April 22, 2020
Revised February 1, 2021

Poulos & Bennett, LLC
2602 E. Livingston Street
Orlando, Florida 32803

Attention: Mr. R. Lance Bennett, P. E.
lbennett@poulosandbennett.com

Reference: **Limited Geotechnical Exploration**
Cyrils Drive Roadway Widening
Osceola County, Florida
UES Project No. 0130.1700290.0013
UES Report No. ***1765631.V3***

Dear Mr. Bennett:

Universal Engineering Sciences, LLC (UES) has completed a limited geotechnical exploration at the above referenced site in Osceola County. The scope of our exploration was planned in conjunction with and authorized by you. This exploration was performed in accordance with UES Proposal No. 1493717.V2 revised on April 15, 2019 and with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made. The following sections present the results of our field exploration program.

Note that based on conversations with Tavistock and Poulos and Bennett (P&B) in March 2020, the scope of work was limited to borings at the mast arm locations and roadway cores within the southbound turn lane on Narcoossee Road. Further, due to the presence of various utility easements and overhead electric lines at the proposed mast arm locations, UES was approved to perform Advanced Continuous Surface Wave (ACSW) test at the four locations and provide Stiffness parameters (E) for the design of mast arm foundations.

PROJECT DESCRIPTION

UES was requested to perform two (2) roadway cores the southbound turn lane of Narcoossee Road to obtain asphalt, base and stabilized subgrade thicknesses. We were also requested to provide the Structural Number according to FDOT standards at the core locations. UES engineering technicians visited the site to visually observe any distress and to perform the field work.

ACSW testing was performed at the four corners of the intersection between Narcoossee Road and Cyrils Drive. The results of this exploration are presented in the attached ACSW Report.

UES performed twenty (20) SPT borings, designated CD-01 through CD-20, along Cyrils Drive as shown on the attached Boring Location Plan.

In December 2020 and January 2021, we were requested to perform additional SPT borings along the entire stretch of Cyrils Drive. We were also requested to perform muck probes within the wetland areas that bound the existing Cyrils Drive alignment.

FIELD EXPLORATION

PAVEMENT CORES

Our road core field exploration was performed on April 8, 2020 (along Narcoossee Road) and January 18, 2021 (along Cyrils Drive). Pavement cores were performed and measured in the field to determine the pavement component thicknesses and general condition of the pavement cores. The locations of the pavement cores are presented in the appendix as a Pavement Core Location Plan.

The pavement core locations were selected during our visual survey of the roadways, and marked in the field using paint. The core locations were patched with cold patch upon completion of the field work. The pavement cores were also returned to our Orlando laboratory for inspection.

SPT BORINGS

The SPT soil borings were performed on May 6, 2020 and January 13-18, 2021 with a truck mounted drilling rig. Horizontal and vertical survey control was not provided for the test locations prior to our field exploration program. UES located the test borings by using the provided site plan, measuring from existing on-site landmarks shown on an aerial photograph, and by using handheld GPS devices. The indicated test locations should be considered accurate to the degree of the methodologies used. The approximate boring locations are shown on the attached Boring Location Plan.

The SPT borings, designated CD-01 through CD-20 on the attached Boring Location Plan in Appendix B, were performed in general accordance with the procedures of ASTM D 1586 "Standard Method for Penetration Test and Split-Barrel Sampling of Soils". SPT sampling was performed continuously to 10 feet to detect variations in the near surface soil profile and on approximate 5 feet centers thereafter.

MUCK PROBE SURVEY

As part of this limited assessment, a series of muck probes were performed within the three wetland areas outlined within the subject site as identified on the attached Figure A-3. The muck probes were performed at a spacing of about 100 feet on-center. The muck probes were performed in general accordance with ASTM D 4544 procedures (Standard Practice for Estimating Peat Deposit Thickness). During these procedures, a cylindrical steel rod is inserted into the near surface soils and the approximate depth of soft/organic soils is estimated by the amount of resistance to penetration. The approximate thicknesses of standing water and surficial muck soils, at the sampled locations, are shown on the attached Figure A-3.

The muck probe locations were determined in the field by measuring on-site landmarks shown on aerial photographs. The transect lines and muck probe locations were not surveyed or horizontal and vertical control prior to our field exploration and therefore should be considered accurate to the degree of the methods employed.

FINDINGS OF FIELD EXPLORATION

PAVEMENT CORES

Based upon the findings of our limited pavement evaluation, the pavement sections found at the core locations consisted of asphalt concrete over a limerock base material, and underlain by composite stabilized subgrade. The pavement section components and corresponding thickness at each core location are summarized in Table I.

Table I – Summary of Pavement Section and Structural Numbers

Core	Existing Pavement Condition	Measured Asphalt Structural Course Thickness (in)	Measured Base Course Thickness (in)	Measured Stabilized Subgrade Course Thickness (in)	Current Structural Number (SN)
NR-01	Good	4.8	10.8	12.0	4.5
NR-02	Good	5.0	11.0	12.0	4.6
CD-05	Fair	2.0	2.5	12.0	1.5
CD-06	Fair	2.0	2.5	12.0	1.5
CD-08	Fair	2.0	2.0	12.0	1.5
CD-12	Fair	2.0	2.0	12.0	1.5
CD-14	Fair	2.0	2.0	12.0	1.5
CD-15	Fair	2.0	1.5	12.0	1.5
CD-17	Fair	2.5	2.0	12.0	1.6
CD-18	Fair	2.0	2.0	12.0	1.5
CD-20	Fair	2.0	2.0	12.0	1.5

Notes: Structural number calculations
Per the FDOT 2020 Flexible Pavement Design Manual:
Asphalt Type SP = 0.44 (new), 0.34 (good), 0.25 (fair), 0.15 (poor), Sand Clay Base = 0.12, LR Base = 0.18, Stabilized Subgrade = 0.08

Based upon the findings of our pavement cores and the observed condition of the roadway along the limits explored, it is our opinion that based on the criteria of Good, Fair and Poor, the existing pavement section is in “Good to Fair” condition per the guidelines outlined with the FDOT Flexible Pavement Design Manual. Using the reduced structural coefficients of asphalt materials presented within Table 7.1 of the FDOT Flexible Pavement Design Manual, we estimate the existing pavement section currently has an estimated Structural Number (SN) ranging from 4.5 to 4.6 at the two (2) core locations on Narcoossee Road. The SN values along Cyrils Drive varied between 1.5 and 1.6. A new pavement section for the "Light Duty" classification would require a minimum Structural Number of 2.7 and a "Heavy Duty" classification would require a minimum Structural Number of 3.5.

SPT BORINGS

The results of our field exploration and laboratory analysis, together with pertinent information obtained from the SPT borings, such as soil profiles, penetration resistance and groundwater levels are shown on the boring logs included in Appendix B. The Key to Boring Logs, Soil Classification Chart is also included in Appendix B. The soil profiles were prepared from field logs after the recovered soil samples were examined by a Geotechnical Engineer. The stratification lines shown on the boring logs represent the approximate boundaries between soil types, and may not depict exact subsurface soil conditions. The actual soil boundaries may be more transitional than depicted.

Please note that the borings were staggered along Cyrils Drive, that is, some of them were performed on the existing roadway and some were performed on the grass shoulder.

The borings encountered very loose to very dense fine sand with varying fines content [SP, SP-SM] to the maximum termination depth of 20 feet below grade. SPT "N-values" ranged from 2 blows per foot (bpf) to 63 bpf.

Based on the results of our exploration, the soils encountered at some of our borings were medium dense to very dense fine sands [SP, SP-SM] between the depths of approximately 5 and 15 feet below existing grade. The SPT "N" blow count values within the dense soils ranged from 25 blows per foot (bpf) to 63 bpf. It has been our experience that excavations through soils with SPT "N" blow counts in excess of about 25 +/- blows per foot may prove difficult with smaller sized excavation equipment. The site contractor should select their excavation equipment for this site with this in mind.

Groundwater Conditions

Groundwater was encountered between 2½ feet and 12 feet below grade at the time of our exploration. Groundwater was typically shallower near the wetland areas and when they were performed on the grass shoulder. The encountered groundwater level at each of the boring locations is shown on the attached boring logs. Fluctuations in groundwater levels should be anticipated throughout the year, primarily due to seasonal variations in rainfall, surface runoff, and other factors that may vary from the time the borings were conducted.

Based on the results of our field exploration and the factors listed above, we estimate that the seasonal high groundwater level the boring locations will form at about the existing ground surface (standing water) to 10 feet and deeper below existing grades for a normal rainfall year. The estimated stabilized seasonal high groundwater level at each of the boring locations is shown on the attached boring logs. The estimated seasonal high groundwater level at each of the boring locations is shown on the individual boring logs in Appendix B.

It should be noted that the estimated seasonal high water levels provided should be considered accurate to about ½ foot +/- and do not provide any assurance that groundwater levels will not exceed these estimated levels during any given year in the future. Should the impediments to surface water drainage be present, or should rainfall intensity and duration, or total rainfall quantities, exceed the normally anticipated rainfall quantities, groundwater levels might exceed our seasonal high estimates. Further, it should be understood that changes in the surface hydrology and subsurface drainage from on-site and/or off-site improvements could have significant effects on the normal and seasonal high groundwater levels.

MUCK PROBE

Based on the results of our limited muck probe assessment, surficial organic soils were encountered at the probe locations performed within the subject site. At the muck probe locations performed the estimated depth of the surficial muck soils ranged from about the existing ground surface to about 10 feet below existing grade. We note that deeper and/or thicker zones of organic soils than those shown on the attached muck probe plans may exist between widely spaced probe locations and within unexplored areas. The contractor should be prepared to over-excavate localized deeper pockets of organic soils to their full depth and width. Due the potential variable nature of subsurface conditions, we recommend that adequate contingency be allowed in the budget for any unforeseen deeper pockets of organic soils.

Standing water on the order of few inches up to about 2 feet deep was found within the subject site along the muck probe transects at the time of our field work (January 2021).

Recommendations

Based upon our surficial visual classification of the soils and the amount of resistance to the probe penetration, it is our professional opinion that the organic soils present on-site will necessitate complete removal and/or some form of remediation/improvement within the limits of construction (i.e. up to the construction boundary and 5 feet beyond) and replacement with compacted structural fill material beneath the impacted portions of the development. *Failure to properly remove and replace highly organic materials (or partial demucking with Geogrid) from beneath the proposed roadways may lead to premature deterioration of the developments.*

We strongly recommend the de-mucking and subsequent backfilling operations be performed under the *full-time* observation of UES representative for the duration of the project. The purpose of the full-time observation is not only to ensure total removal of the organic soils, but also to prevent excess suitable material from being excavated from the site.

It is imperative that dewatering be performed prior to initiating the demucking operations. We strongly recommend that under no circumstances should demucking operations proceed in wet conditions, since this could lead to unnecessary over excavation above and below the anticipated organic soil depths or worse, leaving highly organic soils in-place. Where excavations will extend only a few feet below the groundwater table, a sump pump may be sufficient to control the groundwater table. Deeper excavations will likely require well points and/or horizontal sock drains to adequately control the groundwater table. Regardless of the method(s) used, we recommend drawing down the groundwater level at least 2 feet below the bottom of the deepest anticipated excavation. The actual method(s) of dewatering should be determined by the contractor. The design and discharge of the dewatering system must be performed in accordance with applicable regulatory criteria (i.e. water management district, etc.) and compliance with such criteria is the sole responsibility of the contractor.

Excavations should be sloped as necessary to prevent slope failure and to allow backfilling. As a minimum, temporary excavations below 4-foot depth should be sloped in accordance with OSHA regulations. Where lateral confinement will not permit slopes to be laid back, the excavation should be shored in accordance with OSHA requirements. During excavation, excavated material should not be stockpiled at the top of the slope within a horizontal distance equal to the excavation depth. Provisions for maintaining workman safety within excavations is the sole responsibility of the contractor.

It is important to note that the sandy soils immediately beneath the organic soils may include traces of organic material. Furthermore, the transition from unsuitable to suitable soils may be gradual and not obvious during the demucking operations. Depending on the excavation and demucking technique adopted for this project, these soils may also become cross-contaminated with organic material during demucking operations and may become unsuitable for reuse.

Once the organic soil deposits are completely removed, the backfill material consisting of clean dry sands (less than 10 percent fines) must be placed in thin lifts of 10 to 12 inches thick, and each lift must be compacted to at least 95 percent of the Modified Proctor maximum dry density (ASTM D-1557). Perform compliance tests within the fill at a frequency of not less than one test per 5,000 square feet per lift, or at a minimum of two test locations, whichever is greater.

Muck Probe Survey Limitations

Please note that our muck probe survey was based upon a limited number of test locations. The information provided in this report is based on data obtained from the probes performed at the approximate locations indicated on the attached Muck Survey Plans. Variations in the surficial muck thicknesses will likely exist between the widely spaced probe locations. The information submitted in this report is based on data obtained from the muck probings performed at the approximate locations indicated on the attached Muck Survey Plan. We caution that there may be deeper zones/pockets of organic (muck) soils than found during this limited exploration within unexplored areas of the wetland feature within the proposed Cyrils Drive extension and between the widely spaced muck probe locations.

Please note the manual muck probe procedure involves pushing a slender metal rod into the surficial organics and evaluating the relative resistance of the soil. The manual muck probe cannot determine the type of material encountered since no soil samples are recovered, only whether or not the material is sufficiently loose or soft to allow penetration of the probe. Generally speaking, it is difficult to penetrate loose sandy soils more than several feet. Therefore, organic soils are likely present at test locations where the probe rod was able to penetrate significant depths.

We also caution that the manual muck probe may not detect organic layers which exist beneath or in-between sandy soil layers, and may penetrate loose sandy soils.

Due to these limitations, the depths shown may be an over-estimation or underestimation of the actual depth of organic soils. **Muck probe data shall not be used to estimate earthwork quantities, except on a preliminary basis.** Backhoe test pits or auger borings with horizontal and vertical survey control are recommended where more definite information is needed. UES will not be responsible for any extrapolation or use of our data by others beyond the purpose(s) for which it is applicable or intended.

PAVEMENT RECOMMENDATIONS

GENERAL

We assume that a combination of flexible asphaltic and rigid concrete pavement sections will be used for the pavement areas on this project. Our recommendations for both pavement types are listed in the following sections. The following recommendations are based on the pavement areas being prepared as recommended in this report.

ASPHALTIC PAVEMENTS

Layer Components

We understand that the proposed roadways and parking areas will consist of a flexible pavement section with typical residential traffic and some commercial traffic. At the time of this exploration, specific traffic loading information was not provided to us. We recommend using a three-layer pavement section for the proposed asphaltic parking/drive areas consisting of stabilized subgrade, base course, and surface course. The Osceola County Road Construction Specifications has divided the pavement requirements for commercial or multi-family residential developments into categories as a function of average daily traffic (ADT). Table II summarizes the minimum pavement component thicknesses for pavement design.

TABLE II
MINIMUM ASPHALTIC PAVEMENT COMPONENT THICKNESSES

Traffic Loading	Layer Component (inches)		
	Surface Course	Base Course	Subgrade**
Light Duty	1½	6	12
Heavy Duty	2	8	12

** The upper six inches of subgrade should be stabilized for limerock (or crushed concrete) base (see Section 11.2.2)

Subgrade

The subgrade immediately beneath the base course (sub-base) should be compacted to at least 98 percent of the Modified Proctor maximum dry density (ASTM D 1557) value.

For a limerock or crushed concrete base, the upper 6 inches of subgrade should be stabilized to a minimum Florida Bearing Value (FBV) of 50 psi (or LBR of 40 as specified by FDOT).

Compaction testing of the subgrade should be performed to full depth at a frequency of at least one (1) test per 10,000 square feet.

Base Course

Based on review of the Osceola County roadway design standards, the base course may be either limerock or soil-cement. We also understand the Osceola County will also currently allow the use of Recycled Concrete Aggregate (RCA) base course on projects on a case by case basis.

For a limerock base, the base course should be compacted to a minimum density of 98 percent of the Modified Proctor maximum dry density and exhibit a minimum LBR of 100. The limerock material should comply with the latest edition of the Florida Department of Transportation (FDOT) Road and Bridge Construction specifications.

For a soil-cement base, we recommend the contractor perform a soil-cement design with a minimum seven (7)-day strength of 300 pounds per square inch (psi) on the materials he intends to use. Place soil-cement in maximum 6-inch lifts uniform and compact in place to a minimum density of 95 percent of the maximum dry density according to specifications in ASTM D-558," Moisture Density Relations of Soil Cement Mixtures".

Place and finish the soil-cement according to Portland Cement Association requirements. Final review of the soil-cement base course should include manual "chaining" and/or "soundings" seven days after placement. Shrinkage cracks will form in the soil-cement mixture and you should expect reflection cracking on the surface course.

Recycled Concrete Aggregate (RCA) may provide a cost-effective alternative material in lieu of limerock or soil cement base courses. Local availability, along with municipality standards, typically governs the use of RCA use as an alternative base course material. The advantages of using RCA as a pavement base course include its high strength (stronger than limerock), resistance to groundwater related distress, and lack of reflection cracking caused by thermal expansion and contraction.

If a RCA base is used, the base course material should be sourced from an FDOT approved supplier. The base should be compacted to a minimum density of 100 percent of the Modified Proctor maximum dry density and exhibit a minimum LBR of 150. The base material should comply and be placed in accordance with the latest edition of the FDOT Road and Bridge Construction Specifications Supplemental Section 204-2.2 – "Recycled Concrete Aggregate Base Materials". In order to ensure consistency of the crushed concrete material, additional LBR and sieve gradation tests should be performed at a minimum frequency of one test per 15,000 square feet, and for each visual change in material.

Compaction testing of the base course should be performed to full depth at a frequency of at least one (1) test per 10,000 square feet.

Surface Course

For the roadways, we recommend that the surfacing consist of FDOT SuperPave (SP) asphaltic concrete. The surface course should consist of FDOT SP-9.5 fine mix for light-duty areas and

FDOT SP-12.5 topped with SP-9.5 fine mix for heavy duty areas. The asphalt concrete should be placed within the allowable lift thicknesses for fine Type SP mixes per the latest edition of FDOT, Standard Specifications for Road and Bridge Construction.

The asphaltic concrete should be compacted to an average field density of 93 percent of the laboratory maximum density determined from specific gravity (G_{mm}) methods, with an individual test tolerance of **+2 percent and -1.2% of the design G_{mm}**. Specific requirements for the SuperPave asphaltic concrete structural course are outlined in the latest edition of FDOT, Standard Specifications for Road and Bridge Construction.

Note: If the Designer (or Contract Documents) limits compaction to the static mode only or lifts are placed one-inch thick, then the average field density should be 92 percent, with an individual test tolerance of + 3 percent, and -1.2% of the design G_{mm}.

After placement and field compaction, the wearing surface should be cored to evaluate material thickness and density. Cores should be obtained at frequencies of at least one (1) core per 10,000 square feet of placed pavement, or a minimum of two (2) cores per day's production.

Effects of Groundwater

One of the most critical influences on the pavement performance in Central Florida is the relationship between the pavement base course and the seasonal high groundwater level. Sufficient separation will need to be maintained between the bottom of base course and the anticipated seasonal high groundwater (perched) level. **We recommend that the seasonal high groundwater and the bottom of base course be separated by a minimum of 24 inches per Osceola County requirements**. Areas in which the minimum separation between bottom of base course and groundwater cannot be maintained, underdrains may be required.

Landscape Underdrains

All "green" and landscape areas adjacent to the pavements and sidewalks may require underdrains. The poorly draining silty/clayey sands used in the mass grading require that landscape drains may need to be provided to protect the roadway and sidewalk areas against adverse effects from over-irrigation or excess rainfall. Poorly draining silty and clayey material causes the irrigation and rainwater to perch and migrate laterally into the pavement components, which eventually compromises the integrity of the pavement section.

CONCRETE "RIGID" PAVEMENTS

Concrete pavement is a rigid pavement that transfers much lighter wheel loads to the subgrade soils than a flexible asphalt pavement; therefore, requiring less subgrade preparation. Concrete pavement is recommended under the dumpster area, and 10 feet in front of the trash enclosures, at a minimum.

We recommend using the existing surficial sands or approved structural fill densified to at least 98 percent of Modified Proctor test maximum dry density (ASTM D 1557) without additional stabilization under concrete pavement, with the following stipulations:

1. Prior to placement of concrete, the subgrade soils should be prepared as recommended in Section 12.0 of this report.

2. The surface of the subgrade soils must be smooth, and any disturbances or wheel rutting corrected prior to placement of concrete.

3. The subgrade soils must be moistened prior to placement of concrete.

4. Concrete pavement thickness should be uniform throughout, with exception to the thickened edges (curb or footing).

5. The bottom of the pavement should be separated from the seasonal high groundwater level by at least 12 inches.

Based on review of the Osceola County construction standards and the FDOT Rigid Pavement Design Manual, our recommended minimum concrete pavement design is shown in Table III.

TABLE III
MINIMUM CONCRETE PAVEMENT THICKNESSES

Service Level	Minimum Pavement Thickness	Maximum Control Joint Spacing	Recommended Saw Cut Depth
Light Duty	6 inches	12 feet x 12 feet	2 inches
Heavy Duty	7 inches	14 feet x 14 feet	2⅓ inches

We recommend using concrete with a minimum 28-day compressive strength of at least 4,000 pounds per square inch. Layout of the Saw cut control joints should form square panels, and the depth of saw cut joints should be ⅓ of the concrete slab thickness.

We recommend allowing UES to review and comment on the final concrete pavement design, including section and joint details (type of joints, joint spacing, etc.), prior to the start of construction.

For further details on concrete pavement construction, please reference the "Guide to Jointing of Non-Reinforced Concrete Pavements" published by the Florida Concrete and Products Association, Inc., and "Building Quality Concrete Parking Areas", published by the Portland Cement Association.

Specimens to verify the compressive strength of the pavement concrete should be obtained for at least every 50 cubic yards, or at least once for each day’s placement, whichever is greater.

SITE PREPARATION

We recommend normal, good practice site preparation procedures for the new construction areas. These procedures include: clearing/stripping of the site to remove vegetation, roots, organic topsoils, debris, **complete removal of surficial organic soils etc.** Following stripping, the exposed subgrade soils should be proof-rolled, and all subgrade and subsequent fill/backfill soils should be properly densified. A more detailed description of this work is as follows:

1. Perform any necessary remedial dewatering prior to any earthwork operations. Dewatering should be performed to a depth of at least 2 feet below the bottom of any excavations or compacted surface.

2. Strip the proposed construction limits of vegetation, topsoil, roots, organics, debris, and other deleterious materials within and 5 feet beyond the perimeter of the proposed building and new pavement areas. We strongly recommend that the stripped surface be observed and probed by representatives of UES. Deeper localized pockets of organic soils may be encountered during construction and should be removed as necessary.

3. Proof-roll the exposed subsurface soils under the observation of UES, to locate any soft areas of unsuitable soils, and to increase the density of the shallow loose fine sand soils. If deemed necessary by UES, in areas that continue to "yield", remove any deleterious materials and replace with a clean, compacted sand backfill.

4. Place fill as necessary. All fill should consist of clean sand with less than 12 percent soil fines and be free of organics, debris and other deleterious materials. Place fill in maximum 12-inch loose, uniform lifts and compact each lift at least 95 percent of the Modified Proctor maximum dry density (ASTM D1557).

5. Within the at-grade (or below grade) foundation areas, subgrade compaction of at least 95 percent of the Modified Proctor should be achieved to a depth of at least 2 feet below bottom of foundation/slab levels.

6. Within the pavement areas, the upper 12 inches of subgrade beneath the base course (sub-base) or concrete slabs should be compacted to at least 98 percent of the Modified Proctor maximum dry density. If required, the upper 6 inches of subgrade should be stabilized as recommended in the pavement section of this report.

7. Test the subgrade and each lift of fill for compaction at a frequency of not less than one test per 2,500 square feet in the building areas and one test per 10,000 square feet in the pavement areas, with a minimum of 4 tests in each area.

8. Prior to the placement of reinforcing steel and concrete, verify compaction within the footing trenches to a depth of 2 feet. We recommend testing every column footing and at least one test every 100 feet of wall footing, with a minimum of 4 tests per building.

Stability of the compacted soils is essential and independent of compaction and density control. If the near surface soils or the structural fill experience “pumping” conditions, terminate all earthwork activities in that area. Pumping conditions occur when there is too much water present in the soil-water matrix. Earthwork activities are actually attempting to compact the water and not the soil. The disturbed soils should be dried in place by scarification and aeration prior to any additional earthwork activities.

Vibrations produced during vibratory compaction operations at the site may be significantly noticeable within 100 feet and may cause distress to adjacent structures if not properly regulated. Provisions should be made to monitor these vibrations so that any necessary modifications in the compaction operations can be made in the field before potential damages occur. UES can provide vibration monitoring services to help document and evaluate the effects of the surface compaction operation on existing structures. It is recommended that large vibratory rollers remain a minimum of 50 feet from existing structures. Within this zone, the use of a static roller or small hand guided plate compactors is recommended.

CLOSURE

We hope this letter addresses your requirements at this time. We appreciate the opportunity to assist Poulos and Bennett and look forward to a continued association. Please contact us if you should have any questions, or if we may further assist you as your plans proceed.

Respectfully Submitted,
UNIVERSAL ENGINEERING SCIENCES
Certificate of Authorization No. 549

Gautham S Pillappa 2021.02.01 09:19:18 -05'00'

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Senior Geotechnical Engineer
Florida Registration No. 82816

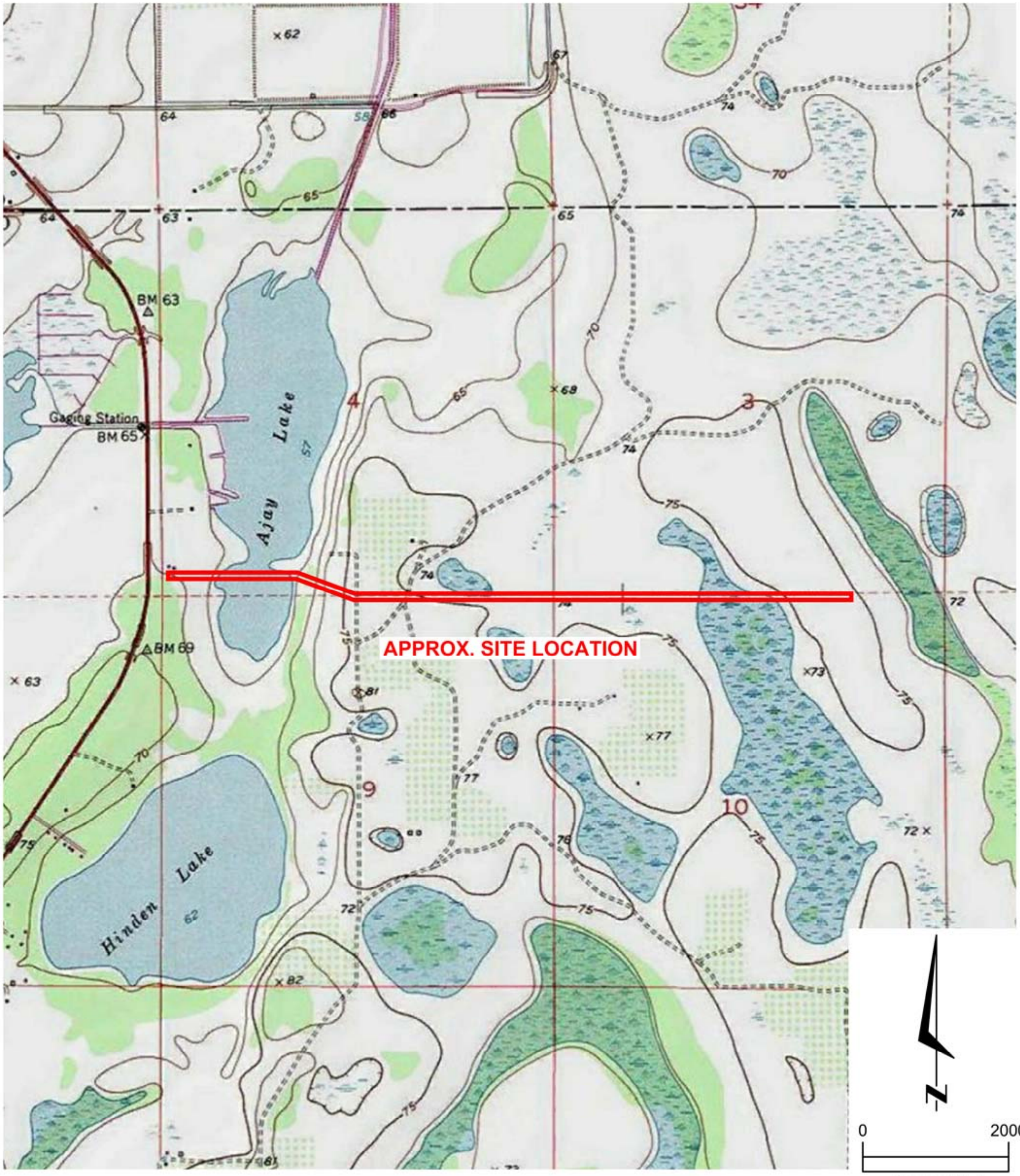
Ricardo C. Kiriakidis L., Ph.D., P.E.
Geotechnical Department Manager

Distribution: Client via email
Mr. Richard Bobletz, P.E., P&B
Ms. Christina Baxter, P.E., P&B

Attachments: Site Location Map
Pavement Core Location Plan
Muck Probe Location Plan
Boring Location Plan (2 sheets)
Boring Logs
Key to Boring Logs
ACSW Report

APPENDIX A

UNIVERSAL
ENGINEERING SCIENCES



SOURCE: USGS QUADRANGLE MAP OF "NARCOOSSEE, FLORIDA".

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LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

SITE LOCATION MAP

DRAWN BY:	N.F.	DATE:	1 - 22 - 2021	CHECKED BY:	G.P.	DATE:	01.28.2021
SCALE:	AS SHOWN	PROJECT NO:	0130.1700290.0013	REPORT NO:	1765631	PAGE NO:	A-1

20-0279-02

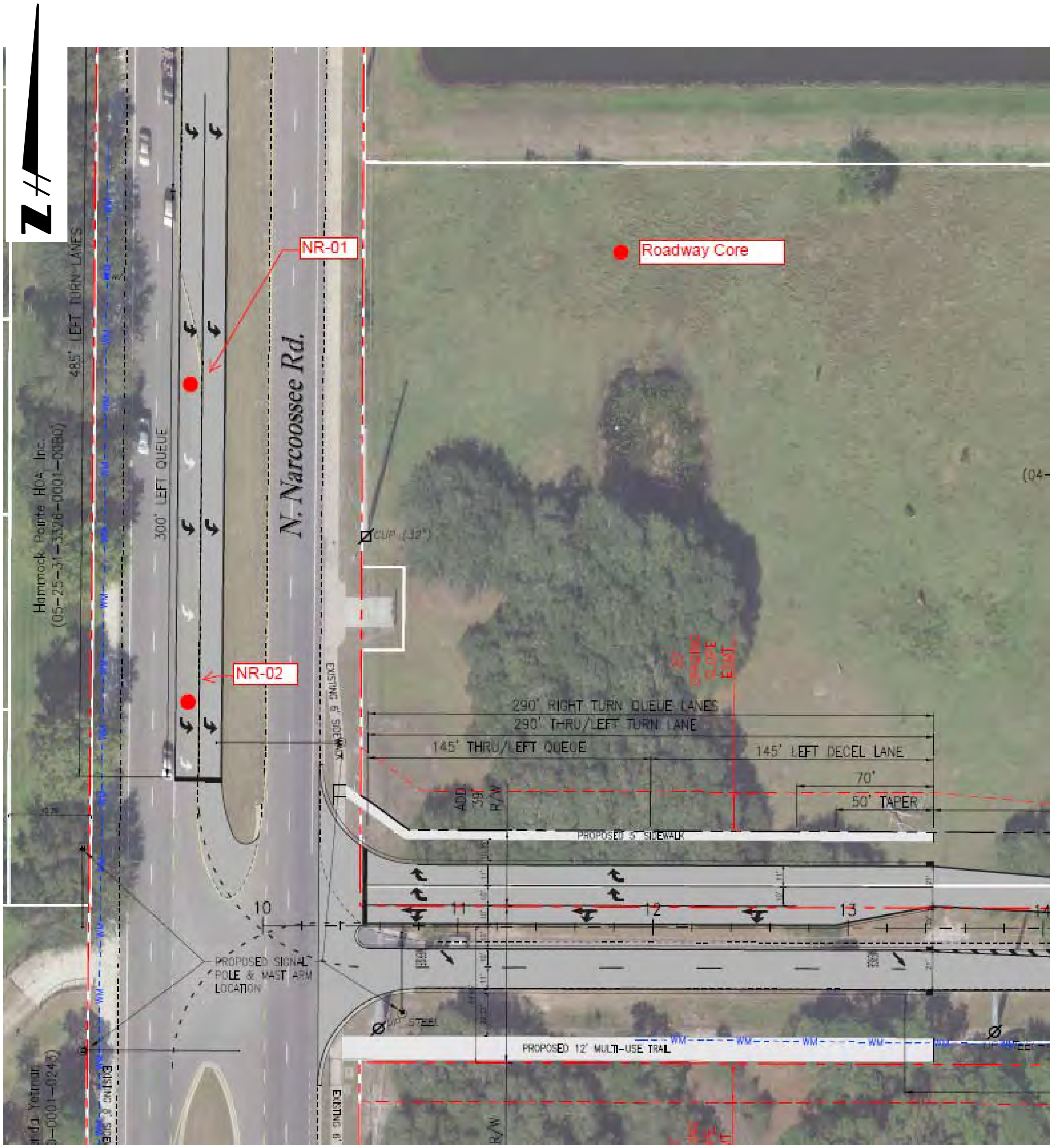


IMAGE SOURCE: Site Plan provided by Client

UNIVERSAL ENGINEERING SCIENCES

ROADWAY CORES – CYRILS DRIVE WIDENING SUNBRIDGE SUBDIVISION OSCEOLA COUNTY, FLORIDA

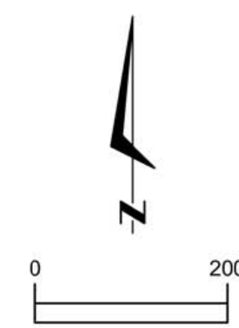
PAVEMENT CORE LOCATION PLAN

DRAWN BY: GSP	DATE: 4.22.2020	CHECKED BY: GSP	DATE: 4.22.2020
SCALE: Not Available	PROJECT NO: 0130.1700290.0013	REPORT NO: 1765631	PAGE NO: **A-2**

LEGEND

- APPROXIMATE PROBE LOCATION SHOWING APPROXIMATE DEPTH OF MUCK (FEET)

W = WATER
M = MUCK
LS = LOOSE SAND (POSSIBLE ORGANICS)



LIMITATIONS OF MUCK PROBE SURVEY

THE MANUAL MUCK PROBE PROCEDURE INVOLVES PUSHING A SLENDER METAL ROD INTO THE SURFICIAL ORGANICS AND EVALUATING THE RELATIVE RESISTANCE OF THE SOIL.
THE MANUAL MUCK PROBE CANNOT DETERMINE THE TYPE OF MATERIAL ENCOUNTERED SINCE NO SOIL SAMPLES ARE RECOVERED, ONLY WHETHER OR NOT THE MATERIAL IS SUFFICIENTLY LOOSE OR SOFT TO ALLOW PENETRATION OF THE PROBE. THE MANUAL PROBE MAY NOT DETECT ORGANIC LAYERS WHICH EXIST BENEATH OR IN-BETWEEN SANDY SOIL LAYERS, AND MAY PENETRATE LOOSE SANDY SOILS.

DUE TO THESE LIMITATIONS, THE DEPTHS SHOWN MAY BE AN OVER-ESTIMATION OR UNDER-ESTIMATION OF THE ACTUAL DEPTH OF ORGANIC SOILS.

MUCK PROBE DATA SHALL NOT BE USED TO ESTIMATE EARTHWORK QUANTITIES, EXCEPT ON A PRELIMINARY BASIS.

BACKHOE TEST PITS OR AUGER BORINGS WITH HORIZONTAL AND VERTICAL SURVEY CONTROL ARE RECOMMENDED WHERE MORE DEFINITE INFORMATION IS NEEDED.

LOOSE SAND MAY CONTAIN VARIABLE AMOUNTS OF ORGANICS AND DEPENDING UPON THE ORGANIC CONTENT MAY BE UNSUITABLE TO REMAIN IN-PLACE BELOW THE PROPOSED SITE IMPROVEMENTS.

20-0279-02

THIS DRAWING CREATED USING PLAN PROVIDED BY CLIENT.

FOR: POULOS & BENNETT

DRAWN BY:	N.F.	DATE:	1 - 22 - 2021
CHECKED BY:	G.P.	DATE:	01.28.2021
REPORT NO:	1765631.V3	SCALE:	AS SHOWN
PROJECT NO:	0130.1700290.0013		

LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

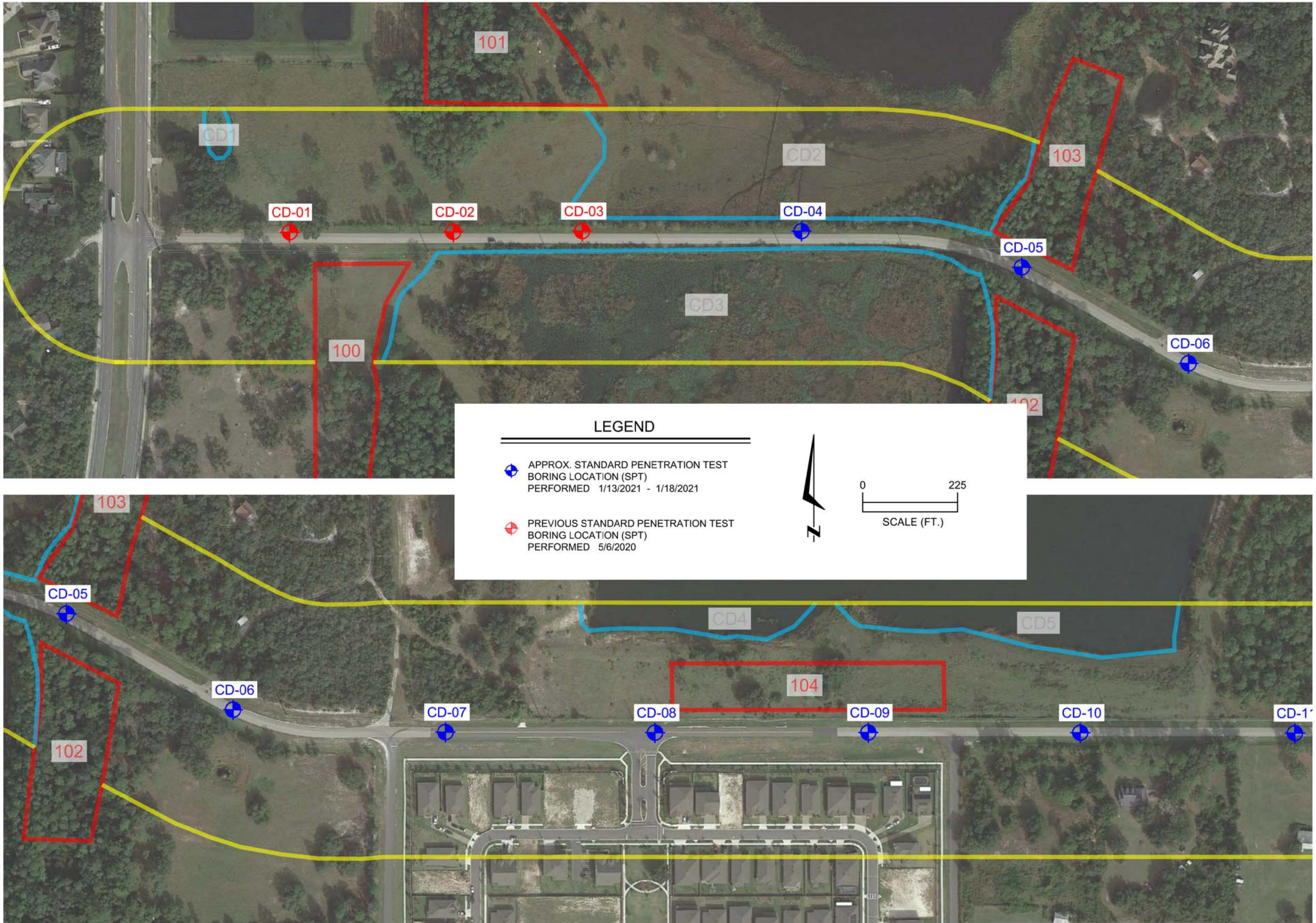
MUCK PROBE LOCATION PLAN

UNIVERSAL
ENGINEERING SCIENCES

PAGE NO: A-3

APPENDIX B

UNIVERSAL
ENGINEERING SCIENCES



THIS DRAWING CREATED USING PLAN PROVIDED BY CLIENT.

20-0279-02

FOR: POULOS & BENNETT

DRAWN BY: N.F. | DATE: 1 - 22 - 2021

CHECKED BY: G.P. | DATE: 01.28.2021

REPORT NO: 1765631.V3 | SCALE: AS SHOWN

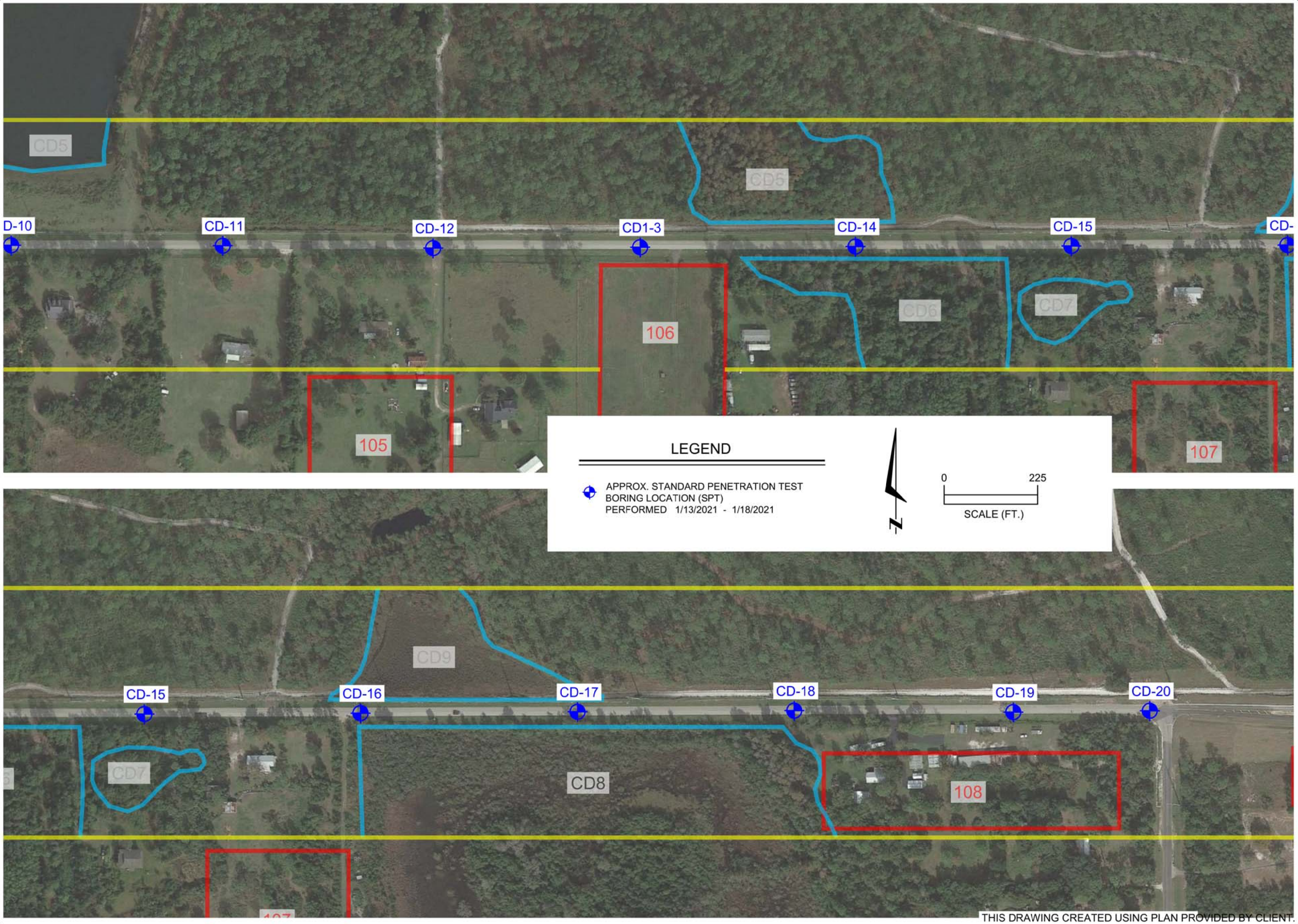
PROJECT NO: 0130.1700290.0013

LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING LOCATION PLAN

UNIVERSAL
ENGINEERING SCIENCES

PAGE NO: B-1.1



20-0279-02

FOR: POULOS & BENNETT

DRAWN BY:	N.F.	DATE:	1 - 22 - 2021
CHECKED BY:	G.P.	DATE:	01.28.2021
REPORT NO:	1765631.V3	SCALE:	AS SHOWN
PROJECT NO:	0130.1700290.0013		

LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING LOCATION PLAN

UNIVERSAL
ENGINEERING SCIENCES

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.1

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-01** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 6.0
DATE OF READING: 5/6/2020
EST. SHGWT (ft): 3.0

DATE STARTED: 5/6/20
DATE FINISHED: 5/6/20
DRILLED BY: ORL - JB/CM/JM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Dark brown fine SAND with silt [SP-SM]						
				▽		-- red brown						
5												
				▼		-- medium dense						
		6-9-8	17									
						Medium dense brown fine SAND [SP]						
		8-9-8	17									
10		4-5-7	12									
15		5-7-9	16									
						BORING TERMINATED AT 15.0 FEET						
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.2

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-02** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 3.5
DATE OF READING: 5/6/2020
EST. SHGWT (ft): 0.5

DATE STARTED: 5/6/20
DATE FINISHED: 5/6/20
DRILLED BY: ORL - JB/CM/JM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0				▽		Mix light grey dark brown fine SAND [SP]						
				▼		-- very light grey						
5												
						-- loose, dark brown						
		3-3-5	8									
						-- medium dense						
		6-7-9	16									
10		6-6-9	15									
						-- loose, brown						
15		7-5-4	9									
						BORING TERMINATED AT 15.0 FEET						
20												

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-03** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 4.0
DATE OF READING: 5/6/2020
EST. SHGWT (ft): 1.0
DATE STARTED: 5/6/20
DATE FINISHED: 5/6/20
DRILLED BY: ORL - JB/CM/JM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Dark brown fine SAND with silt [SP-SM]						
1				▽								
4				▼								
5						-- loose						
		4-3-2	5			-- very loose						
		1-1-1	2			-- loose						
10		3-3-3	6									
						-- medium dense, brown						
15		4-7-6	13			BORING TERMINATED AT 15.0 FEET						
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-04** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 2.5
DATE OF READING: 1/14/2021
EST. SHGWT (ft): S.W.

DATE STARTED: 1/14/21
DATE FINISHED: 1/14/21
DRILLED BY: ORL - DW/DM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	PI	K (FT/DAY)	ORG. CONT. (%)
0						Very dark brown silty fine SAND with trace organics [SM]		22				3
				▼ (2.5)								
4						Mix brown fine SAND with silt [SP-SM]						
5						-- loose, grey						
		2-3-3	6			-- brown grey						
		3-4-4	8									
10		5-3-2	5			Loose brown grey silty fine SAND with trace organics [SM]		37				4
13.5						Loose brown fine SAND with silt [SP-SM]						
15		3-3-4	7									
						-- very dark brown						
20		3-2-3	5			BORING TERMINATED AT 20.0 FEET						

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-05** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 2.9
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 0.5

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0				▽		2" ASPHALT						
						2.5" LIMEROCK BASE						
						Very dense dark grey brown fine SAND with sit [SP-SM]						
	X	16-26-37	63									
	X			▼		-- medium dense, brown						
	X	9-13-12	25									
5	X	7-5-6	11			-- loose						
	X	5-5-4	9									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-06** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): > 7.0
DATE OF READING: 1/18/2021
EST. SHGWT (ft): > 5.0

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW/CM/TA
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2.5" LIMEROCK BASE						
						Dense dark red brown fine SAND [SP]						
	X	22-16-16	32									
						-- medium dense, light brown						
	X	14-14-11	25									
						-- red brown						
5	X	5-6-6	12									
						-- loose						
	X	7-5-4	9									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-07** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 12.0
DATE OF READING: 1/14/2021
EST. SHGWT (ft): > 10.0

DATE STARTED: 1/14/21
DATE FINISHED: 1/14/21
DRILLED BY: ORL - DW/DM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Mix grey fine SAND [SP]						
						-- very light grey						
5						-- medium dense						
		4-6-5	11									
		5-6-5	11			-- grey						
10		6-8-11	19				2	5				
				▼								
						-- dark grey						
15		7-7-9	16									
						-- dark brown						
20		12-13-16	29			BORING TERMINATED AT 20.0 FEET						

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-08**   SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft):	N.S.	DATE STARTED:	1/18/21
WATER TABLE (ft):	> 7.0	DATE FINISHED:	1/18/21
DATE OF READING:	1/18/2021	DRILLED BY:	ORL - DW/CM/TA
EST. SHGWT (ft):	> 5.0	TYPE OF SAMPLING:	ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2" LIMEROCK BASE						
						Very dense light brown fine SAND [SP]						
	X	19-24-32	56									
						-- dense, light grey brown						
	X	18-20-15	35									
						-- medium dense, light brown						
5	X	6-9-8	17									
						-- loose, very light grey						
	X	7-5-5	10									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-09**   SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.   DATE STARTED: 1/18/21
WATER TABLE (ft): > 7.0   DATE FINISHED: 1/18/21
DATE OF READING: 1/18/2021   DRILLED BY: ORL - DW
EST. SHGWT (ft): > 5.0   TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Very dense dark grey brown fine SAND [SP]						
	X	19-24-36	60									
	X	11-14-17	31			-- dense, grey brown						
5	X	11-8-7	15			-- medium dense						
	X	8-7-6	13			-- brown						
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-10**
SHEET: **1 of 1**
SECTION:
TOWNSHIP:
RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 8.0
DATE OF READING: 1/14/2021
EST. SHGWT (ft): 5.5

DATE STARTED: 1/14/21
DATE FINISHED: 1/14/21
DRILLED BY: ORL - DW/DM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Dark grey fine SAND [SP]						
						-- grey						
5				▽		-- loose						
							5	10				
		3-4-3	7			-- grey brown						
		3-4-4	8	▼								
10		4-3-4	7									
						-- medium dense, mix dark brown grey						
15		6-7-6	13									
						Medium dense dark grey fine SAND with silt [SP-SM]						
20		9-11-16	27			BORING TERMINATED AT 20.0 FEET						

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.11

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-11** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 5.0
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 2.5

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	PI	K (FT/DAY)	ORG. CONT. (%)
0						Dense dark grey brown fine SAND [SP]						
	X	10-12-27	39	▽		-- medium dense, red brown						
	X	10-13-10	23			-- light red brown						
5	X	6-7-5	12	▼		-- loose, dark red brown						
	X	4-3-4	7				7	24				
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
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PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-12** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S. DATE STARTED: 1/18/21
WATER TABLE (ft): > 7.0 DATE FINISHED: 1/18/21
DATE OF READING: 1/18/2021 DRILLED BY: ORL - DW/CM/TA
EST. SHGWT (ft): > 5.0 TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2" LIMEROCK BASE						
						Dense grey brown fine SAND with silt [SP-SM]						
	X	16-22-19	41									
						-- medium dense, dark red brown						
	X	7-9-7	16									
5	X	6-8-10	18									
	X	11-9-7	16									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.13

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-13** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 2.5
DATE OF READING: 1/13/2021
EST. SHGWT (ft): S.W.

DATE STARTED: 1/13/21
DATE FINISHED: 1/13/21
DRILLED BY: ORL - DW/DM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						Dark grey fine SAND with silt [SP-SM]						
				▼ (2.5)		-- very dark grey						
						-- mix brown						
5						-- medium dense, dark brown	6	21				
		3-4-7	11									
		6-7-11	18			-- loose						
10		5-6-4	10									
15		4-4-6	10									
						-- dense, brown						
20		12-16-16	32			BORING TERMINATED AT 20.0 FEET						

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.14

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-14** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft):	N.S.	DATE STARTED:	1/18/21
WATER TABLE (ft):	5.0	DATE FINISHED:	1/18/21
DATE OF READING:	1/18/2021	DRILLED BY:	ORL - DW/CM/TA
EST. SHGWT (ft):	2.5	TYPE OF SAMPLING:	ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2" LIMEROCK BASE						
						Very dense dark grey brown fine SAND with silt [SP-SM]						
	X	22-26-34	60	▽								
						-- dense, light brown						
	X	13-17-16	33									
						-- loose, very light brown						
5	X	8-5-3	8	▼								
						-- dense, brown						
	X	8-15-16	31									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.15

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-15** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 5.0
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 2.5
DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						1.5" LIMEROCK BASE						
						Medium dense dark brown fine SAND with silt [SP-SM]						
	X	7-9-11	20	▽		-- light brown						
	X	10-13-10	23			-- brown						
5	X	9-7-9	16	▼		-- dark brown						
	X	7-9-8	17									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.16

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-16** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 5.0
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 2.5

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW/DM
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	PI	K (FT/ DAY)	ORG. CONT. (%)
0						Dark grey fine SAND [SP]						
				▽ (2.5)		-- mix grey						
						Mix grey fine SAND with silt [SP-SM]						
5				▼ (5.0)								
						-- medium dense, brown						
		4-5-6	11									
						-- loose						
							6	20				
		4-3-4	7									
						-- medium dense, dark brown, hard pan						
10		7-8-8	16									
						-- dense, very dark brown						
15		9-16-19	35									
						-- medium dense, brown						
20		10-13-16	29									
						BORING TERMINATED AT 20.0 FEET						

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.17

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-17**
SHEET: **1 of 1**
SECTION:
TOWNSHIP:
RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 6.0
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 3.5

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW/CM/TA
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2.5" ASPHALT						
						2" LIMEROCK BASE						
						Very dense grey brown fine SAND with silt [SP-SM]						
	X	26-29-32	61									
						-- dense, light grey brown						
	X	14-17-14	31	▽								
						-- medium dense, dark red brown						
5	X	6-8-9	17									
				▼		-- loose, grey brown						
	X	6-5-5	10									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.18

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-18**

SHEET: **1 of 1**

SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.

LOCATION: SEE BORING LOCATION PLAN

REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 5.3
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 3.0

DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW/CM/TA
TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2" LIMEROCK BASE						
						Medium dense dark grey brown fine SAND [SP]						
	X	10-13-13	26									
				▽		-- dark red brown						
	X	11-13-16	29									
						Medium dense brown fine SAND with silt [SP-SM]						
5	X	10-9-9	18	▼								
	X	5-8-7	15									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.:	0130.1700290.0013
REPORT NO.:	1765631.V3
PAGE:	B-2.19

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-19** SHEET: **1 of 1**
SECTION: TOWNSHIP: RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S. DATE STARTED: 1/13/21
WATER TABLE (ft): 5.0 DATE FINISHED: 1/13/21
DATE OF READING: 1/13/2021 DRILLED BY: ORL - DW/DM
EST. SHGWT (ft): 2.5 TYPE OF SAMPLING: ASTM D 1586

DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/DAY)	ORG. CONT. (%)
0						Mix grey fine SAND [SP]						
				▽ (2.5)								
4						Brown fine SAND with silt [SP-SM]						
5				▼ (5.0)								
						-- medium dense						
		6-6-7	13									
						-- loose	6	24				
		3-3-4	7									
10		3-4-4	8									
						-- medium dense, dark brown						
15		9-10-17	27									
						-- dense						
20		20-21-20	41			BORING TERMINATED AT 20.0 FEET						

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UNIVERSAL ENGINEERING SCIENCES
BORING LOG

PROJECT NO.: 0130.1700290.0013
REPORT NO.: 1765631.V3
PAGE: B-2.20

PROJECT: LIMITED GEOTECHNICAL EXPLORATION
CYRILS DRIVE ROADWAY WIDENING
OSCEOLA COUNTY, FLORIDA

BORING I.D.: **CD-20**
SHEET: **1 of 1**
SECTION:
TOWNSHIP:
RANGE:

CLIENT: POULOS & BENNETT, INC.
LOCATION: SEE BORING LOCATION PLAN
REMARKS: SHGWT = SEASONAL HIGH GROUNDWATER TABLE, N.S. = NOT SURVEYED, S.W. = STANDING WATER

G.S. ELEVATION (ft): N.S.
WATER TABLE (ft): 4.9
DATE OF READING: 1/18/2021
EST. SHGWT (ft): 2.5
DATE STARTED: 1/18/21
DATE FINISHED: 1/18/21
DRILLED BY: ORL - DW/CM/TA
TYPE OF SAMPLING: ASTM D 1586

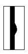
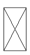
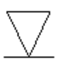
DEPTH (FT.)	SAMPLE	BLOWS PER 6" INCREMENT	N BLOWS / FT	W.T.	SYMBOL	DESCRIPTION	-200 (%)	MC (%)	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	K (FT/ DAY)	ORG. CONT. (%)
0						2" ASPHALT						
						2" LIMEROCK BASE						
						Medium dense dark grey brown fine SAND [SP]						
	X	14-16-11	27	▽								
						-- light grey brown						
	X	10-11-10	21									
5				▼		-- dark grey brown, trace roots						
	X	5-6-6	12									
	X	6-9-10	19									
						BORING TERMINATED AT 7.0 FEET						
10												
15												
20												

W-10998.GPJ

UNIVERSAL ENGINEERING SCIENCES

KEY TO BORING LOGS

SYMBOLS AND ABBREVIATIONS

SYMBOL	DESCRIPTION
N-Value	No. of Blows of a 140-lb. Weight Falling 30 Inches Required to Drive a Standard Spoon 1 Foot
WOR	Weight of Drill Rods
WOH	Weight of Drill Rods and Hammer
	Sample from Auger Cuttings
	Standard Penetration Test Sample
	Thin-wall Shelby Tube Sample (Undisturbed Sampler Used)
RQD	Rock Quality Designation
	Stabilized Groundwater Level
	Seasonal High Groundwater Level (also referred to as the W.S.W.T.)
NE	Not Encountered
GNE	Groundwater Not Encountered
BT	Boring Terminated
-200 (%)	Fines Content or % Passing No. 200 Sieve
MC (%)	Moisture Content
LL	Liquid Limit (Atterberg Limits Test)
PI	Plasticity Index (Atterberg Limits Test)
NP	Non-Plastic (Atterberg Limits Test)
K	Coefficient of Permeability
Org. Cont.	Organic Content
G.S. Elevation	Ground Surface Elevation

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than 50% retained on the No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels and gravel-sand-silt mixtures
			GC	Clayey gravels and gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS 5% or less passing No. 200 sieve	SW**	Well-graded sands and gravelly sands, little or no fines
			SP**	Poorly graded sands and gravelly sands, little or no fines
		SANDS with 12% or more passing No. 200 sieve	SM**	Silty sands, sand-silt mixtures
			SC**	Clayey sands, sand-clay mixtures
FINE-GRAINED SIOLS 50% or more passes the No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diamicaceous fine sands or silts, elastic silts
			CH	Inorganic clays or clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
			PT	Peat, muck and other highly organic soils

*Based on the material passing the 3-inch (75 mm) sieve
** Use dual symbol (such as SP-SM and SP-SC) for soils with more than 5% but less than 12% passing the No. 200 sieve

RELATIVE DENSITY
(Sands and Gravels)
Very loose – Less than 4 Blow/Foot
Loose – 4 to 10 Blows/Foot
Medium Dense – 11 to 30 Blows/Foot
Dense – 31 to 50 Blows/Foot
Very Dense – More than 50 Blows/Foot

CONSISTENCY
(Silts and Clays)
Very Soft – Less than 2 Blows/Foot
Soft – 2 to 4 Blows/Foot
Firm – 5 to 8 Blows/Foot
Stiff – 9 to 15 Blows/Foot
Very Stiff – 16 to 30 Blows/Foot
Hard – More than 30 Blows/Foot

RELATIVE HARDNESS
(Limestone)
Soft – 100 Blows for more than 2 Inches
Hard – 100 Blows for less than 2 Inches

MODIFIERS

These modifiers Provide Our Estimate of the Amount of Minor Constituents (Silt or Clay Size Particles) in the Soil Sample
Trace – 5% or less
With Silt or With Clay – 6% to 11%
Silty or Clayey – 12% to 30%
Very Silty or Very Clayey – 31% to 50%

These Modifiers Provide Our Estimate of the Amount of Organic Components in the Soil Sample
Trace – Less than 3%
Few – 3% to 4%
Some – 5% to 8%
Many – Greater than 8%

These Modifiers Provide Our Estimate of the Amount of Other Components (Shell, Gravel, Etc.) in the Soil Sample
Trace – 5% or less
Few – 6% to 12%
Some – 13% to 30%
Many – 31% to 50%

APPENDIX C

UNIVERSAL
ENGINEERING SCIENCES

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a constructor — a construction contractor — or even another civil engineer. Because each geotechnical- engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. No one except you should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply this report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

Geotechnical Engineers Base Each Report on a Unique Set of Project-Specific Factors

Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical-engineering report that was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical-engineering report is based on conditions that existed at the time the geotechnical engineer performed the study. *Do not rely on a geotechnical-engineering report whose adequacy may have been affected by*: the passage of time; man-made events, such as construction on or adjacent to the site; or natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. *Contact the geotechnical engineer before applying this report to determine if it is still reliable.* A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ — sometimes significantly — from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide geotechnical-construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are Not Final

Do not overrely on the confirmation-dependent recommendations included in your report. *Confirmation-dependent recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations *only* by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's confirmation-dependent recommendations if that engineer does not perform the geotechnical-construction observation required to confirm the recommendations' applicability.*

A Geotechnical-Engineering Report Is Subject to Misinterpretation

Other design-team members' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Constructors can also misinterpret a geotechnical-engineering report. Confront that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing geotechnical construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical-engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make constructors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give constructors the complete geotechnical-engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise constructors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure constructors have sufficient time* to perform additional study. Only then might you be in a position to give constructors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and constructors fail to recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Environmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform an *environmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold- prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical- engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; *none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.*

Rely, on Your GBC-Member Geotechnical Engineer for Additional Assistance

Membership in the Geotechnical Business Council of the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you GBC-Member geotechnical engineer for more information.

GEOTECHNICAL BUSINESS COUNCIL
of the Geoprofessional Business Association

8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 Facsimile: 301/589-2017
e-mail: info@geoprofessional.org www.geoprofessional.org

CONSTRAINTS & RESTRICTIONS

The intent of this document is to bring to your attention the potential concerns and the basic limitations of a typical geotechnical report.

WARRANTY

Universal Engineering Sciences has prepared this report for our client for his exclusive use, in accordance with generally accepted soil and foundation engineering practices, and makes no other warranty either expressed or implied as to the professional advice provided in the report.

UNANTICIPATED SOIL CONDITIONS

The analysis and recommendations submitted in this report are based upon the data obtained from soil borings performed at the locations indicated on the Boring Location Plan. This report does not reflect any variations which may occur between these borings.

The nature and extent of variations between borings may not become known until excavation begins. If variations appear, we may have to re-evaluate our recommendations after performing on-site observations and noting the characteristics of any variations.

CHANGED CONDITIONS

We recommend that the specifications for the project require that the contractor immediately notify Universal Engineering Sciences, as well as the owner, when subsurface conditions are encountered that are different from those present in this report.

No claim by the contractor for any conditions differing from those anticipated in the plans, specifications, and those found in this report, should be allowed unless the contractor notifies the owner and Universal Engineering Sciences of such changed conditions. Further, we recommend that all foundation work and site improvements be observed by a representative of Universal Engineering Sciences to monitor field conditions and changes, to verify design assumptions and to evaluate and recommend any appropriate modifications to this report.

MISINTERPRETATION OF SOIL ENGINEERING REPORT

Universal Engineering Sciences is responsible for the conclusions and opinions contained within this report based upon the data relating only to the specific project and location discussed herein. If the conclusions or recommendations based upon the data presented are made by others, those conclusions or recommendations are not the responsibility of Universal Engineering Sciences.

CHANGED STRUCTURE OR LOCATION

This report was prepared in order to aid in the evaluation of this project and to assist the architect or engineer in the design of this project. If any changes in the design or location of the structure as outlined in this report are planned, or if any structures are included or added that are not discussed in the report, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and the conclusions modified or approved by Universal Engineering Sciences.

USE OF REPORT BY BIDDERS

Bidders who are examining the report prior to submission of a bid are cautioned that this report was prepared as an aid to the designers of the project and it may affect actual construction operations.

Bidders are urged to make their own soil borings, test pits, test caissons or other investigations to determine those conditions that may affect construction operations. Universal Engineering Sciences cannot be responsible for any interpretations made from this report or the attached boring logs with regard to their adequacy in reflecting subsurface conditions which will affect construction operations.

STRATA CHANGES

Strata changes are indicated by a definite line on the boring logs which accompany this report. However, the actual change in the ground may be more gradual. Where changes occur between soil samples, the location of the change must necessarily be estimated using all available information and may not be shown at the exact depth.

OBSERVATIONS DURING DRILLING

Attempts are made to detect and/or identify occurrences during drilling and sampling, such as: water level, boulders, zones of lost circulation, relative ease or resistance to drilling progress, unusual sample recovery, variation of driving resistance, obstructions, etc.; however, lack of mention does not preclude their presence.

WATER LEVELS

Water level readings have been made in the drill holes during drilling and they indicate normally occurring conditions. Water levels may not have been stabilized at the last reading. This data has been reviewed and interpretations made in this report. However, it must be noted that fluctuations in the level of the groundwater may occur due to variations in rainfall, temperature, tides, and other factors not evident at the time measurements were made and reported. Since the probability of such variations is anticipated, design drawings and specifications should accommodate such possibilities and construction planning should be based upon such assumptions of variations.

LOCATION OF BURIED OBJECTS

All users of this report are cautioned that there was no requirement for Universal Engineering Sciences to attempt to locate any man-made buried objects during the course of this exploration and that no attempt was made by Universal Engineering Sciences to locate any such buried objects. Universal Engineering Sciences cannot be responsible for any buried man-made objects which are subsequently encountered during construction that are not discussed within the text of this report.

TIME

This report reflects the soil conditions at the time of exploration. If the report is not used in a reasonable amount of time, significant changes to the site may occur and additional reviews may be required.

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APPENDIX D

Advanced Continuous Surface Wave
Ground Stiffness Profiling

Mast Arms: N. Narcoossee Road & Cyrils Drive 4-6-2020
Advanced Continuous Surface Wave Testing Report

Report ref.:	GSS328	Date of issue:	4/13/2020
Professional	David Wilshaw, MS, PG	Prepared	Checked
Status	FINAL	4/9/2020	4/10/2020

DAVID WILSHAW LICENSE No. 2413 STATE OF FLORIDA PROFESSIONAL GEOLOGIST

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www.groundstiffnesssurveys.com

A bright new wave in geotechnics

Contents

Abbreviations

C-DAS	GSS ACSW data acquisition & analysis software
ACSW	GSS Advanced Continuous Surface Wave testing system
E	Young's Modulus
$E_{X\%}$	Young's Modulus softened to X% strain
GSS	Ground Stiffness Surveys LLC
f	Frequency
G	Shear Modulus
G_0	Small-strain Shear Modulus
V_r	Rayleigh Wave velocity
V_s	Shear Wave velocity
λ	Wavelength
ν	Poisson's Ratio
ρ	Soil density
S/N	Signal to noise (ratio)

1 Project details

Project title	Mast Arms: N Narcoossee Road & Cyrils Drive, St. Cloud, FL
Client	UES
Site location	St. Cloud, FL
Scope of report	Ground Stiffness Surveys LLC (GSS) has been commissioned to undertake Advanced Continuous Surface Wave (ACSW) testing to provide ground stiffness profiles in accordance with the details listed below. This report provides ACSW testing data generated using GSS's C-DAS data acquisition & analysis software. Assumptions and testing standards are listed in Section 4. Average shear wave velocity (V_s) *simple inversion* profiles are provided in Appendix A. Where appropriate *advanced inversion* of the data to generate a layered shear wave velocity (V_s) profile has been undertaken, with data presented as equivalent small-strain Shear Modulus (G_0) in Appendix B. Illustrative strain-softened values of E are provided in Appendix C and separately in an MS Excel spreadsheet with the facility for client adjustment of strain level and other default values. ***A commentary on results for design review purposes is provided as Section 5.***
Report conditions	Numbers and locations of ACSW testing have been determined by the client. The standards under which testing was completed are listed in Section 4. *This report is produced solely for the benefit of the client identified in this report and in accordance with the project description and associated conditions identified below.* No liability is accepted for any reliance placed on this report by any other party. The report is intended for use solely by a suitably qualified and experienced geotechnical engineer in conjunction with other appropriate information on ground conditions. *No design or consultancy advice is offered as part of this report.* Where provided, strain-softened stiffness values are for illustration and information only. Appropriate skill and care by a suitably qualified geotechnical engineer are required in the assessment of ground stiffness or shear wave velocity profile data for design use, including the selection of appropriate strain levels for strain-softening and the applicability of strain-softening functions. Design of ACSW testing, including the suitability of ACSW data for the design, numbers and locations of tests should be determined by a suitably qualified geotechnical engineer. A general description of the terminology, test methodology and analysis techniques used to provide stiffness and shear wave velocity profiles from ACSW test data, including references, is provided as Appendix D. Further information and guidance are available via the GSS website: www.groundstiffnesssurveys.com .
Commercial	Testing was undertaken in accordance with GSS Standard Terms & Conditions. Reference should be made to the relevant ACSW testing proposal. *The report has been produced for and on behalf of Ground Stiffness Surveys LLC and no responsibility for information or opinions included is attached to any individual or implied.*

2 Testing details

<table>
<tr><td>Attendances</td><td colspan="2">Gautham Pillappa</td></tr>
<tr><td>Setting out</td><td colspan="2">GSS</td></tr>
<tr><td>GSS seismic sources</td><td colspan="2">Standard Shaker – GSS Standard 80kg Shaker - 8 to 91Hz
EM Shaker – GSS EM high frequency shaker - 50 to 400Hz
Heavy Shaker – GSS high energy 80kg 'Heavy' Shaker – 4 to 50Hz
Unless otherwise noted below, the GSS Standard Shaker source has been used with a 10-foot long standard test array.</td></tr>
<tr><td rowspan="2">ACSW test equipment</td><td>Shaker Serial No.</td><td>Data Acquisition Unit Serial No.</td></tr>
<tr><td>SS03</td><td>D148</td></tr>
<tr><td rowspan="2">C-DAS software versions</td><td>Data capture</td><td>Reporting</td></tr>
<tr><td>2.9.1.0 'Cashew'</td><td>2.9.3.1 'Cashew'</td></tr>
<tr><td>Project notes</td><td colspan="2">ACSW testing carried out for four new mast arm structures proposed as part of intersection improvements at N. Narcoossee Road and Cyrils Drive, St. Cloud, Osceola County, FL. Overhead power, underground gas, water, fiber optic; conventional SPT borings cannot be used.</td></tr>
</table>

3 Project testing summary

Test	Date	Notes
COMBINED01 SW	Monday, April 6, 2020	Combined CSW01 and CSW02 at SW corner of intersection.
COMBINED02 SE	Monday, April 6, 2020	Combined tests CSW04 and CSW05 at SE corner of intersection. CSW06 excluded due to poor model fit.
COMBINED03	Monday, April 6, 2020	Design curve using combined data from tests CSW01, CSW02, CSW04, CSW05 and CSW07.
CSW01	Monday, April 6, 2020	CSW01 at edge of sidewalk, SW corner of proposed intersection.
CSW02	Monday, April 6, 2020	CSW02 at same location as CSW01 but shaker & geophones flipped to allow data stacking. SW corner of proposed intersection, edge of sidewalk.
CSW03	Monday, April 6, 2020	NW Corner of intersection. Shaker at N end of north to south array, edge of sidewalk. Steep slope to west of array.
CSW04	Monday, April 6, 2020	CSW04 was located on the SE corner of the intersection alongside the overhead power tower, close to tower foundation (assumed drilled shaft). Also, underground gas, water (8-inch), cable and signalization utilities marked
CSW05	Monday, April 6, 2020	CSW05 at SE corner of intersection - moved away from power pole foundation. Shaker at south end of south to north array. Underground gas, water (8-inch), cable & signalization.
CSW06	Monday, April 6, 2020	CSW06 at SE corner, shaker at east end of east to west array. Shaker adjacent to power pole foundation. Underground gas, water (8-inch), cable & signalization.
CSW07	Monday, April 6, 2020	CSW07 at NE mast arm location at bottom of 2-foot bank, adjacent to fence line on right-of-way. Shaker at north end of N-S array.
CSW08	Monday, April 6, 2020	CSW08 also at NE of intersection mast arm but at edge of sidewalk. Shaker at north end of north to south array.

Plate 1 – CSW01

Plate 2 – CSW02

Plate 3 – CSW03

Plate 4 – CSW04

Plate 5 – CSW05

Plate 6 – CSW06

Plate 7 – CSW07

Plate 8 – CSW08

4 ACSW data

4.1 Data acquisition

Data acquisition was undertaken using GSS's C-DAS data acquisition & analysis software which automatically controls testing, assesses data quality and provides field outputs.

C-DAS automatically identifies frequencies where there is inconsistency in velocities and frequencies measured between geophones. Outlying data or very scattered data which may not be reliable has also been excluded from the analyses undertaken but is still presented for transparency using a different symbol.

4.2 Data plots

Data plots generated using GSS's C-DAS data acquisition and analysis software are presented in Appendices A & B. For each test, the following plots, including an appropriate smoothed best fit curve, are provided:

- The *field dispersion curve* – measured Rayleigh Wave velocity (V_r) against measured frequency (Appendix A)
- The *simple inversion* – average V_s against approximate depth based on the dispersion curve data (Appendix A)
- The *synthetic dispersion curve* (where appropriate) - generated by the advanced inversion process (Appendix B)
- The *advanced inversion* results (where appropriate) – layered V_s profile with depth (Appendices A & B)

Deleted invalid, scattered or outlying data not used in the analyses is shown on the field dispersion plots only. Commentary on data quality is given in Section 3 (individual test notes) and in Section 5 (commentary on all results), including any tests where advanced inversion was not deemed appropriate.

Advanced inversion results are converted to G_0 and E_0 stiffness profiles in Appendix C using the relationships and soil density and Poisson's ratio values shown. Softened Young's Modulus (E) values are also provided using a published strain softening model and default strain level. This data is provided separately in MS Excel format to allow any of the default parameters to be adjusted to reflect site specific conditions for design purposes. Note that the strain softened stiffness values provided may not be appropriate for some ground conditions (e.g. in rock) or design applications. Further guidance on use of ACSW data is available at www.groundstiffnesssurveys.com.

A key to data plots presented is given in Appendix D. *All data should be assessed in conjunction with the notes on use of ACSW data provided in Appendix D.*

4.3 Data inversion

Simple (average with depth) and advanced (layered) inversion shear wave velocity (V_s) profiles have been generated by C-DAS in accordance with the procedures and references set out in Appendix D and the default model constraints below. Unless otherwise stated, an effective dispersion curve modelling approach using the WAVe model (Leung & Aung, 2013) is used. Model defaults are reviewed as part of initial inversion and considering available site information; ***any modifications from the default analysis settings below are set out in Section 5.***

C-DAS model constraint	Value	Basis
Poisson's ratio	0.5	Conservative for natural range (has very small impact on derivation of V_s from V_r)
Soil density	1.8 Mg/m^3	Conservative for natural range (has only limited impact on inversion)
Simple inversion depth	wavelength/ 2.5	Foti *et al* 2017
Minimum V_s	50m/s	Minimum natural value for soils; Foti et al 2017
Maximum V_s	1500m/s	Maximum value for non-crystalline rock; Foti *et al* 2017
Minimum layer thickness	1m (Standard & Heavy Shaker sources) 0.5m (EM Shaker source)	Practical minimum layer resolution. May be adjusted to the *minimum* value which meets stiff-soft-stiff layer and layer thickness resolution checks or in line with available site information.
Maximum layer thickness	1m to 10m	Adjusted to the *minimum* value which meets stiff-soft-stiff layer and layer thickness resolution checks or in line with available site information.
Minimum number of model layers	10	Adjusted to ensure approximately 1 layer per 1m of profile (Foti *et al* 2017).
Maximum model depth validity	Simple inversion maximum depth for site	Foti *et al* 2017
Top layer thicknesses	No shallower than depth of first simple inversion point	Foti *et al* 2017
Simple inversion weighting	0.05 (Normally Dispersive profiles) 0.1 (Inversely Dispersive profiles)	Standard calibrated value providing an appropriate degree of constraint to the simple inversion as prescribed by Foti *et al* 2017. Adjusted if required based on available site information.
Numbers of stiff-soft-stiff layers check	1 or 2	Foti *et al* 2017; where greater numbers generated by the inversion the number of layers and layer thicknesses are adjusted.
Layer thickness resolution check	Max 0.5m at shallow depth (typical minimum resolution); min 1m to 2m at base of profile (minimum practical resolution at 10 Hz).	Foti *et al* 2017; where thinner layers generated by the inversion the number of layers and layer thicknesses are adjusted.

Guidance and relevant standards on data inversion are listed in Section 4.5. Notes on the inversions undertaken for each test are given in Section 3. A commentary on the inversions completed is provide in Section 5.

4.4 Conversion of shear wave velocity to stiffness

Advanced inversion layered shear wave velocity profile results are presented in Appendix C as equivalent values of G & E using the parameters and relationships set out.

Default parameters can be changed by the user based on other site data or design requirements in the MS Excel version of the Appendix C data issued with this report - *see GSS website for guidance.*

4.5 Testing standards

ACSW testing has been undertaken in accordance with the following GSS standard guidance documents;

- GSSGN010 Description & limitations of ACSW technique
- GSSSPEC01 ACSW Standard Specification
- GSSMS01 Method Statement: ACSW Stiffness Profiling
- GSSDWG001 ACSW Test Layout

The documents above and further guidance on ACSW testing practice and application are available at www.groundstiffnesssurveys.com.

Key references are listed in Appendix D.

5 Commentary on results

5.1 Notes on results commentary

The qualitative assessment and observations below are based on available ACSW test data only and should be read in conjunction with the limitations set out in Appendix D.

For simplicity, higher shear wave velocity values are described qualitatively as 'stiff' or 'stiffer' and lower shear wave velocity values 'soft' or 'softer'. Guidance for preliminary interpretation of shear wave velocity data in conjunction with available information on ground conditions is provided in Appendix C.

Where appropriate the total range of data quality is indicated as well as the typical range within this through the use of light (total range) and dark blue (typical range) shading (*see example below*).

Example key for qualitative assessment of results

Very poor		
Poor	Total range of data quality observed in results	
Fair		Typical range
Good		
Excellent		

Appropriate interpretation of data presented, based on available geologic and geotechnical information and project design criteria, should be undertaken by a suitably qualified and experienced geotechnical engineer when assessing and utilizing this data. Notes on individual tests are provided in Section 3.

In reviewing the results, reference should be made as necessary to the testing standards listed in Section 4.5, the references listed in Appendix D and guidance available via the GSS website.

5.2 Data & results assessment

Review element	Class	Description	Typical impact
Available ground investigation information *Qualitative assessment of extent of site ground investigation information available to constrain modelling.* *See project notes in Section 2 and Observations section*	None	No reliable site-specific ground investigation data available	No reliable check on modelled results against ground investigation data possible; further review/remodelling may be required once ground investigation data available.
	Poor	Some site-specific ground investigation data available but soil types and/or variation in layer boundaries could vary significantly across site.	Limited assessment of results of modelling possible against ground investigation data.
	Fair	Soil types and/or range of variation in layer boundaries across site well defined.	Accuracy of V_s modelling enhanced by constraints on layer boundaries, allowing reliable assessment of model results against ground investigation data.
	Good	Soil types well-understood and layer boundaries known or very well defined at each test location.	Highest degree of accuracy of V_s modelling possible where layer boundaries well defined.

Review element	Class	Description	Typical impact
Data quality *Qualitative assessment within normal valid data frequency range for source or sources used.*	**Very poor**	Most of the data do not meet data quality requirements and/or are multi-modal.	Data unlikely to be reliably analysable but may provide qualitative evidence of variable ground conditions.
	Poor	Many data points not meeting data quality requirements and/or significant multi-modal data.	Data may not be reliably analysable, unless supported by the results of other nearby tests but may provide qualitative evidence of variable ground conditions.
	Fair	Some data points not meeting data quality requirements and/or some multi-modal data.	Normal minimum standard for data analysis.
	Good	Few data points not meeting data quality requirements and little multi-modal data.	Data likely to support reliable analysis.
	Excellent	Very few data points not meeting data quality requirements and very little to no multi-modal data.	Data highly likely to support reliable analysis.

Review element	Class	Description	Typical impact
Advanced inversion model fit *Confidence level subject to comparison with other adjacent tests and available geotechnical data prior to use.* *Notes on individual tests are provided in Section 3.*	**Very poor**	Average fit of synthetic dispersion curve to field dispersion curve data >30m/s.	Indicates very low level of model confidence, well below normally acceptable levels; *if reported, results should only be used with caution.*
	Poor	Average fit of synthetic dispersion curve to field dispersion curve data >20m/s and <30m/s.	Indicates low level of model confidence, results may be acceptable if comparable with other similar tests; *caution in use of results required.*
	Fair	Average fit of synthetic dispersion curve to field dispersion curve data >10m/s and <20m/s.	Indicates acceptable level of model confidence
	Good	Average fit of synthetic dispersion curve to field dispersion curve data >5m/s and <10m/s.	Indicates high level of model confidence
	Excellent	Average fit of synthetic dispersion curve to field dispersion curve data <5m/s.	Indicates very high level of model confidence

Review element	Class	Description	Typical impact
Strain value used for adjustment of small strain stiffness (G_0, E_0) *Reporting uses a well-established soil softening model applicable to a wide range of soil types. However, this model may not be applicable to rock and problematic soils such as collapsible ground or peat, which may exhibit strain hardening behaviour – see Appendix D.* *Applicability to be reviewed by Designer against project design criteria and available geotechnical information.*	**0%**	Unadjusted very small strain value.	Seismic strain level value. Upper bound value for most soils which typically strain soften. Provides a lower bound estimate of stiffness for geomaterials which strain harden.
	0.01%	Small strain value	Typical upper bound value of strain around propped excavations, anchored walls and machine base foundations.
	0.1%	Moderate strain value	Typical upper bound value of strain associated with typical geotechnical projects. Provided as the default value in the MS Excel output spreadsheet.
	1%	Large strain value	Typical upper bound value associated with standard field (e.g. Plate Load Test) and laboratory (e.g. oedometer consolidation) testing.

Review element	Class	Description	Typical impact
Overall assessment of results – *see Observations section for more detail.* *Qualitative assessment, to be reviewed by Designer based on project geotechnical categorization, against available site information and in relation to design objectives as part of assessment of suitability for use.*	**Poor**	Data quality and analysis results variable and not consistent with available information.	Data not normally issued and, if reported, may be indicative or qualitative only. *To be used with caution only.*
	Fair	Data quality and analysis results generally consistent with each other and/or available information, though some variation in individual test results may be present.	Additional design review required for some or all data prior to use; as appropriate, conservatism to be applied on outliers or for selection of design values. *Some results to be used with caution or qualitatively only.*
	Good	Data quality and analysis results consistent with each other and/or available information.	Standard level of design review appropriate for project required before use.

5.3 Observations

Simple inversion profiles generated extend to between 6m and 11m depth (~20 to 36-feet depth).

Advanced inversion was undertaken using an effective dispersion curve (WAVe) model with 10 layers and a minimum 1m and maximum 2m layer thickness. Advanced inversion profiles generated reflect the simple inversion profiles and have been reported to simple inversion profile depths.

Individual tests were carried out at all four corners of the intersection. Combined test data was used at the south west and south east corners. CSW03 should be used in the design of the mast arm foundation at the northwest corner and CSW07 used for the northeast corner. A single combined "design line" test for the whole project including tests CSW01, CSW02, CSW04, CSW05 and CSW07 was also analysed.

For the purposes of mast arm foundation design, the shear wave velocity, V_s can be correlated with the SPT N_{60} value using the published relationships presented in Appendix C. For ease of use, the relationships are presented below using V_s values in both m/s and ft/s:

SPT N_{60}	2	4	10	30	50	60
V_s m/sec	151	174	210	263	292	303
V_s ft/sec	495	571	689	863	958	994

Using the combined "design line" data, the soil profile comprises loose soil to around 7-feet below grade, medium dense soil from 7 to 11-feet, dense soil from 11 to about 18-feet, then medium dense from 18 to at least 38-feet below grade.

The weakest soil profile was CSW06, where the soil was very loose to 6-feet, medium dense to 13-feet then loose again up to the maximum imaged depth of 26-feet. This may represent disturbance due to utility / power pole foundation construction, however, since this weaker profile was not replicated in adjacent tests CSW04 and CSW05.

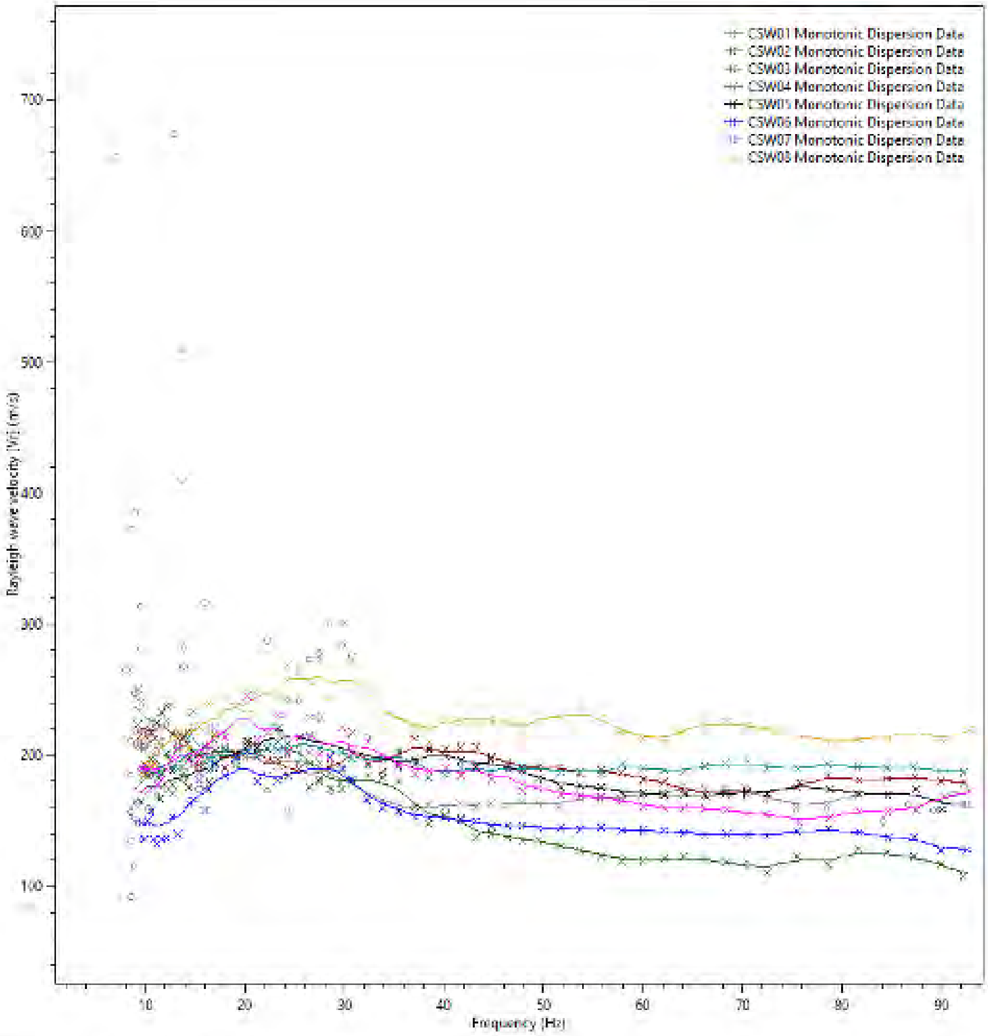


Figure 5.3.1: C-DAS dispersion curve outputs

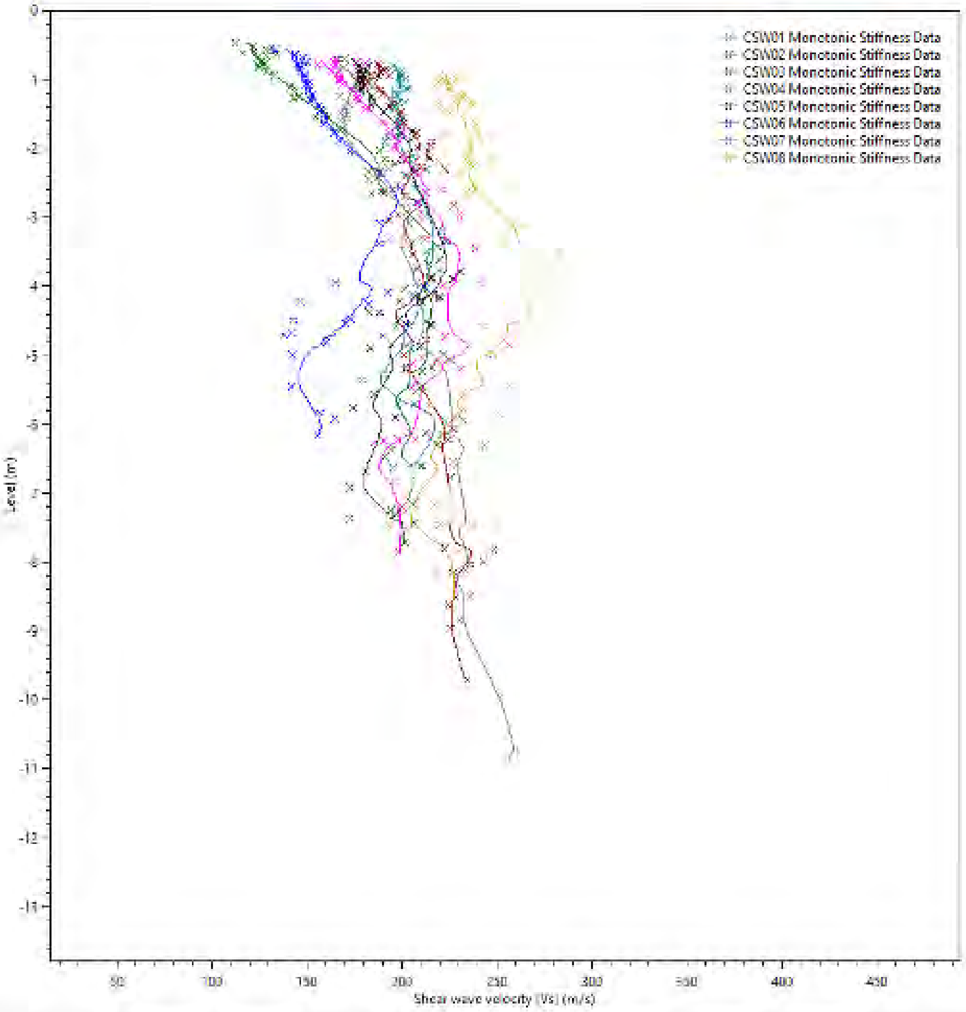


Figure 5.3.2: C-DAS simple inversion outputs

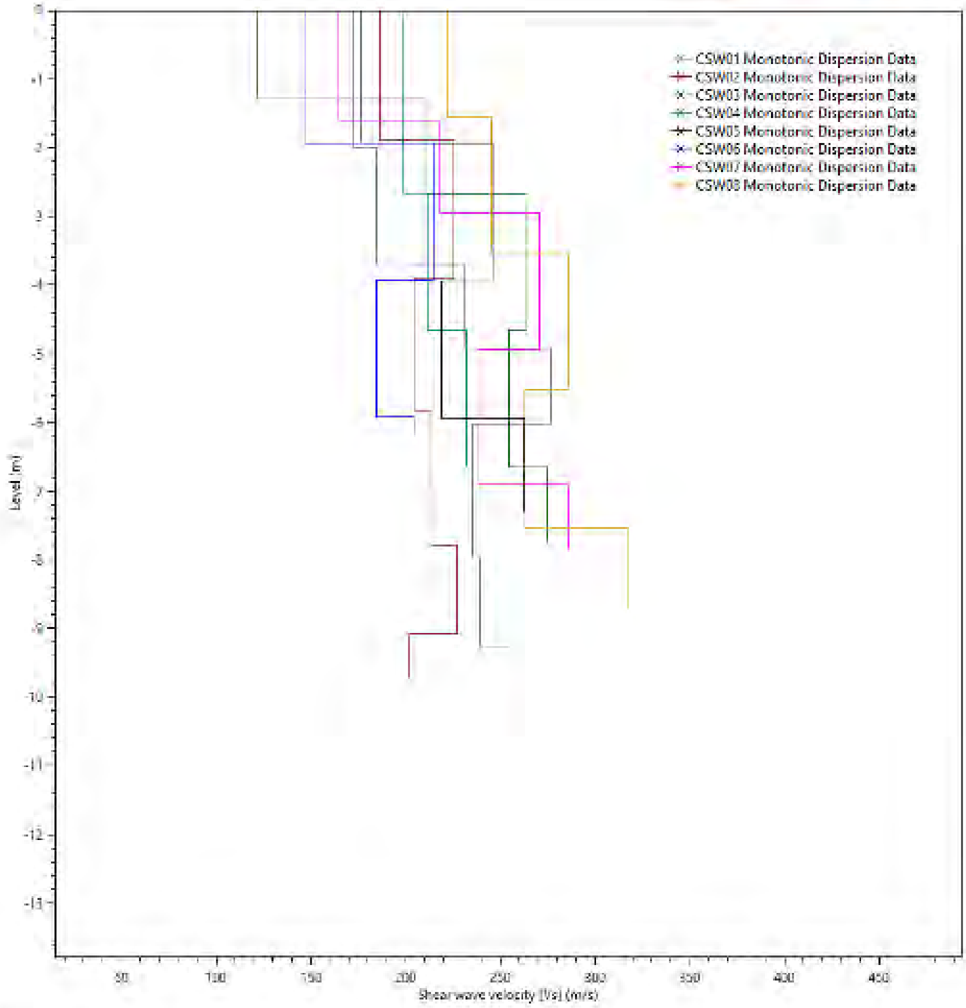


Figure 5.3.3: C-DAS advanced inversion outputs

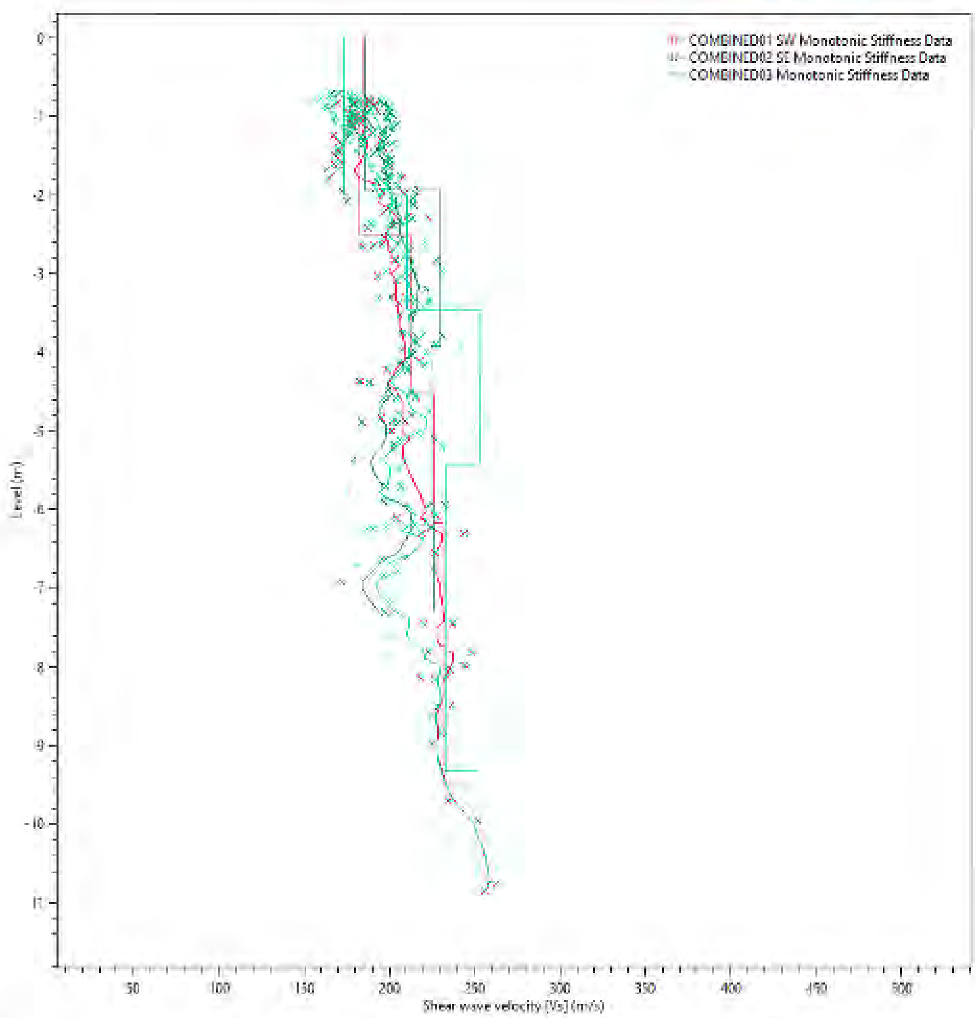
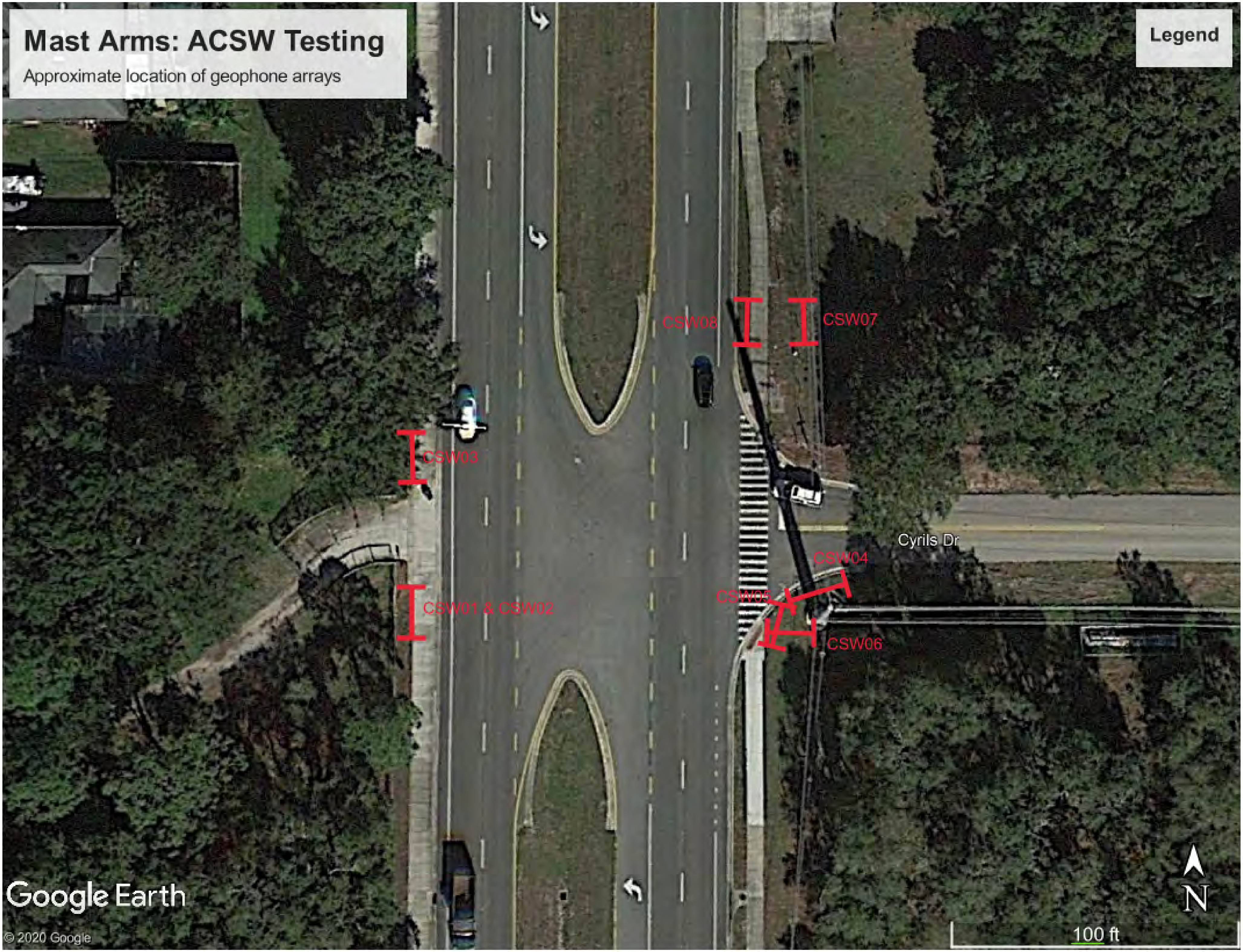


Figure 5.3.4: C-DAS advanced inversion outputs for combined tests

ACSW test location plan

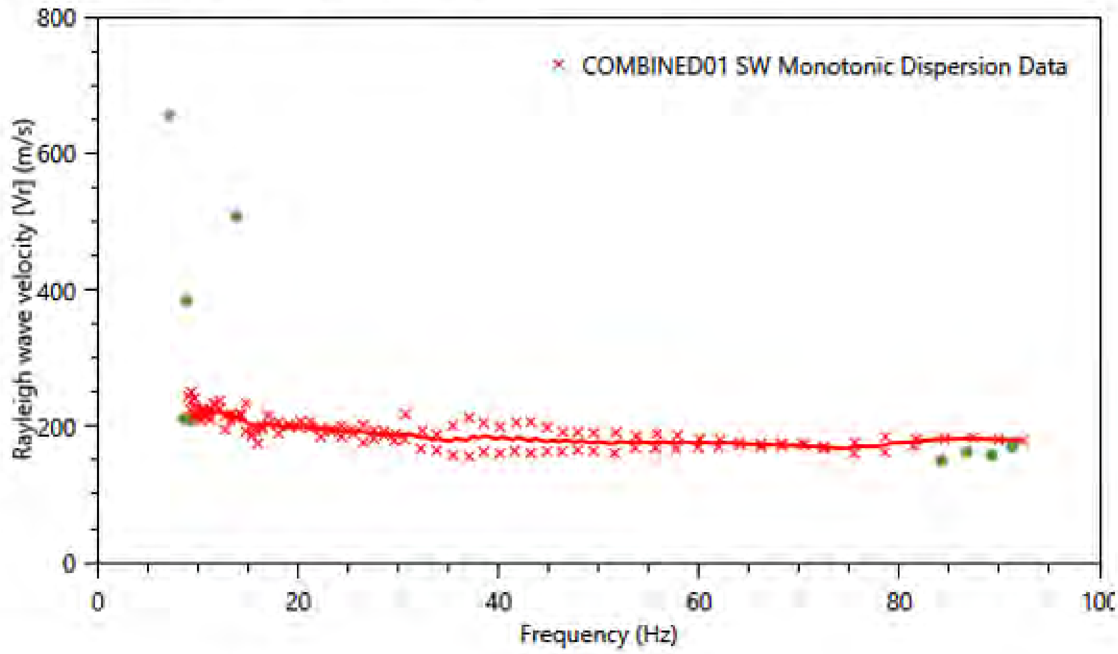


Mast Arms: ACSW Testing
Approximate location of geophone arrays
Legend
CSW08
CSW07
CSW03
Cyrils Dr
CSW04
CSW05
CSW01 & CSW02
CSW06
Google Earth
© 2020 Google
100 ft
N

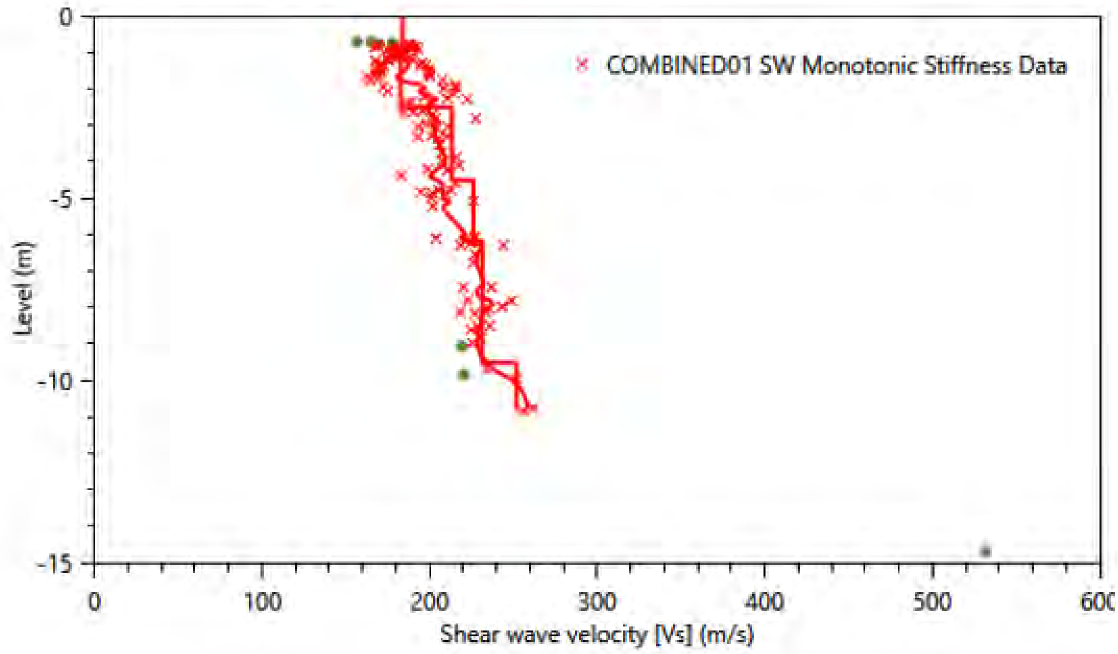
Appendix A: Field dispersion curves & combined simple and advanced inversion plots

See Appendix D for key

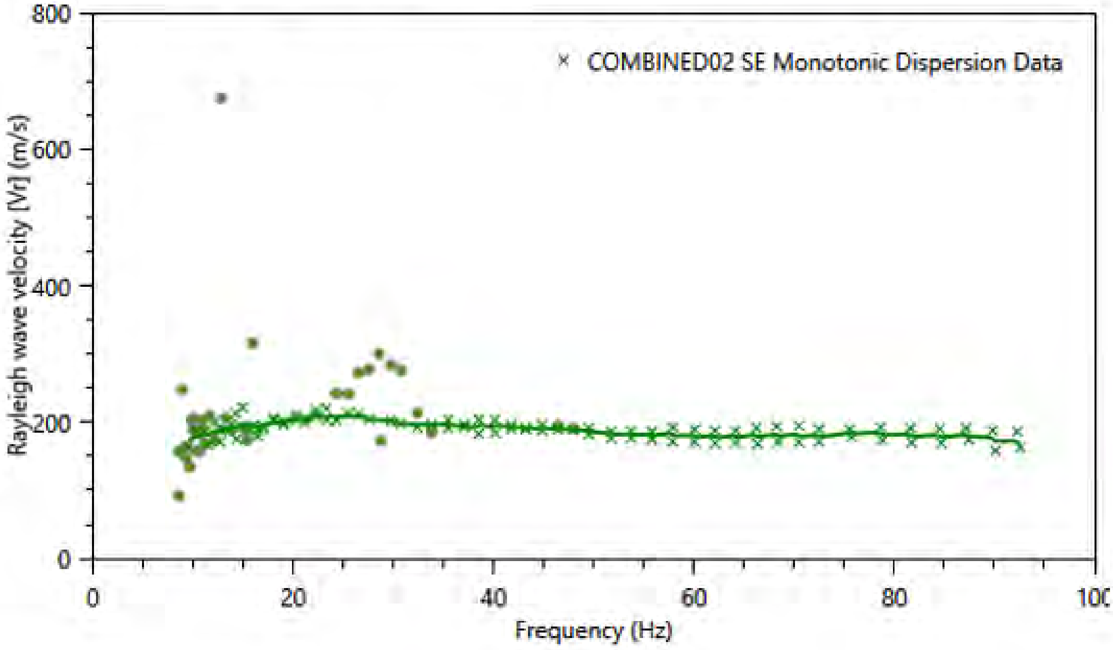
COMBINED01 SW Field dispersion curve



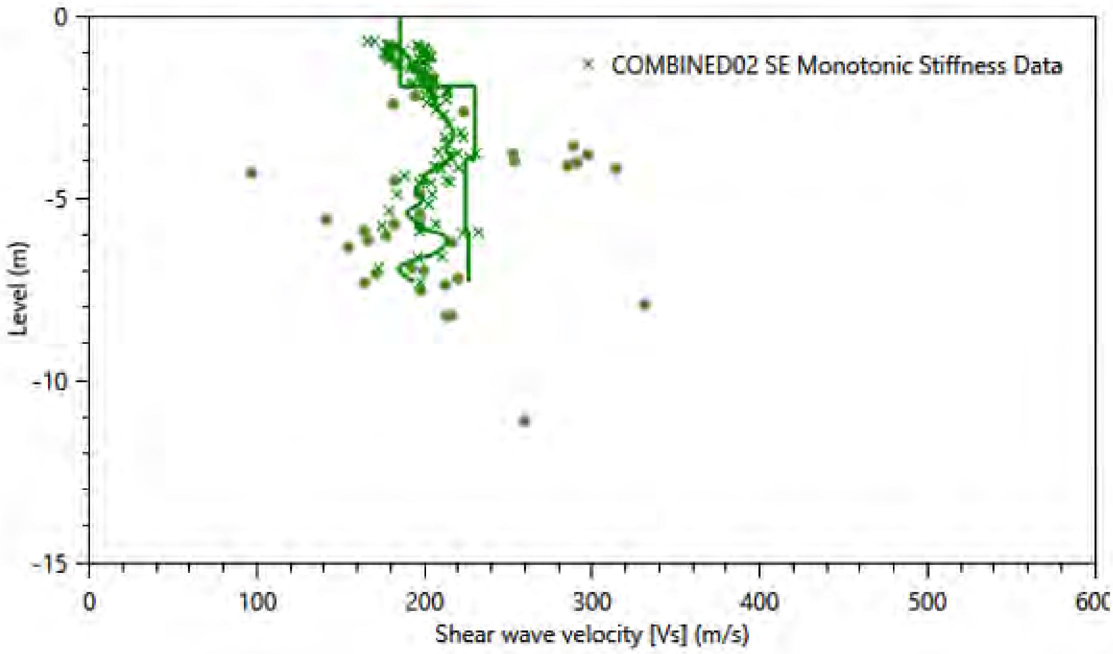
COMBINED01 SW Simple & advanced inversion



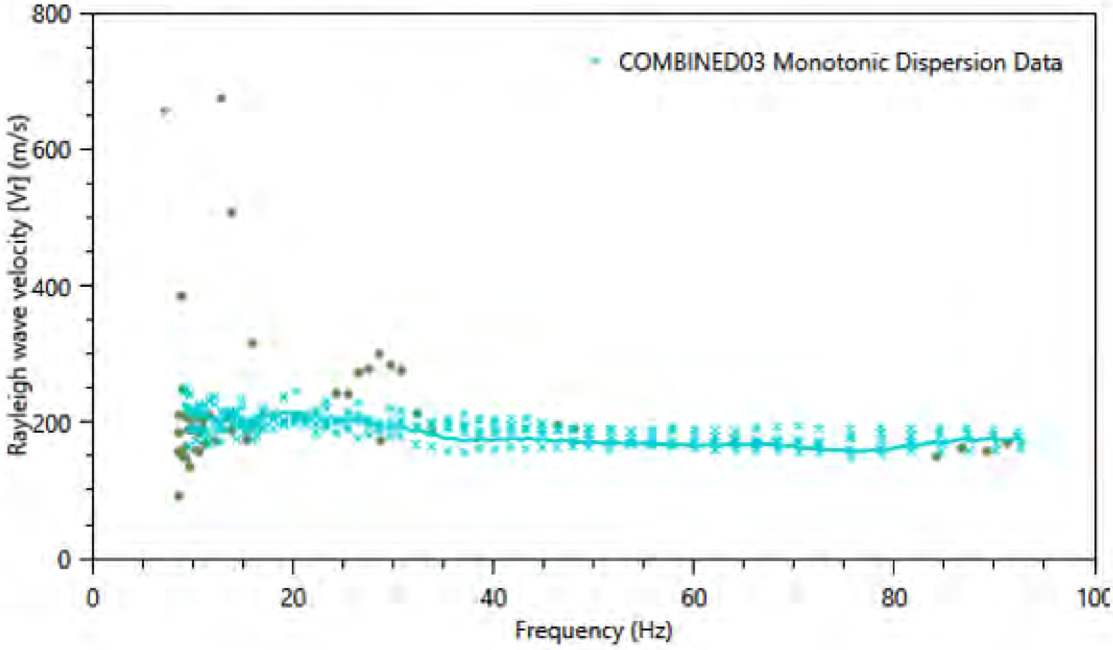
COMBINED02 SE Field dispersion curve



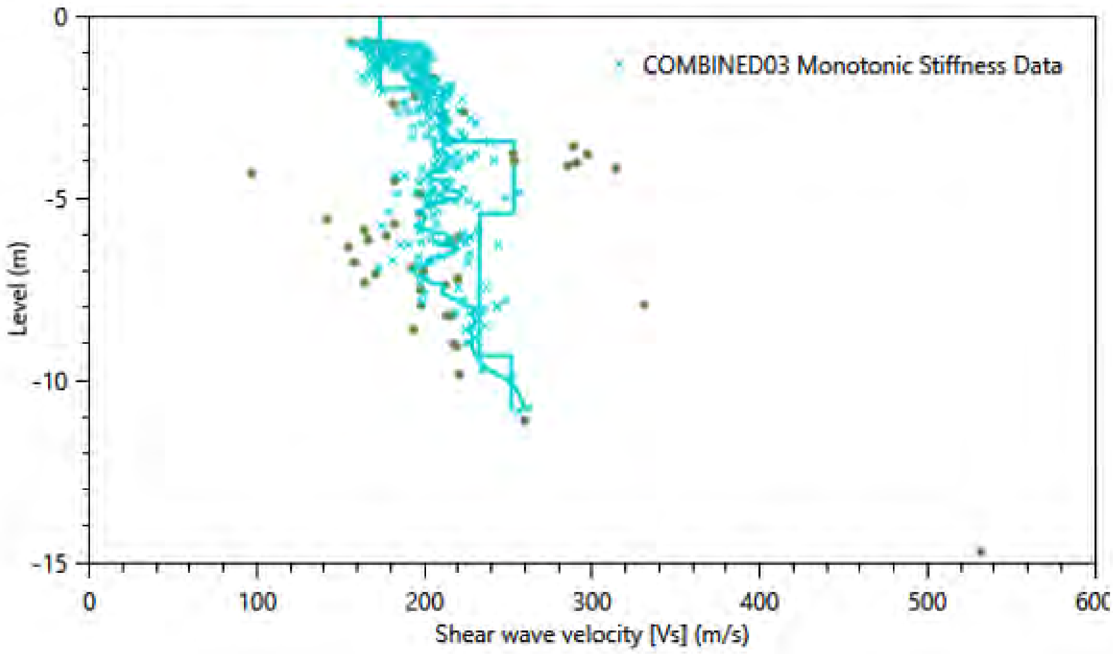
COMBINED02 SE Simple & advanced inversion



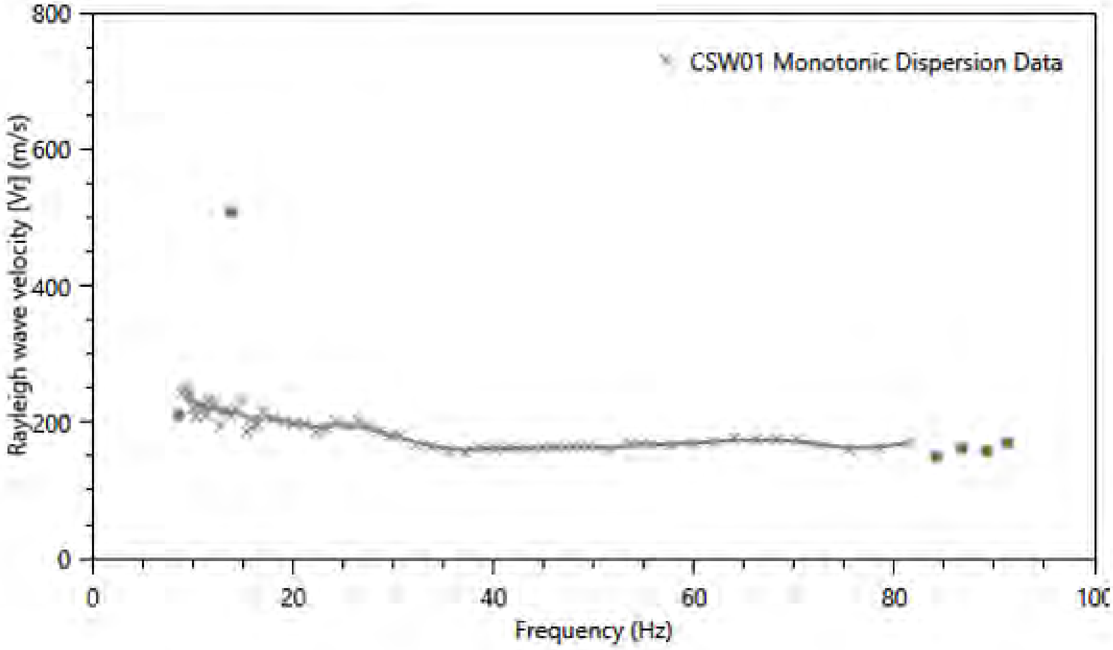
COMBINED03 Field dispersion curve



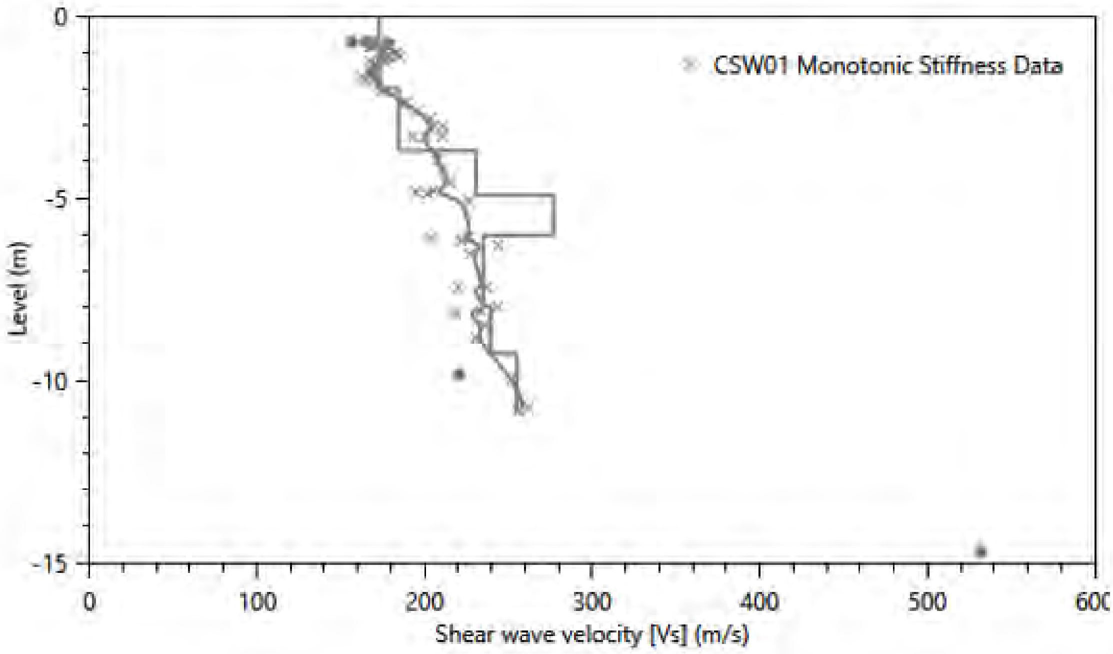
COMBINED03 Simple & advanced inversion



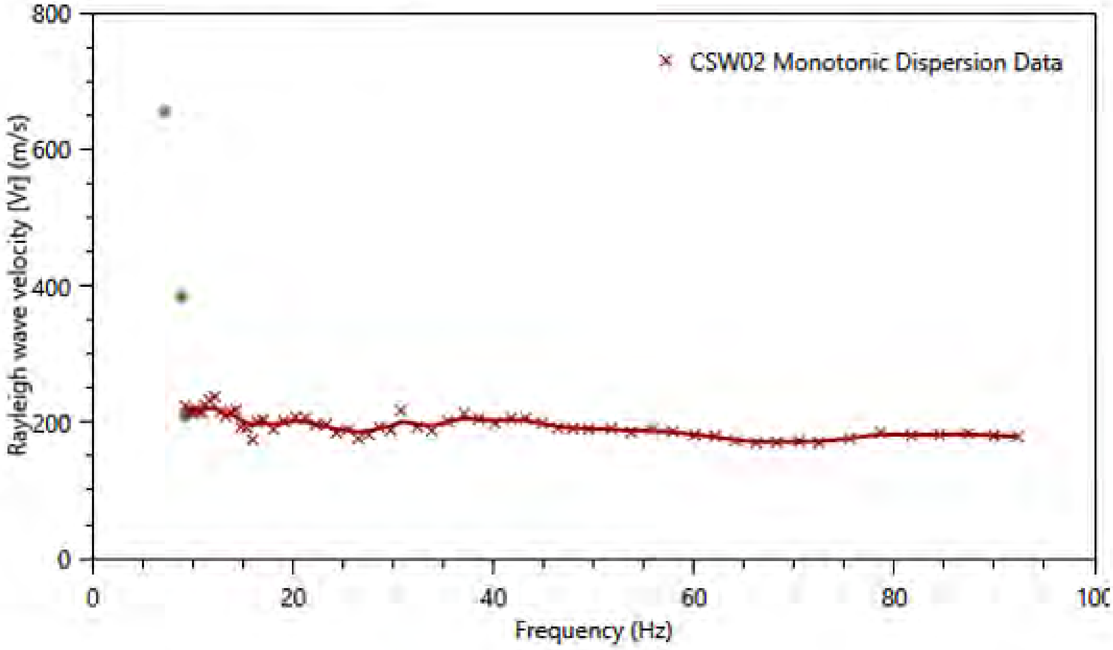
CSW01 Field dispersion curve



CSW01 Simple & advanced inversion



CSW02 Field dispersion curve



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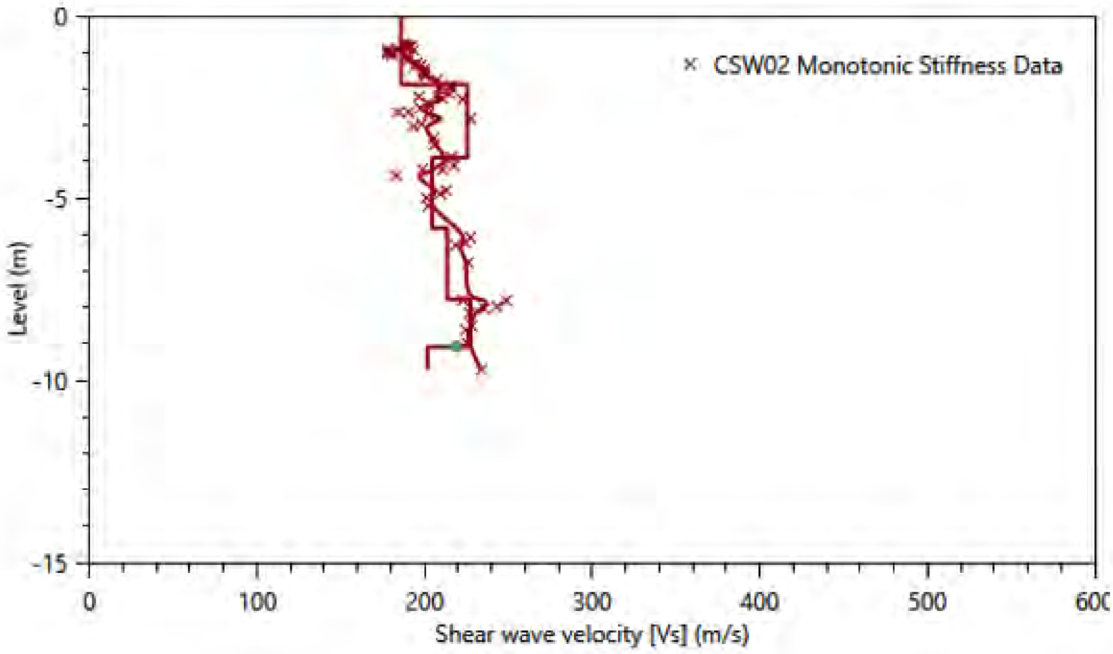
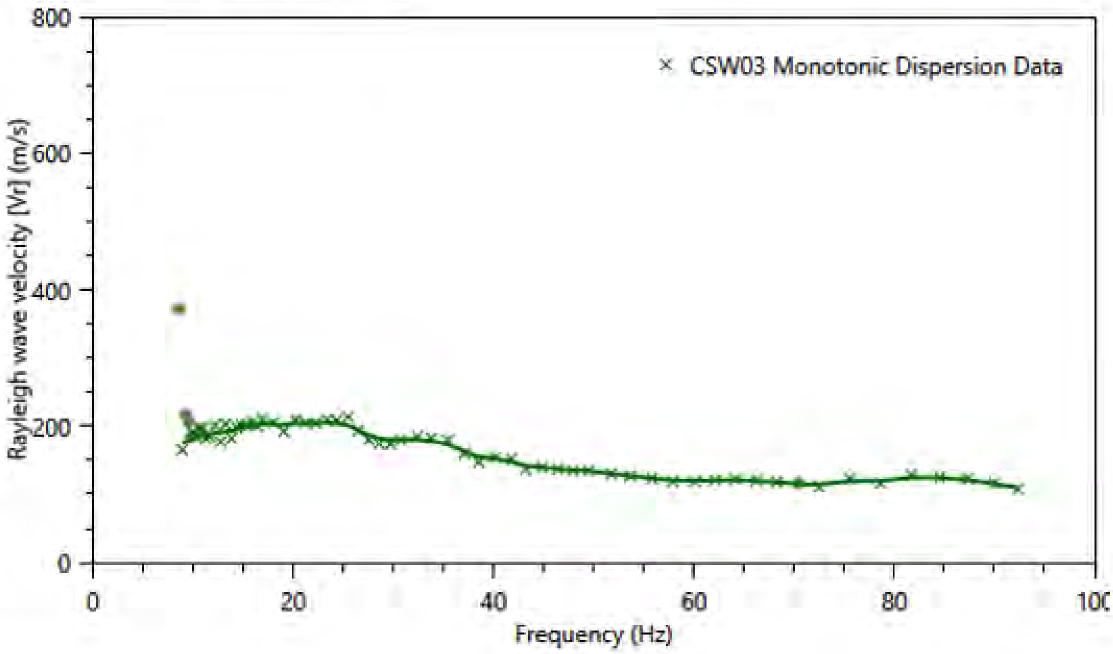
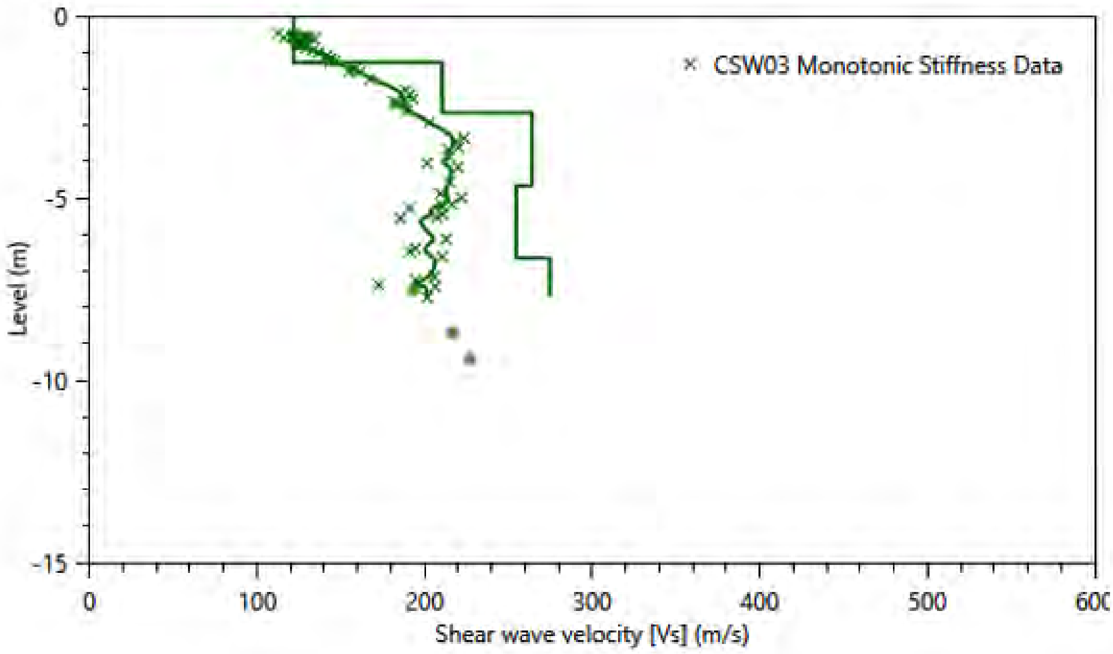


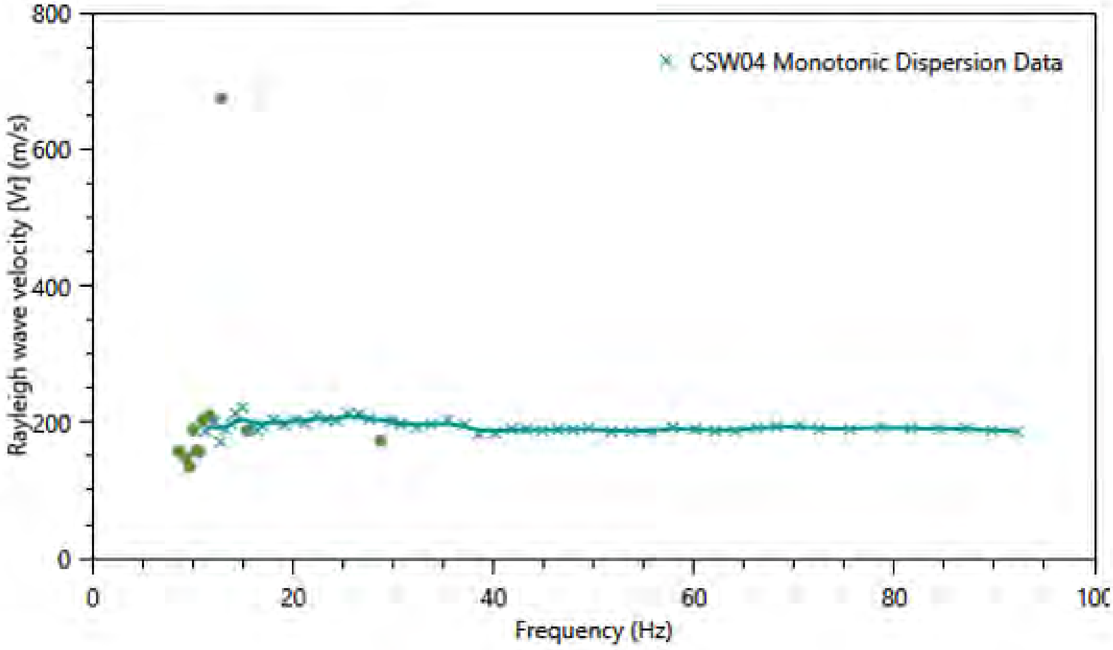
CSW03 Field dispersion curve



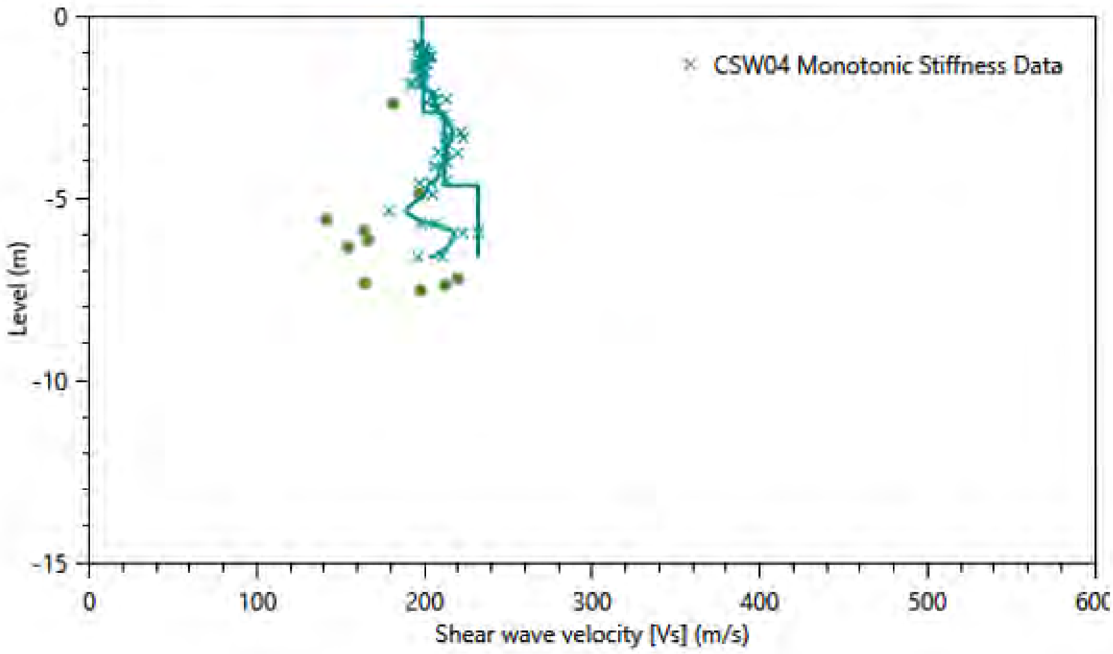
CSW03 Simple & advanced inversion



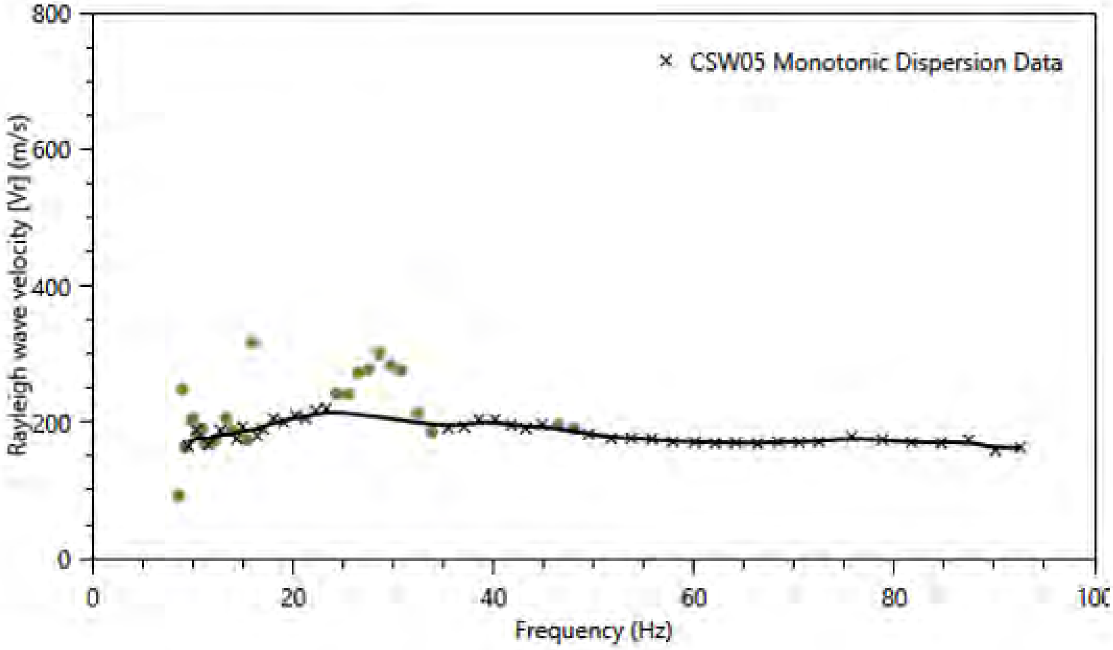
CSW04 Field dispersion curve



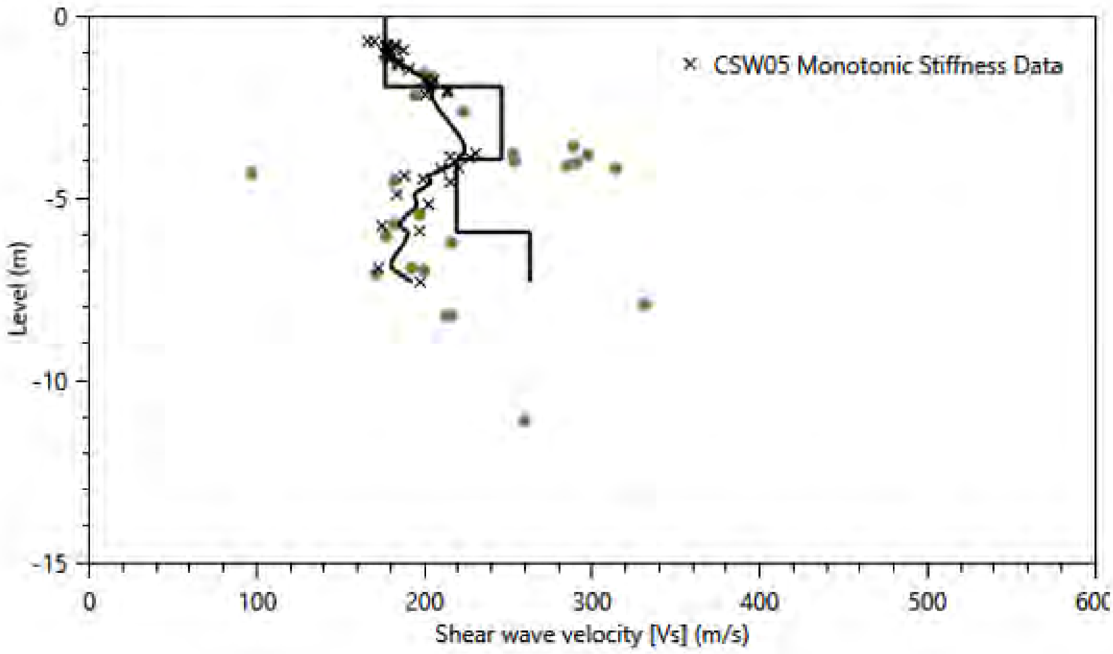
CSW04 Simple & advanced inversion



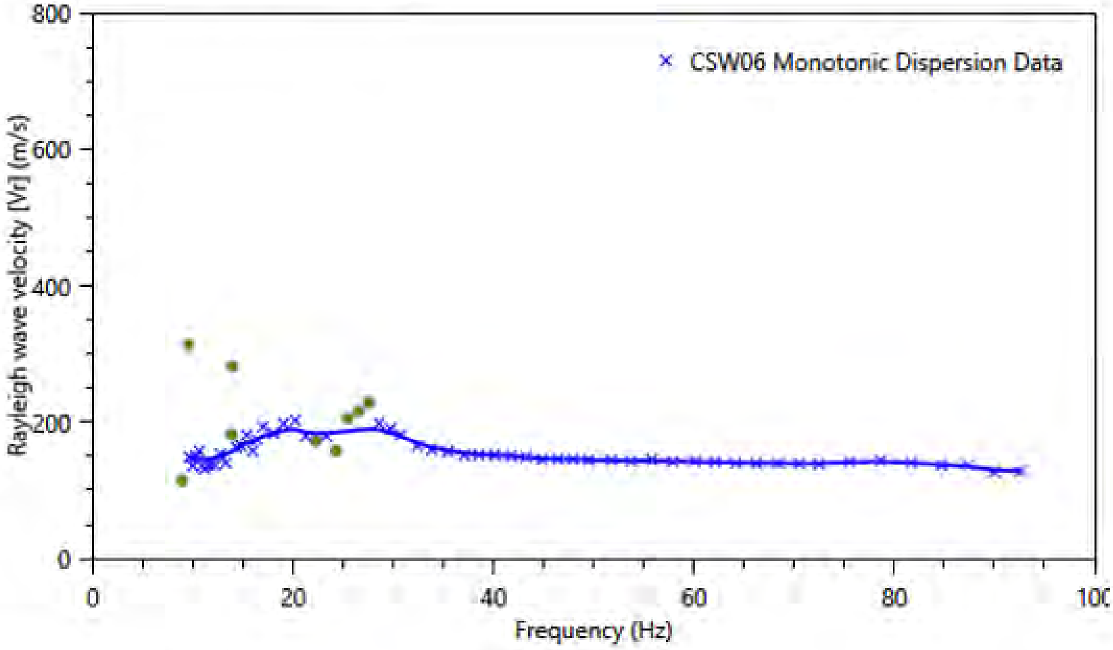
CSW05 Field dispersion curve



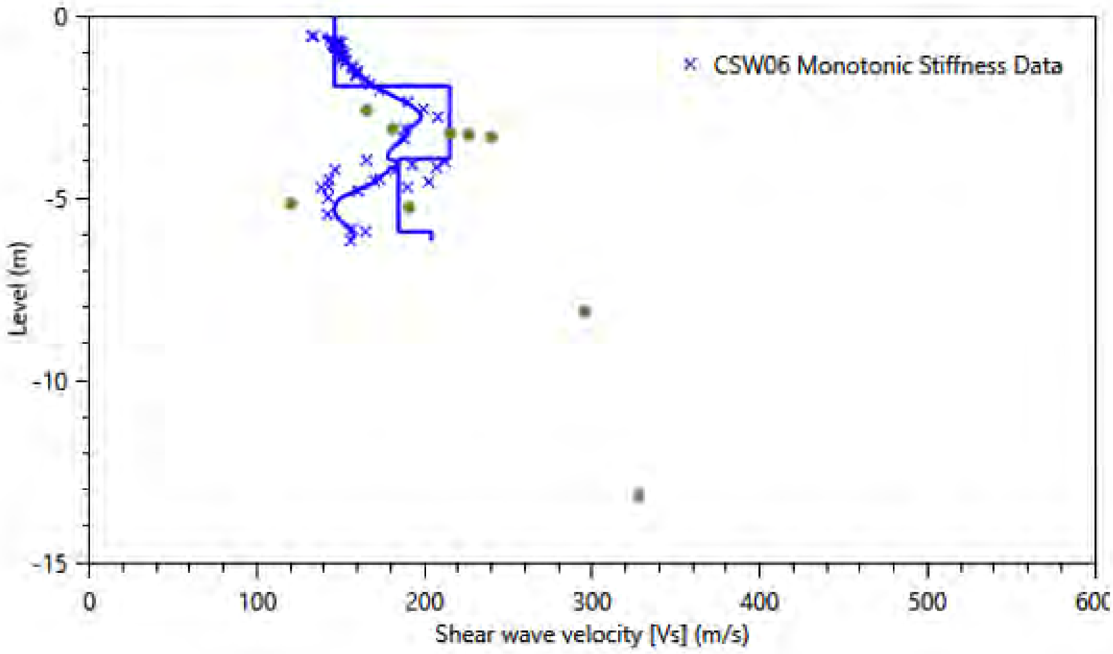
CSW05 Simple & advanced inversion



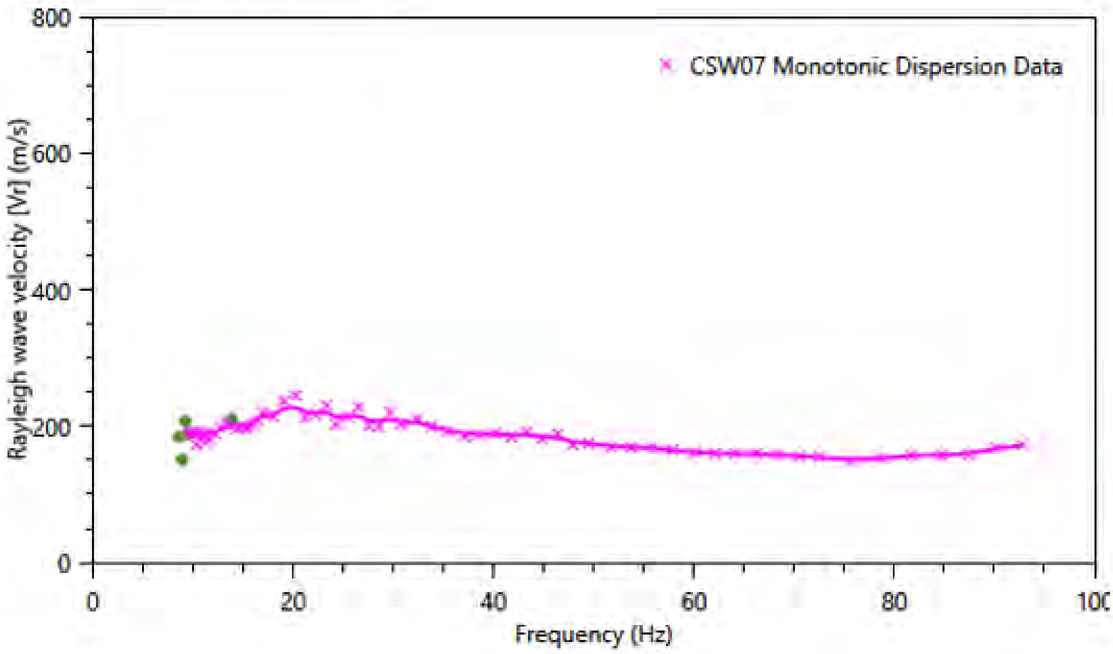
CSW06 Field dispersion curve



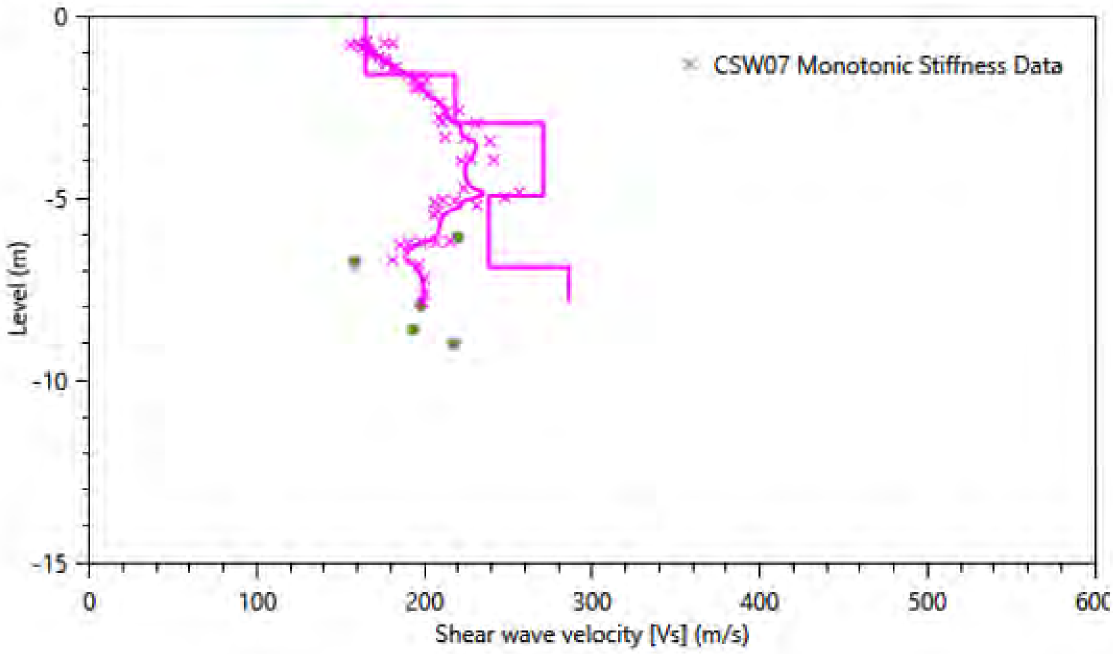
CSW06 Simple & advanced inversion



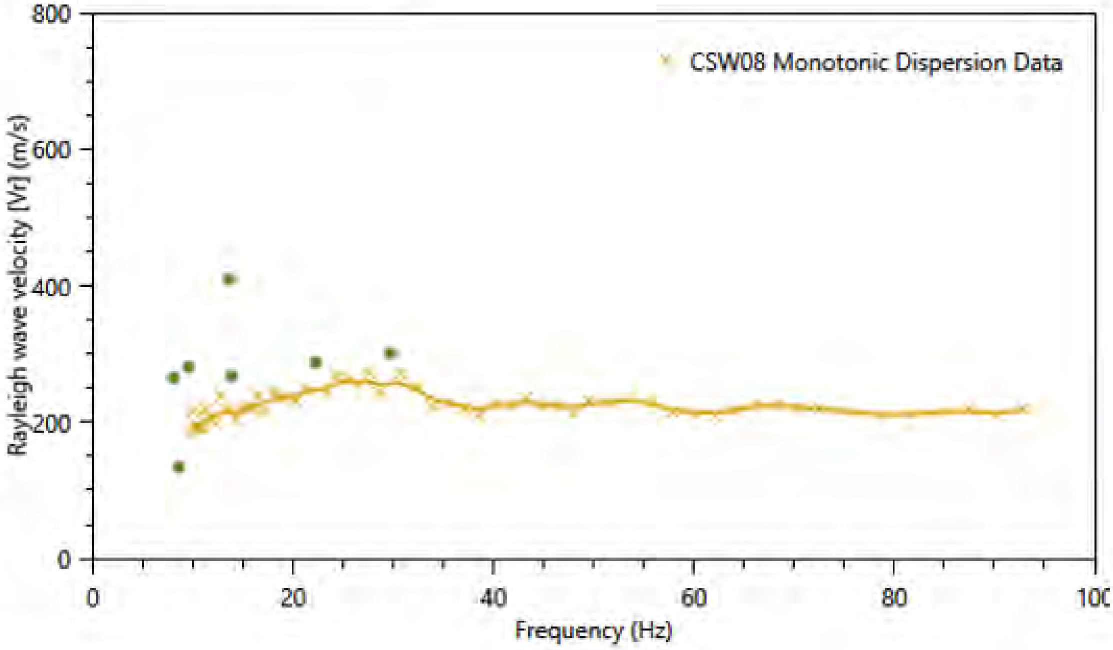
CSW07 Field dispersion curve



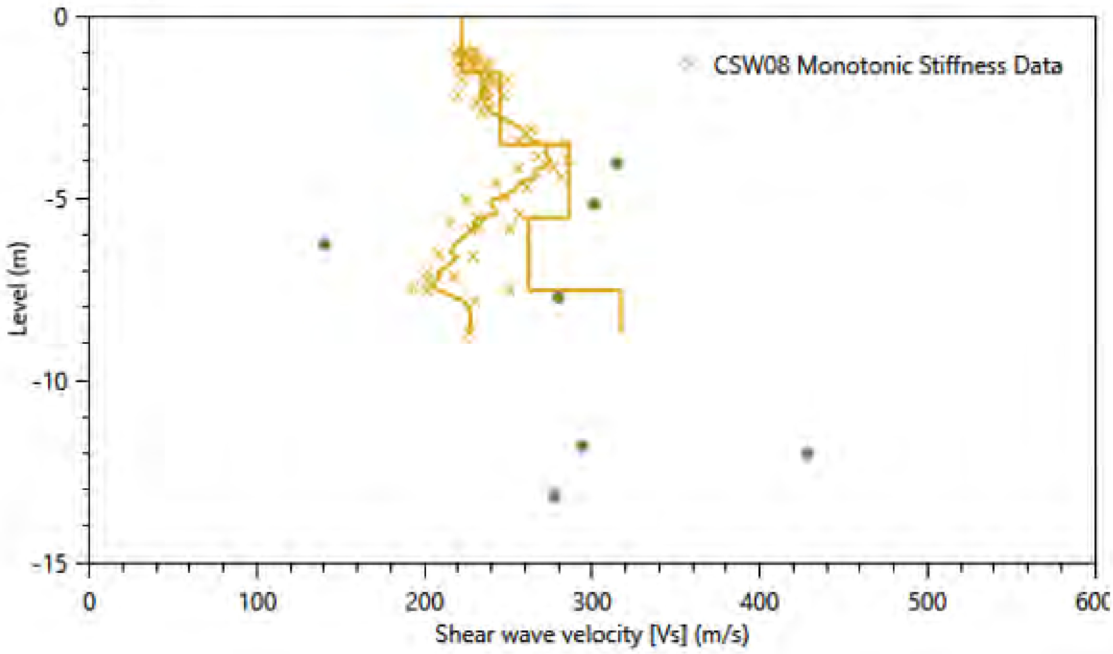
CSW07 Simple & advanced inversion



CSW08 Field dispersion curve



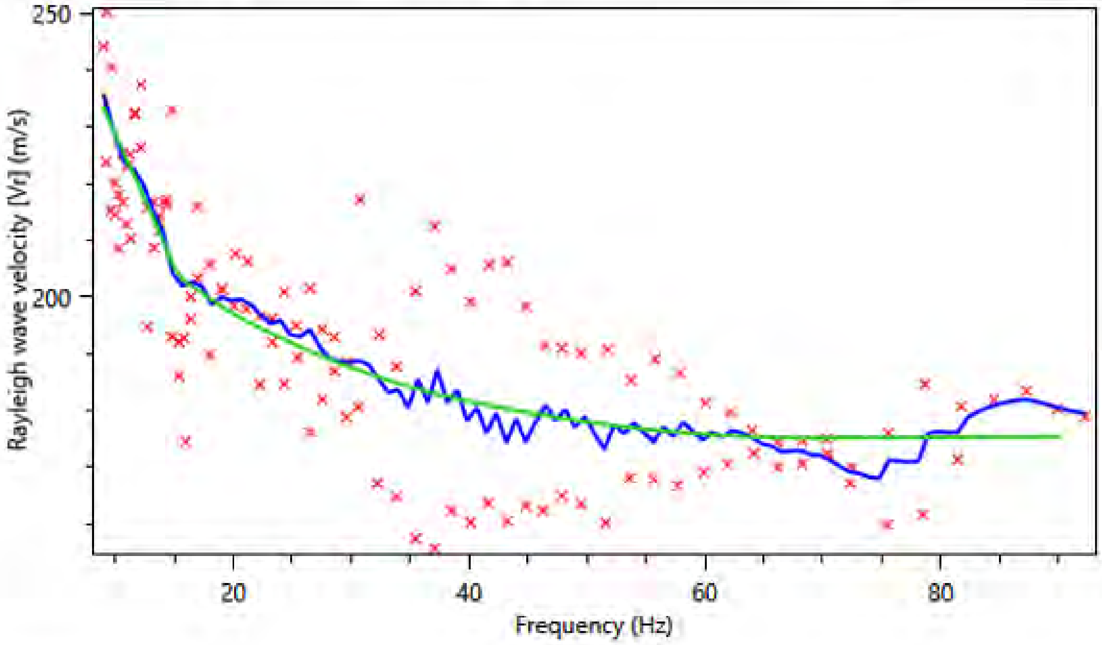
CSW08 Simple & advanced inversion



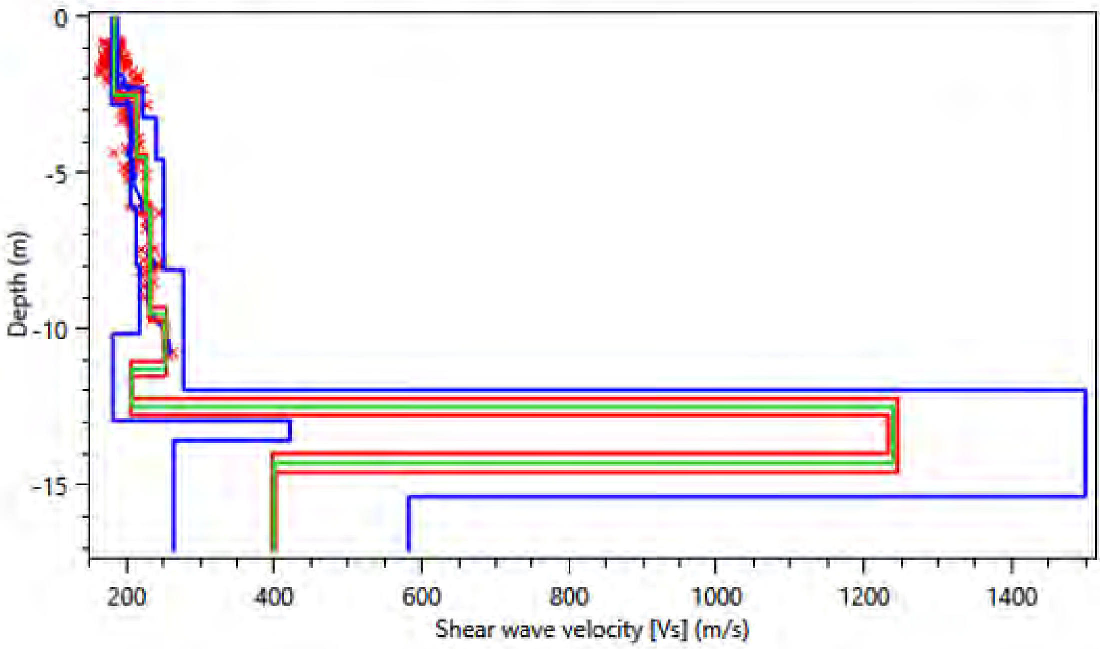
Appendix B: Synthetic dispersion curves & advanced inversion profiles

See Appendix D for key

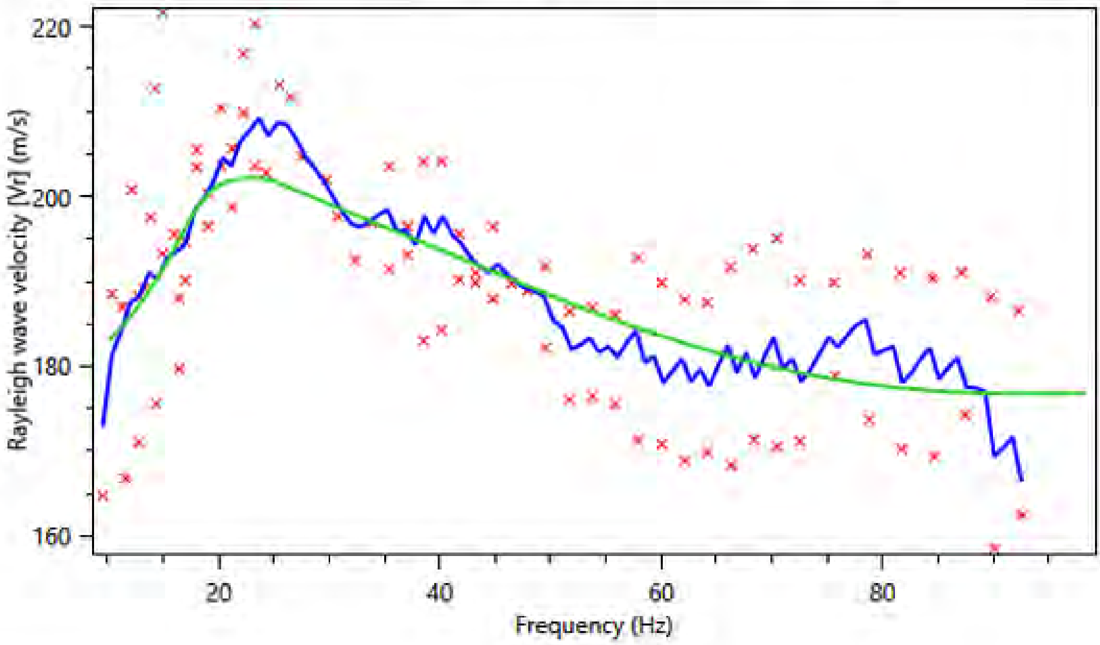
COMBINED01 SW Advanced inversion synthetic dispersion curve



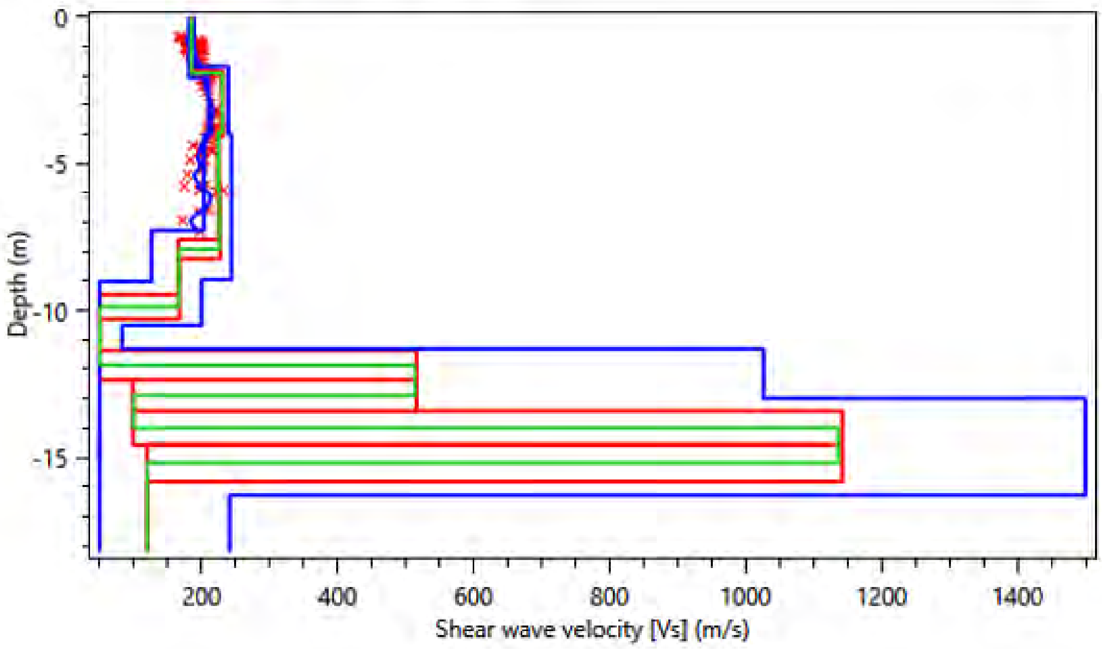
COMBINED01 SW Advanced inversion



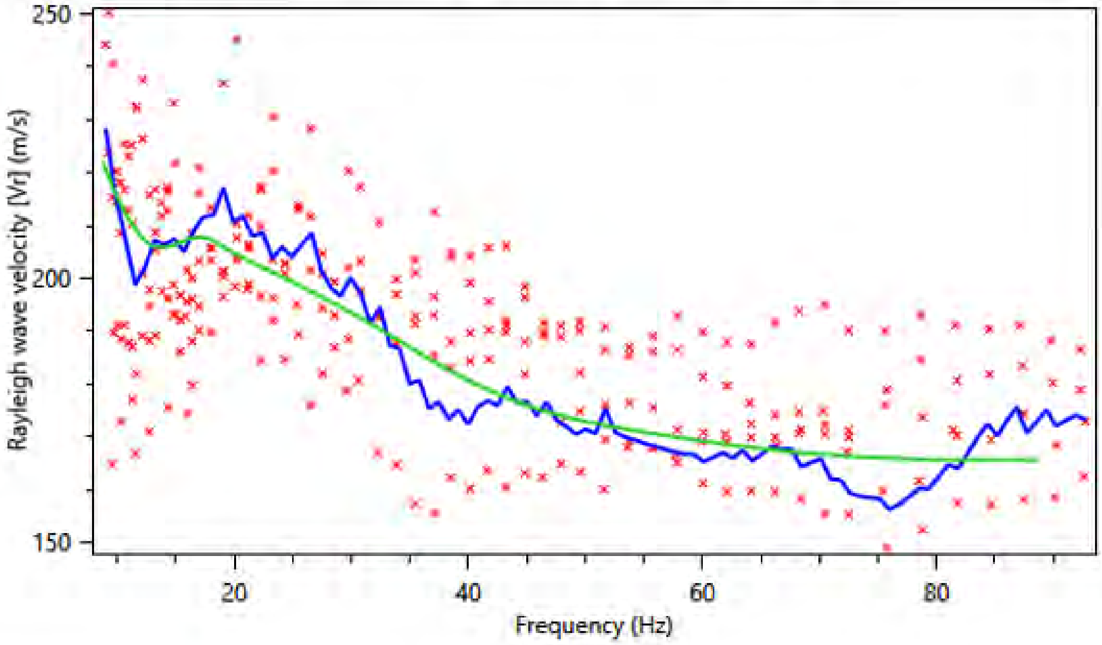
COMBINED02 SE Advanced inversion synthetic dispersion curve



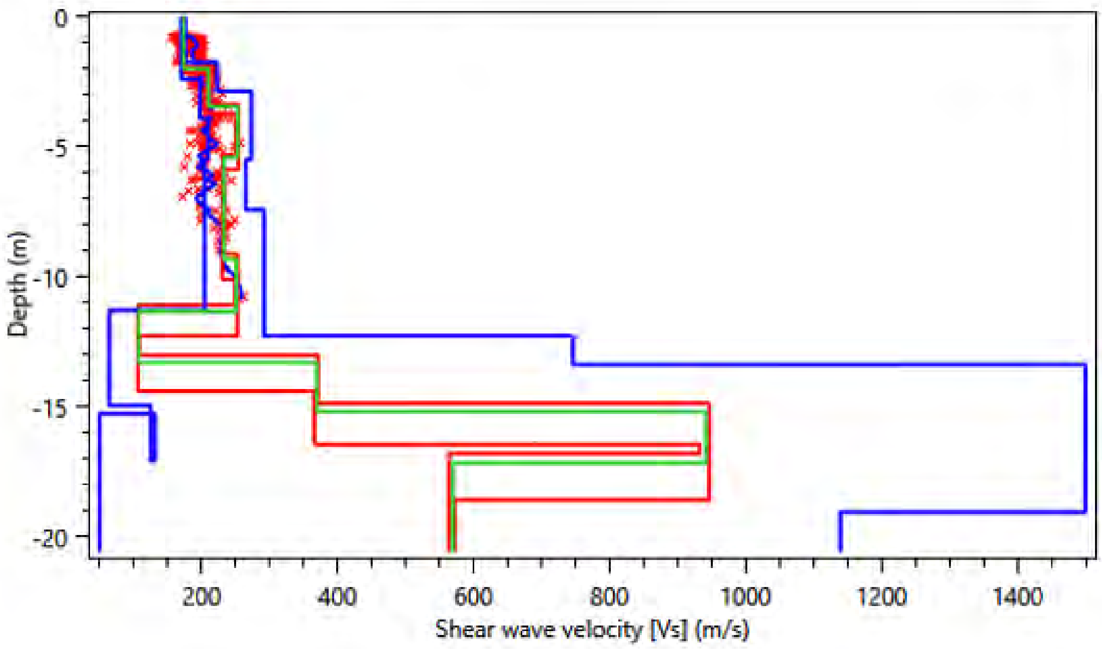
COMBINED02 SE Advanced inversion



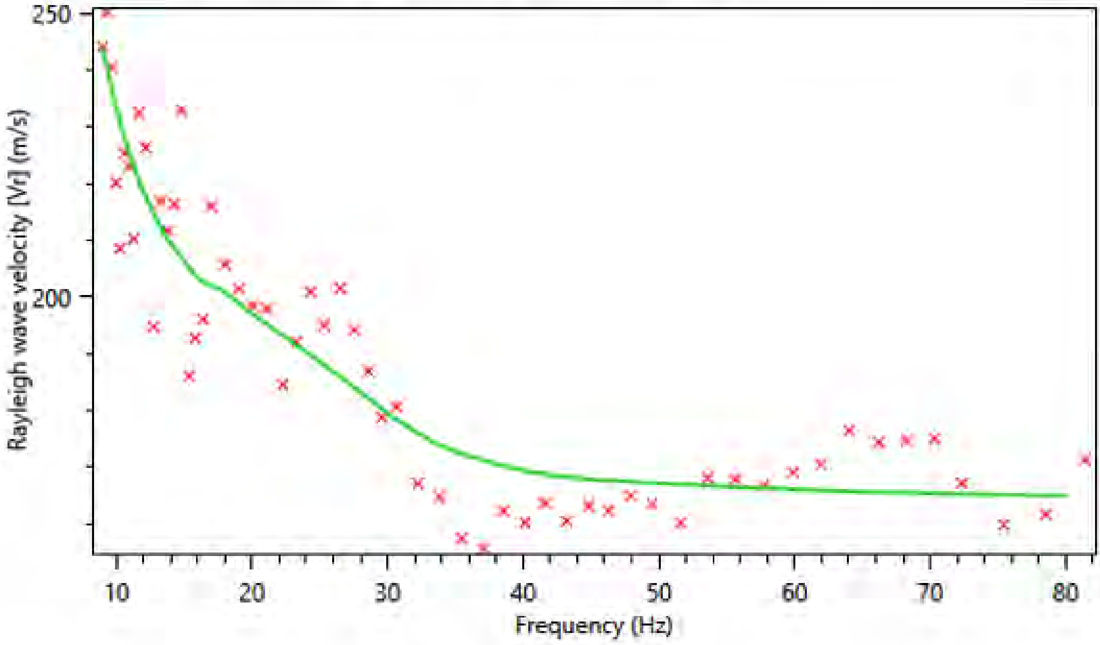
COMBINED03 Advanced inversion synthetic dispersion curve



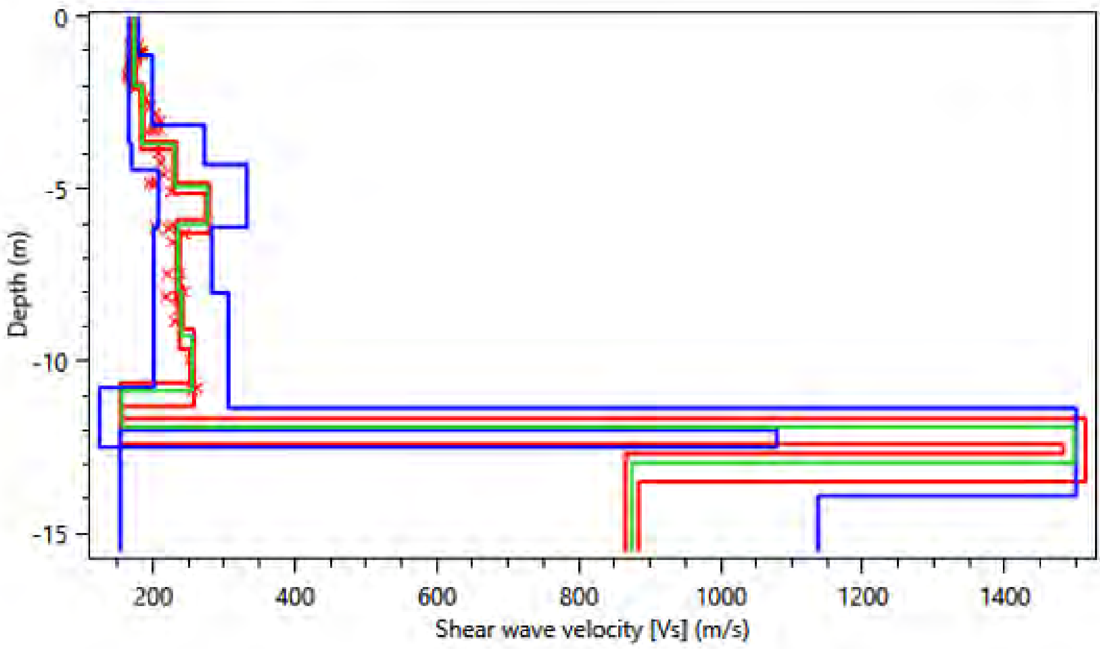
COMBINED03 Advanced inversion



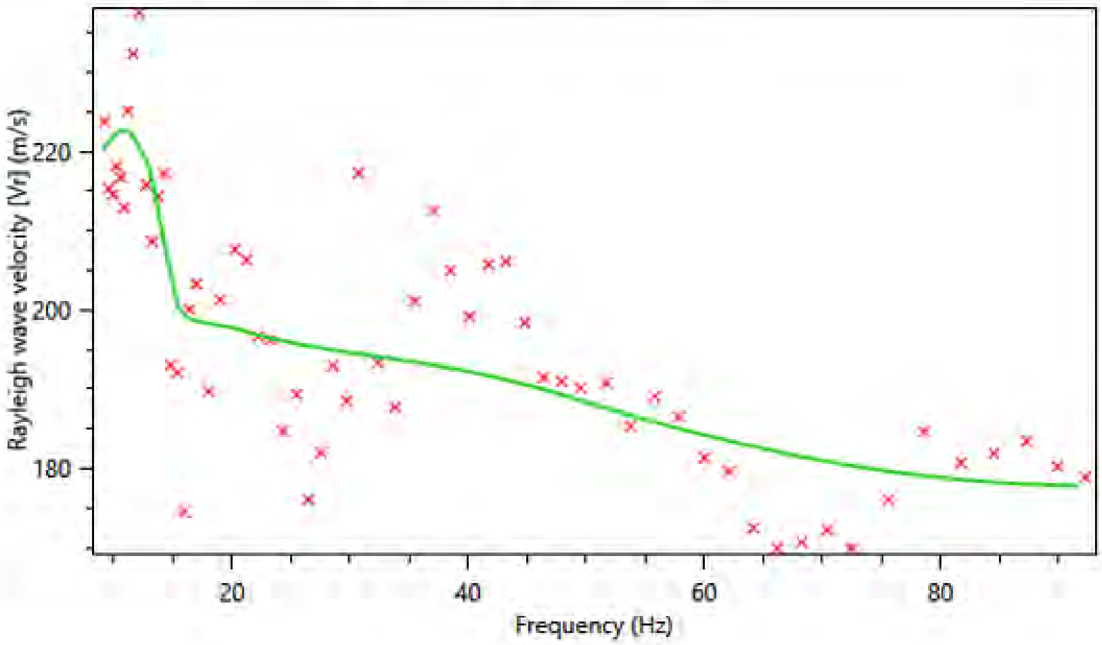
CSW01 Advanced inversion synthetic dispersion curve



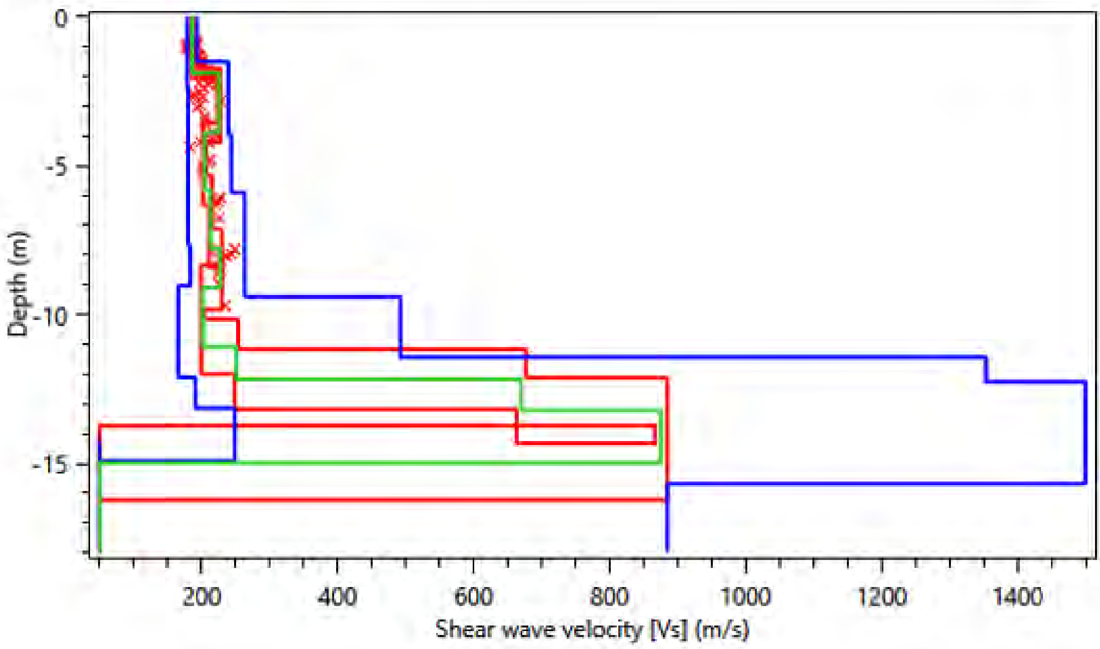
CSW01 Advanced inversion



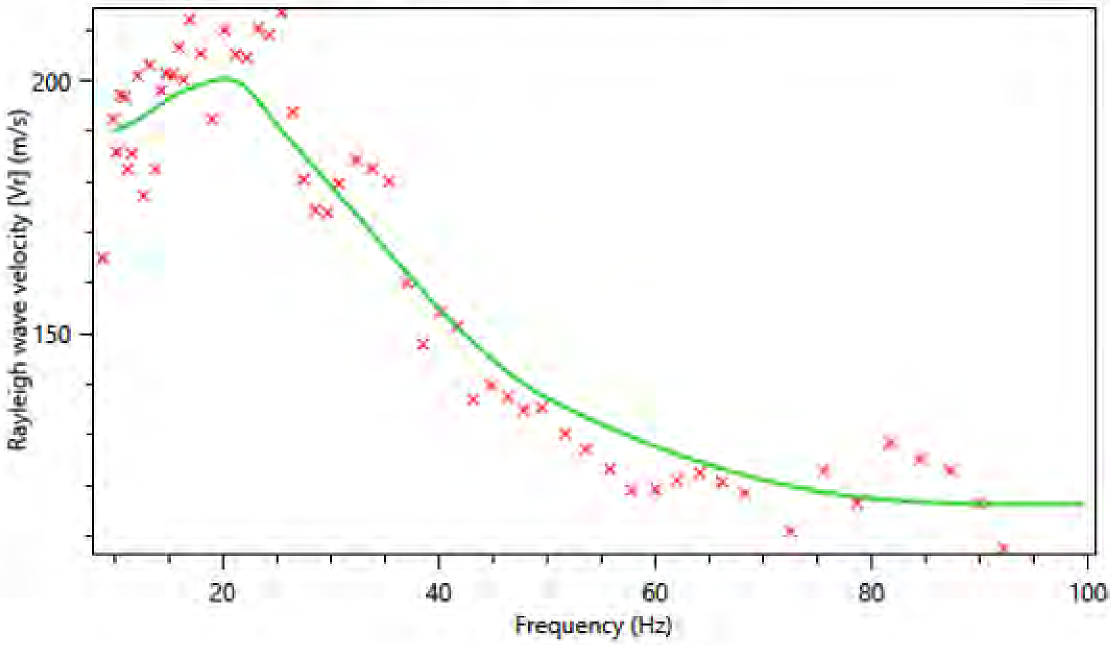
CSW02 Advanced inversion synthetic dispersion curve



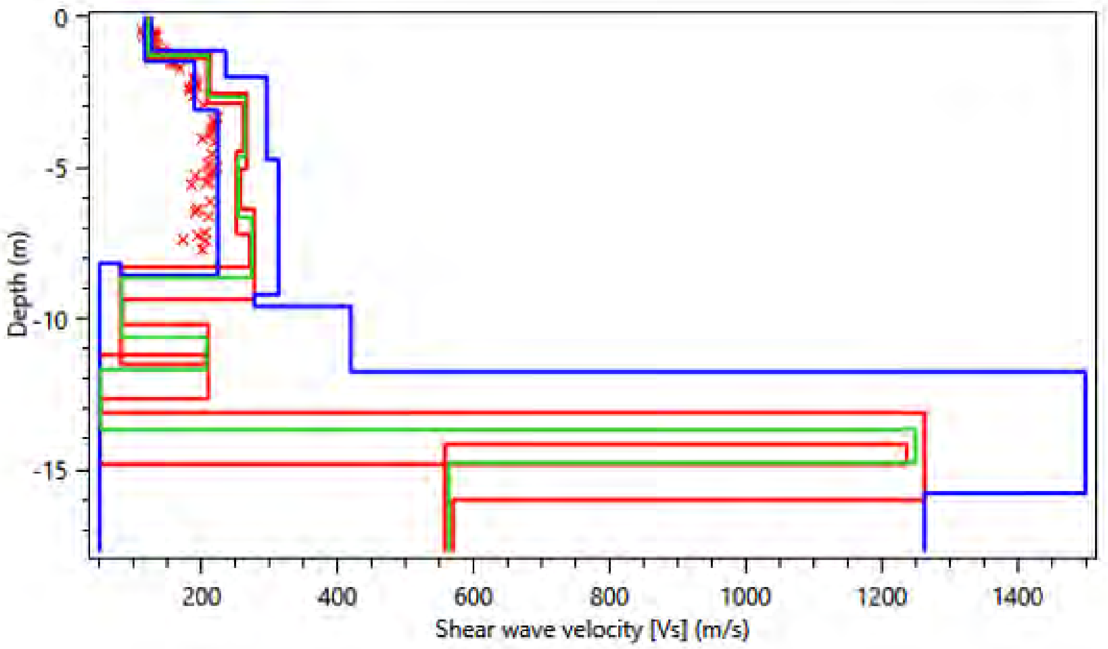
CSW02 Advanced inversion



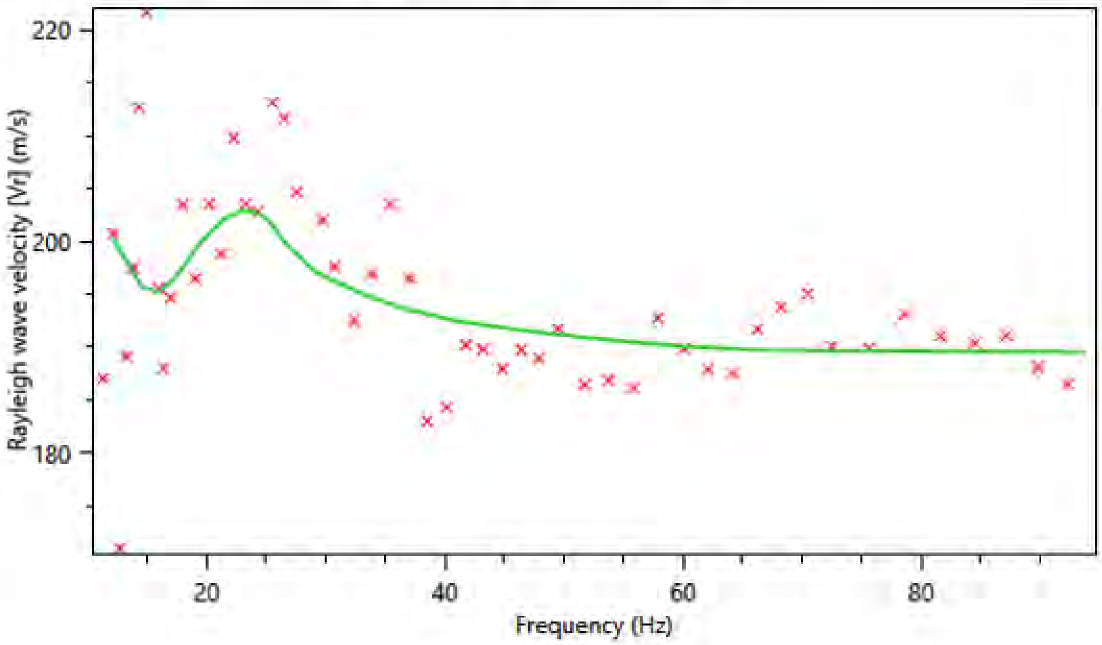
CSW03 Advanced inversion synthetic dispersion curve



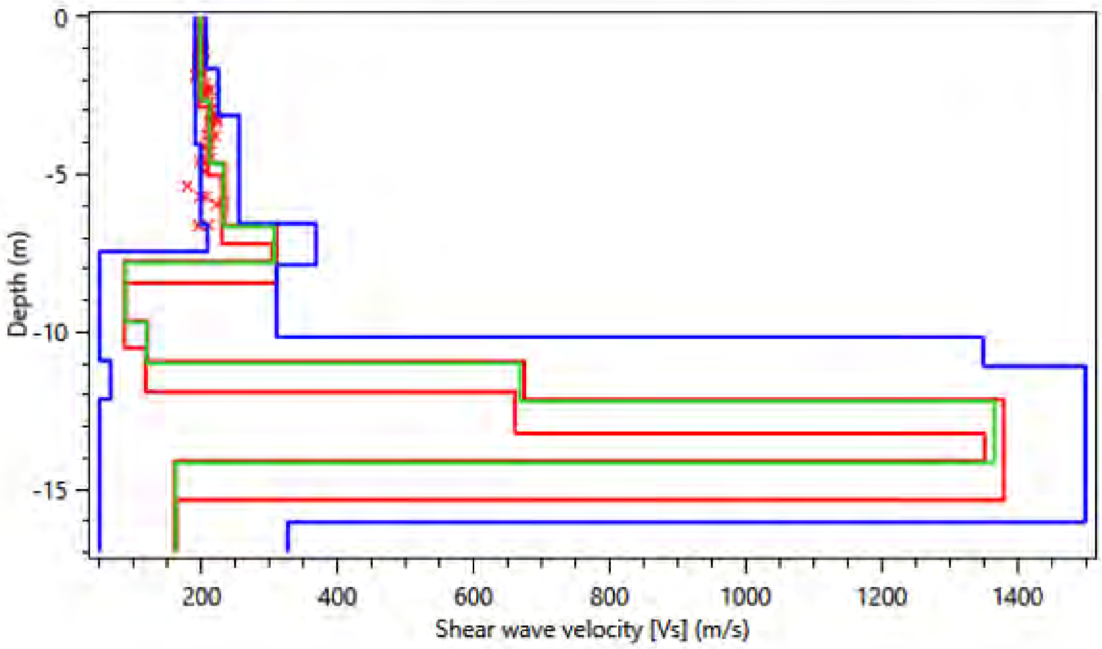
CSW03 Advanced inversion



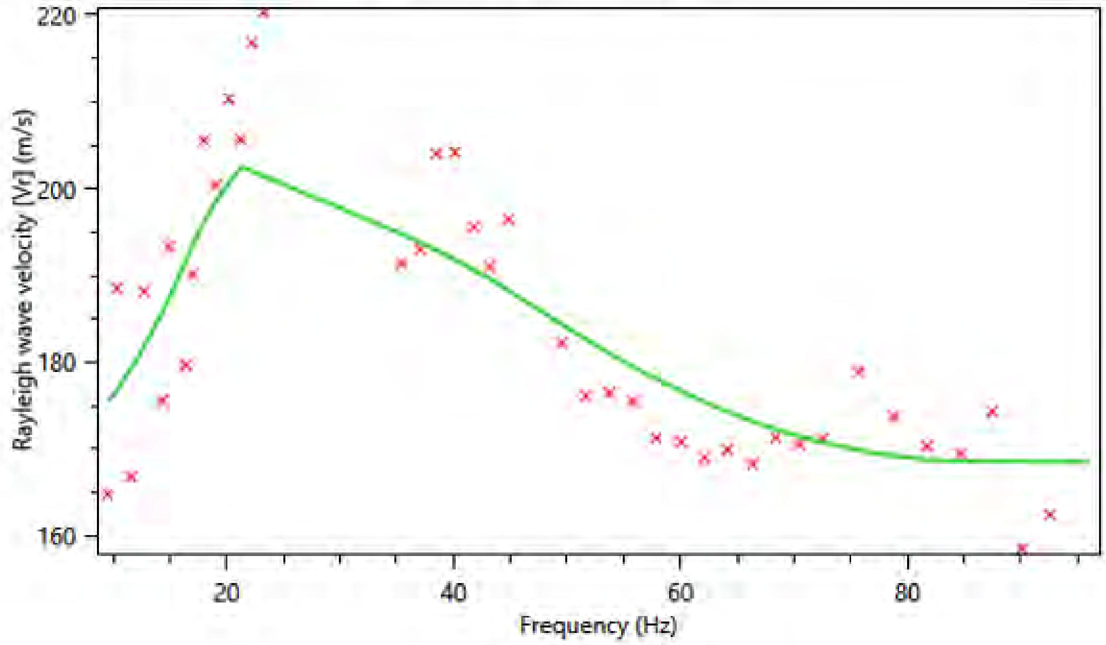
CSW04 Advanced inversion synthetic dispersion curve



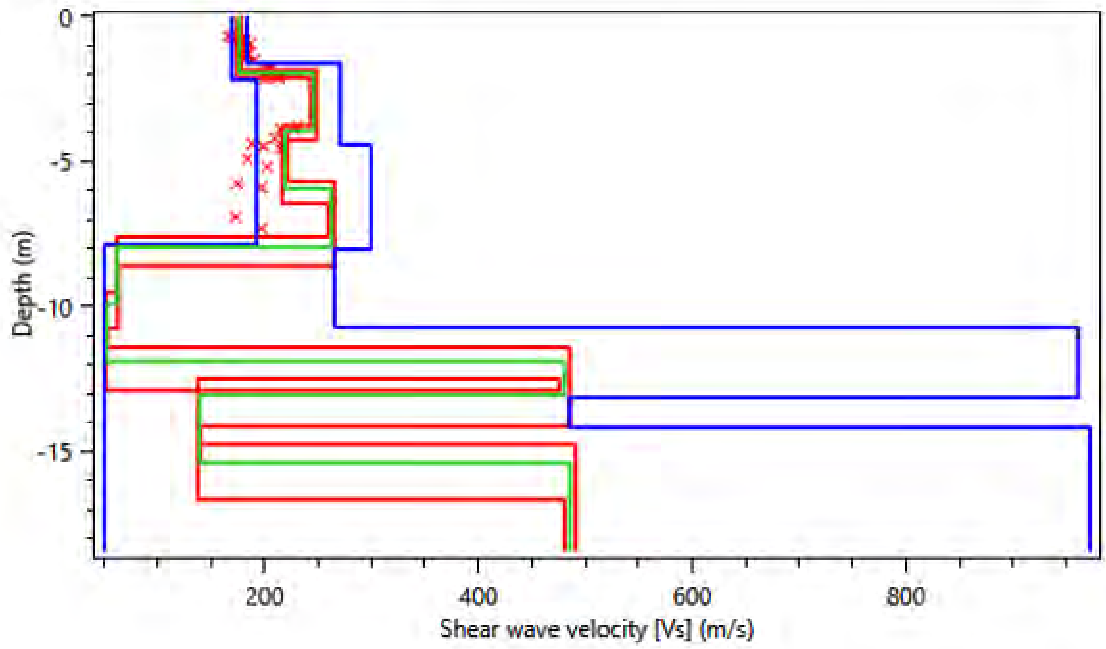
CSW04 Advanced inversion



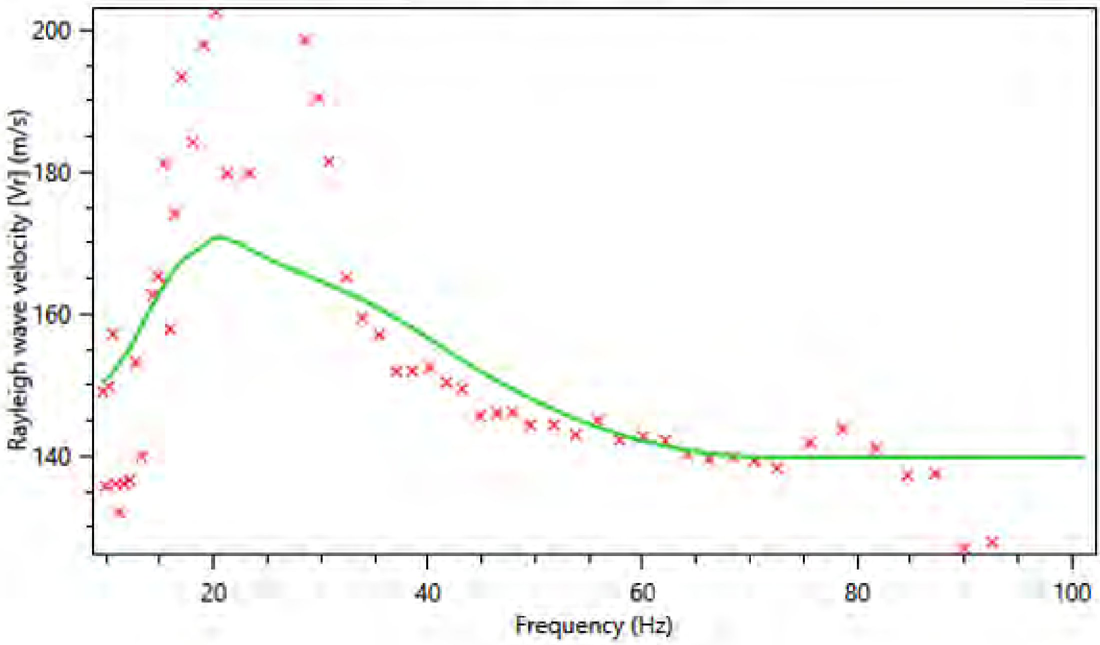
CSW05 Advanced inversion synthetic dispersion curve



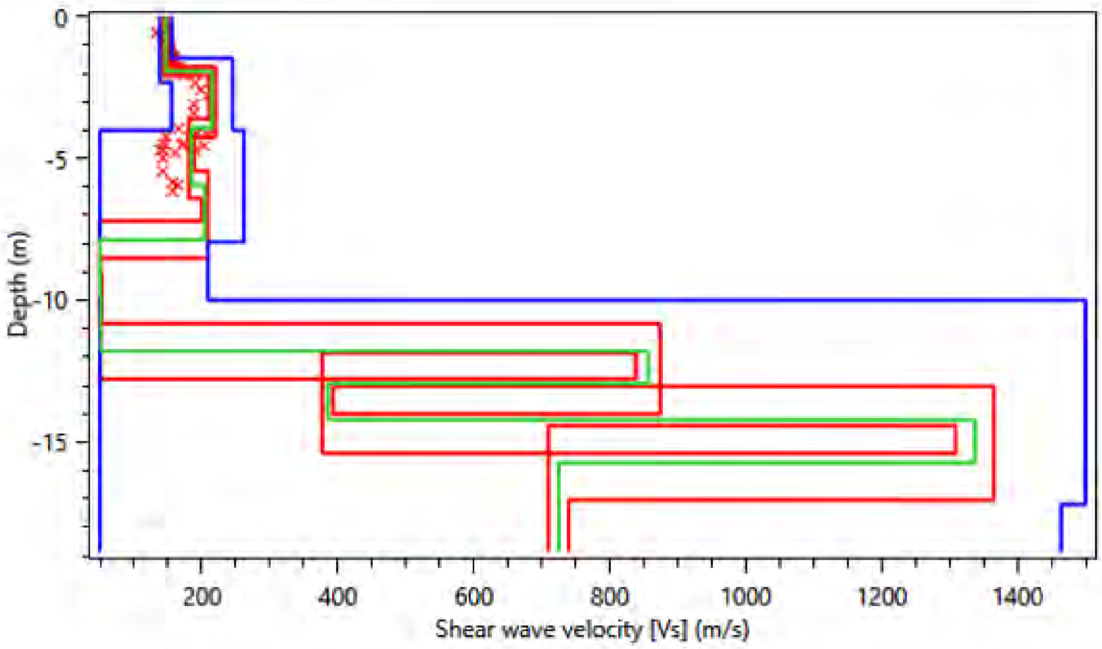
CSW05 Advanced inversion



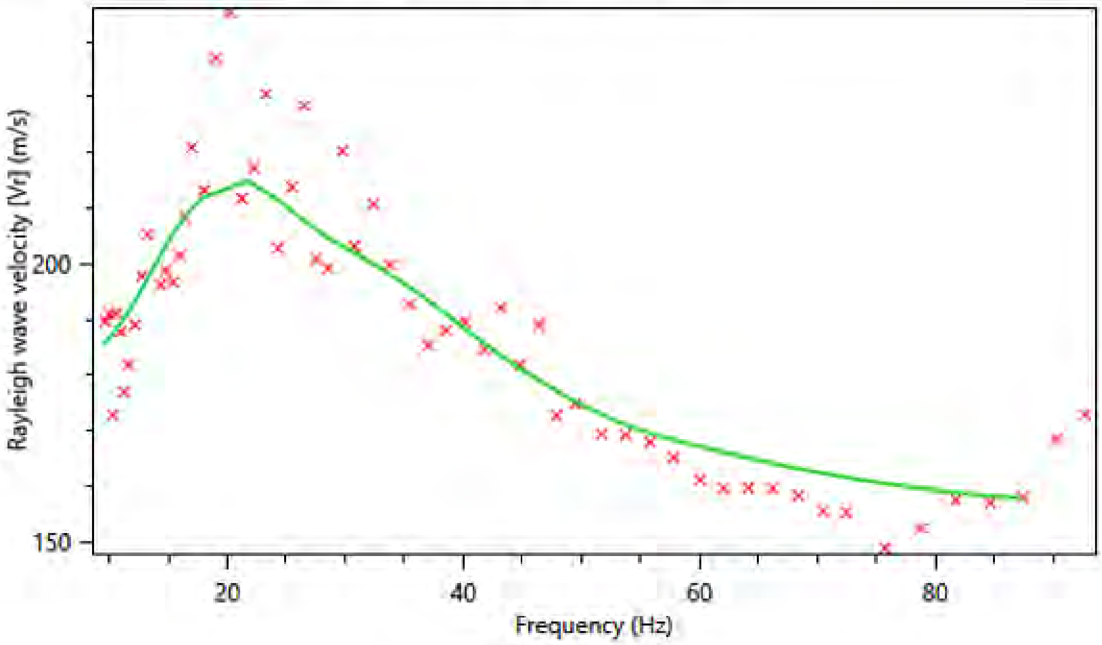
CSW06 Advanced inversion synthetic dispersion curve



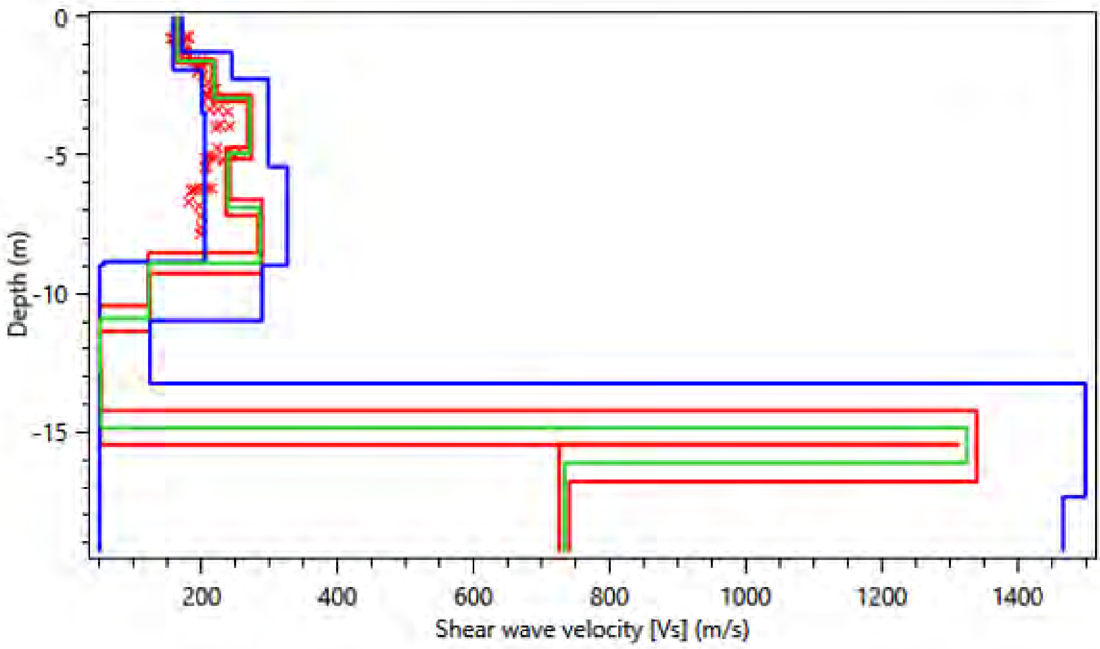
CSW06 Advanced inversion



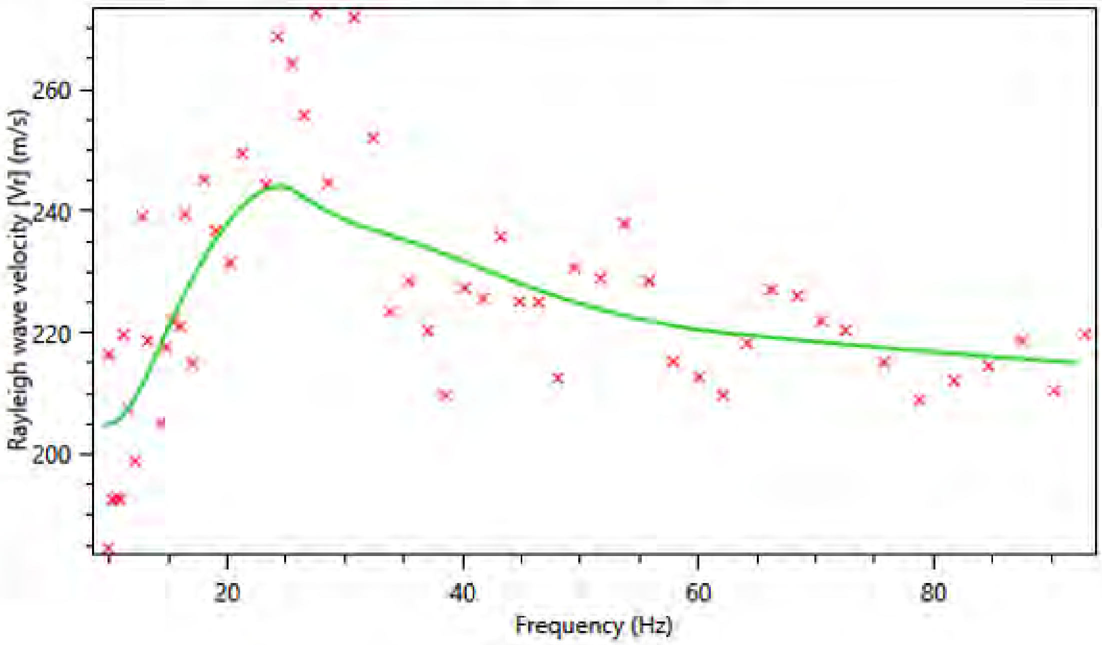
CSW07 Advanced inversion synthetic dispersion curve



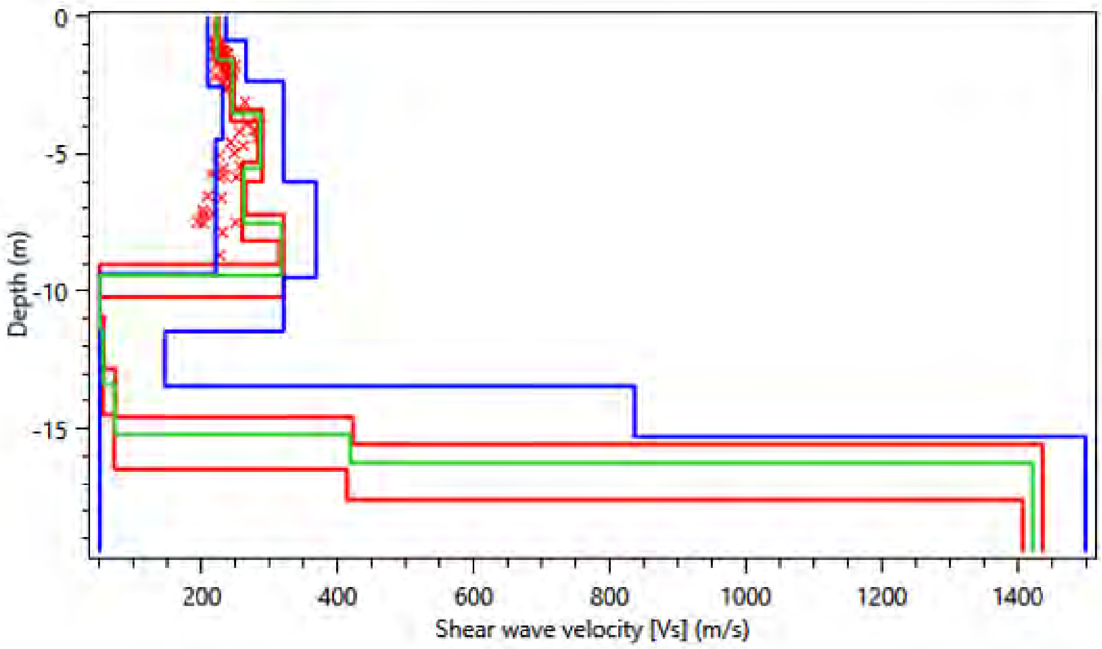
CSW07 Advanced inversion



CSW08 Advanced inversion synthetic dispersion curve



CSW08 Advanced inversion



Appendix C: Advanced inversion data

Project:	Mast Arms Narcoossee & Cyrils	**Report:**	GSS328
Shift:	4/6/2020	**Client:**	UES
Test:	COMBINED03	**Date:**	4/6/2020

Test notes: Design curve using combined data from tests CSW01, CSW02, CSW04, CSW05 and CSW07.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings | |
Northings | |
Level (m) |
Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
569	7	0.0	112	503	0.26	1268.0	431.9
691	5	6.6	112	742	0.26	1870.5	637.1
831	6	11.3	112	1072	0.26	2702.7	920.5
764	6	17.8	112	907	0.26	2286.0	778.6
763	6	24.1	112	905	0.26	2280.5	776.7
825	7	30.6	112	1059	0.26	2667.5	908.5

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

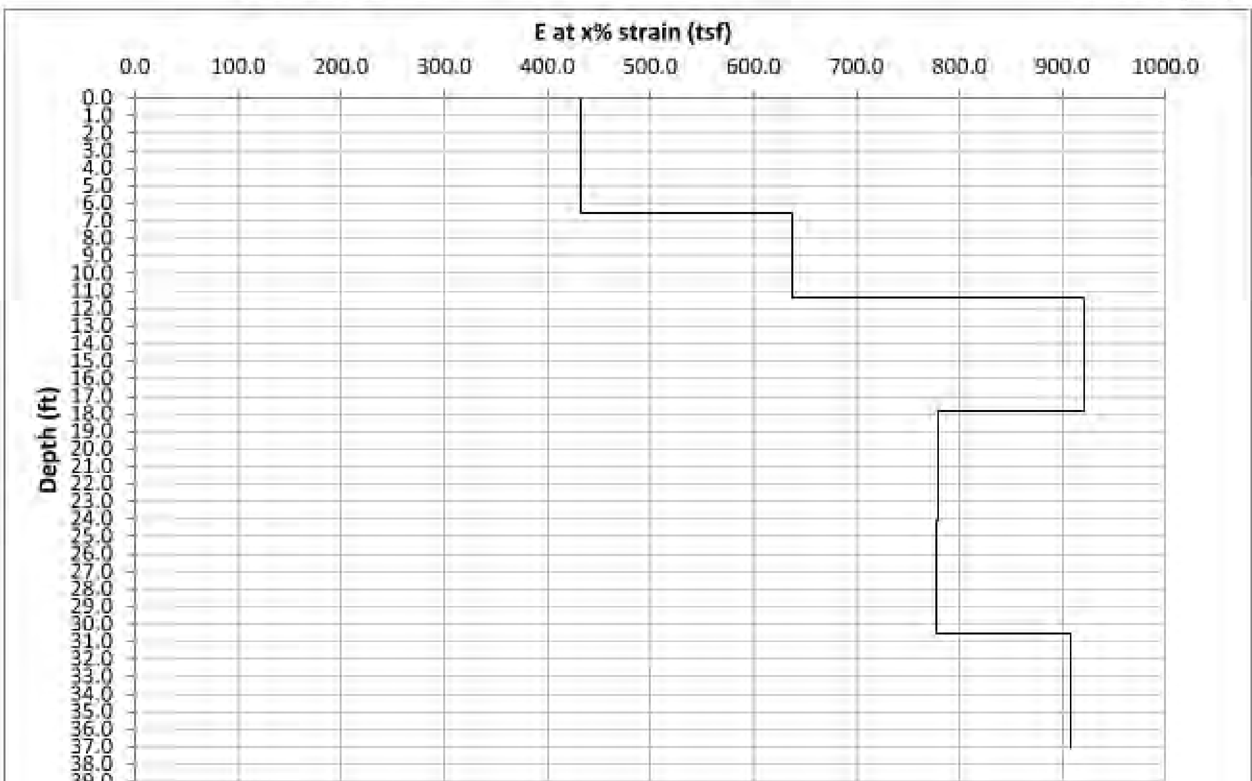
4 Shear modulus = $G = \rho v_s^2$

5 Youngs modulus = E=G.(2.(1+v))

6 Softened values of stiffness are calculated using Rollins equation: where γ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



www.GroundStiffnessSurveys.com

Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	COMBINED01 SW	Date:	4/6/2020

Test notes: Combined CSW01 and CSW02 at SW corner of intersection.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings
Northings
Level (m)
Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
603	3	0.0	112	566	0.26	1425.4	485.5
599	5	3.4	112	558	0.26	1405.9	478.8
700	7	8.2	112	762	0.26	1919.8	653.9
742	5	14.8	112	855	0.26	2155.8	734.3
760	6	20.3	112	897	0.26	2261.6	770.3
759	5	26.4	112	896	0.26	2256.8	768.7
826	6	31.2	112	1060	0.26	2671.7	910.0

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Y=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = Y_t / g$ (where Y_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

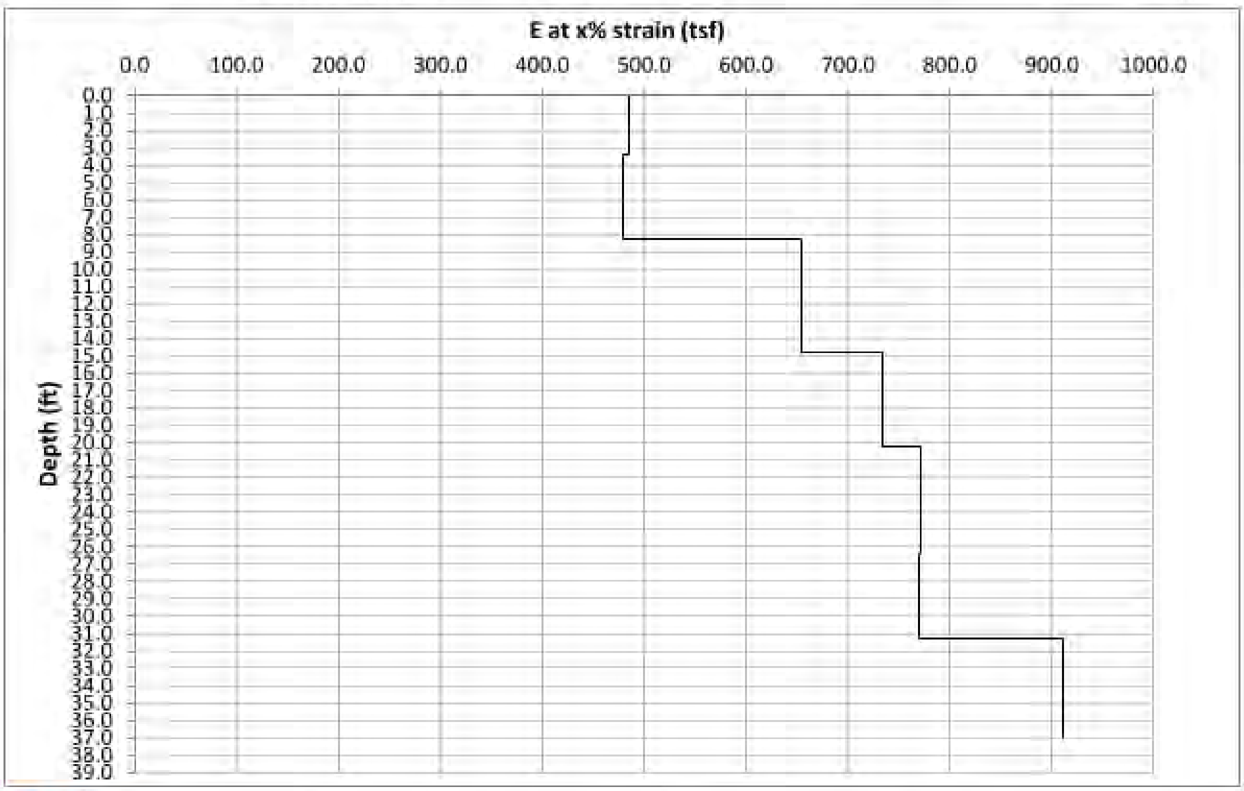
4 Shear modulus = $G = \rho . v_s^2$

5 Youngs modulus = $E = G.(2.(1+v))$

6 Softened values of stiffness are calculated using Rollins equation: where γ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{-20\gamma}\right)\right]}$$

Rollins et al, (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	COMBINED02 SE	Date:	4/6/2020

Test notes: Combined tests CSW04 and CSW05 at SE corner of intersection. CSW06 excluded due to poor model fit.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below
See the GSS report ref GSS328 for conditions of use of data

Eastings
Northings ***Level (m)***

Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
607	6	0.0	112	573	0.26	1444.4	492.0
755	7	6.3	112	886	0.26	2231.5	760.0
736	7	12.9	112	843	0.26	2123.6	723.3
742	7	19.4	112	856	0.26	2156.8	734.6

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

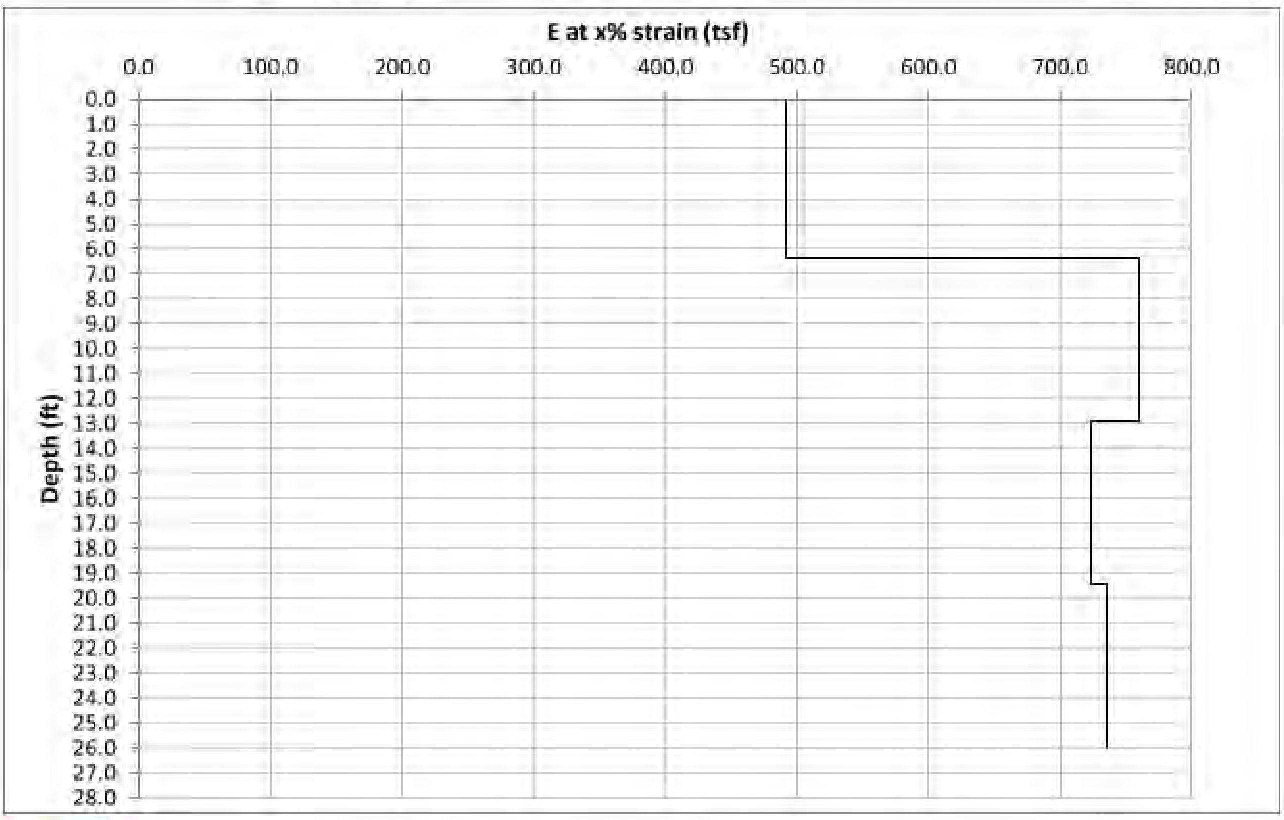
4 Shear modulus = $G = \rho.v_s^2$

5 Youngs modulus = E=G.(2.(1+v))

6 Softened values of stiffness are calculated using Rollins equation:
where Υ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1+16\gamma\left(1.2+10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW01	Date:	4/6/2020

Test notes: CSW01 at edge of sidewalk, SW corner of proposed intersection.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings
Northings
Level (m)
Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
567	7	0.0	112	499	0.26	1258.0	428.5
605	6	6.5	112	570	0.26	1435.4	488.9
757	4	12.1	112	890	0.26	2243.7	764.2
908	4	16.2	112	1283	0.26	3232.1	1100.8
771	6	19.8	112	925	0.26	2330.6	793.8
786	4	26.1	112	959	0.26	2417.8	823.5
837	5	30.4	112	1088	0.26	2740.9	933.6

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

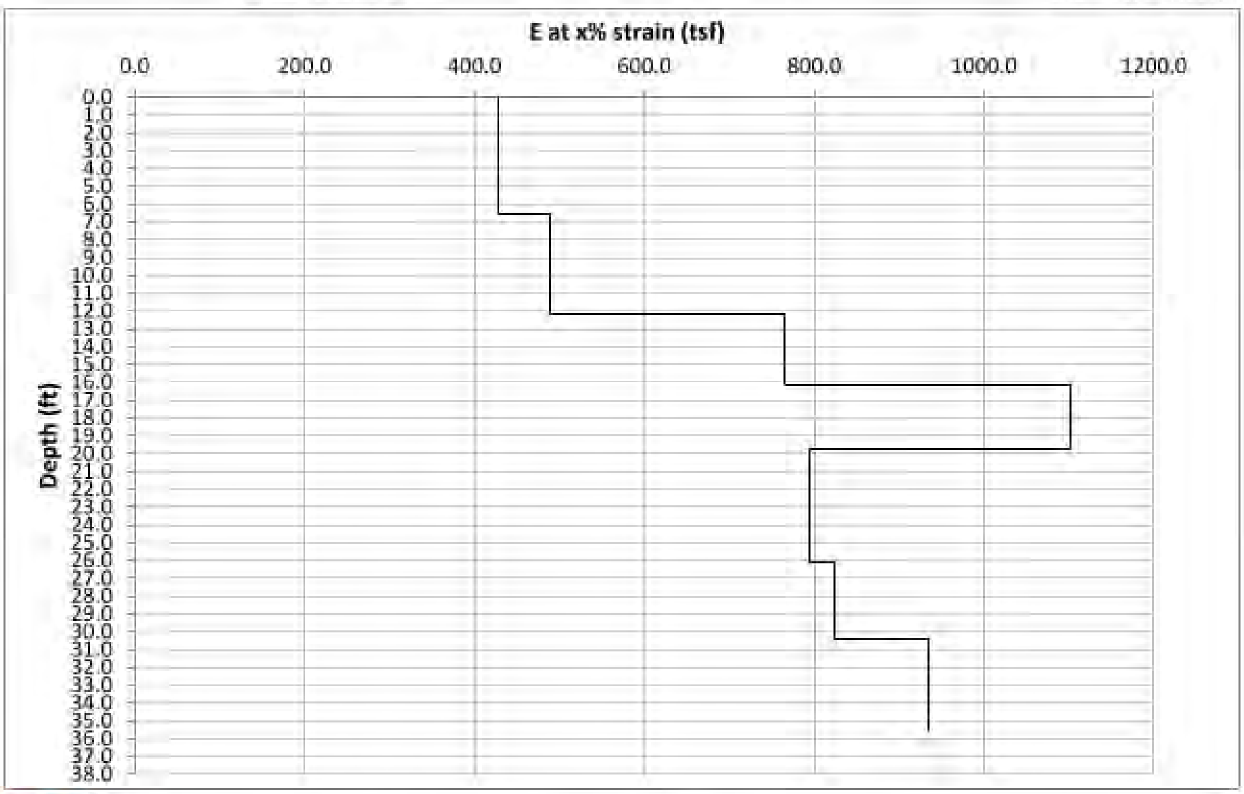
4 Shear modulus = $G = \rho . v_s^2$

5 Youngs modulus = $E = G.(2.(1+v))$

6 Softened values of stiffness are calculated using Rollins equation:
where Υ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	**Report:**	GSS328
Shift:	4/6/2020	**Client:**	UES
Test:	CSW02	**Date:**	4/6/2020

Test notes: CSW02 at same location as CSW01 but shaker & geophones flipped to allow data stacking. SW corner of proposed intersection, edge of sidewalk.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings
Northings
Level (m)
Strain level softened to: 0.1 %

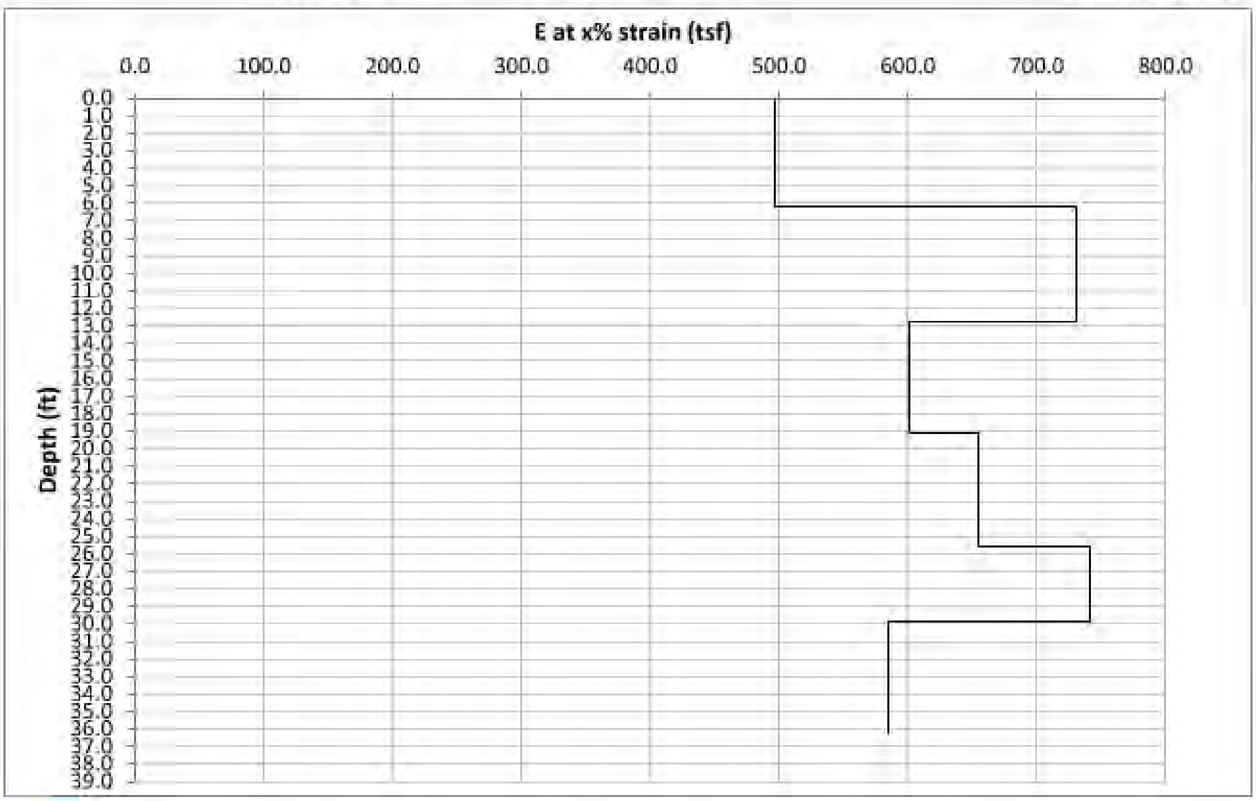
Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
611	6	0.0	112	579	0.26	1460.0	497.3
740	7	6.2	112	851	0.26	2143.8	730.2
671	6	12.8	112	700	0.26	1764.4	601.0
701	6	19.1	112	763	0.26	1921.7	654.5
745	4	25.5	112	864	0.26	2176.1	741.2
662	7	29.8	112	682	0.26	1717.8	585.1

Notes:

1. Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of γ=112 lb/ft^3 and ν=0.26 are assumed. *Refer to above GSS report conditions for further information.*
2. Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)
3. Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs
4. Shear modulus = $G = \rho . v_s^2$
5. Youngs modulus = $E = G.(2.(1+\nu))$
6. Softened values of stiffness are calculated using Rollins equation: where Υ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1+16\gamma\left(1.2+10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW03	Date:	4/6/2020

Test notes: NW Corner of intersection. Shaker at N end of north to south array, edge of sidewalk. Steep slope to west of array.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values. Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings
Northings
Level (m)

Strain level softened to: 0.1 %

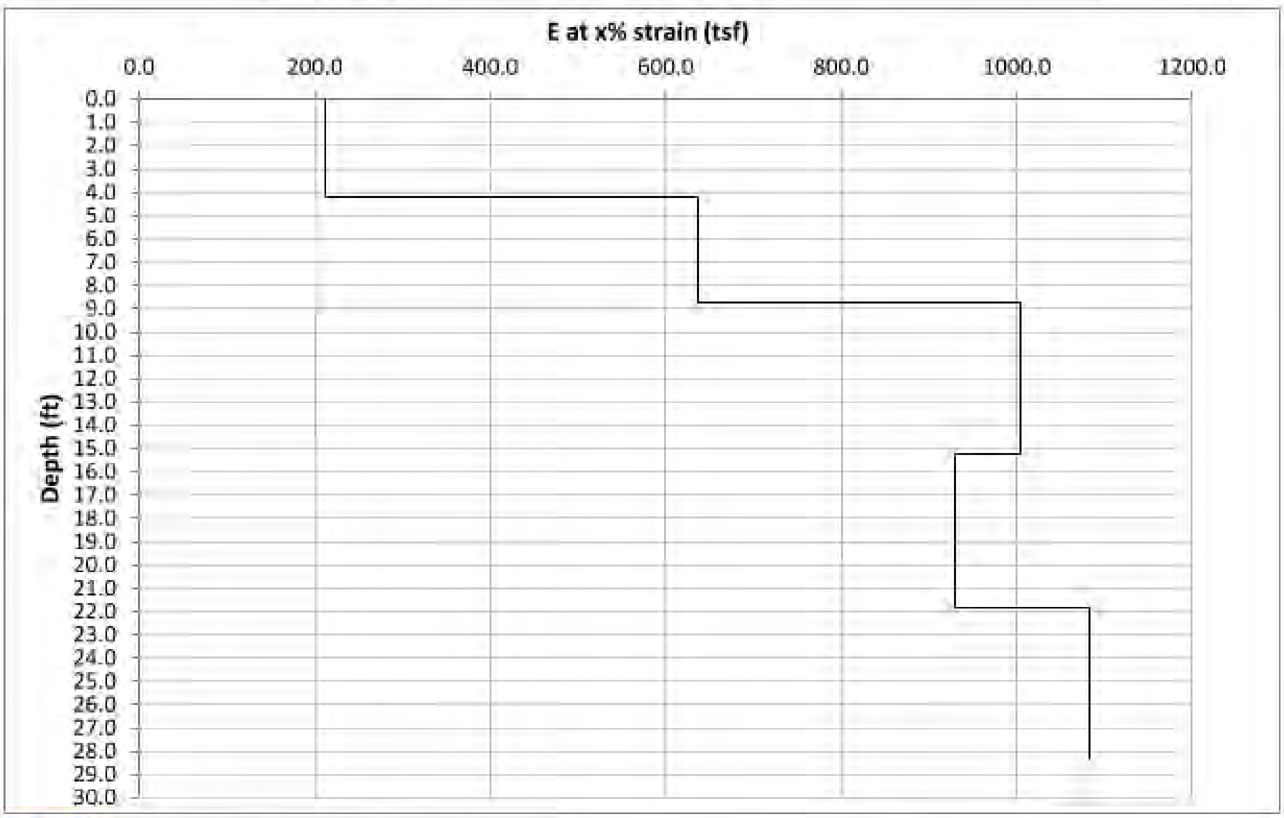
Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
400	4	0.0	112	248	0.26	625.3	213.0
691	5	4.2	112	742	0.26	1868.8	636.5
867	7	8.7	112	1169	0.26	2945.6	1003.3
835	7	15.3	112	1084	0.26	2731.3	930.3
901	7	21.8	112	1263	0.26	3181.6	1083.6

Notes:

1. Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of γ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*
2. Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)
3. Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs
4. Shear modulus = $G = \rho . v_s^2$
5. Youngs modulus = $E = G.(2.(1+v))$
6. Softened values of stiffness are calculated using Rollins equation: where Υ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW04	Date:	4/6/2020

Test notes: CSW04 was located on the SE corner of the intersection alongside the overhead power tower, close to tower foundation (assumed drilled shaft). Also underground gas, water (8-inch), cable and signalization utilities marked

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below
See the GSS report ref GSS328 for conditions of use of data

Eastings		
Northings		

Level (m)

Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
651	4	0.0	112	658	0.26	1658.6	564.9
653	5	4.1	112	663	0.26	1671.7	569.4
695	7	8.7	112	751	0.26	1891.5	644.2
762	7	15.3	112	901	0.26	2271.3	773.6

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

4 Shear modulus = $G = \rho . v_s^2$

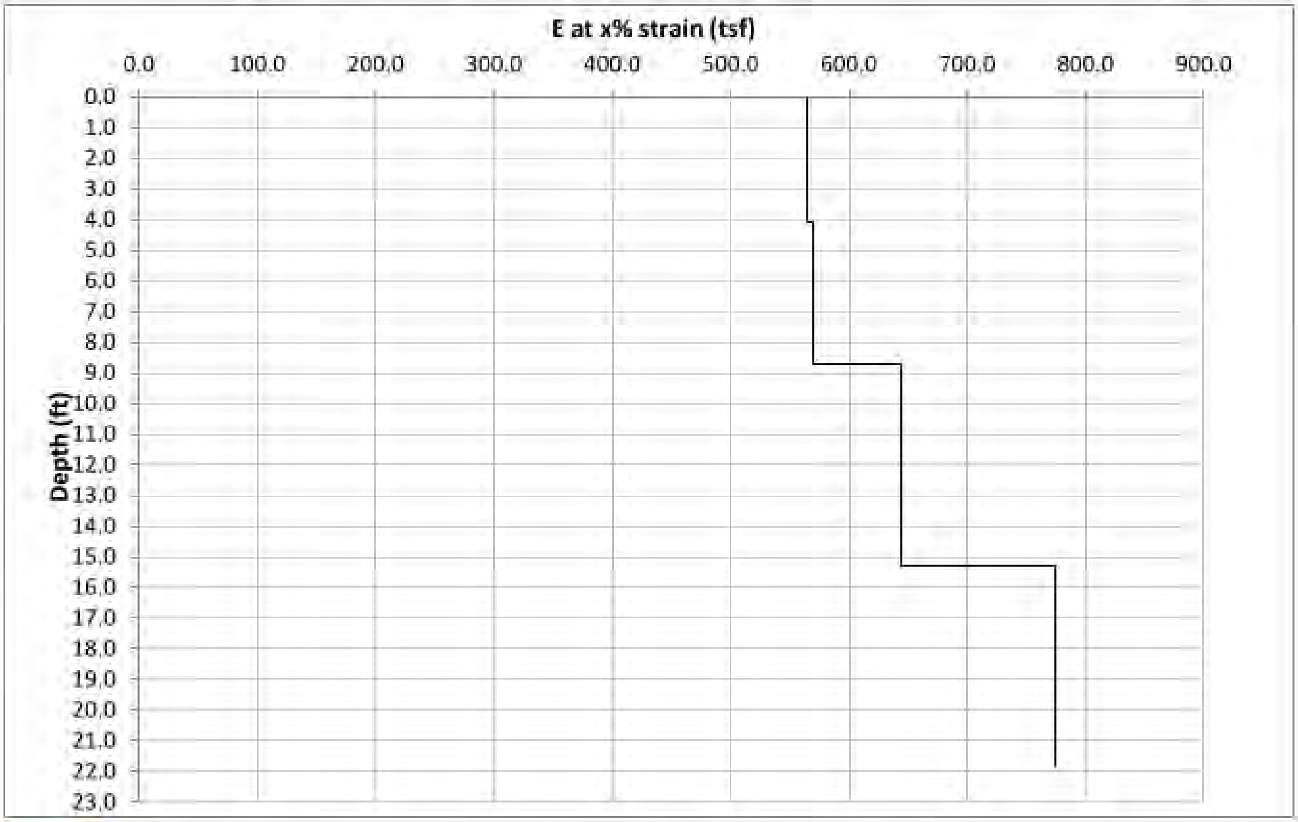
5 Youngs modulus = E=G.(2.(1+v))

6 Softened values of stiffness are calculated using Rollins equation:

$$\frac{G}{G_o} = \frac{1}{\left[1+16\gamma\left(1.2+10^{20\gamma}\right)\right]}$$

where Υ is shear strain

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW05	Date:	4/6/2020

Test notes: CSW05 at SE corner of intersection - moved away from power pole foundation. Shaker at south end of south to north array. Underground gas, water (8-inch), cable & signalization.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below
See the GSS report ref GSS328 for conditions of use of data

Eastings		
Northings		

Level (m)

Strain level softened to: 0.1 %

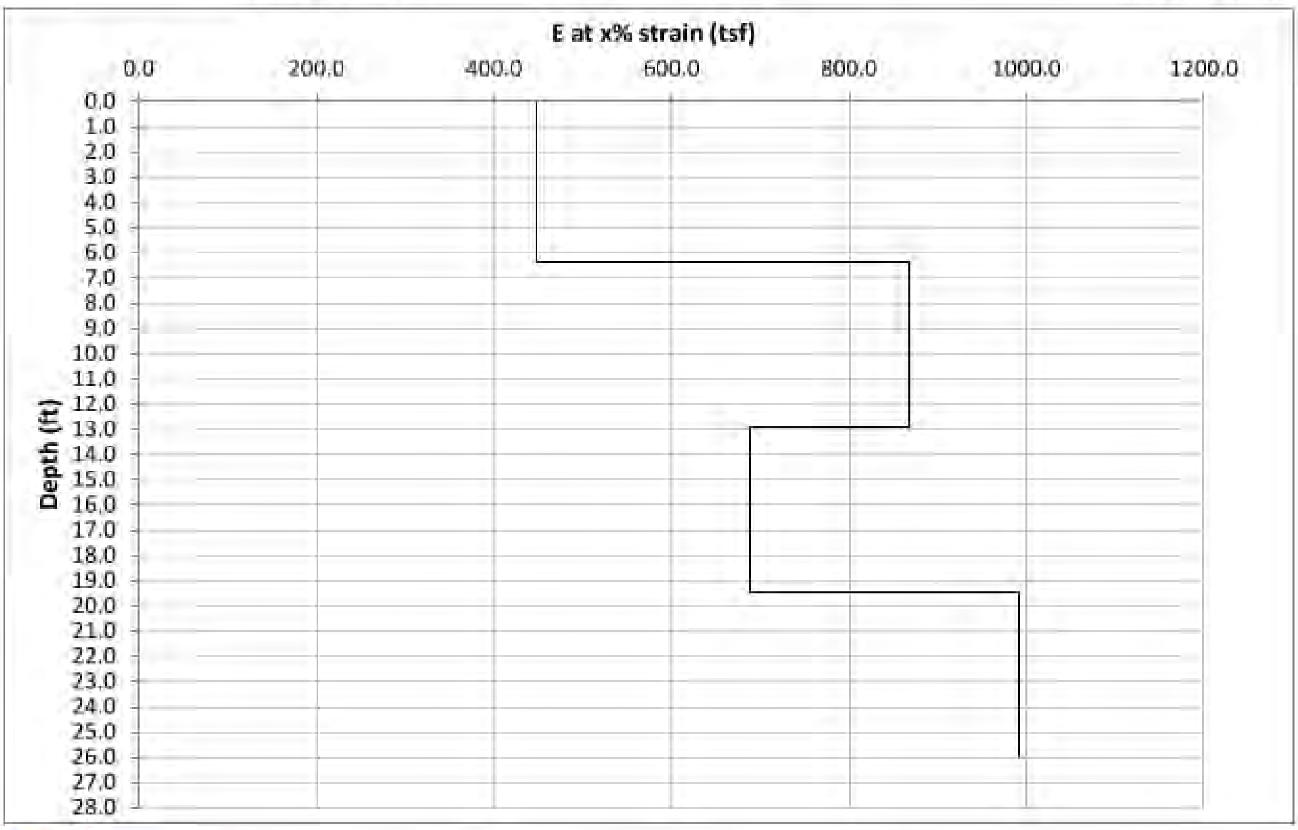
Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
579	6	0.0	112	521	0.26	1312.5	447.0
807	7	6.4	112	1012	0.26	2549.5	868.4
719	7	12.9	112	803	0.26	2022.9	689.0
862	7	19.5	112	1155	0.26	2910.3	991.2

Notes:

1. Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information*
2. Density = $\rho = \Upsilon_1 / g$ (where Υ_1 = unit weight in lb/ft^3)
3. Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs
4. Shear modulus = $G = \rho . v_s^2$
5. Youngs modulus = $E = G.(2.(1+v))$
6. Softened values of stiffness are calculated using Rollins equation: where γ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW06	Date:	4/6/2020

Test notes: CSW06 at SE corner, shaker at east end of east to west array. Shaker adjacent to power pole foundation. Undergroun gas, water (8-inch), cable & signalization.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings		
Northings		

Level (m)

Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
480	6	0.0	112	359	0.26	903.7	307.8
705	7	6.3	112	772	0.26	1946.5	663.0
605	7	12.9	112	569	0.26	1434.0	488.4
670	6	19.4	112	698	0.26	1759.8	599.4

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

4 Shear modulus = $G = \rho . v_s^2$

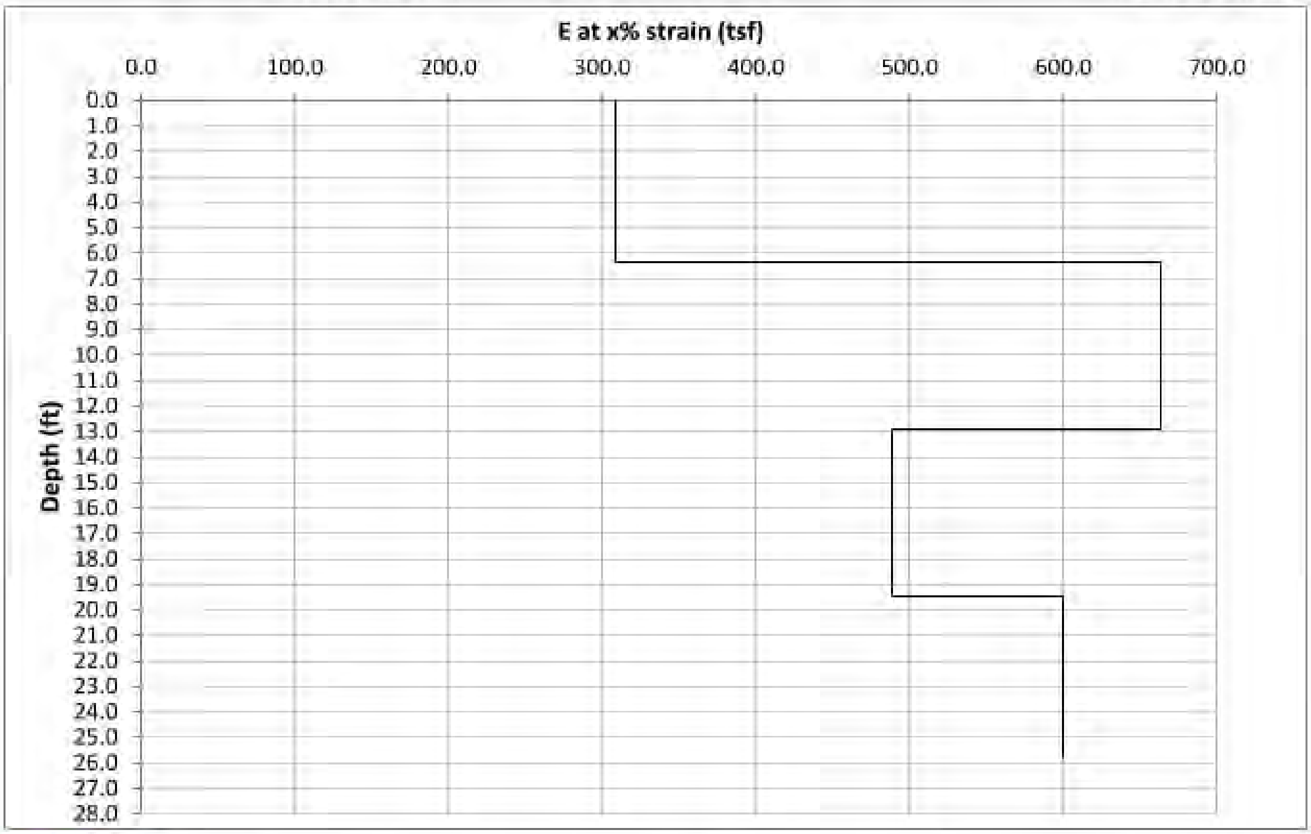
5 Youngs modulus = E=G.(2.(1+v))

6 Softened values of stiffness are calculated using Rollins equation:

where Υ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1 + 16\gamma\left(1.2 + 10^{20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW07	Date:	4/6/2020

Test notes: CSW07 at NE mast arm location at bottom of 2-foot bank, adjacent to fence line on right-of-way. Shaker at north end of N-S array.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below
See the GSS report ref GSS328 for conditions of use of data

Eastings

Northings ***Level (m)*** Strain level softened to: 0.1 %

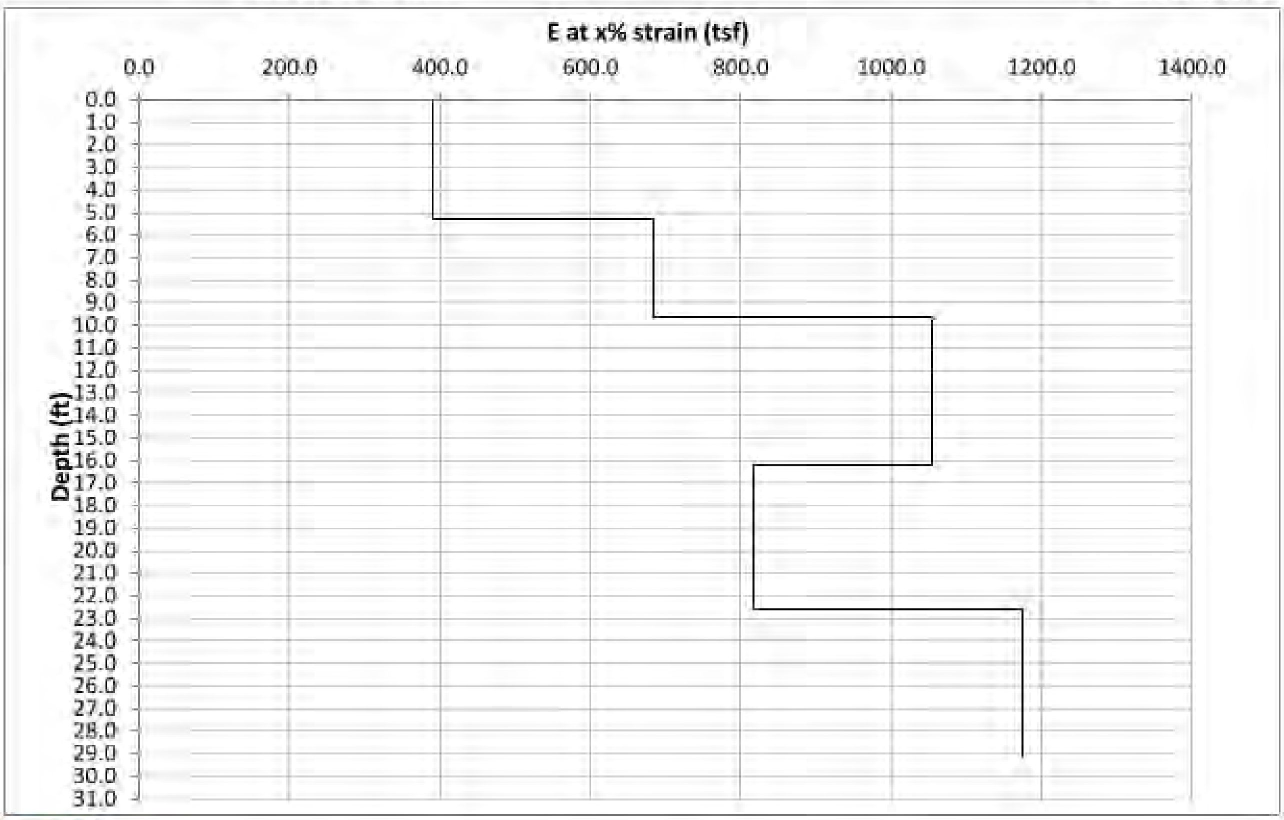
Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
540	5	0.0	112	453	0.26	1142.2	389.0
716	4	5.3	112	797	0.26	2008.7	684.2
889	7	9.7	112	1227	0.26	3092.1	1053.2
783	6	16.2	112	952	0.26	2398.8	817.0
938	7	22.6	112	1369	0.26	3448.8	1174.7

Notes:

1. Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Y=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*
2. Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)
3. Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs
4. Shear modulus = $G = \rho . v_s^2$
5. Youngs modulus = $E = G.(2.(1+v))$
6. Softened values of stiffness are calculated using Rollins equation: where γ is shear strain

$$\frac{G}{G_o} = \frac{1}{\left[1+16\gamma\left(1+10^{-20\gamma}\right)\right]}$$

Rollins et al. (1998)



Project:	Mast Arms Narcoossee & Cyrils	Report:	GSS328
Shift:	4/6/2020	Client:	UES
Test:	CSW08	Date:	4/6/2020

Test notes: CSW08 also at NE of intersection mast arm but at edge of sidewalk. Shaker at north end of north to south array.

Default values of density and Poisson's Ratio in the highlighted columns may be adjusted to known values
Strain level of softened value of Young's Modulus using the Rollins equation can be adjusted in the cell below.
See the GSS report ref GSS328 for conditions of use of data

Eastings		
Northings		

Level (m)

Strain level softened to: 0.1 %

Vs (ft/s)	Thickness (ft)	Depth (ft)	Unit weight (lb/ft^3)	Go (tsf)	v	Eo (tsf)	E at x% strain (tsf)
729	5	0.0	112	826	0.26	2080.4	708.6
805	6	5.1	112	1007	0.26	2537.0	864.1
938	7	11.6	112	1369	0.26	3448.9	1174.7
860	7	18.1	112	1151	0.26	2899.4	987.5
1041	6	24.7	112	1684	0.26	4242.7	1445.1

Notes:

1 Vs values have been determined from advanced inversion of field dispersion data. Vs values derived by inversion rely on assumptions of soil density and Poisson's Ratio. Where no project specific data is provided then default values of Υ=112 lb/ft^3 and v=0.26 are assumed. *Refer to above GSS report conditions for further information.*

2 Density = $\rho = \Upsilon_t / g$ (where Υ_t = unit weight in lb/ft^3)

3 Stiffness is provided in units of short tons/ft^2 or tsf where 1 short ton = 2,000lbs

4 Shear modulus = G = $\rho . v_s^2$

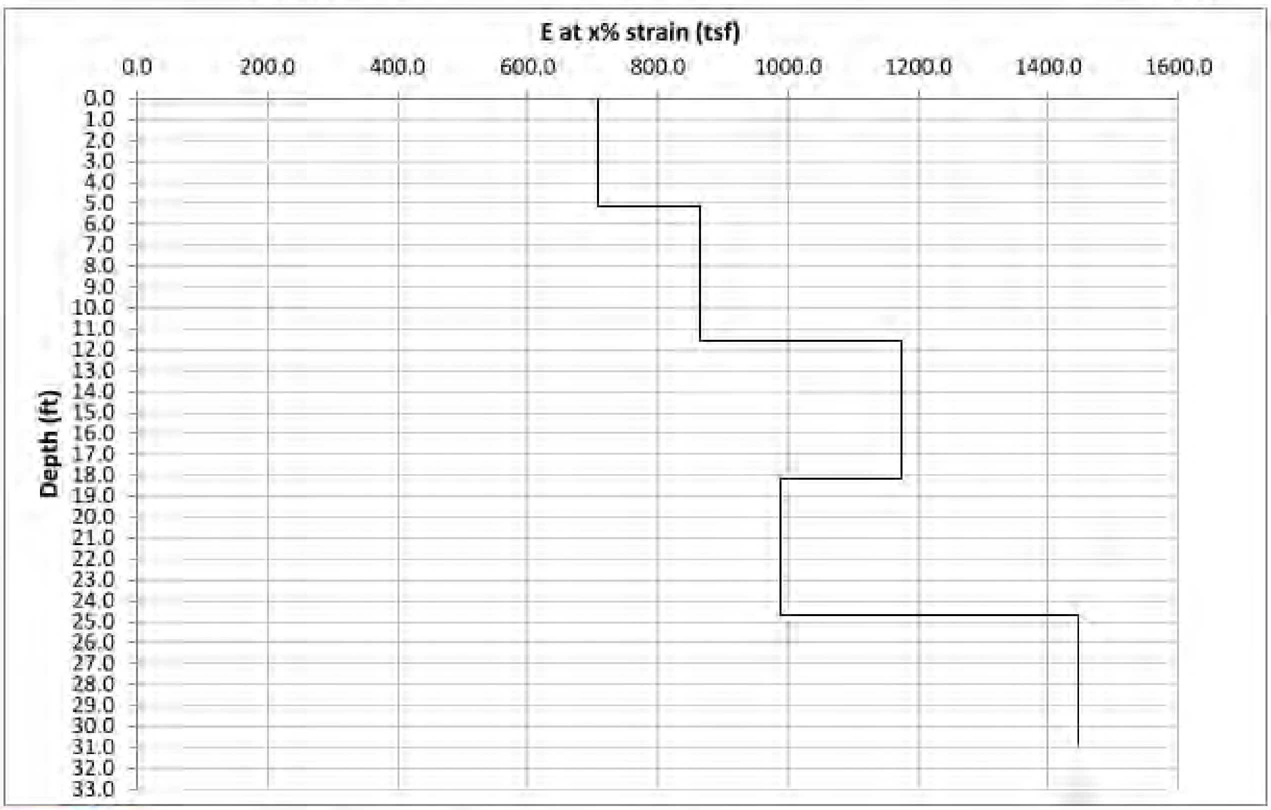
5 Youngs modulus = E=G.(2.(1+v))

6 Softened values of stiffness are calculated using Rollins equation:

$$\frac{G}{G_o} = \frac{1}{\left[1+16\gamma\left(1.2+10^{-20\gamma}\right)\right]}$$

where Υ is shear strain

Rollins et al. (1998)



Ground Stiffness Surveys

INTERPRETATION OF SHEAR WAVE VELOCITY VALUES

Ground Stiffness Surveys

SITE CLASSIFICATION USING V_s

V_s (m/s) for upper 30m of geologic profile	ASCE 7-10 seismic site class	ASCE 7-10 description
>1524	A	Hard Rock
762 - 1524	B	Rock
366 - 760	C	Very Dense Soil and Soft Rock
365 - 183	D	Stiff Soil
<183	E	Soft Clay Soil

From ASCE 7-10 Table 20.2-1 seismic site classification using V_{s30} Shear Wave Velocity

V_s RELATIONSHIP WITH UNDRAINED SHEAR STRENGTH

Dickenson, 1994 $V_s = 23S_u^{0.475}$

See PEER Report 2012/08 (2012) Guidelines for Estimation of Shear Wave Velocity Profiles

Vs (m/s)	Cu (kPa)	BS5930 classification: Shear strength of cohesive soils	Range kPa
49	5	Extremely Low	<10
69	10	Very Low	10-20
95	20	Low	20-40
133	40	Medium	40-75
178	75	High	75-150
249	150	Very High	150-300
345	300		

V_s RELATIONSHIP WITH RELATIVE DENSITY

Hasancebi and Ulusay, 2007 for sand $V_s = 131N_{60}^{0.205}$

See PEER Report 2012/08 (2012) Guidelines for Estimation of Shear Wave Velocity Profiles

Vs (m/s)	SPT N value	BS5930 classification: Relative density of granular soils	Range SPT N
151	2	Very loose	0-4
174	4	Loose	4-10
210	10	Medium dense	10-30
263	30	Dense	30-50
292	50	Very dense	>50
303	60		

V_s RELATIONSHIP WITH CBR

Vs (m/s)	Density (kg/m^3)	Go (MPa)	v	Eo (MPa)	E at 0.1% strain (MPa)	CBR
105	1800	20	0.26	50	17	1
130	1800	30	0.26	77	26	2
150	1800	41	0.26	102	35	3
165	1800	49	0.26	123	42	4
190	1800	65	0.26	164	56	6
210	1800	79	0.26	200	68	8
225	1800	91	0.26	230	78	10
235	1800	99	0.26	251	85	12

TRRL Laboratory Report 1132 (Powell et al, 1984) $E = 17.6(CBR)^{0.64}$ MPa

Notes & limitations

See GSS Guidance Note GN020 for limitations and references - to be used with relevant intrusive investigation information.

This document is intended to indicate potential approaches for the use of ACSW data by suitably qualified geotechnical engineers as part of a general design review. It may be subject to periodic review and change.

No guarantees as to accuracy are made and where necessary original references and relevant design guidance should be reviewed. ACSW test data should be reviewed against all available information on ground conditions as part of an appropriately scoped ground investigation.

Appendix D: Basis and interpretation of ACSW data

Basis and interpretation of ACSW data

Introduction

Advanced Continuous Surface Wave (ACSW) testing is a proprietary engineering testing system developed by Ground Stiffness Surveys LLC (GSS) based on the general methodology for Continuous Surface Wave testing set out in Heymann, 2007. Surface Rayleigh wave velocities over a range of frequencies are accurately measured using a short array of geophones to produce a *dispersion curve* plot of Rayleigh wave velocity (V_r) against frequency. These data can then be used to generate a reliable shear wave velocity (V_s) with depth profile, which in turn can be converted to a stiffness profile using standard relationships. Typical ACSW profile depths are 20 to 30-feet using the GSS Standard Shaker but are dependent on the stiffness of the ground (deeper profile depths are obtained in stiffer ground for the same test frequency).

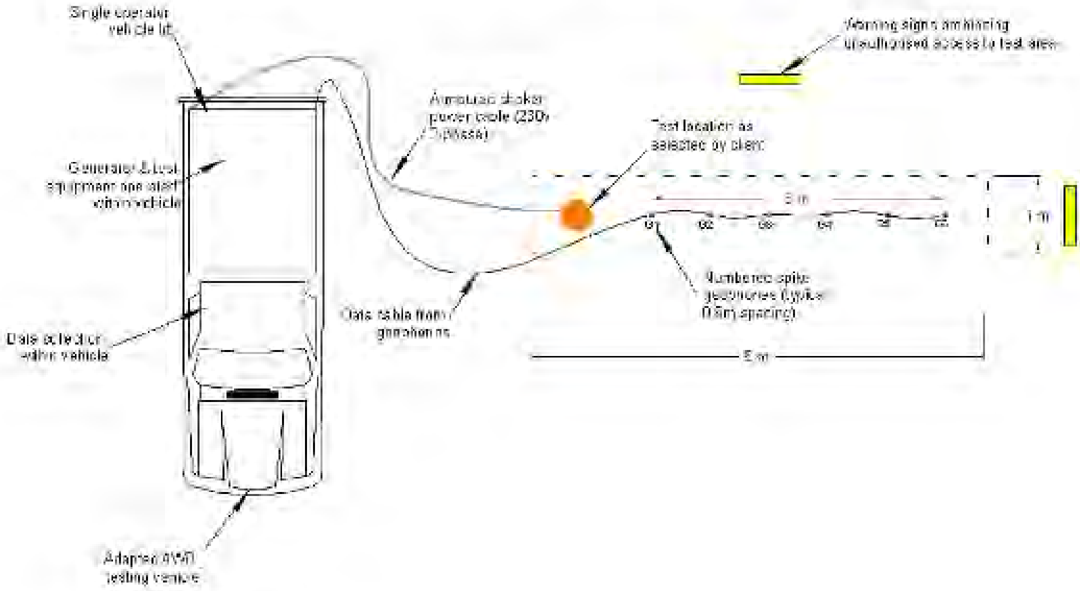


Figure 1 – Standard ACSW test layout

There is a wealth of publications available on the application of surface wave testing for shear wave velocity and stiffness profiling. The reliability of CSW data is such that it is the recommended means of assessing the stiffness of some kinds of geomaterials; for example, chalk (*CIRIA C574 Engineering in Chalk, 2002*).

The ACSW testing is controlled, reviewed and the results analysed using GSS's proprietary integrated custom testing software, C-DAS. The software allows easy comparison between tests in the field and during processing, by which data quality and consistency can be assessed. Test reports are automatically generated by the software, removing the risk of any transcribing errors.

ACSW measurement over 100 cycles at known frequencies allows effective exclusion of noise during data processing by C-DAS. C-DAS automatically compares phase angle consistency between geophones and measured against generated frequency, providing continuous calibration checks. Data out of tolerance is automatically removed. Outlying or highly scattered data can be graphically reviewed using C-DAS and removed from subsequent analysis.

C-DAS generates the following test plots, each of which provides valuable information on the ground profile:

- A *dispersion curve* of Rayleigh wave velocity against frequency
- A *simple inversion* average shear wave velocity (or stiffness) with approximate depth profile
- An *advanced inversion* shear wave velocity (or stiffness) with depth profile

Dispersion curve

The form of the *dispersion curve* defines the shear wave velocity (and stiffness profile). Test frequency data which are not consistent over the geophone array are removed automatically by C-DAS. Review and comparison of test profiles in C-DAS then allows any outlying data or parts of the *dispersion curve* which are unacceptably scattered to be removed.

For a layered deposit with increasing stiffness with depth (a '*normally dispersive*' profile), the form of the *dispersion curve* should be an even polynomial curve with a single inflection point within the lower frequencies. Changes from this form can indicate, for example, where significantly stiffer or softer layers are present (an '*inversely dispersive*' profile). Very rapid oscillations or breaks in the profile can indicate the presence of sharp stiffness contrast boundaries, which cannot be addressed by the available advanced inversion analysis methods but are reported when assessing the quality of data.

In some data sets, a '*multimodal*' response occurs where the ground is excited to behave in a different manner to the normal '*fundamental mode*', particularly at higher frequencies (shallower depths). This *multimodal* response can be apparent as:

- Very high Rayleigh wave velocities at low frequencies
- A rising dispersion curve at high frequencies
- Gaps or jumps in the dispersion curve

Multimodal data within the dispersion curve will affect the advanced inversion analysis process and expert user assessment of these effects is required. The presence of *multimodal* effects and any concerns over the resultant quality of analyses is commented on in the report.

Simple Inversion

The *simple inversion* profile is an average shear wave velocity (or stiffness) profile against approximate depth generated from the *dispersion curve* using a set of standard assumptions included in the report. Shear wave velocity (and stiffness) is generated from the measured Rayleigh wave velocity at each frequency applying conservative assumptions regarding Poisson's ratio and unit weight and using standard relationships which are relatively insensitive to the assumptions made.

Equation 1 (Heymann, 2007) - relationship between V_s, V_r and Poisson's Ratio (v)

$$\frac{V_r}{V_s} \cong \frac{0.874 + 1.117\nu}{1 + \nu}$$

Equation 2 - relationship between Vs, small-strain Shear Modulus (G_0) & soil density (ρ)

$$G_0 = \rho . V_s^2$$

The approximate depth of each data point in the *dispersion curve* is determined as a proportion of the measured wavelength. Common practice is that this is normally wavelength divided by 2.5 (Foti *et al.* 2017), but it can be locally calibrated to range between 2 and 4.

The *simple inversion* profile is a good indication of small-scale local variation in stiffness, which cannot be resolved by the *advanced inversion* process. The *simple inversion* allows qualitative comparison between tests and an independent check on the *advanced inversion* results. For *normally dispersive* conditions, the averaging effect of the profile will mean that the *simple inversion* will be conservative at any depth.

The *simple inversion* has been traditionally and successfully used for design purposes and construction control; however care must be taken in using these data in that:

- Depths are approximate only; more accurate boundaries may be generated by the *advanced inversion*
- In some circumstances, the averaging effect may mean that stiffnesses indicated may not be conservative (for example where the ground is *inversely dispersive*)
- Where *multimodal* data is present, this may provide an overestimate of stiffness (particularly at shallow depth)

In some circumstances (e.g. very complex or poor data) it may be possible only to present the *simple inversion*. Comments on the *simple inversion* data for assessment of the *advanced inversion* results are included in the report.

Advanced inversion

Advanced inversion involves the generation of a layered stiffness profile from the *dispersion curve* data. Published algorithms, selected depending on the extent of *multimodal* data, are used to generate a *synthetic dispersion curve* from an assumed ground profile, which is then compared with the *field dispersion curve* using standard model constraints in line with guidance given in Foti *et al* 2017. An appropriate automatic iterative search methodology is then selected, which refines the model until the minimum statistical misfit between the field and synthetic *dispersion curve* is achieved. Checks are made in the modelling process against the *simple inversion* profile, adjacent test locations and, where available, any information on known ground profile.

In using the *advanced inversion* profile, it should be noted that:

- The level of resolution of layer thicknesses and accuracy of layer boundary depth possible is around 1.5-feet at shallow depth, increasing to 3 to 6-feet at the typical maximum depth of the profile
- Within each modelled layer, the stiffnesses of any thinner layers will be averaged
- Transitional boundaries will be represented as a stepped boundary and allowance for this simplification will be required in subsequent analysis
- Strongly *multimodal* data are more difficult to model; the fit of any model generated and therefore the accuracy of any results will tend to be poorer
- Model profiles extending significantly beyond the depth of the *simple inversion* profile will not generally be reliable and hence will normally not be reported in the absence of other information
- It is theoretically possible in some cases for more than one solution to the advanced inversion. Whilst the modelling undertaken follows appropriate guidance and uses the *simple inversion* to limit this possibility, comparison with other tests and against available information on ground conditions is required
- In some cases, it may not be considered possible to present a reliable *advanced inversion* profile.

The fit of the *synthetic dispersion curve* to the field data is assessed statistically by C-DAS as a misfit value; the lower the misfit value the greater confidence in the model. The misfit of the final inversion model is reported qualitatively using the following ranges:

- >30m/s Very Poor
- ≤30m/s Poor
- ≤20m/s Fair
- ≤10m/s Good
- ≤5m/s Excellent

Having calculated the most likely layered profile, C-DAS provides a graphical indication of the uncertainty with the model in two formats, using a threshold of the change in the statistical fit of 5% or less. The first calculation is made by adjusting all layers in the model at once, for both stiffness and depth, which represent the most likely 5% error range in the inversion process. The second calculation shows the maximum extent of adjusting each layer individually to achieve a 5% change in the model fit and provides the maximum extent of the search area in which the model could reasonably lie. Larger error extent areas indicate greater uncertainty in the model. The modelling approach used and any site-specific cautions regarding the use or validity of data are included in the report (including the quality of fit).

Advanced inversion data is output as a shear wave velocity profile. The profile is provided in editable spreadsheet format which provides conversions to small-strain shear stiffness (G_0), small strain Young's modulus (E_0) and a strained softened value of E based on published functions. Default values of Poisson's ratio, unit weight and percentage strain in the spreadsheet can be adjusted based on site specific user knowledge and requirements.

Use of data

The ACSW report is intended for use by an experienced geotechnical engineer, considering the general and site-specific qualifications for the ACSW data set out above and in the test report, including the overall model fit and the extent of layer misfit bars presented. Suitable intrusive investigation data will be required to determine the nature of the materials included within the profiles for design purposes. As with all geotechnical test data, the user should:

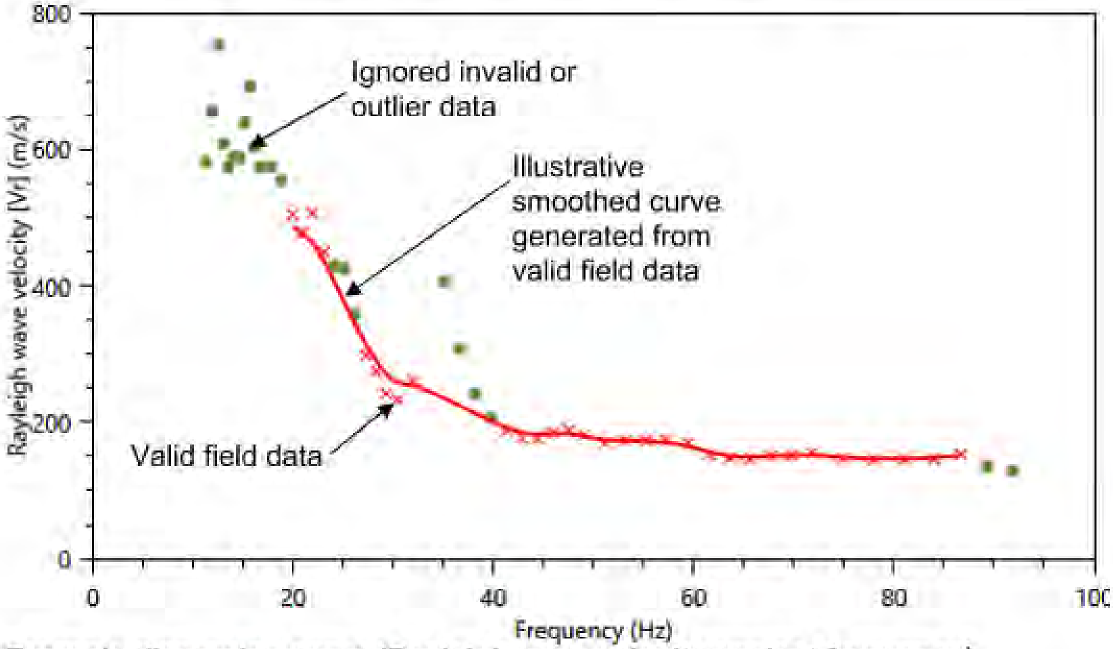
- Review the assumptions used based on available information and design requirements (these can be altered in the *advanced inversion* output spreadsheet)
- For stiffness data consider the application of strain-stiffness functions, drainage conditions and the appropriate stiffness modulus to apply
- Compare tests to assess the variability of data and to select design values and profiles
- Compare test data against other information including published information, intrusive investigation and other data
- Apply appropriate conservatism based on the intended design use, design codes and any uncertainties

References & further information

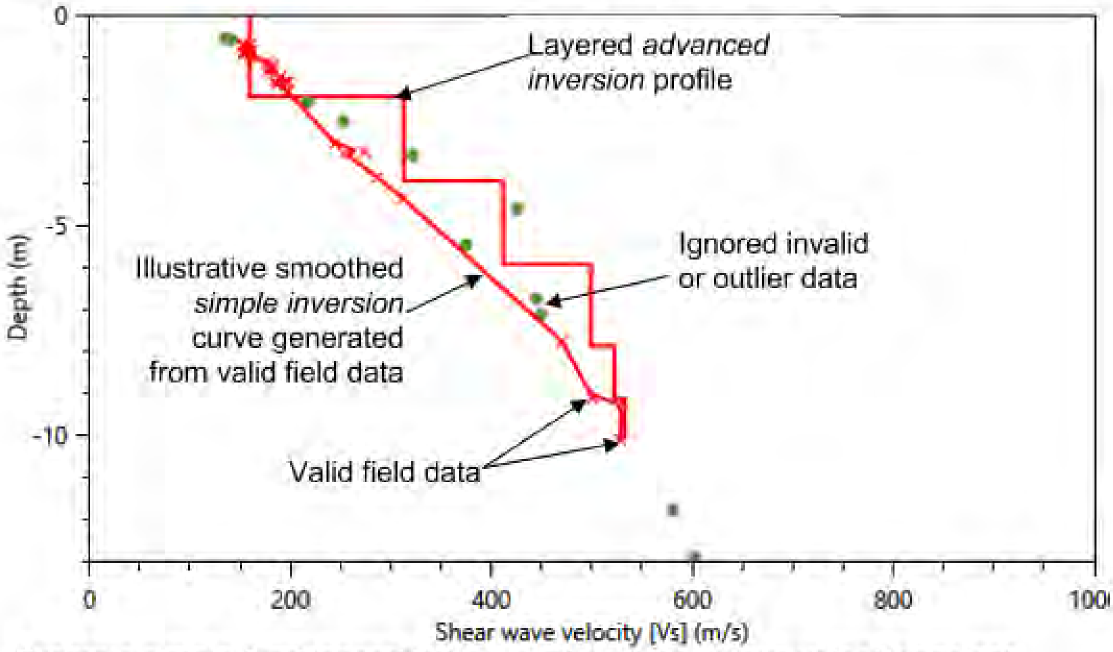
- Heymann, G. (2007) Ground stiffness measurement by the continuous surface wave test. *Journal of the South African Institution of Civil Engineering*. Vol.49, No.1, p25-31.
- Foti, S. *et al.* (2017) Guidelines for the good practice of surface wave analysis: a product of the InterPACIFIC project *Bull Earthquake Eng* DOI 10.1007/s10518-017-0206-7
- Leong, E. and Aung, A. (2013) Global Inversion of Surface Waves Dispersion Curves Based on Improved Weighted Average Velocity (WAVe) Method. *Journal of Geotechnical and Geoenvironmental Engineering*, 10.1061/(AS CE)GT.1943-5606.0000939 (Apr. 8, 2013).
- Wathelet, M (2008) An improved neighbourhood algorithm: Parameter conditions and dynamic scaling. *Geophysical Research Letters*, 35(9), DOI:10.1029/2008GL033256, 2008.

The above is intended as a brief introduction to ACSW testing for assessment by an experienced geotechnical engineer user. Additional information on the ACSW technique including specification, limitations and application is available on the GSS website. A full *range of references is also available. Further advice should be sought where there are concerns as to the use of ACSW test data reported.*

Key to C-DAS output graphs: *Appendix A*

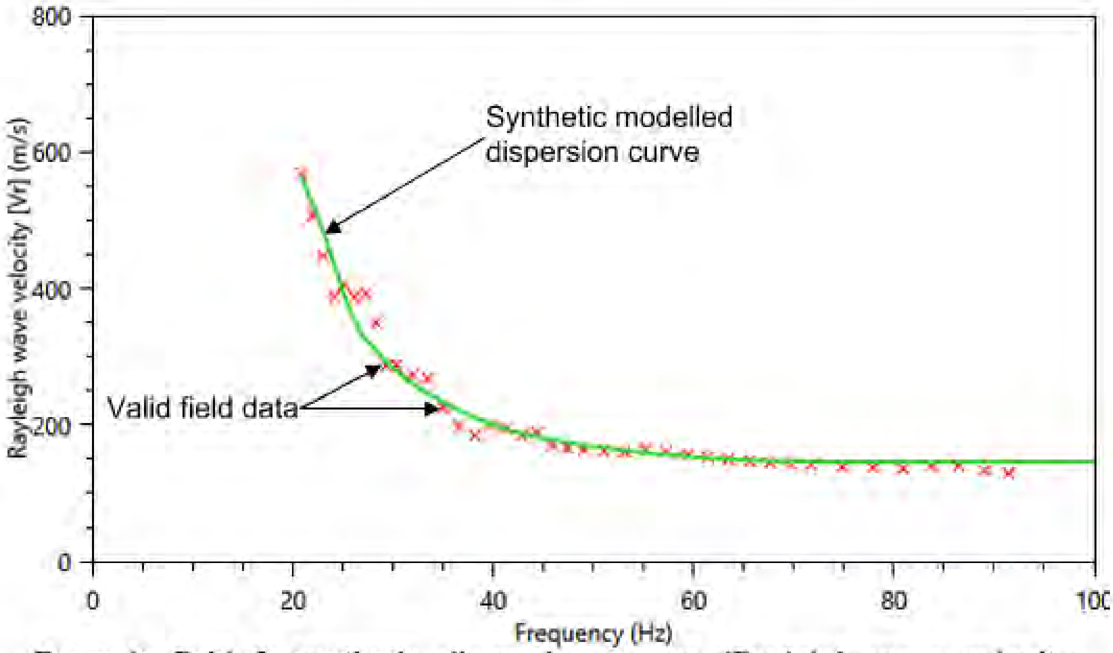


Example dispersion curve (Rayleigh wave velocity against frequency)

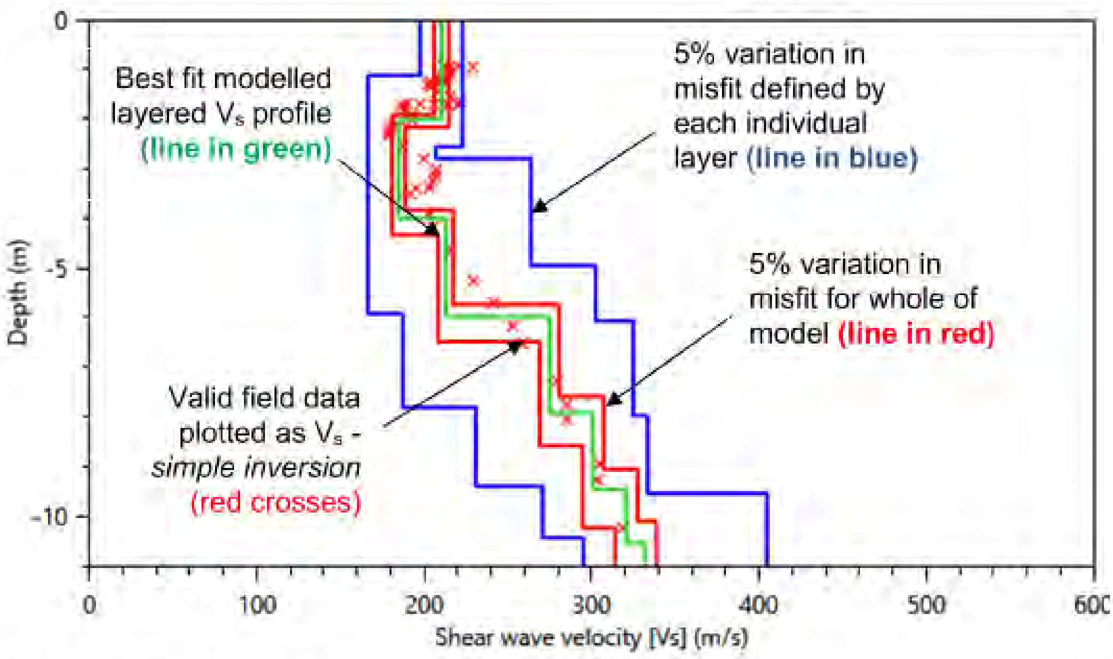


Example simple & advanced inversion plots (shear wave velocity against depth)

Key to C-DAS output graphs: *Appendix B*



Example field & synthetic dispersion curves (Rayleigh wave velocity against frequency)



Example modelled shear wave velocity profile

Ground Stiffness Surveys

Ground Stiffness Surveys

A bright new wave in geotechnics

More details are available at

www.GroundStiffnessSurveys.com