:	20
DOI:	98m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	32	99.00	1.74	1.001	1.74	1.001
2	28.4	1.42	1.97	1.001	3.71	1.001
3	19.7	1.48	2.22	1.001	5.93	1.001
4	16.9	1.44	2.51	1.001	8.44	1.000
5	22.5	1.42	2.83	1.001	11.3	1.000
6	42.3	1.57	3.2	1.001	14.5	1.000
7	82.1	1.71	3.61	1.001	18.1	1.000
8	140	1.82	4.07	1.001	22.1	1.000
9	302	1.90	4.6	1.001	26.7	1.000
10	345	1.94	5.18	1.001	31.9	1.000
11	270	1.94	5.86	1.001	37.8	1.000
12	213	1.91	6.62	1.001	44.4	1.000
13	150	1.85	7.47	1.001	51.9	1.000
14	84.7	1.79	8.44	1.001	60.3	1.000
15	38.6	1.88	9.52	1.001	69.9	1.000
16	16.6	2.45	10.8	1.001	80.6	1.000
17	12.8	3.96	12.1	1.001	92.8	1.000
18	17.5	2.00	13.7	1.001	106	1.000
19	21.6	2.67	15.5	1.001	122	1.000
20	21.6	3.33				

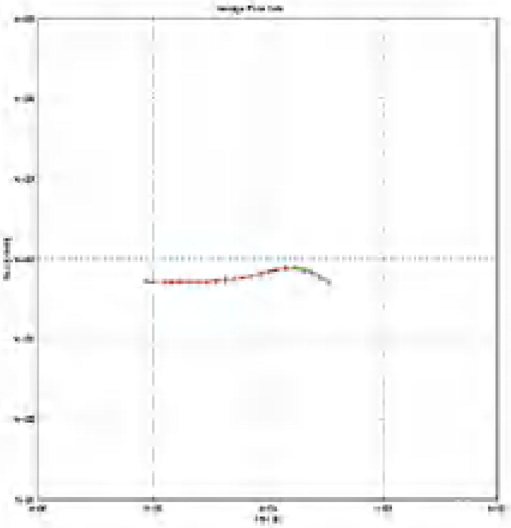


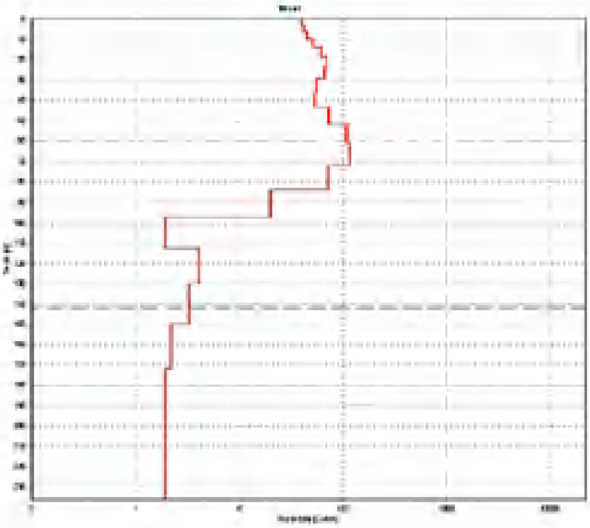


MT_21

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	261358
UTMY:	2352978
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	142m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res:STD	Thk	Thk:STD	Dep	Dep:STD
1	40.3	99.00	2.81	1.001	1.81	1.001
2	42.1	1.40	3.18	1.001	5.99	1.001
3	45.1	1.51	3.59	1.001	8.57	1.001
4	51.6	1.47	4.05	1.001	13.6	1.000
5	82	1.47	4.57	1.001	18.2	1.000
6	70.1	1.52	5.16	1.001	23.4	1.000
7	87.7	1.51	5.83	1.001	29.2	1.000
8	57.1	1.44	6.58	1.001	35.8	1.000
9	53.7	1.42	7.43	1.001	43.2	1.000
10	74	1.48	8.38	1.001	51.6	1.000
11	109	1.56	9.47	1.001	61	1.000
12	116	1.71	10.7	1.001	71.7	1.000
13	72.1	1.94	12.1	1.001	83.8	1.000
14	20.3	2.10	13.6	1.001	97.4	1.000
15	1.89	1.28	15.4	1.001	113	1.000
16	4.1	1.40	17.4	1.001	130	1.000
17	3.3	4.71	19.6	1.001	150	1.000
18	2.16	2.00	22.1	1.001	172	1.000
19	1.82	2.87	25	1.001	197	1.000
20	1.82	4.82				

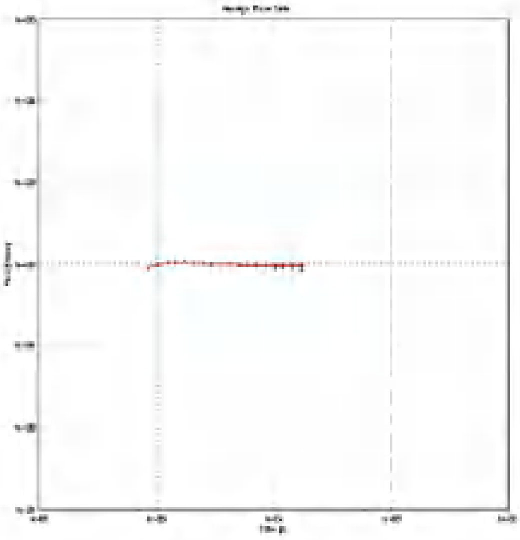


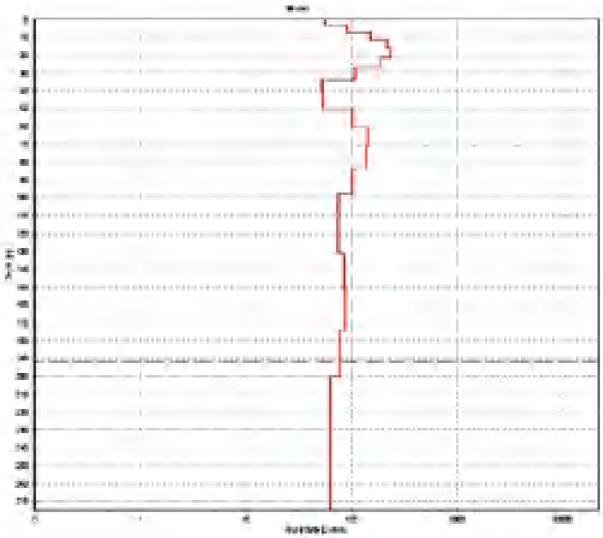


MT_22

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	263671
UTMY:	2352440
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	192m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	RhoSTD	Thk	ThkSTD	Dep	DepSTD
1	58.1	99.00	3.27	1.001	3.27	1.001
2	90.6	1.46	3.69	1.001	6.97	1.001
3	155	1.46	4.17	1.001	11.1	1.001
4	220	1.71	4.71	1.001	15.8	1.000
5	238	1.61	5.32	1.001	21.1	1.000
6	190	1.56	6	1.001	27.1	1.000
7	108	1.47	6.78	1.001	33.9	1.000
8	52.1	1.35	7.65	1.001	41.6	1.000
9	54.6	1.32	8.64	1.001	50.2	1.000
10	102	1.45	9.75	1.001	60	1.000
11	145	1.48	11	1.001	71	1.000
12	139	1.46	12.4	1.001	83.4	1.000
13	101	1.44	14	1.001	97.5	1.000
14	75.1	1.38	15.8	1.001	113	1.000
15	74.7	1.45	17.9	1.001	131	1.000
16	84.7	1.07	20.2	1.001	151	1.000
17	88.9	99.00	22.8	1.001	174	1.000
18	76.9	99.00	25.7	1.001	200	1.000
19	63.4	99.00	29.1	1.001	229	1.000
20	63.4	99.00				

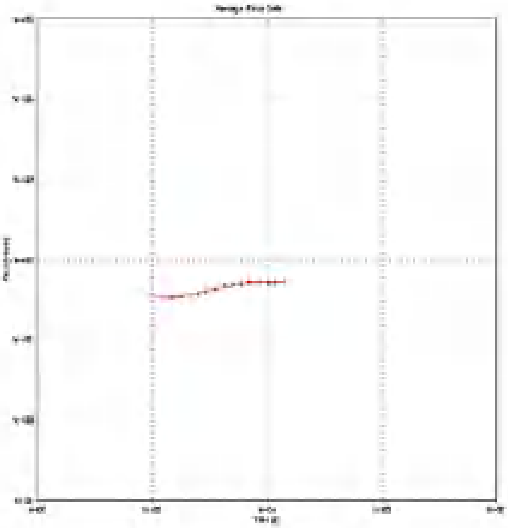


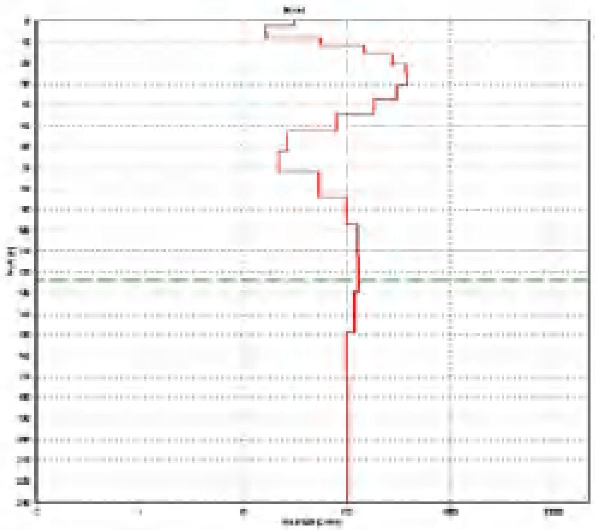


MT_23

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	264513
UTMY:	2353619
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.6
No. of Layers:	20
DOI:	124m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	31	99.00	2.43	1.001	2.43	1.001
2	16.4	1.31	2.74	1.001	5.17	1.001
3	16.5	1.39	3.1	1.001	8.27	1.001
4	56.8	1.52	3.5	1.001	11.8	1.000
5	132	1.75	3.93	1.001	15.7	1.000
6	278	1.91	4.46	1.001	20.2	1.000
7	374	1.99	5.03	1.001	25.2	1.000
8	388	1.99	5.68	1.001	30.9	1.000
9	312	1.92	6.41	1.001	37.3	1.000
10	188	1.78	7.24	1.001	44.5	1.000
11	80.8	1.58	8.17	1.001	52.7	1.000
12	27.1	1.38	9.23	1.001	61.9	1.000
13	32.7	1.34	10.4	1.001	72.4	1.000
14	54.4	1.53	11.8	1.001	84.1	1.000
15	100	1.90	13.3	1.001	97.4	1.000
16	130	2.81	15	1.001	112	1.000
17	133	3.80	16.9	1.001	129	1.000
18	117	4.50	19.1	1.001	148	1.000
19	100	5.24	21.6	1.001	170	1.000
20	103	6.02				

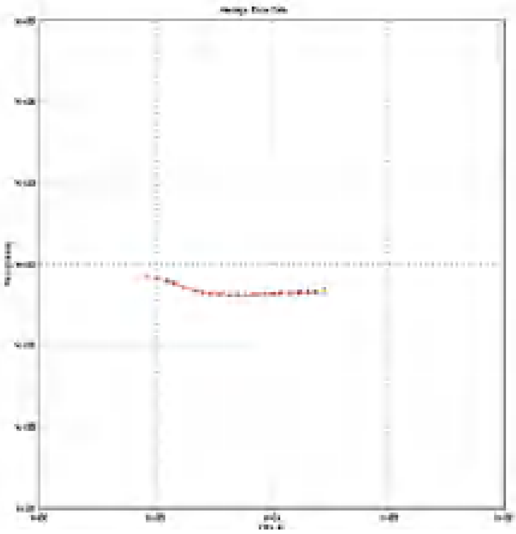


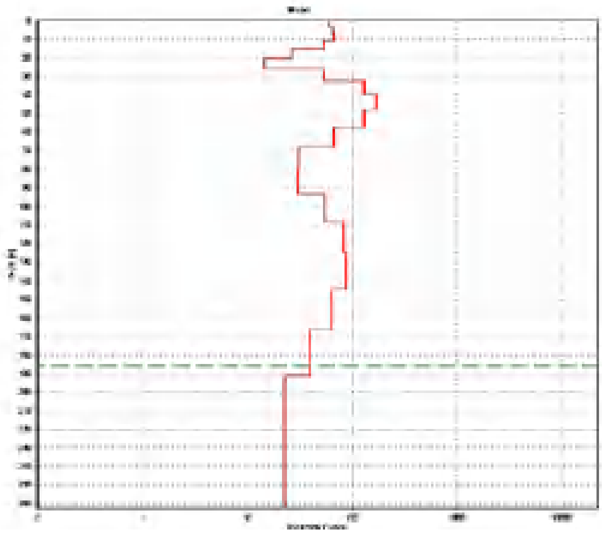


MT_24

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	267230
UTMY:	2353130
EPSG:	32644--UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	186m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	60.8	99.00	3.13	1.001	3.13	1.001
2	65.5	1.41	3.53	1.001	6.66	1.001
3	67.8	1.55	3.99	1.001	10.6	1.001
4	54.8	1.47	4.5	1.001	15.1	1.000
5	27.1	1.30	5.08	1.001	20.2	1.000
6	14.8	1.17	5.74	1.001	26	1.000
7	53.9	1.46	6.48	1.001	32.4	1.000
8	132	1.61	7.31	1.001	39.8	1.000
9	173	1.67	8.26	1.001	48	1.000
10	133	1.64	9.33	1.001	57.3	1.000
11	67.3	1.52	10.5	1.001	67.8	1.000
12	31.4	1.36	11.9	1.001	79.7	1.000
13	30.7	1.39	13.4	1.001	93.1	1.000
14	54.9	1.52	15.1	1.001	108	1.000
15	83.4	1.74	17.1	1.001	125	1.000
16	86.6	2.39	19.3	1.001	145	1.000
17	64.2	3.88	21.8	1.001	166	1.000
18	39.4	4.58	24.6	1.001	191	1.000
19	23	5.33	27.8	1.001	219	1.000
20	23	6.12				

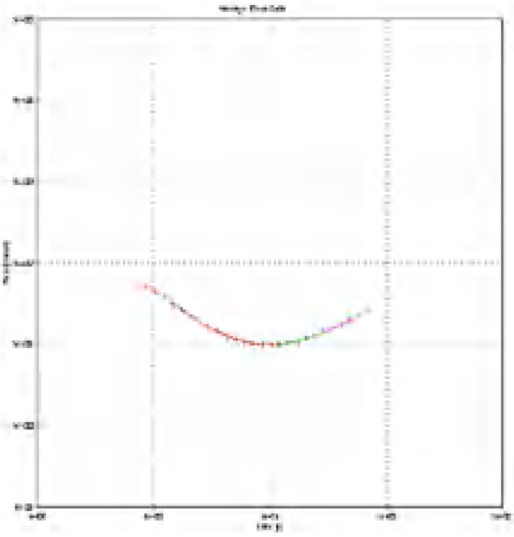


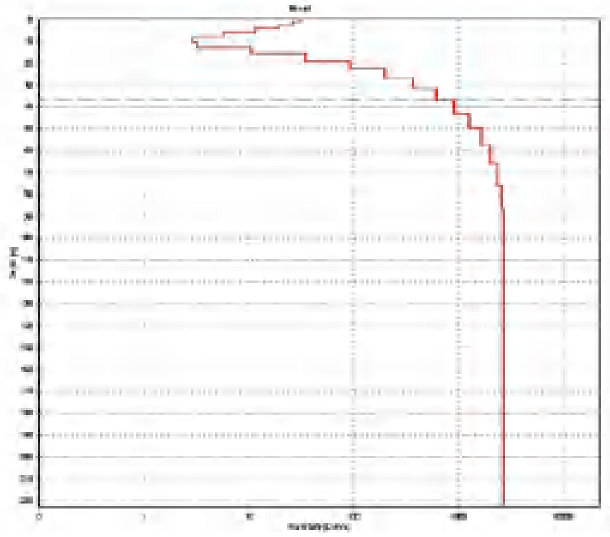


MT_25

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	270257
UTMY:	2352577
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	37m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	30.4	99.00	1.24	1.001	1.24	1.001
2	26.3	1.50	1.4	1.001	2.64	1.001
3	19.2	1.50	1.58	1.001	4.22	1.001
4	11.5	1.52	1.79	1.001	6.01	1.000
5	5.73	1.38	2.02	1.001	8.03	1.000
6	2.94	1.24	2.28	1.001	10.3	1.000
7	3.22	1.22	2.57	1.001	12.9	1.000
8	10.5	1.43	2.9	1.001	15.8	1.000
9	35	1.66	3.28	1.001	19	1.000
10	92.3	1.83	3.7	1.001	22.7	1.000
11	190	2.14	4.18	1.001	26.9	1.000
12	367	2.53	4.71	1.001	31.6	1.000
13	605	2.99	5.32	1.001	37	1.000
14	912	3.53	6.01	1.001	43	1.000
15	1.27E003	4.13	6.78	1.001	49.7	1.000
16	1.66E003	4.80	7.66	1.001	57.4	1.000
17	2.05E003	5.54	8.65	1.001	66.1	1.000
18	2.37E003	6.34	9.76	1.001	75.8	1.000
19	2.6E003	7.19	11	1.001	86.8	1.000
20	2.71E003	8.09				

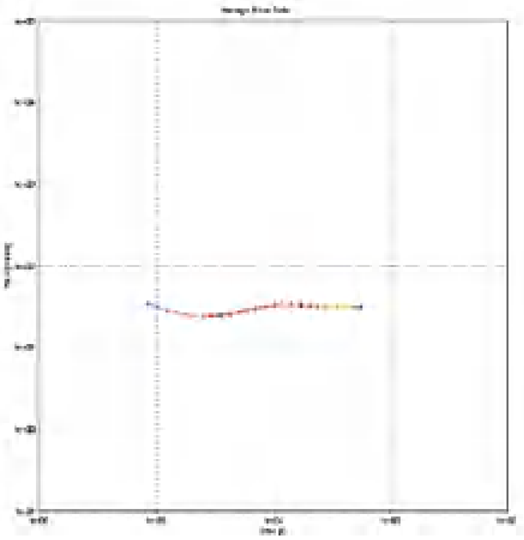


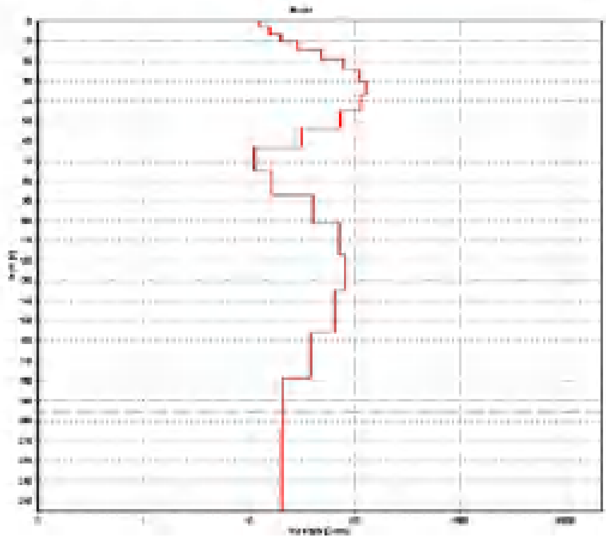


MT_26

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	273782
UTMY:	2355809
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	195m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	12.6	1.20	2.92	1.001	2.92	1.001
2	15.5	1.30	3.3	1.004	6.22	1.001
3	30.1	1.36	3.72	1.004	9.94	1.001
4	29.2	1.44	4.2	1.004	14.1	1.000
5	48.4	1.53	4.79	1.001	18.9	1.000
6	79	1.60	5.36	1.001	24.2	1.000
7	111	1.67	6.05	1.001	30.3	1.000
8	127	1.72	6.83	1.001	37.1	1.000
9	113	1.70	7.71	1.001	44.8	1.000
10	72.8	1.62	8.7	1.001	53.5	1.000
11	22	1.48	9.82	1.001	63.4	1.000
12	11.2	1.26	11.1	1.001	74.5	1.000
13	16.1	1.37	12.5	1.001	87	1.000
14	41.1	1.53	14.1	1.001	101	1.000
15	71.6	1.70	16	1.001	117	1.000
16	81.9	2.08	18	1.001	135	1.000
17	65.3	2.90	20.3	1.001	155	1.000
18	38.9	3.56	23	1.001	178	1.000
19	21.1	4.25	25.9	1.001	204	1.000
20	20.8	4.97				

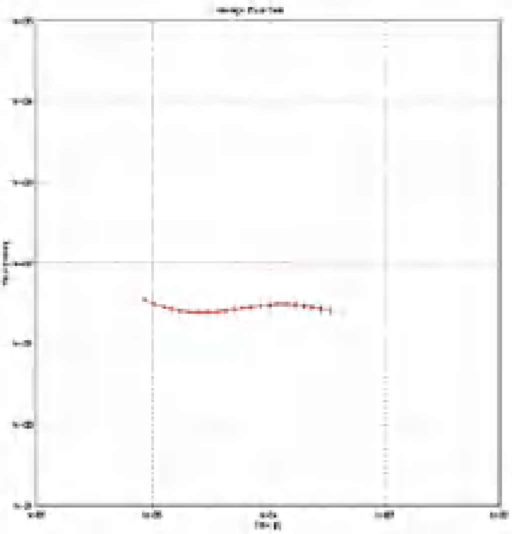


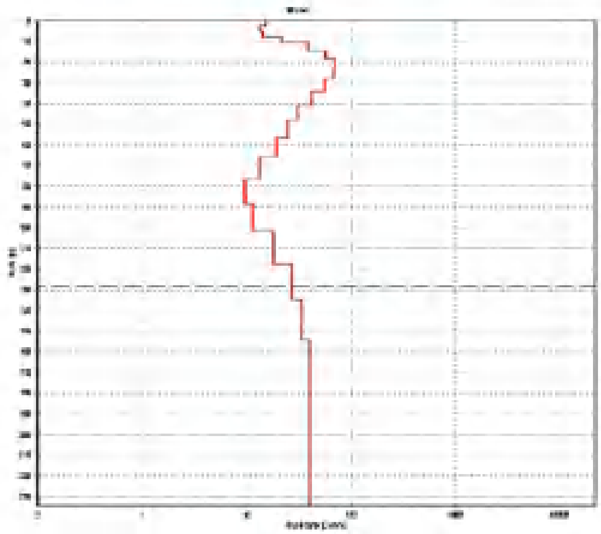


MT_27

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	289773
UTMY:	2346060
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	128m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	15.2	1.34	2.21	1.001	2.21	1.001
2	13.3	1.38	2.49	1.001	4.7	1.001
3	14.1	1.38	2.82	1.001	7.52	1.001
4	22.2	1.42	3.18	1.001	10.7	1.000
5	38.7	1.57	3.59	1.001	14.3	1.000
6	57.8	1.84	4.05	1.001	18.3	1.000
7	69.5	1.84	4.57	1.001	22.9	1.000
8	60.3	1.82	5.16	1.001	28.1	1.000
9	56.9	1.59	5.83	1.001	33.9	1.000
10	42.8	1.54	6.58	1.001	40.5	1.000
11	31.5	1.40	7.43	1.001	47.9	1.000
12	24.9	1.47	8.39	1.001	56.3	1.000
13	18.7	1.46	9.47	1.001	65.8	1.000
14	13.5	1.37	10.7	1.001	76.5	1.000
15	9.56	1.34	12.1	1.001	88.5	1.000
16	11.5	1.52	13.6	1.001	102	1.000
17	18.5	2.95	15.4	1.001	118	1.000
18	27.8	3.00	17.4	1.001	135	1.000
19	33.9	2.67	19.6	1.001	155	1.000
20	40.8	8.82				

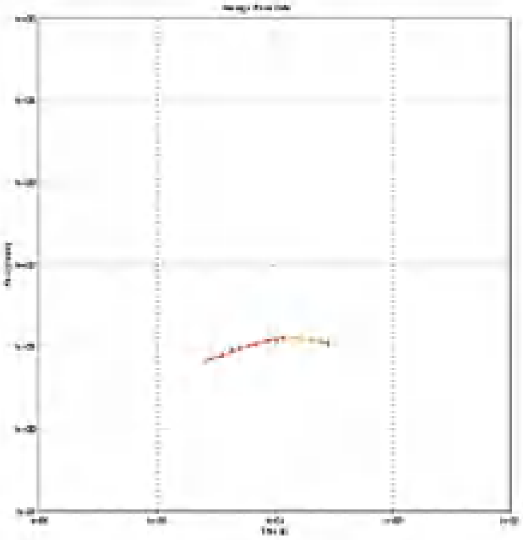


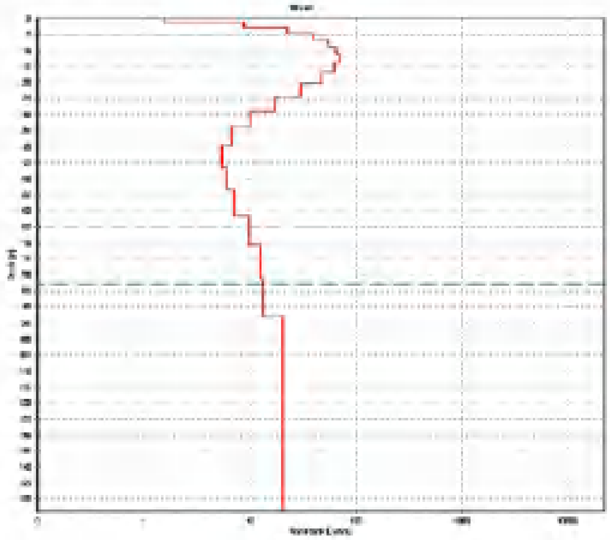


MT_27.1

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	289719
UTMY:	2346020
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.7
No. of Layers:	20
DOI:	83m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	1.52	99.00	1.33	1.001	1.33	1.001
2	8.87	1.60	1.5	1.001	2.83	1.001
3	23	1.76	1.7	1.001	4.53	1.001
4	39.9	1.82	1.91	1.001	6.44	1.000
5	55.5	1.85	2.18	1.001	8.6	1.000
6	66.5	1.88	2.44	1.001	11	1.000
7	69.9	1.90	2.75	1.001	13.8	1.000
8	62.7	1.88	3.11	1.001	16.9	1.000
9	47.5	1.84	3.51	1.001	20.4	1.000
10	30.5	1.73	3.96	1.001	24.4	1.000
11	17.2	1.57	4.47	1.001	28.8	1.000
12	10.1	1.42	5.05	1.001	33.9	1.000
13	6.74	1.37	5.7	1.001	39.6	1.000
14	5.40	1.34	6.44	1.001	46	1.000
15	6.33	1.35	7.27	1.001	53.3	1.000
16	7.35	1.36	8.21	1.001	61.5	1.000
17	9.79	99.00	9.27	1.001	70.8	1.000
18	12.5	2.00	10.5	1.001	81.2	1.000
19	15.2	2.67	11.8	1.001	93	1.000
20	20.8	3.32				

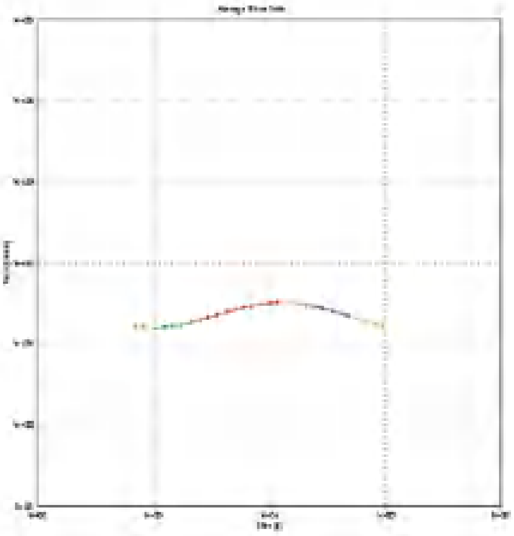


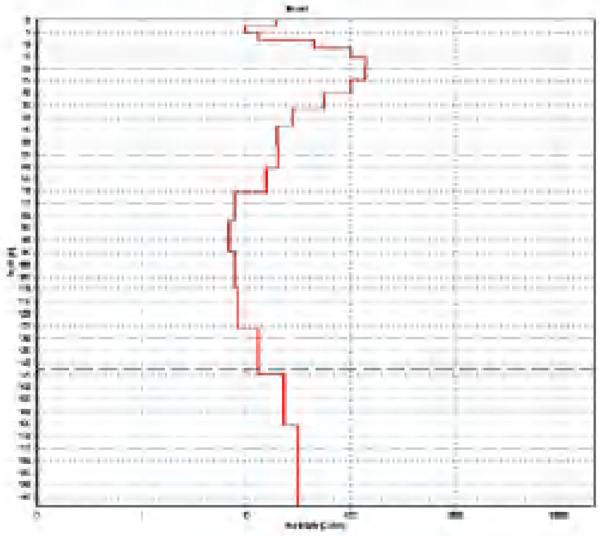


MT_27.2

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	289719
UTMY:	2346020
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.5
No. of Layers:	20
DOI:	143m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res-STD	Thk	Thk-STD	Dep	DepSTD
1	19.8	99.00	2.38	1.001	2.38	1.001
2	9.93	1.31	2.67	1.001	5.03	1.001
3	13.1	1.28	3.01	1.001	8.05	1.001
4	41	1.53	3.4	1.001	11.4	1.000
5	101	1.66	3.84	1.001	15.3	1.000
6	145	1.78	4.34	1.001	19.6	1.000
7	142	1.75	4.9	1.001	24.5	1.000
8	101	1.68	5.53	1.001	30.1	1.000
9	51.9	1.57	6.24	1.001	36.3	1.000
10	28.4	1.43	7.05	1.001	43.3	1.000
11	20.4	1.38	7.95	1.001	51.3	1.000
12	20.6	1.44	8.98	1.001	60.3	1.000
13	11.5	1.38	10.1	1.001	70.4	1.000
14	7.97	1.46	11.4	1.001	81.9	1.000
15	8.93	1.29	12.9	1.001	94.8	1.000
16	7.98	1.91	14.6	1.001	109	1.000
17	8.52	4.14	16.5	1.001	126	1.000
18	13.1	2.00	18.6	1.001	144	1.000
19	22.3	2.87	21	1.001	165	1.000
20	32.1	3.32				

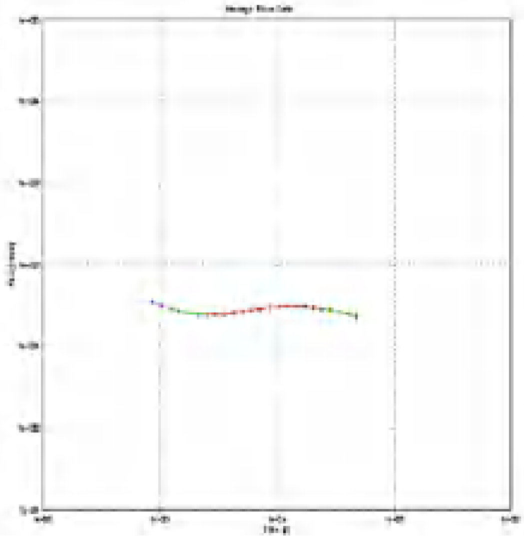


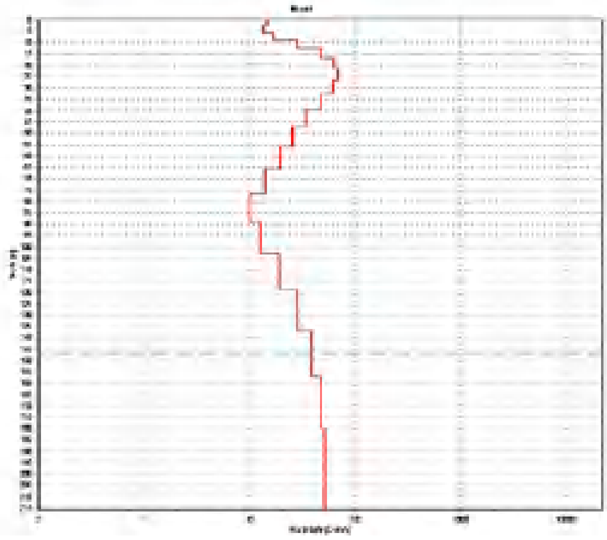


MT_27.3

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	289719
UTMY:	2346020
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	147m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	14.5	99.00	2.57	1.001	2.57	1.001
2	13.3	1.37	2.9	1.001	5.47	1.001
3	16.9	1.36	3.28	1.001	8.75	1.001
4	28.4	1.48	3.7	1.001	12.5	1.000
5	47	1.57	4.18	1.001	16.6	1.000
6	65.5	1.60	4.72	1.001	21.3	1.000
7	68.9	1.60	5.32	1.001	26.7	1.000
8	61.5	1.58	6.01	1.001	32.7	1.000
9	47.4	1.54	6.79	1.001	39.5	1.000
10	34.3	1.49	7.68	1.001	47.1	1.000
11	25.8	1.44	8.65	1.001	55.8	1.000
12	19.9	1.38	9.77	1.001	65.5	1.000
13	13.8	1.31	11	1.001	76.6	1.000
14	10.2	1.30	12.4	1.001	89	1.000
15	12.4	1.34	14.1	1.001	103	1.000
16	19.3	1.34	15.9	1.001	119	1.000
17	28.6	99.00	17.9	1.001	137	1.000
18	38.9	99.00	20.2	1.001	157	1.000
19	47.4	99.00	22.8	1.001	180	1.000
20	51.8	99.00				

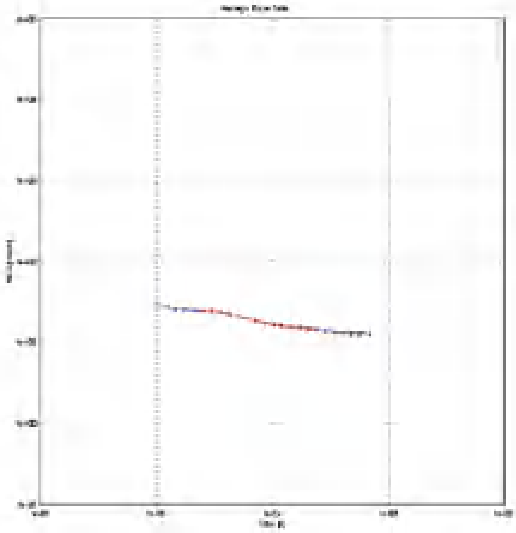


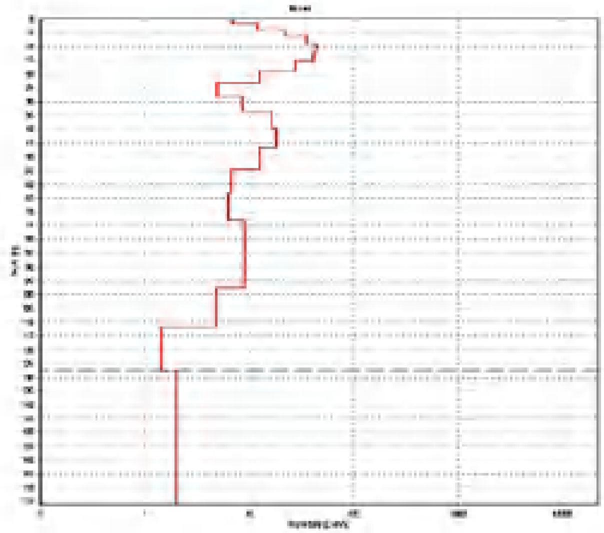


MT_28

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	287585
UTMY:	2346707
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	127m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res STD	Thk	ThkSTD	Dep	DepSTD
1	7	99.00	1.83	1.001	1.83	1.001
2	17	1.45	2.06	1.001	3.89	1.001
3	22.4	1.51	2.33	1.001	6.22	1.001
4	35.8	1.58	2.63	1.001	8.85	1.000
5	44.8	1.68	2.97	1.001	11.8	1.000
6	42	1.84	3.35	1.001	15.2	1.000
7	27.9	1.58	3.78	1.001	19	1.000
8	12.5	1.41	4.27	1.001	23.2	1.000
9	5.02	1.24	4.82	1.001	28	1.000
10	8.59	1.38	5.45	1.001	33.5	1.000
11	16.3	1.49	6.15	1.001	39.6	1.000
12	18.4	1.58	6.94	1.001	46.6	1.000
13	12.5	1.53	7.84	1.001	54.4	1.000
14	6.74	1.34	8.85	1.001	63.3	1.000
15	6.38	1.54	9.99	1.001	73.3	1.000
16	6.06	1.54	11.3	1.001	84.5	1.000
17	6.05	5.48	12.7	1.001	97.2	1.000
18	4.94	8.23	14.4	1.001	112	1.000
19	1.44	7.07	16.2	1.001	128	1.000
20	1.80	7.97				

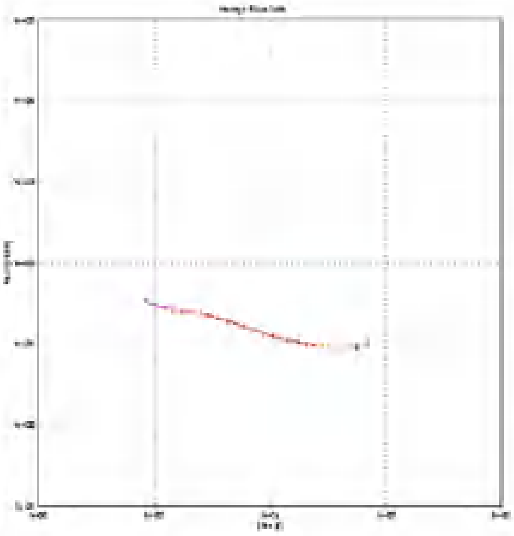


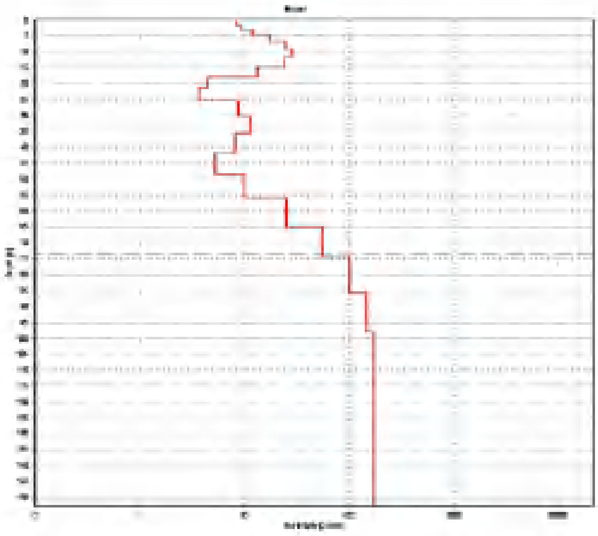


MT_28.1

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	287602
UTMY:	2346732
EPSG:	32644–UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.5
No. of Layers:	20
DOI:	74m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res STD	Thk	Thk STD	Dep	Dep STD
1	8.42	99.00	1.4	1.001	1.4	1.000
2	9.25	1.41	1.58	1.001	2.98	1.000
3	12.1	1.58	1.79	1.001	4.77	1.000
4	17.8	1.58	2.02	1.001	6.79	1.000
5	25.1	1.57	2.28	1.001	9.08	1.000
6	29.1	1.63	2.57	1.001	11.6	1.000
7	24.5	1.60	2.9	1.001	14.5	1.000
8	13.3	1.47	3.28	1.001	17.8	1.000
9	4.43	1.27	3.7	1.001	21.5	1.000
10	3.78	1.25	4.18	1.001	25.7	1.000
11	8.77	1.45	4.72	1.001	30.4	1.000
12	11.5	1.46	5.32	1.001	35.7	1.000
13	8.33	1.43	6.01	1.001	41.7	1.000
14	5.35	1.36	6.79	1.001	48.5	1.000
15	10.1	1.44	7.66	1.001	56.2	1.000
16	23.8	1.96	8.65	1.001	64.8	1.000
17	58.1	3.25	9.77	1.001	74.6	1.000
18	102	3.92	11	1.001	85.6	1.000
19	151	4.63	12.4	1.001	98.1	1.000
20	177	5.38				

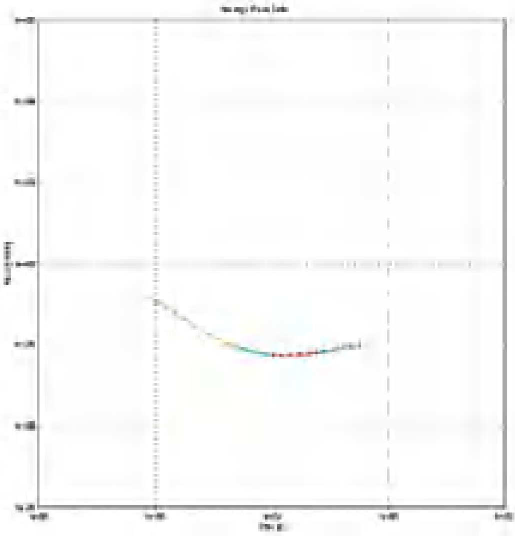


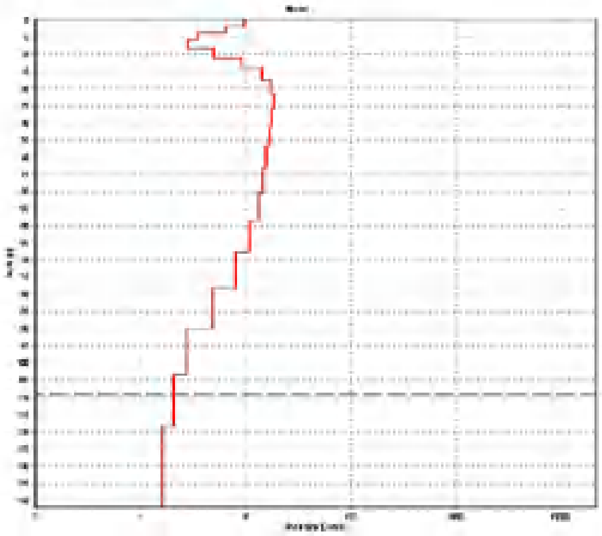


MT_29

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	284815
UTMY:	2348107
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.913E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	109m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	Res STD	Thk	Thk STD	Dep	Dep STD
1	9.61	99.06	1.69	1.001	1.69	1.001
2	6.54	1.38	1.91	1.001	3.6	1.001
3	3.52	1.30	2.16	1.001	5.76	1.001
4	2.85	1.38	2.43	1.001	8.19	1.000
5	5.02	1.38	2.75	1.001	10.9	1.000
6	9.27	1.47	3.1	1.001	14	1.000
7	14.1	1.55	3.5	1.001	17.5	1.000
8	17.6	1.81	3.96	1.001	21.5	1.000
9	18.9	1.85	4.47	1.001	26	1.000
10	18.3	1.85	5.06	1.001	31	1.000
11	16.9	1.80	5.69	1.001	36.7	1.000
12	15.6	1.58	6.43	1.001	43.1	1.000
13	14.5	1.81	7.26	1.001	50.4	1.000
14	13.2	1.80	8.19	1.001	58.6	1.000
15	11.1	1.59	9.25	1.001	67.8	1.000
16	8.07	1.82	10.4	1.001	78.3	1.000
17	4.88	3.49	11.8	1.001	90.1	1.000
18	2.77	4.17	13.3	1.001	103	1.000
19	2.02	4.89	15	1.001	118	1.000
20	1.82	5.66				

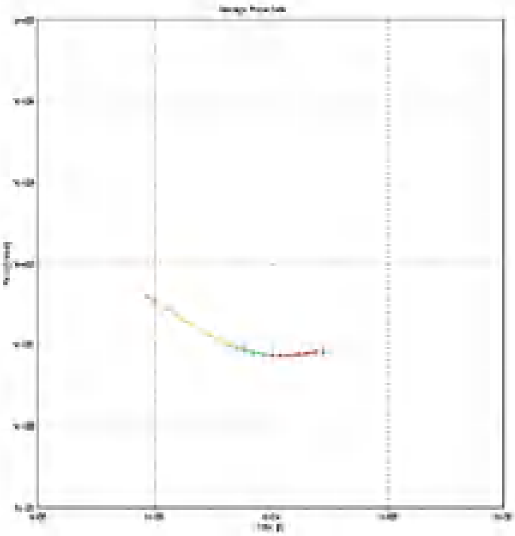


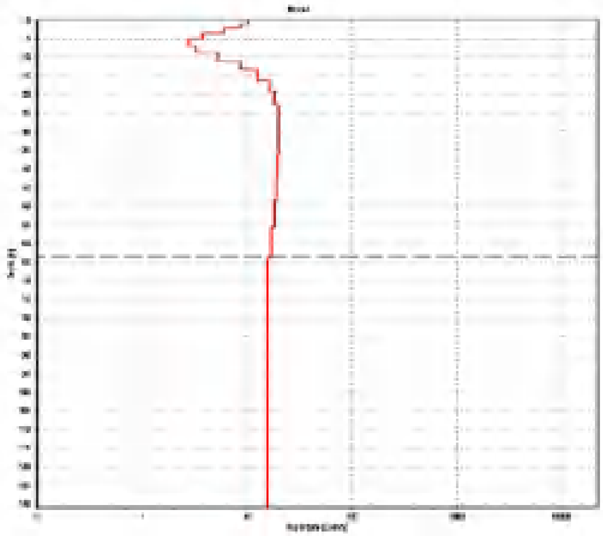


MT_29.1

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	284852
UTMY:	2348042
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.2
No. of Layers:	20
DOI:	63m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	10.2	1.69	1.04	1.001	1.04	1.001
2	8.57	1.43	1.18	1.001	2.22	1.001
3	6.07	1.40	1.33	1.001	3.55	1.001
4	3.87	1.44	1.5	1.001	5.06	1.000
5	2.81	1.32	1.7	1.001	6.75	1.000
6	3.27	1.38	1.92	1.001	8.67	1.000
7	5.3	1.44	2.18	1.001	10.8	1.000
8	8.65	1.53	2.44	1.001	13.3	1.000
9	12.6	1.60	2.78	1.001	16	1.000
10	16.2	1.65	3.11	1.001	19.1	1.000
11	18.7	1.70	3.51	1.001	22.7	1.000
12	20.1	1.74	3.97	1.001	26.6	1.000
13	20.4	1.74	4.48	1.001	31.1	1.000
14	20.2	1.70	5.06	1.001	36.2	1.000
15	19.8	1.70	5.71	1.001	41.9	1.000
16	19.2	2.08	6.45	1.001	48.3	1.000
17	18.4	2.98	7.28	1.001	55.6	1.000
18	17.1	3.62	8.22	1.001	63.8	1.000
19	15.4	4.32	9.28	1.001	73.1	1.000
20	15.4	5.04				

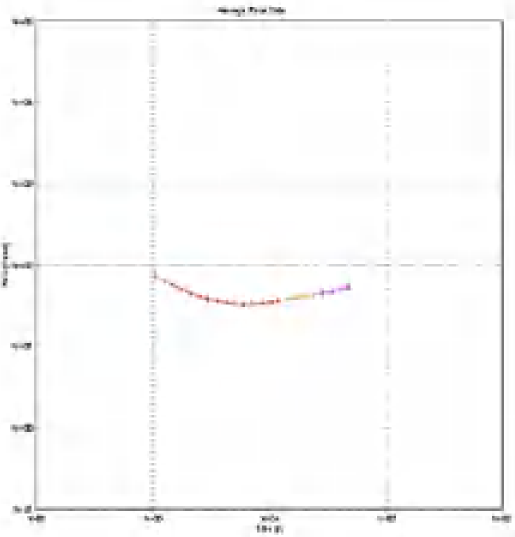


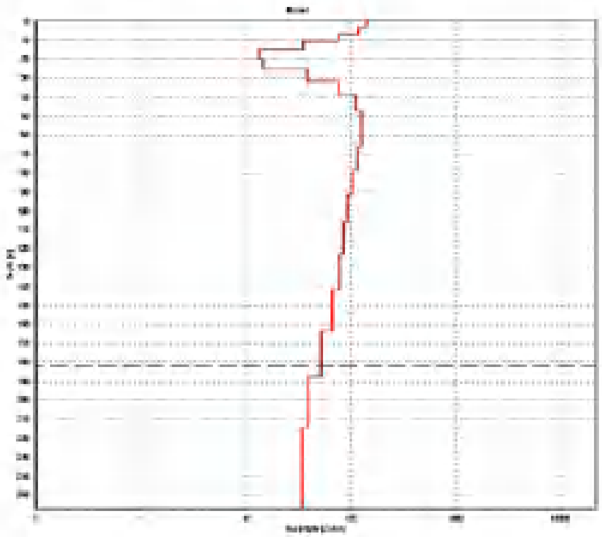


MT_29.2

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	284852
UTMY:	2348042
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.365E-04 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	182m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	145	99.00	3.07	1.001	3.07	1.001
2	119	1.69	3.46	1.001	6.53	1.001
3	78.3	1.50	3.91	1.001	10.4	1.001
4	35.6	1.47	4.41	1.001	14.8	1.000
5	13.2	1.28	4.98	1.001	19.8	1.000
6	14.6	1.29	5.63	1.001	25.5	1.000
7	38.5	1.45	6.25	1.001	31.8	1.000
8	78.6	1.63	7.17	1.001	39	1.000
9	131	1.75	8.09	1.001	47.1	1.000
10	127	1.79	9.14	1.001	56.2	1.000
11	127	1.66	10.3	1.001	66.5	1.000
12	117	1.81	11.6	1.001	78.2	1.000
13	105	2.17	13.1	1.001	91.3	1.000
14	94.2	2.32	14.8	1.000	106	1.000
15	86.1	1.79	16.8	1.001	123	1.000
16	78	2.24	18.9	1.001	142	1.000
17	67.1	99.00	21.4	1.001	163	1.000
18	52.9	99.00	24.1	1.001	187	1.000
19	36.8	99.00	27.2	1.001	215	1.000
20	35.2	99.00				

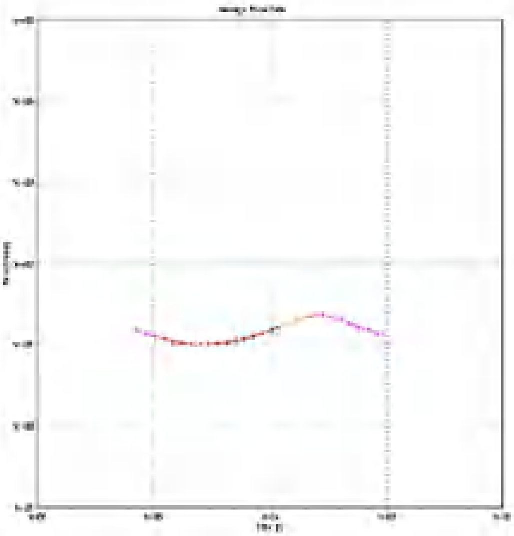


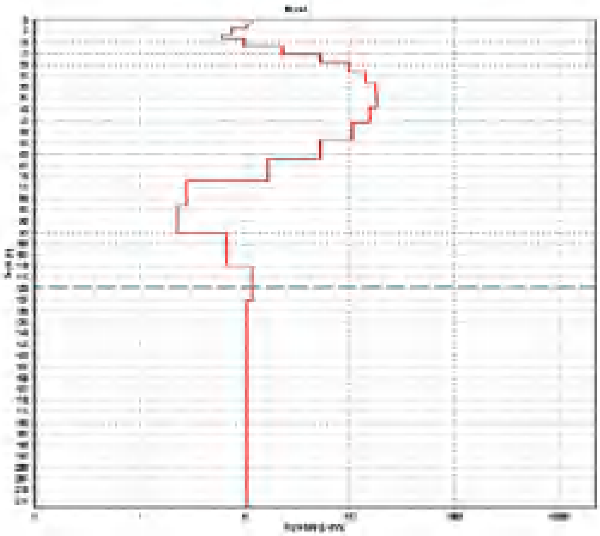


MT_30

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	280683
UTMY:	2347891
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	119m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	11.7	99.00	1.79	1.001	1.79	1.001
2	10.5	1.41	2.02	1.001	3.82	1.001
3	7.61	1.49	2.29	1.001	6.1	1.001
4	6.96	1.28	2.58	1.001	8.68	1.000
5	9.78	1.44	2.91	1.001	11.6	1.000
6	23.8	1.71	3.29	1.001	14.9	1.000
7	53.1	1.78	3.71	1.001	18.6	1.000
8	97.5	1.80	4.19	1.001	22.8	1.000
9	146	2.27	4.73	1.001	27.5	1.000
10	180	3.38	5.34	1.001	32.9	1.000
11	185	5.15	6.03	1.001	38.9	1.000
12	157	7.46	6.81	1.001	45.7	1.000
13	106	9.16	7.69	1.001	53.4	1.000
14	52.6	8.05	8.68	1.001	62.1	1.000
15	18.5	3.49	9.8	1.001	71.9	1.000
16	2.98	3.29	11.1	1.001	82.9	1.000
17	2.25	4.21	12.5	1.001	95.4	1.000
18	6.76	2.00	14.1	1.001	110	1.000
19	11.8	2.87	15.9	1.001	125	1.000
20	10.5	3.32				

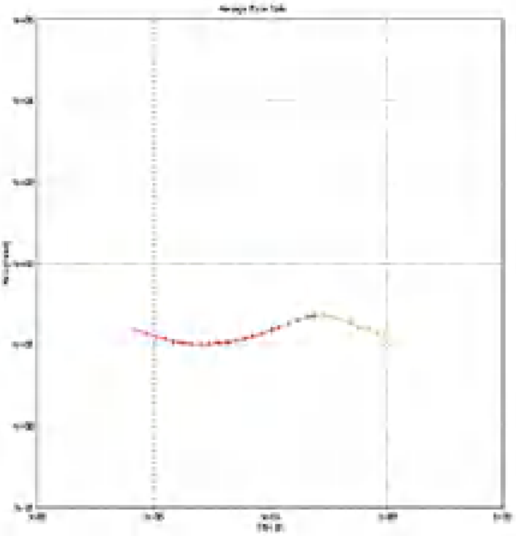


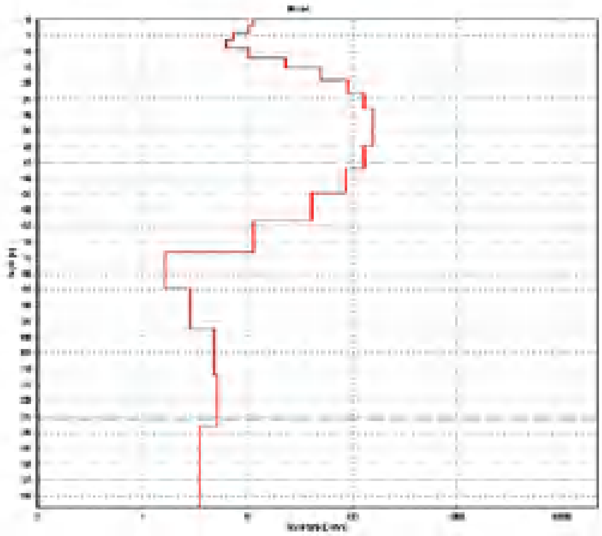


MT_30.1

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	280883
UTMY:	2347891
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.080E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	126m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res.	Res.STD	Thk.	Thk.STD	Dep	Dep.STD
1	11.5	99.00	1.83	1.001	1.83	1.001
2	10.3	1.39	2.07	1.001	3.9	1.001
3	7.47	1.34	2.33	1.001	6.23	1.001
4	6.39	1.28	2.63	1.001	8.86	1.000
5	10.3	1.34	2.97	1.001	11.8	1.000
6	23.7	1.52	3.36	1.001	15.2	1.000
7	51.1	1.76	3.79	1.001	19	1.000
8	94.2	1.88	4.28	1.001	23.3	1.000
9	133	1.90	4.83	1.001	28.1	1.000
10	160	1.93	5.45	1.001	33.5	1.000
11	160	2.12	6.16	1.001	39.7	1.000
12	134	2.53	6.95	1.001	46.7	1.000
13	97.8	3.07	7.85	1.001	54.5	1.000
14	41.3	3.40	8.86	1.001	63.4	1.000
15	11.5	2.84	10	1.001	73.4	1.000
16	1.65	1.57	11.3	1.001	84.7	1.000
17	2.89	4.18	12.8	1.001	97.4	1.000
18	4.9	2.90	14.4	1.001	112	1.000
19	5.58	2.67	16.3	1.001	128	1.000
20	3.5	3.32				

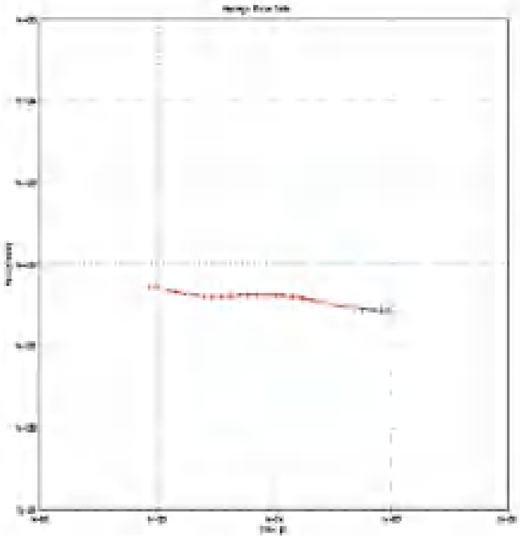


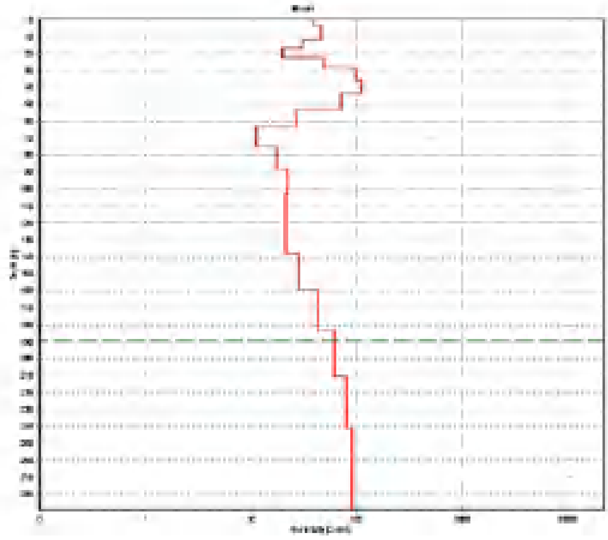


MT_31

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	276653
UTMY:	2347031
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	189m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	39.5	1.35	3.44	1.001	3.44	1.001
2	46.9	1.42	3.89	1.001	7.33	1.001
3	46.6	1.47	4.39	1.001	11.7	1.001
4	31	1.33	4.96	1.001	16.7	1.001
5	30.2	1.27	5.59	1.001	22.3	1.001
6	40.1	1.42	6.32	1.001	28.6	1.001
7	98.1	1.35	7.13	1.001	35.7	1.001
8	112	1.59	8.05	1.001	43.8	1.001
9	71.5	1.51	9.09	1.001	52.9	1.001
10	28.7	1.27	10.3	1.001	63.1	1.001
11	21.2	1.22	11.6	1.001	74.7	1.001
12	17.9	1.40	13.1	1.001	87.8	1.001
13	22.8	1.43	14.8	1.001	103	1.001
14	21.4	1.45	16.7	1.001	119	1.001
15	21.6	1.63	18.8	1.001	138	1.001
16	28.9	1.52	21.3	1.001	159	1.001
17	43.3	3.41	24	1.001	183	1.001
18	62.3	6.30	27.1	1.001	210	1.001
19	80.8	7.04	30.6	1.001	240	1.001
20	90.7	7.68				

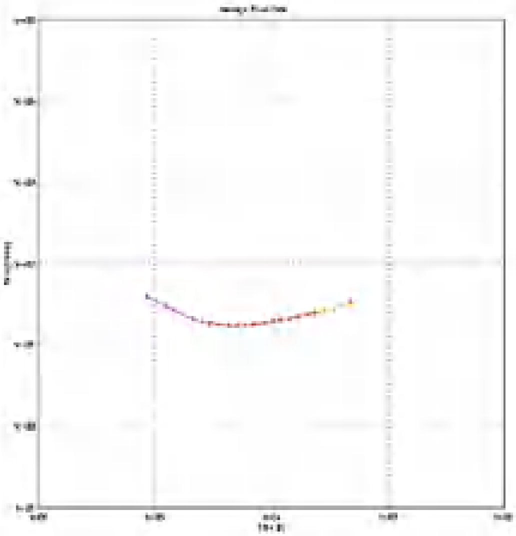


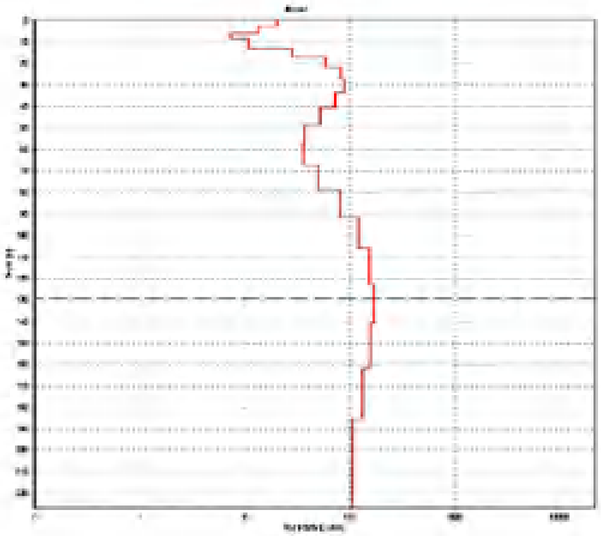


MT_32

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	280119
UTMY:	2345660
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	9.565E-04 sec
Data Residual:	0.4
No. of Layers:	20
DOI:	129m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	20.7	1.40	2.65	1.001	2.65	1.001
2	13.5	1.35	2.99	1.001	5.64	1.001
3	7.33	1.25	3.37	1.001	9.01	1.001
4	10.9	1.33	3.81	1.001	12.8	1.000
5	29	1.49	4.3	1.001	17.1	1.000
6	59	1.62	4.86	1.001	22	1.000
7	84.4	1.71	5.48	1.001	27.5	1.000
8	89.3	1.73	6.19	1.001	33.6	1.000
9	74	1.68	6.99	1.001	40.6	1.000
10	52.3	1.59	7.89	1.001	48.5	1.000
11	37.7	1.51	8.9	1.001	57.4	1.000
12	36.4	1.52	10.1	1.001	67.5	1.000
13	50.9	1.58	11.4	1.001	78.8	1.000
14	81.4	1.66	12.8	1.001	91.6	1.000
15	122	1.80	14.5	1.001	106	1.000
16	158	2.48	16.3	1.001	122	1.000
17	171	3.44	18.4	1.001	141	1.000
18	161	4.12	20.8	1.001	162	1.000
19	135	4.84	23.5	1.001	185	1.000
20	106	5.60				

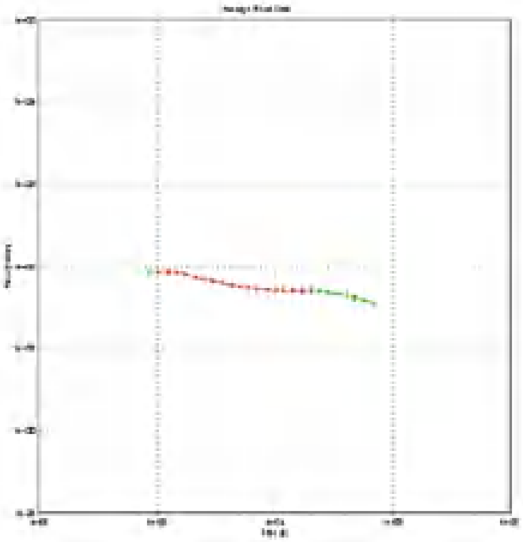


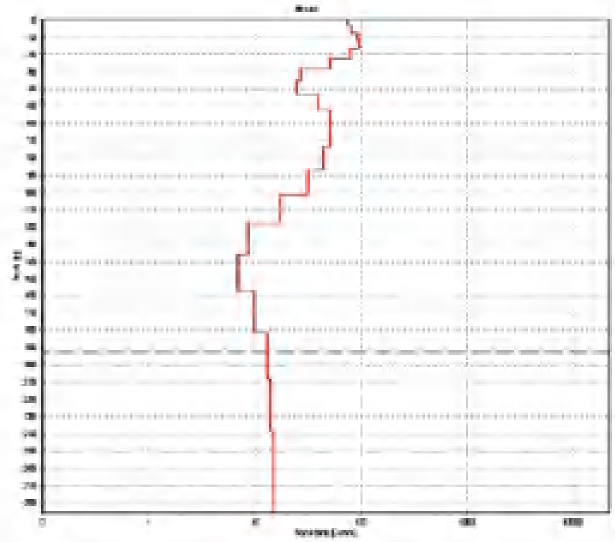


MT_33

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	267670
UTMY:	2356850
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	1.530E-02 sec
Data Residual:	0.5
No. of Layers:	20
DOI:	193m
Program:	ViewTEM.exe, version 1.0.1.19

#	Rho	Rho STD	Thk	Thk STD	Dep	Dep STD
1	74.6	99.00	3.4	1.001	3.4	1.001
2	82.4	1.42	3.84	1.001	7.25	1.001
3	92.3	1.58	4.34	1.001	11.6	1.001
4	95	1.57	4.9	1.001	16.5	1.000
5	80.8	1.48	5.53	1.001	22	1.000
6	51.9	1.39	6.24	1.001	28.3	1.000
7	27.3	1.27	7.05	1.001	35.3	1.000
8	25.1	1.27	7.96	1.001	43.3	1.000
9	39.5	1.37	8.98	1.001	52.2	1.000
10	51.3	1.42	10.1	1.001	62.4	1.000
11	52	1.44	11.5	1.001	73.8	1.000
12	44.3	1.46	12.9	1.001	86.8	1.000
13	31.7	1.52	14.6	1.001	101	1.000
14	17.7	1.61	16.5	1.001	118	1.000
15	8.6	1.36	18.6	1.001	136	1.000
16	6.93	1.40	21	1.001	157	1.000
17	8.74	4.14	23.7	1.001	181	1.000
18	12.9	2.00	26.8	1.001	208	1.000
19	13.9	2.67	30.2	1.001	238	1.000
20	14.9	3.32				

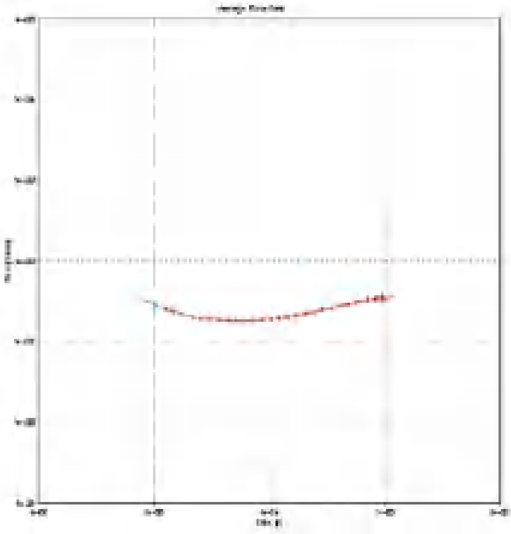


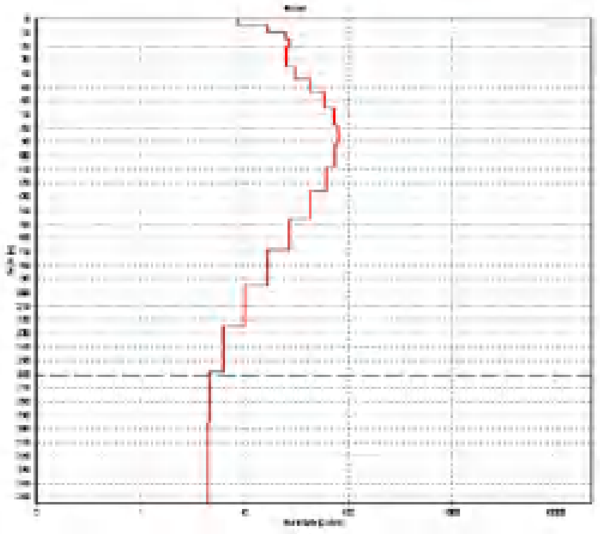


MT_34

Print Date:	02.05.2014
Database Name:	AQMAH.gdb
UTMX:	270749
UTMY:	2355800
EPSG:	32644=UTM Zone 44N (WGS 84)
Number of Data Points:	0 points in use
First Gate:	4.060E-06 sec
Last Gate:	3.826E-03 sec
Data Residual:	0.3
No. of Layers:	20
DOI:	261m
Program:	ViewTEM.exe, version 1.0.1.19

#	Res	ResSTD	Thk	ThkSTD	Dep	DepSTD
1	8.59	99.00	4.22	1.001	4.22	1.001
2	16.5	1.28	4.78	1.001	8.98	1.001
3	23.1	1.38	5.38	1.001	14.4	1.001
4	27.3	1.40	6.07	1.001	20.4	1.000
5	25.5	1.38	6.86	1.001	27.3	1.000
6	25.6	1.40	7.34	1.001	35	1.000
7	31.5	1.44	8.74	1.001	43.8	1.000
8	40.5	1.51	9.87	1.001	53.6	1.000
9	59.2	1.58	11.1	1.001	64.8	1.000
10	73.2	1.67	12.6	1.001	77.3	1.000
11	79.5	1.72	14.2	1.001	91.5	1.000
12	74.9	1.68	16	1.001	108	1.000
13	63.1	1.61	18.1	1.001	126	1.000
14	40.5	1.55	20.4	1.001	146	1.000
15	22.6	1.53	23.1	1.001	169	1.000
16	16.5	1.45	26	1.001	195	1.000
17	10.1	2.99	29.4	1.001	225	1.000
18	6.4	2.00	33.2	1.001	258	1.000
19	4.63	2.87	37.5	1.001	295	1.000
20	4.46	3.32				





ANNEXURE-V: Well wise Salient features of Ground Water Exploration

1. EXPLORATORY WELL DRILLED AT PARDI (DESHMUKH)

Location of Site

The village Pardi lies between north latitude 21°16'40.7" and east longitude 78°46'05" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at about 25 kms from Kalmeshwar on Ramgiri road and the site is located near overhead tank of village.

History of Drilling Operations:

The exploratory well was drilled by DTH cum Rotary rig. The rig unit was shifted on 25/7/13 to well site. The drilling started on 25/7/13 at 1246 hrs and completed on 25/7/13 at 1959 hrs.

Details of Drilling:

a) Rock Formation : Basalt
b) Type : Deccan Traps
c) Total depth drilled : 173.00 m.
d) Drilling started on : 25/7/13 at 1246 hrs
e) Drilling completed on : 25/7/13 at 1959 hrs
f) Total depth drilled in Weathered Formation (with 279.4mm; Button Bit): 6.00 m.
g) Total depth drilled in Hard rock Formation (with 165.1 mm Button Bit):167.00 m.
h) Length of casing : 6.00 m bgl and 0.60 m agl = 6.60 m
i) Diameter of Casing : 203mm (8”)
j) Gauge of casing pipe :7.5mm
k) Material of Casing pipe : M.S. Pipe

Drilling was stopped at Pardi on 25/7/13 at 173 m bgl due to sudden drop of penetration and also due to falling of strata from Collapsible red bole encountered at 87 to 96 m bgl.

Geological Data:

The village Pardi in general comprises of basaltic formation of Deccan traps. Thickness of top soil is 1 m bgl while the thickness of weathered basalt is 6.00 mbgl. The collapsible red bole encountered at 87 to 96 m bgl.

Table1.1: Drill Time log of the Exploratory well drilled at village Pardi, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
25/07/2013	0	5.65	5.65	12.46	13.04	8	1.42
	5.65	11.3	5.65	13.46	13.51	5	0.88
	11.3	16.95	5.65	13.53	14.02	9	1.59
	16.95	22.6	5.65	14.04	14.11	7	1.24
	22.6	28.25	5.65	14.13	14.21	8	1.42
	28.25	33.9	5.65	14.23	14.32	9	1.59
	33.9	39.55	5.65	14.34	14.43	9	1.59
	39.55	45.2	5.65	14.45	14.54	10	1.77
	45.2	50.85	5.65	14.56	15.05	9	1.59
	50.85	56.5	5.65	15.06	15.15	9	1.59
	56.5	62.15	5.65	15.17	15.28	11	1.95
	62.15	67.8	5.65	15.3	15.41	11	1.95
	67.8	73.45	5.65	15.43	15.54	11	1.95

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	73.45	79.1	5.65	15.56	16.04	8	1.42
	79.1	84.75	5.65	16.04	16.18	12	2.12
	84.75	90.4	5.65	16.2	16.29	9	1.59
	90.4	96.05	5.65	16.31	16.41	10	1.77
	96.05	101.7	5.65	16.43	16.52	9	1.59
	101.7	107.35	5.65	16.54	17.04	10	1.77
	107.35	113	5.65	17.06	17.16	10	1.77
	113	118.65	5.65	17.18	17.9	12	2.12
	118.65	124.3	5.65	17.32	17.42	10	1.77
	124.3	129.95	5.65	17.44	17.54	10	1.77
	129.95	135.6	5.65	17.56	18.05	11	1.95
	135.6	141.25	5.65	18.07	18.17	10	1.77
	141.25	146.9	5.65	18.19	18.29	10	1.77
	146.9	152.55	5.65	18.31	18.41	10	1.77
	152.55	158.2	5.65	18.43	18.55	12	2.12
	158.2	163.85	5.65	18.58	19.08	10	1.77
	163.85	169.5	5.65	19.1	19.49	10	2.86
	169.5	173	3.5	19.52	19.59	7	2.00

Table1.2: Consolidated lithological log of the Exploratory well drilled at village Pardi, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	1.5	1.5	Top Soil: Grey mixed with silt and sand grains.
1.5	4.5	3	Basalt: Weathered; brownish grey and black; irregular pebbles.
4.5	19	14.5	Basalt: Fresh; hard; black with irregular chips
19	27	8	Basalt: Vesicular; hard; compact; partially filled with Green Earth Minerals.
27	39	12	Basalt: Massive; fresh; hard and compact with irregular chips.
39	47	8	Basalt: Amygdular; fresh; hard filled with secondary minerals.
47	60	13	Basalt: Massive; fresh; hard and compact with irregular chips.
60	67	7	Basalt: Amygdular; dark, fresh, hard and partially filled with secondary minerals.
67	87.5	20.5	Basalt: Massive; fresh; hard and compact with irregular chips.
87.5	96.05	8.55	Red bole: Red; pure, sticky mixed with friable irregular pebbles.
96.05	101.7	5.65	Basalt: Amygdular, brown, hard mixed with secondary minerals.
101.7	104.7	3	Green bole: green, sticky friable pebbles of 10-15cm, with negligible basalt chips.
104.7	118.65	13.95	Basalt: Amygdular, dark brown, hard fresh mixed/filled with

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
			secondary minerals.
118.7	152	33.35	Basalt: Massive, dark, fresh, compact medium grained with negligible chips.
152	152.55	0.55	**Fractured Basalt:** brown, medium grained mixed with friable chips.Q:0.8 lps
152.6	160	7.45	Basalt: Massive, dark, fresh medium to fine grained
160	161	1	**Fractured Basalt**: brown, medium grained mixed with friable chips;Q:4.30 lps
161	173	12	Basalt: Massive, dark, fresh, compact medium grained with negligible chips.

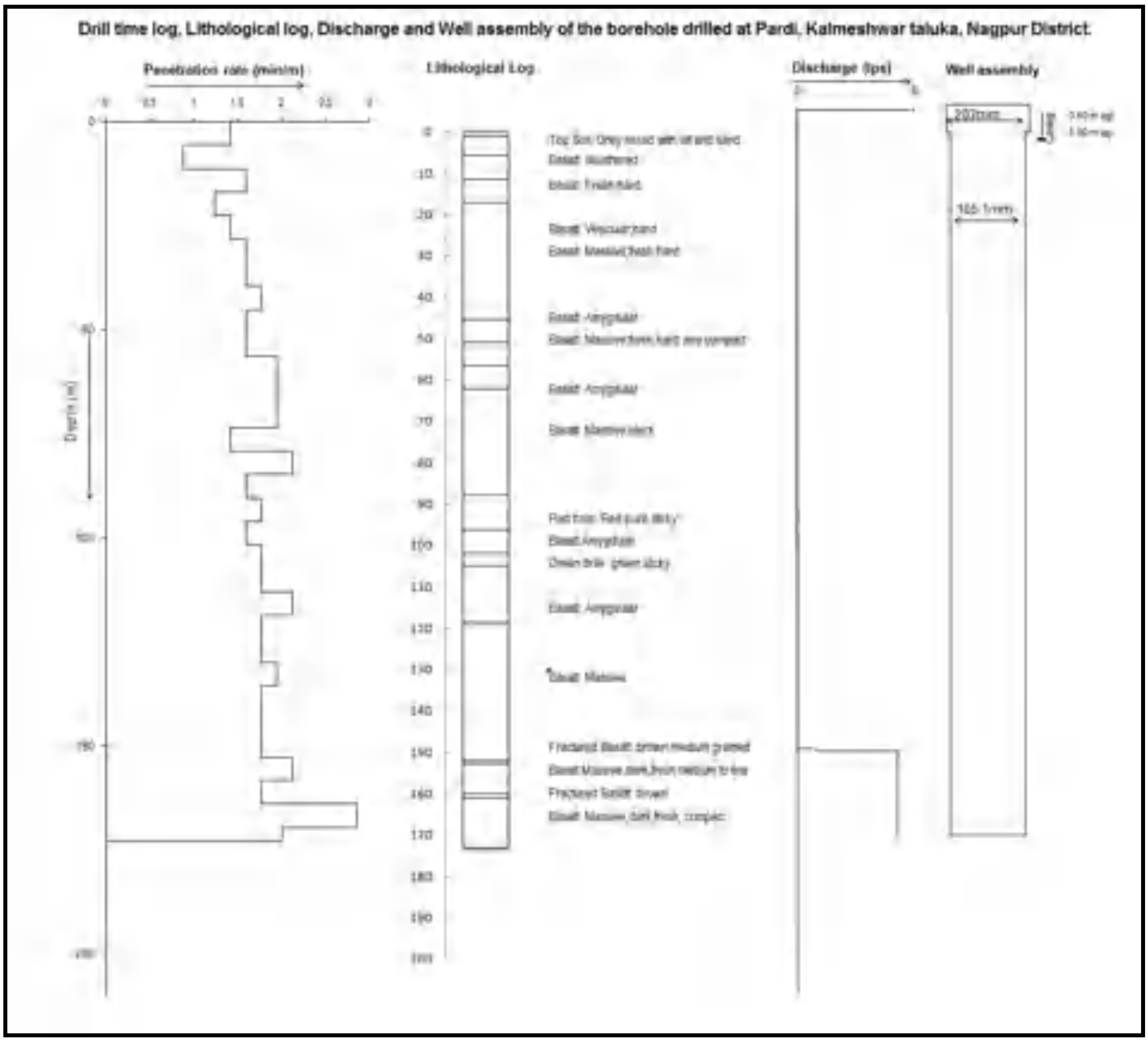


Fig. 1.1: Composite Log of Exploratory Well Drilled at Pardi, Chandrabhaga Watershed (WGKKC-2)

Table1.3: Fracture Zones encountered

S.No	Zones encountered		Cumulative Discharge	Lithology
	From	To		
1	152	152.55	0.8 lps	**Fractured Basalt:** brown, medium grained mixed with friable chips.
2	160	161	4.30 lps	**Fractured Basalt**: brown, medium grained mixed with friable chips.

Well Hydraulics and water quality

The well at village Pardi has been filled up just after the removal of drill rods due to encounter of collapsible formation at different depths. Therefore no pumping test has been conducted and no water sample has been collated for ascertaining the water quality.

2. EXPLORATORY WELL DRILLED AT SONKHAMB

Location of Site

The village Sonkhamb lies between north latitude 21°16'21.1" and east longitude 78°43'22.1" and falls in the Survey of India Toposheet No. 55 K/12. It is situated at about 20 kms from Kalmeshwar on Katol road and the site is located north of village near railway track., locally known as " Kund of Village".

History of Drilling Operations:

The exploratory well was drilled by DTH cum Rotary rig. The rig unit was shifted on 26/7/13 to well site. The drilling started on 26/7/13 at 1140 hrs and completed on 26/7/13 at 2040 hrs. The drilling details and drilling time log is as follows

Details of Drilling:

a) Rock Formation: Basalt
b) Type: Deccan Traps
c) Total depth drilled: 197.75 m.
d) Drilling started on 26/7/13 at 1140 hrs
e) Drilling completed on 26/7/13 at 2040 hrs
f) Total depth drilled in Weathered Formation (with 279.4mm; Button Bit): 11.20 m.
g) Total depth drilled in Hard rock Formation (with 165.1 mm Button Bit):186.55 m.
h) Length of casing: 11.20 m.bgl and 0.51m.agl=11.71
i) Diameter of Casing: 203mm(8")
j) Gauge of casing pipe:7.5mm
k) Material of Casing pipe: M.S.Pipe

Drilling stopped at Sonkhamb on 26/7/13 at 197.75 mbgl as normal rate of penetration drops due to encounter of Gondwana Sandstone.

Geological Data:

The village Sonkhamb in general comprises of basaltic formation of Deccan traps. Thickness of top soil is 1 m bgl while the thickness of weathered basalt is 11.20 mbgl. The green bole encountered at 20.00 to 22.5 m bgl.

Table 2.1: Drill Time log of the Exploratory well drilled at village Sonkhamb, Katol taluka, Nagpur district.

DATE	Depth range (m)		Drilling time (min)		Total time(min)	penetration rate min/m
	From	To	From	To		
26/07/2013	0	5.65	11.40	11.55	15	2.65
	5.65	11.3	11.56	12.10	5	0.88
	11.3	16.95	13.56	14.09	13	2.30
	16.95	22.6	14.36	14.39	3	0.53
	22.6	28.25	14.40	14.49	9	1.59
	28.25	33.9	14.50	14.58	8	1.42
	33.9	39.55	14.59	15.07	6	1.06
	39.55	45.2	15.08	15.18	10	1.77
	45.2	50.85	15.19	15.31	12	2.12
	50.85	56.5	15.32	15.41	9	1.59
	56.5	62.15	15.42	15.54	12	2.12
	62.15	67.8	15.55	16.08	13	2.30
	67.8	73.45	16.09	16.20	7	1.24
	73.45	79.1	16.21	16.27	6	1.06
	79.1	84.75	16.28	16.34	6	1.06
	84.75	90.4	16.37	16.44	7	1.24
	90.4	96.05	16.45	16.58	13	2.30
	96.05	101.7	17.00	17.08	8	1.42
	101.7	107.35	17.10	17.17	7	1.24
	107.35	113	17.19	17.25	6	1.06
	113	118.65	17.26	17.34	8	1.42
	118.65	124.3	17.36	17.49	13	2.30
	124.3	129.95	17.51	17.58	7	1.24
	129.95	135.6	18.00	18.10	10	1.77
	135.6	141.25	18.13	18.24	11	1.95
	141.25	146.9	18.28	18.41	13	2.30
	146.9	152.55	18.45	18.53	8	1.42
	152.55	158.2	18.57	19.06	9	1.59
	158.2	163.85	19.10	19.17	7	1.24
	163.85	169.5	19.19	19.26	7	1.24
	169.5	175.15	19.29	19.37	8	1.42
	175.15	180.8	19.41	19.55	14	2.48
	180.8	186.45	19.58	20.10	12	2.12
	186.45	192.1	20.14	20.22	8	1.42
	192.1	197.75	20.26	20.40	14	2.48

Table 2.2: Consolidated lithological log of the Exploratory well drilled at village Sonkhamb, Katol taluka, Nagpur district.

Depth range(m)		Thickness (m)	Consolidated Lithology
0	1	1.0	Top Soil: Dark brown, loose, silt mixed with chips
1	6	5.0	Basalt: Weathered, brownish-black, mixed with coarse grains and friable chips
6	13	7.0	Basalt: Dark-brown, fresh, hard with irregular chips. Fracture between:11.10-11.20:Q; Traces
13	20	7.0	Basalt: Grey, fractured friable chips mixed with coarse grains.
20	22.5	2.5	Green Bole: Green, clayey, sticky, plastic mixed with fragile chips and negligible basaltic grains; fracture between
22.6	31	8.4	Massive Basalt: Dark grey, fresh, hard compact mixed with grains and chips fracture 22.60-23.0 m. with Q:0.78 lps
31	34	3.0	Amygdaloidal Basalt: Pinkish-grey, vesicles filled with secondary minerals fragile and friable chips and grains.
34	48	14.0	Massive Basalt: Dark grey, fresh, hard compact mixed with grains and chips
48	50.5	2.5	Green Bole: Green, clayey, sticky, plastic
50.5	60	9.5	Fractured Basalt: Light grey, mixed with hard and friable irregular chips and pebble; Q:1.73 lps.
60	70	10.0	Massive Basalt: Dark grey, fresh, hard compact mixed with grains and chips
70	71.5	1.5	Green Bole: Green, clayey, sticky, plastic
71.5	78	6.5	Amygdaloidal Basalt: Light green, filled with secondary friable minerals and irregular chips.
78	96	18.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
96	98	2.0	Green Bole: Green, clayey, sticky, plastic
98	106	8.0	Amygdaloidal Basalt: Light green, filled with secondary friable minerals and irregular chips.
106	118	12.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
118	125	7.0	Amygdaloidal /vesicular Basalt: Light green, filled with secondary minerals
125	132.5	7.5	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
133	135	2.5	Green Bole: Green, clayey, sticky, plastic
135	139	4.0	Amygdaloidal /vesicular Basalt: Light green, filled with secondary minerals
139	147	8.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
147	149	2.0	Green Bole: Green, clayey, sticky, plastic
149	153	4.0	Amygdaloidal /vesicular Basalt: Light green, filled with secondary minerals
153	156	3.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
156	171	15.0	Amygdaloidal /vesicular Basalt: Light green, filled with secondary minerals

Depth range(m)		Thickness (m)	Consolidated Lithology
171	182	11.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
182	189	7.0	Amygdaloidal /vesicular Basalt: Light green, filled with secondary minerals
189	195	6.0	Massive Basalt: Dark brown, fresh, hard compact mixed with coarse grains and irregular chips.
195	197.75	2.8	Sand stone: Grey, permeable, medium to coarse grains; Q:5.15 lps

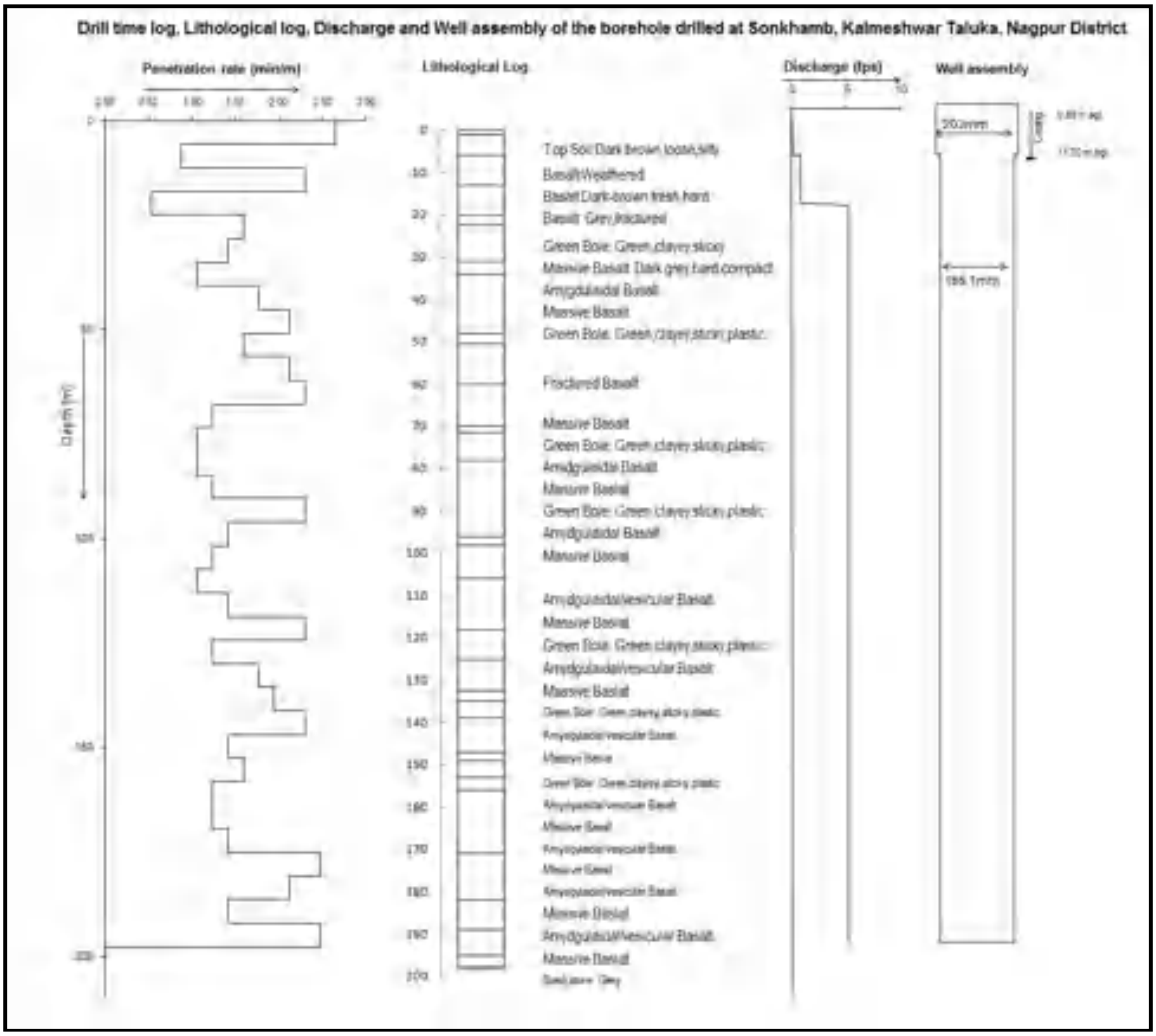


Fig.2.1: Composite Log of Exploratory Well Drilled at Sonkhamb, Chandrabhaga Watershed (WGKKC-2)

Table 2.3: Fracture Zones encountered

S.No	Zones encountered		Cumulative Discharge	Lithology
	From	To		
1	11.20	12.20	**Traces**	Basalt: Dark-brown, fresh, hard with irregular chips .Fractured
2	22.60	23.00	**0.78**	Fractured Basalt
3	76.45	79.1	1.73	**Fractured Basal**t: Light grey, mixed with hard and friable irregular chips and pebble;

S.No	Zones encountered		Cumulative Discharge	Lithology
	From	To		
4	195.1	197.75	5.15	Sand stone: Grey, permeable, medium to coarse grains.

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and Discharge measured was 5.15 lps.

Well Hydraulics:

Aquifer Performance Test (APT)

For estimation of aquifer parameters, APT conducted on exploratory well for 1000 minutes duration and 90% recuperation recorded.

Table 2.4: The details of the Aquifer Performance Test (APT) Conducted on Exploratory Well at Sonkhamb, Kalmeshwar Taluka, Nagpur District.

Date	28/12/13
Static Water Level (SWL)	11.27 mbgl
Discharge (Q)	2.25 lps
Drawdown (Δs)	1.177 m
Transmissivity (T)	30 m^2/day
Specific Capacity	166.15 m^3/day/m

Chemical Quality

During drilling of exploratory well, water sample was collected for determination of Chemical quality. The Sample is analyzed in the chemical laboratory of CGWB,CR, Nagpur.

Table 2.5: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm…………….										
Sonkhamb	Zone-I (22.60-23 m)	8.3	857	400	26	81	16	0.23	3	128	160	147	11	1.40
	Zone-I(76.45-79.10)	8.2	641	285	8	64	15	0.26	0	354	25	5	2	0.76
	Pumping Test	8.2	525	250	30	43	4	0.07	0	244	28	9	29	0.6

Chemical analysis of water sample collected from the Zone-I of the exploratory well reveals that the range of concentration in parameters viz TH, Mg are more than desirable limit while the concentration of F is more than desirable limit. In Zone-II of the exploratory well the analysis revealed that the range of concentration in parameters viz Mg, HCO_3 are more than desirable limit while all other parameters are within the desirable limit. While In the sample collected during pumping test of the exploratory well representing cumulative discharge, the analytical results reveals that the range of concentration in parameters viz Mg is more than desirable limit while all other parameters are within the desirable limit as per “Drinking Water Standards” laid down by Bureau of Indian Standards (BIS 10500-2013).

3. Exploratory well drilled at Sonegaon

Location of Site

The village Sonegaon lies north latitude 21°13'49.1" and east longitude 78°49'54.7" and falls in the Survey of India Toposheet No. 55 K/16. It is situated at about 12 kms from Kalmeshwar on Linga road and the site is located 20 m South of Village in the premises of Smashanbhumi.

History of Drilling Operations:

The exploratory well was drilled by DTH cum Rotary rig. The rig unit was shifted on 28/7/13 to well site. The drilling started on 28/7/13 at 1014 hrs and completed on 28/7/13 at 1836 hrs . The drilling details and drilling time log is as follows

Details of Drilling:

a) Rock Formation: Basalt
b) Type: Deccan Traps
c) Total depth drilled: 135.60 m.
d) Drilling started on 28/7/13 at 1014 hrs
e) Drilling completed on 28/7/13 at 1836 hrs
f) Total depth drilled in Weathered Formation (with 279.4mm; Button Bit): 12.00 m.
g) Total depth drilled in Hard rock Formation (with 165.10 mm Button Bit):123.60 m.
h) Length of casing: 12.00 m.bgl and 0.60m.agl=12.60
i) Diameter of Casing: 203mm(8")
j) Gauge of casing pipe:7.5mm
k) Material of Casing pipe: M.S.Pipe

Drilling was stopped at Sonegaon on 28/7/13 at 135.60 mbgl as normal rate of penetration drops due to Collapsible red boles at various depths.

Geological Data:

The village Sonegaon in general comprises of basaltic formation of Deccan traps. Thickness of top soil is 0.5 m bgl while the thickness of weathered basalt is 12.00 mbgl. The collapsible green bole and red bole beds are encountered at 23.5 to 26.5 & 70.00 to 79.00 m bgl and 79 to 84.75 and 84.75 to 96.05 m bgl. And 116 to 118.65 and 118.65 to 124.3 mbgl.

Table3.1: Drill Time log of the Exploratory well drilled at village Sonegaon, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
28/07/2013	0	5.65	5.65	10.14	10.30	16	0.35
	5.65	11.3	5.65	10.31	10.44	13	0.43
	11.3	16.95	5.65	12.55	13.03	8	0.71
	16.95	22.6	5.65	13.04	13.15	11	0.51
	22.6	28.25	5.65	13.16	13.25	9	0.63
	28.25	33.9	5.65	13.26	13.31	5	1.13
	33.9	39.55	5.65	13.33	13.38	5	1.13
	39.55	45.2	5.65	13.39	13.51	12	0.47
	45.2	50.85	5.65	13.52	13.57	5	1.13
	50.85	56.5	5.65	13.58	14.06	8	0.71
	56.5	62.15	5.65	14.07	17.19	12	0.47
	62.15	67.8	5.65	14.23	14.29	6	0.94

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	67.8	73.45	5.65	14.30	14.38	8	0.71
	73.45	79.1	5.65	14.39	14.46	7	0.81
	79.1	84.75	5.65	14.47	14.56	9	0.63
	84.75	90.4	5.65	14.57	15.04	7	0.81
	90.4	96.05	5.65	15.06	15.13	7	0.81
	96.05	101.7	5.65	15.14	15.30	16	0.35
	101.7	107.35	5.65	15.37	15.43	6	0.94
	107.35	113	5.65	15.46	15.58	12	0.47
	113	118.65	5.65	16.00	16.08	8	0.71
	118.65	124.3	5.65	16.10	16.20	10	0.56
	124.3	129.95	5.65	16.22	17.02	40	0.14
	129.95	135.6	5.65	17.55	18.36	41	0.14

Table 3.2: Consolidated lithological log of the Exploratory well drilled at village Sonegaon, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness	Consolidated Lithology
From	To	(m)	
0	2	2	Top Soil: light grey, weathered silt
2	9.2	7.2	Basalt: Light grey; weathered and fractured friable irregular chips and grains.
9.2	23.5	14.3	Massive Basalt: Dark grey, fresh, hard, compact mixed with irregular chips. Minor Facture between:**6.0-7.0 mt. with Q:0.14 lps** and **14.30-15.30 m. Q:0.14 lps**
23.5	26.5	3	Green Bole: green, clayey ,sticky with friable boles(Chips)
26.5	34	7.5	Amygdaloidal Basalt: Light grey, vesicles filled with sec minerals and friable irregular chips
34	44	10	Massive Basalt: Greyish-brown, fresh, hard, compact with irregular chips and grains.
44	50	6	Vesicular Basalt: Vesicular, Greyish brown, filled with sec. minerals and fragile grains and chips
50	68	18	Massive Basalt: Greyish-brown, fresh, hard, compact with irregular chips and grains.
70	79	9	Red Bole: Red, sticky and plastic clayey with friable boles.
79	84.75	5.75	Green Bole: green, clayey ,sticky with friable boles(Chips)
84.75	96.05	11.3	Red Bole: Red, sticky and plastic clayey with friable boles.
96.05	113	16.95	Massive Basalt: Greyish-brown, fresh, hard, compact with irregular chips and grains.
113	116	3	Amygdaloidal Basalt: Light grey, vesicles filled with green sec. minerals and friable irregular chips
116	118.65	2.65	Red Bole: Red, sticky and plastic clayey with friable boles.
118.65	124.3	5.65	Green Bole: green, clayey ,sticky with friable boles(Chips)
124.3	135.6	11.3	Amygdaloidal Basalt: Light and dark grey friable green boles and sec minerals.

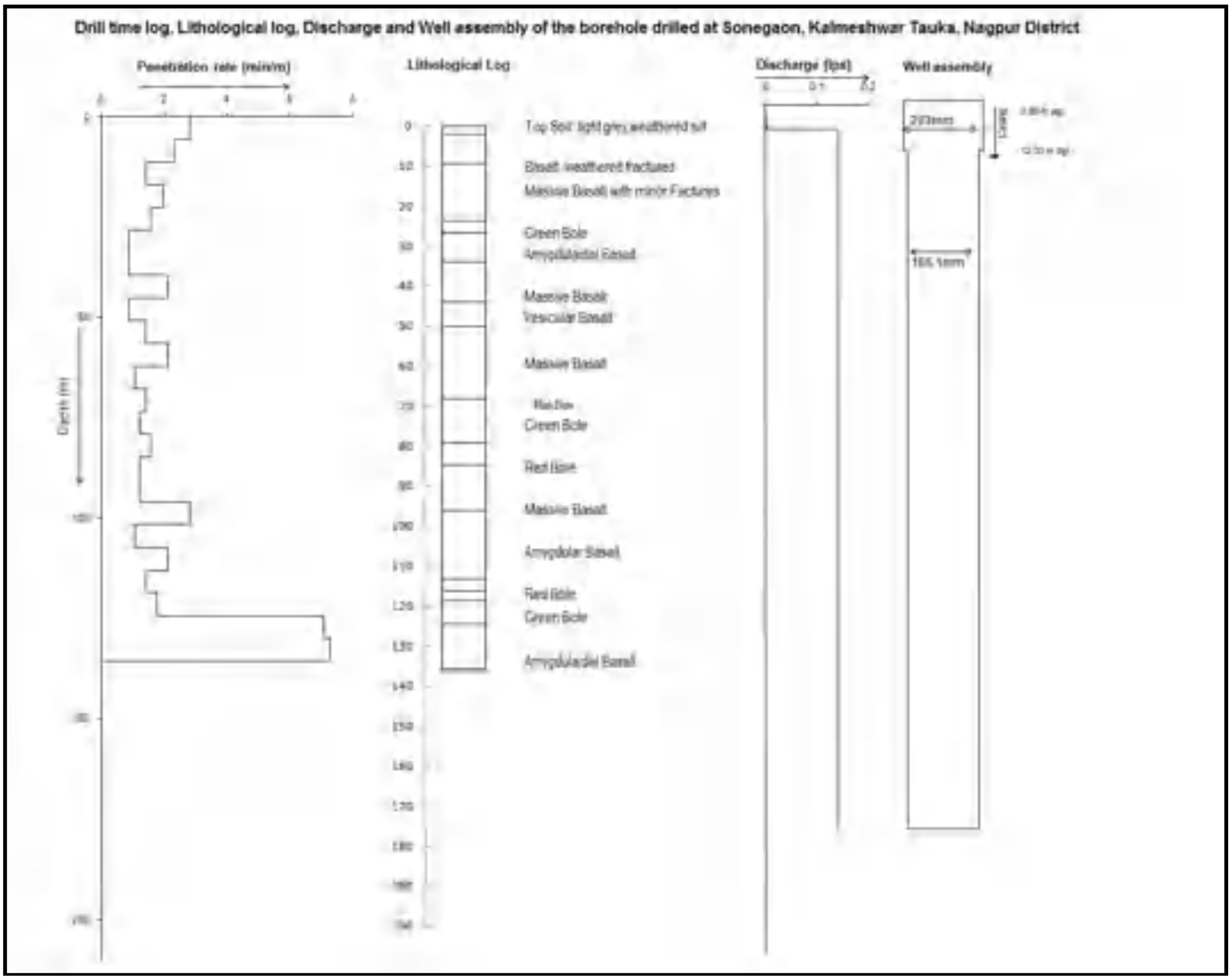


Fig.3.3: Composite Log of Exploratory Well Drilled at Sonegaon, Chandrabhaga Watershed (WGKKC-2)

Table3.3: Fracture Zones encountered

S.No	**Drilling Depth**		**Cumulative Discharge**	**Lithology and Zones encountered**
	From	To		
1	5.65	25.6	0.14 lps	Massive Basalt: Dark grey, fresh, hard, compact mixed with irregular chips. Minor Facture between**: 6.0-7.0 mt. with Q:0.14 lps** and **14.30-15.30 m. Q:0.14 lps**

Well Hydraulics Chemical Quality

The well at village Sonegaon has been filled up just after the removal of drill rods due to encounter of collapsible formation at different depths. Therefore no pumping test has been conducted and no water sample has been collated for ascertaining the water quality.

4. EXPLORATORY WELL DRILLED AT RAMGIRI

Location of Site

The village Ramgiri lies north latitude 21°18'4.2" and east longitude 78°45'27.2" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at 28 kms from Kalmeshwar on Pardi road and the site is located near water supply dug well 15 m west of village. .

History of Drilling Operations:

The rig unit was shifted to well site on 30/7/13. The drilling started on 30/7/13 at 1403 hrs and completed on 31/7/13 at 1650 hrs. The drilling details and drilling time log is as follows Details of Drilling:

a) Rock Formation: Basalt
b) Type: Deccan Traps
c) Total depth drilled: 179.00 m.
d) Drilling started on 30/7/13 at 1403 hrs
e) Drilling completed on 31/7/13 at 1650 hrs
f) Total depth drilled in Weathered Formation (with 279.4mm; Button Bit): 11.53 m.
g) Total depth drilled in Hard rock Formation (with 165.10 mm Button Bit):167.47 m.
h) Length of casing: 11.53 m.bgl and0.60m.agl=12.13
i) Diameter of Casing: 203mm(8”)
j) Gauge of casing pipe:7.5mm
k) Material of Casing pipe: M.S.Pipe

Drilling is stopped at Ramgiri on 31/7/13 at 179.00 mbgl as normal rate of penetration drops due to Collapsible red boles occurred from 127 m bgl. The Gondwana sandstone encountered at 172.5 m bgl.

Geological Data:

The village Ramgiri in general comprises of basaltic formation of Deccan traps. Thickness of top soil is 0.5 m bgl, which followed by massive basaltic formation. The remarkable Red Sticky and plastic Clay with friable chips have been encountered at the depth between 127.30 and 172.50 m bgl, which is 45 m thick.

Table 4.1: Drill Time log of the Exploratory well drilled at village Ramgiri, Kalmeshwar taluka, Nagpur district.

DATE	Depth range (m)		Thickness(m)	Time taken(min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
30/07/2013	0	3	3	1403	1408	5	1.67
	3	5.65	2.65	1408	1415	7	2.64
	5.65	8.65	3	1418	1433	15	5.00
	8.65	11.3	2.65	1433	1502	29	10.94
31/07/2013	11.3	14.3	3	1144	1149	5	1.67
	14.3	16.95	2.65	1149	1152	3	1.13
	16.95	19.95	3	1153	1156	3	1.00
	19.95	22.6	2.65	1156	1201	5	1.89
	22.6	25.6	3	1202	1209	7	2.33
	25.6	28.25	2.65	1209	1217	8	3.02
	28.25	31.25	3	1217	1220	3	1.00
	31.25	33.9	2.65	1220	1223	3	1.13
	33.9	36.9	3	1224	1228	4	1.33
	36.9	39.55	2.65	1228	1233	5	1.89
	39.55	42.65	3.1	1236	1241	5	1.61
	42.65	45.2	2.55	1243	1247	4	1.57
	45.2	48.2	3	1249	1251	2	0.67

DATE	Depth range (m)		Thickness(m)	Time taken(min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
	48.2	50.85	2.65	1251	1255	4	1.51
	50.85	53.85	3	1256	1301	5	1.67
	53.85	56.5	2.65	1301	1303	2	0.75
	56.5	59.5	3	1304	1308	4	1.33
	59.5	62.15	2.65	1308	1311	3	1.13
	62.15	65.15	3	1311	1314	3	1.00
	65.15	67.8	2.65	1314	1318	4	1.51
	67.8	70.8	3	1319	1324	5	1.67
	70.8	73.45	2.65	1324	1330	6	2.26
	73.45	76.45	3	1332	1336	4	1.33
	76.45	79.1	2.65	1336	1342	6	2.26
	79.1	82.1	3	1345	1358	13	4.33
	82.1	84.75	2.65	1358	1408	10	3.77
	84.75	87.75	3	1414	1423	9	3.00
	87.75	90.4	2.65	1423	1433	10	3.77
	90.4	93.4	3	1435	1440	5	1.67
	93.4	96.05	2.65	1440	1448	8	3.02
	96.05	99.05	3	1449	1451	2	0.67
	99.05	101.7	2.65	1451	1455	4	1.51
	101.7	104.7	3	1456	1459	3	1.00
	104.7	107.35	2.65	1459	1505	6	2.26
	107.35	110.35	3	1507	1511	4	1.33
	110.35	113	2.65	1511	1517	6	2.26
	113	116	3	1520	1523	3	1.00
	116	118.65	2.65	1523	1526	3	1.13
	118.65	121.65	3	1528	1530	2	0.67
	121.65	124.3	2.65	1530	1533	3	1.13
	124.3	127.3	3	1535	1539	4	1.33
	127.3	129.95	2.65	1539	1544	5	1.89
	129.95	132.95	3	1547	1551	4	1.33
	132.95	135.6	2.65	1551	1555	4	1.51
	135.6	138.6	3	1558	1560	2	0.67
	138.6	141.25	2.65	1600	1602	2	0.75
	141.25	144.25	3	1605	1607	2	0.67
	144.25	146.9	2.65	1607	1610	3	1.13
	146.9	149.9	3	1612	1615	3	1.00
	149.9	152.55	2.65	1615	1618	3	1.13
	152.55	155.55	3	1621	1625	4	1.33
	155.55	158.2	2.65	1625	1627	2	0.75
	158.2	161.2	3	1629	1631	2	0.67
	161.25	163.85	2.6	1631	1634	3	1.15
	163.85	166.85	3	1635	1639	4	1.33
	166.85	169.5	2.65	1639	1640	1	0.38
	169.5	172.5	3	1641	1643	2	0.67
	172.25	175.15	2.9	1643	1646	3	1.03

Table4.2: Consolidated lithological log of the Exploratory well drilled at village Ramgiri, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	0.5	0.5	Top Soil: Grey, silty and sandy.
0.5	25.6	25.1	Massive Basalt: Dark gritty, fresh, hard, compact mixed with friable irregular chips with minor Fr:7.0-8.0:Q:0.78 LPS
25.6	28	2.4	Green Bole: Green, clayey, sticky, plastic
28	33.9	5.9	Amygdular Basalt: Light green, fresh mixed with irregular and friable chips and secondary green minerals.
33.9	53	19.1	Massive Basalt: Dark gritty, fresh, hard, compact and mixed with friable irregular chips.
53	56	3	Green Bole: Green, clayey, sticky, plastic
56	59.6	3.6	Amygdular Basalt: Light green, fresh mixed with irregular and friable chips and secondary green minerals.
59.6	91	31.4	Massive Basalt: Dark grey, fresh, hard, compact and mixed with irregular chips
91	92.5	1.5	Green Bole: Green, clayey, sticky, plastic
92.5	112	19.5	Amygdular Basalt: Light green, fresh mixed with irregular and friable chips and secondary green minerals.
112	127	15	Massive Basalt: Dark grey, fresh, hard, compact and mixed with irregular chips
127	172.5	45.5	Clay: Red. Sticky and plastic with friable chips.
172.5	179	6.5	Sand Stone: Grey, medium to fine grained, quartz feldspathic; Q:6.18

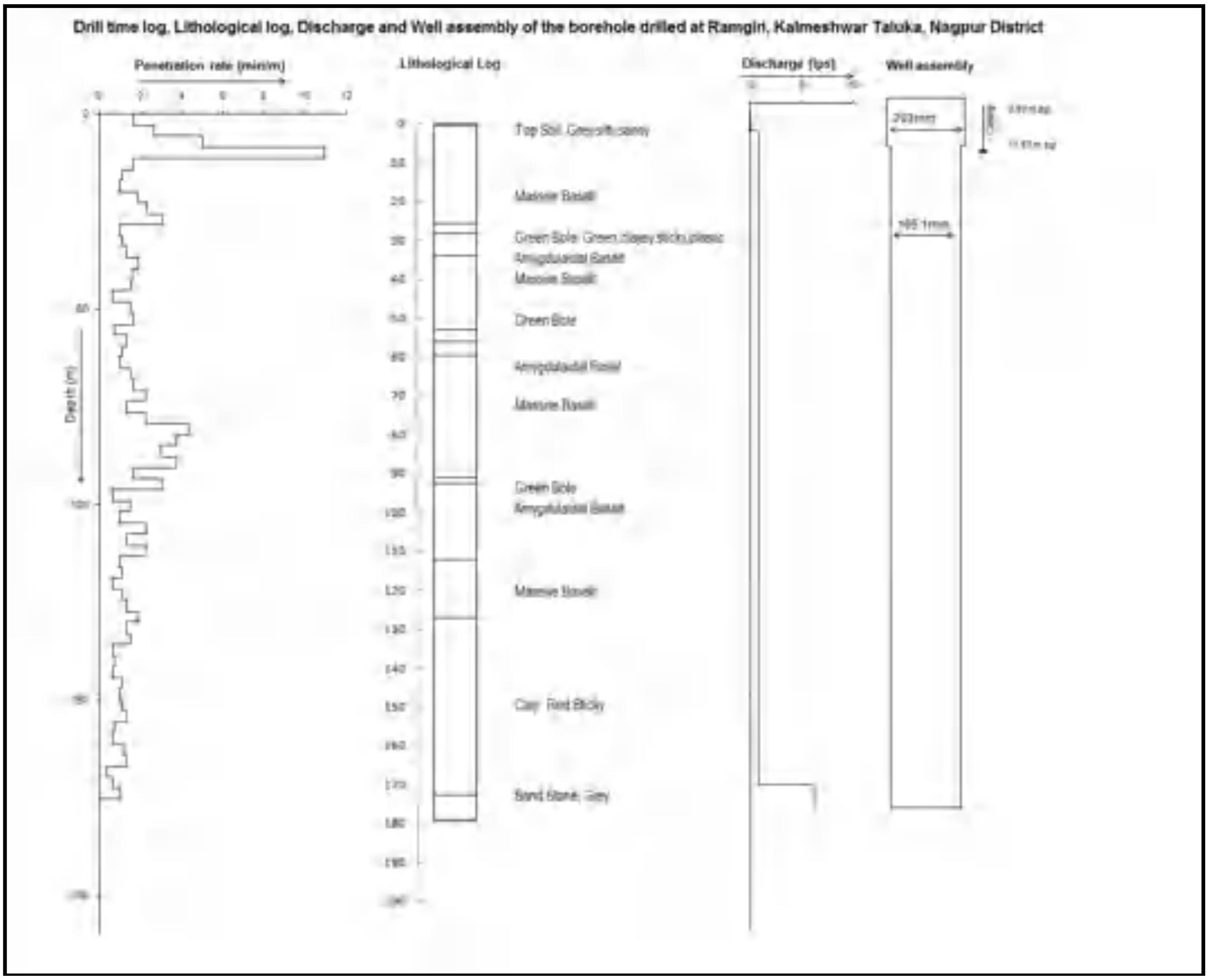


Fig.4.1: Composite Log of Exploratory Well Drilled at Ramgiri, Chandrabhaga Watershed (WGKKC-2)

Table 4.3: Fracture Zones encountered

S.No	**Drilling Depth**		**Cumulative Discharge**	**Lithology and Zones encountered**
	From	To		
1	7.00	8.00	0.78 lps	**Fractured Massive Basalt:** Dark gritty, fresh, hard, compact mixed with friable irregular chips.

Well Hydraulics

The well at village Ramgiri has been filled up just after the removal of drill rods due to encounter of collapsible formation at different depths. Therefore no pumping test has been conducted

Chemical Quality

During drilling of exploratory well, water sample was collected for determination of Chemical quality. The Sample is analyzed in the chemical laboratory of CGWB,CR, Nagpur.

Table 4.4: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				………………………….ppm……………..										
Ramgiri	Zone-I (7-8m)	8.2	798	325	48	50	6	0.19	0	128	89	95	65	0.50
	Cum. Discharge	8.1	642	290	10	64	15	0.26	0	366	32	3	2	0.64

Chemical analysis of water sample collected from the Zone-I (7-8 mbgl) of the exploratory well revealed that the range of concentration in parameters viz TH is more than desirable limit while the concentration of all other parameters are within the desirable limit. While sample representing cumulative discharge from both the aquifers, the analysis result revealed that the range of concentration of parameters viz Mg, HCO3 have found more than desirable limit while all other parameters are within the desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

5. EXPLORATORY WELL DRILLED AT MALEGAON

Location of Site

The village Malegaon lies between north latitude 21°13'49.1" and east longitude 78°49'54.7" and falls in the Survey of India Toposheet No. 55 K/11. It is situated at 6 kms North of Metpanjra, which is 15 kms from Kalmeshwar on Katol road and the site is located 10 m northwest of railway gate in the primises of kund of village.

History of Drilling Operations:

The rig unit shifted to well site on 16/9/13. The drilling started on 16/9/13 at 14.11 hrs and completed on 17/9/13 at 14.56 hrs. The drilling details and drilling time log is as follows

Details of Drilling:

a) Rock Formation: Basalt
b) Type: Deccan Traps
c) Total depth drilled: 200.00 m.
d) Drilling started on 16/9/13 at 14.11 hrs
e) Drilling completed on 18/9/13 at 9.44 hrs
f) Total depth drilled in Weathered Formation (with 279.4mm; Button Bit): 17.64 m.
g) Total depth drilled in Hard rock Formation (with 190.5 mm Button Bit):182.36 m.
h) Length of casing: 17.64m.bgl and0.60m.agl=18.24
i) Diameter of Casing: 203mm(8")
j) Gauge of casing pipe:7.5mm
k) Material of Casing pipe: M.S.Pipe

Geological Data:

The village Malegaon in general comprises of basaltic formation of Deccan traps. Thickness of top soil is 0.5 m bgl. The collapsible bole beds are encountered at 16.90 to 19.95 m bg. The water bearing zones are encountered at 7.0 -8.0 m. with Cumulative Discharge:0.38 lps and 127.3 to129.95 m. With Cumulative Discharge:1.37 lps during drilling.

Table 5.1: Drill Time log of the Exploratory well drilled at village Malegaon, Katol taluka, Nagpur district.

DATE	Depth range(m)		Thickness ESS(m)	Time taken (min)		Total time (min)	Penetration rate m/min
	From	To		From	To		
16/09/2013	0	3	3	1411	1422	11	3.67
	3	5.65	2.65	1422	1434	12	4.53
	5.65	8.65	3	1438	1501	13	4.33
	8.65	11.3	2.65	1501	1524	23	8.68
	11.3	14.3	3	2044	2104	20	6.67
	14.3	16.95	2.65	2104	2122	18	6.79
	16.95	19.95	3	2124	2139	15	5.00
	19.95	22.6	2.65	2139	2150	11	4.15
17/09/2013	22.6	25.6	3	900	911	11	3.67
	25.6	28.25	2.65	911	929	18	6.79
	28.25	31.25	3	931	943	12	4.00
	31.25	33.9	2.65	2006	2014	8	3.02
	33.9	36.9	3	2016	2020	4	1.33
	36.9	39.55	2.65	2020	2024	4	1.51
	39.55	42.65	3.1	2026	2029	3	0.97
	42.65	45.2	2.55	2029	2033	4	1.57
	45.2	48.2	3	2035	2039	4	1.33
	48.2	50.85	2.65	2039	2044	5	1.89
	50.85	53.85	3	2046	2050	4	1.33
	53.85	56.5	2.65	2050	2054	4	1.51
18/09/2013	56.5	59.5	3	930	933	3	1.00
	59.5	62.15	2.65	933	935	2	0.75
	62.15	65.15	3	936	940	4	1.33
	65.15	67.8	2.65	940	944	4	1.51
	67.8	70.8	3	946	951	5	1.67
	70.8	73.45	2.65	951	957	6	2.26
	73.45	76.45	3	958	1004	6	2.00
	76.45	79.1	2.65	1004	1010	6	2.26
	79.1	82.1	3	1012	1018	6	2.00
	82.1	84.75	2.65	1018	1024	6	2.26
	84.75	87.75	3	1026	1034	8	2.67
	87.75	90.4	2.65	1034	1039	5	1.89
	90.4	93.4	3	1041	1044	3	1.00
	93.4	96.05	2.65	1044	1049	5	1.89
	96.05	99.05	3	1052	1055	3	1.00
	99.05	101.7	2.65	1055	1058	3	1.13
	101.7	104.7	3	1100	1105	5	1.67
	104.7	107.35	2.65	1105	1110	5	1.89

DATE	Depth range(m)		Thickness ESS(m)	Time taken (min)		Total time (min)	Penetration rate m/min
	From	To		From	To		
	107.35	110.35	3	1113	1121	8	2.67
	110.35	113	2.65	1121	1128	7	2.64
	113	116	3	1130	1135	5	1.67
	116	118.65	2.65	1135	1140	5	1.89
	118.65	121.65	3	1144	1147	3	1.00
	121.65	124.3	2.65	1147	1149	2	0.75
	124.3	127.3	3	1151	1155	4	1.33
	127.3	129.95	2.65	1155	1158	3	1.13
	129.95	132.95	3	1159	1203	4	1.33
	132.95	135.6	2.65	1203	1209	6	2.26
	135.6	138.6	3	1211	1216	5	1.67
	138.6	141.25	2.65	1216	1224	8	3.02
	141.25	144.25	3	1227	1231	4	1.33
	144.25	146.9	2.65	1231	1235	4	1.51
	146.9	149.9	3	1237	1242	5	1.67
	149.9	152.55	2.65	1242	1250	8	3.02
	152.55	155.55	3	1253	1258	5	1.67
	155.55	158.2	2.65	1258	1306	8	3.02
	158.2	161.2	3	1308	1316	8	2.67
	161.25	163.85	2.6	1316	1325	9	3.46
	163.85	166.85	3	1328	1335	7	2.33
	166.85	169.5	2.65	1335	1342	7	2.64
	169.5	172.5	3	1343	1347	4	1.33
	172.25	175.15	2.9	1347	1353	6	2.07
	175.15	178.15	3	1356	1400	4	1.33
	178.15	180.8	2.65	1400	1405	5	1.89
	180.8	183.8	3	1407	1408	1	0.33
	183.8	186.45	2.65	1409	1413	4	1.51
	186.45	189.45	3	1418	1422	4	1.33
	189.45	192.1	2.65	1422	1426	4	1.51
	192.1	195.1	3	1429	1436	7	2.33
	195.1	197.75	2.65	1436	1441	5	1.89
	197.75	200	2.25	1444	1456	12	5.33

Table5.2: Consolidated lithological log of the Exploratory well drilled at village Malegaon, Katol taluka, Nagpur district.

Depth range (m)		**Thickness (m)**	**Consolidated Lithology**
From	To		
0	0.5	0.5	Top soil: Buff coloured; silty and lose sandy soil
0.5	16.5	16	Basalt: Light grey; Weathered and fractured; fragile chips of 3-

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
			6mm. Fracture between 7.0 -8.0 m. with Cumulative Discharge:0.38 lps.
16	18.5	2.5	Bole: brownish to light green ; friable pieces of 5-8 mm. mixed with angular chips and coarse grains and with sticky material.
18.5	30	11.5	Amygdaloidal Basalt: light green; vesicular, moderately hard; vesicles filled with Sec minerals.
30	54	24	Massive Basalt: Dark brown; fresh; hard; angular chips of 2-5 mm. with coarse to fine grains.
54	57	3	Bole: brownish to light grey;
57	72	15	Amygdaloidal Basalt: light grey to dark grey; moderately hard; fresh vesicles filled with Quartz and green Sec minerals.
72	90	18	Massive Basalt: Dark grey; hard; fresh; angular chips of 3-6 mm. mixed with medium grains. Fracture between 72.5 to 74.5 m
90	95	5	Amygdaloidal Basalt: Light green; fresh; moderately hard; vesicles filled with green Sec. minerals.
95	114	19	Massive Basalt: Dark grey and Blackish; fresh; hard; angular chips of 3-7 mm. Fracture between 112 to 114 m
114	116	2	Bole: brownish to light greyish green
116	133	17	Amygdaloidal Basalt: Light grey and green; fresh; moderately hard; friable chips of green friable negligible 'bole'. Fracture between 127.3 to129.95 m. With Q:1.37 lps
133	155	22	Massive Basalt: Dark grey; fresh; hard; with angular chips of 3-6mm
155	158	3	Fracture Massive Basalt Dark grey and Blackish; fresh; hard; angular
158	178.15	20.15	Massive Basalt: Dark grey; fresh; hard; angular with negligible quartz grains.
178.15	200	21.85	Massive Basalt: Dark grey; fresh; hard; and angular/irregular chips of 2-6mm

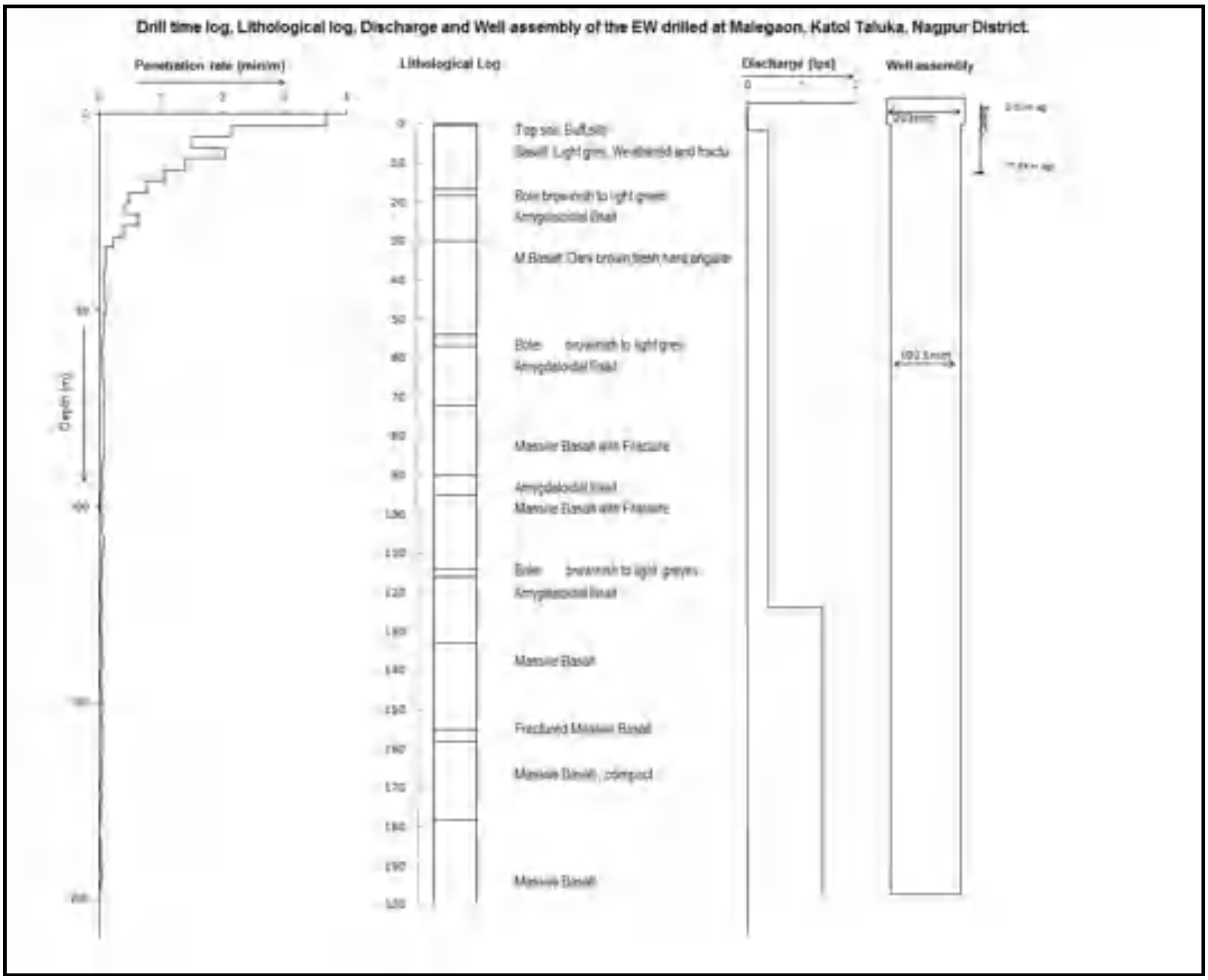


Fig.3.32: Composite Log of Exploratory Well Drilled at Malegaon, Chandrabhaga Watershed (WGKKC-2)

Table 5.3: Fracture Zones encountered

S.No	Drilling Depth		Cumulative Discharge (lps)	Lithology and Zones encountered
	From	To		
1	0.5	16.5	0.38	Basalt: Light grey; Weathered and fractured; fragile chips of 3-6mm. Fracture between 7.0 -8.0 m. with Cumulative Discharge:0.38 lps.
2	116	133	1.37	Amygdaloidal Basalt: Light grey and green; fresh; moderately hard; friable chips of green friable negligible 'bole'. Fracture between 127.3 to129.95 m. With Q:1.37 lps

Well Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and final cumulative discharge measured 1.37 lps.

Well Hydraulics:

Aquifer Performance Test (APT)

For estimation of aquifer parameters APT conducted on exploratory well for 100 minutes duration and 90% recuperation recorded.

Table 5.4: The details of the Aquifer **Performance Test (APT)** Conducted on Exploratory Well at Malegaon, Katol Taluka, Nagpur District.

Date	28/12/13
Static Water Level	11.74 mbgl
Discharge (Q)	1.00 lps
Drawdown	22.32m
Transmissivity (T)	0.90 m2/day
Specific Capacity	2.81 Lpm/m

Chemical Quality

During drilling of exploratory well, water sample collected for determination of Chemical quality. The Sample is analyzed in the chemical laboratory of CGWB, CR, Nagpur. The results of the analysis are presented in the Table 5.5

Table 5.5: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………..ppm……………..										
Malegaon	Zone-I (7-8 m)	8	519	235	42	32	5	0.31	0	171	46	21	42	0.46
Malegaon	Pumping Test	7.9	795	350	52	53	10	0.17	0	189	124	64	17	0.28

Chemical analysis of water sample collected from the Zone-I (7-8 mbgl) of the exploratory well revealed that the range of concentration in all the parameters are within the desirable limit as well as maximum permissible limit. While sample representing cumulative discharge from both the aquifers, the analysis result revealed that the range of concentration of parameters viz TH and Mg, have found more than desirable limit while all other parameters are within the desirable limit as per “Drinking Water Standards” of Bureau of Indian Standards (BIS 10500-2013).

6. OBSERVATION WELL (OW) DRILLED AT MALEGAON

Location of Site

In view of determining the aquifer parameter an observation well (OW) at Malegaon has been constructed about 10 m northwest of railway gate and 10 m away from exploratory well in the same premises.

History of Drilling Operations:

The rig unit was shifted OW site on 19/9/13. The drilling details and drilling time log is presented as below

Details of Drilling:

a) Rock Formation: Basalt
b) Type: Deccan Traps

c) Total depth drilled: 200.00m.
d) Drilling started on 19/9/13 at 13.10 hrs
e) Drilling completed on 20/9/13 at 13.43 hrs
f) Total depth drilled in Weathered Formation(with 279.4 mm Button Bit): 21.00 m.
g) Total depth drilled in Hard rock Formation (with 190.5 mm Button Bit):179.00 m.
h) Length of casing: 21.00 mbgl+0.60 m agl=21.60 m.
i) Diameter of Casing: 203mm(8")
j) Gauge of casing pipe:7.5mm
k) Material of Casing pipe: M.S.Pipe

Geological Data:

In the OW the thickness of top soil was recorded 0.5 m bgl. Whereas 3 water bearing zones were recorded in the well at 7.0 -8.0 m. with of discharge:0.38 lps and 79.10 to 82.10 m. with cumulative discharge of traces and between 139.00 -140.00 m bgl with cumulative discharge:0.38 lps.

Table 6.1: Drill Time log of the Observation well drilled at village Malegaon, Katol taluka, Nagpur district

Date	Depth range (m)		Thick-ness(m)	Drilling Time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
19/09/2013	0	3	3	1310	1320	10	3.33
	3	5.65	2.65	1320	1332	12	4.53
	5.65	8.65	3	1334	1345	11	3.67
	8.65	11.3	2.65	1345	1358	13	4.91
	11.3	14.3	3	1400	1412	12	4.00
	14.3	16.95	2.65	1412	1432	20	7.55
	16.95	19.95	3	1520	1530	10	3.33
	19.95	22.6	2.65	1530	1540	10	3.77
	22.6	25.6	3	1542	1550	8	2.67
	25.6	28.25	2.65	1552	1601	9	3.40
	28.25	31.25	3	1603	1608	5	1.67
	31.25	33.9	2.65	1609	1616	7	2.64
	33.9	36.9	3	2038	2044	6	2.00
	36.9	39.55	2.65	2043	2047	4	1.51
	39.55	42.65	3.1	2048	2052	4	1.29
	42.65	45.2	2.55	2052	2056	4	1.57
	45.2	48.2	3	2058	2102	4	1.33
	48.2	50.85	2.65	2102	2106	4	1.51
	50.85	53.85	3	2108	2112	4	1.33
	53.85	56.5	2.65	2112	2117	5	1.89
	56.5	59.5	3	2119	2123	4	1.33
	59.5	62.15	2.65	2123	2128	5	1.89
	62.15	65.15	3	2130	2134	4	1.33
	65.15	67.8	2.65	2134	2139	5	1.89
	67.8	70.8	3	2141	2144	3	1.00
	70.8	73.45	2.65	2144	2148	4	1.51
	73.45	76.45	3	2150	2156	6	2.00
	76.45	79.1	2.65	2156	2201	5	1.89
	79.1	82.1	3	2203	2206	3	1.00
	82.1	84.75	2.65	2208	2214	6	2.26
	84.75	87.75	3	2216	2222	6	2.00

Date	Depth range (m)		Thick-ness(m)	Drilling Time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	87.75	90.4	2.65	2222	2226	4	1.51
	90.4	93.4	3	2228	2235	7	2.33
	93.4	96.05	2.65	2235	2239	4	1.51
	96.05	99.05	3	2241	2246	5	1.67
	99.05	101.7	2.65	2246	2253	7	2.64
	101.7	104.7	3	2255	2301	6	2.00
	104.7	107.35	2.65	2301	2307	6	2.26
	107.35	110.35	3	2309	2315	6	2.00
	110.35	113	2.65	2315	2321	6	2.26
	113	116	3	2323	2329	6	2.00
	116	118.65	2.65	2329	2335	6	2.26
	118.65	121.65	3	2337	2343	6	2.00
	121.65	124.3	2.65	2343	2348	5	1.89
	124.3	127.3	3	2350	2355	5	1.67
	127.3	129.95	2.65	2355	2359	4	1.51
20/09/2013	129.95	132.95	3	2402	2406	4	1.33
	132.95	135.6	2.65	2408	2410	2	0.75
	135.6	138.6	3	1134	1140	6	2.00
	138.6	141.25	2.65	1140	1144	4	1.51
	141.25	144.25	3	1148	1152	4	1.33
	144.25	146.9	2.65	1152	1157	5	1.89
	146.9	149.9	3	1159	1203	4	1.33
	149.9	152.55	2.65	1203	1211	8	3.02
	152.55	155.55	3	1213	1218	5	1.67
	155.55	158.2	2.65	1218	1223	5	1.89
	158.2	161.2	3	1225	1232	7	2.33
	161.25	163.85	2.6	1232	1238	6	2.31
	163.85	166.85	3	1240	1245	5	1.67
	166.85	169.5	2.65	1245	1249	4	1.51
	169.5	172.5	3	1251	1254	3	1.00
	172.25	175.15	2.9	1254	1258	4	1.38
	175.15	178.15	3	1300	1303	3	1.00
	178.15	180.8	2.65	1303	1306	3	1.13
	180.8	183.8	3	1308	1312	4	1.33
	183.8	186.45	2.65	1312	1315	3	1.13
	186.45	189.45	3	1317	1321	4	1.33
	189.45	192.1	2.65	1321	1324	3	1.13
	192.1	195.1	3	1325	1330	5	1.67
	195.1	197.75	2.65	1330	1335	5	1.89
	197.75	200	2.25	1337	1340	3	1.33

Table 6.2: Consolidated lithological log of the Observation well drilled at village Malegaon, Katol taluka, Nagpur district

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0.00	0.50	0.50	**Top Soil:** Buff to Dark grey; fine silty lose soil

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0.50	8.65	8.15	**Basalt:** Weathered and fractured: Dark grey; irregular pebbles with fragile chips; **Fracture:7.0-8.0 m., Q; 0.38 lps**
8.65	50.85	42.20	**Massive Basalt:** Dark grey; fresh; hard angular/irregular chips 2-5mm mixed with medium grains.
50.85	67.80	16.95	**Amygdaloidal Basalt:** Light green, moderately hard; vesicles filled with green and Quartz sec minerals.
67.80	96.05	28.25	**Massive Basalt:** Dark grey; fresh; hard; irregular and angular chips of 2-5 mms. Mixed with medium grains.**Fracture:79.1- 82.1 m.,Q:traces.**
96.05	104.70	8.65	**Amygdaloidal Basalt**: Light green and black: moderately hard with quartz and green sec. minerals.
104.70	127.30	22.60	**Massive Basalt:** Dark grey; fresh; hard angular chips of 2-4 mm. mixed with medium grains.
127.30	141.25	13.95	**Amygdaloidal Basalt:** Light grey; moderately hard; angular chips of 2-4 mm. with green and Quartz minerals.**Fracture:139.0-140 m.,Q: Traces**
141.25	200.00	58.75	**Massive Basalt:** Dark grey; fresh; moderately hard; very coarse angular chips.

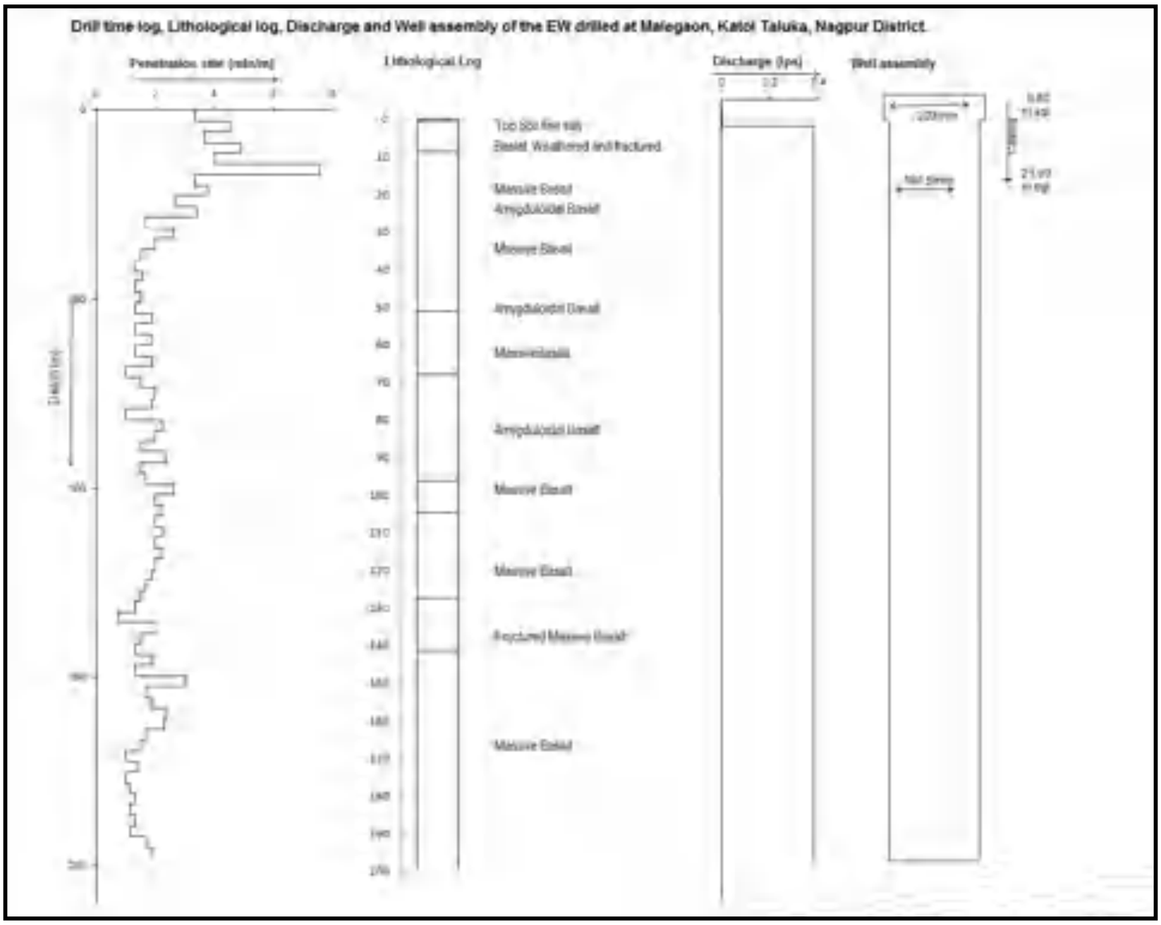


Fig. 3.33: Composite Log of Observation Well Drilled at Malegaon, Chandrabhaga Watershed (WGKKC-2)

Table 6.3: Fracture Zones encountered, Observation Well Drilled at Malegaon, Chandrabhaga Watershed (WGKKC-2)

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
	From	To		
1	0.50	8.65	8.15	**Basalt:** Weathered and fractured: Dark grey; irregular pebbles with fragile chips; **Fracture:7.0-8.0 m., Q; 0.38 lps**
2	67.80	96.05	28.25	**Massive Basalt:** Dark grey; fresh; hard; irregular and angular chips of 2-5 mms. Mixed with medium grains.**Fracture:79.1- 82.1 m.,Q: traces.**
3	127.30	141.25	13.95	**Amygdaloidal Basalt:** Light grey; moderately hard; angular chips of 2-4 mm. with green and Quartz minerals.**Fracture:139.0-140 m.,Q: Traces**

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and measurement of Cumulative Discharge was done which is found to be 1.37 lps. !

Chemical Quality

During drilling of observation well, water sample collected for determination of Chemical quality. The Sample is analyzed in the chemical laboratory of CGWB, CR, Nagpur.

Table 6.4: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				..................................ppm..................										
Malegaon	Zone-I (127.30-129.95)	8.1	445	205	38	27	4	0.29	0	171	35	9	44	0.36

Chemical analysis of water sample collected from the Zone-I (127.30-129.95 mbgl) of the exploratory well revealed that the range of concentration in all the parameters are within the desirable limit as well as maximum permissible limit as per “Drinking Water Standards” laid down by Bureau of Indian Standards (BIS 10500-2013).

7. Exploratory Well drilled at Raulgaon

Location of Site

The village Raulgaon lies between north latitude 21°14'17.4" and east longitude 78°47'04" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at 30 kms from Nagpur on Katol road via Dorli and the site is located in Jhopadpatti area on the eastern outskirts of village. .

History of Drilling Operations:

The rig unit was shifted to well site on 24/09/13. The drilling started on 24/09/13 at 1005 hrs and completed on 27/09/13 at 1755 hrs. The drilling details and drilling time log is presented as below.

Details of Drilling:

a) Rock Formation: Trap Covered Gondwana
b) Type: Basalt & Sandstone
c) Drilling Started on 24/09/2014 at 10.05 hrs
d) Drilling Completed on 27/09/13 at 17.55 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in Hard rock Formation (with 184.00 mm Button Bit):144.00 m.

g) Total depth drilled in soft rock Formation (with 254.00 mm Button Bit):59.75 m.
h) Depth of reaming (with 254.00 mm Button Bit) : 144.25 m
(with 254.00 mm Button Bit) : 144.25 to 200.00 m
i) Well construction Depth : 199.80 m
j) Length of pipes
   a. Blank Pipes: (152.4 mm) 6" pipes = 59.37 m (101.6 mm) 4" pipes = 104.07 m
   b. Slotted pipes : (101.6 mm) 4" pipes = 36.36 m
   c. Slot Size : 1.5 mm
k) Diameter of Pipe :
   d. Blank Pipes : 152.4 mm
   e. Slotted Pipes : 101.6 mm
l) Gauge of Pipes
   f. Blank Pipes : 7.1 mm
   g. Slotted pipes : 5.0 mm
   h. Material of Pipes (Blank & slotted): MS

Geological Data:

Geologically the site is located in Trap covered Gondwana area. The basalt and Gondwana contact at site was encountered at 143 m bgl.

Table 7.1: Drill Time log of the Exploratory well drilled at village Raulgaon, Kalmeshwar taluka, Nagpur district.

DATE	Depth range (m)		Thickness(m)	Time taken (min)		Total time (min)	Penetration min/m
	From	To		From	To		
24/09/2013	0	3	3	1005	1007	2.00	0.67
	3	5.65	2.65	1007	1008	1.00	0.38
	5.65	8.65	3	1008	1011	3.00	1.00
	8.65	11.3	2.65	1011	1014	3.00	1.13
	11.3	14.3	3	1015	1018	3.00	1.00
	14.3	16.95	2.65	1018	1021	3.00	1.13
	16.95	19.95	3	1022	1024	2.00	0.67
	19.95	22.6	2.65	1024	1028	4.00	1.51
	22.6	25.6	3	1029	1032	3.00	1.00
	25.6	28.25	2.65	1032	1035	3.00	1.13
	28.25	31.25	3	1036	1040	4.00	1.33
	31.25	33.9	2.65	1040	1045	5.00	1.89
	33.9	36.9	3	1046	1053	7.00	2.33
	36.9	39.55	2.65	1053	1100	7.00	2.64
	39.55	42.65	3.1	1101	1102	1.00	0.32
	42.65	45.2	2.55	1102	1105	3.00	1.18
	45.2	48.2	3	1107	1109	2.00	0.67
	48.2	50.85	2.65	1109	1113	4.00	1.51
	50.85	53.85	3	1114	1118	4.00	1.33
	53.85	56.5	2.65	1118	1122	4.00	1.51
	56.5	59.5	3	1122	1133	11.00	3.67
	59.5	62.15	2.65	1133	1155	22.00	8.30
	62.15	65.15	3	1156	1203	7.00	2.33
	65.15	67.8	2.65	1203	1213	10.00	3.77
	67.8	70.8	3	1214	1225	11.00	3.67

DATE	Depth range (m)		Thickness(m)	Time taken (min)		Total time (min)	Penetration min/m
	From	To		From	To		
	70.8	73.45	2.65	1225	1232	7.00	2.64
	73.45	76.45	3	1234	1242	8.00	2.67
	76.45	79.1	2.65	1242	1253	11.00	4.15
	79.1	82.1	3	1254	1306	12.00	4.00
	82.1	84.75	2.65	1306	1316	10.00	3.77
	84.75	87.75	3	1317	1328	11.00	3.67
	87.75	90.4	2.65	1328	1340	12.00	4.53
	90.4	93.4	3	1341	1350	9.00	3.00
	93.4	96.05	2.65	1350	1404	4.00	1.51
	96.05	99.05	3	1406	1416	10.00	3.33
	99.05	101.7	2.65	1416	1426	10.00	3.77
	101.7	104.7	3	1428	1431	3.00	1.00
	104.7	107.35	2.65	1431	1435	4.00	1.51
	107.35	110.35	3	1436	1438	2.00	0.67
	110.35	113	2.65	1438	1441	3.00	1.13
	113	116	3	1443	1447	4.00	1.33
	116	118.65	2.65	1447	1453	6.00	2.26
	118.65	121.65	3	1455	1503	8.00	2.67
	121.65	124.3	2.65	1503	1514	11.00	4.15
	124.3	127.3	3	1517	1522	5.00	1.67
	127.3	129.95	2.65	1522	1527	5.00	1.89
	129.95	132.95	3	1530	1535	5.00	1.67
	132.95	135.6	2.65	1535	1540	5.00	1.89
	135.6	138.6	3	1543	1551	8.00	2.67
	138.6	141.25	2.65	1551	1556	5.00	1.89
	141.25	144.25	3	1558	1606	8.00	2.67
	144.25	146.9	2.65	1606	1612	6.00	2.26
	146.9	149.9	3	1615	1618	3.00	1.00
	149.9	152.55	2.65	1618	1621	3.00	1.13
	152.55	155.55	3	1623	1627	4.00	1.33
	155.55	158.2	2.65	1627	1630	3.00	1.13
	158.2	161.2	3	1632	1634	2.00	0.67
	161.25	163.85	2.6	1634	1638	4.00	1.54
	163.85	166.85	3	1640	1642	2.00	0.67
	166.85	169.5	2.65	1642	1643	1.00	0.38
	169.5	172.5	3	1646	1648	2.00	0.67
	172.25	175.15	2.9	1648	1654	6.00	2.07
	175.15	178.15	3	1657	1706	9.00	3.00
	178.15	180.8	2.65	1706	1716	10.00	3.77
	180.8	183.8	3	1722	1747	25.00	8.33
	183.8	186.45	2.65	1705	1753	8.00	3.02
	186.45	189.45	3	1755	1810	15.00	5.00
27/09/2013	189.45	192.1	2.65	1605	1635	30.00	11.32

DATE	Depth range (m)		Thickness(m)	Time taken (min)		Total time (min)	Penetration min/m
	From	To		From	To		
	192.1	195.1	3	1640	1701	21.00	7.00
	195.1	197.75	2.65	1701	1735	34.00	12.83
	197.75	200	2.25	1735	1755	20.00	8.89

Table 7.2: Consolidated lithological log of the Exploratory well drilled at village Raulgaon, Kalmeshwar taluka, Nagpur district.

Depth range (m)		**Thickness (m)**	**Consolidated Lithology**
From	To		
0	0.5	0.5	**Top Soil**: Gritty; silty, lose material.
0.5	15.5	15	**Vesicular Basalt:** light grey to Dark grey, weathered, friable chips, vesicles filled with sec minerals
15.5	24	8.5	**Massive Basalt:** Dark grey, moderately hard angular chips, **fracture 16.95-19.95** with negligible water, mixed with sec. minerals.
24	28	4	**Vesicular Basalt:** Dark grey, fresh; mod hard, angular chips 2-6 mm. vesicles filled with sec. minerals.
28	40	12	**Massive Basalt:** Dark grey; fresh, hard, irregular/angular chips of 2-5mm mixed with coarse grains.
40	48.2	8.2	**Red Bole**: Red to greyish red, irregular shape friable pieces, with sticky clayey material.
48.2	56.5	8.3	**Green Bole:** Light green to brown, irregular firable pieces if 3-8mm, mixed with sticky material.
56.5	62.15	5.65	**Amygdular Basalt:** light grey and green mod. hard; angular chips vesicle filled with sec. minerals.
62.15	101	38.85	**Massive Basalt:** light grey fresh hard irregular/angular chips of 2-5 mm. with coarse grains.
101	112	11	**Green bole**: light green, fresh, friable irregular pieces of 3-8mm with sticky material
112	123.5	11.5	**Vesicular Basalt:** light green to grey vesicle filled with sec. minerals angular chips of 3-5mm
123.5	143	19.5	**Massive basalt:** Reddish brown to Dark grey fresh hard irregular chips of 2-5mm,fracture between:**127.3 to129.95, with Q:0.78 LPS.Fracture:135.60-138.60 m., with Q:3.0 lps** mixed with occasional sec. minerals
143	149.9	6.9	**Sand Stone:** Pinkish Red, ferruginous; fine to medium grained Quartzfeldspathic angular to sub rounded; Water struck between**144.25 to 146.9 with Q:8.0 LPS**
149.9	200	50.1	**Sandstone:** Greyish and pink Quartz feldspathic fine to medium grained.

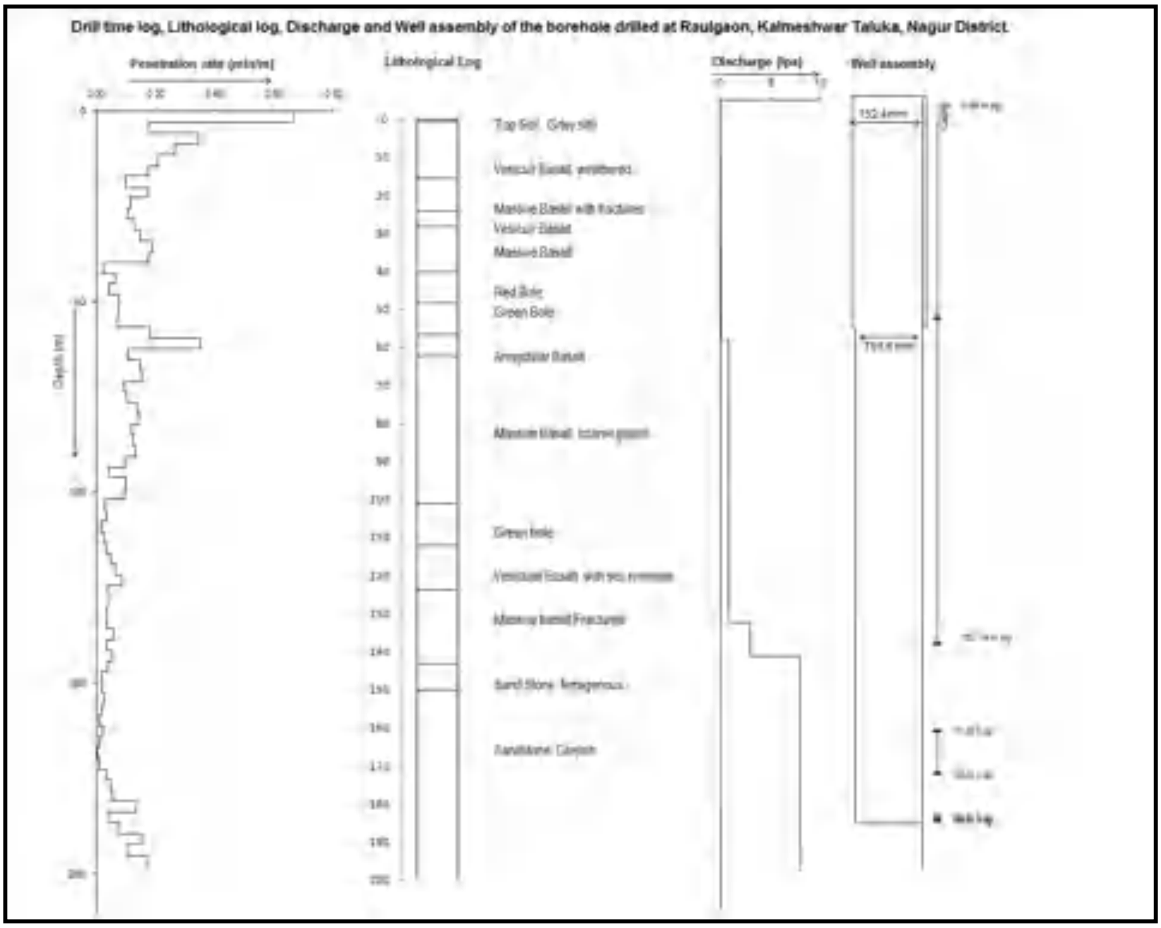


Fig. 7.1: Composite Log of Exploratory Well Drilled at Raulgaon, Chandrabhaga Watershed (WGKKC-2)

Table 7.3 Fracture Zones encountered

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
	From	To		
1	15.5	24	Traces	**Massive Basalt:** Dark grey, moderately hard angular chips, **fracture 16.95-19.95** with negligible water, mixed with sec. minerals.
2	123.5	143	**3.0**	**Massive basalt:** Reddish brown to Dark grey fresh hard irregular chips of 2-5mm,fracture between:**127.3 to129.95, with Q:0.78 LPS.Frecture:135.60-138.60 m., with Q:3.0 lps** mixed with occasional sec. minerals
3	143	149.9	8.0	**Sand Stone:** Pinkish Red, ferruginous; fine to medium grained Quartzfeldspathic angular to sub rounded; Water struck between**144.25 to 146.9 with Q:8.0 LPS**

WELL DESIGN

Based on the interpretation of litholog and Electrical log the following well assembly was recommended and lowered for construction of exploratory tube well. The details of well assembly is given in Table

Table 7.4: Recommended well design, Exploratory Well Drilled at Raulgaon, Chandrabhaga Watershed (WGKKC-2)

S/N	Depth Range (mbgl)		Thickness	Description of Pipes
	From	To	(m bgl)	
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank MS pipe
2	0.00	59.37	59.37	6" (152.4 mm) dia M S Blank MS pipe
3	59.37	59.50	0.13	6" (152.4 mm) dia M S Blank reducer
4	59.50	150.34	90.84	4" (101.6 mm) dia M S Blank MS pipe
5	150.34	174.59	24.25	4" (101.6 mm) dia M S Slotted MS pipe
6	174.59	186.69	12.10	4" (101.6 mm) dia M S Blank MS pipe
7	186.69	198.80	12.11	4" (101.6 mm) dia M S Slotted MS pipe
8	198.80	199.80	1.00	4" (101.6 mm) dia M S Blank MS pipe with bail blug

Development

The well was developed using air compressor for 15 hrs on 8/10/13 from 16.40 hrs to 21.40 hrs and on 9/10/13 from 8.00 hrs to 18.00 hrs. till the water was free from sand particles. Cumulative Discharge recorded was 8.0 lps.

WELL HYDRAULICS

Aquifer Performance Test (APT)

Table 7.5: The details of the Aquifer Performance Test (APT) Conducted on Exploratory Well at Raulgaon, Kalmeshwar Taluka, Nagpur District.

Date	**1/3/2014**
Static Water Level	36.52
Discharge (Q)	4.50
Drawdown (∆s)	2.030
Transmissivity (T)	35.05
Specific Capacity	21.51

Chemical Quality

Table 7.6: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				………………………………ppm………………										
Raulgaon	Zone-I (127.30-129.95)	8	1503	690	44	141	26	0.28	0	73	351	239	18	1.25
Raulgaon	Zone-II (135.60-138.60)	8.3	920	430	12	97	20	0.29	6	183	181	72	46	1.46
Raulgaon	Pumping Test	8.2	904	395	22	83	17	0.23	0	146	110	139	46	1.23

Chemical analysis of water sample collected from the Zone-I (127.30-129.95) revealed that the range of concentration of parameters viz Ec, TH, Mg, Cl, SO4 and F are found more than desirable limit. Whereas in Zone-II the range of concentration of parameters viz TH, Ca, Mg, NO_3 are found more than desirable limit while all other parameters are within the desirable limit. While sample collected during well development and representing cumulative discharge from Gondwana sandstone aquifers, the analysis result revealed that the range of concentration of parameters viz TH, Ca, Mg and NO_3 have found more than desirable limit while all other parameters are within the desirable limit as per “Drinking Water Standards” of Bureau of Indian Standards (BIS 10500-2013).

8. Exploratory Well drilled at Mohgaon

Location of Site

The village Mohgaon lies between north latitude 21°15'54.9"and east longitude 78°48'33.8" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at 12 kms from kalmeshwar on Mohpa road and the site is located in 5 m North of Madhuganga River, southeast of the village. .

Details of Drilling:

a) Rock Formation: Trap Covered Gondwana
b) Type: Basalt & Sandstone
c) Drilling Started on 13/10/2013 at 13.02 hrs
d) Drilling Completed on 13/10/2013 at 24.00 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in Hard rock Formation (with 190.50 mm Button Bit):90.40 m.
g) Total depth drilled in soft rock Formation (with 190.50 mm Button Bit):109.60 m.
h) Depth of reaming (with 254.00 mm Button Bit) : 90.40 m
   (with 254.00 mm Button Bit) : 90.40 m to 200.00 m
i) Well construction Depth 200.00 m
j) Details of Casing
   1) Length of pipes
      a. Blank Pipes : (152.4 mm) 6" pipes = 59.50 m
         (101.6 mm) 4" pipes = 113.28 m
      b. Slotted pipes : (101.6 mm) 4" pipes = 27.22 m
      c. Slot Size : 1.58 mm
   2) Dia of Pipe :
      a. Blank Pipes :152.4 mm
      b. Slotted Pipes :101.6 mm
   3) Gauge of Pipes
      a. Blank Pipes :7.1 mm
      b. Slotted pipes :5.0 mm
   4) Material of Pipes
      a. Blank Pipes :MS
      b. Slotted pipes :MS

Geological Data:

Geologically the site is located in Trap covered Gondwana area. The contact between basalt and Gondwana encountered at 85 m bgl.

Table 8.1: Drill Time log of the Exploratory well drilled at village Mohgaon, Kalmeshwar taluka, Nagpur district.

DATE	Depth range(m)		Thickness ESS(m)	Time taken (min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
13.10.13	0	3	3	13.02	13.06	4	0.75
	3	5.65	2.65	13.06	13.12	6	0.44
	5.65	8.65	3	13.40	13.50	10	0.30
	8.65	11.3	2.65	13.50	14.05	15	0.18
	11.3	14.3	3	14.07	14.15	8	0.38
	14.3	16.95	2.65	14.15	14.22	7	0.38
	16.95	19.95	3	14.24	14.27	3	1.00

DATE	Depth range(m)		Thickness ESS(m)	Time taken (min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
	19.95	22.6	2.65	14.27	14.31	4	0.66
	22.6	25.6	3	14.33	14.34	1	3.00
	25.6	28.25	2.65	14.34	14.37	3	0.88
	28.25	31.25	3	14.39	14.49	10	0.30
	31.25	33.9	2.65	14.49	14.59	10	0.27
	33.9	36.9	3	15.02	15.09	7	0.43
	36.9	39.55	2.65	15.09	15.14	5	0.53
	39.55	42.65	3.1	15.16	15.21	5	0.62
	42.65	45.2	2.55	15.21	15.28	7	0.36
	45.2	48.2	3	15.30	15.37	7	0.43
	48.2	50.85	2.65	15.37	15.43	6	0.44
	50.85	53.85	3	15.45	15.50	5	0.60
	53.85	56.5	2.65	15.50	15.59	9	0.29
	56.5	59.5	3	16.04	16.07	3	1.00
	59.5	62.15	2.65	16.07	16.10	3	0.88
	62.15	65.15	3	16.12	16.18	6	0.50
	65.15	67.8	2.65	16.18	16.23	5	0.53
	67.8	70.8	3	16.25	16.30	5	0.60
	70.8	73.45	2.65	16.30	16.34	4	0.66
	73.45	76.45	3	16.37	16.40	3	1.00
	76.45	79.1	2.65	16.40	16.42	2	1.32
	79.1	82.1	3	16.44	16.50	6	0.50
	82.1	84.75	2.65	16.50	16.54	4	0.66
	84.75	87.75	3	16.56	17.00	4	0.75
	87.75	90.4	2.65	17.00	17.03	3	0.88
	90.4	93.4	3	17.05	17.06	1	3.00
	93.4	96.05	2.65	17.06	17.08	2	1.33
	96.05	99.05	3	17.09	17.10	1	3.00
	99.05	101.7	2.65	17.10	17.12	2	1.33
	101.7	104.7	3	17.13	17.16	3	1.00
	104.7	107.35	2.65	17.16	17.19	3	0.88
	107.35	110.35	3	17.19	17.20	1	3.00
	110.35	113	2.65	17.20	17.21	1	2.65
	113	116	3	17.22	17.23	1	3.00
	116	118.65	2.65	17.23	17.26	3	0.88
	118.65	121.65	3	17.27	17.29	2	1.50
	121.65	124.3	2.65	17.29	17.30	1	2.65
	124.3	127.3	3	17.31	17.32	1	3.00
	127.3	129.95	2.65	17.32	17.34	2	1.33
	129.95	132.95	3	17.35	17.36	1	3.00
	132.95	135.6	2.65	17.36	17.38	2	1.33
	135.6	138.6	3	17.39	17.40	1	3.00

DATE	Depth range(m)		Thickness ESS(m)	Time taken (min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
	138.6	141.25	2.65	17.40	17.41	1	2.65
	141.25	144.25	3	17.43	17.44	1	3.00
	144.25	146.9	2.65	17.44	17.46	2	1.33
	146.9	149.9	3	17.50	17.52	2	1.50
	149.9	152.55	2.65	17.52	17.54	2	1.33
	152.55	155.55	3	17.57	18.00	3	1.00
	155.55	158.2	2.65	18.00	18.01	1	2.65
	158.2	161.2	3	18.03	18.06	3	1.00
	161.25	163.85	2.6	18.06	18.09	3	0.87
	163.85	166.85	3	18.12	18.15	3	1.00
	166.85	169.5	2.65	18.15	18.18	3	0.88
	169.5	172.5	3	18.21	18.25	4	0.75
	172.25	175.15	2.9	18.25	18.29	4	0.73
	175.15	178.15	3	18.33	18.38	5	0.60
	178.15	180.8	2.65	18.38	18.44	6	0.44
	180.8	183.8	3	18.47	18.55	8	0.37
	183.8	186.45	2.65	18.55	19.13	8	0.33
	186.45	189.45	3	19.17	19.47	30	0.10
	189.45	192.1	2.65	21.30	22.00	30	0.09
	192.1	195.1	3	22.10	22.40	30	0.10
	195.1	197.75	2.65	22.40	23.00	20	0.13
	197.75	200	2.25	23.90	24.00	10	0.22

Table 8.2: Consolidated lithological log of the Exploratory well drilled at village Mohgaon, Kalmeshwar taluka, Nagpur district.

Depth range (m)		**Thickness (m)**	**Consolidated Lithology**
From	To		
0	3	3	Top Soil, sandy mixed with basalt massive, compact, coarse, black.
3	19.5	16.5	Basalt, Black, hard compact.
19.5	26	6.5	Vesicular Basalt, Black filled with green earth minerals.
26	39	13	Basalt, Black, hard compact.
39	42	3	**Green Bole:** Green, clayey, sticky, plastic
42	48	6	Basalt minutely vesicular filled with green earth and secondary minerals.**Fracute:42.55-48.70 m.,Q:1.37 lps**
48	55	7	Basalt, Black, hard compact.
55	61	6	Amygdular basalt filled with secondary minerals.
61	70.5	9.5	Basalt, Black, hard compact.
70.5	72	1.5	**Green Bole:** Green, clayey, sticky, plastic
72	80	8	Vesicular filled with green earth and secondary minerals.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
80	85	5	Basalt compact black mixed with sand fine to medium (Yellowish); **Fracture:82.0 to 85m m.,Q:2.16 lps**
85	101.7	16.7	Clay, brownish black mixed with very fine sand.
101.7	113	11.3	Clay, brownish yellow, mixed with very fine sand.
113	127.3	14.3	Clay, brownish black mixed with very fine sand , yellow
127.3	129.95	2.65	Sand medium grained, yellow
129.95	132.95	3	Sand fine grained, yellow
132.95	135.6	2.65	Sand medium grained, yellow
135.6	138.6	3	Sand very fine, yellow
138.6	141.25	2.65	Sand coarse grained, yellow
141.25	152.55	11.3	Sand medium to coarse grained, yellow
152.55	178.15	25.6	Sand medium grained, yellow
178.15	189.45	11.3	Sand, very fine to medium, yellow
189.45	200	10.55	Sand, very fine to medium, yellowish brown

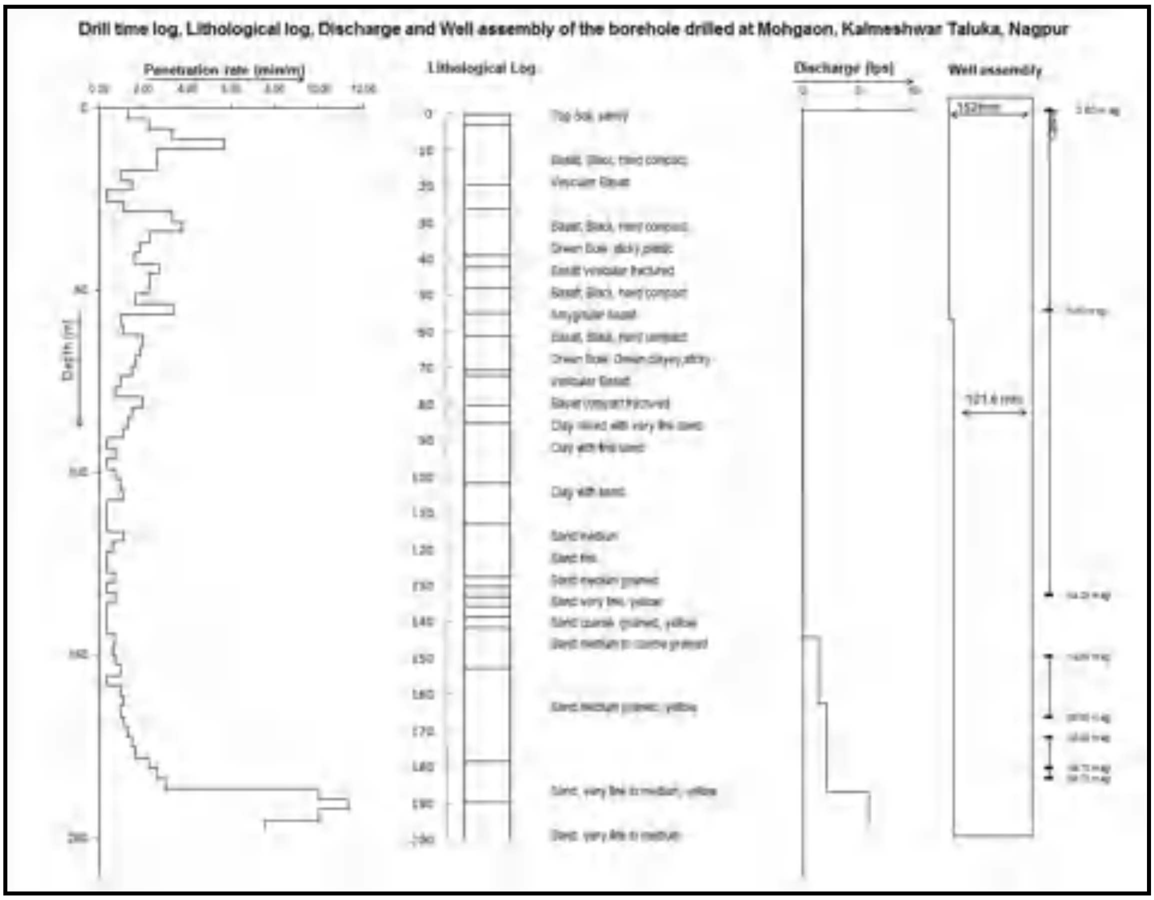


Fig.8.1: Composite Log of Exploratory Well Drilled at Mohgaon, Chandrabhaga Watershed (WGKKC-2)

Table 8.3: Fracture Zones encountered

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
	From	To		
1	42	48	**1.37**	Basalt minutely vesicular filled with green earth and secondary minerals.**Fracute:42.55-48.70 m.,Q:1.37 lps**
2	80	85	**2.16**	Basalt compact black mixed with sand fine to medium (Yellowish); **Fracture:82.0 to 85m m.,Q:2.16 lps**
3	127.3	200	5.94	**Sand Stone:** Pinkish Red, ferruginous; fine to medium grained

Table 8.4: Well Assembly of Exploratory Well at at MOHGAON EW, Kalmeshwar Taluka, Nagpur District.

S/N	Depth Range (mbgl)		Thickness	Description of Pipes
	From	To	(m bgl)	
1	0.00	0.6 (m agl)	0.60	6" (152.4 mm) dia M S Blank pipe
2	0.00	59.50	59.50	6" (152.4 mm) dia M S Blank pipe
3	59.50	**144.23**	84.73	4" (101.6 mm) dia M S Blank pipe
4	**144.23**	162.38	18.15	**4" (101.6 mm) dia M S Slotted pipe**
5	162.38	**180.53**	18.15	4" (101.6 mm) dia M S Blank pipe
6	**180.53**	186.60	6.07	**4" (101.6 mm) dia M S Slotted pipe**
7	186.60	**195.72**	9.12	4" (101.6 mm) dia M S Blank pipe
8	**195.72**	198.73	3.01	**4" (101.6 mm) dia M S Slotted pipe**
9	198.72	**200.00**	1.28	4" (101.6 mm) dia M S Blank pipe with bail plug.

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and cumulative discharge measured was 5.94 lps.

WELL HYDRAULICS

Pumping Test could not conducted at Mohgaon due to encounter of deep ground water level ie is more than 63.00 mbgl.

Chemical Quality

During drilling of exploratory well water samples were collected for Chemical analysis. The Samples were analyzed in the chemical laboratory of CGWB,CR, Nagpur. The results of the analysis are presented in the Table 8.5

Table8.5: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm……………..										
Mohgaon	Zone-I (42.55-48.70m)	8.4	563	275	50	36	3	0.34	9	207	57	26	21	0.36
Mohgaon	Zone-II (79.10-87.75m)	7.9	693	335	44	55	2	0.13	0	354	39	5	10	0.73

Chemical analysis of water sample collected from the Zone-I (42.55-48.70m bgl) revealed that the range of concentration of Mg is found more than desirable limit and all other parameters are within desirable limit. In Zone-II (79.10-87.75m) the analysis revealed that the range of concentration of parameters viz TH, Mg, HCO_3 are more than desirable limit while all other parameters are within the desirable limit. as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

9. Exploratory Well drilled at Khapri

Location of Site

The village KHAPRI lies between north latitude 21°14'22"and east longitude 78°58'26" and falls in the Survey of India Toposheet No. 55 K/16. It is situated at 7 kms from kalmeshwar on Katol road and the site is located near Jalswaraj Dug Well of the village.

Details of Drilling:

a) Rock Formation: Trap Covered Gondwana
b) Type: Basalt & Sandstone
c) Drilling Started on 22/10/2013 at 07.10 hrs
d) Drilling Completed on 22/10/2013 at 16.30 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in Hard rock Formation (with 254 mm Button Bit):160.00 m.
g) Total depth drilled in soft rock Formation (with 190.50 mm Button Bit):40.00 m.
h) Depth of reaming (with 254.00 mm Button Bit) : 160.00 m
   (with 254.00 mm Button Bit) : 160.00 m to 200.00 m
i) Well construction Depth 200.00 m
j) Details of Casing
   1) Length of pipes
      a. Blank Pipes : (152.4 mm) 6" pipes = 60.60 m
         (101.6 mm) 4" pipes = 73.54 m
      b. Slotted pipes : (101.6 mm) 4" pipes = 18.18 m
      c. Slot Size :1.58 mm
   2) Dia of Pipe
      a. Blank Pipes 152.4 mm
      b. Slotted Pipes :101.6 mm
   3) Gauge of Pipes
      a. Blank Pipes :7.1 mm
      b. Slotted pipes :5.0 mm
   4) Material of Pipes
      a. Blank Pipes :MS
      b. Slotted pipes :MS

Geological Data:

Geologically the site is located in Trap covered Gondwana area. The contact between basalt and Gondwana encountered at 116 m bgl.

Table 9.1: Drill Time log of the Exploratory well drilled at village Khapri, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
22/10/2013	0	3	3	710	713	3	1.00
	3	5.65	2.65	715	716	1	0.38
	5.65	8.65	3	800	805	5	1.67
	8.65	11.3	2.65	805	806	1	0.38
	11.3	14.3	3	807	809	2	0.67
	14.3	16.95	2.65	809	810	1	0.38

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
	16.95	19.95	3	811	816	5	1.67
	19.95	22.6	2.65	816	822	6	2.26
	22.6	25.6	3	822	832	10	3.33
	25.6	28.25	2.65	832	839	7	2.64
	28.25	31.25	3	840	842	2	0.67
	31.25	33.9	2.65	842	845	3	1.13
	33.9	36.9	3	846	850	4	1.33
	36.9	39.55	2.65	850	853	3	1.13
	39.55	42.65	3.1	854	859	5	1.61
	42.65	45.2	2.55	859	905	6	2.35
	45.2	48.2	3	906	910	4	1.33
	48.2	50.85	2.65	910	914	4	1.51
	50.85	53.85	3	915	920	5	1.67
	53.85	56.5	2.65	920	926	6	2.26
	56.5	59.5	3	927	935	8	2.67
	59.5	62.15	2.65	935	940	5	1.89
	62.15	65.15	3	941	945	4	1.33
	65.15	67.8	2.65	945	950	5	1.89
	67.8	70.8	3	951	956	5	1.67
	70.8	73.45	2.65	956	1003	7	2.64
	73.45	76.45	3	1003	1006	3	1.00
	76.45	79.1	2.65	1006	1009	3	1.13
	79.1	82.1	3	1010	1014	4	1.33
	82.1	84.75	2.65	1014	1020	6	2.26
	84.75	87.75	3	1020	1026	6	2.00
	87.75	90.4	2.65	1026	1029	3	1.13
	90.4	93.4	3	1030	1033	3	1.00
	93.4	96.05	2.65	1033	1035	2	0.75
	96.05	99.05	3	1036	1039	3	1.00
	99.05	101.7	2.65	1039	1041	2	0.75
	101.7	104.7	3	1042	1046	4	1.33
	104.7	107.35	2.65	1046	1049	3	1.13
	107.35	110.35	3	1050	1054	4	1.33
	110.35	113	2.65	1054	1059	5	1.89
	113	116	3	1100	1104	4	1.33
	116	118.65	2.65	1104	1108	4	1.51
	118.65	121.65	3	1108	1112	4	1.33
	121.65	124.3	2.65	1112	1115	3	1.13
	124.3	127.3	3	1116	1118	2	0.67
	127.3	129.95	2.65	1118	1120	2	0.75
	129.95	132.95	3	1123	1125	2	0.67
	132.95	135.6	2.65	1125	1130	5	1.89

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate min/m
	From	To		From	To		
	135.6	138.6	3	1133	1135	2	0.67
	138.6	141.25	2.65	1135	1138	3	1.13
	141.25	144.25	3	1140	1143	3	1.00
	144.25	146.9	2.65	1143	1147	4	1.51
	146.9	149.9	3	1150	1153	3	1.00
	149.9	152.55	2.65	1153	1156	3	1.13
	152.55	155.55	3	1159	1206	7	2.33
	155.55	158.2	2.65	1206	1214	8	3.02
	158.2	161.2	3	1217	1225	8	2.67
	161.25	163.85	2.6	1225	1234	9	3.46
	163.85	166.85	3	1237	1248	11	3.67
	166.85	169.5	2.65	1248	1259	11	4.15
	169.5	172.5	3	1302	1314	12	4.00
	172.25	175.15	2.9	1314	1326	12	4.14
	175.15	178.15	3	1329	1344	15	5.00
	178.15	180.8	2.65	1344	1359	15	5.66
	180.8	183.8	3	1402	1416	14	4.67
	183.8	186.45	2.65	1418	1426	8	3.02
	186.45	189.45	3	1428	1436	8	2.67
	189.45	192.1	2.65	1436	1501	25	9.43
	192.1	195.1	3	1503	1517	14	4.67
	195.1	197.75	2.65	1517	1537	20	7.55
	197.75	200	2.25	1538	1548	10	4.44

Table 9.2: Consolidated lithological log of the Exploratory well drilled at village Khapri, Kalmeshwar taluka, Nagpur district.

Depth range (m)		**Thickness (m)**	**Consolidated Lithology**
From	To		
0	0.5	0.5	**Top Soil:** brown; sandy and silty lose material.
0.5	16.95	16.45	**Amygdular Basalt**: brown, highly weathered ; vesicles filled with pink secondary minerals.
16.95	26	9.05	**Massive Basalt**: greyish black fresh moderately hard; irregular chips of 2-8 mm mixed with clay
26	29	3	**Clay**: Grey sticky plastic mixed with gravelly Amygdular basaltic friable chips
29	44.5	15.5	**Amygdular Basalt**: brown, highly weathered ; vesicles filled with pink secondary minerals.
44.5	70	25.5	**Massive Basalt:** Dark grey; fresh; moderately hard; gravelly 3-10 mm slightly fractured filled with quartz minerals and clay material. Fracture at 44.8 to 50.4m **Q:1.05 lps**
70	76	6	**Clay:** Bole Brownish red friable pieces mixed with grey irregular basaltic chips
76	103	27	**Bole:** Green to reddish green friable pieces mixed with about 10%

Depth range (m)		**Thickness (m)**	**Consolidated Lithology**
From	To		
			of irregular chips.
103	116	13	**Massive Basalt**: Dark grey; fresh; moderately hard; irregular chips of 3-6 mm
116	119	3	**Gravel**: Grey hard; sub rounded to rounded ;4-5mm very coarse to gravelly mixed with quartz crystels.**Q:3.17 lps**
119	154	35	**Sand Stone**: Fresh greyish white to white; fine to medium grained; sub rounded , siliceous.**Q:6.0 lps**
154	158.5	4.5	**Sand Stone**: Fresh greyish white to white; fine to medium grained; sub rounded , siliceous.**Q:6.0 lps**
158.5	200	41.5	**Basement**: Dark grey; fresh; hard; malenocratic, crystalline rock, mixed with sand grains and bole pieces.

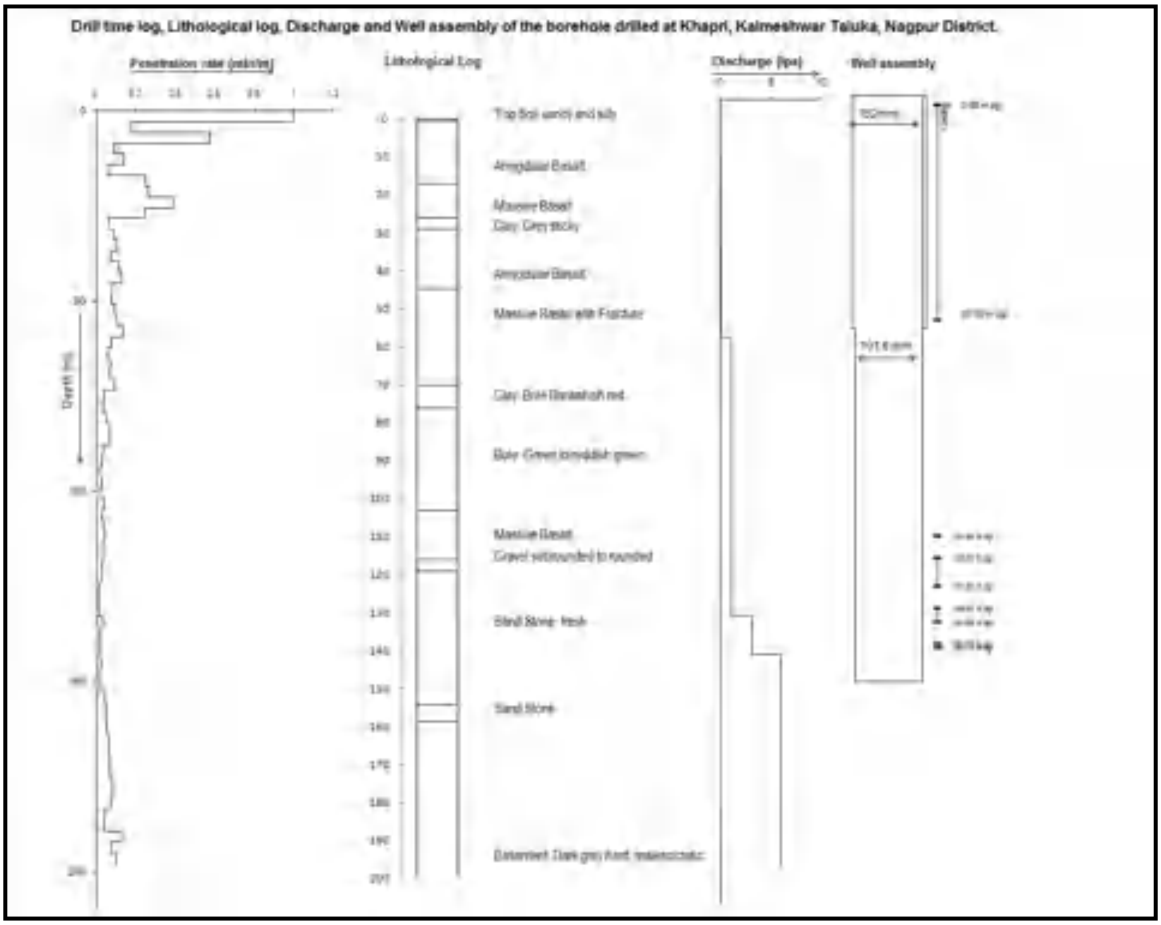


Fig.3.36: Composite Log of Exploratory Well Drilled at Khapri, Chandrabhaga Watershed (WGKKC-2)

Table 9.3: Fracture Zones encountered

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
	From	To		
1	44.5	70	**1.05**	**Massive Basalt:** Dark grey; fresh; moderately hard; gravelly 3-10 mm slightly fractured filled with quartz

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
				minerals and clay material. Fracture at 44.8 to 50.4m
2	116	118.85	**3.17**	**Gravel**: Grey hard; sub rounded to rounded ;4-5mm very coarse to gravelly mixed with quartz crystals.
3	118.85	158.5	**12.0**	**Sand Stone**: Fresh greyish white to white; fine to medium grained; subrounded , siliceous.

WELL DESIGN

Table 9.3: Recommended well design

S/N	Depth Range (mbgl)		Thickness	Describtion of Pipes
	From	To	(m bgl)	
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank MS pipe
2	0.00	60.00	60.00	4" (101.6 mm) dia M S Blank MS pipe with reducer
3	60.00	**120.49**	**60.49**	4" (101.6 mm) dia M S Blank MS pipe
4	**120.49**	126.55	6.06	**4" (101.6 mm) dia M S slotted (1/16") pipe**
5	126.55	**134.60**	**8.05**	4" (101.6 mm) dia M S Blank MS pipe
6	**134.60**	140.66	6.06	**4" (101.6 mm) dia M S slotted (1/16") pipe**
7	140.66	**144.66**	**4.00**	4" (101.6 mm) dia M S Blank MS pipe
8	**144.66**	150.72	6.06	**4" (101.6 mm) dia M S slotted (1/16") pipe**
9	150.72	151.72	1.00	4" (101.6 mm) dia M S Blank MS pipe with bail plug

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and cumulative discharge measured was 1.05 lps.

WELL HYDRAULICS

Pumping Test could not be conducted at KHAPRI due to deep ground water level condition, which is more than 68.00 mbgl.

Chemical Quality

Table 9.4: Results of the chemical analysis of Exploratory Well

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm………………										
Khapri	Zone-I (48.2-50.85m)	8.5	492	225	12	47	9	0.33	12	226	25	7	21	1.31
Khapri	Zone-II(67.8-70.8m)	8.4	512	240	30	40	7	0.22	12	232	28	13	17	0.94

Chemical analysis of water sample collected from the Zone-I (48.2-50.85m bgl) revealed that the range of concentration of Mg and F is found more than desirable limit and all other parameters are within desirable limit. In Zone-II (67.8-70.8m bgl) the analysis revealed that the range of concentration of parameters viz Mg is more than desirable limit while all other parameters are within the desirable limit. as per “Drinking Water Standards” of Bureau of Indian Standards (BIS 10500-2013).

10. Exploratory Well drilled at Dahegaon

Location of Site

The village DAHEGAON lies between north latitude 21°15'48.8" and east longitude 78°54'17.4" and falls in the Survey of India Toposheet No. 55 K/16. It is situated at 13 kms from Nagpur on Klameshwar road, and the site is located premises of smashanbhumi.. .

Details of Drilling:

a) Rock Formation: Trap Covered Gneiss
b) Type: Basalt & Gneiss
c) Drilling Started on 30/10/2013 at 1936 hrs
d) Drilling Completed on 31/10/2013 at 13.30 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in Weathered Formation (with 279.4 mm Button Bit):29.80m.
g) Total depth drilled in Hard rock Formation (with 190.5 mm Button Bit):170.20 m.
h) Assembly Details:
    a) Length of Casing : 29.80 mbgl and 0.63 magl= 30.43 m
    b) Diameter of Casing : 8" (203 mm)
    c) Material of Casing Pipe : M S Pipe

Geological Data:

The village Dahegaon in general comprises of basaltic formation of Deccan traps fallowed by lameta and Archean formation. Thickness of top soil is 1 m bgl, which further followed by clay of 1.5 m thick. The collapsible clay formation (bole bads) encountered at various depth of 1-2.5, 20-27, 44-45.5, 59.5-74 and 90.4-96.5 m bgl, which ultimately filled up the well.

Table 10.1: Drill Time log of the Exploratory well drilled at village Dahegaon, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
30/10/2013	0	3	3	1936	1957	21	7.00
	3	5.65	2.65	2000	2015	15	5.66
	5.65	8.65	3	2015	2220	5	1.67
	8.65	11.3	2.65	2021	2226	5	1.89
	11.3	14.3	3	2028	2038	10	3.33
	14.3	16.95	2.65	2038	2047	9	3.40
	16.95	19.95	3	2050	2059	9	3.00
	19.95	22.6	2.65	2059	2110	11	4.15
	22.6	25.6	3	2112	2122	10	3.33
	25.6	28.25	2.65	2122	2133	11	4.15
	28.25	31.25	3	2135	2145	10	3.33
	31.25	33.9	2.65	2145	2157	12	4.53
	33.9	36.9	3	2159	2211	12	4.00
	36.9	39.55	2.65	2211	2222	11	4.15
	39.55	42.65	3.1	2224	2235	11	3.55
	42.65	45.2	2.55	2235	2240	5	1.96
	45.2	48.2	3	2240	2245	5	1.67
	48.2	50.85	2.65	2245	2250	5	1.89
	50.85	53.85	3	2250	2300	10	3.33

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	53.85	56.5	2.65	2300	2306	6	2.26
31/10/2013	56.5	59.5	3	2400	2407	7	2.33
	59.5	62.15	2.65	2407	2420	13	4.91
	62.15	65.15	3	2422	2429	7	2.33
	65.15	67.8	2.65	2429	2435	6	2.26
	67.8	70.8	3	2436	2447	11	3.67
	70.8	73.45	2.65	2447	2456	9	3.40
	73.45	76.45	3	130	136	6	2.00
	76.45	79.1	2.65	136	142	6	2.26
	79.1	82.1	3	144	154	10	3.33
	82.1	84.75	2.65	154	203	9	3.40
	84.75	87.75	3	205	211	6	2.00
	87.75	90.4	2.65	211	222	11	4.15
	90.4	93.4	3	235	242	7	2.33
	93.4	96.05	2.65	242	250	8	3.02
	96.05	99.05	3	511	513	2	0.67
	99.05	101.7	2.65	513	517	4	1.51
	101.7	104.7	3	518	523	5	1.67
	104.7	107.35	2.65	523	526	3	1.13
	107.35	110.35	3	527	530	3	1.00
	110.35	113	2.65	530	535	5	1.89
	113	116	3	536	540	4	1.33
	116	118.65	2.65	540	543	3	1.13
	118.65	121.65	3	544	547	3	1.00
	121.65	124.3	2.65	547	551	4	1.51
	124.3	127.3	3	552	556	4	1.33
	127.3	129.95	2.65	556	601	5	1.89
	129.95	132.95	3	602	607	5	1.67
	132.95	135.6	2.65	607	613	6	2.26
	135.6	138.6	3	615	621	6	2.00
	138.6	141.25	2.65	621	630	9	3.40
	141.25	144.25	3	632	639	7	2.33
	144.25	146.9	2.65	639	647	8	3.02
	146.9	149.9	3	648	655	7	2.33
	149.9	152.55	2.65	655	704	9	3.40
	152.55	155.55	3	705	710	5	1.67
	155.55	158.2	2.65	710	720	10	3.77
	158.2	161.2	3	1330	1335	5	1.67
	161.25	163.85	2.6	1335	1342	7	2.69
	163.85	166.85	3	1344	1350	6	2.00

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	166.85	169.5	2.65	1350	1358	8	3.02
	169.5	172.5	3	1400	1410	10	3.33
	172.25	175.15	2.9	1410	1416	6	2.07
	175.15	178.15	3	1418	1426	8	2.67
	178.15	180.8	2.65	1426	1434	8	3.02
	180.8	183.8	3	1436	1444	8	2.67
	183.8	186.45	2.65	1444	1454	10	3.77
	186.45	189.45	3	1456	1510	14	4.67
	189.45	192.1	2.65	1510	1514	4	1.51
	192.1	195.1	3	1518	1528	10	3.33
	195.1	197.75	2.65	1528	1534	6	2.26
	197.75	200	2.25	1536	1546	10	4.44

Table 10.2: Consolidated lithological log of the Exploratory well drilled at village Dahegaon, Kalmeshwar taluka, Nagpur district.

Depth range(m)		Thickness (m)	Consolidated Lithology
From	To		
0	1	1	Top Soil: Light grey and brown; silty and clayey lose material.
1	2.5	1.5	Clay: Light yellow and grey, silty and clayey sticky
2.5	8.65	6.15	Basalt: Yellowish-grey, highly weathered and fractured; silty; loose material with angular 3-5 mm chips.
8.65	14.13	5.48	Basalt: Dark grey; fresh; moderately hard; angular chips of 3-5 mm., with coarse grains.
14.13	20	5.87	Basalt: Dark grey; fresh ; hard; irregular/angular chips of 2-4 mm. mixed with 10% clay material. Fractured bet5ween; **14.3-19.65 with Q:0.38 LPS**
20	27	7	Clay: Light brown; sticky; plastic like "dough"
27	34	7	Vesicular Basalt: Dark grey to light grey; moderately hard; vesicular chips of 3-6mm
34	44	10	Basalt: Massive ; Dark grey; fresh; hard; chips of 1-3 mm. mixed with green clay bole.
44	45.5	1.5	Green Bole: Green to light green sticky plastic with friable pieces;
41	59.5	18.5	Basalt: Dark grey; Massive fresh; hard; chips of 2-6 mm.
59.5	74	14.5	Green Bole: Green to light green sticky plastic like with friable pieces;
74	79.1	5.1	Vesicular Basalt: Vesicular; fresh; moderately hard; light grey; fragile chips of 2-6 mm with coarse grains
79.1	82.1	3	Amygdular Basalt: Amygdular light grey; fresh; moderately hard chips; the vesicles filled with secondary minerals.
82.1	90.4	8.3	Basalt: Massive; dark grey; fresh; hard; compact medium to fine grained
90.4	96.05	5.65	Clay(Bole): Reddish-brown, sticky; plastic; like "dough" mixed with brittle limestone chips of 3-5 mm
96.05	129.95	33.9	Lametas: Limestone; cherty; light brown to light grey; brittle

Depth range(m)		Thickness (m)	Consolidated Lithology
From	To		
			chips of 2-6 mm
129.95	132.95	3	Gneiss: light brown; fresh; Quartz and micaceous mixed with 20% of brittle chips of Limestone.
132.95	163.85	30.9	Gneiss: light grey; fresh; hard; thick micaceous flakes mixed with quartz minerals.
163.85	172.5	8.65	Gneiss: Dark grey; fresh; hard; thick micaceous flaked with malenocratic minerals.
172.5	200	27.5	Gneiss: light grey to dark grey; fresh; hard quartz and feldspathic coarse grains with 10% mica flakes.

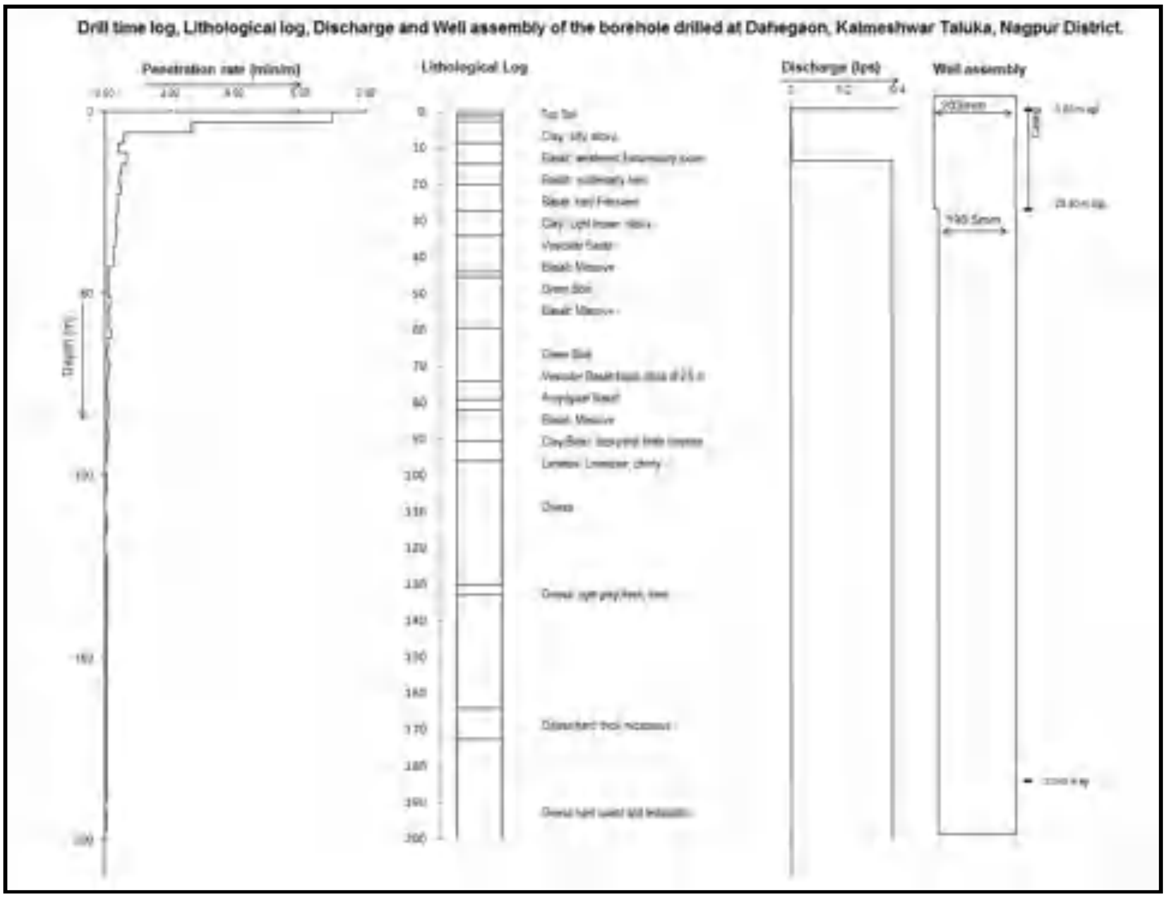


Fig. 10.1: Composite Log of Exploratory Well Drilled at Dahegaon, Chandrabhaga Watershed (WGKKC-2)

Table 10.3: Fracture Zones encountered

S.No	Zones encountered		Cumulative Discharge	Lithology
	From	To		
1	14.13	20	0.38 Lps	Basalt: Dark grey; fresh ; hard; irregular/angular chips of 2-4 mm. mixed with 10% clay material. Fracture between; 14.3-19.65 m bgl.

Well Hydraulics

Pumping Test could not be conducted at Dahegaon site due to well have been collapsed at various depths.

Chemical Quality

Table 10.4: Results of the chemical analysis of Exploratory Well

Location	**Type**	**pH**	**Ec µS/cm**	**TH**	**Ca**	**Mg**	**Na**	**K**	**CO_3**	**HCO_3**	**Cl**	**SO_4**	**NO_3**	**F**
				……………………………ppm……………..										
Dahegaon	Zone-I (14.3-16.95 m)	8.3	540	235	30	39	8	0.41	9	134	67	33	28	0.68

Chemical analysis of water sample collected during drilling operation revealed that the range of concentration in all the parameters are found within desirable limit as per “Drinking Water Standards” of Bureau of Indian Standards (BIS 10500-2013).

11. Exploratory Well drilled at Dhapewada

Location of Site

The village Dhapewada lies between north latitude 21°18'15.7"and east longitude 78°54'18" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at about 10 km distance from Kalmeshwar on Saoner road, and the site is located in the the open space on the road to grave yard behind” kade” farm. .

History of Drilling Operations:

The rig unit was shifted to well site on 01/11/13. The drilling started on on 01/11/13 at 17.00 hrs and completed on 02/11/13 at 14.35 hrs. The drilling details and drilling time log are presented below.

Details of Drilling:

a) Rock Formation: Gondwana
b) Type: Sandstone
c) Drilling Started on 01/11/2013 at 17.00 hrs
d) Drilling Completed on 02/11/2013 at 14.35 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in soft rock Formation (with 190.5mm Button Bit):200.00 m.
g) Depth of reaming : (with 304.8 mm Drag Bit) :187.50 m
h) Well Construction Depth : 187.30 m bgl

Details of Casing

1) Length of pipes
   a. Blank Pipes : 151.65 m
   b. Slotted pipes : 36.25 mbgl
   c. Slot Size : 1.58 mm
2) Dia of Pipe :
   a. Blank Pipes : 152.4 mm
   b. Slotted Pipes : 152.4 mm

3) Gauge of Pipes
   a. Blank Pipes : 7.1 mm
   b. Slotted pipes : 7.1mm

4) Material of Pipes
    a. Blank Pipes : MS
    b. Slotted pipes : MS

Geological Data:
Geologically, the area is underlined by Gondwana group of rocks. These formations are exposed in the surface as well as seen in well sections

Drill Time log:

During drilling lithological samples were collected , washed and preserved in the labelled sample box for detailed examination. The samples were collected at every 3 m interval or wherever there is change in lithology and the drill time log is prepared during drilling and shown in table-1.

Table 11.1: Drill Time log of the Exploratory well drilled at village Dhapewada, Kalmeshwar taluka, Nagpur district.

DATE	Depth range (m)		Thick-ness(m)	Drilling time (min)		Time taken (min)	Penetration rate min/m
	From	To		From	To		
	0	3	3	1700	1701	1	0.33
11-01-2013	3	5.65	2.65	1701	1703	2	0.75
	5.65	8.65	3	1730	1733	3	1.00
	8.65	11.3	2.65	1733	1734	1	0.38
	11.3	14.3	3	1735	1740	5	1.67
	14.3	16.95	2.65	1740	1741	1	0.38
11-02-2013	16.95	19.95	3	800	802	2	0.67
	19.95	22.6	2.65	802	806	4	1.51
	22.6	25.6	3	808	813	5	1.67
	25.6	28.25	2.65	813	817	4	1.51
	28.25	31.25	3	908	913	5	1.67
	31.25	33.9	2.65	913	916	3	1.13
	33.9	36.9	3	917	923	6	2.00
	36.9	39.55	2.65	923	925	2	0.75
	39.55	42.65	3.1	926	930	4	1.29
	42.65	45.2	2.55	930	932	2	0.78
	45.2	48.2	3	932	934	2	0.67
	48.2	50.85	2.65	934	9.37	3	1.13
	50.85	53.85	3	938	942	4	1.33
	53.85	56.5	2.65	942	944	2	0.75
	56.5	59.5	3	945	950	5	1.67
	59.5	62.15	2.65	950	958	8	3.02
	62.15	65.15	3	1000	1002	2	0.67
	65.15	67.8	2.65	1002	1004	2	0.75
	67.8	70.8	3	1005	1009	4	1.33
	70.8	73.45	2.65	1009	1013	4	1.51
	73.45	76.45	3	1014	1016	2	0.67
	76.45	79.1	2.65	1016	1019	3	1.13
	79.1	82.1	3	1020	1022	2	0.67

DATE	Depth range (m)		Thick-ness(m)	Drilling time (min)		Time taken (min)	Penetration rate min/m
	From	To		From	To		
	82.1	84.75	2.65	1022	1025	3	1.13
	84.75	87.75	3	1026	1030	4	1.33
	87.75	90.4	2.65	1030	1034	4	1.51
	90.4	93.4	3	1035	1039	4	1.33
	93.4	96.05	2.65	1039	1041	2	0.75
	96.05	99.05	3	1043	1046	3	1.00
	99.05	101.7	2.65	1046	1050	4	1.51
	101.7	104.7	3	1051	1053	2	0.67
	104.7	107.35	2.65	1053	1056	3	1.13
	107.35	110.35	3	1057	1058	1	0.33
	110.35	113	2.65	1058	1102	4	1.51
	113	116	3	1103	1105	2	0.67
	116	118.65	2.65	1105	1107	2	0.75
	118.65	121.65	3	1108	1111	3	1.00
	121.65	124.3	2.65	1111	1114	3	1.13
	124.3	127.3	3	1115	1118	3	1.00
	127.3	129.95	2.65	1118	1121	3	1.13
	129.95	132.95	3	1122	1124	2	0.67
	132.95	135.6	2.65	1124	1129	5	1.89
	135.6	138.6	3	1130	1133	3	1.00
	138.6	141.25	2.65	1133	1136	3	1.13
	141.25	144.25	3	1137	1141	4	1.33
	144.25	146.9	2.65	1141	1147	6	2.26
	146.9	149.9	3	1150	1155	5	1.67
	149.9	152.55	2.65	1155	1200	5	1.89
	152.55	155.55	3	1200	1205	5	1.67
	155.55	158.2	2.65	1205	1210	5	1.89
	158.2	161.2	3	1213	1216	3	1.00
	161.25	163.85	2.6	1216	1221	5	1.92
	163.85	166.85	3	1223	1228	5	1.67
	166.85	169.5	2.65	1228	1233	5	1.89
	169.5	172.5	3	1236	1241	5	1.67
	172.25	175.15	2.9	1241	1246	5	1.72
	175.15	178.15	3	1249	1256	7	2.33
	178.15	180.8	2.65	1256	1302	6	2.26
	180.8	183.8	3	1304	1311	7	2.33
	183.8	186.45	2.65	1311	1319	8	3.02
	186.45	189.45	3	1321	1336	15	5.00
	189.45	192.1	2.65	1336	1356	20	7.55
	192.1	195.1	3	1406	1417	11	3.67
	195.1	197.75	2.65	1417	1431	14	5.28
	197.75	200	2.25	1435	1448	13	5.78

Table 11.2: Consolidated lithological log of the Exploratory well drilled at village Dhapewada, Katol taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	3	3	**Top soil**: Grey; silty; loamy; loose material
0.5	4.5	4	**Alluvium**: Greyish; loose; mixed with kankar with clay and silt.
4.5	13	8.5	**Alluvium**: Dark grey to black loose sand mixed with basaltic chips of 3-5 mm
13	27	14	**Alluvium**: Dark grey to black loose sand mixed with clay and basaltic chip sand of 3-5 mm 22.6-25.6 mts. Q:0.14 lps
27	30.5	3.5	**Basalt**: light grey-dark grey; fractured chips, mixed with negligible sand grains.
30.5	36.9	6.4	**Sandstone**: Ferruginous; light pink to grey; very coarse grain to gravelly with quartz particles; angular to sub rounded
36.9	43	6.1	**Shale**: light pink mixed with clayey and silt material
43	47	4	**Sandstone**: Ferruginous; light pink to grey; medium to coarse grain to gravelly with quartz particles; angular to sub rounded
47	51	4	**Clay**: Reddish -pink, sticky plastic like "dough"
51	55	4	**Sandstone**: Ferruginous; light pink to grey; medium to coarse grain to gravelly with quartz particles; angular to sub rounded
55	60	5	**Sandy clay**: Reddish pink; sticky mixed with fine sand grains.
60	62.15	2.15	**Clay**: Pinkish grey; sticky; plastic mixed with fragile shale chips.
62.15	65.5	3.35	**Sandstone**: Light grey to pink; medium to course grained angular to subrounded. Cumulative Discharge between:**62.15-65.15 m.,2.16 lps**
65.5	68.6	3.1	**Clayey sand**: light grey; fine grained mixed with 10% clayey material.
68.6	74	5.4	**Sandstone**: light pink; medium to coarse grained angular to sub angular. With little **clay intercalation**
74	77	3	**clayey sand**: Dark grey; 2-3 mm fragile chips with negligible sand grains.
77	79.1	2.1	**Sandstone**: Dark grey; medium to coarse grains mixed with 30% shale chips of 2-3 mm
79.1	84.5	5.4	**Sandstone**: light pink; Ferruginous medium to coarse gained angular to sub rounded
84.5	89.5	5	**Shale**: light grey to dark grey mixed with sand grains and clayey material.
89.5	101	11.5	**Sandstone**: Light grey; medium very fine grained; sub angular to angular with **clay intercalations**
101	103	2	**Sandstone**: light grey; medium to very fine grained; angular to sub rounded
103	104	1	**clay** dark grey in color sticky
104	110.35	6.35	**Sandstone**; light grey; medium to coarse grained; angular to sub angular.
110.35	112	1.65	**clay** dark grey in color sticky
112	129.95	17.95	**Sandstone**: light grey; medium to fine grained; angular to subrounded. Cumulative Discharge between **116.0 -118.65 m., 4.43 lps With little clay intercalation**
129.95	144.25	14.3	**Sandstone**: light grey; medium to coarse grained; ferruginous

			angular to sub rounded
144.25	158.2	13.95	**Sandstone**: light grey; medium to fine grained; siliceous; angular to sub angular. With little clay intercalation
158.2	187	28.8	**Sandstone**: light grey; medium to coarse grained; angular to sub rounded mixed with occasional shale chips. With little clay intercalation
187	197.75	10.75	**Shale**: Dark grey; fragile chips of 3-5 mm. mixed with 20% sand grains.

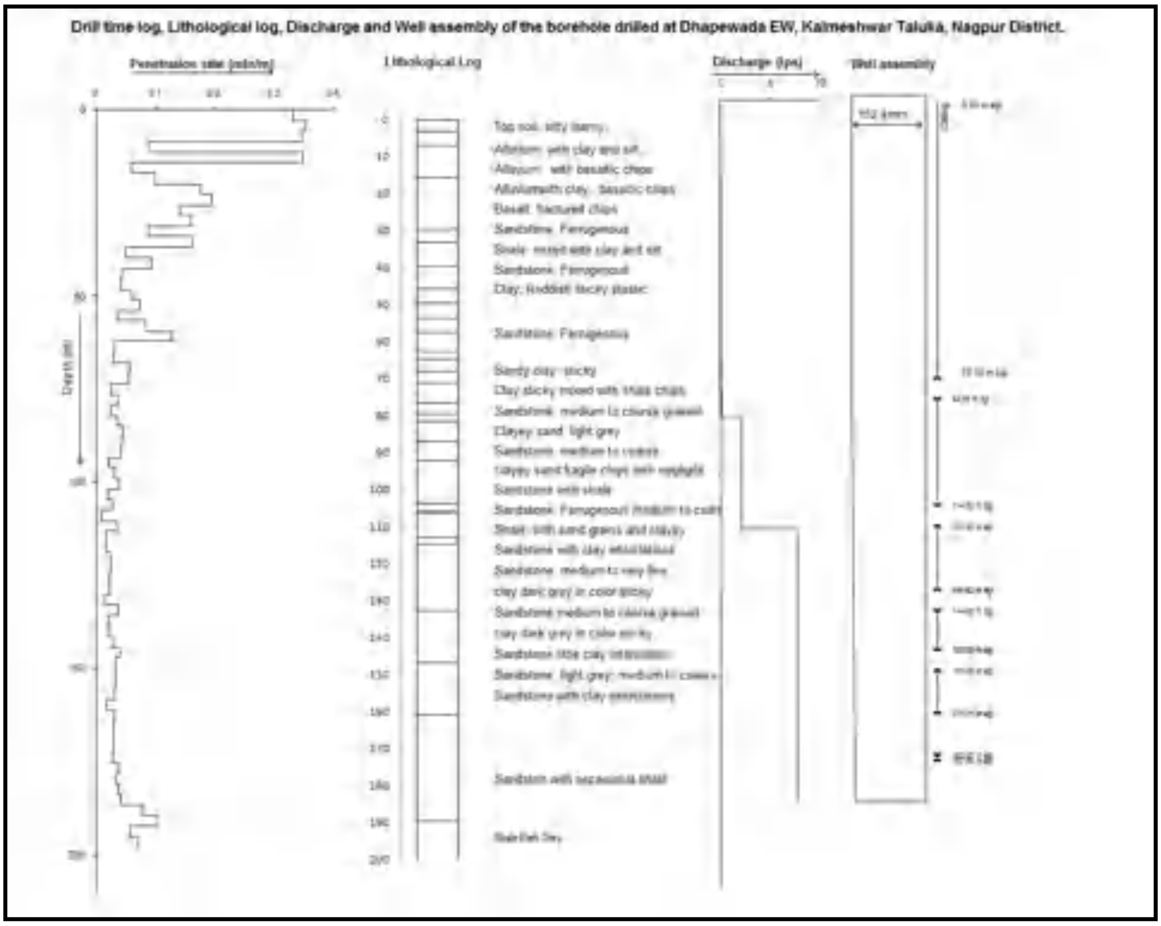


Fig.11.3: Composite Log of Exploratory Well Drilled at Dhapewada, Chandrabhaga Watershed (WGKKC-2)

WELL DESIGN

Table 11.3: Recommended Well design

S/N	Depth Range (mbgl)		Thickness	Description of Pipes
	From	To	(m bgl)	
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank MS pipe
2	0.00	78.00	78.00	6" (152.4 mm) dia M S Blank MS pipe with reducer
3	**78.00**	**84.85**	6.85	**6" (152.4 mm) dia M S slotted (1/16") pipe**
4	84.85	114.30	29.45	6" (152.4 mm) dia M S Blank MS pipe
5	**114.30**	**120.30**	6.00	**6" (152.4 mm) dia M S slotted (1/16") pipe**
6	120.30	138.42	18.12	6" (152.4 mm) dia M S Blank MS pipe

S/N	Depth Range (mbgl)		Thickness	Description of Pipes
	From	To	(m bgl)	
7	**138.42**	**144.48**	6.06	**6" (152.4 mm) dia M S slotted (1/16") pipe**
8	144.48	155.53	11.05	6" (152.4 mm) dia M S Blank MS pipe
9	**155.53**	**161.58**	6.05	**6" (152.4 mm) dia M S slotted (1/16") pipe**
10	161.58	173.71	12.13	6" (152.4 mm) dia M S Blank MS pipe
11	**173.71**	**185.80**	12.09	**6" (152.4 mm) dia M S slotted (1/16") pipe**
12	185.80	187.30	1.50	6" (152.4 mm) dia M S Blank MS pipe with bail blug

Development

The well was developed using air compressor for 15 hrs on 10/11/13 to 11/11/13 till the water was free from sand particles and cumulative discharge measured 7.76 lps.

WELL HYDRAULICS

Aquifer Performance Test (APT)

Table 11.4: The details of the Aquifer Performance Test (APT) Conducted on Exploratory Well at DHAPEWADA, Kalmeshwar Taluka, Nagpur District.

Date	15/12/13
Static Water Level	11.37 mbgl
Discharge (Q)	7.76 lps
Drawdown (Δs)	1.897
Transmissivity (T)	65m^2/day
Specific Capacity	28.18 lpm/m

CHEMICAL QUALITY

The ground water sample collected during the pumping test was analysed at the Regional Chemical Laboratory of CGWB (CR) Nagpur. The analytical results are given in Table

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………….ppm………………..										
Dhapewada	PT	8.2	859	330	22	67	9	0.19	0	250	64	72	24	0.44

The analytical result of water sample collected during pumping test revealed that the range of concentration of parameters viz TH, Mg are more than desirable limit while all other parameters are within the desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

12. Observation Well drilled at Dhapewada

Location of Site

In view of determining the aquifer parameter an observation well (OW) at Dhapewara has been constructed about 12 m away from exploratory well in the same premises.

Details of Drilling:

a) Rock Formation: Gondwana
b) Type: Sandstone
c) Drilling Started on 13/11/2013 at 13.50 hrs
d) Drilling Completed on 14/11/2013 at 22.17 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in soft rock Formation (with 190.5mm Button Bit):200.00 m.
g) Depth of reaming : (with 318.00 mm Drag Bit) :188.50 m
h) Well Construction Depth : 188.35 m bgl

i) Details of Casing
1) Length of pipes
   a. Blank Pipes : 152.56 m
   b. Slotted pipes : 36.39 mbgl
   c. Slot Size : 1.58 mm
2) Dia of Pipe :
   a. Blank Pipes : 152.4 mm
   b. Slotted Pipes : 152.4 mm
3) Gauge of Pipes
   a. Blank Pipes : 7.1 mm
   b. Slotted pipes : 7.1mm
4) Material of Pipes
   a. Blank Pipes : MS
   b. Slotted pipes : MS

Table 12.1: Drill Time log of the Observation well drilled at village Dhapewada, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
13.11.2013	0	3	3	13.50	13.52	2	0.67
	3	5.65	2.65	13.52	13.55	3	1.13
	5.65	8.65	3	14.11	14.12	1	0.33
	8.65	11.3	2.65	14.12	14.14	2	0.75
	11.3	14.3	3	14.15	14.19	4	1.33
	14.3	16.95	2.65	14.19	14.23	4	1.51
	16.95	19.95	3	14.33	14.36	3	1.00
	19.95	22.6	2.65	14.36	14.41	5	1.89
	22.6	25.6	3	14.42	14.46	4	1.33
	25.6	28.25	2.65	15.20	15.21	1	0.38
	28.25	31.25	3	15.22	15.26	4	1.33
	31.25	33.9	2.65	15.26	15.30	4	1.51
	33.9	36.9	3	15.41	15.43	2	0.67
	36.9	39.55	2.65	15.43	15.46	3	1.13
	39.55	42.65	3.1	15.47	15.50	3	0.97
	42.65	45.2	2.55	15.50	15.53	3	1.18
	45.2	48.2	3	15.55	16.00	5	1.67
	48.2	50.85	2.65	16.00	16.03	3	1.13
	50.85	53.85	3	16.04	16.08	4	1.33
	53.85	56.5	2.65	16.08	16.11	3	1.13
	56.5	59.5	3	16.12	16.14	2	0.67
	59.5	62.15	2.65	16.14	16.17	3	1.13
	62.15	65.15	3	16.18	16.22	4	1.33
	65.15	67.8	2.65	16.22	16.27	5	1.89
	67.8	70.8	3	16.28	16.30	2	0.67
	70.8	73.45	2.65	16.30	16.32	2	0.75
	73.45	76.45	3	16.33	16.35	2	0.67
	76.45	79.1	2.65	16.35	16.39	4	1.51
	79.1	82.1	3	16.40	16.42	2	0.67
	82.1	84.75	2.65	16.42	16.44	2	0.75
	84.75	87.75	3	16.46	16.50	4	1.33

Date	Depth range (m)		Thick-ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	87.75	90.4	2.65	16.50	16.53	3	1.13
	90.4	93.4	3	16.54	16.57	3	1.00
	93.4	96.05	2.65	16.57	17.00	3	1.13
	96.05	99.05	3	17.00	17.04	4	1.33
	99.05	101.7	2.65	17.04	17.08	4	1.51
	101.7	104.7	3	17.09	17.12	3	1.00
	104.7	107.35	2.65	17.12	17.16	4	1.51
	107.35	110.35	3	17.17	17.24	7	2.33
	110.35	113	2.65	17.24	17.26	2	0.75
	113	116	3	17.27	17.35	8	2.67
	116	118.65	2.65	17.35	17.39	4	1.51
	118.65	121.65	3	17.40	17.43	3	1.00
	121.65	124.3	2.65	17.43	17.49	6	2.26
	124.3	127.3	3	17.50	17.54	4	1.33
	127.3	129.95	2.65	17.54	18.01	7	2.64
	129.95	132.95	3	18.02	18.08	6	2.00
	132.95	135.6	2.65	18.08	18.14	6	2.26
	135.6	138.6	3	18.16	18.21	5	1.67
	138.6	141.25	2.65	18.21	18.26	5	1.89
	141.25	144.25	3	18.28	18.33	5	1.67
	144.25	146.9	2.65	18.33	18.39	6	2.26
	146.9	149.9	3	18.41	18.47	6	2.00
	149.9	152.55	2.65	18.47	18.55	8	3.02
	152.55	155.55	3	18.57	19.04	7	2.33
	155.55	158.2	2.65	19.04	19.10	6	2.26
	158.2	161.2	3	19.10	19.18	8	2.67
	161.25	163.85	2.6	19.18	19.25	7	2.69
	163.85	166.85	3	19.26	19.34	8	2.67
	166.85	169.5	2.65	19.34	19.44	10	3.77
	169.5	172.5	3	19.46	19.55	9	3.00
	172.25	175.15	2.9	19.55	20.09	14	4.83
	175.15	178.15	3	20.11	20.22	11	3.67
	178.15	180.8	2.65	20.22	20.33	11	4.15
	180.8	183.8	3	20.35	20.48	13	4.33
	183.8	186.45	2.65	20.48	21.01	53	20.00
	186.45	189.45	3	21.03	21.21	18	6.00
	189.45	192.1	2.65	21.21	21.39	18	6.79
	192.1	195.1	3	21.42	21.52	10	3.33
	195.1	197.75	2.65	21.52	21.59	7	2.64
	197.75	200	2.25	22.00	22.17	17	7.56

Table 12.2: Consolidated lithological log of the Observation well drilled at village Dhapewada, Katol taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	3	3	**Top soil**: Grey; silty; loamy; loose calcareous material (kankar)

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
3	19.95	16.95	Alluvium mixed with predominant argillaceous and calcareous material.
19.95	28.25	8.3	Alluvium with few chips of basalt, medium chips, hard compact
28.25	33.9	5.65	Basalt , black hard compact mixed with secondary minerals, medium grained
33.9	62.15	28.25	Clay, red, fine
62.15	65.15	3	Sand, light brown medium to coarse grained
65.15	67.8	2.65	Sandstone mixed with shale blakish brown
67.8	70.8	3	Sandstone blakish brown, medium grained
70.8	76.45	5.65	Sand fine to medium, blakish brown
76.45	79.1	2.65	Sandstone with shale, yellow
79.1	84.75	5.65	sand, fine to medium grained
84.75	93.4	8.65	Sand, light brown, medium mixed with shale yellow
93.4	99.05	5.65	Sandstone medium grained mixed with shale, brownish red.
99.05	101.7	2.65	Shale, brownish red
101.7	110.35	8.65	Sandstone whitish brownish medium grained
110.35	144.25	33.9	Sandstone light yellow, medium grained
144.25	155.55	11.3	Sandstone medium grained mixed carbonaceous shale
155.55	158.2	2.65	Sandstone, light yellow, fine grained
158.2	161.2	3	Sandstone medium to coarse grained mixed with carbonaceous shale
161.2	166.85	5.65	Sandstone fine to medium mixed with shale, yellow
166.85	169.5	2.65	Sand, light yellow very fine
169.5	172.5	3	Shale mixed with sand fine to medium
172.5	180.8	8.3	Sandstone light yellow, medium grained mixed with shale
180.8	183.8	3	Shale very fine yellow
183.8	186.45	2.65	Sandstone, fine to medium grained mixed with shale.
186.45	189.45	3	Sandstone, fine to medium grained mixed with shale argillaceous
189.45	192	2.55	Shale argillaceous yellow
192	197.1	5.1	Sandstone medium mixed with shale

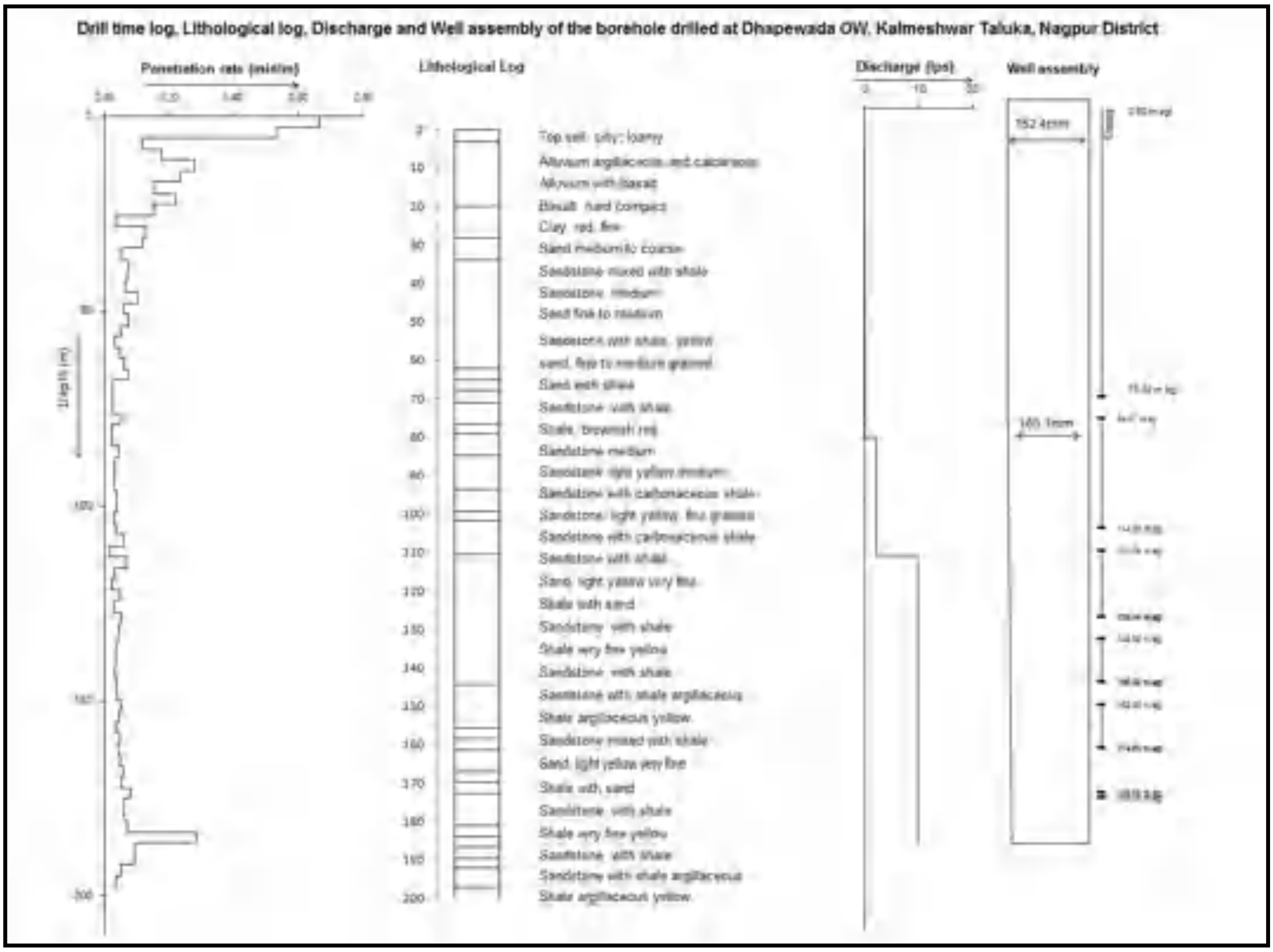


Fig.12.1: Composite Log of Observation Well Drilled at Dhapewada, Chandrabhaga Watershed (WGKKC-2)

Table 12.3: Granular Zones encountered

S.No	Drilling Depth		Cumulative Discharge	Lithology and Zones encountered
	From	To		
1	78.02	84.07	9.84 lps	Sand fine to medium, blackish brown
2	114.33	120.38		Sandstone light yellow, medium grained
3	138.54	144.59		Sandstone light yellow, medium grained
4	156.52	162.60		Sandstone medium to coarse grained
5	174.69	186.85		Sandstone light yellow, medium grained

WELL DESIGN

Table 12.4: Recommended well assembly

S/N	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
1	0.00	0.6 (m agl)	0.60	6" (152.4 mm) dia M S Blank MS pipe
2	0.00	78.02	78.02	6" (152.4 mm) dia M S Blank MS pipe with reducer
3	78.02	**84.07**	6.05	**6" (152.4 mm) dia M S slotted (1/16") pipe**
4	**84.07**	114.33	30.26	6" (152.4 mm) dia M S Blank MS pipe

S/N	Depth Range (mbgl)		Thickness	Description of Pipes
	From	To	(m bgl)	
5	114.33	**120.38**	6.05	**6" (152.4 mm) dia M S slotted (1/16") pipe**
6	**120.38**	138.54	18.16	6" (152.4 mm) dia M S Blank MS pipe
7	138.54	**144.59**	6.05	**6" (152.4 mm) dia M S slotted (1/16") pipe**
8	**144.59**	156.52	11.93	6" (152.4 mm) dia M S Blank MS pipe
9	156.52	162.60	6.08	**6" (152.4 mm) dia M S slotted (1/16") pipe**
10	162.60	174.69	12.09	6" (152.4 mm) dia M S Blank MS pipe
11	174.69	185.85	11.16	**6" (152.4 mm) dia M S slotted (1/16") pipe**
12	185.85	188.35	2.50	6" (152.4 mm) dia M S Blank MS pipe with bail blug

Development

The well was developed using air compressor for 15 hrs on 18/11/13 to 19/11/13 at 19.30 hrs till the water was free from sand particles and cumulative discharge measured was 9.84 lps.

CHEMI CAL QUALITY

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm………………										
Dhapewada	OW	8.1	747	330	58	45	6	0.25	0	250	78	41	32	0.53

The analytical result of water sample collected during pumping test revealed that the range of concentration of parameters viz TH, Mg are more than desirable limit while all other parameters are within the desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

13. Exploratory Well drilled at Gowri

Location of Site

The village Gowri lies between The north latitude 21°16'06.8" and east longitude 78°56'58.5" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at about 7 km distance from Kalmeshwar on Kalmeshwar – Jhunki – Saoner road, and the site is located 2 m west of Z.P. School and 10 m north of village road in school premises. .

History of Drilling Operations:

The rig unit was shifted to well site on 20/11/13,. The drilling started on 20/11/14 at 16.16 hrs and completed on 16/12/13 at 15.00 hrs. The drilling details and drilling time log are presented below.

Details of Drilling:

a) Rock Formation: Gondwana
b) Type: Sandstone
c) Drilling Started on 20/11/2013 at 16.16 hrs
d) Drilling Completed on 16/12/2014 at 3.00 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in soft rock Formation (with 215 mm Button Bit):200.00 m.
g) Details of Casing
    5) Length of pipes
        a. Blank Pipes : 0.60 m agl + 106.92 m bgl =107.52 m
        b. Slotted pipes : 42.25 mbgl
        c. Slot Size : 1.5 mm

6) Dia of Pipe
   a. Blank Pipes : 152.4 mm
   b. Slotted Pipes : 152.4 mm
7) Gauge of Pipes
   a. Blank Pipes : 7.1 mm
   b. Slotted pipes : 7.1mm
8) Material of Pipes
   a. Blank Pipes MS
   b. Slotted pipes : MS

Geological Data:

Geologically, the area is underlained by Gondwana group of rocks. These formations are exposed in the surface as well as seen in well sections

Table 13.1: Drill Time log of the Exploratory well drilled at village Gowri, Kalmeshwar taluka, Nagpur district.

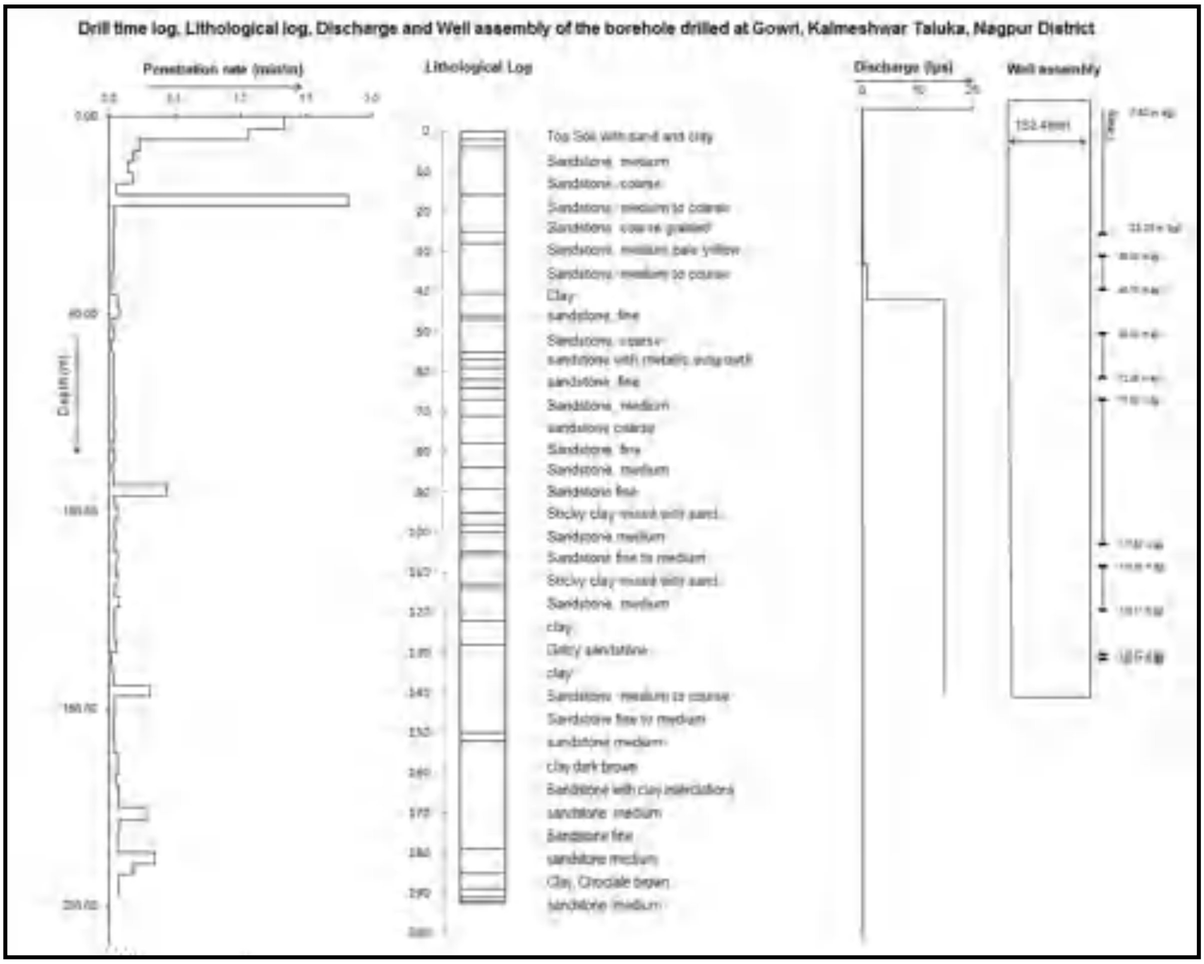
DATE	Depth range (m)		Thick-ness(m)	Drilling time (min)		Time taken (min)	Penetration rate min/m
	From	To		From	To		
20.11.2013	0	3	3	16.16	16.20	4	1.33
	3	5.65	2.65	16.40	16.46	6	2.26
	5.65	8.65	3	16.47	16.49	2	0.67
	8.65	11.3	2.65	16.49	16.51	2	0.75
	11.3	14.3	3	16.52	16.54	2	0.67
	14.3	16.95	2.65	16.54	16.57	3	1.13
	16.95	19.95	3	16.58	16.59	1	0.33
	19.95	22.6	2.65	16.59	17.00	41	15.47
	22.6	25.6	3	17.01	17.02	1	0.33
	25.6	28.25	2.65	17.02	17.03	1	0.38
	28.25	31.25	3	17.03	17.04	1	0.33
	31.25	33.9	2.65	17.04	17.05	1	0.38
	33.9	36.9	3	17.06	17.07	1	0.33
	36.9	39.55	2.65	17.07	17.08	1	0.38
	39.55	42.65	3.1	17.09	17.10	1	0.32
	42.65	45.2	2.55	17.10	17.11	1	0.39
	45.2	48.2	3	17.12	17.15	3	1.00
	48.2	50.85	2.65	17.15	17.19	4	1.51
	50.85	53.85	3	17.20	17.21	1	0.33
	53.85	56.5	2.65	17.21	17.23	2	0.75
	56.5	59.5	3	17.24	17.25	1	0.33
	59.5	62.15	2.65	17.25	17.27	2	0.75
	62.15	65.15	3	17.27	17.29	2	0.67
	65.15	67.8	2.65	17.29	17.31	2	0.75
	67.8	70.8	3	17.32	17.34	2	0.67
	70.8	73.45	2.65	17.34	17.37	3	1.13
	73.45	76.45	3	17.38	17.41	3	1.00
	76.45	79.1	2.65	17.41	17.43	2	0.75
	79.1	82.1	3	17.44	17.47	3	1.00

DATE	Depth range (m)		Thick-ness(m)	Drilling time (min)		Time taken (min)	Penetration rate min/m
	From	To		From	To		
	82.1	84.75	2.65	17.47	17.49	2	0.75
	84.75	87.75	3	17.50	17.53	3	1.00
	87.75	90.4	2.65	17.53	17.55	2	0.75
	90.4	93.4	3	17.56	17.59	3	1.00
	93.4	96.05	2.65	17.59	18.01	42	15.85
	96.05	99.05	3	18.02	18.06	4	1.33
	99.05	101.7	2.65	18.06	18.12	6	2.26
	101.7	104.7	3	18.14	18.18	4	1.33
	104.7	107.35	2.65	18.18	18.23	5	1.89
	107.35	110.35	3	18.25	18.29	4	1.33
	110.35	113	2.65	18.29	18.36	7	2.64
	113	116	3	18.37	18.42	5	1.67
	116	118.65	2.65	18.42	18.49	7	2.64
21.11.2013	118.65	121.65	3	7.10	7.15	5	1.67
	121.65	124.3	2.65	7.15	7.24	9	3.40
	124.3	127.3	3	7.25	7.30	5	1.67
	127.3	129.95	2.65	7.30	7.35	5	1.89
	129.95	132.95	3	7.36	7.41	5	1.67
	132.95	135.6	2.65	7.41	7.48	7	2.64
	135.6	138.6	3	7.49	7.51	2	0.67
	138.6	141.25	2.65	7.51	7.54	3	1.13
	141.25	144.25	3	7.55	7.59	4	1.33
	144.25	146.9	2.65	7.59	8.04	45	16.98
	146.9	149.9	3	8.08	8.13	5	1.67
	149.9	152.55	2.65	8.13	8.19	6	2.26
	152.55	155.55	3	8.23	8.28	5	1.67
	155.55	158.2	2.65	8.28	8.33	5	1.89
	158.2	161.2	3	8.38	8.44	6	2.00
	161.25	163.85	2.6	8.44	8.54	10	3.85
	163.85	166.85	3	9.00	9.10	10	3.33
	166.85	169.5	2.65	9.10	9.18	8	3.02
	169.5	172.5	3	9.24	9.36	12	4.00
	172.25	175.15	2.9	9.36	9.48	12	4.14
	175.15	178.15	3	9.52	10.02	50	16.67
	178.15	180.8	2.65	10.02	10.16	14	5.28
	180.8	183.8	3	10.20	10.31	11	3.67
	183.8	186.45	2.65	10.31	10.43	12	4.53
	186.45	189.45	3	10.50	11.15	65	21.67
	189.45	192.1	2.65	11.15	11.49	34	12.83
	192.1	195.1	3	12.00	12.13	13	4.33
	195.1	197.75	2.65	12.13	12.26	13	4.91
	197.75	200	2.25	12.30	13.05	75	33.33

Table13.2: Consolidated lithological log of the Exploratory well drilled at village Gowri, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	2	2	Top Soil mixed with sand and clay
2	4	2	Sandstone, medium grained, yellowish brown
4	16	12	Sandstone, coarse grained, yellowish brown
16	25	9	Sandstone, medium to coarse
25	28	3	Sandstone, coarse grained, yellowish brown
28	40.5	12.5	Sandstone, medium pale yellow
40.5	46	5.5	Sandstone, medium to course, brown.
46	47	1	Clay yellowish in color
47	55	8	sandstone, fine pale yellow.
55	57	2	Sandstone, coarse grained, yellowish brown
57	59	2	sandstone with metallic outgrowth
59	62	3	sandstone, fine pale yellow.
62	64	2	Sandstone, medium, Pale yellow.
64	67	3	sandstone course grained pale yellow.
67	71	4	Sandstone, fine, Pale yellow.
71	78	7	Sandstone, medium grained, Chocolate brown.
78	84	6	Sandstone fine
84	89	5	Sticky clay mixed with sand.
89	95	6	Sandstone, medium, pinkish grey.
95	98	3	Sandstone fine to medium
98	100	2	Sticky clay mixed with sand.
100	104.7	4.7	Sandstone, medium, ill sorted.
104.7	105.7	1	clay
105.7	113	7.3	Gritty sandstone medium grained
113	114	1	clay
114	122	8	Sandstone medium to course
122	128	6	Sandstone fine to medium
128	150	22	sandstone medium .
150	152	2	clay dark brown
152	179	27	Sandstone whitish grey, with clay intercalations
179	185	6	sandstone medium, grey.
185	189	4	Sandstone fine .
189	191	2	sandstone medium .
191	192	1	Clay, Chocolate brown.
192	200	8	sandstone medium, grey.

Fig.13.1: Composite Log of Exploratory Well Drilled at Gowari, Chandrabhaga Watershed (WGKKC-2)



WELL DESIGN

Table 13.3: Well Assembly of Exploratory Well at Gowri, Kalmeshwar Taluka, Nagpur District.

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
1	0.00	0.6 (m agl)	0.60	6" (152.4 mm) dia M S Blank pipe
2	0.00	33.00	33.00	6" (152.4 mm) dia M S Blank pipe
3	33.00	**39.05**	6.05	**6" (152.4 mm) dia M S Slotted pipe**
4	**39.05**	48.10	9.05	6" (152.4 mm) dia M S Blank pipe
5	48.10	**60.20**	12.10	**6" (152.4 mm) dia M S Slotted pipe**
6	**60.20**	72.28	12.08	6" (152.4 mm) dia M S Blank pipe
7	72.28	**78.33**	6.05	**6" (152.4 mm) dia M S Slotted pipe**
8	**78.33**	117.63	39.30	6" (152.4 mm) dia M S Blank pipe
9	117.63	**123.68**	6.05	**6" (152.4 mm) dia M S Slotted pipe**
10	**123.68**	135.67	11.99	6" (152.4 mm) dia M S Blank pipe
11	135.67	147.67	12.00	**6" (152.4 mm) dia M S Slotted pipe**
12	147.67	149.17	1.50	6" (152.4 mm) dia M S Blank pipe with bail plug.

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles and Cumulative Discharge recorded was 14.88 lps.

WELL HYDRAULICS

Aquifer Performance Test (APT)

Table 13.4: The details of the Aquifer Performance Test (APT) Conducted on Exploratory Well at GOWRI, Kalmeshwar Taluka, Nagpur District.

Date	20/12/13
Static Water Level	8.03 mbgl
Discharge (Q)	5.50 lps
Drawdown (Δs)	0.729 m
Transmissivity (T)	119 m2/day
Specific Capacity	37.45 lpm/m

CHEMICAL QUALITY

The ground water sample collected during the pumping test was analysed at the Regional Chemical Laboratory of CGWB (CR) Nagpur. The analytical results are given in Table

Location	**Type**	**pH**	**Ec µS/cm**	**TH**	**Ca**	**Mg**	**Na**	**K**	**CO3**	**HCO3**	**Cl**	**SO4**	**NO3**	**F**
				……………………………ppm……………..										
Gowri(PT)	EW	8.1	648	270	56	32	5	0.51	0	122	92	44	47	0.43

The analytical result of water sample collected during pumping test revealed that the range of concentration of parameters viz Mg, NO3 are more than desirable limit while all other parameters are within the desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

14. Exploratory Well drilled at Kohli

Location of Site

The village Kohli lies between north latitude 21°15'54.9"and east longitude 78°48'33.8" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at 1 on kms from Kohli Phata which is located kalmeshwar - Katol road and the site is located in 10 m North of Z P primary School.

Details of Drilling:

a) Rock Formation: Trap Covered Gondwana
b) Type: Basalt & Sandstone
c) Drilling Started on 31/12/13 at 23.15 hrs
d) Drilling Completed on 8/1/14 at 11.50 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in Hard rock Formation (with 184.00 mm Button Bit):125.00 m.
g) Total depth drilled in soft rock Formation (with 254.00 mm Button Bit):75.00 m.
h) Depth of reaming (with 254.00 mm Button Bit) : 125.00 m
   (with 254.00 mm Button Bit) : 125.00 to 195.00 m
i) Well construction Depth 193.37 m
j) Details of Casing
   1) Length of pipes
      a. Blank Pipes : (152.4 mm) 6" pipes = 97.16 m
         (101.6 mm) 4" pipes = 57.08 m
      b. Slotted pipes : (101.6 mm) 4" pipes = 39.73 m

c. Slot Size : 1.5 mm

2) Dia of Pipe :

a. Blank Pipes : 152.4 mm

b. Slotted Pipes : 101.6 mm

3) Gauge of Pipes

a. Blank Pipes : 7.1 mm

b. Slotted pipes : 5.0 mm

4) Material of Pipes

a. Blank Pipes : MS

b. Slotted pipes : MS

Geological Data:

Geologically the site is located in Trap covered Gondwana area. The basalt and Gondwana contact at site was encountered at 125 m bgl.

Table 14.1: Drill Time log of the Exploratory well drilled at village Kohli, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
31-12-2014	0	3	3	23.15	23.35	20	6.67
	3	5.65	2.65	23.35	23.55	20	7.55
	5.65	8.65	3	23.56	23.58	2	0.67
	8.65	11.3	2.65	23.58	24.00	42	0.75
	11.3	14.3	3	24.00	24.06	6	2.00
	14.3	16.95	2.65	24.06	24.11	5	1.89
	16.95	19.95	3	24.12	24.16	4	1.33
	19.95	22.6	2.65	24.16	24.19	3	1.13
	22.6	25.6	3	24.20	24.23	3	1.00
	25.6	28.25	2.65	24.23	24.28	5	1.89
	28.25	31.25	3	24.29	24.33	4	1.33
	31.25	33.9	2.65	24.33	24.37	4	1.51
	33.9	36.9	3	24.38	24.42	4	1.33
	36.9	39.55	2.65	24.42	24.46	4	1.51
	39.55	42.65	3.1	24.49	24.53	4	1.29
	42.65	45.2	2.55	24.53	24.59	6	2.35
	45.2	48.2	3	1.02	1.04	2	0.67
	48.2	50.85	2.65	1.06	1.14	8	3.02
	50.85	53.85	3	1.20	1.23	3	1.00
	53.85	56.5	2.65	1.23	1.26	3	1.13
	56.5	59.5	3	1.27	1.33	6	2.00
	59.5	62.15	2.65	1.33	1.38	5	1.89
	62.15	65.15	3	1.40	1.46	6	2.00
	65.15	67.8	2.65	1.46	1.52	6	2.26
	67.8	70.8	3	1.56	2.10	54	4.67
	70.8	73.45	2.65	2.10	2.16	6	2.26
	73.45	76.45	3	2.23	2.30	7	2.33
	76.45	79.1	2.65	2.30	2.40	10	3.77
	79.1	82.1	3	2.45	2.50	5	1.67

Date	Depth range (m)		Thick ness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	82.1	84.75	2.65	2.50	2.55	5	1.89
	84.75	87.75	3	2.58	3.03	45	1.67
	87.75	90.4	2.65	3.03	3.06	3	1.13
	90.4	93.4	3	3.08	3.12	4	1.33
	93.4	96.05	2.65	3.12	3.17	5	1.89
	96.05	99.05	3	3.20	3.26	6	2.00
	99.05	101.7	2.65	3.26	3.32	6	2.26
	101.7	104.7	3	3.34	3.40	6	2.00
	104.7	107.35	2.65	3.40	3.44	4	1.51
	107.35	110.35	3	3.45	3.49	4	1.33
	110.35	113	2.65	3.49	3.52	3	1.13
	113	116	3	3.52	3.57	5	1.67
	116	118.65	2.65	3.57	4.00	43	1.13
	118.65	121.65	3	4.01	4.03	2	0.67
	121.65	124.3	2.65	4.03	4.06	3	1.13
	124.3	127.3	3	4.07	4.09	2	0.67
	127.3	129.95	2.65	4.09	4.11	2	0.75
	129.95	132.95	3	4.12	4.14	2	0.67
	132.95	135.6	2.65	4.14	4.17	3	1.13
	135.6	138.6	3	4.18	4.20	2	0.67
	138.6	141.25	2.65	4.20	4.24	4	1.51
	141.25	144.25	3	4.25	4.30	5	1.67
	144.25	146.9	2.65	4.30	4.35	5	1.89
	146.9	149.9	3	4.38	4.40	2	0.67
	149.9	152.55	2.65	4.40	4.43	3	1.13
	152.55	155.55	3	4.44	4.46	2	0.67
	155.55	158.2	2.65	4.46	4.48	2	0.75
	158.2	161.2	3	4.49	4.51	2	0.67
	161.25	163.85	2.6	4.51	4.53	2	0.77
	163.85	166.85	3	4.54	4.56	2	0.67
	166.85	169.5	2.65	4.56	4.58	2	0.75
31-12-2013	169.5	172.5	3	5.00	5.02	2	0.67
	172.25	175.15	2.9	5.02	5.03	1	0.34
08-01-2014	175.15	178.15	3	21.30	21.41	11	3.67
	178.15	180.8	2.65	21.41	22.10	69	10.94
	180.8	183.8	3	23.25	23.55	30	10.00
	183.8	186.45	2.65	23.55	24.55	100	22.64
	186.45	189.45	3	1.10	2.10	100	20.00
	189.45	192.1	2.65	2.10	3.15	105	24.53
	192.1	195.1	3	3.31	4.32	101	20.33
08-01-2014	195.1	197.75	2.65	4.32	6.33	201	45.66
	197.75	200	2.25	7.10	8.30	120	44.44

Table 14.2: Consolidated lithological log of the Exploratory well drilled at village Kohli, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	4	4	Top soil mixed with Basalt, weathered
4	5.2	1.2	Basalt black, Amygdular with very small grains of secondary minerals, fractured
5.2	10.5	5.3	Basalt black compact with secondary minerals minutely vesicular.
11.5	13	1.5	Clay grey
13	27	14	Basalt, Amygdular black hard compact with sec. minerals.
27	31.5	4.5	Basalt black hard compact.
31.5	32.4	0.9	Clay grey
32.4	37	4.6	Amygdular vesicular basalt, black with secondary minerals.
37	46	9	Basalt black hard with veins of metallic growth.
46	52	6	Grey Bole.
52	59.5	7.5	Basalt Vesicular filled with sparse secondary fillings.
59.5	62	2.5	Basalt black hard compact. with very few Vesicles filled with secondary fillings
62	65	3	Basalt black hard compact. with vary few Vesicles filled with secondary fillings and fracture.
65	73	8	Basalt black hard compact.
73	81	8	Basalt vesicular black filled with secondary minerals.
81	87	6	Basalt with vary few Vesicles filled with secondary fillings
87	90.4	3.4	Basalt, very fine, black hard.
90.4	93.4	3	Amygdular basalt black hard mixed with secondary minerals.
93.4	113	19.6	Basalt black hard with very coarse grains, jointed.
113	117	4	Basalt Amygdular black compact.
117	125	8	Basalt, steel black, massive hard compact.
125	135.6	10.6	Sand, gritty, medium, dark brown, with medium to coarse grains of quartz.
135.6	141.25	5.65	Sand, gritty, medium to coarse, brown to reddish brown
141.25	144.25	3	Sandstone, brown, medium to coarse, with quartz grains predominantly medium grained.
144.25	145	0.75	sand, fine to coarse, with qtz pebbles of pale brown colour.
145	151	6	sand, pale brown, fine to medium
151	160	9	sand, very fine, light brown to yellow.
160	164	4	sand, medium, yellow
164	170	6	sand, medium to coarse, pale yellow
170	183	13	sand fine to medium with argillaceous material like silt or clay
183	200	17	sand, medium with clay intercalations

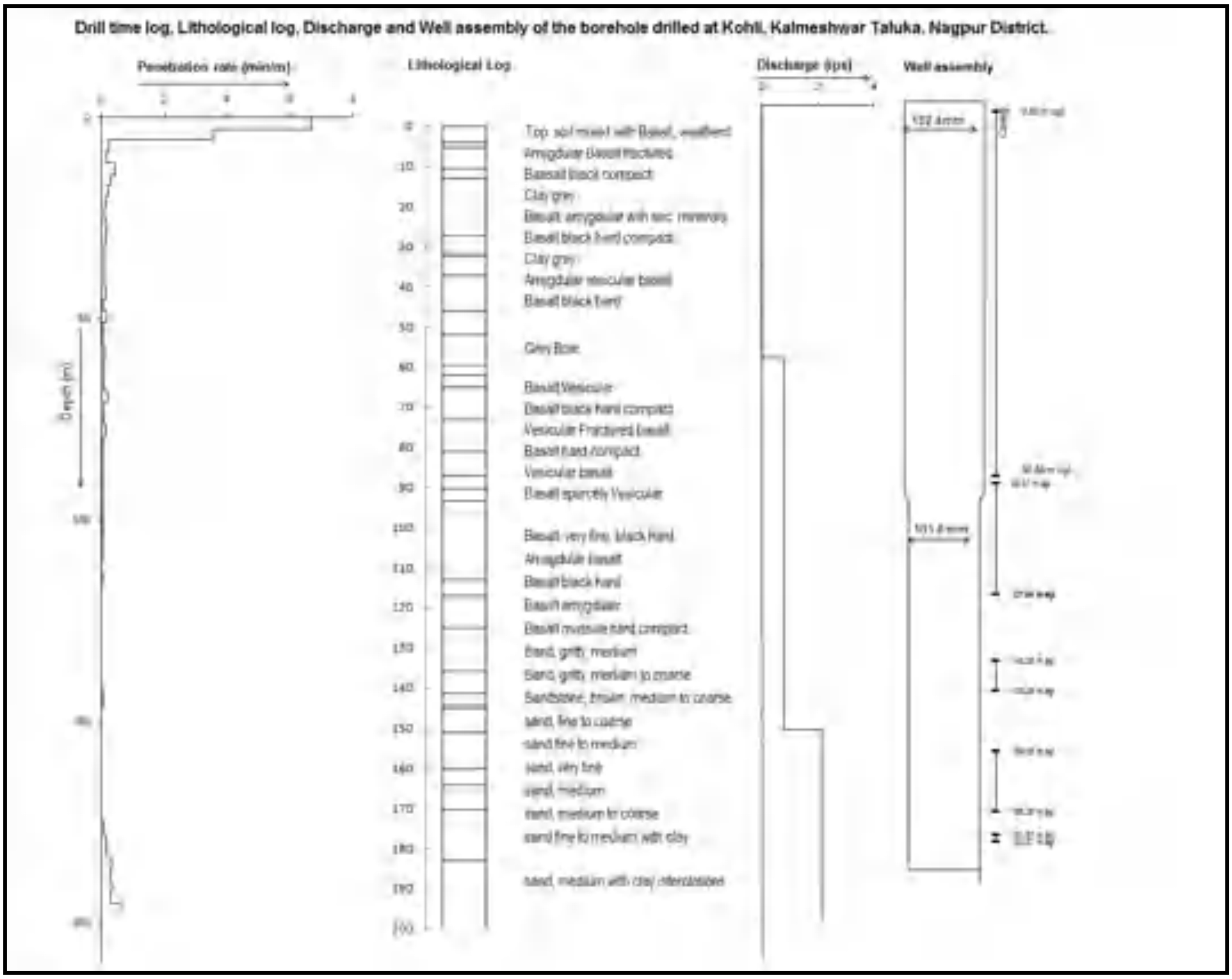


Fig.14.1: Composite Log of Exploratory Well Drilled at Kohli, Chandrabhaga Watershed (WGKKC-2)

WELL DESIGN

Table 14.3: Well Assembly of Exploratory Well at vKohli, Kalmeshwar Taluka, Nagpur District.

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Describtion of Pipes
	From	To		
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank pipe
2	0.00	96.56	96.56	6" (152.4 mm) dia M S Blank pipe
3	96.56	**127.64**	31.08	4" (101.6 mm) dia M S Blank pipe
4	**127.64**	145.28	17.64	**4" (101.6 mm) dia M S Slotted pipe**
5	145.28	**153.28**	8.00	4" (101.6 mm) dia M S Blank pipe
6	**153.28**	169.28	16.00	**4" (101.6 mm) dia M S Slotted pipe**
7	169.28	**185.28**	16.00	4" (101.6 mm) dia M S Blank pipe
8	**185.28**	191.37	6.09	**4" (101.6 mm) dia M S Slotted pipe**
9	191.37	**193.37**	2.00	6" (152.4 mm) dia M S Blank pipe with bail plug.

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles Cumulative Discharge measured was 4.00 lps.

WELL HYDRAULICS

Aquifer Performance Test (APT)

For estimation of aquifer parameters APT conducted on exploratory well for 1000 minutes duration and 90% recuperation recorded.

Table 14.4: The details of the **Aquifer Performance Test (APT)** Conducted on Exploratory Well at GOWRI, Kalmeshwar Taluka, Nagpur District.

Date	23/01/14
Static Water Level	78.12 mbgl
Discharge (Q)	4.00 lps
Drawdown (∆s)	0.366 m
Transmissivity (T)	172.93 m2/day
Specific Capacity	50.63 lpm/m

CHEMICAL QUALITY

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				………………………………ppm………………										
Kohli-Zone-1	EW	7.7	917	175	84	55.9	5.2	0.12	0	214	92	116.2	37.2	0.18
Kohli-Zone-2	EW	8.3	886	150	38	80.2	7.3	0.16	0	183	113	73.5	34.7	0.16
Kohli-(PT)	EW	7.9	1436	250	60	130	7.8	0.22	0	305	227	110.8	36.6	0.27

The analytical result of water sample collected from the Zone-I of the Exploratory well revealed that the range of concentration of parameters viz Ca, Mg are more than desirable limit and all other parameters are within desirable limit. In Zone-II of the Exploratory well the analytical result revealed that the range of concentration of parameters viz Mg is more than desirable limit while all other parameters are within the desirable limit. While In sample collected during pumping test the analytical result of water sample collected revealed that the range of concentration of parameters viz EC, Mg, HCO3 are more than desirable limit while all other parameters are within desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

15. Exploratory Well drilled at Khairi (lakhmaji)

Location of Site

The village Khairi (Lakhmaji) loies between north latitude 21°15'10.1"and east longitude 78°57'05.8" and falls in the Survey of India Toposheet No. 55 K/15. It is situated at about 5 km distance from Kalmeshwar on Tondakhairi road, and the site is located in th premises of Smashanbhumi of the village.

Details of Drilling:

a) Rock Formation: Gondwana
b) Type: Sandstone
c) Drilling Started on 20/12/2013 at 19.02 hrs
d) Drilling Completed on 26/12/2013 at 8.33 hrs
e) Total depth drilled: 200.00 m.
f) Total depth drilled in soft rock Formation (with 215 mm Button Bit):200.00 m.
g) Details of Casing
    1) Length of pipes

a. Blank Pipes : 136.65 m
b. Slotted pipes : 54.62 mbgl
c. Slot Size : 1.58 mm

2) Dia of Pipe
a. Blank Pipes : 152.4 mm
b. Slotted Pipes : 152.4 mm

3) Gauge of Pipes
a. Blank Pipes : 7.1 mm
b. Slotted pipes : 7.1mm

4) Material of Pipes
a. Blank Pipes : MS
b. Slotted pipes : MS

Geological Data:

Geologically, the area is underlined by Gondwana group of rocks. These formations are exposed in the surface as well as seen in well sections

Table 15.1: Drill Time log of the Exploratory well drilled at village Khairi Lakhmaji, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thick ness (m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
20/12/13	0	3	3	19.02	19.06	4	1.33
	3	5.65	2.65	19.06	19.12	6	2.26
	5.65	8.65	3	19.13	19.17	4	1.33
	8.65	11.3	2.65	19.17	19.24	7	2.64
	11.3	14.3	3	19.25	19.30	5	1.67
	14.3	16.95	2.65	19.3	19.36	6	2.26
	16.95	19.95	3	19.37	19.50	13	4.33
	19.95	22.6	2.65	19.5	20.07	17	6.42
	22.6	25.6	3	20.5	21.30	40	13.33
	25.6	28.25	2.65	24.12	24.40	28	10.57
	28.25	31.25	3	24.47	1.30	43	14.33
	31.25	33.9	2.65	1.30	1.50	20	7.55
	33.9	36.9	3	2.00	2.40	40	13.33
	36.9	39.55	2.65	2.40	3.10	30	11.32
	39.55	42.65	3.1	3.12	3.40	28	9.03
	42.65	45.2	2.55	3.40	4.30	50	19.61
	45.2	48.2	3	4.30	5.00	30	10.00
	48.2	50.85	2.65	5.00	5.30	30	11.32
	50.85	53.85	3	10.15	10.55	40	13.33
	53.85	56.5	2.65	10.55	11.30	35	13.21
	56.5	59.5	3	11.31	12.01	30	10.00
	59.5	62.15	2.65	12.01	12.33	32	12.08
	62.15	65.15	3	12.34	13.31	57	19.00
	65.15	67.8	2.65	13.31	14.34	63	23.77
22.12.2013	67.8	70.8	3	16.57	17.30	33	11.00
	70.8	73.45	2.65	17.3	17.58	28	10.57
	73.45	76.45	3	17.58	18.30	32	10.67
	76.45	79.1	2.65	18.3	21.45	195	73.58
	79.1	82.1	3	23	24.10	70	23.33
	82.1	84.75	2.65	24.1	1.10	60	22.64

Date	Depth range (m)		Thickness (m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	84.75	87.75	3	1.11	2.12	61	20.33
	87.75	90.4	2.65	2.12	3.13	61	23.02
	90.4	93.4	3	3.14	5.00	104	34.67
25.12.2013	93.4	96.05	2.65	22.3	22.45	15	5.66
	96.05	99.05	3	22.47	22.59	12	4.00
	99.05	101.7	2.65	22.59	23.10	11	4.15
	101.7	104.7	3	23.12	23.33	21	7.00
	104.7	107.35	2.65	23.33	23.43	10	3.77
	107.35	110.35	3	23.45	23.56	11	3.67
	110.35	113	2.65	23.56	24.10	14	5.28
	113	116	3	24.12	24.30	18	6.00
	116	118.65	2.65	24.3	24.40	10	3.77
	118.65	121.65	3	24.42	24.56	14	4.67
	121.65	124.3	2.65	24.56	1.10	14	5.28
	124.3	127.3	3	1.12	1.22	10	3.33
	127.3	129.95	2.65	1.22	1.32	10	3.77
	129.95	132.95	3	1.36	1.47	11	3.67
	132.95	135.6	2.65	1.47	1.58	11	4.15
	135.6	138.6	3	2	2.12	12	4.00
	138.6	141.25	2.65	2.12	2.21	9	3.40
	141.25	144.25	3	2.23	2.34	11	3.67
	144.25	146.9	2.65	2.34	2.44	10	3.77
	146.9	149.9	3	2.46	2.57	11	3.67
	149.9	152.55	2.65	2.57	3.10	13	4.91
	152.55	155.55	3	3.12	3.22	10	3.33
	155.55	158.2	2.65	3.22	3.30	8	3.02
	158.2	161.2	3	3.32	3.42	10	3.33
	161.25	163.85	2.6	3.42	3.52	10	3.85
	163.85	166.85	3	3.54	4.03	9	3.00
	166.85	169.5	2.65	4.03	4.12	9	3.40
	169.5	172.5	3	4.14	4.24	10	3.33
26.12.2013	172.25	175.15	2.9	4.24	4.36	12	4.14
	175.15	178.15	3	23.13	24.13	60	20.00
	178.15	180.8	2.65	24.13	1.23	70	26.42
	180.8	183.8	3	1.25	2.25	60	20.00
	183.8	186.45	2.65	2.25	3.25	60	22.64
	186.45	189.45	3	3.27	4.28	61	20.33
	189.45	192.1	2.65	4.28	5.30	62	23.40
	192.1	195.1	3	5.32	6.33	61	20.33
	195.1	197.75	2.65	6.33	7.32	59	22.26
	197.75	200	2.25	7.32	8.33	61	27.11

Table 15.2: Consolidated lithological log of the Exploratory well drilled at village Khairi Lakhmaji, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	8	8	Top soil, mixed with clay, yellowish black
8	14	6	Sand, light yellow, very fine,
14	20	6	Sand, light yellow, very fine, with clay intercalations
20	62	42	Sand dark brown, medium to coarse, with prominent quartz grains. with little at various depths clay intercalations
62	67	5	Sandy clay dark brown,
67	85	18	Sand dark brown, coarse, with prominent quartz grains. with little clay intercalations
85	89	4	Sand, medium medium to coarse, dark brown.
89	94	5	clay / shale chocolate brown .
94	113	19	sand, dark brown, fine to coarse
113	115	2	clay / shale greyish brown .
115	120	5	Sandstone, light grey, fine grained, mixed with black shale intercalations.
120	144	24	Sandstone dark grey, mixed with black shale, with intercalated ferruginous sandstone.
144	159	15	Sand, light grey mixed with coarser chips of fine grained black shale intercalations.
159	161	2	Clay black
161	177	16	clay blackish with Sand light pink to grey
177	180	3	sand, light grey, fine mixed with shale
180	200	20	sandstone, hard compact, light pink to dark pink, fine to medium.
0	8	8	Top soil, mixed with clay, yellowish black
8	14	6	Sand, light yellow, very fine,
14	20	6	Sand, light yellow, very fine, with clay intercalations
20	62	42	Sand dark brown, medium to coarse, with prominent quartz grains. with little at various depths clay intercalations
62	67	5	Sandy clay dark brown,
67	85	18	Sand dark brown, coarse, with prominent quartz grains .with little clay intercalations
85	89	4	Sand, medium medium to coarse, dark brown.
89	94	5	clay / shale chocolate brown .
94	113	19	sand, dark brown, fine to coarse
113	115	2	clay / shale greyish brown .
115	120	5	Sandstone, light grey, fine grained, mixed with black shale intercalations.
120	144	24	Sandstone dark grey, mixed with black shale, with intercalated ferruginous sandstone.
144	159	15	Sand, light grey mixed with coarser chips of fine grained black shale intercalations.
159	161	2	Clay black
161	177	16	clay blackish with Sand light pink to grey
177	180	3	sand, light grey, fine mixed with shale
180	200	20	sandstone, hard compact, light pink to dark pink, fine to medium.

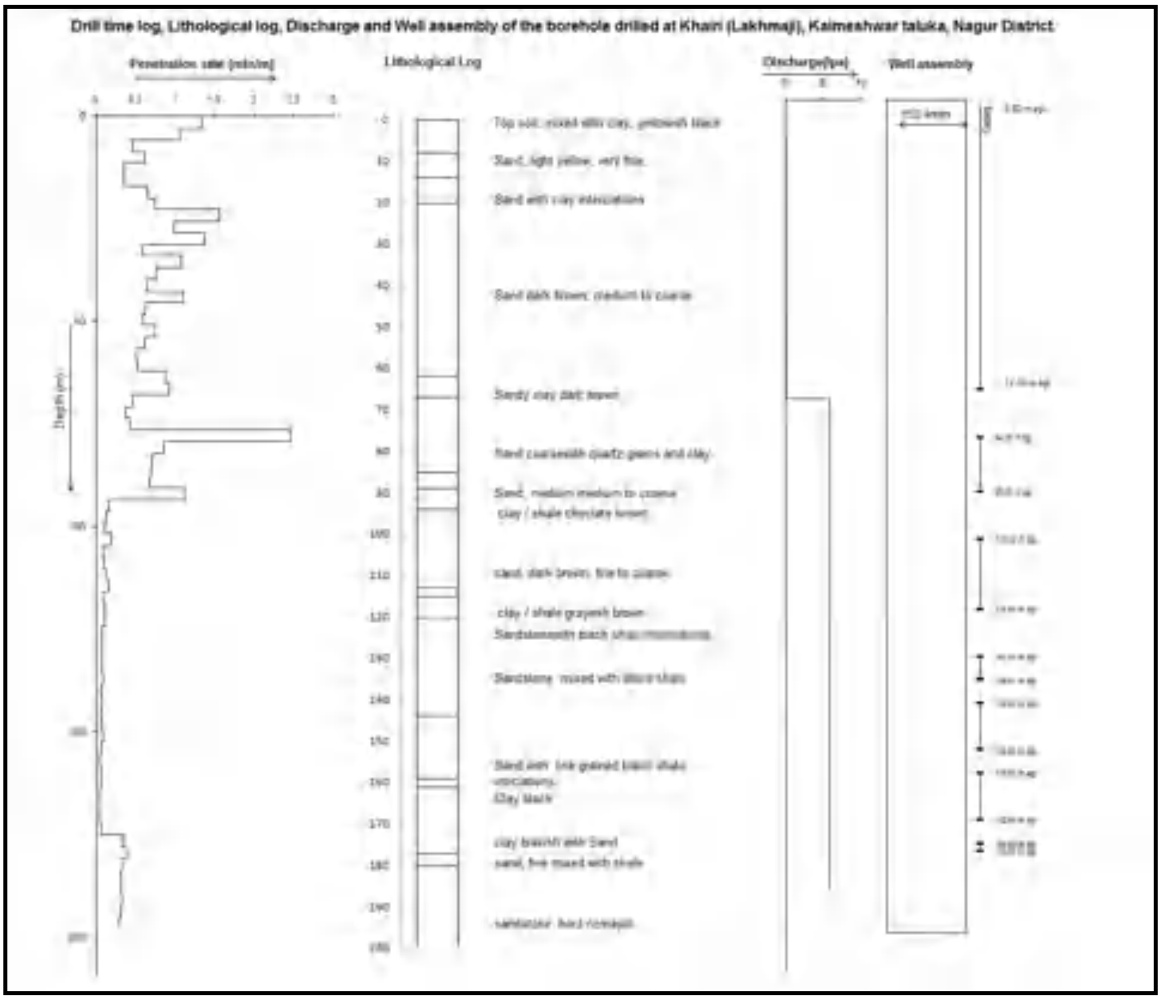


Fig. 15.1: Composite Log of Exploratory Well Drilled at Khairi(Lakhamaji), Chandrabhaga Watershed (WGKKC-2)

WELL DESIGN

Table 15.3: Well Assembly of Exploratory Well at Khairi (Lakhmaji), Kalmeshwar Taluka, Nagpur District.

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank pipe
2	0.00	72.00	72.00	6" (152.4 mm) dia M S Blank pipe
3	72.00	**84.29**	12.29	**6" (152.4 mm) dia M S Slotted pipe**
4	**84.29**	98.29	14.00	6" (152.4 mm) dia M S Blank pipe
5	98.29	**110.44**	12.15	**6" (152.4 mm) dia M S Slotted pipe**
6	**110.44**	128.44	18.00	6" (152.4 mm) dia M S Blank pipe
7	128.44	**140.56**	12.12	**6" (152.4 mm) dia M S Slotted pipe**
8	**140.56**	146.61	6.05	6" (152.4 mm) dia M S Blank pipe
9	146.61	**152.66**	6.05	**6" (152.4 mm) dia M S Slotted pipe**
10	**152.66**	164.66	12.00	6" (152.4 mm) dia M S Blank pipe
11	164.66	170.63	5.97	**6" (152.4 mm) dia M S Slotted pipe**
12	170.63	182.59	11.96	6" (152.4 mm) dia M S Blank pipe

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
13	182.59	188.63	6.04	**6" (152.4 mm) dia M S Slotted pipe**
14	188.63	190.63	2.00	6" (152.4 mm) dia M S Blank pipe with bail plug.

Development

The well was developed using air compressor for 15 hrs on 30/12/13 at 11.00 hrs to31/12/13 at 2.00 hrs till the water was free from sand particles and Cumulative Discharge measured was 5.94 lps.

WELL HYDRAULICS

Aquifer Performance Test (APT)

For estimation of aquifer parameters APT conducted on exploratory well for 1000 minutes duration and 90% recuperation recorded.

Table-4 The details of the Aquifer Performance Test (APT) Conducted on Exploratory Well at KHAIRI (LAKHMAJI), Kalmeshwar Taluka, Nagpur District.

Date	15-1-2014
Static Water Level	6.01 mbgl
Discharge (Q)	5.50 lps
Drawdown (Δs)	5.682 m
Transmissivity (T)	15 m2/day
Specific Capacity	58.07 lpm/m

CHEMICAL QUALITY

The ground water samples collected during the pumping test were analysed at the Regional Chemical Laboratory of CGWB (CR) Nagpur. The analytical results are given in Table

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm……………..										
Khairi lakhmaji	(PT)	7.9	1233	535	58	95	9	0.74	0	171	216	132	41	0.33

The analytical result of water sample collected during pumping test revealed that the range of concentration of parameters viz TH, Mg, are more than desirable limit while all other parameters are within the desirable limit as per "Drinking Water Standards" of Bureau of Indian Standards (BIS 10500-2013).

16. Exploratory Well drilled at Waroda

Location of Site

The village Waroda lies between north latitude 21°15'48.8" and east longitude 78°54'17.4" passes through this village and falls in the Survey of India Toposheet No. 55 K/15. It is situated at 28 kms from Nagpur, 3 Kms from Klameshwar on Dhapewada road, and the site is located 5 m east Grampanchayat Bhavan and 5 m north of village road in Grampanchayat premises. .

Details of Drilling

Rock Formation: Trap Covered Gondwana

a) Type: Basalt & Sandstone
b) Drilling Started on 5.02.14 at 18.50 hrs
c) Drilling Completed on 5.02.14 at 23.05 hrs
d) Total depth drilled: 200.00 m.
e) Total depth drilled in Hard rock Formation (with 215 mm Button Bit):62.15 m.
f) Total depth drilled in soft rock Formation (with 215 mm Button Bit):137.85 m.
g) Details of Casing

1) Length of pipes
   a. Blank Pipes : (152.4 mm) 6” pipes = 0.60 magl + 92.29 m bgl =92.89 m
      (101.6 mm) 4” pipes = 37.15 m
   b. Slotted pipes : (152.4 mm) 6” pipes = 6.08 m
      (101.6 mm) 4” pipes = 52.48 m
   c. Slot Size : 1.5 mm
2) Dia of Pipe :
   a. Blank Pipes : 152.4 mm
   b. Slotted Pipes : 152.4 mm & 101.6 mm
3) Gauge of Pipes
   a. Blank Pipes : 7.1 mm
   b. Slotted pipes : 7.1mm
4) Material of Pipes
   a. Blank Pipes : MS
   b. Slotted pipes : MS

Geological Data:

Geologically the site is located in Trap covered Gondwana area. The contact between basalt and Gondwana encountered at 62.00 m bgl.

Table 16.1: Drill Time log of the Exploratory well drilled at village Waroda, Kalmeshwar taluka, Nagpur district.

Date	Depth range (m)		Thickness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
5.02.2014	0	3	3	18:50	19:00	10	3.3
	3	5.65	2.65	19:00	19:06	6	2.3
	5.65	8.65	3	19:40	19:47	7	2.3
	8.65	11.3	2.65	19:47	19:52	5	1.9
	11.3	14.3	3	19:53	20:02	9	3.0
	14.3	16.95	2.65	20:02	20:12	10	3.8
	16.95	19.95	3	20:13	20:18	5	1.7
	19.95	22.6	2.65	20:18	20:25	7	2.6
	22.6	25.6	3	20:26	20:30	4	1.3
	25.6	28.25	2.65	20:30	20:35	5	1.9
	28.25	31.25	3	20:36	20:40	4	1.3
	31.25	33.9	2.65	20:40	20:44	4	1.5
	33.9	36.9	3	20:45	20:50	5	1.7
	36.9	39.55	2.65	20:50	20:55	5	1.9
	39.55	42.65	3.1	20:56	21:04	8	2.6
	42.65	45.2	2.55	21:04	21:14	10	3.9
	45.2	48.2	3	21:15	21:20	5	1.7
	48.2	50.85	2.65	21:20	21:25	5	1.9
	50.85	53.85	3	21:26	21:28	2	0.7
	53.85	56.5	2.65	21:28	21:30	2	0.8
	56.5	59.5	3	21:30	21:35	5	1.7
	59.5	62.15	2.65	21:35	21:39	4	1.5

Date	Depth range (m)		Thickness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	62.15	65.15	3	21:40	21:44	4	1.3
	65.15	67.8	2.65	21:44	21:47	3	1.1
	67.8	70.8	3	21:48	21:50	2	0.7
	70.8	73.45	2.65	21:50	21:53	3	1.1
	73.45	76.45	3	21:54	21:57	3	1.0
	76.45	79.1	2.65	21:57	22:00	3	1.1
	79.1	82.1	3	22:01	22:03	2	0.7
	82.1	84.75	2.65	22:03	22:06	3	1.1
	84.75	87.75	3	22:07	22:10	3	1.0
	87.75	90.4	2.65	22:10	22:13	3	1.1
	90.4	93.4	3	22:14	22:16	2	0.7
	93.4	96.05	2.65	22:16	22:19	3	1.1
	96.05	99.05	3	22:20	22:23	3	1.0
	99.05	101.7	2.65	22:23	22:26	3	1.1
	101.7	104.7	3	22:27	22:30	3	1.0
	104.7	107.35	2.65	22:30	22:32	2	0.8
	107.35	110.35	3	22:33	22:35	2	0.7
	110.35	113	2.65	22:35	22:38	3	1.1
	113	116	3	22:39	22:42	3	1.0
	116	118.65	2.65	22:42	22:44	2	0.8
	118.65	121.65	3	22:45	22:47	2	0.7
	121.65	124.3	2.65	22:47	22:51	4	1.5
	124.3	127.3	3	22:52	22:55	3	1.0
	127.3	129.95	2.65	22:55	22:58	3	1.1
	129.95	132.95	3	22:59	23:03	4	1.3
	132.95	135.6	2.65	23:03	23:05	2	0.8
	135.6	138.6	3	23:06	23:09	3	1.0
	138.6	141.25	2.65	23:09	23:13	4	1.5
	141.25	144.25	3	23:14	23:19	5	1.7
	144.25	146.9	2.65	23:19	23:23	4	1.5
	146.9	149.9	3	23:24	23:29	5	1.7
	149.9	152.55	2.65	23:29	23:35	6	2.3
	152.55	155.55	3	23:36	23:42	6	2.0
	155.55	158.2	2.65	23:42	23:48	6	2.3
	158.2	161.2	3	23:50	23:59	9	3.0
	161.25	163.85	2.6	00:06	00:10	4	1.5
	163.85	166.85	3	00:10	00:16	6	2.0
	166.85	169.5	2.65	00:16	00:21	5	1.9
	169.5	172.5	3	00:22	00:27	5	1.7
	172.25	175.15	2.9	00:27	00:33	6	2.1

Date	Depth range (m)		Thickness(m)	Drilling time(min)		Total time (min)	Penetration rate. min/m
	From	To		From	To		
	175.15	178.15	3	00:34	00:39	5	1.7
	178.15	180.8	2.65	00:39	00:45	6	2.3
	180.8	183.8	3	00:46	00:49	3	1.0
	183.8	186.45	2.65	00:49	00:56	7	2.6
	186.45	189.45	3	00:57	01:03	6	2.0
	189.45	192.1	2.65	01:03	01:07	4	1.5
	192.1	195.1	3	01:08	01:14	6	2.0
	195.1	197.75	2.65	01:14	01:20	6	2.3
	197.75	200	2.25	01:21	01:26	5	2.2

Table 16.2: Consolidated lithological log of the Exploratory well drilled at village Waroda, Kalmeshwar taluka, Nagpur district.

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
0	5.65	5.65	**Top Soil**: Gritty; silty, lose material.
5.65	8.65	3	Vesicular Basalt, Weathered brownish black.
8.65	11.3	2.65	Basalt, Black, Jointed with chips of quartz.
11.3	14.3	3	Basalt, black, medium to coarse with grey bole
14.3	19.95	5.65	Basalt black hard compact
19.95	22.6	2.65	Basalt black hard compact with few chips of Secondary Minerals.
22.6	28.25	5.65	Basalt black hard vesicular with sparse green earth.
28.25	31.25	3	Basalt black hard compact
31.25	33.9	2.65	Basalt hard jointed with few chips of secondary minerals.
33.9	45.2	11.3	Basalt black hard compact.
45.2	50.85	5.65	Red bole bed mixed with vesicular basalt.
50.85	53.85	3	Basalt black hard compact.
53.85	56.5	2.65	Red bole bed mixed with vesicular basalt.
56.5	59.5	3	Basalt black hard compact.
59.5	62.15	2.65	Basalt brownish black mixed with gritty sandstone of brownish red colour.
62.15	65.15	3	gritty sandstone blackish brown hard compact.
65.15	70.8	5.65	Gritty sandstone brownish black micaceous mixed with black shale
70.8	76.45	5.65	Shale black mixed with sandstone blackish brown micaceous.
76.45	79.1	2.65	Shale, blackish brown mixed with greyish brown sandstone which is micaceous.
79.1	84.75	5.65	Shale, black mixed with dark grey sandstone compact.
84.75	93.4	8.65	Shale black medium grained.
93.4	96.05	2.65	Shale mixed with dark grey sandstone.
96.05	99.05	3	Sandstone dark grey, micaceous with few quartz chips.
99.05	118.65	19.6	Sandstone grey medium grained mixed with shale dark brown.
118.65	124.3	5.65	Shale brownish red mixed with gray sandstone.
124.3	138.6	14.3	Sandstone dark grey medium to coarse.
138.6	141.25	2.65	Sandstone dark grey gritty mixed with shale.
141.25	144.25	3	gritty sandstone, dark brownish grey, hard

Depth range (m)		Thickness (m)	Consolidated Lithology
From	To		
144.25	158.2	13.95	Sandstone dark grey mixed with shale brick red.
158.2	163.85	5.65	sandstone dark grey compact coarser chips.
163.85	166.85	3	sandstone dark grey with few chips of brick red sandstone which is compact medium grained
166.85	180.8	13.95	sandstone dark grey mixed with brownish red sandstone medium to coarse
180.8	186.45	5.65	sandstone dark grey hard compact micaceous.
186.45	200	13.55	sandstone dark grey with chocolate brown shale.

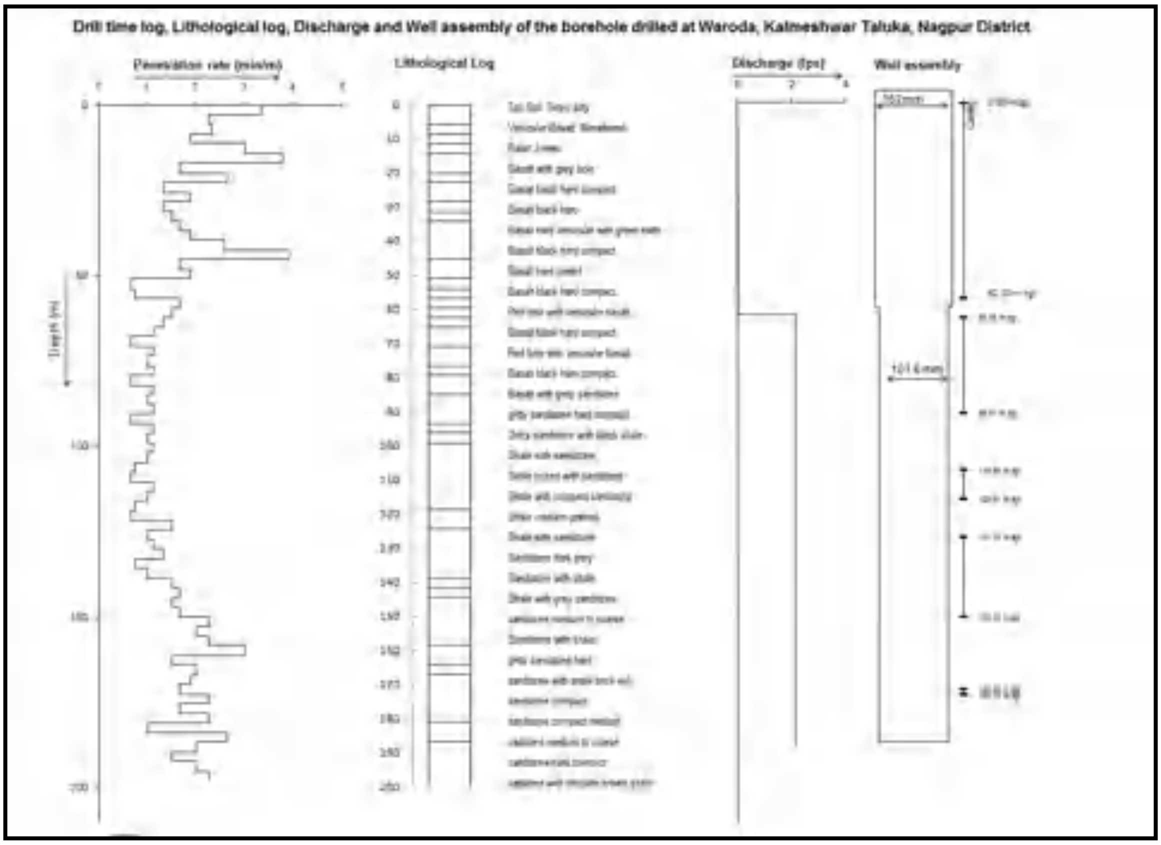


Fig.16.1: Composite Log of Exploratory Well Drilled at Waroda, Chandrabhaga Watershed (WGKKC-2)

WELL DESIGN

Table 16.3: Well Assembly of Exploratory Well at at Waroda EW, Kalmeshwar Taluka, Nagpur District.

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
1	0.00	0.6 (magl)	0.60	6" (152.4 mm) dia M S Blank MS pipe
2	0.00	62.00	62.00	6" (152.4 mm) dia M S Blank MS pipe
3	**62.00**	**68.08**	**6.08**	**6" (152.4 mm) dia M S Slotted MS pipe**
4	68.08	98.37	30.29	6" (152.4 mm) dia M S Blank MS pipe
5	**98.37**	**116.56**	**18.19**	**4" (101.6 mm) dia M S Slotted MS pipe**
6	116.56	125.57	9.01	4" (101.6 mm) dia M S Blank MS pipe

Sl. No.	Depth Range (mbgl)		Thickness (m bgl)	Description of Pipes
	From	To		
7	**125.57**	**137.76**	**12.19**	**4" (101.6 mm) dia M S Slotted MS pipe**
8	137.76	163.09	25.33	4" (101.6 mm) dia M S Blank MS pipe
9	**163.09**	**186.00**	**22.91**	**4" (101.6 mm) dia M S Slotted MS pipe**
10	186.00	188.00	2.00	4" (101.6 mm) dia M S Blank MS pipe with bail blug

Development

The well was developed using air compressor for 15 hrs till the water was free from sand particles. Cumulative Discharge measured was 2.16 lps.

WELL HYDRAULICS

No pumping test was conducted due to low discharge.

CHEMICAL QUALITY

The ground water samples collected during the well development and the PYT test were analysed at the Regional Chemical Laboratory of CGWB (CR) Nagpur. The analytical results are given in Table

Location	Type	pH	Ec µS/cm	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				……………………………ppm……………..										
Waroda	Well development	8.1	519	110	40	36.5	2.5	0.04	0	134	43	51.9	32.6	0.12

The analytical result of water sample collected during pumping test revealed that the range of concentration of parameters viz Mg, are more than desirable limit while all other parameters are within the desirable limit as per “Drinking Water Standards” of Bureau of Indian Standards (BIS 10500-2013).

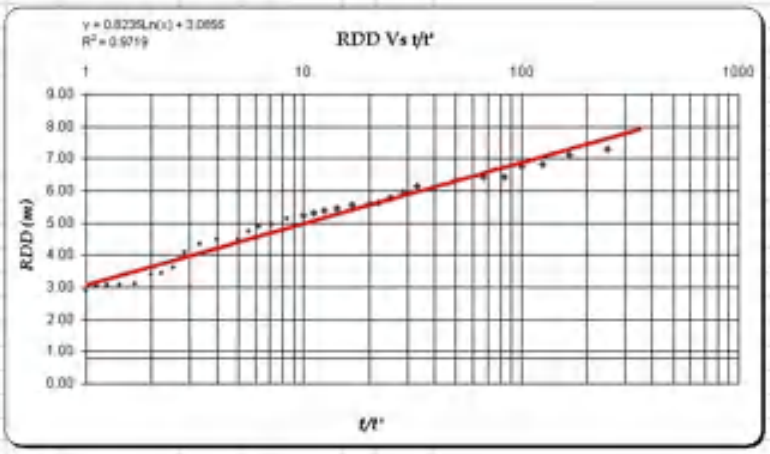
ANNEXURE-VI: Pumping test data analysis

To estimate the deeper aquifer parameters pumping tests were conducted on seven exploratory wells drilled in the Chandrabhaga watershed. The drawdown recorded during pumping test ranges between 6.34 and 36.97 m, whereas aquifer parameters viz Transmissivity (T) ranging from aquifer in basalts is 30 m^2/day (Sonkhamb) and in Gondwana sandstone 15 m^2/day (khairi Lakhmaji) to 173 m^2/day (Kohli). The storativity (S) of 0.001 is measured at Dhapewada. The site wise plot depicting RDD Vs T/T' are presented graphs as under

PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT DHAPEWADA EW, NAGPUR DISTRICT KALMESHWAR TALUKA, NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2		
4	250.00	7.30
6	166.67	7.13
8	125.00	6.84
10	100.00	6.75
12	83.33	6.45
15	66.67	6.44
20	50.00	6.32
25	40.00	6.10
30	33.33	6.16
35	28.57	5.97
40	25.00	5.79
45	22.22	5.65
50	20.00	5.62
60	16.67	5.56
70	14.29	5.47
80	12.60	5.39
90	11.11	5.31
100	10.00	5.23
120	8.33	5.12
140	7.14	4.94
160	6.25	4.87
180	5.56	4.72
200	5.00	4.50
250	4.00	4.47
300	3.33	4.35
350	2.86	4.09
400	2.50	3.60
450	2.22	3.43
600	1.67	3.10
700	1.43	3.08
800	1.25	3.08
900	1.11	3.02
1000	1.00	2.90

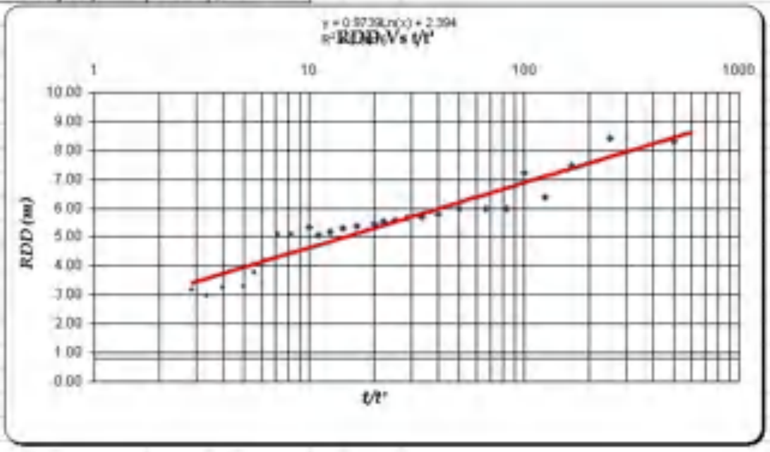
Date	=	15/12/13	
SWL	=	11.37	mbgl
Q	=	7.76	lps
Δ s	=	1.897	m
T	=	65	m2/day
Specific Capacity		28.18 lpm/m	



PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT DHAPEWADA, NAGPUR DISTRICT KALMESHWAR TALUKA, NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2	500.00	8.33
4	250.00	8.44
6	166.67	7.47
8	125.00	6.38
10	100.00	7.21
12	83.33	5.98
15	66.67	5.98
20	50.00	6.00
25	40.00	5.78
30	33.33	5.71
35	28.57	5.67
40	25.00	5.60
45	22.22	5.53
50	20.00	5.48
60	16.67	5.40
70	14.29	5.30
80	12.50	5.19
90	11.11	5.07
100	10.00	5.34
120	8.33	5.11
140	7.14	5.10
160	6.25	4.17
180	5.56	3.77
200	5.00	3.30
250	4.00	3.26
300	3.33	2.96
350	2.86	3.18

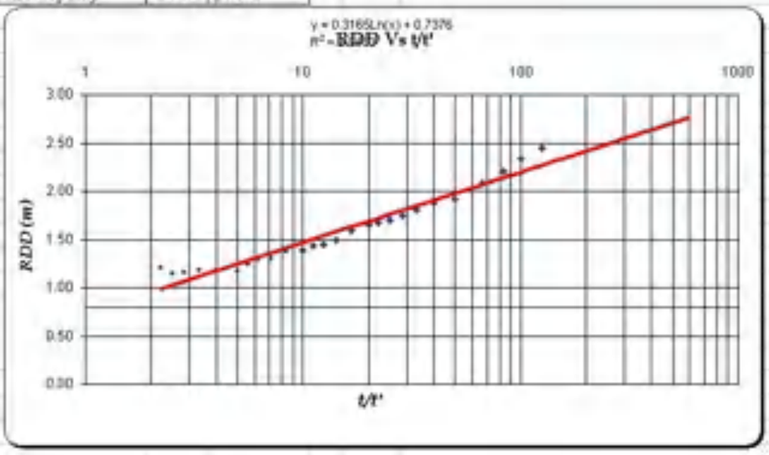
Date	=	15/12/13	
SWL	=	12.42	mbgl
Q	=	9.84	lps
Δ s	=	2.243	m
T	=	69	m2/day
Specific Capacity		76.27	lpm/m



PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT GOWRI, NAGPUR DISTRICT KALMESHWAR TALUKA, NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2	500.00	
4	250.00	
6	166.67	
8	125.00	2.45
10	100.00	2.34
12	83.33	2.21
15	66.67	2.08
20	50.00	1.92
25	40.00	1.88
30	33.33	1.81
35	28.57	1.75
40	25.00	1.70
45	22.22	1.67
50	20.00	1.65
60	16.67	1.59
70	14.29	1.50
80	12.50	1.45
90	11.11	1.43
100	10.00	1.38
120	8.33	1.37
140	7.14	1.30
160	6.25	1.29
180	5.56	1.24
200	5.00	1.17
250	4.00	1.18
300	3.33	1.18
350	2.86	1.16
400	2.50	1.15
450	2.22	1.21

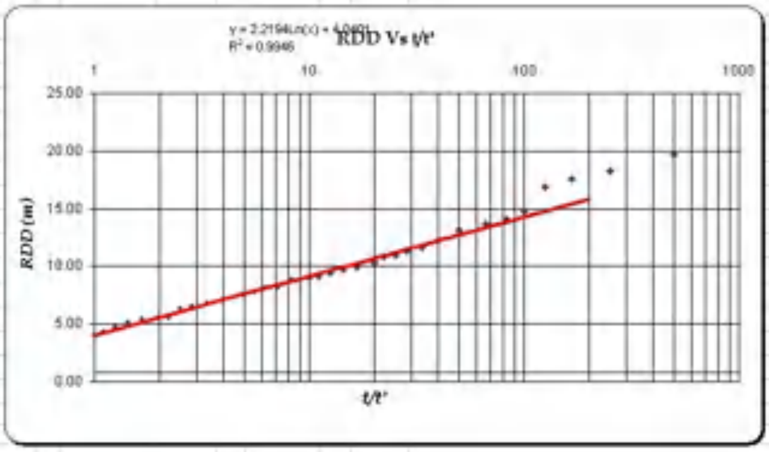
Date	=	20/12/13	
SWL	=	8.03	mbgl
Q	=	5.50	lps
Δ s	=	0.729	m
T	=	119	m2/day
Specific Capacity		37.45	lpm/m



PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT KHAIRI LAKHMAJI, NAGPUR DISTRICT KALMESHWAR TALUKA, NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2	500.00	19.69
4	250.00	18.25
6	166.67	17.59
8	125.00	16.86
10	100.00	14.79
12	83.33	14.04
15	66.67	13.63
20	50.00	13.11
25	40.00	12.26
30	33.33	11.66
35	28.57	11.33
40	25.00	10.99
45	22.22	10.82
50	20.00	10.32
60	16.67	9.97
70	14.29	9.69
80	12.50	9.47
90	11.11	9.14
100	10.00	9.05
120	8.33	8.81
140	7.14	8.15
160	6.25	8.09
180	5.56	7.76
200	5.00	7.55
250	4.00	7.10
300	3.33	6.78
350	2.86	6.51
400	2.50	6.35
450	2.22	5.57
600	1.67	5.38
700	1.43	5.14
800	1.25	4.76
900	1.11	4.29
1000	1.00	4.02

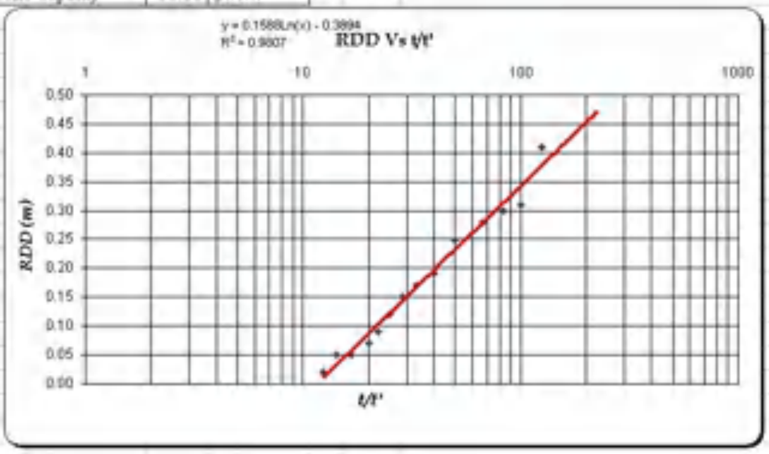
Date	=	15/1/2014	
SWL	=	6.01	mbgl
Q	=	5.50	lps
Δ s	=	5.11	m
T	=	17.02	m2/day
Specific Capacity		8.92	lpm/m



PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT KOHLI NAGPUR DISTRICT KALMESHWAR TALUKA, NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2		
4		
6		
8	125.00	0.41
10	100.00	0.31
12	83.33	0.30
15	66.67	0.28
20	50.00	0.25
25	40.00	0.19
30	33.33	0.17
35	28.57	0.15
40	25.00	0.12
45	22.22	0.09
50	20.00	0.07
60	16.67	0.05
70	14.29	0.05
80	12.50	0.02

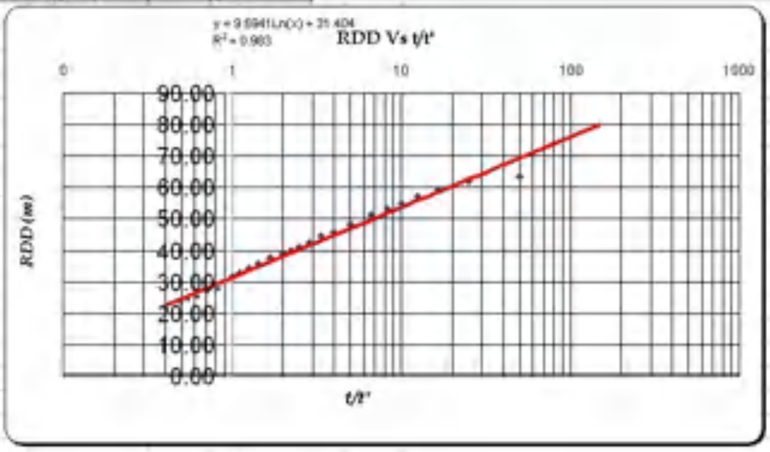
Date	=	23/1/2014	
SWL	=	8.03	mbgl
Q	=	4.00	lps
Δ s	=	0.366	m
T	=	173	m2/day
Specific Capacity		50.63	lpm/m



PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT MALEGAON NAGPUR DISTRICT
KALMESHWAR TALUKA, NAGPUR DISTRICT.

Date	=	25/12/2013	
SWL	=	11.74	mbgl
Q	=	1.00	lps
Δ s	=	22.320	m
T	=	1	m2/day
Specific Capacity			lpm/m

t (min)	t/t' (min)	RDD (m)
2	50.00	63.26
4	25.00	61.93
6	16.67	59.36
8	12.50	57.31
10	10.00	54.85
12	8.33	53.08
15	6.67	51.09
20	5.00	48.20
25	4.00	45.85
30	3.33	44.46
35	2.86	42.40
40	2.50	41.04
45	2.22	39.75
50	2.00	38.93
60	1.67	37.54
70	1.43	36.68
80	1.25	34.39
90	1.11	32.74
100	1.00	31.54
120	0.83	27.74
140	0.71	26.61
160	0.63	25.26
180	0.56	24.38
200	0.50	23.34
250	0.40	21.46

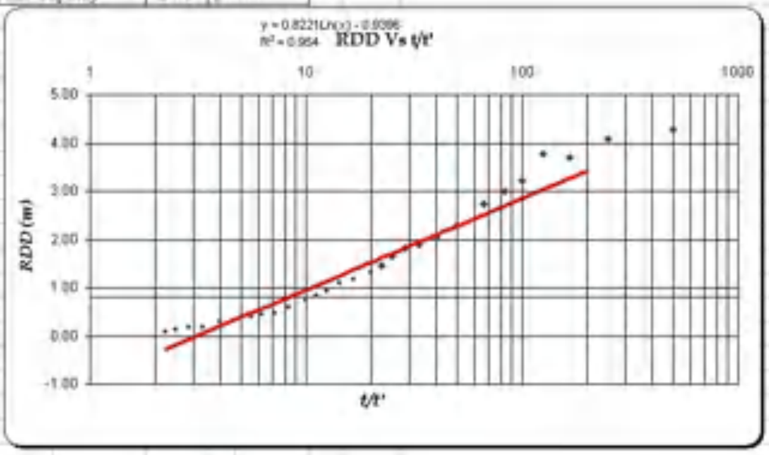


PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT RAULGAON NAGPUR DISTRICT
KALMESHWAR TALUKA, NAGPUR DISTRICT.

Date	=	1/3/2014	
SWL	=	36.52	mbgl
Q	=	4.50	lps
Δ s	=	2.030	m
T	=	35.05	m2/day
Specific Capacity		21.51	lpm/m

lpm

t (min)	t/t' (min)	RDD (m)
2	500.00	4.27
4	250.00	4.08
6	166.67	3.71
8	125.00	3.78
10	100.00	3.22
12	83.33	3.01
15	66.67	2.74
20	50.00	2.30
25	40.00	2.04
30	33.33	1.88
35	28.57	1.82
40	25.00	1.66
45	22.22	1.46
50	20.00	1.32
60	16.67	1.18
70	14.29	1.10
80	12.50	0.92
90	11.11	0.83
100	10.00	0.74
120	8.33	0.60
140	7.14	0.48
160	6.25	0.44
180	5.56	0.40
200	5.00	0.38
250	4.00	0.29
300	3.33	0.19
350	2.86	0.17
400	2.50	0.13
450	2.22	0.08

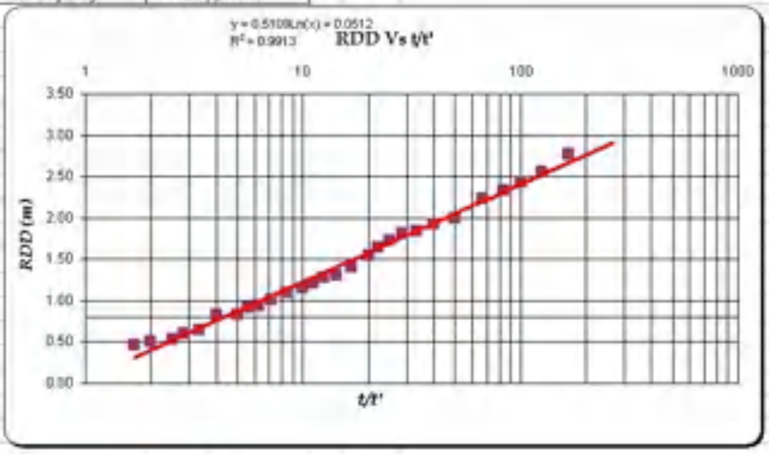


PUMPING TEST DATA AND PLOT OF RDD V/S T/T' OF EXPLORATORY WELL AT SONKHAMB NAGPUR DISTRICT KATOL TALUKA,NAGPUR DISTRICT.

t (min)	t/t' (min)	RDD (m)
2		
4		
6	166.67	2.77
8	125.00	2.56
10	100.00	2.43
12	83.33	2.34
15	66.67	2.24
20	50.00	2.00
25	40.00	1.92
30	33.33	1.84
35	28.57	1.81
40	25.00	1.73
45	22.22	1.65
50	20.00	1.54
60	16.67	1.41
70	14.29	1.31
80	12.50	1.28
90	11.11	1.21
100	10.00	1.15
120	8.33	1.09
140	7.14	1.01
160	6.25	0.94
180	5.56	0.92
200	5.00	0.83
250	4.00	0.83
300	3.33	0.65
350	2.86	0.60
400	2.50	0.54
450	2.22	
600	1.67	0.47

Date	=	28/12/13	
SWL	=	11.27	mbgl
Q	=	2.25	lps
Δ s	=	1.177	m
T	=	30	m2/day
Specific Capacity		7.23	lpm/m

136 lpm



ANNEXURE-VII: Details of well inventory data of Key Observation wells, Chandrabhaga Watershed (WGKKC-2), Nagpur district, Maharashtra

Sl. No.	Well No.	Village	Taluka	District	Toposheet No.	Latitude			Longitude			Elevation	Lining	Basin	Sub-basin	Minor basin	Geology	Aquifer	MP	Dia	Total Depth
						Deg	Min	Sec	Deg	Min	Sec	m A MSL	(m bgl)						(magl)	(m)	(mbgl)
1	DW1	Phetri	Nagpur	Nagpur	55K/16	21	12	162	78	59	354	342.6700	2.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.55	3	10.41
2	DW2	Khairgaon	Nagpur	Nagpur	55 K/16	21	11	93	78	57	248	342.7000	2.88	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	2.1	12.8
3	DW3	Kalambi	Kalmeshwer	Nagpur	55 K/16	21	11	396	78	55	131	337.0900	4.05	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.25	2.21	11.05
4	DW4	Selu	Kalmeshwer	Nagpur	55 K/16	21	12	334	78	53	934	351.7600	4.66	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.7	3.02	10.28
5	DW5	Kalmeshwer (RH)	Kalmeshwer	Nagpur	55 K/16	21	14	50	78	54	765	329.1050	4.7	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	2.5	10.35
6	DW6	Dahegaon	Kalmeshwer	Nagpur	55 K/16	21	12	611	78	56	873	338.1100	6.75	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.65	3.7	8.55
7	DW7	Ashti	Kalmeshwer	Nagpur	55 K/16	21	12	677	78	58	57	328.0050	8.65	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.35	2.7	13.25
8	DW8	Pardi	Kalmeshwer	Nagpur	55 K/16	21	14	886	78	57	727	321.7050	6.5	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.9	2.6	10.2
9	DW9	Gowari	Kalmeshwer	Nagpur	55 K/15	21	16	197	78	56	878	318.1150	8.25	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.45	3	8.55
10	DW10	Tondakhairi	Kalmeshwer	Nagpur	55 K/16	21	16	941	78	57	867	319.0050	7.8	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.5	6.2	19.1
11	DW11	Borgaon(Kh)	Kalmeshwer	Nagpur	55 K/15	21	17	836	78	57	674	305.7100	9.25	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.75	3	9.95
12	DW12	Silori	Kalmeshwer	Nagpur	55 K/15	21	18	778	78	58	233	302.9100	10.48	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.52	2.65	10.53
13	DW13	Dhapewada	Kalmeshwer	Nagpur	55 K/15	21	18	20	78	54	968	328.1100	8.95	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.8	3	14.25
14	DW14	Bhadangi	Kalmeshwer	Nagpur	55 K/15	21	17	874	78	56	60	310.4300	3	Godavari	Wainganga	Kanhan	Gondwana	Sandstone	0.5	2.35	11.85
15	DW15	Warode	Kalmeshwer	Nagpur	55 K//5	21	16	773	78	54	665	322.1750	5.25	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.8	4.4	21.3
16	DW16	Brahmni	Kalmeshwer	Nagpur	55 K/15	21	14	624	78	54	381	322.0000	5.45	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.65	3.15	15.85
17	DW17	Sawli	Kalmeshwer	Nagpur	55 K//5	21	16	295	78	55	530	318.1300	8.95	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.55	3.05	15.5
18	DW18	Ketapar	Kalmeshwer	Nagpur	55 K/16	21	11	81	78	53	893	358.6000	1.95	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	4	10.1
19	DW19	Sahuli	Kalmeshwer	Nagpur	55 K/16	21	11	228	78	56	545	351.2900	2.5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.4	3	12.2
20	DW20	Gumthala	Kalmeshwer	Nagpur	55 K/16	21	11	951	78	52	237	359.7000	4.35	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.65	1.6	11.6
21	DW21	Sawangi (IW)	Kalmeshwer	Nagpur	55 K/15	21	13	305	78	13	305	339.8500	3.62	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	3.5	9.9
22	DW22	Uparwahi	Kalmeshwer	Nagpur	55 K/16	21	13	43	78	51	373	356.2700	5.55	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.55	3	8.55
23	DW23	Nimboli	Kalmeshwer	Nagpur	55 K/16	21	12	387	78	50	542	358.7000	2.5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	2.9	6.37
24	DW24	Linga	Kalmeshwer	Nagpur	55 K/16	21	12	966	78	49	171	364.1100	0.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.6	4.6	7.8
25	DW25	Sonegaon	Kalmeshwer	Nagpur	55 K/16	21	14	10	78	49	979	356.8050	5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0	6.4	8.3
26	DW26	Khapri	Kalmeshwer	Nagpur	55 K/16	21	14	646	78	50	569	364.1100	6.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.6	1.75	12.3
27	DW27	Ghogali	Kalmeshwer	Nagpur	55 K/16	21	14	519	78	52	76	338.0050	7.65	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.75	2.95	12.15
28	DW28	Brahmni(IW)	Kalmeshwer	Nagpur	55 K/16	21	14	554	78	53	598	333.0150	6.4	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.7	4.65	10.85
29	DW29	Ghorad	Kalmeshwer	Nagpur	55 K/15	21	15	74	78	52	922	332.0900	3.95	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.7	1.26	9.45
30	DW30	Ubali	Kalmeshwer	Nagpur	55 K/15	21	15	990	78	52	133	338.1050	5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	1.6	14
31	DW31	Wadhone Buzrug	Kalmeshwer	Nagpur	55 K/15	21	17	541	78	53	56	333.0900	4.65	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.4	1.5	16.25
32	DW32	Sawali Khurd	Kalmeshwer	Nagpur	55 K/15	21	16	831	78	51	831	338.3150	3.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.4	4.05	18
33	DW33	Wathoda	Kalmeshwer	Nagpur	55 k/15	21	16	932	78	50	288	348.1100	7.2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.95	1.35	10.4
34	DW34	Sawangi (Anganwadi)	Kalmeshwer	Nagpur	55 K/15	21	17	42	78	50	50	344.6100	2.25	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.7	0.55	7.3
35	DW35	Susundri	Kalmeshwer	Nagpur	55 K/15	21	17	515	78	48	937	352.7000	2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.6	1.9	7.8
36	DW36	Khairi	Kalmeshwer	Nagpur	55 K/15	21	17	551	78	47	461	363.8100	3.2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.65	1.1	6.75
37	DW37	Pardi	Kalmeshwer	Nagpur	55 K/15	21	16	877	78	46	277	374.9900	2.17	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.23	1.17	8.12
38	DW38	Ramgiri	Kalmeshwer	Nagpur	55 K/15	21	18	70	78	45	451	422.1650	2.1	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	5.05	8.85
39	DW39	Dorli	Katol	Nagpur	55 k/15	21	15	166	78	46	741	382.1150	12.7	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.6	3.6	12.7
40	DW40	Ubgi	Kalmeshwer	Nagpur	55 K/15	21	15	52	78	49	581	369.9000	4.75	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0	2.3	14.05
41	DW41	Kohli	Kalmeshwer	Nagpur	55 K/15	21	15	773	78	48	587	361.0050	4	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.45	2.8	11.25
42	DW42	Kotwali Bardi	Katol	Nagpur	55 K/16	21	13	431	78	46	909	389.2050	2.2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.3	4	6.25
43	DW43	Raulgaon	Katol	Nagpur	55 K/16	21	13	868	78	46	883	396.1100	2.6	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.6	3.6	9.25
44	DW44	Chargaon	Katol	Nagpur	55 K/15	21	15	888	78	45	43	396.1000	3.5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.4	3.6	10.5
45	DW45	Sonkhamb	Katol	Nagpur	55 k/11	21	15	761	78	43	648	403.0800	1.5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.3	4.3	11.8
46	DW46	Metpanjra	Katol	Nagpur	55 K/11	21	15	578	78	42	46	426.1600	6.42	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.38	4.15	12.17
47	DW47	Malegaon	Katol	Nagpur	55 K/11	21	18	426	78	43	236	517.1100	3.25	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.4	3	7.35
48	DW48	Vasboli	Katol	Nagpur	55 K/12	21	13	750	78	42	773	483.1600	3.4	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.8	3	13.55
49	DW49	Pohi	Kalmeshwer	Nagpur	55 K/16	21	14	189	78	48	694	366.1150	2.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.75	3.65	7.25
50	DW50	Yerla	Kalmeshwer	Nagpur	55 K/16	21	12	475	78	57	917	339.0800	6.2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0	4.6	13.75
51	DW51	Chicholi	Nagpur	Nagpur	55 K/16	21	11	674	78	58	725	348.7100	5.77	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.45	3.15	12.25

Sl. No.	Well No.	Village	Taluka	District	Toposheet No.	Latitude			Longitude			Elevation	Lining	Basin	Sub-basin	Minor basin	Geology	Aquifer	MP	Dia	Total Depth
						Deg	Min	Sec	Deg	Min	Sec	m A MSL	(m bgl)						(magl)	(m)	(mbgl)
52	DW52	Kalmeshwer (NE of SELU)	Kalmeshwer	Nagpur	55 K/16	21	12	976	78	54	338	334.3400	8.4	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	4.3	16
53	DW53	Sawangi (SW of Kalmeshwar)	Kalmeshwer	Nagpur	55 K/16	21	13	332	78	53	866	344.1150	5.2	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0	2.75	18
54	DW54	Kalmeshwer (S of Gowari)	Kalmeshwer	Nagpur	55 K/16	21	14	916	78	56	217	319.7700	9	Godavari	Wainganga	Kanhan	Trap covered Gondwanas	Basalt/Sandstone	0.75	3.24	17.9
55	DW55	Kalmeshwer (Ashti Road	Kalmeshwer	Nagpur	55 K/16	21	13	826	78	56	774	327.0050	5.8	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	2.9	13.55
56	DW56	Waroda	Kalmeshwer	Nagpur	55 K/15	21	15	891	78	54	397	326.0150	7.5	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.8	1.93	10.72
57	DW57	Lakholi	Katol	Nagpur	55 K/11	21	16	696	78	41	508	433.0100	3.6	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.5	3.5	8.8
58	DW58	Kalmeshwar (Rly Gate)	Kalmeshwer	Nagpur	55 K/16	21	13	304	78	56	84	328.9100	8.45	Godavari	Wainganga	Kanhan	Decan Traps	Basalt	0.55	3.05	12.85

ANNEXURE-VIII: Details of Irrigation well inventory data, Chandrabhaga Watershed (WGKKC-2), Nagpur District

Sl. No.	Village	Taluka	Latitute			Longitude			Topo sheet wise well No.	Elevation	Depth of well	DTWL	Top Soil	Thickness of weathering		Depth to Fractures	Thickness of fracture	Geology
			D	M	S	D	M	S		m a MSL	m bgl	m bgl	m bgl	Highly	Moderately	m bgl		
1	Phetri	Nagpur	21	12	25	78	59	7	55K/16-01	330	13.67	6.67	00-1.0	3.5	3.5-9.0	12.0-13.0	9.0-13.0	Basalt
2	Phetr-East	Nagpur	21	12	30	78	51	15	55K/16-02	295	14	9.4	00-1.0	6.95	106.95-9.0	13.0-14.0	9.0-14.0	Basalt
3	Phetri-South	Nagpur	21	12	24	78	59	20	55K/16-03	296	14.3	5.9	00-1.0	2.15	2.5-6.3	8.0-10.0	6.3-13.0	Basalt
4	Chicholi	Nagpur	21	11	22	78	58	30	55K/16-04	317	19.7	15.6	00-1.0	3	3.0-8.0	18.0-19.0	8.0-19.0	Basalt
5	Yerla	Nagpur	21	11	30	78	58	6	55K/16-05	363	13.3	10	00-1.0	3	3.0-6.7	11.0-12.0	6.7-12.0	Basalt
6	Khargaon	Nagpur	21	11	18	78	57	45	55K/16-06	375	10.85	9.8	00-1.0	2	2.0-8.0	8.0-10.0	8.0-10.0	Basalt
7	Khargaon	Nagpur	21	11	12	78	57	17	55K/16-07	372	10	6.5	00-1.0	2.4	2.5-7.0	7.0-8.0	7.0-9.0	Basalt
8	Khargaon	Nagpur	21	10	55	78	57	30	55K/16-08	374	17.2	10.6	00-1.0	2.5	8	15.0-16.0	8.0-16.0	Basalt
9	Khargaon	Nagpur	21	11	4	78	56	52	55K/16-09	369	14.5	7.35	00-1.0	4	8	12.0-13.0	8.0-13.0	Basalt
10	Chicholi	Nagpur	21	11	47	78	58	34	55K/16-10	367	15.6	15.4	00-1.0	6.4	8	11.0-12.0	8.0-15.0	Basalt
11	Bhorgaon	Nagpur	21	13	27	78	38	47	55K/16-11	319	16	9.85	00-1.0	6.65	8.6	11.0-13.0	8.06-14.0	Basalt
12	Gondini	Nagpur	21	12	38	78	58	49	55K/16-12	342	16.05	12.9	00-1.0	4.55	8.5	11.0-12.0	8.5-14.0	Basalt
13	Yerla	Nagpur	21	12	57	78	57	58	55K/16-13	342	12.1	6	00-1.0	3.2	5.6	6.0-8.0	5.6-10.0	Basalt
14	Ashti	Nagpur	21	13	40	78	58	1	55K/16-14	336	15.9	10.4	00-1.0	9.55	10	10.-13.0	10.0-15.0	Basalt
15	Pardi	Nagpur	21	14	16	78	57	56	55K/16-15	333	12.5	8.6	00-1.0	5.35	5.35	8.0-9.0	5.35-10.0	Basalt
16	Pardi	Nagpur	21	14	52	78	57	48	55K/16-16	331	12.4	11.05	00-1.0	6.4	6.4	9.0-10.0	6.4-11.0	Sandstone
17	Dahegaon	Kalmeshwer	21	12	42	78	56	57	55K/16-17	374	17.1	15	00-1.0	2.75	8.5	8.75-10.0	8.5-15.0	Basalt
18	Yerla	Nagpur	21	12	25	78	57	59	55K/16-18	346	9.7	7	00-1.0	2.35	3	8.0-9.0	3.0-9.0	Basalt
19	Dahegaon	Kalmeshwer	21	12	4	78	57	2	55K/16-19	354	8.2	5.5	00-1.0	3.1	5	7.5-8.0	5.0-8.0	Basalt
20	Kalmeshwer-Bypass	Kalmeshwer	21	13	20	78	56	2	55K/16-20	351	15.5	9.15	00-1.0	4	9.15	10.13-12.0	9.015-15.5	Basalt
21	Kalmeshwer-East	Kalmeshwer	21	13	35	78	53	35	55K/16-21	336	14	11.8	00-1.0	9.7	10	12.0-13.0	10.-13.0	Basalt
22	Kalmeshwer-NE	Kalmeshwer	21	13	58	78	55	57	55K/16-22	338	16	13.5	00-1.0	7.7	8	14.0-15.0	8.0-16.0	Basalt
23	Kalmeshwer-Ashti	Kalmeshwer	21	13	40	78	55	16	55K/16-23	328	14.3	5.4	00-1.0	3.6	10	12.0-13.0	10.0-14.0	Basalt
24	Kalmeshwer-Pardi	Kalmeshwer	21	14	11	78	56	41	55K/16-24	370	16	13.2	00-1.0	9.05	9	14.0-15.0	9.0-15.0	Basalt
25	Kalmeshwer-Khairi	Kalmeshwer	21	14	28	78	56	16	55K/16-25	350	15	9.1	00-1.0	8	11	13.0-14.0	11.0-14.0	Basalt
26	Kalmeshwer-Gowari	Kalmeshwer	21	14	18	78	55	48	55K/16-26	352	13.44	10.67	00-1.0	7.3	10	12.0-13.0	10.0-13.0	Basalt
27	Kalambi	Kalmeshwer	21	11	52	78	55	17	55K/16-27	337	19.25	9.58	00-1.0	3.9	8	14.0-15.0	8.0-16.0	Basalt
28	Selu-Kalmeshwer	Kalmeshwer	21	13	8	78	54	14	55K/16-29	337	13.15	10	00-1.0	3.2	7	12.0-12.50	0.50	Basalt
29	Sahuli	Kalmeshwer	21	11	10	78	56	15	55K/16-31	380	16.2	14.6	00-1.0	3.1	11.5	14-16.20	2.2	Basalt
30	Kalambi-East	Kalmeshwer	21	11	11	78	55	25	55K/16-32	353	13.65	11.985	00-1.0	3	5.5	12.80-13.00	5.5-13.0	Basalt
31	Kalambi-NE	Kalmeshwer	21	11	59	78	56	13	55K/16-33	351	14.1	11.35	00-1.0	5.1	8.2	9.0-13.0	8.2-13.0	Basalt
32	Selu	Kalmeshwer	21	11	59	78	54	22	55K/16-34	374	14.3	9.3	00-1.0	2.25	9	13	9.0-13.5	Basalt
33	Selu-SW	Kalmeshwer	21	11	51	78	53	29	55K/16-35	375	12.35	11.9	00-1.0	2.8	10	11	11.0-12.0	Basalt
34	Selu	Kalmeshwer	21	12	23	78	53	37	55K/16-36	348	14.2	9.5	00-1.0	4.1	7.4	10.0-11.0	7.4-13.0	Basalt
35	Gumthala	Kalmeshwer	21	12	20	78	52	28	55K/16-37	350	15.3	8.1	00-1.0	7.7	10	11.0-12	10.0-14.0	Basalt
36	Sawangi	Kalmeshwer	21	13	3	78	52	31	55K/16-38	355	15.7	14.65	00-1.0	5.3	7.5	14.0-15.0	7.5-15.0	Basalt
37	Sawangi-South	Kalmeshwer	21	12	45	78	53	4	55K/16-39	355	16.05	12.85	00-1.0	2.8	9	13-14.0	9.0-16.0	Basalt
38	Selu	Kalmeshwer	21	12	11	78	53	2	55K/16-40	364	17.05	13.3	00-1.0	2.4	9.4	14.0-15.0	9.4-16.0	Basalt
39	Nimboli	Kalmeshwer	21	12	20	78	50	25	55K/16-41	358.7	9.5	5.2	00-1.0	3.5	6.2	8.0-9.0	6.2-9.0	Basalt
40	Uperwahi	Kalmeshwer	21	12	43	78	50	14	55K/16-42	356.27	10.3	6.95	00-1.0	6.7	8	9.30-10.0	8.0-10.0	Basalt
41	Linga	Kalmeshwer	21	12	17	78	48	57	55K/16-43	364.11	8.3	8.05	00-1.0	3.5	6.1	7.6	6.1-8.0	Basalt
42	Tarabudi	Kalmeshwer	21	13	19	78	49	59	55K/16-44	371	14.8	10.4	00-1.0	3.9	9.4	11.3	9.4-14.0	Basalt
43	Sonegaon	Kalmeshwer	21	14	10	78	50	2	55K/16-45	356.8	15.6	14.7	00-1.0	1.2	9.8	13.0-14.0	9.8-15.0	Basalt
44	Ghorad	Kalmeshwer	21	14	31	78	52	58	55K/16-46	392	19.7	11.32	00-1.0	12.1	12	15-18 mts.	12.0-19.0	Basalt
45	Ghogali	Kalmeshwer	21	14	42	78	51	58	55K/16-47	338	11.8	4	00-1.0	4.8	4.80-7.00	9.00-11.00	2	Basalt
46	Khapri	Kalmeshwer	21	14	34	78	50	35	55K/16-48	384	12	3.08	00-1.0	5.3	5.30-7.0	9.50-11.00	1.5	Basalt
47	Kohli	Kalmeshweer	21	15	11	78	48	22	56K/15-49	395	16.83	2.7	00-1.0	8.1	12	12.00-14.00	12.0-16.0	Basalt
48	Raulgaon	Katol	21	14	2	78	48	49	55K/16-50	403	10.3	1	00-1.0	2	6	6.0-10.0	6.0-10.3	Basalt
49	Dorli	Katol	21	15	40	78	46	35	55K/15-59	399	11.9	1.8	00-1.0	5.2	9	9.0-11.	9.0-11.0	Basalt
50	Chargaon	Katol	21	15	47	78	45	21	55K/15-52	414	12.4	3.45	00-1.0	1.5	8	11.0-12.0	8.0-12.0	Basalt
51	Tarabudi	Katol	21	15	31	78	42	57	55K/11-53	400	10	0.5	00-1.0	3	8	8.0-9.0	8.0-10.0	Basalt
52	Metpanjra	Katol	21	15	30	78	42	2	55K/11-54	458	13.38	2.24	00-1.0	4	8	11.0-12.0	8.0-13.0	Basalt
53	Sonekhamb	Katol	21	15	50	78	43	47	55K/11-55	422	10.1	0.56	00-1.0	2	7	9.0-10.0	7.0-10.0	Basalt
54	Dorli	Katol	21	15	42	78	47	4	55K/11-56	386	13.81	3.74	00-1.0	3.74	8	10.0-12.0	8.0-13.0	Basalt

Sl. No.	Village	Taluka	Latitute			Longitude			Topo sheet wise well No.	Elevation	Depth of well	DTWL	Top Soil	Thickness of weathering		Depth to Fractures	Thickness of fracture	Geology
			D	M	S	D	M	S		m a MSL	m bgl	m bgl	m bgl	Highly	Moderately	m bgl		
55	Kohli	Kalmeshwer	21	16	12	78	48	49	55K/15-57	374	10.3	1.1	00-1.0	2	7	7.0-9.0	7.0-10.0	Basalt
56	Susundri	Kalmeshwer	21	16	45	78	48	54	55K/15-58	366	14.5	3	00-1.0	5	9	10.0-12.0	9.0-14.0	Basalt
57	Khairi	Kalmeshwer	21	17	36	78	48	8	55K/15-59	364	13	3.52	00-1.0	6.2	9	11.0-13.0	9.0-13.0	Basalt
58	Khairi-Deshmukh	Kalmeshwer	21	17	20	78	47	21	55K/15-60	366	10.96	4.05	00-1.0	4.12	8.5	8.50-10.0	8.05-10.0	Basalt
59	Pardi-Deshmukh	Kalmeshwer	21	17	9	78	46	33	55K/15-61	158	17.88	5.6	00-1.0	6	8	10.0-12.0	8.0-17.0	Basalt
60	Pardi-Deshmukh	Kalmeshwer	21	16	30	78	46	5	55K/15-62	390	12	2.5	00-1.0	5.5	9	10.0-11.0	9.0-12.0	Basalt
61	Chakdo	Katol	21	16	42	78	45	24	55K/15-63	404	9.05	1.12	00-1.0	2.6	6	6.0-9.0	6.0-9.0	Basalt
62	Pardi-Deshmukh	Kalmeshwer	21	17	31	78	45	47	55K/15-64	399	12.6	1.5	00-1.0	2.5	8	9.0-11.0	8.0-12.0	Basalt
63	Susundri	Kalmeshwer	21	17	41	78	48	47	55K/15-65	385	9.4	2.58	00-1.0	3	7	7.0-9.40	7.0-9.40	Basalt
64	Sawangi	kalmeshwer	21	17	36	78	50	43	55K/15-66	352	10.62	3.38	00-1.0	4.3	8	8.0-10.0	8.0-10.0	Basalt
65	Wathoda	Kalmeshwer	21	17	7	78	51	6	55K/15-67	358	10	6.5	00-1.0	6.75	9	9.0-10.0	9.0-10.0	Basalt
66	Wathoda	Kalmeshwer	21	16	53	78	50	27	55K/15-68	353	11.46	3.1	00-1.0	4.3	8	8.0-9.0	8.0-11.0	Basalt
67	Ghorad	Kalmeshwer	21	15	26	78	52	54	55K/15-69	333	15.2	6.2	00-1.0	6.2	10	10.0-13.0	10.0-15.0	Basalt
68	Ubali	Kalmeshwer	21	15	46	78	52	15	55K/55-70	342	16.9	8.5	00-1.0	6.4	10	12.0-15.0	10.-16.0	Basalt
69	Khapri	kalmeshwer	21	15	8	78	51	10	55K/15-71	362	12.1	3.2	00-1.0	9	9	9.0-12.0	9.0-12.0	Basalt
70	Sawli Khurd	Kalmeshwer	21	16	31	78	51	44	55K/15-72	353	15.4	2.1	00-1.0	7	10	11.0-14.0	10.-15.0	Basalt
71	Sawali Khurd	Kalmeshwer	21	16	52	78	51	57	55K/15-73	345	16.1	6	00-1.0	5.4	8	12.0-13.0	8.0-15.0	Basalt
72	Wadhana Buzruk	Kalmeshwer	21	17	14	78	52	39	55K/15-74	338	18.5	9.4	00-1.0	3.35	7	16.0-18.0	7.0-18.0	Basalt
73	Susundri	Kalmeshwer	21	17	13	78	49	37	55K/15-75	360	12.5	7.8	00-1.0	5.6	9	9.0-11.0	9.0-12.0	Basalt
74	Wathoda	Kalmeshwer	21	16	48	78	50	9	55K/15-76	344	7.2	1.6	00-1.0	3	5	6.0-7.0	5.07.0	Basalt
75	Malegaon	Katol	21	18	2	78	43	7	55K/11-77	509	16.3	0.5	00-1.0	8	10	10.0-14.0	10.0-15.0	Basalt
76	Tarabudi	Katol	21	14	59	78	42	23	55K/12-78	434	15.4	1.9	00-1.0	4.1	8.5	11.0-12.0	8.5-15.0	Basalt
77	Wasboli	Katol	21	13	45	78	42	38	55K/12-79	478	17	3.1	00-1.0	3.1	8	15.0-17.0	8.0-17.0	Basalt
78	Sonekhamb	Katol	21	16	18	78	43	35	55K/11-80	409	9.5	2.05	00-1.0	2.1	6	9	6.0-9.0	Basalt
79	Brahmni	Kalmeshwer	21	14	47	78	54	29	55K/16-81	322	10.3	4.7	00-1.0	5.55	8	9.0-10.0	8.0-10.0	Basalt
80	Waroda	Kalmeshwer	21	15	45	78	54	38	55K/15-82	314	17.5	3.5	00-1.0	6	6.0-7.50	12.0-16.0	7.50-16.0	Basalt
81	Waroda	Kalmeshwer	21	15	55	78	53	41	55K/15-83	348	21.9	12.7	00-1.0	14.5	00-16.0	16.0-20	16.0-21.0	Basalt
82	Ubali	Kalmeshwer	21	16	0	78	52	14	55K/15-84	338	16	12.8	00-1.0	6.5	00-8.0	10.--0-13.0	8.0-15.0	Basalt
83	Sawali	Kalmeshwer	21	16	7	78	55	27	55K/15-85	323	17	3.3	00-1.0	8	8.0-10.0	12.0-14.0	10.0-16.0	Basalt
84	Waroda	Kalmeshwer	21	16	31	78	54	36	55K/15-86	336	16.2	11.5	00-1.0	12	00-12.0	12.0-15.0	12.0-16.0	Basalt
85	Kalmeshwer-sindi	Kalmeshwer	21	14	38	78	55	21	55K/16-87	321	14.1	7	00-1.0	8.3	8.3-10.0	11.0-13.0	10.0-14.0	Basalt
86	Sindi	Kalmeshwer	21	16	20	78	56	19	55K/16-88	322	12	3.8	00-1.0	11	00-11.00	11.0-12.0	11.0-12.0	Sandstone
87	Jhunki	Kalmeshwer	21	15	41	78	56	0	55K/15-89	327	17	7.4	00-1.0	7.4	7.4-9.0	10-14.0	9.0-16.0	Basalt
88	Dhapewada Khurd	Kalmeshwer	21	17	23	78	54	57	55K/15-90	341	16	7.3	00-1.0	9	9	10.0-12.0	10.0-12.0	Basalt
89	Dhapewada Khurd	Kalmeshwer	21	18	5	78	55	10	55K/15-91	333	17.8	11.5	00-1.0	11	11.0-12.0	12.0-16.0	12.0-16.0	Basalt
90	Dhapewada Khurd	Kalmeshwer	21	17	28	78	54	12	55K/15-92	324	18.5	14.9	00-1.0	7.2	7.2-9.0	16.0-17.0	9.0-17.0	Basalt
91	Badangi	Kalmeshwer	21	17	49	78	55	53	55K/15-93	336	16.9	11	00-1.0	15.3	15.3-15.5	15.5-16.5	15.5-16.5	Basalt
92	Durkheda	Kalmeshwer	21	17	54	78	57	29	55K/15-94	325	16.7	14	00-1.0	12.95	00.-12.95	13.00-16.0	13.0-16.0	Sandstone
93	Bhadangi	Kalmeshwer	21	17	56	78	56	37	55K/15-95	332	17	14.3	00-1.0	13.2	14	14.0-16.50	14.0-16.5	Sandstone
94	Ton dakhairi	Kalmeshwer	21	17	11	78	15	50	55K/15-96	326	14.8	12.5	00-1.0	6.7	6.7	7.0-14.0	7.0-14.0	Feldspathic
95	Gowari	Kalmeshwer	21	16	26	78	56	53	55K/15-97	316	10.9	5.7	00-1.0	2.7	3	3.0-10.0	3.0-10.0	Feldspathic
96	Gowari	Kalmeshwer	21	15	59	78	57	26	55K/15-98	302	22	15.7	00-1.0	6.7	7	7.0-20.0	7.0-20.0	Feldspathic
97	Khairi-Lakma	Kalmeshwer	21	15	31	78	57	13	55K/15-99	297	13.2	10	00-1.0	12	12	12.0-13.0	12.0-130-.0	Feldspathic
98	Khairi-Lakma	Kalmeshwer	21	15	6	78	55	6	55K/15-100	320	18	15.5	00-1.0	11	11.0-12.0	12.0-13.0	12.0-17.0	Basalt
99	Yerla	Kalmeshwer	21	12	23	78	58	48	55K/15-101	345	18	13.4	00-1.0	8.4	8.4-10.0	15.50-16.50	10.0-16.50	Basalt
100	Yerla	Kalmeshwer	21	12	40	78	57	31	55K/16-102	353	13.4	9	00-1.0	6	6.0-8.0	11.0-12.0	8.0-12.0	Basalt
101	Dahegaon	Kalmeshwer	21	13	12	78	56	60	55K/16-103	352	10.5	5.3	00-1.0	1.8	9	9.0-10.0	9.0-10.0	Basalt
102	Kalmeshwer	Kalmeshwer	21	13	13	78	55	48	55K/16-104	340	16.2	8.5	00-1.0	9	9.0-11.0	12.0-13.50	11.0-15.50	Basalt
103	Kalmeshwer	Kalmeshwer	21	13	19	78	54	51	55K/16-105	338	14	10.7	00-1.0	3	3.0-7.0	11.0-12.0	7.0-13.0	Basalt
104	Kalmeshwer	Kalmeshwer	21	13	15	78	54	13	55K/16-106	345	13.5	7.45	00-1.0	5.1	5.1-8.0	11.0-12.0	8.0-12.0	Basalt
105	Kalmeshwer	Kalmeshwer	21	13	55	78	53	24	55K/16-107	338	8.25	2.4	00-1.0	4	4.0-6.0	6.0-8.0	6.0-8.0	Basalt
106	Ghorad	Kalmeshwer	21	14	11	78	52	35	55K/16-108	348	17	13	00-1.0	10.7	10.7-12.0	15.0-16.0	12.0-16.0	Basalt
107	Khapri	Kalmeshwer	21	14	26	78	51	22	55K/16-109	352	12	10.7	00-1.0	4	4.0-6.0	9.0-11.0	6.0-11.00	Basalt
108	Khapri	Kalmeshwer	21	14	58	78	50	58	55K/16-110	350	7.4	4.8	00-1.0	1.65	5	5.0-6.0	5.0-7.0	Basalt
109	Waroda	Kalmeshwer	21	15	56	78	54	47	55K/15-111	325	15.9	11.1	00-1.0	8.65	8.65-10.0	12.0-14.0	10.0-15.0	Basalt
110	Ghogali	Kalmeshwer	21	14	33	78	52	21	55K/16-112	353	17.2	6.08	00-1.0	7	7.0-8.0	8.0-9.0 & 12.0-13.0	8.0-15.0	Basalt
111	Sawangi	Kalmeshwer	21	13	6.3	78	52	35	55K/16-113	329	15.5	10.9	00-1.0	4.5	4.5-6.0	11.0-13.0	6.0-13.0	Basalt

Sl. No.	Village	Taluka	*Latitute*			*Longitude*			Topo sheet wise well No.	Elevation	Depth of well	DTWL	Top Soil	Thickness of weathering		Depth to Fractures	Thickness of fracture	Geology
			D	M	*S*	*D*	*M*	*S*		m a MSL	m bgl	m bgl	m bgl	Highly	Moderately	m bgl		
112	Khairi	Kalmeshwer	21	13	*14*	*78*	*50*	*28*	55K/15-114	332	11	6.3	00-1.0	4.25	4.25-6.50	8.00-10.0	6.5-10.0	Basalt
113	Uparwahi	Kalmeshwer	21	12	*38*	*78*	*50*	*39*	55K/16-115	349	6.5	3.3	00-1.0	1.3	1.3-2.0	5.0-6.0	1	Basalt
114	Linga	Kalmeshwer	21	12	*40*	*78*	*49*	*34*	55K/16-116	358	12.6	6.3	00-1.0	3.3	3.0-7.0	8.0-9.0 & 10.0-11.0	7.0-11.0	Basalt
115	Pohi	Kalmeshwer	21	14	*55*	*78*	*48*	*33*	55K/16-117	366	15.25	7.25	00-1.0	1.5	1.5-6.0	8.0-9.0 & 13.0-14.0	7.0-14.0	Basalt
116	Sonegaon	Kalmeshwer	21	14	*11*	*78*	*49*	*39*	55K/16-118	359	13.4	8.8	00-1.0	2.3	2.30-8.08	9.0& 12.0	8.0-12.0	Basalt
117	Pohi	Kalmeshwer	21	14	*8.7*	*78*	*48*	*44*	55K/16-119	371	9.2	6.15	00-1.0	2.4	2.4-7.0	7.0m&8.50	7.0-9.0	Basalt
118	Chargaon	Katol	21	15	*50*	*78*	*45*	*1.2*	55K/16-120	401	15.5	10.15	00-1.0	4.8	4.8-6.0	11.0-12.0 & 15	6.0-15.0	Basalt

ANNEXURE-IX: Monthly ground water level data of Key Observation Wells, Aquifer-I, Chandrabhaga Watershed (WGKKC-2), Nagpur district, Maharashtra

Sl. No.	Well No.	Village	lat_deci	long_deci	RL (m A MSL)	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12
1	DW1	Phetri	21.2027	78.9892	342.6700	2.45	4.45	5.95	6.95	7.85	7.60	8.25	8.20	8.07	6.95	1.95	1.55	3.10	4.50	5.95
2	DW2	Khairgaon	21.1849	78.9541	342.7000	3.44	4.50	7.90	7.90	9.30	9.90	10.05	10.50	10.88	7.75	2.70	1.75	3.65	6.70	7.70
3	DW3	Kalambi	21.1899	78.9189	337.0900	3.00	5.00	5.63	5.80	6.75	6.75	9.55	10.75	7.03	3.85	2.25	1.65	2.90	5.05	6.25
4	DW4	Selu	21.2056	78.8989	351.7600	3.43	5.20	7.10	7.60	9.30	9.15	9.65	9.80	9.95	7.80	2.60	1.35	3.05	5.00	6.20
5	DW5	Kalmeshwer (RH)	21.2342	78.9128	329.1050	1.92	2.35	2.70	2.75	3.30	3.50	3.80	4.30	4.11	1.95	1.50	1.20	1.85	2.40	2.80
6	DW6	Dahegaon	21.2102	78.9479	338.1100	1.10	1.90	3.65	4.75	7.35	6.55	7.45	8.05	7.60	3.60	0.10	0.10	0.10	1.85	5.45
7	DW7	Ashti	21.2113	78.9676	328.0050	2.75	4.66	6.25	6.65	8.15	8.65	9.05	9.45	9.00	8.35	3.25	1.40	3.35	5.75	6.95
8	DW8	Pardi	21.2481	78.9621	321.7050	2.75	3.65	6.20	7.00	8.50	8.25	10.00	9.80	10.00	4.65	2.60	2.25	2.70	4.40	6.20
9	DW9	Gowari	21.2700	78.9480	318.1150	5.55	6.75	6.85	6.70	6.85	6.85	6.95	6.60	6.62	6.70	6.35	4.75	6.80	6.25	7.15
10	DW10	Tondakhairi	21.2824	78.9645	319.0050	9.10	9.50	9.62	12.50	15.20	16.50	16.10	16.10	15.82	15.40	14.10	10.80	13.50	14.30	10.20
11	DW11	Borgaon(Kh)	21.2973	78.9612	305.7100	5.55	6.02	6.25	6.10	6.55	6.65	7.25	8.15	7.25	6.25	5.45	4.85	5.80	6.50	6.55
12	DW12	Silori	21.3130	78.9706	302.9100	6.28	7.43	8.38	8.38	8.48	8.53	8.78	8.93	8.96	8.33	6.98	5.33	7.18	8.68	8.68
13	DW13	Dhapewada	21.3003	78.9161	328.1100	9.50	10.45	11.20	11.10	12.00	12.15	12.30	12.80	12.37	12.05	10.90	9.05	10.00	11.70	12.70
14	DW14	Bhadangi	21.2979	78.9343	310.4300	8.10	8.60	8.50	8.70	9.10	9.30	10.50	11.80	9.65	9.75	8.60	7.80	8.50	NA	0.00
15	DW15	Warode(IW)	21.2796	78.9111	322.1750	6.25	7.05	8.00	7.60	9.20	10.50	11.48	12.80	12.73	12.95	9.20	6.80	7.25	8.90	9.10
16	DW16	Brahmni	21.2437	78.9064	322.0000	2.35	3.25	4.35	4.95	5.05	6.45	6.95	7.25	6.97	4.25	1.15	0.95	2.05	3.95	4.45
17	DW17	Sawli	21.2716	78.9255	318.1300	7.35	7.95	8.45	8.65	13.45	9.80	10.65	10.65	10.98	10.65	8.85	7.30	7.85	8.06	9.35
18	DW18	Ketapar	21.1847	78.8982	358.6000	4.45	4.85	5.00	4.90	5.00	4.95	5.30	5.30	5.28	3.90	3.40	2.70	3.95	5.20	5.30
19	DW19	Sahuli	21.1871	78.9424	351.2900	4.00	8.10	8.30	9.50	11.10	11.40	11.80	11.80	12.10	10.95	3.50	2.30	4.25		7.60
20	DW20	Gumthala	21.1992	78.8706	359.7000	2.25	2.85	4.85	4.45	7.75	6.65	8.00	8.45	8.77	8.45	4.85	1.95	2.15	3.75	5.25
21	DW21	Sawangi (IW)	21.2218	78.8847	339.8500	3.60	4.20	6.45	5.70	6.50	5.60	6.55	6.30	6.30	5.40	3.20	1.90	4.00	7.05	7.90
22	DW22	Uparwahi	21.2174	78.8562	356.2700	3.70	4.20	4.85	4.95	5.15	5.35	5.75	5.85	6.12	5.90	4.65	3.60	3.66	4.65	5.15
23	DW23	Nimboli	21.2065	78.8424	358.7000	2.25	3.00	3.00	2.55	3.30	2.80	4.05	5.10	5.17	3.10	1.50	1.20	2.10	2.60	2.40
24	DW24	Linga	21.2161	78.8195	364.1100	2.85	3.14	3.30	3.30	3.40	3.50	3.90	4.40	4.20	3.20	2.90	2.40	2.80	3.40	3.60
25	DW25	Sonegaon	21.2335	78.8330	356.8050	1.30	2.35	3.00	3.75	5.50	7.30	7.65	8.00	8.10	7.20	0.80	0.25	1.30	2.10	2.70
26	DW26	Khapri	21.2441	78.8428	364.1100	4.70	6.27	7.95	8.85	9.80	10.25	10.80	10.90	11.20	9.60	5.60	3.38	4.76	6.30	8.20
27	DW27	Ghogali	21.2420	78.8679	338.0050	6.30	7.10	8.05	8.25	8.95	9.05	9.35	9.35	9.25	8.80	7.35	5.70	6.45	8.15	8.75
28	DW28	Brahmni(IW)	21.2426	78.8933	333.0150	3.30	4.50	6.70	8.90	5.30	11.45	7.95	11.60	14.30	5.70	3.90	2.50	4.40	15.00	9.80
29	DW29	Ghorad	21.2346	78.8820	332.0900	7.00	7.32	7.60	7.60	8.00	8.20	8.85	9.00	9.27	9.24	8.30	7.15	7.20	8.10	8.20
30	DW30	Ubali	21.2665	78.8689	338.1050	7.60	9.21	9.70	10.20	12.00	12.25	13.30	13.70	13.35	12.60	9.00	7.05	7.70	9.10	9.80
31	DW31	Wadhone Buzrug	21.2924	78.8843	333.0900	11.60	13.82	12.20	12.10	12.30	12.30	13.30	13.30	13.26	12.40	11.70	10.85	11.25	11.90	11.80
32	DW32	Sawali Khurd	21.2805	78.8639	338.3150	7.90	10.00	10.80	10.90	9.50	15.10	14.20	14.50	14.10	13.65	8.90	5.40	8.00	8.80	9.50
33	DW33	Wathoda	21.2822	78.8381	348.1100	4.30	4.30	4.45	4.40	4.55	4.45	4.80	4.85	4.67	3.45	3.85	2.75	4.45	4.85	4.95
34	DW34	Sawangi (Anganwadi)	21.2903	78.8333	344.6100	4.25	4.60	4.75	4.55	5.95	5.00	5.45	5.20	5.08	4.20	3.90	2.95	4.10	4.80	4.80
35	DW35	Susundri	21.2919	78.8156	352.7000	1.85	1.90	2.00	1.90	2.50	2.70	3.10	4.65	3.18	2.15	1.90	1.00	1.80	NA	0.00
36	DW36	Khairi	21.2925	78.7911	363.8100	3.20	3.55	3.95	4.25	4.80	5.25	5.55	5.65	5.73	3.90	2.55	1.85	3.10	3.75	4.15
37	DW37	Pardi	21.2813	78.7713	374.9900	2.97	3.57	3.97	4.67	4.97	6.17	6.07	6.37	6.04	4.57	2.87	1.67	2.87	3.77	3.97
38	DW38	Ramgiri	21.3012	78.7575	422.1650	3.60	6.30	5.60	4.10	8.70	8.70	7.75	7.50	6.87	1.75	2.10	0.80	3.00	4.90	5.20
39	DW39	Dorli	21.2528	78.7790	382.1150	2.68	5.50	5.20	5.65	6.40	4.80	7.25	7.60	7.14	4.50	1.40	1.00	2.90	3.70	5.00
40	DW40	Ubgi	21.2509	78.8264	369.9000	8.95	9.70	3.90	3.70	4.00	4.50	5.25	6.50	7.15	2.90	1.70	1.75	4.00	11.70	6.30
41	DW41	Kohli	21.2629	78.8098	361.0050	6.80	6.50	6.25	6.15	6.85	7.05	9.05	9.75	10.30	7.35	4.25	3.95	4.75	5.05	5.65
42	DW42	Kotwali Bardi	21.2239	78.7818	389.2050	1.80	1.80	1.90	1.60	1.45	1.45	7.05	2.50	2.38	6.35	1.00	0.30	1.84	2.00	2.10
43	DW43	Raulgaon	21.2311	78.7814	396.1100	2.10	3.00	3.35	3.40	3.70	3.90	4.65	4.70	4.50	3.05	1.10	0.20	1.70	3.10	3.50
44	DW44	Chargaon	21.2648	78.7507	396.1000	2.50	4.40	5.40	5.40	6.90	7.40	8.00	8.30	7.64	4.10	1.20	0.60	2.40	4.10	5.90
45	DW45	Sonkhamb	21.2627	78.7275	403.0800	3.00	2.55	4.30	6.20	10.60	9.40	9.90	11.10	11.42	7.15	1.00	0.55	3.15	4.60	6.80
46	DW46	Metpanjra	21.2596	78.7008	426.1600	4.82	5.97	6.82	7.32	8.22	8.52	9.07	9.22	9.47	8.47	3.92	3.27	5.17	6.62	7.42
47	DW47	Malegaon	21.3071	78.7206	517.1100	3.65	5.70	7.20	6.20	6.30	7.50	6.95	7.35	6.84	1.30	1.40	0.95	3.60	6.50	6.60
48	DW48	Vasboli	21.2292	78.7129	483.1600	0.60	1.00	2.30	3.00	4.70	5.00	5.60	6.55	5.30	2.65	0.80	0.50	0.90	2.20	3.20
49	DW49	Pohi	21.2365	78.8116	366.1150	4.95	5.60	6.18	6.35	6.55	6.65	7.10	6.95	6.85	5.15	3.15	2.55	4.46	5.75	6.05
50	DW50	Yerla	21.2079	78.9653	339.0800	5.15	6.22	8.00	9.15	12.30	11.20	13.90	13.10	12.20	9.00	3.30	2.50	4.80	6.85	7.70
51	DW51	Chicholi	21.1944	78.9788	348.7100	NA	3.75	4.45	5.35	7.45	7.60	7.95	11.95	8.58	5.10	2.25	2.05	2.65	3.85	4.25
52	DW52	Kalmeshwer (NE of Selu)	21.2163	78.9055	334.3400	NA	6.40	6.65	8.35	12.30	10.50	15.70	15.00	11.25	14.51	1.57	2.00	NA	11.30	11.40
53	DW53	Sawangi (SW of Kalmeshwar)	21.2222	78.8977	344.1150	NA	5.55	9.10	9.10	12.90	13.20	14.40	15.40	16.10	13.10	5.10	0.90	3.40	6.70	9.70
54	DW54	Kalmeshwer (South of Gowari)	21.2494	78.9369	319.7700	NA	6.05	13.05	7.15	6.85	12.45	14.10	15.65	14.90	8.45	4.60	3.95	11.76	11.95	9.65
55	DW55	Kalmeshwer (Ashti Road	21.2305	78.9461	327.0050	NA	3.60	5.10	5.30	6.40	12.50	6.85	7.05	7.10	5.73	4.10	2.00	5.39	5.50	6.20
56	DW56	Waroda	21.2647	78.9066	326.0150	NA	6.40	6.50	6.50	6.70	7.00	7.55	7.80	7.68	6.80	6.20	5.45	6.20	6.90	7.00
57	DW57	Lakholi	21.2783	78.6916	433.0100	NA	6.85	3.10	3.85	7.00	6.10	8.60	6.20	4.02	3.35	4.80	1.50	5.30	2.70	3.30
58	DW58	Kalmeshwar (Rly Gate)	21.2216	78.9347	328.9100	NA	7.20	8.65	10.00	11.25	11.65	12.45	12.65	12.75	10.25	5.55	3.30	6.55	7.45	8.75

Continued

Monthly ground water level data of Key Observation Wells…continued

Sl. No.	Well No.	Village	lat_deci	long_deci	RL (m A MSL)	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14
1	DW1	Phetri	21.2027	78.9892	342.6700	7.05	7.35	7.40	7.75	7.80	5.35	0.85	1.25	1.65	2.15	3.35	5.65	5.00	6.95	5.55	7.90	6.95
2	DW2	Khairgaon	21.1849	78.9541	342.7000	8.55	8.70	9.25	10.00	9.90	6.00	0.80	1.00	2.20	2.60	4.20	6.30	7.30	8.30	8.10	8.55	9.26
3	DW3	Kalambi	21.1899	78.9189	337.0900	5.95	5.15	6.15	6.25	6.45	2.55	0.65	1.15	1.90	2.55	4.10	5.69	6.25	6.45	6.65	9.65	8.95
4	DW4	Selu	21.2056	78.8989	351.7600	6.80	7.55	8.40	8.70	9.20	3.95	0.60	0.94	1.75	2.45	3.55	4.95	5.60	6.80	6.40	7.00	8.1
5	DW5	Kalmeshwer (RH)	21.2342	78.9128	329.1050	2.60	2.80	3.20	3.40	4.00	1.20	0.70	1.10	1.35	1.50	1.90	2.15	2.30	2.40	2.20	2.65	3.12
6	DW6	Dahegaon	21.2102	78.9479	338.1100	5.65	5.85	6.15	6.85	7.70	2.65	0.00	0.00	0.00	0.00	0.00	1.85	2.65	4.65	4.78	4.15	5.25
7	DW7	Ashti	21.2113	78.9676	328.0050	7.45	8.20	8.75	8.95	9.35	5.50	0.45	0.55	1.45	3.85	4.35	5.50	6.15	7.55	6.60	7.25	7.62
8	DW8	Pardi	21.2481	78.9621	321.7050	7.55	8.35	9.30	9.50	10.20	2.40	0.90	1.82	2.00	2.30	2.60	3.50	5.10	5.10	5.35	7.50	7.82
9	DW9	Gowari	21.2700	78.9480	318.1150	6.85	6.55	6.85	6.70	6.65	3.20	1.75	2.70	3.05	3.15	4.85	6.05	7.65	6.65	7.55	7.15	6.58
10	DW10	Tondakhairi	21.2824	78.9645	319.0050	17.30	14.35	15.51	15.95	16.20	15.35	9.90	8.20	7.65	6.60	8.65	10.80	10.50	11.50	11.90	12.80	13.14
11	DW11	Borgaon(Kh)	21.2973	78.9612	305.7100	6.25	6.20	6.25	6.90	7.05	4.80	2.25	3.85	4.20	4.65	5.35	5.75	5.85	6.05	6.05	6.35	7.51
12	DW12	Silori	21.3130	78.9706	302.9100	8.38	8.38	8.48	8.53	9.28	6.73	1.98	3.00	4.03	3.63	5.98	7.08	6.78	7.38	7.48	7.28	7.88
13	DW13	Dhapewada	21.3003	78.9161	328.1100	11.40	11.70	11.25	11.85	12.45	11.45	9.90	7.00	6.95	1.70	8.25	8.80	12.00	9.90	9.50	10.30	10.55
14	DW14	Bhadangi	21.2979	78.9343	310.4300	NA	9.45	NA	10.00	NA	10.10	6.00	6.10	7.00	7.33	7.65	7.30	7.19	7.17	7.29	10.10	9.8
15	DW15	Warode(IW)	21.2796	78.9111	322.1750	9.05	9.20	7.00	11.15	12.30	11.80	5.50	3.20	2.75	1.45	2.40	3.90	4.70	6.00	6.10	7.00	8.05
16	DW16	Brahmni	21.2437	78.9064	322.0000	4.75	5.05	5.85	6.40	6.45	2.50	0.25	0.70	1.10	1.05	2.45	3.45	4.15	6.85	4.75	9.45	6.85
17	DW17	Sawli	21.2716	78.9255	318.1300	9.30	8.95	8.85	10.65	4.05	10.60	4.55	4.65	4.70	3.65	5.05	5.80	6.25	6.85	6.90	7.55	7.85
18	DW18	Ketapar	21.1847	78.8982	358.6000	4.60	4.80	5.90	4.90	4.50	3.55	0.55	2.21	3.10	3.50	4.40	4.90	4.70	4.70	4.65	4.75	4.82
19	DW19	Sahuli	21.1871	78.9424	351.2900	9.20	10.20	10.90	11.60	12.10	9.25	1.35	1.80	2.50	2.60	3.75	7.10	7.30	9.10	8.70	6.80	10.15
20	DW20	Gumthala	21.1992	78.8706	359.7000	5.15	5.45	7.20	8.65	9.65	7.35	1.35	0.72	0.75	1.95	1.65	2.30	11.45	3.95	4.25	5.35	6.35
21	DW21	Sawangi (IW)	21.2218	78.8847	339.8500	5.30	6.90	8.40	8.10	6.50	4.60	1.20	1.85	1.95	2.40	5.05	6.35	6.49	4.00	4.20	5.00	4.58
22	DW22	Uparwahi	21.2174	78.8562	356.2700	5.20	4.95	5.35	5.35	5.75	5.45	1.35	2.72	3.25	3.05	3.55	4.25	4.45	4.65	4.70	5.00	5.2
23	DW23	Nimboli	21.2065	78.8424	358.7000	1.95	2.00	2.00	2.50	4.00	1.75	0.44	0.82	1.25	1.40	1.90	1.75	1.70	2.00	2.15	3.20	3.8
24	DW24	Linga	21.2161	78.8195	364.1100	3.40	3.30	3.40	3.30	3.94	2.95	1.16	1.80	2.30	2.50	2.80	3.25	3.20	3.40	3.30	3.65	3.67
25	DW25	Sonegaon	21.2335	78.8330	356.8050	3.50	5.60	7.10	6.20	7.00	5.10	0.15	0.00	0.10	0.90	1.50	1.75	2.75	4.30	5.20	5.70	-
26	DW26	Khapri	21.2441	78.8428	364.1100	8.90	9.40	10.20	10.40	10.65	9.94	2.37	2.30	3.00	3.40	4.80	6.55	7.71	8.90	9.30	10.00	11.03
27	DW27	Ghogali	21.2420	78.8679	338.0050	8.55	8.35	8.95	8.85	9.25	8.60	5.55	5.10	5.40	4.75	5.75	6.55	6.85	7.45	7.45	8.25	8.25
28	DW28	Brahmni(IW)	21.2426	78.8933	333.0150	8.25	8.20	9.70	11.45	11.20	4.60	1.30	1.75	2.85	2.60	10.40	4.40	7.80	5.60	6.50	11.30	7.77
29	DW29	Ghorad	21.2346	78.8820	332.0900	7.85	7.90	8.20	8.55	8.90	8.45	6.70	5.35	5.90	5.30	6.10	6.40	6.90	7.20	8.15	7.60	7.84
30	DW30	Ubali	21.2665	78.8689	338.1050	10.00	10.30	11.30	12.10	12.60	11.70	5.10	4.65	5.30	4.50	6.00	6.70	6.90	8.20	8.30	9.70	11.15
31	DW31	Wadhone Buzrug	21.2924	78.8843	333.0900	11.50	11.55	11.85	12.15	12.80	11.00	10.80	10.48	10.60	10.80	10.80	11.20	11.40	11.10	11.40	8.90	12.4
32	DW32	Sawali Khurd	21.2805	78.8639	338.3150	9.60	10.45	10.25	12.40	13.00	12.95	6.10	3.70	4.00	3.50	9.90	10.80	7.00	8.20	8.15	7.90	10.07
33	DW33	Wathoda	21.2822	78.8381	348.1100	4.55	4.55	4.65	4.60	4.85	2.40	2.15	3.35	3.95	5.05	4.30	4.15	4.25	5.05	4.25	4.85	5.51
34	DW34	Sawangi (Anganwadi)	21.2903	78.8333	344.6100	4.75	4.55	4.85	4.95	5.10	3.45	2.30	3.05	3.70	3.60	4.00	4.00	4.30	4.40	4.60	4.80	4.9
35	DW35	Susundri	21.2919	78.8156	352.7000	0.60	1.90	2.00	2.25	NA	1.80	1.13	1.25	1.55	1.65	1.87	1.51	1.65	1.91	1.99	NA	NA
36	DW36	Khairi	21.2925	78.7911	363.8100	4.20	4.20	4.60	4.80	5.25	3.80	1.31	2.00	2.50	2.75	3.25	3.55	3.65	4.05	3.70	4.35	4.82
37	DW37	Pardi	21.2813	78.7713	374.9900	3.87	4.17	7.07	5.22	5.67	4.92	1.67	1.67	1.97	2.07	3.27	3.12	3.62	4.07	4.27	4.97	5.12
38	DW38	Ramgiri	21.3012	78.7575	422.1650	5.50	4.30	6.50	7.75	9.10	0.70	0.26	1.85	1.60	2.30	2.85	3.80	5.20	4.00	6.20	8.10	8.7
39	DW39	Dorli	21.2528	78.7790	382.1150	5.20	5.25	6.00	6.10	7.40	1.65	0.67	1.00	1.00	1.70	2.50	1.75	4.20	4.90	6.10	5.50	6.97
40	DW40	Ubgi	21.2509	78.8264	369.9000	9.55	10.60	11.30	5.00	5.40	2.10	0.52	1.00	1.25	1.50	2.10	2.75	3.10	10.80	5.20	11.30	10.72
41	DW41	Kohli	21.2629	78.8098	361.0050	5.75	5.75	7.25	7.80	9.55	5.40	3.80	4.35	4.60	4.35	5.15	4.85	5.35	5.85	6.05	6.55	7.37
42	DW42	Kotwali Bardi	21.2239	78.7818	389.2050	1.85	1.50	1.20	1.67	2.10	0.15	0.10	0.55	0.60	1.30	1.15	1.40	1.30	1.30	1.40	1.35	1.7
43	DW43	Raulgaon	21.2311	78.7814	396.1100	3.00	3.10	3.70	3.65	4.50	1.25	0.07	0.20	0.45	0.80	1.90	2.80	2.90	3.00	2.80	3.50	3.8
44	DW44	Chargaon	21.2648	78.7507	396.1000	5.70	5.30	6.50	6.45	8.20	2.20	0.32	0.65	0.90	1.30	2.90	4.70	5.10	6.20	5.25	7.50	7.65
45	DW45	Sonkhamb	21.2627	78.7275	403.0800	8.90	6.00	7.70	8.55	10.60	2.10	0.27	0.45	0.65	3.30	3.20	2.90	4.30	5.50	5.60	6.60	7.5
46	DW46	Metpanjra	21.2596	78.7008	426.1600	7.57	7.97	8.92	9.00	9.22	7.62	1.32	2.12	3.32	3.62	5.07	6.32	6.62	7.52	7.42	8.12	8.39
47	DW47	Malegaon	21.3071	78.7206	517.1100	6.10	5.85	6.20	6.40	7.30	2.20	0.84	1.15	1.30	2.30	6.10	6.25	6.29	6.00	6.90	6.60	6.03
48	DW48	Vasboli	21.2292	78.7129	483.1600	3.60	3.65	4.40	4.55	5.50	0.45	0.20	0.55	0.10	0.60	0.60	1.80	2.80	3.90	2.70	3.70	4.23
49	DW49	Pohi	21.2365	78.8116	366.1150	6.20	6.30	6.55	6.65	6.80	5.15	0.73	2.00	2.90	3.85	4.85	5.30	5.45	6.05	6.25	6.60	6.59
50	DW50	Yerla	21.2079	78.9653	339.0800	9.05	9.70	11.20	11.50	12.20	5.80	1.30	2.33	2.75	3.20	5.00	5.75	6.60	8.20	7.35	8.50	9.5
51	DW51	Chicholi	21.1944	78.9788	348.7100	4.85	5.40	6.35	7.15	7.65	4.05	1.35	1.73	2.01	2.15	2.60	3.25	3.85	4.55	4.25	4.75	5.45
52	DW52	Kalmeshwer (NE of Selu)	21.2163	78.9055	334.3400	9.70	9.40	13.25	12.70	14.80	5.00	3.85	1.14	1.70	1.91	1.82	1.05	1.11	1.29	10.60	12.80	13.4
53	DW53	Sawangi (SW of Kalmeshwar)	21.2222	78.8977	344.1150	9.90	9.90	8.90	11.70	14.20	9.50	0.70	1.10	4.30	5.30	6.40	8.05	7.10	9.80	9.60	10.50	12.57
54	DW54	Kalmeshwer (South of Gowari)	21.2494	78.9369	319.7700	14.55	13.95	17.20	16.75	16.75	9.30	1.05	1.45	1.60	2.25	2.39	1.99	2.26	2.99	4.25	13.65	8.45
55	DW55	Kalmeshwer (Ashti Road	21.2305	78.9461	327.0050	5.60	6.10	7.30	9.30	7.20	4.15	2.90	1.00	2.10	2.23	2.47	2.68	2.79	2.98	15.15	6.40	5.7
56	DW56	Waroda	21.2647	78.9066	326.0150	6.60	6.40	4.80	7.30	8.50	6.65	4.80	4.90	5.00	4.90	5.60	5.70	5.90	6.30	5.90	6.20	6.77
57	DW57	Lakholi	21.2783	78.6916	433.0100	6.35	3.75	8.00	3.85	7.50	2.80	1.22	1.90	2.05	2.70	5.50	2.15	2.46	2.70	3.65	3.60	NA
58	DW58	Kalmeshwar (Rly Gate)	21.2216	78.9347	328.9100	8.20	10.35	11.25	11.75	12.45	5.90	1.45	2.16	3.10	3.85	5.25	6.45	7.75	9.05	8.65	9.55	10.5

Sl. No.	Well No.	Village	lat_deci	long_deci	RL (m A MSL)	June-14	July-14	Aug-14	Sept-14	Oct-14	Nov-14
1	DW1	Phetri	21.2027	78.9892	342.6700	7.35	1.60	2.40	3.40	3.90	4.95
2	DW2	Khairgaon	21.1849	78.9541	342.7000	8.80	2.20	3.45	3.90	5.00	7.20
3	DW3	Kalambi	21.1899	78.9189	337.0900	5.75	1.75	3.30	4.10	4.95	5.55
4	DW4	Selu	21.2056	78.8989	351.7600	7.60	2.45	3.75	4.30	5.60	6.10
5	DW5	Kalmeshwer (RH)	21.2342	78.9128	329.1050	3.30	1.35	1.85	2.20	2.75	10.10
6	DW6	Dahegaon	21.2102	78.9479	338.1100	6.55	0.10	0.45	filled up	filled up	filled up
7	DW7	Ashti	21.2113	78.9676	328.0050	7.95	3.40	4.05	4.30	5.20	7.05
8	DW8	Pardi	21.2481	78.9621	321.7050	7.40	2.25	2.50	3.50	3.30	4.90
9	DW9	Gowari	21.2700	78.9480	318.1150	6.65	5.10	5.90	6.20	7.05	7.35
10	DW10	Tondakhairi	21.2824	78.9645	319.0050	13.70	12.00	11.70	11.60	13.20	13.30
11	DW11	Borgaon(Kh)	21.2973	78.9612	305.7100	5.85	4.35	5.00	5.90	6.30	5.85
12	DW12	Silori	21.3130	78.9706	302.9100	8.08	6.13	6.58	6.55	8.10	8.38
13	DW13	Dhapewada	21.3003	78.9161	328.1100	10.40	9.25	8.35	9.35	10.90	10.90
14	DW14	Bhadangi	21.2979	78.9343	310.4300	9.10	5.95	7.90	6.05	6.15	-0.50
15	DW15	Warode(IW)	21.2796	78.9111	322.1750	8.00	6.85	6.05	5.00	5.40	4.81
16	DW16	Brahmni	21.2437	78.9064	322.0000	6.25	0.90	2.25	2.40	3.30	4.25
17	DW17	Sawli	21.2716	78.9255	318.1300	8.05	7.10	7.35	4.30	7.90	7.95
18	DW18	Ketapar	21.1847	78.8982	358.6000	4.50	1.50	4.00	4.15	4.80	5.70
19	DW19	Sahuli	21.1871	78.9424	351.2900	10.80	5.25	3.95	4.20	5.85	7.90
20	DW20	Gumthala	21.1992	78.8706	359.7000	6.55	5.20	4.20	4.20	5.30	5.85
21	DW21	Sawangi (IW)	21.2218	78.8847	339.8500	6.70	2.90	3.20	7.30	5.75	5.41
22	DW22	Uparwahi	21.2174	78.8562	356.2700	5.65	4.85	5.60	5.00	5.20	4.75
23	DW23	Nimboli	21.2065	78.8424	358.7000	4.00	5.05	2.05	2.70	2.60	2.40
24	DW24	Linga	21.2161	78.8195	364.1100	3.70	2.90	3.00	3.80	3.70	3.40
25	DW25	Sonegaon	21.2335	78.8330	356.8050	7.70	1.40	1.05	1.80	3.30	2.60
26	DW26	Khapri	21.2441	78.8428	364.1100	10.20	5.65	5.95	6.30	7.30	3.60
27	DW27	Ghogali	21.2420	78.8679	338.0050	8.55	7.20	7.40	7.70	9.00	8.45
28	DW28	Brahmni(IW)	21.2426	78.8933	333.0150	5.80	7.85	5.00	7.35	10.80	6.50
29	DW29	Ghorad	21.2346	78.8820	332.0900	7.70	7.40	7.30	7.40	7.70	6.60
30	DW30	Ubali	21.2665	78.8689	338.1050	10.40	7.95	8.10	7.70	8.70	9.00
31	DW31	Wadhone Buzrug	21.2924	78.8843	333.0900	12.10	11.50	11.30	5.10	12.20	11.80
32	DW32	Sawali Khurd	21.2805	78.8639	338.3150	10.80	8.10	9.60	7.75	13.10	15.70
33	DW33	Wathoda	21.2822	78.8381	348.1100	4.45	3.75	4.00	11.80	5.30	4.45
34	DW34	Sawangi (Anganwadi)	21.2903	78.8333	344.6100	5.00	3.90	4.30	4.50	5.10	5.10
35	DW35	Susundri	21.2919	78.8156	352.7000	1.90	1.10	filled up	1.15	1.21	-0.60
36	DW36	Khairi	21.2925	78.7911	363.8100	4.85	2.20	2.85	3.70	3.95	3.75
37	DW37	Pardi	21.2813	78.7713	374.9900	5.17	2.87	3.27	3.40	3.95	4.17
38	DW38	Ramgiri	21.3012	78.7575	422.1650	8.30	0.65	0.20	1.50	2.40	3.10
39	DW39	Dorli	21.2528	78.7790	382.1150	7.20	1.00	1.85	2.80	3.70	5.30
40	DW40	Ubgi	21.2509	78.8264	369.9000	5.90	1.80	1.70	1.90	2.40	4.20
41	DW41	Kohli	21.2629	78.8098	361.0050	5.45	5.65	5.95	5.20	5.80	5.05
42	DW42	Kotwali Bardi	21.2239	78.7818	389.2050	2.50	0.70	1.40	1.40	2.00	1.79
43	DW43	Raulgaon	21.2311	78.7814	396.1100	3.90	0.80	1.80	1.90	3.60	3.70
44	DW44	Chargaon	21.2648	78.7507	396.1000	7.70	0.90	1.55	2.60	5.30	5.50
45	DW45	Sonkhamb	21.2627	78.7275	403.0800	9.20	0.55	0.80	3.10	2.80	4.60
46	DW46	Metpanjra	21.2596	78.7008	426.1600	8.72	2.92	4.62	4.90	6.10	6.82
47	DW47	Malegaon	21.3071	78.7206	517.1100	7.30	1.25	1.70	3.00	7.15	6.89
48	DW48	Vasboli	21.2292	78.7129	483.1600	4.50	0.55	0.70	1.30	1.40	1.70
49	DW49	Pohi	21.2365	78.8116	366.1150	6.45	2.35	4.10	5.50	5.70	5.85
50	DW50	Yerla	21.2079	78.9653	339.0800	10.30	3.25	4.40	4.40	6.35	6.55
51	DW51	Chicholi	21.1944	78.9788	348.7100	6.05	1.95	2.25	2.70	4.05	6.85
52	DW52	Kalmeshwer (NE of Selu)	21.2163	78.9055	334.3400	17.10	3.77	4.55	5.81	5.99	5.63
53	DW53	Sawangi (SW of Kalmeshwar)	21.2222	78.8977	344.1150	14.65	4.50	6.05	7.30	11.60	13.30
54	DW54	Kalmeshwer (South of Gowari)	21.2494	78.9369	319.7700	7.95	11.95	5.35	11.90	8.70	12.65
55	DW55	Kalmeshwer (Ashti Road	21.2305	78.9461	327.0050	6.10	2.88	4.25	3.88	5.70	5.90
56	DW56	Waroda	21.2647	78.9066	326.0150	6.80	5.75	5.85	6.55	7.00	6.50
57	DW57	Lakholi	21.2783	78.6916	433.0100	3.90	3.05	1.80	6.20	2.75	2.49
58	DW58	Kalmeshwar (Rly Gate)	21.2216	78.9347	328.9100	3.25	5.00	7.55	6.55	8.00	10.05

ANNEXURE-X: Monthly ground water level data of Exploratory Wells, Aaquifer-II, Chandrabhaga Watershed (WGKKC-2), Nagpur District

Sl No	Village	Aquifer	North Latitude	East Longitude	Elevation (m a MSL)	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sept-14	Oct-14	Nov-14	Dec-14	Jan-15
1	Pardi	Basalt	21°16'40.2"	78°46'05.7"	381	Filled Up													
2	Ramgiri	Basalt	21°18'04.0"	78°45'27.1"	416	Filled Up													
3	Sonegaon	Basalt	21°13'49.0"	78°49'56.0"	358	Filled Up													
4	Malegaon OW	Basalt	21°18'25.4"	78°43'06.7"	518	more than 100													
5	Dahegaon	TCG	21°12'58.8"	78°56'43.9"	340	Filled Up													
6	Sonkhamb	Basalt	21°16'20.1"	78°43'21.1"	411	11.27	11.6	12.4	11.6	12.9	13.12	13.8	7.2	8.8	9.5	10.5	11.5	11.83	12.75
7	Malegaon EW	Basalt	21°18'24.9"	78°43'06.7"	518	11.74	12.26	14.85	15.15	69.5	70	14.55	1.45	35.1	3.9	7.3	11.01	14.67	15.8
8	Kohli	TCG	21°15'54.9"	78°48'33.8"	371	Drilling in Progress	78.36	Villagers fixed new lock				74.33	79.34	DRY	76.1	78.33	78.00	78.36	79
9	Mohgaon	TCG	21°17'47.4"	78°50'51.2"	343	63	63.79	58.7	62.7	69.2	73	70.2	67.68	75.5	66.1	66.13	66.7	65.1	72.2
10	Khapri	TCG	21°14'22.8"	78°50'26.9"	359	68	68.71	63.6	65.55	68.86	69.55	49.1	54.7	--	67	67.19	68	69	64.5
11	Raulgaon	TCG	21°14'15.2"	78°46'59.3"	394	36.21	37.19	38.05	37.55	39.8	40.77	41.85	40.4	39.3	38.16	39.12	40.1	39.32	40.3
12	Dhapewada EW	Sandstone	21°18'11.9"	78°54'18.4"	323	11.47	11.7	12.1	11.2	12.2	13.1	13.2	11.5	12.6	11.6	11.9	12.3	11.96	12.1
13	Dhapewada OW	Sandstone	21°18'11.6"	78°54'18.3"	322	11.51	11.8	12.3	11.4	12.45	13.5	13.5	11.7	12.4	12.1	12.35	12.7	12.13	12.45
14	Gowari	Sandstone	21°16'06.8"	78°56'58.5"	322	7.9	9.3	10.3	9.45	10.6	10.83	12.1	8.8	10.2	7.7	10.3	12.2	12.27	13.1
15	Khairi Lakhmaj	Sandstone	21°15'10.1"	78°57'05.8"	320	6	6.11	7.5	5.85	7.65	7.85	8.8	5.5	2.8	1.15	3.5	6.6	7.72	10.75
16	Waroda	TCG	21°15'48.8"	78°54'17.4"	349	Well Not Constructed	Well Not Constructed	14.9	12.3	14.05	15.07	14.5	11.8	12.2	12.2	13.8	15.2	12.06	12.2

TCG- Trap Covered Gondwana

Annexure-XI: Analysis of water sample of Aquifer –I, Chandrabhaga Watershed (WGKKC-2), Post monsoon- Nov 2011

Well No	Village	Aquifer-I (Lithology)	pH	EC	TDS	TA	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
1	Phetri	Basalt	7.6	970	582	252	171	36	20	82	87	0	307	44	38	122	0.23
2	Khairgaon	Basalt	7.3	1390	834	176	508	125	48	78	4	0	215	158	112	203	0.11
3	Kalambi	Basalt	7.7	1303	782	300	526	96	69	74	4	0	366	146	41	116	0.33
4	Selu	Basalt	7.6	1603	962	400	640	136	73	102	6	0	488	152	142	101	0.26
5	Kalmeshwer	Basalt	7.4	1427	856	220	588	90	88	75	2	0	268	340	48	32	0.29
15	Warode	Basalt	7.7	1237	742	304	452	54	77	79	1	0	371	92	47	199	0.24
16	Brahmni	Basalt	7.7	667	400	296	272	56	32	71	5	0	361	38	11	7	0.18
17	Sawli	Basalt	7.8	1267	760	504	592	70	101	65	2	0	615	72	38	109	0.24
18	Ketapar	Basalt	7.7	807	484	151	272	67	25	57	2	0	184	62	68	72	0.19
19	Sahuli	Basalt	7.5	1273	764	340	308	91	19	120	44	0	415	68	65	150	0.56
20	Gumthala	Basalt	7.7	1142	685	300	292	54	38	131	21	0	366	102	66	91	0.44
21	Sawangi	Basalt	8.5	1697	1018	176	420	19	90	152	74	2.4	215	252	141	178	0.35
22	Uparwahi	Basalt	7.7	1630	978	320	348	37	62	136	112	0	390	146	107	181	0.52
23	Nimboli	Basalt	7.8	1038	623	248	312	32	56	101	2	0	303	94	75	78	0.6
24	Linga	Basalt	8.5	1287	772	128	320	29	60	80	85	0	156	132	81	228	0.25
26	Khapri	Basalt	8.1	767	460	184	376	56	57	18	1	0	224	56	48	112	0.4
27	Ghogali	Basalt	8.4	1253	752	532	600	59	110	81	1	0	649	104	69	7	0.51
28	Brahmni (IW)	Basalt	8.2	1187	712	212	444	48	79	100	5	0	259	232	78	30	0.35
29	Ghorad	Basalt	8.7	1340	804	392	350	60	49	110	84	7.2	478	108	46	60	0.37
30	Ubali	Basalt	8.3	2097	1258	84	768	62	149	119	8		102	330	204	320	0.15
31	Wadhone Buzrug	Basalt	8.6	1058	635	112	96	18	13	121	92	4.8	137	146	74	90	0.13
32	Sawali Khurd	Basalt	8.5	887	532	92	316	38	53	45	1	2.4	112	88	174	74	0.25
33	Wathoda	Basalt	7.6	1725	1035	190	492	138	36	95	91	0	232	242	126	183	0.21
34	Sawangi	Basalt	8.3	787	472	288	200	30	30	116	1	0	351	38	33	39	0.65
35	Susundri	Basalt	8.6	987	592	124	248	22	47	112	2	0	151	144	100	85	0.38
36	Khairi	Basalt	7.9	1113	668	148	396	96	38	65	1	0	181	172	94	109	0.23
37	Pardi	Basalt	8.2	937	562	248	412	45	73	54	1	0	303	106	46	74	0.34
38	Ramgiri	Basalt	8.2	567	340	184	236	35	36	36	0	0	224	16	59	40	0.26
39	Dorli	Basalt	7.8	1337	802	184	444	96	50	66	44	0	224	132	119	181	0.21
40	Ubgi	Basalt	8.4	1987	1192	188	720	110	108	92	49	0	229	274	236	200	0.27
41	Kohali	Basalt	8.9	760	456	116	316	24	62	47	1	9.6	142	88	48	107	0.37
42	Kolwali Bardi	Basalt	7.8	1338	803	148	468	110	47	77	1	0	181	111	178	177	0.16

Well No	Village	Aquifer-I (Lithology)	pH	EC	TDS	TA	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
43	Raulgaon	Basalt	7.9	1220	732	192	372	70	48	85	6	0	234	116	137	144	0.2
44	Chargaon	Basalt	8	620	372	212	272	21	53	34	1	0	259	32	34	68	0.26
45	Sonkhamb	Basalt	8.4	597	358	176	224	40	30	37	0	0	215	18	15	104	0.22
46	Metpanjra	Basalt	7.9	1497	898	168	576	114	71	76	3	0	205	254	59	171	0.22
47	Malegaon	Basalt	8.4	800	480	256	220	48	24	53	46	0	312	48	52	46	0.2
48	Vasboli	Basalt	8.2	1003	602	232	364	56	54	51	24	0	283	36	97	139	0.29
49	Pohi	Basalt	8.7	420	252	84	152	18	26	43	1	7.2	102	28	27	48	0.25
50	Yerla	Basalt	8.2	807	484	180	304	42	49	52	2	0	220	56	90	74	0.24
51	Chicholi	Basalt	8	1415	849	232	404	74	53	76	81	0	283	76	175	163	0.24
52	Kalmeshwer	Basalt	8.6	1075	645	256	352	40	61	96	1	4.8	312	48	108	114	0.48
53	Sawangi(IW)	Basalt	8.1	823	494	248	356	40	62	43	1	0	303	34	73	84	0.24
55	Kalmeshwer (Or. Farm)	Basalt	9	880	528	198	172	16	32	77	49	12	242	18	174	33	0.51
56	Waroda	Basalt	8	2353	1412	352	676	70	122	178	79	0	429	302	174	202	0.37
57	Lakholi	Basalt	7.9	1463	878	264	536	48	101	94	43	0	322	200	99	130	0.24
58	Kalmeshwer (Rly Gate)	Basalt	7.7	1843	1106	160	696	109	103	112	5	0	195	282	219	167	0.45
6	Dahegaon	Sandstone	7.6	710	426	248	296	53	40	40	1	0	303	40	36	46	0.27
7	Ashti	Sandstone	8.1	1467	880	252	404	85	47	108	100	0	307	308	34	45	0.53
8	Pardi	Sandstone	7.4	1520	912	222	440	93	51	136	28	0	271	315	49	46	0.28
9	Gowari	Sandstone	7.7	1000	600	248	264	69	22	83	31	0	303	114	79	50	0.25
10	Tondakhairi	Sandstone	7.5	720	432	252	256	35	41	60	15	0	307	56	26	43	0.4
11	Borgaon(Kh)	Sandstone	7.7	1750	1050	249	552	78	87	35	6	0	304	264	145	249	0.19
12	Silori	Sandstone	7.7	1962	1177	320	572	70	96	105	135	0	390	200	98	271	0.16
13	Dhapewada	Sandstone	8	1117	670	300	400	43	71	91	1	0	366	120	76	79	0.25
14	Bhadangi	Sandstone	7.7	1327	796	540	468	74	69	127	29	0	659	124	4	42	0.29
54	Kalmeshwer (IW)	Sandstone	7.8	2532	1519	152	792	130	114	247	6	0	185	782	24	14	0.26
Aquifer-I Basalt		Min	7.30	420.00	252.00	83.61	96.00	16.00	13.00	18.00	0.00	0.00	102.00	16.00	11.00	7.00	0.11
		Max	9.00	2353.00	1412.00	531.97	768.00	138.00	149.00	178.00	112.00	12.00	649.00	340.00	236.00	320.00	0.65
		Avg	8.08	1184.70	710.79	228.72	395.30	60.53	59.23	82.21	25.02	1.10	279.04	124.11	92.45	115.79	0.31
Aquifer-I Sandstone		Min	7.40	710.00	426.00	151.64	256.00	35.00	22.00	35.00	1.00	0.00	185.00	40.00	4.00	14.00	0.16
		Max	8.10	2532.00	1519.00	540.16	792.00	130.00	114.00	247.00	135.00	0.00	659.00	782.00	145.00	271.00	0.53
		Avg	7.72	1410.50	846.20	278.28	444.40	73.00	63.80	103.20	35.20	0.00	339.50	232.30	57.10	88.50	0.29

All values in mg/l except pH and EC

Annexure-XII: Analysis of water sample (Ground water Exploration) Aquifer –II, Chandrabhaga Watershed (WGKKC-2), Post monsoon- May 2014

Well No	Village	Aquifer-I (Lithology)	pH	EC	TA	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
1	Sonkhamb (22.60-23m)	Basalt	8.3	857	105	400	26	81	16	0.23	3	128	160	147	11	1.40
2	Sonkhamb (76.45-79.10m)	Basalt	8.2	641	290	285	8	64	15	0.26	0	354	25	5	2	0.76
23	Sonkhmab (PT)	Basalt	8.2	525	200	250	30	43	4	0.07	0	244	28	9	29	0.6
3	Ramgiri (7-8m)	Basalt	8.2	798	105	325	48	50	6	0.19	0	128	89	95	65	0.50
4	Ramgiri (final discharge)	Basalt	8.1	642	300	290	10	64	15	0.26	0	366	32	3	2	0.64
5	Malegaon (7-8m)	Basalt	8	519	140	235	42	32	5	0.31	0	171	46	21	42	0.46
6	Malegaon (127.30-129.95m)	Basalt	8.1	445	140	205	38	27	4	0.29	0	171	35	9	44	0.36
22	Malegaon (PT)	Basalt	7.9	795	155	350	52	53	10	0.17	0	189	124	64	17	0.28
28	Kohli (PT)	Basalt	8.1	852	55	375	16	81	16	0.23	0	67	106	189	44	1.4
13	Dahegaon (14.3-16.95m)	Basalt	8.3	540	110	235	30	39	8	0.41	9	134	67	33	28	0.68
9	Khapri (48.2-50.85m)	Basalt	8.5	492	185	225	12	47	9	0.33	12	226	25	7	21	1.31
10	Khapri (67.8-70.8m)	Basalt	8.4	512	190	240	30	40	7	0.22	12	232	28	13	17	0.94
11	Mohgaon (42.55-48.70m)	Sandstone	8.4	563	170	275	50	36	3	0.34	9	207	57	26	21	0.36
12	Mohgaon (79.10-87.75m)	Sandstone	7.9	693	290	335	44	55	2	0.13	0	354	39	5	10	0.73
14	Dhapewada (Zone-I)	Sandstone	8	1093	60	505	48	94	14	1.07	0	73	124	340	6	1.35
15	Dhapewada (Zone-II)	Sandstone	8.4	815	235	390	28	78	8	0.23	15	287	57	49	26	0.46
16	Dhapewada (Comp.Dvlpmt)	Sandstone	8.6	695	120	300	26	57	9	0.34	6	146	78	89	17	0.44
17	Dhapewada	Sandstone	8.1	747	205	330	58	45	6	0.25	0	250	78	41	32	0.53

Well No	Village	Aquifer-I (Lithology)	pH	EC	TA	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
	(Drilling)															
18	Dhapewada	Sandstone	8.2	859	205	330	22	67	9	0.19	0	250	64	72	24	0.44
19	Gowri (Zone-I)	Sandstone	8.3	470	95	210	26	35	5	0.67	9	116	85	13	1	0.36
20	Gowri (Zone-II)	Sandstone	8.1	528	120	250	30	43	5	0.65	0	146	85	16	29	0.31
21	Gowri (Comp.Dvlpmt)	Sandstone	8.1	648	100	270	56	32	5	0.51	0	122	92	44	47	0.43
24	Khairi lakhmaji (Zone-I)	Sandstone	7.2	2211	110	960	246	84	10	17.94	0	134	557	187	31	0.9
25	Khairi lakhmaji (Drilling)	Sandstone	8.2	1479	85	645	64	118	8	6.71	0	104	241	276	43	0.43
27	Khairi lakhmaji (PT)	Sandstone	7.9	1233	140	535	58	95	9	0.74	0	171	216	132	41	0.33
7	Raulgaon (127.3-129.95m)	Sandstone	8	1503	60	690	44	141	26	0.28	0	73	351	239	18	1.25
8	Raulgaon (135.6-138.6m)	Sandstone	8.3	920	150	430	12	97	20	0.29	6	183	181	72	46	1.46
26	Raulgaon (PT)	Sandstone	8.2	904	120	395	22	83	17	0.23	0	146	110	139	46	1.23
29	Khairi (L)-development	Sandstone	7.8	728	160	160	56	51	5	0.25	0	195	92	69.2	2.6	0.57
30	Kohli Zone-1	Sandstone	7.7	917	175	175	84	55.9	5.2	0.12	0	214	92	116.2	37.2	0.18
31	Kohli Zone-2	Sandstone	8.3	886	150	150	38	80.2	7.3	0.16	0	183	113	73.5	34.7	0.16
32	Kohli Development	Sandstone	7.9	1436	250	250	60	130	7.8	0.22	0	305	227	110.8	36.6	0.27
33	Waroda Zone 1	Sandstone	8	1421	250	250	60	120.3	9.8	0.23	0	305	202	100.2	39.1	0.41
34	Waroda Zone 2	Sandstone	8.1	1430	195	195	74	122.7	9.5	0.23	0	238	149	226.3	39.1	0.99
35	Waroda Development	Sandstone	8.1	519	110	110	40	36.5	2.5	0.04	0	134	43	51.9	32.6	0.12
Aquifer-I Basalt		Min	7.90	445.00	55.00	205.00	8.02	26.73	3.73	0.07	0.00	67.10	24.82	3.30	1.60	0.28
		Max	8.50	857.00	300.00	400.00	52.10	81.42	16.27	0.41	12.00	366.00	159.53	189.00	65.00	1.40

Well No	Village	Aquifer-I (Lithology)	pH	EC	TA	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
		Avg	8.15	786.08	156.40	350.00	44.01	58.38	8.34	1.31	3.00	190.81	101.53	75.40	25.97	0.66
Aquifer-I Sandstone		Min	7.20	470.00	60.00	110.00	12.02	31.60	2.39	0.04	0.00	73.20	39.00	4.50	0.75	0.12
		Max	8.60	2211.00	290.00	960.00	246.49	140.96	26.07	17.94	15.00	353.80	556.57	340.00	47.00	1.46
		Avg	8.08	986.87	154.57	353.91	54.25	76.29	8.86	1.38	1.96	188.58	144.88	108.13	28.67	0.60

All values in mg/l except pH and EC

Annexure-XIII: %Na, SAR, SSP, RSC, KR, MR and CR in groundwater samples from Aquifer-I Basalt and Sandstone (dugwells)

Well no.	Village/Location	Aquifer-I	%Na	SAR	SSP	RSC	KR	MR	CR
1	Phetri	Basalt	38.58	2.72	50.85	1.59	1.03	47.77	1.28
2	Khairgaon	Basalt	24.76	1.50	24.95	-6.68	0.33	38.73	4.53
3	Kalambi	Basalt	23.32	1.41	23.49	-4.48	0.31	54.19	4.16
4	Selu	Basalt	25.49	1.75	25.72	-4.81	0.35	46.91	4.52
5	Kalmeshwer	Basalt	21.66	1.35	21.73	-7.35	0.28	61.68	9.62
15	Warode	Basalt	27.48	1.62	27.54	-2.96	0.38	70.12	2.65
16	Brahmni	Basalt	35.69	1.87	36.23	0.48	0.57	48.47	1.08
17	Sawli	Basalt	19.24	1.16	19.31	-1.73	0.24	70.37	2.11
18	Ketapar	Basalt	31.22	1.51	31.43	-2.39	0.46	38.05	1.79
19	Sahuli	Basalt	41.88	2.98	46.04	0.69	0.85	25.58	2.01
20	Gumthala	Basalt	47.22	3.34	49.43	0.17	0.98	53.67	2.96
21	Sawangi	Basalt	39.19	3.23	44.16	-4.75	0.79	88.63	7.20
22	Uparwahi	Basalt	37.57	3.17	45.96	-0.56	0.85	73.39	4.26
23	Nimboli	Basalt	41.23	2.49	41.43	-1.24	0.71	74.23	2.73
24	Linga	Basalt	28.87	1.95	35.25	-3.83	0.54	77.30	3.76
26	Khapri	Basalt	9.43	0.40	9.46	-3.82	0.10	62.62	1.61
27	Ghogali	Basalt	22.65	1.44	22.68	-1.36	0.29	75.42	3.08
28	Brahmni (IW)	Basalt	32.50	2.06	32.81	-4.66	0.49	73.04	6.60
29	Ghorad	Basalt	34.24	2.55	40.48	1.04	0.68	57.34	3.12
30	Ubali	Basalt	24.94	1.87	25.19	-13.69	0.34	79.82	9.37
31	Wadhone Buzrug	Basalt	54.86	5.30	72.76	0.44	2.67	54.31	4.15
32	Sawali Khurd	Basalt	23.73	1.11	23.81	-4.35	0.31	69.66	2.55
33	Wathoda	Basalt	25.30	1.86	29.52	-6.06	0.42	30.04	6.92
34	Sawangi	Basalt	55.80	3.58	55.96	1.78	1.27	62.21	1.11
35	Susundri	Basalt	49.24	3.09	49.50	-2.49	0.98	77.86	4.11
36	Khairi	Basalt	26.22	1.42	26.28	-4.96	0.36	39.45	4.90
37	Pardi	Basalt	22.08	1.16	22.14	-3.29	0.28	72.75	3.03
38	Ramgiri	Basalt	24.93	1.02	24.93	-1.04	0.33	62.87	0.50
39	Dorli	Basalt	22.22	1.36	24.35	-5.24	0.32	46.16	3.81
40	Ubgi	Basalt	20.36	1.49	21.75	-10.63	0.28	61.78	7.90

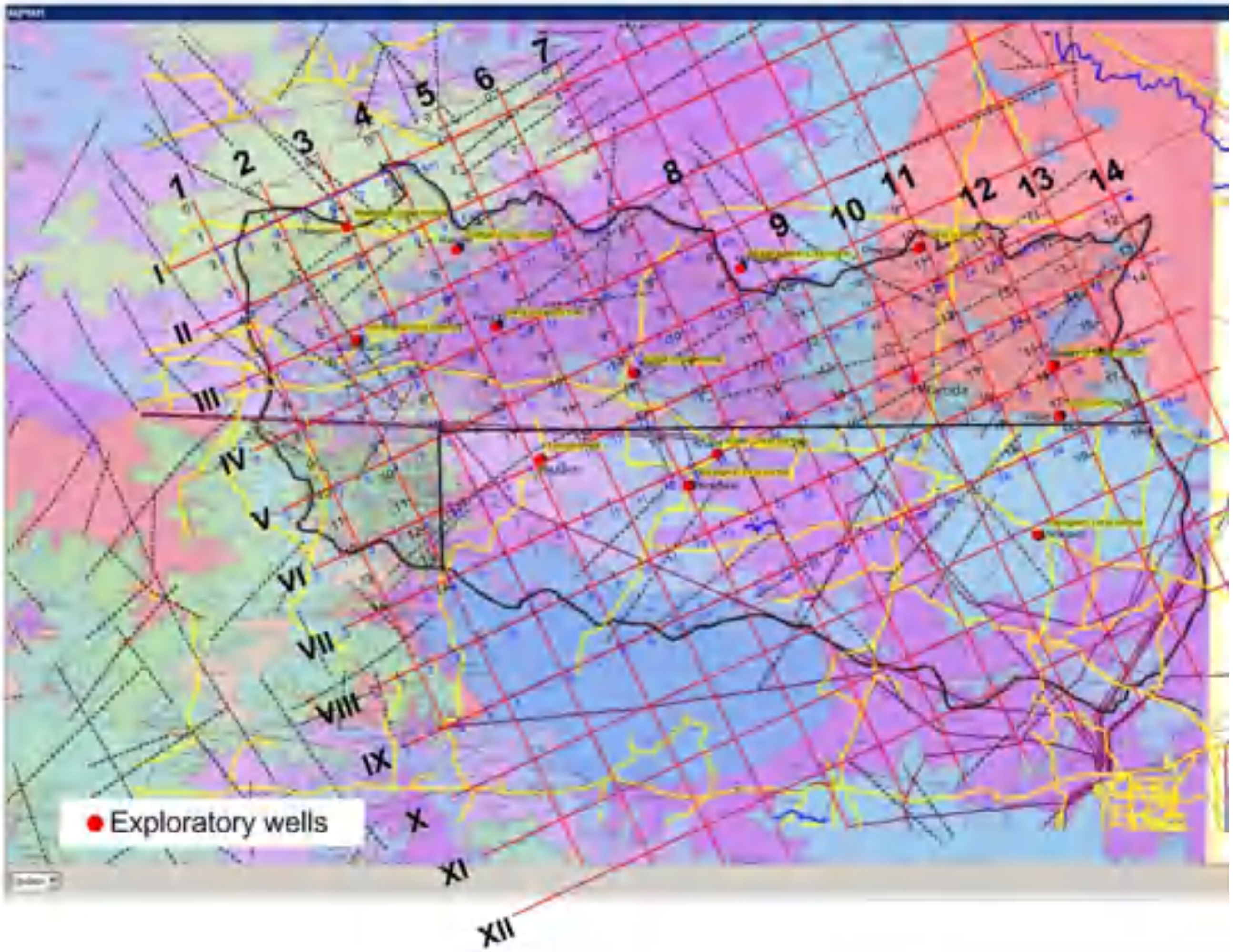
Well no.	Village/Location	Aquifer-I	%Na	SAR	SSP	RSC	KR	MR	CR
41	Kohali	Basalt	24.41	1.15	24.48	-3.66	0.32	80.96	2.51
42	Kolwali Bardi	Basalt	26.27	1.55	26.33	-6.40	0.36	41.29	3.24
43	Raulgaon	Basalt	32.70	1.91	33.16	-3.61	0.50	53.02	3.38
44	Chargaon	Basalt	21.37	0.90	21.45	-1.17	0.27	80.60	0.93
45	Sonkhamb	Basalt	26.47	1.08	26.47	-0.94	0.36	55.25	0.52
46	Metpanjra	Basalt	22.14	1.38	22.25	-8.18	0.29	50.62	7.20
47	Malegaon	Basalt	29.32	1.56	34.50	0.74	0.53	45.15	1.41
48	Vasboli	Basalt	22.00	1.17	23.44	-2.61	0.31	61.35	1.11
49	Pohi	Basalt	37.88	1.52	38.08	-1.13	0.62	70.39	0.80
50	Yerla	Basalt	26.77	1.29	26.94	-2.53	0.37	65.76	1.65
51	Chicholi	Basalt	24.58	1.65	29.07	-3.42	0.41	54.11	2.31
52	Kalmeshwer	Basalt	37.20	2.23	37.29	-1.75	0.59	71.51	1.47
53	Sawangi(IW)	Basalt	20.78	0.99	20.84	-2.14	0.26	71.84	1.03
55	Kalmeshwer (Or. Farm)	Basalt	41.65	2.56	49.37	0.93	0.97	76.70	0.67
56	Waroda	Basalt	33.21	2.97	36.37	-6.51	0.57	74.15	8.76
57	Lakholi	Basalt	25.70	1.77	27.62	-5.43	0.38	77.60	5.74
58	Kalmeshwer (Rly Gate)	Basalt	25.73	1.85	25.91	-10.73	0.35	60.87	8.09
6	Dahegaon	Sandstone	22.57	1.01	22.64	-0.97	0.29	55.40	1.16
7	Ashti	Sandstone	30.53	2.33	36.64	-3.09	0.58	47.65	8.71
8	Pardi	Sandstone	38.20	2.81	40.06	-4.40	0.67	47.44	8.92
9	Gowari	Sandstone	37.34	2.23	40.69	-0.29	0.69	34.42	3.29
10	Tondakhairi	Sandstone	32.14	1.63	33.73	-0.09	0.51	65.85	1.60
11	Borgaon(Kh)	Sandstone	11.95	0.65	12.09	-6.08	0.14	64.74	7.59
12	Silori	Sandstone	23.50	1.91	28.59	-5.01	0.40	69.30	5.76
13	Dhapewada	Sandstone	33.04	1.98	33.11	-1.99	0.49	73.10	3.48
14	Bhadangi	Sandstone	35.30	2.55	37.06	1.42	0.59	60.55	3.50
54	Kalmeshwer (IW)	Sandstone	40.11	3.81	40.34	-12.85	0.68	59.08	22.04

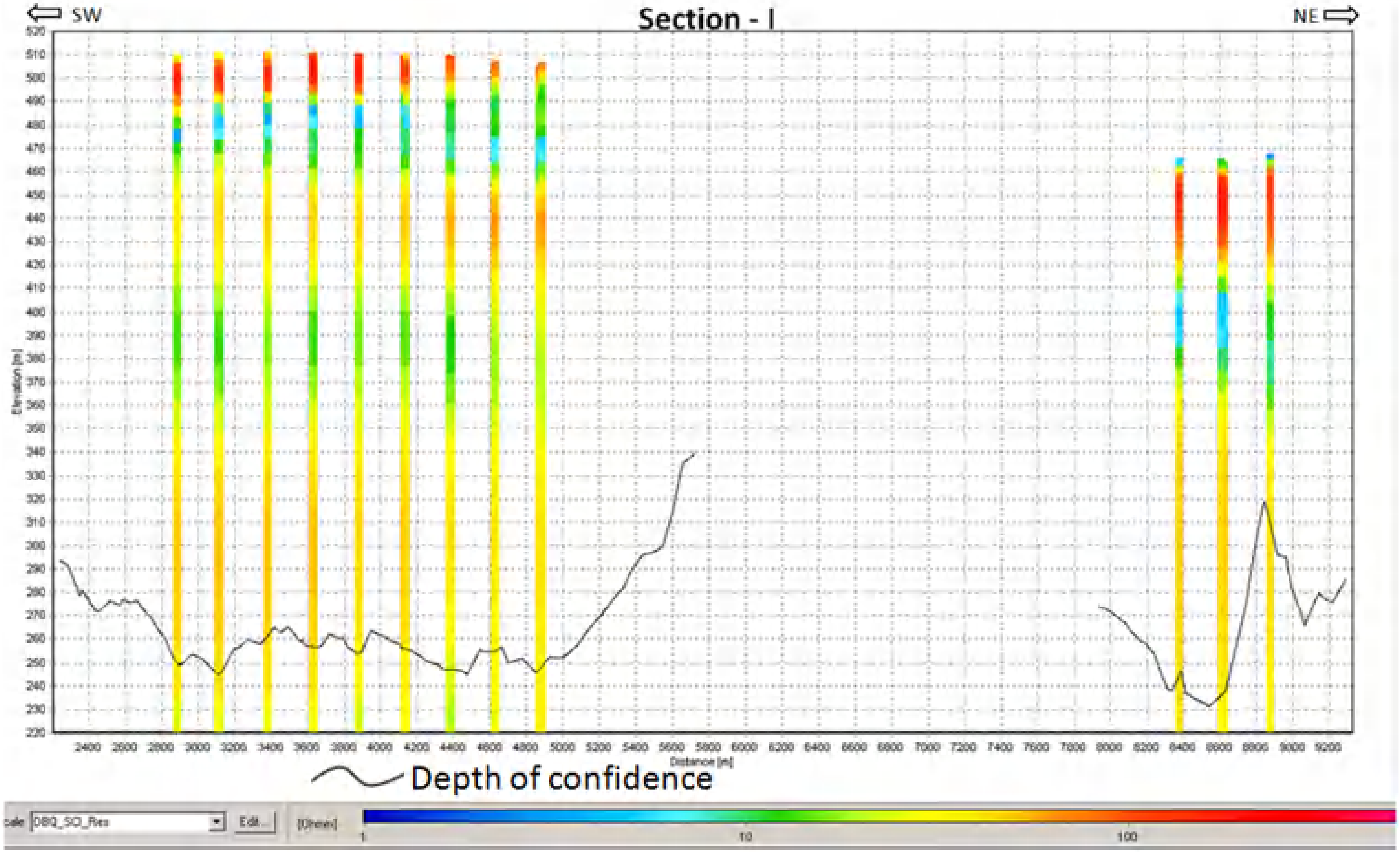
Annexure-XIV: %Na, SAR, SSP, RSC, KR, MR and CR in groundwater samples from Aquifer-II Basalt and Sandstone (Ground water explortation)

Well no.	Village/Location	Aquifer-II	%Na	SAR	SSP	RSC	KR	MR	CR
1	Sonkhamb (22.60-23m)	Basalt	8.01	0.35	8.02	-5.80	0.09	83.73	4.56
2	Sonkhamb (76.45-79.10m)	Basalt	10.20	0.38	10.22	0.10	0.11	92.97	0.71
23	Sonkhmab (PT)	Basalt	3.14	0.10	3.14	-1.00	0.03	69.96	0.81
3	Ramgiri (7-8m)	Basalt	4.06	0.15	4.06	-4.41	0.04	63.03	2.54
4	Ramgiri (final discharge)	Basalt	9.96	0.38	9.97	0.20	0.11	91.36	0.90
5	Malegaon (7-8m)	Basalt	3.99	0.13	4.00	-1.90	0.04	55.27	1.31
6	Malegaon (127.30-129.95m)	Basalt	4.50	0.14	4.51	-1.30	0.05	53.61	1.00
22	Malegaon (PT)	Basalt	5.75	0.23	5.75	-3.91	0.06	62.81	3.54
28	Kohli (PT)	Basalt	8.61	0.37	8.62	-6.40	0.09	89.32	3.04
13	Dahegaon (14.3-16.95m)	Basalt	6.79	0.22	6.81	-2.20	0.07	68.05	1.91
9	Khapri (48.2-50.85m)	Basalt	8.15	0.27	8.16	-0.40	0.09	86.65	0.71
10	Khapri (67.8-70.8m)	Basalt	5.86	0.19	5.87	-0.60	0.06	68.71	0.81
11	Mohgaon (42.55-48.70m)	Sandstone	2.66	0.09	2.66	-1.81	0.03	54.50	1.62
12	Mohgaon 79.10-87.75m)	Sandstone	1.53	0.06	1.53	-0.91	0.02	67.12	1.10
14	Dhapewada (Zone-I)	Sandstone	5.64	0.27	5.65	-8.91	0.06	76.20	3.58
15	Dhapewada (Zone-II)	Sandstone	4.42	0.18	4.42	-2.60	0.05	82.02	1.65
16	Dhapewada (Comp.Dvlpmt)	Sandstone	5.97	0.22	5.98	-3.40	0.06	78.30	2.25
17	Dhapewada (Drilling)	Sandstone	3.56	0.13	3.56	-2.51	0.04	56.02	2.23
18	Dhapewada	Sandstone	5.37	0.21	5.38	-2.50	0.06	83.31	1.86
19	Gowri(Zone-I)	Sandstone	5.09	0.16	5.11	-2.00	0.05	69.01	2.40
20	Gowri(Zone-II)	Sandstone	4.31	0.14	4.32	-2.60	0.05	69.96	2.40
21	Gowri(Comp.Dvlpmt)	Sandstone	3.80	0.13	3.81	-3.41	0.04	48.10	2.61

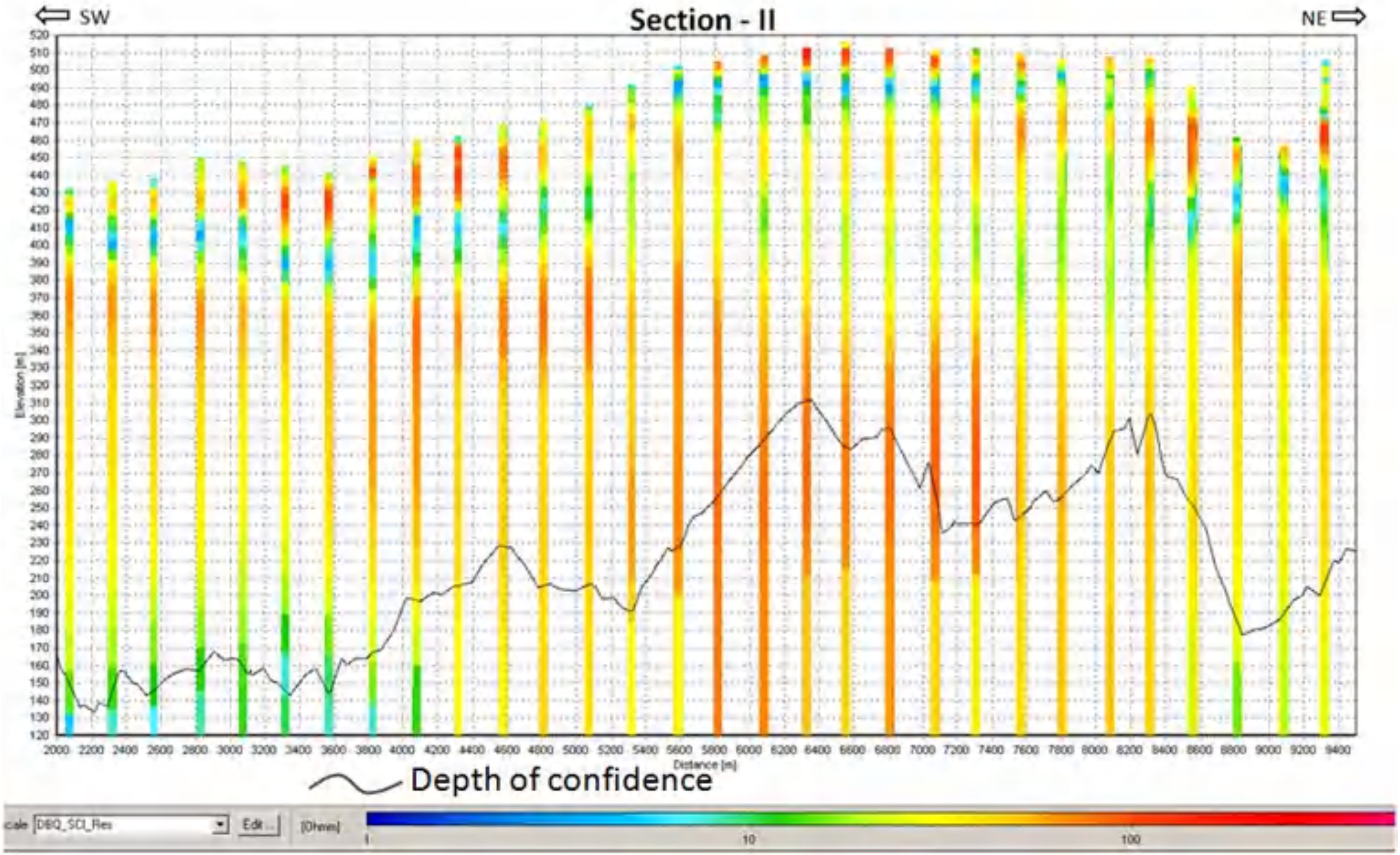
Well no.	Village/Location	Aquifer-II	%Na	SAR	SSP	RSC	KR	MR	CR
24	Khairi lakhmaji (Zone-I)	Sandstone	2.09	0.14	2.14	-17.03	0.02	35.90	15.76
25	Khairi lakhmaji (Drilling)	Sandstone	2.63	0.14	2.66	-11.21	0.03	75.16	6.89
27	Khairi lakhmaji (PT)	Sandstone	3.65	0.18	3.65	-7.91	0.04	72.86	6.17
7	Raulgaon (127.3-129.95m)	Sandstone	7.58	0.43	7.59	-12.61	0.08	84.03	9.95
8	Raulgaon (135.6-138.6m)	Sandstone	9.23	0.42	9.24	-5.40	0.10	93.01	5.14
26	Raulgaon (PT)	Sandstone	8.55	0.37	8.56	-5.50	0.09	86.05	3.17
29	Khairi (L)-development	Sandstone	3.01	0.12	3.01	-3.80	0.03	59.99	2.64
30	Kohli-Zone-1	Sandstone	2.50	0.11	2.50	-5.29	0.03	52.28	2.68
31	Kohli-Zone-2	Sandstone	3.60	0.15	3.60	-5.50	0.04	77.65	3.23
32	Kohli-Development	Sandstone	2.41	0.13	2.42	-8.70	0.02	78.10	6.51
33	Waroda-Zone 1	Sandstone	3.20	0.17	3.20	-7.90	0.03	76.75	5.79
34	Waroda-Zone 2	Sandstone	2.91	0.16	2.91	-9.90	0.03	73.19	4.38
35	Waroda-Development	Sandstone	2.13	0.07	2.13	-2.81	0.02	60.03	1.24

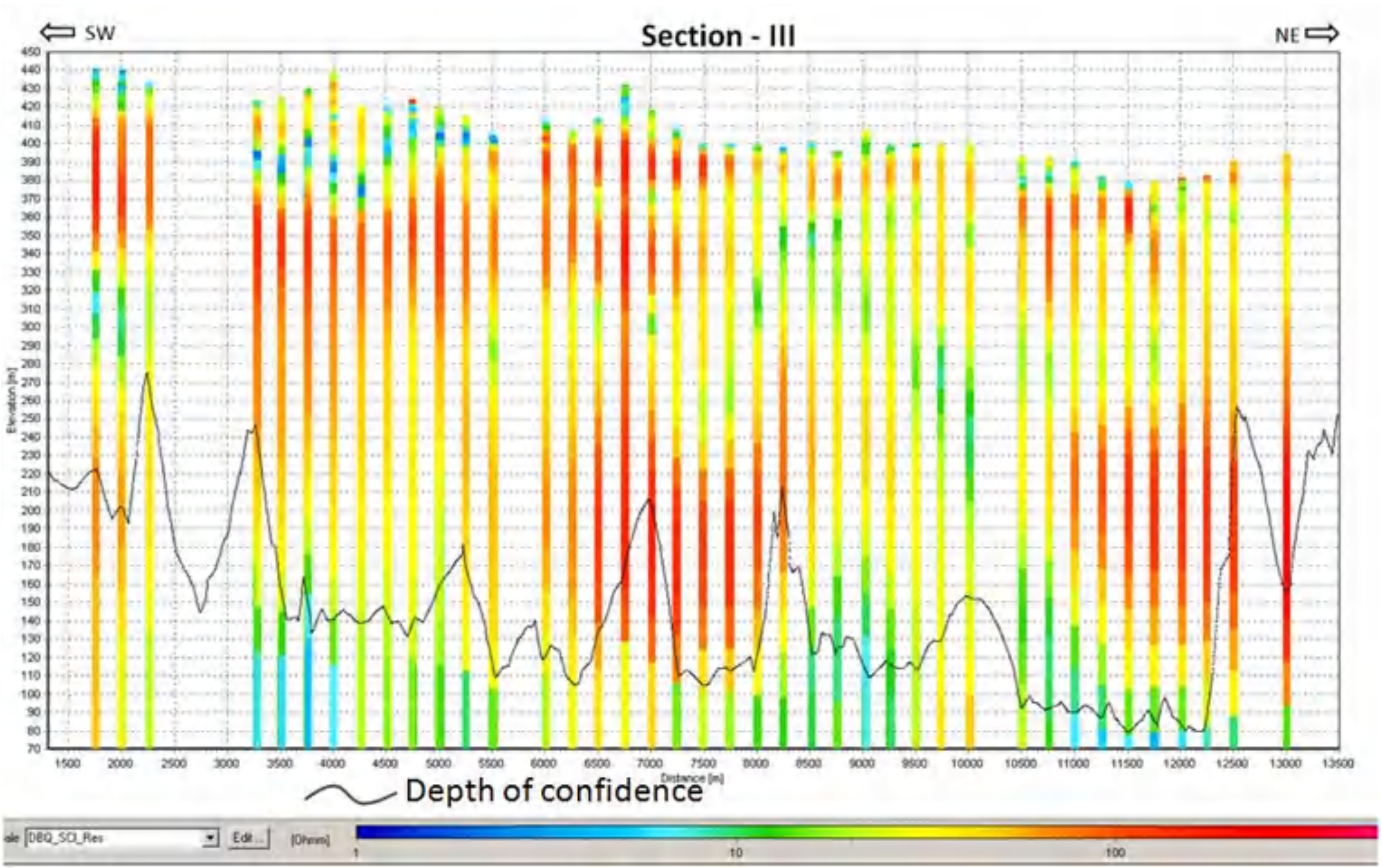
ANNEXURE-XV: HeliTEM SCI section in grid fashion (NGRI, 2015b)



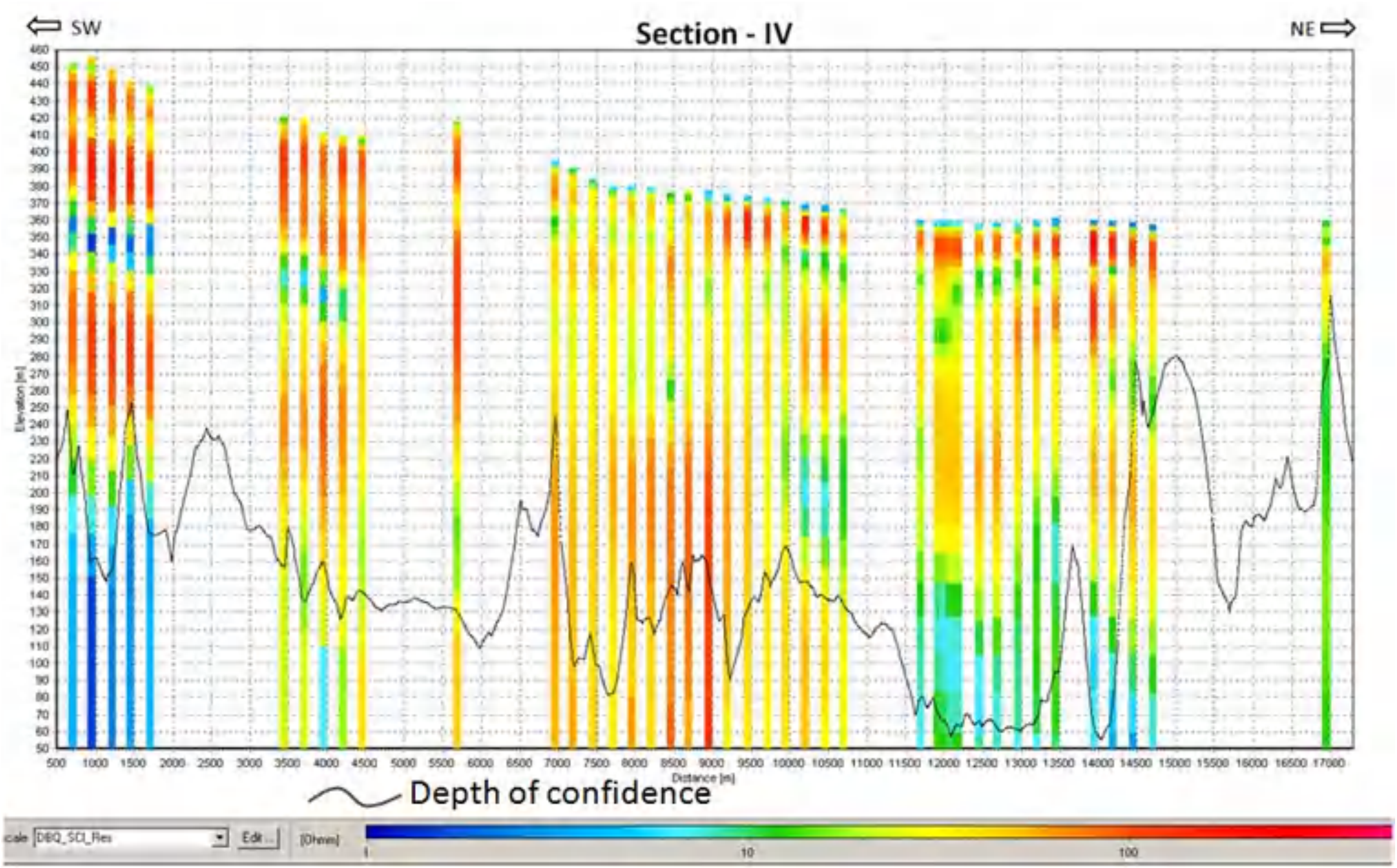


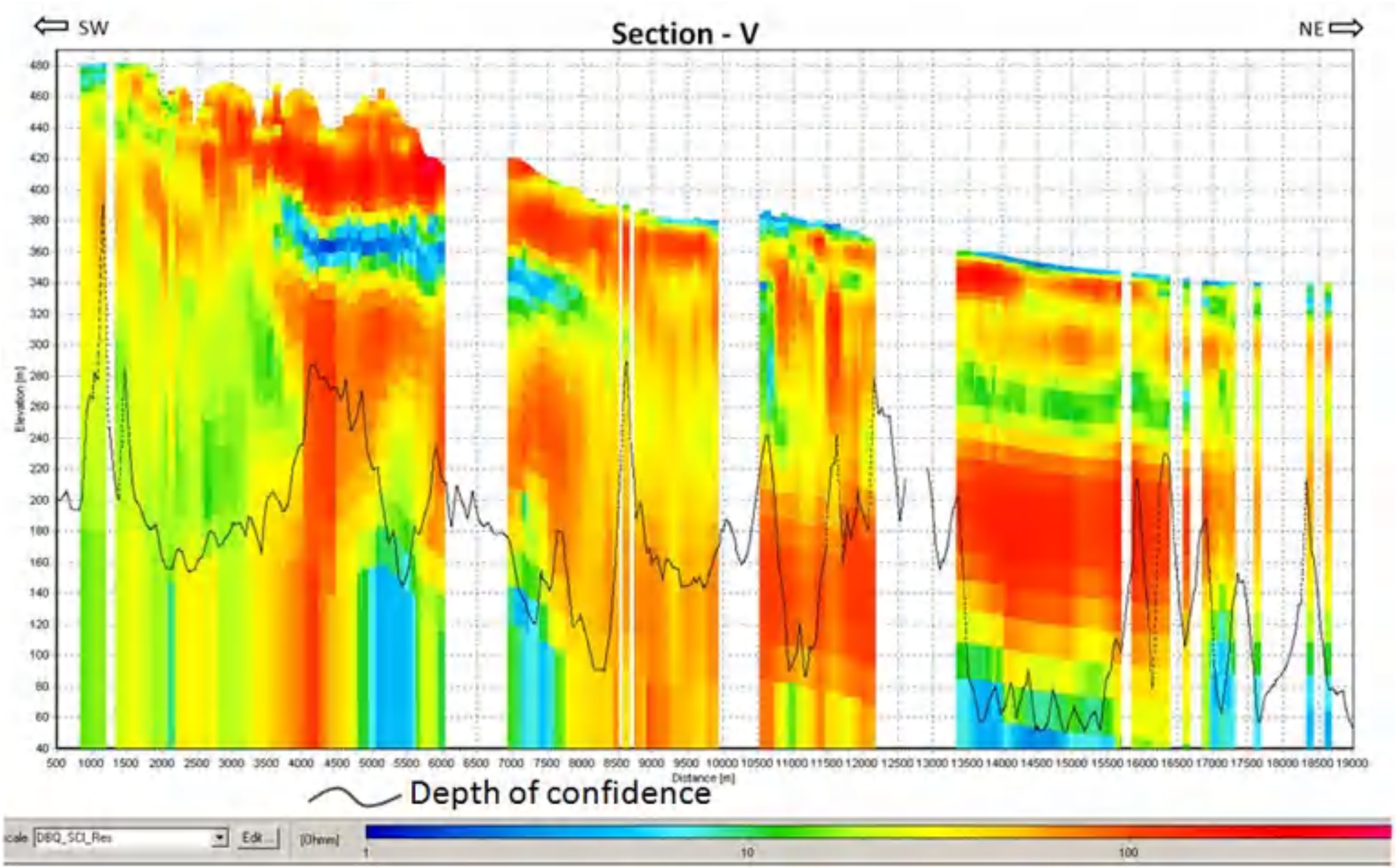
SW
Section - I
NE
Elevation [m]
Distance [m]
Depth of confidence
DBQ_SCI_Res
Edit...
[Ohmm]
1
10
100

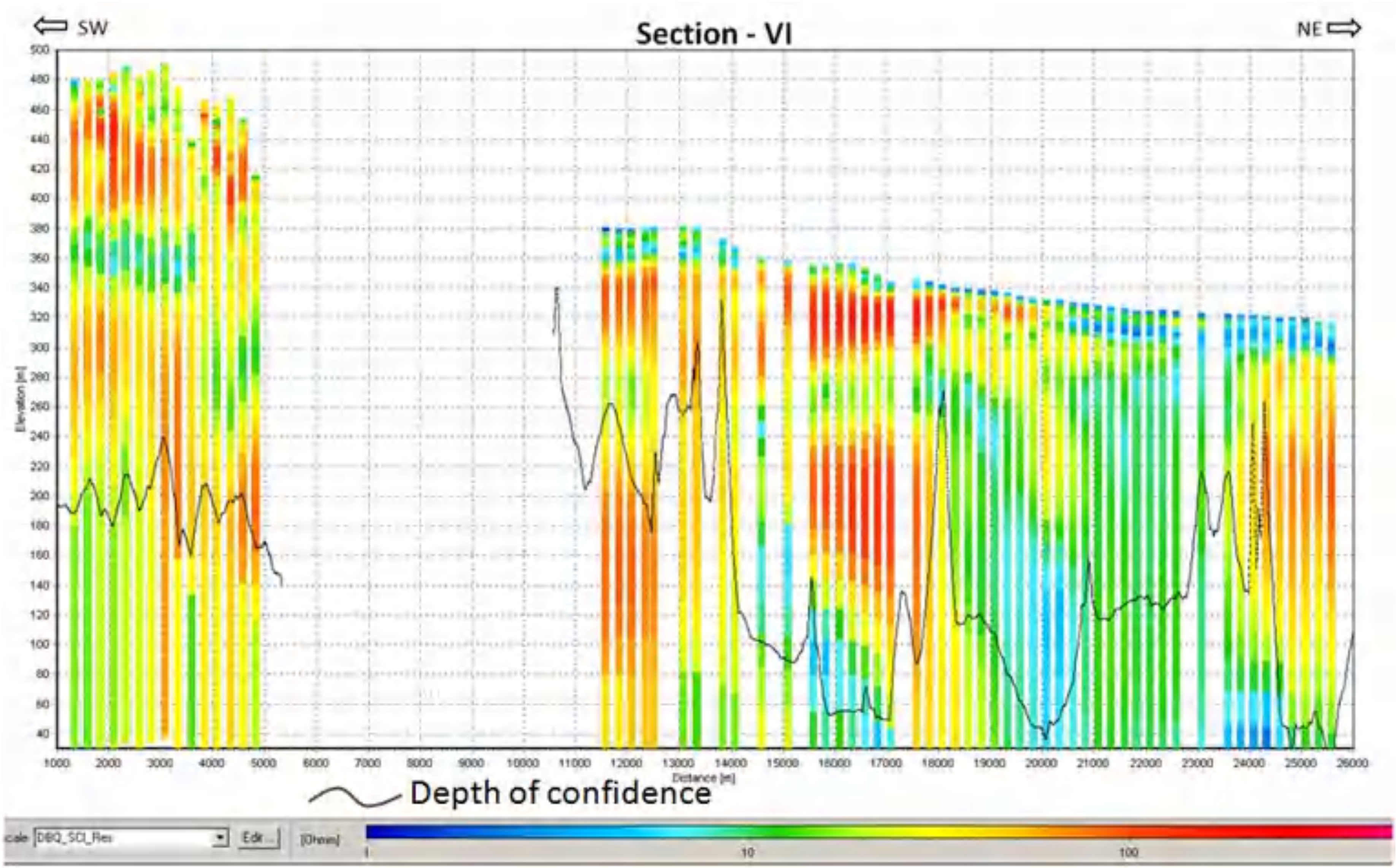

SW
Section - II
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
10
100

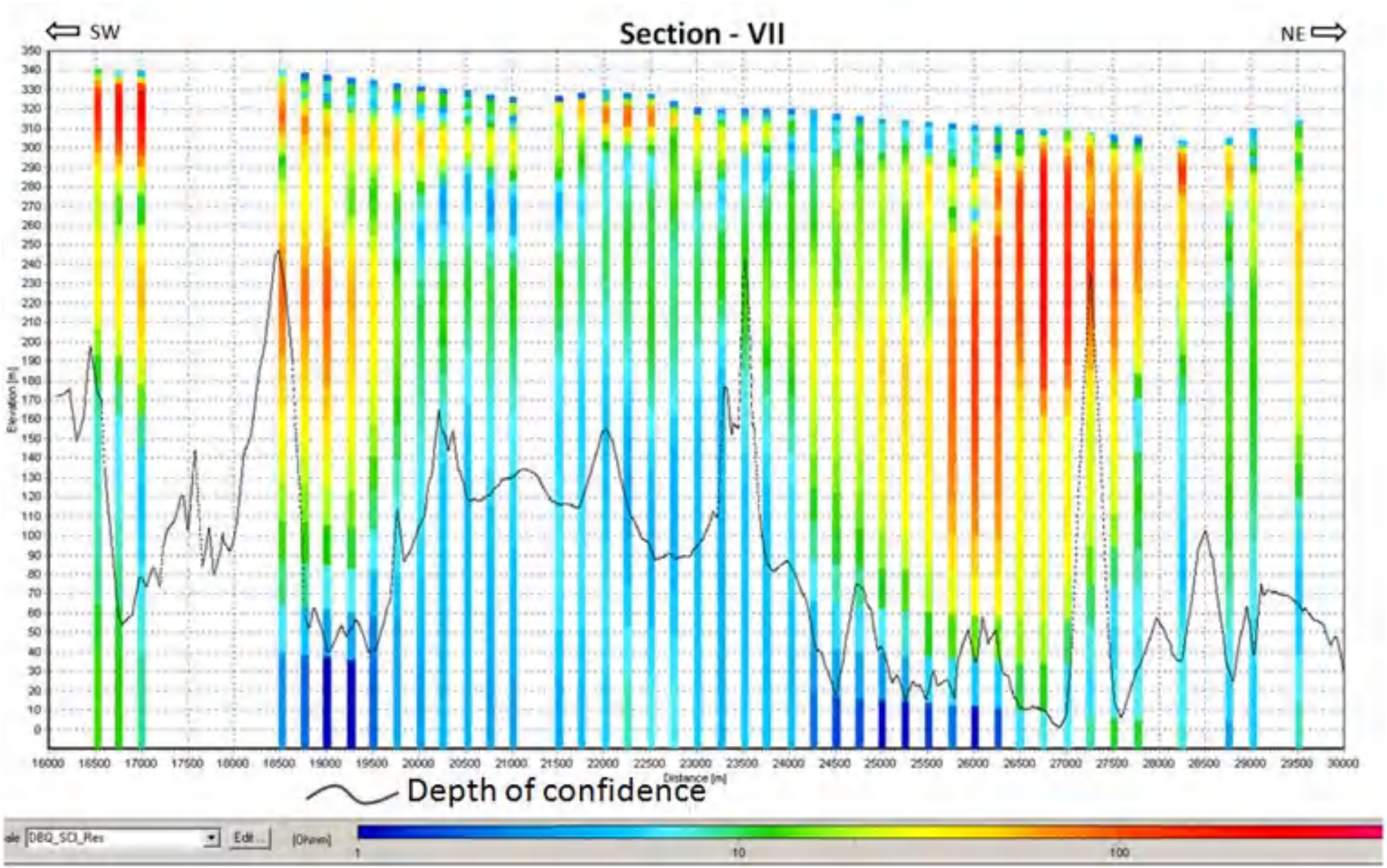


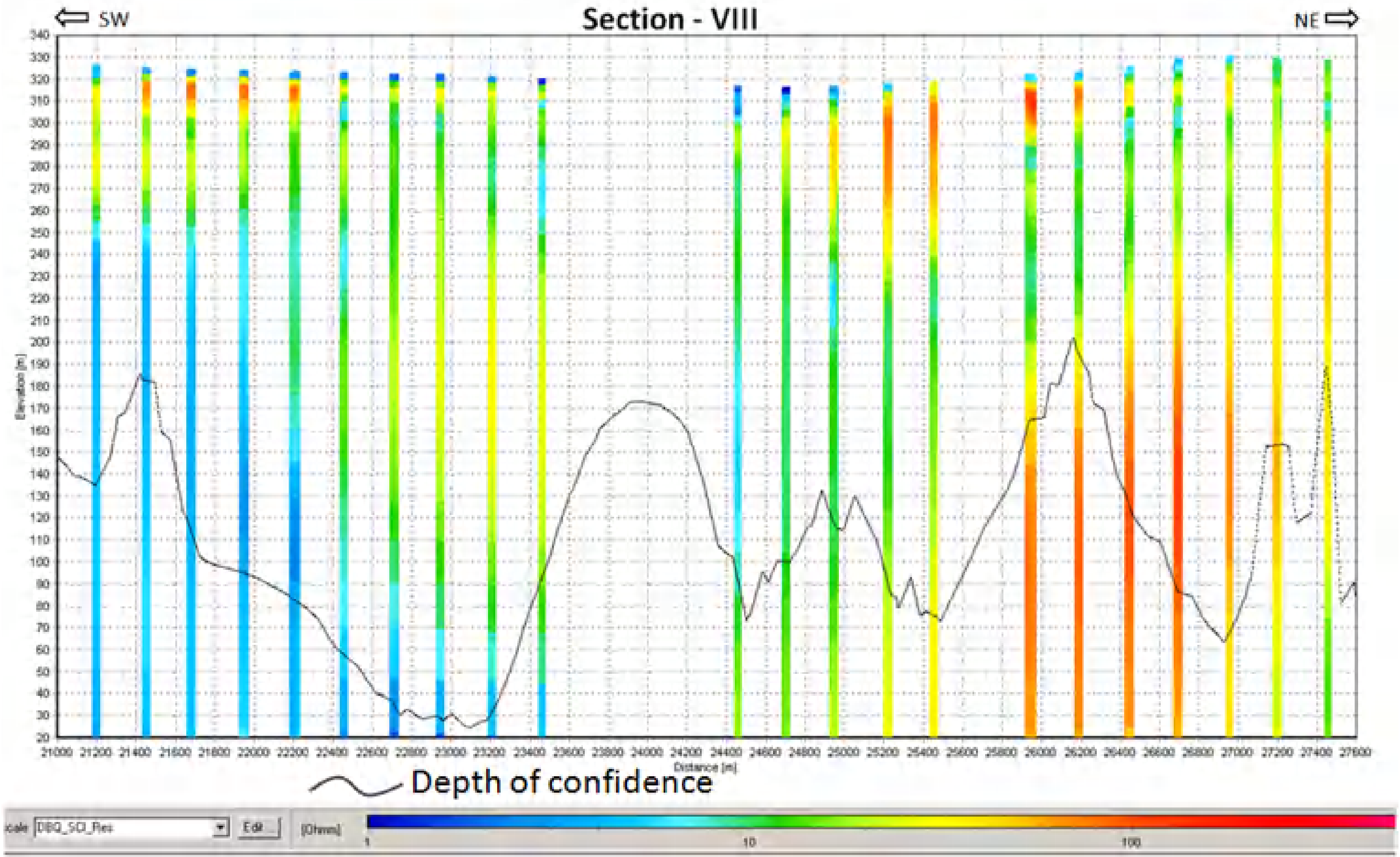
SW
Section - III
NE
Elevation [m]
Distance [m]
Depth of confidence
DBQ_SCI_Res
Edit...
[Ohmm]
1
10
100


SW
Section - IV
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
10
100


SW
Section - V
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100


SW
Section - VI
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
10
100


Section - VII
SW
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100


Section - VIII
SW
NE
Elevation [m]
Distance [m]
Depth of confidence
[Ohms]
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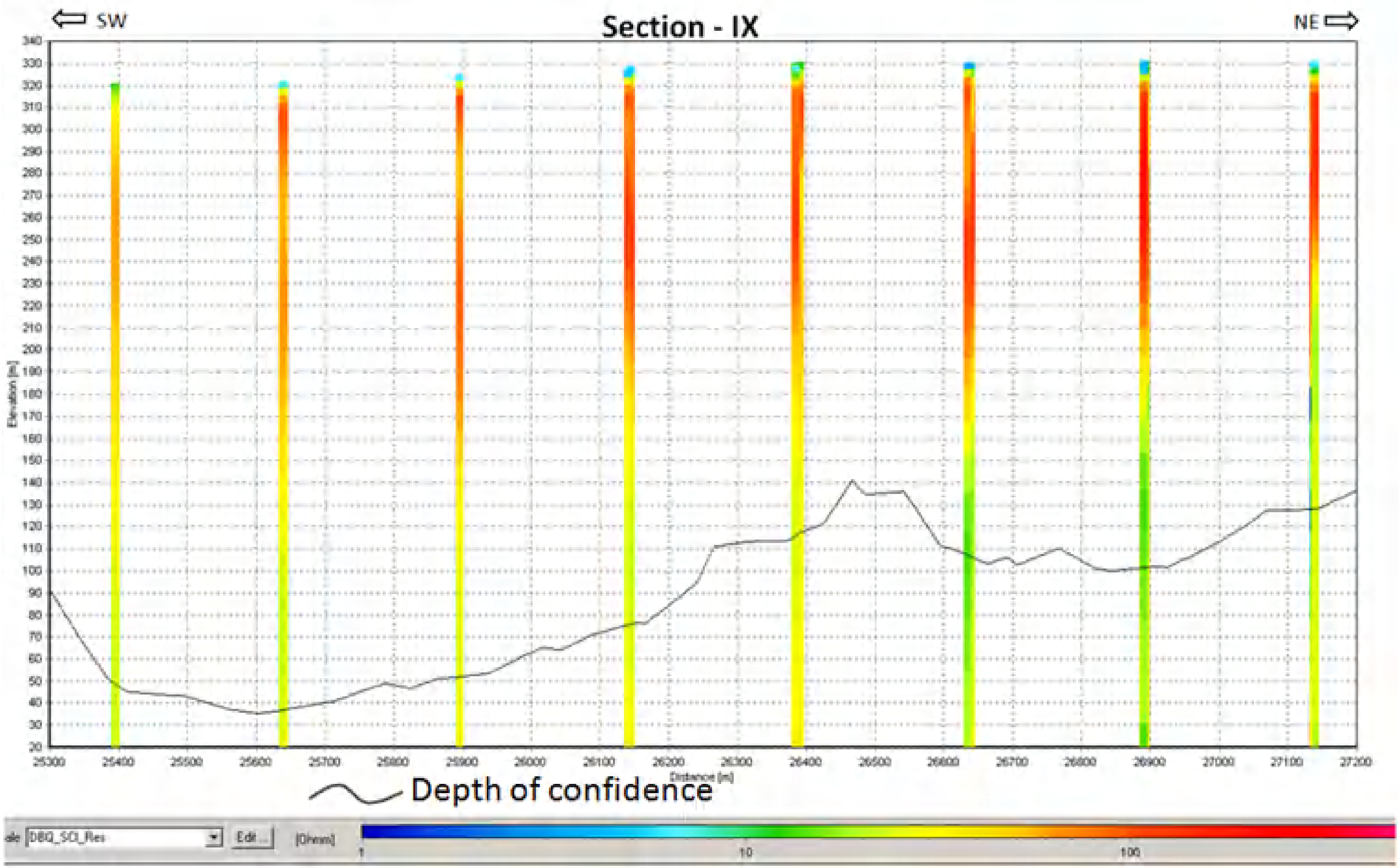
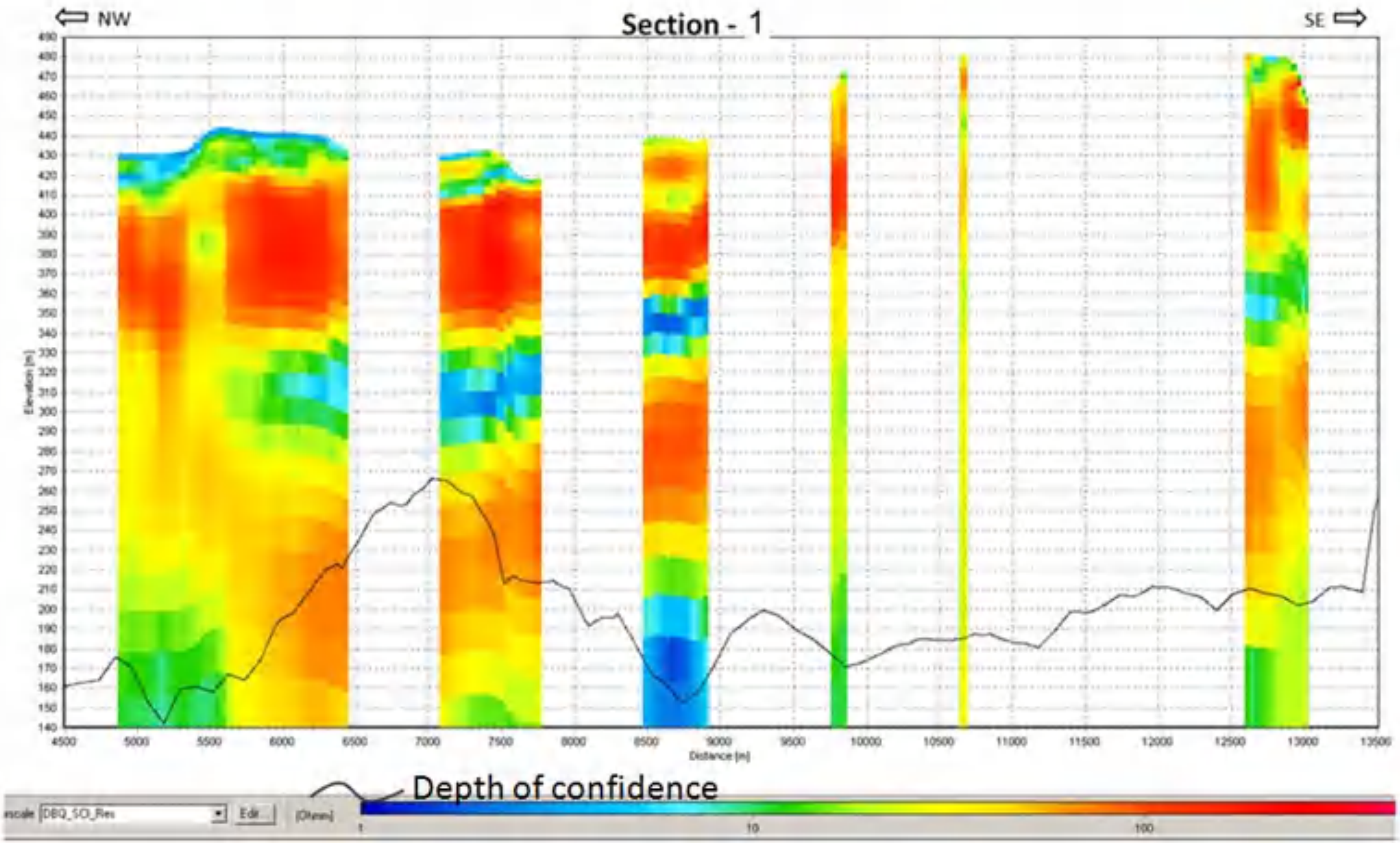
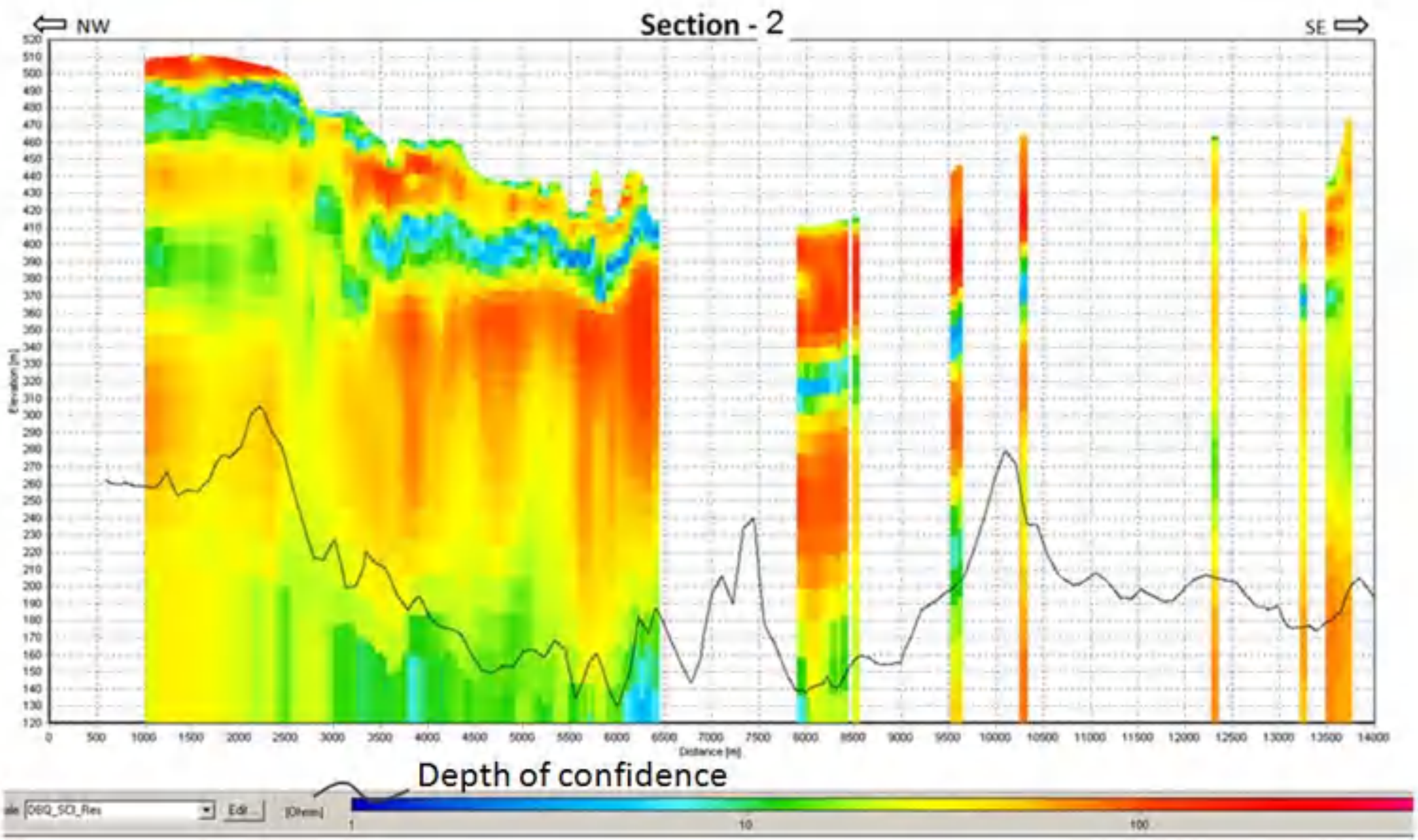
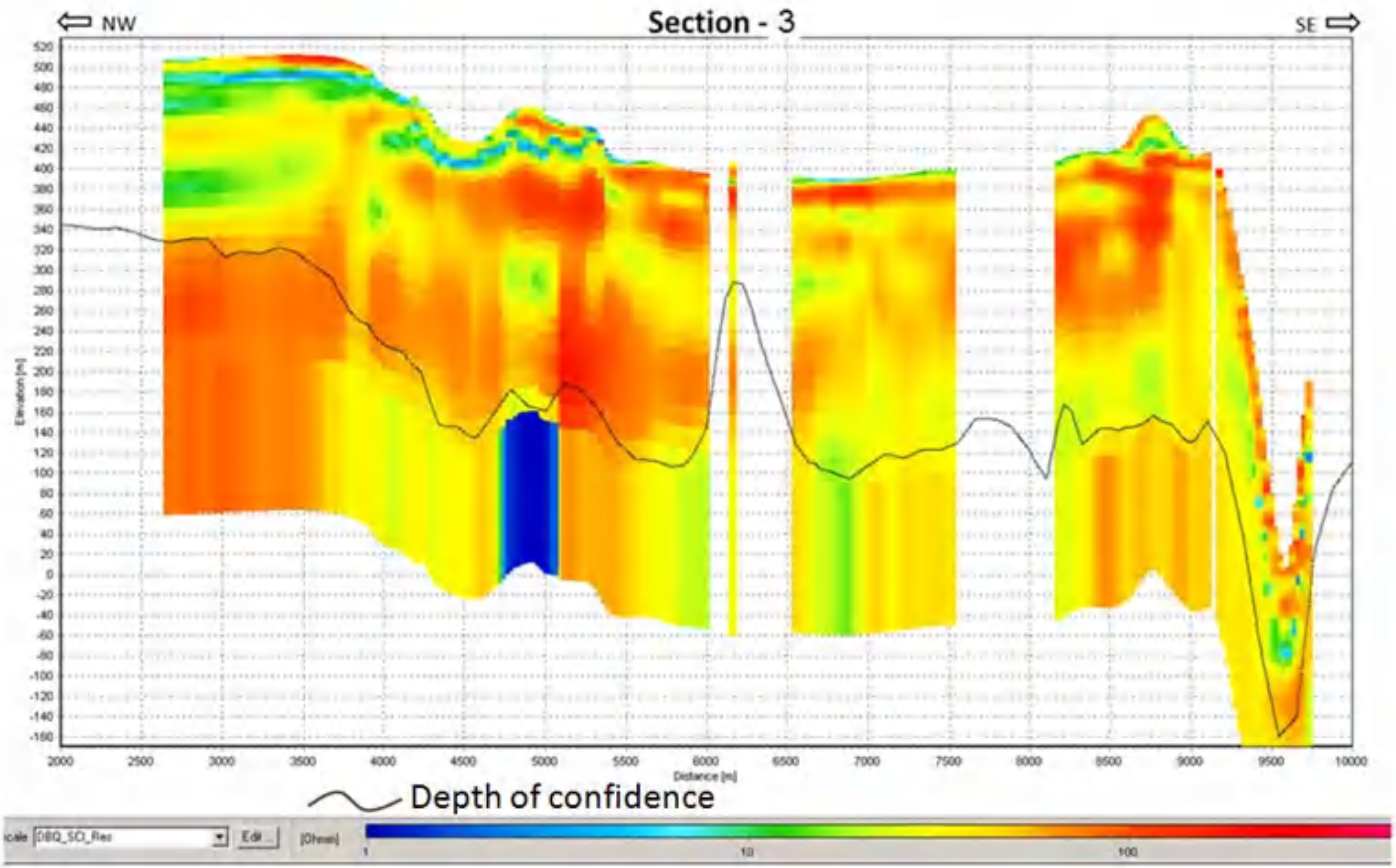
10
100
Edit
DBQ_SCI_Res


SW
Section - IX
NE
Elevation [m]
Distance [m]
Depth of confidence
DBQ_SCI_Res
Edit...
[Ohmm]
1
10
100

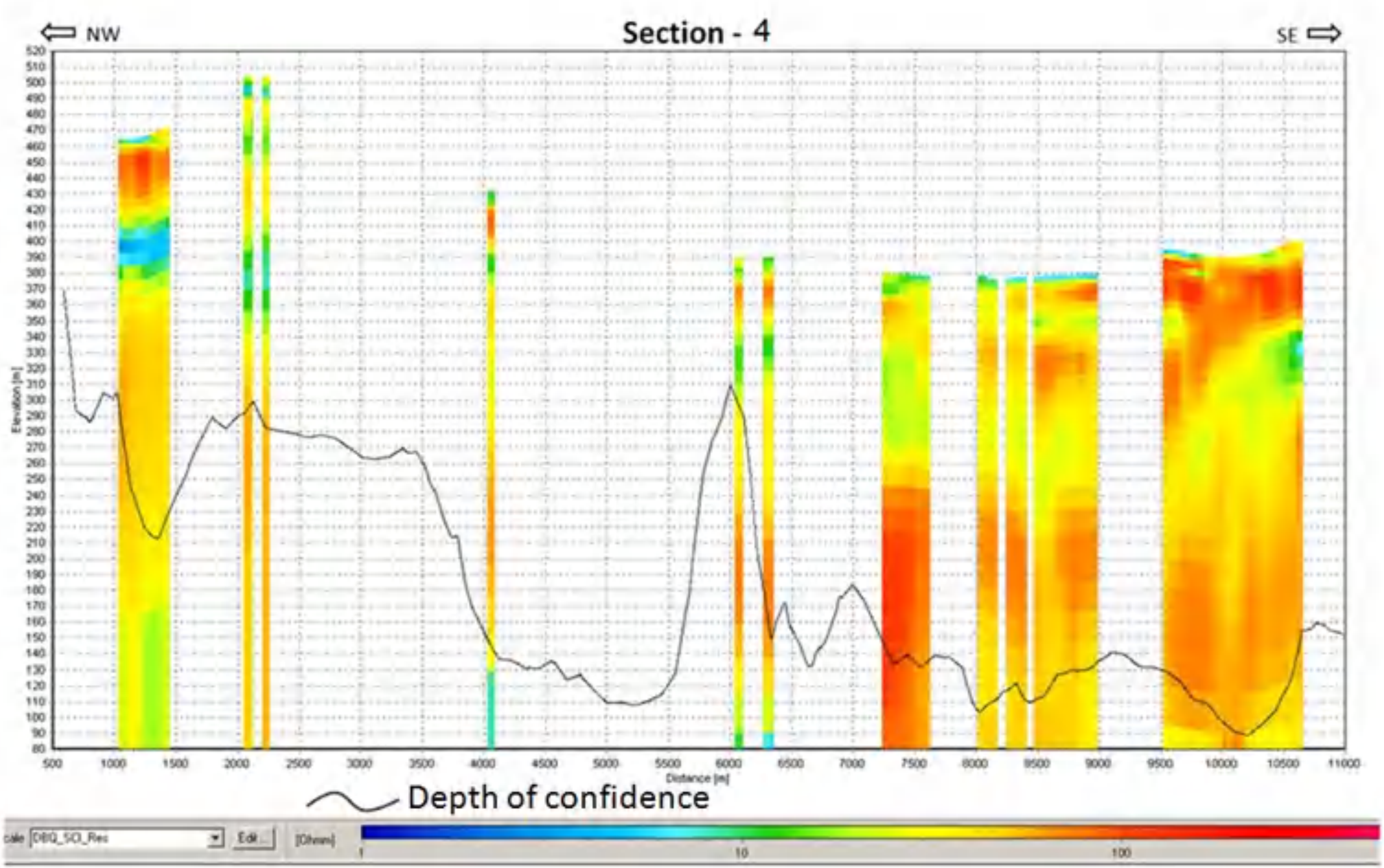

NW
Section - 1
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100

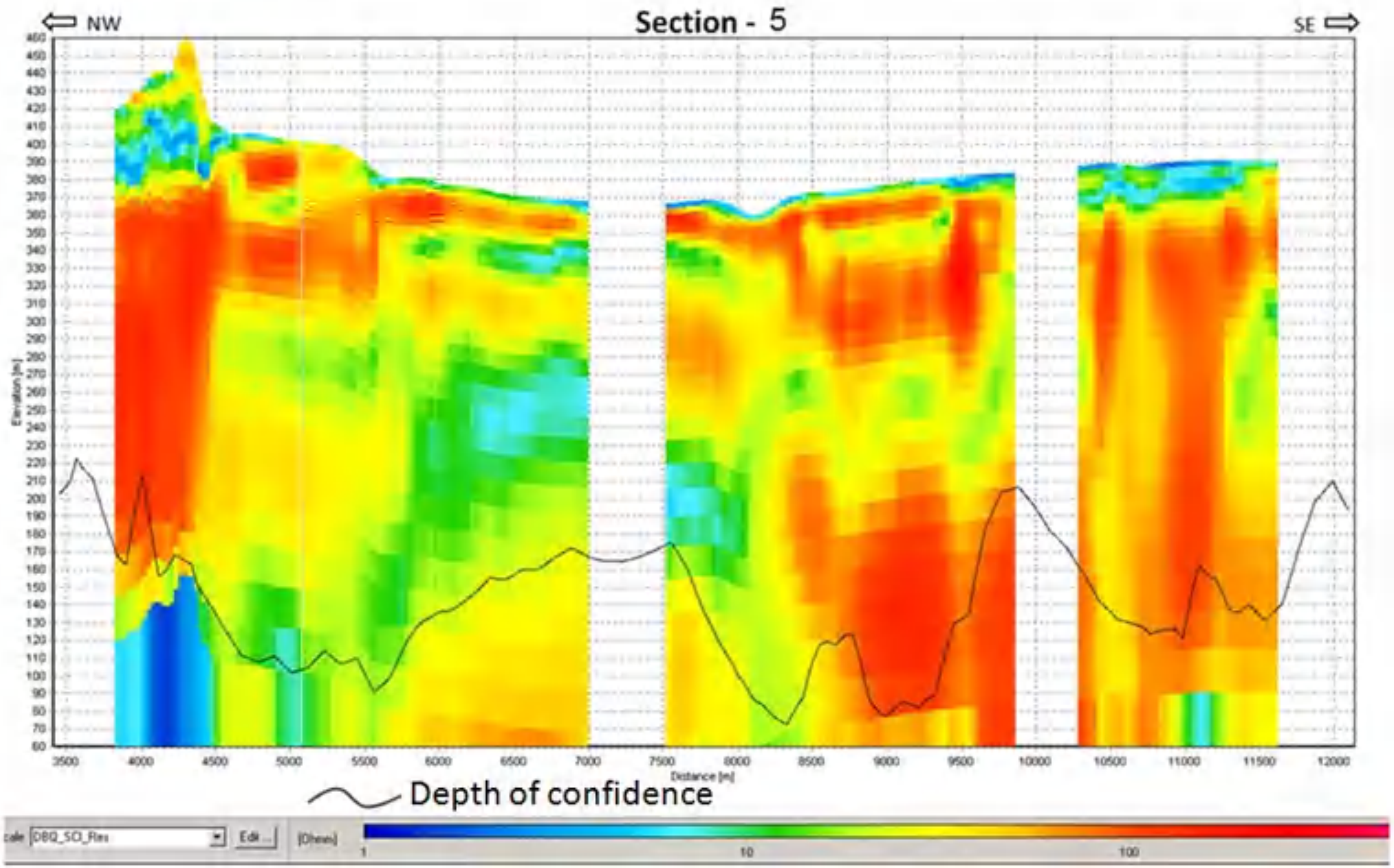


Section - 2
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
DSQ_SCI_Res
Edit...
[Ohmm]
1
10
100

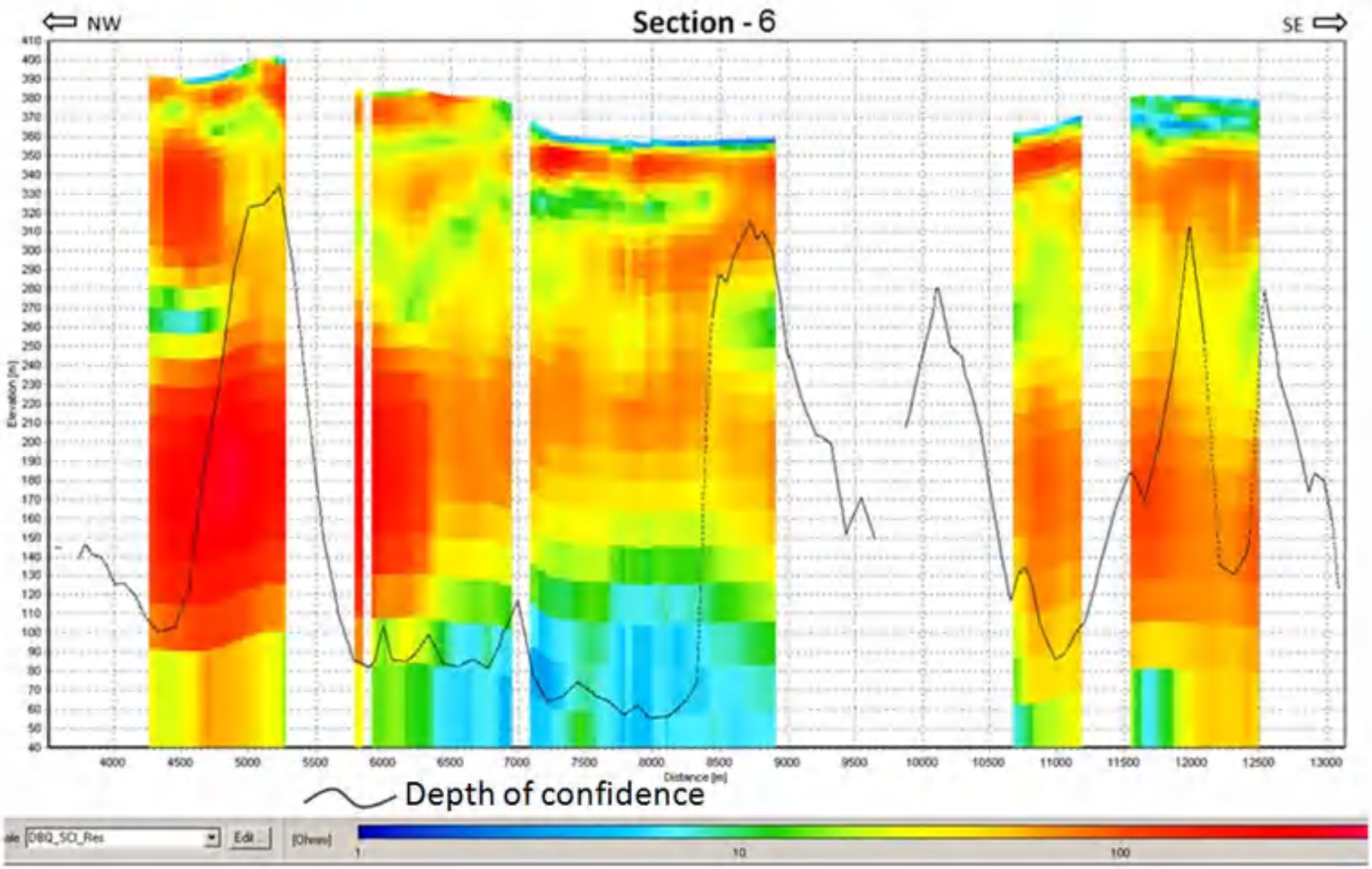


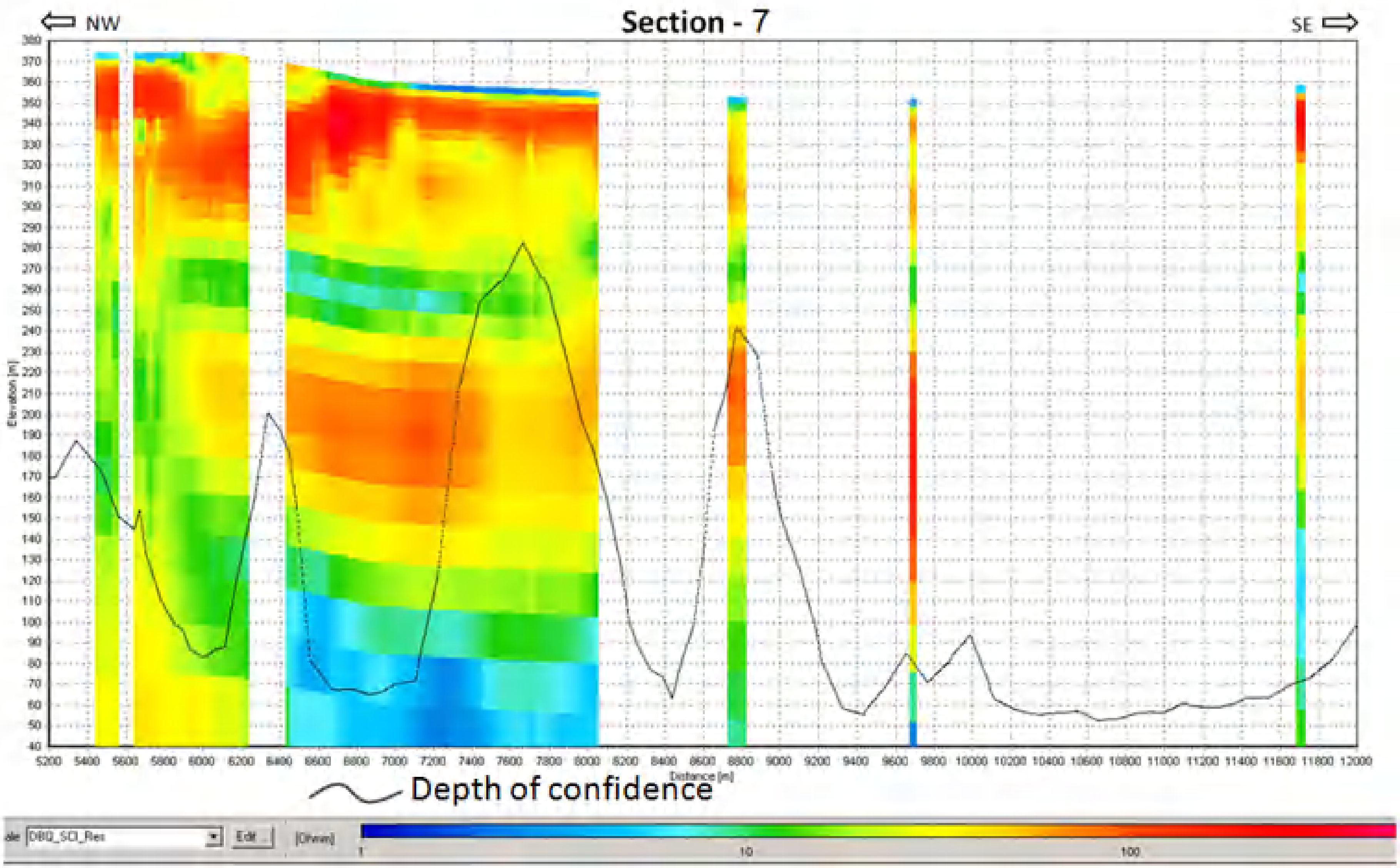
NW
Section - 3
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100

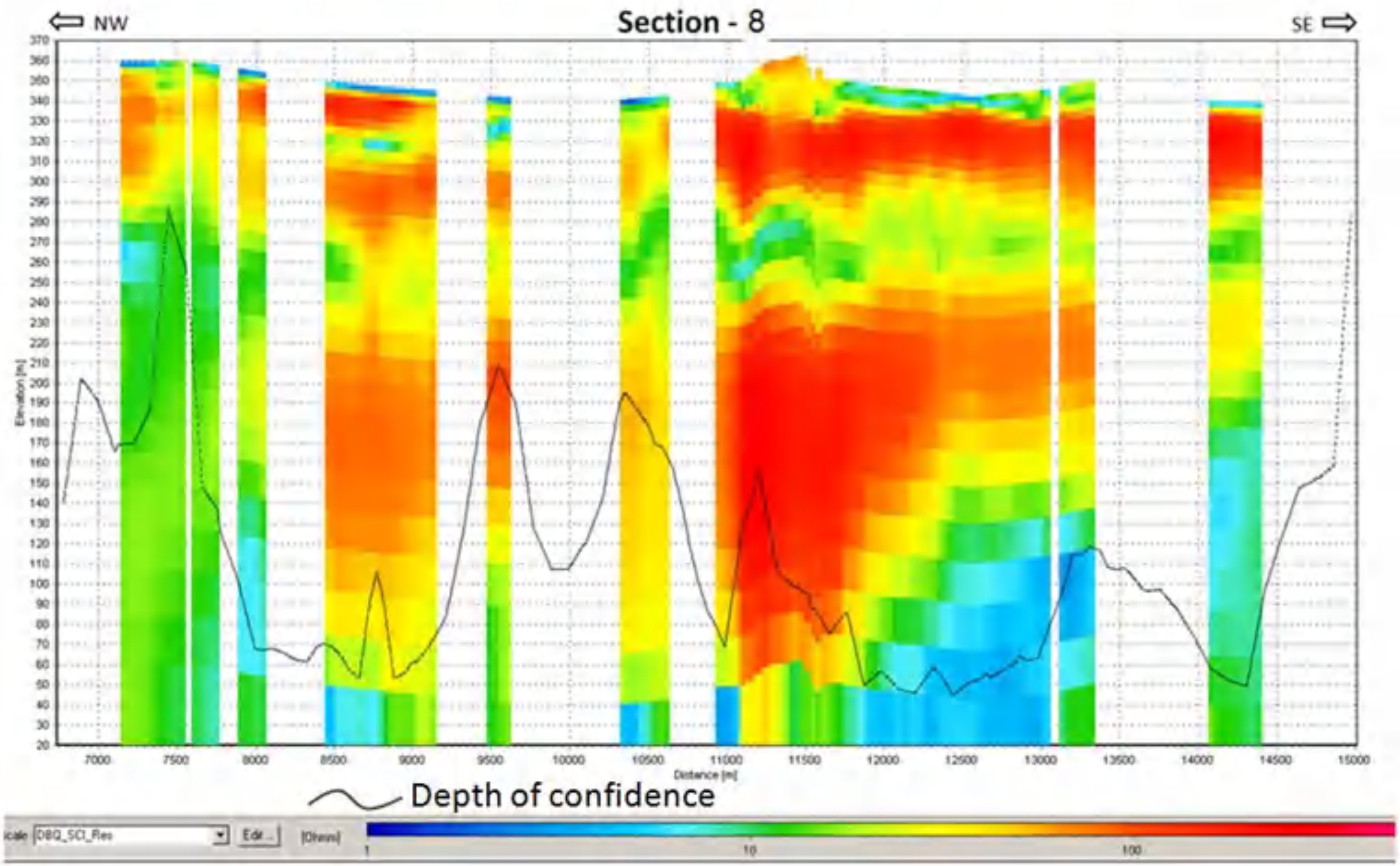

Section - 4
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100

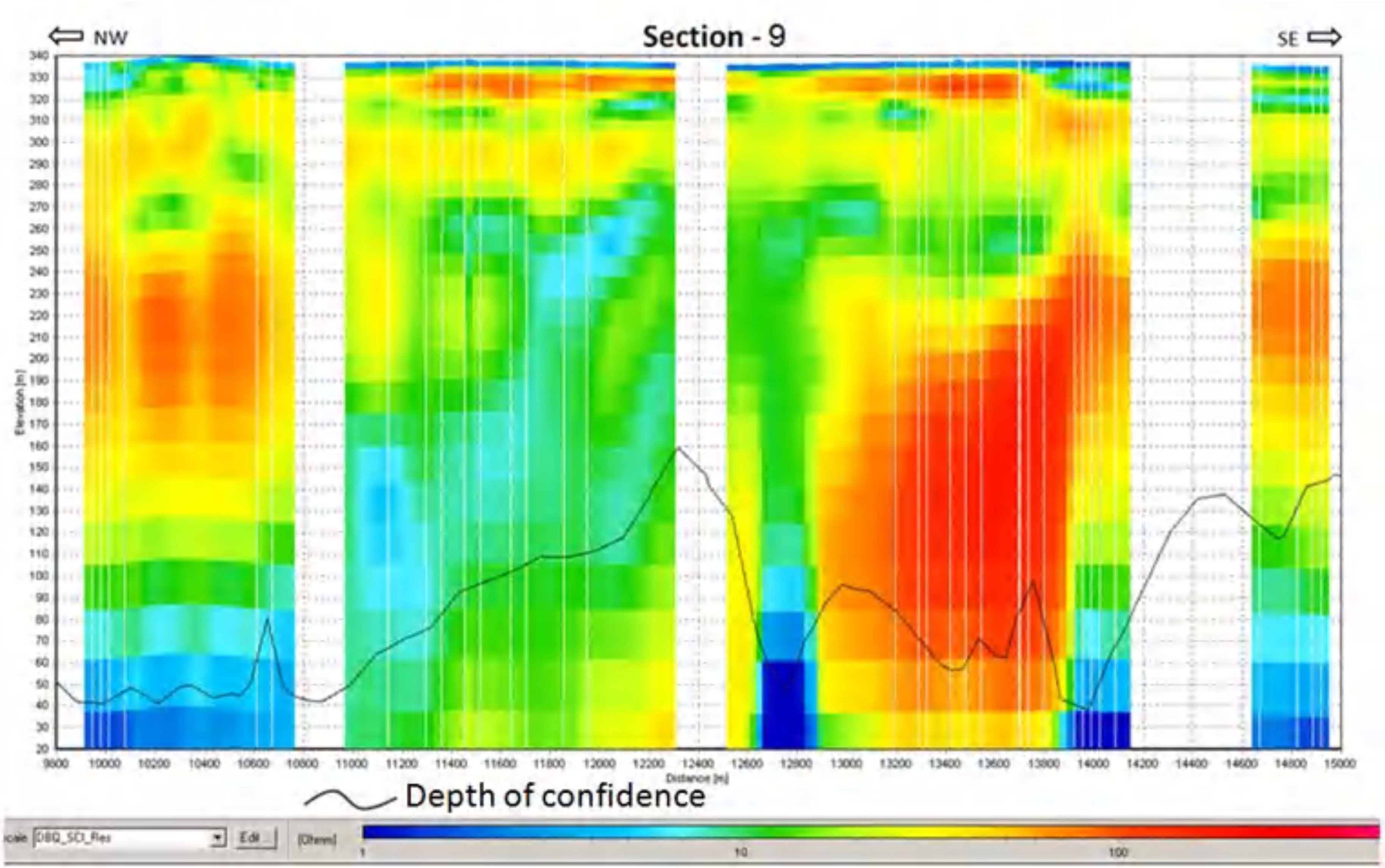


Section - 5
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohm]
1
10
100

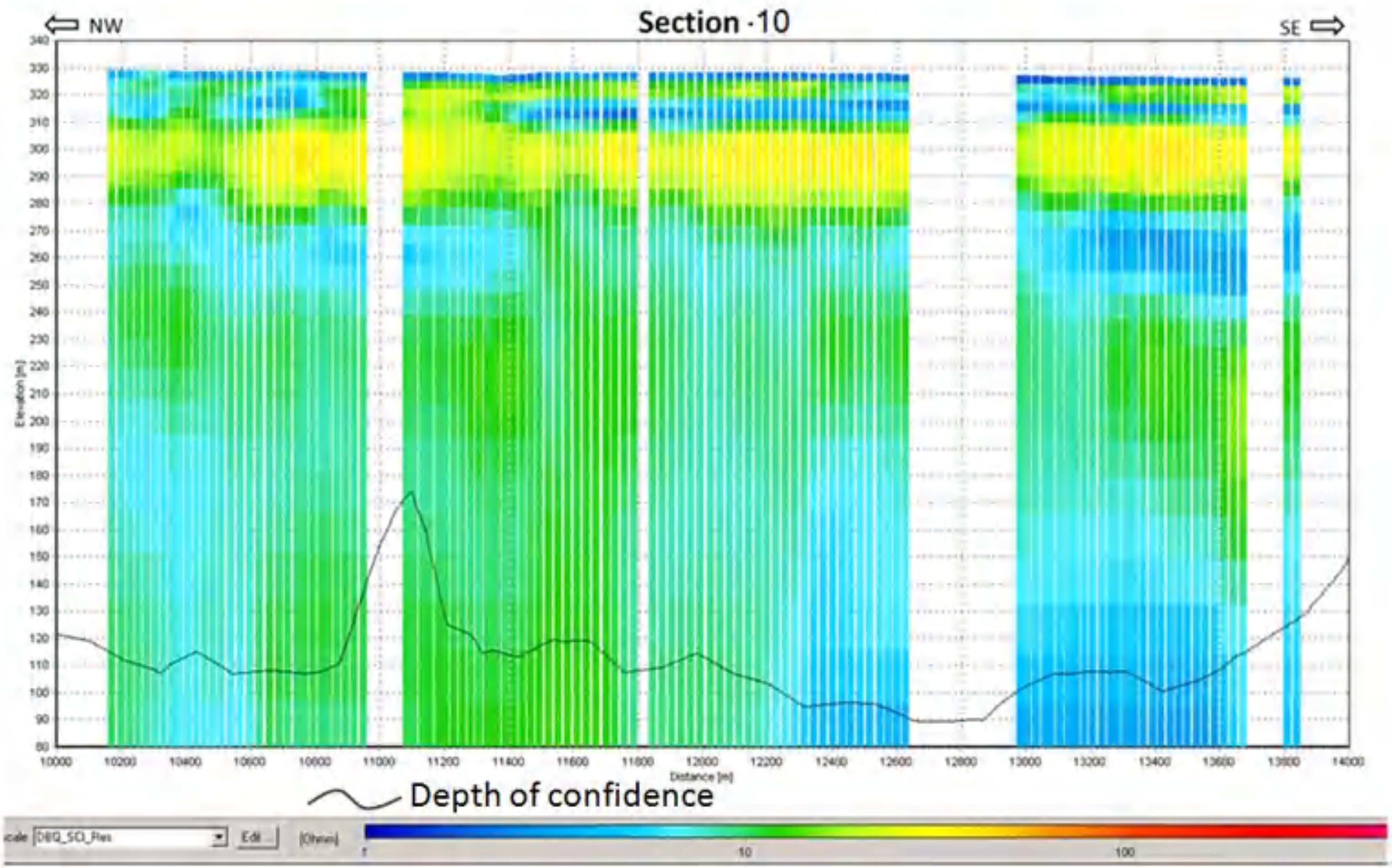

Section - 6
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohm m]
1
10
100

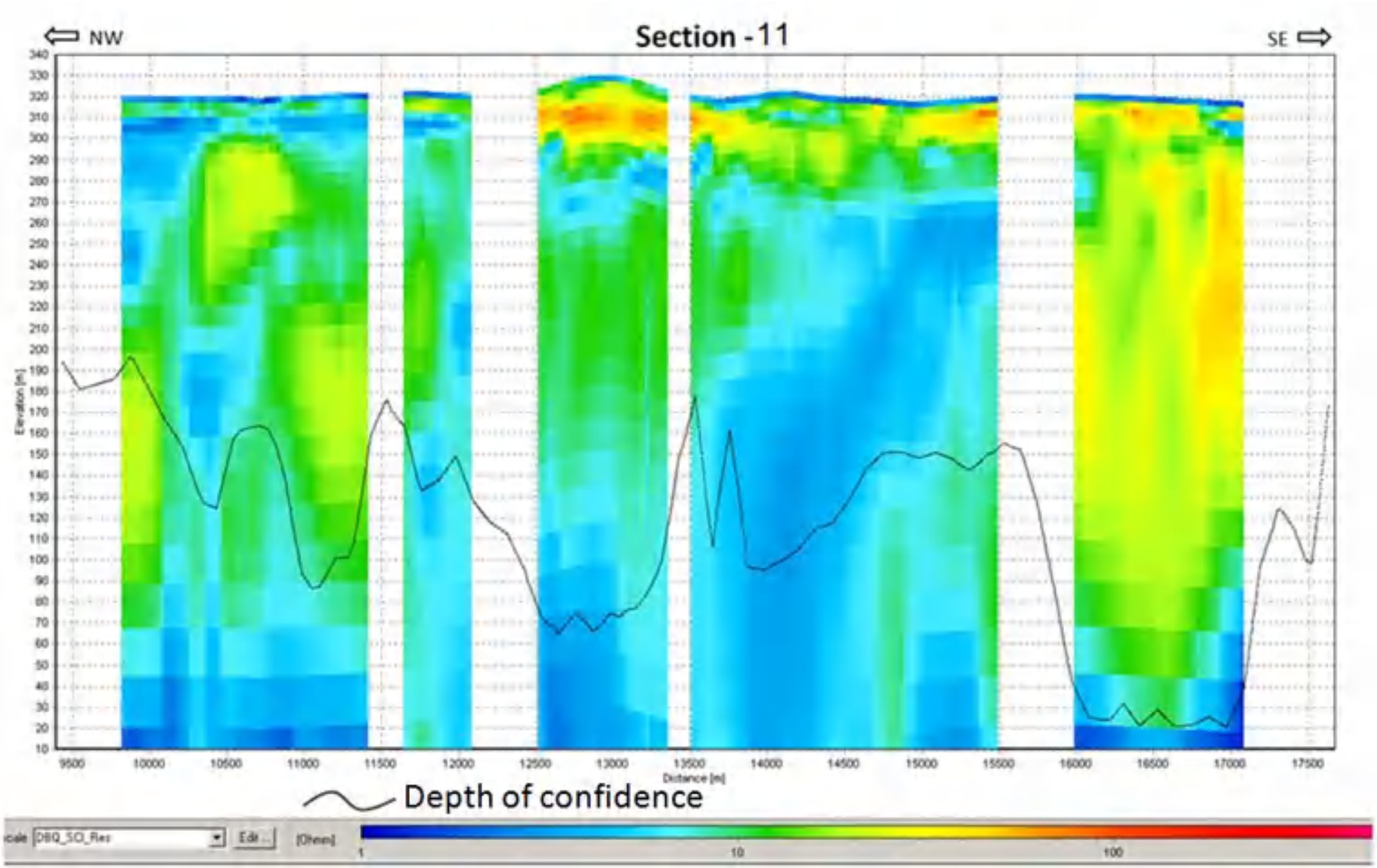

NW
Section - 7
SE
Elevation [m]
Distance [m]
Depth of confidence
DBQ_SCI_Res
Edit
[Ohmm]
1
10
100

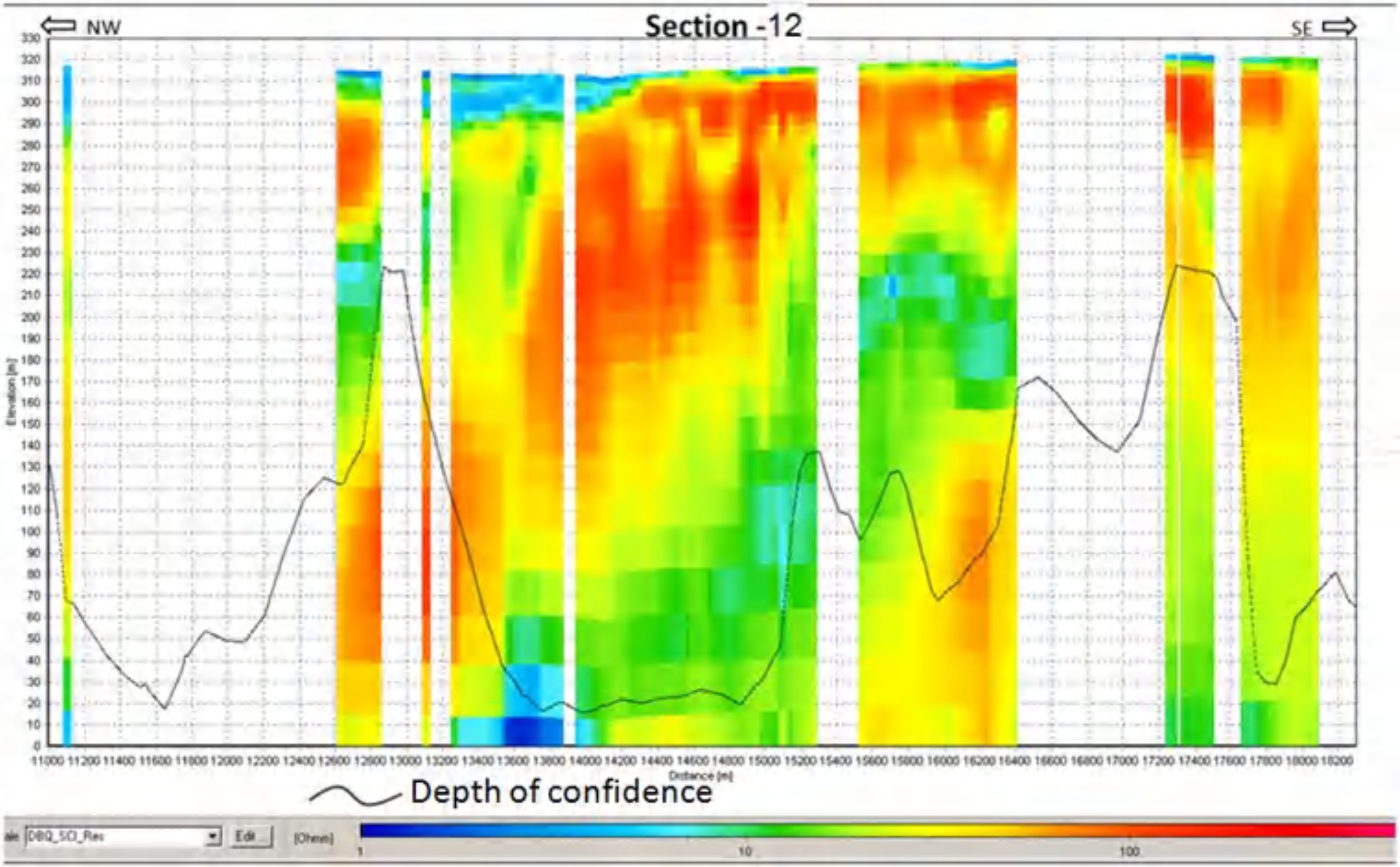

Section - 8
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]

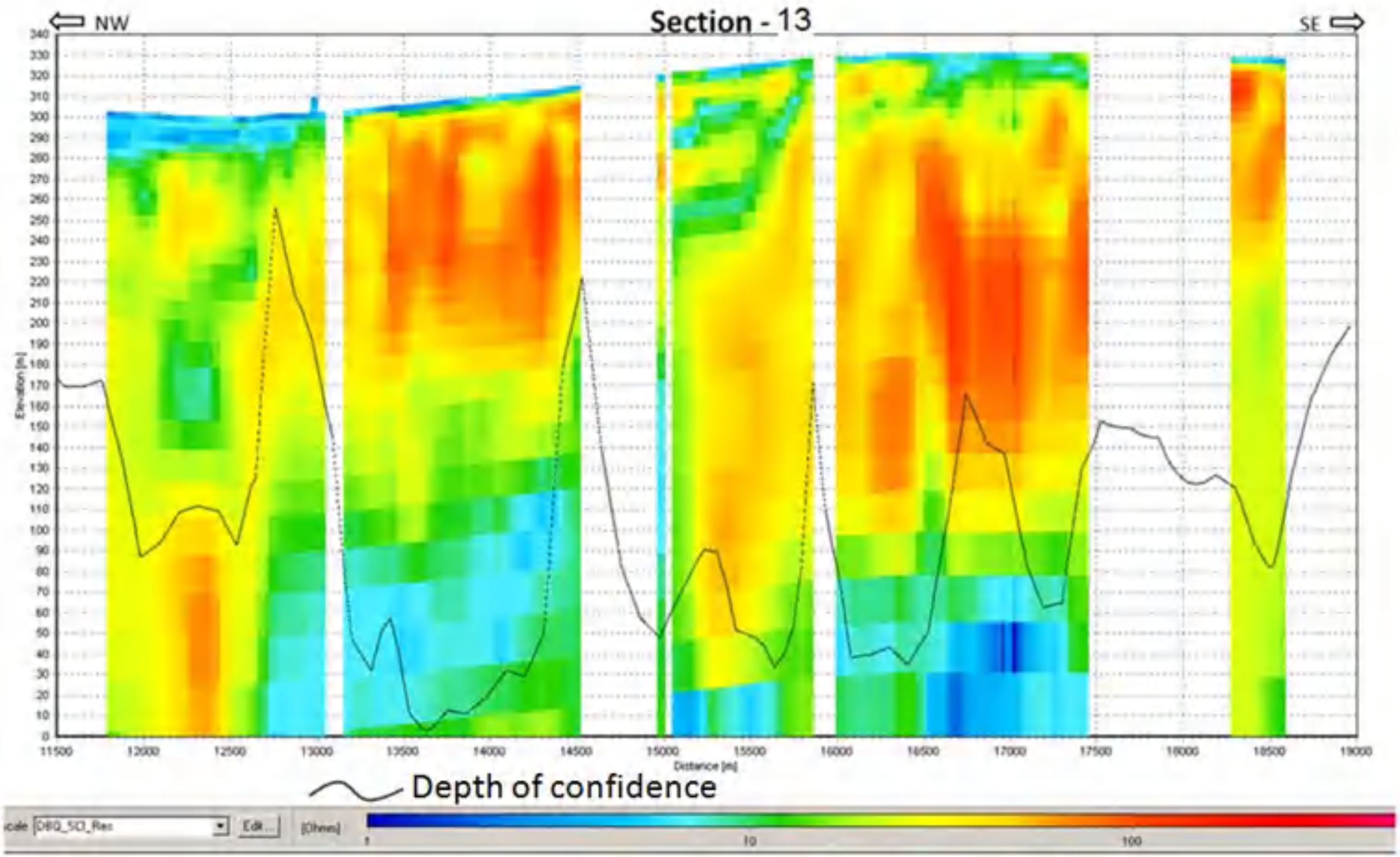


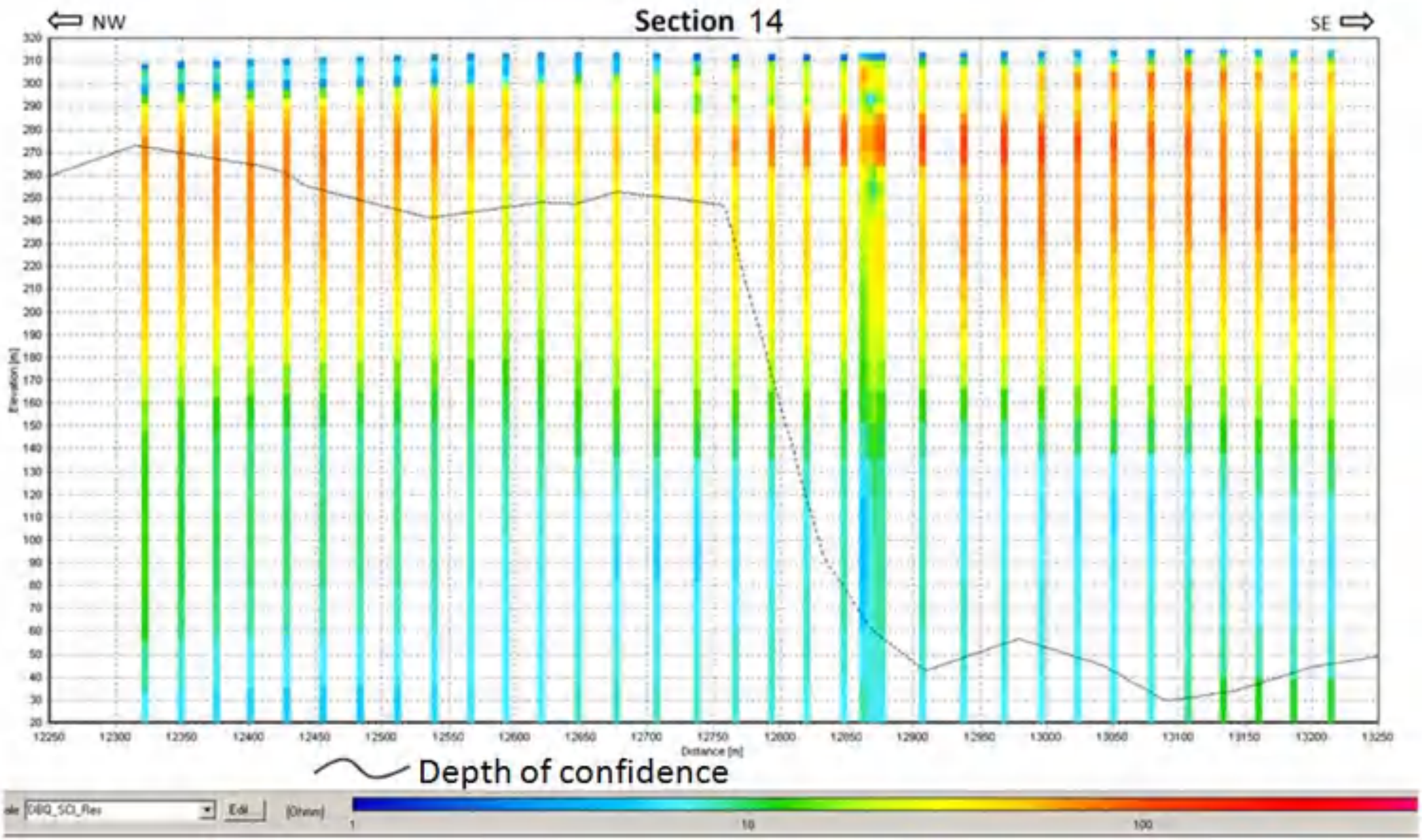
NW
Section - 9
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100


Section -10
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
(Ohm-m)
1
10
100


Section - 11
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
10
100


Section -12
NW
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohmm]
1
10
100


NW
Section - 13
SE
Elevation [m]
Distance [m]
Depth of confidence
[Ohms]
1
10
100


NW
Section 14
SE
Elevation [m]
Distance [m]
Depth of confidence
DBQ_SCI_Res
Edit
[Ohmm]
1
10
100

ANNEXURE-XVI: Mean Resistivity maps, Chandrabhaga Watershed (NGRI, 2015b)

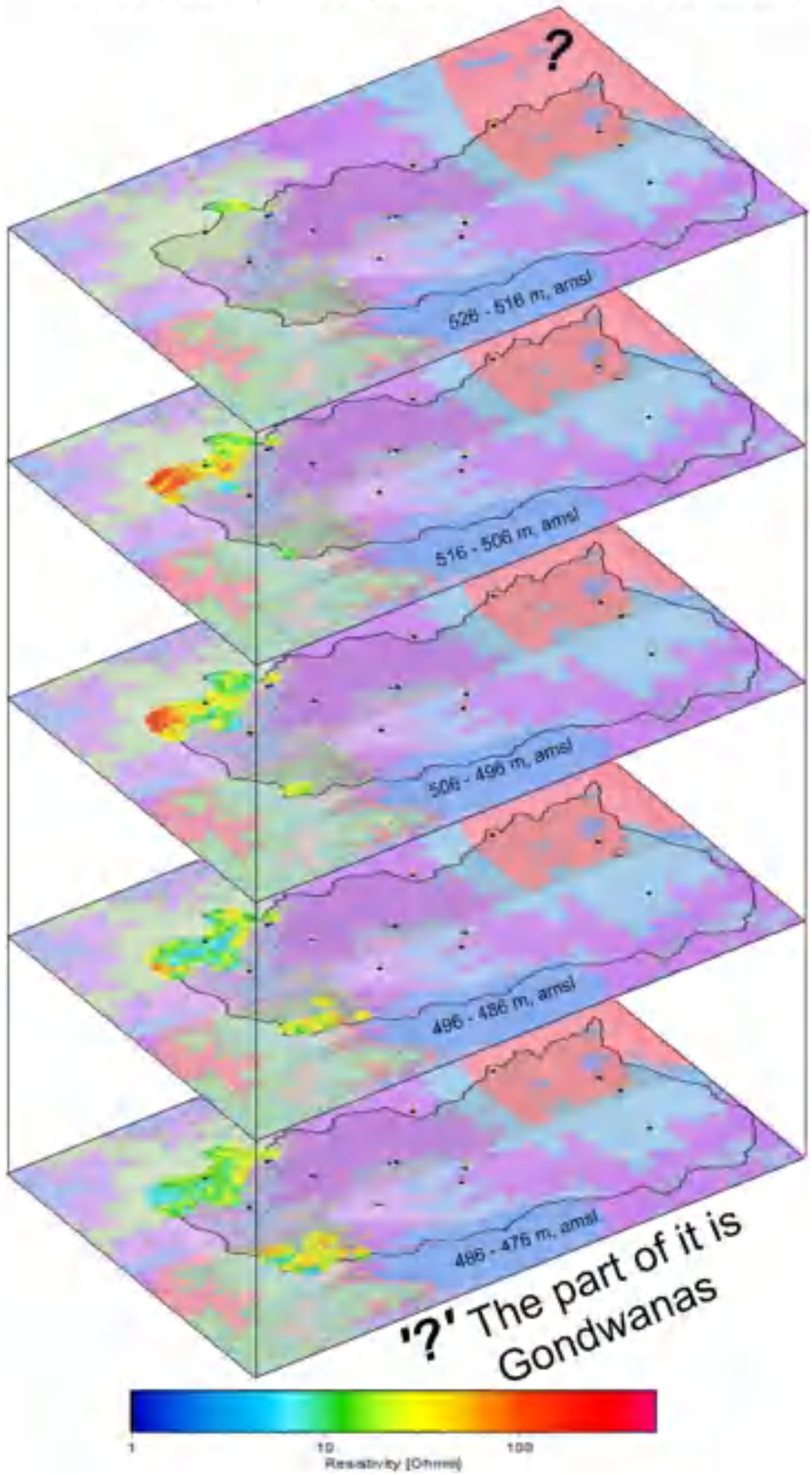
This appendix shows mean resistivity maps generated from the smooth model inversion result. The inversion result consists of a large number of 1D-models described by depth intervals (i.e. layers) and resistivities within each model. These are then normally used to calculate mean resistivities to obtain a visualization of the resistivity distribution in the mapping area.

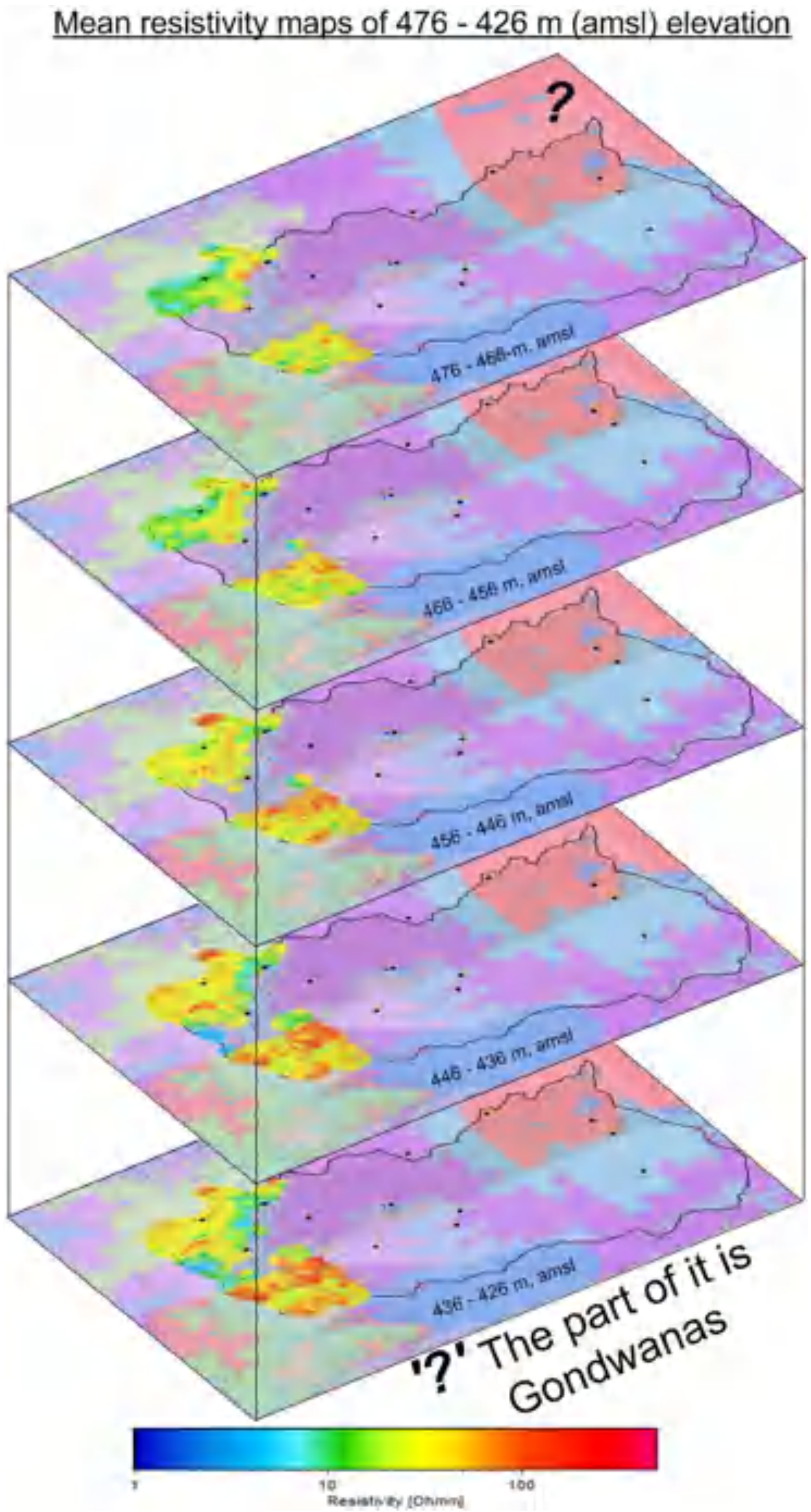
The mean resistivity maps have been generated with 10 m elevation intervals from 526 m top to 6 m down above mean sea level. Thus a total of 42 mean resistivity maps have been generated with 10 m interval and arranged one below another in descending order. Models below the DOC lower have been blinded. The gridding is done using the Kriging method, with a node spacing of 30 m and a search radius of 200 m. The nodes have further been subdivided by a factor of 3 to obtain the interpolated resistivity pixels for the bitmaps that make up the maps.

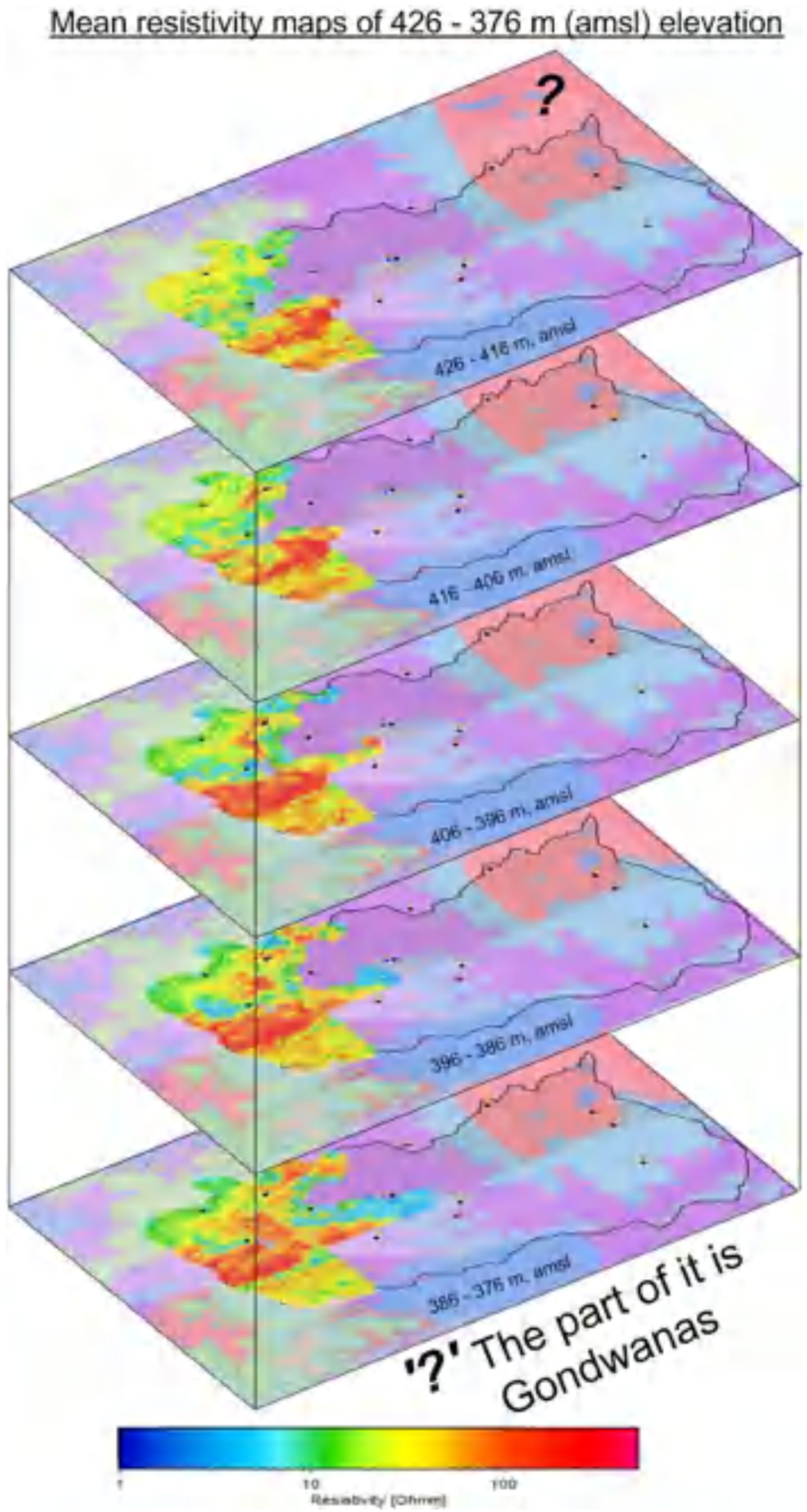
The interpretation of mean resistivity maps denotes that the flow no. 27 and 26 in the western part extends up to 50 m depth which covered in mean resistivity maps of 476-526 m, amsl. Similarly, the subsequent flows are also identified with each flow thickness range 20-40 m. The depth wise mean resistivity maps also follow the step like topography on regional scale sloping towards north-east. Moreover, the exposed Gondwanas in the north-east of study area is clearly demarcated from its lateral basalt contact with the relative low resistivity obtained on the mean resistivity maps of 306-326 m, amsl. This elevation is also well correlates with the topographic elevation of surface Gondwanas in the N-E part.

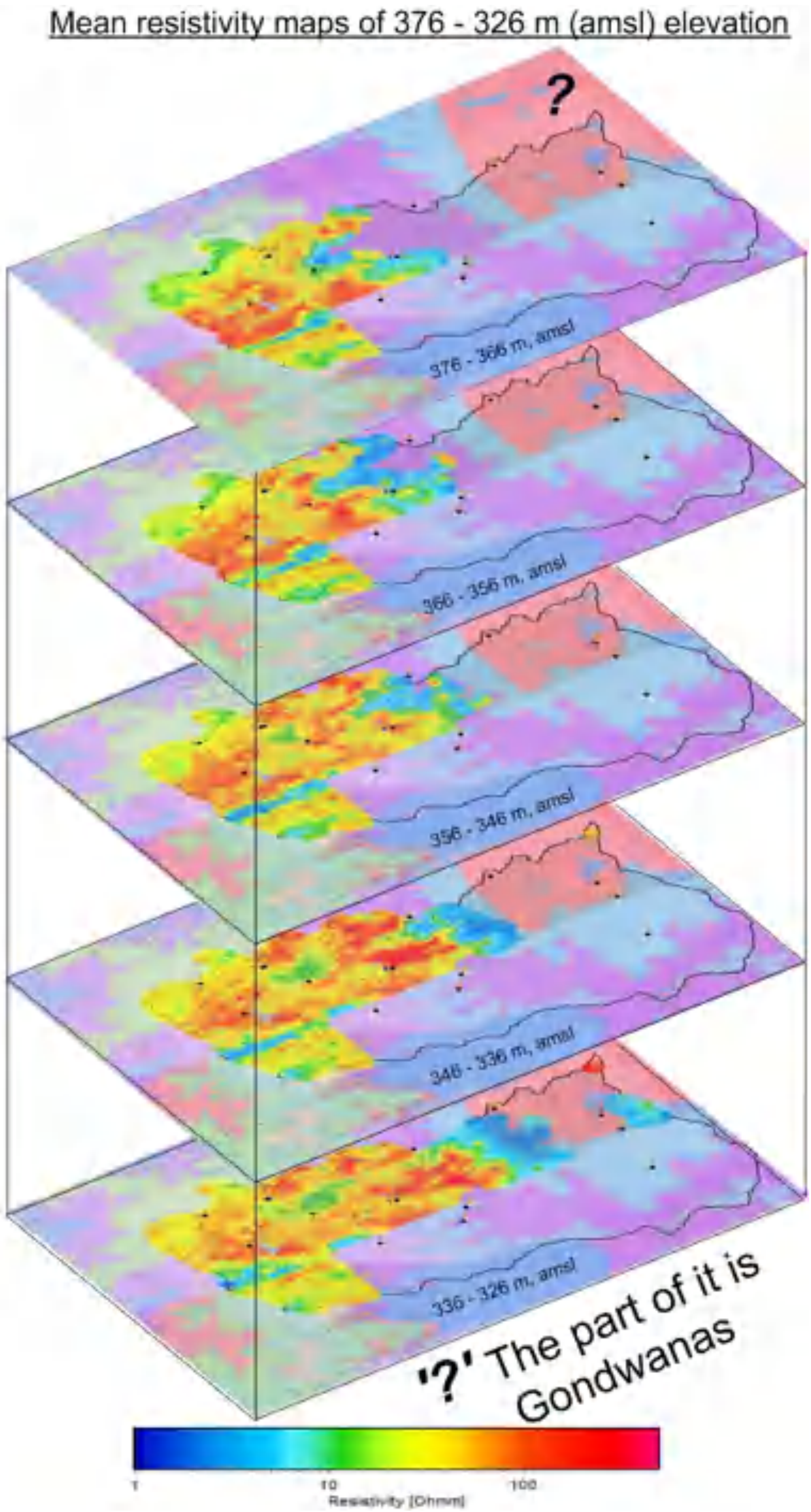
The regional fault which is abutting in the SW part with its orientation SE-NW is successfully delineated in the mean resistivity maps of below 486 m, amsl. The relative high resistivity anomaly trending in NW-SE direction in the central part has been observed at the depth of 216-116 m, amsl which is also matching with the maps of gravity and magnetic anomalies has to be resolved. The depth wise spatial variations acquired in the mean resistivity maps have been imperative in view of mapping aquifer zones which corresponds the relative low resistivity.

Mean resistivity maps of 526 - 476 m (amsl) elevation

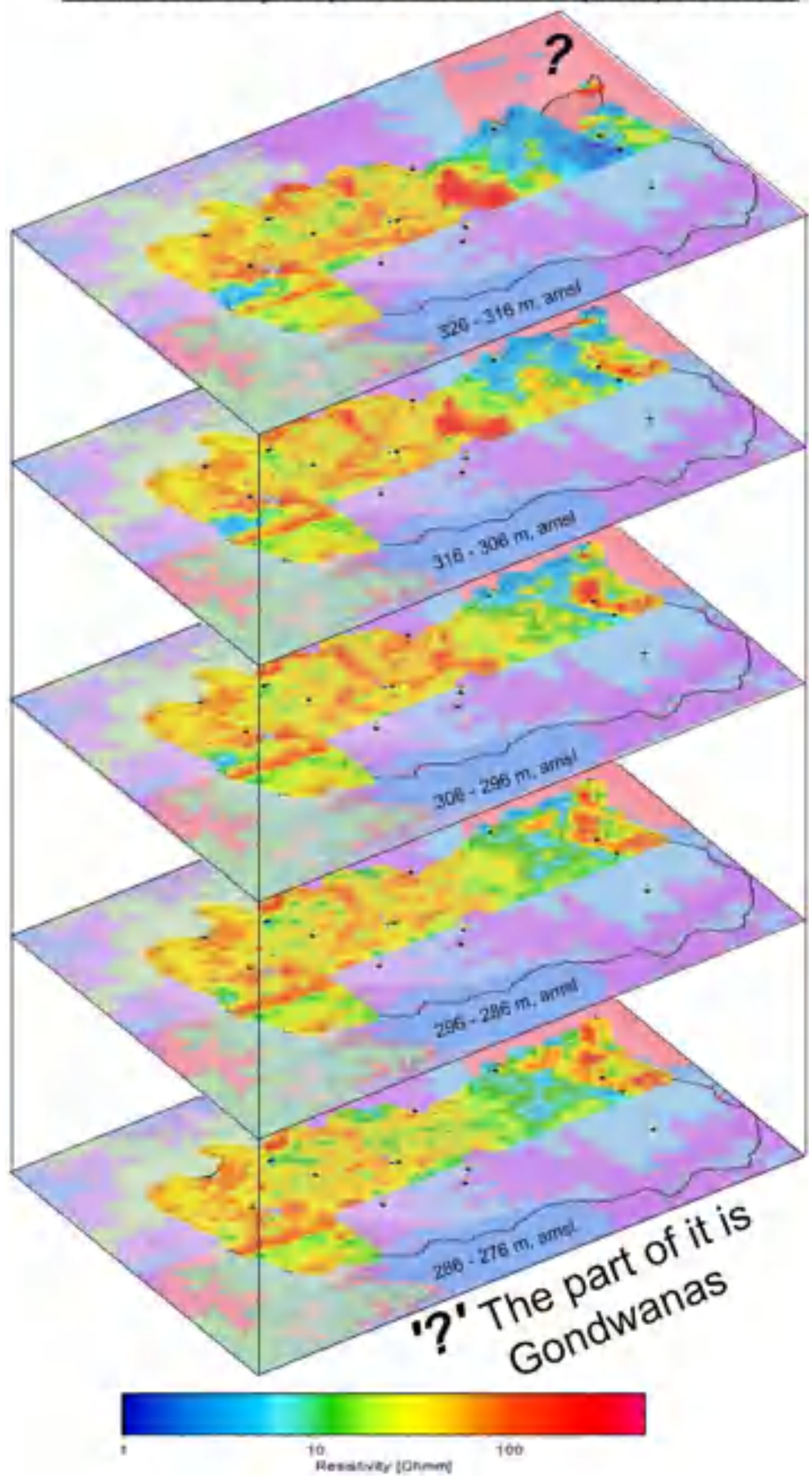



Mean resistivity maps of 476 - 426 m (amsl) elevation
?
476 - 466 m. amsl
466 - 456 m. amsl
456 - 446 m. amsl
446 - 436 m. amsl
436 - 426 m. amsl
'?' The part of it is Gondwanas
1
10
100
Resistivity [Ohmm]

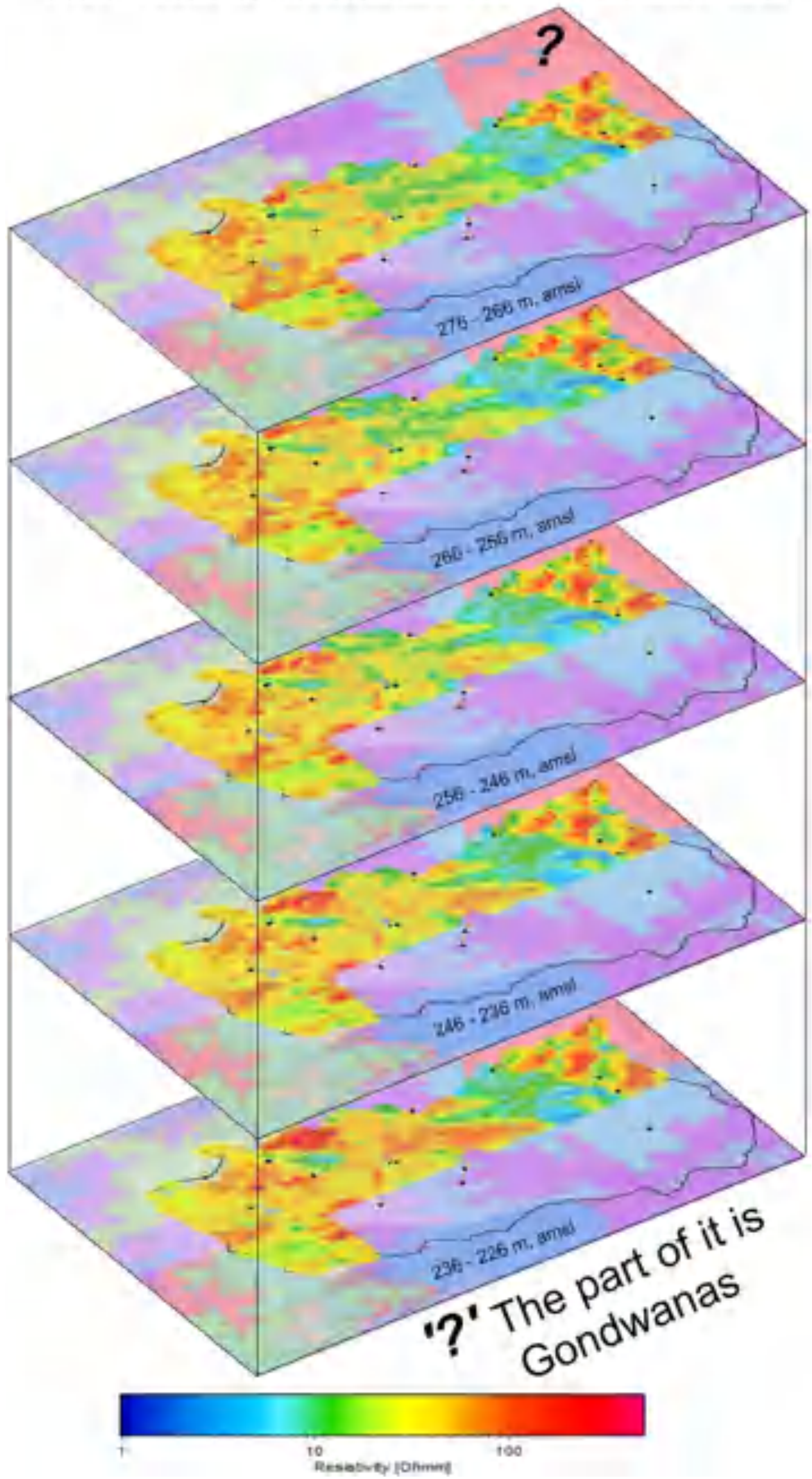

Mean resistivity maps of 426 - 376 m (amsl) elevation
?
426 - 416 m, amsl
416 - 406 m, amsl
406 - 396 m, amsl
396 - 386 m, amsl
386 - 376 m, amsl
'?' The part of it is Gondwanas
1
10
100
Resistivity [Ohmm]


Mean resistivity maps of 376 - 326 m (amsl) elevation
?
376 - 366 m, amsl
366 - 356 m, amsl
356 - 346 m, amsl
346 - 336 m, amsl
336 - 326 m, amsl
'?' The part of it is Gondwanas
1
10
100
Resistivity [Ohmm]

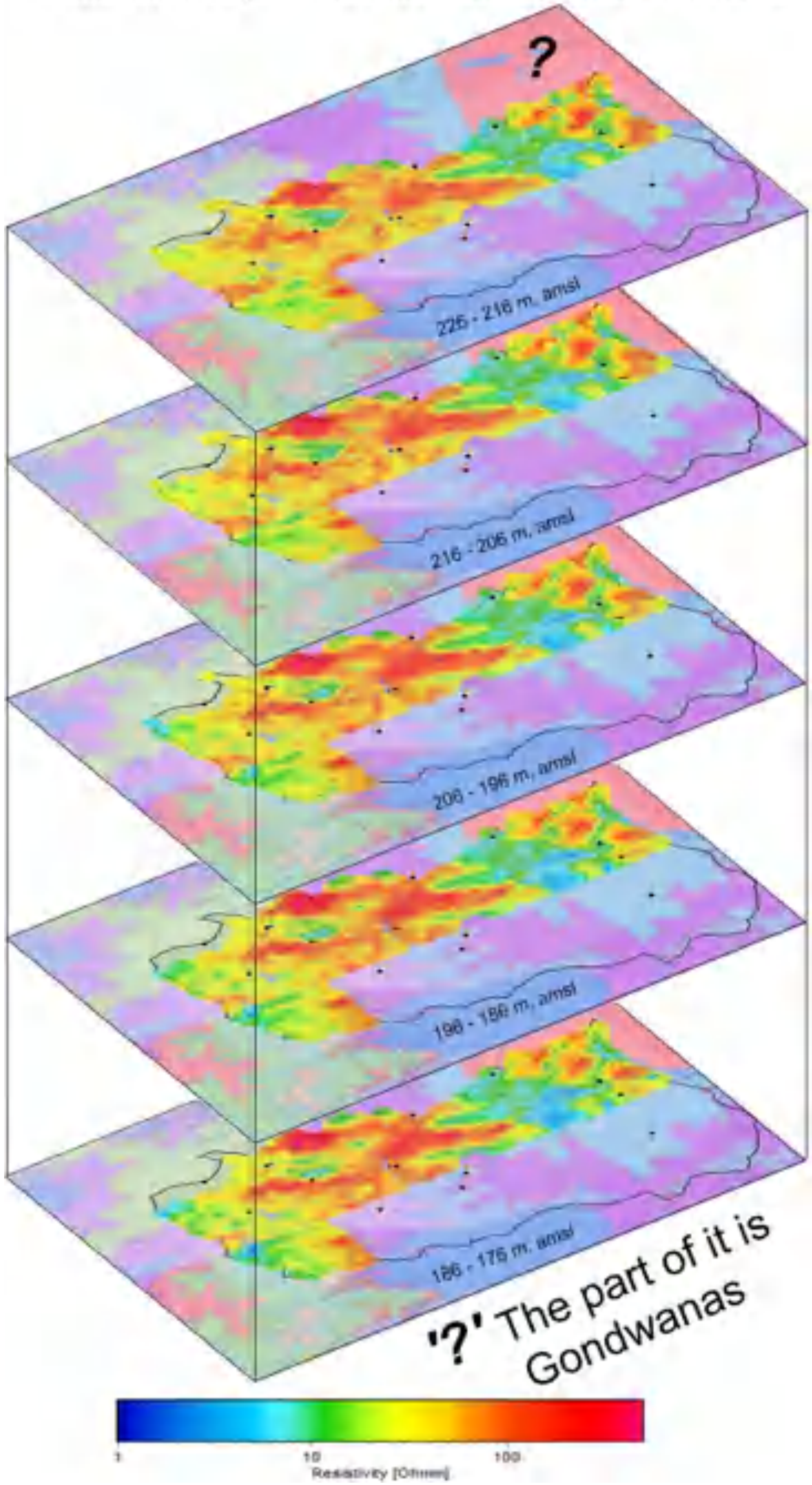
Mean resistivity maps of 326 - 276 m (amsl) elevation



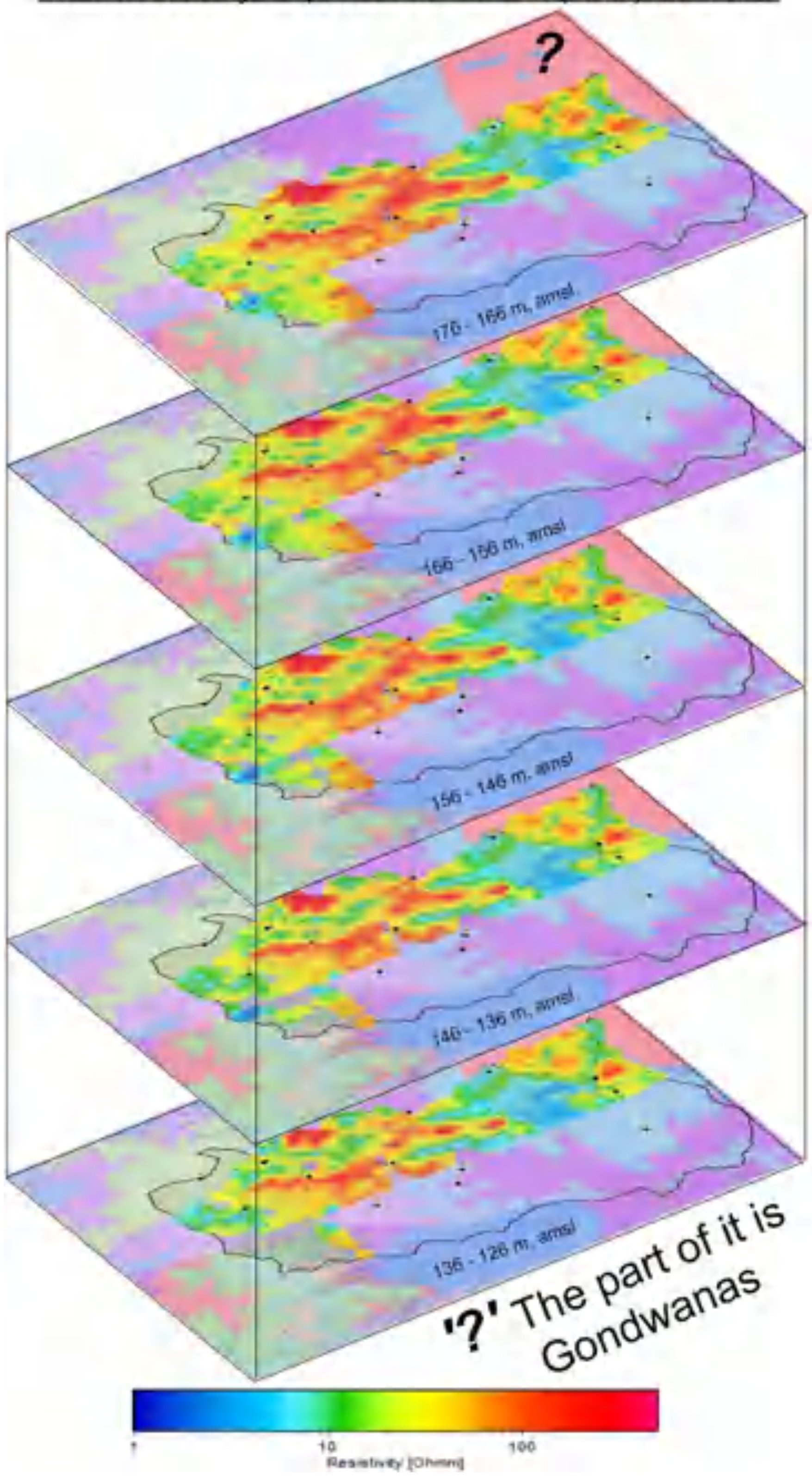
Mean resistivity maps of 276 - 226 m (amsl) elevation



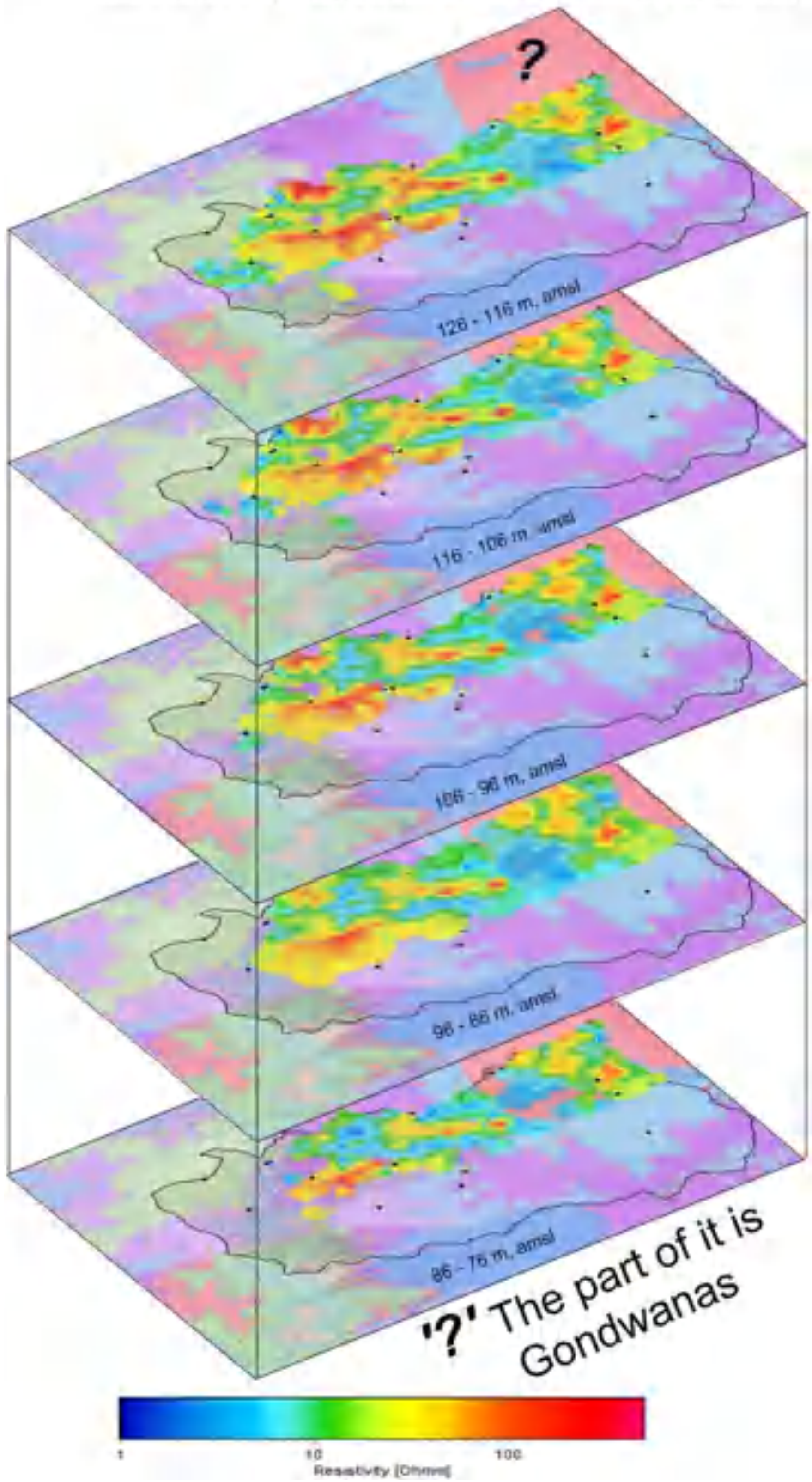
Mean resistivity maps of 226 - 176 m (amsl) elevation



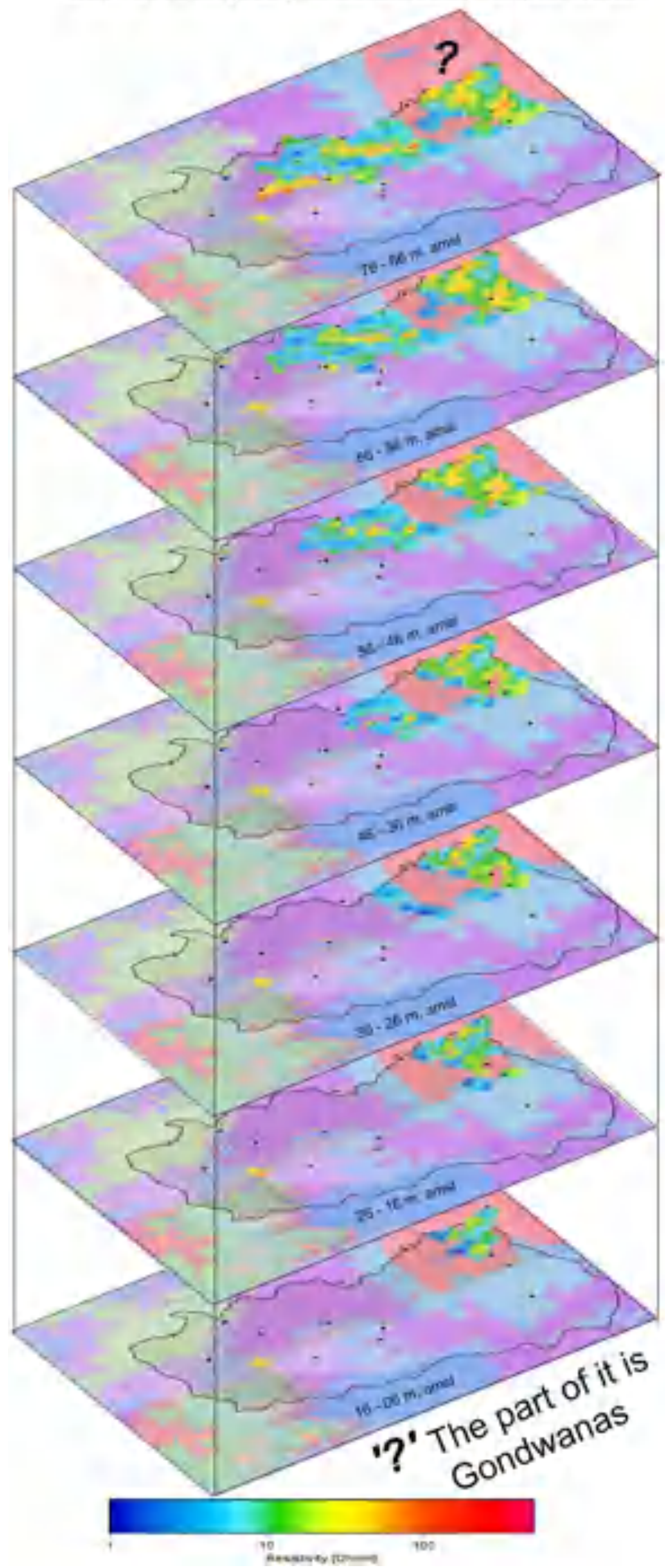
Mean resistivity maps of 176 - 126 m (amsl) elevation



Mean resistivity maps of 126 - 76 m (amsl) elevation



Mean resistivity maps of 76 - 06 m (amsl) elevation



ANNEXURE-XVII: Georeferenced elevation of the principal hydrogeological layers at each node of the grids of the AQMAH study area (NGRI, 2015b)

Sl. No	Coordinates (UTM)		Grid Info & RL (m, AMSL)	Possible formation thickness (m, AMSL)	Gondwana depth (m, AMSL)	Aquifer Thickness (m, AMSL)	Remarks
	X	Y					
1	261350	2357786	I, 2 RL= 511	V & M Basalt = 511-311	Below 311	Aq1 = 382-371	Aquifer in F.A.B
2	265230	2359367	I, 4 RL= 466	V & M basalt = 466-266	Below 266	Aq1 =378-369	Aquifer in F.A.B
3	260189	2355108	II, 1 RL = 432	V & M basalt = 432-181	181	Aq1 = 389-383	Aquifer in F.A.B
4	262254	2355985	II, 2 RL = 459	V & M basalt = 459-182	182	Aq1 = 380-371	Aquifer in F.A.B
5	264179	2356712	II, 3 RL = 509	V & M basalt = 509-132	132	Aq1 = 386-379	Aquifer in F.A.B
6	266161	2357540	II, 4 RL = 506	V & M basalt = 506-143	143	Aq1 = 340-323	Aquifer in F.A.B
7	261120	2353281	III, 1 RL = 441	V & M basalt = 441-155	155	Aq1 = 430-422 Aq2 = 360-353	Aquifer in F.A.B. Aquifer in F.A.B.
8	263157	2354108	III, 2 RL = 439	V & M basalt = 439-203	203	Aq1 = 382-370 Aq2 = 326-315	Aquifer in F.A.B. Aquifer in F.A.B.
9	265084	2354911	III, 3 RL = 412	V & M basalt = 412-156	156	Aq1 = 350-342	Aquifer in F.A.B.
10	267037	2355664	III, 4 RL = 401	V & M basalt = 401-207	207	Aq1 = Non-aquifer	Non-aquifer A. B
11	268964	2356518	III, 5 RL = 395	V & M basalt = 395-138	138	Aq1 = Non-aquifer	Non-aquifer A. B
12	270890	2357272	III, 6 RL = 382	V & M basalt = 382-126	126	Aq1 = Non-aquifer	Non-aquifer A. B
13	262051	2351429	IV, 1 RL = 402	V & M basalt = 402-218	218	Aq1 = 399-396 Aq2 = 373-367 Aq3 = 331-325	Aquifer in F.A.B. Aquifer in F.A.B. Aquifer in F.A.B.
14	264088	2352281	IV, 2 RL = 378	V & M basalt = 378-149	149	Aq1 = 374-373 Aq2 = 347-337 Aq3 = 307-297	Aquifer in F.A.B. Aquifer in F.A.B. Aquifer in F.A.B.
15	265987	2353059	IV, 3 RL = 368	V & M basalt = 368-148	148	Aq1 = 342-336	Aquifer in F.A.B.
16	267969	2353888	IV, 4 RL = 344	V & M basalt = 344-69	69	Aq1 = 195-194 Aq2 = 181-180	Aquifer in F.B. Aquifer in F.B
17	269785	2354618	IV, 5 RL = 336	V & M basalt = 336-174	174	Aq1 = 224-223 Aq2 = 122-118	Aquifer in F.B. Aquifer in TCG
18	271766	2355421	IV, 6 RL = 327	V & M basalt = 327-124	124	Aq1 = 113-108	Aquifer in TCG
19	273693	2356251	IV, 7 RL = 325	V & M basalt = 325-110	110	Aq1 = 92-85	Aquifer in TCG
20	275591	2357005	IV, 8 RL = 327	V & M basalt = 327-194	194	Aq1 = 167-148 Aq2 = 128-122 Aq3 = 115-108	Aquifer in TCG Aquifer in TCG Aquifer in TCG
21	262960	2349590	V, 1 RL = 480	V & M basalt = 480-416	416	Aq1 = 415-407	Aquifer in TCG
22	264985	2350435	V, 2 RL = 465	V & M basalt = 465-333	333	Aq1 = 333-320 Aq2 = 314-299 Aq3 = 289-278	Aquifer in TCG Aquifer in TCG Aquifer in TCG
23	266919	2351240	V, 3 RL = 417	V & M basalt = 417-313	313	Aq1 = 313-295 Aq2 = 289-274	Aquifer in TCG Aquifer in TCG
24	268852	2352024	V, 4 RL = 394	V & M basalt = 394-259	259	Aq1 = 259-213 Aq2 = 202-178	Aquifer in TCG Aquifer in TCG
25	270740	2352810	V, 5 RL = 382	V & M basalt = 382-180	180	Aq1 = 183-166 Aq2 = 158-148 Aq2 = 141-133	Aquifer in TCG Aquifer in TCG Aquifer in TCG
26	272650	2353574	V, 6 RL = 367	V & M basalt = 367-206	206	Aq1 = 205-189 Aq2 = 183-174 Aq3 = 168-159	Aquifer in TCG Aquifer in TCG Aquifer in TCG
27	274606	2354379	V, 7	V & M basalt +	231	Aq1 = 220-200	Aquifer in TCG

			RL = 353	Clay = 353-231		Aq2 = 181-171	Aquifer in TCG
						Aq3 = 153-139	Aquifer in TCG
28	276516	2355186	V, 8 RL = 341	V & M basalt + Clay = 341-219	219	Aq1 = 209-186	Aquifer in TCG
						Aq2 = 168-158	Aquifer in TCG
						Aq3 = 150-142	Aquifer in TCG
29	263883	2347765	VI, 1 RL = 480	V & M basalt + Clay = 480-328	328	Aq1 = 322-297	Aquifer in TCG
						Aq2 = 279-262	Aquifer in TCG
30	265908	2348569	VI, 2 RL = 473	V & M basalt + Clay = 473-323	323	Aq1 = 321-292	Aquifer in TCG
						Aq2 = 236-216	Aquifer in TCG
						Aq3 = 172-158	Aquifer in TCG
31	267843	2349416	VI, 3 RL = 419	V & M basalt + Clay = 419-248	248	Aq1 = 247-235	Aquifer in TCG
						Aq2 = 214-197	Aquifer in TCG
						Aq3 = 179-170	Aquifer in TCG
32	269753	2350138	VI, 4 RL = 396	V & M basalt + Clay = 396-244	244	Aq1 = 244-230	Aquifer in TCG
						Aq2 = 221-194	Aquifer in TCG
						Aq3 = 179-171	Aquifer in TCG
33	271664	2350944	VI, 5 RL = 379	V & M basalt + Clay = 379-237	237	Aq1 = 237-215	Aquifer in TCG
						Aq2 = 212-196	Aquifer in TCG
						Aq3 = 181-171	Aquifer in TCG
34	273598	2351750	VI, 6 RL = 379	V & M basalt + Clay = 379-236	236	Aq1 = 235-217	Aquifer in TCG
						Aq2 = 210-197	Aquifer in TCG
						Aq3 = 183-175	Aquifer in TCG
35	275531	2352535	VI, 7 RL = 364	V & M basalt + Clay = 364-277	277	Aq1 = 272-264	Aquifer in TCG
						Aq2 = 230-217	Aquifer in TCG
						Aq3 = 181-174	Aquifer in TCG
36	277418	2353321	VI, 8 RL = 355	V & M basalt + Clay = 355-300	300	Aq1 = 295-290	Aquifer in TCG
						Aq2 = 248-236	Aquifer in TCG
						Aq3 = 163-149	Aquifer in TCG
37	279351	2354128	VI, 9 RL = 339	V & M basalt = 339-319	319	Aq1 = 320-308	Aquifer in TCG
						Aq2 = 284-272	Aquifer in TCG
						Aq3 = 193-187	Aquifer in TCG
38	281283	2354893	VI, 10 RL = 334	V & M basalt = 334-322	322	Aq1 = 322-314	Aquifer in TCG
						Aq2 = 247-223	Aquifer in TCG
						Aq3 = 170-163	Aquifer in TCG
39	283170	2355679	VI, 11 RL = 324	Exposed Gondwana (Alluvial soil +Sandstone + Shale) = 324 and below	324	Aq1 = 245-238	Aquifer in F. G
						Aq2 = 209-203	Aquifer in F. G
						Aq3 = 184-178	Aquifer in F. G
						Aq4 = 169-162	Aquifer in F. G
						Aq5 = 151-137	Aquifer in F. G
40	285125	2356507	VI, 12 RL = 319	Exposed Gondwana (Alluvial soil +Sandstone + Shale) = 319 and below	319	Non –Aquifer zone	Alternate layers of Massive Sandstone + Shale
41	268743	2347509	VII, 3 RL = 398	Exposed Gondwana (Alluvial soil +Sandstone + Shale) = 398 and below	398	Aq1 = 259-238	Alternate layers of Massive Sandstone + Shale
42	270723	2348314	VII, 4 RL = 383	V & M basalt + Clay = 383-288	288	Non-Aquifer	Non Aquifer
43	272611	2349120	VII, 5 RL = 379	V & M basalt + Clay = 379- below 220	Below 220	Aq1 = 338-337	Aquifer in W. B
						Aq2 = 330-329	Aquifer in F. B
44	274477	2349948	VII, 6 RL = 365	V & M basalt + Clay = 365-below 220	Below 220	Aq1 = 352-351	Aquifer in W. B
						Aq2 = 344-343	Aquifer in F. B
45	276410	2350733	VII, 7 RL = 360	V & M basalt + Clay	250	Aq1 = 239-232	Aquifer in TCG
						Aq2 = 224-218	Aquifer in TCG

				= 360-250		Aq3 = 214-208	Aquifer in TCG
46	278344	2351539	VII, 8 RL = 340	V & M basalt + Clay = 340-240	240	Aq1 = 238-228	Aquifer in TCG
						Aq2 = 218-201	Aquifer in TCG
						Aq3 = 191-178	Aquifer in TCG
47	280298	2352262	VII, 9 RL = 338	V & M basalt + Clay = 338-266	266	Aq1 =264-248	Aquifer in TCG
						Aq2 = 144-134	Aquifer in TCG
						Aq3 = 126-117	Aquifer in TCG
48	282186	2353090				Aq4 =89-68	Aquifer in TCG
			VII, 10 RL = 327	V & M basalt + bole beds = 327-280	280	Aq1 = 289-280	Aquifer in B-G contact
						Aq2 = 252-231	Aquifer in TCG
						Aq3 = 221-207	Aquifer in TCG
						Aq4 =185-163	Aquifer in TCG
49	284096	2353898	VII, 11 RL = 320	V & M basalt + bole beds = 320-294	294	Aq1 = 301-294	Aquifer in B-G contact
						Aq2 = 266-252	Aquifer in TCG
						Aq3 = 214-199	Aquifer in TCG
						Aq4 =193-168	Aquifer in TCG
50	286028	2354705	VII, 12 RL = 323	Exposed Gondwana = 323	323	Aq1 = 40-19	F. Sandstone
51	287937	2355471	VII, 13 RL = 306	Exposed Gondwana = 306	306	Aq1 = 70-39	F. Sandstone
52	271602	2346470	VIII, 4 RL = 391	Exposed Gondwana = 391	391	Aq1 = 328-305	F. Sandstone
53	273491	2347276	VIII, 5 RL =371	V & M basalt + bole beds = 371-294	294	Aq1 = 294-290	Aquifer in B-G contact
54	275447	2348082	VIII, 6 RL =360	V & M basalt + bole beds = 360- below 263	Below 263	Aq1 = 352-351	Aquifer in W.B.
						Aq1 = 344-343	Aquifer in F.A.B.
55	277379	2348805	VIII, 7 RL = 352	V & M basalt + bole beds = 352-below 279	Below 279	Aq1 = 279-274	Aquifer in B-G contact
56	279223	2349675	VIII, 8 RL = 345	V & M basalt + bole beds = 345-285	285	Aq1 = 285-281	Aquifer in B-G contact
57	281246	2350439	VIII, 9 RL = 336	V & M basalt + bole beds = 336-276	276	Aq1 = 276-274	Aquifer in B-G contact
58	283133	2351184	VIII, 10 RL = 327	V & M basalt + bole beds = 327-266	266	Aq1 = 266-264	Aquifer in B-G contact
59	285043	2352012	VIII, 11 RL = 322	V & M basalt = 322-276	276	Aq1 = 276-272	Aquifer in B-G contact
60	286908	2352799	VIII, 12 RL = 319	Exposed Gondwana (Sandstone + Shale) = 319 and below	319	Aq1 = 291-279	Alternate layers of Massive Sandstone + Shale
						Aq2 = 275-264	
						Aq3 = 251-244	
						Aq4 = 205-198	
						Aq5 = 186-175	
61	288840	2353607	VIII, 13 RL = 330	Exposed Gondwana (Sandstone + Shale) = 330 and below	330	Aq1 = 298-293	Alternate layers of Massive Sandstone + Shale
						Aq2 = 273-260	
62	274415	2345432	IX, 5 RL = 380	Exposed Gondwana (Sandstone + Shale) = 380 and below	380	Aq2 = 376-372	F. Sandstone
63	276394	2346237	IX, 6 RL = 367	V & M basalt + bole beds = 367-309	309	Aq1 = 309-304	Aquifer in B-G contact
64	278305	2347023	IX, 7 RL = 356	V & M basalt + bole beds	297	Aq1 = 297-294	Aquifer in B-G contact

				= 356-297			
65	280171	2347831	IX, 8 RL = 346	V & M basalt + bole beds = 346-287	287	Aq1 = 287-285	Aquifer in B-G contact
66	282126	2348595	IX, 9 RL = 351	V & M basalt + bole beds = 351-292	292	Aq1 = 292-287	Aquifer in B-G contact
67	283992	2349403	IX, 10 RL = 330	V & M basalt + bole beds = 330-254	254	Aq1 = 323-319 Aq2 = 254-250	Aquifer W. V. B Aquifer in B-G contact
68	285970	2350210	IX, 11 RL = 326	V & M basalt + bole beds = 326-250	250	Aq1 = 319-315 Aq2 = 250-254	Aquifer W. V. B Aquifer in B-G contact
69	287857	2350976	IX, 12 RL = 322	V & M basalt + bole beds = 322-305	305	Aq1 = 314-310 Aq2 = 305-301	Aquifer W. V. B Aquifer in B-G contact
70	289743	2351743	IX, 13 RL = 335	V & M basalt + bole beds = 335-330	330	Aq1 = 330-327	Aquifer in B-G contact
71	279185	2345138	X, 7 RL = 368	Exposed Gondwana (Sandstone + Shale) = 368 and below	368	Aq1 = 315-307	Aquifer in F. G
72	281141	2345924	X, 8 RL = 356	V & M basalt + bole beds = 356-215	215	Aq1 = 215-211	Aquifer in B-G contact
73	283052	2346752	X, 9 RL = 339	V & M basalt + bole beds = 339-221	221	Aq1 = 336-228 Aq1 = 221-217	Aquifer in W.V.B Aquifer in B-G contact
74	284939	2347518	X, 10 RL = 333	V & M basalt + bole beds = 333-245	245	Aq1 = 334-227 Aq1 = 245-242	Aquifer in W.V.B Aquifer in B-G contact
75	286918	2348345	X, 11 RL = 335	V & M basalt + bole beds = 335-245	245 Followed by Lametas (245-205) And Archaeans at 205 and below	Aq1 = 326-323 Aq1 = 318-314 Aq1 = 278-275 Aq1 = 224-221	Aquifer in F. W.B Aquifer in F. W.B Aquifer in F. W.B Aquifer in F. W.B
76	288805	2349112	X, 12 RL = 335	V & M basalt + bole beds = 335-290	290 followed by Lametas and Archaeans	Aq1 = 326-323 Aq1 = 318-314	Aquifer in F. W.B Aquifer in F. W.B
77	290692	2349920	X, 13 RL = 336	V & M basalt + bole beds = 336-328	328 followed by Lametas and Archaeans	Aq1 = 328-324	Aquifer in contact Basalt-Archaean
78	281977	2344164	XI, 8 RL = 355	V & M basalt + bole beds = 355-280	280	Aq1 = 340-336 Aq1 = 280-276	Aquifer in F. W.B Aquifer in B-G contact
79	283978	2344949	XI, 9 RL = 344	V & M basalt + bole beds = 344-270	270	Aq1 = 334-330 Aq1 = 270-267	Aquifer in F. W.B Aquifer in B-G contact
80	285821	2345737	XI, 10 RL = 342	V & M basalt + bole beds = 342-268	268 followed by Lametas and Archaeans	Aq1 = 330-326 Aq1 = 268-264	Aquifer in F. W.B Aquifer in Basalt -Gneiss contact
81	287799	2346544	XI, 11 RL = 347	V & M basalt + bole beds = 347-276	276 followed by Lametas and Archaeans	Aq1 = 335-334 Aq1 = 276-271	Aquifer in F. W.B Aquifer in Basalt -Gneiss contact
82	289687	2347331	XI, 12 RL = 337	V & M basalt + bole beds = 337-292	292 followed by Lametas and Archaeans	Aq1 = 292-288	Aquifer in Basalt -Gneiss contact
83	284881	2343023	XII, 9 RL = 374	V & M basalt + bole beds = 374-270	270	Aq1 = 270-265	Aquifer in B-G contact

84	286814	2343809	XII, 10 RL = 359	V & M basalt + bole beds = 359-280	280 followed by Lametas and Archaeans	Aq1 = 280-76	Aquifer in Basalt - Gneiss contact
85	288702	2344638	XII, 11 RL = 357	V & M basalt + bole beds = 357-270	270 followed by Lametas and Archaeans	Aq1 = 270-67	Aquifer in Basalt - Gneiss contact
86	290612	2345384	XII, 12 RL = 350	V & M basalt + bole beds = 350-273	273 followed by Lametas and Archaeans	Aq1 = 273-269	Aquifer in Basalt - Gneiss contact

F. A. B = Fractured Amygdaloidal Basalt; A. B = Amygdaloidal Basalt; F. B = Fractured Basalt; TCG = Trap Covered Gondwanas; F. G = Fractured Gondwanas; W. B = Weathered Basalt; B-G = Basalt-Gondwana; W. V. B = Weathered Vesicular Basalt; F. W. B = Fractured Weathered Basalt

ANNEXURE-XVIII: Details of Aquifer System and Aquifer Management Plan, Chandrabhaga Watershed (WGKKC-2), Nagpur District

Aquifer (Prominent Lithology)	Depth Range of Occurrence (m bgl)	Thickness Range (m)	Range of Yield Potential (Cu. m / Day)	Range of Storage Characteristics	Range of Permeability (m/day)	Transmissivity (m^2/day)	DTWL (m bgl) Pre-mon	VES Resistivity (Ohm. m)	Suitability for Irrigation	Suitability for Domestic Purposes	Water quality
Aquifer I (Basalt)	8 to 14	0.5 to 6	12 to 432	1.33×10^{-5} 9.06×10^{-2}	0.01 to 15	1.04 to 72.56	1.7 to 14.8	3.5 to 35	yes	yes	• *Nitrate* (> 45 mg/L) and High EC (> 2000) • *Lead contamination* around Kalmeshwar town • *Iron contamination* around Kalmeshwar town and Ubgi village
Aquifer I (Sandstone)	3 to 16	1 to 13	118 to 504	2.73×10^{-4} 4.4×10^{-4}	0.59 to 15	3.64 to 11.37	5.25 to 16.75	3.80 to 15.70	yes	yes	
Aquifer II (Basalt)	30 to 161	76-79 = 3 116-118 = 2 127-130 = 3 139-140 = 1 152-153 = 1 160-161 = 1	5 to 155	5.50×10^{-5}	--	7 to 30	13 to 70	7 to 40	yes	yes	--
Aquifer II (Sandstone)	45 to >197	45 – 77 = 32 82 – 109 = 27 111– 125 =14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 = 4	255 to 650	1×10^{-2}	--	3.14 to 119	40.70 to 73	152 to 1343	yes	yes	--

Aquifer (Prominent Lithology)	Depth Range of Occurrence (m bgl)	Thickness Range (m)	Range of Yield Potential (Cu. m / Day)	Range of Storage Characteristics	Range of Permeability (m/day)	Transmissivity (m^2/day)	DTWL (m bgl) Pre-mon	VES Resistivity (Ohm. m)	Suitability for Irrigation	Suitability for Domestic Purposes	Water quality
Aquifer III Trap covered Gondwana (Sandstone)	27 to > 198	36-52 = 16 71-75 = 4 120-126 = 6 195-198 = 3	40 to 256	--	--	5.55 to 173	--	1.8 to 87	yes	yes	--

Aquifer (Prominent Lithology)	Depth of Occurrence (m bgl)	Thickness (m)	Current Use	Recommendations for Aquifer Development					Aquifer Management Plan
				Type	Zones/Depth to be tapped	HP of pump to be lowered	Pumping Hours	Yield (Cu. m / Day)	
Aquifer I (Basalt and Sandstone)	8 to 14 (Basalt) 3 to 16 (Sandstone)	0.5 to 6 (Basalt) 3 to 16 (Sandstone)	Drinking, domestic and irrigation	Dug well, Bore well	Depth Range of Zones : 6 – 15 m Depth : 15 - 25 m	3 to 5	1 to 8	10 to 400	1 Construction of Recharge Wells-25 no's, Depth-20-30 m along the river / tributaries. 2 Construction of 3 Percolation Tanks on 2nd & 3rd order stream. 3 Construction of 4 KT weirs. 4 Construction of check dams on Chandrabhaga River & tributaries. 5 Desilting of existing water conservation and artificial recharge structures.
Aquifer II (Basalt)	30 to 161	76-79 = 3 116-118 = 2 127-130 = 3 139-140 = 1 152-153 = 1 160-161 = 1	Irrigation	Bore well	Depth : 60 to 90 m	3 to 5	3 to 8	50 to 150	1 Occurrence of collapsible red bole at various depths necessitates construction of tube wells in some parts. 2 Construction of Injection wells for artificial recharge.
Aquifer II (Sandstone)	Confined (45 to >197)	45 – 77 = 32 82 – 109 = 27 111– 125 =14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 = 4	Irrigation	Tube Well	45 – 77 = 32 82 – 109 = 27 111– 125 = 14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 =4	5 to 15	3 to 12	250 to 500	1 Development through Tube Well for domestic and irrigation purpose. 2 Development of Regional Rural Water Supply Scheme for supply to cluster of villages, particularly for scarcity areas.

Aquifer (Prominent Lithology)	Depth of Occurrence (m bgl)	Thickness (m)	Current Use	Recommendations for Aquifer Development					Aquifer Management Plan
				Type	Zones/Depth to be tapped	HP of pump to be lowered	Pumping Hours	Yield (Cu. m / Day)	
Aquifer III Trap covered Gondwana (Sandstone)	27 to > 198	36-52 71-75 120-126 195-198	Irrigation	Tube Well	36-52 =16 71-75 = 4 120-126 = 6 195-198 = 3	5 to 15	3 to 12	50 to 200	1 Development through Tube Well for domestic and irrigation purpose. 2 Development of Regional Rural Water Supply Scheme for supply to cluster of villages, particularly for scarcity areas.

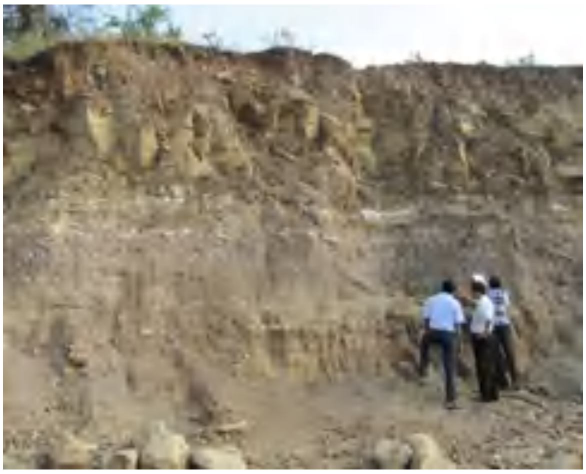
PHOTOGRAPHS


Fractured and jointed Massive Basalt (Aquifer-I) exposed in dug well section at Malegaon village, weathered basaltic zone has been lined by rock brick.


Weathered Basalt due to Spheroidal weathering exposed near Lakholi village.


Variagated Sandstone outcrop exposed at Tondakhairi


Outcrop of massive Basalt exposer at Raulgaon


Intertrappeans exposed near Dahpewada


Dr. P. K. Jain, Superintending Hydrogeologist, explaining the litho section exposed at Dhapewada.

Sh. M. K. Raffiuddin, Junior Hydrogeologist explaining hydrogeological set up near Chandrabhaga river bank, Dhapewada to Sh. B. Jayakumar, Word Bank representative & Regional Director, CGWB

Sh. Sandeep Waghmare, Assistant Hydrogeologist explaining KOW's behaviour, at Kalmeshwar to Sh. B. Jayakumar, Word Bank representative & Regional Director, CGWB

Ground Water Exploration - Various drilling activites during the project period

Double ring infiltrometer set up and collection of infiltration rate data.

Irrigation Prectices: Flood irrigation for pulses, papaya and seasonal vegitables during Rabi season.

Geophysical Survey (in-House) : Logging by UPTRON Logger

Geophysical Survey (in-House) VES by ABEM Terameter

SkyTEM survey

Sh. Pradeep Dubey, the then Regional Director, Dr. Shakeel Ahmad, Chief Scientist, NGRI and others during field along with experts from Dutch team

Sh. P. Narendra, Scientist C CGWB, Nagpur explaining geophysical findings of CGWB, Nagpur

Field visit and inspection of KOW at Kalmeshwar with experts from USGS, with officers from CGWB, NGRI and NEERI

Inspection of KOW at Kalmeshwar by experts from Dutch team

Discussion with field Hydrogeologist and expert team from USGS during field visit

Inspection of large diameter dug well by Sh. Pradeep Dubey, Regional Director and Dr. P. K. Jain Suptg. Hg. CGWB, CR, Nagpur.


Technical presentation to experts from USGS, at CGWB, Nagpur

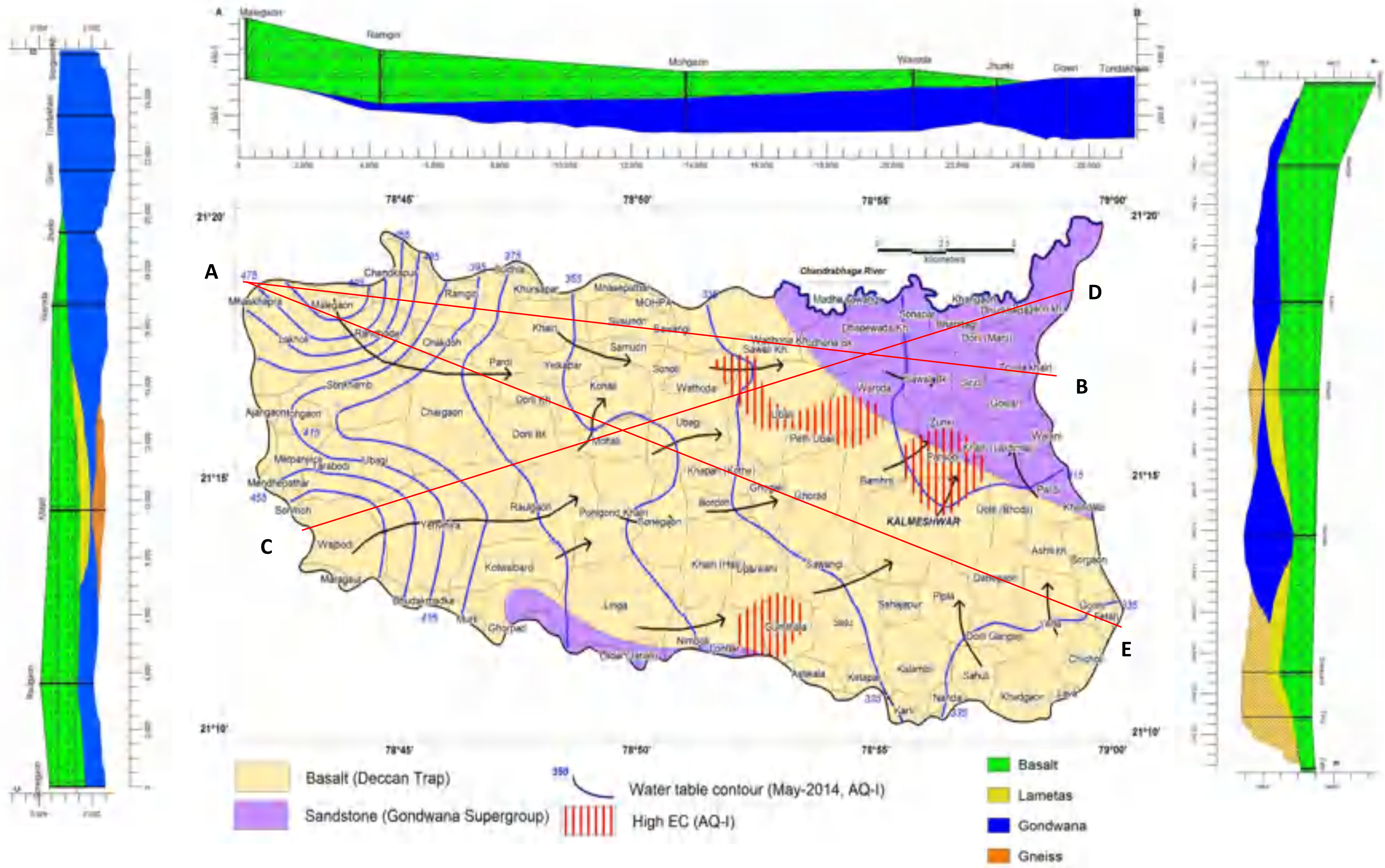

Technical discussion with experts from team Denmark


Technical meeting with experts from USGS, with officers from CGWB, NGRI and NEERI, at CGWB, Nagpur


Technical discussion with experts from USGS at CGWB, Nagpur

Pilot Project on Aquifer Mapping, Chandrabhaga Watershed (WGKKC-2), Nagpur District, Maharashtra

AQUIFER MAP



Aquifer	Prominent Lithology	Depth Range of Occurrence (m bgl)	Thickness Range (m)	Range of Yield Potential (Cu. m / Day)	Range of Storage Characteristics	Range of Permeability (m/day)	Suitability for Irrigation	Suitability for Domestic Purposes	Remarks
Aquifer I	Basalt	8 to 14	0.5 to 6	43 to 432	1.33×10^{-5} 9.06×10^{-2}	0.01 to 15	yes	yes	• *Nitrate contamination* (> 45 mg/L)in almost entire area and High EC (> 2000) • *Lead contamination* around Kalmeshwar town • *Iron contamination* around Kalmeshwar town and Ubgi village
	Sandstone	3 to 16	1 to 13	118 to 504	2.73×10^{-4} 4.4×10^{-4}	0.59 to 1.43	yes	yes	
Aquifer II	Basalt	30 to 161	76-79 = 3 116-118 = 2 127-130 = 3 139-140 = 1 152-153 = 1 160-161 = 1	43 to 155	5.50×10^{-5}	--	yes	yes	--
	Sandstone	45 to >197	45 – 77 = 32 82 – 109 = 27 111– 125 =14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 = 4	255 to 650	1×10^{-2}	--	yes	yes	--
Aquifer III Trap covered Gondwana	Sandstone	27 to > 198	36-52 = 16 71-75 = 4 120-126 = 6 195-198 = 3	40 to 256	--	--	yes	yes	--

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Government of India

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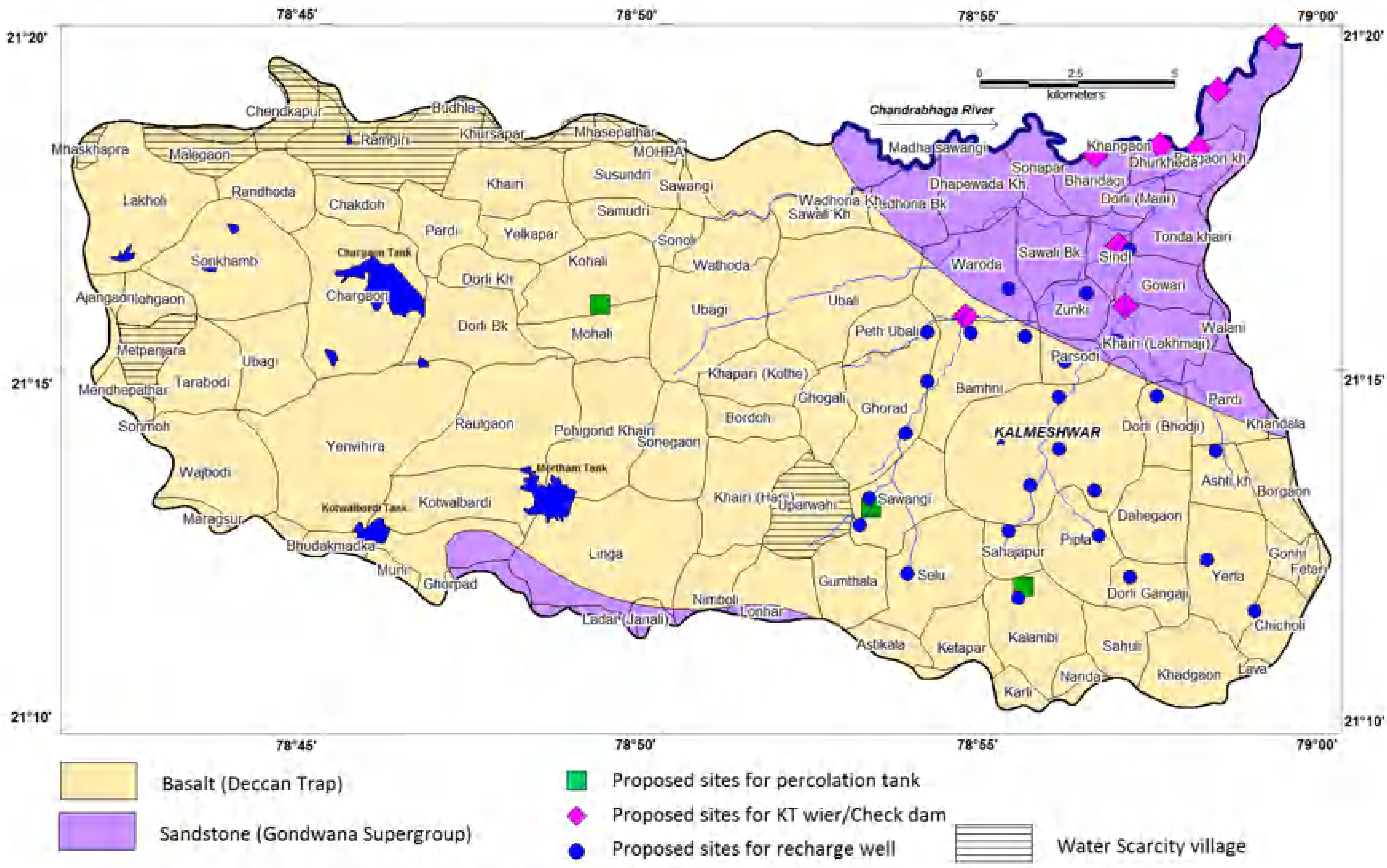
AQUIFER MANAGEMENT PLAN



Aquifer	Depth of Occurrence (m bgl)	Thickness (m)	Current Use	Recommendations for Aquifer Development					Aquifer Management Plan
				Type	Zones/Depth to be tapped	HP of pump to be lowered	Pumping Hours	Yield (Cu. m / Day)	
Aquifer I (Basalt and Sandstone)	8 to 14 (Basalt) 3 to 16 (Sandstone)	0.5 to 6 (Basalt) 3 to 16 (Sandstone)	Drinking, domestic and irrigation	Dug well, Bore well	Depth Range of Zones : 6 – 15 m Depth : 15 - 25 m	3 to 5	1 to 8	10 to 400	1 Construction of Recharge Wells-25 no's, Depth-20-30 m along the river / tributaries. 2 Construction of 3 Percolation Tanks on 2nd & 3rd order stream. 3 Construction of 4 KT weirs. 4 Construction of check dams on Chandrabhaga River & tributaries. 5 Desilting of existing water conservation and artificial recharge structures.
Aquifer II (Basalt)	30 to 161	76-79 = 3 116-118 = 2 127-130 = 3 139-140 = 1 152-153 = 1 160-161 = 1	Irrigation	Bore well	Depth : 60 to 90 m	3 to 5	3 to 8	50 to 150	1 Occurrence of collapsible red bole at various depths necessitates construction of tube wells in some parts. 2 Construction of Injection wells for artificial recharge.
Aquifer II (Sandstone)	45 to >197	45 – 77 = 32 82 – 109 = 27 111– 125 =14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 = 4	Irrigation	Tube Well	45 – 77 = 32 82 – 109 = 27 111– 125 = 14 127–137 = 10 142–146 = 4 156–160 = 4 162–165 = 3 167–178 = 11 183–187 = 4 193–197 =4	5 to 15	3 to 12	250 to 500	1 Development through Tube Well for domestic and irrigation purpose. 2 Development of Regional Rural Water Supply Scheme for supply to cluster of villages, particularly for scarcity areas.
Aquifer III Trap covered Gondwana (Sandstone)	27 to > 198	36-52 = 16 71-75 = 4 120-126 = 6 195-198 = 3	Irrigation	Tube Well	36-52 =16 71-75 = 4 120-126 = 6 195-198 = 3	5 to 15	3 to 12	50 to 200	1 Development through Tube Well for domestic and irrigation purpose. 2 Development of Regional Rural Water Supply Scheme for supply to cluster of villages, particularly for scarcity areas.

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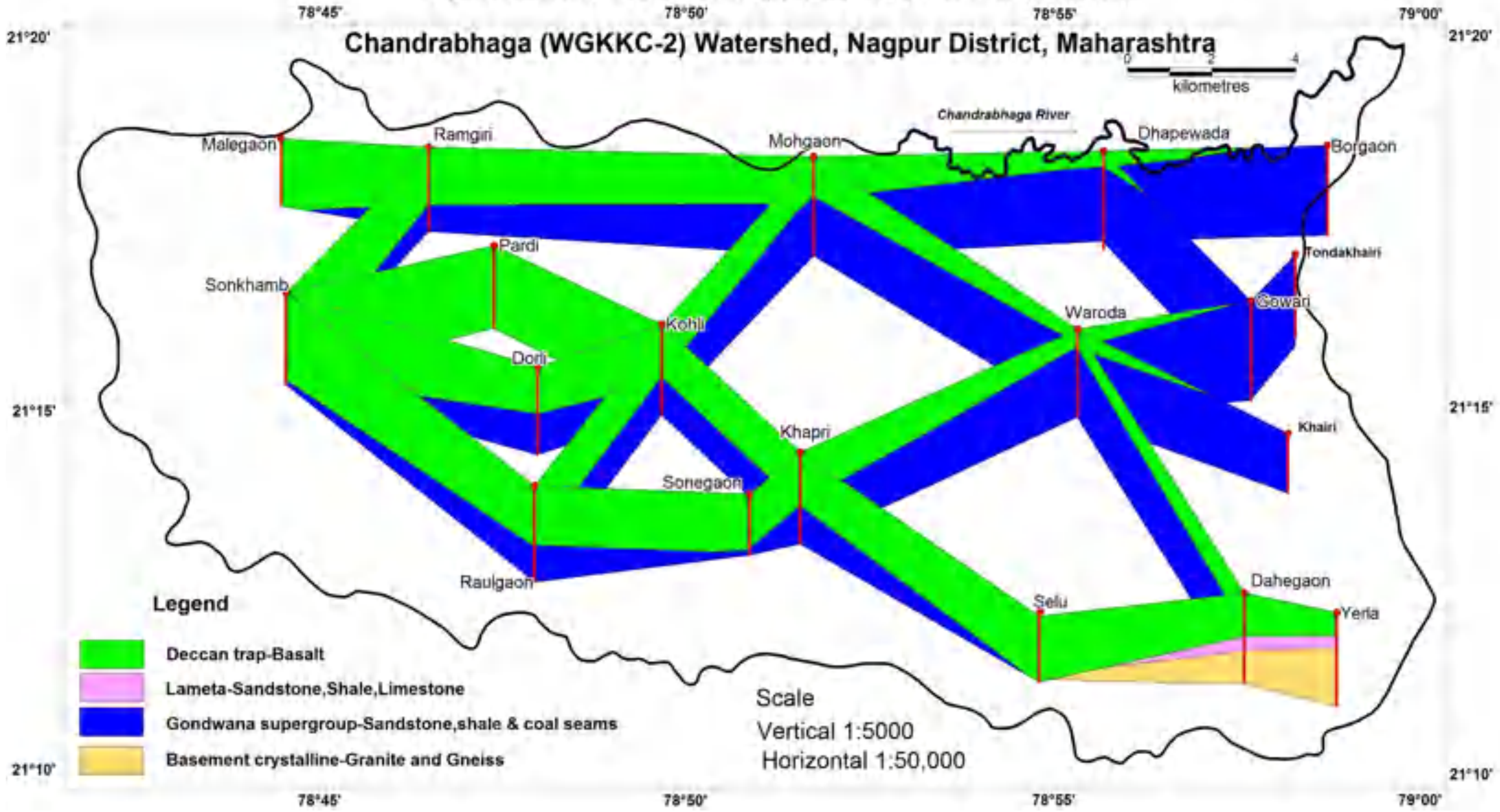
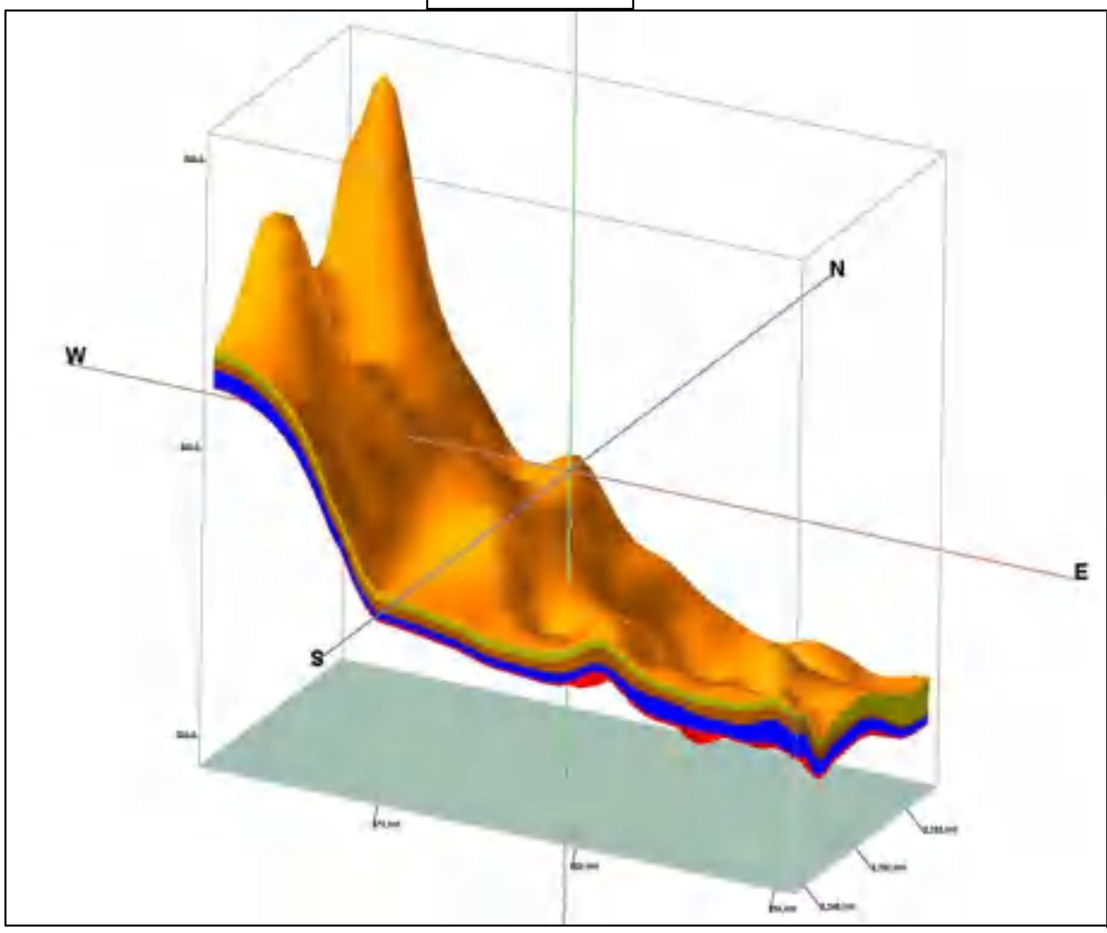
3D AQUIFER DISPOSITION

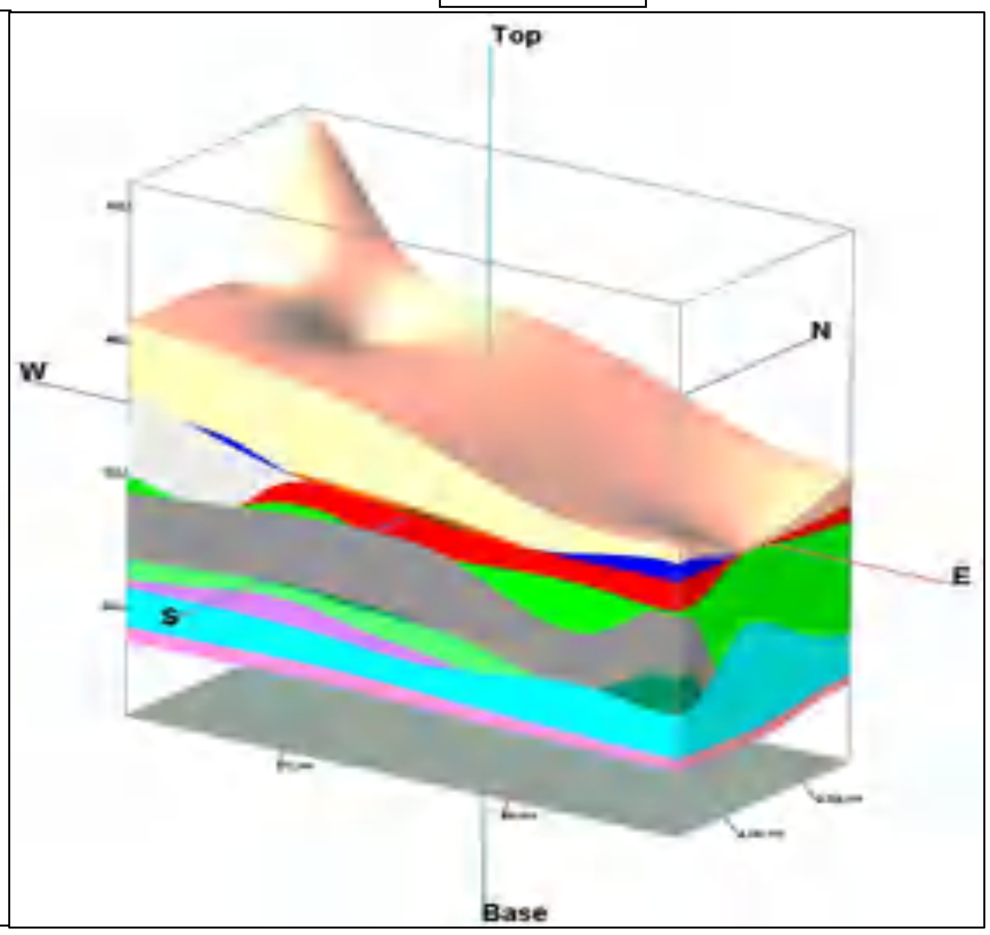
AQUIFER - I (SHALLOW BASALTIC AND SANDSTONE AQUIFER)
Depth of occurrence : 0 to 30
AQUIFER - II (DEEPER BASALTIC AND SANDSTONE AQUIFER)
Depth of occurrence : 30 to >161 m bgl (Basalt) & 30 to >197 m bgl (Sandstone)



Aquifer - I



Aquifer - II



- Top Soil
- HW_Basalt
- MW_Weathred Basalt
- F_Basalt
- M_ basalt

- Basalt_Weathered
- Basalt_Vesicular
- Basalt_Amygdular
- Basalt_Fractured
- Basalt_Massive
- Grey Bole
- Red Bole
- Green Bole
- Clay
- Lametas
- Sandstone_Kamthi
- Sandstone_Barakar
- Sandstone with shale
- Shale
- Sandy Clay
- Sand
- Gneiss

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