Revealing Pathway of Leakage Under a Small Pond, Using Dipole-Dipole Resistivity and Shallow Seismic Reflection; A Case History at Tum Huai Luk Project, Chiang Mai, Thailand.

N. Poomvises, N. Sangthong and A. Kongsuk
Geophysics group, Geology Section, Office of Topographical and Geotechnical Survey, Royal Irrigation Department, Bangkok, Thailand

ABSTRACT

Dipole-dipole resistivity and shallow reflection seismic surveys were used to delineate the water leakage of a small buffer pond that is used as a water reserve, the water coming from an upstream cave. The surveys included 11 resisitivity profiles and two seismic profiles. The resistivity profiles show that there are three shallow layers underlying the buffer pond. These layers are nearly flat-lying and are interpreted to be a sequence of unconsolidated and semi-consolidated sediments. Inversion modeling of apparent resistivity, combined with discontinuity tracing on stacked seismic sections, shows that water movement is southwest to northeast and that downward leakage is along fractures.

KEYWORDS: Dipole-dipole survey, shallow reflection seismic survey, leakage, inversion modeling, Huai Luk cave.

BACKGROUND

Storing water in limestone reservoirs is very difficult, with the possibility of failure being much greater than the possibility of success. An exceptional case of this was a cave impounding water project under his Majesty, King Bhumibol, and which was overseen by Her Royal Highness Mahajakri Sirinthorn. This project was at the Tam-Huai-Luk cave, where water from a small stream flows in at the cave's western end as a water fall. This water fills cavities, though some water escapes through fractures. Some water flows out of the eastern end of the cave, but only in the rainy season, and this especially 2 to3 days after a heavy rainfall. The eastern end of cave is in Tambol Ping Kong, Chiang Dao District, Chiang Mai Province and is approximately 2 kilometers from the west side of highway 107 at kilometer stone 90. Figure 1 shows the location of the cave and its geological setting.

The cave is approximately 600 meters long, trends east-west, and is in a north-south ridge of Permian limestone. This limestone mountain is underlain by a sequence of Carboniferous sandstone, siltstone, shale, and mudstone. Basement in this area is Ordovician limestone. The deposit in front of the cave is mostly transported sediment, being a mixture of boulders, cobbles, gravel, sand, silt, and clay. The study area is mainly a combination of alluvial fan and talus deposits that cap Permian limestone.

Figure 1. Location, topography, and geology of the study area.

The project of impounding water in the cave involved having a limestone reservoir and constructing a concrete dam, a buffered pond, and a water distribution system. Water was first stored in the cave in 2005 and met the goal of 20,000 cubic meters. However, the buffer pond, which was outside of the cave, did not work properly and caused trouble in the distribution of water to farmers downstream. The serious problem was water leakage out of the buffer pond, so much so that this leakage emptied the buffer pond.

The buffer pond is made of specific soil material and is situated 20 meters northeast of the concrete dam. Its floor is 583 meters above mean sea level, this being 10 meters lower than the concrete floor. Its area is approximately 4,800 square meters, it has an irregular in shape, and its long axis trends northeast. An earth dam obstructs an ancient stream at the northeast side of the pond. This dam is 100 meters long, 6 meters high, and has a spillway and a river outlet. The floor of the buffer pond was constructed by using a layer of compacted clay as a blanket. The dam was built of impervious material. At the end of the 2005 rainy season, the water level in the buffer pond began to drop approximately 10 centimeters each a day. There was no apparent cause for this, though possible causes could be leakage via the floor, the edges, and the dam body. After the pond was finally dry, small holes and traces of green grass were seen in the pond floor. These suggested that the pond floor should be checked as the possible leakage source. To do this, geophysical measurements would be needed.

INVESTIGATION AND RESULT

Two geophysics methods were used to determine the location of the leaking water in the buffer pond and the flow direction the leaking water. The first method was resistivity profiling using a dipole-dipole configuration to locate anomalous bodies of abnormally high or low resistivity in the depth domain. The second method was reflection seismic profiling to delineate discontinuities that could be interpreted as fracture zones. A match of any resistivity and seismic anomaly could, theoretically, indicate the location and direction of water leakage under the floor of the buffer pond.

The resistivity investigation consisted of 11 profile lines (Figure 2). This survey used a SYSCAL R1 switch, a French IRIS instrument, 24 nodes, 2.5-meter electrode spacing, and had a 20-meter penetration depth. Survey lines 1, 2, 3, and 4 were designed to check the lower edge of the pond on the floor level. Lines 1, 5, 6, 7, 8, and 9 were perpendicular to the axis of the buffer pond. Lines 10 and 11 were parallel to the pond's axis. The resistivity raw data were good and were modeled using RES2DINV processing software of M.H. Loake, GEOELECTRIC, Malaysia. Modeling results showed three different layers on most of the processed lines (Figure 3).

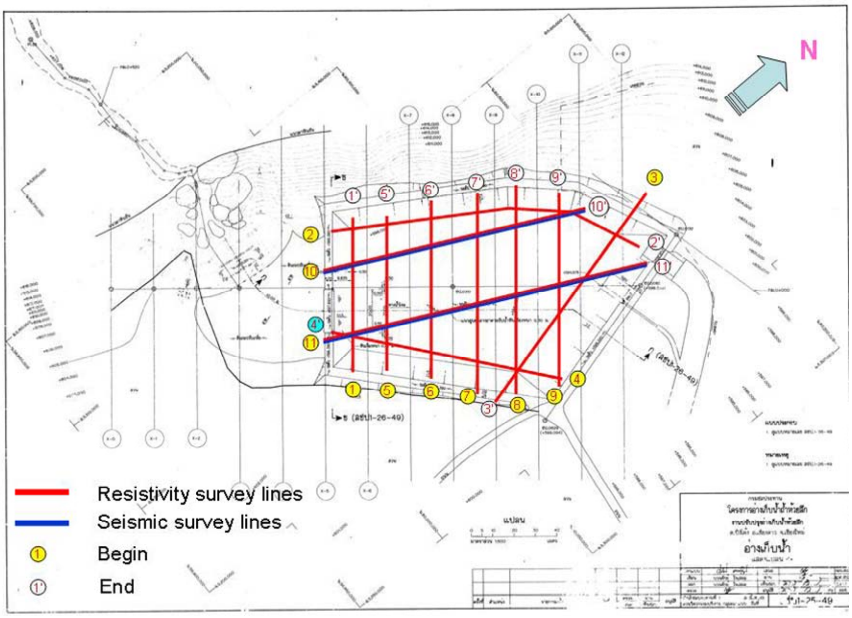

Figure 2. Geophysical survey lines

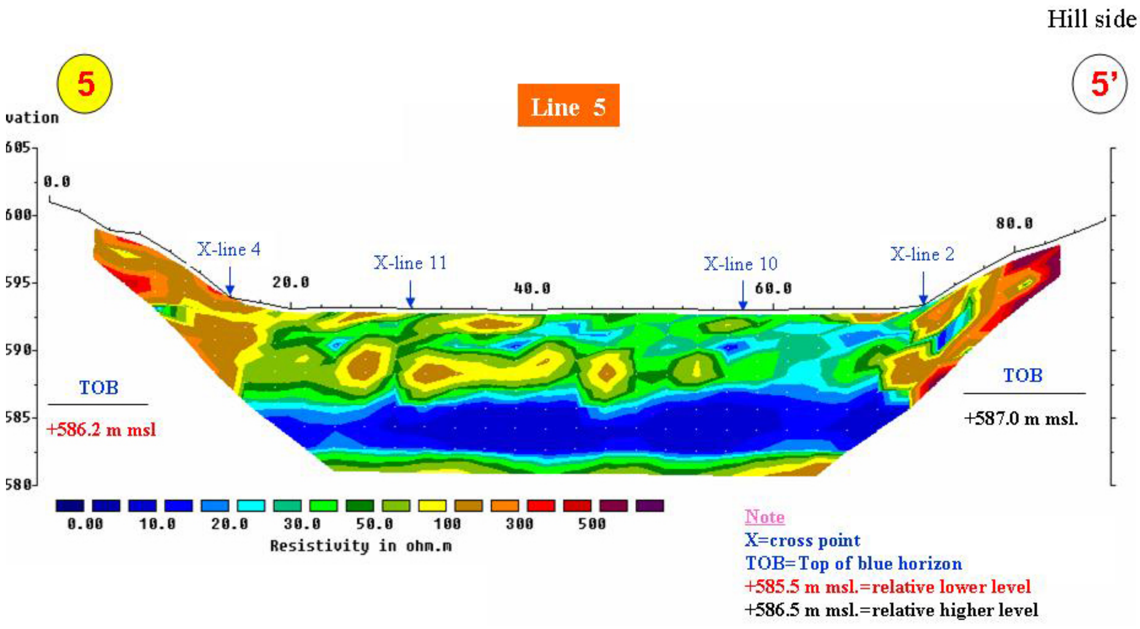

Figure 3. Typical three-layer model by inversion modeling in this study

The reflection seismic profiling was only done over lines 10 and 11 because a minimum line length was required for surveying. The other lines were too short. An elastic wave was generated using a hammer sound source. Recording was with a McSeis 170*f*, OYO, Japan, 12-channel recording instrument. Group spacing was 2.5 meters and the configuration was split-spread. Depth penetration of this seismic wave was approximately 30 meters. The resultant seismic records were processed using SEISTRIX E software from INTERPEX Co., Ltd., U.S.A. The time domain wavelets of the stacked seismic sections were rather low resolution, though with rather broad peaks. This was because of the 40 hertz dominant frequency generated by the hammer sound source. The time stacked sections were converted to depth sections to make the seismic and resistivity results comparable for interpretation. On these seismic depth sections, four horizons are evident from the top of the compacted soil to the top of the weathered rock. Discontinuities occur within these four horizons and were interpreted as fractures, fracture zones, and a possible sink hole (Figure 4).

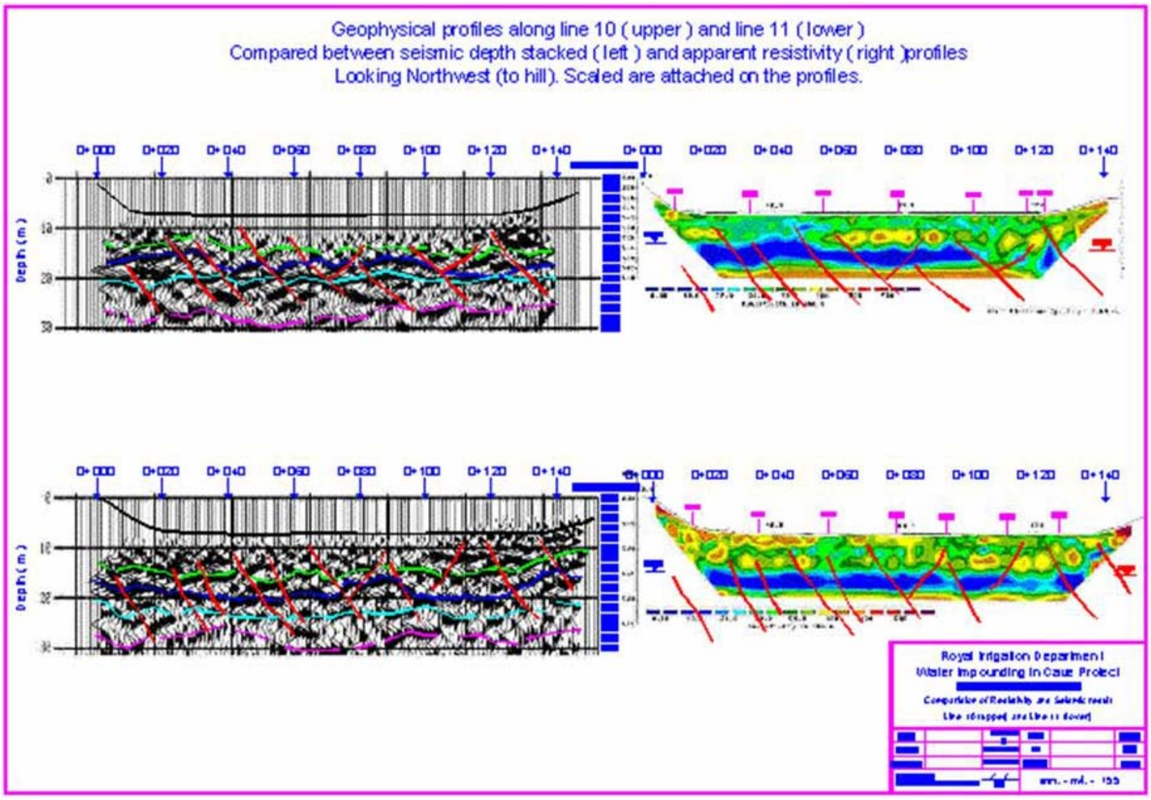

Figure 4. Comparison of geophysical results on lines 10 and 11

The results of the resistivity and seismic surveys have a close relationship. There are three different layers under the buffer pond. The topmost layer is a compacted clay blanket that receives various sizes of sediment during flooding in rainy seasons. The intermediate layer is a highly to completely weathered sedimentary rock. The third later, the basement, is moderately weathered sedimentary rock. The topmost layer is probably a pervious layer where water can flow along the trend of the brown to yellow shaded areas in Figure 5. The intermediate layer is probably an impervious layer of silt and shale and the basement is likely an impervious, high density layer. The fractures detected by seismic survey are probably the cause of leakage from the buffer pond, allowing water to move to the underlying basement. The two-dimensional dipole-dipole resistivity profiles were used to form fence diagrams, Figures 5 and 6. These diagrams show that the intermediate layer has good continuity and is, thus, an impervious layer. Water would flow on top of this layer. The gradient of the impervious layer was determined from the elevations of the top layer of the fence diagram profiles. The top of the intermediate layer is high in the west and low in the east, indicating that the intermediate layer slopes slightly to the east. The gradient of the top layer, the direction of seepage of the top layer, and the position and angle of dip of fractures indicate that water leaking from the top layer flows from southwest to northeast and that it goes down to the basement in the overlapping area of lines 8 and 9 with lines 10 and 11.

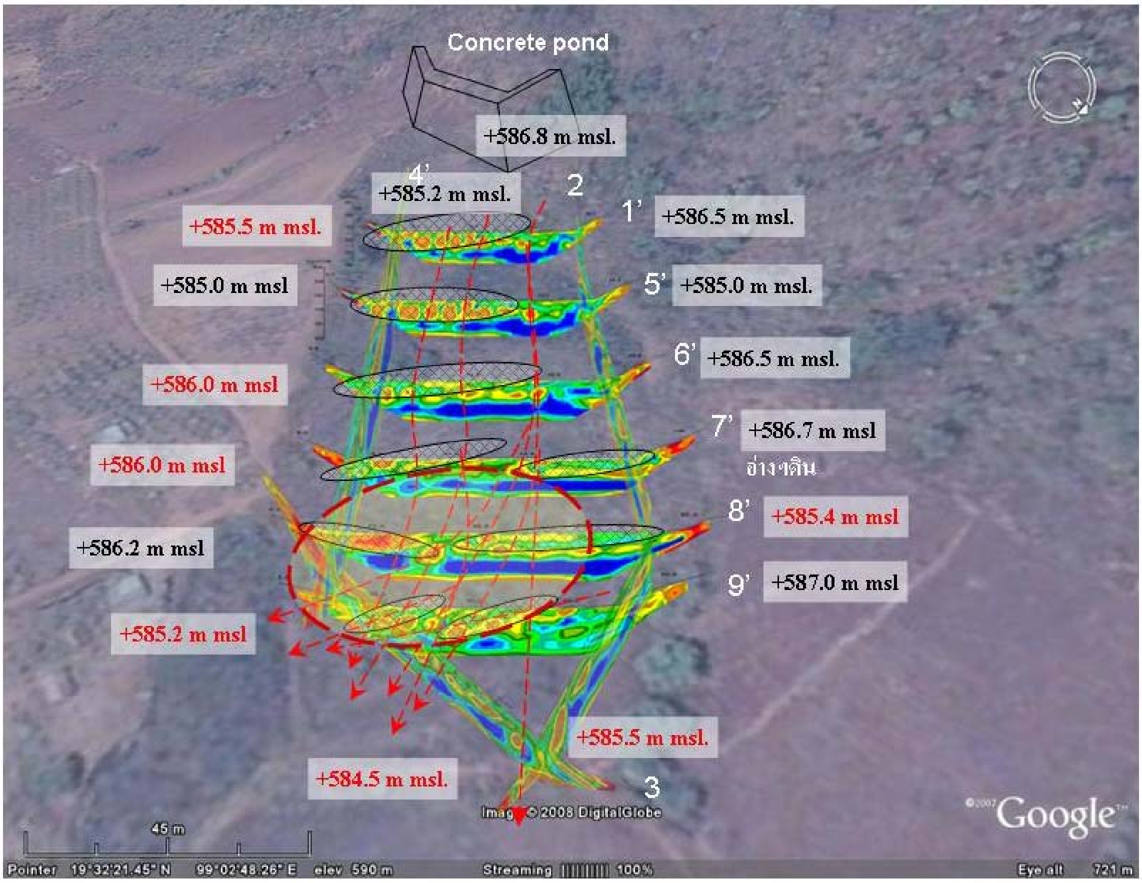

Figure 5. Fence diagram showing direction of flow along gentle slope

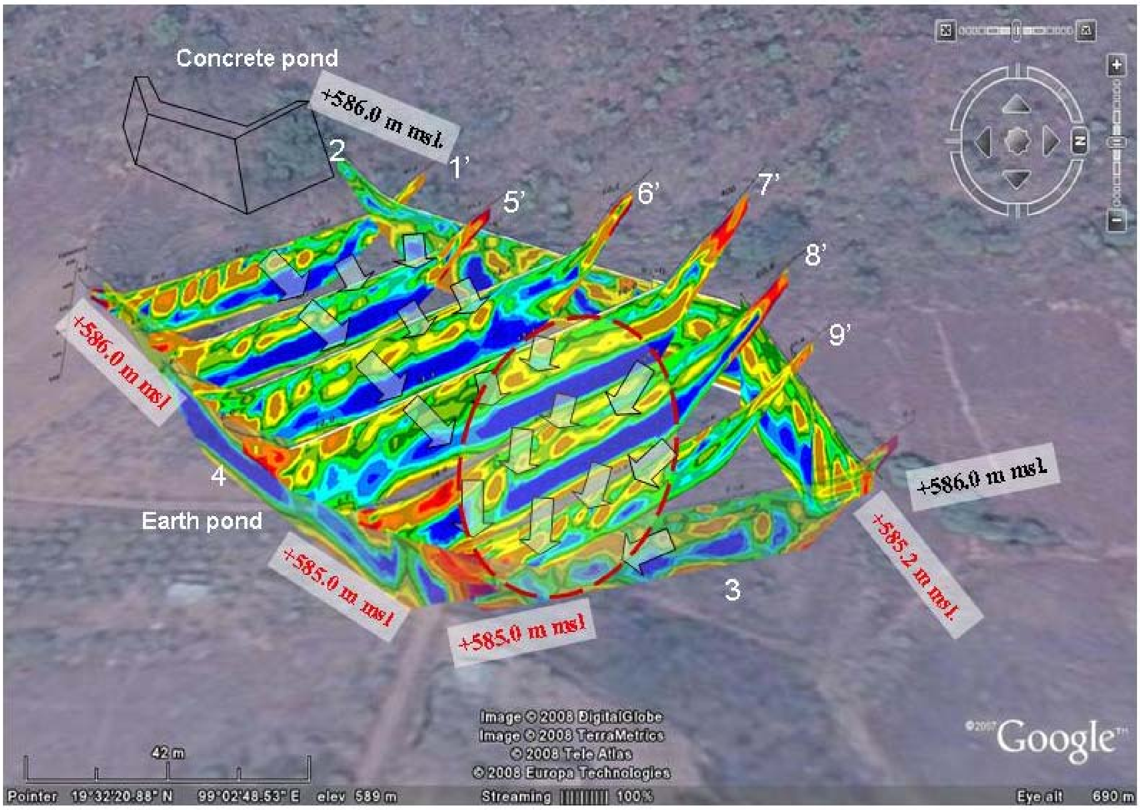

Figure 6 . Fence diagram showing an overlapping area where the water seeps downward

CONCLUSIONS

1. There are two main leakage paths in the study area:

(a) lateral leakage along the yellow to brown zone of irregular shape in the resistivity top layer (Figure 6) and

(b) vertical leakage along the fractures shown in stacked seismic sections (Figure 4)

2. The leakage pathway starts southwest of the earth pond, flows northeast in the top layer, and then goes down at the overlapping area of lines 8 and 9 with lines 10 and 11.

3. The combination of dipole-dipole and seismic reflection surveys was an effective method of determining water leakage and its pathway in the study area.

ACKNOWLEDGEMENT

The authors thank the Royal Irrigation Department and the Office of Topographical and Geotechnical Survey for permission to write and distribute this paper. Other persons also helped the authors during the survey and subsequent interpretation of the results.

REFERENCES

Cooray, P.G. 1989. Geoscientific writing and editing, AGID course notes no.2, 46p.

ICID, 1996. Guidelines to authors preparation of papers, 11p.

Matsubara, Y., Kudo, H., Makano, T. and Takeuchi, T. 1988.Geotechnical engineering investigation, lecture notes for advance course on seismic surveys, Irrigation Engineering Center, Royal Irrigation Department., 100p.

Milsom, J. 1996. Field geophysics, 2nd edn., John Wiley & Son press, 187p.

Mooney, H.M. 1980.Handbook of engineering geophysicists, Bison Inc. Co. Ltd., USA.

Royal Irrigation Department (RID). 2005. Feasibility report of water impounding in cave project under His majestic the King, Tum Huai Luk, Tumbole Ping Kong, Amphoe Chiang Dao, Chiang Mai, Thailand, Section of engineering and management, Royal Irrigation Department Regional office I, 60 p. (unpublished).

Sharma, P.V. 1997. Environmental and engineering geophysics, Cambridge press, 475p.

Telford, W.M., Geldart, L.P. and Sheriff, R. E. 1990. Applied Geophysics, 2nd ed., 77 p.

Yilmaz, O. 1987. Seismic Data Processing. The Society of Exploration Geophysicist, Tulsa, 526 p.