NCKRI Report of Investigation 3

Electrical Resistivity Survey of Intrepid Potash Injection Well Site: Eddy County, New Mexico

National Cave and Karst Research Institute

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NATIONAL CAVE AND KARST RESEARCH INSTITUTE
REPORT OF INVESTIGATION 3

ELECTRICAL RESISTIVITY SURVEY OF INJECTION WELL SITE: EDDY COUNTY, NEW MEXICO

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Front cover photo: Dr. Lewis Land analyzing data collected from an electrical resistivity survey of the Intrepid injection well site. Disturbed soil in the background is the product of the pipeline excavation that accidentally broke into a shallow cave formed in gypsiferous soil at the site. The AGI SuperSting resistivity meter is the yellow box on the ground next to Dr. Land.

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NCKRI Organization and Mission

NCKRI was created by the U.S. Congress in 1998 in partnership with the State of New Mexico and the City of Carlsbad. Initially an institute within the National Park Service, NCKRI is now a non-profit 501(c)(3) corporation that retains its federal, state, and city partnerships. Federal and state funding for NCKRI is administered by the New Mexico Institute of Mining and Technology (aka New Mexico Tech or NMT). Funds not produced by agreements through NMT are accepted directly by NCKRI.

NCKRI's enabling legislation, the National Cave and Karst Research Institute Act of 1998, 16 U.S.C. §4310, identifies NCKRI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and
6) promote and develop environmentally sound and sustainable resource management practices.

NCKRI Report of Investigation Series

NCKRI uses this report series to publish the findings of its research projects. The reports are produced on a schedule whose frequency is determined by the timing of the investigations. This series is not limited to any topic or field of research, except that they involve caves and/or karst. To minimize environmental impact, few or no copies are printed. Digital copies of this and previous reports are available for free at www.nckri.org.

Table of Contents

List of Figures

Electrical Resistivity Survey of Intrepid Potash Injection Well Site: Eddy County, New Mexico

Lewis Land and George Veni
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Introduction

In October 2012, Intrepid Potash Company was in the process of constructing a well pad, access road, and pipeline for an injection well as part of a larger potash solution mining project in eastern Eddy County, New Mexico. During excavation of the pipeline trench, Intrepid employees discovered a small cavity (Figure 1) that extended approximately 1 m below ground level and opened into a cave approximately 8 m long by 5 m wide and extending to a maximum depth of about 10 m. Observations of the cave interior (Figure 2) by Bureau of Land Management (BLM) personnel indicate that the cave is formed entirely in compacted gypsiferous soil, not bedrock, and that the cave might be deeper and more extensive than their preliminary examination indicated.

Ground penetrating radar (GPR) surveys conducted by Pettigrew and Associates (2012a, 2012b) showed anomalous features 1.5 to 3 m below ground level in the vicinity of the proposed revised pipeline route along the bypass road, shown in Figure 3, that may be caused by additional undiscovered deeper voids. BLM staff expressed concern about the risk of subsidence or catastrophic collapse during or after construction activities, and proposed that Intrepid conduct additional geophysical surveys to determine the extent of the cave that was discovered during excavation, and the depth and extent of the anomalies identified on the GPR profiles in the area.

Photo courtesy of James Goodbar, US Bureau of Land Management

Figure 1: *Cave entrance excavated during construction of pipeline ditch.*

Photo courtesy of James Goodbar, US Bureau of Land Management

Figure 2: *Cave entrance, view from near the bottom of the cave.*

The National Cave and Karst Research Institute (NCKRI) was contracted to conduct electrical resistivity (ER) surveys of the site to address the BLM's concerns. This report provides the results of those surveys, conducted over a period of three days from 24 to 26 October 2012.

Methods

NCKRI personnel Dr. Lewis Land and Dianne Joop, assisted by Intrepid staff, conducted 12 electrical resistivity surveys over and adjacent to the identified cave, and over the GPR anomalies using 56-electrode dipole-dipole arrays. The basic operating principal for electrical resistivity surveys involves generating a direct current between two metal electrodes implanted in the ground, while the ground voltage is measured between two additional implanted electrodes. Given the current flow and measured voltage drop between two electrodes, the subsurface resistivity between the electrodes can be determined and mapped. The resistivity method detects vertical and lateral variations in resistivity in the subsurface. Previous work has shown that resistivity surveys are one of the most effective methods for identifying air-filled voids in the unsaturated zone since air has near-infinite resistivity, in contrast with the more conductive surrounding bedrock. Depth of investigation is approximately one-fifth the length of the resistivity array. Closer spacing of electrodes generally provides higher resolution imagery of the subsurface.

NCKRI conducted four ER surveys on 24 October 2012 using 56 electrode arrays at 2 m spacing. On 25-26 October 2012, eight additional surveys were conducted using 56 electrode arrays at 1 m intervals to achieve better resolution of near surface voids. The positions of the survey lines relative to the cave, each other, and other features in the immediate area are shown in Figure 3. The ER surveys were conducted with an Advanced Geosciences Inc. Su-

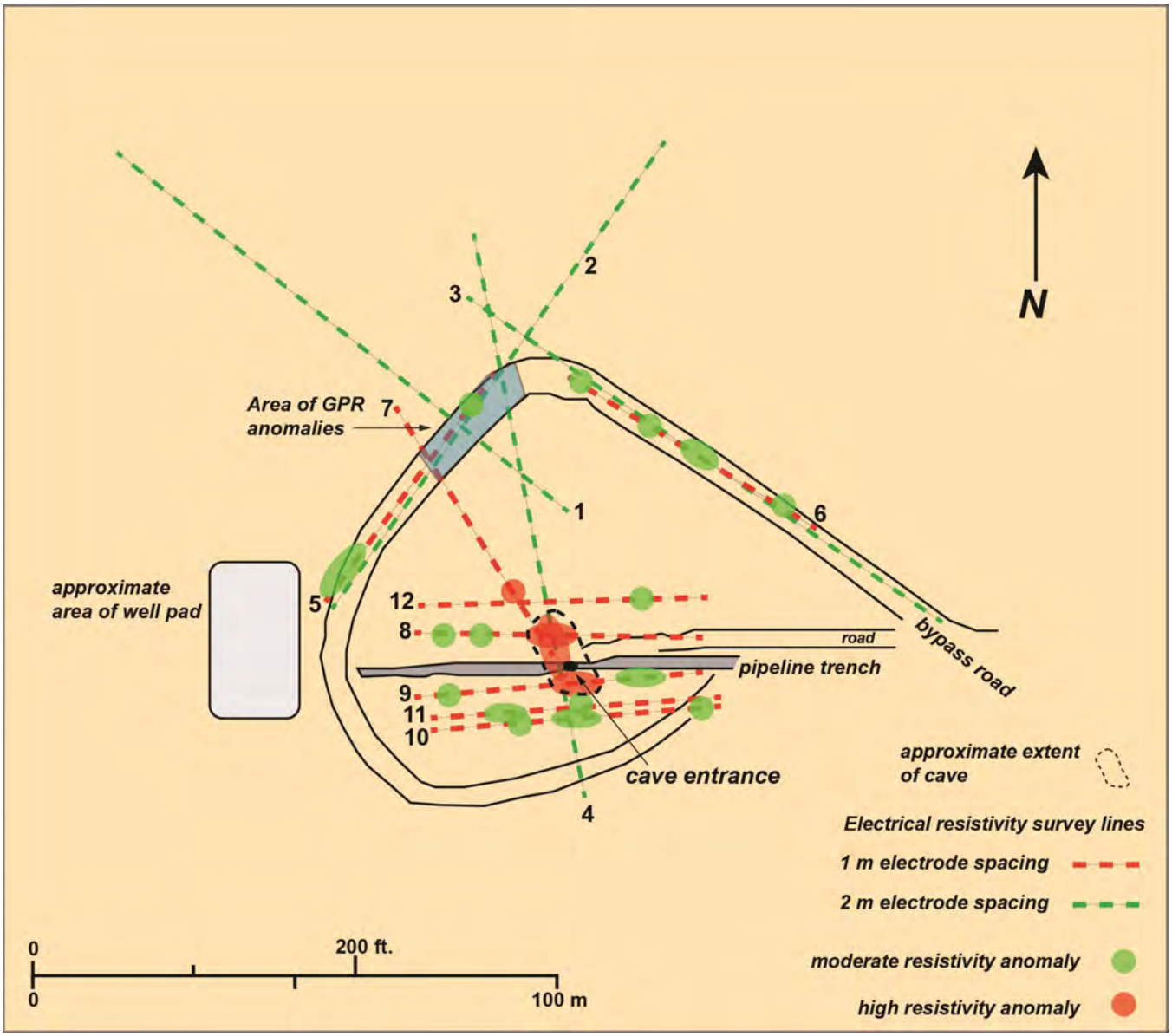

***Figure 3**: Map showing Intrepid Potash injection well site and electrical resistivity survey lines. Dashed line shows approximate extent of*

perSting R8/IP Earth Resistivity/IP Meter. The data were processed using EarthImager™ software, and terrain-corrected using data collected with a Topcon™ GR3 survey -grade GPS unit.

Results

The depth of investigation for ER survey lines 1-4 ranges from 18-27 m below ground level, and 10-14 m for lines 5-12. On all profiles warmer colors, yellow to red, indicate zones of higher resistivity, while cooler colors, blue to green, show zones of lower resistivity. Most of the lines show moderate to high resistivity features within 1-3 m of the surface. These probably represent small air pockets or air-filled porosity in the soil and are unlikely sites of significant collapse or subsidence.

ER Survey Line 1 extends SE-NW across the area where GPR anomalies were identified beneath the bypass road (Figure 3). There is no evidence on this line of any features that would likely cause significant collapse or subsidence (Figure 4).

Lines 2 and 5 extend parallel to the west leg of the bypass road and across the GPR anomalies (Figure 3) discovered by Pettigrew and Associates (2012b). Line 2 is the longer line and Line 5 overlaps the southwest half of its length with higher resolution imaging but at shallower depths (Figure 5). Lines 2 and 5 show moderate resistivity anomalies at 36 m, indicated by green to yellow shading. Line 5 also shows such an anomaly at 45 m and Line 2 at 62 m. These anomalies may warrant monitoring and possibly further investigation but do not seem likely sites of significant collapse or subsidence at this time.

Lines 3 and 6 extend parallel to the east leg of the bypass road (Figure 3). Line 3 is the longer line and Line 6 overlaps half its length along the middle of Line 3 with higher resolution but shallower imaging (Figure 6). Line 3 shows a moderate resistivity anomaly between 88 and 94 m, about 8 to 10 m below ground level. Line 6 indicates several moderate resistivity anomalies at 7, 28, 38, and 50 m. These moderate resistivity features warrant monitoring and possibly further analysis but do not seem likely sites of significant collapse or subsidence at this time.

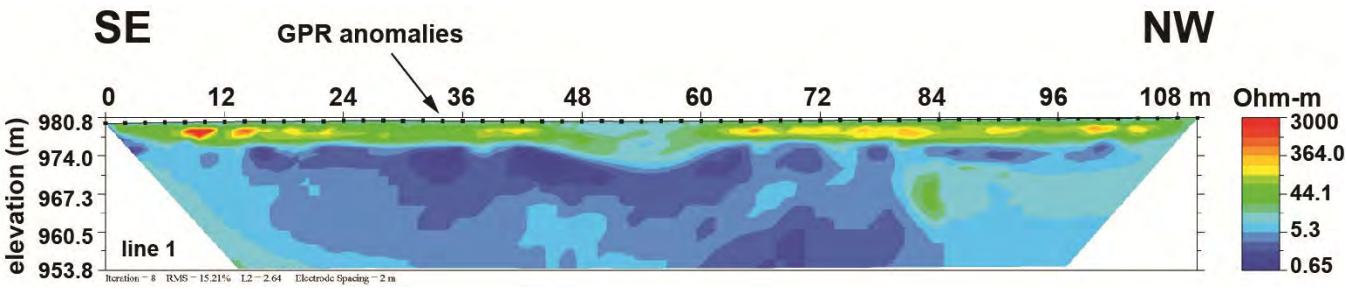

Figure 4: *Electrical Resistivity Survey Line 1*

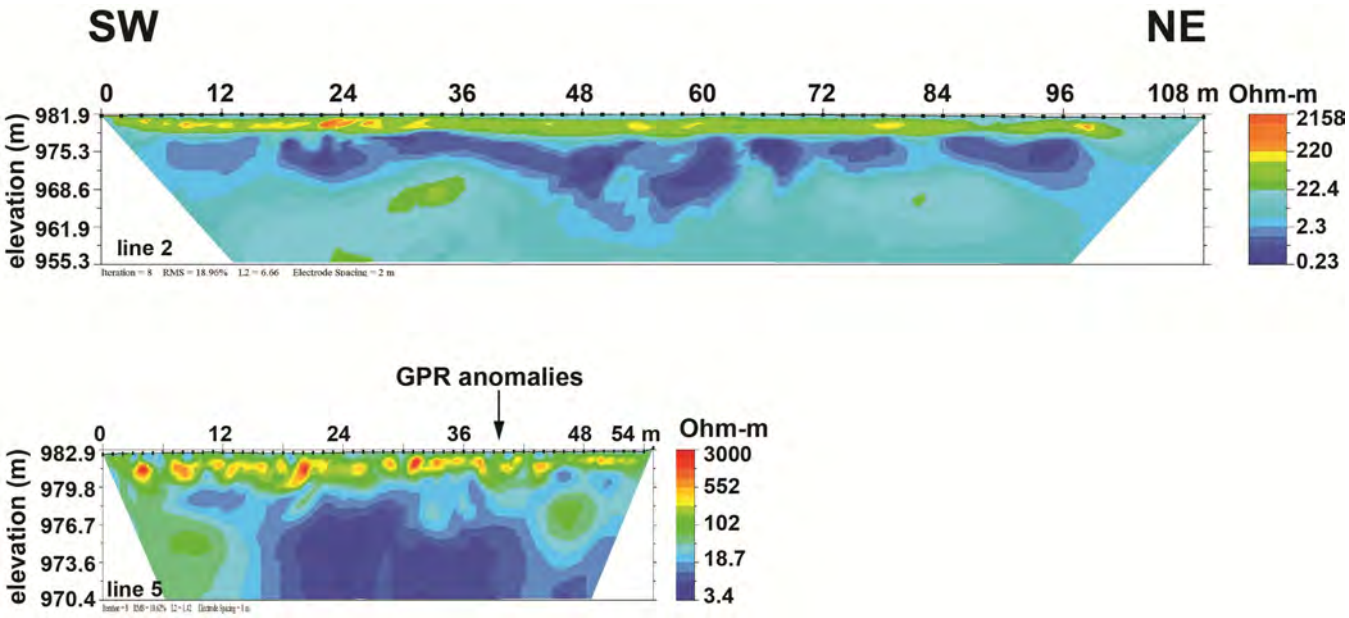

Figure 5: *Electrical Resistivity Survey Lines 2 and 5*

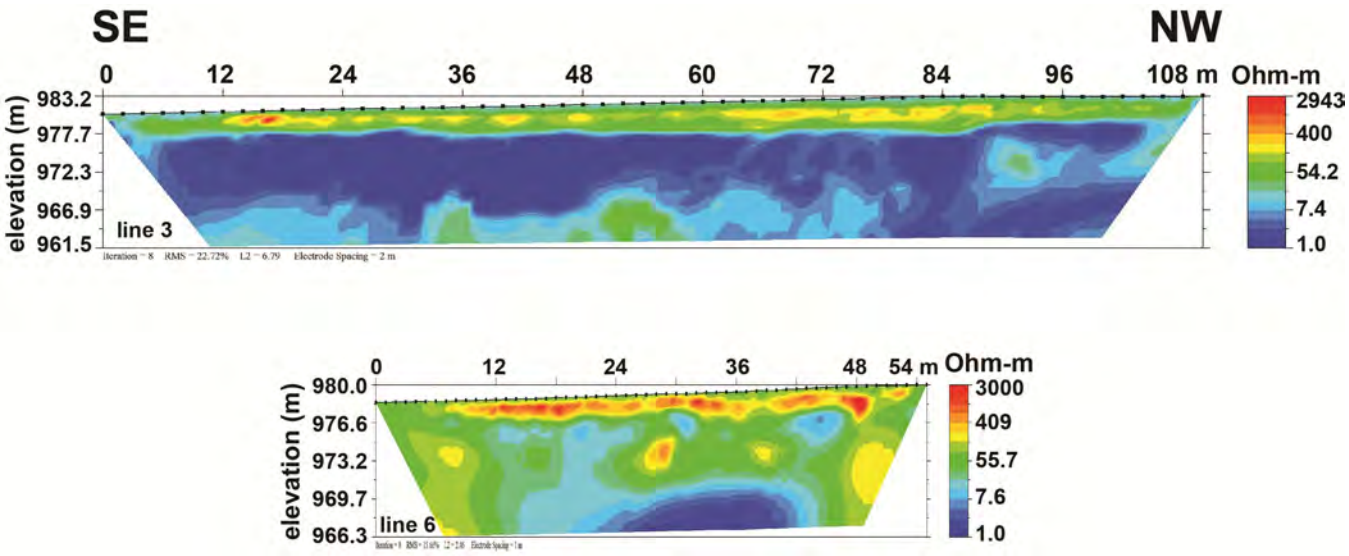

Figure 6: Electrical Resistivity Survey Lines 3 and 6

Line 4 crosses the pipeline ditch 30 m from the line's south end (Figure 3). It shows a part of the known cave between 26 and 34 m, indicated by higher resistivity values 2-6 m below ground level (Figure 7). Line 2 intersects this transect at 81 m.

Line 7 (Figure 8) extends SE-NW across the uncompacted area between the bypass road and trench, and crosses the area where GPR anomalies were identified at around 45 m along the line (Figure 3). No ER anomalies were identified in that area that might indicate a danger of significant collapse or subsidence. However, a small cave is indicated at 13 m, about 5 m below ground level. This cave presents a moderate risk of collapse, and placement of infrastructure over it should be avoided.

Lines 8 -12 run west to east parallel to the pipeline trench. In north to south order, Line 12 is 10.5 m north of the trench, Line 8 is 2 m north, Line 9 is 4.5 m south of the trench, Line 11 is 9 m south, and Line 10 is 15 m south (Figure 3). The purpose of this line grouping was to delineate the extent of the cave for assurance that it did not approach the bypass road or other infrastructure and was not related to the moderate to high resistivity anomalies found in the other lines, which might have changed the interpretation of their significance.

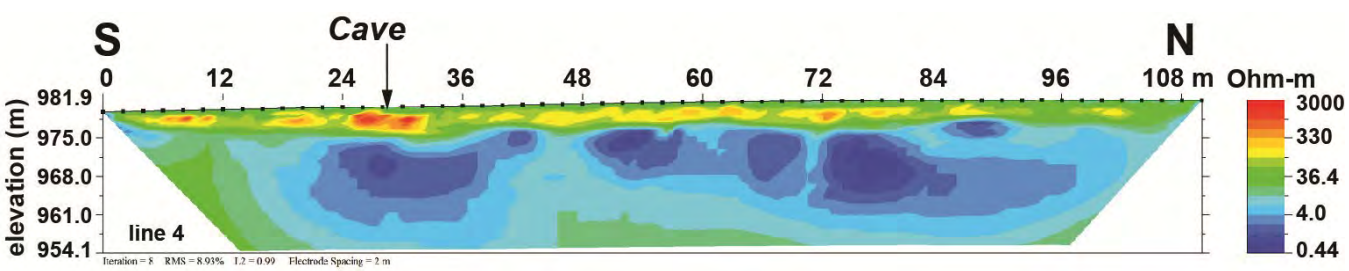

Figure 7: Electrical Resistivity Survey Line 4

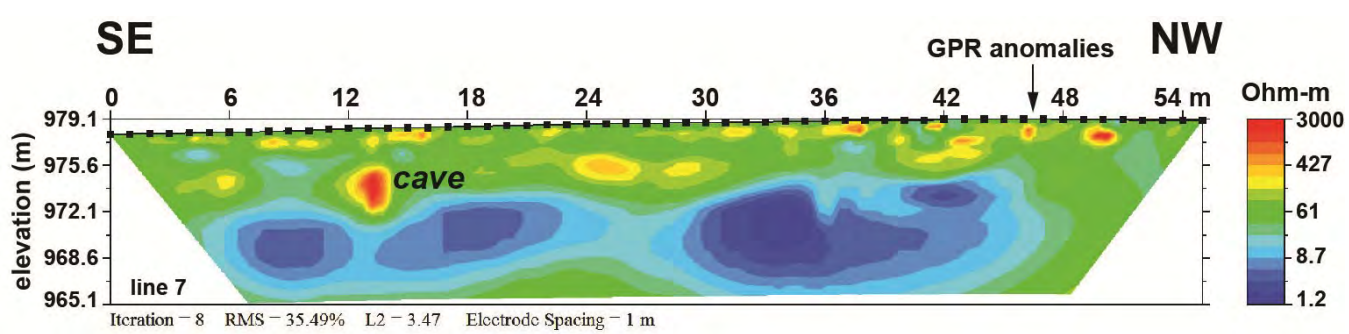

Figure 8: Electrical Resistivity Survey Line 7

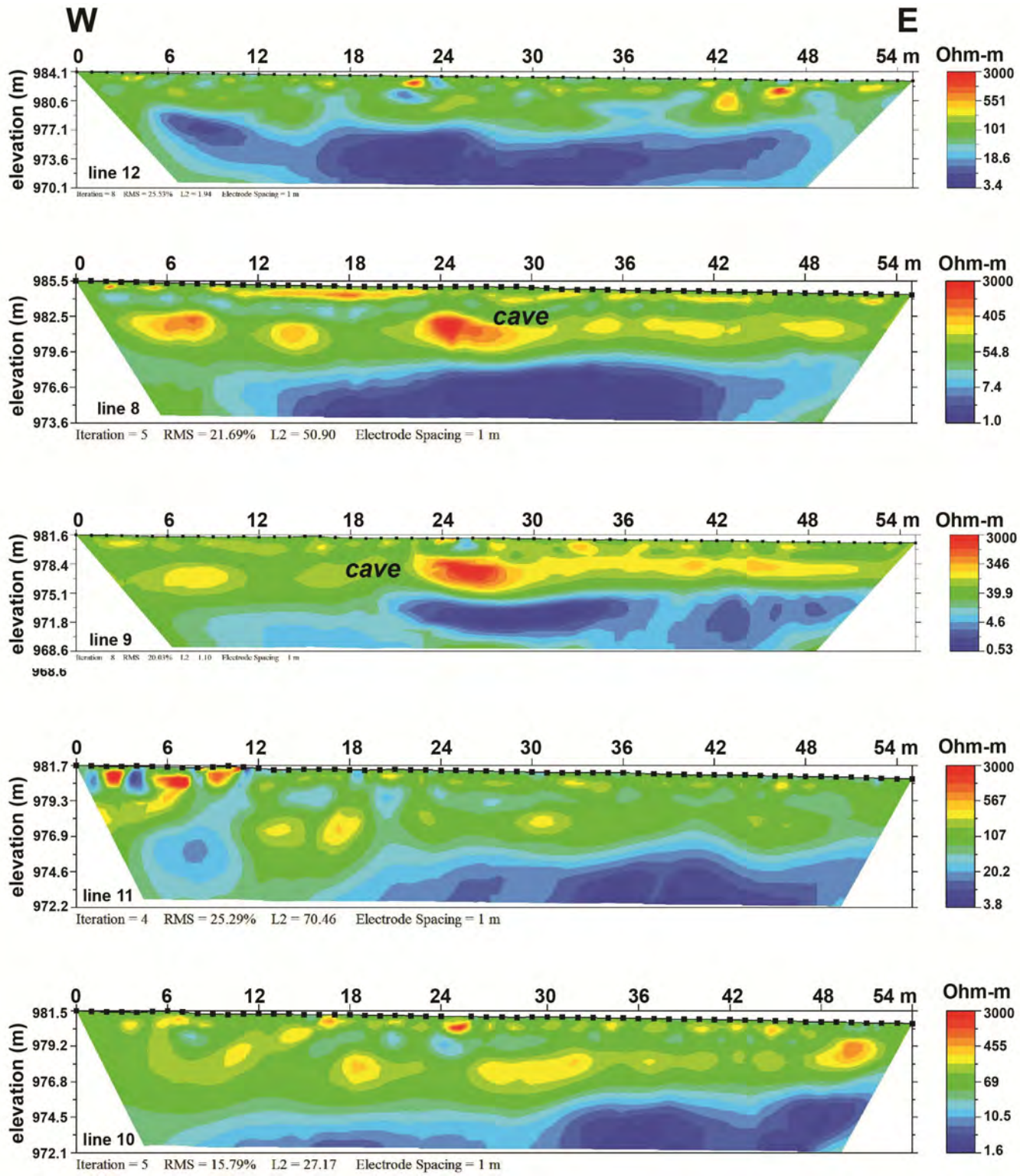

Figure 9: Electrical Resistivity Survey lines 8-12

Figure 9 shows the profiles of lines 8-12. Lines 8 and 9 cross the known cave between about 22 and 30 m. The cave is indicated by a high resistivity zone 3 to 6 m below ground level in lines 8 and 9, but is not present on lines 10, 11, and 12. Moderate resistivity anomalies are also present on line 8 at 8 and 16 m and between 40 and 46 m; on line 10 at 18, 32 and 50 m; on line 11 between 12 and 18 m; and on line 12 between 42 to 47 m (Figures 3 and 9). Line 10 also shows a very shallow high resistivity anomaly at 26 m, immediately adjacent to a pothole where a truck driver

for Intrepid reported evidence of subsidence. This feature may be caused by a shallow air pocket in gypsiferous soil. Further investigations with a hand auger could confirm this hypothesis.

Conclusions

Electrical resistivity survey lines 2, 3, 5 and 6 (Figure 3) do not indicate any significant evidence of large caves beneath the bypass road. Smaller, shallow resistivity anomalies may be the result of air pockets in gypsiferous soil, and as such may present a minor traffic hazard because of subsidence. Such features could also account for the GPR anomalies observed in previous surveys.

The known cave was successfully imaged on electrical resistivity lines 8 and 9, demonstrating the effectiveness of the ER method in identifying air-filled voids in compacted gypsiferous soil. A second small cave has also been identified on line 7. Placement of infrastructure or roads in that area should be avoided.

References

Pettigrew and Associates. 2012a. Letter report to AMEX. 5 October.

Pettigrew and Associates. 2012b. Letter report to AMEX. 8 October.

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