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Evaluation of Fresh Groundwater Potentials for Future Urban Planning of Sandwip, an Offshore Island in Bangladesh

Md. Ahsan Habib[1*], Abu Syed Mohammed Faisal[1], Md. Azahar Hossain[1] and Salma Akter[1]

[1]Environmental Geology and Natural Hazard Assessment Branch, Geological Survey of Bangladesh, Segunbagicha, Dhaka, Bangladesh

(*Corresponding E-mail: gsb.habib@gmail.com)

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Abstract: Sandwip, an offshore island of Chittagong District, Bangladesh, requires a substantial amount of fresh groundwater mainly for industrial and household uses. This study integrates resistivity and borelog data to explore fresh groundwater potential in a complex deltaic environment for sustainable urban development. A total of 15 Vertical Electrical Soundings (VES) and two Electrical Resistivity Tomography (ERT) profiles were acquired using Schlumberger and Wenner arrays, respectively. Resistivity data, interpreted through computer modeling and calibrated with borehole lithology, reveal highly heterogeneous subsurface conditions with frequent aquifer–aquitard alternations. The topsoil (2.35–12.16 Ωm) is underlain by silty clay (Aquitard 1). A shallow aquifer (Aquifer 1) is located at depths of 10–60 m, composed of fine to medium sand with resistivity of 14.51–94.24 Ωm. A second aquitard (5–61 m thick) separates Aquifer 1 from an intermediate aquifer (Aquifer 2), encountered at 60–130 m with a thickness of 4.15–82.13 m. A deeper clay unit (Aquitard 3) underlies Aquifer 2. Although sand layers are present, both aquifers exhibit resistivity signatures of brackish to saline water, with only isolated pockets of freshwater. Hence, large-scale groundwater development within 130 m depth appears limited. Future investigations should employ extended electrode spreads to explore aquifers below 300 m, where more prolific freshwater reserves may occur.

Keywords: ***Resistivity, Bore log, Groundwater, Sustainable, Development, Offshore.***

Introduction

One of the world's most densely populated nations is Bangladesh, where groundwater is essential for industrial, agricultural, and residential purposes. Due to the geographic location of Sandwip, the island is vulnerable to storms, increasing sea levels, and tidal surges, all of which have a substantial effect on the quantity and quality of groundwater (Uddin et al., 2014). A serious problem for the island's expanding population and agricultural economy is saline water intrusion, which has decreased the amount of water suitable for irrigation and drinking.

According to Zahid et al. (2016), groundwater in subsurface sedimentary aquifers is very accessible. Therefore, accurate aquifer characterization is crucial for groundwater management that is needed for sustainable development. A resistivity survey was conducted in Mirsharai, on the mainland on the other side of Sandwip Channel to identify the groundwater aquifer (Woobaidullah et al., 2020). With a focus on locating freshwater aquifer zones, this study uses an integrated geo-electrical and borehole approach to assess Sandwip Island's groundwater potential.

Methodology

Schlumberger and Wenner arrays were used to perform two Electrical Resistivity Tomography (ERT) profiles and fifteen Vertical Electrical Soundings (VES) respectively. For VES and ERT, the maximum current electrode separation (AB/2) was 800 m and 100 m, respectively. To analyze the data, curves must be manually matched and then inverted using 1X1D software. To validate lithological units and calibrate resistivity models, 21 bore log data points from the study area were used.

Results and interpretation

The resistivity results reveal a heterogeneous subsurface typical of deltaic environments. The topsoil (0.49–6.65 m thick) shows resistivity values between 2.35 and 12.16 Ωm. Beneath this, Aquitard 1 (silty clay) has resistivity of 2–13 Ωm with thickness of 1.40–10.55 m. Aquifer 1 (10–60 m depth) comprises fine to medium sand with resistivity values of 14.51–94.24 Ωm. Aquitard 2, a silty clay layer 5–61 m thick, separates Aquifer 1 from Aquifer 2. Aquifer 2 occurs at 60–130 m depth with thickness ranging from 4.15 to 82.13 m, composed of fine to medium sand, but showing resistivity of 2.4–12.8 Ωm, indicating brackish to saline water saturation. A deeper clay layer (Aquitard 3) underlies Aquifer 2. ERT profiles and bore log data confirmed lateral lithological variability and the presence of isolated freshwater sand pockets.

Discussion

The combined analysis of resistivity and bore log data indicates highly irregular aquifer–aquitard distribution

due to deltaic deposition. The need for bore log calibration is shown by the overlap between the resistivity ranges of clay and saline sands. Most of the water in shallow and intermediate aquifers is brackish to saline, which restricts the growth of groundwater. Similar circumstances have been seen in other Bangladeshi coastal areas, underscoring the problem of freshwater scarcity in deltaic aquifers more broadly.

Conclusion

This study uses comprehensive fieldwork to analyze the availability and sustainability of groundwater resources in Sandwip Island. In this area the surface water and groundwater are both vital sources for domestic, agricultural and industrial usage. Considering groundwater exploration, the electrical resistivity sounding method is well recognized as an effective geophysical tool. The freshwater aquifer in the area was discovered using Vertical Electrical Sounding, which measures the apparent resistivity of the subsoil along an 800-meter profile.

The lithological cross-sections, constructed from Vertical Electrical Sounding (VES) data and borehole drilling results, confirm that the subsurface is primarily composed of sand and clay, with minor occurrences of silt. However, due to the frequent changes in the facies, their distribution is quite irregular, both, laterally and vertically. The findings align with the three-tier coastal aquifer system- a shallow aquifer (Aquifer 01), an intermediate aquifer (Aquifer 02), and a deeper aquifer (Aquifer 03) that Aggarwal et al. (2000) proposed for Bangladesh.

Low resistivity values in the shallow and intermediate aquifers indicate saline water intrusion. The irregular lithological distribution of the first aquitard allows saltwater intrusion into deeper strata more easily due to insufficient hydraulic interactions between aquifers 01 and 02. Although there are indications that a deeper freshwater aquifer (Aquifer 03) may exist at a depth of about 150 m, its exact length is unknown because of the limits of the current study. Future studies should use hydro-geochemical analysis and deep geophysical surveys to assess the availability of freshwater reserves beyond 150 m and gain a deeper understanding of the deep aquifer potential. Expanding the study deeper than 300 m may reveal important information about the area's possible groundwater supplies for sustainable urban development.

Recommendations

- Perform hydro-geochemical and resistivity surveys at greater depths (>300 m).
- Maintain regular salinity monitoring in shallow aquifers.
- Used techniques for regulated aquifer recharging such as rainwater harvesting.
- Enforce controlled groundwater abstraction policies to prevent saline intrusion.

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