Microgravity Survey
Warm Mineral Springs Park
Geotechnical Site Investigation
City of North Port, Florida

DRAFT

Ardaman & Associates, Inc.

CORPORATE HEADQUARTERS

8008 S. Orange Avenue, Orlando, Florida 32809 - Phone: (407) 855-3860 Fax: (407) 859-8121

Branch Office Locations

Florida: Bartow, Cocoa, Fort Myers, Miami, Orlando, Port St. Lucie, Sarasota, Tallahassee, Tampa, West Palm Beach
Louisiana: Baton Rouge, New Orleans, Shreveport
Texas: Houston

MEMBERS:

ASTM International
Society of American Military Engineers
American Council of Engineering Companies

Ardaman & Associates, Inc.

Geotechnical, Environmental and
Materials Consultants

May 24, 2024
Ardaman File No. 23-7038

City of North Port
6644 W. Price Boulevard
North Port, Florida 34291

Attention: Ms. Tricia Wisner, MBA
Assistant Director, Public Works

Subject: Microgravity Survey
Warm Mineral Springs Park
Geotechnical Site Investigation
City of North Port, Florida

Dear Ms. Wisner:

As requested and authorized, a microgravity survey was carried out by Ardaman & Associates, Inc. (Ardaman) as part of the geotechnical site investigation at Warm Mineral Springs Park (WMSP) in the City of North Port, Florida. Ardaman prepared this report providing a summary and evaluation of the microgravity survey. Based on the findings from the microgravity survey, a recommended subsurface exploration program is included.

The enclosed report has been prepared in accordance with generally accepted geotechnical engineering practice for the exclusive use of the City of North Port for specific application of the above referenced project.

It has been a pleasure assisting you with this phase of the geotechnical site investigation. We trust that the enclosed report and supporting documents meet your current planning needs.

Please contact us if you have any questions or need additional information or assistance.

Very truly yours,
ARDAMAN & ASSOCIATES, INC.
Certification of Authorization No. 5950

Virginia A. Goff, P.E.
Sarasota Branch Manager

Jason Parker, P.E.
Vice President, Senior Engineer

DRAFT

1724 Barber Road, Sarasota, Florida 34240 Phone (941) 922-3526 FAX (941) 922-6743

Florida: Bartow, Cocoa, Fort Myers, Miami, Orlando, Port St. Lucie, Sarasota, Tallahassee, Tampa, W. Palm Beach
Louisiana: Baton Rouge, New Orleans, Shreveport
Texas: Houston

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1. Background

As part of the geotechnical investigation proposed at WMSP, a microgravity survey was performed to assess subsurface conditions within the future footprints of selected development areas. A total of 1,203 survey stations were established and the microgravity data was subsequently acquired by Ardaman between November 2023 and May 2024.

Area	Description
D	Indigenous Village & Museum
E	Amphitheater & Event Venue
G	Food Truck Park & Event Plaza
J	Resort Hotel & Spa
K	Eco Cabins
N	Restaurant
P	Multi-Floor Residential Building (20 Units)
Q	Multi-Floor Residential Building (115 Units)

The results of the microgravity survey and a summary of our pertinent findings and relevant recommendations are provided below.

2. Microgravity Methodology

Microgravity is a non-invasive method that can map karst features based on their density contrast with the surrounding material. It measures changes in the Earth's gravity due to subsurface density variations by collecting a precision gravity survey in which near surface features are of interest. These features may include lateral changes in soil or rock density, buried channels, large fractures, faults, dissolution-enlarged joints and cavities. Man-made features such as mines, tunnels, and large structures are also appropriate targets for microgravity surveys. A microgravity survey can be used to map the lateral boundaries of anomalous features, estimate variations in bulk density within an anomalous area, and guide confirmatory borings. Standard survey procedures are outlined in ASTM D6430-99.

3. Microgravity Grid Spacing

Microgravity measurements are subject to variability influenced by earth tides (gravitational effects of the sun and moon), vibration/noise (wind), and instrument drift that must be corrected by repeating measurements at a base station during the survey while determining the Bouguer gravity. Corrections are also required to account for free air (i.e., changes attributed to variation in elevation at survey stations), meter height (above the surface), and Bouguer slab (attraction of the material between the measurement station and a constant datum), as well as latitude, topographic terrain variations and regional trends. For natural ground areas (or areas with limited variability), an anomaly detectability threshold of 10 µGals is deemed reasonable. On the other hand, prior Ardaman experience in Central Florida suggests that local gravity lows of 10 to 30 µGals are generally expected in certain areas such as mined-out areas due to variability and unaccounted density variations in the subsurface profile and due to unaccounted topographic variations in the near-field terrain variations. Significant geologic anomalies, such as erosion features or large voids are generally associated with gravity anomalies characterized by a magnitude greater than 100 µGals, which makes them more readily detectible.

The first step in the microgravity data collection and interpretation is establishing survey grid or station spacing that will enable detecting expected anomaly sizes. Based on our experience in prior microgravity projects in Central Florida, a 20-foot sampling interval was deemed appropriate for the project.

4. Limitations of the Microgravity Methodology

- Microgravity data relies on variations in subsurface density and can generally be used to map lateral locations of low or high gravity areas. However, it is important to note that microgravity data alone cannot be used to determine the absolute depth of low or high gravity subsurface zones. Therefore, confirmatory drilling and subsequent geotechnical interpretation of subsurface soil\rock layers, groundwater conditions, Standard Penetration Test (SPT) results, and determination of undisturbed densities is required to reasonably identify the correct depth of the anomalous zones.

- Since gravity varies inversely with the square of the distance, the microgravity measurements are very sensitive to changes in elevation. An elevation difference of 1 inch can result in a nominal gravity error of 7.8 µGals (i.e., a gravity measurement can change by 94.06 µGals per foot of elevation difference). According to ASTM Standard D6430, an elevation control for a microgravity survey requires a relative elevation accuracy of about 3 mm.

- In addition to its sensitivity to elevation differences, microgravity measurements are also noticeably sensitive to slight changes in density. For example, a 400x400-ft mass consisting of approximately 6% less dense material to a depth of 50 feet could result in a gravity anomaly of approximately 55 µGals. As discussed in the following sections, a gravity anomaly of 55 µGals is quite significant compared to the gravity data range observed in this study.

5. Data Acquisition

Prior to the acquisition of the microgravity data, the survey locations needed to be cleared of underbrush. Ardaman reviewed the provided “Threatened and Endangered Species Survey” report for locations of gopher tortoise burrows within WMSP and these burrow locations (including an area around the burrow with a minimum radius of 25 feet), heritage trees, and palms were excluded from the clearing operations. The survey area was then cleared by Abbotts Construction Services, Inc. to provide access to the stations shown on Figure 1. Ardaman established 1,203 stations on a 20x20-foot survey grid in accessible areas using 60d nail and stake whisker. Some stations were offset from the design grid to avoid surface obstructions. The stations were surveyed using a real-time kinematic Global Positioning System (GPS), Trimble R12, by Ardaman. To achieve the required elevation accuracy for microgravity survey, stations that are close to tall trees with canopy hindering GPS signal were surveyed by our Subcontractor (Pickett & Associates, Inc.) using Total Station. Station positions are referenced to Florida State Plane (West) coordinates in feet (NAD83). Surveyed elevations have an accuracy within 0.1 feet and are referenced to the National Geodetic Vertical Datum of 1988 (NAVD 88).

The Microgravity data were acquired by Ardaman using Scintrex CG-6 gravimeter (S/N 21010315) using a 30-second cycle averaging window and automatic corrections for tides and meter leveling. A total of 1,203 survey stations and a reference base station (see Figure 1) were used to acquire the microgravity data.

The Scintrex gravimeter was set-up and operated in accordance with the manufacturer's instructions and ASTM standard D6430.

The data quality was monitored by re-acquiring data at stations throughout the survey in a pseudo-random fashion and checking the repeatability of the measurements. The repeated data have an average deviation of ±2 μGals, which indicates low levels of ambient noise.

6. Microgravity Survey Data Processing

The processing of the microgravity survey data involves two steps. The first step is where the field data acquisition standard operating procedures are verified by checking location of surveys, tilt, temperature stability, and drift calibration factors, and where firsthand post-deployment statistics are measured to ensure survey repeatability and remove outlier data. The second step in processing is gravity data reduction. In this step, the data is compiled and corrected for the effects of temporal and spatial dependent factors such as latitude, terrain density, topography, earth tides, free-air, and Bouguer slab. The reduction process yields residual gravities that correlate to lateral density changes in the subsurface.

The gravity data processing involving the following elements were performed by Ardaman and Spotlight Geophysical Services, LLC (Spotlight).

- Preparation of survey files by removing erroneous readings and outliers.
- Performing base station loop closure to remove base station drift using beginning and end of day base station readings. The base station loop closure is required since all relative gravity meters have an inherent drift that must be corrected by repeating measurements at the base station during the survey.
- Applying tidal and dynamic drift corrections in Scintrex CG-6 instrument.
- Applying latitude correction.
- Merging all daily surveys to obtain a master database.

- Applying Free Air correction to account for variations in gravity due to elevations including meter height above ground surface. The instrument height correction is based on meter height measured at each station using a standard tape measure with a precision of 0.05 feet.

- Performing Bouguer Anomaly corrections to obtain Complete Bouguer Anomaly

- Applying regional planar trend correction to isolate residual gravity anomalies.

7. Microgravity Survey Findings

A color-coded residual gravity map, with values ranging from -53 to +42 μGals, relative to a median value of 0 μGals is displayed on Figure 2. Low-gravity trends with magnitudes below -20 μGals are shaded blue and violet, while high-gravity trends above +20 μGals are shaded yellow, orange and red. Small fluctuations of residual gravity values between -20 and +20 μGals (shaded green and light yellow) are likely due to small variations in near-surface density and resolution limitations of the elevation data.

As shown on Figure 2, most (81 percent) of the surveyed future building footprints show background conditions between -20 and +20 μGal, indicating that no large density variations or no large karst features exist within those areas. However, there is a trend of lower gravity on the western portions of the Areas closest to the spring, in particular Area D/E, where the lowest gravity values are located. There is also a low gravity trend identified at Area P and around the eastern portions of Area Q North and South. The trend appears to be broad, likely indicating a zone of deeper rock or a preferential dissolution zone in the upper rock. The microgravity data is not necessarily locating isolated conduits (although they may be within the low-gravity zones).

8. Recommended Confirmatory Subsurface Exploration Program

Based on the results of the microgravity survey, a field exploration and laboratory testing program consisting of 14 borings (Figure 3) is recommended to confirm if the identified low-gravity areas are due to subsurface geologic anomalies (such as erosion features or large voids) or variation in subsurface density. The selection of the check borings is based on the following criteria.

- Seven check borings (TH-4, TH-5, TH-6, TH-10, TH-11, TH-13 and TH-14) are proposed to explore subsurface conditions at locations with low residual gravity ranging from -44 μGal to -15 μGal.
- Six check borings (TH-1, TH-2, TH-3, TH-7, TH-8 and TH-12) are proposed to establish background subsurface conditions at locations with background or high residual gravity ranging from -12 μGal to +36 μGal.
- One boring (TH-9) is proposed to compare subsurface condition at a location inaccessible for microgravity survey in Area K with a background gravity location (TH-8).

8.1 *Subsurface Soil Exploration (Area J: Resort Hotel & Spa)*

The field exploration program in Area J (Resort Hotel & Spa) included performing 3 Standard Penetration Test (SPT) borings (TH-1, TH-2 and TH-3). The SPT borings were advanced to a depth of 50 feet below the existing ground surface generally using the methodology outlined in ASTM D-1586. A summary of this field procedure is included in Appendix I. Soil samples recovered during performance of the borings were visually classified in the field and representative portions of the samples were transported to our laboratory in sealed sample jars. The groundwater level at each of the boring locations was measured during drilling. The borings were backfilled with cement grout upon completion.

The approximate locations of the borings are schematically illustrated on an aerial image shown on Figure 3. These locations were determined in the field by Global Positioning System (GPS) utilizing hand-held GPS equipment and coordinates obtained from Google Earth Pro. Boring locations should be considered accurate only to the degree implied by the method of locating used.

TH-1 was advanced at a location with background residual gravity of -6 µGal. The visual classification of the soil samples recovered from the SPT split spoons indicated that the upper 8 feet of soils consists of light brown to brown fine sand, followed by 4.5 feet thick light brown to brown silty fine sand and 37.5 feet thick partially cemented to cemented silt.

TH-2 was advanced at a location with background residual gravity of -8 µGal. The visual classification of the soil samples recovered from the SPT split spoons indicated that the upper 6 feet of soil consist of light brown to gray fine sand, followed by 6.5 feet of light brown to brown clayey fine sand, and 32.5 feet of partially cemented to cemented silt.

TH-3 was advanced at a location with background residual gravity of -12 µGal. The visual classification of the soil samples recovered from the SPT split spoons indicated that the upper 4 feet of soil consist of light gray to gray to orange-brown fine sand, followed by 5.5 feet of orange-brown clayey fine sand, and 40.5 feet of partially cemented to cemented silt.

The groundwater level was measured in the boreholes during drilling. As shown on Figure 4, groundwater was encountered at a depth of approximately 2½ feet below the existing ground surface on the dates indicated. Fluctuation in groundwater levels should be anticipated throughout the year primarily due to seasonal variations in rainfall and other factors that may vary from the time the borings were conducted.

The three borings completed to-date do not show voids, erosion cavities, raveled zones, drilling fluid circulation loss zones or other anomalous conditions that would be associated with a structural anomaly or discontinuity up to the termination depths of the borings. The findings from the borings will be evaluated along with the proposed borings shown on Figure 3.

The findings from the borings do not reflect any variations which may occur adjacent to or between the borings. The nature and extent of the variations between the borings may not become evident until during further exploration and/or construction. If variations then appear evident, it will be necessary to re-evaluate the evaluations presented in this report after performing on-site observations during the construction period and noting the characteristics of the variations.

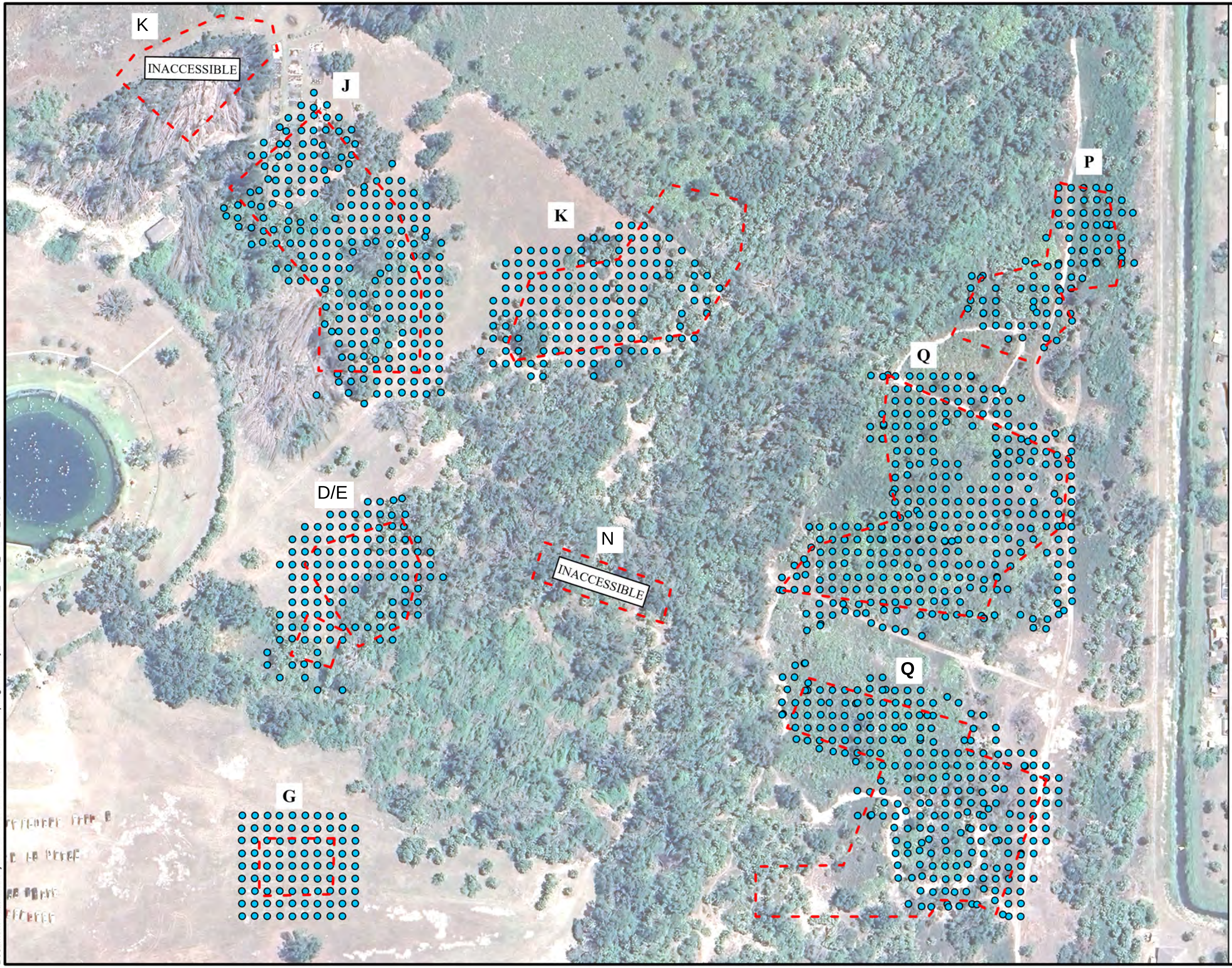
9. Conclusion

- A microgravity survey was performed to assess the subsurface conditions and investigate if karst features such as subsurface voids are present beneath the acquired stations within the future footprints of Buildings D/E, G, J, K, P, Q (north and south).

- The microgravity survey was acquired using 1,203 stations at center-to-center spacings of 20 feet. Some stations were offset from the design grid to avoid surface obstructions. The residual gravity values range between -53 and +42 μGals relative to the median value of 0 μGal. The range of residual gravity magnitudes obtained is typical for the geologic regime in Central Florida and consistent with the range of residual gravities obtained in previous projects.

- Most (approximately 81 percent) of the surveyed future building footprints reveal background (non-anomalous) conditions between -20 and +20 μGal, indicating that no large density variations or no large karst features exist within those areas. A broad trend of lower gravity was located on the western portions of the areas closest to the spring, in particular Area D/E. There is also a low gravity trend identified at Area P and around the eastern portions of Area Q (both North and South). The trend appears to be broad, likely indicating a zone of deeper rock or preferential dissolution zone in the upper rock. Verification borings are recommended to verify if the low gravity areas are due to subsurface geologic anomalies (such as erosion features or large voids) or variation in subsurface density.

- Based on the results of the microgravity survey, a confirmatory field exploration and laboratory testing program consisting of 14 borings is recommended. To-date, three borings were advanced at the future footprint of Building J. The borings do not show voids, erosion cavities, raveled zones, drilling fluid circulation loss zones or other anomalous conditions that would be associated with a structural anomaly or discontinuity up to the termination depths of the borings.



N

0 75 150

SCALE: 1" =150'

IMAGERY SOURCE:
GOOGLE EARTH, APRIL 26, 2023

LEGEND

Completed Microgravity Stations

Area	Number of Stations
E	122
G	88
J	298
K	146
P	76
Q	299
Q	240

PRELIMINARY

WMSP MICROGRAVITY STATION MAP

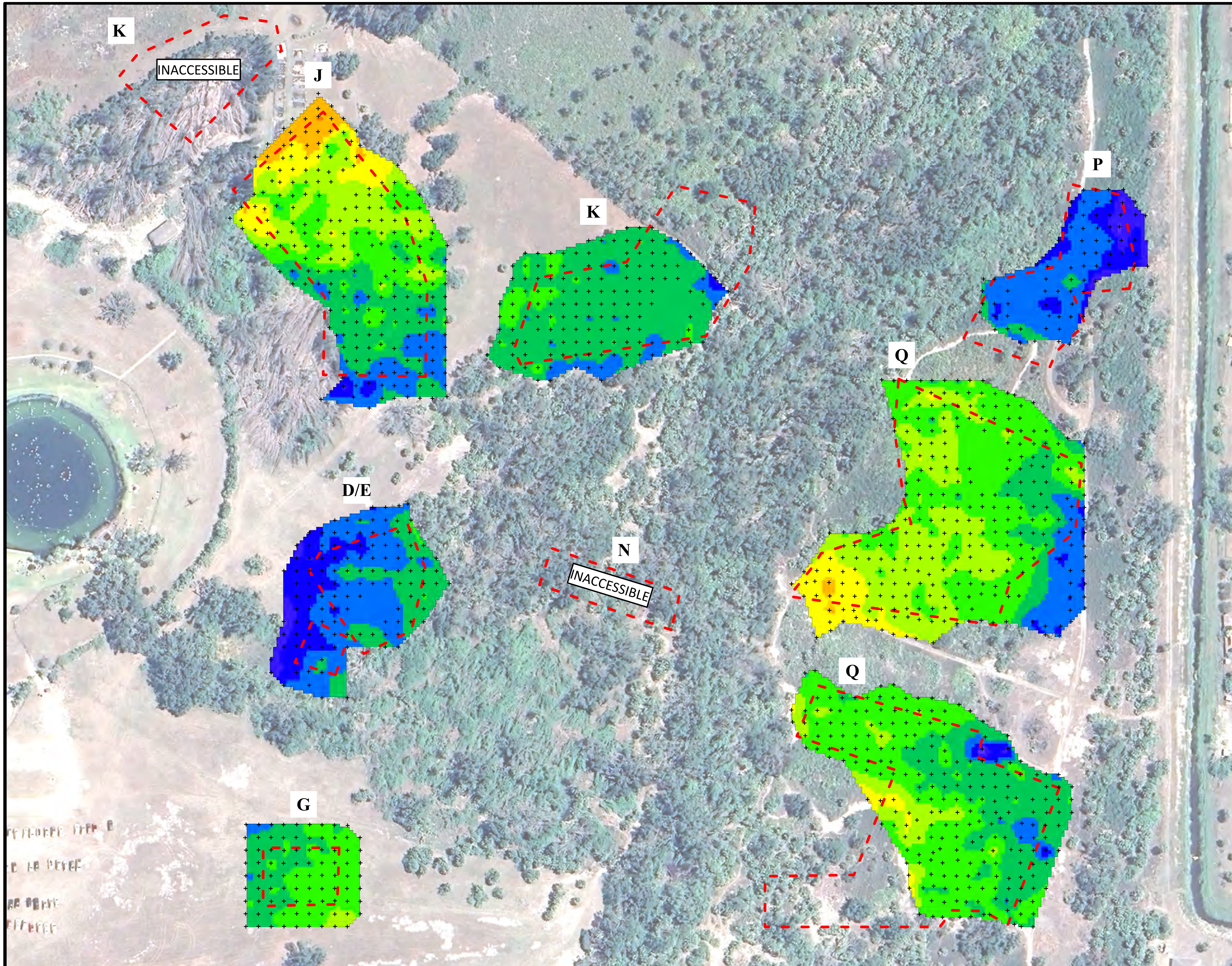
Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

WARM MINERAL SPRINGS PRELIMINARY MICROGRAVITY SURVEY

North Port City

DRAWN BY: ACV	CHECKED BY: EF	DATE: 5/7/2024
FILE NO. 23-36-7038	APPROVED BY:	FIGURE NO.: 1

Document Path: W:\Projects\2023\23-16-7038 Warm Mineral Springs\Arc Layouts\20231211_Warm_Mineral_Springs.aprx



0 75 150

SCALE: 1" =150'

IMAGERY SOURCE:
GOOGLE EARTH, APRIL 26, 2023

LEGEND

+ Completed Microgravity Station

Residual Gravity
(MicroGals)

High Gravity (High Density)
Background
Low Gravity (Low Density)

60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60

PRELIMINARY

WMSP RESIDUAL GRAVITY MAP

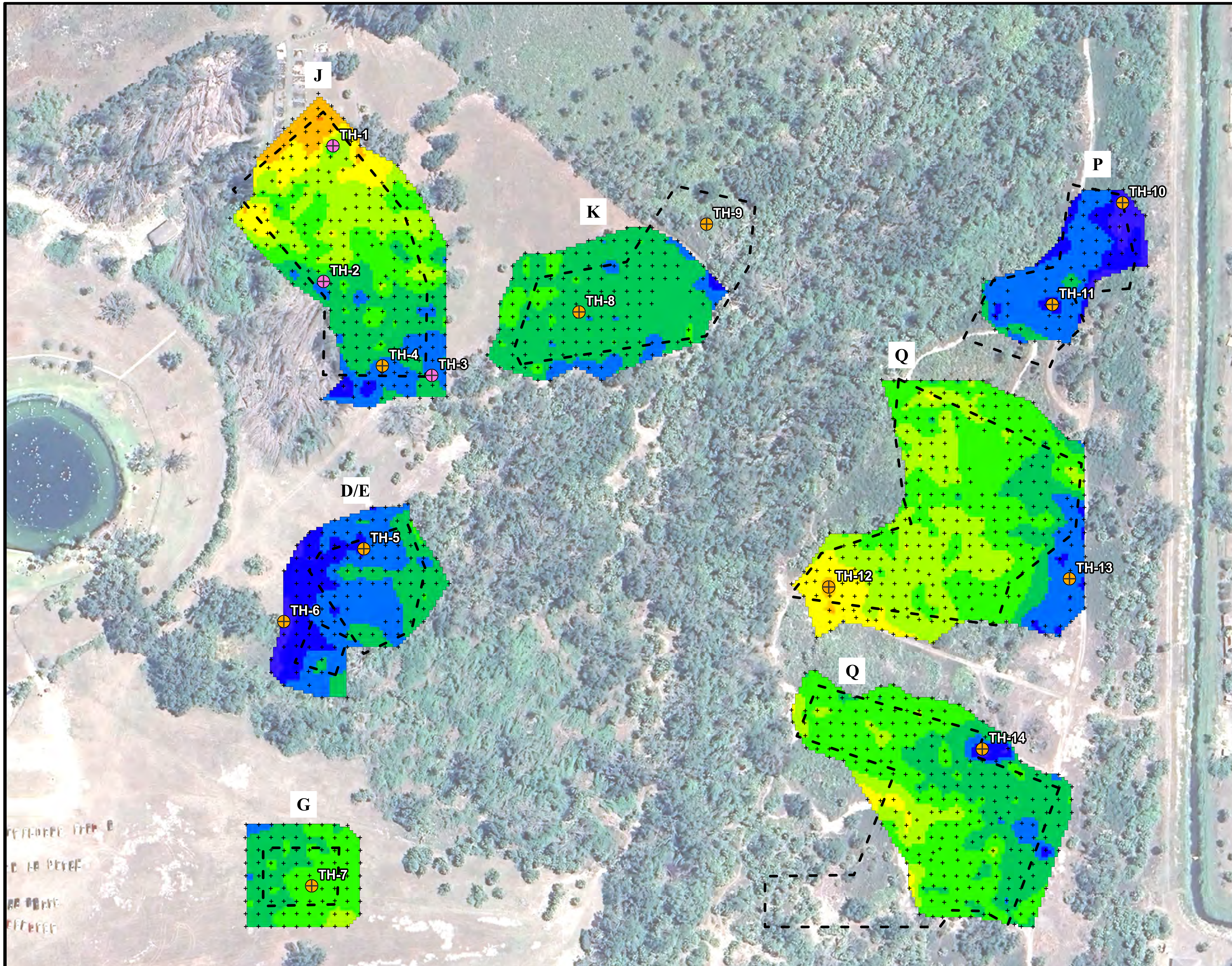
Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

WARM MINERAL SPRINGS
PRELIMINARY MICROGRAVITY SURVEY

North Port City

DRAWN BY: ACV	CHECKED BY: EF	DATE: 5/9/2024
FILE NO. 23-36-7038	APPROVED BY:	FIGURE NO.: 2

Document Path: W:\Projects\2023\23-16-7038 Warm Mineral Springs\Arc Layouts\20231211_Warm_Mineral_Springs.aprx



N

0 75 150

SCALE: 1" =150'

IMAGERY SOURCE:
GOOGLE EARTH, APRIL 26, 2023

LEGEND

- Microgravity Station
- Proposed Borings
- Completed Borings

Residual Gravity
(MicroGals)

High Gravity (High Density): 60, 50, 40, 30
Background: 20, 10, 0, -10, -20
Low Gravity (Low Density): -30, -40, -50, -60

PRELIMINARY

PROPOSED BORING LOCATION MAP

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

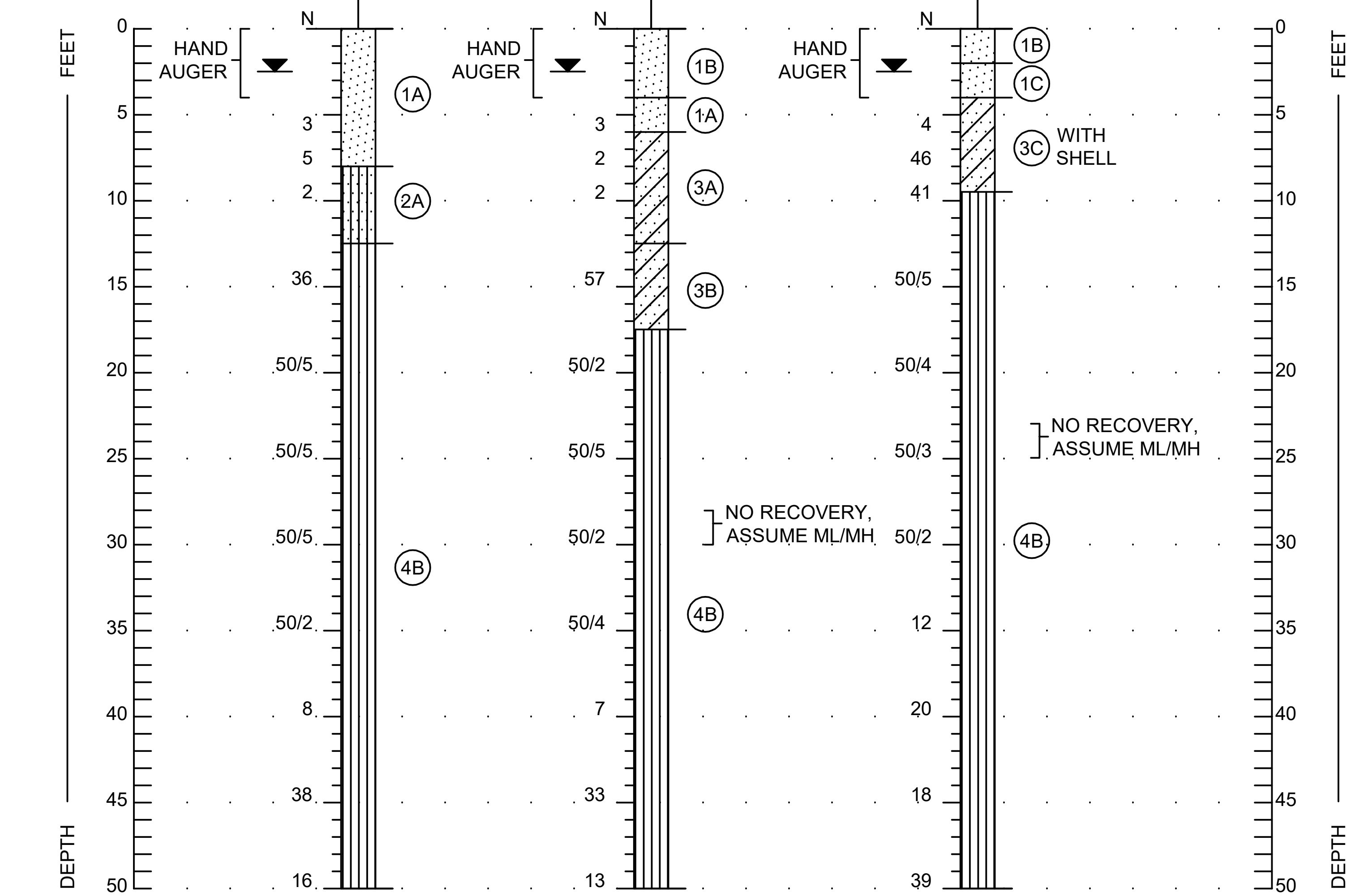
**WARM MINERAL SPRINGS
PRELIMINARY MICROGRAVITY SURVEY**

North Port City

DRAWN BY: ACV	CHECKED BY: EF	DATE: 5/9/2024
FILE NO. 23-36-7038	APPROVED BY:	FIGURE NO.: 3

Document Path: W:\Projects\2023\23-16-7038 Warm Mineral Springs\Arc Layouts\20231211_Warm_Mineral_Springs.aprx

BORING:	TH-1	TH-2	TH-3
DATE:	01/23/24	01/22/24	01/22/24
LATITUDE:	27.062160	27.061702	27.061852
LONGITUDE:	-82.261718	-82.261307	-82.260900



LEGEND

SOIL DESCRIPTIONS

1. FINE SAND (SP)
2. SILTY FINE SAND (SM)
3. CLAYEY FINE SAND (SC)
4. PARTIALLY CEMENTED TO CEMENTED SILT (ML/MH)

COLORS

A. LIGHT BROWN TO BROWN
B. LIGHT GRAY TO GRAY
C. ORANGE-BROWN

TH STANDARD PENETRATION TEST (SPT) BORING LOCATION

N STANDARD PENETRATION RESISTANCE IN BLOWS PER FOOT

50/3 50 BLOWS FOR 3-INCHES PENETRATION INTO SOIL

▼ GROUNDWATER LEVEL MEASURED ON DATE DRILLED

SP,SP-SM SM,SC,CH UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

NOTES:
1. UPON COMPLETION OF EACH SPT BORING, THE BOREHOLE WAS GROUTED WITH CEMENT-BENTONITE SLURRY.

2. ALL SPT BORINGS WERE PERFORMED USING AN AUTOMATIC HAMMER TO THE BORING TERMINATION DEPTH. AUTOMATIC HAMMER N-VALUES MAY BE CONVERTED TO EQUIVALENT SAFETY HAMMER N-VALUES BY MULTIPLYING BY 1.24.

GRANULAR MATERIALS-RELATIVE DENSITY	SAFETY HAMMER SPT N-VALUE (BLOWS/FOOT)	AUTOMATIC HAMMER SPT N-VALUE (BLOWS/FOOT)
VERY LOOSE	LESS THAN 4	LESS THAN 3
LOOSE	4 TO 10	3 TO 8
MEDIUM DENSE	10 TO 30	8 TO 24
DENSE	30 TO 50	24 TO 40
VERY DENSE	GREATER THAN 50	GREATER THAN 40
SILTS AND CLAYS CONSISTENCY	SAFETY HAMMER SPT N-VALUE (BLOWS/FOOT)	AUTOMATIC HAMMER SPT N-VALUE (BLOWS/FOOT)
VERY SOFT	LESS THAN 2	LESS THAN 1
SOFT	2 TO 4	1 TO 3
FIRM	4 TO 8	3 TO 6
STIFF	8 TO 15	6 TO 12
VERY STIFF	15 TO 30	12 TO 24
HARD	GREATER THAN 30	GREATER THAN 24

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.

SOIL BORING PROFILES

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

WARM MINERAL SPRINGS PRELIMINARY MICROGRAVITY SURVEY

NORTH PORT CITY

DRAWN BY: JV	CHECKED BY: EF	DATE: 05/15/24
FILE NO. 23-36-7038	APPROVED BY:	FIGURE NO: 4

C:\Users\joshua.vasquez\Documents\Ardaman\23\23-7038\23-7038.dwg 5/24/2024 8:17:13 AM, JOSHUA.VASQUEZ

APPENDIX I

Standard Penetration Test Boring Procedure

STANDARD PENETRATION TEST

The standard penetration test is a widely accepted test method of *in situ* testing of soils (ASTM D 1586), and Ardaman & Associates generally follows this test method. A 2-foot long, 2-inch O.D. split-barrel sampler attached to the end of a string of drilling rods is driven 18 or 24 inches into the ground by successive blows of a 140-pound hammer freely dropping 30 inches. The number of blows needed for each 6 inches of penetration is recorded. The sum of the blows required for penetration of the second and third 6-inch increments of penetration constitutes the test result or N-value. After the test, the sampler is extracted from the ground and opened to allow visual examination and classification of the retained soil sample. The N-value has been empirically correlated with various soil properties.

The tests are usually performed at 5-foot intervals. The test holes are advanced to the test elevations by rotary drilling with a cutting bit, using circulating fluid to remove the cuttings and hold the fine grains in suspension. The circulating fluid, which is a bentonitic drilling mud, is also used to keep the hole open below the water table by maintaining an excess hydrostatic pressure inside the hole. In some soil deposits, particularly highly pervious ones, flush-coupled casing must be driven to just above the testing depth to keep the hole open and/or prevent the loss of circulating fluid.

Representative split-spoon samples from the soils are brought to our laboratory in air-tight jars for further evaluation and testing, if necessary.

APPENDIX II

Microgravity Survey Technical Report by Spotlight Geophysical Services

Technical Report: Microgravity Survey Warm Mineral Springs North Port, Florida

Prepared By

SPOTLIGHT
GEOPHYSICAL SERVICES
4618 NW 96th Avenue
Doral, FL 33178 (USA)
(305) 607-2377
info@spotlightgeo.com

Submittal Information

Status:	Draft
Date:	May 24, 2024
Client:	Ardaman & Associates, Inc.
Spotlight Project:	2024548

Ardaman & Associates, Inc.

CERTIFICATION

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

Authored by:

Ronald Kaufmann, PGp
President – Spotlight Geophysical Services, LLC
Licensed Professional Geophysicist - California #1071

TABLE OF CONTENTS

LIST OF FIGURES

BACKGROUND

Ardaman & Associates, Inc. (Ardaman) is investigating subsurface conditions within a proposed development at Warm Mineral Springs, North Port, Florida. Warm Mineral Springs contains a large circular spring within a sinkhole that formed in the Miocene-age carbonate rocks underlying the area (Rupert, 1994). The investigation includes seven areas located east of the spring and covering a total of approximately 12 acres (Figure 1). Ardaman is assessing these areas for large karst features (voids) and low-density zones.

Ardaman carried out a microgravity survey as part of their investigation. Ardaman retained Spotlight Geophysical Services, LLC (SGS) to process and analyze the microgravity data. Microgravity responds to variations in subsurface density and is an effective tool to non-invasively detect subsurface voids and low-density zones. The results of the survey are used to guide borings into anomalous areas for further characterization. Fieldwork was carried out by Ardaman personnel between January and May, 2024. This report provides a summary of the microgravity methodology and documents the results of the survey.

TECHNICAL APPROACH

SURVEY AREAS

Ardaman established survey grids within areas labeled E, G, J, K, P, Q, and R (Figure 1). Microgravity stations were marked at a nominal 20x20-foot spacing with 60d survey nails and stake whiskers. Some of the stations were offset to avoid surface obstructions such as heavy vegetation. A total of 1,203 stations and 1 base station were included in the microgravity survey. Ardaman retained a land surveyor to survey the lateral locations and elevations of the gravity stations with an accuracy within 0.1 feet. Station positions are referenced to Florida State Plane (West) coordinates in feet (NAD83).

MICROGRAVITY SURVEY

A microgravity survey measures spatial changes in the Earth's gravitational field due to variations in subsurface density. A microgravity survey consists of making sensitive gravity measurements at discrete points along a profile line or within a grid (ASTM, 2018). 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

Microgravity data were acquired by Ardaman personnel using a Scintrex CG-6 gravimeter (S/N 21010315). 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 raw gravity data were corrected for external factors such as tidal and elevation gravitational effects using standard reduction formulas in Microsoft EXCEL (Long and Kaufmann, 2013). The processed data are known as the Bouguer gravity (g_{Boug}). 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. The gravity values have units of microGals (μGals).

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.

<u>INSTRUMENT DRIFT</u>

All relative gravity meters have an inherent drift that must be corrected by repeating measurements at a base station during the survey. The base station (Base1) was established on a concrete pad located at 571726.9E, 990998.3N at an elevation of 10.46 feet. Base station data were acquired at the beginning, middle, and end of each survey day. At least three consistent measurements with a standard deviation within ±5 μGals were recorded at each base station occupation. The drift during the data acquisition was linear and typically less than 10 μGals per day. The drift between base station occupations (g_d) was removed from the raw data.

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-6 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 (g_l) due to latitude is shown in Equation 2. At mid-latitudes, the gravitational gradient is approximately 0.2039 μGals/foot in the north direction.

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.

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. The free air correction was also applied to the data to account for variations in the gravity meter height above the ground surface. The meter height was measured at each station using a standard tape measure with a precision of 0.05 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 (g_{slab}) 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.

The purpose of the Bouguer slab correction is to remove the gravitational effects of topographic variations beneath each microgravity station. A density value of 1.80 g/cc was used for the Bouguer Slab correction, which is representative of the average density of the surficial sands.

TERRAIN CORRECTION

Terrain corrections account for the gravitational effects of topography near the measurement station. Since the site and surrounding area are generally flat, terrain corrections are insignificant and were not applied to the data.

Residual Gravity

Bouguer gravity values are directly related to subsurface density variations. However, broad trends due to deep crustal features within the Earth must be removed from the dataset to properly assess density variations in the upper several hundred feet. This process is analogous to identifying small and narrow topographic features within a topographic survey of a mountain.

Broad trends in the gravity data were calculated by fitting a planar trend to the Bouguer gravity values using Surfer software (Golden Software). This trend was subtracted from the Bouguer gravity values and the resulting dataset is termed the *residual gravity*. The residual gravity values are referenced to the median value, where localized low-gravity values (negative values) represent areas of lower density compared with background conditions.

Quality Control

The Scintrex gravimeter was set-up and operated in accordance with the manufacturer's instructions and ASTM standards (ASTM, 2018). The data quality was monitored by re-acquiring data at approximately 10% of the stations throughout the survey in a pseudo-random fashion and checking the repeatability of the measurements. The repeated measurements have an average deviation of ±2 μGals, which indicates low levels of ambient noise.

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 significant microgravity variations and the depth of any anomalous features.

DETECTABILITY

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.

In general, karst features are detectable to a depth of 3 to 5 times their diameter. The detectability of laterally extensive features such as weathered zones and epikarst zones are independent of their depth, with gravity anomaly magnitudes that are directly related to the thickness and density contrast of the feature (Telford et. al., 1990).

RESULTS

Residual gravity values range between -53 and +42 μGals relative to the median value of 0 μGals (Figure 2). Low-gravity trends (<-10 μGals) are shaded blue and violet, while high-gravity trends (>20 μGals) are shaded orange and red. Small fluctuations of residual gravity values between -10 and +20 μGals (shaded green) are due to small variations in near-surface density (e.g. saturation variations of the sand) and are considered "background conditions".

Low-gravity zones are clustered into two primary areas that span all of the survey areas (Figure 2). The lowest-magnitude gravity values are located within the western portion of Area E and the eastern portion of Area P. The low-gravity zones are discontinuous and do not indicate well-defined linear trends that would be characteristic of a large cave system.

The low-gravity zones are due to subsurface features with a lower bulk density than surrounding background conditions. These low-density features may include thicker overburden, weathered upper limestone, and voids within the upper limestone. Borings are necessary to determine the exact causes of the low-density. We suggest a boring exploration program planned at the site to include three borings placed into areas containing the lowest-magnitude values (Table 1 and Figure 2).

Table 1. Suggested Boring Locations

Area	Station #	Easting (ft)	Northing (ft)	Surface Elevation (ft)
P	10	573136.2	991465.4	12.88
R	62	572915.3	990605.4	11.39
E	94	571815.6	990806.1	9.74

REFERENCES

ASTM, 2018, Standard guide for using the gravity method for subsurface investigation, ASTM D6430-18, West Conshohocken, Pennsylvania.

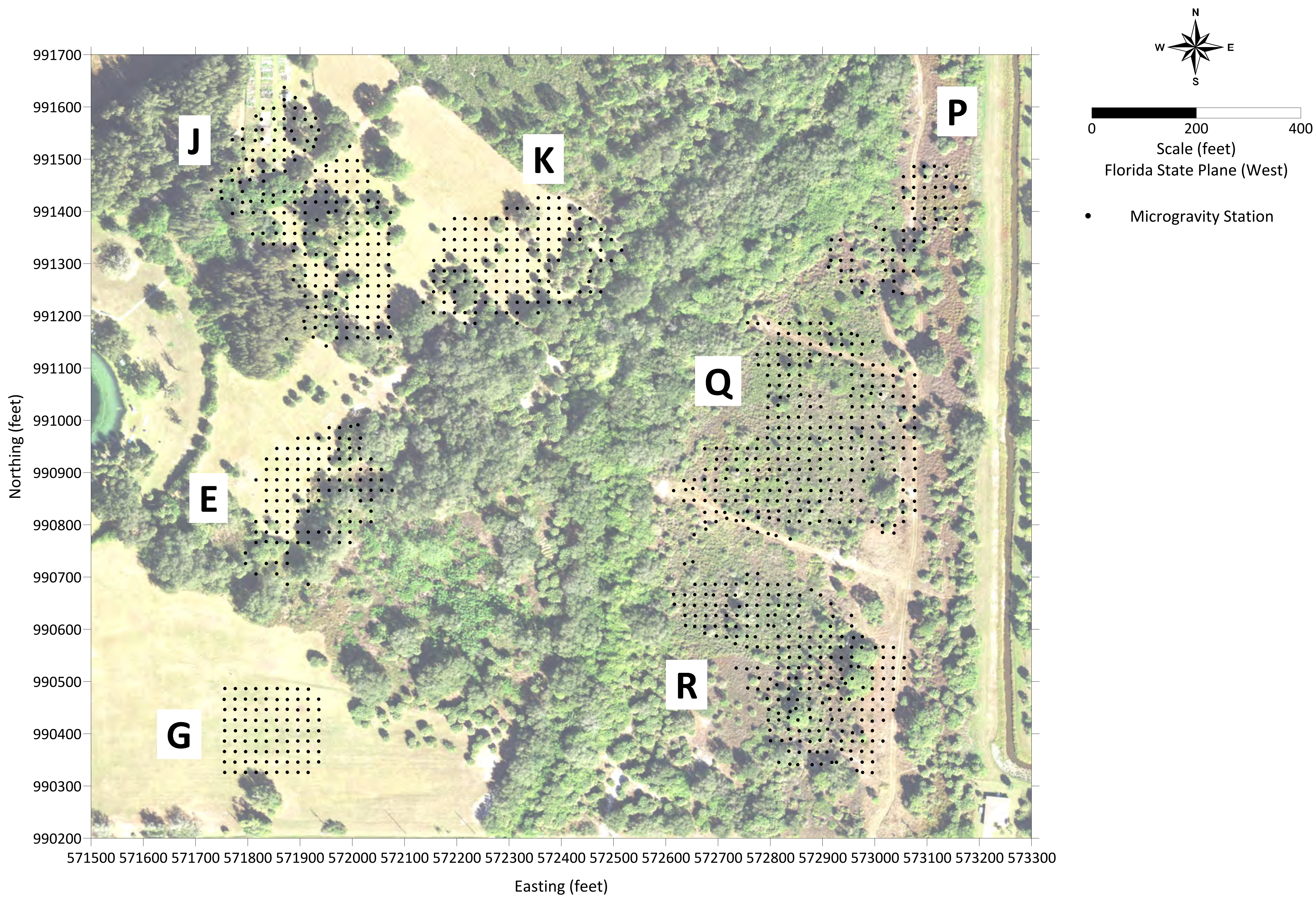
Long, L. T. and Kaufmann, R. D., 2013, *Acquisition and analysis of terrestrial gravity data,* Cambridge University Press, First Edition, ISBN: 978-1107024137, 192 p.

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

Rupert, F. R., 1994, The geology of Warm Mineral Springs, Sarasota County, Florida, OFR 60, Florida Geological Survey, Tallahassee, FL, 7 p.

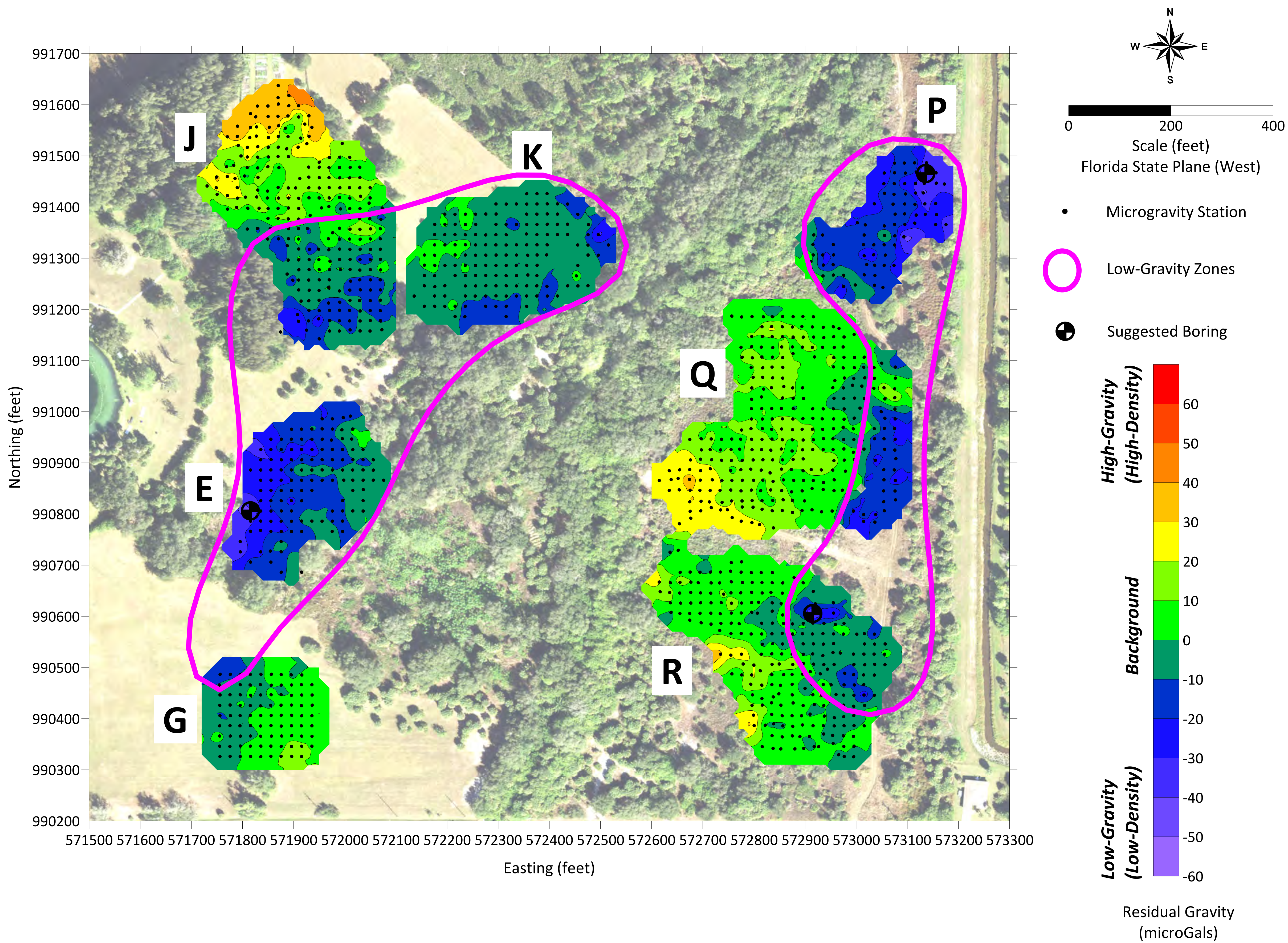
Seigel, H.O., 1995, *High precision gravity survey guide,* Scintrex Ltd., Concord, Ontario,

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. Microgravity station locations



SPOTLIGHT GEOPHYSICAL SERVICES

Figure 2. Residual gravity contour map