CITY OF VANCOUVER

CITY CLERK'S DEPARTMENT
Access to Information & Privacy Division

File No.: 04-1000-20-2023-038

April 18, 2023

s.22(1)

Dear s.22(1)

Re: **Request for Access to Records under the Freedom of Information and Protection of Privacy Act (the "Act")**

I am responding to your request of January 23, 2023 under the ***Freedom of Information and Protection of Privacy Act*** for:

> **Geotechnical report prepared by Horizon Engineering, regarding an excavation shoring failure at 138 E 8th Avenue. Date range: February 1, 2020 to December 31, 2020.**

All responsive records are attached.

Under section 52 of the Act, and within 30 business days of receipt of this letter, you may ask the Information & Privacy Commissioner to review any matter related to the City's response to your FOI request by writing to: Office of the Information & Privacy Commissioner, info@oipc.bc.ca or by phoning 250-387-5629.

If you request a review, please provide the Commissioner's office with: 1) the request number (#04-1000-20-2023-038); 2) a copy of this letter; 3) a copy of your original request; and 4) detailed reasons why you are seeking the review.

Yours truly,

[Signed by Cobi Falconer]

Cobi Falconer, MAS, MLIS, CIPP/C
Director, Access to Information & Privacy
cobi.falconer@vancouver.ca
453 W. 12th Avenue Vancouver BC V5Y 1V4

If you have any questions, please email us at foi@vancouver.ca and we will respond to you as soon as possible. Alternatively, you can call the FOI Case Manager at 604-871-6584.

Encl. (Response Package)

:dl

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GEOTECHNICAL COMMENTS ON CAUSES AND FACTORS CONTRIBUTING TO COLLAPSE OF WEST EXCAVATION SHORING

Proposed Development

138 East 8th Avenue

Vancouver, BC

Our File: 120-4694

March 31, 2020

EXECUTIVE SUMMARY

On January 31, 2020, a significant portion of the West Elevation shoring wall constructed for the Grand development along the west property line at 138 East 8th Avenue (henceforth the Development Site) failed, collapsing into the deep excavation at the Development Site, taking with it part of the parking lot in the neighbouring property at 141 East Broadway which is occupied by the Congee Noodle House restaurant (CNH hereafter).

As a requirement of the City of Vancouver, Horizon Engineering Inc (Horizon hereafter) was retained by Georgia Pacific Holdings Corp, the current developer of the Development Site to:

- determine the cause of the shoring failure that had occurred at 138 East 8th Avenue,
- determine the impact on the adjacent property at 141 East Broadway, and
- evaluate the viability of the proposed remediation plan.

Our comments regarding the impact on the adjacent property at 141 East Broadway are provided and to this end, we have retained Read Jones Christofferson (RJC hereafter) as Structural Engineers to assess the impact of the shoring failure on the CNH building located on the south portion of the 141 East Broadway property. The RJC report is appended to this document. The RJC report provides a recommendation to immediately re-establish the connection between the east and north foundation walls of the CNH building.

Remediation plans are still being developed by the engineers retained by the owner of 141 East Broadway. The viability of the geotechnical and structural aspects of these plans will be evaluated by Horizon and RJC, respectively, when available.

As stated herein,

- multiple factors are generally found to contribute to, cause, or otherwise result in a particular failure,
- a breakdown in communication is usually a significant contributing factor,
- often, failure mechanisms cascade, and
- water is usually a culprit in failures of a geotechnical nature.

For the subject failure, all of the above are true. The subject failure was a result of a set of antecedent conditions which are described in Sections 2.0 and 4.0 of this report. In the days prior to collapse, there was increasing evidence that a failure was occurring. This evidence included accelerating subsidence of the ground surface east of the eventual failure scarp, formation and expansion of cracks in the shoring face, as well as progressive punching of anchors through the shotcrete (one, two then five anchors punched through on January 29, 30 and 31, respectively). Ultimately, as a result of antecedent conditions, the aforementioned decrease in the capacity of the shoring system and significant rainfall on January 31, 2020, the subject collapse occurred.

Based on the information available to us, it does not appear that the responses by various parties were commensurate with the urgency of the situation. If the contractor or the Geotechnical Engineer of Record had appreciated the increasing risk of failure, interim slope stabilization measures of a sufficient size to manage the slope deterioration could have been implemented. The City could then have been engaged to liaise with the neighbour in order to expedite investigation and mitigation measures at 141 East Broadway.

In our opinion, there were 22 contributing factors that resulted in the subject failure with the five main causes as follows:

1) Ineffective communication, including regarding the slope deterioration and the urgency of timely placement of backfill,
2) Significant antecedent rainfall conditions,

3) Poor workmanship and inappropriate field review pertinent to installation of weep holes,
4) Unfavourable location and condition of pipe infrastructure, and
5) Lack of implementation of recommended measures and lack of follow-up.

These causes / factors and relative importance are discussed in more detail herein.

It is recommended that the following be immediately carried out to improve the stability and monitoring of the excavation shoring system at 138 East 8th Avenue:

- weep holes be drilled through the shotcrete shoring,
- lift-off tests be performed on all anchors,
- best practices be employed to manage surface water, and
- more comprehensive survey monitoring points be installed and monitored.

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PART A – DISCOVERY

1.0 INTRODUCTION

On January 31, 2020, at approximately 5:00pm, a significant portion of the West Elevation shoring wall constructed for the Grand development along the west property line at 138 East 8th Avenue (henceforth the Development Site) failed, collapsing into the deep excavation at the Development Site. As a requirement of the City of Vancouver, Horizon Engineering Inc was retained by Georgia Pacific Holdings Corp, the current developer of the subject site:

- determine the cause of the shoring failure that had occurred at 138 East 8th Avenue,
- determine the impact on the adjacent property at 141 East Broadway, and
- evaluate the viability of the proposed remediation plan.

With respect to the cause of the subject shoring failure, our comments regarding our understanding of the facts related to this failure are summarized within this document. These facts have been based on our interpretation and consideration of over 70 reference documents and over 1400 photographs as well as our on-site investigations. These investigations included interior and exterior reconnaissance of the CNH building, scanning for and select scoping of buried utilities at 141 East Broadway and surround, surveying of the relative elevations of a portion of the interior slab-on-grade of the CNH, as well as our interviews with select parties and a test pit investigation.

In order to inform development of the 'train of thought' useful to understanding our hypotheses regarding causes of and factors contributing to the subject failure, there is some limited discussion on soil mechanics / properties / deformation, failure geometry and Factor of Safety. A chronology of events leading up to the failure is presented, followed by a discussion of the 22 causes / factors which we hypothesize contributed to the failure. The importance of these causes / factors is qualitatively weighted and our conclusions are presented regarding governing failure mechanisms.

Our comments regarding the impact on the adjacent property at 141 East Broadway are also provided and to this end, we have retained Read Jones Christofferson (RJC hereafter) as Structural Engineers to assess the impact of the shoring failure on the Congee Noodle House (CNH hereafter) building located on the south portion of the 141 East Broadway property and immediately south of the scarp associated with the subject failure; their report is appended to this document.

We close this report, and RJC closes their report, with recommendations for immediate action.

We trust that the remediation plans still being developed by the engineers retained by the owner of 141 East Broadway will provide recommendations for other works which should be implemented in the short and long term. The viability of the geotechnical and structural aspects of these plans are to be evaluated by Horizon Engineering Inc and Read Jones Christofferson, respectively.

Please refer to Appendix A for a summary of the parties and individuals we understand to be involved with the subject failure. Please note that the units used throughout this document vary from Imperial to metric depending on what was used in the referenced source document.

2.0 BACKGROUND INFORMATION

For the purpose of preparation of this report, Horizon Engineering has reviewed the geotechnical reports, construction records and memoranda, daily logs, and photographic records associated with the development at 138 East 8th Avenue. A list of documents considered and found to be relevant to the preparation of this report is presented in Appendix B. We have considered the general chronology of construction activities and damage-related events which occurred prior to our involvement with the project, including observations verbally provided to us by various parties including the client, general contractor, Geotechnical Engineer of Record, and neighbour.

In addition to the above, we have viewed and interpreted results of post-failure investigations and monitoring directed by Horizon Engineering or others and have attended the subject site on several occasions during February and March 2020.

2.1 Site Description

The Development Site is located at 138 East 8th Avenue in Vancouver, BC. The site is rectangular in plan. It is bounded:

- to the north by East 8th Avenue,
- to the west by 141 East Broadway occupied by a single storey, at-grade commercial building (housing the CNH Restaurant) at its south and central portions and by an at-grade paved parking lot with space for approximately 20 cars at its north portion. Stairs from the parking lot climb approximately 2.5 feet to a rear entry landing accessing the restaurant.
- to the south by a single storey, at grade commercial building at its south portion with two to three stalls of at-grade parking at its north portion, and
- to the east by a municipal lane, in turn bounded by commercial developments fronting on the west side of Main Street.

Topography in the vicinity of the Development Site slopes down from south to north. According to information publicly available on the City of Vancouver GIS map, the grade difference across the Development Site is approximately (1.5 metres.

Prior to the current development (i.e. pre-2019), the Development Site is understood to have been improved with a single storey commercial development founded over a partial basement (located beneath the south portion of the building), with this building extending to within close proximity of the north, west, and east property lines and approximately 7.0 metres from the south property line. Excavation shoring for the current development was completed in May 2019 at which point construction at the Development Site was put on hold. At the time of the shoring failure event, the Development Site was an open excavation as the hiatus was just coming to an end (refer to Section 3.0 and Appendix B for a detailed timeline).

2.2 Referenced Documents

As previously mentioned, a list of documents considered and found to be relevant to the preparation of this report is presented in Appendix B. The following subsections present a synthesis and discussion of the information contained therein.

2.2.1 Geological Survey of Canada

Based on published information from the Geological Survey of Canada (Map 1486A, Surficial Geology New Westminster, 1979), the surficial geology expected at the subject site consists of Vashon Drift and Capilano Sediments underlain by Tertiary Bedrock.

The Capilano Sediments comprise “glaciomarine and marine stony to stoneless silt loam to clay loam with minor sand and silt, that are normally less than 3.0 metres but in places up to 10.0 metres thick”. These sediments overlie the Vashon deposits that include "lodgment and minor flow till, lenses and interbeds of substratified glaciofluvial sand to gravel, and lenses and interbeds of glaciolacustrine laminated stony silt”. Tertiary Bedrock is expected to be within 10.0 metres or less of ground surface and generally comprises “sandstone, siltstone, shale conglomerate, and minor volcanic rocks”.

Based on the Peat and Waterways Map published by the City of Vancouver (Engineering Services Department, November 2003), there are no buried streams or peat zones located in the vicinity of the subject site.

2.2.2 GeoPacific Consultants Geotechnical Reports

GeoPacific Consultants Ltd (GeoPacific hereafter), the geotechnical engineering consulting firm retained by both the previous and current owners of the Development Site (and the Geotechnical Engineer of Record for the DS), published two Geotechnical Recommendations Reports for the development at 138 East 8th Avenue for Green Oak Development. The first report pertained to a proposed development with a one level underground parkade, while the second report was for a proposed development with a two-level underground parkade. In both reports, the subsurface conditions were characterized solely using in-house information based on uncited nearby field investigations. It is noted that no subsurface investigations were carried out.

Both of the reports state that “it is expected that the site will be underlain by weathered silt and sand in the upper 1.5 to 2 metres. This is expected to be underlain by dense to very dense glacially consolidated till–like sand and silt with trace to some gravel to a depth of 4.5 to 5.0 metres, which is further underlain by siltstone bedrock”. This description correlates well with published geological information

It is further stated that the long-term static groundwater level is expected to be well below the depth of excavation envisaged for the proposed development; however, variable levels of perched groundwater may be encountered overlaying the relatively impermeable (till-like) strata.

In addition, the reports provide geotechnical recommendations for the design and construction of the respective proposed developments.

Included are recommendations pertaining to the temporary excavations envisaged to be required to facilitate construction of the proposed single level of below grade parking (February 1, 2017 report), and later, the proposed two levels of below grade parkade structure (October 16, 2018 report). The reports recommend that vertical excavation faces may be supported with the use of a shotcrete membrane tied back with post-tensioned soil anchors. The reports further state that a GeoPacific representative must be on-site for all soil anchor testing and provide estimates for the expected, “normally tolerable” magnitude of movement behind the excavation faces, as follows:

- 5 to 15 mm at the excavation face, decreasing to half that within 3 metres away from the excavation face in the February 1, 2017 report, and
- 15 to 25 mm at the excavation face, decreasing to half that within 3 metres away from the excavation face in the October 16, 2018 report.

It should be noted that a shoring system comprising a shotcrete membrane tied back with post-tensioned soil anchors is the most common excavation shoring methodology in Metro Vancouver.

2.2.3 City of Vancouver

2.2.3.1 Utility Mains and Connections

Information regarding the utilities (i.e. storm sewers, sanitary sewers, and water mains) were obtained from the publicly available City of Vancouver GIS website. In general, the GIS indicates that storm and sanitary sewers, all dated 2006, exist along both East 8th Avenue and East Broadway. A storm sewer dated 1910 is documented to exist along the city lane to the east of the Development Site, parallel to a 2006 sanitary sewer. Additionally, a GVRD combined (sanitary and storm) sewer exists along East 8th Avenue.

No information regarding sanitary sewer, storm sewer, combined sewer, or water connections are shown on the GIS maps for either the Development Site or 141 East Broadway. However, based on our conversations dated February 20, 2020 with City of Vancouver representatives and information obtained via a BC One Call placed March 9, 2020, the following information regarding the locations of utility connections has been provided to us:

For **141 East Broadway (the CNH property):**

Connections off of East 8th Avenue:

Water: 3.3 metres west of the east property line (58.2 metres East of Quebec Street) is the documented location per City records (however the actual location determined in the field is about 0.7 metres west of this property line). The utility was noted to comprise copper pipe installed circa 1986. It was destroyed during shoring failure event;

Combined Sewer: 5.79 metres east of west property line; and

Gas: Immediately adjacent to the east property line, based on pre-failure photographs of the gas meter. However, records were removed from the BC One Call database following destruction of the service during the shoring failure event.

Connections off of East Broadway:

Sanitary: 1.83 metres east of west property line,

Storm: 1.83 metres east of west property line, and

Combined (abandoned): Approximately 2 metres west of the east property line.

2.2.3.2 Historical Developments

We have reviewed the Goad's 1912 Fire Insurance Plan available on the City of Vancouver GIS website in order to gain an appreciation of the previously existing improvements at the Development Site and 141 East Broadway and how these may have influenced shoring performance. This map indicates the locations of the buildings existing at the time of the map creation and has been used to infer potential abandoned utility paths and areas of present-day fill and/or abandoned elements of past structures. These are expected to be factors which may have influenced groundwater interflow, potentially in an unfavourable pattern, with respect to the excavation at the Development Site.

Our review of the 1912 Fire Insurance Plan has been reconciled against historical aerial photographs obtained from the Geography Department at the University of British Columbia and information available on the City GIS map. It is inferred that the sites were originally developed some time pre-1912 and both re-developed in the late 1940's. The main 1940's building remains at the south and central portions of141 East Broadway, however a smaller building at the north portion is no longer present.

2.2.4 Design Drawings for the Previous Development at 138 East 8th Avenue

The City of Vancouver has provided us with architectural drawings for a renovation at the previously existing development at 138 East 8th Avenue. The drawings, prepared by Matthew Cheng Architect Inc., dated November 1997, indicate that the building was a single storey structure constructed at grade within the northern and central portions of the property and featuring a single storey basement beneath the south portion of the building, with an adjacent loading bay located to the south of this.

2.2.5 Design Drawings for the Congee Noodle House Building

We have received the following drawings related to the Congee Noodle House building, which we have forwarded to RJC for their impact assessment and review of the viability of the proposed remediation plan for the CNH building:

- Sanitary plumbing plan, prepared by Edward J.Y. Lee, dated December 26, 2007;
- Architectural plans and elevations, prepared by Urban Design Group Architects Ltd., checked October 1998;
- Design drawings related to kitchen exhaust replacement including an architectural site plan, prepared by Paul's Metal Service Inc., accepted October 2, 1986;
- Architectural interior alteration plan, prepared by Po-Wah Ng Architect, dated July 30, 1986; and
- Structural design drawings, author unknown, date unknown.

In general, this collection of drawings indicates that the building at 141 East Broadway has undergone numerous renovations since its original construction in the 1940's.

2.2.6 GeoPacific Geotechnical Design Drawings

GeoPacific prepared the shoring design for the Development Site. We have reviewed the design drawings signed and sealed January 28, 2019, as this set is understood to be the most recent issue and that used for construction. Our review of the shoring design is summarized in Section 4.0 below.

The subject excavation shoring / underpinning drawings show presumed founding conditions for the CNH building. They do not show the extent of the basement for the building previously existing on the Development Site nor do they show services to the CNH building.

2.2.7 Bogdonov Lerer Strapping Design

We are in receipt of two details dated March 2019 by Bogdonov Lerer (the structural engineering consulting firm retained by both the previous and current owners of the Development Site (DS), and the Structural Engineer of Record for the DS). These documents detail timber and steel strapping to be installed at the east and north (including around the northeast corner) sides of the CNH building in order to secure these cinder block walls. It is understood that this strapping was to be installed on the CNH building prior to demolition of the previous building at the Development Site. We have forwarded these details to Kunimoto Engineering (the structural engineering consulting firm retained by the owner of 141 East Broadway) and to RJC for their consideration in developing and assessing, respectively, a structural remediation plan.

2.2.8 Green Oak 2019 Daily Logs and Photographs

We have reviewed the Daily Logs prepared in 2019 by Green Oak, the developer who previously owned the site, and in 2020 by Prima West, the current general contractor, to obtain information

regarding the activities, events, and observations on site during and after, respectively, installation of the excavation and shoring works as they relate to the shoring failure event and to inform our understanding of the timeline of events. The Daily Logs contain over 1400 photographs taken between November 2018 and February 2020 which we have viewed, interpreted and considered. In the photographs taken in 2019, we have observed several details which have informed our assessment of the subject failure. These details are presented below in a generally chronologic order and some opinions and/or discussion may be provided (in square brackets) which advance our 'train of thought' and that of the reader.

- It appears that the west foundation wall of the at-grade portion of the former building at 138 East 8th Avenue, located immediately north of the CNH building, sufficiently encroached into 141 East Broadway such that it was retained as the upper south portion of the West Elevation shoring. [The design depth of the first row of shoring anchors placed these anchors immediately above the base of this 'legacy' wall (acting as a shoring element) such that the composite shotcrete / concrete shoring membrane may not have had the flexural strength to act in a manner consistent with the design intent that would otherwise be provided by a continuous membrane.]
- One photograph shows an anchor plate offset several inches to the east of the aforementioned former west foundation wall [this unrestrained anchor would not be useful in resisting the soil pressures imposed on this wall (Photo 1)].
- Two photographs (Photo 2 and Photo 3) taken March 25, 2019 indicate a location where the water connection leading to the CNH building was leaking. This location appears to be near the north portion of the West Elevation (and near the future location of concentrated seepage). It is east of the documented location of this connection per City information. [We understand from discussions with Marco Sakamoto of Prima West on March 18, 2020, that this leak was repaired by a plumber using a rubber clamp.]

Photo 1: Anchor with loose plate and nut, efflorescence present - January 30, 2020

Photo 2: Water connection leak – March 25, 2019

Photo 3: Inferred location of water connection leak March 25, 2019

- There is a location just below the south end of the aforementioned legacy concrete shoring element where fresh shotcrete was inferred to have washed off the welded wire mesh (WWM) reinforcing (Photo 1 and Photo 5). Efflorescence is evident in later photographs at horizontal cracks below this 'washout' location. Efflorescence generally indicates ongoing discharge of groundwater. The weep holes proximate to this location do not appear functional (as will be further discussed in Section 2.4.1).
- There is a location approximately 30 feet south of the north end of the West Elevation near the first row of anchors where concentrated seepage out of the shoring face is evident, even on dry days, as early as May 1, 2019. We note that the above-noted repair of the CNH water service is near this seepage zone, as is the catch basin located in the parking lot of 141 East Broadway, approximately west of this seepage zone. With the passage of time, seepage at this elevation became progressively more extensive in a southward direction (Photos 4A, 4B and 5). Note that a reference point is used to indicate the same location in all the aforementioned photos.

Photo 4A: West Elevation seepage - May 1, 2019

Photo 4B: West Elevation seepage - May 9, 2019

Photo 5: West Elevation Seepage - May 23, 2019

- Beneath the CNH building, the west basement foundation wall for the former building at 138 East 8th Avenue also encroached beyond the shared property line. Progressive saw-cutting and removal at the property line is evident on the photographs, with an inferred pilaster remnant (as indicated on Photo 6) that was subsequently geometrically incorporated into the underpinning located immediately beneath the north end of the east wall of the CNH building. There would have been a significant backfill zone associated

with this basement wall and photographs indicate that this backfill zone may extend beneath the north wall of the CNH building as well as beneath its slab-on-grade. [Pre-failure cracking of the north and east walls of the CNH building and settlement and cracking of its slab-on-grade and settlement-sensitive utilities beneath it could have been expected to result from the movements associated with this demolition and consolidation of subgrade fills.]

- Photographs indicate that underpinning installation did not follow the 3-day sequence specified in the GeoPacific drawings. Most notably, on May 9, 2019 it is estimated that approximately 60% of the subgrade supporting underpinning beneath the east wall of the CNH building fronting the Development Site was removed (rather than 33%). [It is inferred that the first lift of underpinning acted as a beam supported at its north end on the pilaster remnant. Pre-failure cracking of the CNH building walls could have been expected to result from this and subsequent load redistribution.]

Photo 6: 3-day panel excavation sequence not followed, May 9, 2019

- Based on many of the photographs, it does not appear that weep holes were correctly or effectively installed.
- Also, based on many of the photographs, shotcrete-covered post-grout tubes are present at anchor heads, but grout splash on the shotcrete is not present. Additionally, the anchor tips proud of the anchor nuts have not been cut back. [These are signs that indicate that anchor free lengths had not been post-grouted and lift off tests and/or re-tensioning of anchors should therefore (have been) possible.]

2.2.9 GeoPacific 2019 Field Review Memos

We have been provided with 16 memos and one letter from GeoPacific Consultants for site reviews and instructions between January 24, 2019 and September 18, 2019. This documentation includes information regarding regular geotechnical field reviews during construction at the Development Site, as well as recommendations pertaining to the construction hiatus as discussed in Section 2.2.12.

In summary, and in reference to the GeoPacific drawings dated January 28, 2019, sheets G-S1 through G-S5 inclusive, during the 2019 excavation and shoring works, anchor testing had been reviewed and reported as follows:

- Section A1: of 26 total anchors tested, seven tests were reviewed by GeoPacific and no failed anchors were noted.
- Section A: of 58 total anchors tested, 22 tests were reviewed by GeoPacific and one failed anchor was noted.

- Section B/B1: of 35 total anchors tested, 13 tests were reviewed by GeoPacific and no failed anchors were noted.
- Section C/C1/C2/C3: of 49 total anchors (i.e. discounting soil nails) tested, 30 tests were reviewed by GeoPacific and six failed anchors were noted.
- Section D: of 23 total anchors tested, six tests were reviewed by GeoPacific and no failed anchors were noted.

For the purposes of this report, failed anchors are considered as anchors that were documented to have been locked off below the design load, unable to pass the proof test (i.e. 2-minute hold at 133% of the design lock-off load), or punched through or otherwise cracked the surrounding shotcrete.

Based on the number of anchors indicated on the GeoPacific design drawing, it is estimated that 41% of the anchors tested were reviewed by GeoPacific. Of the anchors reviewed, 22% were noted to have failed. There was no documentation regarding the success or failure of any other anchors tested without review.

The bulk of GeoPacific anchor review was carried out during testing of the top rows of anchors. We note that these are commonly the anchors which exhibit decreased capacity in the soil-grout bond and/or of the anchor plate bearing surface behind the shotcrete.

It is noted that none of the failed anchors noted above were reported to have been successfully repaired as recommended.

Also included in the memos issued during construction was the observation of two voids. The first was noted to be a relatively deep void located along the Row 2 anchor level of the East Elevation (memo dated April 3, 2019), with “deep” being inferred to refer to the extent of void beyond the shoring face. The second was a void along the Row 2 anchor level of the West Elevation (memo dated April 9, 2019), located beneath the CNH parking lot

[Noted to be lacking in the field review memos are observations related to the preparation of the underpinning panels supporting the CNH building. The underpinning panels are intended to incrementally lower the foundations of the CNH building so that they bear at an elevation matching the base of the excavation as it is advanced. Field review of the preparation of the bases of the underpinning panels would confirm that adequate bearing support for the structure was being maintained.]

2.2.10 Survey Monitoring

It is understood that a survey monitoring program was initiated during demolition of the previously existing building at the Development Site in order to monitor for potential movement of the buildings neighbouring the Development Site to the west (i.e. the CNH building) and to the south. The survey monitoring program consisted of approximately weekly measurements of 10 monitoring points (MP1 to MP9B) placed on the exterior walls of the aforementioned buildings. This monitoring program commenced on January 15, 2019 and an additional seven monitoring points were installed on March 6, 2019 (MP10 to MP16).

Monitoring measurements generally comprised a ‘vertical control’ (i.e. elevation) and a ‘horizontal control’ (i.e. plan location); however, it appears that not all monitoring points were monitored for the vertical control. Additionally, it is noted that the horizontal control presented on the plans available to us provides only one direction of monitoring – specifically, offset distance from the Development Site property line – as opposed to two directions (i.e. northing and easting), as is typically required for an accurate and comprehensive interpretation of such data. It is further noted that no survey monitoring points were installed on the shoring walls until January 6, 2020.

In January 2020, when cracking and settlement was observed in the parking lot of 141 East Broadway behind the West Elevation shoring wall, additional monitoring points were installed as per GeoPacific recommendation. On January 6, 2020, four monitoring points (new MP1 to MP4) were initiated on the parking surface between the crack and the face of the shoring wall and another four monitoring points (new MP5 to MP8) were initiated near the crest of the west shoring wall. Subsequently, as signs of movement became more evident and the deterioration of the West Elevation shoring wall progressed, the following additional monitoring points were initiated:

- two monitoring points (new MP9 and MP10) behind the East Elevation shoring wall on January 28, 2020, and
- four monitoring points (new MP11 to MP14) at the base of the West Elevation shoring wall on January 31, 2020.

After the slope failure event, a total of 36 new survey monitoring points were initiated at various locations along all sides of the development site between February 4 and February 14, 2020.

Plots of the survey monitoring points initiated since January 6, 2020 can be found in Appendix C. Figure 1 and Figure 2, respectively, show the settlement and lateral displacement of the West Elevation shoring wall recorded since January 6, 2020 leading up to the shoring failure (a plan showing the locations of MP1 to MP8 referenced in Figures 1 and 2 can be found in Appendix C).

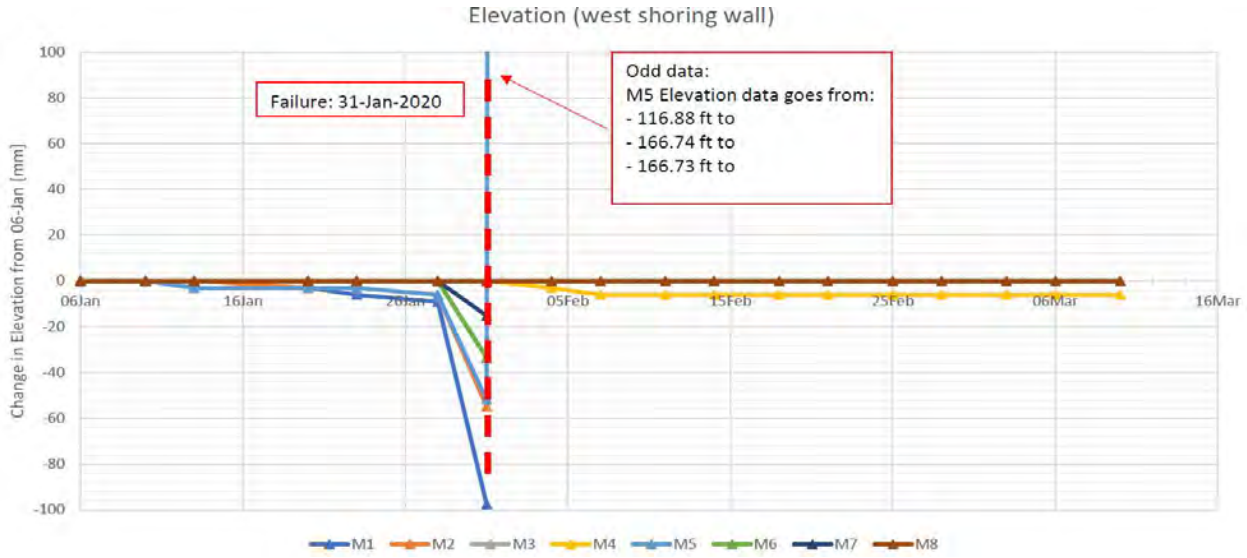


Figure 1: Survey monitoring data for West Elevation ('new') monitoring points

The above plot indicates a trend of increasing movement between January 6 and January 28, with January 28 movements exceeding the threshold where they might be considered to be within typical survey error. Rapid deterioration is evident between January 28 and the final, pre-failure measurements on January 31, 2020. The movement trends shown on these plots is consistent with qualitative observations of the progressively worsening cracking on the west shotcrete shoring wall and the subsidence and cracking in the asphalt immediately to the west.

2.2.11 Development Site Stop Work Documentation

In June 2019, the developer undertook to put construction activities at the Development Site on hold following completion of bulk excavation and shoring. Green Oak received comments from the City of Vancouver and subsequently from the Geotechnical Engineer of Record related to the proposed Development Site hiatus.

2.2.11.1 Comments from the City of Vancouver

In response to the construction hiatus proposal from Green Oak Development, the City of Vancouver provided Green Oak with a list of requirements. We have not been provided with the original document prepared by the City. However, in an email sent by Green Oak to Horizon Engineering on June 13, 2019 requesting that Horizon undertake Item 3 below (we were unable to undertake this scope), the City requirements were understood to include the following:

1) A signed and sealed letter from the Geotechnical engineer to demonstrate the stability of the site during an inactive state which is to include ground and storm water management;

2) A letter from the Owner to indemnify the City. The Owner must also include an estimated timeframe of when a decision will be made to resume construction, or fill the open pit with clean fill;

3) A third-party Geotechnical engineer to review the current design with respect to Item 1);

4) A means to monitor the site for any movement or changes of the current Geotechnical condition. Should any movement take place, provide a procedure to rectify the movement and stabilize the excavation;

5) The letter from the Geotechnical engineer must address any potential surcharge at any point adjacent to the excavation;

6) Interlocking concrete barriers or water-filled barriers marked with reflective tape are to be provided around the perimeter of the site;

7) The erosion sediment control system to be put back in place, and;

8) The hoarding must be designed for guard load.

Of the above noted requirements set by the City, it is unknown to us whether Items 2 or 8 were carried out by the Development Site. At the time of preparation of this report, based on the available documentation, it does not appear that Items 3, 4, and 7 were carried out.

2.2.11.2 GeoPacific Comments

We have been provided with a June 13, 2019 letter by GeoPacific issued to Green Oak Development regarding the proposed construction hiatus. This letter states that at the time of preparation of their letter, the length of time of the proposed hiatus had not yet been determined but was assumed to be of the order of 12 months. The letter further states that the shoring had been completed in compliance with GeoPacific's design and recommendations, and that no groundwater had been encountered on site to the full excavation depth. The letter continues by stating that "the conditions of the excavation are considered stable as of the existing conditions of the site for 12 months" and included the following list of recommendations:

A. No additional surcharge loading is placed behind the shoring walls,

B. Storm water is pumped out in an ESC compliant manner such that no more than 300mm of ponded water is present within the excavation at any time,

C. A remote tilt meter system should be implemented on all sides of the shoring which would allow for continuous, remote monitoring of the walls for any potential movement. Continuous monitoring should be confirmed by periodic survey readings at pre-determined monitoring points.

There is no discussion of the possible consequences if the above recommendations were to be disregarded. Nor is there any discussion regarding the geotechnical risks associated with a decreased level of oversight, including professional, for the duration of the project hiatus.

It is noted that there was no recommendation for lift-off testing or re-tensioning of anchors as might be suitable following a period of sustained sub-zero temperatures.

Based on the available information, it appears that none of these recommendations were implemented. Periodic surveys were carried out, although they were limited to the monitoring points established on the exterior walls of the neighbouring buildings to the west (i.e. the CNH building) and to the south. Survey monitoring points were not established on the West Elevation shoring wall until January 2020 and on the other three walls until after the shoring failure event.

2.2.12 Prima West 2020 Daily Logs and Photographs

Prima West has indicated that the outline of the future failure scarp was observable as early as January 2, 2020, as reported by CNH personnel, manifesting as a linear subsidence feature with a series of cracks in the asphalt. A GeoPacific field review dated January 15, 2020 shows their photographs of this cracking taken January 3, 2020. Photo 7 was taken on January 28, 2020 by Prima West and shows their earliest available photographic record of the aforementioned subsidence / cracking.

Photo 7: Parking lot cracking, January 28, 2020 (from Prima West)

On January 27, 2020, Mr Mitch Wilson of Prima West, started on the site at Site Superintendent. Hairline cracks in the shotcrete at the West Elevation were observed and photographed by Prima West on this date and included documentation of a significant, vertically oriented crack which had developed at the north end (Photo 8).

The Daily Reports indicate that Prima West ‘dewatered’ (ie lowered the level of the ponded water in) the excavation since at least January 27, 2020 and that the water level had been lowered by a few feet by January 31, 2020. [Note that photos related to the failure indicate only nominal water at the base of the excavation on February 1, 2020.]

Photo 8: Cracking in the West Elevation, north end (Prima West, Jan. 27, 2020)

Although his visit to the site was not documented in the Prima West Daily Logs, in his letter dated February 1, 2020, Mr Matt Kokan, P.Eng., makes reference to personally visiting the site on February 28, 2020. Although Mr Kokan documents that "clear water visible entering the excavation wall from cracks and weep holes in the shoring wall at about the north west corner of the excavation," the Prima West Daily Logs document that when they discussed the possibility of this being "City water" with Mr Ben Shalansky, EIT, of GeoPacific, this idea was dismissed. The subject letter documents that Mr Kokan was convinced that there was a sewer into which material was eroding associated with the subject subsidence and that this pipe should be investigated and repaired.

The Prima West Daily Log documents that no agreement could be made with respect to who would pay for this, Prima West or Mr Bon Wong (the owner of 141 East Broadway), and the investigation did not proceed.

The Daily Logs indicate that Prima West received instructions (presumably verbal as no corresponding documentation could be found) from Ben Shalansky, EIT, of GeoPacific on January 29, 2020, to install monitoring points on the West Elevation shoring wall (Photo 9). These logs record that Prima West believed this to be an unsafe activity and that they questioned the qualifications of this Engineer-in-Training to 'quarterback' the geotechnical aspects of this project.

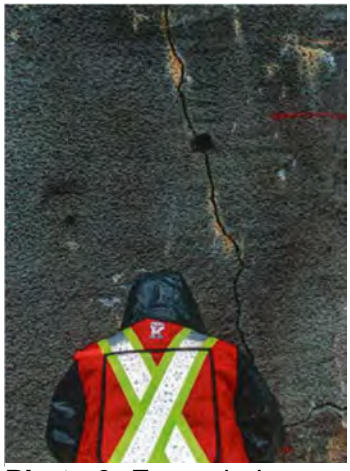


Photo 9: Expanded cracks in the West Elevation (GeoPacific, January 31, 2020)

On January 29, 2020, Prima West reported that they observed that one anchor in the bottom row of anchors at the north end of the West Elevation had 'punched through' the shotcrete. This was followed by "two more anchors punching through on January 30, and a few more on January 31" based on subsequent email correspondence between the Prima West Site Superintendent and Horizon. The GeoPacific Technical Memorandum dated January 31, 2020 documents that eight anchors along the bottom two rows of the West Elevation shoring wall (of the approximately 29 total anchors where Section A applies to the West Elevation) had punched through the shotcrete wall as of the time of the field review documented by this memo.

The Daily Logs indicate that Site Superintendent, Mitchell Wilson, exhorted Bon Wong to prohibit, and have his tenants prohibit, cars from parking in the CNH parking lot numerous times beginning on January 29, 2020, according to the Daily Logs. Furthermore, GeoPacific was reported to have been requested to attend at site to try and convince Bon Wong that this matter was urgent.

Daily Logs indicate that Ben Shalansky, EIT, attended to site on January 30, 2020 for this purpose, and that probing / tapping of the parking lot indicated "other subsurface void areas were (likely) present"; however the CNH representatives were unconvinced and use of the parking lot continued, with heavy vehicle loads associated with Chinese New Year (shown on Photo 7). The GeoPacific Technical Memorandum documenting their January 30, 2020 site visit was issued on January 31, 2020 under the seal of Kazunori Fujita, P.Eng., and included a recommendation to backfill the excavation in order to support the west shoring wall.

Based on the Prima West Daily Logs, it is understood that Fortis BC attended the subject site on January 31, 2020 for the purpose of disconnecting the gas service to the CNH building as a response to the subsidence and apparent movement of the CNH parking lot and adjacent shoring wall. The daily logs note that "heavy rushing water" was encountered during this street-level excavation to access the gas connection and that Fortis personnel stated that the line was "very close to breaking" due to the subject movement. It is further noted in the Daily Log that, upon excavation to expose the gas line, the rate of seepage flow through one of the weep holes along the West Elevation shoring wall significantly decreased. This suggests a hydraulic connection between the subject weep hole and the excavation for the gas connection located beneath the sidewalk along East 8th Avenue fronting 141 East Broadway.

Finally, while attending the site on January 31, 2020, The Daily Logs indicate that WorkSafe BC instructed the restaurant owner to clear the vehicles from the parking lot and evacuate the restaurant.

Over the time period between January 27 and 31, 2020, the subsidence and respective cracking of the parking lot area and the damage to the shotcrete shoring wall had been recorded by Prima West in their Daily Logs to be continually worsening and the rate of movement suggestive of a failure to be accelerating (Photos 3 and 4). However there was no recommendation to backfill the excavation in order to support the failing west shoring wall until January 31, 2020.

2.2.13 Weather Records

We have referred to weather records for the City of Vancouver in order to consider the potential effects of temperature and precipitation on the subject shoring wall.

Temperature records indicate that the minimum temperature was below 0 on January 9 (-1.8°C) and that sustained low temperatures manifest during a period between January 12 and January 17 (low of -8.0°C, high 4.4°C). Temperature records indicate that the daily high was above freezing while the daily low was below freezing on January 12, 16, and 17, 2020.

it is noted that a total of 256.6 mm of precipitation was recorded in the City of Vancouver during January 2020, making it the 4th wettest January over the last 83 years. Although it is recorded to have precipitated on 30 of the 31 days in January, three significant rainfall events are noted: 22.8 mm on January 10, 28.6mm on January 23, and 34.8mm on January 31.

2.2.14 GeoPacific 2020 Field Review Memos - Prior to Shoring Failure Event

Two memos were issued in January 2020 which include an account of the events leading up the shoring failure event and related recommendations. GeoPacific is reported to have attended site on January 3, 28 and 30, 2020 to review the site condition and issued two memos, dated January 15 and 31, 2020, signed and sealed by Mr Matt Kokan, P.Eng., and Mr Kazunori Fujita, P.Eng., respectively, and pertaining to site visits by Mr Ben Shalansky, EIT, dated January 3 and 15, 2020. [The site visit by Mr Matt Kokan, P.Eng.,, carried out on January 28, 2020 was documented in his post-event letter dated February 1, 2020.] The eight recommendations provided in these two memos are presented in Table 1 of Section 3.0, along with the status of the implementation of each.

Table 1: Summary of Pre-Failure (January 2020) Recommendations from GeoPacific

No.	Recommendation	Date	Status
1	Utility locate to be conducted to confirm the alignment of the storm drain beneath the parking lot	January 15, 2020	Not implemented
2	Crack sealing in neighbouring parking lot	January 15, 2020	Not implemented

3	Continue to collect survey monitoring data twice weekly with one additional monitoring point to be added outside of the zone of influence (as a control point)	January 15, 2020	Implemented
4**	Lift-off test all anchors on the west shoring wall	January 15, 2020	Not implemented
5	Backfill with a 4.5m tall berm immediately	January 31, 2020	Not implemented +
6	Remove asphalt in the CNH parking lot for investigation	January 31, 2020	Not implemented +
7	Clean / drill out accessible weep holes (after berm placement	January 31, 2020	Not implemented +
8** (4)	Lift-off test all anchors along the west shoring wall	January 31, 2020	Not implemented +

\+ *Recommendation received too late to implement*

** *Note this recommendation was initially made January 15 and repeated January 31*

2.2.15 GeoPacific 2020 Field Review Memos and Letter - After the Shoring Failure Event

Following the shoring failure event, nine memos, one letter and drawings (discussed in Section 2.2.17) indicating a conceptual excavation shoring remedial plan have been issued which present observations, recommendations and conceptual details related to the temporary and permanent remediation. Following the shoring failure event, in order to temporarily stabilize the now-collapsed West Elevation shoring wall, backfill materials were placed up to 1.5 metres below the adjacent parking lot grade under the direction of GeoPacific.

2.2.16 Video and Photographs of the Failure Event

A video of the shoring failure taken by a resident of the neighbouring building to the north of the Development Site was uploaded to the internet (Gregory Geipel, February 1, 2020) and can be found at the following link:

https://youtu.be/IW733VVPWg4

We have referred to this video during our assessment of the failure mechanisms. In addition, an aerial photograph of the failure has also been referred to for the same purpose (Photo 8).

Photos 11 to 13 show the pattern of failure as indicated in the above referenced video. It is noted that the failure initiated in the north-south centre of the West Elevation shoring wall immediately adjacent to and encompassing the CNH parking lot (i.e. Section A). An splash of standing water at the base of the excavation can be seen being as a result of impact by collapsing material.

Photo 10: Aerial view of shoring failure (Vancouver is Awesome, February 4, 2020)

The segment of foundation wall corresponding to the basement of the previously existing building at 138th East 8th Avenue, which was re-used as the shoring wall at the southern extent of Section A, failed sequentially approximately 40 seconds after the initial, centrally-located failure. This in turn undermined a portion of the north foundation of the CNH building and destroyed the gas meter attached to the building.

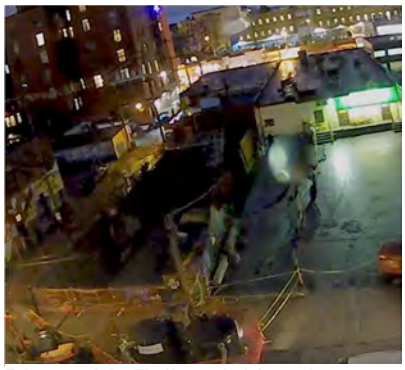


Photo 11: Failure initiated

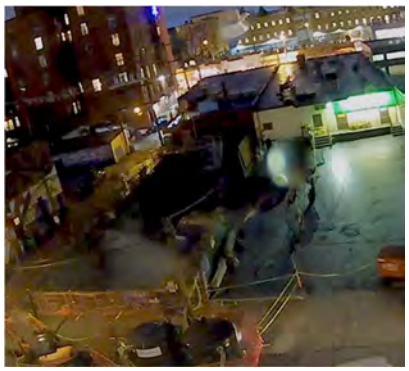


Photo 12: Material collapses

Photo 13: Material retained by existing basement wall collapses, 40 seconds after failure initiation

2.2.17 Conceptual Remediation Plan

A conceptual excavation shoring remediation plan was prepared by GeoPacific dated March 2, 2020 presenting an option for the works required on 141 East Broadway to allow construction of the west parkade wall at the Development Site. This unsigned / unsealed plan shows:

- proposed underpinning beneath the north foundation wall of the CNH building,
- a proposed slope cut extending into the CNH parking lot, and
- proposed shoring at the north end of the parking lot to support the adjacent portion of East 8th Avenue.

We understand that the subject plan was prepared by Ben Shalansky, E.I.T. It shows a soil profile comprising weathered soils and fill in the surficial 4 feet underlain by glacial till for the balance of the depth of the excavation. Generally, the conceptual design of works is similar to the excavation shoring design previously published as signed and sealed for the Green Oak Development project. The exception to this is that the base of the underpinning proposed to support the north wall of the CNH building is inclined at 4 Vertical : 3 Horizontal, rather than level as is shown for each underpinning lift supporting the east side of the CNH building (and as would be preferred).

However, we further understand that this GeoPacific plan was presented for discussion purposes only, and that the geotechnical and structural engineering of remedial works to be implemented at 141 East Broadway will be undertaken by consultants retained by Bon Wong; with German Cajigas, P.Eng., and Dan Kunimoto, P.Eng., being the respective Qualified Professionals.

2.2.18 Roto-Rooter Utility Scoping of the Congee Noodle House Building

We have been provided with an invoice from Roto-Rooter Plumbing and Drain Service dated February 19, 2020. It is understood that the CNH tenants of 141 East Broadway retained Roto-Rooter to investigate the conditions of the water, storm sewer, and sanitary sewer utilities within the building. Based on brief comments provided on the 1-page invoice, it is also understood that only the sanitary sewer line was investigated with a camera, which is understood to have been advanced through the toilet in the northern of the two men's washrooms (in the northeast portion of the building). The only issues reported were an "issue under the sidewalk" in the sanitary sewer

line, and visually identified partial clogging of the storm sewer line running off the rear of the building. We infer that the partially clogged storm sewer line referred to in the invoice is the roof downspout (ie rainwater leader). During our interior reconnaissance of the CNH building on February 21, 2020, representatives of the CNH were able to reach the author of the Roto-Rooter comments by phone in order that Horizon could solicit additional information. Based on a clarifying conversation between the undersigned and Vince of Roto-Rooter, who prepared the subject report based on an investigation by another technician, the investigation revealed that the pipes at the north portion of the building comprised "plastic, diving down to original cast iron at the south portion of the building".

2.2.19 Historical Google Imagery

We have referred to historical google imagery dating back to approximately 2000 for the area encompassing the subject site. Circa 2008, it appears that asphalt patching was done in the parking lot of 141 East Broadway and an adjacent north-south alignment in East 8th Avenue. The locations of these patches are west of the area encompassed by the future scarp and so are not considered further herein.

2.3 Observations by Others

2.3.1 From Prima West

Substantial observations by Prima West are documented in their Daily Logs which have been previously discussed.

Prima West verbally conveyed to us that they did not observe any sediment-laden water coming into the excavation from the weep holes at the West Elevation, however it does not appear that any water was collected for 'still' observation of sediment load or testing of Turbidity or Total Suspended Solids.

2.3.2 From GeoPacific

At the time of the Horizon test pit investigation on March 6, 2020, Mr, Ben Shalansky, EIT, from GeoPacific shared his January 2020 observations regarding the amount of sediment which had collected in the base of the excavation prior to the failure event. He recalled walking in up to 6 inches of sediment and surmised that the total amount of sediment at the base of the excavation might be represented by an average of 3 inches over the western two-thirds of the excavation proximate to the CNH parking lot where subsidence and sink holes were concurrently being observed to manifest.

2.3.3 From WorkSafeBC

The Prima West Daily Logs indicate that the WorkSafeBC officer who attended at the site on January 31, 2020 approximately 2 hours before the 5pm shoring collapse (and fortuitously evacuated the CNH building and parking lot) was Mr. Robert Glancy. We contacted Mr. Glancy by phone on March 17, 2020 and he indicated that he had prepared no report as there had been no injuries, but that he had received and accepted an Employer Incident Investigation Report prepared by Prima West.

Mr. Glancy noted that he typically attends sites soon after construction commences, as he receives a "Notice of Project"', as is required to be filed by a contractor when construction works commence at a site with works valued over $100,000. He noted, however, that there is no requirement to file or refile a Notice of Project when a site is 'reactivated'.

Mr. Glancy recalled speaking with many parties, hearing that there was “a lot of finger pointing going on” and opining to me that “all parties could have done more to mitigate issues when they were brought to their attention”.

2.3.4 From the City of Vancouver

A City of Vancouver Water Crew attended the subject site on February 7, 2020 to disconnect water service lines along East 8th Avenue leading to 138 East Avenue and 141 East Broadway. City of Vancouver Geotechnical Engineers attended on three occasions during the course of this day and summarized their observations in an Engineering Services Geotechnical Field Review Report. This augments the observations recorded on the Prima West Daily Log for the time period encompassing 10am to 7pm.

At first glance, the observations recorded by Prima West and the City of Vancouver are inconsistent with regard to when leaking of City infrastructure occurred. A video was taken of the excavation work carried out by the City and provided to us by Prima West, which indicates that groundwater was present in the excavation up to approximately the top-of-asphalt elevation; this is similar to the groundwater elevation encountered on January 31, 2020 by Fortis. As will be concluded in Section 7.0, the service pipe connecting from the City of Vancouver water main on East 8th Avenue to the CNH building was leaking in at least one location prior to the subject excavation shoring collapse. This documented leak location was identified in 2019 and repaired but is indicative that the subject pipe was in poor condition and other leaks may have been present. There is no way to determine if the locations of the leak(s) were on CNH or City property (or both), nor to determine if the leaking was initiated or worsened by deformations of the excavation shoring.

We do know from the City that this connecting pipe was installed in 1986. We also know from their report that the water main had been previously repaired at a location immediately adjacent to the ‘service saddle’ comprising the connection leading to 141 East Broadway.

It is noted that the City report states that a leak at the service saddle did not occur until after the service connection was disconnected and cut. Based on Horizon’s significant experience with utility work (over 800 ‘call-outs’ to District of North Vancouver utilities crews to assess excavation trench safety), we infer that this particular leak could have occurred as a result of pipe disturbance (ie during cutting) and that this (and the nearby repair) can be taken as signs that the subject infrastructure was vulnerable.

2.4 Observations by Horizon

The following sections provide a summary of our investigations on-site following the failure event.

2.4.1 Site Reconnaissance

As mentioned in Section 2.0, we have attended the subject site on several occasions during February and March 2020 for the purpose of making post-failure observations and obtaining information regarding various aspects of the Development Site and surround, including of the property occupied by the CNH. These site visits informed our understanding of the events leading up to and including the shoring failure event, potential causes of and factors contributing to the event, and the effects of the slope failure event on the CNH property.

Prior to being engaged for the subject services, a curious Horizon Engineering staff engineer attended the vicinity of the site on February 1, 2020 and took many photographs from publicly accessible areas of the Development Site and failure scarp prior to any backfill being placed.

We first attended the subject site under contract on February 6, 2020. Based on our initial observations made in the vicinity of the shoring failure, the northern extent of the crest of the failure scarp is at the northwest corner of the Development Site property. From there, it continued

in a southwest bearing up to a distance of approximately 20 feet west of the design location of the excavation face and 26 feet south of the north property line. The scarp then continued directly southward to approximately 18 feet south of the CNH building at which point it jogged 3 feet westward and continued south until it met the stairs on the north side of the CNH building.

At the time of this reconnaissance, we estimated that approximately 80% of the unaffected area of the CNH asphalt-paved parking lot was graded to direct surface runoff towards a catch basin located in its northeast portion. This catch basin was observed to be full of sediment and debris.

Additionally at the time of our February 6, 2020 site reconnaissance, apertures in the lane east of the site between the general lane asphalt and the patch for the storm sanitary sewer trench as well as between the east edge of the asphalt and the adjacent building were observed. The gap between the asphalt and the neighbouring building to the east was measured to be approximately 1 inch wide. These apertures as observed did not appear to be very old as they were free of built up sediment and weed growth in comparison to the proximate areas; it is therefore inferred that these deformations may have happened as the excavation was advanced, as opposed to more recently. Accordingly, these apertures (especially the gap between the asphalt and the neighbouring building to the east) indicate that there has been some minor movement of the anchored soil block toward the west (i.e. extending behind the top row of anchors). Movement of this magnitude in this location is inconsistent with the statement in the geotechnical report (Section 2.2.2) which estimates that 7mm to 12 mm of movement is expected 3 metres away from the excavation face.

On February 21, 2020, we attended at the interior of the CNH in the company of RJC, Bon Wong and his tenant. In general, cracks in the north wall of the building and in slab-on-grade located in a central north-south hallway were generally aligned with an extrapolation of the scarp. In addition, other cracks were observed in the men's bathroom (where pipes had been or were subsequently camera'd)

It is noted that a significant amount of kitchen equipment and other material was installed or placed against the interior of the perimeter walls of the building, especially in the northeast area, which obscured a large proportion of the walls from visual observation.

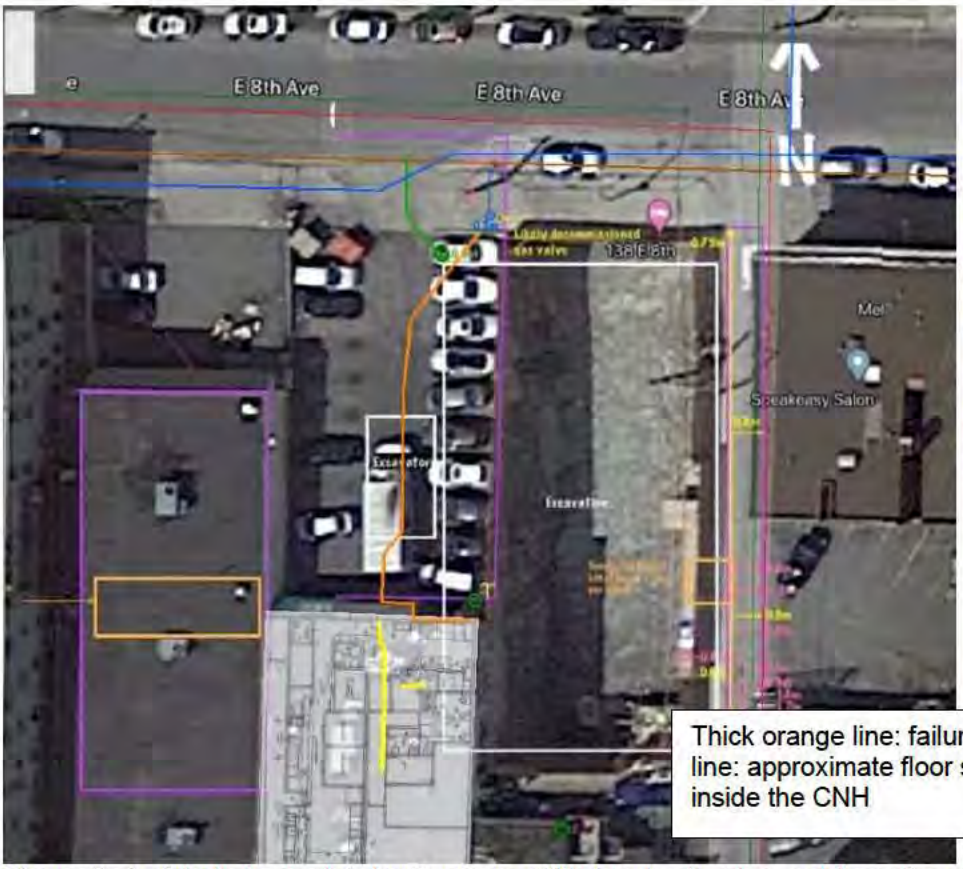


Figure 2: Aerial photo overlain by GeoScan utility locate site plan and floor plan of the CNH

The observable cracks, as well as the crest of the scarp are indicated on Figure 1 of Appendix D attached and (at a less useful scale) below.

Please refer to the RJC report attached in Appendix F for further discussion of the condition of the CNH building.

A subsequent site reconnaissance of the Development Site was carried out by Horizon Engineering on March 9, 2020 within the excavation. At this time, we investigated the accessible weep holes along the East, and South Elevation shoring walls. In many locations, the weep holes were observed to not be fully installed through the shotcrete (i.e. shotcrete was observable at the back of the weep hole). At these locations, ***no*** *hydraulic connection* to the retained soil was provided that would allow drainage (Photo 11).

Photo 14: Example of non-functional 'weep hole', South Elevation

Specifically:

- Nine of 18 weep holes investigated along the East Elevation were not functional. Of the nine weep holes that were deemed to be functional, three showed signs of active seepage.
- one of 12 weep holes investigated along the South Elevation was found to be functional. It was noted that comparatively significant levels of seepage were observed to be occurring through four of the anchors along the South Elevation wall.

Therefore, of the 30 weep holes able to be accessed for investigation, Horizon found that 20 (i.e. two thirds) were <u>not</u> functional. Of the 10 which were found to be functional, three (i.e. one third) showed signs of active seepage. Where weep holes were generally found to be not functional,

active seepage was occurring through some anchor heads, and as evidenced by previous photos, through cracks in the shotcrete.

2.4.2 Utility Investigation

On February 21, 2020, Horizon Engineering attended the site and surrounding area with GeoScan Subsurface Surveys Inc. of Burnaby, BC to perform a utility locate at the accessible areas of the parking lot at the CNH property, along the lane to the east of the Development Site, as well as other proximate areas. Ground Penetrating Radar (GPR) and Electromagnetic (EM) scanning was employed to investigate as these are common methods of locating buried conductive and non-conductive utilities. The detailed utility locate report can be found in Appendix E attached. The purpose of the utility locate was to identify any remaining utilities in the parking lot area of the CNH, including the storm connection hypothesized by GeoPacific to be the cause of the shoring failure event, as well as any other potential flow paths located behind (or in proximity to) the subject shoring wall. In particular, we were interested to learn whether the voids noted at Row 2 of both the East and West shoring Elevations were associated with a buried feature that continued off site and may have facilitated groundwater flow and erosion.

In general, no (remaining) utilities were identified within the CNH parking lot. However, the water, gas, and storm sewer connections, as well as one unknown connection (later identified to be an approximately 1" diameter metal conduit) were all identified between the north property line of 141 East Broadway and the respective mains beneath East 8th Avenue. It is noted that the location of the water service connection to the CNH was found to be inconsistent with the information provided to us by the City of Vancouver (as discussed in Section 2.2.3). The service connection was found to be approximately 0.7 metres rather than 3.3 metres west of the east property line, with the connection pipe having been destroyed by the subject failure.

Furthermore, although it was noted that the storm sewer connection extended from the catch basin located in the northeast corner of the CNH parking lot to the storm sewer main along East 8th Avenue, there was no evidence of a storm sewer connection between the CNH building and this catch basin. Additionally, the abandoned combined storm and sanitary sewer system connection noted by the City to exist at a location 5.79 metres west of the east property line (as discussed in Section 2.2.3.1) was not found.

In addition, numerous unidentified connections were found to enter the Development Site from the municipal lane to the east. Included amongst these was a 2.2-metre-deep connection that may correlate to the void identified by GeoPacific in their field review memo dated April 3, 2019.

It should be noted that the GPR is able to detect buried features up to a maximum depth of approximately 2.0 to 2.5 metres, only. Furthermore, the radar signal may be impeded and/or experience reduced effectiveness in areas of standing water and/or where large gravel particles or cobbles are present in subsurface materials. Therefore, a GPR scan cannot be relied upon to guarantee the absence of buried features.

2.4.3 Scoping of Drainage at 141 East Broadway

On March 5, 2020, Horizon Engineering visited 141 East Broadway with Modern Drainage of North Vancouver, BC to conduct an investigation of the storm and sanitary drainage systems at the subject property. Specifically, the goal of the investigation was to identify the issue(s) with the roof downspout in the northeast corner of the CNH building and to identify any potential issues with the sanitary or storm drainpipes within the building and parking lot that may have been associated with the shoring failure event.

The corrugated metal roof downspout located at the northeast corner of the CNH building is the only observable downspout serving the approximately 121 feet by 47 feet roof. It discharges into an approximately 8 inch diameter, cast iron pipe which then leads southward beneath the slab-

on-grade of the CGH building. We were not able to camera this pipe more than approximately 3 feet south of the north wall of the CNH building as an unidentified blockage was present. It is noted that the moisture present on the scoping equipment as it was removed from the pipe was observed to be greasy. A roto-router was subsequently used in attempt to clear the blockage; however, it too was not able to pass beyond 3 feet down the pipe. The scoping contractor noted that the pipe appeared to begin to curve towards the west at the location of the blockage.

A bucket of dyed water was poured into the top of the cast iron discharge pipe at a rate which did not allow any overflow to occur. Within about 20 seconds, coloured water was observed to exit the crack in the foundation wall beneath the cast iron discharge pipe as well as from the hole drilled for the upper underpinning anchor closest to the northeast corner of the CNH building. No coloured discharge was observed through any weep holes in the West Elevation wall.

The northernmost toilet was removed in the women's washroom located along the east side of the CNH building, approximately 20 feet south of the north building wall. The results of camera-ing of the pipe leading from this toilet were consistent with those reported by Roto-Rooter (i.e. the sanitary drainage is in good condition where observable). In addition, dyed water was flushed down the balance of the toilets in the women's bathroom; no seepage of dyed water was subsequently observed within the Development Site.

The catch basin at the northeast corner of the CNH parking lot was also assessed. Its outlet was observed to have an intake comprising a downward-turned, 90 degree elbow fitting. Between this fitting and the connection to the City storm sewer, there was a backflow preventer, the lid for which was loose. The inlet portion of the elbow on this outlet pipe was buried in sediment within the catch basin sump but access for scoping was possible once we lifted the unsecured lid of the backflow valve. Our scoping observations indicated that the storm sewer connection between the catch basin and the storm sewer along East 8th Avenue was in good condition and dry, with some evidence of spider webs suggesting that it had not conducted water for quite some time.

2.4.4 Congee Noodle House Micro-Topographical Survey

A micro-topographic survey of the slab-on-grade of the northeast portion of the CGN building was carried out by Horizon Engineering Inc on February 24, 2020. The results of this survey are presented on Figure 2 of Appendix D attached and generally indicate that the slab-on-grade at the northeast area of the CNH building has settled up to of the order of 9.5cm with respect to the slab at the central portion of the building. Given the local nature of the differential settlement, it is reasonable to attribute most of it to the shoring / underpinning activities, but not possible to differentiate between what could be pre- versus post-failure.

2.4.5 Test Pit Investigation

A test pit investigation was carried out on March 6, 2020 under the direction of Horizon Engineering Inc at the east portion of the CNH parking lot, immediately west of the scarp location. Mr. Ben Shalansky, EIT, from GeoPacific attended the beginning portion of the investigation and Mr. German Carigas, P.Eng., representing Cornerstone Engineering (the geotechnical engineering consulting firm retained by the owner of 141 East Broadway), attended the final portion of the investigation. In general, a continuous shallow test pit was advanced from a location approximately 17 feet north of the north wall of the CNH building extending to the catch basin in the northeast portion of the parking lot for 141 East Broadway.

The test pit ranged in depth from 4 and 6 feet below the elevation of the adjacent surface of the parking lot, to a depth sufficient to encounter natural soil. The surficial fill can generally be described as greyish brown to dark grey, very loose to compact / soft to firm, moist, silty sand to sandy silt. The fill material was mixed with respect to composition and contained occasional debris including bricks and wood waste.

The fill generally ranged in depth from 0.7 to 0.9 metre. However, at a location approximately 12.2 metres north of the north CNH wall, the depth of fill was locally observed to be 1.0 metre deep for a width of approximately 3 metres.

The fill was underlain by light brown, moist, dense, silty fine-grained sand (inferred to be a Capilano Sediment) which transitioned to contain coarser sand and some gravel towards the north. Two vertical discontinuities were observed, comprising light brownish grey, fine-grained silty sand with the vertical interface with the adjacent silty sand observed to be oxidized (Photo 7).

Below the aforementioned stratum was a brown to grey, very dense silty sand to sand with some silt, inferred to be a Vashon Deposit (i.e. glacial till). The colour transition from brown to grey occurred at depths ranging from approximately 0.8 to 1.4 metres below the parking lot grade. The till-like material observed within the test pit was blocky and fractured. Within the grey portion of the stratum, oxidation of some vertical fracture faces was noted.

Photo 15: Vertical discontinuities in Capilano Deposits

Photo 16: Oxidized sub-vertical discontinuity in Vashon Deposits

At a location approximately 6.4 metres north of the north wall of the CNH building, a buried foundation wall, oriented east – west, was encountered. This wall had been formed using ship lap (indicating construction likely prior to 1970), was about 1.1 metres high and was sitting on, but not structurally connected to, an approximately 400 mm by 250 mm deep foundation. The concrete appeared to be of good quality.

The north end of the test pit extended to the east side of the catch basin in the northeast portion of the CNH parking lot. When the soil on the east side of this catch basin was removed, it was observed that a hole (approximately 10 cm in diameter) was present, with an invert approximately 67cm from the rim of the catch basin.

The top and invert of the outlet pipe from this catch basin (ie connecting to the City storm sewer in East 8th Avenue) were measured to be 50 cm and 70 cm below the rim elevation, respectively, and the outlet was observed to be plugged by sediment that had gathered in the basin, as noted above. Based on these observations, it is concluded that water directed to this basin either over-flowed at surface or preferentially drained out of the eastern hole. Both of these scenarios would have allowed infiltration of water beneath the parking lot rather than discharge to the East 8th storm sewer.

2.5 Failure Geometry

To appreciate the mechanisms of the subject failure, the following discussion is provided as background information.

2.5.1 Slope Failure Geometries

An oversteep (infinitely long) slope in a homogeneous, strictly cohesive soil type tends to fail in a circular pattern (Figure 3).

Figure 3: Circular failure

By contrast, an oversteep (infinitely long) slope in a homogeneous, strictly granular soil type tends to fail on a plane inclined at 45-(ϕ/2) from vertical. In shoring design, this inclined plane is commonly taken at 30 degrees from vertical and referred to as 'the active wedge', which can manifest as a 'sliding block' as described below once mobilized. The bond zone of *soil anchors* is typically developed behind this active wedge, as indicated on the GeoPacific sections (except on Section C and C1 of the signed / sealed drawings where the middle row(s) of restraint elements comprise fully grouted soil nails). Section A in the location of the subject failure is indicated on Figure 4, with this active wedge marked in red. Note that the approximate locations of the water and gas connections to the CNH building are shown on this figure, with their associated trenches shown in blue.

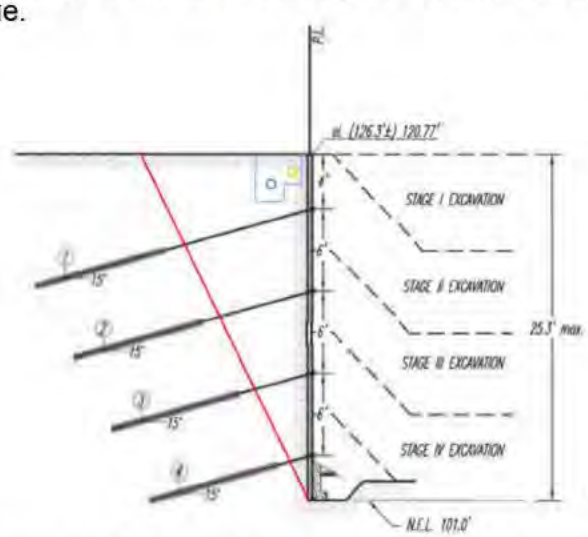


Figure 4: Active wedge and proximate utilities

Figure 5: Rock slope failure mechanisms

Slope failures of bedrock or soil types acting in a similar manner to bedrock (e.g. fissured clays) are governed by jointing, with 'sliding block', 'wedge' or 'toppling' failures manifesting, depending on joint spacing and orientation. These failure types are indicated in Figure 5.

Of course, slopes are not infinitely long, so the failure scarp in plan tends have the largest dimension measured from its original slope crest at or near the mid-point of the crest length.

Additionally, it should be noted that drained slope geometries are more stable than undrained slope geometries.

However, despite the conditions described above, a soil stratum more often demonstrates cohesive as well as granular characteristics, and lack of homogeneity as well as the introduction of discontinuities or reinforcing elements can affect the geometry of a slope failure.

2.5.2 Geologic Model at Subject Site

Based on our test pit at the site and our local experience in this neighbourhood, we are in general agreement with the GeoPacific geologic model described in their geotechnical report as:

- weathered silt and sand in the upper 1.5 to 2 metres (i.e. Capilano Sediments as noted in Section 2.2.1),
- underlain by dense to very dense glacially consolidated till–like sand and silt with trace to some gravel to a depth of 4.5 to 5.0 metres (i.e. Vashon Drift),
- further underlain by siltstone bedrock (i.e. Tertiary Bedrock).

However, we note that Section A of their conceptual remediation plan indicates the glacial till to extend below the base of the excavation.

The Capilano Sediments and Vashon Drift are both typically 'massive' (ie relatively homogeneous and contiguous) rather than blocky and fractured in Metro Vancouver, with failures typically a hybrid of 'circular' and 'active wedge / sliding block' depending on antecedent conditions. The interface between these two strata can also be a location of a sub-horizontal sliding block slip surface.

2.5.3 Geometry of Subject Failure Scarp

Based on the available pre-failure photographs, it appears that the failure scarp initiated 'in section' at a location 14.5 feet west of the property line shared between 138 East 8th Avenue and 141 East Broadway. This is at the front of the bond zone of the (top row of) soil anchors as indicated in Figure 4 above, and west of the west edge of the utility trench(es) associated with the water and gas connections to the CNH building. The photographs, taken at about the same time, show the bottom row(s) of anchors 'punching through' the shotcrete (Photo 17) and the concurrent condition of the CNH parking lot to the west of the punched anchors (Photo 18), are evidence that a failure has initiated.

Photo 17: Punched anchors/cracking along West Elevation shoring wall, January 30, 2020

Photo 18: Subsidence of the CNH parking lot, January 30, 2020, January 30, 2020

In plan, based on the video referenced in Section 2.2.16, for which select still shots are provided (Photos 11 to 13, Page 14), the collapse initiated at the mid portion of the north-south length of shoring. It is noted that this same north-south mid-point is the location of maximum deformation in the lane to the east of the site, as evidenced by a comparison between 2018 Google Imagery and 2020 conditions.

Photo 19: Google street view, July 2018 east side of lane east of Development Site

Photo 20: February 6, 2020 east side of lane east of Development Site

It can be noted that the east-west boundary between the primary failure and the subsequent failure of the retained portion of the existing basement wall is located at the 'jog' in the pre-failure subsidence / crack feature and along the buried foundation wall of a previous structure, as encountered in our test pit investigation. The location of this is a few feet south of the location of the recorded location of a 1912 building indicated on the Goad map.

Based on photographs taken immediately post-failure, the ultimate failure scarp extended to 6.0 metres west of the shared property line and, although it encompassed soil occupied by anchors, post failure, the upper anchor(s) remained secured to their bond zones.

Photo 21: Post failure, visible anchors remain secured

3.0 CHRONOLOGY OF EVENTS

A chronology of relevant events leading up to the shoring failure, and source documents for associated information, is presented following:

Table 2: Chronology of Events and Source Documents

Information Source	Fact or Observation	Relevance
Design Development – up to January, 2019		
Geotechnical Report, prepared by GeoPacific, dated October 5, 2018.	Assumed Soil Profile: 1.5 – 2 metes of weathered silt and sand, underlain by dense to very dense glacial till to a depth of 4.5 - 5 metres where it is underlain by siltstone bedrock, based on uncited proximate experience. Variable perched groundwater expected. Expected movement of shoring wall: 15-25mm at excavation face, decreasing to half that within 3 metres away from the excavation face. This magnitude of excavation induced movement noted to be normally be tolerable for in-ground services on City property and for adjacent buildings	Outlines the basis for design recommendations and communicates the expected amount of shoring wall movement to the Client (Green Oak) [and by virtue of the BP submission, to the City of Vancouver]. Does not communicate risks if this movement is exceeded or under what circumstances it would not be tolerable for in-ground services on City property or adjacent buildings.

Shoring Design Drawings, prepared by GeoPacific, dated January 28, 2019	Drawing set used for construction	Refer to Section 4.0
February 2019 - Construction		
Field review memo, prepared by GeoPacific, dated February 13, 2019	The foundation wall for the previously existing building encroaches up to approximately 12" beneath the CNH building footings.	The existing foundation was allowed to be re-used as the underpinning wall with the tie-back anchors installed through, provided that the condition of the wall was reviewed during anchor installation to confirm the suitability of the wall for this purpose (no record of these reviews exists).
Photo, March 25, 2019	Leaking pipe	Water leak in the 'active wedge' zone behind the West Elevation shoring wall. Apparent water connection location does not agree with information provided by City, which indicated that it is 3.3 metres west of the east property line.
Field review memo, prepared by GeoPacific, dated April 4, 2019	Deep void encountered along the East Elevation, Row 2 level. The void was instructed to be backfilled with shotcrete under GeoPacific review.	No record of the backfilling exists. Potential pre-construction connectivity between this void and the void observed in the April 9, 2019 memo could not be proven.
Field review memo, prepared by GeoPacific, dated April 9, 2019	Void encountered along the West Elevation, Row 2 level. The void was instructed to be backfilled with shotcrete under GeoPacific review.	No record of the backfilling exists. Potential pre-construction connectivity between this void and the void observed in the April 4, 2019 memo inferred, investigated and disproven by Horizon.
Photos, May 9 to 23, 2019	Seepage through the West Elevation shoring wall increasing from north to south over time	Evidence of the build-up of hydrostatic pressure behind the West Elevation shoring wall
Field review memo, prepared by GeoPacific, dated May 7, 2019	Underpinning wall must be advanced 2.2 feet deeper than the GeoPacific shoring design drawings allow. Design lock-off load and bond length for the bottom 2 rows of anchors along underpinning section increased.	Design load increased from 18 kips to 22 kips for the bottom 2 rows of underpinning anchors.
Photograph from Green Oak, May 9, 2019	Approximately 20-foot-wide single underpinning panel excavated.	Undermining of CNH building.
Field review memo, prepared by Camphora (the Certified Professional for the project), dated May 31, 2019	Excavation has been completed.	Site is entering construction hiatus.

May 2019 to January 2020 – Construction Hiatus		
Field review memo, prepared by Camphora, dated June 10, 2019	Site work has stoped and ESC tanks have been removed. Placement of jersey barriers around the excavation is recommended.	Removal of an ESC compliant method of removing stormwater from the site.
Recommendations letter, prepared by GeoPacific, dated June 14, 2019	The site is safe for a 12-month hiatus, provided that a list of recommendations (Section 2.2.11.2) is adhered to.	Only one of the four listed recommendations was (partially) implemented.
Email from Marco Sakamoto to Horizon, dated July 5, 2019	City of Vancouver provided a list of requirements to be fulfilled in order to allow the site to stop work (Section 2.2.11.1).	Only 2 of the 8 requirements from the City were fulfilled at the time that site work ceased (2 more requirements were fulfilled much later).
Field review memo, prepared by Camphora, dated November 14, 2019	Jersey barriers placed around the excavation per City requirements.	Surcharge load placed immediately behind the shoring walls (i.e. violation of GeoPacific recommendations).
Field review memo, prepared by Camphora, dated December 20, 2019	Site preparing for construction resumption. Some of the plywood fencing removed.	General contractor and personnel returning to site.
January 2020 – Events leading up to failure		
Field review memo, prepared by GeoPacific, dated January 15, 2020	Cracking first reported in CNH parking lot on January 2. Cracks up to 10 mm wide were present 4-5 metres away from the face of the West Elevation shoring wall at the time of review subject (January 3, 2020). Excavation contains up to 3 feet of standing water throughout.	First signs of shoring related movement recorded. Recommendations to perform a utility locate, seal cracks, and lift-off test all West Elevation anchors were not carried out. Water ponding contravenes GeoPacific hibernation recommendation.
Environment and Climate Change Canada	Freezing conditions on January 9, 2020; as well as between January 12 and 17, 2020.	Potential frost heave of silty soil behind shotcrete and freezing of free water behind shotcrete face.
Environment and Climate Change Canada	71.0 mm of precipitation in the week starting January 20, 2020. 61.6 mm of precipitation in the week starting January 27, 2020. 34.6 mm of precipitation on the day of January 31, 2020	Contributes to the build-up of hydrostatic pressure behind the shoring wall.
Daily Log by Prima West, January 28, 2020 and Letter prepared by GeoPacific, dated February 1, 2020	Prima West requests GeoPacific review the settlement (which was observed to be up to 200 mm) and resultant cracking at CNH, Prima West speculates that the water connection between the water main along East 8th Avenue and the CNH building could be leaking.	Water connection leak was reportedly dismissed as a possibility by GeoPacific. GeoPacific suggests, based on the appearance of a trench patch in the parking lot surface, that the observed settlement is due to a breakage in a sewer line that is causing soil migration through said sewer line.

Daily Log by Prima West, January 29, 2020	First record of Prima West exhorting the owner of the CNH building to disallow parking behind the West Elevation shoring wall (requests subsequently continue multiple times per day going forward).	Request ignored, parking behind the shoring wall continued, exerting a surcharge load on the shoring
Daily Log by Prima West, January 29, 2020	Submersible pumps were set up in the excavation and a 'few feet' of water was pumped out.	Beginning of lowering of the water level in the excavation. 'Rapid Drawdown' is often a trigger for slope failure, especially if drainage (i.e. weep holes in this case) is compromised.
Daily Log by Prima West, January 31, 2020	GeoPacific requested that Prima West enter the excavation to install new survey monitoring points near the base of the West Elevation shoring wall, despite the expression of concern from Prima West about the safety of this request	Personnel put into a high-risk situation as anchors had already began to punch through the shotcrete wall and significant cracking of the wall and the parking lot had manifest; both of which indicate that a failure has commenced.
Field review memo, prepared by GeoPacific, dated January 31, 2020 for Field Review dated January 30, 2020	Depression in the parking lot (corresponding to the aforementioned cracks) had increased to an approximate depth of 150 mm. Cracking had first been observed in the shotcrete shoring wall January 28, with seepage from the cracks. 8 anchors punched through the shotcrete along the bottom two rows of anchors along the north end of the West Elevation.	Signs of shoring related movement worsening, failure of the shotcrete wall (anchors progressively punching). Recommendations to backfill immediately, remove asphalt in the CNH parking lot for the purpose of investigation, install new weep holes, and lift-off test all anchors along the West Elevation were not carried out. Time of distribution of this memo unknown.
Daily Log by Prima West, January 31, 2020	CNH parking lot in area of cracking was sinking at a rate where movement was observed every 30-40 minutes	Shoring related movement has become extreme.
Daily Log by Prima West, January 31, 2020	Fortis arrives on site at 3pm to disconnect the gas service between the gas main along East 8th Avenue and the CNH building. The connection line was close to breaking and significant water flows were present in the excavation.	The gas connection was reportedly inferred to being subject to pulling by the shoring movement and water was present behind (ie to the west of) the shoring wall.
Daily Log by Prima West, January 31, 2020	WorkSafeBC arrives on site towards the end of the Fortis site work. Cars are cleared from the CNH parking lot and the building is evacuated at the direction of WorkSafeBC.	Vehicles and potentially people saved from catastrophic consequences of shoring collapse.
January 31 at approximately 5:00pm - Shoring Failure Event		
Field review memo, prepared by	A backfill berm was placed against the West Elevation shoring wall. The backfilling works were carried out following recommendations from	Risk of further collapse mitigated.

GeoPacific, dated February 10, 2020	GeoPacific and in the presence of GeoPacific review. Backfilling commenced February 4 and was completed to within 1.5 metres of the adjacent CNH parking lot grade on February 10.	
Field review report, prepared by the City of Vancouver, dated February 7, 2020	City of Vancouver disconnected the water service to the CNH on February 7. Excavation encountered water near the ground surface.	Water service connection to the CNH found to be susceptible to movement and/or damaged. Proximate water main found to have been previously repaired.

PART B – HYPOTHESES REGARDING CAUSES OF OR FACTORS CONTRIBUTING TO SHORING FAILURE

Forensic analysis of engineering-related failures generally finds that:

- multiple factors contribute to, cause, or otherwise result in a particular failure,
- a breakdown in communication is usually a primary factor, and
- often, failure mechanisms cascade (e.g. an electrical failure causes a fire which results in structural collapse).

In geotechnical engineering, water is usually a culprit.

For any given geotechnical engineering design, it is important to note that Factor of Safety is inversely proportional to deformation and that some deformation of shoring should always be expected to manifest. In other words, even though some shoring deformation should be expected, the amount of deformation can be limited by designing to a higher Factor of Safety. Factors of Safety relating to the geotechnical design of many types of elements, including retention structures, are recommended in the Canadian Foundation Engineering Manual.

For the subject collapse, we have identified 18 potential factors contributing to the subject failure, which can be grouped in six categories. The potential factors contributing to the subject failure are described in detail in Sections 4.0 through 9.0 following and summarized, with my qualitative weighting as to importance, in Section 10.0. I hypothesize that these factors inter-related and cascaded so as to result in the subject failure and eventual collapse. The manner is which I hypothesize that these factors inter-related and cascaded is described In Section 11.0.

4.0 UNEXPECTED SOIL CONDITIONS

Although it might be appropriate to include consideration of the effects of trenches for buried utilities in this section, these are discussed in Section 6.0, Location and Condition of Pipe Infrastructure.

4.1 Vertical Discontinuities in Soil Strata

Photo 15 and Photo 16 (on page 24) show vertical discontinuities in the Capilano Sediments and Vashon Drift. Where these discontinuities allow water to enter and are sufficiently hydraulically continuous, they can result in development of significant hydrostatic pressures which can act to destabilize blocks of soil. Such discontinuities are not typical and may not be easily identifiable in either Capilano Sediments or Vashon Drift. With respect to the subject failure, I envisage that these discontinuities had a low relative importance in terms of contributing to the risk of failure.

4.2 Lack of Investigation

Although GeoPacific did not carry out a site-specific subsurface investigation and did not cite the nearby investigations upon which their conclusions were based, I do not believe that this had much of an effect on the performance and failure of the shoring. Specifically, the previous development at the subject site precluded investigation everywhere except the south end where a drill hole could have been advanced in the loading bay area. However, it would be typical for a deep investigation to comprise an auger drill hole, as opposed to a continuous sonic core (which *may* have been successful in obtaining a soil sample where the aforementioned discontinuities *might* have been able to be observed).

The lack of investigation did not allow determination of the elevation of the top of the Tertiary Bedrock, nor installation and monitoring of a piezometer to determine (seasonal) groundwater elevations.

With respect to the subject failure, I envisage that the lack of investigation had a low relative importance in terms of contributing to the risk of failure.

4.3 Buried Elements

The old foundation wall and deeper pocket of fill in the parking lot of 141 East Broadway, as encountered in our test pit investigation, could both have served to contain and therefore concentrate infiltrated groundwater. With respect to the subject failure, I envisage that the lack of investigation had a low relative importance in terms of contributing to the risk of failure.

With respect to the subject failure, I envisage that the presence of buried elements had a low relative importance in terms of contributing to the risk of failure.

5.0 SHORING DESIGN, INSTALLATION AND FIELD REVIEW

5.1 Design

Based on our back-analysis of the shoring design evident in the GeoPacific excavation shoring design drawings, the design appears to be somewhat non-conservative. Specifically, even when utilizing relatively idealistic input parameters, the Factors of Safety for all of the GeoPacific design sections are close to unity.

For our back-analysis, friction angles of 38 and 42 degrees and a unit weight of 19 kN/m^3 were used as input soil parameters. Surcharge loads of 10 kPa and 4 kPa were employed to account for vehicle loading behind the walls and slab-on-grade loading at the underpinned section, respectively. No hydrostatic pressure was applied.

Based on our review of the GeoPacific design, it appears that a triangular pressure distribution was utilized to model the earth pressure acting against the shoring walls. Our analysis has considered both triangular and rectangular distributions. We note that publications by the US Federal Highway Administration (FHWA) state that applying a rectangular distribution better represents actual stress conditions which manifest for retention systems which are constructed in a ‘top-down’ manner, such as the subject reinforced shotcrete restrained by soil anchors / nails. In addition, where average soil strength parameters are applied over the height of a soil profile, we find that a rectangular distribution better accounts for the comparatively lower friction angle materials present in upper soil strata (eg fills, near surface weathered soil, Capilano Sediments, etc).

In general, based on our back-analysis of the GeoPacific design, we infer that the design does not appear to account for surcharges due to:

- The height of soil above the foundation of the CNH building (ie 2.5 feet to underside of slab-on-grade from exterior grades at the northeast portion of the building),
- loads on the slab-on-grade due to material storage inside the CNH building, or
- vehicles in adjacent parking lots and laneways.

Although GeoPacific's testing of the tie-back anchors involved loading the anchors to 133 % of the Design Load (DL), as the load on the anchors was subsequently reduced to DL at lock-off, the deformation of the shoring would be expected to be associated with a Factor of Safety of 1.0. The 'Proof Test' proves only that the soil grout bond of the anchors will not ultimately fail up to a loading of 133 % of the DL.

It should be appreciated that the definition of 'Failure' as it relates to the design Factor of Safety is not governed by the ultimate tensile strength of the anchor tendon or the soil-grout bond; rather, it is governed by a specific design section deformation tolerance. This tolerance could be large if there were not adjacent buildings or other infrastructure, or quite small if infrastructure was present that was particularly vulnerable or sensitive to movement. Managing the deformation to magnitudes that do not result in damage to infrastructure or other adjacent properties is an important design consideration.

For a lateral earth pressure calculated based on an active condition and the soil properties noted above, the expected deformation would be approximately 0.2% of the total excavation height. For the 25.3 feet maximum height of the West Elevation, this would be 15 mm, which is the lower range of the estimated shoring deformation stated in Geopacific's report. However, it is noted that the water and gas services to CNH were located within the 'active wedge' of the West Elevation shoring wall where deformations would be expected to be relatively large.

Application of additional loads would be expected to increase deformation, decrease the Factor of Safety and possibly mobilize a fully active condition. As the active wedge is mobilized and stresses are transferred to the tie-back anchors, deformations will accumulate.

Irrespective of the magnitude of deformations associated with the subject design, Factors of Safety as prescribed in Canadian Foundation Manual do not appear to have been met. Factors of Safety at the lower end of the prescribed range of 1.3 to 1.5 for earth retention systems might be expected to govern, as the subject works are of a temporary nature. However, where infrastructure is known to be present, in order to achieve a typically expected design intent and performance, a higher Factor of Safety might be suitable if this infrastructure was vulnerable or if its failure could result in significant negative consequences.

Finally, it is noted that the Anchored Shotcrete Detail on drawing no. G-1 of the GeoPacific excavation shoring drawings details a recessed anchor head with generally smooth geometric transitions, except for that shown at the top of the anchor plate. At this location, stress concentrations can increase the risk of cracking. The flexural strength of reinforced shotcrete shoring relies on the shotcrete and reinforcing being relatively continuous and strength is compromised where the shoring is significantly cracked.

With respect to the subject failure, I envisage that the Factor of Safety was associated with sufficiently high deformation near the shotcrete face such that the integrity of the water service connection pipe could have been compromised. Accordingly, I envisage that the shoring design had a medium to high relative importance in terms of contributing to the risk of failure.

5.2 Workmanship

Stress concentrations can also develop at other locations where poor workmanship results in a 'sharp' geometry. Soil conditions behind the anchor head which are not dense as well as insufficient concrete cover on reinforcing or insufficient reinforcing can also increase the risk of

shotcrete cracking at the anchor head. In general, concrete cover on reinforcing is a workmanship item that I have found to be worthy of field review.

As noted in Section 2.4.1, two thirds of the weep holes assessed on the East and South Elevations were determined to have sufficiently poor workmanship so as to be incapable of allowing passage of water. These drains were specified in Section 3.4 of the GeoPacific drawings, to be implemented by the shoring sub-contractor. It is reasonable to assume that weep holes on the West Elevation were similarly compromised, and a review of the available photographs supports this hypothesis. This is considered to have a significant effect on the negative outcome at the subject site.

With respect to the subject failure, I envisage that the inadequacy of the weep holes had a very high relative importance in terms of contributing to the risk of failure.

5.3 Field Review

In Section 6.2 of the GeoPacific excavation shoring drawings, it is specified that daily inspection is required during anchor installation and full-time field review is required during anchor testing. A total of four technical memorandums issued by GeoPacific between April 16 and April 29, 2019 state that all anchor tests shall be reviewed by GeoPacific personnel. Although there are no field review reports or daily logs to support that these requirements were subscribed to, a schedule of fewer field reviews of these items is not unreasonable.

Testing of approximately 41% of the 191 anchors indicated on the drawing was documented in the GeoPacific technical memorandums. These memos indicate that of those anchors where testing was witnessed to have had unsatisfactory results (generally in the top row), the cause was generally attributed to shotcrete performance at the anchor head. Where repair of shotcrete at the anchor head was mandated ('chipping out' the failed shotcrete around anchor heads, per the GeoPacific memo dated April 17, 2019), there is no record of field review that would indicate that reinforcing at the anchor head was suitably continuous with adjacent reinforcing in the area of the repair. This 'chipping out' practice is not considered to be a satisfactory remedial measure unless the reinforcing is verified to be suitably continuous so that the subject anchor does not become isolated from the shoring diaphragm. Without suitable continuity of reinforcing, the anchor would work independently of the shoring face and earth pressures acting on the proximate reinforced shotcrete of the shoring diaphragm could transfer to, and exceed the capacity of, nearby anchors.

None of the field review reports comment on the West Elevation anchor which did not have its plate and nut in contact with the shoring wall.

Field review requirements to confirm that installation details are in general conformance with design is not specified for shoring or underpinning reinforcing or preparation of underpinning bases and no field reviews of these items are documented.

Field reviews to confirm that weep holes were functional were not carried out.

Punching of anchors through the shotcrete is an indication that a shoring system is failing. It is the start of a cascading failure type as disconnection of anchors from the shotcrete membrane results in adjacent anchorage being overstressed, resulting in additional failures. Subsidence across an arc-shaped discontinuity on or adjacent to a slope (cut) is a classic sign that a global slope stability failure has initiated. These signs should have been appreciated by the on-site representative of the geotechnical consultant and a timely recommendation made to backfill the Development Site. As it is apparent that these signs were not appreciated by this representative as indicating that a failure was underway, it appears that the professional oversight of the geotechnical Engineer-in-Training was ineffective. It is possible that this could have been mitigated by more frequent on-site professional field review.

With respect to the subject failure, I envisage that the limited nature of the field reviews and ineffective professional oversight resulted in a recommendation to backfill being made too late and that this had a high relative importance in terms of contributing to the risk of failure.

6.0 LOCATION AND CONDITION OF PIPE INFRASTRUCTURE

6.1 Age / Condition of CNH / CoV Water Connection

The water connection to 141 East Broadway was installed in 1986. The 150mm diameter, cement-lined, ductile iron water main along East 8th Avenue was installed in 1973.

It is theorized that the water connection that connected the present-day CNH building to the watermain along East 8th Avenue was in a poor state of repair due to its age. Photographs of the connection location and of a (subsequently repaired) leak location at the north end of the property are consistent with this conclusion.

As a result of the inferred poor condition of the water connection, it *may* have been leaking. The leaking *may* have been occurring for some time, inconsequentially infiltrating into the surficial permeable fills in the vicinity of the subject site, until the deep excavation and associated shoring was constructed. Subsequent movement of the active wedge behind the shoring wall would have induced shear stress on the connection pipe, exacerbating any existing leaks as well as potentially damaging weak portions of the pipe, thereby producing new leaking points.

With respect to the subject failure, I envisage that the condition of the water connection pipe had a medium relative importance in terms of contributing to the risk of failure.

6.2 Locations of Water and Gas Connection

As shown Appendix E or Figure 5 in Section 2.5.1, the connection between the watermain along East 8th Avenue and the CNH building is located approximately 2 feet to the west of the property line shared with the Development Site. As inferred from site photographs, the gas connection was located immediately adjacent to this shared property line. Both of these locations are within the active wedge of the subject shoring wall. As such, any water that may have leaked from the water connection pipe or from other sources would have relatively easily been able to travel along its trench and that of the gas service. This could have consolidated the looser fills associated with these trenches, thereby contributing to the subsidence observed in the parking lot. In addition, it would have facilitated infiltration of water into the retained soil mass at a vulnerable location.

Specifically, it is likely that the trench for the subject water connection pipe hydraulically conducted leaking water (from the connection and/or from the catch basin) and allowed it to infiltrate immediately behind the shoring wall. This would have directly contributed to hydrostatic pressure acting on the shoring wall, especially in a circumstance where there were insufficient weep holes.

With respect to the subject failure, I envisage that the locations of the water connection and gas service pipes had a high relative importance in terms of contributing to the risk of failure.

6.3 Location and Condition of Rainwater Leader and Discharge at 141 East Broadway

The rainwater leader at the northeast corner of the CNH building discharges into a cast iron pipe leading southward beneath the building. Our investigation of the drainage systems at the CNH (Section 2.4.3) showed that this pipe is partially plugged and cracked such that most, if not all, water entering it leaks out, discharging into the ground below the slab-on-grade. It is expected that this water would infiltrate behind the shoring wall, and likely travel preferentially along the utility trenches for the water and gas connections. It is possible that surcharged a local area confined by buried foundation walls and created a particularly high hydrostatic pressure on the

west side of the foundation wall used as the upper portion of the south end of the west shoring face.

There do not appear to be any other rainwater leaders serving the approximately 5,700 ft^2 roof of the CNH building.

With respect to the subject failure, I envisage that the location and condition of the CGN downspout and discharge had a high relative importance in terms of contributing to the risk of failure.

6.4 Condition of Storm Catch Basin at 141 East Broadway

Based on our investigations, we conclude that water entering the CNH catch basin discharged out of the eastern hole rather than being directed to the East 8th Avenue storm sewer.

This location of the catch basin is within the active wedge of the subject shoring wall. As such, any water that entered the catch basin would have leaked from the hole, directly into the relatively high permeability fill material, and would have directly contributed to the hydrostatic pressure acting on the shoring wall.

It is noted that the hydrologic catchment for this catch basin is less that that of the roof. As well, the catch basin is on the downslope of the 141 East Broadway property and relatively distant from the collapse location.

Therefore, despite hydrostatic pressures developing to the point where a significant relief crack could manifest, with respect to the subject failure, I envisage that the location and condition of the catch basin at 141 East Broadway had a medium relative importance in terms of contributing to the risk of failure.

7.0 SITE HIBERNATION

The following subsections describe the site conditions at the Development Site following the construction hiatus initiated in June 2019 as they relate to the subject shoring failure event. Specifically, the ramifications of the non-compliance to the recommendations mentioned in Section 2.2.12 are discussed.

7.1 Stormwater Accumulation

As mentioned in the letter of recommendations prepared by GeoPacific, dated June 14, 2019, the ESC equipment was recommended to be left in place in order to maintain stormwater control on-site. Specifically, it was recommended that no more than 300 mm of ponded be allowed to accumulate at any time. Based on the site review report prepared by Camphora, dated June 10, 2019, the ESC equipment was removed around this time and the Development Site was left without a means to remove stormwater from the site in an ESC compliant manner.

At the time that ESC measures were restored and pumping out of water accumulated at the base of the excavation commenced in January, 2020, the depth of this water was estimated to be 3 feet. As it had been allowed to collect for quite some time, the elevation of the groundwater behind the shotcrete shoring face would have equilibriated with the water level in the excavation. If the water level inside the excavation was lowered (relatively) quickly, a ‘rapid drawdown’ condition would manifest, with elevated hydrostatic pressures on the ‘soil’ side of the shoring wall. This would contribute to the overall pressures required to be resisted by the shotcrete face. In the event that the column of water behind the undrained shotcrete was sufficiently high, the shotcrete could fail. This would result in cracking. If this occurred at the anchor heads, the anchors would be observed to punch through. In either case, the elevated hydrostatic pressures

would be reduced as water drained through the cracks and/or newly-created anchor head apertures.

With respect to the subject failure, I envisage that the lack of management of site water had a medium relative importance in terms of contributing to the risk of failure.

7.2 Lack of 3rd Party Review

It is understood that the City of Vancouver required a third-party review by a Qualified Professional of the geotechnical recommendations associated with the proposed construction hiatus put forth by GeoPacific. We have not received documentation indicating that this requirement was fulfilled.

Had the third-party review been fulfilled, it is expected that it could have:

- further impressed the importance of implementation of the recommendations made by GeoPacific;
- allowed these recommendations to be augmented, perhaps with a requirement for lift-off testing and re-tensioning of anchors at specified, weather- or time-related intervals;
- potentially allowed deficiencies in installation to be discovered, and/or
- allowed review of the GeoPacific design.

All of these are envisaged to have been worthwhile strategies to better manage the risks associated with having an unattended site.

With respect to the subject failure, I envisage that the lack of 3rd party review had a medium relative importance in terms of contributing to the risk of failure.

7.3 Surcharge Load Without Geotechnical Review

A requirement stated in the letter of recommendations prepared by GeoPacific was that no additional surcharge load due to product storage or outrigger was allowed within 3 metres of the shoring walls without review by the geotechnical engineer. According to the site review report prepared by Camphora, dated November 14, 2019, concrete jersey barriers were placed around the perimeter of the site. There is no documentation that indicates that GeoPacific was provided with the opportunity to review the surcharge load imposed on the shoring walls by the concrete jersey barriers.

Typical 10-foot-long jersey barriers have a weight of approximately 4000 lbs, which is spread over a 2-foot-wide base. This results in a surcharge pressure of 200 psf, per block, located immediately behind the shoring walls. The addition of this surcharge load would contribute to a decrease in the overall Factor of Safety and would be expected to contribute to deflections of the shoring wall (Section 6.1), although this cannot be verified due to a lack of displacement monitoring of the shoring wall during the time that they were in place.

With respect to the subject failure, I envisage that the imposition of surcharge loads without geotechnical review had a low relative importance in terms of contributing to the risk of failure.

7.4 Lack of Displacement Monitoring

As described in Section 2.2.10, displacement monitoring of all sides of the shoring walls was recommended by GeoPacific to be carried out during the construction hiatus using a remote tilt-meter system. A remote monitoring system such as this would continuously monitor the shoring walls for movement with the real-time monitoring data able to be accessed remotely. Movement thresholds are established, for which the system would automatically alert pre-determined recipients via email or text message immediately if they are exceeded. We consider this, or a suitable alternative, to be an important safety measure during the extended period of time for

which no personnel were on site to visually monitor the shoring walls for signs of movement. Moreover, it should be noted that the City of Vancouver required "a means to monitor the site for any movement or changes on the current geotechnical condition" and this would have been a suitable methodology to meet this requirement.

Furthermore, it was recommended that survey monitoring points be established on the faces of the shoring walls in order to truth the proposed remote displacement monitoring. Survey points were monitored during the construction hiatus; however, the monitoring points were only located on the adjacent buildings (i.e. none on the shoring walls). As neither the remote displacement monitoring nor the survey monitoring was implemented, there were no means to monitor potential movements of the shoring walls during the site hiatus.

In the case that these monitoring recommendations had been implemented, the movement of the shoring wall may have been recognized at an earlier date, and the severity of the movement would have been well documented, allowing for the possibility of more timely and appropriate responses. However, given that the site was staffed and geotechnical field reviews were being carried out while the failure was initiating, with respect to the subject failure, I envisage that the negligible survey monitoring carried out during the construction hiatus had a low relative importance in terms of contributing to the risk of failure.

8.0 WEATHER

8.1 Antecedent Freezing Conditions

The sustained sub-zero temperatures in mid-January 2020 would have been expected to result in heaving of frost susceptible soil and freezing of free water. Generally, soil with greater than 8% fines content is found to be frost susceptible. Thus, the upper silty fills, underlying weathered 'silty fine-grained sand' Capilano Sediments, and deeper glacially consolidated till–like 'silty sand' Vashon Drift would all be frost susceptible and expected to heave when in a moist condition. As water was infiltrating to ground at both the south and north ends of the east portion of the CNH parking lot (i.e. due to the overflowing and leaking discharge pipe for the rainwater leader and parking lot catch basin as well as (more than likely, a leaking water connection pipe), that these soil types would be moist is very likely.

Heaving of the soil and freezing of free water behind the shoring face would result in the shotcrete moving eastward.

Daytime thawing of the heaved soil behind the shotcrete face would create a gap into which more water would flow. [Based on our experience, thawing of this soil could also result in partial detensioning of the inclined anchors.]

Water flowing into this gap may not have been able to drain, as many of the weep holes were not functional. This trapped water could freeze in the overnight sub-zero temperatures, thereby creating a scenario where frost jacking of the shotcrete face progressively occurred (possibly also over-stressing anchors due to the associated increased elongation), the strength of the soil immediately behind the shotcrete face weakened to the point where the bearing provided to the anchor heads was compromised, water trapped behind the shotcrete exerted hydrostatic pressure on it, and some anchor heads 'punched through' the shotcrete.

With respect to the subject failure, I envisage that the antecedent freezing weather conditions had a medium relative importance in terms of contributing to the risk of failure, becoming high due to the trapped water.

8.2 Antecedent Rainfall Conditions

As noted in Section 2.2.14, the precipitation events antecedent to the subject excavation failure were significant and the runoff associated with this rainfall was discharged into, and concentrated at (especially the active wedge of), the excavation shoring along the property line shared between 138 East 8th and 141 East Broadway.

It would be unreasonable to require that excavation shoring be designed to resist hydrostatic pressure, however the construction of a condition which is undrained significantly increases the risk / likelihood of failure under such sustained, then intense, wet weather conditions.

With respect to the subject failure, I envisage that the antecedent sustained then intense rainfall condition had a very high relative importance in terms of contributing to the risk of failure.

9.0 IMPLEMENTATION OF RECOMMENDATIONS

The following are considered to have been the responsibility of the general contractor to organize / implement and of the Geotechnical Engineer of Record to review. Oversight of the subject excavation by the Geotechnical Engineer of Record should have been sufficient to ascertain whether, when and how their recommendations were being implemented. If their recommendations were not being implemented, follow-up with their client would have been appropriate. If public safety, health or welfare and/or the protection of the environment was at risk, it could also have been appropriate to engage the City of Vancouver.

9.1 Monitoring

Based on the information available to Horizon, monitoring during the construction hiatus was a requirement of both the City of Vancouver ("*means to monitor the site for any movement or changes of the current Geotechnical condition*") and GeoPacific, as follows:

> *A remote tilt meter system should be implemented on all sides of the shoring which would allow for continuous, remote monitoring of the walls for any potential movement. Continuous monitoring should be confirmed by periodic survey readings at pre-determined monitoring points.*

As discussed in Section 2.2.10, survey monitoring of the shoring walls was not initiated until January 6, 2020, at which time signs of movement of the shoring wall had already been reported. Moreover, the four survey monitoring points initiated on the shoring wall at this time were limited to locations near the crest of the wall, at approximately the same elevations (ie El. 117 feet geodetic).

In addition to these monitoring points being initiated much later than recommended, they did not encompass the full height of the shoring wall. Circular global movements preceding failure may have manifest but would not necessarily be measurable if the point about which the failure circle was rotating was the crest of the shoring.

With respect to the subject failure, I envisage that the limited and late nature of the survey monitoring had a medium relative importance in terms of contributing to the risk of failure.

9.2 Erosion and Sediment Control

Based on the information available to Horizon, monitoring during the construction hiatus was a requirement of both the City of Vancouver ("t*he erosion sediment control system to be put back in place*") and GeoPacific, as follows:

> *Storm water is pumped out in an ESC compliant manner such that no more than 300mm of ponded water is present within the excavation at any time.*

With respect to the subject failure I envisage that the lack of implementation of the recommended ESC measure during the hiatus had a medium to high relative importance in terms of contributing to the risk of failure.

9.3 Lift-Off Testing

Lift-off testing of "all anchors on the west shoring wall" was recommended by GeoPacific on January 15, 2020. This was not carried out. This recommendation was reiterated on January 31, 2020, presumably to be carried out on anchors above the 4.5-metre high backfill berm also recommended at that time.

Had the lift-off testing recommended on January 15 (a Wednesday) been carried out in a timely fashion (ie commencing Friday, Saturday or Monday), it is possible that:

- Any gap behind the shotcrete created by freezing conditions (which extended to January 17) would have been minimized,
- Anchors which were over- or under-stressed could have been identified and the total anchor resistance loads of the west shoring system could have been rebalanced, and
- There would have been an opportunity to observe that some weep holes were not functional.

With respect to the subject failure, I envisage that the lack of implementation of the recommended lift-off testing had a high relative importance in terms of contributing to the risk of failure.

10.0 COMMUNICATION

A significant cause of the failure was ineffective communication in addition to the leaking pipe infrastructure, ineffective weep holes, lack of geotechnical recommendations (or lack of their implementation) and wet weather. Based on the information available to us, ineffective communication was demonstrated between the Geotechnical Engineer of Record and their Engineer-in-Training (EIT, hereafter). Ineffective communication was also demonstrated between the Project Team and the City of Vancouver.

With respect to the communication between the Geotechnical Engineer of Record and their Engineer-in-Training, effective communication for a situation similar to the subject circumstances would typically comprise an EIT conveying their observations to their supervising professional. If these observations were not sufficiently detailed, the professional may query the EIT to ascertain a clear understanding of conditions, and/or attend at the site themselves. The professional would then recommend a course of action for which the EIT may be given the responsibility to convey to the balance of the Project Team and to carry out field reviews during implementation, with a similar cycle of communication. Should implementation not be timely, this would be reported by the EIT and the professional would follow up. Thus, ineffective communication may result from:

- inaccurate observations or reporting on the part of the EIT,
- recommendations from the professional which are unclear,
- a lack of opportunity to communicate, and/or
- a lack of timeliness in this communication.

With respect to the communication between the contractor and the Geotechnical Engineer of Record, ineffective communication may also arise if there is no sense of urgency or possible consequences due to disregarding a recommendation conveyed by the professional to the contractor.

If the aforementioned ineffective communication between the contractor and the Geotechnical Engineer of Record results in a lack of implementation of professional recommendations which cannot be resolved and which gives rise to a risk to public safety, health or welfare and/or the protection of the environment, it could also be appropriate to communicate with the City of Vancouver. The City could also then have been engaged to liaise with the neighbour in order to expedite investigation and mitigation measures at 141 East Broadway.

It is my perception that the relationships between the contractor and the City of Vancouver and between GeoPacific and the City of Vancouver could be improved. It is my opinion that all parties should work toward attaining relationships which are ***trusted and trusting partnerships*** in order to best protect the health, safety and welfare of the public.

With respect to the subject failure, I envisage that ineffective communication had a very high relative importance in terms of contributing to the risk of failure.

11.0 FOLLOW-UP

It is unknown whether all of the requirements of the City of Vancouver to allow a construction hiatus were implemented or if there was a mechanism in place to allow follow-up in order to ensure the intent of these recommendations were met.

It appears that insufficient systems were in place by the project team at the Development Site to ensure that the:

- recommended works were carried out, and
- results of the recommended monitoring were conveyed to and assessed by the geotechnical consultant.

It would have been appropriate for the Geotechnical Engineer of Record to follow-up as discussed above in order to ensure that the intent of their recommendations was met and to protect public safety, health or welfare and/or the environment

With respect to the subject failure, I envisage that lack of follow-up had a medium to high relative importance in terms of contributing to the risk of failure.

12.0 WEIGHTED SUMMARY OF POTENTIAL FACTORS CONTRIBUTING TO FAILURE

The potential factors contributing to the subject failure are described in detail in Sections 4.0 through 9.0. The following provides a summary along with my opinion as to importance, provided as a qualitative weighting.

Table 3: Qualitative Weighting of List of Potential Contributing Factors

Cause Number	Report Heading	Potential Contributing Factor	Qualitative Weighting Regarding Contribution to Failure and Discussion
Unexpected Soil Conditions			
1	4.1	Vertical discontinuities in soil strata	Low
2	4.2	Lack of investigation	Low
3	4.3	Buried elements	Low

Shoring Design, Installation, and Field Review			
4	5.1	Design	Medium to High
5	5.2	Workmanship	Very high
6	5.3	Field Review	High
7	5.4	Monitoring	Medium
Location and Condition of Pipe Infrastructure			
8	6.1	Age and condition of CNH water connection	Medium
9	6.2	Locations and conditions of CNH water (and gas) connections	High
10	6.3	Condition of CNH rainwater leader	High
11	6.4	Condition of CNH parking lot stormwater catch basin	Medium
Site Hibernation			
12	7.1	Stormwater accumulation	Medium
13	7.2	Lack of 3rd party review	Medium
14	7.3	Surcharge load without geotechnical review	Low
15	7.4	Lack of displacement monitoring	Low
Weather			
16	8.1	Antecedent freezing conditions	Medium to High
17	8.2	Antecedent rainfall conditions	Very High
Lack of implementation of recommendations			
18	9.1	Monitoring	Medium
19	9.2	ESC measures	Medium to High
20	9.3	Lift-off testing	High
21	10.0	Poor communication	Very High
22	11.0	Lack of follow-up	Medium to high

13.0 CONCLUSIONS

13.1 Regarding Failure Mechanisms

Based on the available information and our geotechnical experience, the following hypothesis is provided to provide rationale and describe the sequence of events that are expected to have contributed to the resulting excavation slope failure.

It is important to understand that design and implementation of temporary excavation slopes for construction of proposed developments is different from excavation slope supports that are designed and required for permanent conditions. The design life of temporary geotechnical works ranges from a few hours to 2 years (per the Engineers and Geoscientists of BC practice guideline, "Guidelines for Geotechnical Engineering Services for Building Projects") while the design life for permanent works, such as buildings, is generally taken to be between 50 and 75 years.

Thus, there would be different geotechnical engineering design considerations for temporary vs permanent works with the effects of seismicity and corrosivity generally disregarded in design of temporary works and generally higher Factors of Safety (including for global slope stability) being adopted for permanent works. Depending on the project-specific anticipated design life, frost action may or may not be considered, however, professional engineers are obligated to consider the effects of climate change. Regardless of the temporary or permanent design conditions, there are parameters that are fundamental to the analysis, design, and construction process for supported excavation slopes. These parameters include accurate soil properties, realistic ground water conditions, surcharge loads, and slope geometry.

For the subject site, the slope geometry was designed as a vertical slope cut that would be stabilized by a reinforced shotcrete shoring face that is connected to tie back anchors. The shotcrete face would function as a retaining wall, relying on the tie-back anchors to provide lateral resistance to the retained soil mass behind the wall, including any surcharge loads (e.g. vehicle traffic), behind the slope crest. The required lateral resistance is based on a portion of the soil mass (i.e. the 'active wedge', as previously described) being allowed to mobilize to an 'active condition' and the locations and magnitudes of surcharge loads. An active condition can be simplistically visualized as activating the soil friction or shear strength along a design slip surface (generally taken in typical excavation shoring design as being the back of the active wedge, as previously described).

The active condition results in an active lateral earth pressure that pushes against the shotcrete face (i.e. retaining wall) and is calculated based on slope cut geometry, soil internal friction angle, and soil unit weight. The soil unit weight is in turn related to where the local ground water table is situated. Soil situated below the ground water table has a higher unit weight than soil above the water table and a heavier soil results in greater lateral earth pressures. For conventional retaining wall systems, the presence of ground water is managed by ensuring that water does not accumulate behind the wall. For shotcrete retaining walls, this ground water management is typically achieved by installation of weep holes through the shotcrete face at regular intervals both laterally and vertically; thus, allowing ground water to seep through the wall face and prevent the accumulation of water that could result in development of hydrostatic water pressures.

At the subject site, there were multiple, other sources of water contributing to an elevated ground water table. These sources include:

- utility trenches located adjacent to the slope crest,
- leaking water lines,
- leaking catch basin,

- leaking rainwater leader discharge pipe, and
- general rainwater runoff from proximate surfaces.

It should be understood that utility trenches may function as preferential drainage paths where water is collected from other areas and allowed to accumulate and/or transport in the trench fill materials. It is estimated that the water from these trenches would flow down and into the surficial fill materials and underlying weathered soil. The difference in hydraulic conductivity between the surficial fill materials and underlying dense (till-like) soil conditions would result in perched ground water or interflow conditions. This near-surface ground water would be expected to have seepage towards the shotcrete retaining wall. If there was insufficient drainage behind the shotcrete retaining wall to accommodate both the natural ground water and water from local fill and trench sources, hydrostatic water pressures would develop. It should be noted that it is not reasonable to design a temporary excavation shoring system to resist hydrostatic pressure. That being said, the stability of such systems relies on them being drained. Although, extreme weather events could be expected to challenge some ordinary drainage systems installed in conformance with best practice, site observations of the shotcrete face at the subject property found that most of the weep holes were inadequately installed. More specifically, there were many weep holes that did not extend all the way through the shotcrete face. Thus, drainage of water from behind the shotcrete wall was reduced sufficiently so as to allow development of hydrostatic water pressures.

Water may have also preferentially infiltrated into the till-like soil below the perched groundwater table via fissures (as observed). If these fissures were sufficiently hydraulically continuous and unfavourably oriented, water that accumulated within them could exert hydrostatic pressure on a block of soil; this could have helped to mobilize a sliding block.

It is envisaged that hydrostatic water pressures may have initially only developed at comparatively discrete portions behind the shotcrete face since the stability of the shoring did not deteriorate rapidly after installation despite most of the weep holes having been inadequately installed. It is also envisaged that as water accumulated near the bottom of the excavation shoring, additional lateral stress from the water pressure would be transferred to the shoring face and tie-back anchors. Where soil is located under this zone of water accumulation, it is possible for water-softening to occur in fine-grained soil such as silt. This could result in a reduction of the interface friction angle between the shotcrete and the retained soil which in turn would increase the active lateral earth pressure that pushed against the shotcrete face. With this increased lateral earth pressure, the shotcrete face would be expected to deflect farther outwards to achieve strain compatibility. Although this deformation is typically small in magnitude and would not be expected to result in progressive deterioration of the shoring stability, it would be expected to have allowed more water to accumulate behind the wall face, leading to a condition of frost-jacking, as described below.

With winter conditions, water that had accumulated behind the shotcrete face would be expected to freeze with below zero temperatures. It should be noted that the shotcrete of temporary shoring systems should not be relied on to provide frost protection, however it is best practice to re-tension soil anchors following a period of sustained cold weather, immediately after the frost has ‘come out of’ the ground. As documented in local climate records, there were repeated cycles of below and above zero temperatures in the days leading up to the rainy weather that preceded the failure. It is envisaged that this resulted in freeze-thaw cycles of water accumulated behind the shotcrete face. The stress from expansion of frozen water is significantly greater than hydrostatic water pressures and with each cycle of water freezing and thawing, there would be progressively greater strain developed at the shotcrete face relative to the installation condition. This would have allowed additional water to enter the gap behind the shotcrete face, thereby creating a progressive ‘frost jacking’ effect. The increased gap dimension in conjunction with water-softening of the adjacent soil could have increased the potential for soil erosion, thereby exacerbating this failure cascade. It is envisaged that lateral strain at the shotcrete face was eventually sufficient such

that the associated stress exceeded the strength of the reinforced shotcrete near the anchor heads and 'punching' occurred (with the shotcrete partially or completely separating from the anchor head). This type of punching failure at the shotcrete / anchor head connection was reported to have occurred at the subject property.

When the shotcrete face-to-anchor head connection became compromised, the resistance that the anchor provided to the shoring system was lost and, in turn, the lateral support that the shoring system provided to the retained soil mass was also lost. With progressive deterioration of the shoring system, progressively increasing lateral displacement of the retained soil mass occurred which resulted in additional tension cracks both in the shoring face and slope crest areas. Where tension cracks developed in the retained soil mass behind the shotcrete face, water could accumulate in these cracks and hydrostatic water pressures could develop at depths where such pressures would not have originally been present above the local ground water table and at locations acting on a larger soil mass than that immediately behind the shotcrete face. With increased tension crack depths and extents, possibly exacerbated as a result of pre-existing fissures, this allowed further introduction of water into the subsurface, especially as preferential drainage or flow paths for surface and near surface water flows. This in turn resulted in increased ground displacements as the cyclic slope deterioration condition continued.

For the subject site, it is estimated that the lack of effective drainage, especially in conjunction with frost heave of silty soil behind the shotcrete face created a condition where a gap was created and allowed to progressively widen until the shotcrete failed at some anchor heads. The design lateral earth pressures and unintended hydrostatic pressure would have been required to be resisted by few anchors, and the loads on these anchors would have increased. Compromised anchors at the bottom of the excavation could have allowed for localized slope movement and even ground failure which would adversely affect the support and geometry of the overlying soil. Deterioration and failure of the lower portion of the excavation slope could have resulted in an overhanging geometry that allowed the overlying soil to collapse or slide, as is suggested by the pattern of post-failure deposition of debris evident in photographs. The overlying soil may have mobilized along pre-defined surfaces that had developed during the progressive deterioration of the soil mass and slope. This failure mechanism would initially have resulted in failure or collapse of the material closest to the face, as opposed to a single soil mass rotating at the base (while maintaining an approximately coherent geometry above the failure surface). Similarly, a toppling mechanism or base sliding failure in the soil mass would not be expected.

13.2 Regarding Causes

As stated in the introduction,

- multiple factors are generally found to contribute to, cause, or otherwise result in a particular failure,
- a breakdown in communication is usually a significant contributing factor,
- often, failure mechanisms cascade, and
- water is usually a culprit in failures of a geotechnical nature.

For the subject failure, all of the above are true. The subject failure was a result of a set of antecedent conditions which are described in Sections 2.0 and 4.0 of this report. In the days prior to collapse, there was increasing evidence that a failure was occurring. This evidence included accelerating subsidence of the ground surface east of the eventual failure scarp, formation and expansion of cracks in the shoring face, as well as progressive punching of anchors through the shotcrete (one, two then five anchors punched through on January 29, 30 and 31, respectively).

Ultimately, as a result of antecedent conditions, the aforementioned decrease in the capacity of the shoring system and significant rainfall on January 31, 2020, the subject collapse occurred.

Based on the information available to us, it does not appear that the responses by various parties were commensurate with the urgency of the situation. If the contractor or the Geotechnical Engineer of Record had appreciated the increasing risk of failure, interim slope stabilization measures of a sufficient size to manage the slope deterioration could have been implemented. The City could then have been engaged to liaise with the neighbour in order to expedite investigation and mitigation measures at 141 East Broadway.

In our opinion, the five main causes as follows:

1) Ineffective communication, including regarding the slope deterioration and the urgency of timely placement of backfill,
2) Significant antecedent rainfall conditions,
3) Poor workmanship and inappropriate field review pertinent to installation of weep holes,
4) Unfavourable location and condition of pipe infrastructure, and
5) Lack of implementation of recommended measures and lack of follow-up.

If 1) had been more favourable, it is likely that the subject collapse would not have happened. If more than two of the other above causes had been more favourable, it is possible that the subject collapse would not have happened.

PART C - RECOMMENDATIONS

At the Development Site, in order to protect the health safety and welfare of the public, it is recommended that:

- weep holes be immediately drilled through the shotcrete shoring at nominal 6 feet on centre, completely through to the soil behind (with suitable filtering measures, if required)
- lift-off tests be performed on all anchors,
- more comprehensive survey monitoring points be installed,
- the City storm sewer located on East 8th Avenue presently servicing and 'downstream' of this area be checked to see if it requires maintenance, and
- best practices be employed to manage surface water, including but not limited to grouting / patching of cracks in the proximate laneway and appropriate re-direction of roof runoff from adjacent buildings (which is currently directed to the ground).

PART D - IMPACT ON ADJACENT PROPERTY (141 EAST BROADWAY)

The impact of the shoring failure on the adjacent property includes impact to the building, to the parking lot and to buried utilities.

14.0 BUILDING

The one-storey building at 141 East Broadway was constructed in 1948 and has undergone many renovations in the intervening decades. Most notably in areas affected by the shoring failure or possibly impacting its remediation plan, the following changes were undertaken:

- a coal bin adjacent to the east end of the north wall was removed and the appurtenant coal chute infilled,
- two loading bays at the north wall were infilled, leaving two man-doors,
- a vent opening was added to the north wall, but appears to have been located clear of a pilaster, and
- new plumbing to service new bathrooms at the northeast portion of the building was installed which would have required cutting and patching of the original slab-on-grade.

Prior to demolition of the former building on the Development Site, this building exhibited many signs of age, including cracking of the north wall and reportedly the slab-on-grade in the northeast portion of the building. Timber and steel strapping designed by Bogdonov Lerer (the structural engineering consulting firm retained by both the previous and current owner-developers of the Development Site) was pre-emptively installed prior to demolition of the previous building on the Development Site in order to manage risks associated with this demolition and subsequent excavation shoring.

As a result of the subject shoring collapse, additional distress to the subject building was incurred. This included additional cracking of the north wall and the slab-on-grade in the northeast portion of the building.

More information with respect to the impact of the shoring failure on the building at 141 East Broadway is provided in the report dated March 26, 2020 by RJC, attached in Appendix F.

15.0 PARKING LOT

Failure of the shoring at the east side of the parking lot at 141 East Broadway resulted in the loss of approximately 35% of the parking lot area. Subsequently, the test pit removed asphalt and disturbed the upper 5 to 7 feet of soil for an additional approximately 40 m^2 (10%). Restoration of this portion of the parking lot will be required.

16.0 UTILITIES

The gas and water connections to the CNH building were destroyed during the subject failure. They will require replacement. The catch basin located at the northeast corner of the parking lot was partially exhumed during the test pit investigation and was determined to require significant servicing, or possibly complete replacement. The discharge connection to the City of Vancouver storm sewer in East 8th Avenue is unrecorded and some upgrading of this connection may be required. The discharge from the rainwater leader at the northeast corner of the CNH building will be required to be redirected. It is envisaged that this would most easily be done to the same location that new parking lot catch basin(s) will discharge.

PART E – PROPOSED REMEDIAL PLAN

Comments regarding the viability of geotechnical and structural remediation plans are pending receipt of such plans.

17.0 CLOSURE

This report has been prepared for the sole use of our Client, the City of Vancouver, and other consultants for this project. Any use or reproduction of this report for other than the stated intended purpose is prohibited without the written permission of Horizon Engineering Inc.

I am pleased to be of assistance to you on this project and I trust that my comments and recommendations are both helpful and sufficient for your current purposes. If you would like further details or require clarification of the above, please do not hesitate to contact the undersigned.

For:
HORIZON ENGINEERING INC

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
K. E. SAVAGE

31 Mar 2020

Karen E. Savage, P.Eng., FEC
President

APPENDIX A: LIST OF RELATED PARTIES

For the ease of the reader of this and any subsequent documents relating to remediation plans, the following is a list of related parties:

Georgia Pacific Holding Corp

- current owner of Development Site,
- current director: Mehdi Motahari,
- current employees: Kiana Motahari;

Green Oak Development

- previous owner of Development Site,
- past employees: Michael Habibi and Marco Sakamoto;

Prima West Construction

- current general contractor,
- current employees: Marco Sakamoto, Mitchell Wilson and Michael Habibi;

GeoPacific

- previous and current geotechnical engineering consultant for Development Site,
- previous and current Geotechnical Engineer of Record: Matt Kokan, M.A.Sc., P.Eng.;
- previous and current Field Engineer: Ben Shalansky, E.I.T.
- previous Project Manager: Khidhir Jorj, M.Sc.
- previous Senior Reviewer: Kazunori Fujita, P.Eng.

Bogdonov Lerer

- previous and current structural engineering consultant for Development Site,
- previous and current Structural Engineer of Record: Stephen Lerer, P. Eng., Struct.Eng.;

Horizon Engineering Inc

- geotechnical engineering consultant,
- Review Engineer under contract to Georgia Pacific Holdings Corp as required by the City of Vancouver to assess collapse, impact and remediation plan;

Read Jones Christofferson

- structural engineering sub-consultant retained by Review Engineer;

Bon Wong

- owner of 141 East Broadway;

Congee Noodle House

- tenant of 141 East Broadway;

Kunimoto Engineering Ltd

- structural engineering consultant retained by Bon Wong;

Cornerstone Engineering

- Calgary-based engineering consultant retained by Bon Wong to assess and advise on geotechnical issues;

Golden Summit Geotechnical Engineering Ltd

- Local geotechnical engineering sub-consultant of Cornerstone Engineering,
- employee: German Cajigas, P.Eng.

APPENDIX B: LIST OF DOCUMENTS CONSIDERED

Number	# Pages	Date	Item Type	Author	**Relevancy Comment** (Red: Item recommended but not implemented/carried out)
1	8	2017-02-01	Geotech. Report	GeoPacific	No investigation, assumed soil conditions: "1.5-2m of weathered silt and sand, underlain by dense to very dense glacial till to a depth of 4.5-5 metres where it is underlain by sandstone." Variable perched GW expected. Expected shoring movement: 5-15mm at excavation face, decreasing to half that within 3 metres away from the excavation face.
2	9	2018-05-02	Shoring Drawings	GeoPacific	
3	23	2018-05-02	Encroachment Agreement		States that the development property must suitably protect the neighbours from damage (i.e. adequate underpinning) during development, and any damage incurred must be restored by the development property
4	7	2018-10-05	Geotech. Report	GeoPacific	Same as original report, except for Expected shoring movement: 15-25mm at excavation face, decreasing to half that within 3 metres away from the excavation face.
5	1	2019-01-24	Memo	GeoPacific	details pertaining to demo of existing foundation wall with respect to CNH stability
6	9	2019-01-28	Shoring Drawings	GeoPacific	Updated per storm line along East Elevation
7	1	2019-02-13	Memo	GeoPacific	Existing basement wall extends under CNH footings - allowed to keep and use this as underpinning. Condition of existing wall to be reviewed during anchor drilling.
8	27	2019-03-01	Report	RCS Tech	Construction implementation plan
9	2	2019-03-13	Email	GeoPacific	Accepting alternative anchor bar (con-tech instead of DYWIDAG)
10	2	2019-03-19	Memo	Camphora	Progress report, excavation has commenced
10	1	2019-03-28	Memo	GeoPacific	Anchor testing
11	2	2019-04-03	Memo	GeoPacific	Deep void along East Elevation, including photo. Geopacific to review removal of loose material and backfill of the void with shotcrete.
12	1	2019-04-09	Memo	GeoPacific	Void along West Elevation wall (unclear location, anecdotally confirmed to be beneath CNH parking lot). GeoPacific to review backfilling of the void with shotcrete or lean mix concrete.
13	1	2019-04-16	Memo	GeoPacific	Anchor testing. "GeoPacific to continue reviewing all anchor tests"
14	1	2019-04-17	Memo	GeoPacific	Anchor testing. "GeoPacific to continue reviewing all anchor tests"
15	2	2019-04-28	Memo	Camphora	Progress report
16	1	2019-04-29	Memo	GeoPacific	Anchor testing. "GeoPacific to continue reviewing all anchor tests"
17	1	2019-05-07	Memo	GeoPacific	West Elevation, Underpinning section is found to be 2.2 feet deeper that originally estimated (19.8 to 22 feet wall height). Revised design increases lockoff and bond length of bottom 2 rows.

18	1	2019-05-13	Memo	GeoPacific	Anchor testing
19	1	2019-05-24	Memo	GeoPacific	Anchor testing
20	1	2019-05-27	Memo	GeoPacific	Anchor testing. Found that a power pole support anchor along the East Elevation was not installed
21	2	2019-05-31	Memo	Camphora	Excavation completed, site entering hiatus. Notes that City Building Inspector will be invited to review the stop work condition.
22	2	2019-06-10	Memo	Camphora	Construction has ceased and ESC tanks have been removed
23	2	2019-06-05	email	Marco Sakamoto	inquiry for Horizon to review shoring design regarding site hibernation. List of requirements from the City to allow site hibernation (8 items, many not completed)
23	2	2019-06-14	Letter	GeoPacific	Recommendations for site hibernation. Safe for 12 months provided no additional surcharge load is placed behind the walls, storm water pumped out (being ESC compliant) such that no more than 300mm of ponded water is present at any time, continuous monitoring using tiltmeter on all sides plus monthly survey readings
24	2	2019-07-22	Memo	GeoPacific	Review of hibernating site. No signs of movement or seepage noted.
25	1	2019-09-18	Memo	GeoPacific	Review of proposed mobile crane outrigger load adjacent to shoring walls
26	2	2019-11-14	Memo	Camphora	Perimeter jersey barriers placed as per June 2019 City requirements; this is a surcharge load.
27	2	2019-12-20	Memo	Camphora	Preparing for construction to resume
28	12	2020-01-15	Memo	GeoPacific	Cracking first noticed in the parking lot of CNH on Jan. 3, 2020. Cracks up to 10mm wide observed 4-5m west of the western shoring face on Jan 3 site visit. Cracks are located within a zone of local subsidence following a period of heavy rain and freezing temperatures on Dec. 26, 2019. Excavation full of water up to bottom row of anchors along the West Elevation (water estimated to be 3 feet deep). Additional survey monitoring points, utility locate in the parking lot, crack sealing, and lift off tests on all West Elevation anchors recommended.
29	4	2020-01-31	Memo	GeoPacific	Depression in the parking lot has increased to a depth of 150mm approx. 4-5m away from the shoring face. Contractor reported that 'small cracking' in the parking lot was first observed in October 2019. Attributing cracking/subsidence to dysfunctional storm utility that runs beneath the parking lot. Cracking in the west shoring wall was first observed on Jan 28, with significant seepage through the cracks during rain events. 8 anchors have punched along the bottom 2 rows along the West Elevation. Recommendations: backfill against West Elevation wall immediately, remove all asphalt in the parking lot to find the source of water, drill new weepholes in the shoring wall, lift off test all anchors on the west shoring wall.

30	5	2020-02-01	Letter	GeoPacific	GeoPacific on site Jan 28 to review cracking and subsidence, noted to be up to 200mm deep approx. 4-5m behind the shoring face. Clear water was observed to be seeping through cracks in the shoring wall into the excavation. Theorized that there is a beak in the sewer line that is causing soil migration into the sewer during heavy rainfall events, resulting in the subsidence. 'In our opinion, there is no risk to [141 E Broadway] ... the structure remains safe as does the municipal lane along the west (sic) elevation, East 8th along the north elevation, and 145 E Broadway to the south." Recommendations for backfill berm.
31	6	2020-02-02	Memo	GeoPacific	Recommends backfill berm to be constructed up to the adjacent parking lot grade, detailing options for backfilling process with sketches
32	2	2020-02-04	Memo	GeoPacific	Review of backfilling process. No work occurred on site on Feb 3rd. Recommend installing additional survey monitoring points.
33	2	2020-02-05	Unsafe Order	CoV	
34	6	2020-02-05	Memo	GeoPacific	Review of backfilling process. Observed crack in foundation wall of CNH seeping water "approximately that of a garden hose." Recommended that "once the berm is complete, ...repairs be made to the defective storm line beneath the 141 E Broadway parking lot."
35	1	2020-02-05	Memo	CoV Development services, buildings and licensing	Authorizing Prima West to access CNH
35	5	2020-02-06	Memo	GeoPacific	Review of backfilling. Water continuing to seep from the crack in the CNH foundation wall
36	4	2020-02-07	Memo	GeoPacific	Review of backfilling. Observations regarding the City repairs to the water line along 8th Ave., noting that there is a high-pressure leak. Recommend removing the asphalt in the east poriton of the parking lot to investigatie the subsurface soil and utility lines.
37		2020-02-07	Memo	CoV	Detailing the City work on the leaking water connection to the CNH on East 8th Avenue
38	5	2020-02-07	Daily Log	Prima West	Detailing the City work on the leaking water connection to the CNH on East 8th Avenue
39	4	2020-02-10	Memo	GeoPacific	Backfill berm complete and the excavation is safe for worker entry. Recommend that the storm line beneath the CNH parking lot be investigated and the downspout at the NE corner of CNH be investigated.
40	1	2020-02-19	Invoice	Roto-rooter	CNH sanitary line has blockage beneath the sidewalk along E Broadway. Both sanitary and storm connections are towards the south to E Broadway.
41	22	2020-02-21	Memo	GeoPacific	Refutes the fact that apertures are present in the lane to the east of the site. Notes that no storm line has been found beneath the CNH parking lot. Contains survey monitoring plots.

42	13	2020-02-21	Report	GeoScan	No utilities identified under CNH parking lot. Found water and gas connections between CNH and main lines along E 8th Ave. Found a storm connection between the catchbasin in the northeast corner of the CNH parking lot and the main line along E 8th Ave. Found a discontinuity, possibly near the deep void identified in the East Elevation shoring wall by GeoPacific
43	7	2020-03-02	Memo	GeoPacific	Remedial excavation/underpinning design

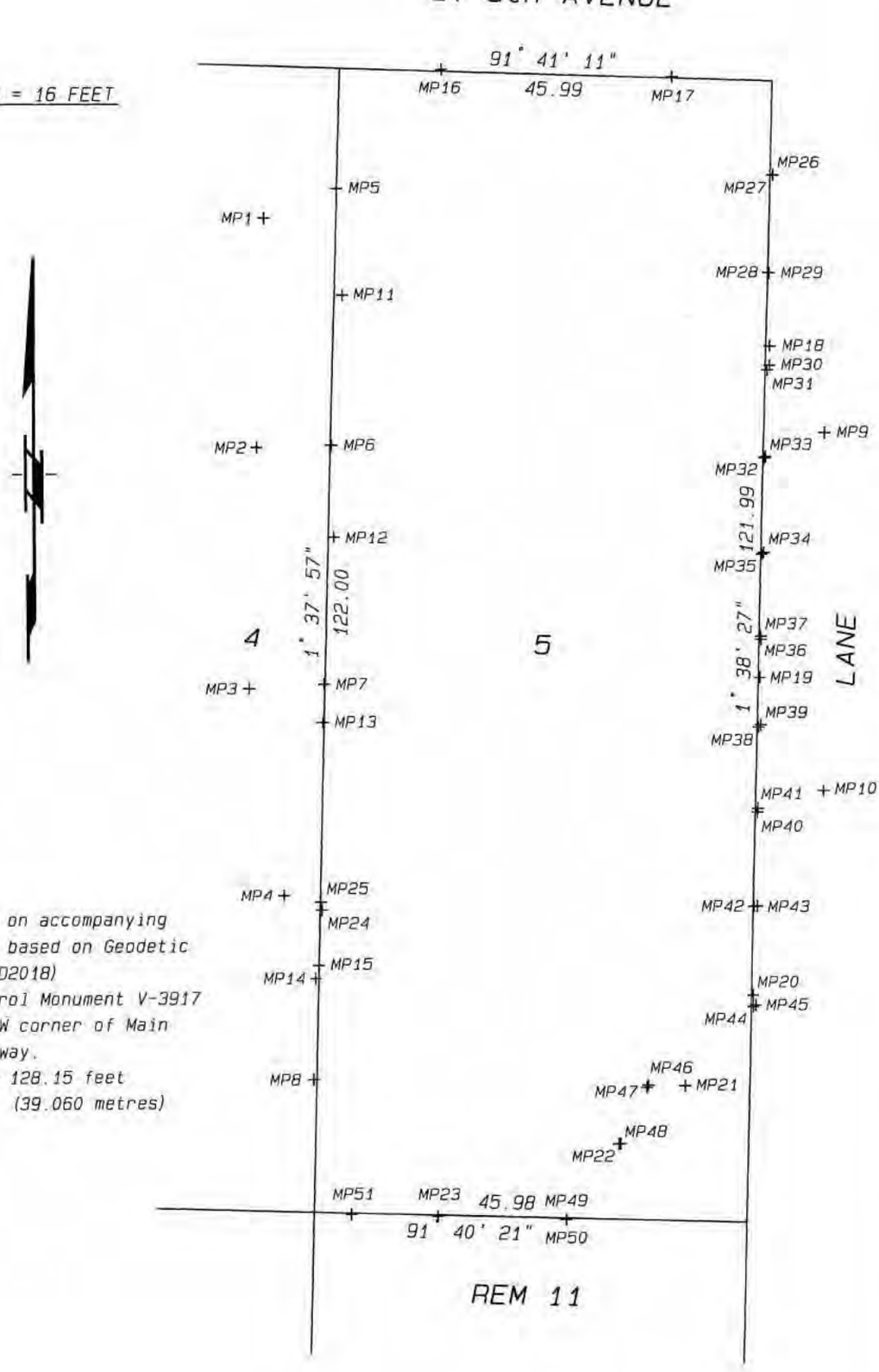
Number	# Pages	Date	Item Type	Author	Relevancy Comment
B1		Undated	Percipitation Records	Environment and Climate Change Canada	Rainfall logs for the City of Vancouver. Week starting January 27: 61.6mm Week starting January 20: 71.0mm Week starting January 13: 28.0mm Week starting January 6: 75.0mm
B2		Undated	Temperature Records	Environment and Climate Change Canada	Temperature logs for the City of Vancouver. Below freezing conditons on January 9 and cycling between freezing/above freezing between January 12 to 17.
B3		1912	Map	Goad's Fire Insurance Map	Shows the footprint of developments circa 1912

APPENDIX C: SURVEY MONITORING PLOTS

PLAN SHOWING LOCATION OF MONITORING POINTS FOR LOT 5, BLOCK 51, DISTRICT LOT 200A, GROUP 1, NEW WESTMINSTER DISTRICT, PLAN 197

138 E.8th Avenue
Vancouver, B.C.

SCALE: 1 INCH = 16 FEET

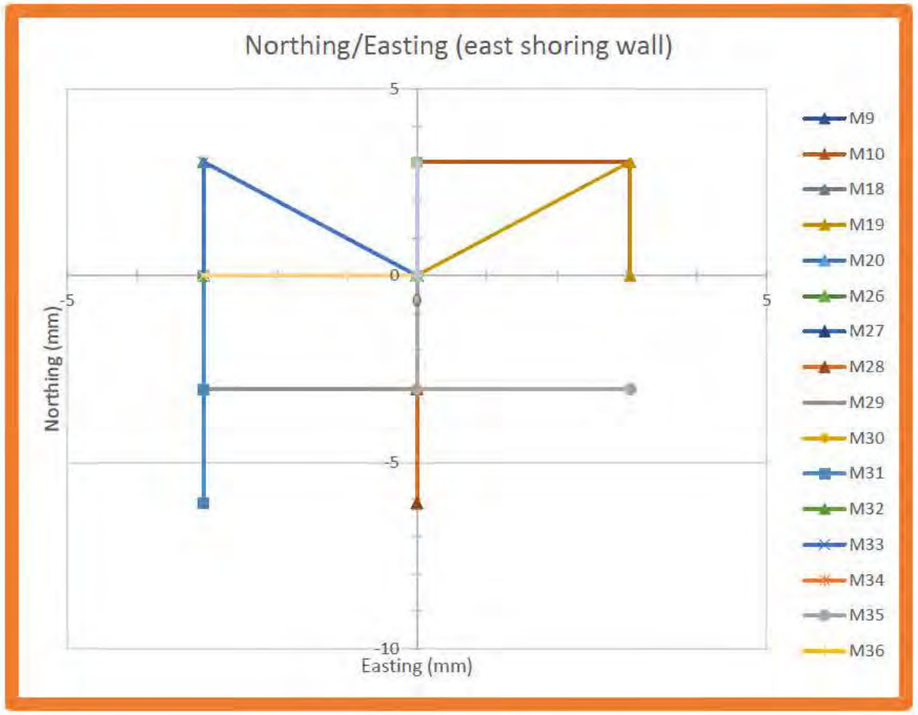


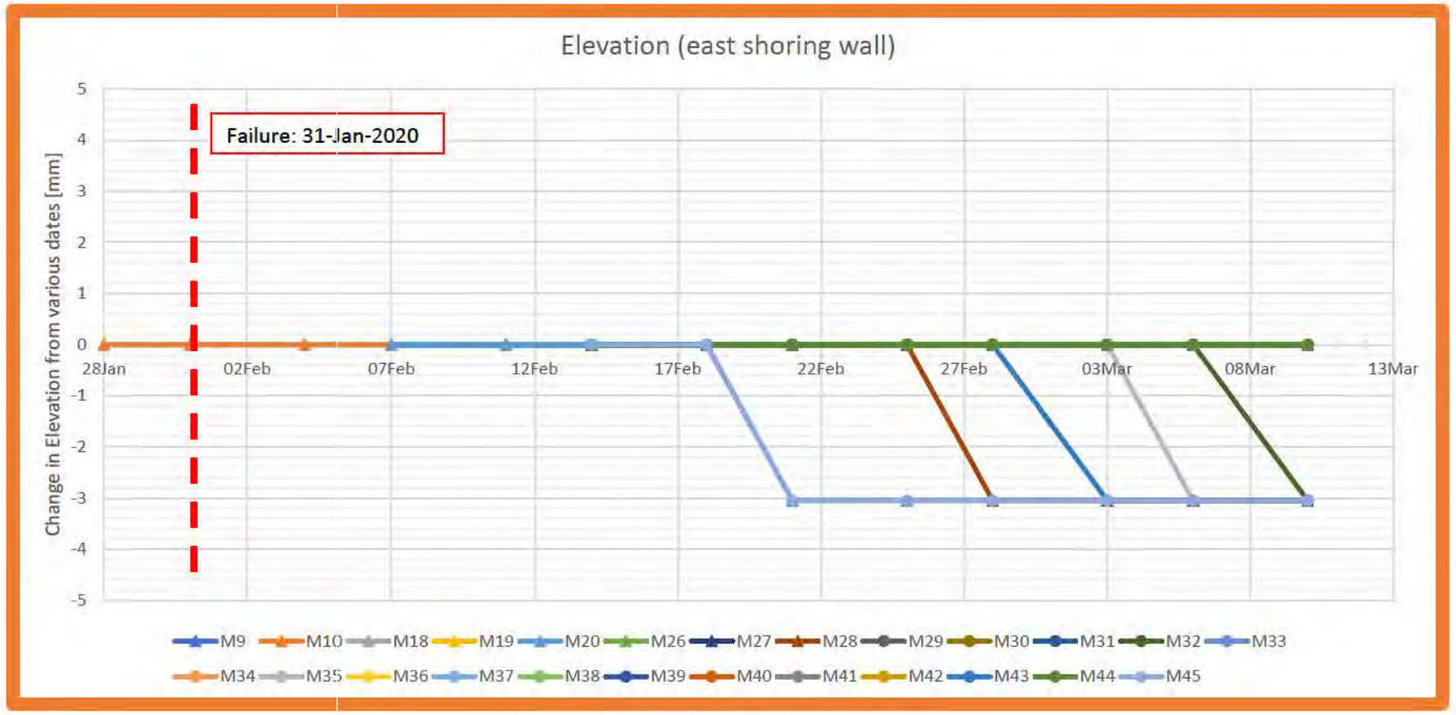
NOTE:
Elevations shown on accompanying spread sheet are based on Geodetic Datum. (CVD28GVRD2018)
Bench Mark: Control Monument V-3917 located at the SW corner of Main Street and Broadway.
B.M. Elevation = 128.15 feet
(39.060 metres)

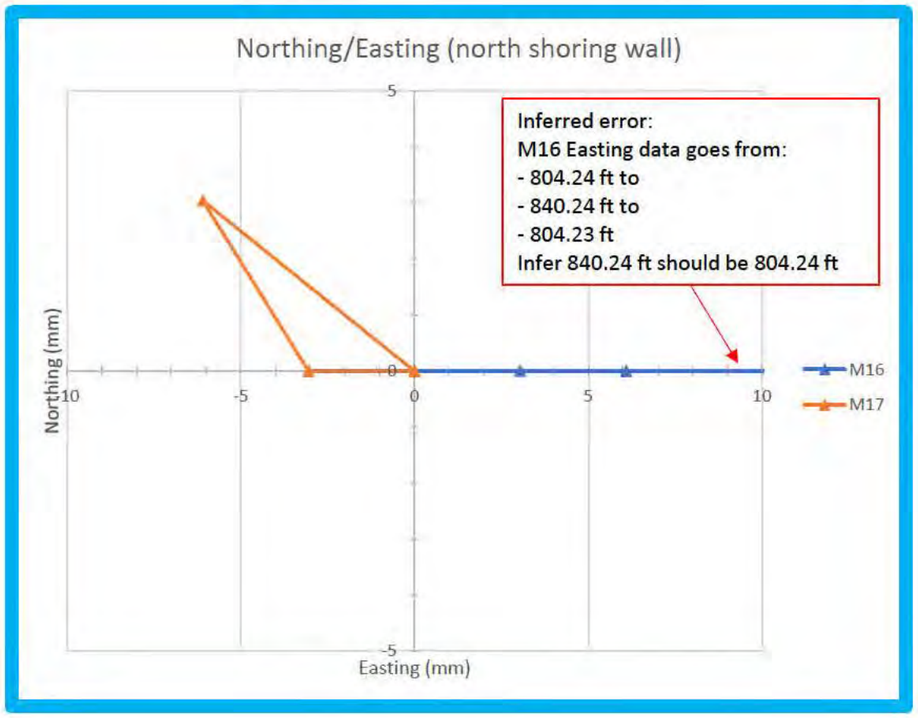
February 14, 2020

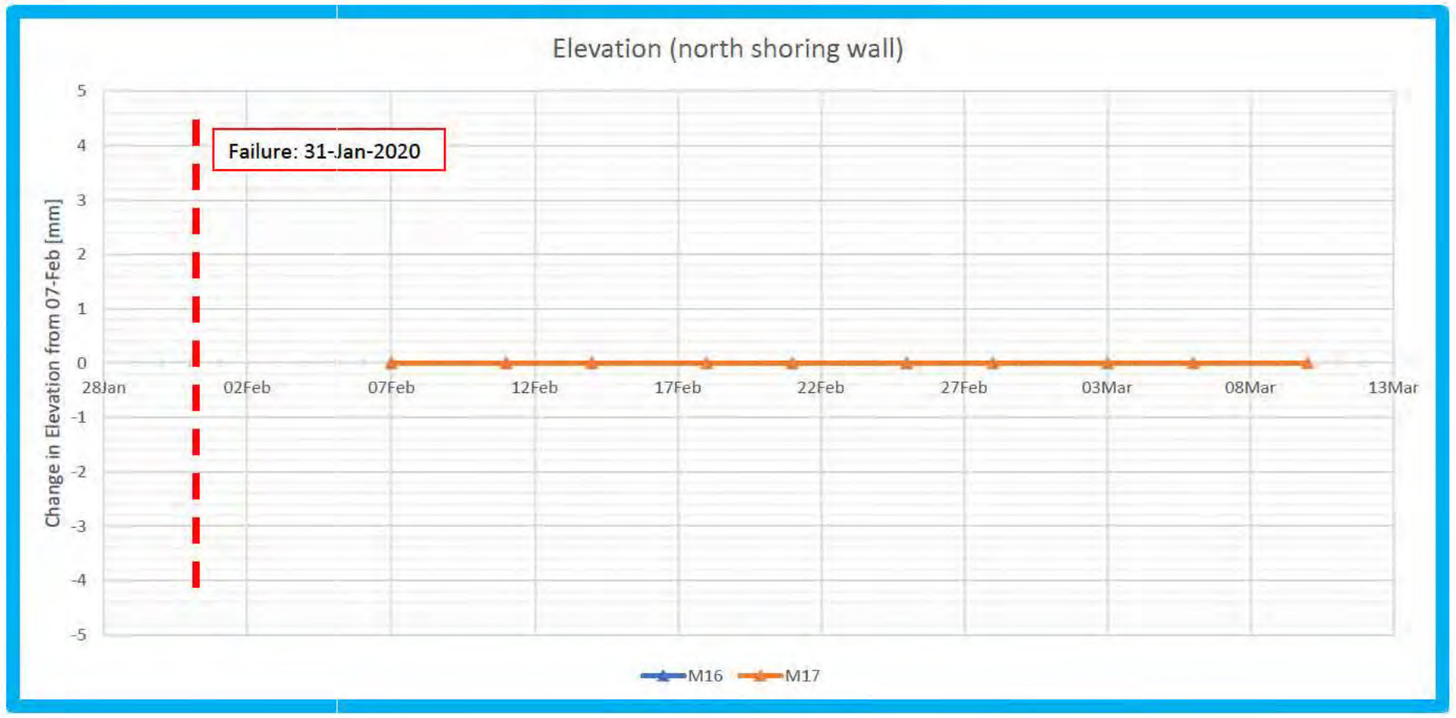
FILE: SH-6712A

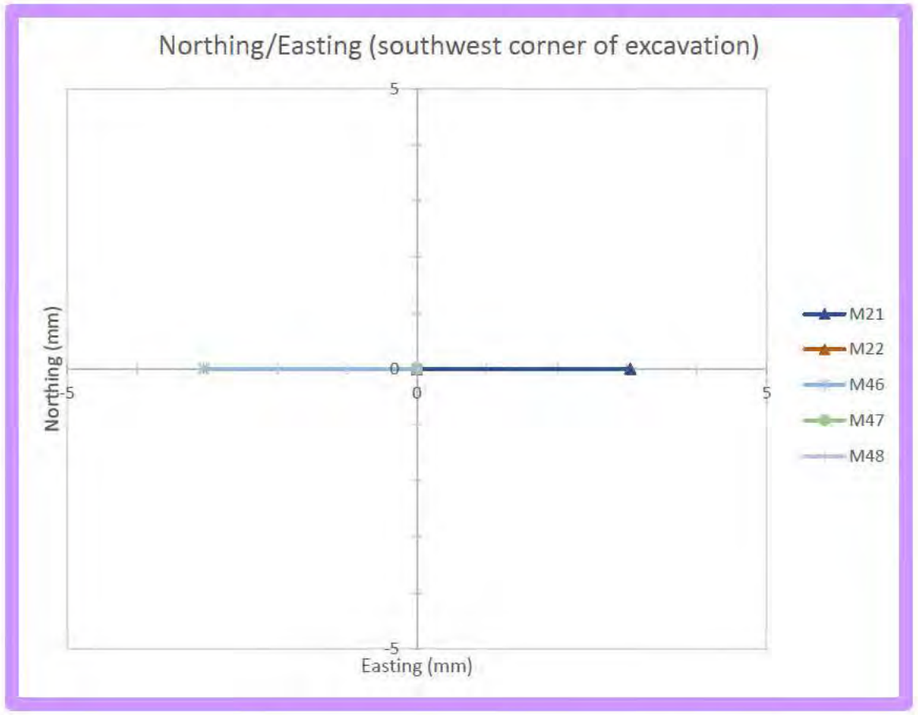
Ken K. Wong and Associates
B.C. Land Surveyor
5624 E. Hastings Street
Burnaby, B.C. V5B 1R4
Telephone: 604-294-8881
Fax: 604-294-0625
Email: wong_associates@shawbiz.ca
200059
TF-5101A
Drawn by: RH

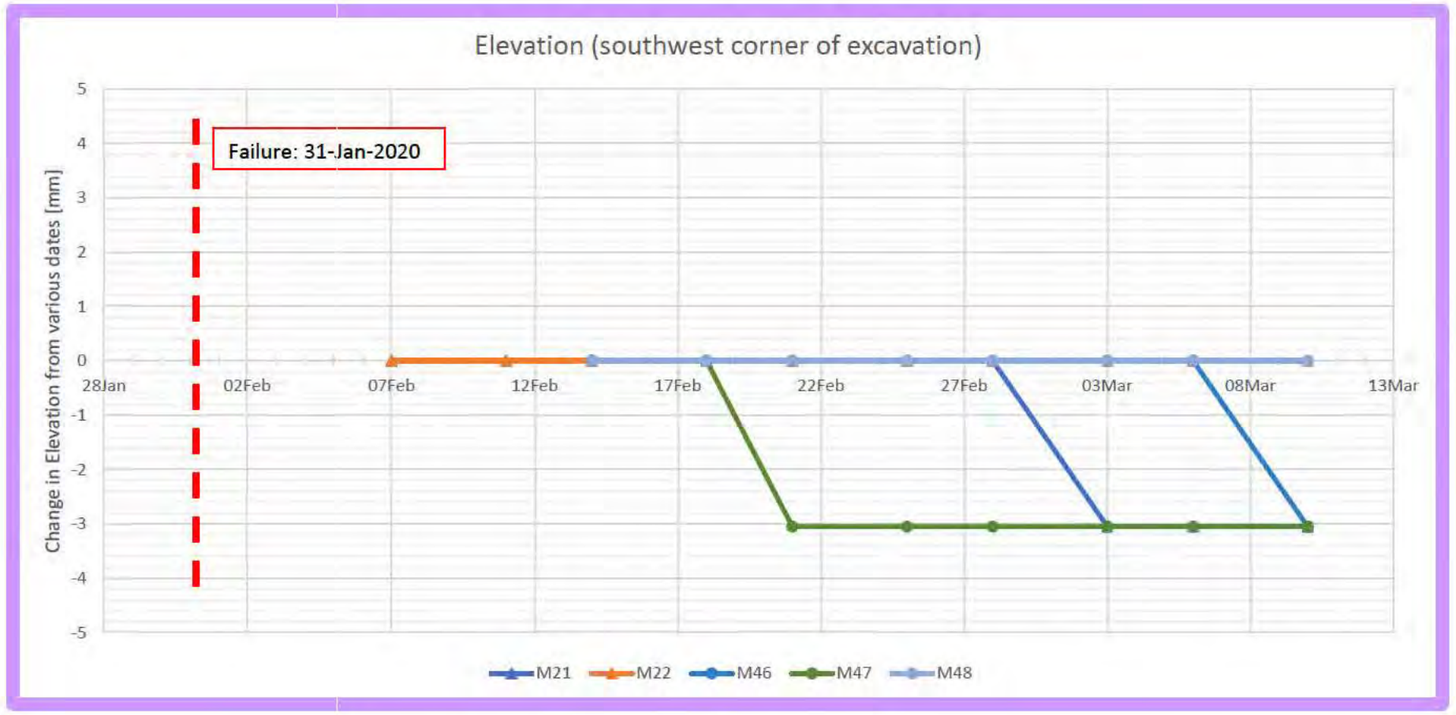

Northing/Easting (east shoring wall)
Northing (mm)
Easting (mm)
5
0
-5
-10
M9
M10
M18
M19
M20
M26
M27
M28
M29
M30
M31
M32
M33
M34
M35
M36

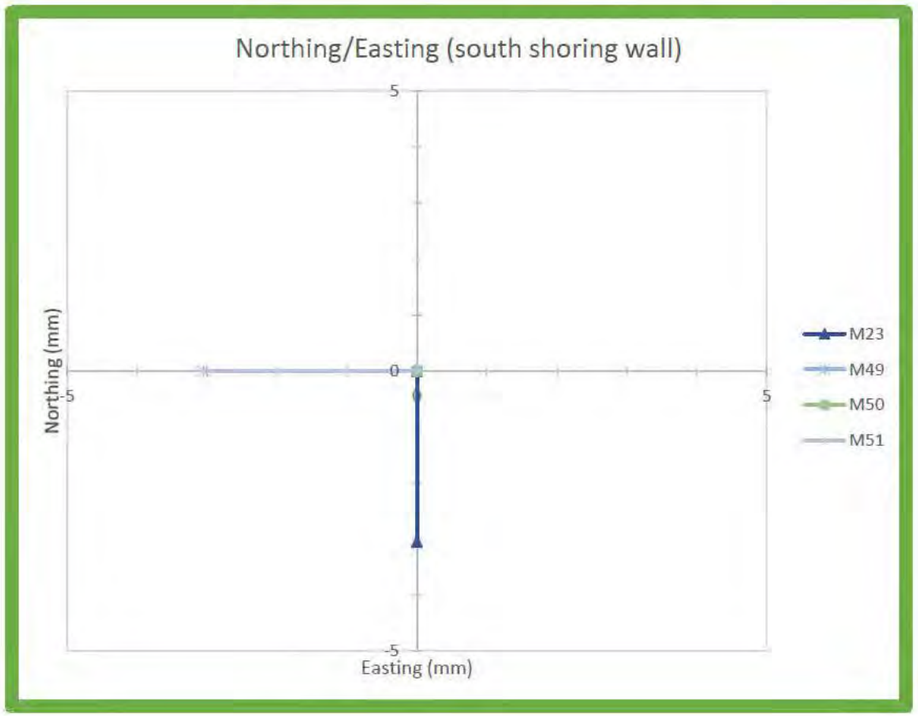

Elevation (east shoring wall)
Failure: 31-Jan-2020
Change in Elevation from various dates [mm]
28Jan
02Feb
07Feb
12Feb
17Feb
22Feb
27Feb
03Mar
08Mar
13Mar
M9
M10
M18
M19
M20
M26
M27
M28
M29
M30
M31
M32
M33
M34
M35
M36
M37
M38
M39
M40
M41
M42
M43
M44
M45

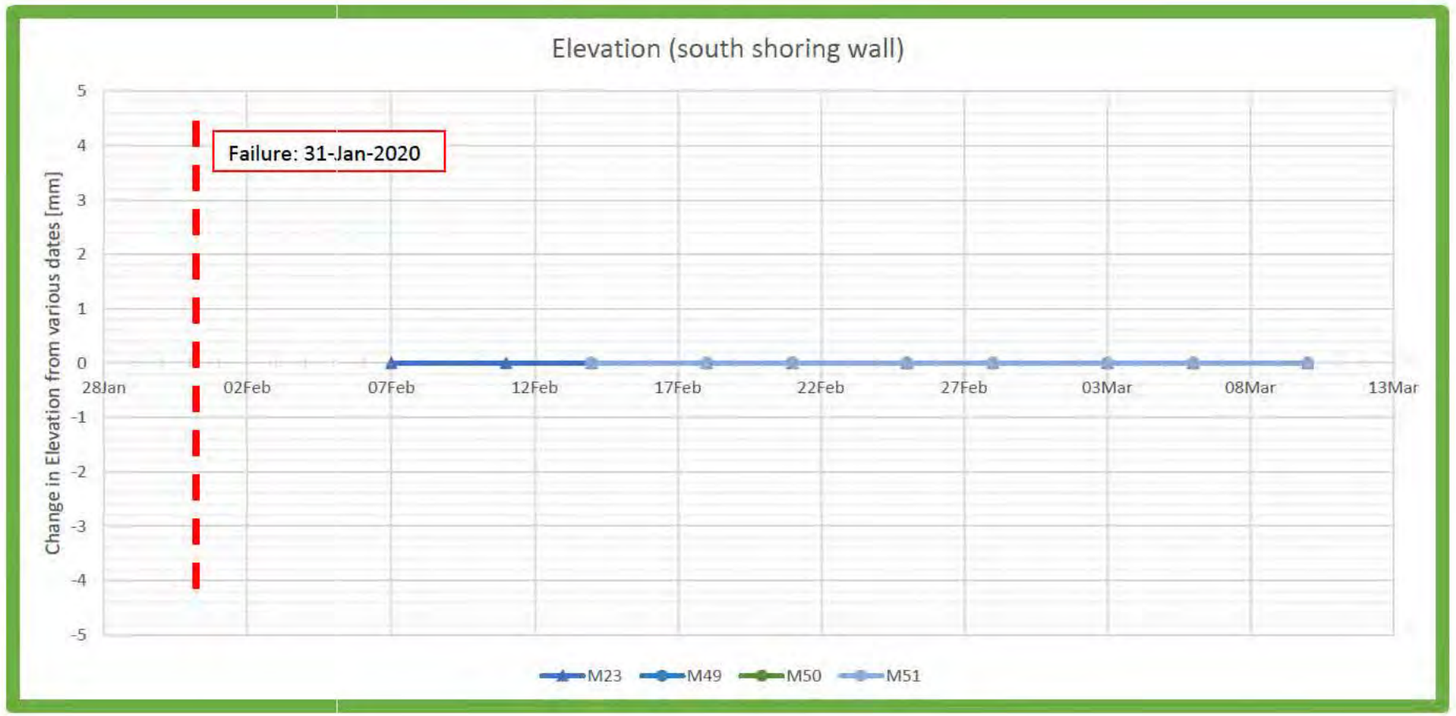

Northing/Easting (north shoring wall)
Inferred error:
M16 Easting data goes from:
- 804.24 ft to
- 840.24 ft to
- 804.23 ft
Infer 840.24 ft should be 804.24 ft
Northing (mm)
Easting (mm)
M16
M17

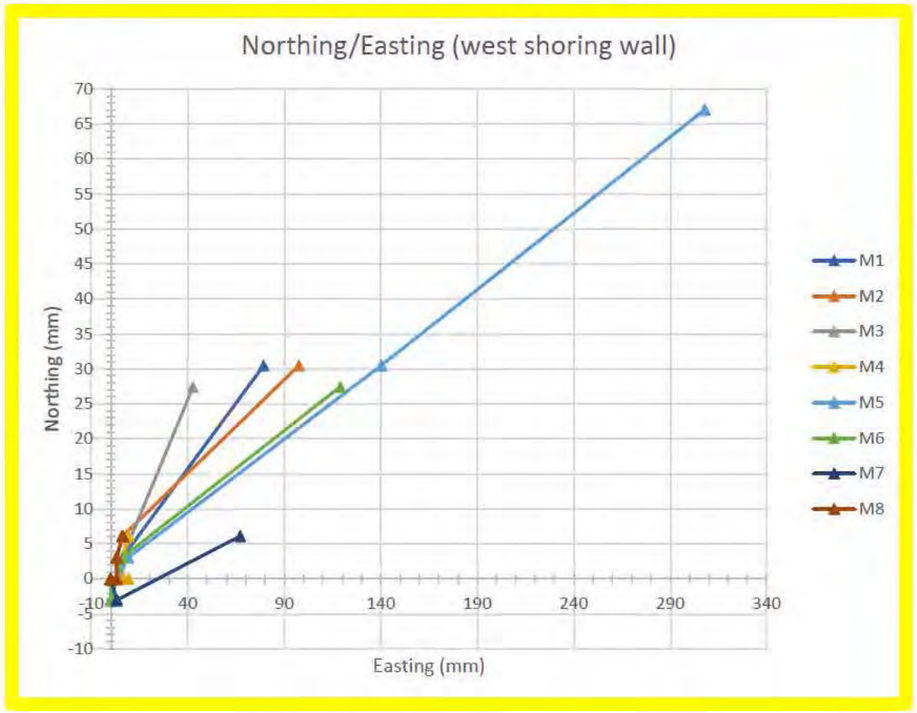

Elevation (north shoring wall)
Failure: 31-Jan-2020
Change in Elevation from 07-Feb [mm]
28Jan
02Feb
07Feb
12Feb
17Feb
22Feb
27Feb
03Mar
08Mar
13Mar
M16
M17

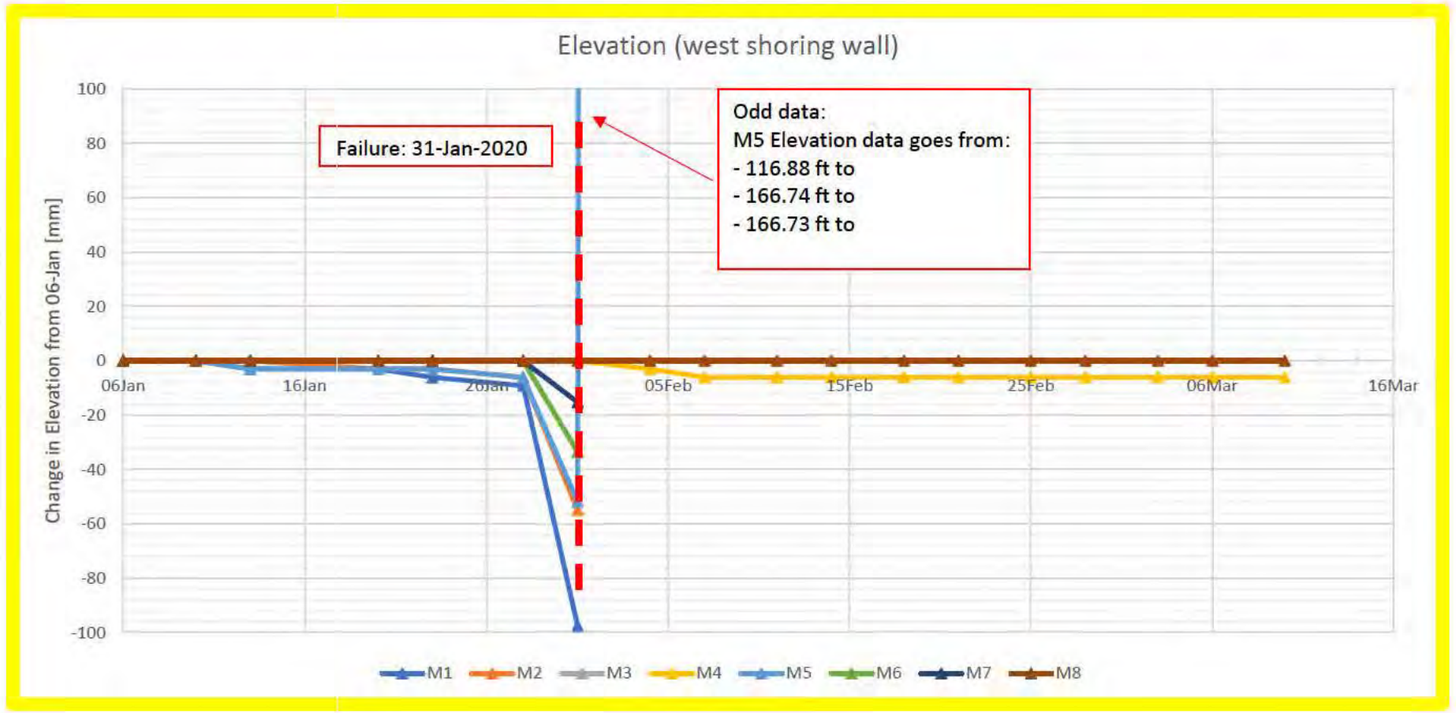

Northing/Easting (southwest corner of excavation)
Northing (mm)
Easting (mm)
5
0
-5
M21
M22
M46
M47
M48

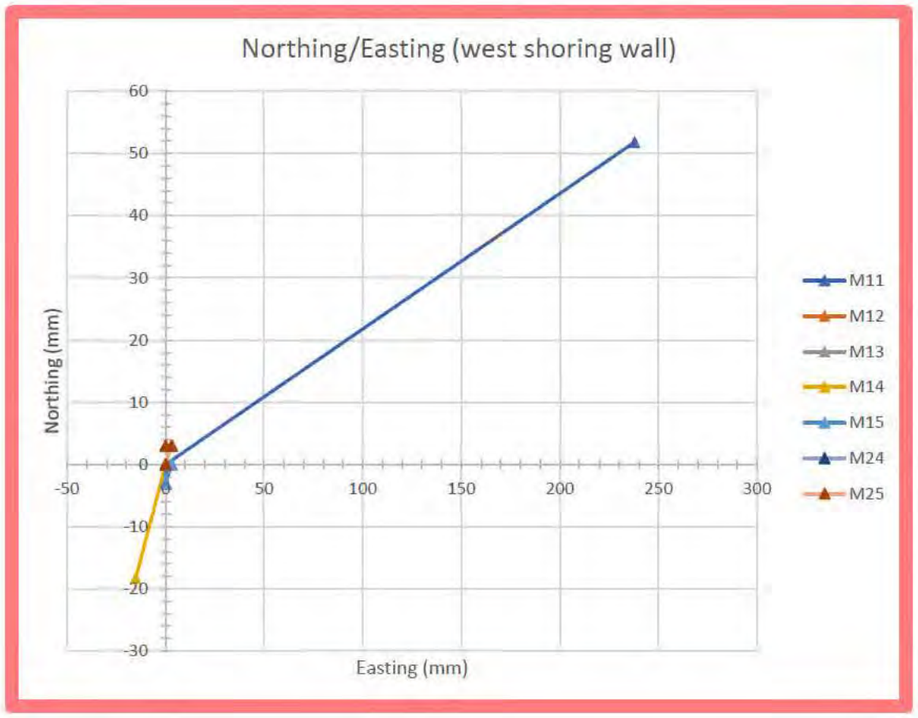

Elevation (southwest corner of excavation)
Failure: 31-Jan-2020
Change in Elevation from various dates [mm]
28Jan
02Feb
07Feb
12Feb
17Feb
22Feb
27Feb
03Mar
08Mar
13Mar
M21
M22
M46
M47
M48

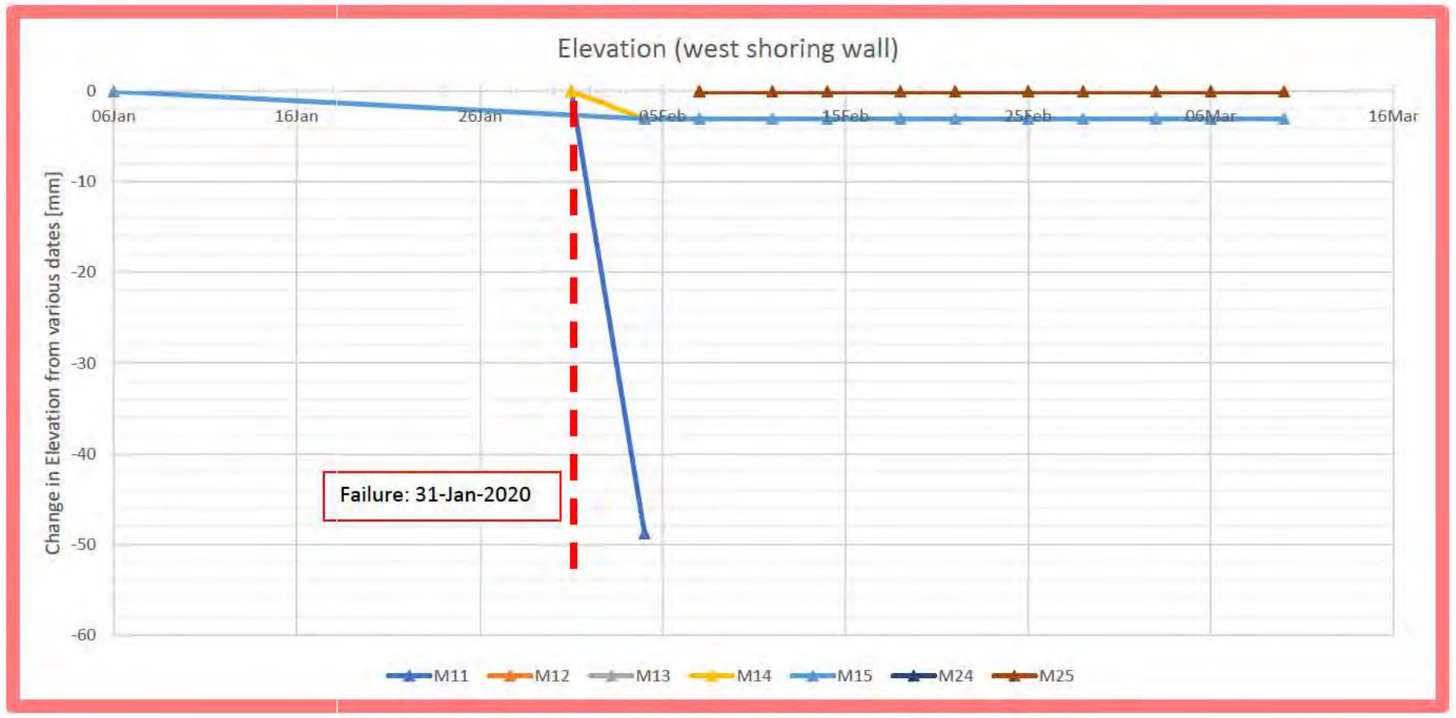

Northing/Easting (south shoring wall)
Northing (mm)
Easting (mm)
5
0
-5
M23
M49
M50
M51


Elevation (south shoring wall)
Failure: 31-Jan-2020
Change in Elevation from various dates [mm]
28Jan
02Feb
07Feb
12Feb
17Feb
22Feb
27Feb
03Mar
08Mar
13Mar
M23
M49
M50
M51


Northing/Easting (west shoring wall)
Northing (mm)
Easting (mm)
M1
M2
M3
M4
M5
M6
M7
M8


Elevation (west shoring wall)
Failure: 31-Jan-2020
Odd data:
M5 Elevation data goes from:
- 116.88 ft to
- 166.74 ft to
- 166.73 ft to
Change in Elevation from 06-Jan [mm]
06Jan
16Jan
26Jan
05Feb
15Feb
25Feb
06Mar
16Mar
M1
M2
M3
M4
M5
M6
M7
M8


Northing/Easting (west shoring wall)
Northing (mm)
Easting (mm)
M11
M12
M13
M14
M15
M24
M25


Elevation (west shoring wall)
Failure: 31-Jan-2020
Change in Elevation from various dates [mm]
06Jan
16Jan
26Jan
05Feb
15Feb
25Feb
06Mar
16Mar
M11
M12
M13
M14
M15
M24
M25

APPENDIX D: SUPPLEMENTAL FIGURES

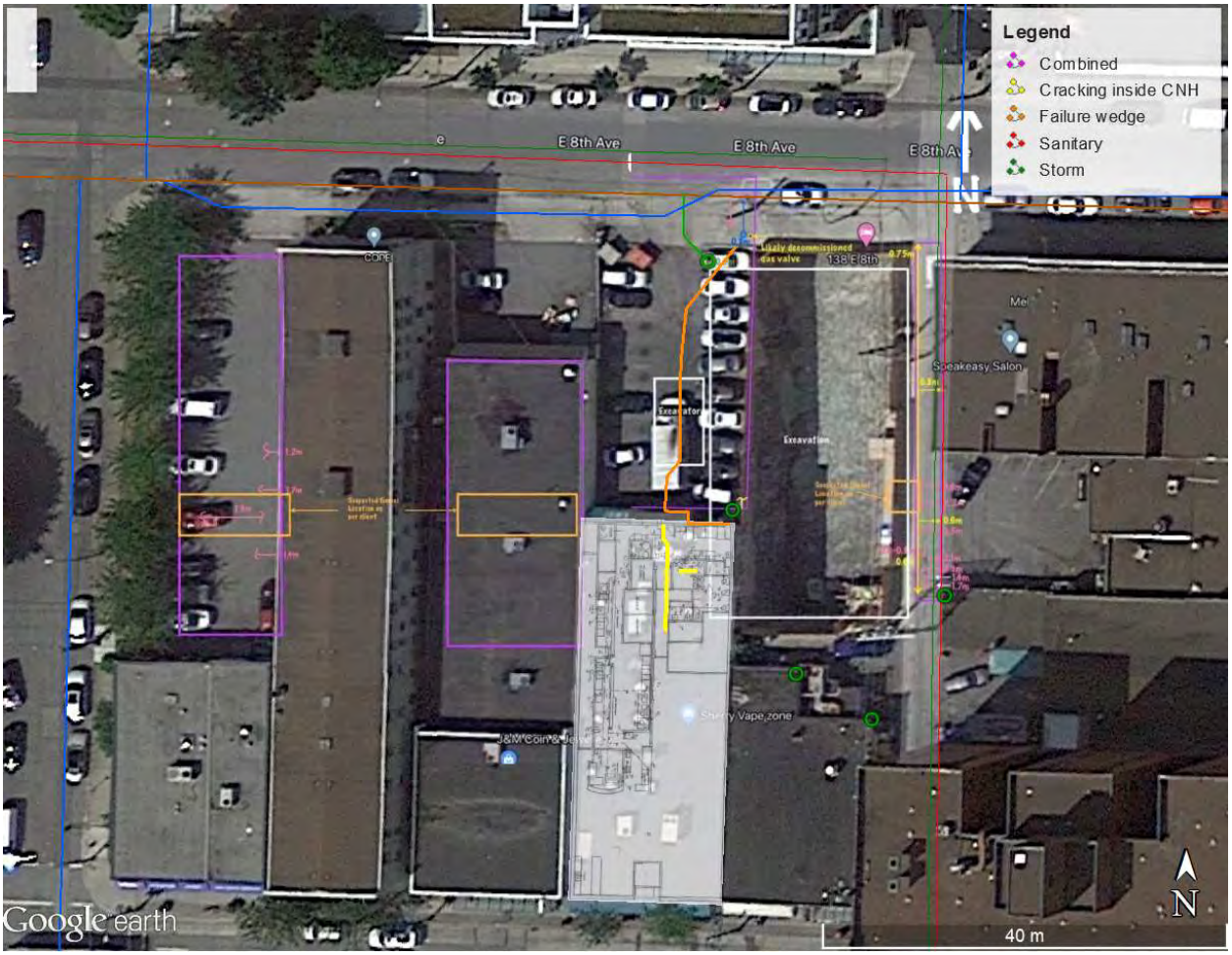


Figure 1: Google maps overlay

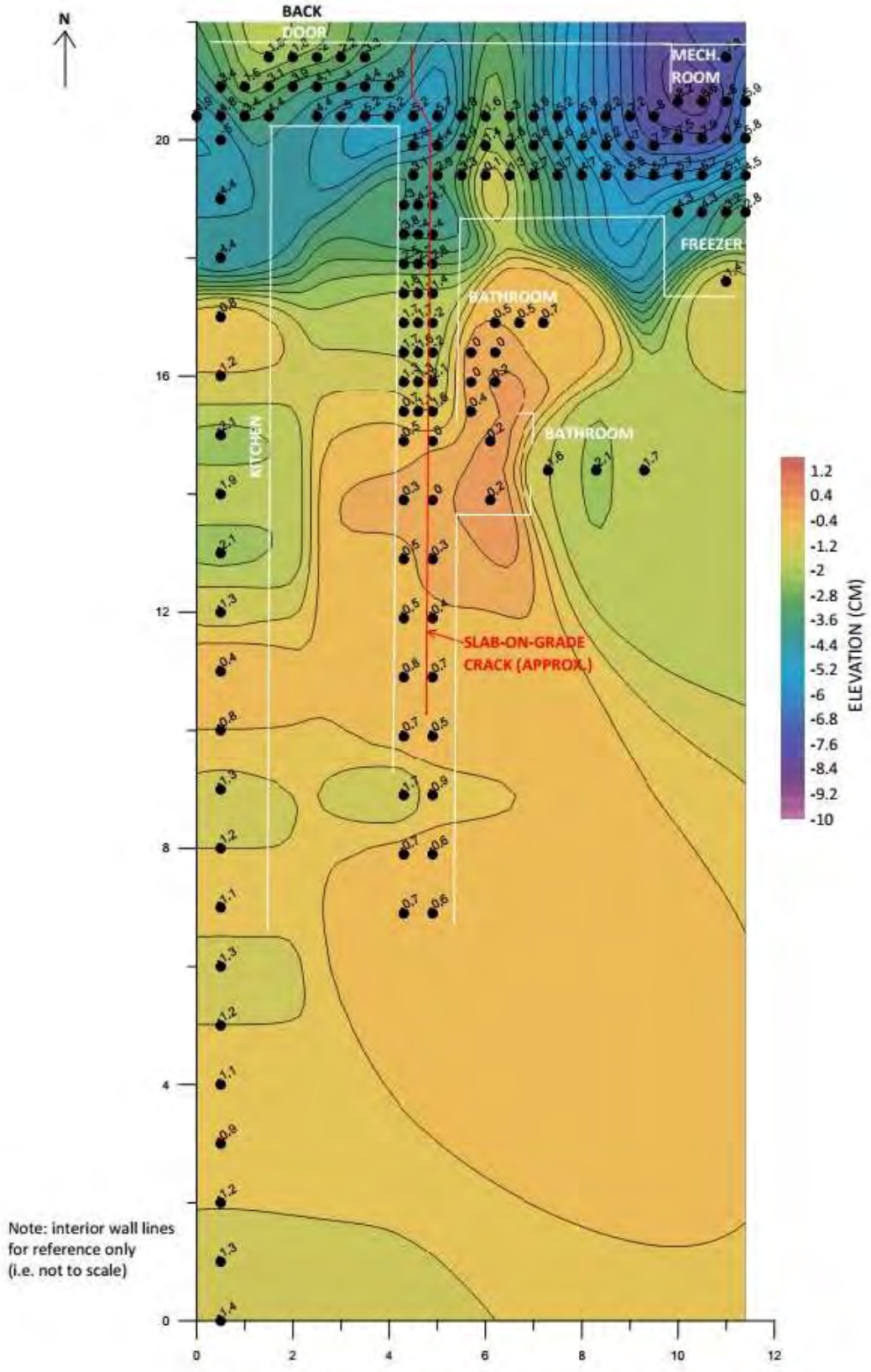


Figure 2: Laser level microtopographical survey

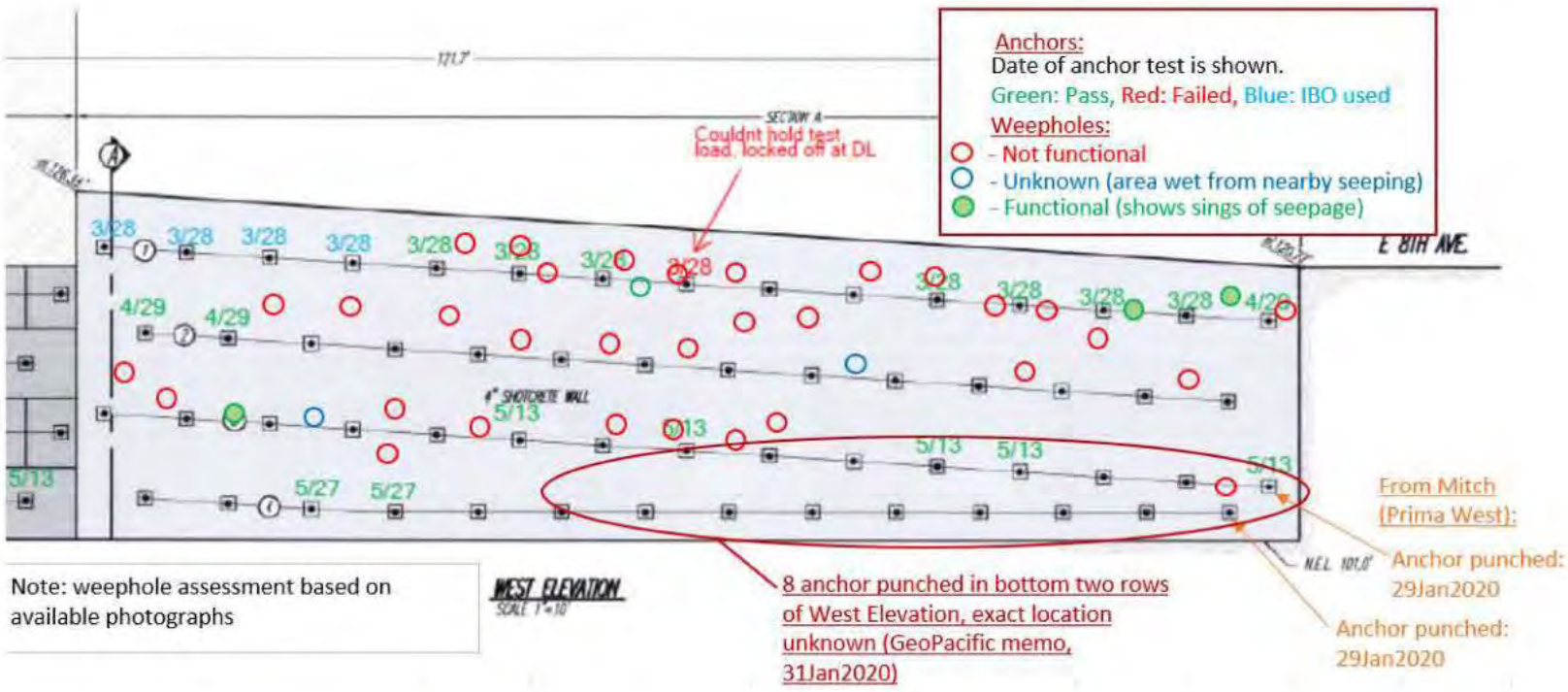


Photo 1: Reference Photo A

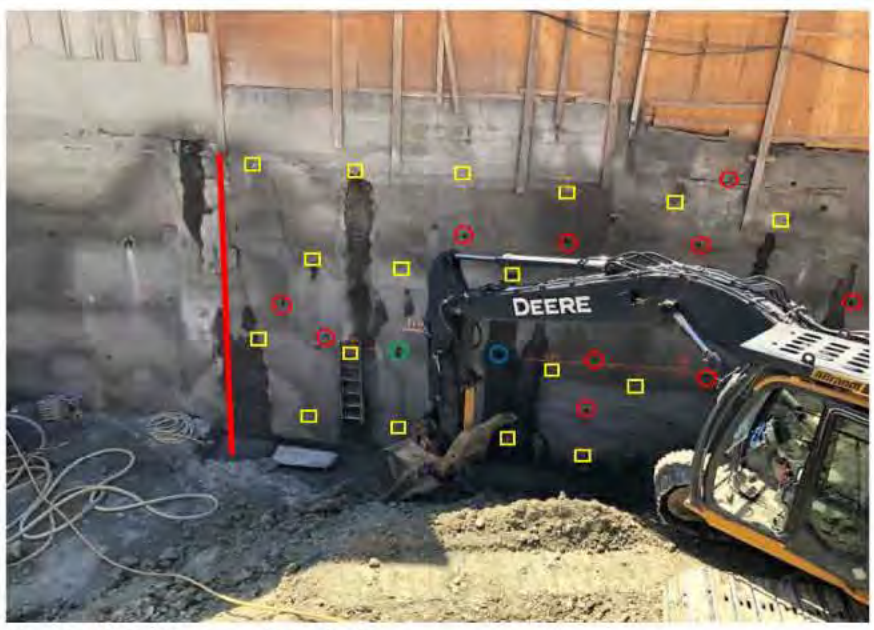


Photo 2: Reference Photo B

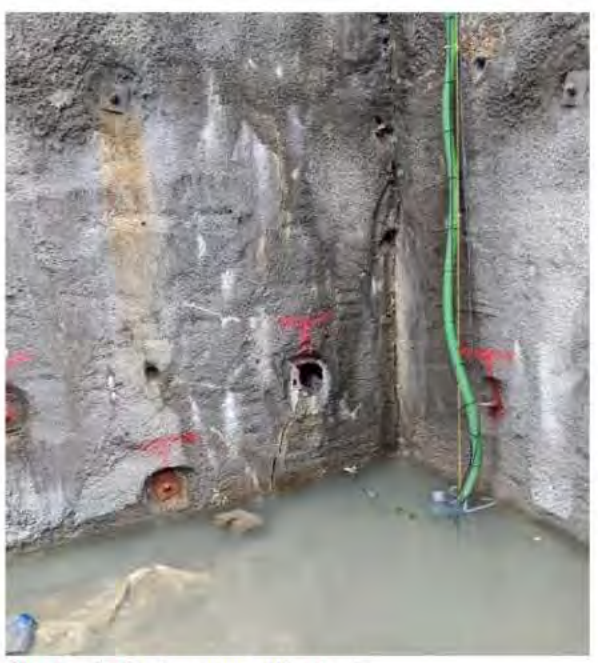


Photo 3: Reference Photo C

Photo 4: Zoomed Photo 2, shownig non functional weepholes versus a weephole showing signs of seepage

Photo 5: Example of non functional weephole (weephole located on North Elevation)

APPENDIX E: GEOSCAN UTILITY LOCATE REPORT

GeoScan
SUBSURFACE SURVEYS
A9 - 5279 Still Creek Ave, Burnaby, BC V5C 5V1
T: 604.436.7226 E: info@geoscan.ca

Utility Locate Work Order

GeoScan Project # J200221-03

Project Address: 141 E Broadway, Vancouver BC

Survey Date: 21 February 2020

Client: Horizon Engineering

GeoScan SUBSURFACE SURVEYS

Summary	
Item	Details
Survey Date:	21 February 2020
Project Address:	141 E Broadway, Vancouver BC
Site Contact:	Jonah
GeoScan Lead Technician:	Eunan Gillen 
Days on Site:	Single Call Out
Time on Site:	07:15-12:00
Additional GeoScan Personnel:	Yes
Role:	Trainee
Name:	James Berglund
Days on Site:	Single Call Out
Time on Site:	07:15-12:00
Travel Time (One Way):	30mins
Job Complete:	Yes
Further Reporting Required:	No
Vapour Probes Installed:	No
Concrete Coring Required:	No
One Call Provided By:	Not Provided / Available
Notes:	No One Call was available during locate.
PLEASE ENSURE THAT A BC ONE CALL IS CARRIED OUT BY YOU (THE CLIENT) AND THE CONTRACTOR BREAKING GROUND BEFORE ANY WORKS ARE CARRIED OUT (AS PER CURRENT LEGAL REQUIREMENTS). UTILITY OWNERS WHO ARE NOT PART OF THE BC ONE CALL SYSTEM SHOULD ALSO BE CONTACTED TO VERIFY WHETHER THEY HAVE UTILITIES BURIED IN THE AREA.	
P.O. Number:	120-4694

Quoted Job:	No
Xradar Concrete Scanning Required:	No

Scope of Work	
Item	Details
Other:	Other
Notes:	Client requested utility locate after shoring fail.

Utilities	
Item	Details
Marked With:	Paint

Gas Line(s) Located:	Yes
Equipment Used:	EM
Signal Quality:	Average
General Depth:	0.6-0.8m
Other Notes:	Gas connection to building on East side of building was cut. Gas meter no longer in service of building. Appears to run North and connect with the decommissioned gas valve at North end of site. Could not locate due to excavation. Gas located in laneway East of excavation. No fortis drawing available during locate.

Connection to building	
Laneway gas lines	

Electrical Line(s) Located:	Overhead
Details:	Electrical running overhead across site connecting to the building. No BC Hydro drawing available during locate. Power sweeps conducted at 141 E Broadway, Vancouver.

Communication Line(s) Located:	Overhead
Details:	Communication line runs overhead across site connecting to the building.

	No Telus drawing available during locate.

Water Line(s) Located:	Yes
Equipment Used:	Ground Penetrating Radar
Signal Quality:	Average
General Depth:	0.8m
Other Notes:	As per City of Vancouver, there is to be a water line running 3.3m West of East property line. The line was located from a valve due North of the site. Unable to trace line across site due to excavation. Valve appeared to be decommissioned and could not be scanned further.
Water line from valve	

Storm Line(s) Located:	Yes
Equipment Used:	Ground Penetrating Radar
Signal Quality:	Average
General Depth:	0.5m
Other Notes:	Storm line running North out of site from catch basin. As per City of Vancouver, there is a storm connection to the South side of the building. Building owners previously had Storm lines snaked, exits to South end of property.

Storm line	

Sanitary Line(s) Located:	No
Details:	As per City of Vancouver, there is supposed to be a combined sewer exiting property to the North at 5.79m West of East, could not be located. As per City of Vancouver, there is a sanitary connection to the South side of the building. Building owners previously had sanitary lines snaked, exits to South end of property.

Additional Line(s):	Unknown
Line(s) Located:	Yes
Equipment Used:	Ground Penetrating Radar
Signal Quality:	Average
General Depth:	Depths vary across scope
Other Notes:	GPR used to try and locate suspected tunnel in laneway and parking lots adjacent to site. Several unknowns located.

General Notes & Limitations	
Item	Details
Maximum Penetration Depth of Ground Penetrating Radar at time of locate:	0.8m
THE PRESENCE AND LOCATION OF UTILITIES BELOW THIS DEPTH CANNOT BE CONFIRMED USING GPR ALONE.	
Utilities Based On:	Locate Boundary

Additional Notes:	No BC One Call available during locate. Client said there would be no excavation on site. No scanning possible within zones of excavation and excavator. Unable to access water valve and water meter. Scan area of laneway and parking lot were solely to locate underground tunnel. Offsets as per City of Vancouver. GPR can only be used for up to 1m of obstruction (fence lines, excavation)

GeoScan Standard Limitations

- Hydrovaccing or hand exposing is recommended within 2 meters of all marked lines. Do not drill, dig and/or excavate within 2 meters of all marked utilities.

- Unable to scan within 1.0m of an object on the surface of the ground. The presence and location of targets below the ground within 0.5m of an object on the surface cannot be confirmed.

- An area of at least 3.0m X 3.0m is required to perform a GPR sweep over a borehole location.

- Stated depths of targets below the surface of the ground identified using GPR are accurate to within 20%

- Poor radar signal in areas of standing water. Where standing water is present, the presence and location of utilities below the surface of the ground cannot be confirmed in these areas using GPR alone.

- Utilities outside of the location boundary have not been located and their presence and location cannot be confirmed.

- Drawings provided are not to scale and should not be relied upon for locating the utilities.

-Any changed to the project (including but not limited to the location of boreholes or trenches) require a new locate and the results of the previous locate are not to be relied upon.

Where:

1. The presence and/or location and/or depth of utilities below the surface of the ground cannot be confirmed due to any of the limitations set out above;

2. The recommendations set out above are not followed;

3. The presence of a utility is impossible to detect by GPR or electromagnetic scans due to ground conditions at the time the utility locate is carried out; or

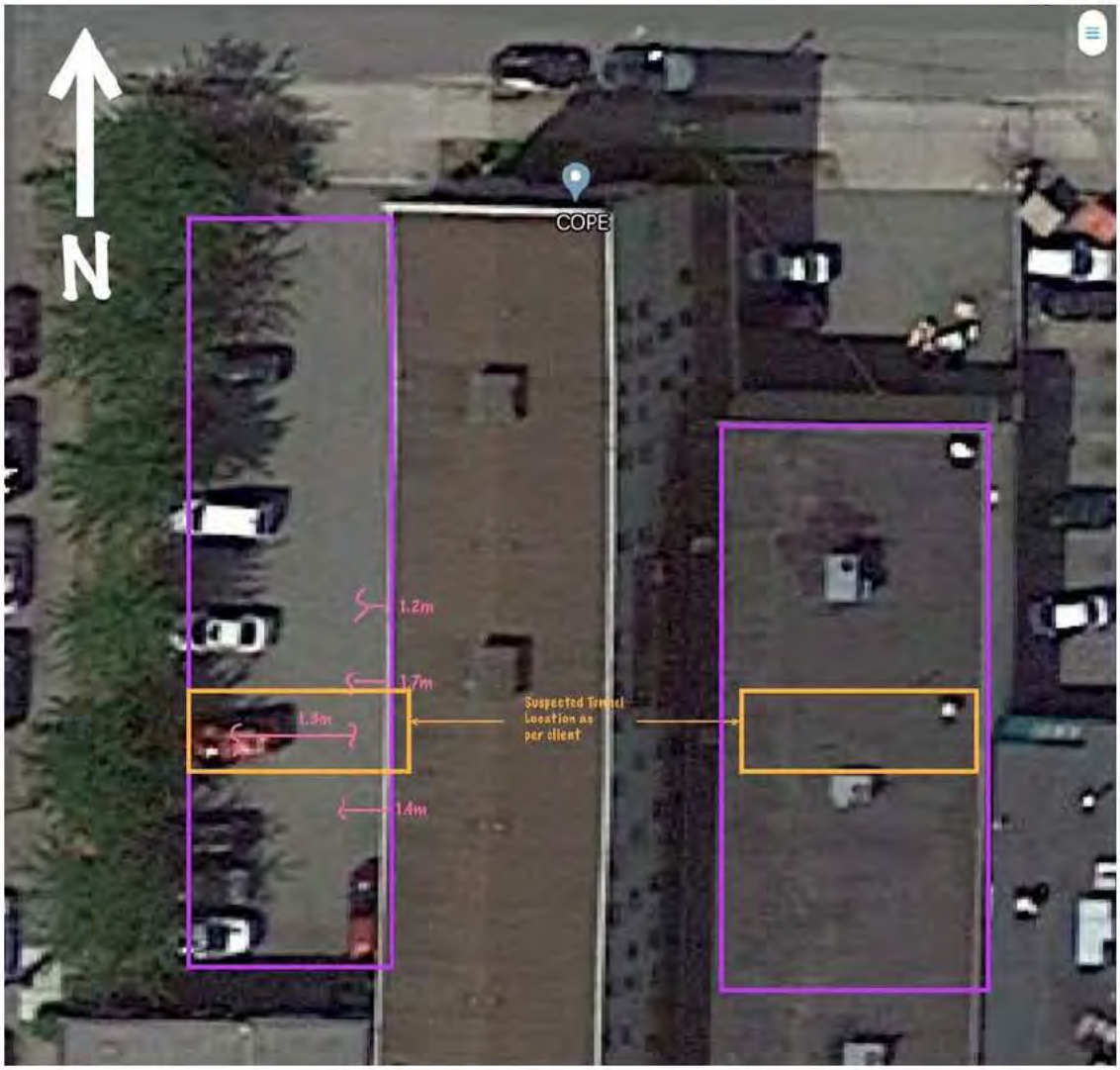
4. The markings on the ground indicating the location of utilities are no longer present,

GeoScan shall not be liable for any loss or damage caused in respect of any such utilities hit when breaking ground.

Client Representative Name:	Jonah

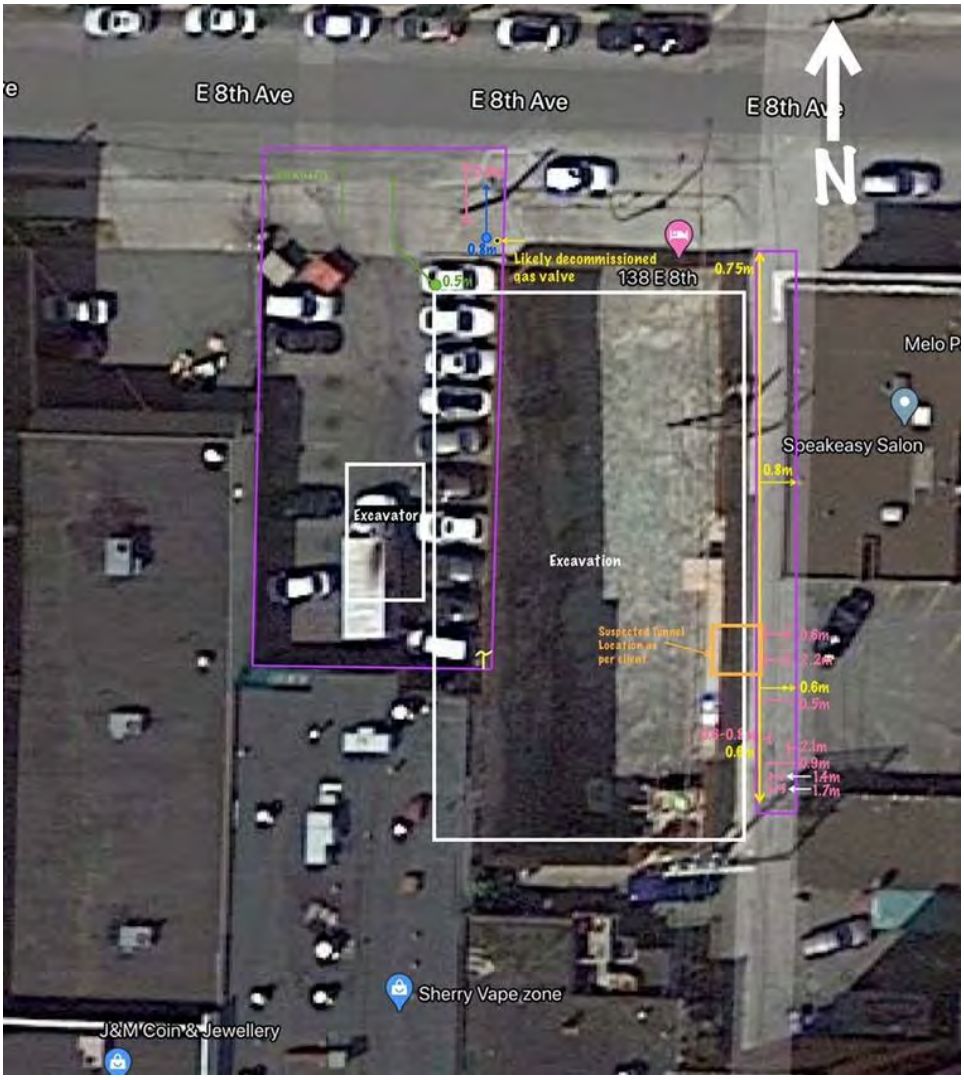
GeoScan
SUBSURFACE SURVEYS

Locate Drawing



Parking lot locate

- SCAN AREA
- GAS
- ELECTRICAL
- COMMUNICATIONS
- WATER
- STORM
- SANITARY
- UNKNOWN SERVICE
- UTILITY LINE CONTINUES BEYOND SITE BOUNDARY
- UNABLE TO LOCATE UTILITY LINE PAST THIS POINT
- BOREHOLE



Locate drawing 141 E Broadway & laneway

SCAN AREA
GAS
ELECTRICAL
COMMUNICATIONS
WATER
STORM
SANITARY
UNKNOWN SERVICE
UTILITY LINE CONTINUES BEYOND SITE BOUNDARY
UNABLE TO LOCATE UTILITY LINE PAST THIS POINT
BOREHOLE

Site Images	
Image Annotation	**Image**
Unknowns in laneway	
Unknowns and gas line in laneway	

Site Images	
Image Annotation	**Image**
Gas line in laneway	
Unknowns in West parking lot	

APPENDIX F: RJC STRUCTURAL IMPACT ASSESSMENT REPORT

141 East Broadway

Impact Review Related to 138 East 8th Development (Rev. 1)

141 East Broadway
Vancouver, BC V5T 1W1

March 26, 2020
RJC No. VAN.126673.0001

Prepared for:

Horizon Engineering
18 Gostick Place, Suite 220
North Vancouver, BC V7M 3G3

Attention: Karen Savage

Prepared by:

Read Jones Christoffersen Ltd.
1285 West Broadway, Suite 300
Vancouver, BC V6H 3X8

Table of Contents

1.0 INTRODUCTION

At the request of Horizon Engineering Ltd (Horizon), Read Jones Christoffersen Ltd. (RJC) has conducted a building condition review related to the development at 138 East 8th Avenue in Vancouver, BC. This review was conducted to record the condition of the building at 141 East Broadway after a failure at the west side of the excavation at the development site. Figure 1 below outlines the area reviewed adjacent to the development site.

Figure 1 - Area reviewed West of Development

Our scope of services included the following:

1. Visual review of the property southwest of 138 East 8th Avenue, documenting existing conditions including cracks and observed settlement.
2. Photographic documentation of various surfaces and areas of obvious cracks and signs of settlement identified during the visual review.
3. Preparation of a written report of our findings, including photographs, survey results, observations and recommendations.

2.0 VISUAL REVIEW

RJC conducted a visual review of 141 East Broadway on February 21 and 24, 2020. Appendix A of this report contains photographic documentation of our observations, with accompanying descriptions. Appendix A also includes a schematic plan of observed crack locations for convenience. Some photographs may not show a clear view of the item noted (i.e., cracks, etc.), but have been included to give the reader an indication of the location.

In general, our scope included the portions of the building immediately adjacent to the construction.

As the review was entirely visual in nature, no materials were cut, probed or removed. Likewise, design reviews of specific building elements were not conducted.

Our observations include major cracks on the slab on grade in the north south direction near the northeast corner of the building, and northern exterior walls, as well as separation of tiles in the north center corridor and inside the adjacent men's washroom.

We have marked and measured significant cracks in these locations which is documented in Appendix A. We are available to continue monitoring these cracks upon request. It should also be noted that some cracking is common in buildings, and it is usually the result of a combination of several factors, including shrinkage, earth settlements of differential movement, stress accumulation, and temperature changes.

Horizon provided RJC with photos of the building, which we understand to have been taken in 2019. We have used these in comparison with current observations.

3.0 SURVEY RESULTS REVIEW

RJC has reviewed the survey results prepared by Ken K. Wong and Associates throughout the months of January, February and March 2020. These results provide information regarding the survey points along the northern and eastern walls and foundations.

Our findings of the survey results suggest that the base of the wall may be moving towards the excavation to the east, in relation to the top of the wall. It is noted that this continued movement could compromise the structure.

4.0 RECOMMENDATIONS AND CLOSING COMMENTS

The presence or magnitude of specific deficiencies cannot necessarily be directly attributed to the subject failure. However, based on:

- Review of the 2019 photos,
- Visual review, and
- Our experience,

It is reasonable to conclude that observed cracks and deficiencies were either caused or exacerbated by the excavation failure, in particular the cracks on:

- Foundation east of north exterior masonry wall,
- North exterior masonry wall, and
- North portion of the slab on grade.

Refer to Appendix A for more details.

We recommend immediately repairing the east foundation wall so as to re-establish its connection to the north foundation wall.

It is also recommended that additional surveys of the top and bottom of the eastern and northern masonry walls be conducted to measure lateral displacements of the walls. We recommend that surveys be conducted and reviewed weekly until such time that the development construction reaches grade. If survey results demonstrate sustained, minimal, movement, it may be possible to reduce the frequency of surveys as construction progresses.

We recommend that Horizon consider requesting permission to install crack monitor gauges in areas where we have marked and measured cracks.

At the request of Horizon, RJC is available to install and/or monitor crack monitors. We are also available to conduct additional visual reviews during construction, and/or after construction is complete, and provide regular review of survey results.

Please contact the undersigned of there are any questions or concerns regarding the content of this report.

Yours truly,

READ JONES CHRISTOFFERSEN

Reviewed by:

Hossein Bajehkian, EIT, MEng
Design Engineer

Jennifer Durham, M.A.Sc., P.Eng., LEED® AP
Project Engineer

Enclosed: Appendix A: Photographs and Summary

Appendix A: Photographs & Summary

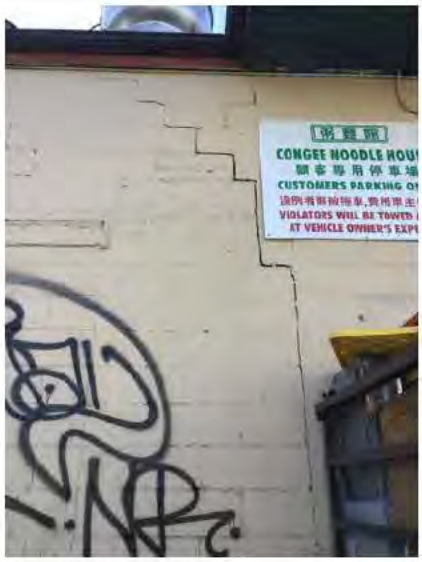
TABLE A1 – GENERAL OBSERVATIONS	
North Elevation, Shot from back alleyway	 Photo 1
Center of North wall with cracks between mortar joints of exterior masonry wall.	 Photo 2
Front view of center of North wall with cracks between mortar joints of masonry wall. Crack width at the bottom portion was measured to be about ¼" inches (as shown in Photo 29).	 Photo 3

TABLE A1 – GENERAL OBSERVATIONS	
East corner of north wall with existing steel strapping anchored to masonry wall. We understand that the steel straps were in place prior to the subject failure.	 Photo 4
Bottom portion of east corner of north wall with visible foundation cracks extending into the masonry wall above. (Cracks in this portion have been recorded and close ups can be found from Photo 24 to Photo 28)	 Photo 5

TABLE A1 – GENERAL OBSERVATIONS	
Full view of the east wall of the building adjacent to the excavation. We understand that the wooden temporary wall support was placed prior to the subject failure.	 Photo 6
Looking south through the north south corridor with the slab on grade cracks visible at the bottom of photo extending into the tiles. (Tile crack measurement is shown on Photo 12)	 Photo 7

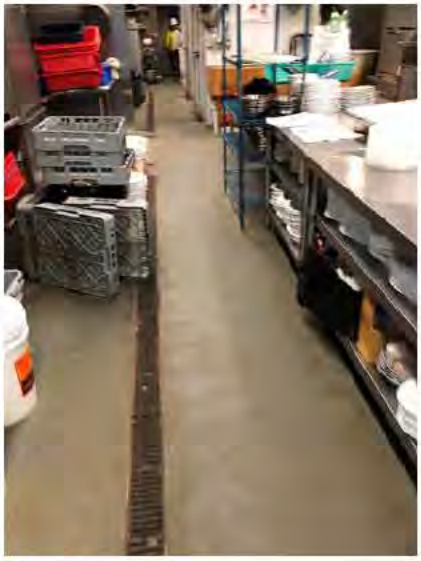
TABLE A1 – GENERAL OBSERVATIONS	
Looking east into the inside face of eastern wall at north corner with interior sheet metal and plaster finish.	 Photo 8
Slab on grade and trench drain in the kitchen on the west side of the building with no visible cracks.	 Photo 9

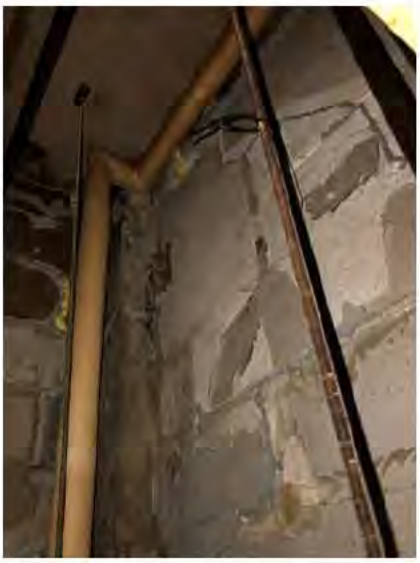
TABLE A1 – GENERAL OBSERVATIONS	
Service room at the northeast corner with masonry walls cracks visible from the inside.	 Photo 10
North corner of east wall shown from the inside of service room.	 Photo 11

TABLE A1 – GENERAL OBSERVATIONS	
Corridor tiles shifted and opened up to a width of 3/8" inches (compared to regular tile gap of 1/8" inches).	 Photo 12
Tile gaps opening up inside the male washroom up to 5/16" inches (line of crack is in the east-west direction).	 Photo 13

TABLE A1 – GENERAL OBSERVATIONS	
Major cracks in the slab on grade observed in the north center of the building have initiated previously, as caulking appeared to be in place at these locations. Caulking/sealant was observed along some cracks, indicating that some cracks are not recent; however stretched material across the width of the cracks indicates that movement occurred after installation of the caulking/sealant. (Cracks in this portion have been recorded and close ups can be found from Photo 16 to Photo 22)	 Photo 14
Another view of the major cracks in the slab on grade observed in the north center of the building. (Cracks in this portion have been recorded and close ups can be found from Photo 16 to Photo 22)	 Photo 15

TABLE A1 – GENERAL OBSERVATIONS	
North center slab on grade crack at location labeled "1" with ½" of width.	  Photo 16
North center slab on grade crack at Location labeled "2" with 5/8" of width.	  Photo 17

TABLE A1 – GENERAL OBSERVATIONS	
North center slab on grade crack at location labeled "3" with 1 3/16" of width.	  Photo 18
North center slab on grade crack at location labeled "4" with 7/8" of width.	  Photo 19

TABLE A1 – GENERAL OBSERVATIONS	
North center slab on grade crack at location labeled "5" with 1/2" of width.	  Photo 20
North center slab on grade crack at location labeled "6" with 5/16" of width.	  Photo 21

TABLE A1 – GENERAL OBSERVATIONS	
North center slab on grade crack at Location labeled "7" with 5/16" of width.	 Photo 22
Close up of the slab on grade crack with membrane detached and concrete exposed.	 Photo 23

TABLE A1 – GENERAL OBSERVATIONS	
East of north masonry wall, mortar joint crack at location labeled "1" with ½" of width.	 Photo 24

TABLE A1 – GENERAL OBSERVATIONS	
East of north masonry wall; mortar joint crack at location labeled "2" with 1/4" of width.	  Photo 25

TABLE A1 – GENERAL OBSERVATIONS	
East of north masonry wall; mortar joint crack at location labeled "3" with ½" of width.	  Photo 26

TABLE A1 – GENERAL OBSERVATIONS	
East of north masonry wall; mortar joint crack at location labeled "4" with ½" of width.	  Photo 27

TABLE A1 – GENERAL OBSERVATIONS	
East of north masonry wall; Foundation crack at location labeled "5" with 1 7/8" of width.	 Photo 28

TABLE A1 – GENERAL OBSERVATIONS	
Masonry wall joint crack at north wall center with a width of ¼ inches.	 Photo 29
Foundation wall crack at northeast corner with out of plane crack of about 1 ¼ inches.	 Photo 30

TABLE A2 – CRACK LOCATION SUMMARY

Plan outline of crack locations at the northeast corner with locations illustrated in table A1