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Groundwater Prospective Zones and Precise Location Using Integrated Geological, Geomorphological, and Geophysical Methods in Sholgara District, Balkh Province

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Abstract

All over the world, studies of groundwater reserves are highly important. One of the best ways to identify groundwater reservoirs without negative impacts on the environment is to study geology and geomorphology based on remote sensing data and geophysical methods. The main purpose of this paper is to delineate the groundwater prospective zones and to determine the relative depth and thickness of layers that accumulate groundwater. The groundwater reservoir depends on several factors such as geology, geomorphology, land use, slope, and physical properties. Thus, the mapping and groundwater potential zones were identified in Sholgara District, and then geophysical methods were used in Qazel Kand village to find the water table depth and location. Exploration geophysical methods, especially electric, are one of the most important ways to study and solve the problems of drinking water in the study area Based on the VES investigations, at least five layers were identified with different lithology. The top three layers consist of clay, sand, and gravel, which are mostly dry. These rocks do not have many water resources but could recharge the aquifer, particularly in the wet season. The field data also show that water table depth ranges between 80 to 100 m with limestone and marl formations that mostly belong to Neogene. These are carbonate rocks having secondary porosity in the form of fractures and wreathing. The formations formed a karst aquifer to a maximum of 130 depths. The water in this aquifer seems fresh and suitable for drinking.

Keywords: Groundwater Prospective Zones, Remote Sensing and Geophysical Methods, Balkh Province.

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1. Introduction

In nature, water resources are divided into two parts: surface and underground. From a groundwater point of view, the earth's crust is divided into water-saturated and unsaturated zones. The water which has taken place in the porous media and voids of the upper layers of the crust is called underground water. All around the world, groundwater studies play a vital role in human beings. Therefore, groundwater investigations and management are getting increased day by day all around the world. One of the very important investigation methods is the integrated geological, geomorphological, and geophysical methods which do not affect badly on the environment. Using Remote Sensing together with geological, geomorphological, and geophysical methods is an easy and effective way to delineate groundwater zones and solve the drinking water problem in the study area. Using geophysical methods, we can measure the physical properties of underground rocks. Then we acquire important information using geophysical methods that we cannot sample or measure directly. Geological, geomorphological, and geophysical investigations are amongst the best tools for understanding the landform and physical context of the earth's surface.

The under-research area is located in the Sholgara district southern part of Balkh Province – Afghanistan. Currently, in Sholgara including the study area, there is a depletion of the river and groundwater storage and an increase in concern of overdraft of groundwater due to over-abstraction, drought, low recharge, and high evaporation. The groundwater quality has progressively deteriorated with water hardness, salinity, nitrate and boron concentrations, etc., which become a real threat to the health of inhabitants and agricultural activities [1] .

The research method of this work is based on valid theoretical bases and practical experiences. Primary data for this research paper includes the geologic map, initial field data, and satellite imagery. A geological map was used to study the geology of the area in detail. Remote sensing and geographic information systems (GIS) are used to prepare geomorphological information and thematic maps from various satellite imageries. For the geomorphological study, different satellite images were used. The initial geophysical field data was collected during fieldwork by Danish Committee for Aid to Afghan Refugees (DACAAR) in 2013, includes of Vertical Electrical Sounding (VES). These methods are used to study, map and assess groundwater in Qazel Kand village, Sholgara District [2]

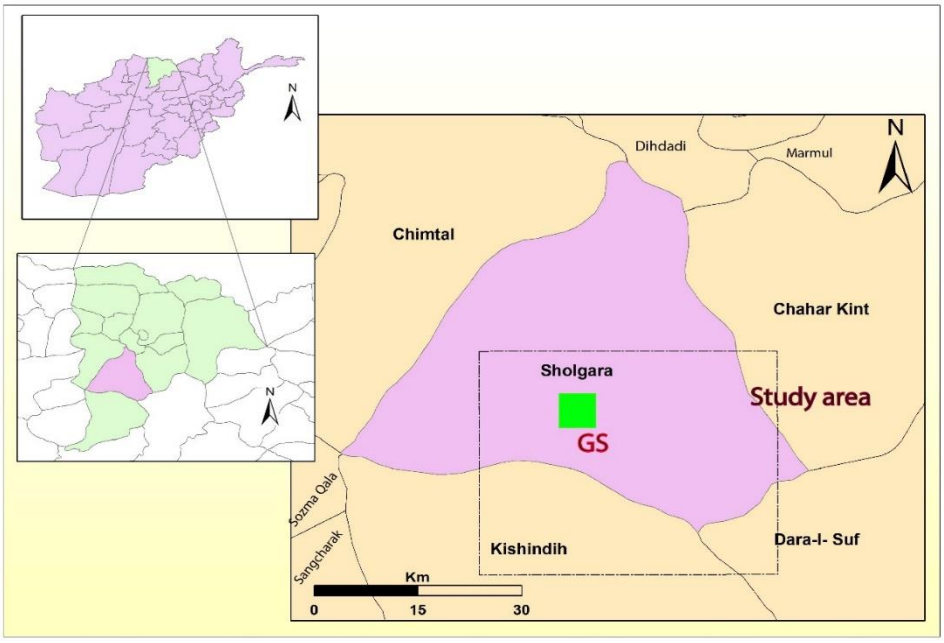


Figure 1: Location of the Sholgara District situated in the southern part of Balkh Province in Afghanistan. Hallow square with a black dash-line shows the location of the study area. Green-filled square with GS indicates the location of the geophysical survey shown in figure 8.

The main concern of this study is: How to extract and evaluate geomorphological features such as slope, elevation, and drainage from remotely sensed data? What is the geology of the study area? Which geologic formations are located there? How to delineate groundwater potential zones? Can the location of drinking water be determined in the area to some extent? Is it possible to determine the position and thickness of aquifers using electrical methods? Hence, the overall goal of this paper is to interpret thematic maps and the graphs of the electrical method (VES) to determine the potential zones of groundwater, to study the geology and geomorphology of the area, and to find the boundary and depth of an aquifer as well as the water table in Sholgara District and specifically in the Qazel Kand Village.

2. Regional Setting of the Study Area

2.1. Geology of the study area and northern part of Afghanistan

Based on geophysics and borehole records in northern Afghanistan, shows clear boundaries between the associated layers. The pre-Palaeozoic, Palaeozoic, Mesozoic, and Cainozoic rocks form the geological structure of the platform. Northern Afghanistan has a Pre-Jurassic basement unconformably overlain by Jurassic and Paleogene sediments, which in turn overlain by Neogene and post-orogenic continental clasts [3] Relatively undeformed mostly clastic Jurassic to recent sediments overlay deformed Triassic and older age rocks. Also, the geophysical researches show a gradual passage into the Murghab and Tajik Basin, which is filled with dominantly clastic Mesozoic-Quaternary sediments [4]. In general, the platform formed a single Mesozoic to Paleogene

sedimentary basin, which existed until Neogene time [5,6]. According to [6,7] the Amu Darya and Afghan-Tajik Basins' Pre-Neogene history and stratigraphy consist of (1) Paleozoic to Triassic basement complex, (2) Jurassic to Paleogene sedimentary cover, and (3) Neogene to Holocene orogenic clastic. Neogene to Holocene orogenic clastic were deposited in Oligocene time as a result of tectonic deformation due to the Indian and Eurasian tectonic plates [5,6,7]

However, the geology of northern Afghanistan is studied particularly in the west and very limited research works have been done due to the unstable political situation in the country. Mostly Russian researchers worked and prepared maps of the study area. They mapped northern Afghanistan at a 1:500,000 scale [3,8,9,10,11,12] summarized the geology and tectonics of the area.

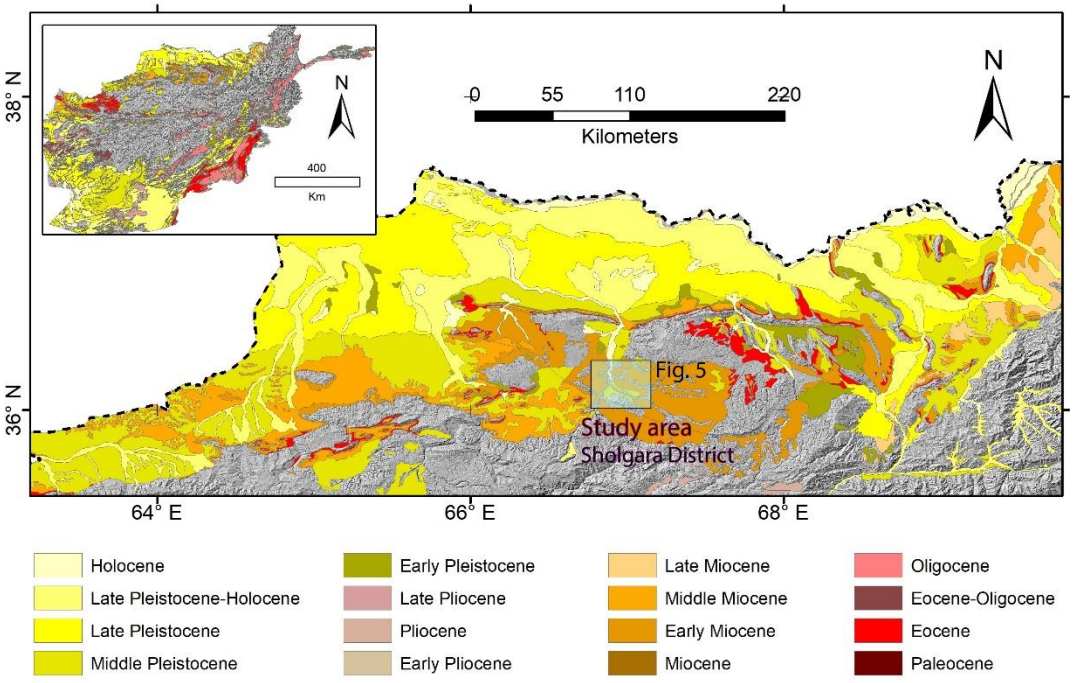


Figure 2: Geological map (Cainozoic) of northern Afghanistan. The map is modified from [13]

The lithology of the northern part of Afghanistan has similar sediments the same as the neighboring regions of Central Asian Countries (the southwestern area of the mount Hesar and Bukhara oil and gas fields). The lithology of the northern Afghan platform usually consists of bitumen graphite, tuff-andesite, sandstone, sand, conglomerates, calcite, dolomite, dense limestone, salt, anhydrite, gypsum, argillite with the remnants of coal, mud, and others . The formation of the underground geology of the study area is as follows: Quaternary sediments: sand, gravel, mud, and loess that have been deformed by climate. Medium quaternary sediments: sand, gravel, mud, loess, silt, and travertine or limestone. Miocene sediments: red muds, sandstones, siltstones, conglomerates, and calcites. Paleocene sediments: lime-stones, calcites, dolomites, conglomerates, sandstones, and siltstones [13,14,15] (Fig. 2).

The Northern Afghan platform is separated from the Turan platform of southern Eurasia by the Amu Darya and Afghan Tajik basins [3]. The ongoing collision of the

Indian plate with the Eurasian plate is accommodated by faults that have historically caused devastating earthquakes in the region. On the east and south, the North Afghan Platform is bordered by the Herat right-lateral and Darwaz left-lateral strike-slip and related faults (Shnizai, 2020b). The study area is located close to the Alburz-Marmul fault lies between the Northern Afghan High to the south and Afghan-Tajik Basin to the north (Figs. 3a, b). The Alburz-Mormul fault also separates the Tajikistan depression from the Parapamiz Bande-Turkistan uplift. The Dosi Mirzavalang fault has continuous and sub-linear scarps on middle and late Pleistocene alluvial deposits and bedrock [16,17] (Figs. 3a, b).

2.2. Geomorphic Setting

Generally, landscapes in Afghanistan are tectonically active due to vertical and horizontal crustal blocks motion as well as erosion and deposition process (Fig. 3a). Afghanistan is dominated by rugged mountainous terrains like the massive Hindu Kush Mountains, which form a barrier between the Northern Afghan Platform and the rest of the country. The Hindu Kush plays a watershed role between the northern Amu Darya and Afghan Tajik Basins to the north and Indus Basin to the south (Figs. 3a, 4). Northern Afghanistan is located in desert and semi-desert areas. Two big basins are located inside the platform, which encompasses approximately 87,000 square kilometers in those portions that lie within Afghanistan [6]. The Afghan-Tajik Basin is located to the east of the Afghan platform while the Amu Darya Basin is to the west. These two basins are separated from one another by a Gissar mega anticline called Gissar [6] (Fig. 4). In general, the northern Afghan occupies a narrow zone between Alburz-Marmul Fault North Afghan High and Bande Turkistan Rang to the south, and Amu

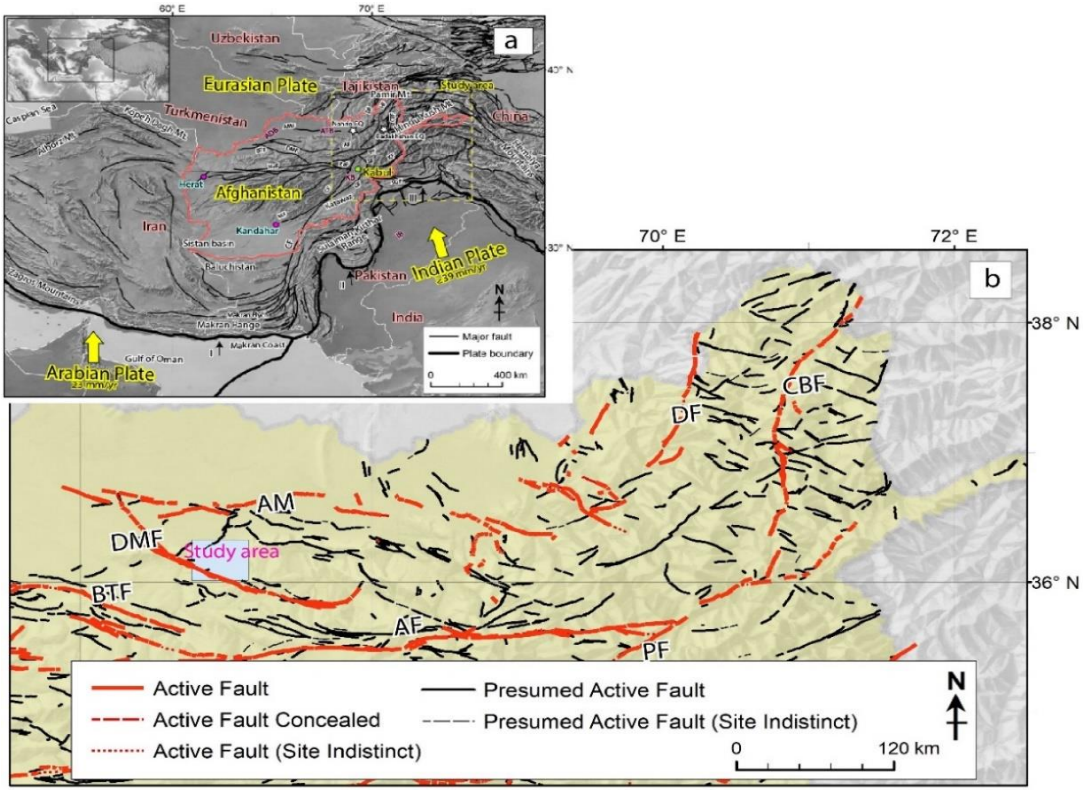


Figure 3. a) Tectonic setting of Afghanistan and the surrounding regions. Yellow-filled arrows show relative plate motion directions between the Arabian and Indian plates concerning the Eurasian plate (plate velocities from [18] and active faults are from [16] and [17]. The plate boundaries are marked with numbers: I) Makran subduction zone, II) fold-and-thrust belt east of the Chaman fault, and III) Himalaya collision zone. ATB, Afghan-Tajik Basin; ADB, Amu Darya Basin; IB, Indus Basin; KB, Kabul Basin. b) Active faults map of northern Afghanistan. Faults names in both figures: AMF, Alburz Marmul; AF, Andarab; BTF, Band-e Turkestan; CF, Chaman; CBF, Central Badakhshan; DF, Darvaz; DMF, Dosi Mirzavalang; GF, Gardez; HeF, Herat; HF, Henjvan; KF, Konar; MF, Mokur; PaF, Paghman; PF, Panjshir; SGF, Spinghar. The active fault maps is modified from Shnizai (2020)

3. Site description and research background

The district is located in the southern part of Balkh Province, just south of Mazari Sharif about 450 km north of the Capital Kabul. The main occupation of the residents here is agriculture and livestock. This district is the sole producer of industrial products in Balkh Province. The people generally use drinking water from wells, most of which are without hand pumps. In summer, the water of the pits and drilled wells dry out, and people cannot dig deeper wells due to the presence of hard rocks. Therefore, people use water from streams or ditches located a few hundred meters from their homes. These waters are muddy, polluted, and contain bacteria. Since the main problem of this village is the lack of healthy and safe water in terms of quantity and quality, it is necessary to provide safe drinking water by drilling deep wells and constructing a water supply system [2]

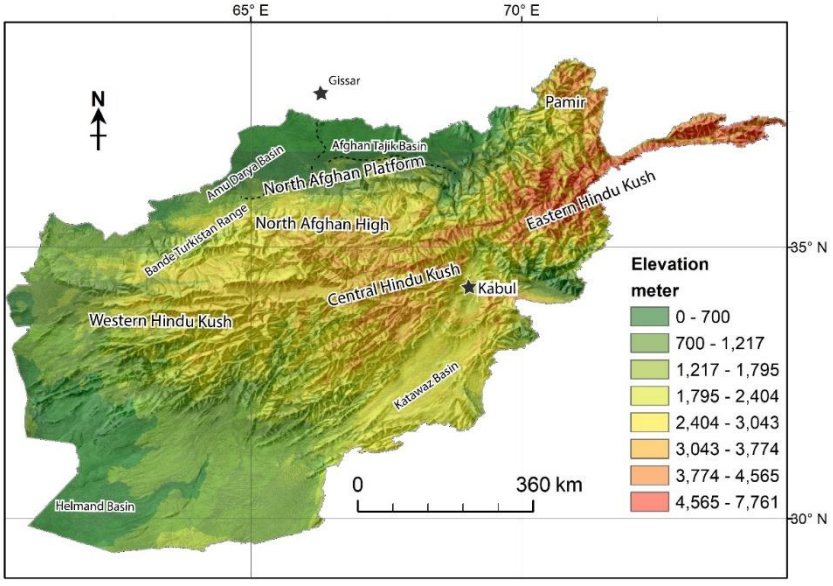


Figure 4. Geomorphology of northern Afghanistan.

4. Methods

The people's demand for water supply is met by surface and groundwater. The current drought and population growth have caused serious problems, particularly in groundwater pollution over abstraction. In shallow wells and streams within the research area, the water level drops and even completely dried particularly in the summer season. Thus, the residents of the area are faced with rapid decline and shortage in water for their livestock and even drinking. To identify groundwater conditions through surface and subsurface features, we have integrated geological, geomorphological, and geophysical methods. We have conducted geological and geomorphological research to map geomorphic features such as slope, landform, geology, watershed, and groundwater potential zones in the study area with the help of thematic maps prepared using a remote sensing geographical information system. We, therefore, analyzed the geology and geomorphology of the Qazel Kand Village and the surrounding region in the Sholgara District using several satellite images. Remote sensing and GIS together with Adobe Illustrator have proved to be important tools to prepare thematic maps from various satellite imageries. Application of GIS and Remote Sensing in geology and geomorphology for groundwater evaluation has been proven to be efficient [19,20].They are also used as a multi-criteria decision tool for analysis and rapid assessment of surface geologic formation, surface water drainage, groundwater, and other natural resources. However, after the delineation of groundwater zones, we focus on a small research area located in Qazel Kand village to estimate the water table. Therefore, DACAAR Institution conducted a geophysical survey for groundwater exploration in Qazel Kand village on the 23rd of November 2013 that was used as primary geophysical data in the research area.

Large-scale images were constructed from SPOT (Satellite Pour l' Observation de la Terre) earth observation satellite that is freely available from ESRI (Environmental Systems Research Institute) as a base map [17]. All the images were imported to ArcMap for geo-referencing into a global framework and manipulated to highlight the scenes to

map the critical geomorphic elements of the study area. Fieldwork was also conducted in the broader area, particularly along the riverside, to examine the details underground structure. So, DACAAR funded team did a Vertical Electrical Sounding (VES) survey using Schlumberger Electrodes Array to explore and prepare drinking water for the people in the Qazel Kand village [2]. Field measurements were done by the Syscal Pro Resistivity Meter and interpreted by IPI2 win software. Then the data were analyzed and interpreted to determine the location, depth, and boundary of the water table in the Qazel Kand Village.

5. Result and Discussion

Based on the availability of data and resources, this research is limited to the use of geology, geomorphology, and geophysics that focus on lithology, rock properties, slope, land use, and electrical properties of underground layers. The lithology and rock properties affect the early stage of erosion as well as water infiltration into the ground. The slope and land use are variables and have significantly influenced the geomorphological control of groundwater occurrence. The electrical properties of rocks and groundwater are measured by Vertical Electrical Sounding (VES) to obtain information about the aquifer.

5.1. Geology

The study area represents a clay steppe or semi-desert. The surface geological formation includes recent Quaternary (gravel, sand, clay, and loess), middle Quaternary (gravel, sand, clay loess, loam, and travertine), early Miocene (red clay, sandstone, siltstone, conglomerate, and limestone), and Palaeocene (sandstone, siltstone, conglomerate, marl, limestone, and dolomite) (Fig. 5).

In this region, the geological map [13] serves as a basis for the study of groundwater conditions (Fig. 5). The geological units play an important role in affecting the movement, accumulation, and quality of groundwater. The basement of the study area is constituted of granite and metamorphic rocks. They have very less porosity and are classified into low groundwater potential zones. The basement is cropped out in the south, east and west parts of the area. The stratigraphic sequence occurring in the area is listed in table 1. The Holocene, Late Pleistocene, and Middle and Early Miocene deposits have high porosity and seem to be good sources of groundwater. Among these deposits, the Holocene and Late Pleistocene have a high possibility of the occurrence of groundwater. These sediments have a high amount of porosity, so it has good groundwater potential. The stratigraphic sequence of Paleocene and Late Cretaceous in the study area are hard rock and located in a higher elevated area of this region. These rocks do not have much water resources but could be a good rechargeable region, particularly in the wet season (winter and spring) for the low elevated areas (Holocene and Late Pleistocene deposits) (Fig. 5).

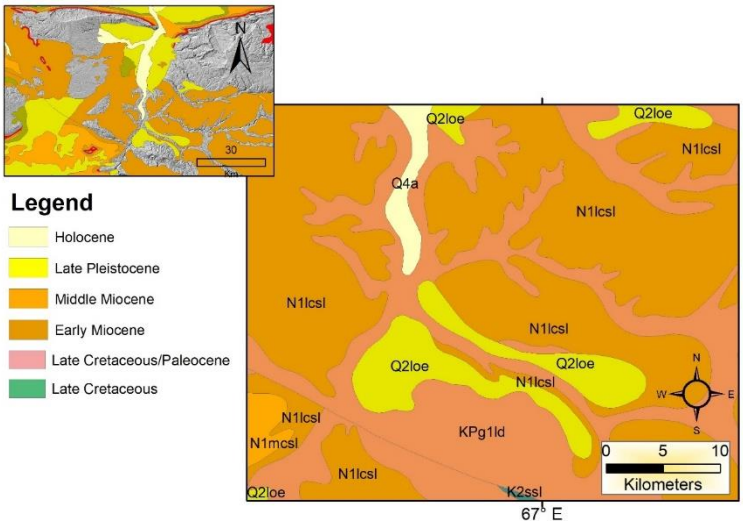


Figure 5. Geologic map of the study area simplified from [13]

Table 1: stratigraphic sequence of the study area (after [13]).

No	Unit Symbol	Lithology
1	Q4a	Conglomerate and sandstone (narrative: red clay, siltstone > sandstone, conglomerate, limestone)
2	Q2loe	Loess (narrative: Loess more abundant than sand, clay)
3	N1Lcsl	Clay and siltstone (narrative: red clay, siltstone > sandstone, conglomerate, limestone)
4	N1mosl	Clay and siltstone (narrative: brown clay, siltstone > sandstone, conglomerate, limestone)
5	Kpg1ld	Limestone and dolomite (narrative: limestone, marl, dolomite > sandstone, clay, siltstone, gypsum, conglomerate)
6	K2ssl	Sandstone and siltstone (narrative: sandstone, siltstone > clay, limestone, marl, conglomerate, gypsum (North Afghanistan); limestone)

5.2. Geomorphology

5.2.1. Land Use

The dependence on groundwater is determined by the land used in an area. The land use in the study area (Sholgara Drainage Basin) contains agricultural land (plantation, cropland, and fallow farmland), water bodies (steam and pound), and build-up area (Fig. 6). Based on the satellite imageries, irrigation in few areas is reliant on groundwater, while irrigation mainly is dependent on surface water. The Band-e Amir river nearly disappears in Balkh Province in the sands at the meeting place of desert and semi-desert without reaching the Amu Darya River (Figure 4).

5.2.2. Geomorphic features

The geomorphic features of different landforms are created by tectonic and geologic processes (temperature change, freezing, chemical reactions, water, and wind). Some active faults affect the landform such as the Alburz-Marmul fault and the Samangan fault. Foothill, linear ridges, peneplain, pediments, and valley fill are present in the area and can be identified from DEM and ESRI base-map (Figs. 6a, b). Weathering and erosion process create denudational hills, which reduce to infiltration of surface water [19,22]. Valley fill is developed due to the deposition of transported and weather materials, which mostly belongs to the Holocene and Late Pleistocene age (Figs. 5 and 6). The valleys are considered as having a very high groundwater potential as they are porous rock (conglomerates, sandstone, and siltstone) and have high infiltration. Linear ridges and residual hills are considered very low groundwater sources and have low infiltration due to high slopes and elevated areas particularly in the south (Figs. 6b, 7a).

Drainage area depends on the surface characteristics, topography, and slope (Fig. 7a). The Bande-e Amir River flows from the Sholgara District. This river is mostly seasonal and flows from south to north. Many pounds, springs, and small reservoirs are present in the depressed parts of the low topography. In some areas, a few wide-lined Kariz (canal networks) are dug for irrigation purposes.

5.2.3. Slope

From a hydrogeological point of view, the study area is located in the developed zone of seamed basins containing waters related to the northern slope of the western Hindu Kush. The slope of the study area has outstanding effects on the infiltration of surface water from the surface to the underground (Fig. 7). If the area has a low slope, the amount of infiltration of surface water will be in great amounts. Also, the precipitation has more time to remain on the earth's surface and penetrate the underground. If the ground has more slope, then the run-off is more rapid and greatly reduces the recharging potential of the groundwater. As the slope of an area greatly depends on the elevation, therefore it is good to know the topography of the area.

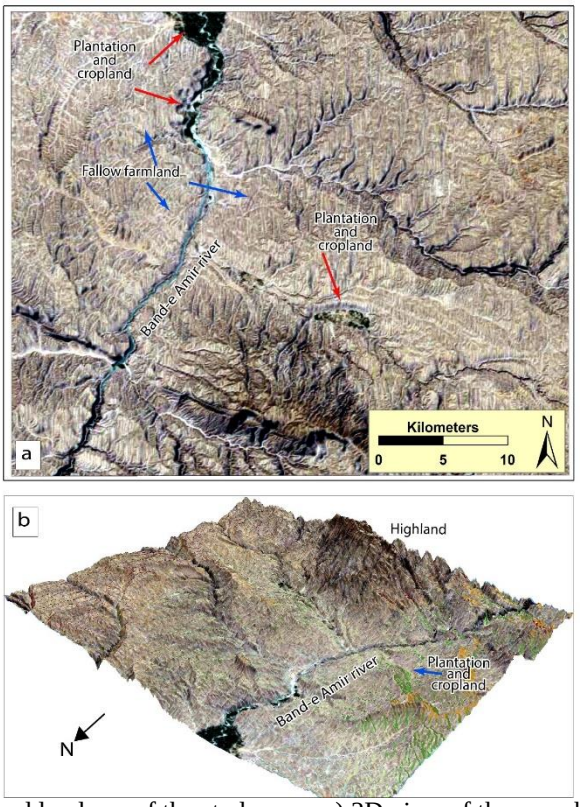


Figure 6. Geomorphology and land use of the study area. a) 2D view of the area. b) 3D view of the area. The satellite image is modified from the ESRI base map.

The highest elevation of the study is approximately 1800 m and the lowest is 575 meters above sea level. The ground surface slopes toward the river (Figs. 6b, 7a). For determining the slope, we used SRTM 1-arcsecond DEM. The slope of the area varies from 1^{o} to 73,6 degrees. Most of the region has a slope from 5.1^{o} - 20^{o} (Fig. 7b). The east and west areas have slopes ranging from 6 – 15 degrees. For the assessment of underground water, the area is classified into three zones based on the slope. A higher slope of 20^{o} - 73.6^{o} is giving a low rank of infiltration rate as well as accumulation [19,23]. The area with a slope of 0-5 has a higher rank as it increases the infiltration rate (Fig. 7b).

5.3. Geophysical survey

The geophysical survey helps us in determining the location and condition of groundwater in the study area. To achieve this goal, the electrical resistivity method was used. The method to obtain geophysical information is Vertical Electrical Sounding (VES) survey in the Qezel Kand village, Sholgara District (Figs. 1, 8). In this method, artificially-generated electric currents are transmitted into the ground and the resulting potential differences are measured at the surface. The resistivity of rocks is defined as the resistance in ohms between the opposite faces of a unit cube of the material [24]. Resistivity is one of the most variables of the physical properties of materials and rocks. Certain types of rocks and minerals conduct electricity through the passage of electrons, while most types

of minerals are insulators. On the other hand, the electrical current is carried through rocks/rock mainly by the passage of ions in pore waters. Thus, most rocks conduct electricity by electrolytic rather than electronic processes.

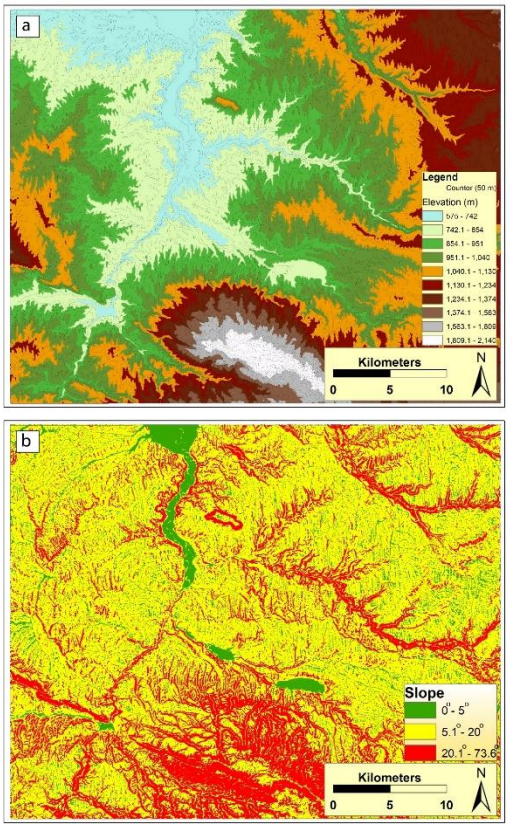


Figure 7. Geomorphic features. a) Topography of the study area. b) Slope characteristics

Many configurations of electrodes have been designed and are occasionally employed in specialized surveys. Here, the Schlumberger configuration method was used. In the Schlumberger configuration, potential electrodes have spaces which is a small proportion of that of the outer current electrodes. In Vertical Electrical Sounding surveys, the potential electrodes remain fixed and the current electrodes are expanded symmetrically about the center of the spread [24]. With a very large area, it is necessary to increase also the distance between current electrodes to maintain a measurable potential.

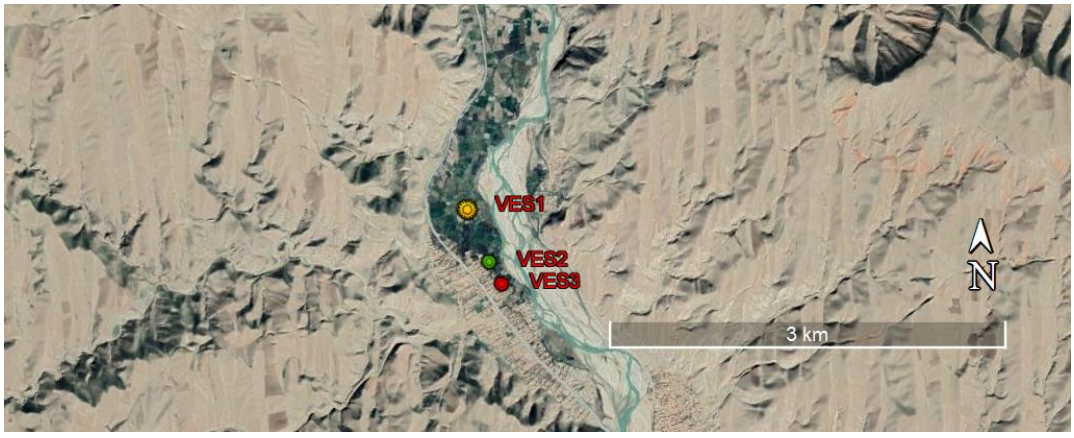


Figure 8: Location of electrical vertical sounding profiles on top of the google earth image in Qazel Kand village, Sholgara District (location of the geophysical survey is shown in figure 1).

The Schlumberger method was also used by introducing an electrical current into the ground from DC (direct current) or low-frequency sources by two electrodes (P1 and P2). The potential difference between a second pair of electrodes (C1 and C2) was measured (Fig. 9). This Schlumberger configuration is characterized by following up the vertical variations in the subsurface layers in each VES, together with horizontal variations through compiling and correlating the measured VES's along geoelectrical profiling [25].

During the process, first, we measure I_{P1P2} and Δu_{C1C2} for short distances P1P2/2, and later for long distances P1P2/2. Then the potential difference is calculated as follows:

$$\Delta u = I\rho C1C2/\Pi P1C1P1C2$$

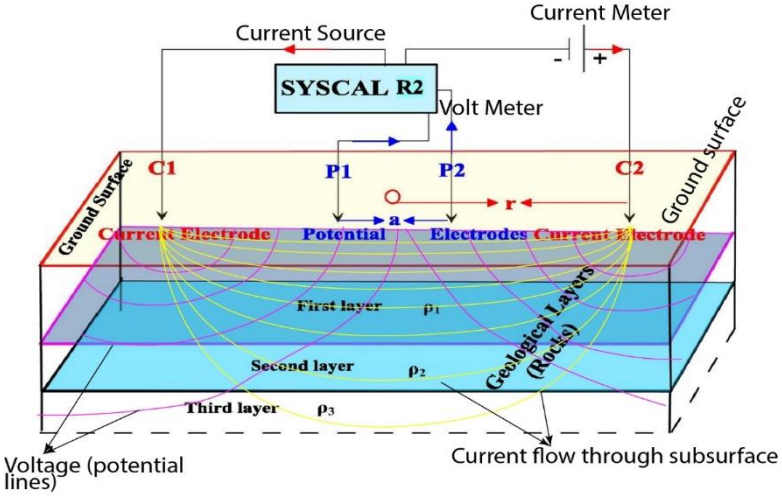


Figure 9: Schlumberger configuration for Vertical Electrical Sounding (VES) measurements. The figure is modified from [25]

From the above formula, calculate the specific electrical resistance as follow:
Here: ρ - apparent is electrical resistance, K- is the geophysical factor or coefficient of the device, Δu- is the potential difference between P1 and P2 electrodes, and the current intensity. Potential difference measure in millivolts (mV), current intensity in milliamperes (mA), and apparent electrical resistance in ohmmeters [25,26]. The values of apparent electrical resistance of water and some rocks are as follows: (Fig. 10):

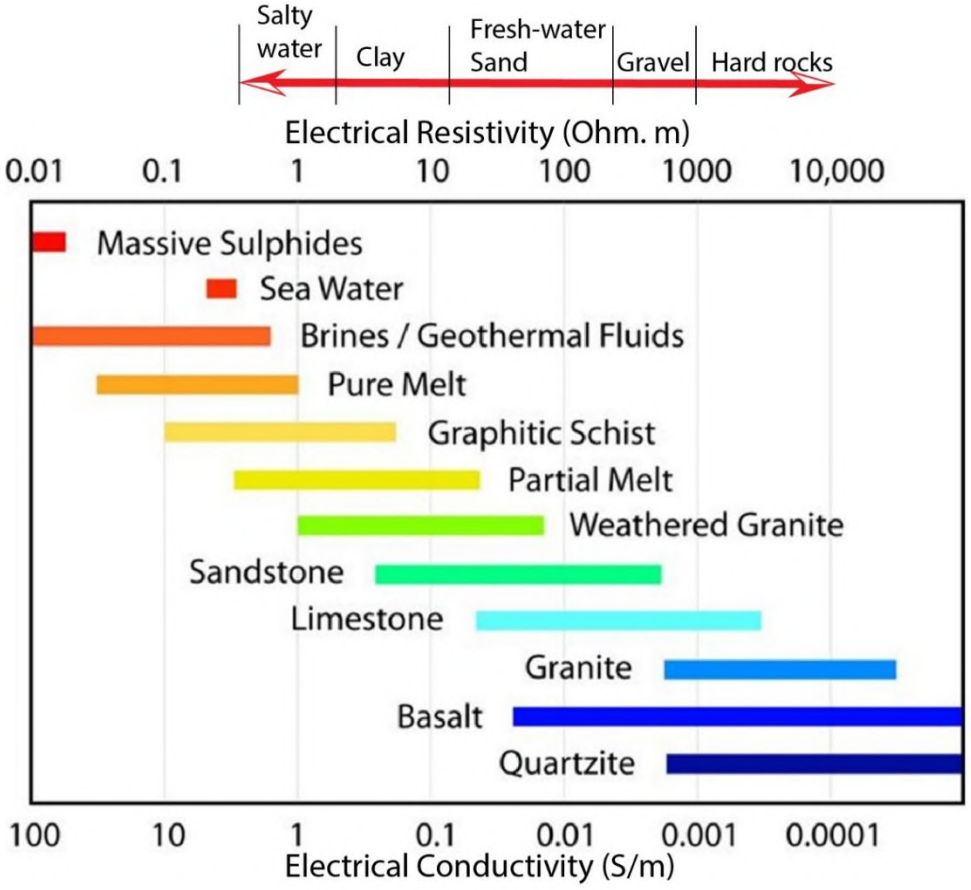


Figure 10: The electrical conductivity and resistivity values of water and different rock types. Ranges of values are shown as bars. Blue color shows high conductivity and low resistivity and red color shows high resistivity and low conductivity. The figure is modified from [27].

The value geophysical survey of vertical electric sounding (VES) conducted in Qazel Kand village such as absolute height, position, and length of vertical electrical sounding (VES) are listed in the tables 2 .

Table 2: Position and length of vertical electrical sounding

No	Location	Vertical Electric Sounding No.	Lat.	Lon.	VES Length (m)	Elev. (asl)
1	Qazel Kand village	1	66.89246	36.231613	600	-
2	-//-	2	66.89153	36.23494	600	648
3	-//-	3	66.89317	36.234443	600	643

Field data are measured by a Syscal Pro resistivity meter and their values are listed below (tables 3-5).

Table 3: Vertical Electrical Sounding values along the geophysical profile Number-1.

Distance between Current electrodes C1C2/2 (m)	Distance between Receiving electrodes P1P2/2 (m)	Apparent electrical resistance ρ_k (Ohm.m)	Potential differences Vp (mV)	Intensity of electric current in (mA)	Device coefficient K (m)
1	1	83.4769	1389.589	39.119	2.35
2	1	55.4316	158.276	33.693	11.8
3	1	55.007	93.498	46.743	27.5
4	1	57.1318	54.666	47.358	49.5
5	1	59.6179	18.678	24.343	77.7
6	1	61.82028	19.294	34.955	112
8	1	67.1214	9.396	27.997	200
10	1	72.4564	9.411	40.654	313
15	1	94.715	2.858	21.265	705
15	10	86.0596	29.134	21.262	1250
20	10	115.25	41.223	42.203	1960
20	1	123.47	4.168	42.194	62.8
25	1	142.95	2.679	36.732	118
25	10	135.77	26.434	36.601	188
30	10	157.35	14.274	24.946	275
35	10	176.55	16.021	34.209	377
40	10	196.117	25.353	63.991	495
50	10	230.73	9.64	32.588	780
60	10	259.1	2.886	12.475	1120
70	10	293.74	2.564	13.355	1530
80	10	332.68	2.464	14.813	2000
80	60	263.099	13.493	14.77	3130
100	60	296.102	16.866	27.056	4900
100	10	363.42	3.187	27.448	288
125	10	419.083	1.137	13.294	475
125	60	350.66	5.994	13.164	770
150	60	390.996	2.865	8.28	1130

175	60	415.21	3.186	11.97	1560
200	60	426.74	3.903	18.658	2040
250	60	446.231	1.573	11.386	3230
300	60	430.07	1.033	11.193	4660

Table 4: Vertical Electrical Sounding data along the geophysical profile Number-2.

Distance between Current electrodes C1C2/2 (m)	**Distance between Receiving electrodes P1P2/2 (m)**	**Apparent electrical resistance ρ_k (ohm.m)**	**Potential difference Vp (mV)**	**The intensity of electric current in (mA)**	**Device coefficient K(m)**
1	1	304.455	623.939	4.816	2.35
2	1	222.443	156.257	8.289	11.8
3	1	146.611	17.604	3.302	27.5
4	1	108.6682	11.251	5.125	49.5
5	1	84.34576	6.365	5.242	77.7
6	1	87.148.3	7.806	10.032	112
8	1	85.37498	9.13	21.388	200
10	1	95.22	3.65	11.998	313
15	1	112.101	6.234	39.204	705
15	10	109.48	68.346	39.203	1250
20	10	135.907	16.644	14.451	1960
20	1	135.011	4.813	44.561	62.8
25	1	156.27	2.825	35.431	118
25	10	158.024	29.886	35.555	188
30	10	179.0258	5.486	8.427	275
35	10	195.318	9.081	17.528	377
40	10	206.8685	3.317	7.937	495
50	10	231.576	6.746	22.722	780
60	10	245.929	1.893	8.621	1120
70	10	263.235	3.303	19.198	1530
80	10	264.8	3.789	28.617	2000
80	60	247.83	24.966	29.012	3130
100	60	230.07	42.276	87.282	4900
100	10	241.05	6.696	86.945	288
125	10	236.531	3.23	66.913	475
125	60	227.71	20.024	20.024	770
150	60	225.67	6.89	34.5	1130
175	60	254.529	4.412	27.041	1560
200	60	273.91	3.796	28.271	2040
250	60	236.55	3.882	53.006	3230
300	60	250.95	15.283	283.792	4660

Table 5: Vertical Electrical Sounding value along the geophysical profile Number-3.

Distance between Current electrodes C1C2/2 (m)	Distance between Receiving electrodes P1P2/2 (m)	Apparent electrical resistance ρ_k (ohm/m))	Potential difference Vp (mV)	The intensity of electric current in (mA)	Device coefficient K (m)
1	1	201.45	4843.389	56.498	2.35
2	1	240.34	1114.223	54.704	11.8
3	1	233.17	438.505	51.715	27.5
4	1	156.89	121.357	38.288	49.5
5	1	112.45	58.204	40.215	77.7
6	1	86.159	39.555	51.418	112
8	1	64.011	13.973	43.658	200
10	1	59.379	5.694	30.014	313
15	1	83.918	0.985	8.275	705
15	10	83.915	8.465	6.335	1250
20	10	118.369	7.685	7.661	1960
20	1	112.898	0.695	7.695	62.8
25	1	138.68	1.054	14.896	118
25	10	145.97	11.466	14.767	188
30	10	168.64	10.822	17.647	275
35	10	191.32	10.019	19.742	377
40	10	216.91	5.78	13.19	495
50	10	256.01	6.861	20.903	780
60	10	300.714	3.524	13.125	1120
70	10	327.898	0.394	1.843	1530
80	10	368.968	1.296	7.025	2000
80	60	351.969	8.831	7.226	3130
100	60	416.069	15.914	18.168	4900
100	10	424.06	2.457	18.135	288
125	10	443.1153	2.981	30.874	475
125	60	472.8989	9.754	15.882	770
150	60	488.59	21.731	50.258	1130
175	60	504.696	26.757	82.705	1560
200	60	484.6	4.331	18.232	2040
250	60	441.739	4	29.248	3230
300	60	357.05	6.052	78.987	4660

5.3.1. Geophysical Data Interpretation

The graphic interpretation of Vertical Electrical Sounding (VES) is shown in figures 11-13. Field data of the Vertical Electrical Sounding (VES-1, 2, 3) is interpreted with the win IPI2 software. Boundaries, thickness, and depth of rock layers are measured and calculated according to the apparent strength of the rocks. Thus the lithology of

underground layers was determined. Apparent electrical resistance is determined on VES-1, VES-2, and VES-3 as shown in (tables 3, 4, and 5). The specific electrical resistivity evaluates the special image of the underground structure in the study area. With the increase in porosity and water content in the underground layer, there is a change in the specific resistance figures that leads us to detect and identify waterlogged strata. During this research work, the specific resistivity is always measured by giving current through the electrodes (C1C2) and measuring the potential difference between the potential electrodes (P1P2) (Fig. 9).

The VES-1 shows five different layers (table 3; Fig. 11). Apparent resistivity of the first layer is 133 ohmmeters. This layer is located at the shallow surface from the ground (0.5 m) with a thickness of 0.5 m. The expected lithology of this layer mostly contains clay with sand and gravel. The second layer has dry sand and gravel, which have apparent resistivity of 16.3 ohmmeters. At the depth of 0.676 m, the thickness of this layer is 0.18 m. Layer three has 58 ohmmeters of apparent resistivity. The boundary of this layer is from 0.17 to 7.403 m. The computed apparent resistivity of layer four is 529 ohmmeters. Layer five is unknown due to no data afterward. Based on the electrical resistivity of the various earth materials (Fig. 9), the lithology of this layer seems to be carbonate stones. As the computed apparent resistivity graph goes up, therefore we cannot identify the thickness, depth for layers 4 and 5, and expected lithology of layer 5 (Fig. 11).

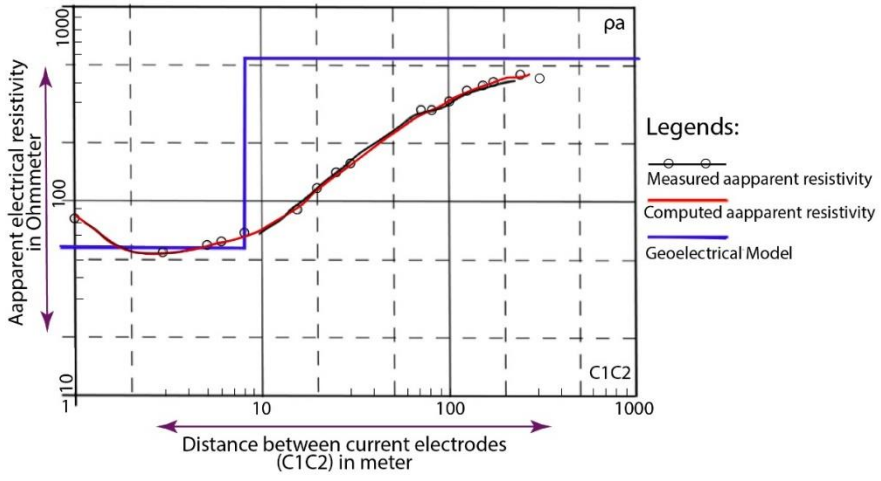


Figure 11: Graphic Interpretation of Vertical Electrical Sounding (VES-1) of table 3.

The VES-2 data shows about five layers having different resistivity, thickness, and depth. The expected lithology of each of these layers is different from the others. From surface to depth, the apparent electrical resistivity of the first layer is 327 ohmmeters. The depth of this layer is 1.27 m with the expected lithology of gravel, sand, and clay. The apparent resistivity of the second layer is 28.9 ohmmeters. With decreasing the apparent electrical resistivity, the electrical conductivity is getting increased, which seems to have wet clay with sand and gravel. The depth of this layer is 2.09 m with 0.86 m thickness. The third layer is located at the depth of 12.2 m with a thickness of ~10 m. The resistivity of this layer is 90 ohmmeters. This layer seems to have the potential of

groundwater. In this regard, we can say that the water table is located at the depth of approximately 90 m. While the two the depth the apparent electrical resistivity is getting increased. For example, the fourth layer has apparent resistivity of 531 ohmmeters, while the rest of the layers are unknown due to raising the measured and computed apparent resistivity graphs with no data (Fig. 12).

VIS-3 graphical interpretation shows five distinct layers. The apparent resistance of the first layer is 200 ohmmeters with a depth of 1 m. The expected lithology of this layer is dried clay with some sand, silt, and gravel. The second layer has a depth of 1.8 m with a thickness of 0.8 m. The apparent resistivity of this layer is 412 ohmmeters, which seems to have carbonate rocks such as limestone and marl. These rocks have no primary porosity but can form fractures inside the rocks as secondary porosity, where water occurrence can be taken place. The third layer has a depth of 4 m, with a thickness of 2.8 m. This layer has very low resistivity and seems to have some water.

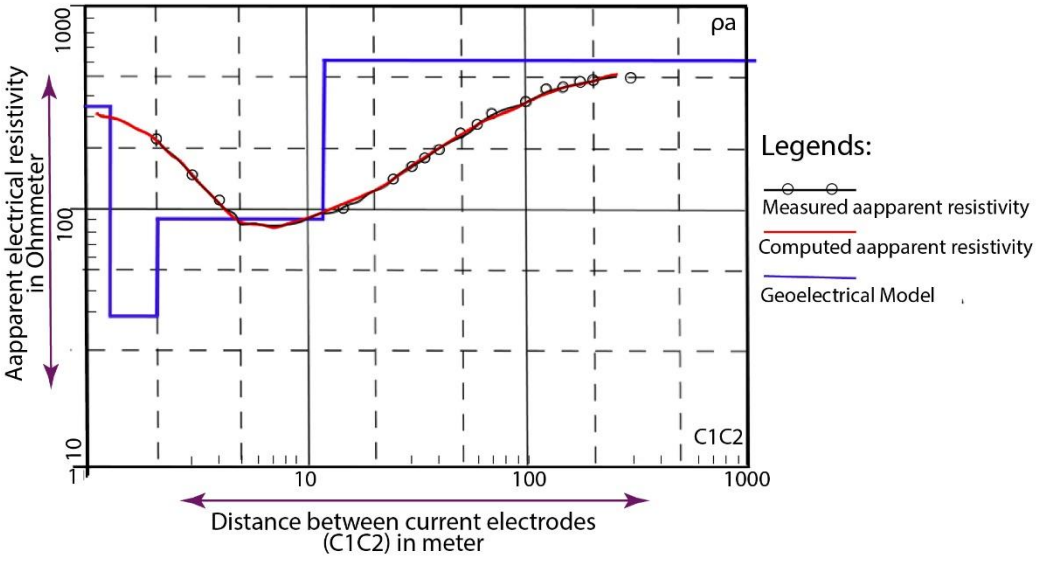


Figure 12: Graphic Interpretation of Vertical Electrical Sounding (VES-2) (table 4).

The expected lithology of this layer is clay with sand and silt. Again for the rest of the layer resistivity is getting increased, while we do not have VES-3 data to imagine the boundary and depth of the layers (Fig. 13; table 5).

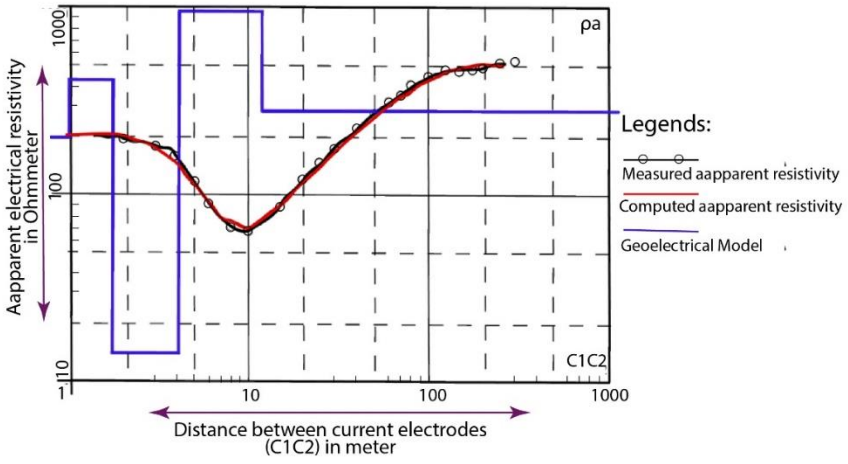


Figure 13: Graphic Interpretation of Vertical Electrical Sounding (VES-3)

Generally, after joining the three VES (VES-1, VES-2, and VES-3) data, the graphical interpretation of the Qazel Kand village, Sholgara District shows that the water accumulation is in carbonate rocks. These rocks have secondary fractures and can accumulate a large amount of groundwater and make a big reservoir. The secondary porosity in carbonate rocks (limestone and dolomite) can be formed by freshwater dissolution or dissolution by chemically aggressive subsurface fluid in the deep-burial environment. Also, the figures show that the water table depth ranges from 80 to 100 m in the study area. The water could be very clean and feasible for drinking.

This research is not enough in the study area. To better understand the area's geology, geomorphology, and physical properties, detailed fieldwork is needed to be done in the area. It is highly suggested to use high-resolution satellite images and increase the number of VESs in different parts of the study area, which can allow us to get more information about the thickness, depth, and lithology of the undersurface layer. To confirm the results of the geologic, geomorphic, and electric methods, it is necessary to drill several exploratory wells at least 120 m depth. It is also strongly recommended to take groundwater samples and analyze them quantitatively and qualitatively in a laboratory to know about groundwater contaminations.

6. Conclusion

Geological, geomorphological, and geophysical investigations provide a full description of the surface and underground. Satellite imagery examines landforms and hydrogeology in a remote area. As this method is reliable and cheap, and it gives the best result in detecting geomorphic features in Sholgara District. Geological maps and satellite images were used to prepare geomorphological and thematic maps. Geologically, Pre-Paleozoic, Paleozoic, Mesozoic, and Cainozoic rock form the structure of the north Afghan platform. Geophysical researches show that the central and northern side of the north Afghan platform (the Amu Darya and Afghan-Tajik Basins) consists of sedimentary rocks which gradually decrease their thickness toward the south and east. The Amu Darya and Afghan-Tajik Basins separate the northern Afghan platform from the Turan platform

of southern Eurasia. The landscape is tectonically active due to vertical and horizontal crustal blocks motion, and deposition and erosion process.

From the surface geological formation, the Holocene and late Pleistocene deposits have high porosity and seem to be a good source of groundwater. The Paleocene and late Cretaceous are hard rocks and mostly located in high elevation. The dependence on groundwater is determined by the land used in an area. The areas located close to the riverside or at a low elevation above sea level, have crops that spend more water. Thus, the cropping pattern depends on the availability of water resources and climatic conditions. On the other hand, the drainage of water depends on the characteristics, topography, and slope. The area with a slope of 5 degrees has a higher rate of infiltration. The valley developed due to the deposition of transported and weather rocks throughout the Holocene and Late Pleistocene times, which have high groundwater potential as having high porosity.

The geophysical survey helped us to determine the location and condition of groundwater in the Qazel Kand Village, Sholgara District. Boundaries, thickness, and depth of underlying layers were measured depending on the rock's apparent resistivity. Then the lithology was determined. Generally, based on the Vertical Electrical Sounding data five different layers are identified. From the surface to 15 m depth, the first 3 layers are located. The graphical interpretation shows that the water table ranges from 50 to 100 m in depth. The water mostly takes place in the karst aquifer with lithology of limestone and marl.

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References

[1] Shnizai, Z. and Iqbal, A.R. (2021) 'Physico-Chemical Properties of Groundwater In The Kabul Basin, Afghanistan', KPU INTERNATIONAL JOURNAL OF ENGINEERING & TECHNOLOGY, 1(1), pp. 61–79. , Saffi, M.H. (2011) Groundwater natural resources and quality concern in Kabul Basin, Afghanistan, Kabul: Afghanistan.

[2] Saffi, M.H. and Jawid, A. (2014) Geophysical Survey in Qezel Kand village, Sholgara District of Balkh Province.

[3] Brookfield, M.E. and Hashmat, A. (2001) 'The geology and petroleum potential of the North Afghan platform and adjacent areas (northern Afghanistan, with parts of southern Turkmenistan, Uzbekistan, and Tajikistan)', Earth-Science Reviews, 55(1–2), pp. 41–71. Available at: https://doi.org/10.1016/S0012-8252(01)00036

[4] Kingston, J. and Clarke, J.W. (1995) 'Petroleum geology and resources of Afghanistan', International Geology Review, 37, pp. 111–127.

[5] Ulmishek, G.F. (2004) 'Petroleum geology and resources of the Amu-Darya Basin, Turkmenistan, Uzbekistan, Afghanistan, and Iran', U.S.

[6] Klett, B.T.R., et al. (2006) 'Assessment of Undiscovered Technically Recoverable Conventional Petroleum Resources of Northern Afghanistan'.

[7] Orudzheva, D.S. and Kornenko, G.Y. (1991) 'South Tadzhik depression', Petroleum Geology, 25(7/8), pp. 263–268.

[8] Sborshchikov, M.I. and Et, A. (1973) 'Geology and Minerals of Northern Afghanistan', Department of Geology and Mineral Survey [Preprint].

[9] Bratash, V.I. et al. (1970) 'Geologiya i neftegazonosnost severa Afghanistana Vsesyuznyi Nauchno-issledovatelskii Geolorazvedochnyii Neftiyanoi Trudy', Nedra, Moskva, 80, p. 106.

[10] Abdullah, S. and Chmyriov, V.M. (1977) 'Geologiya I poleznye iskopaemye Afganistana, Kniga 1', Nedra, Geologiy. Moscow [Preprint], (535).

[11] Abdullah, S., Chmyriov, V.M. and Dronov, V.I. (2008) Geology and Mineral Resources of Afghanistan. London: British Geological Survey.

[12] Shnizai, Z., Matsushi, Y. and Tsutsumi, H. (2020) 'Late Pleistocene slip rate of the Chaman fault based on 10Be exposure dating of offset geomorphic surfaces near Kabul, Afghanistan', Tectonophysics, 795, pp. 1–14. Available at: https://doi.org/10.1016/j.tecto.2020.228593.

[13] Doebrich, J.L. et al. (2006) 'Geologic and Mineral Resource Map of Afghanistan. 1:850,000', U.S. Geological Survey, No.2006-10. Available at: https://doi.org/https://doi.org/10.3133/ofr20061038.

[14] Iqbal, A.R. and Shnizai, Z. (2014) 'Interpretation and Analyzing of Vertical Electrical Sounding (VES) Data, in Kochi-abad Village, Bagrami District, Kabul Afghanistan', Journal of Science and Technology, Kabul Polytechnic University, 52(64).

[15] Shnizai, Z. (2020a) Active Tectonics and Seismic Hazard Assessment of Afghanistan and Slip-rate Estimation of the Chaman Fault Based on Cosmogonic 10 Be Dating. Doshisha University. Available at: https://doi.org/10.14988/00027636.

[16] Shnizai, Z. (2020b) 'Mapping of active and presumed active faults in Afghanistan by interpretation of 1-arcsecond SRTM anaglyph images', Journal of Seismology [Preprint]. Available at: https://doi.org/10.1007/s10950-020-09933-4.

[17] Shnizai, Z. and Tsutsumi, H. (2020) 'Active Faults and Seismic Hazard in the Kabul Basin, Afghanistan', THE HARRIS SCIENCE REVIEW OF DOSHISHA UNIVERSITY, 61(2), pp. 96–107.

[18] Ruleman, C.A. et al. (2007) 'Map and Database of Probable and Possible Quaternary Faults in Afghanistan', U.S. Geological Survey. Open-File Report 2007-1103, (150), pp. 1–45. Available at: https://doi.org/10.3133/ofr20071103.

[19] Rajaveni, S.P., Brindha, K. and Elango, L. (2015) 'Geological and geomorphological controls on groundwater occurrence in a hard rock region', Applied Water Science [Preprint]. Available at: https://doi.org/10.1007/s13201-015-0327-6.

[20] Ndatuwong, L. and Yadav, G. (2014) 'Integration of hydrogeological factors for identification of groundwater potential zones using remote sensing and GIS techniques.', Journal Geosci Geomat, 2(1), pp. 11–16.

[21] Industries, M. of M. and (2008) Geological characteristics of oil-rich areas in northern Afghanistan, Ministry of Mines and Industries: Kabul, Afghanistan.

[22] Ramaiah, S.N. et al. (2012) 'Geomorphological mapping for identification of groundwater potential zones in hard rock areas using geo-spatial information—a case study in Malur Taluk, Kolar District, Karnataka, India.', Nat Environ Pollut Technol, 11(3), pp. 369–376.

[23] Bagyaraj, M. et al. (2013) 'Application of remote sensing and GIS analysis for identifying groundwater potential zone in parts of Kodaikanal Taluk, South India', Front Earth Sci, 7(1), pp. 65–75.

[24] Kearey, P., Brooks, M. and Hill, I. (2002) An Introduction to Geophysical Exploration. 3rd Editio. Blackwell Science.

[25] Helaly, A.S. (2017) 'Assessment of groundwater potentiality using geophysical techniques in Wadi Allaqi basin, Eastern Desert, Egypt – Case study', NRIAG Journal of Astronomy and Geophysics [Preprint]. Available at: https://doi.org/10.1016/j.nrjag.2017.09.003.

[26] Milsom, J. (2003) Field Geophysics (Resistivity Methods). Edited by 3rd. London: Willy.

[27] Comeau, M.J. (2015) Electrical Resistivity Structure of the Altiplano-Puna Magma Body and Volcan Uturuncu from Magnetotelluric Data. The University of Alberta. Available at: ttps://doi.org/10.13140/RG.2.2.10150.32329

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