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Application of Multi-Channel Analysis of Surface Waves Method to Determine Optimum Parameter Settings in Karst Terrain in Southwest Missouri

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Abstract: ***Active MASW data were acquired in karst areas in southwest Missouri in an effort to characterize the parameter settings of multi-channel analysis of surface waves. Our experience falling behind the quality of MASW data acquired is highly variable, especially where soils are less than 30 feet thick. In an effort to determine why the quality of active MASW data acquired in karst terrain is frequently highly variable, we acquired Electrical Resistivity Tomography (ERT) data along linear traverse at study location to find the parameter settings of MASW. The MASW data profiles were acquired at multiple locations along ERT traverse. The data acquisition of MASW were performed by using a 24-channels geophone and both 2.5 feet geophone spacing and 5 feet geophone spacing. In order to confirm the accuracy of parameter settings we made the depth of bedrock as a standard, this depth should have to be comparable on both MASW and ERT data. After comparing MASW and ERT data results, it is determined that smaller geophone spacing, and off-set distance recommended in karst terrain.***

Keywords: MASW, ERT, Karst Terrain, seismograph, Missouri

1. Introduction

1.1. Overview

Missouri is generally known as the state of caves, there are many karst terrains discovered in study area. The formation of karst terrain happens when a part of sedimentary rock is dissipated by the feat of groundwater. In (Figure.1) an area shown is categorized byunderground caves, fissures, and sinkholes. Karst is the most challenging environment in terms of groundwater engineering and environmental issues (W. Zhou and B. F. Bec 2011). The strength of soil ominously affects due to the continual drainage through karst soil subsoil, this changes the shape and size of karst voids. The variation in karst soil strength add more problems for engineers in the building of diverse transportation infrastructure components (M. Dhital and S. Giri 2011, P. Gautam, S. Raj Pant, and H. Ando 2000).

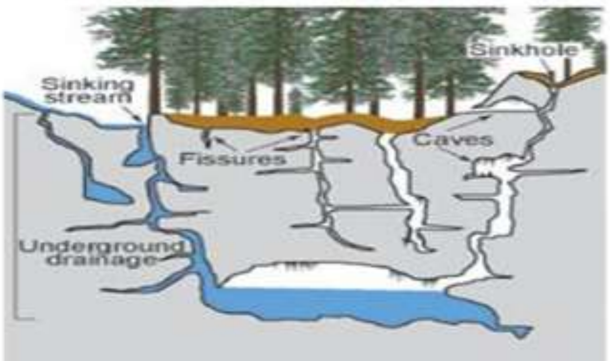


Figure 1: Formation of Karst Terrain (Environmental Science Institute, 2012).

There are several geotechnical and environmental problems that belongs to land usage in Karst areas [1]. No matter karst structures are uncovered or not, the structures build on karst always remain under threat these structures can be buildings, agricultural farmland, infrastructures, and railways. It is the understanding of engineers to ensure construction in karst areas can associate with many engineering challenges, such challenges can be dreadful failure of the ground surface or a deliberate invisible subsidence, these failures can easily disturb the foundation system of the structures and eventually collapse will occur due to subsidence. The area lie beneath the carbonate rocks has the tendency to form enormous cavities may lead to either a continuing ground subsidence because of the gradual movement of fine grains from the subbase or to an abrupt and tragic pavement failure such as a sinkhole [1, 4]. Therefore, picking a correct geophysical method of investigation plays an important role to acquire useful results in karst topography.

The purpose of this study was to illustrate how parameter settings of MASW method can be used in karst terrain. Using MASW method in karst is challenging because of the unpredictable depth to bedrock and soil thickness. The properties of soil play an essential role when construction starts in karst environment. In MASW method elastic properties of surface waves are used for imaging the subsurface while dispersive properties are utilized to attain shear wave velocity (Vs) profiles. The values of shear wave velocity (Vs) are directly correlated to its shear modulus which attest how the soil will respond through dynamic loading. Karst features such as underground cavities, jointing and subsidence heavily effect to evaluate the shear-wave velocity due to high signal to noise ratio (S/N). High signal to noise ratio (S/N) can be overcome during data acquisition and processing by proper arrangements of parameter seating, it plays an important role on the quality of data.

The other geophysical method was used in this investigation is Electrical Resistivity Tomography (ERT). This technique was used to confirm the MASWshear wave velocity (Vs) results. The Electrical Resistivity Tomography (ERT) method was used to fully understand the karst features. This method images and differentiates the lateral variations of subsurface in study area, itmeasures the voltages associated with electric current flowing in the ground. These currents are categorized in two types these may be the natural currents or the currents introduced into the earth through electrodes. This study is an effort to enhance the understanding of choosing a result oriented parameter setting of MASW array in karst environment. Generally longer arrays are recommended in MASW method but in this investigation results did not achieve by longer array. The MASW and ERT results are followed by a discussion that demonstrate its worth for research in Karst environment.

1.2 Study Area Description

The study site is located in Greene County close to the city of Springfield in southwest Missouri. Missouri state is mostly lie beneath the carbonate rocks and known as a karst terrain. The development of karst in Missouri occurred where Mississippian limestone and Ordovician and Cambrian age dolomite. The study area consists of two main physiographic regions; the Salem Plateau and Springfield Plateau. The area we studied in this paper comes in

Springfield Plateau. Bedrock in this study area is the Mississippian Burlington-Keokuk Limestone, about 150ft-270ft. thick. It is characterized by karstic features such as underground caves, losing streams, solution-widened joints, and sinkholes. Below the limestones and cherty limestones of the Burlington-Keokuk are Ordovician and Cambrian-aged strata. The depth to top of rock is 5-35 feet. Additional demands and concerns need to deal when selecting the parameters settings of a geophysical method in strength variant karst soils.

2. Data Acquisition

2.1ERT Data

The acquisition of ERT data was performed with SuperSting R8 device along East-West traverses (Figure.2). A detailed subsurface coverage of the study area was required, in order to achieve this, we need high lateral resolution. For this purpose, we used dipole-dipole array. The measured length of the traverse was 835-ft, with the spacing of 5-ft 168 metal stakes were set up. There were eight cables spread along the array each cable consists of 21 electrodes. These electrodes were attached to the metal stakes.

2.2MASW Data

The MASW data were acquired at specific locations perpendicular to ERT traverse (Figure.2). Data were acquired using twenty-four 4.5 Hz geophones spaced at 2.5 ft. intervals, a 20-pound sledge hammer source and an aluminum strike plate. Where necessary, MASW data acquisition locations were shifted because of access issues (ponded water, roadways, dense vegetation, etc.). The MASW data were acquired with primary goal of determining the parameter settings in karst terrain. These MASW parameter settings will evaluate by finding the top of rock depth through shear wave velocity value and confirm this depth by comparing results with ERT profile.

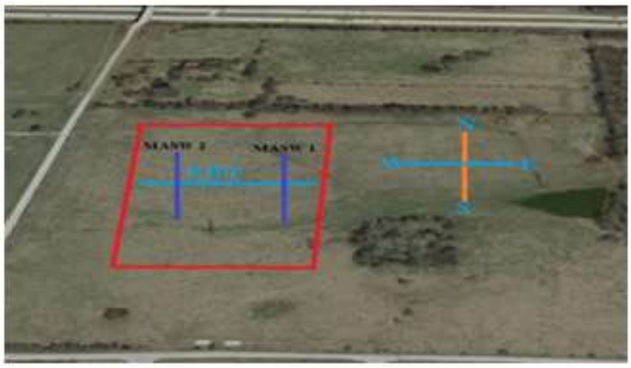
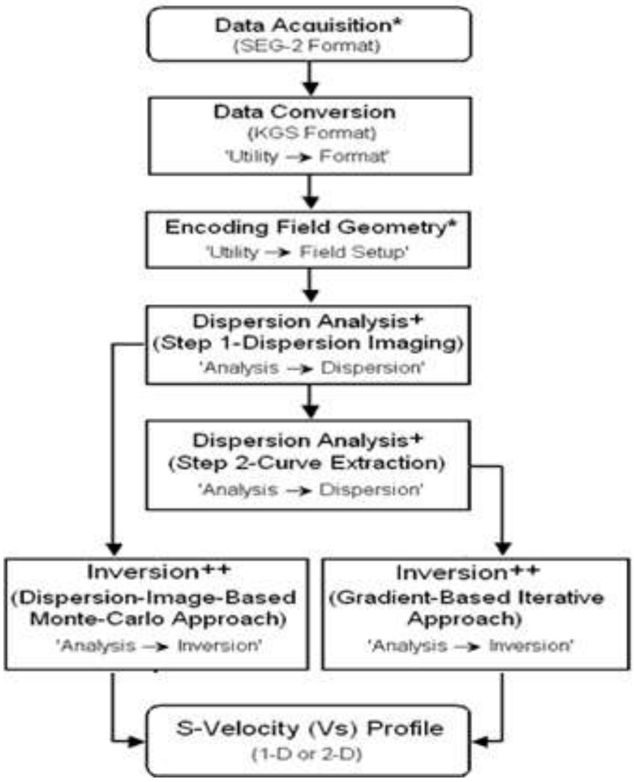


Figure 2: ERT East-West traverse and MASW North-South, courtesy to google earth.

3. Data Processing and Inversion

In order to transfer field data to estimates shear wave velocity, three steps have been performed: first processed the field data to get frequency and phase velocity of surface wave for attaining the dispersion curves, second recognition of fundamental mode, and inversion of fundamental mode curve into an illustrative shear wave profile.Surfeis software package was used for the processing of MASW data developed by the Kansas Geological Survey. The first step of data processing is uploading the SEG-2 field records in Surfeis. Then convert these records into KGS format (flowchart.1) provides a flow chart for evaluating MASW profiles. The algorithms in the Surfeis are used to evaluate each KGS file and define the properties phase velocity and frequency of surface wave, and used to draw descriptive dispersioncurve (Park et al., 2009).



Flow chart 1: A step by step approach for data processing and analyzing MASW profiles (Kansas Geological Survey, 2014)

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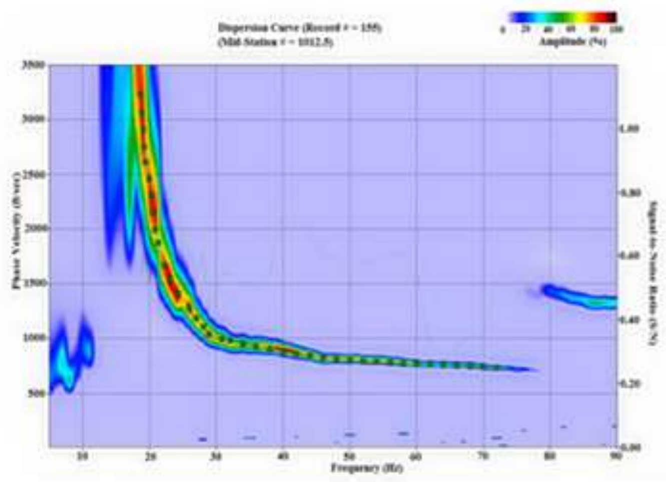
The AGI administrator software was used to perform data processing and inversion while AGI EarthImager 2D analysis software was used to download and convert field data in readable data files. To recreate an earth model the EarthImager 2D software used calculated apparent resistivity during the inversion process (Advanced Geosciences, Incorporated, 2009).

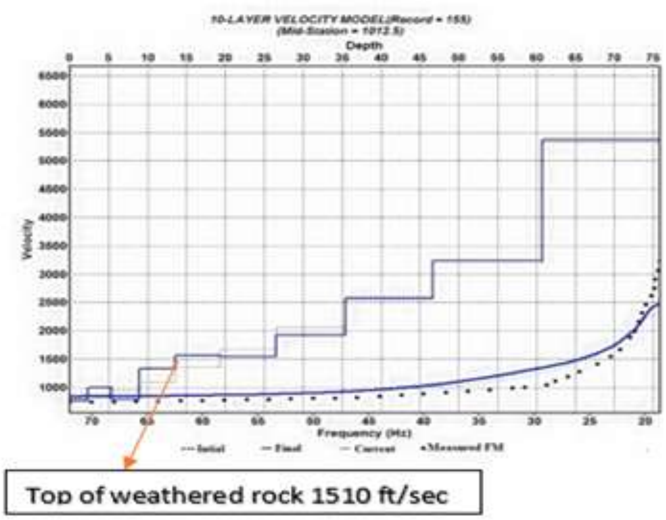
4. Results and Discussion

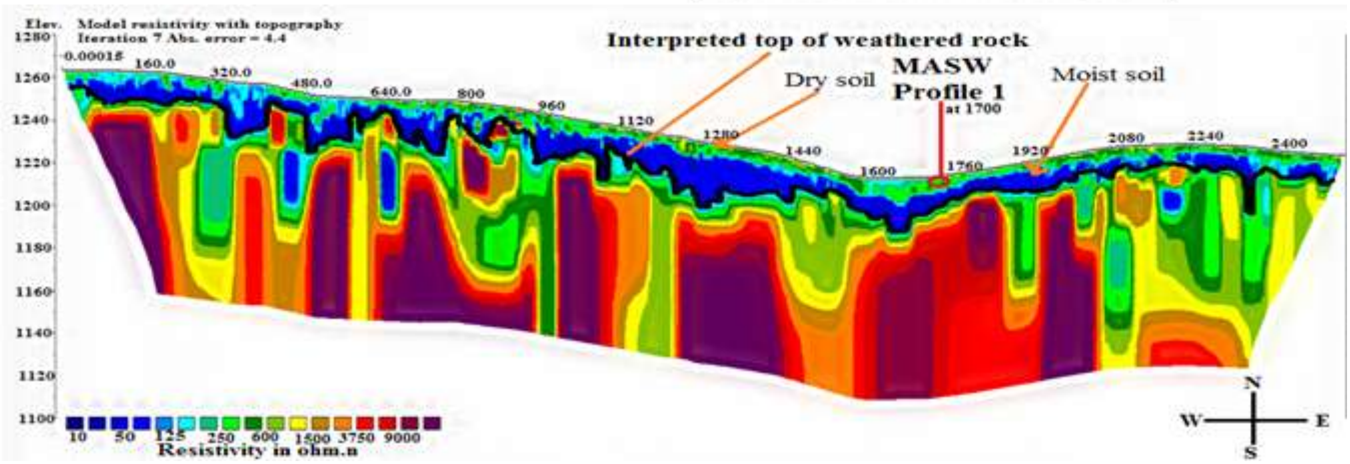
The shear wave velocity (Vs) of MASW profiles was used to confirm the depth of bed rock. The accuracy of shear wave velocity (Vs) profile entirely rely on the generation of a decent quality dispersion curve, which is very important step confronted during processing of surface wave data profiles. The good quality and accuracy of dispersion curve can be achieved through noise free field data. The results of two data sets with 2.5 ft. spacing and 10 ft. off set distance are presented here as an emphasizing the salient features of MASW using shorter array in karst and then compared the MASW and ERT. Although, figure. (3b) and (4b) shown 10layervelocity models, only three/four layers were used to interpretation of shear wave velocity images. In Figure (3b) the first layer velocity (Vs) range in 600-1000 ft./s identified the soil thickness of this layer is 5-6 ft. followed by dripping wet sand /silt/clay zone with a velocity 1000-1350 ft./s covering the depth 6-13 ft. and then the following layer with 1500 ft./s velocity corresponding with depth to top of weathered bed rock. This depth to bed rock was confirmed through ERT interpreted profile in Figure. (3c). These results of MASW and ERT are described in (Table.1).

(3a)



(3b)





(3c)

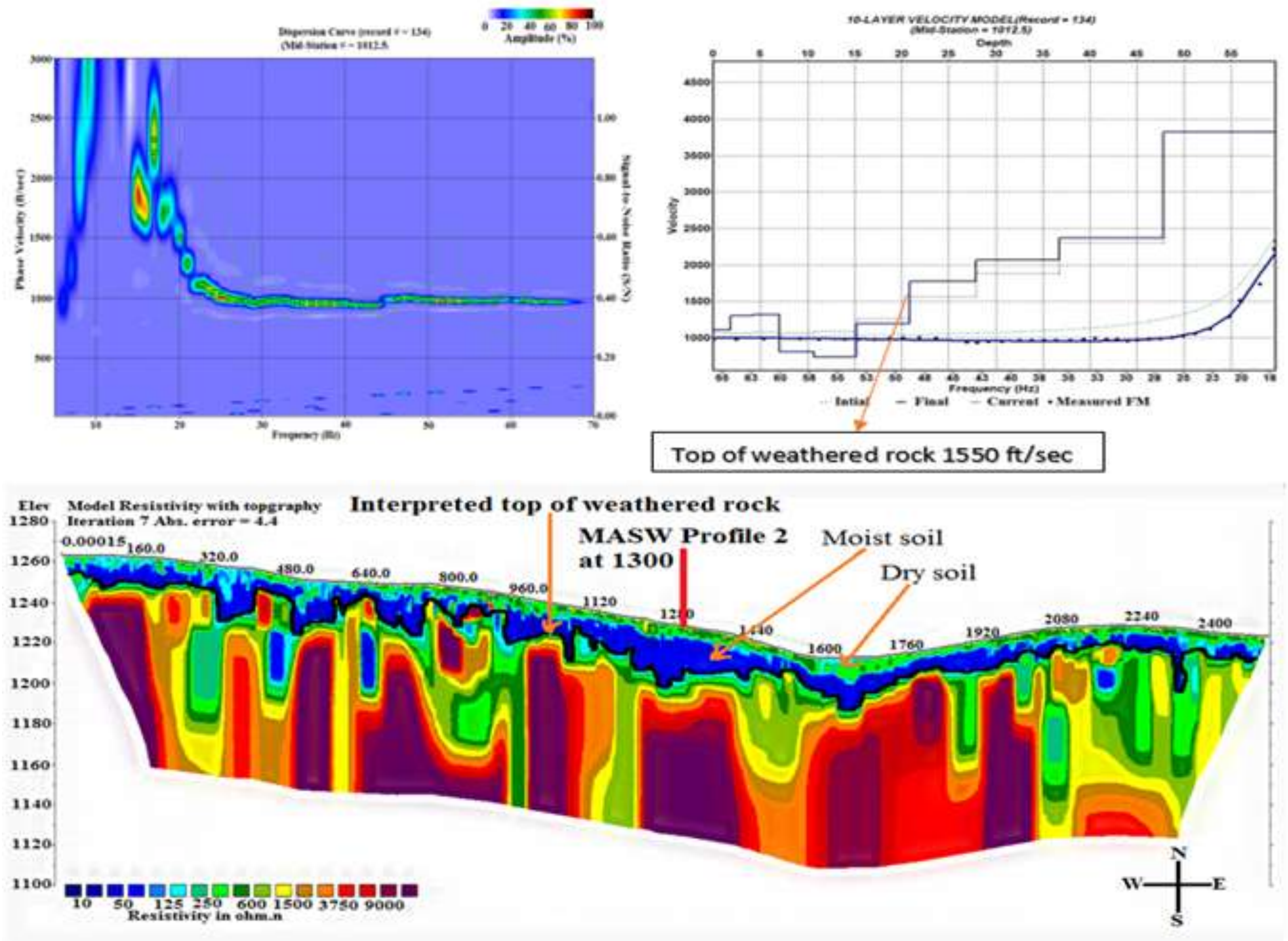
Figure 3: (a) MASW dispersion curve (phase velocity versus frequency); (b) 1-D shear-wave velocity model of profile 1 (derived from dispersion curve); (c) ERT data profile along traverse trending East-West

Table1

Profile 1	Depth to Top of Rock (feet)	Estimated Soil Velocity (feet/second)	Frequency Range (Hz)
MASW profile 1	13 (MASW-estimate of depth to top of rock)	1000	22-72
ERT (ties @ ~1700 feet mark)	14 (ERT-estimate of depth to top of rock)		

Similarly, in Figure (4b) the first layer velocity (Vs) range in 1100-1300 ft./s identified the soil thickness of 6-7 ft., this layer followed by wet sand /silt/clay zone with a velocity 600-1200 ft./s covering the depth 8-20 ft. and then the following layer with 1200-1700 ft./s velocity corresponding with depth to top of weathered bed rock. This depth to bed rock was confirmed through ERT interpreted profile in Figure(4c). These results of MASW and ERT are described in(Table.2).

(4a) (4b)



(4c)

Figure4: (a) MASW dispersion curve (phase velocity versus frequency); (b) 1-D shear-wave velocity model of profile 1 (derived from dispersion curve); (c) ERT data profile along traverse trending East-West.

Table 2

Profile 2	Depth to Top of Rock (feet)	Estimated Soil Velocity (feet/second)	Frequency Range (Hz)
MASW Profile 2	21 (MASW-estimate of depth to top of rock)	1100	15-68
ERT (ties @ ~1300 feet mark)	20 (ERT-estimate of depth to top of rock)		

When weused the 5-ft. geophone spacing and off-set distance 10ft. and 30ft at the locations of MASW profile 1 and 2, the estimated depth to top of bedrock was found 26-ft.This depth to top of the rock did not match with the ERT result which presented the depth range from 14-ft. to 20-ft. Therefore, these parameter settings cannot image the subsurface properly in karst environment. The example of 5 –ft. geophone spacing used has shown in figure. (5a, 5b).

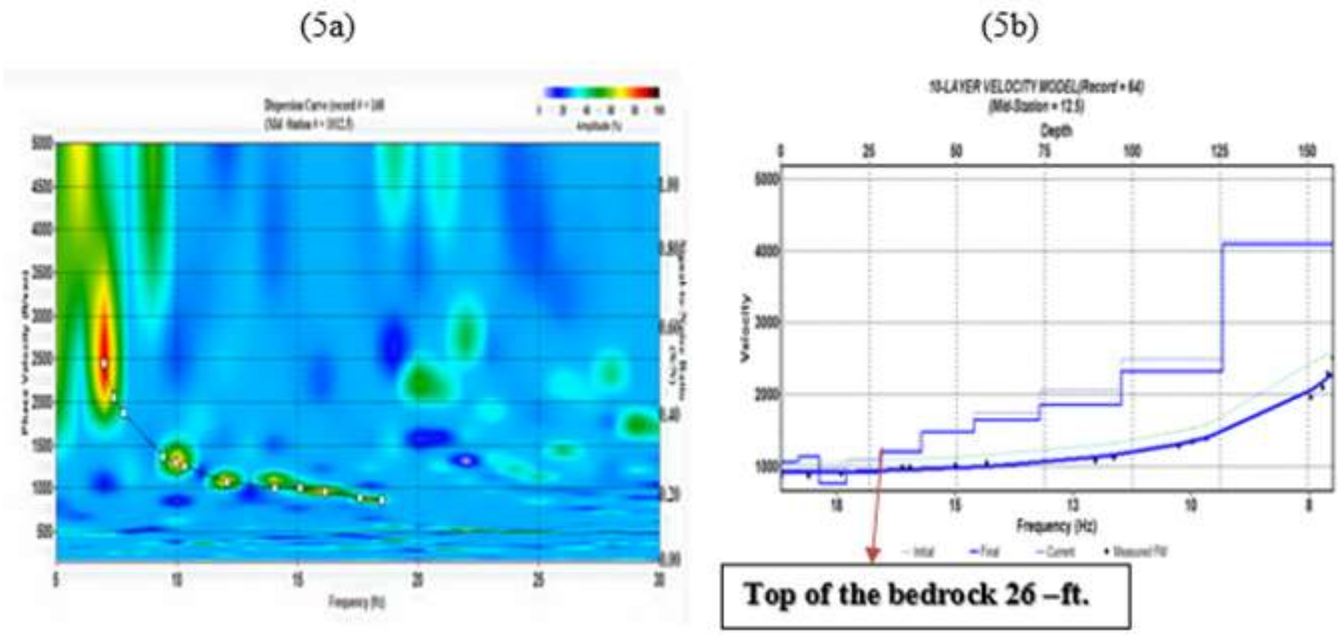


Figure 5: (a) MASW dispersion curve (phase velocity versus frequency); (b) 1-D shear-wave velocity model of profile 1 (derived from dispersion curve)

5. Conclusions

Our conclusion was drawn on comparative analysis of depth to bedrock on MASW and ERT. It is concluded that the Optimum Parameter Settings in Karst Terrain depends on three factors. These three factors are orientation of traverse, geophone spacing and offset distance. In this study the top of bedrock is ranges between 14-21 ft., these results were gained through 2.5 ft. geophones spacing and 10 ft. offset distance. The range of bedrock depth is confirmed by interpreted ERT data profile. Normally, the users of MASW method recommend longer geophone spacing and offsets distance to get precise results. On the contrary in karst terrain smaller geophone spacing and off-set distance is recommended because of rapid lateral changes in depth to bedrock.

References

[1] Karst Topography: Noninvasive Geophysical Dectection Methods and Construction Techniques. Prepared By: The University of Virginia.

[2] Richard D. Miller, Jianghai Xia, Choon B. Park, And Julian M. Ivanov, Multichannel Analysis of Surface Waves to Map Bedrock, Kansas Geological Survey, Lawrence, Kansas, U.S.

[3] Martina Armstrong, Multichannel Analysis of Surface Waves (MASW) determined surface-wave velocity profile and its relation to observations of the near-surface polar firn layers GCAS 2008/09.

[4] Jeffery J. Nolan*, Steven D. Sloan, Seth W. Broadfoot, Jason McKenna, and Owen M. Metheny, Near-surface void identification using MASW and refraction tomography techniques US Army Engineer Research & Development Center.

[5] Neil Anderson, David Hoffman Wanxing Liu, Dr. Ronaldo Luna, Dr. Richard Stephenson and Thanop Thitimakorn. Comprehensive Shear-Wave Velocity Study in the Poplar Bluff Area, Southeast Missouri

[6] Surface Geophysical Methods, Volume 1, Fall 2004

[7] Multichannel Analysis of Surface Wave (MASW) Method for Geotechnical Site Characterization Dayakar Penumadu1 and Choon B. Park2

[8] Environmental Science Institute. The Features of a Karst System. University of Texas at Austin, 2012 http://www.esi.utexas.edu/outreach/caves/karst.php. Accessed May 3, 2013.

[9] Thanop Thitimakorn, Ahmed Ismail, Neil Anderson, and David Hoffman, 2009: Mapping a NEHRP Site Class Using Multi-Channel Analysis of Surface Waves (MASW) Method in Southeast Missouri, USA. Bulletin of Earth Sciences of Thailand (BEST), Vol.2, No.1, p.31-39.

[10] Orndorff, W. VA Counties Containing Karst Topography. Richmond, VA: Virginia Department of Conservation and Recreation, 2013 http://www.dcr.virginia.gov/natural_heritage/karsthome .shtml. Accessed August 1, 2013.

[11] Neil l. Anderson, Ahmed Ismail, and Thanop Thitimakorn, 2007: Ground-Penetrating Radar: A Tool for Monitoring Bridge Scour, Environmental and Engineering Geosciences, Volume 13, p.1-10.

[12] Thanop Thitimakorn, Neil Anderson, David Hoffman and Ahmed Ismail, 2006: A Comparative Analysis of 2-D MASW Shear Wave Velocity Profiling Technique, Electronic Journal of Geotechnical Engineering (EJGE), Volume 11-Bundle A, p.1-17.

[13] Choon B. Park, Richard D. Miller, Jianghai Xia, And Julian Ivanov, Multichannel Analysis of Surface Waves (MASW) Active and Passive Methods Kansas Geological Survey, Lawrence, USA

[14] Jeffery J. Nolan*, Steven D. Sloan, Seth W. Broadfoot, Jason R. McKenna, and Owen M. Metheny, Near surface void identification using MASW and refraction tomography techniques, US Army Engineer Research & Development Center

[15] Myat, M.T., Wamweya, A., Kovin, O., Anderson, N., & Robison, J.L, "Application of Electrical Resistivity

Method in Steeply Dipping Karst Terrain." Sinkholes and the Engineering and Environmental Impacts of Karst, 91-97, 2008.

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