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Electrical Resistivity Survey For Exploration Of Groundwater In Akhter Zai Shah Area, Qila Saifullah, Balochistan, Pakistan

Muhammad Saeed*[1], Muhammad Mubasher Aziz[2], Nisar Ahmed[3]
[1,2&3]Geological Survey of Pakistan, P.O. Box. 15, Sariab Road, Quetta, Balochistan, Pakistan.
m_saeed@gsp.gov.pk

ABSTRACT

A team from the Geological Survey of Pakistan conducted a groundwater exploration survey in the Akhtar Zai Shah area of Qila Saifullah district. Electrical Resistivity method, employing Vertical Electrical Sounding (VES) with Schlumberger Electrode Configuration. Data along five (5) profile lines has been conducted targeting depth ranging from 300 to 400 meters. The depth range achieved in the observation points are predominantly in recent quaternary deposits, comprising mainly clay, silt, gravel, underlying by Jurassic Loralai Formation. Out of 5 points, the VES-2 point was recommended for groundwater potential at 350 feet with recommendation of simple tripod percussion drilling. Subsequently, a good quantity of high-quality drinking water was discovered within the Phyllite layer of the Loralai Formation. Nonetheless, there has been no systematic exploration of groundwater in the region. The drilling conducted at VES-1 exemplifies blind drilling in the quest for water sources. The success achieved at VES-2 further confirms the presence of groundwater in the Loralai Formation following confirmation of water bearing Shirinab Formation with secondary porosity in Quetta Valley.

Keywords: Qila Saifullah, VES, Loralai Formation, Electrical Resistivity, Balochistan, Pakistan.

INTRODUCTION

Balochistan is an Arid to Semi-arid region with very low and subsurface water. The Ground water is the only source of household and agriculture use for the fertile land in the valleys. Globally, Electrical resistivity survey is well tested method for ground water exploration. Following the successful completion of the project titled "Electromagnetic and Electrical Resistivity Survey for Hardrock Aquifer Configuration in Quetta Valley, Balochistan" (Nazirullah. et al. 2004) requests from Balochistan residents to the Geological Survey of Pakistan (GSP) for groundwater exploration in their areas have become frequent. Responding to one such request, GSP dispatched a team for investigations. Five (05) Vertical Electrical Soundings (VES) were conducted in the area. VES-1 was located at a site where a previous attempt to access groundwater failed after drilling to a depth of 300 feet. The decision to obtain electrical signatures from this unsuccessful borehole to serve as a reference for subsequent investigations in the area proved to be successful.

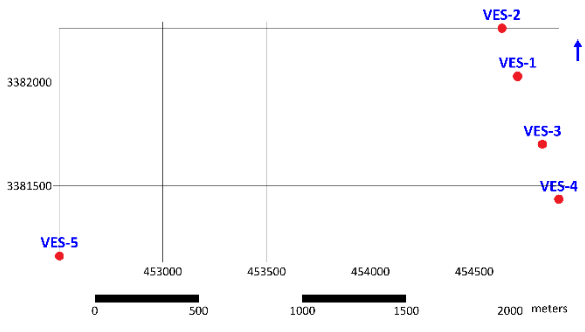


Fig.1. *Location Map of the Area.*

Fig.2. Location Map of the Area on Google Earth (Topo Sheet No.39B/10)

The area lies SE of Qila Saifullah and north of Loralai city and easily accessible through metaled roads connecting N-50 and N-70 and falls in topo sheet No. 39B/10 (Fig.1&2). A valley type area with good fertile land which can be used for agriculture if supplemented with groundwater in addition to the needs of residents (Fatmi. et al. 1985). The location of the sites is as under:

Table 1. Location of VES (UTM, Zone 42R)

VES NO.	EASTING (42R)	NORTHING (42R)
1	454709	3382028
2	454632	3382259
3	454828	3381699
4	454907	3381433
5	452503	3381161

Objective and Scope

The province of Balochistan is the largest in regard to area with water shortage in most area is the main concern. Geological Survey of Pakistan has been serving the province since long in the quest of groundwater for the inhabitants. After the successful completion of the project titled “Electromagnetic and Electrical Resistivity Survey for Hardrock Aquifer Configuration in Quetta Valley, Balochistan" the demand for groundwater surveys increased manifold. GSP with its capable team of geophysicists and power tools to look deep into the earth has put it on the top list.

An attempt was made in the area for search of groundwater by drilling at the location of VES-1 down to the depth of 300 feet, but failed. Therefore, the request was made to GSP and accordingly campaign initiated which proved successful.

GENERAL GEOLOGY

The investigated points are on the Recent/Sub recent deposits (Table 2). The stratigraphic sequence at the project location is as follows:

Table 2. Stratigraphy of the study Area.

AKHTER ZAI SHAH AREA				
Era	**Period**		**Formation**	**Lithology**
Cenozoic	Quaternary		Recent/ Sub-Recent	Loose debris, gravel, sand and clay
			Parh Limestone	Thin to moderate bedded limestone
			Goru formation	Shale, Marl and thin bedded Limestone
	Cretaceous	**Parh Group**	Sembar Formation	Shale and Marl
			Loralai Formation	Limestone, Marl and
	Jurassic		Spingwar Formatio	Shale, Marl and
Messosoic	Triassic	**Alozai Group**	Wulgai Formation	Limestone and

Recent/Sub-recent Deposits

They are dominantly composed of loose or semi-consolidated mudstone interbedded with subordinate sandstone / siltstone and/or pebbly conglomerate. Due to its flat-lying and loose character, we envisage that they are of Holocene age. Under the Recent/ Sub-recent deposits the Parh Group which is divided into three Formations, Sember Fm, Goru Fm and Parh Limestone. The age of the group is cretaceous. (Fatmi. et al. 1985).

Sember Formation

It is composed of pale green to brownish grey shale interbedded with minor proportion of siltstone, arenaceous limestone and sandstone.

Loralai Formation

The Loralai Fm of Jurassic age is divided into two members:

Lower Member: Consists of limestone interbedded with shale and/or marl. Limestone is grey, dark grey to black, weathers dark grey, thin to medium bedded, dense, micritic, hard, argillaceous and lithographic. it Some beds are mottled and contain chert and ammonites of Toarcian age. Shale is black to dark grey splintery, papery and calcareous and is abundant in this member. Marl is greenish grey, splintery and soft.

Upper Member: Consist of limestone with shale/marl intercalations. Limestone is dark grey weathers brownish grey, thin to thick bedded grained sub lithographic and hard. Oolitic, pisolitic and pelletal beds at places with cherty lenses and nodules. Marl/Shale is light grey and thinly bedded. it has a nodular uneven top limestone bed suggests an erosional unconformable surface, it forms cliffs and steep ridges.

Spingwar Formation

The Spingwar Fm of Jurassic age is divided into three members.

Lower Member: Consists of Shale and sub-ordinate limestone. Shale is grey, green, fissile with siliceous, ferruginous concretions. Limestone is grey and micritic.

Middle Member: Consists of limestone with sub-ordinate thin calcareous shale partings. it is grey to dark grey, weathers brown, thin to medium bedded, lithographic, micritic argillaceous, muddy and hard.

Upper Member: Consists of marl and shale with sub-ordinate limestone. the marl is greenish grey, very pale grey, splintery and soft. Pencil-shaped weathering is common. The shale is greenish grey, maroon to purple, silty, flaky and fissile. Limestone is grey to dark grey, black, weathers brownish grey, thin to thick bedded, fine to medium grained, lithographic, hard, muddy, marly and fossiliferous

Wulgai Formation

It contains various types of trace fossils, characteristic of pelagic / hemipelagic sedimentation. The limestone is dark gray, greenish gray to black, and possesses the characters of distal turbidites. The succession is also intruded by several doleritic sills and dykes, which range in thickness from 10 cm to 40 m and laterally extend for several hundreds of meters. The age of Formation is Triassic. (Fig.3). Kazmi & Jan 1997.

METHODOLOGY

Schlumberger Electrode Configuration was adopted for field data acquisition in Vertical Electrical Soundings.

Vertical Electrical Soundings (VES):

The Schlumberger Electrode Configuration was used for field measurements at the VES probe sites. Initially, readings were taken with current electrode spacing set at 3 meters and the inner potential electrodes at 1 meter. Subsequent readings were taken with gradually increasing spacing between the current electrodes. If the potential difference reading became too low or unmeasurable for the receiver, the distance between the potential electrodes was increased. The separation between the current electrodes was maintained at least 5 times greater than the spacing between the potential electrodes. (Dobrin. et al. 1988)

To minimize inaccuracies caused by sloping terrain, the probes were oriented on a flat stretch of land whenever possible. Any deviation of the Schlumberger sounding field curve from the theoretically expected pattern of discontinuities would suggest lateral inconsistencies. These discrepancies on the curve could be corrected by adjusting the displaced segment either upward or downward to align with other segments of the curve.

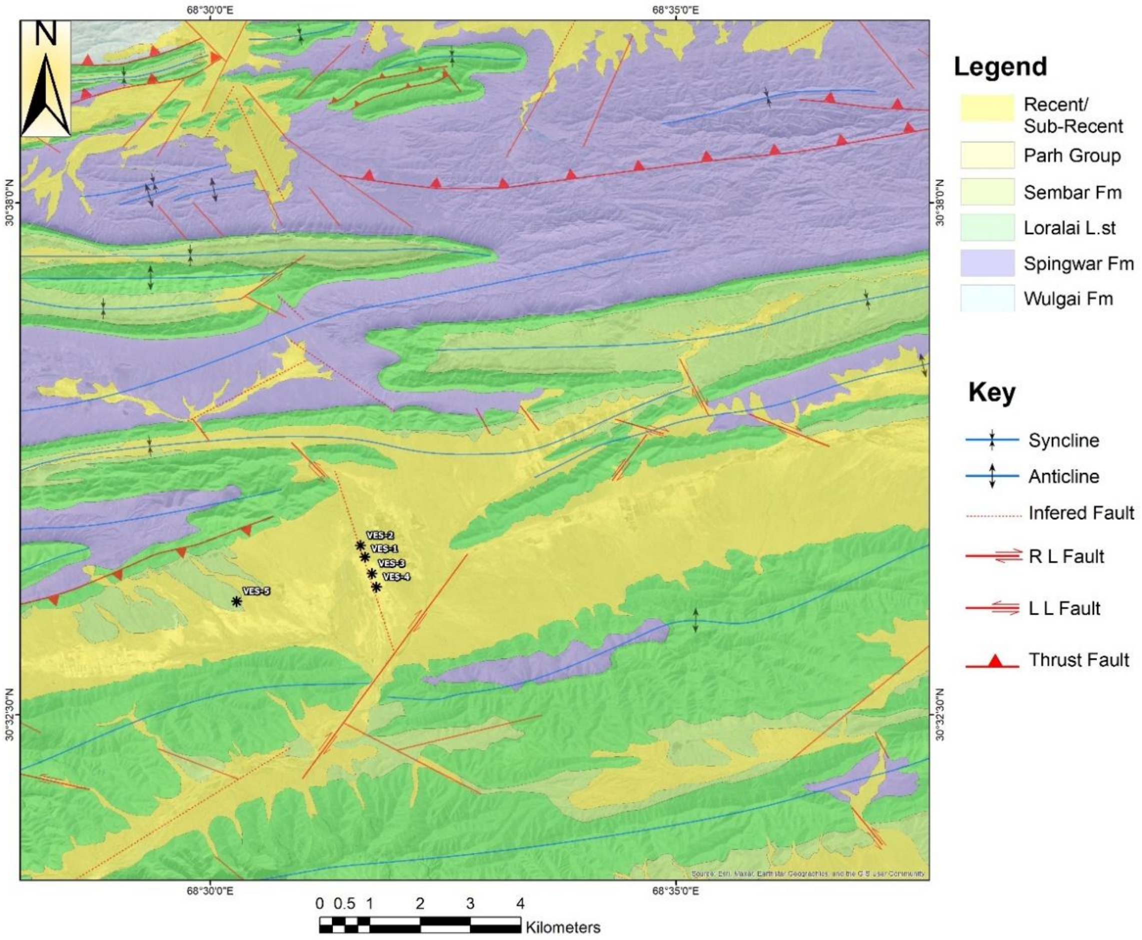


Fig.3. *Geological Map of the Area*.

Equipment and Field Procedure

The Schlumberger electrode configuration was utilized for conducting site investigations (Telford et. al. 1976). The method, known as Vertical Electrical Soundings, was implemented in the field as follows:

Instrument

The following instruments were used for electrical resistivity survey;

I. Resistivity Transmitter: TSQ-3 Transmitter of Scintrex was used for ground energizing. Specification of transmitter is as follows:
- Output power:3000 VA maximum
- Output Voltage:300 to 1500 volts selectable in 9 discrete steps.
- Output Current:10 amperes maximum.

II. Resistivity Receiver: Signal enhancement IP Receiver IPR-10 A of Scintrex was used for measurement of potential difference. The instrument can measure primary voltage in 12 ranges from 30 microvolts to 30 volts.

III. Resistivity Generator: Resistivity generator supplies 220 volts AC output for step up transformer in the transmitter, for maximum 1500 volts DC input ground current.

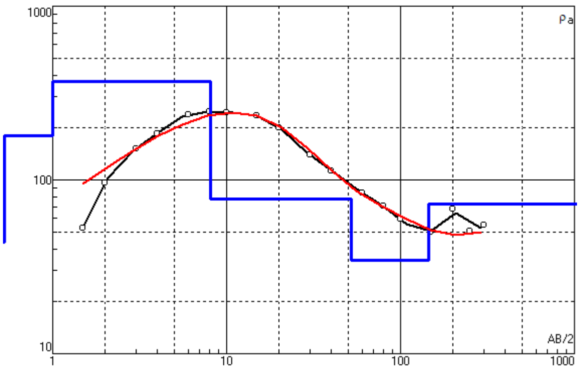
IV. Global Positioning System: A hand held GPS-12 Garmin was used for the determination of the coordinates of the Vertical Electrical Soundings Probe Sites.

DATA SET

The observed field data (apparent resistivity values) at the probe sites (Schlumberger electrode configuration) were plotted on 2*3 cycle Bi-log (modulus 60 mm) graph to obtain the field resistivity curves. (Dobrin. et al. 1988)

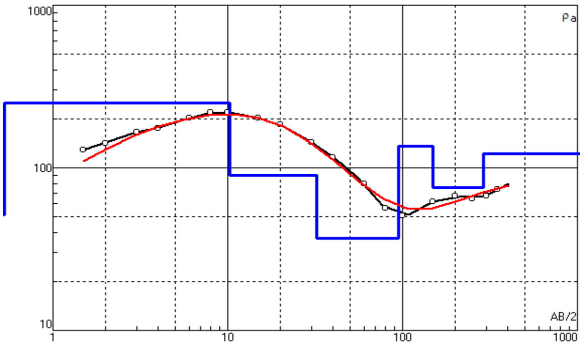
Processing and Modeling of Resistivity Data

For the processing and modeling of VES curves software program "IPI2Win" was used. Simulation of actual subsurface configuration of the lithological units was done by getting the best fit (Zohdy. et. al.1980) of the observed and calculated curve with a minimum RMS (Root Mean Square Error) (Dobrin, M.B.,1988). The interpreted curves (Fig.4 and 8) gave a most plausible subsurface model simulating the actual lithological setup occurring at the probe sites. (IPI2win 1990-2003)



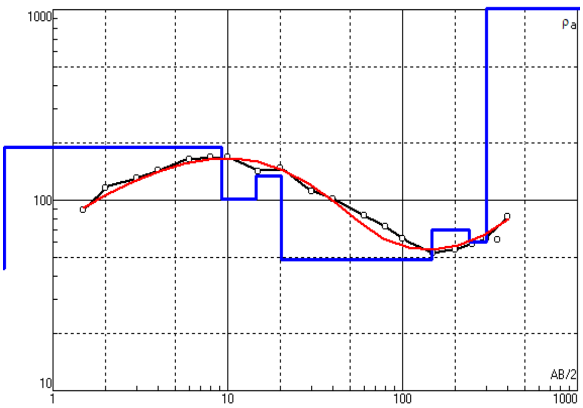
N	1	2	3	4	5	6					
ρ	43.8	180	369	77.7	34.5	72.7					
h	0.475	0.525	7.08	44	92.9						
d	0.475	1	8.08	52.1	145						
Alt	-0.475	-1	-8.08	-52.08	-145						

***Fig.4**. Modeled Resistivity Curve for VES-1.*



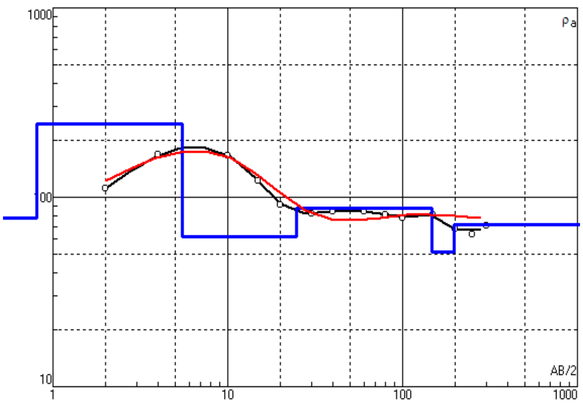
N	1	2	3	4	5	6	7				
ρ	51.1	251	89.9	36.9	136	75.6	122				
h	0.456	9.81	22	62.6	54.2	141					
d	0.456	10.3	32.3	94.9	149	290					
Alt	-0.456	-10.27	-32.27	-94.87	-149.1	-290.1					

***Fig.5**. Modeled Resistivity Curve for VES-2.*



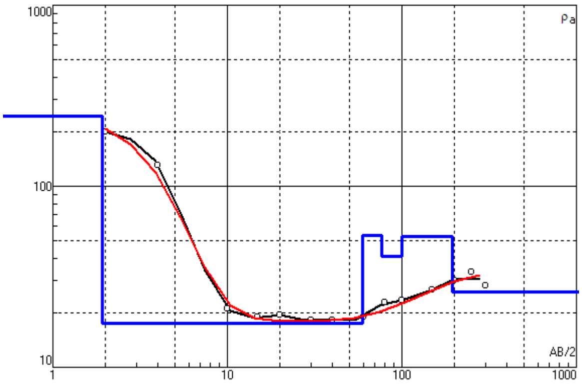
N	1	2	3	4	5	6	7	8			
ρ	44.1	189	101	134	48.7	69.8	60.3	1013			
h	0.455	8.78	5.28	5.73	127	93.6	61.1				
d	0.455	9.23	14.5	20.2	147	241	302				
Alt	-0.455	-9.235	-14.51	-20.24	-147.2	-240.8	-301.9				

***Fig.6**. Modeled Resistivity Curve for VES-3.*



N	1	2	3	4	5	6					
ρ	77.2	244	61.9	87.5	51.4	71.7					
h	0.808	4.69	19.2	122	50						
d	0.808	5.5	24.7	147	197						
Alt	-0.808	-5.498	-24.7	-146.7	-196.7						

***Fig.7**. Modeled Resistivity Curve for VES-4.*



N	1	2	3	4	5	6					
ρ	244	17.4	53.5	41	52.8	26.1					
h	1.92	57.6	17.1	23.3	94.5						
d	1.92	59.5	76.6	99.9	194						
Alt	-1.92	-59.52	-76.62	-99.92	-194.4						

***Fig.8.** Modeled Resistivity Curve for VES-5.*

INTERPRETATION

VES-01: The total depth of investigation is 300 meters with resistivity variation of 34.5 Ohm-m to 369 Ohm-m. The surface material has resistivity of 43.8 Ohm-m. The recent deposits comprised of Gravels/sand/silts are present down to 8.08 meters. The resistivity variation within recent deposits is 180-369 Ohm-m. The clays extend down to the depth of 145 meters with corresponding resistivity of 34.5 Ohm-m. An ascending behavior of resistivity is observed down to the explored depth with corresponding resistivity of 72.7 Ohm-m.

VES-2: The resistivity variation at this point is from 36.9 to 251 Ohm-m with total depth of investigation is 300 meters. The surface material corresponds to resistivity of 51.1 Ohm-m with thickness of 0.456 meters. The recent deposits (Gravels/Sand/Silts) are present down to the depth of 9.81 meters with resistivity of 251 Ohm-m. Clays are present down to the depth of 94.9 meters with resistivity of 26.9 Ohm-m. An ascending behavior of resistivity is observed down to the explored depth with maximum resistivity of 136 Ohm-m. The resistivity of 136 & 122 Ohm-m is well inside in the range of water bearing lithologies as observed in the province of Balochistan (Nazirullah. et al. 2004).

VES-3: The resistivity variation in the explored depth of 300 meters is from 44.1 to 1013 Ohm-m. The recent deposits comprised of gravels/sand/silts are present down to the depth of 20.2 meters with maximum resistivity of 189 Ohm-m. Clays are inferred dominantly down to 147 meters with some alternating sequences of silts as descending behavior of resistivity is not so steep. An ascending behavior is observed in resistivity down to the explored depth with some low resistive zones due to change in lithology or presence of incompetent zones within the same lithological unit.

VES-4: The resistivity variation at this point of investigation is from 51.4 to 244 Ohm-m in the 300 meters, i.e. investigated depth. A surface layer with resistivity of 77.2 Ohm-m and thickness of 0.808 meters is inferred. Recent deposits in general with resistivity of 244 Ohm-m are available down to 5.5 meters. The deposits are dominantly, inferred as gravels. Clays are inferred down to 24.7 meters. Shales/silts with considerable compactness are inferred down to the explored depth.

VES-5: The resistivity variation is from 16.8 to 244 Ohm-m with in the investigated range of 300 meters. A compact and resistive surface layer of thickness of 1.92 meters which exhibits on resistivity range of 244 Ohm-m. Clays are dominantly present down to 67.6 meters. Resistive rock unit, may be comprised of silts/shale with compactness, down to the explored depth is available. However, incompetent strata are also available for about 23.3 meters' thickness at 76.6 meters' depth.

RESULTS & DISCUSSIONS

The investigated points are on the recent deposits which are generally comprised of Gravels/sand/silts (Table 2). Generally, Loralai Formation and Spingwar Formation (Comprised of alternated beds of Shale and Limestone) are dipping towards approximately due South in the North of Investigated area.

The explored area is comprised of Recent Deposits on top, clays and compact shales and limestones are inferred with depth, after interpretation of investigated points. A drill hole down to the depth of 300 feet was drilled before conducting of Electrical Resistivity Survey (ERS) at VES-1. However, no groundwater was found. The ERS at this point offered good relationship about true resistivity with actual lithology in the area and produced reference to the other points of investigations. Accordingly, the Lower Member of Loralai Formation with alternative sequence of Limestone and Shale is inferred after clays at depth. The true resistivity range of water bearing fractured zones Lower Member of Loralai Formation is 70-250 Ohm-m (GSP Information Release No. 797; 2007 Russell et al).

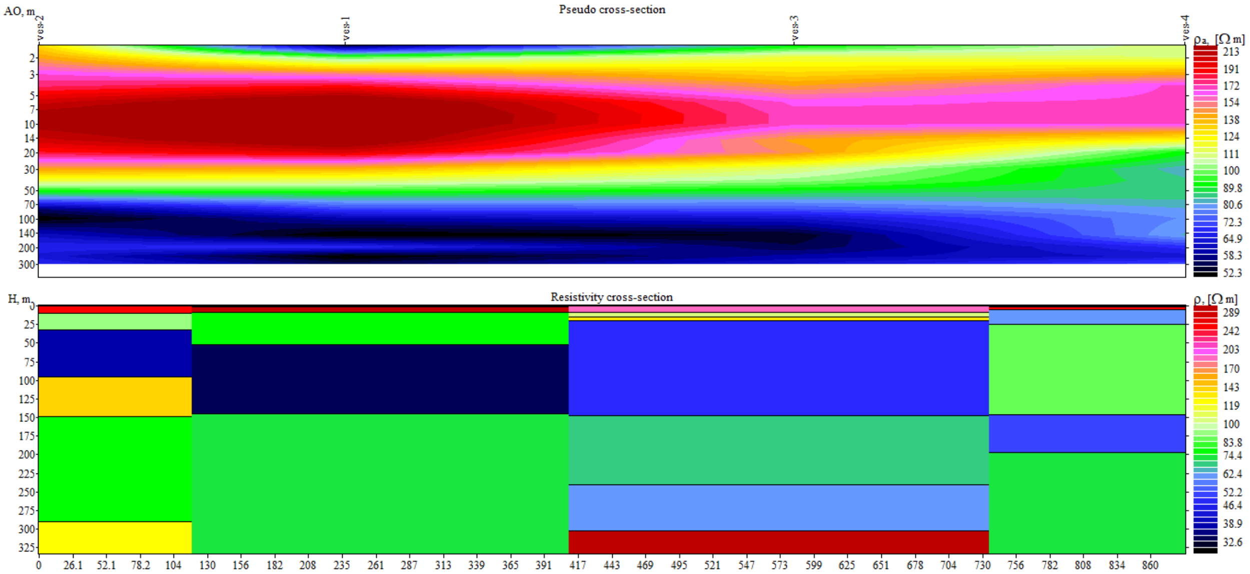


***Fig.8**. Pseudo Cross-section & Resistivity Cross-section for VES-1,2,3 & 4*

RECOMMENDATIONS

The Vertical Electrical Sounding (VES-2) was recommended for groundwater search. The point was drilled down to the depth of 350 ft with tripod percussion drilling. Good quantity & quality of drinking groundwater was found in Phyllite (Lower Member of Loralai Formation). The approximate lithological log provided by the driller at the site is as under:

Table 2. Lithological Log of Drill Hole.

S. No.	**Lithology**	**Depth (ft)**
1	Gravels	0-120
2	Clays	120-230
3	Silts	230-260
4	Phyllite	260-350

CONCLUSIONS

A fertile land is available in abundance in the valleys surrounded by exposed rock units of Jurassic and Triassic age. However, no systematic groundwater investigations were conducted in the area. The drilling at VES-1 is also the example of blind drilling for search of water. The success at VES-2 has supplemented the fact about presence of groundwater in the Lower Member of Loralai Formation (Phyllite with secondary porosity) after successful signature exhibited in Quetta valley during the project of titled “Electromagnetic and Electrical Resistivity Survey for Hardrock Aquifer Configuration in Quetta Valley, Balochistan” (Nazirullah et. al. 2004)

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REFERENCES

Dobrin, M.B., 1988 Introduction to Geophysical Prospecting (4th edition), McGraw-Hill Book Company.

IPI2win. Version 3.0.1.a.7.01.03., Resistivity Sounding Interpretation., Moscow State University (1990-2003)

Fatmi S.F. et al. 1985 Groundwater Investigation of part of Kharan District, (Kalat Division) Pakistan. GSP I.R. No. 258

Kazmi and Jan 1997 Geology and tectonics of Pakistan.

Nazirullah. R. et al. 2004 Electromagnetic and Electrical Resistivity Surveys for Hard Rock Aquifer Configuration in Quetta Valley. (Investigation Phase). GSP I.R. No. 797

Telford, W.M. et al. 1976 Applied Geophysics (1st edition), Cambridge University Press, London.

Zohdy. A. A. R. et. al. 1980 Techniques of Water-Resources Investigations of the United States Geological Survey (2nd edition). United States Government Printing Office, Washington.

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CONTACT US

Email Address:

info@geologica.gov.pk

Website Address:

www.geologica.gov.pk

Phone Number:

+92-51-9255135

Office Address:

Geoscience Advance Research Laboratories,

Geological Survey of Pakistan,

Park Road, Link Kuri Road, Shehzad Town,

Islamabad

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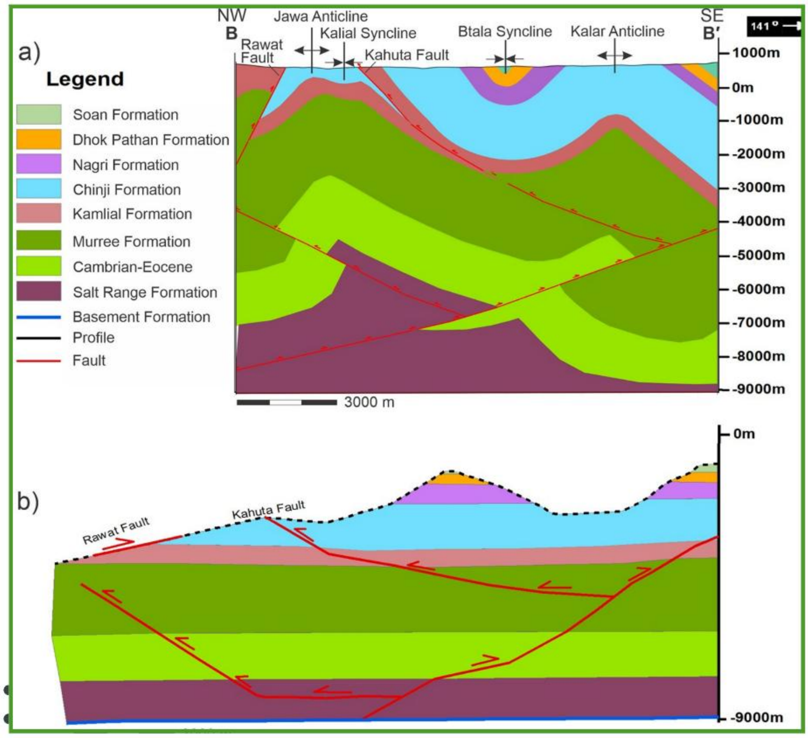

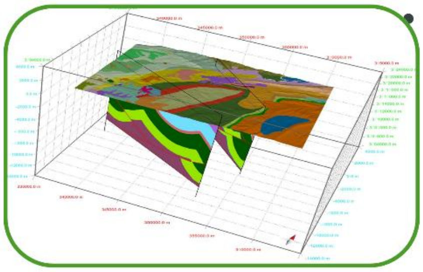

BY:

GEOSCIENCE ADVANCE RESEARCH LABORATORIES,
GEOLOGICAL SURVEY OF PAKISTAN

Park Road, Link Kuri Road Shahzad Town Islamabad
www.gsp.gov.pk

FOR MORE INFORMATION

+92-51-9255135
www.geologica.gov.pk
info@geologica.gov.pk