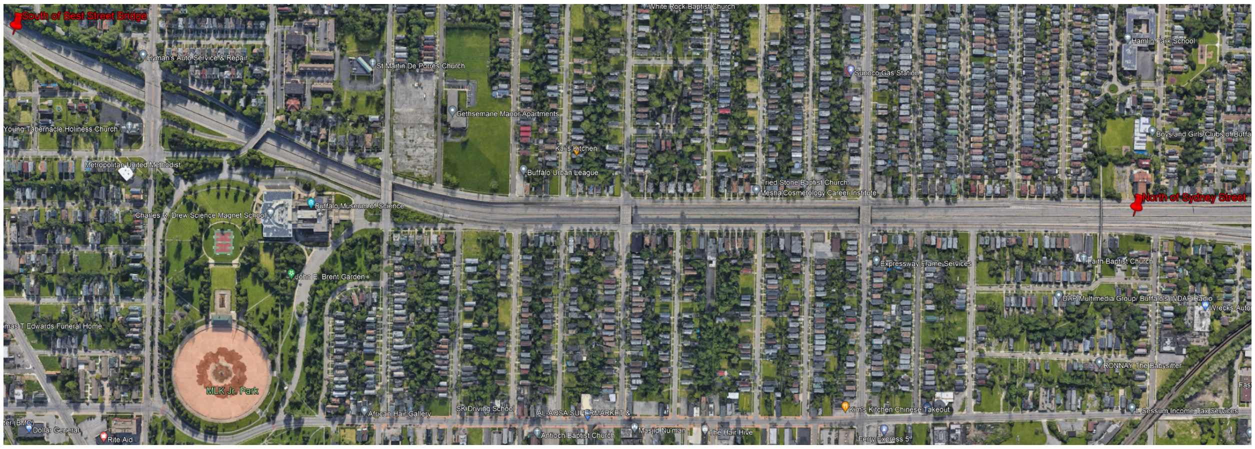
Appendix A3

Ground Penetrating Radar Report

Subsurface Mapping
PIN 5512.52 – Kensington Expressway in Buffalo, NY

FINAL REPORT



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EXECUTIVE SUMMARY

The top of bedrock was mapped using a ground penetrating radar (GPR) system along profiles along an approximately 1-mile section of Rt. 33 (Kensington Expressway) between approximately Northland Street and Best Street. The field data collection was carried out using a two-step approach. The first step involved equipment verification testing, where multiple antenna frequencies and settings were tested at the project site. Upon verification of the step one testing, Infrasense completed step two, which consisted of testing along all prescribed lanes within the project section.

Step one of testing included the use of 80-MHz and 270-MHz GPR systems, collected in tandem at walking speed. The lower frequency 80-MHz system provided more depth of penetration and therefore was chosen for the bedrock mapping survey. Profiles were collected at 4-offsets, including the right shoulder line and center of the left lane in both the EB and WB travel directions. The data collected along these profiles was analyzed to determine the estimated depth to bedrock. The results of this analysis are shown graphically in Attachment A.

In addition, several GPR profiles were collected targeting the suspected location limits of the Scajaquada Creek Interceptor (SCI), under the grassy area between the pedestrian bridge and the first houses to the South. Several profiles show a horizontal target that could be related to the SCI, or at least showing a structure that is continuous across Kensington Expressway south of the grassy area more towards the first buildings (e.g. Faith Baptist Church). It is recommended to compare the location of the horizontal targets to as-built utility maps, to make sure that there are no other pipes in the vicinity, especially from the sewer network.

1. INTRODUCTION

The overall objective of the ground penetrating radar (GPR) survey was to map the top of bedrock along an approximately 1-mile section of Kensington Expressway, along 4-offsets from approximately Northland Street to Best Street as shown on the title page. Infrasense used a low frequency GPR antenna to map the changing bedrock elevation that boring logs indicate varies between 6-feet and 35-feet below the roadway surface. The night surveys were conducted between May 5th and 7th, 2023. During both nights, the Eastbound (EB) lane was closed to traffic due to repair work on the W. Parade Avenue bridge. The Westbound (WB) data were collected with the help of a mobile traffic closure.

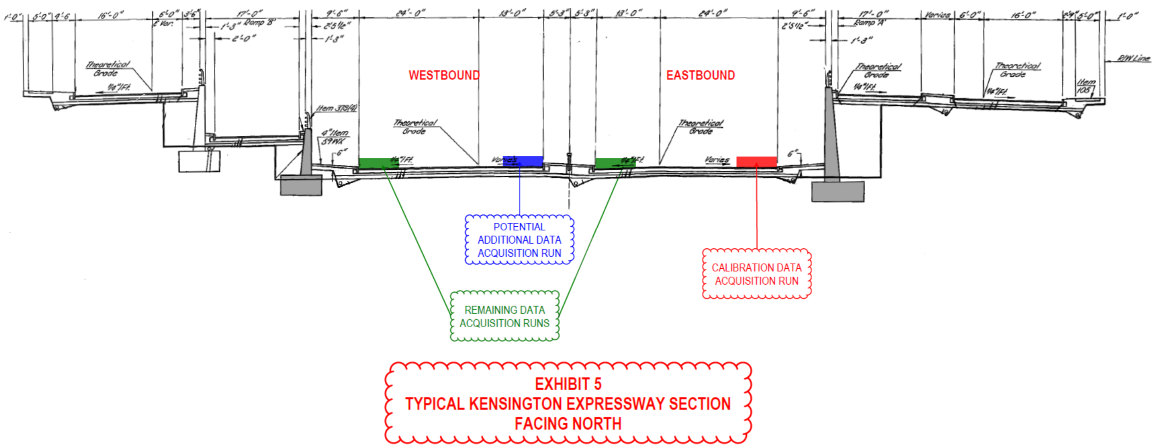


Figure 1. Exhibit 5 from the solicitation showing the prescribed lateral positions of GPR profiles.

2. DATA COLLECTION

A Mala GX80 80-MHz GPR Collection system (Mala, 2023) was used for the bedrock exploration. In addition, a 270 MHz GSSI antenna (GSSI, 2023a) with a GSSI SIR-4000 control unit (GSSI, 2023b) was used for the purpose of delineating the shallower bedrock.

Figure 2. Picture of the GPR systems used during the field work. (Left) the 270 MHz GSSI GPR pushcart system and (right) the pulled 80 MHz Mala system.

The first night of data collection included testing various system settings and collected test alignments on the EB side of the Kensington Expressway within a total road closure. These first profiles were used to establish the effectiveness of the GPR systems and determine if further data collection would be completed.

In addition, various profiles were collected to better narrow down the horizontal location of the Scajaquada Creek Interceptor (SCI).

Data collected on May 6th were reviewed and it was determined that there was sufficient depth of penetration and resolution to map the depth to bedrock. Figure 3 below shows sample data collected along the EB right shoulder on the first night. A brief data review document was provided to LaBella to summarize the data quality and get permission to complete the remaining data collection. The night 1 data review document is included as Attachment C.

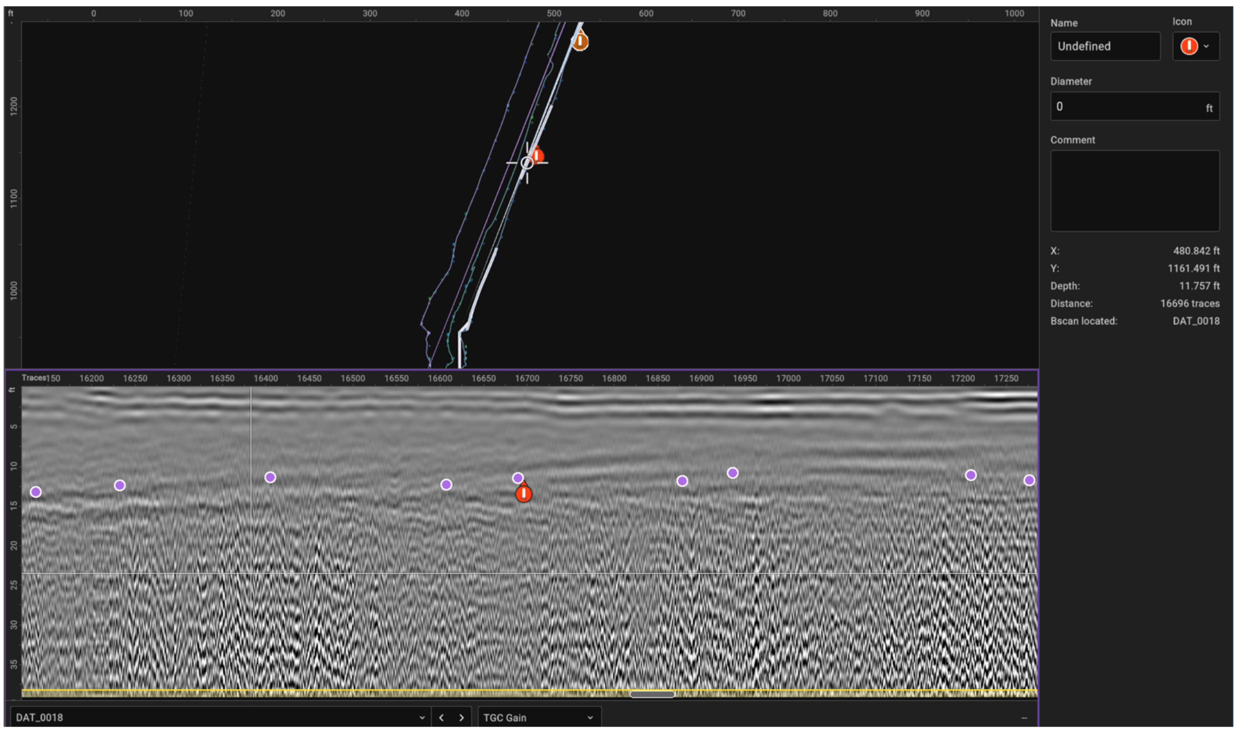


Figure 3. Night 1 data sample showing top of bedrock tracked in purple. The known core location shown as red tag.

Table 1 – Summary of GPR profile locations relative to CL stations.

GPR Antenna Freqency	GPR profile #	Start relative to CL station	End relative to CL station	Location realtive to Fig 1.	Date collected
80 MHz	41	12307	6491	WB left shoulder	05/06/23
80 MHz	42	12316	6491	WB right shoulder	05/06/23
80 MHz	43	6508	7425	EB right shoulder	05/06/23
80 MHz	44	7390	6491	EB left shoulder	05/06/23
80 MHz	48	12303	7600	EB left shoulder	05/06/23
80 MHz	49	7595	12311	EB right shoulder	05/06/23
80 MHz	7	all in the vicinity of 12100 to 12300, see Figure 6 for detailed locations		Scajaquada Creek	05/05/23
80 MHz	8			Scajaquada Creek	05/05/23
80 MHz	10			Scajaquada Creek	05/05/23
80 MHz	11			Scajaquada Creek	05/05/23
80 MHz	37			Scajaquada Creek	05/06/23
270 MHz	1			Scajaquada Creek	05/05/23
270 MHz	2			Scajaquada Creek	05/05/23
270 MHz	5			Scajaquada Creek	05/05/23
270 MHz	6			Scajaquada Creek	05/05/23

3. DATA PROCESSING

The data were processed and visualized for picking with RADAN (GSSI, 2023c) and GPR Insights Software (Proseq, 2023). Google Earth was used to check the locations accuracy. The general GPR data processing flow was:

1. Correct time zero
2. Wobble removal
3. Bandpass filtering. Typically, 20 MHz to 220 MHz
4. Background removal
5. Gain control

In some instances, the data were migrated or a Hilbert transform performed to optimize resolution in select areas of the project section.

The borehole information provided by LaBella was used to calibrate the GPR data. Borehole coordinate information was provided by the client and used together with the Centerline (CL) stationing and the elevation in feet of the boreholes accumulated from the client provided CAD drawing (Soil Boring & Retaining Wall Inventory 2022-10-06.pdf). This allowed us to calculate the depth from the surface to the bedrock relative to the closest CL station (Attachment B). In addition, the GPR profile use of this information was by the lateral proximity of the borehole on the Kensington Expressway. Boreholes not on the Kensington Expressway and located on off and on ramps were not considered.

GPS data in the below the bridges deviated from the straight survey path significantly for some of the GPR profiles and were eliminated and a straight path between the remaining points on either side of the bridge was assumed.

4. DATA ANALYSIS

4.1 BEDROCK

Mapping of the top of bedrock was completed using 6 of the 80 MHz GPR profiles collected during the second night of collection based on the quality of the GPR data. The position of each of the profiles is represented in Figure 4 and described in Table 1.

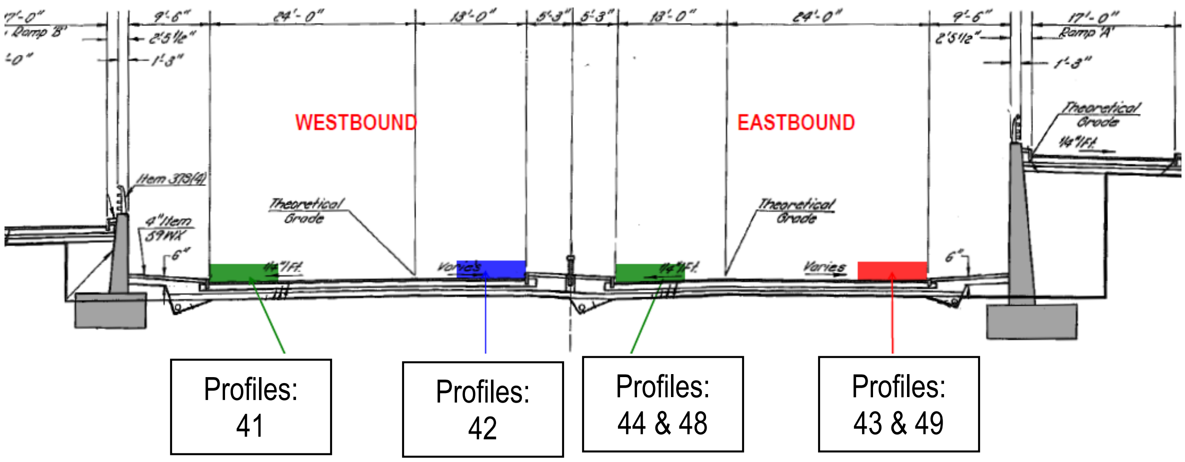


Figure 4. A cross section of the four offsets collected for bedrock profile mapping.

The top of bedrock was tracked manually by an experienced analyst across the four offset positions based on continuous subsurface interface reflections, interpreted subsurface diffractions of the GPR signal, and abrupt changes amplitudes. The various types of reflections are common in bedrock mapping due to inconsistencies in the rock surface. The bedrock surface was "picked" at regular intervals as shown in Figure 5. The core information was then used to calibrate the calculated depths and make adjustments to best fit the known depth elevations. When the rock dropped below 25 feet the GPR datasets were unable to resolve the top of rock with sufficient accuracy, and therefore were not mapped. The vertical resolution of the GPR data is approximately +/- 2 feet in the top 10 feet, and +/- 4 at depths greater than 15 feet.

The mapped bedrock layers were exported in tabular format and are provided in Attachment A as a set of 4 depth profiles.

The tabular results are included as file "Infrasense_FinalBedrockPlots_BuffaloBedrock_230601.xlsx"

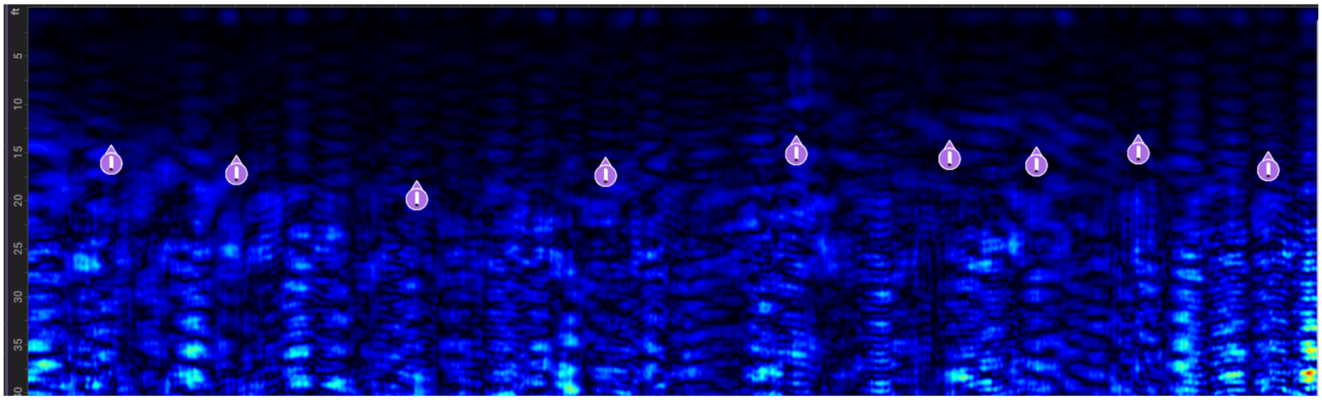


Figure 5. Sample GPR profile showing top of rock tracked with discrete "picks."
From Profile 48 near Station 12000.

4.2 SCAJAQUADA CREEK INTERCEPTOR (SCI)

Several radar profiles were collected specifically targeting the suspected location limits of the SCI. These files were collected and analyzed independently of the bedrock mapping files, and their positions are shown in Figure 6. A total of 9 GPR profiles (five 80-MHz and four 270-MHz) were used to map the limits of the SCI with the clearest signal being along the edges of the Kensington Expressway, over the sidewalks and grassy areas.

Additional profiles in the vicinity of the SCI on the Kensington Expressway are not shown as they show little evidence of the channel in the top 10 feet. It is believed that the increased road structure is limiting the shallow resolution of the GPR antennas, and thus the relatively shallow channel is blending in with the roadbase. The SCI was expected to be between the pedestrian bridge and the first houses to the South.

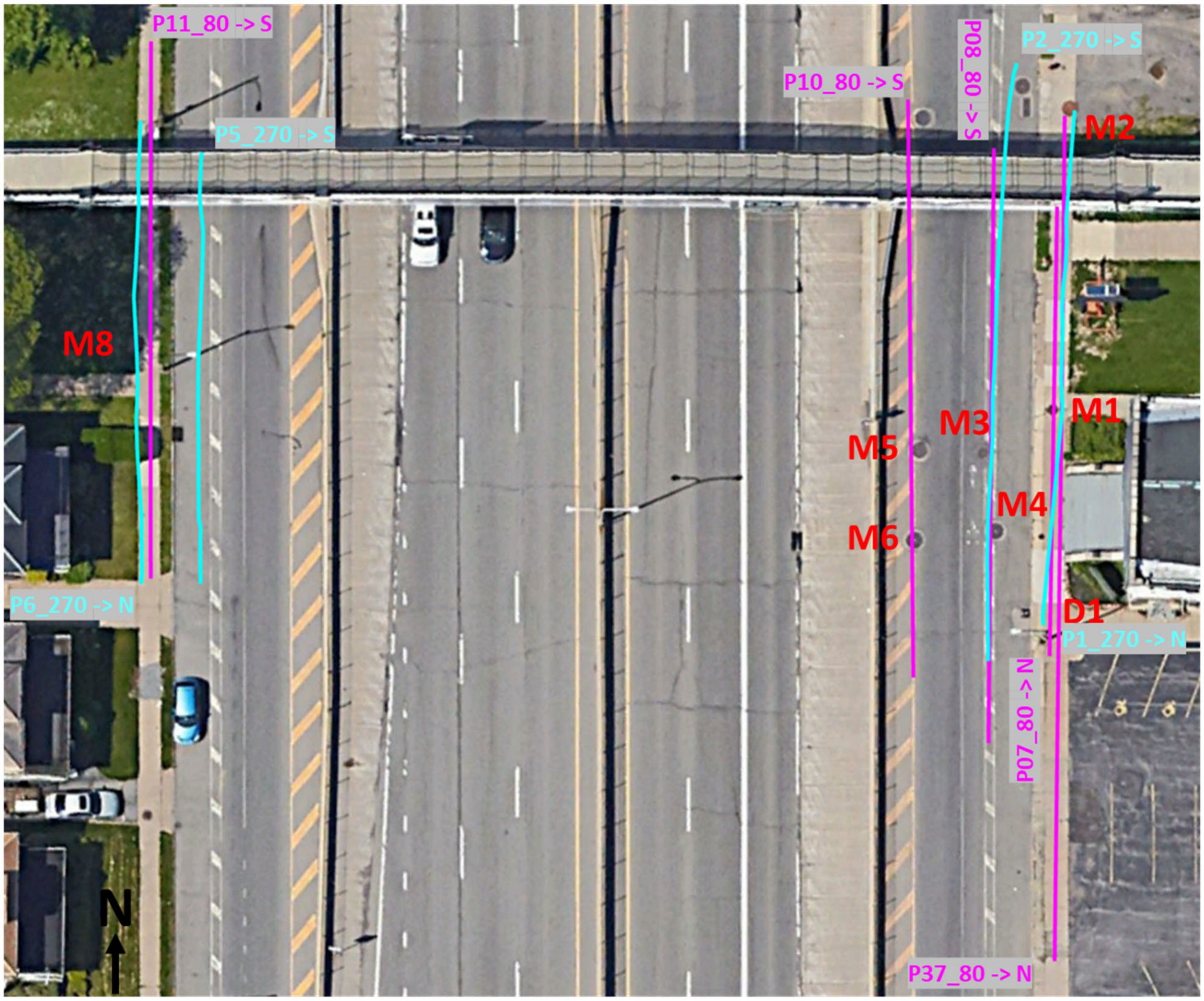


Figure 6. Google Earth map with various 80 MHz profile paths overlaid in pink and 270 MHz profiles paths in blue. Also indicated are eight manholes (red M#) and one drainage as red D1.

The profiles P1, P7, and P37 (Figure 7) show a horizontal target (red line) that may be related to the SCI. The red line anomaly could potentially be related to drainage or sewer lines that cross below M1 and should be compared against known utility information in the area. The same feature can be observed in P5, P6, and P11 in (Figure 8) on the Westbound side of the expressway. The horizontal feature (shown in red) is also in close proximity to manhole M8. However, its size and similar profile shape suggests that this is the result of a continuous structure across the Kensington Expressway.

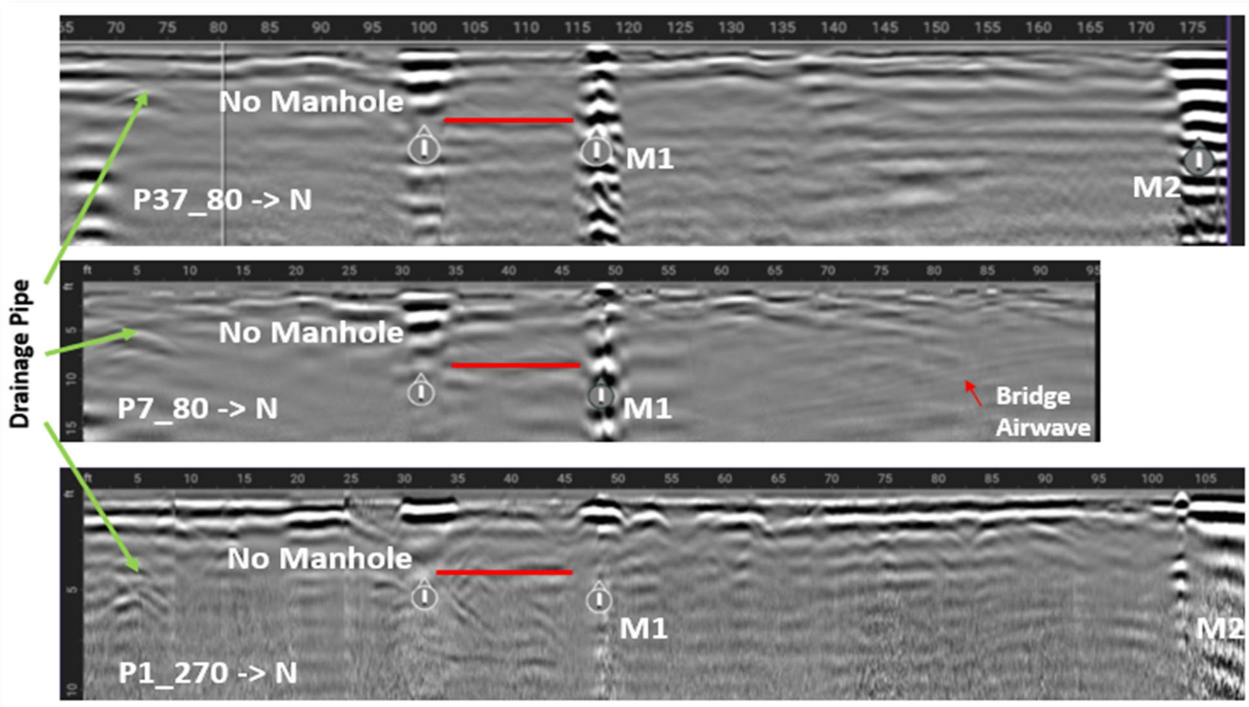


Figure 7. Three parallel GPR profiles on the EB side of the Kensington Expressway showing a horizontal target with similar appearance that is in close proximity to a known sewer manhole, but may represent the top of the SCI.

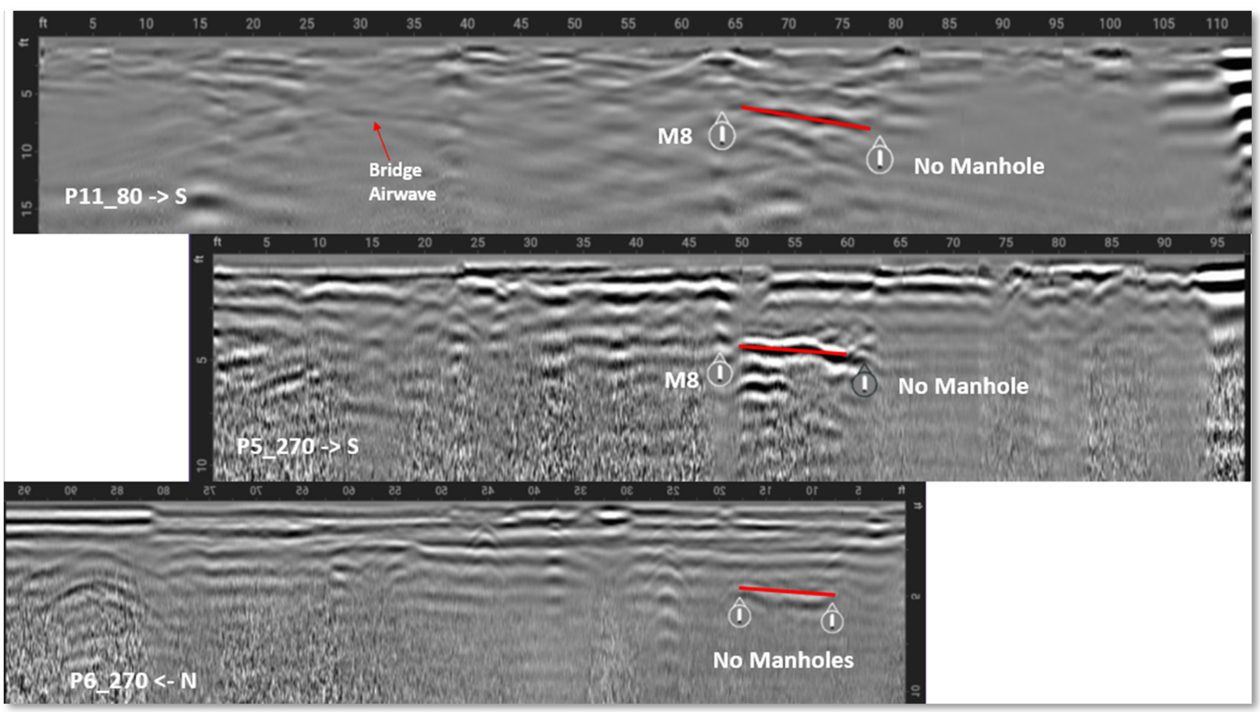


Figure 8. Three parallel GPR profiles on the WB side of the Kensington Expressway showing a horizontal target with similar appearance that is in close proximity to a known drainage manhole, but may represent the top of the SCI.

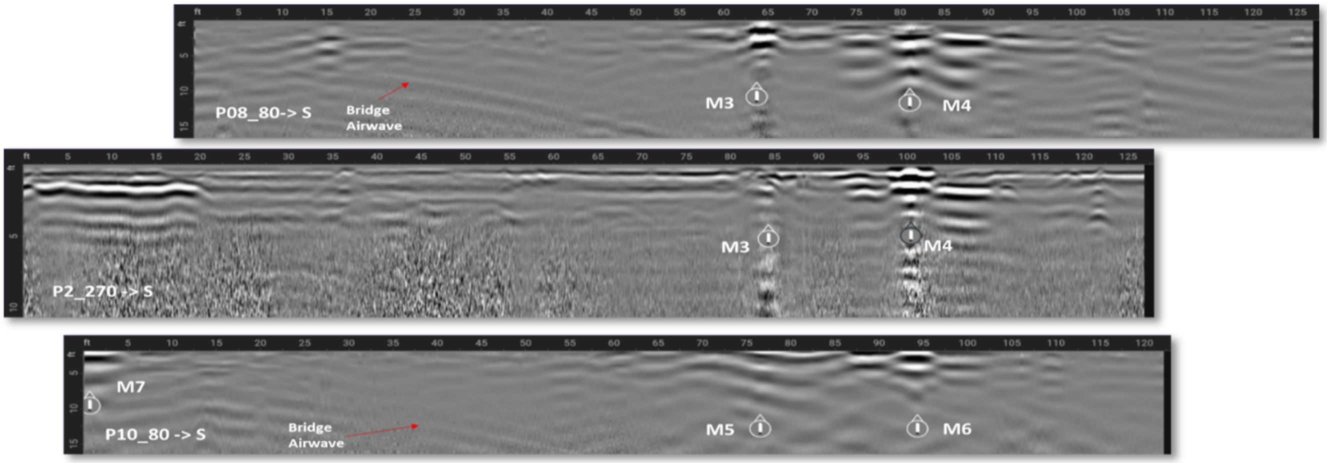


Figure 9. Three parallel GPR profiles on the EB side of the Kensington Expressway showing little evidence of the SCI, potentially due to attenuation from the roadway above.

It is our recommendation to compare these findings as-builts, especially the sewer network, to verify the presence of pipes in the areas marked with a red line. If there are no pipes expected, then this feature is unknown. It is possible that these horizontal features are directly related to the SCI. However, the alignment is not within the grass area as expected. The alignment of these targets shows it crossing beneath the northern corner of the Faith Baptist Church, and crossing the Kensington Expressway at an angle that places it close to the northern property line of 617 Humbolt parkway.

5. KEY FINDINGS

- GPR was an effective tool in mapping bedrock stratigraphy to approximately 25-feet maximum depth penetration.
- Bedrock depth varied in depth from approximately 3 feet to more than 25 feet between Station 8000 and 9000.
- Borehole records were used to calibrate the GPR layer picks.
- The 80-MHz GPR system was the primary system used for the analysis work.
- Mapping the position of the Scajaquada Creek Interceptor proved challenging, and the location of the presumed channel is further south, than originally expected. Further investigation of the position is recommended through targeted test pits.

6. REFERENCES

GSSI, 2022a, Digital Antennas 350MHz, https://www.geophysical.com/antennas, last visited 7/8/22.

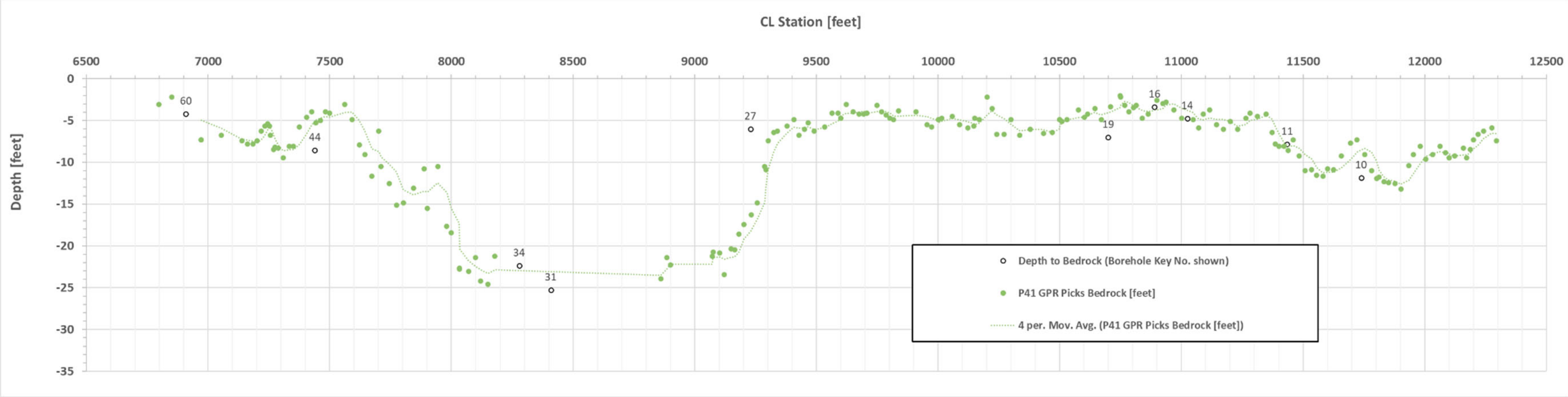
GSSI, 2022b, SIR 4000, https://www.geophysical.com/products/sir-4000, last visited 7/8/22.

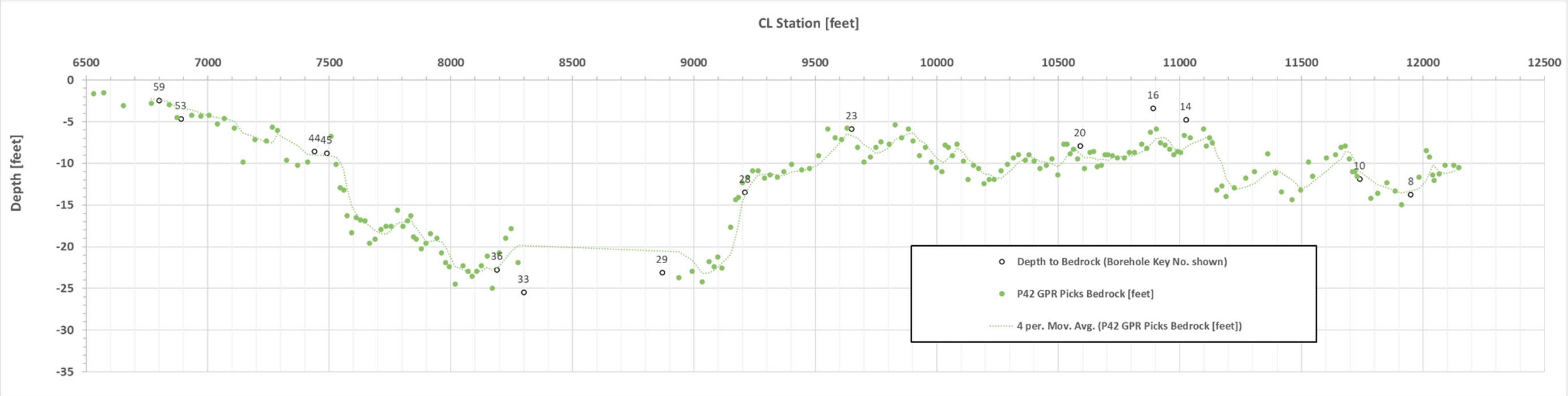
GSSI, 2022c, RADAN software, https://www.geophysical.com/software, last visited 7/8/22.

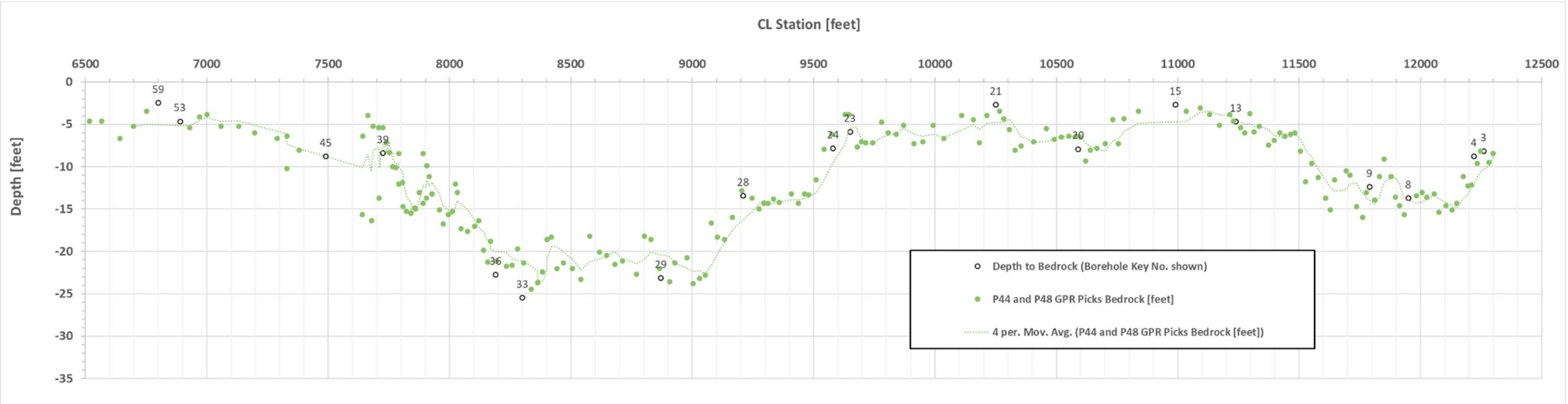
Mala, 2023, GX80, https://www.guidelinegeo.com/product/mala-groundexplorerxxx/, last visited 6/2/23.

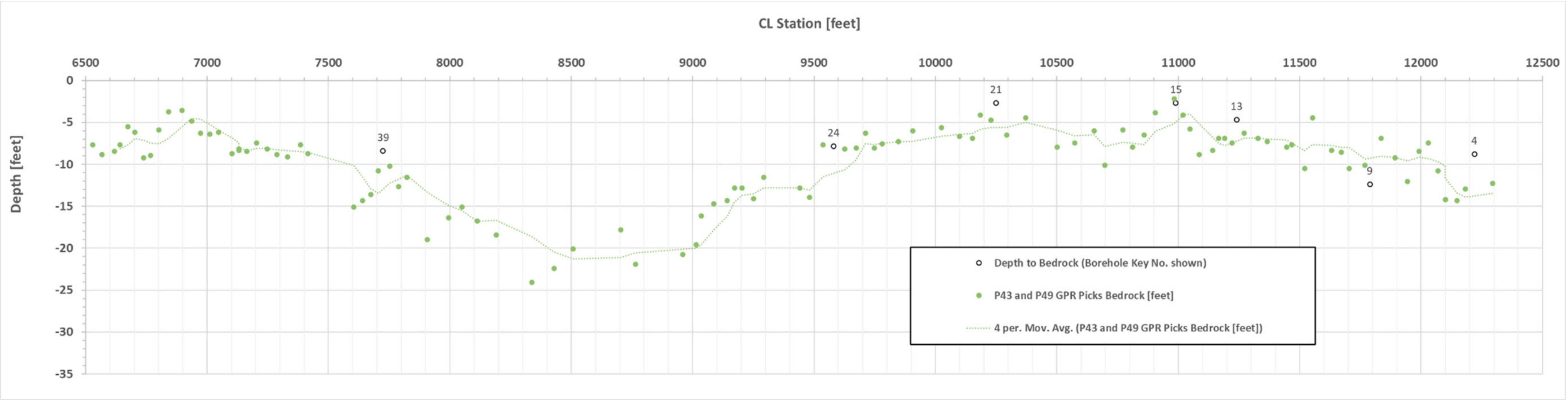
Proseq, 2023, https://www.screeningeagle.com/en/products/category/software/gpr-slice-insights, last visited 6/2/23.

ATTACHMENT A
BEDROCK DEPTH PROFILES
(DISTANCE IN CENTERLINE STATIONING)






CL Station [feet]
Depth [feet]
Depth to Bedrock (Borehole Key No. shown)
P44 and P48 GPR Picks Bedrock [feet]
4 per. Mov. Avg. (P44 and P48 GPR Picks Bedrock [feet])


CL Station [feet]
Depth [feet]
Depth to Bedrock (Borehole Key No. shown)
P43 and P49 GPR Picks Bedrock [feet]
4 per. Mov. Avg. (P43 and P49 GPR Picks Bedrock [feet])

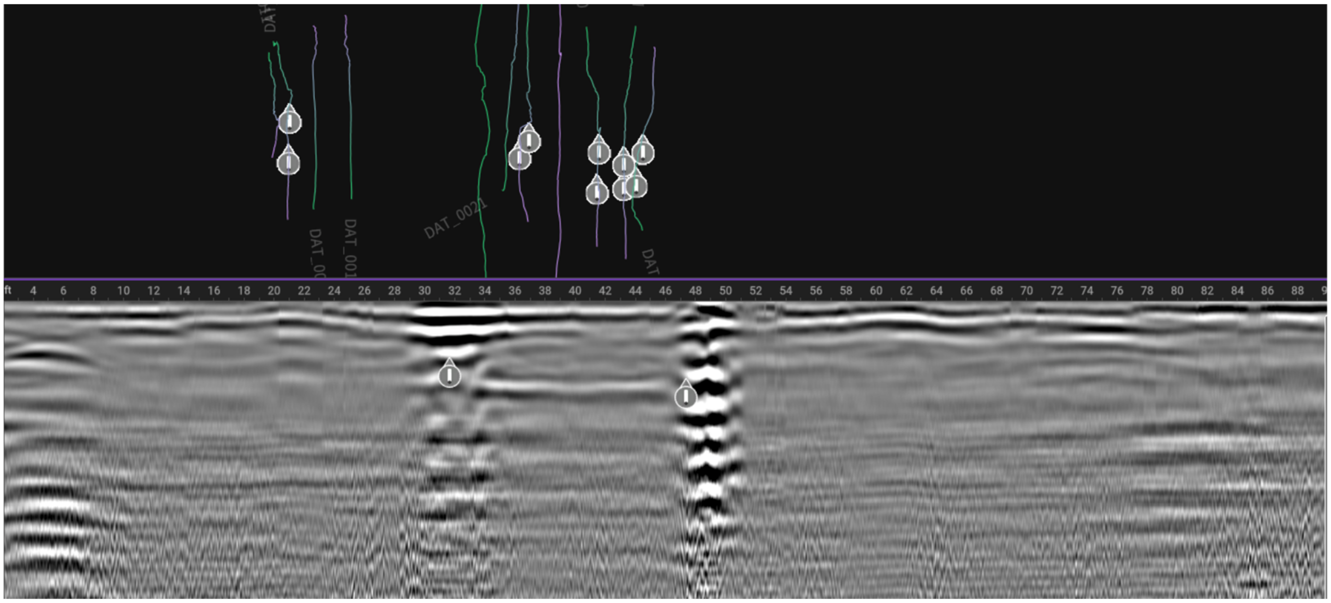
ATTACHMENT B
BOREHOLE INFORMATION TABLE

Table 2 – Table used to calculate the depth to bedrock from the surface and when used in a particular GPR profile.

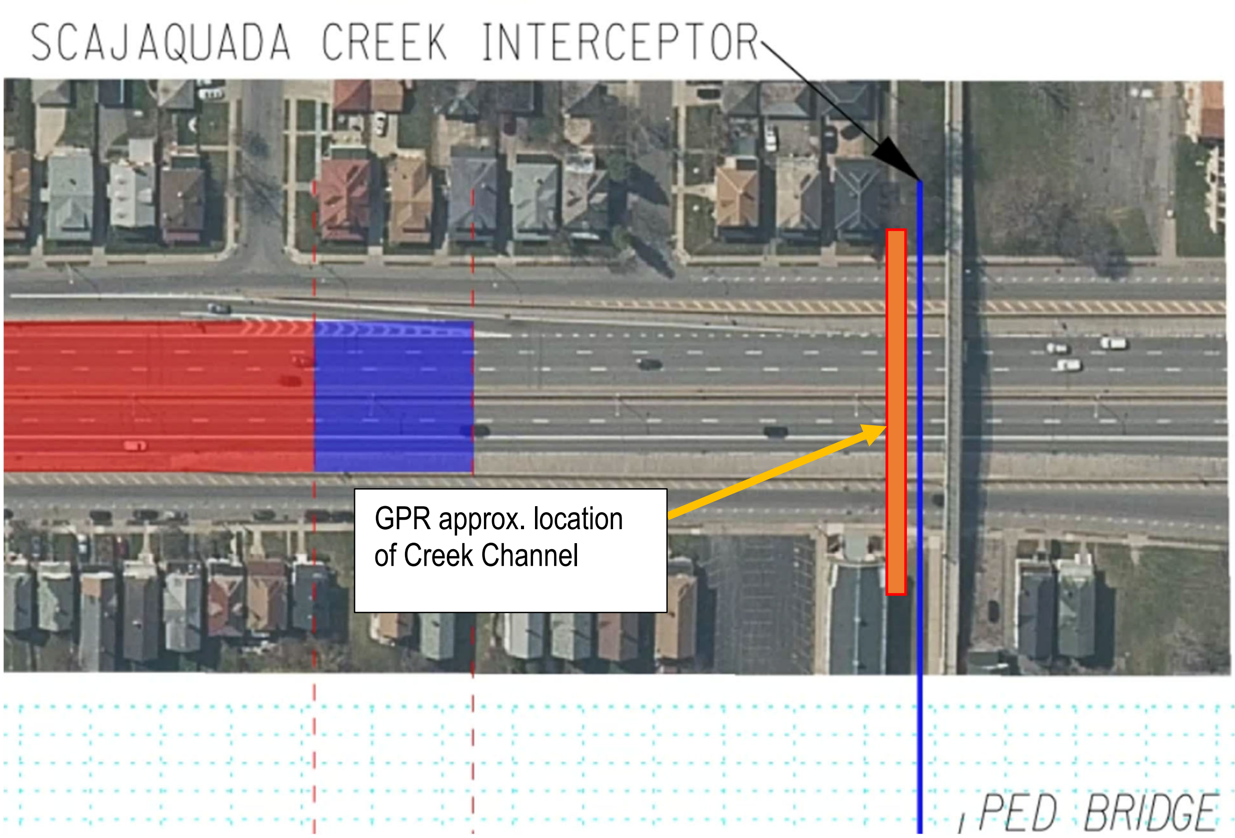
Boring ID (From Log)			NAD83		WGS84		NAVD88				Used for GPR profile (if=1)			
Key No.	Hole	Boring Date	Northing	Easting	Latitude	Longitude	Estimated Elevation of top of bedrock [feet]	Estimated Elevation of road surface [feet]	Depth to bedrock [feet]	CL Station (+/- 10 feet) (from client pdf maps)	WB emergency lane	WB near CL	EB near CL	EB emergency lane
3	FH-2	Sep 11 1959	1063403.514	1078631.919	42.9182896	-78.8433937	621.5	629.7	8.2	122+60	0	0	1	0
4	DH-G4	Mar 29 1957	1063356.494	1078647.88	42.9181607	-78.8433336	621.3	630.1	8.8	122+20	0	0	1	1
8	DH-W11	OCT 6 1965	1063083.51	1078622.67	42.9174115	-78.8434246	618.8	632.5	13.7	119+50	0	1	1	0
9	DH-E13	OCT 14 1965	1062928.5	1078641.55	42.9169863	-78.8433523	620.4	632.8	12.4	117+90	0	0	1	1
10	DH-W10	OCT 13 1965	1062878.54	1078595.51	42.9168488	-78.8435236	620.6	632.5	11.9	117+40	1	1	0	0
11	DH-W9	OCT 15 1965	1062625.55	1078581.32	42.9161545	-78.8435737	620.6	628.4	7.8	114+35	1	0	0	0
13	DH-E11	OCT 26 1965	1062378.49	1078656.13	42.9154773	-78.8432915	618.3	623.0	4.7	112+40	0	0	1	1
14	DH-G3	MAR 27 1957	1062163.53	1078595.96	42.9148869	-78.8435137	612.7	617.5	4.8	110+25	1	1	0	0
15	DH-S2-4	DEC 07 1965	1062128.49	1078655.93	42.9147913	-78.8432894	613.9	616.6	2.7	109+90	0	0	1	1
16	UD-S2-1	DEC 07 1965	1062028.54	1078585.85	42.9145165	-78.8435499	612.1	615.5	3.4	108+90	1	1	0	0
18	DH-G2	MAR 26 1957	1061933.49	1078653.78	42.9142562	-78.8432952	614.7	615.4	0.7	108+00	0	0	1	1
19	DH-W7	OCT 26 1965	1061833.55	1078580.7	42.9139814	-78.8435668	608.9	615.9	7.0	107+00	1	0	0	0
20	UD-GA-3	APR 26 1966	1061731.52	1078620.62	42.9137018	-78.8434166	608.5	616.4	7.9	105+90	0	1	1	0
21	DH-E8	NOV 01 1965	1061368.48	1078655.34	42.912706	-78.8432828	615.6	618.3	2.7	102+30	0	0	1	1
23	DH-G1	MAR 20 1957	1060785.51	1078614.89	42.911106	-78.8434271	615.7	621.6	5.9	96+50	0	1	1	0
24	DH-S1-2	DEC 28 1965	1060723.48	1078654.84	42.9109362	-78.8432773	614.1	621.9	7.8	95+80	0	0	1	1
27	DH-W14	NOV 07 1955	1060371.45	1078581.65	42.9099696	-78.8435464	623.8	629.8	6.0	92+30	1	1	0	0
28	PH-10E	OCT 19 1955	1060343.93	1078608.83	42.9098944	-78.8434446	617.9	631.4	13.5	92+10	0	1	1	0
29	DH-E3	NOV 09 1965	1060006.507	1078609.279	42.9089685	-78.8434391	615.7	638.8	23.1	88+70	0	1	1	0
31	DH-5B	SEP 16 1955	1059578.123	1078475.032	42.907792	-78.8439352	613.1	638.4	25.3	84+10	1	0	0	0
33	PH-1A	SEP 16 1955	1059448.963	1078498.044	42.9074378	-78.8438478	611.9	637.4	25.5	83+00	0	1	1	0
34	DH-3B	SEP 22 1944	1059449.352	1078439.033	42.9074383	-78.8440681	614.4	636.8	22.4	82+80	1	0	0	0
36	DH-4B	SEP 08 1955	1059346.232	1078457.704	42.9071555	-78.8439972	613.5	636.3	22.8	81+90	0	1	1	0
39	UD-US2	MAR 19 1956	1058902.218	1078317.488	42.9059361	-78.8445154	622.6	631.0	8.4	77+25	0	0	1	1
44	DH-3B	SEP 28 1955	1058663.876	1078151.959	42.9052807	-78.8451305	619.7	628.3	8.6	74+40	1	1	0	0
45	PH-2A	SEP 29 1955	1058699.926	1078198.989	42.90538	-78.8449554	620.1	628.9	8.8	74+90	0	1	1	0
53	DH-5B	OCT 10 1955	105144.871	1077960.202	42.9038549	-78.8458402	617.3	622.0	4.7	68+90	0	1	1	0
59	DH-2A	OCT 10 1955	1,058,046.711	1077967.913	42.9035857	-78.8458103	619	621.4	2.4	68+00	0	1	1	0
60	DH-2B	OCT 11 1955	1058087.151	1077893.883	42.903696	-78.8460871	618.3	622.5	4.2	69+10	1	0	0	0

ATTACHMENT C

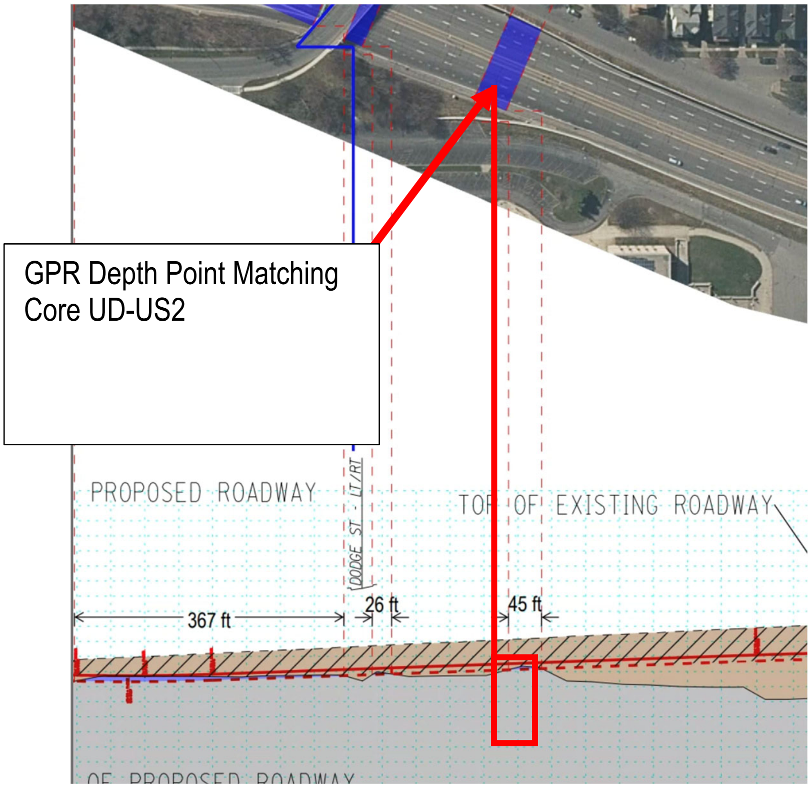
DISTRIBUTED FIRST NIGHT'S DATA REVIEW DOCUMENT



Grey tags show location of Sajaquada Creek Interceptor

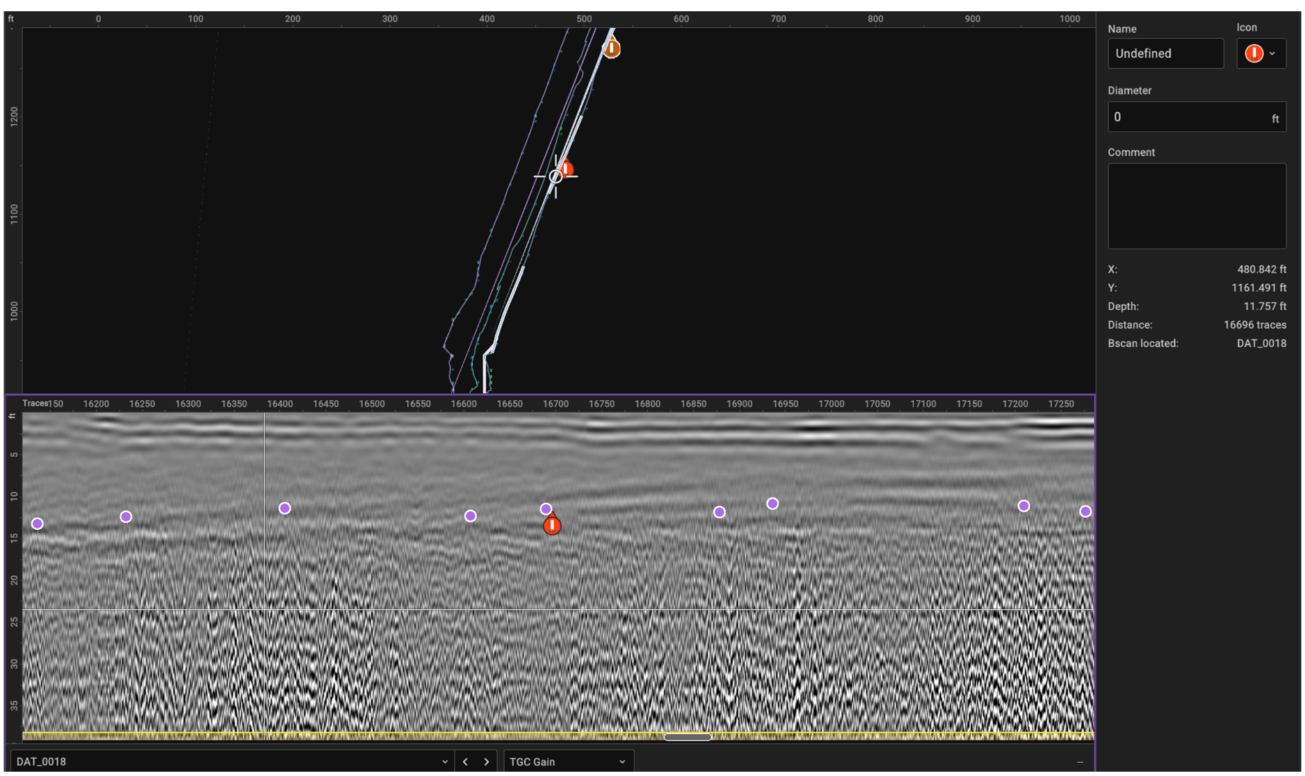


GPR location is approximately where the orange box appears…closer to the church property on the east side and the house property on the west.

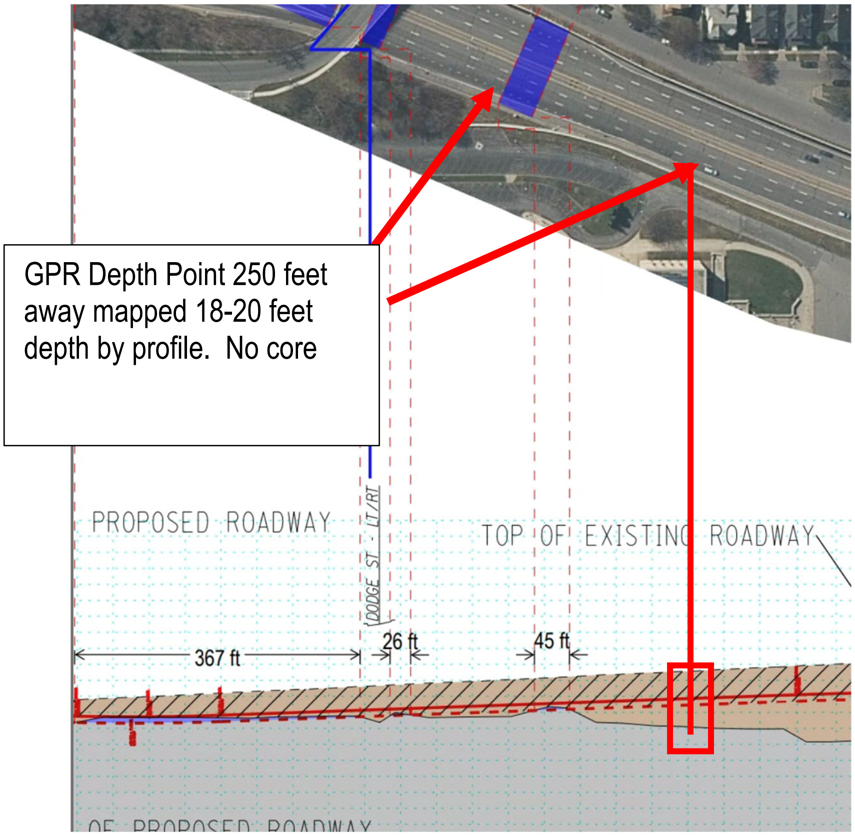


Red box – shows core related depth of 10-12 feet

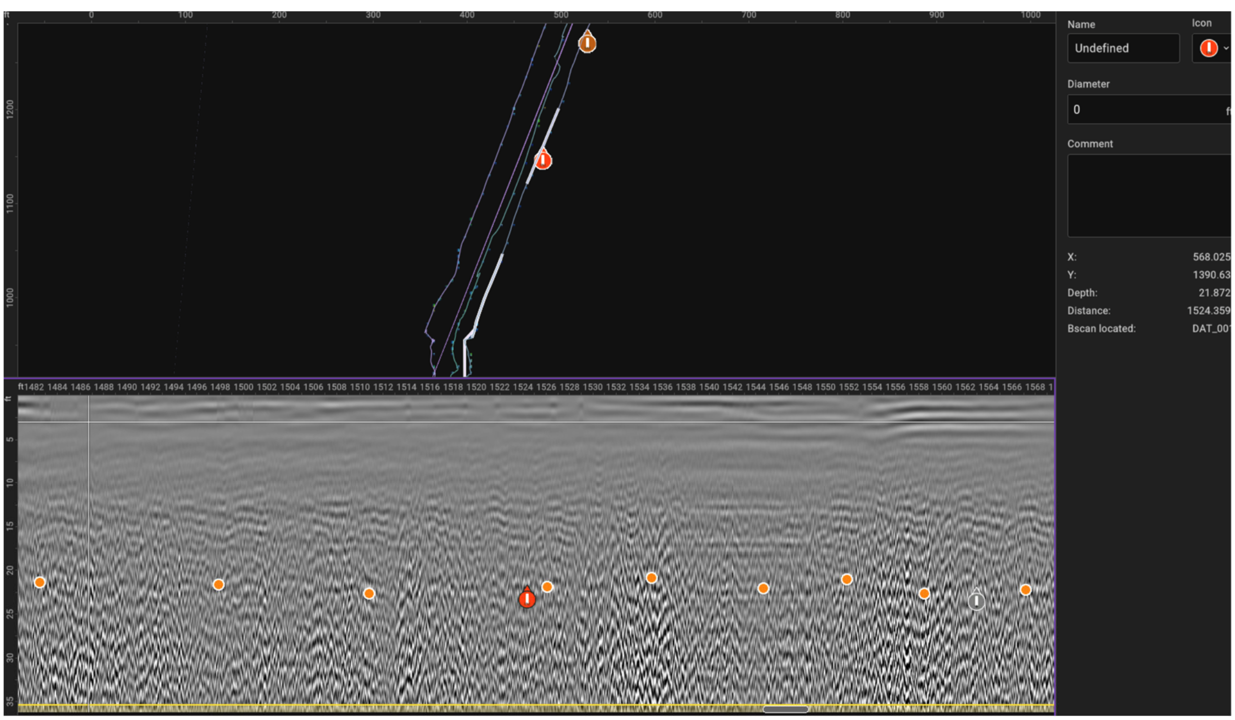
GPR data shows top of rock profile at UD-US2 – 11.757 foot depth



Layer tracked in purple, Core location shown in Red



GPR data shows top of rock profile hovering around 21-22 foot depth which is a bit deeper than the expected profile.



Layer tracked in orange, Core location shown in Red

Further calibration with additional data offsets near cores will help to refine the dielectric material and more closely represent the true depth.

Current depths are based on the proximity to a single core location and thus the second deeper location may change in the final analysis.