Report of Preliminary Subsurface Exploration, Geophysical Exploration, and Geotechnical Engineering Evaluation of the Prospective Levy Avenue Site for the Proposed FSU Integrated Research Building at Innovation Park, Tallahassee, Leon County, Florida

Ardaman & Associates, Inc.

File No. 113-14-40-1166(1)
August 13, 2014

OFFICES

Orlando - 8008 S. Orange Avenue, Orlando, Florida 32809 - Phone (407) 855-3860
Alexandria - 3609 Mac Lee Drive, Alexandria, Louisiana 71302 - Phone (318) 443-2888
Bartow - 1525 Centennial Drive, Bartow, Florida 33830 - Phone (863) 533-0858
Baton Rouge - 316 Highlandia Drive, Baton Rouge, Louisiana 70884 - Phone (225) 752-4790
Cocoa - 1300 N. Cocoa Blvd., Cocoa, Florida 32922 - Phone (321) 632-2503
Fort Myers - 9970 Bavaria Road, Fort Myers, Florida 33913 - Phone (239) 768-6600
Miami - 2608 W. 84th Street, Hialeah, Florida 33016 - Phone (305) 825-2683
Monroe - 1122 Hayes Street, West Monroe, Louisiana 71292 - Phone (318) 387-4103
New Orleans - 1305 Distributors Row, Suite I, Jefferson, Louisiana 70123 - Phone (504) 835-2593
Port St. Lucie - 460 Concourse Place NW, Unit 1, Port St. Lucie, Florida 34986 - Phone (772) 878-0072
Sarasota - 78 Sarasota Center Blvd., Sarasota, Florida 34240 - Phone (941) 922-3526
Shreveport - 7222 Greenwood Road, Shreveport, Louisiana 71119 - Phone (318) 636-3673
Tallahassee - 3175 West Tharpe Street, Tallahassee, Florida 32303 - Phone (850) 576-6131
Tampa - 3925 Coconut Palm Drive, Suite 115, Tampa, Florida 33619 - Phone (813) 620-3389
West Palm Beach - 2200 North Florida Mango Road, Suite 101, West Palm Beach, Florida 33409 - Phone (561) 687-8200

MEMBERS:
A.S.F.E.
American Concrete Institute
ASTM International
Florida Institute of Consulting Engineers

Ardaman & Associates, Inc.

Geotechnical, Environmental and
Materials Consultants

August 13, 2014
File No. 113-14-40-1166(1)

Wilson Architects, Inc.
374 Congress Street, Suite 400
Boston, Massachusetts, 02210

Attention: Ms. Kristine J. Renner, AIA, LEED AP

Subject: Report of Preliminary Subsurface Exploration, Geophysical Exploration and Geotechnical Engineering Evaluation of the Prospective Levy Avenue Site for the Proposed FSU Integrated Research Building at Innovation Park, Tallahassee, Leon County, Florida

Dear Ms. Renner:

As authorized, Ardaman and Associates, Inc. (Ardaman) has completed the preliminary subsurface exploration and geotechnical engineering evaluation for the subject project. The purposes of the authorized scope were to evaluate subsurface conditions encountered via geophysical techniques and in widely spaced test borings performed at the site, and to provide preliminary geotechnical evaluations and opinions regarding: the relative potential for karst development; problematic soil conditions (if any); preliminary recommendations regarding site preparation and foundations for structures; and suitability of on-site soils for reuse as fill.

This report has been prepared for the exclusive use of Wilson Architects, for specific application to the Levy Avenue site. This report is Part 1 of 3. Part 2 will evaluate the E. Paul Dirac Drive site, which is a nearby prospective site for the Integrated Research Building, and Part 3 will provide a comparison of the two sites.

We are pleased to be of assistance to you on this phase of your project. When we may be of further service to you or should you have any questions, please do not hesitate to contact us.

Sincerely,

ARDAMAN & ASSOCIATES, INC.
Florida Certificate of Authorization No. 5950

JEREMY MATTHEW CLARK
LICENSE
No. 77660
STATE OF
8-13-2014
FLORIDA
PROFESSIONAL ENGINEER

Jeremy M. Clark, P.E.
Project Engineer
FL Eng. License No. 77660

WILLIAM SMALLWOOD JORDAN
LICENSE
No 33026
STATE OF
8-13-2014
FLORIDA
PROFESSIONAL ENGINEER

William S. Jordan, P.E.
Senior Project Manager
FL Eng. License No. 33026

JMC/WSJ/mss

1.0 PROJECT DESCRIPTION AND SCOPE OF SERVICES

Based on our discussions with Wilson Architects, Inc., we understand the proposed development includes an approximate 100,000 square foot Integrated Research Building. The site is being evaluated and compared to the East Paul Dirac site. The Levy Avenue Site is southeast of the intersection of Levy Avenue and Engineer Drive, and the East Paul Dirac Drive Site is just north of the FSU Research Foundation Building B.

Geotechnical and geophysical services were based on the scope defined in our authorized proposal for the project, as follows:

1. Ardaman contracted an independent geophysical testing agency, Spotlight Geophysical Services (SGS), to perform a geophysical reconnaissance of the site, along 6 "transects" using: Electric Resistivity Imaging (ERI); Microgravity Survey; and Ground Penetrating Radar (GPR). The geophysical report for the Levy Site is attached in **Appendix A** for review. The geophysical results were analyzed, reported, and authenticated by the Geophysical Professional.

2. Ardaman mobilized a drill crew to the site to locate the proposed test borings and direct minor clearing for drill rig (CME-55) access to two of the boring locations. The test borings were located using a wheel tape measuring from site features. Therefore the boring locations shall be considered accurate only to the degree implied by the methods used. The approximate test boring locations are shown on **Figure 1**.

3. Ardaman drillers performed six (6) deep test borings at the Levy Avenue Site. The boring depths were varied by our engineers from 65 to 85-feet below grade, depending upon subsurface conditions encountered. The test borings were performed in general accordance with ASTM D1586 (the Standard Penetration Test "SPT" method).

4. During performance of each SPT boring, Ardaman's Drill Crew Chief prepared a field log and recorded SPT "N"-values, estimated depths of soil strata changes based on visual classification of the soils, estimated the depth to groundwater, and communicated conditions encountered to our engineers, for further instructions.

   Portions of the soils sampled were transported to our office in "sealed" containers for further classification and index testing directed by our engineers. Following classification of the soil samples, *Subsurface Profiles* were developed by our engineers, which are presented on **Figure 1**.

5. Our engineers reviewed the Geophysical report, analyzed and evaluated the soil conditions encountered, and performed a review of the regional geology to develop preliminary evaluations and opinions regarding foundation alternatives and site selection.

2.0 LABORATORY TESTING OF SOILS

Laboratory tests included: Nature Moisture Content (NM)(ASTM D 2216); Percent Finer than the U.S. No. 200 Sieve (-200)(ASTM D 1140, percent silt and clay); Atterberg Limits determinations (LL&PI)(ASTM D 4318, plasticity); and soil pH for environmental corrosion classification (FM 5-550). The results of the laboratory tests are presented adjacent to the *Subsurface Profiles* on the attached Figure 1, at the respective depths which the tested samples were recovered.

3.0 SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

3.1 General

The soil descriptions shown on the *Soil Legend* on Figure 1 are based upon visual and laboratory test-based classification procedures in general accordance with ASTM D 2488; ASTM D 2487; and AASHTO M145.

3.2 Interpreted Subsurface Conditions Encountered by Geophysical Testing

Referring to the SGS Report in Appendix A, a total of five (5) anomalous zones were identified in the ERI cross-sections at the Levy Site. The extents of the anomalous zones were on the order of 30 to 50-feet wide. Two (2) anomalies were identified by the GPR, which were "apparently" consistent with soil "raveling", which is the process of a karst feature migrating toward the surface over the course of time. Note that Ardaman's Engineer "seal" of this overall geotechnical report does not apply to the SGS report, which is certified by SGS's professional.

The microgravity survey indicated two (2) areas of low gravity. Some of the features observed in the ERI lines fell within these areas of low gravity. Spotlight indicated that the low gravity areas at the Levy Site were anomalies in the upper 100-feet of the profile and may be related to deeper limestone, lower density overburden, or a combination of both of these factors.

Based on the geophysical survey and interpretation of the reported results, we estimate that approximately 35% of the survey line segments at the Levy Site identified anomalous features that may be karst related. Spotlight recommended that these features be explored with test borings to better define the nature of the anomaly. Test borings were performed among three (3) of the five (5) resistivity anomalies, one (1) of the two (2) GPR anomalies, and one (1) of the low gravity anomalies.

3.3 Soil and Groundwater Conditions Encountered in Test Borings

In general, the upper 55 to 65-feet of the profiles consisted of silty to clayey fine sands, sandy clays, and elastic silts to fat clays. The shallower silty to clayey sands, Strata 1 through 3, about 35-feet thick, were typically loose to medium dense, and the relatively deeper elastic silts to fat clays were medium stiff. Calcareous clay and limestone was generally encountered below 55 to 65-feet. This generalized profiles correlates well with the ERI profiles.

Shallow problematic soils such as highly plastic clays (locally known as "pipe clay") were <u>not</u> encountered. The exploration generally encountered low plasticity soils in the top 20 to 30 feet.

Extremely soft or very loose to loose zones (See SPT "N" values) of variable thicknesses were encountered in three (3) of our test borings (TH-L1, L2 and L6), but were fairly minor at TH-L6. These zones of concern are colored "red" and "orange" on the *Subsurface Profiles* on Figure 1. The test boring "targets"/locations on Figure 1 which encountered these conditions are color coded depending on the quality of subsurface conditions, as follows:

- The green targets indicate "fair to good" subsurface conditions at the respective location, implying *general* conditions encountered were of minor to negligible concern.
- The orange targets indicate "marginal" subsurface conditions; implying *general* conditions encountered were somewhat of concern.

- The red targets indicate "poor" subsurface conditions which were relatively thick, and ground subsidence/collapse may occur at these locations at some future time.

The soft zones were generally encountered within the deeper elastic silts to fat clays, often mixed with the shallower silty to clayey sands. Mixing of soil strata (denoted by dual strata numbering for a single layer) was more prevalent in the borings where marginal to poor subsurface conditions were encountered, which may be the result of soil raveling.

Encountering trace organics in the deeper elastic silts to fat clays (Stratum 5 – Figure 1) soils is an indicator of possible prior "karst" activity, in-filled in the geologic past. Furthermore, occurrences of drill fluid loss (indicated by the open or closed horizontal arrows next to the profiles on Figure 1) may indicate an open limestone joint or a cavity connected to the test hole.

At the time our test borings were performed, groundwater was typically encountered between 25 and 33-feet below grade.

Several of the anomalies identified by Spotlight were explored with test borings. Notably, not all anomalies are "bad"; as they may just indicate "normal" subsurface variations. That is why at least some are explored with test borings.

In general, the features identified appeared to be a dipping limestone formation, which may be the result of paleo-karst activity but not necessarily of a developing sinkhole. The worst test boring, TH-L1, encountered approximately 16-feet of very loose/soft conditions which were not identified as an anomalous feature in the geophysical study, although an anomalous feature was encountered nearby.

4.0 DESK-TOP KARST EVALUATION

4.1 Geologic Setting

According to the Soil Survey for Leon County, the County is subdivided into three major physiographic divisions: the Northern Highlands in the southern limit of the Tallahassee Hills (aka Red Hills), the Gulf Coastal Lowlands (aka Woodville Karst Plain), and the River Valley Lowlands.

The geologic feature dividing the Tallahassee Hills from the Woodville Karst Plain is the Cody Escarpment; an ancient topographical remnant of the Okefenokee Terrace and the Wicomico Terrace, which are two Pleistocene interglacial shorelines. Instead of the typical steep slopes of a scarp, the Cody Scarp has slopes of 5% to 12% which transition the landscape from the Tallahassee Hills (elevation +150 to 200-feet MSL) to the Woodville Karst Plain (elevation +50 to 80-feet).

Based on the Florida Geological Survey Bulletin No. 47 for Leon County (1966), our understanding of the local geologic formations, and our interpretation of topographical data, the subject site is located on the Cody Scarp, the geological transition from the Tallahassee Hills to the lower elevation gently sloping Woodville Karst Plain.

The moniker "Woodville Karst Plain" is the result of the sinkhole-sand dune topography. The lakes in this area tend to be relatively numerous, typically circular, and generally of sinkhole origin. The Tallahassee Limestone in this area is characterized as crystalline, in part argillaceous, with common chert and gypsum.

According to the Geologic Bulletin, the geological formations in this area consist of the following formations, in descending order: Pleistocene Series; Hawthorne Formation; St. Mark's Formation; and Suwannee Limestone, described further (paraphrased) below:

The Pleistocene Series consists mainly of sandy (sometimes discontinuous) recent sediments. The Hawthorne Formation is composed of quartz sand, sand-size phosphorite, silt; kaolinite, montmorillonite and attapulgite clays, and sandy phosphoritic limestone. In southern Leon County the thickness of the Hawthorne Formation is 60 to 70 feet; the sequence is usually sandy, clayey, silt at the top; sand and sandy clays in the middle; and sandy limestone at the base of the formation.

The St. Marks Formation is composed of predominantly fine to medium grained, partially recrystallized, silty to sandy limestone (calcilutites and calcarenites). The Suwannee Limestone is abundantly micro-fossiliferous, granular, partially recrystallized, and partially dolomitized throughout the entire section.

The Floridan Aquifer underlies all of Leon County and is the source of practically all groundwater used in the area. This aquifer is composed entirely of limestones and dolomites of Middle Eocene to Miocene Age, and is known to contain potable water to a depth of at least 600 feet.

Recharge to the Floridan aquifer is mostly from rain which falls on Leon County and Georgia counties to the north. Most of the water which enters the aquifer in this area discharges through the underlying limestone formations into the Gulf of Mexico, some through numerous springs in the Florida panhandle's southern Counties.

4.2 Local Codes

In the Leon County Code of Ordinances, Article 1, Section 10-1, the definition of an *active karst* feature is: *A collapse, subsidence, or solution in the earth's surface that is formed over limestone, dolomite, or gypsum, caused by the dissolution, or infiltration of this soluble formation overlying the groundwater that allows direct contact between surface water and the groundwater table and is characterized by closed depressions such as sinkholes, caves, springs and underground drainage.*

Also, based upon the City of Tallahassee Code of Ordinances and Land Development Code Article 1, Section 5-12, "*the definition of a sinkhole or sink is: a collapse or subsidence in the earth's surface, caused by infiltration through a limestone formation to the groundwater, also known as a single "karst feature."*

For purposes of these regulations, an active sink means any karst feature with an exposed seasonal or permanent water table, and no natural sand filter medium between the water and the underlying limestone formation.

4.3 Desk-top Karst Risk Assessment

The Weight of Rod (WOR) and Weight of Hammer (WOH) conditions encountered are typically indicative of void spaces in the formations, particularly when the rods advance in a "free fall" (FF) manner. The extents and occurrences of these extremely soft zones provide insight to the level of concern for sinkhole development. Notably, these types of conditions are rather prevalent along the Cody Scarp described in report Section 4.1.

In order to quantitatively and qualitatively assess the risk of sinkhole potential at the site, Ardaman performed a desk-top karst risk assessment. The desk-top assessment considers the above presented geologic information and definitions, the encountered subsurface conditions, and mapping of actual sinkholes in the area surrounding the site.

The data utilized in the evaluation are based upon the attached **Figure 2,** which presents the sinkholes reported to the Florida Geologic Survey Database (1975-2011). Figure 2 shows, with "blue dots", the locations of fourteen (14) reported sinkholes in the general region of the site. The Florida Geological Survey (FGS) database at the web site: http://www.dep.state.fl.us/geology/gisdatamaps/SIRs_database.htm provided the locations of the reported sinkholes shown. Note that the FGS database only includes reported incidents and is not necessarily inclusive of all surface/subsurface collapses.

The relative karst risk for a site is quantified using a classification system developed by Ardaman's John E. Garlanger, Ph.D., P.E. The method is statistically based upon the number of known and reported sinkholes within a moveable 4-square mile area overlapping the site, within which the maximum number of features is encompassed. The *Sinkhole Potential* classification system is shown in the following table:

Sinkhole Potential	Annual Frequency (sinkholes per square mile)
Extremely High	>1.0
High	0.1 to 1.0
Moderate	0.01 to 0.1
Low	0.001 to 0.01
Extremely Low	<0.001

On Figure 2, we have delineated the moveable 4-square mile area within which the maximum number of sinkholes was documented; that being eight (8) reported or known sinkholes. Therefore, we calculate the Annual Frequency as follows:

- Eight (8) sinkholes have been reported since 2000, or 14 years from present date. The annual frequency is (number of sinkholes/square miles/number of years) 8/4/14= 0.14. According to the above table, the annual frequency equates to "High" sinkhole potential.

Based upon the above analyses, combined with our understanding of the geology of the region and local experience and professional judgment, we conclude that there is a "High" risk for development of a sinkhole at the Levy Site, and at the Paul Dirac site, reported separately.

The same can be said of the Mag Lab building site, the FAMU-FSU College of Engineering, much of the Seminole Golf Course, the Morcom Aquatics Center, and numerous other buildings.

The results of the potential sinkhole analyses are consistent with our expectations for this transitional zone between the Tallahassee Hills and the Gulf Coastal Lowlands. Sinkholes tend to be more prevalent to the south, as the clay units become thinner, and less prevalent to the north, as the clay units become thicker.

5.0 PRELIMINARY ENGINEERING EVALUATION AND EARTHWORK RECOMMENDATIONS

5.1 Preliminary General Soils and Foundation Evaluation

Although the sinkhole potential at the site is "High", we judge that this should not preclude development. However, it appears prudent to design the site layout such that buildings and other pertinent structures are located nearer the "green" targets and away from the "red" targets on Figure 1.

Additional borings will be needed during the final phase of the project to characterize the conditions beneath the proposed building footprint. The final exploration may reveal that subsurface remediation, such as deep pressure grouting is necessary. Such a remediation program appears feasible. Deep pressure grouting was performed at the FSU Research Foundation Building site.

In our opinion, subsurface conditions encountered in some of the preliminary test borings performed at the site (Orange and Green targets on Figure 1) appear suitable for supporting light to moderate structural loads (column loads up to approximately 250 to 300 kips) on conventional shallow spread footings, or on a mat foundation. Depending upon the findings in the final test borings, a mat foundation may have to be selected, designed rigid enough to span a potential surface collapse, the size of which will be determined during the final exploration.

Moderately to highly plastic clays, locally known as "pipe clay", do not appear to be much of a concern due to the depths encountered. Pipe clay has a high propensity to shrink and swell during seasonal variations in moisture when present in the top 10 feet or so below grade, foundations and slabs. The shrinking and swelling cycles can result in cosmetic and structural cracking/damage unless slabs and foundations are stiffened. Pipe clay is common in this area, so it may be present at shallower depths between borings.

Based upon our preliminary findings, and assessments, we believe that shallow foundations may be designed for an allowable soil contact pressure of 2.0 to 3.0 ksf. The recommended allowable soil contact pressure will yield a minimum factor of safety in excess of two against bearing capacity failure. Settlement is estimated to be on the order of 1-inch based on the above allowable soil contact pressure range.

For foundation loads in excess of about 250 to 300 kips, deep foundation alternatives are usually more appropriate. Auger-cast piles (mostly frictional) appear to be the preferable and economical deep foundation type. Drilled shafts (caissons) may also be used, but would likely be more costly due to the depth to limestone, unless column loads are very high, on the order of 500 to 600+ kips. Driven piles, such as steel pipe piles or "H"-Piles also appear to be viable.

5.2 Preliminary Site Preparation Procedures

The following are our preliminary site soil preparation recommendations for shallow foundation support, which, in our opinion appears suitable for the proposed construction and existing soil conditions:

- Construction area "footprints", must be stripped and grubbed.

- The cleared surfaces in construction areas must be proof-rolled using appropriate compaction equipment for site and soil conditions. Sufficient passes must be made to develop a stable base, and achieve the required compaction. The encountered clayey soils on-site will tend to retain moisture during wet periods, which may delay construction.

- Remove any materials, if determined to be deleterious, in areas that "yield" during the proof-rolling operation, and replace with select fill.

- Planned filling may proceed in relatively thin level lifts, compacted by repeated passes with appropriate compaction equipment, to achieve the required compaction density.

- Fill required in the slab and footing undercuts (if any), and to elevate the structure areas should preferably consist of "Select Fill", defined as uniformly graded, natural, clean silica sand to silty sand (A-3 to A-2-4) (SP or SP-SM or SM), free of organics, plastic soils, and deleterious materials, and with less than 15% passing the U.S. No. 200 Sieve. Meaningful quantities of select fill were not encountered at the site.

  Fill materials may also consist of "Suitable Fill". This includes certain silty to clayey sands (A-2-4, SM-SC materials), but with no more than 35% passing the US No. 200 sieve (% of fines); liquid limit (LL) less than 40%; and plasticity index (PI) less than 15%; free of organics, highly plastic soils, and other deleterious materials. Strata 1A and some of Stratum 2 appears to meet Suitable Fill criteria.

  "Suitable Fill" materials with more than 15% fines are likely to retain excess moisture, and be difficult to dry and compact. Construction delays are more likely during rainy periods when such soils are used than when Select fills are used.

6.0 CLOSURE

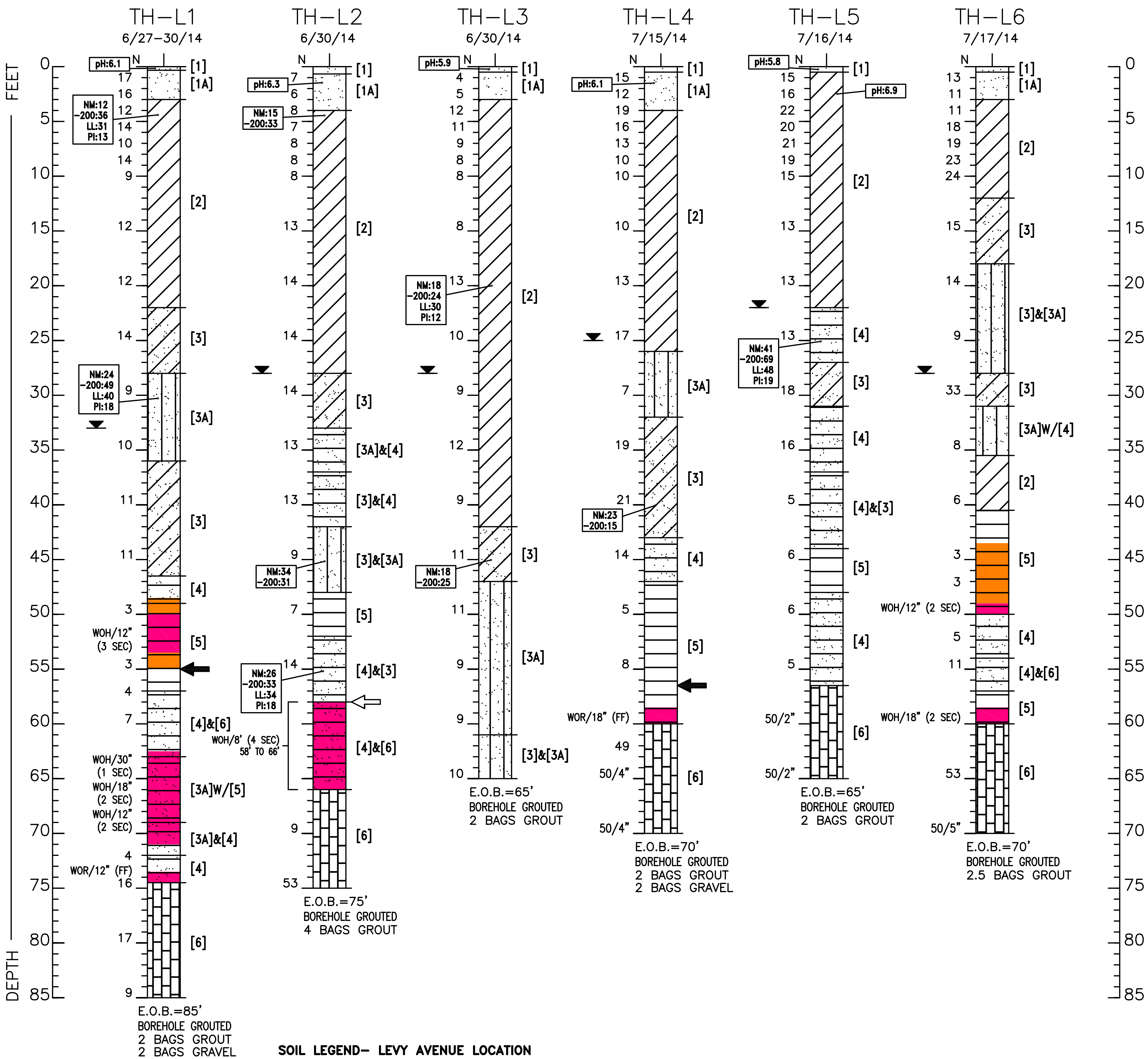
The preliminary recommendations submitted in this report are based upon the limited data obtained from widely spaced soil borings presented on the attached Figure 1. This report does not address a specific building footprint.

The stratification lines on the *Subsurface Profiles* represent approximate boundaries between the soil types but the actual transitions may be more gradual than implied. This report does not reflect any variations which may occur between or away from the borings. The nature and extent of subsurface variations may not become evident until the time of the final exploration, or construction. The recommendations, evaluations, and opinions submitted in this report may have to be revisited and/or altered depending on variations encountered during the final exploration.

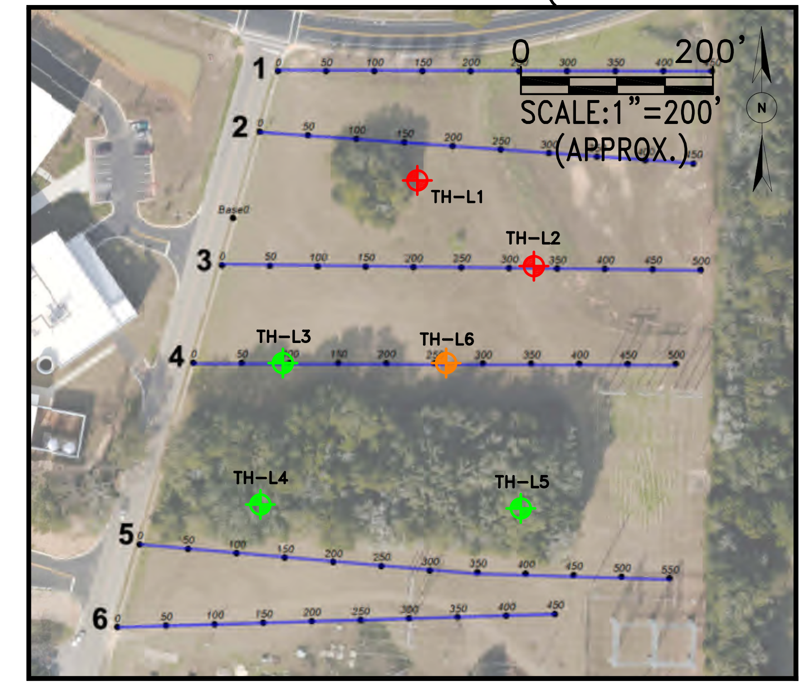
This report has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

End of Report

SUBSURFACE PROFILES– LEVY AVENUE LOCATION



TEST BORING LOCATION PLAN (GOOGLE EARTH)



LEGEND

⊕	STANDARD PENETRATION TEST (SPT) BORING LOCATION
⊕ (green)	"FAIR TO GOOD" SUBSURFACE CONDITIONS ENCOUNTERED
⊕ (orange)	"MARGINAL" SUBSURFACE CONDITIONS ENCOUNTERED
⊕ (red)	"POOR" SUBSURFACE CONDITIONS ENCOUNTERED
EOB	END OF BORING
N	STANDARD PENETRATION RESISTANCE IN BLOWS PER FOOT (ASTM D–1586)
WOR/18" (2 SEC)	SAMPLER ADVANCED 18" IN 2 SEC BY STATIC WEIGHT OF RODS ONLY
WOH/18" (FF)	SAMPLER ADVANCED 18" IN A "FREE FALL" CONDITION BY STATIC–WEIGHT OF HAMMER AND RODS ONLY
50/2"	REQUIRED 50 BLOWS TO ADVANCE SAMPLER 2–INCHES
▼	GROUNDWATER DEPTH ESTIMATED ON DATE DRILLED
⇦	PARTIAL LOSS OF DRILLING FLUID CIRCULATION
⬅	COMPLETE LOSS OF DRILLING FLUID CIRCULATION
(pink)	POOR SUBSURFACE CONDITIONS
(orange)	MARGINAL SUBSURFACE CONDITIONS
NM	NATURAL MOISTURE CONTENT IN PERCENT (ASTM D–2216)
–200	PERCENT PASSING NO. 200 SIEVE SIZE (PERCENT FINES)(ASTM D–1140)
LL	LIQUID LIMIT (ASTM D–4318)
PI	PLASTICITY INDEX (ASTM D–4318)
pH	SOIL pH (FM 5–550)
SP–SM,SM,SC	UNIFIED SOIL CLASSIFICATION SYSTEM
A–3,A–2–4	AASHTO SOIL CLASSIFICATION SYSTEM
DRILLERS:	KM, LT, JA, SH
DRILL RIG:	CME 55, MANUAL HAMMER ABOVE & AUTO HAMMER

ENGINEERING CLASSIFICATION

I COHESIONLESS SOILS

DESCRIPTION	BLOW COUNT "N"
VERY LOOSE	0 TO 4
LOOSE	4 TO 10
MEDIUM DENSE	10 TO 30
DENSE	30 TO 50
VERY DENSE	>50

II COHESIVE SOILS

DESCRIPTION	UNCONFINED COMPRESSIVE STRENGTH, QU, TSF	BLOW COUNT "N"
VERY SOFT	<1/4	0 TO 2
SOFT	1/4 TO 1/2	2 TO 4
MEDIUM STIFF	1/2 TO 1	4 TO 8
STIFF	1 TO 2	8 TO 15
VERY STIFF	2 TO 4	15 TO 30
HARD	>4	>30

WHILE THE BORINGS ARE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THEIR RESPECTIVE LOCATIONS AND FOR THEIR RESPECTIVE VERTICAL REACHES, LOCAL VARIATIONS CHARACTERISTIC OF THE SUBSURFACE MATERIALS OF THE REGION ARE ANTICIPATED AND MAY BE ENCOUNTERED. THE BORING LOGS AND RELATED INFORMATION ARE BASED ON THE DRILLER'S LOGS AND VISUAL EXAMINATION OF SELECTED SAMPLES IN THE LABORATORY. THE DELINEATION BETWEEN SOIL TYPES SHOWN ON THE LOGS IS APPROXIMATE AND THE DESCRIPTION REPRESENTS OUR INTERPRETATION OF SUBSURFACE CONDITIONS AT THE DESIGNATED BORING LOCATIONS ON THE PARTICULAR DATE DRILLED.

GROUNDWATER ELEVATIONS SHOWN ON THE BORING LOGS REPRESENT GROUNDWATER SURFACES ENCOUNTERED ON THE DATES SHOWN. FLUCTUATIONS IN WATER TABLE LEVELS SHOULD BE ANTICIPATED THROUGHOUT THE YEAR. ABSENCE OF WATER SURFACE DATA ON CERTAIN BORINGS IMPLIES THAT NO GROUNDWATER DATA IS AVAILABLE, BUT DOES NOT NECESSARILY MEAN THAT GROUNDWATER WILL NOT BE ENCOUNTERED AT THESE LOCATIONS OR WITHIN THE VERTICAL REACHES OF THESE BORINGS IN THE FUTURE.

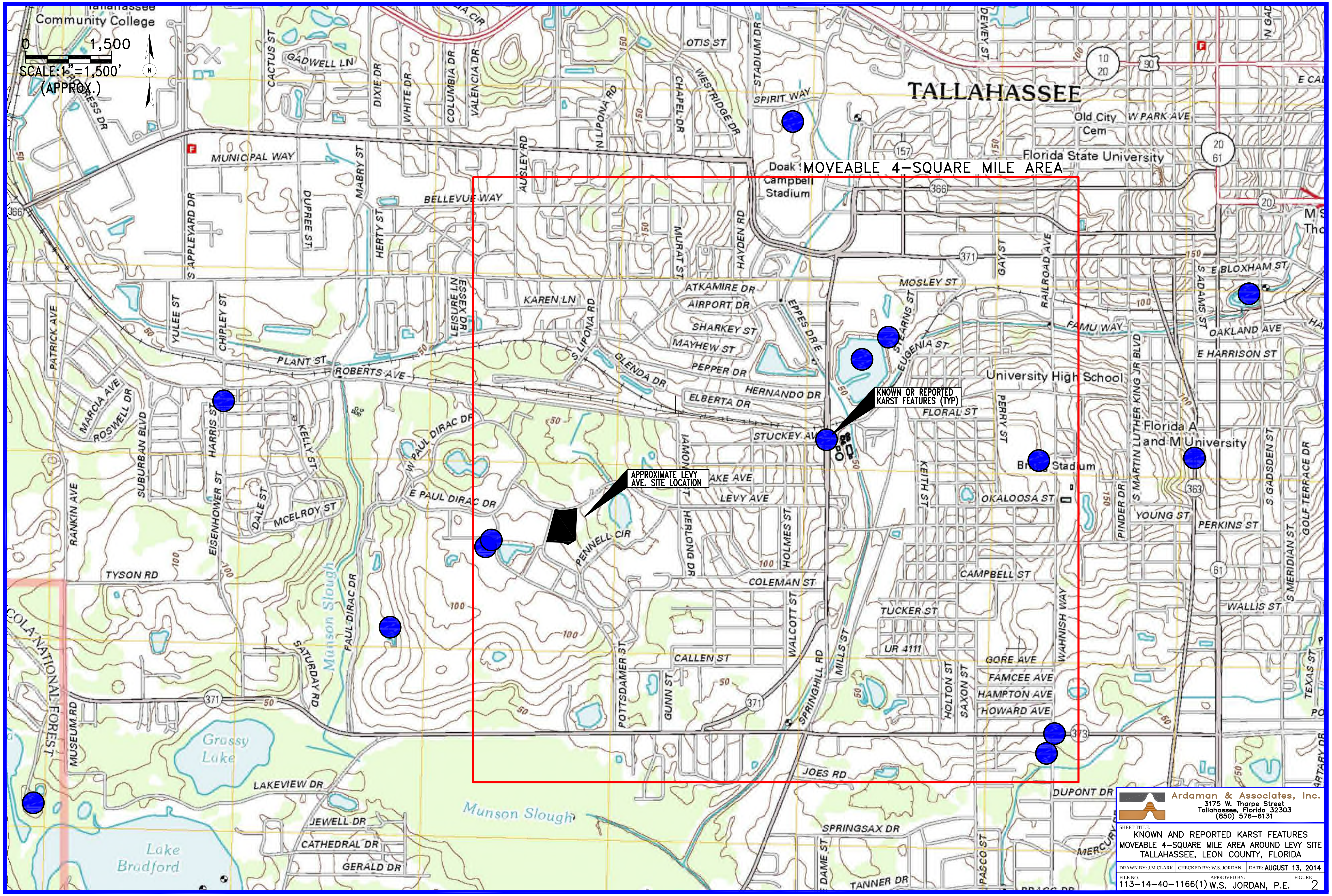
SOIL LEGEND– LEVY AVENUE LOCATION

[1]	DARK BROWN MEDIUM TO FINE SAND W/ SILT & SURFICIAL ROOTS; TOPSOIL (SP–SM W/ OL; A–3 W/ A–8)
[1A]	BROWN TO LIGHT BROWN SILTY FINE SAND, SOMETIMES W/ CLAY (SM; A–2–4)
[2]	BROWN TO REDDISH–BROWN TO ORANGISH–BROWN SILTY, CLAYEY TO VERY CLAYEY FINE SAND, SOMETIMES MOTTLED W/ GRAY FINE SAND (SC; A–2–4/A–2–6 TO A–4/A–6)
[3]	MOTTLED LIGHT GRAY & LIGHT BROWN CLAYEY, SILTY FINE SAND, SOMETIMES W/ CEMENTED SAND PIECES (SC; A–2–4)
[3A]	MOTTLED LIGHT GRAY & LIGHT BROWN VERY CLAYEY FINE SAND TO VERY SANDY LEAN CLAY (SC TO CL; A–6/A–7)
[4]	GREENISH–GRAY VERY SANDY FAT CLAY MOTTLED W/ BROWN TO DARK BROWN & WHITE CLAYEY SAND (CH W/ SC; A–7 W/ A–2–4)
[5]	DARK BROWN SLIGHTLY SANDY ELASTIC SILT MARBLED W/ LIGHT GRAY FAT CLAY, SOMETIMES W/ TRACE ORGANICS (~2–5%) (MH W/ CH; A–7)
[6]	TAN CALCAREOUS CLAY TO GRAVEL SIZE PARTICLES & LIMESTONE

Ardaman & Associates, Inc.
3175 W. Tharpe Street
Tallahassee, Florida 32303
(850) 576–6131

SHEET TITLE:
SUBSURFACE SOIL EXPLORATION FOR FSU INTEGRATED RESEARCH BUILDING– LEVY AVE. LOCATION
TALLAHASSEE, LEON COUNTY, FLORIDA

DRAWN BY: J.M.CLARK	CHECKED BY: W.S. JORDAN	DATE: AUGUST 13, 2014
FILE NO. 113–14–40–1166(1)	APPROVED BY: W.S. JORDAN, P.E.	FIGURE 1



Ardaman & Associates, Inc.
3175 W. Tharpe Street
Tallahassee, Florida 32303
(850) 576-6131

SHEET TITLE:
KNOWN AND REPORTED KARST FEATURES
MOVEABLE 4-SQUARE MILE AREA AROUND LEVY SITE
TALLAHASSEE, LEON COUNTY, FLORIDA

DRAWN BY: J.M.CLARK | CHECKED BY: W.S. JORDAN | DATE: AUGUST 13, 2014

FILE NO. 113-14-40-1166(1) | APPROVED BY: W.S. JORDAN, P.E. | FIGURE 2

APPENDIX A

Geophysical Survey Reports
Performed by Spotlight Geophysical Services

SPOTLIGHT
GEOPHYSICAL SERVICES

Technical Report

Reconnaissance Geophysical Survey
Levy Avenue Site – Innovation Park
Tallahassee, Florida

for

Ardaman & Associates, Inc.
Tallahassee, Florida

July 3, 2014

SGS Project No.: 2014248

CERTIFICATION

I hereby certify that this document has been prepared in accordance with generally accepted geophysical exploration and interpretation practices.

Authored by:

____
Ronald Kaufmann
President
Licensed Professional Geophysicist - California #1071

TABLE OF CONTENTS

LIST OF FIGURES

BACKGROUND

Ardaman & Associates, Inc. (Ardaman) is conducting a geotechnical investigation of two sites at Innovation Park in Tallahassee, Florida. The sites include an approximate 8-acre area south of Levy Avenue and an approximate 10-acre area east of Paul Dirac Drive (Figure 1). This report addresses the site south of Levy Avenue.

The stratigraphy at the site consists of post Hawthorn undifferentiated sediments overlying the Torreya Formation of the Hawthorn Group and the limestone of the St. Marks Formation (Scott, 1988). The depth to the top-of-rock (St. Marks Formation) is expected to be highly variable and be 50 to 100 feet below grade at the site (Hendry and Sproul, 1966). The limestone is regionally known to contain karst features such as cavities and conduits that can be the origin points for soil raveling, surface subsidence, and sinkholes.

Ardaman retained Spotlight Geophysical Services (SGS) to carry out a non-invasive geophysical survey of the site to screen for karst features. Electrical resistivity imaging (ERI), microgravity, and ground penetrating radar (GPR) data were acquired along transects within the site to provide a reconnaissance level of coverage. Fieldwork was completed between June 24th and 29th, 2014.

TECHNICAL APPROACH

SURVEY LINES

Geophysical data were acquired along six survey lines (Labeled Lines 1 to 6) that are positioned within the site to provide a reconnaissance level of coverage (Figure 2). The survey lines are oriented west-to-east in open, grass-covered areas. A dry retention pond is located in the northeastern portion of the survey area, and power lines are present along the eastern and southern boundaries of the site. GPR and microgravity data were acquired along each of the survey lines and ERI data were acquired along Lines 2, 3, 4, and 5.

Stations along the survey lines are referenced to distance in feet from the west end of each line (Figure 2). A Trimble ProXT differential GPS was used to provide the geographic locations of the survey lines in Florida State Plane (north) coordinates (NAD-83).

ELECTRICAL RESISTIVITY IMAGING (ERI)

Electrical resistivity measurements are made by placing electrodes in contact with the soil. A DC electrical current is injected between one pair of electrodes while the voltages across other pairs of electrodes are measured. The resistivity measurement represents the apparent resistivity averaged over a volume of the earth determined by the resistivity of the subsurface materials, along with the electrode geometry and spacing (ASTM, 2005a).

Multiple resistivity measurements made by different combinations of electrode spacings provide a dense dataset from which a 2D resistivity model can be developed. The resistivity model is a function of soil and rock type, porosity, its permeability as well as the composition of fluids that fill the pore spaces. If a sufficient resistivity contrast exists, the model can be used to identify stratigraphic layers, variations in clay and moisture content, and anomalous zones such as karst features.

Data Acquisition

ERI data were acquired along Lines 2, 3, 4, and 5 for a total of 2,100 linear-feet. The data were acquired with an AGI Supersting R8 system using up to 56 electrodes spaced 10 feet apart (Figure 3). The electrodes were attached to stainless steel stakes that were driven approximately 4 inches into the soil. Saltwater was used to improve the electrical coupling between the stakes and soil. The contact resistance between the stakes and soil was checked prior to the measurements to ensure good electrical coupling. A Wenner-Schlumberger array geometry was used to obtain over 450 voltage measurements per 550 feet of survey line.

Data Processing

The resistivity data were processed with EarthImager software by AGI. An iterative inversion modeling scheme was used to calculate 2D models of subsurface resistivity to a maximum depth of approximately 100 feet. The data were corrected for surface elevation using the USGS National Elevation Dataset (1/3 arc-second resolution). The resulting models were contoured and presented as 2D resistivity cross-sections in SURFER v.12 software (Golden Software).

Quality Control

The ERI system was operated according to the manufacturer's instructions, ASTM Standards (ASTM, 2005a), and SGS standard operating procedures. The quality of the resistivity data is excellent, with a high signal-to-noise ratio. Model RMS errors range between 3.1% and 5.4% along Lines 2, 3, and 4, indicating a very low level of noise and an excellent model fit to the observed data. The model RMS error along Line 5 is 27%, indicating a higher level of noise along this line due to interference from grounded metal objects and the adjacent power lines.

Limitations

The detection of subsurface features with surface geophysical methods is dependent upon their size, composition, and depth of burial. Additional features may be present within the survey area that have not been identified in the data. Borings or excavations are necessary to verify the interpretations made from ERI data.

MICROGRAVITY SURVEY

A microgravity survey measures variations in the Earth's gravitational field caused by changes in subsurface density. A microgravity survey consists of making sensitive gravity measurements at discrete points along a profile line or within a grid (ASTM, 2005b). Microgravity data can be used to map karst-related features, variations in depth to bedrock, faults, voids, soft zones, and man-made features such as mines and tunnels. *Note: In this report the terms “Microgravity” and “Gravity” are synonymous.*

Data Acquisition

A total of 65 microgravity stations were positioned along each of the survey lines at a nominal spacing of 50 feet. The microgravity stations were marked with a 60d nail and stake chaser (Figure 3). Precise relative elevations of the microgravity stations were obtained with a Topcon DL-102 digital level. The elevations are tied to the USGS National Elevation Dataset datum at the location of the base station (Base0). The elevations were measured with an estimated loop closure precision within 0.01 feet per linear-mile, which is within the necessary precision for the microgravity data processing.

Microgravity data were obtained with a Scintrex CG-5 gravimeter (S/N 40800077), using a 30-second averaging window and automatic corrections for tides and meter leveling (Figure 3). The data were recorded to a field notebook and digitally to the gravimeter memory. The data were downloaded to a computer after each day of data acquisition.

Data Processing

The gravity data were reduced to Bouguer values using standard reduction formulas in Microsoft EXCEL (Long and Kaufmann, 2013). Note that since this is a local microgravity survey, the data were not tied to an absolute gravity datum. The Bouguer values were calculated with the corrections applied as shown in Equation 1.

Eqn. (1) $$g_{Boug} = g_o - g_d - g_t - g_l + g_{fa} - g_{slab} + g_{tc}$$

Where: g_o= observed gravity values;

g_d = instrument drift;

g_t = tide correction;

g_l = latitude correction;

g_{fa} = free air correction;

g_{slab} = Bouguer slab correction; and

g_{tc} = terrain correction.

INSTRUMENT DRIFT

All relative gravity meters have an inherent drift that must be corrected for by repeated occupations at base stations during the survey. A base station (Base0) was established on the sidewalk at 2026015.9E, 517487.5N (Figures 2 and 3). Data were acquired at the base station at the start and end of each day of data acquisition and at approximately 2-hour intervals during data acquisition. At least three consistent measurements with a standard deviation within ±5 μGals were acquired at each base station occupation. The drift during a full day of surveying ranged between 0 and 20 μGals. The drift was removed from the raw data by assuming a linear drift between base station occupations.

TIDAL CORRECTION

The gravitational effects of the sun and moon can be as much as 300 μGals over the course of a day (Long and Kaufmann, 2013). The Scintrex CG-5 automatically removes the tidal effects using the Longman formula (Seigel, 1995; Longman, 1959). Any residual tidal effects (< 10 μGals) due to tidal loading and earth deformation are removed during the drift correction.

LATITUDE CORRECTION

There is an increase in gravity with increasing latitude. Standard equations for the latitude correction are presented in Long and Kaufmann (2013) and Telford et al. (1990). The calculation of the gravitational gradient due to latitude is shown in Equation 2.

Eqn. (2): $$g_l = \frac{\Delta g}{\Delta s} = 0.811 \sin 2\varphi \; mGal/km$$

Where: $\frac{\Delta g}{\Delta s}$ is the gravity change (mGal) in the north-south distance (km) and φ is the latitude in degrees.

At this site (Latitude 30.43° N), the gravitational gradient due to latitude is approximately 0.216 μGals/foot in the north direction.

FREE AIR CORRECTION

Since gravity varies inversely with the square of the distance, it is necessary to apply a *free air correction* that accounts for changes in gravity due to elevation (Long and Kaufmann, 2013; Telford et al., 1990). The free air correction is 94.06 μGals/foot of elevation. Precise elevations were measured with a Topcon DL-102 digital level as described above and used to calculate the free air correction. In order to account for variations in the gravity meter height above the ground surface, a free air correction (94.06 μGals/foot) for the gravity meter height was also applied to the data. The meter height was measured at each station using a standard tape measure with a precision of 0.01 feet.

BOUGUER SLAB CORRECTION

The *Bouguer Slab Correction* accounts for the attraction of the material between the measurement station and a constant datum (Long and Kaufmann, 2013; Telford et al., 1990). The calculation of the Bouguer slab correction is shown in Equation 3.

Eqn. (3): $g_{slab} = \frac{\Delta g}{\Delta r} = 0.01278\, \rho\, mGal/ft$

Where: $\frac{\Delta g}{\Delta r}$ is the gravity change (mGals) per foot of elevation change and ρ is the density in g/cc.

In this survey, a Bouguer slab density of 1.9 g/cc was used to approximate the density of near-surface topographic features, which consist mainly of sandy overburden. Using this density, the Bouguer Slab correction is 24.28 µGals/foot of elevation.

NEAR-FIELD TERRAIN CORRECTION

Terrain corrections account for the gravitational effects of topography near the measurement station. The terrain correction was applied using the USGS NED and processed with LASERTC software (Cogbill, 1990). At this site, the terrain corrections are minimal; ranging between 0 and 5 µGals.

PLANAR TREND

A planar trend was calculated from the Bouguer data (Equation 4). This regional trend was subtracted from the Bouguer values and the resulting values are defined as the *residual gravity,* which are directly related to subsurface density variations.

Eqn. (4): $Regional\ (mGals) = A - (0.000052304 * E) - (0.00016688 * N)$

Where: A=851.348 (a constant based on the Bouguer values), E=Easting (State Plane feet), and N=Northing (State Plane feet)

Interpretation

The microgravity data were assessed for low-gravity zones that may be due to subsurface mass deficits such as karst-related features. Low-gravity zones were assessed with the ERI data define anomalous areas.

Quality Control

The gravimeter was set-up and operated in accordance with the manufacturer's instructions and ASTM standards (ASTM, 2005b). The data quality was monitored by re-acquiring data at stations throughout the survey and checking the repeatability of the measurements. Data were re-acquired at a total of 12 stations (18% of total) at different times throughout the survey. The average deviation of repeated measurements is ±3 μGals, which indicates a low level of ambient noise for the site.

Limitations

Microgravity data will respond to variations in subsurface density and can be used to map the lateral locations of anomalous areas. However, microgravity data alone cannot determine the vertical distribution of the anomalous zones or the absolute depth to stratigraphic layers. Borings must be used to positively identify the causes of the microgravity variations and the depth of the anomalous features.

DETECTABILITY AND RESOLUTION

The detectability of subsurface features with microgravity is dependent on their density contrast, depth, size, and geometry. Shallow targets produce a short wavelength (narrow) response. Deeper targets produce a longer wavelength (wide) response. In order to be detected, a subsurface feature must be large enough and shallow enough to produce a response above the noise threshold with a wavelength that can be defined by the survey station layout.

Lateral resolution is limited by the spacing between measurements and by the geometry of subsurface targets. The lateral resolution of a discrete subsurface feature is approximately 20% of its depth (i.e. a target at a depth of 50 feet can be defined with a lateral resolution of approximately ±10 feet).

GROUND PENETRATING RADAR

Ground penetrating radar (GPR) uses high frequency electromagnetic energy to acquire subsurface information. Energy is radiated downward into the ground from a transmitter and is reflected back to a receiving antenna. Reflections of the radar wave occur where there is a change in the dielectric constant between two materials. The reflected signals are recorded and produce a continuous cross-sectional image of shallow subsurface conditions. Applications include mapping shallow stratigraphy, identifying near surface anomalies such as soil raveling and voids, and locating man-made structures such as utilities and underground storage tanks.

GPR provides high-resolution images of the shallow subsurface, typically within the upper 20 feet (much deeper depths can be obtained under ideal conditions). Generally, radar penetration is better in coarser, sandy conditions or massive rock; poorer results are obtained in fine-grained, clayey, and electrically conductive soils.

Instrumentation and Field Procedures for GPR Measurements

GPR data were acquired along the six survey lines for a total of 2,900 linear-feet. A Sensors and Software Noggin Plus radar system with a 250 MHz antenna was used for this work (Figure 3). The depth range was set to a maximum depth of 12 feet based on a radar velocity of 0.225 ft/ns measured at the site.

Data Processing and Interpretation

The GPR data were processed with EKKO_Project2 software (Sensors and Software). The data were assessed for large hyperbolas, dipping reflectors, discontinuous reflectors and ringing reflectors that are generally described as anomalies.

Quality Control

The GPR was calibrated and operated according to the manufacturer's instructions, ASTM Standards (ASTM, 2005c), and SGS standard operating procedures.

Limitations

The detection of subsurface features with GPR (naturally occurring or man-made) is dependent on the size, depth, and dielectric properties of the feature. It is possible that anomalous features will not be detected if they are beyond the depth range of the GPR, are too small to generate a significant response, or do not have a sufficient dielectric contrast with the surrounding material. This survey was not designed to map utilities.

RESULTS

The results of each geophysical method are described below. Anomalies due to possible karst features are discussed and annotated on the figures.

> *"Geophysical anomaly" is defined as a deviation from uniformity in physical properties (Sheriff, 2002). It is a term often used in geophysics to denote an area that is different than surrounding materials. Anomalies identified in this report are not confirmed as karst features until they are drilled and verified.*

ERI

The ERI cross-sections along Lines 2, 3, 4, and 5 are shown in Figures 4 to 7, respectively. The resistivity values have a range of 10 to over 2,000 ohm-meters. In general, high resistivity values (>100 ohm-meters) are evident from the surface to an elevation of approximately +20 feet (thickness of 40 to 50 feet). This high resistivity layer likely corresponds with unsaturated and partially saturated sandy overburden. Below an elevation of +20 feet, there is a trend towards lower resistivity values that likely corresponds with the saturated limestone and possibly greater clay content in the overburden above the limestone.

The ERI cross-sections were assessed for lateral changes in resistivity that may be related to karst features. In particular, zones of high-resistivity that extend deeper than the surrounding areas may indicate zones of soil with less clay content (greater sand content) that are filling localized lows in the limestone. Table 1 summarizes five anomalous zones identified in the ERI cross-sections. The anomalous zones are 40 to 130 feet wide. The anomalous zones along Lines 2 and 5 correlate with microgravity lows (discussed later). Note that the ERI data along Line 5 is noisy due to surface metal debris and power lines, and the resulting model may contain artifacts from this noise.

Table 1. ERI Anomalies

Line	Station	Easting	Northing	Comments
2	285	2026327.4	517555.7	40 ft wide Correlates with gravity low
3	300	2026301.3	517435.8	80 ft wide
4	255	2026229.1	517337.2	50 ft wide
4	315	2026289.0	517337.1	50 ft wide
5	100	2026019.3	517140.9	130 ft wide Correlates with gravity low. Noisy data due to surface metal debris and power lines.

Microgravity

The microgravity data are shown on a plan-view contour map in Figure 8 and in profile with the ERI cross-sections in Figures 4 to 7. The residual gravity values range between -30 to +23 μGals with a median value of 0 μGals. Zones of low gravity are evident in the northern portion of the site and in the southwestern corner of the site, both of which appear to extend beyond the boundaries of the survey.

The -30-μGal low gravity zone in the northern portion of the site trends south and correlates with a deeper zone of high-resistivity along Line 2 (Figure 4). The half-width of the anomaly is approximately 100 feet, which indicates that the source of the anomaly is within the upper 100 feet and likely correlates with the anomalous zone identified in the ERI cross-section.

The -30-μGal low gravity zone in the southwestern corner of the site correlates with a deeper zone of high-resistivity along Line 5 (Figure 7). The anomaly has a similar half-width as the northern anomaly, which indicates that the source of the anomaly is within the upper 100 feet.

These anomalous zones may be related to deeper limestone, lower density overburden, or a combination of both of these factors. Borings are necessary to confirm the causes of the anomalies.

GPR

The GPR data were limited in penetration to maximum depths of approximately 5 feet due to the clay content of the soil. In the upper 5 feet, the GPR data contain numerous diffractions that are likely due to tree roots and rocks. Only two anomalies appear to be due to more significant disturbed soil conditions. These anomalies include a ringy zone of reflections and diffractions at Station 255 along Line 2 and a bright reflector and diffractions at Station 55 along Line 4 (Figure 9). The anomalous zone along Line 2 correlates with the locations of the microgravity and ERI anomalies. Both of these anomalies are characteristic of disturbed soil conditions such as soil raveling.

CONCLUSIONS

Electrical resistivity imaging (ERI), microgravity, and ground penetrating radar (GPR) data were acquired within the Levy Avenue site to provide a reconnaissance level sampling of possible karst conditions. The data indicate the following anomalous conditions, which are summarized in Figure 10:

- Trends of high-resistivity that extend deeper than the surrounding areas may indicate zones of soil with less clay content (greater sand content) that are filling localized lows in the limestone. The five identified anomalous zones are 40 to 130 feet wide and are evident along each of the ERI survey lines (Lines 2, 3, 4, and 5). Two of the anomalous zones correlate with areas of low gravity.
- Two areas of low gravity are evident within the site with a magnitude of -30 μGals. The gravity lows are centered in the northern and southwestern portions of the site and appear to extend beyond the boundaries of the survey. The half-width of the anomalies are approximately 100 feet, which indicates that the sources of the anomalies are within the upper 100 feet and likely correlate with the anomalous zones identified in the ERI cross-sections. The gravity anomalies may be related to deeper limestone, lower density overburden, or a combination of both of these factors.
- Two GPR anomalies were identified that are consistent with disturbed soil conditions such as soil raveling. One of these GPR anomalies is coincident with the gravity low and ERI anomalous zone in the northern portion of the site.

Approximately 35% of the survey lines contain some type of geophysical anomaly that may be karst related. The interpretations derived from the geophysical data are based on these non-invasive measurements alone. Borings are necessary to confirm these interpretations and characterize the causes of the anomalies. Note that additional anomalous areas may be present in areas that were not sampled by the geophysical survey. Additional geophysical characterization and borings are recommended in areas where multiple geophysical methods show coincident anomalies.

REFERENCES

ASTM, 2005a, Standard guide for using DC resistivity measurements for subsurface investigations, D6431-99 (2005), ASTM International, West Conshohocken, Pennsylvania.

ASTM, 2005b, Standard guide for using the gravity method for subsurface investigation, ASTM D6430-99, West Conshohocken, Pennsylvania.

ASTM, 2005c, Standard guide for using the surface ground penetrating radar method for subsurface investigation, D6432-99 (Reapproved 2005), ASTM International, Conshohocken, PA, 17 p.

Cogbill, Allen H. (1990) Gravity terrain corrections calculated using Digital Elevation Models, Geophysics, 55(1), p. 102-106.

Hendry, C. W. and Sproul, C. R., 1966. Geology and Ground-Water Resources of Leon County, Florida Geological Survey, Bulletin 47, Tallahassee.

Long, L. T. and Kaufmann, R. D., 2013, *Acquisition and analysis of terrestrial gravity data,* Cambridge University Press, First Edition, ISBN: 978-1107024137, 192 p.

Longman, I.M, 1959, Formulas for computing the tidal accelerations due to the sun and moon, J. Geophysical Research, 64, p. 2351.

Scott, Thomas, 1988. The Lithostratigraphy of the Hawthorn Group (Miocene) of Florida, Florida Geological Survey, Bulletin 59, Tallahassee.

Seigel, H.O., 1995, *High precision gravity survey guide,* Scintrex Ltd., Concord, Ontario, 120 p.

Sheriff, R.E., 2002, *Encyclopedic dictionary of applied geophysics*, Society of Exploration Geophysicists, Fourth Edition, ISBN: 0-931830-47-8, 429 p.

Telford, W.M., Geldart, L.P., and Sheriff, R.E., 1990, *Applied Geophysics,* Cambridge University Press, Second Edition, 770 p.

SPOTLIGHT GEOPHYSICAL SERVICES

Figure 1. Survey area locations

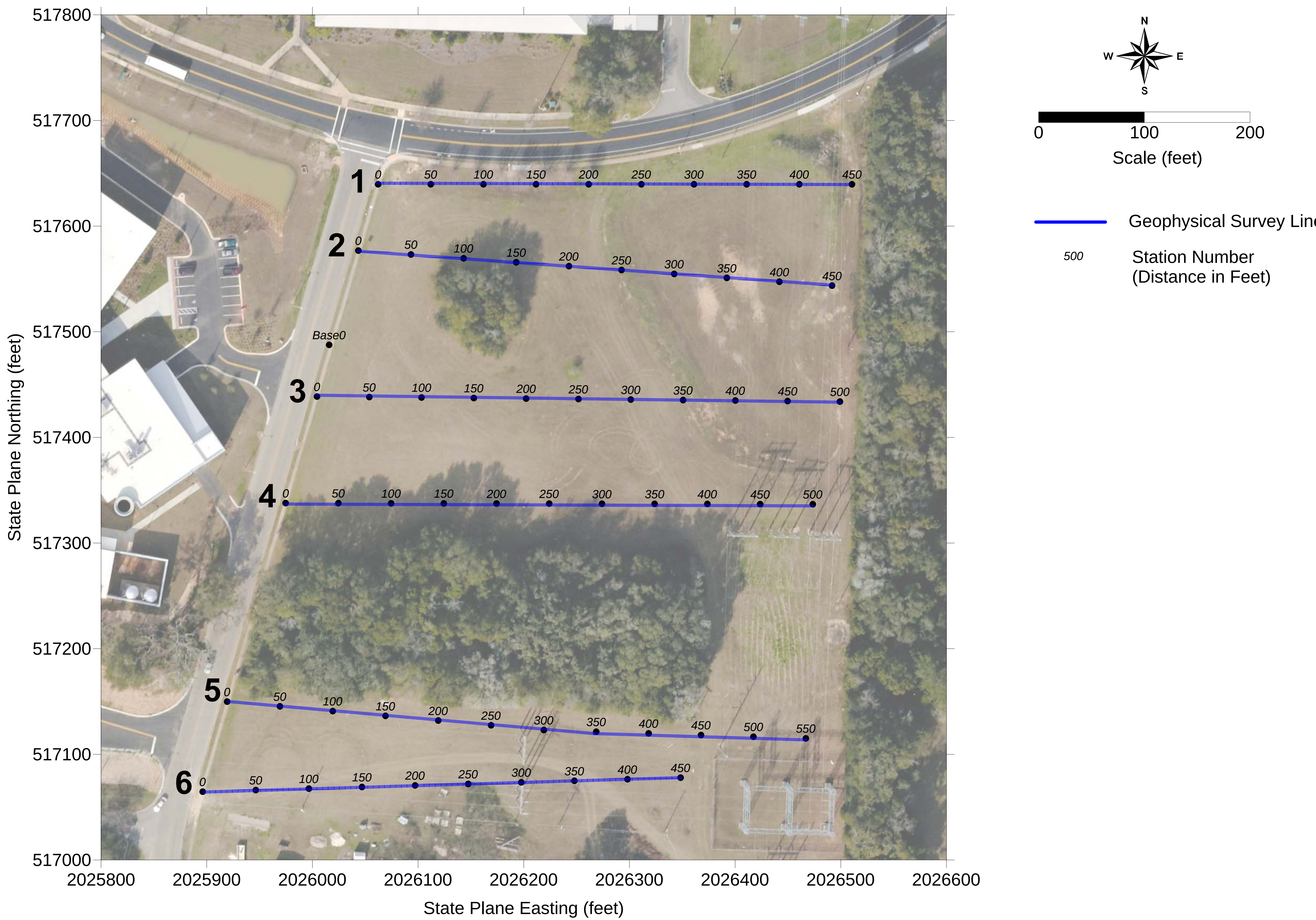


Figure 2. Levy Avenue site survey lines

SPOTLIGHT
GEOPHYSICAL SERVICES

Ground penetrating radar

Microgravity station

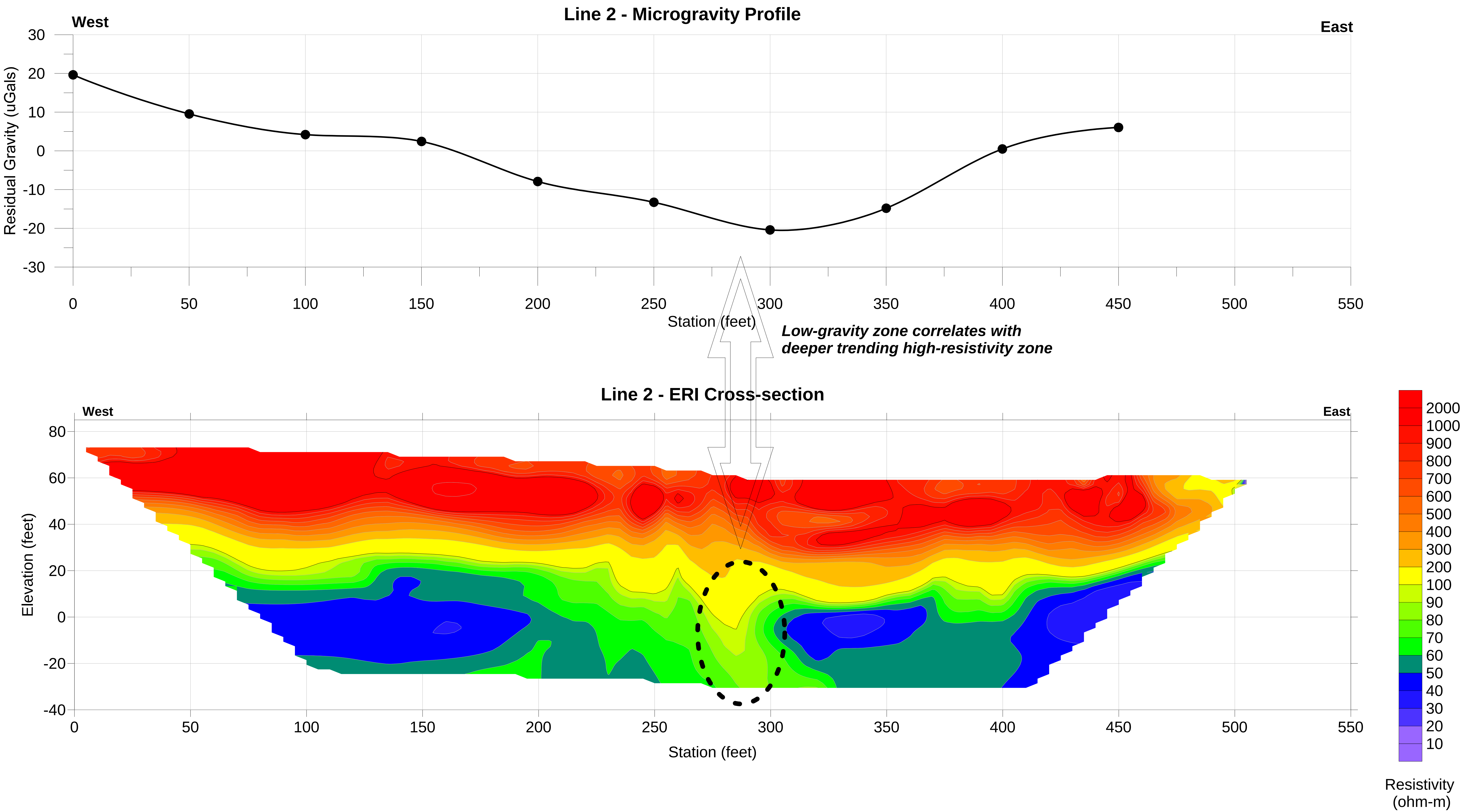
Microgravity base station “Base0”

Electrical resistivity imaging Supersting

Electrode stakes

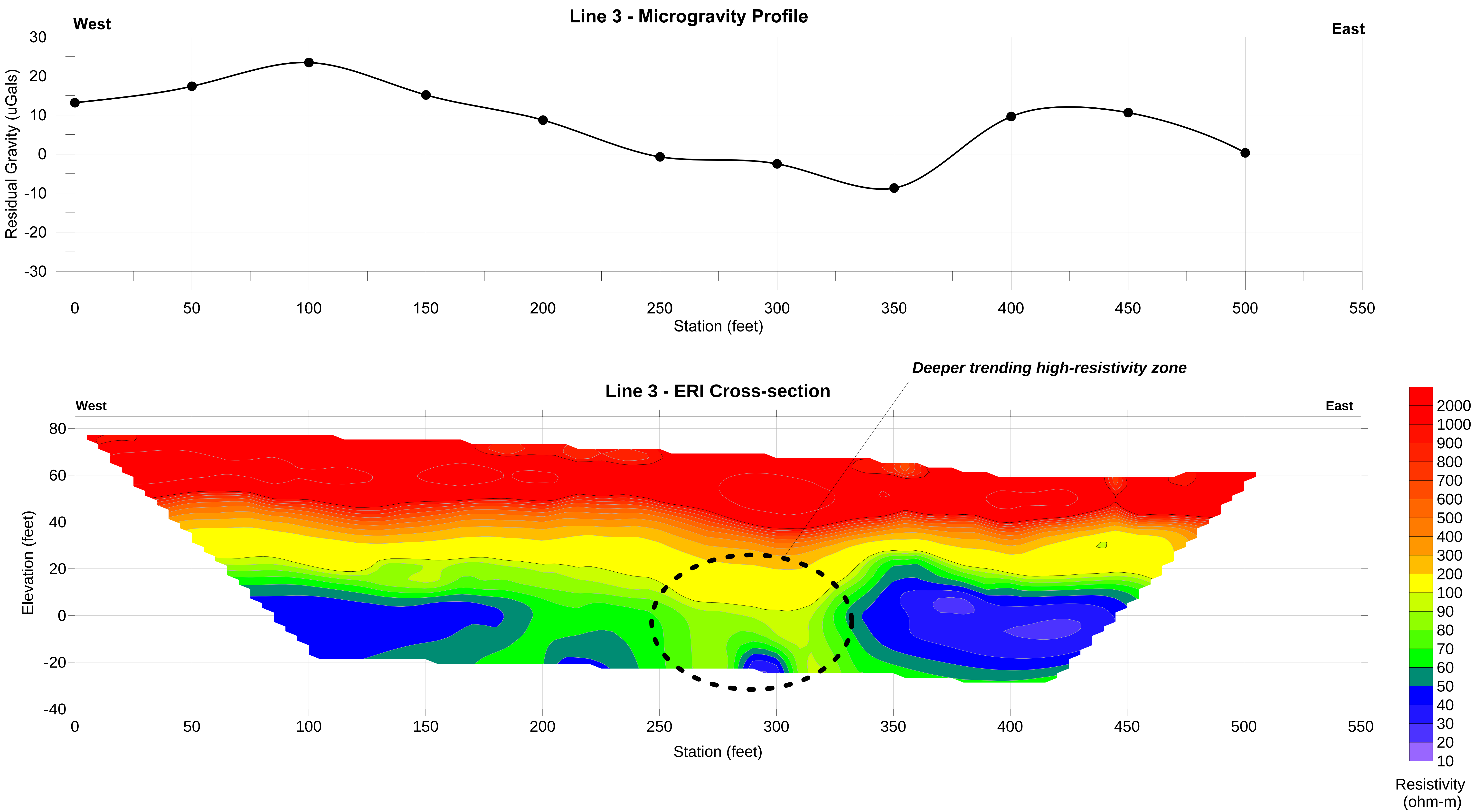
Microgravity base station “Base1”

Figure 3. Data acquisition photos



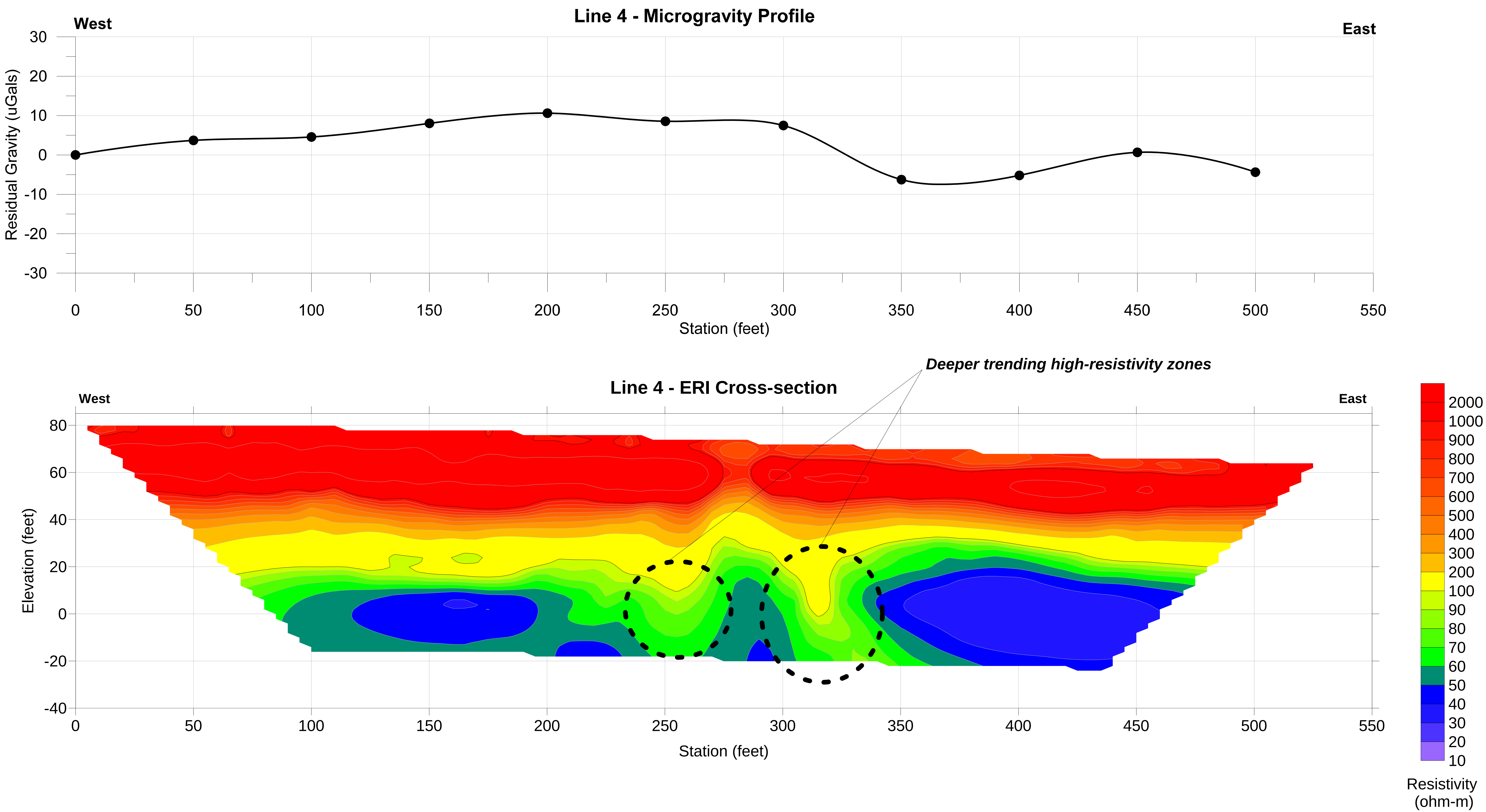
SPOTLIGHT GEOPHYSICAL SERVICES

Figure 4. Line 2 ERI cross-section and microgravity profile



SPOTLIGHT
GEOPHYSICAL SERVICES

Figure 5. Line 3 ERI cross-section and microgravity profile



SPOTLIGHT GEOPHYSICAL SERVICES

Figure 6. Line 4 ERI cross-section and microgravity profile

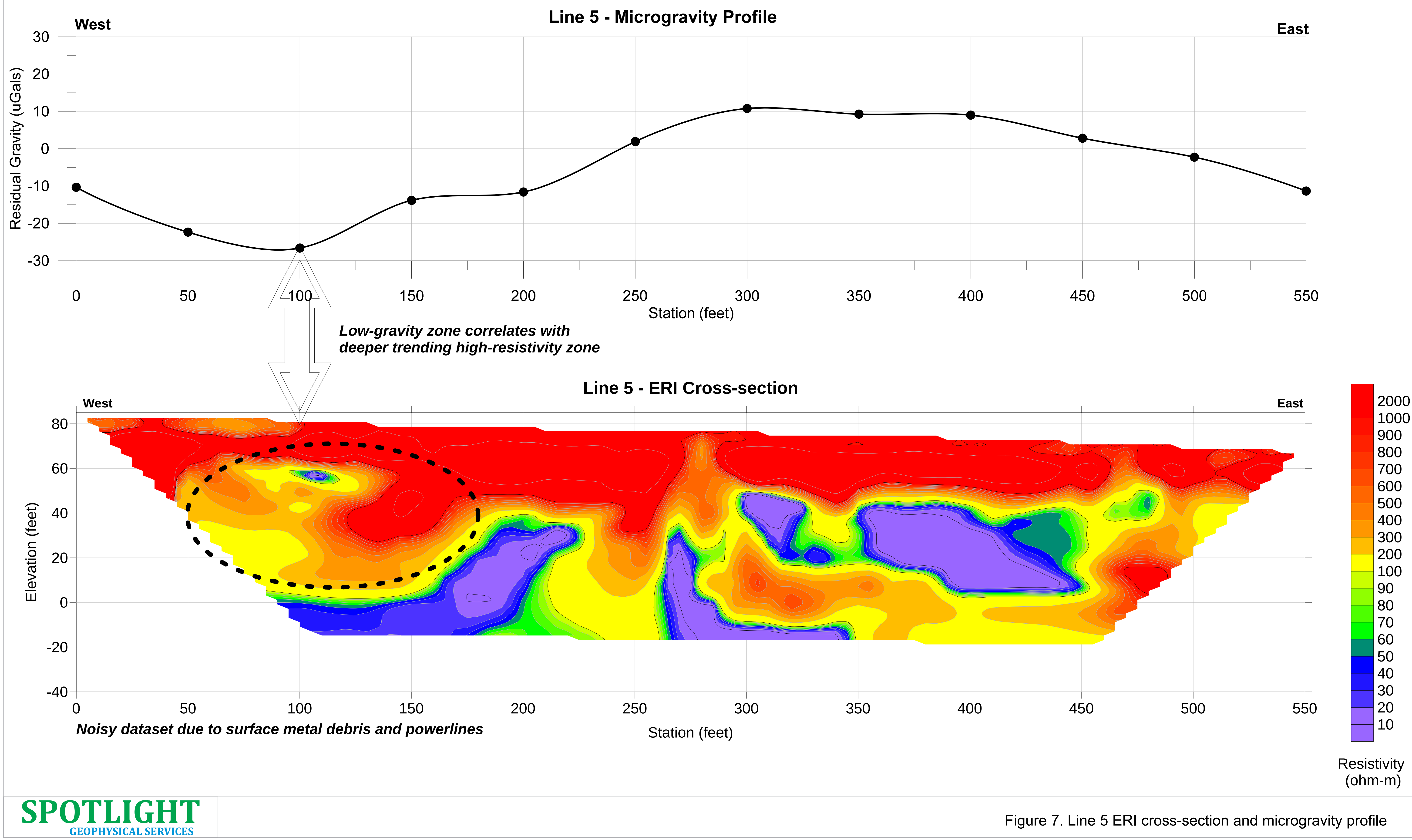
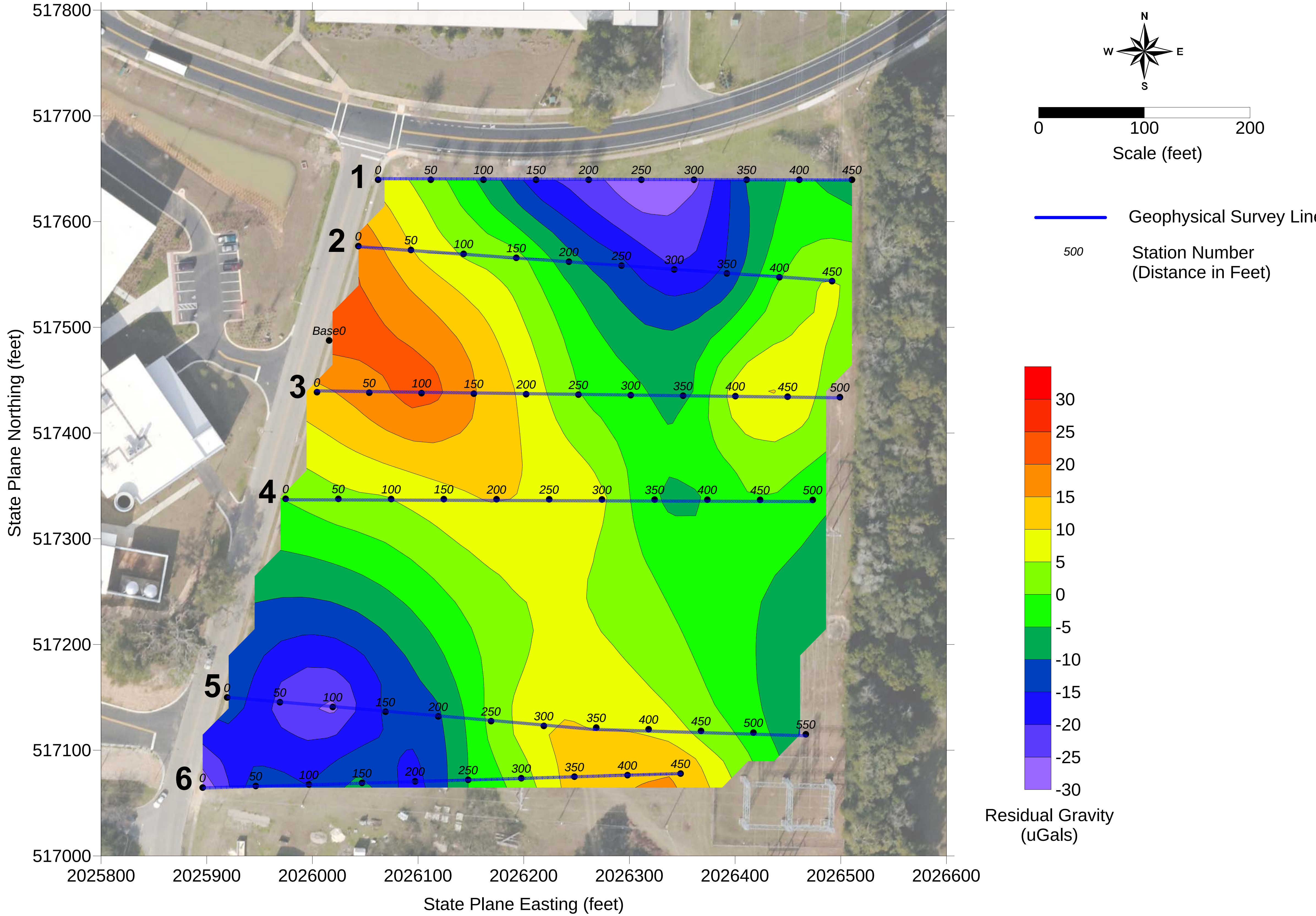
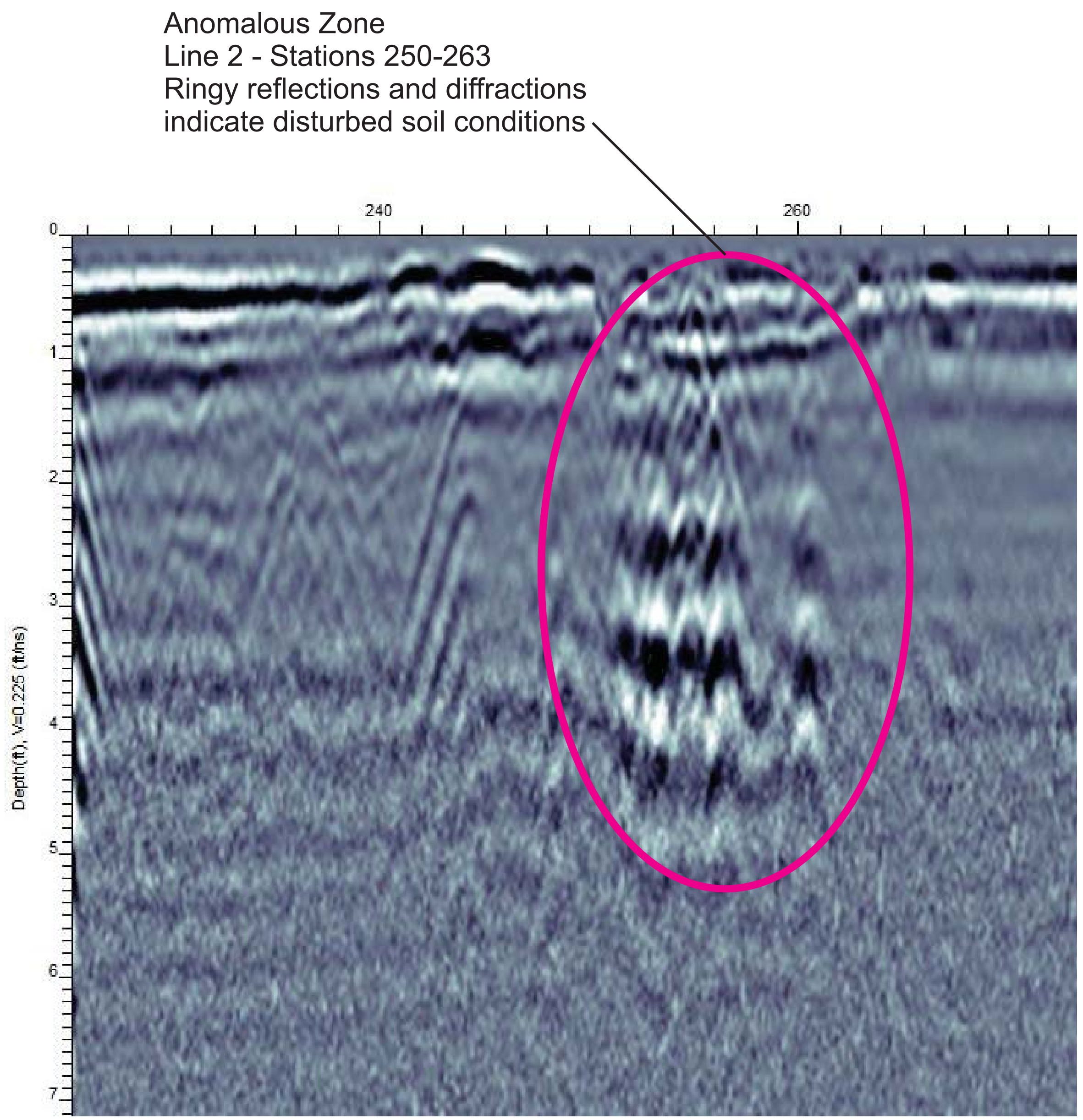


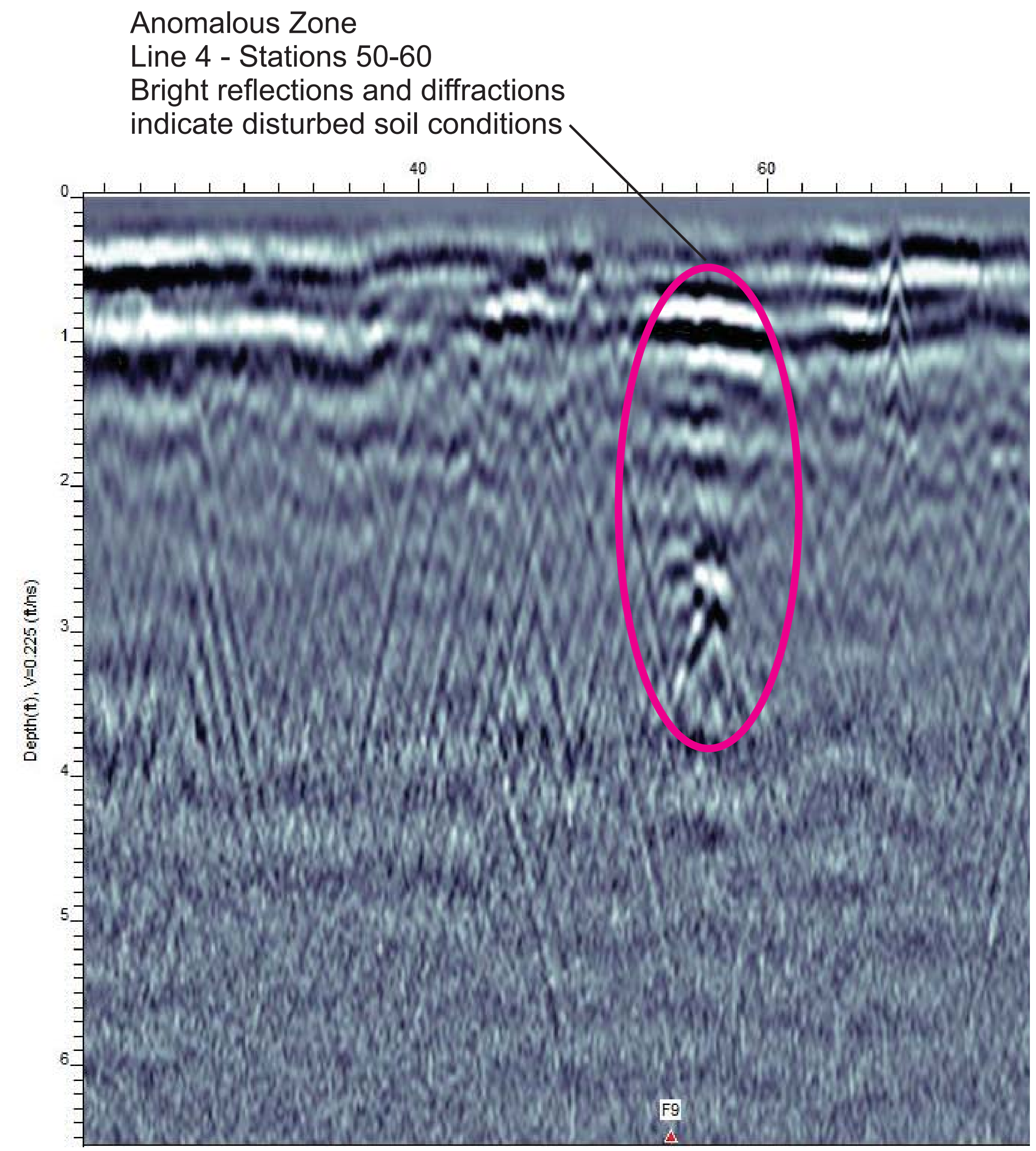
Figure 7. Line 5 ERI cross-section and microgravity profile



SPOTLIGHT
GEOPHYSICAL SERVICES

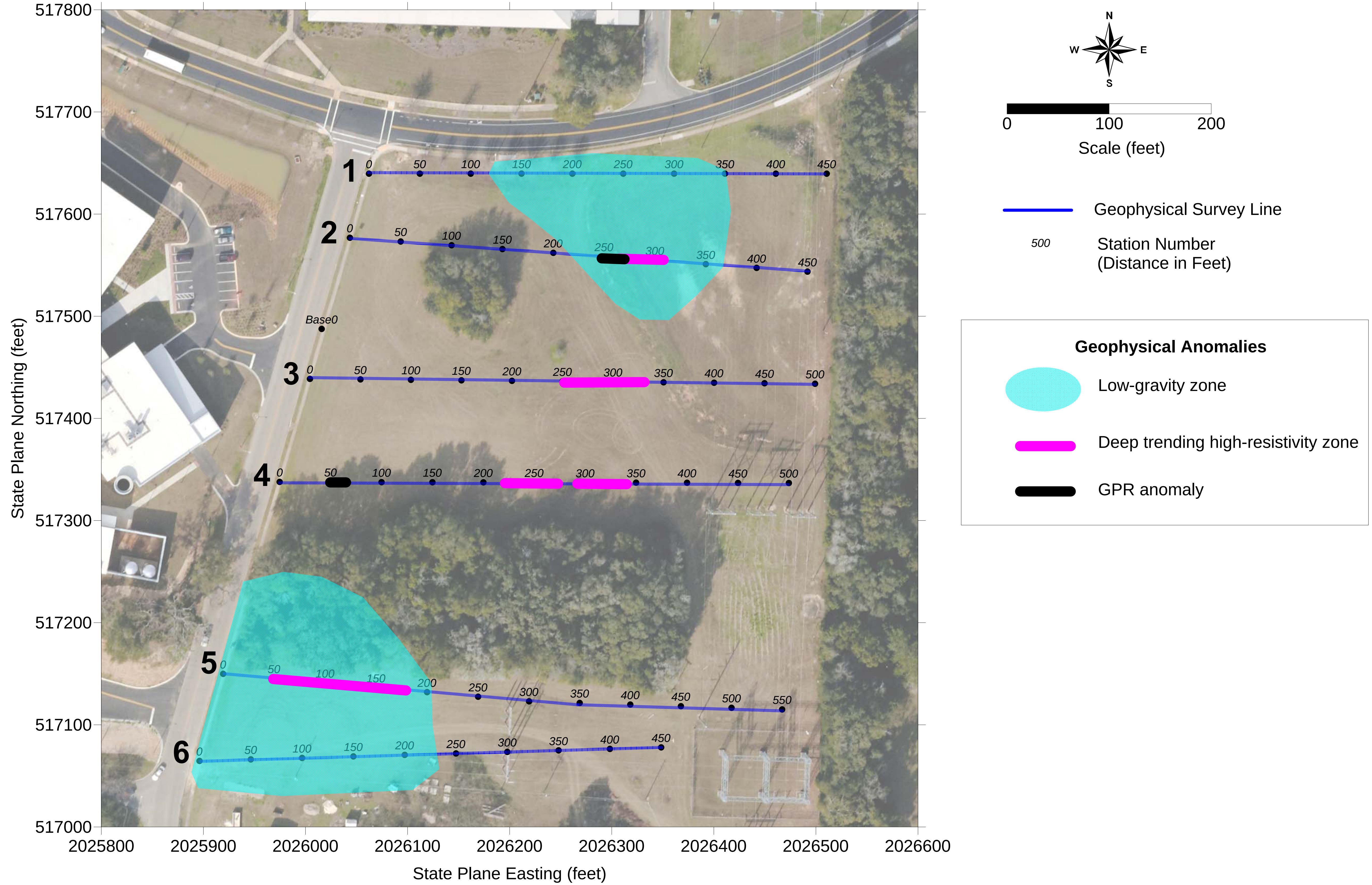
Figure 8. Microgravity contour map





SPOTLIGHT
GEOPHYSICAL SERVICES

Figure 9. Examples of GPR data showing anomalous conditions



SPOTLIGHT
GEOPHYSICAL SERVICES

Figure 10. Summary of geophysical anomalies