

**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH AT NEW DELHI**

ORIGINAL APPLICATION NO. 288/2019

Balkrishan Vyas

Applicant

Versus

State of Rajasthan

Respondent

**COMPLIANCE REPORT OF THE HON'BLE TRIBUNAL
ORDER DATED 19.06.2020, ON BEHALF OF
RAJASTHAN STATE POLLUTION CONTROL BOARD.**

I, Mahaveer Mehta S/o Late Shri S. S. Mehta, aged about 57 years, at present working as Regional Officer, Rajasthan State Pollution Control Board, Bhilwara (Raj.) do, hereby submits the compliance report as follows:-

- 1) That the Hon'ble Tribunal by order dated 19.06.2020 directed inter-alia as follows:-

“4. Since the report has confirmed the cracks and water leakage from the cracks in the underground water tanks and has also mentioned that further investigation is to be carried out at minimum five locations, it would be appropriate that result of the further studies and the remedial and mitigation measures taken and planned may also be mentioned in the next report. Since four months have already passed after the report was submitted, the rest of the studies may be completed in next two months and report furnished on or before 30.09.2020 by e-mail at judicialngt@gov.in preferably in

File

the form of searchable PDF/ OCR Support PDF and not in the form of Image PDF.”

- 2) That the interim study reports of CSIR – CIMFR, Bilaspur (CG), CSIR-CBRI, Roorkee (UK) and Department of Hydrology, IIT, Roorkee (UK) has been received from District Collector vide letter no. 24567 dated 29.09.2020 is annexed herewith and marked as **Annexure-1(Coll.)**.
- 3) That the team of experts has submitted the interim status report and also intimated about planning of further remaining examination/ study at the level of CSIR-CBRI, Roorkee through e-mail dated 24.09.2020 to District Administration, Bhilwara & RSPCB, Bhilwara. At present, the team of CSIR-CBRI, Roorkee (UK) has started the remaining study of geotechnical investigations and monitoring of cracks in houses of Village Pur (Bhilwara) from 28.09.2020, which shall be completed shortly.
- 4) That the delay occurred in submission of final report and preparation of holistic guidelines for effective measures of the existing problem of Village-Pur (Bhilwara) due to present COVID-19 pandemic, as per intimation letter dated 24.09.2020 received from Dr. Shantanu Sarkar, Chief Scientist & Head, Geotechnical Engineering Group, CSIR-CBRI, Roorkee (UK) , which is annexed herewith and marked as **Annexure-2**.
- 5) That Dr. Harsh Kuamr verma, Sr. Pr. Scientist & Project Leader, CSIR- CIMFR, Bilaspur (CG) and one more key member of the investigating team got infected with COVID-19 virus and works got delayed as per intimation letter dated 24.09.2020, which is annexed herewith and marked as **Annexure-3**.
- 6) That the field and analytical work related to Hydro- Geological study of Pur village have been completed at the level of IIT, Roorkee (UK) . The concluding remark related to the observed findings of this study would be submitted together with



CIMFR and CBRI reports after completion of their study work along with preparation of holistic guidelines for effective mitigation measures of the existing problem in Pur village. In this context letter dt. 24.09.2020 received from Dr. Brijesh Yadav, Associate Professor, Department of Hydrology, IIT, Roorkee is annexed herewith and marked as **Annexure-4**.

- 7) That in the light of submissions made herein above, it is requested that the interim study reports may kindly be taken on record and delay in submission of final reports along with mitigation measures for the existing problems in Pur village may be acknowledged due to present pandemic situation. The final report shall be submitted at the earliest since the remaining study of geotechnical investigations and monitoring of cracks in houses of Village Pur (Bhilwara) is undergoing from 28.09.2020.


(Mahaveer Mehta)

Regional Officer, RSPCB,
Bhilwara

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 (Mahaveer Mehta)
 Regional Officer, RSPCB,
 Bhilwara

NGT MATTER

MOST URGENT

राजस्थान-सरकार

कार्यालय जिला मजिस्ट्रेट, भीलवाडा

क्रमांक : न्याय/ 2020/ 24567

दिनांक : 29. 09.2020

प्रेषिति,

क्षेत्रीय अधिकारी,
राजस्थान राज्य प्रदूषण नियंत्रण मण्डल,
भीलवाडा



विषय :- प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली के आदेश की पालना में रिपोर्ट प्रस्तुत करने के संबंध में।

उपर्युक्त विषयान्तर्गत लेख है कि माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली के आदेश की पालना में प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में रिपोर्ट प्रस्तुत करनी है। प्रकरण में पेशी दिनांक 30.09.2020 नियत है। वर्तमान में उपनगर पुर में सर्वे एजेन्सियों (CIMFR, CBRI and IIT Roorkee) द्वारा किये गये अनुसंधान के क्रम में उपखण्ड मजिस्ट्रेट, भीलवाडा के पत्र क्रमांक 3853 दिनांक 25.09.20 से प्राप्त अद्यतन स्थिति का प्रतिवेदन संलग्न कर भिजवाया जा रहा है।

अतः आपको निर्देश दिये जाते हैं कि विषयक प्रकरण में माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली में नियत दिनांक से पूर्व संलग्न रिपोर्ट अनुसार जवाब प्रस्तुत कर पालना से इस कार्यालय को अवगत करावें।

संलग्न:- उक्तानुसार

(शिव प्रसाद, एम. नकाते)
जिला मजिस्ट्रेट,
भीलवाडा

राजस्थान-सरकार
कार्यालय उपखण्ड मजिस्ट्रेट, भीलवाडा

दिनांक: 25.09.2020

क्रमांक:-न्याय/2020/

3853

प्रेषित,

श्रीमान जिला मजिस्ट्रेट महोदय
भीलवाडा

विषय:-प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य
व अन्य में माननीय एन0जी0टी0न्यायालय, नई दिल्ली के आदेश
दिनांक 19.06.2020 की पालना के संबंध में।

प्रसंग:- आपका पत्र क्रमांक: न्याय/2020/24498 दिनांक 22.09.2020

महोदय,

उपरोक्त विषयान्तर्गत एवं प्रासंगिक पत्र के सन्दर्भ में निवेदन है कि
प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में माननीय
एन0जी0टी0न्यायालय, नई दिल्ली के आदेश दिनांक 19.06.2020 की पालना के संबंध
में संबंधित वैज्ञानिक अनुसंधान एजेन्सियों द्वारा रिपोर्ट प्रस्तुत की गई जो मूल ही संलग्न
कर आवश्यक कार्यवाही बाबत श्रीमान को सादर प्रेषित है।

संलग्न:-उक्तानुसार


उपखण्ड मजिस्ट्रेट
भीलवाडा

Interim Report

on

Scientific studies on blast induced ground vibration and air overpressure and investigation on its damage potential vis-à-vis housing structures in Pur village, Bhilwara Distt., Rajasthan

CIMFR PROJECT NO. SSP/R/421/19-20



CSIR-CIMFR

CSIR-Central Institute of Mining and Fuel Research

Regional Research Centre Bilaspur (CG) 495001

Scientific studies on blast induced ground vibration and air overpressure and investigation on its damage potential vis-à-vis housing structures in Pur village, Bhilwara Distt., Rajasthan

1.0 INTRODUCTION

Pur is an old village located in Bhilwara District of Rajasthan. Geographically, it is situated at 25°27'50"N & 74°03'75"50"E & 410 m above the Mean Sea Level (MSL). Population of Pur village is approximately 250000 and there are roughly 4500 housing structures. Many of the houses/structures/roads/drains in and around this village have developed cracks and major structural damage rendering structures non-habitable.

It is pertinent to mention here that there is a low grade iron ore (Magnetite) reserve near Pur village. This reserve is allotted to Dhedwas Iron Ore and Associated Mineral Mine of M/s Jindal Saw Limited (JSL) for commercial exploitation. M/s JSL is carrying out mining activities. The rock containing iron ore is broken down in small pieces by drill and blasting method. The fragmented rock material is further processed to prepare iron pallets for use in steel industry. Villagers have made complaints to District Magistrate that the blasting operation in the Dhedwas Iron Ore mine is the primary cause of the cracks in the domestic houses. The mine is approx.. 2.5 m away from the village. A location map showing relative position of the Dhedwas Iron Ore mine and Pur village is presented in Figure 1.

A high level meeting chaired by Chief secretary, Govt of Rajasthan was held on 5th July 2019 at Jaipur and it was decided to carry out a comprehensive scientific study to identify and characterize the root causes of cracks in the housing structures by engaging expert institutions. It was decided in this meeting that three institutes namely IIT Roorkee, CSIR-Central Building Research Institute (CBRI), Roorkee and CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad be engaged for scientific investigation. IIT Roorkee was entrusted to carry out investigation of crack by evaluating hydro-geological and sub-surface investigation. CBRI Roorkee was advised to look into the contribution of building foundation and geotechnical part.

Bhilwara District Magistrate and Collector vid their Letter no Ref: Jud/19/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad to evaluate the impact of the blast induced ground vibration.

CSIR-CIMFR Team have carried out scientific study by conducting field trials in the Dhedwas Iron Ore mine by conducting blasting experiments by varying various blast design parameters and investigation of blast Induced ground vibration & air overpressure (AoP) in and around Pur Village. This report is record of the investigations carried out by CSIR-CIMFR Team at Pur village. This report includes details of the blasting field trials in the mine, monitoring of the blast induced ground vibration and compiles status of the works done so far. Further analysis is being carried out.



Fig. 1: Map showing relative location of Dhedwas Iron Ore Mine and Pur Village

2.0 STATEMENT OF THE PROBLEM

CSIR-CIMFR team initially made survey of the damage in the housing structures of Pur village. Various domestic houses were surveyed and have taken observation on cracks, their characteristics, location, width etc. Photographs of the cracks in the domestic houses and temple of Pur village are presented in Fig(s) 2 to 10.

Initially CSIR-CIMFR Team carried out a detailed survey of the house to evaluate the problem of the cracks in the housing structures along with district administration team. During survey of the cracks in the housing structures, it was informed by the local authorities that there are more than 350 buildings in which cracks developed. These cracks were present in the double storey as well as single storey buildings. Cracks were present almost in every location of the house such as outer wall, inner wall and floor in the houses, ceiling and floor level. crack in walls were vertical to sub-vertical cracks. It was also noticed that this crack prone area is situated at higher elevation compare to other locality of the Pur village. The elevation of the village varies from 410m to 435m above MSL. It is important to mention here that the mine is approx. 2.5 km from the village. Most of the houses having cracks are at certain elevated location of the village. Some of houses closer to mine does not have cracks. Further, as per IMD data, no seismic activity has taken place during period of July, 2018 to January, 2019. It is surprising to note that > 350 buildings have suffered such kind of damage without any seismic event.

During interaction with villager, they have apprehension that the crack were due to blasting activities carried out at Dhedwas Iron Ore mine. CSIR-Central Institute of Mining and Fuel research was entrusted to carry out investigation to evaluate the damage potential of the blasting vibration and contribution of the blasting vibration in development of the crack in the housing structures of the village.

CSIR-CIMFR Team conducted three round of the filed visits to Pur village and mine site as part of this investigation. During these field visit, a comprehensive investigation was carried out by conducting experimental blast were carried-out in mine site and vibration monitoring were carried out at more than 50 different locations.



Fig 2: Cracks along column in Laxminarayan Temple



Fig 3: Cracks in the corners of the Laxminarayan Temple

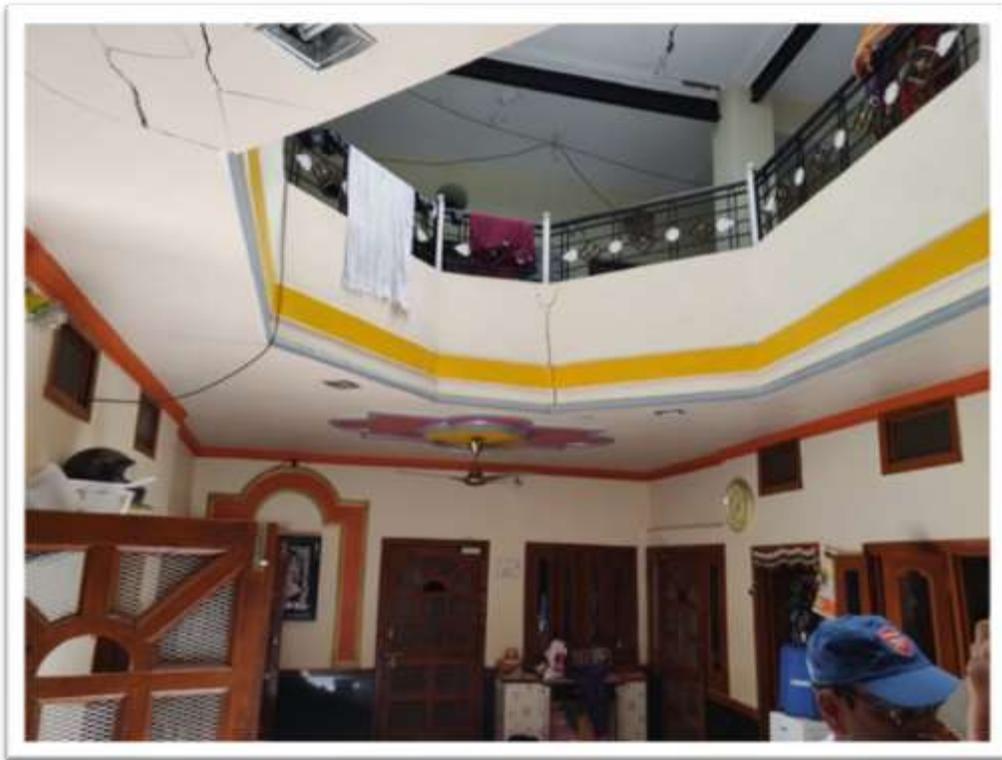


Fig. 4: Cracks in the housing structure at middle level



Fig 5: Cracks along the joints of the domestic structures



Fig 6: Cracks along the joints of the domestic structures



Fig 7: Widening of Separation joint along two joints indicating settlement of the foundation



Fig 8: Cracks across the beam and column of housing structure



Fig 9: Cracks in the floor level of housing structures



Fig 10: Cracks in the floor level of housing structures

3.0 GEOLOGY OF THE AREA

Predominant geological formation includes rock types belonging to Bhilwara Super group, Aravallis and Vindhyan Super group. The depth of soil varies from 5 to 10 m, and in some areas

rock outcrops are seen above the ground. Predominant soil found in the area are Clay loam or medium black (in northeastern hilly areas), loam (predominant soil type) and, sand and sandy loam (near the banks of rivers/streams). The origin of landform is fluvial (alluvial) along River Kothari, denudational (buried pediment) in most places, and structural hills in the northeastern outskirts of the city.

The topography of the area is characterized as rugged in North- Eastern and South- Western part and the remaining part is nearly peneplain. The maximum elevation is 529 m above msl towards the North- Western direction of the Pur village and the minimum elevation is 410 m above msl near the Government Senior Secondary school, Pur. Kothari River with several nallas forms the main drainage of the area. Drainage pattern in the area is dendritic. Small water bodies are present.

Pur Village Located on the southern edge of Aravali hills. This area comes under the Potla Formation of the Mangalwar Group. Its basement is basically consisting of Granite gneiss-amphibole gneiss and garnetiferous mica schist trending NE-SW moderate to high dip towards NW Bhilwara super group.

As per the seismic zoning map of India, Pur Village, Bhilwara District falls under the Zone II, which is the lowest earthquake risk zone in India. This zone is termed as “low damage risk zone.

Bhilwara is located near the right bank of River Kothari, a tributary of River Banas, an important river of Rajasthan. River Kothari originates in the eastern slopes of the Aravali ranges in Rajsamand District. The river flows through Rajsamand and Bhilwara Districts for about 51 km in a hilly region, and 100 km through plains, before joining the Banas near Nandrai village in Bhilwara District. The other tributaries of Banas in Bhilwara District are Bedach and Khari. River is rain-fed and is a seasonal flowing river. River carries good flow during normal and above normal rainfall years. Meja Baandh (Meja Dam) constructed across Khari River, about 20 km northwest of Bhilwara is an important source of water for irrigation, industrial and drinking purposes.

Major water bearing formations are gneiss and schist (Bhilwara Supergroup); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium. Ground water occurs under unconfined to semi-confined condition. Weathered zone below the water table acts as a good storage. The joints, fissures and other plains of structural weakness as well as their extent, size, opening and inter connection control

occurrence & movement of ground water. Phyllites and schists are predominating in Bhilwara City and these formations are intercalated with dolomitic limestone, quartzite and basic intrusives.

4.0 FIELD INVESTIGATIONS

Before commencement of the field investigation, a team was constituted in co-ordination with the district official which have representative from villagers to ensure transparency and witnessing of the experimental blasts. Two persons from the Pur villager were dominated by the district official to represent the villagers and they were made part of all the experimental blasting study in all the field visits. Fig 10 shows Photographs of Dhedwas Iron Ore mine working in different benches. Photograph of CSIR-CIMFR team along with representatives of Pur village is presented in Fig. 12.



Fig 11: Photograph showing Dhedwas Iron Ore mine working in different benches

CSIR-CIMFR Team also reviewed blasting practices of the iron ore mine by collecting all the blasting data since April 2018 to Dec 2019. Most of the cracks were reported to have developed during this period only. The parameters of the experimental blast were decided to represent the day to day blasting operations of iron ore mine. Usual blasting practices in the mine have holes depth ranging from 6.0 m to 10.0 m. Few blasts with 12.0 m depth have also been taken in the past. Site mixed emulsion explosive with cast booster is used for blasting operation. The total charges in blasting round as per usual practice are mostly in the range of 8 tons- 10 tons. No of holes in blasting round are in the range of 100 – 150 holes having dia. 165 mm.



Fig. 12: CSIR-CIMFR team along with representatives of Pur Village at Dhedwas Iron Ore mine during field experiment in the mine.

The experimental blast design parameters were chosen to represent day to day blasting operation with an endeavor to constitute severe condition so that the maximum damage potential of the blast vibration may be evaluated and its impact of the surrounding housing structure of the Pur village be quantified.

During field experiment comprehensive vibration and air overpressure monitoring was also carried out. The monitoring locations were chosen in close consultation with the all the stake holder including representative from the Pur village. The objective of the team was to conduct the experimental blasts and monitor the blast induced ground vibration and air over pressure at different locations in Pur village and to analyse its adverse impact on domestic houses/structures in Pur village.

4.1 Details of Experimental Blasts

CSIR- CIMFR Team conducted altogether 15 experimental blast rounds in two different phases of field investigation at the Dhedwas Iron ore mine of M/s Jindal Saw Ltd., Bhilwara. First phase of experimental blasts and monitoring was carried out during 01.02.2020 to 06.02.2020 and second phase of the investigations was carried out in during 03.03.2020 to 06.03.2020. The parameters of the experimental blast round were decided after review of the data of mine blasting operations carried out during April 2018 to Dec 2019. The parameters of the experimental blast round are presented in Table 1.

Experimental blasts were conducted in both overburden (upper benches) and iron ore benches (lower benches) of JSL mine. Bulk explosive were used for charging the blast holes along with cast booster of 100g as primer charge. Bottom hole initiation is followed using Down-The-Hole Shock tube/NONEL initiation system. The blast holes having depth more than 10m were double decked with solid decking. Two shock tubes were used with deck separating two explosive decks in one blast hole. Shock tube with lower delay of 450ms was used in bottom and of 500ms was kept in top deck. Trunk line connection was done by using Shock tube/NONEL of varying length and different delay for providing delay between holes and rows in a blast round.

Detailed data of blasting experiment data are presented in Table 1 which include information and such as date of blast, number of holes, average hole depth, Total and maximum chare per delay, average burden and spacing used in experiment blast rounds. Different steps involved in charging and firing of the blast holes during experimental blast at mine site are presented in Fig(s) 13(A to H) for a detailed illustration. Locations of various experimental blasts in mine are presented in Fig 14.

It may be noted that in experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of no of holes and total explosive quantity in blasts rounds were conducted both in overburden as well as in bottom benches. In

experimental blast holes depth varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as this as 10.06 tons, no of holes varied from 39 holes to 195 holes. The range of experimental blast design parameter covered the day to day blasting practices of Dhedwas iron ore mine, Bhilwara.



13(A): 10 Ton Capacity Site Mix Emulsion (SME) Truck



13(B): Measuring of Explosive Density at Site before loading into blast holes



13(C): Measuring depth of experimental blast holes before charging



13(D): Loading of experimental blast holes



13(E): Double decked loaded blast holes



13(F): Stemming in loaded blast holes



13(G): Use of TLD for surface connection of blast holes



13(H): View of charged blast holes

Fig. 13: Photographs of different steps involved during experimental blast conducted at Dhedwas Iron ore Mine of M/s JSL

Table 1: Details of the parameters experimental blasts conducted by CSIR-CIMFR Team at Dhedwas Iron Ore Mine, Bhilwara

Sr. No	Date	No of Holes	Hole Depth	Average Spacing (m)	Average Burden (m)	Average Stemming (m)	Max. Charge Per Delay (Kg)	Total Charge (kg)
1	1.02.2020	90	4.0 - 12	4.0	4.0	2.8 - 4.2	60	9450
2	1.02.2020	166	3.5 - 11	3.5	4.0	2.8 - 3.9	190	8430
3	3.02.2020	195	3.5 - 6.0	3.5	4.0	2.8 - 4.0	50	8800
4	4.02.2020	88	6.0 - 11.8	4.0	4.0	2.0 - 4.0	60	9660
5	5.02.2020	88	7.0 - 12	4.0	4.0	2.4 - 4.3	60	9020
6	5.02.2020	116	7.0 - 12	4.0	4.0	2.4 - 4.3	60	5215
7	6.02.2020	86	7.0 - 12	4.0	4.0	2.4 - 4.3	60	8720
8	6.02.2020	114	7.0 - 12	4.0	4.0	2.4 - 4.3	60	9500
9	3.03.2020	76	4.0 - 6.0	3.0	4.0	2.8 - 4.0	85	3065
10	3.03.2020	119	5.0 - 10	3.0	4.0	3.4 - 3.5	90	10365
11	4.03.2020	39	6.0 - 9.0	3.0	4.0	4.0 - 3.5	80	2800
12	4.03.2020	134	4.0 - 10	3.0	4.0	2.8 - 3.5	90	9790
13	5.03.2020	161	4.0 - 9.5	3.0	4.0	2.8 - 4.0	100	10060
14	6.03.2020	75	4.0 - 6.0	4.0	4.0	2.8 - 4.0	55	4100
15	6.03.2020	180	4.0 - 8.0	3.0	4.0	2.8-5	100	9400



Fig.14: Location of Experimental Blasts Conducted at Dhedwas Iron Ore Mine of M/s JSL Mine, Bhilwara

4.2 Monitoring of Blast Induced Ground Vibration and AOP

During two rounds of the field investigations altogether 15 experimental blast have been carried out incorporating wide range of blast design parameters which represent the day to day blasting

operation at Dhedwas iron ore mine of M/s JSL, Bhilwara. Blast vibration and air overpressure monitoring have been carried out at more than 60 locations such as housing structures, temples, mosque in and around Pur village during experimental blasts. In each phase of field investigations, four set of engineering seismographs of InstanTel Canada Make have been used. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity. One such seismographs namely MiniMate Blaster is viewed in **Figure- 15**.



Figure 15: View of MiniMate Seismograph along with external geophone and microphone

One of the most critical aspects of ground vibration monitoring is the mounting (placement) of transducers in the field. Good coupling refers to the transducer that maintains proper contact with the ground. Poor coupling can cause slippage or toppling of the transducer resulting in distorted, often higher vibration levels. Most recommendations agree that the best coupling can be

achieved by burying the transducer when the measurement surface consists of soil and by bolting or quick setting cement (plaster of paris) when the measurement on surface consists of rock or concrete. Burial is desirable for particle acceleration exceeding 0.2 g but it is essential if it is greater than 1.0 g (Dowding, 1996; Stagg and Engler, 1980; ISEE, 2005, ISRM, 1991). Coupling of sensors is illustrated in Fig 16. Below.



Fig 16: Photograph illustrating sensor coupling using Plaster of Paris during vibration monitoring

In this study, coupling of the transducers were carried out using burial techniques in soil and plaster of paris (POP) in case of hard rock surface (**Figure-16**). During most of the blasting experiments simultaneous monitoring at different housing structure and ground surface using velocity meter were carried out.

During all these blasting experiments, monitoring of vibration and air overpressure/ noise in more than 50 locations were carried out using different types of engineering seismographs. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. In all the cases, measurements were carried out in the

direction with an intention to record maximum vibration as well as air overpressure intensity. The geophone trigger level for all the seismographs were fixed at 0.5mm/s. This indicates that the vibration value of $\geq 0.5\text{mm/s}$ will be recorded in instrument. The consolidated plan showing different vibration monitoring locations are presented in Figure 17.

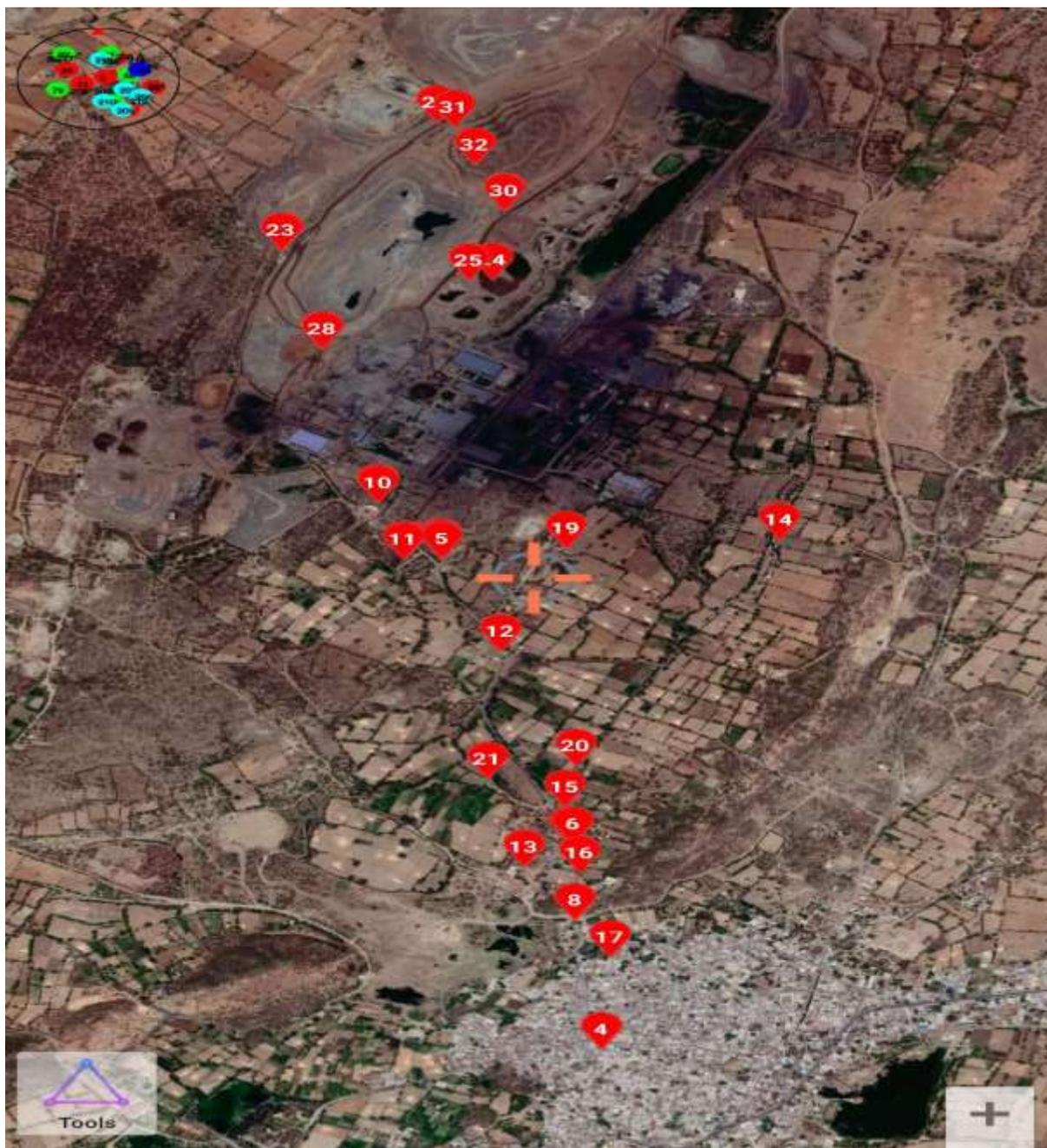


Fig. 17: Location of blast induced ground vibration & AOP monitors in M/s JSL Mine and Pur Village, Bhilwara

It is important to mention here that during initial rounds field investigation in the month of Feb 2020, far-field monitoring was carried out. Most of the houses of the monitoring was in the village houses of Pur Village. In second phase of investigation, close field monitoring of the vibration was carried out. Therefore, In second phase experimental investigations, majority of the minoring location were intermediate location between mines and Pur village and few locations within the mine premises. This is required for developing mathematical model of blast vibration propagation characteristics precisely. Photographs of the vibration and air overpressure monitoring locations during experimental investigations are presented in Figure 18.



A. Near mine Gate 1, Jindal plant, Tiranaga Mata Temple, Pur Village



B. Guru-Kripa Restaurant, Roadside, Pur Village



C. Roof top, Sunarogi Temple, Pur Village



D. House near Kali Babadi, Pur Village



E. House in Mundar road, Pur Village



F. Miththu Ji Mali Farm House, along Pur Road



G. Laxminath Bada Madir



H. JSL Electric Grid, M/s JSL Mine



I. Mine site office, in M/s JSL Mine



J. JSL Weigh bridge no.2, in M/s JSL Mine

	
K. Mill Tailing Road, NE in M/s JSL Mine	L. Dump yard road in M/s JSL mine
	
M. Sunarogi Temple, Pur Village	N. Eidgaah Masjid, Pur Village
	
O. Rajshree Kirana & Bhojnalay, Pur village	P. Hanuman Temple, Pur Village

Figure 18 (A-P). Various vibration monitoring location completed by CSIR-CIMFR Team during two phases of field investigations in Pur Village

Future Course of Action

CSIR-CIMFR Team have completed majority of the field works. The team has so far conducted two rounds of field investigation in the month of Feb and March 2020 and 15 nos. of experimental blasts have been conducted with various parameters of blast design. Vibration monitoring have been carried out at more than 60 location in different structures and places in Pur village and around the mine premises.

Last round of field investigation with other team of participating institutes to validate the analysis is to be taken up. Thereafter data analysis and report submission will be done. Further, after completion of the field works of all the participating institutes, a holistic conclusion and remedial measures will be submitted.

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Dr. Shantanu Sarkar

to dm-bhi-raj, sdobhilwara, me, SINGH, drharsh77, brijeshy

Dear Sir/Madam,

Please find attached the letter related to geotechnical investigation e

With best regards,

S. Sarkar

Dr Shantanu Sarkar

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Meet

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Join a meeting

Hangouts



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Chief Scientist & Head
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Professor, Academy of Scientific and Innovative Research (ASIR)

Provisional Report on
**Hydro-Geological Study of Pur Village Area,
Bhilwara, Rajasthan**



by

Dr. B.K. Yadav and Dr. P. K. Sharma
(Associate Professors)
Dr. D C Singhal
(Retired Professor)

Indian Institute of Technology Roorkee

Submitted to

District Magistrate
Bhilwara, Rajasthan
India

[September 24, 2020]

1. Introduction

A survey team comprised of Prof. Brijesh Kumar Yadav (Department of Hydrology), Prof. Pramod Kumar Sharma (Department of Civil Engineering), and Dr. D. C. Singhal (Retired Prof. Department of Hydrology), Mr. Manik Goel (Research Scholar), Mr. Shubham Tiwari (Research Scholar), Mr. Uttam Singh (Senior Research Scholar), Shri Raj Kumar (Senior Laboratory Technician), and Shri Ashok Kumar (Laboratory Technician) from IIT Roorkee visited the Pur village, Bhilwara district, and its nearby areas along with the required instruments during 07 Nov to 11 Nov 2019 for conducting the field study. Mrs. Tina Dabi, SDM Bhilwara, along with her team from the DM office, joined the team during the field survey. All geological and hydrological data collected in this first field visit was analysed in the laboratories of IIT Roorkee. A total of six one-dimensional, eight two-dimensional electrical soundings were conducted along with two GMR soundings during this first field work. The results are assessed to find the existing hydro-geological conditions of the area for possible causes of the cracks in problematic region. After assessing the results, it was observed that some additional locations in the target area were required to be covered for improving the findings of the first field work. Keeping this in mind, a second field visit was planned for collecting more data from eleven locations in the target area during 28 Jan to 01 Feb 2020. A total of three 2-D electrical soundings, two aquifer pumping tests, and thirteen water samples from seven different locations were collected during the second field visit.

2. Scope of the study

The following scope of the study is mutually agreed:-

- a) Conducting in-depth Hydrogeological survey of the area within 2 km radius from center of the Pur village using a series of field experiments.
- b) Development of a lithofacies map of subsurface zone of the study area using a series of geophysical investigation techniques. About 10-15 multidimensional electrical resistivity soundings will be performed based on availability of suitable sounding locations in and around the Pur village.
- c) Aquifer characterization at different depths using appropriate pumping and recovery tests along with Ground magnetic resonance (GMR) equipment. Existing tube-wells and open well of the site be used for conducting the pumping and recovery tests.

- d) Estimating groundwater flow regime of the area based on field survey and other observed data of groundwater resources. Coordinates of all monitoring points to be taken and marked along with the existing groundwater flow pattern.
- e) Chemical analysis of water supplied to the village and ground water samples using existing hand-pumps/tube-well and groundwater outflow location observed in the village school. This is required to investigate interaction between water supply network of the village and existing groundwater resources of the site.
- f) Preparation of general guidelines for effective measures of the existing problem.

3. Study Area

Bhilwara district in Rajasthan is famous for its mineral resources and textile industries. It is situated between latitude North 25.0167° to 25.967° and longitude East 74.01° to 75.467° , covering a geographical area of 10,455 sq. Km. It is divided into 7 sub-divisions: Bhilwara, Shahpura, Gangapur, Gulabpura, Asind, Mandalgarh, and Jahajpur that are further divided into 12 tehsils having a total population of about 24.1 lakh as per the census of 2011. It is bounded from the north, east, south, and west by Ajmer, Bundi, Chittorgarh, and Rajsmand districts, respectively. Bhilwara district comprises of fairly open plains in the north and southeast with a few hillocks and undulating plains/hills in the south and northeastern part. Most of the district area drains to the Banas river basin except the eastern part that drains to the Chambal river basin. Geologically, Bhilwara Super Group occupies a major part of the district. The area comprises of the Vindhyan group in the south-eastern part, the Gogunda group in the north-western part, and the Kumbhalgarh group in the southwestern part. The average groundwater table in the district varies from 3 to 23 m and 1 to 16 m bgl during pre- and post- monsoon seasons, respectively.

The study revolves around the Pur village and the Jindal Saw Ltd. of Bhilwara District. The study area is located towards southwest of Bhilwara town, between the latitude $26^{\circ}18'$ - $26^{\circ}20'$ N and longitude $74^{\circ}31'$ – $74^{\circ}33'$ E having an area of about 24 sq. Km. The map of the target area along with grid range marked by selected locations used for surveying during first field work is shown in figure 1.

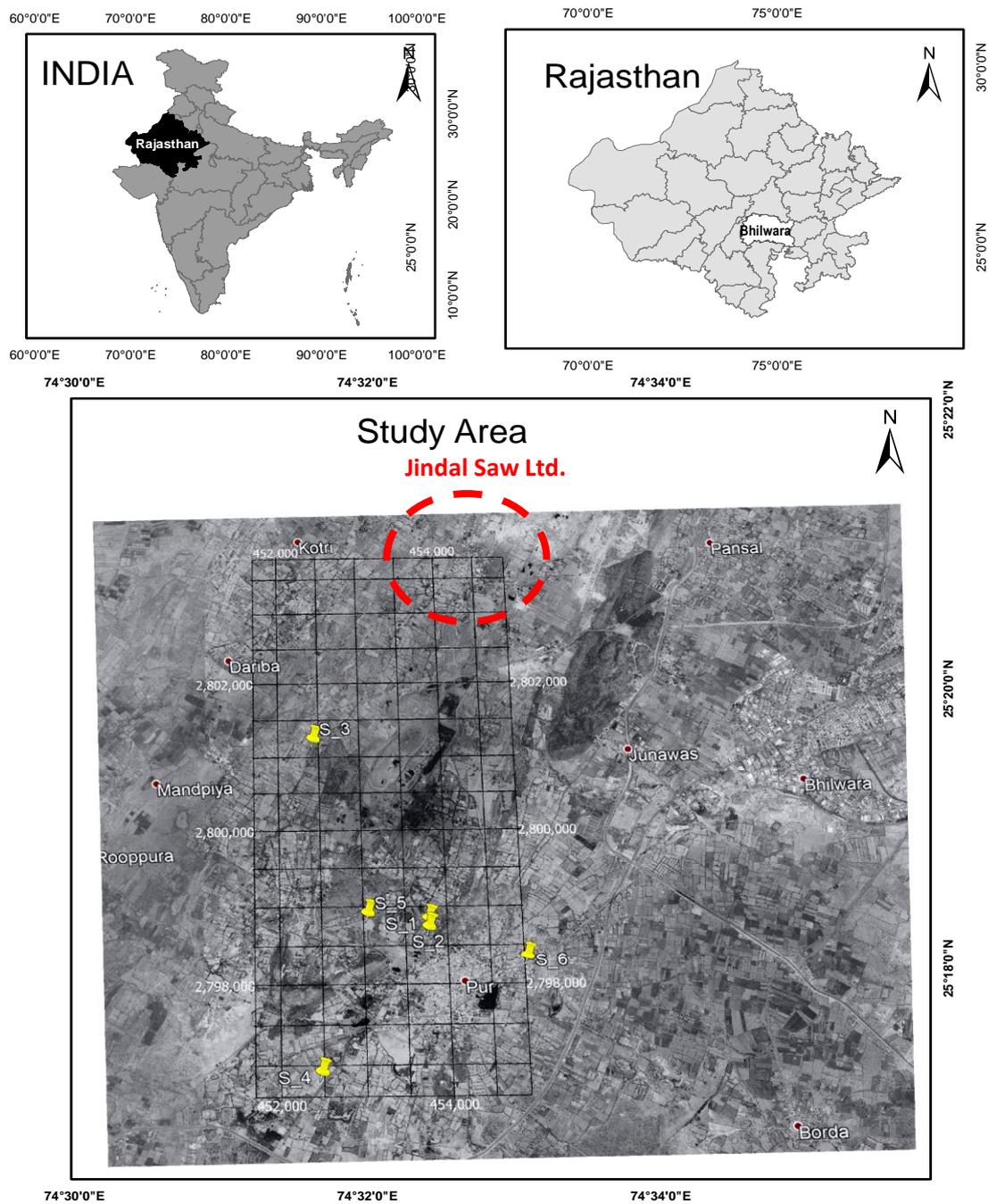


Figure 1: Figure showing the extent (grid) and location of the study area with marking for survey sites correspond to first field visit and Jindal saw Ltd. Area

The Digital Elevation Model (DEM) of the Bhilwara District showing the anomaly in surface elevation along with mark for the initial survey sites is shown in figure 2.

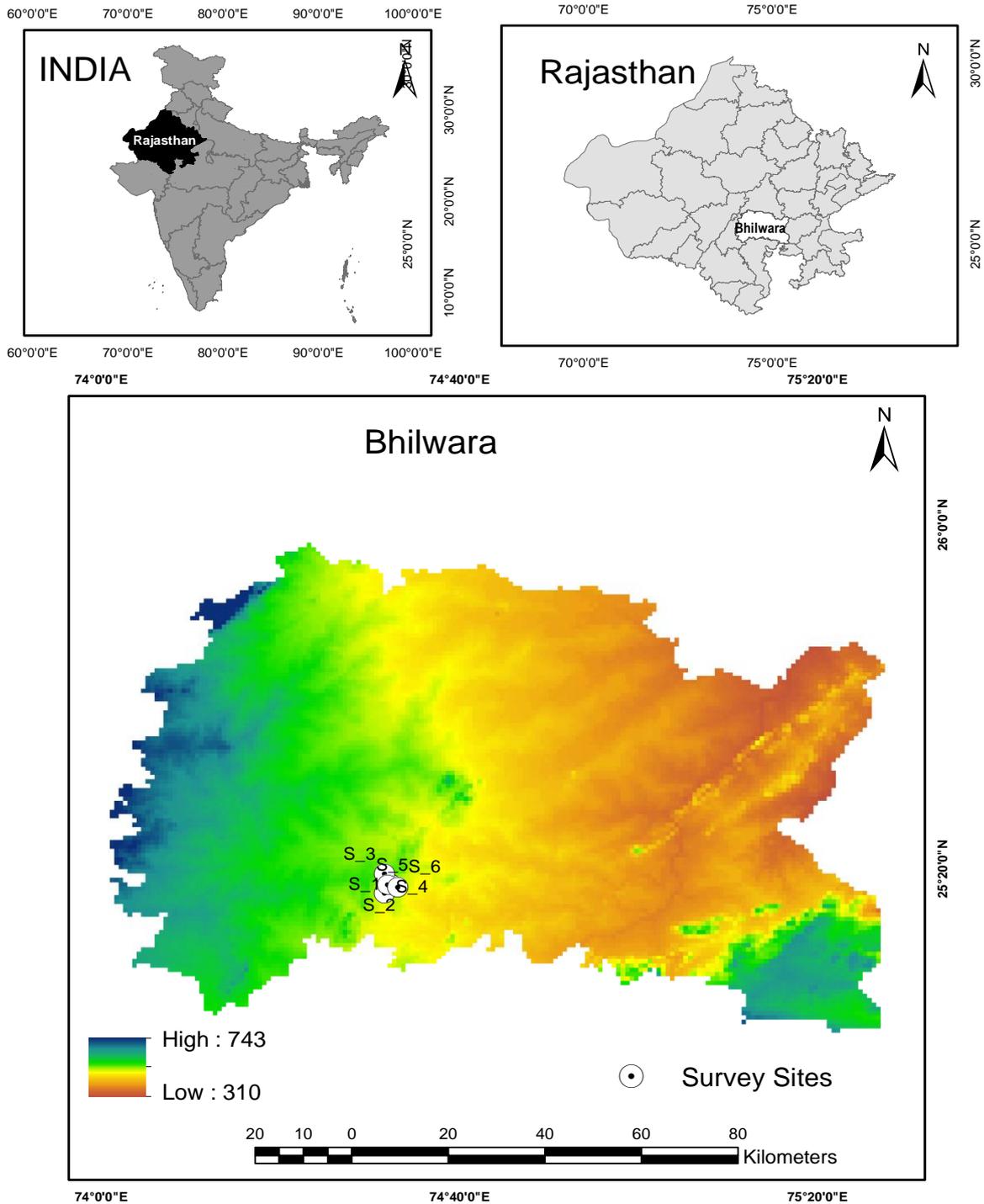


Figure 2: Digital elevation map (DEM) of the Bhilwara District showing surface elevation in meters with mark for survey sites correspond to first field visit.

3.1 Hydro-geological Setup

The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium as major water bearing formations. The aquifers formed are localized within the weathered, fractured and jointed hard rock areas zones. The geomorphological map of the area is shown in figure 3.

Weathered gneiss forms upper part of the bedrock in the central part. Weathered gneiss with schist occupies most of the northern part under thin cover of alluvium. In schists, phyllites and slates, weathered zone extends to greater depth than in granites and gneisses. Muscovite schist often grades into gneiss. These have well-developed foliation and irregular joints and are intruded by granite, pegmatite and quartz veins. The contact between these intrusives and schists provides good channel for ground water circulation. These formations are intercalated with dolomitic limestone, quartzite and basic intrusive. Dolomitic limestone is grey to light brown and compact at the surface. It forms aquifer in intercalations with slates and phyllites around Bagota, Laxmipura, Rampura, Amargarh, Dolpura, Kishangarh, Bakli, Bhajgarh, west of Banakhera, Mal Ka Khera, northeast of Mohanpura, Ladpura and Ratiya Khera. Quartzites are generally intercalated with phyllites and slates. These are brown coloured, hard and jointed.

Lithologs of eight boreholes derived from coring in the mining area merely 2-3 km towards north-northwest of Pur village have revealed that the subsurface geological formations in Pur area are mainly composed of garnetiferous, quartz-biotite, kyanite schist along with banded magnetite quartzite rocks and calc- gneisses with disseminations of pyrite, pyrrhotite and specks of sphalerite and chalcopyrite. The depth of these boreholes varied between 147 m and 307 m bgl and these are distributed on different parts of Tiranga hills, the main mining area of the Jindal Saw.

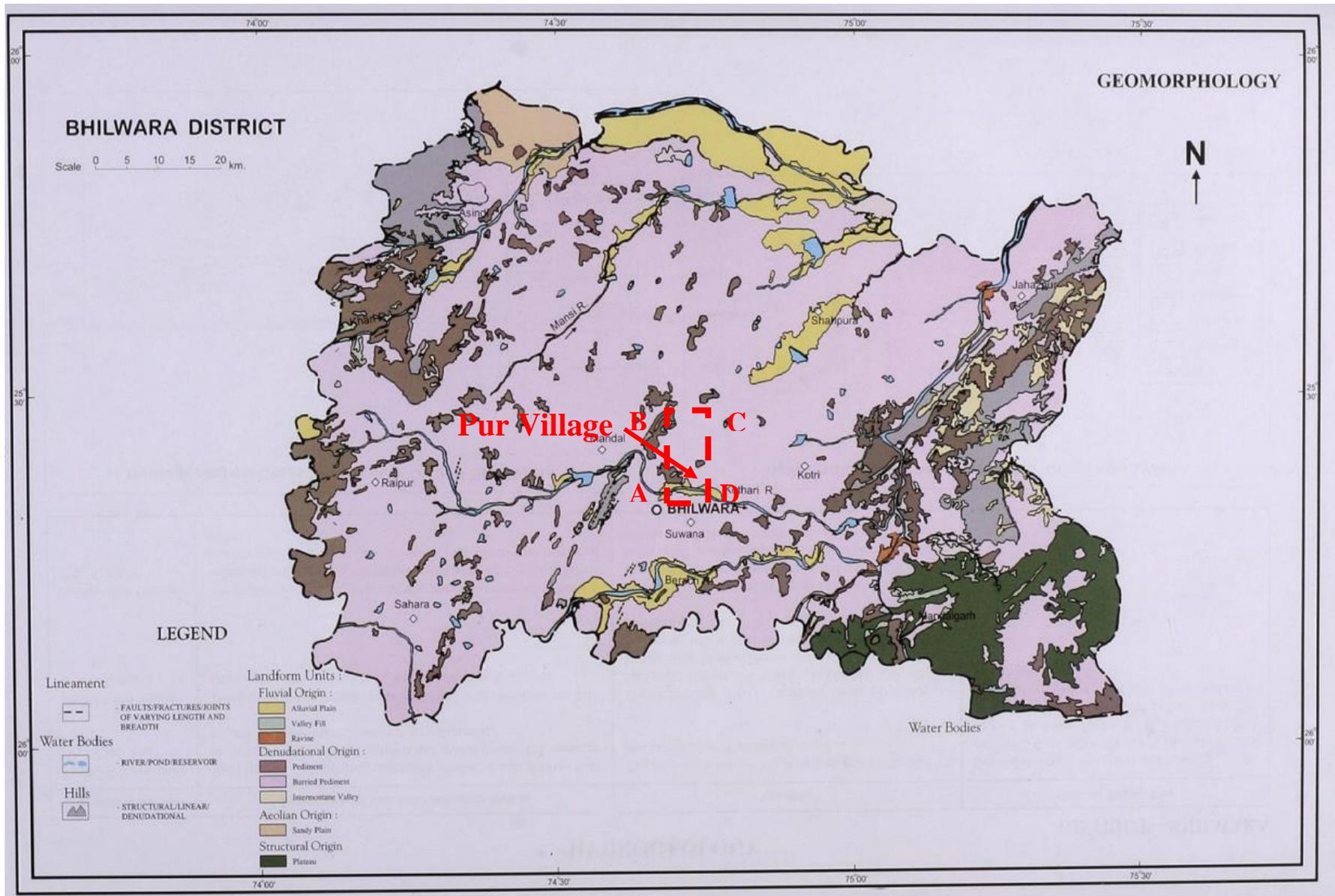


Figure 3: Geological map of the Bhilwara District, with marking of the target area (adopted from Indianwaterportal.org)

Geological Features Observed during the Field Survey

It was observed that the in-situ rock exposures have been significantly affected as a result of growing inhabitations in the area. Due to such incursions, only partially eroded and isolated remnants of hillocks are now found in the study area. Besides, many of the hillocks have virtually disappeared in the vastly expanding village. During the visit to the Laxmi (Teli) Mandir, prolific cracks and fissures were clearly visible in transverse, vertical-horizontal directions. As such, examination of one partially eroded hillock near 'Baoli Naka' revealed fragile exposures of grey black schists with dip of 75-80 deg in the N-130 deg direction, implying strike of N40-220 deg, which also seems to be slightly disturbed in nature. The dip direction also seemed to be vaguely towards an adjoining pond. Further, in a nearby open lined dug well of Sh Radhey Shyam S/o Baloji, situated in the vicinity of the Mata 'mandir', the static water level was reported to hover around 20 ft bgl with the total well depth being approx. 60 ft. The well had a centrifugal pump and reportedly got empty within 3-4 hrs of pumping which was told to recover in 6-7 hrs. An area of around 2 bigha of vegetable orchard is irrigated by the slight brackish groundwater pumped from the well. The spot examination of the geological formations in the Sukhadia stadium, situated on the periphery of Pur indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement due to faulting in the geological past as manifested by presence of slicken sides with visible silicification on the steep rock face(s).

3.2 Meteorological Information

The climate of Bhilwara is characterized by hot and dry climate receiving precipitation mostly in the form of southwest monsoon during July-September. The average annual rainfall of the area is 635.1 mm and the average monthly rainfall for the last decade is listed in table 1. Drought analysis based on agriculture index indicates that the area is prone to mild and normal types of droughts. Occurrence of severe and very severe types of droughts is very rare. The average air temperature of the area is 25.47⁰ C. January is the coldest month with mean, max and min temperatures being 22.2⁰C & 7.3⁰C. Temperature in summer month of June reaches up to 46⁰C. The humidity is highest in August with mean daily relative humidity at 80%. The annual potential evapotranspiration in the district is 1495 mm with average pressure of 1007.5 mb. A high rainfall of amount more than 1200 mm observed in 2019 was accompanying by accelerated aggravation of building cracks as reported by the residents.

Table 1: The monthly rainfall average in mm from year 2010 to 2019 for the Bhilwara District

	January	February	March	April	May	June	July	August	September	October	November	December	Total
2019	68.5	135.4	24.2	23.8	36.8	16.6	265.54	415.12	265.6	15.6	0	0	1247.16
2018	6.39	12.83	8.69	8.63	12	27.62	112.37	153.5	78.73	5.4	16.1	1.5	443.76
2017	23.27	2.32	8.42	13.74	5.37	21.6	64.65	83.7	66.08	0	1.22	15.49	305.86
2016	2.72	8.69	14.28	3.73	1.52	35.25	174.11	56.47	10.64	0	0	0.24	307.65
2015	4.25	13.83	51.15	13.98	1.38	21.44	126.11	100.57	52.26	1.1	2.01	4.32	392.4
2014	8.81	23.24	12.64	2.73	13.28	10.4	47.74	71.38	35.34	2.01	0	7.6	235.17
2013	13.83	31.9	7.64	4.78	2.67	98.61	179.29	129.95	16.15	7.96	0.49	2.41	495.68
2012	2.98	3.77	3	18.82	3.66	3.07	116.05	207.7	129.21	0.19	0.05	3.87	492.37
2011	3.45	13.12	2.01	16.69	26.55	64.81	162.39	232.82	76.55	5.07	0	0.47	603.93
2010	7.56	26.37	0.96	0.67	5.21	1.87	191.52	145.08	222.75	7.75	0.81	9.44	619.99

4.0 Field Test Results

Three main equipment setups comprising 1) sounding terrameter for 1-D VES 2), Earth resistivity meter for 2-D ERT and 3) Ground magnetic resonance (GMR) were used for this study along with the dip-meter, water quality probe and other relevant accessories. Six locations were selected for performing VES, ERT, and GMR soundings during the first field visit based on the topography and area availability. Three more locations were selected for ERT during the second field visit. The locations and elevation above msl of sites is listed in table 2 and marked in figure 4. A total of 17 resistivity (6 VES and 11 ERT) soundings and 2 GMR surveys were conducted. In-situ water quality analysis were conducted at 4 different locations during the first visit while 9 water samples were collected during the second field visit for analysis of isotopic and other physio-chemical water quality parameters. It is to be noted that most of the soundings were performed at the periphery of the Pur village facing towards the mining site to map the existing hydrogeological profile of the severely affected area.

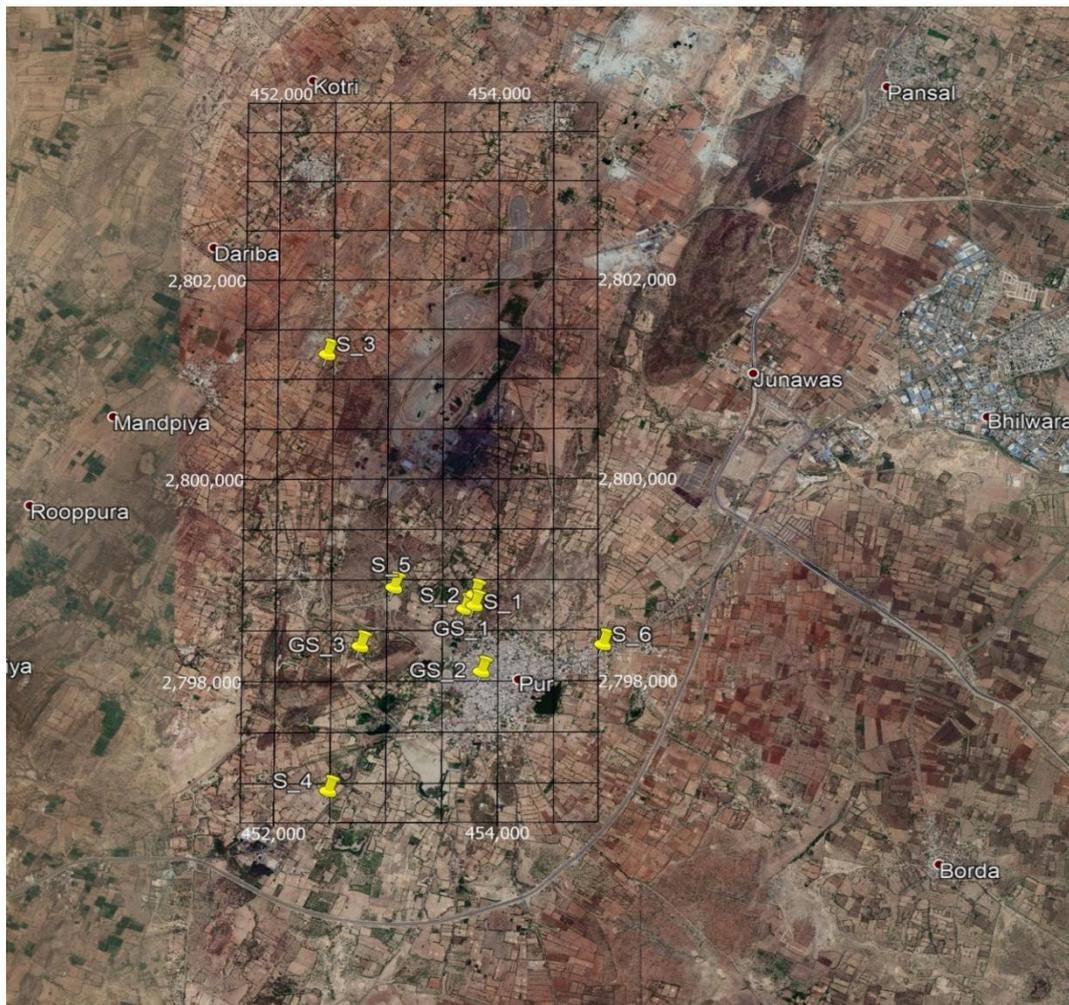


Figure 4: Locations of all survey sites used for resistivity and tomography surveys.

Table 2: Location of all survey sites with their spatial coordinates in WGS 1984 coordinates system.

Site Code	Location	Latitude	Longitude	Elevation (m)	Performed Sounding			
					VES	GMR	ERT	Total
S_1	Pathwari	25.301319	74.540528	455	1 (VES_1)	0	1	2
S_2	Ghati Ke Hanuman	25.303355	74.540543	454	0	1	1	2
S_3	Jindal Mata Mandir	25.325926	74.527081	456	1(VES_5)	0	1	2
S_4	Moldi Ke Shyam	25.2869106	74.52765	438	1(Ves-6)	1	1	3
S_5	Sukhadia Stadium	25.30495	74.53331666	448	2(VES_3 and VES_4)	1	4	7
S_6	Gyas Mata Colony	25.2998833	74.5520166	448	1(VES_2)		0	1
GS_1	Near Old Masjid	25.30305	74.53965		0	0	1	1
GS_2	Infront of Bada Mandir	25.297467	74.541183		0	0	1	1
GS_3	Ghata rani temple	25.2997167	74.53035		0	0	1	1

4.1 VES using Terrameter

The ABEM SAS 300B terrameter shown in figure 5 was used for performing the one-dimensional vertical electrical soundings (VES) at sites denoted as S_1, S_3, S_4, S_5 and S_6. It is necessary to mention here that at the site S_5, two VES (one parallel and another perpendicular to the Strike direction, NE-SW, of the area) were conducted for better assessment of subsurface. The VES works on the principle of measuring resistivity anomaly in the subsurface. It gives the one dimensional geological characterization of the area in term of apparent electrical resistivity along the survey line.



Figure 5: Terrameter installed in the field along with connecting cables and other supportive accessories.

Soundings are carried out using Schlumberger configuration with maximum current electrode spacing (AB) of 400 m to delineate the subsurface. The field data (Apparent resistivity and half current electrode separation, $AB/2$) along with the spatial coordinates of VES locations are interpreted using Masters Curves and also by using a geophysical exploration software (Zondip 1D). The resistivity data is analyzed and depth to resistivity models are prepared using forward modelling followed by inverse modeling for more accurate results. The plots of field apparent resistivity versus $AB/2$ on log-log graph are given in figure 6 (a-f). The results of the interpretation of the field data in terms of layer thicknesses and true resistivity are shown in figure 7 (a-f). Along with the software interpretation, all the VES performed in the field are also interpreted manually. A perusal of the interpreted results indicates that each VES location is comprised of 4-5 layers and showing possibility of cracks, fissures, and fractures in the subsurface. In general, the topsoil layer in the Project area is found to be composed of grey black schist and quartzite often overlain by thin top layer of alluvial soil with sand and clay mixture.

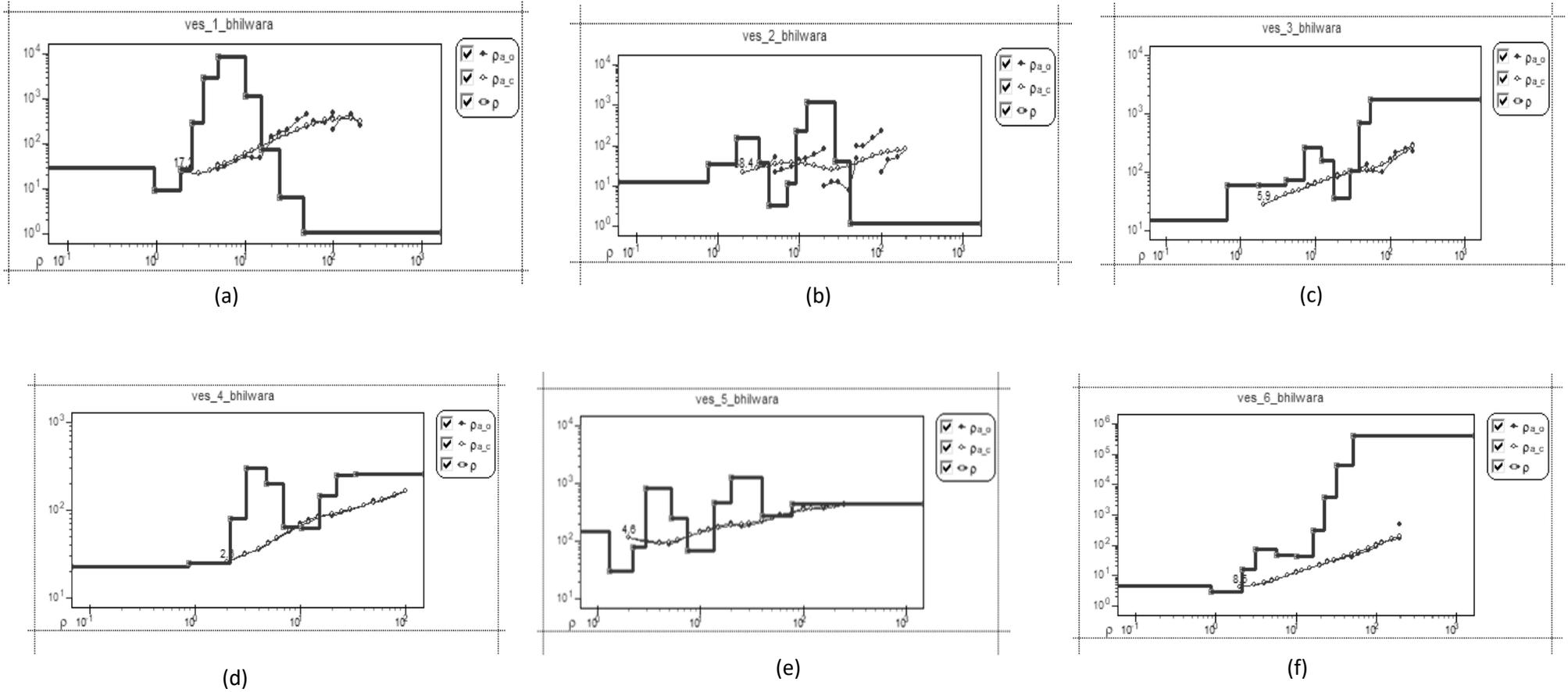


Figure 6. Field resistivity curves plotted by the Zondip 1D for the site: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4.

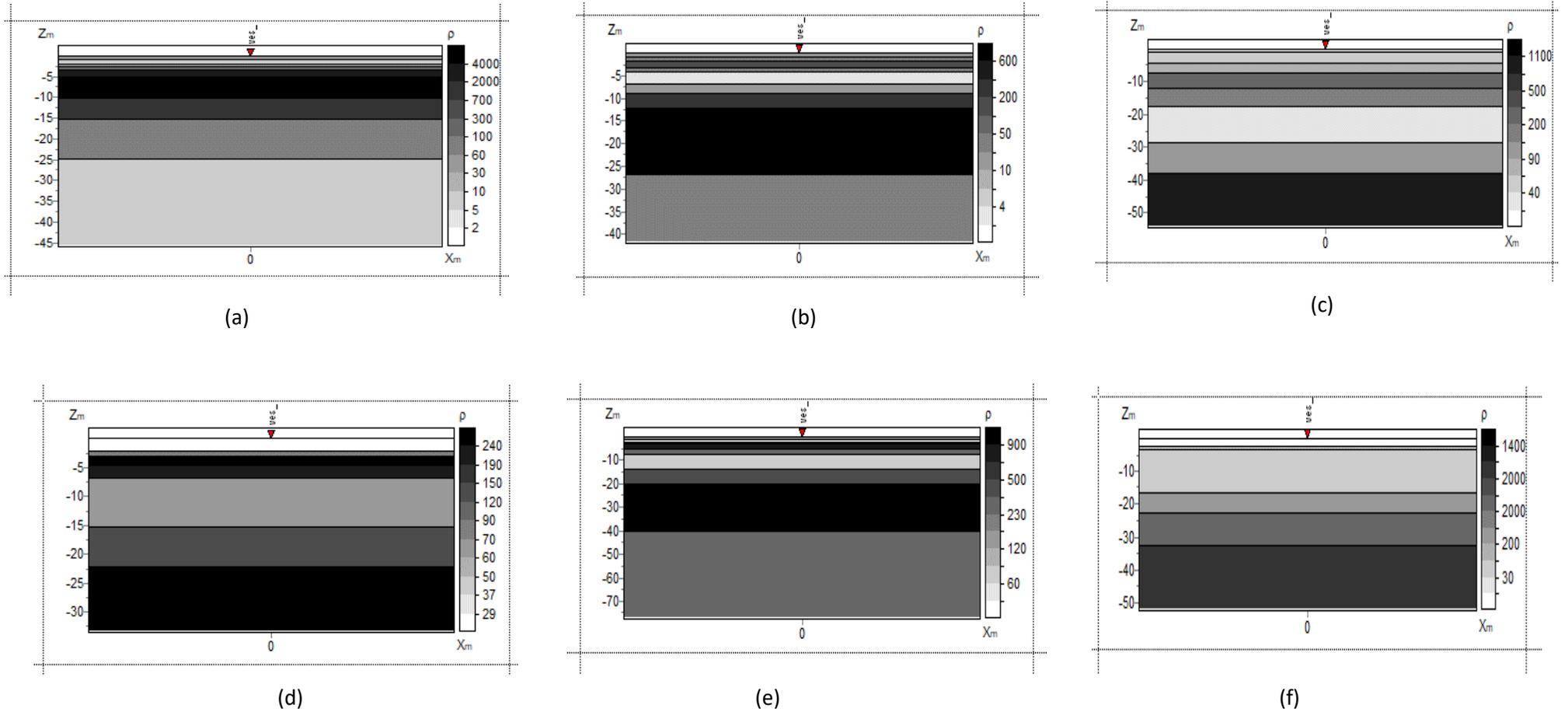
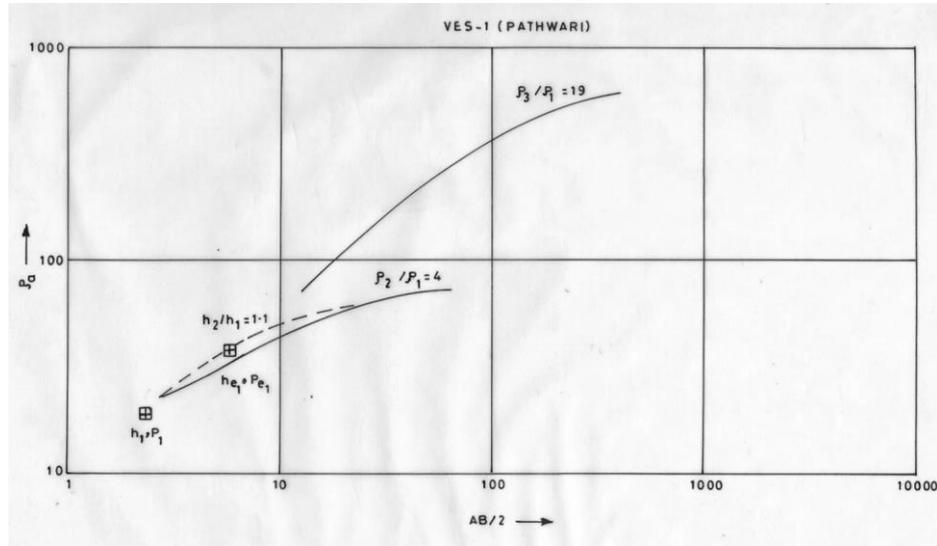
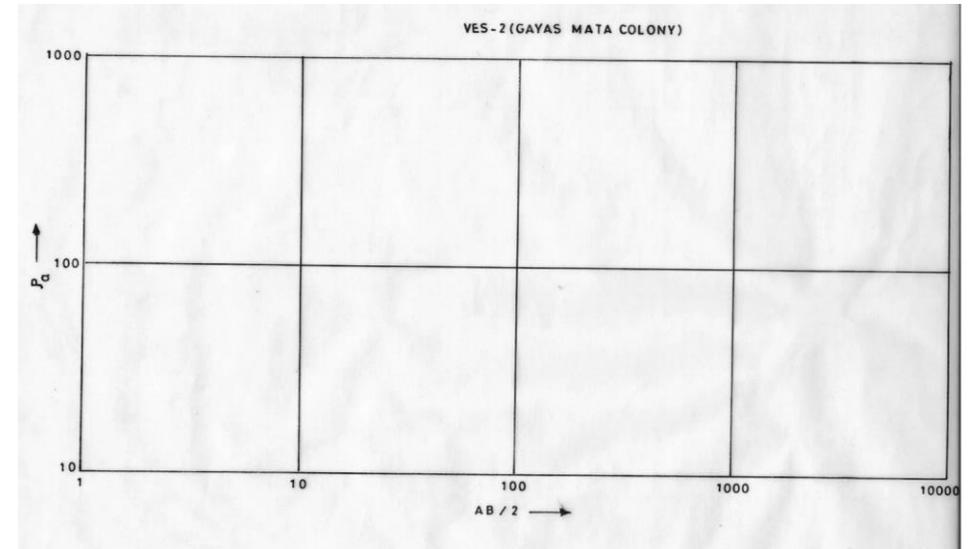


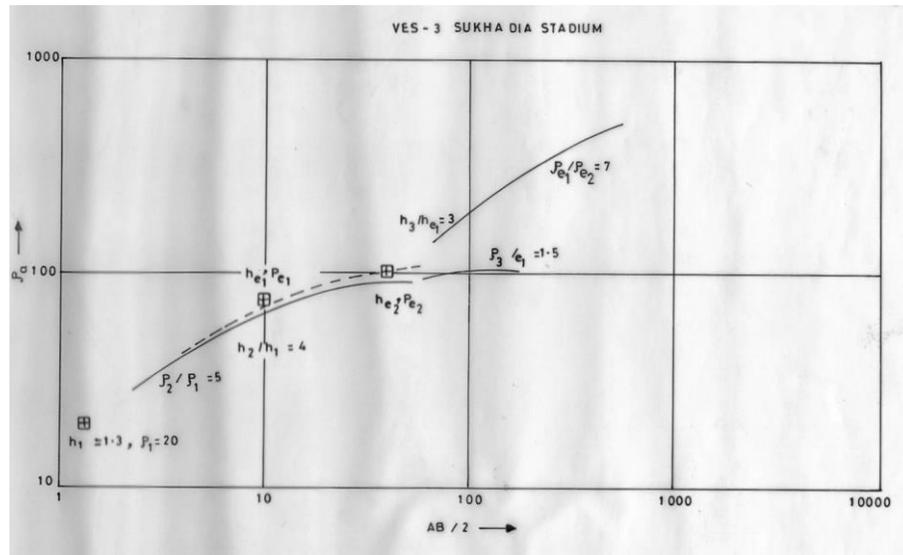
Figure 7: Depth-Resistivity models for the sites: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4. The depth (Z_m) is shown in meters and resistivity (ρ) is in Ohm-meters ($\Omega\text{-m}$).



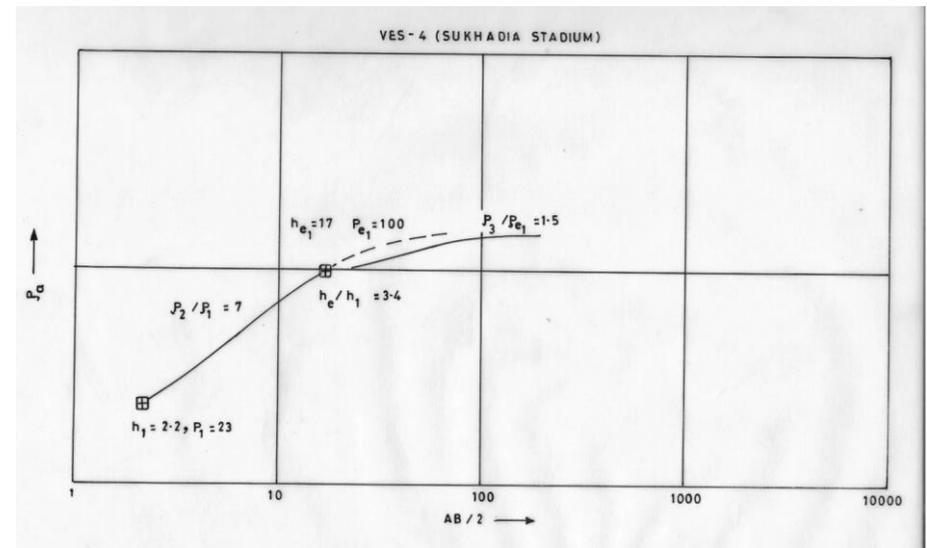
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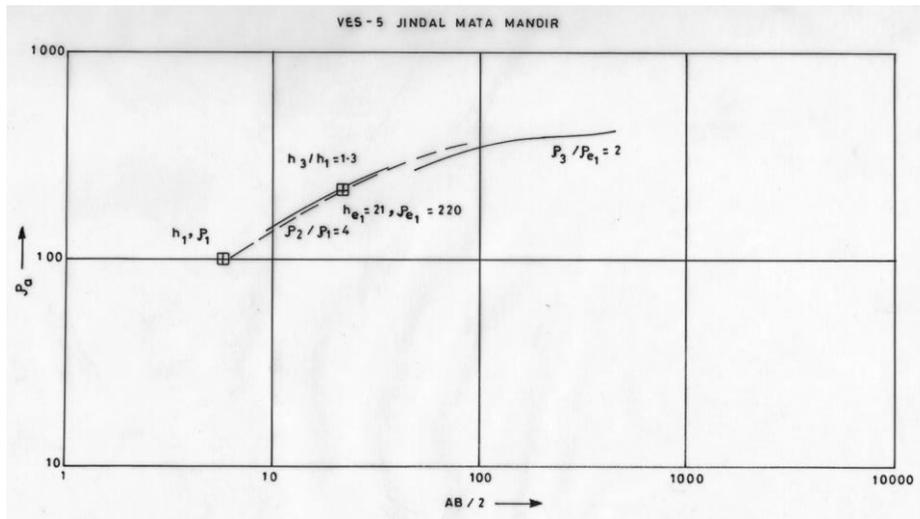
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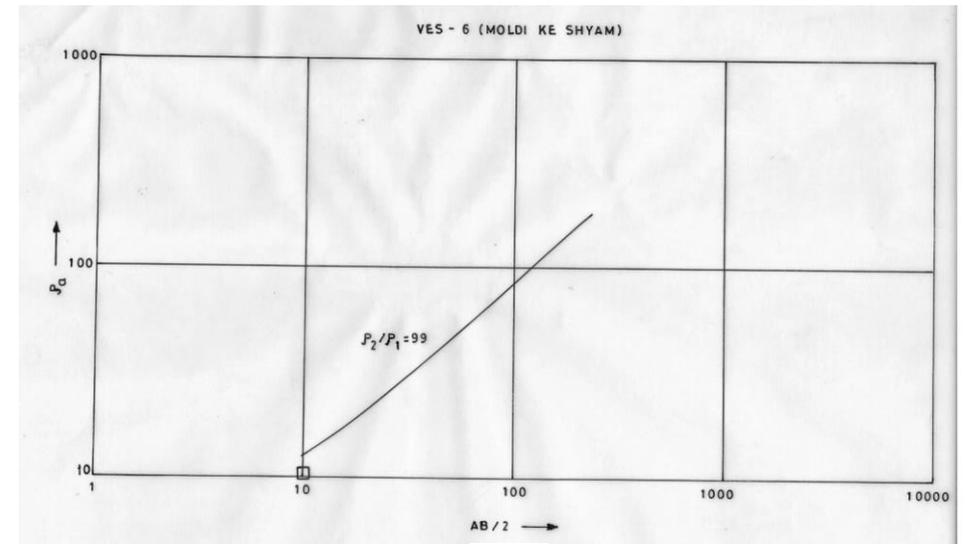
(c)



(d)



(e)



(f)

Figure 8: Smoothed Field data curves matched over the master curve manually for the sites: (a) S_1 (VES_1), (b) S_6 (VES_2) (c) S_5 parallel to dip (VES_3), (d) S_5 perpendicular to dip direction (VES_4), (e) S_3 (VES_5), and (f) S_4 (VES_6).

The data of plotted apparent resistivity curves are shown in Figures 8(a) to figure 8(f). A visual analysis of these plots indicates that the curves display A-A (double ascending) pattern in general, whereas the plots recorded in Sukhadia stadium (VES 3 and VES 4) displayed K-A type of resistivity curves. However, the sounding VES-2 recorded at Gyas Mata colony (Figure 8b) displayed lot of scatter of plotted points, and thus could not be interpreted. The plotted graphs of apparent resistivity versus $AB/2$ were interpreted by partial curve matching techniques, using Master curves given by Orellana and Mooney (1966). Table 3 shows the data of true resistivities and layer thicknesses derived from the partial curve matching for all the six soundings. Attempts made to interpret the field resistivity data using Zondip 1-D software were found inconsistent, mainly due to anisotropic nature of geological formation(s) in the area. Yet, the field resistivity data interpreted by inverse modeling are also presented in Figure 6.

A perusal of the table 4 generally indicates presence of a thin top soil/alluvium, having resistivity of 2 to 20 ohm-m, of thickness varying between 1m to 5 m. The top soil/alluvium is underlain by weathered hard rock, schistose quartzite, having resistivity in the range 76 to 161 ohm-m and thickness ranging from 2 m to 7 m, with a maximum thickness of 34 m at Sukhadia stadium observed in VES-3. However, at VES-5 location nearby to Jindal Mata Mandir, the top veneer is directly comprised of weathered hard rock as seen from the high resistivity of 100 ohm-m. The above interpretation is corroborated by the presence of isolated outcrops of schistose quartzite dotting the area. The rocks in these outcrops show steep dips towards SE, with presence of slicken sides in Sukhadia stadium, at sites VES-3 and VES-4, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite having resistivity of 440-9900 ohm-m at depths varying between 5 m below the surface at Pathwari and 36m bgl at Sukhadia stadium.

It is to be noted that results from graphical interpretation are almost in line with the Zondip 1-D except for the site S_6 (Gyas Mata Colony). Hence, the results of VES performed in these sites are validated itself indicating greater accuracy. The apparent resistivity points from the site S_6 (Figure 8b) are very scattered that their manual interpretation in term of field curve could not be done. Depth-resistivity curves are further decoded in probable lithologs listed in table 4 (a-f) using the secondary data collected from the field and available literature on subsurface lithology as revealed from coring data of eight borewells in the Tiranga hill area.

Table 4: Subsurface characterization by depth-resistivity models prepared for VES at:**(a) Site S_1: Pathwari (VES_1)**

Thickness Interval (m)	Resistivity(ohm-m)	Probable Lithologs
0 - 2.3	19	Clayey/ silty soil
2.3 - 4.8	76	Grey black phyllite
4.8 - (++)	684	Schistose Quartzite

(b) Site S_6: Gyas Mata Colony (VES_2)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0-12	12.65	Saturated Clay, Sand
12-27	1185	Hard grey black phyllite
27-(++)	40.236	Weathered grey black phyllite

(c) Site S_5: Sukhadia Stadium Parallel to Rock Strike (VES_3)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 - 1.3	20	Surface Soils (Clayey)
1.3 – 36.5	100	Weathered phyllite/ Schistose Rock
36.5 - indefinite	700	Hard Quartzite rock

(d) Site S_5: Sukhadia Stadium Parallel to Strike (VES_4)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 2.2	19	Surface Soils (Clayey)
2.2 – 9.7	161	Partially saturated Garnite Schist
9.7 - indefinite	500	Hard Quartzite rock

(e) Site S_3: Jindal Mata Mandir (VES_5)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 5.5	100	Weathered Schistose Rock
5.5 – indefinite	400 - 440	Hard Quartzite (Schistose)

(f) Site S_4: Moldi Ke Shyam (VES_6)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 10	10	Clayey Soil
10 – indefinite	990	Hard Quartzite (Schistose)

The table 4 is prepared considering the results from Zondip 1-D and graphical interpretations in combination with lithology of cored bore wells drilled long back in Tiranga hill area. Whole area is found to be composed of grey black garnetiferous schist and quartzite schist whether weathered, hard, or in saturated state. Hard quartzite (metamorphic rock) is found at a depth of 5m approximately at site S_1. Out of the two VES (3 and 4) performed at Survey site S_5, the VES-3 performed parallel to the strike seems to be more logical and accurate when compared to the VES-4 performed perpendicular to the Strike.

4.2 Electrical resistivity tomography (ERT)

The earth resistivity meter shown in figure 9 is a 4-point light 10W high precision instrument for determination of soil resistivity. The electrical resistivity allows determination of the water content in the soil and of the types of soils and rock. It can be applicable to groundwater prospecting, mining, and other environmental investigations. The phase shift between output current and voltage provides information about the induced polarization (IP). The accuracy of the instrument is about 0.1 % with a resolution of max. 100 nV. From the current I , the voltage U and a geometric configuration factor the specific electrical resistivity ρ (Ohm-m) is calculated. The receiver of the instrument is highly selective and only records voltages at the set frequency. However, noise at the measurement frequency degrades the quality of the measurement and should be suppressed. Major reasons for noise may include Mains (electric) interferences, magnetic interferences, wind, rain, and mechanical instability of the electrodes. The ERT is performed over sites S_1, S_2, S_3, S_4, S_5, GS_1, GS_2, and GS_3 in this study.



Figure 9: Earth Resistivity Meter installed in the field

The resistivity values obtained by Earth resistivity meter is interpolated in lithological formations using G.J. Palacky (1988). The 2-D inverse resistivity model and subsurface characterization for different sites are as follows:

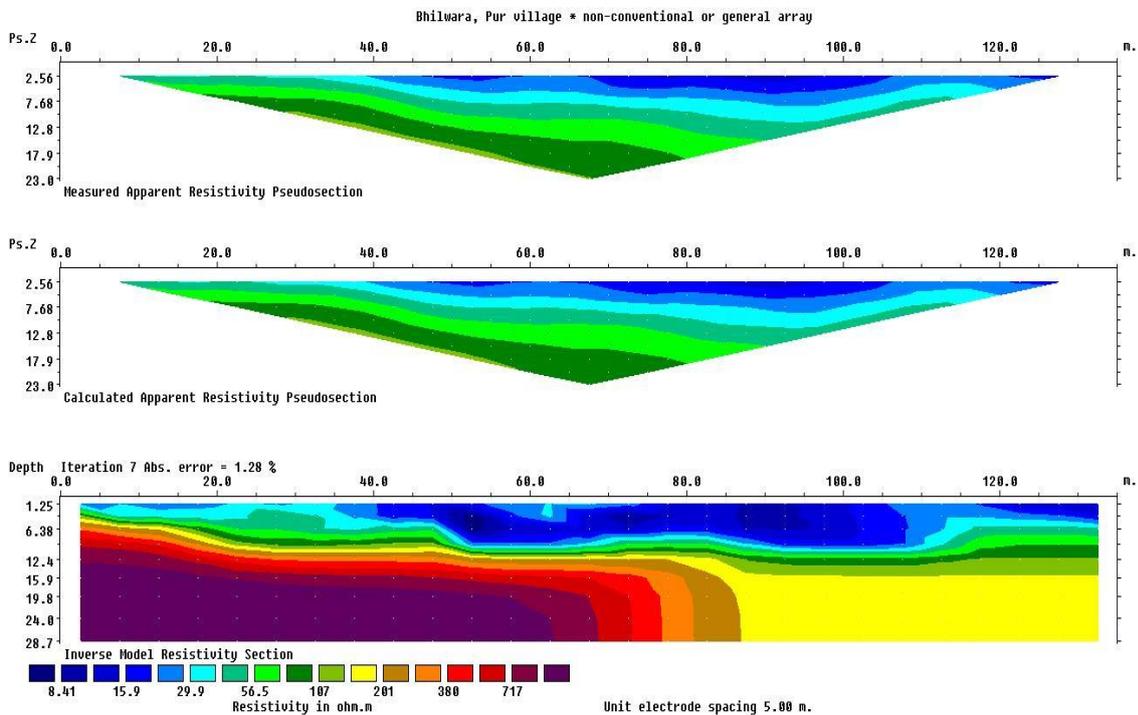


Figure 10: 2D resistivity inverse model by Wenner method at S_1.

Table 4: Subsurface characterization by ERT at S_1

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable lithologs
0-4	8.74-42.8	Sandy Soil
4-12	42.8-463	saturated sand and clay, sandstone, lignite, coal
12-22	463-1024	Gravel and Sand, garnetiferous Quartzite
22-26	463-2266	Metamorphic Quartzite

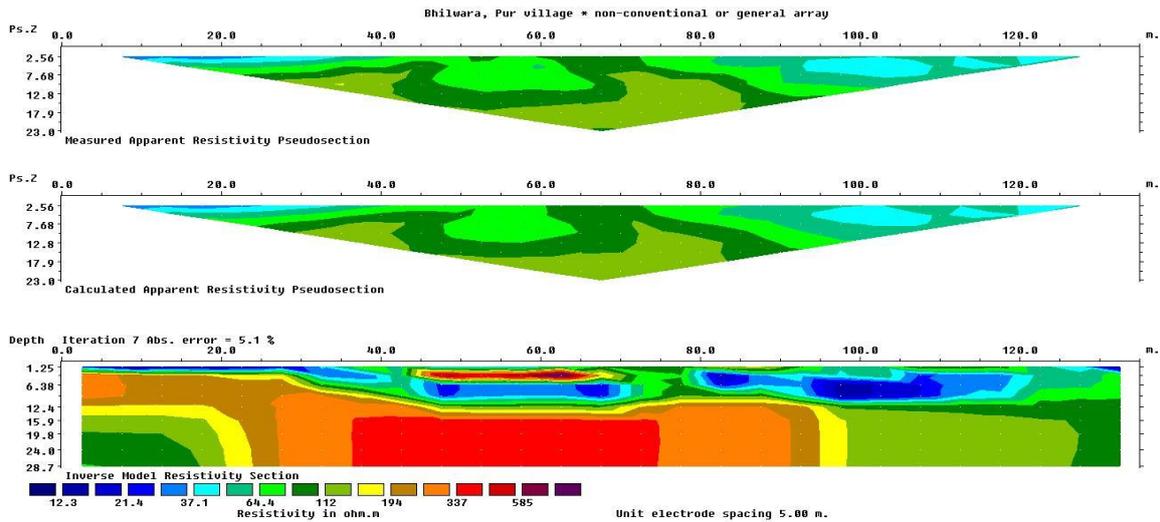


Figure 11: 2D resistivity inverse model by Wenner method at site S_2.

Table 5: Subsurface characterization by electrical resistivity tomography (ERT) at S_2 (Ghati ke Hanuman)

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable lithologs
0-7	11.5-472	Clayey soil
7-26.2	137-877	Schistose Quartzite/gneiss with water in fractures

Site S_3

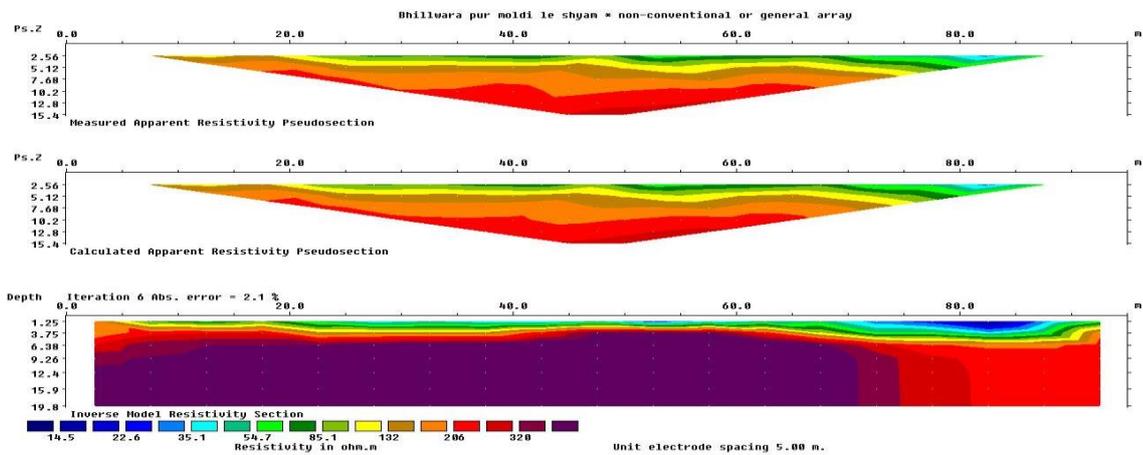
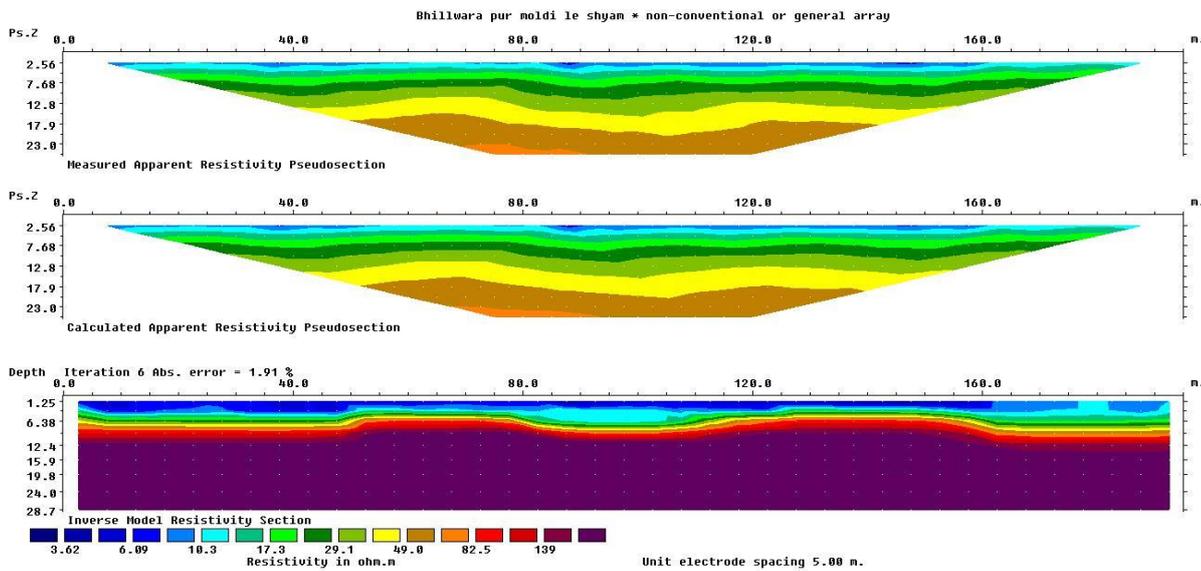


Figure 12: 2D resistivity inverse model by Wenner method at S_3.

Table 6: 2D resistivity inverse model by Wenner method at east direction of S_3.

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-4	15.7-202	Topsoil and saturated Schist
7-32	202-308	Schist

Site S_4**Figure 13:** 2D resistivity inverse model by Wenner method at S_4.**Table 7:** 2D resistivity inverse model by Wenner method at east direction of S_4

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-7	3.53-38.3	Clayey soil
7-32	38.3-229	Granite Schist

Site S_5: Sukhadia Stadium

At this site, the survey was conducted in east, west, north and south direction up to 100-meter length on earth surface.

East

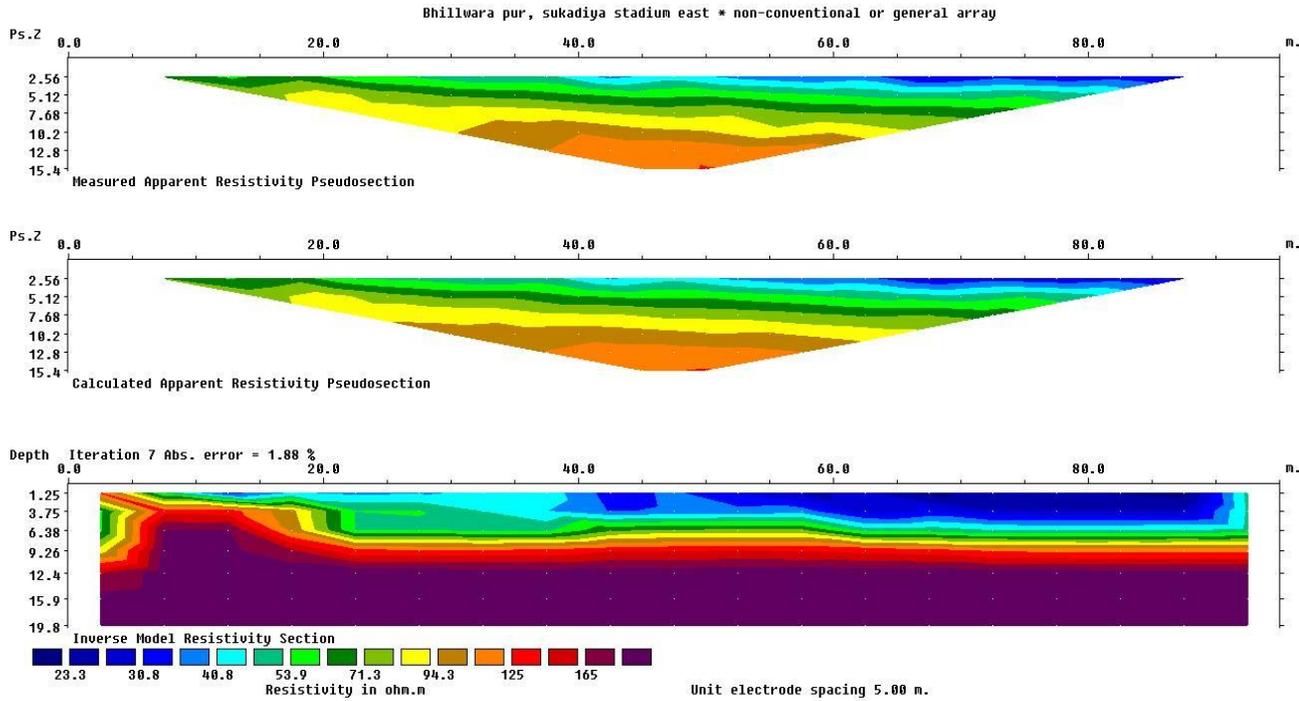


Figure 14: 2D resistivity model by Wenner method at east direction of Sukadiya stadium.

Table 8: Subsurface characterization by electrical resistivity tomography at east direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable lithologs
0-3	23.2-76.5	Clayey soil, Weathered schist
3-10	76.5-114	Weathered schist
10-17.3	114-375	Sandstone schist

West

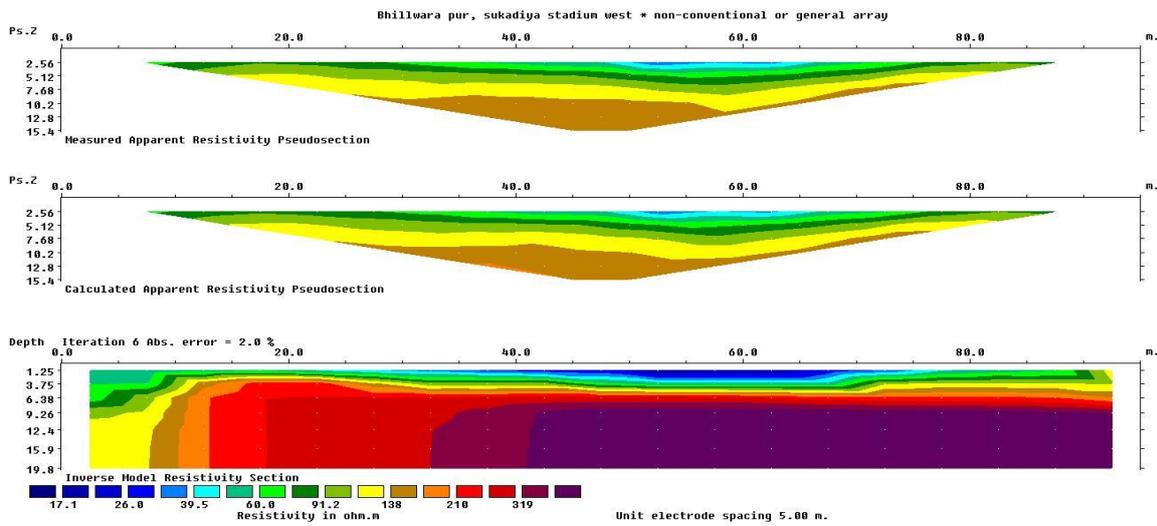


Figure 15: 2D resistivity model by Wenner method at West direction of Sukadiya stadium

Table 9: 2D resistivity inverse model by Wenner method at West direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-3	16.7-215	Clayey soil
3-10	129-357	Partially saturated Schist
10-17.3	215-595	Schist

North

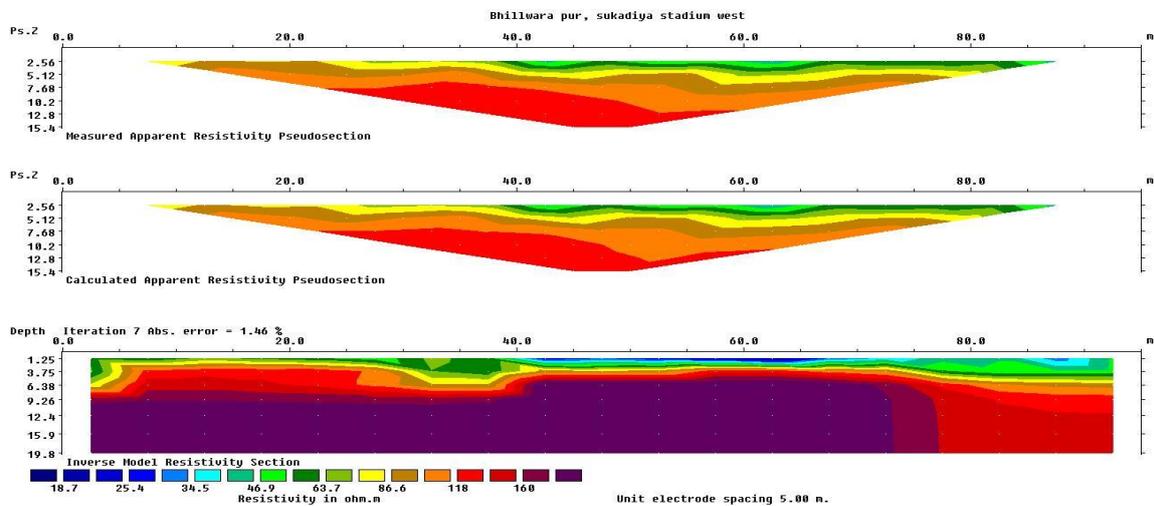


Figure 16: 2D resistivity model by Wenner method at north direction of Sukadiya stadium

Table 10: 2D resistivity inverse model by Wenner method at north direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-3	10.4-86.7	Clayey soil, Sandstone
3-17.3	86.7-161	Schist

South

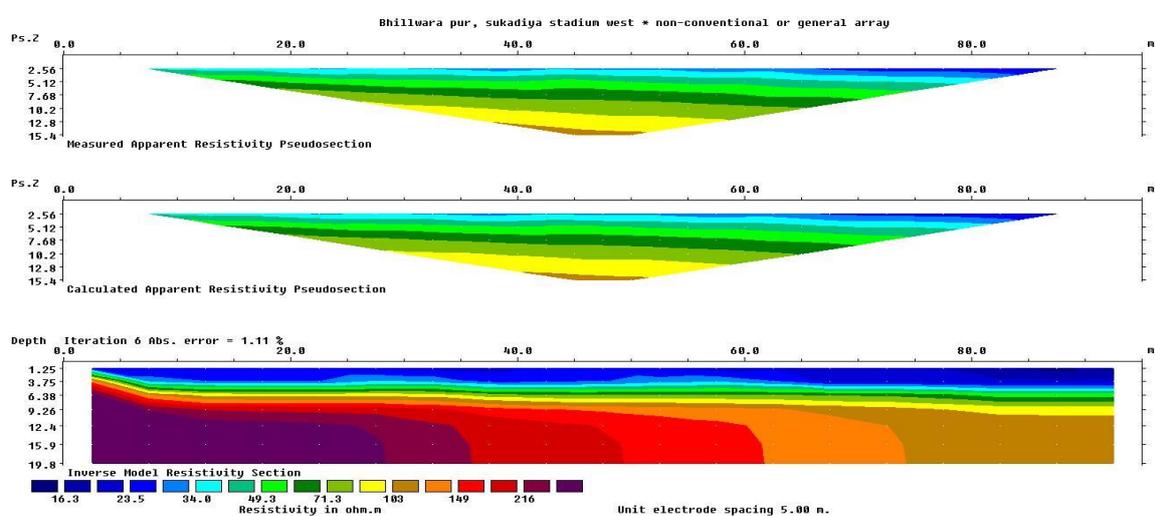


Figure 17: 2D resistivity model by Wenner method at south direction of Sukadiya stadium

Table 11: 2D resistivity inverse model by Wenner method at south direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-3	15.8-90.4	Clayey soil
3-17.3	90.4-335	schistose rock

Site GS_1: Near Old Masjid

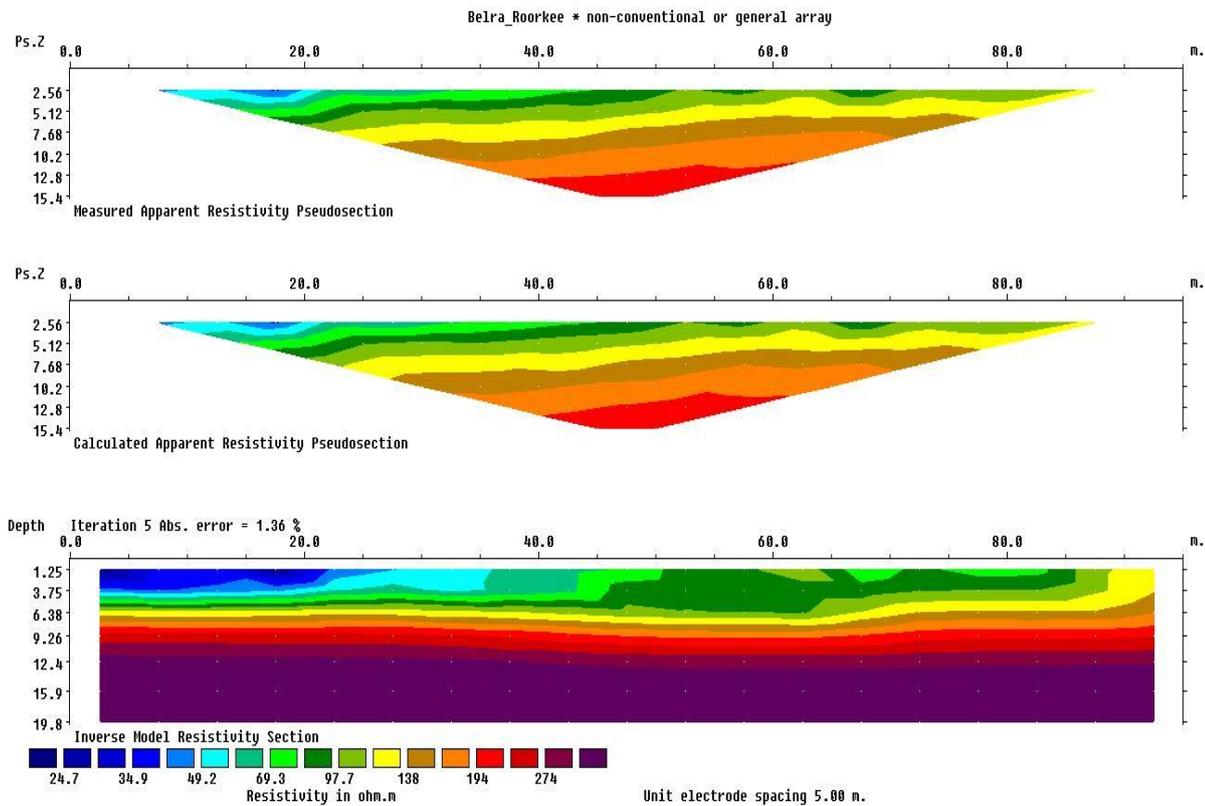


Figure 18: 2D resistivity inverse model by Wenner method near old masjid beside the pond

Table 12: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_1

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	Probable litho log
0-5	95	Top Soil
5-10	194	Schistose rock
10-25	274	Weathered Schist

Site GS_2: Near Bada Mandir

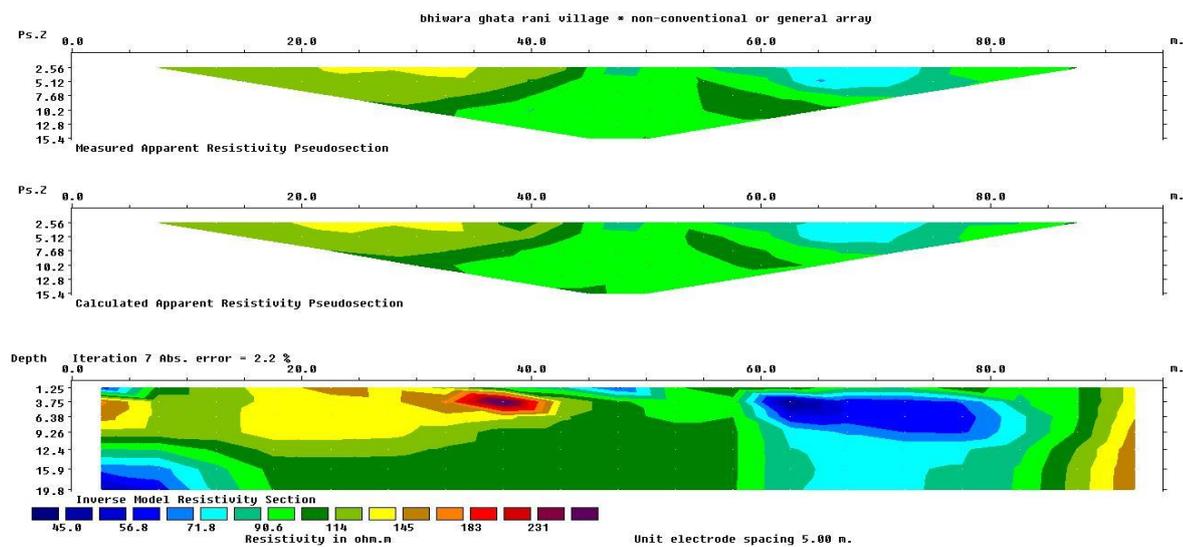


Figure 19: 2D resistivity inverse model by Wenner method near Bada Mandir

Table 13: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_2

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	Probable litho log
0-5	50	Top Soil
5-10	85	Fractured Schistose
10-15	228	Weathered schist
15-20	243	Weathered schist

Site GS_3: Near Ghata Rani Temple

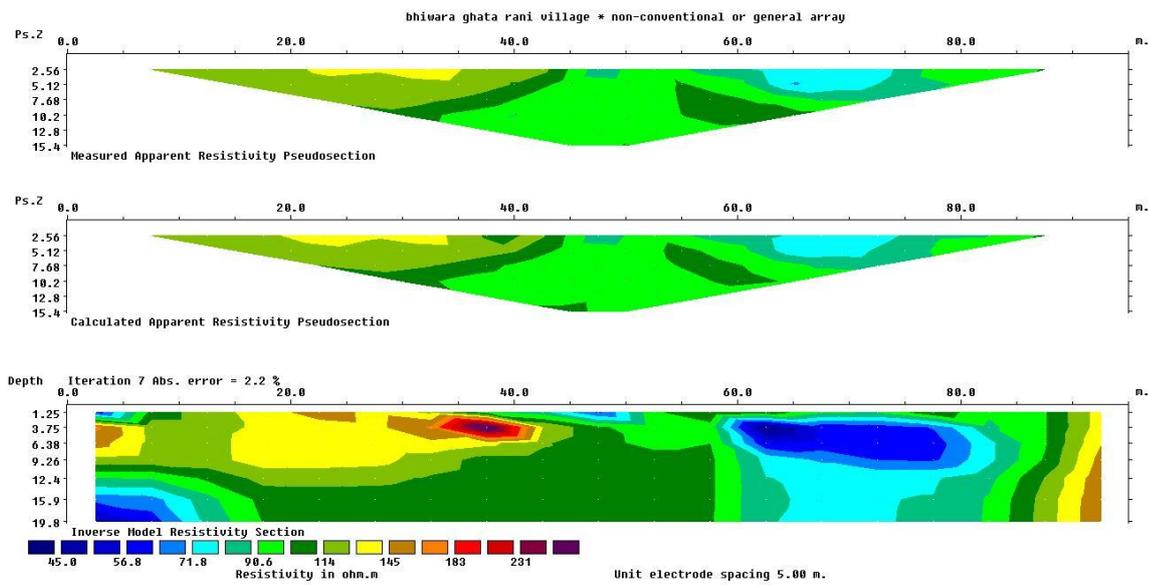


Figure 20: 2D resistivity inverse model by Wenner method near Bada Mandir.

Table 14: Subsurface characterization by ERT at site GS_2

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	Probable litho log
0-5	126	Weathered schist
5-10	125	Weathered schist
10-15	104	Grey Phyllite Rock
15-20	104	Grey Phyllite Rock

The finding of both 1-D vertical electrical soundings and 2-D electrical resistivity tomography gives similar subsurface resistivities at different locations.

Three-Dimensional modelling of Subsurface

The existing geological picture of the study area obtained by performing various VES and ERT can be understood by a professional hydro-geologist but may not be easy to conclude by others. In order to clearly explain the current geological scenario in the area, results of both these tests are clubbed together and 3-dimensional solid model, strip log diagrams, and fence diagrams are developed using ROCKWARE modelling software. The grid network used as base for 3-D lithological modelling is shown in figure 21. The problematic area i.e., in and around Pur village is situated near to edge AD of grid whereas mining site is located near the BC edge of this grid.

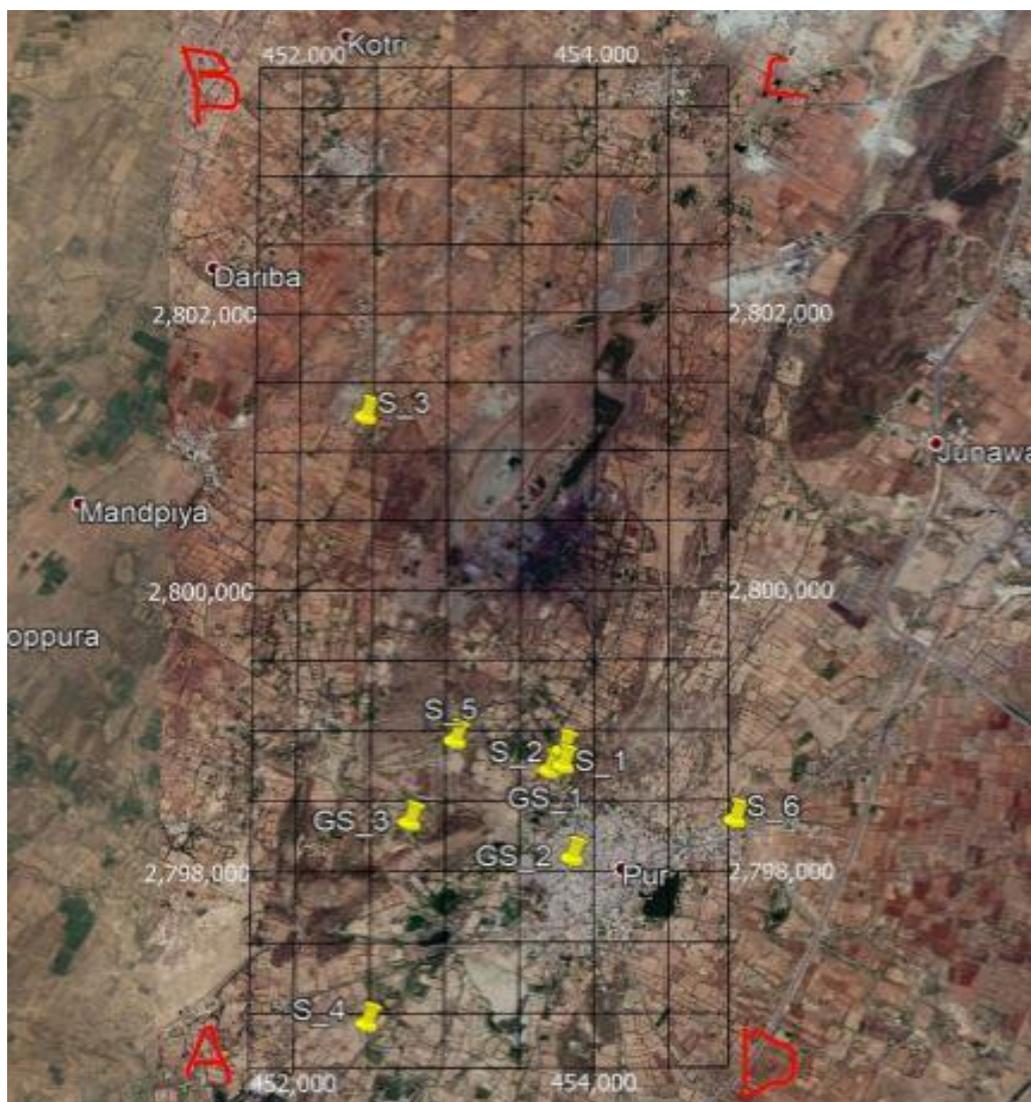


Figure 21: Google map of study area with marking for testing sites and grid ABCD used in lithological modelling.

A three dimensional geological model of the study area is shown in figure 22. This model gives the overall picture of the existing subsurface conditions in the area. As single view side of this complex model seems insufficient to deliver the whole information, an animated GIF depicting this 3-D model from 360⁰ angle is also prepared with this report. This 3-D solid model is the interpolation of well lithologs obtained from different VES and ERT field tests. The strip log diagram for these well logs is also shown in figures 23 and 24 with the South-East and South-West face forward. GIF of strip log diagram is also developed.

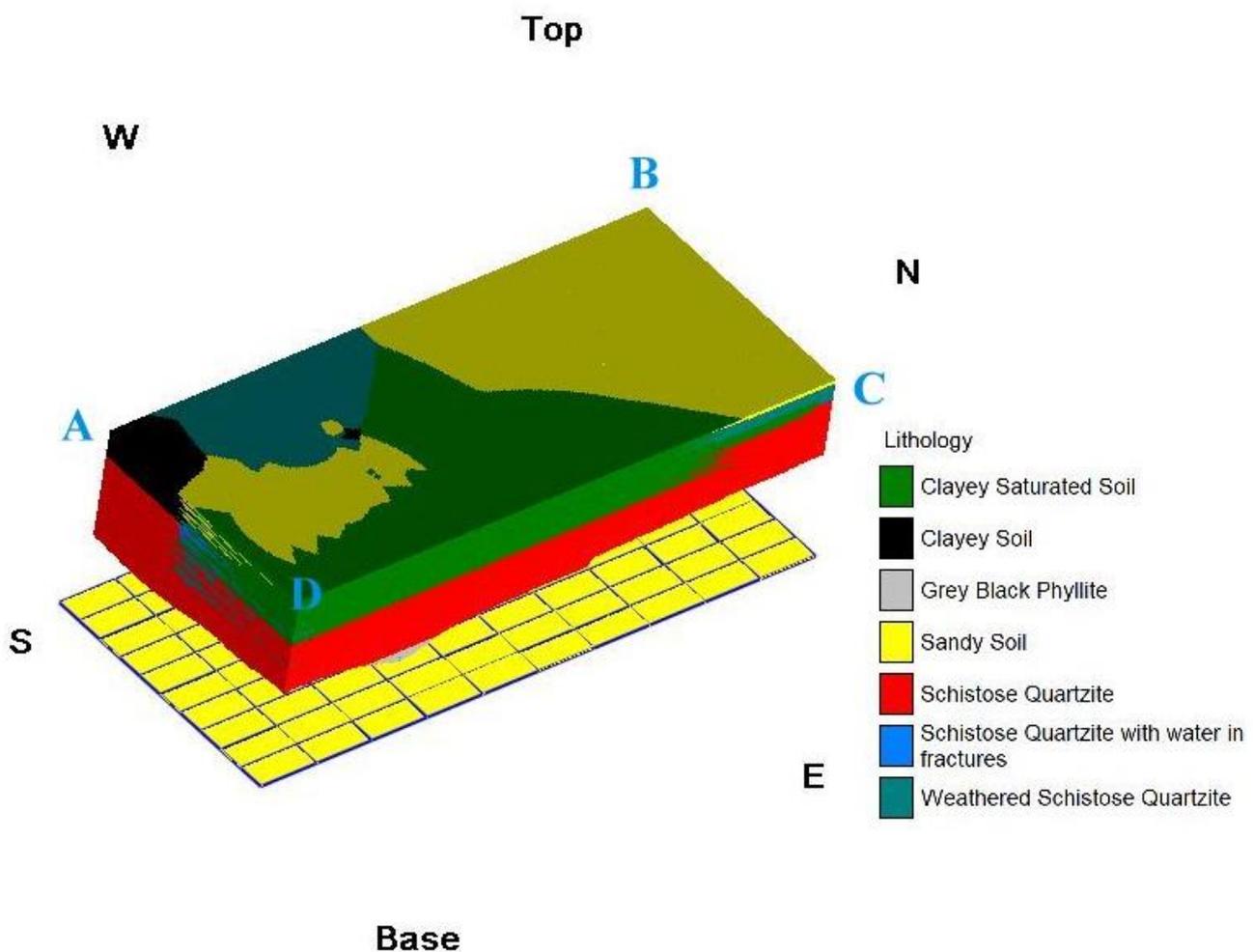


Figure 22: Three dimensional solid geological model of the study area with direction and grid marking for better understanding.

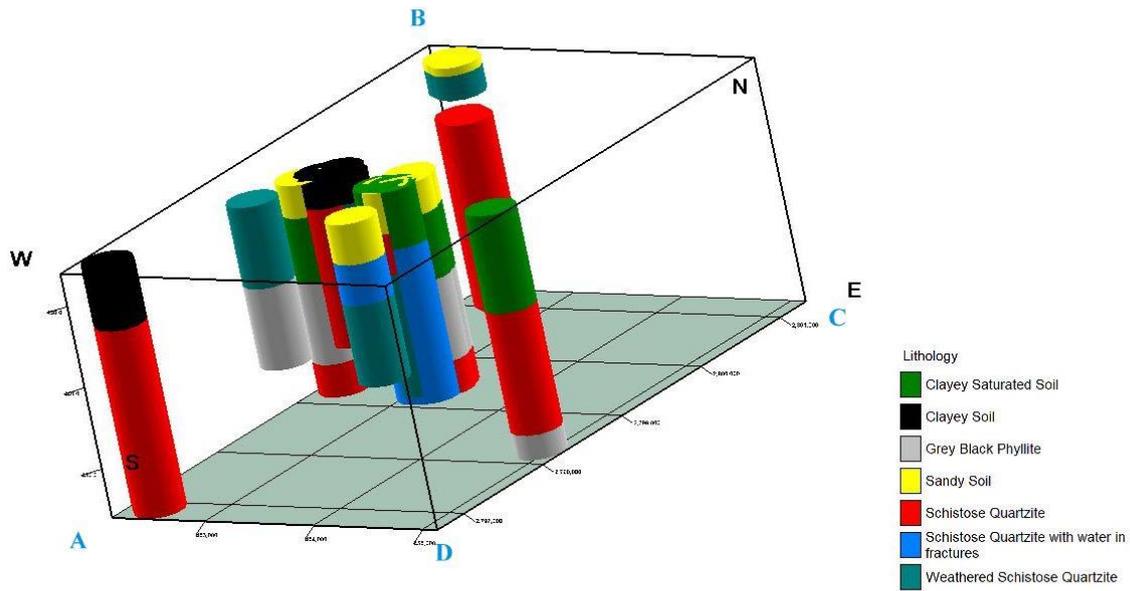


Figure 22: Three-D strip log model of the study area with South-East face forward.

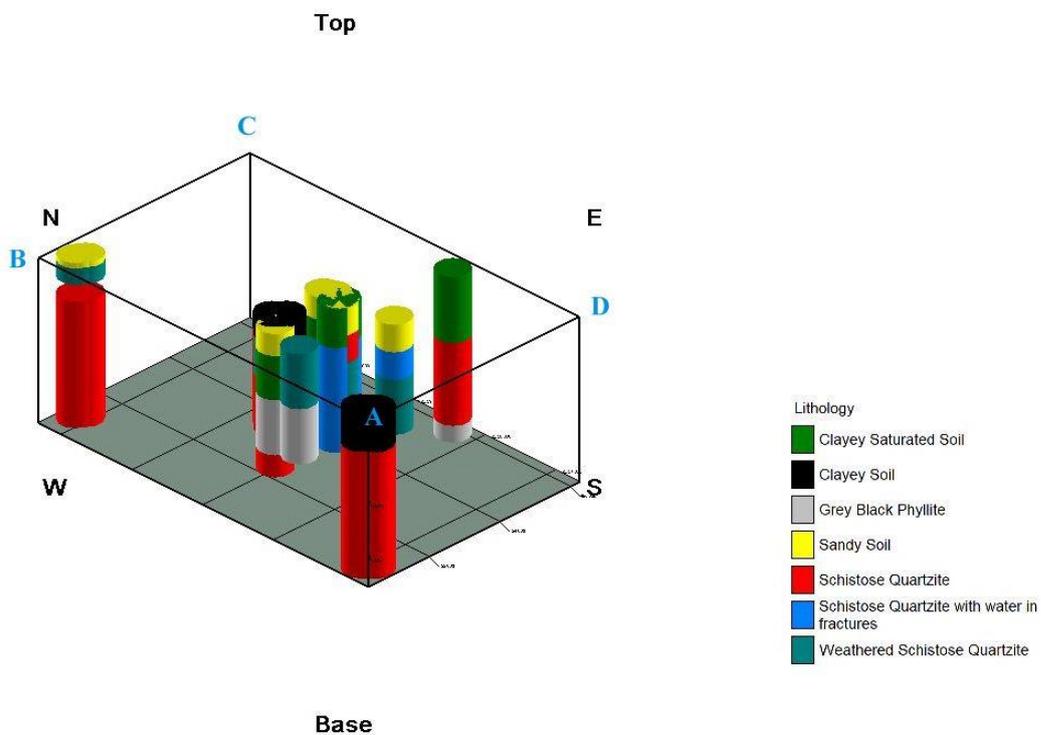
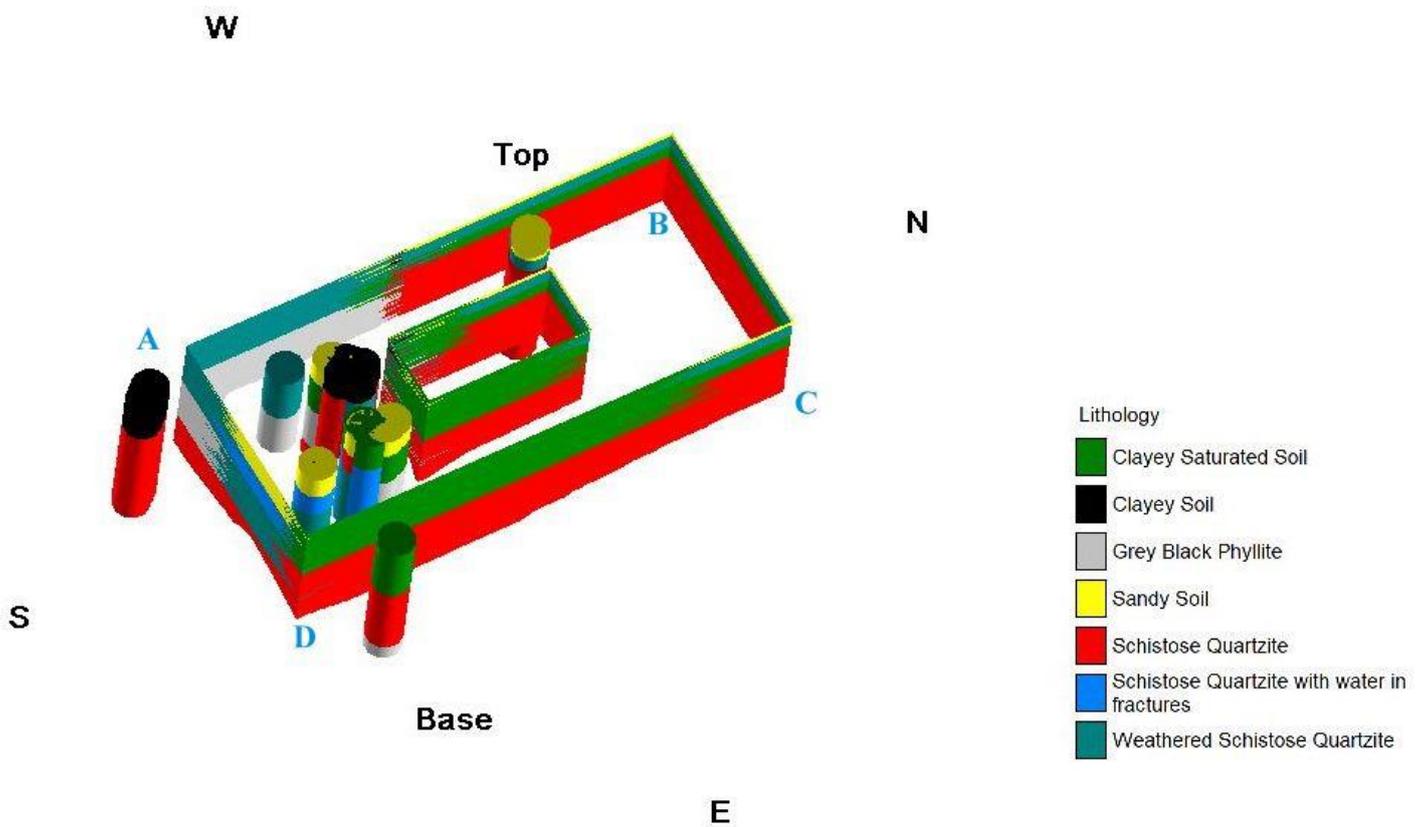
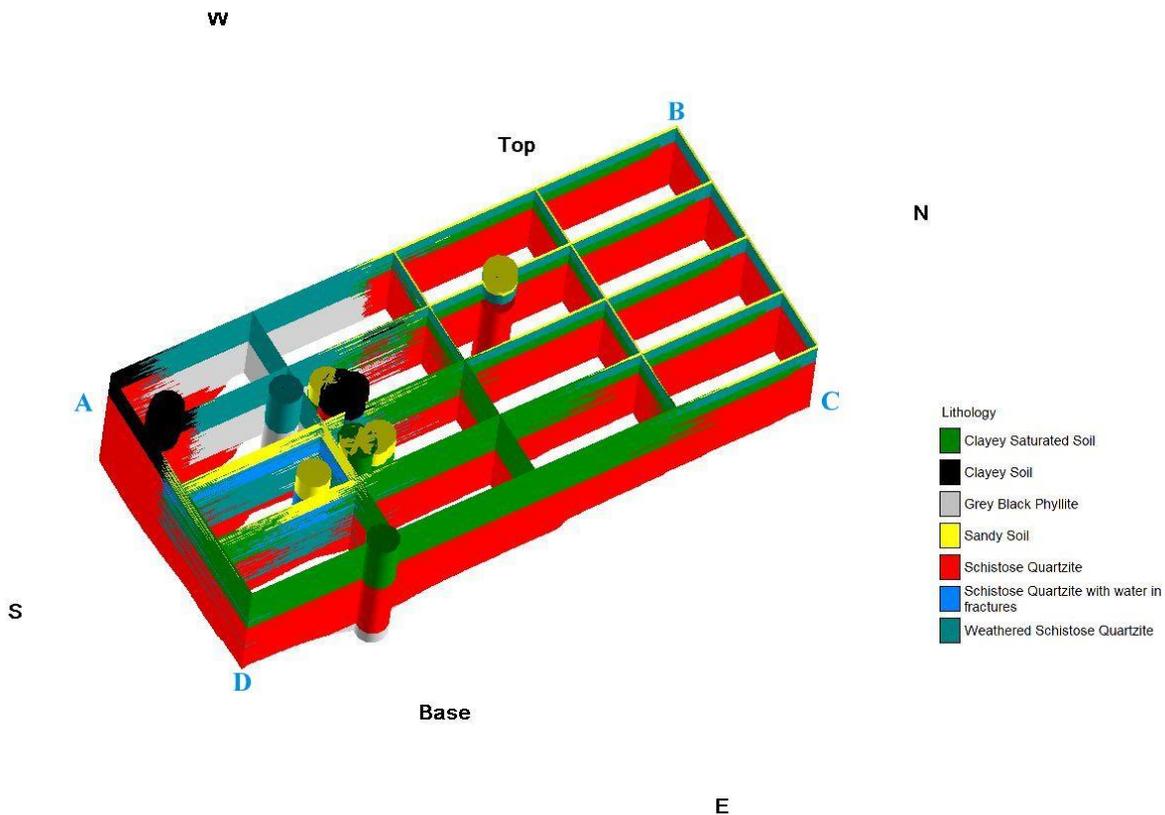


Figure 23: Three-D strip log model of the study area with South-West face forward.

Apart from solid 3-D model and strip log diagrams, fence diagram is useful to depict the geological condition more clearly. Fence diagram refer to three or more geologic sections showing the relationship of wells to subsurface formations. The scales diminish with distance from the foreground to give a proper perspective of the whole area. Similar in some respect to a block diagram, fence diagram has the advantage of transparency, which is not possible in a block diagram. The fence diagrams for the study area are shown in figure 24 (a) and (b).



(a) Fence consisting of Collinear Rectangles



(b) Fence consisting of Collinear Grids

Figure 24: Three dimensional geological fence diagrams of the study area for different fence geometry

4.3 Ground Magnetic Resonance (GMR)

The GMR system directly detects the presence of soil water utilizing a phenomenon known as proton nuclear magnetic resonance (NMR). Proton NMR observed when proton spins associated with hydrogen atoms in groundwater are subjected to perturbation in the background magnetic field. In the static magnetic field, the proton spins will preferentially align in the same direction as the field and so form a small magnetic moment. The GMR system provides unambiguous detection of soil water because the measured signal is generated by hydrogen in fluids. By measuring the NMR properties of the subsurface, GMR provides quantitative images of moisture content as along with estimation of hydro-geologic parameters, including specific yield and permeability. Using GMR, it is possible to obtain detailed aquifer characterization before ever drilling a well. The field setup of GMR is shown in figure 16. GMR applications include direct detection of groundwater, non-invasive imaging of groundwater to depths of 100m (Approx.), quantitative determination of water

content, estimates of mobile water volume and specific yield, groundwater exploration and well site selection, and vadose zone characterization. Factors like electric and magnetic interferences can affect the accuracy of the GMR.



Figure 25: Field setup of ground magnetic resonance (GMR)

The sites S_2, S_4, and S_5 are initially selected for performing the GMR. But due to high noise disturbance at site S_2, data of GMR cannot be concluded to some certain results at that site. Figure 26 and 27 show the variation of water content, hydraulic conductivity and soil strata at different depths below the surface of the soil at site S_4 and S_5.

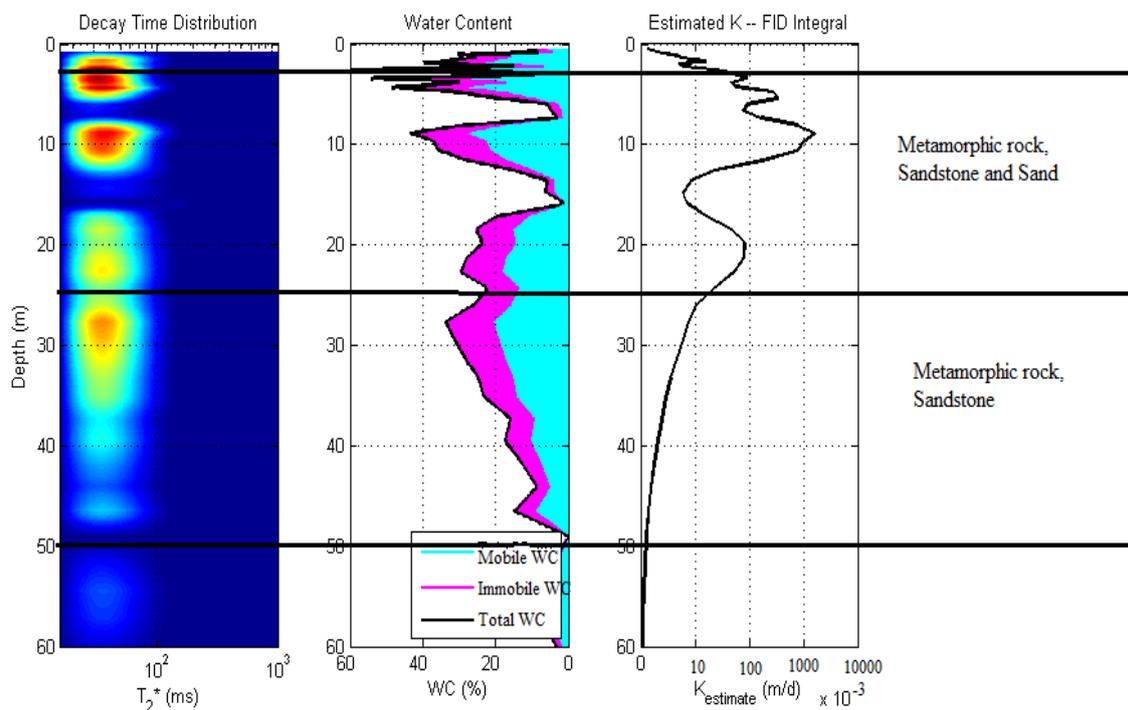


Figure 26. Distribution of water content, hydraulic conductivity and soil strata at site of Sukhadia stadium at Pur-Village

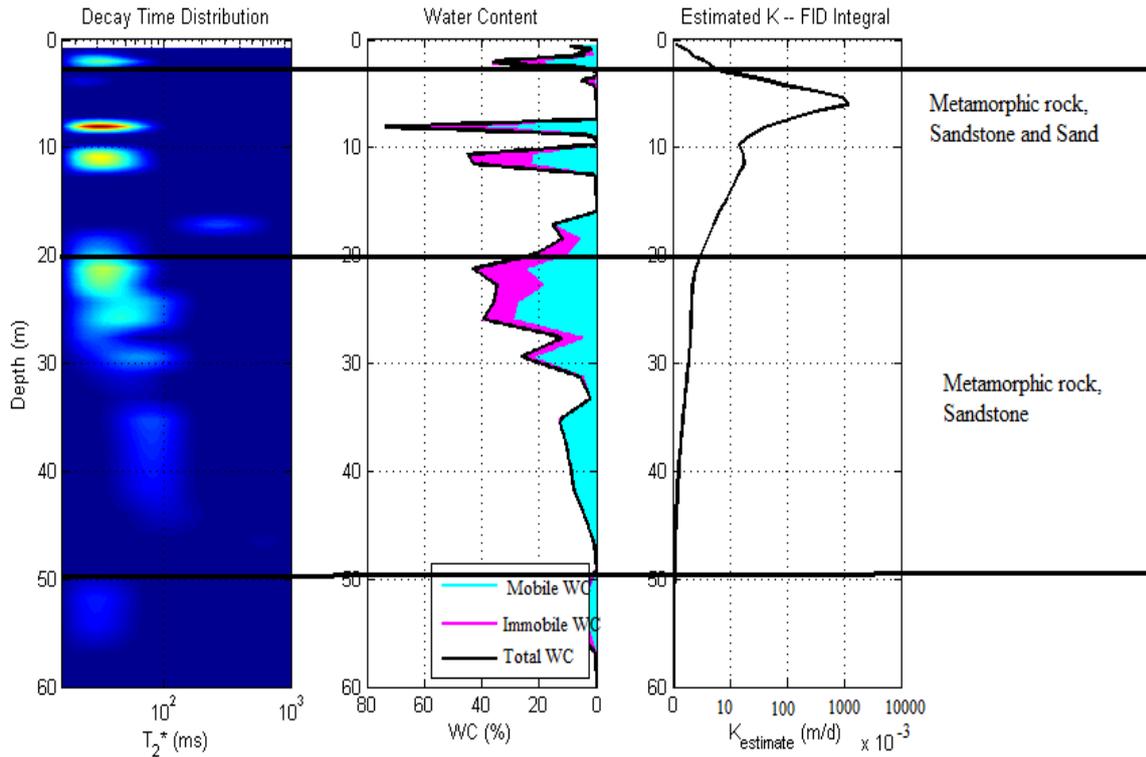


Figure 27. Distribution of water content, hydraulic conductivity and soil strata at site of Moldyka Shyam at Pur-Village

4.4 Aquifer Tests

Aquifer test (pump test) is a field experiment performed in controlled condition for estimation of hydraulic properties of the aquifer system such as storativity (S) and transmissivity (T). It is often followed by recovery test for the validation of parameters obtained. Depending on the geology of the concern area and available resources, aquifer test can be performed either constant head or constant discharge type. The data collected in field test is then analyzed either using Theis, Cooper-Jacob, Neuman or any other suitable methods. Cooper-Jacob method is generally suitable for unconfined and transient flow conditions. It relates the drawdown (s) after time (t) from start of pumping with well function $W(u)$ as,

$$s = \frac{Q}{4\pi T} W(u)$$

The well function is represented in form of auxiliary parameter (u) as,

$$W(u) = -0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} \dots \dots$$

The auxiliary parameter is defined as $u = \frac{r^2 S}{4Tt}$, where t is the time from start of pumping and r is the radial distance from control well. Plot of drawdown (s) versus time since pumping starts (t), known as data curve is matched with the Theis type curve for obtaining the s and $r^2/4t$ values for a corresponding well function value. Then the value of S and T can be calculated from the well function. After pumping has stopped, value of residual drawdown (s') is also measured in the observation well. A plot of residual drawdown s' versus the logarithm of t/t' is then plotted to obtain a best fit line. The slope of the line ($\Delta s'$ per log cycle of $\frac{t}{t'}$) given by Cooper and Jacob as,

$$\Delta s' = \frac{2.303Q}{4\pi T}$$

The results of recovery test are used to validate the pumping test results. In this study, two pump test at different sites (table 15) both followed by recovery tests are performed in the study area for determining aquifer parameters, Storativity (S) and Transmissivity (T). The detail of test at both places is described below.

Table 15: Location of Pumping well test sites

S.No.	Location Name	Latitude	Longitude	Type of Control Well
1	Banshi Mali ka kuwa	25.3038833	74.54033	Open Well
2	Mukesh Mali ka kuwa	25.3129166	74.53845	Bore Well

Test at Banshi Mali ka Kuwa: The test was performed on 31/01/2020 using an existing dug well of diameter 5m as control well and an existing bore well of diameter 0.1016m as observation well. Both the wells are situated in an unconfined aquifer of approximate thickness 10m, extending from 14m to 24m bgl. Pump test with a constant discharge of 689.645 m³/day were performed for a period of 90 minutes followed by recovery test for 20 minutes. The plot of time vs. drawdown data of monitoring well obtained from the pumping

test is shown in figure 28. This Data Curve is then matched with the Theis type curve with the help of software AQTESOLV 4.5. Transmissivity (T) and Storativity (S) of the aquifer system is calculated using Cooper Jacob equation and were found as 501.90 m²/day and 3.00% respectively. A plot of residual drawdown s' vs. $\log(t/t')$ is plotted (figure 29) and slope of best fit straight line is obtained (figure 10) as, $\Delta s = 0.2554$ from which,

$$T = \frac{2.303Q}{4\pi\Delta s} = 499.96 \text{ m}^2/\text{day}$$

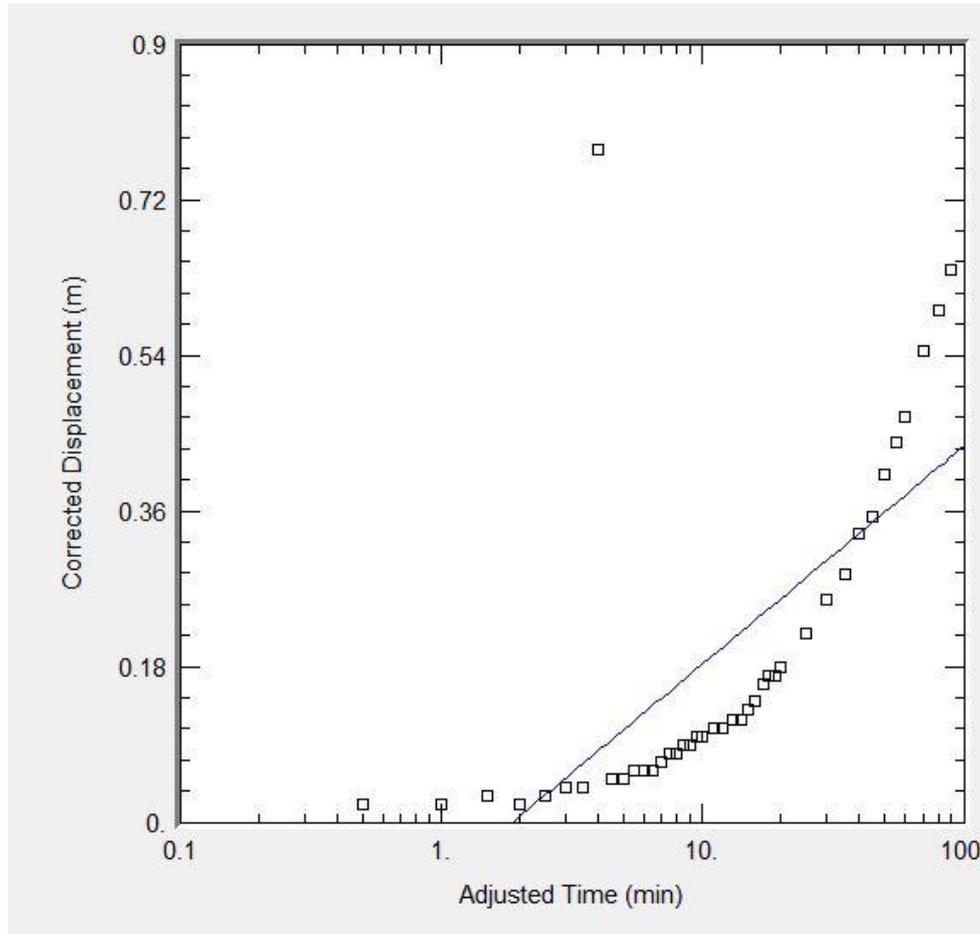


Figure 28: Data curve obtained after plotting the corrected drawdown recorded in the observation well against adjusted time since pumping start.

These values of T and S obtained are in good agreement with the study carried out by CGWB in 2013. Furthermore, result of recovery test also validates the test results.

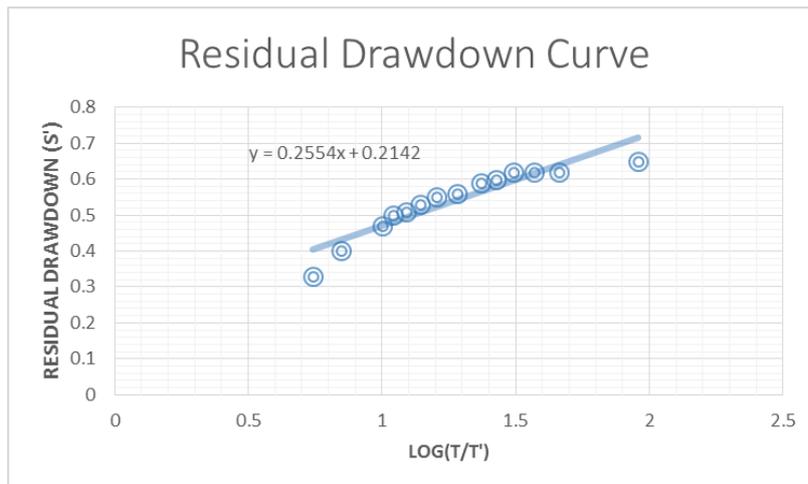


Figure 29: Recovery test plot of the observation well obtained after plotting the residual drawdown per log cycle of time.

Test at Mukesh Mali ka Kuwa: The test was performed on 31/01/2020 using two existing bore wells each of diameter 0.33 m as control well and observation well. Pump test with a constant discharge of 264.835 m³/day were performed for a period of 100 minutes followed by recovery test for 30 minutes. But the observed drawdown obtained from this test cannot be concluded to yield accurate value of any aquifer parameter. This disturbances can be mainly due to operating of one or more nearby wells either before or during the pump test without the knowledge of engineer in charge.

4.5 Water Quality Parameters

A general water quality analysis for the target area has been performed for assessment of mineral composition in the groundwater of the area. A total of 9 sampling points scattered in the entire area are selected for the analysis of various physio-chemical water quality parameters. The location, site code along with the source of water sample is mentioned in the table 16. The direct and random samplings of groundwater from the wells of each site are used to collect the samples. Sample from Q_1, Q_2, Q_3, and Q_4 are analyzed in-situ using multi-meter sensors for temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, pressure, and absolute conductivity. The result of in-situ analysis is listed in table 17.

Table 16: Location of water sample collection sites along with their respective site codes used in this study.

<i>Site Code</i>	<i>Sample Location</i>	<i>Latitude</i>	<i>Longitude</i>	<i>Source of Water</i>
Q_1	Shukhada Stadium	25.30356	74.53331666	Hand Pump
Q_2	Bhramano Ka Kua	25.2869166	74.5276333	Open Well
Q_3	Ghati Ke Hanuman	25.303355	74.540543	Open Well
Q_4	Pumping Site	25.30395	74.5405433	Tube Well
Q_5	Bada Mandir	25.029755	74.5411833	Hand Pump
Q_6	School	25.29505	74.542683	Seepage
Q_7	School	25.29505	74.542683	Water Supply
Q_8	School	25.29505	74.542683	Drain Water
Q_9	School	25.29505	74.542683	Handpump

Apart from the in-situ analysis, samples from the site Q_5, Q_6, Q_7, Q_8, and Q_9 are analyzed in the lab of Department of Hydrology, IIT Roorkee using the AAS (Atomic Adsorption Spectroscopy). Concentration of heavy metals and trace elements like Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead are calculated and listed in table 18. The concentration of Na, K, Mg, Cd and Pb in water samples were estimated through Atomic Emission Spectroscopy. The study samples were diluted appropriately before undertaking the experiment. Calibration curve were plotted using various concentration of these elements along with the blank solution before the analysis. Groundwater in the area is found safe except the little high salinity.

Table 17: The obtained values of the temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, pressure, and absolute conductivity of collected groundwater samples in the study area, measured in-situ.

Site Code	Temperature (⁰ C)	Conductivity (μ S/cm)	Abs. Conductivity (μ S/cm)	Resistivity ($\mu\Omega$ -cm)	TDS (ppm)	Salinity (PSU)	Pressure (Pound/inch ²)
Q_1	29.6	1036	1126	963	519	0.51	14.0434
Q_2	23.74	643	629	1553	322	0.31	13.99
Q_3	27.28	1178	1236	840	598	0.59	13.973
Q_4	26.9	1564	1617	644	774	0.77	13.969

Table 18: The concentration (in ppb) of the Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead of collected water samples in the study area.

Site Code	Li	Na	Mg	Al	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
Q_5	5.34	22653.39	2269.72	16.85	79672.61	4238.609	0.303	0.169	0	0.023	0.235	0.328	25.82	0.282	0
Q_6	3.36	26204.02	1550.619	11.357	104548.06	1639.082	1.518	0	0	0.041	0.142	1.922	8.003	0.09	0.021
Q_7	0.25	2373.903	1223.062	28.774	1398.69	4279.941	0	4.415	0	0.388	0.29	4.014	205.784	0.717	2.841
Q_8	2.34	26840.59	4359.73	11.197	57642.56	12221.14	0.333	0	0	0.043	0.346	1.216	9.064	0.734	0
Q_9	3.98	44323.83	8933.544	5.671	95448.49	10091.815	0.043	6.969	0	0.138	0.445	0.792	96.545	0.185	0

4.6 Groundwater Flow Pattern

The groundwater table or hydraulic head from various locations uniformly distributed throughout the study area was taken during the field visits. These heads are collected from both open wells and tube wells. The groundwater table is then interpolated by inverse distance weightage (IDW) technique to prepare a virtual distribution of groundwater table throughout the area, as shown in figure 30.

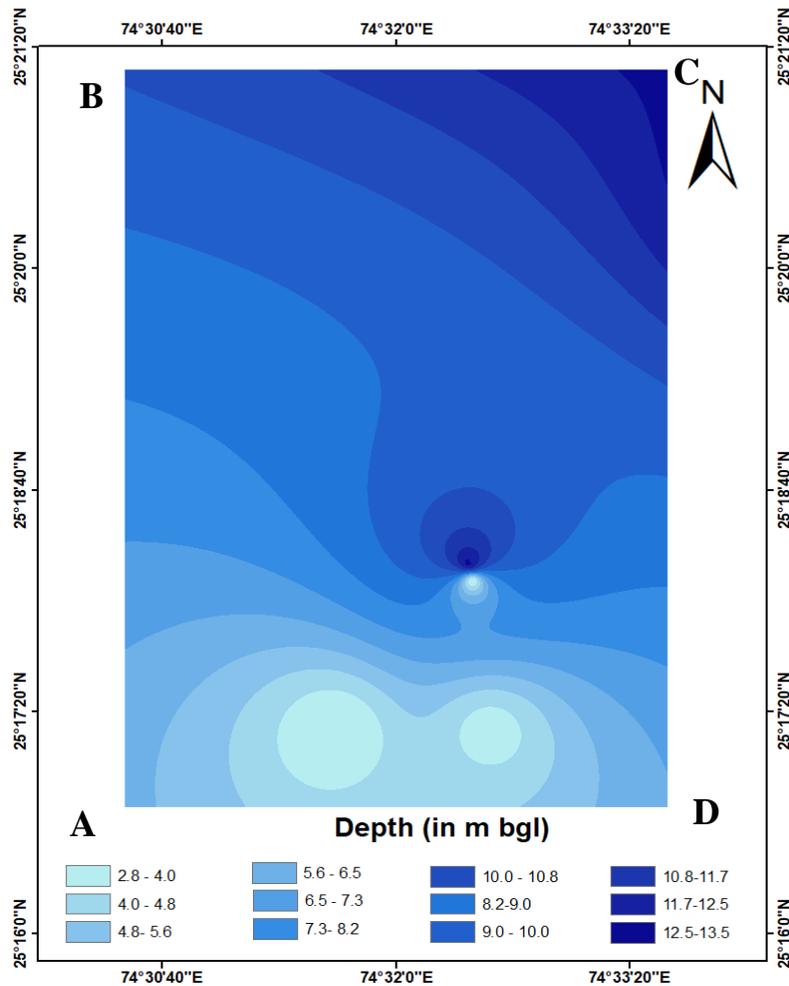


Figure 30: Variation of Groundwater table (Hydraulic head) in and around the study area with grid mark ABCD for better understanding.

4.7 Isotopic Analysis

Isotopes are the element having same atomic number with different molecular masses. Water (H_2O) is composed of two hydrogen and one oxygen atom. Oxygen has three stable isotopes, ^{16}O , ^{17}O , and ^{18}O whereas hydrogen has two stable isotopes, 1H (Protium or P) and 2H (deuterium or D), and one radioactive isotope, 3H (Tritium or T). The oxygen and hydrogen combine in various forms to make water, thus making their isotopic composition a powerful tracer of the hydrosphere.

Waters develop unique isotopic compositions that can be indicative of their source or the processes that formed them. Isotopic composition differs for sea water, polar ice, atmospheric water vapor, and meteoric water. There are nine possible isotopic configurations for water, which are distinguished by their mass numbers as well as their characteristics. However, because of the low abundance of the heavier isotopes, almost all water molecules are of three isotopic combinations. Table 19 indicates the characteristics of three isotopic combination of water found generally.

Table 19: Characteristics of Water molecules with different isotopic combination

<i>Properties</i>	$^1H_2^{16}O$	$^2H_2^{16}O$	$^1H_2^{18}O$
<i>Density @ 20°C</i>	0.997	1.1051	1.1106
<i>Boiling Point</i>	100.0	101.42	100.14
<i>Vapour Pressure @ 100°C</i>	760	721.60	
<i>Temperatory Density Max</i>	3.98	11.24	4.30

Oxygen and hydrogen isotopic ratios are measured using gas source isotope ratio mass spectrometry (IRMS). Oxygen and hydrogen compositions are reported as delta values. Delta values (δ) are commonly used in light stable isotope geochemistry to express isotopic composition in terms of per mil (‰) deviation from a standard. Stable isotope ratios of deuterium/hydrogen ($^2H/^1H$) and $^{18}O/^{16}O$ of water are conventionally expressed as a per mil (‰) deviation from SMOW (Standard Mean Ocean Water) or VSMOW (Vienna SMOW). In carbonates, the isotopic composition of oxygen is sometimes compared instead to PDB, a standard based on the Peedee Formation, a carbonate rock found in South Carolina.

Isotopic study is carried out in this study on four water samples collected from Rajkiya Uchh Madhaymik Vidhayalaya Pur (School in Pur village), which has a problem of water leakage from the ground surface. The leakage started from July 2018, and water is oozing at surface.

This isotope analysis was conducted to identify the source of this seepage water. Measure of the ratio of stable isotopes oxygen-18 and oxygen-16, $\delta^{18}\text{O}$ and deuterium D are measured for the groundwater samples collected from hand pump, Drains (flowing outside from school), Government supply water, and seepage water from the school. Table 20 shows the location, source, isotope analysis results, EC (electrical conductivity) and pH of collected water samples.

Table 20: Result of Isotope analysis along with code, source, and isotopic analysis along with In-situ measured Electrical Conductivity and pH.

S. No.	Code	Location	Source	δD	δO18	EC (mS/cm)	pH
1	BW4	N 25-degree 17.703 m E 074-degree 32.561 m (School)	Seepage	-16.43	-1.54	2.4	9.22
2	BW5		Water supply from chambal	-45.28	-6.11	0.32	8
3	BW6		Drain water from school	-33.17	-4.15	2.06	7.15
4	BW7		Hand pump	-22.69	-2.47	4.37	7.55

Way Forward: The field and analytical work related to this study has been completed by team IIT Roorkee. The conclusion section related to the above observed findings of this investigation needs to be finalized after completion of the pending work of the other participating institutes particularly CBRI Roorkee. Also, the planned drilling work of CBRI Roorkee could help in further improving the findings of non-intrusive soundings performed by team IIT Roorkee. Common guidelines for effective measures of the existing problem of the Pur village would be prepared altogether with CIMFR and CBRI in near future.

**CSIR- CENTRAL BUILDING RESEARCH INSTITUTE***(A Constituent Establishment of CSIR)***ROORKEE - 247 667, UTTARAKHAND (INDIA)****Tel:** (+91) 1332 283418 (O); **Fax:** (+91) 1332 272272, 272543**Website:** www.cbri.res.in**E-mail:** ssarkar@cbri.res.in, shantanu_cbri@yahoo.co.in**DR. SHANTANU SARKAR**

Chief Scientist & Head

Geotechnical Engineering Group

Professor- Academy of Scientific and Innovative Research (AcSIR)

Dated: 24.09.2020

GE/Bhilwara

The District Magistrate**Bhilwara****Rajasthan**

Sub: Geotechnical and crack monitoring investigation at Pur Village, Bhilwara

Dear Sir,

This is to bring your kind notice that the drilling at few locations at Pur village, Bhilwara, Rajasthan was planned to know the sub-surface geology and collection of samples for determining the geotechnical properties of the soil. The village was surveyed and crack meters for monitoring the cracks in the houses (more than 50 houses) were installed. The drilling sites were also identified. The tender for bore hole drilling was also initiated in March 2020 but due to sudden lock-down the official process could not proceed further at that time. Later, several agencies were requested to carry out the drilling operation, but due to COVID-19 pandemic, no agency has agreed to do the job.

Now we have finalised a drilling agency who is going to start the drilling operation at the site from 28th September. CSIR-CBRI team is also visiting the site to supervise the drilling and collection of samples which will be tested in the laboratory for evaluating the geotechnical engineering properties. Once the work is completed, report will be submitted. Further, the visiting team will also measure the cracks and find out the crack enlargement (if any) during the last six months and after interpreting the results report will be submitted at the earliest.

We are sorry for the delay but it was only due to the present pandemic and we hope you can understand the situation.

With best regards,

(Shantanu Sarkar)

सीएसआईआर-केन्द्रीय खनन एवं ईंधन अनुसंधान संस्थान

(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद)
पो.बा.41, 27 खोली चौक, मुंगेली रोड, बिलासपुर (छ.ग.)
एक आई एस ओ 9001 प्रमाणित संस्थान



CSIR-Central Institute of Mining and Fuel Research

(Council of Scientific and Industrial Research)
P.B 41, 27 Kholi Chowk, Mungeli Road, Bilaspur (C.G.)
An ISO 9001 Certified Institute

Ref:CSIR-CIMFR/BSP-MN/SSP-421/20-21/101

Dated 24.09.2020

To,
The District Magistrate
Bhilwara District, Govt of Rajasthan

Sub: Interim Report on Scientific studies on blast induced ground vibration and air overpressure and investigation on its damage potential vis-à-vis housing structures in Pur village, Bhilwara Distt., Rajasthan

Sir,

Please find attached herewith interim report on *scientific studies on blast induced ground vibration and air overpressure and investigation on its damage potential vis-à-vis housing structures in Pur village, Bhilwara Distt., Rajasthan*. The report is record of the works completed so far by CSIR-CIMFR team.

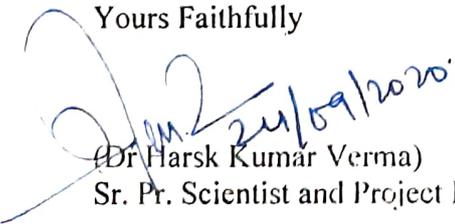
Altogether two phases of field investigation have been carried out by the CIMFR team. The team have conducted 15 experimental blasts and carried out extensive vibration monitoring in more than 60 locations in and around the Pur village and Dhedwas Iron Ore mine. CSIR-CIMFR team have completed majority of the field works. Data analysis of the data is under process. A final round of field visit will be made to validate the outcome of the analysis along with other participating institute.

Unfortunately, due to Covid-19 Pandemic progress of the works was adversely affected. Further, I would like to inform you that undersigned along with one more key member of the investigating team got infected with Covid-19 virus and works got delayed.

The remaining works will be completed very soon and report will be submitted at the earliest.

Thanking you,

Yours Faithfully


(Dr Harsk Kumar Verma)
Sr. Pr. Scientist and Project Leader

Encl: Interim Report

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डा० ब्रिजेश कुमार यादव
सह – प्राध्यापक

Dr. Brijesh Kumar Yadav
Associate Professor

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Annexure-4

IIT Roorkee

To

Date: Sept 24, 2020

District Magistrate
Bhilwara, Rajasthan

Dear Sir,

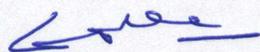
In reference to the letter No JUD/2019/26230 dated 22 July 2019, a joint site visit by investigators from CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee and I.I.T. Roorkee was carried out during 18-20 August 2019 to Pur village followed by a meeting in the office of the DM, Bhilwara for undertaking this scientific study to evaluate the possible causes of the cracks in the domestic houses of Pur village.

In this context, the group of expert from I.I.T. Roorkee took the assignment for carrying out the Hydro-Geological study of Pur Village, Bhilwara under the research and consultancy rules of the institute. The following scope of the study was mutually agreed.

- Conducting in-depth Hydrogeological survey of the area within 2 km radius from centre of the Pur village using a series of field experiments.
- Development of a lithofacies map of subsurface zone using a series of geophysical investigation techniques. About 10-15 multidimensional electrical resistivity soundings will be performed based on availability of suitable sounding locations in and around the Pur village.
- Aquifer characterization at different depths using appropriate pumping and recovery tests along with Ground magnetic resonance (GMR) equipment. Existing tube-wells and open well of the site be used for conducting the pumping and recovery tests.
- Estimating groundwater flow regime of the area based on field survey and other observed data of groundwater resources. Coordinates of all monitoring points to be taken and marked along with the existing groundwater flow pattern.
- Chemical analysis of water supplied to the village and ground water samples using existing hand-pumps/tube-well and groundwater outflow location observed in the village school. This is required to investigate interaction between water supply network of the village and existing groundwater resources of the site.
- Preparation of general guidelines for effective measures of the existing problem

The field and analytical work related to this study, i.e. from tasks a-e, have been completed and presented in the attached draft report for your kind perusal. The concluding remark related to the observed findings of this study would be submitted together with CIMFR and CBRI reports after completion of their work along with preparation of holistic guidelines for effective measures of the existing problem.

Sincerely


(Brijesh K Yadav)