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To: Ministry of Transportation, Ontario      Date: October 4, 2023

Attn: Minkyung Kwak, P.Eng.,      File: 39323  
Tony Sangiuliano, P.Eng.

From Mark Popik, M.Eng., P.Eng.

Reviewer: P.K. Chatterji, Ph.D., P.Eng.

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**HIGHWAY 400 VOID DETECTION MEMORANDUM  
NORTH OF 5<sup>TH</sup> LINE INTERCHANGE  
BRADFORD, ONTARIO, CENTRAL REGION  
RETAINER ASSIGNMENT NO. 2020-E-0049, ASSIGNMENT NO. 8**

Thurber Engineering Ltd (Thurber) was retained by the Ontario Ministry of Transportation (MTO) to complete an investigation to detect the potential for subsurface voids on Highway 400 northbound (NB) and southbound (SB) platforms, north of 5<sup>th</sup> Line interchange in Bradford, Ontario. The investigation to detect void potential was completed using Ground Penetrating Radar (GPR) survey equipment. The entire highway platform was surveyed in both directions, as permitted by traffic control restrictions. The GPR equipment was used to determine potential void development along the culvert crossing, with an estimation of size, and location should potential voids be identified. This memorandum presents the findings of the completed GPR survey.

It is a condition of this memorandum that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

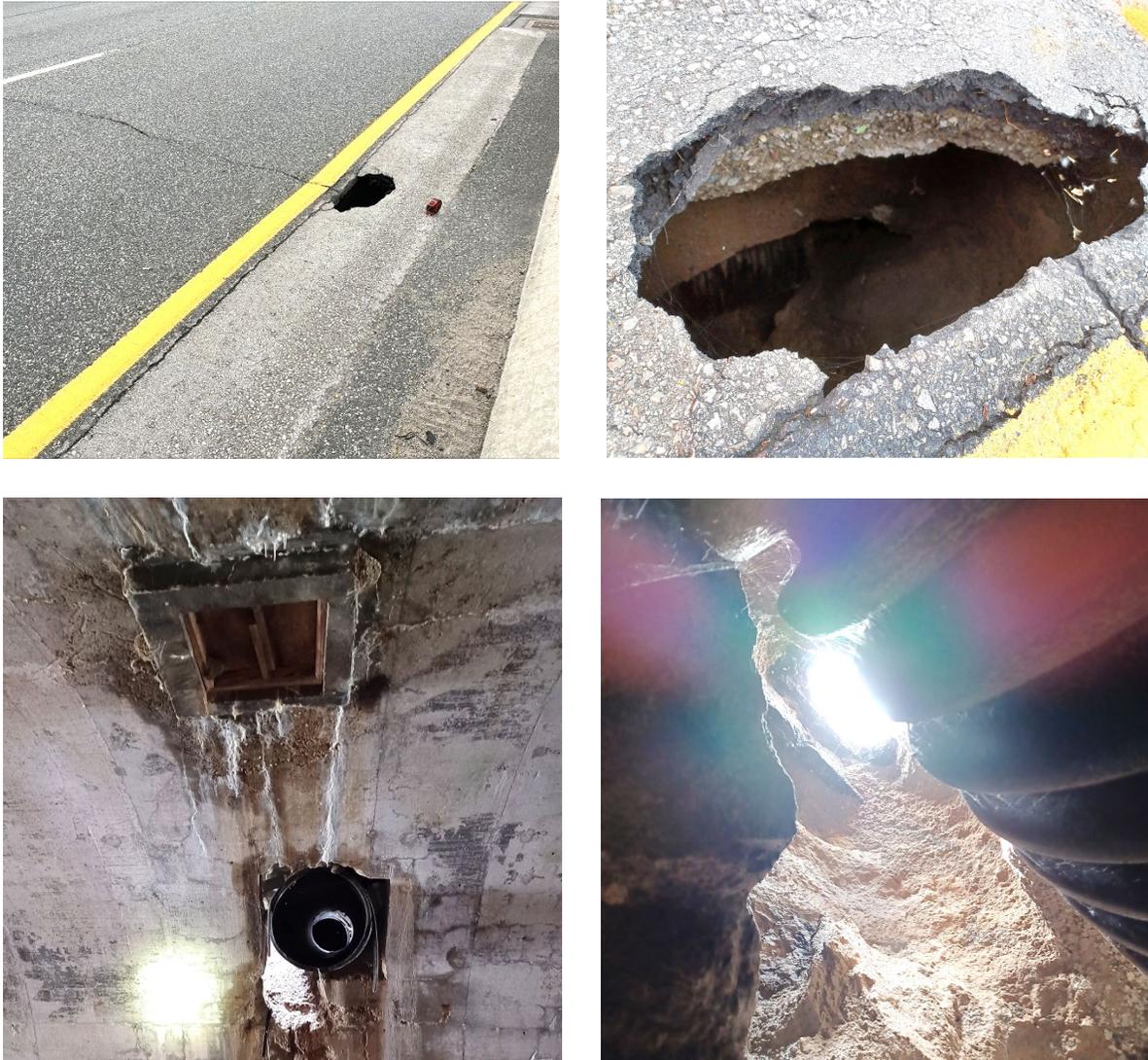
## **1. BACKGROUND**

It is understood that a sinkhole was observed in the southbound left (median) lane and shoulder on Highway 400, approximately 360 m north of 5<sup>th</sup> Line on August 7, 2023. Further examination of the sinkhole indicated that this sinkhole formed directly above an existing arch culvert (Culvert #30-400/C) carrying sucker creek under Highway 400, where a storm sewer pipe was connected to the culvert without sealing the perimeter of the pipe. Over the years, backfill and granular material continued to migrate through the opening around the sewer pipe and into the culvert, creating a large cavity that extended to the pavement surface.



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The sinkhole was subsequently repaired on August 9, 2023, with the patching of the sewer pipe and filling of the void with unshrinkable fill (U-fill) material. Photographs of the surface void, void cavity, and culvert connection within the sinkhole area are provided in Figure 1.1.



***Figure 1.1: Void Cavity Beneath Highway 400 SB Inside Shoulder***

Based on the discovery of the void cavity, the Ministry retained the services of Thurber to complete a GPR survey across the entire Highway 400 pavement platform to assess whether additional subsurface voids could be detected. The GPR survey was completed using a 500 MHz antenna, manufactured by Sensors & Software and owned and operated by Thurber. The collected data was analyzed by Thurber staff, with results highlighted in the following section.

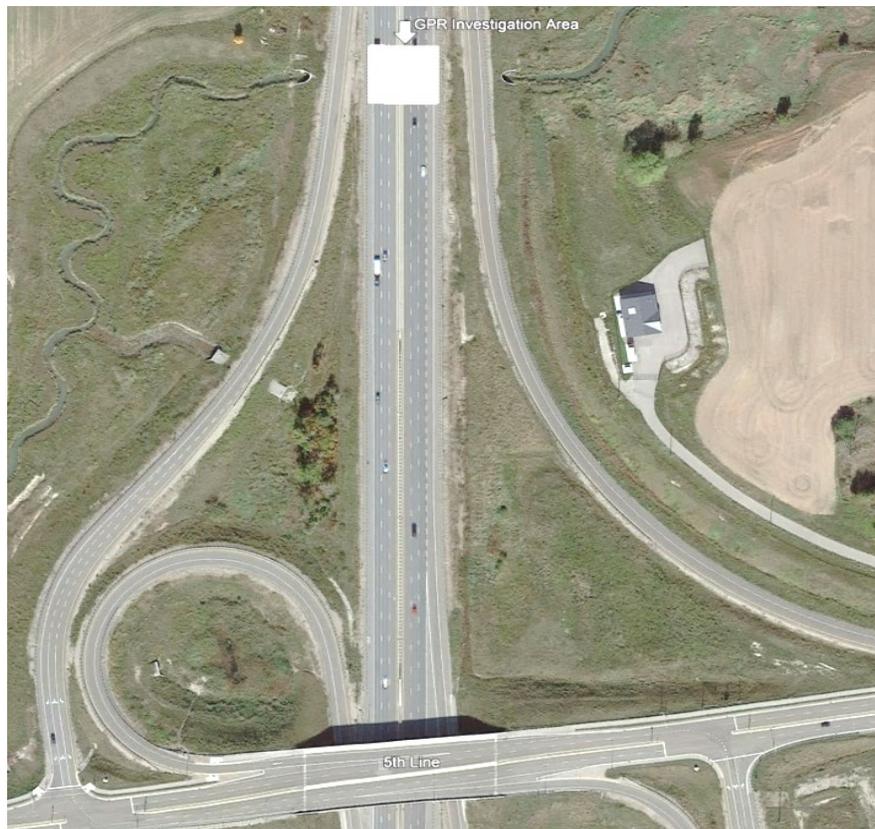


## 2. SURVEY METHODOLOGY

The GPR survey was completed August 27 to 30, 2023, using a Noggin 500 MHz antenna, supported by a manually operated SmartCart system. The GPR survey was completed in a grid pattern with individual scans on 500 mm intervals. The GPR grid survey was completed after filling of the sinkhole and extended across the highway platform (NB and SB lanes and shoulders) along the length of the arch-culvert, with the scanning extending approximately 15 m north and south of the culvert edges. The grid scanning commenced 0.5 m from the concrete barrier in the median and extended across the highway platform and ended 0.5 m from the guardrails at the edge of the outside shoulders. In consideration of the large area to be scanned, the scan area was divided into four (4) individual grid scans, completed under separate traffic control closures.

The individual grid scans collected as part of the GPR survey were combined and analyzed to assess the potential for voids (or anomalies) beneath the paved surface. A series of depth images are provided Appendix A, while the results of an individual line scan analysis in areas of interest are provided in Appendix B.

A photograph of the investigated area is provided in the figure below.



**Figure 2.1: GPR Survey investigation Area**



### 3. RESULTS OF GPR ANALYSIS

The GPR grid scans were compiled and analyzed to assess subsurface conditions. The results of the GPR analysis provides a series of colour contour images that can slice through the pavement and backfill structure. The colour contours indicate areas with varying material dielectric constant, which is a direct correlation to material densities and/or moisture conditions. Areas within the colour contours with similar colours (mainly blue) indicate consistent conditions, while areas with yellow to red colours may indicate areas with different densities or the potential for subsurface anomalies. Without field verification, it is not possible to identify the type or cause of the anomalies; however, these results can be used to develop a verification plan for further exploration.

The results of the GPR grid scan provide a comparison of subsurface conditions in a series of images up to the scan depths. These images are generally on 50 mm depth increments, with a select sample of images provided in Appendix A. The initial GPR image at depths between 150 to 200 mm should be positioned within the existing asphalt; therefore, most of the scanned area is a relatively consistent blue colour, with only slight variation along longitudinal joints where reduce asphalt density can be anticipated.

The total asphalt thickness for this section of Highway 400 is expected to vary from 200 to 350 mm; however, as indicated in Area of Interest #2, as much as 400 mm of asphalt in localized areas can be anticipated. The variable asphalt thickness is suspected to be the reason behind many of the yellow to dark red areas within the travel lanes in the images above 450 mm. An area not suspected to be caused by increased asphalt thickness is identified as Area of Interest #1, located along the median barrier wall generally throughout the scan area. In this area, strong signal intensity is observed at a depth of 250 mm, particularly between the catchbasins on both sides of the culvert. With depth, the signal intensity is reduced with the areas concentrated near the catchbasins that dissipate at depths of 0.5 m. This seems to indicate that potential voids or wet conditions may exist in the vicinity of the catchbasins. It is also noted that anomalies are visible in the SB median shoulder in the vicinity of the NB shoulder catchbasin, south of the culvert.

With depth, the areas with thicker asphalt in lanes 2 and 3 (both directions) continue to reduce, with new areas of anomalies develop longitudinally along the edge of the outside travel lane in both directions. These areas start to appear at a depth of 0.5 m, and continue to depths below 0.8 m. These areas of anomalies were identified as Area of Interest #3 and discussed in further detail in the following sections.

Below depths of 1.2 m, the results of the GPR survey did not identifying any large anomaly areas that may be indicative of potential void development within the survey area.



## **4. AREAS OF INTEREST DISCUSSION**

The results of the GPR survey provided in Appendix A identified three (3) areas that yielded unusual contour patterns where a secondary analysis was completed using individual line scans. Images of the line-scan analysis are provided in Appendix B, with the results discussed in the ensuing sections.

### **4.1 Area of Interest #1: Median Shoulders**

The first area of interest was located along the median concrete barrier wall, in both direction of travel. These locations were selected for further analysis because of the strong signal intensity in the SB direction. From the individual line scans, the locations of both catchbasins in the NB median shoulder could be identified, as well as the catchbasin in the SB median shoulder, north of the culvert. In addition to the catchbasin locations, an area of deeper disturbance was identified, which may represent the repair area of the observed sinkhole. Each of these features are noted on the line-scan image.

In comparing the results of the line scans in each direction, the subsurface strata along the NB median shoulder appear to be more consistent (with less irregular signal patterns) than the comparable SB plot. It is the irregular signal pattern along the SB median shoulder that seems to be the zone of observed anomalies in this area, which seems to extend to depths of 1.2 m in the area adjacent to the NB catchbasin south of the culvert.

It is recommended that the anomalies and areas of disturbance along the concrete barrier wall and in the SB shoulder near the NB catchbasin south of the culvert be further investigated and assessed.

### **4.2 Area of Interest #2: Historical Backfill Settlement**

A second area of interest was identified along the edges of the culvert in lanes 2 and 3 in both directions. The results of the GPR analysis indicate anomaly areas in this location with high intensity signals at a depth between 250 and 400 mm. Although the colour contour images appear to indicate an area of possible anomaly in this area, a secondary analysis of the individual line scan indicate the asphalt thickness in this area may be increased as a result of historical settlement of the culvert backfill. The reflection of the GPR signal within the granular base/subbase appear to follow the outline of the arch culvert, which may indicate material movement at the edges of the culvert. The movement of the granular also matches the assumed interface at the bottom of asphalt. With the increase in asphalt thickness and no observed distortions visible, the observed movement of the granular material are assumed to be historical that have since been addressed.



#### **4.3 Area of Interest #3: Potential water in outside of Lane 3.**

The third area of interesting anomalies was located along the edge of the outside travel lane in both directions. In the NB direction, this anomaly zone was located between the outside travel lane and the speed change lane constructed as part of the 5<sup>th</sup> Line interchange, while in the SB direction, the area of interest was located along the outside travel lane and the outside shoulder.

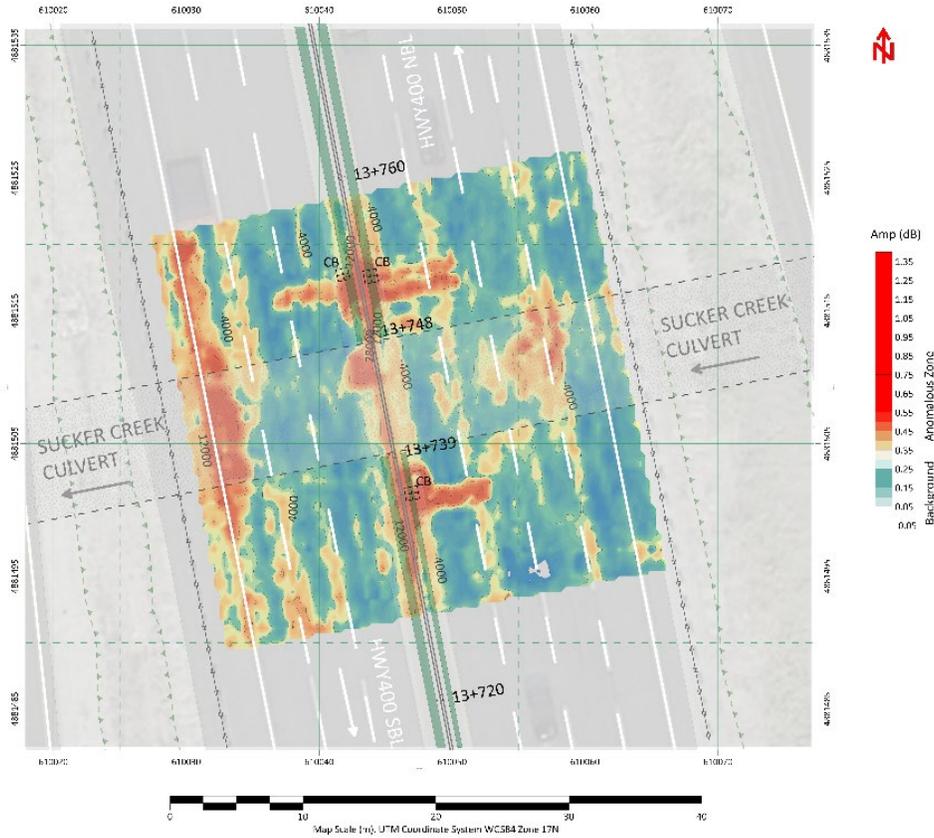
In this area, a strong GPR signal was visible along the outside edges of Lane 3 (in both directions) at a depth ranging from 500 mm to almost 1.0 m. Visual assessment of a transverse line scan indicate an area of disturbance at the pavement edges that do not extend beyond the travel lane. In consideration of the location and the depth of disturbance, it is suspected that this disturbance is not void cavity, but rather associated with increased moisture conditions from impeded subsurface pavement drainage.

Investigations along the Highway 400 corridor have identified several areas where the outside shoulders have reduced pavement thickness, as compared with the outside travel lane; however, boreholes would be required to confirm these conditions exist in this specific area. Although the impeded drainage conditions may lead to premature pavement deterioration in the outside travel lane, the increased moisture conditions would not be related to potential void developed at this culvert location.

### **5. GPR EQUIPMENT VERIFICATION**

In addition to the GPR survey completed by Thurber staff, Geophysics HM Ltd. (GHM) was retained to complete a comparable GPR survey within the same survey area. The GPR survey completed by GHM used two (2) different frequency antennas (300 and 800 MHz) manufactured by GSSI. The combination of these antenna frequencies are expected to improved image scan clarity in the pavement and culvert backfill.

The results of the GPR survey completed by GHM is provided in the figure below, that identify similar results to the areas of interest described above. The only notable difference includes areas of anomalies extending transversely into the travel lane from each of the catchbasin locations. The depth of these anomaly zones are estimated to be near 800 mm, with each of these areas extending partly into Lane 2.



**Figure 5.1: GHM GPR Survey Results**

It is recommended that the survey results of the pavement surface focus in these areas to assess whether any settlement is observed, as a result of potential void development or material densification. Should settlements be verified in these areas, consideration should be given to advancing boreholes to confirm subsurface conditions.

## 6. CLOSURE

In closure, this memorandum outlines the methodology applied in the completion of the GPR survey, with a summary of key areas of interest, with all areas showing a low likelihood of containing any significant voids. It is very important to note that the GPR technology is non-destructive, with the interpretation of the results providing potential areas of anomalies that must be confirmed by further investigation. A more detailed investigation would be required to attempt an assessment for the cause of these disturbances.



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It is also important to note that the GPR survey at this location was completed within 3 weeks of the repair to fill the observed sinkhole. It is understood that subsequent visits by MTO staff to this area observed continued seepage of water into the culvert from the perimeter of the sewer pipe. Furthermore, an inspection of the catchbasins observed water and granular material entering the storm sewer system through failed connections. This loss of material was also confirmed by a CCTV inspection of the storm sewer system, as areas with considerable granular material accumulation were observed. These assessments completed after the GPR indicate that possible void development may be continuing. Consideration should be given to further assessment of these possible void development areas, as well as the development of an appropriate strategy to repair the failed sewer connections that are causing backfill erosion and formation of voids.

We trust the information provided in this memorandum provides the information required at this time. Please let us know if you have any questions or need additional information.

Respectfully Submitted,

**Thurber Engineering Ltd.**

P.K. Chatterji, Ph.D., P.Eng.  
Principal | Senior Geotechnical Engineer

Mark Popik, M.Eng., P.Eng  
Partner | Senior Pavement Engineer

Attachments:

- Statement of Limitation and Conditions
- Appendix A - GPR Results (Depth Slice Images)
- Appendix B – Areas of Interest



## STATEMENT OF LIMITATIONS AND CONDITIONS

### 1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

### 2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

### 3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

### 4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

### 5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

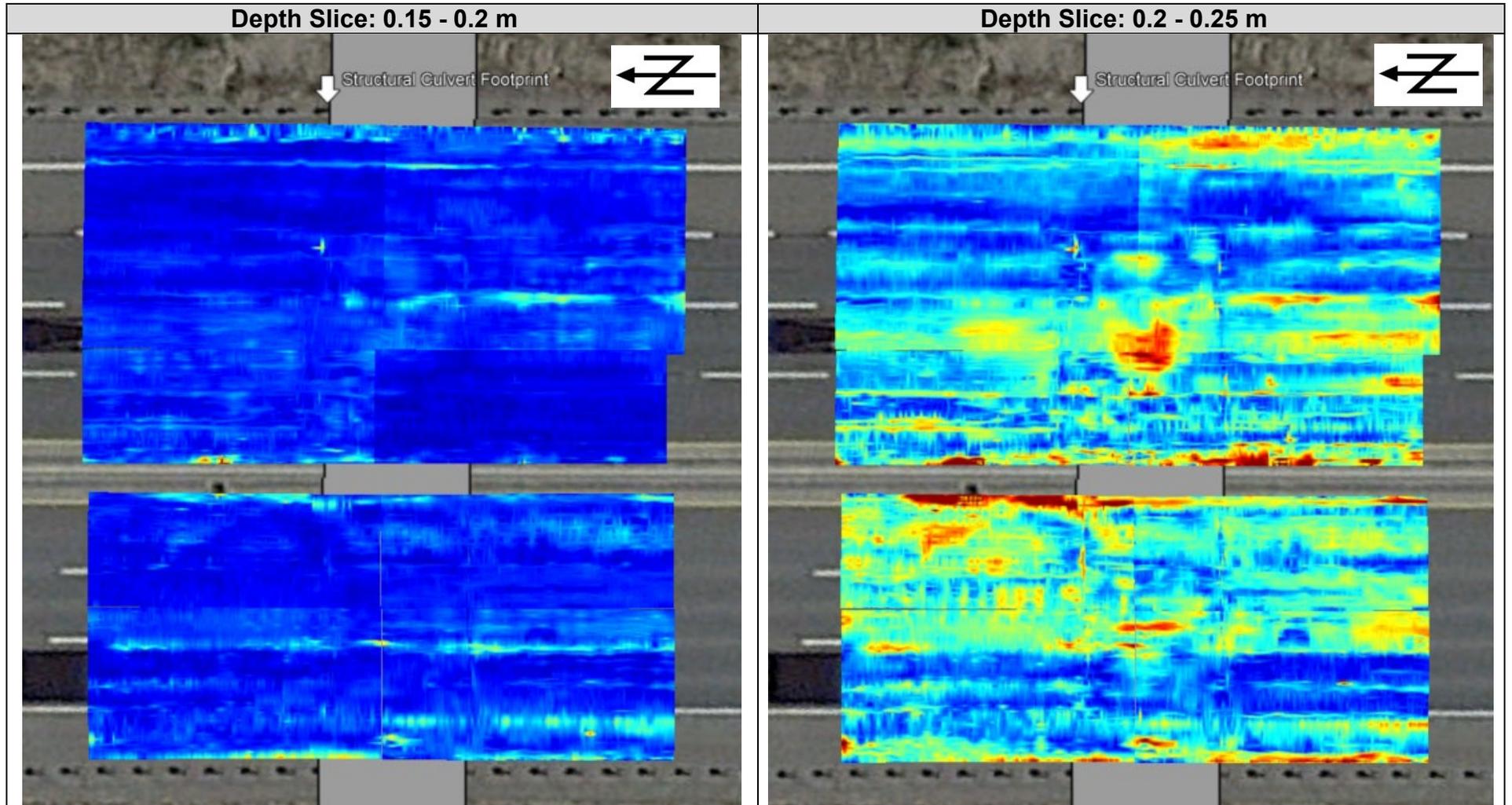
### 6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

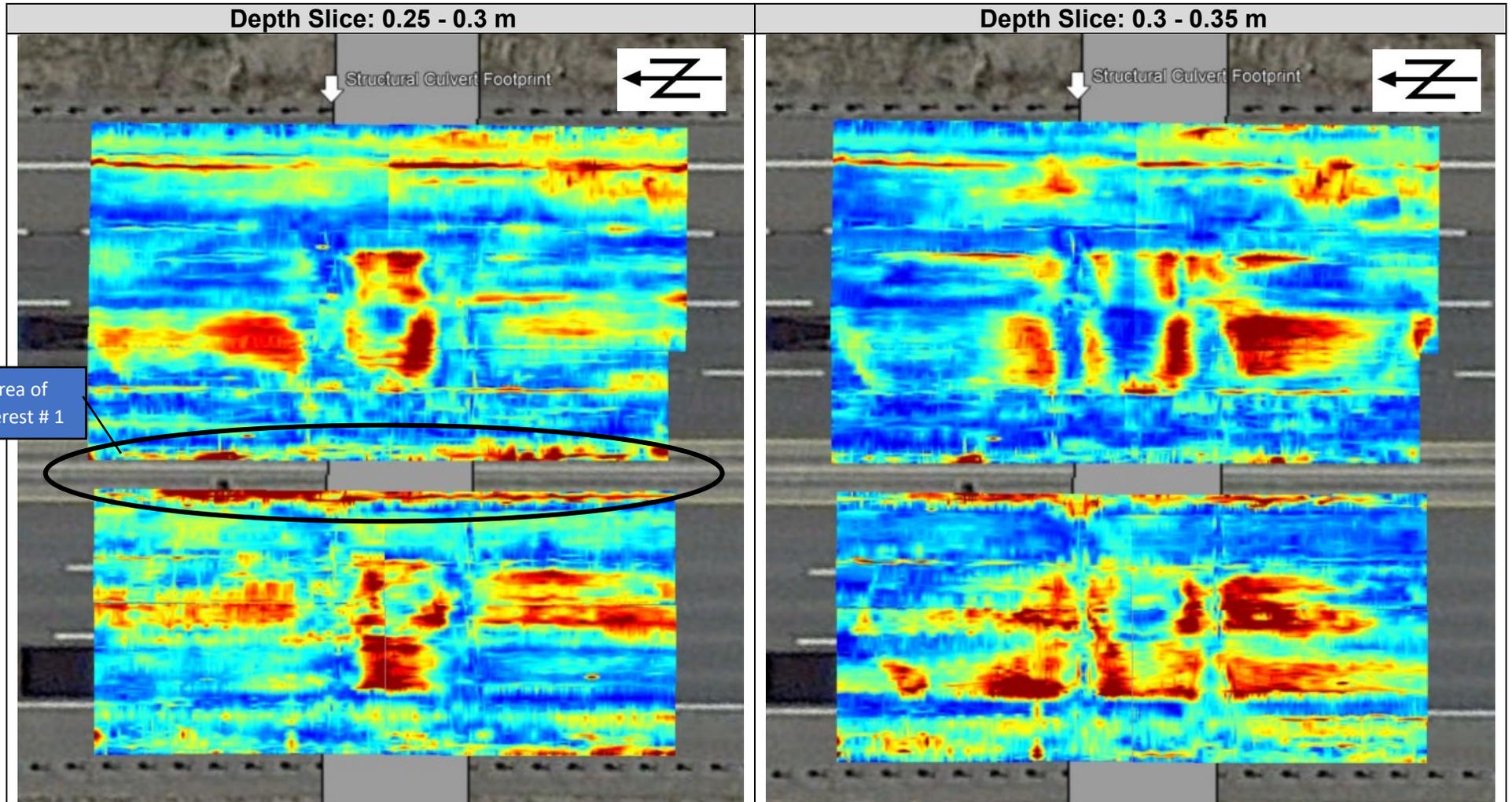
### 7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

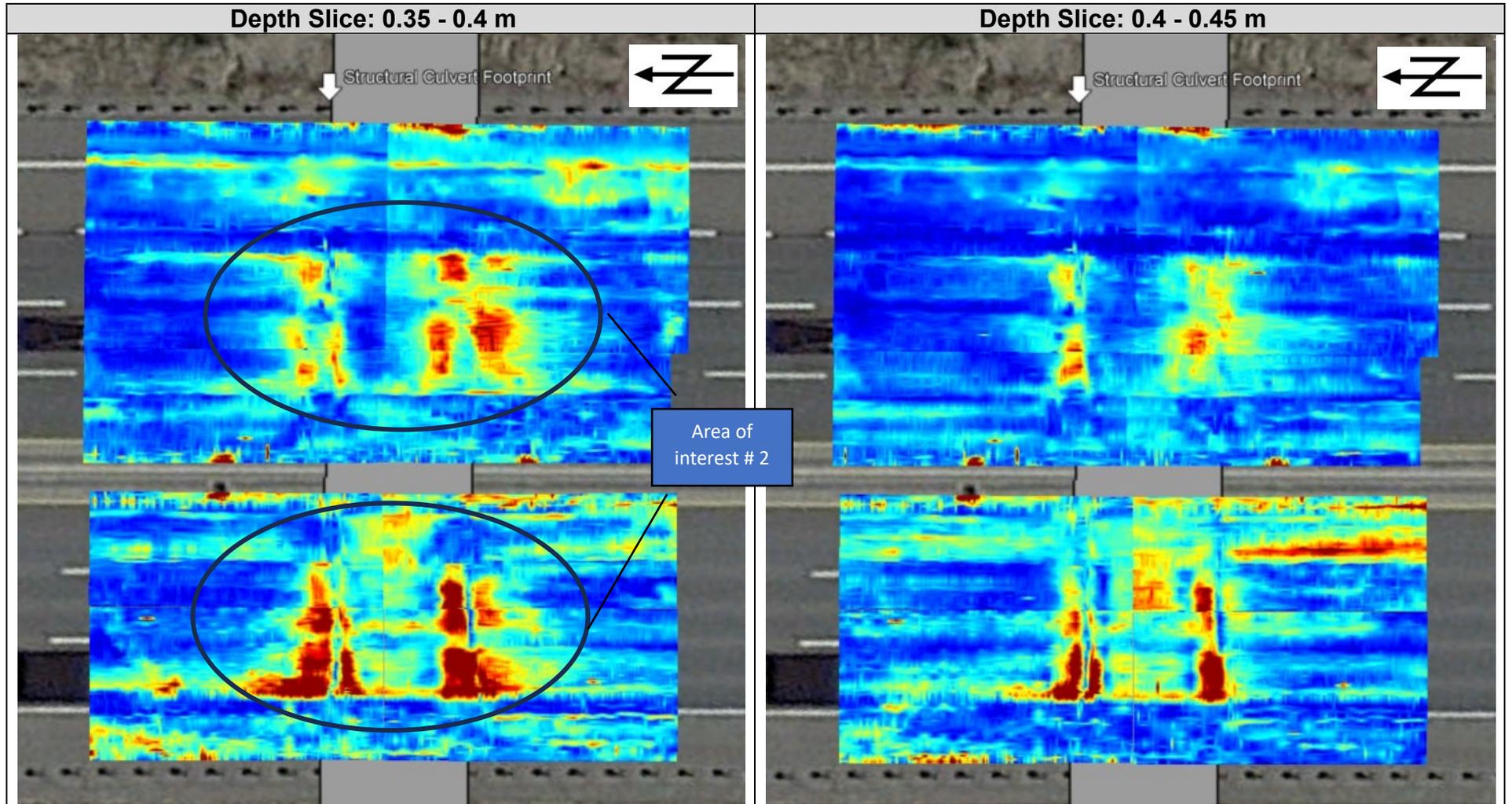
Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection  
Appendix A - GPR Results (Depth Slice Images)



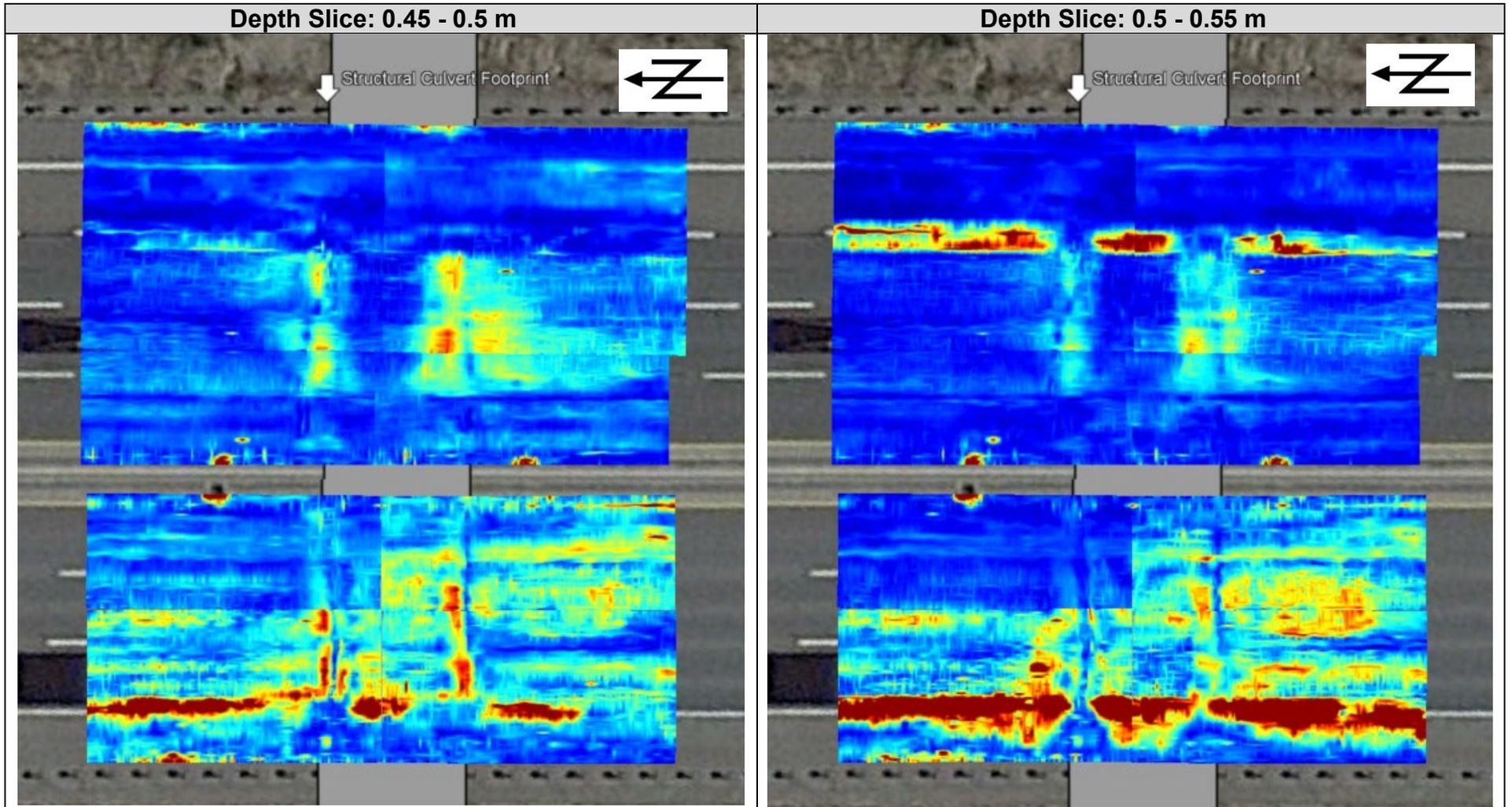
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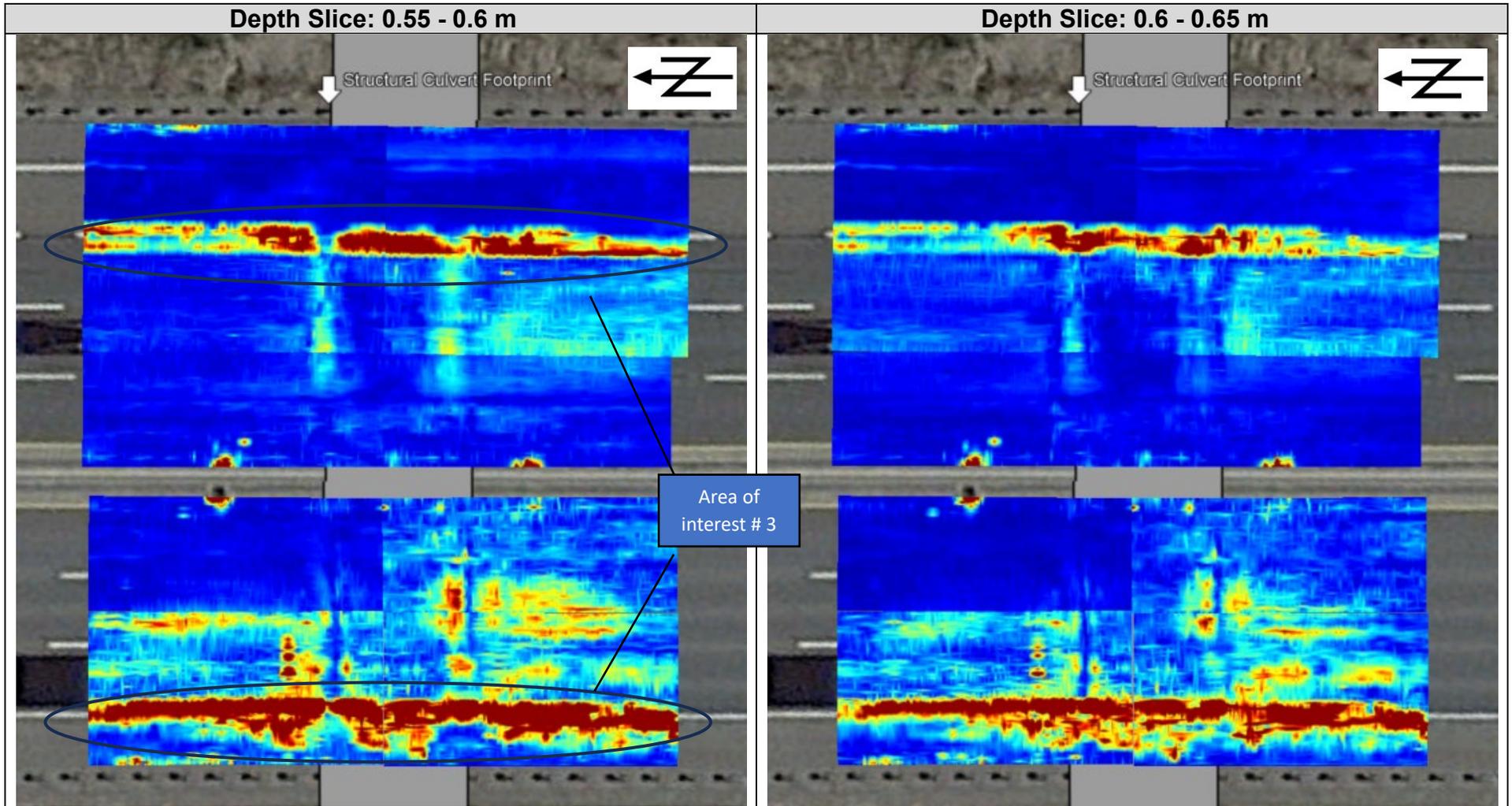
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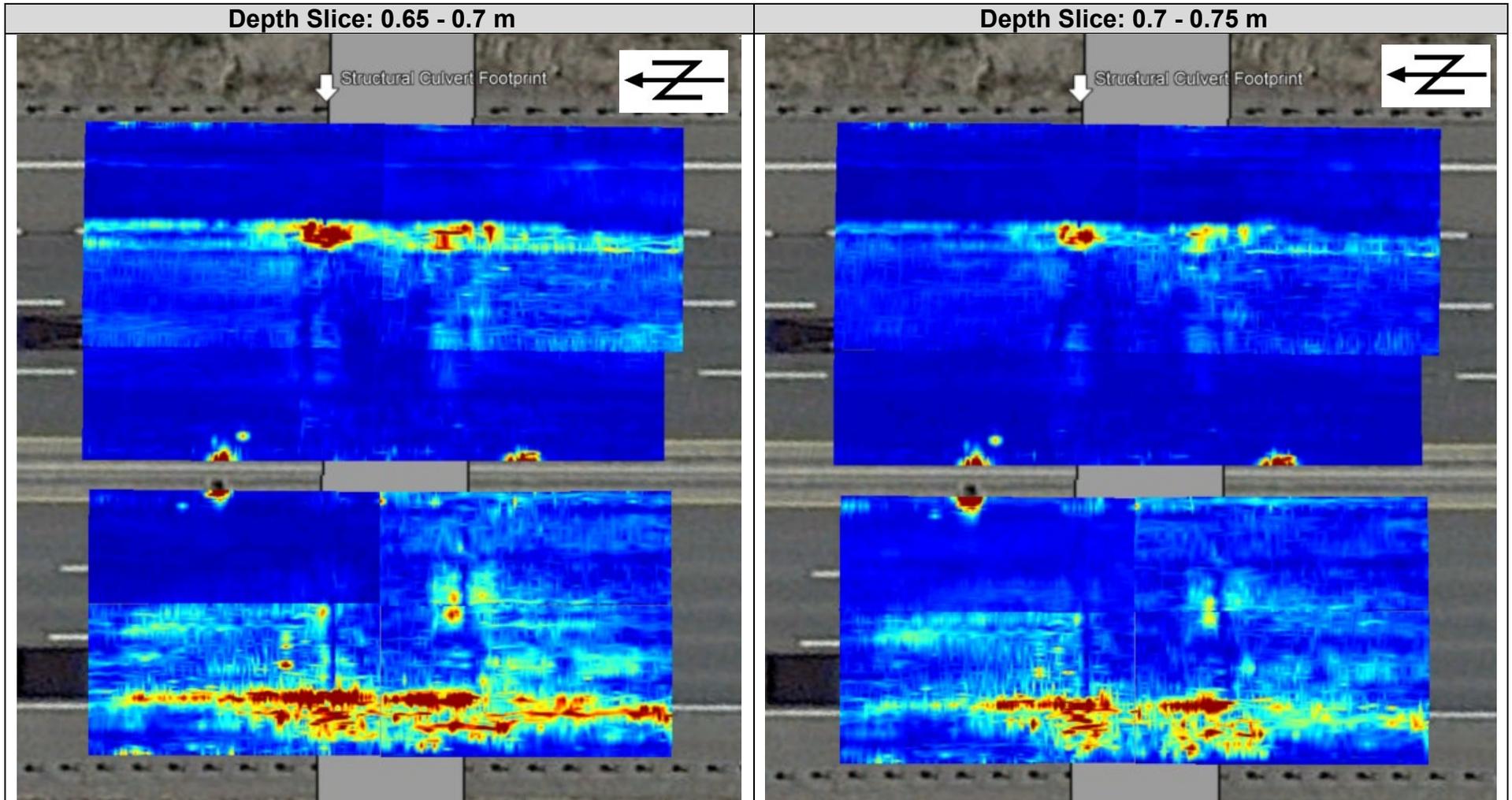
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Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection  
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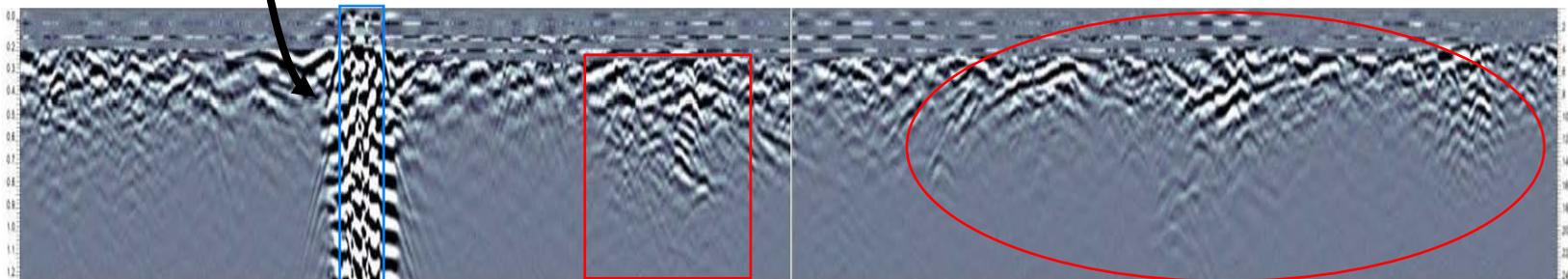
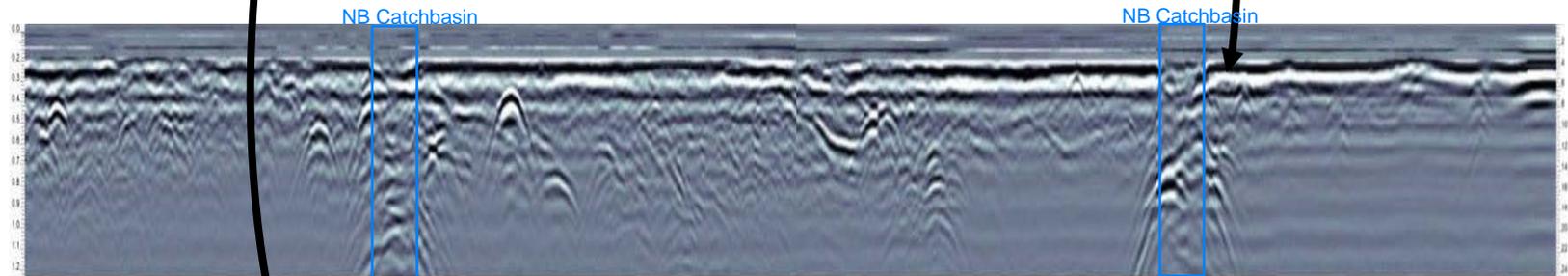
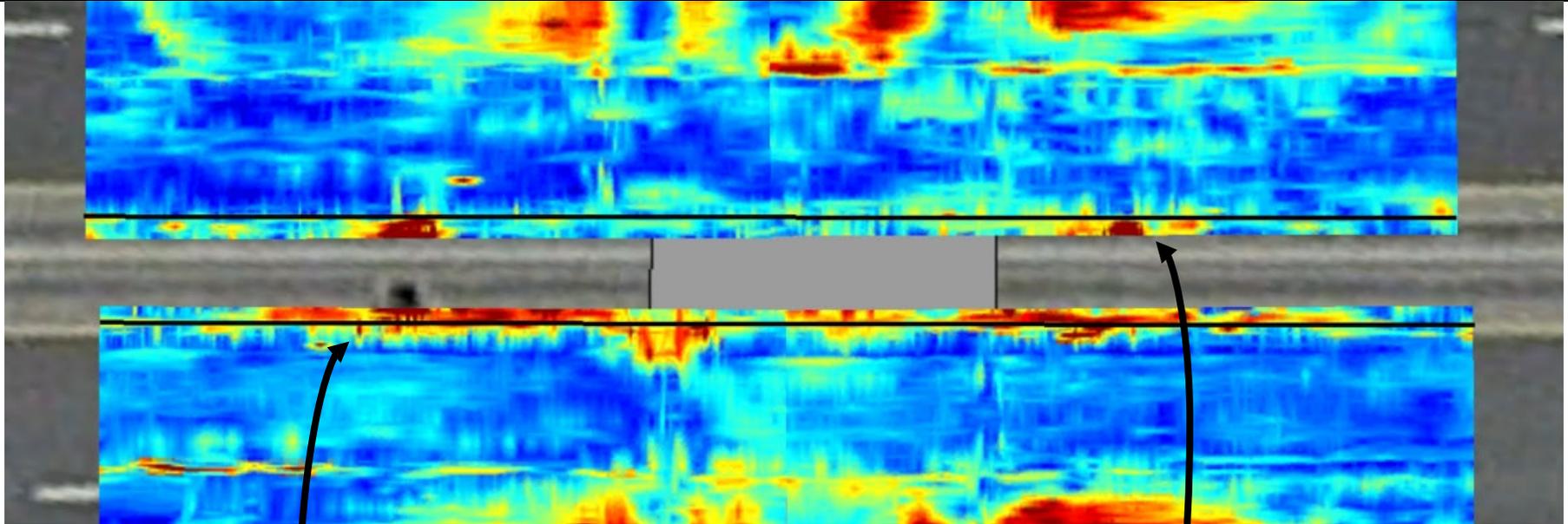


Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection  
Appendix A - GPR Results (Depth Slice Images)



# Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection Appendix B – Areas of Interest

## Area of Interest 1: NB/SB ISH (250 - 300 mm)



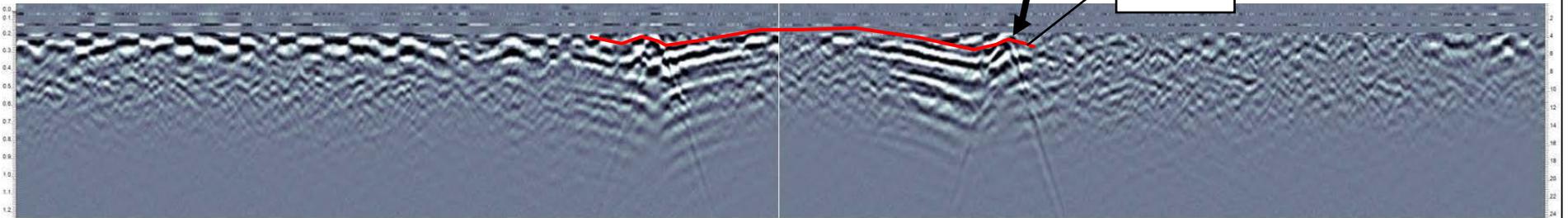
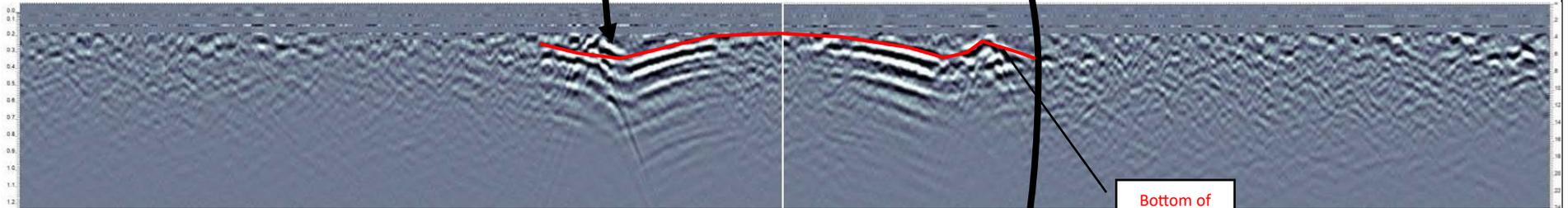
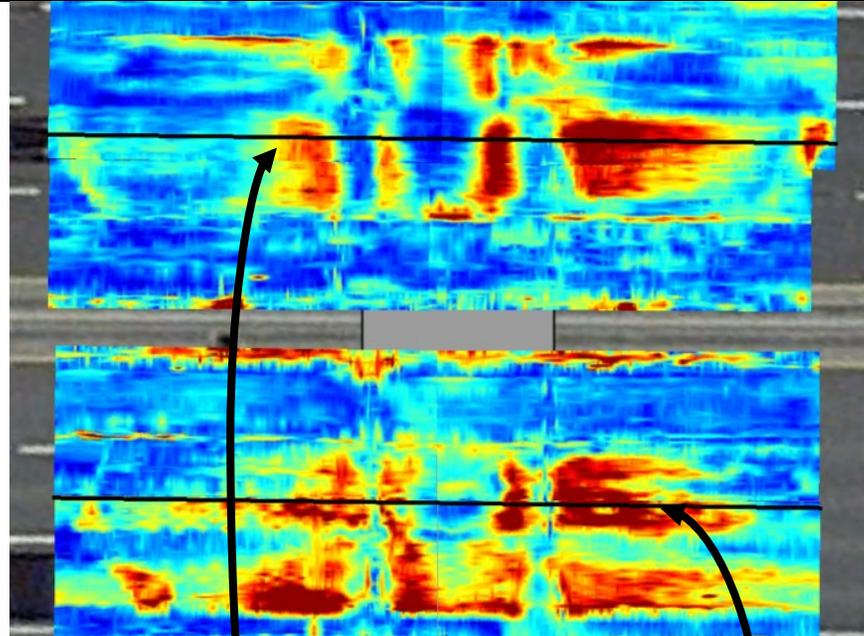
SB Catchbasin

Sinkhole Repair  
Area

Area of Disturbance

# Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection Appendix B – Areas of Interest

## Area of Interest 2: NB/SB Lanes 2 and 3 (300 - 350 mm)



Highway 400 – 5<sup>th</sup> Line Interchange – Void Detection  
Appendix B – Areas of Interest

Area of Interest 3: NB/SB Edge of Lane 3 (550 - 600 mm)

