Assessment of Levees Using Field Instrumentation and Geophysical Methods.

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Abstract

Levees along the Mississippi River play an important role in ensuring the security of life and property in flooding events. The degree of saturation and moisture content of levees containing high-plastic clay soils can increase their vulnerability to shallow slope failures. The frequent fluctuation of the water levels of the Mississippi River increases the potential of water infiltration which in turn increases the risk of shallow slope problems. Therefore, it is critical to monitor the water level inside the levees to evaluate the effects of the water table elevation on the levee performance. Field instrumentation and Electrical Resistivity Imaging (ERI) are used to investigate the soil subsurface conditions in terms of soil moisture variation, and perched water zones. The objective of the current study is to integrate the data collected from electrical resistivity imaging (ERI) with the change in subsurface water pressure to evaluate the performance of two levee sections on the Mississippi east levee system in Norfolk north of Mississippi. A piezometer was installed at the toe of each levee section to monitor the water table levels. Moreover, a 2D ERI test was conducted along three survey lines at the crest and middle of each levee slope to investigate the soil subsurface conditions in terms of soil moisture variation and perched water zones.

Introduction

Levees along the Mississippi river are earthen structures raised along the banks of the river and its Tributary to retain water and to protect life and property in flooding events. In the past, many catastrophic levee failures were recorded due to three main reasons: Overtopping, piping failure or internal erosion, and instability and slope failures (9). The instability and slope failures are sensitive to the structures, materials, impacting forces and configurations of the levee (1). Many of the levees along the Mississippi river lie on an alluvial material, those alluvial materials are usually eroded soils deposited by the river during previous flooding events, and those materials are usually loose or unconsolidated, which can be problematic during high water events. The differential hydrostatic head resulting from high water events allows seepage through the pervious layers which elevates the hydraulic gradient and increases the moisture through the impervious blanket above (10).

Seepage problems, high uplift pressures, and differential settlement can develop cracks that weaken the foundation layers of the embankment and allow perched water zones to develop within the impervious blanket and may lead to slope instability and slope failures (1). The stability of the side slopes of an embankment depends on the resisting forces against driving forces (19; 4).

The primary visual indicators of levee slope instability are cracks, bulges, depressions, and slides (7). The presence of cracks, bulges and depressions indicate the beginning stages of an embankment slide and generally do not provide adequate indication of the severity of the slide through progression. Levee blankets constructed with expansive soils are prone to cracking problems caused by the variations of the soil moistures because it impacts its physical volume change (12). It is usually challenging to discover problems caused by moisture variations since it is usually hidden within subsurface soils (6). Since the moisture content variation is one of the primary reasons behind soil strength and slope stability (13), understanding the relationship of moisture variations in the levee foundation in respect to the changes to the Mississippi river stages can help with assessing the levee performance.

The soil moisture content can be estimated either directly by laboratory testing or determined in the field by advancing CPTs or other destructive methods, such as vane shear (VST) and standard penetration test (SPT) (5), however those methods of estimating moisture content are destructive, costly, require extensive planning and preparation, and generally only provide one point of measurement data. On the other hand, Geophysical techniques are indirect methods that can be used to estimate and understand the moisture content variations of soils (2). Electrical Resistivity Imaging (ERI) is a non-destructive geophysical method that can be used to study slopes seasonally to capture the variations of soil moisture contents and to monitor the slope performance to take early actions (16). The ERI can capture the soil resistivity based on the porosity, saturation, and the material texture which can be used to detect the moisture content, perched water zones, and crack development (14). Furthermore, depending on the electrodes spacing the electrical currents can penetrate large depths in soils, thus engineering judgment based on the project is needed to determine the spacing and configuration of the electrodes to help understand the soil resistivity (18). ERI started to get more popularity in the recent years to produce subsurface maps that can help understand the and identify the moisture content of the soils (3; 15).

Site Selection

The study was conducted on two different levee sections of the Yazoo Levee system, in Norfolk, Mississippi. Site 1 is a 1000ft levee section between river miles 718 and 720 with height of 34ft and landside slope of 1V:4.35H the inspected landside slope is approximately 6000ft away from the Mississippi riverbank. Site 2 is a 480ft levee section between river miles 708 and 709 with height of 18ft and landside slope of 1V:5.5H. The inspected landside slope is approximately 1240ft away from the Mississippi riverbank. Figure 1. Below represents the two inspected levee sites.

Table 1. Study site's location and configuration.

Study Site	Distance from MS river (ft)	Landside Slope	Latitude	Longitude
Norfolk 1	6000	1V:4.35H	34°59'56.26"N	90°14'23.20"W
Norfolk 2	1240	1V:5.5H	34°55'33.03"N	90°14'4.28"W

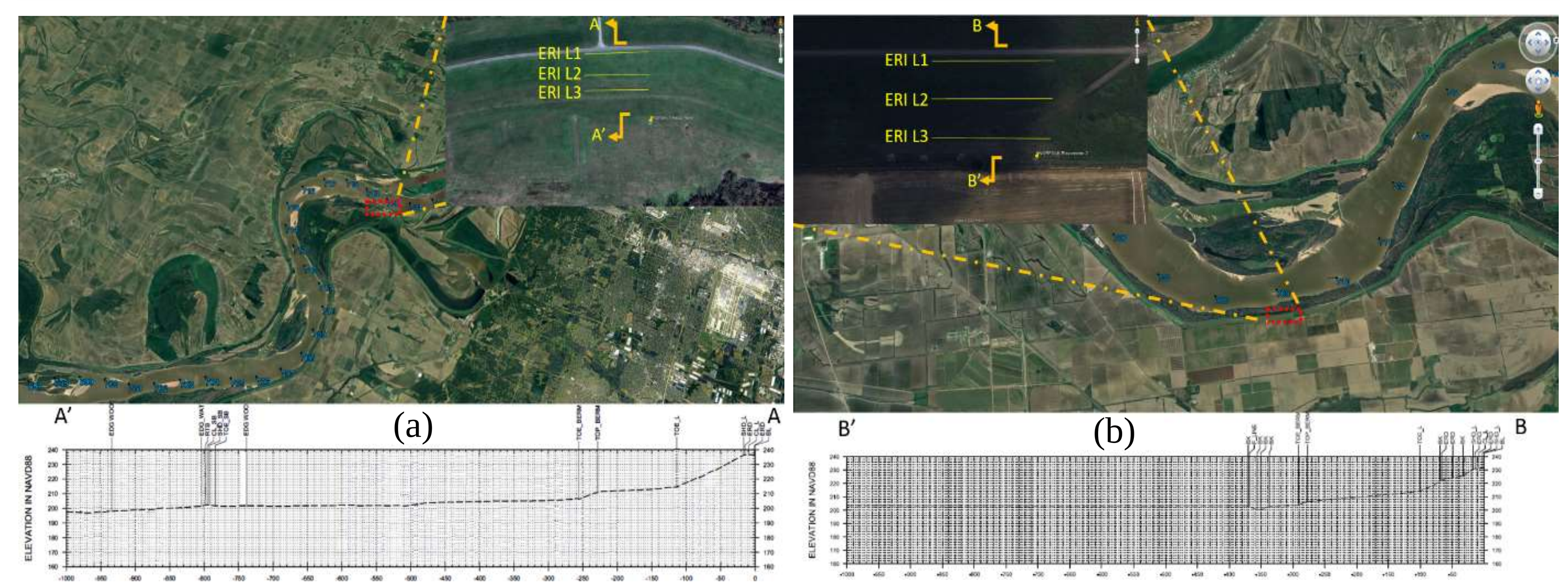

Figure 1. (a) Norfolk 1 site location and details (b) Norfolk 2 site location and details.

Methodology

Electrical Resistivity Imaging (ERI)

An ERI test was performed to examine the surface resistivity of the shallow subsurface on the levee landside slope and toe of the two sites. The equipment used for the study is a SuperSting R8/IP resistivity meter manufactured by Advanced Geosciences Inc. (AGI). To run this multichannel system a total of 56 electrodes were used. The electrodes were hammered at least 6 inches into the ground and spaced at 5 ft. center to center spacing covering 275 ft. The electrodes were connected through cables on a dipole-dipole array.

Field Instrumentation

A vibrating wire (VW) piezometer sensor was installed at 48ft depth on each site to monitor the fluctuation of the water table in the levee foundation with the change of the river stages over time. The sensors are installed in the relief wells at the landside levee toe of each levee section. The sensors are connected to a data logger placed at the side of the relief well screen. The data is recorded every 15 minutes increment. The pressure readings collected by the piezometers were converted to total head and plotted against the river gage reading of the Mississippi water levels at each corresponding river mile. The data from the river gages at each river mile was interpolated between the Memphis gage (between RM 734 & 735) and the Mhoon landing river gage (between RM 687 & 688). Figure 3. Shows the used VW sensors installed in site 1.

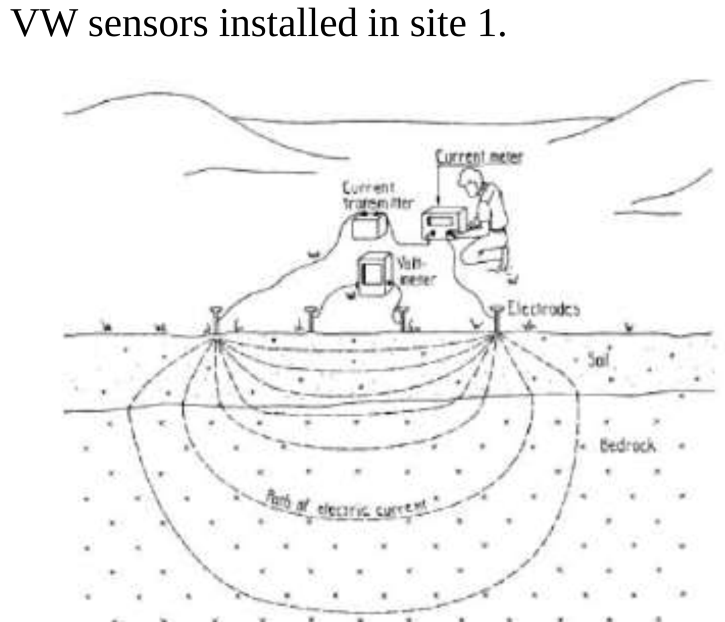

Figure 2. ERI test equipment and survey line placement.

Figure 3. Geokon data logger and VW piezometer installation at Norfolk site 1.

Results

Norfolk Site 1

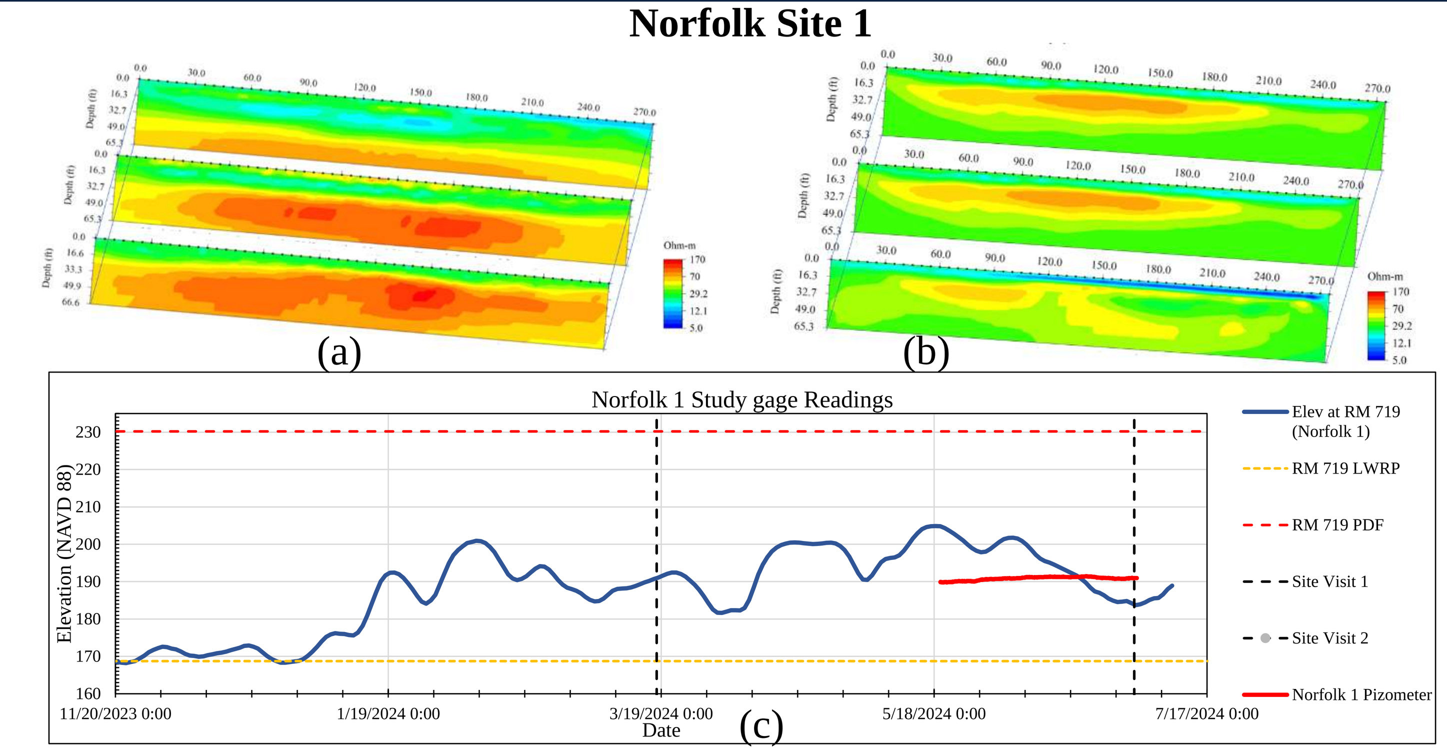

Figure 4. (a) ERI Survey Lines on March 19th (b) ERI Survey Lines on July 1st (c) Interpolated River stages at river mile 719 with piezometer sensor data.

Norfolk Site 2

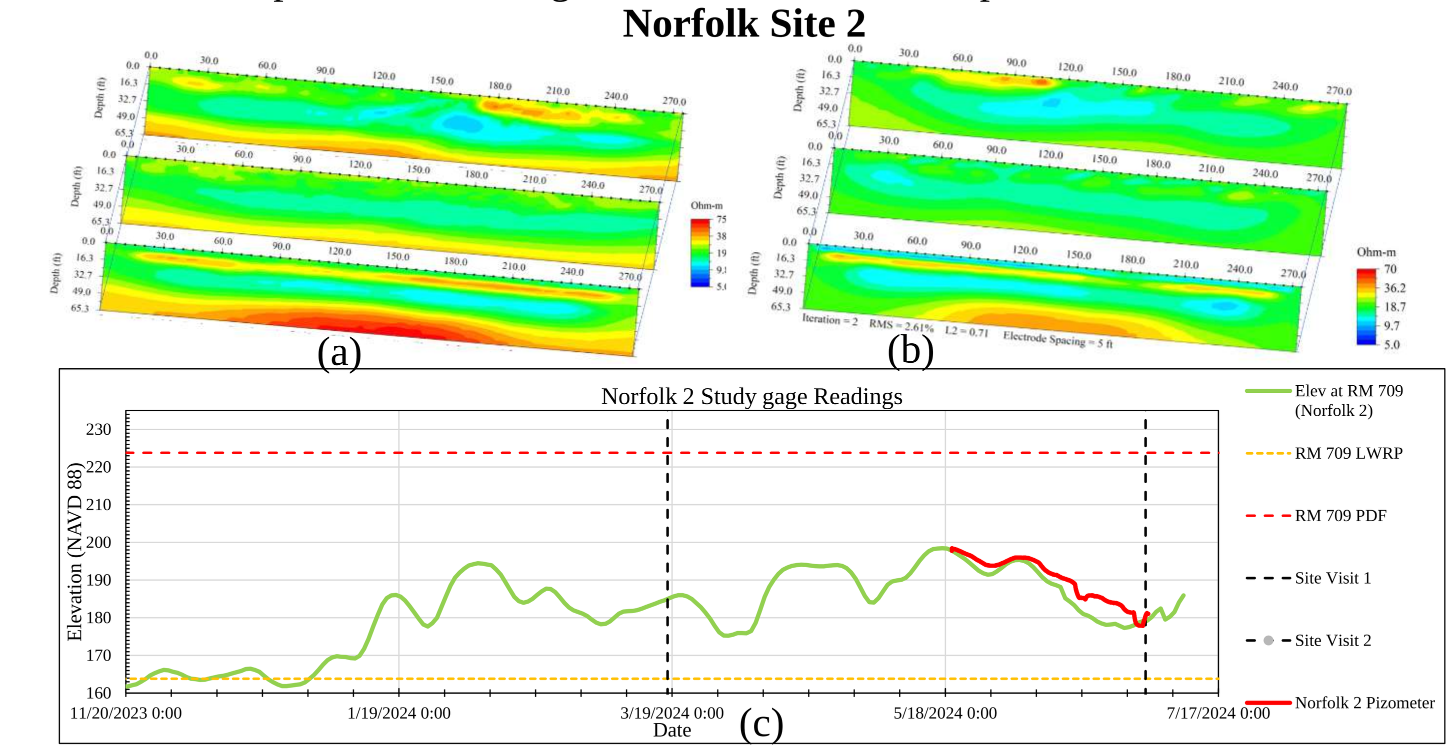

Figure 5. (a) ERI Survey Lines on March 19th (b) ERI Survey Lines on July 1st (c) Interpolated River stages at river mile 719 with piezometer sensor data.

Summary and Conclusion

- Norfolk 1 site, the effect of the Mississippi river stages is not reflected on the soil resistivity immediately due to the long distance from the landside toe and the river, approximately 6000ft.
- Based on the notable lag of the ground water changes Norfolk site 1, it can be hard to evaluate the effect of the river stages fluctuations using the ERI, but it can be useful to understand and back calculate permeability parameters of the foundation soils.
- Norfolk 2 site, the effect of the Mississippi river stages is reflected on the soil resistivity immediately due to the short distance from the landside toe and the river, approximately 1240ft. It was noted that the resistivity of the soil foundations drops when the river stages go up.
- Norfolk 2 site, the changes in the water table due to the changes in the river stages is rapid and it was affected directly by the river stages.
- ERI can be a good field investigation option because it allows continuous monitoring of the site conditions over seasonal changes.

Disclaimer

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