MEMO

TO: Diamond Schmitt Architects and KWC Architects
FROM: WSP Canada Inc.
SUBJECT: Revised Supplementary comments to the final geotechnical report
DATE: **April 6, 2020**

In the comments from the site Site Plan Application Plan (City of Ottawa File Number: D07-12-19-0205) it was requested that WSP Canada Inc. (WSP) geotechnical provide updates to the geotechnical report. The following sections are to complete the geotechnical report, dated December 2019.

SEISMIC SITE CLASSIFICATION

Multichannel analysis of surface waves (MASW) has been carried out on site. The aim of MASW testing is to evaluate the shear wave velocities of subsurface materials through the analysis of the dispersion properties of Rayleigh surface waves ("ground roll"). The dispersion properties are measured as a change in phase velocity with frequency. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. The Vs30 values calculated for the minimum and the maximum envelopes ranged from 189 to 2160m/s. Based on the average Vs30 values (as determined through the MASW method) and table 4.1.8.4.A of the National Building Code of Canada, 2015 Edition, the investigated area is site class "B" (760 < VS30 ≤ 1500 m/s), however as this value is not to be applied to if there is more than 3 m of soil between the rock surface, a site classification of "C" has been applied. For foundations placed within 3 meters of the underlying bedrock, on either engineered fill or the native soil, a site classification of "B" could be applied.

The shear-wave velocity measurement for seismic site classification from Geophysics GRP International Inc. has been included as an attachment to this memo.

GRADE RAISE

It is understood that a grade raise of up to 3.0 m is being proposed. Given that the building will be supported on deep foundations, a grade raise of up to 3.0 m will not cause settlement of the proposed building.

Underlying the surface in all the boreholes is a layer of fill which extends to depths ranging from 1.4 m to 6.9 m below the existing ground surface. The density of this fill was highly variable and ranged from a loose to very dense state of packing. Underlying the fill in the northwest section of the site, as well as borehole BH19-7 a layer of silty clay was encountered which may experience minor settlement with additional loading. However, in the southern section of the site, where the majority of the grade raise is proposed, the silty clay deposit was not encountered and the underlying sand and gravel or glacial till can accept a grade raise of 3.0 m.

Prior to the placement of any additional fill, unsuitable materials such as organic soils, frozen soils, etc. should be stripped and the underlying subgrade inspected by a qualified geotechnical engineering. Additional compaction and densification may be required as well as the removal of localized areas of unsuitable material which will be replaced with suitable approved fill compacted to 95%. All additional material needs to be approved prior to placement.

DEEP FOUNDATIONS

The soil pile interactions went into several rounds of soil data and relevant pile calculations. Considering similar piling experience within the same type of rock for the university main garage building, the following pile information and loading conditions were eventually agreed upon;
Pile size: 245 DIAMx13thk

- Factored Lateral Pile Load per pile (At underside of pile cap/top of pile): 110kN-120kN
- Lateral Displacement at top of Pile/Underside of Pile Cap: 21mm-32mm
- Factored Stiffness at top of pile/underside of pile cap for a pinned pile to the pile cap: 6.0kN/mm-12kN/mm (It takes 6kN to 12KN to move the soil 1mmat the top of the pile)

These displacement values for the soil given the cyclical/dynamic seismic loading are be considered acceptable and this can be supported by the fact that piles will be installed in the native soil (Sand Layer/Till Layer) and not in the built up/95% compacted granular B, as excavation will only be to the base of the pile cap and piles will be installed from there.

Piles Uplift Reduction Factor

A reduction factor of 0.65 would be utilized for piles with 2.5 d spacing and the reduction factor will be increased linearly to be factor of 1 at piles spacing of 6d, where d is the pile dimeter.

Slab on Grade

24kPa at SLS below the slab on grade may be used. A modulus of subgrade reaction of 10,000 KN/m3 can be used, as long as the subgrade is compacted properly and 200 - 300mm of well-graded crushed sand and gravel meeting the requirements of OPSS Granular A is used under the slab as the soil at this elevation is considered fill material.

Modulus of Subgrade – Wall basement

The lateral modulus of subgrade for the soil adjacent to the basement wall can be calculated using Broms method mentioned in the report. Typically, the lateral modulus will increase along the depth of the wall until it reaches approximately 11000 - 12000 KN/m3 at 3 m depth from the ground surface. An average value may be considered between 7000 – 10,000 KN/m3 along the wall.

Concrete/Soil Friction

sliding can be resisted between the concrete and soil using 0.4 friction factor relative to vertical loads. This friction factor is provided at elevation of 61.00, which could be suitable to silty clay and clayey Sand.

Soil Corrosivity

The corrosivity in the soil ranged from severe (389 ohm-cm) to moderate (2270 ohm-cm). A corrosive soil is anticipated, especially the silty clay. Class S-3 for any concrete works at the 4 meters just below ground surface only (The reason is that the top 4 meters material is a mixed fill)

Liquefaction Potential

The soils at the site are not considered to be susceptible to seismic liquefaction, as it is mainly silty clay and Till material while the sandy soils under the ground water table exhibits a medium to very dense state of packing with an average SPT counts ranges from 18 to more than 45.

In preparation for this report, the site, the Carleton University New Student Residence – Grading Plan dated March 13, 2020 was provided by Diamond Schmitt Architects and KWC Architects and is provided as an attachment to this document. Other than the topics covered above, the recommendations of the geotechnical report dated December 2019 are still applicable after reviewing this grading plan.

Daniel Wall

Intermediate Geotechnical Engineer, P.Eng.

Mohamed Elsayed

Senior Geotechnical Engineer, M.Eng., P.Eng

Attachment:

Carleton University New Student Residence – Grading Plan (03/13/20)

GPR19-01875_WPS Canada_Carleton University

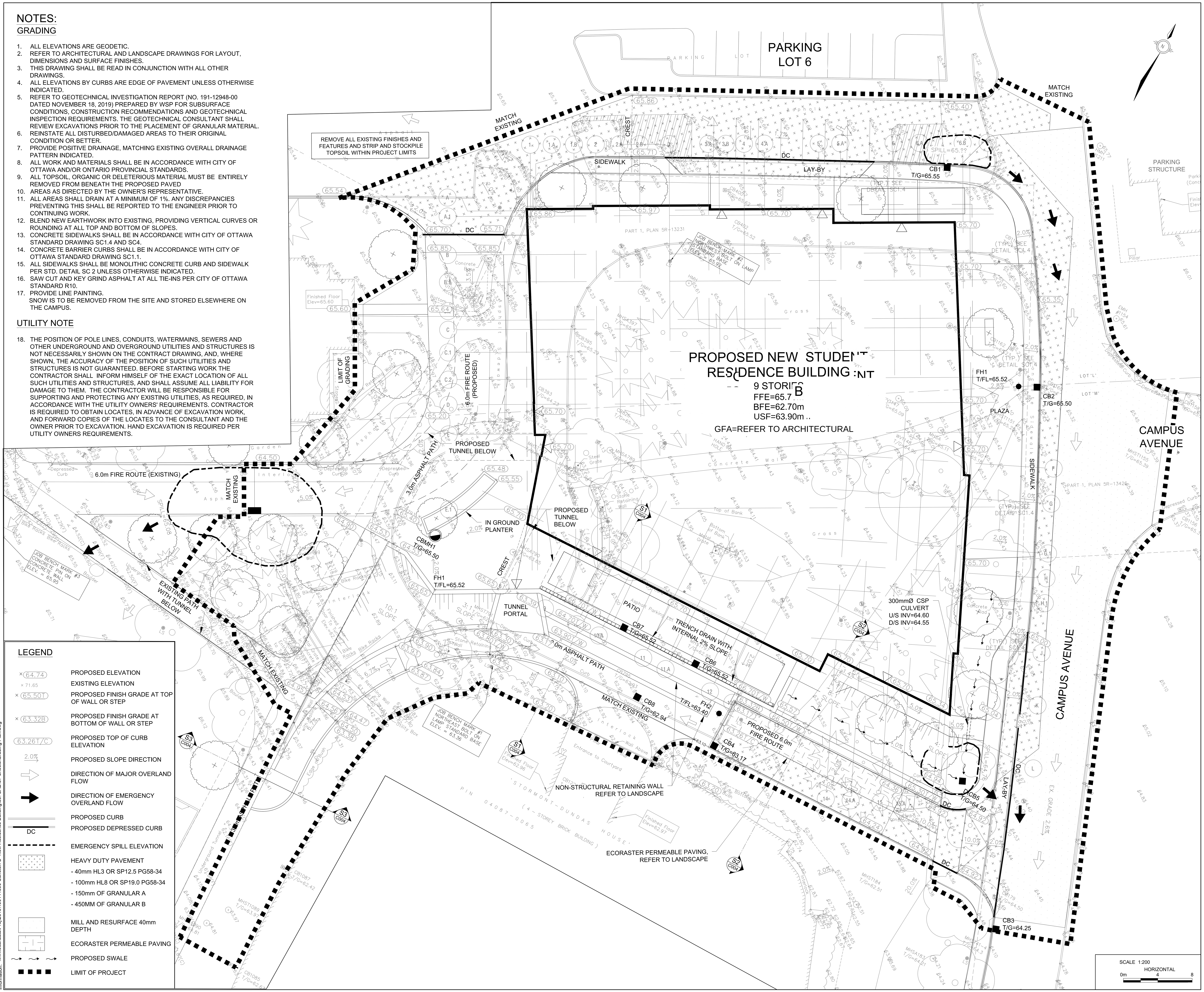
NOTES:

GRADING

1. ALL ELEVATIONS ARE GEODETIC.
2. REFER TO ARCHITECTURAL AND LANDSCAPE DRAWINGS FOR LAYOUT, DIMENSIONS AND SURFACE FINISHES.
3. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL OTHER DRAWINGS.
4. ALL ELEVATIONS BY CURBS ARE EDGE OF PAVEMENT UNLESS OTHERWISE INDICATED.
5. REFER TO GEOTECHNICAL INVESTIGATION REPORT (NO. 191-12948-00 DATED NOVEMBER 18, 2019) PREPARED BY WSP FOR SUBSURFACE CONDITIONS, CONSTRUCTION RECOMMENDATIONS AND GEOTECHNICAL INSPECTION REQUIREMENTS. THE GEOTECHNICAL CONSULTANT SHALL REVIEW EXCAVATIONS PRIOR TO THE PLACEMENT OF GRANULAR MATERIAL.
6. REINSTATE ALL DISTURBED/DAMAGED AREAS TO THEIR ORIGINAL CONDITION OR BETTER.
7. PROVIDE POSITIVE DRAINAGE, MATCHING EXISTING OVERALL DRAINAGE PATTERN INDICATED.
8. ALL WORK AND MATERIALS SHALL BE IN ACCORDANCE WITH CITY OF OTTAWA AND/OR ONTARIO PROVINCIAL STANDARDS.
9. ALL TOPSOIL, ORGANIC OR DELETERIOUS MATERIAL MUST BE ENTIRELY REMOVED FROM BENEATH THE PROPOSED PAVED
10. AREAS AS DIRECTED BY THE OWNER'S REPRESENTATIVE.
11. ALL AREAS SHALL DRAIN AT A MINIMUM OF 1%. ANY DISCREPANCIES PREVENTING THIS SHALL BE REPORTED TO THE ENGINEER PRIOR TO CONTINUING WORK.
12. BLEND NEW EARTHWORK INTO EXISTING, PROVIDING VERTICAL CURVES OR ROUNDING AT ALL TOP AND BOTTOM OF SLOPES.
13. CONCRETE SIDEWALKS SHALL BE IN ACCORDANCE WITH CITY OF OTTAWA STANDARD DRAWING SC1.4 AND SC4.
14. CONCRETE BARRIER CURBS SHALL BE IN ACCORDANCE WITH CITY OF OTTAWA STANDARD DRAWING SC1.1.
15. ALL SIDEWALKS SHALL BE MONOLITHIC CONCRETE CURB AND SIDEWALK PER STD. DETAIL SC 2 UNLESS OTHERWISE INDICATED.
16. SAW CUT AND KEY GRIND ASPHALT AT ALL TIE-INS PER CITY OF OTTAWA STANDARD R10.
17. PROVIDE LINE PAINTING. SNOW IS TO BE REMOVED FROM THE SITE AND STORED ELSEWHERE ON THE CAMPUS.

UTILITY NOTE

18. THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWERS AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONTRACT DRAWING, AND, WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED. BEFORE STARTING WORK THE CONTRACTOR SHALL INFORM HIMSELF OF THE EXACT LOCATION OF ALL SUCH UTILITIES AND STRUCTURES, AND SHALL ASSUME ALL LIABILITY FOR DAMAGE TO THEM. THE CONTRACTOR WILL BE RESPONSIBLE FOR SUPPORTING AND PROTECTING ANY EXISTING UTILITIES, AS REQUIRED, IN ACCORDANCE WITH THE UTILITY OWNERS' REQUIREMENTS. CONTRACTOR IS REQUIRED TO OBTAIN LOCATES, IN ADVANCE OF EXCAVATION WORK, AND FORWARD COPIES OF THE LOCATES TO THE CONSULTANT AND THE OWNER PRIOR TO EXCAVATION. HAND EXCAVATION IS REQUIRED PER UTILITY OWNERS REQUIREMENTS.



LEGEND

×64.74	PROPOSED ELEVATION
× 71.65	EXISTING ELEVATION
× 65.50T	PROPOSED FINISH GRADE AT TOP OF WALL OR STEP
× 63.32B	PROPOSED FINISH GRADE AT BOTTOM OF WALL OR STEP
63.26T/C	PROPOSED TOP OF CURB ELEVATION
2.0%	PROPOSED SLOPE DIRECTION
	DIRECTION OF MAJOR OVERLAND FLOW
	DIRECTION OF EMERGENCY OVERLAND FLOW
	PROPOSED CURB
DC	PROPOSED DEPRESSED CURB
	EMERGENCY SPILL ELEVATION
	HEAVY DUTY PAVEMENT - 40mm HL3 OR SP12.5 PG58-34 - 100mm HL8 OR SP19.0 PG58-34 - 150mm OF GRANULAR A - 450MM OF GRANULAR B
	MILL AND RESURFACE 40mm DEPTH
	ECORASTER PERMEABLE PAVING
	PROPOSED SWALE
	LIMIT OF PROJECT

CONTRACTOR MUST CHECK & VERIFY ALL DIMENSIONS ON THE JOB.

DO NOT SCALE DRAWINGS.

THIS DRAWING IS NOT TO BE USED FOR CONSTRUCTION UNTIL SIGNED BY THE ARCHITECT.

MORRISON HERSHFIELD
200-2932 BASELINE ROAD, OTTAWA, ON K2H 1B1

KEY PLAN — SITE

ISSUED

No.	Date	Description
1	13/12/2019	ISSUED FOR SITE PLAN APPROVAL
2	30/01/2020	ISSUED FOR 100% DD
3	13/03/2020	REISSUED FOR GRADING PLAN APPROVAL

LICENSED PROFESSIONAL ENGINEER J. G. FOCKES 100202820 Mar 13, 2020 PROVINCE OF ONTARIO

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KWC Architects Inc. 383 Parkdale Avenue Suite 201 Ottawa, Ontario K1Y 4R4 Canada Tel: 613 238 2117 Fax: 613 238 6595 kwc@kwc-arch.com www.kwc-arch.com

CARLETON UNIVERSITY NEW STUDENT RESIDENCE

CARLETON UNIVERSITY
1125 COLONEL BY DRIVE
OTTAWA ON
K1S 5B6

GRADING PLAN

Scale: 1:200
Project No: 190444600
Date: 03/13/20

C003

GEOPHYSICS GPR INTERNATIONAL INC.

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Longueuil (Québec)
Canada J4K 3P7
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January 6th , 2020

GPR Ref.: GPR-19-01875

Daniel Wall, P.Eng.
Geotechnical Engineer
WSP Canada Inc.
2611 Queensview Dr., Suite 300
Ottawa (ON) K2B 8K2

RE: Shear-Wave Velocity Sounding for Site Class Determination at Campus Avenue, Carleton University, Ottawa, ON.

Dear Mr. Wall:

Geophysics GPR International Inc. has been requested by WSP Canada Inc. to carry out a shear-wave velocity measurement for seismic site classification at the above site in Ottawa. Figure 1 shows the regional location of the site and Figure 2 illustrates the location of the seismic spreads.

The MASW surveys were performed on December 6th, 2019.

The investigation included the multi-channel analysis of surface waves (MASW) and the Extended SPatial AutoCorrelation (ESPAC) methods.

The following paragraphs describe the survey design, the principles of the test method, the methodology for interpreting the data, and provide a culmination of the results in table format.

METHODS PRINCIPLES

MASW Survey

The *Multi-channel Analysis of Surface Waves* (MASW) and the *Extended SPatial AutoCorrelation* (ESPAC or MAM for *Microtremors Array Method*) are seismic methods used to evaluate the shear wave velocities of subsurface materials through the analysis of the dispersion properties of the Rayleigh surface waves ("ground roll"). The MASW is considered an "active" method, as the seismic signal is induced at known location and time in the geophones spread axis. Conversely, the ESPAC is considered a "passive" method, using the low frequency "noises" produced far away. The method can also be used with "active" seismic source records. The dispersion properties are expressed as a change of phase velocities with frequencies. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. The inversion of the Rayleigh wave dispersion curve yields a shear wave (V_S) velocity depth profile (sounding). Figure 3 schematically outlines the basic operating procedure for the MASW method.

Figure 4 illustrates an example of one of the MASW/ESPAC records, the corresponding spectrogram analysis and resulting 1D V_S model. The ESPAC method allows deeper Vs soundings, but generally with a lower resolution for the surface portion. Its dispersion curve can then be merged with the higher frequency one from the MASW to calculate a more complete inversion.

Seismic Refraction Survey

The method consists in measuring the propagation delays of the direct and refracted seismic waves (P and/or S) produced by an artificial source in the axis of a seismic linear spread. The seismic velocities of the materials can be directly calculated, then the refractors depths.

SURVEY DESIGN

The geometry of an MASW survey is similar to that of a seismic refraction investigation (i.e. 24 geophones in a linear array). The fundamental principle involves intentionally generating an acoustic wave at the surface and digitally recording the surface waves from the moment of source impact with a linear series of geophones on the surface. This is referred to as an "active source" method. A sledgehammer was used as the primary energy source with traces being recorded at 6 locations: approximately 20 m off both ends and at both ends of the spread. Data were collected with geophones spacing of 3 m and 1m for a total of 8 shot records.

The theoretical maximum depth of penetration (34.5 m) is half of the maximum seismic array length (69 m), in practice the maximum depth of penetration is often influenced by the geology.

The seismic records counted 12,000 data, sampled at 250 µs for the MASW surveys, and 16,000 data, sampled at 62.5 µs for the seismic refraction. A stacking procedure was also used to improve the Signal / Noise ratio for the seismic records. Unlike the refraction method, which allows producing a result point beneath each geophone, the shear wave depth sounding can be considered as the average of the bulk area within the geophone spread, especially for its central half-length. The seismic records were made with a Geometrics Geode Seismograph, and the geophones were 4.5 Hz.

Interpretation Method and Accuracy of Results

MASW Surveys

The main processing sequence involved plotting, picking, and 1-D inversion of the MASW shot records using the SeisimagerSW™ software package. In theory, all MASW shot records should produce a similar shear-wave velocity profile. In practice, however, differences can arise due to energy dissipation and localized surface variations. The results of the inversion process are inherently non-unique and the final model must be judged to be geologically realistic. The inversion modelling also assumes that all layering is flat/horizontal and laterally uniform.

The results of the MASW tests are presented in chart format as Figure 5. The chart presents the 1-D shear wave velocity values from the inversion models of the seismic records.

The Vs30 values for the soundings are presented in Table 1. The Vs30 values are based on the harmonic mean of the shear wave velocities over the upper 30 m. The Vs30 value is calculated by dividing the total depth of interest (e.g. 30 m) by the sum of the time spent in each velocity layer up to that depth. This harmonic mean value reflects the equivalent single layer response.

The estimated error in the average Vs30 value determined through MASW tests is typically +/-10 to 15% for overburden sites. The shear-wave velocities modelled through the MASW method within bedrock have a higher estimated error.

Seismic Refraction surveys

The General Reciprocal Method was used, with signal sources at both ends of the seismic spreads, to consider seismic wave propagation for two opposite directions. The seismic wave's arrival times were identified for each geophone. The measurements were realised to calculate the rock depth (using P waves).

More detailed descriptions of these methods are presented in *Shear Wave Velocity Measurement Guidelines for Canadian Seismic Site Characterization in Soil and Rock*, Hunter, J.A., Crow, H.L., et al., Geological Surveys of Canada, General Information Product 110, 2015.

CONCLUSION

The approximate location of the shear-wave sounding is indicated in Figures 1 and 2.

The shear-wave models are presented in Figure 5. The results are summarized in Table 1. The background seismic noise levels at this site were low. The quality of the seismic records and the resulting dispersion curves was good; the shear-wave velocities for the bedrock were constrained by the MASW and refraction methods indicate bedrock between depths of 12 m and 13 m.

Borehole data from previous studies indicate bedrock around depths of 10.7 m and 17.8 m below grade. Simple seismic refraction calculation reached the depth to a competent bedrock where a compressional wave velocity of approximately 4100 m/s. The MASW models have been constrained to fit with the seismic refraction data with consideration for the nearby borehole data.

Table 1. Calculated Vs30 values (m/s) from the MASW data

Depth	Vs		
	Min.	Median	
(m)	(m/s)	(m/s)	(m/s)
0	219.2	227.1	233.1
0.9	181.7	186.4	189.8
2.0	176.2	202.3	231.1
3.3	231.7	301.2	352.6
4.8	730.2	1012.5	1418.2
6.5	984.6	1190.6	1439.4
8.3	1234.3	1322.3	1465.9
10.4	1383.5	1432.2	1509.7
12.6	2083.5	2085.2	2138.2
15.1	2098.3	2100.0	2150.3
17.7	2105.7	2107.4	2155.1
20.5	2123.0	2124.6	2160.0
23.5	2132.8	2134.5	2155.0
26.6	2150.0	2151.6	2155.5
30			

Vs30 (m/s)	**836.2**
Site class	**C***

* Conditional on the NBC 2015 Commentary 'J' requirements

Based on the average Vs30 values (0 to 30 m below grade) as determined through the MASW method, and table 4.1.8.4.A of the National Building Code of Canada, 2015

Edition, site class “C” (360 < VS30 ≤ 760 m/s) could be considered for the investigated site; however, this site class could be superseded by the presence of peat (indicated in historic boreholes) and/or other sensitive soils. Sites with more than 3 m of soft soils may require application of seismic site class ‘E’ or ‘F’ based on the geotechnical data and liquefaction risk analysis.

The use of site class “B” is conditional on the requirements of Commentary “J” sentence 100, specifically, *“Site Classes A and B, are not to be used if there is more than 3 m of soil between the rock surface and the bottom of the spread footing or mat foundation, even if the computed average shear wave velocity is greater than 760m/s*”.

As noted, the site classification provided in this report is based solely on the Vs30 value as derived from the MASW method and it can be superseded by other geotechnical information. This geotechnical information includes, but is not limited to, the presence of sensitive and/or liquefiable soils, peat, more than 3m of soft clays, high moisture content, etc. The reader is referred to section 4.1.8.4 of the National Building Code of Canada, 2015 Edition for more information on the requirements for site classification.

The V_S values calculated are representative of the in-situ materials and are not corrected for the total and effective stresses.

The interpretation of the seismic data and preparation of this report was performed by Andrés Rincón, M.Sc., and reviewed by Lhoucin Taghya, P.Geo.

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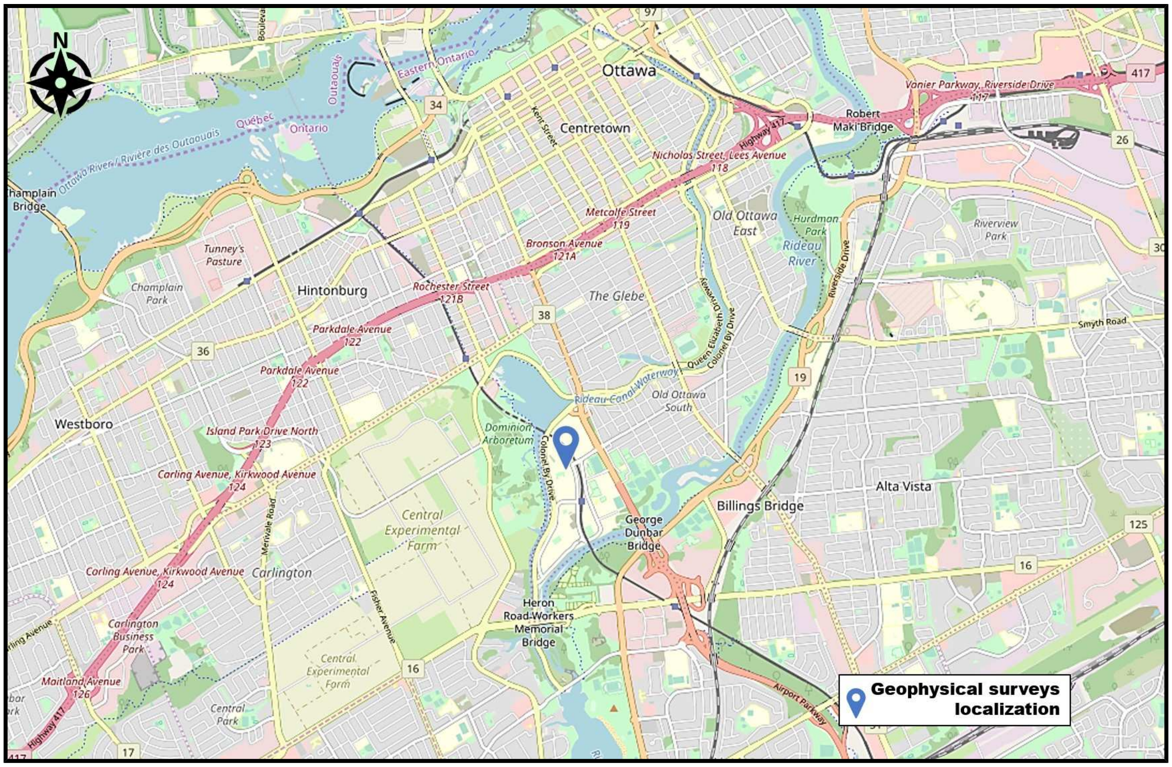

Figure 1: Regional location of the Site
(source: *OpenStreetMap™*)

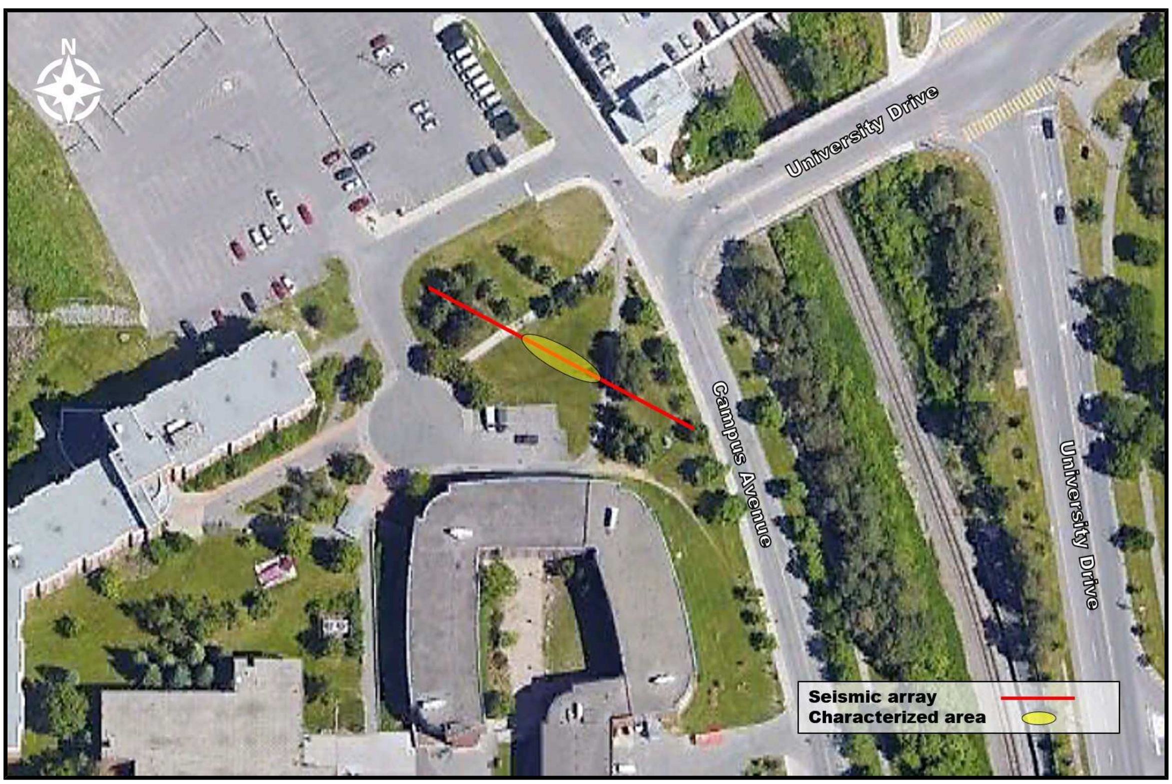

Figure 2: Location of the seismic spreads
(source: *Google Earth™*)

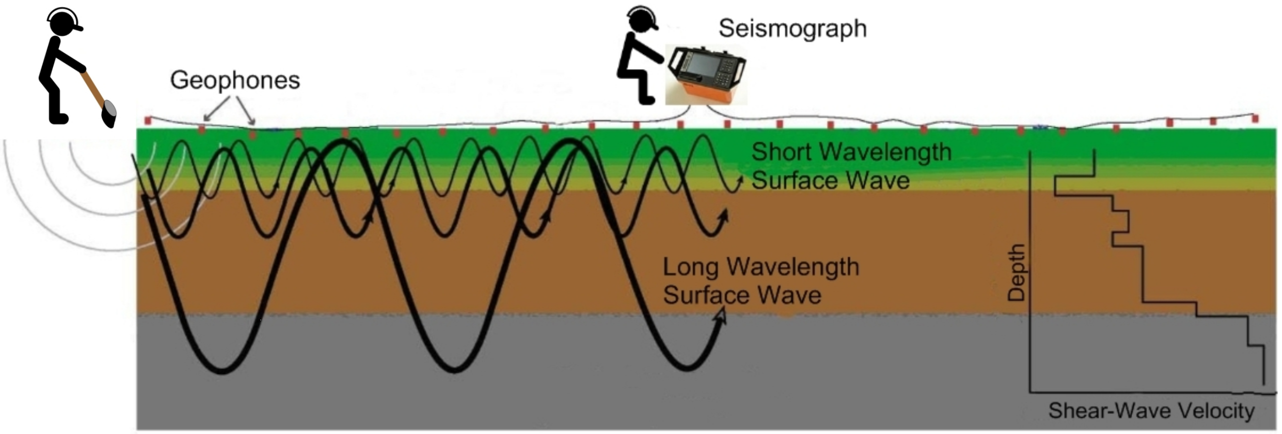

Figure 3: MASW Operating Principle

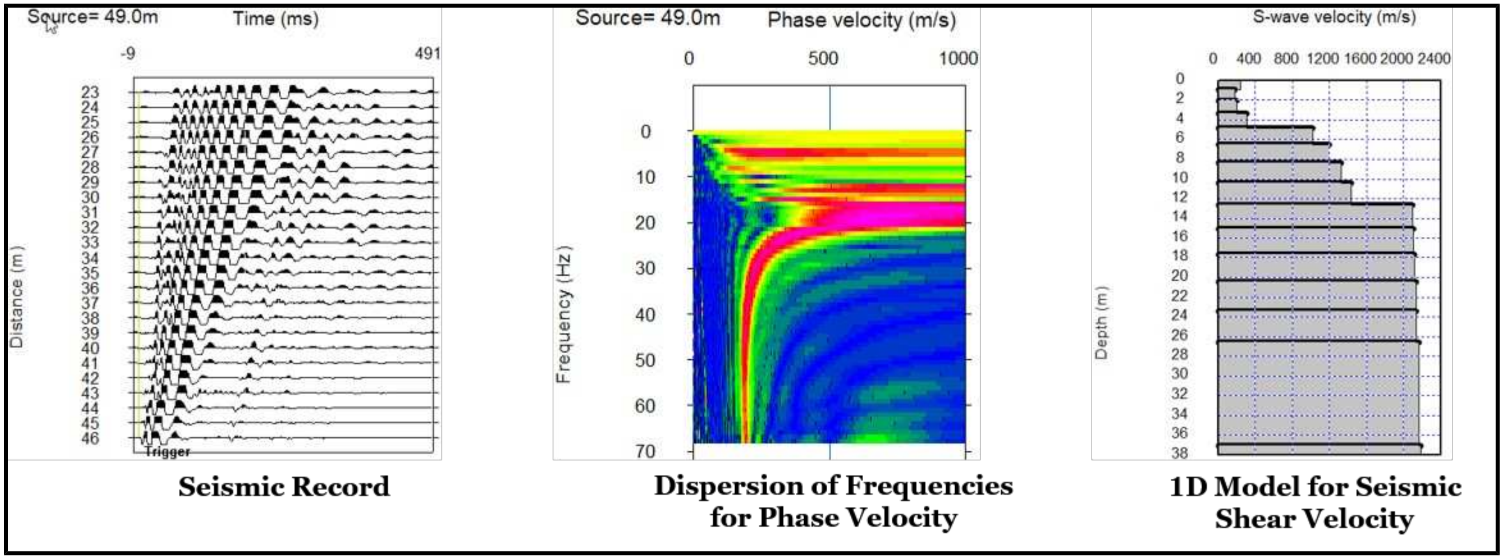

Figure 4: Example of a MASW/ESPAC record, Phase Velocity - Frequency curve and resulting 1D Shear Wave Velocity Model

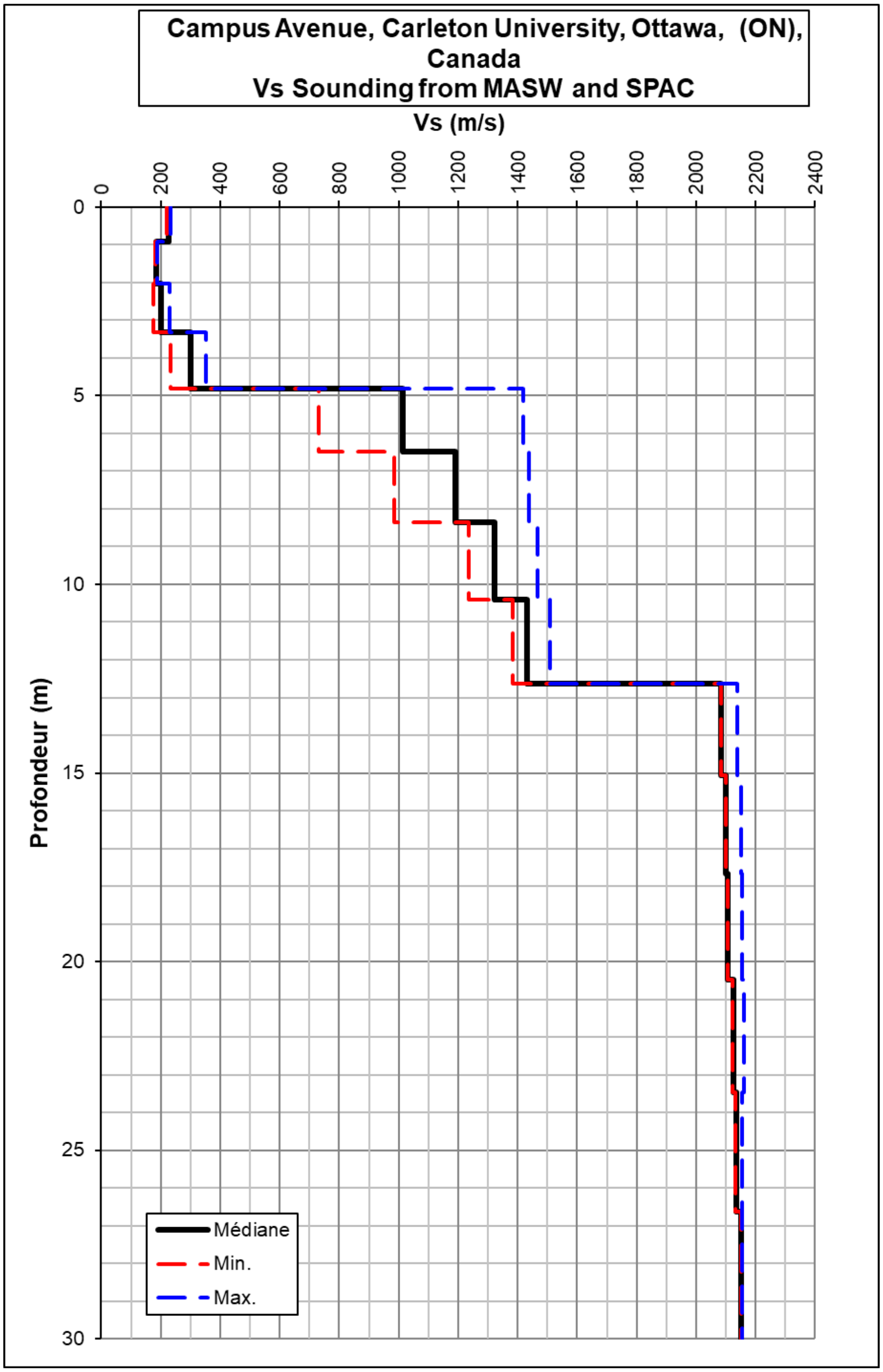

Figure 5: MASW Shear-Wave Velocities Sounding