Highway 20 & West Street, Smithville, Ontario

L0R 2A0

Karst Hazard Assessment

Client:

Elite Smithville Developments Inc.
102-3140 South Service Road,
Burlington, ON
L7N 3T2

Attention:

Wajmah Safi

Type of Document:

FINAL

Project Name:

Highway 20 & West Street, Smithville, Ontario

Project Number:

GTR-22015175-C1

EXP Services Inc.
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Date Submitted:

2024-09-19

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1 Introduction

1.1 Project Description

EXP Services Inc. (EXP) was retained by Elite Smithville Developments Inc. to prepare a Karst Hazard Assessment Report associated with the proposed development located at Highway 20 & West Street, Smithville, Ontario (hereinafter referred to as the 'Site').

It is understood that the development is to comprise townhouses constructed in seven blocks and situated on the east side and two adjoining six-storey condominium buildings along the west end of the site. It is understood that the condominium buildings will include one level of underground parking and the townhouses will not include a basement level. The site is currently vacant agricultural/forested land and is located on the east side of West Street, across from the intersection with South Grimsby Road 6. The Site location plan is shown on Figure 1.

EXP conducted a Preliminary Geotechnical Investigation in conjunction with this investigation. A Hydrogeological Investigation is reported under separate cover. The pertinent information gathered from the noted investigations is utilized for this report.

1.2 Scope of Work

To achieve the investigation objectives, EXP has completed the following scope of work:

- Reviewed available geological and hydrogeological information for the Site;
- Monitored water levels and flows at three (3) locations along the stream using staff gauges, and flow measurements;
- Surveyed identified sinkholes using SokkiaGPS;
- Installed two (2) electronic data loggers to monitor on continuous basis surface water elevation with staff gauge;
- Installed two (2) electronic data loggers to monitor continuous groundwater conditions with piezometers adjacent to stream;
- Took surface water flow measurements during wet weather conditions in Spring 2023 to Fall 2023 for 12 events;
- Prepared a Karst Hazard Assessment Report; and,
- Prepared a mitigation and contingency plan.

1.3 Review of Previous Reports

The following reports were reviewed as part of this Karst Hazard Assessment:

- EXP Services Inc. (August 25, 2022), Preliminary Geotechnical Investigation, West Street, Smithville, ON, prepared for Elite Smithville Developments Inc.
- EXP Services Inc. (September 9, 2022), Preliminary Hydrogeological Investigation, West Street, Smithville, ON, prepared for Elite Smithville Developments Inc.

Additionally, a review of previous studies within the Smithville Area was conducted, including the following reports:

- Terra-Dynamics Consulting Inc. (April 2006) Geologic Hazard Mapping Study, Karst Topography, Phase I, NPCA Watershed Area, prepared for Niagara Peninsula Conservation Authority
- Township of West Lincoln (February 24, 2023) Subwatershed Study Phase 1: Characterization and Integration
- Township of West Lincoln (February 24, 2023) Subwatershed Study Phase 2: Impact Assessment
- Township of West Lincoln (February 24, 2023) Subwatershed Study Phase 3: Management, Implementation, and Monitoring Plan

Any past and/or future geotechnical, hydrogeological, environmental and risk assessments, and updated development/architectural plans should be provided to update this hydrogeological report prior to submission of permits and approvals by the municipalities and agencies.

2 Methodology

2.1 Surface Water Level Monitoring

Surface water levels were monitored at two (2) locations (MP/SG1 and MP/SG2) located in the forested area along the stream leading to the sinkhole (karstic feature) between April 21 2023 and October 11, 2023. Results of the monitoring is reported in Table 2-1, and monitoring locations are provided in Figure 2.

Table 2-1: Summary of Surface Water Level Measurement

Monitoring Well ID	Ground Surface Elevation (masl)	Depth	4/21/2023	6/9/2023	6/15/2023	6/27/2023	8/3/2023	8/16/2023	8/24/2023	9/7/2023	9/21/2023	9/28/2023	10/5/2023	10/11/2023
MP1	187.09	mbTOP	DRY	1.8	1.8	DRY	1.53	DRY	1.75	1.7	1.84	DRY	DRY	DRY
		mbgs	-	1.03	1.03	-	0.76	-	0.98	0.93	1.07	-	-	-
		masl	-	186.06	186.06	-	186.33	-	186.11	186.16	186.02	-	-	-
SG1	186.32	mbTOP	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
		mbgs	-	-	-	-	-	-	-	-	-	-	-	-
		masl	-	-	-	-	-	-	-	-	-	-	-	-
MP2	189.59	mbTOP	DRY	1.72	1.31	1.67	1.28	1.32	1.37	1.53	1.74	DRY	DRY	1.32
		mbgs	-	0.85	0.44	0.80	0.41	0.45	0.50	0.66	0.87	-	-	0.45
		masl	-	188.74	189.15	188.79	189.18	189.14	189.09	188.93	188.72	-	-	189.14
SG2	189.23	mbTOP	0.05	DRY	0.03	0.1	0.04	0.11	0.04	0.05	DRY	DRY	DRY	0.04
		mbgs	0.05	-	0.03	0.10	0.04	0.11	0.04	0.05	-	-	-	0.04
		masl	189.28	-	189.26	189.33	189.27	189.34	189.27	189.28	-	-	-	189.27

2.2 Karst Monitoring

One (1) sinkhole was mapped onsite as part of the Smithville Subwatershed Study and Stormwater Management Plan, dated February 2, 2023 on the property (See Appendix C) and additional Karst Assessments are required by the Niagara Region Conservation Authority. The sinkhole is identified as NW3, and is described in the Subwatershed Study as a "large streamsink and blind valley located between train tracks and Highway 20, with flow south/southwest along a visible overflow channel.".

Staff gauges and data loggers were installed and measured in two (2) locations, one in the visible karst feature (SG/MP 1) and one upstream of the location (SG/MP 2). Figure 5 depicts the above installations.

2.2.1 Seasonal Water Monitoring at Karstic Feature

Data was logged at SG1, and SG2 between April 21 2023 and October 11, 2023. Hydrographs depicting the above can be seen in Appendix D. Based on the Hydrograph J-1, the two monitoring locations show that the surface water elevations respond strongly to precipitation events. Hydrographs J-2 and J-3 display the infiltration of rainwater into the soil surrounding the SG/MPs, with water level peaks coinciding with rain events that drop down in between events.

2.2.2 Flow Rate Measurements

Flow rate was monitored at stream flow stations SF1 (SG1 – downgradient), SF2 (SG2 – upgradient) and SF3 (between the two) in twelve rain events between April 21, 2023 to October 11, 2023.

SG1 was determined to be a sinkhole on initial site visit, and SF1 was installed adjacent to the karst feature on April 21, 2023. Despite presence of ponding and disappearance of surface water into sinkhole (as per photo dated March 23, 2023 in Appendix B) initial site visit, over twelve subsequent visits in Spring and Fall 2023, no stream flow data was determined to the sink, the stream running dry prior to arrival at the feature. SF2 was selected from an upstream point on the creek to determine difference in flow rate. An additional stream flow station (SF3) was installed in the midpoint between the two locations to capture flow when stream dried during summer months.

Estimated flow rates at SF1 (downgradient) could not be measured within the sampling period. Estimated flow rates at SF2 (upgradient) ranged from approximately 0.027 to 7.87 m3/hr (0.0074 to 2.19 L/s) during this period. Estimated flow rates at SF3 (midgradient) ranged from approximately 0.31 m3/hr and 3.85 m3/hr (0.087 to 1.07 L/s) during this period. Tables depicting the above can be seen in Appendix D.

2.3 Electrical Resistivity Tomography

Geophysics GPR International Inc. (GPR) was requested by EXP to carry out a geophysical survey within an area bounded by Highway 20, South Grimsby Road Six and railway tracks in Smithville, Ontario, described in the attached report Geophysical Investigation For Mapping Potential Karst Features, Smithville, Ontario (Appendix E).

At the initiation of the project, the most suitable geophysical method was discussed with the geophysical subcontractor based on the desired depth of investigation and subsurface conditions. Ground penetrating Radar was considered not suitable for this assessment due to the thickness of overburden, soil type, and the required depth of geophysics. Electrical resistivity was considered by the geophysicist as the most suitable method based on the geology and the desired depth of exploration. The geophysical survey consisted of electrical resistivity tomography (ERT) profiles to generate depth profiles of variations in the electrical properties of the subsurface material across the property.

ERT was completed along three profiles. Based on the ERT, several distinct low resistivity zones were noted, particularly in the intersection of Line 1 and Line 2. These low resistivity zones can be indicative of zones of increased bedrock weathering, fractures, or infilled karst features and based on the relative resistivity values when compared to the variation across the site. The locations of these profiles as well as locations of potential voids/sinkholes/weathered bedrock can be seen on Figure 4.

3 Environmental Impact

3.1 Surface Water Features

The Site is within the Twenty Mile Creek watershed. No surface water features exist onsite. The nearest surface water feature is Twenty Mile Creek, approximately located 330 meters southwest of the Site boundary. An unnamed intermittent stream is mapped onsite. Lake Ontario is approximately 10 km from the Site boundary to the northeast.

3.2 Karst Features

3.2.1 Sinkhole NW3

NW3 is situated at the downstream terminus of a tributary characterized by its predominant flow being sourced from snowmelt, particularly during the spring season. Nestled within a wooded valley, it boasts a natural riparian zone filled with indigenous vegetation. This specific attribute classifies it as a hazardous location, necessitating adherence to NPCA guidelines for hazardous sites. (NPCA, 2022)

To safeguard its current role in the watershed and karst system, a 50-meter protective buffer (see Figures 4 and 5) must be imposed around this feature. Stormwater management practices employed in the upstream development area should be designed to retain pre-development peak flows and maintain the natural water balance, and drainage plans must be designed to route surface water run-off through filtration measures before entering the karst system. No underground or aboveground storage tanks or salt storage facilities may be placed within the buffer.

Stormwater and flooding concerns will be addressed in the stormwater assessment completed by the civil engineer.

In order to confirm soil stability within karst hazardous region, boreholes are recommended at each corner of single residential unit or townhomes, and at each footing of multistorey structures within the 50-meter buffer.

3.2.2 Additional Potential Karst Features

Additional karst features discovered onsite during construction should be addressed with the same methodology and practices described above, in addition to a 50-meter buffer extending from a new feature. During course of construction in the event that additional karstic features are identified, the same mitigation measures as described above should be employed.

3.3 Karst Mitigation and Contingency Plan

More karstic features may exist on the property and should bedrock excavation become necessary for the foundation construction and underground services installation at the locations other than the identified karst site, a qualified karst specialist should inspect these excavations and, if any evidence of karst hazard is found, immediately inform the NPCA and provide further recommendations on the hazard elimination. In the event of the discovery of a karstic feature at the base of excavation, the following tasks should be followed to mitigate the features.

3.3.1 Communication Plan

- Contractor observes karst, calls geotechnical engineer and karst specialist
- Karst specialist notifies NPCA of encountered karst

3.3.2 Measures to be Implemented

- Excavation of the perimeter area of the karst feature and manual excavation of the throat area (opening or void into the bedrock) of the feature;
- Pressure washing and water-vacuuming of the bedrock surface at least 1.0 m away from the perimeter of the karst feature until bedrock surface and throat area are clean of clay and any other materials such as loose rock or debris;
- Mapping of the karst feature by a karst expert and obtaining geodetic elevations and UTM coordinates of all relevant bedrock features;
- Infilling of the bottom section of the karst feature with washed, permeable aggregate like river rock;
- Covering aggregate with geotextile then infilling of the upper section of the karst feature with a low slump concrete to the native grade of the bedrock and allowing the concrete to cure. The thickness of the concrete and any potential structural reinforcement should be designed and carried-out by a Professional Engineer;
- Regrading of the area to conform with future construction activities;
- Ensuring that the area is not subject to any future stormwater drainage; and
- Documenting the above remedial action in a report under a separate cover to be submitted to the Niagara Region Conservation Authority and City of Smithville.

4 Conclusions and Recommendations

Based on the findings of the Karst Hazard Assessment, the following conclusions and recommendations are provided:

- Geophysics GPR International Inc. (GPR) was requested by EXP to carry out a geophysical survey within an area bounded by Highway 20, South Grimsby Road Six and railway tracks in Smithville, Ontario, described in the attached report Geophysical Investigation. Based on the report several distinct low resistivity zones were noted, particularly in the intersection of Line 1 and Line 2 in the noted karst sinkhole. These low resistivity zones can be indicative of zones of increased bedrock weathering, fractures, or infilled karst features and based on the relative resistivity values when compared to the variation across the site. Information collected so far is satisfactory for SPA submission, and mitigation measures have been developed to address any unforeseen conditions.
- Estimated flow rates at SF1 (downgradient) could not be measured within the sampling period - Despite presence of ponding on initial site visit, over twelve subsequent visits in Spring and Fall 2023, no stream flow data was determined to the sink, the stream running dry prior to arrival at the feature. Estimated flow rates at SF2 (upgradient) ranged from approximately 0.027 to 7.87 m3/hr (0.0074 to 2.19 L/s) during this period. Estimated flow rates at SF3 (midgradient) ranged from approximately 0.31 m3/hr and 3.85 m3/hr (0.087 to 1.07 L/s) during this period. Tables depicting the above can be seen in Appendix D.
- To safeguard its current role in the watershed and karst system, a 50-meter protective buffer must be imposed around NW3. Stormwater management practices employed in the upstream development area should be designed to retain pre-development peak flows and maintain the natural water balance, and drainage plans must be designed to route surface water run-off through filtration measures before entering the karst system. Conducting dye tracing experiments is recommended to determine the flow pathways downstream of the karst feature.
- More karstic features may exist on the property and should bedrock excavation becomes necessary for the foundation construction and/or underground service installation at the locations other than the identified karst sites, a qualified karst specialist should inspect these excavations and, if any evidence of karst hazard is found, immediately inform the NPCA and provide further recommendations on the hazard elimination.
- In the event that a karstic feature is found, contractors are to proceed according to communication plan will implement the necessary measures as detailed in the report.

The conclusions and recommendations provided above should be reviewed in conjunction with the entirety of the report. They assume that the present design concept described throughout the report will proceed to construction. This report is solely intended for the construction assessment. Any changes to the design concept may result in a modification to the recommendations provided in this report.

5 Limitations

This report is based on a limited investigation designed to provide information to support an assessment of the current hydrogeological conditions within the study area. The conclusions and recommendations presented within this report reflect Site conditions existing at the time of the assessment. EXP must be contacted immediately, if any unforeseen Site conditions are experienced during construction activities. This will allow EXP to review the new findings and provide appropriate recommendations to allow the construction to proceed in a timely and cost-effective manner.

Our undertaking at EXP, therefore, is to perform our work within limits prescribed by our clients, with the usual thoroughness and competence of the geoscience/engineering profession. No other warranty or representation, either expressed or implied, is included or intended in this report.

This report was prepared for the exclusive use of Elite Smithville Developments Inc.. This report may not be reproduced in whole or in part, without the prior written consent of EXP, or used or relied upon in whole or in part by other parties for any purposes whatsoever. Any use which a third party makes of this report, or any part thereof, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. EXP Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust that this information is satisfactory for your purposes. Should you have any questions or comments, please do not hesitate to contact this office.

Sincerely,

EXP Services Inc.

PROFESSIONAL GEOSCIENTIST
FRANCOIS CHARTIER
PRACTISING MEMBER
2270
ONTARIO

Nicolas Sabo, B.Sc., M.E.S.
Junior Project Manager
Environmental Services

Francois Chartier, M. Sc., P. Geo.
Discipline Manager, Hydrogeology
Environmental Services

6 References

- Cashman and Preene (2013) Groundwater Lowering in Construction, 2nd Edition.
- Chapman, L.J. and Putnam, D.F. (2007). Physiography of Southern Ontario, 3rd Edition, Ontario Geological Survey.
- EXP Services Inc. (August 25, 2022), Preliminary Geotechnical Investigation, West Street, Smithville, ON, prepared for Elite Smithville Developments Inc.
- EXP Services Inc. (September 9, 2022), Preliminary Hydrogeological Investigation, West Street, Smithville, ON, prepared for Elite Smithville Developments Inc.
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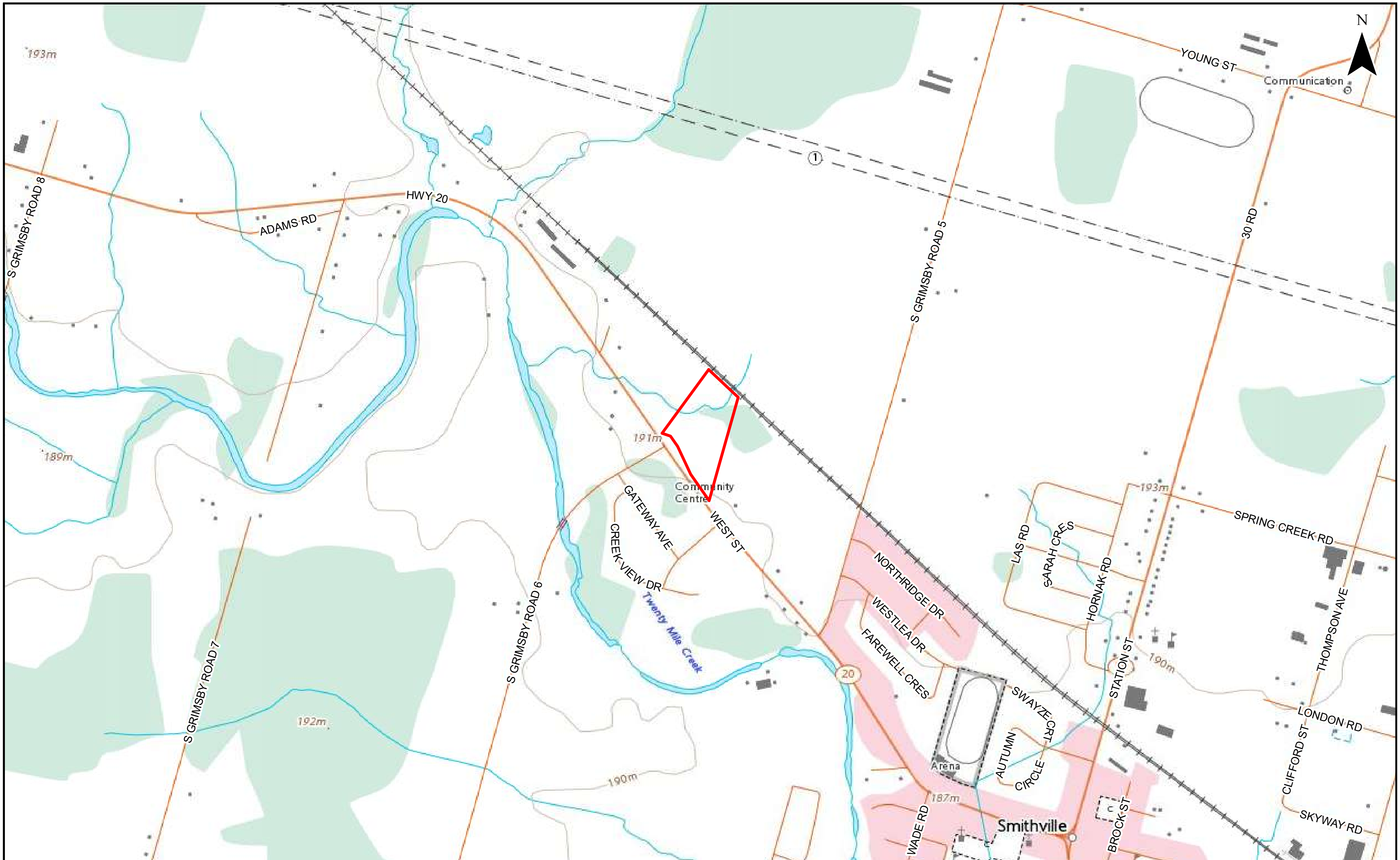
- Township of West Lincoln (February 24, 2023) Subwatershed Study Phase 2: Impact Assessment
- Township of West Lincoln (February 24, 2023) Subwatershed Study Phase 3: Management, Implementation, and Monitoring Plan
- Niagara Peninsula Conservation (November 18, 2022) Policies for Planning and Development in the Watersheds of the Niagara Peninsula Conservation Authority
- J.P. Powers, A.B. Corwin, P.C. Schmall and W.E. Kaeck (2007). Construction Dewatering and Groundwater Control, Third Edition.
- Ministry of Northern Development and Mines (May, 2012). OGS Earth. Retrieved from http://www.mndm.gov.on.ca/en/mines-and-minerals/applications/ogsearth.
- Oak Ridges Moraine Groundwater Program. Accessed to the website (https://oakridgeswater.ca/) dated October 2018.
- Toronto and Region Conservation (2008/2009), Humber/Don River State of the Watershed Report – Geology and Groundwater Resources.

Appendix A - Figures



SCALE:

0 150 300 450 600 750 m

LEGEND:

APPROXIMATE SITE BOUNDARY

SITE LOCATION PLAN

FIGURE: 1

HYDROGEOLOGICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT - WEST STREET
SMITHVILLE, ONTARIO

exp.

DRAWN BY: AC

CHECKED BY: NS

PROJECT NUMBER: HAM-22015175-B0

DATE: AUGUST 2022

SCALE:

0 30 60 90 120 150 m

LEGEND:

- BOREHOLE (EXP, 2022)
- BOREHOLE / MONITORING WELL (EXP, 2022)
- APPROXIMATE SITE BOUNDARY

exp.

DRAWN BY:	CHECKED BY:
AC	NS

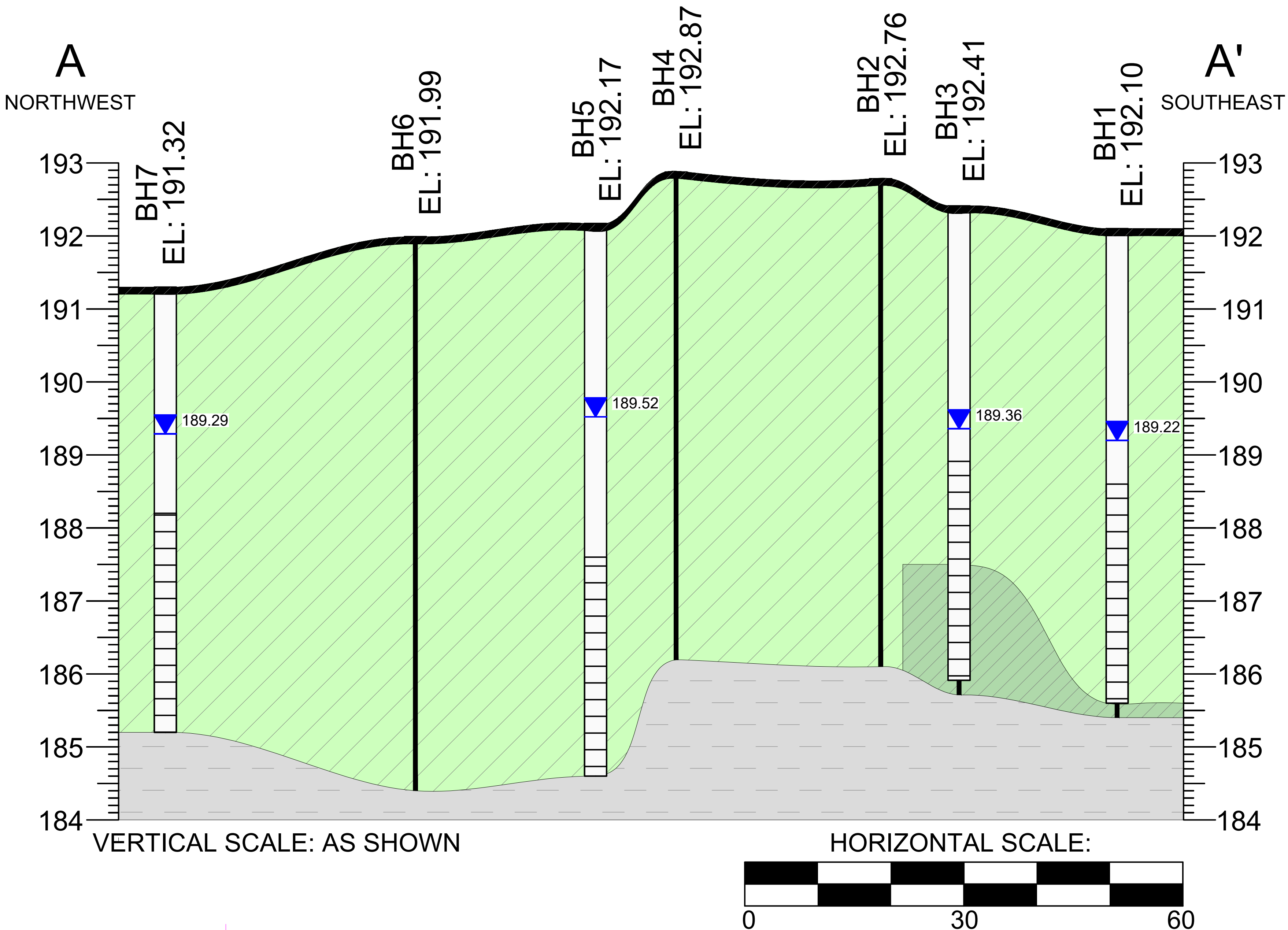
BOREHOLE / MONITORING WELL LOCATION PLAN

FIGURE: 4

HYDROGEOLOGICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT - WEST STREET
SMITHVILLE, ONTARIO

PROJECT NUMBER: HAM-22015175-B0

DATE: AUGUST 2022



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LEGEND:
- FILL
- SILTY CLAY
- CLAYEY SILT TILL
- PRESUMED BEDROCK
- GROUNDWATER ELEVATION ON AUGUST 24, 2022

TITLE AND LOCATION:
CROSS SECTION A-A'
WEST STREET, SMITHVILLE, ONTARIO

PROJECT NO.: HAM-22015175-B0	DWN.: NS
SCALE: AS NOTED	CK: FC
DATE: AUGUST 2022	FIG. NO.: 5

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LEGEND:

- ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) PROFILE (2023)
- POTENTIAL ZONE OF INFILLED KARST OR INCREASED BEDROCK WEATHERING
- POTENTIAL VOID / SINKHOLE
- KARST FEATURE
- 50 METER BUFFER AROUND SINKHOLE

TITLE AND LOCATION:

ERT / VOID SPACE LOCATION OVERLAY
HIGHWAY 20 & WEST STREET, SMITHVILLE, ONTARIO

PROJECT NO.:	DWN.:
GTR-22015175-C1	NS
SCALE: AS NOTED	CK: FC
DATE: OCTOBER 2023	FIG. NO.: 4

SCALE:

0 30 60 90 120 150 m

LEGEND:

- BOREHOLE / MONITORING WELL (EXP, 2022)
- XX.XX GROUNDWATER ELEVATION (m asl) AS MEASURED ON OCTOBER 11, 2023
- GROUNDWATER CONTOUR
- GROUNDWATER FLOW DIRECTION
- WATERCOURSE
- APPROXIMATE SITE BOUNDARY
- 50 METER BUFFER AROUND SINKHOLE

GROUNDWATER CONTOUR PLAN

FIGURE: 6

HYDROGEOLOGICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT - WEST STREET
SMITHVILLE, ONTARIO

exp.

DRAWN BY: AC

CHECKED BY: NS

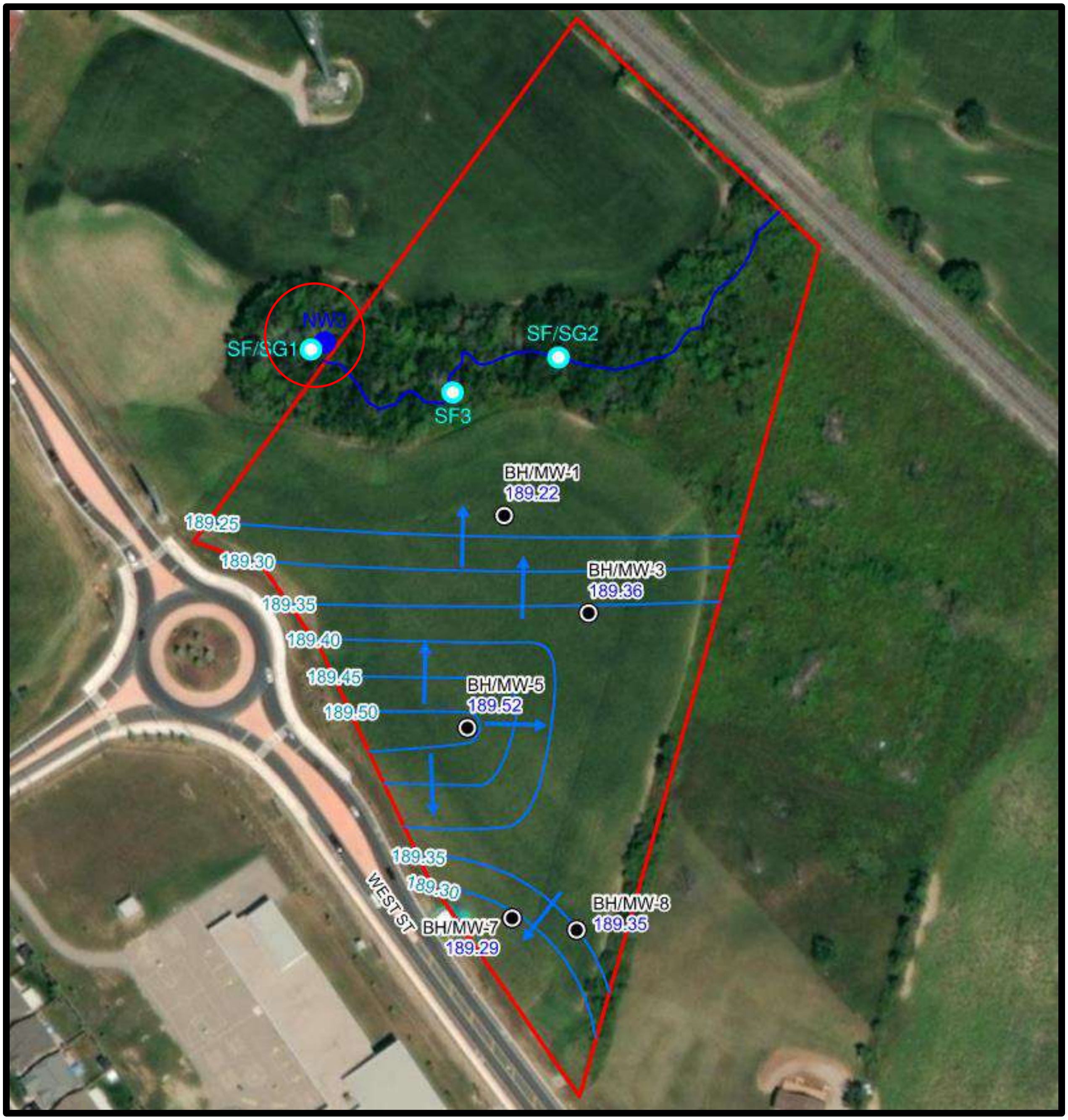
PROJECT NUMBER: HAM-22015175-B0

DATE: OCTOBER 2023

Appendix B – Karst Photos

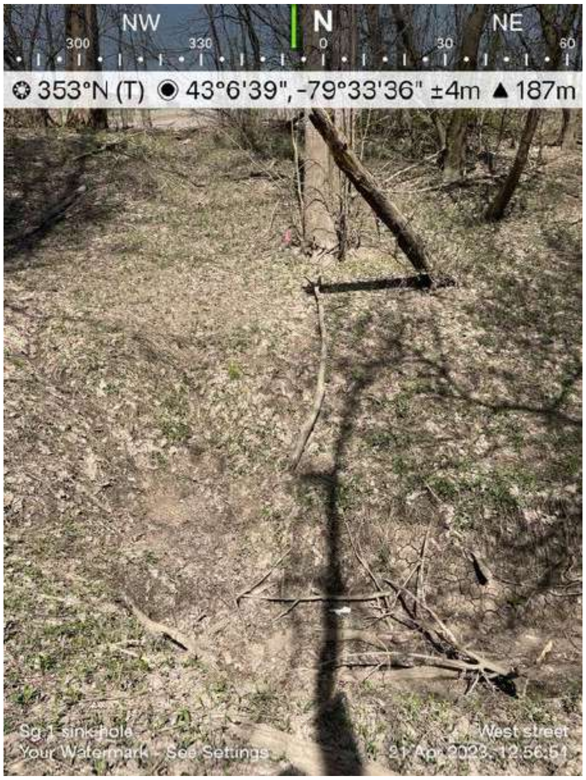
SF/SG 1 location (sinkhole)
West street – Smithville
April 21, 2023

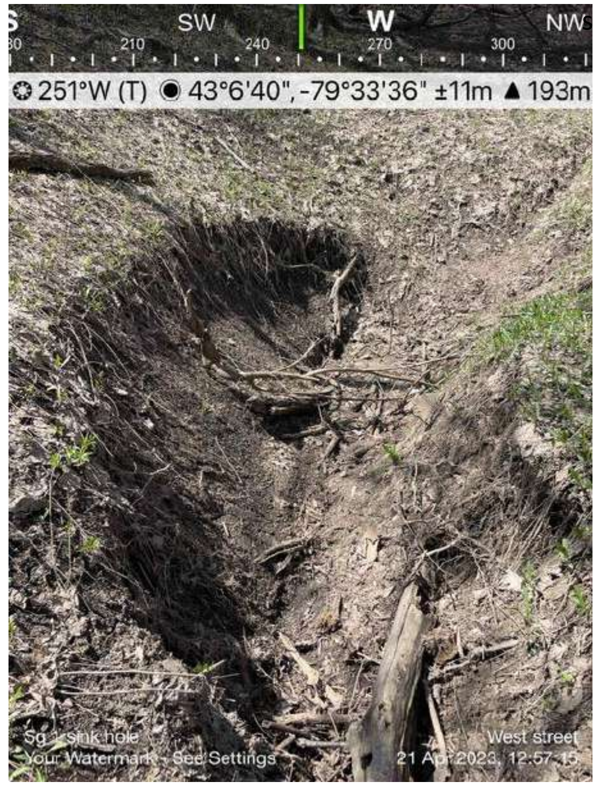
MP SG installations
MP1 – 187.092masl
SG1 – 186.317masl

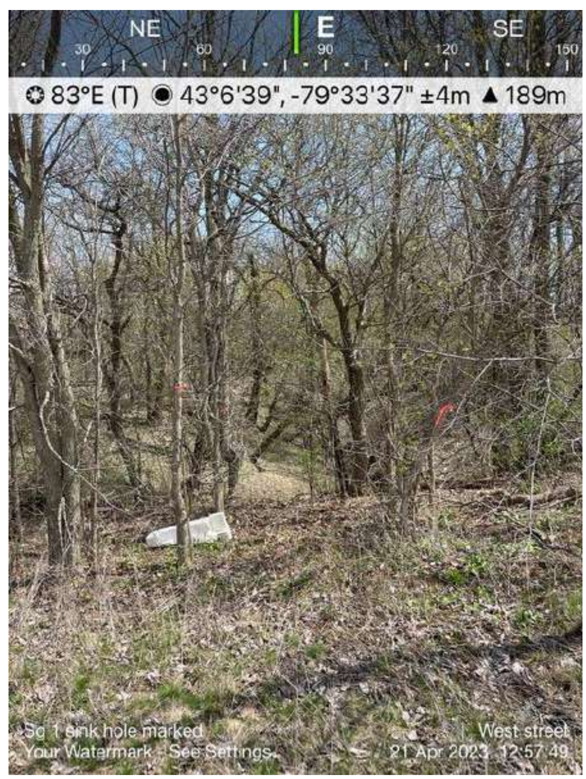


March 23, 2023 – Initial Visit

April 21 2023 – Rain Event








E SE S
90 120 150 180
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Sg 1 sink hole
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West street
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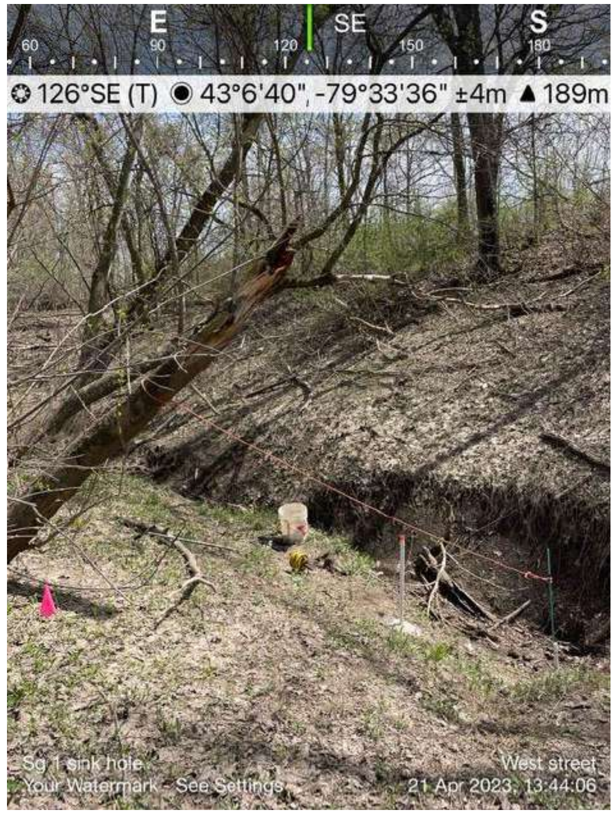
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S SW W
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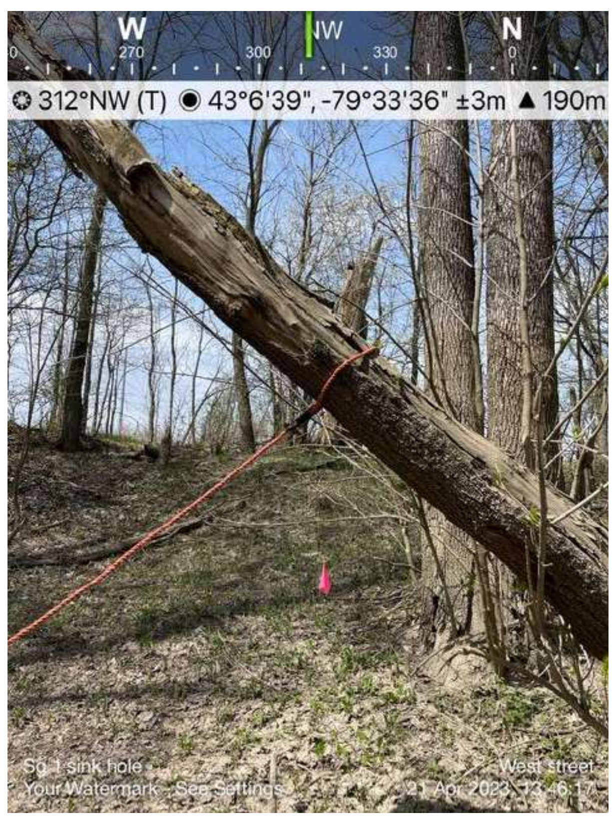
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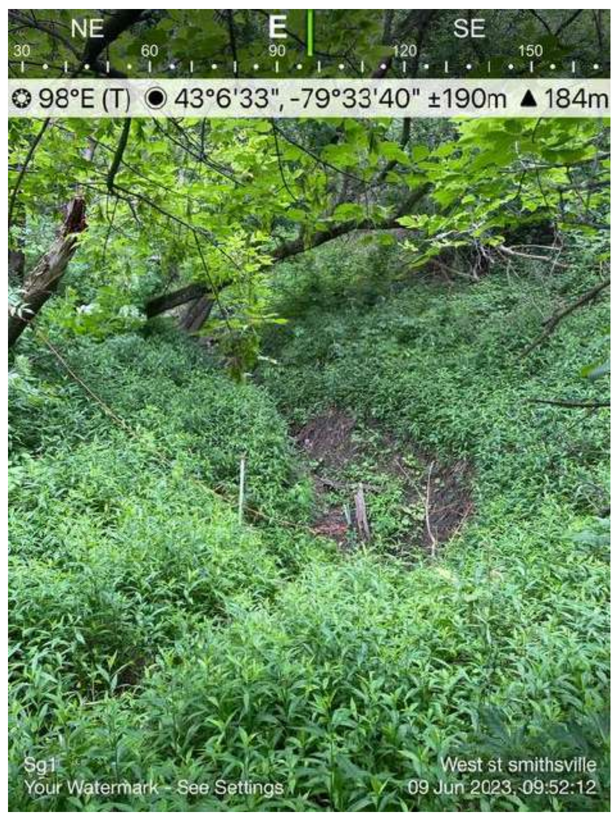
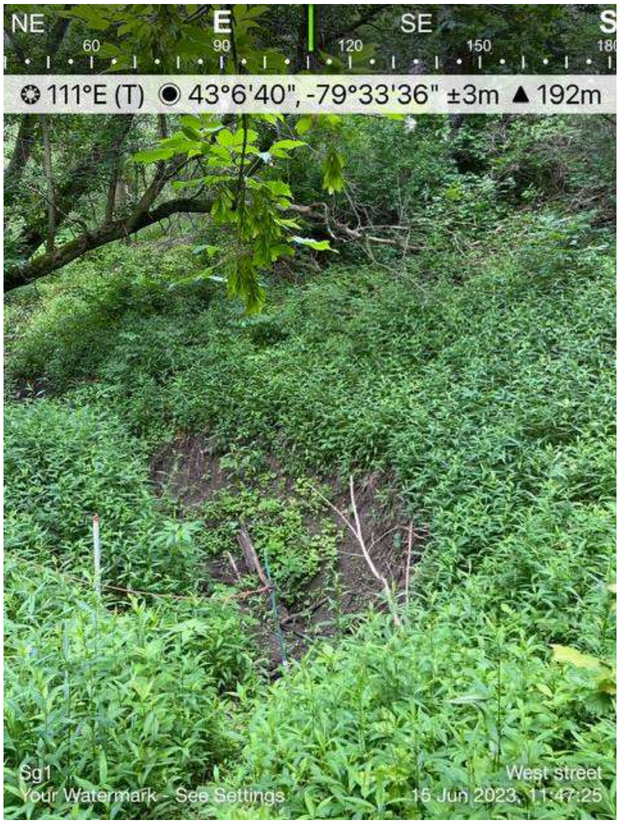
June 8 2023 – Rain Event



June 15, 2023


NE E SE S
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Sg1
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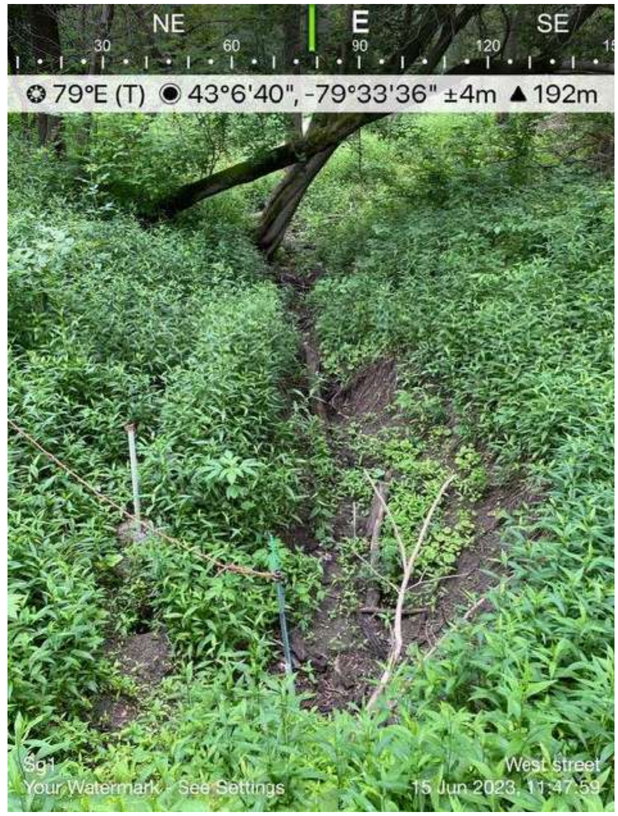
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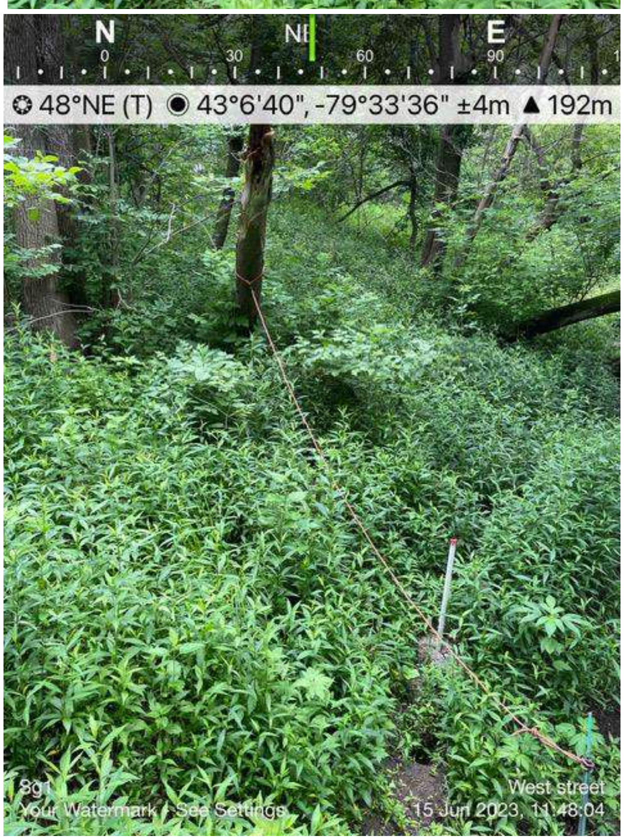
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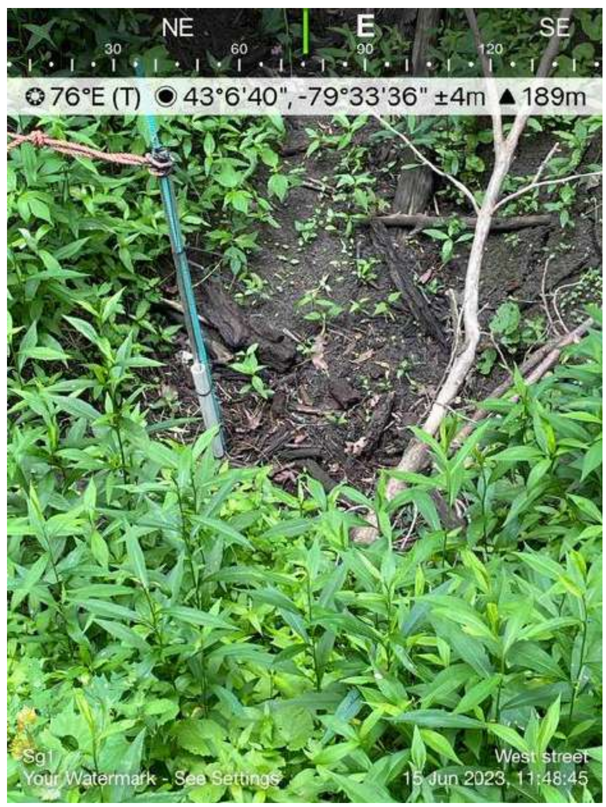
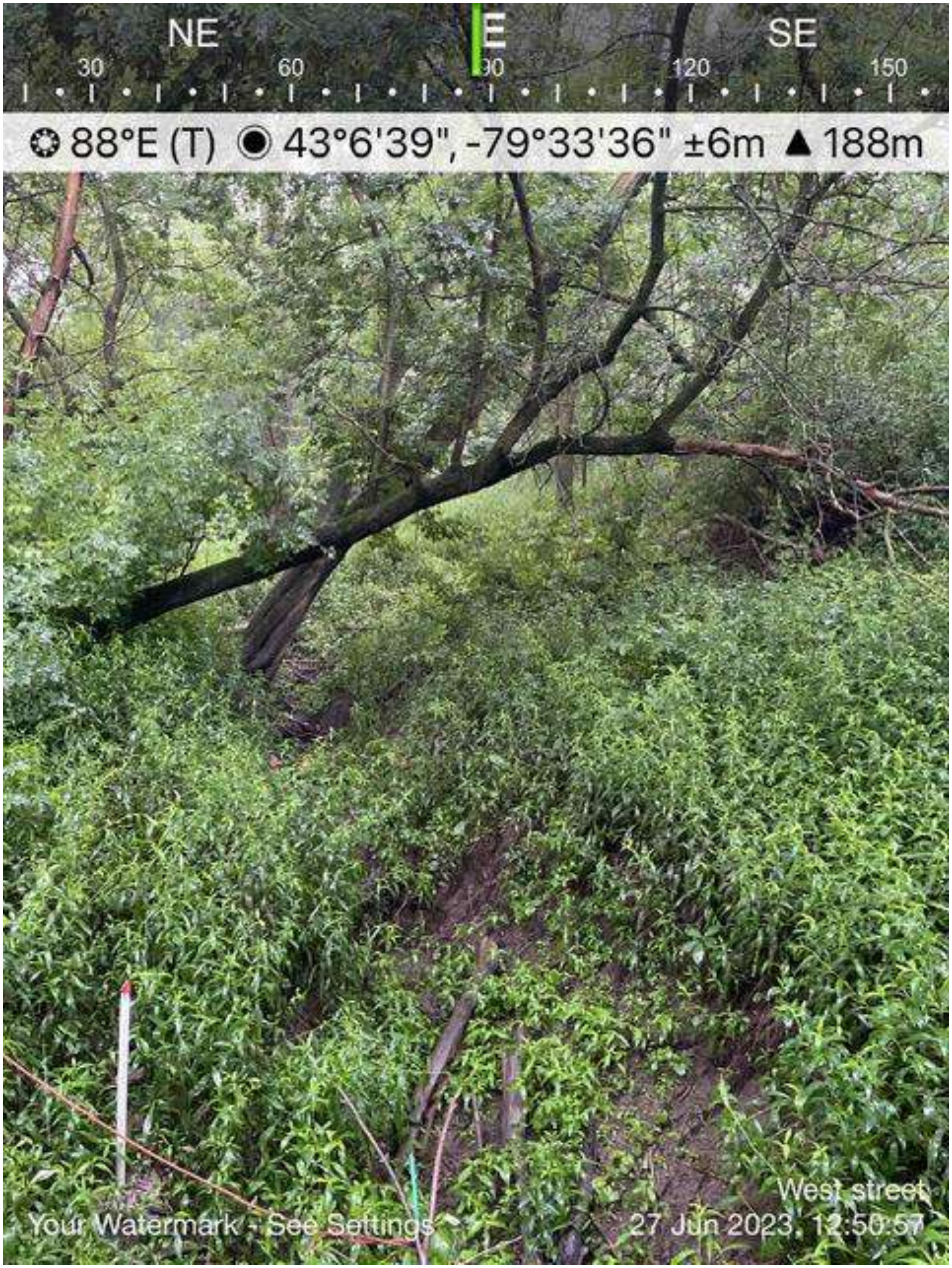
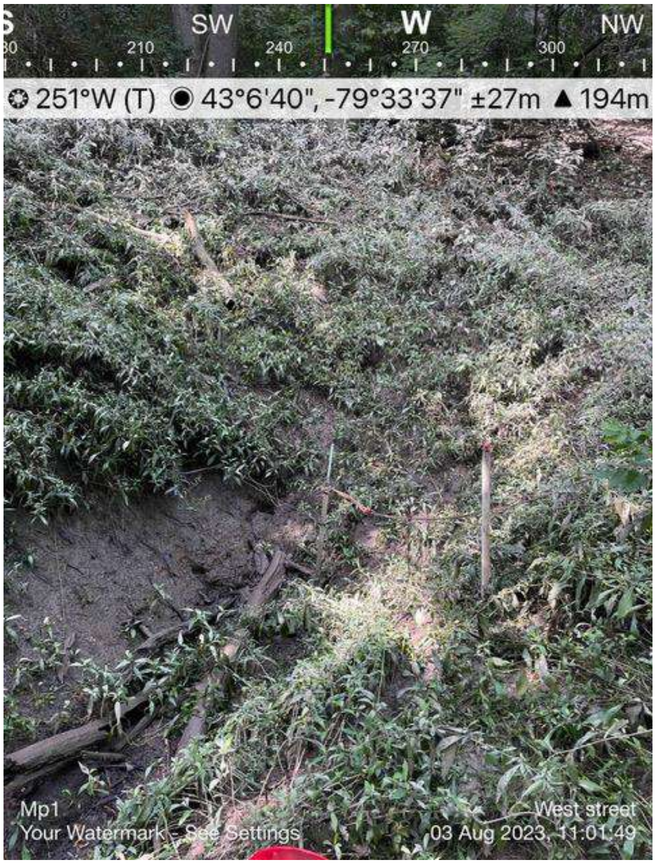

NE E SE
30 60 90 120
76°E (T) 43°6'40", -79°33'36" ±4m ▲189m
Sg1
Your Watermark - See Settings
West street
15 Jun 2023, 11:48:45

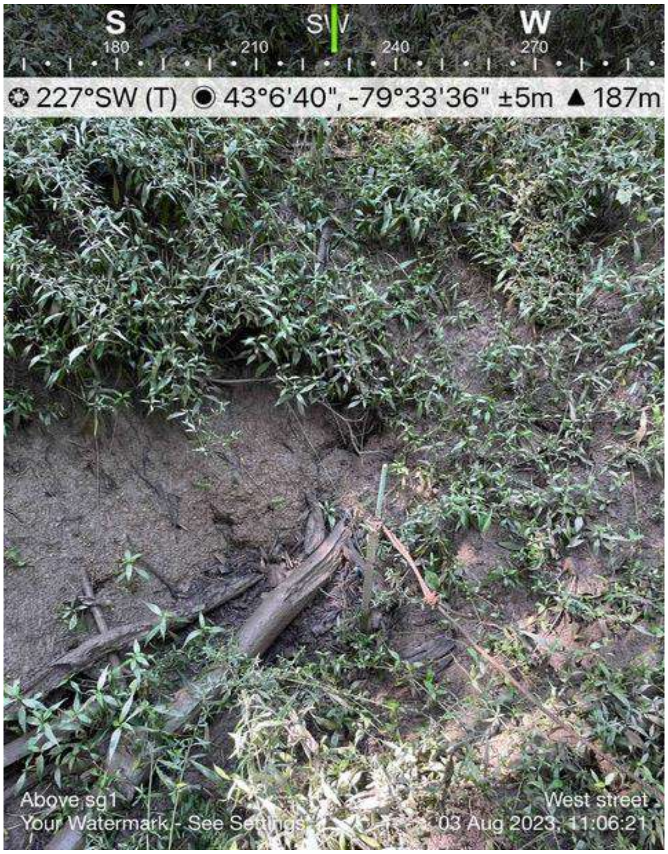
June 27 2023

Area not safe for entry due to rain conditions



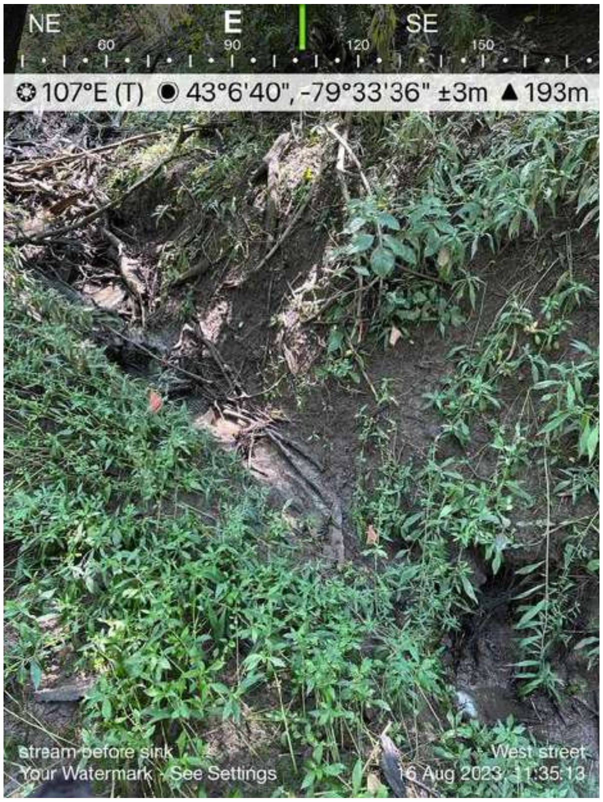
August 3 2023



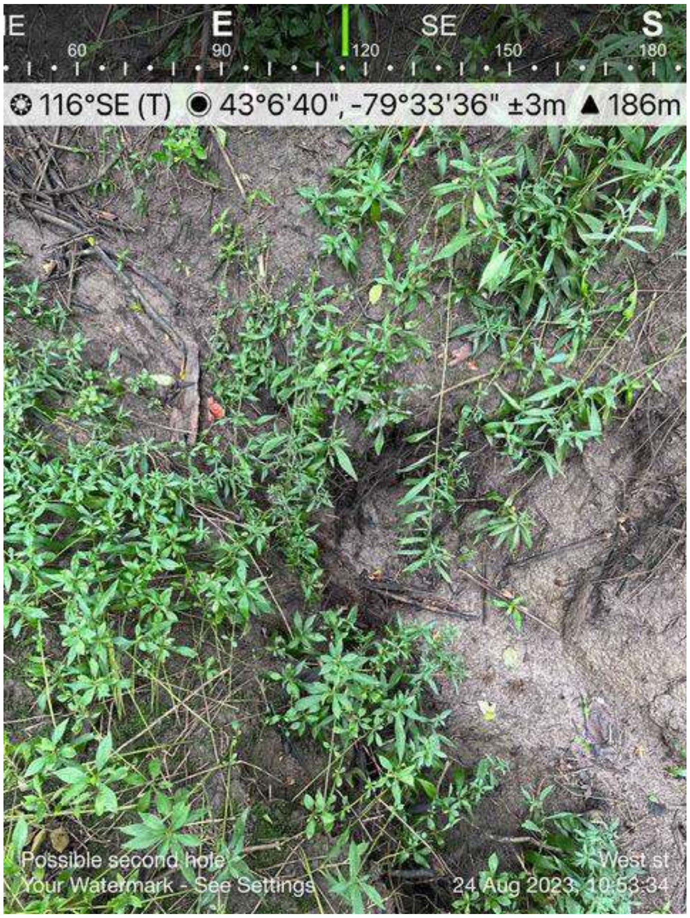


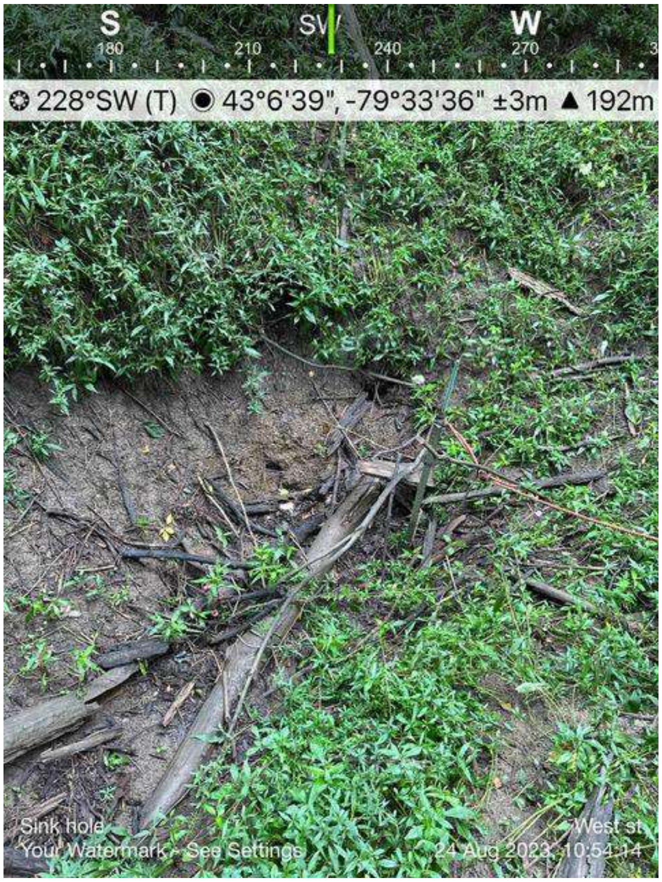
August 26 2023 – post rain event

Previous days rain – 38mm

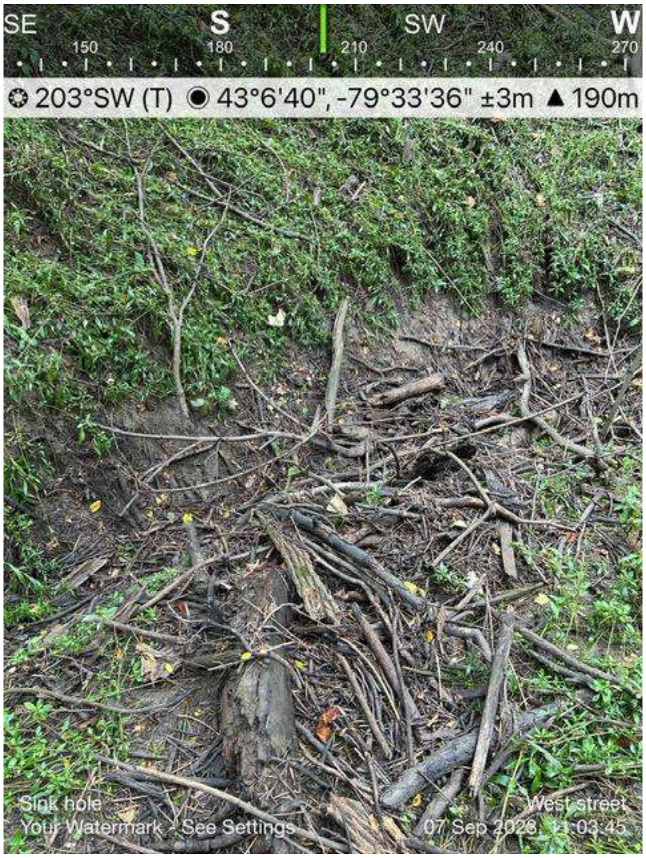


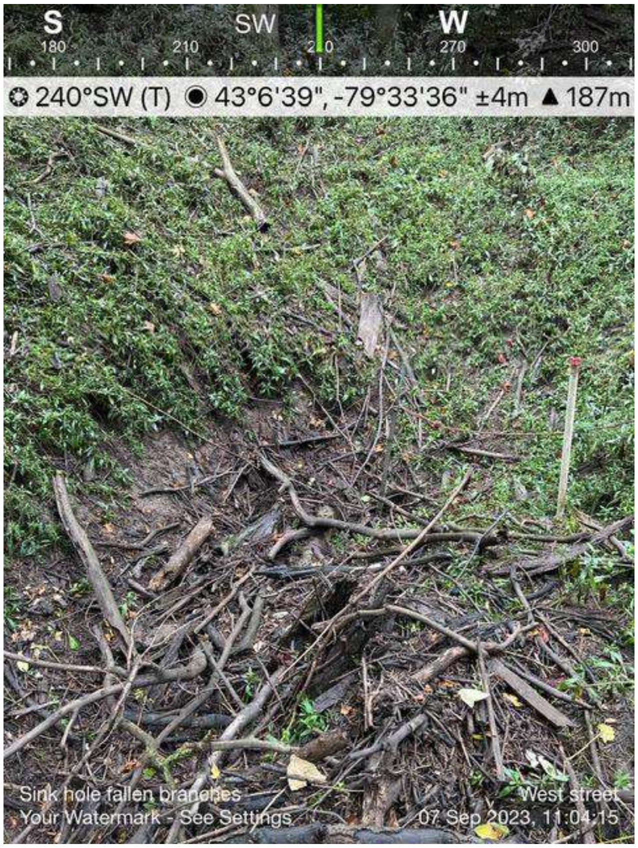
Aug 24 2023 Rain Event

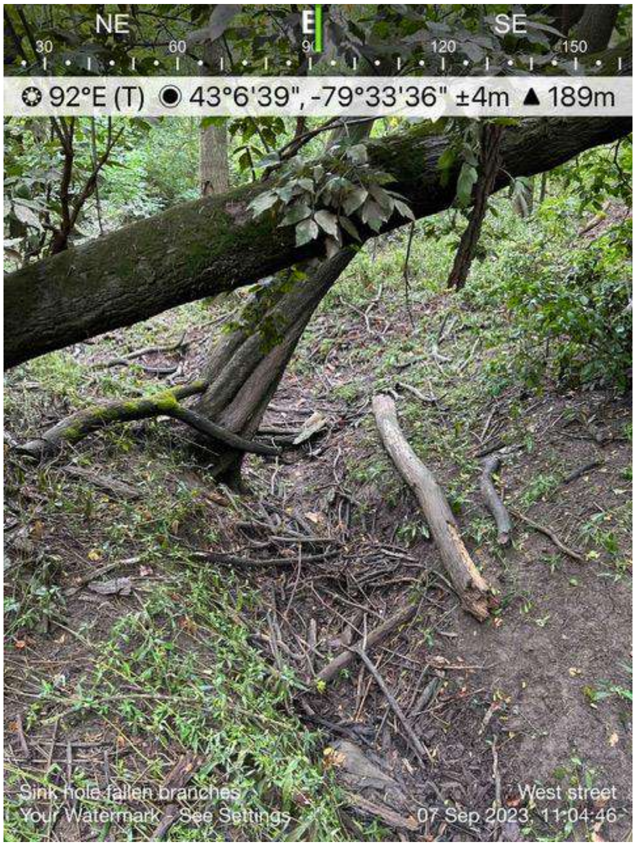


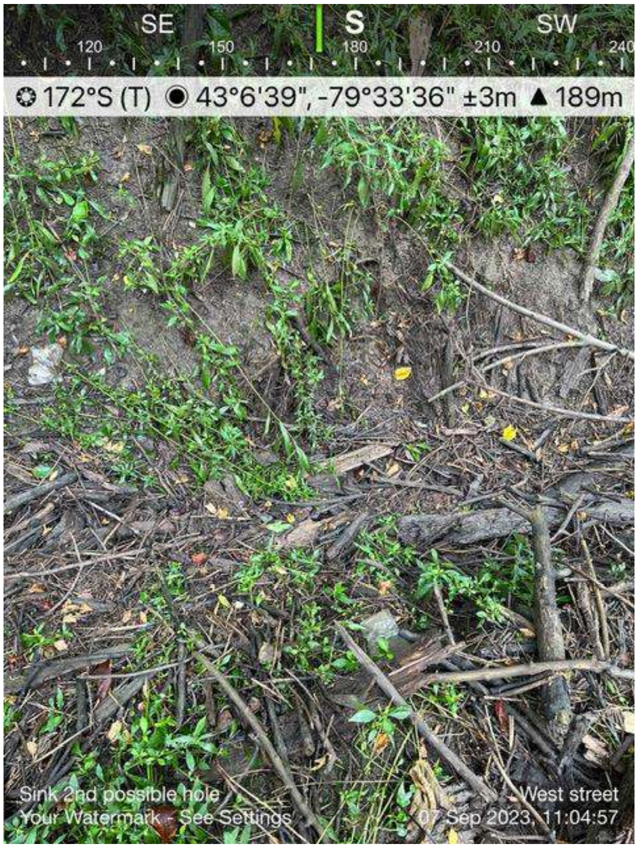


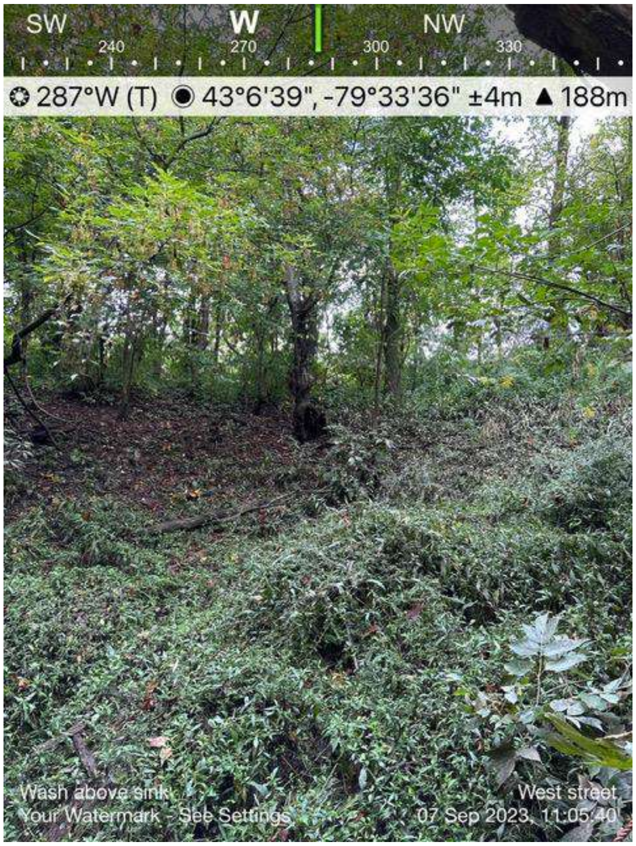
September 7, 2023

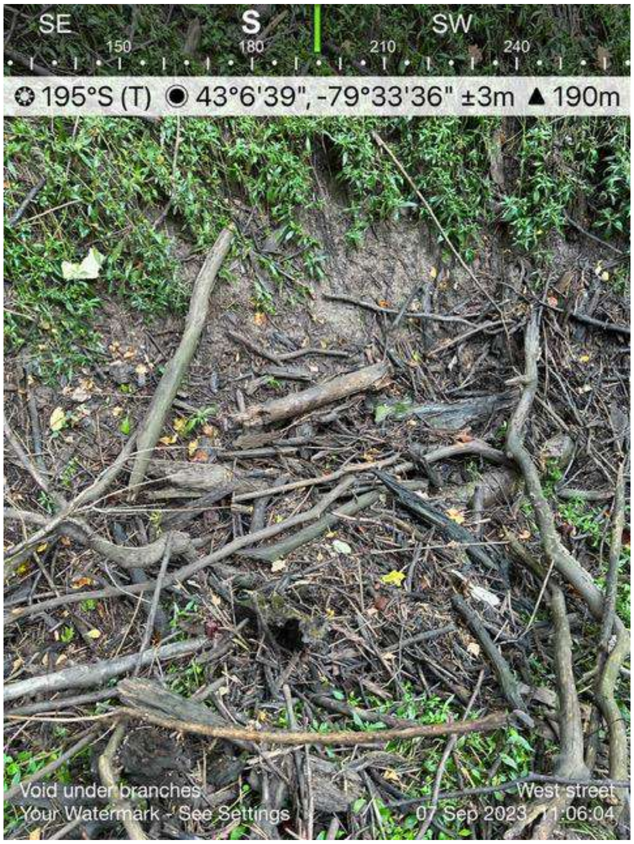


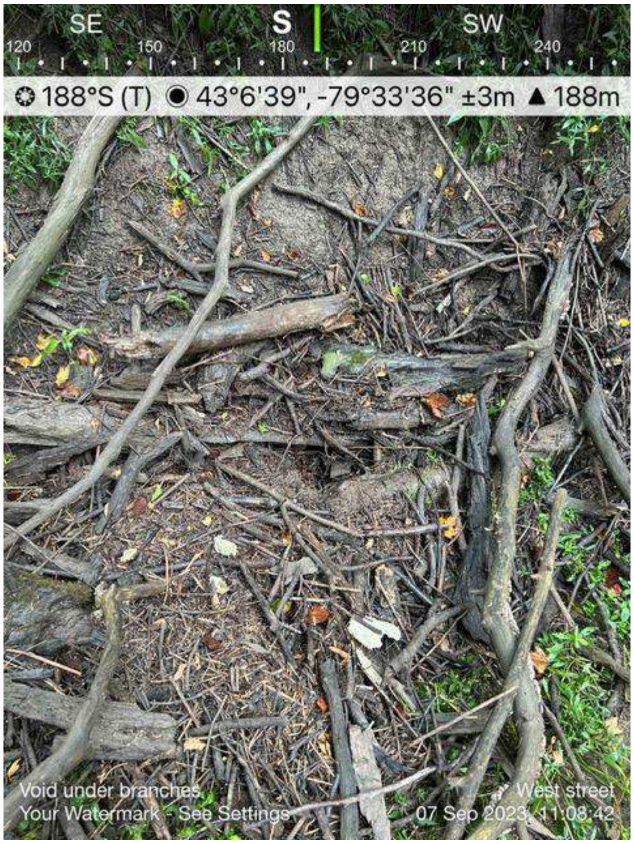






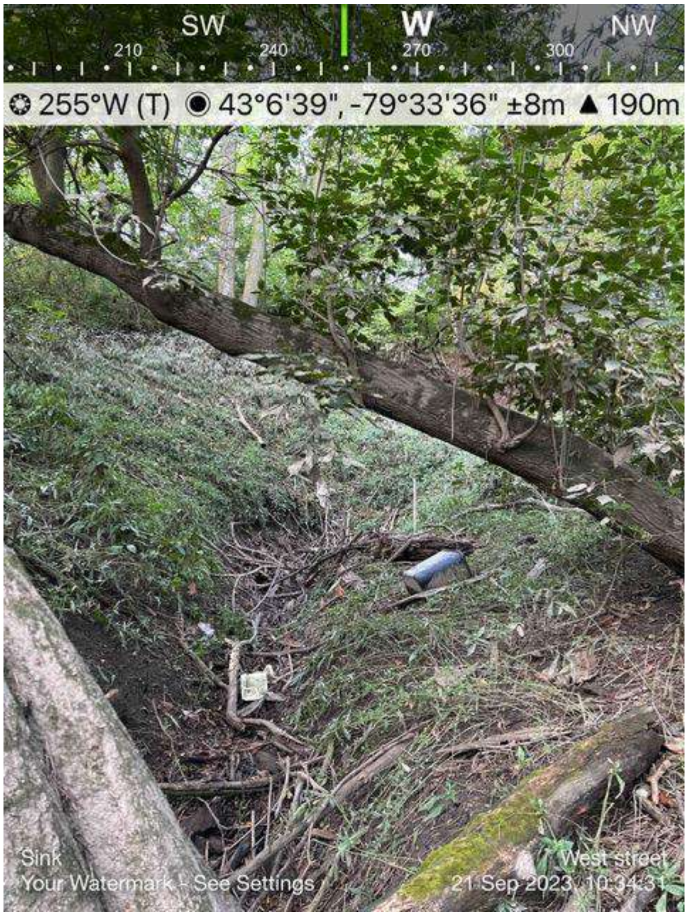

SW W NW
240 270 300 330
287°W (T) 43°6'39", -79°33'36" ±4m 188m
Wash above sink
Your Watermark - See Settings
West street
07 Sep 2023, 11:05:40

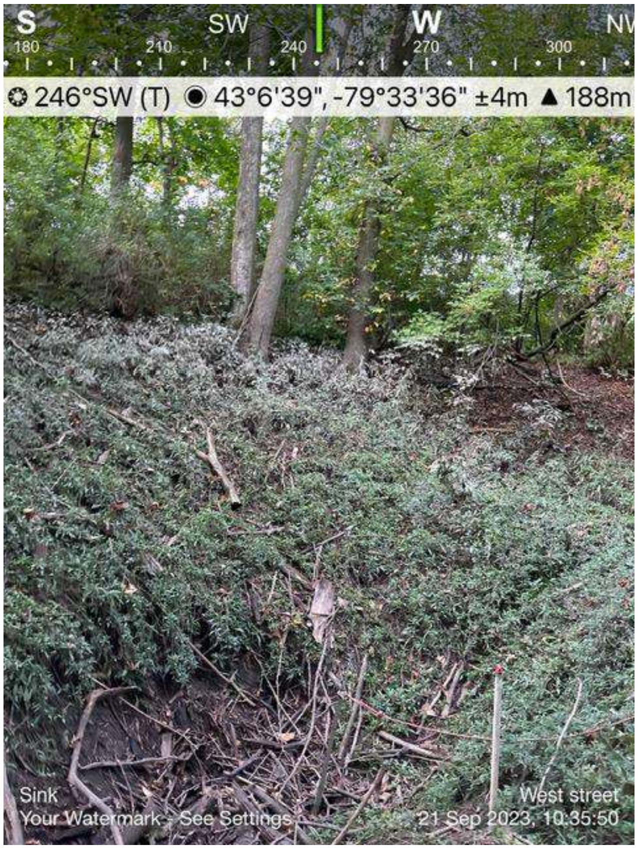

SE S SW
150 180 210 240
195°S (T) 43°6'39", -79°33'36" ±3m 190m
Void under branches
Your Watermark - See Settings
West street
07 Sep 2023, 11:06:04

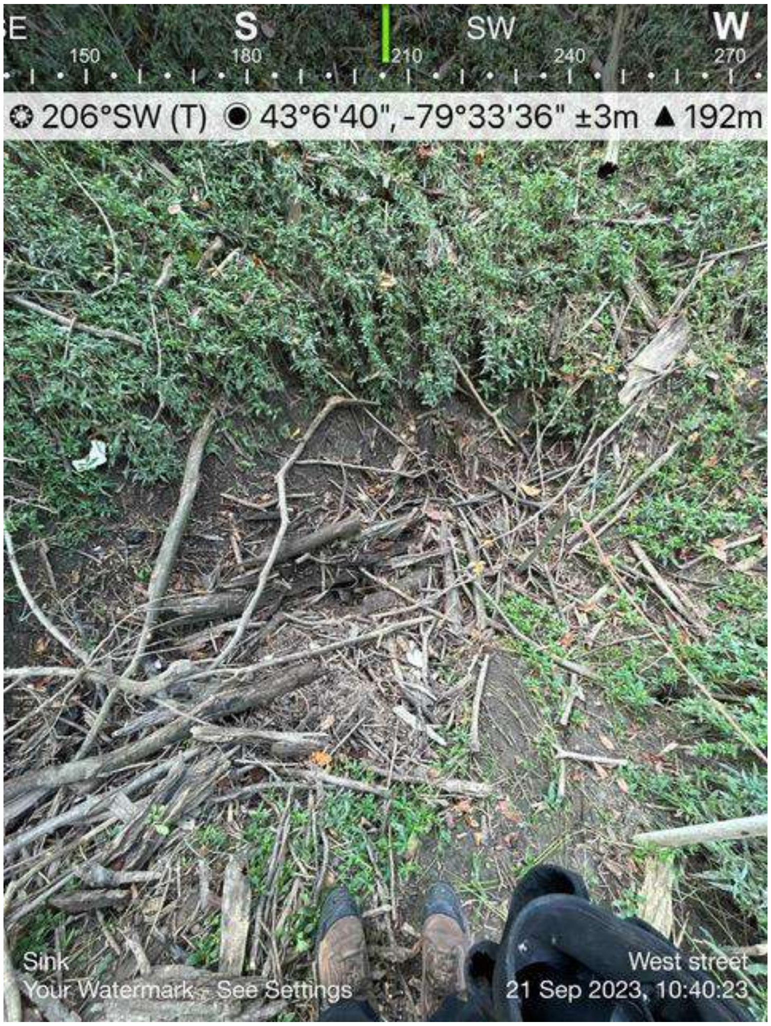

SE S SW
120 150 180 210 240
188°S (T) 43°6'39", -79°33'36" ±3m 188m
Void under branches
Your Watermark - See Settings
West street
07 Sep 2023, 11:08:42

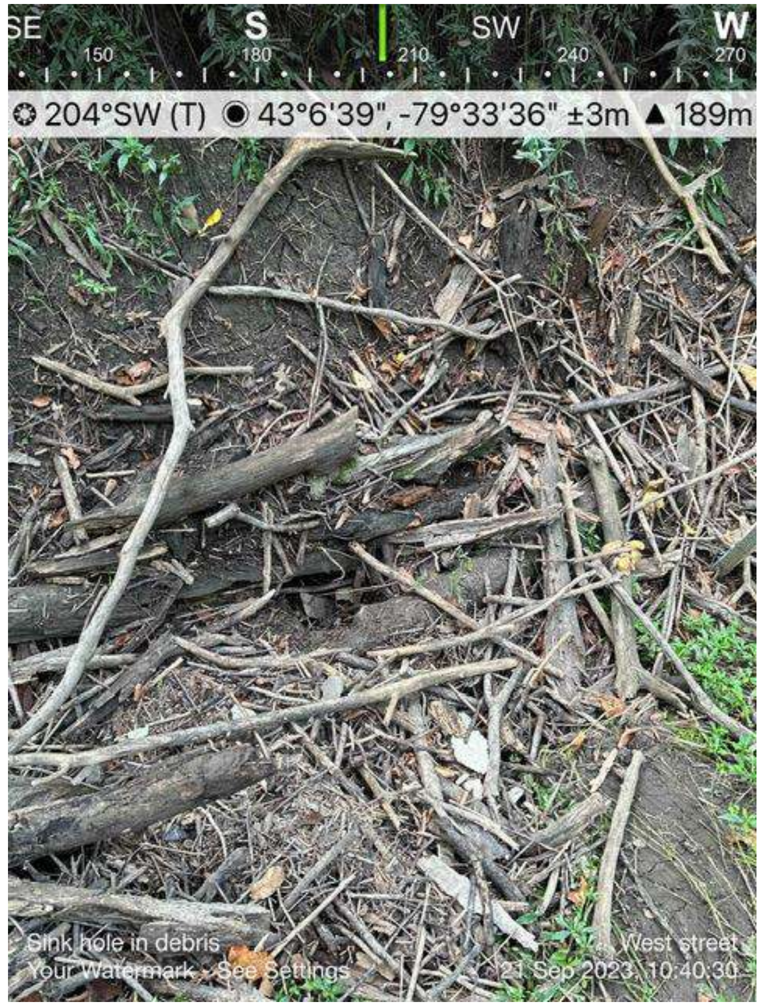

S SW W
180 210 240 270
223°SW (T) 43°6'39", -79°33'36" ±3m 187m
Void under branches
Your Watermark - See Settings
West street
07 Sep 2023, 11:13:01

September 21 2023

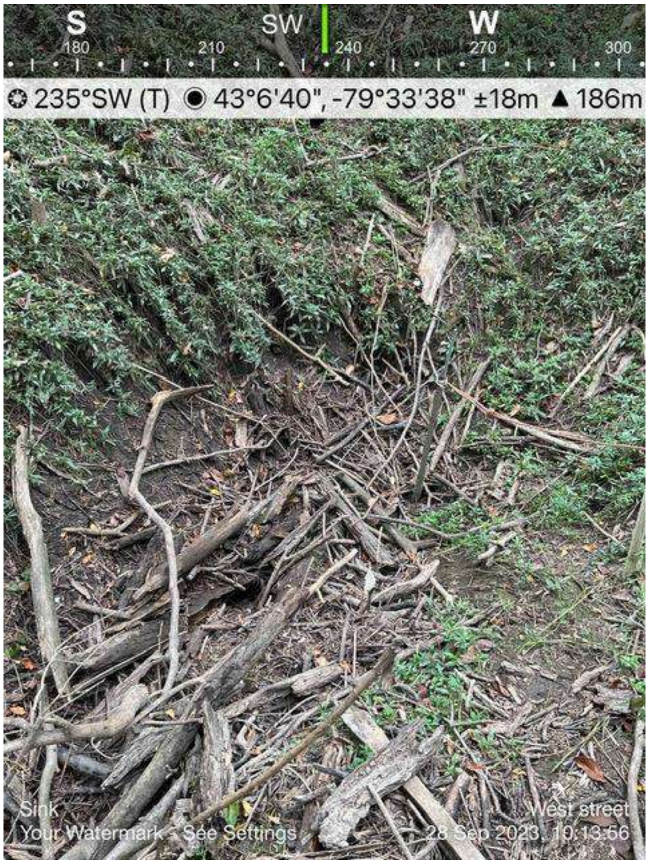





SE
S
SW
W
150
180
210
240
270
206°SW (T) 43°6'40", -79°33'36" ±3m 192m
Sink
Your Watermark - See Settings
West street
21 Sep 2023, 10:40:23


SE
S
SW
W
150
180
210
240
270
204°SW (T) 43°6'39", -79°33'36" ±3m 189m
Sink hole in debris
Your Watermark - See Settings
West street
21 Sep 2023, 10:40:30

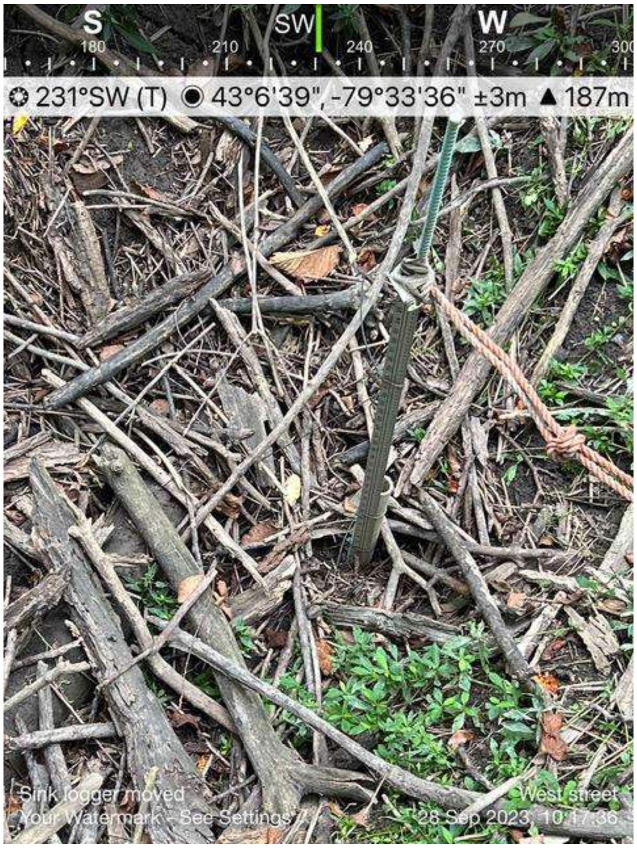
Sept 28 2023


S
SW
W
180
210
240
270
300
235°SW (T) 43°6'40", -79°33'38" ±18m ▲ 186m
Sink
Your Watermark - See Settings
West street
28 Sep 2023, 10:13:56


S
SW
W
180
210
240
270
300
248°W (T) 43°6'39", -79°33'36" ±4m ▲ 188m
Sink
Your Watermark - See Settings
West street
28 Sep 2023, 10:14:10


S
SW
W
180
210
240
270
224°SW (T) 43°6'39", -79°33'36" ±4m ▲ 189m
Sink
Your Watermark - See Settings
West street
28 Sep 2023, 10:14:35

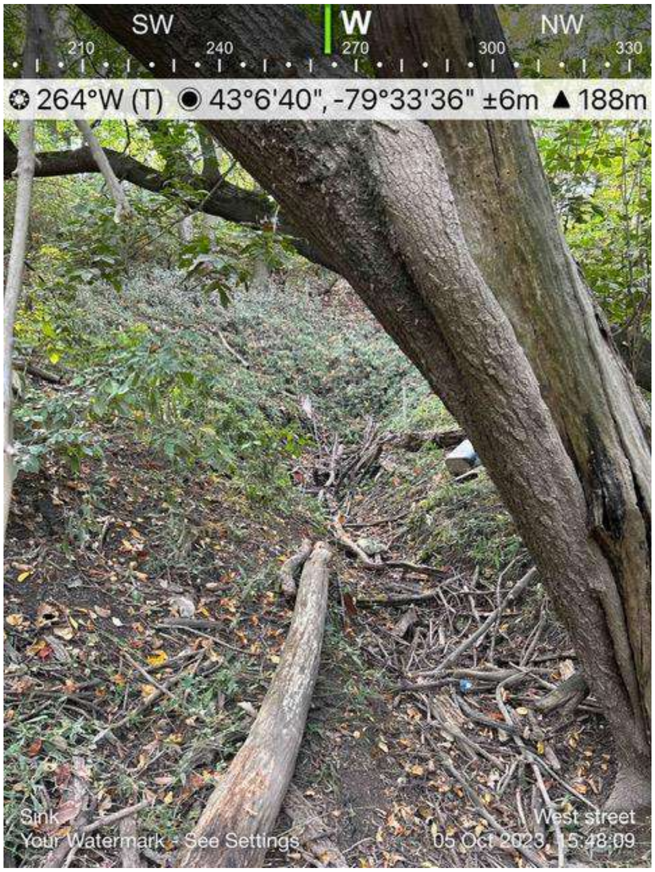

SW
W
NW
240
270
300
330
283°W (T) 43°6'39", -79°33'36" ±3m ▲ 189m
Sink
Your Watermark - See Settings
West street
28 Sep 2023, 10:14:28

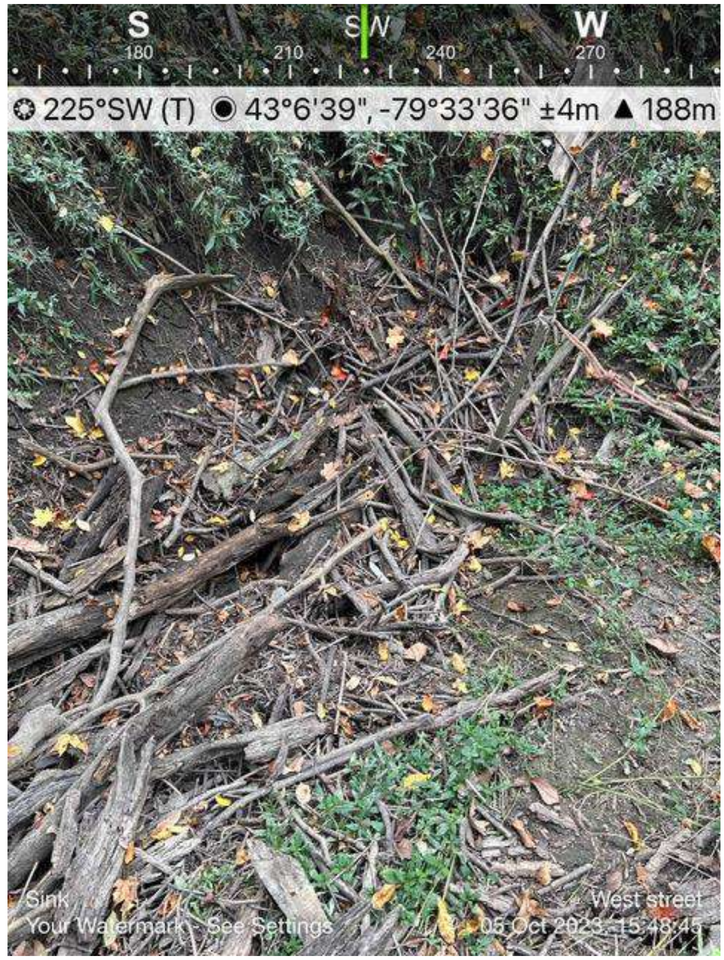

S SW W
180 210 240 270 300
231°SW (T) 43°6'39", -79°33'36" ±3m 187m
Sink logger moved
Your Watermark - See Settings
West street
28 Sep 2023, 10:17:36

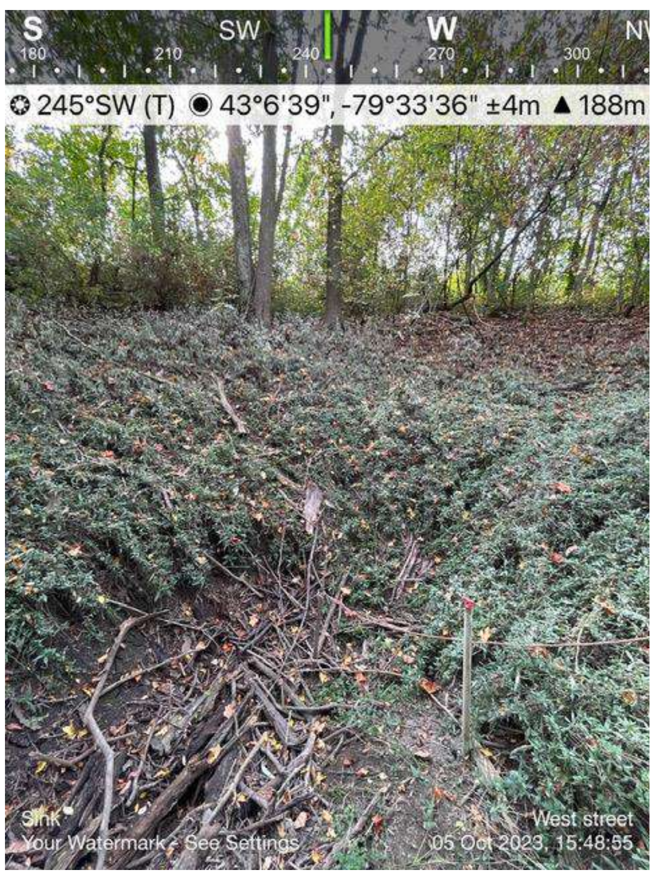

E SE S SW
90 120 150 180 210
158°(null) (T) 43°6'39", -79°33'36" ±4m 188m
Sink, second hole
Your Watermark - See Settings
West street
28 Sep 2023, 10:20:25


NW N NE
300 330 30 60
359°N (T) 43°6'39", -79°33'36" ±3m 188m
Mp construction
Your Watermark - See Settings
West street
28 Sep 2023, 10:21:27

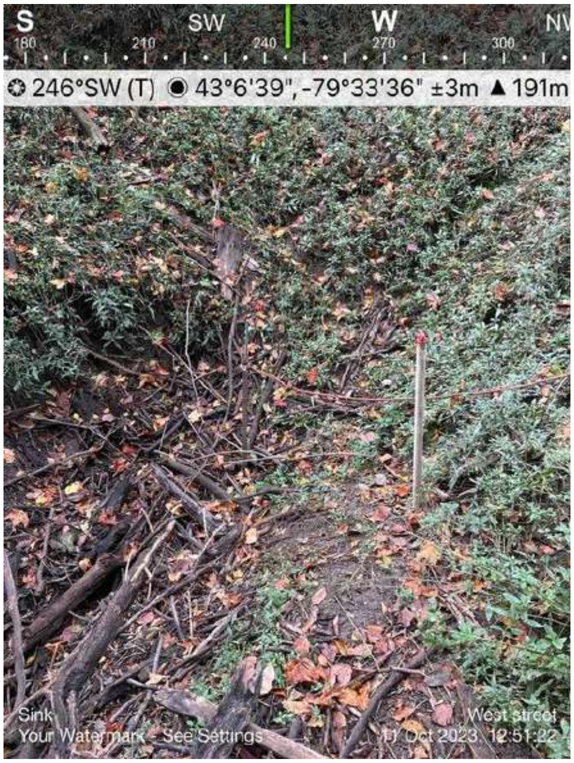
October 5 2023

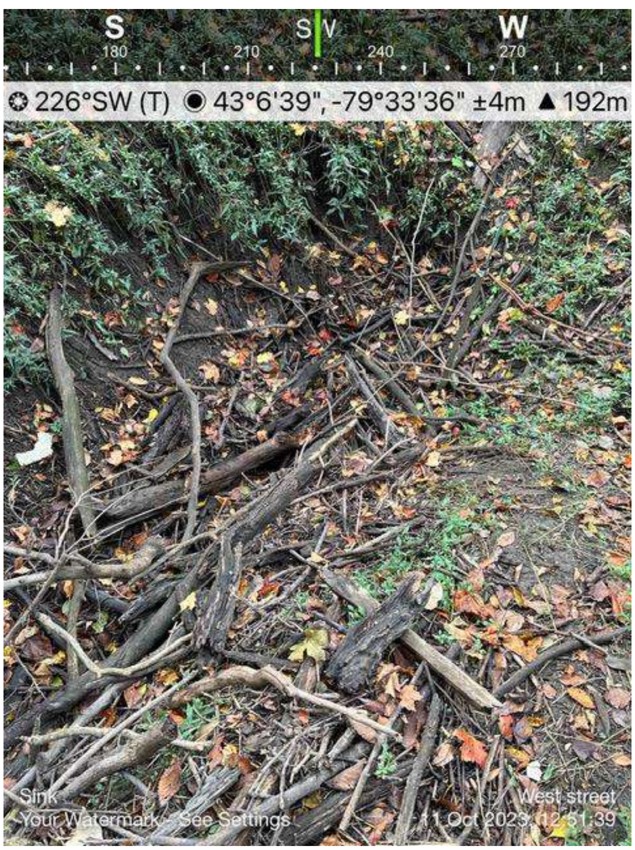


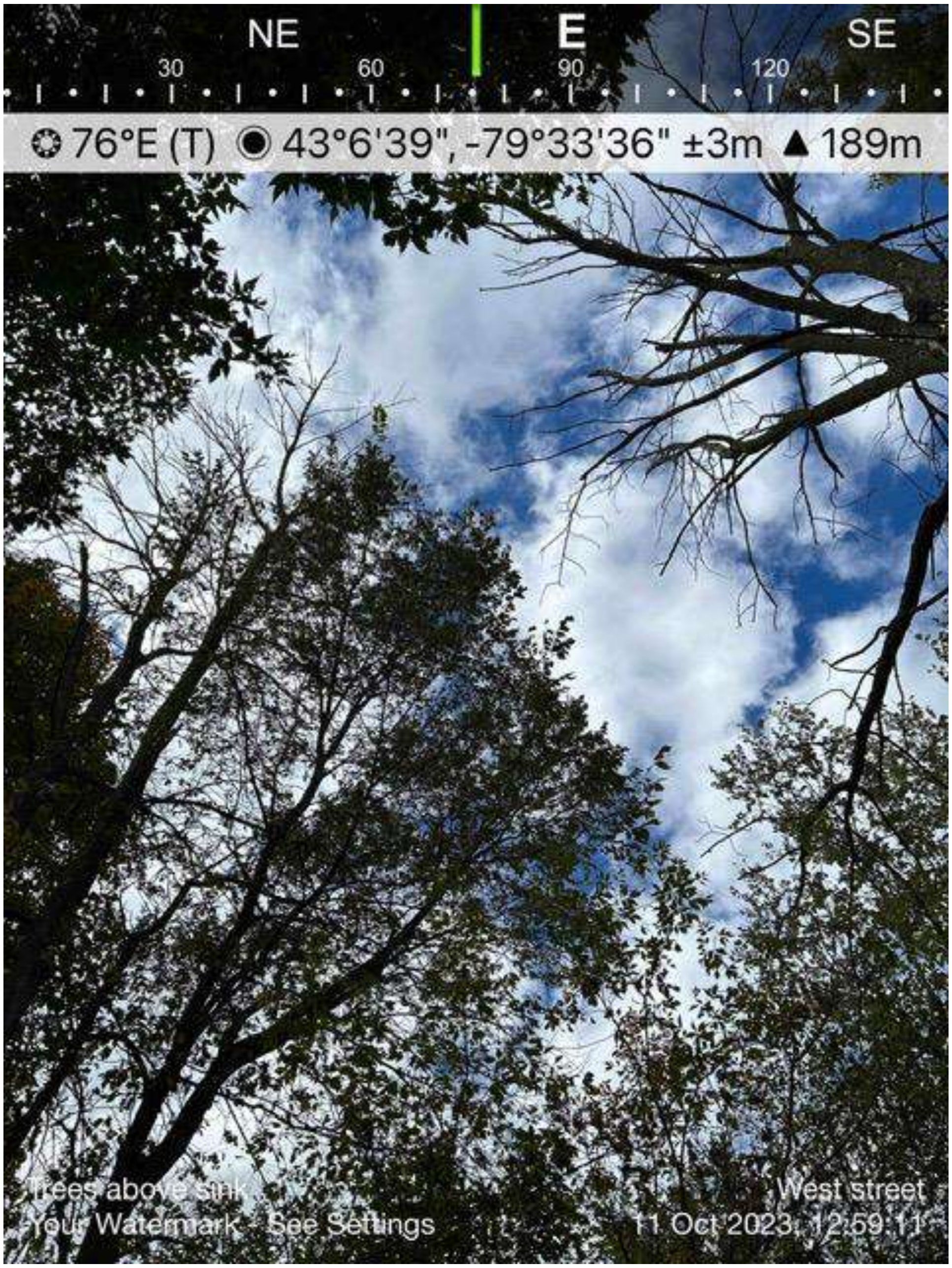




October 11 2023

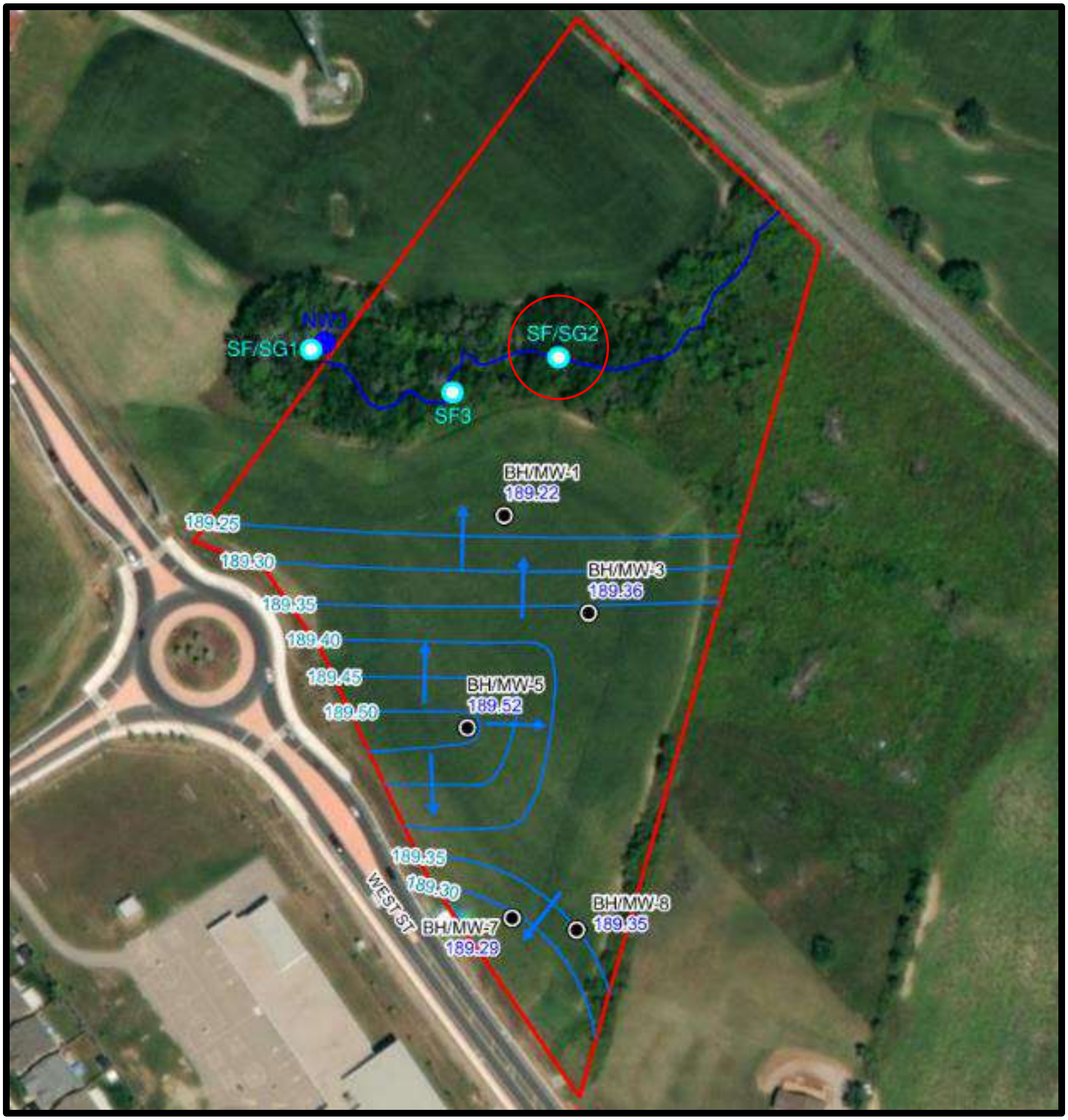





NE
E
SE
30
60
90
120
76°E (T) 43°6'39", -79°33'36" ±3m 189m
Trees above sink
Your Watermark - See Settings
West street
11 Oct 2023, 12:59:11

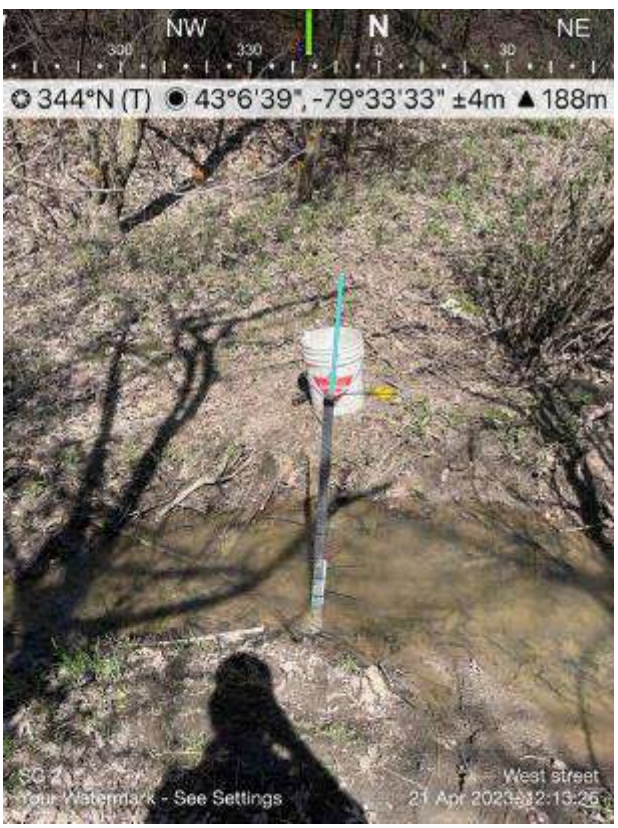
SF/SG 2 Location (upstream)
West Street – Smithville
April 21, 2023

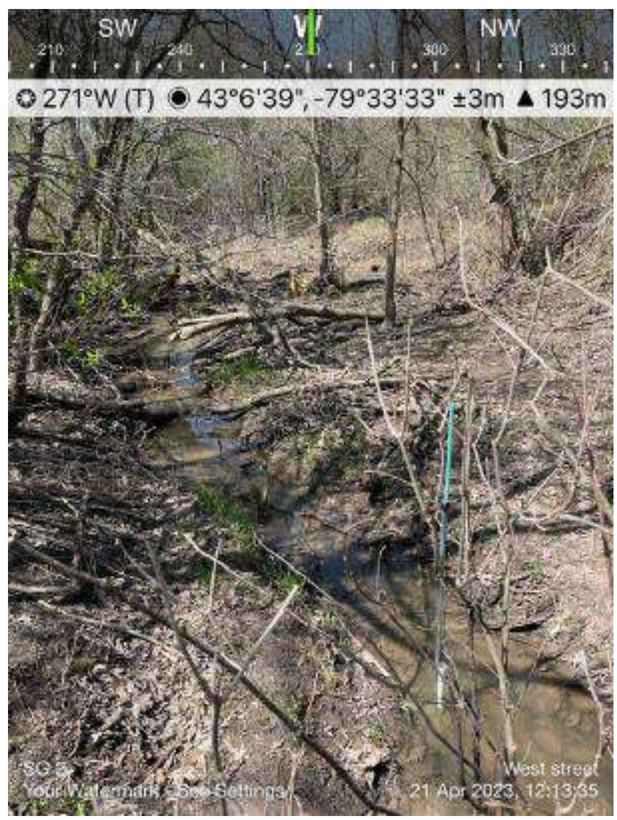
MP SG installation
MP2 – 189.59
SG2 – 189.23

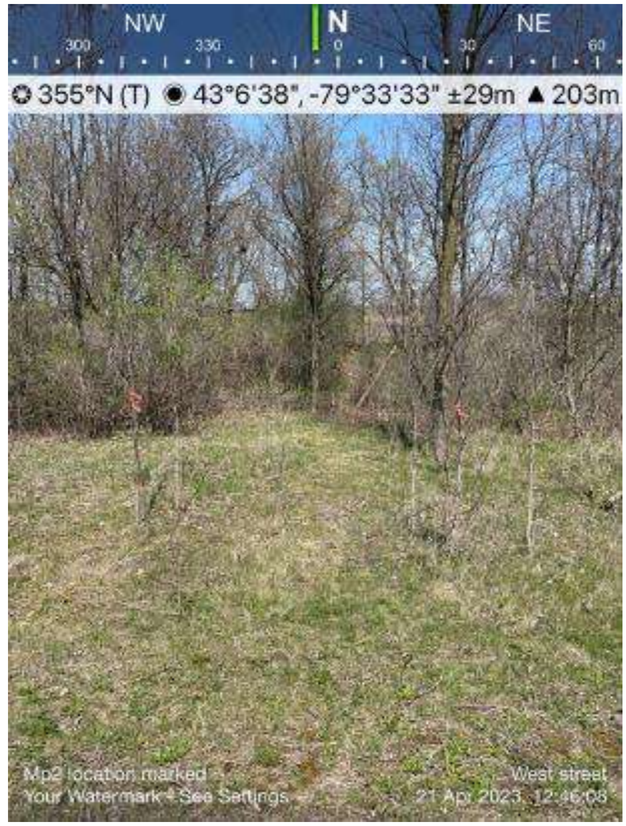



NW N NE
340°N (T) 43°6'39", -79°33'33" ±8m ▲192m
SG 2
Your Watermark - See Settings
West street
21 Apr 2023, 11:33:38

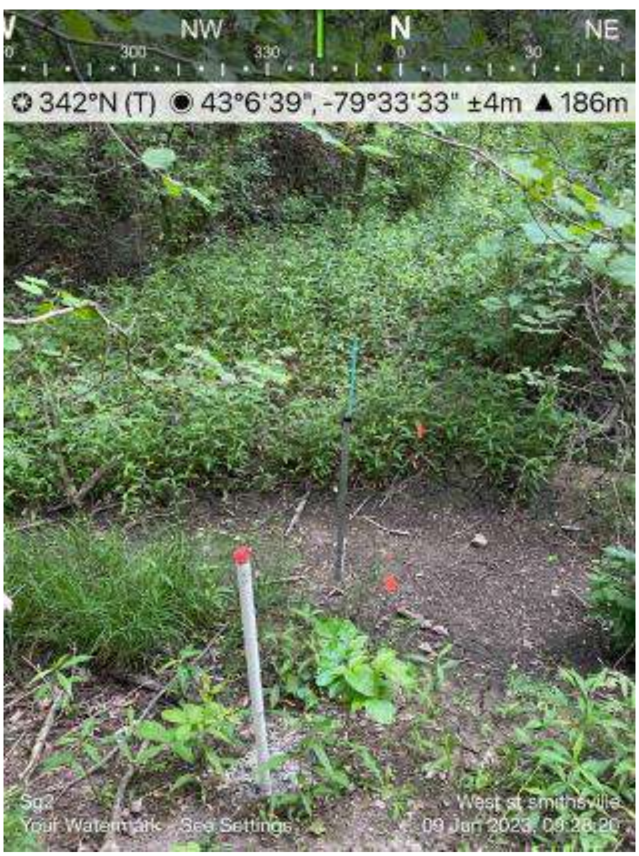

NE E SE
83°E (T) 43°6'39", -79°33'33" ±4m ▲189m
SG 2
Your Watermark - See Settings
West street
21 Apr 2023, 12:13:16

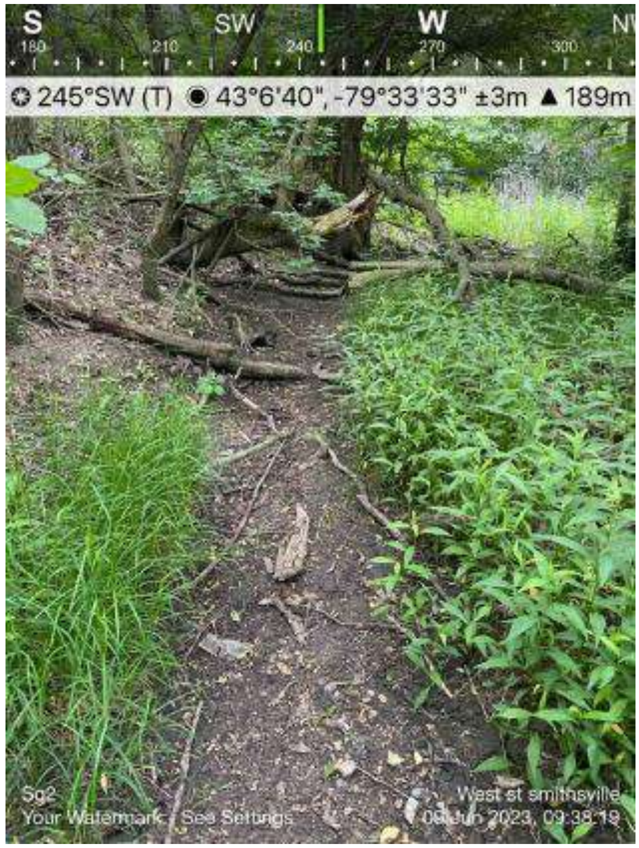

NW N NE
344°N (T) 43°6'39", -79°33'33" ±4m ▲188m
SG 2
Your Watermark - See Settings
West street
21 Apr 2023, 12:13:26

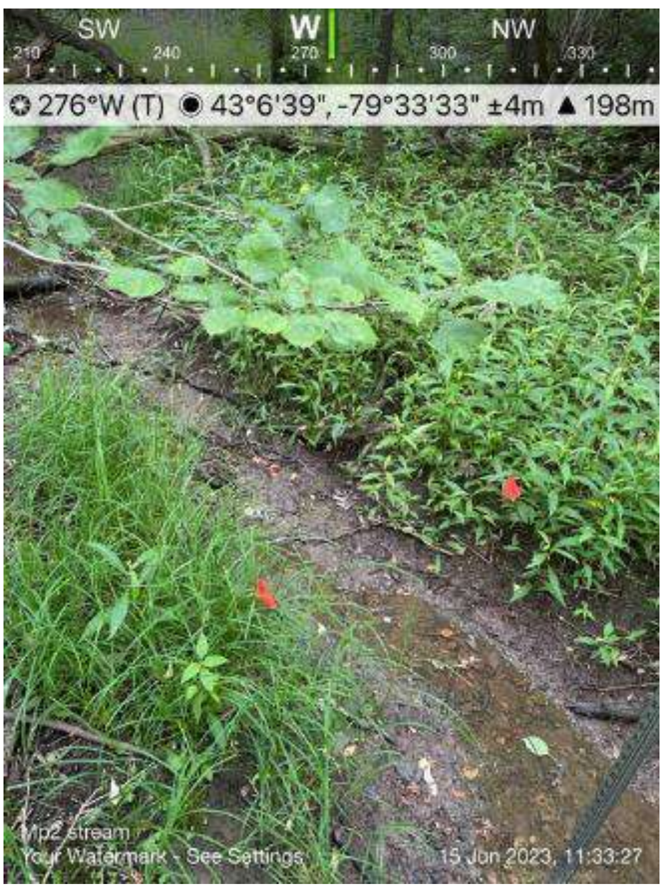

SW W NW
271°W (T) 43°6'39", -79°33'33" ±3m ▲193m
SG 2
Your Watermark - See Settings
West street
21 Apr 2023, 12:13:35



June 9 2023 – Rain event




S
SW
W
NW
180
210
240
270
300
245°SW (T) 43°6'40", -79°33'33" ±3m ▲ 189m
Sg2
Your Watermark - See Settings
West st smithsville
09 Jun 2023, 09:38:19

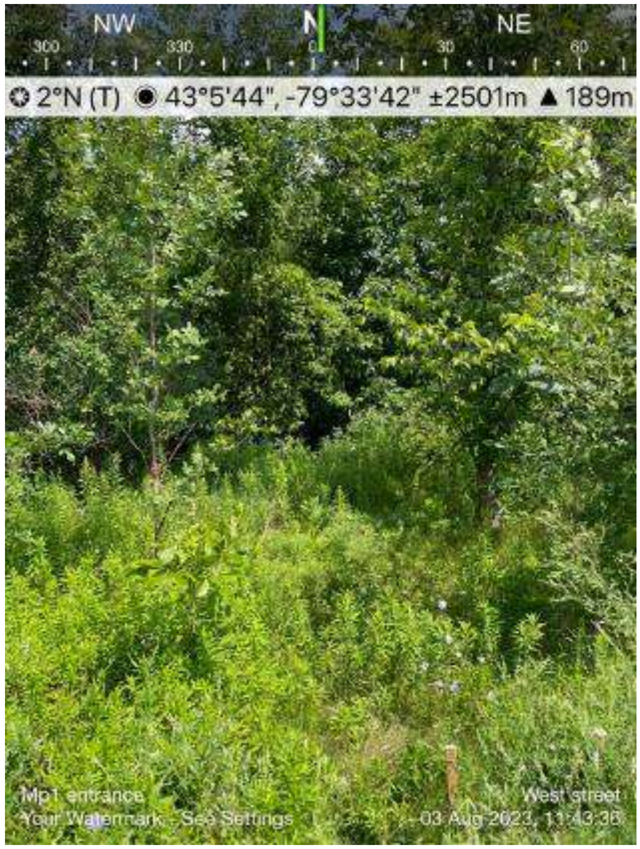

SW
W
NW
210
240
270
300
330
276°W (T) 43°6'39", -79°33'33" ±4m ▲ 198m
Mp2 stream
Your Watermark - See Settings
15 Jun 2023, 11:33:27

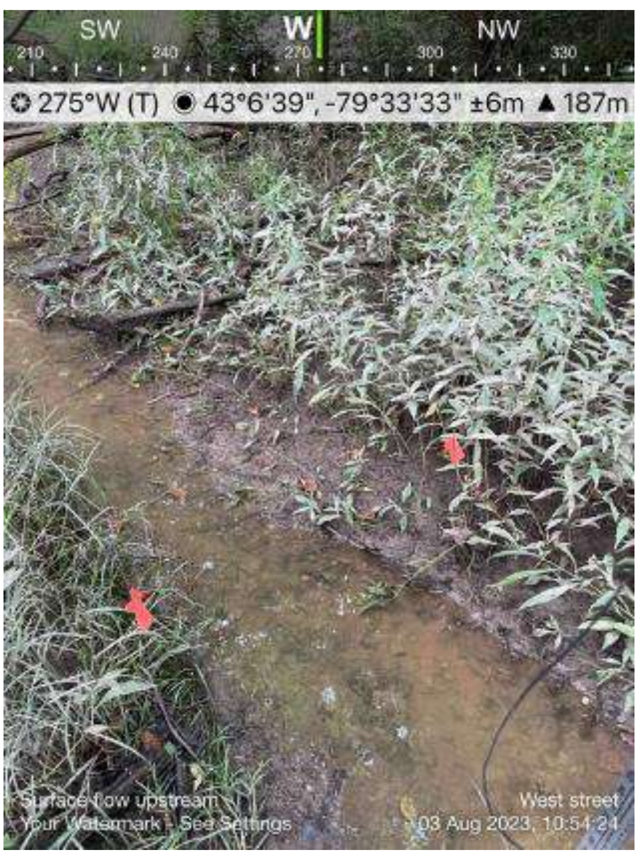

W
NW
N
270
300
330
0
30
335°NW (T) 43°6'40", -79°33'33" ±21m ▲ 0m
Mp2
Your Watermark - See Settings
West street
15 Jun 2023, 11:32:44

June 27 2023

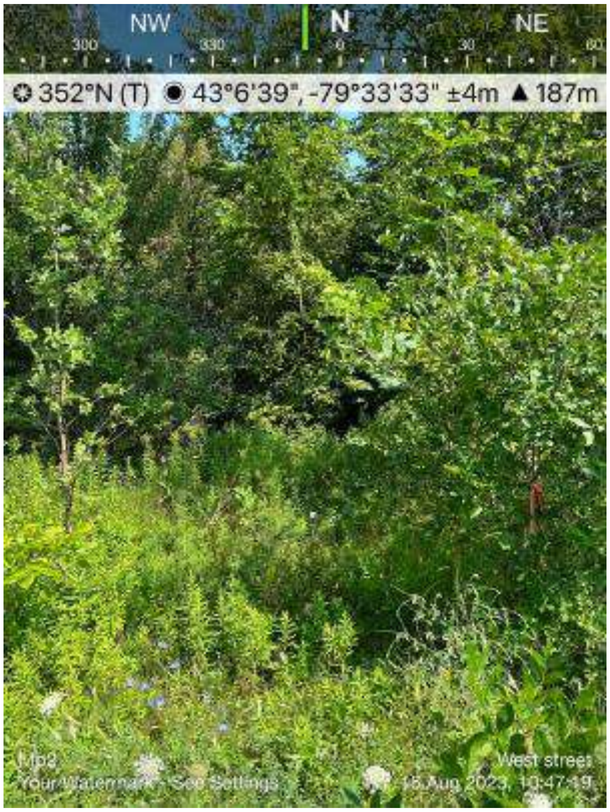

W
NW
N
270
300
0
30
331°NW (T) 43°6'39", -79°33'33" ±27m ▲186m
Your Watermark - See Settings
27 Jun 2023, 13:21:25

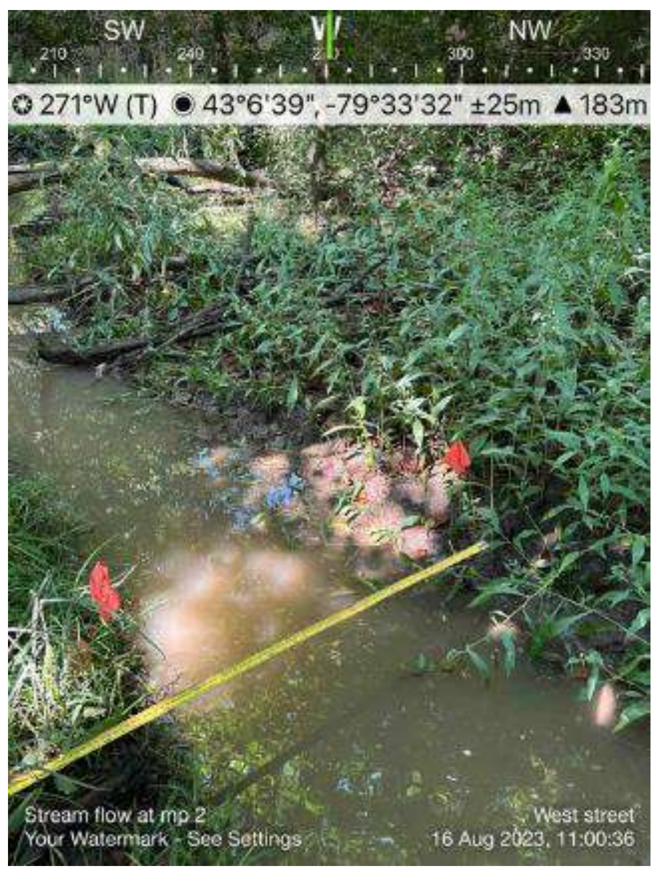
August 3 2023



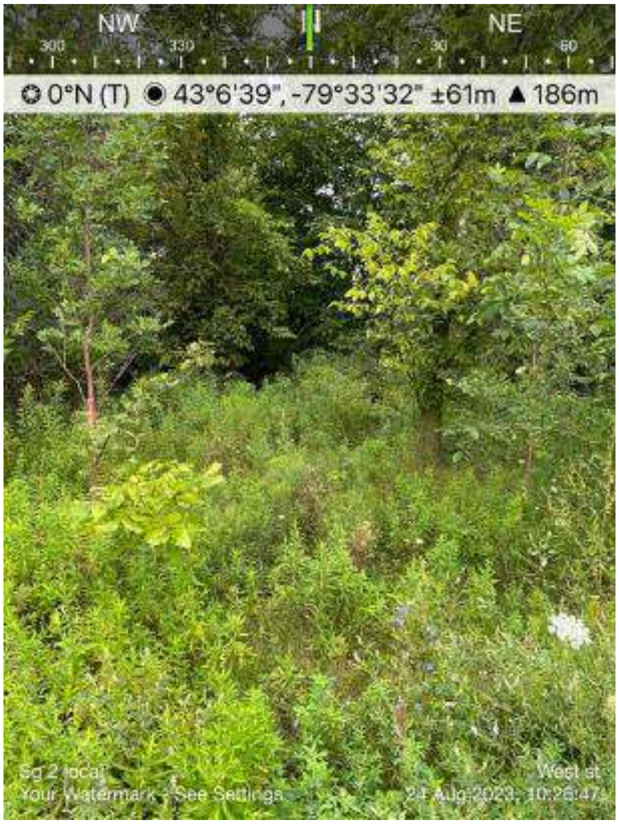


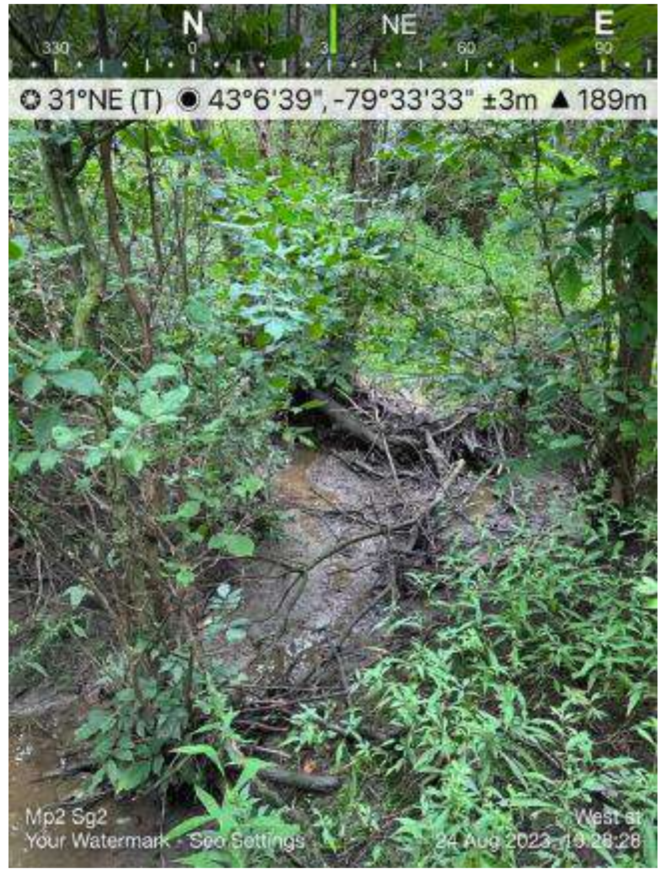
August 16 2023 – Post rain 38mm

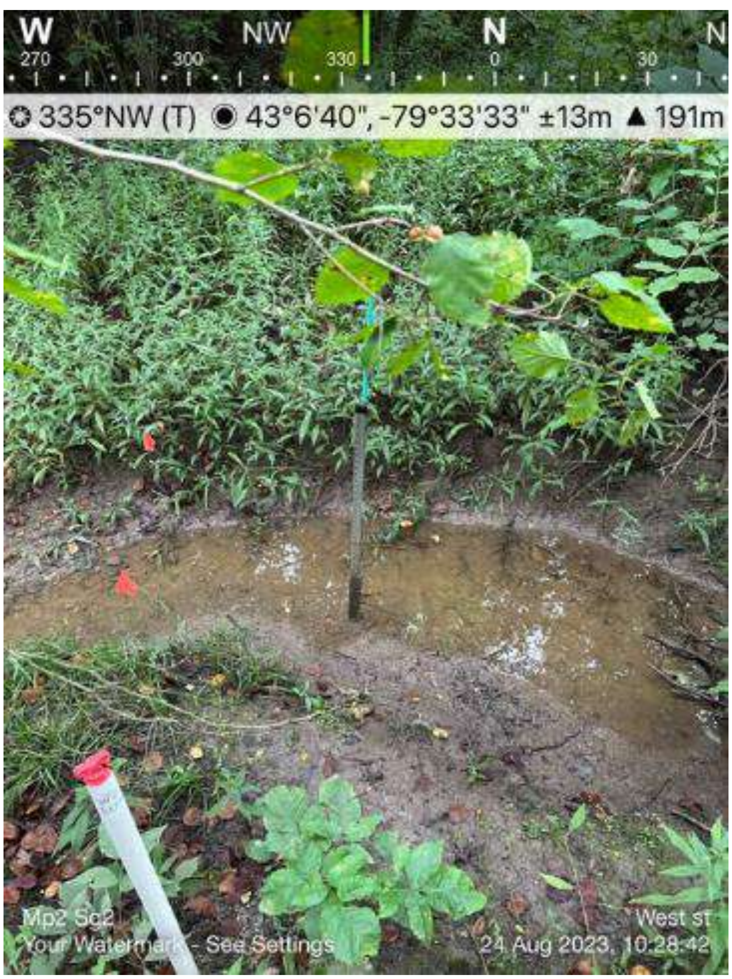




Aug 24 2023 – Rain Event








SW
W
NW
210
240
270
300
330
267°W (T) 43°6'39", -79°33'33" ±4m ▲ 194m
Mp2 Sg2
Your Watermark - See Settings
West st
24 Aug 2023, 10:28:48

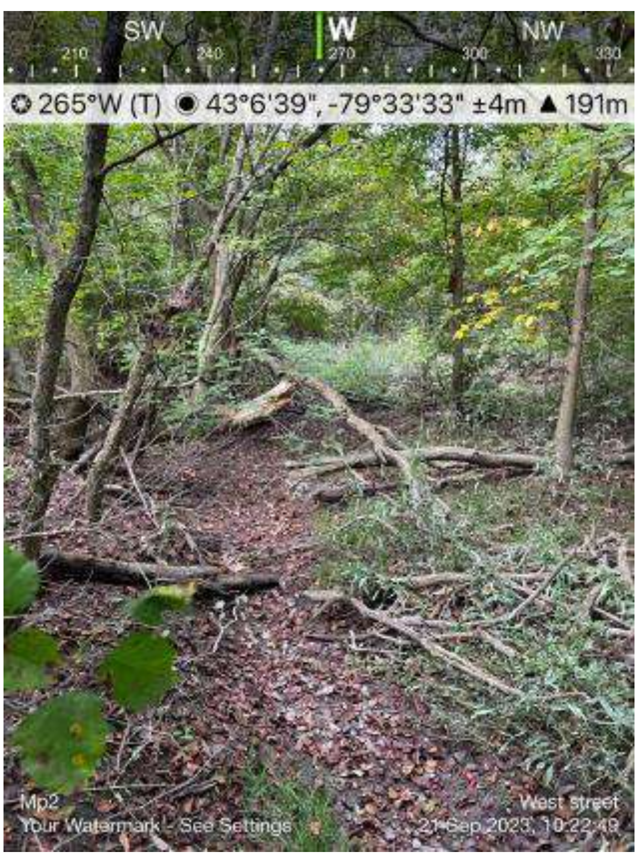

SW
W
NW
N
240
270
300
330
0
294°NW (T) 43°6'39", -79°33'33" ±4m ▲ 189m
Mp2 Sg2 stream flow
Your Watermark - See Settings
West st
24 Aug 2023, 10:36:51

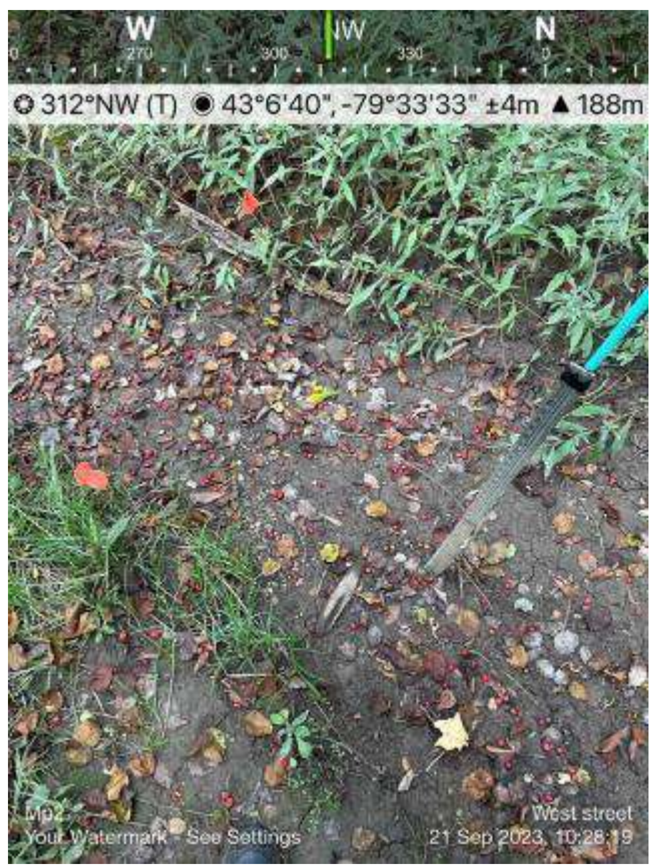
September 7, 2023

Sept 21 2023


NW N NE
345°N (T) 43°6'39", -79°33'33" ±4m ▲ 188m
Mp2
Your Watermark - See Settings
West street
21 Sep 2023, 10:22:18


N E
48°NE (T) 43°6'39", -79°33'33" ±6m ▲ 187m
Mp2
Your Watermark - See Settings
West street


SW W NW
265°W (T) 43°6'39", -79°33'33" ±4m ▲ 191m
Mp2
Your Watermark - See Settings
West street
21 Sep 2023, 10:22:49


W N
312°NW (T) 43°6'40", -79°33'33" ±4m ▲ 188m
Mp2
Your Watermark - See Settings
West street
21 Sep 2023, 10:28:19


SW
W
NW
210
240
270
300
330
266°W (T) 43°6'40", -79°33'33" ±4m 189m
Mp2
Your Watermark - See Settings
West street
21 Sep 2023, 10:28:24

Sept 28 2023

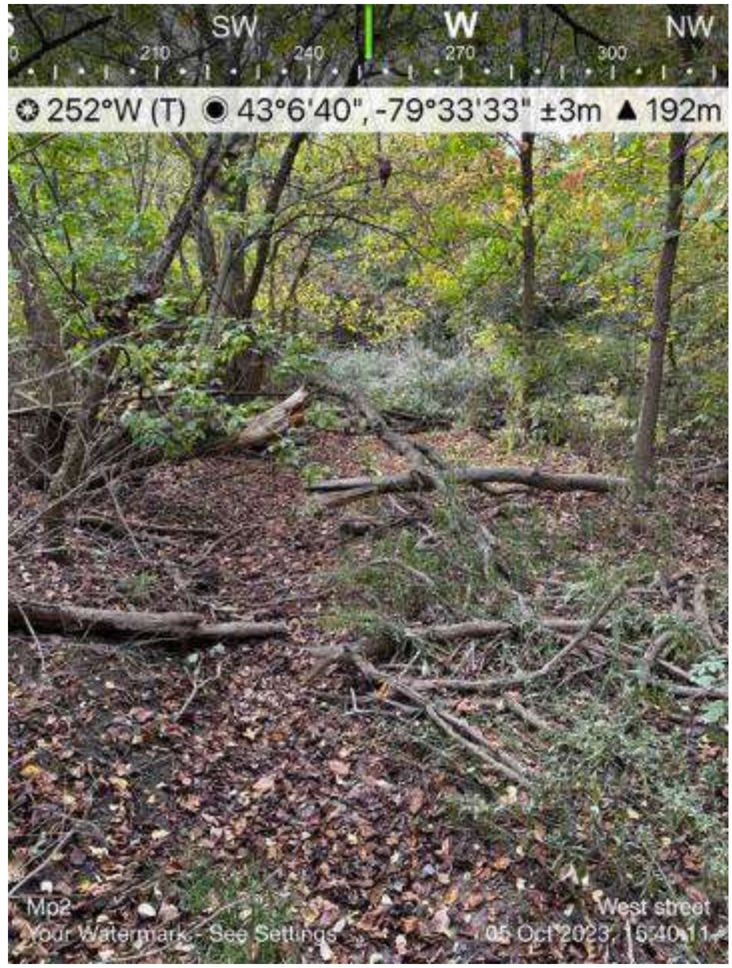

W NW N
240 270 300 330 0
305°NW (T) 43°5'53", -79°32'52" ±1414m ▲ 185m
Mp2
Your Watermark - See Settings
West street
28 Sep 2023, 09:56:10


SW W NW
210 240 270 300 330
270°W (T) 43°6'39", -79°33'33" ±3m ▲ 192m
Mp2
Your Watermark - See Settings
West street
28 Sep 2023, 09:56:24

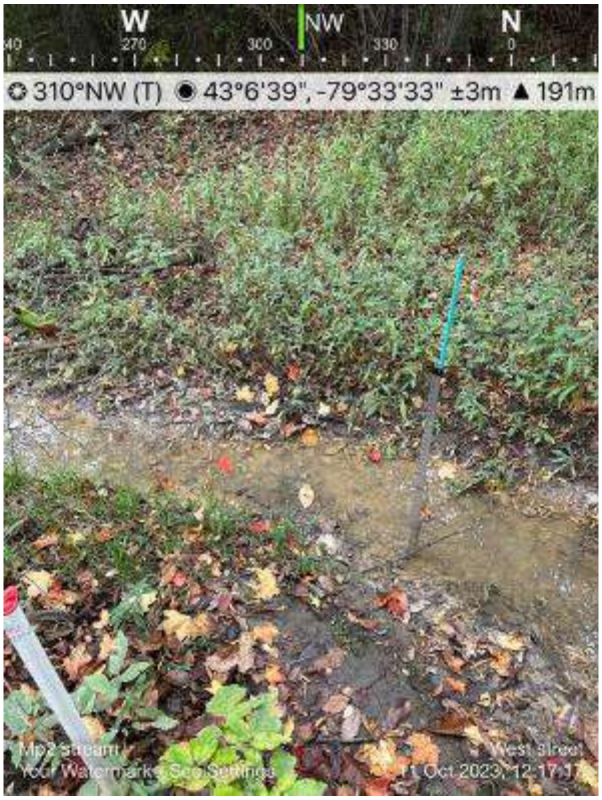

NW N NE
300 330 0 30 60
353°N (T) 43°6'39", -79°33'33" ±4m ▲ 193m
Mp2
Your Watermark - See Settings
West street
28 Sep 2023, 09:56:29

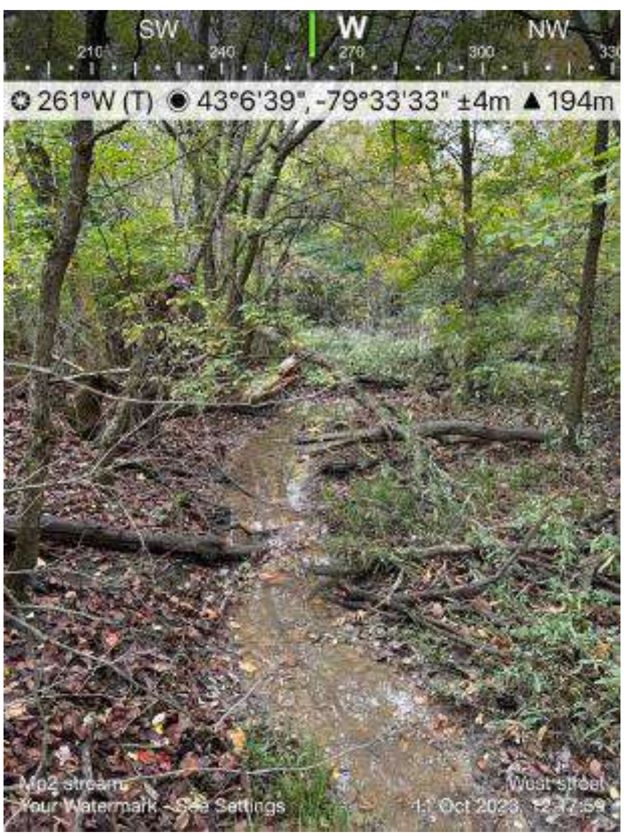

N NE E
0 30 60 90 120
56°NE (T) 43°6'39", -79°33'33" ±4m ▲ 192m
Mp2
Your Watermark - See Settings
West street
28 Sep 2023, 09:56:38

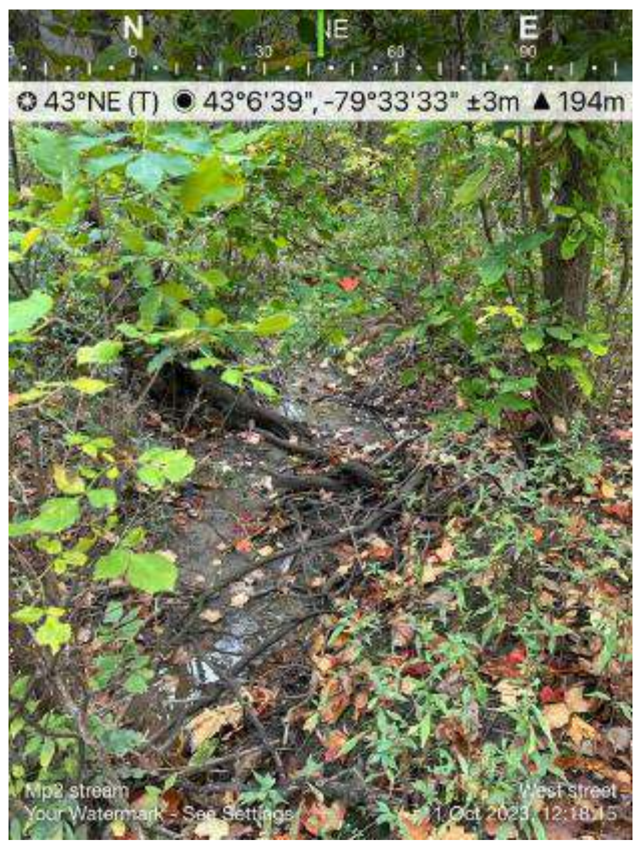
October 5 2023



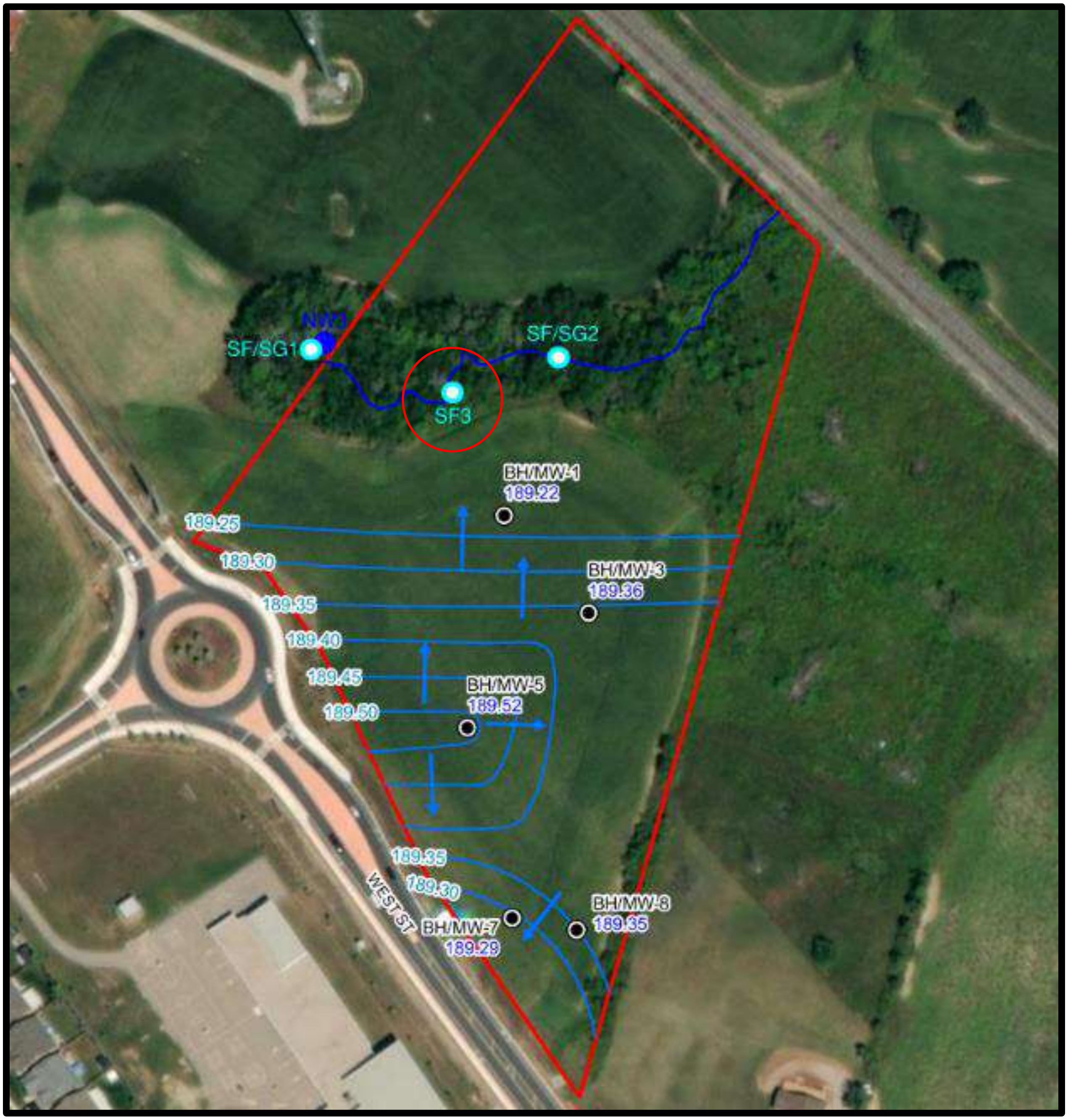
October 11 2023





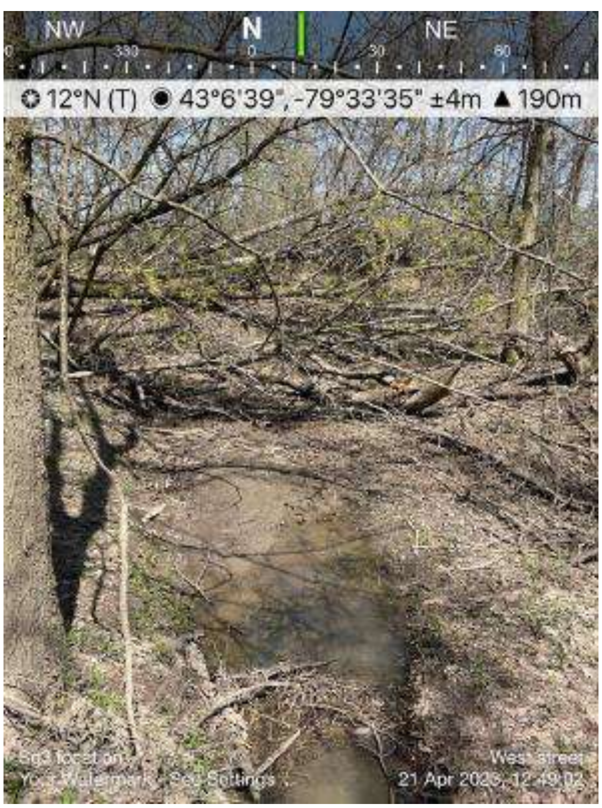


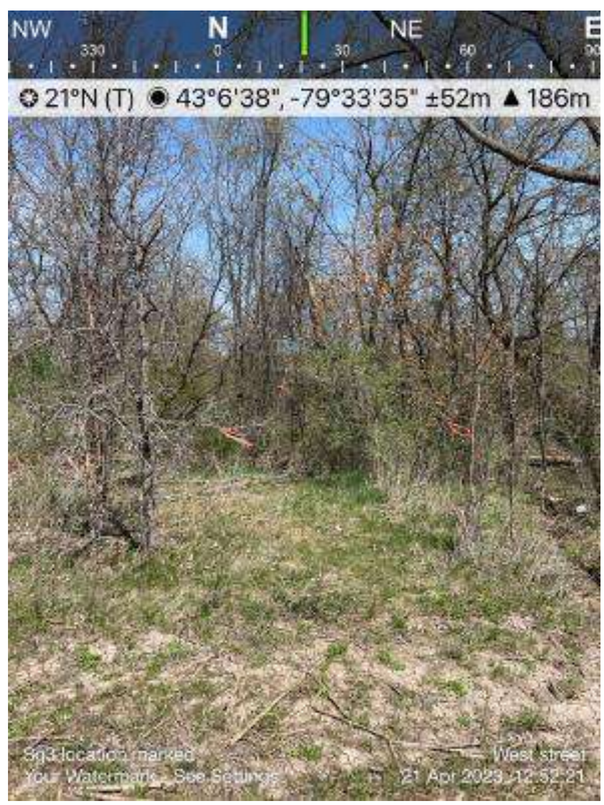
MP/SG3 Location (midstream)
West Street – Smithville
April 21, 2023



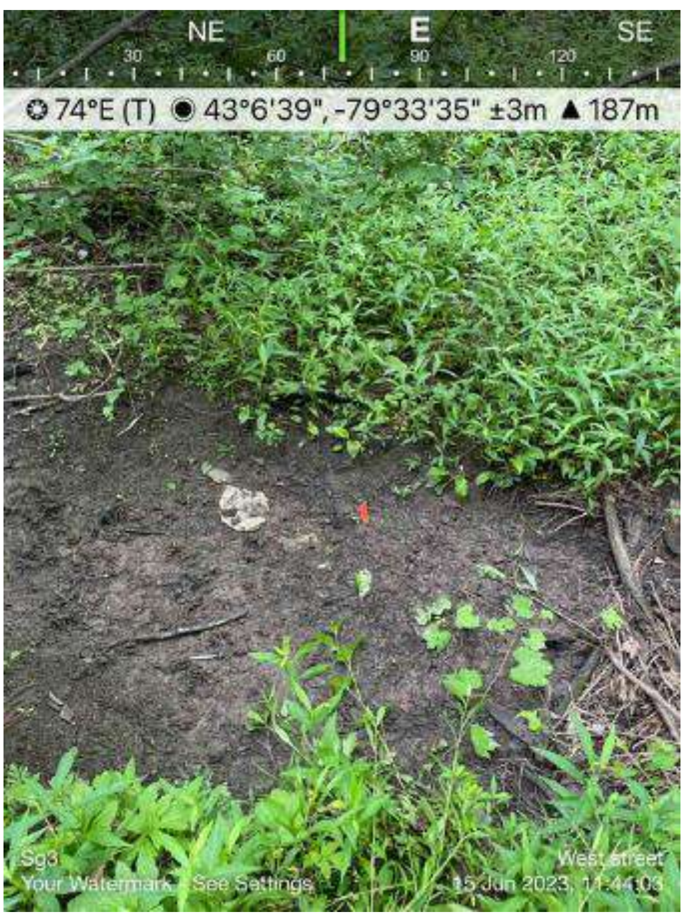

E
SE
S
121°SE (T) 43°6'39", -79°33'34" ±25m ▲ 213m
Sg3 location
Your Watermark - See Settings
West street


E
SE
S
149°SE (T) 43°6'39", -79°33'35" ±4m ▲ 189m
Sg3 location
Your Watermark - See Settings
West street
21 Apr 2023

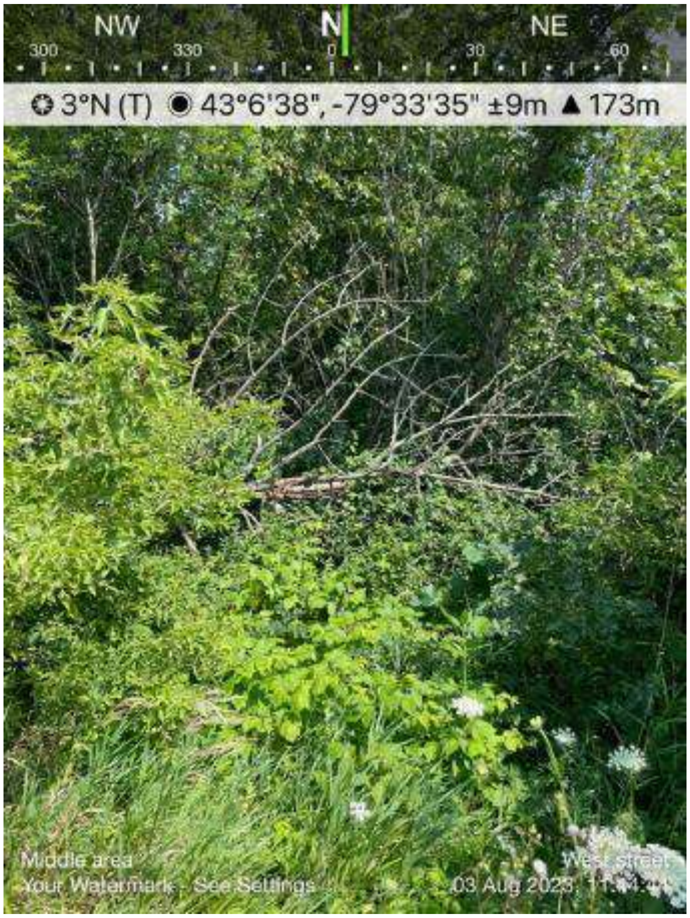

NW
N
NE
12°N (T) 43°6'39", -79°33'35" ±4m ▲ 190m
West street

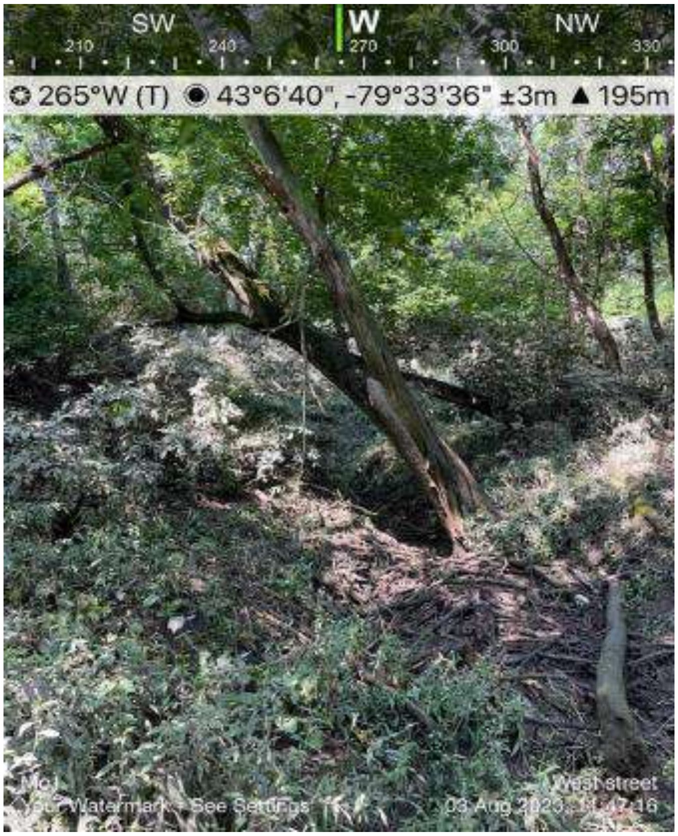

NW
N
NE
21°N (T) 43°6'38", -79°33'35" ±52m ▲ 186m
Sg3 location marked
Your Watermark - See Settings
West street
21 Apr 2023 12:52:21

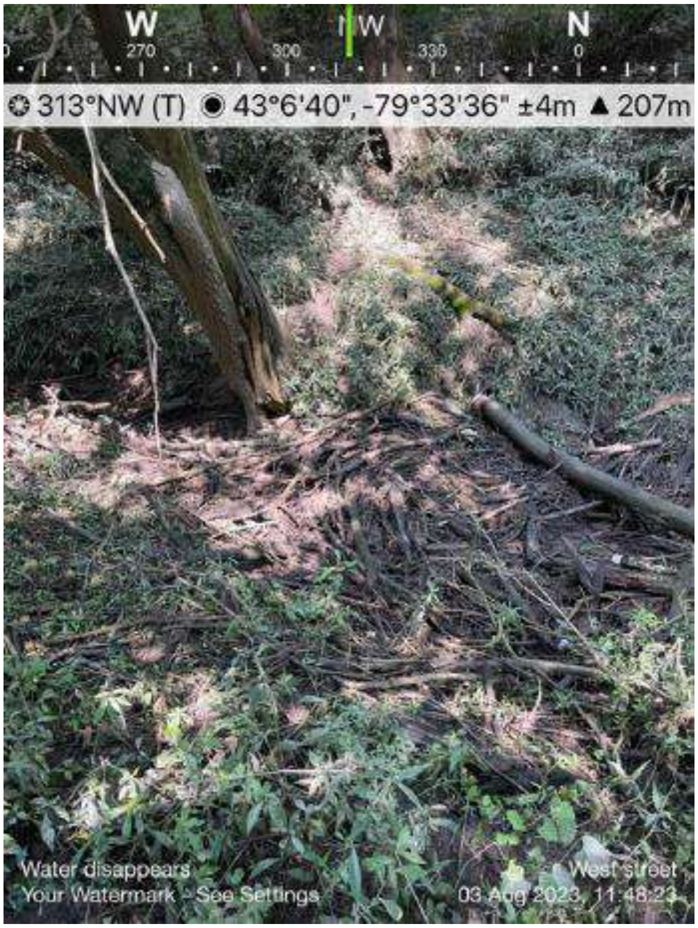
June 9 2023 – Rain Event

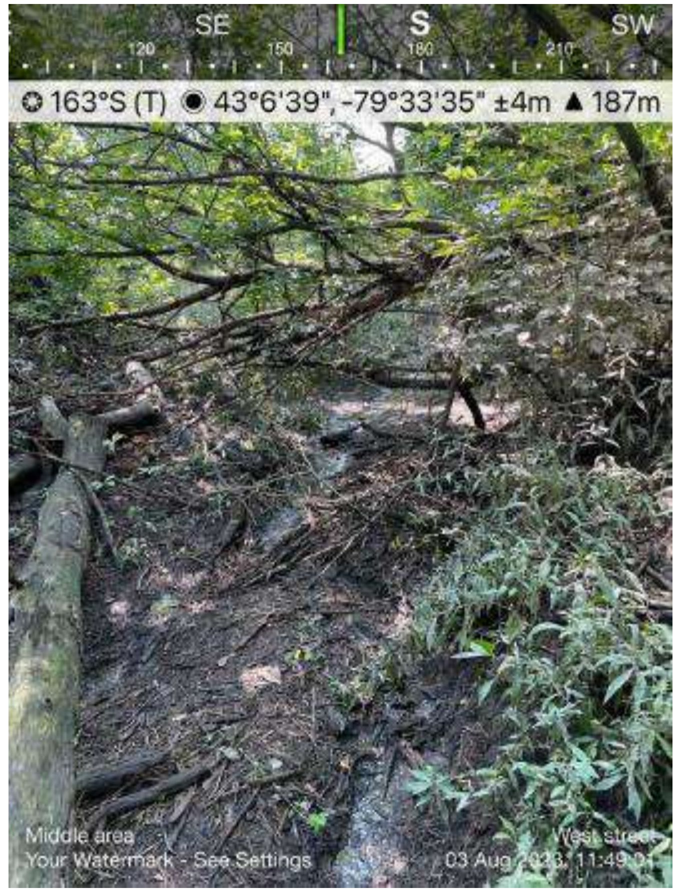


August 3 2023

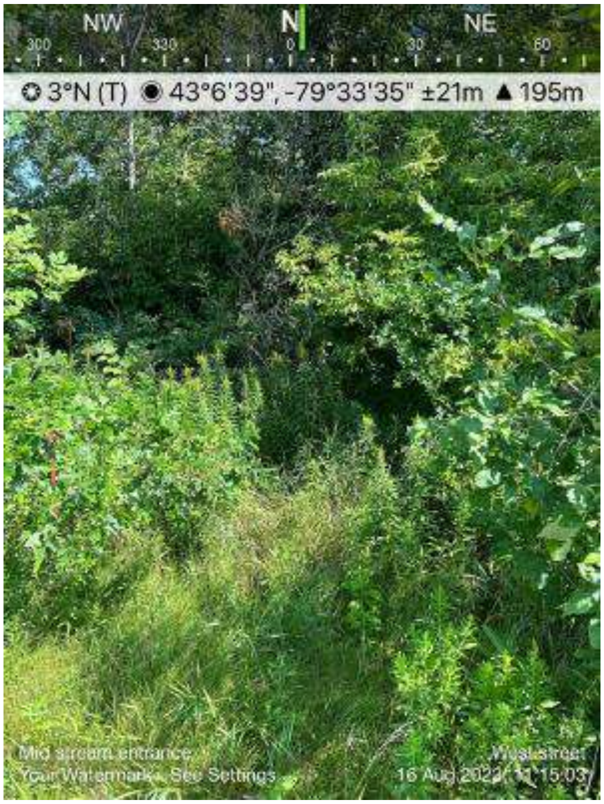


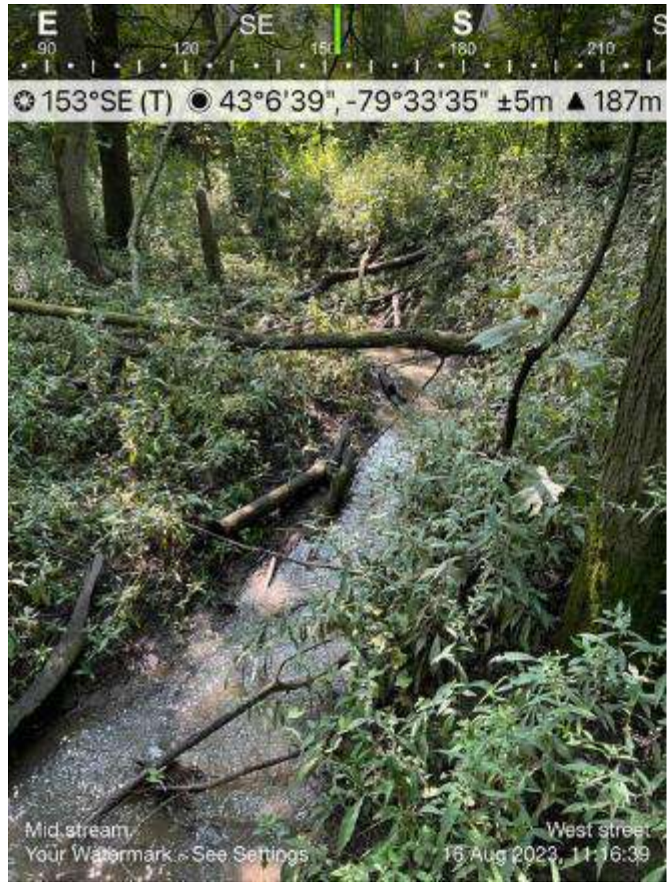


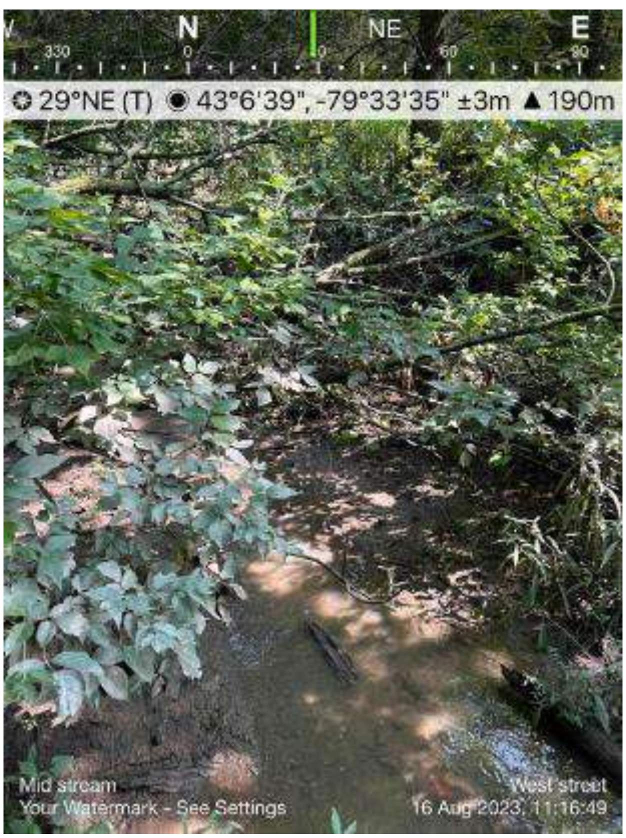

W
NW
N
270
300
330
0
313°NW (T) 43°6'40", -79°33'36" ±4m ▲ 207m
Water disappears
Your Watermark - See Settings
West street
03 Aug 2023, 11:48:23

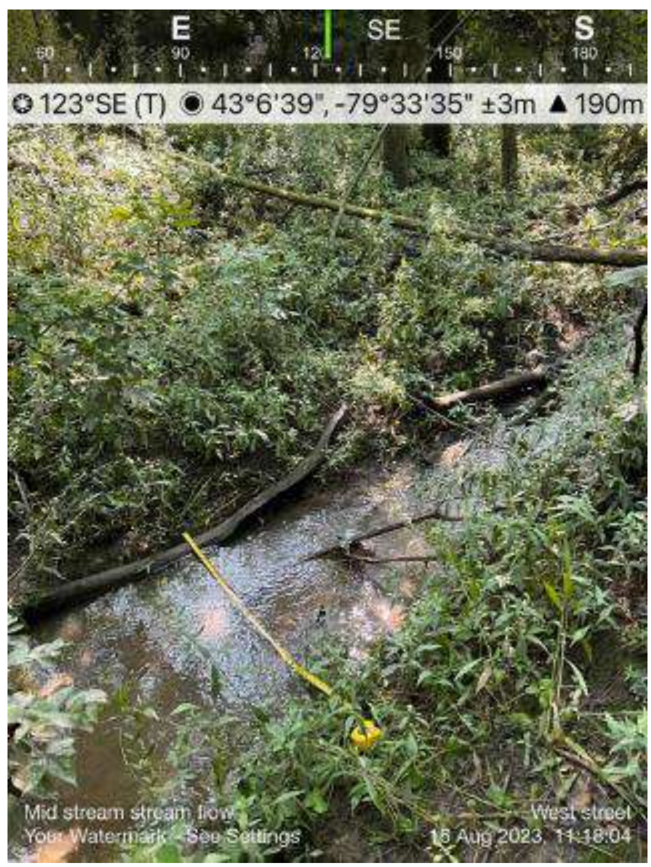

SE
S
SW
120
150
180
210
163°S (T) 43°6'39", -79°33'35" ±4m ▲ 187m
Middle area
Your Watermark - See Settings
West street
03 Aug 2023, 11:49:04

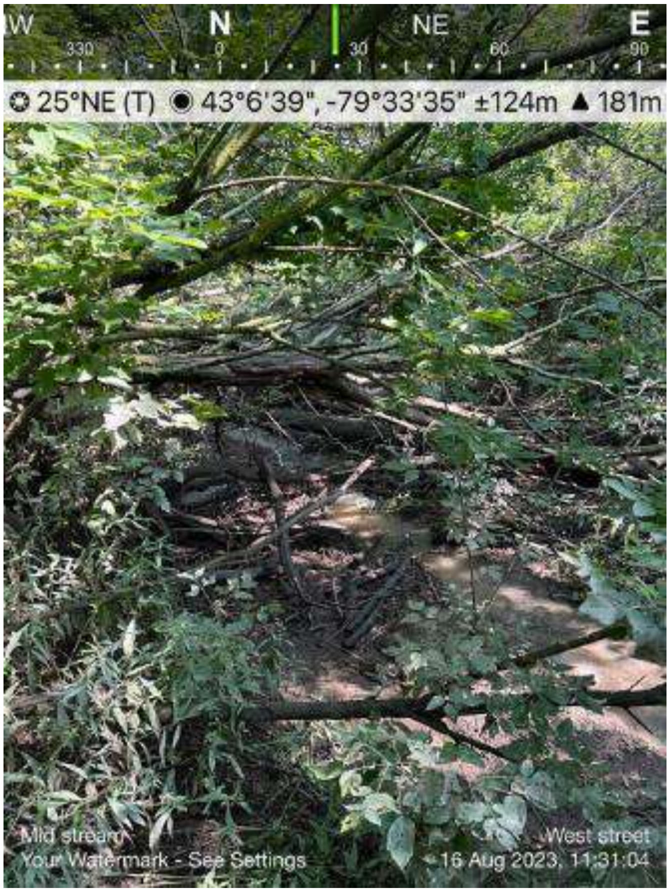
August 16 2023 – Post Rain Event 38mm

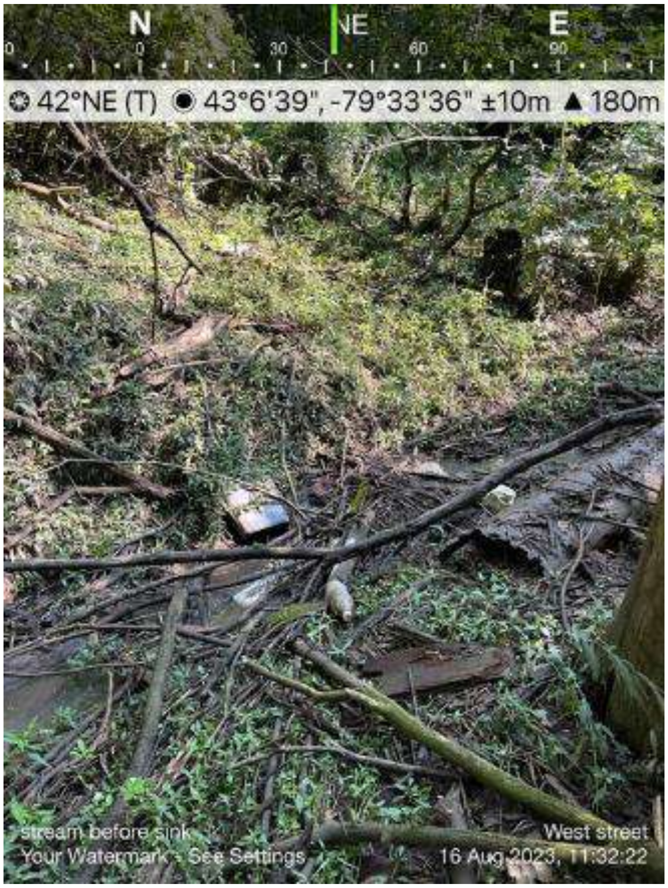


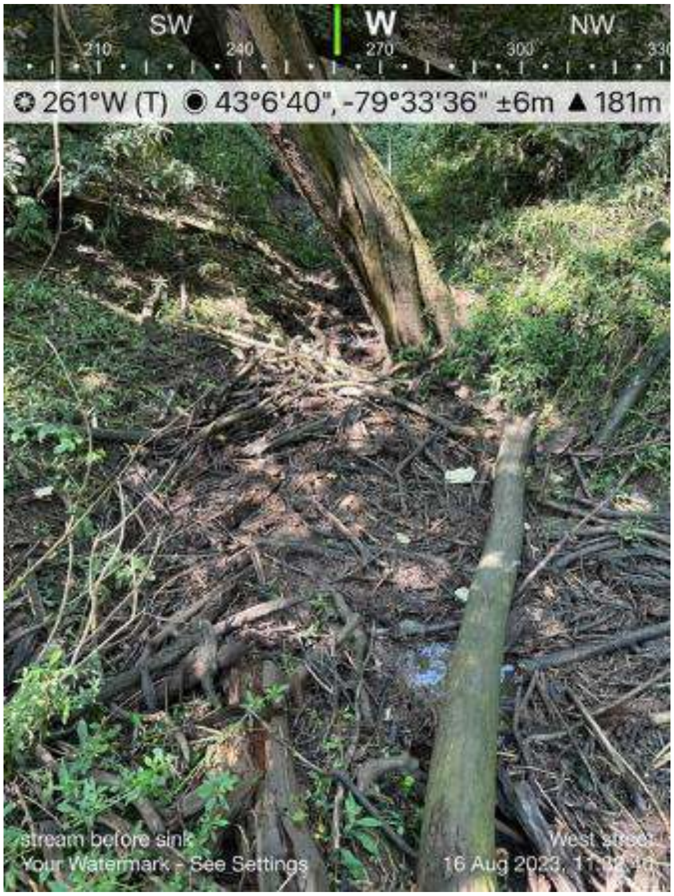






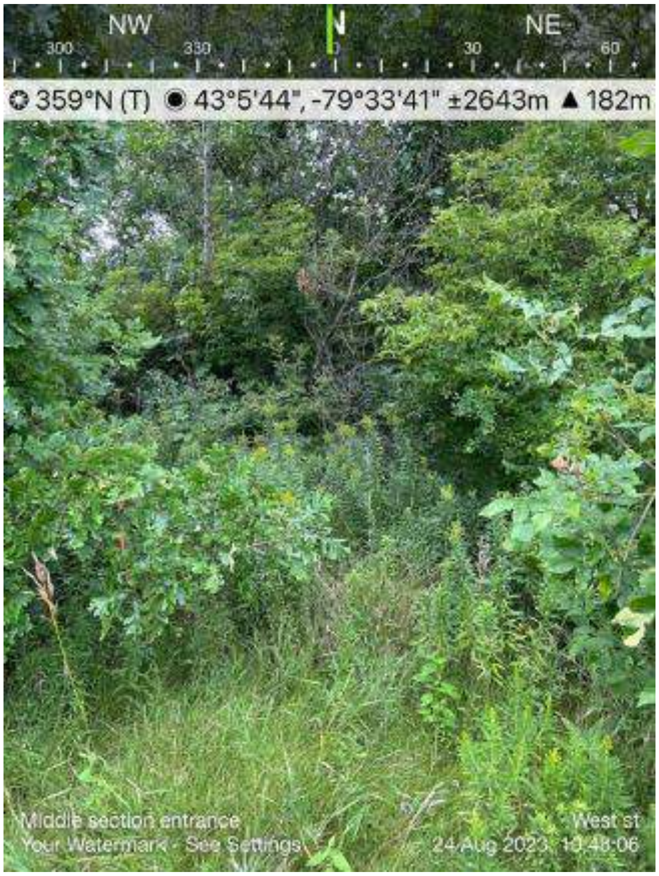

N
NE
E
25°NE (T) 43°6'39", -79°33'35" ±124m ▲ 181m
Mid stream
Your Watermark - See Settings
West street
16 Aug 2023, 11:31:04

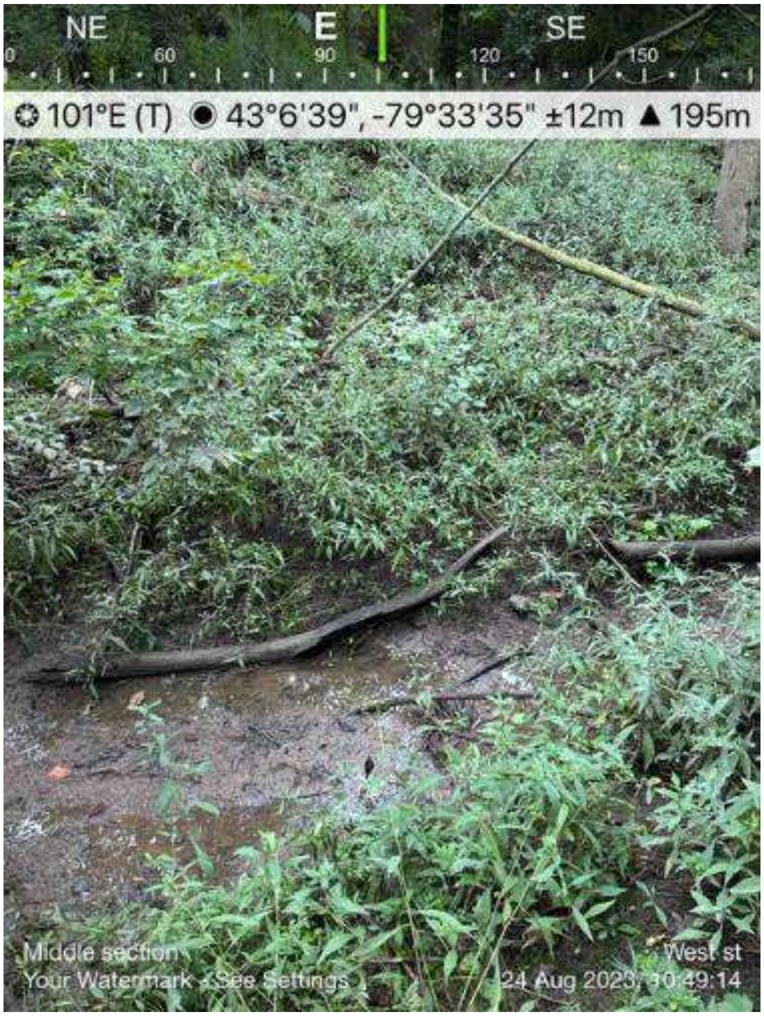

N
NE
E
42°NE (T) 43°6'39", -79°33'36" ±10m ▲ 180m
stream before sink
Your Watermark - See Settings
West street
16 Aug 2023, 11:32:22

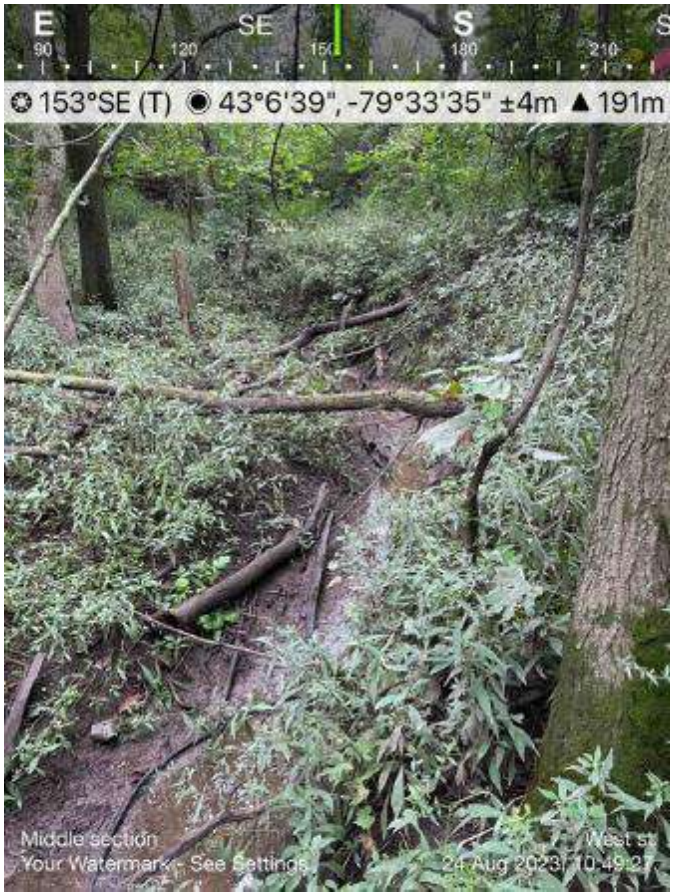

SW
W
NW
261°W (T) 43°6'40", -79°33'36" ±6m ▲ 181m
stream before sink
Your Watermark - See Settings
16 Aug 2023

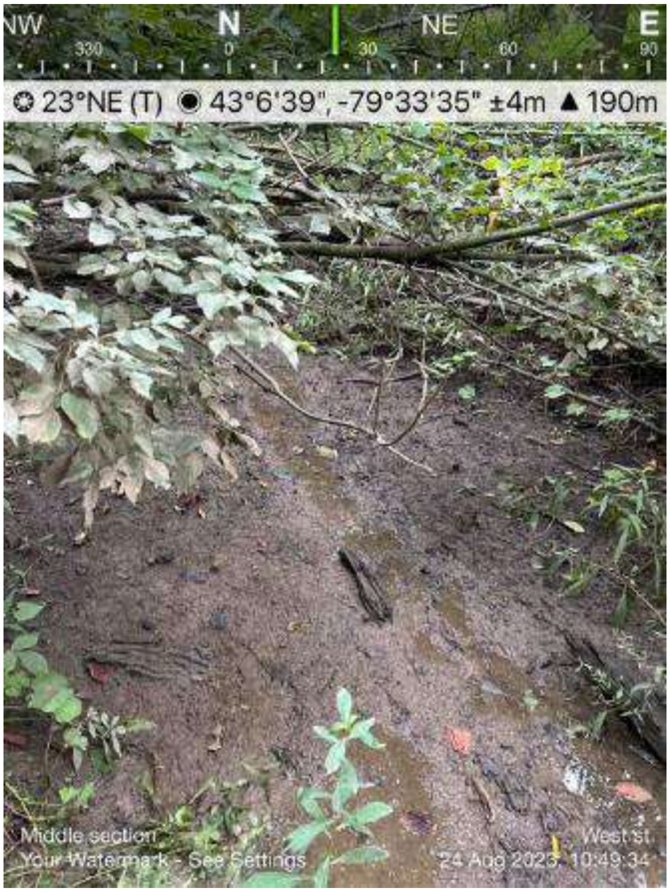

SW
W
NW
270°W (T) 43°6'40", -79°33'36" ±3m ▲ 188m
stream before sink
Your Watermark - See Settings
West street
16 Aug 2023, 11:32:52

Aug 24 2023 – Rain Event

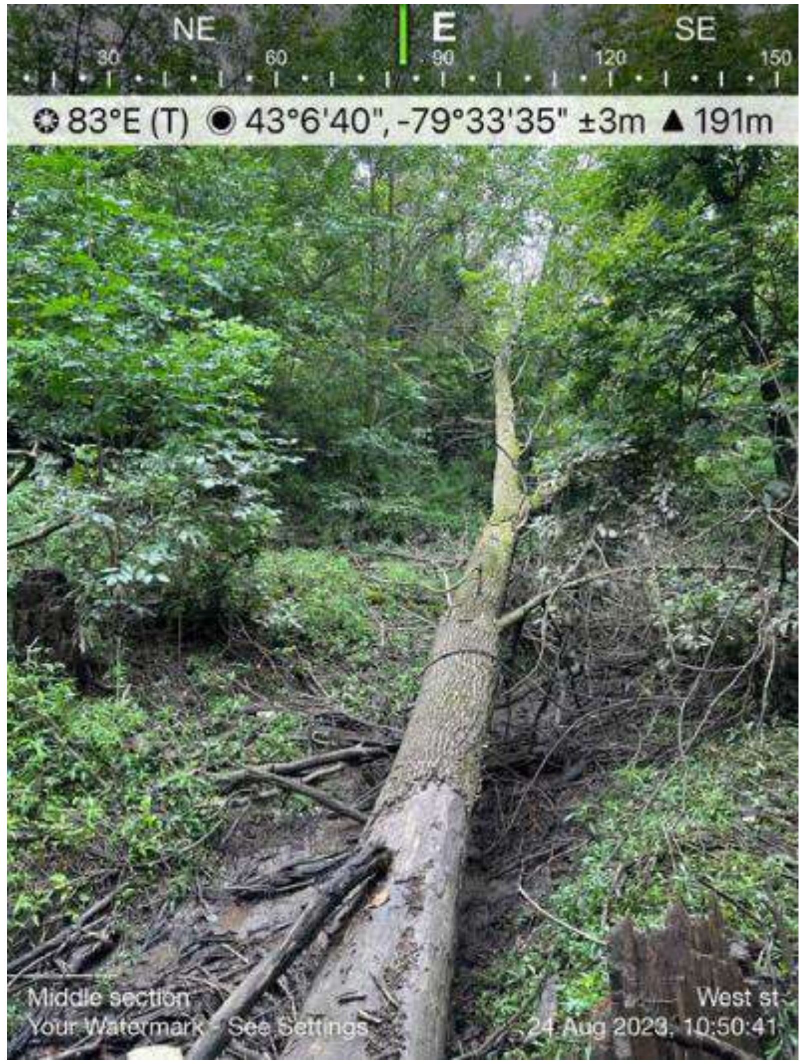






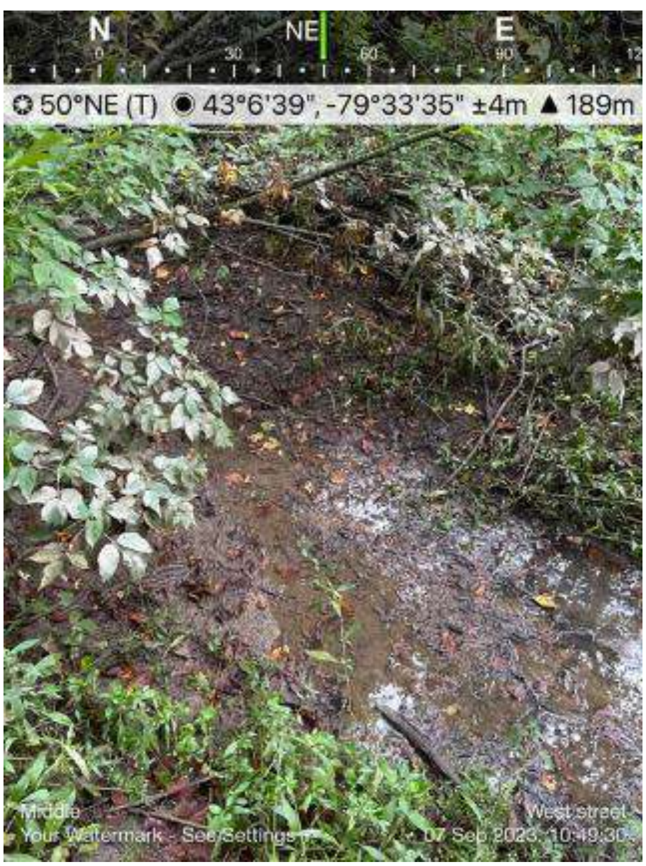


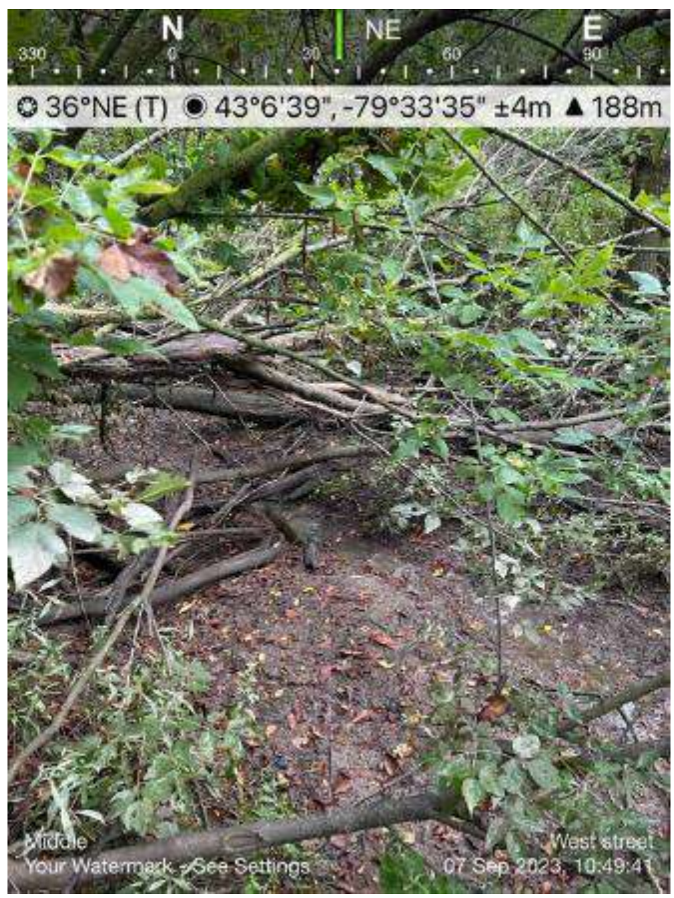

NW N NE
330 0 30 60
12°N (T) 43°6'39", -79°33'35" ±4m ▲190m
Middle section
Your Watermark - See Settings
West st
24 Aug 2023, 10:49:41

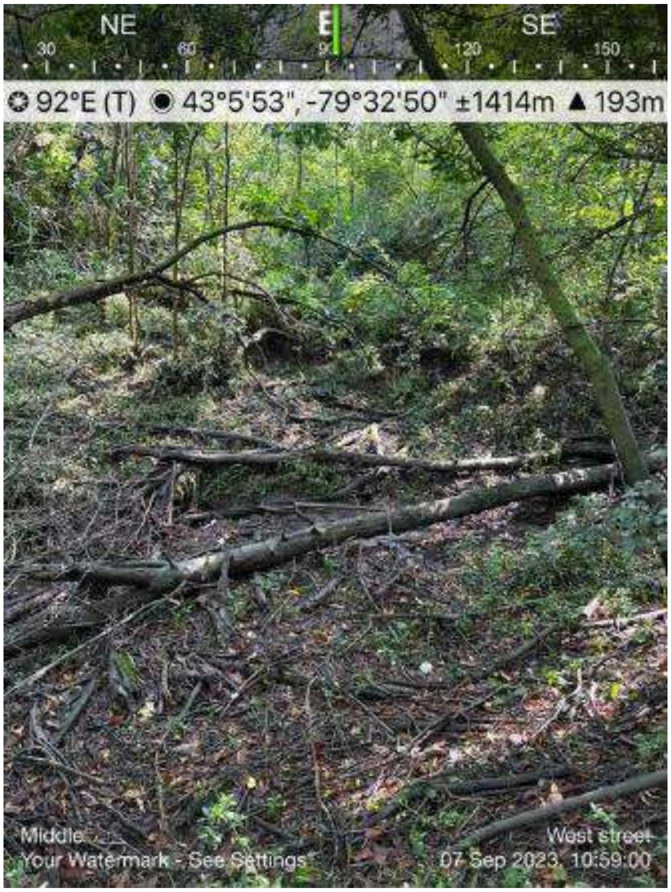

NE E SE
30 60 90 120 150
83°E (T) 43°6'40", -79°33'35" ±3m ▲191m
Middle section
Your Watermark - See Settings
West st
24 Aug 2023, 10:50:41


SW W NW
210 240 270 300 330
261°W (T) 43°6'39", -79°33'36" ±4m ▲189m
Middle section before sink
Your Watermark - See Settings
West st
24 Aug 2023, 10:50:51

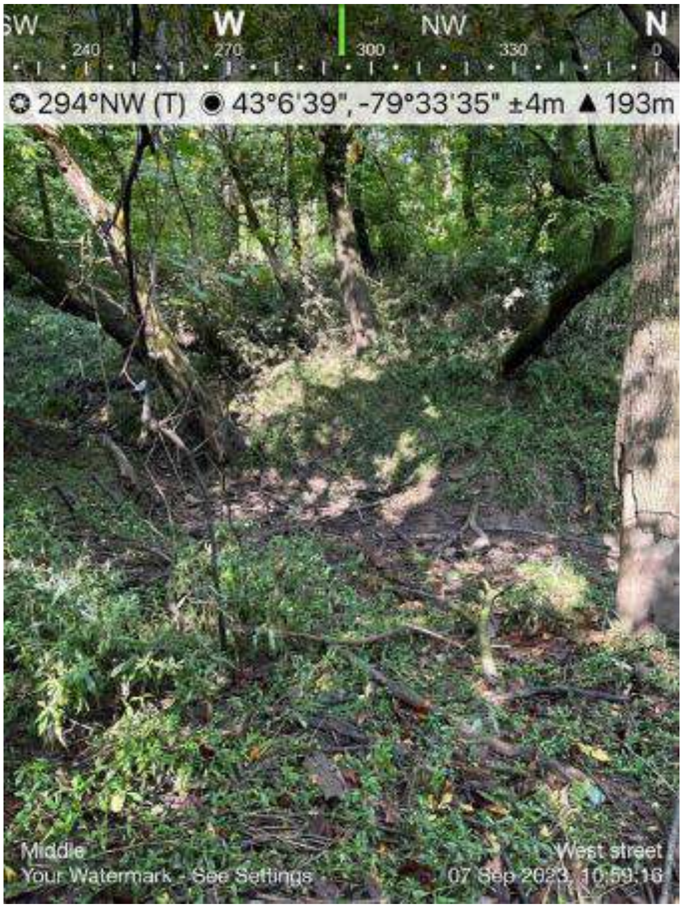
September 7, 2023

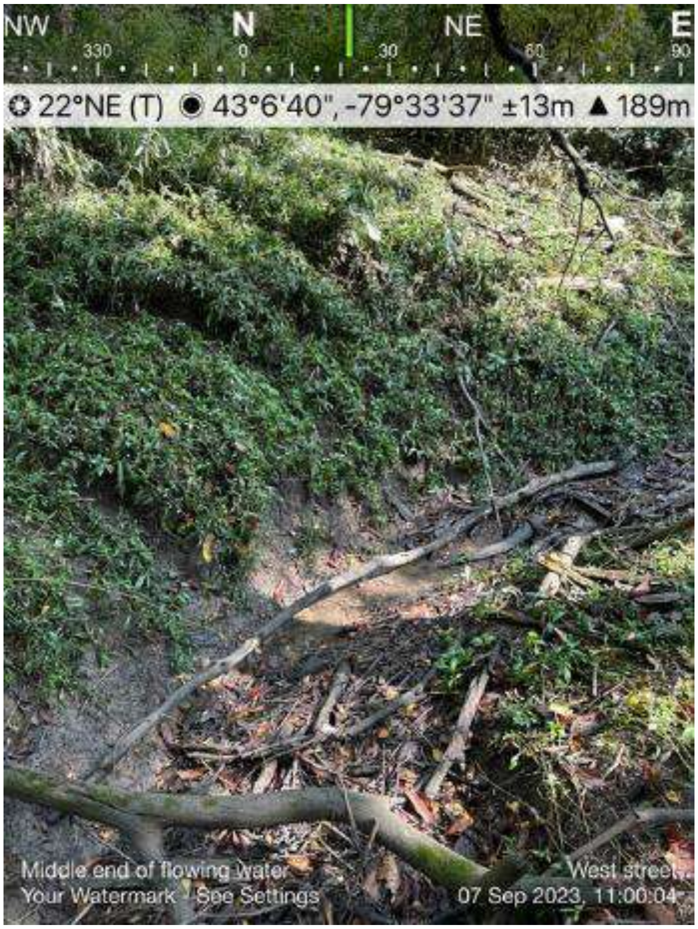





NE
E
SE
30 60 90 120 150
92°E (T) 43°5'53", -79°32'50" ±1414m ▲ 193m
Middle
Your Watermark - See Settings
West street
07 Sep 2023, 10:59:00


NW
N
NE
300 330 0 30 60
356°N (T) 43°6'39", -79°33'35" ±3m ▲ 191m
Middle
Your Watermark - See Settings
West street
07 Sep 2023, 10:59:10

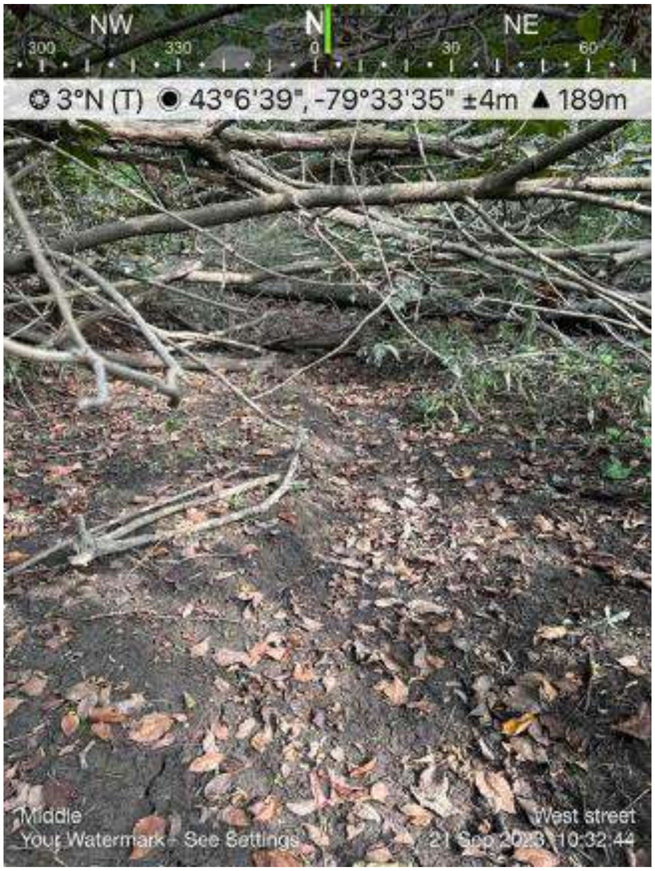

SW
W
NW
N
240 270 300 330 0
294°NW (T) 43°6'39", -79°33'35" ±4m ▲ 193m
Middle
Your Watermark - See Settings
West street
07 Sep 2023, 10:59:16


NW
N
NE
E
330 0 30 60 90
22°NE (T) 43°6'40", -79°33'37" ±13m ▲ 189m
Middle end of flowing water
Your Watermark - See Settings
West street
07 Sep 2023, 11:00:04


SW
W
NW
210
240
270
300
260°W (T) 43°6'40", -79°33'36" ±4m 195m
Middle to sink hole
West street
Your Watermark - See Settings
07 Sep 2023, 11:00:26

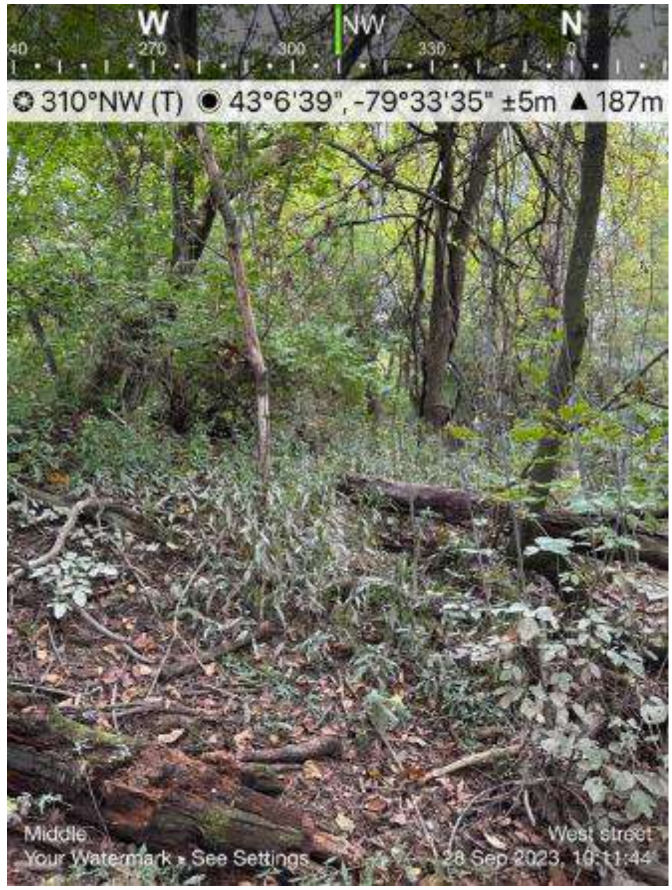

NW
N
NE
300
330
0
30
60
352°N (T) 43°6'40", -79°33'36" ±3m 190m
Middle new ground breaks near dead tree
West street
Your Watermark - See Settings
07 Sep 2023, 11:02:01

September 21 2023

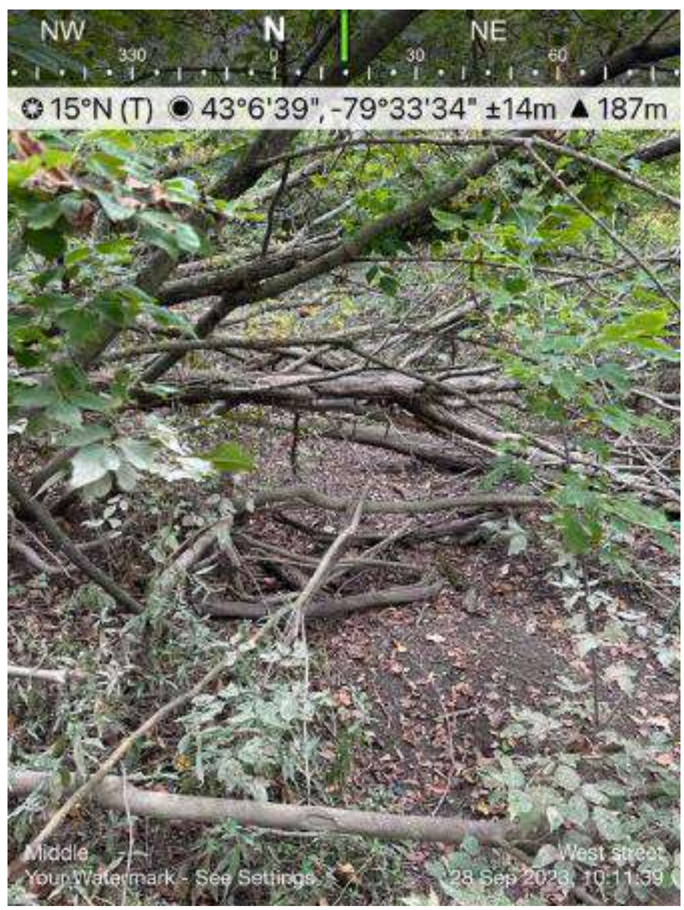


Sept 28 2023

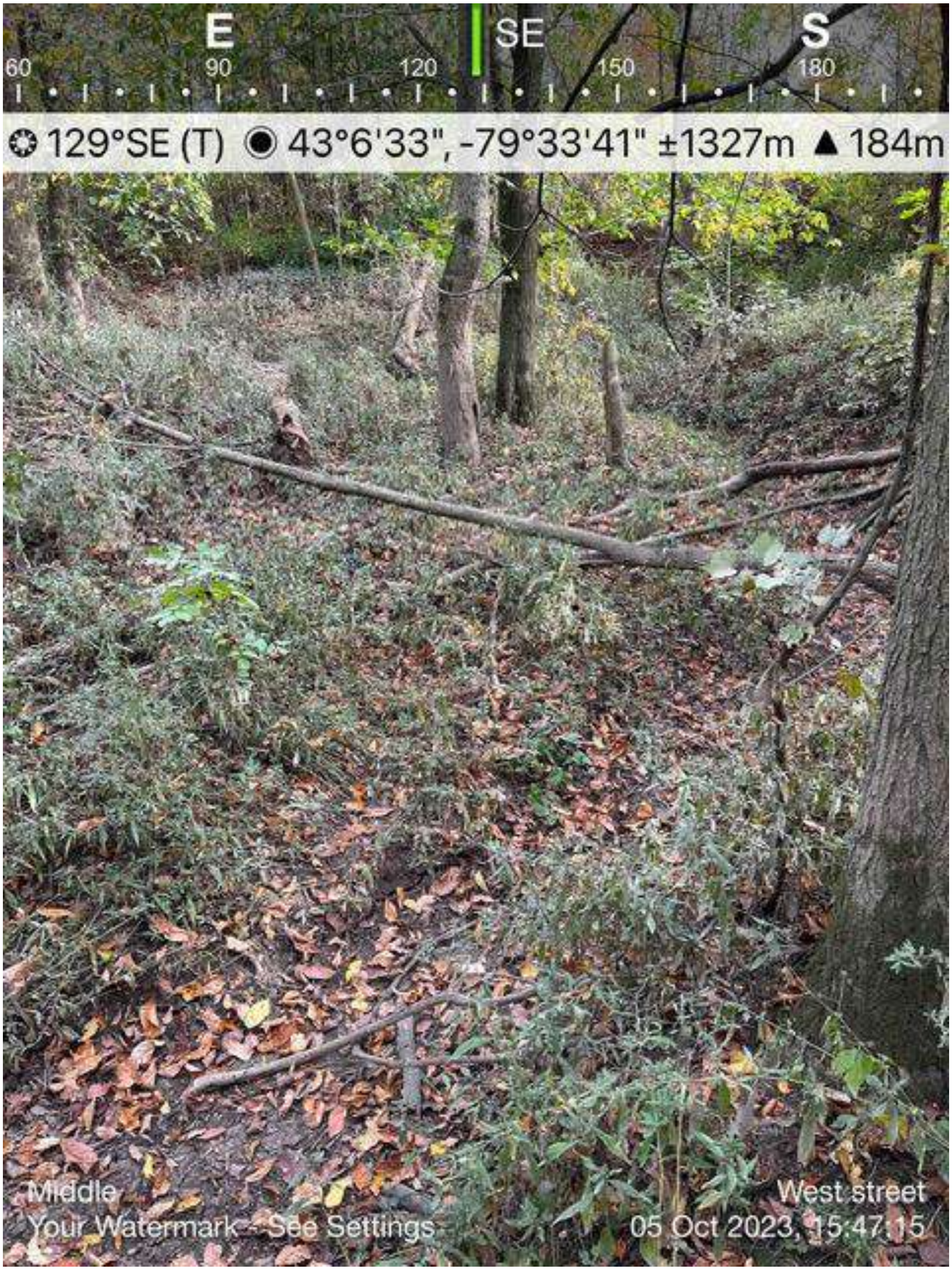

NE
E
SE
93°E (T) 43°6'39", -79°33'35" ±3m ▲ 188m
Middle
Your Watermark - See Settings
West street


W
NW
N
270
300
330
310°NW (T) 43°6'39", -79°33'35" ±5m ▲ 187m
Middle
Your Watermark - See Settings
West street
28 Sep 2023, 10:11:44

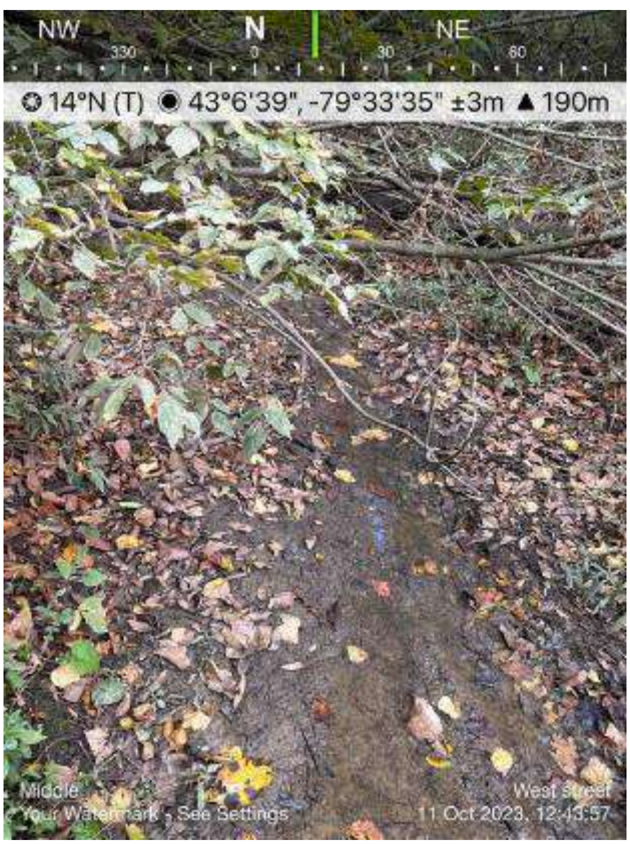

E
SE
S
90
120
150
180
140°SE (T) 43°6'1", -79°33'1" ±1414m ▲ 185m
Middle
Your Watermark - See Settings
West street
28 Sep 2023, 10:11:29

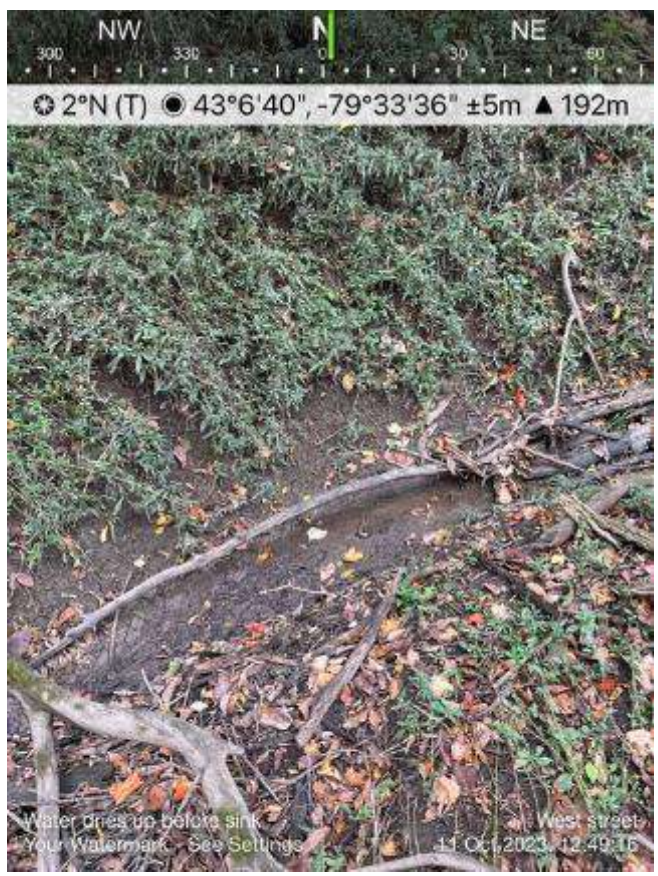

NW
N
NE
330
0
30
60
15°N (T) 43°6'39", -79°33'34" ±14m ▲ 187m
Middle
Your Watermark - See Settings
West street
28 Sep 2023, 10:11:39

October 5 2023

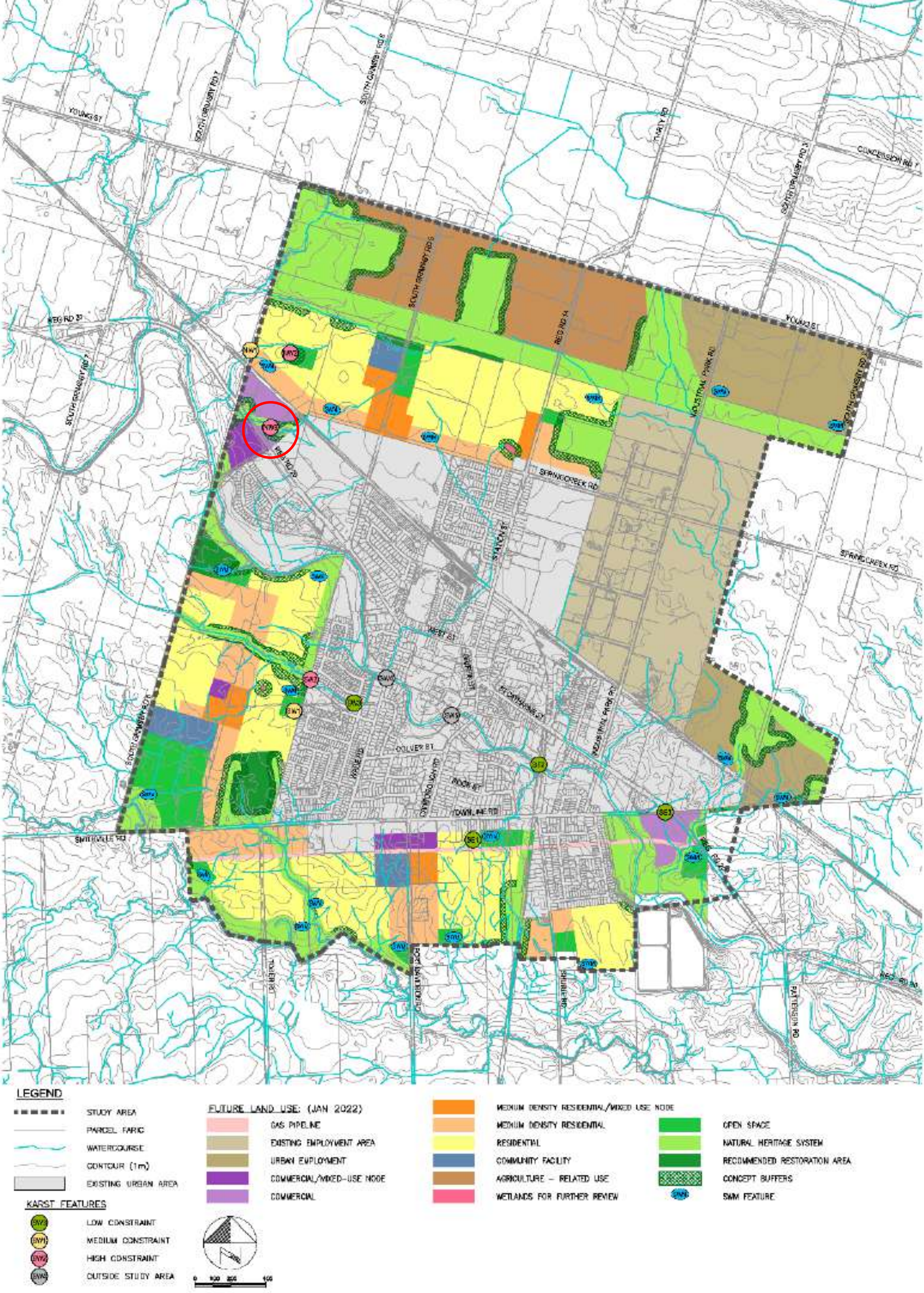


October 11 2023



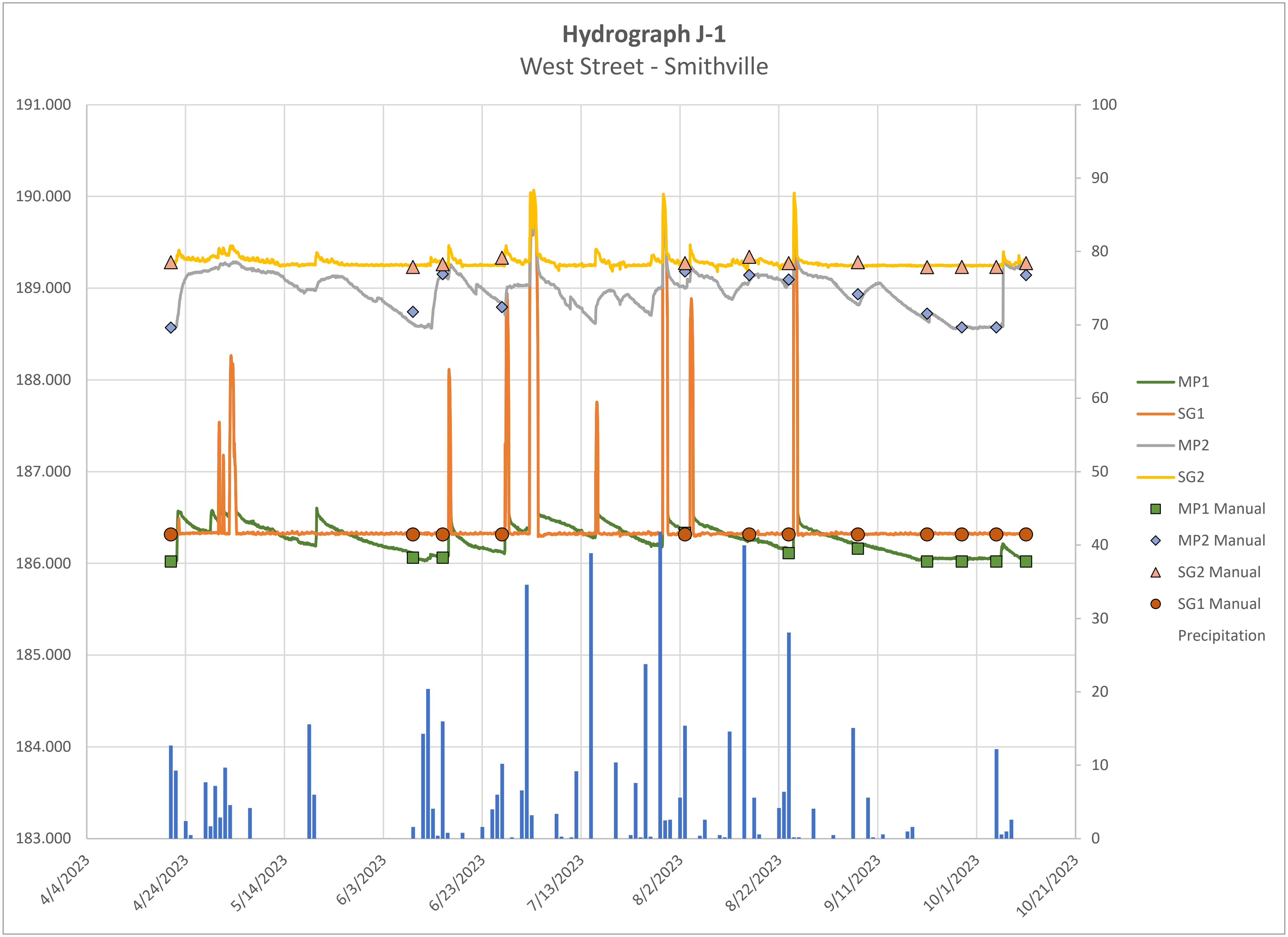


Appendix C – Karst Location Map

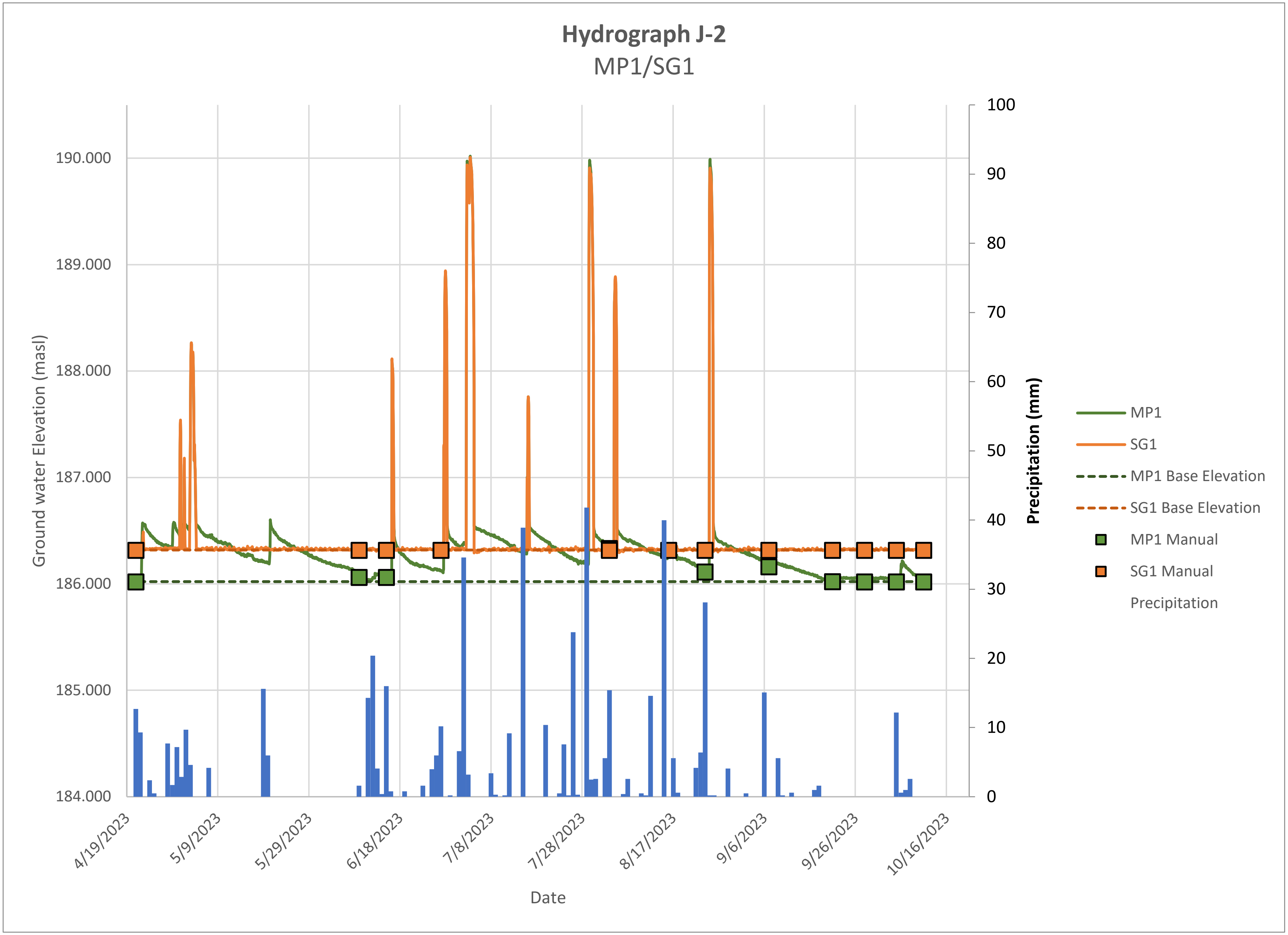


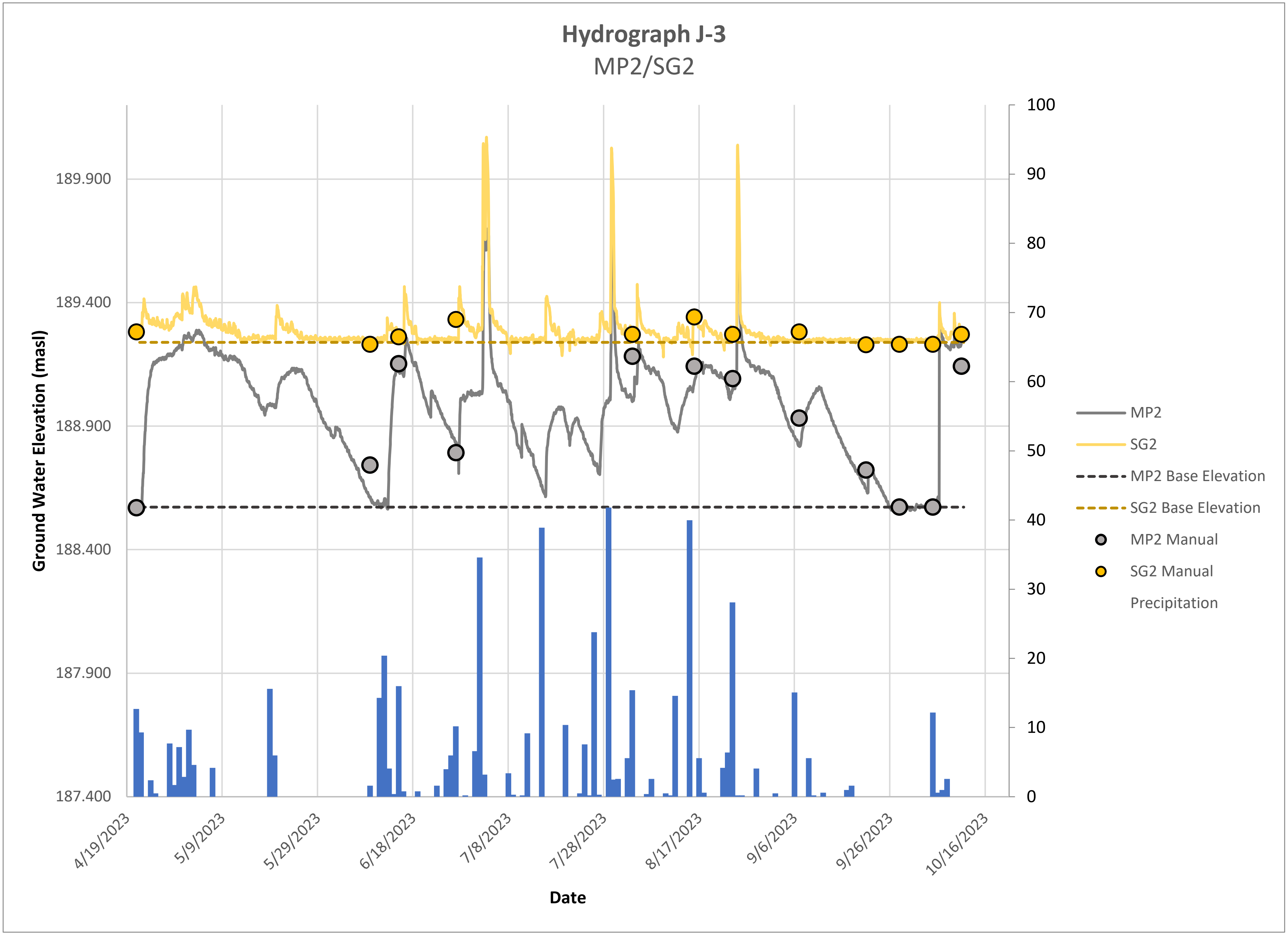
YOUNG ST
SOUTH GRIMSBY RD 7
SOUTH GRIMSBY RD 5
CONCESSION RD 7
SOUTH GRIMSBY RD 3
SOUTH GRIMSBY RD 6
REG RD 14
INDUSTRIAL PARK RD
SPRINGCREEK RD
STATION ST
WEST ST
COLVER ST
TOWNLINE RD
SMITHVILLE RD
PATTERSON RD
LEGEND
STUDY AREA
PARCEL FABRIC
WATERCOURSE
CONTOUR (1m)
EXISTING URBAN AREA
KARST FEATURES
LOW CONSTRAINT
MEDIUM CONSTRAINT
HIGH CONSTRAINT
OUTSIDE STUDY AREA
FUTURE LAND USE: (JAN 2022)
GAS PIPELINE
EXISTING EMPLOYMENT AREA
URBAN EMPLOYMENT
COMMERCIAL/MIXED-USE NODE
COMMERCIAL
MEDIUM DENSITY RESIDENTIAL/MIXED USE NODE
MEDIUM DENSITY RESIDENTIAL
RESIDENTIAL
COMMUNITY FACILITY
AGRICULTURE – RELATED USE
WETLANDS FOR FURTHER REVIEW
OPEN SPACE
NATURAL HERITAGE SYSTEM
RECOMMENDED RESTORATION AREA
CONCEPT BUFFERS
SWM FEATURE

Appendix D – Karst Data and Graphs



Hydrograph J-1
West Street - Smithville
191.000
190.000
189.000
188.000
187.000
186.000
185.000
184.000
183.000
100
90
80
70
60
50
40
30
20
10
0
4/4/2023
4/24/2023
5/14/2023
6/3/2023
6/23/2023
7/13/2023
8/2/2023
8/22/2023
9/11/2023
10/1/2023
10/21/2023
MP1
SG1
MP2
SG2
MP1 Manual
MP2 Manual
SG2 Manual
SG1 Manual
Precipitation


Hydrograph J-2
MP1/SG1
Ground water Elevation (masl)
190.000
189.000
188.000
187.000
186.000
185.000
184.000
Precipitation (mm)
100
90
80
70
60
50
40
30
20
10
0
4/19/2023
5/9/2023
5/29/2023
6/18/2023
7/8/2023
7/28/2023
8/17/2023
9/6/2023
9/26/2023
10/16/2023
Date
MP1
SG1
MP1 Base Elevation
SG1 Base Elevation
MP1 Manual
SG1 Manual
Precipitation



Hydrograph J-3
MP2/SG2
Ground Water Elevation (masl)
189.900
189.400
188.900
188.400
187.900
187.400
100
90
80
70
60
50
40
30
20
10
0
4/19/2023
5/9/2023
5/29/2023
6/18/2023
7/8/2023
7/28/2023
8/17/2023
9/6/2023
9/26/2023
10/16/2023
Date
MP2
SG2
MP2 Base Elevation
SG2 Base Elevation
MP2 Manual
SG2 Manual
Precipitation

Number	Date	Precipitation (mm)	Creek Observation	Vertical Transect (m)	Depth of Vertical transect (m)	Widths of Vertical Transect (m)	Area of Vertical Transect (m2)	Velocity Measurement (m/s)			Average velocity (m/s)	Flow Rate at each Transect (m3/s)	Flow Rate of Stream at Location (m3/s)	Flow Rate of Stream at Location (m3/hr)	Flow Rate of Stream at Location (L/s)	Flow Rate of Stream at Location (L/hr)
								1	2	3						
Station: SF 1 at Sinkhole NW3/MP1/SG1 (Downstream)																
1	21-Apr-23	12.7	No Stream flow data													
2	9-Jun-23	1.6	No Stream flow data													
3	15-Jun-23	16	No Stream flow data													
4	27-Jun-23	10.2	No Stream flow data													
5	3-Aug-23	15.4	No Stream flow data													
6	16-Aug-23	0, previous day 40	No Stream flow data													
7	24-Aug-23	28.1	No Stream flow data													
8	7-Sep-23	0, previous day 15.1	No Stream flow data													
9	21-Sep-23	0, light rain	No Stream flow data													
10	28-Sep-23	0, light rain	No Stream flow data													
11	5-Oct-23	0, light rain	No Stream flow data													
12	11-Oct-23	0 + previous days rain	No Stream flow data													

Number	Date	Precipitation (mm)	Creek Observation	Vertical Transect (m)	Depth of Vertical transect (m)	Widths of Vertical Transect (m)	Area of Vertical Transect (m2)	Velocity Measurement (m/s)			Average velocity (m/s)	Flow Rate at each Transect (m3/s)	Flow Rate of Stream at Location (m3/s)	Flow Rate of Stream at Location (m3/hr)	Flow Rate of Stream at Location (L/s)	Flow Rate of Stream at Location (L/hr)
								1	2	3						
Station: SF 2 at MP/SG2 (Upstream)																
1	21-Apr-23	12.7	No Stream flow data													
2	9-Jun-23	1.6	No Stream flow data													
3	15-Jun-23	16	No Stream flow data													
				1 (embankment)	0.06	0.26	**0.0078**	0.066	0.057	0.055	**0.0593**	0.0005				
4	27-Jun-23	10.2	Flowing Water	2	0.08	0.26	**0.0208**	0.028	0.024	0.023	**0.0250**	0.0005	0.0011	3.8438	1.0677	3,843.84
				3 (embankment)	0.04	0.26	**0.0052**	0.017	0.015	0.017	**0.0163**	0.0001				
				1 (embankment)	0.01	0.2	**0.001**	0	0	0	**0**	0				
5	3-Aug-23	15.4	Water	2	0.04	0.2	**0.008**	0.003	0.006	0.006	**0.005**	0.00004	0.0001	0.2880	0.0800	288.00
				3 (embankment)	0.04	0.2	**0.004**	0.009	0.01	0.011	**0.01**	0.00004				
				1 (embankment)	0.07	0.26	**0.0091**	0.032	0.035	0.038	0.0350	0.000319				
6	16-Aug-23	0, previous day 40	Flowing Water	2	0.1	0.26	**0.026**	0.05	0.046	0.049	0.0483	0.001257	0.0022	7.8671	2.1853	7,867.08
				3 (embankment)	0.08	0.26	**0.0104**	0.059	0.06	0.057	0.0587	0.000610				
				1 (embankment)	0.005	0.185	**0.0004625**	0	0	0	0.0000	0.000000				
7	24-Aug-23	28.1	Flowing Water	2	0.02	0.185	**0.0037**	0.002	0.002	0.002	0.0020	0.000007	0.0000	0.0266	0.0074	26.64
				3 (embankment)	0.005	0.185	**0.0004625**	0	0	0	0.0000	0.000000				
				1 (embankment)	0.02	0.22	**0.0022**	0.002	0.003	0.005	0.0033	0.000007				
8	7-Sep-23	0, previous day 15.1	Flowing Water	2	0.04	0.22	**0.0088**	0.008	0.006	0.006	0.0067	0.000059	0.0001	0.3590	0.0997	359.04
				3 (embankment)	0.04	0.22	**0.0044**	0.007	0.008	0.008	0.0077	0.000034				
9	21-Sep-23	0, light rain	No Stream flow data													
10	28-Sep-23	0, light rain	No Stream flow data													
11	5-Oct-23	0, Light rain	No Stream flow data													
12	11-Oct-23	0 +previous days rain	Lightly Flowing Water	1	0.02	0.58	0.0116	0.001	0.002	0.001	0.001333333	0.00002	0.00002	0.0557	0.0155	55.68

Number	Date	Precipitation (mm)	Creek Observation	Vertical Transect (m)	Depth of Vertical transect (m)	Widths of Vertical Transect (m)	Area of Vertical Transect (m2)	Velocity Measurement (m/s)			Average velocity (m/s)	Flow Rate at each Transect (m3/s)	Flow Rate of Stream at Location (m3/s)	Flow Rate of Stream at Location (m3/hr)	Flow Rate of Stream at Location (L/s)	Flow Rate of Stream at Location (L/hr)
								1	2	3						
Station: SF 3 (Midstream)																
1	21-Apr-23	12.7	No Stream flow data													
2	9-Jun-23	1.6	No Stream flow data													
3	15-Jun-23	16	No Stream flow data													
4	27-Jun-23	10.2	No Stream flow data													
5	3-Aug-23	15.4	No Stream flow data													
6	16-Aug-23	0, previous day 40	Flowing water	1 (embankment)	0.02	0.33	**0.0033**	0.137	0.135	0.135	**0.1357**	0.000448	0.0011	3.8452	1.0681	3,845.16
				2	0.02	0.33	**0.0066**	0.073	0.065	0.07	**0.0693**	0.000458				
				3 (embankment)	0.04	0.33	**0.0066**	0.023	0.024	0.027	**0.0247**	0.000163				
7	24-Aug-23	28.1	No Stream flow data													
8	7-Sep-23	0, previous day 15.1	Tight Stream of water	1 (embankment)	0.01	0.13	**0.00065**	0	0	0	**0.0000**	0.000000	0.0001	0.3120	0.0867	312.00
				2	0.04	0.13	**0.0052**	0.014	0.019	0.017	**0.0167**	0.000087				
				3 (embankment)	0.01	0.13	**0.00065**	0	0	0	**0.0000**	0.000000				
9	21-Sep-23	0, light rain	No Stream flow data													
10	28-Sep-23	0, light rain	No Stream flow data													
11	5-Oct-23	0, light rain	No Stream flow data													
12	11-Oct-23	0, light rain	No Stream flow data													

Appendix E – Geophysics Report

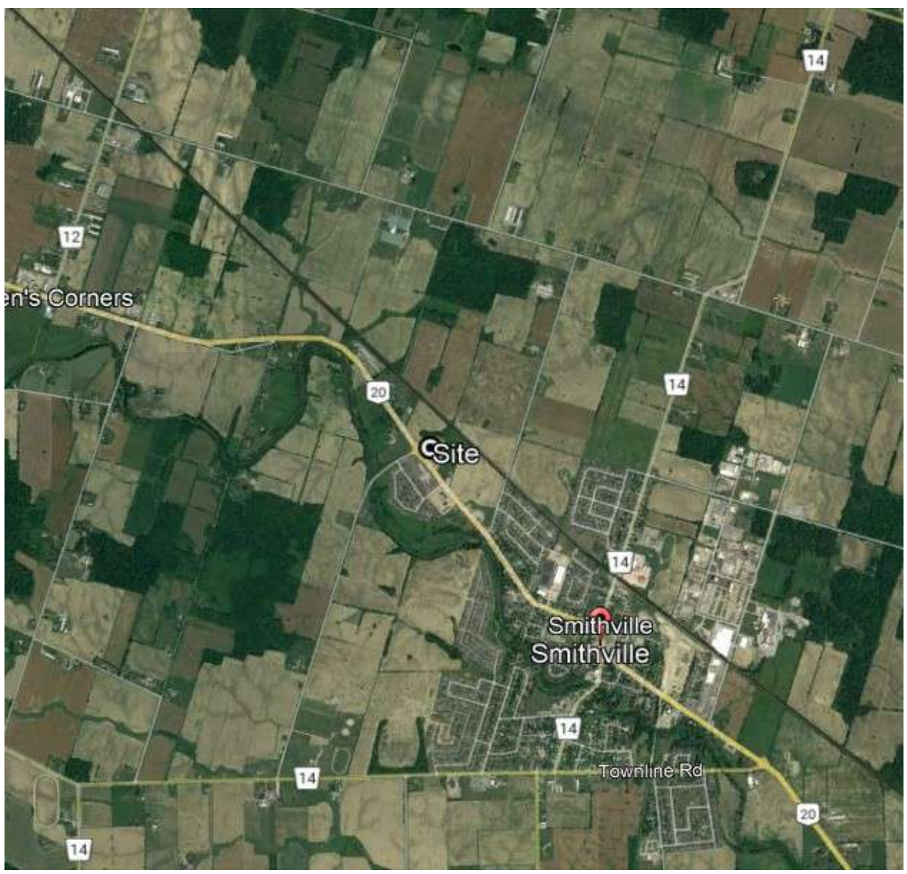
GEOPHYSICS GPR INTERNATIONAL INC.

GEOPHYSICAL INVESTIGATION FOR MAPPING POTENTIAL KARST FEATURES, SMITHVILLE, ONTARIO

Presented to :

EXP

1595 Clark Boulevard
Brampton, ON
L6T 4V1



Geophysics GPR International Inc.
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May 2023 GPR-23-4361

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1 INTRODUCTION

Geophysics GPR International Inc. (GPR) was requested by EXP to carry out a geophysical survey within an area bounded by HWY 20, S Grimsby Rd Six and Railway tracks in Smithville, Ontario (Figure 1).

The aim of the investigation was to map potential karst features that may be present within the surveyed area based on observed surficial features.

The geophysical survey consisted of electrical resistivity tomography (ERT) profiles to generate depth profiles of variations in the electrical properties of the subsurface material across the property.

The following report describes the survey design, the principles of the applied methods, the methodology for interpreting the data and finally a culmination of the results in the form of interpreted profiles.

Throughout this report, geophysical parameters (electrical resistivity) are used to infer the nature of the subsurface materials. Drill hole or test pit data should be used to support the interpretations provided.

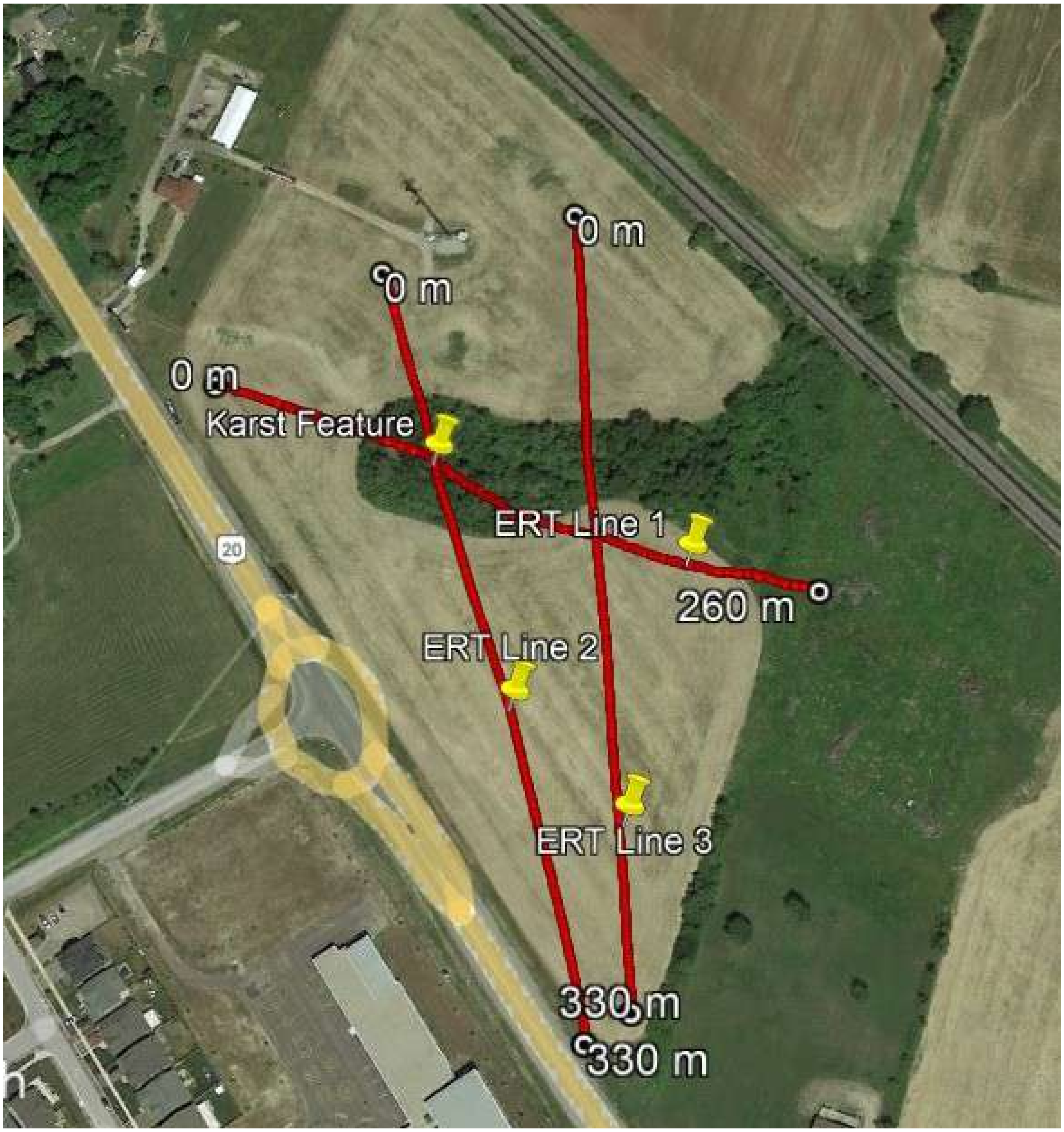

Figure 1: Survey Area with ERT Lines, HWY 20 and S Grimsby Rd Six, Smithville, Ontario

2 METHODOLOGY

2.1 Personnel

The GPR field personnel involved in this project and the dates that they were on-site are outlined in Table 1, below:

Table 1: Field personnel and survey dates

Employee	Title/Role	Dates On-Site
Duro Zeljkovic	Operator	April 12^{th}, 13^{th}, 2023
Simon MacDiarmid		April 12^{th}, 13^{th}, 2023
Johan Mireles		April 12^{th}, 13^{th}, 2023

1

2.2 Positioning, Topography and Units of Measurement

The location of the ERT profiles (Figure 1) were chosen in discussion with the client based on observed surface features with focus on site coverage and budget.

Positioning of the data was controlled by differentially corrected GPS (DGPS) measurements.

The horizontal positions are in the WGS84, UTM Zone 17N datum.

Elevation data were extracted from a point topography map provided by the client. Topography points along the lines are interpolated/extrapolated from the surveyed point elevations.

2.3 Electrical Resistivity Tomography

Basic Theory

The electrical resistivity method involves measuring the variation in potential (ΔV) at the surface due to the current flow through the subsurface. Individual readings involve injecting current (I) into two outer probes and measuring the potential (ΔV) across two inner probes. Different combinations of outer and inner electrodes are used along the array to sample from varying depths and positions (Figure 2). A multiple gradient array was used for this investigation. The resistance is given by: $R = \frac{\Delta V}{I}$

The measured resistance is then converted into an apparent resistivity. This apparent resistivity (ρ_a) is an average of the different true resistivities crossed by the current over the investigated volume. It provides a good indication of the variation of resistivity with depth as the electrode spacing increases. The apparent resistivity for a gradient array at each station is given by:

$$\rho_a = R\frac{2\pi}{\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right)}$$

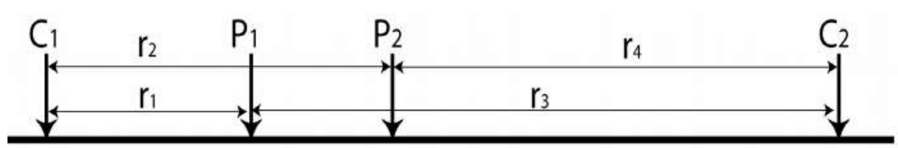

Figure 2: Gradient array electrode configuration

Survey Design

A standard survey uses a series of four cables laid out with 80 electrodes (Figure 3). Software and a control unit select combinations of electrodes to produce readings at various locations and various electrode separations, thus at varying depths of investigation.

Electrode separations of 2 m was used for this investigation. The electrode spacing controls both the resolution and depth of penetration. There is a trade-off between depth of penetration, horizontal resolution and survey efficiency. The maximum depth of investigation is approximately 1/5 of the profile length.

The length of the profiles can be extended by “rolling-over” the cables.

The standard multiple gradient array generates over 1000 readings along the length of cable layout.

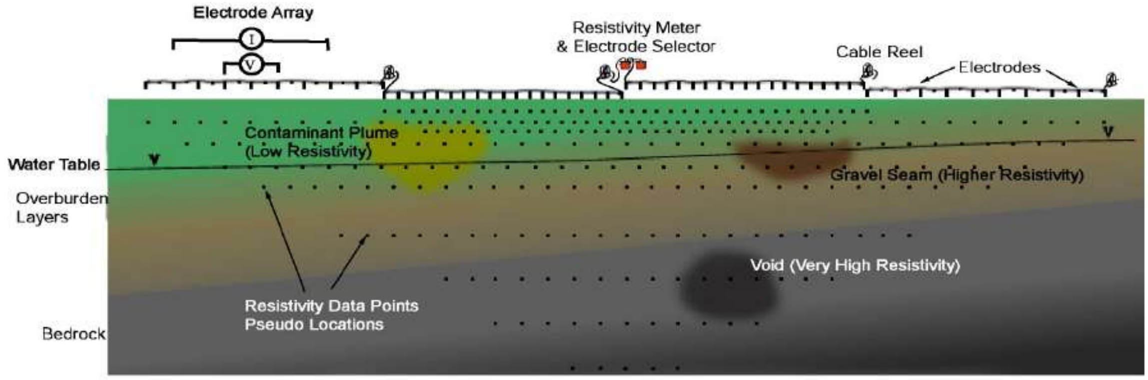

Figure 3: Resistivity Profiling Operating Principle and Applications

Resistivity Quality Control

Electrodes (steel rods) are usually planted to a minimum depth of 100 mm into soil. The electrodes are attached to the cables and a connectivity test is run to check for contact resistance. If the contacts are adequate then the system initiates data collection. If there is a poor contact then a warning is given to improve the contacts by various means including adding the following:

- Add Water
- Sink the rods deeper into the ground
- Use two or more electrodes
- Add water, salt and dish soap

Consecutive readings are taken automatically and the resistivity meter averages the measured results continuously. Measurement cycles are taken until the standard deviation falls below a preset threshold (typically 2%) or until a maximum number of readings are taken.

Processing, Interpretation and Accuracy of Results

Processing of the resistivity data involves running a 2D inversion routine to generate an inversion model with resistivity values and depths.

The main processing sequence was completed using the Res2Dinv© software package.

The 2D resistivity profiles generated by the Res2Dinv software are presented in Appendix B. The top pseudo-section on each figure is a plot of the measured resistivity values, the raw data. Through an inversion process, a physical model with depths and resistivity values is generated. This model is presented as the third pseudo-section of each figure. The middle pseudo-section represents the calculated resistivity values based on the inversion model. How well the calculated apparent resistivity data compares with the measured apparent resistivity data is calculated as the root mean square (RMS) error. Lower RMS errors indicate a better fitting model.

The RMS error for the three profiles collected at this site were all less than 2%. RMS errors below 5% are general considered excellent. As mentioned above, the higher RMS errors imply that the resistivity values based on the inversion model do not match the raw data as well. This typically occurs where there is noise in the data that cannot be fit by the inversion, or fine detailing which the software cannot accurately model. The higher RMS does not necessarily imply that the final interpretation is any less accurate.

The calculated inversion model is a resistivity model and must be interpreted in terms of geologic units or subsurface features. Geological materials will have different resistivities based primarily on variations in water content and the dissolved ions in the water. Table 2 and Table 3 provide a general overview of the resistivity values for various geologies encountered for typical karst mapping projects.

The interpretation will not extend the entire length of the profile because of the geometry. The depth of the readings decreases towards the ends of the profiles such that there are no readings directly beneath the end electrodes.

In regards to the accuracy of the results, it is difficult to assign a true error estimate. The following factors must be considered when interpreting 2D inversion models:

- 3D geology – The process is assuming a 2D subsurface model. Larger electrode separations are influenced not only by deeper features but also by features offset horizontally from the profile line. Variations in the subsurface perpendicular to the survey line can distort the results.
- Non-uniqueness – The inversion process is inherently non-unique; that is, different models can be generated from similar data sets. In general however, the main features of the models will be similar. Constraints can be placed on the inversion process given knowledge of the geology.
- The resolving power of the resistivity method decreases exponentially with depth.
- A contrast in resistivity is required to distinguish geologic layers.
- Geological distinct materials can have similar electrical properties.

Table 2: Generalized site specific interpretation based on relative resistivity values for areas of shallow bedrock.

Resistivity Values	Interpretation in areas of very shallow/exposed bedrock
Very High Resistivity	Air filled voids/karst features
High Resistivity	Competent limestone with low shale content
	Weathered bedrock with air-filled fractures
Moderate Resistivity	Competent limestone with higher shale content
	Moderately weathered limestone
Low Resistivity	Weathered limestone
	Limestone with high shale content
Very Low Resistivity	Heavily weathered limestone
	Infilled karst features, filled sinkholes

Table 3: Generalized site specific interpretation based on relative resistivity values for areas of thicker overburden.

Resistivity Values	Interpretation in Overburden
High Resistivity	Dry sands/gravel
Moderate Resistivity	Sands/gravels below the water table
Low Resistivity	Higher clay content

3 RESULTS

The locations of the ERT profiles are plotted in Figure 1.

The output of the inversion modelling are presented in Appendix B.

The Interpreted ERT profiles are presented in Figure 4. The left figures present the results of the computer modelling. The right figures present an interpretation of the model in terms of resistivity values and geology. The models and interpretations must be viewed with the limitations outlined in section 2.3.

The locations of the interpreted zones/anomalies along the ERT profiles are indicated in plan view in Figure 5.

Figures 6 and 7 provide 3D perspective images of the ERT profiles.

There is a table of the typical ranges of resistivity values for various geologic materials in Appendix A and more site specific relative ranges provided in Table 2 and Table 3.

The interpretation divides the models into five zones based on the resistivity values.

Overburden: Overburden material will have the lowest resistivity values, typically under 100 Ohm.m for silt, clays and wet sands and gravels.

Bedrock: The top of bedrock is typically defined by the steepest gradient of the resistivity models, in this case, corresponding approximately to the 150 Ohm.m contour.

Weathered Bedrock, Infilled Karst, or Increased Shale content: Weathering, fractures and karst features infilled with clay or moist soils will lower the bulk resistivity of the bedrock and tend to lower the resistivity gradient along the bedrock surface. Increased shale content will also lower the bulk resistivity of the bedrock. These zones are defined based on the relative values, intrusive testing can provide details on the true competency of these zones.

Competent Bedrock: Competent bedrock is defined by relatively high and uniform resistivity values. The resistivity values do not provide a direct measurement of bedrock strength/competence; however, tighter sedimentary rock formations with lower moisture content will generally have higher resistivity values.

Potential Void/Sinkhole: Air filled voids will appear as very high (infinite) resistivity values.
irregularly spaced air filled fractures can raise the bulk resistivity of the rock. An infilled, or water filled void may have the opposite response (e.g. a resistivity low within the bedrock)

Below are general comments on each of the lines.

Line 1:

Line 1, completed in the west to east direction has relatively shallow bedrock. The interpreted bedrock elevation is approximately between 186 m and 184 m. The bedrock is outcropping at chainage 80 m and is observed at its deepest at chainage 120 m to an approximate depth of 4 m.

The resistivity model indicates consistent, moderate to high resistivity values along the western portion of the profile between chainages 0 to 50 m. The eastern portion of the profile is suggesting relatively uniform and competent bedrock (chainages 140 to 260 m).

The central (chainage 70 to 110m) of Line 1 exhibits very high resistivity values suggesting the presence of air-filled voids. These very high resistivity zones can potentially distort the modelling within the adjacent and underlying zones so the confidence at depth is decreased; however, there is also the possibility that the air-filled voids are underlain by water or sediment in-filled voids. This is particularly feasible for the anomaly at a chainage of 86m.

Line 2:

The western most line completed in the North South direction has an interpreted bedrock elevation of 187 to 179 meters. The bedrock is outcropping at approximate chainage 75 m and is observed at its deepest at chainage 160 m to an approximate depth of 12 m.

The resistivity model indicates consistent, moderate to high resistivity values along the northern portion between chainages 0 to 36m. At approximate chainages 100 m to 330 m the profile is suggesting relatively uniform weathered bedrock.

The anomaly at chainage of 74m exhibits very high resistivity values suggesting the presence of an air-filled void. This very high resistivity zone can potentially distort the modelling within the adjacent and underlying zones so the confidence at depth is decreased in the near vicinity.

Line 3:

The eastern most line completed in the North South direction has an interpreted bedrock elevation of 186 to 185 meters with a slight dip in elevation at chainage 100 to approximately 182 m. The depth range along the profile is between 4.5 and 9 meters.

The resistivity values are relatively uniform with a noted decrease in resistivity towards the south end. This could be attributed to a change in rock lithology or potentially increased weathering.

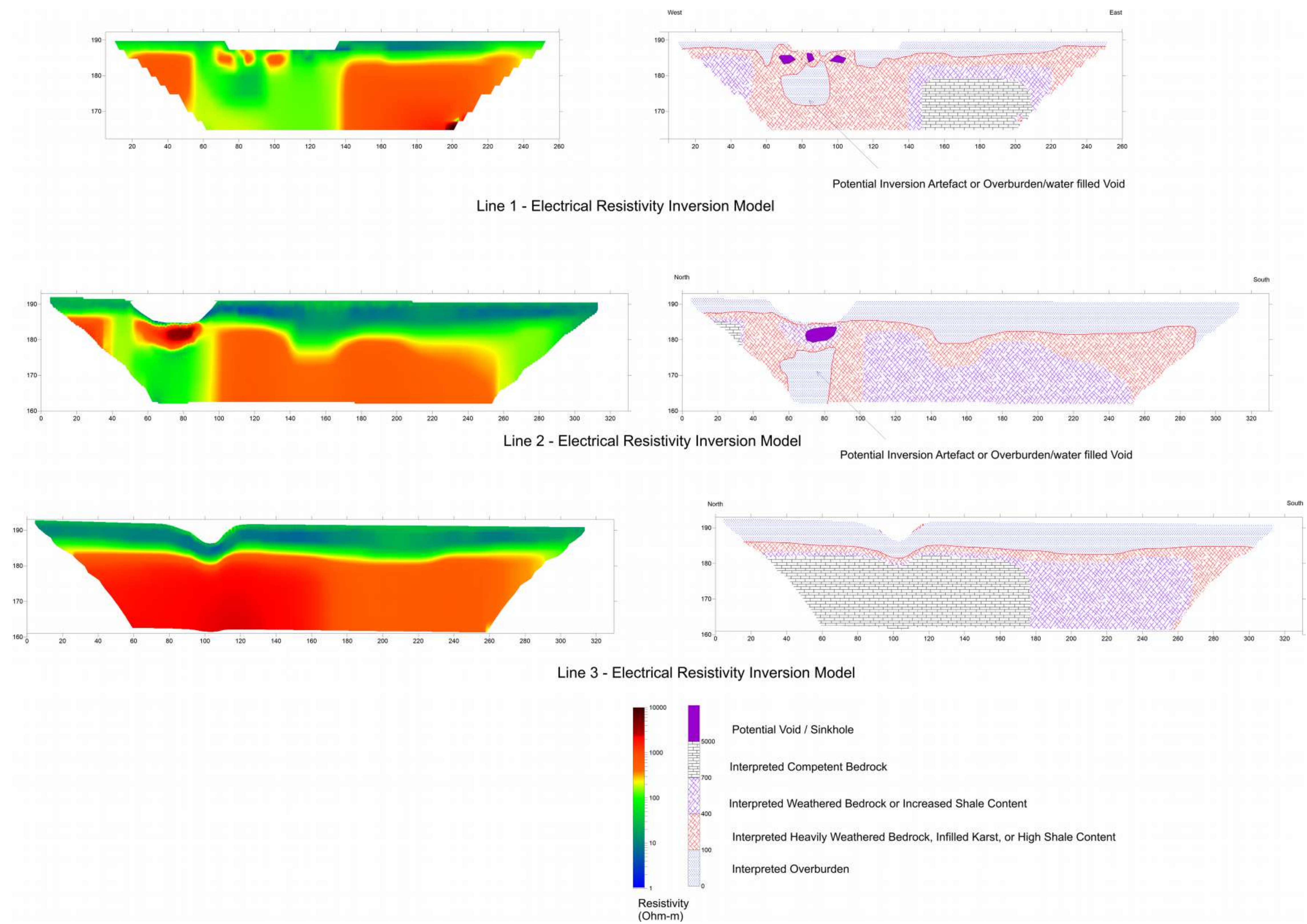

Figure 4: ERT Inversion and Interpreted Geologic Models

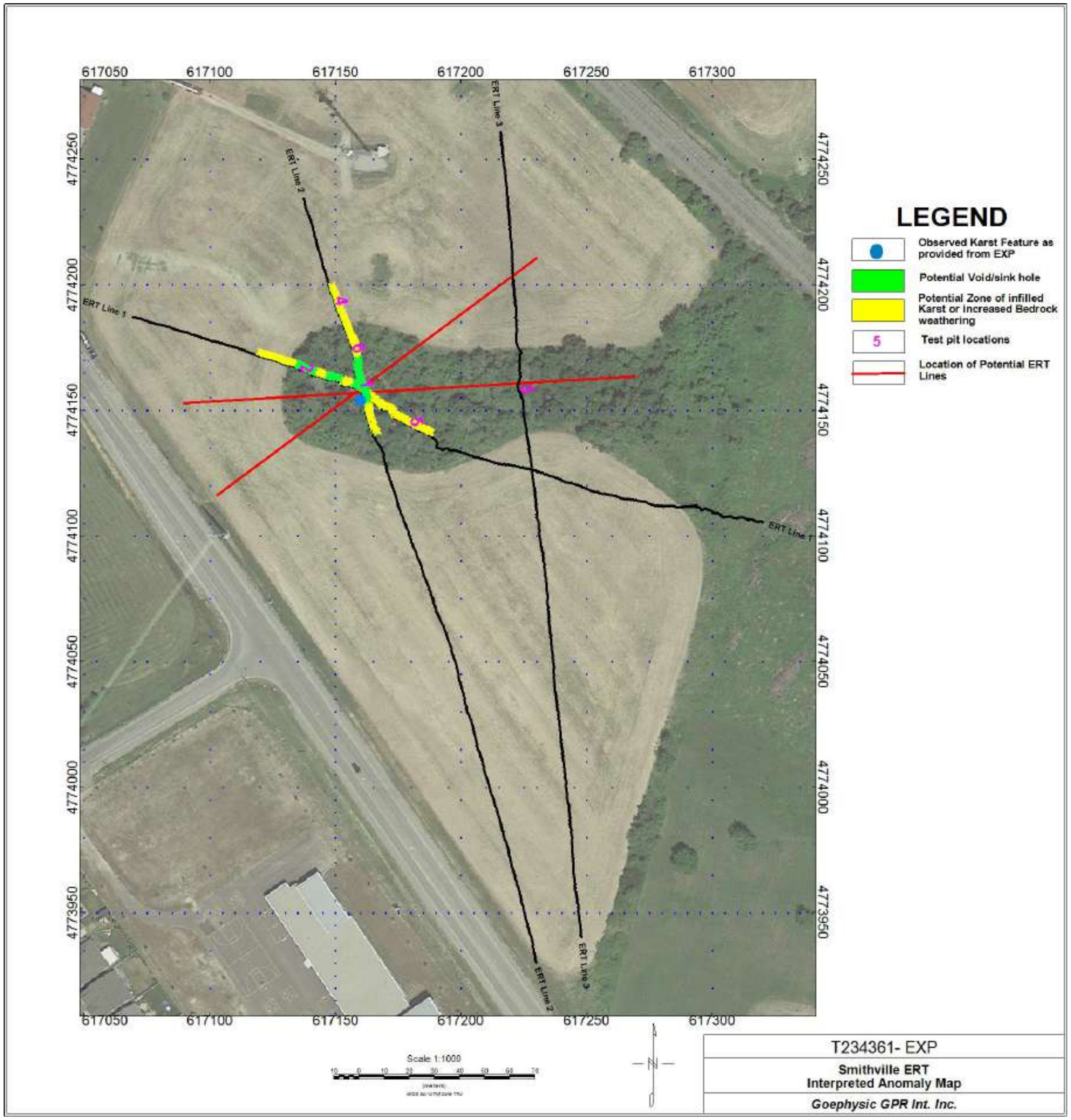

Figure 5: Plan view interpreted anomaly map

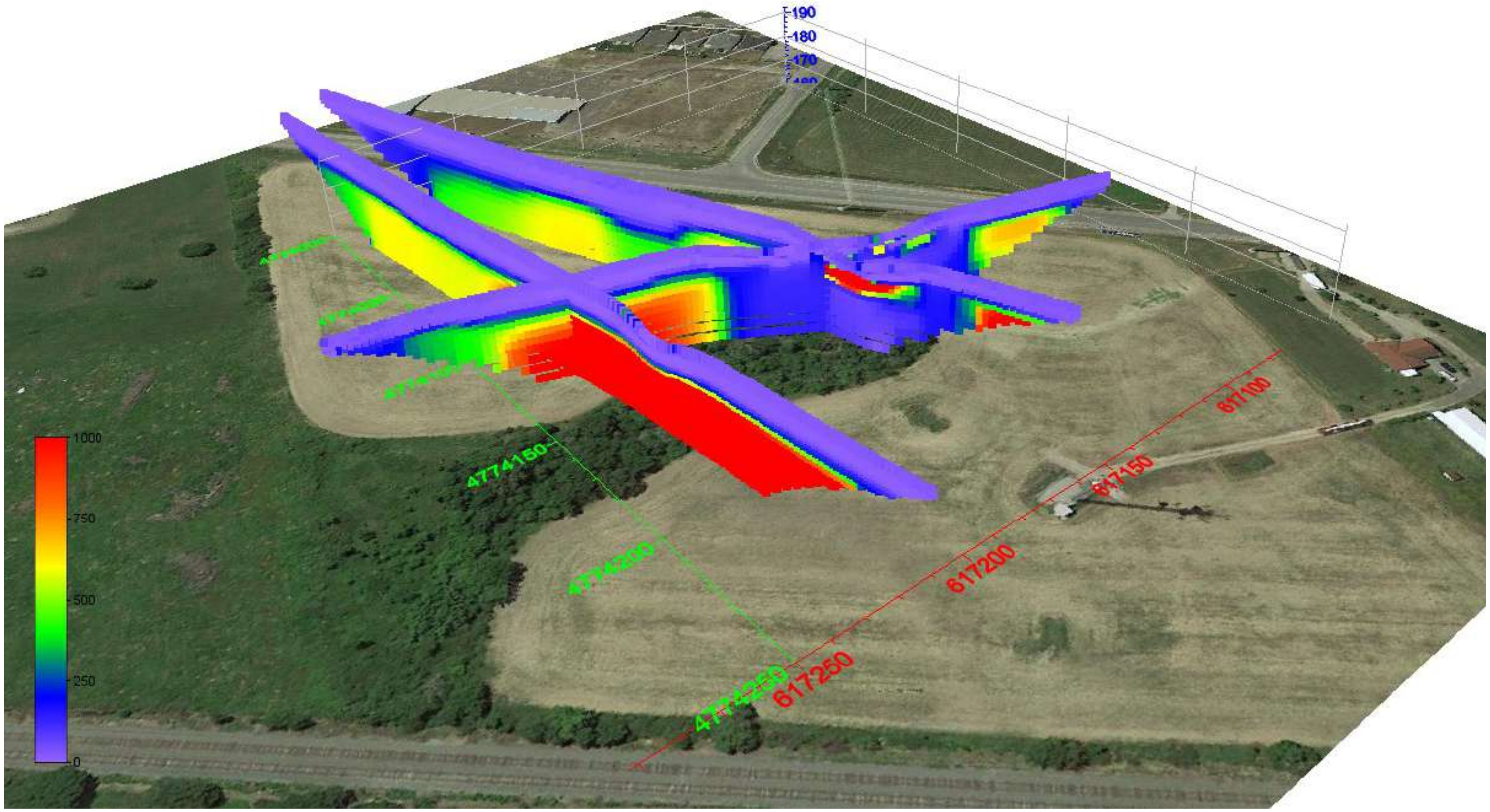

Figure 6: 3D ERT Data sets, looking southwest

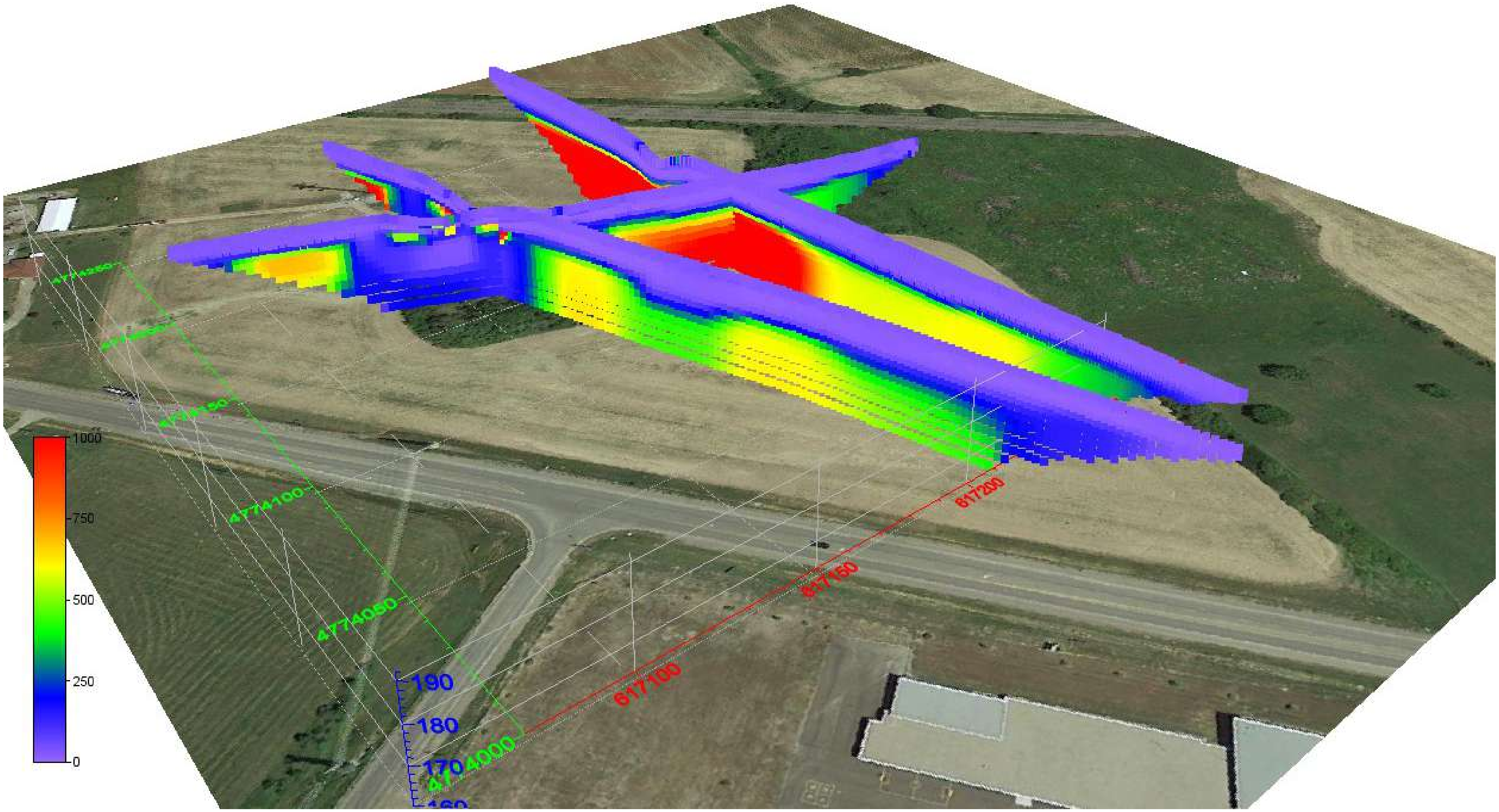

Figure 7: 3D ERT, looking northeast

4 CONCLUSIONS & RECOMMENDATIONS

Geophysics GPR International Inc. (GPR) was requested by EXP to carry out a geophysical survey within an area bounded by HWY 20, S Grimsby Rd Six and railway tracks in Smithville, Ontario (Figure 1).

The aim of the investigation was to map potential karst features that may be present within the surveyed area based on observed surficial features.

Geophysical mapping of karst features is not a straight-forward endeavour as there is not an ideal individual methodology that can be employed to fully investigate a project site given the desired site coverage, resolution, target size and realistic budget limitations. With that said, the geologic conditions at this particular site appear well suited to the ERT methodology.

ERT data were collected along three profiles. Based on the ERT data, several distinct low resistivity zones extending to depths are noted. These low resistivity zones can be indicative of zones of increased bedrock weathering, fractures, or infilled karst features. As noted above, these zones are based on the relative resistivity values when compared to the variation across the site.

Anomalies are also noted at the edges of the profiles, but these zones are typically lower in confidence and subject to modelling limitations.

The results of this report are based on interpreted, non-intrusive geophysical data without borehole or corroborating evidence. Ground truthing is required to reveal the true nature of the interpreted features. The geophysical method employed for this survey provides no measurement of material strength or competence.

Further testing is recommended to provide additional insights into the degree of weathering of the bedrock and lateral extents of the interpreted anomalous zones. Further testing could include additional ERT profiles or seismic refraction measurements along with intrusive geotechnical borehole or test-pit data. Two potential ERT options are presented in the anomaly map if the Karst feature is to be mapped in more detail. Seismic refraction is ideal for determining the competence and degree of weathering along the rock surface over 70 to 100m lengths. Test-pits will provide information on the degree of weathering and fracturing along the rock surface at point locations. Borehole information is ideal for determining the rock quality at a point location at depth.

Coordinates for suggested intrusive testing based on the results of the geophysical survey are provided in the table below. These locations do not target all detected anomalies merely a sampling of the instrument responses. The results of the testing can be used to further refine the geophysical interpretation. Additional testing, based on recommendations of the geotechnical design engineer, may also be required. These locations do not consider the logistics of site access, drilling requirements, clearances etc.

Seismic refraction profiles could also be collected at various locations across the site. Two to three hundred metres of profiles could be collected in one day to give rock velocity and rock competence information. Seismic methods could also be used to determine seismic site class for building code requirements.

Table 4: Suggested intrusive test locations

Proposed Test ID	Easting	Northing	Resistivity	Comment
#1	617160	4774160	Very High	Potential void/sinkhole, near surface and at depth (Void/sinkhole observed on Line 2)
#2	617136.5	4774166	High	Potential void observed on Line 1 near chainage 70 m
#3	617224	4774158	High	Suspected competent rock
#4	617150	4774193	Low	Suspected weathered rock
#5	617180	4774145	Low	Suspected weathered rock (On Line 1)
#6	617156.9	4774174.13	High	Suspected weather rock (Test pit selected around chainage 65 m)

The Interpretation and reporting was performed by Duro Zeljkovic, GIT and reviewed by Carolyn Boone, P.Geo.

Carolyn Boone, P.Geo
Geophysicist

PROFESSIONAL GEOSCIENTIST
23/10/05
CAROLYN R. BOONE
PRACTISING MEMBER
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ONTARIO

APPENDIX A

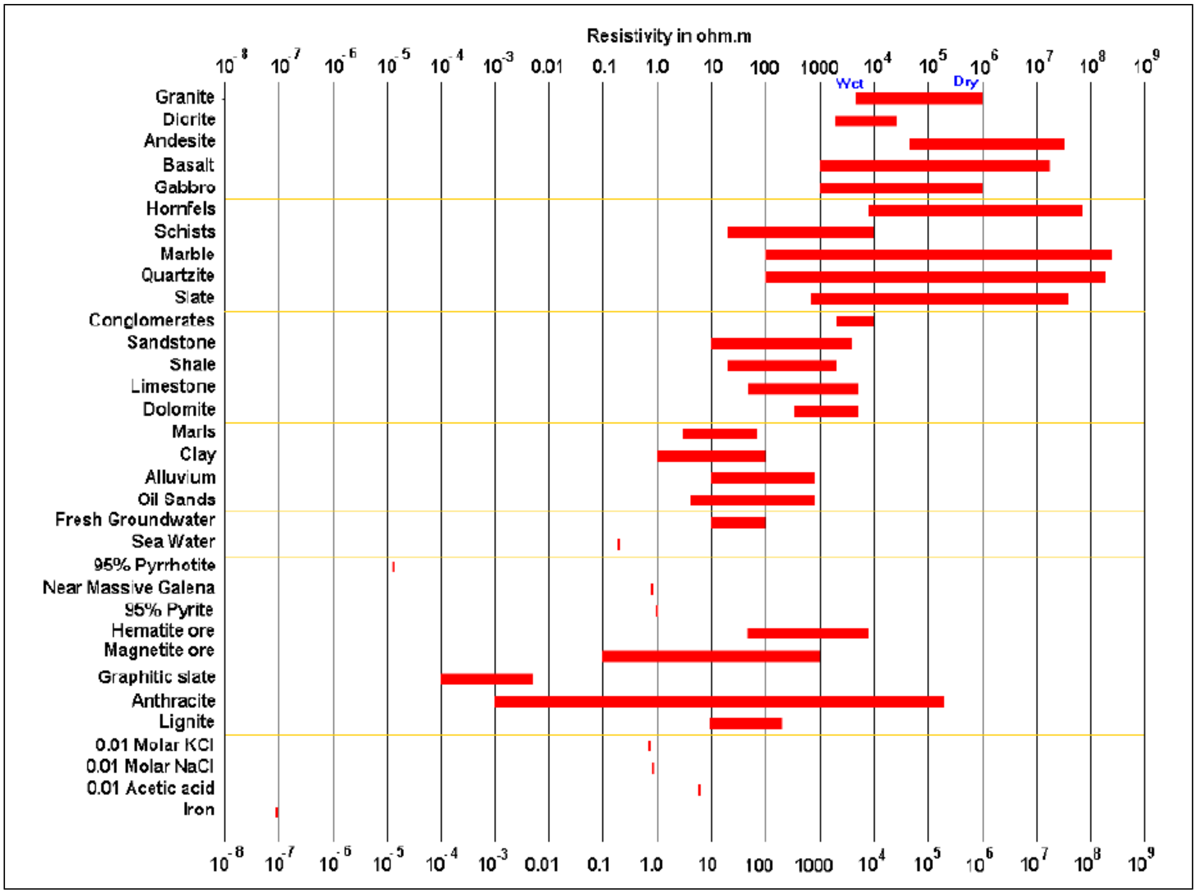
Equipment and Methodology Fact Sheets

Terrameter LUND Imaging System

Automatic System for Resistivity and IP Imaging

Terrameter LS is a world leading resistivity instrument that offers high quality data. The instrument can be used for several applications and is developed to be useful for universities, contractors/consultants, governments and aid organisations. As the Terrameter LS concept is modular it offers individually tailored solutions to meet each clients specific needs.

ABEM Terrameter LUND Imaging System - designed for optimum versatility in infrastructure projects and environmental studies.	Automated roll-along capability for 2D and 3D surveys
Built-in quality control and feedback to operator	High productivity rate thanks to speed-optimized software



Resistivity in ohm.m
10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 0.01 0.1 1.0 10 100 1000 10^4 10^5 10^6 10^7 10^8 10^9
Wet
Dry
Granite
Diorite
Andesite
Basalt
Gabbro
Hornfels
Schists
Marble
Quartzite
Slate
Conglomerates
Sandstone
Shale
Limestone
Dolomite
Marls
Clay
Alluvium
Oil Sands
Fresh Groundwater
Sea Water
95% Pyrrhotite
Near Massive Galena
95% Pyrite
Hematite ore
Magnetite ore
Graphitic slate
Anthracite
Lignite
0.01 Molar KCl
0.01 Molar NaCl
0.01 Acetic acid
Iron

APPENDIX B

ERT Inversion Modelling Results

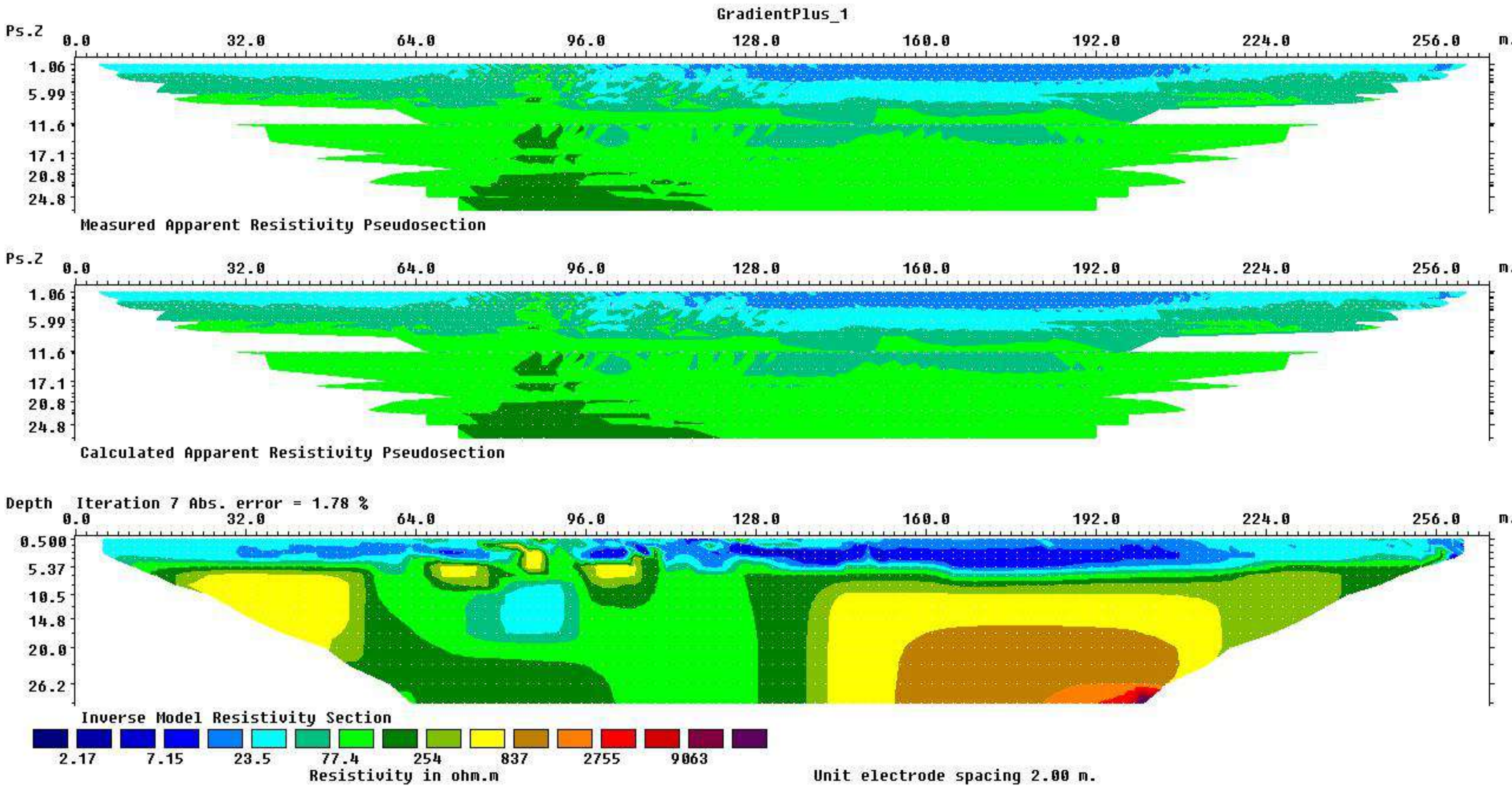


Figure 8: Line 1 - ERT Raw data and Inversion model

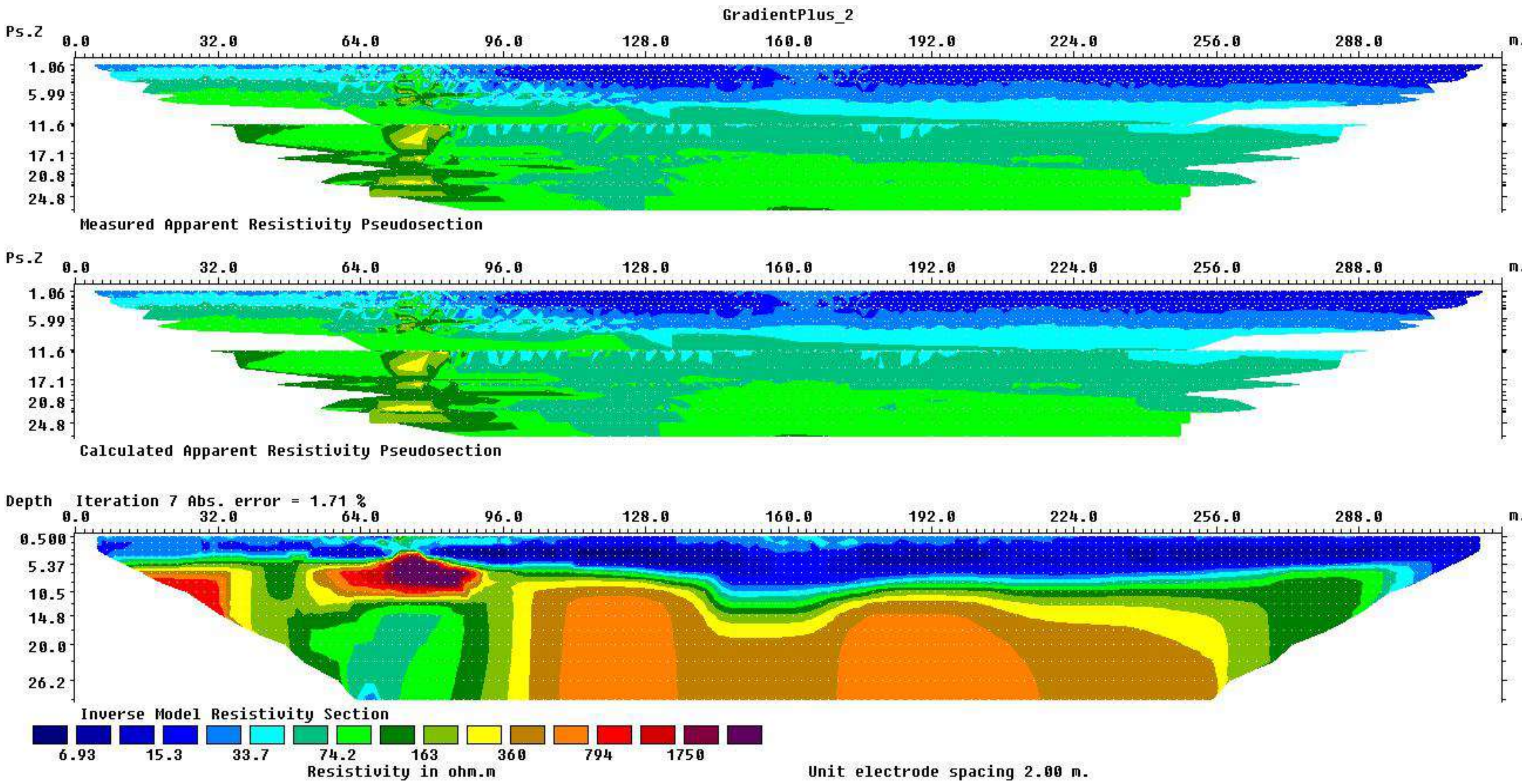


Figure 9: Line 2 - ERT Raw data and Inversion model

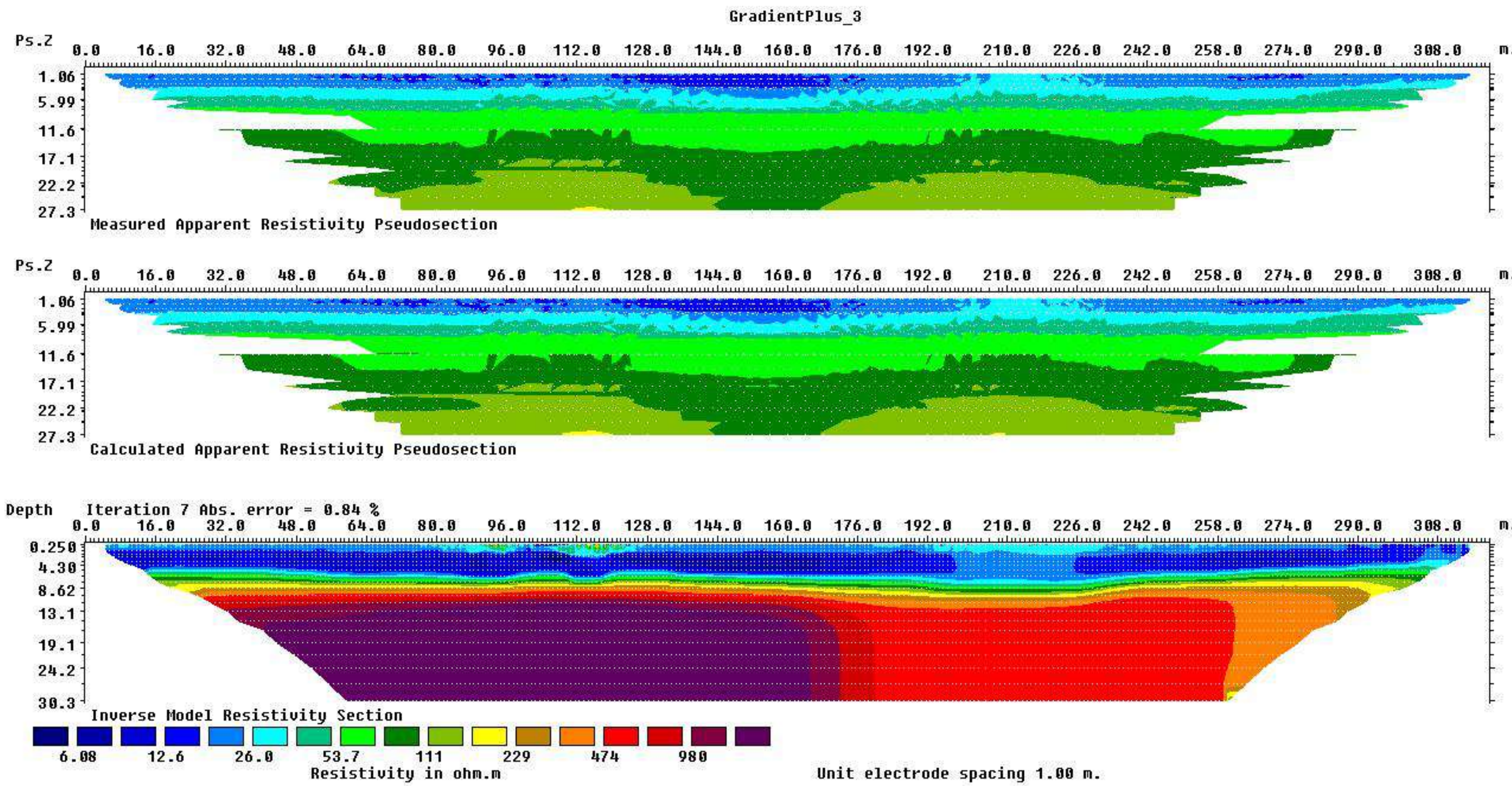
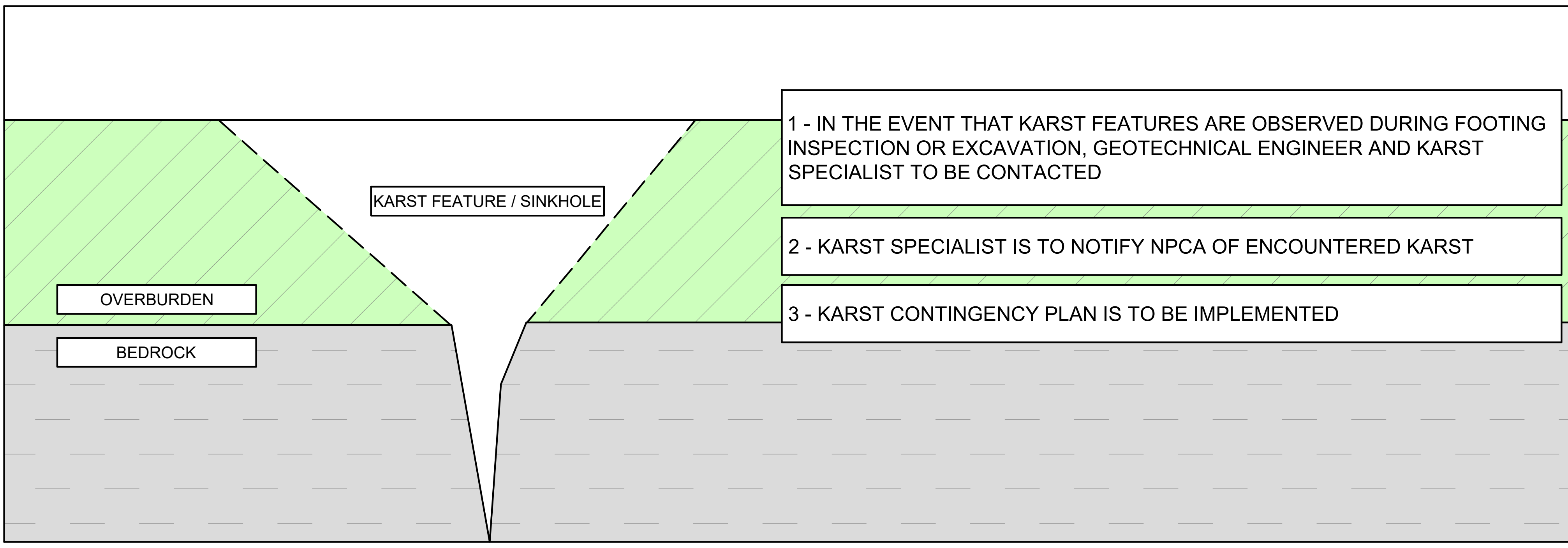


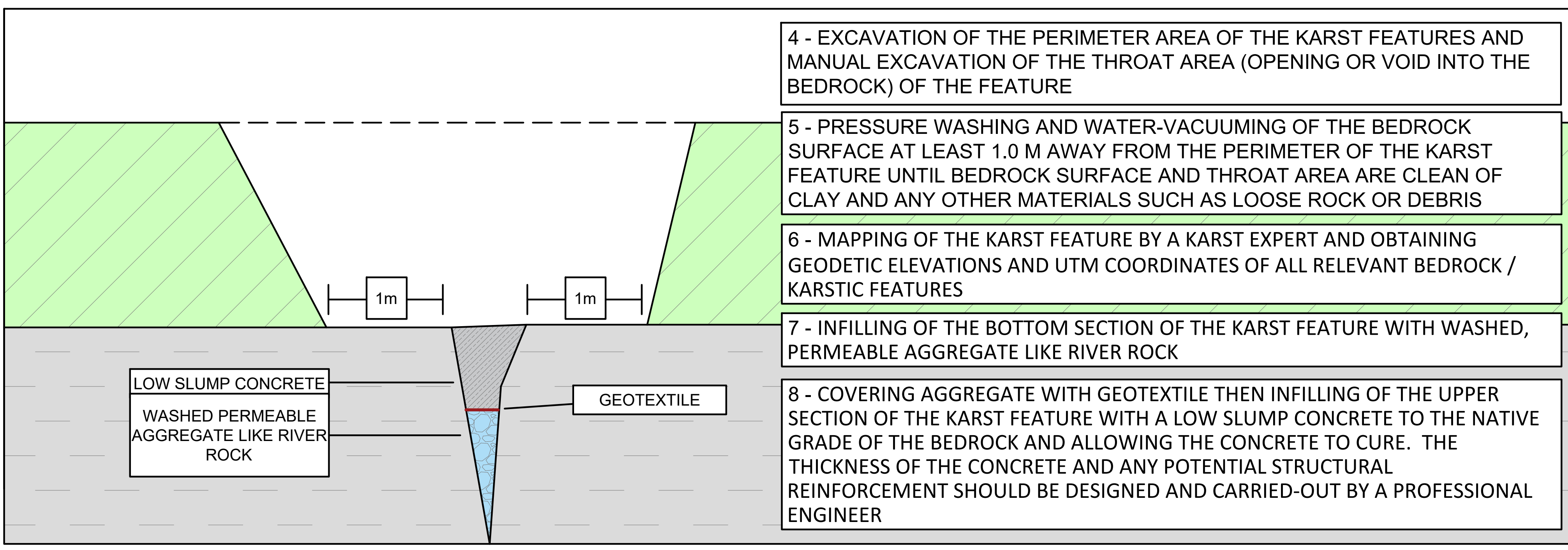
Figure 10: Line 3 - ERT Raw data and Inversion model

Appendix F – Karst Contingency Plan

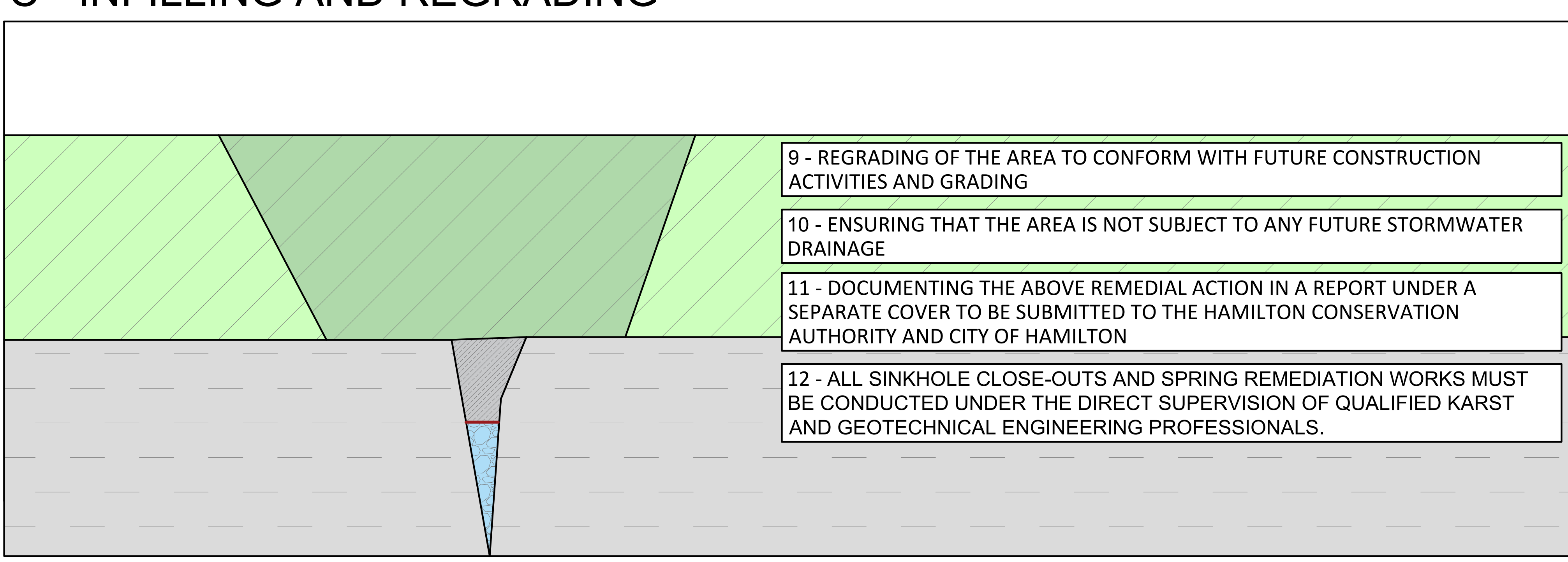
A - IDENTIFIED KARST



B - KARST EXCAVATION AND CLEANING



C - INFILLING AND REGRADING



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PROJECT NO.:

GTR-22015175-C1

TITLE AND LOCATION:

KARST CONTINGENCY PLAN

HIGHWAY 20 & WEST STREET, SMITHVILLE, ONTARIO

DATE:

OCTOBER 4, 2023

Appendix G – Additional Potential Karst Features