

Assessment of Embankment Integrity of Ureje Dam Ado-Ekiti Using Integrated Geophysical Approach

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Abstract: This study presents a comprehensive geophysical evaluation of the Ureje Dam embankment in Ekiti State, Nigeria, using Electrical Resistivity Imaging (ERI), Spontaneous Potential (SP), and Electromagnetic (EM) techniques. A 210 m N–S traverse with 10 m electrode spacing was surveyed. ERI (dipole–dipole, 50 m depth) revealed highly conductive anomalies at 7–10 m depth and a deep low-resistivity zone (70–100 m, > 40 m depth), indicating compromised structure. SP profiling (5 m gradient array) showed negative potential troughs at 70–120 m, pointing to seepage. Multi-frequency EM data (PQWT-TC150, probing to 150 m) confirmed conductive zones at 0–25 m, 45–135 m, and 180–210 m. The convergence of anomalies across methods supports the presence of weak, water-saturated zones and potential failure pathways. These findings underscore the urgency for remedial measures. The integrated geophysical strategy proves effective for non-invasive dam stability assessment.

Keywords: Basement complex, Electrical Resistivity Imaging, embankment, Spontaneous Potential, Ureje Dam

1. Introduction

Dams are vital hydraulic structures designed for water supply, flood control, irrigation, and hydroelectric power generation. Among the various types, earth-fill embankment dams are widely used due to their cost-effectiveness and ease of construction. However, these structures are particularly susceptible to internal erosion, piping, differential settlement, and seepage, which may lead to catastrophic failures if undetected and unaddressed in time [1][2].

Globally, numerous dam failures have been attributed to unnoticed internal seepage, especially within earthen embankments. These failures often begin as minor structural weaknesses that evolve into extensive internal erosion under hydraulic gradients [3][4]. In many developing regions, routine structural assessments are lacking, creating the need for fast, cost-effective, and non-invasive investigation tools.

Geophysical methods offer a robust suite of non-destructive techniques that are widely recognized for subsurface diagnostics. Electrical Resistivity Imaging (ERI), Spontaneous Potential (SP), and Electromagnetic (EM) profiling are among the most commonly used methods for assessing embankment integrity [5][6][7]. These methods allow the identification

of anomalous zones of high conductivity, low natural potentials, or electromagnetic responses—signals that often correlate with weak, saturated, or eroded materials [8][9].

In Nigeria, several small- and medium-scale dams such as Erelu Dam, Awba Dam, and Ero Dam have been subjected to geophysical surveys to assess potential failure risks [10][11]. These studies have emphasized the efficacy of integrated geophysical approaches in identifying latent structural weaknesses within dam embankments.

This study focuses on the Ureje Dam in Ado-Ekiti, southwestern Nigeria. The objective is to apply a combination of ERI, SP, and EM methods to assess the stability and integrity of its earthen embankment. By comparing anomalies across all three techniques, the study aims to provide a robust diagnostic of potential seepage paths and structurally compromised zones within the dam body.

2. Location and geology of the study area

Ureje Dam, located in Ado Local Government Area of Ekiti State, is situated on basement terrain where the aquiferous units are limited to the weathered overburden zones and fracture systems. The geology falls within the Precambrian basement complex of the southwest, which is part of the larger West African Craton. The rocks constituting the basement complex, despite disagreements over lithological delineations, are loosely categorized into three major groups: the migmatite-gneiss complex, the schist belts, and the Pan-African granites. A variety of metamorphic and igneous rocks, including migmatite, gneiss, quartzite, granite, and charnockite, characterizes the geological setting of Ado-Ekiti. These formations reveal the complex tectonic history and the dynamic geological processes that have shaped the region. The Basement Complex of Ekiti State, Nigeria, is fed by two rivers and features a compacted earth embankment. It is constructed across a north–south traverse approximately 210 m long, passing over the constructed embankment axis.

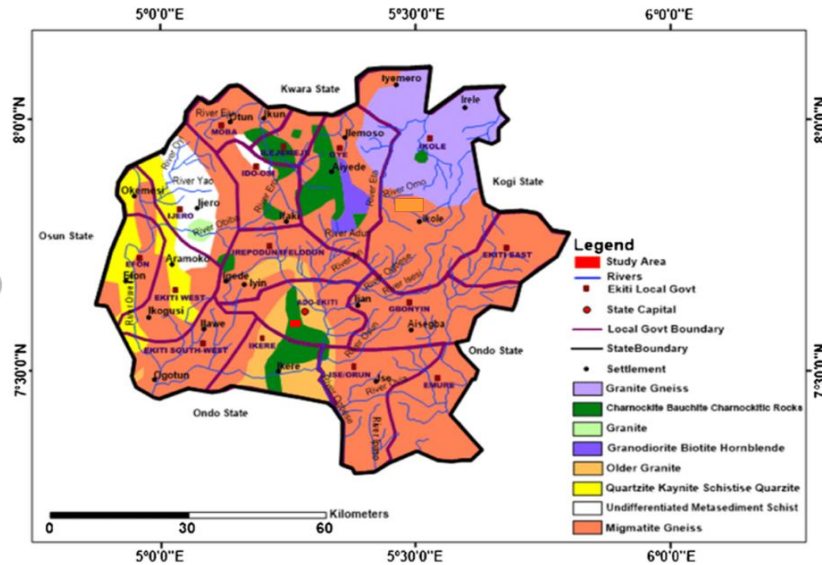


Figure 1: Location of the study area on the geological map of Nigeria

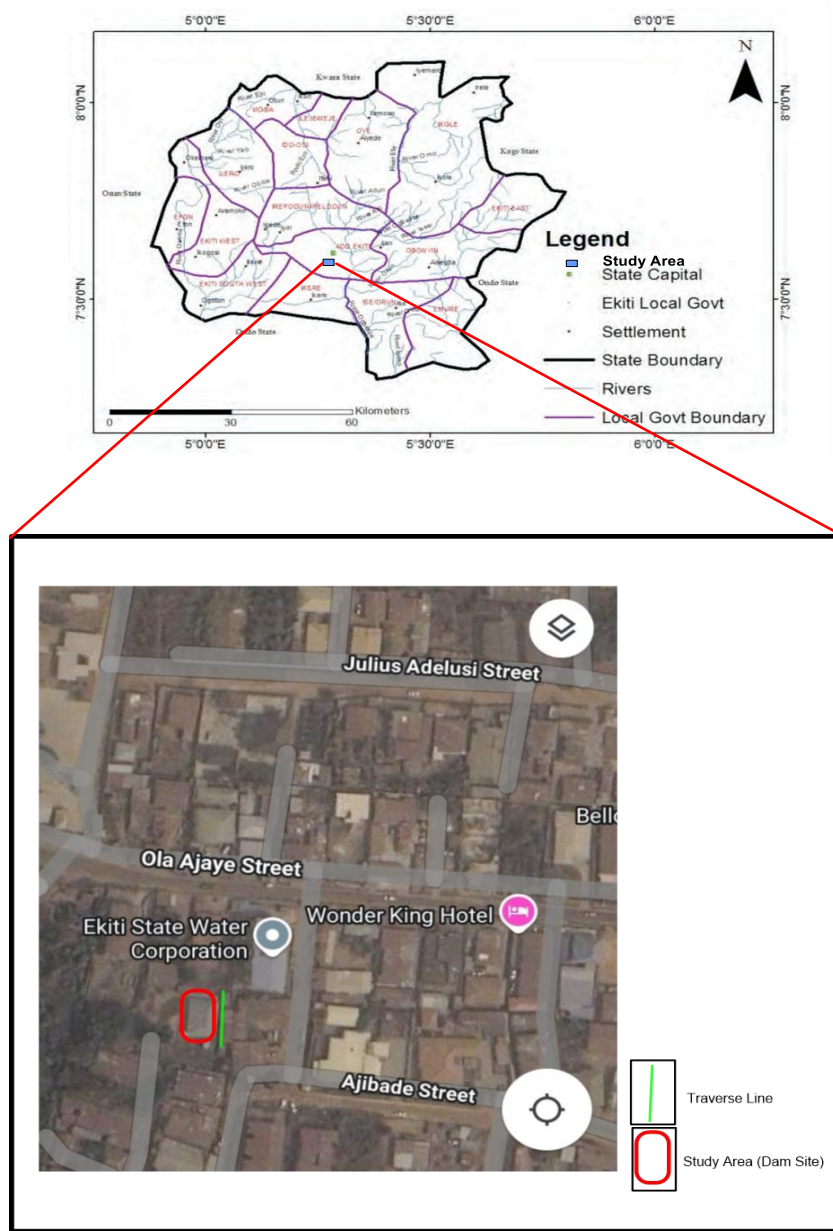


Figure 2: Location of the study area in geographical map of Ekiti-State

3. Methodology

3.1. Electrical Resistivity Imaging

A 2D resistivity survey used the dipole–dipole configuration, with five spreads at 10 m electrode spacing, achieving a depth of ~50 m. ERI combines horizontal profiling with vertical sounding—a proven method for detecting seepage and structural defects in embankments.

3.2. Spontaneous Potential

SP measurements, using a gradient array with 5 m spacing, map natural electric potentials driven by groundwater flow and electrochemical gradients. SP is sensitive to seepage-related anomalies and has been successfully employed in dam surveys.

3.3. Electromagnetic Survey

The PQWT-TC150 EM instrument recorded multi-frequency responses at 210 m traverse with 5 m station intervals. EM profiling to ~150 m depth highlights variations in subsurface conductivity due to moisture or clay content.

4. Results

4.1. Electrical Resistivity Imaging

The ERI pseudo-section shows extensive shallow low-resistivity zones (7–10 m depth) and a deep conductive anomaly between 70–100 m extending beyond 40 m depth—consistent with water-saturated zones and potential piping.

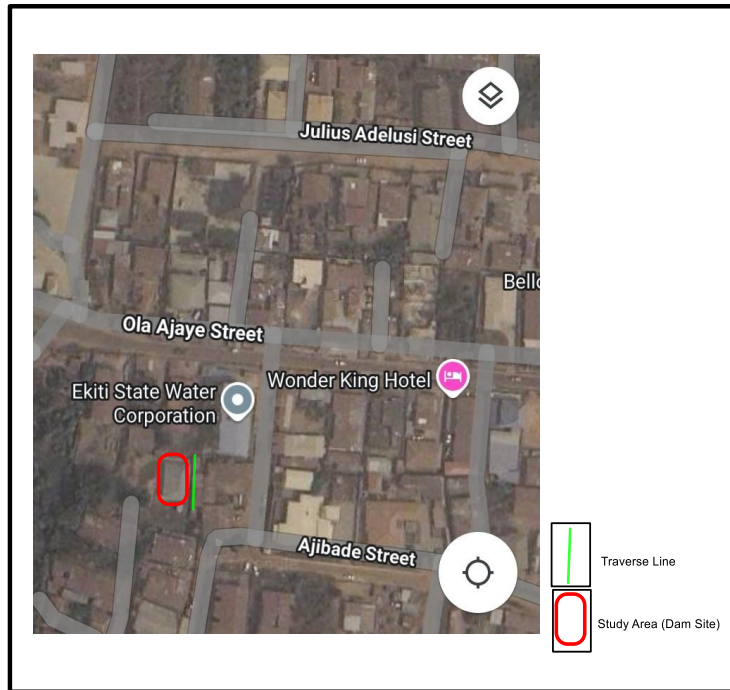


Figure 3: Field layout of the study area

4.2 Spontaneous Potential Profile

SP data reveal a pronounced negative potential trough between 70–120 m, coinciding with the resistivity anomaly. This negative deflection reflects an electrochemical gradient produced by fluid seepage.

4.3. Electromagnetic Survey

EM frequency responses show low-conductivity trends (high conductivity) at 0–100 m and 180–210 m across the full profile, with shallow anomalies at 0–25 m, 45–135 m, and 180–200 m. These correspond to moist or clay-rich zones prone to instability.

5. Results and Interpretation

The investigation employed three complementary geophysical techniques—Electrical Resistivity Imaging (ERI), Spontaneous Potential (SP), and Electromagnetic (EM) surveying—to characterize subsurface conditions of the Ureje Dam embankment. Each method provided unique insights into the dam's structure and potential weaknesses.

5.1. Electrical Resistivity Imaging (ERI) Results

The 2D resistivity sections derived from the dipole-dipole configuration revealed significant variability in subsurface resistivity along the 210 m traverse. A shallow, continuous, low-resistivity zone extending from the surface to depths of 7-10 m was observed consistently across the entire profile. Such low resistivity values are commonly associated with saturated zones or materials with elevated clay content, indicating areas of moisture accumulation or potential seepage [1][5].

More critically, a distinct and extensive low-resistivity anomaly was detected between the 70 and 100 m mark along the traverse, extending to depths exceeding 40 m. This feature suggests a major subsurface weakness likely related to seepage channels or zones of internal erosion within the embankment structure [6]. Low resistivity at such depth often corresponds to highly conductive pore fluids filling fractures or voids, which compromises the mechanical strength of the dam core [9]. If unmitigated, this could escalate to piping failure and catastrophic embankment breach.

The 2D-geosection also shows weaknesses in this embankment at distances 0 to 25 and 180 to 200 m at a shallow depth of about 20 m, while other weakness responses are observed at 45 to 135 m across the embankment.

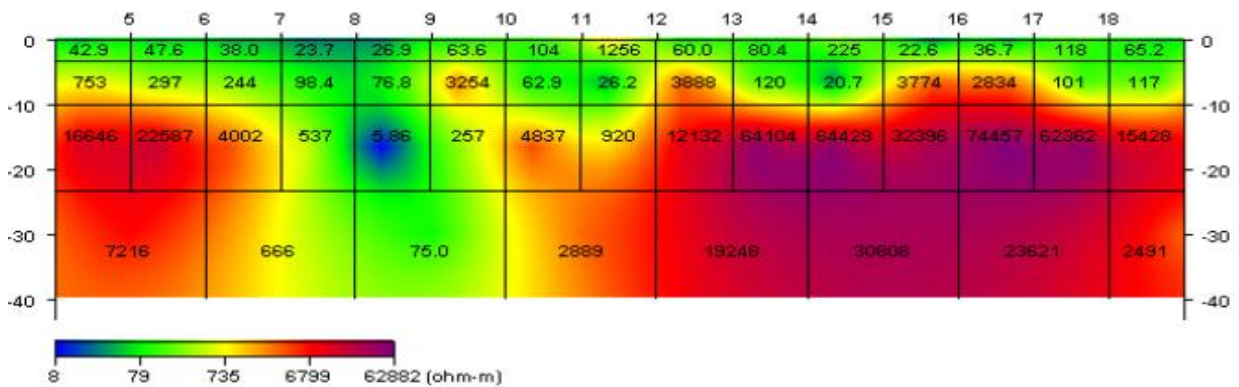


Figure 4: 2D-resistivity structure of the study area

5.2. Spontaneous Potential (SP) Profile

The SP survey produced a continuous potential profile across the dam embankment, reflecting natural electrochemical gradients typically induced by fluid movement. The most notable feature is a pronounced negative SP anomaly between 70 and 120 m along the traverse, coinciding spatially with the ERI-identified conductive zone.

Negative SP values generally indicate zones of inward water flow or seepage within embankments [7][8]. The observed drop in natural potential here suggests active seepage of water through compromised portions of the dam, possibly due to infiltration from surrounding groundwater or surface water. The alignment of SP low-potential zones with resistivity lows strengthens the interpretation of seepage pathways and validates the presence of hydrologically active defects [5].

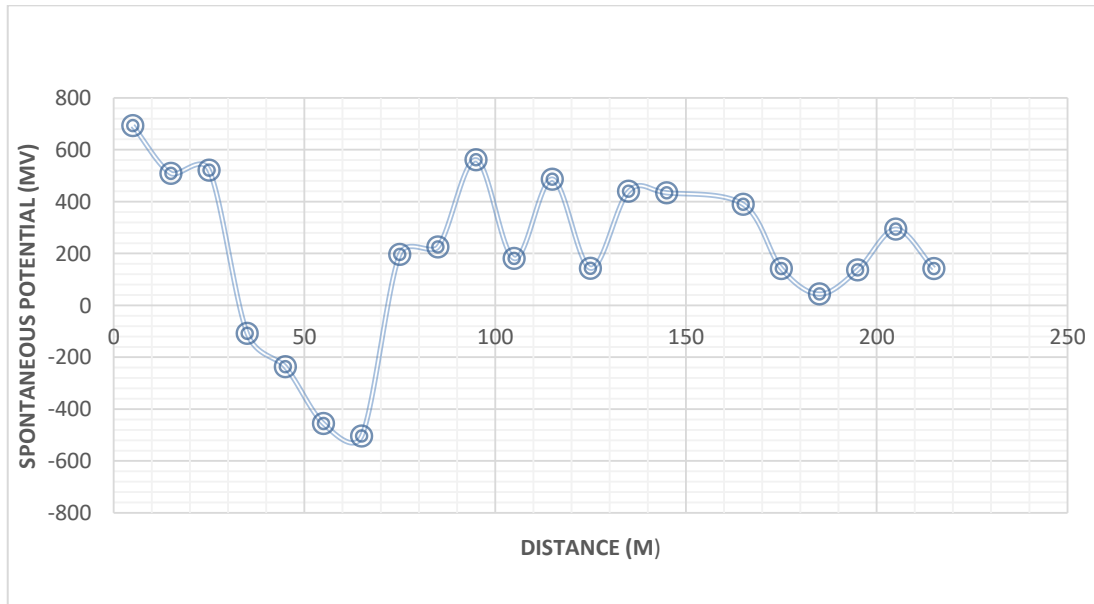


Figure 5: Spontaneous potential profile across the study area

5.3. Electromagnetic (EM) Survey Results

Electromagnetic profiling across 19 frequencies provided additional depth-sensitive conductivity data extending to about 150 m. The EM frequency response curves exhibited low-resistivity trends—interpreted as high conductivity—at shallow depths (0–20 m) near 0–25 m and 180–210 m distances. These zones likely correspond to water-saturated or clay-rich deposits within or adjacent to the embankment, consistent with moisture accumulation detected by ERI and SP.

Furthermore, the midsection of the dam (45–135 m) displayed moderate conductivity anomalies at intermediate depths (20–50 m), indicative of heterogeneity in material composition or localized weak zones. The deeper conductive anomaly at 70–100 m, also reflected in ERI and SP data, was clearly delineated in the EM geosections, confirming the presence of extensive subsurface conductive materials—most probably linked to seepage or degraded embankment materials [6].

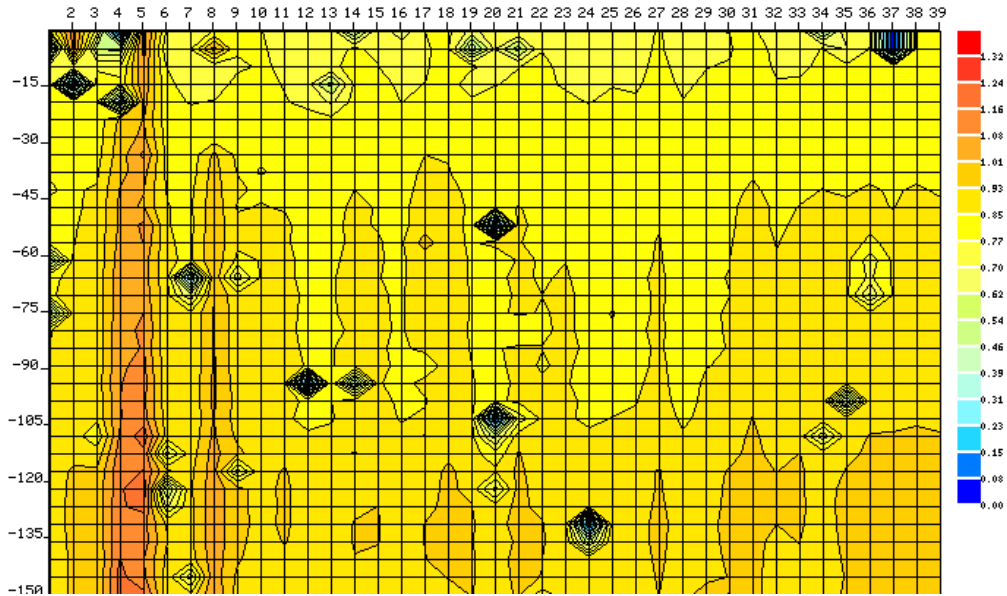


Figure 6: 2D-electromagnetic structure of the study area

5.4. Integration of Geophysical Results

The spatial correspondence among low resistivity in ERI, negative potentials in SP, and high conductivity in EM surveys underscores the robustness of the integrated approach for identifying structural weaknesses and seepage zones within the dam embankment. These overlapping anomalies identify at least two critical zones of concern:

1. A shallow, laterally extensive weak zone (0–10 m depth) spanning the entire traverse, possibly related to surface moisture infiltration, unsaturated zones with clayey materials, or shallow seepage paths.

2. A deeper, more localized anomaly (70–100 m distance, >40 m depth), interpreted as a major internal erosion or seepage channel, representing a significant threat to dam integrity if left unaddressed. The detection of these features is consistent with documented cases in the literature where combined geophysical techniques successfully delineated embankment defects before visible failure [2][6]. The integration of methods compensates for the limitations of individual techniques and provides a more comprehensive understanding of subsurface hydrological and mechanical conditions [5].

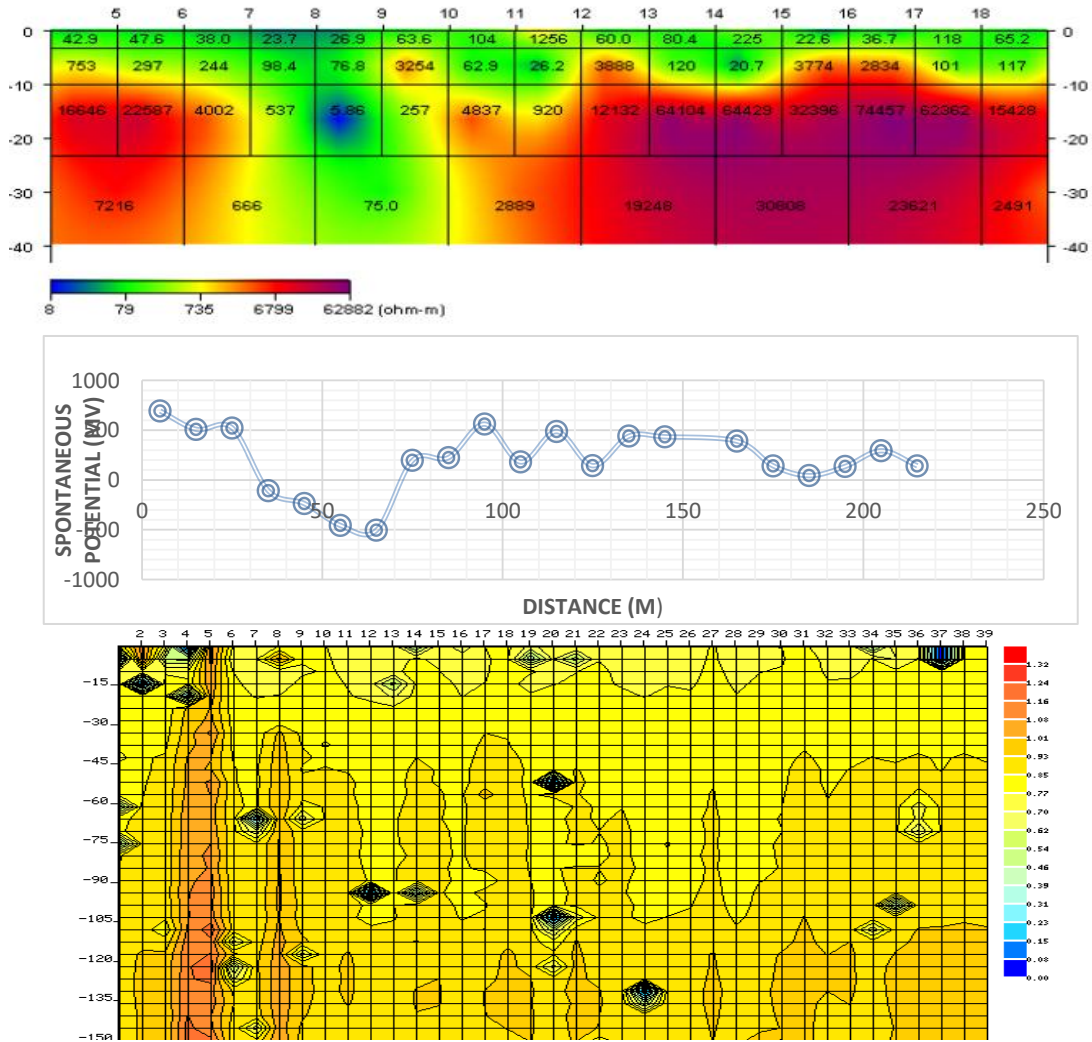


Figure 7: Synchronization of results from electrical resistivity, spontaneous potential and electromagnetic method

6. Conclusion

This study has successfully employed an integrated geophysical approach—comprising 2D Electrical Resistivity Imaging, Spontaneous Potential profiling, and Electromagnetic surveying—to evaluate the structural integrity of the Ureje Dam embankment in southwestern Nigeria. The synergy of these techniques enabled the detection of subsurface anomalies, specifically zones of high conductivity, reduced natural potential, and low-frequency electromagnetic signals. These anomalies strongly suggest the presence of moisture-saturated materials, probable seepage paths, and compromised zones that extend both laterally and vertically within the embankment.

Significant weaknesses were identified between distances 70–100 m and at shallow depths near the 0–25 m and 180–210 m marks. The depth of conductive anomalies extending beyond 40 m within the dam's critical middle section underscores the potential risk of internal erosion and piping—mechanisms implicated in numerous dam failures globally [1][4].

The alignment of findings across three independent geophysical techniques provides high confidence in the interpretations and underscores the reliability of integrated geophysical investigations for dam safety monitoring [5][6]. In line with international best practices, such as those recommended by ICOLD (2013), remedial actions—including grouting, embankment reconstruction, and the installation of impermeable barriers—should be undertaken to mitigate the risk of dam failure.

Additionally, the study highlights the need for periodic monitoring of aging dam structures in Nigeria, especially amid increasing hydrological stress from climate change. Continued application of cost-effective, non-invasive geophysical techniques should form a core part of proactive water infrastructure management strategies in the region [9][11].

7. References

- [1] Foster, M., Fell, R., & Spannagle, M. (2000). A method for assessing the relative likelihood of failure of embankment dams by internal erosion and piping. *Canadian Geotechnical Journal*, 37(5), 1025–1061. DOI:10.1139/t00-040.
- [2] Fell, R., Foster, M., & Spannagle, M. (2003). A method for assessing the likelihood of internal erosion in embankment dams and their foundations. *Australian National Committee on Large Dams Bulletin*, 121.
- [3] International Commission on Large Dams (ICOLD). (2013). *Internal Erosion of Existing Dams, Levees and Dikes, and their Foundations*. Bulletin 164.
- [4] Singh, V. P. (1996). *Dam Breach Modeling Technology*. Springer.
- [5] Reynolds, J. M. (2011). *An Introduction to Applied and Environmental Geophysics* (2nd ed.). Wiley-Blackwell.
- [6] Sjö Dahl, P., Dahlin, T., & Johansson, S. (2009). Using resistivity measurements for dam safety evaluation: A case study from Røssvatn Dam, Norway. *Near Surface Geophysics*, 7(5-6), 463–474. DOI:10.3997/1873-0604.2009023.
- [7] Corwin, R. F., & Hoover, D. B. (1979). The self-potential method in geothermal exploration. *Geophysics*, 44(2), 226–245. DOI:10.1190/1.1440954.
- [8] Dahlin, T., & Loke, M. H. (1998). Resolution of 2D Wenner resistivity imaging as assessed by numerical modeling. *Journal of Applied Geophysics*, 38(4), 237–249.
- [9] Yilmaz, I. (2011). A new technique in dam body investigation using electrical resistivity and self-potential methods: A case study from Turkey. *Environmental Earth Sciences*, 64, 1037–1046. DOI:10.1007/s12665-010-0916-5.
- [10] Bayowa, O. G., Ilufoye, D. T., & Animasaun, A. R. (2011). Geoelectric investigation of Awba Dam, University of Ibadan, Southwestern Nigeria. *Ife Journal of Science*, 13(2), 219–226.
- [11] Adepelumi, A. A., Ako, B. D., Ajayi, T. R., Afolabi, O., & Omotoso, E. J. (2009). Delineation of saltwater intrusion into the freshwater aquifer of Lekki Peninsula, Lagos, Nigeria. *Environmental Geology*, 56(5), 927–933. DOI:10.1007/s00254-008-1194-3.

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