Appendix B.6

Electrical Resistivity Imaging and Seismic Refraction Report

July 30, 2025, Revised August 7, 2025

RETTEW

We answer to you.

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Engineers

Environmental Consultants

Surveyors

Landscape Architects

Safety Consultants

July 30, 2025
Revised August 7, 2025

Mr. Bradford L. Fish
Sunoco Pipeline LP
100 Green Street
Marcus Hook, PA 19061

RE: Electrical Resistivity Imaging and Seismic Refraction Report
Upper Makefield Township Site
Bucks County, PA
RETTEW Project No. 0963003386

Dear Brad:

From February 20 through March 7, 2025, RETTEW Field Services completed electrical resistivity imaging (ERI) Profiles 1 through 5 in the Mount Eyre neighborhood of Upper Makefield Township, Bucks County, PA (see **Figure 1**). A report on the results of this survey was submitted to Sunoco Pipeline LP (SPLP on March 26. On May 8, 2025, RETTEW recorded ERI Profile 0. Draft results were sent to SPLP on May 13; however, they were not previously incorporated into a formal report, but rather were used for mapping of field conditions and are now included herein. On Jun 25, RETTEW recorded ERI Profile 6. Between June 24 and July 1, RETTEW recorded seismic refraction profiles coincident with, and numbered the same as, ERI Profiles 0 through 6. The purpose of the ERI surveying was to detect and delineate underground electrically conductive semi-planar features that could represent water-bearing fractures or bedding plane partings. The purpose of the seismic refraction surveying was to produce a top-of-rock elevation map of the site.

Existing literature from the US Geological Survey (USGS)[1] indicates the following:

- The Lockatong has little primary porosity and permeability. Instead, water resides and moves along bedrock fractures.
- One fracture set is parallel to bedding, striking roughly North 50° East and dipping approximately 10° Northwest. These fractures reportedly dominate at shallow depths.
- A second fracture set, dominant at greater depths, has the same strike and a near-vertical dip.
- Groundwater flow is reportedly controlled more by the presence and orientation of these fractures than by hydraulic head (i.e., water elevation and pressure).
- Water supply wells in the Lockatong Formation tend to tap multiple fractures, each of which may have different hydraulic head.
- Wells along strike are likely to be hydraulically connected, while those separated across strike tend to be unconnected – even if the hydraulic gradient is strong. Pumping wells develop a cone of depression that is highly elongated parallel to strike.

Given these observations and the nearby presence of the Delaware River (a major groundwater discharge feature), groundwater flow should be generally from SW to NE in this area. **Figure 1** shows aerial photo/topo linears (red lines) that were identified by RETTEW, the trends of which generally agree with the existing published literature. The red lines highlighting possible photo/topo linears are generally too short to represent significant fractures but are intended to show the structural fabric or grain of the underlying bedrock which strongly affects groundwater flow. **Figure 1** also shows (light blue line) the composite or dominant overall fracture trend based on the literature and photo/topo linears. This blue line also connects properties where light non-aqueous phase liquid (LNAPL) was detected in late January and early February of 2025. The dark blue symbols are domestic wells from global navigational satellite systems (GNSS) surveying by RETTEW.

Electrical resistivity measurements involve driving an electrical current in the earth using two current electrodes at the ground surface. The apparent resistivity of the subsurface is determined by measuring the voltage or potential difference between two other potential electrodes with a known separation and position/orientation relative to the current electrodes. The depth and volume of the subsurface zone represented by the measured apparent resistivity are a function of the geometry of the four (2-current and 2-potential) electrodes. Apparent resistivities are converted to model or true resistivities by performing a joint inversion of all the measured apparent resistivities along a profile. The Mt. Eyre ERI survey consisted of six profiles oriented roughly perpendicular to the structural fabric (although modified by property access constraints). The lines of electrodes are shown as green dots on **Figure 1**, and across the top of each cross-sectional profile in **Figure 2**. Discrete measurements are not collected at individual electrodes, but by four electrodes at a time, sometimes widely spaced and spanning multiple individual lots. For each profile, many hundreds of four-electrode measurements were collected to allow statistically significant inversion of the field apparent resistivities.

Apparent resistivities were collected using dipole-dipole electrode arrays (which maximize sensitivity to steeply dipping features of the type that are expected to control local groundwater flow) with dipole lengths (i.e., current and electrode pair spacing) between 10 feet and 100 feet, and spacings between the dipoles from 10 feet to nearly the length of each profile. An Advanced Geosciences, Inc. (AGI) Sting R-8 meter with internal digital memory and an automated switch box were used to select electrode pairs/foursomes, drive the injected current, and record resulting voltages.

The field apparent resistivities with their electrode geometries were inverted to produce cross-sectional images beneath each profile as depicted in **Figure 2**. These images were generated by joint inversion of all apparent resistivity measurements along each profile using EarthImager2D by AGI. On the profiles, possible water-bearing fractures may be indicated by low-resistivity (high-conductivity) blue contours extending down into higher-resistivity (low-conductivity) red contours which should represent relatively non-porous and impermeable intact bedrock. Red arrows at the surface of each profile indicate where they cross photo/topo linears and the overall expected groundwater flow direction. The locations where Walker and Spencer Roads intersect the profiles are also shown.

Top-of-bedrock elevation profiling and mapping was completed by recording seismic refraction profiles coincident with the ERI electrode arrays. Seismic refraction involves striking the ground surface to generate primary or compressional elastic waves (P-waves). These radiate outward from the shot point in an expanding hemisphere in the Earth. These waves are bent or refracted where they cross interfaces between materials with differing P-wave velocity (Vp). In particular, a wave that encounters the top-of-rock (where there is a strong Vp contrast) at the so-called critical angle is bent to travel along the bedrock surface, from which it sends a head wave (like the bow wake of a ship) back to the surface. By recording the travel times from the shot to an array of receivers (geophones), it is possible to construct a velocity model of the subsurface beneath the geophone array. For the Mt. Eyre neighborhood survey, RETTEW employed arrays of Mark Products 4.5-Hertz geophones connected by cables to a Geometrics Geode seismograph. Shot points were spaced at 40-foot intervals (see **Figure 1**), with P-waves generated by repeated or stacked blows of a 30-pound airless jackhammer. The recorded travel times were inverted using SeisImager by Oyo Corp. The seven seismic profiles are shown on **Figure 3**. The velocity contours are colored such that unconsolidated soils or sediments are in shades of blue, a soil to rock transition or weathering zone is in light brown, and hard competent rock is dark brown. As with the ERI profiles in **Figure 2**, photo/topo linears and the dominant structural trend are shown, as well as road crossings. Shot point locations are shown, but not the individual geophones at 10-foot intervals (to preserve clarity).

Figures 4 through **10** provide side-by-side comparisons of the ERI and seismic results for Profiles 0 through 6, respectively. Careful examination of the ERI profiles supports the interpretation of low-resistivity features as possible fractures. There are underground utilities (electric and communication) generally parallel to the roadways and offset from them by 5 to 15 feet. Ten of the inferred fractures have surficial traces within about 20 feet of roadways. Twenty-nine are not near roadways. In addition, the ERI profiles are nearly perpendicular to the utilities parallel to Glenwood, Spencer and Walker making the ERI measurements nearly immune to utility interference. There is clear utility interference on the northern end of Profile 6 from presumed utilities, and as is standard practice, these data were culled from the inversion and interpretation (see **Figure 10**).

Further support for the interpretation of the ERI anomalies as possible water-bearing fractures comes from the general correlation of ERI anomalies with seismic anomalies; i.e., zones where competent rock is locally slightly deeper (blue symbols on the seismic profiles in **Figures 4-10**). This is consistent with deeper weathering of the rock surface along fractures. On the seismic profiles, it is apparent that rock is shallowest (thinnest blue unconsolidated layer) in the northwest of the site and deepens to the south and east. The shallowest rock is about six feet deep, and the deepest is approximately 42 feet deep.

The individual ERI anomalies are mapped onto the profile traces/electrode lines in **Figure 11**. On **Figure 12**, these anomalies have been connected by lines representing possible fracture traces. These connections were made by experienced geophysicists following these rules:

- Inferred traces (yellow-dashed lines) must be sub-parallel to the structural grain (known from photo/topo linear analysis and borehole geophysical logging) wherever possible.
- Inferred traces must connect as many anomalies as possible without crossing an ERI profile where there is no anomaly.
- Any anomaly must be connected to at least one other anomaly on an adjacent profile.
- Any inferred fracture trace must be defined by a minimum of three anomalies, unless it is oriented such that a two-anomaly line "misses" the next adjacent profile.
- Anomalies can be used to define one or more traces (i.e., they could represent intersections of fractures).

The numbers on the eastern end of each inferred possible fracture on **Figure 12** represent the number of anomalies that the trace continuously connects without crossing a profile with no anomaly in the proper location. The best-defined ("6") trace crosses the site almost exactly following the dominant fracture orientation/groundwater flow direction that was drawn months prior to the geophysical surveys based on the available literature, aerial photo and topo analysis, and the early detections of LNAPL in domestic wells. Three other inferred traces that are labelled just south of the "6" trace are labelled 4, 5, and 5. Because these cross Profile 6 on the end where data were culled to remove cultural interference (i.e., signal related to human infrastructure), they could easily be labelled "5", "6" and "6" since the anomalies that were dismissed as cultural interference could actually represent fracture anomalies, or were masked by the interference, but are truly present. These anomaly alignments/inferred fractures have now been ground-truthed by recovery wells on Glenwood Drive that were sited to intercept them, and now produce LNAPL. Note that none of the inferred fracture traces lie uniformly 5 to 15 feet from a roadway edge – suggesting that they are unlikely to be utility artifacts.

Since many possible lines could be drawn, some of the fractures drawn on **Figure 12** according to the rules above may yield false positives (i.e., not actually a fracture). In addition, these fractures (which are much more laterally extensive than the photo/topo linears on **Figure 1**) may represent averages of fracture swarms composed of many closely spaced fractures too small to be resolved individually.

Figure 12 also provides a rose diagram (top left inset) depicting the azimuths of planar features recorded in geophysical televiewer logging of three domestic wells and four recovery wells. The azimuths of photo/topo linears, and the ERI anomaly alignments are depicted on rose diagrams inset at the lower right of **Figure 12**. These diagrams show a consistent pattern that matches the overall fracture trend (light blue line on **Figure 1**.)

Figure 13 provides a top-of-bedrock elevation map based on interpolating elevations of the 9,500 fps Vp contours from **Figures 4-10**. The highest bedrock elevations are in the northwest of the site (north of Spencer Road on both sides of Glenwood Drive). From there, bedrock elevations decline to the south and east, with the deepest rock where Spencer Road meets Crestwood Road. In the vicinity of the LNAPL release on the west side of Glenwood Drive north of Walker Road, the widely-spaced contours indicate a relatively level bedrock surface.

Figure 14 provides an interpolated seismic cross section along the suspected dominant/overall trend that was recognized in early 2025 (light blue line in **Figures 1, 11,** and **13**). No actual seismic profile was recorded along this trend, but the vertical velocity profiles from each actual profile where it crosses the trend were compiled and interpolated to produce this virtual seismic profile.

We appreciate this opportunity to have worked with you. If you have any questions, please do not hesitate to contact us.

Sincerely,

Felicia Kegel Bechtel

Felicia Kegel Bechtel, MSc, PG
Senior Geophysical Advisor

Charles Rhine

Charles Rhine, MSc, PG
Senior Geophysics Project Manager

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[1] Literature Resources

Greenman, D. W. (1955). Ground Water Resources of Bucks County, Pennsylvania (Vol. 11). Department of Internal Affairs, Topographic and Geologic Survey.

Lewis, J. C. (1992). Effect of anisotropy on groundwater discharge to streams in fractured Mesozoic basin rocks: American Water Resources Association Monograph Series 17.

Low, D. J., Hippe, D. J., & Yannacci, D. (2002). Geohydrology of southeastern Pennsylvania (No. 4166). US Department of the Interior, US Geological Survey.

Morin, Roger H.; Senior, Lisa A.; and Decker, Edward R., (2000) Fractured-Aquifer Hydrogeology from Geophysical Logs: Brunswick Group and Lockatong Formation, Pennsylvania. US Department of the Interior, US Geological Survey.

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Sloto, R. A., & Schreffler, C. L. (1994). Hydrogeology and ground-water quality of northern Bucks County, Pennsylvania (Vol. 94, No. 4109). US Department of the Interior, US Geological Survey.

Vecchioli, J., Carswell, L. D., & Kasabach, H. F. (1969). Occurrence and Movement of Ground Water Brunswick Shale at a Site near Trenton, New Jersey. US Geological Survey Professional Paper, 154-157.

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ENCLOSURES

REDACTED

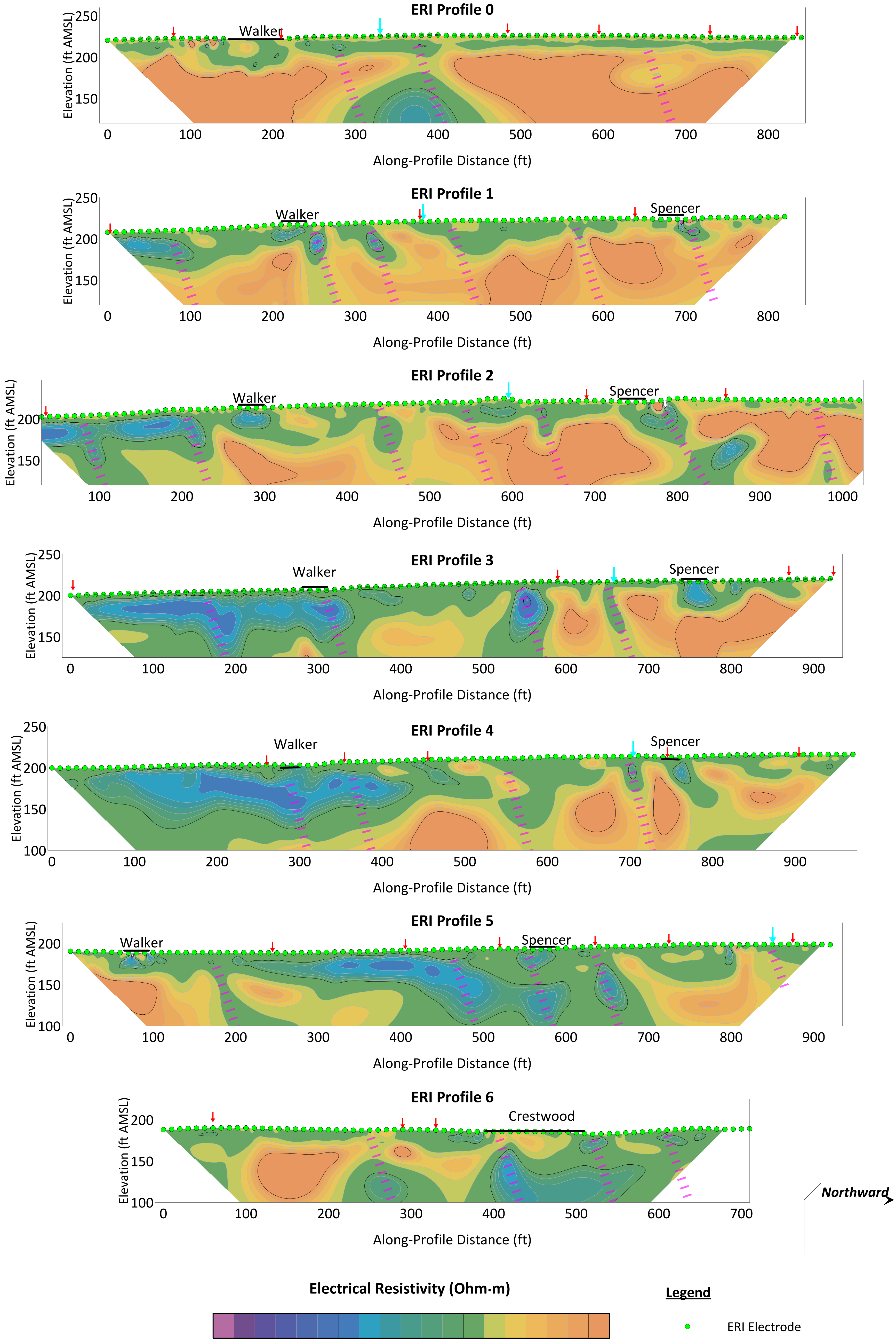
Figure 1: Seismic and ERI Data Coverage

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP   BUCKS COUNTY, PA

RETTEW[SM]
RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

SURVEY DATE:	06/12/2025
RETTEW No.:	0963003386
REVIEWED BY:	FKB
DRAWN BY:	CHR
REVISION DATE:	07/24/2025
SCALE:	1"=160'
FIGURE NO.	**1 of 14**



Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)

Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.

Figure 2: ERI Profiles

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP

BUCKS COUNTY, PA

RETTEW[SM]

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RETTEW No.:	0963003386
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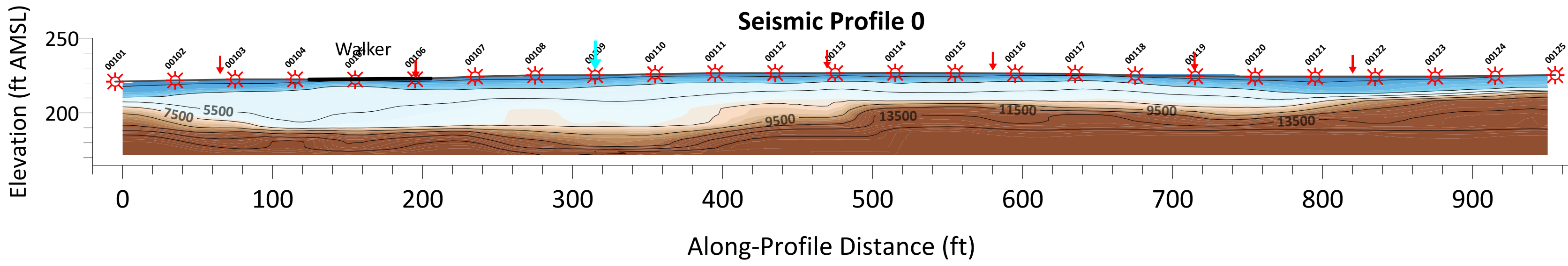
SCALE:	GRAPHICAL
FIGURE NO.	2 of 14

Seismic Profile 0



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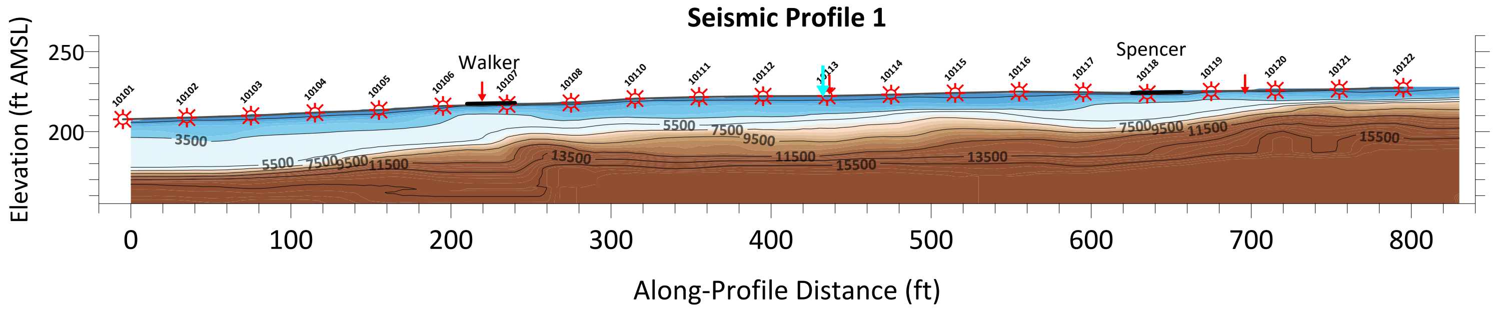
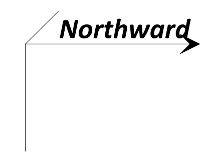
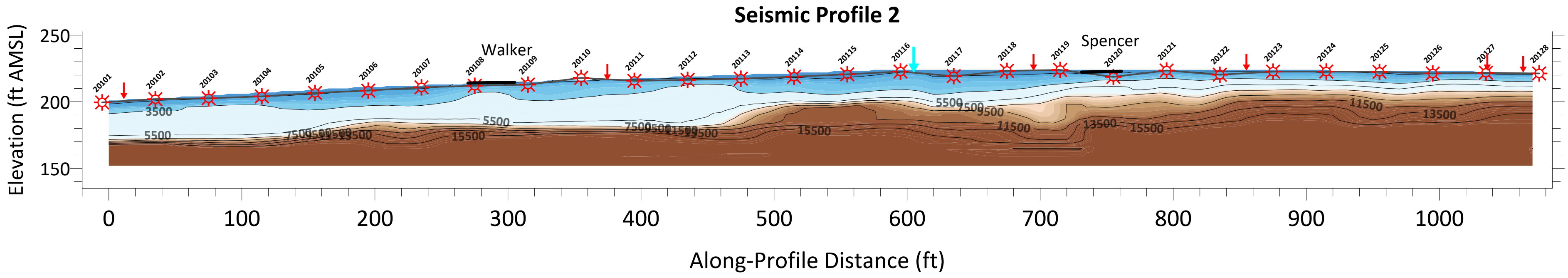




Seismic Profile 2



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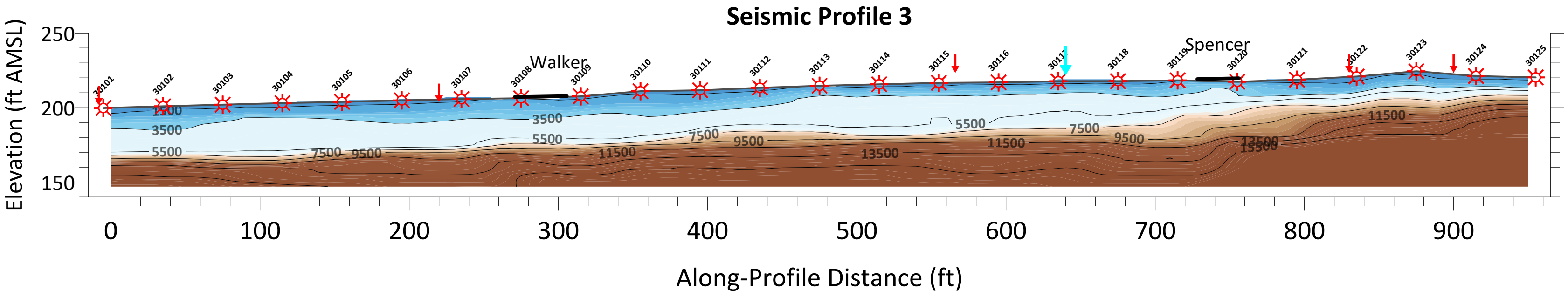

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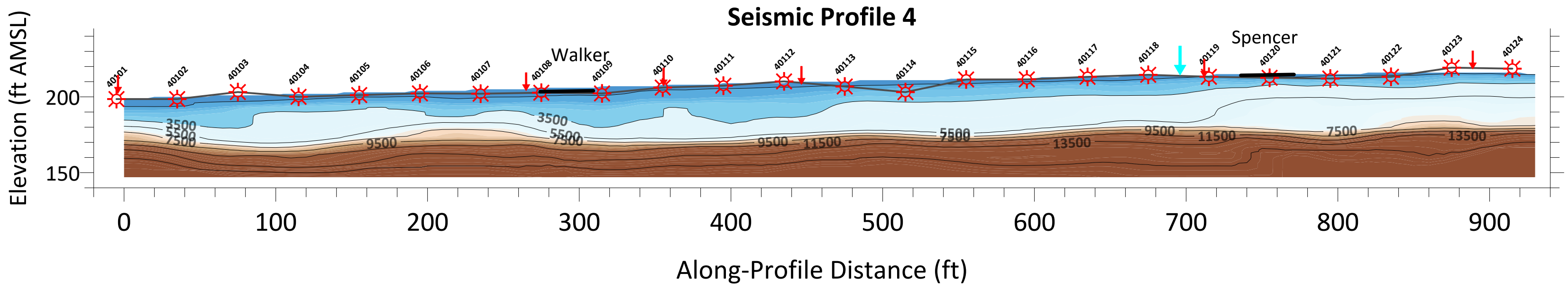
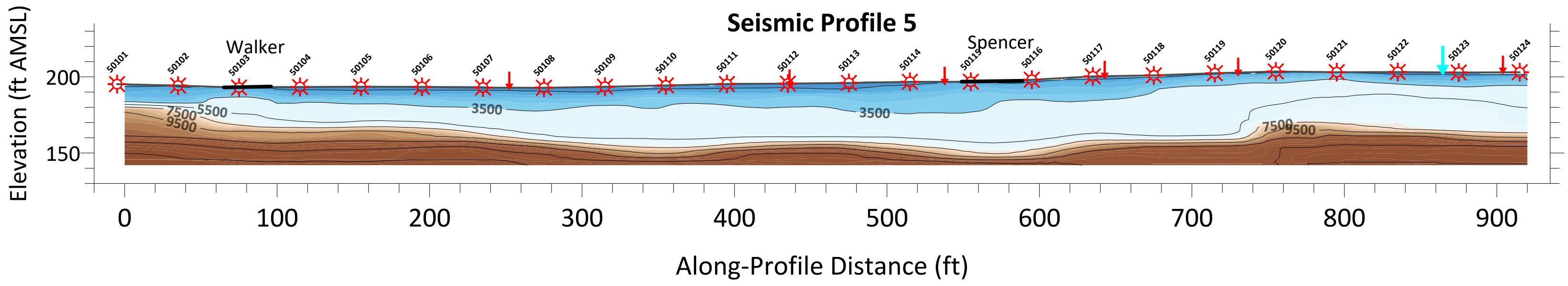
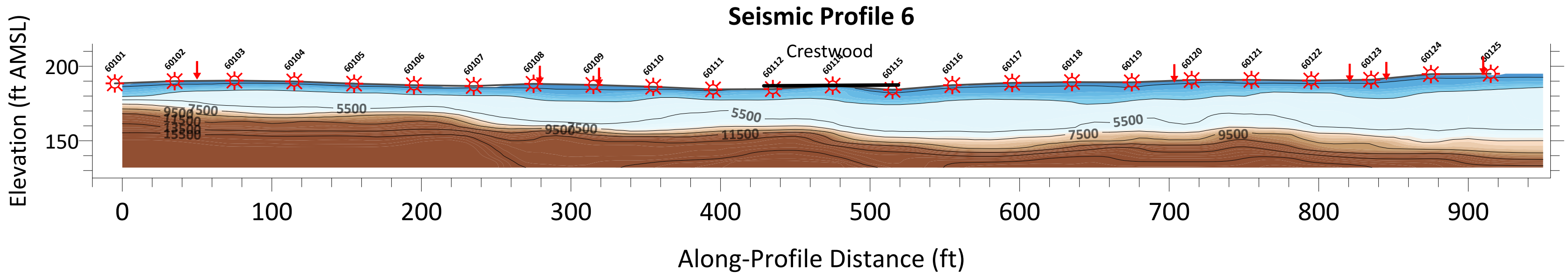


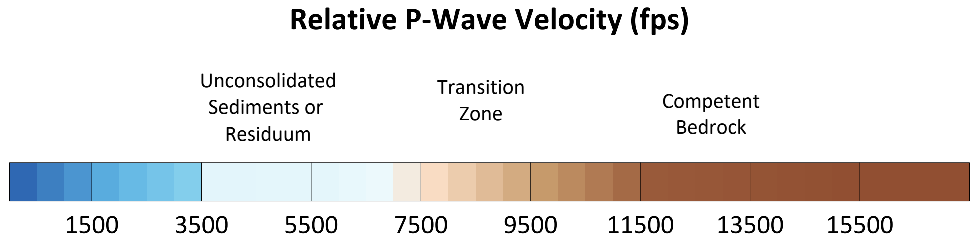
Seismic Profile 5



Seismic Profile 6



Relative P-Wave Velocity (fps)



Legend

- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Seismic Shot Location

Notes:
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

Figure 3: Seismic Profiles

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP — BUCKS COUNTY, PA

RETTEW[SM]

RETTEW Field Services, Inc.
3020 Columbia Avenue, Lancaster, PA 17603
Phone 1-800-738-8395

SURVEY DATE:	05/08/2025
RETTEW No.:	0963003386
REVIEWED BY:	FKB
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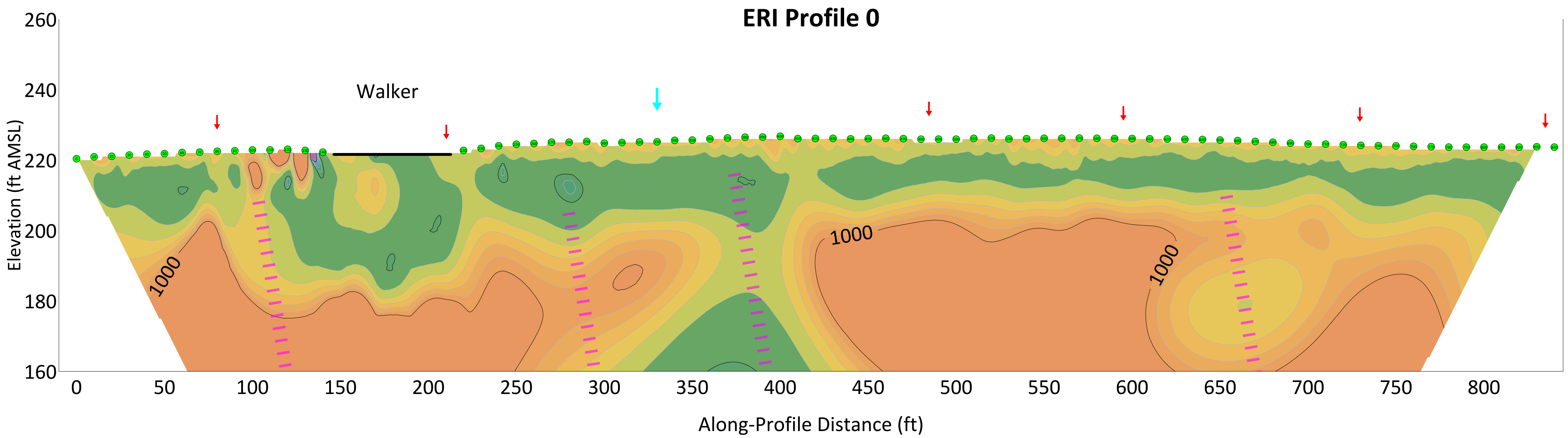
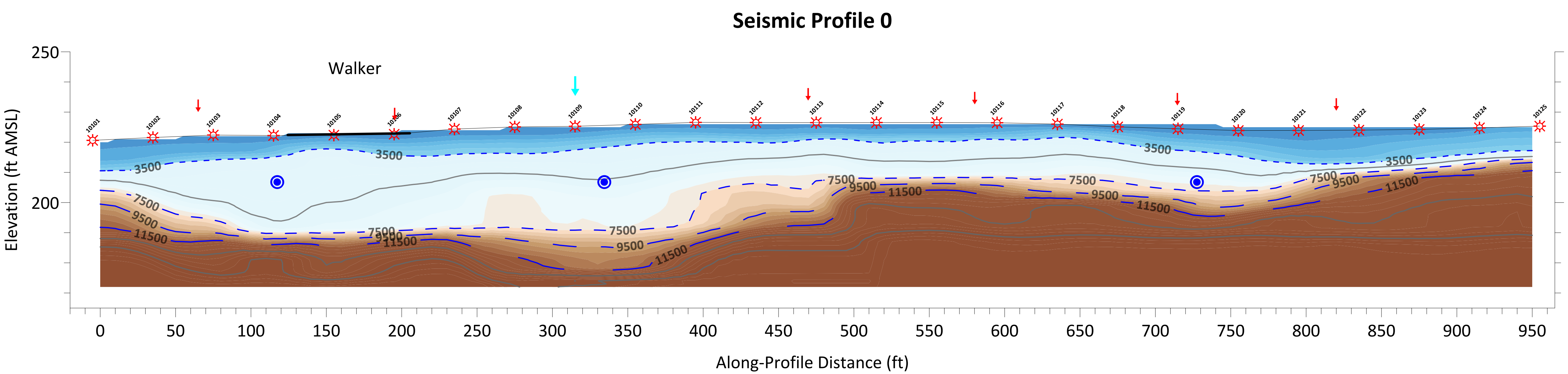
REVISION DATE:	07/24/2025
SCALE:	GRAPHICAL
FIGURE NO.	**3 of 14**

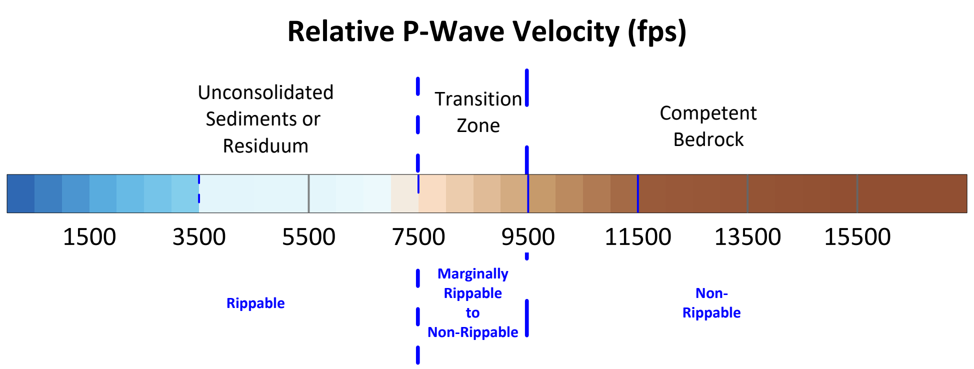


Northward

Rippability
Average P-wave
Velocity (fps)

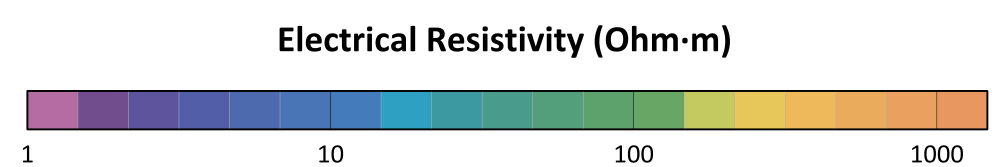
1,285
5820
16,222





Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature



Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

SURVEY DATE: 05/08/2025
RETTEW No.: 0963003386
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DRAWN BY: CHR
REVISION DATE: 07/24/2025
SCALE: GRAPHICAL
FIGURE NO. 4 of 14

RETTEW[SM]

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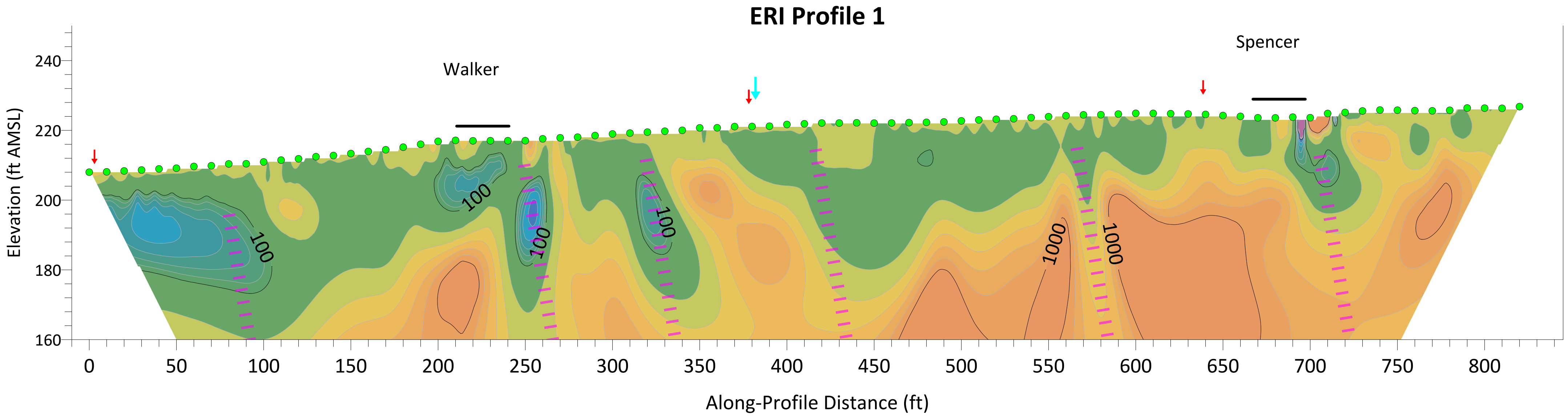
Phone 1-800-738-8395

BUCKS COUNTY, PA

Figure 4: ERI and Seismic Profiles
Profile 0

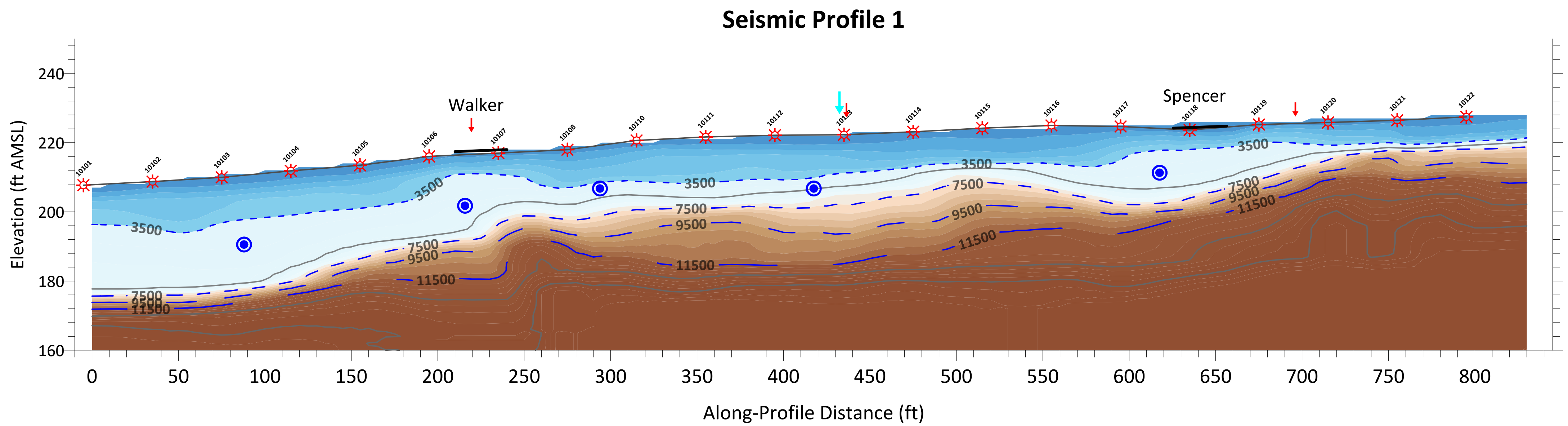
Geophysical Survey
Upper Makefield Site

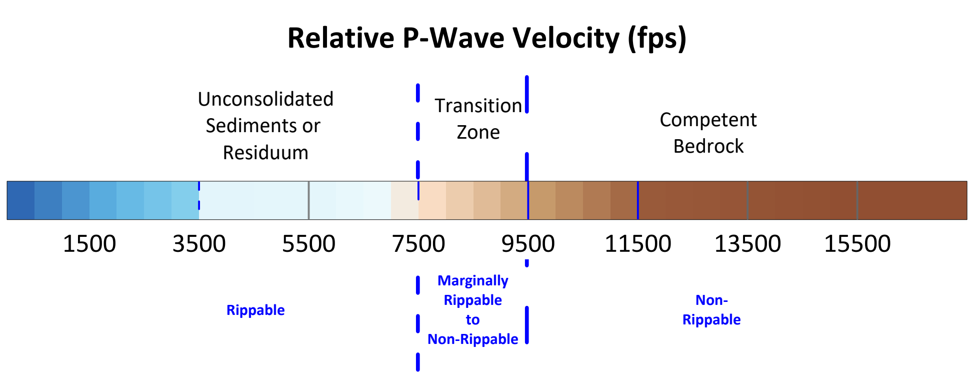
UPPER MAKEFIELD TOWNSHIP



Rippability
Average P-wave
Velocity (fps)

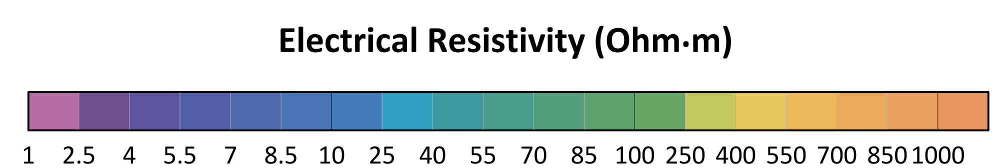
1,347
3,863
16,049





Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature



Notes:
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FIGURE NO.: 5 of 14

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3020 Columbia Avenue, Lancaster, PA 17603
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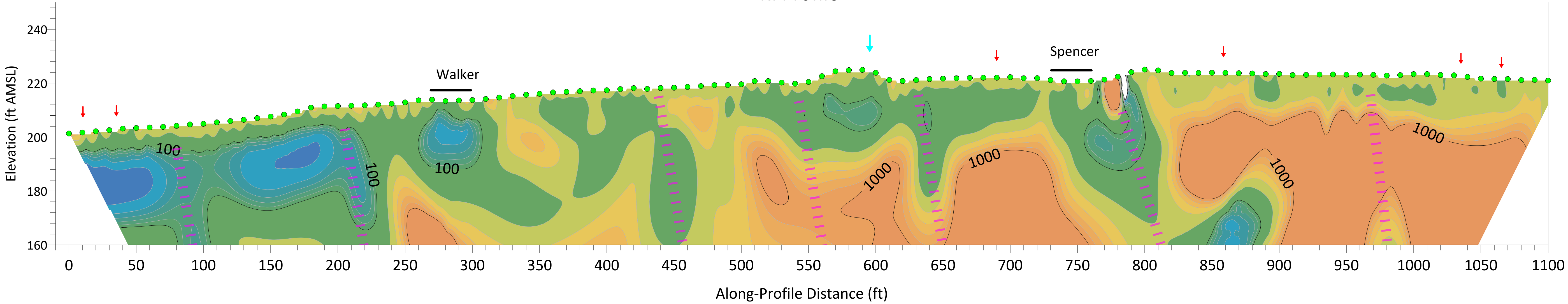
BUCKS COUNTY, PA

Figure 5: ERI and Seismic Profiles
Profile 1

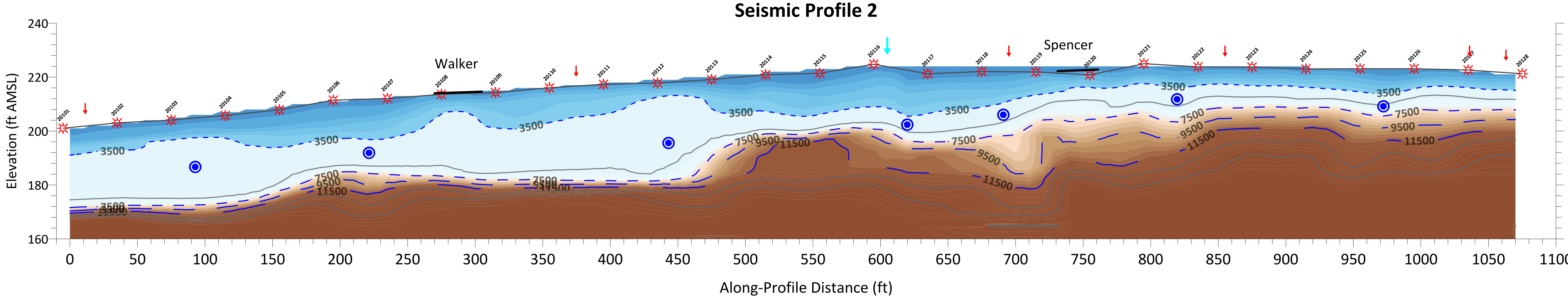
Geophysical Survey
Upper Makefield Site

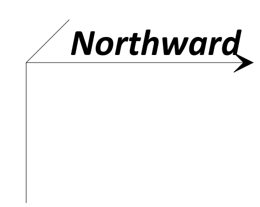
UPPER MAKEFIELD TOWNSHIP

ERI Profile 2

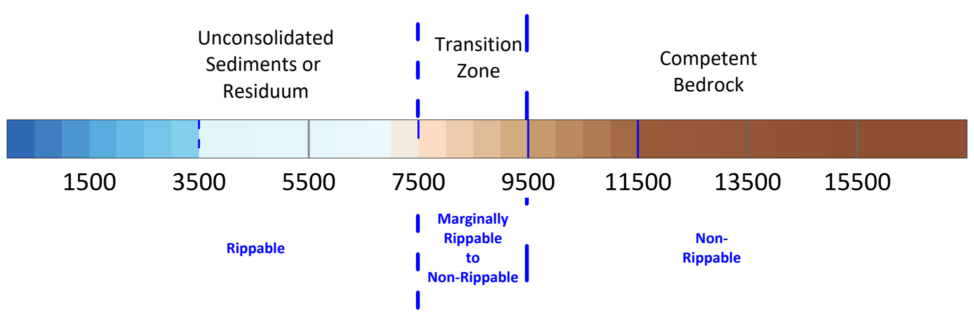


Seismic Profile 2





Relative P-Wave Velocity (fps)



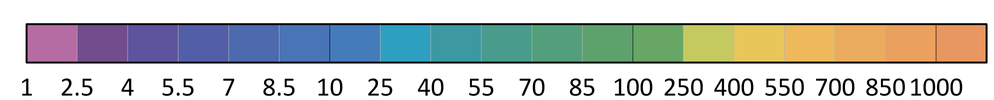
Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature

Rippability Average P-wave Velocity (fps)

1,347
3,863
16,049

Electrical Resistivity (Ohm·m)



Notes:
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Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

SURVEY DATE:	05/08/2025
RETTEW No.:	096303386
REVIEWED BY:	FKB
DRAWN BY:	CHR
REVISION DATE:	07/24/2025
SCALE:	GRAPHICAL
FIGURE NO.	6 of 14

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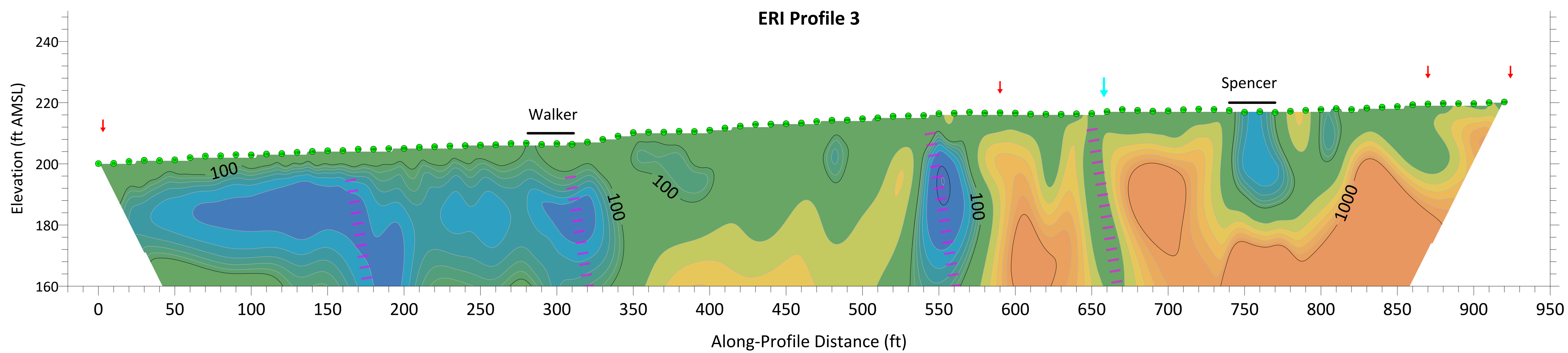
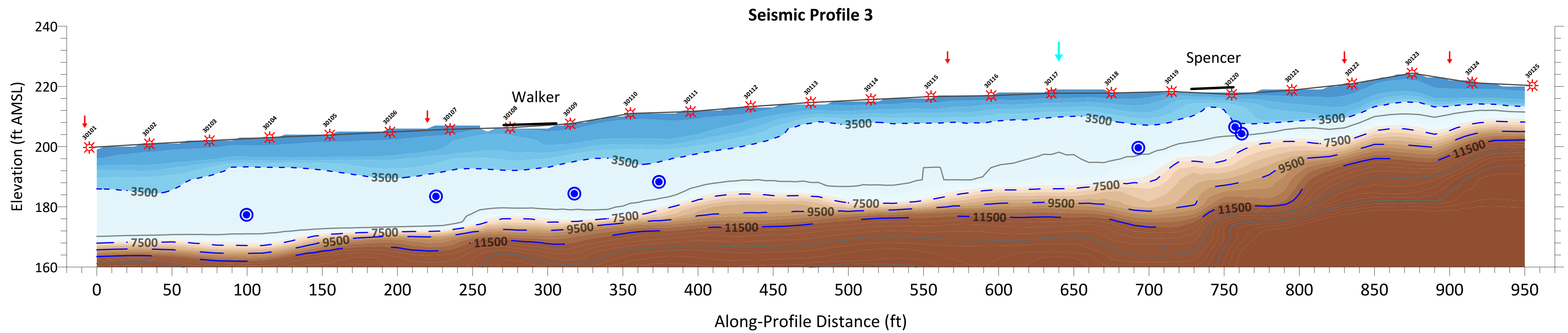
Figure 6: ERI and Seismic Profiles
Profile 2

Geophysical Survey
Upper Makefield Site

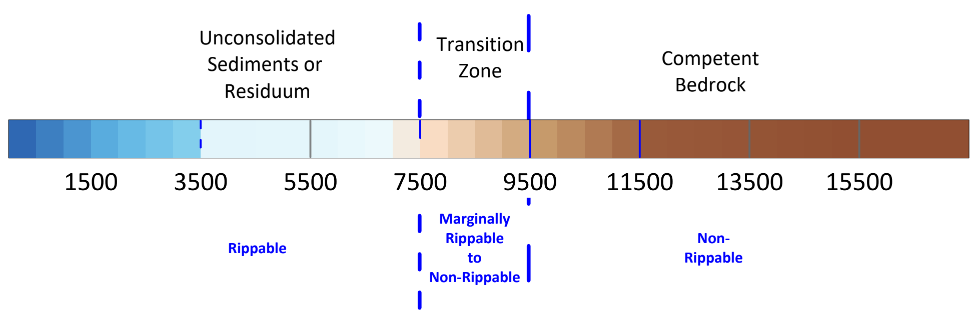
BUCKS COUNTY, PA
UPPER MAKEFIELD TOWNSHIP





Northward

Relative P-Wave Velocity (fps)



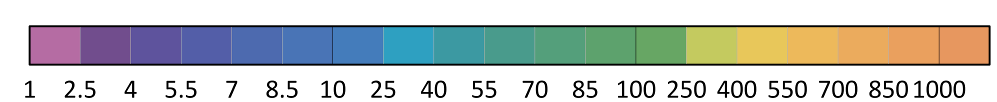
Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature

Rippability Average P-wave Velocity (fps)

1,347
3,863
16,049

Electrical Resistivity (Ohm·m)



Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

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DRAWN BY: CHR
REVISION DATE: 07/24/2025
SCALE: GRAPHICAL
FIGURE NO.: 7 of 14

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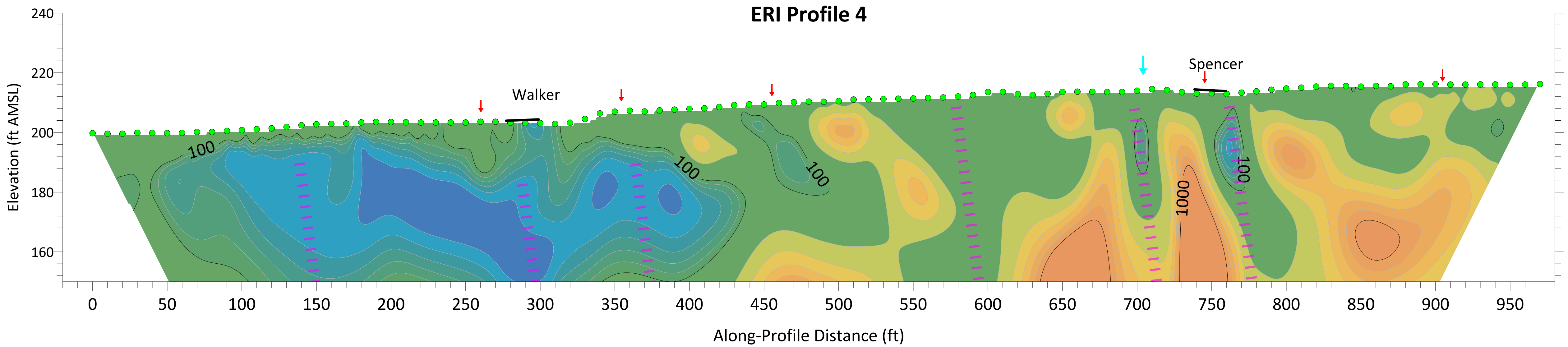
Figure 7: ERI and Seismic Profiles Profile 3

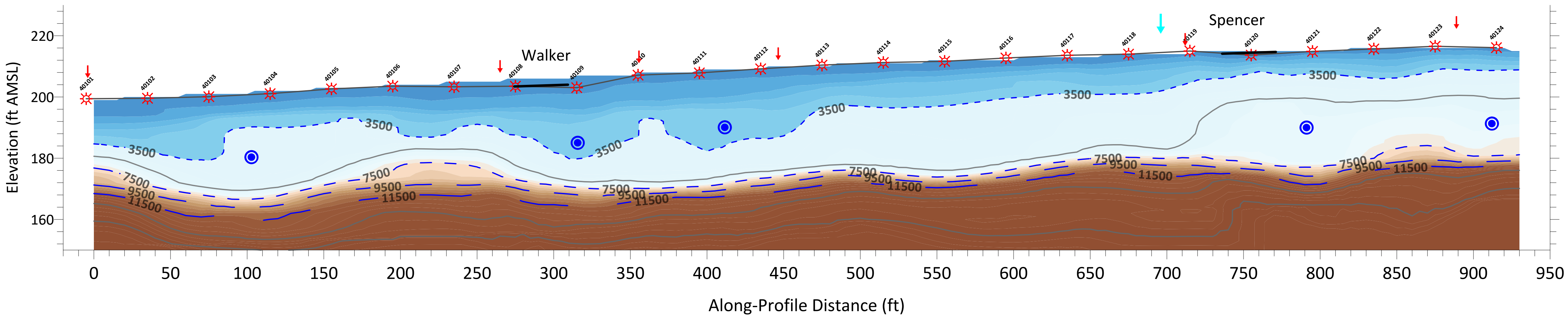
Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP

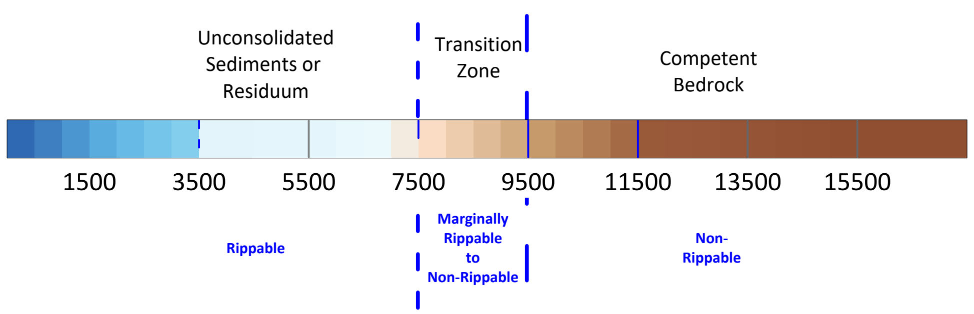
ERI Profile 4



Seismic Profile 4



Relative P-Wave Velocity (fps)



Legend

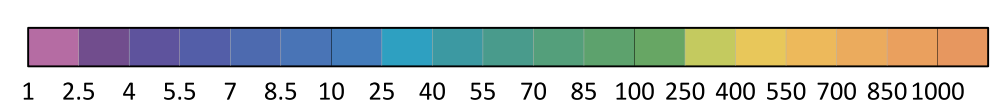
- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature

Northward

Rippability Average P-wave Velocity (fps)

1,347
3,863
16,049

Electrical Resistivity (Ohm·m)



Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

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FIGURE NO.	8 of 14

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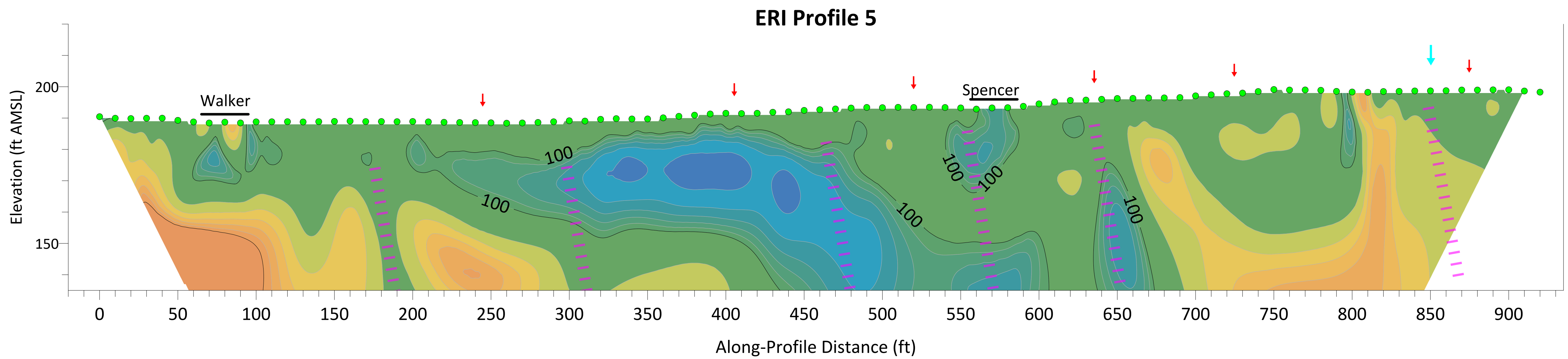
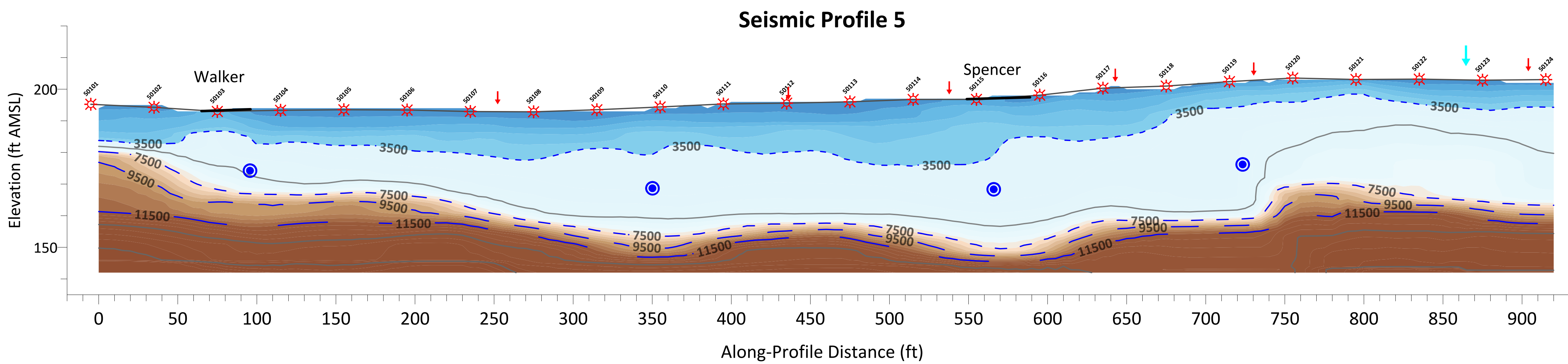
Figure 8: ERI and Seismic Profiles
Profile 4

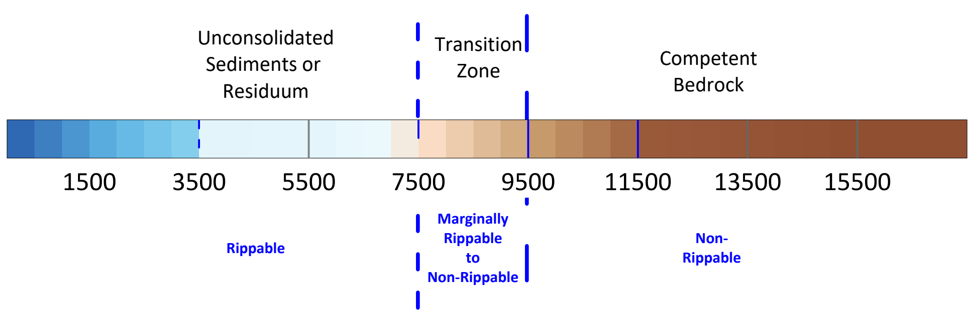
Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP





Relative P-Wave Velocity (fps)



Legend

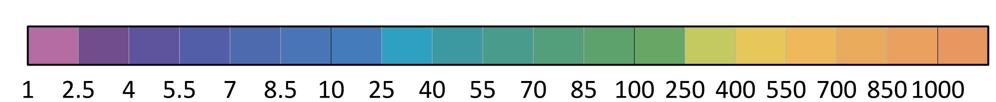
- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature

Northward

Rippability Average P-wave Velocity (fps)

1,347
3,863
16,049

Electrical Resistivity (Ohm·m)



Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

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FIGURE NO.	9 of 14

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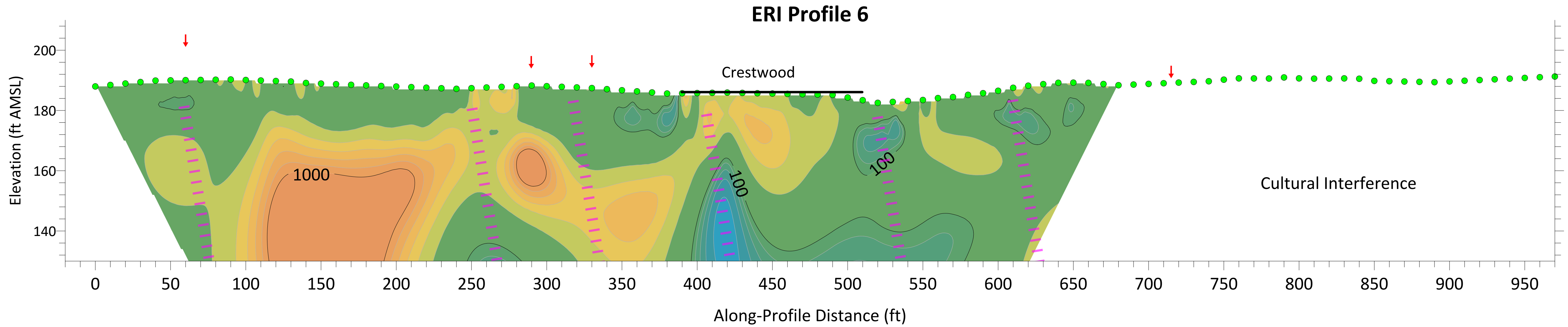
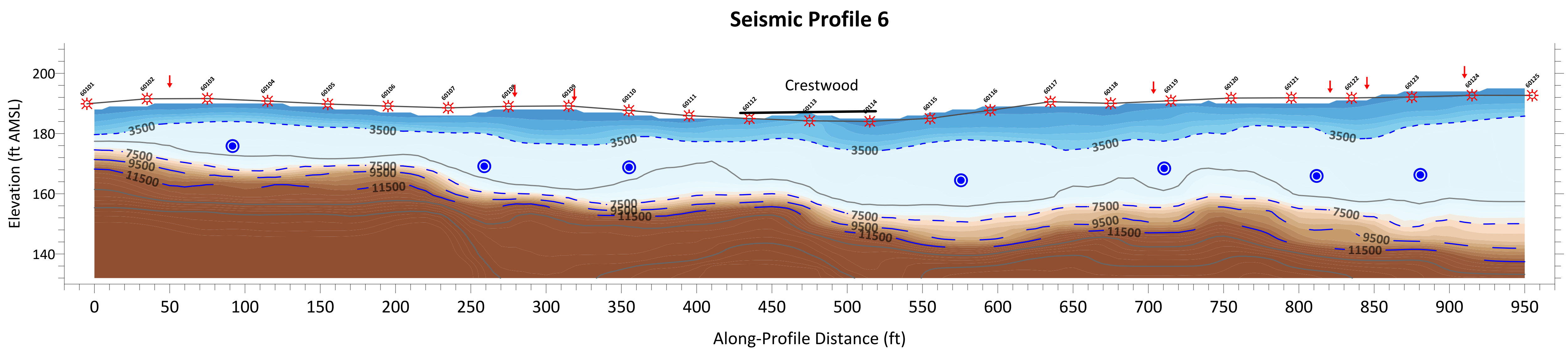
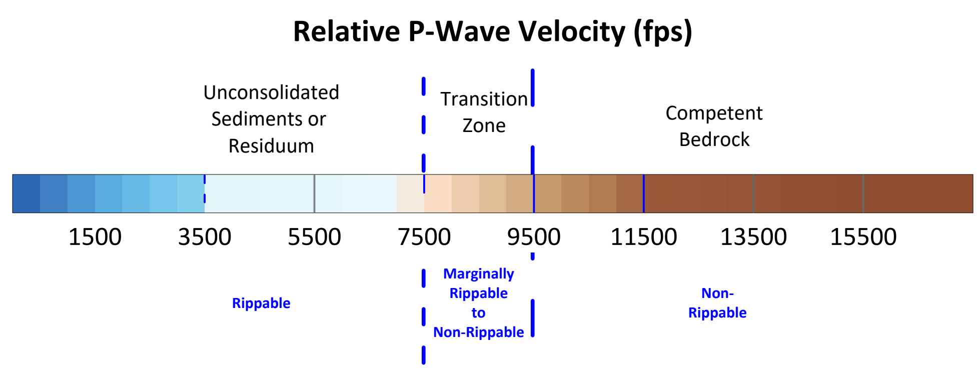
Figure 9: ERI and Seismic Profiles
Profile 5

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP

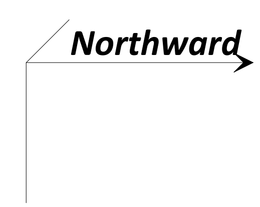






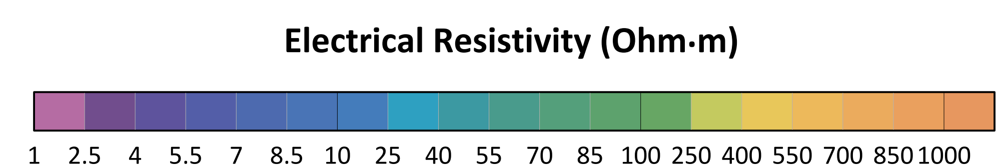
Legend

- ERI Electrode
- Photo/Topo Linears
- Suspected Overall Fracture Trend
- Inferred Fracture (from ERI)
- Seismic Shot Location
- Inferred Seismic Refraction Feature



Rippability Average P-wave Velocity (fps)

1,347
3,863
16,049



Notes:
Resistivity data acquired using AGI Super Sting 56 channels, 10-ft electrode spacing, dipole-dipole arrays.
Resistivity models generated with EarthImager2D by AGI.
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.

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FIGURE NO.:	10 of 14

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Figure 10: ERI and Seismic Profiles
Profile 6

Geophysical Survey
Upper Makefield Site

BUCKS COUNTY, PA
UPPER MAKEFIELD TOWNSHIP

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SURVEY DATE: 06/12/2025
RETTEW No.: 0963003386
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DRAWN BY: CHR
REVISION DATE: 07/24/2025
SCALE: 1"=160'
FIGURE NO. **11 of 14**

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Figure 11: ERI Anomaly Locations

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP
BUCKS COUNTY, PA

REDACTED

SURVEY DATE: 06/12/2025
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DRAWN BY: CHR
REVISION DATE: 07/24/2025
SCALE: 1"=160'
FIGURE NO. **12 of 14**

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Figure 12: ERI Anomaly Alignments

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP
BUCKS COUNTY, PA

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Figure 13: Inferred Bedrock Elevations
9,500 fps Velocity Contour

Geophysical Survey
Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP
BUCKS COUNTY, PA

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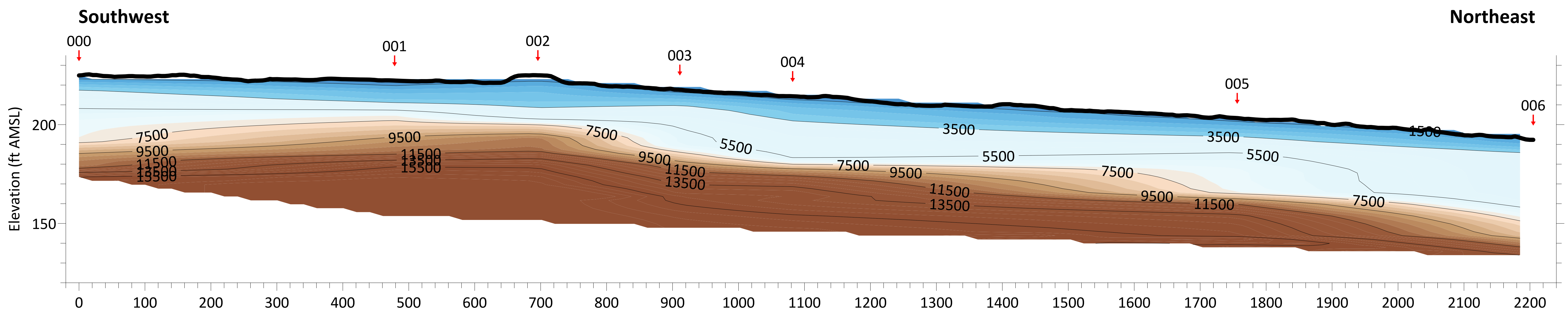
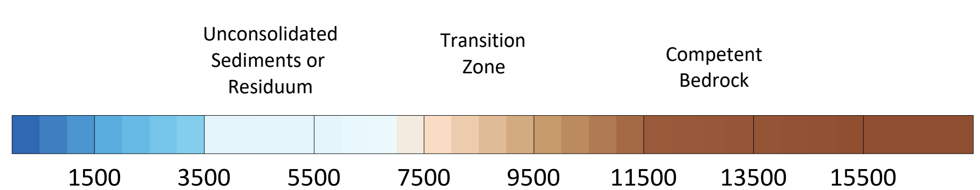
SURVEY DATE:	06/12/2025
RETTEW No.:	0963003386
REVIEWED BY:	FKB
DRAWN BY:	CHR
REVISION DATE:	08/07/2025
SCALE:	1"=160'
FIGURE NO.	13 of 14



Relative P-Wave Velocity (fps)



Legend

↓ Seismic Profile Crossing Points

Notes:
Seismic data from Geometrics 24-channel Geode with 4.5-Hz geophones.
Relative seismic velocity models from SeisImager (by Oyo Corporation) tomographic inversions.
Contours interpolated from individual profiles (**Figures 4-10**).
See **Figure 1** for suspected overall fracture trend.
3x vertical exaggeration.

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RETTEW No.: 0963003386
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REVISION DATE: 07/24/2025
SCALE: 1"=160' Hrz, 1"=53.33' Vrt
FIGURE NO.: **14 of 14**

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Figure 14: Interpolated Seismic Profile Along the Suspected Overall Fracture Trend

Geophysical Survey Upper Makefield Site

UPPER MAKEFIELD TOWNSHIP
BUCKS COUNTY, PA