Progress Energy

Serial: NPD-NRC-2008-050 10CFR52.79
November 17, 2008

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

SHEARON HARRIS NUCLEAR POWER PLANT, UNITS 2 AND 3
DOCKET NOS. 52-022 AND 52-023
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 019 RELATED TO STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

Reference: Letter from Manny Comar (NRC) to James Scarola (PEC), dated September 25, 2008, "Request for Additional Information Letter No. 019 Related to SRP Section 02.05.04 for the Harris Units 2 and 3 Combined License Application"

Ladies and Gentlemen:

Progress Energy Carolinas, Inc. (PEC) hereby submits our response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter.

A response to each NRC request is addressed in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Shearon Harris Nuclear Power Plant Units 2 and 3 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (919) 546-6107.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on November 17, 2008.

Sincerely,

Garry D. Miller
General Manager
Nuclear Plant Development

Enclosure/Attachments

cc : U.S. NRC Director, Office of New Reactors/NRLPO
U.S. NRC Office of Nuclear Reactor Regulation/NRLPO
U.S. NRC Region II, Regional Administrator
U.S. NRC Resident Inspector, SHNPP Unit 1
Mr. Manny Comar, U.S. NRC Project Manager

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NRO

**Shearon Harris Nuclear Power Plant Units 2 and 3
Response to NRC Request for Additional Information Letter No. 019 Related to
SRP Section 02.05.04 for the Combined License Application, dated September 25, 2008**

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.05.04-1	H-0115	Response enclosed – see following pages
02.05.04-2	H-0116	Response enclosed – see following pages

Attachments	Associated NRC RAI #	Pages Included
Figure A-1	02.05.04-1	1 page
Figure A-2	02.05.04-1	1 page
Figure A-3	02.05.04-1	1 page
Figure A-4	02.05.04-1	1 page
Figure A-5	02.05.04-1	1 page
Figure A-6	02.05.04-1	1 page
Figure A-7	02.05.04-1	1 page
Figure A-8	02.05.04-1	1 page
Report Number 06-144c	02.05.04-2	23 pages

NRC Letter No.: HAR-RAI-LTR-019

NRC Letter Date: September 25, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.04-1

Text of NRC RAI:

In Section 2.5.4.4.1.7, you stated that "Upon review of the MASW survey results, V_s interpreted by this method are not consistent with results from other methods, and the method is not considered representative of the HAR 2 and HAR 3 subsurface materials. The MASW results are therefore not further considered in this FSAR". Please provide a detailed assessment of why the results obtained by this method should not be considered representative of the subsurface structures beneath the nuclear islands. Explain apparent problems that might have occurred during data collection and/or data processing.

PGN RAI ID #: H-0115

PGN Response to NRC RAI:

A copy of the MASW report (Technos, 2007) is provided in the response to NRC RAI # 02.05.04-2. Figures 2 and 3 of the MASW report show the two-dimensional MASW profiles generated at HAR 2 and HAR 3 (called Area A and Area B, respectively, in the report). MASW survey locations are shown on Figure 1 of the MASW report and also on Figures A-1 and A-2 attached to this response.

Determination that the MASW data was not considered representative of subsurface conditions at the HAR sites was based on the following considerations:

1. A timeline of V_s field investigation activities and decision points.
2. A detailed comparison of the MASW V_s results with those obtained from other V_s survey methods. Significant differences are observed between the results of these methods.
3. A discussion of the apparent problems that may have occurred during data collection and/or data processing. The limitations of two-dimensional MASW surveys relative to other methods are also summarized.

1. Timeline of investigation activities and decision points regarding MASW.

The MASW surveys were performed in September 2006, after completion of the majority of the geotechnical boreholes at the HAR sites (including boreholes BPA-1 through BPA-46) by the end of August 2006. At the time the MASW surveys were performed, suspension logging surveys had only been performed in Boreholes BPA-5, BPA-25, and BPA-39. The intent of the MASW surveys was to provide independent measurements of V_s values for comparison with suspension logging results in upper layers of soil and rock and to acquire information about surficial soil and rock variability for use in developing representative soil cross-sections.

The preliminary MASW V_s profiles from these surveys (the same as Figures 2 and 3 of the Technos 2007 report) were initially reviewed in October 2006 and compared with the suspension logging V_s results at boreholes BPA-5 and BPA-25 at that time. Figures A-1 and A-2 (attached) are plan views showing the locations of these two boreholes with respect to the MASW survey stations, and Figures A-3 and A-4 (attached) show the corresponding borehole locations along the MASW survey V_s profiles.

Significant differences between the V_s results from the MASW surveys and the adjacent suspension logging surveys were apparent upon this initial comparison (see Number 2 of this response for details). Based on these differences, a decision was made to perform additional suspension logging surveys and perform alternate investigative methods to help resolve the discrepancies. The alternate methods employed were one-dimensional SASW surveys and downhole surveys. The SASW method was selected because of the higher order data processing used to interpret V_s. The downhole method was added to provide comparative values of V_s at the same depths as evaluated by suspension logging.

The additional investigations to characterize the V_s profiles were performed at the HAR sites in November and December 2006. Four deep boreholes (BPA-47 through BPA-50) were advanced at the site, and suspension logging surveys were performed in each. Downhole surveys were performed in boreholes BPA-48 and BPA-49, and SASW surveys were centered near boreholes BPA-5, BPA-25, BPA-48, and approximately 60 feet west of BPA-49. The SASW surveys near BPA-5, BPA-25, and west of BPA-49 were performed coincident with the MASW survey lines to allow direct comparison of the MASW and SASW results. The suspension and downhole surveys in boreholes BPA-47 through BPA-50 and the SASW survey performed at BPA-48 were also available for comparison with the MASW data, but the boreholes were not located directly on the MASW lines. The locations of these four boreholes were selected based on reasons outlined in FSAR Subsection 2.5.4.2.1.1.1, in addition to allowing comparison with the MASW results.

The V_s results from the additional suspension logging, downhole, and SASW surveys were initially compared with the MASW results in January and February 2007. Detailed comparisons are presented in Number 2 of this response. As described, significant corroboration was found between the results of the suspension logging, downhole, and SASW results at each location, whereas clear discrepancies between these method results and the MASW results were found at some depth intervals.

CH2M HILL also engaged GeoVision Geophysical Services to perform a separate review of the MASW survey data and to evaluate possible reasons for the discrepancies. Technos and GeoVision were in direct communication during this review, and GeoVision reviewed sample MASW data files and the associated processing. GeoVision concluded that the MASW surveys had been performed and the data processed in accordance with standard practice, but that site conditions (such as dipping beds at the contact between soil and rock and zones of significant velocity contrasts) likely resulted in limitations in the frequency range of the MASW surface wave dispersion data, which would directly affect the accuracy of the shear wave velocity interpretations. GeoVision documented their conclusions in a letter to CH2M HILL, dated February 19, 2007. Additional details on these possible MASW data limitations, based on the GeoVision letter, are presented in Number 3 of this response.

GeoVision recommended that the MASW velocity models not be used for validation purposes but for identification of possible lateral variations of subsurface velocity structure (i.e., such as to help optimize location of boreholes). Technos concurred with this recommendation, and the subsequent final MASW report (Technos 2007) presents this same recommendation.

Numbers 2 and 3 provide additional details.

2. Comparison of HAR MASW results with other V_s data sources.

Figures A-5 through A-8 (attached) present plots of available V_s data (from suspension logging, downhole, SASW, and MASW surveys) with depth collected within or near boreholes BPA-5, BPA-41, BPA-25, and BPA-27. Locations of the boreholes and SASW survey locations relative to the MASW survey lines are shown on Figures A-1 through A-4 (attached). The MASW V_s

data shown at specific survey stations nearest borehole locations on the two-dimensional MASW profiles (Figures A-3 and A-4) were used to create the one-dimensional profiles shown on Figures A-5 through A-8 for the corresponding boreholes.

Significant observations from comparison of these V_s data at each HAR site are discussed below. Velocity comparisons in the upper 10 to 15 feet are not specifically discussed in all locations observed, as this depth interval appears to be too shallow to make reliable MASW velocity measurements. Measurement limitations at shallow depths are discussed later in this response.

HAR 2: Variations between the MASW results and results from other methods are apparent at HAR 2, as follows:

- Near BPA-5, as shown on Figure A-5, the MASW survey results indicate significantly lower V_s than the associated suspension logging and SASW methods in the shallow interval between approximate depths of 10 to 20 ft bgs, directly under an anomalous high velocity reported in the upper few feet of the MASW profile (over 5000 fps at ground surface). Below this interval, between approximately 30 and 35 ft bgs, the MASW survey does not detect a slight inversion observed in the suspension logging results. In this location, the size of the inversion detected by the suspension logging method may be too thin to affect the MASW results. Other than these shallow intervals, the deeper MASW results are generally consistent with the other methods.
- MASW survey results near borehole BPA-41 are shown on Figure A-6, along with the suspension logging results from nearby boreholes BPA-47 and BPA-48 and downhole and SASW survey results at borehole BPA-48. These borehole locations relative to the MASW survey line are shown on Figure A-1; the MASW survey line was advanced near the BPA-41 location, and BPA-47 and BPA-48 bound this location to the north and south. As shown on Figure A-6, the MASW results are generally consistent with results of other methods performed north and south of BPA-41. One significant exception is the low-V_s interval shown on the MASW profile between approximate depths of 50 to 65 ft bgs, in which the lowest MASW V_s result (approximately 3500 fps) is approximately 40 percent lower than the corresponding results from other methods at nearby boreholes BPA-47 and BPA-48 at the same depth. Review of the BPA-41 borehole log, which was advanced at the MASW profile location, does not indicate any features such as low RQD, low recovery, or clay seams within this depth range that would indicate such an inversion is present.
- The locations of boreholes BPA-6 and BPA-7 are shown along the MASW profile on Figure A-3. No supplemental V_s data from other methods are available at these locations. As shown on Figure A-3, a V_s inversion is indicated commencing north from BPA-7 and extending past BPA-6, between approximate elevation 195 and 215 feet. The MASW data indicate that the low V_s within this interval is less than 1800 fps. Review of the BPA-7 borehole log does not indicate any features (low RQD or recovery, clay seams, etc.) that would support such an inversion in this elevation range. The BPA-6 borehole log shows some reduction of RQD in this elevation range, but nothing to indicate such a low V_s. Deeper weathered rock and soil intervals encountered at BPA-6 (especially between elevation 160 and 175 feet) are below the depth extent of the MASW investigation.

HAR 3: Variations between the MASW results and results from other methods are apparent at HAR 3, as follows:

- Near BPA-25, as shown on Figure A-7, the MASW survey results indicate significantly lower V_s than the associated suspension logging and SASW methods between approximate depths of 30 to 70 ft bgs. The MASW results are typically 20 to 50 percent lower than those from the other methods in this depth range. This is a depth interval where a few relatively low V_s values were observed among the predominantly higher V_s values in the suspension logging results, due to differential weathering and the occurrence of thin fracture intervals and clay seams; therefore, V_s does not increase consistently with depth. The V_s results approximately 30 feet west of the BPA-25 location on the MASW profile are closer to, but still lower than, results from suspension logging and SASW profiles at BPA-25, as shown on Figure A-4.

- Near BPA-27, as shown on Figure A-8, the MASW survey results indicate significantly lower V_s than the other methods between approximate depths of 25 to 65 ft bgs. As with BPA-25, this is a depth interval where relatively low V_s values were observed among the predominantly higher V_s values in the suspension logging results, due to differential weathering and the occurrence of thin fracture intervals and clay seams; therefore, V_s does not increase consistently with depth. The suspension logging and downhole survey results shown on Figure A-8 were performed in borehole BPA-49, which is located approximately 60 feet east of the MASW location, whereas the SASW survey was collocated on the MASW line and centered very close to BPA-27. The lowest MASW result in this elevation interval (V_s of approximately 2100 fps at approximately 58 ft bgs) is more than 50 percent lower than the results of other methods at similar depth.

Based on the above data comparisons at HAR 2 and HAR 3, it is apparent that the MASW survey method often produced lower V_s results than the other survey methods. The MASW results are often 30 to 50 percent lower than those from the other methods at similar depths, especially at locations where V_s does not increase consistently with depth.

3. Discussion of possible MASW data collection or processing problems.

GeoVision Geophysical Services provided a review of the MASW data and associated processing in January/February 2007, with coordination support from Technos, Inc. GeoVision evaluated the MASW shot record data files and corresponding processing results for MASW surveys near BPA-5, BPA-25, BPA-48, and BPA-49, including comparison with the adjacent SASW surveys and suspension logging results. During their review, GeoVision independently generated the dispersion curves using an alternative program (Pickwin95) for comparison with the dispersion curves generated by Technos, Inc. using SurfSeis. They also considered the possibility that alternate MASW velocity models could be interpreted which better fit the SASW and suspension logging datasets. Detailed comparisons of the datasets near BPA-25 and BPA-49 were performed for this purpose.

The key findings and recommendations from GeoVision's review of the MASW data are summarized as follows:

- It was clear that the investigation was conducted using experienced personnel and state of the practice acquisition and analysis procedures.
- Use of alternate values of Poisson's ratio and density for soil and rock would have relatively small effect on the resulting V_s values.
- The smallest wavelength extracted from the MASW data is about 20 feet (possibly less at HAR 2), resulting in the MASW model being sensitive to only the average material properties in the upper 10 feet. This limitation is also mentioned in the Technos report (p. 4, second paragraph in "Results"), which states that "Many of the shot records produced dispersion curves that were not well defined at the higher frequencies. Therefore, the shear-wave model values in the uppermost 10 ft are not well constrained and the velocities should be interpreted with some level of caution." This may have resulted in the anomalous V_s

inversions seen in the upper 20 ft bgs for the MASW profiles at HAR 2 (Figures A-3, A-5, and A-6).

- The dispersion curves in the 40- to 70-foot wavelength range at BPA-25 and BPA-49 may have overestimated phase velocities (and hence underestimated layer V_s) due to mechanisms such as higher mode contamination, surface wave scattering, and varying bedrock depth. This may have led to the inverse MASW models being significantly different from the SASW and borehole velocity measurements. The atypical shapes of the dispersion curve in this frequency range, especially at BPA-49, are indicative of possible higher mode influence.
- The MASW surface wave dispersion data collected at the HAR sites is consistent with the SASW dispersion data but does not cover as wide a wavelength/frequency range as is typical for two-dimensional surface wave imaging. Alternate V_s models that better fit borehole/SASW velocity data could be generated for the MASW data collected in the vicinity of borehole BPA-25 (i.e., generally higher interpreted layer V_s). Better-fitting velocity models could not be generated for the MASW data collected in the vicinity of BPA-49, unless the assumption was made that a portion of the surface wave dispersion curve contained artifacts due to dominant higher modes, dipping layers, undulating bedrock, etc.
- Surface wave dispersion data obtained during two-dimensional MASW surveys is not always as robust (i.e., less averaging, narrower bandwidth, more artifacts or noise) as that derived from one-dimensional SASW/MASW soundings, which utilize forward and reverse source locations, multiple source types, source offsets, receiver spacings, etc. Therefore, unless geologic conditions are ideal, velocity models resulting from inversion of two-dimensional MASW data sets cannot be expected to be as accurate as those from one-dimensional soundings.
- In general, GeoVision does not typically recommend that two-dimensional MASW models be used for validation of borehole velocity measurements because surface wave dispersion data often has limited bandwidth relative to that generated from a highly focused one-dimensional SASW or MASW sounding. The two-dimensional MASW method uses a fixed source to receiver array geometry, a necessary sacrifice for two-dimensional imaging, and does not benefit from high data redundancy and averaging generated from the forward and reverse shot geometry, multiple source types and offsets, variable receiver spacing, etc. of one-dimensional sounding techniques.
- Based on their review of the site-specific data and their experience with the limitations of surface geophysical methods, GeoVision recommended that the MASW velocity models not be used for validation purposes but for the identification of possible lateral variation of subsurface velocity structure (i.e., such as to help optimize location of boreholes).

Based on the observations and recommendations from GeoVision (including potential problems with data collection and processing as summarized in the bulleted list above) and on the discrepancies between the MASW data and V_s data from other methods described in Number 2, the MASW V_s values were determined not to be sufficiently representative of HAR subsurface conditions to serve as a basis for HAR engineering analyses. For this reason, the MASW data were not included in the HAR FSAR.

References:

Technos, Inc. "MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina". Technos Report Number 06-144c. February 15, 2007 (Revised July 18, 2007).

Associated HAR COL Application Revisions:

The following change will be made to the HAR FSAR in a future amendment:

1. The citation for Reference 2.5.4-229 will be revised from:

   Technos, MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina, February 15, 2007.

   to read:

   Technos, Inc. "MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina". Technos Report Number 06-144c. February 15, 2007 (Revised July 18, 2007).

Attachments/Enclosures:

Figure A-1, Geophysical Survey Locations at HAR 2

Figure A-2, Geophysical Survey Locations at HAR 3

Figure A-3, MASW Profiles at HAR 2 (Area A)

Figure A-4, MASW Profiles at HAR 3 (Area B)

Figure A-5, V_S Data Comparisons – Near BPA-5

Figure A-6, V_S Data Comparisons – Near BPA-41

Figure A-7, V_S Data Comparisons – Near BPA-25

Figure A-8, V_S Data Comparisons – Near BPA-27

NRC Letter No.: HAR-RAI-LTR-019

NRC Letter Date: September 25, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.05.04-2

Text of NRC RAI:

Please provide a copy of Reference 2.5.4-229 detailing the multi-channel analysis of surface wave (MASW) site investigation results for the staff to be able to provide an independent evaluation of the procedures and results obtained by this method.

PGN RAI ID #: H-0116

PGN Response to NRC RAI:

A copy of Reference 2.5.4-229 is provided as an attachment to this response. Note that the correct reference citation should read as follows:

Technos, Inc. "MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina". Technos Report Number 06-144c. February 15, 2007 (Revised July 18, 2007).

This reference citation will be changed accordingly, as presented in the response to NRC RAI # 02.05.04-1.

Associated HAR COL Application Revisions:

See response to NRC RAI # 02.05.04-1.

Attachments/Enclosures:

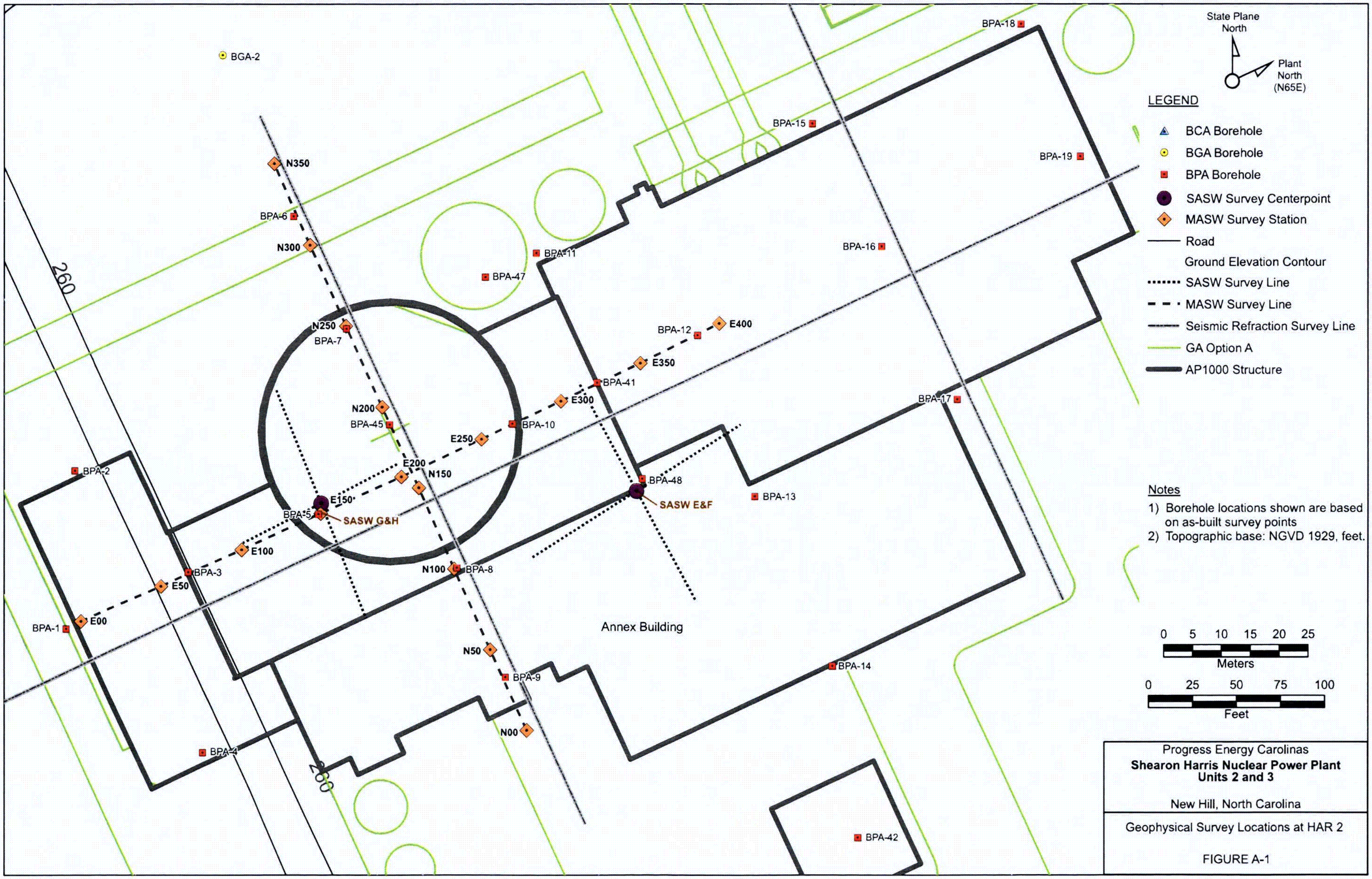
Final Report: MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina, Technos Report Number 06-144c.

List of Attachments:

1. NRC RAI #02.05.04-1 (PGN RAI ID #H-0115):
   a. Figure A-1, Geophysical Survey Locations at HAR 2 (1 page)
   b. Figure A-2, Geophysical Survey Locations at HAR 3 (1 page)
   c. Figure A-3, MASW Profiles at HAR 2 (Area A) (1 page)
   d. Figure A-4, MASW Profiles at HAR 3 (Area B) (1 page)
   e. Figure A-5, V_S Data Comparisons – Near BPA-5 (1 page)
   f. Figure A-6, V_S Data Comparisons – Near BPA-41 (1 page)
   g. Figure A-7, V_S Data Comparisons – Near BPA-25 (1 page)
   h. Figure A-8, V_S Data Comparisons – Near BPA-27 (1 page)

2. NRC RAI #02.05.04-2 (PGN RAI ID #H-0116):

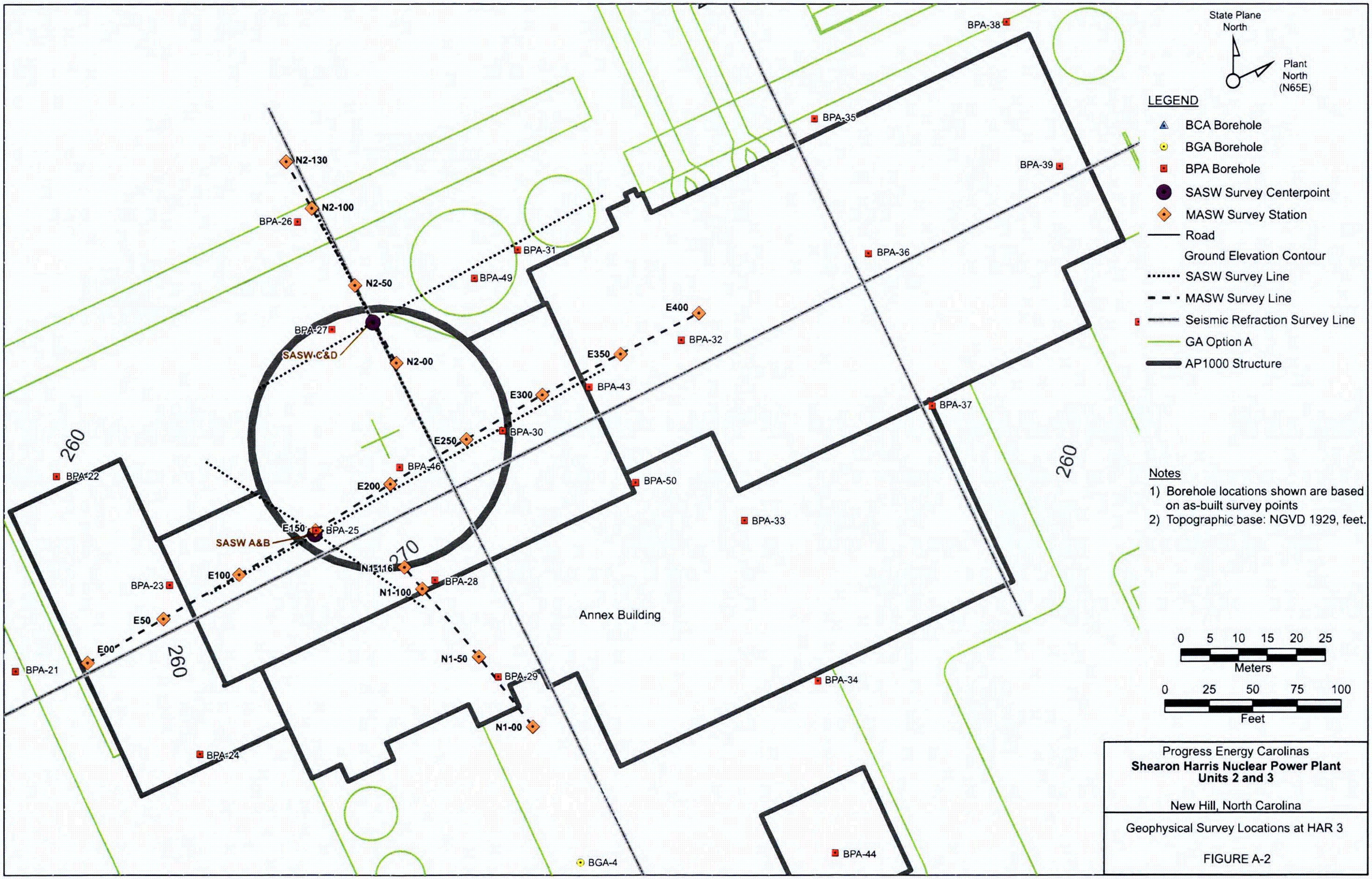
   Final Report: MASW Survey Services – Harris Nuclear Plant – COLA Site – Raleigh, North Carolina, Technos Report Number 06-144c (23 pages)



Progress Energy Carolinas
Shearon Harris Nuclear Power Plant
Units 2 and 3
New Hill, North Carolina

Geophysical Survey Locations at HAR 2

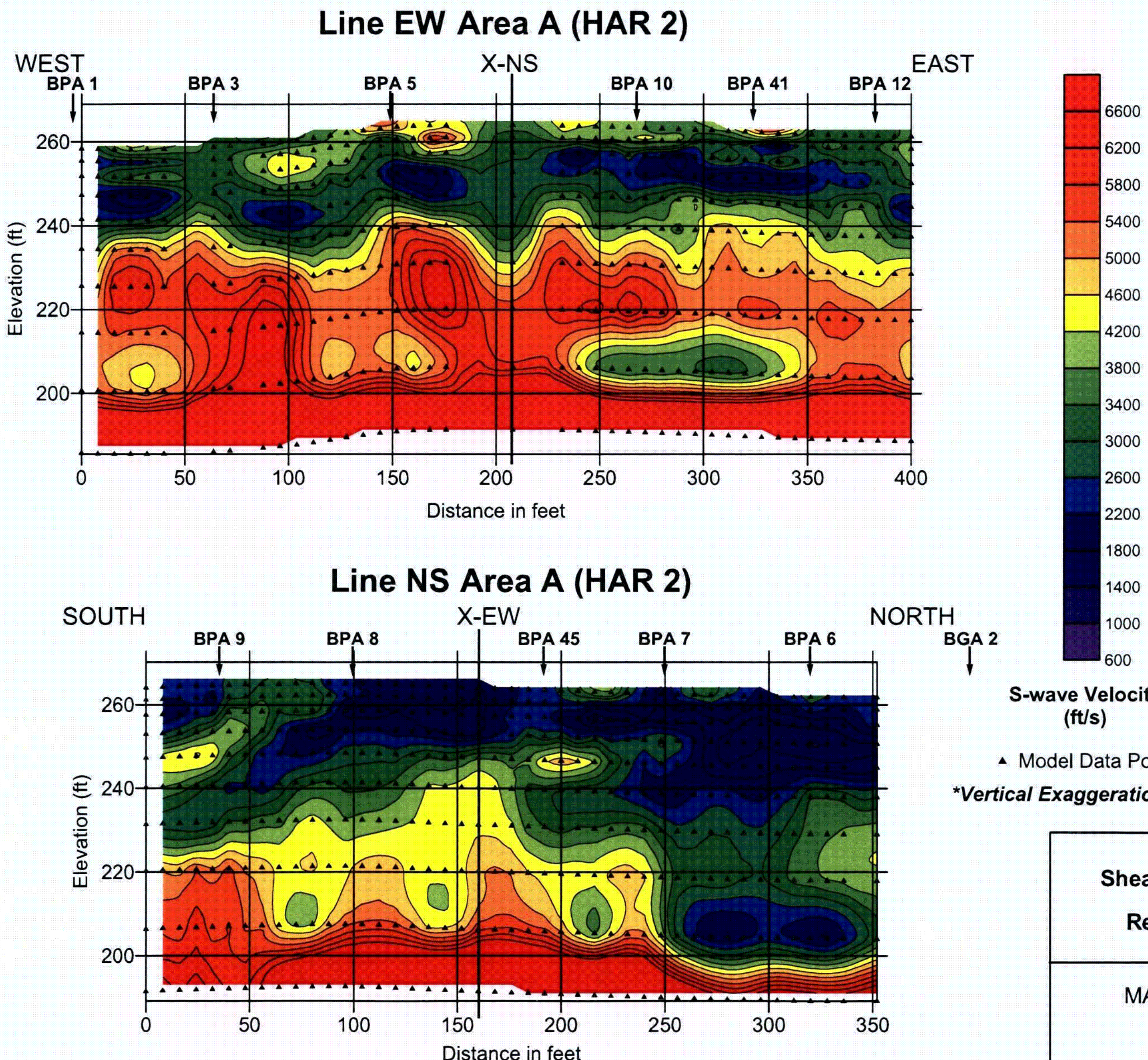
FIGURE A-1



Progress Energy Carolinas
Shearon Harris Nuclear Power Plant Units 2 and 3
New Hill, North Carolina

Geophysical Survey Locations at HAR 3

FIGURE A-2



NOTES:

1) Approximate borehole locations are shown along the top of each profile.
2) Directions "West", "East", and "EW" as shown on this figure correspond to "Plant South" and "Plant North" as presented in the FSAR; likewise, "North", "South", and "NS" as shown on this figure correspond to "Plant West" and "Plant East" as presented in the FSAR.
3) The NS and EW profiles intersect at approximate locations marked "X-NS" and "X-EW" on these profiles.
4) Source: TECHNOS, 2007, FIGURE 2

Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Response to HAR RAI 02.05.04-1

New Hill, North Carolina

MASW Profiles at HAR 2 (Area A)

FIGURE A-3

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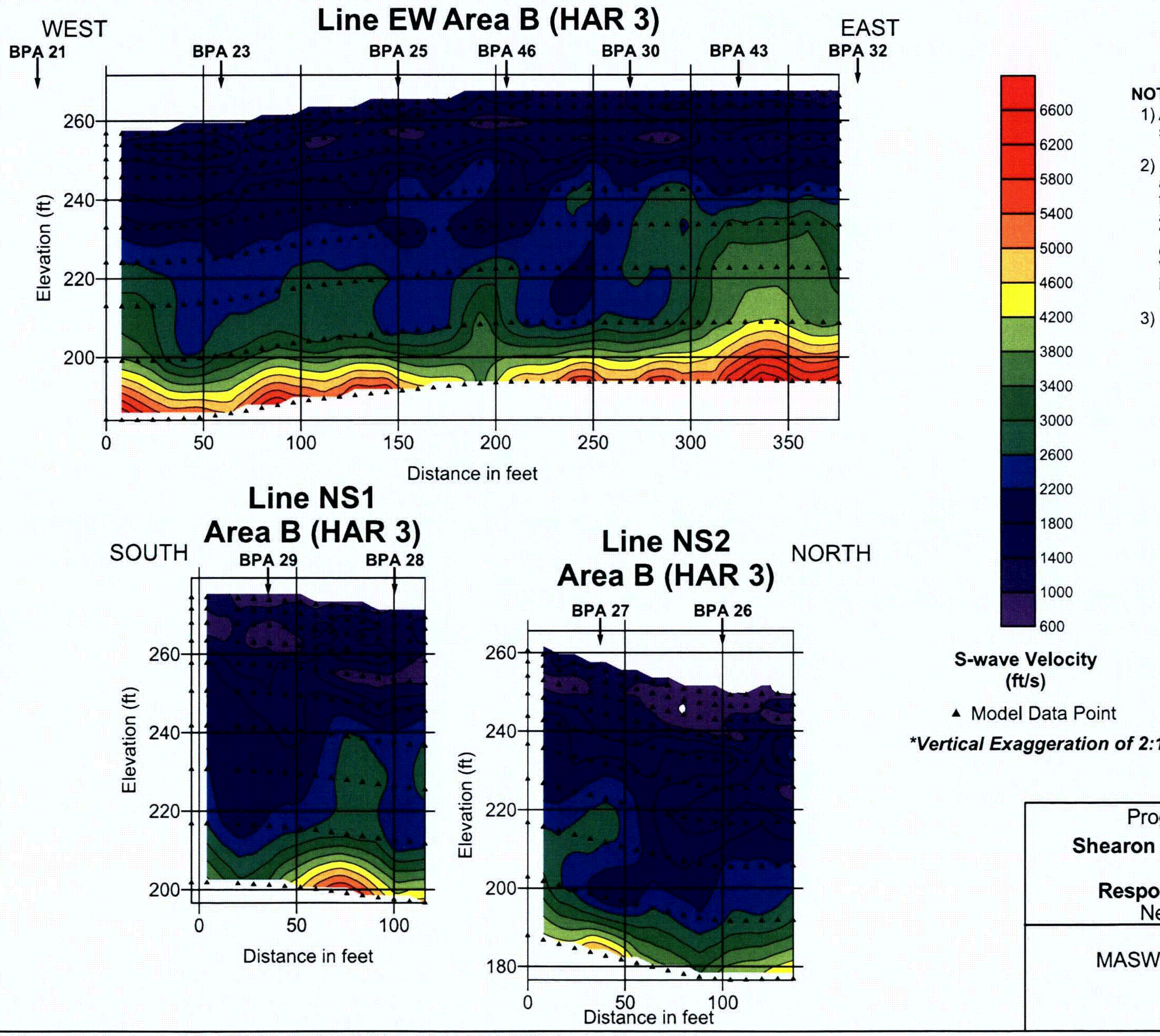

NOTES:

1) Approximate borehole locations are shown along the top of each profile.

2) Directions "West", "East", and "EW" as shown on this figure correspond to "Plant South" and "Plant North" as presented in the FSAR; likewise, "North", "South", and "NS" as shown on this figure correspond to "Plant West" and "Plant East" as presented in the FSAR.

3) Source: TECHNOS, 2007, FIGURE 3

Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Response to HAR RAI 02.05.04-1
New Hill, North Carolina

MASW Profiles at HAR 3 (Area B)

FIGURE A-4

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Figure A-5: V_s Data comparisons - Near BPA-5

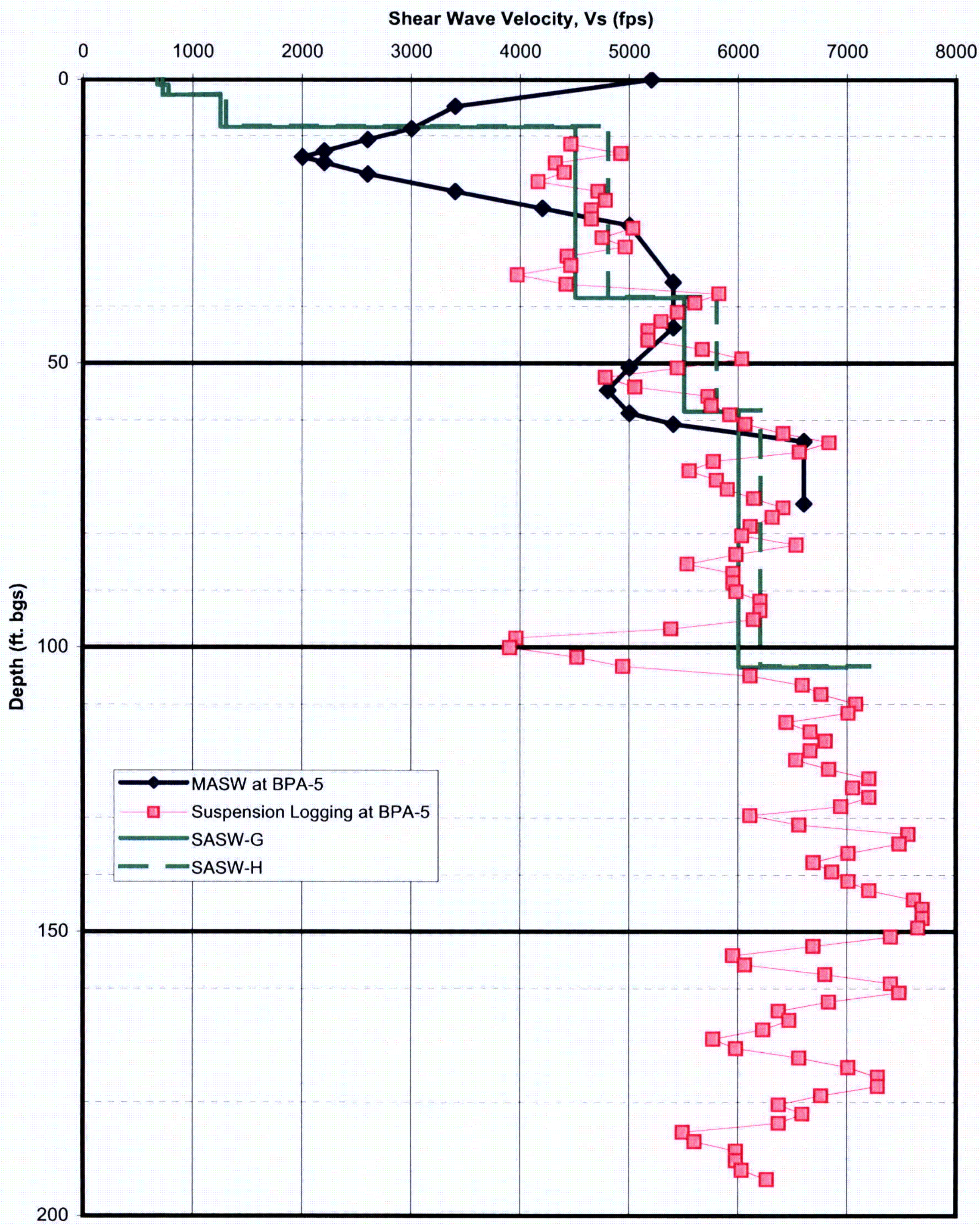


Figure A-6: V_s Data Comparisons - Near BPA-41
(Including BPA-47 and BPA-48 Borehole V_s Data)

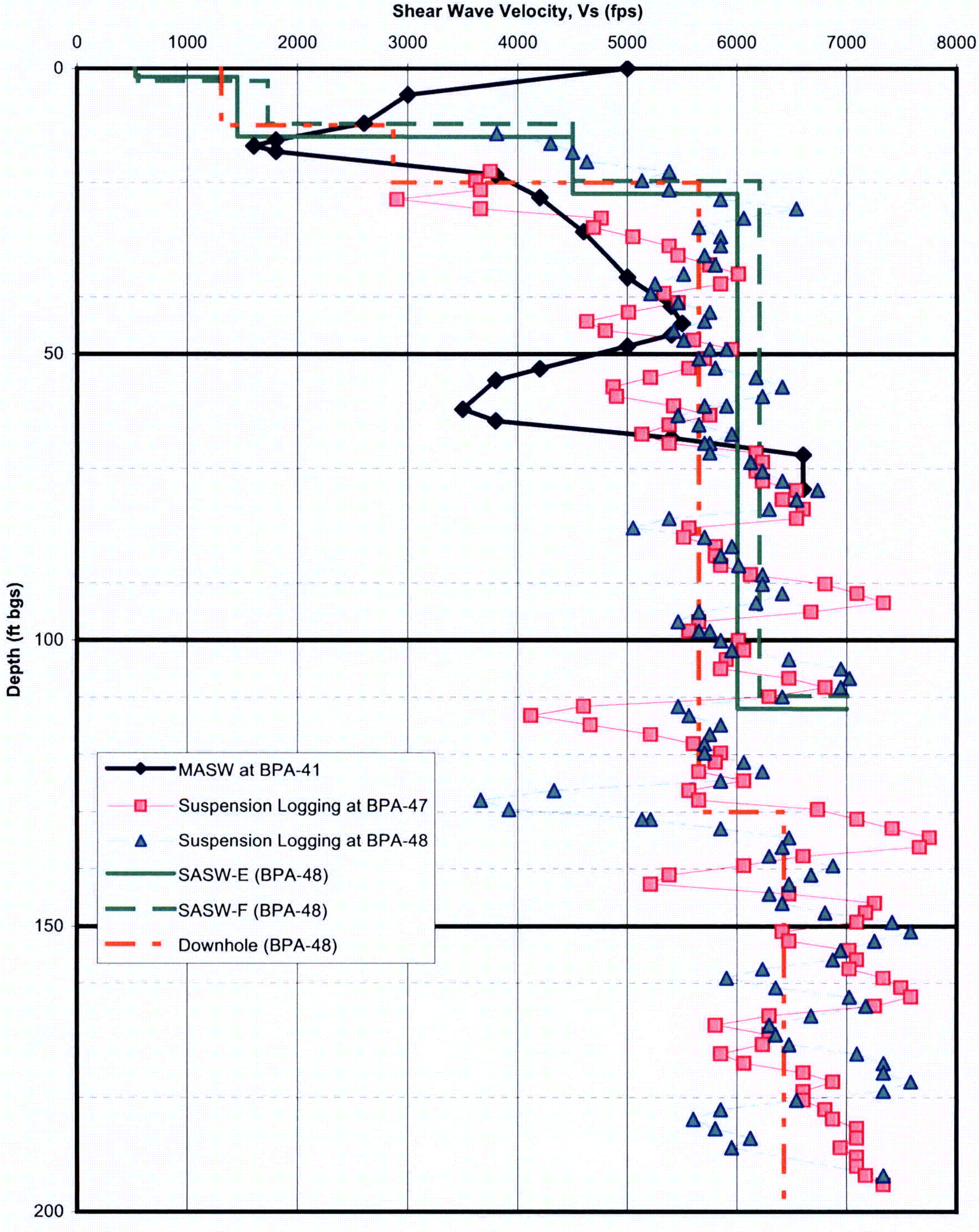


Figure A-7: V_s Data Comparisons - Near BPA-25

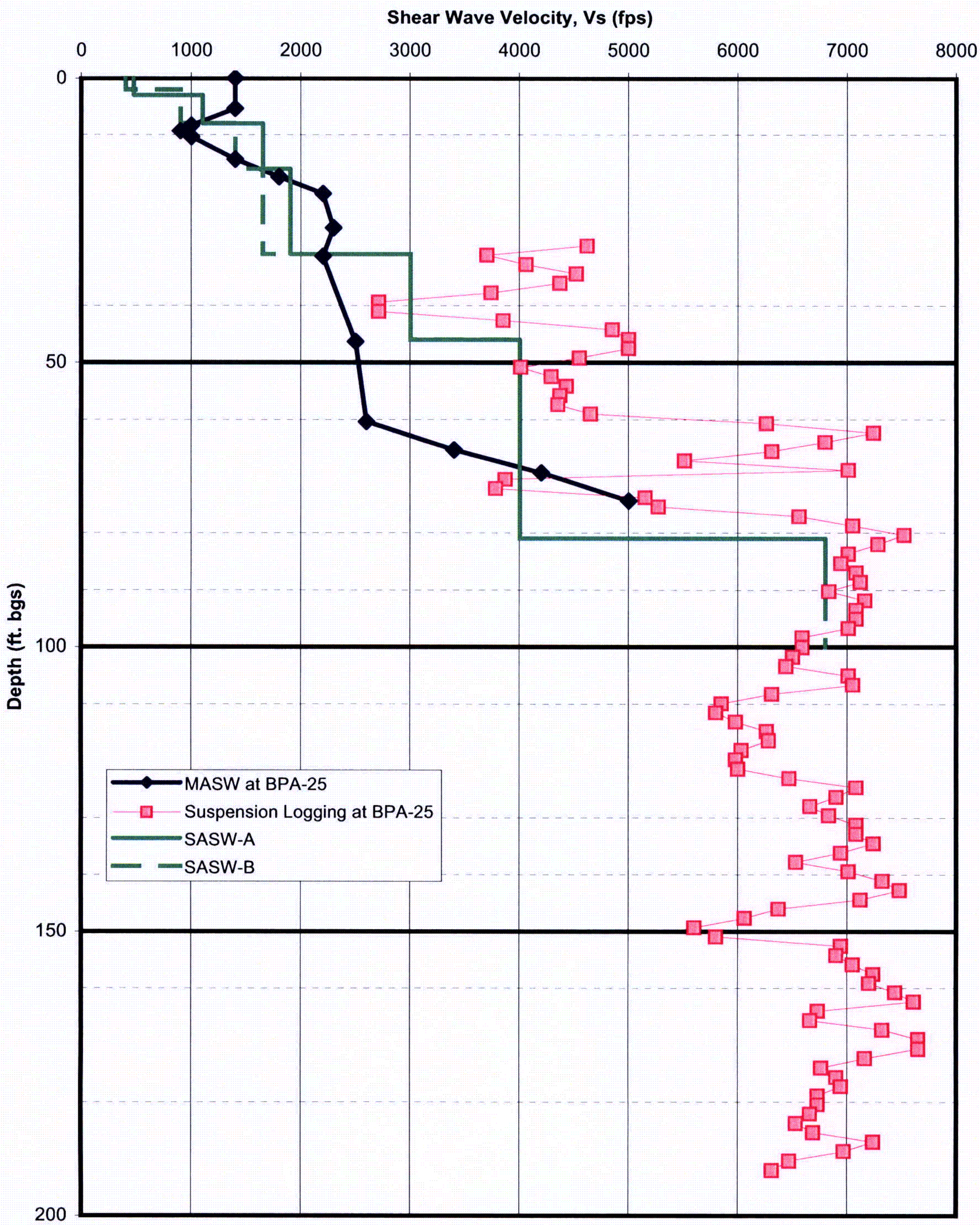
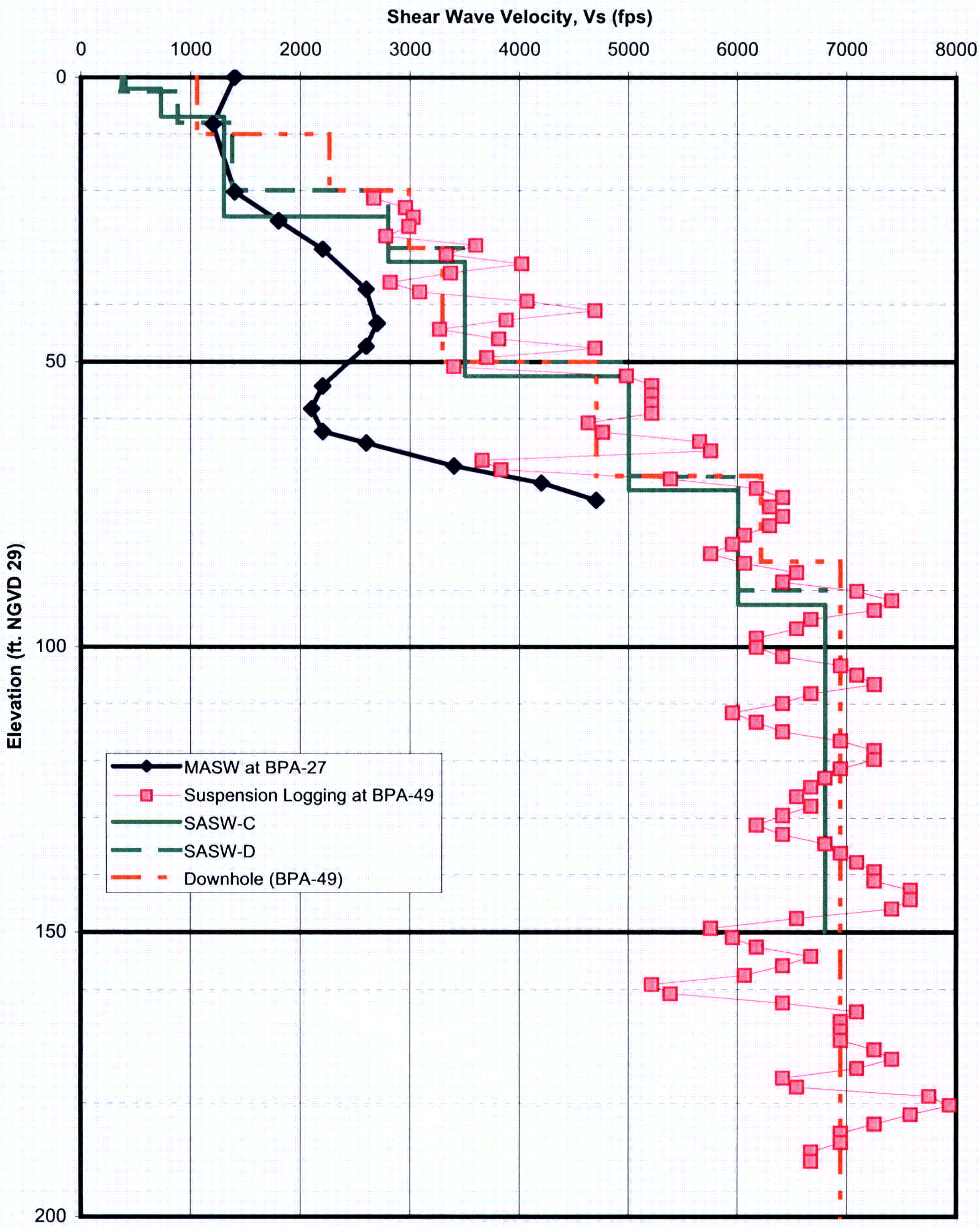


Figure A-8: V_s Data Comparisons - Near BPA-27
(BPA-49 Located ~ 60 ft. NE of MASW and SASW)



TECHNOS INC.

FINAL REPORT

MASW Survey Services
Harris Nuclear Plant – COLA Site
Raleigh, North Carolina

For
CH2M Hill, Inc.
And
Progress Energy Service Co.

February 15, 2007
(Revised July 18, 2007)

Technos Project Number: 06-144c
CH2M Hill P.O. Number: 914899

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

TECHNOS INC.

PURPOSE AND SCOPE

PURPOSE

The Harris Nuclear Plant is located 22 miles southwest of Raleigh, North Carolina. The plant is owned and operated by Progress Energy. Two areas have been identified for additional facility structures north of the plant. A subsurface investigation of these areas is being completed as part of a combined construction and operating license application being developed for Progress Energy by CH2M Hill.

In September 2006, a geophysical survey was requested as part of this subsurface investigation to provide shear-wave velocities in the vicinity of the proposed structures. Two areas of investigation were identified by CH2M Hill and labeled as Areas A and B (see Figure 1).

SCOPE OF WORK

Multi-channel analysis of surface waves (MASW) was used for the geophysical survey. MASW measurements were used to provide shear-wave velocities in the vicinity of the proposed structures in both Area A and B. A total of five (5) survey lines (two in Area A and 3 in Area B) were established over the centers of the proposed structures (see Figure 1).

All work was performed in accordance with CH2M Hill's Project Quality Plan.

TECHNICAL APPROACH

SURVEY LINES

Prior to beginning this work, CH2M Hill identified the areas to be surveyed and had local reference grids established by Smith and Smith Surveyors of Apex. NC and brush clearing completed where appropriate.

The two areas identified for the MASW survey are referred to as Areas A and B. Independent reference grids were established for each area using easting and northing in feet from a 0,0 reference point. The reference grids used the site-north which is about 25 degrees west from State Plane North. Wooden stakes were used to mark the end points of the survey lines and center points or turns. The surveyor provided these locations in State Plane NAD 83/88 coordinates. See Figure 1 for these survey areas and surveyed points.

The MASW survey lines are presented as distance in feet along the lines. Technos placed surveyor pin flags along the MASW survey lines at 50-feet intervals and used a Trimble Ag-132 differential GPS system with an accuracy better than ±3 feet to acquire the lateral locations at the ends of the MASW survey lines and at each pin flag. Appendix A contains the geographic coordinates of all survey line points acquired at each of the areas of investigation.

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

Multi-channel Analysis of Surface Waves (MASW) is a seismic method that uses the dispersive characteristics of surface waves to determine the variation of shear-wave (S-wave) velocity with depth. S-wave data are calculated by analyzing seismic surface waves generated by an impulsive source and recorded with an array of geophones. The resulting shear-wave profiles from multiple locations along a survey line are combined and contoured into a 2-D cross-section of shear-wave velocity. Shear-wave velocity is a function of the elastic properties of the soil and rock and is directly related to the hardness (N-values) and stiffness of the materials. The MASW measurements were made along the survey lines using twenty-four 4.5 Hz geophones spaced 4 feet apart. An elastic weight drop and sledgehammer were used as the energy sources and shot records were acquired every 8 feet. A more complete discussion of the MASW method and survey procedures is presented in Appendix B.

RESULTS

Several seismic techniques have been used at the Harris Nuclear Plant. Prior to the MASW survey, Technos, Inc. completed a seismic refraction survey (Technos Inc., 2006 and 2007). In addition, GEOVision Inc. employed 1D spectral analysis of surface waves (SASW), vertical seismic profiling and suspension logging (GEOVision Inc., 2007). All of these methods measure either compressional-wave or shear-wave velocities in different ways and through different volumes of earth. General comparisons between methods can be made, but direct correlation between borehole and surface measurements should not be made. For example, shear wave velocities from suspension logging (smaller volume of measurement) would be more accurate and typically higher within the rock than shear-wave velocities from MASW data (larger bulk volume of measurement).

The quality of the MASW data ranged from fair to good. The data provide reasonably well-defined dispersion curves over a large frequency range. Where dispersion curves were not well defined, they were omitted from the inversion process and not used in the velocity models. Many of the shot records produced dispersion curves that were not well defined at the higher frequencies. Therefore, the shear-wave model values in the uppermost 10 feet are not well constrained and the velocities should be interpreted with some level of caution.

Velocity values generally increase with depth and range between approximately 600 and 6,600 ft/s. The data produced models with a maximum depth of approximately 75 feet. Figures 2 and 3 present the MASW modeled shear-wave data from Areas A and B, respectively.

AREA A

The shear-wave velocities at Area A range from about 1,000 to 6,600 ft/sec. Area A shows generally higher shear-wave velocities than Area B. This compares well with the suspension logs and the seismic refraction data previously acquired at both sites that also show higher velocities at Area A than Area B.

Area A shows a fair bit of lateral and vertical variations in velocities. Two features identified on both the south-north and the west-east lines of data include a low-velocity zone within the higher-velocity materials at a depth of about 210 feet MSL. One feature occurs on the south-north survey line between stations 250 and 340. A similar feature occurs on the west-east survey line between stations 250 and 340. The three suspension logs we have reviewed (BPA-5, BPA-25 and BPA-39) all show at least one layer of low-velocity materials within higher-velocity materials. However, based upon these two MASW survey lines, it is not clear whether these features are isolated and independent or spatially associated.

AREA B

The shear-wave velocities at Area B range from 600 to 6,200 ft/sec and are overall lower than those measured at Area A. The MASW models from Area B show very gradually increasing velocities with depth with little lateral variability over the area surveyed. No particular features of interest are seen in these data.

CONCLUSIONS

The MASW data provided good quality models of bulk shear-wave velocities that show larger scale trends in the subsurface as compared to the suspension logs which sample a much smaller volume. The MASW data indicated higher velocities at Area A with more vertical and lateral variability than that seen at Area B. Two low-velocity anomalies within high-velocity materials were identified at Area A. Area B shows very gradually increasing velocities with depth with little lateral variability over the area surveyed.

Geologic conditions at this site consist of low velocity soils (and fill material in Area A) overlying relatively high-velocity, dipping sedimentary rock. These conditions are not ideal for the application of surface wave methods. However, even under these adverse geologic conditions, the MASW method remains a useful tool to map the lateral variation in the subsurface bulk velocity.

Acquisition parameters for 2D MASW are designed to maximize efficiency in the field and provide good coverage to identify lateral trends. Compared to 1D sounding techniques (e.g. SASW) that benefit from high data redundancy, data averaging and multiple source types, source offsets and receiver spacings, the 2D MASW acquisition parameters are somewhat limited. Therefore, the MASW models should not be used to validate borehole velocity measurements (e.g. suspension logging, vertical seismic profiling, etc.), but rather be used solely to map lateral variation of geologic structure and guide the placement of boreholes for further site characterization.

TECHNOS INC.

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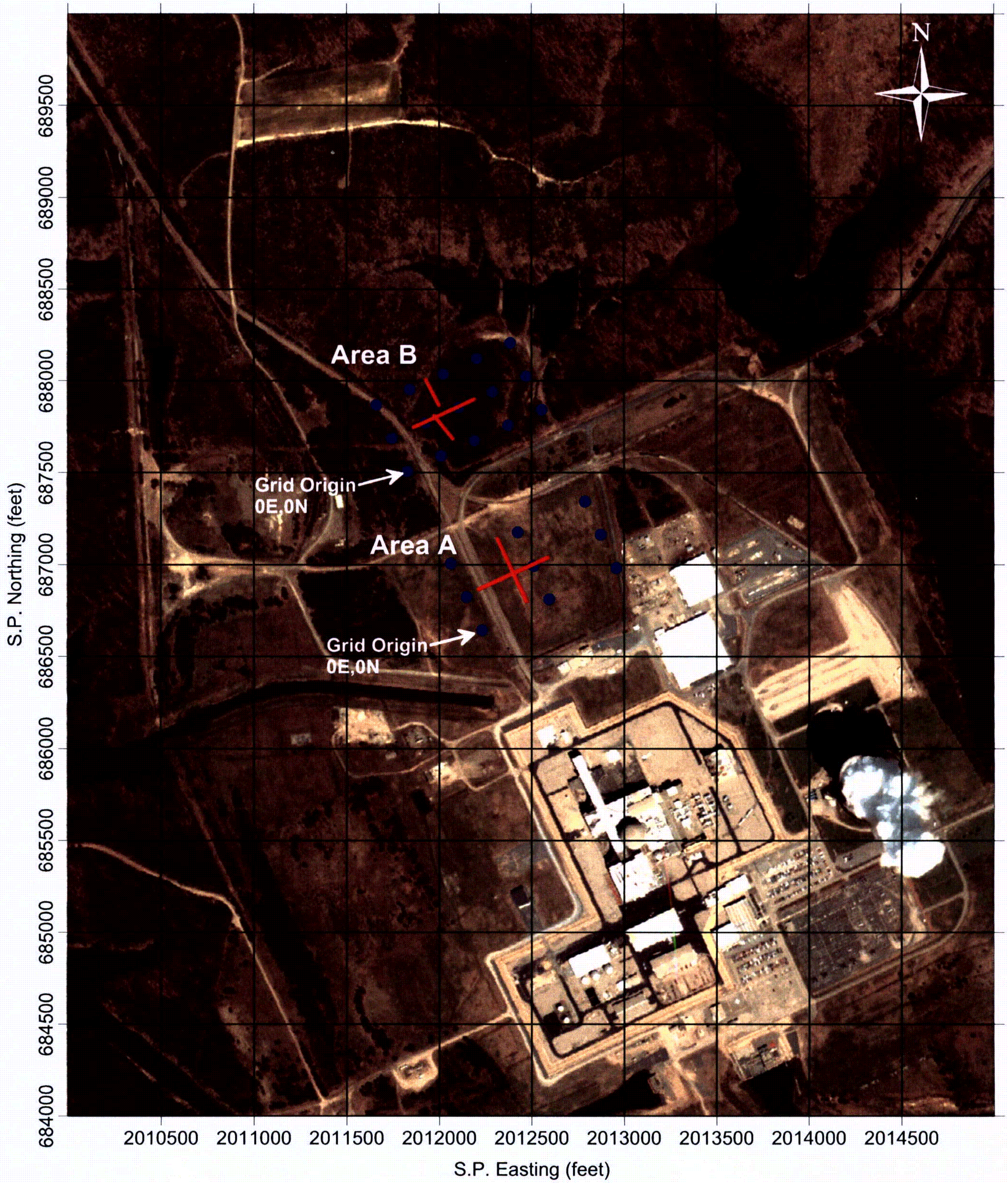

MASW Survey Lines

Survey Reference Grid

Figure 1. Site map showing areas of interest and MASW survey lines

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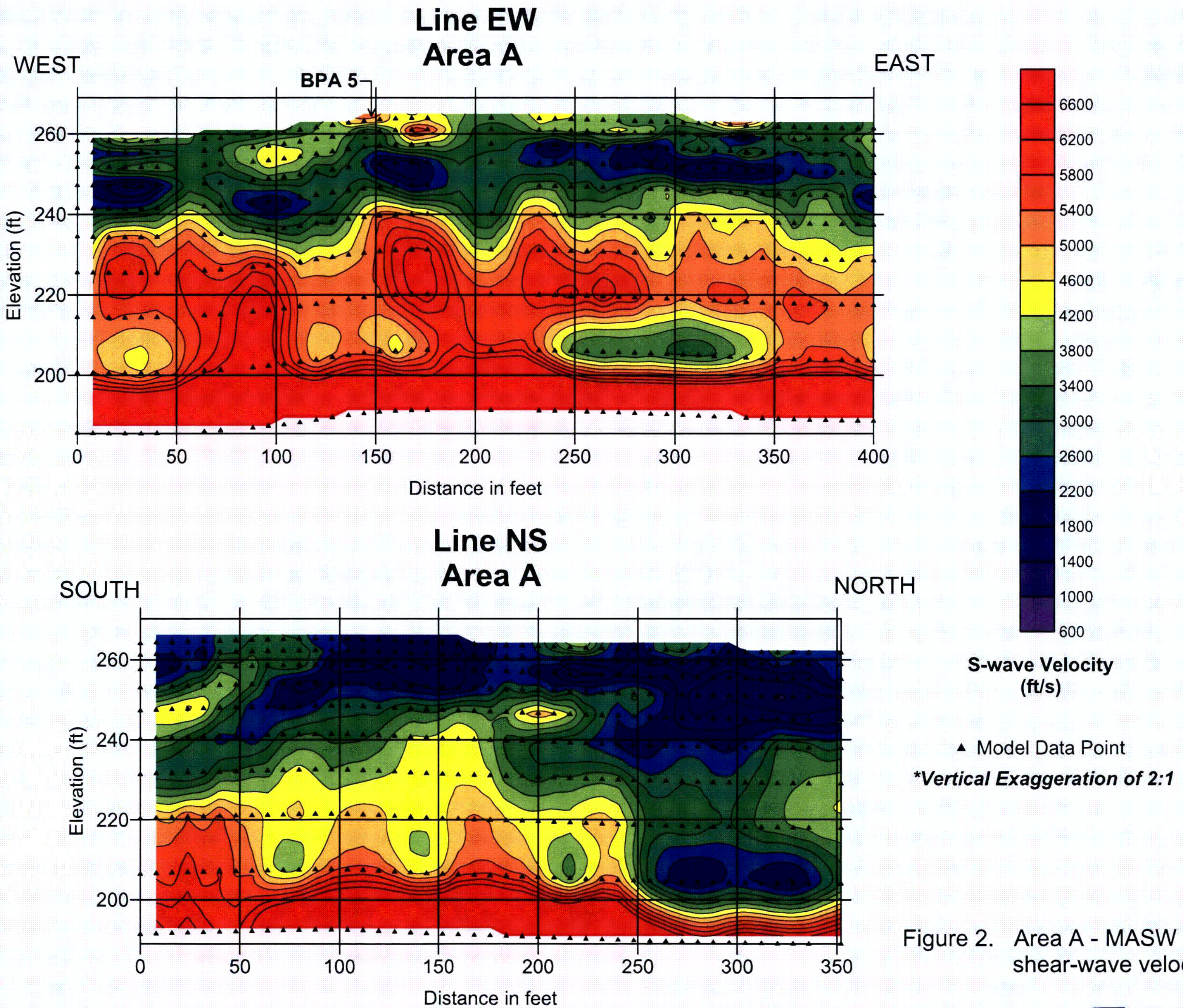

Figure 2. Area A - MASW models of shear-wave velocities

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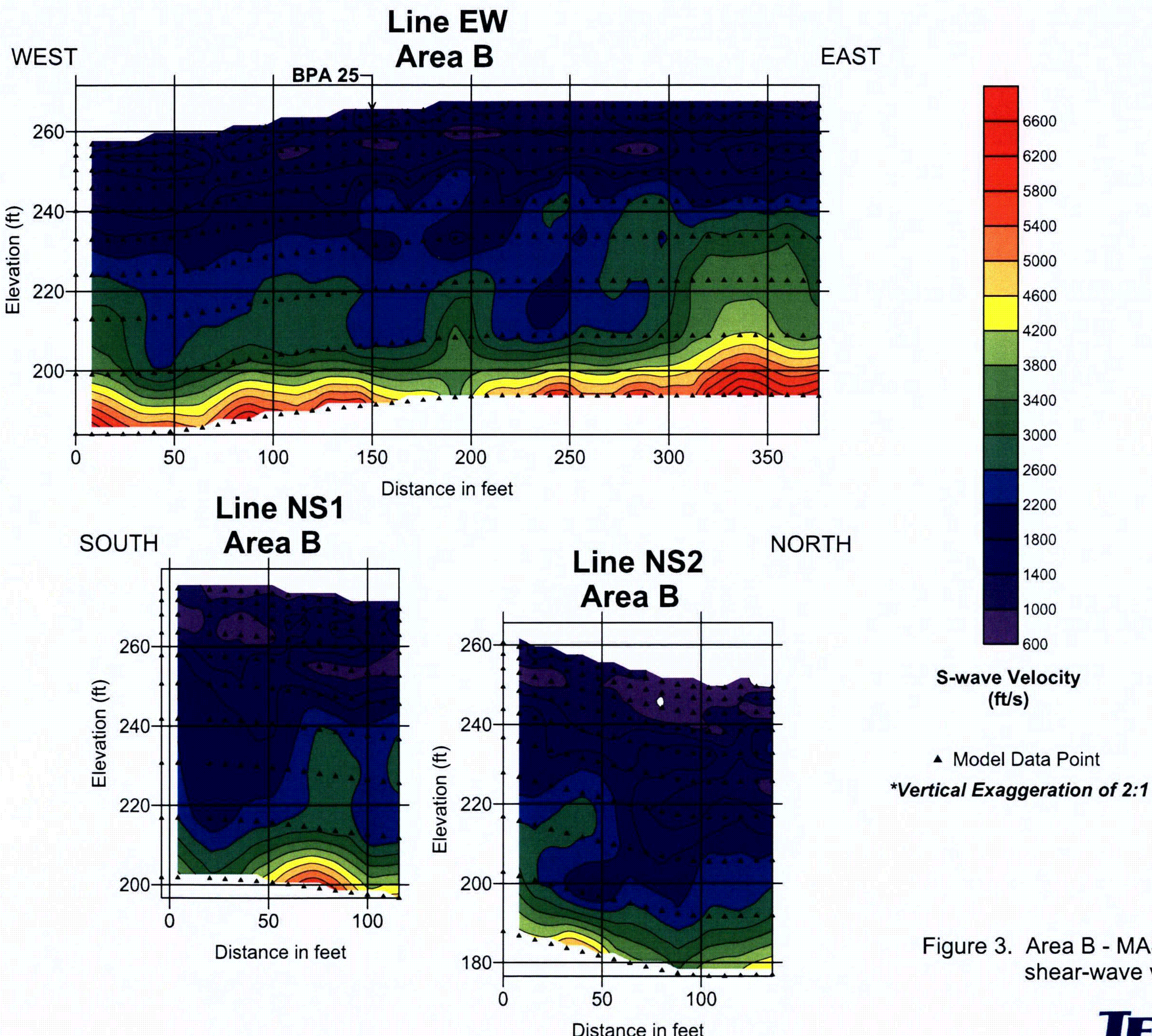

Figure 3. Area B - MASW models of shear-wave velocities

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APPENDIX A
SURVEY LINE LOCATIONS

Two areas were identified for investigation and are referred to as Areas A and B. Independent reference grids were established for each area using easting and northing in feet from a 0,0 reference point. The reference grids used the site north which is 25 degrees west of State Plane North. Smith and Smith Surveyors staked these locations prior to commencement of geophysical survey activities. The surveyor provided these locations in State Plane NAD 83/88 coordinates (Table A-1).

The MASW work completed in September of 2006 in both Areas A and B did not make use of the previously established reference grids for positioning in either area, but rather used relative distances along each MASW survey line in similar west-east, south-north grid directions. Technos placed surveyor pin flags along the MASW survey lines at 50-feet intervals. The positions of survey line endpoints and pin flags every 50 feet were acquired with a Trimble Ag-132 differential GPS system (s/n 0224022455) with an accuracy better than ±3 feet. The geographic coordinates were converted to NAD 83 North Carolina State Plane coordinates (feet) using Corpscon coordinate conversion software (V5.11.08, U.S. Army Corps of Engineers, Topographic Engineering Center, Alexandria, VA). This data has been summarized in Table A-2 and A-3.

Data Quality

For quality control, repeat measurements at established survey grid points in Area A were recorded with the Trimble GPS system.

Table A-1
Surveyor Reference Grid Points

Name	XNAD83	YNAD83
A-0-0	2012230.83	686643.60
A-0-200	2012146.30	686824.86
A-0-400	2012061.78	687006.12
A-400-0	2012593.35	686812.65
A-400-200	2012508.82	686993.91
A-400-400	2012424.30	687175.17
A-800-0	2012955.87	686981.70
A-800-200	2012871.35	687162.96
A-800-400	2012786.82	687344.22
B-0-0	2011827.84	687504.99
B-0-200	2011743.31	687686.25
B-0-400	2011658.79	687867.51
B-200-0	2012009.10	687589.51
B-200-200	2011924.58	687770.77
B-200-400	2011840.05	687952.03
B-400-0	2012190.36	687674.04
B-400-200	2012105.84	687855.30
B-400-400	2012021.31	688036.56
B-600-0	2012371.62	687758.56
B-600-200	2012287.10	687939.82
B-600-400	2012202.57	688121.08
B-800-0	2012552.88	687843.08
B-800-200	2012468.36	688024.34
B-800-400	2012383.84	688205.61

Table A-2					
Area A					
Easting	**Northing**	**Lat**	**Long**	**State-Northing**	**State-Easting**
MASW 0E	Line EW	35 38.56848	78 57:53281	686881.3523	2012217.915
MASW 50E	Line EW	35 38.24183	78 57.52367	686901.6932	2012263.169
MASW 100E	Line EW	35 38.54514	78 57.51452	686921.7915	2012308.473
MASW 150E	Line EW	35 38.24800	78 57.50545	686939.1599	2012353.382
MASW 200E	Line EW	35 38.25193	78 57.49622	686963.0196	2012399.08
MASW 250E	Line EW	35 38.25550	78 57.48702	686984.6955	2012444.631
MASW 300E	Line EW	35 38.25903	78 57.47791	687006.1286	2012489.736
MASW 350E	Line EW	35 38.26253	78 57.46877	687027.3798	2012534.989
MASW 400E	Line EW	35 38.26619	78 57.45973	687049.6015	2012579.747
Line NS	MASW 0N	35 38.22838	78 57.48165	686820.1887	2012471.293
Line NS	MASW 50N	35 38.23586	78 57.48593	686865.5557	2012450.079
Line NS	MASW 100N	35 38.24337	78 57.49006	686911.1049	2012429.607
Line NS	MASW 150N	35 38.25095	78 57.49409	686957.0791	2012409.631
Line NS	MASW 200N	35 38.25844	78 57.49830	687002.5069	2012388.763
Line NS	MASW 250N	35 38.26592	78 57.50242	687047.8742	2012368.341
Line NS	MASW 300N	35 38.27343	78 57.50650	687093.4236	2012348.118
Line NS	MASW 350N	35 38.28091	78 57.51059	687138.7911	2012327.844

Table A-3					
Area B					
Easting	**Northing**	**Lat**	**Long**	**State-Northing**	**State-Easting**
MASW 0E	Line EW	35 38.37702	78 57.61221	687721.617	2011824.377
MASW 50E	Line EW	35 38.38129	78 57.60302	687747.5384	2011869.876
MASW 100E	Line EW	35 38.38530	78 57.59432	687771.8816	2011912.948
MASW 150E	Line EW	35 38.38925	78 57.58549	687795.8612	2011956.665
MASW 200E	Line EW	35 38.39362	78 57.57747	687822.3871	2011996.369
MASW 250E	Line EW	35 38.39771	78 57.56856	687847.2162	2012040.481
MASW 300E	Line EW	35 38.40192	78 57.55974	687872.7732	2012084.147
MASW 350E	Line EW	35 38.40567	78 57.55076	687895.5401	2012128.607
MASW 400E	Line EW	35 38.40942	78 57.54178	687918.307	2012173.066
Line NS1	MASW 0N	35 38.37100	78 57.56095	687685.2007	2012078.232
Line NS1	MASW 50N	35 38.37747	78 57.56705	687724.4374	2012048.009
Line NS1	MASW 100N	35 38.38375	78 57.57349	687762.5207	2012016.102
Line NS1	MASW 116N	35 38.38573	78 57.57544	687774.5281	2012006.441
Line NS2	MASW 0N	35 38.40482	78 57.57645	687890.3317	2012001.392
Line NS2	MASW 50N	35 38.41208	78 57.58170	687934.3625	2011975.377
Line NS2	MASW 100N	35 38.41918	78 57.58630	687977.424	2011952.58
Line NS2	MASW 130N	35 38.42356	78 57.58908	688003.9888	2011938.803

APPENDIX B
MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

DESCRIPTION OF MASW METHOD

Introduction

MASW (Multi-channel Analysis of Surface Waves) is a geophysical method that uses the dispersive characteristics of surface waves to determine the variation of shear wave (S-wave) velocity with depth (Park, et al., 1999). MASW is a non-intrusive method that is performed on the ground surface. Data are acquired by analyzing seismic surface waves generated by an impulsive source and received by an array of geophones. A dispersion curve that shows the velocity of the surface waves as a function of frequency is calculated from the data. A shear wave velocity profile (1-D profile of velocity as a function of depth) is then modeled from the dispersion curve. The resulting shear wave profiles from multiple locations along a survey line are combined and contoured into a 2-D cross-section of shear wave velocity. Shear wave velocity is a function of the elastic properties of the soil and rock and is directly related to the hardness (N-values) and stiffness of the materials.

MASW has advantages over the more traditional spectral analysis of surface waves (SASW), since data are recorded at 24 or more geophone locations with MASW compared with only 2 geophones with SASW. The additional data allow the surface waves to be extracted from other seismic waves more easily in the processing and increase the signal to noise ratio. MASW also allows a higher production rate than SASW, providing a greater data density.

Applications

MASW measurements are applicable in mapping subsurface conditions for various uses including geologic, geotechnical, hydrogeologic, environmental and archeological investigations. The MASW method is used to map anomalous geologic conditions including weak zone detection, void detection, fault/fracture detection, etc. Seismic shear-wave velocities are related to mechanical material properties. Therefore, characterization of the material (type of rock, degree of weathering, and rippability) is made on the basis of the modeled shear-wave velocities.

Principles

Seismic energy is introduced into the subsurface by a source at or very near the surface. Surface waves (Rayleigh waves) are created and propagate outward from the source location. In a heterogeneous subsurface, the surface waves undergo dispersion as they travel along the surface. That is, different frequencies (wavelengths) have different phase velocities as they travel outward. The amount of surface wave dispersion is a function of shear-wave velocity changes with depth.

Once a dispersion curve is defined over a finite distance from the source, a one-dimensional subsurface model of shear-wave velocities can be modeled. For the MASW method, several dispersion curves are determined for adjacent, overlapping geophone spreads to produce adjacent 1-D models of the subsurface. These models can be contoured to produce a two-dimensional cross-section of subsurface shear-wave velocities. Data processing is performed with an inversion program on a computer.

Depth

The depth of investigation can range from 10's of feet to 100's of feet or more using the MASW method. The depth of investigation is governed primarily by the frequency of the surface waves that are recorded. Deeper investigations may require larger sources of energy and longer spreads of geophones.

Equipment

Measurements of subsurface conditions by the MASW method require a seismic energy source, trigger cable, geophones, geophone cable, and a seismograph. The seismic source may be a sledgehammer, a mechanical impact device, a shotgun, or explosives, depending upon the depth of investigation and site-specific conditions. Typically, 24 to 48 geophones are used for a single spread, with a spacing determined by the depth of investigation and the desired spatial resolution. A multi-channel seismograph (typically 24 to 48) is used to digitally record the data.

Quality Control

The seismograph, geophones, and cables are set-up and operated in accordance with the manufacturer's instructions and the Technos, Inc. SOP for MASW. Quality control procedures will be followed to obtain a level of repeatability for the data and to ensure that the equipment is operating correctly throughout the survey.

Resolution

Vertical resolution of a MASW survey is approximately 20% of the depth (e.g. features at a depth of 20 feet, will be averaged over a thickness of approximately 4 feet). Lateral resolution is approximately 25% of the geophone spread length. Comparisons of MASW measurements and borehole measurements indicate that MASW velocity models are accurate to within 15% of actual values (Xia, et al., 2002).

Precision and Accuracy

Precision (repeatability) of a MASW measurement will be affected by the sources used, placement of geophones, soil conditions, the defining of dispersion curves, and the site-specific noise levels.

Accuracy (bias) of a MASW measurement is improved by using additional information (e.g. borehole information), which can be used to constrain the interpretation of the data. Field procedure errors, processing errors, instrument errors, noise, topography, and lateral geologic variability can contribute to errors in the interpretation.

Calibration
The MASW equipment is calibrated by the manufacturers.

Limitations
The depth of investigation is limited by the seismic source, the frequency of the geophones, and the geophone spread length. In addition, the presence of some cultural features such as large utility conduits can interfere with the propagation of surface waves. The MASW model of S-wave velocities is a gradational model, and may not represent true S-wave velocities in areas with sharp geologic contacts or within hard rock.

Personnel
The success of any MASW survey is dependent upon many factors. One of the most important is the competency of the person(s) responsible for planning, carrying out the survey and interpreting the data. An understanding of the theory, field procedures and methods for interpretation of data along with an understanding of the site geology is necessary to successfully complete a MASW survey. Personnel not having specialized training and/or experience should be cautious about using the MASW method and solicit assistance from qualified practitioners.

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SUMMARY OF MASW DATA

Field Procedures

MASW data were obtained along five (5) survey lines during this investigation, two lines in Area A and three lines in Area B. MASW data were recorded using Geometrics' StrataVisor NZII seismograph (S/N:82141) and 4½-Hz geophones. An 80-Lb elastic weight drop (EWD) mounted on the back of an ATV (Kawasaki MULE) with a steel plate was used as the seismic energy source for most of the seismic records. A 10-Lb sledge hammer was used at a few shot point locations due to accessibility limitations.

The seismograph, geophones, and cables were set-up and operated in accordance with the manufacturer's instructions (Geometrics, 2002) and the Technos, Inc. SOP for MASW (Technos, 2006). A quality assurance daily checklist maintained by CH2M Hill personnel was completed each day in order to ensure that the equipment was operating correctly throughout the survey.

Acquisition parameters were based on established procedures (Zhang, et al., 2004) and on-site testing. The geophones have 3-inch spikes that were planted firmly into the ground for optimum energy coupling. Each geophone spread consisted of 24 geophones spaced at 4-foot increments along the survey lines for a total spread length of 92 feet. The source was located 32 feet from the first geophone in the spread, and shots were spaced at 8-foot intervals along the survey lines.

A total of 48 geophones were planted in the ground at any one time, and the 24-channel geophone spread was moved down the survey lines with each shot using an electronic roll box, physically moving 24 channels at the end of each roll cycle. For each shot record, the seismic data were vertically stacked (enhanced) three to four times to improve the signal to noise ratio. The data were digitally recorded on the seismograph at a 0.5 msec sample rate with a total record length of 1 second. A 24dB pre-amp gain was applied to all of the channels during acquisition. There were no acquisition filters applied during the recording of the data.

Data Processing

Data were processed using SurfSeis software (Kansas Geological Survey, 2006). Dispersion curves for each shot were manually picked by analyzing the phase-velocity of the surface waves as a function of frequency. These dispersion curves were then input into the SurfSeis inversion algorithm to produce 2D cross-sections of shear-wave velocity. The final models were output as text files for plotting purposes. The shear-wave velocity cross-sections are presented using Surfer (Golden Software, 2004).

Results Summary

The shear-wave velocity cross-sections for Area A and Area B are presented in Figures 2 and 3 of the report, respectively. Table B-1 shows a very general classification of soil and rock based on shear wave velocities (BSSC, 2000). In general, lower velocity values correspond with softer or weaker materials. At this site, low velocity values

(<1,400 ft/s) are interpreted as soil (clays) or fill material, mid-range velocity values (~1,400 to 2,400 ft/s) are interpreted as soft, weathered limestone, and high velocity values (>2,400 ft/s) are interpreted as harder limestone.

Table B-1. Soil and Rock Shear Wave Velocity Classification

Velocity (ft/s)	Classification
> 2,400	Limestone
1,400 to 2,400	Weathered Limestone
<1,400	Soil (Clay)

Data Quality

Most of the MASW data can be generally characterized as of "fair" to "good" quality. That is, the data provide reasonably well-defined dispersion curves with frequencies ranging from as low as 10 Hz to greater than 100 Hz. A high-frequency cutoff value of 100 Hz was used when generating the dispersion curves. Velocity values generally increase with depth and range between approximately 600 and 6,600 ft/s. These variables yield reliable models to a maximum depth of approximately 75 feet. Shot points that did not yield coherent dispersion curves were discarded and only well defined dispersion curves were input into the inversion.

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