GEOPHYSICAL DATA REPORT

US95 MP ES 0.5

January 2015

NEVADA DOT
GEOTECHNICAL ENGINEERING

MATERIALS DIVISION

STATE OF NEVADA

DEPARTMENT OF TRANSPORTATION

MATERIALS DIVISION

GEOTECHNICAL SECTION

GEOPHYSICAL DATA REPORT
US95 PAVEMENT PRESERVATION, SLOPE FLATTENING, SHOULDER WIDENING, AND OTHER IMPROVEMENTS

.796MI SOUTH OF DRY WASH TO 1.198MI SOUTH OF ES/NY COUNTY LINE
MP ES 0.00 TO ES 44.19

E.A. 73784

January 2015

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TABLE OF CONTENTS

Disclaimer

The data and commentary provided in this report is for informational use only. The data presented herein is valid for only the locations where testing was performed. The statements made are professional opinions based on individual interpretation of the data. The actual conditions could vary significantly from reported values. This report is intended to be a general estimate for the typical type and condition of geological features in the project area. Variability in subsurface features, including rock type, state of weathering, and competency should be expected.

Limitation of Methods

Geophysical exploration methods should never be used as the sole and definitive source of information for rippability studies. Many variables can affect the rippability of a rock material including age, composition, competency, and jointing characteristics. Also, excavation equipment other than referenced may encounter different results, as ability to penetrate can be more important than seismic velocity. This information can be used to generally characterize the site and aid in expanded subsurface exploration techniques. Additional exploration including borings, core holes, or trench excavations could be used to provide further verification of the reported values. Geophysical data presented is valid for only the locations where testing was performed.

Picture 1: Looking South along U.S. 95 near M.P. ES 0.5

1.0 Introduction

1.1 Project Location and Purpose

The Nevada Department of Transportation (NDOT) has planned to make pavement, safety, and operational improvements to U.S. 95 in Esmeralda county from just south of Tonopah, Nevada on the north to near the Nye county line on the south. The project, to be contracted, aims to flatten slopes, widen roadway shoulders, and perform pavement reconstruction. The improvements are to be constructed from MP ES 0.00 to ES 44.19. As part of these improvements, a protruding rock and soil slope near the south end of the project will need to be cut to allow for wider shoulders and shallower back slopes.

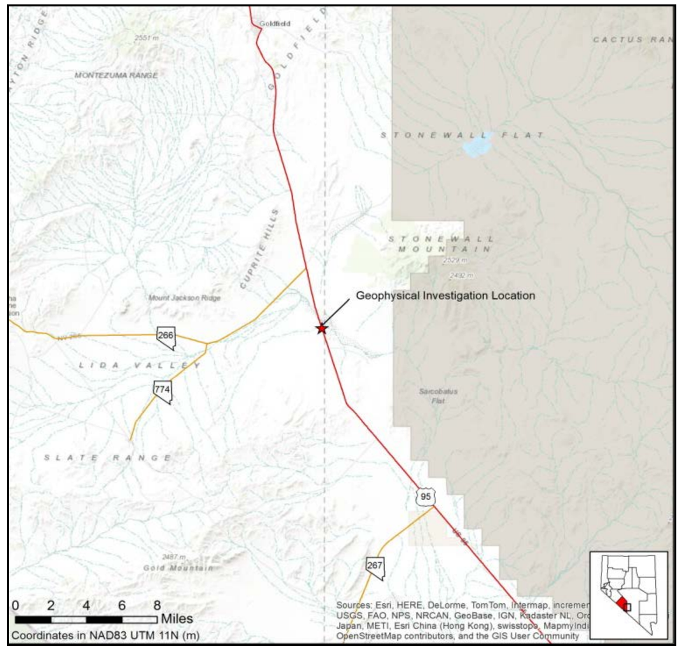

Figure 1: Project Investigation Location Map
(ESRI ArcMap, BaseMap-World Topographical)

1.2 Project Investigation

The main purpose of this report is to characterize the rippability of a rock slope identified along the alignment. This report will also summarize the results of a geophysical site study performed in the spring of 2014 and provide general interpretations of the collected data. During the geophysical survey, seismic data was collected at four locations along the roadway alignment, utilizing both seismic refraction and ReMi ™ (Refraction Mictrotremor) methods. The locations were selected in an attempt to be the most representative of the overall geologic formation.The site geology, field exploration methods, and analysis and interpretations will be discussed in more detail later in the report.

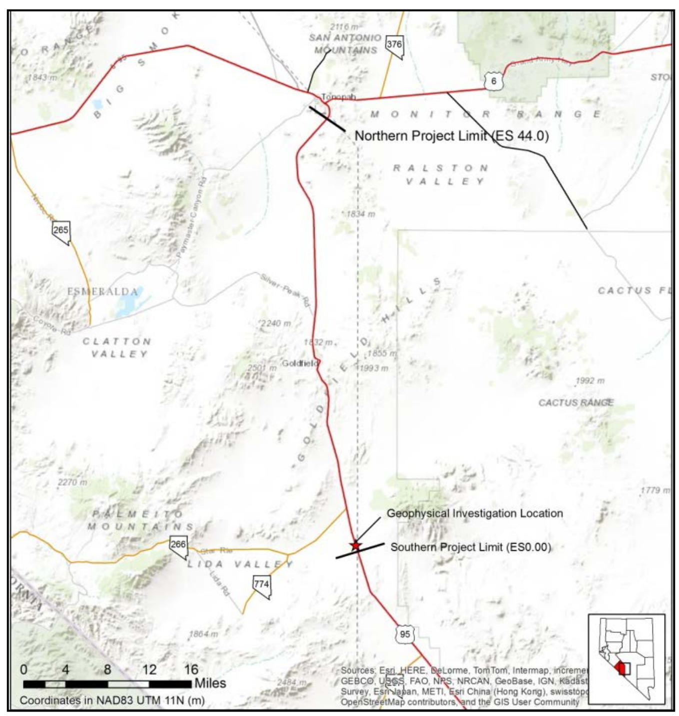

Figure 2: Project Limits Map
(ESRI ArcMap, BaseMap-World Topographical)

2.0 Site Geology

The geologic information was obtained from United States Geological Survey (USGS) and Nevada Bureau of Mines and Geology (NBMG) geologic mapping. The geologic map covering this area was produced at the 1:250,000 scale. The project location and surrounding area is characterized by several alluvial and lakebed deposits including Q_{al} (Alluvium Undifferentiated), Q_{ya} (Younger Alluvium), and Q_{pl} (Playa, Lake Bed, and Flood Plain Deposits). The geologic unit T_{t3} (Younger Silicic Ash Flow Tuffs (Miocene)) is also mapped in the area as the primary bedrock type. Due to the scale this geologic map is produced, it is believed that some of the lower lying bedrock outcrops were not mapped, including the location of this survey. Photographs of the outcrop are shown below.

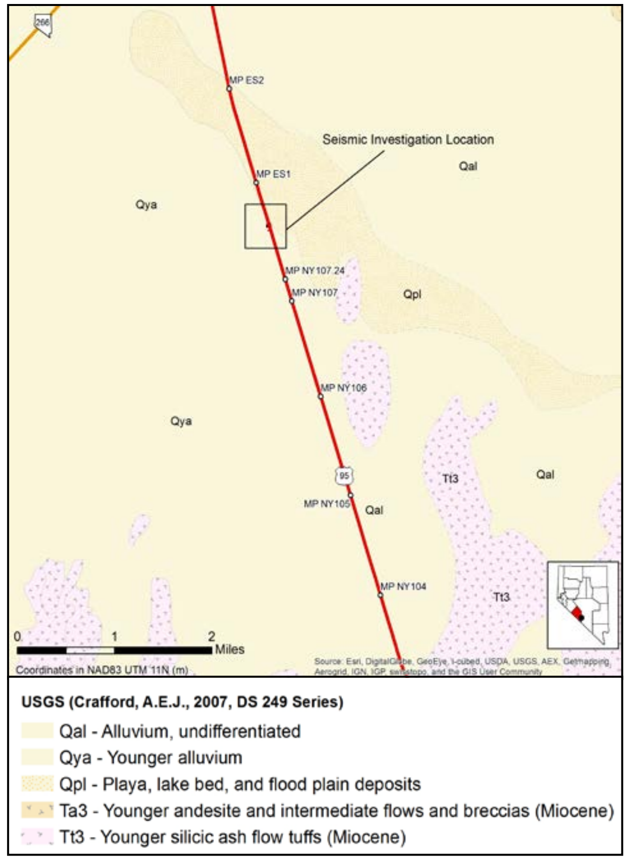

Figure 3: Geologic Map of Investigation Area

Picture 2: Bedrock west of US95 near MP ES 0.6

Picture 3: Bedrock west of US95 near MP ES 0.6

3.0 Field Exploration Method

The field exploration consisted of collecting geophysical data at four different locations along the outcrop . The locations were selected to be representative of the geological formation in this area. Since bedrock and soil properties can vary greatly depending on the location(s) tested, caution should be used when utilizing the data. The equipment and procedures for each method will be described below.

3.1 Equipment and Procedures

General

Both methods, seismic refraction and ReMi™, are able to utilize the same basic equipment for data collection. The geophysical data is collected with a 220 ft. long seismic array (line) cable with 12 available channels for geophones. The default geophone spacing on the cable is 20 ft. on center when fully stretched. Twelve 10Hz vertical P-wave geophones are attached to the cable.

The data is recorded using a 24 channel DAQlink III Seismograph produced by Seismic Source. VibraScope software installed on a Windows based Dell ”toughbook” is used to configure the seismograph for data acquisition as well as observe recorded records, pre-process seismic data, and save noise records for further analysis.

Individual geophones were located for display purposes using resource grade Global Positioning System (GPS) handheld unit (Trimble GeoXT). These coordinates were used to display the seismic line locations on the map and to calculate approximate stationing and offset. The horizontal accuracy is estimated to range from 1 ft. to 3 ft. with post processing. In the case where topographical elevation variation along the line exceeds 3% to 5% of total line length, relative geophone elevations and distances are recorded using a construction grade survey instrument. These measurements may or may not be tied into an existing benchmark, depending on project location and purpose.

Seismic Refraction

For this survey, geophone spacing was set at 20 ft. for seismic lines one, two, and four. Shot locations were located at 10 ft. offset from each end, as well as between geophones 3 and 4, at geophone 6, and between geophones 9 and 10 for intermediate shots. For seismic line three, geophone spacing was set at 10 ft. to increase the resolution of the velocity model. The shot locations were identical to seismic lines one, two, and four.

A 12 lb. sledge-hammer and metal striking plate were used to generate the “impulse” p-wave energy for the seismic refraction survey. The sledge hammer is equipped with a piezoelectric trigger, which starts the record at t=0 when the hammer impacts the steel plate. For seismic refraction, noise data was collected in 0.5 second recording periods with a .125ms sampling interval. The individual strike records are stored in SEG-2 format. Records are not stacked or modified until final processing. In general, 10

Individual noise records (10 hammer strikes) are collected at each plate shot location along the line. The number of offset shots and their distances, as well as intermediate line shot locations are determined based on the inferred complexity of the subsurface and topographical variation along the line. The minimum is generally one offset shot off each end of the line and three intermediate locations.

ReMi™

For this survey, geophone spacing was set at 20 ft. for seismic lines one, two, and four. For seismic line three, geophone spacing was set at 10 ft. to increase the resolution of the velocity model.

Background (ambient) noise was used to generate seismic waves during the ReMi™ survey. Occasionally, light hammer strikes offset from the end of the seismic line were utilized to increase the high frequency energy during noise recordings. This process can aid interpretation of subsurface shear wave velocity at shallow depths. Occasionally, walking and other light disturbances can be used to increase the amplitude of noise energy over a variety of frequencies when working in quiet environments. Noise recordings for ReMi™ analysis were 30 second recording periods with a 2ms sampling interval. Each individual record is stored in SEG-Y format. In general, 10 individual recordings are made for each line. Individual records are not stacked or modified until final processing.

Picture 4: Seismic Data Collection for Seismic Line # 1

4.0 Analysis Methods and Data Interpretation

The analysis and interpretation of the seismic data collected for this project was performed by a consultant, Optim of Reno, NV. The field exploration, data acquisition, location survey, and preliminary data verification was performed by NDOT. A short description of each process is described below.

4.1 Seismic Refraction

The seismic refraction data collected was analyzed using proprietary software, SeisOpt® @2D™ and SeisOpt® @Pro™ developed by Optim of Reno, NV. The analysis and interpretation of the data is a proprietary method owned and developed by Optim. The method uses a simulated annealing algorithm to invert for velocities within the subsurface from refraction picks. This method is based on Simulated Annealing Optimization (SA) and can be used to find optimum solutions to complex subsurface imaging problems in the geotechnical and energy industry (Optim Software, 2014).

The algorithm works by first discretizing the model space into grids. The geophone spacing determines the grid dimensions and these can be different in horizontal and vertical directions. The travel time picks and array geometry (shot and geophone locations, including elevation) are then read in and the algorithm samples thousands of models before settling on the one that best fits all the picks from all the shots equally well. In this process, velocity values for each grid point are determined thus allowing for lateral and vertical velocity variations and imaging of anomalous zones (Optim Software, 2014).

4.2 ReMi ™ (Refraction Microtremor)

The noise data collected for ReMi™ analysis was analyzed using the proprietary software SeisOpt R ReMi™, developed by Optim of Reno, NV. The analysis and interpretation of the data is a proprietary method owned and developed by the University of Nevada, Reno. The process is currently licensed exclusively to Optim of Reno, NV (Optim Software, 2014).

The process uses ambient noise energy to produce surface wave data, more specifically Rayleigh waves. The Rayleigh wave noise data is converted from time domain to frequency domain using wavefield transformation techniques. This process produces a slowness-frequency spectral image. This image is used to select a "fundamental mode" dispersion curve that represents the minimum phase velocity of the Rayleigh wave energy (Optim Software,2014).

A forward modeling process is then used to produce a shear wave velocity profile that would create the given dispersion curve. This process can involve some individual interpretation and judgment. Other data, such as seismic refraction and soil boring logs can be used to further constrain the shear wave velocity model and improve the reliability of the interpretation. However, this methodology has been shown to produce accurate Vs_{100ft} (Average shear wave velocity in the upper 100 ft.) values as well as reasonable estimations of shear wave velocities of individual layers at depth.

5.0 Summary and Conclusions

Using the seismic refraction data collected, two-dimensional p-wave velocity models were created for each seismic line. The velocity models for lines 1 and 2 were combined into one because they overlapped one another by three geophones. These models show the variation in seismic velocity along the line as well as with depth. Although the cut depth is limited for the project, the full depth velocity model was provided.

Using ReMi ™ data analysis, one dimensional average shear wave velocity profiles were provided for each line. Although these models are traditionally used for site classifications, they can also be used to compliment some of the weaknesses in seismic refraction method. Layer velocity reversals, with lower velocity layers underlying higher velocity layers, and other features may be hidden during refraction, but may be identified using ReMi™ methods.

The criterion for estimating rippability of the cut slopes was based on the Seismic (P- Wave) Velocity vs. Rippability developed by the California Department of Transportation (CALTRANS) (Leeds, 2001). These values are based on unpublished CALTRANS data for a Caterpillar D9G series bulldozer with a single-tooth ripper (CALTRANS, 2011).

Seismic Velocity (P-wave) (Feet/Second)	**Rippability**
<3400	Easily Ripped
3400-4900	Moderately Difficult
4900-6500	Difficult ripping/Light Blasting
>6500	Blasting Required

Table 1: CALTRANS Rippability Recommendations

The recorded maximum p-wave velocities, at the maximum depth of the proposed cut, for each line, are shown below. These values are reported to provide clarification to the range shown on the 2-D seismic wave velocity models shown in Appendix A. Full tables of numerical values at each depth and distance along the line are available on request, but are not provided in this report.

Seismic Line #	Maximum Seismic Velocity @ Max Depth of Cut	CALTRANS Rippability Criteria
Seismic Line #1 & Seismic Line #2	6240 ft/s	Difficult Ripping/Light Blasting
Seismic Line #3	6812 ft/s	Blasting Required
Seismic Line #4	6536 ft/s	Blasting Required

Table 2: Recorded P-wave velocities at maximum proposed cut depth.

Based on the seismic velocities observed, difficult to rip materials may be encountered. In certain cases, some blasting may be required depending on the depth of the cut, processes used, and equipment available. Velocity models and cross sections can be found in the Appendix B and Appendix F respectively.

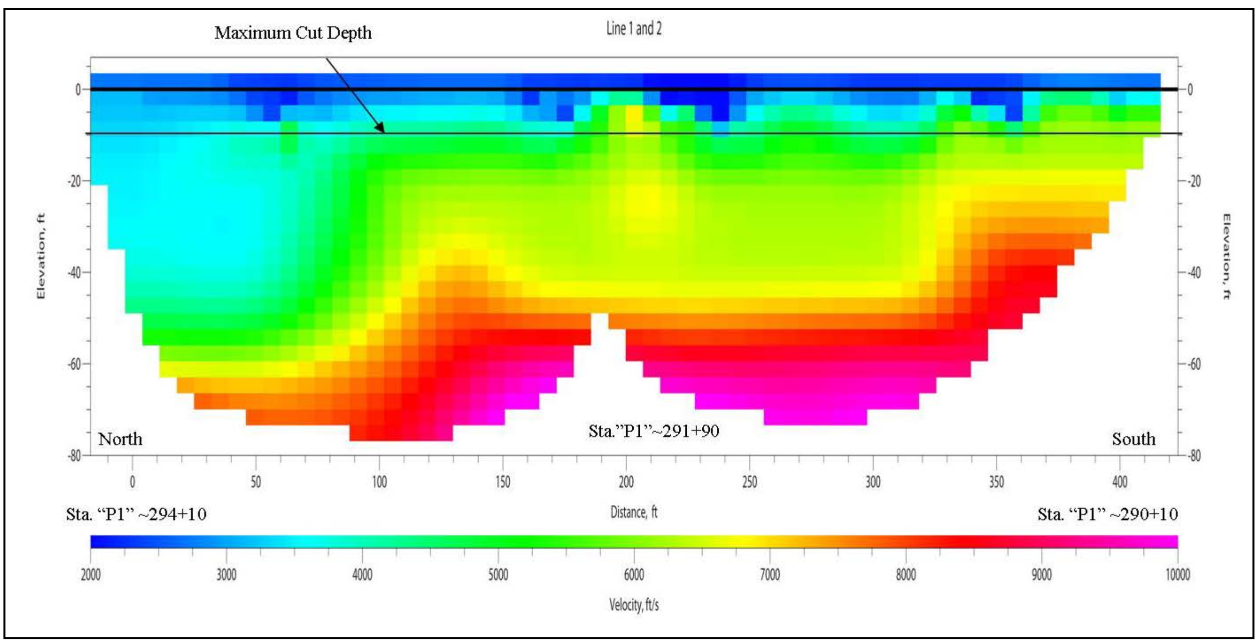

Figure 4: P-Wave Seismic Velocity Model for Seismic Lines One and Two

6.0 References

1. California Department of Transportation (CALTRANS), "Seismic Refraction Survey, Route 299, North Fork Curve Project", 02-TRI-299 PM36.6/36.8, September 6, 2011. Accessed from http://www.dot.ca.gov/hq/esc/oe/project_ads_addenda/02/02-3E8204/pdf/02-3e8204IH.pdf

2. Leeds, D.K, Repeatability of Pre- and Post-Excavation Seismic Refraction Data at the New Benicia-Martinez Bridge Toll Plaza, Northern California, California Department of Transportation (2001).

3. Crafford, A.E.J., 2007, Geologic Map of Nevada: U.S. Geological Survey Data Series 249, 1:250,000 Scale, Accessed using ESRI ArcMap software.

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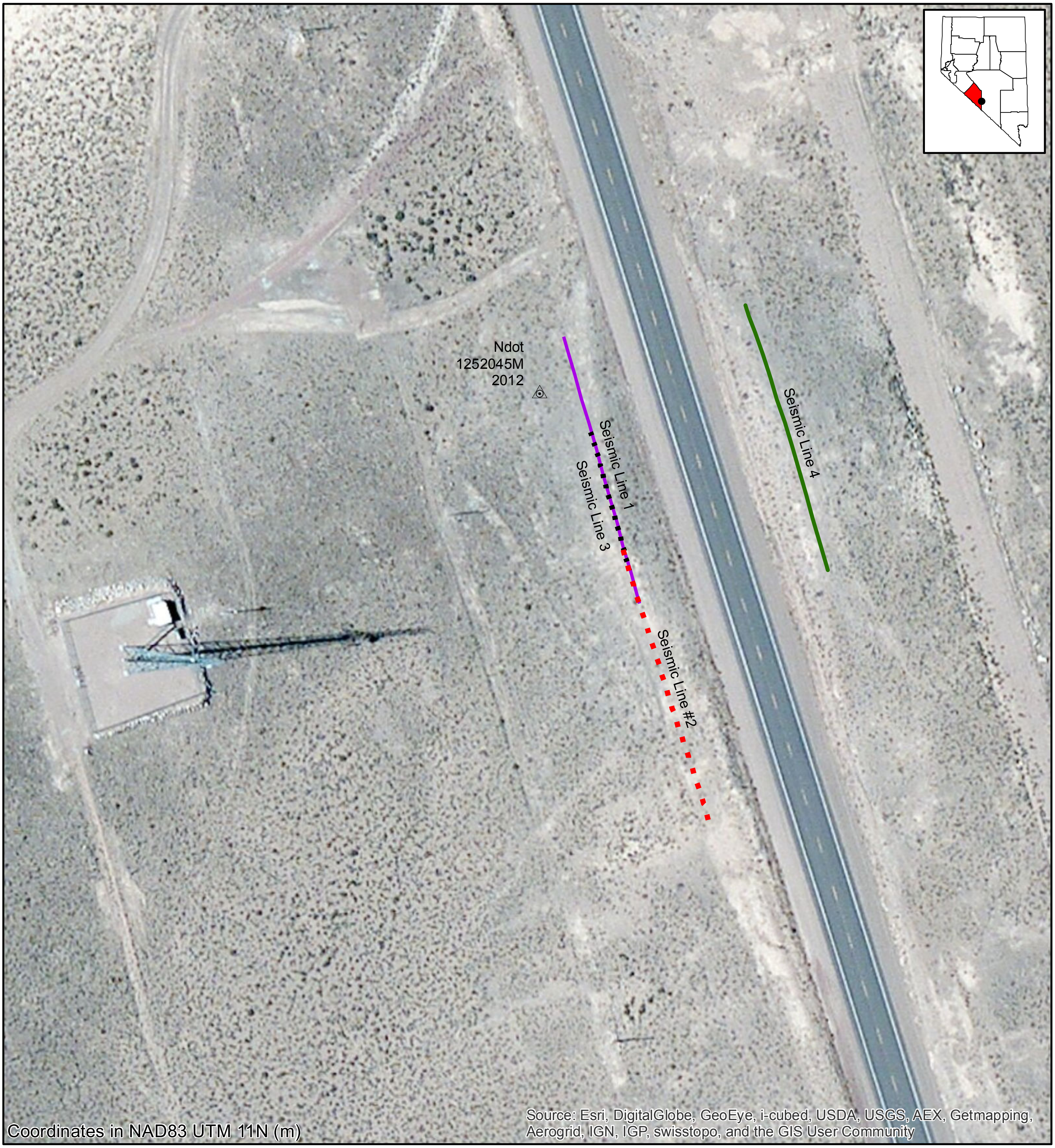
5. Google Maps. (2014) [Veterans Memorial Highway U.S 95 near Goldfield, NV.][Street Map Imagery] Retrieved from https://maps.google.com/maps?hl=en&tab=wl&output=classic&dg=brw

6. Optim Software. (2014) Retrieved from- http://www.optimsoftware.com/ Accessed on 12/22/2014.

APPENDIX A



N

NDOT Survey Monument
Seismic Line #1
Seismic Line #2
Seismic Line #3
Seismic Line #4

THIS MAP IS FOR DISPLAY PURPOSES ONLY.
MAP COMPILED FROM BEST AVAILABLE DATA SOURCES.
NOT ALL FEATURES PORTRAYED DUE TO SCALE.

Seismic Investigation
US95 MP ES 0.5 +/-

0 115 230 Feet

1:1,250

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12/22/2014:AL

Brian Sandoval
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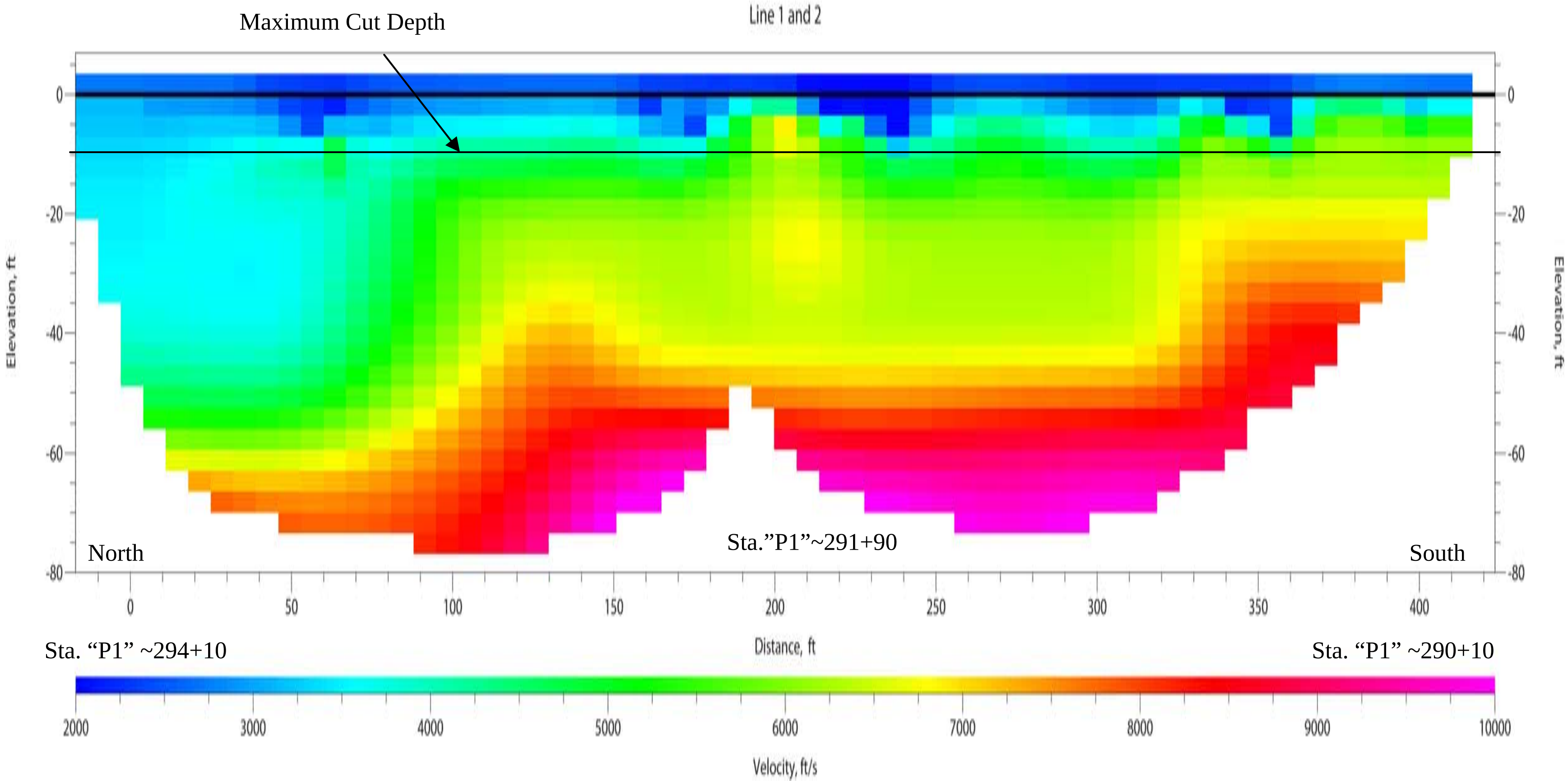
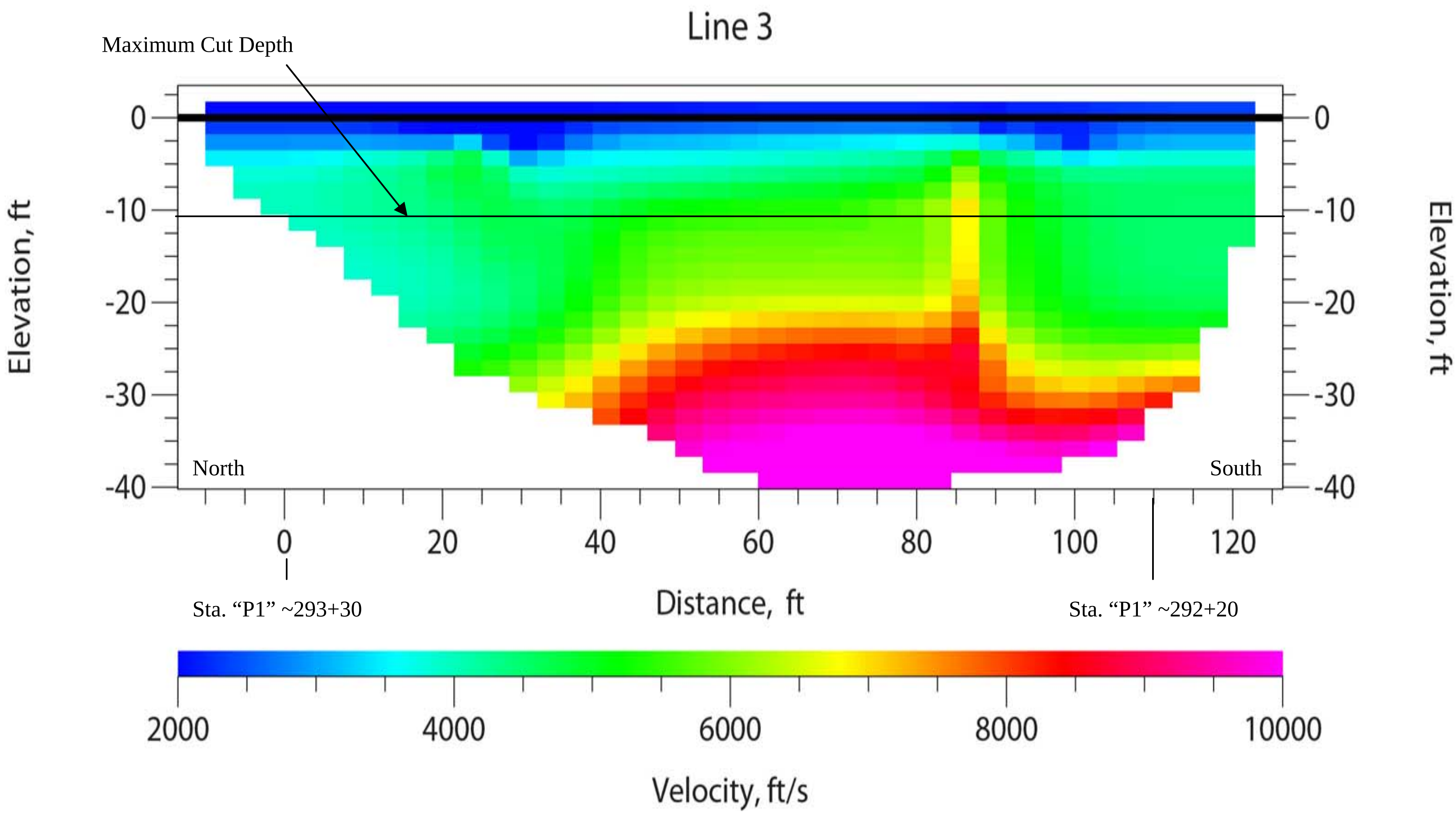
APPENDIX B



Data Provided By:
NDOT Geotechnical Section
Andrew Lawrence P.E.
Date: 12/12/2014

73784 US95 MP ES 0.5
Seismic Lines 1&2: Combined P-Wave Velocity Model
Offset 78' Lt. from Existing Roadway CL



Data Provided By:
NDOT Geotechnical Section
Andrew Lawrence P.E.
Date: 12/12/2014

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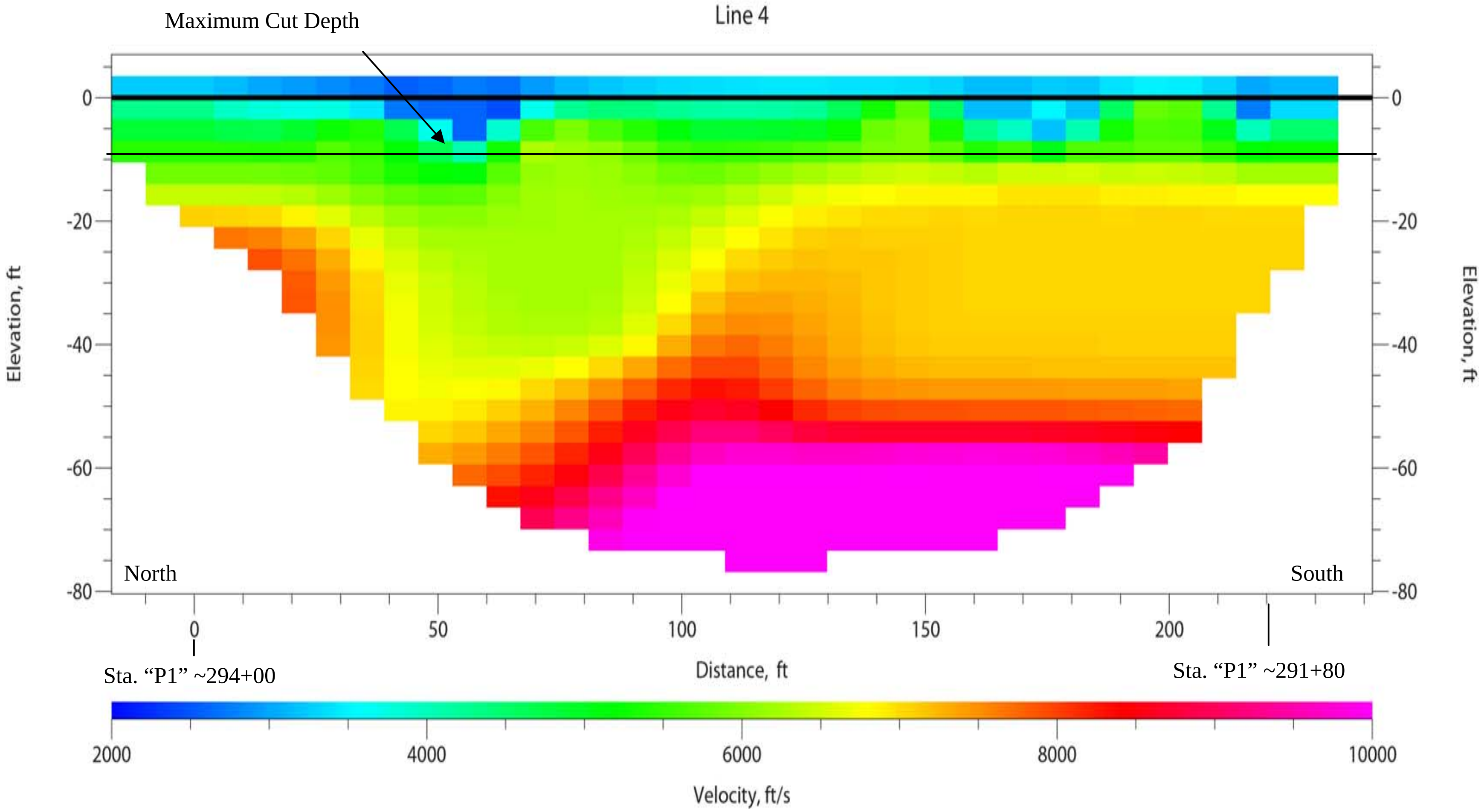
Seismic Line 3: P-Wave Velocity Model
Offset 78' Lt. from Existing Roadway CL



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NDOT Geotechnical Section
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Date: 12/12/2014

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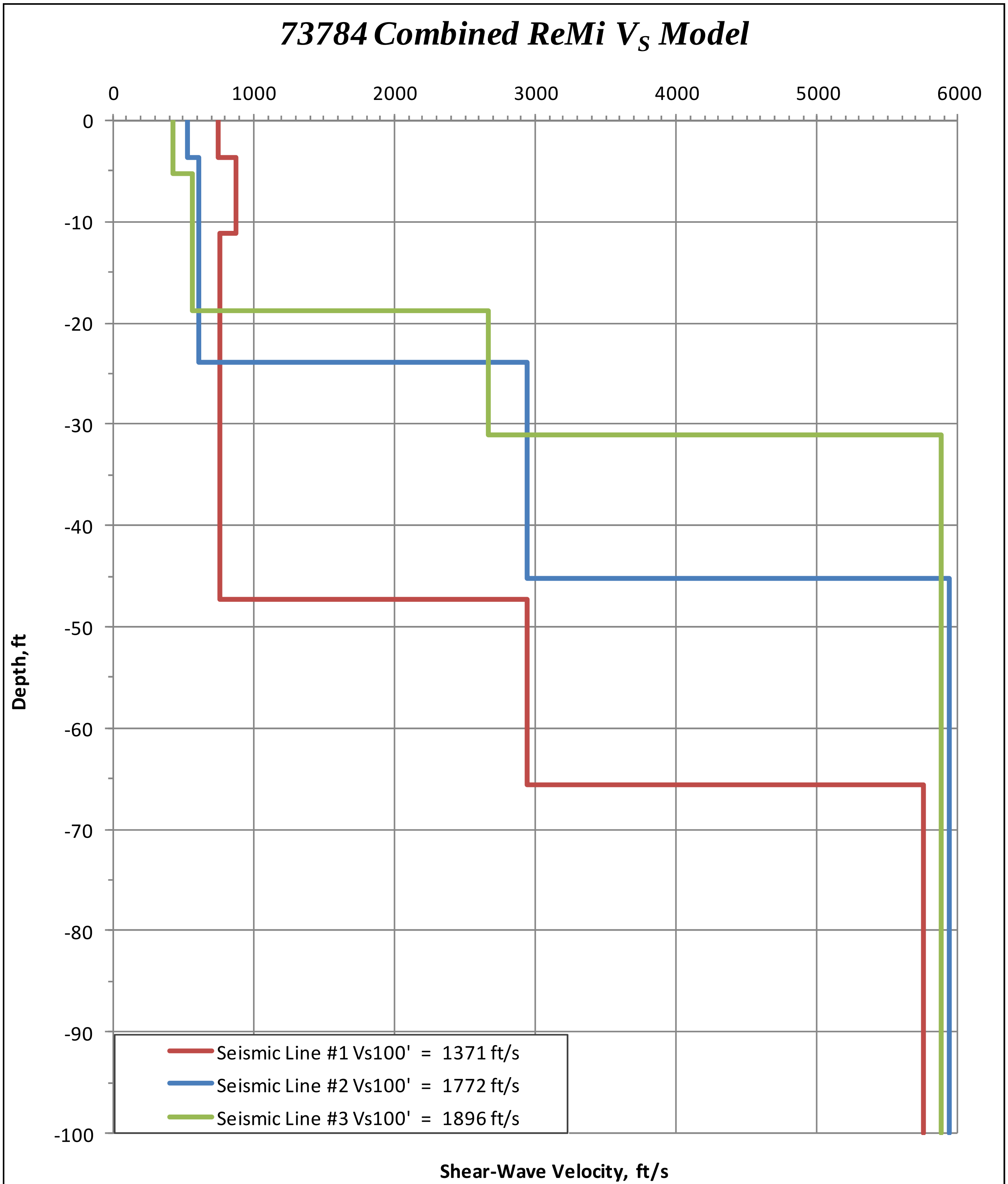
Seismic Line 4:P-Wave Velocity Model
Offset 75' Rt. from Existing Roadway CL

APPENDIX C

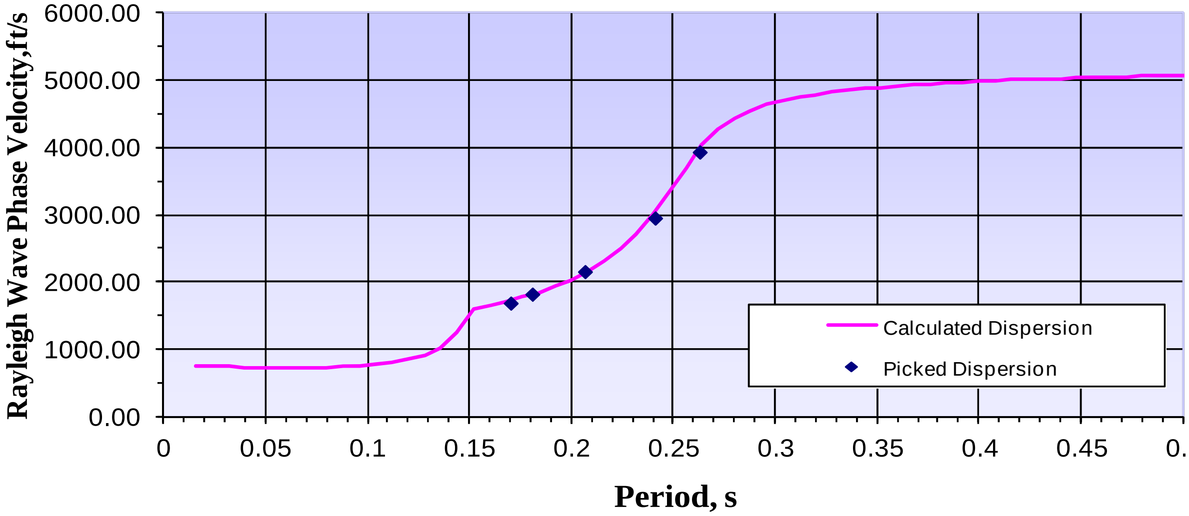


NEVADA DOT GEOTECHNICAL ENGINEERING

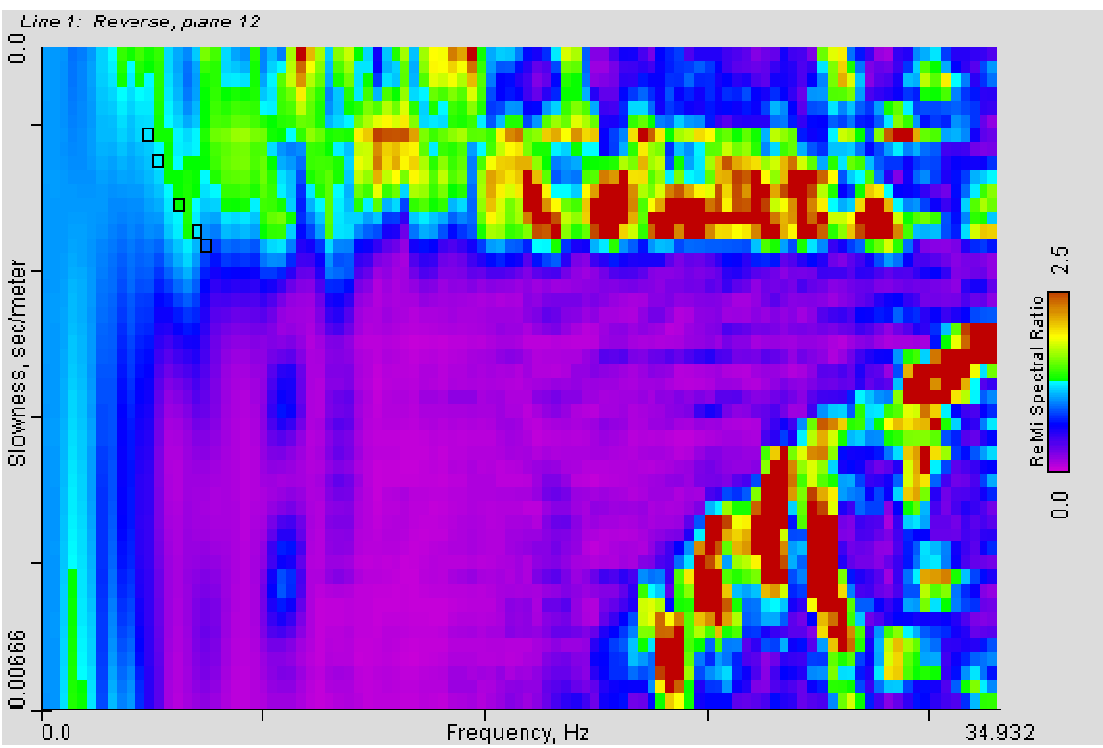
73784 US95 MP ES 0.5
Seismic Line #1-3: 1D Avg, S-Wave Velocity
Offset 79' Lt. From Existing Roadway CL

73784, Line 1: Supportive Illustration

Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks

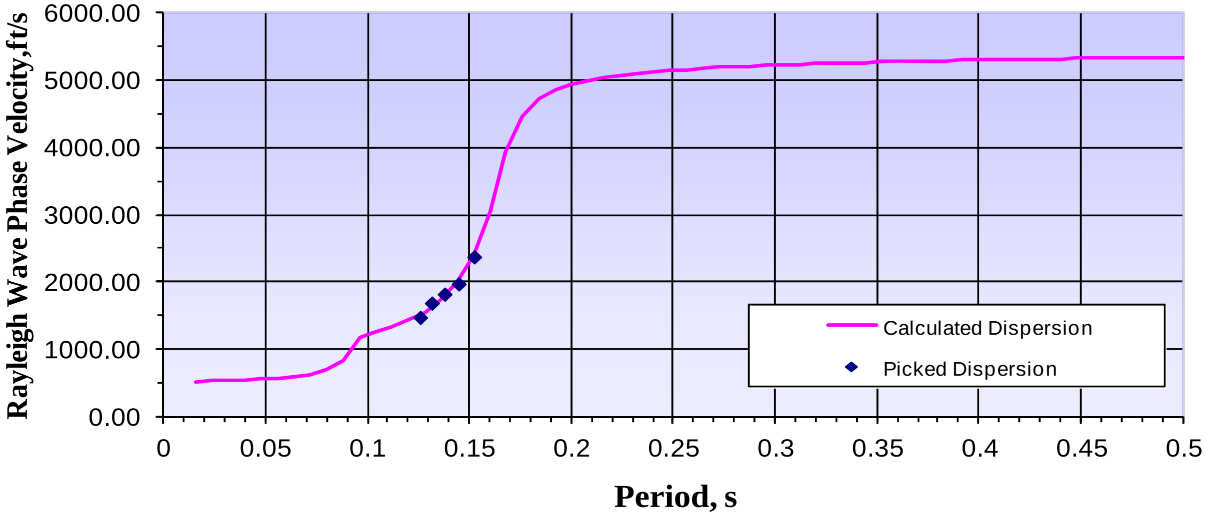


73784 US95 MP ES 0.5
Seismic Line #1:
ReMi™ Spectral Image and Dispersion Picks

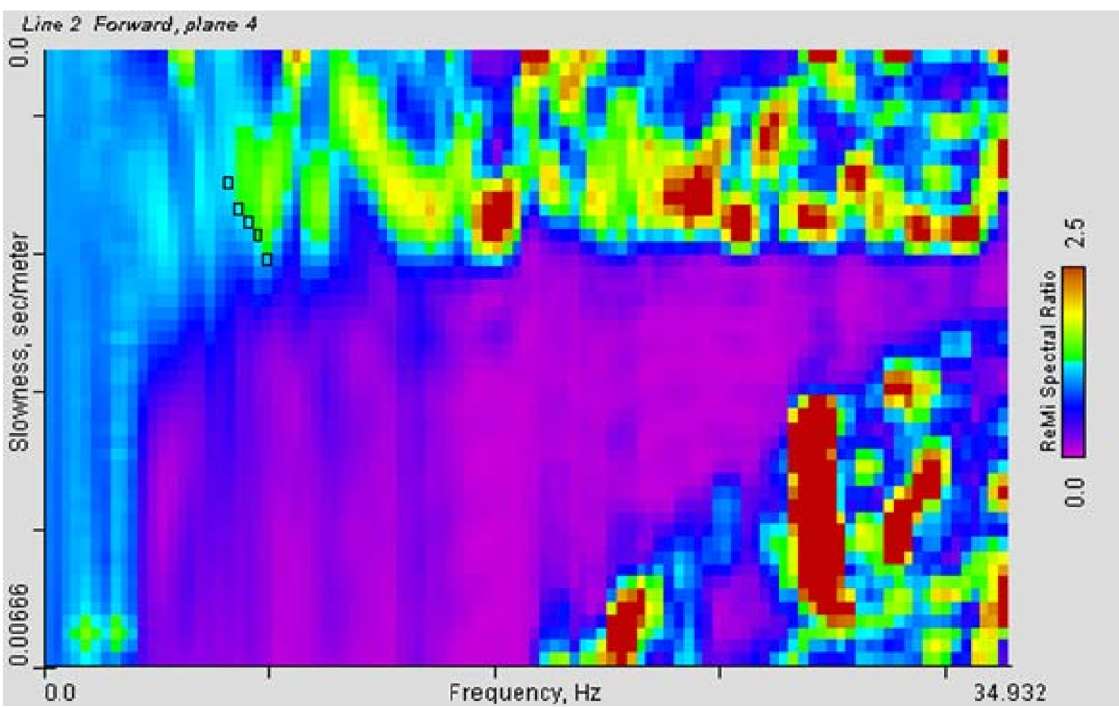
NEVADA DOT GEOTECHNICAL ENGINEERING

73784, Line 2: Supportive Illustration

Dispersion Curve Showing Picks and Fit



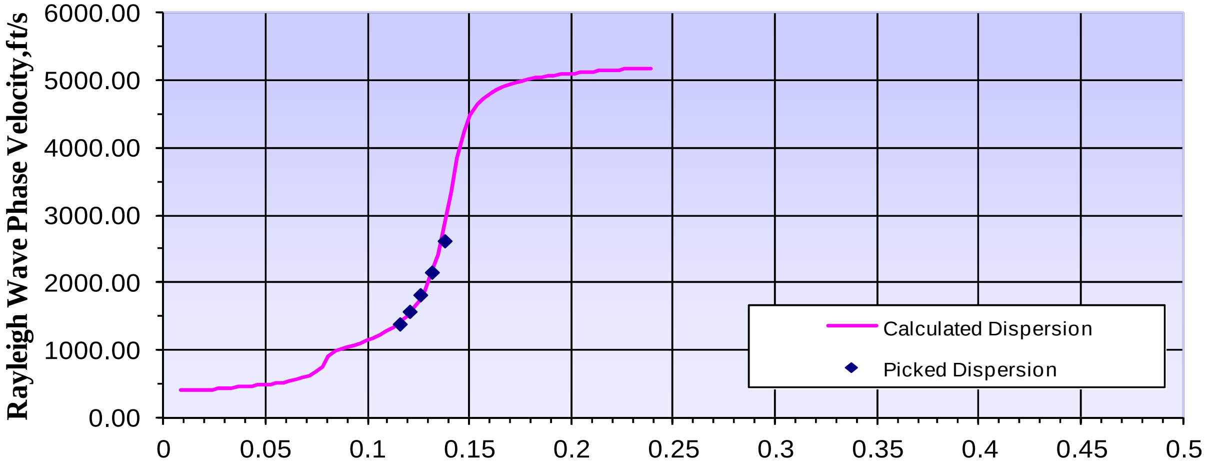
p-f Image with Dispersion Modeling Picks



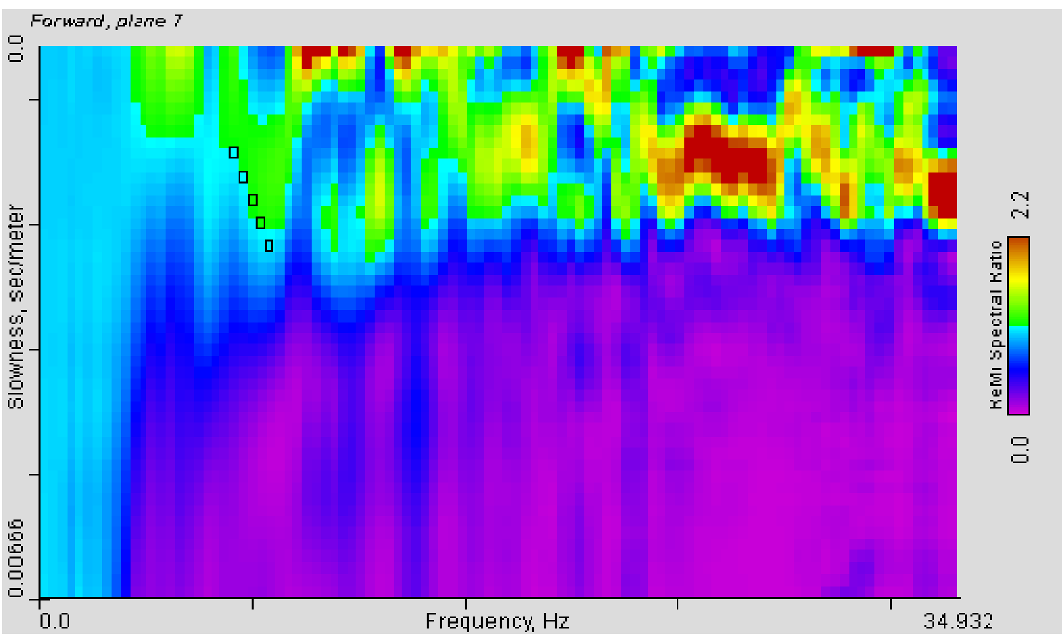
73784 US95 MP ES 0.5
Seismic Line #2:
ReMi™ Spectral Image and Dispersion Picks

73784, Line 3: Supportive Illustration

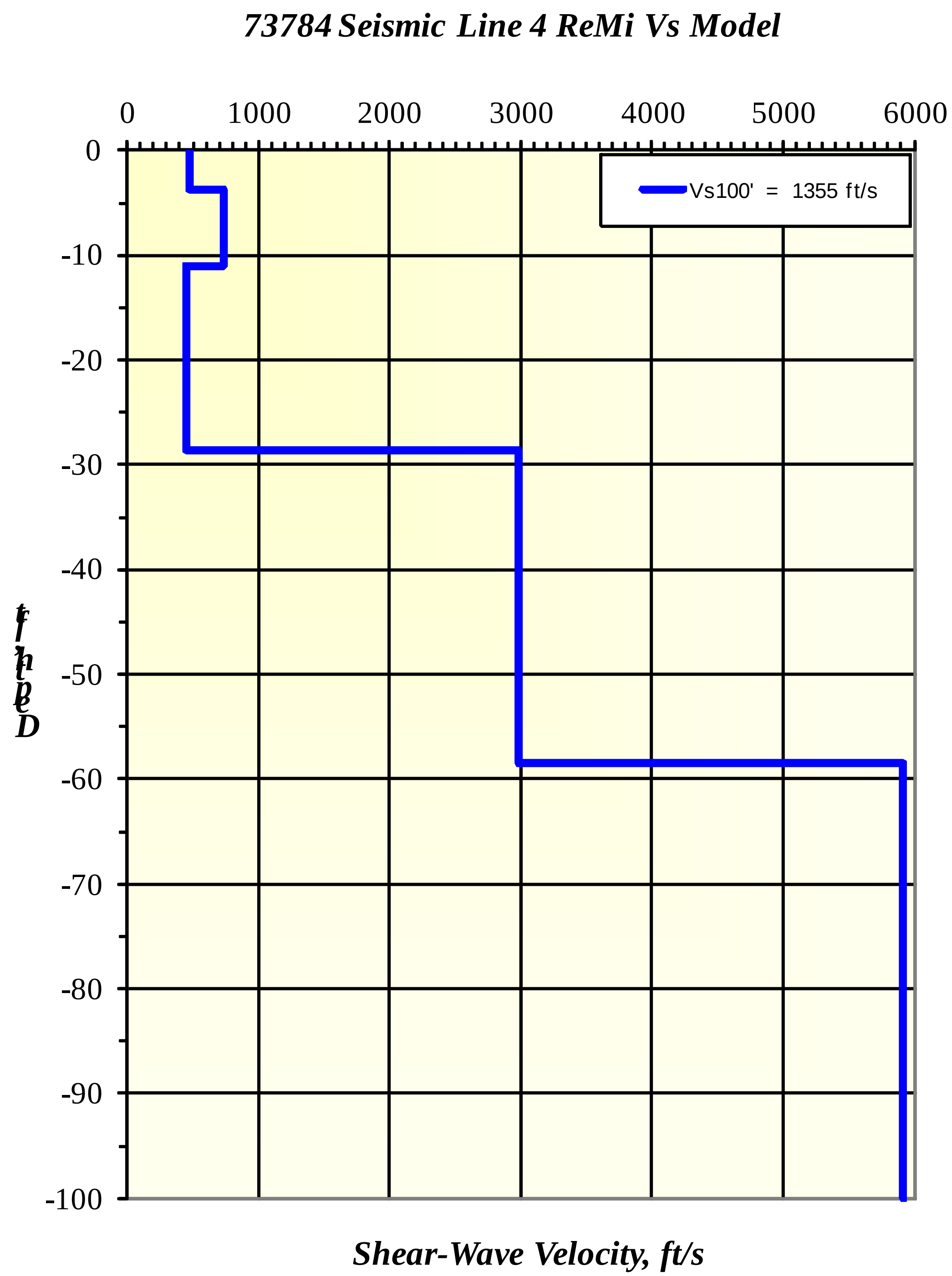
Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks



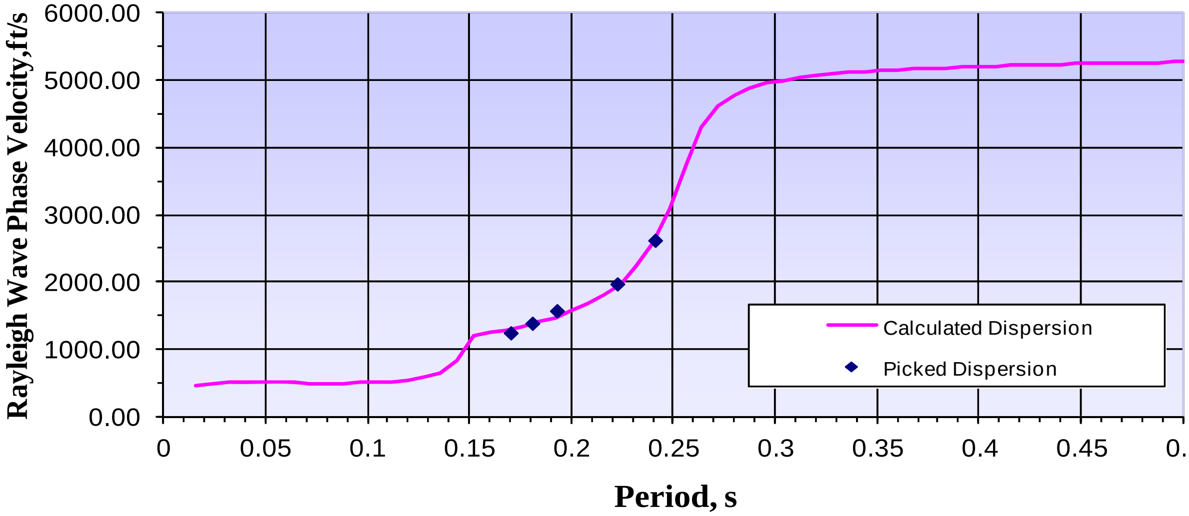
73784 US95 MP ES 0.5
Seismic Line #3:
ReMi™ Spectral Image and Dispersion Picks



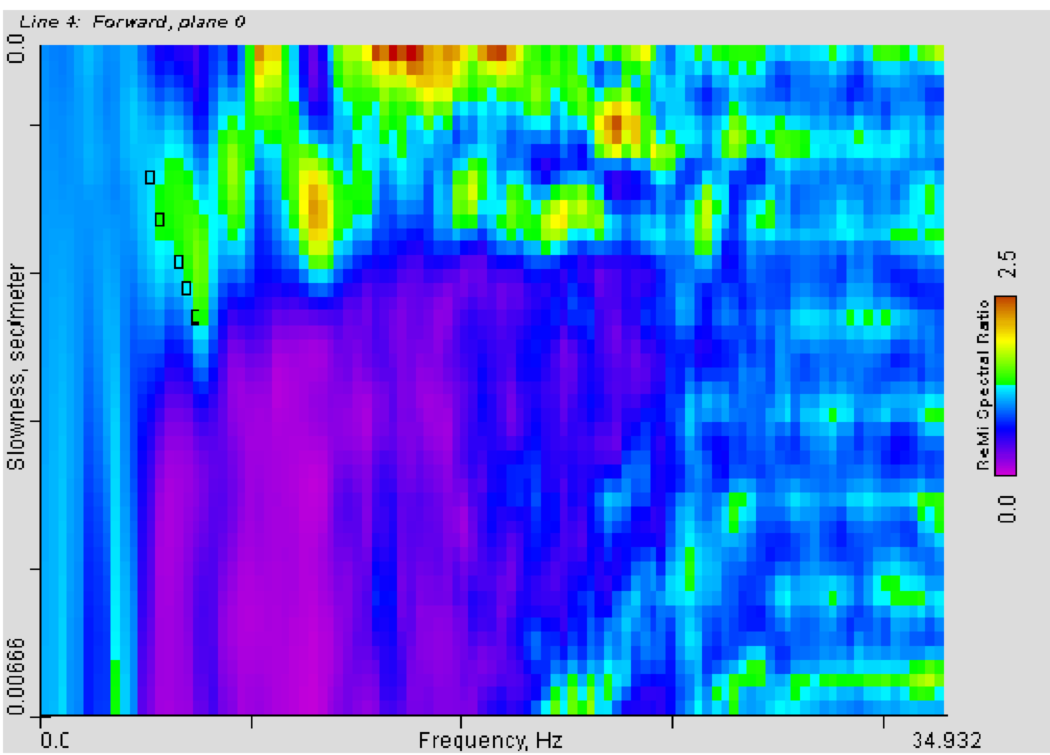
73784 US95 MP ES 0.5
Seismic Line #4: 1D Avg, S-Wave Velocity
Offset 75' Rt. From Existing Roadway CL

73784, Line 4: Supportive Illustration

Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks



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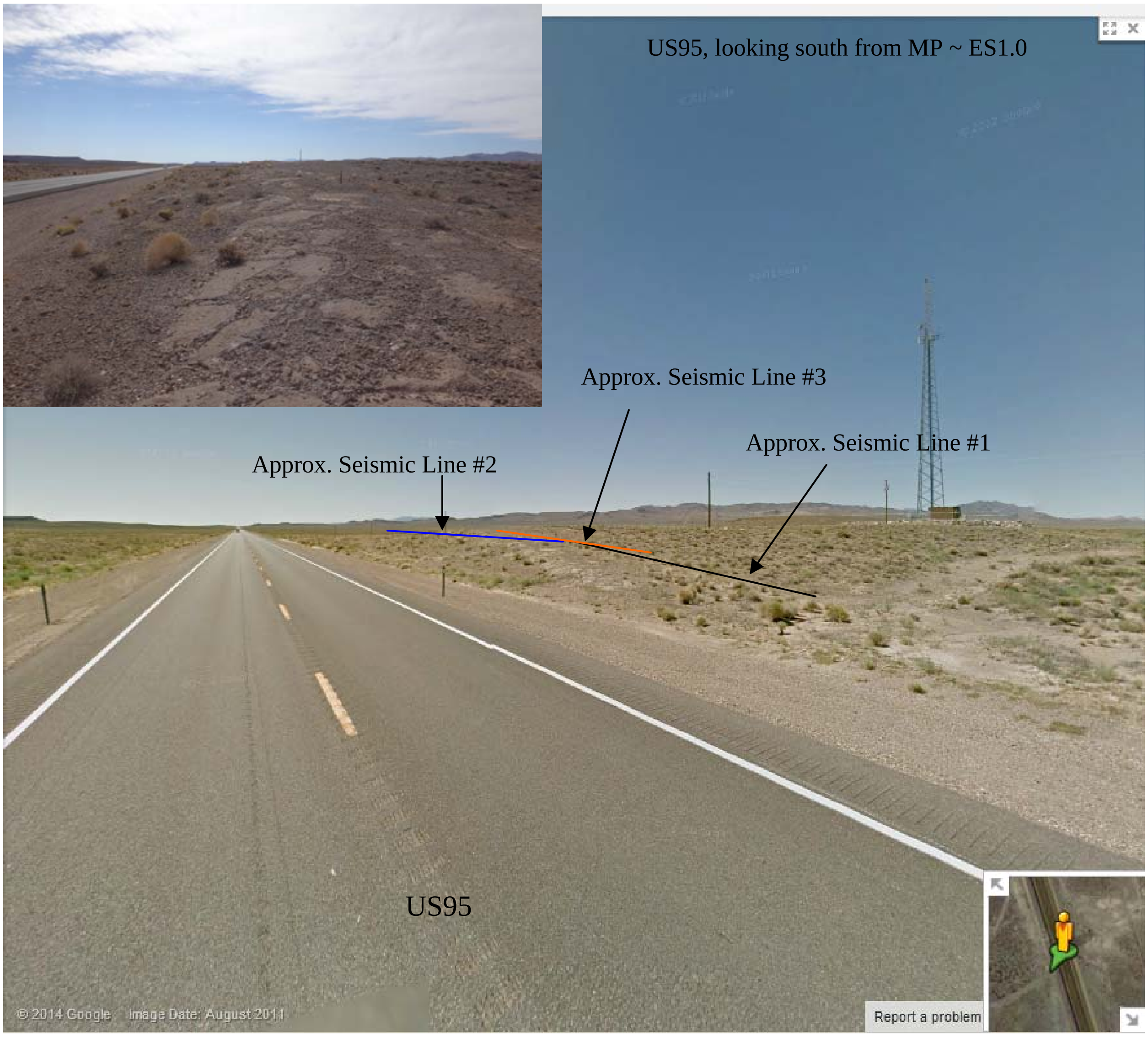
Seismic Line #4:
ReMi™ Spectral Image and Dispersion Picks

APPENDIX D



Seismic Line Description:

Seismic Lines #1 and #2, overlapped by three geophones, running parallel to the roadway, offset 78 ft. Lt. from centerline. Station "P1" 290+10 to "P1" 294+10.

Seismic Line #3, overlapped both Seismic Lines #1 & #2, geophone spacing reduced to 10 ft. , running parallel to the roadway, offset 78 ft. Lt. from centerline. Station "P1" 292+20 to "P1" 293+30.

Image obtained from Google Maps Imagery

NEVADA DOT GEOTECHNICAL ENGINEERING

73784 US95 MP ES 0.5
Geophysical Survey Line Locations
NDOT Geotechnical Section (028)

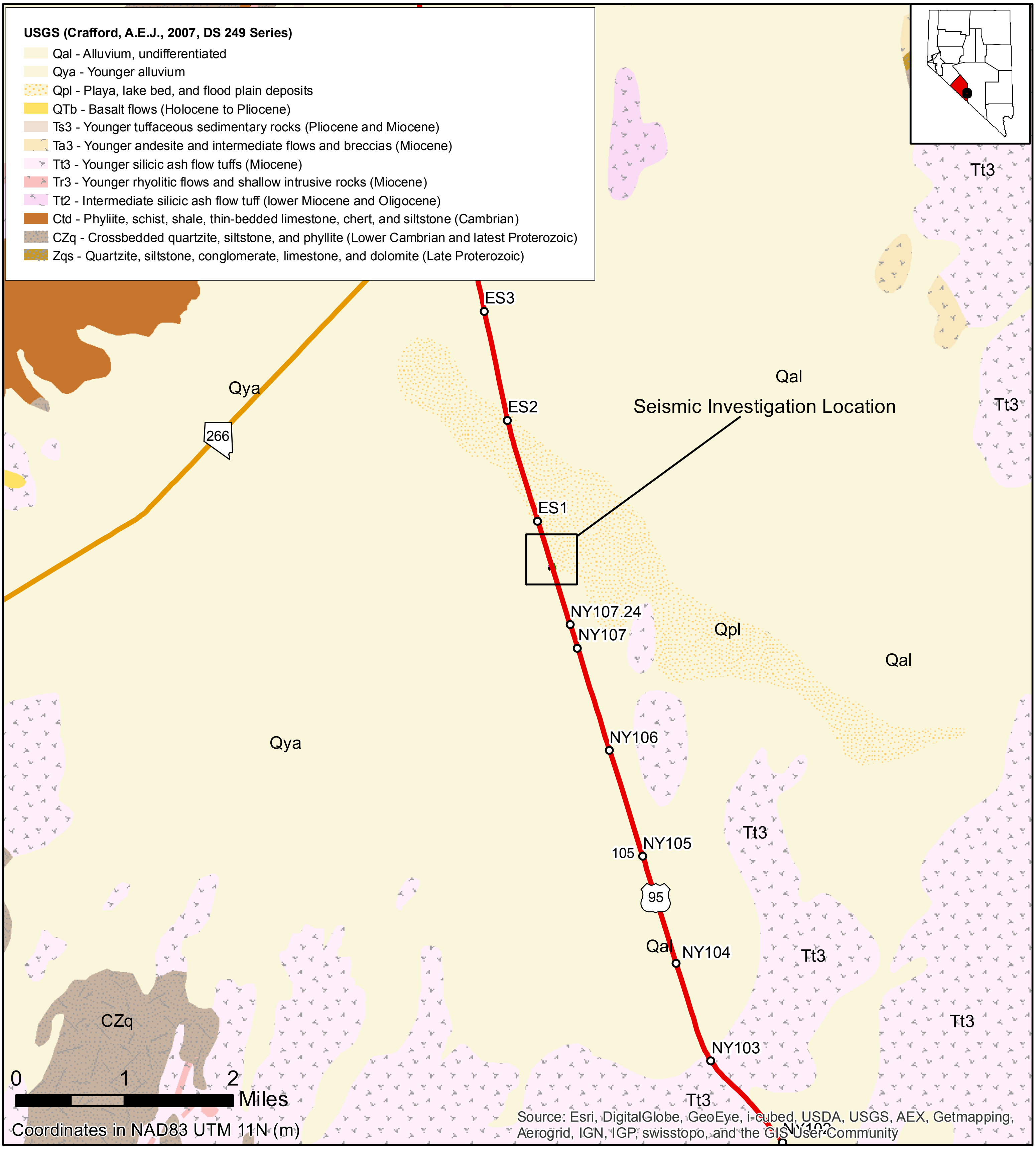
Seismic Line Description:

Seismic Line #4, running parallel to the roadway, offset 75 ft. Rt. of centerline.
Station "P1" 291+80 to "P1" 294+00.

Image obtained from Google Maps Imagery

73784 US95 MP ES 0.5
Geophysical Survey Line Locations
NDOT Geotechnical Section (028)

APPENDIX E



N

Milepost

SR - State Route

US - US Route

1:75,000

Geologic Map (USGS DS 249)
US95 MP ES 0.5 +/-

12/23/2014:AL

THIS MAP IS FOR DISPLAY PURPOSES ONLY.
MAP COMPILED FROM BEST AVAILABLE DATA SOURCES.
NOT ALL FEATURES PORTRAYED DUE TO SCALE.

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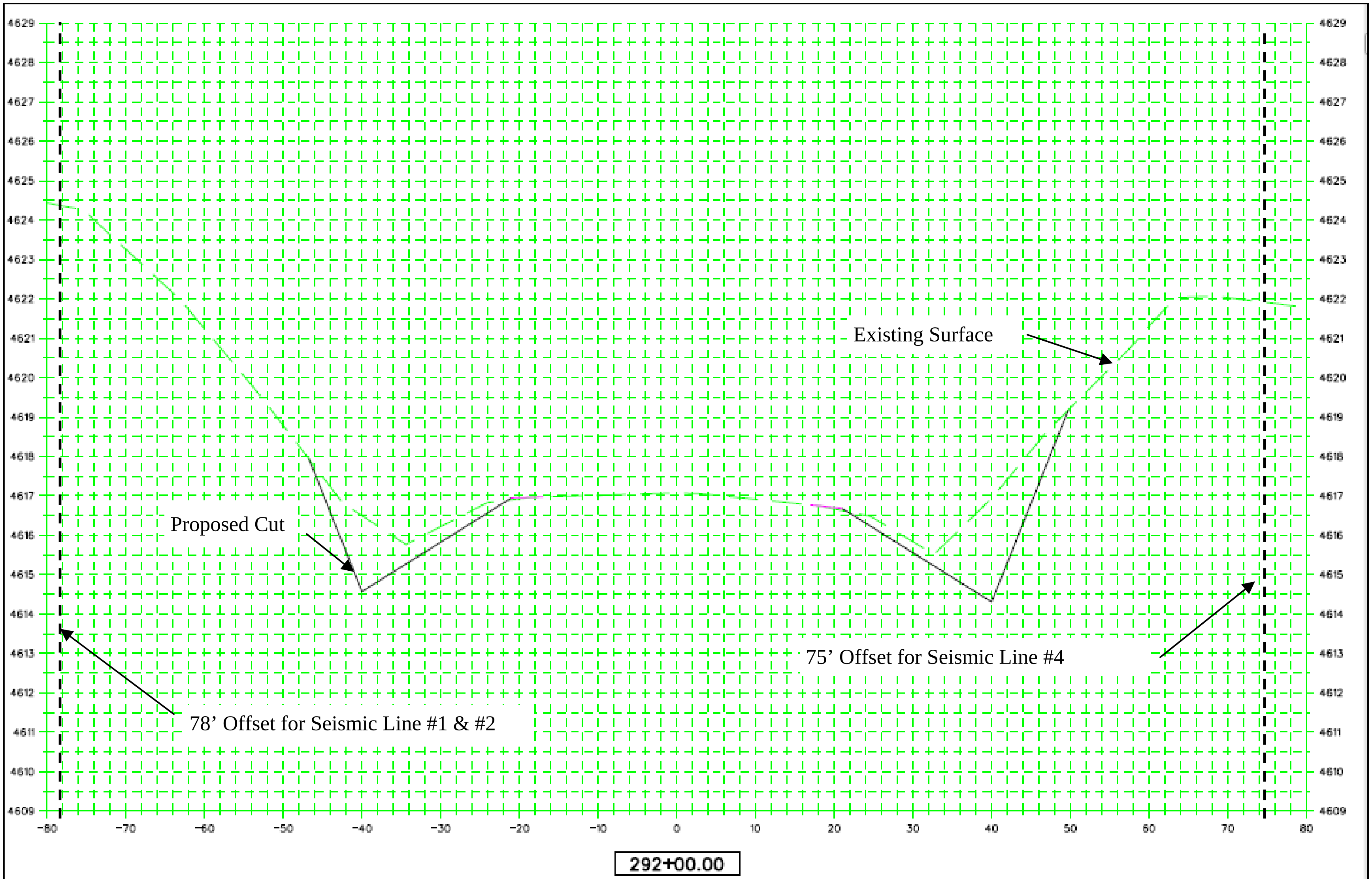
APPENDIX F



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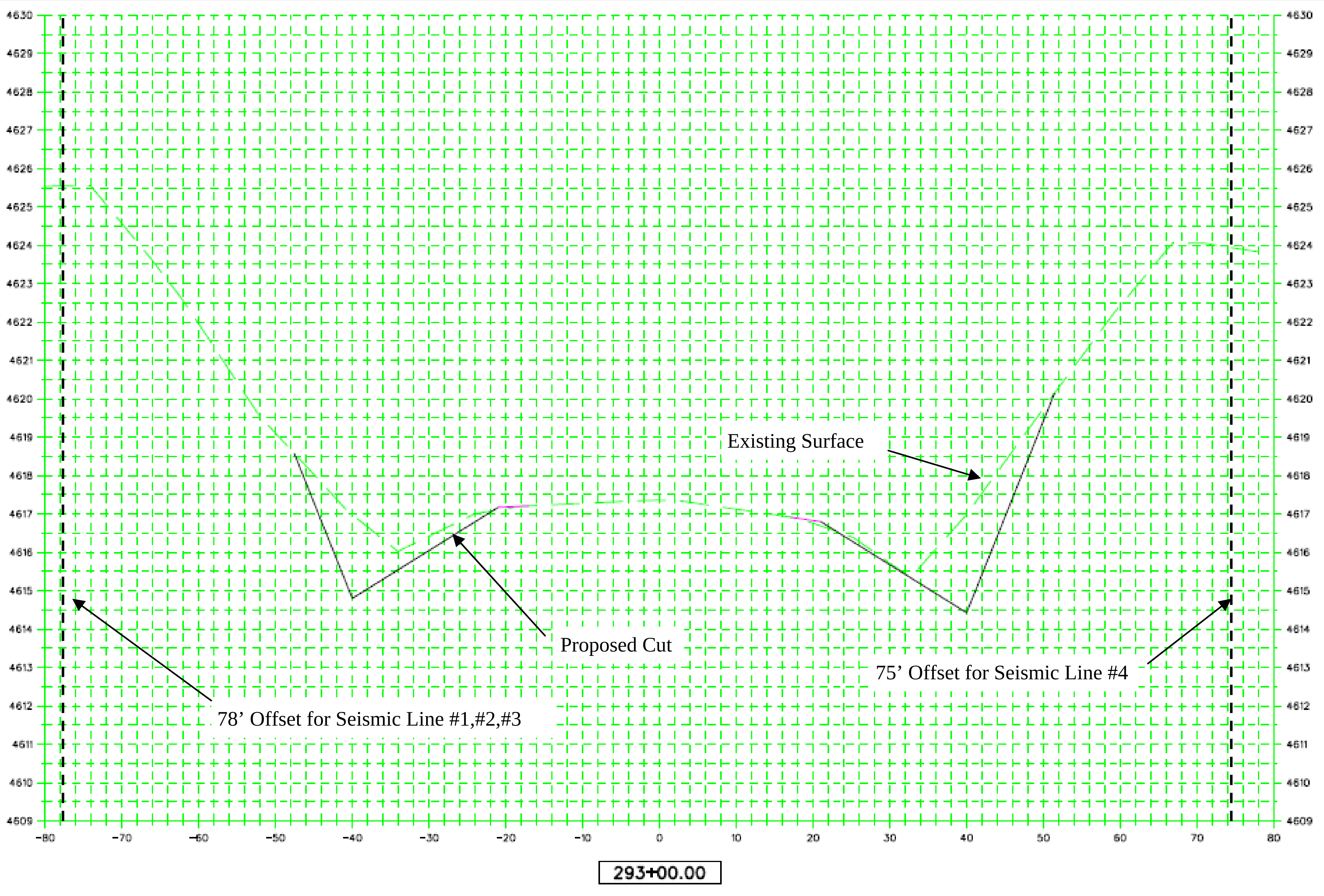
73784 US95 M.P. ES0.5
Seismic Line #1, #2, #4
Cross Section @ “P1” 292+00.00



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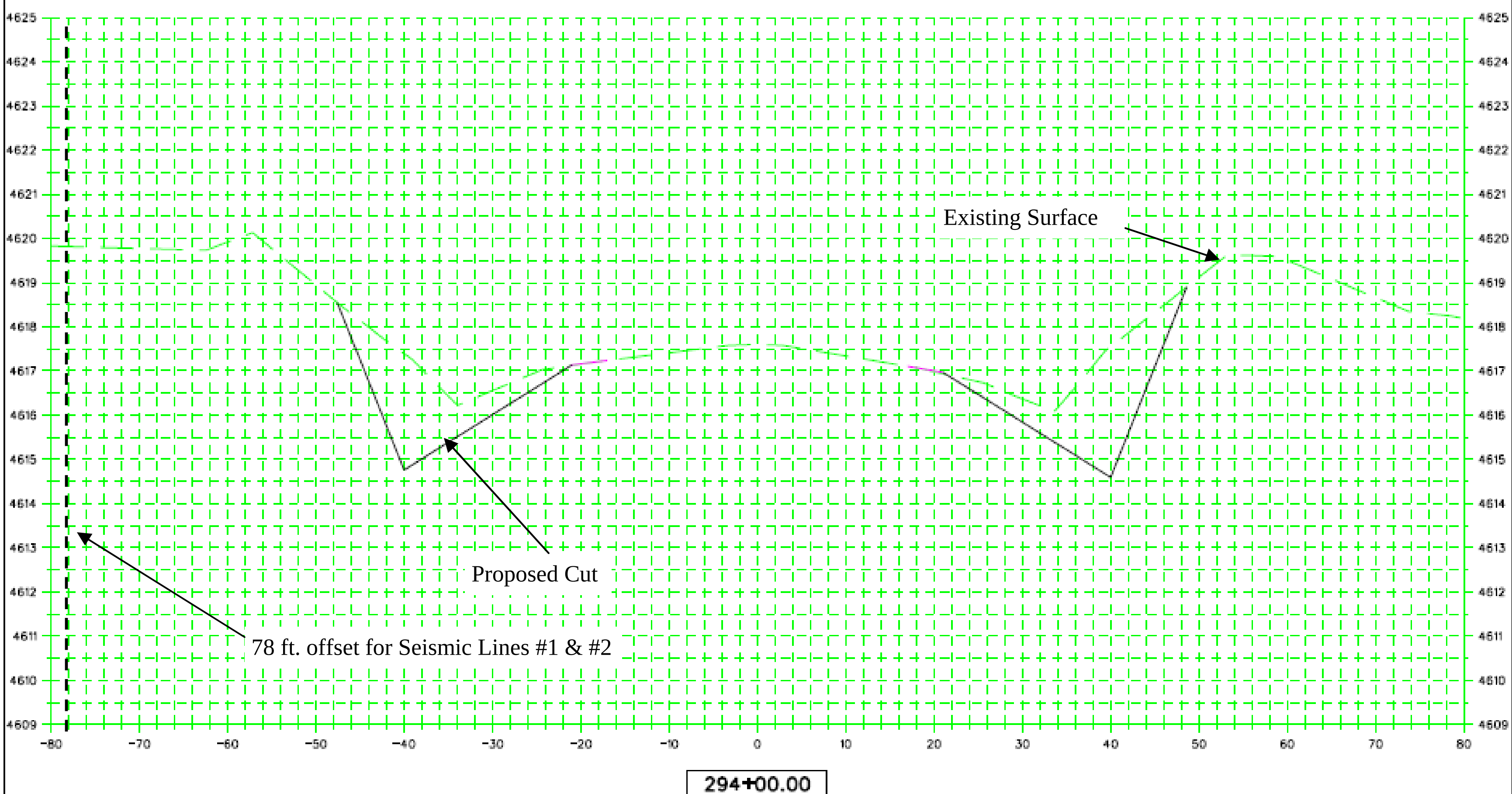
Seismic Line #1,#2,#3, #4
Cross Section @ "P1" 293+00.00



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Andrew Lawrence P.E.
Date: 12/14/2014

73784 US95 M.P. ES 0.5
Seismic Line #1 & #2
Cross Section @ "P1" 294+00.00