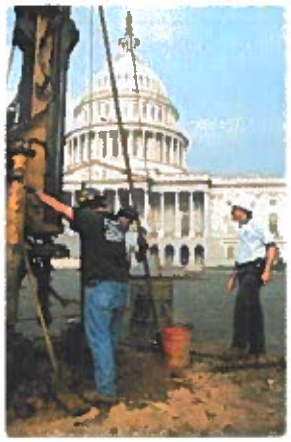

ECS Mid-Atlantic, LLC

Karst Study Report

23 Hamilton Avenue

23 Hamilton Avenue
Frederick, Maryland

ECS Project Number 13:9380

December 20, 2019

December 20, 2019

Ms. Jennifer Minnick
Habitat for Humanity of Frederick County
117 E. Church Street
Frederick, Maryland 21701

ECS Project No. 13:9380

Reference: Karst Study Report
23 Hamilton Avenue
Frederick, Frederick County, Maryland

Dear Ms. Minnick:

As requested, ECS Mid-Atlantic, LLC (ECS) has conducted a karst study for the above referenced site. This report presents the findings of our study.

PROJECT INFORMATION

We understand that a large sinkhole was recently repaired at a property adjacent to the above referenced residence. In order to help evaluate the karst geology and potential presence of sinkholes at the site, a geophysical study consisting of Electrical Resistivity (ER) and Ground Penetrating Radar (GPR) was conducted.

SITE DESCRIPTION

Geographic Location

The project site is located on the west side of Hamilton Avenue, south of East Patrick Street, and north of South Street in Frederick, Maryland. Please see the attached Geology Map for the approximate location of this site.

General Geology

According to the Physiographic Map of Maryland (2008)[1], the site is located within the Frederick Valley District of the Piedmont Plateau Province. The Piedmont Plateau Province is an area underlain by ancient igneous and metamorphic rock. The virgin soils encountered in this area are the residual product of in-place chemical weathering of the parent rock presently underlying the site. The typical residual soil profile consists of silty to clayey soils near the surface where soil weathering is more advanced, underlain by more sandy silts and silty sands that generally become harder and denser with depth to the top of parent bedrock. The boundary between soil and rock,

[1] James P. Reger and Emery T. Cleaves. *Physiographic Map of Maryland.* 1:250,000. Maryland Geological Survey, 2008.

termed weathered rock, is not sharply defined. This transitional zone can contain boulders of more resistant rock as well as highly weathered materials.

The Frederick Valley District is described as a carbonate valley of low relief, punctuated with more than 1,000 sinkholes, but very few limestone caves.

Based upon the Karst Features of the Frederick Quadrangle, Frederick County, Maryland (2004)[2], the site is underlain by the Ceresville Member of the Grove Formation. The Ceresville Member is described as medium light gray to medium gray, thickly bedded and crossbedded, arenaceous limestone and sandy dolomitic limestone with thin interbeds of medium light gray, sandy dolomite.

The Ceresville Member is highly susceptible to the formation of sinkholes. A review of the karst map shows two mapped sinkhole (circles with hash marks and a black dot) and one closed depression (circles with hash marks) in close proximity to the site.

STUDY PROCEDURE

Electrical Resistivity (ER) Survey

ECS Mid-Atlantic, LLC performed an ER study as shown on the attached Location Diagram. One (1) ER line was conducted in the test area.

The purpose of an electrical resistivity survey is to estimate the electrical subsurface characteristics through measurements recorded on the ground surface. Based upon the results of the measured electrical properties, estimates of the true resistivities of subsurface features can be made. These estimated values can then be correlated to various geologic parameters including saturated soils, water interfaces, rock, and void spaces. For this study, the Syscal Kid Automatic Switching resistivity meter with 21 probes was utilized in a dipole-dipole array layout. In this configuration, a constant spacing between electrodes is utilized to measure the apparent resistivities at different depths. Based on the amount of space available in the test areas, the ER line was run with probe spacing of 10 feet. The length of the ER line was 200 feet.

Data collected during this study was analyzed utilizing Resix 2DI, an electrical resistivity two-dimensional modeling program. The specific modeling method used was a smooth modeling inversion method, which uses a rapid least squares inversion of apparent resistivities to develop a smooth model of the subsurface characteristics.

The results of this study provide subsurface information to an approximate depth of 25 feet below the ground surface. Elevations shown on the attached ER profile are arbitrary.

Ground Penetrating Radar (GPR) Survey

ECS Mid-Atlantic, LLC utilized GPR as shown on the attached Location Diagram. GPR testing was conducted with a Sensors and Software Conquest II GPR system with 1000 and 250 MHz antennas. These antennae provide maximum depths of investigation of approximately 24 inches

[2] David K. Brezinski. *Karst Features of the Frederick Quadrangle, Frederick County, Maryland.* 1:24,000. Department of Natural Resources and Maryland Geological Survey, 2004.

and 8 feet respectively. These antennae were selected in an attempt to locate voids or other subsurface anomalies within the test area with the 1000 MHz antenna used to locate potential voids beneath the asphalt pavement and the 250 MHz antenna to observe conditions deeper in the soil profile. During this study, GPR lines were systematically recorded in approximately 5 foot spacing increments, but varied depending upon surface obstructions encountered.

OBSERVATIONS AND FINDINGS

Review of the ER profile developed during this study shows subsurface features that indicate fairly high potential for the formation of a sinkhole. Specifically from 45 feet to 65 feet along the ER line, a low resistive zone is observed between higher resistive zones, most likely indicating the presence of a potential fracture zone. Additionally, a deep weathered zone can be seen on the ER line from approximately 75 feet to 135 feet, exhibited by a large low resistive zone that is bounded by shallower higher resistive zones, which likely represent rock.

Review of the 250 MHz GPR data indicated the presence of numerous buried objects in the backyard. Multiple linear anomalies were identified within the backyard, which could be buried utilities or other unknown buried objects. Some isolated targets were also identified, which could be construction debris or other unknown buried objects. Review of the 1000 MHz GPR data indicates a variable pavement section depth throughout the asphalt. This could be the result of variable grading at the surface when asphalt was installed or could be the result of settlement of the driveway that was later leveled with subsequent paving activities. The GPR data collected at this site does not appear to indicate that voids are present below the asphalt pavement. GPR data also does not exhibit indications of sinkhole activities, though the maximum effective depth of investigation with the GPR was approximately 5 feet below the ground surface.

Attached to this report, please find the ER and GPR Location Diagrams, a copy of the ER Profile, and representative GPR Profiles collected during this study. When reviewing the attached ER Profile, please consider the following:

1. Low resistive regions are blue on the attached profiles. Low resistivities typically indicate clay soils, saturated soils, or fractured rock that is saturated or includes soil filled seams.

2. Highly resistive regions are red on the attached profiles. High resistivities typically indicate rock, fractured rock, drier soils, or sandy materials.

3. Air-filled voids will typically appear as red bullseyes or other isolated shapes.

4. Water-filled voids will typically appear as blue bullseyes or other isolated shapes.

5. The resistive properties of subsurface materials may vary across sites as it may be affected by several factors such as water content, soil types and distributions, lithology (rock properties) and other factors. As such, there is no direct standardized correlation between the numeric values shown on the ER profiles and geology. Instead the reviewer must look at the relative variation across a profile, consider the geologic setting that the profile was collected in, review recent weather conditions, and use his experience to help develop an interpretation of the resistivity profiles. It must also be noted that features

that are deeper in the profile need to be larger than shallow features in order to be observed in the data set.

6. Due to the many variables that may influence the measured electrical resistivity of the subsurface, there is no direct correlation between resistivity values and the presence of rock. We have not provided any interpretation regarding potential rock interfaces as we do not have correlative data to support such interpretations.

RECOMMENDATIONS

Based upon the ER data collected during this study, a potential fracture zone and deep weathered zone are believed to exist at the site. While noticeable settlement has not been observed currently at this site, it is possible that these karst features could develop further. In order to identify the full extent and limits of these karst features, ECS recommends that rock probe testing be conducted at selected locations near the residence to further characterize the subsurface conditions at the site.

Please note that due to the inherent variability associated with karst geology, it is not possible to eliminate all risks associated with potential sinkholes or other karst activity. The likelihood of karst conditions developing at a site typically increases during periods of widespread surface disturbance such as construction activities. During such times, changes in the flow of runoff after rain events may result in the opening of voids or sinkholes that otherwise may not have developed prior to disturbance. Point load water discharges, such as those caused by broken pipes or stormwater discharges following significant precipitation events may also increase the potential for sinkholes to form. Limiting or minimizing disturbances to the surface conditions of a site may help reduce the risk for the formation of sinkholes.

We are pleased to have been of service to you on this report. Should you have questions about this report please feel free to contact us at 301-668-4303.

Respectfully,

ECS MID-ATLANTIC, LLC

Paul D. Pinkerton
Geophysical Manager
ppinkerton@ecslimited.com

Jeffrey A. McGregor, P.E.
Principal Engineer
jmcgregor@ecslimited.com

Professional Certification. I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland.

License No.: 30901 Expiration Date: 08/15/2020

Attachments: Geology Map (1)
ER Location Diagram (1)
ER Profile (1)
GPR Location Diagram (3)
Representative GPR Profiles (2)

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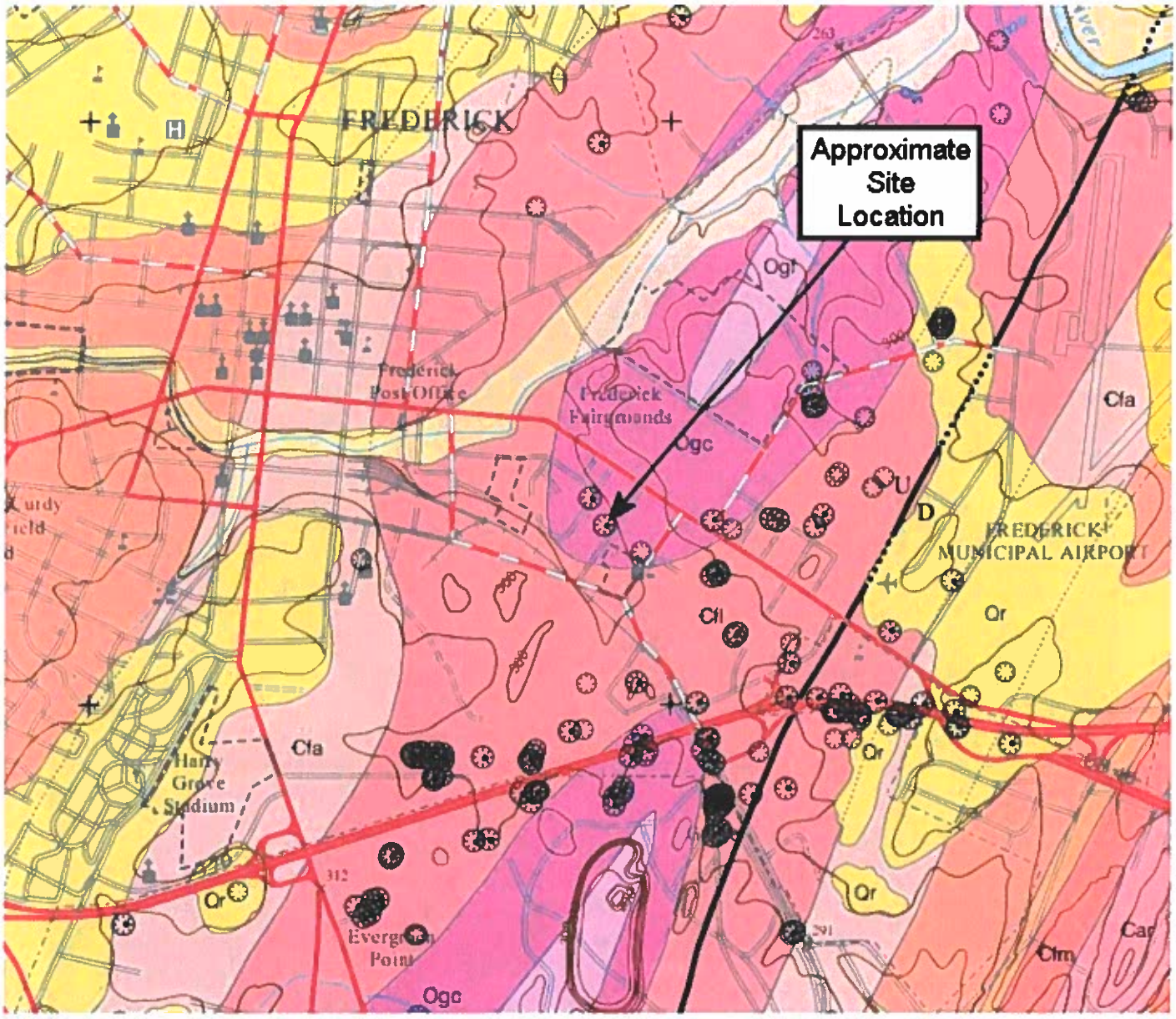


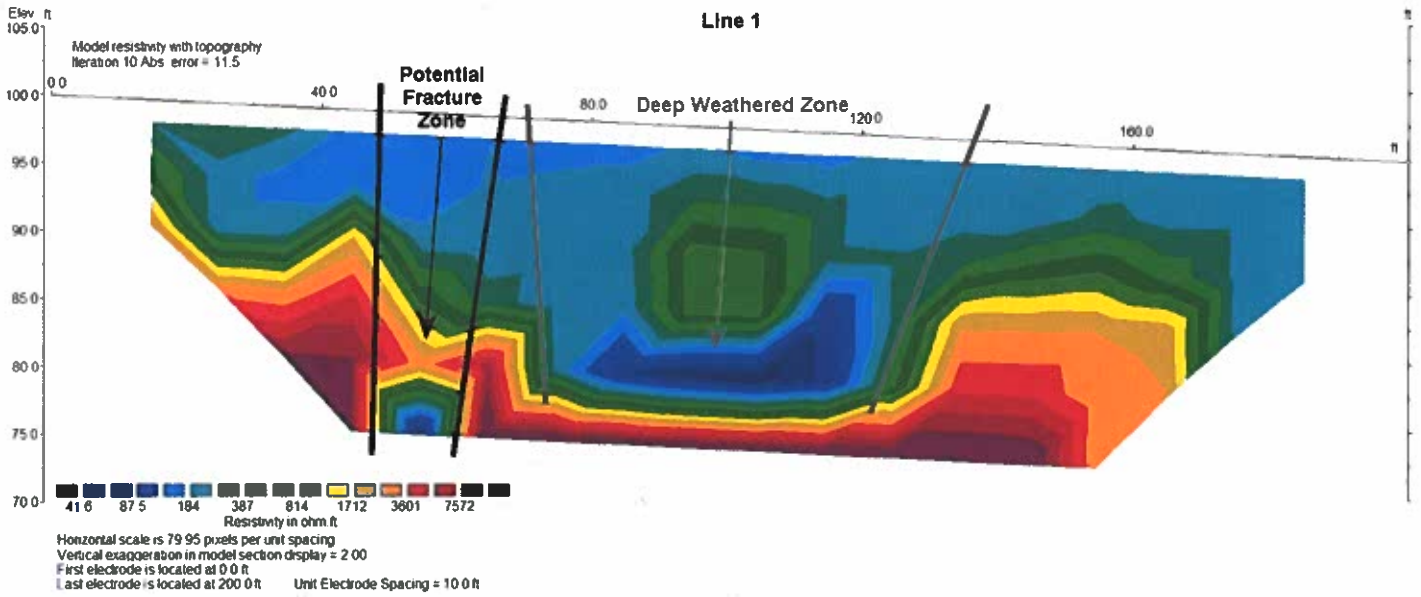
GEOLOGY MAP
KARST FEATURES OF THE FREDERICK QUADRANGLE
KARST MAP

ECS

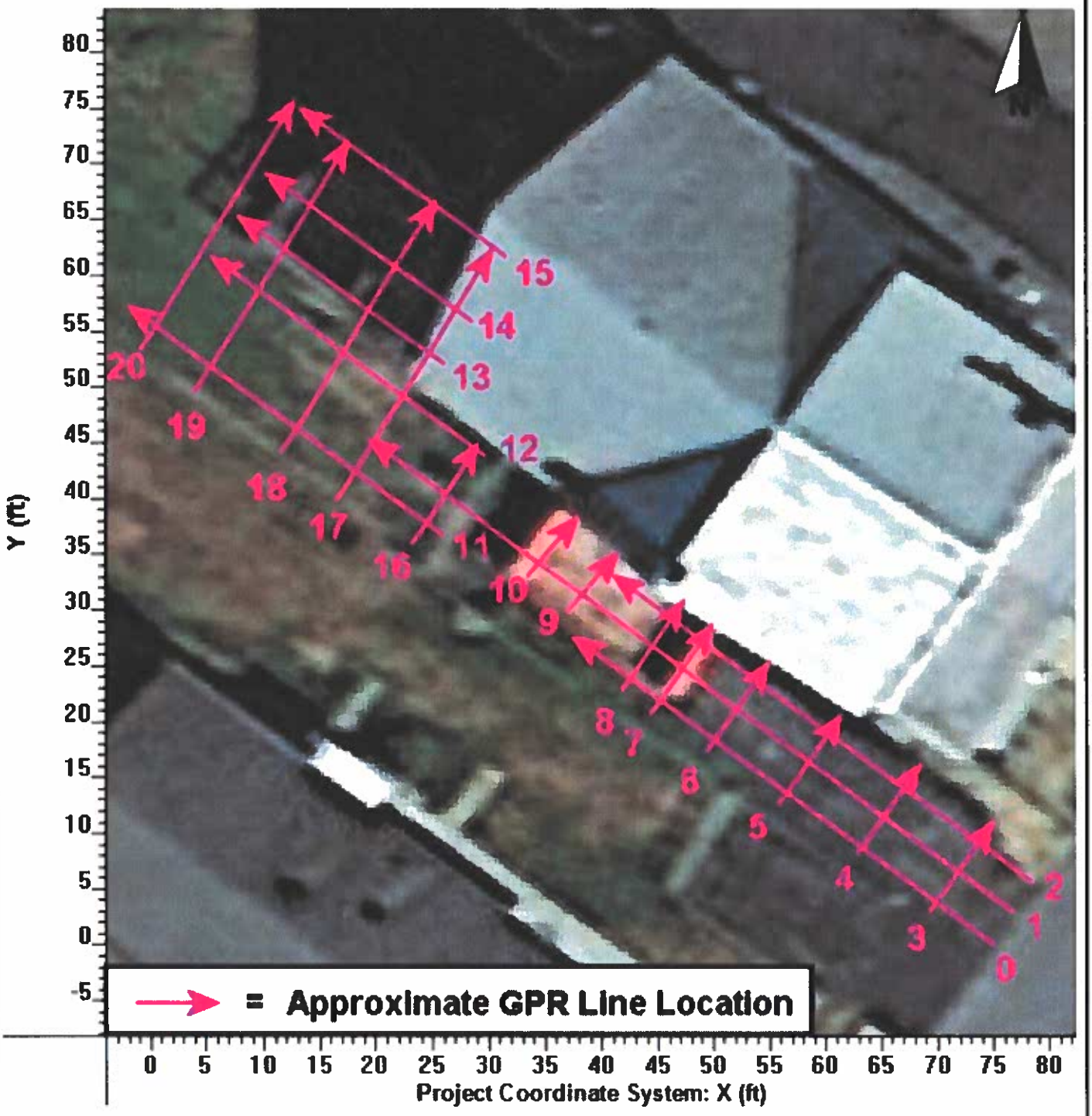
23 HAMILTON AVENUE KARST STUDY
ECS PROJECT NO. 13-9380
FREDERICK, MARYLAND

ER LOCATION DIAGRAM
HABITAT FOR HUMANITY OF FREDERICK COUNTY

23 HAMILTON AVENUE KARST STUDY
ECS PROJECT NO. 13-9380
FREDERICK, MARYLAND



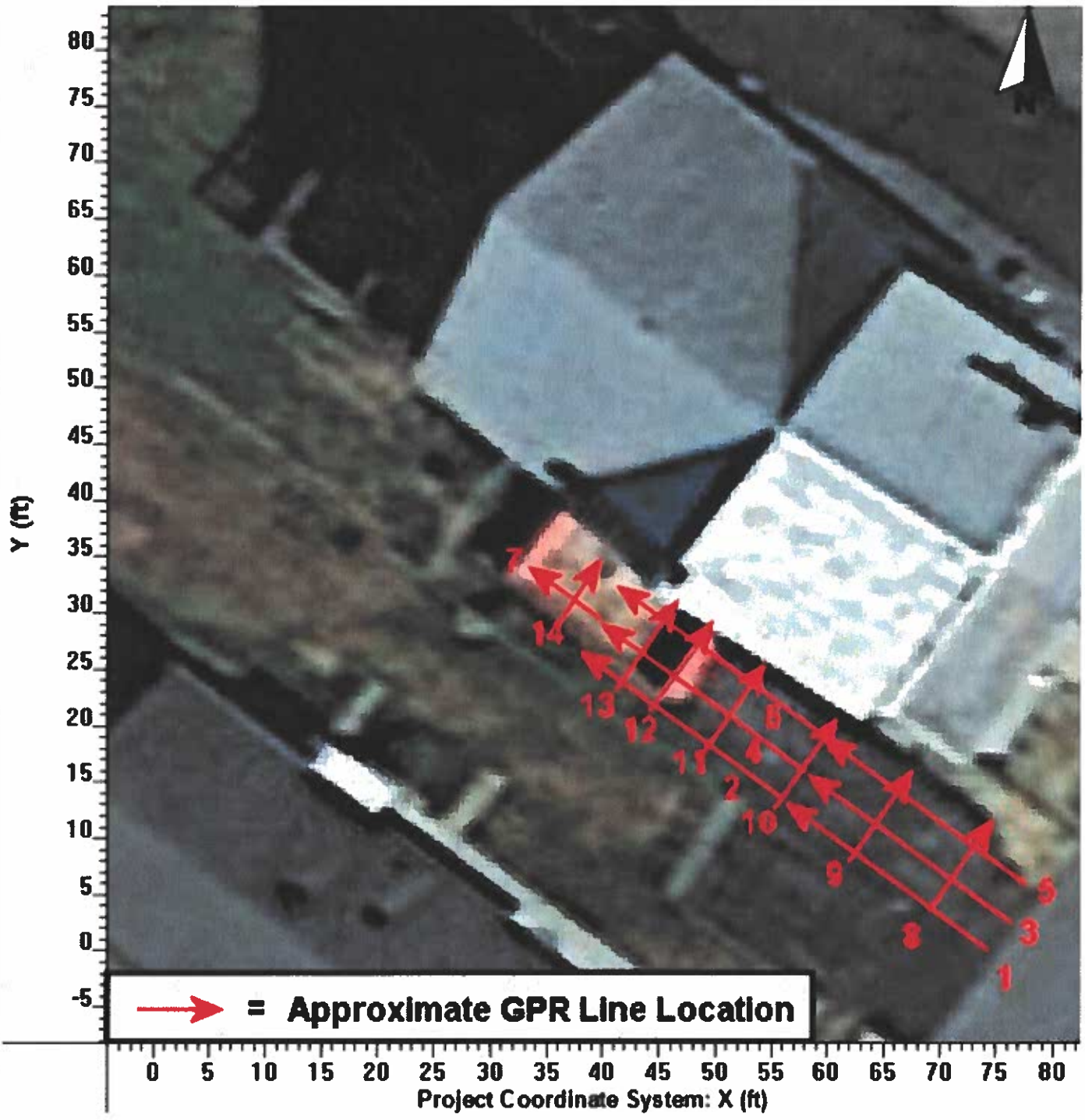
ER PROFILE HABITAT FOR HUMANITY OF FREDERICK COUNTY	ECS	23 HAMILTON AVENUE KARST STUDY ECS PROJECT NO. 13-9380 FREDERICK, MARYLAND



GPR Location Diagram
250 MHz Antenna
Habitat for Humanity of Frederick County

ECS

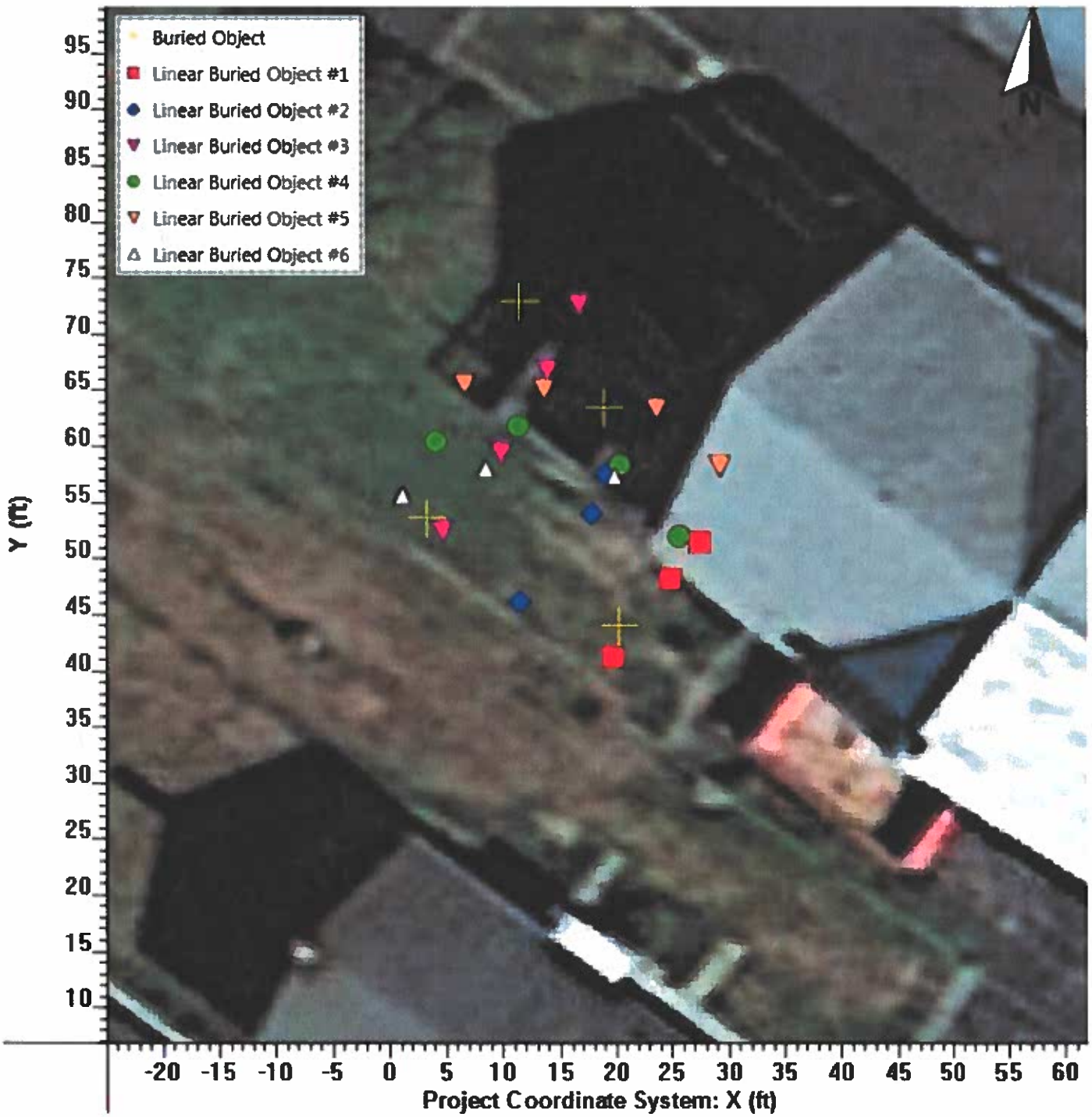
23 Hamilton Avenue Karst Study
ECS Project No. 13-9380
Frederick, MD



GPR Location Diagram
1000 MHz Antenna
Habitat for Humanity of Frederick County

ECS

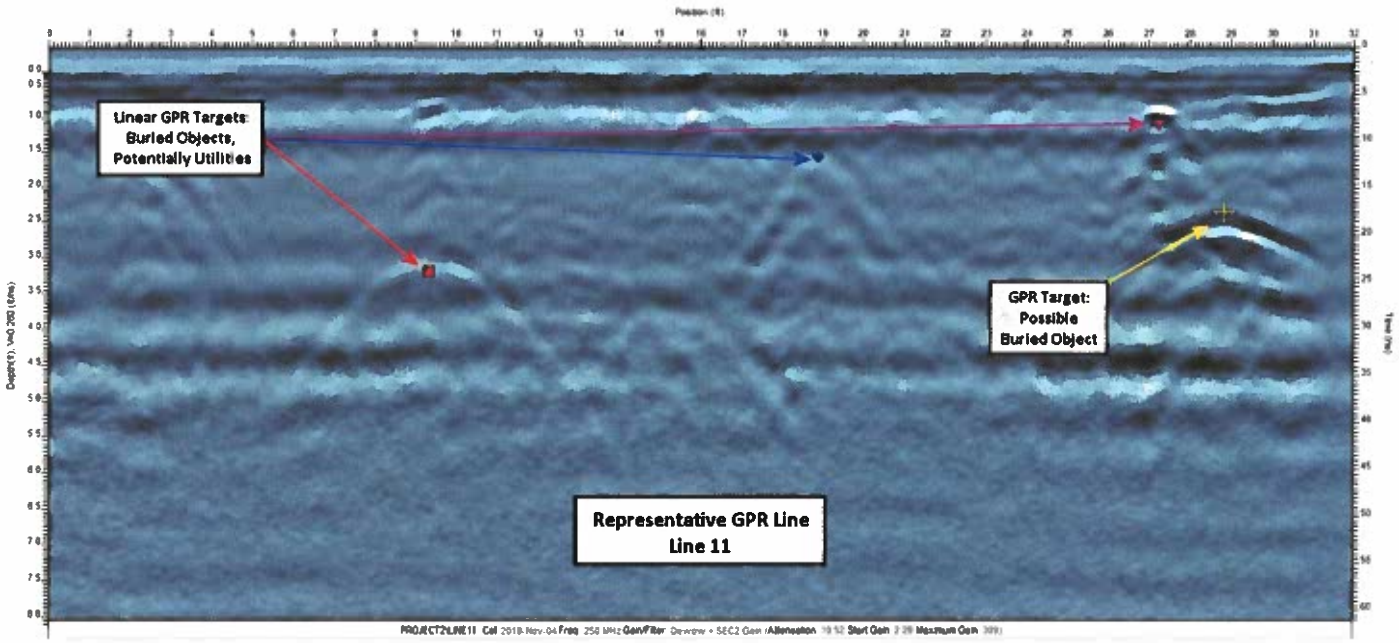
23 Hamilton Avenue Karst Study
ECS Project No. 13-9380
Frederick, MD

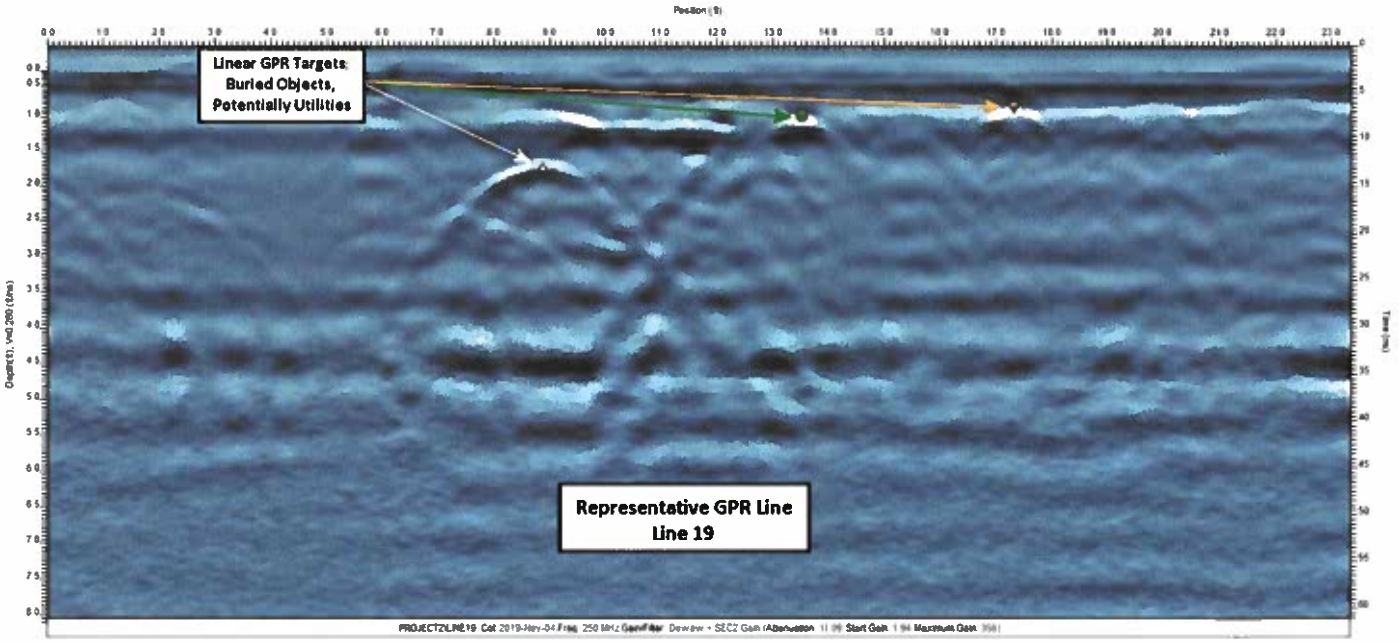


GPR Location Diagram
250 MHz Antenna – Buried Targets
Habitat for Humanity of Frederick County

ECS

23 Hamilton Avenue Karst Study
ECS Project No. 13-9380
Frederick, MD

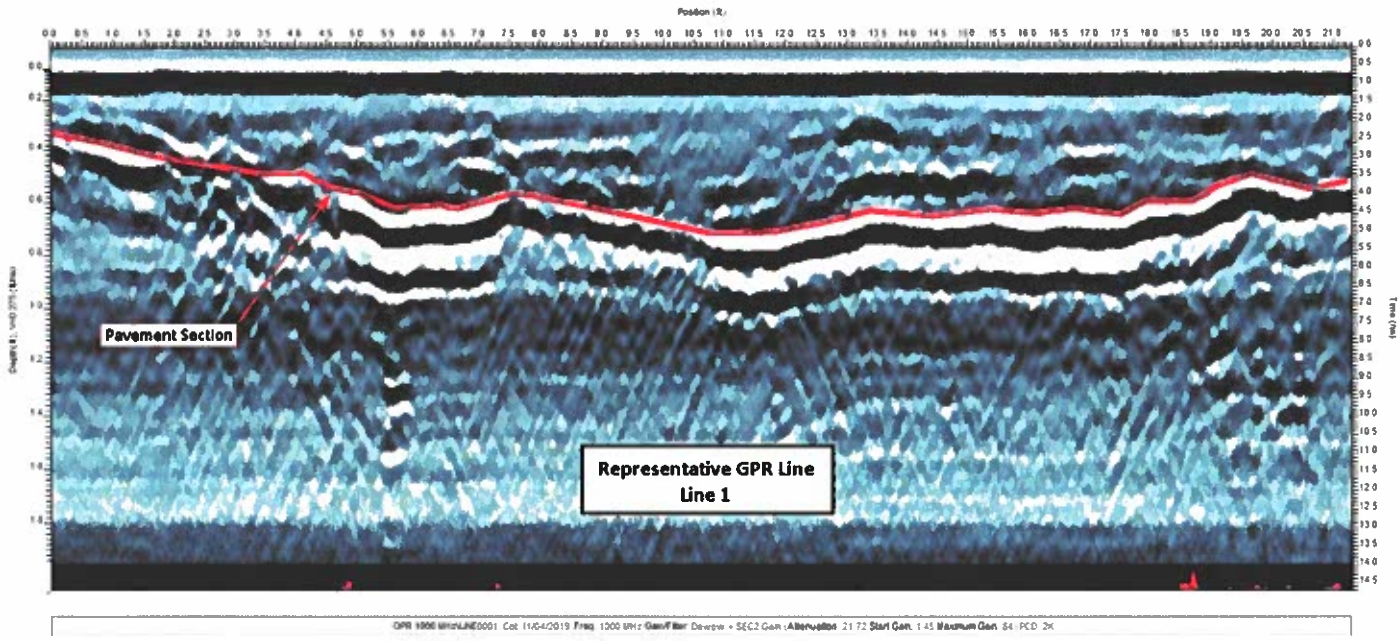


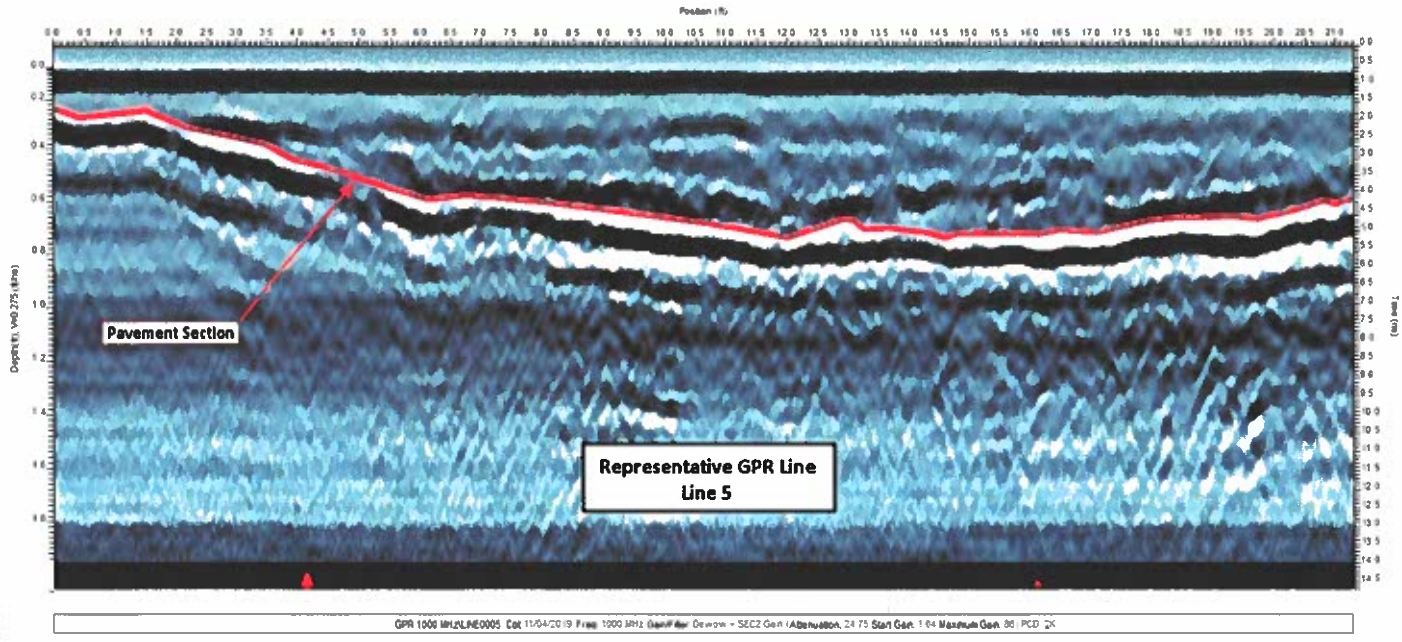


REPRESENTATIVE GPR PROFILES
250 MHZ ANTENNA
HABITAT FOR HUMANITY OF FREDERICK COUNTY

ECS

23 HAMILTON AVENUE KARST STUDY
ECS PROJECT NO. 13-9380
FREDERICK, MD





REPRESENTATIVE GPR PROFILES
1000 MHz ANTENNA
HABITAT FOR HUMANITY OF FREDERICK COUNTY

ECS

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