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Wells G&H OU1
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455199

GEOPHYSICAL INVESTIGATION
WELLS G&H (OLYMPIA) SUPERFUND SITE
WOBURN, MASSACHUSETTS

Prepared for:

Metcalf and Eddy
30 Harvard Mill Square
P.O. Box 4071
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Prepared by:

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File 200207
June 2002

Hager GeoScience, Inc.

EXECUTIVE SUMMARY

In March 2002, Hager GeoScience, Inc. (HGI) performed a geophysical survey for Metcalf and Eddy (M&E) of Wakefield, Massachusetts at the Wells G&H (Olympia) Superfund Site in Woburn, Massachusetts. The primary objective of the survey was to determine, using appropriate geophysical techniques, the location, depth and extent of a confining clay layer encountered during previous geotechnical investigations. A secondary objective was to complete a sedimentary facies analysis of the mappable overburden to the top of bedrock where possible, and, if discovered, to map the location and extent of secondary confining beds.

The geophysical study at the Wells G&H (Olympia) Superfund Site was designed to acquire a distribution of data suitable for mapping the spatial extent of a confining near-surface silty-clay layer and delineating deeper stratigraphy. To meet the primary objectives of the survey, the two geophysical methods of ground penetrating radar (GPR) and resistivity were used.

Based on the results of these geophysical surveys, we note that:

- As evident in GPR records, the cutting of horizontal stratigraphy (including the target silty clay unit) and reflectivity patterns originating in the material above this cut boundary are consistent with stream channel activity and subsequent deposition in a low- to moderate-energy fluvial depositional environment;

- Stream channel activity resulted in the creation of a NNW-trending sand channel between 18 to 20 feet in depth, and possibly deeper locally;

- Six mappable stratigraphic horizons have been identified from GPR records: 1) the base of fill/channel sand deposit; 2) the top of a sub-fill, silt horizon; 3&4) the top and bottom of the target silty clay unit, respectively; 5) a compositional transition from sandy silt to sand; and, 6) bedrock.

Sufficient spatial data were obtained to map four of the six stratigraphic horizons. These include:

- base of fill/channel sand
- top of silt
- top and thickness of clay
- top of bedrock

The study shows that the stratigraphy mapped in the survey area is continuous from the west and is consistent with low- to moderate-energy Pleistocene glacio-fluvial deposits in the area. A facies change a short distance to the east of the survey area produces stratigraphy with the characteristics of a late Pleistocene (glacial) to recent, high-energy fluvial environment.

Hager GeoScience, Inc.

1.0 INTRODUCTION

In March 2002, Hager GeoScience, Inc. (HGI) performed a geophysical survey for Metcalf and Eddy (M&E) of Wakefield, Massachusetts at the Wells G&H (Olympia) Superfund Site in Woburn, Massachusetts. The site location is shown in Figure 1. The primary objective of the survey was to determine, using appropriate geophysical techniques, the location, depth and extent of a confining clay layer encountered during previous geotechnical investigations. A secondary objective was to complete a sedimentary facies analysis of the mappable overburden to the top of bedrock where possible, and, if discovered, to map the location and extent of secondary confining beds.

The near-surface geologic units of the study area are comprised primarily of glacial sediments deposited during the Late Wisconsin glacial retreat through the Aberjona River valley approximately 14,000 years ago. Recent near-surface alluvial deposits associated with the Aberjona River overlie the glacial deposits. Existing boring logs constrain site stratigraphy to consist of, in order of increasing depth: i) fill and organic swamp deposits; ii) silty sand with traces of clay; iii) silty clay; iv) sand and silt; v) sand; and vi) till. Bedrock depth is greater than 100 feet. Borehole logs from offsite wells to the east, west, and south reveal substantial lateral variation in stratigraphic composition and thickness, including a discontinuous silty clay layer.

Surface topography at the site was nominally level, with the exception of a 4-foot ridge and 5-foot berm paralleling the western and southeastern boundaries of the grid, respectively. In addition, two sizable utility conduits ran the entire of the survey area north-south along 5E and 25E. Localized patches of vegetation, pieces of drilling equipment, a large lifting crane, and both metallic and non-metallic debris were scattered over the site. At the time the borings were drilled, the water table varied from 3 to 5 feet below grade.

2.0 TECHNICAL APPROACH

The geophysical study at the Wells G&H (Olympia) Superfund Site was designed to acquire a distribution of data suitable for mapping the spatial extent of both the target near-surface silty-clay layer and additional stratigraphy. To meet the objectives of the survey, the two geophysical methods of ground penetrating radar (GPR) and resistivity were used. Brief descriptions of these two methods are given below, with more detailed information about these techniques and their limitations provided in Section 6.0.

The GPR investigation consisted of two components: a) a survey designed to resolve stratigraphy to the top of clay; and, b) a survey to identify deeper and significant stratigraphic features. The former objective was achieved using a 200-MHz antenna and a survey geometry consisting of an orthogonal grid with a 25-foot spacing. The deeper investigation was limited by access to two north-south and two east-west-oriented traverses using HGI's Multiple Low Frequency (MLF) antenna system operated in both 40- and 20-MHz configurations.

The resistivity survey was designed to optimize the depth of investigation while maintaining the ability to resolve shallow stratigraphy. Electrode spacings of four and eight feet were used for the east-west and north-south directions, respectively.

The GPR method is amenable to the interrogation and mapping of discontinuous subsurface interfaces, such as changes in stratigraphy. GPR data were collected as two-way travel time, in which the measurements are made of the time for the input radar wave pulse to travel to a subsurface discontinuity and reflect back to the antenna at the ground surface. Depths to discontinuous interfaces were recovered from the recorded travel-time data using radar propagation velocities estimated through calibration with borehole logs and from material specific velocity tables.

The objective of the resistivity survey was to determine the subsurface resistivity distribution from surface-based observations. Resistivity data were collected using four electrodes at one time, two as sources through which an electric current was driven, and two as receivers between which the resulting voltage was measured. From these readings, the true resistivity of the subsurface was estimated by computational methods, and subsequently related to site stratigraphy based on inter-unit variation of physical parameters such as mineral and fluid content, and porosity.

The multidisciplinary survey program combining GPR and resistivity produced two distinct data sets that yielded complementary constraints on subsurface structure. As such, these data sets required integration before affording more comprehensive results. One goal of such an integrated geophysical approach is to determine geologic interpretations consistent with all interpreted data. However, innate differences between geophysical survey types (i.e. differing resolution abilities) and the uncertainty in the interpretation of geophysical data (i.e. imprecise knowledge of the radar velocity profile) produced inconsistency in the geological conclusions rendered from the different investigation types. Thus, to minimize the uncertainty present in this investigation, interpretations from individual data sets were iteratively updated to achieve a more globally consistent geologic section. Overall, the combination of borehole constraints and GPR and resistivity data provided an effective means of bounding study area stratigraphy and establishing reliable stratigraphic trends.

3.0 DATA ACQUISITION

A survey grid was established using the eastern edge of the railway easement and the staked northern edge of the swamp as the 0E and 0S baselines, respectively. North-south and east-west traverses were marked out to create the rectilinear grid required for survey control. The elevations and locations of existing boreholes and "staked" survey stations were surveyed subsequent to data collection by a representative of M&E, and the results incorporated herein. The locations of both GPR and resistivity survey lines are plotted on Plate 1.

3.1 GPR Survey

The GPR survey was performed using a Geophysical Survey Systems, Inc. (GSSI) SIR System 2 digital ground penetrating radar system. Data were displayed on a color monitor and simultaneously recorded for processing and interpretation. GPR data were collected along survey traverses using two different antennae: a bistatic multiple low frequency (MLF) and a monostatic 200-MHz. MLF data were used to derive deeper stratigraphic information, while the 200-MHZ data were used to constrain silt and clay unit boundaries. MLF and 200-MHz data were collected using discrete, stacked measurements at 2-foot intervals and continuous acquisition regulated by a calibrated survey wheel, respectively. Acquisition windows for MLF and 200 MHz data collection were set at 1200 ns and 400 ns, respectively. Data from a total of 25 GPR lines totaling 3000 linear feet contributed to the contour maps included in this report.

3.2 Resistivity Survey

The resistivity survey was performed using a Swift Sting® resistivity unit with an acquisition array up to 56-electrodes. The survey electrodes and instrumentation were configured for a dipole-dipole array, which represented a trade-off in resolution between lateral and depth dimensions. The Sting® unit was capable of automatically adjusting for the dipole sizes and separations required for constructing the resistivity profile. To improve the electrical contact between survey electrodes and the ground, readings acquired in dry, resistive sandy soils were pre-dampened with salt water. A total of six resistivity profiles were acquired, half oriented north-south and the remainder in the shorter east-west direction. Longer lines were acquired at an 8-foot electrode spacing, which permitted interrogation of the subsurface to 70 feet below grade. Due to limited survey area dimensions, electrode spacing on shorter lines was restricted to 4 feet, enabling the imaging of overburden resistivity to a depth of 26 feet.

4.0 DATA REDUCTION AND ANALYSIS

Following the field data collection, GPR and resistivity data were downloaded to a PC at the HGI office. The data were processed and analyzed using the following proprietary software:

- GPR: GSSI's RADAN for Windows NT® with Structural and Stratigraphic Interactive Interpretation Module®.
- .Resistivity: Ray2DINV V.3.4®.
- Graphic Presentation: Surfer® 7.0 and AutoCAD® 2000.

4.1 GPR Survey

Site stratigraphy along GPR traverses was determined using GPR reflections that arose due to the back-scattering of the input GPR wave from discontinuous stratigraphic interfaces. However, before the data could be analyzed, significant processing was required to reduce the detrimental

effects of noise associated with radio frequency signals and reflections from surface structures and buried debris. High-pass filters, horizontal smoothing, background removal, gain adjustments, and wavelet deconvolution were performed as essential processing steps. Two-way travel times to the tops of GPR reflectors were then picked and entered into an ASCII file according to file number and traverse offset. All generated ASCII files were then incorporated into a collective database.

Site- and unit-specific GPR propagation velocities were estimated using onsite borehole log constraints. GPR travel-time data were then mapped into the depth domain using these velocity estimates. Maximum penetration depths were 25 and 80 feet for the 200-MHz and MLF antennas, respectively. Modeling results were imported into Surfer® for Windows for final contouring and graphical presentation.

4.2 Resistivity Survey

Following acquisition, resistivity data were downloaded from the Sting® unit to a PC for processing with Res2DINV® modeling software. Data analysis was restricted to data points observing less than a 5% fluctuation between successive readings. In addition, strong outliers were eliminated to generate smoother models. Final models were characterized by a 15-30% root mean square (R.M.S.) error indicating limited resolution of shorter wavelength structure. Modeling results were imported into Surfer® for Windows for final contouring and graphical presentation.

4.3 Data Synthesis

Data from the geophysical surveys and boreholes were compiled to form an integrated database from which a best-fit grid model was developed using Surfer® for Windows' kriging algorithm. Areas where data were not acquired have been accordingly blanked in the grid model. Final contour maps were then produced with Surfer® for Windows and integrated into the M&E AutoCAD base map. Slices through the generated grid models were used to construct depth profiles of the interpreted stratigraphy. In total, two cross-section figures, four contour map plates, and two model cross section plates were created from the results of individual techniques and the integrated database. Additional resistivity profiles are found in Appendix A attached below.

Figure 2 shows a representative GPR record acquired along Traverse 275S. Note that the vertical units are two-way travel time (ns), not depth. Two significant features illustrated by this figure are: 1) in the center of the line, the partial cutting of horizontal stratigraphic units by a shallower unit, and, 2) to the west, the hyperbolic reflector from the deeper of two buried pipes. Scattered energy also arises from the interpreted coarser-grained deposits possibly associated with alluvial deposition (0-40E), pipe construction (25E), and the berm (105-123E).

Figure 3 presents a representative resistivity line acquired at 100S from 5E to 100E. Resistivity highs and lows are represented by "warmer" and "cooler" colors, respectively. Water table depth coincides with the change in resistivity values from yellow/red to green. The top and bottom of the silt layer in the west is demarcated by green-to-blue and blue-to-green transitions at depths of 5 and 17 feet, respectively.

The cutting of horizontal stratigraphy evident in Figure 2 is important for interpreting the geologic history of the site. This feature, and the degree of radar-wave scattering in the material above this boundary, is consistent with stream-cutting activity and deposition in a high-energy fluvial environment. Since this signature persists throughout the data set, it reinforces the interpretation of a stream channel, and allows for it to be mapped across the study area.

Based on the 200-MHz GPR program, three mappable stratigraphic horizons have been identified: i) the base of continuous silty sand and channel deposits collectively termed sandy fill; ii) the top of a discontinuous intermediate silt boundary; and iii) the top of a continuous silty clay unit. Plate 2 shows the interpreted base of the sandy fill unit. The main stratigraphic feature is the NNW-trending stream channel approximately 20 feet below ground surface. The stream channel may be locally deeper, since the amplitudes of the associated GPR reflector weaken due to the combined effects produced by lack of GPR signal penetration and energy scattering from the two buried conduits. Sand depths to the southeast are between 8 and 12 feet. Plate 3 presents the top of an intermediate silt horizon situated between the overlying fill and underlying silty clay units. Since GPR records show evidence that this silt horizon has been truncated by the overlying fill layer, locations where this occurs have been blanked. The depth to the top of the silty clay unit is between 12 and 14 feet, except for the locations abutting the sand channel where partial erosion has reduced the thickness to zero and the clay horizon is accordingly deeper.

Contour maps of the top and thickness of the target silty clay unit are presented in Plates 4 and 5. The depth to the top of this unit varies between 15 to 17 feet, except at the locations where it has been partially eroded by the stream channel and is cut as deep as 20 feet (or locally greater). Although not as well constrained, the base of this unit is modeled between 24 and 28 feet in depth. Topographic relief of the silty clay horizon (Plate 4) is similar to that for the silty unit (Plate 3). Based on the resolution limits afforded by this survey and well data west of the railroad tracks, the target layer appears to be continuous, dips gently to the east, and, where not affected by channel erosion, has a fairly uniform thickness.

Though less robustly constrained, a bedrock grid model constructed from the GPR MLF data is included in this report (Plate 6).

One north-south and two east-west cross sections of the mapped stratigraphy are included as Plates 8 through 10. The locations of the cross sections are shown in Plate 7. The cross-sections are presented in pairs to illustrate all mapped stratigraphy to the top of bedrock and emphasize the shallow stratigraphy to the target horizon. Plate 8 includes the shallow and deep north-south

(A-A') cross sections. Plates 9 and 10 include the deep and shallow sections, respectively, for B-B' and C-C'.

Based on the geophysical results, the geological evolution of the survey area was as follows: The Aberjona River valley, eroded by glacial activity, received glacio-fluvial deposits including till (diamictite) and outwash (sand and silty sand). Late- to post-glacial activity formed a low-energy, possibly lacustrine, depositional environment accompanied by the alternating deposition of silt and clay. Later (and perhaps episodically), changes in the drainage pattern of the Aberjona River caused localized moderate- to high-energy streams to cut through the lacustrine deposits. During one of these events, the silt and underlying target clay unit were partially eroded, and the eroded channel filled with a sequence fining upward from cobbles and gravel to sand and silty sand deposits. The intensity of the erosion was greater in the main region of the Aberjona River valley. As inferred from resistivity results, more recent deposition included deposition of a silty sand layer in, and over, the eroded channels. The final stage of geologic evolution included the deposition of organic matter and anthropogenic reworking of the near-surface materials.

5.0 CONCLUSIONS

Based on the geophysical survey results, we note that:

- As evident in GPR records, the cutting of horizontal stratigraphy (including the target silty clay unit), and reflectivity patterns originating in the material above this cut boundary, are consistent with stream channel activity and subsequent deposition in a low- to moderate-energy fluvial environment;

- Stream channel activity resulted in the creation of a NNW-trending channel 18 to 20 feet deep, and possibly deeper locally;

- Six mappable stratigraphic horizons were identified from GPR records: 1) the base of fill/channel sand deposit; 2) the top of a sub-fill, silt horizon; 3&4) the top and bottom of the target silty clay unit, respectively; 5) a compositional transition from sandy silt to sand; and 6) bedrock.

Sufficient spatial data were obtained to map four of the six stratigraphic horizons. These include:

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The study shows that the stratigraphy mapped in the survey area is continuous from the west and is consistent with low- to moderate-energy Pleistocene glacio-fluvial deposits in the area. A facies change a short distance to the east of the survey area produces stratigraphy with the characteristics of a late Pleistocene (glacial) to recent, high-energy fluvial environment.

6.0 THE GEOPHYSICAL TECHNIQUES

6.1 Ground Penetrating Radar

6.1.1 Description of the Method

The principle of ground penetrating radar (GPR) is the same as that of weather or police radar, except that GPR transmits electromagnetic energy into the ground, which is reflected back to the surface from interfaces between materials with contrasting electrical (dielectric and conductivity) properties. The greater the contrast between two materials in the subsurface, the stronger the reflection observed on the GPR record. The depth of GPR signal penetration depends on the properties of the subsurface materials and the frequency of the antenna used to collect radar data. The lower the antenna frequency used, the deeper the signal penetration, but the lower the signal resolution.

We collect GPR data using a Geophysical Survey Systems SIR System 2 or 2000 digital ground penetrating radar unit, which consists of a computer connected to a transmit/receive antenna. Radar data are collected in point, continuous, or survey wheel mode while moving the antenna across the ground. Data are displayed in color on the computer monitor and simultaneously recorded on the unit's hard drive for later processing and interpretation using proprietary RADAN for Windows® software. Hard copies of the data may be printed in the field on a thermal printer.

6.1.2 Data Analysis and Interpretation

The horizontal scale of the GPR record shows distance along the survey traverse. In the continuous data collection mode, the horizontal scale on each GPR record is determined by the antenna speed. When a survey wheel is used, as at this site, the GPR record is automatically marked at specified intervals along the survey line. The vertical scale of the radar records is determined by the recording interval. The recording interval represents the maximum two-way travel time in which data are recorded. The conversion of two-way travel time to depth depends on the propagation velocity of the GPR signal, which is site specific. In the absence of site-specific subsurface information about stratigraphy, we estimate propagation velocities from handbook values and experience at similar sites.

The size, shape, and amplitude of GPR reflections are used to interpret GPR data. Metal objects such as USTs and utilities produce reflections with high amplitude and distinctive hyperbolic shapes in GPR records when traverses are made perpendicular to their long axes. Clay or concrete pipes and boulders may produce radar signatures of similar shape but lower amplitude. The boundaries between saturated and unsaturated materials, sand and clay, and bedrock and overburden, generally also produce strong reflections.

6.1.3 Limitations of the Method

GPR signal penetration is site specific, determined by the dielectric properties of local soil and fill materials. GPR signals propagate well in resistive materials such as sand and gravel; however, soils containing clay, ash- or cinder-laden fill, or fill saturated with brackish or otherwise conductive groundwater cause GPR signal attenuation and loss of target resolution (i.e., limited detection of small objects). Concrete containing rebar or mesh also inhibits signal penetration.

Interpreted depths of objects detected using GPR are based on on-site calibration, handbook values, and/or estimated GPR signal propagation velocities from similar sites. GPR velocities and depth estimates may vary if the medium of investigation or soil water content is not uniform throughout the site. (Electromagnetic waves do not travel as fast through water as air, so the distance to a reflector below the water table may appear farther than in actuality.)

Utilities are interpreted on the basis of reflectors of similar size and depth that show a linear trend, but GPR cannot unambiguously determine that all such reflectors are related. Fiberglass USTs or utilities composed of plastic or clay may be difficult to detect, as well as objects underneath reinforced concrete pads.

Changes in the speed at which the GPR antenna is moved between stations causes slight variations in distance interpolations, and hence in interpreted object positions.

The GPR antenna produces a cone-shaped signal pattern that emanates approximately 45 degrees from horizontal fore and aft of the antenna. Therefore, buried objects may be detected before the antenna is located directly over them, and GPR anomalies may appear larger than actual target dimensions.

GPR is an interpretive method, based on the subjective identification of reflection patterns that may not uniquely identify a subsurface target. Borings, test pits, or site utility plans must verify the results.

6.2 Resistivity

6.2.1 Description of the Method

The purpose of an electrical resistivity survey is to acquire electrical measurements made at the surface of the earth to be used in inferring the subsurface resistivity profile. A typical survey involves two metal rods used as conduits through which an electric current is driven into the ground. This current subsequently propagates through the earth in a manner described by Ohm's Law. At any given point, the resulting potential difference (i.e. voltage) between a different pair of electrodes may be measured and used to generate a resistivity reading. In situations where a

similar source and receiver geometry is moved along the surface at regular intervals, an apparent resistivity profile may be generated from the measurements.

When the subsurface consists of a single layer of homogeneous material, the resulting potential differences of a resistivity profile are straightforward to model. However, in situations where vertical or lateral changes in the resistivity distribution exist (such as electrically better or poorer conduction layers), the potential field will be distorted away from that produced by a homogeneous resistivity distribution. In most cases, though, it is these variations in the resistivity distribution that are sought since they are usually related to variations in geological parameters such as a layers' mineral and fluid content, and porosity.

One of the difficulties of the resistivity method is that the resistivity distribution is almost always not known in advance, and resistivity profiles calculated from the acquired data are inherently non-unique and require additional regularization such as seeking the smoothest model. In addition, this calculation must remove from the data set the effects of acquisition geometry and the varying amount of current introduced into the ground. This calculation procedure, termed inversion, involves the construction a resistivity model that best approximates real subsurface conditions. Generally, the inversion procedure is as follows: i) an initial trial resistivity model is assumed; ii) the acquisition geometry is recreated, and Ohm's Law is used to estimate the resistivity measurements through the trial model; iii) a measure of the difference between estimated and observed resistivity data sets is obtained; iv) the trial model is adjusted to better account for the observed data; and v) steps ii) through iv) are repeated until the data estimated through the trial model converges to the field data. The final resistivity model is taken to be the best approximation of subsurface resistivity.

We collect resistivity data using a Swift Sting® resistivity meter unit consisting of a programmable control instrument and switching box duo connected to an array of electrodes via individually addressed "smart" cables. Unlike conventional manual resistivity surveys, the switching box enables source and receiver electrodes to be changed automatically, thus greatly reducing acquisition time. Data are saved in the solid-state memory of the Swift unit during acquisition, and then transferred to a PC for processing and interpretation using Res2DINV® inversion modeling software.

6.2.2 Data Analysis and Interpretation

The horizontal scale of the inverted resistivity record corresponds to the overall length of the resistivity array. The vertical scale of the resistivity records is determined by a combination of factors including electrode spacing, configuration type, and overall length, as well as environmental variables such as electrode ground coupling and the resistivity distribution itself. Resistivity inversion results are presented in contoured format with 'cooler' and 'warmer' colors representing more conductive and resistive bodies, respectively.

Since types of agglutinated material (i.e. silty clays) generally have variable and overlapping ranges of resistivity values, it is not possible to uniquely attribute observed resistivity anomalies to geology without additional information. However, in situations where data from drillers' logs is available, site stratigraphy and modeled resistivity values may be correlated locally, which permits lateral mapping of observed stratigraphic units.

6.2.3 Limitations of the Method

Resistivity values are influenced by proximity to coupled in-ground metal objects, such as fences, vehicles, or buildings.

The shape and amplitude of resistivity anomalies do not uniquely describe a buried object or material, and may be influenced by the orientation of survey lines to this buried object(s).

Dry and highly resistive, near-surface soils provide weak electrical coupling with the source electrodes and distort the flow path of electromagnetic energy. Accordingly, less current may be transmitted into the ground, and as a result the readings are noisier and resistivity anomalies may be mispositioned.

Since types of agglutinated material generally have variable and overlapping ranges of resistivity values, it is not possible to uniquely attribute observed resistivity anomalies to geology without additional information.

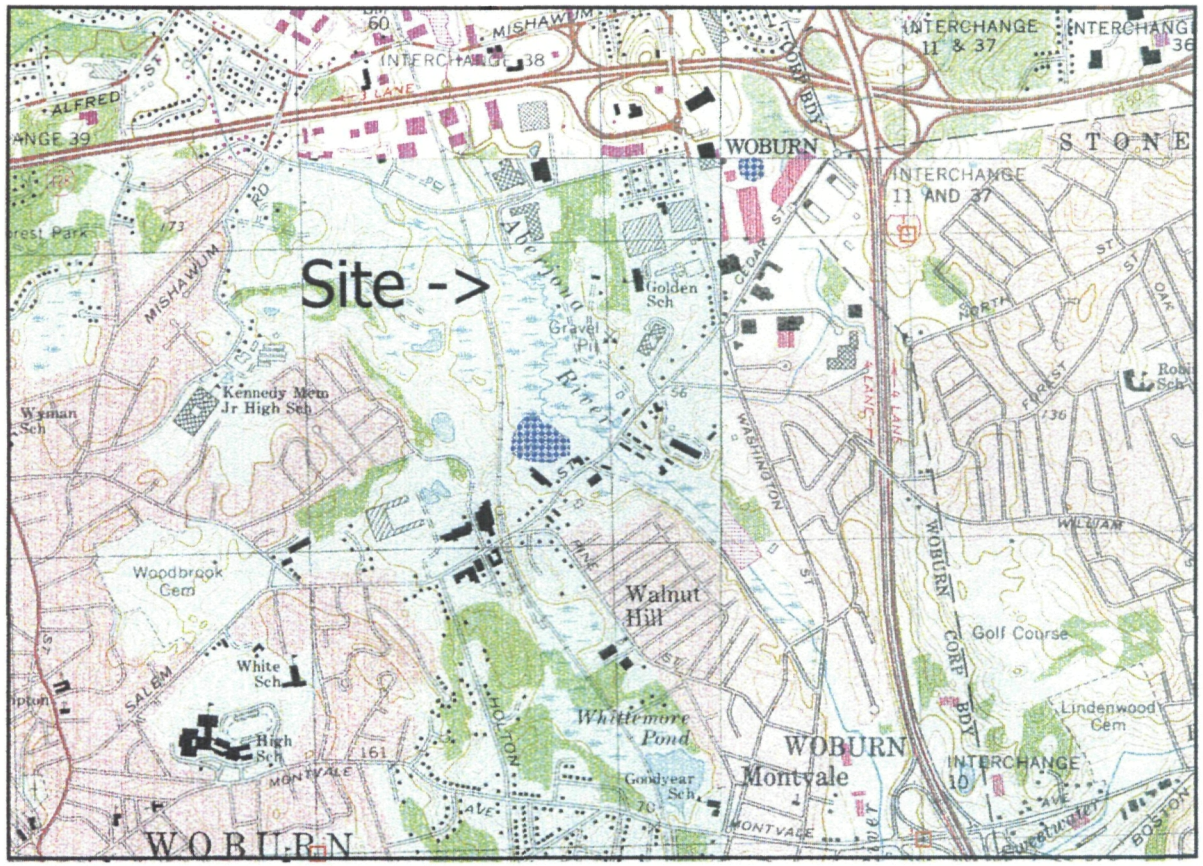


Figure 1. Location of the geophysical survey site.

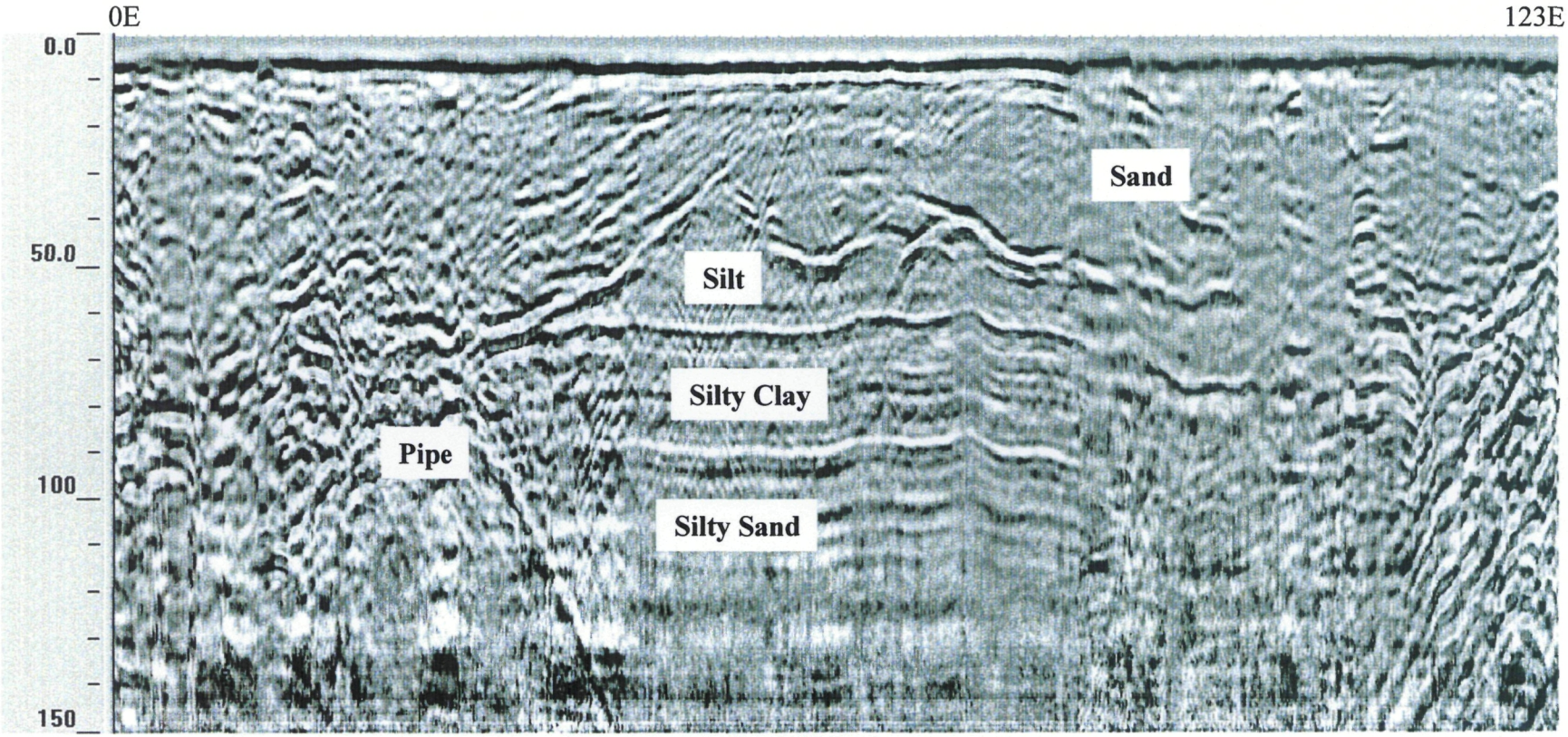


Figure 2. Portion of GPR Traverse 275S from 0E to 123E. Note cutting of horizontal stratigraphy interpreted to be clay unit. Scattered energy from pipe and berm is evident to the left and extreme right of the record, respectively.

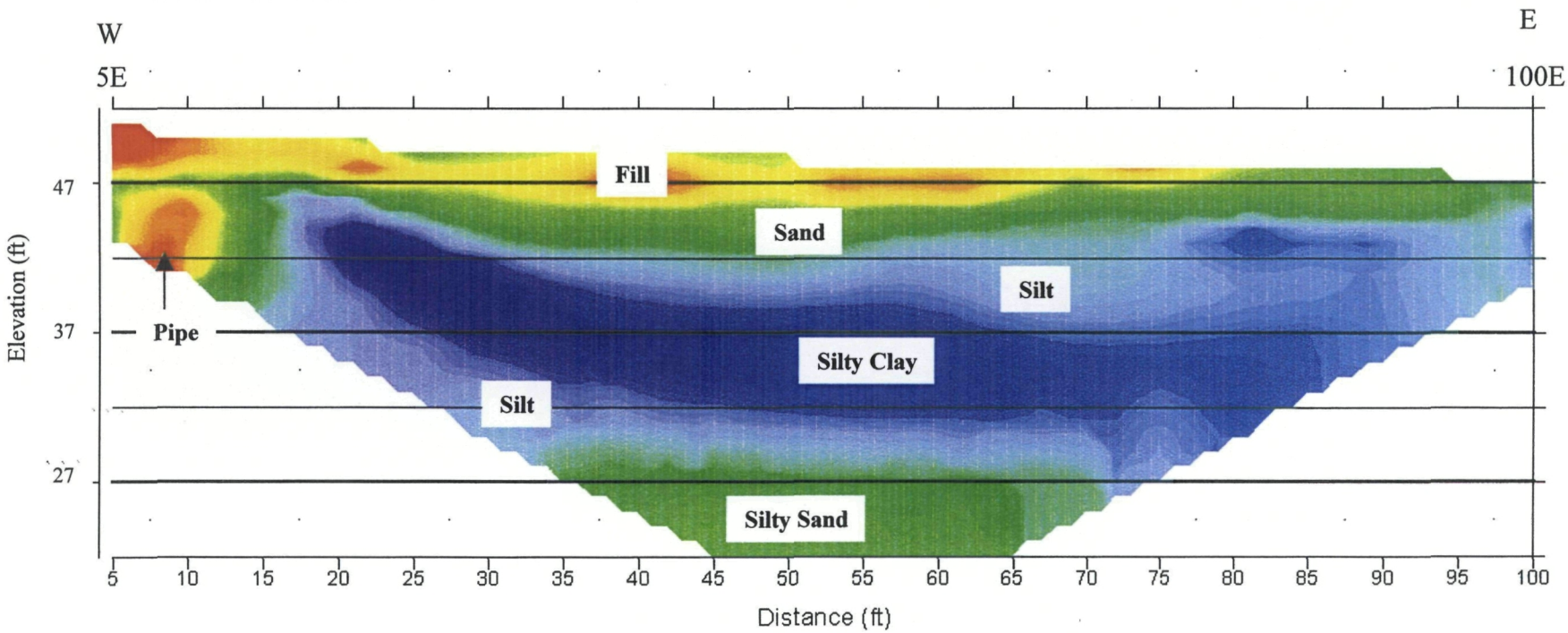
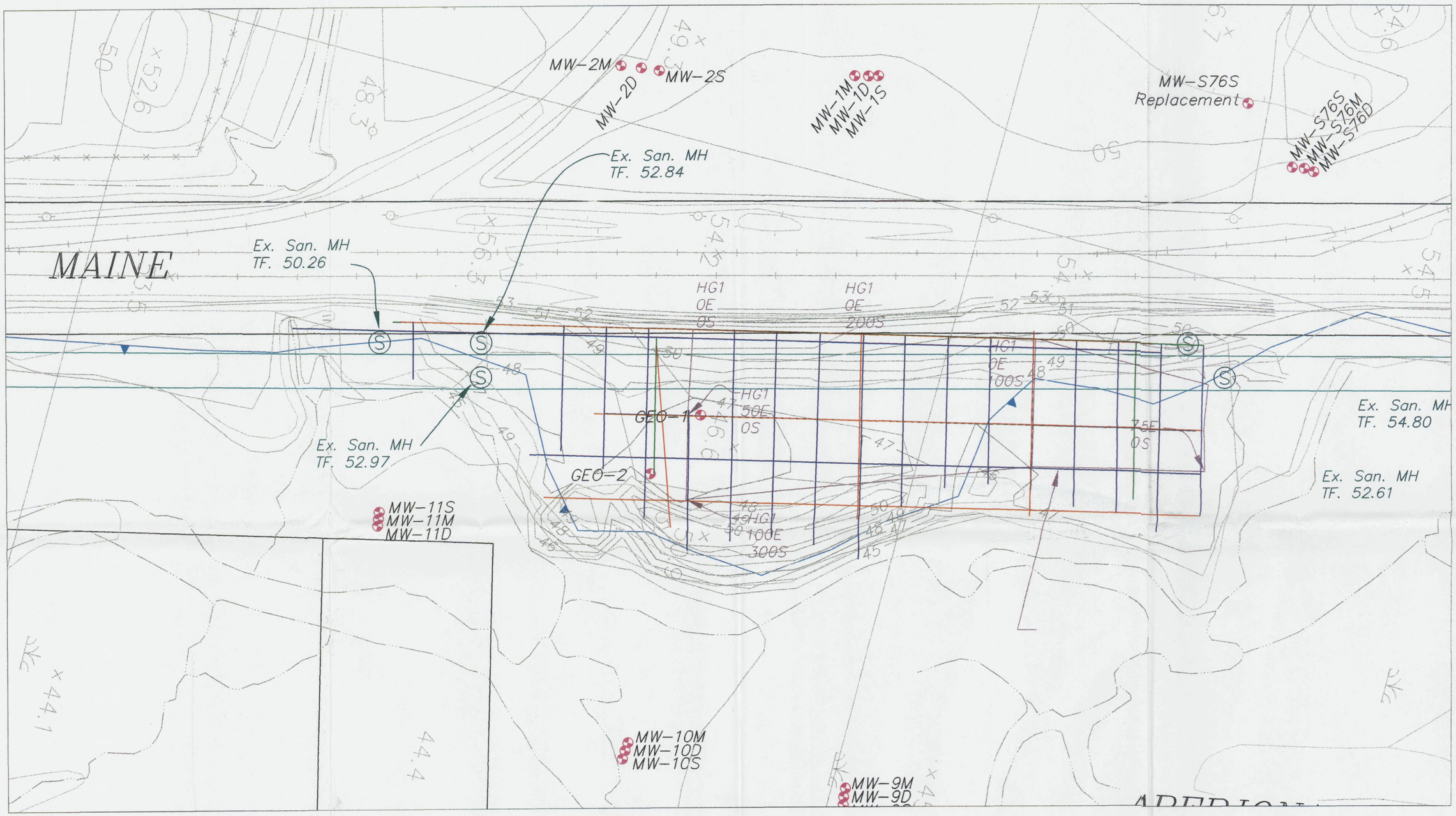


Figure 3. Resistivity Traverse 100S from 5E to 100E. Resistive and conductive material contoured as "warmer" and "cooler" colors, respectively. Interpretation of stratigraphy based on extrapolation from borehole information.



GPR Traverse-200MHz

GPR Traverse-40MHz

Resistivity Profile

GRAPHIC SCALE

80 40 20 0 40 120

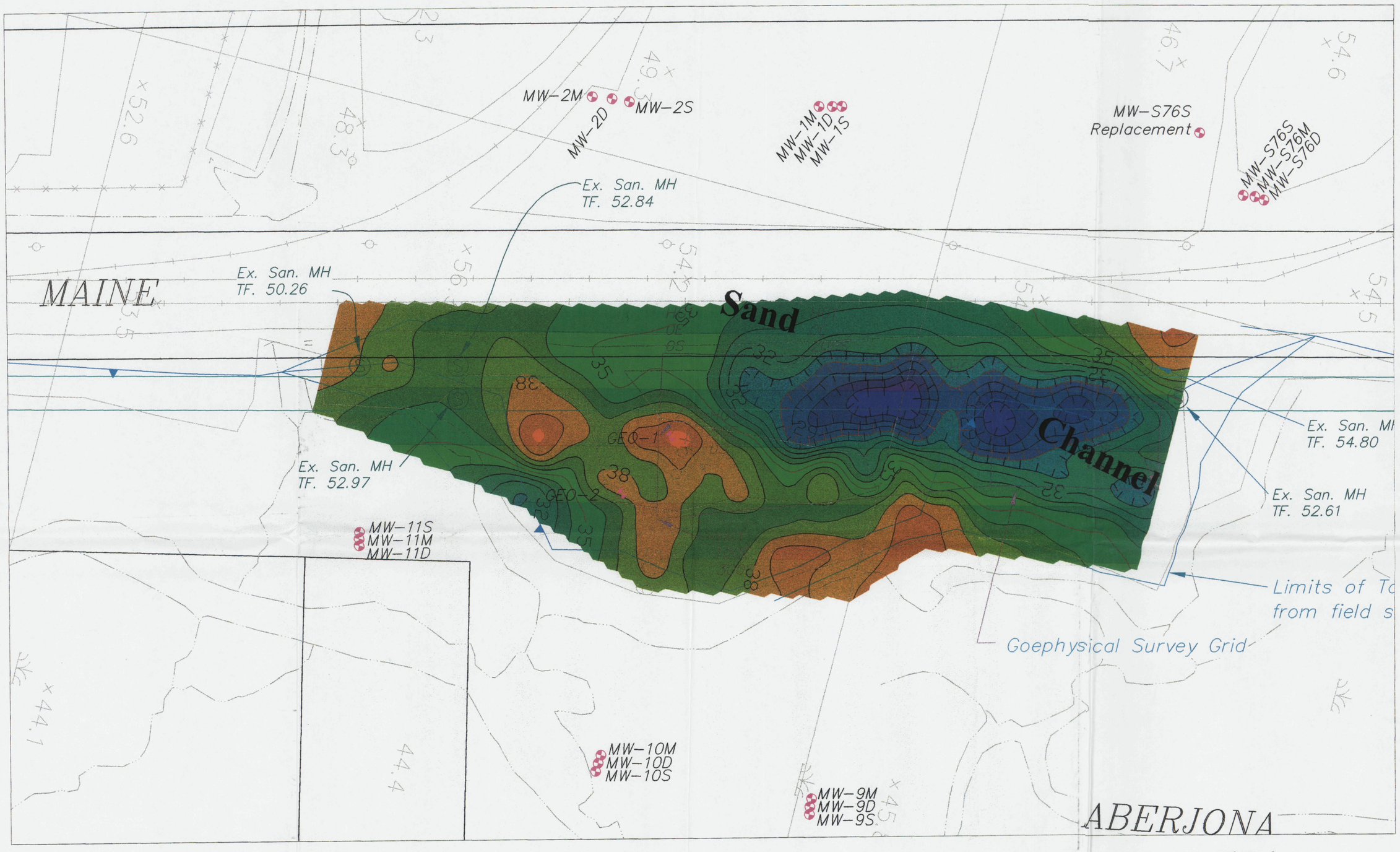
(IN FEET)
1 inch = 40 ft.

Plate 1

June 2002	File No. 200207

Location Map
Geophysical Survey Data
Olympia Superfund Site
Woburn, Massachusetts

Hager GeoScience, Inc.
596 Main Street Woburn, MA
Tel 781.935.8111 Fax 781.935.2717



Elevation Contour
(Hot to Cool Colors=High to Low Elevation)
Contour Interval=1-foot

GRAPHIC SCALE

80 40 20 0 40 120

(IN FEET)
1 inch =40 ft.

Plate 2

June 2002	File No. 200207

Elevation Contour Map
Bottom of Fill/Channel Sand
Olympia Superfund Site
Woburn, Massachusetts

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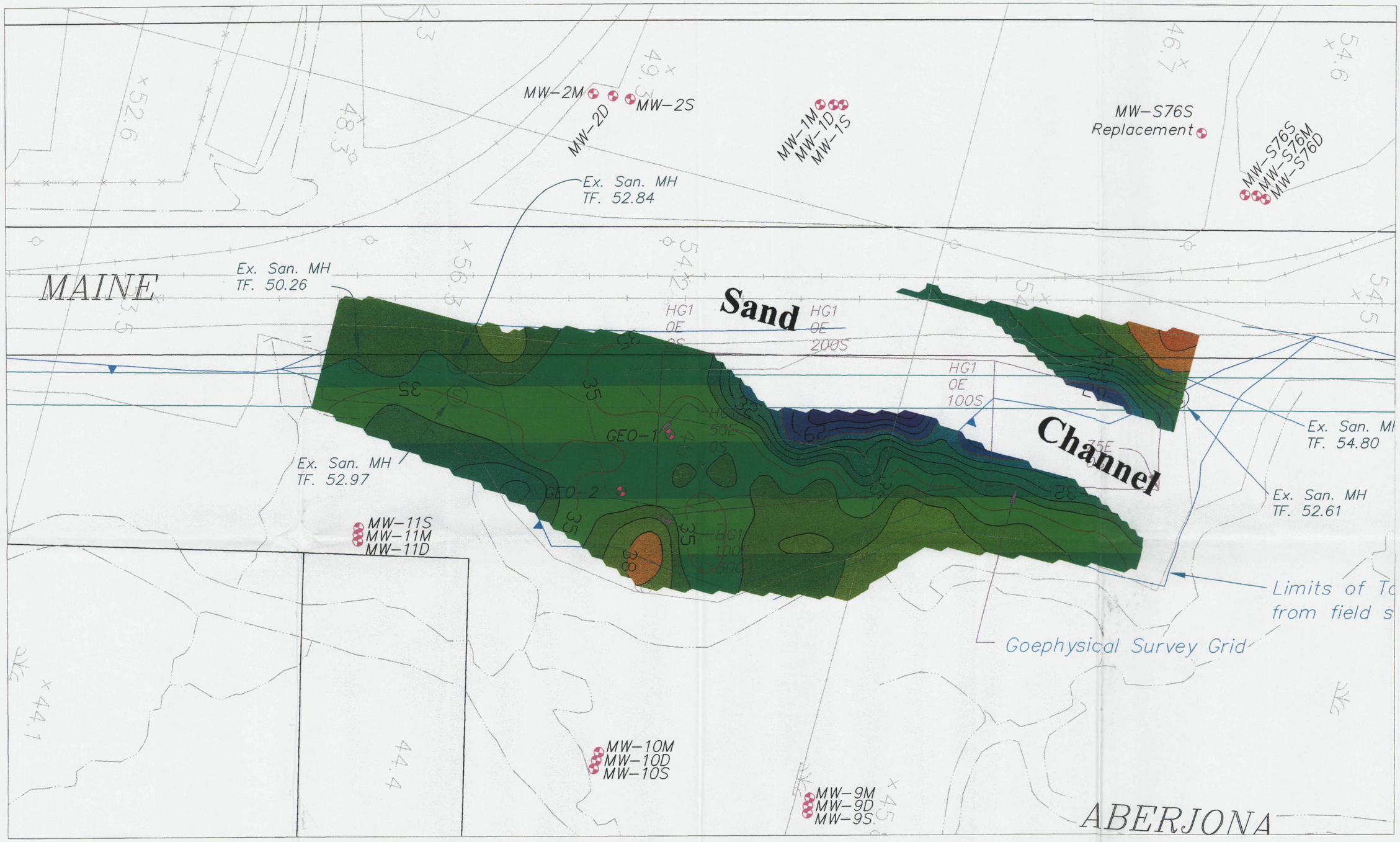
596 Main Street Woburn, MA
Tel 781.935.8111 Fax 781.935.2717



Elevation Contour
(Hot to Cool Colors=High to Low Elevation)
Contour Interval=1-foot

GRAPHIC SCALE

80 40 20 0 40 120

(IN FEET)
1 inch = 40 ft.

Plate 3

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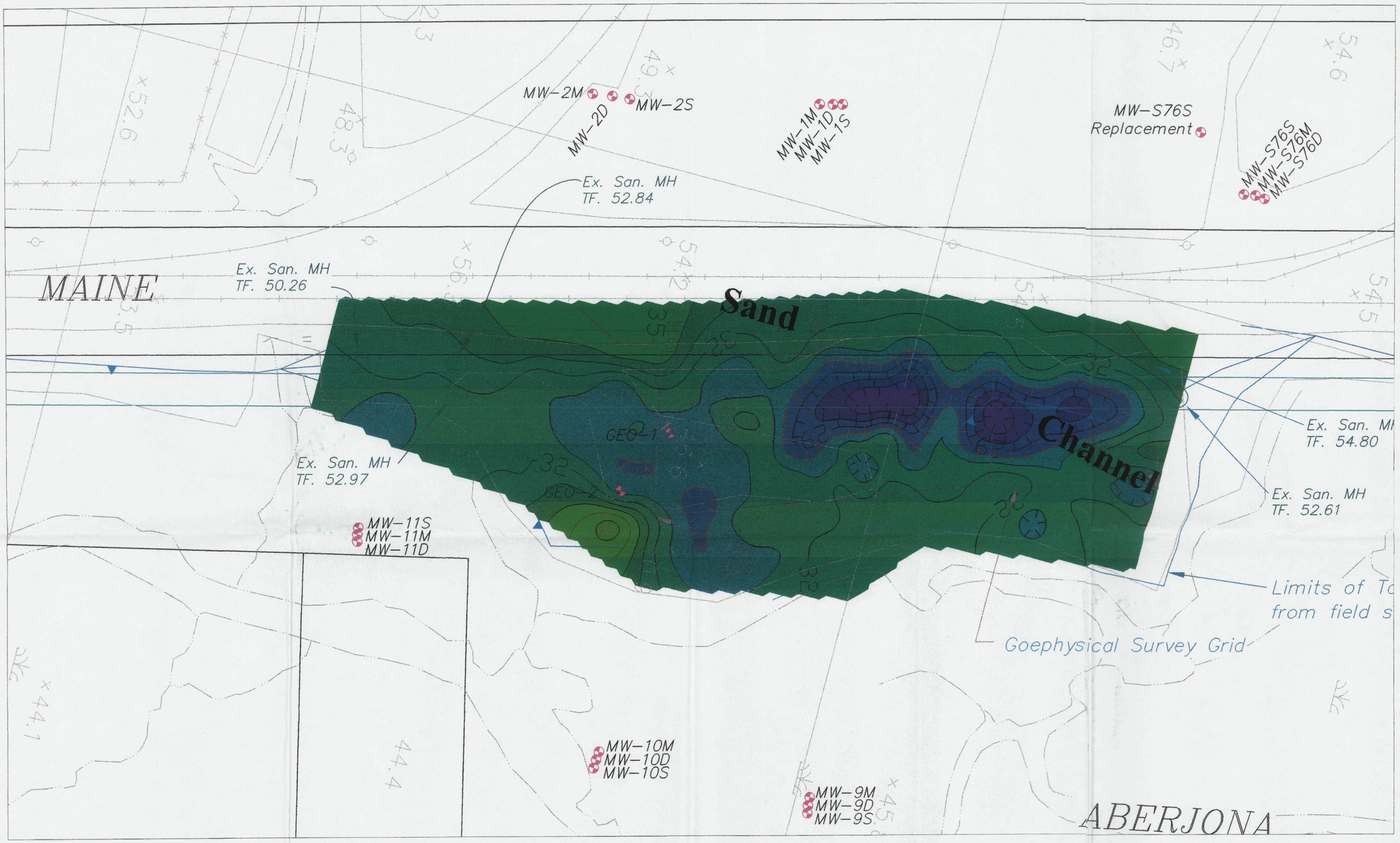
Elevation Contour Map
Top of Silt
Olympia Superfund Site
Woburn, Massachusetts

Hager GeoScience, Inc.
596 Main Street Woburn, MA
Tel 781.935.8111 Fax 781.935.2717



Elevation Contour
(Hot to Cool Colors=High to Low Elevation)
Contour Interval=1-foot

GRAPHIC SCALE

80 40 20 0 40 120

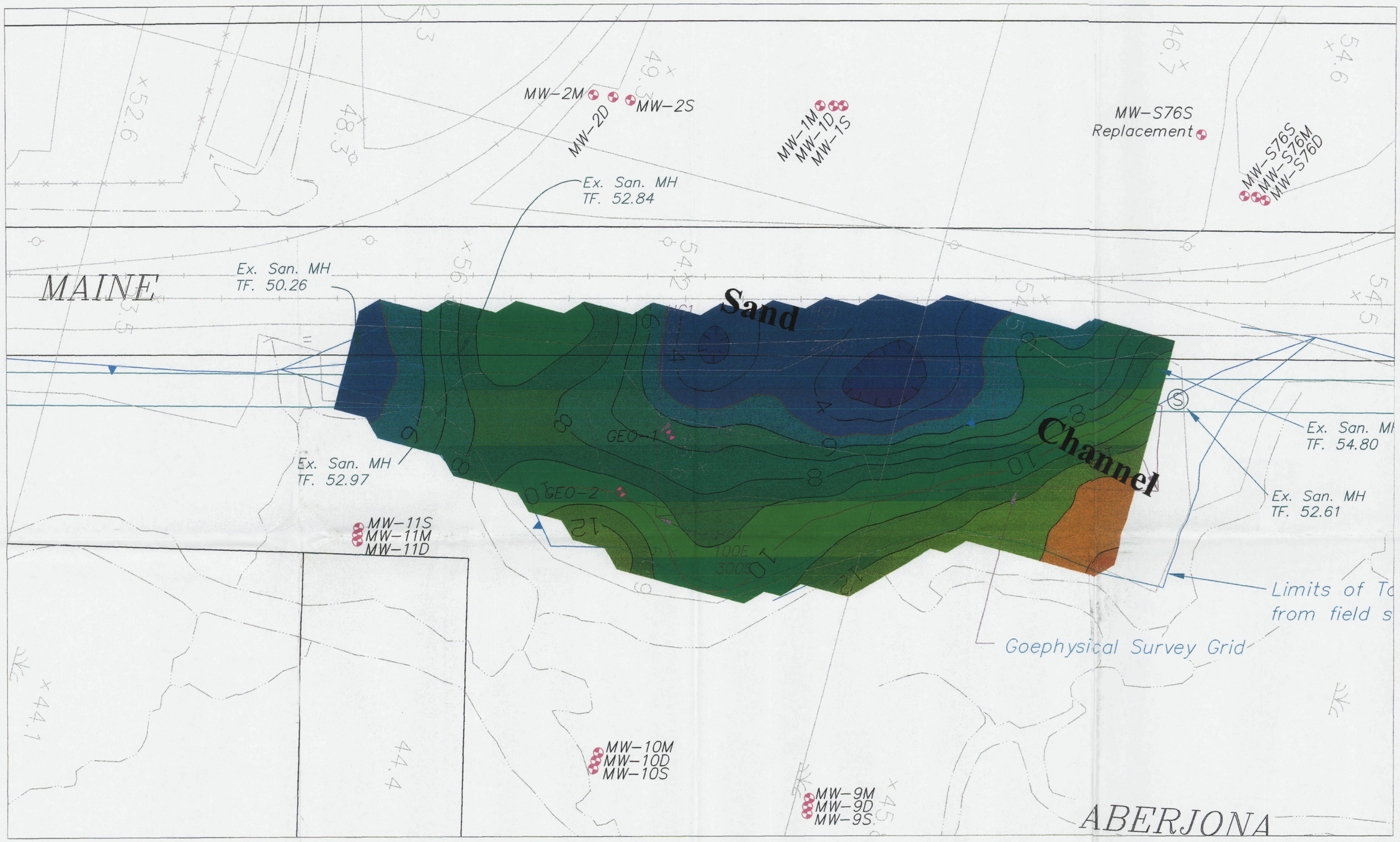
(IN FEET)
1 inch =40 ft.

Plate 4

June 2002	File No. 200207

Elevation Contour Map
Top of Clay
Olympia Superfund Site
Woburn, Massachusetts

Hager GeoScience, Inc.
596 Main Street Woburn, MA
Tel 781.935.8111 Fax 781.935.2717



Isopach (Thickness) Contour
(Hot to Cool Colors=Thick to Less Thick)
Contour Interval=1-foot

GRAPHIC SCALE

80 40 20 0 40 120

(IN FEET)
1 inch =40 ft.

Plate 5

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Clay Isopach Map
(Clay Thickness)
Olympia Superfund Site
Woburn, Massachusetts

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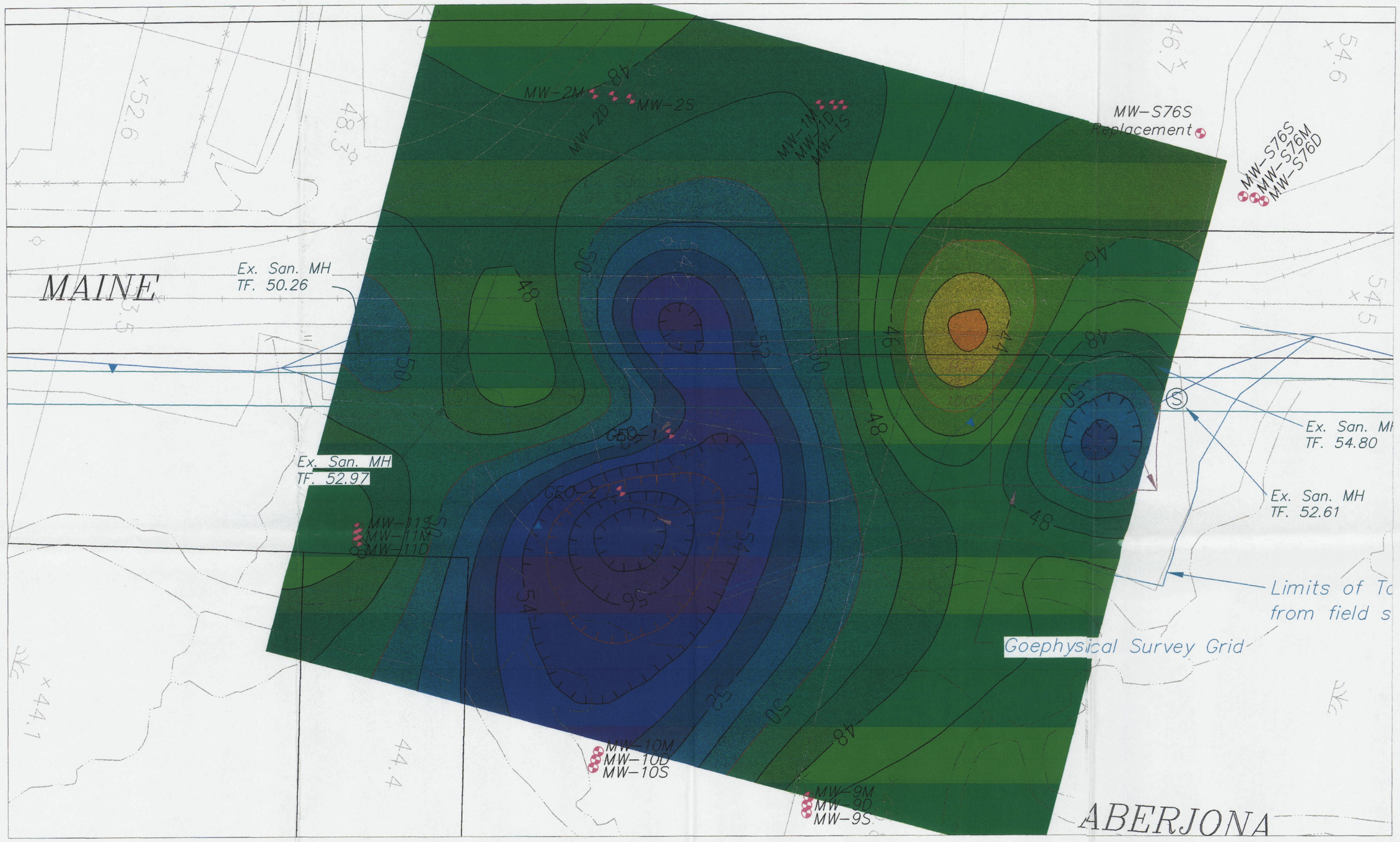
596 Main Street Woburn, MA
Tel 781.935.8111 Fax 781.935.2717



Elevation Contour
(Hot to Cool Colors=High to Low Elevation)
Contour Interval=1-foot

GRAPHIC SCALE

80 40 20 0 40 120

(IN FEET)
1 inch = 40 ft.

Plate 6

June 2002	File No. 200207

Elevation Contour Map
Top of Bedrock
Olympia Superfund Site
Woburn, Massachusetts

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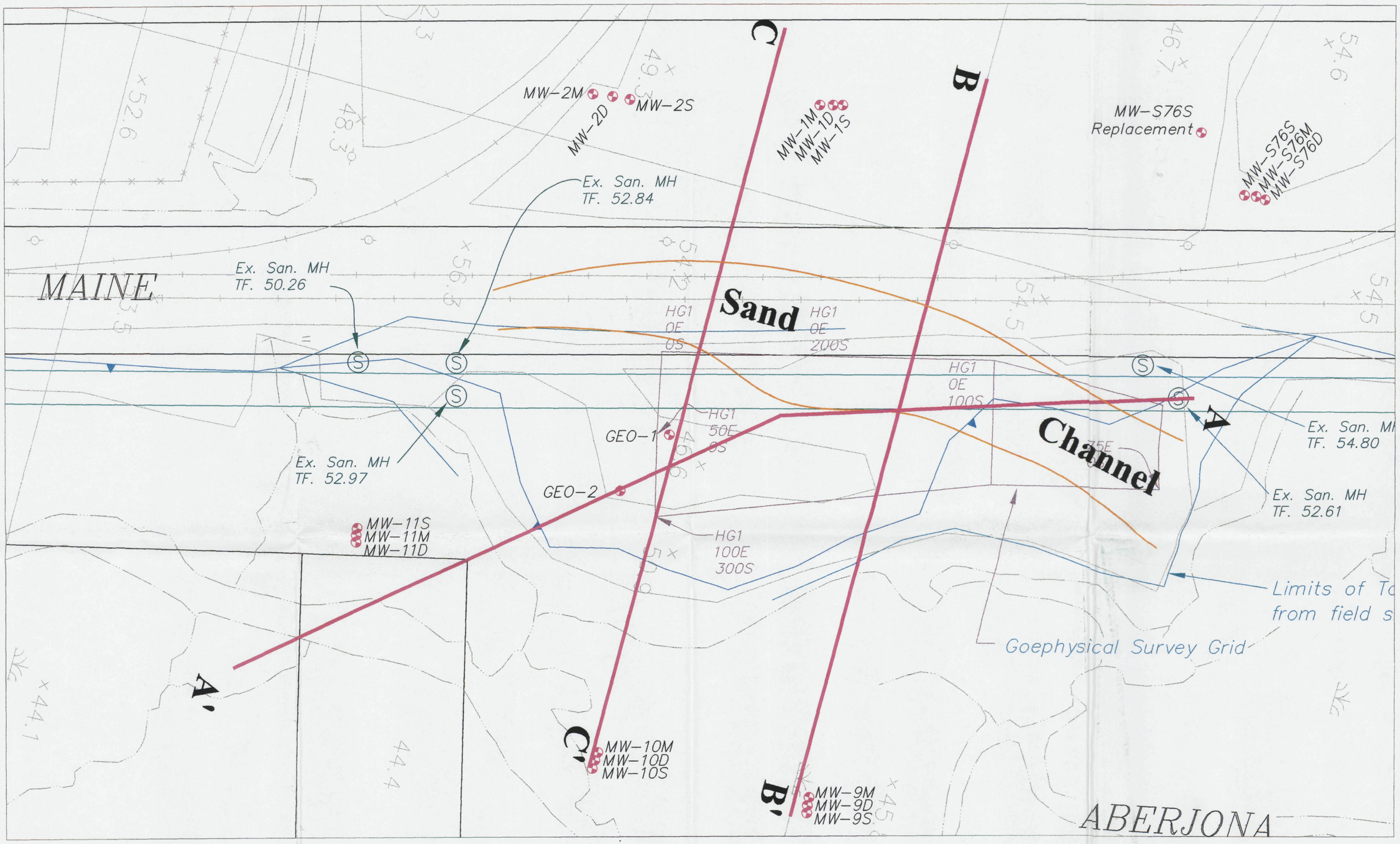
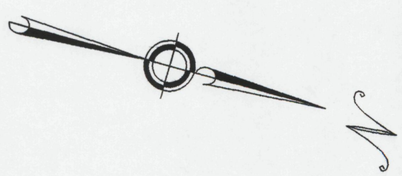
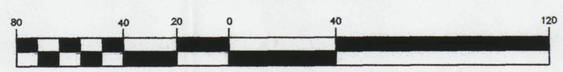




GRAPHIC SCALE



(IN FEET)
1 inch = 40 ft.

Plate 7

June 2002	File No. 200207

Cross-section Location Map
Shallow and Deep Sections
Olympia Superfund Site
Woburn, Massachusetts

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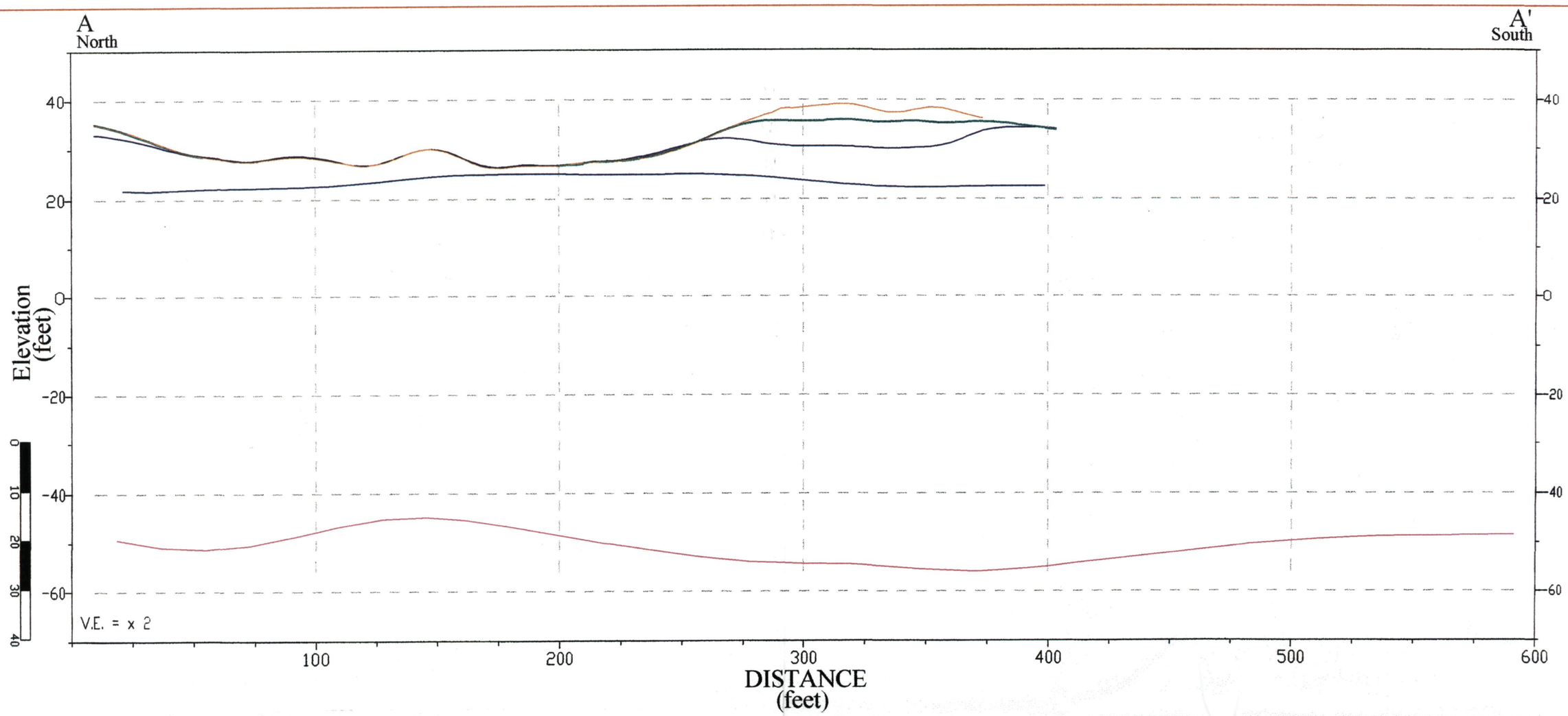

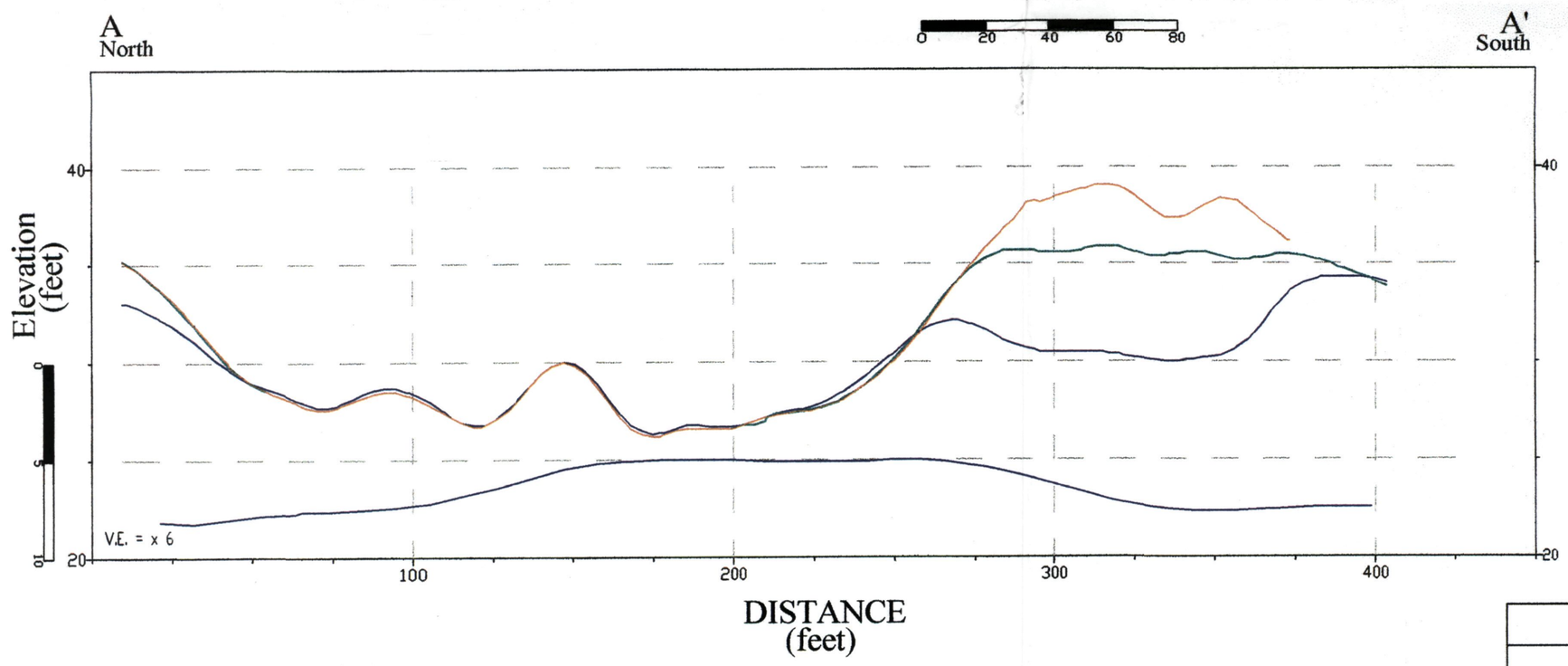

Base of Fill
Top of Silt
Top of Clay
Base of Clay
Top of Bedrock

Plate 8

June 2002	File No. 200207

Grid Cross Sections
A - A'
Olympia Superfund Site
Woburn, Massachusetts

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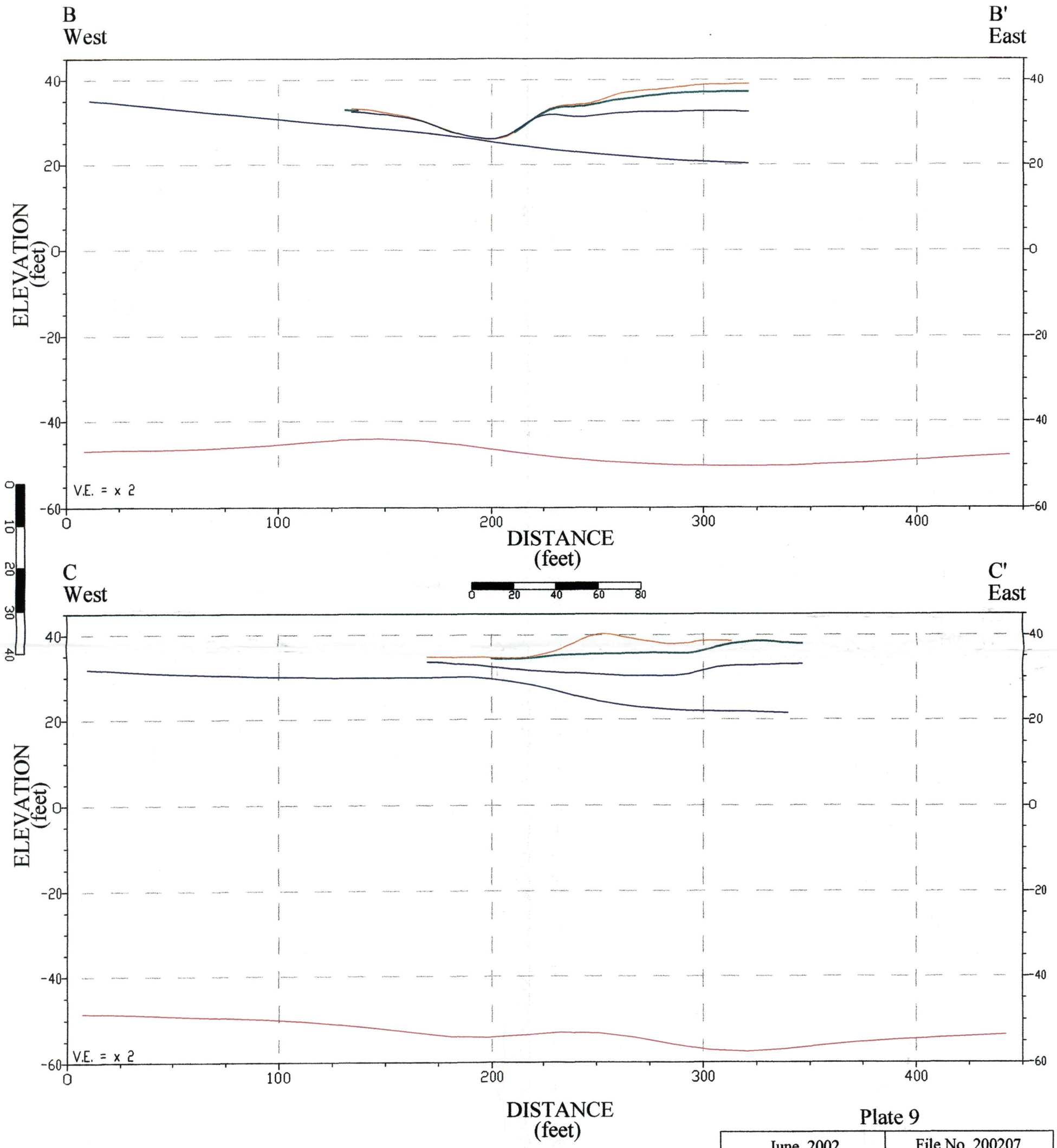

Base of Fill
Top of Silt
Top of Clay
Base of Clay
Top of Bedrock

Plate 9

June 2002	File No. 200207

Grid Cross Sections
B-B' & C-C' Deep Sections
Olympia Superfund Site
Woburn, Massachusetts

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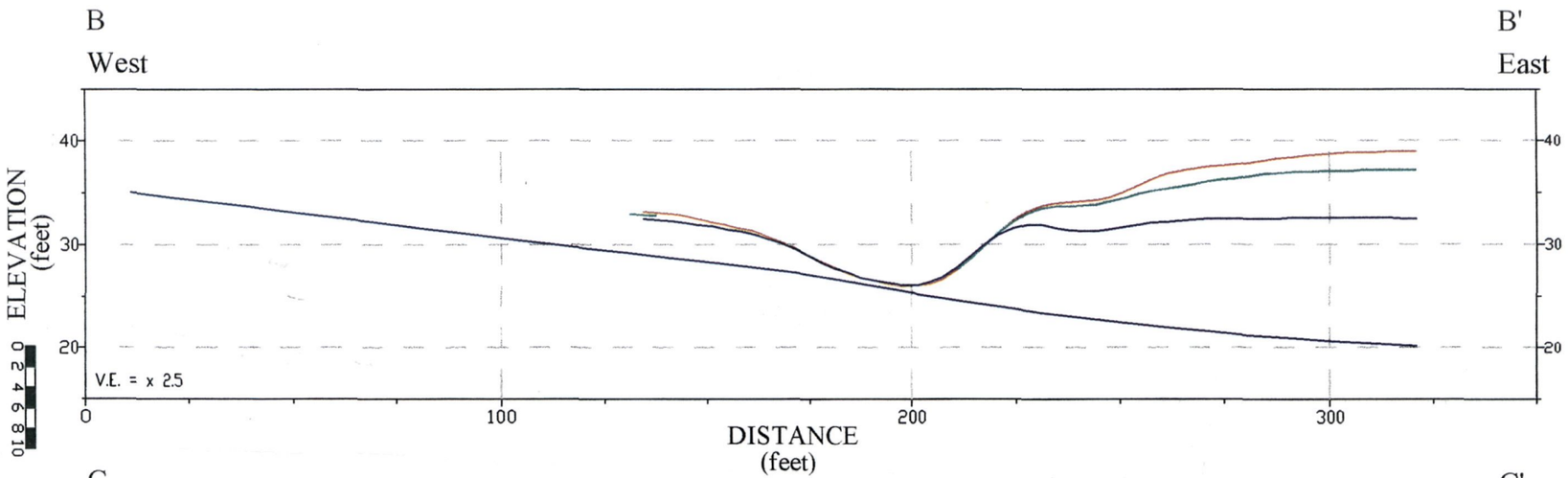

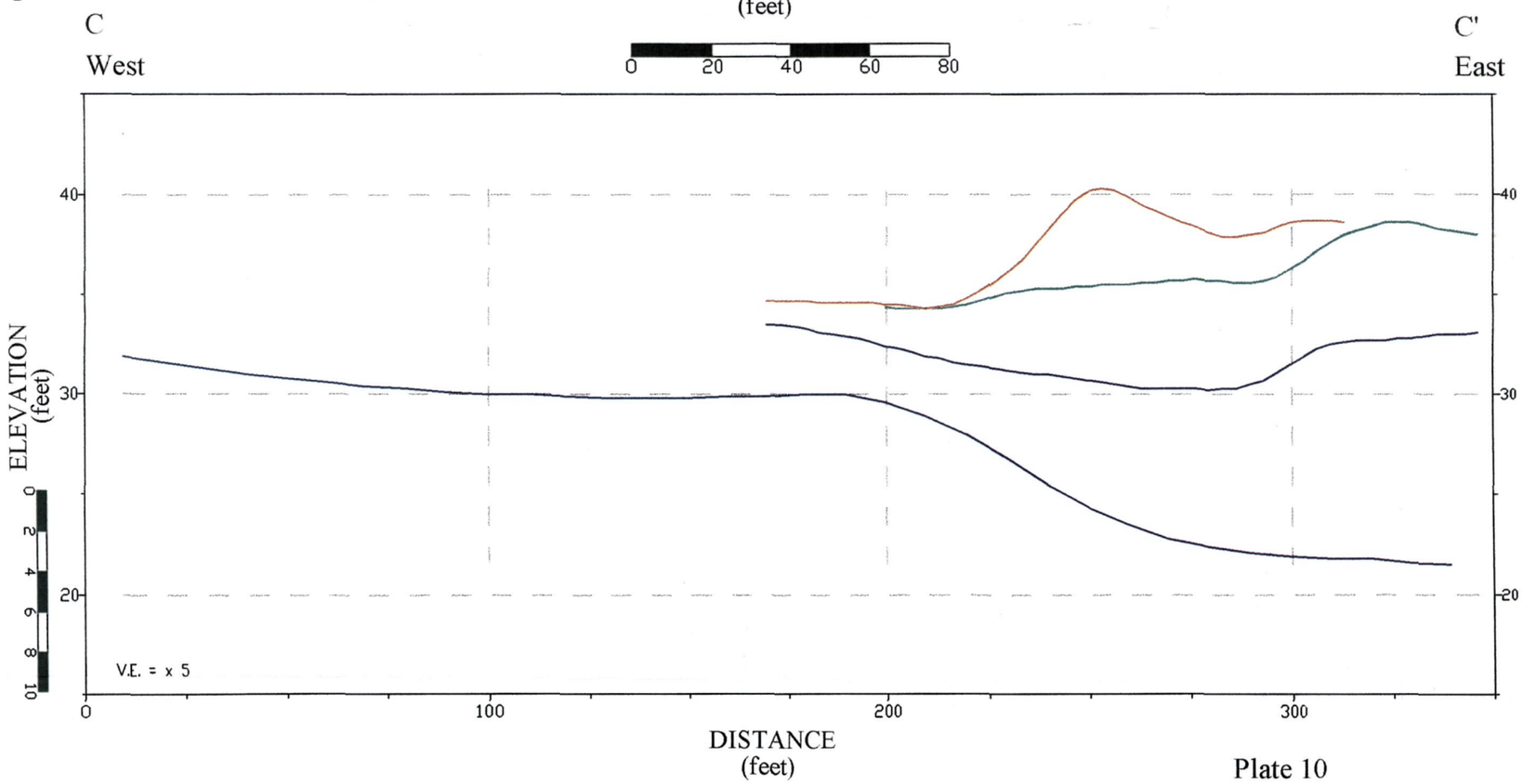

Plate 10

June 2002	File No. 200207

Grid Cross Sections
B-B' & C-C' Shallow Sections
Olympia Superfund Site
Woburn, Massachusetts

Base of Fill
Top of Silt
Top of Clay
Base of Clay
Top of Bedrock

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