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Geology and Geophysics
Subsurface Exploration Non-Destructive Evaluation

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March 21, 2019
Via Email Pages 1-5 + Attachments

Vadnais Trenchless Services, Inc.
2130 La Mirada Drive
Vista, California 92081

Attention: Mr. Russell Pollard
Project Manager

Re: **SUMMARY REPORT**
Geophysical Investigation for Possible Subsurface Voids
Area 1- Stations 86+50 to 88+25
Venice Dual Force Main Sewer Tunnel
Los Angeles, California

INTRODUCTION

This report summarizes the geophysical investigation performed by Advanced Geoscience, Inc. at the referenced site to investigate possible subsurface voids. This field investigation was performed on March 11 and 12, 2019 in Area 1 shown in Figure 1 using two subsurface geophysical survey procedures: ground-penetrating radar (GPR) profiling and seismic shear-wave velocity profiling. The GPR profiles were evaluated for anomalous, higher-amplitude reflection patterns which are typically observed below interfaces bridging subsurface voids. The seismic shear-wave velocity profiles were generated using the multi-channel analysis of surface waves (MASW) method along two survey lines and evaluated for anomalous, lower shear-wave velocity zones which could be associated with deeper subsurface voids.

The following sections summarize our field procedures and methods of data processing and display. A concluding section discusses the geophysical profiles and our current evaluation of possible subsurface void conditions in this area.

FIELD SURVEY PROCEDURES

Advanced Geoscience's mobilized a survey crew to the site to conduct a two-day field program to record a series of closely-spaced GPR profiles and two seismic shear-wave velocity profiles across Area 1 shown in Figure 1. This field program required coordination with Vadnais Trenchless Services' site operations and the layout of traffic control.

A measurement grid was first set up across the survey area to reference the locations of the GPR and seismic profiles. This measurement grid was referenced to a baseline set up along the curb face on the west side of Via Marina as shown on the grid maps in Figures 2A and 2B.

The GPR profiles were recorded along grid lines paralleling Via Marina spaced 2-feet apart for higher-density subsurface coverage. This GPR profiling started from the edge of Shaft No. 8 and extended to the south parallel to the force main alignment to cross over a ground settlement area where possible subsurface voids could occur. The GPR profiles extended 170 feet to the south of Shaft No. 8 and 44 feet east of the curb line shown in Figures 2A and 2B.

The GPR profiles were recorded using a higher-power, SIR System-2000 manufactured by Geo-Physical Survey Systems, Inc. This GPR system was equipped with 400 and 200-MegaHertz (MHz) radar antennas. This system was used to record radar waves transmitted into the ground in a continuous scanning mode as the antennas were moved slowly along the grid lines. The 400-MHz GPR profiles were recorded along grid lines spaced 2-feet apart to image possible void spaces immediately below the pavement layer in the upper 5 feet. The 200-MHz GPR profiles were recorded along grid lines spaced 4-feet apart for a deeper investigation of possible voids to 10 feet below ground surface (BGS).

Two seismic survey lines designated as Lines 1 and 2 were also set up across Area 1 for the MASW shear-wave velocity profiling. The positions of Lines 1 and 2 are shown in Figures 2A and 2B. The centers of these survey lines were positioned to cross over the 54-inch force main which is about 40 feet BGS in this area.

Each survey line was set up with 48 geophones spaced 3-feet apart which were connected to a Seistronix EX-6 data recording system. The geophones were 4-Hertz, vertically-aligned velocity transducers commonly used for surface wave surveys. To improve the data recording the geophones were firmly spike-mounted to sand bags placed on the asphalt surface.

The following procedures were used to record "active source", 30-channel, MASW data for shear-wave velocity profiling of the upper 60 feet.

1. The seismic energy source was generated for each recording using a 20-pound sledge hammer. This energy source was first positioned in-line at 6-foot offset from the first geophone position. The sledge hammer was used to make three impacts on a heavy steel plate placed on the ground surface. The seismic vibration patterns from each impact were recorded into the first 30 geophone channels set up on the survey line. The

recordings from the three impacts were summed together to increase the signal to noise ratio. Two separate "field record" files were saved at this offset location with 1.2-second recording time and sampling rate of 0.5 milliseconds.

2. The seismic energy source was moved forward 6 feet to record the next source point. The pattern of 30 active geophone channels was also moved forward 6 feet. The above recording procedures were repeated. This process of recording source points at 6-foot intervals down the survey line was continued until the last geophone position in the active pattern of 30 geophones reached the end of the survey line.

DATA PROCESSING AND DISPLAY

The 400 and 200-MHz GPR profiles underwent color-amplitude enhancement and re-display on a computer screen in our office. These enhanced profiles were evaluated for evidence of possible subsurface void conditions. The areas where we detected anomalous, higher-amplitude reflections indicating possible voids were delineated on the grid maps in Figures 2A and 2B.

The field records from the MASW surveys were processed using the SurfSeis software developed by the Kansas Geological Survey (www.kgs.ku.edu/software/surfseis). SurfSeis was used to conduct MASW data processing and modeling. The field records were first used to generate wave field amplitude displays of the phase velocity versus frequency. These displays were then used to pick dispersion curves showing our evaluation of the Rayleigh waves (fundamental mode) phase velocity versus frequency variation. The set of dispersion curves generated for each survey line were used to conduct a least-squares inversion to calculate 1D models of Vs layering to a depth of 65 feet that simulated a good fit to the picked dispersion curves. For consistency each 1D Vs profile was generated using a 7-layer model with variable thickness layers. The location of each 1D Vs profile was referenced to the seismic stationing spaced 3-apart.

The complete set of 1D Vs profiles for each survey line were gridded by SurfSeis and color-contoured using the Surfer software (www.goldensoftware.com/products/surfer) to prepare the 2D Vs profiles for Lines 1 and 2 shown in Figures 2A and 2B. The same scale and color velocity spectrum was used to image shear-wave velocity layering on each of these profiles.

DISCUSION OF RESULTS

The higher resolution 400-MHz GPR profiles did not show patterns of anomalous, higher-amplitude reflections starting at the pavement-to-ground interface which would indicate thicker void conditions immediately below the pavement surface. However, both the 400 and 200-MHz profiles did show two areas where deeper anomalous reflections could indicate possible void conditions. These areas were detected between grid lines 10 and 30 feet south of Shaft No. 8. The approximate lateral bounds of these two areas are shown in Figure 2A with the estimated depths to their reflection interfaces. It is recommended that each of these areas be further investigated by cone penetrometer tests (CPTs) or borings to help rule out the possibility of voids. Locations for positioning exploratory CPTs or borings in these areas are shown in Figure 2A.

It also recommended that an exploratory CPT or boring also be positioned between grid lines 70 and 80 feet south of shaft No. 8 as shown in Figure 2A in the center of an area where the GPR profiles reveal a down-dropped surface which could possibly indicate deeper ground subsidence. Figure 2A shows the approximate lateral bounds of this down-dropped area.

The GPR profiles also showed reflections indicating the former excavation and fill trench area associated with the east-west sewer line crossing Via Marina. These north-south oriented GPR profiles also detected various pipeline alignments. However, it is noted that not all subsurface utility lines and abandoned pipelines in this area where accurately detected and shown on the maps in Figures 2A and 2B. The construction plan drawing and direct investigations should be used to confirm the locations of subsurface utility lines and other obstructions.

The seismic shear-wave velocity profiles in Figures 3 and 4 show two zones of less than 500 ft/sec at deeper locations below 40 feet BGS. The positioning of each of these locations near the center of the valid shear-wave velocity profiling area (shown by the solid line in Figure 2A) is consistent with the location of the void area associated with 54-inch diameter force main. In addition to these areas, there are two other localized areas above the 40 foot depth shown on the shear-wave velocity profile for Line 2 (in Figure 4) where lower than 500 ft/sec velocity zones could indicate the possibility of deeper subsurface void conditions in the saturated alluvium. It is recommended that each of these areas also be investigated by exploratory CPTs or borings.

Advanced Geoscience appreciates this opportunity to be of service to Vadnais Trenchless Services and the City of Los Angeles. If you have any questions or additional requests concerning this investigation please contact the undersigned.

Sincerely,

Advanced Geoscience, Inc.

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Attachments:

Figure 1-	Construction Plan Drawings Showing Location of Area 1
Figures 2A and 2B-	Site Grid Maps for GPR and Seismic Shear-Wave Velocity Profiling
Figure 3-	Line 1 Seismic Shear-Wave Velocity Profile
Figure 4-	Line 2 Seismic Shear-Wave Velocity Profile

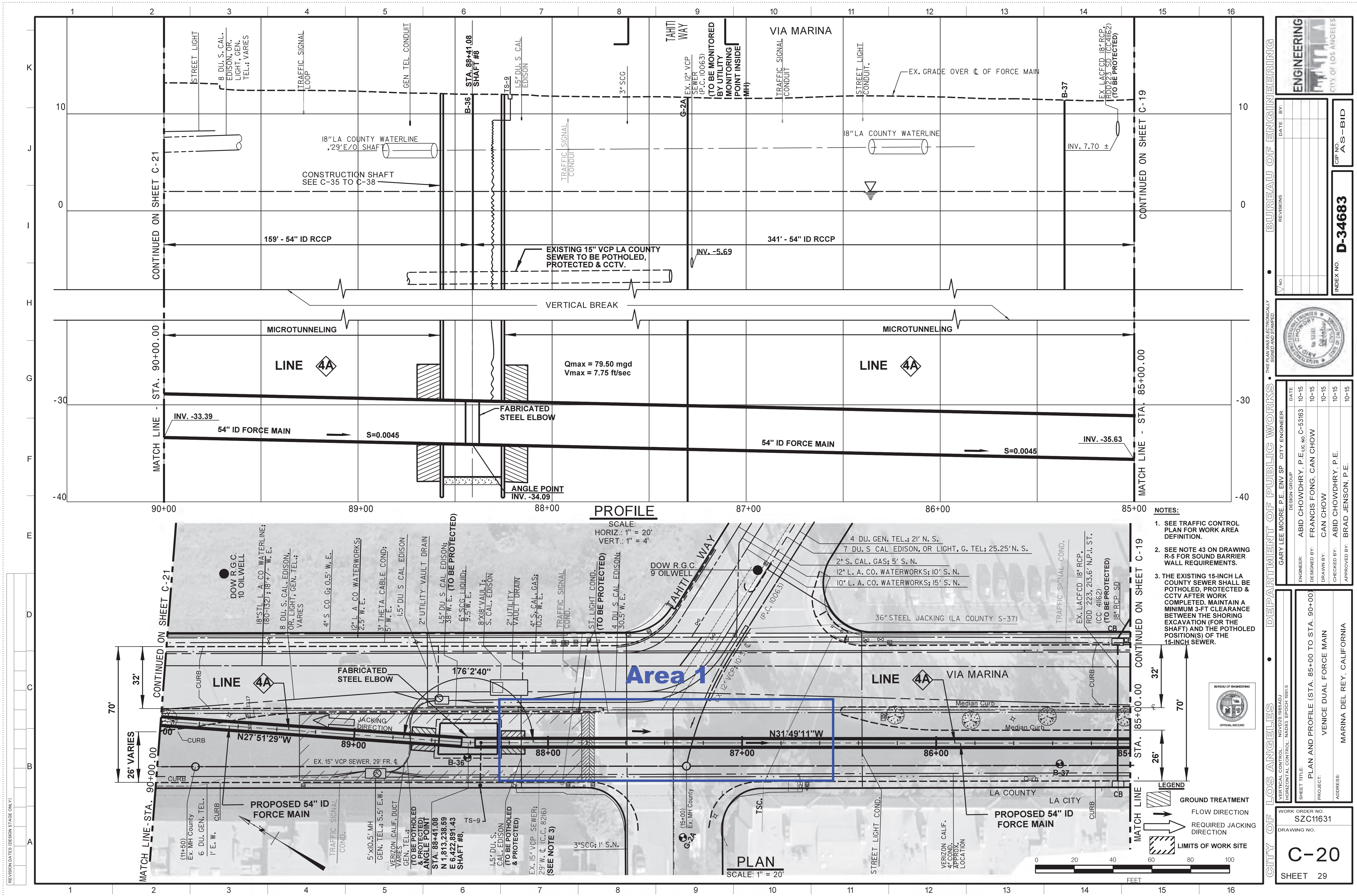
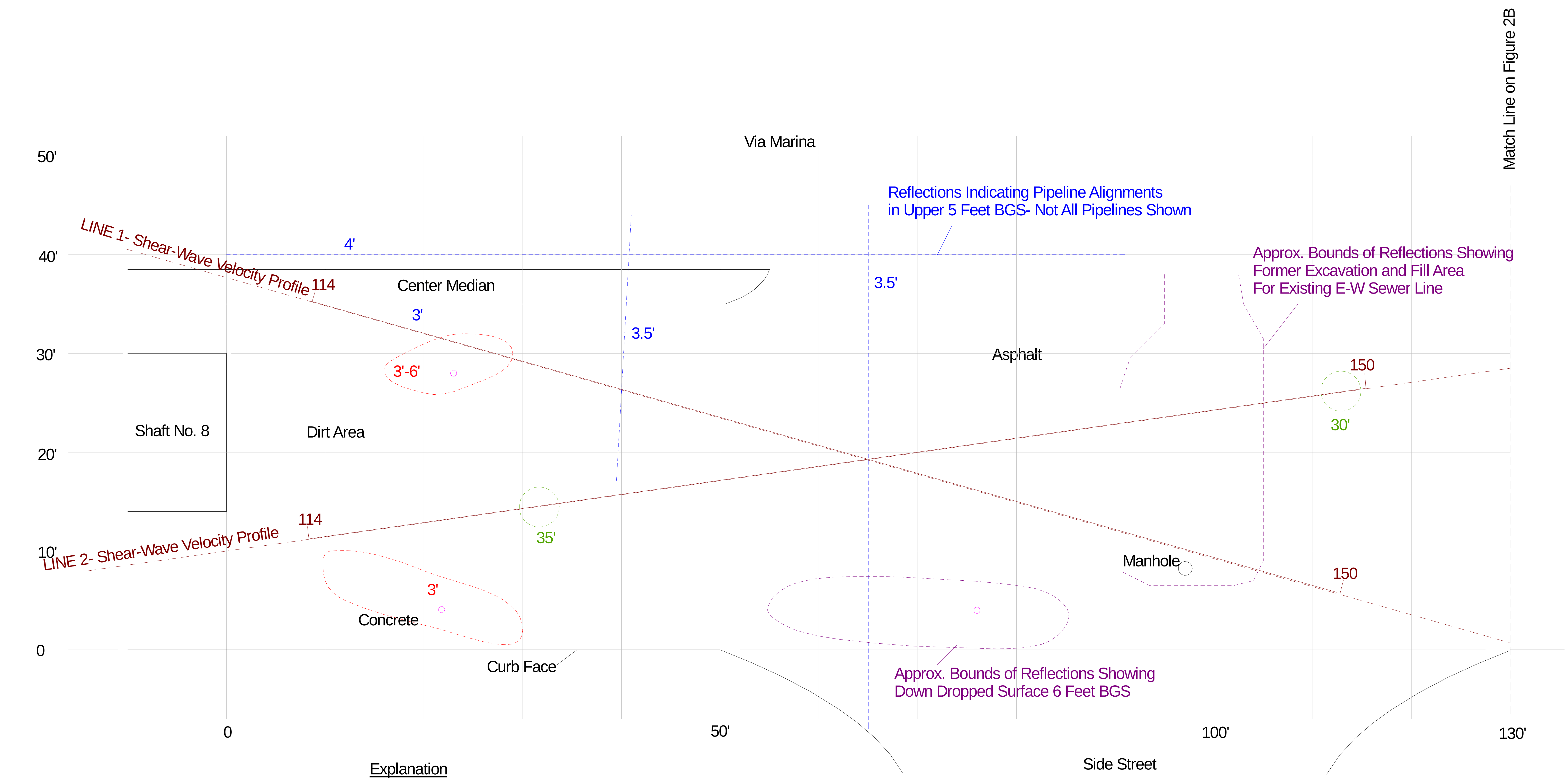


Figure 1 ADVANCED GEOSCIENCE, INC.



Explanation

35' Center of Anomalous Lower Seismic Shear-Wave Velocity Zones with Estimated Depth Below Ground Surface (BGS)

3'-6' Approx. Bounds of Anomalous Higher Amplitude Reflections Indicating Possible Subsurface Voids With Estimated Depth BGS

Recommended Locations for Exploratory CPTs/Borings

Approx. North
Scale 1 Inch= 10 Feet

Grid Map for Ground-Penetrating Radar and Seismic Shear-Wave Velocity Profiling
For Investigation of Possible Subsurface Voids
Venice Dual Force Main Stations 86+50 to 88+25

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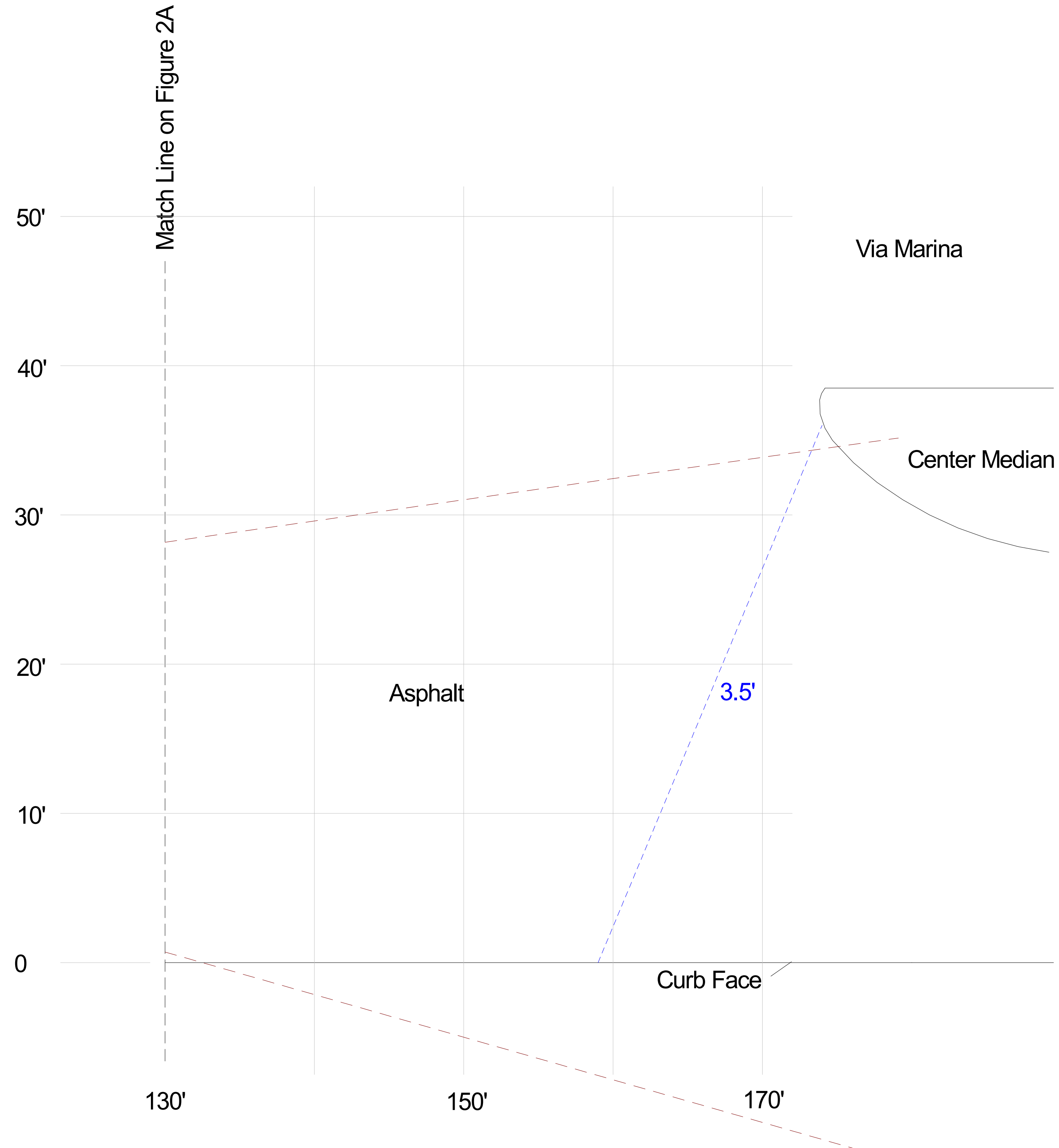
Figure 2A



Approx. North
Scale 1 Inch= 10 Feet

Grid Map for Ground-Penetrating Radar and
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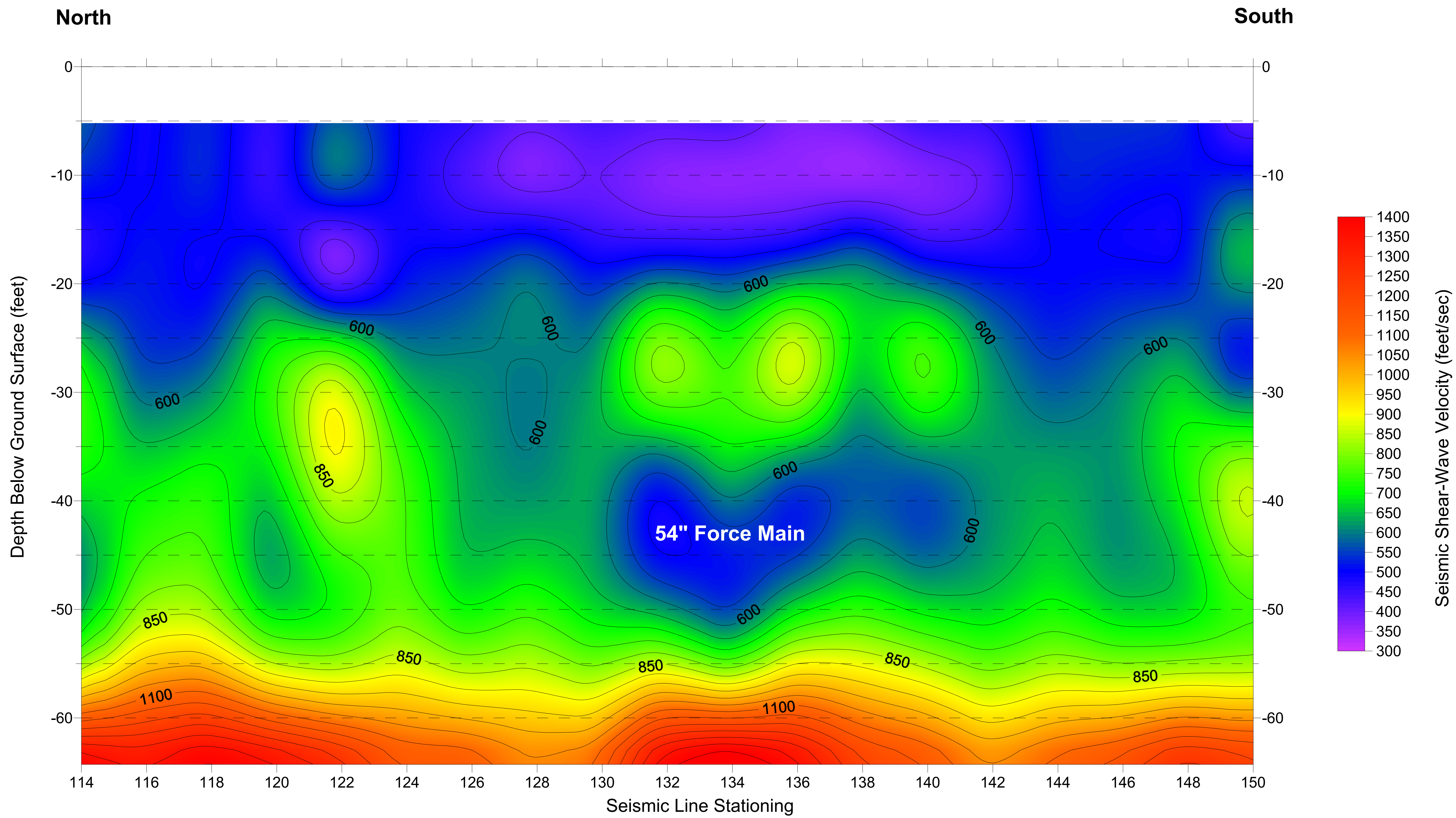
Figure 2B

Line 1- Seismic Shear-Wave Velocity Profile



Based on SurfSeis MASW Processing
Dispersion Curves Fitted with 7-Layer Velocity Models

Horizontal and Vertical Scales 1 inch= 10 feet

Line 1- Seismic Shear-Wave Velocity Profile
Seismic MASW Surveys for Venice Force Main Subsurface Voids Investigation
Marina Del Ray   Los Angeles, California

Figure 3
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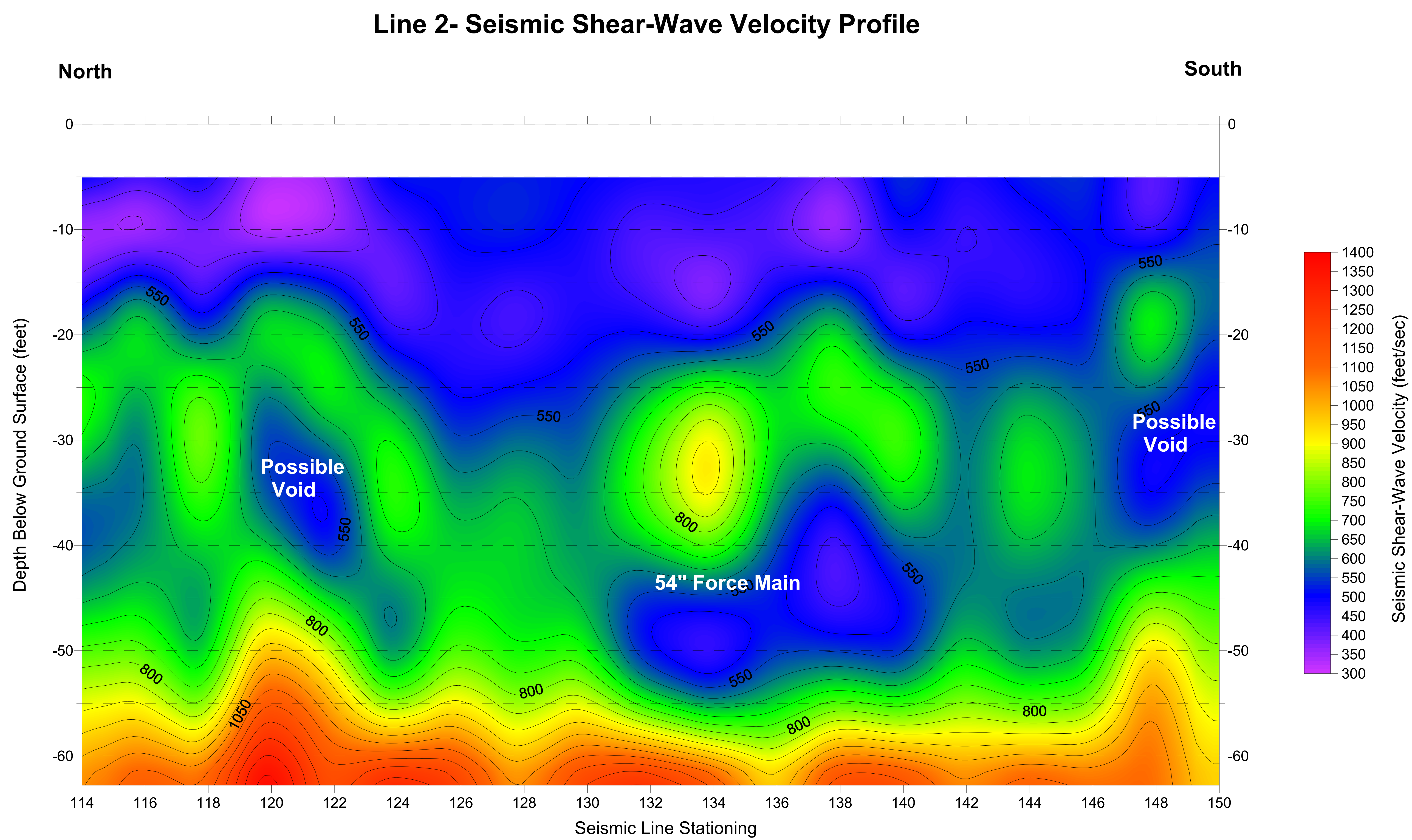

Based on SurfSeis MASW Processing
Dispersion Curves Fitted with 7-Layer Velocity Models

Horizontal and Vertical Scales 1 inch= 10 feet

Line 2- Seismic Shear-Wave Velocity Profile
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Figure 4
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