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Groundwater Resources Assessment in Alluvial and Basement aquifers of Central Darfur State, Western Sudan

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Abstract

The study area represents Central Darfur state, that lies in western Sudan. The area is extremely suffering from shortage in water supply. The area is mainly covered by basement complexes, with steeply slope topography, hence the bulk of surface water lost due to surface runoff. The objectives of the current study are to investigate the geological units of the area acting as water bearing formations, to define aquifers parameters and to assess water levels fluctuations in different aquifer types. The methods applied for this study including, remote sensing, GIS and hydrogeological investigations, to assess the groundwater potentiality in the study area. The main geological units in the study area include the old Precambrian Basement Complex and Pleistocene to Recent Alluvial sediments. The width of alluvial aquifer ranges between 800m and 2400m, and it covers a total area of about 36,965 km^2, the thickness of these deposits ranges between 5 and 25 m. The groundwater showed continuous declination due to over-exploitation of the aquifers, while seasonal variation referred to annual aquifer's recharge and discharge. The transmissivity for the alluvial aquifers and basement rocks varies between 2.9 m^2/d to 33.4 m^2/d with average of 18.2 m^2/d and from 4.8 m^2/d to 20.4 m^2/d through the fracture's zones with average of 12 m^2/d. The specific yield ranges between 6% and 28% in alluvial deposits and between 1.1% to 4.0%.in basement rocks.

Key words: *Groundwater resources, sedimentary aquifer, aquifer parameters, water levels, Darfur region*

Introduction

Central Darfur state is located within arid to semi-arid zones that are characterized by low rates of rainfalls duration during the rainy season extended from June to September. Thus, the state is very vulnerable to drought (Barry and Chorley, 1992). It is mainly dependent on groundwater for water supply, consequently high-water demand and abstraction coupled with low average rainfall in some parts of the state. The area often experiences a drop-in groundwater levels in many IDP locations and other high population density areas particularly when the rainfall is poor (UNESCO/Flanders FUST Project, 2010). The issue of groundwater deterioration/depletion is drawing high attention, where groundwater is the main source of water supply in IDPs camps and host communities (UNEP, 2007). Central Darfur is located between latitudes; 10^o 30' to 15^o N and longitudes 21^o 54' to 25^o E (Fig. 1).

The area of the Central Darfur states is about 55,000 km^2. The total population of the state is estimated to be 553,515 people out of which over 320,487 people are internally displaced living in 26 camps, due to Darfur conflict erupted since 2003 (Brosché and Rothbart, 2012).

Objectives of the study

The e overall objective of the present study is to assess the groundwater potentiality of the alluvial and basement aquifers in the study area.

The specific objectives are:

1. To investigate the geological units of the area acting as water bearing formations.
2. To define aquifers parameters.
3. To assess water levels fluctuations in different aquifers types.

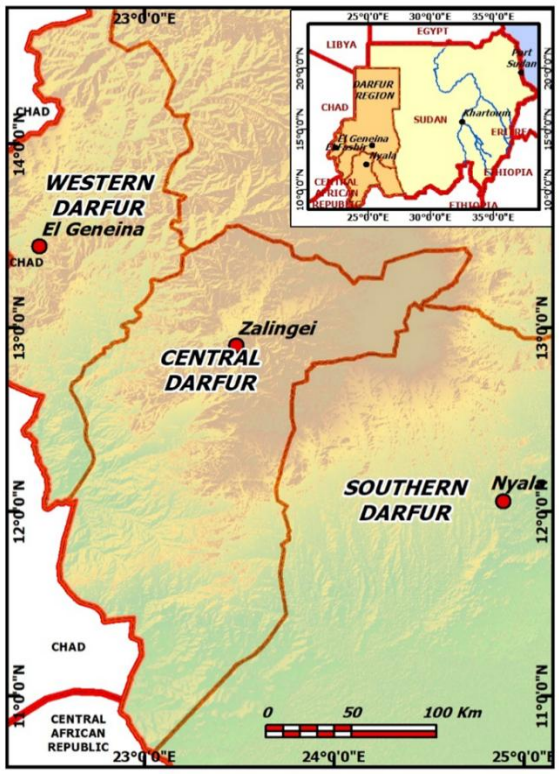

Fig. (1): Location map of the study area.

Methodology

In this study, various supporting remote sensing techniques was utilized for groundwater investigations which are Landsat 7 imageries (ETM+), Radar images and Shuttle Radar Topography Mission (SRTM) data. Their products such as color composite of bands 7, 4, 1 and Merge- Sultan band ratio with DEM image are used. The use of all data together gives very useful information as direct or indirect indicators for groundwater occurrences in the region.

Geological and hydrogeological survey field activities were carried out comprises geological and hydrogeological measurements to determine lithological units and groundwater availability in different rock units. Pumping tests were conducted to determine aquifers parameters, boreholes data and logger's data are regularly collected and measuring water table fluctuation. The geological survey was mainly based on the existed compiled geological map and the Landsat imageries in addition to the field survey conducted during this work. The purpose of the geological survey is to verify and authenticate the favorable structure and rock types that enhancing and controlling the occurrence and distribution of groundwater, GIS and remote sensing techniques are used for maps production and for the creation of database

Geological Setting

The geological setting of the study area is represented as alluvial deposits (Pleistocene to Recent) overlain the Basement Complex. The Basement Complex Rocks are the oldest formation, belong to Precambrian periods. It composed generally of two main rock groups; old poly metamorphosed group, composed of high and medium-to low-grade metamorphic rocks and post orogenic intrusions that represent 70% of the study area (Fig. 2).

The Wadi alluvial deposits represent a surface of 17,600 km², almost represent of about 13% of the total study area and play a major role in superficial groundwater distribution. They are found at the beds and along the banks of seasonal streams draining the study area. They are particularly broad, and their alluvium composed of loose aggregates representing the upper parts of the geologic formations through which the Wadi runs (Fig. 2).

Hydrogeological Investigations

The main water bearing rocks in the study area comprising the Alluvial deposits (Pleistocene to Recent), the weathered and fractured basement rocks (Precambrian).

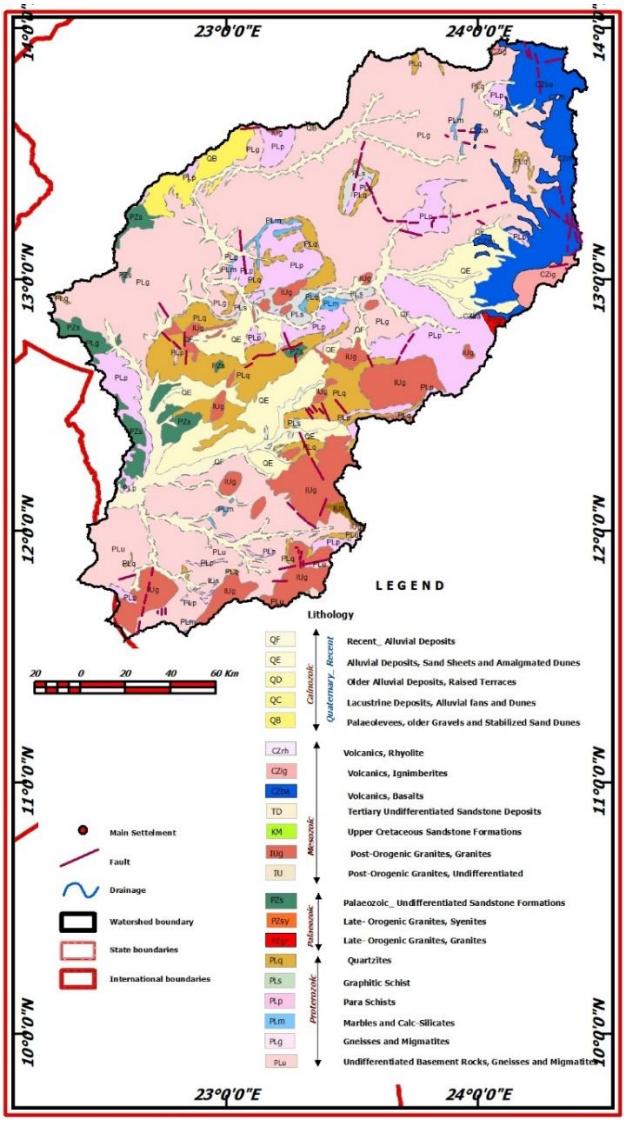

Fig. (2): Geological Map of Central Darfur-Rock Units (modified after GRAS, 2004).

Alluvial Aquifers

Wadi Azum and its tributaries are the main streams draining the western slopes of Jebel Marra from 2,600 m to 600 m. It drains an area of 36,965 km² and is collecting annually 23.9 billion cubic meters of water from June to September. The greatest part of the catchment area is very rugged and dominated by crystalline basement influenced by the basaltic slopes of Jebel Marra on the Northeast part of the catchment area as shown on the geologic map (Fig. 3).

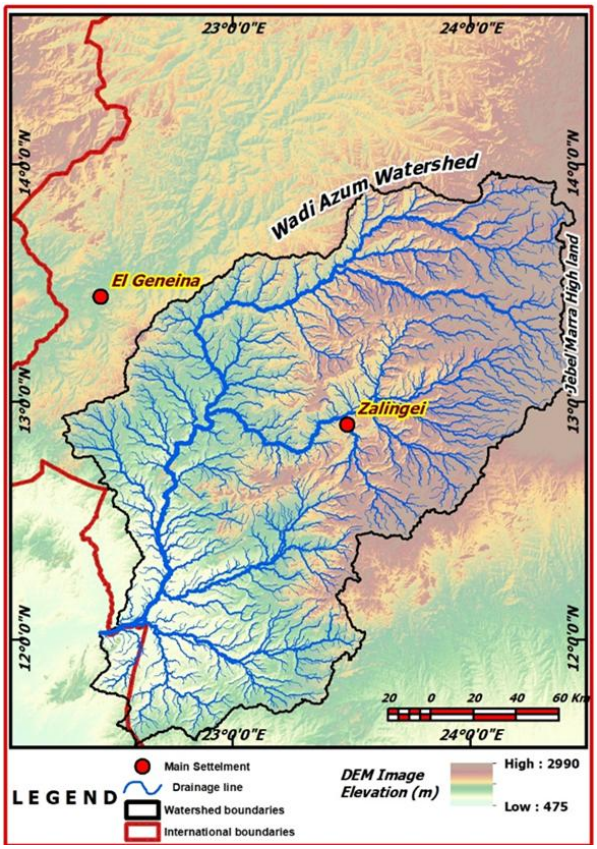

Fig. (3): Topographic and drainage map of the study area.

The thickness of the alluvial sediments range between 5 and 25 m. Wadi deposits consist of sequence of clayey or sandy layers of varying thicknesses. Wadi Azum is the most important hydrogeological alluvial aquifers in the study area. The hydraulic properties of the alluvial

deposits vary strongly from place to place in accordance to the presence of clayey and/or sandy layers, the highest permeability found in the sandy parts of the aquifer. The availability of water in alluvial deposits depends mainly on the potential recharge in the area. Pumping tests were carried out in some boreholes to obtain the hydraulic characteristics of the aquifer. (Fig. 4).

The purpose of the pumping test data is to estimate the hydraulic parameters of the aquifers such as transmissivity (T), hydraulic conductivity (K) and specific capacity (Sc), in addition to the amount of yielding and drawdown values (Table 1).

The obtained values of transmissivity for alluvial deposits approximately varies from 2.92 m^2/d to 33.38 m^2/d with average of 18.15m^2/d. The specific yield in alluvial aquifer ranges between 6% to 28%.

The Groundwater level fluctuations reflect the variation of the atmospheric pressure of the aquifer. The aquifer' water recharging and withdrawal are one of the most crucial factors that cause groundwater level fluctuations (Mandel and Shiftan, 1981).

Groundwater level in Wadi Azum alluvial aquifer which providing Zalingei town and surrounding IDPs camps with water supply requirements, showed clear stability during April, May, June and July, while showed clear raise in water table during August to October. After November it showed gentle continuous drop of water table, with the total drawdown of 1.6 m. The direct link of the aquifer to the annual precipitation and stream runoff is clearly observed. Despite the heavy daily water extractions, there is vast recovery indicating good recharge capacity of the aquifer.

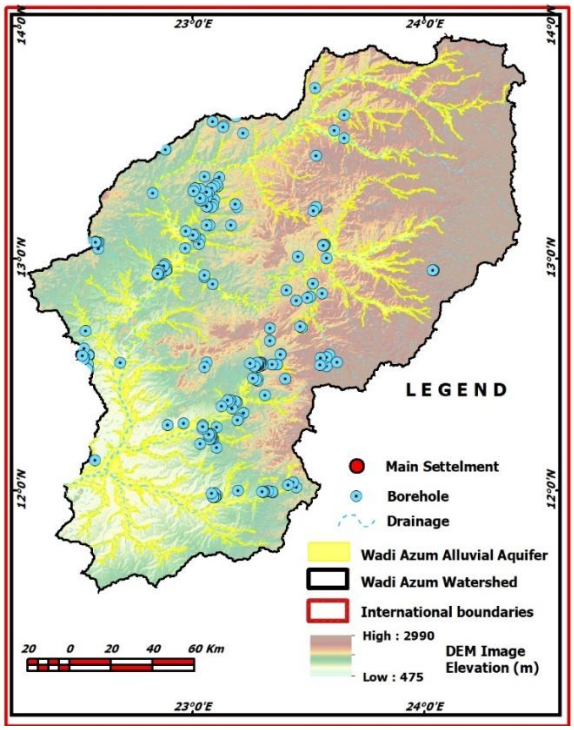

Fig. (4): Wadi Azum Alluvial and Basement Aquifer's Wells.

Table (1): Hydraulic parameters from pumping test data analysis for alluvial deposits.

Location	**Transmissivity (m^2/h)**	**Static water level (m)**	**Dynamic water level (m)**	**Max Drawdown(m)**	**Max Discharge m^3/h**	**Specific capacity**
Umshalaya	12.16×10^{-2}	3	18.7	15.7	13	0.83
Elsalam-Zalingei	13.91×10^{-1}	4.55	8.5	3.95	30	7.59
Taiba –Zalingei	41.62×10^{-2}	4.55	6.53	1.98	45	22.73
Nertiti	8.49×10^{-1}	5.4	14.1	8.7	16	
Eshbara	20.1×10^{-2}	3.5	19.64	16.4	18	

The groundwater levels in the alluvial deposits shows clear continuous drop after the rainy seasons, which indicate severe water lose as a result of seepage due to the high permeability of the alluvial formations (Fig. 5 and 6).

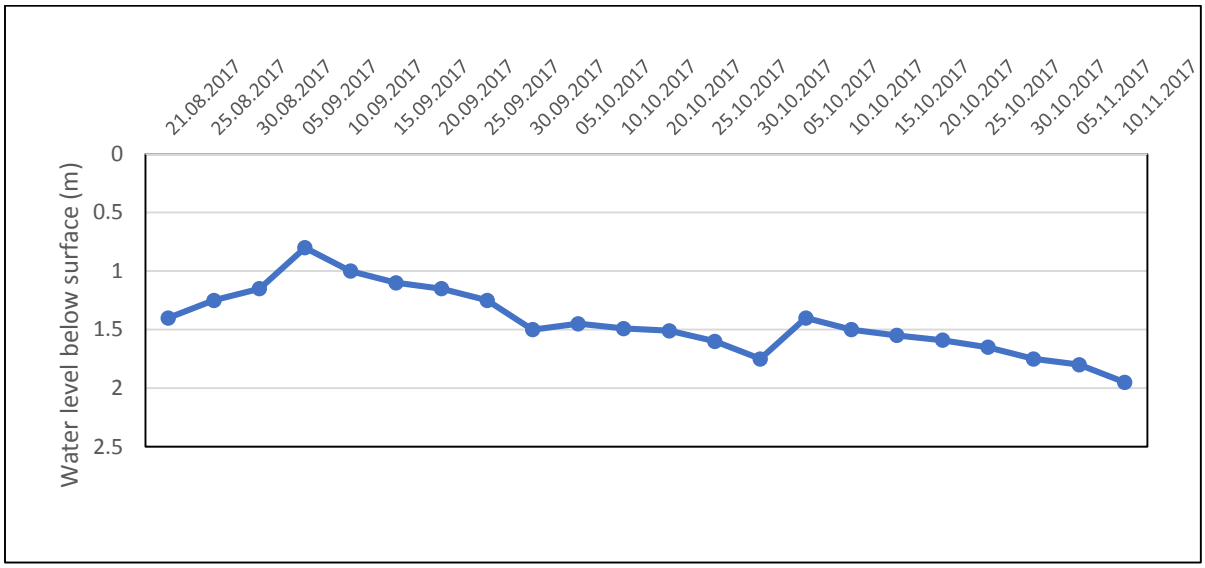

Fig. (5): Groundwater level fluctuations: Wadi Arebu- Khamsa Dagaieg camp Zalingei (Logger. 142, coordinates: 23.54811^{O}E and 12.90517^{O}N).

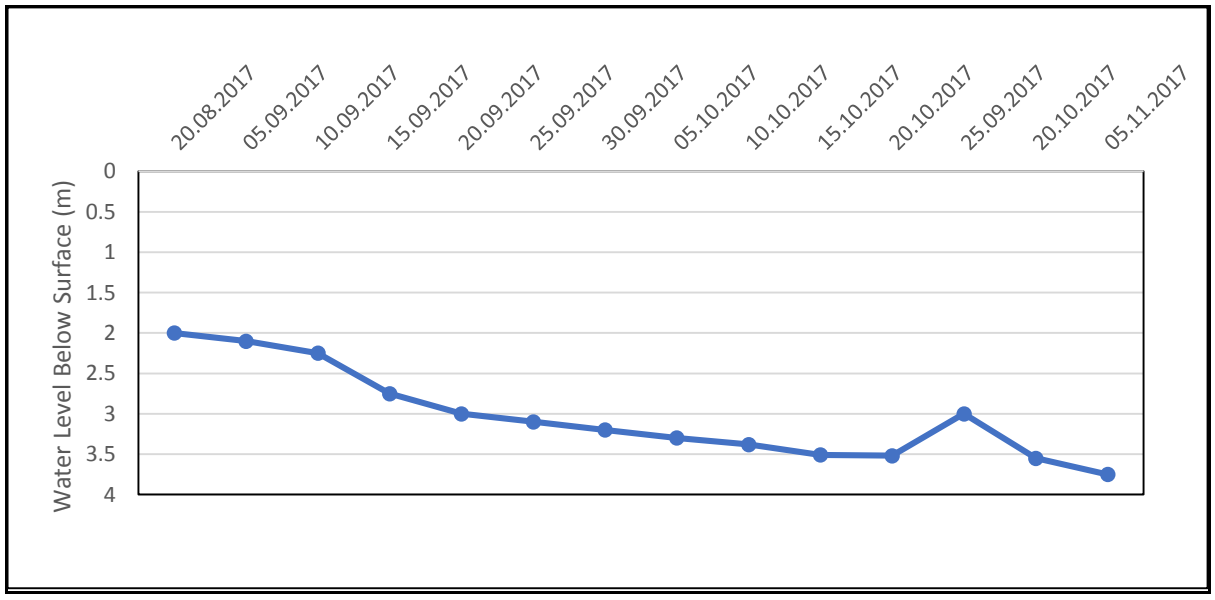

Fig. (6): Groundwater level fluctuations: Wadi Bary alluvial deposits at Mornei Camp (Logger 141, coordinates: 22.88750^{O}E and 12.95744^{O}N).).

Wadi Azum Groundwater flow direction is taking the same direction of Wadi Azum surface water direction and matching the general topography and general study area slop direction from Northeast to Southwest direction (Fig. 7)

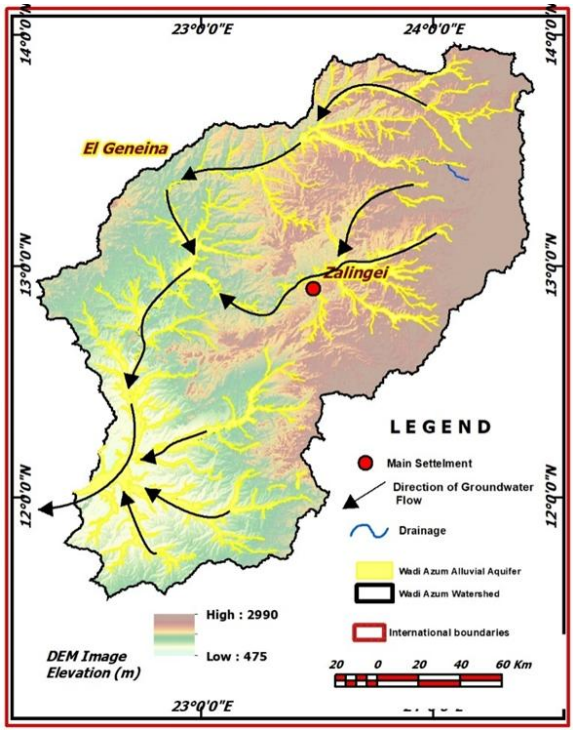

Fig. (7): The Groundwater Flow path through Wadi Azum Alluvial Aquifer.

Transmissivity for the weathered and fractured Basement complex range from 4.8 m^2/d to 20.4 m^2/d with approximately average of 12 m^2/d. The specific yields range between 1.1% to 4.0% (Table 2).

The groundwater levels in the study area were measured during the years (2007-2018) all through wet and dry seasons.

The measurement and collection of groundwater levels data are of fundamental importance signs in Hydrogeological investigations. Zalingei area was selected to monitor the interconnectivity of the basement fractures system. Continuous groundwater rise with the total of 0.8 m. was recorded from Aug. to Nov. (2017), which indicates good recharge capacities within the basement fracture systems (Fig. 8).

Table (2): Hydraulic parameters from pumping test data analysis for Basement Complex.

Location	**Transmissivity (m^3/d)**	**Static water level (m)**	**Dynamic water level (m)**	**Max drawdown (m)**	**Max Discharge m^3/h**	**Specific capacity**	**Storativity**
Baida	11.424	19.7	27.9	8.2	16	1.95	2.56×10^{6}
Habila	19.32	13.5	18.2	4.7	18	3.83	
Nertiti	20.376	5.4	14.1	8.7	16	1.84	3.29×10^{6}
Forbranga	2.398	3	6.5	3.5	14	4.00	4.27×10^{-8}
Eshbara	4.824	3.5	19.64	16.4	18	1.10	

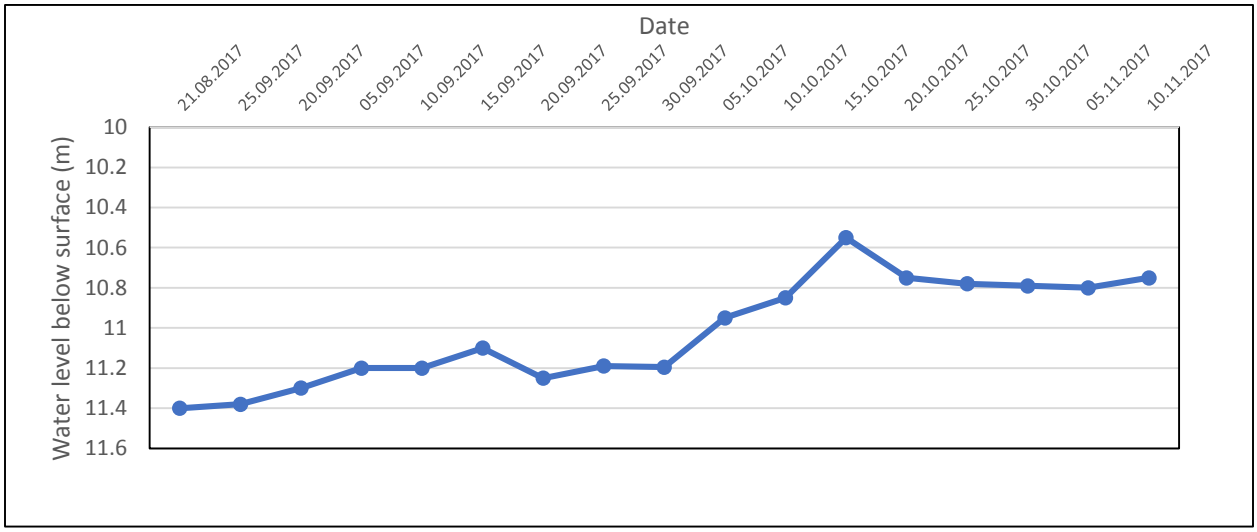

Figure 8. Groundwater level fluctuations, Hai Althawra-Zalingei (Logger 138 coordinates: 23.47856^{O}E and 12.90767^{O}N).).

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Conclusion

The study area lies in Central Darfur states, western Sudan. The population in the study area is about 553,515 people out of which over 320,487 people are internally displaced living in 26 camps. The area is characterized by arid to semi-arid climate with annual average rainfall around 590 mm. The main geological units are: Precambrian Basement Complex and Pleistocene to Recent Alluvial deposits. The Basement Complex Rocks are the oldest formation; belong to Precambrian periods. The alluvial aquifer covers a total area of 80,000 km^{2}approximately, their thickness ranges between 5 and 25 m.

The obtained transmissivity values for alluvial deposits varies between 2.92 m^2/d to 33.38 m^2/d with average of 18.15 m^2/d, while transmissivity for the weathered and fractured basement complex ranging from 18.15 m^2/d, from 4.8 m^2/d to 20.4 m^2/d with average of 12 m^2/d.

Groundwater level in Wadi Azum alluvial aquifer showed direct link of the groundwater situation to the annual precipitation and stream runoff in which the water table in alluvial aquifers are rises during and after the rainy seasons while a clear drop in water table was observed during the dry seasons (April – June).

Zalingei area was selected to monitor the interconnectivity of the basement fractures system. Continuous groundwater rise with the total of 0.8 m. was recorded from Aug. to Nov. 2017, which indicates good recharge capacities within the basement fracture systems.

Since 70% of the study area is covered by Basement complexes, which have limited groundwater, subsequently, to ensure sustaining water supply to Central Darfur populations, effective water resources development and management strategies should be considered to maintain storage of water through

construction of conservation works to ensure sustainable availability of water, besides, adopting uniform water strategy plan with the participation of all sector partners that includes water facilities sighting, design and control, evaluation of available water resources and limitation of sustainable safe water withdrawal.

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