Technical Memorandum
Geophysics Prove-Out Study
Task 2.2

West Valley Demonstration Project and Western New York Nuclear Service Center

Prepared for:

**United States Department of Energy and
New York State Energy Research and Development Authority**

Prepared by:

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Under Contract to:

ECS

**Enviro Compliance Solutions Inc.
An SDB, MBE, and DBE Company
4795 Blue Mountain Drive
Yorba Linda, CA 92887**

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West Valley Demonstration Project and Western New York Nuclear Service Center

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April 2017

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LIST OF ACRONYMS

AMSL	above mean sea level
ATV	all-terrain vehicle
DOE	U.S. Department of Energy
ECS	Enviro Compliance Solutions, Inc.
EM	Electromagnetic
ERI	Electrical resistivity imaging
GIS	Geographical Information System
Hz	Hertz
MASW	Multi-channel analysis of surface waves
NDA	NRC Licensed Disposal Area
NRC	Nuclear Regulatory Commission
NYSERDA	New York State Energy Research and Development Authority
P	primary seismic wave
S	shear seismic wave
SDA	State Licensed Disposal Area
SRT	Seismic refraction tomography
TPMC	TerranearPMC, LLC
WNYNSC	Western New York Nuclear Service Center
WVDP	West Valley Demonstration Project

TECHNICAL MEMORANDUM
GEOPHYSICS PROVE-OUT STUDY

1.0 INTRODUCTION

1.1 Background

TerranearPMC, LLC (TPMC) prepared this Geophysics Prove-out Study Technical Memorandum under contract to Enviro Compliance Solutions, Inc. (ECS). The prove-out study was performed to support the Phase 1 studies being performed by ECS and the Exhumation Working Group (EXWG) under contract to the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA). The EXWG is evaluating various exhumation technologies for their applicability to various waste disposal areas at the West Valley Demonstration Project (WVDP) and the Western New York Nuclear Service Center (WNYNSC). This geophysics prove-out study was performed at the State Licensed Disposal Area (SDA) shown in Figure 1. All figures are presented in Appendix A.

Detailed inventories of the wastes disposed in the SDA have been developed from historic disposal records. An improved understanding of the uncertainty associated with the historic disposal records and the estimated radionuclide inventories is important to the development and defense of exhumation alternatives, particularly any selective removal scenarios that are being evaluated based on the amount and type of waste expected to be found and removed. As such, this prove-out study was performed to improve this understanding and to increase the level of confidence in the existing inventories.

1.2 Objectives and Relationship to Phase 1 Studies

The geophysics study was conceived at a point in time when the EXWG was planning to perform an intrusive field investigation at the SDA through which downhole radiation measurements would be correlated to the published inventories as a field-based line of evidence of inventory reliability. Within that context, the first objective of the geophysics study was to define the lateral boundaries of individual waste trenches within the SDA to allow for safe boring installation as near as possible to the waste.

In planning the geophysics work to satisfy this objective, it was recognized that other information could potentially be gained from the geophysics study to supplement the broader Phase 1 studies in reducing technical uncertainty related to the future evaluation of exhumation alternatives. This included information on the bottom/depth of the waste trenches, as well as information on the water elevation within both the waste trenches and the surrounding soil, which defined two additional objectives for the geophysical study. A fourth objective was to determine if the use of geophysics could provide an independent line of evidence of inventory reliability by identifying specific segments within the waste trenches that contain waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or significant metallic waste quantities for comparison to the inventory records for those same segments.

While the geophysics study was being procured, the planned intrusive field investigation being supported by the geophysics investigation was aborted due to modeling results showing that the desired data would not be obtainable due to excessive shielding by the waste containers. This finding eliminated the primary line of evidence for substantiating the reliability of the waste inventories, and shifted attention to the geophysics study as the only line of direct field evidence available to the EXWG. As a result, the fourth objective given above became the primary objective for the geophysics study.

The degree to which geophysics studies would satisfy the above objectives was difficult to predict due to the heterogeneous nature of the buried waste and the potential interferences of both the membrane liner overlying the disposal areas and the high clay content in the soil cap that lies between the waste units and the membrane liner. Another uncertainty in applying some of the methods was the degree to which the resolution of the geophysical measurements could be improved if the probes (geophones) are inserted through the membrane liner to circumvent liner interference with the signals.

Given these uncertainties, a prove-out study of the candidate geophysical methods was performed to determine which methods would resolve the study objectives and would be appropriate for potential future studies. The question related to the insertion of probes through the liner was addressed in the prove-out study by repeated applications of the relevant methods with and without liner penetrations within the footprint of the prove-out study area. The purpose of this report is to document the results of the geophysical prove-out study at the SDA.

2.0 PROVE-OUT STUDY

The following five geophysical methods were evaluated during the prove-out study to determine which have the greatest potential to satisfy the above objectives.

- Electromagnetic (EM) survey
- Magnetometer survey
- Multi-channel analysis of surface waves (MASW)
- Seismic refraction tomography (SRT)
- Electrical resistivity imaging (ERI)

Figure 1 shows the location of the prove-out study conducted within the SDA. The SDA was selected to allow greater focus on the uncertain trench conditions, and because the SDA is outside the more stringent controls imposed on work at the NRC-licensed disposal area (NDA) that is located within the West Valley Demonstration Project (WVDP). The prove-out study of each of the five proposed geophysical methods was conducted across an approximate 200-foot (ft) x 50-ft area spanning Trenches 1, 3, 4, and 5, as illustrated on Figure 1. The EM and magnetometer data were collected on a 5-foot traverse spacing (Figure 2), and the MASW, SRT, and ERI profiles were collected on a 15-foot traverse spacing (Figure 3).

The prove-out study was performed both with and without penetrations for the appropriate methods to evaluate potential interferences associated with the membrane liner overlying the SDA. The technologies applied across the identified area(s) both with and without cover penetrations included MASW and SRT. ERI was performed only with cover penetrations, whereas the EM and magnetometer surveys were not influenced by the membrane cover and were completed only under non-penetration conditions.

The prove-out study was completed in 13 field days on the following schedule:

- August 17, 2016 – On-site training, safety indoctrination, and equipment set up.
- August 18 and August 22, 2016 – ERI survey of the four profile lines A, B, C, and D.
- August 23 - 25 and August 29, 2016 – MASW survey of the four profile lines A, B, C, D with both geophone penetration of the liner and with a land streamer that did not require penetrating the liner with a geophone.
- August 30 – 31 and September 1, 2016 - SRT surveys of the four profile lines A, B, C, D with both geophone penetration of the liner and with a land streamer that did not require penetrating the liner with a geophone.
- September 6, 2016 – EM survey of nine profiles.
- September 7 - 8, 2016 – Magnetometer survey of nine profiles.

A photo log of the prove-out study field effort is presented in Appendix B.

2.1 EM Survey

The EM survey data collection, processing, and analysis work was performed by TPMC subcontractor Applus Geophysics and is documented in a separate report included as Appendix C to this Prove-Out Study Report. EM data was collected using the GSSI Profiler system. The EM method provided sufficient data to identify the edges of the individual trenches and to indicate variability in both the inphase (metallic response) and the quadrature (conductivity response) components of the EM field.

2.2 Magnetometer Survey

The magnetometer survey data collection, processing, and analysis activities were performed by TPMC subcontractor Applus Geophysics and are documented along with the EM survey in the Appendix C report. The magnetometer method was able to collect data deeper than the EM methods and performed well in identifying the outer edges of the outside trenches, Trenches 1 and 5, and in indicating variability in the ferrous magnetic response.

2.3 MASW Survey

The MASW survey data collection, processing, and analysis activities were performed by TPMC subcontractor ACE Geophysics and are documented in a separate report attached as Appendix D. The data show shear wave velocity variability within the study area. An air gap existed between the liner and soil to the west of Trench 5. Seismic geophone contact was difficult where the air gap existed; therefore, MASW data quality over Trench 5 was poor. Data quality using this technique could be increased by using a larger seismic source.

2.4 SRT Survey

The SRT survey data collection, processing, and analysis work was performed by TPMC subcontractor Applus Geophysics and is documented in the Appendix E report. The SRT data does not show much lateral primary (P) wave velocity that would have indicated the location of trenches or the materials within the trenches. Seismic noise at the site may have overwhelmed the sledge hammer source, resulting in the lack of velocity variation in the SRT data. There are some vertical variations with the P wave data that suggest the location of the soil cap and the bottom of the excavated areas. The SRT survey indicated that seismic geophone penetration provided better data quality than the use of a landstreamer (non-penetration).

The site's seismic noise interference with SRT data collection could be corrected by using a larger seismic source such as an all-terrain vehicle (ATV) with a mechanical seismic source. A man-portable mechanical source can be employed in areas where an ATV cannot be used. The addition of more seismic sources within the spread may also improve the lateral resolution.

2.5 ERI Survey

The ERI survey data collection, processing, and analysis work was performed by TPMC subcontractor ACE Geophysics and is documented along with the MASW method in the Appendix D report. The ERI data are very noisy and the tomography inversions did not produce definitive models. The interference in the data is most likely due to the extensive metal in the trenches.

3.0 INTEGRATED DATA ANALYSIS AND INTERPRETATION

Processed data and results were imported into a project specific Geographical Information System (GIS) as separate layers to facilitate spatial data analysis and correlation between the inventory data and the prove-out study field measurements. The GIS system allowed the TPMC geophysicists to integrate the results of selected methods for a more comprehensive interpretation of the geophysics data. The integrated geophysical results were then compared to the types of waste forms and the locations of those waste forms reported to be within the same trench segments as a measure of the reliability of the published inventories. The inventory of waste forms and locations was interpreted from data provided by ECS, and is presented in map format in Figure 4.

3.1 EM and Magnetometer Results

As described in the Appendix C report, the EM method measures two components of the EM field (quadrature and inphase). The quadrature reflects the apparent conductivity of the subsurface and the inphase data reflects the metallic response in the subsurface. Thus areas with high inphase response indicate more metal, and areas with low inphase response indicate less metal in the subsurface. In areas with low inphase data, and thus less metallic content, high apparent conductivity data can infer the presence of more conductive fill such as non-metallic waste boxes or saturated materials. Areas with low inphase data and low apparent conductivity data would infer less conductive non-metallic features such as concrete casks.

Using this combined inference between the inphase and quadrature response, the 1000 Hz and 8000 Hz data were interpreted, with the results presented on Figures 5 and 6, respectively. The GSSI EM Profiler 1000 Hz data represents an effective depth of approximately 13 feet, and the 8000 Hz has an effective depth of approximately 10 feet. The effective depth is the depth at which 75% of the response of the EM profiler is measured based on its frequency, with a value that is dependent on the subsurface conductivities. The EM method can, however, identify metals much deeper than the theoretical effective depth since the response caused by metal on the EM field is so strong. Data from the Interpreted Waste Inventory Map, Figure 4, were integrated and compared with the interpreted EM results shown in Figures 5 and 6. The integrated results are presented on Figures 7 and 8.

The magnetometer data results infer the presence of ferrous metal in the subsurface. As described in the Appendix C report, higher or stronger negative or positive responses indicate more ferrous metal in the subsurface. The magnetometer does not have a depth limit as constrained as the EM method, and a large mass of metal at the bottom of a 20- to 30-foot deep trench would still provide a ferrous response with the magnetometer. Using the results from the magnetometer survey, the data were interpreted and presented in Figure 9. In Figure 10, the interpreted results shown in Figure 9 are compared to the Interpreted Waste Inventory Map, Figure 4. The comparative results for each trench are discussed in the following sections.

3.1.1 Trench 1

- The location of the eastern boundary of Trench 1 is distinct in both sets of EM and magnetic data. The boundary between Trench 1 and Trench 3 is not obvious, however. The lack of clear delineation may be caused by the trenches being more saturated or closer than reported.
- In Trench 1, the EM results (Figures 7 and 8) reveal a high density of drums and other metallic waste containers in the northern portion of the trench segment that compares well with the inventory records. The results then show a lesser density of metal as one moves south, consistent with the inventory records that indicate a shift to concrete casks as the dominant waste form in the southern portion of the trench segment.
- The same general trend is shown by the magnetometer results (Figure 10), in which case there is an elevated magnetic response in the northwest corner of the trench segment with a low metallic and moderate response across most of the segment that is consistent with the large inventory of concrete casks in these areas. The stronger EM signal likely indicates that the drums are located in the upper portions of the trench within the primary vertical zone of response of the EM method. The anomalous magnetometer 'hot spot' in the south-central portion of the trench segment is due to the metal standpipe that protrudes through the membrane layer to above ground surface in that area.

3.1.2 Trench 3

- The location of the western boundary of Trench 3 is distinct in both sets of EM and magnetic data. The boundary between Trench 1 and Trench 3 is not obvious, as described in the previous section.
- There is a strong metallic response in the EM data in the southern portion of Trench 3, with a mix of metallic and non-metallic response across much of the northern portion of the trench. The inventory indicates that disposal of a large shipment of steel bins containing dry active waste from Argonne National Laboratory began in the trench segment of interest and extended more than 100 feet to the south. It is noted in the inventory that the location along the trench segment where the disposal began was not recorded. The observed strong metallic response indicates that placement of the bins began near the southern end of the trench segment and extended south from there.
- The waste placed in the segment north of the steel bins was a wide-ranging mix of comparatively small shipments made up of concrete casks, wooden boxes, steel drums, and fiber drums. This mix of waste types is consistent with the geophysical results that show bands of metallic and non-metallic wastes within the northern portion of the Trench 3 segment.

3.1.3 Trench 4

- The location of the boundary of Trench 4 is distinct in the EM data. The data suggest that the trench may be shifted to the west of the historical documentation of the trench location. Trench 4 is approximately 8 (east side) to 15 (west side) feet west of the GIS location.
- Magnetometer data does not provide sufficient information to delineate the boundaries between adjacent trenches or to corroborate the EM trench location.
- The disposal records for this portion of Trench 4 do not provide sufficient detail to distribute the waste throughout the segment of interest, as all waste disposed in this area is linked to a single location in the inventory as shown in Figure 4. However, the single record reveals a large volume of metallic waste that was likely distributed through the segment of interest in Trench 4. The strong metallic response reported by the EM analysis is consistent with the presence of drums and steel boxes as reported in the inventory for this segment. A stronger metallic response was reported in the central and southern portions of the prove-out study area that could indicate a higher density of drums or steel boxes.
- There appears to be an area of low metallic EM response along the eastern edge of the trench that is linked with higher conductivity values. This response is indicative of less metallic, yet conductive material such as saturated boxes. It could also represent an area along the trench boundary where less waste was disposed and more soil backfill was used.

3.1.4 Trench 5

- The location of the boundary of Trench 5 is distinct in the EM data. The data suggest that the trench may be shifted 9 to18 feet to the west of the historical documentation of the trench location. The boundaries between adjacent trenches are not obvious in the magnetic data.
- In Trench 5, the EM results are very consistent with the reported large inventory of drums and other metal containers reported to be disposed within the north and south segments of the prove-out study footprint. In contrast, the level of metallic detection decreased in the middle portion of the trench segment where less waste was disposed according to the inventory records. As with Trench 1, the magnetometer results are less conclusive due probably to the depth of waste burial in the trench, although the results in the northernmost segment indicate the presence of a large number of drums in the trench consistent with the EM results and the inventory records. It is also noted that the location of the metal standpipe in Trench 1 is easily discerned and could have influenced magnetometer results in its immediate vicinity.

3.2 MASW and SRT Results

The combined MASW and SRT results may be used to interpret the waste conditions and the morphology of trenches along the profile lines presented on Figure 3. Interpretation of subsurface conditions is presented for each of the profiles on Figure 11. A shallow low velocity layer is present in both the MASW and SRT data across all the profiles that would be consistent with the soil cap, as shown on Figure 11. Based on the MASW results, there are areas along

Profile A-D shown on Figure 11 where the extent of the trenches is interpreted. In some areas, the lateral edges are not as clearly defined in the MASW S wave model; this lack of detail is related to the signal-to-noise ratio in the data.

The bottom elevations of the trenches as interpreted from the SRT data are presented in Table 1 for the four profiles crossing each trench from east to west. The SRT data indicate that the bottom elevations of the excavated trenches can be inferred only to within +- 4 feet. While this level of uncertainty would not be unexpected given the sloping bottom of the trenches and the fact that the SRT results are based on depths from a mounded ground surface, a comparison of the SRT results to the bottom elevations of the trenches as reported in Widrig (1998) would indicate that SRT was unable to reliably define the trench bottoms. For example, with reference to Table 1, the SRT results indicate depths on the order of 10 feet below the bottom elevations reported by Widrig. There is a possibility that the consistently lower elevations from the SRT survey can be explained by different reference elevations, but this could not be determined given the available information. The results from the MASW survey showed an even wider range of values and, therefore, were unreliable for determining trench depths.

Table 1 – Interpreted Bottom Elevations of Trenches – MASW Results

Trench	Widrig's Reported Elevation	Interpreted Bottom Elevations Along Survey Lines (Ft MSL)				Variation In MASW Elevations
		Line 1	Line 2	Line 3	Line 4	
1	1363	Approximately Horizontal 1352	Approximately Horizontal 1350	Dipping West 1355-1357	Not detected	+-7 ft.
3	1361.2	Dipping West 1349-1352	Approximately Horizontal 1348	Not detected	Not detected	+-4 ft.
4	1362.8	Dipping West 1350-1355	Approximately Horizontal 1349	Not detected	Not detected	+- 6 ft.
5	1359	Not detected	Not detected	Not detected	Not detected	n/a

The MASW shear wave velocities d can, however, differentiate the following conditions, as illustrated on Figure 11:

- Dry dense materials/metal/concrete
- Saturated dense materials/metal/concrete
- Dry cardboard/wood
- Saturated cardboard/wood

These conditions are discussed on a trench-by-trench basis in the following sections.

3.2.1 Trench 1

- On three of the profiles (B, C, and D) shown on Figure 11, the MASW data indicate that the contents of the trench are dense materials consistent with concrete and steel. The waste inventory provided by ECS indicates a large volume of steel drums and concrete casks deposited in this area. Profile B indicates lower MASW shear wave and SRT primary wave velocities. The lower velocities may be due either to waste composition of mostly cardboard and similarly conductive material or to the material being saturated.
- The MASW-SRT results for Trench 1 show a more uniform distribution of dense waste in the lower reaches of the trench in the north-south direction (Figure 11). These results are consistent with the large volume of either metallic drums or non-metallic concrete casks reported in the inventory to have been disposed throughout this segment of Trench 1. The MASW-SRT results are indicative of mass density regardless of whether the waste container is metallic or concrete (as opposed to the EM results which segregate the two waste forms).

3.2.2 Trench 3

- In general, the MASW seismic shear wave velocities in Trench 3 are slower than typically interpreted to be concrete or metal. This observation is consistent with the waste inventory that suggests that a large portion of Trench 3 was filled a mixture of concrete casks, wooden boxes, steel drums, and fiber drums.
- The MASW data also indicate high velocity material at depth along Profile A, which is located near the south boundary of the prove-out study area. This result indicates the presence of metal or concrete in this area, which is consistent with the waste inventory and the EM data that suggest the presence of a large number of metal bins near and beyond the south end of the trench segment.

3.2.3 Trench 4

- Trench 4 includes areas of high MASW shear wave velocities, consistent with metal or concrete, and slower shear wave velocities that may indicate less dense material such as cardboard boxes. As indicated above, the one disposal record of what went into this trench segment indicates a mix of waste forms for which specific locations were not provided. Therefore, while there is general agreement between the geophysical results and the waste inventory, no more conclusive statement can be made regarding the degree of correlation.

3.2.4 Trench 5

- The MASW/SRT results across the four profiles of Trench 5 (Figure 11) show high densities of waste at Profiles 2 and 4, corresponding to the southern and northern limits of the segment investigated, whereas the results at Profile 3 (located in the center of the segment) show a less dense waste condition. These results are fully consistent with the waste inventory that shows a higher volume of containerized waste disposed at the northern and southern ends of the prove-out study segment.

4.0 EVALUATION OF RESULTS IN MEETINGS OBJECTIVES

Based on the TPMC analysis of the results of the five methodologies, the following conclusions were made regarding the effectiveness of the geophysical survey in meeting the study objectives.

Objective 1: Define the lateral boundaries of individual waste trenches and other disposal units within the SDA and NDA to allow for safe boring installation as near as possible to the waste.

Objective 1 was initially developed for the purpose of avoiding the trenches when installing vertical borings adjacent to the trenches. Even though the boring investigation was subsequently cancelled, it is likely that the results of the prove-out study would not have been able to distinguish trench boundaries well enough to allow borings to be installed within the desired tolerance of a foot or two from the trench. A possible shift in trench location for Trenches 4 and 5 relative to the reported locations was, however, discernible from the geophysical results.

Objective 2: Define the bottom/depth of the waste trenches and other disposal units.

Variation in elevation of the bottom of trenches and comparison to historical information indicate that the seismic interpretation was unable to reliably define the depth of excavation, and thus there is little if any additional value gained by retaining Objective 2 as a justification for any future geophysics study regardless of the methods carried forward.

Objective 3: Determine the water surface elevation within the waste trenches, as well as the water surface elevation in the surrounding soil.

Information on leachate depths and volumes is important due to complications of the saturated conditions on waste exhumation operations. However, it is expected that any exhumation scenario will include trench dewatering that will limit the need for precise water depth elevations. Existing standpipes in each trench already provide information on leachate depth to an accuracy greater than what has been shown to be achievable from geophysical methods.

Objective 4: Identify specific segments within the waste trenches that contain waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or significant metallic waste quantities that can be compared against the inventory records for those same segments to support inventory reliability.

The geophysical results broadly support the reported inventory at the scale of interest. Both the reported waste inventories for the SDA trenches and the EXWG Phase 1 studies have used 50-foot trench segments as the smallest spatial scale of interest. Ongoing evaluations of selective removal scenarios are using this same spatial scale. Within this context, and with reference to the plotted comparisons of the geophysical results versus the reported waste inventories (Figures 7, 8, 10, and 11) and the interpretative results discussed in Section 3.0, there is a high degree of correlation between the geophysical results and the waste inventories even at spatial scales less than a 50-foot trench segment. For example, the following are noted:

- In Trench 1, the EM and magnetometer results reveal the high density of drums and other metallic waste containers in the northern portion of the trench segment that compares well with the inventory records. The results then show a lesser density of metal as one moves south, consistent with the inventory records that indicate a shift to concrete casks as the dominant waste form in the southern portion of the trench segment. The MASW-SRT results for Trench 1 show a more uniform distribution of dense waste in the lower reaches of the trench in the north-south direction (Figure 11). These results are consistent with the large volume of either metallic drums or non-metallic concrete casks reported in the inventory to have been disposed throughout this segment of Trench 1.

- In Trench 3, the results of all four methods across the segment are highly consistent with the characteristics of the reported waste shipments. The single large shipment of metal bins with dry waste from Argonne National Laboratory that was reported to begin in the segment of interest and extend more than 100 feet to the south is evident by the higher level of metallic waste noted near the southern end of the trench segment. The geophysical results from the remainder of the trench segment are consistent with a large number of small shipments of various types of metallic and non-metallic waste containers.

- In Trench 4, the single disposal record that was available inhibited the interpretation of geophysical results at a scale less than the full trench segment. Nevertheless, the geophysical results generally reveal large quantities of drums and concrete casks across the Trench 4 segment that are consistent with the waste forms reported in the single disposal record.

- In Trench 5, the EM results are very consistent with the reported large inventory of drums and other metal containers reported to be disposed within the north and south segments of the prove-out study footprint. On the other hand, the level of metal detection decreased in the middle portion of the trench segment where less metallic waste was disposed according to the inventory records. The magnetometer results are less conclusive due probably to the depth of waste burial in the trench, although the results in the northernmost segment indicate the presence of a large number of drums in the trench consistent with the inventory records. The MASW/SRT results across the four profiles of Trench 5 (Figure 11) show high densities of waste at Profiles 2 and 4 corresponding to the southern and northern limits of the segment investigated, whereas the results at Profile 3 (located in the center of the segment) show a less dense waste condition. These results are fully consistent with the waste inventory that shows a higher volume of containerized waste disposed at the northern and southern ends of the prove-out study segment.

5.0 RECOMMENDATIONS

One objective of the prove-out study was to determine which of the five geophysical methods contributed sufficiently to the overall geophysical study objectives to warrant their inclusion in any potential future full-scale application. Based on the results of the prove-out study discussed above, the following recommendations are made:

Recommendation #1:

The magnetometer and EM surveys were effective in meeting Objectives 1 and 4, thus TPMC recommends these two technologies be carried forward for any potential future full-scale survey. In addition to the GSSI Profiler EM survey, TPMC would recommend adding a Geonics EM-31 EM survey which has an effective depth of 18 feet, which is deeper than the GSSI Profiler. This EM survey method will provide additional vertical characterization. The magnetometer and EM surveys are also the least intrusive, least costly, and easiest to implement from a radiological control standpoint when compared to the other three methods.

Although less effective at the primary Objective 4, the MASW and SRT surveys can provide useful data to the inventory evaluation. The MASW shows it can meet Objective 4 and demonstrated some success with meeting Objective 1. SRT may be effective at providing meaningful data to address Objective 2. The resolution and data quality of both the MASW and SRT seismic methods can be improved significantly by using a larger mechanical source (Elastic Wave Generator). The SRT did provide better data with liner penetration, but it is believed that with an improved source and more source locations, the SRT would still be a viable method without penetrations.

Recommendation #2:

The ERI method effectiveness proved to be impacted by the metal in the trenches and would not be recommended for further consideration to meet the geophysical objectives.

6.0 REFERENCES

Widrig, Ann, “Review of 10/30/80 MTF from J. P. Duckworth Regarding Trench Bottom Elevations,” Memo to Paul Bembia, July 27, 1998

APPENDIX A
FIGURES

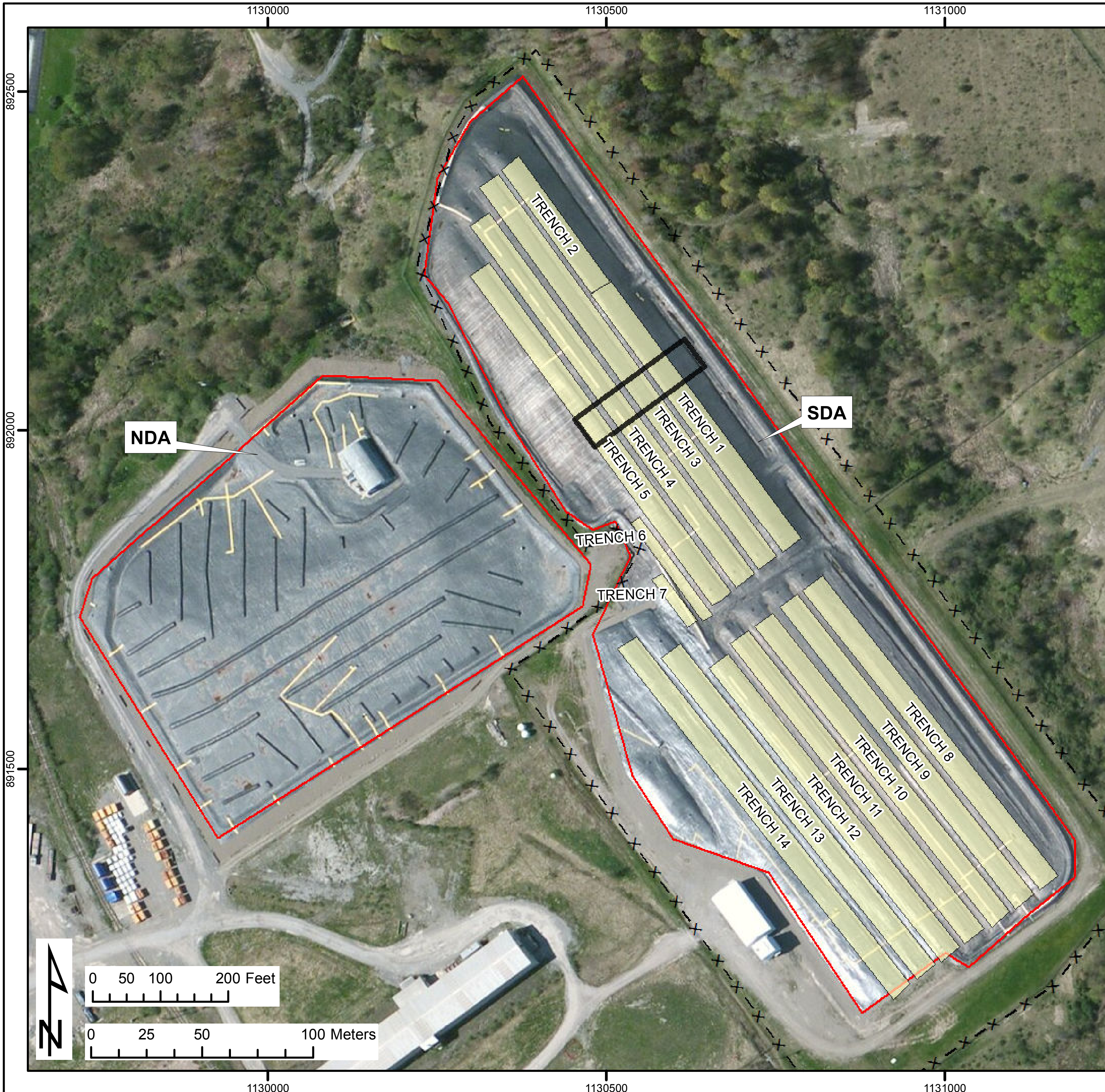

Figure 1
Pilot Study Overview

West Valley Demo Project and Western New York Nuclear Center

TerranearPMC

Date: 10/17/2016
Rev: CM
Drafted by: TPMC

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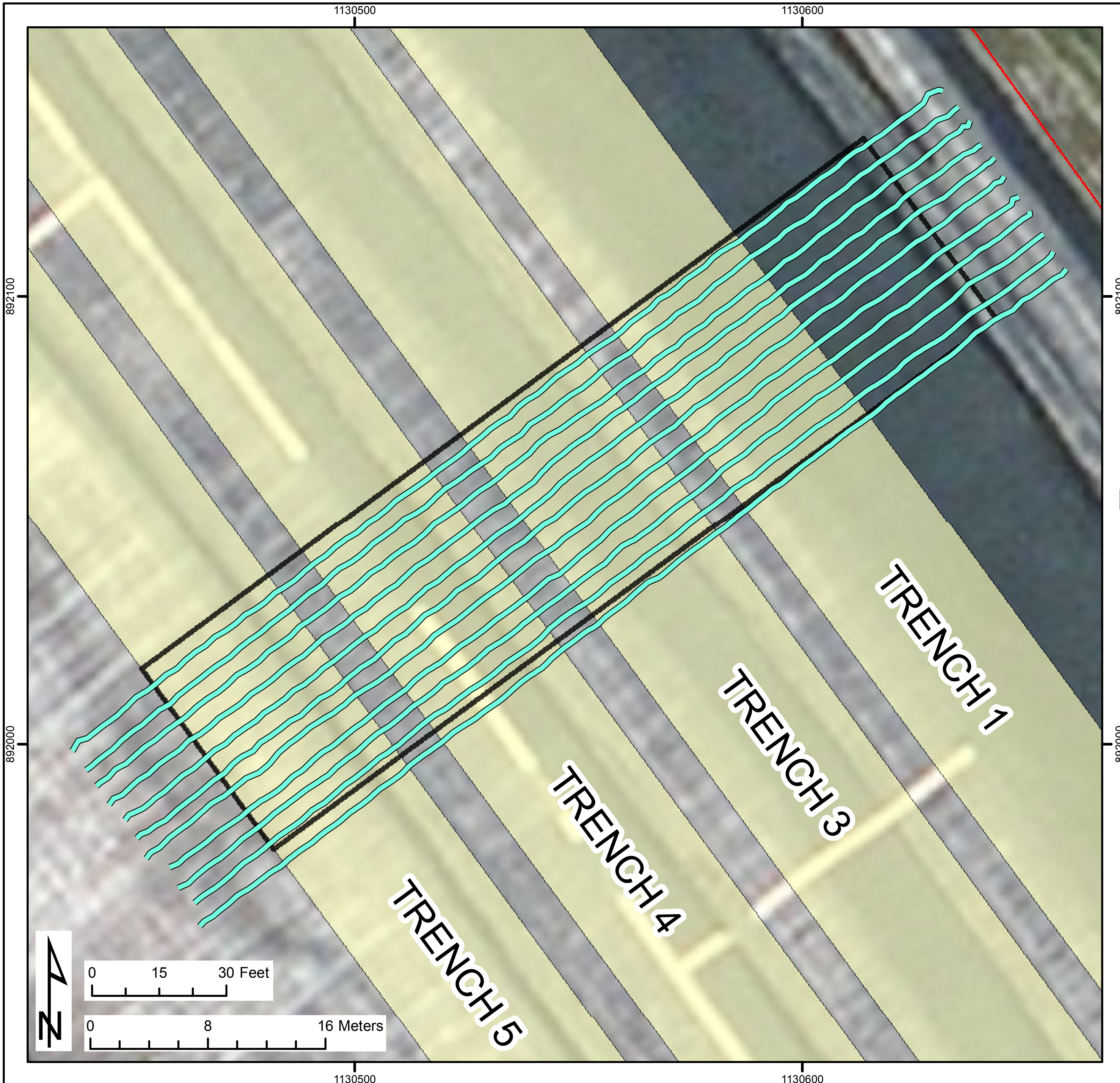

Legend

- EM and Mag Profile Lines
- Pilot Study Area
- Reported SDA Trench
- Site Boundary

Figure 2
EM and Magnetometer Profile Lines

West Valley Demo Project and
Western New York Nuclear Center

TerranearPMC

Date: 10/17/2016
Rev: CM
Drafted by: TPMC

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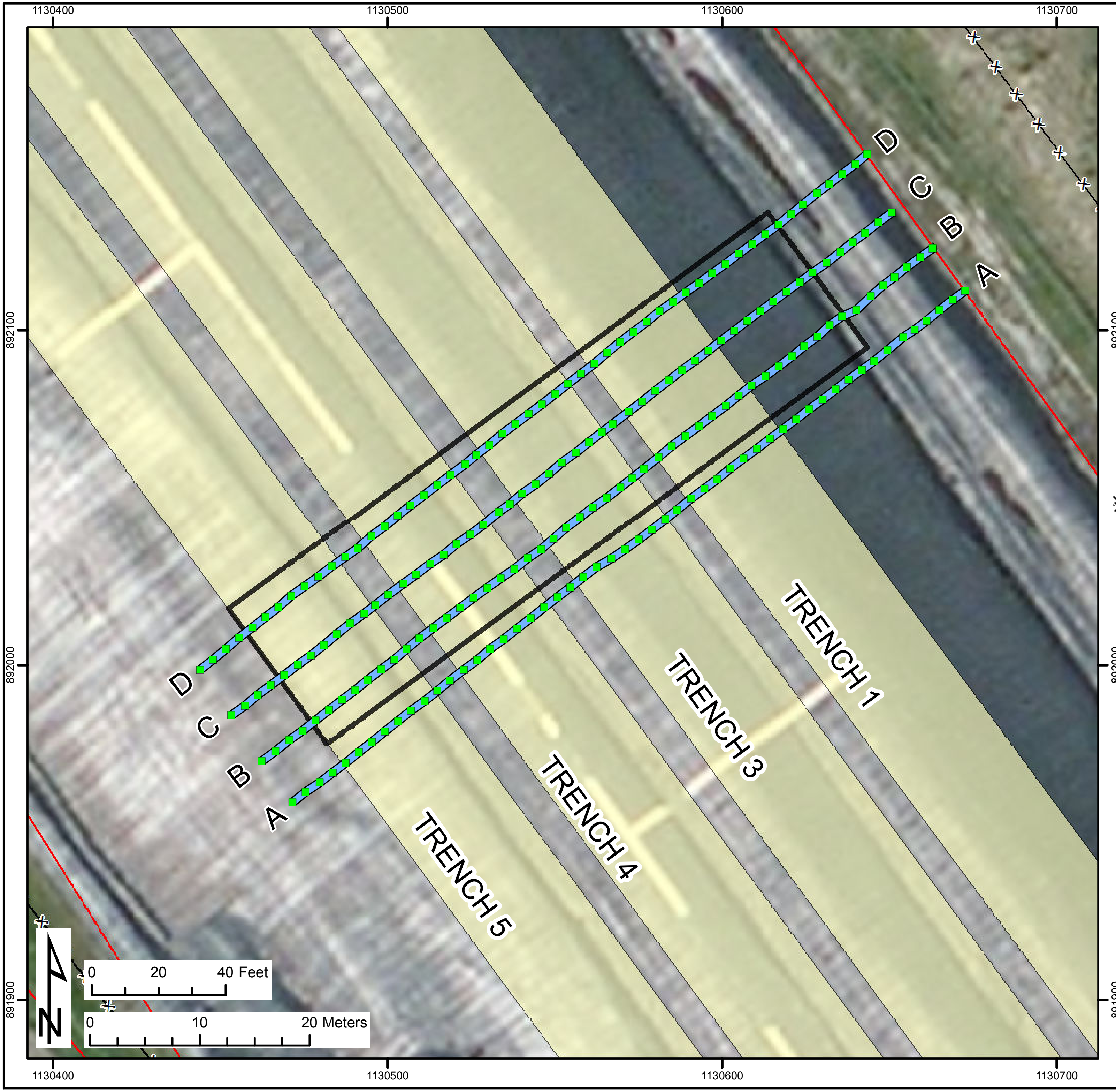

Legend

- ERT, SRT, MASW Profile Line
- Geophone/Electrode Location
- Pilot Study Area
- Fence Line
- Reported SDA Trench
- Site Boundary

Figure 3
ERT, SRT, and MASW Profile Lines

West Valley Demo Project and
Western New York Nuclear Center

TerranearPMC

Date: 10/17/2016
Rev: CM
Drafted by: TPMC

Coordinate System: NAD 83, State Plane NY West (ft)
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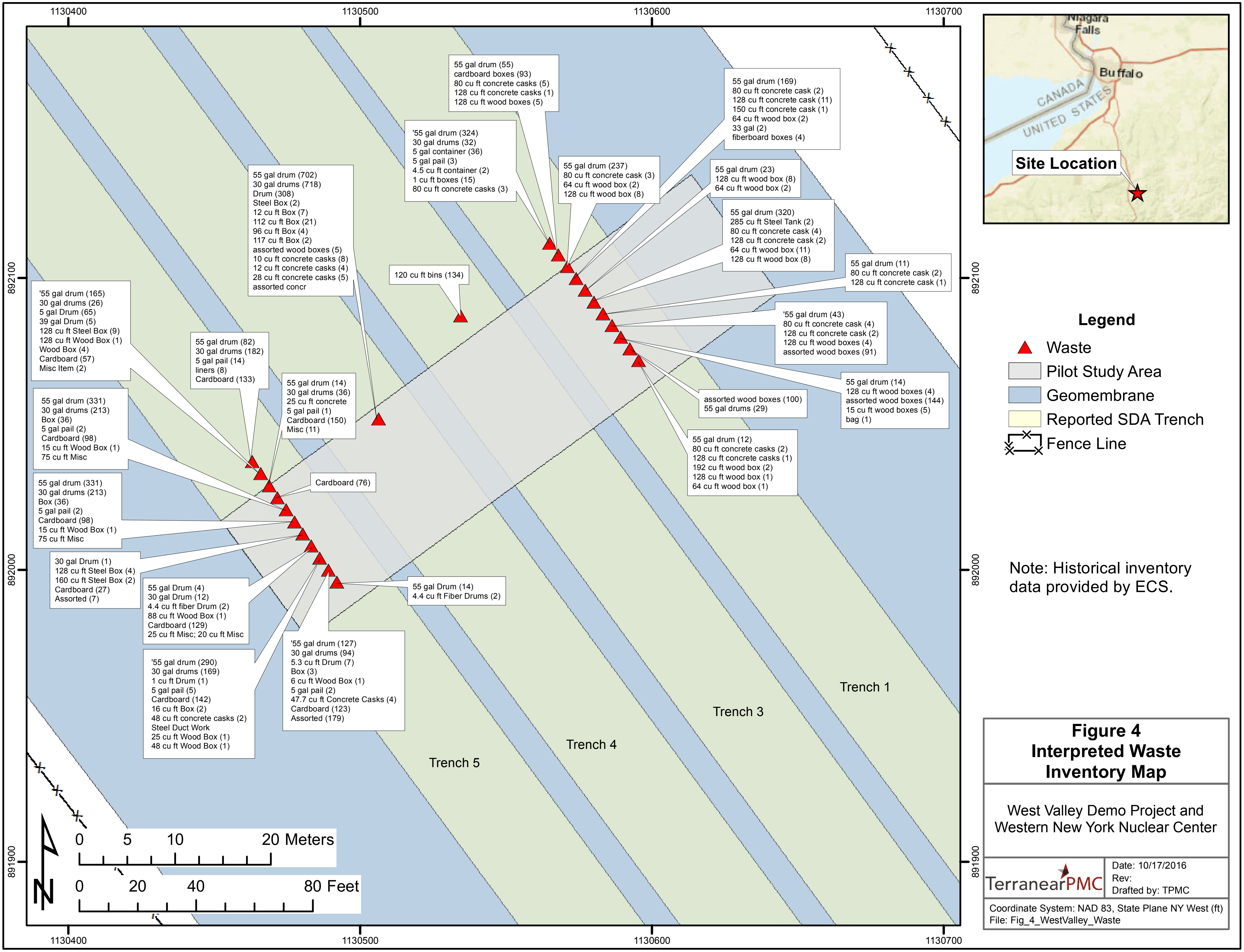
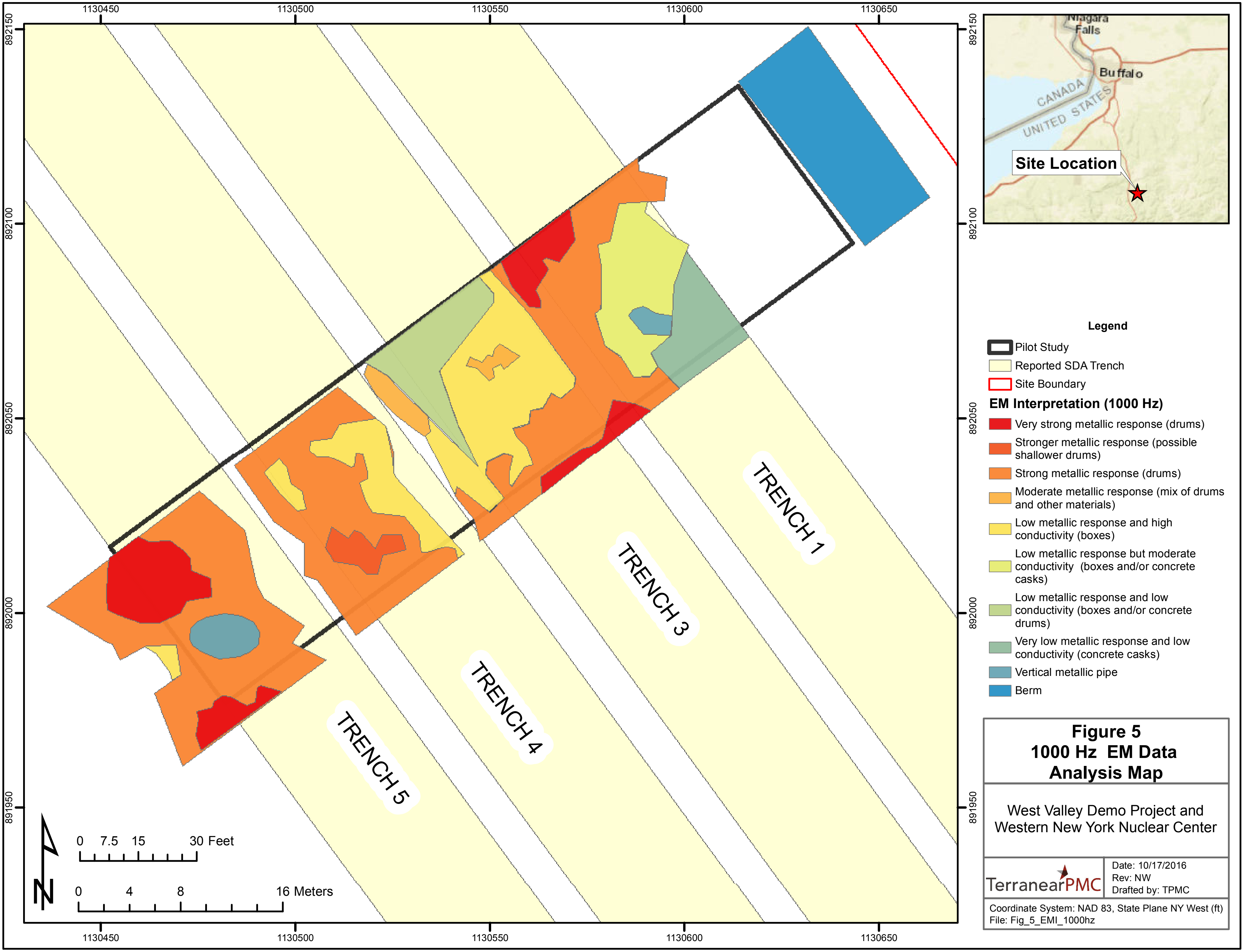


Figure 4
Interpreted Waste Inventory Map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1130500
1130550
1130600
1130650
892150
892100
892050
892000
891950
TRENCH 1
TRENCH 3
TRENCH 4
TRENCH 5
0 7.5 15 30 Feet
0 4 8 16 Meters
N
Niagara Falls
Buffalo
CANADA
UNITED STATES
Site Location
Legend
Pilot Study
Reported SDA Trench
Site Boundary
EM Interpretation (1000 Hz)
Very strong metallic response (drums)
Stronger metallic response (possible shallower drums)
Strong metallic response (drums)
Moderate metallic response (mix of drums and other materials)
Low metallic response and high conductivity (boxes)
Low metallic response but moderate conductivity (boxes and/or concrete casks)
Low metallic response and low conductivity (boxes and/or concrete drums)
Very low metallic response and low conductivity (concrete casks)
Vertical metallic pipe
Berm
Figure 5
1000 Hz EM Data
Analysis Map
West Valley Demo Project and
Western New York Nuclear Center
TerranearPMC
Date: 10/17/2016
Rev: NW
Drafted by: TPMC
Coordinate System: NAD 83, State Plane NY West (ft)
File: Fig_5_EMI_1000hz

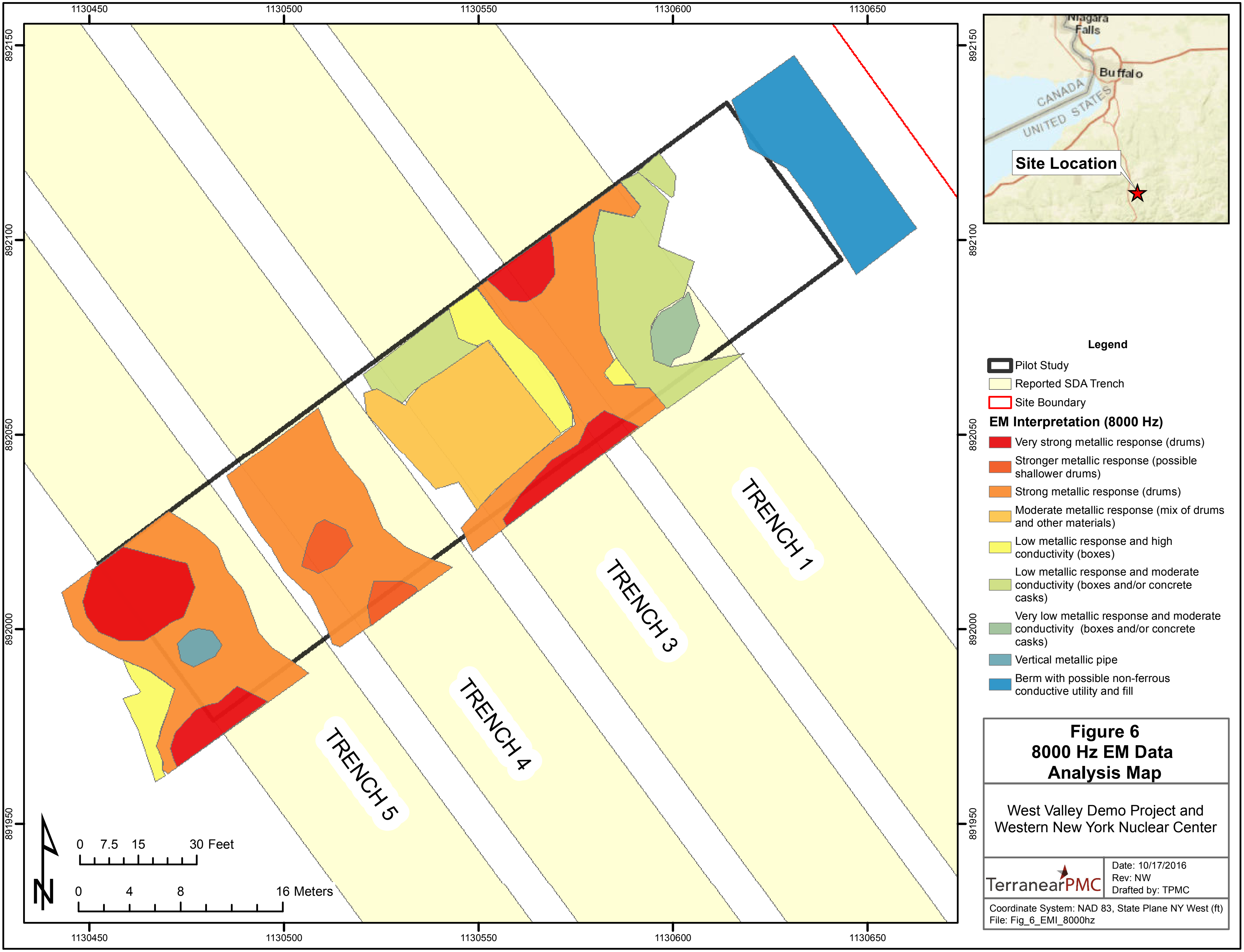


Figure 6
8000 Hz EM Data Analysis Map

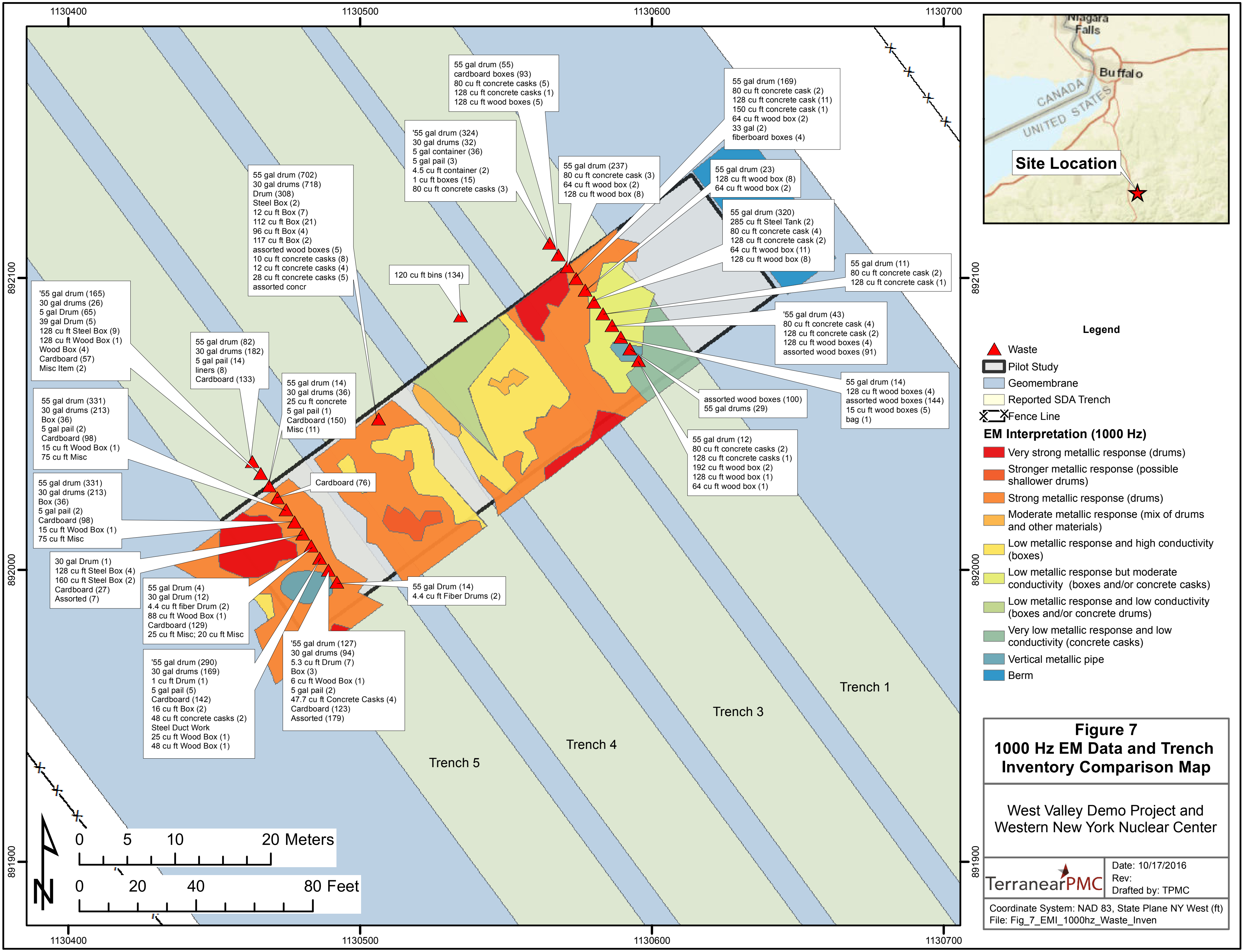
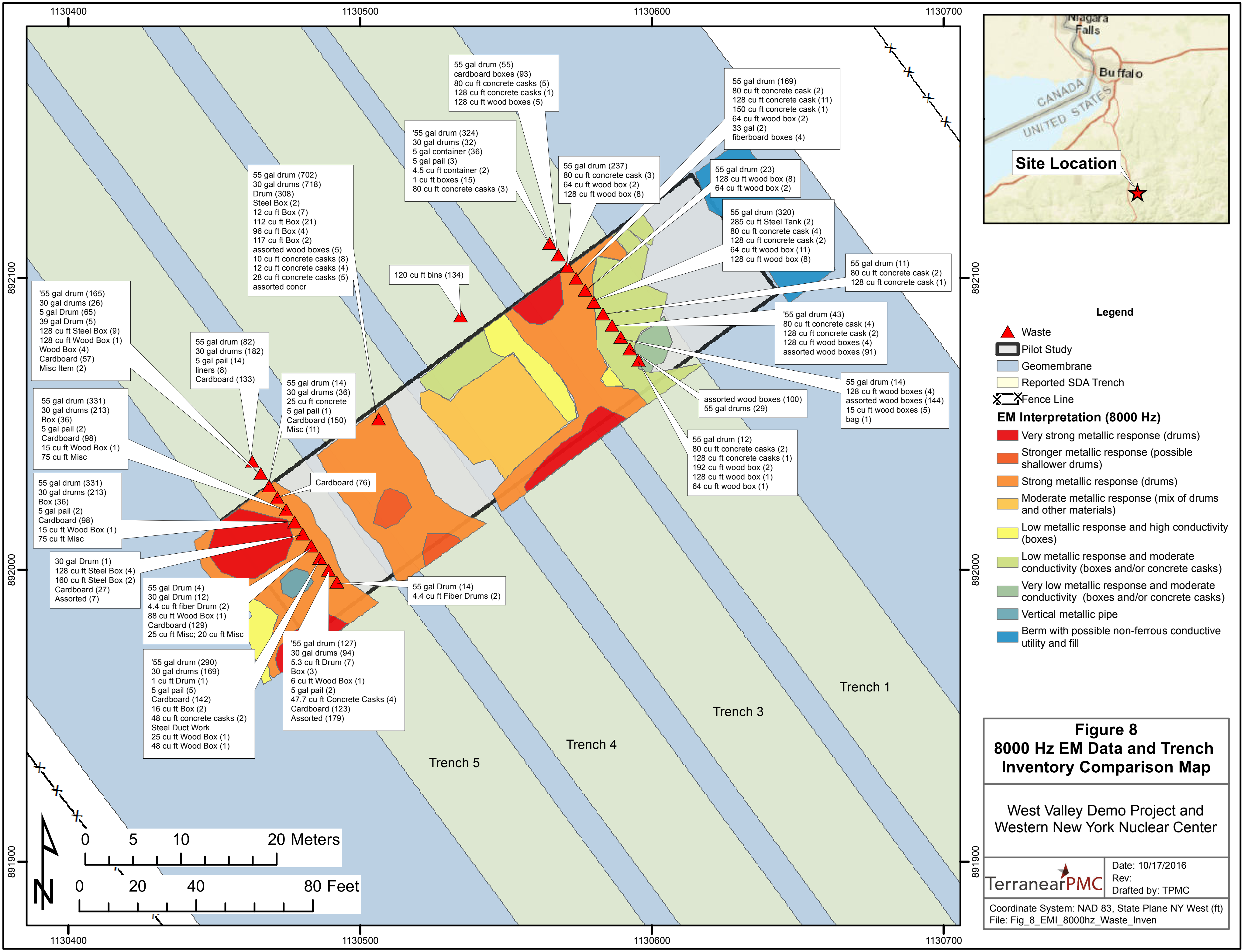
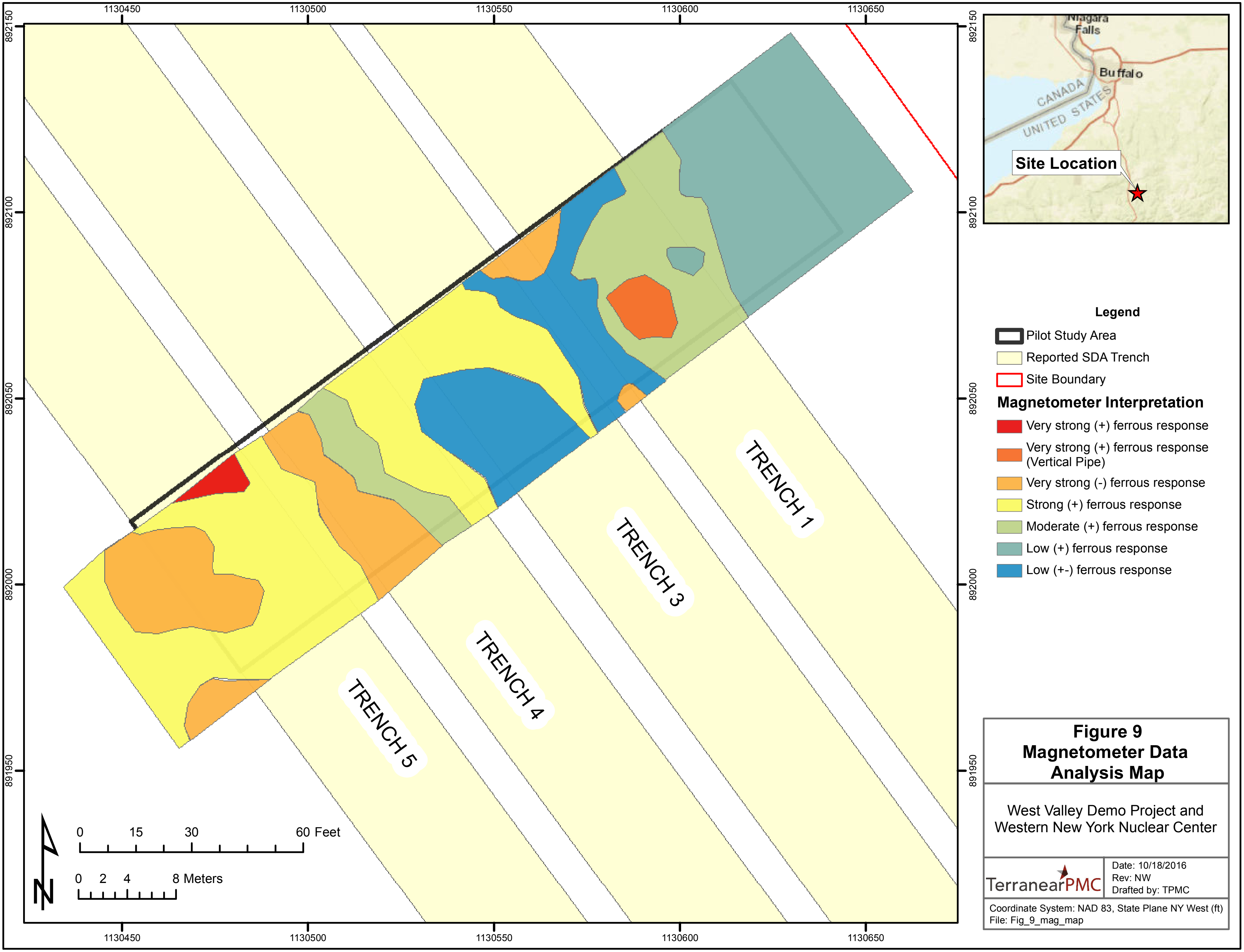


Figure 7
1000 Hz EM Data and Trench Inventory Comparison Map



1130400
1130500
1130600
1130700
892100
892000
891900
55 gal drum (55)
cardboard boxes (93)
80 cu ft concrete casks (5)
128 cu ft concrete casks (1)
128 cu ft wood boxes (5)
55 gal drum (169)
80 cu ft concrete cask (2)
128 cu ft concrete cask (11)
150 cu ft concrete cask (1)
64 cu ft wood box (2)
33 gal (2)
fiberboard boxes (4)
'55 gal drum (324)
30 gal drums (32)
5 gal container (36)
5 gal pail (3)
4.5 cu ft container (2)
1 cu ft boxes (15)
80 cu ft concrete casks (3)
55 gal drum (237)
80 cu ft concrete cask (3)
64 cu ft wood box (2)
128 cu ft wood box (8)
55 gal drum (23)
128 cu ft wood box (8)
64 cu ft wood box (2)
55 gal drum (702)
30 gal drums (718)
Drum (308)
Steel Box (2)
12 cu ft Box (7)
112 cu ft Box (21)
96 cu ft Box (4)
117 cu ft Box (2)
assorted wood boxes (5)
10 cu ft concrete casks (8)
12 cu ft concrete casks (4)
28 cu ft concrete casks (5)
assorted concr
55 gal drum (320)
285 cu ft Steel Tank (2)
80 cu ft concrete cask (4)
128 cu ft concrete cask (2)
64 cu ft wood box (11)
128 cu ft wood box (8)
120 cu ft bins (134)
55 gal drum (11)
80 cu ft concrete cask (2)
128 cu ft concrete cask (1)
'55 gal drum (165)
30 gal drums (26)
5 gal Drum (65)
39 gal Drum (5)
128 cu ft Steel Box (9)
128 cu ft Wood Box (1)
Wood Box (4)
Cardboard (57)
Misc Item (2)
55 gal drum (82)
30 gal drums (182)
5 gal pail (14)
liners (8)
Cardboard (133)
'55 gal drum (43)
80 cu ft concrete cask (4)
128 cu ft concrete cask (2)
128 cu ft wood boxes (4)
assorted wood boxes (91)
55 gal drum (14)
30 gal drums (36)
25 cu ft concrete
5 gal pail (1)
Cardboard (150)
Misc (11)
55 gal drum (14)
128 cu ft wood boxes (4)
assorted wood boxes (144)
15 cu ft wood boxes (5)
bag (1)
assorted wood boxes (100)
55 gal drums (29)
55 gal drum (331)
30 gal drums (213)
Box (36)
5 gal pail (2)
Cardboard (98)
15 cu ft Wood Box (1)
75 cu ft Misc
55 gal drum (12)
80 cu ft concrete casks (2)
128 cu ft concrete casks (1)
192 cu ft wood box (2)
128 cu ft wood box (1)
64 cu ft wood box (1)
Cardboard (76)
55 gal drum (331)
30 gal drums (213)
Box (36)
5 gal pail (2)
Cardboard (98)
15 cu ft Wood Box (1)
75 cu ft Misc
30 gal Drum (1)
128 cu ft Steel Box (4)
160 cu ft Steel Box (2)
Cardboard (27)
Assorted (7)
55 gal Drum (4)
30 gal Drum (12)
4.4 cu ft fiber Drum (2)
88 cu ft Wood Box (1)
Cardboard (129)
25 cu ft Misc; 20 cu ft Misc
55 gal Drum (14)
4.4 cu ft Fiber Drums (2)
'55 gal drum (127)
30 gal drums (94)
5.3 cu ft Drum (7)
Box (3)
6 cu ft Wood Box (1)
5 gal pail (2)
47.7 cu ft Concrete Casks (4)
Cardboard (123)
Assorted (179)
'55 gal drum (290)
30 gal drums (169)
1 cu ft Drum (1)
5 gal pail (5)
Cardboard (142)
16 cu ft Box (2)
48 cu ft concrete casks (2)
Steel Duct Work
25 cu ft Wood Box (1)
48 cu ft Wood Box (1)
Trench 1
Trench 3
Trench 4
Trench 5
0 5 10 20 Meters
0 20 40 80 Feet
N
Niagara Falls
Buffalo
CANADA
UNITED STATES
Site Location
Legend
Waste
Pilot Study
Geomembrane
Reported SDA Trench
Fence Line
EM Interpretation (8000 Hz)
Very strong metallic response (drums)
Stronger metallic response (possible shallower drums)
Strong metallic response (drums)
Moderate metallic response (mix of drums and other materials)
Low metallic response and high conductivity (boxes)
Low metallic response and moderate conductivity (boxes and/or concrete casks)
Very low metallic response and moderate conductivity (boxes and/or concrete casks)
Vertical metallic pipe
Berm with possible non-ferrous conductive utility and fill
Figure 8
8000 Hz EM Data and Trench Inventory Comparison Map
West Valley Demo Project and Western New York Nuclear Center
TerranearPMC
Date: 10/17/2016
Rev:
Drafted by: TPMC
Coordinate System: NAD 83, State Plane NY West (ft)
File: Fig_8_EMI_8000hz_Waste_Inven



1130450
1130500
1130550
1130600
1130650
892150
892100
892050
892000
891950
TRENCH 1
TRENCH 3
TRENCH 4
TRENCH 5
0 15 30 60 Feet
0 2 4 8 Meters
N
Niagara Falls
Buffalo
CANADA
UNITED STATES
Site Location
Legend
Pilot Study Area
Reported SDA Trench
Site Boundary
Magnetometer Interpretation
Very strong (+) ferrous response
Very strong (+) ferrous response (Vertical Pipe)
Very strong (-) ferrous response
Strong (+) ferrous response
Moderate (+) ferrous response
Low (+) ferrous response
Low (+-) ferrous response
Figure 9
Magnetometer Data Analysis Map
West Valley Demo Project and Western New York Nuclear Center
TerranearPMC
Date: 10/18/2016
Rev: NW
Drafted by: TPMC
Coordinate System: NAD 83, State Plane NY West (ft)
File: Fig_9_mag_map

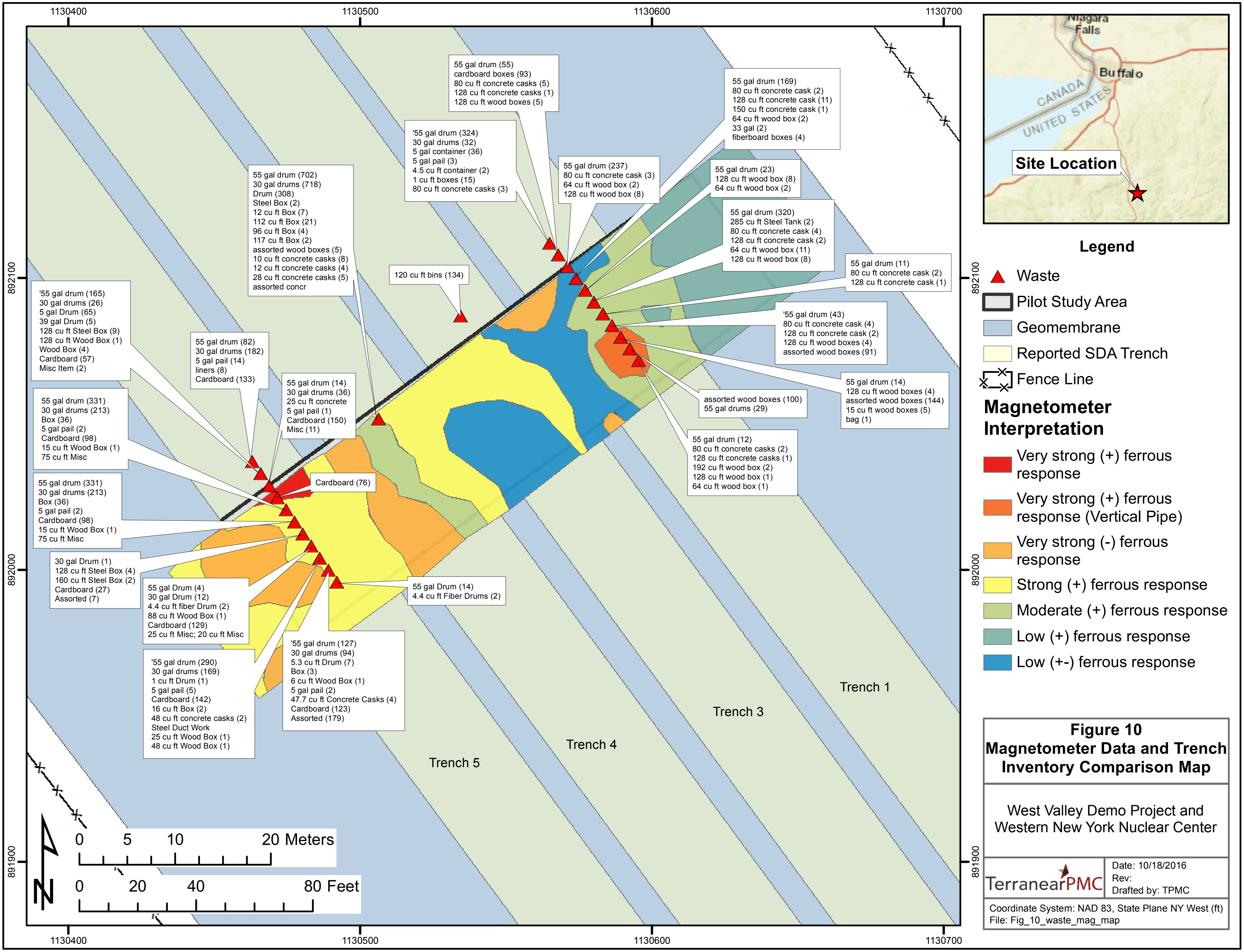
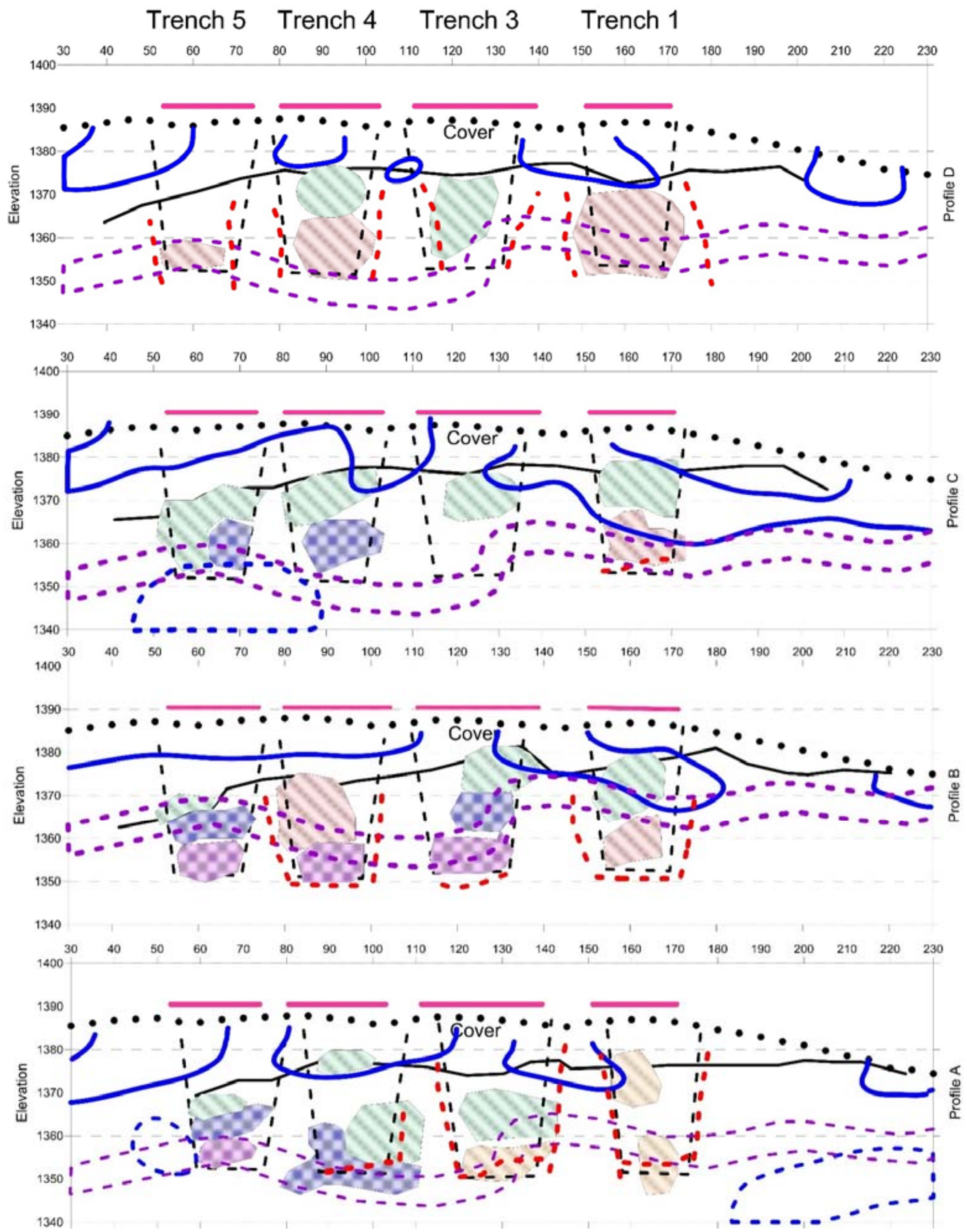


Figure 10
Magnetometer Data and Trench Inventory Comparison Map

West Valley Demo Project and Western New York Nuclear Center



Legend

- Dense Material/Metal/Concrete Dry Conditions
- Dense Material/Metal/Concrete Saturated Conditions
- Cardboard/Wood Dry
- Cardboard/Wood Saturated Conditions
- SRT Interpreted Bottom of Excavations
- Interpreted Bottom of Cover Material
- Location of Trenches (Aerial Photographs)
- Reported Location of Trenches
- Interpreted MASW Sides/Bottom of Trench
- Ground Surface Elevation
- SRT Low Velocity Lobes
- SRT Low Velocity Anomaly (Deep)

Figure 11
MASW and SRT Analysis Cross Sections

West Valley Demo Project and Western New York Nuclear Center

TerranearPMC

Date: 10/17/2016
Rev: CM
Drafted by: TPMC

Coordinate System: NAD 83, State Plane NY West (ft)
File: Fig_11_cross_sections

APPENDIX B
PHOTOGRAPHIC LOG

Photo 01

Description:
Aerial photo of pilot study area

Photo 02

Description:
SuperSting Electrical Resistivity Tomography (ERT) System

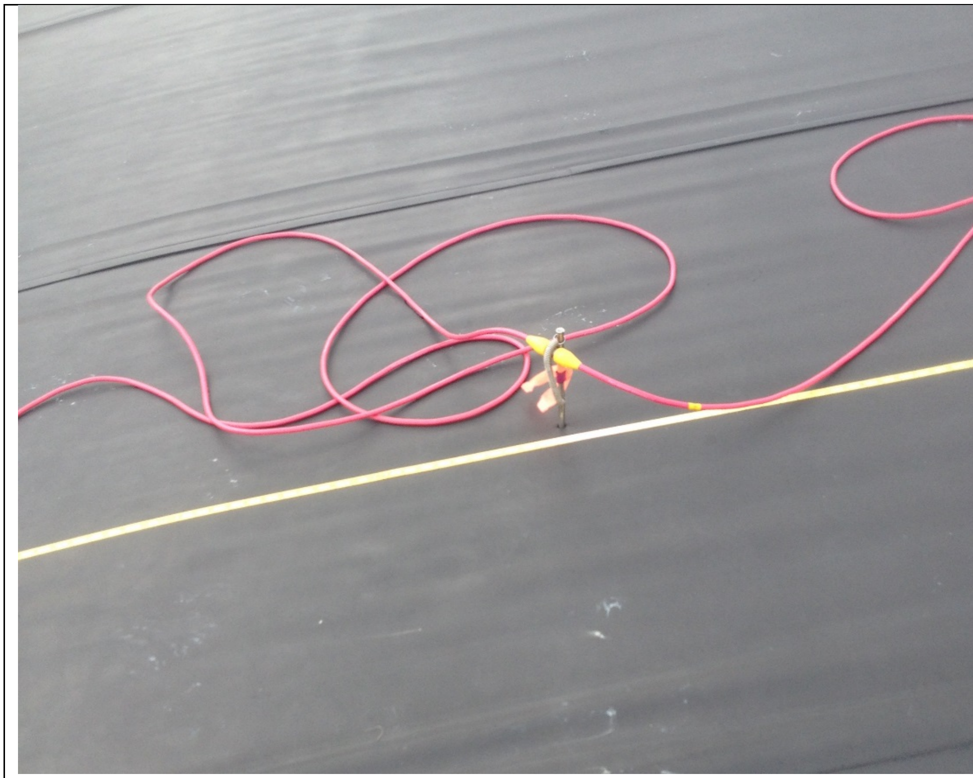


Photo 03

Description:
ERT electrode penetrating liner.

Photo 04

Description:
ERT electrode array across pilot study area.

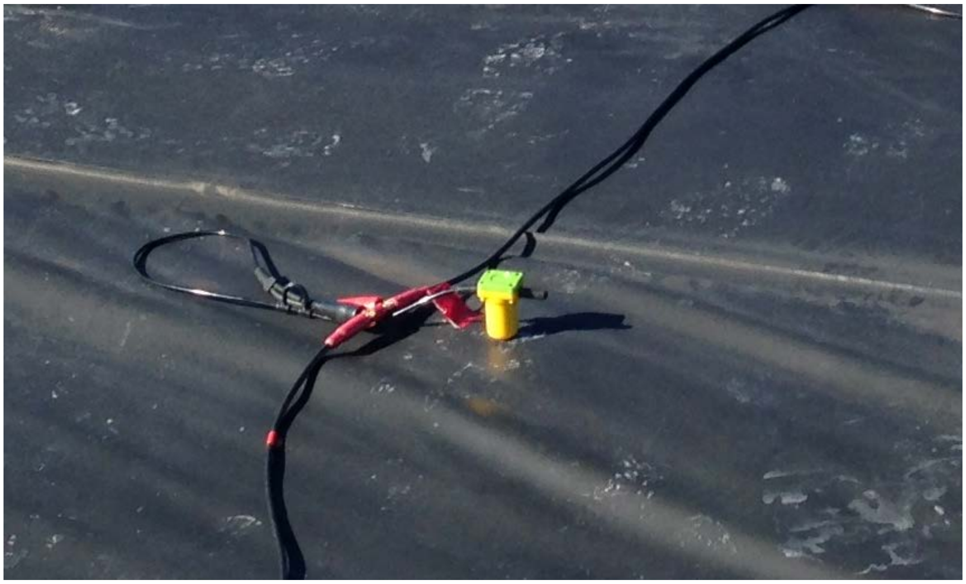


Photo 05

Description:
MASW and Seismic Refraction Tomography (SRT) geophone penetrating liner.

Photo 6

Description:
MASW geophone array and data collection with Geometrics Geode Seismograph.

Photo 7

Description:
MASW and SRT seismic source striking plate (12” x 12” x 1” steel, weight 53 lbs).

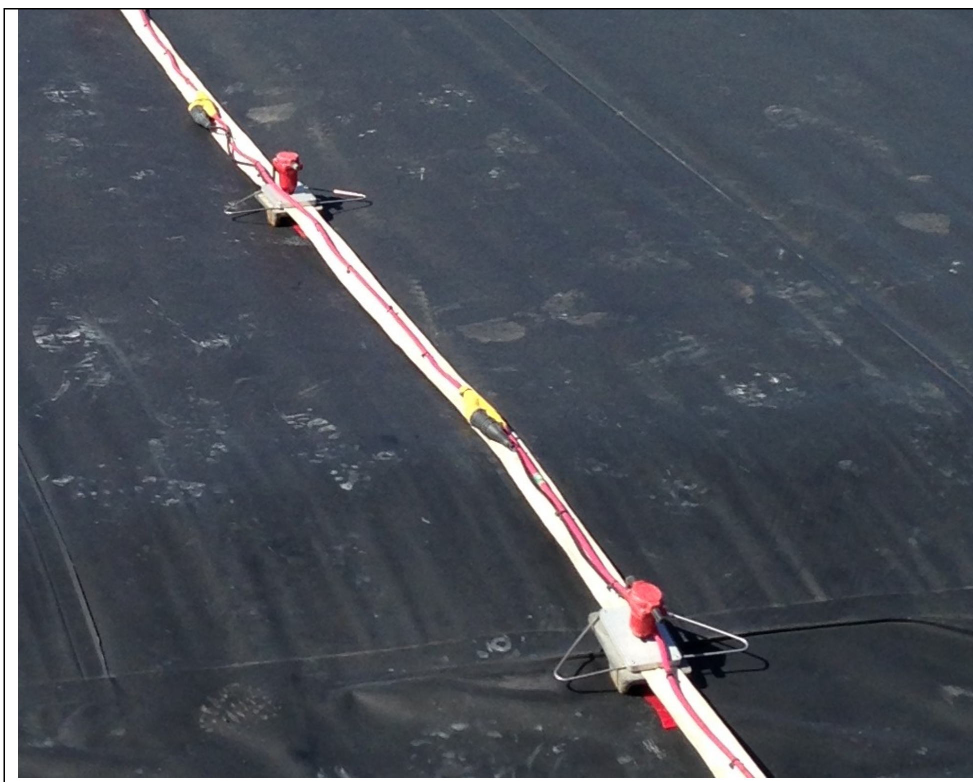


Photo 8

Description:
MASW and SRT seismic geophone land streamer – no liner penetration required.

Photo 9

Description:
MASW and SRT seismic geophone land streamer spread / array – no liner penetration required.

Photo 10

Description:
SRT Geometrics Geode Seismograph setup.

Photo 11

Description:
SRT seismic source with sledge hammer striking steel plate.

Photo 12

Description:
SRT geophones on liner with sand bags holding them down for comparison with land streamer geophone data.

Photo 13

Description:
Geometrics G-858G-Gradiometer data collection with integrated GPS positioning.

Photo 14

Description:
GSSI Profiler Electromagnetic (EM) data collection with integrated GPS positioning.

Photo 15

Description:
Geometrics G-858G-Gradiometer data collection with integrated GPS positioning.

APPENDIX C
ELECTROMAGNETIC INDUCTION AND MAGNETOMETRY GEOPHYSICAL SURVEY

Final Report
Electromagnetic Induction and Magnetometry Geophysical Survey
West Valley Geophysics Prove-Out Study
West Valley, New York

Prepared for

TerranearPMC, LLC
222 Valley Creek Boulevard
Suite 210
Exton, Pennsylvania 19341

Prepared by

Applus RTD
80 Lawrence Bell Dr.
Buffalo, New York 14221

4/21/2017

Applus RTD Work Order Number: 07.018018/001

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Table

1 INTRODUCTION

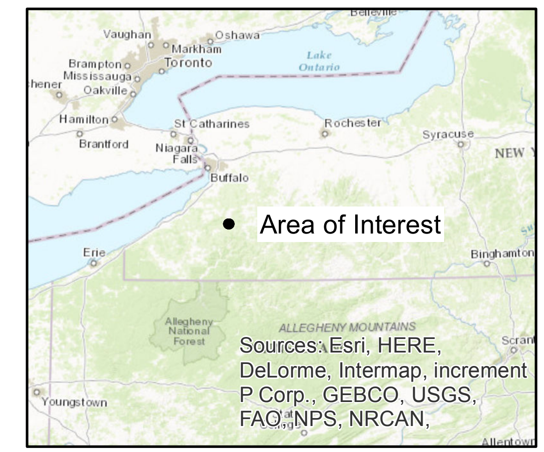
On September 6^{th} and 8^{th}, 2016, Applus RTD conducted an Electromagnetic Induction (EMI) and a Magnetometry (MAG) geophysical investigation for TerranearPMC, LLC (Terranear). These investigations were part of the data collection program for the West Valley Geophysical Prove-Out Study. Figure 1-1 is a site map of the Prove-Out Study work area. The following sections provide a detailed analysis of the work performed and the results obtained from the EMI and MAG investigations.

Legend

AOI

SDA Trenches

Buildings



1:1,836

140 70 0 140 280

Feet

N

West Valley Demonstration
Western New York Nuclear Service Center

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive Yorba Linda, California 92887
Figure 1-1

Applus RTD

2 SURVEY METHODOLOGY

2.1 ELECTROMAGNETIC INDUCTION (EMI)

2.1.1 Description

The EMI method applies the principles of electromagnetic induction to determine apparent conductivity and the presence of metal in the subsurface. The Profiler EMP-400 is a frequency-domain, electromagnetic induction (EMI) instrument. The instrument is a multi-frequency instrument that acquires data at three frequencies simultaneously and is capable of operating at frequencies between 1000 Hertz (Hz) and 16,000 Hz (at whole kHz intervals), and has a 1.21-meter (m) long boom separating the transmitter and receiver coils. The transmitter generates a pulsed primary magnetic field, which generates small currents in the subsurface. These small currents generate a secondary magnetic field which, along with the primary field, is detected by the receiver coil. The instrument compares the secondary field with the primary field to produce two components. The component that has the same phase as the primary field is the in-phase component. The quadrature component, reported as parts per million (PPM), is the portion of the field that is 90 degrees out of phase with the primary field. The in-phase component, also reported in PPM, is sensitive to buried metal while the quadrature component is proportional to the terrain conductivity. Conductivity is derived from the Quadrature data and has units of mS/ft (milliSiemens/foot).

2.1.2 Equipment

The Profiler EMP-400 is a compact lightweight unit capable of being interfaced with a GPS for real-time locations. The ability of this instrument to collect rapid EM data over large areas is a key for its use on this project. During this investigation a Profiler EMP-400, manufactured by Geophysical Survey Systems, Inc. was used to collect the data. The Profiler data were also collected simultaneously with an attached global positioning system (GPS) to collect horizontal and vertical position of the data to within 1 foot accuracy.

2.1.3 Field Survey Design

Survey design was based on the pre-determined Prove-Out Study area. The project coordinates were based on NAD83 New York State Plane West in US feet as noted by Terranear. The EMI portion of the Prove-Out Study encompassed the same area that had been laid out by ACE Geophysics LLC (ACE) for the Electrical Resistivity Imaging (ERI) and the Multi-Channel Analysis of Surface Waves (MASW) Survey performed prior to these surveys. Two (2) complementary EMI data sets were acquired for the survey that was performed across the area of interest with a sample interval of 0.25 second with a 1000 Hz response frequency, and encompassing the same area with a sample interval of 0.5 second between readings utilizing

5,000 Hz, 8,000 Hz and 15,000 Hz response frequencies. The depth of investigation of an EMI survey is determined by the soil type, target size, and target composition. The depth of investigation for a frequency domain EMI survey is inversely proportional to the frequency of the survey. Typical responses as reported by the manufacturer GSSI are as follows.

Frequencies (Hz)	Target Depth of Investigation
16,000 / 15,000 / 14,000 / 13,000	Upper 1 meter/3-4 feet
12,000 / 11,000 / 10,000 / 9,000	Upper 2 meters/6-7 feet
8,000 / 7,000 / 6,000 / 5,000	Upper 3 meters/9-10 feet
4,000 / 3,000 / 2,000 / 1,000	Upper 4 meters/13-15 feet

Table 2-1 Table of EMI Frequency versus Target Depth of Investigations

All lines in both data sets were acquired traversing from southwest to northeast to maximize repeatability and limit lag errors including those due to changing topography. Applus RTD ran two different EMI surveys in order to maximize sampling interval for the lower 1000 Hz dataset.

EMI surveys were proposed to be performed with transect spacing of 2 meters over an area of approximately 61 meters by 15 meters in the proposal. The adjusted English scale area of interest utilized five (5) foot transect spacing and measured 245 feet by 50 feet.

2.1.4 Quality Control

A QC station was established near the survey area, but not within the survey area. This QC station was marked with a semi-permanent marker. The area was scanned for metallic items and sources of EM interference and the lowest EM response area was chosen. The Profiler was calibrated at the QC station as described within the operator’s manual. Times and site conditions of the calibration are recorded on field data sheets.

At the beginning of each field day, the Profiler was brought to the QC station and calibrated according to the equipment manual. The instrument was also recalibrated every time the instrument is cycled off and on (i.e. battery change).

Instrument function and quality control checks that occurred on a daily basis during frequency domain electromagnetic field operations included the following:

- Instrument warmup – Typically less than 5 minutes to stabilize fields. Can be performed during power up of GPS system and location lock of GPS signal.
- Operator self-check – minimize metallic presence and no cell phone.

- Begin system calibrations – at area defined for calibration; keep single location for entire project.
    - Confirm Time Interval and Transmit Frequencies
    - Perform Field Calibration
    - Set Carry Height and Perform Operator Calibration.
    - Set In-Phase Zero
- Daily Static No Object and Object QC Checks
- QC Latency Tests
- Known position check – within 3.5 ft. of monument or control point.

The results for all the EMI QC tests are presented in Appendix A of this document.

2.2 MAGNETOMETRY

2.2.1 Description

The magnetic method measures variations in the Earth's magnetic field. Surveys are typically conducted by measuring the magnetic field strength along survey transects that are spaced at regular intervals across the investigation area. Subsurface disposal trenches and large quantities of metallic waste may contribute to localized variations in the Earth’s magnetic field, which in turn are measured and recorded by the magnetometer instrumentation. After data are processed, they are plotted either as line profiles or gridded contour maps. Localized variations or distortions in the magnetic field within a survey area are considered magnetic anomalies. These anomalies are interpreted and analyzed to determine their source (i.e. subsurface geologic conditions, surface cultural features, or buried ferromagnetic objects). In comparing the magnetic data sets with those acquired by other geophysical methods, geophysical analysts can make informed assessments on anomaly sources and characterize anomalies based on shape, size, amplitude, target composition, and geophysical correlation.

2.2.2 Equipment

The equipment used was a dual sensor portable G-858 Gradiometer manufactured by Geometrics. The primary application for the G-858 was detection of burial trenches and pits that contain large aggregates of ferrous metal buried in excess of 10 to 15 feet below the ground surface. The G-858 Gradiometer was operated with the two sensors vertically offset one meter from one another and integrated with a sub-foot GPS system for positioning. A G-856 Base Station system was used to collect diurnal or other site specific magnetic variations during magnetometer investigations for background data corrections.

2.2.3 Field Survey Design

As the project coordinates are based on NAD83 New York State Plane West, US feet, the project proceeded with English feet rather than metric meters. The MAG portion of the Prove-Out Study encompassed the same area that had been laid out by ACE for the ERI and the MASW survey. The MAG survey was proposed to be performed with transect spacing of 2 meters over an area of approximately 61 meters by 15 meters. The adjusted English scale area of interest utilized five (5) foot transect spacing and measured 245 feet by 50 feet. All lines in the survey were acquired traversing from southwest to northeast to maximize repeatability and limit lag errors including those due to changing topography. The sampling frequency set for the G-858 was set to 10 Hz.

2.2.4 Quality Control

Instrument function and quality control checks that occurred on a daily basis during magnetometer field operations included the following:

- Instrument Warm-Up –typically 5-10 minutes and readings have stabilized
- Instrument Operator(s) Metal Check (ensure no metal present on data acquisition personnel)
- Daily Static No Object and Object QC Checks
- QC Latency Tests
- Known Position Check – within 3.5 ft. of monument or control point

The results for all the Mag QC tests are presented in Appendix A of this document.

3 DATA PROCESSING AND ANALYSIS

3.1 ELECTROMAGNETIC INDUCTION

3.1.1 Quality Control

The QC tests were performed as discussed in Section 2 of this document. Applus RTD conducted standard instrumentation QC checks for the equipment. The EMI QC performance tests were performed in a quiet and protected portion of the site in the vicinity of the staging shed. The elevated EMI response portion of the QC checks were performed with a large metallic object (manhole) due to it availability and the requirement of the radiological testing for bringing additional objects into the survey area. The background electromagnetic response in the area of the non-object QC checks was quiet and consistent, but non zero. The large response of the manhole was overwhelming to the electromagnetic response and well beyond the scale of any anomaly encountered during the survey. For any future EMI survey, a smaller QC calibration object should be brought to site to be utilized as a daily benchmark of response. All EMI QC results are shown in Appendix A.

3.1.2 Gridding

The data are georeferenced using an integrated sub-foot GPS. The EMI data were gridded using Geosoft Oasis Montaj software and the resultant images were exported to a PDF file. Georeferenced data were gridded using the Minimum Curvature calculation method utilizing a 0.25 grid cell spacing and a 5 foot blanking distance.

3.1.3 Data Production

The data from all four (4) frequencies collected were mapped as Inphase Component, Quadrature Component, and Apparent Conductivity. A color scheme and data limits that emphasizes the differences and similarities of the results are used for the maps. Map images of the 1,000 Hz and 8,000 Hz with the Inphase Component and the Apparent Conductivity are provided in the document, as these most clearly demonstrate what features the data can illustrate about the structure of the subgrade.

3.1.4 Data Results

Data results include the following highlights of descriptors of structure for anomalous readings as per location.

Figure 3-1: 1000 Hz Apparent Conductivity EMI

- Approximate effective depth of the Apparent Conductivity portion of the 1000 Hz survey is the upper 4 meters (approximately 13 feet) of the subgrade. The depth of investigation is related to the material composition as well as the frequency of the survey. The 1000 Hz frequency has the greatest depth of investigation for the EMI Profiler EMP-400.
- Five (5) high amplitude Apparent Conductivity anomalies (>170 mS/ft.) were observed. Approximate dimensions of the high amplitude anomalies are as follows:
    - A – 35 feet by 25 feet
    - B – 30 feet by 10 feet
    - C – 20 feet by 13 feet
    - D – 28 feet by 10 feet
    - E – 7 feet by 10 feet
- One distinct elevated Apparent Conductivity anomaly was also recorded at the western portion of the survey area – Interpreted Trench #5
- A general elevated response (100 – 170 mS/ft.) was recorded in the middle of the survey area
- A general low response (< 70 mS/ft.) was observed at the eastern portion of survey area, including the swale area where a slight linear trend of weak positive anomaly was recorded near eastern edge of swale

Figure 3-2: 8000 Hz Apparent Conductivity EMI

- Approximate effective depth of the Apparent Conductivity portion of the 8000 Hz survey is the upper 3 meters (approximately 10 feet) of the subgrade. The depth of investigation is related to the material composition as well as the frequency of the survey.
- Two (2) high amplitude Apparent Conductivity anomalies (>70 mS/ft.) were observed with the following approximate dimensions:
    - A – 38 feet by 20 feet
    - B – 23 feet by 20 feet
- Three distinct elevated Apparent Conductivity anomalies were recorded trending north south from the western portion of survey area to the east – Interpreted Trenches #5, #4 and #3 with possible indicators for partial Interpreted Trench #1
- A general low response was observed at the eastern portion of the survey area, excluding the swale area (< 45 mS/ft.)
- A strong linear trend of elevated positive anomaly was observed near eastern edge of swale.

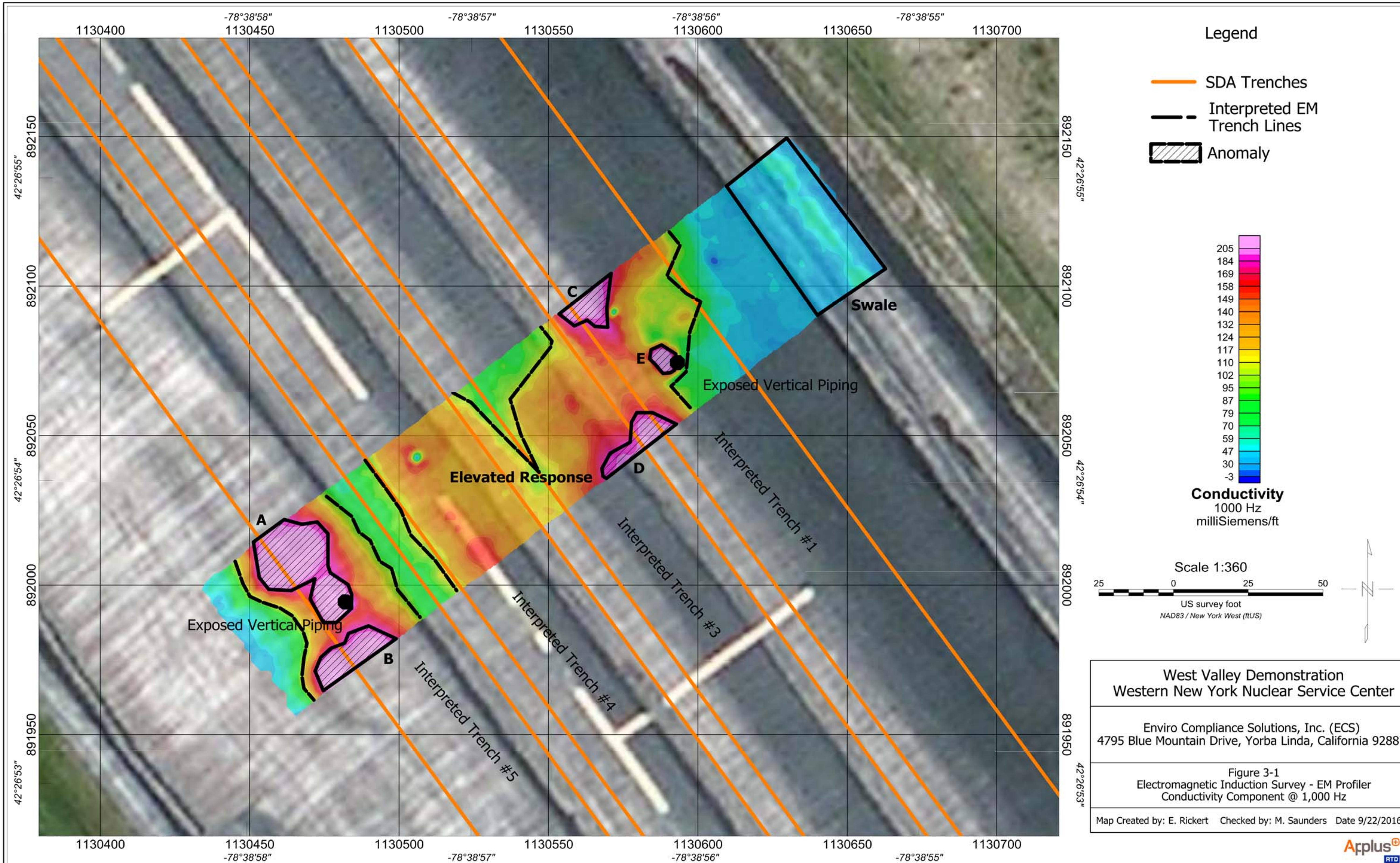
Figure 3-3: 1000 Hz Inphase Component EMI

- Approximate effective depth of the Inphase Component of the 1000 Hz survey is the upper 4 meters (approximately 13-15 feet) of the subgrade. The depth of investigation is related to the material composition as well as the frequency of the survey. The 1000 Hz frequency has the greatest depth of investigation for the EMI Profiler EMP-400.
- Four (4) high amplitude positive Inphase Component anomalies (>1600 ppm) were observed with the following approximate dimensions:
    - A – 22 feet by 23 feet
    - B – 9 feet by 23 feet
    - C – 21 feet by 15 feet
    - D – 35 feet by 8 feet
- A distinct dipole response is shown for one of the two exposed vertical metal pipes
- Two distinct north south trending elevated Inphase Component anomalies were observed at the western portion of the survey area - Interpreted Trenches #5 and #4 with possible indicators for partial Interpreted Trenches #1 and #3
- Two non-linear elevated Inphase Component anomalies were recorded at the central portion of the survey area
- General low negative responses were observed at the eastern portion of survey area, including the swale area (< 200 ppm).

Figure 3-4: 8000 Hz Inphase Component EMI

- Approximate effective depth of Inphase survey for the 8000 Hz survey is the upper 3 meters (approximately 10 feet) of the subgrade. The depth of investigation is related to the material composition as well as the frequency of the survey.
- Four (4) high amplitude positive Inphase Component anomalies (>3300 ppm) were observed with the following approximate dimensions:
    - A – 28 feet by 24 feet
    - B – 10 feet by 28 feet
    - C – 19 feet by 10 feet
    - D – 41 feet by 10 feet
- A response is shown for one of the two exposed vertical pipes

- Four (4) distinct north south trending elevated Inphase Component anomalies were observed from the western portion of the survey area encompassing approximately 80% of the survey area - Interpreted Trenches #5, #4 and #3 and partial Interpreted Trench #1
- General low negative response was observed at the eastern portion of the survey area, including the swale area (>800 ppm).



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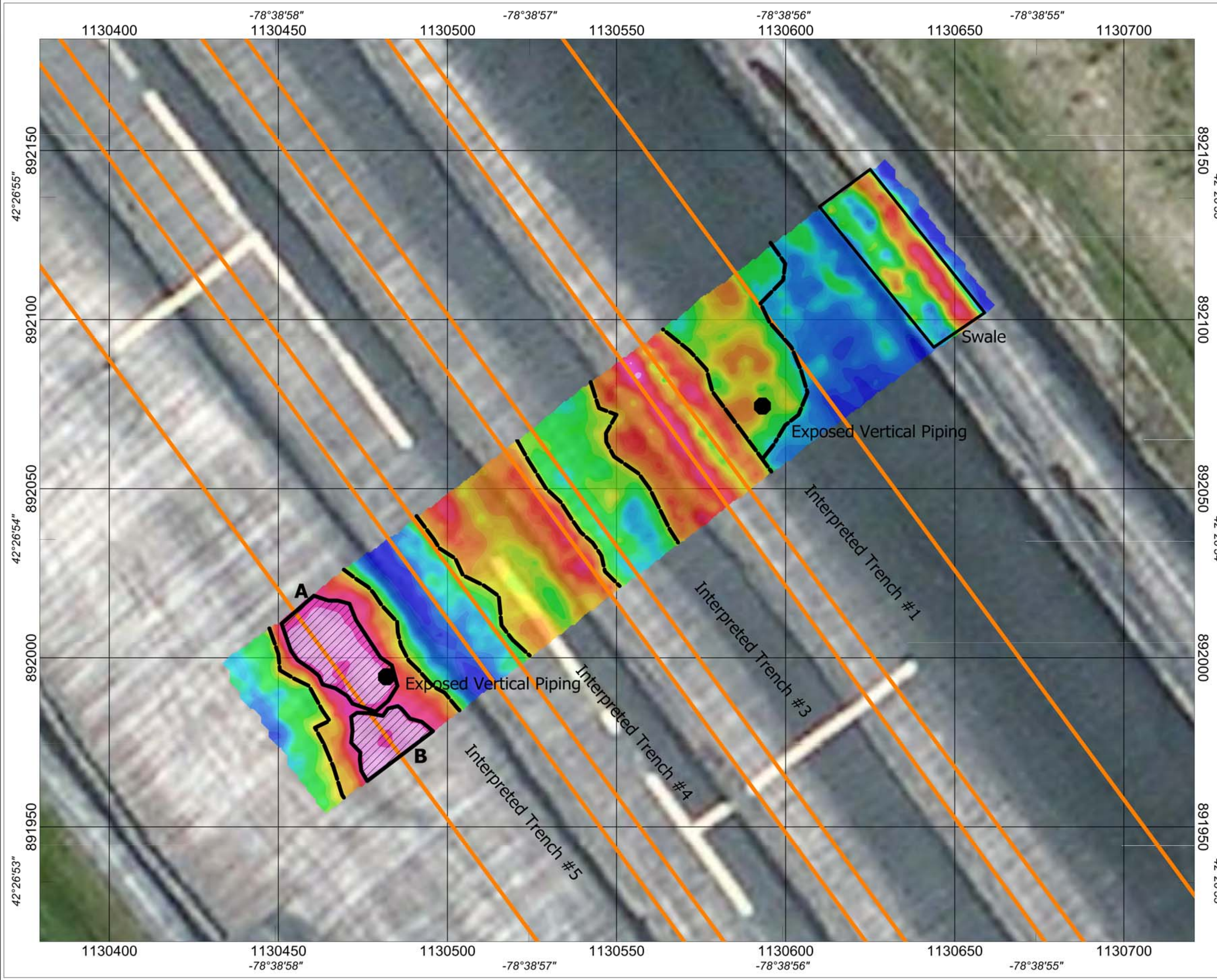
-78°38'58"
1130450
1130500
-78°38'57"
1130550
-78°38'56"
1130600
1130650
-78°38'55"
1130700
892150
892100
892050
892000
891950
42°26'55"
42°26'54"
42°26'53"
Swale
C
E
Exposed Vertical Piping
D
Elevated Response
A
Exposed Vertical Piping
B
Interpreted Trench #1
Interpreted Trench #3
Interpreted Trench #4
Interpreted Trench #5
Legend
SDA Trenches
Interpreted EM Trench Lines
Anomaly
205
184
169
158
149
140
132
124
117
110
102
95
87
79
70
59
47
30
-3
Conductivity
1000 Hz
milliSiemens/ft
Scale 1:360
25
0
25
50
US survey foot
NAD83 / New York West (ftUS)
West Valley Demonstration
Western New York Nuclear Service Center
Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive, Yorba Linda, California 92887
Figure 3-1
Electromagnetic Induction Survey - EM Profiler
Conductivity Component @ 1,000 Hz
Map Created by: E. Rickert Checked by: M. Saunders Date 9/22/2016
Applus RTD



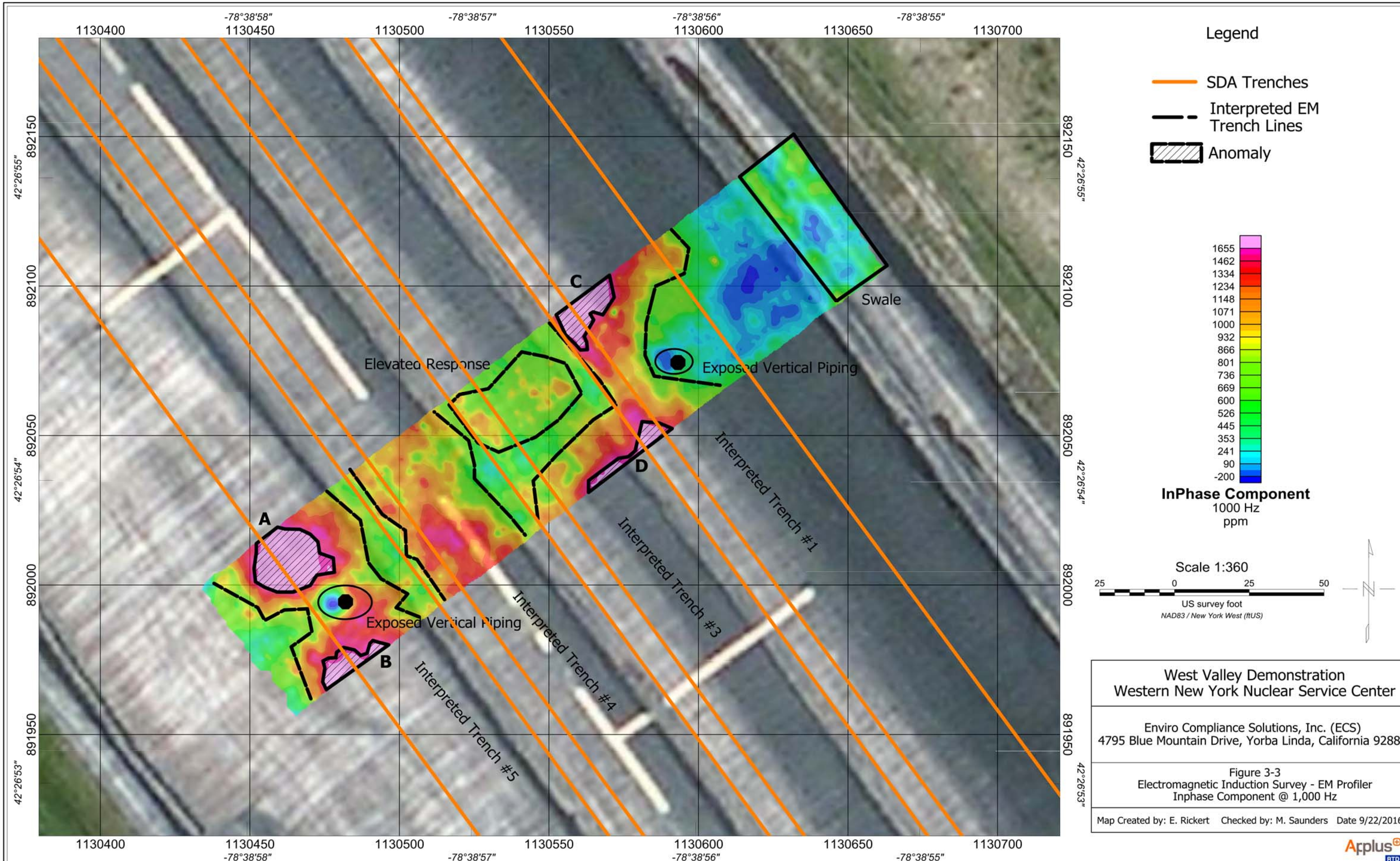
West Valley Demonstration
Western New York Nuclear Service Center

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive, Yorba Linda, California 92887

Figure 3-2
Electromagnetic Induction Survey - EM Profiler
Conductivity Component @ 8,000 Hz

Map Created by: E. Rickert Checked by: M. Saunders Date 9/22/2016

Applus RTD



West Valley Demonstration Western New York Nuclear Service Center
Enviro Compliance Solutions, Inc. (ECS) 4795 Blue Mountain Drive, Yorba Linda, California 92887
Figure 3-3 Electromagnetic Induction Survey - EM Profiler Inphase Component @ 1,000 Hz
Map Created by: E. Rickert Checked by: M. Saunders Date 9/22/2016

Applus RTD

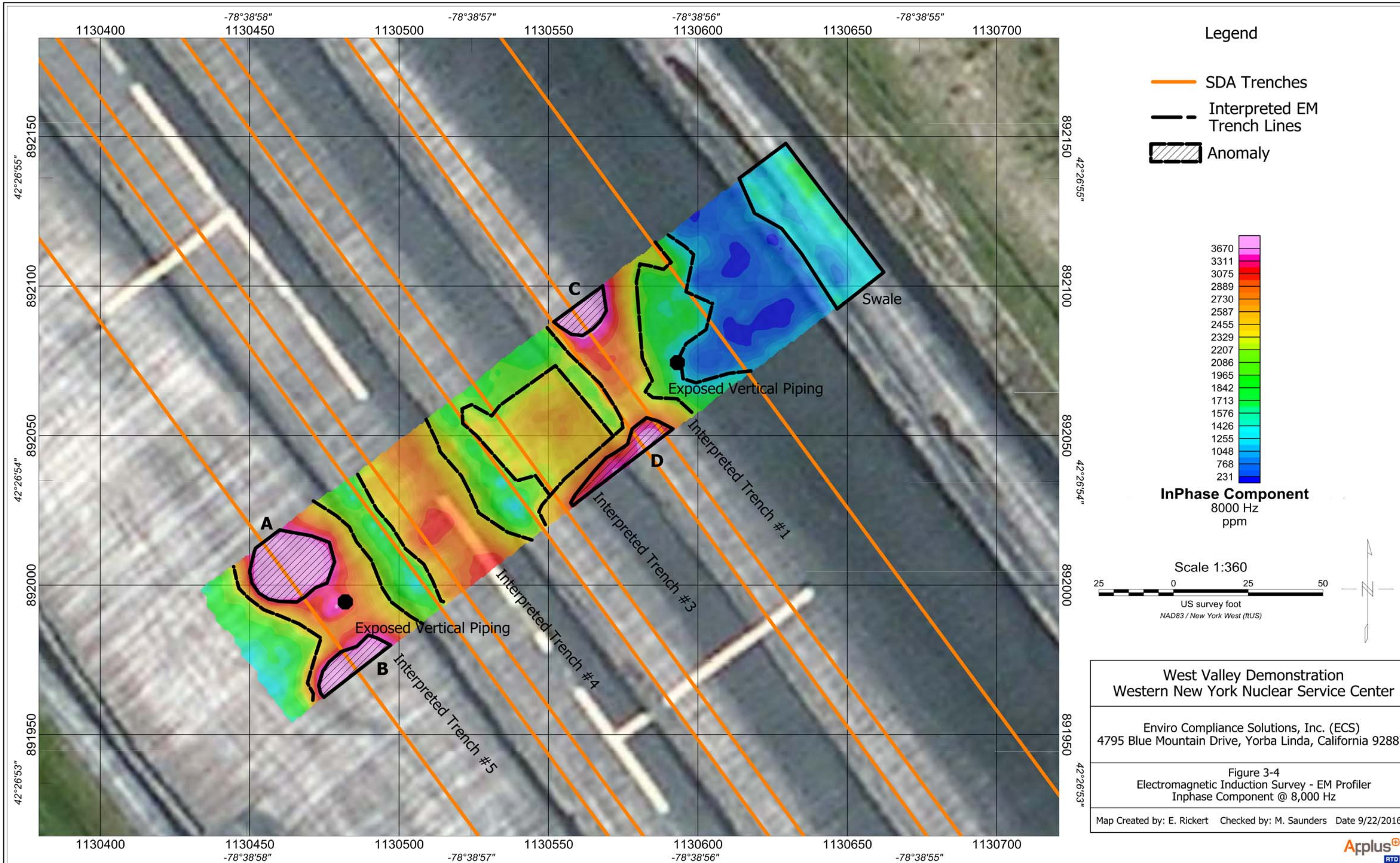


Figure 3-4
Electromagnetic Induction Survey - EM Profiler
Inphase Component @ 8,000 Hz

3.2 MAGNETOMETRY

3.2.1 Quality Control

The QC tests were performed as discussed in Section 2 of this document. Applus RTD conducted standard instrumentation QC checks for the equipment. The MAG QC performance tests were performed in a quiet and protected portion of the site in the vicinity of the staging shed. The elevated MAG response portion of the QC checks was performed with a set of keys. The background electromagnetic response in the area of the non-object QC checks was quiet and consistent, but non zero. For any future MAG survey a specific and consistent QC calibration object should be brought to the site to be utilized as a daily benchmark of response. All Mag QC data is displayed in Appendix A.

A G-856 base station was used on site for the Mag portion of the survey; however, the data was not usable. The data dropped by approximately 8,000 nT over one read and never returned to normal signal. The explanation is not known for certain, but there was rain and lightning in the area near the time of the event. The G-856 base station data was not used in the correction of the G-858 data. The G-858 data exhibited no signs of affected data and no noticeable drift was experienced in the short survey time window.

3.2.2 Gridding

The data were georeferenced using an integrated sub-foot GPS. The Mag data were gridded using Geosoft Oasis Montaj software and the resultant image was exported to a PDF file. Georeferenced data were gridded using the Minimum Curvature calculation method utilizing a 0.25 grid cell size and a 5 foot blanking distance.

3.2.3 Data Production

The data from the vertical gradient were mapped and an appropriate color scheme for the data limits was chosen to emphasize the anomalous areas present.

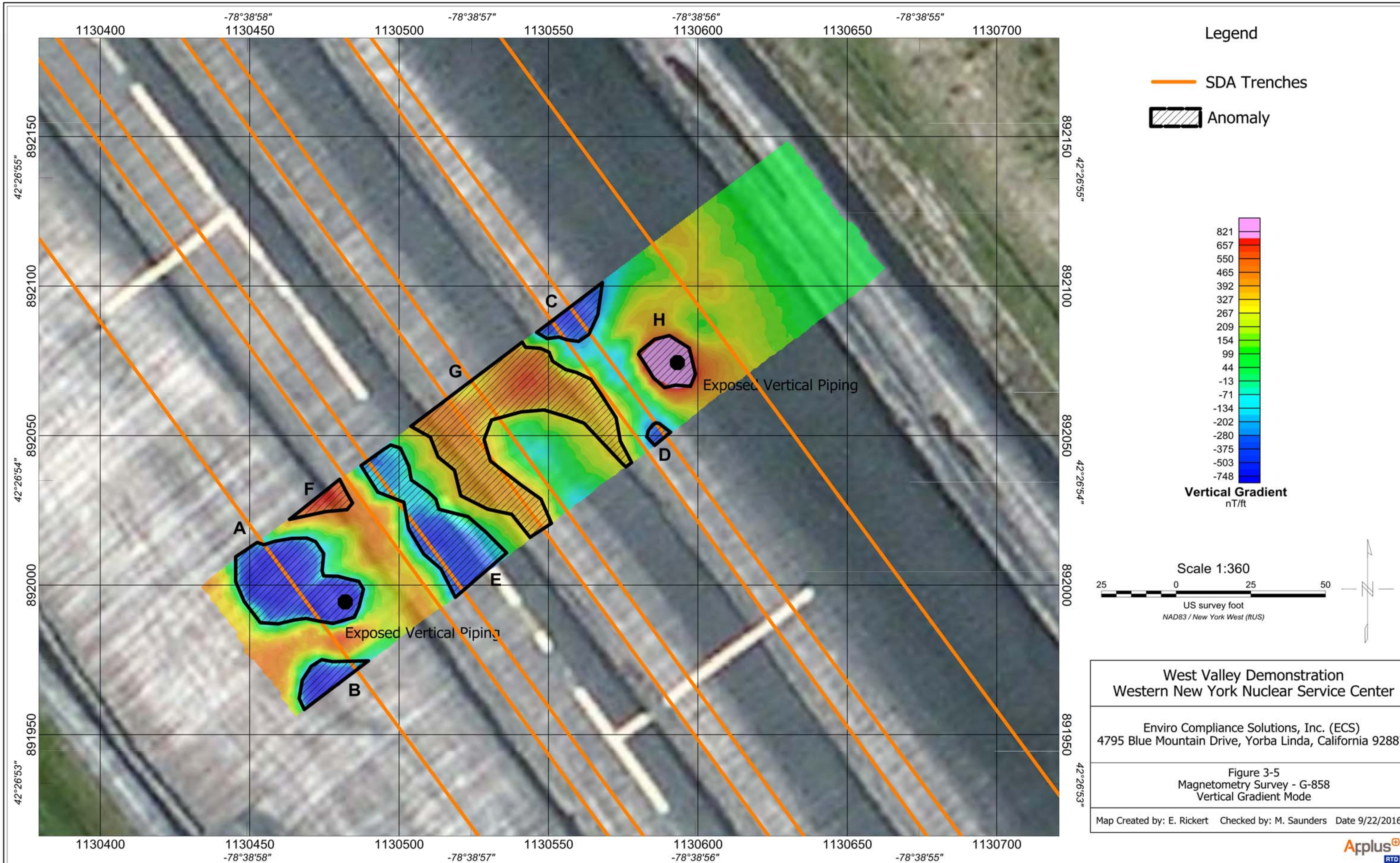
3.2.4 Data Results

Data results include the following highlights of descriptors for structure of anomalous readings for the Mag data.

Figure 3-5: Magnetometry Vertical Gradient

The following anomalies were recorded during the MAG survey:

- One (1) high amplitude positive MAG anomaly (> 700 nT/ft.)
- Two (2) moderate amplitude positive MAG anomalies (400 - 600 nT/ft.)
- Five (5) high amplitude negative MAG anomalies (< -300 nT/ft.)
- General neutral response at the eastern portion of the survey area, including the swale area (-70 to 250 nT/ft.)



Legend
SDA Trenches
Anomaly
821
657
550
465
392
327
267
209
154
99
44
-13
-71
-134
-202
-280
-375
-503
-748
Vertical Gradient
nT/ft
Scale 1:360
25 0 25 50
US survey foot
NAD83 / New York West (ftUS)
A
B
C
D
E
F
G
H
Exposed Vertical Piping
Exposed Vertical Piping
1130400
1130450
1130500
1130550
1130600
1130650
1130700
-78°38'58"
-78°38'57"
-78°38'56"
-78°38'55"
892150
892100
892050
892000
891950
42°26'55"
42°26'54"
42°26'53"
West Valley Demonstration
Western New York Nuclear Service Center
Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive, Yorba Linda, California 92887
Figure 3-5
Magnetometry Survey - G-858
Vertical Gradient Mode
Map Created by: E. Rickert Checked by: M. Saunders Date 9/22/2016
Applus RTD

4 INTERPRETATION

4.1 ELECTROMAGNETIC INDUCTION

4.1.1 Apparent Conductivity EMI

Figures 3-1 and 3-2 are images of the Apparent Conductivity mapped at 1,000 Hz and 8,000 Hz, respectively. The Apparent Conductivity portions of the EMI data are derived from the Quadrature Phase portion of the signal. The Apparent Conductivity can be the result of metallic or non-metallic material at the surface or within the subgrade, or to moisture content within the clay matrix.

Figure 3-1 shows five (5) high amplitude anomalies of elevated conductivity in approximately the upper 12-15 feet of the subgrade, labeled A through E on Figure 3-1. A high amplitude anomaly may be indicative of either a large physical object or a large material difference from the background. The magnitude of an anomaly can also be related to the depth of burial. The lateral extent of the anomaly is indicative of the lateral extent of the object or objects that is producing the anomaly.

The high amplitude anomalies are likely a response to metallic content. The western portion of the area of interest has a general elevated response that can be inferred to be a response to conductive and likely metallic material buried deeper in the subgrade, or metallic objects within a matrix of non-metallic material. Additionally, two high amplitude anomalies are present that are interpreted to be within one of the waste trenches. Waste Trench #5 is distinctly apparent while the eastern trenches are a general low level elevated response and not easily discerned as separate, which may indicate a change in construction practice, i.e. greater thickness of coverage cap, or it can be the result of difference in conductive material in the waste trench. NYSERDA's 2016 data on water levels in the trenches (NYSERDA, 2016), when compared to previously reported trench bottom elevations, indicates very limited leachate in Trenches #3 and #4 and only about 2 feet of leachate in Trench #1 (compared to 3.5 feet in Trench #5), which is unlikely to be a contributing factor in the change in observed anomalies as one moves to the east. Changes in waste composition would provide an overwhelming response over the leachate at the reported depths. The swale at the far eastern portion of the area of interest has some linear trends that may be due to soil moisture or drainage structures within the near surface, but does not show structure of the subgrade.

Figure 3-2 depicts the approximate upper 9-10 feet of the subgrade and shows two (2) high amplitude anomalies of elevated conductivity due to increased conductivity related to increased moisture or metallic content, labeled A and B in Figure 3-2. There are three distinct elevated response areas that are interpreted to be Waste Trenches #5, #4, and #3 and possibly the northern portion of Waste Trench #1. The swale at the far eastern portion of the area of interest has several elevated and depressed linear trends that appear to correspond to moisture levels in the near surface.

Anomalies A and B in Figures 3-1 and 3-2 correspond in location and approximate shape indicating that these anomalies are due to conditions within the depth of influence of the 8,000 Hz response, approximately the upper 3 meters. Anomalies C to E from Figure 3-1 are not apparent in Figure 3-2 indicating that that these anomalies are due to conditions deeper than the depth of influence of the 8,000 Hz response but within the response depth of the 1,000 Hz survey, between the approximate 3 meter and 4 meter depths of investigation.

4.1.2 Inphase Component EMI

Figures 3-3 and 3-4 are images of the Inphase Component response mapped at 1,000 Hz and 8,000 Hz, respectively. The Inphase Component of the Electromagnetic Induction signal is directly correlated to Apparent Magnetic Susceptibility, which is often referred to as metallic response.

Both Figures 3-3 and 3.4 show four (4) high amplitude positive anomalies in the upper 12-15 feet of the subgrade, labeled A through D in Figure 3-3. The four (4) high amplitude positive anomalies in Figure 3-3 appear very similar to the high amplitude positive anomalies shown in Figure 3-4, indicating that they are within the depth of investigation of the 8,000 Hz response. A high amplitude anomaly may be indicative of either a large metallic object or a collection of metallic objects. The magnitude of a metallic anomaly can also be related to the depth of burial, the shallower the depth of burial of a metallic object will correlate to higher amplitude of response. The lateral extent of the anomaly is representative of the lateral extent of the object or objects that is producing the anomaly. The negative data observed in the eastern side of the map in both figures are indicative of a background signal for the site away from the trenches. The Inphase data were zero-offset corrected in data processing to account for this negative (background) data.

In Figures 3-3 and 3-4, the vertical piping locations are shown to have a dipole effect in the data. The effect is more pronounced in the 1000 Hz data. The waste trenches are apparent in both the 1,000 Hz and the 8,000 Hz data as elevated levels with a diminished response between the trenches. Waste Trenches #5 and #4 in the southwest portion of the survey area appear similar in both data sets, as well as the response in the area of Anomalies C and D. The northern portion of Interpreted Waste Trench #3 has a moderate response in the 8,000 Hz data from the approximately upper 10 feet of the subgrade and has a muted but elevated response in the 1,000 Hz data from approximately the upper 12-15 feet of the subgrade, indicating that the material is in the upper zone but not of sufficient response to have as large response at the lower frequency. There is a moderate linear response in the swale at the far eastern portion of the survey area, which is more pronounced in the 8,000 Hz data than in the 1,000 Hz data.

4.2 MAGNETOMETRY

Figure 3-5 is an image of the Vertical Gradient of the Magnetometer (MAG) survey. Variation from near-zero is indicative of buried ferrous metal; both positive and negative responses are due to a metallic response. Geometry and location of the ferrous metallic object are responsible for whether a given ferrous metal object produces a net positive anomaly or a net negative anomaly. The MAG map shows five (5) high amplitude anomalies of negative response, labeled A through E in Figure 3-5. The MAG map also shows two (2) moderate amplitude anomalies of positive response, labeled F and G, and one high amplitude positive anomaly labeled as H in Figure 3-5. Anomaly G is a moderate amplitude positive anomaly arching around a low amplitude negative zone. Vertical surface and near surface ferrous objects produce a dipole effect that can alter the regional response from a larger, deeper object. The two exposed vertical pipes are in the middle of a strong negative and positive MAG anomaly. The level of the anomaly is greater than the expected response from either vertical pipe. The dipole effect expected from the vertical pipes appears muted by the larger subsurface anomaly at each location. The limits of the waste trenches are not apparent in the MAG data.

4.3 INTEGRATED INTERPRETATION

A limitation of all indirect measurements (geophysical investigation) is that there are more than one possible set of subsurface configurations that can be interpreted from a given data set. Other information that can be correlated, such as historic information with different direct and indirect measurements, results in greater confidence in the resultant interpretation.

Figures 3-1 and 3-2 are Apparent Conductivity maps of the survey area. The positive areas on these maps that have been interpreted to be the locations of the waste trenches that are of similar in size and approximate location to the provided mapped locations of the waste trenches. There are differences between the mapped locations of the waste trenches and the interpreted waste trench locations. The interpreted locations of Waste Trenches #1 and Waste Trench #3 approximate the GIS locations provided by Terranear. Waste Trench #4 is approximately 8 (east side) to 15 (west side) feet west of the GIS mapped location and Waste Trench #5 is approximately 9 to 18 feet west of the GIS mapped location.

In Figures 3-1 to 3-5 the high amplitude response in the approximate location of the historically mapped Waste Trench #5 area of the survey area is similar in all figures. Anomalies A and B stand out as distinct high amplitude anomalies within a moderate level elevated response in all of the data sets. This can indicate a pair of large metallic objects or group of tightly spaced metallic objects in a material with a metallic component, i.e. a pair of large metallic boxes or stacks of drums in trenches with other metallic debris. Steel boxes of 125 cubic feet or 935 gallons and Vanderberg casks have been listed in the trench inventory for Waste Trench #4. Alternatively, it may be a pair of objects that are significantly shallower than metallic objects in Waste Trench #4. The elevated response separated by an approximately 10 foot wide background level adjacent to western anomaly has a more muted response, except for the very negative MAG Anomaly E in Figure 3-5. The MAG is the instrument that has the deepest investigative response and the anomaly may be indicative of a large mass of ferrous metallic material at the edge of the detectable range for the Mag investigation.

EMI Anomalies C and D are similar in each of Figures 3-1, 3-3 and 3-4, and in similar locations to mirrored negative MAG Anomalies C and D in Figure 3-5. This indicates a likely large ferrous metallic object or cluster of objects at these locations. The MAG data have been able to emphasize the ferrous metallic response that correlates well to most, but not all, of the EMI anomalies. The magnitude of the MAG Anomaly H and the shape of the MAG Anomaly G do not correlate to the EMI data.

The area mapped as Waste Trench #1 has a metallic anomaly in the northern portion of the interpreted trench location. Waste Trench #1 does not have a metallic response or elevated apparent conductivity in the southern portion of the waste trench, which may indicate an area with concrete casks or wood or cardboard boxed materials. The area east of the mapped location and interpreted location of Waste Trench #1 does not have any indications of waste material. The apparent conductivity at 8000 Hz on Figure 3-2 does show an elevated conductivity in that area, likely related to drainage or saturated clay soils at the near surface.

4.4 ACHIEVING GOALS OF THE PROJECT

As defined by the original request for proposal, the geophysical studies have multiple objectives, as follows:

1. Define the lateral boundaries of individual waste trenches and other disposal units within the SDA and NDA both to allow for the safe installation of intrusive borings as near as possible to the waste and to globally support the future development and evaluation of exhumation alternatives.

2. Define the bottom/depth of the waste trenches and other disposal units. To be able to determine the elevation of the metallic waste within the disposal cell would be of additional benefit.

3. Determine the elevation of the top surface of water that is known to be present within the waste trenches, as well as the elevation of the water table in the surrounding glacially-deposited fine grained silty-clay soil.

4. Identify specific segments within the waste trenches that contain either waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or large quantities of metallic waste that can be compared against the inventory records for those same segments as a measure of inventory reliability.

- Objective 1 - The Electromagnetic Induction and Magnetometry portions of the Prove-Out Study have illustrated that the historic maps of the limits of the waste do not precisely match the geophysical location of the waste trenches.
- Objective 2 – The EM and Magnetic data do not provide information on the depth or bottom of the trenches.
- Objective 3 - The EM and Magnetic data do not provide information on the depth to the water table. The apparent conductivity results from the Electromagnetic Induction survey were unable to discern clear indicators of water depth due to large changes in the apparent conductivity from the waste material.
- Objective 4 - The Electromagnetic Induction and Magnetometry portions of the survey have shown large scale anomalies that have been interpreted as either masses of metallic material (i.e. stack of drums) or a massive metallic object, as well as areas with less metallic materials that would be consistent with concrete casks and wood / cardboard boxes filled with material.

5 SUMMARY

In summary, the EMI survey and the MAG survey independently provide reliable data to investigate the area around the trenches. Together the surveys provide a more complete picture of what is in the subgrade. Using different frequencies with the EMI survey has been able to provide relative depth response information about some of the anomalies in high amplitude and moderate amplitude anomalies within the survey area. The MAG data have been able to emphasize the ferrous metallic response that correlates well to most, but not all, of the EMI anomalies.

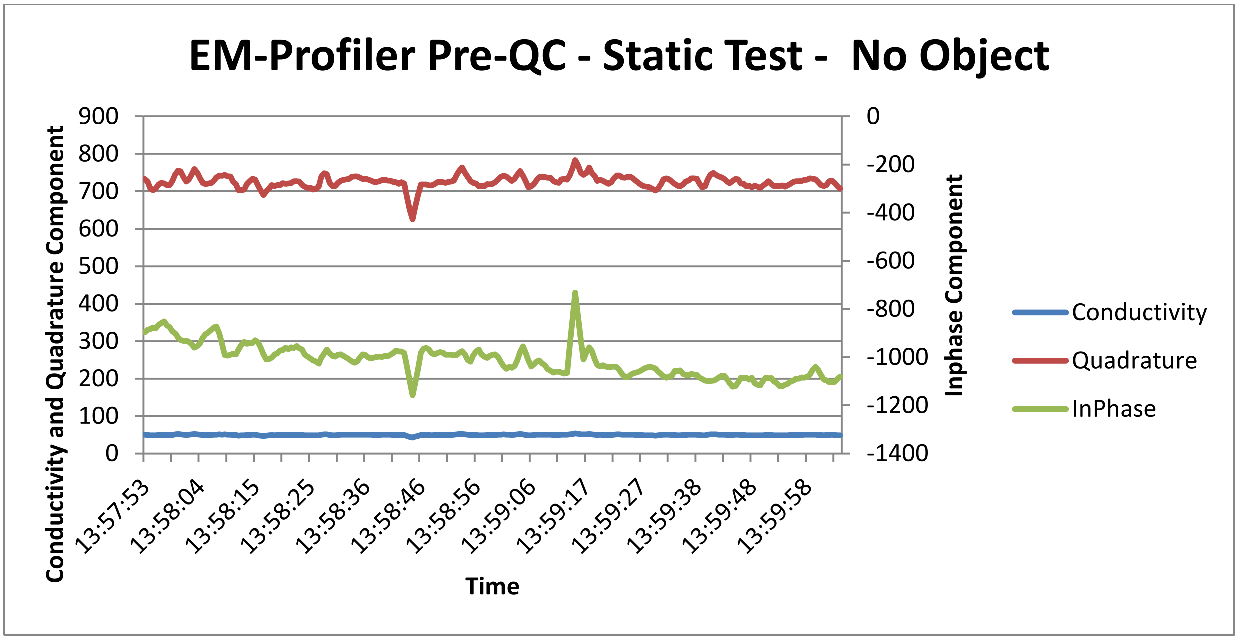
6 LIMITATIONS

Applus RTD performs geophysical services (for locating utilities, subsurface features) in compliance with latest available industry standard practices and guidance. Although these guidance's establish criteria for stringent quality control, it must be understood that due to the complexities in the electrical properties inherent in various materials (i.e. dielectrics) these methods have limitations. As a result of these conditions some utilities or objects may go undetected by geophysics and may require other methods to identify them. Therefore Applus RTD makes no guarantee with respect to the location of any subsurface objects.

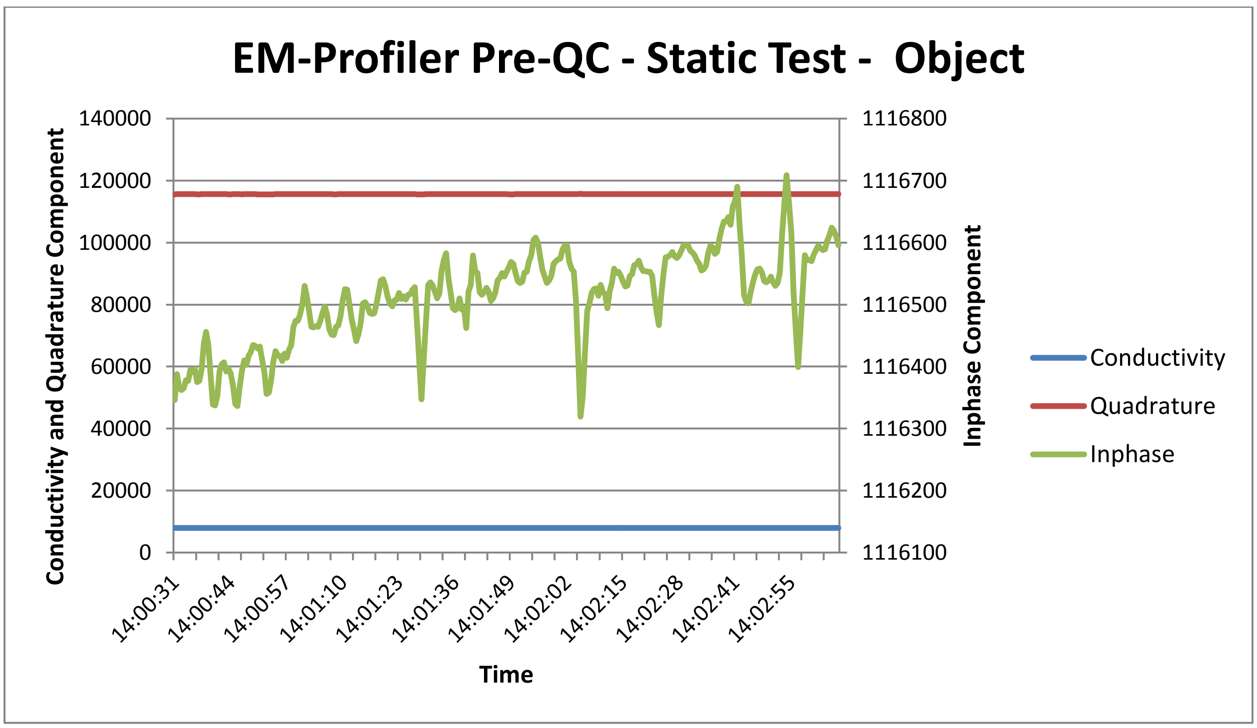
7 APPENDIX A

Electromagnetic Induction (EMI)

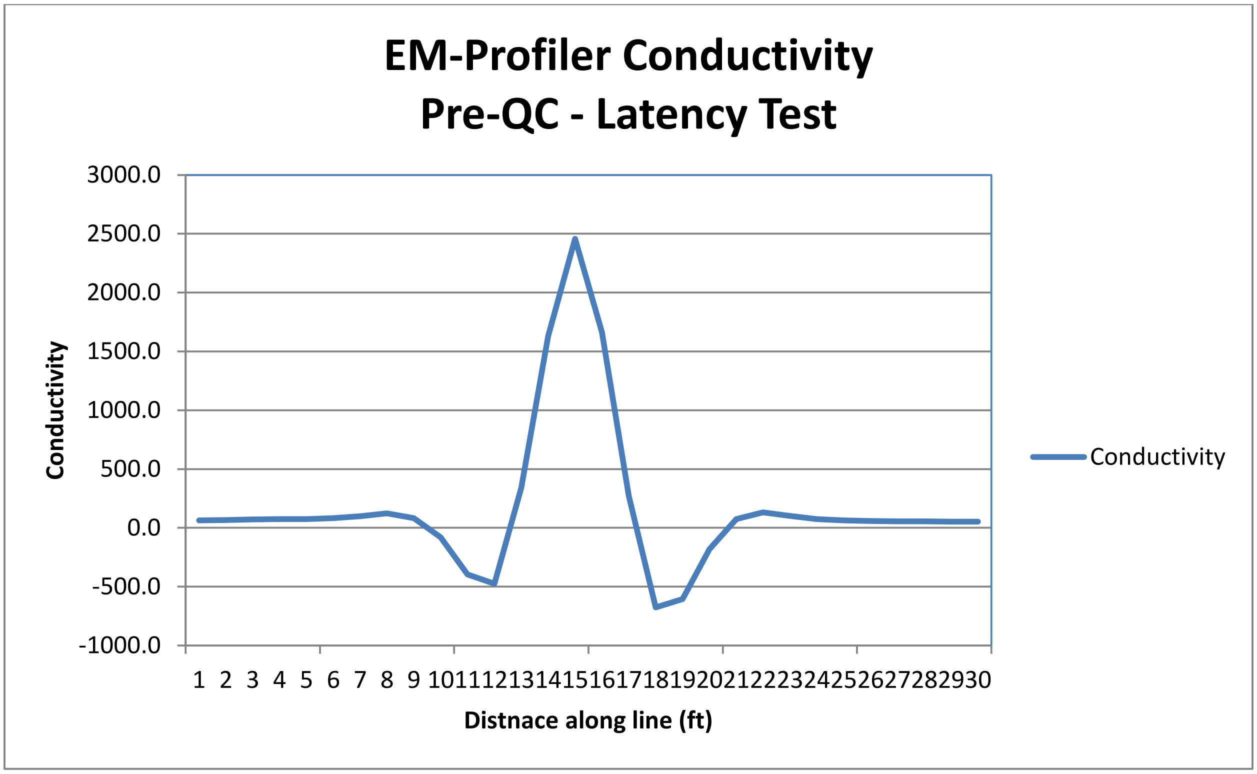
EMI-Pre-Static Tests – No Object



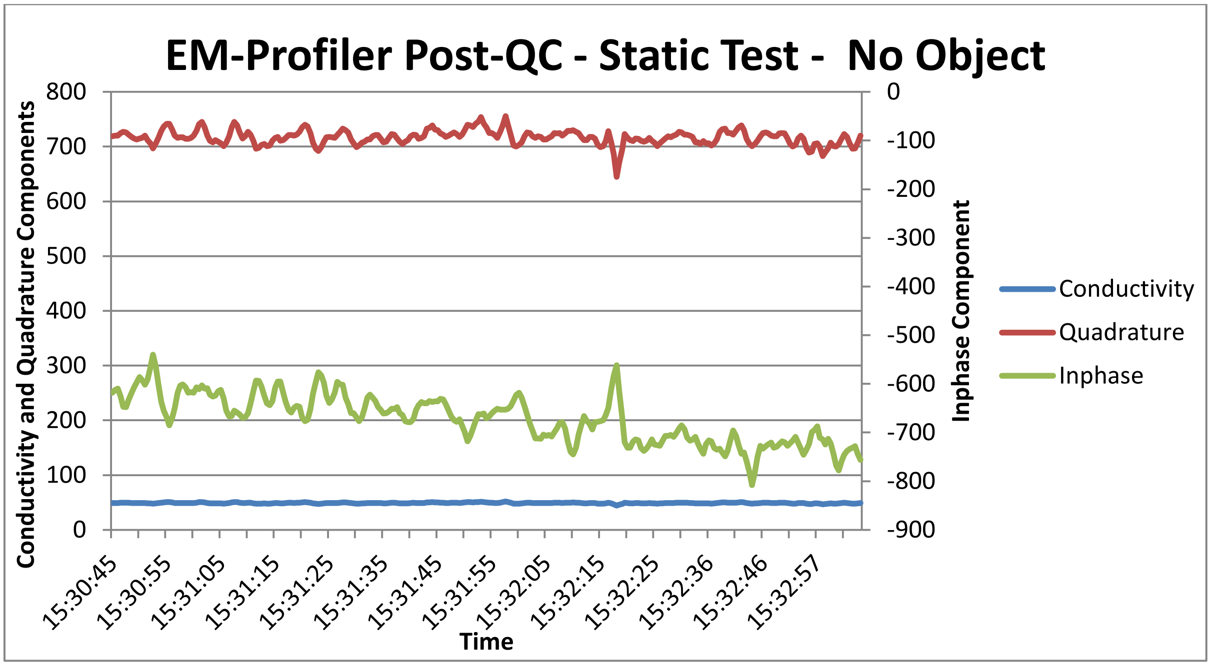
EMI-Pre-Static Tests –Object



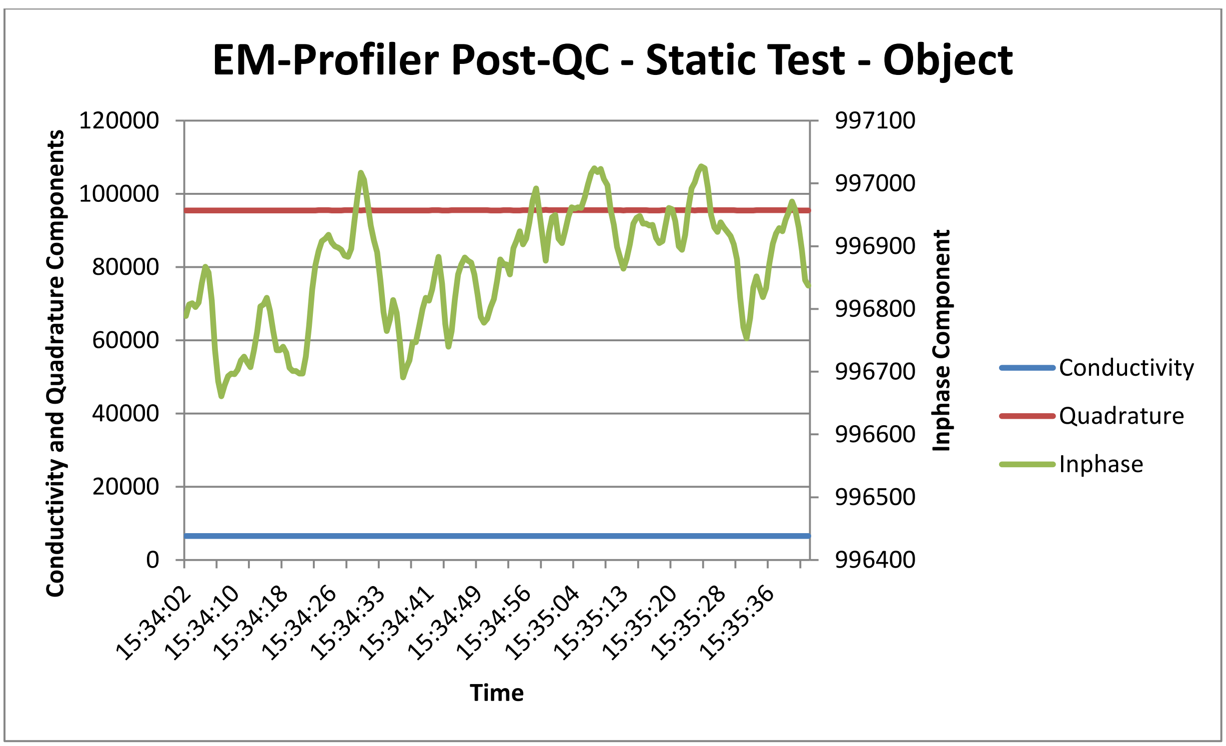
EMI-Pre-Tests –Latency



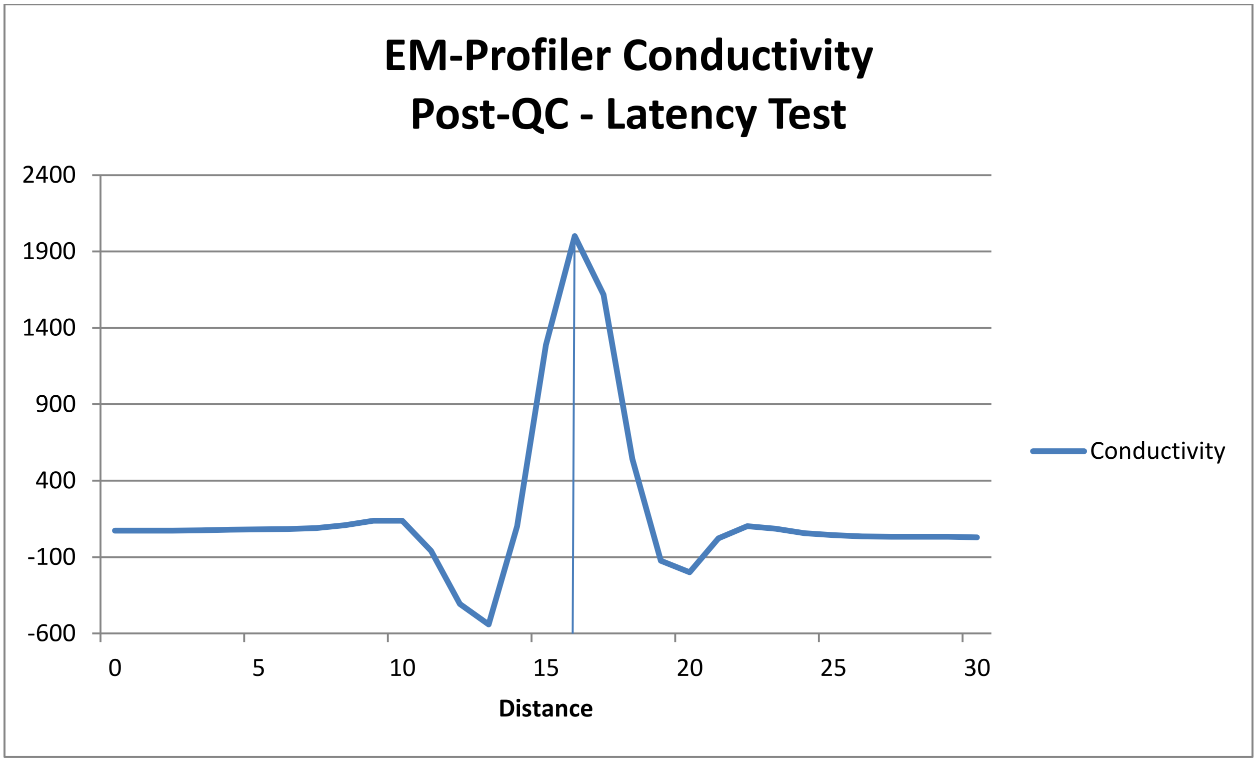
EMI-Post-Static Tests – No Object



EMI-Post-Static Tests –Object

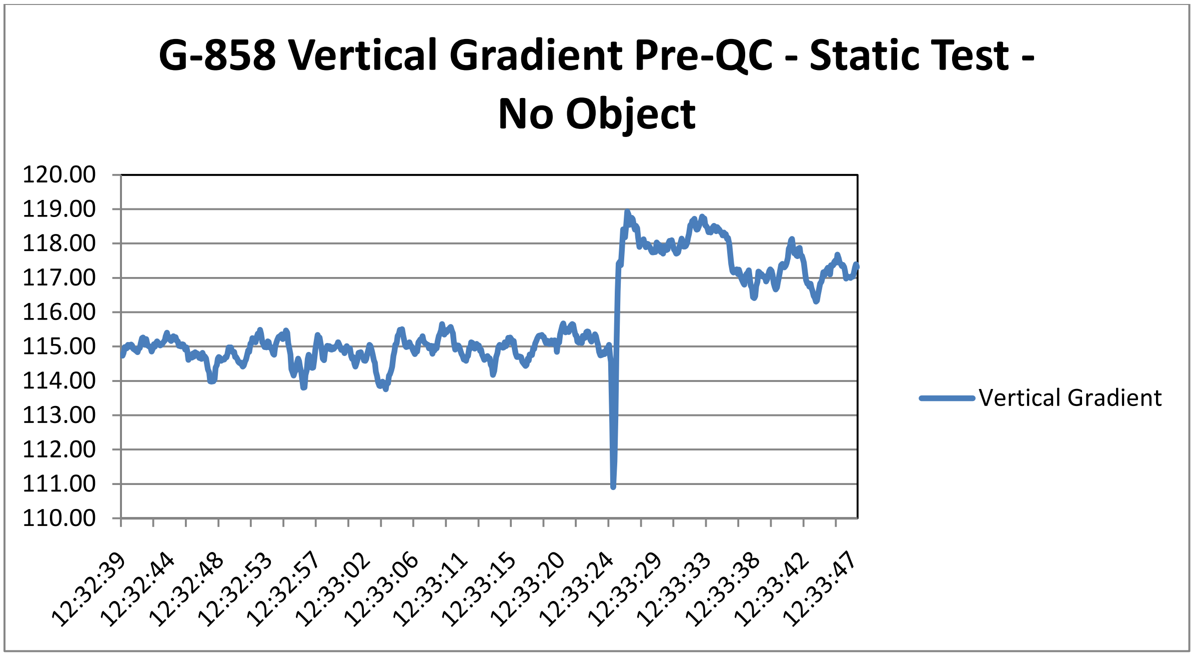


EMI-Post-Tests –Latency

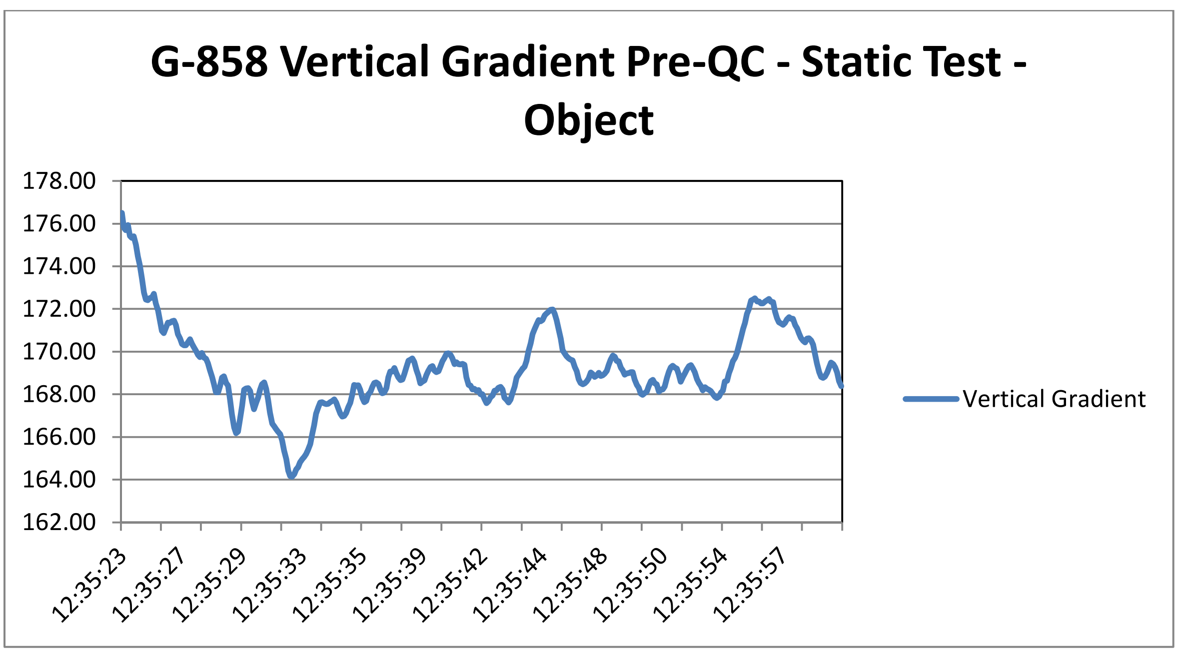


Magnetometry (MAG)

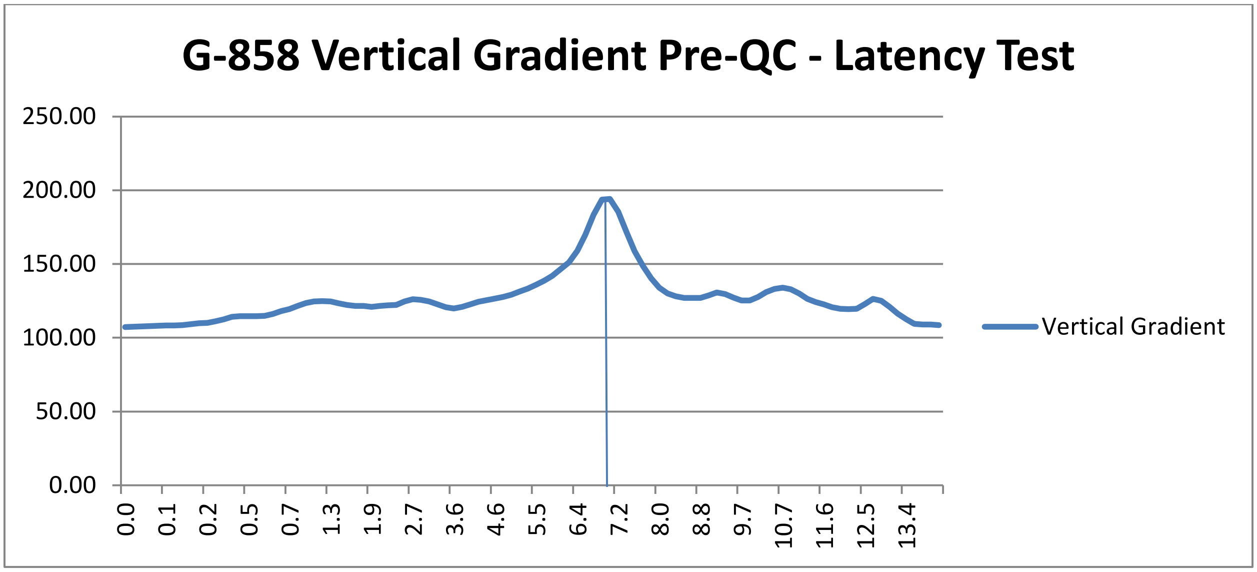
MAG-Pre-Static Tests – No Object



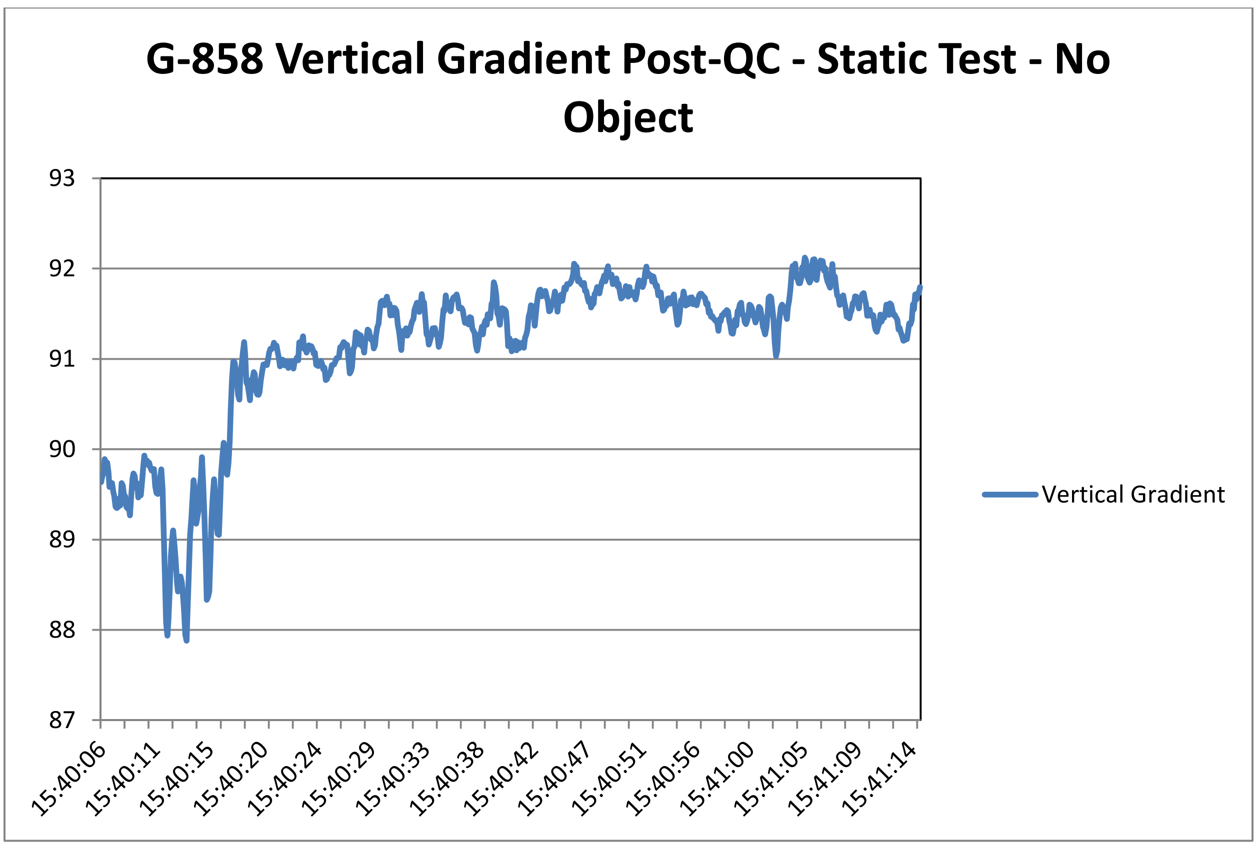
MAG-Pre-Static Tests –Object



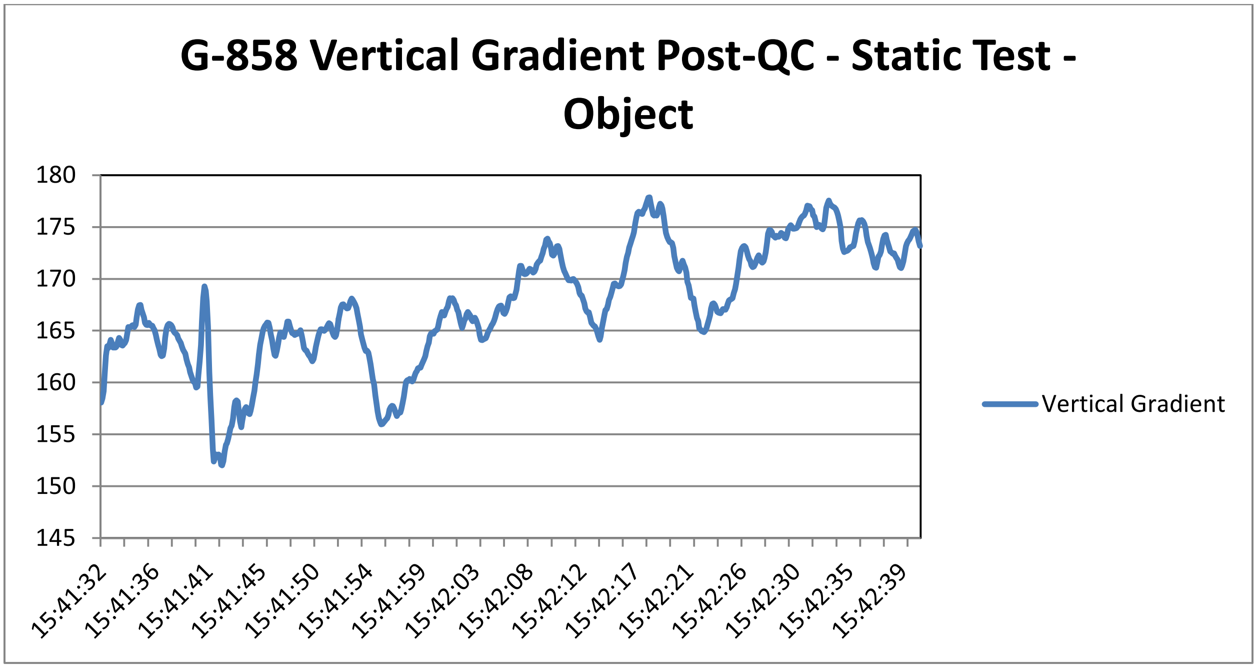
MAG-Pre-Tests –Latency



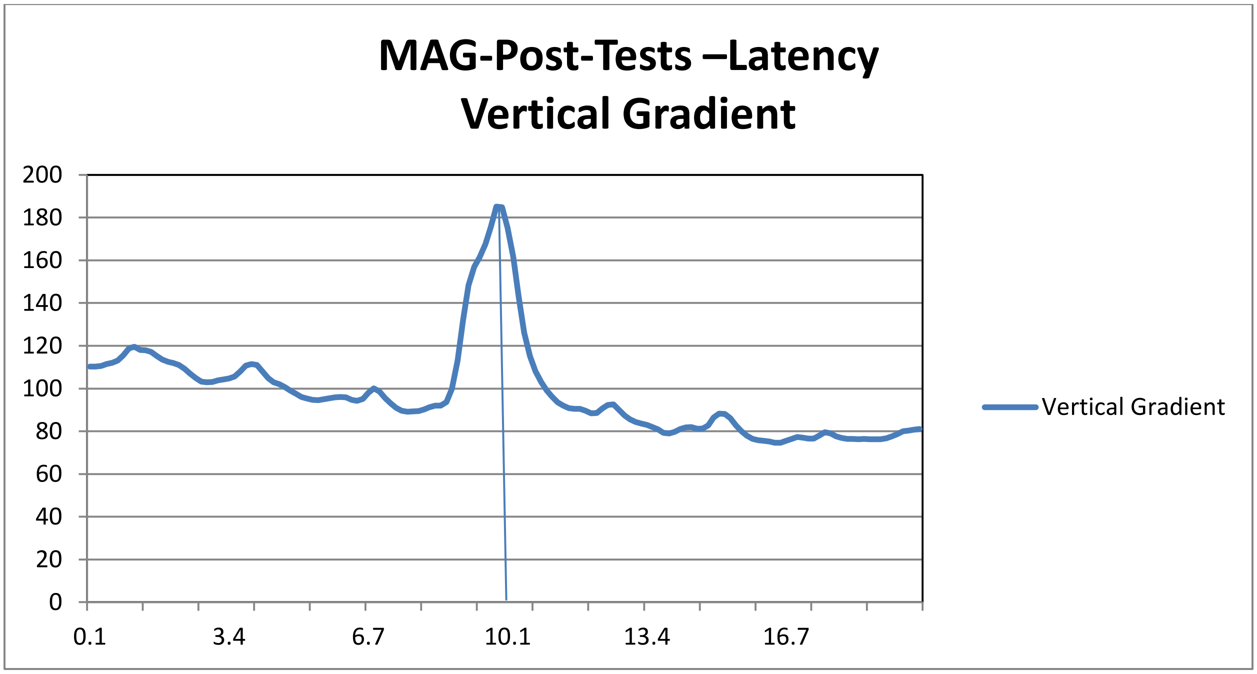
MAG-Post-Static Tests – No Object



MAG-Post-Static Tests –Object



MAG-Post-Tests –Latency



APPENDIX D
MULTI-CHANNEL ANALYSIS OF SEISMIC WAVES AND ELECTRICAL RESISTIVITY IMAGING GEOPHYSICAL SURVEY

Multi-Channel Analysis of Seismic Waves and Electrical Resistivity Imaging Geophysical Surveys
West Valley Geophysical Prove-Out Study
West Valley Demonstration Project
West Valley, New York

Prepared for:
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April 18, 2017

ACE Geophysics

Table of Contents

1. Introduction

ACE Geophysics (ACE) has prepared this report for TerranearPMC LLC (TPMC) to summarize two aspects of the geophysical prove-out study performed at the West Valley Demonstration Project (the Site) located in West Valley, New York TPMC was subcontracted to provide geophysical surveys by Enviro Compliance Solutions, Inc. (ECS), which is evaluating exhumation technologies under contract to the U.S. Department of Energy (DOE) and New York State Energy Research and Development Authority (NYSERDA). ACE performed the surveys during the weeks of August 15, August 22, and August 29, 2016.

As detailed in the request for proposal, there are four objectives of the geophysical prove-out study, these are:

- Define the lateral boundaries of individual waste trenches and other disposal units within the SDA and NDA to allow for safe boring installation as near as possible to the waste.
- Define the bottom/depth of the waste trenches and other disposal units.
- Determine the water elevation within the waste trenches, as well as the water elevation in the surrounding soil.
- Identify specific segments within the waste trenches that contain either waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or significant metallic waste quantities that can be compared against the inventory records for those same segments to support inventory reliability.

A prove-out study of each of the proposed geophysical methods was conducted across an approximate 200-foot x 50-foot area spanning Trenches 1, 3, 4, and 5 (Figure 1). Four transects, labeled A through D, were surveyed during this investigation.

ACE conducted two forms of geophysical methods at the prove out area: multi-channel analysis of surface wave (MASW) seismic and electrical resistivity imaging (ERI). The following sections detail the methodology, analysis, interpretation, and conclusions based on the geophysical investigation.

2. Survey Methodology

2.1. Multi-Channel Analysis of Surface Waves (MASW) Method

2.1.1. Theory of MASW

MASW has been used to map bedrock topography; identify bedrock fractures, abandoned mine workings, waste pits and trenches; and evaluate sink activity (e.g., voids, pinnacles, zones of enhanced weathering) to depths upwards of approximately 100 feet BGS. Unlike refraction, MASW is not constrained by velocity inversion (high speed layer overlying a lower speed layer), and it can be used in urbanized environments where noise associated with vehicle traffic and buried utilities that typically mask body waves do not significantly impact the robust (larger amplitude) surface waves.

Seismic surveys are able to discriminate between and among materials with relatively different physical properties (i.e. density), based on the velocity of the seismic wave as it travels through each discrete layer. In general, the more rigid the material, the faster the wave will travel through it, and inversely the looser or less dense the material the slower the seismic wave will travel through it. The following table includes some general shear velocities of common earth materials.

Material	Shear Wave Velocity (ft/s)
Loose Silt, Sand and Gravel	600
Soft Clay	300
Medium Silt, Sand and Gravel	650
Medium Clay	650
Dense Silt, Sand and Gravel	850
Stiff Clay	980
Soft Rock	2300
Medium Rock	3600
Hard Rock	5300
Concrete	1,100
Steel	2,000

These shear velocities are very generalized and have been provided as a guide to show the common range of values for soils and rock, as well the differences between loose material and dense material.

Propagation velocity (also known as phase velocity) of surface waves is frequency (wavelength) dependent. This property is known as dispersion. The dispersiveness of soils is determined mainly by the vertical variation in shear wave velocity (Vs). By recording fundamental-mode Rayleigh waves propagating from the source to receiver, the dispersive properties directly beneath the seismic spread can be measured and represented by a curve (dispersion curve). This curve is used to estimate the vertical variation of Vs (1-D Vs profile) through a process called inversion.

The MASW method utilizes pattern-recognition techniques. It employs multiple receivers (geophones) equally spaced along a linear survey line and measures the travel-times of seismic waves generated by an implosive source (e.g., sledge hammer). This approach allows recognition of the various propagation characteristics of the seismic wavefield. Once the dispersive properties of the fundamental mode Rayleigh waves are identified (via pattern recognition), a corresponding signal curve is extracted and used in the inversion of a 1-D Vs profile. This profile best represents the vertical Vs distribution at the middle of the receiver spread. By moving the same shot-receiver configuration incrementally along a preset survey line, multiple measurements can be made, each producing a 1-D Vs profile that, when all gathered together, is used to construct a 2-D Vs cross-section along the survey line.

2.1.2. MASW Field Survey at West Valley

MASW profiles were collected along four traverses at the geophysical prove-out area. Two data sets were collected at each traverse. The first data set involved recording data with geophones that penetrated the surface membrane and were seated into the soil beneath. The second data set involved recording data with the geophones attached to a landstreamer (a Kevlar strap with geophones attached to adjustable metal plates). Using the landstreamer allows the geophones to be dragged across the ground surface without penetrating the geomembrane cover.

The survey included a Geometrics Geode 24-channel seismograph and 24 4.5 Hz vertical geophones. Seismic waves were generated by a 12-lb sledge hammer & plate source. The geophones were spaced 5 feet apart during both data collections. After testing offshot (distance between shot and first geophone) distances of 5 feet, 10 feet, and 15 feet, ACE selected the 15-foot offset as the best of the three. Shot locations were recorded every 5 feet along each profile. To ensure as much data as possible were being recorded, the Geode was set to record data for 1 second at a sampling rate of 62.5 microseconds. At each shot location, the data were stacked using three seismic events.

Copies of the field data files, both raw and processed, were uploaded to the TPMC FTP site.

2.2. Electrical Resistivity Imaging (ERI)

2.2.1. Theory of ERI

Resistivity values for earth materials cover a wide range that makes resistivity surveying a viable technique for many applications. The following table describes some typical resistivities of the indicated earth materials:

Material	Resistivity (ohm-meter)
Clay	1-60
Silt	100-10,000
Till	<1000
Sand, dry to moist	100-10,000
Sand, wet to moist	20-200
Shale	1-500
Sandstone	150-450
Porous Limestone	100-1,000
Dense Limestone	10,000-1,000,000
Dolomite	>10,000
Metamorphic Rocks	50-1,000,000
Igneous Rocks	100-1,000,000

In application, a series of measurements is made between a variety of current electrode pairs and potential electrode pairs. Two types of surveys were originally developed by researchers using a series of electrical resistivity measurements. These surveys produce one-dimensional data sets that are either vertical or horizontal. Soundings are created as a way to probe successively deeper into the ground to create a vertical one-dimensional data set. This is achieved by increasing the electrode spacing for each successive measurement. The second technique is called profiling, which requires the electrode pairs to be held at a constant spacing as the pairs laterally traverse the survey area producing a horizontal one-dimensional data set. Combining these two types of surveys into a single survey produces a two-dimensional resistivity profile comprised of apparent resistivity points.

The apparent resistivity p_a of the earth is the product of a large area of the subsurface responding to the impressed current. Interpretation of apparent resistivity data collected in the field without reduction provides a qualitative product that is very similar to electromagnetic (EM) methods. Because the earth is not homogeneous, it is useful to determine true resistivity at discrete locations in order to make a more quantified interpretation. Apparent resistivity data is then inverted to a model of earth resistivities using resistivity inversion processing software, such as Res2Dinv or EarthImager 2D.

2.2.2. ERI Field Survey at West Valley

ACE collected ERI data along five traverses as shown on Figure 1. The ERI traverses were oriented west to east. Along each ERI traverse, stainless steel stakes were driven 8 to 12 inches into the ground at 5-foot intervals to establish earth contact. A multi-conductor cable with a series of electrode take-out points was attached to the stakes to complete the electrical circuits between the resistivity meter and the stakes.

During preparation for data collection, the operator programmed the ERI system (SuperSting™) for the chosen number of current pairs (in electrode spacing measurements) to be used for energizing, and the maximum separation (in electrode spacing measurements) to be used for measuring the potentials. These two numbers (i.e., number of pairs and maximum separation) determine the total number of measurements to be collected along the electrode spread, and the total depth of investigation. Information concerning the survey type, traverse orientation, electrode spacing, recording addresses, and line configuration was programmed. The SuperSting™ digitally records all of this information for use in data processing and as a quality assurance method.

The ERI data were collected using the dipole-dipole array. This array was selected based on the objectives of the geophysical prove out. Dipole-dipole arrays are commonly used in geophysical surveys to provide deeper data with shallow target resolution.

At the start of the survey at each profile, a contact resistance check was run on all electrodes to ensure good contact was established with the ground. Digital copies of these contact resistance files were provided to TPMC. In general, the contact resistances did not exceed 500 ohms during the geophysical prove-out.

Once the command file was completed at each profile, the ERI data file was preliminarily processed in the field to verify the data were reaching the target depth and that there were no quality issues with the data. If there were an excessive number of bad points, the traverse was run again.

Copies of the field data files, both raw and processed, were uploaded to the TPMC FTP site.

3. Data Processing and Analysis

3.1. MASW Processing

The MASW data were processed using the Geogiga *Surface Plus*® processing software. Each shot on the MASW profile was recorded as a separate file. The processing software (Geogiga's Surface MASW) assembles all of the files of a transect into one file for processing. Once merged, the software allows the user to assign the field geometry (geophone spacing and shot offset) and recompiles the data into a roll-along data set.

The surface wave velocity range for each shot record is identified by the software, which then conducts a dispersion curve analysis for all of the records. Plotting the frequency versus propagation velocity (called phase velocity) is called a dispersion curve. Dispersion curves are extracted from ech shot record. When more than one phase velocity exists for a given frequency, it is called multi-modal dispersion. The slowest one in this case is called the fundamental mode- the one most commonly used to produce 1D velocity records and eventually 2D profiles, and the next faster one is called the first higher mode. Higher mode curves are sometimes used during inversions to increase the data resolution on the 1D Vs profiles.

Once all 1D Vs profiles are completed, they are merged together to make a 2D velocity profile across the transect. The 2D velocity profile is then color contoured breaking out velocity ranges of interest. The final file can be presented directly from the MASW software or it can be exported into a data file that other contouring software packages can read. ACE exports the profiles into Surfer to annotate the profiles.

3.2. Electrical Resistivity Imaging (ERI)

The ERI data were initially processed utilizing the program SuperSting™ Administrator written by AGI Inc. This program imports the data downloaded from the SuperSting, and outputs a data set for data processing. This data file includes the x-location of the data point, the electrode spacing, and the measured apparent resistivity.

Inversion of the data to true resistivities provides a more unique or quantitative interpretation of the data. ACE uses the resistivity inversion program EarthImager 2D to produce a two-dimensional resistivity model based on the apparent resistivity data. This software allows the operator to filter (remove) negative data and data points with standard deviation errors above a chosen level. All data points with a standard deviation above 3 percent were removed during the processing of the data. During processing with the EarthImager 2D program, the elevation data were also entered into the data set and accounted for during processing. Changes in topography can cause variations in the modeling of the raw data. The elevation changes at this site were recorded and imported into the dataset during the processing.

Using a three-step process, both programs begin with a pseudo section of the measured apparent resistivity. A homogeneous earth model is used as the starting point for the first iteration of the model. The number and size of the model blocks are loosely tied to the distribution of measured data points. The inversion provides modeled resistivity data which is presented in color electrostratigraphy profiles.

The data are then evaluated for spurious measurements. Data values that are obviously too high or too low relative to adjacent points were considered spurious. These invalid data generally result from electrode relay failure, cable shorting (due to very wet ground conditions), or poor electrode/ground contact (due to dry soils). By eliminating these data points, they will not adversely affect the model otherwise developed from the remaining, reliable data. The edited data are then saved with a different name so that the original data file remains intact.

The data file is then exported as a “.DAT” file for final contouring and presentation using the Surfer® software for the 2D profiles. This processing is employed to allow flexibility in the presentation of the data, and the annotation of surface cultural features that are evident on the land surface or that constitute geophysical data interpretations.

4. Interpretation

4.1. MASW Survey

The results and interpretations of the MASW survey are discussed in the following paragraphs and the attached figures. For each traverse, three profiles are presented. They include the MASW survey using geophone penetration, MASW using the landstreamer fundamental mode data, and the third data profile includes the landstreamer data that was generated using the multi-modal dispersion curves to provide additional data. In order to be consistent, the penetration and landstreamer data profiles have been presented in a standardized color contour scale from 500 to 1,500 feet per second (ft/s). This allows for comparison between profiles. On each profile, anomalies of interest have been identified. The landstreamer data assembled using the multi-modal dispersion curves use a smaller contour range (600 to 900 ft/s).

The lateral locations of the trenches based on surface topography have been placed on all of the MASW profiles as solid pink lines. The depth and width of the trenches depicted on the profiles are based on the cross sections provided by ECS and TPMC. Anomalies located within the depicted trenches are interpreted to be landfilled material.

The following general interpretations can be made when reviewing MASW data:

- More compacted material will have higher velocities.
- The higher the water content, the lower the velocity.
- The higher the density of the material (such as metal or concrete) the higher the velocity. The shear velocity of concrete and steel are approximately 1,100 ft/s and 2,000 ft/s, respectively.
- The shear velocities of soil tend to range around 700 ft/s or slower.

Because of the mixed contents and varying levels of saturation reported to be within the trenches, there is some overlap in ranges between different anomalies. One example would be an area of drums that is surrounded by saturated soil would still have a higher velocity, but not as high as drums surrounded by dry soil. The waste inventory indicated cardboard and wood boxes have been buried within the trench. In areas where the material is dry, the velocities would be in the high hundreds range; however, if this material was saturated the velocities would decrease.

The MASW data cannot identify metallic features directly, but drums can be inferred by very dense material and faster velocities. Lower velocity zones can infer drums mixed with other low velocity material or wood/cardboard boxes.

Data on the west side of survey area did not completely cover Trench 5. Shot locations were collect as far west as possible; however, along the west side there are areas where the membrane is not in contact with the ground surface which creates an air void. Shots were not collected in these areas for two reasons. ECS requested in the work scope any areas where there was obvious water or air under the membrane were to be avoided. In addition, without the membrane contacting the ground surface, when the hammer would have hit the strike plate there would have been a bounce effect once the plate actually hit the surface below the membrane. This would have caused significant data quality issues.

4.1.1. Profile A

MASW data collected on Profile A indicates the presence of several anomalies. Geophone penetration data is shown on Figure 2 and the landstreamer fundamental mode data is presented on Figure 3. The multi-modal landstreamer data is presented on Figure 4.

Penetration and Landstreamer Data

The penetration and landstreamer data indicate the presence of three significant anomalies. High velocity anomalies (greater than 1,000 ft/s) are located at the inline distances of 150-170 feet and 190-200 feet. The third anomaly, located at the inline distance of 80-100 feet depicts a lower velocity (800-900 ft/s).

The anomaly at the inline distance of 80-100 feet is located within Trench 4. The landstreamer data indicates the bottom of the anomaly is at the elevation of 1358 feet (AMSL), while the penetration data indicates the bottom is at 1352 feet AMSL.

The anomaly located at the inline distance of 190-200 feet has seismic velocities greater than 1,000 ft/s. This anomaly location coincides with the perimeter berm. Although the berm is not reported to contain any waste material, the subsurface of the berm consists of some form of denser material.

The higher velocity anomaly located at the inline distance of 150-170 feet is located within Trench 1. Both the landstreamer and penetration data indicate that within the Trench 1 perimeter, higher velocity material (dense/metal/concrete) is located on the west side of Trench 1 and lower velocity material, possibly wood/cardboard or saturated waste material around additional concrete or drums is located on the bottom and east side of the trench.

Multi-Modal Analysis Data

The multi-modal curve data (Figure 4) indicates additional anomalies. On this data set, a significant anomaly is present at the Trench 3 location (inline distance of 110-140 feet). A smaller anomaly has also been detected at the Trench 5 location (inline distance of 50-70 feet). Using this data set, the top of the trenches and corresponding soil cap thickness are depicted in dark blue (less than 650 ft/s).

The multi-modal analysis data indicates the anomaly representing Trench 1 is similar to the anomaly depicted on the landstreamer and penetration profiles. Higher velocity data indicates the presence of denser material (concrete/metal) along the bottom of the trench. The slightly slower velocities (green contours) located above the high anomaly would indicate the material present is not as dense, possibly cardboard or wood boxes. It is most likely not related to saturated conditions because this would indicate the higher water content above areas of lower water content.

The anomaly that corresponds with Trench 3 indicates higher velocities (750 ft/s) at the bottom of the trench (1350 feet AMSL). This area most likely contains dense material such as concrete or metal. The lower velocities above the metal/concrete are most likely less dense material such as cardboard/wood and not related to saturation levels. A thin layer of slower velocities interpreted to be soil or fill is located beneath the bottom of the trench. Beneath the soil are much higher velocities which may indicate natural soil.

The MASW data within Trench 5 indicates the presence of three layers. The bottom layer has velocities ranging from 720-740 ft/s. These higher velocities at depth may indicate the presence of concrete or metal and since the velocities are slightly lower than in other areas, the material surrounding the concrete/metal is most likely saturated. This finding is consistent with NYSERDA's 2016 leachate measurements, which indicate that about 3 feet of leachate is present in Trench 5 compared to very little leachate in Trenches 3 and 4, The low velocity located in the middle of the trench (blue, less than 650 ft/s) would indicate the presence of saturated conditions and low density material such as cardboard and wood. The top layer has slightly higher velocities than the middle layer which would indicate drier conditions with cardboard/wood.

The multi-modal velocity data at the interpreted Trench 4 location depicts several layers of anomalies. At the bottom of the trench, the seismic velocities are very low (less than 650 ft/s), which would indicate less dense materials given that saturated conditions are not expected in Trench 4. A small pocket of low velocities is also present above the bottom layer. The bright green top layer has higher velocities than the bottom layer and would most likely represent denser waste material with low saturation.

Profile A Summary

Profile A spans the southern edge of the trench segment studied. Figure 5 presents the locations of the trenches based on the cross section diagrams provided by ECS. Areas of possible concrete/metal and less dense material such as cardboard and wood are shown on the profile. A shallow low velocity layer is present across the profile that would be consistent with the soil cap. The interface between the cap and trench material is shown in Figure 5. Based on the MASW data, Trenches 1 and 3 have anomalies that could represent concrete or metal objects present. Trench 3 also has a layer of lower velocities above the metal/concrete which is most likely less dense material such as cardboard/wood and not related to saturation levels. Trench 4 has an area of less dense material (cardboard/wood) at the bottom of the trench and an area of higher velocity above this saturation.

The data at the Trench 5 interpreted location is not sufficient to develop a detailed analysis of the material within the trench. Much of the data were removed during processing because of the low signal to noise ratio, which was primarily caused by the poor contact between the membrane cover and the underlying soil. Along the west side of the test plot area, much of the membrane cover is not flush to the soil, therefore each time the seismic source is struck, there is a bounce effect which creates error in the data.

The data that were processed for Trench 5 indicated some denser material at the surface and at depth within the trench. Based on the waste inventory provided by ECS, Trench 5 at this location is reported to contain some drums and cardboard boxes.

Based on the inventory of waste, Trench 1 at the Profile A location is reported to contain concrete casks, steel drums, and wood boxes. The anomalies depicted in red on Figure 5 would be consistent with concrete casks or steel drums. The material surrounding each of these anomalies could represent soil or other waste material such as boxes.

No inventory of waste has been provided for Trenches 3 and 4 at the Profile A area.

4.1.2. Profile B

MASW data collected on Profile B indicates the presence of several anomalies. Geophone penetration data is shown on Figure 6 and the landstreamer fundamental mode data is presented on Figure 7. The multi-modal landstreamer data is presented on Figure 8.

Penetration and Landstreamer Data

The penetration and landstreamer data indicate the presence of three significant anomalies. Velocities of 900-1,000 ft/s are present at the inline distances of 110-130 feet and 150-170 feet. An anomaly at the inline distance of 180-190 feet indicates the presence of high velocity anomalies (greater than 1,000 ft/s).

The anomaly located at the inline distance of 180-190 feet has seismic velocities greater than 1,000 ft/s. This anomaly location coincides with the perimeter berm. Although the berm is not reported to contain any waste material, the MASW results indicate that the subsurface of the berm consists of some form of denser material.

The higher velocity anomalies located at the inline distances of 110-130 feet and 150-170 feet are located within Trench 3 and Trench 1, respectively. Both the landstreamer and penetration data indicate these anomalies have velocities ranging between 900 and 1,000 ft/s, which have been interpreted to represent less dense material such as dry cardboard and wood. In both trenches, the velocities detected beneath these anomalies are less than 700 ft/s which could indicate material such as cardboard and wood under saturated conditions. Based on the data, the bottom of Trench 3 is approximately 1360 feet AMSL and the bottom of Trench 1 is approximately 1352 feet AMSL.

On the landstreamer data, at the inline distance of 80-90 feet, there is a higher velocity anomaly (greater than 1,000 ft/s) that is located within Trench 4. These high velocities are interpreted to represent dense material such as concrete and metal. Below the high velocity anomaly, the velocities decrease (green contours representing 850-900 ft/s), which would indicate this area of the trench may contain less dense waste material as Trench 4 is not highly saturated.

The landstreamer data indicated a small anomaly located near the surface of Trench 5. This anomaly is similar to the surface anomaly detected at Trench 3 and most likely represents material such as dry cardboard and wood. Slower velocities are present beneath this anomaly, which would indicate the wetter conditions found in Trench 5. Due to the limited data collected along the west side of the profile, these anomalies have a higher degree of uncertainty.

Multi-Modal Analysis Data

The multi-modal curve data (Figure 8) indicates additional anomalies. Trench 1 includes higher velocities throughout most of the data. The MASW data at Trench 3 indicate the presence of lower velocity data throughout the trench along Profile B. The area of Trench 4 (80-100 feet inline distance) indicates several layers of different seismic velocities. Trench 5 (inline distance of 50-70 feet) indicates the presence of low velocities, most likely saturated materials at the bottom of the interpreted trench. Using this data set, the top of the trenches and corresponding soil cap thickness are depicted in dark blue (less than 650 ft/s).

The multi-modal data indicates the anomaly representing Trench 1 is similar to the anomaly depicted on the landstreamer and penetration profiles. On all three data sets, the seismic velocities are around 900 ft/s or faster. This velocity data indicates the presence of dense (concrete/metal) material along the bottom of the trench. Lower velocities are present above the concrete/metal area which would indicate the material is more likely less dense material such as cardboard and wood.

The area that corresponds with Trench 3 indicates lower velocities (650 ft/s) near the top of the trench (1360-1370 feet AMSL). This surface low velocity would most likely indicate less dense material such as dry cardboard and wood. The velocities increase with depth which likely indicate denser material.

The data at the interpreted Trench 4 location depicts areas of high velocity (greater less than 760 ft/s) at the bottom of the trench. This has been interpreted to represent areas of dense material such as concrete and metal. The seismic velocities above the dense material are slower that would indicate less dense material such as dry cardboard and wood.

The area that corresponds to Trench 5 indicates increasing velocities with depth. On the bottom west side of the trench, the velocities increase to approximately 780 ft/s, which may indicate the presence of some metal and concrete. The slightly lower velocities present at the lower east side corner of the trench may indicate saturation.

Profile B Summary

Figure 9 presents the interpreted trench dimensions based on the MASW data. Areas of possible concrete/metal, cardboard and wood, as well as saturated conditions are shown on the profile. Based on the MASW data, Trenches 1 and 3 have anomalies that could represent concrete and metal along the bottom of the trenches. Slower velocities located nearer to the surface in these trenches would most likely represent dry material such as cardboard and wood. Trench 4 data indicates a small area on the bottom of the trench that could represent dense material.

Some useable data were recorded at Trench 5. One small anomaly developed in the data that indicated the presence of possible metal or concrete at the bottom of the trench. Based on the waste inventory, Trench 5 at this location is reported to contain some drums and cardboard boxes.

Based on the inventory of waste, Trench 1 at the Profile B location is reported to contain concrete casks, steel drums, and wood boxes. The anomalies associated with Trench 1 are slightly slower than what was depicted on Profile A. This could be the result of more saturated conditions slowing the seismic velocities.

No inventory of waste has been provided for Trenches 3 and 4 at the Profile B area.

4.1.3. Profile C

MASW data collected on Profile C indicates the presence of several anomalies. Geophone penetration data is shown on Figure 10 and the landstreamer fundamental mode data is presented on Figure 11. The multi-modal landstreamer data is presented on Figure 12.

Penetration and Landstreamer Data

The penetration and landstreamer data indicate the presence of several significant anomalies. Overall the seismic data collected on Profile C is lower than the velocities recorded on the other profiles. The anomaly at the inline distance of 150-170 feet (Trench 1) indicates a very low velocity (less than 700 ft/s) through the trench. Trench 4, located at the inline distance of 80-100 feet, also depicts a lower velocity anomaly (800-900 ft/s).

At the inline distance of 190-200 feet, the seismic velocities are greater than 1,000 ft/s. This location coincides with the perimeter berm.

The low velocities detected at the inline distance of 150-170 feet is located within Trench 1. Both the landstreamer and penetration data indicate that within the Trench 1 perimeter, lower velocities are present throughout the trench. This most likely indicates the presence of cardboard and wood.

Multi-Modal Analysis Data

The multi-modal curve data (Figure 12) indicates additional anomalies. Using this data set, the top of the trenches and corresponding soil cap thickness are depicted in dark blue (less than 650 ft/s).

The multi-modal velocity analysis data indicates the anomaly representing Trench 1 has high velocities instead of the lower velocities depicted in the penetration data. Along the bottom of the trench the high velocities (greater than 850 ft/s) are interpreted to represent concrete and metal. Above this anomaly the velocities are slightly slower (720-740 ft/s), which indicates the presence of a larger quantity of dry cardboard and wood.

The anomaly that corresponds to Trench 3 has velocities ranging from 650 ft/s near the surface to 740 ft/s at the bottom of the trench. The higher velocities at the bottom may be dry cardboard.

The multi-modal velocity data at the Trench 4 location depicts areas of velocities of less than 650 ft/s at the bottom of the trench. This has been interpreted to represent cardboard and wood. The higher velocities located closer to the ground surface are interpreted to represent dry cardboard and wood.

The anomaly that corresponds with Trench 5 indicates some areas of velocities ranging from 700-750 ft/s near the top of the trench and lower velocities (lower than 650 ft/s) present at the bottom of the trench (1352 feet AMSL). The lower velocities located at the bottom of the trench are interpreted to represent wet cardboard/wood, consistent with the saturated conditions at the bottom of Trench 5.

Profile C Summary

Figure 13 presents the interpreted trench dimensions based on the MASW data. Areas of saturated conditions, dense material, and possible concrete or metal are shown on the profile. Based on the MASW data, Trench 1 has seismic velocities that could represent concrete or metal objects present. Based on the inventory of waste, Trench 1 at the Profile C location is reported to contain concrete casks, steel drums, steel tanks, and wood boxes. The anomalies depicted in red on Figure 13 would be consistent with this inventory. The material surrounding each of these anomalies could represent soil or other waste material such as boxes.

Trench 3 has an area interpreted to be cardboard or wood nearer to the surface with lower velocities toward the bottom of the trench which most likely represents increased saturation of the material. Trench 4 appears to contain mostly cardboard and wood at the location of Profile C..

Some useable data were recorded at Trench 5. The data that were processed for Trench 5 indicated some denser material at depth within the trench. Based on the waste inventory, Trench 5 at this location is reported to contain steel boxes and cardboard containers.

No inventory of waste has been provided for Trenches 3 and 4 at the Profile C area.

4.1.4. Profile D

MASW data collected on Profile D indicates the presence of several anomalies. Geophone penetration data is shown on Figure 14 and the landstreamer fundamental mode data is presented on Figure 15. The multi-modal landstreamer data is presented on Figure 16.

Penetration and Landstreamer Data

The penetration and landstreamer data indicate the presence of several significant anomalies. Anomalies were located at the inline distance of 80-100 feet (Trench 4), 150-170 feet (Trench 1), and 190-200 feet (berm).

At the inline distance of 190-200 feet, the seismic velocities are greater than 1,000 ft/s. This location coincides with the perimeter berm.

The higher velocities (1,100 ft/s) detected at the inline distance of 150-170 feet are located within Trench 1. Both the landstreamer and penetration data indicate that within the Trench 1 perimeter, higher velocities are present throughout the trench, most likely indicates the presence of concrete and metal.

The landstreamer data indicated the presence of higher velocities within Trench 4. These have been interpreted to represent areas of concrete or metal.

Multi-Modal Analysis Data

The multi-modal curve data (Figure 16) indicates additional anomalies. Using this data set, the top of the trenches and corresponding soil cap thickness are depicted in dark blue (less than 650 ft/s).

The multi-modal data indicate the anomaly representing Trench 1 has high velocities representing the presence of concrete or metal.

The Trench 3 area indicates the subsurface is composed of velocities in the range of 700 to 720 ft/s and have been interpreted to represent areas of cardboard and wood.

The multi-modal curve data at the Trench 4 location depicts areas of velocities greater than 800 ft/s at the bottom of the trench, indicating the presence of concrete and steel.

The anomaly that corresponds with Trench 5 indicates some areas of velocities ranging from 700-750 ft/s near the top of the trench, which is interpreted to represent cardboard and wood. Higher velocities (750-850 ft/s) present at the bottom of the trench (1352 feet AMSL) are interpreted to represent concrete and metal.

Profile D Summary

Figure 17 presents the interpreted trench dimensions based on the MASW data. Areas of saturated conditions, concrete/metal and cardboard/wood are shown on the profile. Based on the MASW data, Trenches 1 and 4 have seismic velocities that have been interpreted to represent concrete or metal. Based on the inventory of waste, Trenches 1 and 4 at the Profile D location are reported to contain concrete casks, steel drums, steel tanks, and wood boxes. The anomalies depicted in red on Figure 17 would be consistent with this inventory.

The seismic velocities detected in Trench 3 are interpreted to represent cardboard/wood. Some useable data were recorded at Trench 5. The data that were processed for Trench 5 indicated some metal or concrete at the bottom of the trench. Based on the waste inventory, Trench 5 at this location is reported to contain steel boxes and cardboard containers.

No inventory of waste has been provided for Trench 3 at the Profile D area.

4.1.5. MASW Summary

Figure 18 presents the summaries of the four profiles with the interpreted dimensions and possible contents of each of the trenches. Due to the poor quality of the data, the geophone penetration data files were not used during interpretation. A shallow low velocity layer is present across all the profile which would be consistent with the soil cap as shown on Figure 18.

As shown on Figure 18, Trench 1 is located at approximately the inline distance of 150-170 feet based off of the aerial photographs and the interpreted data. The bottom of the trench is approximately located at 1352 feet AMSL. On three of the profiles, the MASW data indicate that the contents of the trench contain dense material consistent with concrete and steel. The waste inventory provided by ECS indicates steel drums, cardboard boxes, and concrete casks were deposited in this area. One profile (B) indicated lower velocities in Trench 1. This may be due to only cardboard and similarly composed material is present or the material is saturated.

Trench 3 is located approximately 110-140 feet inline distance. The bottom of the trench was interpreted to be at approximately 1350 feet AMSL. In general, the seismic velocities in Trench 3 are slower than typically interpreted to be concrete or metal. Trench 3 in this area of the SDA may contain mostly non-metal/concrete waste. On one profile (A), there is high velocity material at depth that may indicate the presence of metal or concrete. There was no inventory of waste material for Trench 3 in the data provided by ECS at the time of the study.

Trench 4 is located approximately 80-100 feet inline distance. The bottom of the trench was interpreted to be approximately 1355 feet AMSL. Trench 4 includes areas of high velocities (consistent with metal or concrete) and slower velocities that may indicate less dense material such as the cardboard boxes. Limited waste inventory information was available for Trench 4 at the time of the study; however, notations indicating steel tanks, drums, and concrete casks were available for Profile D.

Trench 5 is located at the inline distance of 50-70 feet. The bottom of the trench was interpreted to be approximately 1350 feet AMSL. Due to the poor seismic data, very limited interpretations can be made for Trench 5. In general, seismic velocities indicating non-metal/less dense material were present. Waste inventories indicated the presence of concrete casks and steel drums and boxes in Trench 5. The data that has been presented for Trench 5 indicate saturated conditions, which is consistent with recent measurements indicating that several feet of leachate is present in Trench 5..

4.2. ERI Survey

The results and interpretations of the ERI survey are discussed in the following paragraphs and the attached figures. The ERI profiles attached to this report are presented using a consistent color contour scale (0 to 100 ohm-meters). This allows for comparison between profiles. On each profile, anomalies of interest have been identified.

The following general interpretations can be made when reviewing the ERI data:

- More compacted materials will have a lower resistivity.
- As air-filled void space increases so does the resistivity.
- The wetter the material the lower the resistivity value.
-

4.2.1. Profile A

The ERI data collected along Profile A are included on Figure 19. The ERI data indicate significant areas of very low resistivity. The resistivity range for the entire profile is 0 to 100 ohm-meters. The arm-looking anomalies that extend from the surface down at 45 degree angles are caused by missing data points (skipped electrodes). Clay and till material would have low resistivity values, however, anomalies such as concrete would have higher resistivity values. The data depicted on this profile essentially shows no significant variation and is therefore unusable.

4.2.2. Profile B

The ERI data collected along Profile B are included on Figure 20. The ERI data indicate significant areas of very low resistivity. The resistivity range for the entire profile is 0 to 100 ohm-meters. The arm-looking anomalies that extend from the surface down at 45 degree angles are caused by missing data points (skipped electrodes). Clay and till material would have low resistivity values, however, anomalies such as concrete would have higher resistivity values. The data depicted on this profile essentially shows no significant variation and is therefore unusable.

4.2.3. Profile C

The ERI data collected along Profile C are included on Figure 21. The ERI data indicate significant areas of very low resistivity. The resistivity range for the entire profile is 0 to 100 ohm-meters. The arm-looking anomalies that extend from the surface down at 45 degree angles are caused by missing data points (skipped electrodes). Clay and till material would have low resistivity values, however, anomalies such as concrete would have higher resistivity values. The data depicted on this profile essentially shows no significant variation and is therefore unusable.

4.2.4. Profile D

The ERI data collected along Profile D are included on Figure 22. The ERI data indicate significant areas of very low resistivity. The resistivity range for the entire profile is 0 to 100 ohm-meters. The arm-looking anomalies that extend from the surface down at 45 degree angles are caused by missing data points (skipped electrodes). Clay and till material would have low resistivity values, however, anomalies such as concrete would have higher resistivity values. The data depicted on this profile essentially shows no significant variation and is therefore unusable.

4.2.5. ERI Summary

Overall the ERI data is not considered to be reliable or useful. Although the data passed all QC tests, two factors influenced the quality of the data. The first was the significant amount of metal within the trenches, as shown in the waste inventory, which essentially shorted out the survey. Electricity induced into the ground during the survey was absorbed by the highly conductive trenches and a very limited depth of investigation was possible. The second reason was the number of electrodes that had to be skipped because of their locations. The membrane could not be pierced in low lying areas which could introduce water beneath the membrane. By skipping these electrodes gaps were created in the data. The ERI could not overcome the skipped data and the metal in the subsurface.

5. Summary

5.1. Objectives

There are four objectives of the geophysical prove-out study. A summary of the MASW applicability to each of the objectives is provided below. Since the ERI survey has been considered to be unusable, it is not included in the summary below each objective.

Objective 1: Define the lateral boundaries of individual waste trenches and other disposal units within the SDA to allow for safe boring installation as near as possible to the waste.

Based on the MASW results, there are areas along the profiles where lateral edges of the trenches are observed. In some areas, the lateral edges are not as clearly defined, which is most likely due to the signal to noise ratio in the data. In areas where the lateral limits were detected, there appeared to be an approximate 10-foot wide soil zone between the interpreted trench locations. A small diameter boring could be placed between the trenches. For safety reasons and allowing for margin of errors, the boring could be placed within three to four feet of the trench.

Objective 2: Define the bottom/depth of the waste trenches and other disposal units.

On some of the profiles, the MASW was able to differentiate the bottom of the trench from surrounding soil. However, the MASW did not consistently complete this objective. There are two sources to this problem. The first was much of the data along the west side of the profile was lost due to poor contact between the membrane and the soil. This caused a bounce effect when the steel plate was struck with the sledge hammer which caused noise in the data. The second issue had to do with the amount of energy that went into the ground. During the survey, a 12-pound sledge hammer was utilized. At several shot locations, a heavier hammer was used but it did not increase the data quality. A heavier source, such as a 50 pound weight drop may increase the data quality at depth.

Objective 3: Determine the water elevation within the waste trenches, as well as the water elevation in the surrounding soil.

The MASW indicated areas of possibly saturated material within the trenches. These areas are depicted on the MASW profiles. Although areas of lower seismic velocity were noted between the trenches, the velocities were in the range of soil and not low enough to be interpreted as saturated conditions.

Objective 4: Identify specific segments within the waste trenches that contain either waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or significant metallic waste quantities that can be compared against the inventory records for those same segments to support inventory reliability.

The MASW indicated areas of very high seismic velocities that are interpreted to represent dense material such as concrete and metal. These areas were highlighted on the MASW profiles.

Information from the waste inventory verified the presence of concrete casks, steel drums, steel bins and boxes were buried in these areas.

5.2. Recommendations

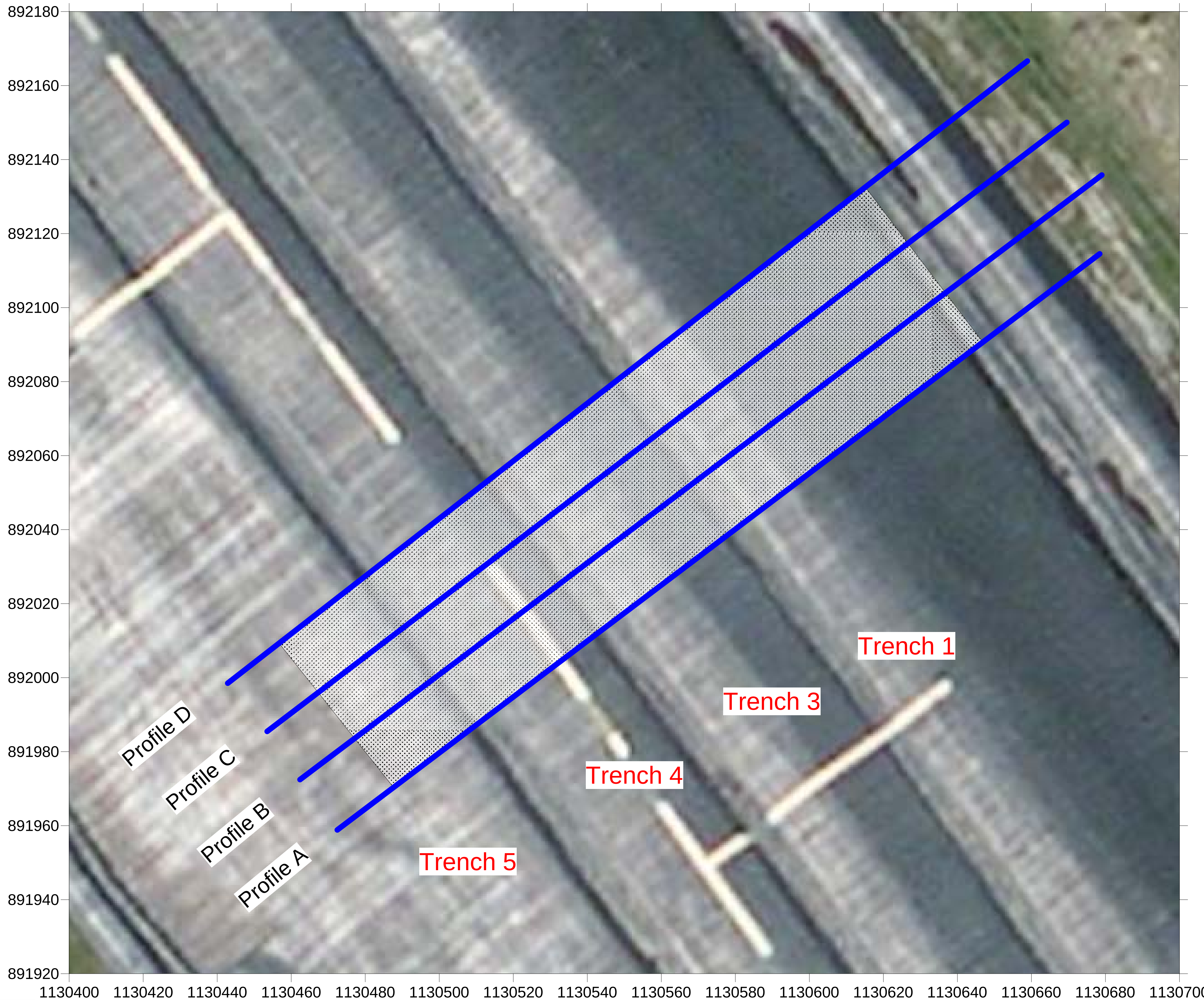
As discovered during the ERI survey, this method did not prove to be effective at the prove-out stage. There may be some areas at the facility where the ERI could be helpful and provide sufficient data where less drums and metallic features are located; however, since this method is labor intensive and relatively slow and not cost effective, ACE does not recommend going forward with any additional ERI surveys.

The MASW method proved much more effective at meeting the survey objectives. During the prove-out study, geophone penetration and landstreamer application modes were utilized. When comparing both data sets, the landstreamer application provided more data with better quality. The data collected using geophone penetration had significant areas where there was insufficient contact between the geophones and the soil beneath the membrane cover. This was caused by the membrane not being stretched tight against the soil in some areas.

Although the MASW landstreamer modes did not meet the objectives over all of the trenches, it did provide a greater level of information along each of the profiles. The data indicated the presence of concrete/metal (very high velocity) and cardboard/wood (lower velocities) in discrete areas of the trenches. Since some data were missing along the west side of the prove-out area, portions of Trench 5 were not comprehensively surveyed. But, overall, the landstreamer with two forms of processing provided data to meet the objectives.

6. Limitations

The results stated and the conclusions drawn from this report furnished by ACE Geophysics to the client hereunder shall represent the opinion, efforts and judgment of ACE Geophysics, based on standard industry practices; however, ACE Geophysics cannot and does not warrant or guarantee that the accuracy or correctness thereof will always meet desired results and expectations. By their inherent capabilities and limitations, geophysical surveys are not 100-percent accurate, nor can they completely define subsurface conditions. ACE will not accept responsibility for inherent technique limitations, survey limitations, potentially foreseen or unforeseen site-specific conditions, or alleged operator error. Any action which client (or those associated with client) may take as a result of or based on such reports and the data to which it refers shall be client's own responsibility and ACE Geophysics shall not be liable or responsible for any loss, cost, damages or expenses whatsoever, including incidental or consequential damages, incurred or sustained by client resulting therefrom for which client hereby releases ACE Geophysics; provided that all such reports, data and information, as well as the basic data upon which they are based, are acquired, compiled and prepared, as the case may be, in accordance with the contract.



Geophysical Pilot Test Grid

Geophysical Profile

Feet (Scale 1 to 30)

0 25 50 75 100

Archeological Construction Environmental

N

Coordinates are in NAD83
New York, West, Feet, WGS 1984

Geophysical Pilot Study

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Western New York Nuclear Service Center

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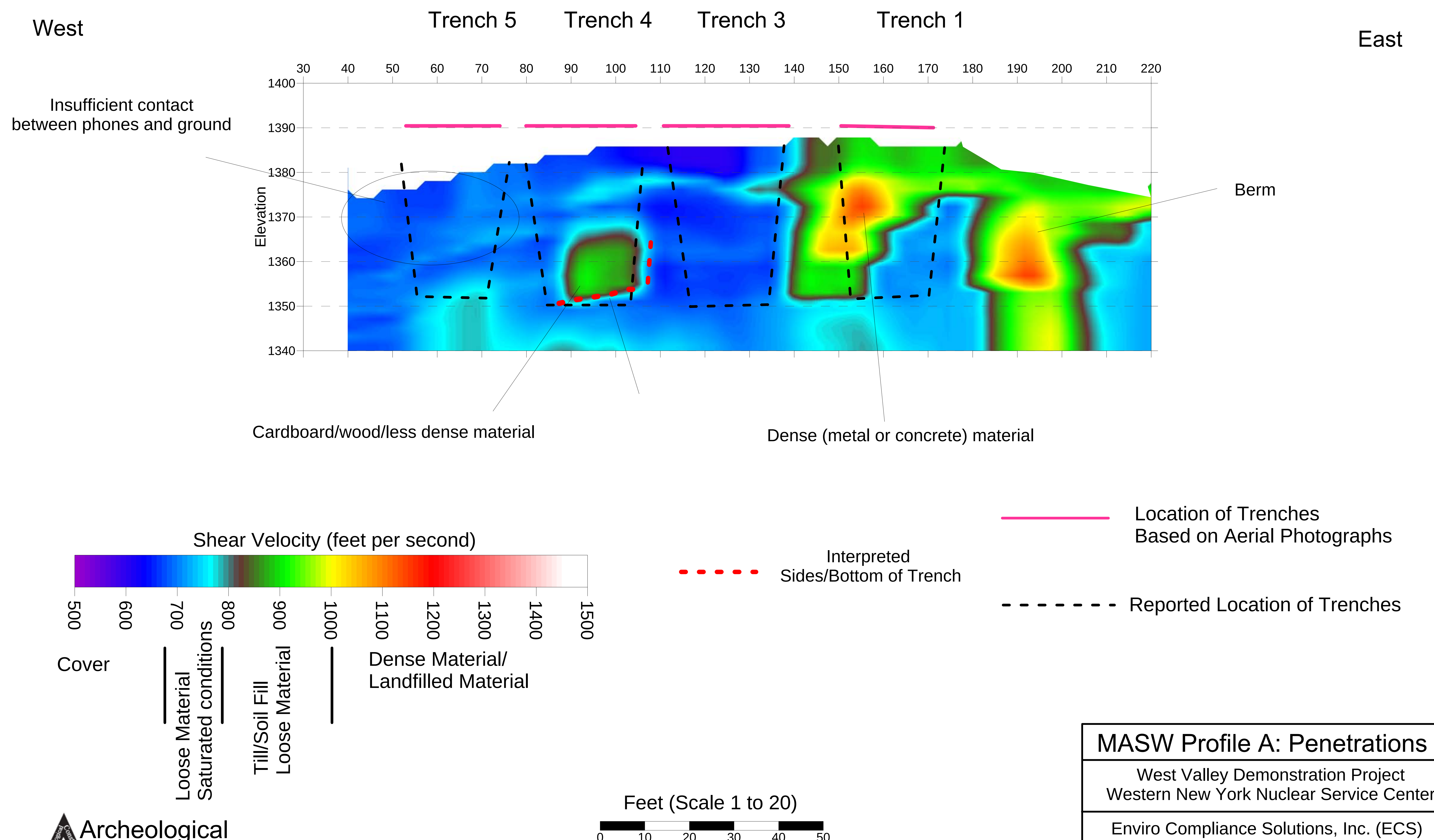

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MASW Profile A: Penetrations	
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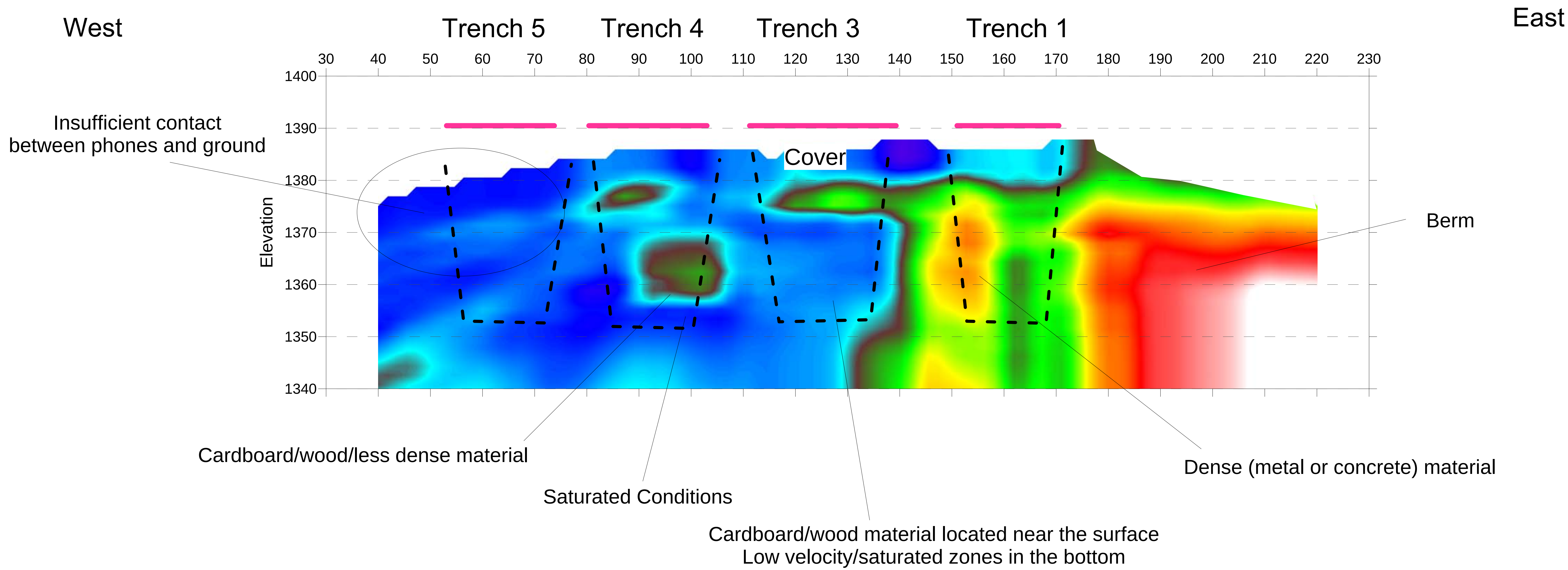

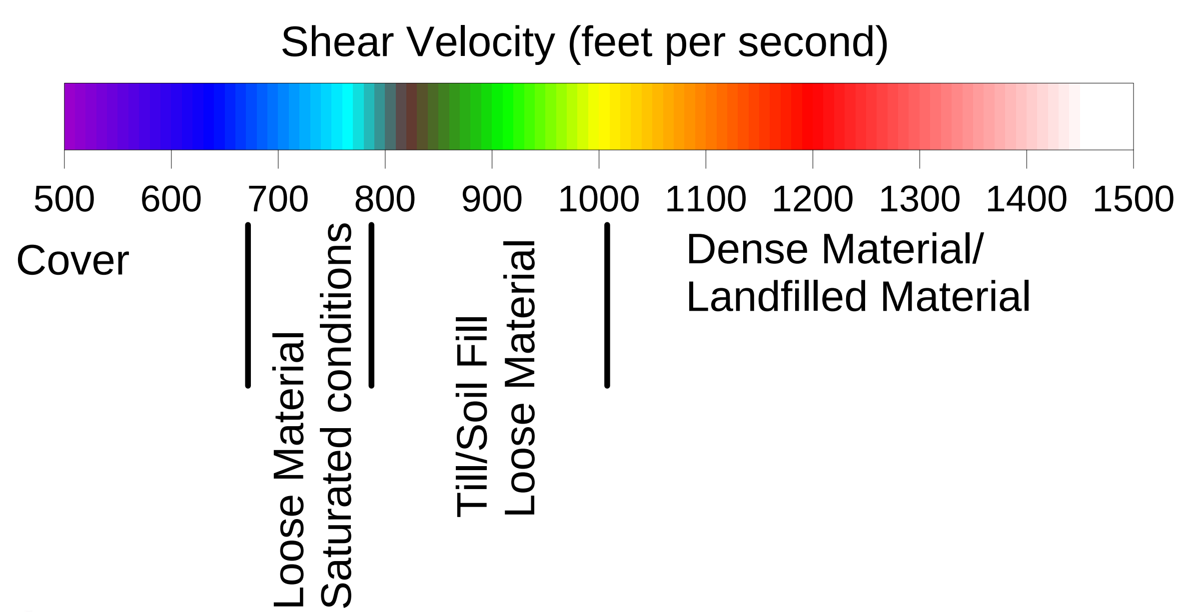

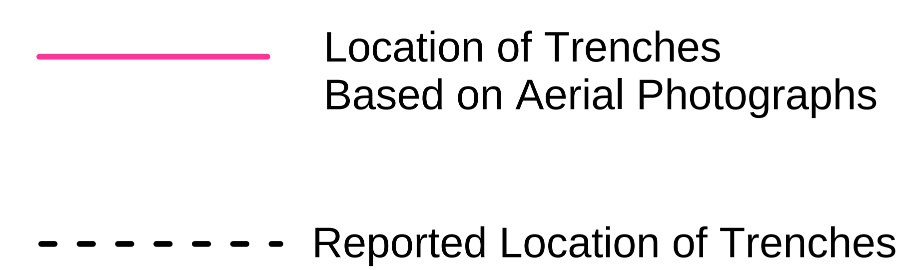

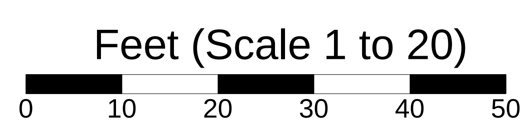

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MASW Profile A: Landstreamer Fundamental Mode	
West Valley Demonstration Project Western New York Nuclear Service Center	
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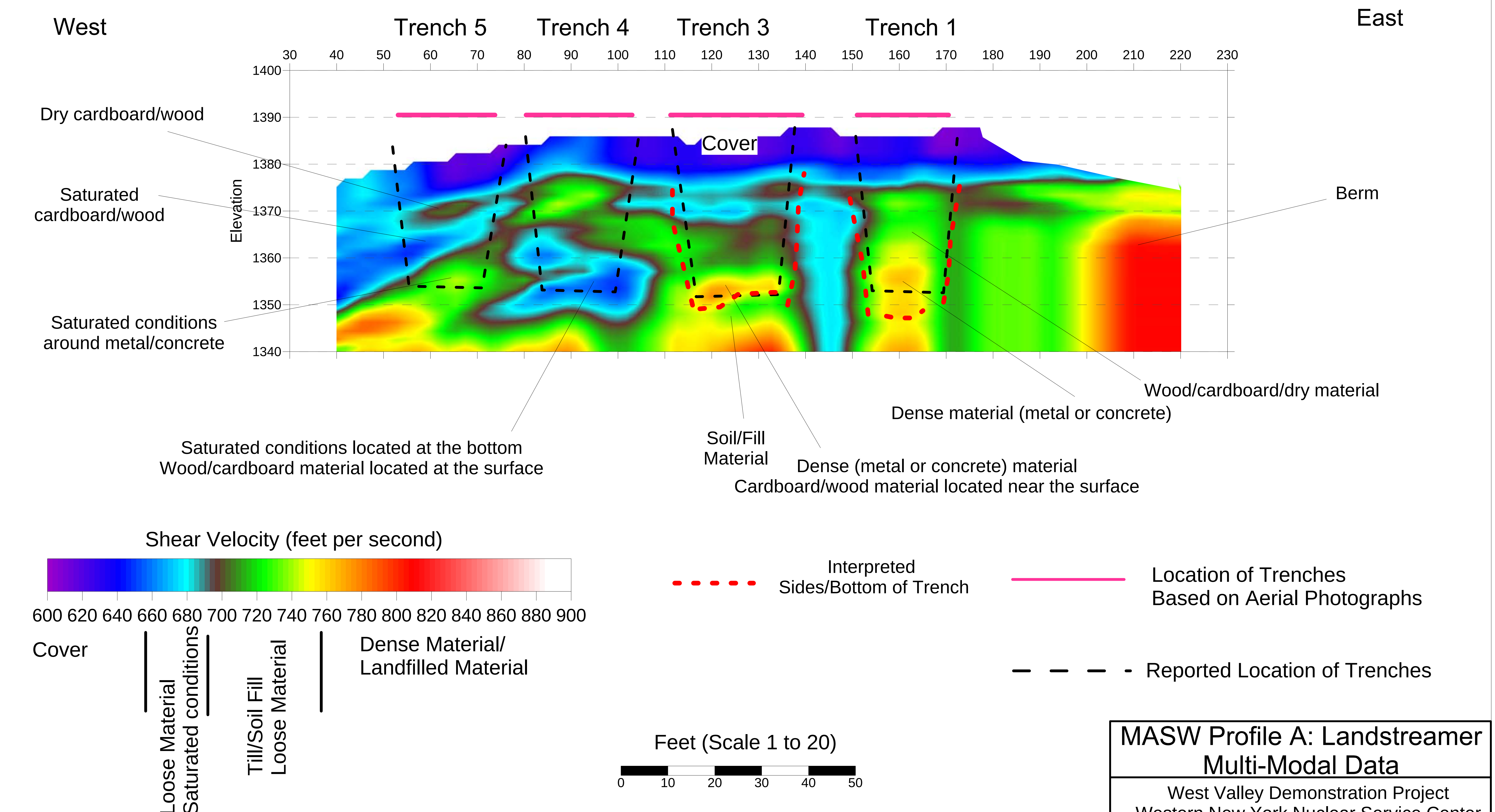

MASW Profile A: Landstreamer Multi-Modal Data

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Figure 4

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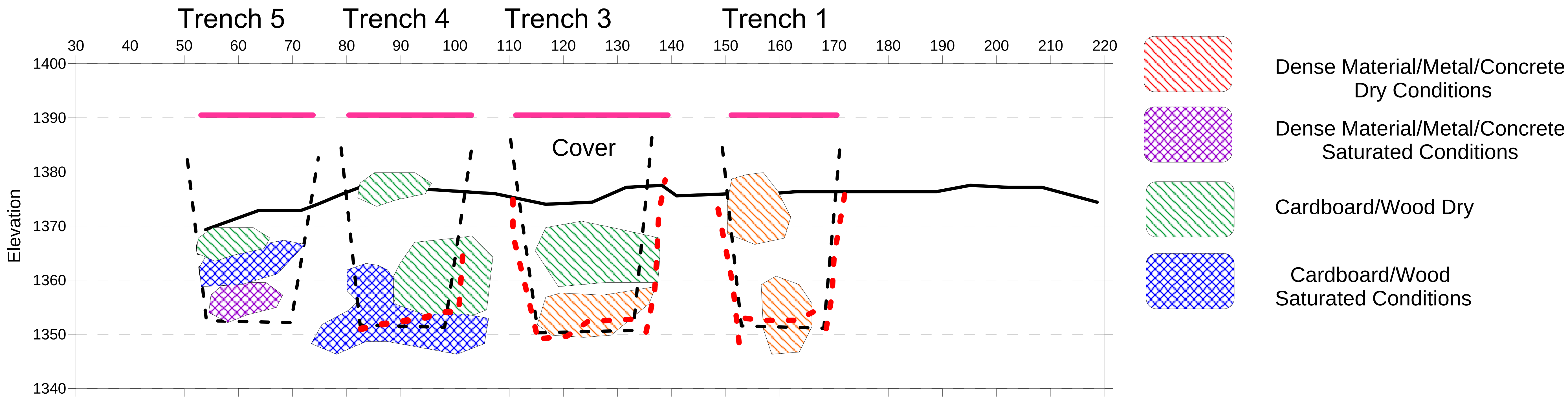

Location of Trenches
Based on Aerial Photographs

Reported Location of Trenches

Interpreted
Sides/Bottom of Trench

Interpreted Bottom of Cover Material

Feet (Scale 1 to 20)

0 10 20 30 40 50

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MASW Profile A: Cross-Section	
West Valley Demonstration Project Western New York Nuclear Service Center	
Enviro Compliance Solutions, Inc. (ECS) 4795 Blue Mountain Drive Yorba Linda, California	
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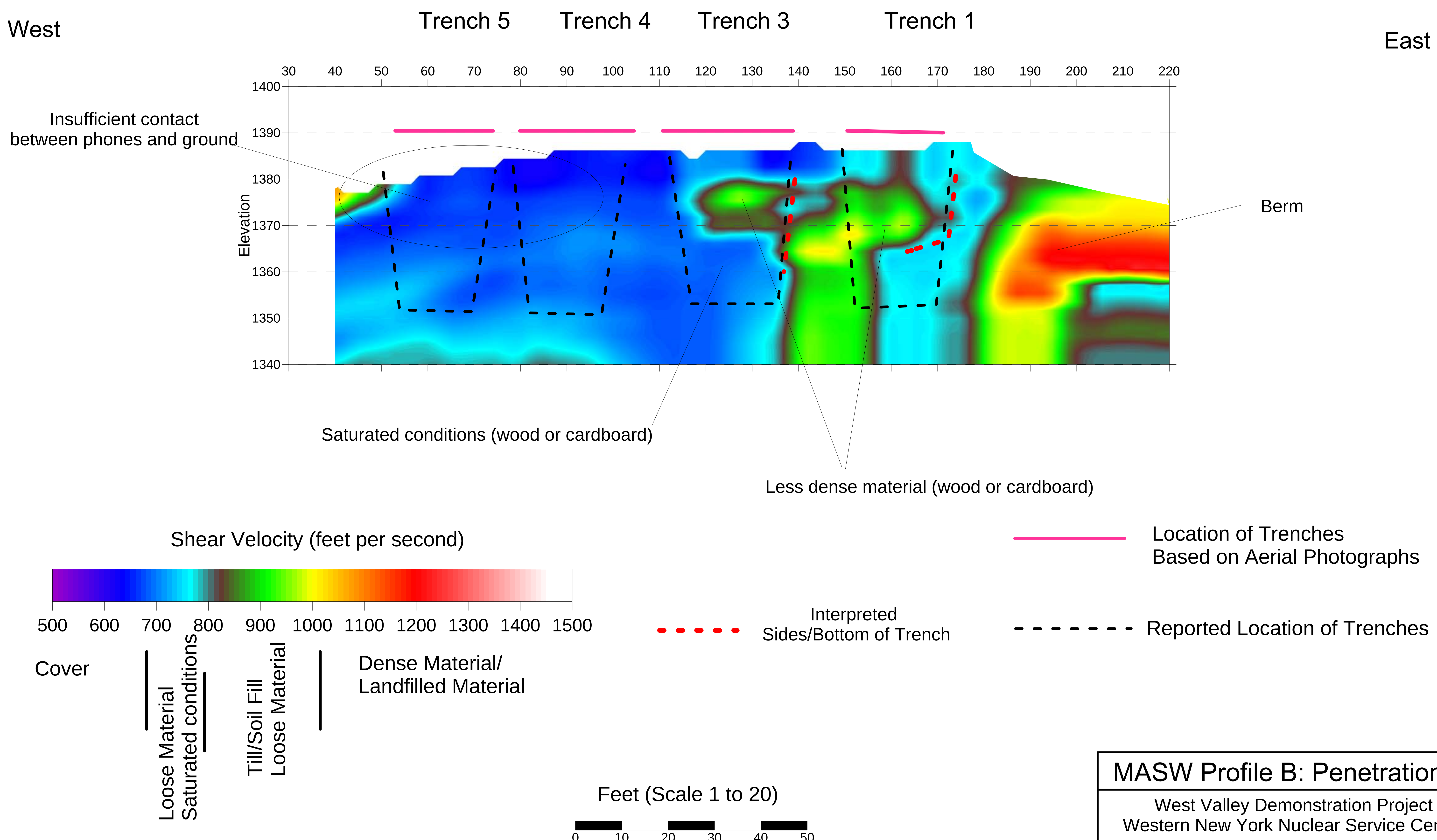

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MASW Profile B: Penetrations

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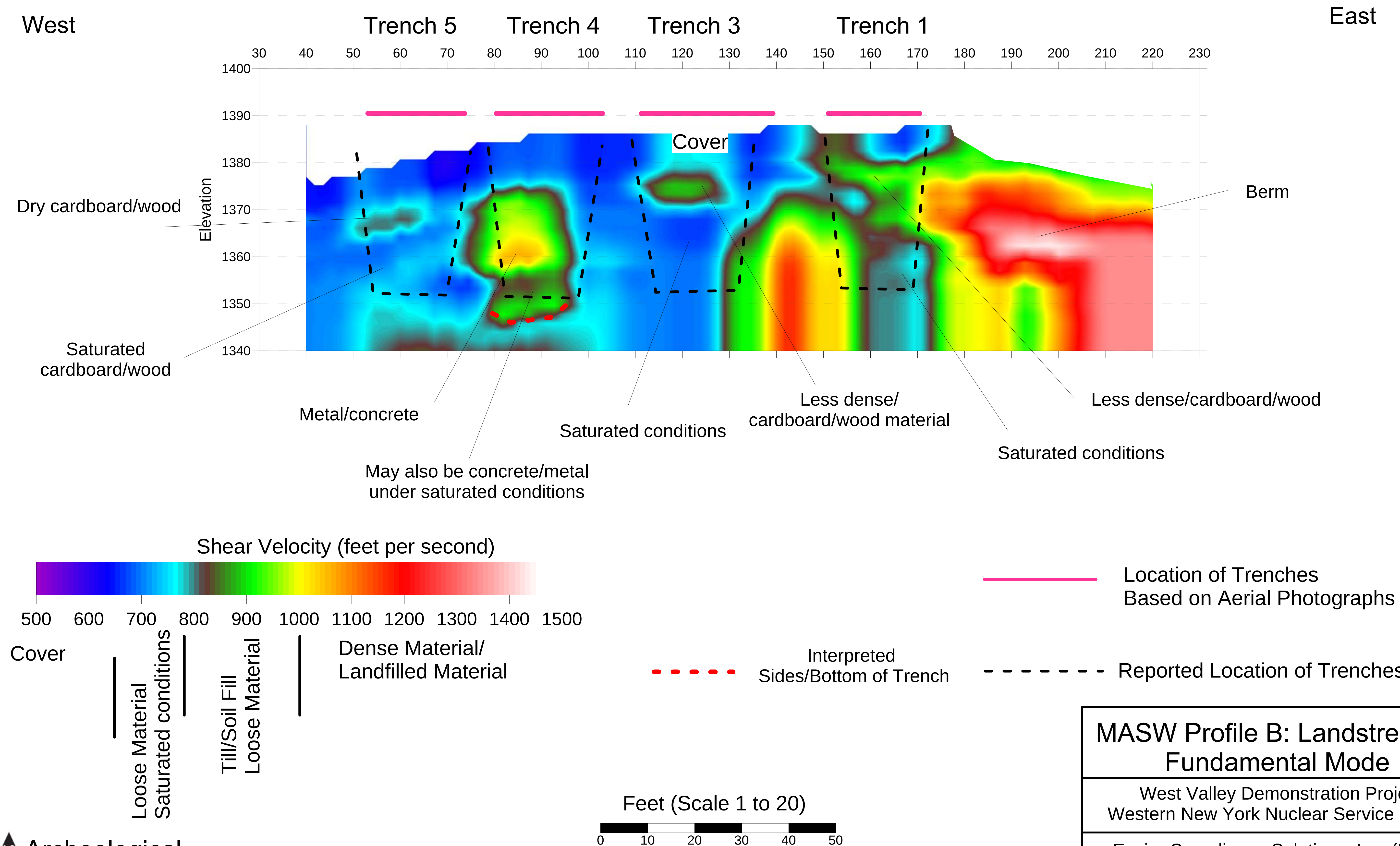
Figure 6



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MASW Profile B: Landstreamer Fundamental Mode	
West Valley Demonstration Project Western New York Nuclear Service Center	
Enviro Compliance Solutions, Inc. (ECS) 4795 Blue Mountain Drive Yorba Linda, California	
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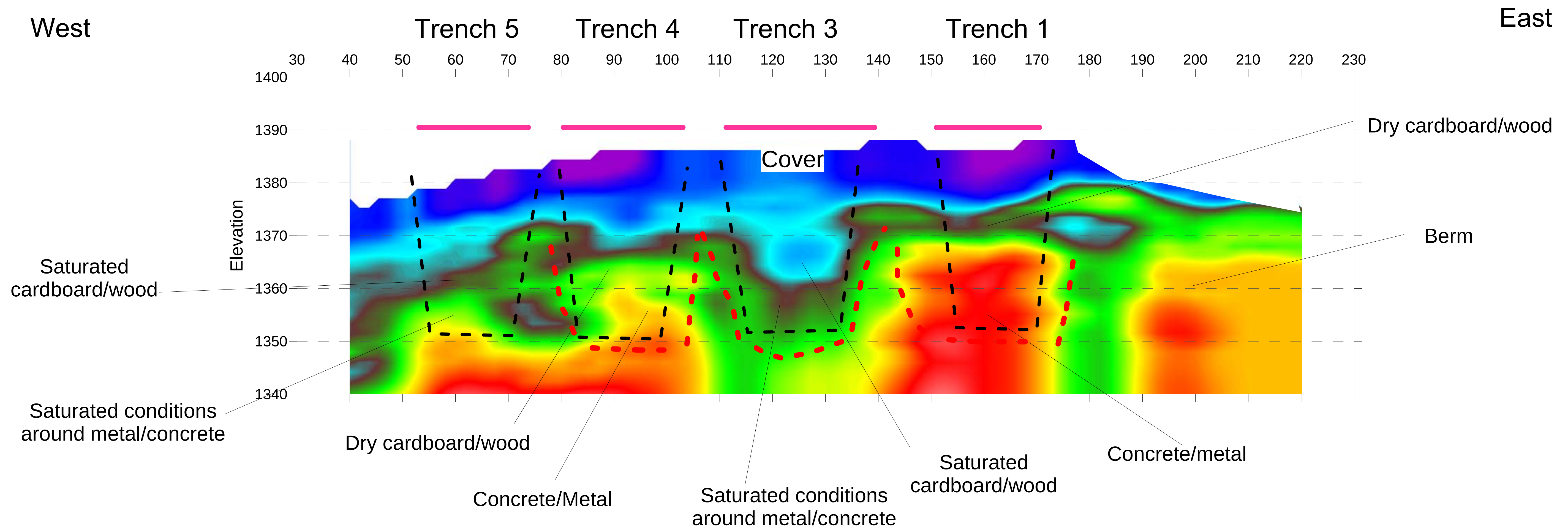

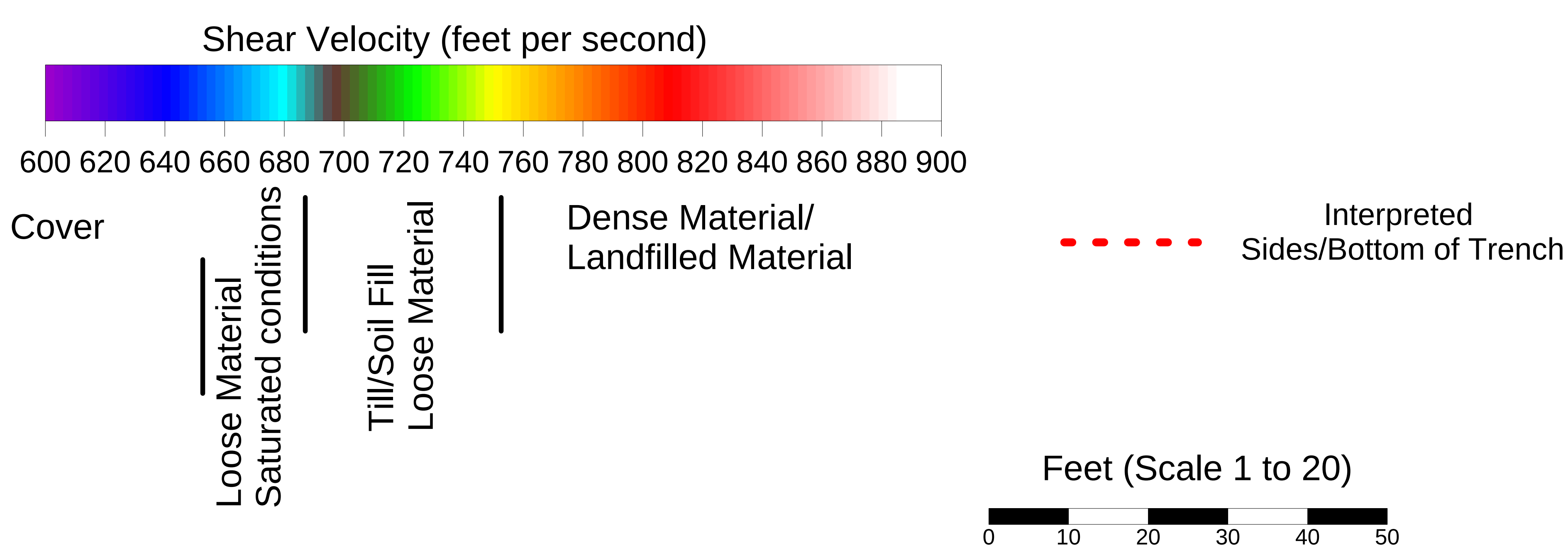

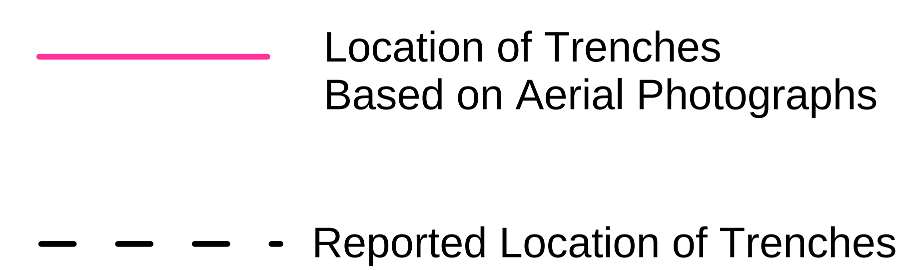

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MASW Profile B: Landstreamer Multi-Modal Data	
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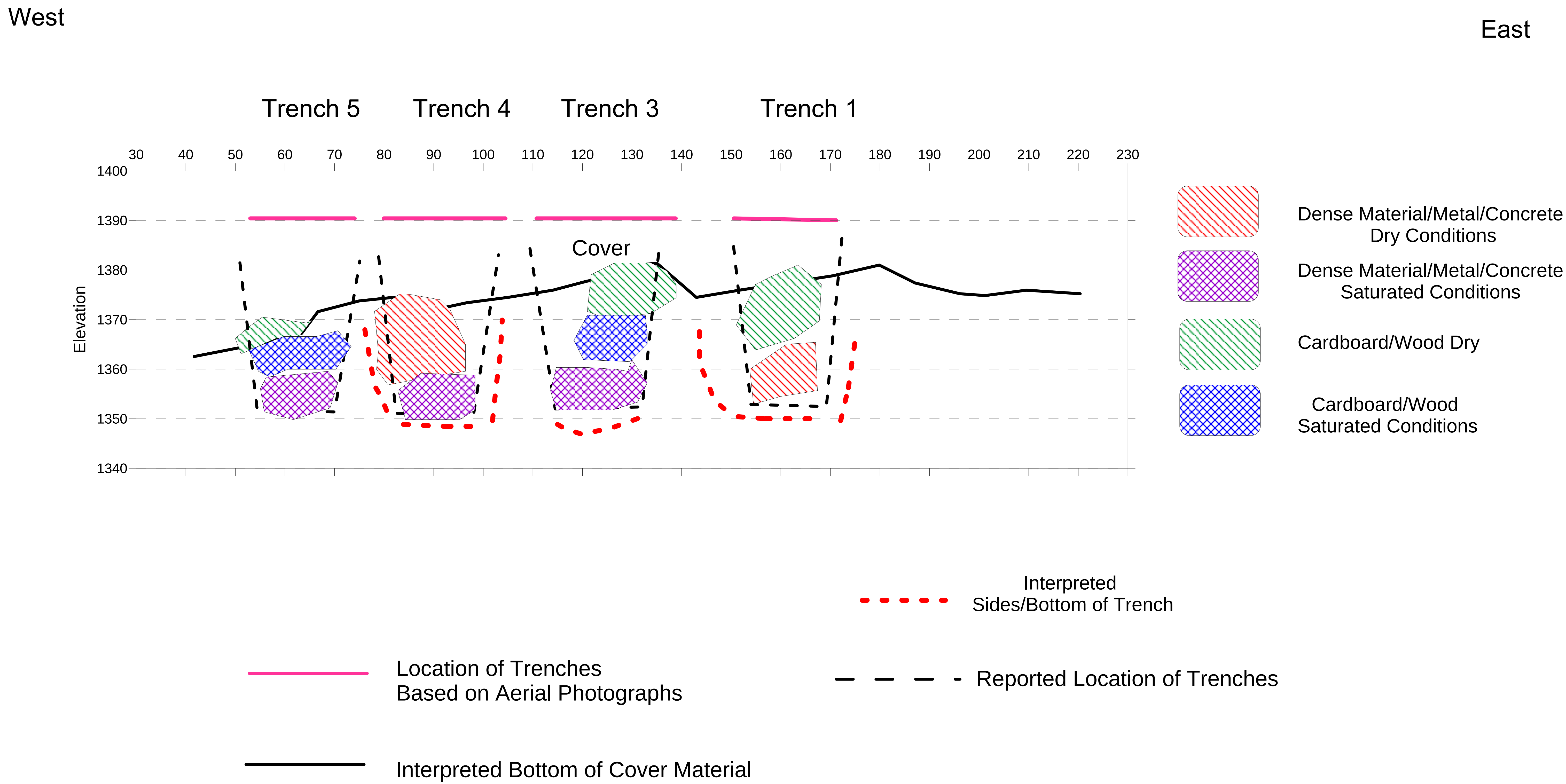

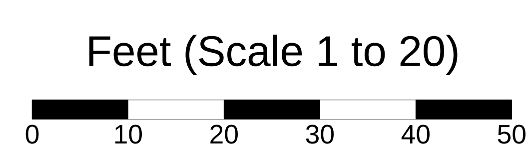

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MASW Profile B: Cross-Section

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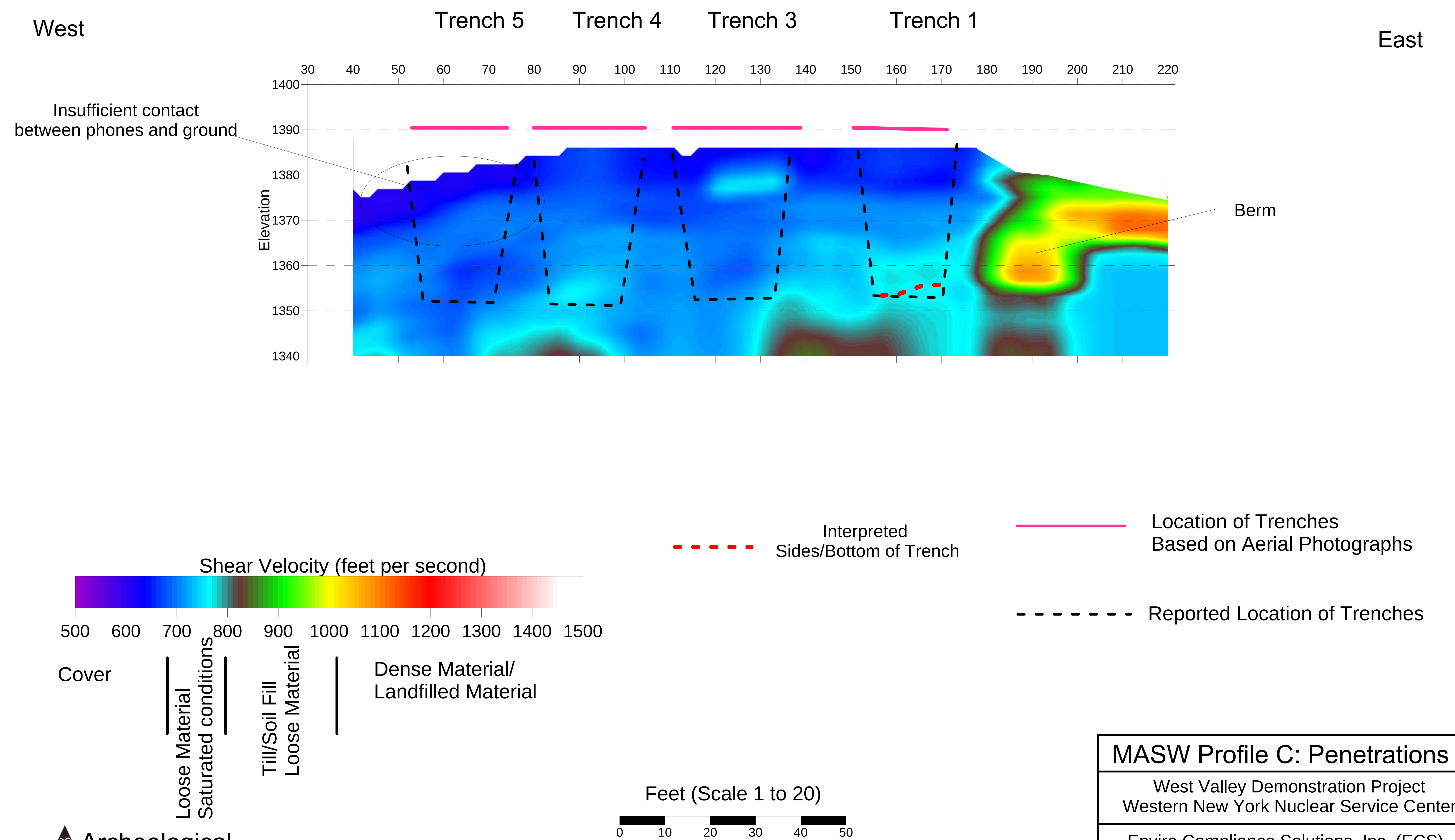

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MASW Profile C: Penetrations

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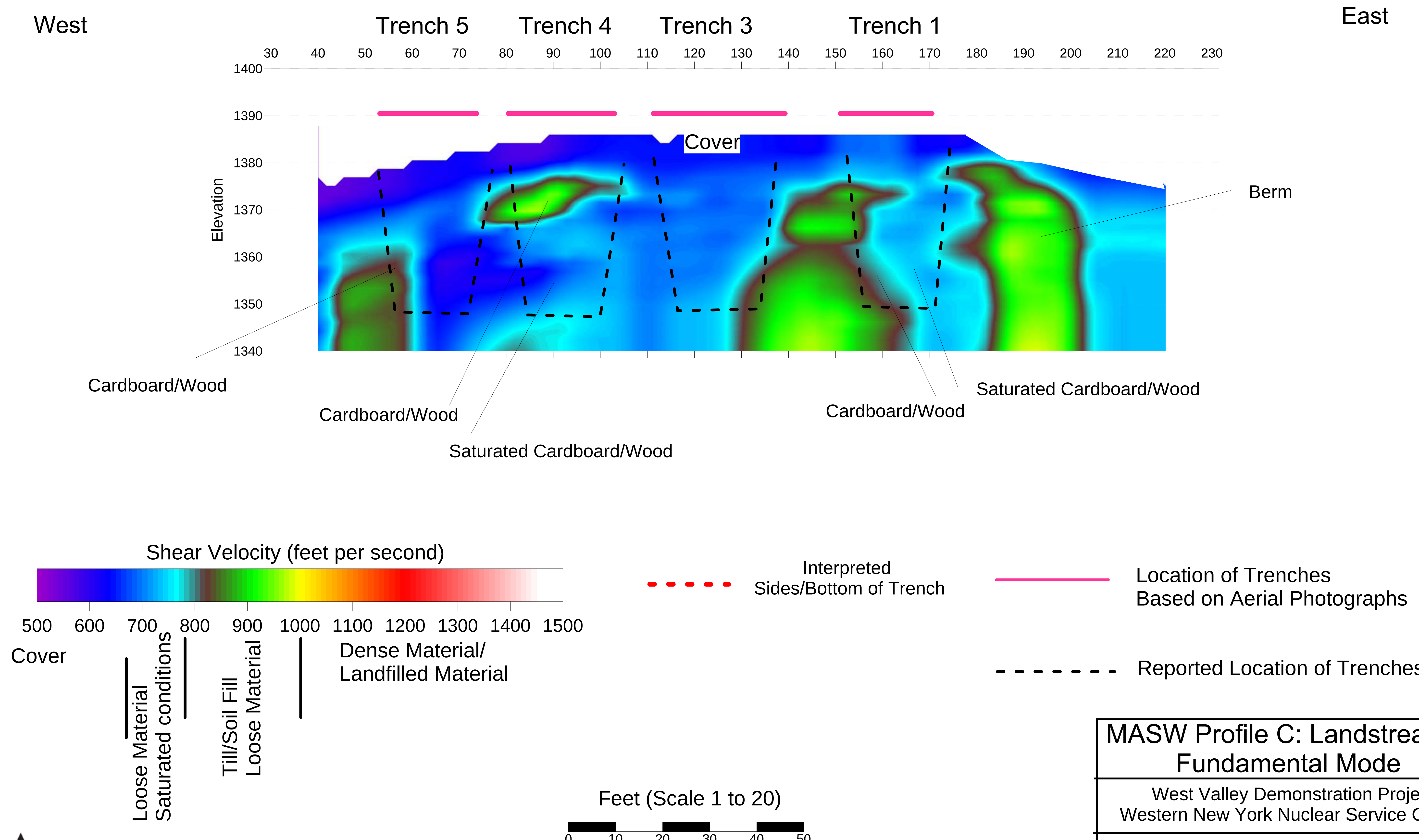
Figure 10



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MASW Profile C: Landstreamer Fundamental Mode

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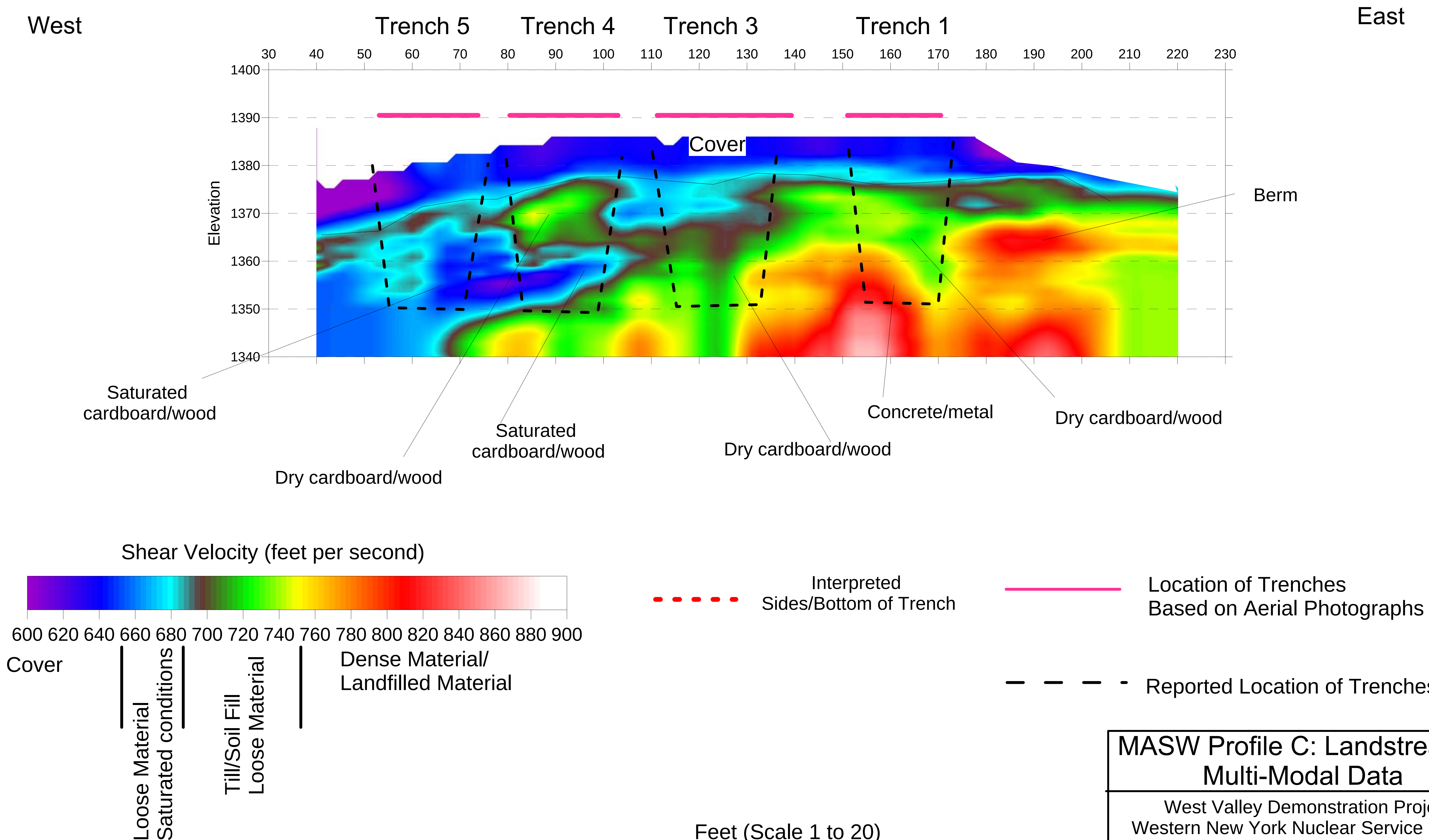
Figure 11



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MASW Profile C: Landstreamer Multi-Modal Data

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Western New York Nuclear Service Center

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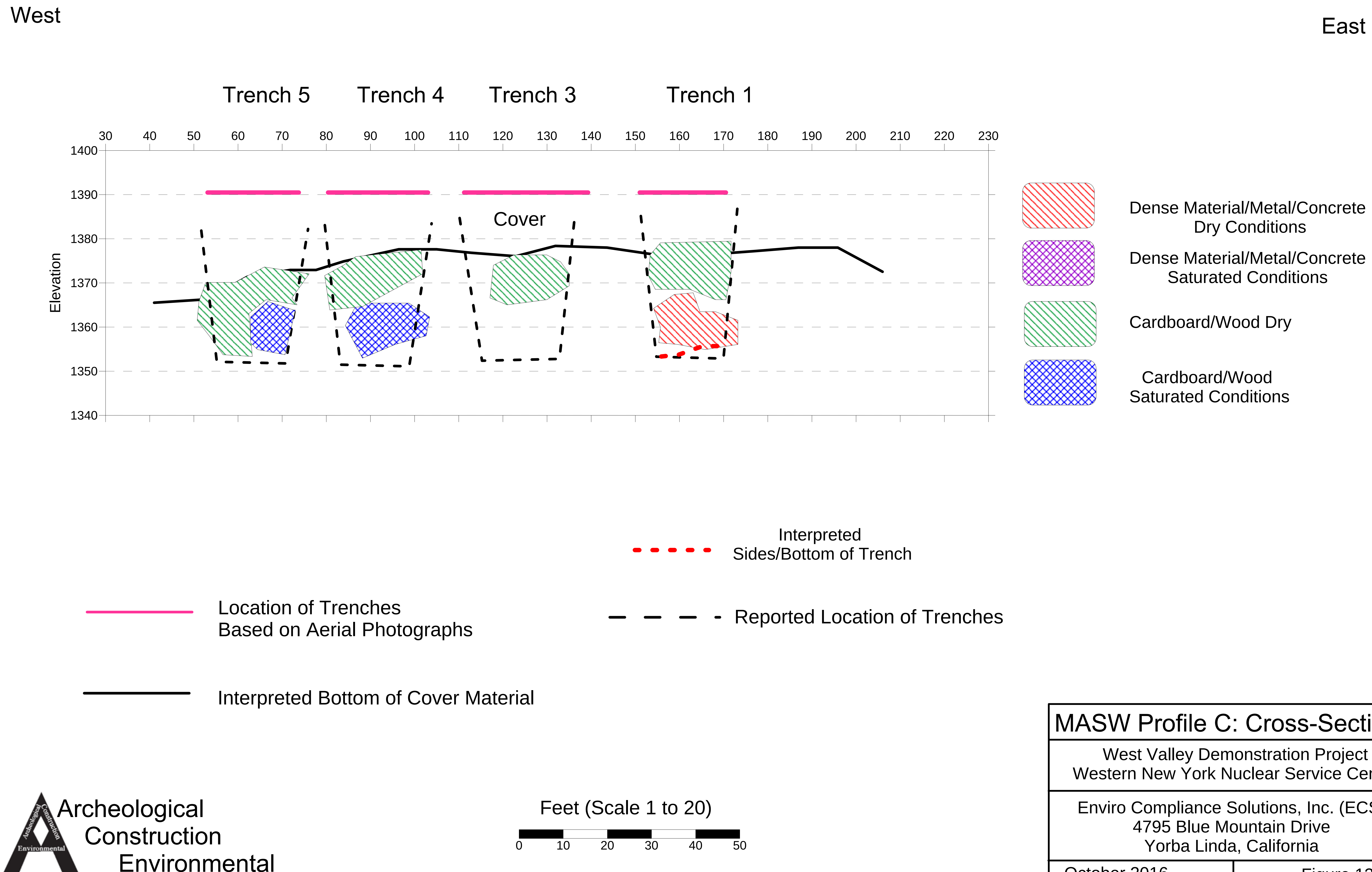

MASW Profile C: Cross-Section

West Valley Demonstration Project
Western New York Nuclear Service Center

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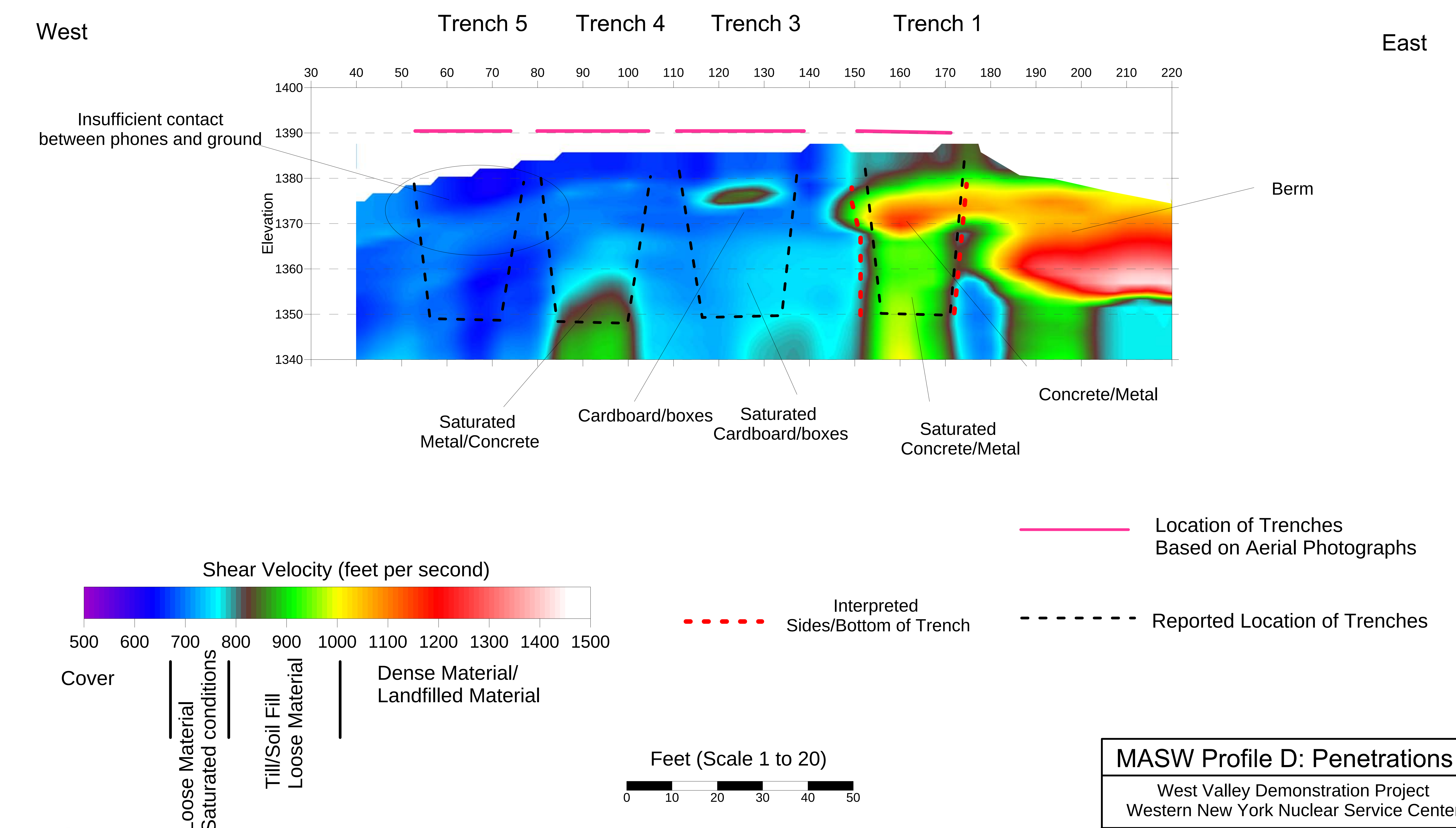

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MASW Profile D: Penetrations	
West Valley Demonstration Project Western New York Nuclear Service Center	
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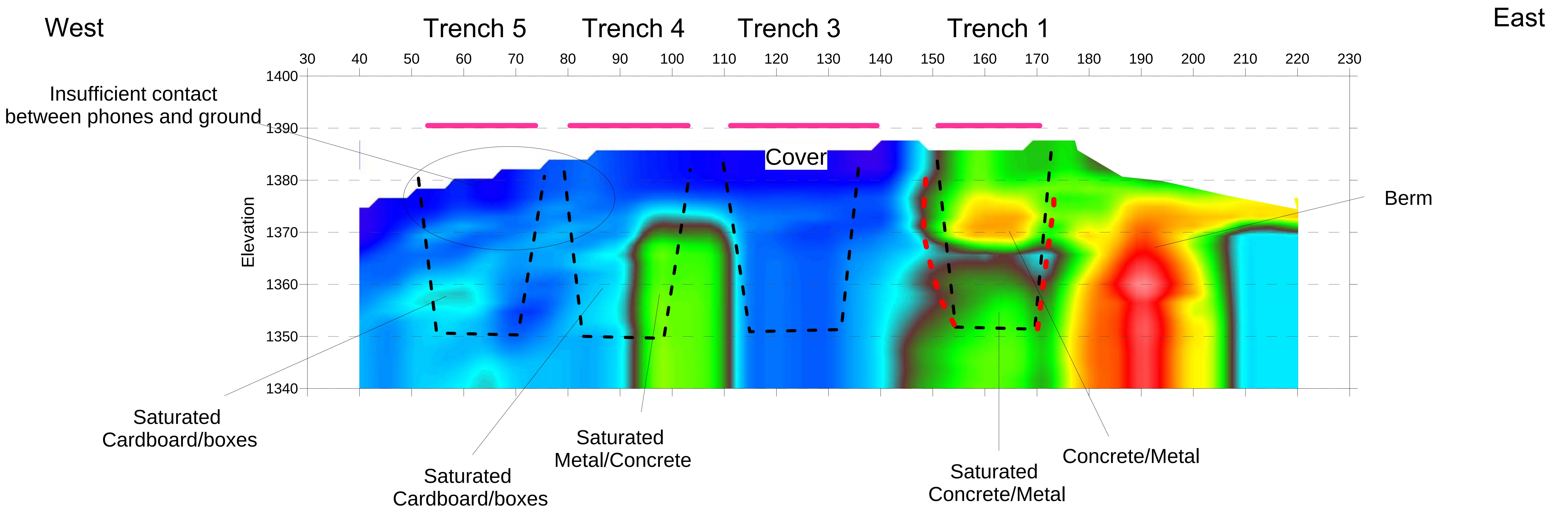
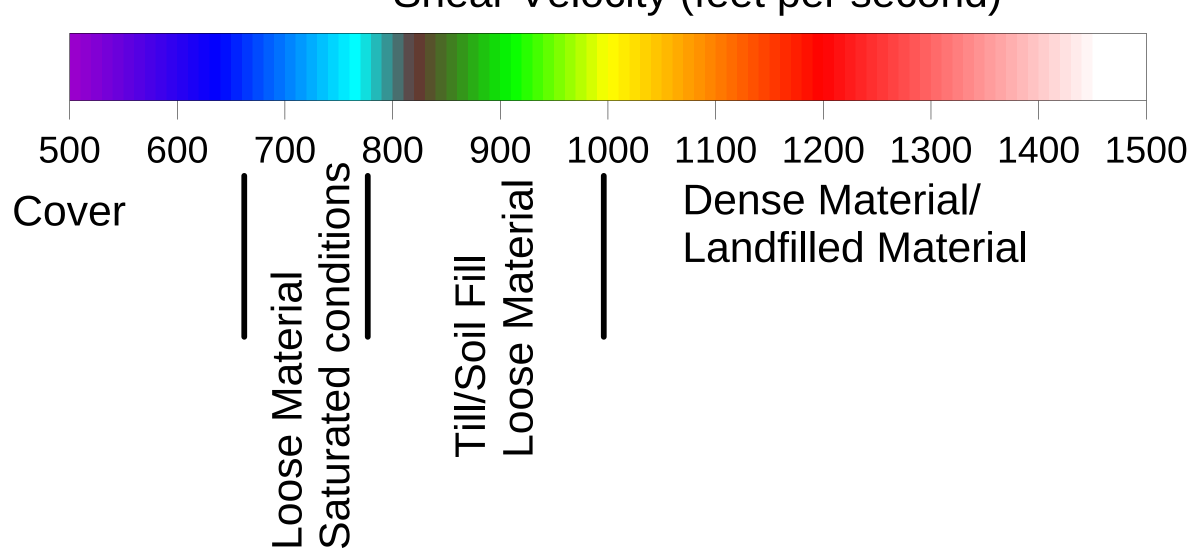
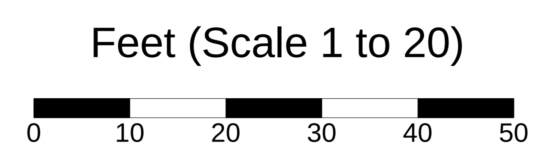




Interpreted Sides/Bottom of Trench

Location of Trenches Based on Aerial Photographs

Reported Location of Trenches



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MASW Profile D: Landstreamer Fundamental Mode	
West Valley Demonstration Project Western New York Nuclear Service Center	
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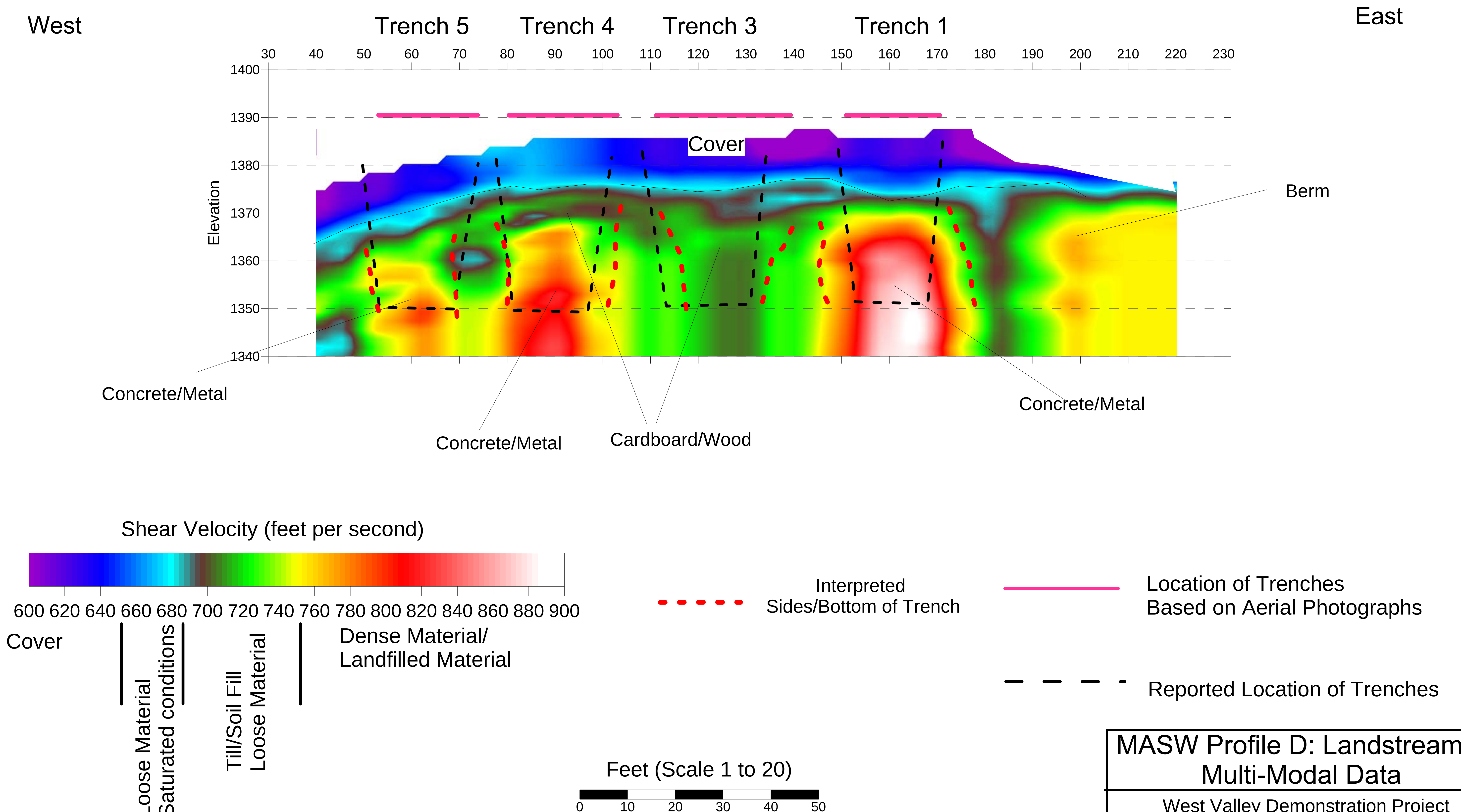

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MASW Profile D: Landstreamer Multi-Modal Data

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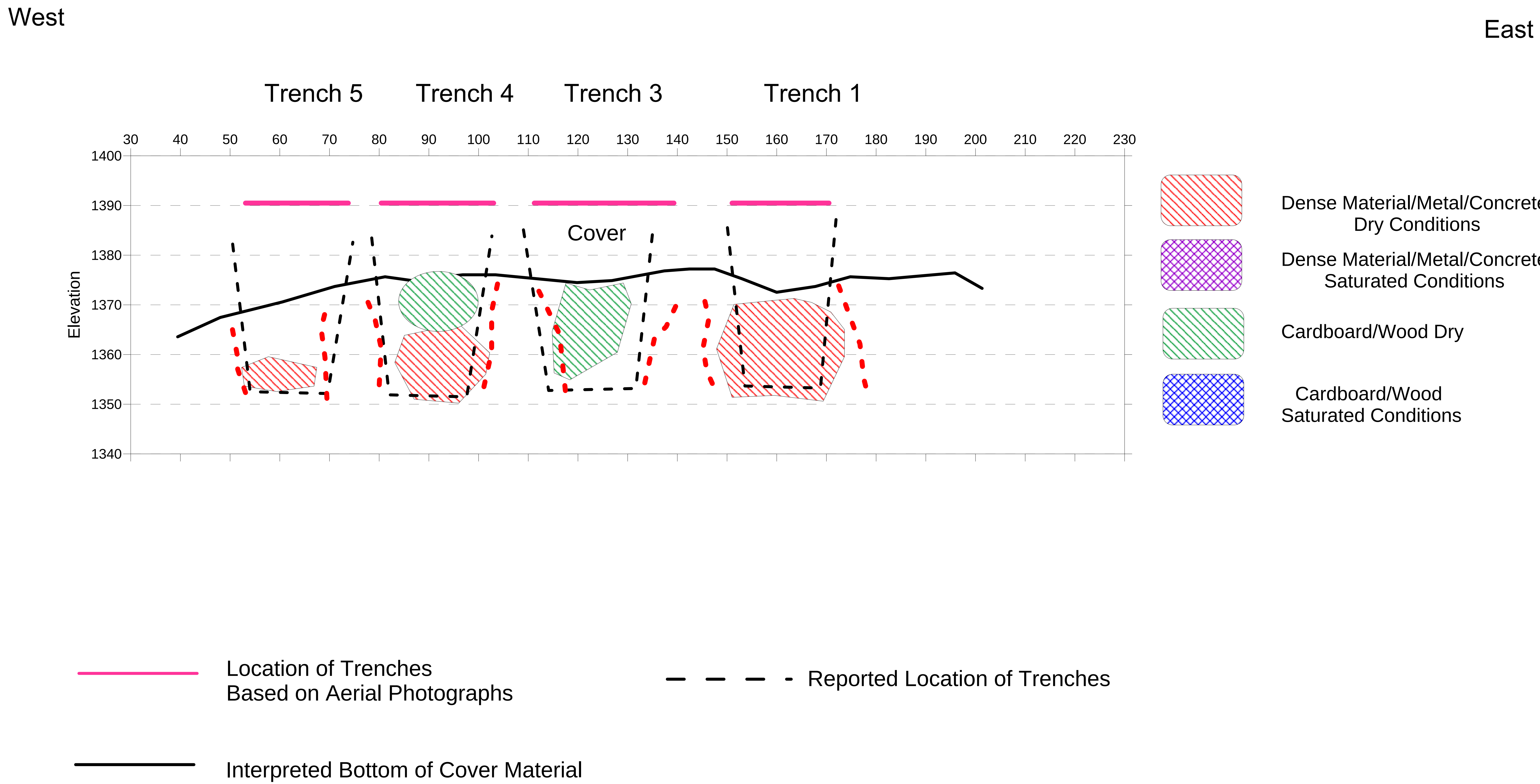

Feet (Scale 1 to 20)

0 10 20 30 40 50

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Construction
Environmental

MASW Profile D: Cross-Section	
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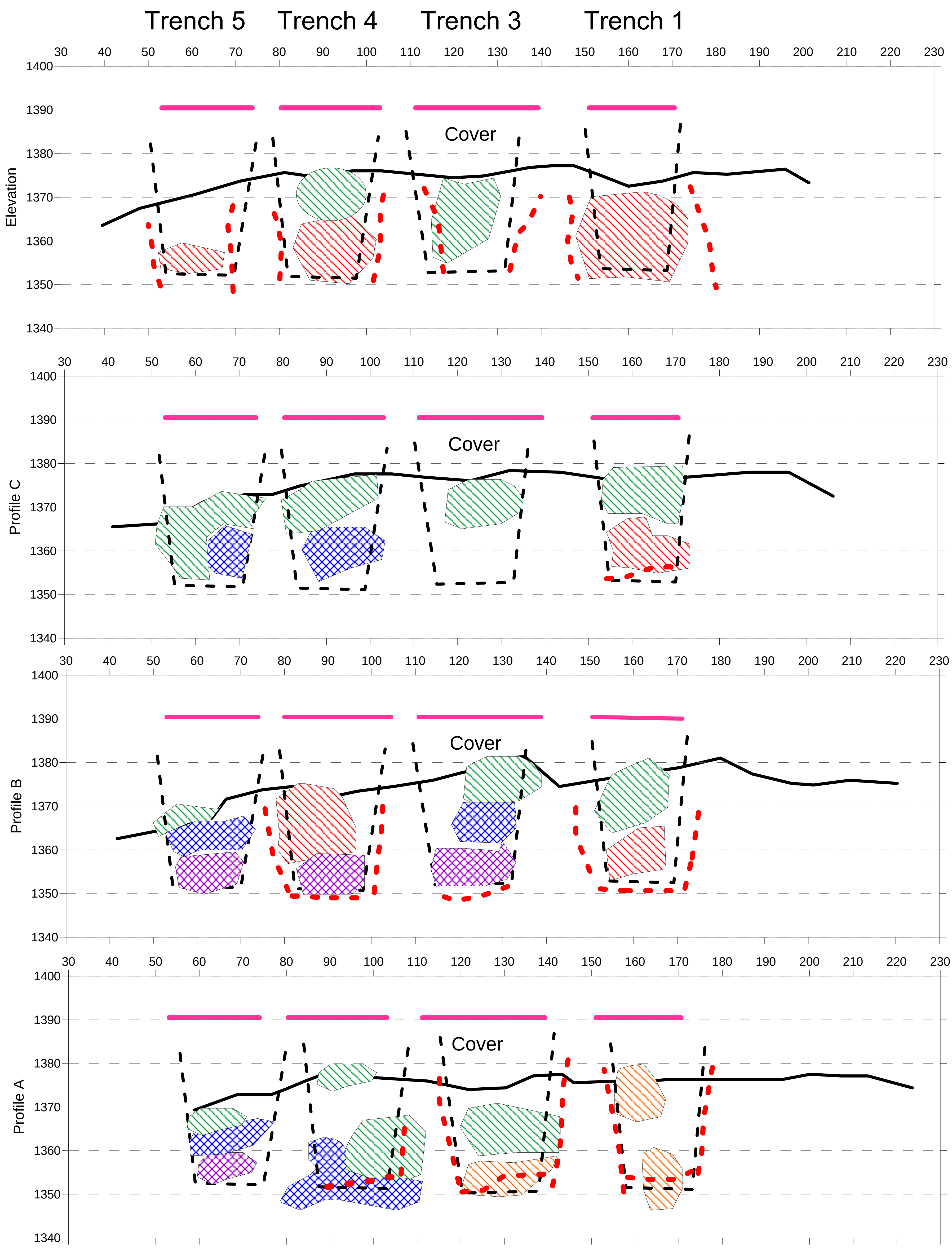

Dense Material/Metal/Concrete
Dry Conditions

Dense Material/Metal/Concrete
Saturated Conditions

Cardboard/Wood Dry

Cardboard/Wood
Saturated Conditions

Interpreted Bottom of Cover Material

Location of Trenches (Aerial Photographs)

Reported Location of Trenches

Interpreted Sides/Bottom of Trench

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Cross-Sections of Trenches	
West Valley Demonstration Project Western New York Nuclear Service Center	
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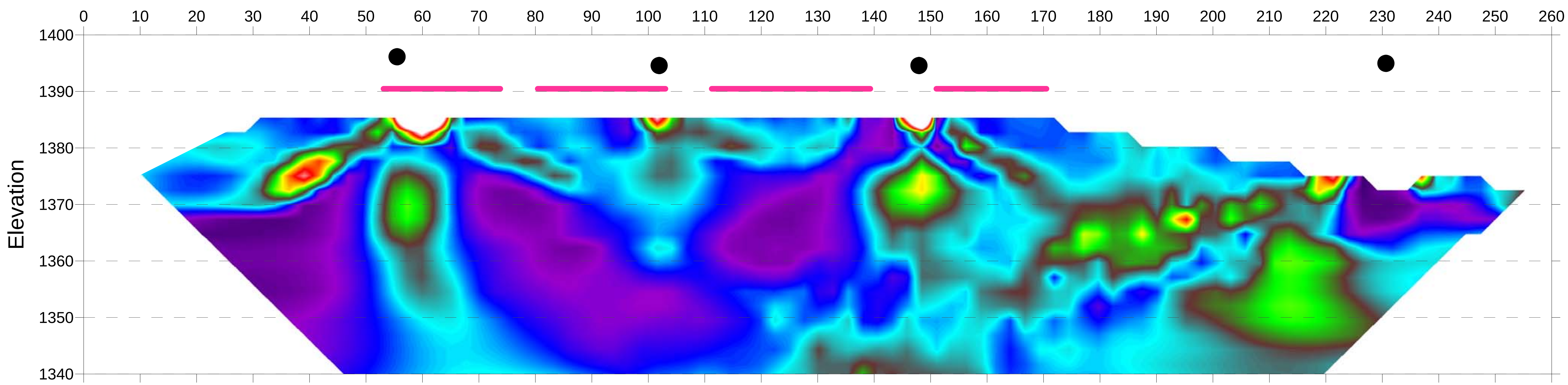

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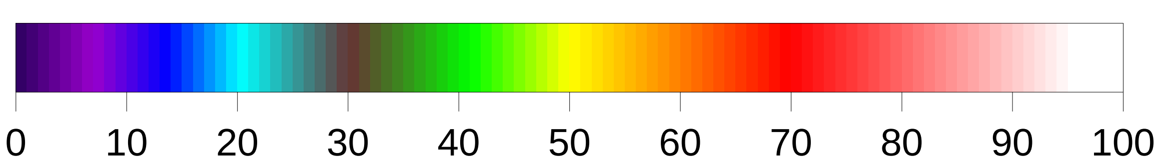

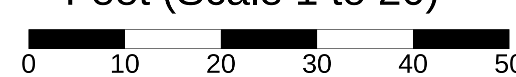

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ERI Profile A	
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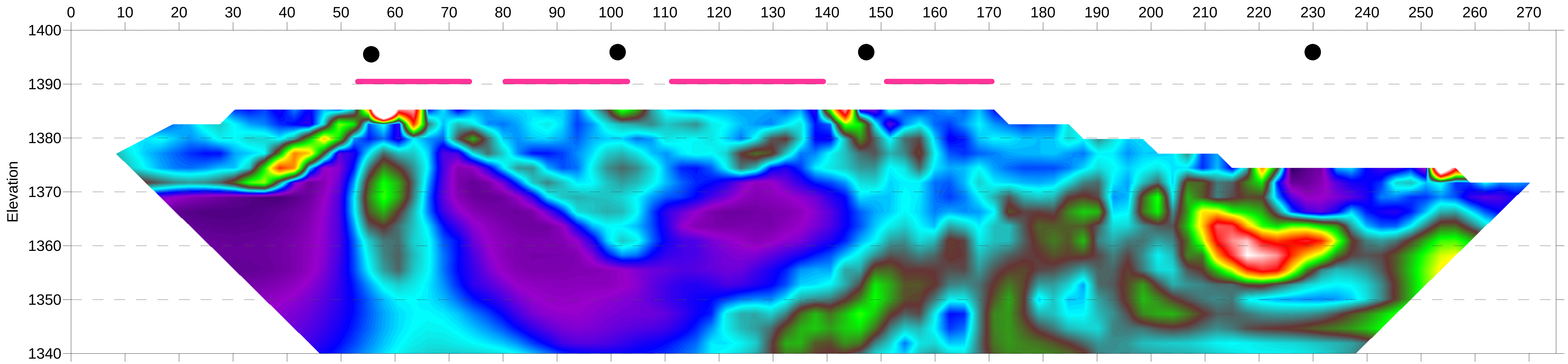

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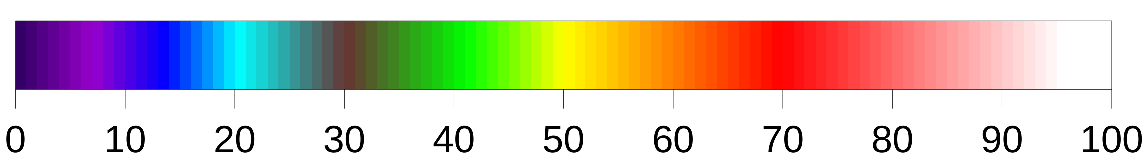
Ohm-Meters



Feet (Scale 1 to 20)

0 10 20 30 40 50

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Construction
Environmental

ERI Profile B	
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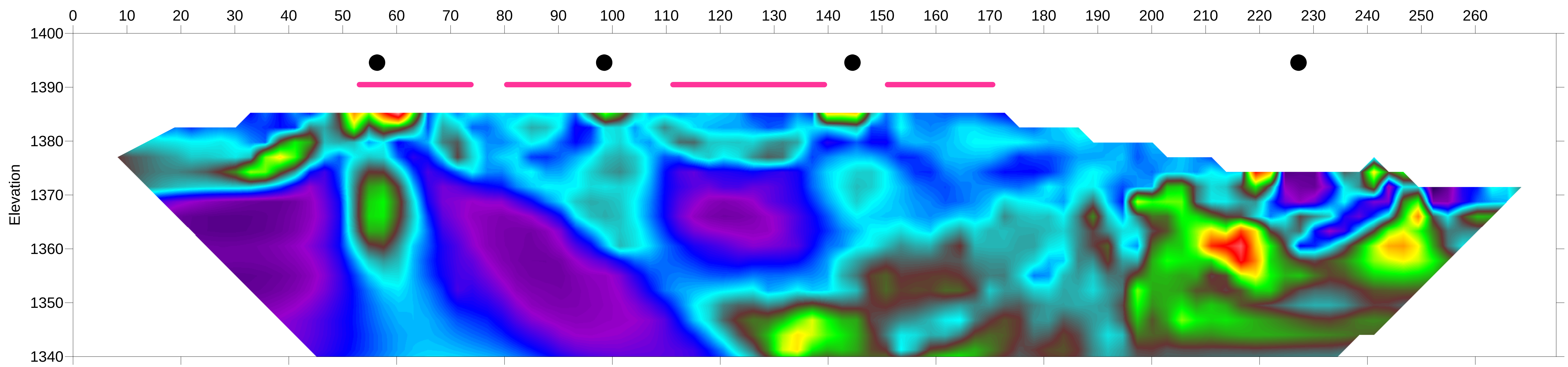

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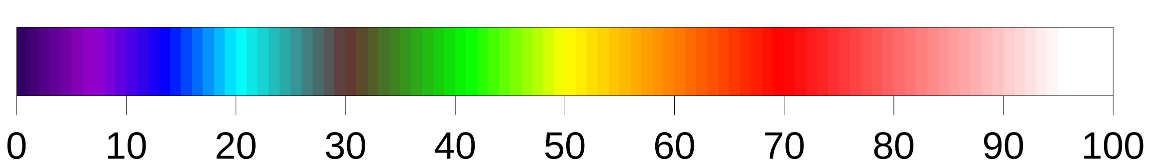
Ohm-Meters



Feet (Scale 1 to 20)

0 10 20 30 40 50

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ERI Profile C	
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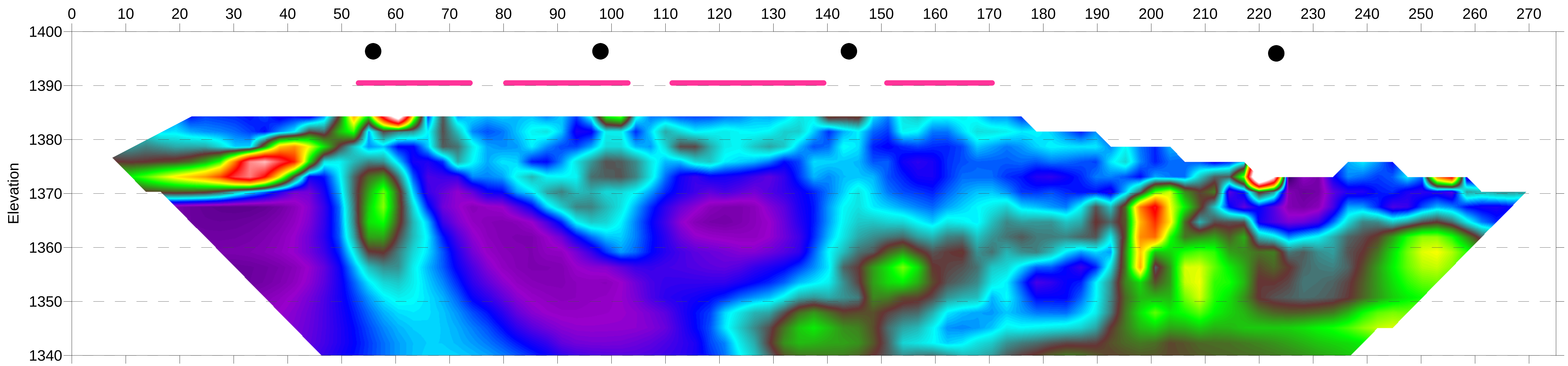

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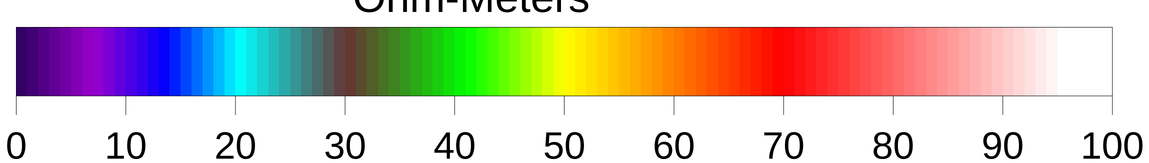
Ohm-Meters



Feet (Scale 1 to 20)

0 10 20 30 40 50

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ERI Profile D

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APPENDIX E
SEISMIC REFRACTION TOMOGRAPHY (SRT) GEOPHYSICAL SURVEY

Final Report
Seismic Refraction Tomography Geophysical Survey
West Valley Geophysical Prove-Out Study
West Valley, New York

Prepared for

TerranearPMC, LLC
222 Valley Creek Boulevard
Suite 210
Exton, Pennsylvania 19341

Prepared by

Applus RTD
80 Lawrence Bell Drive
Buffalo, New York 14221

4/21/2017

Applus RTD Work Order Number: 07.018018/001

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LIST OF FIGURES

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1 INTRODUCTION

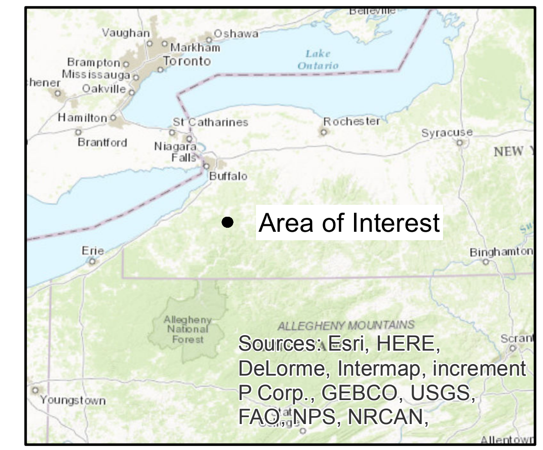
From August 30th to September 1st, 2016, Applus RTD conducted eight (8) Seismic Refraction Tomography (SRT) profiles for Terranear PMC, LLC (Terranear). These data were part of the data collection program for the West Valley Geophysics Prove-Out Study. Figure 1-1 is a site map of the Prove-Out Study survey area. Figure 1-2 is a survey area map showing the mapped trench locations and the locations of the SRT profile locations. The following sections provide a detailed analysis of the work performed and the results obtained from the SRT investigation.

Legend

AOI

SDA Trenches

Buildings



1:1,836

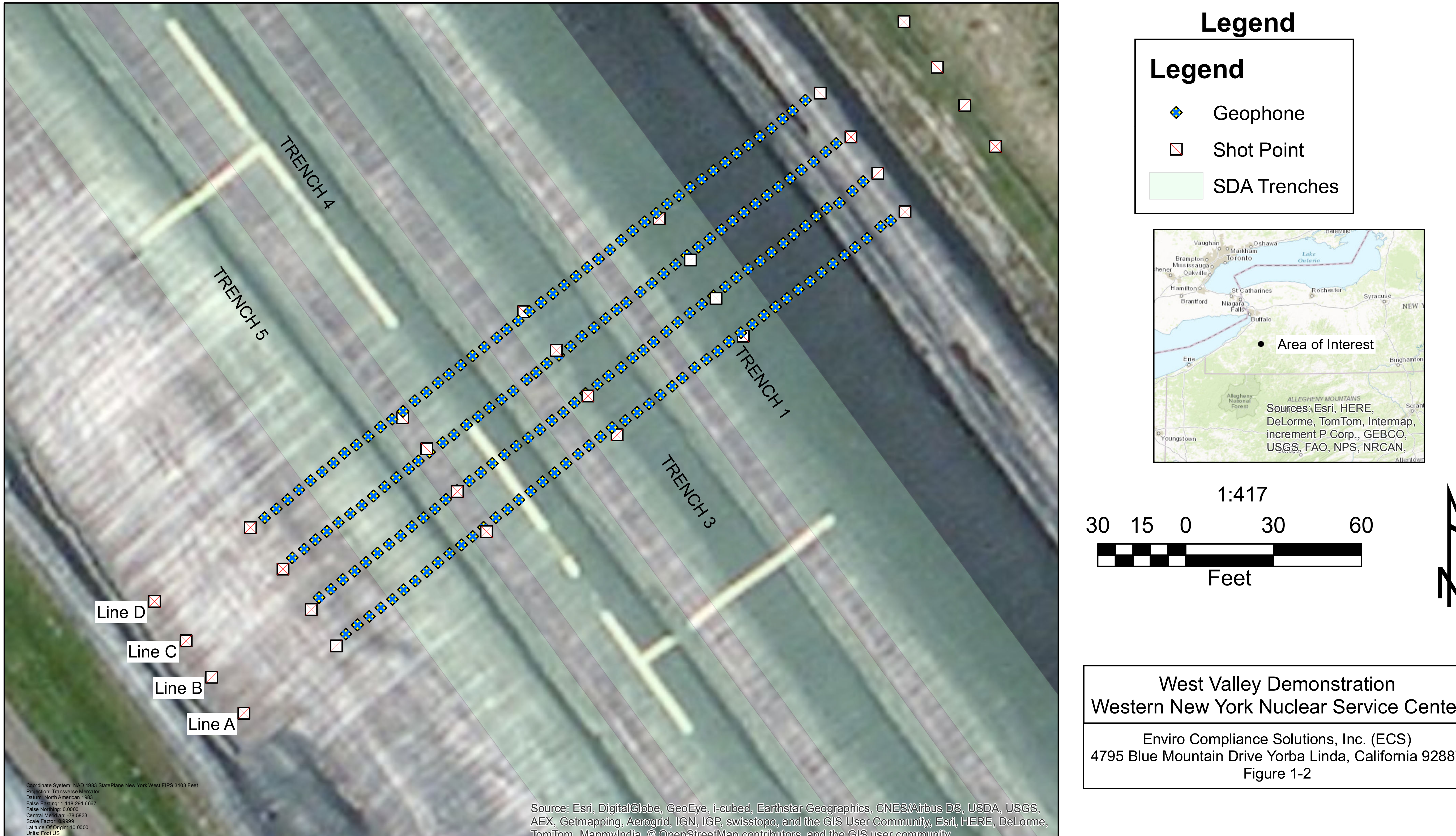
140 70 0 140 280

Feet

N

West Valley Demonstration Western New York Nuclear Service Center
Enviro Compliance Solutions, Inc. (ECS) 4795 Blue Mountain Drive Yorba Linda, California 92887 Figure 1-1

Applus RTD



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Western New York Nuclear Service Center

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4795 Blue Mountain Drive Yorba Linda, California 92887
Figure 1-2

2 SURVEY METHODOLOGY

2.1 SEISMIC REFRACTION TOMOGRAPHY (SRT)

2.1.1 Description

The SRT method utilizes a more robust and iterative modeling analysis than traditional seismic refraction calculations and often uses more shot points for a more detailed model of subsurface velocities. One limitation of traditional seismic refraction analysis is the inability to discern the existence of certain layers, referred to as hidden layers or blind zones. This is due to insufficient velocity contrast of layer thickness. Another limitation of traditional seismic refraction is incorrect depth calculation to certain layers where velocity reversals exist, i.e., where layer velocities do not increase with progressive depth.

SRT is used to model soils with both lateral and vertical velocity gradients, which will be useful at this site to model the trenches of waste materials. SRT is a geophysical method of interpreting seismic refraction data, which uses a gridded, inversion technique to determine the velocity of individual 2-dimension blocks within a profile, as opposed to modeling velocities as layers. Using a process known as raytracing, an initial model is processed through and then adjusted to achieve a better fit to the field data. The iterative process is repeated and refined until a satisfactory RMS (root mean square) error is achieved. In the case where the site contains well log control data, this data can be used to constrain the SRT models and produce more accurate results of the subsurface. As a result, refraction tomography can, in some cases more accurately model and provide better resolution of complex velocity structures of the subsurface.

2.1.2 Equipment

Applus RTD utilized a 48-channel seismic refraction line with two (2) Geode 24-channel seismographs for five (5) of the eight (8) seismic lines and a 24-channel refraction line with a single Geode for three (3) of the eight (8) seismic lines, manufactured by Geometrics, Inc. of California, to collect the data. A set of 14 Hz geophones was used for the five (5) seismic lines utilizing two geodes, and 4.5 Hz geophones were used on a land steamer for the three (3) seismic lines using a single geode. A 12 lb. sledgehammer (as determined by site conditions) was used as the seismic source, and a round, rubber-backed (to limit damage to the geomembrane cover) 54 lb. steel plate (13 inches in diameter) was used as an impact point to trigger the survey. In addition to the seismic data global positioning system (GPS), data were collected for each shot point and every geophone after the survey profile line was collected.

2.1.3 Field Survey Design

Spacing of the SRT transects and the geophones within SRT transects is dependent on the objective of the survey and the proposed depth of investigation, respectively. For the Prove-Out survey a profile spacing of approximately 5 meters (15 feet) across a 61 meter (200 feet) by 15 meter (50 feet) study area was proposed, resulting in four profiles. A 5-foot geophone spacing was used across the 235 foot long transect section.

The four profile locations were labeled by ACE Geophysics as A, B, C, and D from south to north. The transects with penetrations were numbered 1 through 4, corresponding to profile locations A to D. The transects without penetrations were numbered 5 through 8, corresponding to profile locations A to D. Thus the profile location A has transect 1A and 5A as penetrating and non-penetrating transects, respectively.

	Profile Location A	Profile Location B	Profile Location C	Profile Location D
With Penetrations	Line 1A : 48 - 4Hz Geophones	Line 2B : 48 14Hz Geophones	Line 3C : 48 - 14Hz Geophones	Line 4D : 48 - 14Hz Geophones
Without Penetrations	Line 5A : 48 - 14Hz Geophones	Line 6B - 4.5 Hz Land Streamer	Line 7C - 4.5 Hz Land Streamer	Line 8D - 4.5 Hz Land Streamer

Table 2-1: Profile Locations and Naming Convention

As part of the RFP two different types of SRT survey design were performed at the site, one with penetrations of the geomembrane cover and one without penetrations. Figure 2-1 illustrates the geophone layout used for each of the four profiles when the geophone spikes penetrated the cover. In order to accomplish this requirement Applus RTD utilized the same geophones for both surveys, but for the surveys without penetrations the spikes were removed for Line 5A and the land streamer (as used in the MASW survey performed by ACE Geophysics) was used for lines 6B, 7C and 8D.

The survey along seismic line 5A (Figure 2-2) was performed with the same geophones and set up as seismic lines 1A to 4D with the geophone spike removed to eliminate the penetration of the membrane. The set up utilized 48 - 14Hz geophones connected to two Geode seismographs with a 5-foot geophone spacing for a transect length of 235 feet. Seismic lines 6B to 8D (Figure 2-3) were performed using a land streamer with 24 – 4.5 Hz geophones connected to a single Geode seismograph. To correlate the 115-foot long land streamer to the 235-foot long seismic lines, the data was acquired by attaching two lines of 24 geophones, on at locations1-24, and the other at locations 25-48.

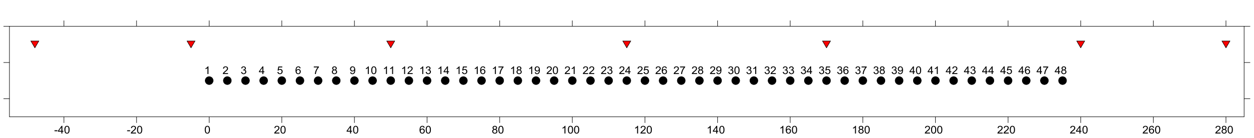


Figure 2-1 Field Design of Geophone Layout for Penetrant Survey – Red Triangles Indicate Shot Point Locations

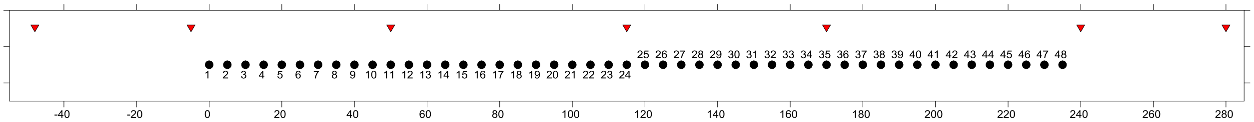


Figure 2-2 Field Design of Geophone Layout for Non-Penetrant Survey (5A) – Red Triangles Indicate Shot Point Locations

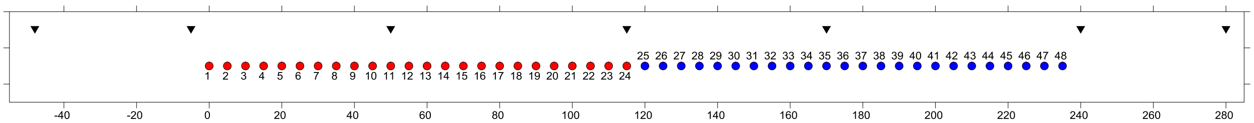


Figure 2-3 Field Design of Geophone Layout for Land Streamer Survey – Red and Blue Circles Indicate Separate Geophone Setups – Black Triangles Indicate Shot Locations Used for Both Setups

2.1.4 Quality Control

For each set up of the seismic gear QC checks were performed. The QC checks included a check to verify that the seismographs were communicating with the computer, as well as a trigger check to verify that the trigger was properly connected and was actuating the strike plate at a geophone location at a zero time offset. Channel mapping was used to verify that the seismographs were connected in the manner to allow the computer to map the data. The noise monitor was tested to verify that the scale was reasonable to observe any extraneous noise at the site that might interfere with the data acquisition. The noise monitor also located any geophones that were noisy. Any problem geophones were replanted if possible, or else additional sandbags were used if replanting was not possible or helpful.

3 DATA PROCESSING AND ANALYSIS

3.1 SEISMIC REFRACTION TOMOGRAPHY WITH PENETRATIONS

Four transects of SRT were performed using penetrations at the site. These were performed at line locations A through D and labeled as A1, B2, C3 and D4.

3.1.1 Quality Control

Internal shot points were used to verify the zero time of the data acquisition software. During data acquisition, data quality was assessed to determine if additional data stacks would produce a greater signal to noise ratio before creating possible damage to the liner.

Data were observed in the field as to the quality and clarity of the signal. Data quality tended to be better for the internal shot locations and decreased for end and offset shot locations. Offset shot locations generally had stack counts of 50 to 75 with very little improvement from the first 15 to 20 stack counts.

3.1.2 Modeling Parameters

The Rayfract™ Seismic Refraction Tomography software was used for this modeling of the data. Rayfract™ has a preference for shot points at half the spacing used or every 6 geophones, but is capable of modeling data at the shot location spacing used of 12 geophones, as listed in the proposal. Applus RTD was unaware of this potential limitation during the data acquisition phase, as several other Seismic Refraction Tomography programs use the wider spacing. We chose the Rayfract™ software because it has more robust modeling algorithms that provide improved subgrade imaging and a better comparison of relative data quality of the penetrating vs non-penetrating data. The modeling software utilizes Wavepath Eikonal Traveltime (WET) inversion for modeling the data.

3.1.3 Data Production

On the first field day, August 30, three lines of SRT data using penetrations were acquired. On the second field day, the final SRT line was acquired with penetrations and the first line using the land streamer were acquired. There was also a 4 hour rain delay. Rain impacting the geomembrane would create a larger than usual response for noise during a seismic survey. The final three lines using the land streamer were acquired on the third day.

3.1.4 Geophone Set up

The penetrations required the assistance of NYSERDA Radiological Technicians for both the planting of the geophones and the removal of the geophones. To minimize the number of penetrations through the geomembrane liner, the geophones were planted in holes that had previously been used for both a Resistivity Imaging survey and a MASW seismic survey. The Resistivity Imaging survey used probes that created a hole ~1/2 inch in diameter, whereas the geophones use a probe that is ~7/16 inch in diameter, making it uncertain as to how well planted the geophones were. Sandbags were installed for each of the geophones to improve coupling to the ground and to attenuate response of the geomembrane.

3.1.5 Data Quality

Line 1A: Data quality was qualified as generally good at the internal shot locations and qualified as acceptable at the end shots.

Line 2B: Data quality was qualified as generally good at the internal shot locations and qualified as acceptable at the end shots. End shot location -5' was poor without improvement to 50 stacks due to windy conditions.

Line 3C: Data quality was qualified as generally good at the internal shot locations and qualified as acceptable at the end shots. Offset shot location -47' was poor without improvement to 60 stacks due to windy conditions.

Line 4D: Data quality was qualified as generally very good at the internal shot locations and qualified as good at the end shots. Low wind conditions were experienced prior to the rain delay. Stacks varied from 25 to 35 for most of the line. Offset shot location -47 ceased at 50 stacks due to commencement of the rain delay.

3.1.6 Data Results

Figure 3-1 shows the results of Line 1A. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth indicating general horizontal homogeneity.

Figure 3-2 shows the results of Line 2B. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth indicating general horizontal homogeneity.

Figure 3-3 shows the results of Line 3C. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth with some deeper low velocity zones, generally indicating mild horizontal heterogeneity.

Figure 3-4 shows the results of Line 4D. Velocity profile shows lobate low velocity material in the near surface. Velocity models for this profile peak at a lower level than the other profiles and do not show deep structure. Velocity generally increases with depth indicating general horizontal homogeneity.

3.2 SEISMIC REFRACTION TOMOGRAPHY WITHOUT PENETRATIONS

Four transects of SRT were performed using non-penetrant methods at the site. These were performed at line locations A through D and labeled as A5, B6, C7 and D8. Transect 5A used 48 – 14Hz geophones while the remaining transects used 24 – 4.5 Hz geophones on a land streamer.

3.2.1 Quality Control

Internal shot points were used to verify the zero time of the data acquisition software. During data acquisition, data quality was assessed to determine if additional data stacks would produce a greater signal to noise ratio before creating possible damage to the liner.

Data were observed in the field as to the quality and clarity of the signal. Data quality tended to be better for the internal shot locations and decreased for end and offset shot locations. Offset shot locations generally had stack counts of 50 to 75 with very little improvement from the first 15 to 20 stack counts.

The lower frequency geophones integral to the land streamer made the picking of first arrivals less distinct, particularly with the shot locations furthest from the geophones. These include offset shots and shot locations at the opposite location from the geophones in place for lines B6, C7 and D8. The normal method of increasing the signal to noise ratio is to increase the number of stacks until the data becomes clear. The total number of stacks at a given location was limited to a maximum of 75 at the site due to concern for tearing the geomembrane with stack counts that may be too extreme.

3.2.2 Modeling Parameters

The Rayfract™ Seismic Refraction Tomography software was also used for modeling of the data in the case of no geomembrane penetrations. As non-penetrant line 5A consisted of 48 – 14Hz, it was modeled similarly to the penetrating lines. Lines 6B, 7C and 8D are two lines of 24 – 4.5 Hz geophones stitched together. The modeling software accepts this as being the same as the 48 geophones. The difference lies with the clarity of the data and the ability to pick first arrivals and the difficulties of picking first arrivals in noisy data with the lower frequency phones.

3.2.3 Data Production

On the second field day, August 31st, the final SRT line was acquired with penetrations and the first line using the land streamer was acquired prior to the 4 hour rain delay. On the final field day, September 1st, three non-penetrating SRT lines were acquired, including one with a full 48 geophones. Production delays resulted from rain delays, windy conditions that made the geomembrane flap, and construction vehicles that were traversing north of the site.

3.2.4 Geophone Set up

All of the geophones were held in place using sandbags; nevertheless, the signal clarity of Line 5A that did not use a landstreamer was superior and easier to pick first arrivals.

3.2.5 Data Quality

Line 5A: Data quality was qualified as generally good, with data quality at the -48 offset shot location qualified as acceptable despite wind interferences.

Line 6B: Data quality was varied from very good at the internal shot locations to acceptable at the end shots. While acquiring the data from geophone locations 1-24, the offset and end shot locations -47, 240 and 280' were poor without improvement to 60 stacks due to windy conditions. The wind dropped during lunch and the data quality for shot locations for geophone 25-48 was good to very good, excepting location corresponding to geophone location 13 (at 60 feet) and offset shot location at -47 feet which, were qualified as acceptable.

Line 7C: Data quality was qualified as generally good to acceptable for the geophones 1-24 and very good to good for geophones 25 to 48. Construction traffic north of the site was intermittent during the geophone 1-24 shot locations.

Line 8D: Data quality was varied from good at the internal shot locations to acceptable and poor at the end shots and offset shots. Data were impacted by significant afternoon wind conditions.

3.2.6 Data Results

Figure 3-5 shows the results of Line 5A. Velocity profile shows lobate low velocity material in the near surface, and in some locations deeper in the profile. Velocity generally increases with depth with some deeper low velocity zones, generally indicating mild horizontal heterogeneity.

Figure 3-6 shows the results of Line 6B. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth with some deeper low velocity zones, generally indicating horizontal homogeneity.

Figure 3-7 shows the results of Line 7C. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth, indicating horizontal homogeneity.

Figure 3-8 shows the results of Line 8D. Velocity profile shows lobate low velocity material in the near surface. Velocity generally increases with depth with some significantly deeper low velocity zones, generally indicating mild horizontal heterogeneity.

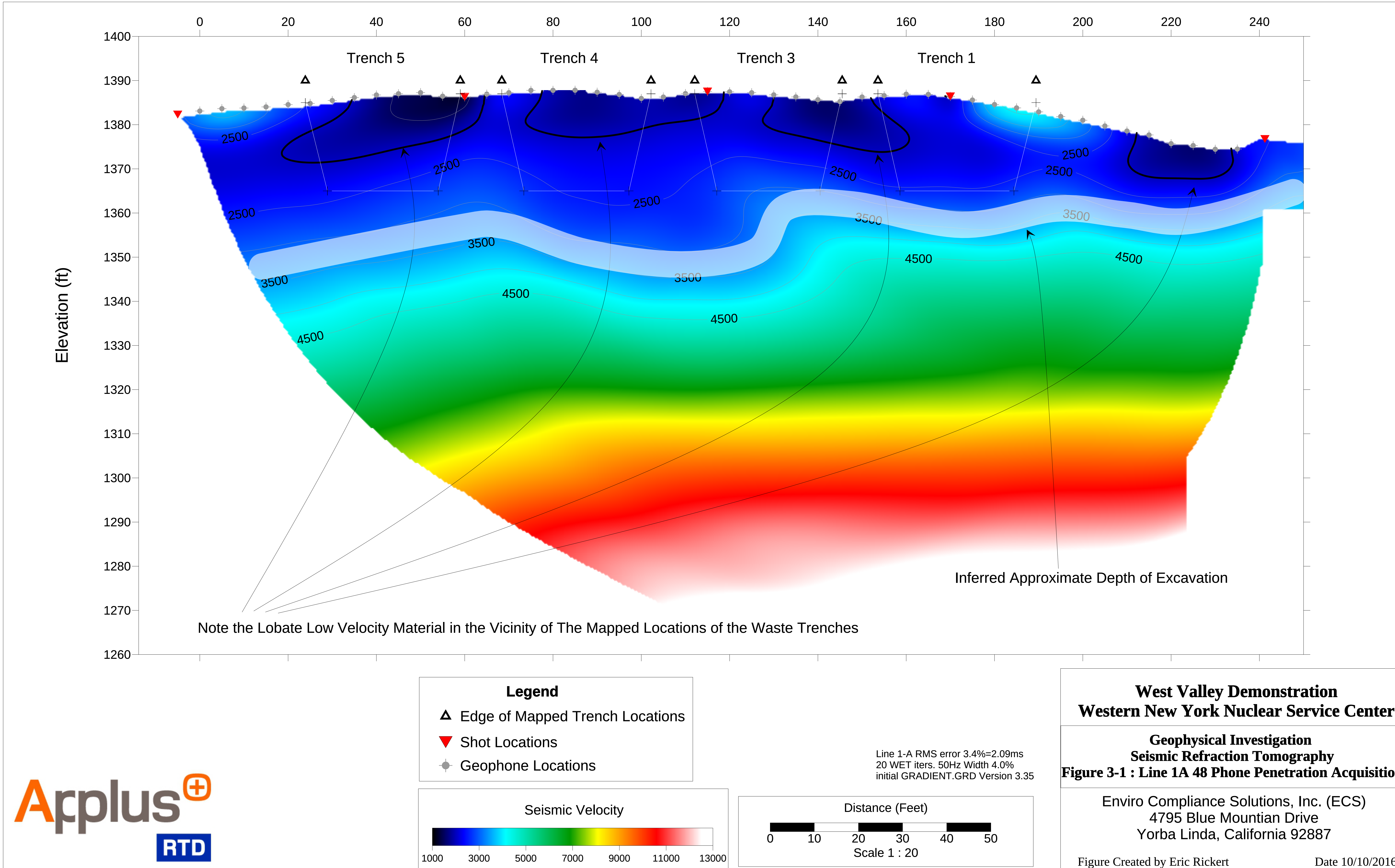
3.2.7 Data Comparisons

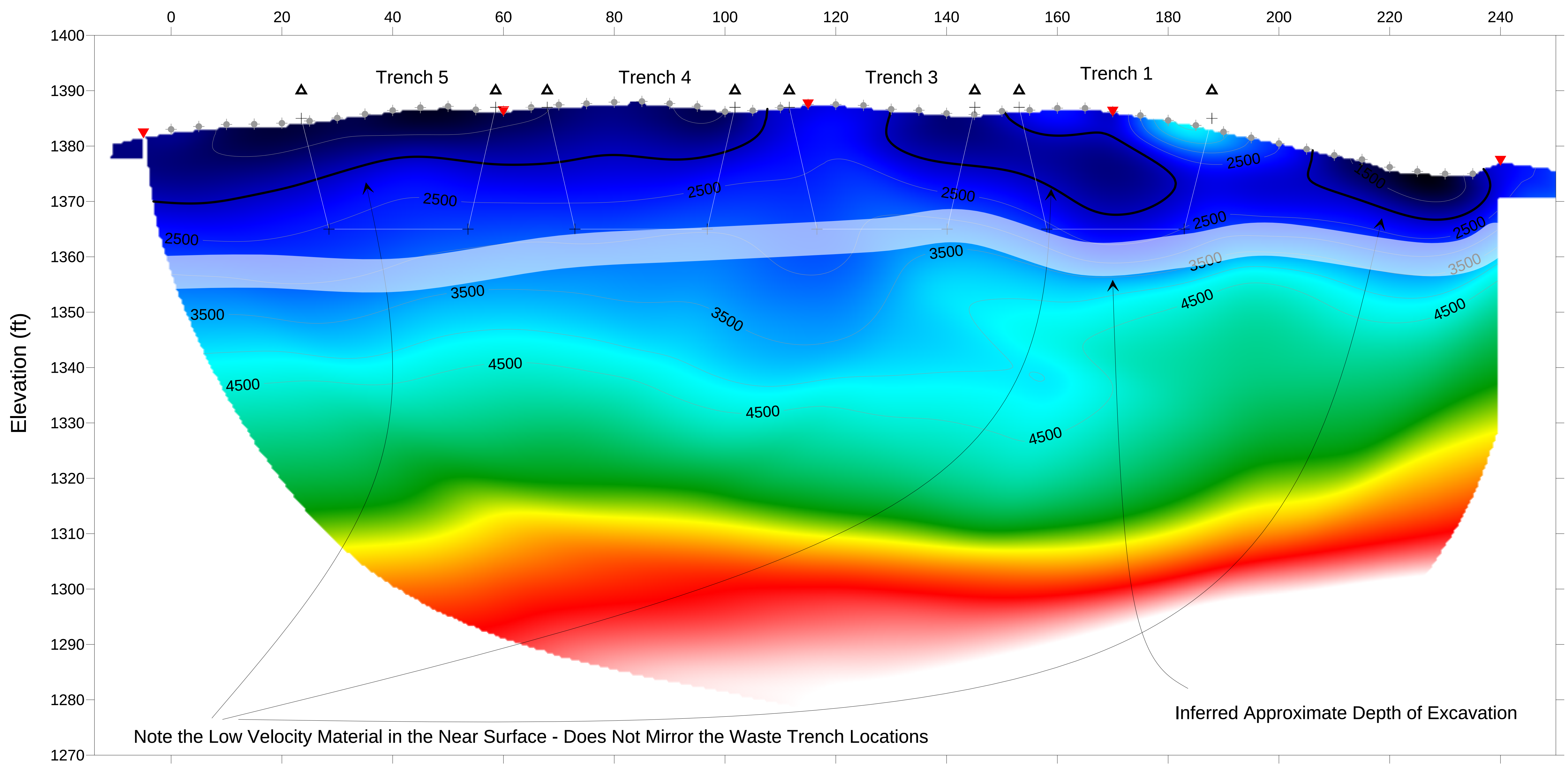
For direct comparison of the results of the penetrant to non-penetrant surveys, figures have been created that illustrate the results of the upper portions of the SRT survey for each of the four locations A thru D.

Figure 3-9 shows the results at Location A, the results of Line 1A and 5A. The results have been truncated at elevation 1340 as the expected depth of excavation within the upper 20 feet based on supplied historical construction blueprints.

Figure 3-10 shows the results at Location B, the results of Line 2B and 6B. Figure 3-11 shows the results at Location C, the results of Line 3C and 7C. Figure 3-12 shows the results at Location D, the results of Line 4D and 8D.

The interpretation of the results shown in Figures 3-9 through 3-12 is the subject of Section 4.3 below.


Trench 5
Trench 4
Trench 3
Trench 1
Elevation (ft)
2500
3500
4500
Inferred Approximate Depth of Excavation
Note the Lobate Low Velocity Material in the Vicinity of The Mapped Locations of the Waste Trenches
Legend
Edge of Mapped Trench Locations
Shot Locations
Geophone Locations
Seismic Velocity
1000 3000 5000 7000 9000 11000 13000
Line 1-A RMS error 3.4%=2.09ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35
Distance (Feet)
0 10 20 30 40 50
Scale 1 : 20
Applus RTD
West Valley Demonstration
Western New York Nuclear Service Center
Geophysical Investigation
Seismic Refraction Tomography
Figure 3-1 : Line 1A 48 Phone Penetration Acquisition
Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountian Drive
Yorba Linda, California 92887
Figure Created by Eric Rickert
Date 10/10/2016



Line 2-B RMS error 2.5%=1.65ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

Legend

- Edge of Mapped Trench Locations
- Shot Locations
- Geophone Locations

Seismic Velocity

1000 3000 5000 7000 9000 11000 13000

Distance (Feet)

0 10 20 30 40 50

Scale 1 : 20

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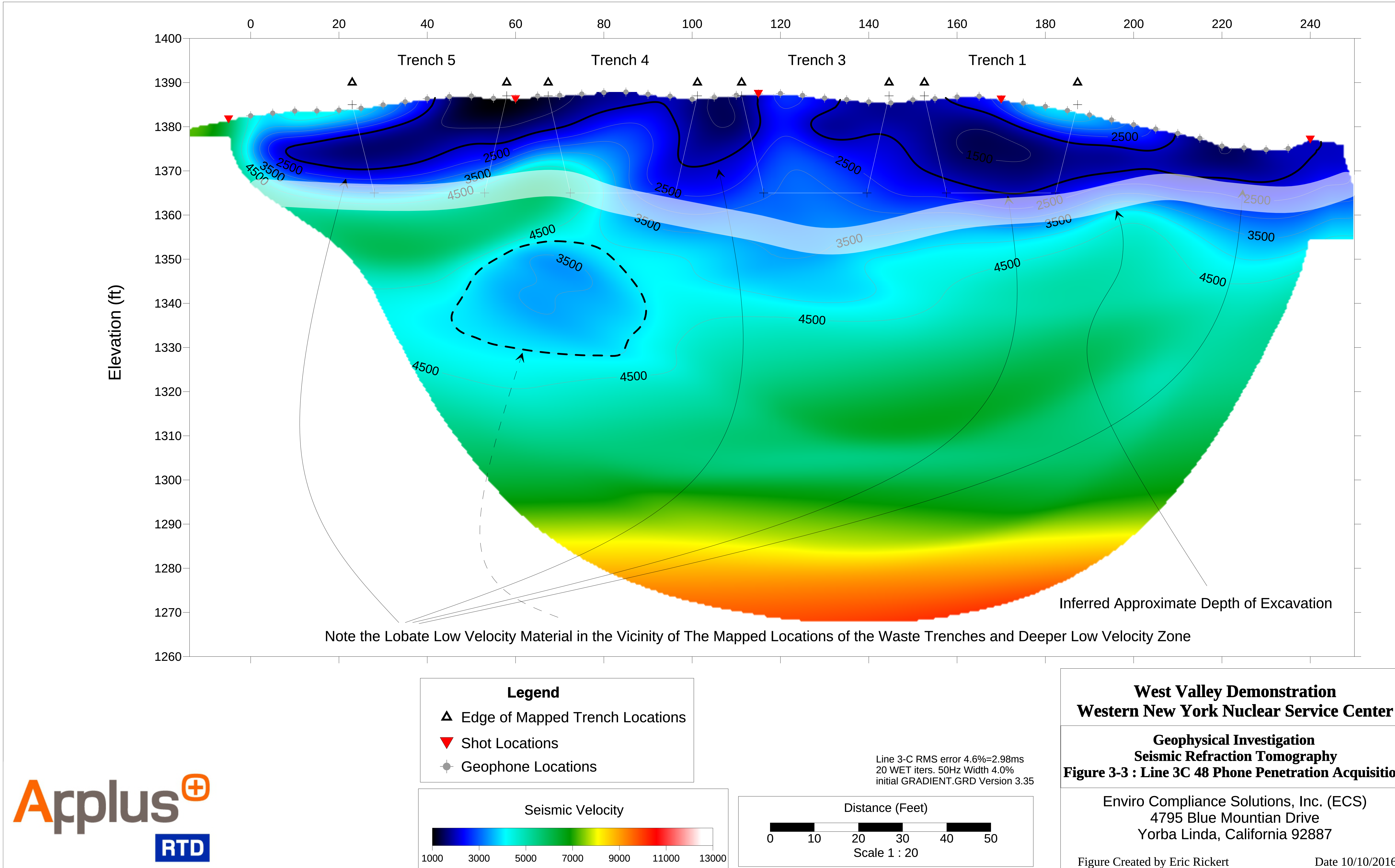
Seismic Refraction Tomography
Figure 3-2 : Line 2B 48 Phone Penetration Acquisition

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountian Drive
Yorba Linda, California 92887

Figure Created by Eric Rickert

Date 10/10/2016



Trench 5
Trench 4
Trench 3
Trench 1
Elevation (ft)
1400
1390
1380
1370
1360
1350
1340
1330
1320
1310
1300
1290
1280
1270
1260
0
20
40
60
80
100
120
140
160
180
200
220
240
2500
3500
4500
1500
Inferred Approximate Depth of Excavation
Note the Lobate Low Velocity Material in the Vicinity of The Mapped Locations of the Waste Trenches and Deeper Low Velocity Zone
Legend
Edge of Mapped Trench Locations
Shot Locations
Geophone Locations
Seismic Velocity
1000
3000
5000
7000
9000
11000
13000
Line 3-C RMS error 4.6%=2.98ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35
Distance (Feet)
0
10
20
30
40
50
Scale 1 : 20
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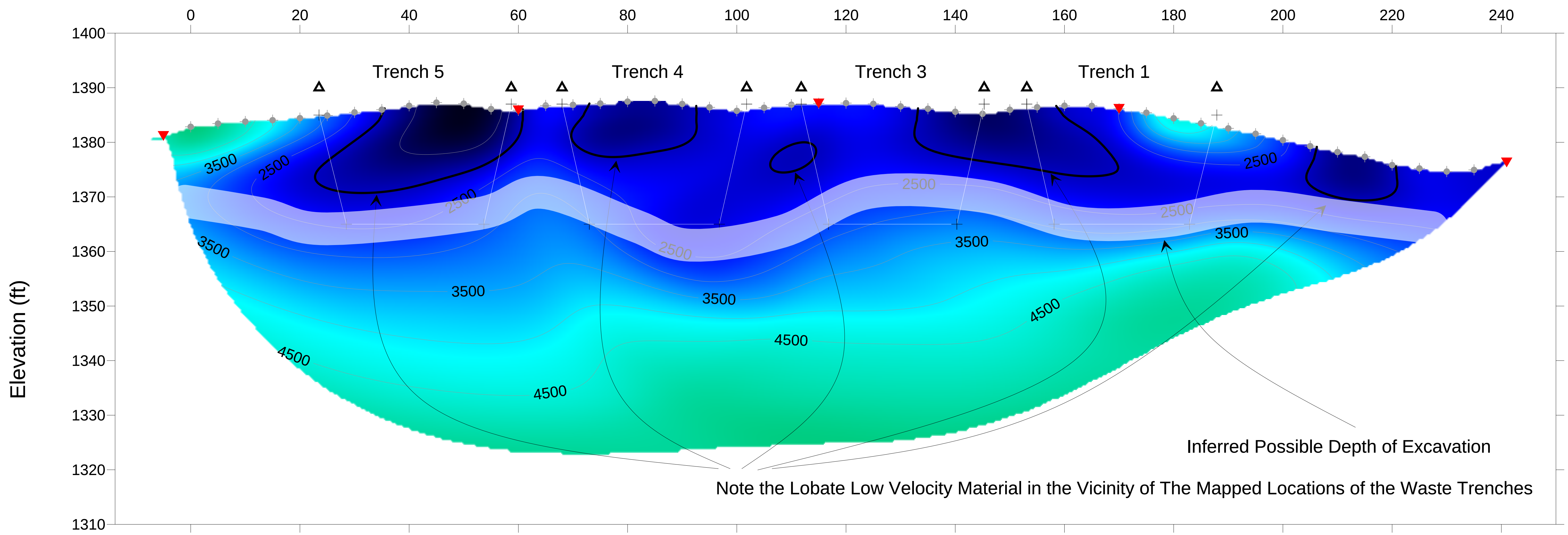
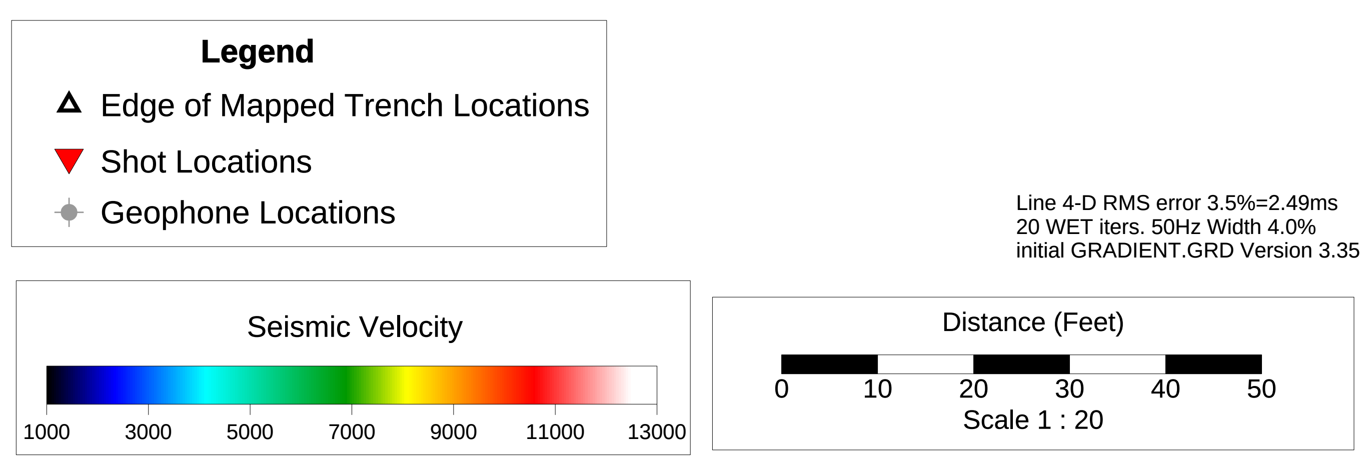
Western New York Nuclear Service Center
Geophysical Investigation
Seismic Refraction Tomography
Figure 3-3 : Line 3C 48 Phone Penetration Acquisition
Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountian Drive
Yorba Linda, California 92887
Figure Created by Eric Rickert
Date 10/10/2016
Applus RTD





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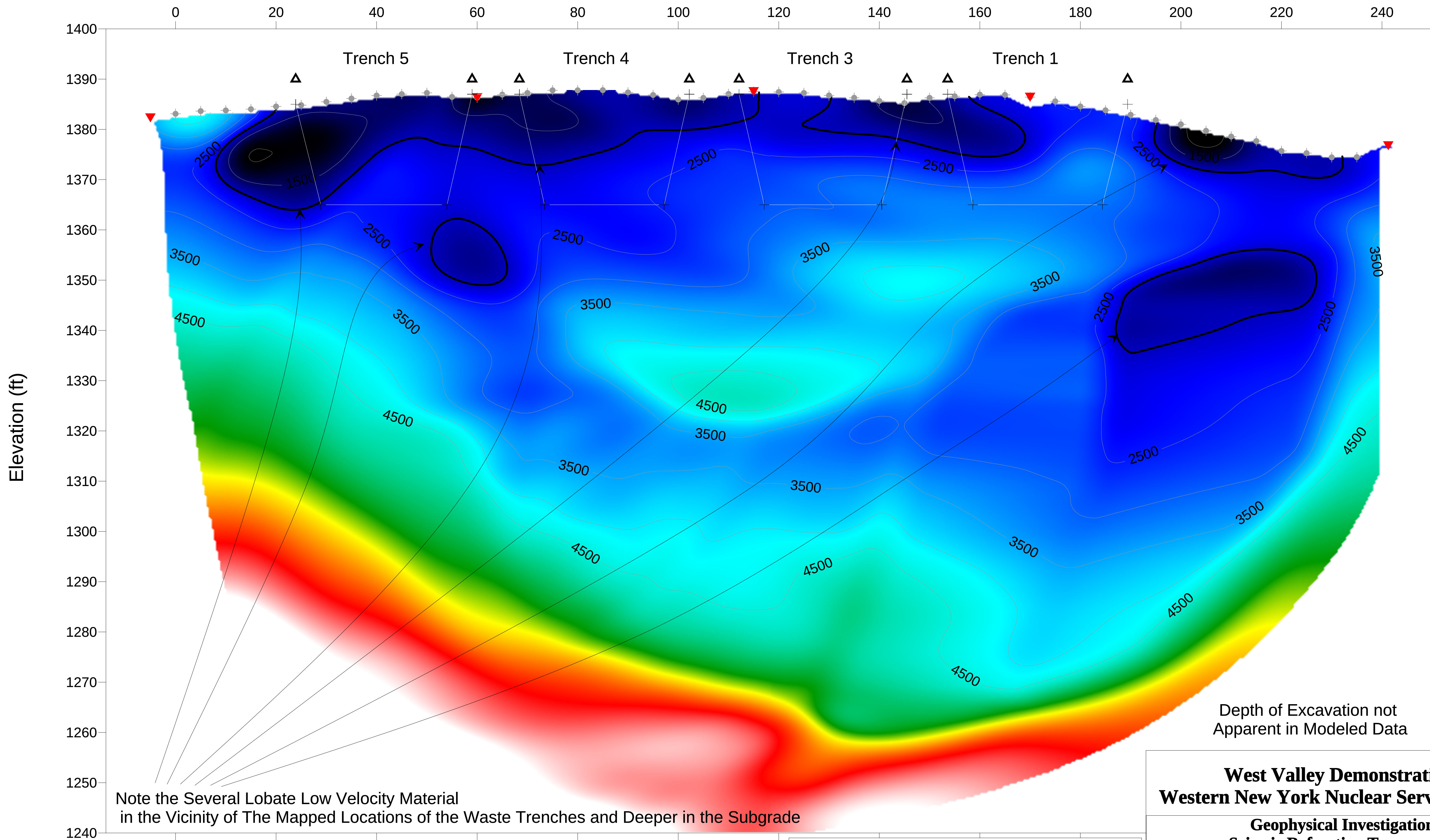
Geophysical Investigation
Seismic Refraction Tomography
Figure 3-4 Line 4D : 48 Phone Penetration Acquisition

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountian Drive
Yorba Linda, California 92887

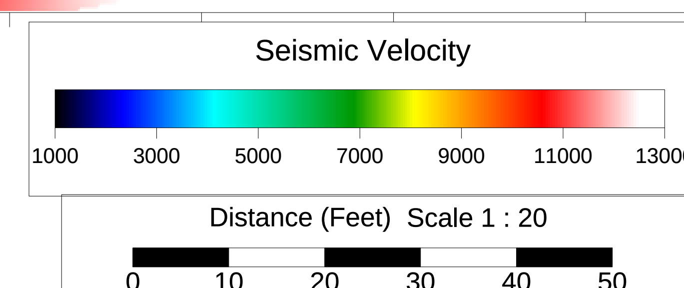
Figure Created by Eric Rickert Date 10/10/2016



Line 5-A RMS error 5.8%=13.30ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

Legend

- △ Edge of Mapped Trench Locations
- ▼ Shot Locations
- Geophone Locations



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Geophysical Investigation
Seismic Refraction Tomography
Figure 3-5 : Line 5A 48 Phone Non-Penetrant Acquisition

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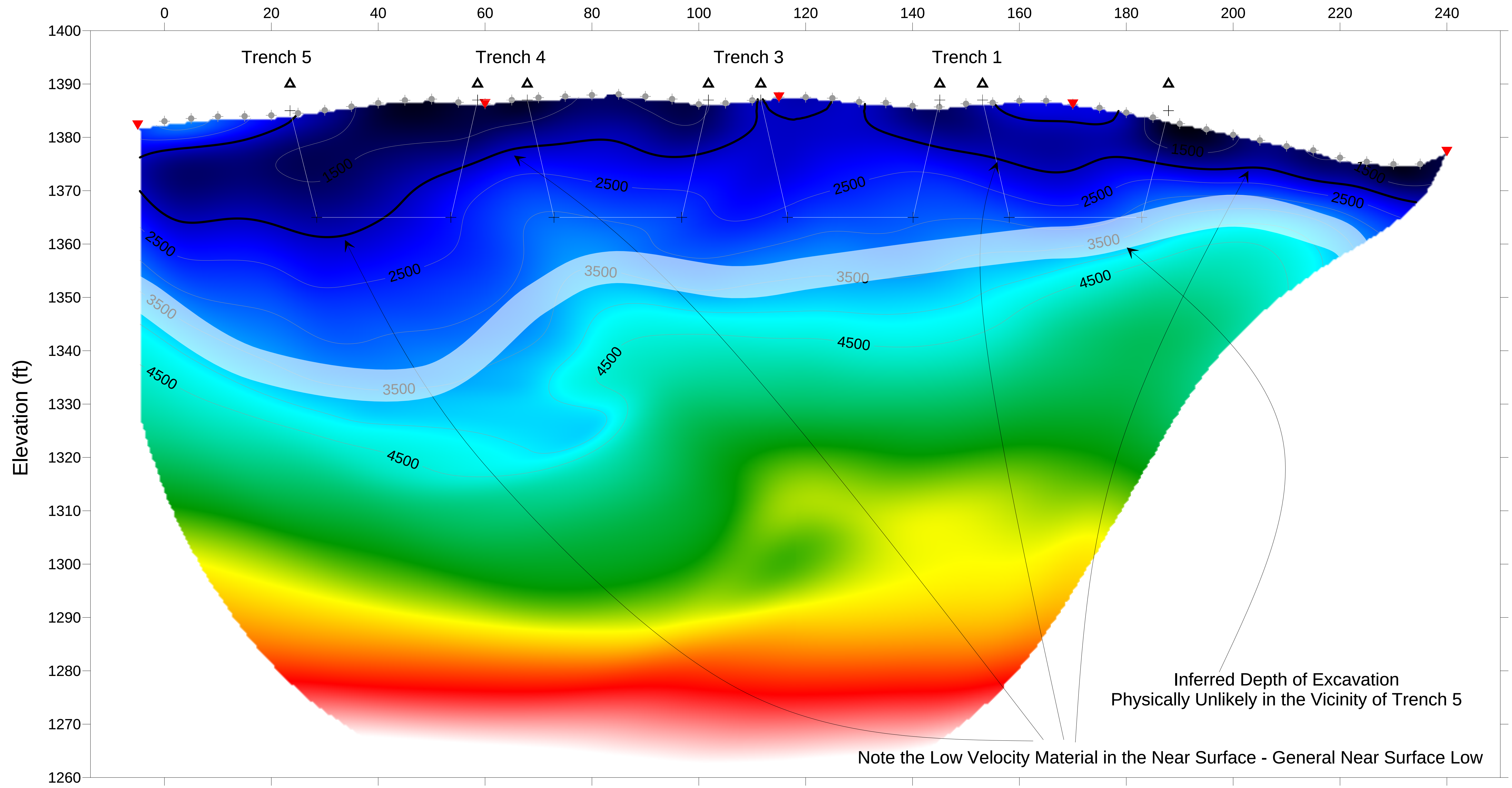
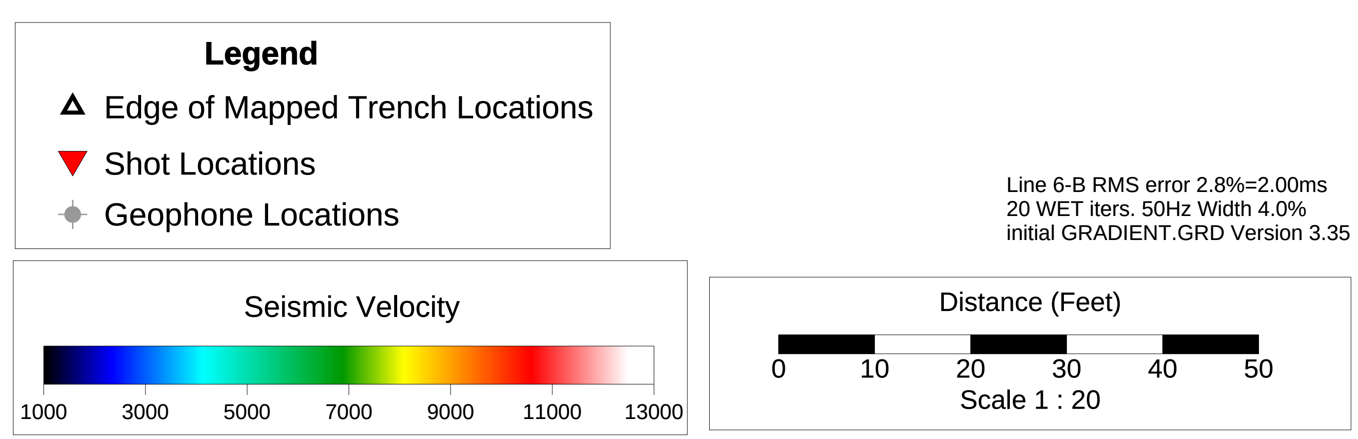
Figure Created by Eric Rickert

Date 10/10/2016





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Seismic Refraction Tomography
Figure 3-6 : Line 6B Land Streamer Acquisition

Enviro Compliance Solutions, Inc. (ECS)
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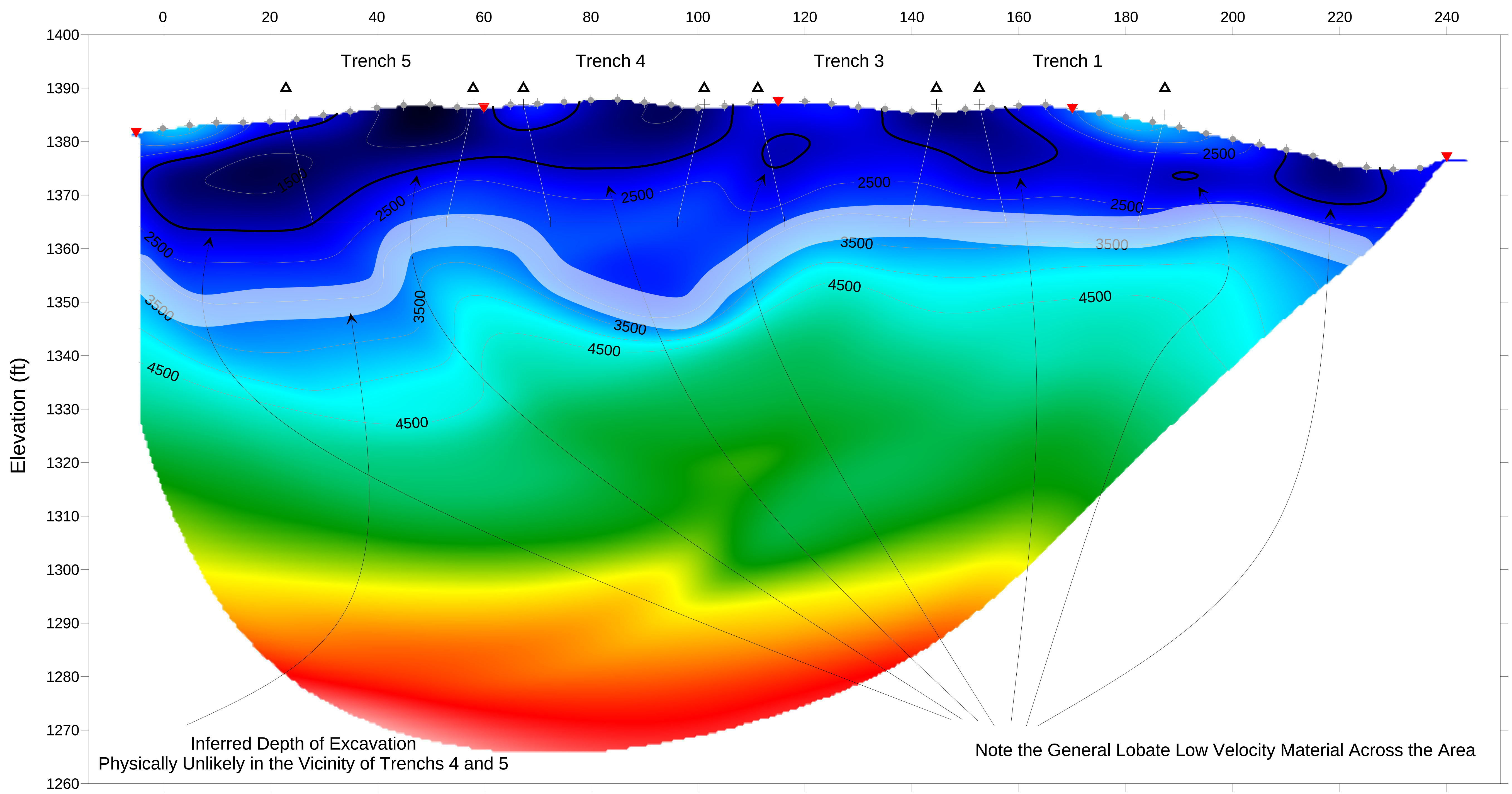
Figure Created by Eric Rickert   Date 10/10/2016



Legend

- △ Edge of Mapped Trench Locations
- ▼ Shot Locations
- Geophone Locations

Seismic Velocity

1000 3000 5000 7000 9000 11000 13000

Line 7-C RMS error 3.0%=2.11ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

Distance (Feet)

0 10 20 30 40 50

Scale 1 : 20

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Geophysical Investigation
Seismic Refraction Tomography
Figure 3-7 : Line 7C Land Streamer Acquisition

Enviro Compliance Solutions, Inc. (ECS)
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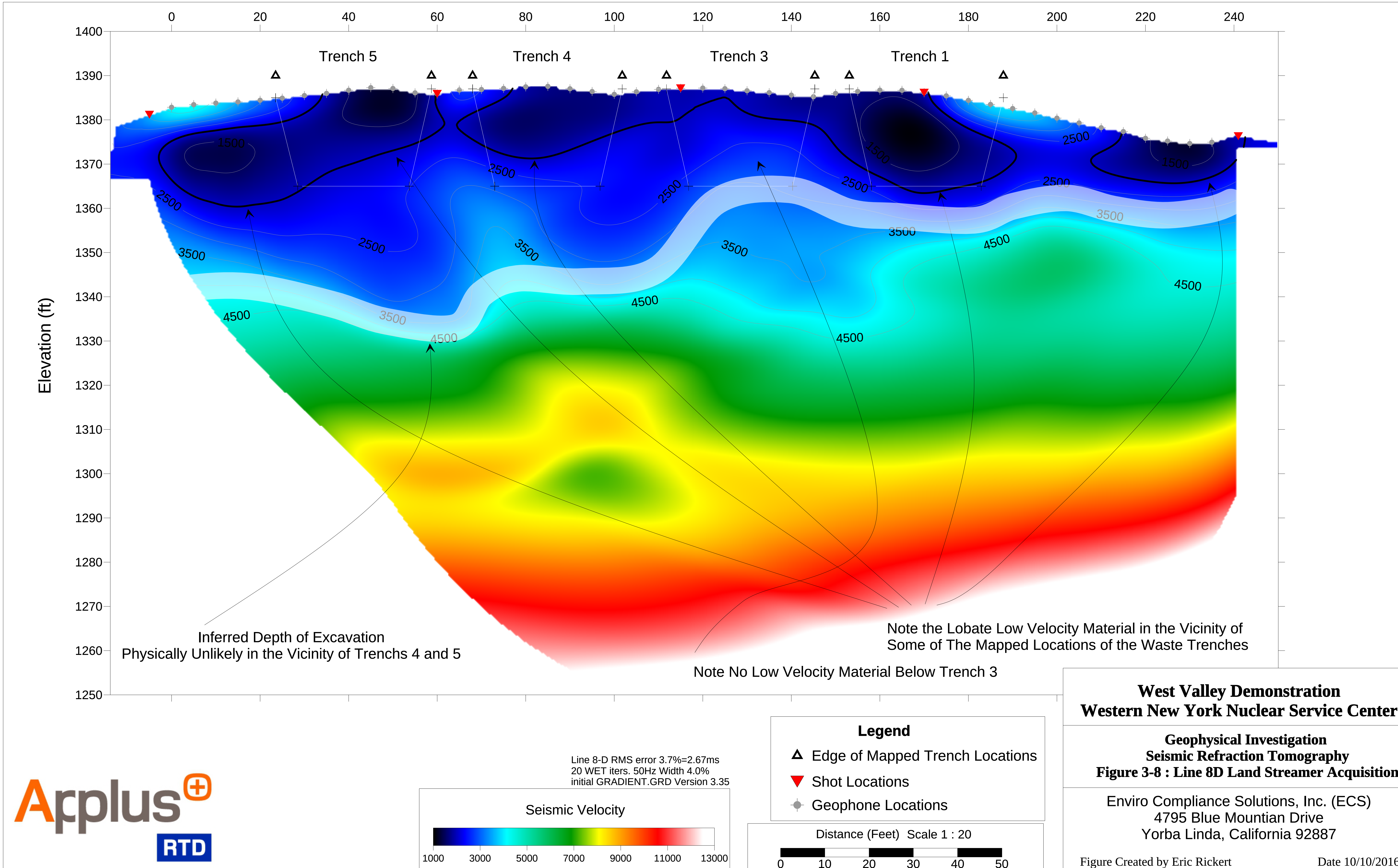
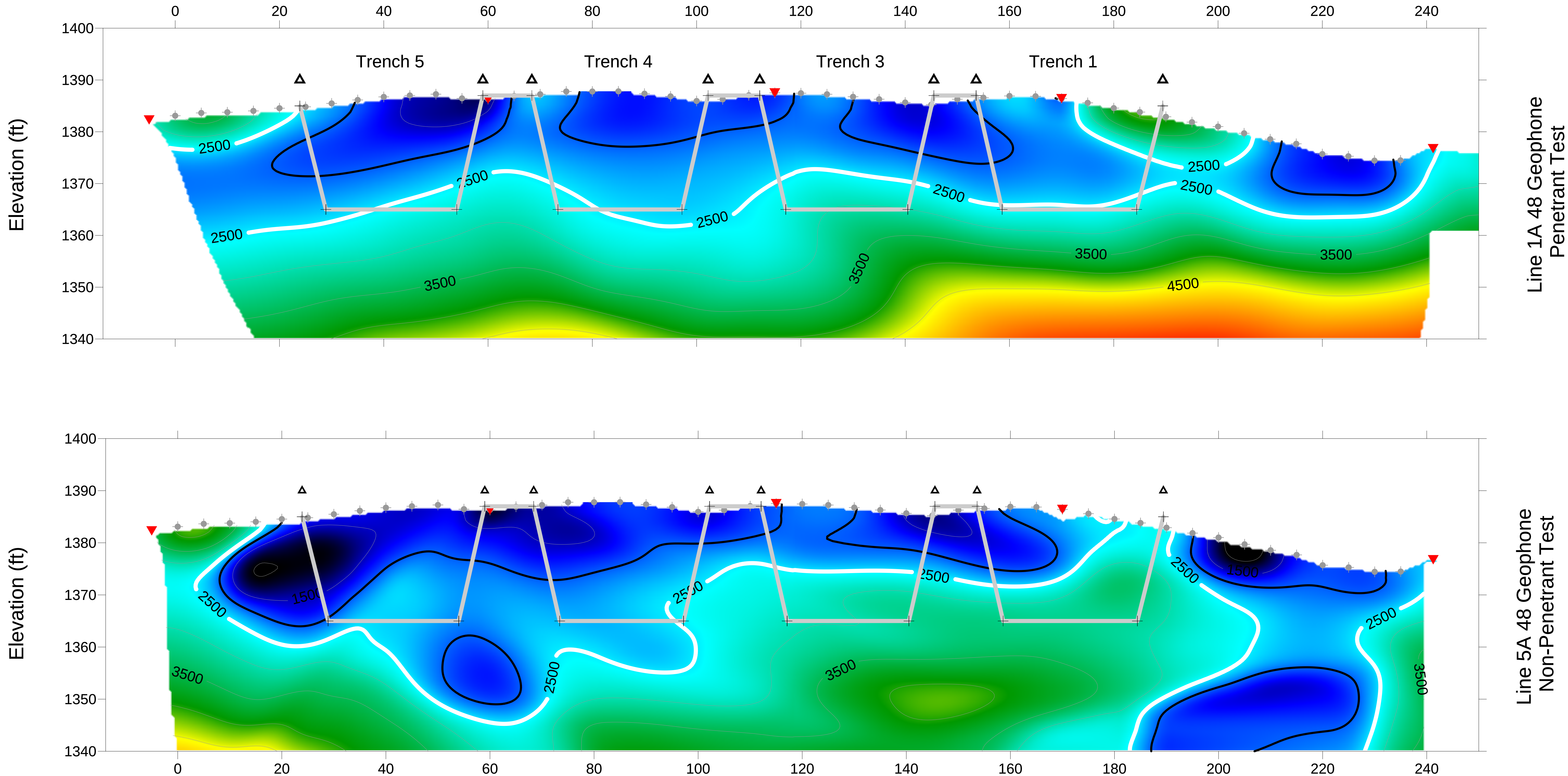
Yorba Linda, California 92887

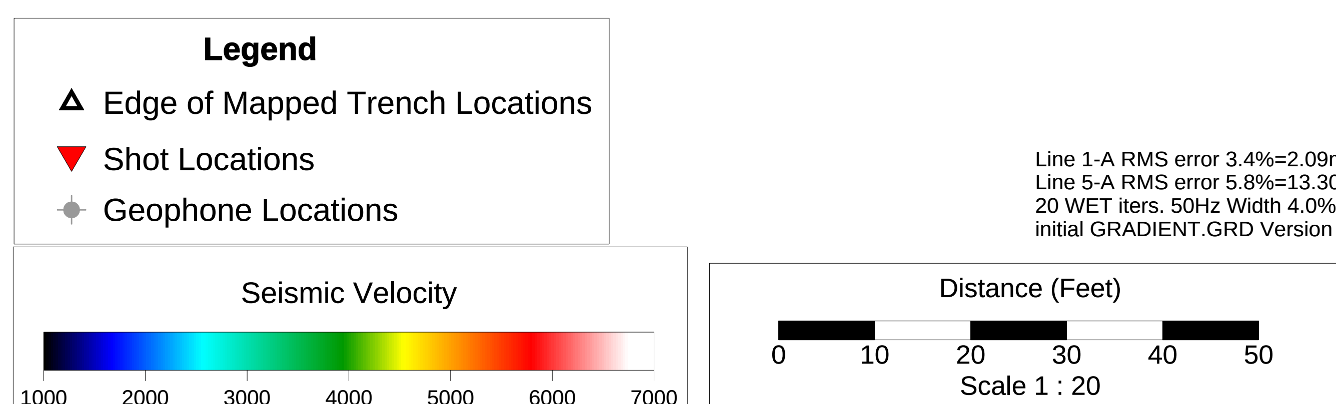
Figure Created by Eric Rickert

Date 10/10/2016



Trench 5
Trench 4
Trench 3
Trench 1
Elevation (ft)
1500
2500
3500
4500
Inferred Depth of Excavation
Physically Unlikely in the Vicinity of Trenchs 4 and 5
Note the Lobate Low Velocity Material in the Vicinity of
Some of The Mapped Locations of the Waste Trenches
Note No Low Velocity Material Below Trench 3
Line 8-D RMS error 3.7%=2.67ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35
Seismic Velocity
1000 3000 5000 7000 9000 11000 13000
Legend
Edge of Mapped Trench Locations
Shot Locations
Geophone Locations
Distance (Feet) Scale 1 : 20
0 10 20 30 40 50
Applus RTD
West Valley Demonstration
Western New York Nuclear Service Center
Geophysical Investigation
Seismic Refraction Tomography
Figure 3-8 : Line 8D Land Streamer Acquisition
Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive
Yorba Linda, California 92887
Figure Created by Eric Rickert
Date 10/10/2016





Line 1-A RMS error 3.4%=2.09ms
Line 5-A RMS error 5.8%=13.30ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

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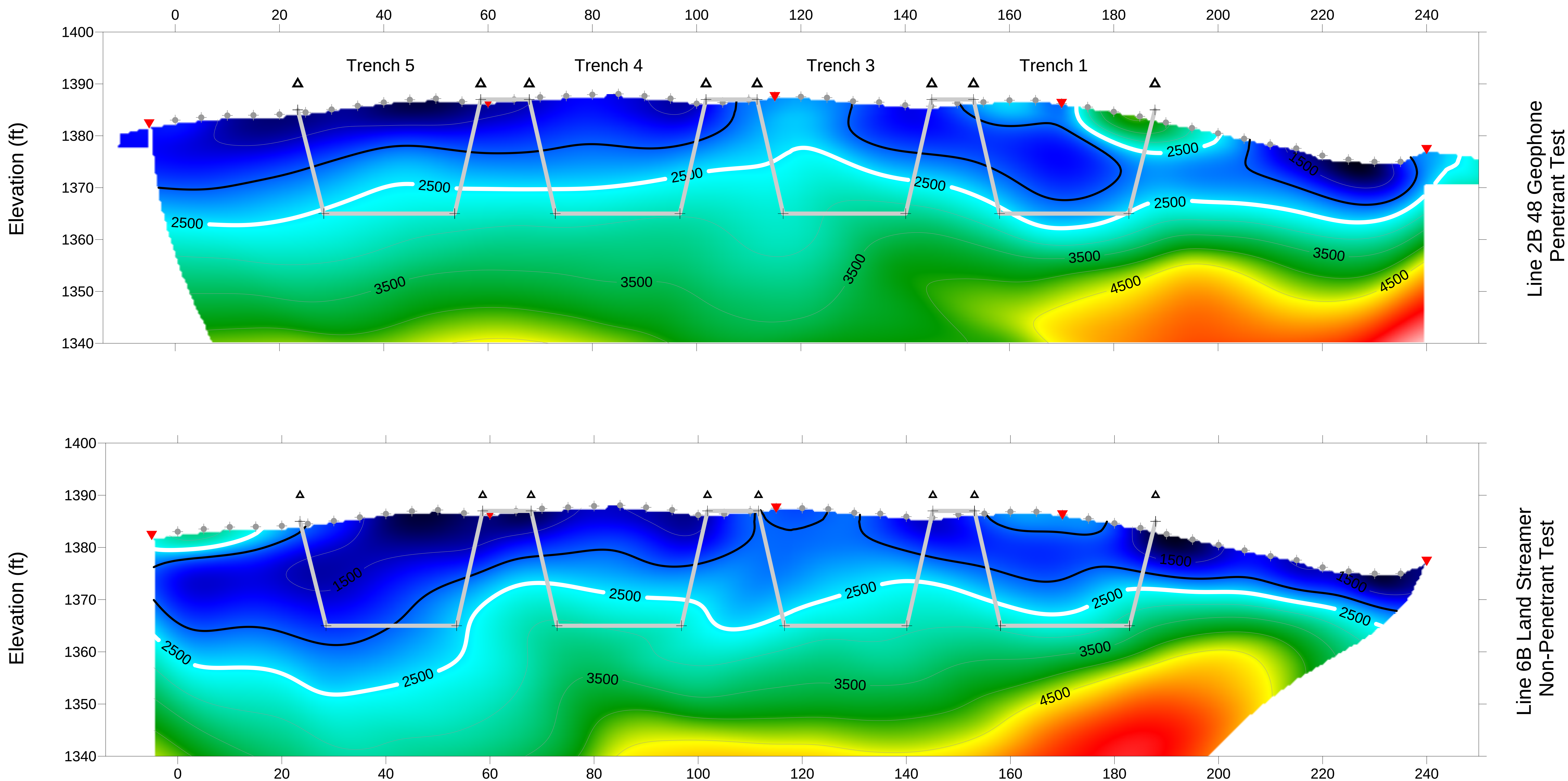
Geophysical Investigation
Seismic Refraction Tomography
Figure 3-9 : Line 1A / 5A
Penetration / Non-Penetration Acquisition

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountian Drive
Yorba Linda, California 92887

Figure Created by Eric Rickert   Date 10/10/2016



Legend

- △ Edge of Mapped Trench Locations
- ▼ Shot Locations
- Geophone Locations

Seismic Velocity

1000 2000 3000 4000 5000 6000 7000

Distance (Feet)

0 10 20 30 40 50

Scale 1 : 20

Line 2-B RMS error 2.5%=1.65ms
Line 6-B RMS error 2.8%=2.00ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

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Geophysical Investigation
Seismic Refraction Tomography
Figure 3-10 : Line 2B / 6B
Penetration / Non-Penetration Acquisition

Enviro Compliance Solutions, Inc. (ECS)
4795 Blue Mountain Drive
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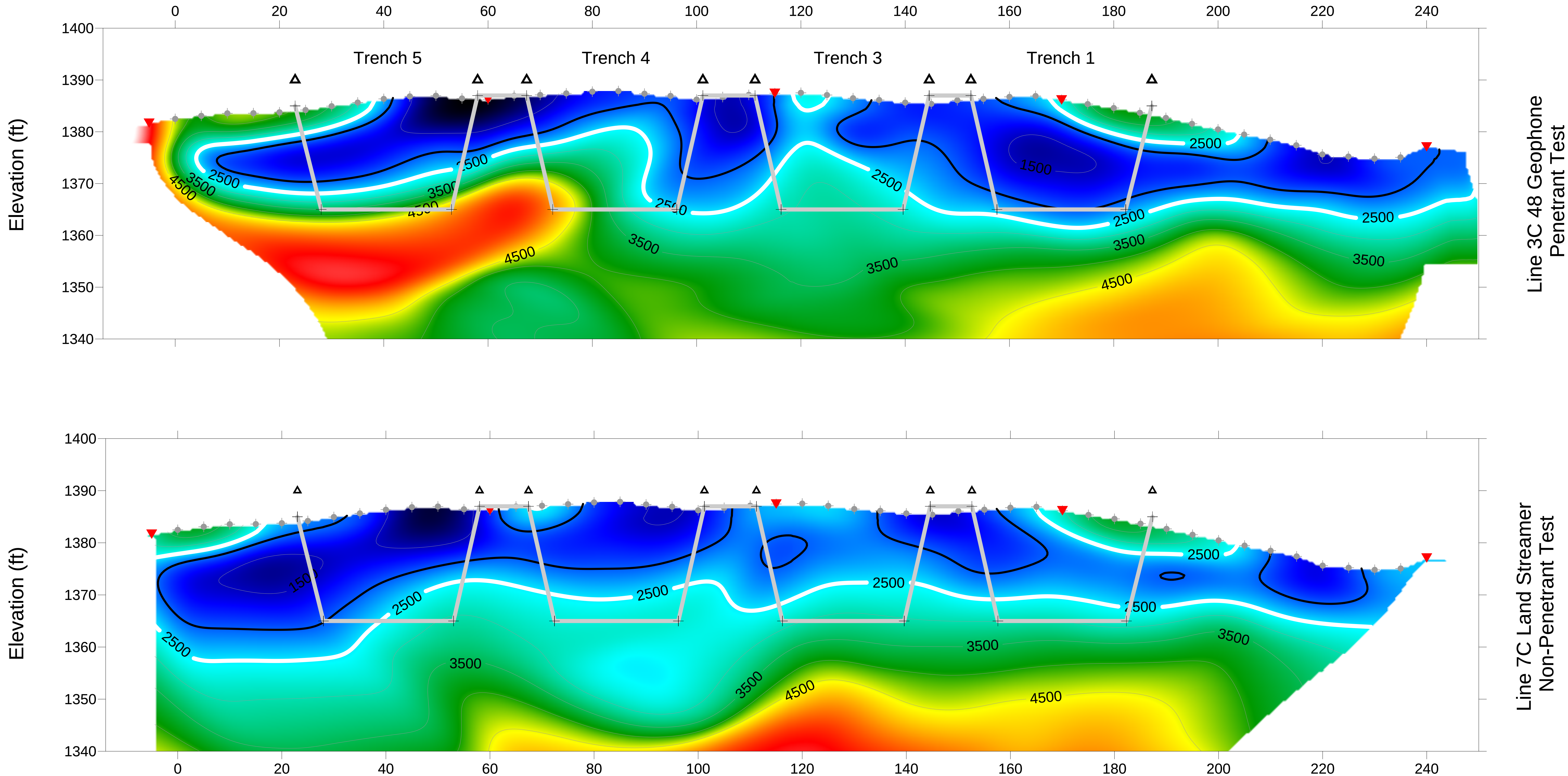
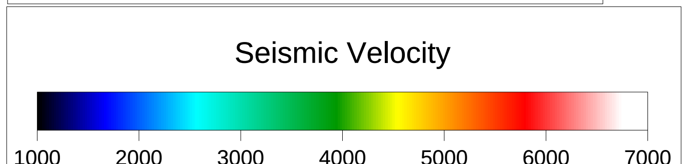
Figure Created by Eric Rickert

Date 10/10/2016

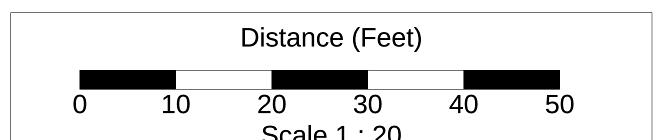


Legend

- △ Edge of Mapped Trench Locations
- ▼ Shot Locations
- Geophone Locations



Line 3-C RMS error 4.6%=2.98ms
Line 7-C RMS error 3.0%=2.11ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35



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Geophysical Investigation
Seismic Refraction Tomography
Figure 3-11 : Line 3C / 7C
Penetration / Non-Penetration Acquisition

Enviro Compliance Solutions, Inc. (ECS)
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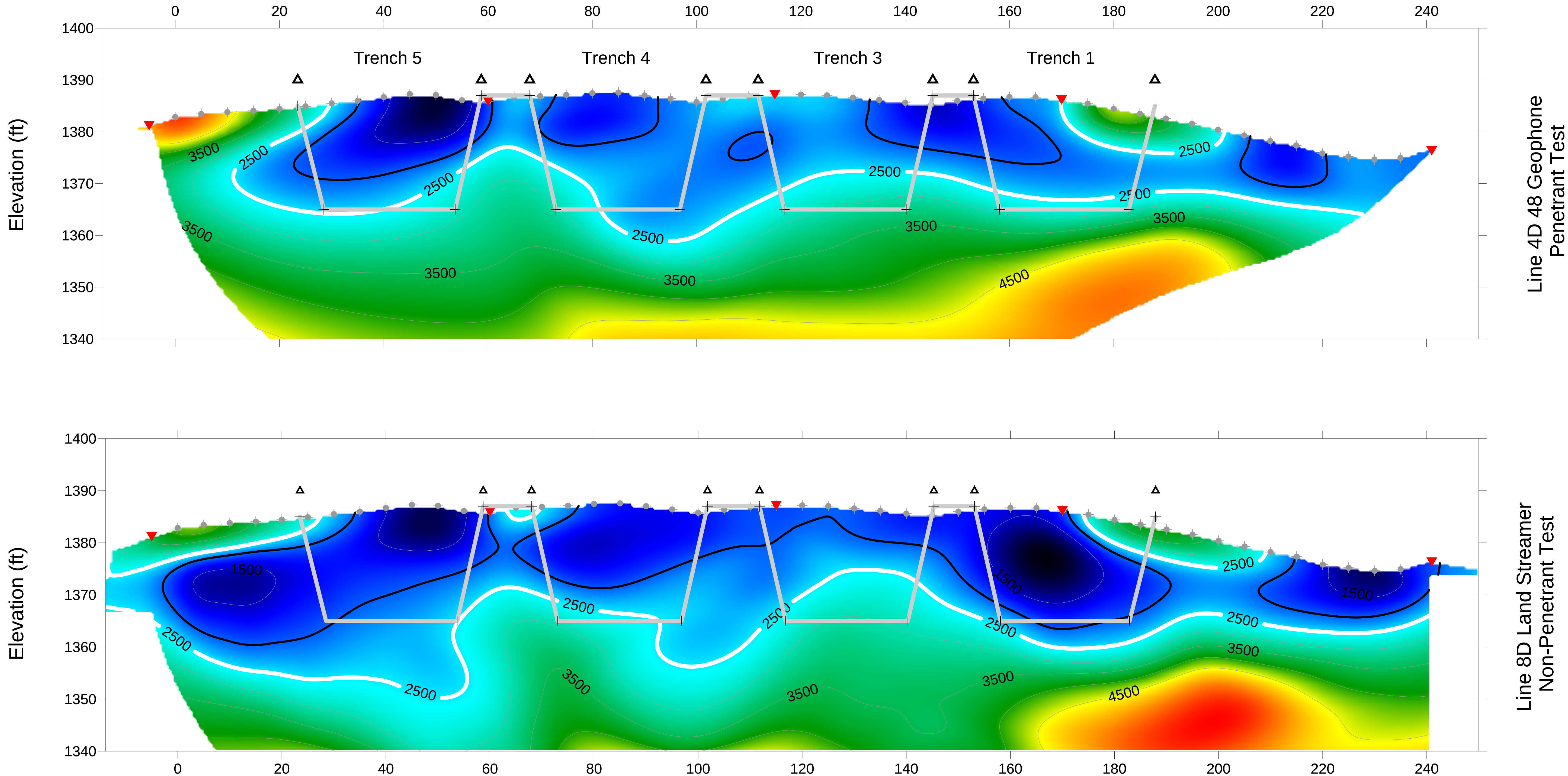
Figure Created by Eric Rickert

Date 10/10/2016



Legend

- Edge of Mapped Trench Locations
- Shot Locations
- Geophone Locations

Seismic Velocity

1000 2000 3000 4000 5000 6000 7000

Line 4-D RMS error 3.5%=2.49ms
Line 8-D RMS error 3.7%=2.67ms
20 WET iters. 50Hz Width 4.0%
initial GRADIENT.GRD Version 3.35

Distance (Feet)

0 10 20 30 40 50

Scale 1 : 20

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Western New York Nuclear Service Center

Geophysical Investigation
Seismic Refraction Tomography
Figure 3-12 : Line 4D / 8D
Penetration / Non-Penetration Acquisition

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4795 Blue Mountian Drive
Yorba Linda, California 92887

Figure Created by Eric Rickert

Date 10/10/2016

Applus RTD

4 DATA INTERPRETATION

4.1 SEISMIC REFRACTION TOMOGRAPHY WITH PENETRATIONS

Overall the SRT data with 14 Hz geophones provided better information than the data collected with 4.5 Hz using a landstreamer without penetration. The 14 Hz geophones with penetrations on profile 1A provided marginally better, cleaner data than the 14 Hz geophone at the same profile location without penetrations.

4.1.1 Line 1A

Figure 3-1 shows the results of the SRT survey for Line 1A. Line 1A shows lobate low velocity material in the vicinity of Trench 5, Trench 4 and Trench 3, which are likely related to the disturbances due to excavation of the Waste Trenches and/or construction of the soil cap. Trench 1 is not distinctly apparent as a low velocity zone, which may be due to compacted soils or error in mapping the location of the trench. The heavy black contour on Figure 3-1 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1, which may be due to construction methodology, either compacted soils or reinforced surface material (i.e. gravel access roadway) and an anomalously low velocity material at the bottom of the eastern swale may be due to disturbed material from the construction of the landfill in general. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-1.

4.1.2 Line 2B

Figure 3-2 shows the results of the SRT survey for Line 2B. Line 2B shows lobate low velocity material in the vicinity of Trench 1, which may be related to the excavation and construction of the waste trench and/or construction of the soil cap. Trench 5, Trench 4, and Trench 3 are not distinctly visible as lobate low velocity zones. The heavy black contour on Figure 3-2 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. The modeled velocity in the vicinity of Trenches 5 to 3 are horizontal without differentiation of trenches. The modeled velocity of the subgrade does not have the fine detail to differentiate the velocity of different waste materials. The general inferred depth of excavation is approximately 20 feet excluding the soil cap across the transect based on a general velocity of approximately 3000 ft./sec and a slight change in the velocity gradient that is more apparent in the vicinity of Trench 1 and east of Trench 1. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1, which may be due to construction methodology, either compacted soils or reinforced surface material (i.e. gravel access roadway) and an anomalously low velocity material at the bottom of the eastern swale may be due to disturbed material from the construction of the landfill in general. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-2.

4.1.3 Line 3C

Figure 3-3 shows the results of the SRT survey for Line 3C. Line 3C shows lobate low velocity material in the vicinity of Trench 1, which may be related to the excavation and construction of the waste trench and/or construction of the soil cap. Trench 5, Trench 4, and Trench 3 are not distinctly visible as lobate low velocity zones. The heavy black contour on Figure 3-3 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. The general inferred depth of excavation is approximately 20 feet across the transect excluding the soil cap, based on the change in the velocity gradient at that approximate depth. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1 and anomalously low velocity material at the bottom of the eastern swale. There is a slight velocity depression modeled beneath the gap between Trench 5 and Trench 4. This velocity depression is likely a modeling error due to the spacing between shot locations and complexity of clearly delineating the first arrivals. The spacing between transects is close enough that the velocity depression between Trench 4 and Trench 5 would be apparent on Lines 2B and 4D if based on geologic response. Similar probable modeling errors are apparent in transect 5A and 8D. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-3.

4.1.4 Line 4D

Figure 3-4 shows the results of the SRT survey for Line 4D. Line 4D shows lobate low velocity material in the vicinity of Trench 5 and Trench 4, which may be related to the excavation and construction of the waste trenchs and/or construction of the soil cap. The heavy black contour on Figure 3-4 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. Trench 3 and Trench 1 are not distinctly visible as a low velocity zone. Using a velocity of 2500 ft./second as the boundary layer between the disturbed material and the undisturbed material, the inferred depth of disturbance for the area of Trench 3 and Trench 1 correlate to the approximate depth of excavation expected. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1 which may be due to construction methodology, either compacted soils or reinforced surface material (i.e. gravel access roadway) and an anomalously low velocity material at the bottom of the eastern swale may be due to disturbed material from the construction of the landfill in general. The possible approximate depth of excavation has been marked as a broad grey line on Figure 3-4.

4.2 SEISMIC REFRACTION TOMOGRAPHY WITHOUT PENETRATIONS

Overall the data without geophone penetrations does not provide as clear information as the data described above with geophone penetration. The non-penetrant seismic data is more prone to seismic noise (wind) and likely modeling errors. As the non-penetrant data is less distinct and more prone to errors in determining first arrivals than the penetrant data, over reliance on analysis of the modeled response is not recommended.

4.2.1 Line 5A

Figure 3-5 shows the results of the SRT survey for Line 5A. Line 5A shows lobate low velocity material in the vicinity of Trench 5 and Trench 4 which may be related to the soil cap and/or the excavated material within Waste Trenches 5 and 4. The heavy black contour on Figure 3-5 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. Trench 3 and Trench 1 are not distinctly visible as a low velocity zone. There are anomalously low velocity material zones at the bottom of the eastern swale and between the mapped location of Trench 5 and Trench 4 which are likely the result of modeling errors. These modeling errors are likely due to data that is less distinct than the Line 1A data in Figure 3-1. The depth of excavation is not apparent in the modeled data for Line 5A.

4.2.2 Line 6B

Figure 3-6 shows the results of the SRT survey for Line 6B. Line 6B shows general low velocity material in the near surface without clear delineation of trenches, which may be related to the excavation and construction of the landfill. The heavy black contour on Figure 3-6 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. The general inferred depth of excavation excluding the soil cap is approximately 20 feet across the eastern portion of the transect based on an approximate velocity of 3500 ft./sec and the velocity gradient, the modeled possible excavation depth increases in the vicinity of Trench 5. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-6. The inferred depth of excavation in the vicinity of Trench 5 could be as much as 60 feet, which is physically unlikely indicating the limitations of modeling the land streamer seismic data.

4.2.3 Line 7C

Figure 3-7 shows the results of the SRT survey for Line 7C. Line 7C shows lobate low velocity material in the vicinity of Trench 5 and Trench 4, which may be related to the soil cap and/or the excavated material within Waste Trenches 5 and 4. The heavy black contour on Figure 3-7 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. Trench 3 and Trench 1 are not distinctly visible as lobate low velocity zones which may be the result of different construction practices or more well-connected waste material within Trenches 3 and 1 resulting in a higher velocity material. The general inferred depth of excavation excluding the soil cap is approximately 20 feet across the transect based on an increased velocity gradient, except for the vicinity of Trench 4 and west of Trench 5 where the inferred depth of excavation can be as much as 40 feet based on the velocity gradients in the modeled data. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1, which may be due to construction methodology, either compacted soils or reinforced surface material (i.e. gravel access roadway), and an anomalously low velocity material at the bottom of the eastern swale that may be due to disturbed material from the construction of the landfill in general. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-7.

4.2.4 Line 8D

Figures 3-8 show the results of the SRT survey for Line 8D. Line 8D shows lobate low velocity material in the vicinity of Trench 5, Trench 4 and Trench 1, which may be related to the soil cap and/or the excavated material within Waste Trenches 5, 4 and 1. The heavy black contour on Figure 3-8 is the 2000 ft./second contour that is inferred as the disturbed soils low velocity material. Trench 3 is not distinctly visible as a low velocity zone which may be the result of different construction practices or more well connected waste material within Trench 3 resulting in a higher velocity material. The inferred depth of disturbance shown as a higher velocity gradient for the area of Trench 1 correlates to the approximate 20-foot depth of excavation expected excluding the soil cap. Inferred depth of excavation near Trench 5 and Trench 4 may be as much as 40 feet, based on the higher velocity gradient. The inferred approximate depth of excavation has been marked as a broad grey line on Figure 3-8. There is an additional anomalously higher velocity material at the eastern edge of the mapped Trench 1, which may be due to construction methodology, either compacted soils or reinforced surface material (i.e. gravel access roadway), and an anomalously low velocity material west of Trench 5 and at the bottom of the eastern swale that may be due to disturbed material from the construction of the landfill in general.

4.3 COMPARISON OF RESULTS - PENETRATIONS VS. NON-PENETRATIONS

Figures 3-1 through 3-8 of the modeled seismic velocities from the SRT survey appear different for each of the lines. The focus of this investigation is the upper 20 to 40 feet. For direct comparison of the results of the penetrant to non-penetrant surveys, Figures 3-9 through 3-12 have been created that illustrate the results of the upper portions of the SRT survey for each of the four profile locations A thru D. The results have been truncated at elevation 1340 as the expected depth of excavation within the upper 20 feet based on supplied historical construction blueprints. For each of the Figures 3-9 to 3-12, a heavy black contour is shown at 2000 feet/sec and a heavy white contour is shown at 2500 feet/sec for illustrative and comparison purposes. The results illustrate a larger correlation in the near surface between penetration and non-penetrant surveys than the full scale Figures tend to indicate.

4.3.1 Location A

Figure 3-9 shows the results at Location A, Lines 1A and 5A. The modeled data in the upper portion of the figure shows clear horizontal lines with a few apparent modeling failures in Line 5A. The model for the penetrant data is clearer and is similar to the expected physical strata in the subgrade.

4.3.2 Location B

Figure 3-10 shows the results at Location B, Lines 2B and 6B. The modeled data in the upper portion of the figure shows clear horizontal lines. The results in the lower portion of the figure are similar with a few large-scale differences between them. The lower figure is slightly less smooth and has peaks and valleys that do not correspond with the historical mapped locations of the waste trenches.

4.3.3 Location C

Figure 3-11 shows the results at Location C, Lines 3C and 7C. In this case the modeled results from the non-penetrant data are closer to the expected physical strata in the subgrade. Line 7C was acquired with the lowest site noise of any of the seismic lines, while Line 3C had significant noise issues.

4.3.4 Location D

Figure 3-12 shows the results at Location D, Lines 4D and 8D. The modeled data in the upper portion of the figure shows clear horizontal lines with disturbances in the near surface. The data in the lower portion of the figure is similar with a few large-scale differences between them. The lower figure is slightly less smooth and has peaks and valleys that do not correspond with the historical mapped locations of the waste trenches.

4.3.5 Comparison Summary

Comparing the upper portions of the figures shows consistency from line to line, as can be expected when similar construction methods have been utilized to build the subgrade in these areas. There are some differences in the modeled data, which may be due in part to noisy data and/or minor differences in the construction of the subgrade. The differences in the non-penetrant data are considerably more notable.

A particular notable difference is east of Trench 1 between Line 5A and Line 6B. There are similarities in the central portion of the transects, but significantly less correlation than in the penetrant testing.

4.4 RECOMMENDATIONS FOR ANY FUTURE SEISMIC SURVEYS AT WEST VALLEY

Wind on the membrane is a large source of seismic noise at the site. Muffling the noise, particularly wind noise, on the membrane is important to increase the signal to noise ratio. Use of sandbags to constrain the motion of the geophones on the geomembrane is a significant help to limiting signal noise. Significant snow cover (>6 inches) on the geomembrane might also have a significant noise dampening effect with limited impact of seismic data acquisition using stand-alone geophones. Note that deployment of the land streamer would be slowed by snow accumulation. The geomembrane would be more brittle at cold temperatures and depth of frost could negatively impact the survey.

A significant addition to the SRT data acquisition at this site would be the inclusion of an Accelerated Weight Drop Seismic Source or an Elastic Wave Generator "EWG" to increase the signal to noise ratio for each stack of the survey, especially at far offset shot locations. Concerns at this site are both the noise from the membrane and the multiple ray paths thorough the different and diverse materials at the site. Any improvement to the signal to noise ratio will be an asset to the modeling of the subgrade.

Because the focus of the survey is shallower than 40 feet, increasing the number of shot points and decreasing the reliance on far offset shots will assist in focusing the survey in the near surface. The present survey design is modeling the upper 100 to 130 feet; adjusting the survey for the upper 40 to 50 feet will improve the model resolution. Collecting SRT data at shot spacing of 6 geophones would allow for better solutions to the SRT data modeling.

5 ACHIEVING GOALS OF THE PROJECT

As defined by the original request for proposal, the geophysical studies have multiple objectives. The objectives and the success and presumed large-scale success for this method are as follows:

Objective 1 Define the lateral boundaries of individual waste trenches and other disposal units within the SDA and NDA both to allow for the safe installation of intrusive borings as near as possible to the waste and to globally support the future development and evaluation of exhumation alternatives.

- The present resolution of the SRT data has not been able to clearly discern definitive lateral boundaries. Increased resolution (increasing the number of shot locations) may provide lateral resolution of the waste trenches.

Objective 2 Define the bottom/depth of the waste trenches and other disposal units. To be able to determine the elevation of the metallic waste within the disposal cell would be of additional benefit.

- The depth of excavation of the waste trenches has been approximately defined by the SRT survey. If the suggested changes to the survey are implemented, improved resolution would be expected.

Objective 3 Determine the elevation of the top surface of water that is known to be present within the waste trenches, as well as the elevation of the water table in the surrounding glacially-deposited fine grained silty-clay soil.

- The SRT survey will be unlikely to reliably discern water levels at any data acquisition resolution.

Objective 4 Identify specific segments within the waste trenches that contain either waste monoliths (e.g., concrete casks or large pieces of equipment), densely-packed waste materials, or large quantities of metallic waste that can be compared against the inventory records for those same segments as a measure of inventory reliability.

- The present resolution of the SRT data has not been able to clearly discern large waste monoliths or densely packed waste materials for comparison against inventory records. The SRT survey will be unlikely to reliably discern individual waste bodies at any data acquisition resolution.

6 SUMMARY

In summary, the SRT surveys provide approximations of the lateral locations and depths of the excavations of the trenches. If SRT is considered for any future seismic surveys at the site, the use of 14 Hz geophones tuned for seismic refraction would simplify picking first arrivals when compared to the 4.5 Hz geophones on the land streamer. Using a closer spacing of shot locations will increase the precision of the SRT modeling results. The far offset shots are difficult to pick first arrivals in this material, in part due to the nature of the material that has many different velocities associated with it. The SRT is not capable of distinguishing different materials within the waste trenches.

7 LIMITATIONS

Applus RTD performs geophysical services (for locating utilities, subsurface features) in compliance with latest available industry standard practices and guidance. Although these guidance's establish criteria for stringent quality control, it must be understood that due to the complexities in the electrical properties inherent in various materials (i.e. dielectrics) these methods have limitations. As a result of these conditions some utilities or objects may go undetected by geophysics and may require other methods to identify them. Therefore Applus RTD makes no guarantee with respect to the location of any subsurface objects.

8 APPENDIX A DAILY REPORTS AND SEISMIC QC SHEETS

Daily Report
Terranear PMC – West Valley, NY

CONTRACT NO:	WORK ORDER NO. 07.018018/001	DATE / TIME ON AND OFF SITE Tuesday 08/30/2016 0700 - 1720

WEATHER/TEMPERATURE: Conditions Clear / 83 °F – Black Geomembrane increased apparent temperature

WORK LOCATION: West Valley, NY

PERSONNEL/AFFILIATION (PRINT)	Title/Duty
Benjamin King-Smith /Applus RTD	Geophysical Technician I
Kyle Jones	Geophysical Technician I
Eric Rickert	Geophysical Field Supervisor

SUBCONTRACTOR:	TRADE/SERVICE:

HEALTH AND SAFETY:

☒ **Daily H&S Brief and Discussion**

- **See Pre-Job Hazard Assessment Paperwork**

Safety Issues/Problems: None

WORK COMPLETED TODAY:

- **COMPLETED SEISMIC TOMOGRAPHY DATA ACQUISITION FOR LINES A, B, AND C**
- **GEOPHONE 1 WAS PLACED AT THE WESTERN EDGE OF THE TRANSECT FOR EACH LINE**
- **DATA QUALITY VARIABLE – INCREASED NOISE DUE TO WIND AS THE AFTERNOON ADVANCED**
- **SOME DATA QUALITY GOOD, SOME DATA QUALITY DIFFICULT TO PICK FIRST ARRIVALS**

MISCELLANEOUS: NA

NOTES: Additional stacking of seismic data did not improve data quality of far field geophones.

Scheduling of summer work may wish to take into account the typical afternoon breeze and adjust start times accordingly.

WORK SCHEDULED NEXT DATE: 8/31 Wednesday – complete the data acquisition for the penetrant phase of the seismic refraction tomography. Resume the GPS location acquisition of geophone locations and shot locations. Begin the seismic tomography with the land streamer.

PREPARED BY:	SIGNATURE:
Eric Rickert, Geophysics Field Supervisor	Eric Rickert

CLIENT: Terranear PMC

SITE NAME: West Valley SRC

OPERATOR: E. Rickert

Date: 8/30/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ________ Result: PASS Initials: ER

Daily Trigger Check: ________ Result: PASS Initials: ER

Daily Channel Mapping: ________ Result: PASS Initials: ER

Daily Noise Monitor Check: ________ Result: PASS Initials: ER

Survey Set Up

Traverse Name: A

Reflection/Refraction/MASW: ________

Geophone Spacing: 5FT

Geophone Frequency: 14 Hz

Location: GPS File Name: TBD ; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 48

Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD

Shot Location Separation: ________

Name of first seismic profile file: 100

Last file: 106

Elevations recorded for topography correction: (Y or N)

NOTES 60', 100', 145', 225, 230 NGT

CLIENT: Terranear PMC

SITE NAME: West Valley SRC

OPERATOR: E. Rivkat

Date: 8/30/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ________ Result: PASS Initials: ER

Daily Trigger Check: ________ Result: PASS Initials: ER

Daily Channel Mapping: ________ Result: PASS Initials: ER

Daily Noise Monitor Check: ________ Result: PASS Initials: ER

Survey Set Up

Traverse Name: B

Reflection/Refraction/MASW: ________

Geophone Spacing: 6 FT

Geophone Frequency: 14 Hz

Location: GPS File Name: TBD ; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 48

Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD

Shot Location Separation: ________

Name of first seismic profile file: 206

Last file: 206

Elevations recorded for topography correction: (Y or N)

NOTES ________

CLIENT: Terranear PMC

SITE NAME: West Valley SRC

OPERATOR: [illegible]

Date: 8-30-16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ________ Result: PASS Initials: BR

Daily Trigger Check: ________ Result: PASS Initials: BR

Daily Channel Mapping: ________ Result: PASS Initials: BR

Daily Noise Monitor Check: ________ Result: PASS Initials: [illegible]

Survey Set Up

Traverse Name: L

Reflection/Refraction/MASW: ________

Geophone Spacing: 5'

Geophone Frequency: 14 Hz

Location: GPS File Name: TBD; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 48

Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD

Shot Location Separation: ________

Name of first seismic profile file: 300

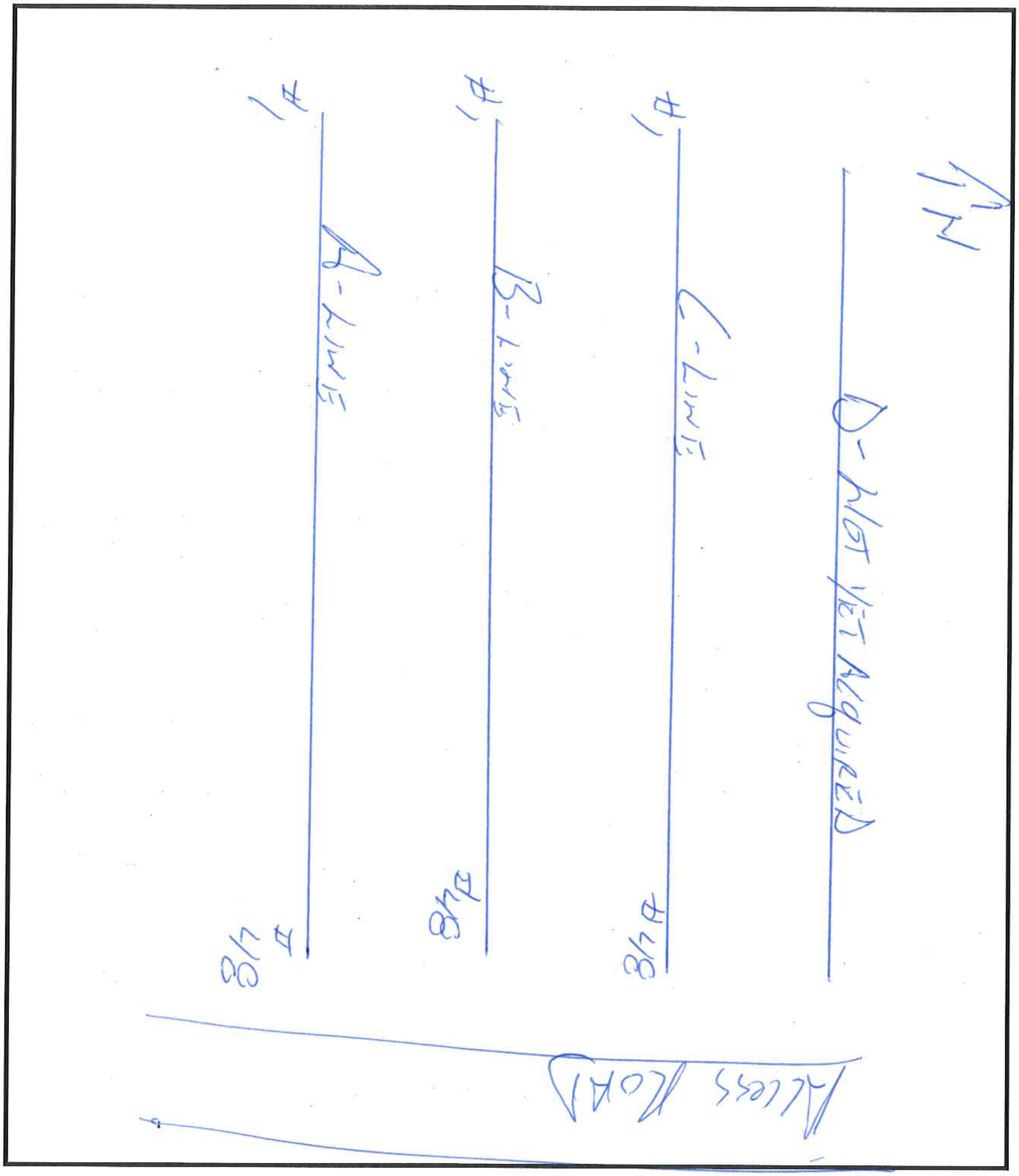
Last file: 306

Elevations recorded for topography correction: (Y or N)

NOTES ________

Applus RTD

Field Diagram:



Daily Report
Terranear PMC – West Valley, NY

CONTRACT NO:	WORK ORDER NO. 07.018018/001	DATE / TIME ON AND OFF SITE Tuesday 08/31/2016 0700 - 1735

WEATHER/TEMPERATURE: Conditions Rain early – Pt Cldy afternoon / 70s °F

WORK LOCATION: West Valley, NY

PERSONNEL/AFFILIATION (PRINT)	Title/Duty
Benjamin King-Smith /Applus RTD	Geophysical Technician I
Kyle Jones	Geophysical Technician I
Eric Rickert	Geophysical Field Supervisor

SUBCONTRACTOR:	TRADE/SERVICE:

HEALTH AND SAFETY:

☒ **Daily H&S Brief and Discussion**

- **See Pre-Job Hazard Assessment Paperwork**

Safety Issues/Problems: Rain delays mid-morning (8:45 – 12:45)

WORK COMPLETED TODAY:

- **COMPLETED SEISMIC TOMOGRAPHY DATA ACQUISITION FOR LINE D – END OF PENETRANT GEOPHYSICAL TESTING**
- **RESUMED GPS DATA ACQUISITION OF SEISMIC LINES AND SHOT LOCATIONS – LINES A, B, AND C COMPLETE**
- **BEGAN SEISMIC TOMOGRAPHY DATA ACQUISITION WITH LAND STREAMER**
- **COMPLETED SEISMIC TOMOGRAPHIC LAND STREAMER DATA ACQUISITION FOR LINE D**
- **GEOPHONE 1 WAS PLACED AT THE WESTERN EDGE OF THE TRANSECT FOR EACH LINE**
- **DATA QUALITY VARIABLE – INCREASED NOISE DUE TO WIND AS THE AFTERNOON ADVANCED**
- **SOME DATA QUALITY GOOD, SOME DATA QUALITY DIFFICULT TO PICK FIRST ARRIVALS**

MISCELLANEOUS: NA

NOTES: Additional stacking of seismic data did not improve data quality of far field geophones.

WORK SCHEDULED NEXT DATE: 9/01 Thursday – complete the data acquisition for the land streamer phase of the seismic refraction tomography. Resume the GPS location acquisition of geophone locations and shot locations for Line D.

PREPARED BY:
Eric Rickert, Geophysics Field Supervisor

SIGNATURE:
Eric Rickert

Applus RTD

CLIENT: Terranear PMC

SITE NAME: West Valley SRC

OPERATOR: B. Rickert

Date: 8/31/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ______ Result: OK-good Initials: ER

Daily Trigger Check: ______ Result: ______ Initials: ______

Daily Channel Mapping: ______ Result: good Initials: ER

Daily Noise Monitor Check: ______ Result: good Initials: ER

Survey Set Up

Traverse Name: D

Reflection/Refraction/MASW: ______

Geophone Spacing: 5 FT

Geophone Frequency: 14 Hz

Location: GPS File Name: TBD ; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 48

Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD

Shot Location Separation: 5 FT

Name of first seismic profile file: 400

Last file: ______

Elevations recorded for topography correction: (Y or N)

NOTES ______

CLIENT: Terranear PMC SITE NAME: West Valley SRC

OPERATOR: E. Rickert Date: 8-31-16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ________ Result: Pass Initials: ER

Daily Trigger Check: ________ Result: Pass Initials: ER

Daily Channel Mapping: ________ Result: Pass Initials: ER

Daily Noise Monitor Check: ________ Result: Pass Initials: ER

Survey Set Up

Traverse Name: D-Streamer Reflection/Refraction/MASW: ________

Geophone Spacing: 5' Geophone Frequency: ~~14 Hz~~ 4.5

Location: GPS File Name: TBD; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 24 Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD Shot Location Separation: ________

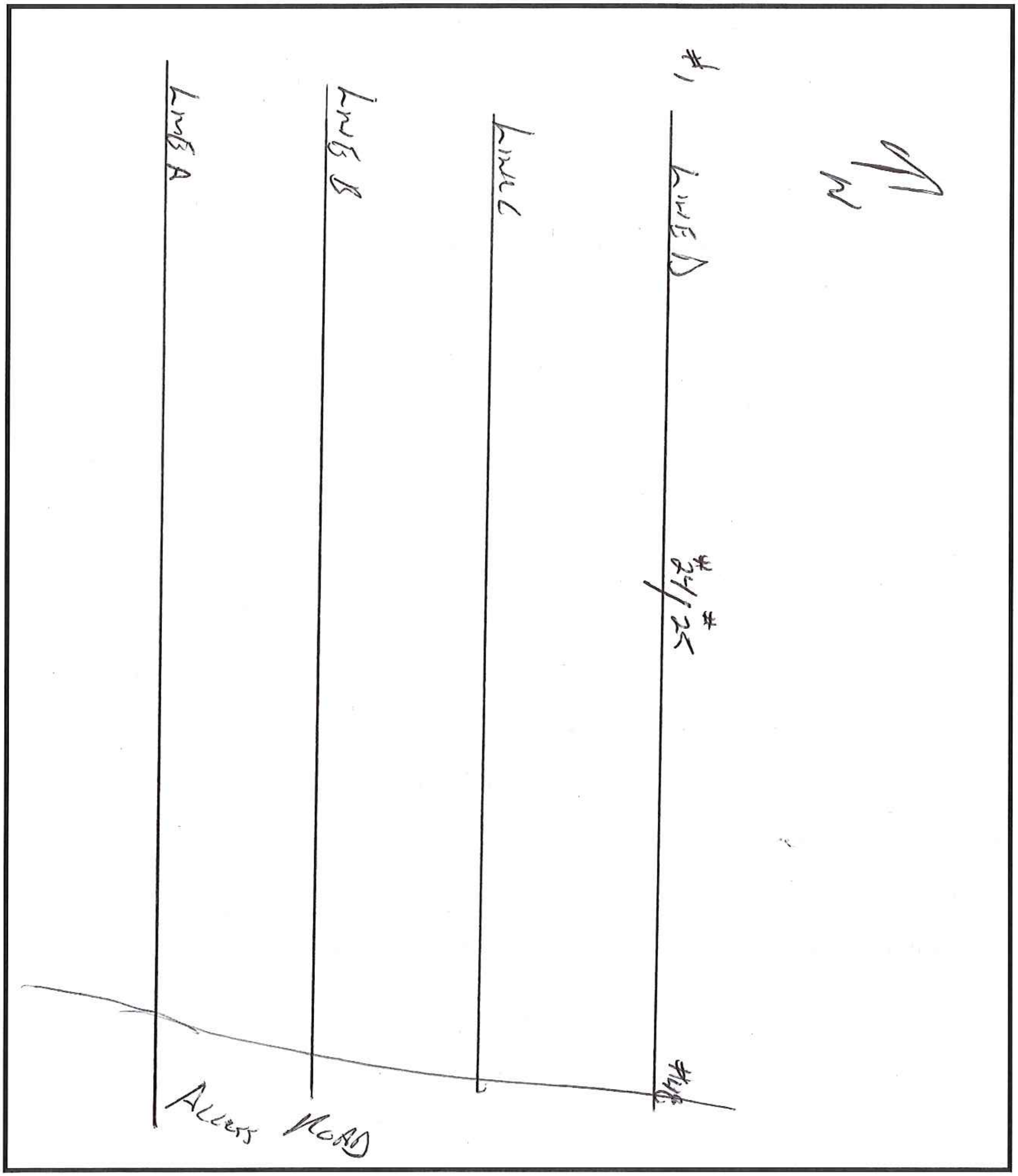
Name of first seismic profile file: 800 Last file: 813

Elevations recorded for topography correction (Y or N)

NOTES ________

Applus RTD

Field Diagram:



Daily Report
Terranear PMC – West Valley, NY

CONTRACT NO:	WORK ORDER NO. 07.018018/001	DATE / TIME ON AND OFF SITE Thursday 09/01/2016 0700 - 1720

WEATHER/TEMPERATURE: Conditions Partly Cloudy / 70s °F

WORK LOCATION: West Valley, NY

PERSONNEL/AFFILIATION (PRINT)	Title/Duty
Benjamin King-Smith /Applus RTD	Geophysical Technician I
Kyle Jones	Geophysical Technician I
Eric Rickert	Geophysical Field Supervisor

SUBCONTRACTOR:	TRADE/SERVICE:

HEALTH AND SAFETY:

☒ **Daily H&S Brief and Discussion**

- **See Pre-Job Hazard Assessment Paperwork**

Safety Issues/Problems: Delays due to construction equipment in area and high wind noise

WORK COMPLETED TODAY:

- **COMPLETED NON-PENETRANT SEISMIC TOMOGRAPHY DATA ACQUISITION FOR LINE A, B AND C**
- **LAND STREAMER USED FOR DATA ACQUISITION OF LINES B AND C**
- **NON-PENETRANT SEISMIC TESTING OF LINE A USED 14 HZ PHONES WITH SPIKES REMOVED AND SANDBAGGED IN PLACE FOR DATA ACQUISITION**
- **END OF SEISMIC GEOPHYSICAL TESTING**
- **COMPLETED GPS DATA ACQUISITION OF SEISMIC LINES AND SHOT LOCATIONS – LINE D COMPLETE**
- **GEOPHONE 1 WAS PLACED AT THE WESTERN EDGE OF THE TRANSECT FOR EACH LINE**
- **DATA QUALITY VARIABLE – INCREASED NOISE DUE TO WIND AS THE AFTERNOON ADVANCED**
- **SOME DATA QUALITY GOOD, SOME DATA QUALITY DIFFICULT TO PICK FIRST ARRIVALS**

MISCELLANEOUS: NA

NOTES: Additional stacking of seismic data did not improve data quality of far field geophones.

WORK SCHEDULED NEXT DATE: 9/06 Tuesday – begin data acquisition with magnetometer.

PREPARED BY:	SIGNATURE:
Eric Rickert, Geophysics Field Supervisor	Eric Rickert

Applus RTD

CLIENT: Terranear PMC SITE NAME: West Valley SRC

OPERATOR: G. Rickert Date: 9/1/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ______ Result: Pass Initials: GR

Daily Trigger Check: ______ Result: Pass Initials: GR

Daily Channel Mapping: ______ Result: Pass Initials: GR

Daily Noise Monitor Check: ______ Result: Pass Initials: GR

Survey Set Up

Traverse Name: A Reflection/Refraction/MASW: ______

Geophone Spacing: 5' Geophone Frequency: 14 Hz

Location: GPS File Name: TBD ; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 48 Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD Shot Location Separation: ______

Name of first seismic profile file: 500 Last file: 506

Elevations recorded for topography correction: (Y or N)

NOTES ______

Applus RTD

CLIENT: Terranear PMC SITE NAME: West Valley SRC

OPERATOR: E. Rickert Date: 9/1/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ______ Result: Pass Initials: ER

Daily Trigger Check: ______ Result: Pass Initials: ER

Daily Channel Mapping: ______ Result: Pass Initials: ER

Daily Noise Monitor Check: ______ Result: Pass Initials: ER

Survey Set Up

Traverse Name: B Reflection/Refraction/MASW: ______

Geophone Spacing: 5 FT Geophone Frequency: 14 Hz

Location: GPS File Name: TBD ; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 24 Seismic Recording Time: 0.3 sec

Number of stacked shots per location: TBD Shot Location Separation: ______

Name of first seismic profile file: 600 Last file: 613

Elevations recorded for topography correction: (Y or N)

NOTES ______

Applus RTD

CLIENT: Terranear PMC SITE NAME: West Valley SRC

OPERATOR: E. Rickert Date: 9/1/16

Seismograph Unit

Model/Serial Number: Geode SN #5410 / #5411

Daily QA/QC Check: ________ Result: PASS Initials: ER

Daily Trigger Check: ________ Result: PASS Initials: ER

Daily Channel Mapping: ________ Result: PASS Initials: ER

Daily Noise Monitor Check: ________ Result: PASS Initials: ER

Survey Set Up

Traverse Name: C Reflection/Refraction/MASW: ________

Geophone Spacing: 5' Geophone Frequency: ~~14~~ 4.5 Hz

Location: GPS File Name: TBD; if no GPS file, describe location in notes.

Data Collection

Number of Geophones: 24 Seismic Recording Time: ________

Number of stacked shots per location: ____ Shot Location Separation: ________

Name of first seismic profile file: 700 Last file: 713

Elevations recorded for topography correction: (Y or N)

NOTES file 713 out of order due to lack of save on original file 706

Applus RTD

Field Diagram: