GEOPHYSICAL SURVEYS ON CARROLL COUNTY DAM

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Abstract

Carroll County Dam (North Mississippi) is an earthen dam approximately 9m high and 229m long, built in 1965 to obstruct an existing little creek and creating a reservoir of approximately 0.12Km^2. In 2016, during a routine visual inspection, sand boils were observed downstream of the dam. The dam usually retains very little water; however, exceptional flood events could significantly increase pore water pressure and potentially lead to dam failure. For this reason, during the spring of 2017, the National Center for Physical Acoustics in collaboration with the Mississippi Department of Environmental Quality Dam Safety Division has been conducting extensive geophysical measurements to investigate the dam.

Several seismic refraction and electric resistivity surveys were conducted at the dam. The as-built plan, historic topographic maps and available borehole information were used to aid the interpretation of the geophysical data. Preliminary results from the study indicate two possible conditions leading to seepage. The location of geophysical anomalies being close to pre impoundment channel support water seeping through an old pre impoundment stream channel. The second possible condition is water seepage through a small lens of silty sand (higher porosity) imbedded within a clay layer that was not properly sealed during preparation of the base of the dam.

Introduction

Carroll County Dam, also known as Potacocawa Watershed Structure Y-31A-06, is an earthen dam located in a rural area of northwest Mississippi (Figure 1a). The dam measures approximately 9m (30 feet) high and 228m (750 feet) long and was constructed in 1965 as watershed infrastructure to regulate the surface hydrology for agriculture purpose. The general topography from a 1954 historical topographic map (Figure 1b) indicates that the embankment was positioned slightly up stream of the conjunction of two small creeks. The dominant stream is to the left whereas the stream to the right is classified as a "seasonal stream". The obstruction of the streams created a water reservoir of approximately 0.12Km^2.

In March 2016, during a routine visual inspection by the Mississippi Department of Environmental Quality Dam Safety Division (MDEQ), moderate seepage and sand boil formation were observed at the toe of the dam (Figure 1c). Sand boils developed despite the dam retaining very little water and it raised concern about the dam integrity and the existence of seepage through the dam structure. During a flood event, when pore pressures increase significantly, the situation could deteriorate rapidly, and potentially lead to a dam failure. This is a high hazard dam with chance for loss of life downstream in case of failure.

The geological baseline characterization for the dam has been derived from geological cross sections and borehole analysis reported in the as-built documentation. The cross-section in Figure 2 represents the subsurface geology along the dam's crest profile. The dotted black line and the solid black line indicate the pre-dam ground and the cut/fill profiles, respectively. The dam was built to close the valley formed by the erosion of a small creek. The valley was about 6m (20 feet) deep and 183 – 213m (600-700feet) wide with both valley flanks formed by a combination of silt and clay with medium to low plasticity (ML, CL). A large portion of the valley subsurface consists of silty sand (SM), in some areas this formation reaches up to 12m (40 feet) thickness. Imbedded in the silty sand (SM) formation are some lenses of gravelly clay or sandy clay (CL). According to the "As built" document, the dam construction involved the excavation of about five feet of material. The dam foundation is represented by high plasticity clay (CH) which is found at the bottom of boreholes PA350, PA451, PA551, and PA50 mainly in the middle of the old valley.

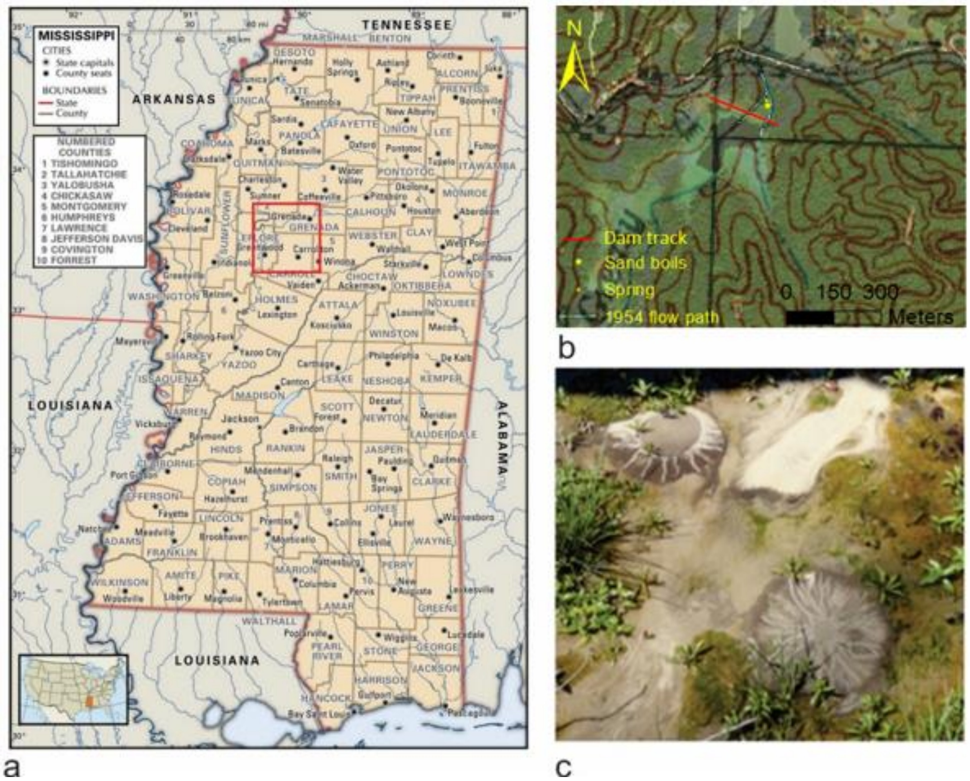

Figure 1: a) Location of the study area. b) 1954 topographic map of the study area prior the dam construction. c) Pictures of the sand boils found dam downstream during the 2016 MDEQ inspection.

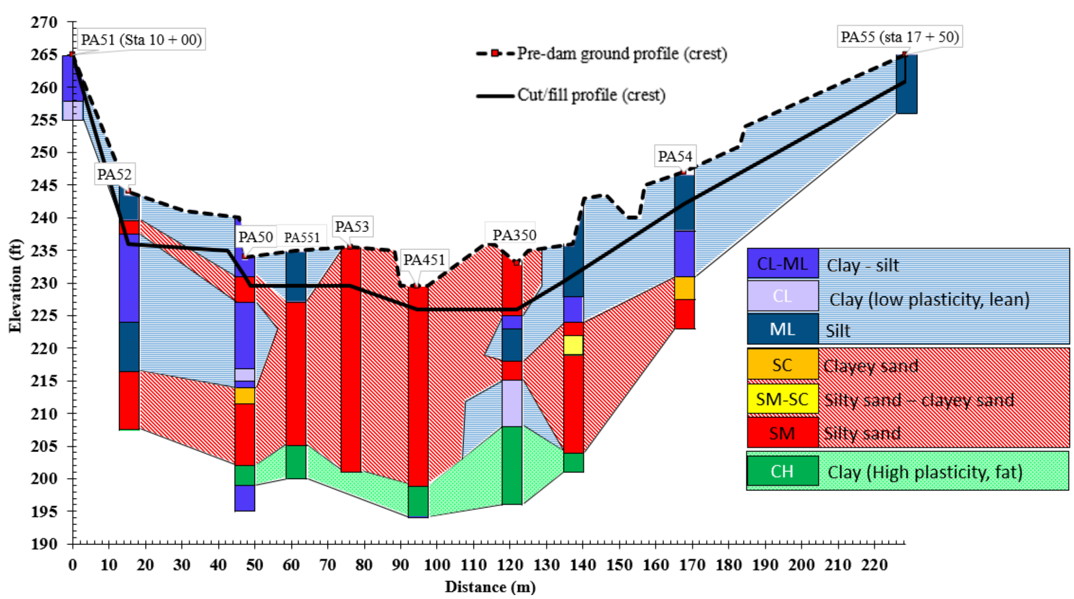

Figure 2: Geological cross-section illustrating the subsurface geology along the dam's crest profile.

Geophysical Surveys

Seismic refraction tomography (SRT) and electrical resistivity tomography (ERT) were the primary geophysical methods used to investigate the subsurface of the dam (Butler and Llopis 1990; Kim et al., 2011; Karastathis et al., 2002; Moustafa et al., 2012; Panthulu et al., 2001). Geophysical measurements were acquired along five lines: Line 1 (waterside), Line 2 (slope), Line 3 (toe), Line 4 (downslope), and Line 5 (crest) (only ERT). For all survey lines, borehole PA 51 is used as reference station (0m) for all horizontal distance measurements (Figure 3).

For the seismic refraction surveys, 10Hz vertical component geophones were used as receivers, while an 8-pound sledgehammer was used as a seismic source. Rayfract™ was used for seismic data inversion and Surfer™ for data visualization. The ERT data were collected using the SuperSting™ R8 in Dipole-Dipole configuration and data inversion was conducted using Erathimager2D™. Table 1 summarizes SRT and ERT survey configurations.

Table 1: Seismic refraction and electrical resistivity survey acquisition geometry.

Survey line	**SRT**			**ERT**		
	Number of geophones	Geophone spacing (m)	Spread length (m)	Number of Electrodes	Electrode spacing (m)	Spread length (m)
Line 1 (waterside)	56	1	55	112	1	111
Line 2 (slope)	96	1	95	112	1	111
Line 3 (toe)	96	1	95	112	1	111
Line 4 (downslope)	56	0.75	41.25	56	0.75	41.25
Line 5 (Crest)	-	-	-	112+56 roll-Along	1	167

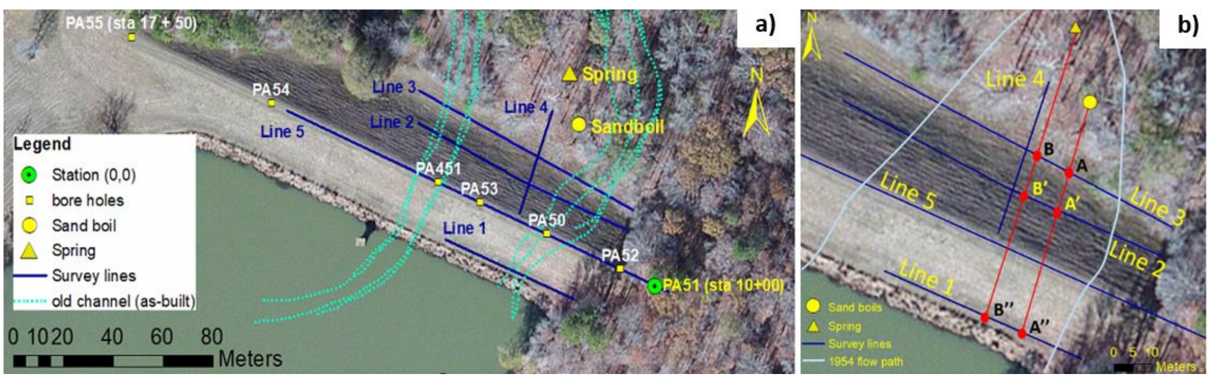

Figure 3: a) Present-day Google Earth images showing the location of survey lines, the position of the boreholes and other points of interest. b) Location of the interpretation points A, A', A"; B, B', B'', which represents the intersections points of two straight lines (in red) one starting from the spring and the other starting from the sand boil, used as reference locations in the interpretation of the geophysical data.

Both seismic and electrical data were analyze to establish the presence of velocity and resistivity anomalies, particular attention was placed to locate areas where low p-wave velocity and low resistivity which could be representative of the presence of deteriorated material and active fluid-flow. Figure 4a (seismic tomograms) and Figure 4b (resistivity section) display the geophysical anomalies of line 3 (toe) which is used as example to illustrate how the geophysical anomalies are mapped. For both data sets, anomalies are annotated using a combination of dotted lines/polygons of different colors. Points of reference in Figure 3 and subsurface horizons (pre-dam topographic profile and cut/fill surface) in Figure 2 are projected onto the geophysical lines to help with the location of the anomalies.

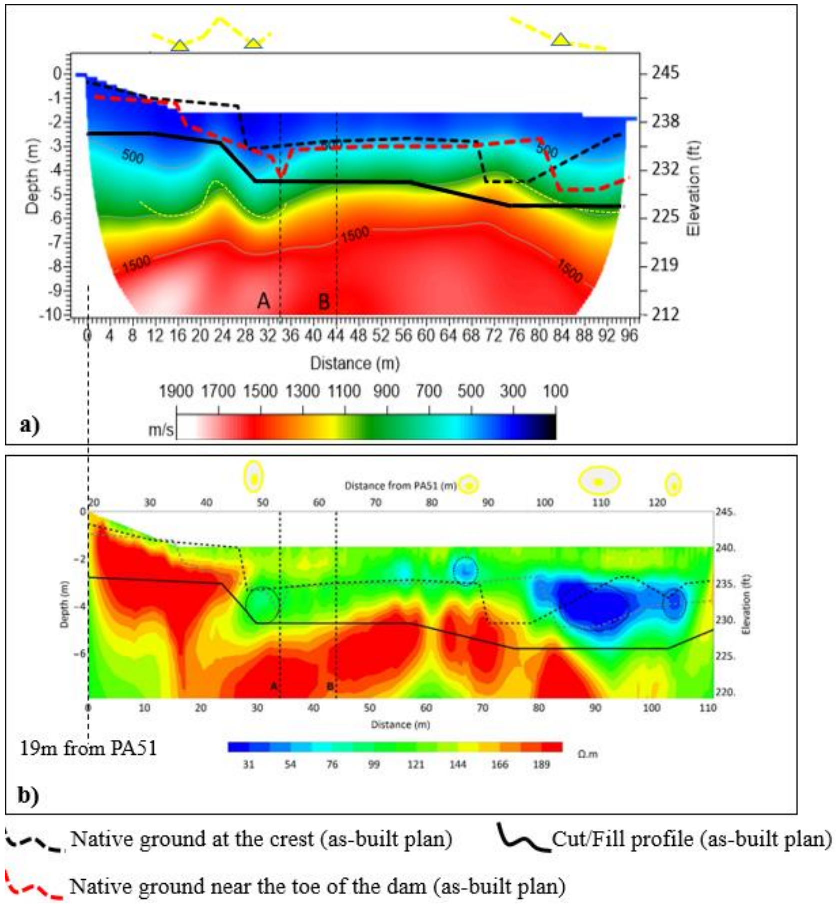

Figure 4: a) P-wave velocity tomogram and b) resistivity tomogram for line 3 (toe). There is a sharp draw-down in the 500m/s and 1000m/s contour lines along intersection point A between depths 2m to 5m. Resistivity also drops near point A. A very shallow (at about 2m depth) circular low resistivity anomaly is present between 60m and 70m horizontal distance. There is also a large low resistivity anomaly extending from 85m to 105 m within the dam body.

Conclusions

To summarize the results of the geophysical investigations, the anomalies identified in the different surveys are displayed both on planar view, using the present day aerial photograph (Figure 5) and in cross section (Figure 6).

The planar distribution highlights that both ERT and SRT anomalies group in two particular areas of the dam: group A and group B. Both groups appear to follow the pre-impoundment surface hydrology, in fact, both groups line up close to the position of the old creeks. Within both zones, geophysical anomalies appear to be present from the waterside through to the dam toe; this is particularly evident for group B, where low resistivity anomalies, that might be indicative of active fluid flow, extend across the dam body. The location of the electrical anomalies in zone B project quite well to the sand boil location but are barely on the left boundary of the seasonal stream path. However, one needs to consider the accuracy of geolocating information from 50-year-old as-built plans and topographic maps.

Figure 6 shows the distribution of geophysical anomalies, in group B, on a cross section of the dam from upstream to downstream. The geology displayed on Figure 6 is based on borehole PA50 (Figure 2) and the two horizontal dotted lines represent a range in depths of cut/fill profile at the crest using the elevations at 35m and 55m from PA51 (Sta 10+00) (Figure 2). Given the limited information, we project this interface horizontally from the upstream to downstream side requiring the cut/fill surface be level in that direction. That might not be the case. However, assuming a level cut/fill interface in the upstream to downstream direction the anomalies mostly occur at depth below the base of the dam. Therefore, the active seepage observed downstream is not coming through the dam but is occurring within the confined sand layer between elevations 225ft and 230ft. Allowing for uncertainty in depth of a few feet (~5ft) the flow could be occurring at the cut/fill interface and located at the lower hinge point in the upward transition of the abutment (see Figure 4).

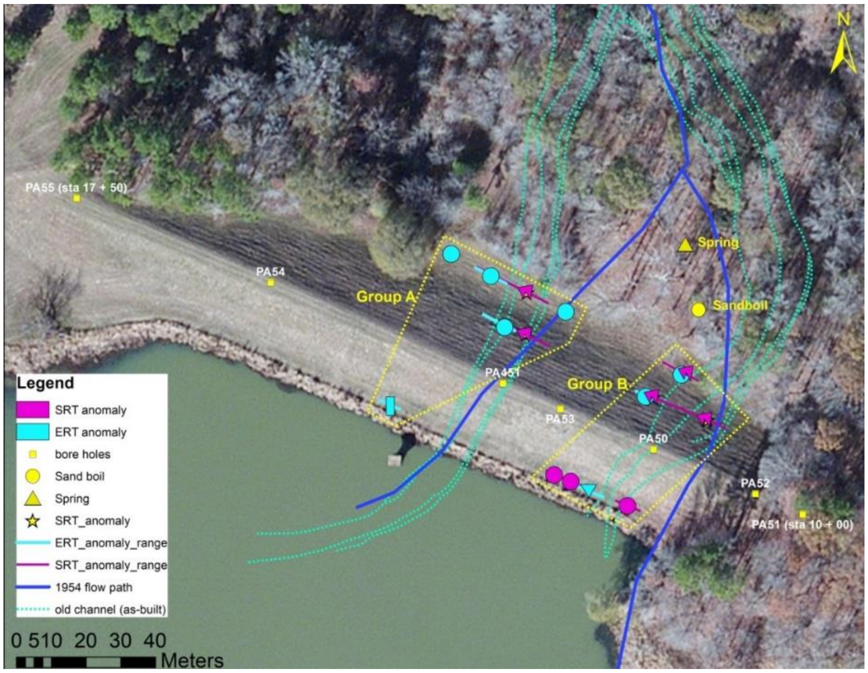

Figure 5: Planar distribution of geophysical anomalies obtained from SRT and ERT survey lines 1, 2, and 3 are shown on a Google Earth image. The two groups of anomalies (group A and group B) are distributed in close proximity to the old channels.

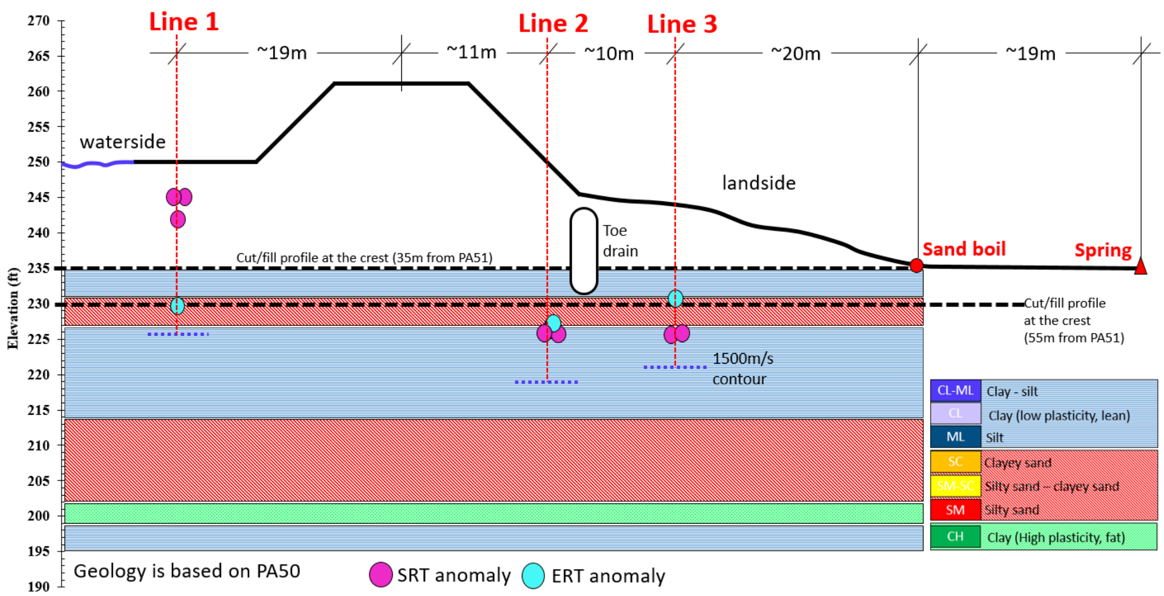

Figure 6: Vertical distribution of geophysical anomalies (group B only) obtained from SRT and ERT survey lines 1, 2, and 3 are shown on a cross-section (upstream to downstream) of the dam. Except for line 1 SRT anomalies, the anomalies occur at depth below the base of the dam indicating no seepage through the body of the dam.

References

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Acknowledgment

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