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Empirical Groundwater Exploration Using Light Interference Technique

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Abstract

In fast-growing cities, the dependence on groundwater has been increased for household requirements and irrigation with the onset of the Green Revolution. This depends on the intensive use of inputs such as groundwater to boost farm production and to take care of population requirements. Private groundwater extraction for farming and drinking as well has been facilitated by policymakers in developing countries. Under exhaustive extraction of groundwater, falling groundwater tables may demand to explore precise groundwater investigation techniques. An instrument developed based on Light Interference technique (LIT) viz. NaAvmeter was proposed in the present study to explore the groundwater in less expenses and with precise measurement. This study investigated successfully a possibility of borewell location using NaAvmeter for irrigation and drinking purpose. The use of NaAvmeter exhibits encouraging results for identifying exact borewell location.

Keywords

Earth radiations; Groundwater exploration; Groundwater veins; Light Interference Technique

1. Introduction

In the 21st century, there is a growing concern over the estimates of freshwater availability all over the world. With a fast increasing population, there is more demand for water. It is, therefore, inevitable that the pressure is and will be on the detection of subsurface water storage. There is a dire need of simple, cheap but reliable methods of groundwater detection in the regions of scanty rainfall (Joshi et al. 2013). At present, groundwater exploration has become a difficult task due to changes in the water cycle, enhanced water requirement by mankind and setting up of habitation in new locations (Mohapatra 2008). From the study, it was observed that most groundwater exploration work that has been carried out from ancient time involves fieldwork and use of knowledge gained from ancestors limited to the local area. However, from the starting of the 19th century, significant updating in utilizing the various groundwater exploration methods has been observed (Badrinarayan 2009).

As the cost of water exploration through modern methods is invariably unaffordable for the average person, traditional knowledge of exploring water sources is still in vogue among many rural and urban communities. On the other hand, the body of knowledge to identify groundwater has been expanded and upgraded through modern science. In the recent past, science and technology have taken long strides in exploring groundwater as a result of which many technologies are available now to identify the groundwater (Mohapatra 2008). The major objective of the current study is to develop a groundwater exploration method which can be utilized in addition to modern techniques. An attempt was made in the present study to use an instrument developed based on light interference technique (LIT) for groundwater exploration in the study area as an alternative to current groundwater exploration methods.

2. Background of Groundwater Exploration

From the literature study, it was observed that various groundwater exploration techniques, methodologies etc. are being in practice to fulfill the water need. Various milestones in changing technology in groundwater exploration through literature survey are summarized in subsequent sections.

2.1. Esoteric Methods

Dowsing or water divining technique is easy to operate and has a very low cost compared to other groundwater exploration methods. Uses of dowsing techniques give relatively faster and reliable results. Dowsing methods sometimes avoid serious or costly errors in groundwater investigation and save both time and money. The operator has to predict groundwater existence considering variations in signals with the help of field hydrological indicators, e.g. primary and lateral tree roots, Termite mounds, colour, dwarfness of the trees/shrubs etc. (Joshi et al. 2013). Various scientists have tried to show the ability of dowser to detect subterranean features. However, science does not show a lot of interest in this phenomenon broadly present in the public as it is human-specific (Dharmadhikari July 2011). It was also observed that the use of dowsing methods doesn't have any mathematical formulae (USGS 1988).

2.2. Aerial Methods

Aerial electromagnetic methods appear very useful for identifying areas of high and low recharge over large regions. Using airborne methods, an area of more than 100 km^2 may be covered in a few days surveying, whereas it would take months to cover the same area using other groundwater exploration methods (Peterson and Bosschart 1987). The aerial method has greater speed, portability improved subsurface resolution, better potential discrimination of conductive aquifer. Groundwater exploration using aerial methods on a regional scale has become technically as well as economically possible (Peterson and Bosschart 1987). However, for local sites, aerial methods prove to be much more expensive. For local site groundwater exploration, aerial techniques prove not of much use.

2.3. Surface Methods

The surface method includes the study of subsurface strata with tests being carried on the surface without going for drilling or any other destructive technique. The subsurface data can be interpreted by identification and correlation of surface phenomenon involving geological features and structures, geomorphology, surface hydrology, soil type, vegetation type and distribution, land use, resistivity, magnetic effect, etc. (Mukherjee et al. 2007). Most of the geophysical techniques are involved in the surface method for groundwater exploration. Although in surface techniques less time is required for exploration, as an interpretation of field testing result is purely on mapping basis, it contains a bit of difficulty in specific areas (Shaikh Md. and Shah 2012). Surface techniques are somewhat more time intensive in the field than other conventional methods, and considerably more time intensive in the lab. Vertical stratification mapping in the field is somewhat coarse. Surface methods need special care when lateral features are encountered, adding greatly to acquisition cost and interpretation (Shaikh Md. and Shah 2012).

2.4. Subsurface methods

Subsurface exploration methods for groundwater investigation are the most reliable methods because these methods involve measurements directly from the aquifer. In comparison, these methods are economic for shallow aquifers than deep-seated aquifers. However, while working at field some limitations arise to adopt subsurface exploration methods such as large space requirement for well and excavated material, the requirement of costly and complicated equipment, skilled workers etc. resulting in high cost of construction (USGS-Borelogging n.d.). There is also a possibility of missing the fractures, fissures, and joints in hard rock areas, the susceptibility of contamination from surface water ingress etc. (USGS-Borelogging n.d.).

3. Objectives of the present study

A major objective of the proposed study is to explore groundwater with accuracy and economy taking into accounts the groundwater exploitation due to increased demand. While developing this objective, the literature review shows that in current practices many techniques exist for groundwater exploration. All exploration techniques have advantages and disadvantages in a particular domain. An attempt is made in the current study, considering the facts observed through literature review, to develop a method for groundwater exploration in which interaction of light with earth rdiation will be studied for investigation of groundwater and which will also overcome limitations for contemporary practices.

4. Light Interference Technique

It is a well-known fact that when light travels from one medium to another medium, it refracts. The refraction depends both upon the densities of medium and angle of incident light. The refraction of light is also evident in the same media with multiple density layers.

4.1. Laser Refraction studies

Laser refraction studies have been conducted for a number of applications by Augustine and Chetty (2014) who have performed an experiment to measure the effects of thermal turbulence on a laser beam propagating in air. The results confirm that the phase and intensity of laser beam increase with respect to temperature (Augustine and Chetty 2014). In another experiment, Klemm et al (2007) had measured air density fluctuations for various phenomena in the close vicinity of different buildings and constructions. They found that there are significant differences in the values of standard deviation for fluctuations of light intensity with a change in air density (Klemm, Krzysztof Pieszynski, and Rozniakowski 2007).

4.2. Earth radiation fields

Gravitational field, Magnetic field, Electric field, Radioactive field, Seismic field, Geothermal field, Geochemical field etc. (Chadwick and Jensen 1971). A variation in one or more of these fields may have some detectable effects. In addition to the natural fields, there are artificial field sources in geoelectric research which are made by grounded electrodes or underground magnetic loops (Jishan 1995). The rationale is that electromagnetic waves will be excited from the earth's surface toward the underground and after reaching a certain impedance interface; they reflect and return to the ground surface. It is evident from the studies conducted that perturbations on the earth's magnetic field may coincide with the existence of groundwater (Chadwick and Jensen 1971). Knowledge of contribution of the earth's magnetic field to field perturbations is important to assess the probability of the correlating presence of groundwater to the magnetic variations of the study area (Jishan 1995). In the explanation of various experiments conducted for groundwater exploration by dowsing, it has been noted that dowser reacts to some type of earth radiation and detects the source of groundwater (Hansen 1982).

LIT based instrument, NaAvmeter, was developed to detect groundwater veins by measuring earth radiations. NaAvmeter basically measures the deflection of a laser beam due to the variation in earth radiation from the subsurface (Dharmadhikari et al. 2010). As per the fundamentals of Physics, light has electromagnetic nature and a discrete bundle of energy. These packets are called quanta and particle of light is a photon (Chester 2003). According to Thurnell (2006), earth radiations may be of electromagnetic nature or subtle energy (Thurnell-Read 2006). As shown in figure 1, ray diagram of the NaAvmeter, has a gap between the laser light source and the detector. In case earth radiations are present in the gap, then interaction occurs between the photons of laser light and earth radiations which changes the current. If earth radiations are not present in the gap of the source and detector, then no interaction occurs keeping the current constant.

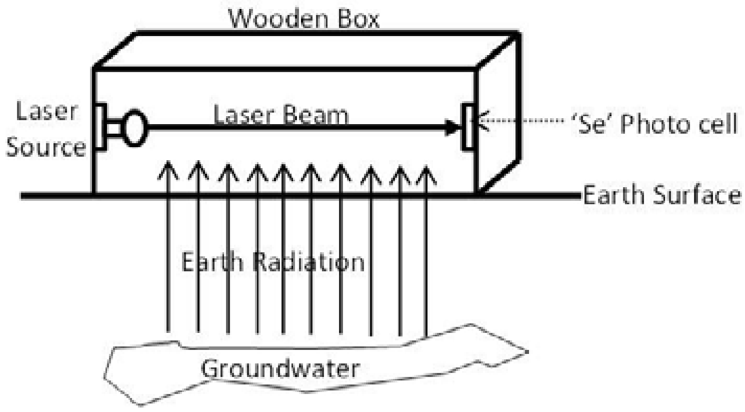

Figure 1. Basic principle of the NaAvmeter (Dharmadhikari et al. 2010)

NaAvmeter is a rectangular wooden box having a 1.0m length between the source and the receiver on sides of the box. Other materials like metals or polymers are not used as they attenuate magnetic field. The gap between the source and the receiver is kept for the interaction of the light beam emitted from the source. The source is a monochromatic coherent laser beam produced by a semiconductor diode which travels and falls on Selenium diode used as a detector. The Selenium diode is connected to a current meter which measures the current of the laser beam falling on the selenium diode (Dharmadhikari et al. 2010). Figure-2 shows the setup of NaAvmeter utilized in the field.

Figure 2. Field setup of the NaAvmeter

5. Methodology for conducting field tests

NaAvmeter may be used to find the variations in earth radiation fields developed due to groundwater. Following procedure shall be adopted for conducting the field tests:
-Field point at which groundwater potential shall be identified.
-Around five (05) profile lines shall be made as shown in figure 3 around the identified point. Each profile shall be distanced by around 2.5m to 3.0m.
-For each profile line, 11 points shall be identified separating each other at around 0.5 to 1.0m apart as shown in figure 3.
-NaAvmeter shall be kept at each point and the reading shall be recorded. Then by rotating instrument around in 150-200 around its center, the reading shall be recorded. Rotation of NaAvmeter at each point shall be considered for up to 3600. Thus, total 19 readings shall be recorded at each point of a profile.
-Adopting the procedure as mentioned above, readings shall be recorded for each point of each profile.

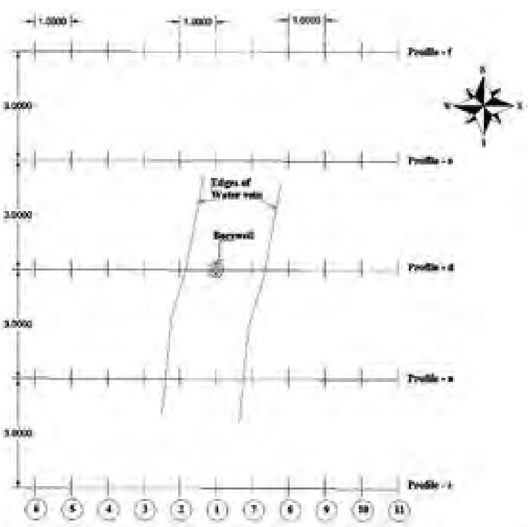

Figure 3. Schematic of profiles for NaAvmeter field reading

6. Field Investigation using NaAvmeter

A series of field experiments were conducted in the identified study area to achieve the objectives of the current study. The study area is located around 35 km from Pune city. Coordinates of the study area are$18^0$33'46.61"N $73^0$30'46.6"E. Refer figure 4a for the location of study area. The study area is a part of the Maharashtra plateau and forms the Western Maharashtra Upland, with its local variation in relief. In the West of the study area, average height is about 900m above sea level. The central part of the study region is, by and large, 600m in height, while the Eastern portion descends between 450 to 600m The mountain and hill ranges in the West, river basins and undulating topography at the center and highland plateaus with wider river basins in the East mark the physical landscape of the region (Bhakare 2010).

6.1. Geology of the study area

Pune region consists of multiple layers of solidified fluid basalt and is more than 2,000m thick and formed 60 to 68 million years ago during the Cretaceous period. The basaltic lava flows are estimated to be around 512,000km^2. The plateau after the catastrophic phase of faulting has remained relatively stable and has undergone a succession of cycles of erosion. The region has a basaltic base on which there are alluvial deposits in river valleys on the terraces and old floodplains. Fault lines are scattered throughout the Pune region and these areas are minor earthquake prone. The basaltic flows of Pune region can be classified into two groups, namely 'Pahoehoe' and 'Aa' types. The

Pahoehoe flows occur at the lower elevation whereas the 'Aa' flows occur at the elevation of about 680m (Bhakare 2010). It was observed that some Steep basalt cliffs, layering of lava flows, wide grassland meet at distant peaks and ridges. At places weathered rocks and weathered outcrops were present. Some of the penetrated fractures represent extensional stresses. The main basalt flow type in this region is compound flows. The dyke was also found in the region. Refer figures 4 b-f for geological details of the study area.

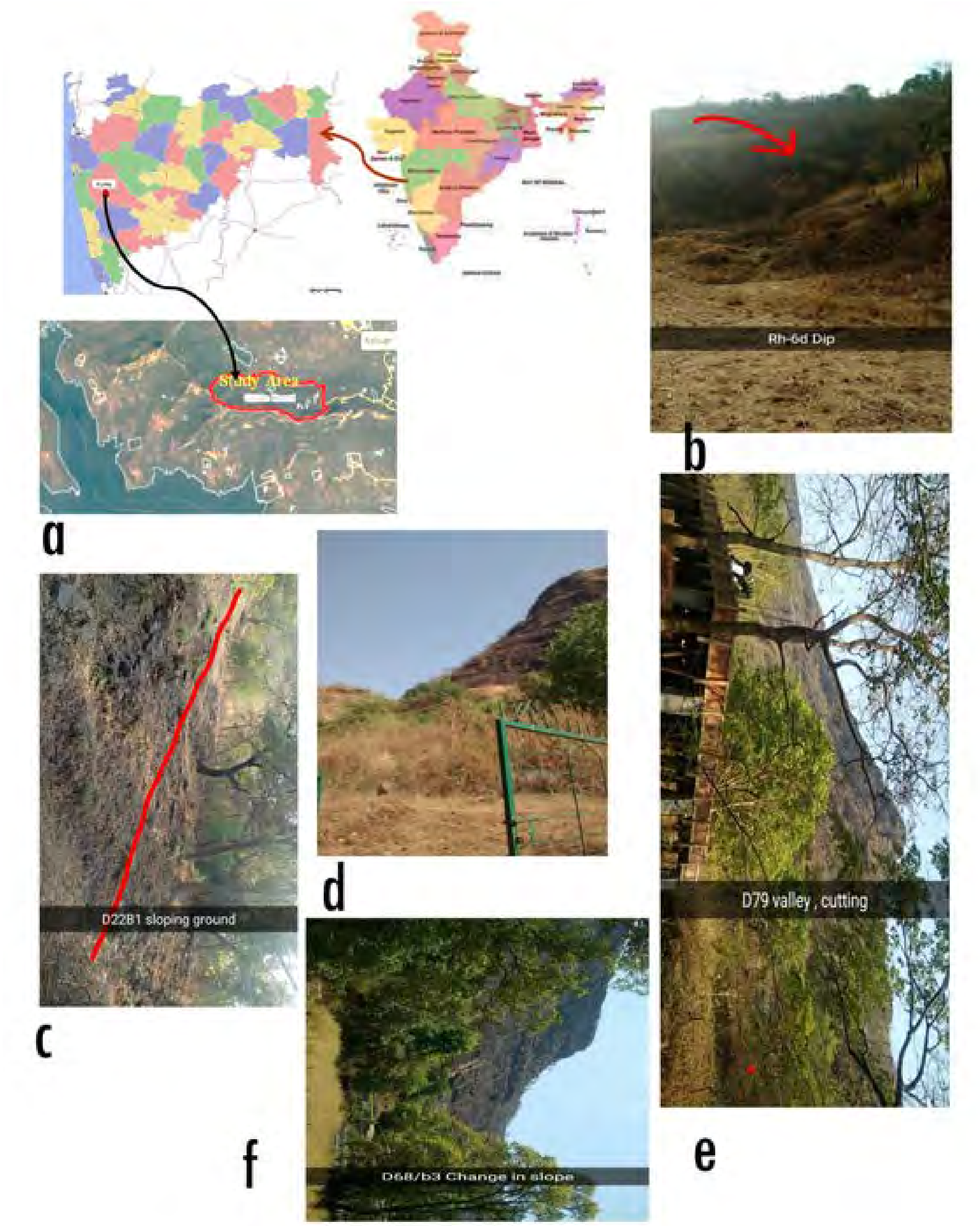

Figure 4. (a) Location of identifies study area (b) Geological details of the study area
(c) Geological details of the study area
(d) Geological details of the study area
(e) Geological details of the study area
(f) Geological details of the study area

6.2. Geomorphology of the study area

Pune region is mainly formed by two major parts that are the Western Ghats and Deccan Plateau. Topographically the region is separated by three belts that are (Bhakare 2010):
a.The Western Belt: It stretches from 16 to 31 km east of Sahyadri- an extremely rugged country cut by deep valleys, which are divided and crossed by hill ranges.
b.The Central Belt: it extends for about 30km East of Western belt across the track whose Eastern belt is roughly marked by a line drawn from Pabal in the North to South up to Purandhar through Pune. In this belt, a series of small hills stretch into valleys and large spurs from Plateaux and
c.The Eastern Belt: it is formed with a rolling topography and low hills sinking slowly into the plains with relatively broader valleys.

6.3. Aquifer parameters

In the study area, the unit area specific capacity of dug wells ranges from 0.77 to 18.9 lpm/dd/sq.m., while permeability ranges from 12 to 65 m/day. The transmissivity of the phreatic aquifer ranges between 18 and 89m^2/day. The specific yield varies 1.7 to 9.7% in the Pune region. In alluvium, the unit area specific capacity ranges from 5.95 to 32.00 lpm/dd/sq.m, transmissivity varies from 97 to 248m^2/day and specific yield ranges between 5 to 9% (Mishra 2013).

6.4. Groundwater scenario in the study area

The groundwater in the Pune region occurs under phreatic, semiconfined and confined conditions. Generally, the shallower zones down to the depth of 20 to 22m below ground level form the phreatic aquifer. The water-bearing zones occurring between the depth 20 and 40m below ground level when weathered or having shear zones yield water under semi-confined condition. The deep confined aquifers generally occur below the depth of 40m below ground level. Seasonal water level fluctuation analysis between pre-monsoon and post-monsoon season reveals that rise in groundwater levels is found between 0.20m to 12.35m. In the major part of the Pune region in North-Western and South-Eastern part, groundwater level fluctuation is varying from 0 to 2m. In central and Eastern part of the Pune region fluctuation is recorded between 2 to 6m. Groundwater level fluctuation of more than 6m is observed in isolated pockets. Fall in groundwater level between pre and the post-monsoon season is also observed at various places and it varies from 0.05m to 2.00m (Mishra 2013).

6.5. Field experiment using NaAvmeter

From the study area, five (05) locations were identified for conducting experiments. Details of the location are given in the Table-1. Field observations at each point of every profile, as mentioned in section 5, for five identified locations were recorded and the variation of NaAvmeter readings for each profile of each location was observed. After completion of field experiments, interpretation of field readings for all locations was completed. As per the working principle of the NaAvmeter, it was observed that at some zones NaAvmeter readings are on a downtrend and at certain locations, field readings are higher. Approximate edges of the water veins for Locations 1-5 were plotted based on the variations in NaAvmeter readings as shown in figures 10-14.

Table 1. Detailsof locations for field experimentation

Location No.	Satellite Locations	
	Latitude	Longitude
Location -1	18033’45.1”	73032’20.5”
Location -2	18034’0.9”	73032’40.9”

Continued on next page

Table 1 continued

Location -3	18033’47.9”	73032’21.5”
Location -4	18033’45.3”	73032’10”
Location -5	18033’42.6”	73031’44.2”

6.6. Field result interpretation

The data obtained from NaAvmeter shall be used for interpreting edges of water veins for probable borewell locations. Figures 5-9 shows the plotting of NaAvmeter readings taken for profiles of Location-1 at study area having coordinates as $18^{0}34'$ 0.9”N $73^{0}32'$ 40.9”E. Similarly, NaAvmeter readings were plotted for all rotations on Y-axis and distance measured from East side on X-axis for Locations 2-5.

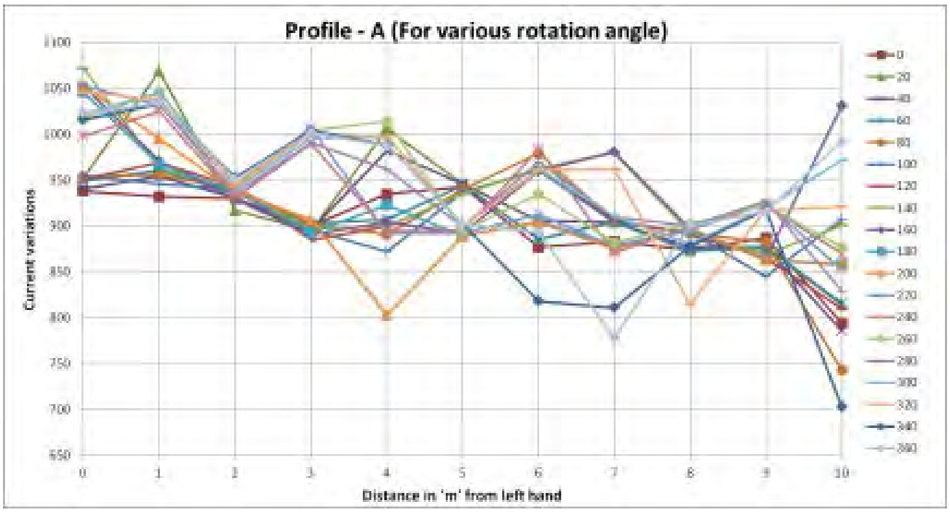

Figure 5. NaAvmeter field reading for Profile – A of Location-1

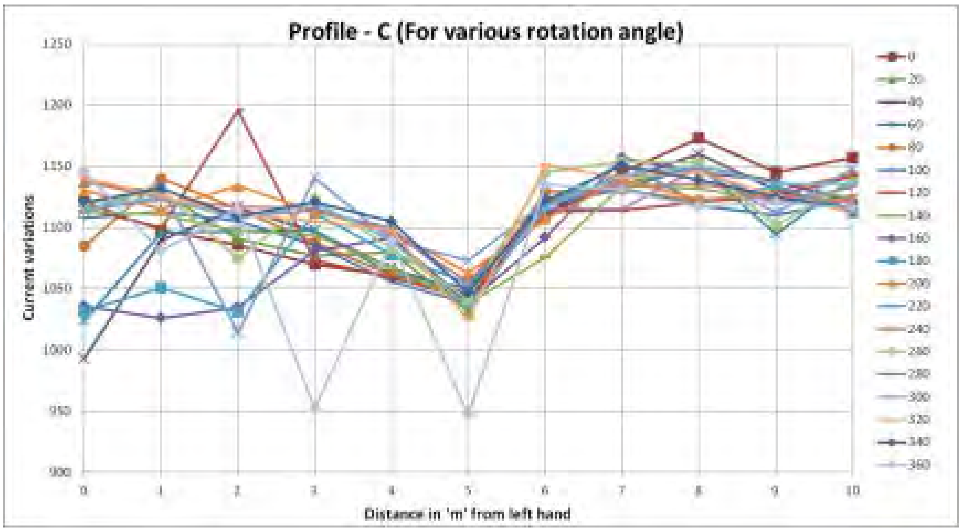

Figure 6. NaAvmeter field reading for Profile – C of Location-1

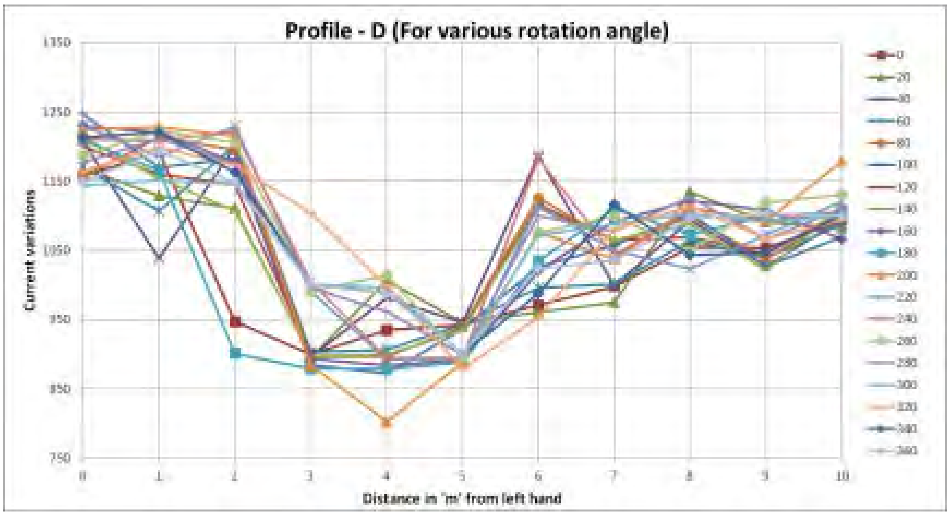

Figure 7. NaAvmeter field reading for Profile – D of Location-1

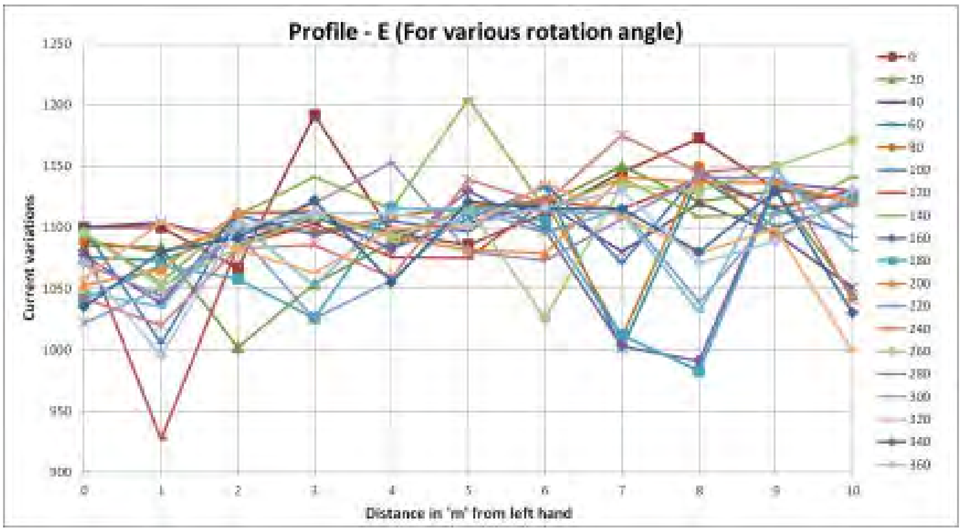

Figure 8. NaAvmeter field reading for Profile - E of Location-1

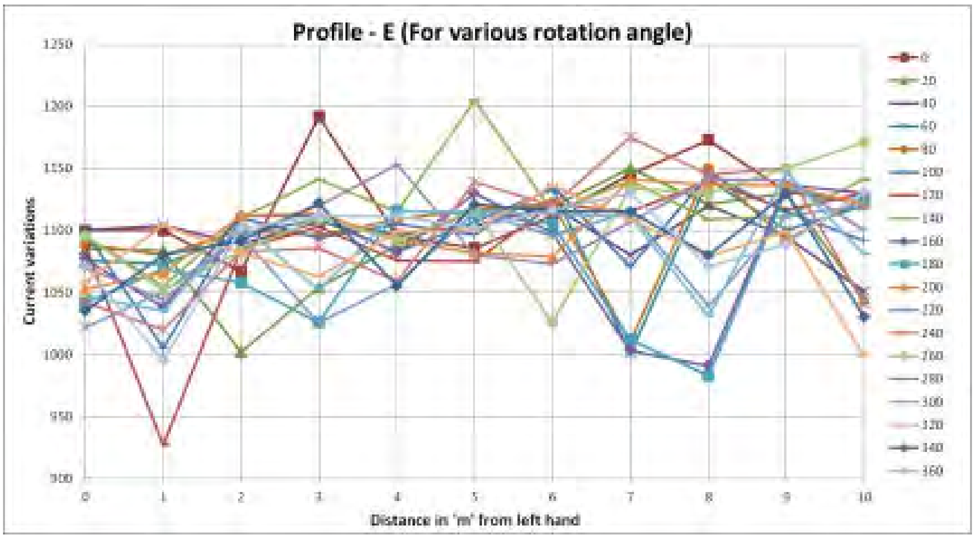

Figure 9. NaAvmeter field reading for Profile - F of Location-1

As per the working principle of the NaAvmeter, the readings inside the edges of groundwater veins are on down-trend with respect to the remaining profile readings at that particular angle. From the field studies it was observed that for the location where water vein is absent, NaAvmeter readings obtained do not show any significant trend. This phenomenon was observed during interpretation of the NaAvmeter field readings for all field locations. The interpretation for each profile for the Location-1 is given in Table-2.

Table 2. Interpretationof field readings of NaAvmeter for Location-1

Profile	Trending of NaAvmeter field readings
Profile - A	- In general, NaAvmeter readings drop was seen from West to East. - NaAvmeter readings drop was seen from 4.0m to 7.0m.
Profile – C	- A trend of NaAvmeter readings drop was seen from 2.0m to 6.0m for all rotations. - A clear NaAvmeter readings drop was seen at 5.0m for all rotations.
Profile – D	- A clear NaAvmeter readings drop was seen from 2.0m to 6.0m for all rotations.
Profile – E	- A multiple NaAvmeter readings drop was seen from 0.0m to 2.0m and 6.0m to 9.0m
Profile – F	- A multiple NaAvmeter readings drop was seen from 1.0m to 3.0m and 6.0m to 8.0m.

Approximate edges of the groundwater veins are plotted based on the variations in instrument readings for each profile of Location-1 to Location-5 at a particular angle as shown in figures 10-14. Location for probable borewell shall be identified based on the groundwater vein mapping.

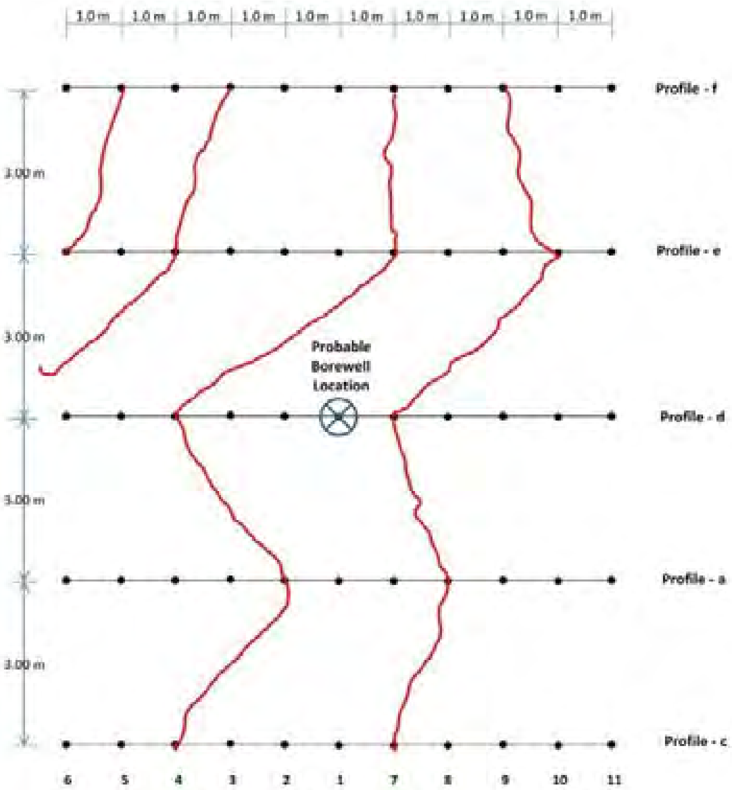

Figure 10. Edges of groundwater veins of Location-1

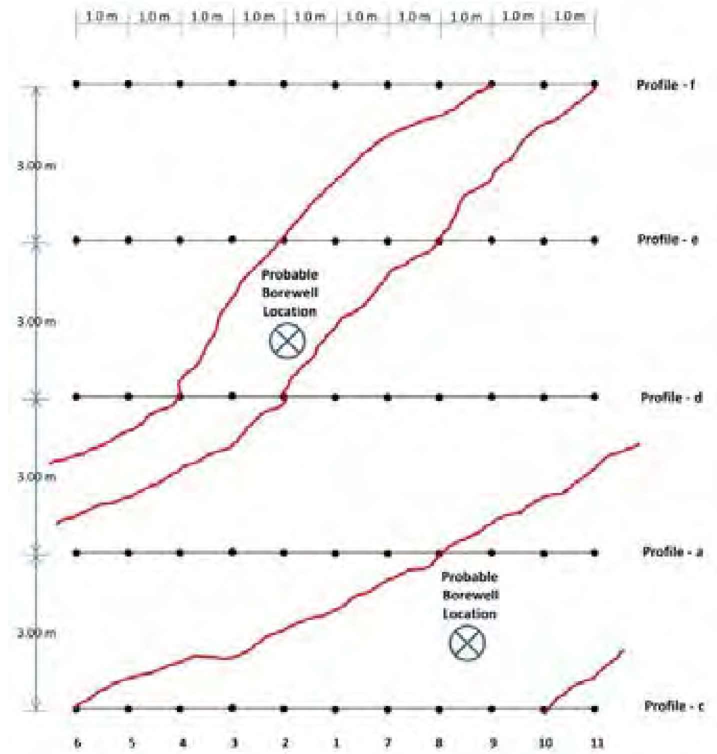

Figure 11. Edges of groundwater veins of Location-2

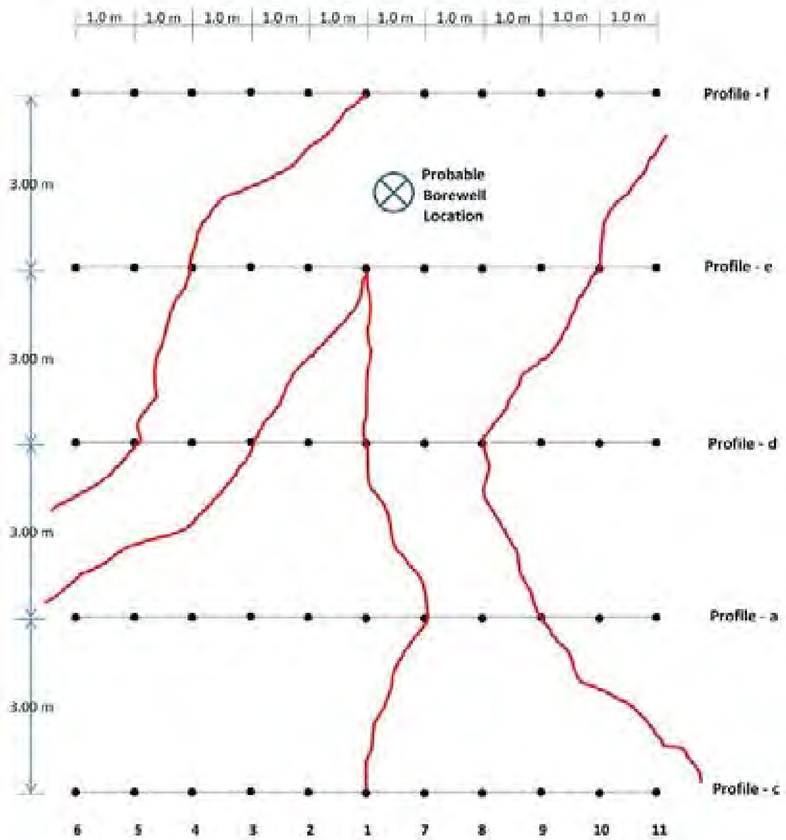

Figure 12. Edges of groundwater veins of Location-3

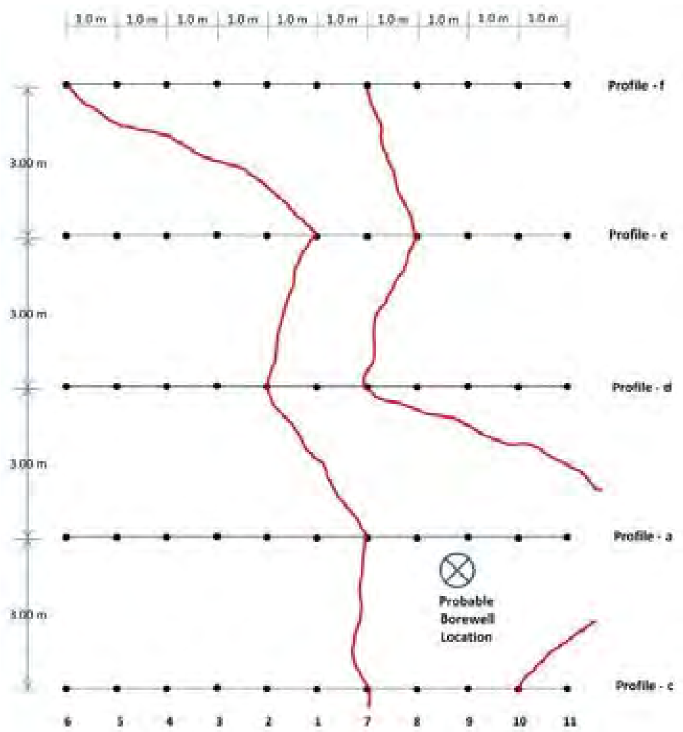

Figure 13. Edges of groundwater veins of Location-4

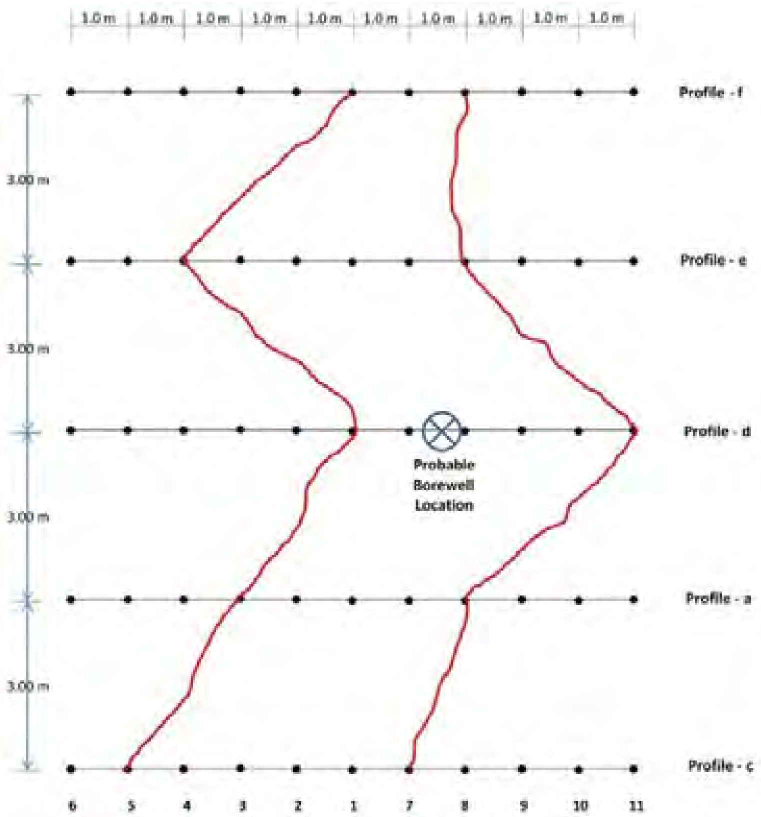

Figure 14. Edges of groundwater veins of Location-5

During interpretation of the NaAvmeter field readings, it was observed that field readings are on downtrend inside the identified edges of water veins. And the field readings outside of the edges of water veins are higher compared to the inside readings. After successful completion of the field result interpretation and drilling of borewell in the study area, water was existing at various depths with varying discharge as detailed in the Table-3.

Table 3. Status of borewell drilled after field interpretation

Location No.	Borewell depth from the ground surface (Ft.)	Discharge (Lit/day)	Remark
Location -1	250.0	5000	
Location -2	250.0	Nil	Out of 2 locations, drilling was conducted at one location only
Location -3	280.0	3500	
Location -4	250.0	5000	
Location -5	290.0	9000	

7. Discussion and Conclusions

After successful completion of the field result interpretation and drilling of borewell, it is evident that NaAvmeter can be successfully practiced for groundwater exploration. From the study following conclusion were drawn:
a.NaAvmeter is capable of identifying groundwater vein or groundwater sources in place of any other contemporary costly groundwater exploration methods. NaAvmeter can be practiced successfully for locating groundwater vein edges.
b.As the experiment setup for NaAvmeter is small in comparison with the setup of existing groundwater exploration method, use of NaAvmeter reduces the operating cost and successive computation efforts for identifying the groundwater locations.
c.In comparison with geophysical methods for groundwater exploration, there is no effect of seasonal variations and requirements of other tests data for utilization of NaAvmeter in the field.

8. Future development for current research work

a.The current study focuses only on basaltic region. Future study may be extended for other geological formations also.
b.From the field experiments conducted using NaAvmeter, it was experienced that NaAvmeter readings show variations under flowing groundwater conditions only. In stagnant groundwater conditions, the instrument doesn't show any reading variations or existence of groundwater. Current research work may be extended to overcome this limitation in the future.
c.Presently, groundwater existence is located by plotting graphs and mapping of various profile variations. Future study may include the development of a mathematical model for predicting groundwater zones. In addition, the study may also be proceeded for developing an equation to predict the depth of borewell drilling with maximum yielding

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experimentation and suggestion for improvement in utilization of NaAvmeter.

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