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Geophysical Investigation of Anomalous Groundwater Seasonal Behaviour of a Well at Ayegbaju-Ekiti, Southwestern Nigeria

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ABSTRACT

Groundwater is the essential criterion for population driven growth and civilization of rural areas which is often accompanied by constructional activities of various type. Anomalous groundwater behaviour of a well at Ayegbaju-Ekiti has been studied with the use of 2D horizontal profiling and 1D vertical electrical sounding (VES) techniques of geophysical prospecting. Two traverses of 100 m length were established with progressive electrode spacings of 5 m, 10 m, 15 m, 20 m, and 25 m using Wenner array. Between station 20 and 30 on traverse 1, anomalous low resistivity (<111 Ωm) zone was observed at a depth up to 15 m. Five (5) VES sounding points were established on the traverses and A, HA, KH and HKH-type curves were identified. The geoelectric sections showed three (3) to five (5) lithologic layers which includes the topsoil, sandy clay, weathered/fractured basement and fresh basement. VES 1 and the well on the geoelectric section were both underlain by fractured basements which revealed that the well is rightly located within the study area. Correlation of 2-D resistivity structures with geoelectric sections revealed that the well is underlain by an aquifer system but abnormal seasonal variation in groundwater supply of the well could have been caused by the delayed recharge or block infiltration during peak rainy season by low resistivity zone which might be a thick column of clay. Borehole with full casing could be preferred instead of well in the study area at a location far from the clayey formation.

Keywords:
Clay expansion,
Electrode spacing,
Geoelectric sections,
Sounding points.
Wenner array.

INTRODUCTION

Importance of water cannot be undermined as it serves major purposes in domestics, industries, agriculture and even in reproductive systems of human's lives (Aranguren-Díaz et al., 2024; Mohammed et al., 2024; Li et al., 2025). Groundwater is one of the good determinants for population growth and healthy living (Olaseeni et al., 2022; Ibrahim et al., 2024; Ojo et al., 2025). Civilization is accompanied with constructional works of various styles which include industrialization and groundwater is germane (Ajayi & Hassan, 1990; Kure et al., 2017; Okereke & Edet, 2023). The major wellbeing of every developing town is good and available groundwater supply (Kumari et al., 2024; Muratoglu, & Wassar, 2025; Adetokunbo et al., 2025). Overdependence on the available groundwater can result into water shortage especially during dry season with inadequate recharge. Population driven growth is observed at Federal University Oye-Ekiti (FUOYE) necessitated by the accreditations of new academic programs and departments in the institution. Some of the staff of Federal University Oye-Ekiti prefer to build houses at Ayegbaju-Ekiti, a nearby town due to overflowing of students at every nook and cranny of Oye-Ekiti. A key issue that prompted this study is the observed irregularity in the performance of a well in the study area. The resident had reported that his well displayed a dynamic water flow, where as it provides sufficient water during the dry season, but fails to yield water during the rainy season. This phenomenon is counterintuitive, as it contradicts the normal expectation that groundwater recharge should increase during the rainy season due to the higher volume of rainfall and surface runoff infiltration. However, in this case, the wells either dry up or provide reduced water yields during the wet season. Meng (2021) established that groundwater flow is influence by several factors such as gravity, pressure, geology, topography among others. Adedokun et al. (2025), Adedokun & Sunmonu (2025) and Mamudua et al. (2025) worked on subsurface conditions for managing groundwater resources effectively which is crucial for sustainable development and improving the quality of life for communities, particularly in rural and semi-urban areas.

Geophysical methods have become indispensable tools in the exploration and evaluation of groundwater resources. Among these, the electrical resistivity method stands out due to its effectiveness in mapping subsurface lithology and identifying potential aquifer zones. This method is non-invasive, cost-effective, and provides valuable information about the subsurface, making it particularly suitable for groundwater exploration in diverse geological settings. The electrical resistivity method encompasses various techniques, notably Horizontal Profiling (HP) and Vertical Electrical Sounding (VES). Horizontal profiling helps in detecting lateral changes in subsurface materials. These techniques are useful for identifying fractures, faults, and other structural features that may influence groundwater flow. Delineation of aquifer units for groundwater development in Crystalline Basement are common practice among many researchers (Olaseeni et al., 2022; Ibrahim et al., 2024; Olaseeni et al., 2024; Ojo et al., 2025). Olaseeni et al. (2024) carried out groundwater study at Oye using electrical resistivity, aeromagnetic, and remote sensing methods to characterized FUOYE campus into high, moderate and low groundwater potential zones.

Vertical electrical sounding of Geophysical methods has been found effective in the search for formations or geological structures that can accumulate or store water because it is responsive to the subsurface materials fluid content (Lawal et al., 2023; Tabassum et al., 2024). Groundwater abstraction zones can be delineated by the electrical resistivity method which can be adopted in the Crystalline Basement for the delineation of fractured/weathered basement, which is associated with the weathering of the crystalline rock.

This study, therefore, seeks to investigate the subsurface lithologic information and nature of the aquifer of the well's underlying layers and also suggest an area for an optimum groundwater substantive yield in raining season using the electrical resistivity method.

Description and Geology of Study Area

The study site is located in Ayegbaju Ekiti, the closest neighbor of Oye-Ekiti, situated in the Oye Local Government Area of Ekiti State. It is on latitude 7º54'19.0''N to 7º54'20.9''N and longitude 8º62'83.9''E to 8º62'84.8''E (Figure 1). Accessibility to Ayegbaju Ekiti is facilitated by a network of regional roads connecting it to major towns and cities in Ekiti State and neighboring states. The site is accessible via the Ifaki–Ikole federal road. The study area is underlain by the Precambrian Basement Complex rocks of Southwestern Nigeria with the main lithology being migmatite gneiss (Figure 2).

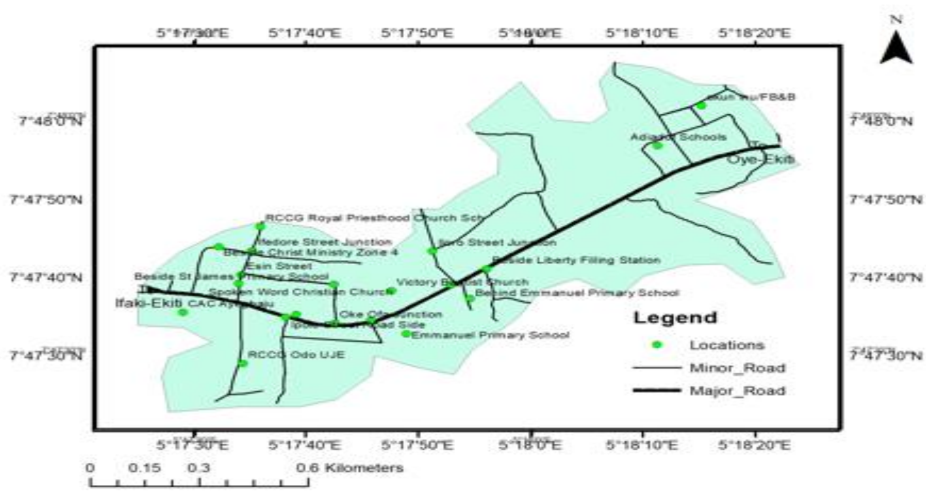

Figure 1: Base Map of the Study Area

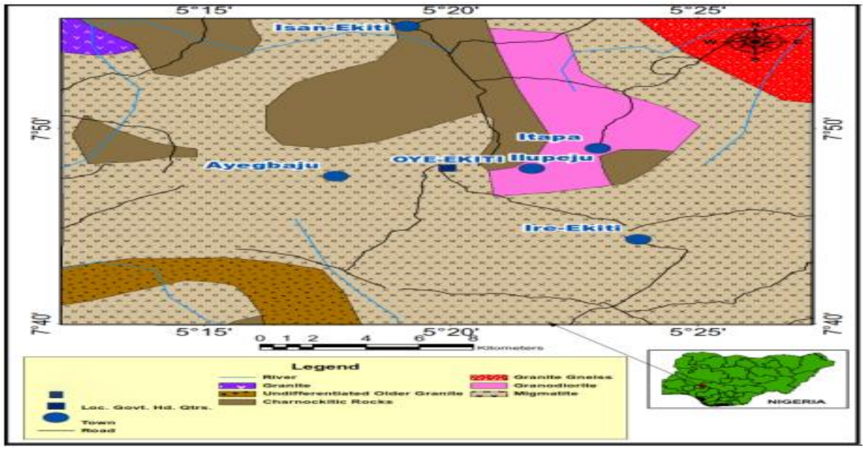

Figure 2: Geological Map of the Study Area (modified after Ademilua, 19

MATERIALS AND METHODS

Water-level monitoring for both wet and dry seasons were observed and the electrical resistivity method involving the Wenner profiling and the Vertical Electrical Sounding (VES) techniques were adopted for data acquisition in the study site.

The Ultra MiniRes resistivity meter was used for the data collection. Two traverse lines of 100 m in length each (north to south and west to east directions) were established within the study area while the Wenner array was employed to obtain horizontal resistivity data along the traverses. The array involves equal spacing between all four electrodes (current and potential), and data were acquired at progressive electrode spacings of 5 m, 10 m, 15 m, 20 m, and 25 m (Figure 3) and processed with Dipro version 4.0, processing and interpretation software for electrical resistivity data. Five Vertical Electrical Sounding (VES) points were carried out along the traverses to examine vertical variations in subsurface resistivity with depth. VES 3 was conducted at the 25 m station on traverse 1 and extended to a maximum current electrode separation of 100 meters. VES 1 was done at the 50 m and also extended to 100 meters of current electrode spread. VES 4, located at the 70 m station, had a maximum electrode spread of 65 m due to site constraints on traverse 1. VES 1 was conducted at the 25 m station on traverse 2. Traverse 1 and 2 have a common mid-point at VES 1, representing the position very close to the well. VES 2 was located at 50 m and VES 5 was established at 70 m on traverse two respectively.

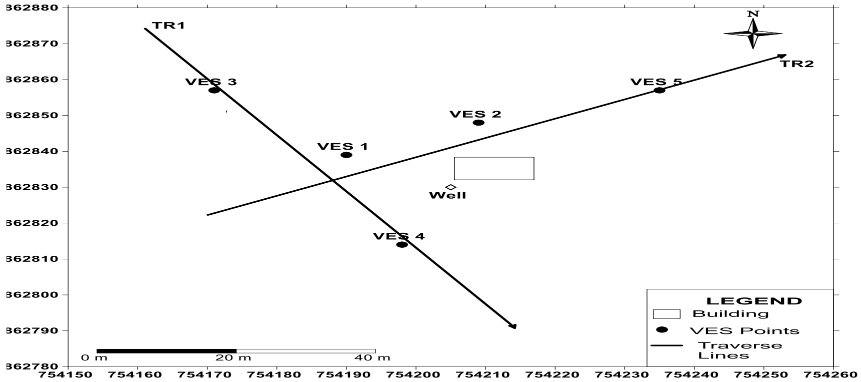

Figure 3: Data Acquisition Map of the Study Area

RESULTS AND DISCUSSION

The results of the study were presented as 2-D resistivity images, VES curves, table and geoelectric sections.

Depth Measurement Taken from the Well

The results of water table measurement taken in both dry season (December, 2024) and rainy/wet season (August, 2025) were documented as 6.4 m and 13.2 m respectively. Another water table measurements were taken both in January, 2026 (dry season) and July, 2026 (wet season) and the values were 7.0 m and 14.5 m respectively before drilling of borehole was recommended.

2-D Resistivity Structure Result along Traverse One

The well was measured during dry season VES 1 and the Well were observed on station 45 and 60 respectively on the 2-D resistivity structures along traverse 1 and both were underlain by fractured basement. This is an

indication of the presence of an aquifer system in the study area.
A low resistivity (<111 Ωm) zone which could have been a thick column of clay was observed between station 30 and 35 (Figure 4). The clay formation might have been responsible for the dynamic behaviour of the well.

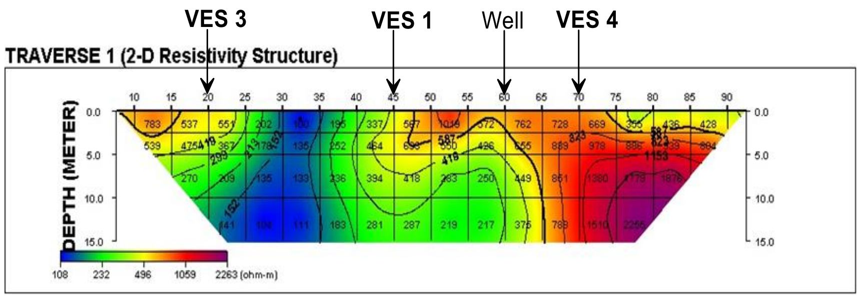

Figure 4: 2-D Resistivity Structure along Traverse One

2-D Resistivity Structure Result along Traverse Two
The first layer observed on the 2-D is observed to be a low resistivity zone of about 100 Ωm followed by a moderately resistive layer which could be a weathered layer (Figure 5). Weathered/fractured basement or basement depression was observed between station 20 and 50 and the well is located within the stations (station 35). The presence of a basement depression represents an aquiferous zone which could have resulted in a good water yield in the study area.

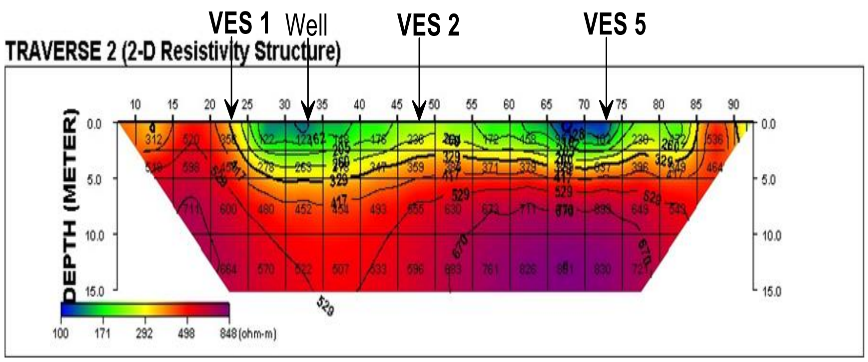

Figure 5: 2-D Resistivity Structure along Traverse Two

Vertical Electrical Sounding Results
The 2-D resistivity structure guided the choice of establishing five (5) VES on the two traverses (Figure 6). Three to five lithologic layers with A, HA, KH and HKH-type curves were established in the study area. HKH-type curve represents a groundwater abstraction zone where groundwater development is feasible. The VES results were presented on Table 1.

Table 1: Summary of VES Results

VES No.	Curve Types	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithological Equivalence
VES 1	HKH	453	0.9	0.9	Topsoil
		131	1.8	2.7	Sandy Clay
		1008	9.6	12.4	Lateritic Clay
		375	25.9	38.2	Weathered Layer
		744	--	--	Fractured Basement
VES 2	A	383	0.8	0.8	Topsoil
		497	21	21.8	Weathered Layer
		1576	--	--	Fresh Basement
VES 3	HA	783	1.1	1.1	Topsoil
		315	2.2	3.3	Weathered Layer
		335	11.4	14.7	Weathered Layer
		758	--	--	Fractured Basement
VES 4	KH	472	1.7	1.7	Topsoil

VES No.	Curve Types	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithological Equivalence
		933	5.8	7.5	Lateritic Clay
		520	43.3	50.8	Weathered Layer
		2740	--	--	Fresh Basement
VES 5	A	227	1.1	1.1	Topsoil
		276	3.7	4.8	Weathered Layer
		371	--	--	Fractured Basement

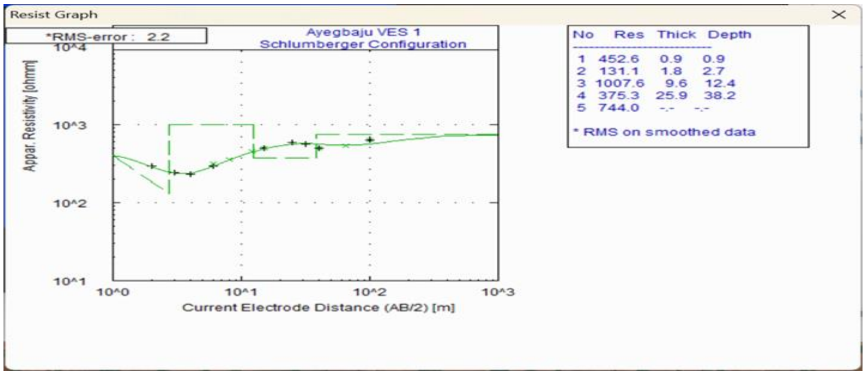

Figure 6: Typical VES Curves from the Study Area

Geoelectric Sections along Traverses 1 and 2

Geoelectric sections were generated from VES result and revealed 3 to 5 geoelectric layers (Figures 7 and 8). The first layer has a resistivity ranging from 227 Ωm to 783 Ωm, and is interpreted to be the thin topsoil. The second layer has resistivity value of 131 Ωm, and is interpreted as sandy clay. The third layer is lateritic/weathered layer, with resistivity values ranging from 933 to 1008 Ωm and 276 Ωm to 520 Ωm respectively. At a depth of 5 to 45 m represents the fourth layer while, the layer was suspected to be fractured/fresh basement with resistivity values greater than 1576 Ωm**.**

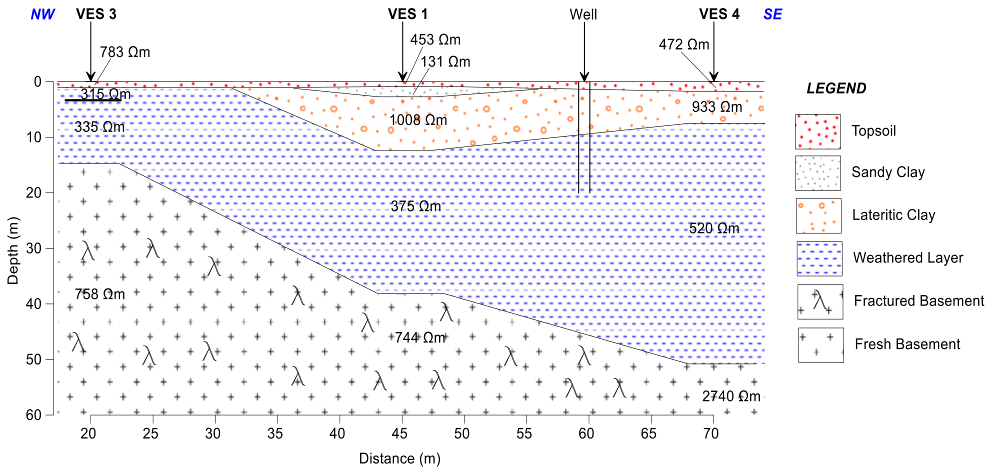

Figure 7: Geoelectric section along traverse one

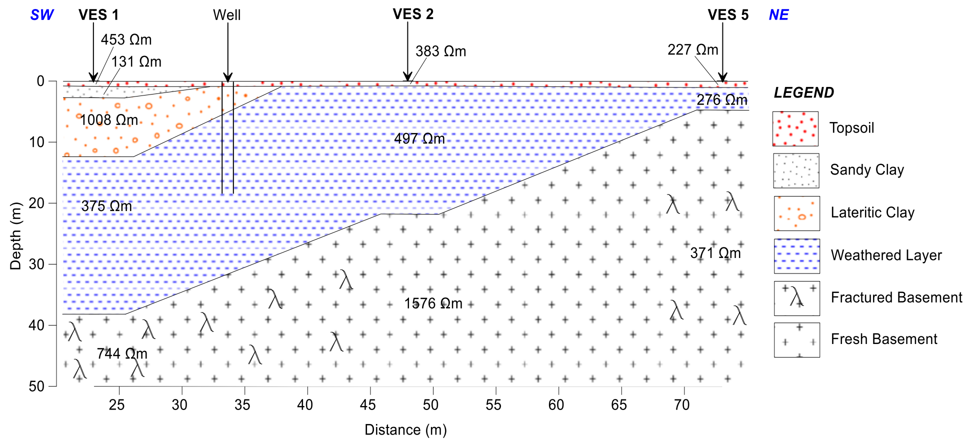

Figure 8: Geoelectric section along traverse two

Correlation of 2-D Resistivity Structures and Geoelectric Sections

A low resistivity zone was identified between stations 20 to 25 m on traverse 1, which is located near the well with irregular water yield. The low resistivity zone might have been filled with materials such as clay which could have caused a delayed recharge or block infiltration during peak rainy season (Figures 9 and 10). The expansion and contraction nature of nearby thick columns of clay could result in water loss during the rainy season due to the contractive and expansive nature of clay (Kure et al., 2017; Abraham & Ibe, 2025). During dry season, clay will contract thereby releasing more water into the well while it will expand during the rainy season by absorbing more water, blocking or preventing the fractured zone from water accumulation and thereby leading to the scarcity of water in the well (Olabode et al., 2020; Aizebeokhai et al., 2021; Doro et al., 2023).

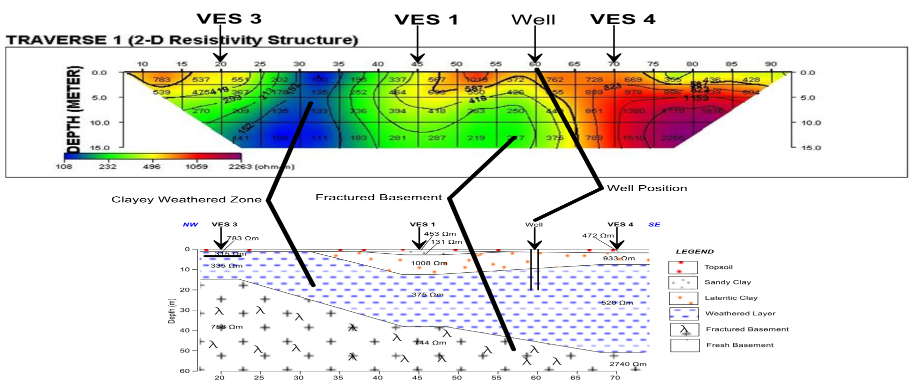

Figure 9: Correlation of 2D and Geoelectric section along Traverse 1

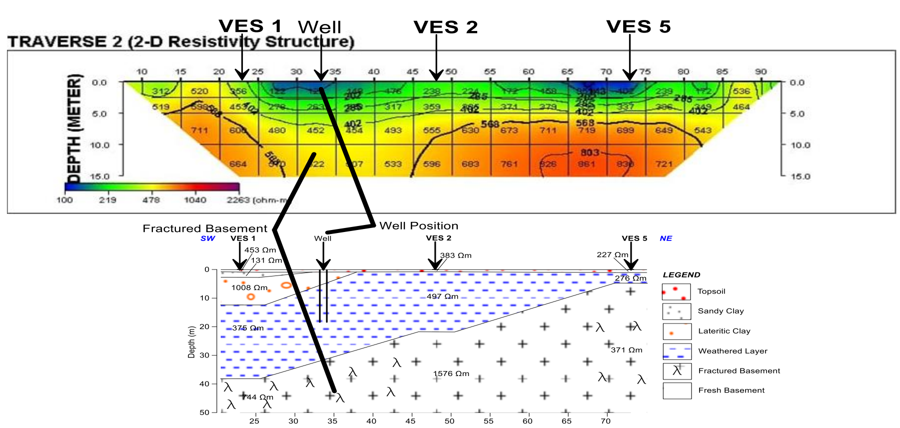

Figure 10: Correlation of 2D and Geoelectric section along Traverse 2

CONCLUSION

Horizontal profiling and vertical electrical sounding techniques have been utilized to observe the dynamic nature of groundwater in a well at Ayegbaju-Ekiti. 2-D resistivity structures generated within the study area revealed anomalous low resistivity (<111 Ωm) zone at a deeper depth between station 30 to 35 m on traverse 1 and overlying clayey formation in the position of well on traverse 2. The anomalous low resistivity observed on traverse 1 could have represented a thick column of clay causing delayed in recharge or block infiltration during peak rainy season. The well is very close to VES 1 and they were underlain by a weathered/fractured basement on traverse 1 and 2.

Vertical Electrical Sounding results identified four VES type curves of A, HA, KH and HKH with three to five subsurface lithologic layers and used to generate geoelectric sections. Correlation of 2-D resistivity structures with geoelectric sections revealed that the well is well positioned on a confined aquifer but greatly affected by the overlain and nearby thick column of clay. The fractured zone might be prevented from water accumulation and thereby leading to the scarcity of water in the well during the rainy season. Preferably, borehole can be drilled in the environment with full casing.

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