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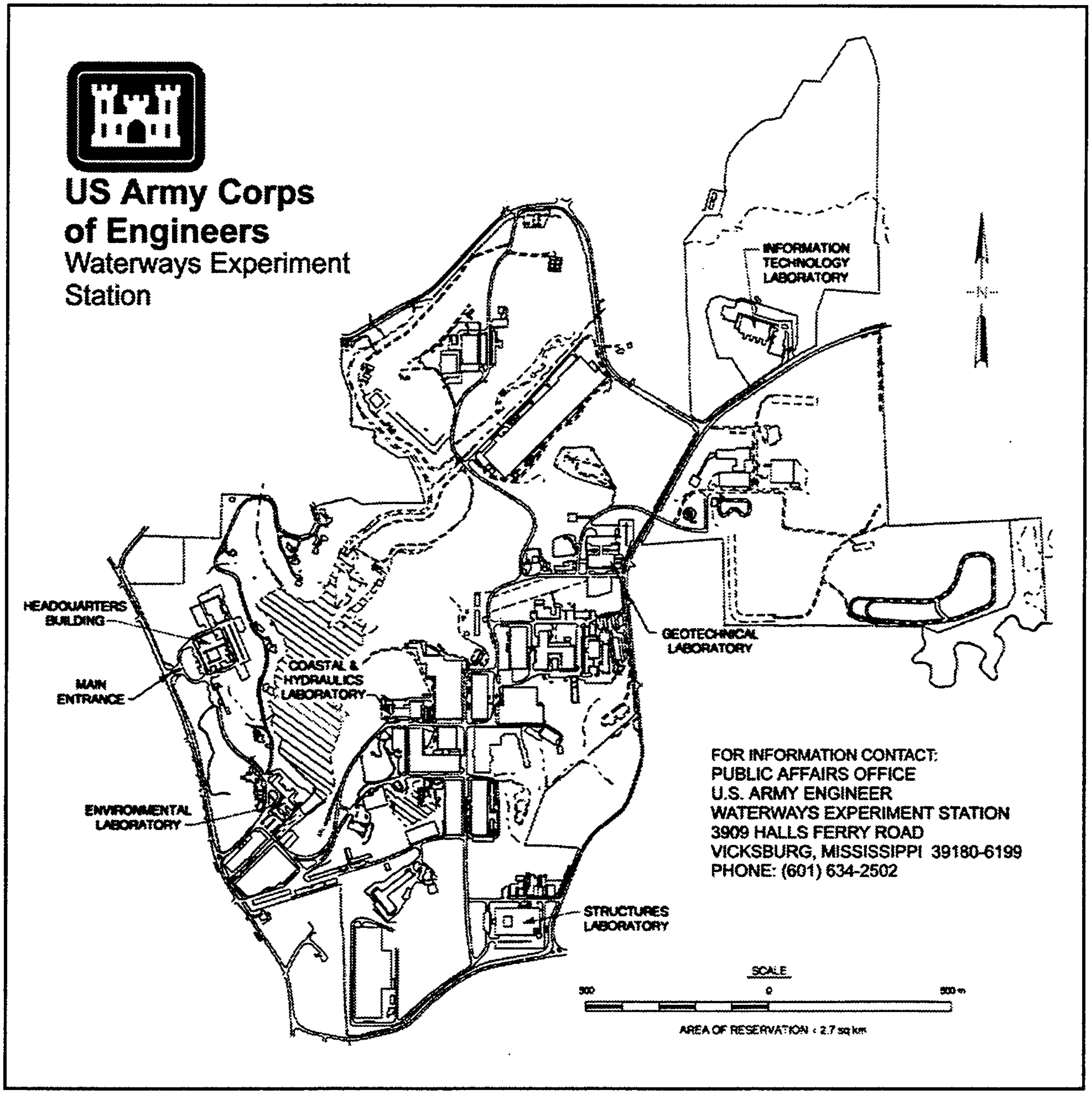

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Contents

Preface

A seismic reflection and side scan sonar investigation was conducted in Newark Bay, Arthur Kill, and Kill Van Kull in Newark and New York Harbors by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), during the period 2-10 June 1996. The investigation was performed under sponsorship of the U.S. Army Engineer District, New York (CENAN). The CENAN Project Coordinator at the time of the survey was Mr. Mark Burlas.

The overall test program was conducted under the general supervision of Drs. W. F. Marcuson III, Director, GL, and A. G. Franklin, Chief, Earthquake Engineering and Geosciences Division (EEGD). Mr. Keith J. Sjostrom was the principal investigator. This report was prepared by Messrs. Sjostrom and Rodney L. Leist under the supervision of Mr. J. R. Curro, Jr., Chief, Engineering Geophysics Branch, EEGD, GL. Data acquisition and instrumentation support were provided by Mr. Thomas S. Harmon, Jr., EEGD, GL. Data presentation and graphics support were provided by Ms. Lori M. Davis, EEGD, GL, and Mr. Grady A. Holley, Jr., Applied Research Associates, Vicksburg, MS.

Acknowledgment is made to Captain Mat Methany of Wilmington, DE, for piloting the WES research vessel *Waterways Explorer* during the geophysical survey. Appreciation is also expressed to personnel of Pedersen's Marina, Keyport, NJ, and Wagner's Twin Towers Marina, Cliffwood, NJ, for their support and assistance.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
microseconds (μsec)	1.0×10^6	seconds
miles (U.S. statute)	1.6093	kilometers

1 Introduction

Background

At the request of the U.S. Army Engineer District, New York (CENAN), the U.S. Army Engineer Waterways Experiment Station (WES) conducted a waterborne seismic reflection survey in Newark Bay, Arthur Kill, and Kill Van Kull, New York/New Jersey. Newark Bay serves as the principal seaport for Newark, New Jersey. Arthur Kill and Kill Van Kull form the New York and New Jersey Channels (see Figure 1) and provide access to ocean-going vessels entering Newark Bay. Kill Van Kull begins at the Upper Bay of New York Harbor and extends approximately 4.5 miles westward to Newark Bay. Arthur Kill begins at Newark Bay and trends southward to Raritan Bay. The ship channels in each area are under consideration to be deepened and widened in order to provide better navigation and allow access of deeper draft cargo vessels to the port facilities. Therefore, information concerning the lithology and thickness of the subbottom geologic units and identification of near-surface sediment layers are necessary for preparing plans and specifications for the proposed deepening of the channels.

Purpose and Scope

The objective of the geophysical investigation was to determine the depth to bedrock and delineate the geologic stratigraphy to elevations of -47 ft Mean Lower Low Water (MLLW); approximately five feet below the current bottom surface. The results are intended to supplement previously obtained borehole information by providing continuous profile line coverage of the bottom and subbottom lithology along the length of each project area. This will facilitate the accurate positioning of any additional borings that may be required. Additional information about the distribution of unconsolidated surface sediments and locations of possible dredging or navigation hazards are also needed for project planning. Overall, the geoacoustic data will provide better descriptions of variations in the actual subbottom sediments and help identify differing geologic layers than could be obtained with borehole information alone. Two high resolution subbottom profiling systems and a side scan sonar system were used to meet the primary objectives of the investigation.

Overview of Site Geology

The New York and New Jersey Channels project area is located at the junction of the Atlantic Coastal Plain, New England Highland, and Newark Lowlands physiographic provinces (U.S. Army Engineer District, New York 1986). Glacial features created from the last advance of the continental ice sheet during the Pleistocene era dominate the surface landscape. The land surface has moderate relief and consists of rounded hills and ridges characteristic of glacial moraines and broad lowland valleys. The Pleistocene glacial deposits overlie the original bedrock surface. The bedrock consists primarily of sandstones, shales, and siltstones and forms a highly fractured and irregular surface. These rock units dip steeply throughout the site and trend in a southwest to northeast direction. Numerous rock pinnacles or entrenched channels exist along the rock surface.

The Pleistocene sediments within the project areas range in thickness from 30 to 45 ft outside of the ship channel margins and consist primarily of glacial outwash deposits and till. Sands, gravels, and cobbles are the major soil types but layers of silts and clays are also present. Layers of silt, clay, and organic material are found on the bottom surface of the waterways and are deposited by the numerous freshwater streams that enter the waterway system. These alluvial sediments are deposited in thin layers and lenses and have a high degree of horizontal and vertical variability.

2 Technical Approach

Seismic Reflection Method

Acoustic subbottom reflections are produced when a source of acoustic energy is deployed just below the water surface and fired. In a homogeneous medium, the acoustic waves extend uniformly in all directions from the source in which the advancing wavefronts are spherical surfaces centered at the source and normal to the direction of propagation. At large distances from the source, the wave fronts may be represented by rays as shown in Figure 2. When the acoustic energy arrives at a boundary between two materials of differing density and elastic velocity, part of the energy will be reflected back towards the surface and part transmitted downward into the medium below (see Figure 2). Portions of the transmitted energy will also undergo absorption or attenuation in the material while the wavefront propagates through to the next stratigraphic boundary.

The amplitudes of the incident, reflected, and transmitted wave energies vary with respect to the density and velocity of the materials through which the wave energy is propagating. The ratio between the amplitudes of incident and reflected wave energy is called the reflection coefficient (R) and is defined as:

$$R = \frac{A_R}{A_I} \tag{1}$$

where A_R and A_I are the amplitudes of the reflected and incident wave energy, respectively. Reflected wave energies are detected using hydrophones or piezoelectric transducers which convert changes in water pressure caused by the acoustic wavefronts into electrical impulses. The electrical signals are amplified, filtered, and recorded using a shallow seismic, digital data acquisition system.

The measured amplitudes of the reflected acoustic waves will vary depending on the angle of incidence the seismic wave pulse confronts the interface. If the wavelet energy encounters a reflection horizon at normal incidence (i.e. perpendicular to the interface), the reflection coefficient can also be expressed by Equation 2.

$$R = \frac{(Z_{i+1} - Z_i)}{(Z_{i+1} + Z_i)} \tag{2}$$

where Z is the acoustic impedance value of the layer and 'I' and 'I+1' identify adjacent stratigraphic layers (see Figure 2). The acoustic impedance of a sediment is defined as the product of the material density (ρ_i) and acoustic velocity (V_i) and represents the influence of the material's characteristics on reflected and transmitted wave energy. Specifically,

$$Z_i = \rho_i \, V_i \tag{3}$$

where 'I' identifies the appropriate layer. Therefore, when there is a distinct acoustic impedance contrast between layers, amplitude reflections will be generated at the interface. However, at a boundary between two materials in which the transmission velocities and densities vary in such a manner that Z_i and Z_{i+1} have similar values, the amplitude of the reflections may be too small to be recorded. The seismic reflection works best when acoustic impedance and reflection coefficient values increase with depth. The amplitudes of the reflection signatures also decrease as the angle of incidence deviates from the perpendicular.

Using the relationships above, the acoustic impedance values of bottom and subbottom sediments may be determined from ratios of the measured incident and reflected wave energy amplitudes as shown below.

$$\frac{A_R}{A_I} = \frac{(Z_{i+1} - Z_i)}{(Z_{i+1} + Z_i)} \tag{4}$$

At the water-sediment interface, the acoustic impedance of the water is a constant of known value. Inserting the impedance value for water along with measured amplitudes of the seismic signals into the above equation, the acoustic impedance of the bottom surface sediments can be calculated. Likewise, once the impedance of the uppermost sediment layer is determined, the impedance of the remaining sediment facies may also be computed using the equation

$$Z_{i+1} = \frac{Z_i * (1+R)}{1-R} \tag{5}$$

where R is the computed reflection coefficient between layers 'I' and 'I+1'. If the seismic velocities of the sediment material comprising each layer are also known, then the material density may also be derived. This is a simplified overview of the concept. It is also important to note that factors such as signal attenuation and transmission loss have not been taken into account in the above equations. For a discussion in more depth, refer to Telford et al. (1976).

Despite the simplistic overview of the basic principles involved, the analysis and interpretation of seismic reflection data requires a good understanding and knowledge of all aspects of the investigation including site conditions, seismic and sonar data quality, regional geology, and available core information. Incorporating this information to produce a comprehensive picture of the subsurface is an involved task. Interfaces are interpreted by mapping the trends of high amplitude reflection values on the colorized amplitude cross-sections. Lithology and material types are interpreted by correlating the detected interfaces with existing core information, bottom samples, or geologic literature. In areas with limited ground truth information, seismic data processing is performed to determine estimates of the sediment characteristics. Besides the subjectivity involved in selecting reflection horizons from the amplitude records or the detail involved in processing the seismic data, other factors may complicate interpretation of the data. One factor is frequent lithologic changes in the near-surface sediments in which numerous reflection horizons exist, each having differing reflection coefficients (Sjostrom and Leist 1996). Surface and subsurface irregularities may also cause the incident and reflected signals to scatter away from the receiver so that reflected events may have anomalously low reflection coefficients or be completely masked. But under favorable conditions, when the geologic structure is not too complicated and noise is minimized, distinct reflections can be identified and information regarding the sediment characteristics can be derived.

Side Scan Sonar Operation

Side scan sonar is an acoustic imaging device used to provide wide-area, large-scale images of the bottom of a body of water. The propagation of the acoustic pulses from the source to the bottom surface and back are the same as that described previously for the seismic reflection method. However, the operating frequency of the side scan sonar acoustic source is nearly 30 times greater than that of sources for the seismic reflection method and, therefore, little to no subbottom penetration is attained. The higher frequency values provide detailed images of the bottom surface.

The side scan sonar system consists of an onboard recording system and control modules, an underwater sensor (typically referred to as a towfish), and a cable linking the two units (see Figure 3). During survey operations, the side scan recorder continually charges capacitors in the towfish at set levels determined as a function of the imaging range. The range may be adjusted between 25 and 600 m. At discrete time intervals, the recorder transmits this stored power to the transducers in the towfish which in turn emit an acoustic pulse or 'ping' having a frequency of either 100 or 500 kilohertz (kHz). The acoustic signals propagate through the water over the set imaging range and reflect off differing interfaces along the bottom surface. The returning signals are received at the transducers, amplified using a time varied gain function, and recorded. The recorder performs further filtering, amplification, and digitizing functions before calculating the proper position of the signals on the final record. The recorder prints out and stores the resultant signature one scan at a time to provide a continuous image of the bottom surface along the survey line.

Images of the bottom features and site characteristics are a result of variations in the recorded acoustic signal amplitudes. Further information concerning the side scan sonar theory of operation may be found in Fish and Carr (1990).

The printed amplitude signatures received from various bottom features can be qualitatively interpreted for the feature geometry, identification, and possible composition (Sjostrom et al. 1996). The reflectivity potential of an underwater surface is a function of the side scan sonar's beam angle of incidence as it encounters that target. When the acoustic pulse ('ping') is normal to a surface, more energy returns to the towfish than when a beam strikes at a differing angle. This angle of incidence, along with bottom surface roughness, are the primary reasons for dark and light areas on the sonar record. The various intensities of these shades assist in better record interpretation. Features such as submerged roads, vegetation, and man-made debris are easily imaged during typical survey conditions. Sandy or gravelly material typically produce darker gray patterns on the side scan record whereby lighter shades may be indicative of more silty or clayey material. However, the beam angle, towfish path, survey vessel speed, signal gain, and other physical parameters may all affect the appearance and resolution of the side scan sonar record. Standard sonar record interpretation involves the identification of bottom features, general characteristics of the bottom sediments, or man-made structures and debris and correlating the location of the interpretations with the positioning information.

Geophysical Survey

Seismic reflection and side scan sonar data were acquired along five survey lines in Kill Van Kull. The survey track lines are denoted as lines PKK1 through PKK5 and presented in Figures 4 through 6. These lines are based on the seismic and positioning data collected with the high-resolution, subbottom profiling 'pinger' system (see next section). The geophysical survey lines, performed parallel to the channel centerline, are approximately 4.5 miles in length and nominally spaced 100 ft apart. Survey lines PKK1 and PKK2 were performed in an easterly direction from Shooter's Island to the Upper Bay of New York Harbor. Survey lines PKK3, PKK4, and PKK5 were performed in a westerly direction as shown on the track line maps. In certain areas, survey line length and/or position were dependent on the amount of barge and commercial vessel traffic.

Side scan sonar images and seismic reflection data were collected along 11 survey lines in Newark Bay. Survey track lines illustrating the seismic file numbers of the 'pinger' system are illustrated in Figures 7 through 9. Survey lines PN02 and PN03 were performed in the entrance channels to the Port Elizabeth and Port Newark Marine Terminals whereas lines PN04 through PN08 were conducted in the anchorage area adjacent to Port Elizabeth. The remaining survey lines, lines PN01 and PN09 through PN11, were performed along the main channel from near Shooter's Island to the Interstate Highway 278 Bridge. These four survey lines are approximately four miles in length and oriented parallel to the channel centerline. Survey lines PN01, PN09, and PN11 were conducted in a northerly direction. All survey track lines are nominally spaced 100 ft apart. In certain areas, the survey line positions are dependent on the amount of barge and commercial vessel traffic.

Survey Method

Acoustic energy was generated by two high resolution subbottom profiling systems. The first system was operated at a frequency of 3.5 kHz and is typically called a 'pinger' because of the audible noise it makes during operation. The second system is a low frequency 'boomer' system and hydrophone which has an output frequency range of 0.5 to 2.0 kHz to interrogate the subbottom sediment and rock structure. The higher operating frequency of the 'pinger' system allows greater resolution of the harbor sediments than the 'boomer' system but shallower depths of energy penetration depending on the characteristics of the subbottom material. The 'pinger' system was used as the primary investigative tool for this study because it provided better resolution of the geologic interfaces and bedrock surface than the 'boomer' system. Seismic reflection data was collected concurrently from the 'pinger' and 'boomer' systems throughout the study.

The source and receiver transducers of the high-resolution 'pinger' system were mounted on the hull of the research vessel. The source/receiver separation was approximately five feet and each set of transducers was positioned three feet below the water surface during data collection. The length of the 'pinger' pulse width at a frequency of 3.5 kHz is typically able to resolve sediment layers having thicknesses greater than or equal to two feet. A total trace length of 700 samples were digitally acquired every 42 μsec which corresponds to a sampling rate of 16 samples/μsec. This sampling rate provides an effective depth of subsurface exploration of approximately 50 ft below the bottom surface depending on the bottom and subbottom sediment characteristics.

The electro-mechanical source of the 'boomer' system is mounted on a sled and, along with the hydrophone, towed approximately 70 ft behind the research vessel during the investigation. The length of the 'boomer' pulse width at the central frequency of 1.0 kHz is typically able to resolve lithologic layers having thicknesses greater than five feet. A total seismic trace length of 700 samples were collected every 52 μsec (sampling rate = 13 samples/μsec) resulting in an approximate depth of exploration of 100 ft below the bottom surface. Reflection data created with the 'boomer' system were digitally acquired along select survey lines but 'shades-of-gray' analog records were collected along each survey transect.

The side scan sonar unit was operated along each survey line in Kill Van Kull and Newark Bay. The purpose of the sonar survey was to provide full areal images of the channel bottom surface to aid in mapping the general sediment characteristics and any geologic features. Possible dredging hazards not indicated on available navigational charts such as pipeline crossings and submerged debris were interpreted from the sonar records. The towfish was rigidly mounted on the port side of the research vessel and positioned at a depth of six feet below the water surface during data acquisition. The sonar was operated at a frequency of 100 kHz along each survey line. The imaging range was set at 100 m to provide detailed resolution of the channel bottom. Time marks and fix points were printed incrementally along the side scan records in order to correlate the data with the positioning information.

Positioning information for each survey line was provided using Differential GPS and recorded concurrently during geophysical data acquisition. Positioning data were obtained with a Trimble 4000SE Differential Global Positioning System with differential corrections received from the U.S. Coast Guard beacon in Sandy Hook, NJ. The accuracy of the GPS positioning data is limited to 3 to 5 m. The WGS-84 geographic coordinates (latitude/longitude) recorded during the investigation are translated to Universal Transverse Mercator (UTM) Zone 18 coordinates (Easting/Northing) for data presentation and mapping. Precision bathymetric data were also simultaneously collected during each survey. The bathymetric data were corrected for tidal fluctuations using tide data recorded at the gaging station located at The Battery (south end of Manhattan Island), NY and correlated to the Shooter's Island locale. The recorded GPS positioning information and corrected channel bottom elevations (in feet MLLW) are presented with respect to the 'pinger' seismic data file numbers in Appendices A and B for data collected in Kill Van Kull and Newark Bay, respectively.

3 Data Analysis and Results

Geoacoustic Data Analysis

Continuous subbottom seismic reflection amplitude profiles plots for Kill Van Kull and Newark Bay illustrate interpreted sediment interfaces and lateral variations of the subbottom reflection signatures. The seismic amplitude records were delivered to CENAN project engineers in August 1996. The seismic records are annotated with survey information, data file numbers, and available core locations. The location of the seismic reflection and side scan sonar survey lines or a particular 'pinger' data file are graphically displayed on the survey track line maps in Figures 4 through 9 for the lines in Kill Van Kull and Newark Bay. It is reiterated that the seismic reflection data acquired with the 'pinger' system was the primary data set used to detect and identify the subsurface reflection horizons. The 'boomer' data was used to assist in mapping the deeper interfaces but lacked the resolution for detailed mapping. The linear arrays of labeled black dots in the track line maps denote a particular survey track line and survey direction. Each dot represents the beginning of every third digitally recorded 'pinger' seismic data file in order to give an indication of the data coverage along each transect and assist in correlating the raw data and interpreted results. The associated label is the 'pinger' data file number. Appendices A and B present the positioning coordinates (in UTM Zone 18 grid coordinates) and channel bottom elevations (in feet MLLW) at the time of the survey for the appropriate 'pinger' data file numbers for the Kill Van Kull and Newark Bay surveys, respectively.

Interpretation of the seismic amplitude records entails the identification of subbottom sediment or rock interfaces along the channel bottoms. Special attention is given to areas where the bedrock outcrops along the channel and unconsolidated, low density sediments exist. The depths to geologic interfaces or thicknesses of sediment zones are determined by measuring the travel times of the transmitted and reflected signals on the amplitude records while taking into account the source/receiver separation and acoustic velocities of the overlying sediment units. The measured depths to the interfaces are referenced to the MLLW datum and plotted on cross-sectional diagrams to illustrate the interpreted geologic stratigraphy at the project areas. The geologic cross-section plots are displayed in Plates 1 through 7 and 8 through 15 in Appendix C for the survey lines performed in Kill Van Kull and Newark Bay, respectively. A sheet outlining the symbol definitions used in the cross-sections precedes the plates. The reflection horizons are mapped in relation to the linear distance along a given survey line. The black dots and corresponding labels represent the data files acquired with the high-resolution 'pinger' system along a survey line. The data files can be correlated with either the survey track lines in Figures 4 through 9 to determine the general location of the results or to the positioning and elevation information presented in Appendices A and B. The five resultant cross-sections for the Kill Van Kull portion of the study are each oriented west to east beginning with survey PKK5 along the north side of the channel and ending with survey PKK1 along the southern margin. Nine of the eleven cross-sections for the Newark Bay study are oriented from south to north. The exceptions are survey lines PN02 and PN03 (see Plate 12) in which the results are presented from the start of the Port Newark entrance channel counter-clockwise to the start of the Port Elizabeth entrance channel. The cross-sections following the length of the main shipping channel (see Plates 8 through 11) begin at the western margin of the channel (survey PN10) and conclude at the eastern side (survey PN01). Categorical grouping and classification of sediment layers are completed through the use of the seismic amplitude records illustrating the bottom and subbottom acoustic signatures, side scan sonar images of the channel bottom, and existing borings provided by CENAN. The approximate location of the CENAN cores are indicated on the geologic cross-sections.

Analysis of the side scan sonar data involves the interpretation of the raw sonar records to identify bottom features (natural or man-made) and sediment textures along the channel bottom. Identified features are correlated with the data acquisition time which is related to the GPS positioning coordinates.

The reflection horizon positions, inferred sediment characterizations, and detected channel bottom features described herein are interpreted from reflected seismic signatures and should not be considered absolute measurements. As with any geophysical method, there are limitations involved with both the side scan sonar and seismic reflection techniques. Some of these limiting factors are outlined below and are also described in further detail by McGee et al. (1995).

Data quality. The ability of this technique to detect subbottom layers accurately is a function of the data quality. Data having a low signal-to-noise ratio will produce poor quality results or no useful results. The data quality along each survey line is good except in isolated areas of excessive barge and ship traffic.

Layer detection and resolution. Unique sediment interfaces can be detected only when a distinct difference in impedance exists between materials. Gradual changes in material type, such as exists between layers of coarse gravel and fractured rock, may not result in an impedance differential large enough to produce a distinct reflection. Therefore the rock interface may be masked or go undetected. Irregular reflection horizon surfaces scatter the reflected signals away from the receiver so that these interfaces may be poorly defined. More competent layers, such as bedrock, may also be masked by lower impedance sediments if significant quantities of organic material (chemical or natural) or gas pockets exist in the overlying sediment unit (Sjostrom and Leist 1994). Organic sediments, which are prevalent in the northern portion of

Newark Bay, may either completely absorb the acoustic signals and thereby prevent any acoustic reflections or appear as a strong bottom reflector.

Vertical resolution of the sediment units and depth of exploration are also dependent on the frequency of the acoustic wave. As stated earlier, higher operating frequencies allow better resolution of the subbottom layers but shallower depths of energy penetration depending on the characteristics of the bottom and subbottom material. In sediments having high attenuation rates such as sands or gravels, higher frequencies are dissipated at a higher rate than low frequency signals and, therefore, layer resolution is further degraded. Signal correlation and enhancement algorithms are typically used to improve the signal-to-noise ratio and interface detection.

Determining a depth to an interface requires measurement of the travel times of the transmitted and reflected wave while taking into account the acoustic velocities within the overlying materials. The accuracy of these results is somewhat restricted because of the discrete pulse lengths of the acoustic signals. The 'pinger' and 'boomer' devices have well-defined acoustic pulse lengths and, under optimum conditions, are capable of resolving the depth to an interface to within approximately ± 2.0 and ± 5.0 ft, respectively. The error bounds of the measured channel bottom elevations are less than ± 0.5 ft because the acoustic device used operates at a much greater frequency, namely 200 kHz.

Acoustic footprint. The term 'footprint' refers to a circular area of the channel bottom interrogated by the acoustic device during a given pulse transmission. The 'footprint' is primarily dependent on the beam angle of the acoustic device. Using a hypothetical water depth of 20 ft, the acoustic 'footprint' of the 'pinger' system is at least 10 ft in diameter when the survey vessel is not moving. During survey conditions, the diameter of the footprint increases dramatically. This is in stark contrast to the area sampled with a drill hole. Therefore, it is easy to see that in highly variable geologic conditions, the acoustic and insitu results may not always agree precisely.

Side scan sonar analysis. As mentioned in the section titled "Side Scan Sonar Operation," the beam angle of the signal, towfish path, survey vessel speed, signal gain, and other physical parameters of the equipment and river bottom all affect the appearance and resolution of the side scan sonar record. During this investigation, the resolution of the channel bottom sediment and characteristics was good except in areas of barge and commercial vessel traffic.

The application of seismic reflection techniques and side scan sonar to detect and delineate the geologic interfaces, channel bottom geometry, and sediment type interpretations represents a geophysically-based engineering solution to the problem of remotely assessing the physical characteristics of harbor sediments and geologic structure. These techniques are not capable of assessing every geoacoustical situation and therefore the afore-mentioned limitations must be remembered.

Existing Borehole Information

During earlier stages of proposed new work or maintenance dredging along the Kill Van Kull and Newark Bay shipping channels, the CENAN has conducted exploratory boring programs throughout the project area. A total of 63 cores were acquired during 1995 and are denoted as 'KVK-95-##' where '##' represents the core number. The positions of the cores are illustrated on the geophysical survey track line maps shown in Figures 4 through 9. The cores penetrated the subsurface sediments to depths ranging from 0.4 to 26.1 ft with an average core length of approximately 8.8 ft. A summary of the boring logs is presented in Table 1. The information listed includes the core name, position, core length, depth to sediment or rock units, layer thicknesses, and brief lithologic descriptions of each unit. None of the insitu sediment information provided prior to the study have measured density values.

The near-surface sediments in Kill Van Kull range from interbedded zones of clayey silts to gravels. Clayey sediments are more prominent at the confluence with the Upper Bay of New York Harbor. Underlying the bottom surface sediments are sands, gravels, cobbles, fractured bedrock, or bedrock. Bedrock is detected near the channel bottom in cores KVK-95-34 through KVK-95-46 at depths varying from 1 to 5 ft below the bottom surface.

Visual analysis of cores collected within the middle and northern portions of Newark Bay indicate that the near-surface sediment consists primarily of clays, clayey silts, and silts. Organic material is also found at the bottom surface in many of these cores. The near-surface sediments in the southern parts of Newark Bay are composed primarily of sands, gravels, and cobbles. The bedrock interface is detected in a number of cores at depths ranging from 0.7 to 5.0 ft. The bedrock interface is also detected in one core in the Port Newark entrance channel.

Results of Investigation

Interpretation of the seismic reflection data is based on variations and impedance contrasts of the acoustic signatures along each survey, available core information, and side scan sonar information. Portions of the actual seismic records are included with the interpretations to help illustrate the bottom and subbottom sediment representations being described. Areas of interest will be referenced according to seismic data file numbers which in turn can be translated to a UTM Zone 18 grid coordinate using Appendices A and B. The side scan sonar was used in conjunction with the seismic equipment to provide an image of the channel bottom along the length of the project area. Each record is analyzed and interpreted to investigate the following: general channel bottom features, gross soil classification, utility crossings, and other anomalous features.

The interpreted results as stated and displayed in the plots and cross-sections highlight the detected reflection horizons within the subbottom sediments, resolve sediment layering, and outline any channel bottom features. Information or inferences pertaining to sediment characterization (material density, soil type, etc.) are estimates inferred from the acoustic data and correlated to the CENAN core information. These results should assist project engineers in understanding the lithology of the project areas in order to better design new work dredging or construction projects.

Kill Van Kull

The Kill Van Kull project area extends from the Upper Bay of New York Harbor to Shooter's Island at the junction of Newark Bay (see Figure 1). Five seismic reflection surveys, lines PKK1 through PKK5, were performed in the 4.5 mile long channel. Existing CENAN core locations and the geophysical survey track lines are presented in Figures 4 through 6. Detected reflection horizons are mapped to produce geologic cross-section maps along each survey line. These maps are found in Plates 1 through 7 in Appendix C.

The quality of the seismic reflection data is good throughout the Kill Van Kull waterway except in isolated areas where barge and ship traffic was passing the survey vessel. Even with good quality data, geologic interfaces are typically detected only to depths of 15 ft below the channel bottom along the majority of the waterway. The limited energy penetration is caused primarily by attenuation and absorption of the acoustic energy in the coarse-grained subbottom material. Generally speaking, acoustic energy experiences higher attenuation rates in more coarse-grained sediments such as sands, gravels, and fractured rock (McGee et al. 1995). The attenuation rate in a particular sediment unit is also a function of frequency in which higher frequency energy is dissipated at a greater rate. Figure 10 illustrates a typical 'pinger' record, collected along survey line PKK1 (files 0130-0155), from the Kill Van Kull survey. Referring to Core KVK-95-34, the left side of the figure illustrates reflection signatures characteristic of sands and gravels overlying bedrock. Similar acoustic impedance values of the sand, gravel, and rock units fails to produce any distinct interfaces between the particular material interfaces although subtle layering may be interpreted. Also, the competent material attenuates the seismic signal and limits energy penetration. At the right side of Figure 10, a change in material type exists such that the seismic energy is not attenuated as much and slightly deeper energy penetration is attained. The change in the near-surface material type also creates more contrasting impedance values which in turn produce more distinct reflection horizons. Referring to Core KVK-95-30, located near this area (see Figure 4), the surface material contains greater percentages of silt and clay. The noted interface is likely till, fractured rock, or bedrock and is interpreted at depths ranging from 7 to 10 ft. Reflection horizons are detected at depths greater than 20 ft below the channel bottom near the confluence of Kill Van Kull and the Upper Bay of New York Harbor. As an example, data collected along PKK1 (files 0530-0555) is shown in Figure 11 and illustrates a reflection horizon dipping towards the east. This interface may represent glacial till, fractured rock, or bedrock.

Characterization of the channel bottom sediments are interpreted from analysis of the seismic data, viewing the side scan sonar records, and reference to the CENAN core data. The bottom sediments are composed primarily of sands intermixed with or containing varying quantities of silts, gravels, or cobbles. A typical record illustrating the seismic reflection signatures from sandy bottom sediments is illustrated in Figure 12. The reflection signatures were acquired along survey line PKK5 (files 0660-0685) near Port Johnson at Core KVK-95-28. Faint sediment facies can be distinguished in the near-surface material and represent sediment variations. No distinct reflection horizons are visible because the acoustic impedance values of the sediments are similar. None of the faint horizons represent the bedrock interface as indicated in Core KVK-95-28. However, other nearby cores suggest these horizons reflect coarse gravel, boulder, or cobble zones in the sand matrix. An image of the channel bottom in the vicinity of Core KVK-95-28, acquired with the side scan sonar unit, is presented in Figure 13 and illustrates a coarse bottom texture indicative of sand and gravel. The more jagged images shown in the lower half of the figure are likely rocks or cobbles. Primarily sand-based bottom material is detected with both the seismic reflection data and CENAN cores along the entire Kill Van Kull waterway except at the following two areas: (1) east of Core KVK-95-10 (see Figure 6) at the confluence of Kill Van Kull and Upper Bay, and (2) along the channel margins. Small, thin layered zones are also detected intermittently along the channel bottom. A sonar image acquired at the confluence of Kill Van Kull and Upper Bay illustrating the transition area from more coarse textured bottom sediments (areas of dark gray images) to a more smooth image texture (areas of light gray) is presented in Figure 14. The interpreted clayey and silty bottom sediments over the right half of the figure were sampled along this portion of the channel and summarized in the core information in Table 1 (see Cores KVK-95-1, 2, 3, 4, 7, and 9).

Subbottom reflection horizons are detected along the entire Kill Van Kull waterway but clear interface definition is limited. The best definition of any stratigraphic interfaces typically occurs in areas where the overlying sediments are composed primarily of silts and clays. A good example is illustrated in Figure 15 where subbottom information was collected along survey line PKK4 (files 0034-0065). The figure indicates numerous subbottom interfaces representing various sediment facies within the upper 15 ft of sediment. The parabolic-shaped interface may represent the outline of a relic stream channel. No core information is available in this immediate area but the nearest core, Core KVK-95-1, detects clayey silt to a depth of 11.2 ft below the channel bottom. The interface detected at the left side of the figure at a depth of 19 ft below the bottom surface is interpreted as the bedrock or glacial till interface. This horizon correlates with the deep interface illustrated in Figure 11 detected along survey PKK1 (files 0530-0555). No cores in this area extend to depths greater than 12 ft and, therefore, verification of this horizon is not possible.

Approximately 600 ft west of the subbottom data presented in Figure 15, the seismic reflection signatures detect the sand, gravel, till, cobble, and/or rock interface trending upwards to the surface. This category of materials is the dominant subbottom sediment group from this location westward to Newark Bay. This trend is illustrated in each of the cross-sections (see Plates 1 through 7 in Appendix C) and may also be determined by reviewing the core information in Table 1. The subbottom interfaces in this more coarse-grained material are generally difficult to differentiate because the acoustic impedance values are similar for each sediment unit and the acoustic energy is absorbed at a higher rate. A good example of subbottom interfaces in this environment was shown earlier in Figure 12. Subbottom interfaces in areas dominated by coarse-grained near-surface material may be more uniquely determined if varying quantities of fine-grained material exist in the sediment regime. A good example of this effect was shown in Figure 10. Near this same area, reflection data collected along survey line PKK3 (files 0420-0445) is presented in Figure 16. At the right-hand portion of the figure, layers of sand, gravel, cobbles, and boulders (as determined from Cores KVK-95-32 and 33) trend toward the surface. Referring to Core KVK-95-30, the subbottom material at the left side of the figure consists of silty sand, sand, and clayey and silty gravel. Figure 17 displays seismic reflection signatures collected along survey line PKK1 (files 0240-0265) at a location where the survey track eases outside of the channel margins. Within the channel (left portion of figure), the near-surface sediments are comprised of sand overlying cobbles and boulders. Outside of the channel boundary (see right side of figure), the sand, cobble, and boulder strata appears as the interface at the same depth as the channel bottom. The overlying material likely contains higher quantities of silt and clay.

The bedrock interface is detected in some portions of Kill Van Kull but the reflection horizons are typically poorly defined and would have been overlooked without the availability of core information. Poor definition of the interface is caused by the overlying sediments, either glacial till or broken rock, having similar acoustic impedance values. As discussed in the 'Seismic Reflection Method' section, the reflection horizons may be too small to be detected between differing geologic units if the two materials have similar impedance values. A good example is presented in Figure 18 for data collected along survey line PKK3 (files 0570-0595). The bedrock interface is noted at an approximate depth of 5 ft by referring to the information from Core KVK-95-42. It is difficult to map the bedrock interface with any certainty beyond the available borehole information as clearly shown in the figure. The bedrock interface is better defined at locations where clayey or silty sediments overlie the rock surface.

Two significant subbottom features in Kill Van Kull are interpreted as relic stream channels. These features are located south of the Constable Hook area as highlighted in Figure 19. The westernmost paleo-channel is located between Cores KVK-95-19 and KVK-95-22 and detected only along survey lines PKK3, PKK4, and PKK5 as illustrated in Plates 1, 2, and 4 of Appendix C. Seismic reflection signatures acquired along survey line PKK4 (files 0460-0485) highlight this relic stream channel as illustrated in Figure 20. The paleochannel is 600 ft wide along survey line PKK4 and approximately 22 ft deep. Cores KVK-95-19 and 22 (see Table 1) indicate that the near-surface sediment structure is defined as silty sand overlying gravel, cobbles, and boulders intermixed with finer grained material; indicative of glacial till. These two cores interrogate the upper 10.5 and 7.1 ft of sediment, respectively. The paleochannel is entrenched in the till material and it is unknown whether the base of the paleochannel encounters the bedrock surface. Sediments within the defined of paleochannel are likely silt or clay but no borehole information is available in this area to substantiate this interpretation. The second paleochannel is located a distance of 2,600 ft east of the first, as shown in Figure 19, and is interpreted as extending across the entire waterway. An excellent illustration of the paleochannel, as defined by the seismic reflection signatures collected along survey line PKK4 (files 0360-0385), is presented in Figure 21. The width of the relic stream channel along survey line PKK4 is approximately 570 ft and the estimated depth is 32 ft. The geologic setting is similar to that described for the first paleochannel. Looking closely at Figure 21 (see also Plate 2 in Appendix C), additional sediment facies within the paleochannel are visible but definition of the soil type is unknown. Another representation of the paleochannel, detected along survey line PKK1 (files 0380-0411), is displayed in Figure 22 and on the cross-section in Plate 7. Core KVK-95-18 is located within the interpreted paleochannel and extends to a depth of 6.0 ft into sandy material. A steeply dipping interface is detected at the left side of Figure 22 and may define the eastern boundary of the first paleochannel described. Core KVK-95-20 extends 13.5 ft into the subbottom sediments of the interpreted paleochannel and indicates the sediments are composed of clayey silt and clay. The bedrock surface is interpreted near the limits of the paleochannels along survey line PKK1 (see Plate 7).

Bottom imaging provided with the side scan sonar system illustrates variations in the bottom reflections which in turn denote varying bottom sediments. Throughout most of Kill Van Kull, the bottom image shows a coarse, irregular texture (as shown in Figure 13) indicative of sands, gravels, cobbles, and/or fractured rock on the channel bottom. These sonar interpretations correlate well with the core information in Table 1. More nondescript bottom images having a smoother texture are detected near and east of the confluence of Kill Van Kull and the Upper Bay. The sonar image of the transition area from a more coarse texture (sands, gravels) to a more smooth image texture (silts, clays) was shown in Figure 14. No navigation or dredging hazards were detected with the side scan sonar in the Kill Van Kull waterway.

Newark Bay

The ship channels and anchorage areas in Newark Bay are situated as shown in Figure 1. Four survey lines, traverses PN01, PN09, PN10, and PN11, were conducted along the main ship channel between Shooter's Island and the Interstate Highway 278 Bridge. Survey lines PN04 through PN08 were conducted in the anchorage area adjacent to the Port Elizabeth Marine Terminal. Survey lines PN02 and PN03 are located in the entrance channels to the Port Elizabeth and Port Newark Marine Terminals. The seismic reflection survey track lines and existing CENAN core locations in Newark Bay are presented in Figures 7 through 9. It is noted that most of the cores are located near the junction of Newark Bay and Kill Van Kull. Interpreted results from the seismic reflection and side scan sonar study are presented in the geologic cross-sections illustrated in Plates 8 through 15 of Appendix C.

The quality of the seismic reflection data collected in the Newark Bay project area is very good. From an interpretation standpoint, the data along the 11 survey lines shows more subbottom detail than any of the data collected in either Arthur Kill or Kill Van Kull. The till, fractured rock, and/or bedrock reflection horizon is detected throughout most of Newark Bay south of and along the Port Elizabeth entrance channel. The rock or till interface is also detected in a 1,500 ft stretch south of the Interstate Highway 278 Bridge. As will be discussed later, the bedrock or till interface is masked by organic sediments between the Port Elizabeth entrance channel and the area south of the Interstate Highway 278 Bridge. The bedrock or till interface is detected at depths ranging from zero to greater than 30 ft.

A typical reflection record is shown in Figure 23 for data collected along survey line PN06 (files 0073-0105) in the anchorage area adjacent to the Port Elizabeth Marine Terminal. The figure illustrates the interpreted glacial till and bedrock interfaces trending upwards toward the bottom surface. The depth to the highly irregular and undulating bedrock interface at the left side of the figure is approximately 15 ft below the bottom surface. No core information is available within the anchorage area but nearby cores in the main channel identify the overlying sediments as silts and clays. As indicated in the discussion of the Kill Van Kull data, silty and clayey sediments provide better impedance contrasts with the underlying rock and till layers and, therefore, the subbottom interfaces are better defined and resolved. Figures 24 through 26 illustrate the deep bedrock and glacial till interfaces at three locations within the project area. Figures 24 and 25 illustrate data collected near the junction of the main channel and Port Elizabeth entrance channel along survey lines PN02 (files 0240-0265) and PN11 (files 0260-0291), respectively. The undulating bedrock interface is also detected south of the Interstate Highway 278 Bridge as shown in Figure 26. These four figures are only a sample of the seismic data in which the bedrock interface was detected, interpreted, and mapped. The interpreted elevations of the bedrock interface along each survey line are presented in the geologic cross-sections shown in Plates 8 through 15 in Appendix C.

The bedrock and glacial till layer is detected at or near the channel bottom in three locations in the southern portion of Newark Bay. These locations are shaded on a site map in Figure 27 and denoted as Areas 1, 3, and 5. The bedrock and till material is interpreted at the channel bottom in Areas 1 and 3 and within four feet of the channel bottom in Area 5. A typical seismic record representing data acquired over Areas 1 and 3 is shown in Figure 28. This particular data set was collected along survey line PN11 (files 0000-0030). Borehole information from Core KVK-95-44 indicates 1.5 ft of gravel overlying rock. Similar acoustic impedance values of the gravel and rock units fail to produce any distinct interfaces between the particular geologic units thereby making interpretation of the rock interface difficult. Another sample data set collected along survey line PN01 (files 0010-0035) is illustrated in Figure 29. Information from Cores KVK-95-40, 41, and 42 indicate that the bedrock interface is near the channel bottom but, because of poor acoustic impedance contrasts and high signal attenuation, the interface is poorly resolved.

The bedrock and glacial till interface is detected at depths of 0 to 4 ft below the channel bottom midway along the anchorage basin. This area is shown as Area 5 in Figure 27. Portions of seismic records illustrating the rock/till reflection horizon sloping upward towards the channel bottom are presented in

Figures 30 and 31. Interpretation of the seismic data along adjacent lines indicate that the bedrock and till form a narrow ridge (see Area 5 in Figure 27) with the depth to the top of the ridge ranging from 0 ft along line PN11 (see Figure 30) to approximately 4 ft along survey PN06. The rock pinnacles penetrating the channel bottom surface are clearly shown in Figure 30 and illustrated in Plates 9 (files 0203-0223) and 10 (files 0230-0233). This ridge may be masked by organic sediments along survey lines PN04 and PN05 in the anchorage area and PN01 in the main channel.

Between Areas 1 and 3, the bedrock and till interfaces dip downward away from the channel bottom. This area is labeled Area 2 and indicated in Figure 27. Borehole information from Cores KVK-95-48, 49, and 50 indicate silts and clays intermixed with sands and gravels to depths of 12.0 to 13.5 ft. Although the overlying sediments consist primarily of silts and clays, there are enough coarse-grained particles in the subbottom to attenuate the acoustic signal which results in poor resolution of the till/bedrock interface. Reflection signatures collected along survey line PN09 (files 0100-0135) are presented in Figure 32 and illustrate the transition from Area 2 to Area 3. The bedrock interface is not detected along the left hand side of the Figure 32. The bedrock and till interfaces also dip away from the channel bottom between Areas 3 and 5. This area is labeled Area 4 in Figure 27 and is approximately 1,800 ft in width. South of the ridge labeled Area 5, the bedrock interface dips downward and levels off at an approximate depth of nine feet below the channel bottom as indicated in Figure 33. The bedrock interface trends towards the surface again at the southern end of the anchorage area as shown in Figures 34 and 35. The dipping bedrock interface is also illustrated in the interpreted geologic cross-sections provided in Appendix C. The bedrock interface is well resolved in this portion of Newark Bay which is indicative of lesser quantities of coarse-grained particles in the overlying sediments.

Organic sediments are detected in a number of areas surveyed in Newark Bay. These sediments contain gas bubbles created by decaying organic material or bacterial activity which reflect and scatter the majority of the incident acoustic energy. Therefore, the reflection signatures from the bottom sediments may have higher amplitudes than those expected from the actual bottom and subbottom material. In turn, the quantity of acoustic energy remaining to propagate deeper into the subbottom material is greatly diminished. Spectral processing of portions of the geoacoustic data indicate polarity changes in the reflection signatures which are unique to data collected over organic sediments (McGee 1996). As mentioned in the discussion of the seismic reflection technique, the best results are achieved when the acoustic impedance and reflection coefficient values increase with depth. However, if the highest values occur at or near the surface, then it is likely that any interfaces present in the subsurface will not be detected. A classic example of the affects caused by organic sediments is presented in Figure 36. This data was collected along survey line PN05 (files 0180-0205) along the Port Elizabeth Marine Terminal. The organic sediments near the surface, as indicated in the figure, generate high amplitude reflections which in turn limit energy penetration and effectively mask the detected till and bedrock interfaces. The high amplitude bottom reflections also make the bottom sediments appear more competent than in reality. Organic sediments are detected in primarily five areas of Newark Bay and are located as follows: (1) main ship channel extending from north of the Port Elizabeth entrance channel to south of the Interstate Highway 278 Bridge, (2) Port Newark entrance channel, (3) connector channel along the Port Newark Marine Terminal, (4) northwestern corner of the anchorage area along survey lines PN04 and PN05, and (5) along the eastern edge of the main ship channel as indicated in portions of survey line PN01. Acoustic windows or gaps in the organic sediments permit deeper subbottom interrogation as shown in Figures 36 and 37. The data in Figure 37 was collected along survey line PN01 (files 0260-0295) and indicates an acoustic window in the organic sediments in which the till or bedrock interface is detected. The extent of the organically-rich surface sediments is illustrated on the geologic cross-sections as shown in Plates 8 through 15.

The side scan sonar system was used to provide imaging of the channel bottom within Newark Bay. The sonar records illustrate variations in the amplitudes of the bottom reflections which in turn denote varying bottom sediments and features. Along the southern one-fourth of the project area, including the southern portion of the anchorage area, the bottom images demonstrate a coarse, irregular texture as shown in Figure 38. These images are indicative of sands, gravels, cobbles, and/or fractured rock on the channel bottom. These are the same areas in which the till or bedrock layers are interpreted at or near the channel bottom using the seismic reflection data. This interpretation is verified with the core information in Table 1 using cores such as Core KVK-95-44. Highly irregular features are presented in the upper half of Figure 39, acquired along survey line PN09, which may suggest bedrock or fractured rock at the bottom surface. Throughout the remainder of the project area, more nondescript bottom images having a smoother texture were found. These images correlate well with the seismic reflection data in which the interpreted results indicate clayey and silty bottom sediments. Isolated pockets of more coarse textured material, likely sand, gravels, or cobbles, were detected along the channels. No navigation or dredging hazards were detected with the side scan sonar.

4 Project Summary

A high-resolution seismic reflection and side scan sonar survey was performed in Kill Van Kull and Newark Bay, NY/NJ. The geophysical data are intended to delineate the subbottom sediment and rock interfaces and provide a general interpretation of the bottom and subbottom sediments with correlation to available core information. Characterization of the sediment and rock material is completed through the analysis of the seismic amplitude records illustrating the bottom and subbottom acoustic signatures, side scan sonar images of the channel bottom, and CENAN core information. The results are illustrated in geologic cross-sections along each survey line.

The Kill Van Kull project area extends from the Upper Bay of New York Harbor to Shooter's Island and the junction with Newark Bay. Five seismic reflection surveys were performed in the 4.5 mile long channel. Interpretation of the seismic reflection and side scan sonar data indicates that the bottom and subbottom sediments throughout the waterway are composed primarily of sands intermixed with or containing varying quantities of silts, gravels, cobbles, or fractured rock. The subbottom interfaces are generally difficult to differentiate because the acoustic impedance contrast between layers is small, thereby producing few distinct reflection horizons. The bedrock interface is detected in some portions of Kill Van Kull but the reflection horizons are typically poorly defined and would have been overlooked without the availability of core information. The best definition of any stratigraphic interfaces typically occurs in areas where the overlying sediments contain greater percentages of fine-grained sediments.

Two well-defined relic stream channels are noted in Kill Van Kull south of Constable Hook. The westernmost paleochannel is located between Cores KVK-95-19 and KVK-95-22 and detected only along survey lines PKK3, PKK4, and PKK5. The paleochannel is 600 ft wide along survey line PKK4 and approximately 22 ft deep. The paleochannel is entrenched in the glacial till material and it is unknown whether the base of the paleochannel encounters the bedrock surface. Sediments within the confines of the paleochannel are likely silt or clay, but no core information is available in this area to substantiate this interpretation. The second paleochannel is located a distance of 2,600 ft east of the first and extends across the entire waterway. The dimensions of the paleochannel along survey line PKK4 are approximately 570 ft wide and 32 ft deep. Additional sediment facies within the paleochannel are detected but definition of the soil type is unknown. Other relic stream channels were detected along the waterway but are not as well-defined as the two described above.

East of Core KVK-95-10 at the confluence of Kill Van Kull and Upper Bay, the near-surface sediments comprise greater percentages of silt and clay and subsurface reflection horizons are better resolved. The interpreted bedrock or glacial till interface is detected at an approximate depth of 20 ft and slopes downward towards the east.

The Newark Bay project area is located north of the junction between the Kill Van Kull and Arthur Kill. Eleven survey lines were conducted within the Newark Bay shipping channels and anchorage area. The glacial till and bedrock units are detected throughout most of the project area south of and along the Port Elizabeth entrance channel. The rock and glacial till interfaces are also detected in a 1,500 ft stretch south of the Interstate Highway 278 Bridge. Depths to the undulating and irregular bedrock interface range from zero feet in areas south of the anchorage area to greater than 30 ft at the Port Elizabeth entrance channel. The composition of the overlying sediments, as determined from the geoacoustic data and available borehole information, is primarily silt and clay. In areas where the bedrock and glacial till layers outcrop at or near the channel bottom, the similar acoustic impedance values of these units fail to produce any distinct interfaces and thereby make delineation of the rock interface difficult.

Areas of organic sediments are detected in the Newark Bay project area. These surface sediments contain gas bubbles which generate reflection signatures having higher amplitude values than those expected from the actual bottom and subbottom material. This in turn makes the bottom sediments appear more competent than in reality. In addition, if the highest impedance values and reflection coefficients occur at or near the bottom surface, then it is likely that any interfaces present in the subsurface will not be detected. The organic sediments are detected in primarily five areas of Newark Bay and are located as follows: (1) main ship channel extending from north of the Port Elizabeth entrance channel to just south of the Interstate Highway 278 Bridge, (2) Port Newark entrance channel, (3) connector channel along the Port Newark Marine Terminal, (4) northwestern corner of the anchorage area along survey lines PN04 and PN05, and (5) along the eastern edge of the main ship channel as indicated in portions of survey line PN01. No subbottom interpretations could be attained in these areas. However, acoustic windows or gaps in the organic sediments did permit deeper subbottom interrogation in isolated areas along the channel bottom.

Analysis of the seismic and side scan sonar information in the Kill Van Kull and Newark Bay provides a continuous profile and general acoustic description of the bottom and subbottom sediments. Depths computed from the seismic records delineate the extent and elevation of the channel bottom and detected sediment and rock reflection horizons. Sediment characteristics derived from existing cores were correlated with the acoustic data to provide a more comprehensive description of the channel bottom lithology. The results of this geophysical investigation are presented as geologic cross-sections in Plates 1 through 15 of Appendix C.

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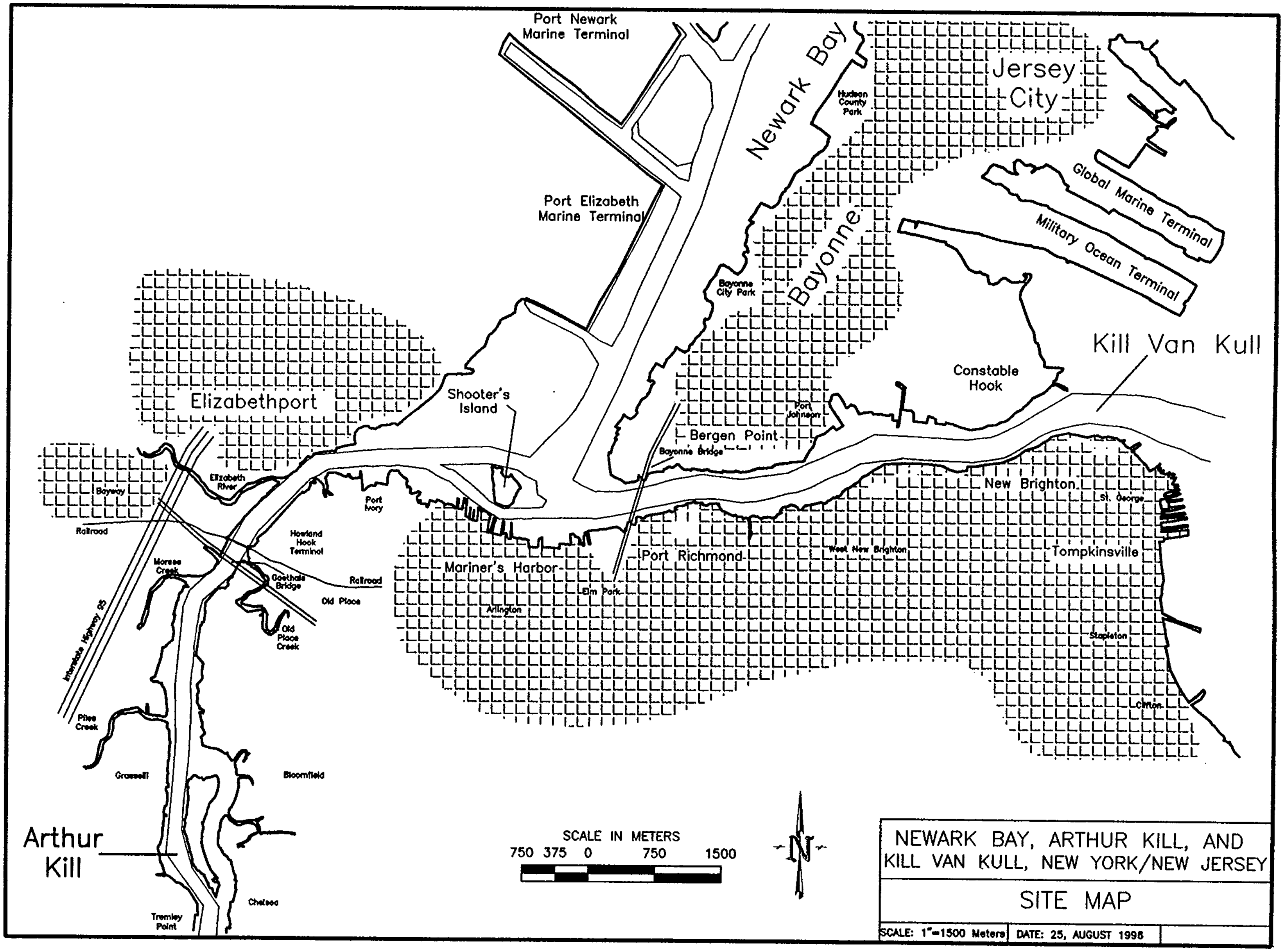


Figure 1. Site map illustrating the location of Arthur Kill, Kill Van Kull, and Newark Bay

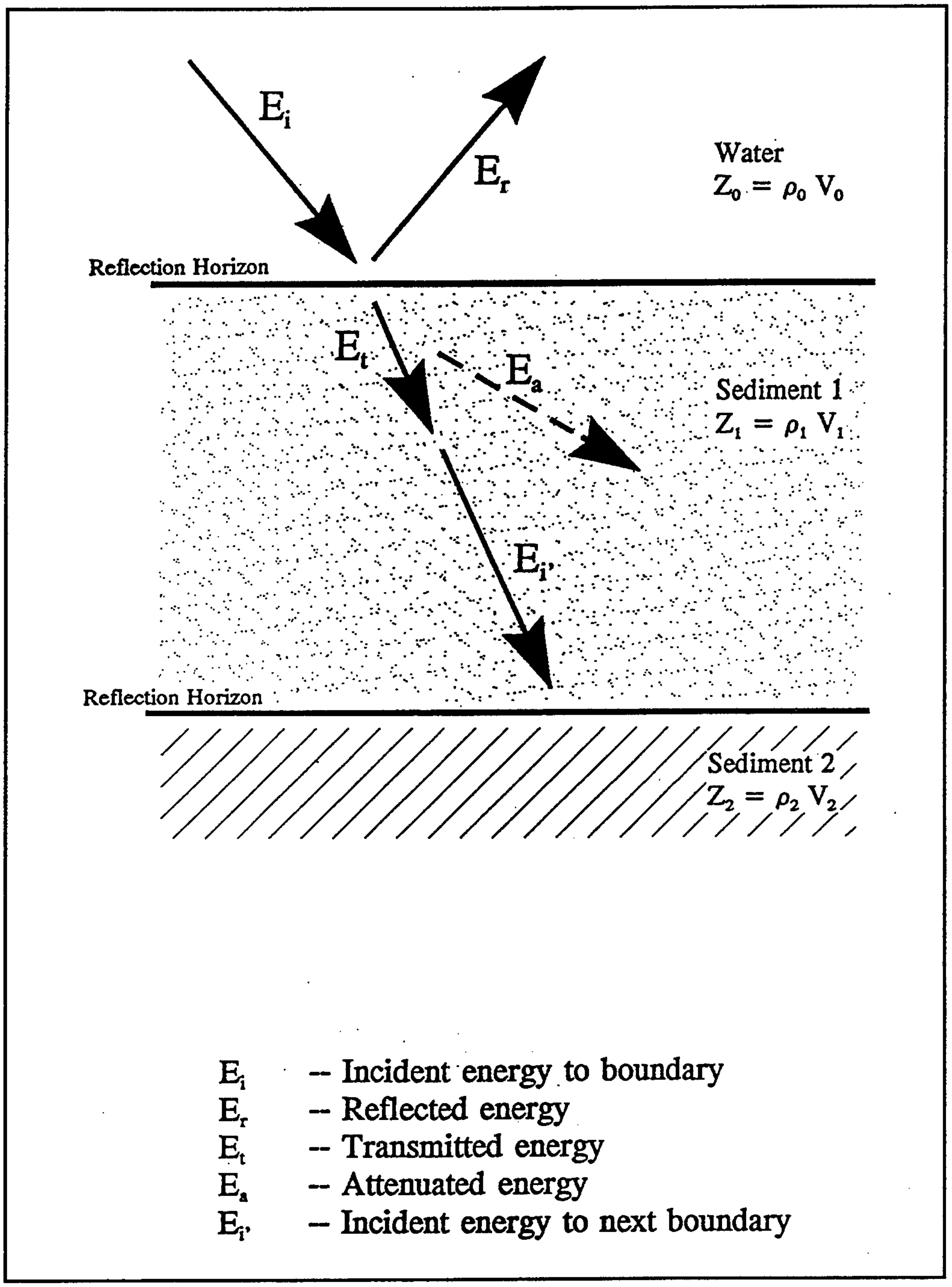


Figure 2. Ray diagram of the seismic reflection technique

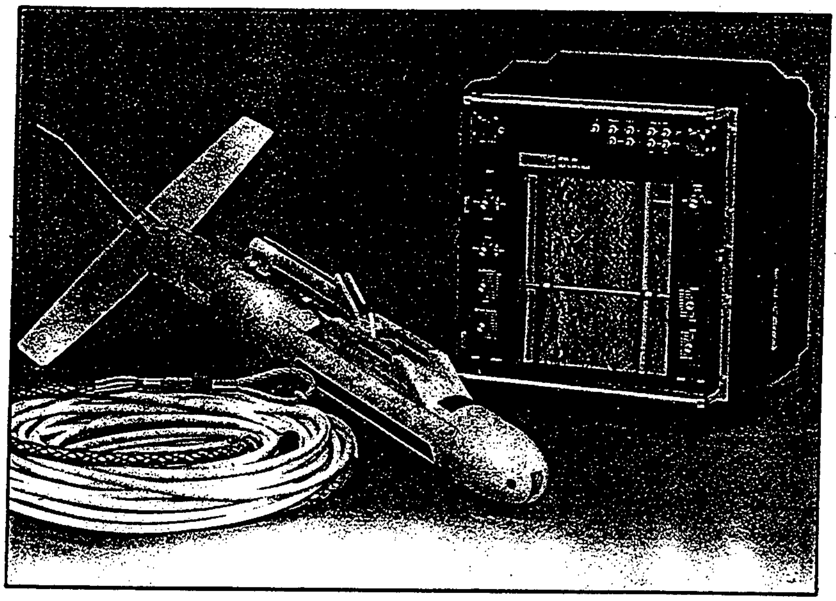


Figure 3. Illustration of the side scan sonar equipment

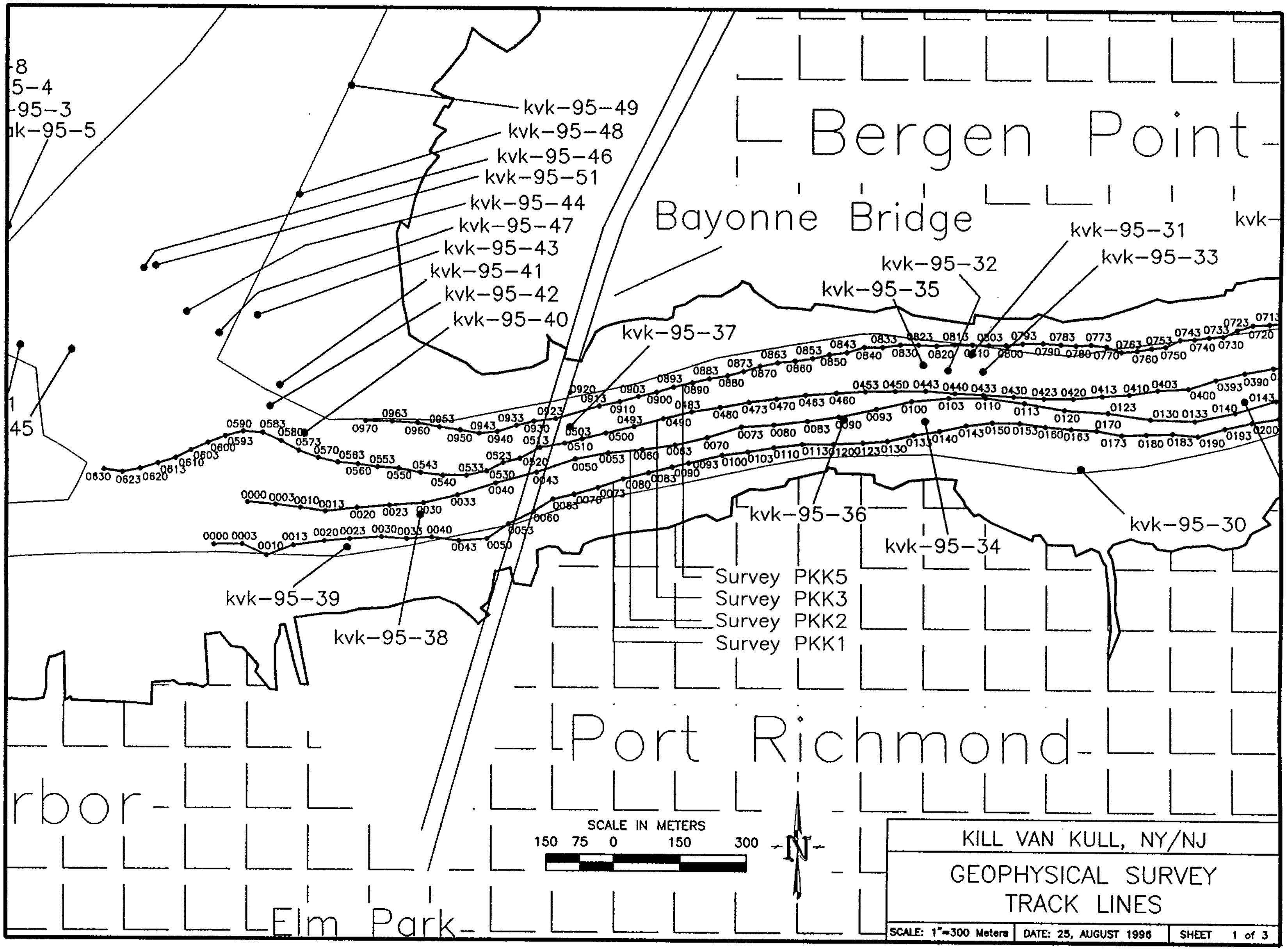


Figure 4. Site map of Kill Van Kull illustrating the location of the geophysical survey track lines

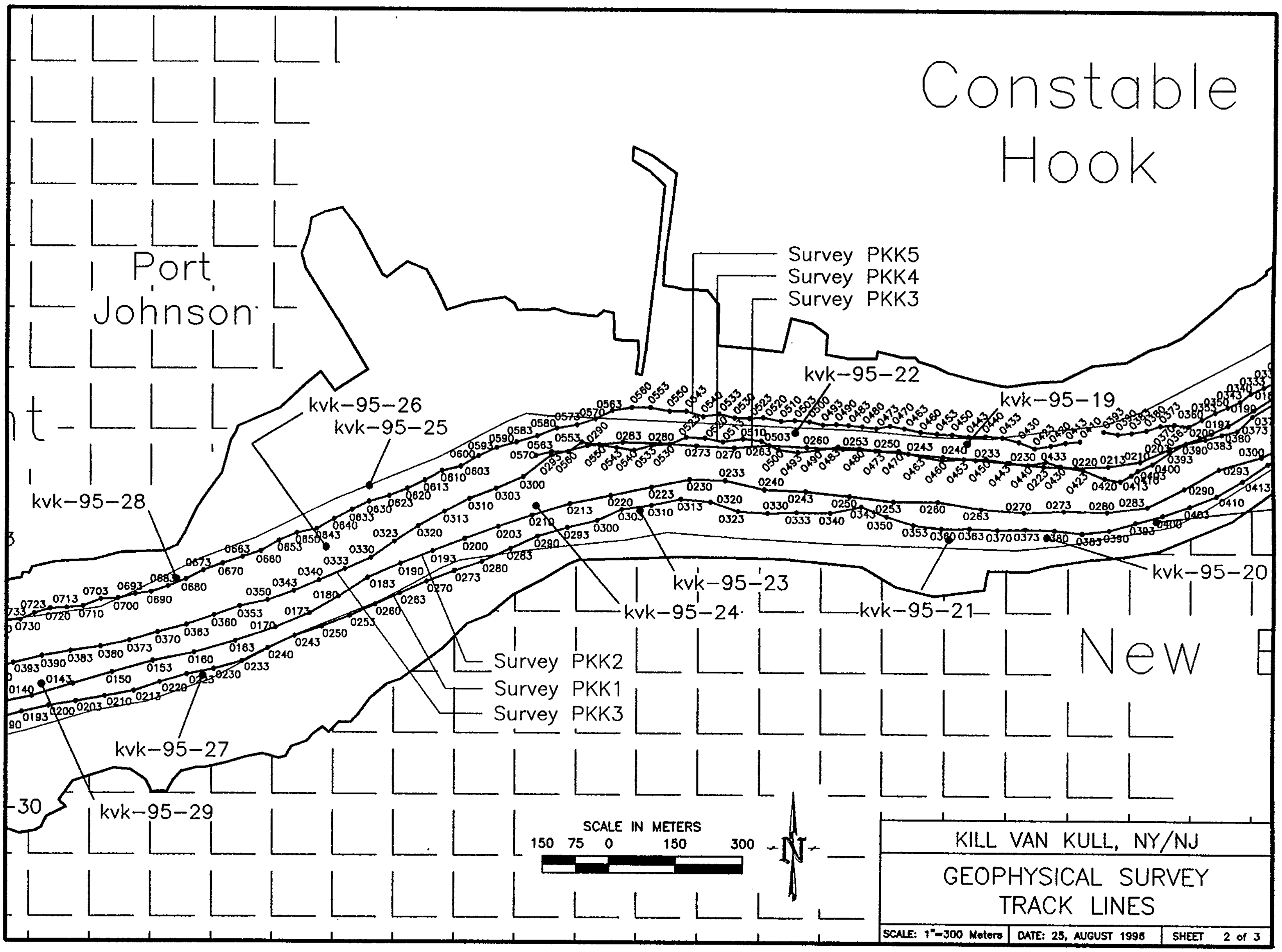


Figure 5. Site map of Kill Van Kull illustrating the location of the geophysical survey track lines

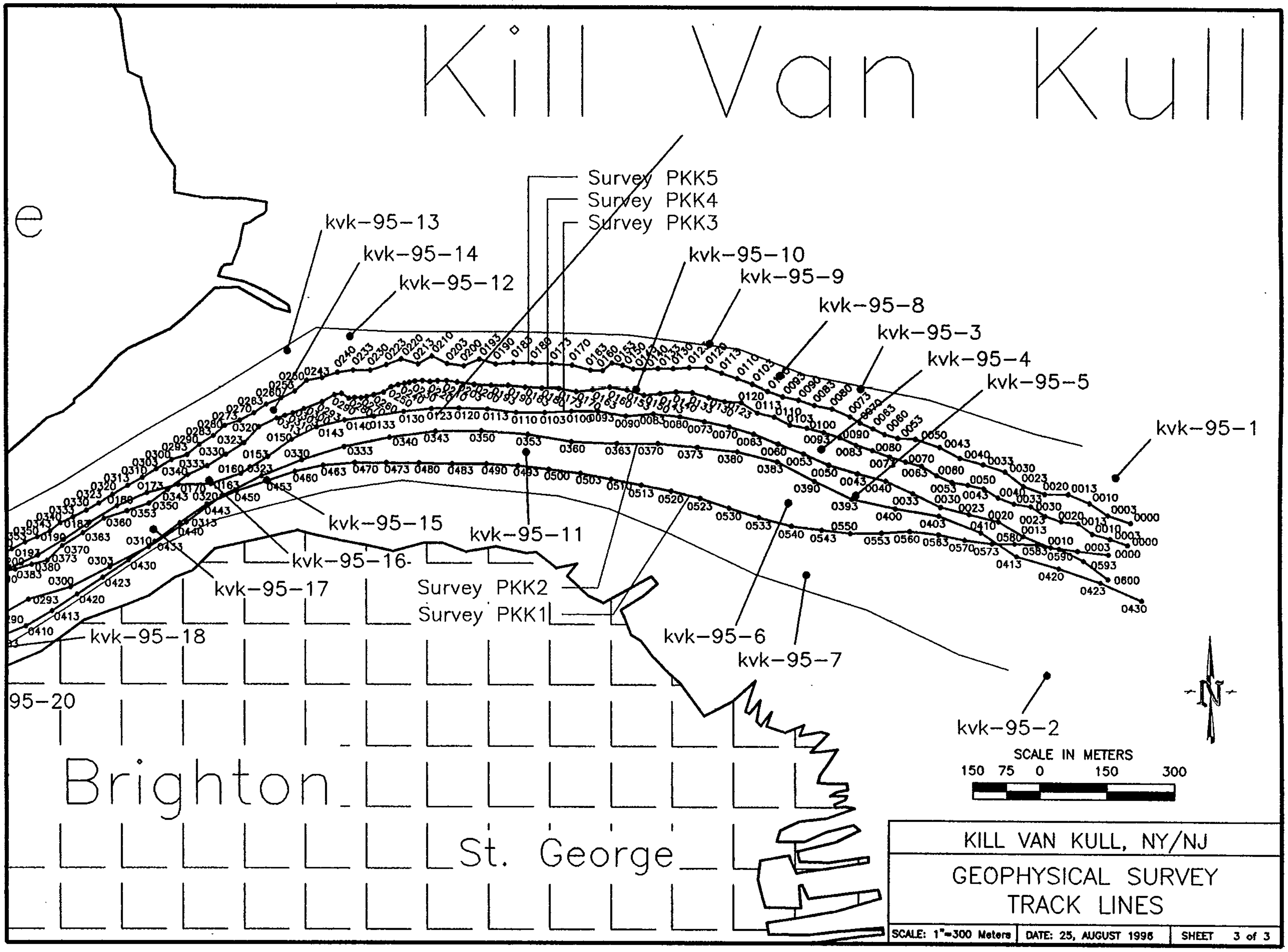


Figure 6. Site map of Kill Van Kull illustrating the location of the geophysical survey track lines

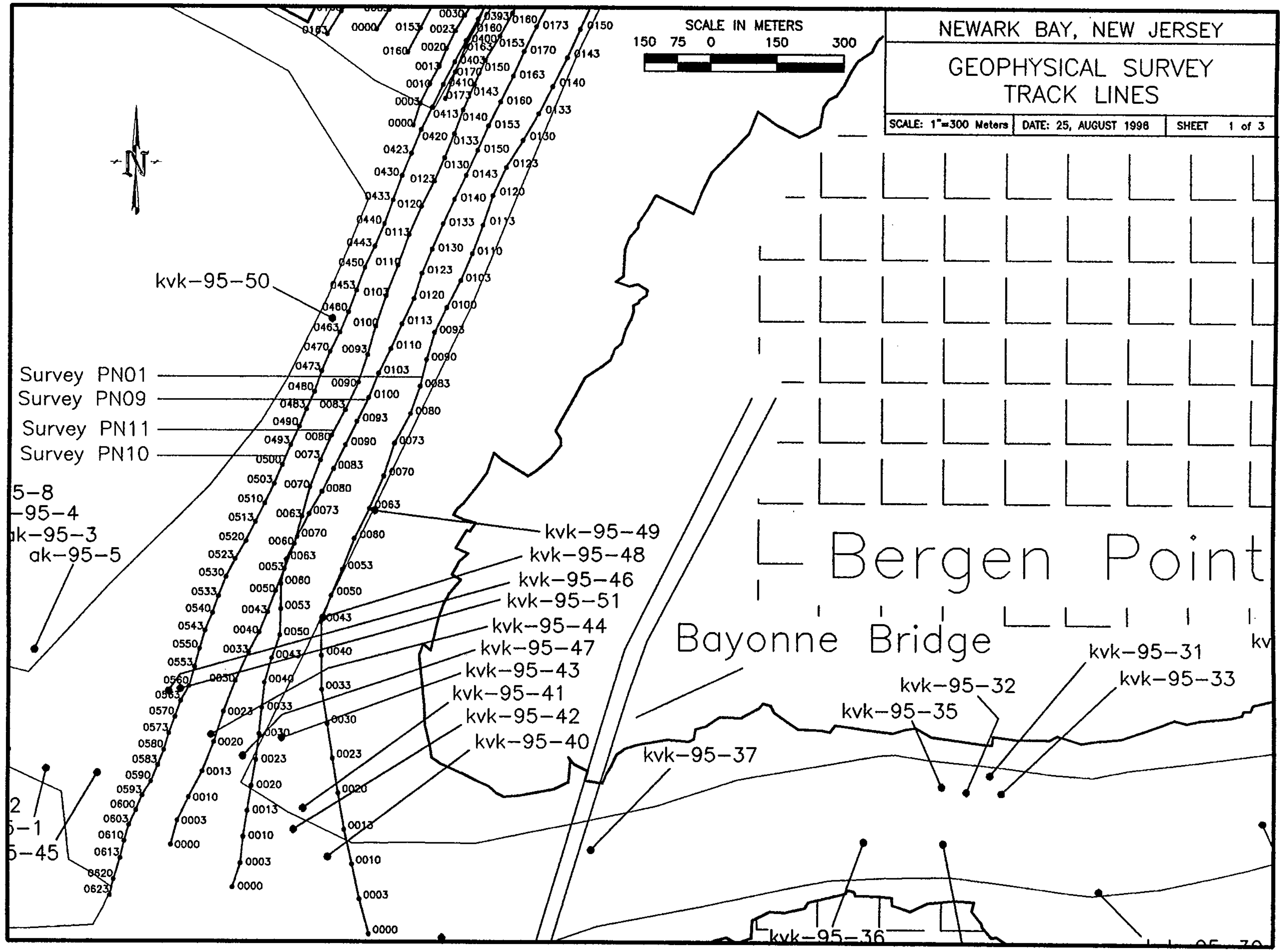


Figure 7. Site map of Newark Bay illustrating the location of the geophysical survey track lines

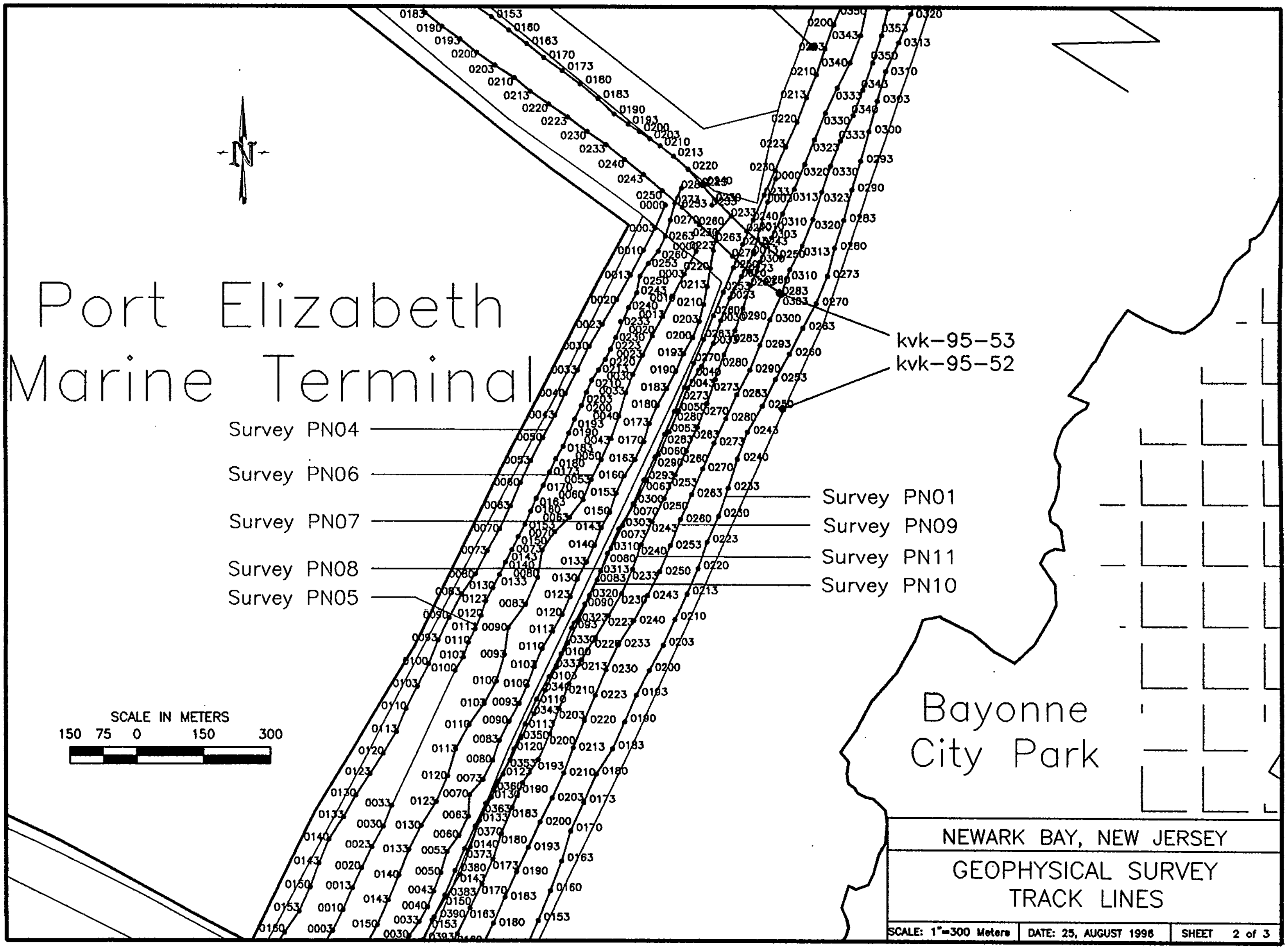


Figure 8. Site map of Newark Bay illustrating the location of the geophysical survey track lines

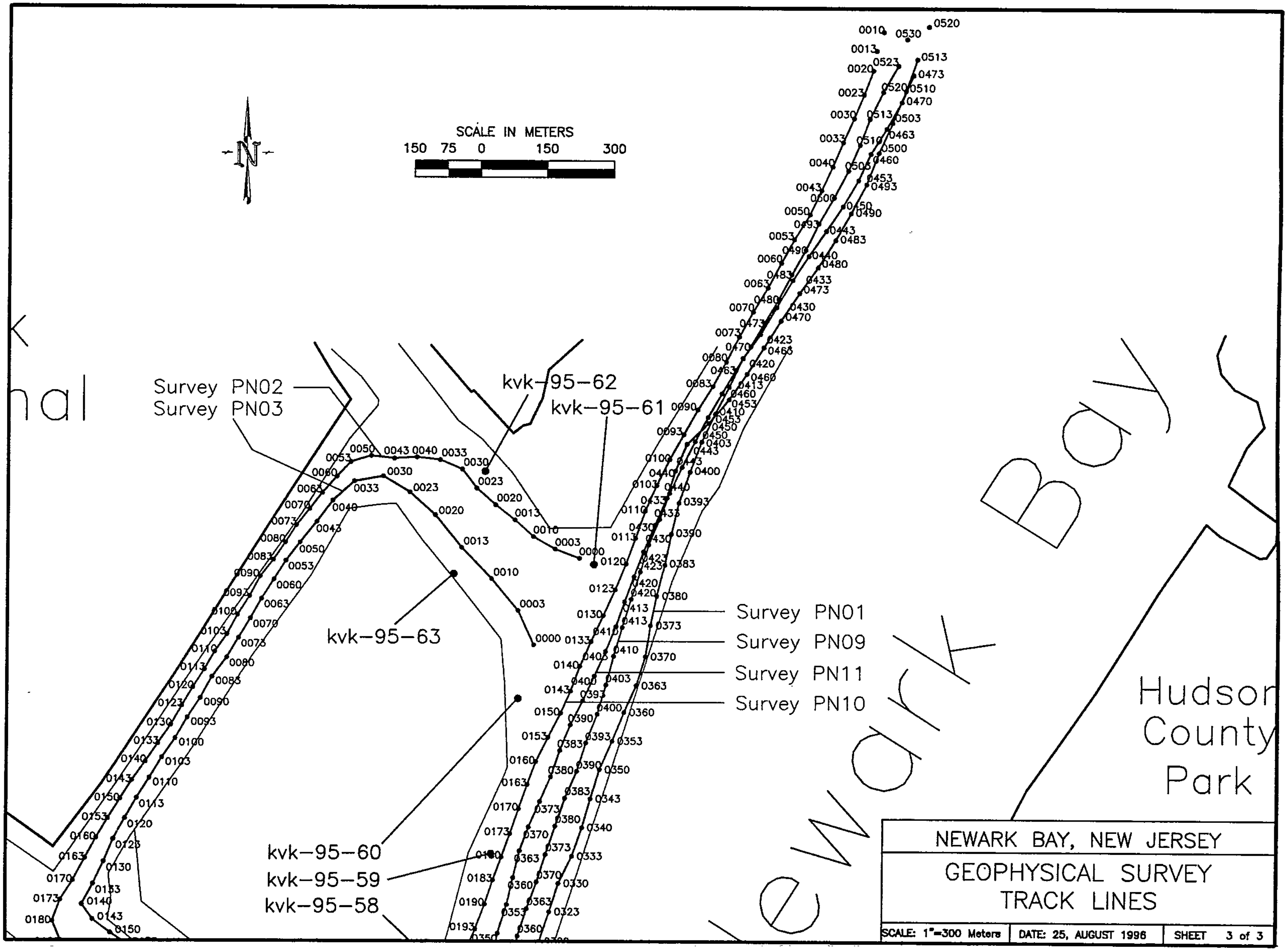


Figure 9. Site map of Newark Bay illustrating the location of the geophysical survey track lines

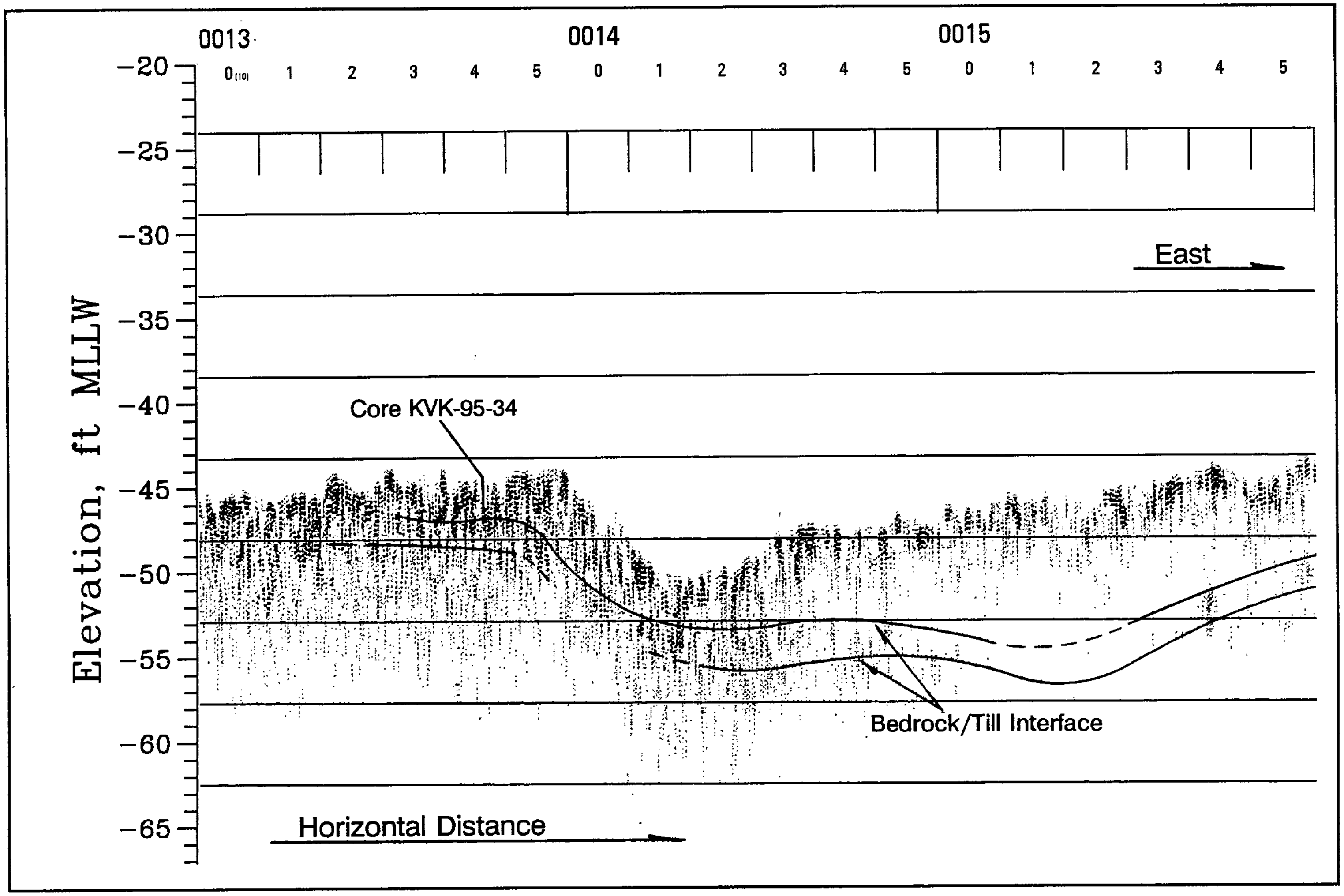


Figure 10. Seismic reflection data collected along survey line PKK1 (files 0130-0155)

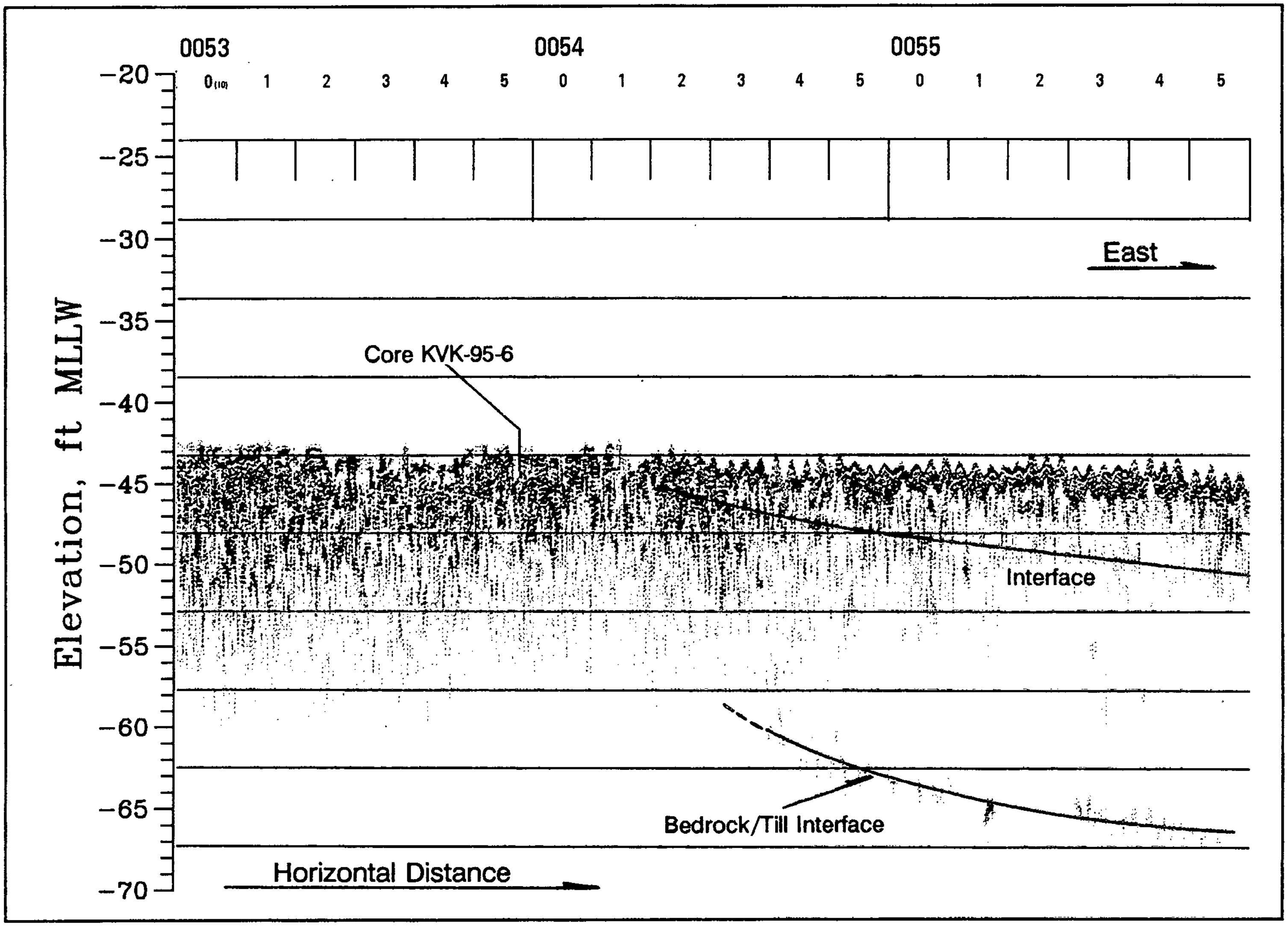


Figure 11. Seismic reflection data collected along survey line PKK1 (files 0530-0555)

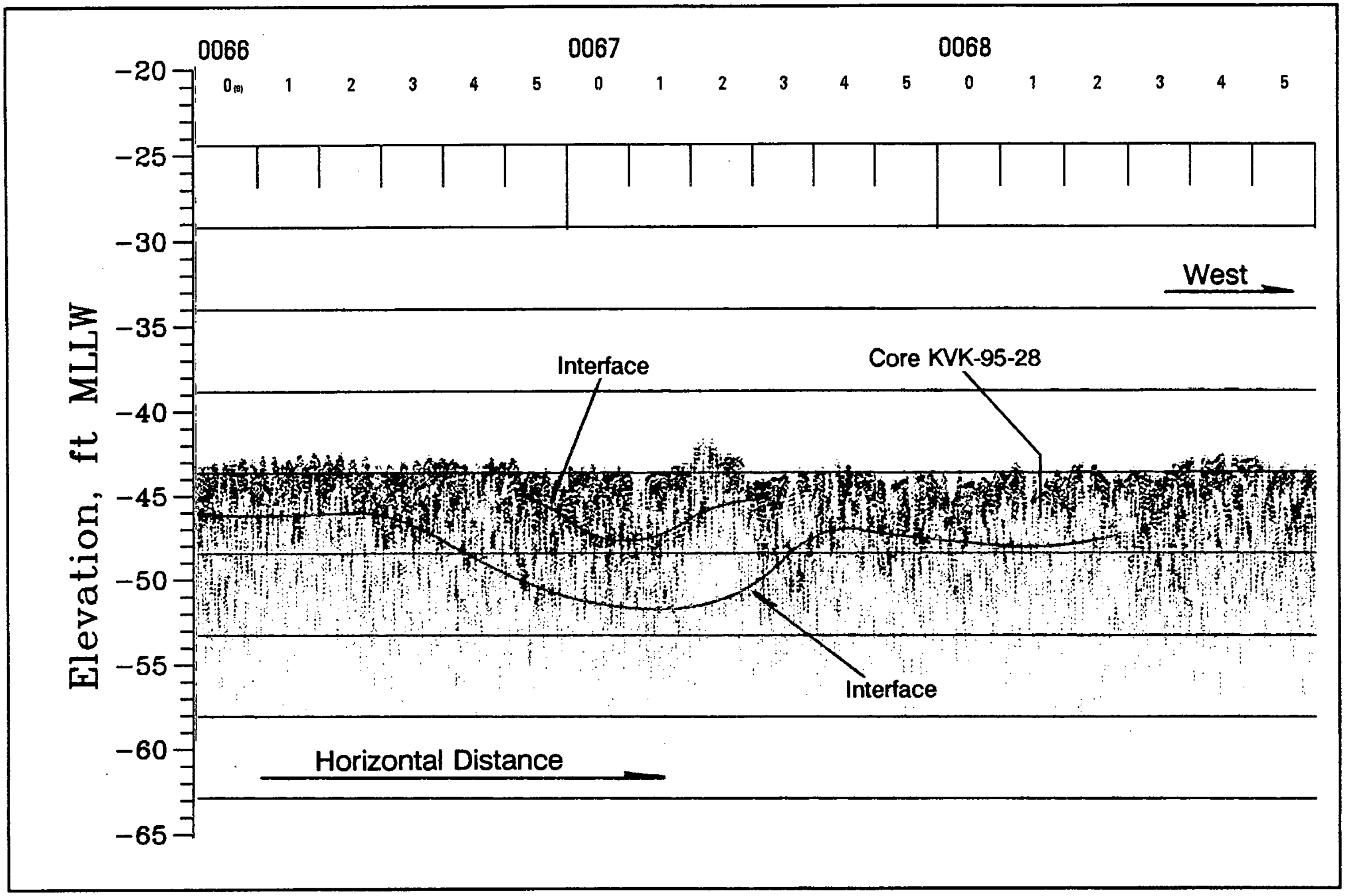


Figure 12. Seismic reflection data collected along survey line PKK5 (files 0660-0685)

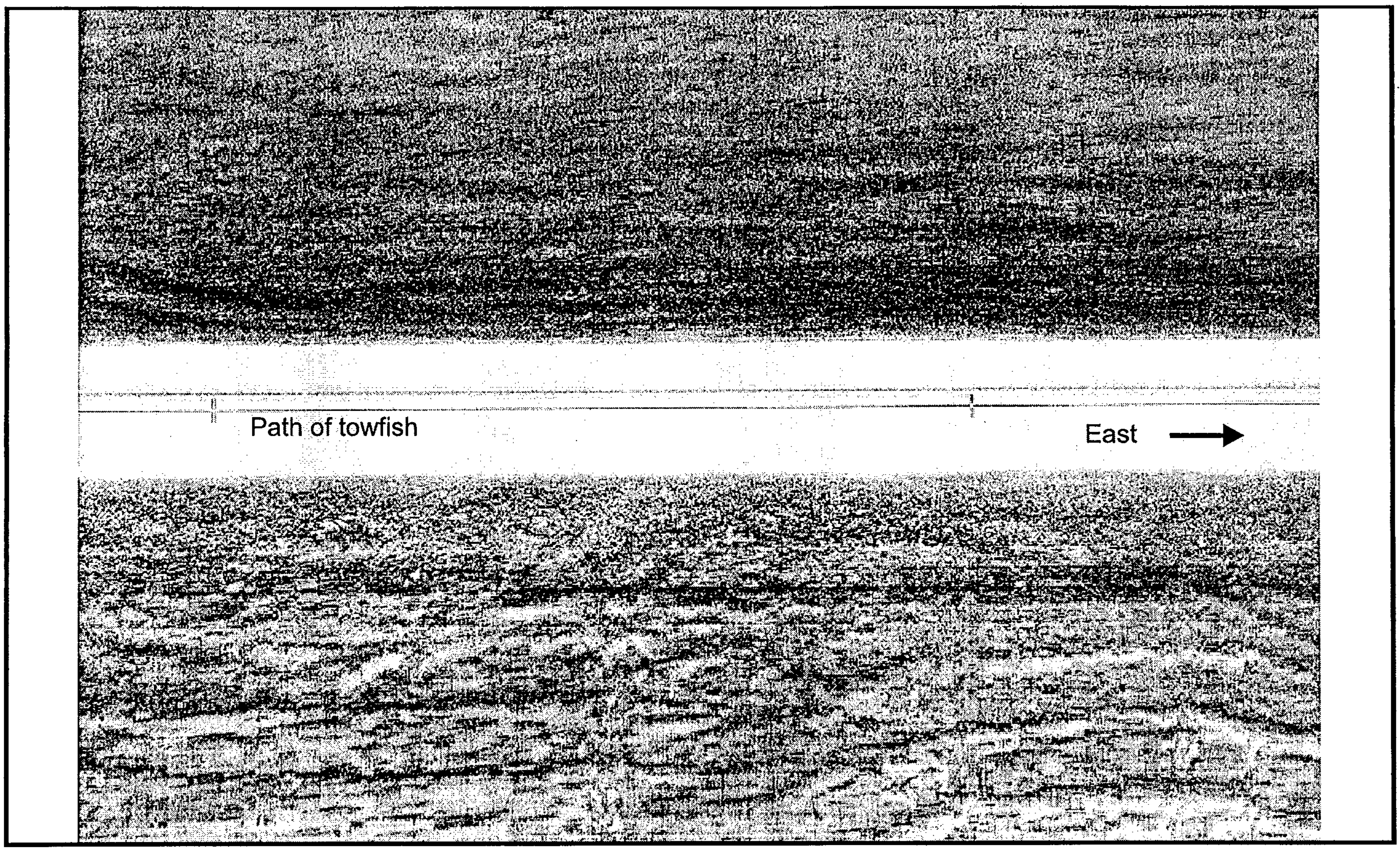


Figure 13. Side scan sonar data collected along survey line PKK3 near Constable Hook.

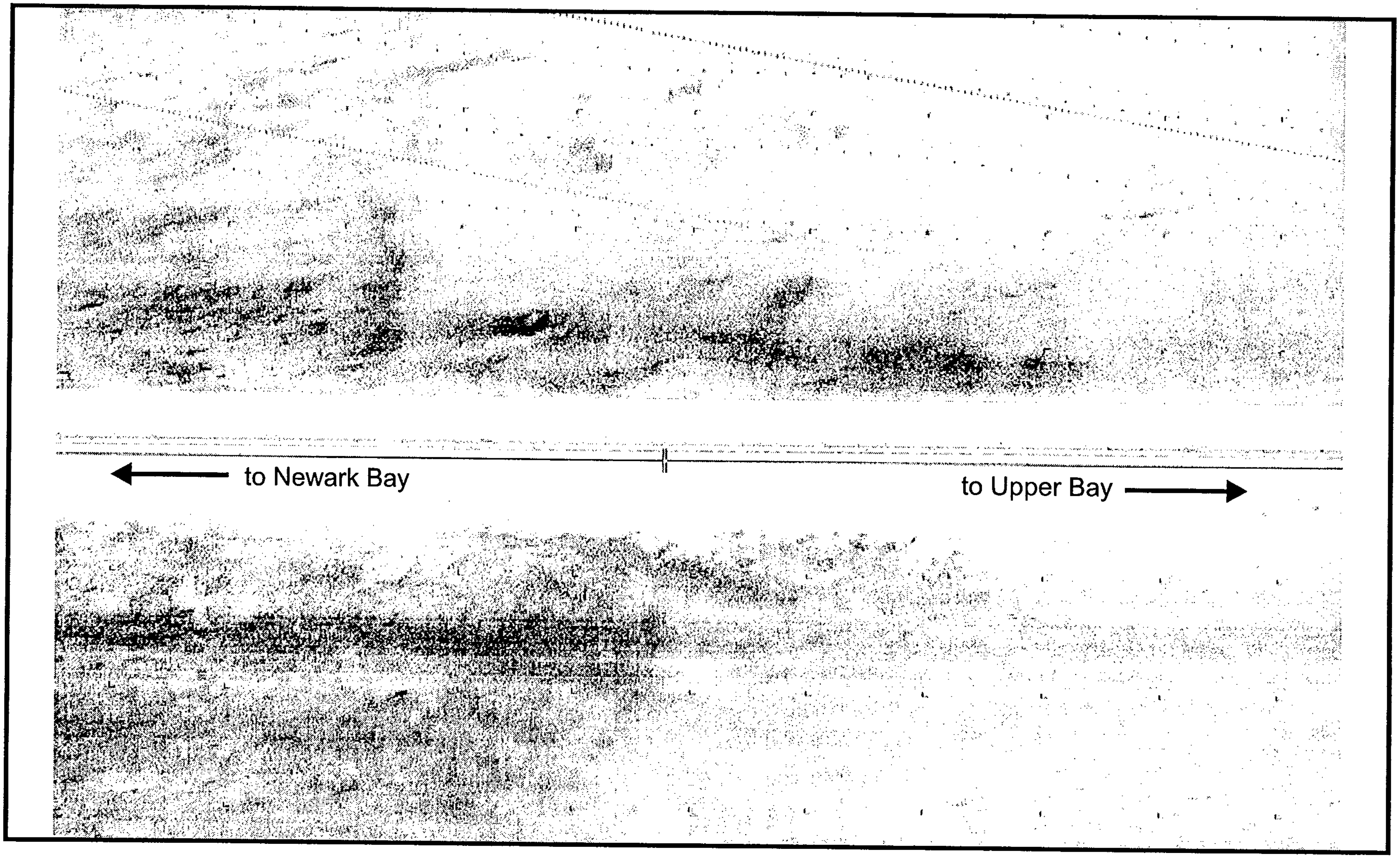


Figure 14. Side scan sonar data collected along survey line PKK3 at confluence of Kill Van Kull and Upper Bay

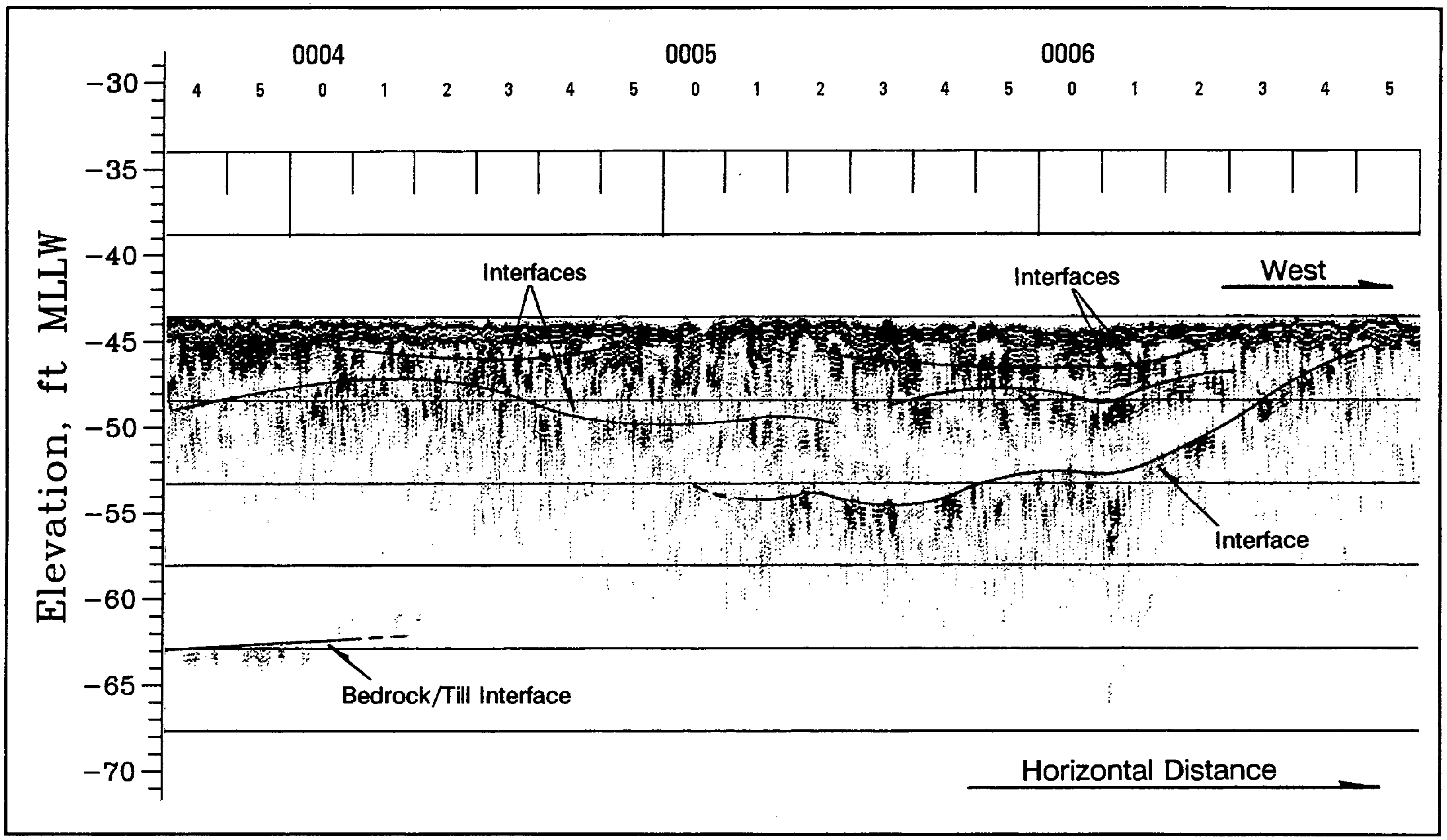


Figure 15. Seismic reflection data collected along survey line PKK4 (files 0034-0065)

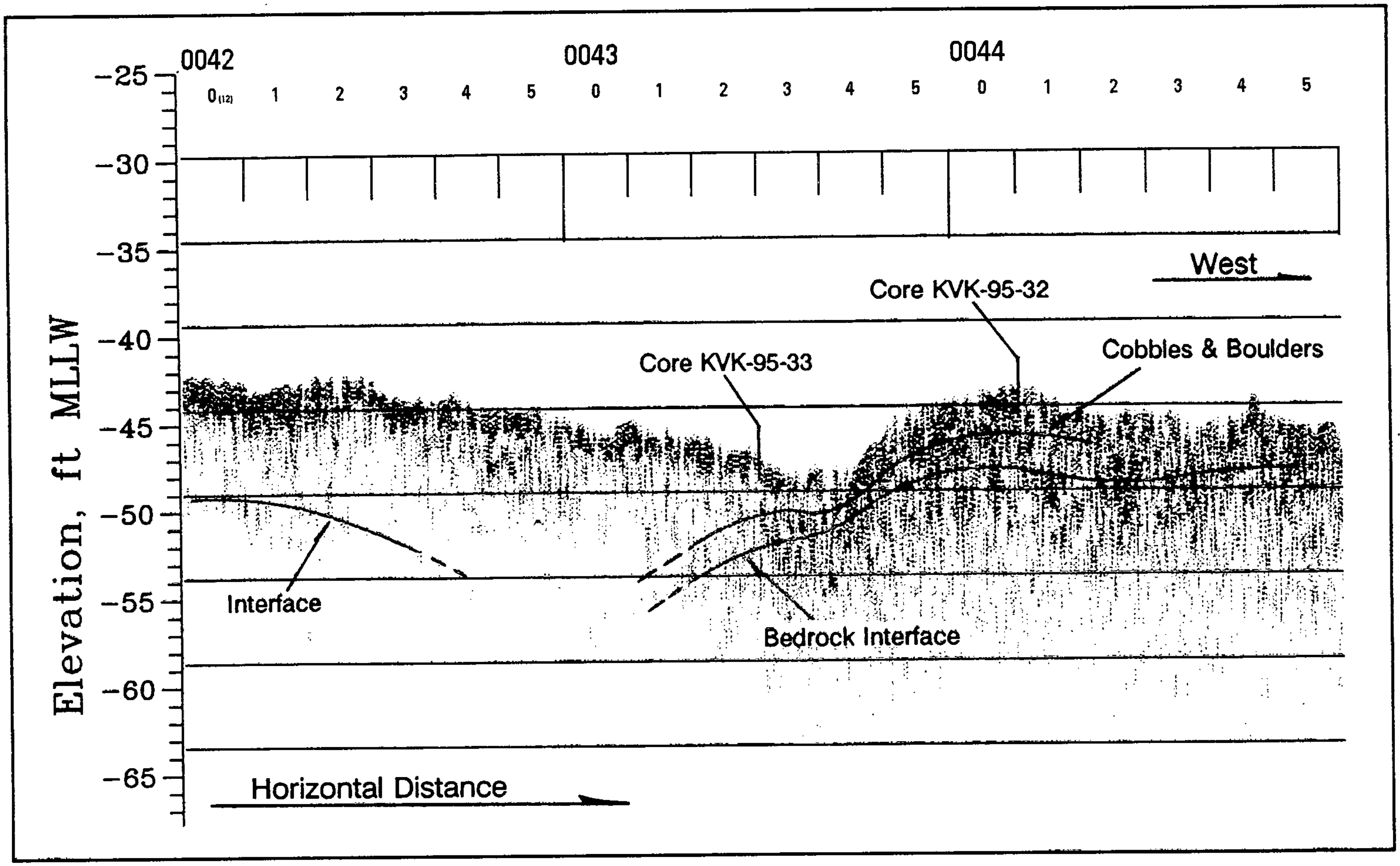


Figure 16. Seismic reflection data collected along survey line PKK3 (files 0420-0445)

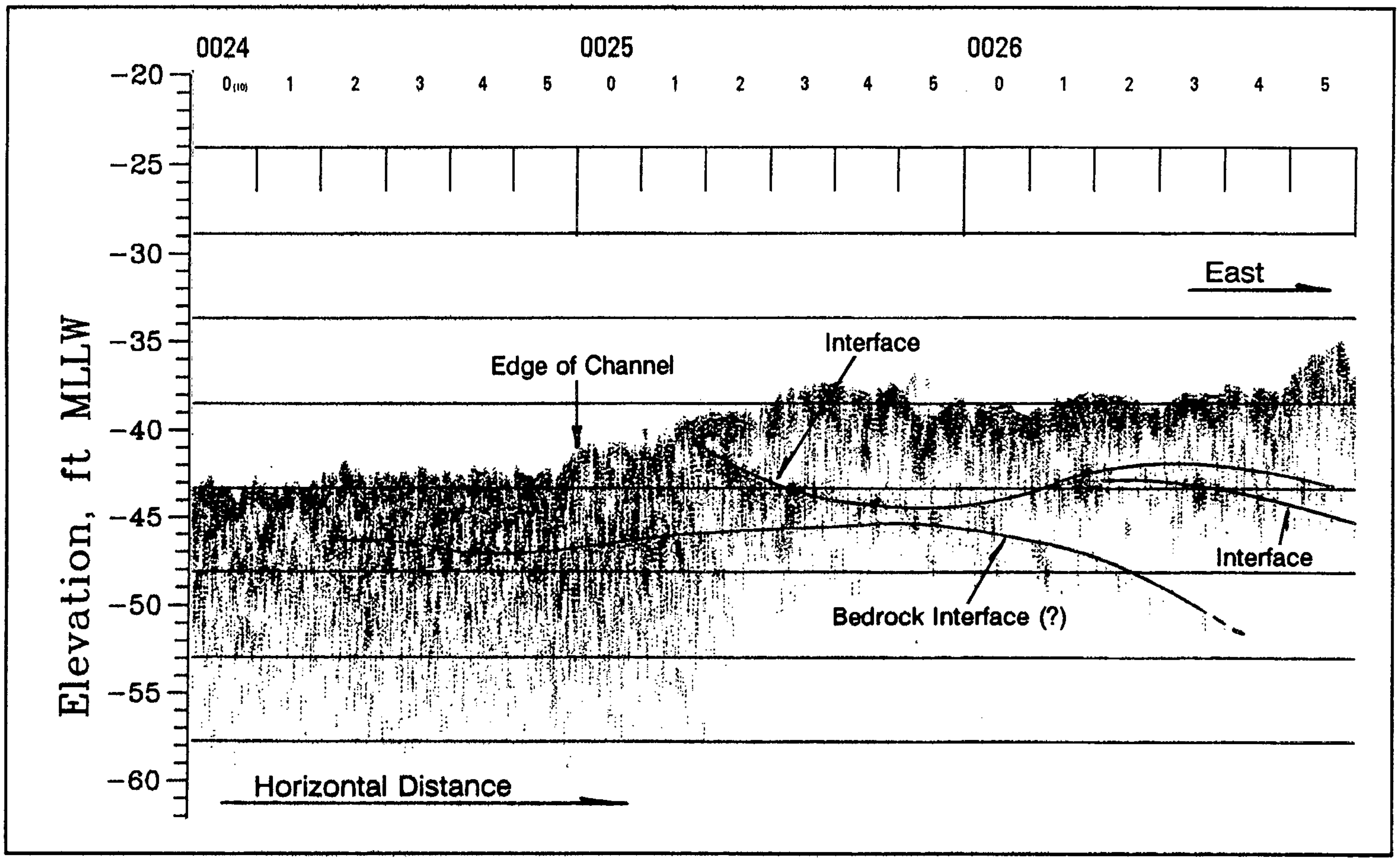


Figure 17. Seismic reflection data collected along survey line PKK1 (files 0240-0265)

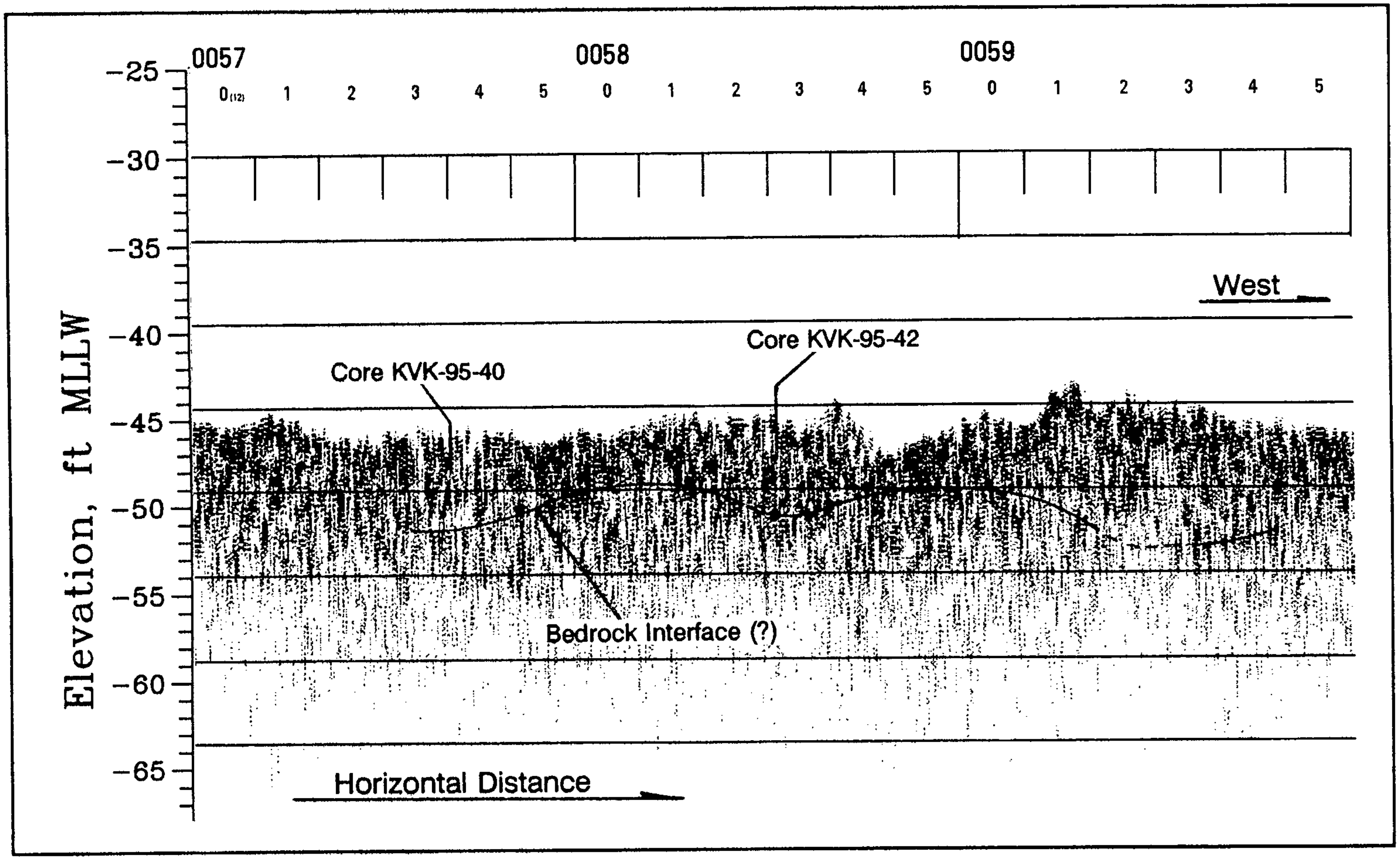


Figure 18. Seismic reflection data collected along survey line PKK5 (files 0570-0595)

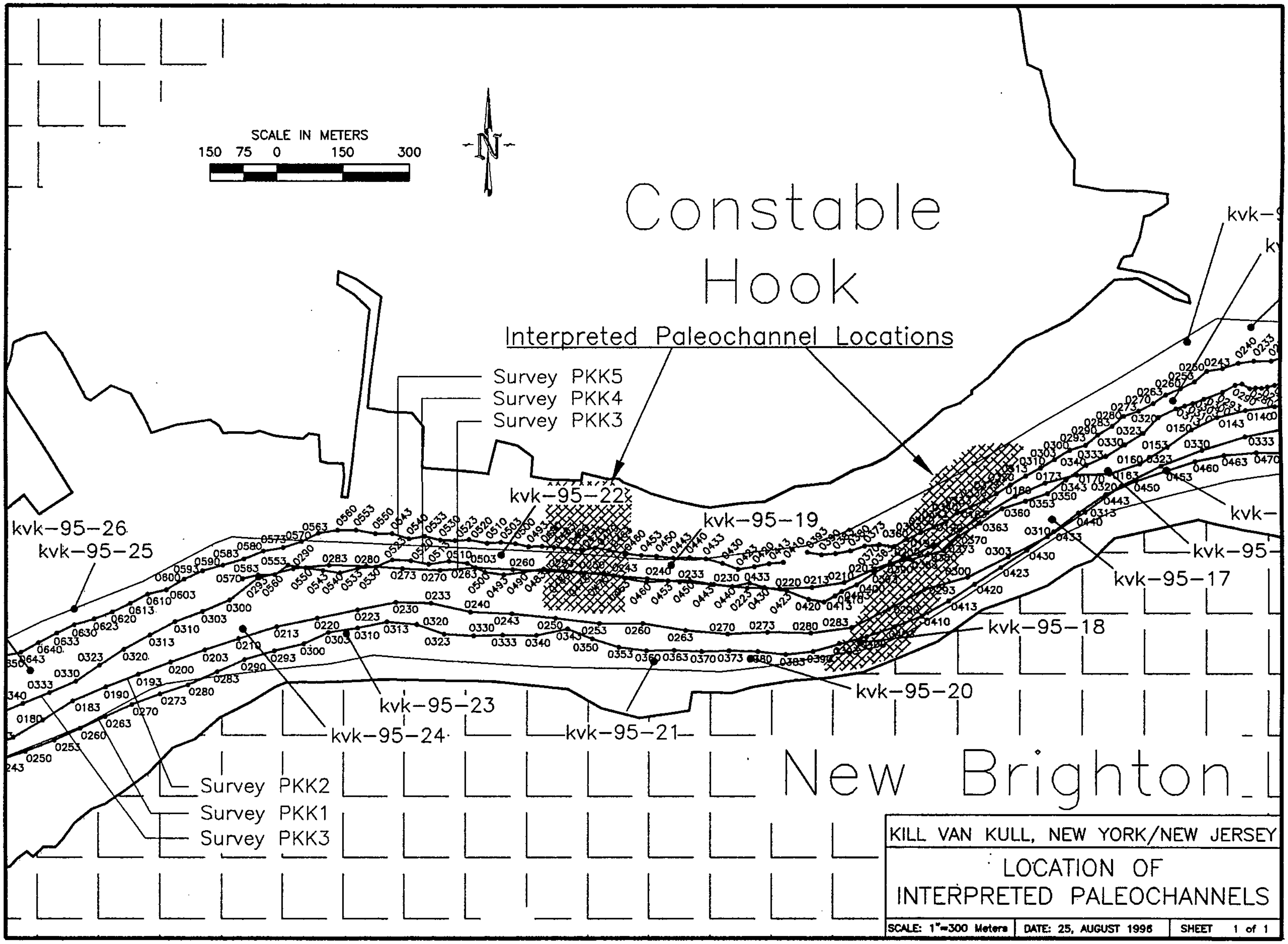


Figure 19. Site map of Kill Van Kull indicating the locations of interpreted paleochannels

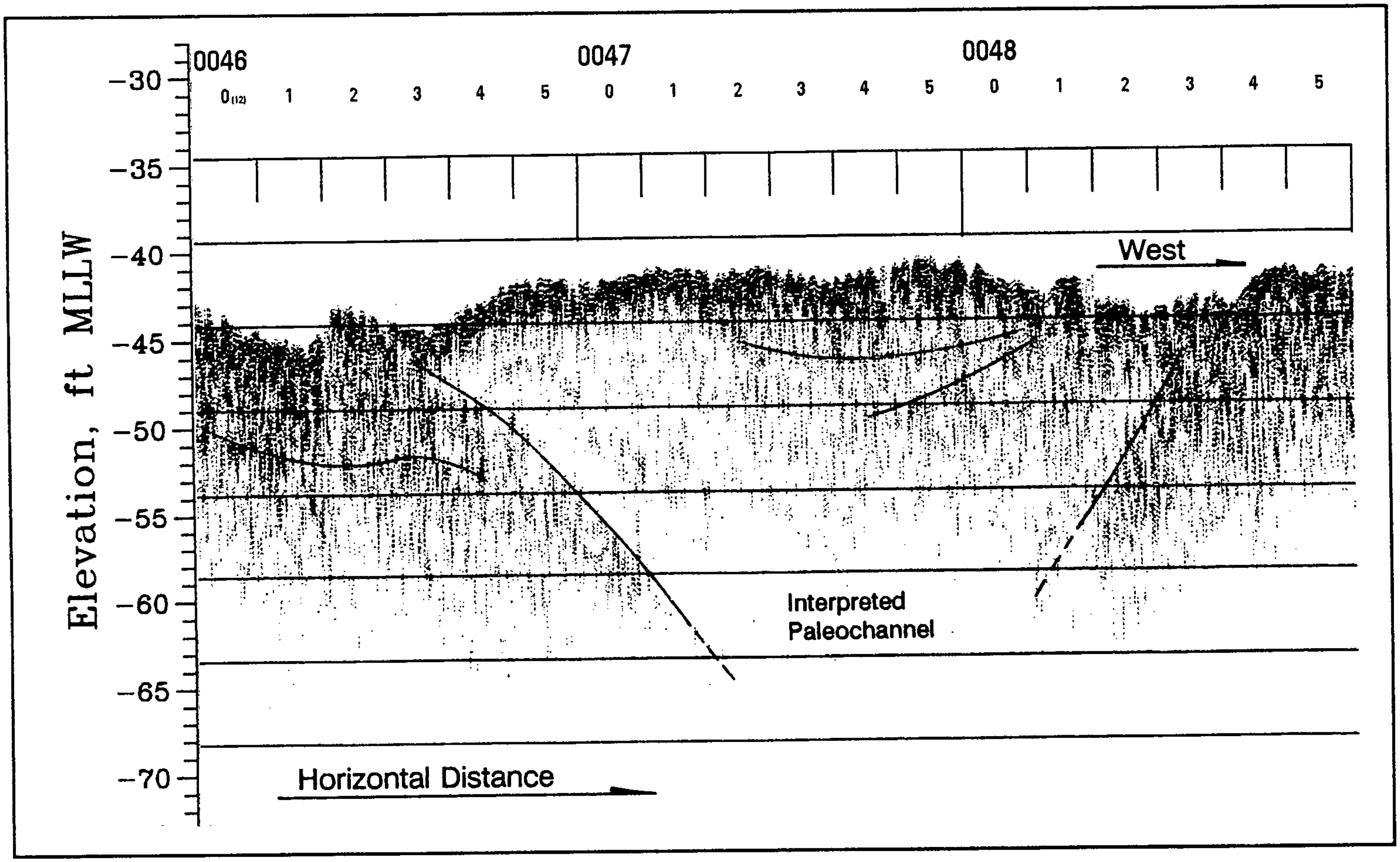


Figure 20. Seismic reflection data collected over an interpreted paleochannel along survey line PKK4 (files 0460-0485)

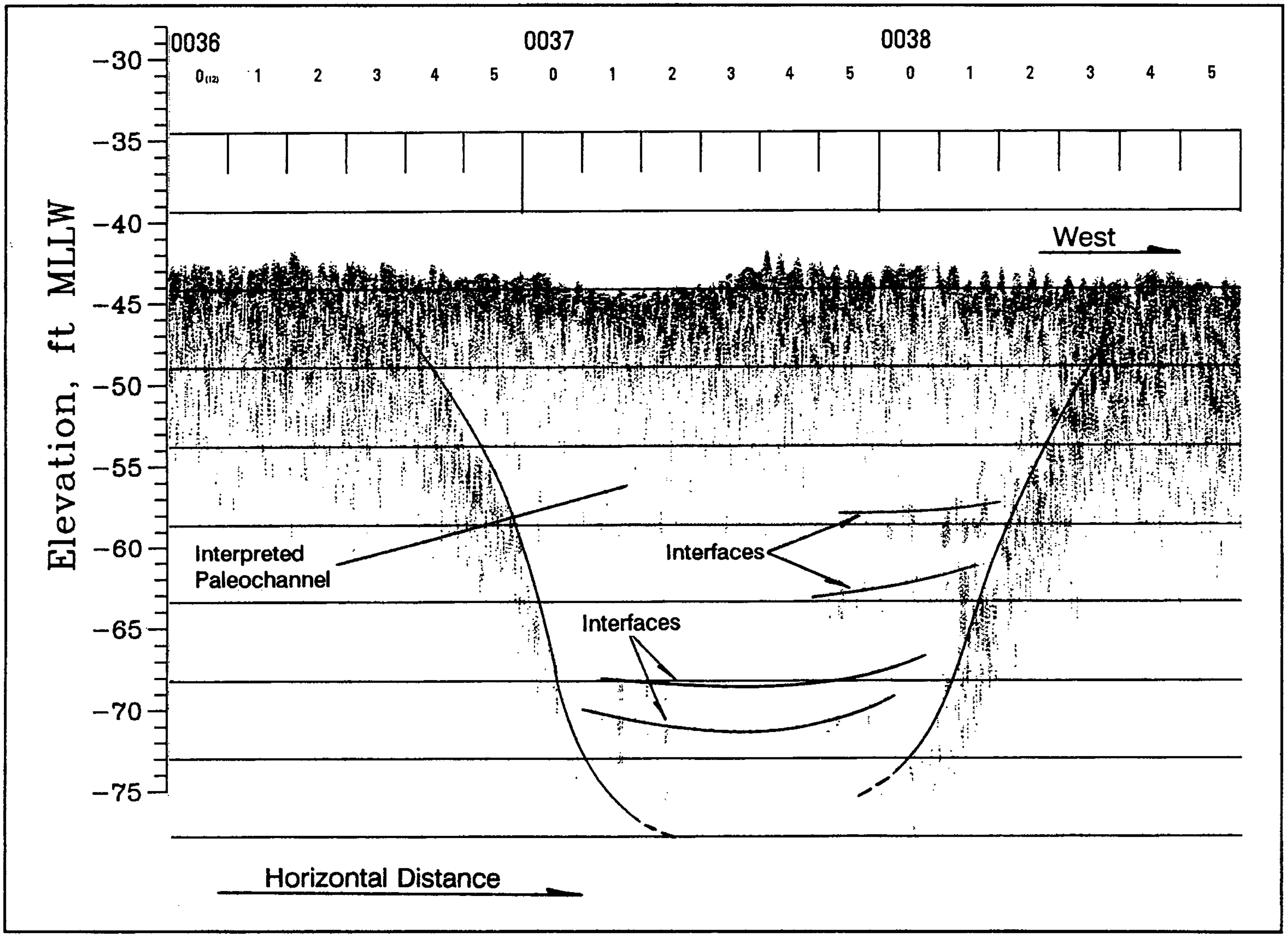


Figure 21. Seismic reflection data collected over an interpreted paleochannel along survey line PKK4 (files 0360-0385)

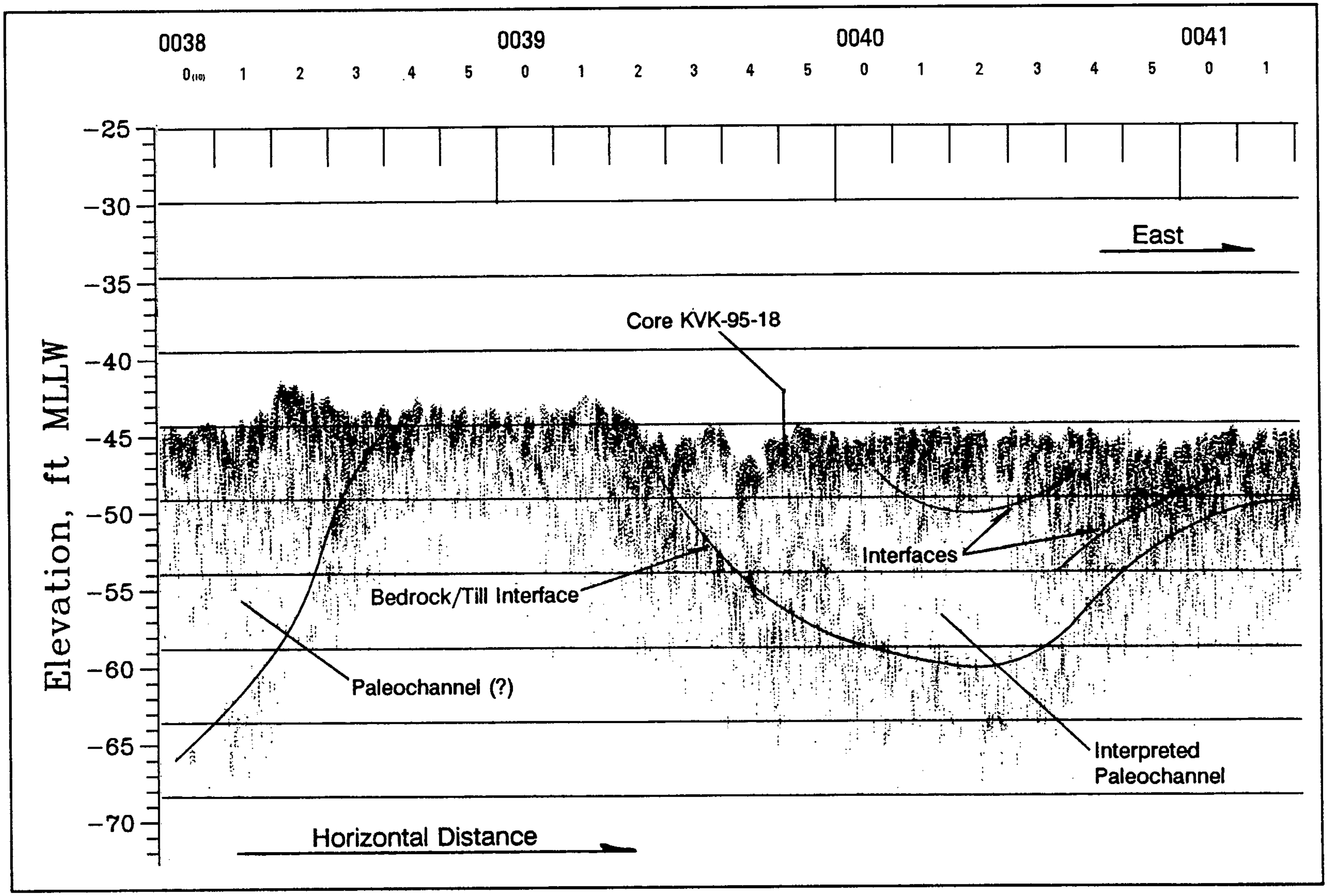


Figure 22. Seismic reflection data collected over an interpreted paleochannel along survey line PKK1 (files 0380-0411)

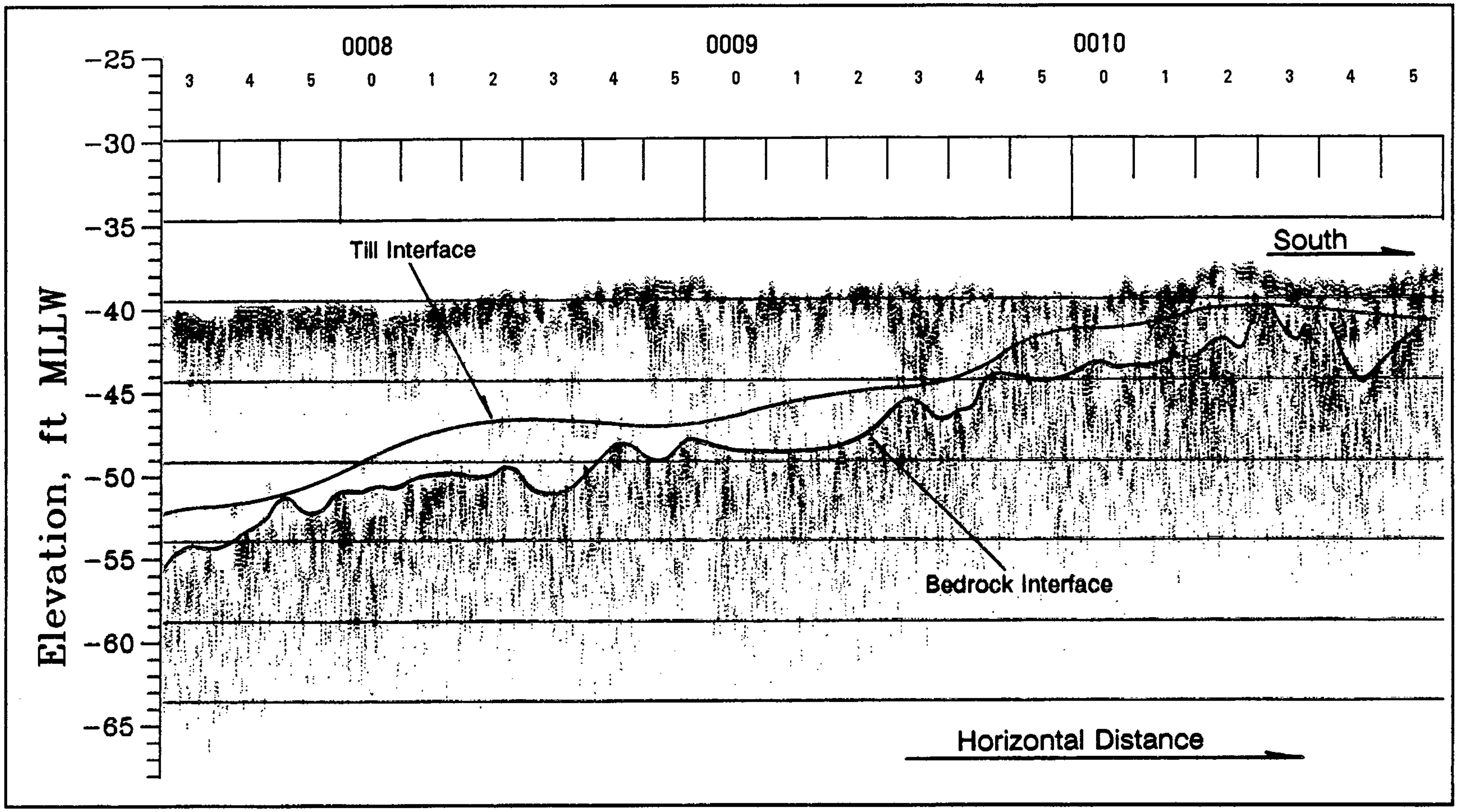


Figure 23. Seismic reflection data collected along survey line PN06 (files 0073-0105)

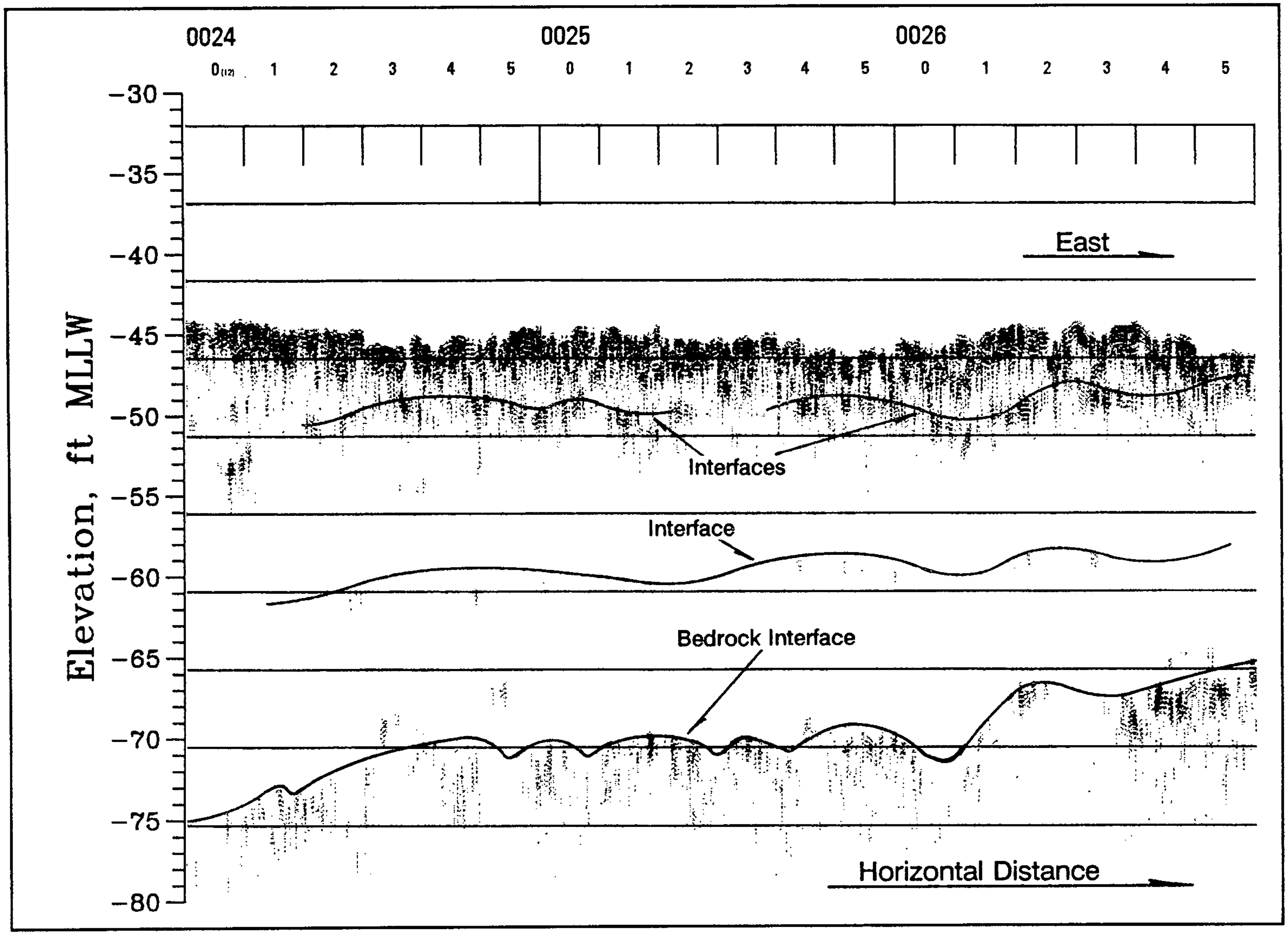


Figure 24. Seismic reflection data collected along survey line PN02 (files 0240-0265)

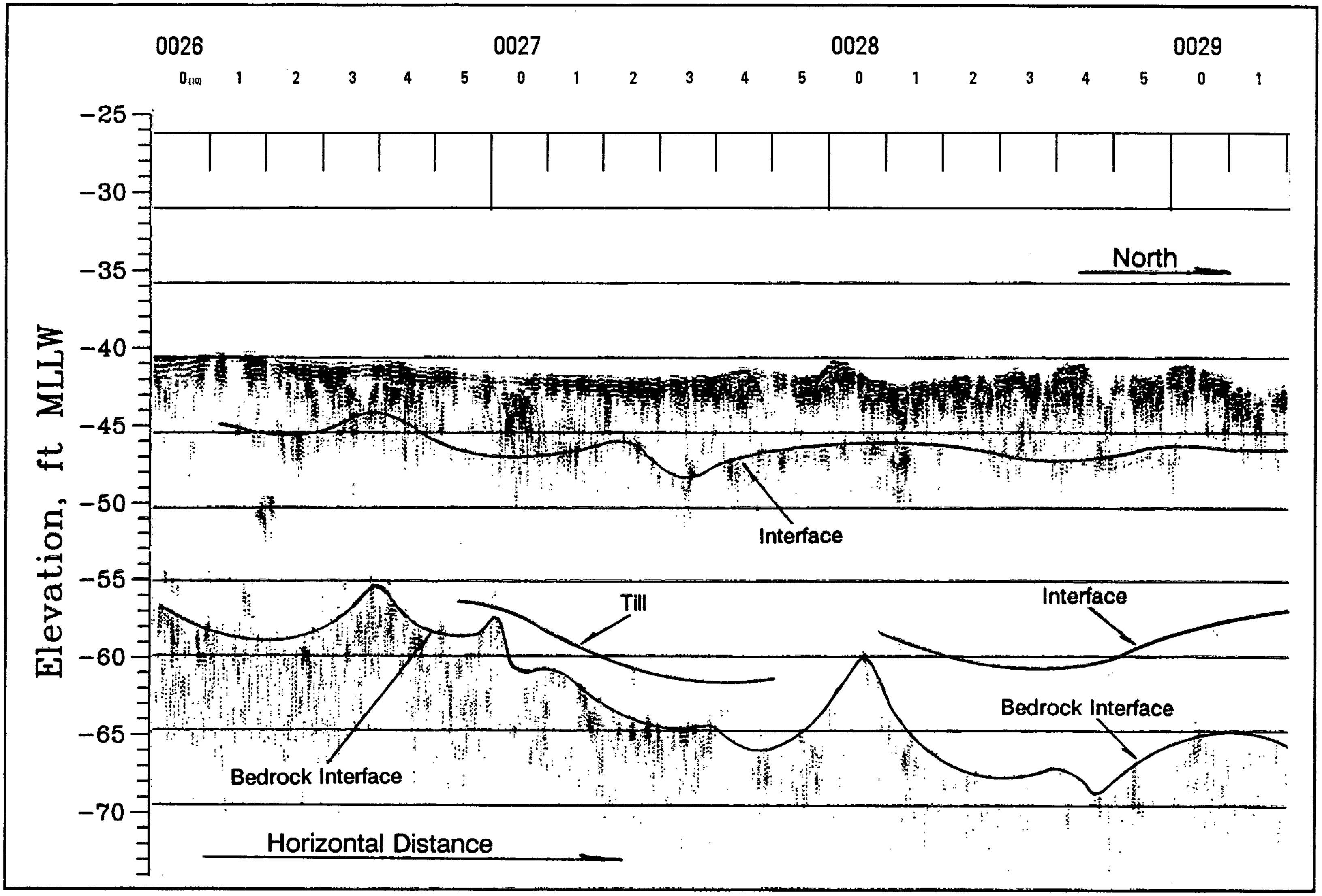


Figure 25. Seismic reflection data collected along survey line PN11 (files 0260-0291)

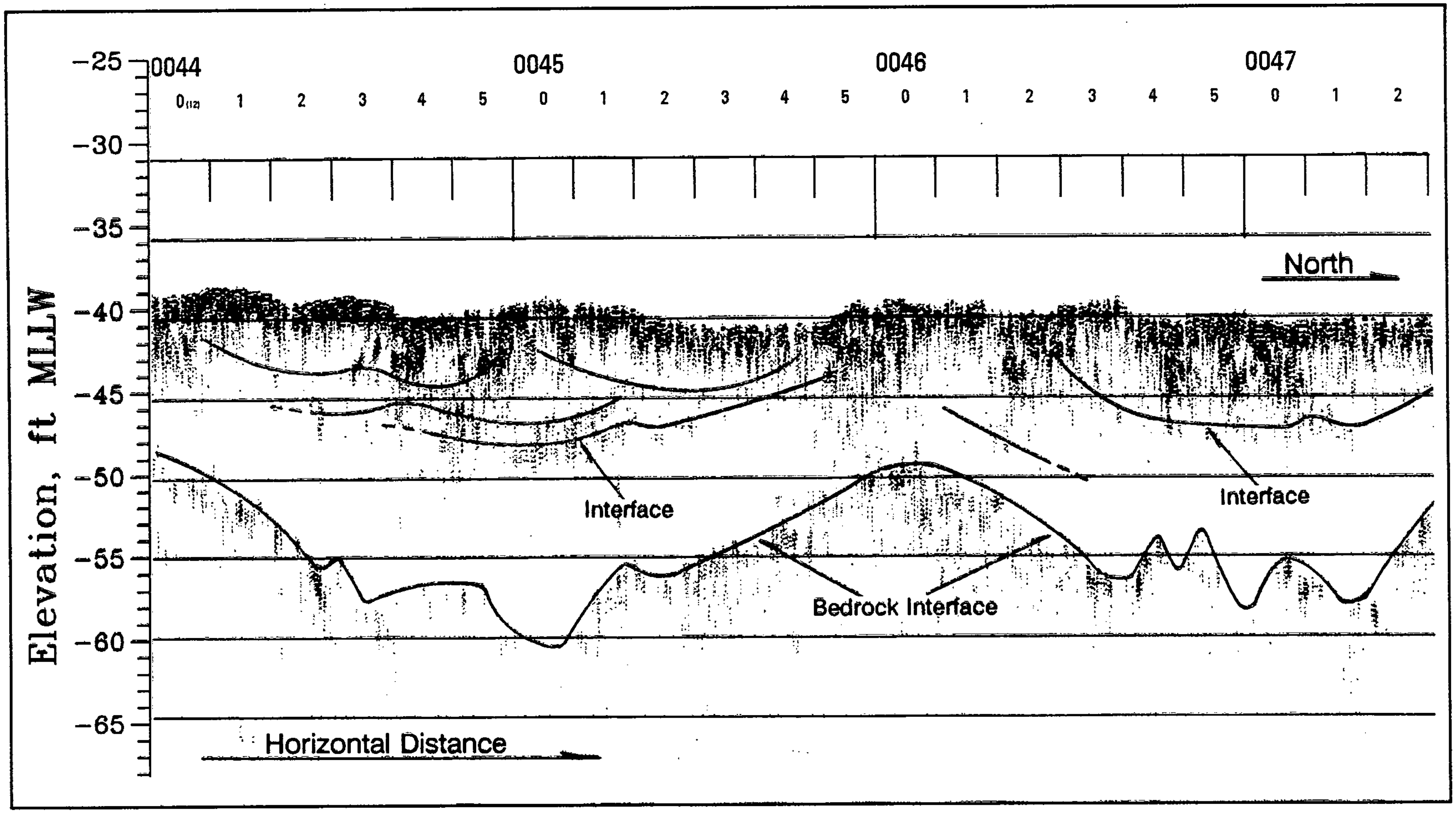


Figure 26. Seismic reflection data collected along survey line PN01 (files 0440-0472) south of the Interstate Highway 278 Bridge

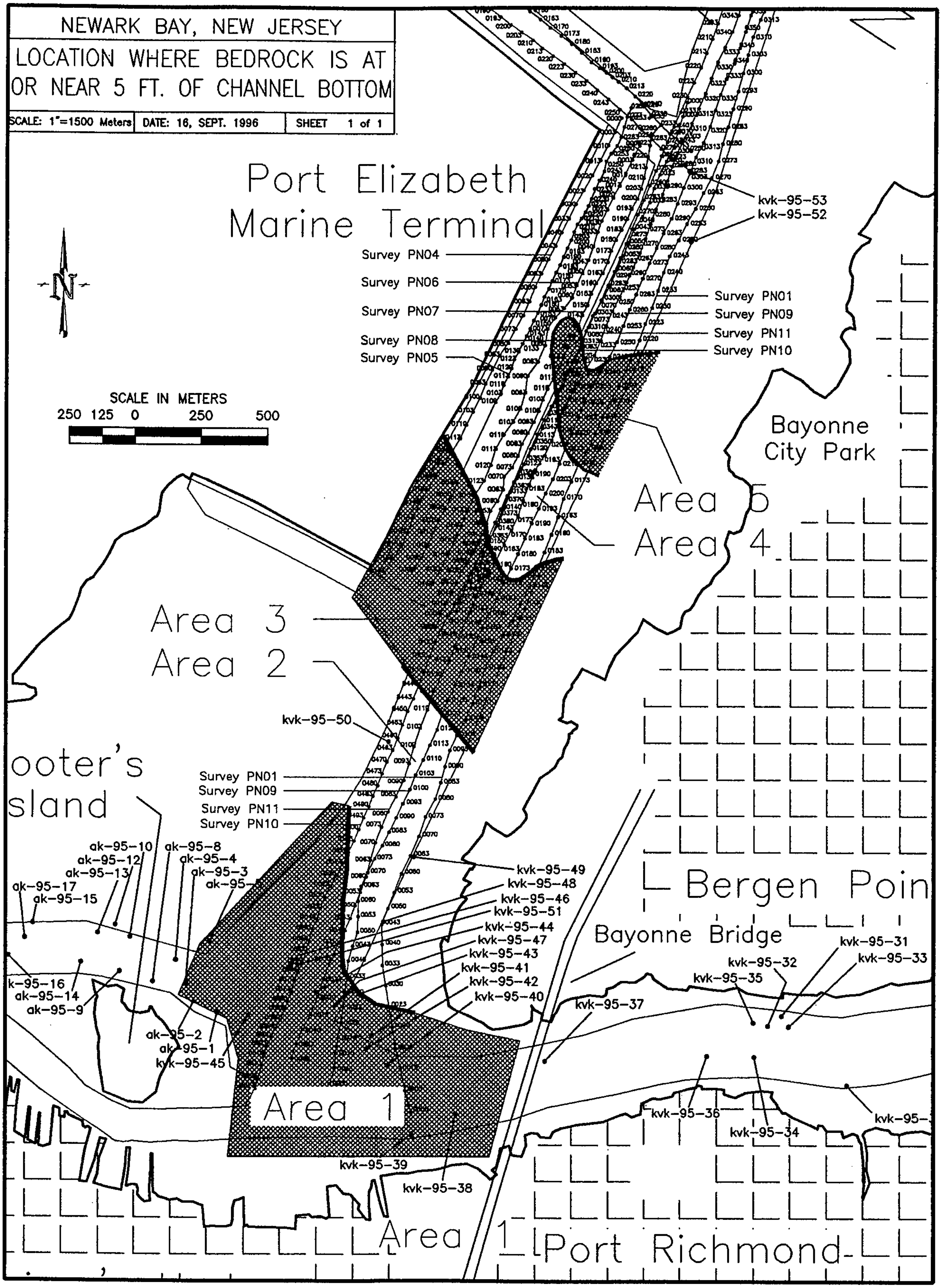


Figure 27. Site map of the southern portion of Newark Bay illustrating areas where glacial till and bedrock are at or near the channel bottom

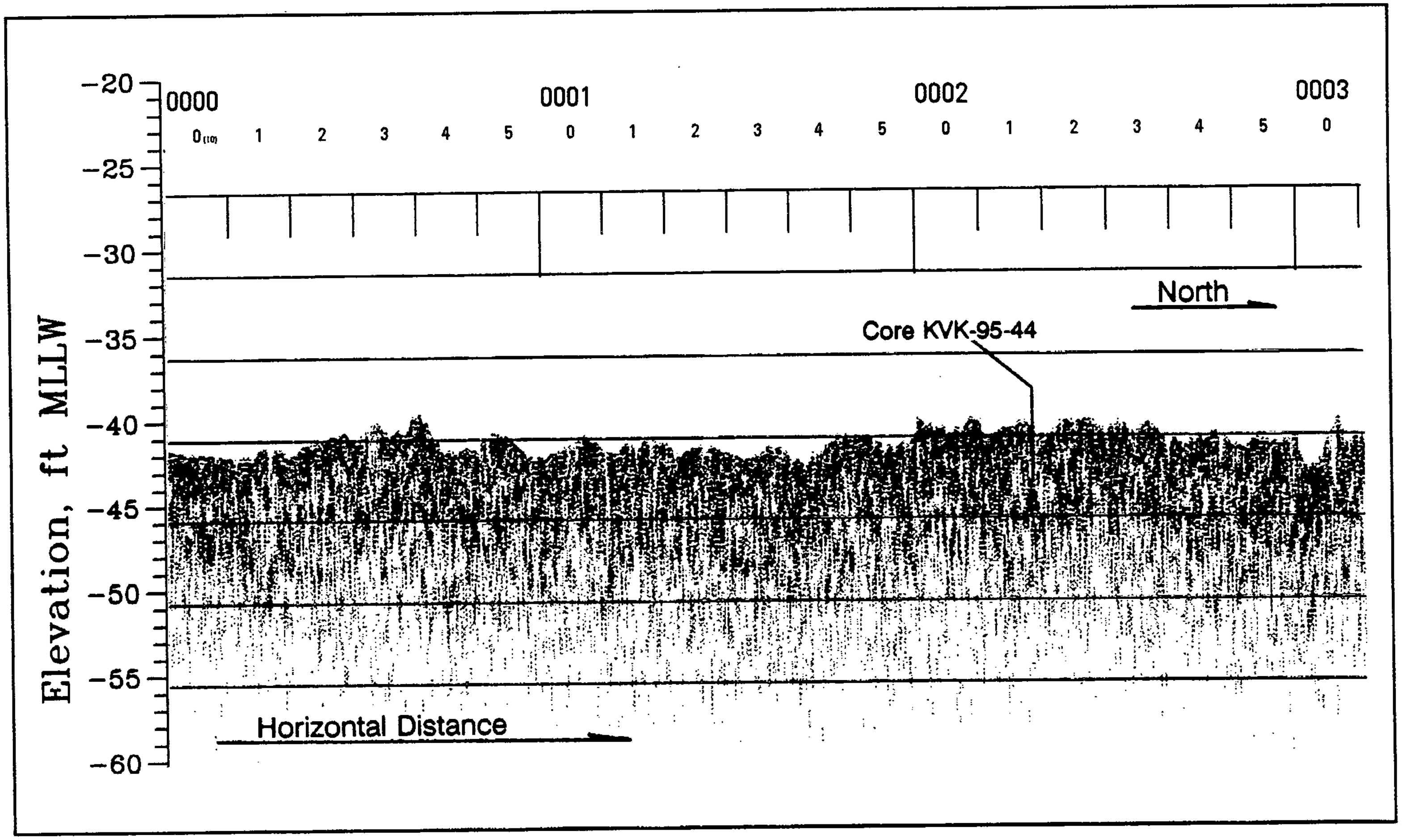


Figure 28. Seismic reflection data collected along survey line PN11 (files 0000-0030)

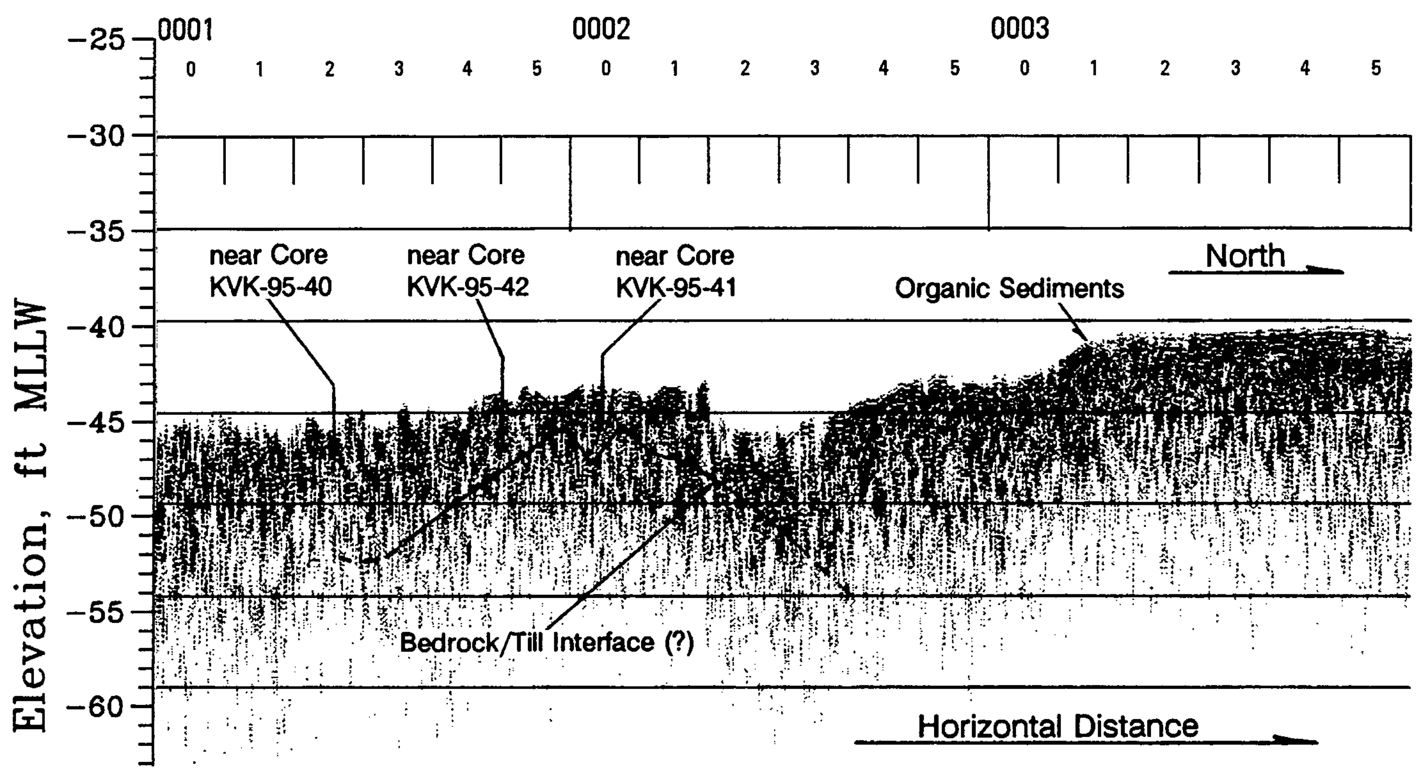


Figure 29. Seismic reflection data collected along survey line PN01 (files 0010-0035)

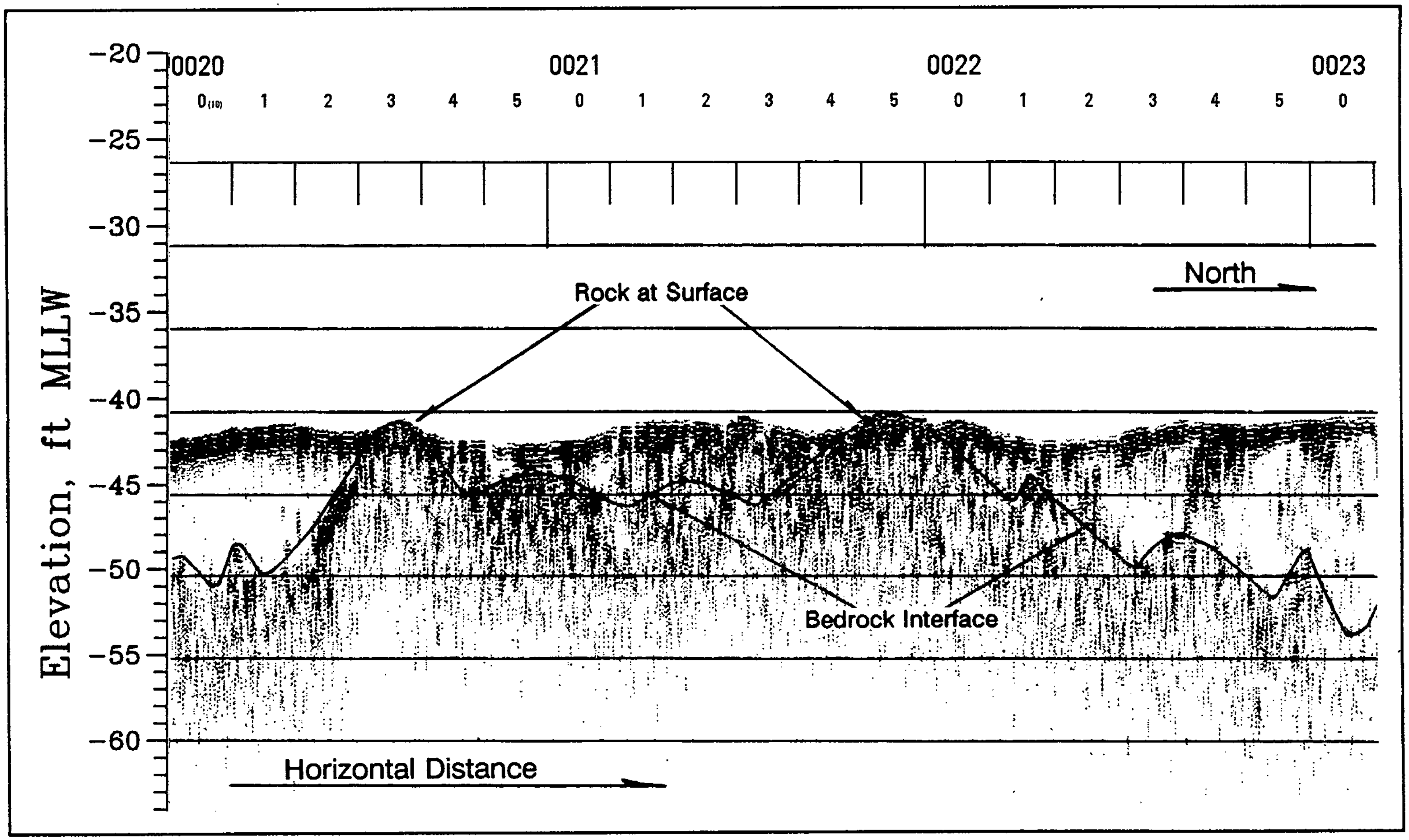


Figure 30. Seismic reflection data collected over a bedrock ridge along survey line PN11 (files 0200-0235)

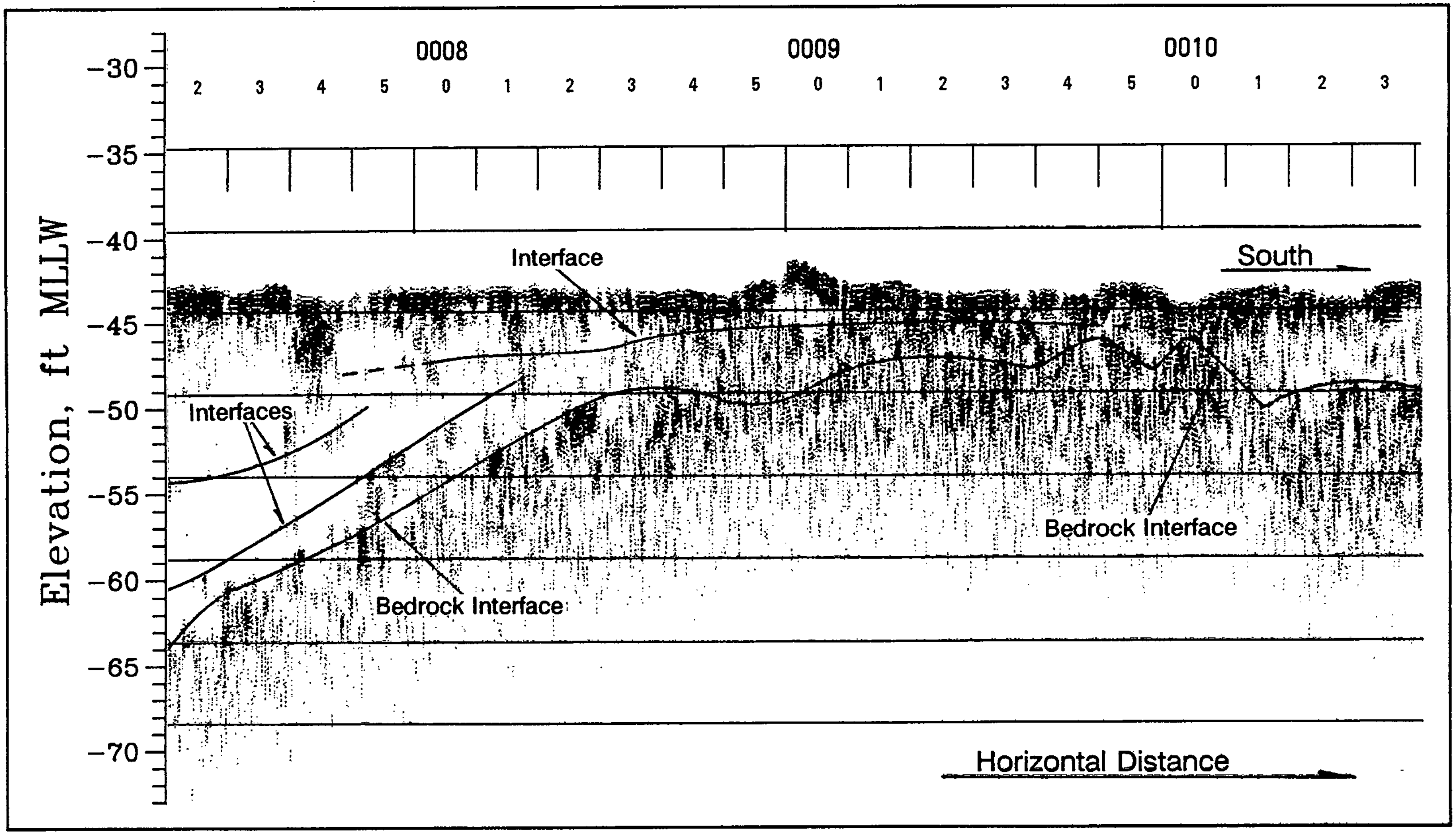


Figure 31. Seismic reflection data collected over a bedrock ridge along survey line PN08 (files 0072-0103)

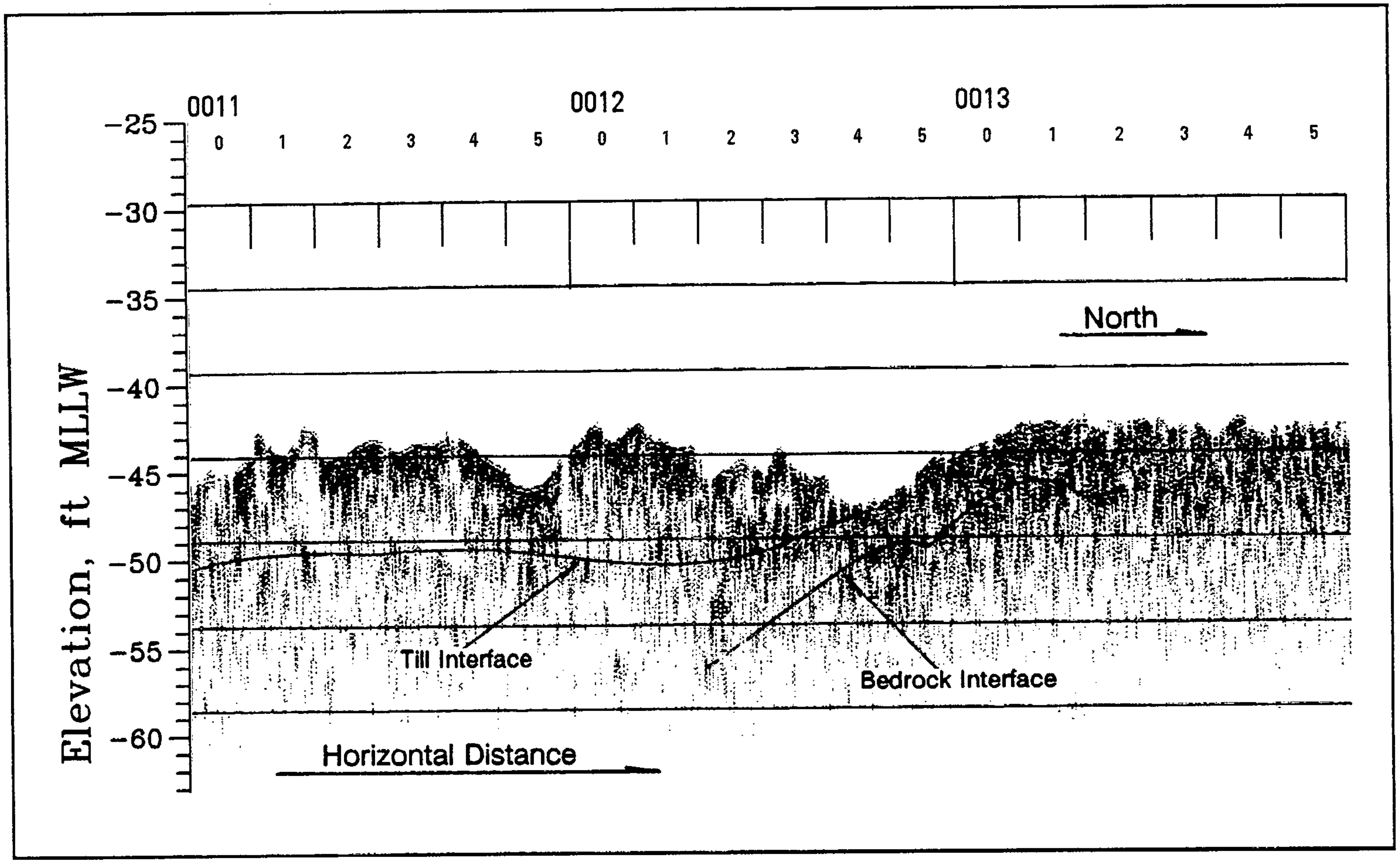


Figure 32. Seismic reflection data collected along survey line PN09 (files 0110-0135)

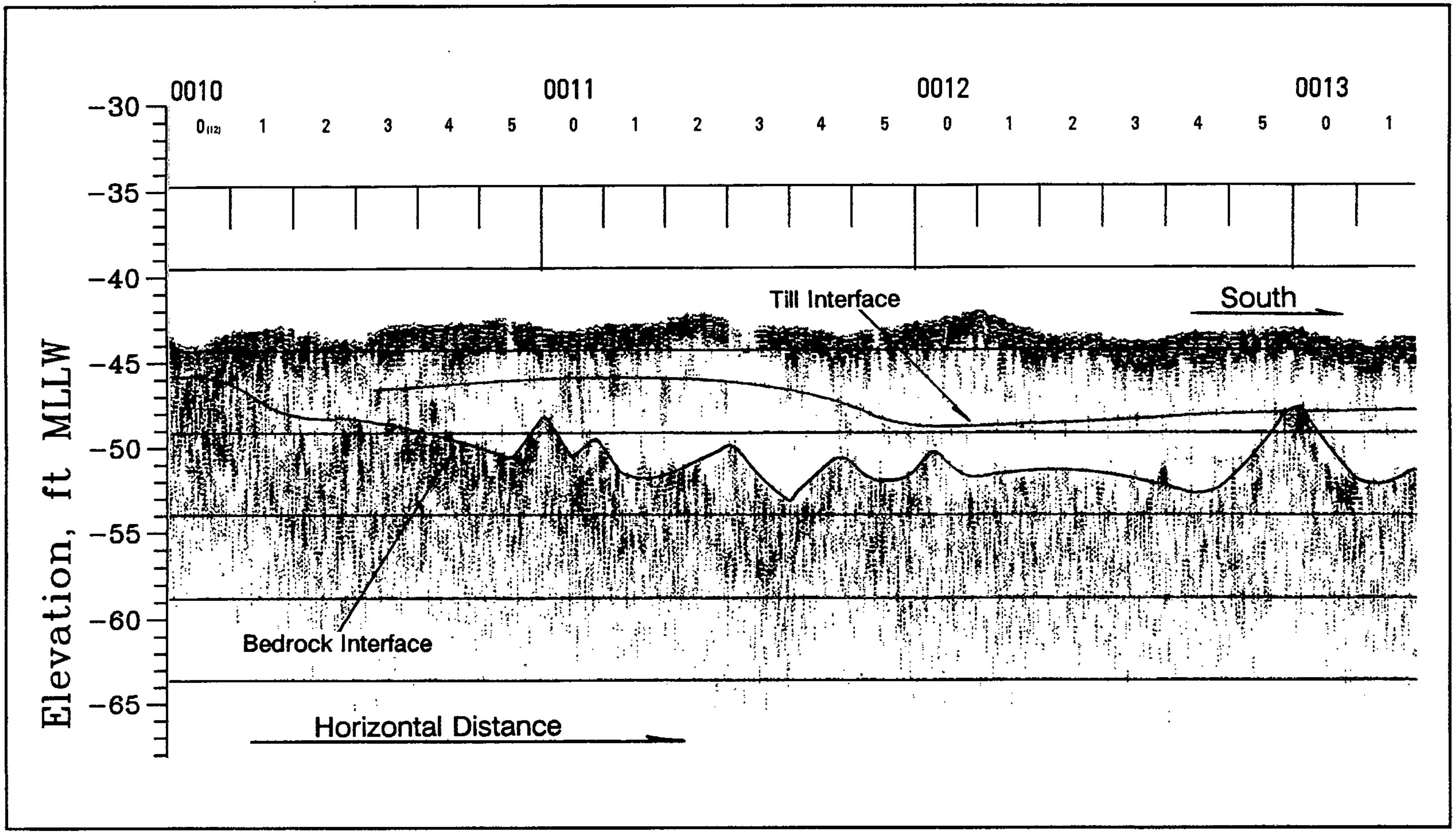


Figure 33. Seismic reflection data collected along survey line PN08 (files 0100-0131)

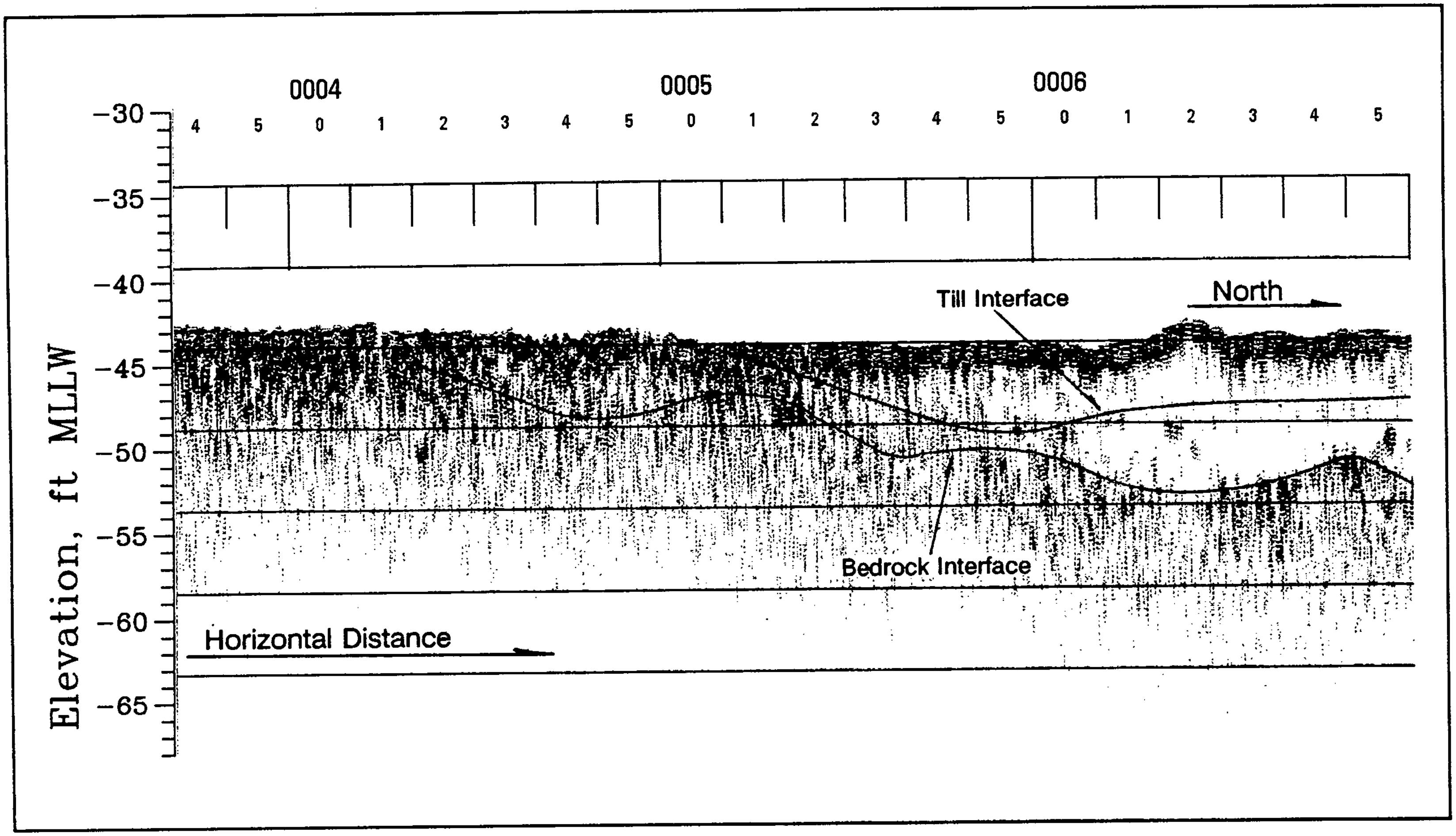


Figure 34. Seismic reflection data illustrating the till and bedrock layers outcropping at the bottom surface along survey line PN07

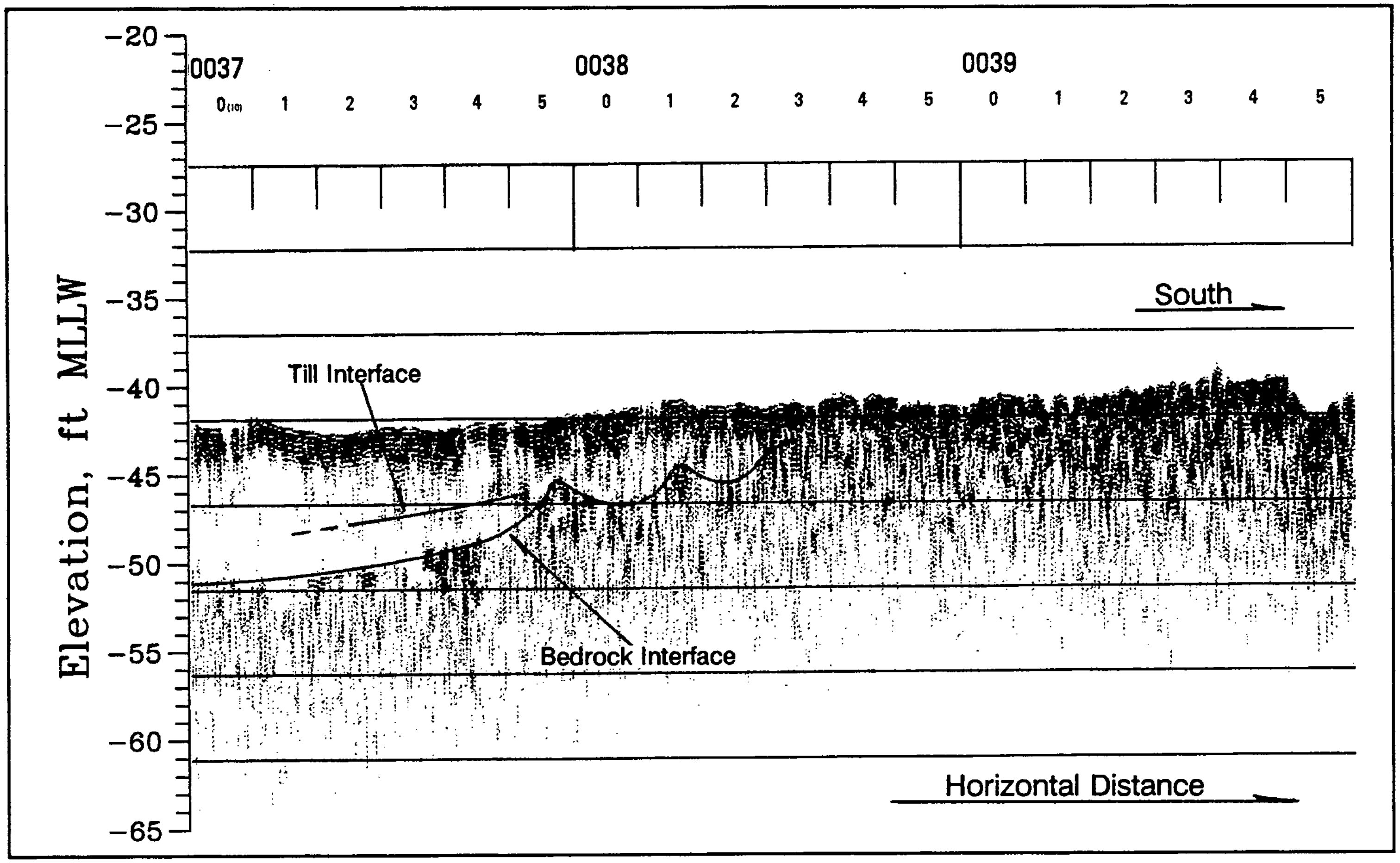


Figure 35. Seismic reflection data collected along survey line PN10 (files 0370-0395)

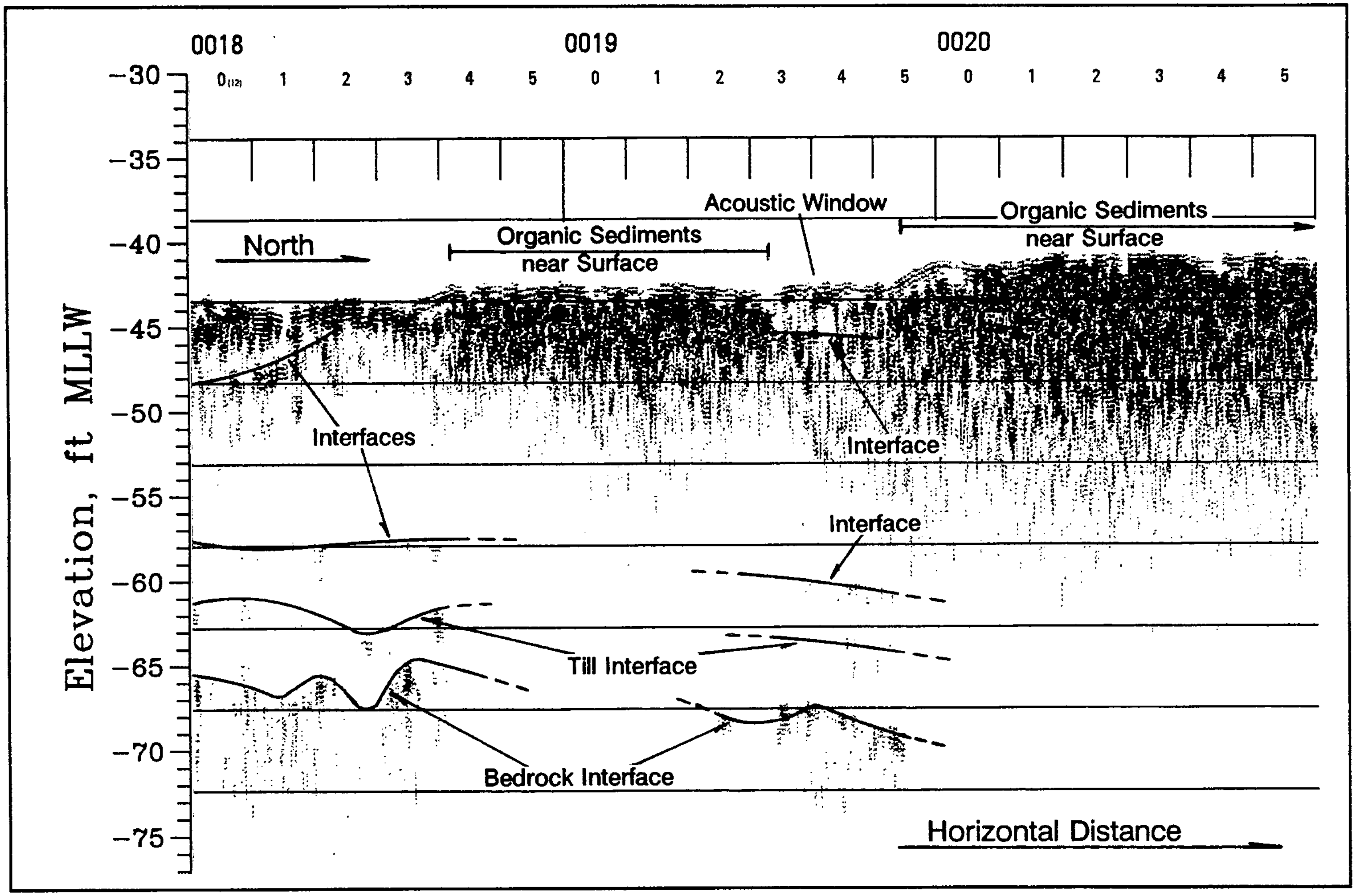


Figure 36. Seismic reflection data collected along survey line PN05 (files 0180-0205)

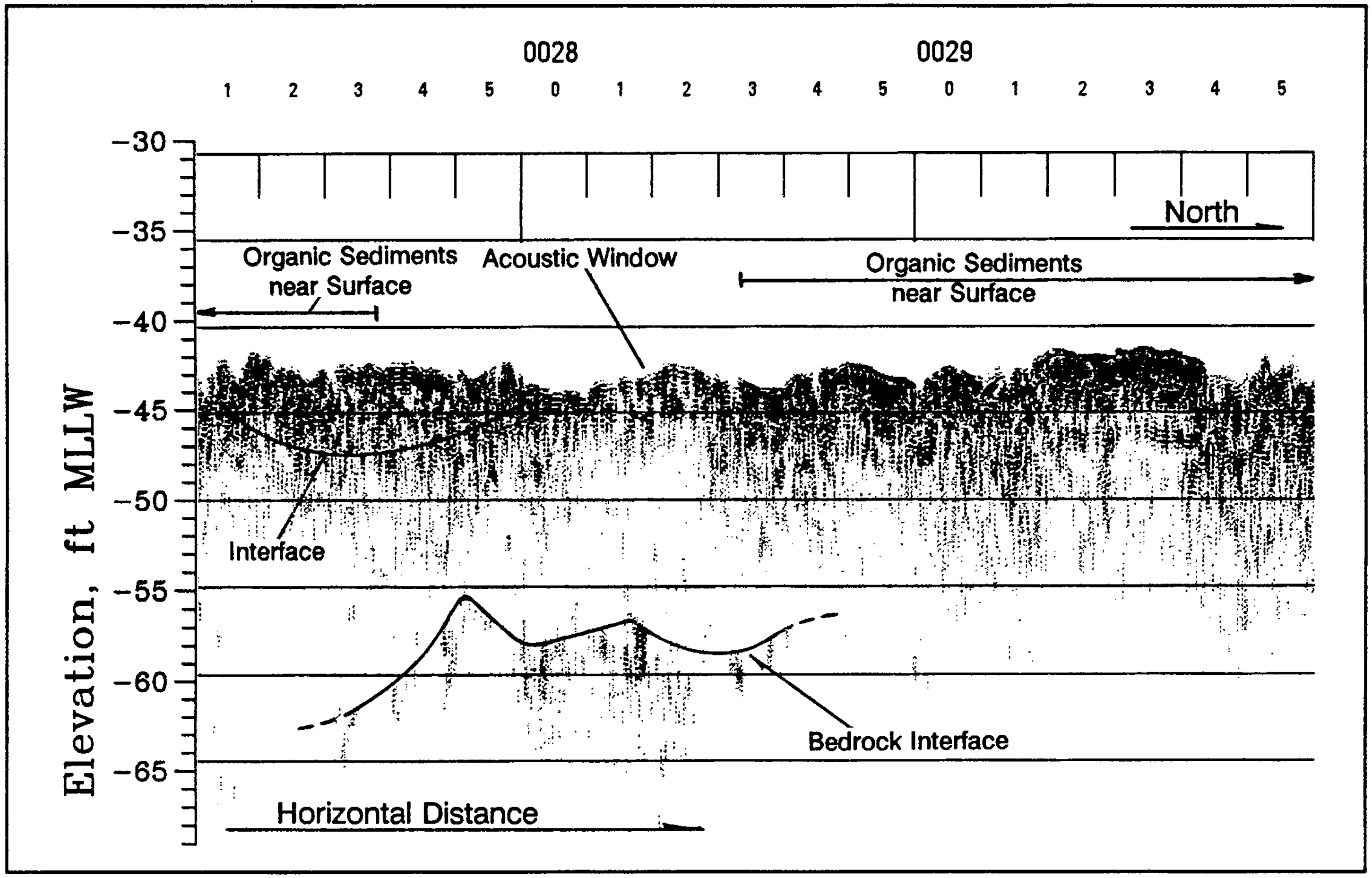


Figure 37. Seismic reflection data collected along survey line PN01 (files 0271-0295)

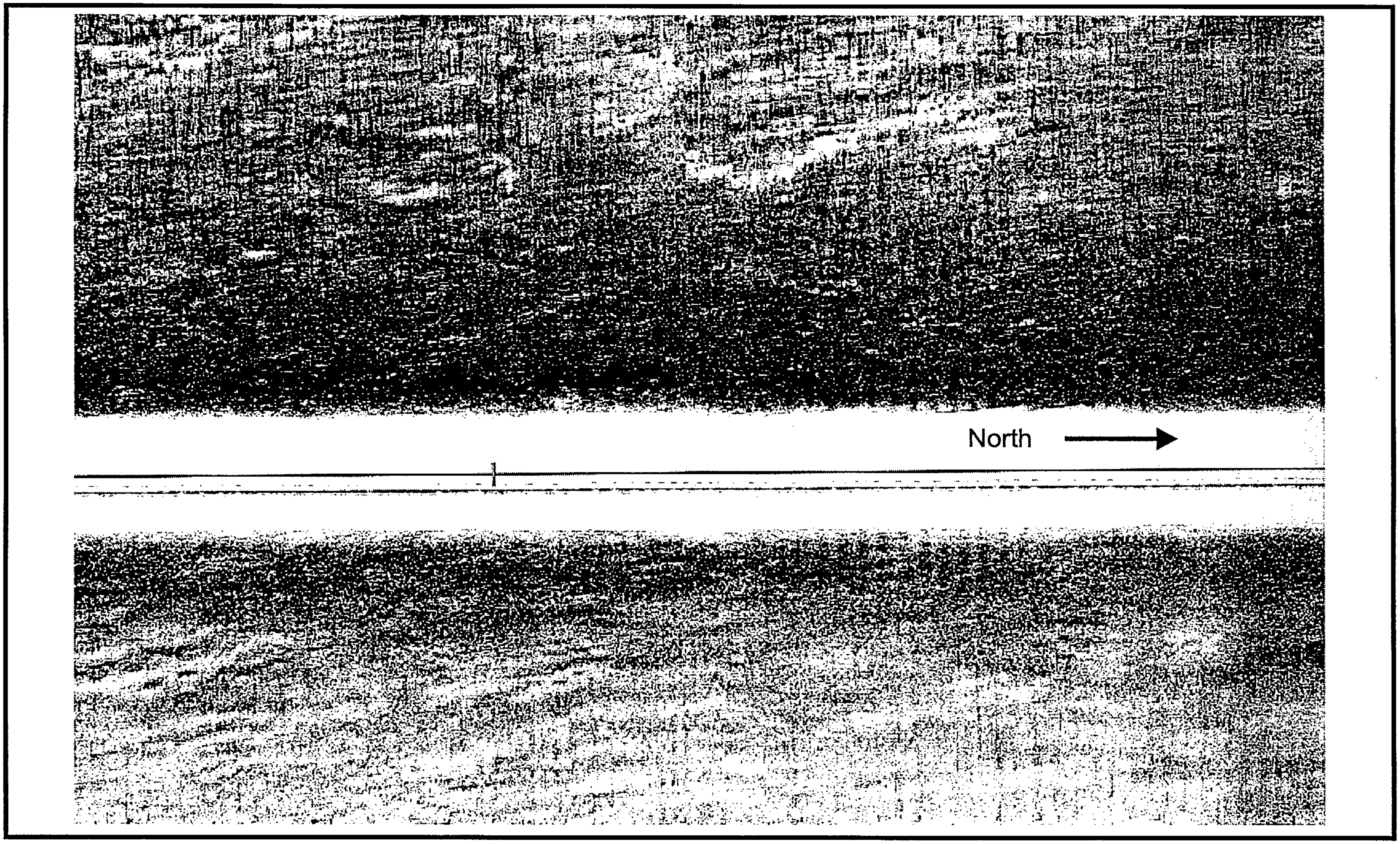


Figure 38. Side scan sonar image collected along survey line PN11 illustrating the sand and gravel on the channel bottom.

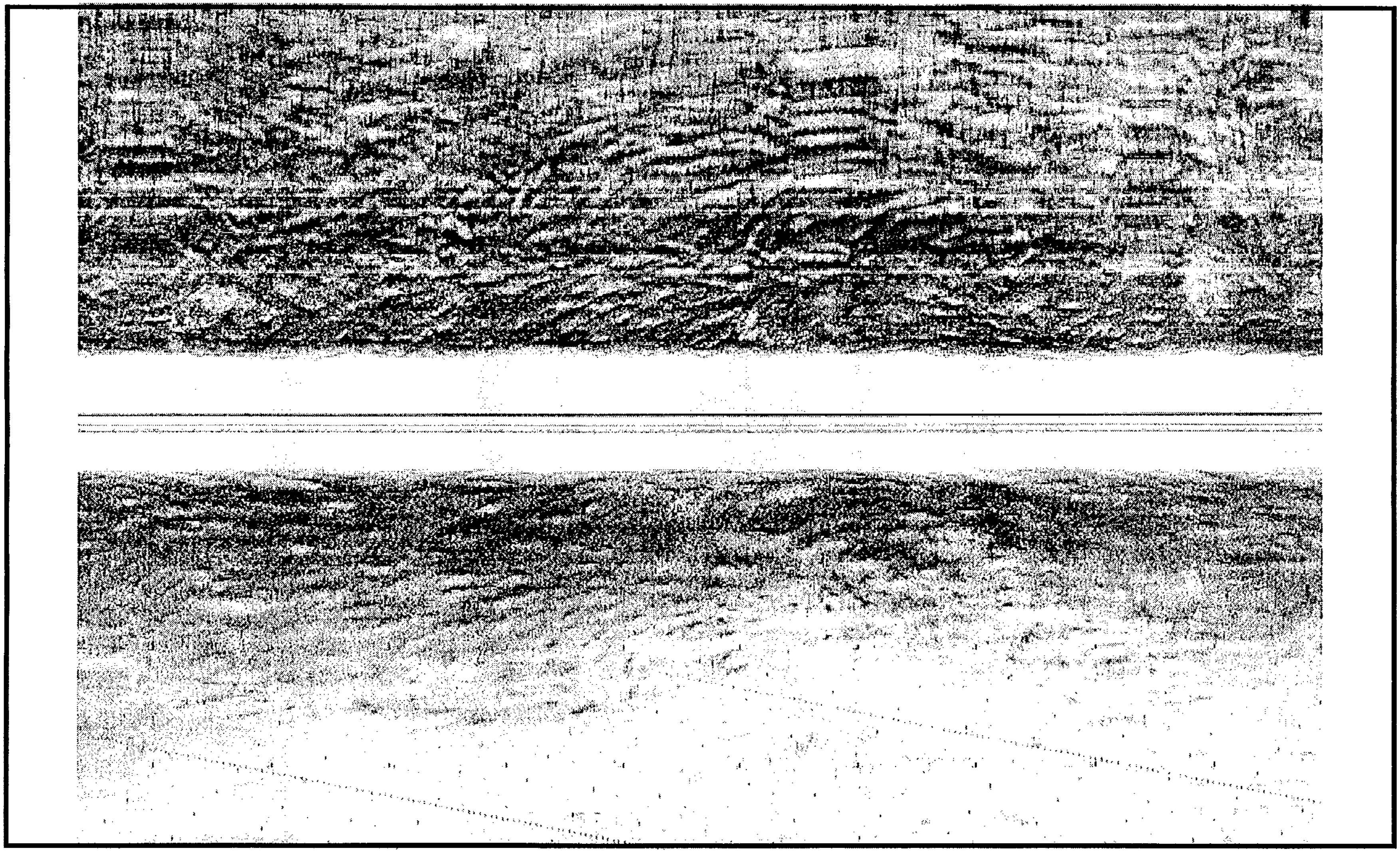


Figure 39. Side scan sonar image of possible bedrock on the channel bottom along survey line PN09.

Table 1
Summary of Core Information, Kill Van Kull and Newark Bay, NY/NJ

Core Number	Easting	Northing	Core Length, ft	Elevation, ft MLLW	Layer Thickness, ft	Sediment Description	USCS Classification
kvk-95-1	579173	4500297	11.2	44.4	---	Clayey silt, some sand	MH
kvk-95-2	579018	4499850	4.6	50.2	---	Clayey silt, some sand, trace wood	MH
kvk-95-3	578606	4500495	10.9	42.9	1.0	Organic silt, some sand	MH
				43.9	3.1	Silt, some sand	ML
				47.0	---	Sand and gravel (till) / possible bedrock at 53 ft	SM-GM
kvk-95-4	578520	4500358	8.1	44.1	0.6	Silt and clay	MH
				44.7	1.0	Silt and clay, little sand and gravel	ML-CL
				45.7	1.1	Sand, some silt	SM
				46.8	---	Cobbles and boulders (till)	GM
kvk-95-5	578595	4500255	8.2	44.3	3.2	Sand, some silt	SM
				47.5	1.8	Sand and gravel	SW-GW
				49.3	---	Silt, some sand / sand and gravel, some silt	ML/SM
kvk-95-6	578448	4500237	7.6	44.4	1.4	Fine sand, some silt	SM
				45.8	---	Gravel, some sand and silt	GM
kvk-95-7	578487	4500075	11.9	43.1	3.4	Silt and clay (organic)	MH
				46.5	1.5	Sand, some silt, trace gravel	SM
				48.0	4.0	No recovery	-----
				52.0	---	Sand, little silt	SM-SP
kvk-95-8	578423	4500524	6.9	44.7	1.5	Sand, some silt	SM
				46.2	2.3	Clayey gravel, some sand	GC
				48.5	---	Fractured bedrock	ROCK
kvk-95-9	578272	4500595	7.4	44.6	2.9	Clayey silt, some sand (organic)	MH
				47.5	---	Clayey gravel, some sand	GC
kvk-95-10	578107	4500493	7.2	44.4	1.6	Sand and gravel, some silt	GM-SM
				46.0	1.5	Clayey silt, some sand and gravel	ML
				47.5	2.5	Sand and gravel, some silt	SM-GM
				50.0	---	Gravel and sand in silt/clay matrix	GM
kvk-95-11	577860	4500350	7.4	45.1	1.9	Sand and gravel, some silt	GM-SM
				47.0	---	Fractured bedrock	ROCK
kvk-95-12	577464	4500610	8.4	43.6	6.4	Sand, trace silt and sand	SP
				50.0	---	Sand, little silt, trace gravel	SP-SM
kvk-95-13	577322	4500577	7.5	44.2	1.5	Sand, trace gravel and silt	SP
				45.7	1.0	Gravel, some sand, trace silt	GP
				48.7	1.5	Gravel, some sand and silt	GM
				50.2	---	Sand, some silt and gravel	GM
kvk-95-14	577291	4500444	0.4	42.6	---	No recovery/ bedrock near surface	-
kvk-95-15	577275	4500286	7.9	45.1	3.5	Gravel, some silt and sand	GM
				48.6	---	Fractured bedrock	ROCK

(Sheet 1 of 5)

Table 1 (Continued)

Core Number	Easting	Northing	Core Length, ft	Elevation, ft MLLW	Layer Thickness, ft	Sediment Description	USCS Classification
kvk-95-16	577146	4500284	7.0	44.5	0.5	Silt and sand	SM-ML
				45.0	---	Bedrock	ROCK
kvk-95-17	577021	4500175	5.8	44.4	0.6	Sand and gravel, some silt	SM-GM
				45.0	---	Fractured bedrock	ROCK
kvk-95-18	576598	4499896	6.0	46.5	1.0	Sand, some silt	SM
				47.5	2.0	Sand, some silt	SM
				49.5	---	Sand, trace silt and gravel	SM-SP
kvk-95-19	576175	4500071	10.5	42.5	1.5	Silty sand, trace gravel	SM
				44.0	1.5	Silty gravel, some sand, trace clay	GM
				45.5	---	Clayey gravel, some sand	GC
kvk-95-20	576352	4499859	13.5	38.5	2.0	Clayey silt, some sand	MH-SH
				40.5	---	Clay, trace silt and sand	CH
kvk-95-21	576135	4499853	7.8	46.2	0.8	Clayey silt	MH
				47.0	2.0	Clay, trace sand and gravel	CH
				49.0	3.0	Sand and gravel, some silt	SM-GM
				52.0	2.0	Cobbles and boulders	GP
				54.0	---	Sand, little silt, trace gravel	SM-SP
kvk-95-22	575792	4500095	7.1	43.0	1.5	Silty sand, some gravel and clay	SM
				44.5	1.5	Clayey gravel, some sand	GC
				46.0	---	Cobbles and boulders	GP
kvk-95-23	575444	4499917	8.3	43.7	2.8	Sand, little gravel, trace silt	SM-SW
				46.5	3.5	Sand and gravel, little silt	SM-GM
				50.0	---	Sand, some gravel, little silt	SM
kvk-95-24	575209	4499927	8.5	43.5	2.5	Sand, some silt, trace gravel	SM
				46.0	3.5	Gravel, some sand, trace silt	GW-GM
				49.5	---	Sand, little gravel, trace silt	SW
kvk-95-25	574831	4499972	9.2	42.8	---	Sand, little silt, trace gravel	SP-SM
kvk-95-26	574733	4499832	11.3	42.5	6.0	Sand, trace gravel and silt	SP
				48.5	---	Cobbles and boulders in sand	GP
kvk-95-27	574455	4499539	15.0	42.8	3.7	Sand, trace gravel and silt	SP
				46.5	6.0	Sand, trace gravel	SP
				52.5	---	Gravel, some sand and silt	GM
kvk-95-28	574395	4499758	10.5	42.3	1.5	Sand, trace silt	SP
				43.8	1.7	Sand, some silt and gravel, trace clay	SM
				45.5	---	Coarse sand, some silt and gravel	SM
kvk-95-29	574090	4499518	11.2	43.8	3.2	Sand, trace silt and gravel	SP
				47.0	0.5	Clayey silt, some sand	ML
				47.5	2.0	Sand, some gravel, trace silt	SW
				49.5	3.0	Sand and gravel	SW-GW
				52.5	---	Sand and gravel, little silt	SM-G

(Sheet 2 of 5)

Table 1 (Continued)							
Core Number	Easting	Northing	Core Length, ft	Elevation, ft MLLW	Layer Thickness, ft	Sediment Description	USCS Classification
kvk-95-30	573727	4499363	12.0	39.1	3.9	Silty sand, trace gravel	SM
				43.0	2.0	Sand, trace silt and gravel	SP
				45.0	2.5	Silty gravel, some sand and silt	GM
				47.5	---	Clayey gravel, some sand	GC
kvk-95-31	573481	4499622	7.3	43.5	1.0	No recovery	-----
				44.5	---	Bedrock	ROCK
kvk-95-32	573428	4499584	4.9	44.7	0.9	Sand, some silt	SM
				45.6	0.8	Sand and gravel, some silt	GM-SM
				46.4	---	Cobbles and boulders	
kvk-95-33	573507	4499582	6.1	43.1	2.9	Sand, trace silt	SP-SM
				46.0	1.9	Sand and gravel, little silt	SM-GM
				47.9	---	Boulders and cobbles	GM
kvk-95-34	573377	4499469	7.9	43.9	1.5	Sand, some gravel and silt	SP
				45.4	1.5	Gravel, trace sand	GP
				46.9	---	Bedrock	ROCK
kvk-95-35	573373	4499596	8.1	43.1	3.4	Sand, some silt, little gravel	SM
				46.5	1.5	Sand, some gravel, little silt	SM
				48.0	---	Cobbles and boulders	GP
kvk-95-36	573200	4499471	4.5	45.0	2.7	Sand and gravel, some silt	SM-GM
				47.7	---	Boulders, cobbles and gravel	GP
kvk-95-37	572587	4499451	2.9	44.8	---	Bedrock	ROCK
kvk-95-38	572251	4499253	3.6	45.1	1.2	Gravel (fragmented rock)	GP
				46.3	---	Bedrock	ROCK
kvk-95-39	572085	4499177	5.5	45.0	1.5	Clayey silt, some gravel	MH
				46.5	1.5	Gravel and rock fragments	GP
				48.0	---	Bedrock	ROCK
kvk-95-40	571990	4499435	5.8	45.0	0.9	Boulders and cobbles	GP
				45.9	---	Bedrock	ROCK
kvk-95-41	571934	4499543	5.2	45.0	---	Bedrock	ROCK
kvk-95-42	571912	4499496	8.9	41.8	5.0	Clayey silt, trace gravel	MH
				46.8	---	Bedrock	ROCK
kvk-95-43	571797	4499660	8.8	42.2	6.3	Cobbles and boulders in silt/clay matrix	GC
				48.5	---	No recovery	-----
kvk-95-44	571725	4499708	6.1	43.8	1.5	Gravel, some sand and silt	GC
				45.3	---	Bedrock	ROCK
kvk-95-45	571467	4499622	14.7	43.7	3.8	Silt	MH
				47.5	1.0	Silty gravel, some sand	GM
				48.5	---	Bedrock	ROCK
kvk-95-46	571629	4499806	0.7	45.4	0.7	Sand, some rock fragments	SM
				46.1	---	Bedrock	ROCK

(Sheet 3 of 5)

Table 1 (Continued)							
Core Number	Easting	Northing	Core Length, ft	Elevation, ft MLLW	Layer Thickness, ft	Sediment Description	USCS Classification
kvk-95-47	571884	4499700	4.3	43.5	1.5	Sand and gravel	SM-GM
				45.0	---	Clayey gravel	GC
kvk-95-48	571977	4499973	12.0	40.5	2.3	Clayey silt, trace sand	MH
				42.8	5.7	Clay, little sand, trace gravel	CH
				48.5	2.5	Sand and gravel, some silt and clay	SC-GC
				51.0	---	Clay	CH
kvk-95-49	572093	4500217	13.5	42.0	1.5	Silt ooze	-----
				43.5	4.5	Clay, trace of silt	CH
				48.0	---	Gravel, trace silt and sand	GC
kvk-95-50	571995	4500652	12.7	44.6	3.7	Silt, trace sand	MH
				48.3	2.2	Clayey sand, trace silt and gravel	SP-SM
				50.5	2.3	Clay, trace sand and gravel	MH
				52.8	2.2	Sand, trace clay	SP
				55.0	---	Clay, some gravel, trace sand	MH
kvk-95-51	571656	4499811	5.3	44.7	1.5	Silty gravel, some sand	GM
				46.2	1.2	Clayey gravel, some sand	GC
				47.4	---	Bedrock	ROCK
kvk-95-52	573134	4502514	15.7	38.8	4.4	Silt (organic)	MH
				43.2	---	Clay, some silt	CH
kvk-95-53	573127	4502776	9.0	43.6	0.6	Silt (organic)	MH
				44.2	---	Clay, some silt	CH
kvk-95-54	571337	4504226	14.3	36.0	6.8	Silt (organic)	MH
				42.8	4.0	Clay, little silt, trace gravel	CH
				46.8	---	Clay, some silt, and gravel	CH
kvk-95-55	571210	4504289	12.9	36.7	4.6	Silt (organic)	MH
				41.3	6.0	Clay, some silt, trace gravel	CH
				47.3	1.9	Clay and silt, some gravel	CH-MH
				49.2	---	Bedrock (shale)	ROCK
kvk-95-56	571173	4504374	8.8	40.7	3.8	Clayey silt (organic)	MH
				44.5	---	Clay, gravel	CH
kvk-95-57	571218	4504394	10.7	39.6	2.9	Clayey silt (organic)	MH
				42.5	5.5	Clay, some gravel	CH
				48.0	---	No recovery	-----
kvk-95-58	573202	4503328	26.1	27.4	5.1	Clayey silt (organic)	MH
				32.5	3.7	Sand, trace silt	SP
				36.2	---	Clay	CH
kvk-95-59	573305	4503599	15.5	36.6	7.4	Clayey silt	MH
				44.0	---	Clay, trace silt	CH
kvk-95-60	573363	4503948	10.6	39.7	2.3	Silt (organic)	MH
				42.0	---	Clay, little silt	CH

(Sheet 4 of 5)

Table 1 (Concluded)							
Core Number	Easting	Northing	Core Length, ft	Elevation, ft MLLW	Layer Thickness, ft	Sediment Description	USCS Classification
kvk-95-61	573532	4504250	6.0	44.6	0.6	Silt (organic)	MH
				45.2	---	Clay, some silt	CH
kvk-95-62	573287	4504461	9.0	41.9	0.5	Silt (organic)	MH
				42.4	---	Clay, little silt	CH
kvk-95-63	573215	4504228	10.7	41.0	---	Bedrock (shale)	ROCK
							(Sheet 5 of 5)

Appendix A
Kill Van Kull 'Pinger' Positioning Information

Survey Line PKK1
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: East
Survey Date/Time: 5 June 1996; 1531 to 1645 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	571787	4499183	-44.1	0200	574107	4499470	-44.9
0003	571851	4499184	-44.0	0203	574168	4499480	-44.2
0010	571905	4499159	-43.8	0210	574233	4499492	-43.9
0013	571965	4499182	-44.1	0213	574299	4499504	-43.3
0020	572035	4499192	-44.0	0220	574358	4499524	-43.3
0023	572092	4499197	-43.8	0223	574419	4499542	-43.7
0030	572163	4499202	-44.1	0230	574479	4499554	-42.5
0033	572220	4499198	-45.0	0233	574543	4499572	-42.8
0040	572277	4499202	-44.7	0240	574601	4499602	-42.8
0043	572338	4499194	-28.6	0243	574662	4499630	-42.5
0050	572402	4499199	-28.0	0250	574724	4499651	-41.3
0053	572450	4499233	-45.3	0253	574788	4499676	-37.7
0060	572507	4499262	-44.1	0260	574846	4499702	-39.3
0063	572550	4499290	-44.2	0263	574902	4499728	-38.1
0070	572597	4499301	-45.1	0270	574962	4499755	-37.7
0073	572650	4499316	-44.5	0273	575025	4499779	-36.3
0080	572707	4499336	-42.8	0280	575087	4499800	-40.3
0083	572764	4499350	-42.9	0283	575152	4499830	-41.5
0090	572817	4499363	---	0290	575213	4499858	-43.8
0093	572854	4499372	-43.4	0293	575280	4499878	-44.3
0100	572930	4499390	-43.3	0300	575347	4499894	-43.6
0103	572988	4499398	---	0303	575403	4499920	-43.3
0110	573046	4499408	-44.3	0310	575470	4499930	-42.2
0113	573109	4499416	-43.8	0313	575536	4499944	-42.4
0120	573177	4499417	-44.0	0320	575603	4499938	-43.3
0123	573241	4499420	-44.5	0323	575664	4499916	-43.6
0130	573295	4499424	-44.7	0330	575730	4499912	-41.6
0133	573353	4499438	-44.3	0333	575795	4499914	-43.8
0140	573410	4499447	-46.6	0340	575871	4499913	-43.1
0143	573469	4499460	-47.1	0343	575941	4499928	-43.7
0150	573528	4499467	-46.0	0350	575997	4499905	-44.4
0153	573590	4499466	-44.3	0353	576057	4499886	-43.4
0160	573647	4499458	-43.8	0360	576119	4499878	-42.7
0163	573705	4499453	-43.9	0363	576181	4499879	-43.2
0170	573762	4499450	-43.1	0370	576243	4499876	-42.8
0173	573817	4499440	-44.5	0373	576304	4499878	-42.3
0180	573872	4499442	-44.0	0380	576369	4499876	-43.7
0183	573930	4499444	-43.2	0383	576431	4499869	-42.6
0190	573986	4499439	-42.7	0390	576492	4499876	-43.3
0193	574046	4499456	-43.8	0393	576551	4499894	-44.4

Survey Line PKK1
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: East
Survey Date/Time: 5 June 1996; 1531 to 1645 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0400	576612	4499910	-44.2				
0403	576674	4499932	-45.0				
0410	576734	4499956	-44.0				
0413	576793	4499990	-43.2				
0420	576850	4500028	-44.0				
0423	576908	4500066	-44.0				
0430	576966	4500105	-43.7				
0433	577025	4500148	-43.9				
0440	577080	4500190	-43.6				
0443	577141	4500232	-44.4				
0450	577208	4500262	-46.2				
0453	577280	4500286	-44.4				
0460	577339	4500306	-43.9				
0463	577403	4500320	-45.6				
0470	577475	4500326	-45.0				
0473	577546	4500326	-45.6				
0480	577620	4500326	-46.4				
0483	577695	4500324	-46.0				
0490	577771	4500324	-44.4				
0493	577842	4500320	-44.3				
0500	577911	4500312	-44.1				
0503	577982	4500303	-43.9				
0510	578051	4500290	-43.4				
0513	578119	4500277	-43.3				
0520	578186	4500264	-43.7				
0523	578251	4500248	-43.1				
0530	578316	4500226	-43.4				
0533	578383	4500205	-44.1				
0540	578455	4500186	-43.9				
0543	578521	4500177	-44.9				
0550	578583	4500170	-44.5				
0553	578651	4500171	-45.1				
0560	578713	4500175	---				
0563	578776	4500168	---				
0570	578834	4500156	---				
0573	578895	4500148	---				
0580	578946	4500148	---				
0583	578996	4500146	---				
0590	579046	4500137	-45.4				
0593	579101	4500109	-46.4				
0600	579156	4500068	-48.0				

Survey Line PKK2
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: East
Survey Date/Time: 5 June 1996; 1908 to 2002 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	571863	4499280	-45.2	0200	575048	4499852	-43.4
0003	571925	4499275	-45.7	0203	575124	4499880	-43.3
0010	571981	4499268	-45.6	0210	575200	4499906	-43.6
0013	572037	4499260	-46.3	0213	575286	4499933	-43.3
0020	572108	4499268	-45.3	0220	575378	4499952	-43.5
0023	572181	4499274	-45.8	0223	575470	4499971	-43.4
0030	572258	4499280	-45.7	0230	575556	4499988	-43.3
0033	572335	4499298	-45.4	0233	575635	4499986	-42.8
0040	572421	4499325	-45.9	0240	575723	4499966	-44.7
0043	572513	4499350	-45.1	0243	575816	4499962	-43.4
0050	572600	4499380	-46.1	0250	575914	4499952	-43.7
0053	572673	4499394	-44.2	0253	576013	4499940	-43.8
0060	572750	4499402	-45.4	0260	576111	4499940	-43.6
0063	572824	4499413	-45.3	0263	576207	4499924	---
0070	572896	4499430	-44.5	0270	576301	4499916	-41.2
0073	572973	4499454	-44.6	0273	576390	4499920	-42.3
0080	573046	4499459	-45.0	0280	576487	4499918	-43.5
0083	573120	4499468	-44.8	0283	576578	4499930	-43.2
0090	573189	4499478	-45.1	0290	576661	4499972	-46.1
0093	573271	4499496	-45.9	0293	576740	4500016	-46.3
0100	573348	4499514	-47.2	0300	576835	4500044	-44.1
0103	573430	4499522	-43.3	0303	576924	4500090	-44.2
0110	573513	4499523	-47.7	0310	577011	4500136	-44.4
0113	573600	4499511	-45.6	0313	577095	4500192	-44.2
0120	573690	4499496	-42.5	0320	577175	4500251	-45.6
0123	573787	4499490	-43.0	0323	577264	4500296	-45.5
0130	573881	4499476	-43.7	0330	577355	4500332	-44.9
0133	573979	4499473	-44.0	0333	577451	4500362	-44.2
0140	574069	4499492	-43.4	0340	577553	4500383	-48.9
0143	574162	4499520	-44.6	0343	577657	4500397	-44.8
0150	574250	4499546	-44.4	0350	577760	4500398	-45.4
0153	574342	4499572	-43.7	0353	577864	4500390	-45.0
0160	574435	4499591	-43.3	0360	577962	4500374	-44.3
0163	574528	4499618	-44.1	0363	578064	4500370	---
0170	574619	4499649	-42.6	0370	578156	4500370	---
0173	574697	4499682	-42.8	0373	578245	4500362	-44.7
0180	574762	4499720	-44.1	0380	578335	4500352	-44.8
0183	574829	4499763	-43.9	0383	578424	4500330	-45.8
0190	574903	4499795	-43.6	0390	578505	4500287	---
0193	574976	4499824	-46.7	0393	578587	4500247	-45.7

Survey Line PKK2
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: East
Survey Date/Time: 5 June 1996; 1908 to 2002 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0400	578681	4500226	-45.9				
0403	578777	4500210	-43.7				
0410	578870	4500173	-43.8				
0413	578950	4500119	-45.1				
0420	579045	4500092	-45.8				
0423	579139	4500060	-47.8				
0430	579231	4500020	-54.1				

Survey Line PKK3 (Channel Centerline)
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 6 June 1996; 1532 to 1650 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	579157	4500124	-46.6	0200	576698	4500087	-43.0
0003	579088	4500132	-45.0	0203	576630	4500063	-43.4
0010	579027	4500140	-43.7	0210	576562	4500032	-43.6
0013	578966	4500165	-43.8	0213	576490	4500021	-43.1
0020	578910	4500198	-43.4	0220	576418	4500018	-42.9
0023	578844	4500214	-43.5	0223	576345	4500020	-43.2
0030	578781	4500230	-43.1	0230	576270	4500028	-43.3
0033	578720	4500260	-43.5	0233	576194	4500034	-41.5
0040	578660	4500288	-42.7	0240	576121	4500041	-42.1
0043	578599	4500304	-42.8	0243	576045	4500048	-41.4
0050	578537	4500323	-44.0	0250	575972	4500055	-41.0
0053	578482	4500348	-43.6	0253	575899	4500058	-42.5
0060	578426	4500370	-43.4	0260	575818	4500062	-41.3
0063	578372	4500392	-44.0	0263	575734	4500066	-42.4
0070	578317	4500408	-43.3	0270	575655	4500060	-41.9
0073	578261	4500420	-44.8	0273	575571	4500064	-42.2
0080	578206	4500431	-44.3	0280	575489	4500070	-41.9
0083	578146	4500437	-44.6	0283	575405	4500072	-42.0
0090	578084	4500432	---	0290	575324	4500064	-44.0
0093	578022	4500443	-44.0	0293	575243	4500042	-45.2
0100	577962	4500443	-43.0	0300	575180	4499993	-45.5
0103	577902	4500440	-43.3	0303	575119	4499967	-44.4
0110	577838	4500440	-45.1	0310	575058	4499944	-42.8
0113	577774	4500448	-45.1	0313	575002	4499914	-43.0
0120	577710	4500450	-43.2	0320	574943	4499881	-43.3
0123	577648	4500449	-44.6	0323	574889	4499845	---
0130	577585	4500442	-45.4	0330	574836	4499808	-43.7
0133	577518	4500431	-44.8	0333	574777	4499782	---
0140	577452	4500422	-44.8	0340	574718	4499757	---
0143	577389	4500406	-45.5	0343	574660	4499732	-43.3
0150	577332	4500378	-45.3	0350	574601	4499711	-43.0
0153	577278	4500339	-44.4	0353	574538	4499697	-42.7
0160	577217	4500301	-44.4	0360	574480	4499676	-42.9
0163	577150	4500278	-44.1	0363	574418	4499654	-44.3
0170	577077	4500276	-44.9	0370	574353	4499637	-43.2
0173	577007	4500258	-42.9	0373	574289	4499618	-42.1
0180	576940	4500228	-43.2	0380	574224	4499604	-42.4
0183	576878	4500191	---	0383	574156	4499594	-41.8
0190	576819	4500152	-43.1	0390	574091	4499582	-42.6
0193	576761	4500116	-43.0	0393	574026	4499566	-43.3

Survey Line PKK3 (Channel Centerline)
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction:	West
Survey Date/Time:	6 June 1996; 1532 to 1650 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0400	573965	4499546	-42.6
0403	573897	4499542	-42.5
0410	573834	4499532	-42.4
0413	573774	4499528	-41.8
0420	573709	4499522	-43.4
0423	573644	4499522	-44.0
0430	573576	4499526	---
0433	573508	4499530	-48.0
0440	573444	4499533	-42.9
0443	573379	4499538	-45.2
0450	573312	4499537	-44.5
0453	573246	4499536	-44.5
0460	573183	4499532	-44.1
0463	573116	4499527	-45.0
0470	573052	4499518	-44.5
0473	572990	4499510	-44.7
0480	572925	4499498	-43.4
0483	572861	4499488	-43.3
0490	572797	4499472	-45.1
0493	572731	4499454	-46.4
0500	572668	4499439	-45.0
0503	572615	4499426	-45.8
0510	572576	4499416	-44.9
0513	572521	4499406	-44.1
0520	572476	4499381	-45.0
0523	572438	4499371	-45.1
0530	572401	4499352	-44.1
0533	572355	4499342	-45.9
0540	572302	4499342	-45.0
0543	572251	4499348	-45.2
0550	572202	4499357	-44.7
0553	572154	4499360	-45.8
0560	572110	4499366	-45.0
0563	572065	4499370	-45.6
0570	572021	4499380	-45.2
0573	571977	4499396	-45.1
0580	571937	4499418	-45.3
0583	571897	4499436	-44.8
0590	571853	4499439	-45.2
0593	571813	4499428	-44.3
0600	571774	4499413	-45.5

File #	Easting	Northing	Bottom Elevation, ft MLLW
0603	571736	4499396	-45.5
0610	571701	4499378	-43.5
0613	571662	4499366	-45.1
0620	571622	4499354	-44.4
0623	571582	4499346	-44.3
0630	571540	4499352	-42.9

Survey Line PKK4
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 5 June 1996; 2013 to 2124 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	579200	4500146	-48.4	0200	577744	4500504	-44.8
0003	579161	4500160	-46.5	0203	577706	4500509	-45.0
0010	579121	4500171	-45.9	0210	577682	4500512	-45.3
0013	579089	4500195	-44.5	0213	577662	4500512	-45.5
0020	579051	4500199	-45.7	0220	577645	4500510	-45.8
0023	579015	4500211	-43.6	0223	577628	4500512	-44.7
0030	578983	4500232	-43.5	0230	577611	4500511	-44.6
0033	578945	4500238	-44.1	0233	577598	4500508	-45.2
0040	578909	4500252	-44.3	0240	577587	4500506	-45.5
0043	578877	4500272	-44.5	0243	577573	4500503	-45.0
0050	578842	4500280	-44.2	0250	577557	4500498	-44.8
0053	578806	4500286	-44.5	0253	577540	4500486	-44.8
0060	578772	4500301	-44.6	0260	577518	4500480	---
0063	578739	4500322	-44.3	0263	577502	4500476	-44.9
0070	578704	4500331	-44.4	0270	577489	4500473	-46.1
0073	578669	4500342	-44.9	0273	577475	4500474	-44.6
0080	578632	4500356	-45.1	0280	577462	4500472	-44.4
0083	578596	4500368	-45.1	0283	577445	4500483	-46.1
0090	578561	4500385	-44.6	0290	577429	4500480	-45.2
0093	578526	4500396	-44.2	0293	577401	4500464	-44.1
0100	578489	4500406	-45.6	0300	577360	4500448	-45.3
0103	578452	4500413	-45.2	0303	577335	4500438	-45.2
0110	578418	4500431	-45.2	0310	577317	4500432	-42.0
0113	578380	4500440	-44.7	0313	577298	4500426	---
0120	578344	4500464	-44.8	0320	577258	4500406	-42.8
0123	578307	4500466	-44.2	0323	577225	4500370	-43.6
0130	578271	4500475	-44.9	0330	577184	4500344	---
0133	578234	4500486	-44.5	0333	577142	4500318	-44.4
0140	578198	4500488	-45.1	0340	577098	4500298	---
0143	578162	4500484	-44.6	0343	577053	4500265	-46.4
0150	578125	4500480	-45.6	0350	577012	4500234	-45.4
0153	578087	4500492	-43.1	0353	576963	4500217	---
0160	578048	4500498	-44.2	0360	576911	4500200	---
0163	578010	4500492	-44.3	0363	576863	4500167	---
0170	577973	4500488	-45.3	0370	576816	4500138	---
0173	577934	4500495	-45.6	0373	576782	4500104	---
0180	577896	4500496	-45.5	0380	576747	4500095	---
0183	577858	4500498	-44.6	0383	576710	4500084	---
0190	577820	4500502	-45.1	0390	576666	4500075	---
0193	577782	4500502	-45.2	0393	576629	4500054	-44.6

Survey Line PKK4
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 5 June 1996; 2013 to 2124 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0400	576590	4500027	---				
0403	576557	4500012	-41.1				
0410	576542	4500002	-42.1				
0413	576517	4499988	-42.6				
0420	576482	4499994	-43.6				
0423	576434	4500013	---				
0430	576383	4500021	---				
0433	576350	4500031	-43.3				
0440	576311	4500023	---				
0443	576264	4500028	-43.6				
0450	576217	4500037	-42.2				
0453	576168	4500036	-42.5				
0460	576119	4500033	-44.5				
0463	576071	4500042	-44.4				
0470	576024	4500054	-42.2				
0473	575980	4500054	---				
0480	575936	4500060	-42.6				
0483	575888	4500063	-43.6				
0490	575842	4500056	-41.6				
0493	575798	4500050	-43.0				
0500	575755	4500056	-43.3				
0503	575716	4500076	-42.9				
0510	575675	4500081	-42.8				
0513	575630	4500074	-43.1				
0520	575590	4500082	-42.8				
0523	575548	4500084	-43.6				
0530	575511	4500068	-43.1				
0533	575470	4500065	-42.0				
0540	575430	4500054	-43.7				
0543	575391	4500060	-43.3				
0550	575352	4500066	-43.7				
0553	575312	4500072	-43.9				
0560	575282	4500050	-43.3				
0563	575244	4500050	-44.2				
0570	575209	4500041	-44.7				

Survey Line PKK5
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 5 June 1996; 1700 to 1859 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	579207	4500196	-46.4	0200	577721	4500545	-44.3
0003	579156	4500213	-44.8	0203	577684	4500550	-44.6
0010	579115	4500240	-45.1	0210	577649	4500567	-44.6
0013	579067	4500260	-44.0	0213	577618	4500549	-44.9
0020	579014	4500260	-42.7	0220	577580	4500560	-45.1
0023	578966	4500278	-41.8	0223	577546	4500547	-45.0
0030	578925	4500310	-42.6	0230	577510	4500535	-45.3
0033	578876	4500326	-42.9	0233	577471	4500535	-45.1
0040	578824	4500340	-43.3	0240	577436	4500530	-44.7
0043	578779	4500364	-43.7	0243	577401	4500518	-45.4
0050	578726	4500382	-43.7	0250	577366	4500512	-44.8
0053	578687	4500384	-43.9	0253	577339	4500488	-45.5
0060	578658	4500392	-44.0	0260	577308	4500472	-45.4
0063	578633	4500405	-44.3	0263	577275	4500458	-44.7
0070	578605	4500418	-43.8	0270	577247	4500438	-44.4
0073	578583	4500432	-43.5	0273	577215	4500421	-44.8
0080	578544	4500450	-44.8	0280	577182	4500409	-45.8
0083	578506	4500458	-44.5	0283	577156	4500386	---
0090	578471	4500470	-44.5	0290	577124	4500366	-43.5
0093	578436	4500478	-43.6	0293	577097	4500343	-44.1
0100	578403	4500490	-43.7	0300	577062	4500332	-44.6
0103	578369	4500506	-44.3	0303	577028	4500311	-43.8
0110	578335	4500518	-44.2	0310	576997	4500292	-42.8
0113	578300	4500530	-44.5	0313	576964	4500274	-42.8
0120	578265	4500542	-43.8	0320	576930	4500254	-42.8
0123	578227	4500542	-43.2	0323	576899	4500234	-43.1
0130	578191	4500540	-44.1	0330	576871	4500218	-43.4
0133	578157	4500540	-44.0	0333	576841	4500203	-42.3
0140	578126	4500538	-44.5	0340	576812	4500190	-42.3
0143	578101	4500539	-44.3	0343	576788	4500171	-43.0
0150	578077	4500547	-45.6	0350	576760	4500158	-44.0
0153	578053	4500552	-46.3	0353	576732	4500146	-43.5
0160	578032	4500535	-44.4	0360	576702	4500130	-43.6
0163	578005	4500536	-43.7	0363	576673	4500114	-44.2
0170	577964	4500547	-44.7	0370	576640	4500118	-43.5
0173	577918	4500550	-44.9	0373	576608	4500115	-42.7
0180	577874	4500551	-45.5	0380	576576	4500104	-42.7
0183	577832	4500552	-45.2	0383	576543	4500098	-43.4
0190	577793	4500549	-45.6	0390	576512	4500095	-43.9
0193	577756	4500560	-43.7	0393	576480	4500101	-40.8

Survey Line PKK5
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 5 June 1996; 1700 to 1859 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0410	576426	4500078	-45.2
0413	576394	4500075	-43.3
0420	576361	4500068	-42.8
0423	576325	4500062	-43.4
0430	576290	4500076	-42.2
0433	576253	4500086	-41.9
0440	576216	4500089	-41.4
0443	576179	4500088	-40.5
0450	576142	4500092	-41.2
0453	576108	4500094	-41.1
0460	576072	4500098	-40.7
0463	576036	4500106	-41.4
0470	576004	4500112	-41.8
0473	575974	4500106	-43.4
0480	575942	4500110	-44.2
0483	575911	4500113	-45.7
0490	575884	4500115	-42.7
0493	575854	4500114	-40.6
0500	575824	4500121	-40.3
0503	575791	4500124	---
0510	575760	4500122	-30.2
0520	575720	4500130	-30.4
0523	575689	4500128	-36.5
0530	575656	4500129	-40.7
0533	575621	4500138	-41.3
0540	575586	4500132	-39.9
0543	575548	4500144	-40.7
0550	575510	4500144	-38.5
0553	575467	4500152	-38.6
0560	575425	4500152	-36.1
0563	575381	4500145	-36.6
0570	575343	4500126	-43.3
0573	575301	4500112	-43.7
0580	575256	4500104	-44.7
0583	575212	4500086	-44.5
0590	575165	4500072	-43.9
0593	575120	4500059	-44.5
0600	575079	4500040	-44.8
0603	575039	4500016	-43.8
0610	574997	4500006	-43.5

File #	Easting	Northing	Bottom Elevation, ft MLLW
0613	574958	4499985	-43.4
0620	574918	4499966	-42.8
0623	574877	4499950	-42.3
0630	574832	4499937	-43.6
0633	574793	4499918	-44.5
0640	574752	4499896	-45.3
0643	574713	4499874	-49.9
0650	574667	4499864	-43.6
0653	574626	4499846	-44.0
0660	574585	4499822	-43.0
0663	574544	4499809	-42.9
0670	574499	4499794	-43.4
0673	574456	4499778	-43.6
0680	574416	4499758	-44.0
0683	574376	4499742	-43.1
0690	574338	4499729	-42.5
0693	574302	4499724	-41.9
0700	574263	4499714	-37.9
0703	574224	4499712	-39.7
0710	574184	4499696	-41.4
0713	574147	4499692	-36.4
0720	574109	4499690	-35.3
0723	574074	4499679	-37.6
0730	574042	4499664	-41.4
0733	574010	4499662	-33.5
0740	573978	4499658	-34.6
0743	573946	4499656	-36.4
0750	573914	4499640	-41.5
0753	573883	4499637	-41.0
0760	573851	4499631	-43.2
0763	573816	4499628	-41.5
0770	573783	4499640	-35.2
0773	573749	4499644	-30.4
0780	573715	4499642	-37.2
0783	573682	4499644	-32.8
0790	573642	4499647	-32.7
0793	573596	4499646	-36.2
0800	573559	4499642	-42.3
0803	573520	4499642	-37.4
0810	573483	4499643	-42.4
0813	573443	4499643	-46.1

Survey Line PKK5
Main Ship Channel (Upper Bay of New York Harbor to Shooter's Island)
Kill Van Kull, New York / New Jersey

Survey Direction: West
Survey Date/Time: 5 June 1996; 1700 to 1859 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0820	573403	4499640	-44.4				
0823	573363	4499642	-44.6				
0830	573323	4499642	-44.3				
0833	573284	4499636	-45.8				
0840	573244	4499636	-45.0				
0843	573206	4499624	-44.7				
0850	573168	4499619	-45.3				
0853	573131	4499610	-43.6				
0860	573093	4499604	-44.9				
0863	573054	4499600	-44.3				
0870	573015	4499592	-44.0				
0873	572978	4499580	-44.9				
0880	572942	4499570	-44.6				
0883	572901	4499563	-44.3				
0890	572863	4499554	-43.5				
0893	572820	4499544	-43.8				
0900	572782	4499532	-47.4				
0903	572741	4499522	-46.2				
0910	572699	4499510	-45.7				
0913	572653	4499500	-46.1				
0920	572588	4499530	-45.2				
0923	572556	4499471	-45.5				
0930	572507	4499465	-45.5				
0933	572468	4499455	-44.2				
0940	572425	4499441	-46.6				
0943	572384	4499437	-44.5				
0950	572341	4499444	-44.5				
0953	572294	4499451	-46.0				
0960	572245	4499460	-44.7				
0963	572187	4499463	-43.9				
0970	572127	4499464	-45.1				

Appendix B
Newark Bay 'Pinger' Positioning Information

Survey Line PN01
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction: North
Survey Date/Time: 6 June 1996; 1705 to 1804 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	572084	4499262	-46.2
0003	572062	4499340	-46.2
0010	572045	4499419	-45.0
0013	572027	4499496	-43.9
0020	572013	4499578	-43.8
0023	572000	4499656	-44.6
0030	571988	4499733	-42.6
0033	571975	4499810	-40.2
0040	571974	4499888	-41.2
0043	571973	4499964	-42.8
0050	571996	4500024	-42.5
0053	572021	4500083	-42.7
0060	572048	4500154	-42.3
0063	572082	4500222	-44.1
0070	572114	4500296	-44.5
0073	572138	4500370	-44.3
0080	572175	4500438	-44.1
0083	572196	4500500	-44.6
0090	572211	4500560	-42.6
0093	572229	4500622	-42.2
0100	572256	4500678	-42.5
0103	572288	4500738	-45.2
0110	572314	4500798	-43.3
0113	572338	4500861	-43.5
0120	572360	4500926	-44.2
0123	572390	4500989	-44.4
0130	572428	4501049	-44.1
0133	572463	4501108	-42.2
0140	572494	4501168	-43.4
0143	572526	4501232	-43.8
0150	572555	4501296	-42.6
0153	572584	4501362	-45.3
0160	572611	4501428	-43.3
0163	572636	4501494	-43.8
0170	572656	4501562	-43.0
0173	572685	4501626	-43.0
0180	572713	4501690	-42.5
0183	572749	4501748	-42.1
0190	572776	4501807	-41.8
0193	572802	4501866	-41.6
0200	572831	4501922	-40.8
0203	572862	4501979	-39.9
0210	572889	4502038	-40.1
0213	572916	4502095	-39.7
0220	572941	4502152	-39.9
0223	572962	4502212	-39.7
0230	572988	4502271	-39.0
0233	573010	4502334	-39.2
0240	573031	4502400	-39.4
0243	573054	4502461	-39.3
0250	573088	4502520	-38.8
0253	573118	4502580	-38.9
0260	573150	4502637	-39.9
0263	573180	4502696	-41.5
0270	573210	4502752	-43.3
0273	573235	4502814	-42.7
0280	573251	4502878	-43.5
0283	573271	4502940	-43.8
0290	573289	4503007	-43.0
0293	573308	4503072	-41.8
0300	573326	4503139	-41.2
0303	573344	4503207	-41.3
0310	573362	4503274	-41.2
0313	573390	4503338	-40.7
0320	573416	4503402	-40.6
0323	573438	4503469	-42.7
0330	573458	4503533	-40.4
0333	573488	4503594	-41.1
0340	573510	4503659	-40.2
0343	573528	4503724	-42.3
0350	573548	4503790	-41.0
0353	573576	4503854	-40.6
0360	573602	4503918	-40.4
0363	573629	4503978	-40.5
0370	573649	4504044	-41.4
0373	573660	4504114	-42.0
0380	573674	4504180	-42.9
0383	573692	4504250	-38.8
0390	573706	4504320	-36.8
0393	573723	4504391	-38.2

Survey Line PN01
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction: North
Survey Date/Time: 6 June 1996; 1705 to 1804 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0400	573747	4504460	-38.7				
0403	573773	4504528	-38.8				
0410	573803	4504592	-39.3				
0413	573834	4504653	-39.2				
0420	573865	4504718	-39.6				
0423	573904	4504772	-39.5				
0430	573940	4504832	-40.0				
0433	573976	4504893	-39.5				
0440	574012	4504948	-39.1				
0443	574051	4505004	-40.2				
0450	574088	4505058	-40.3				
0453	574122	4505116	-41.5				
0460	574149	4505176	-40.2				
0463	574184	4505233	-40.1				
0470	574217	4505293	-41.5				
0473	574243	4505354	-41.3				

Survey Line PN02
Port Newark and Port Elizabeth Entrance Channels
Newark Bay, New Jersey

Survey Direction:	Westerly at start
Survey Date/Time:	6 June 1996; 1822 to 1858 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	573500	4504265	-43.7
0003	573446	4504286	-41.5
0010	573397	4504314	-42.2
0013	573355	4504352	-43.4
0020	573311	4504386	-44.9
0023	573268	4504423	-43.4
0030	573235	4504466	-43.1
0033	573185	4504487	-46.5
0040	573132	4504493	-42.2
0043	573081	4504490	---
0050	573028	4504496	---
0053	572982	4504482	-43.0
0060	572951	4504449	-44.5
0063	572918	4504412	---
0070	572890	4504376	---
0073	572860	4504339	-40.0
0080	572835	4504300	---
0083	572808	4504260	-41.2
0090	572778	4504222	-40.0
0093	572754	4504178	-45.0
0100	572727	4504136	-40.8
0103	572703	4504092	-41.6
0110	572676	4504053	---
0113	572653	4504013	-43.8
0120	572627	4503972	-44.3
0123	572603	4503931	-43.2
0130	572578	4503888	-43.1
0133	572549	4503847	-44.8
0140	572521	4503806	-44.1
0143	572491	4503764	-45.9
0150	572465	4503722	-45.1
0153	572438	4503678	-44.7
0160	572412	4503634	-44.6
0163	572387	4503588	-43.7
0170	572360	4503538	-44.2
0173	572332	4503494	-40.6
0180	572314	4503446	-43.4
0183	572332	4503403	-43.5
0190	572370	4503372	-42.3
0193	572411	4503344	-42.7
0200	572449	4503314	-42.3
0203	572490	4503286	-42.3
0210	572533	4503258	-42.4
0213	572569	4503227	-42.8
0220	572610	4503199	-42.5
0223	572652	4503170	-43.2
0230	572695	4503138	-43.7
0233	572737	4503108	-43.8
0240	572778	4503074	-44.6
0243	572820	4503040	-45.3
0250	572862	4503004	-45.2
0253	572906	4502968	-45.2
0260	572945	4502930	-46.0
0263	572984	4502894	-44.9
0270	573020	4502859	-44.6
0273	573057	4502824	-46.8
0280	573095	4502798	-45.6
0283	573135	4502773	-46.7

Survey Line PN03
Port Newark and Port Elizabeth Entrance Channels
Newark Bay, New Jersey

Survey Direction:	Westerly at start
Survey Date/Time:	6 June 1996; 1910 to 1942 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	573398	4504070	-43.3
0003	573362	4504147	-43.0
0010	573302	4504218	-42.5
0013	573234	4504289	-43.7
0020	573174	4504363	-44.8
0023	573116	4504414	-43.5
0030	573056	4504450	-47.5
0033	572990	4504438	-43.5
0040	572942	4504395	---
0043	572906	4504347	-45.1
0050	572868	4504300	-44.0
0053	572836	4504258	-43.5
0060	572809	4504215	-44.3
0063	572781	4504172	-44.1
0070	572756	4504128	-43.5
0073	572729	4504084	-45.1
0080	572703	4504040	-43.8
0083	572670	4503996	-45.2
0090	572644	4503948	-46.3
0093	572615	4503904	-45.6
0100	572588	4503858	-43.0
0103	572558	4503815	-44.1
0110	572530	4503769	-43.4
0113	572502	4503724	-43.5
0120	572476	4503678	-43.4
0123	572450	4503631	-43.0
0130	572429	4503580	-44.7
0133	572405	4503530	-43.7
0140	572380	4503484	-43.2
0143	572404	4503450	-39.1
0150	572444	4503420	-40.0
0153	572482	4503394	-41.9
0160	572521	4503364	-41.9
0163	572561	4503334	-41.8
0170	572599	4503303	-41.7
0173	572640	4503274	-41.5
0180	572680	4503244	-41.7
0183	572719	4503211	-41.6
0190	572755	4503177	-42.9
0193	572786	4503155	-43.3
0200	572811	4503138	-43.1
0203	572834	4503122	-43.9
0210	572857	4503106	-42.6
0213	572887	4503082	-42.9
0220	572920	4503052	-43.2
0223	572952	4503016	-43.8
0230	572984	4502982	-44.6
0233	573018	4502949	-43.0
0240	573053	4502916	-45.6
0243	573090	4502885	-45.9
0250	573129	4502856	-45.2

Survey Line PN04
Port Elizabeth Anchorage Area
Newark Bay, New Jersey

Survey Direction: South
Survey Date/Time: 6 June 1996; 1954 to 2015 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	572869	4502973	-45.0				
0003	572846	4502922	-42.7				
0010	572820	4502872	-39.8				
0013	572791	4502816	-37.2				
0020	572760	4502760	-35.6				
0023	572728	4502704	-35.9				
0030	572699	4502654	-35.6				
0033	572673	4502600	-37.9				
0040	572646	4502548	-39.5				
0043	572623	4502499	-40.1				
0050	572596	4502448	-40.5				
0053	572569	4502396	-41.2				
0060	572546	4502346	-41.8				
0063	572524	4502294	-41.8				
0070	572500	4502242	-41.7				
0073	572472	4502192	-42.9				
0080	572445	4502140	-42.2				
0083	572413	4502094	-43.5				
0090	572385	4502042	-43.3				
0093	572360	4501990	-40.7				
0100	572339	4501937	-43.4				
0103	572313	4501886	-43.6				
0110	572287	4501836	-43.2				
0113	572265	4501785	-39.4				
0120	572235	4501737	-40.0				
0123	572205	4501690	-40.1				
0130	572173	4501642	-40.5				
0133	572145	4501593	-43.5				
0140	572112	4501543	-43.8				
0143	572090	4501489	-40.8				
0150	572070	4501436	-39.7				
0153	572045	4501382	-39.6				
0160	572012	4501335	-39.1				
0163	571980	4501284	-41.1				

Survey Line PN05
Port Elizabeth Anchorage Area
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	6 June 1996; 2019 to 2051 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	572092	4501295	-43.2
0003	572120	4501339	-41.8
0010	572144	4501386	-42.6
0013	572165	4501434	-42.6
0020	572186	4501478	-42.0
0023	572209	4501526	-42.5
0030	572235	4501572	-41.9
0033	572254	4501619	-42.1
0100	572398	4501922	-43.6
0103	572417	4501952	-44.0
0110	572428	4501985	-44.6
0113	572444	4502016	-44.6
0120	572457	4502047	-44.2
0123	572468	4502079	-44.2
0130	572484	4502108	-43.8
0133	572499	4502138	-43.7
0140	572513	4502166	-44.7
0143	572527	4502194	-44.1
0150	572541	4502224	-44.3
0153	572556	4502252	-44.0
0160	572569	4502282	-43.3
0163	572581	4502311	-43.3
0170	572597	4502340	-43.0
0173	572611	4502370	-42.9
0180	572625	4502400	-43.9
0183	572641	4502428	-43.0
0190	572654	4502458	-42.7
0193	572667	4502490	-42.3
0200	572682	4502521	-41.4
0203	572693	4502551	-41.0
0210	572705	4502578	-40.4
0213	572720	4502601	-39.1
0220	572735	4502624	-40.5
0223	572747	4502648	-39.6
0230	572758	4502674	-40.0
0233	572769	4502710	-39.3
0240	572787	4502742	-40.5
0243	572805	4502776	-41.0
0250	572812	4502813	-40.5
0253	572831	4502842	-41.6
0260	572853	4502870	-42.6
0263	572869	4502904	-44.7
0270	572880	4502940	-46.1
0273	572890	4502977	-44.8
0280	572905	4503010	-43.5

Survey Line PN06
Port Elizabeth Anchorage Area
Newark Bay, New Jersey

Survey Direction: South
Survey Date/Time: 6 June 1996; 2055 to 2116 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	572938	4502870	-45.9				
0003	572911	4502818	-44.6				
0010	572886	4502769	-44.3				
0013	572863	4502722	-43.3				
0020	572839	4502678	-43.4				
0023	572818	4502634	-43.3				
0030	572796	4502591	-43.5				
0033	572780	4502550	-43.4				
0040	572765	4502497	-44.0				
0043	572747	4502446	-43.9				
0050	572725	4502398	-43.4				
0053	572703	4502353	-43.7				
0060	572685	4502308	-44.0				
0063	572655	4502268	-44.1				
0070	572622	4502235	-44.0				
0073	572594	4502193	-44.9				
0080	572584	4502132	-44.6				
0083	572557	4502072	-43.2				
0090	572518	4502018	-43.7				
0093	572510	4501958	---				
0100	572492	4501898	-43.3				
0103	572464	4501848	-42.7				
0110	572429	4501800	-42.8				
0113	572399	4501747	-44.1				
0120	572381	4501686	-43.2				
0123	572355	4501628	-44.0				
0130	572321	4501574	-43.5				
0133	572293	4501520	-43.8				
0140	572270	4501462	-42.8				
0143	572246	4501407	-42.7				
0150	572221	4501352	-43.2				
0153	572192	4501298	-43.0				
0160	572163	4501244	-43.0				

Survey Line PN07
Port Elizabeth Anchorage Area
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	6 June 1996; 2123 to 2153 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	572177	4501082	-41.9
0003	572192	4501130	-45.1
0010	572214	4501173	-42.6
0013	572235	4501212	-42.8
0020	572252	4501252	-42.1
0023	572272	4501292	-44.2
0030	572293	4501327	-43.3
0033	572316	4501359	-42.7
0040	572335	4501392	-43.0
0043	572349	4501427	-43.8
0050	572365	4501468	-44.7
0053	572379	4501515	-44.6
0060	572406	4501552	-44.8
0063	572427	4501595	-44.0
0070	572430	4501643	-42.5
0073	572461	4501678	-43.5
0080	572483	4501722	-43.3
0083	572498	4501766	-43.5
0090	572520	4501808	-44.1
0093	572542	4501848	-42.4
0100	572560	4501888	-43.7
0103	572576	4501931	-43.0
0110	572594	4501972	-43.1
0113	572617	4502011	-43.4
0120	572638	4502049	-43.5
0123	572656	4502089	-44.1
0130	572672	4502128	-44.2
0133	572692	4502166	-43.0
0140	572710	4502204	-43.8
0143	572725	4502244	-44.2
0150	572744	4502280	-44.3
0153	572758	4502322	-43.5
0160	572776	4502361	-42.7
0163	572800	4502398	-43.9
0170	572820	4502439	-44.1
0173	572832	4502480	-43.7
0180	572850	4502521	-44.1
0183	572871	4502559	-43.1
0190	572892	4502598	-42.9
0193	572909	4502637	-43.7
0200	572930	4502674	-43.7
0203	572945	4502711	-43.8
0210	572955	4502750	-44.1
0213	572963	4502790	-43.8
0220	572970	4502831	-44.5
0223	572977	4502872	-44.6
0230	572986	4502912	---
0233	572974	4502973	-42.5
0240	572964	4503019	-42.6

Survey Line PN08
Port Elizabeth Anchorage Area
Newark Bay, New Jersey

Survey Direction: South
Survey Date/Time: 6 June 1996; 2158 to 2221 hours (UTC)
Acoustic Source: Pinger operating at a frequency of 3.5 kHz
Coordinate System: UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	573119	4503031	-45.3				
0003	573101	4502980	-43.0				
0010	573082	4502919	---				
0013	573068	4502866	-45.9				
0020	573041	4502813	-44.0				
0023	573015	4502764	-43.2				
0030	572994	4502713	-42.1				
0033	572977	4502661	-43.6				
0040	572950	4502609	-44.0				
0043	572919	4502561	-42.9				
0050	572898	4502510	-42.4				
0053	572877	4502462	-42.6				
0060	572853	4502410	-43.2				
0063	572827	4502352	-43.1				
0070	572798	4502296	-41.9				
0073	572764	4502242	-43.4				
0080	572739	4502186	-43.1				
0083	572716	4502126	-43.6				
0090	572689	4502072	-43.1				
0093	572659	4502018	-43.5				
0100	572636	4501960	-43.7				
0103	572609	4501908	-43.1				
0110	572581	4501857	-43.3				
0113	572555	4501802	-43.4				
0120	572530	4501747	-42.5				
0123	572506	4501690	-44.0				
0130	572480	4501638	-44.2				
0133	572453	4501586	-43.3				
0140	572432	4501526	-44.1				
0143	572409	4501464	-42.4				
0150	572377	4501414	-42.7				
0153	572345	4501363	-42.8				
0160	572322	4501308	-41.3				
0163	572295	4501256	-42.1				
0170	572272	4501200	-42.4				
0173	572250	4501141	-42.2				

Survey Line PN09
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	9 June 1996; 1320 to 1425 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	571775	4499366	-44.9	0203	572615	4501636	-43.0
0003	571793	4499421	-44.4	0210	572641	4501693	-43.0
0010	571799	4499480	-45.4	0213	572662	4501750	-42.9
0013	571808	4499538	-44.6	0220	572687	4501810	-42.4
0020	571817	4499594	-43.9	0223	572711	4501866	-42.8
0023	571827	4499652	-43.8	0230	572735	4501924	-41.4
0030	571834	4499710	-43.1	0233	572763	4501982	-41.4
0033	571840	4499769	-43.6	0240	572797	4502035	-41.4
0040	571846	4499826	-44.5	0243	572827	4502091	-41.1
0043	571862	4499882	-42.8	0250	572855	4502145	-41.7
0050	571880	4499934	-42.7	0253	572879	4502204	-41.1
0053	571882	4499993	-42.7	0260	572902	4502264	-41.0
0060	571882	4500050	-42.8	0263	572927	4502320	-40.8
0063	571894	4500106	-42.3	0270	572952	4502378	-41.8
0070	571919	4500158	-41.6	0273	572978	4502436	-41.7
0073	571945	4500210	-42.6	0280	573005	4502492	-41.0
0080	571974	4500260	-41.8	0283	573030	4502546	-41.4
0083	572000	4500312	-41.4	0290	573060	4502601	-41.2
0090	572027	4500366	-42.3	0293	573083	4502657	-40.5
0093	572053	4500420	-43.0	0300	573106	4502715	-42.0
0100	572079	4500474	-41.8	0303	573131	4502770	-44.2
0103	572101	4500529	-42.7	0310	573151	4502828	-45.7
0110	572129	4500585	-44.2	0313	573179	4502882	-45.6
0113	572154	4500641	-43.2	0320	573203	4502942	-45.1
0120	572181	4500698	-42.5	0323	573223	4503002	-41.8
0123	572199	4500754	-45.1	0330	573242	4503060	-42.1
0130	572222	4500808	-42.3	0333	573264	4503118	-40.4
0133	572247	4500864	-43.4	0340	573292	4503175	-40.9
0140	572273	4500918	-43.6	0343	573313	4503232	-40.5
0143	572299	4500971	-42.2	0350	573334	4503293	-40.5
0150	572325	4501027	-42.6	0353	573353	4503354	-40.5
0153	572349	4501081	-43.5	0360	573367	4503414	-40.1
0160	572376	4501134	-41.6	0363	573387	4503476	-40.0
0163	572405	4501191	-42.1	0370	573409	4503536	-40.7
0170	572429	4501246	-42.4	0373	573429	4503598	-40.8
0173	572457	4501302	-41.4	0380	573450	4503662	-40.2
0180	572484	4501356	-43.2	0383	573471	4503725	-41.6
0183	572510	4501414	-43.1	0390	573497	4503786	-41.2
0190	572536	4501470	-42.5	0393	573517	4503850	-41.4
0193	572562	4501525	-43.1	0400	573542	4503914	-40.8
0200	572588	4501582	-42.6	0403	573561	4503980	-41.7

Survey Line PN09
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	9 June 1996; 1320 to 1425 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0410	573578	4504045	-41.5				
0413	573597	4504110	-40.8				
0420	573617	4504173	-42.2				
0423	573637	4504234	-41.3				
0430	573656	4504296	-37.3				
0433	573680	4504354	-37.1				
0440	573702	4504413	-36.6				
0443	573729	4504471	-37.2				
0450	573758	4504529	-36.8				
0453	573787	4504584	-37.4				
0460	573818	4504638	-37.2				
0463	573849	4504691	-37.3				
0470	573882	4504744	-37.9				
0473	573913	4504797	-38.1				
0480	573945	4504850	-38.4				
0483	573974	4504906	-38.0				
0490	574005	4504962	-38.1				
0493	574034	4505020	-38.8				
0500	574068	4505077	-38.9				
0503	574100	4505138	-38.9				
0510	574125	4505196	-38.9				
0513	574147	4505255	-39.0				
0520	574176	4505316	-39.2				
0523	574209	4505375	-38.4				
0530	574228	4505434	-36.6				

Survey Line PN10
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	South
Survey Date/Time:	9 June 1996; 1429 to 1548 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	574216	4505585	-18.3	0203	573230	4503324	-40.7
0003	574196	4505532	-20.9	0210	573211	4503266	-40.9
0010	574176	4505450	-32.2	0213	573189	4503214	-41.0
0013	574161	4505408	-35.2	0220	573168	4503160	-39.7
0020	574154	4505364	-37.6	0223	573142	4503104	-39.6
0023	574134	4505310	-38.0	0230	573118	4503050	-42.7
0030	574112	4505256	-39.2	0233	573093	4502995	-41.8
0033	574088	4505202	-38.6	0240	573068	4502941	-41.0
0040	574065	4505147	---	0243	573044	4502886	-42.9
0043	574040	4505093	---	0250	573023	4502833	-41.9
0050	574014	4505040	-38.1	0253	573000	4502778	-42.4
0053	573979	4504985	-37.9	0260	572977	4502724	-41.6
0060	573950	4504932	-37.5	0263	572955	4502670	-41.6
0063	573920	4504876	-36.9	0270	572932	4502616	-41.3
0070	573887	4504822	-35.9	0273	572911	4502562	-40.8
0073	573856	4504766	-35.5	0280	572889	4502508	-41.1
0080	573827	4504710	-35.5	0283	572867	4502456	-40.7
0083	573797	4504654	-36.6	0290	572845	4502404	-41.3
0090	573764	4504601	-36.3	0293	572820	4502352	-41.5
0093	573733	4504545	-36.7	0300	572796	4502299	-40.8
0100	573702	4504489	-36.5	0303	572773	4502250	-41.6
0103	573673	4504430	-36.0	0310	572747	4502198	-41.4
0110	573648	4504373	-36.6	0313	572724	4502146	-41.2
0113	573626	4504311	-37.1	0320	572699	4502092	-40.7
0120	573605	4504252	-40.1	0323	572676	4502038	-41.3
0123	573581	4504194	-41.0	0330	572651	4501984	-41.4
0130	573554	4504136	-40.8	0333	572625	4501930	-42.2
0133	573527	4504078	-40.3	0340	572600	4501877	-41.3
0140	573502	4504022	-41.1	0343	572575	4501825	-40.8
0143	573482	4503966	-40.0	0350	572546	4501772	-41.4
0150	573460	4503916	-40.6	0353	572522	4501722	-41.8
0153	573432	4503862	-40.0	0360	572494	4501674	-41.6
0160	573405	4503808	-39.2	0363	572467	4501624	-42.0
0163	573386	4503756	-39.6	0370	572443	4501573	-41.1
0170	573367	4503701	-40.9	0373	572419	4501522	-42.2
0173	573348	4503645	-41.2	0380	572397	4501472	-40.9
0180	573329	4503592	-41.5	0383	572374	4501418	-40.7
0183	573310	4503540	-40.9	0390	572350	4501370	-40.3
0190	573292	4503486	-41.2	0393	572324	4501318	-39.0
0193	573271	4503430	-40.7	0400	572297	4501270	-39.2
0200	573249	4503378	-41.1	0403	572271	4501222	-40.9

Survey Line PN10
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	South
Survey Date/Time:	9 June 1996; 1429 to 1548 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW
0410	572245	4501172	-40.3
0413	572220	4501122	-40.3
0420	572195	4501072	-41.2
0423	572173	4501020	-40.6
0430	572152	4500970	-41.4
0433	572132	4500916	-40.4
0440	572113	4500864	-40.4
0443	572091	4500814	-43.7
0450	572069	4500767	-42.4
0453	572050	4500716	-43.3
0460	572032	4500668	-41.8
0463	572013	4500622	-41.1
0470	571991	4500578	-40.3
0473	571972	4500534	-41.1
0480	571956	4500488	-44.0
0483	571938	4500448	-42.4
0490	571922	4500408	-43.1
0493	571903	4500366	-43.0
0500	571884	4500321	-42.5
0503	571866	4500278	-42.4
0510	571845	4500234	-43.0
0513	571824	4500192	-43.0
0520	571803	4500148	-44.2
0523	571779	4500107	-43.9
0530	571758	4500066	-44.5
0533	571741	4500022	-44.4
0540	571728	4499984	-43.8
0543	571711	4499944	-42.3
0550	571699	4499903	-44.0
0553	571688	4499862	-43.7
0560	571676	4499818	-42.6
0563	571657	4499784	-43.4
0570	571644	4499748	-43.2
0573	571630	4499711	-42.5
0580	571619	4499674	-41.9
0583	571605	4499640	-42.2
0590	571590	4499604	-41.4
0593	571570	4499572	-41.4
0600	571556	4499539	-41.7
0603	571540	4499506	-41.0
0610	571529	4499470	-42.0
0613	571520	4499432	-41.6
0620	571505	4499384	-40.9
0623	571496	4499348	---

Survey Line PN11
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	9 June 1996; 1552 to 1658 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0000	571635	4499462	-42.0	0203	572631	4501836	-41.4
0003	571650	4499516	-40.3	0210	572653	4501892	-41.6
0010	571676	4499568	-41.5	0213	572681	4501946	-41.5
0013	571706	4499626	-42.1	0220	572711	4501996	-41.6
0020	571732	4499692	-40.2	0223	572740	4502046	-41.0
0023	571754	4499760	-41.6	0230	572770	4502096	-40.7
0030	571780	4499830	-40.7	0233	572794	4502150	-40.3
0033	571810	4499896	-40.7	0240	572814	4502206	-40.8
0040	571833	4499940	-41.2	0243	572838	4502258	-40.9
0043	571852	4499986	-43.8	0250	572865	4502311	-40.6
0050	571870	4500034	-41.3	0253	572890	4502364	-40.0
0053	571890	4500084	-41.3	0260	572915	4502418	-40.1
0060	571912	4500142	-40.6	0263	572940	4502472	-40.8
0063	571929	4500205	-41.7	0270	572962	4502526	-41.6
0070	571947	4500271	-40.6	0273	572981	4502580	-41.5
0073	571970	4500331	-40.3	0280	573001	4502635	-41.9
0080	571995	4500388	-40.8	0283	573026	4502690	-41.4
0083	572026	4500446	-40.9	0290	573044	4502741	-41.6
0090	572056	4500509	-41.8	0293	573062	4502793	-45.0
0093	572076	4500571	-40.0	0300	573083	4502846	-43.4
0100	572094	4500636	-41.7	0303	573110	4502901	-43.1
0103	572117	4500704	-42.1	0310	573135	4502954	-41.8
0110	572144	4500772	-41.2	0313	573161	4503008	-42.4
0113	572169	4500840	-41.7	0320	573185	4503064	-42.3
0120	572197	4500902	---	0323	573207	4503120	-41.4
0123	572226	4500958	-40.8	0330	573231	4503180	-41.2
0130	572249	4501010	-41.0	0333	573257	4503236	-40.3
0133	572271	4501063	-40.1	0340	573285	4503293	-40.1
0140	572291	4501116	-40.7	0343	573308	4503354	-40.2
0143	572316	4501172	-40.6	0350	573322	4503420	-39.8
0150	572341	4501226	-41.5	0353	573342	4503485	-41.2
0153	572374	4501280	-41.2	0360	573356	4503546	-41.0
0160	572402	4501332	-40.5	0363	573370	4503606	-42.0
0163	572431	4501390	-40.9	0370	573390	4503660	-41.6
0170	572458	4501443	-42.2	0373	573415	4503718	-40.0
0173	572483	4501498	-42.2	0380	573439	4503774	-40.1
0180	572502	4501556	-42.9	0383	573459	4503833	-40.2
0183	572526	4501615	-42.5	0390	573482	4503890	-40.2
0190	572549	4501670	-42.1	0393	573509	4503944	-41.8
0193	572584	4501723	-42.2	0400	573535	4504000	-41.2
0200	572610	4501780	-41.4	0403	573560	4504056	-40.8

Survey Line PN11
Main Ship Channel (Kill Van Kull to I-278 Bridge)
Newark Bay, New Jersey

Survey Direction:	North
Survey Date/Time:	9 June 1996; 1552 to 1658 hours (UTC)
Acoustic Source:	Pinger operating at a frequency of 3.5 kHz
Coordinate System:	UTM, NAD 1983, Zone 18

File #	Easting	Northing	Bottom Elevation, ft MLLW	File #	Easting	Northing	Bottom Elevation, ft MLLW
0410	573583	4504112	-40.0				
0413	573602	4504167	-41.2				
0420	573623	4504223	-40.4				
0423	573644	4504280	-37.2				
0430	573670	4504341	-36.4				
0433	573696	4504402	-36.6				
0440	573715	4504463	-36.7				
0443	573740	4504523	-36.2				
0450	573789	4504571	-36.9				
0453	573834	4504624	-36.8				
0460	573874	4504682	-37.0				
0463	573912	4504742	-37.4				
0470	573950	4504802	-36.8				
0473	573992	4504864	-36.4				
0480	574033	4504922	-35.9				
0483	574072	4504984	-37.0				
0490	574106	4505043	-38.0				
0493	574140	4505107	-38.9				
0500	574167	4505178	-37.9				
0503	574197	4505246	-39.0				
0510	574226	4505318	-39.4				
0513	574251	4505389	-39.6				
0520	574276	4505462	-37.5				
0523	574308	4505520	-36.9				

Appendix C
Interpreted Seismic Cross Sections

DEFINITION OF SYMBOLS AND TERMS
KILL VAN KULL AND NEWARK BAY SEISMIC CROSS–SECTIONS

0623 –Data file location and associated file number. Refer to Appendices A and B for Easting / Northing coordinates and channel bottom elevations. Refer to the track line maps in Figures 4 through 9 for location in project area.

–Detected and interpreted seismic interfaces.

Core KVK–95–46 –Core locations. Core information is outlined in Table 1. The length of each core is accurately represented on the cross–sections.

–No data because of equipment malfunction or no interpretation because area outside of project boundary.

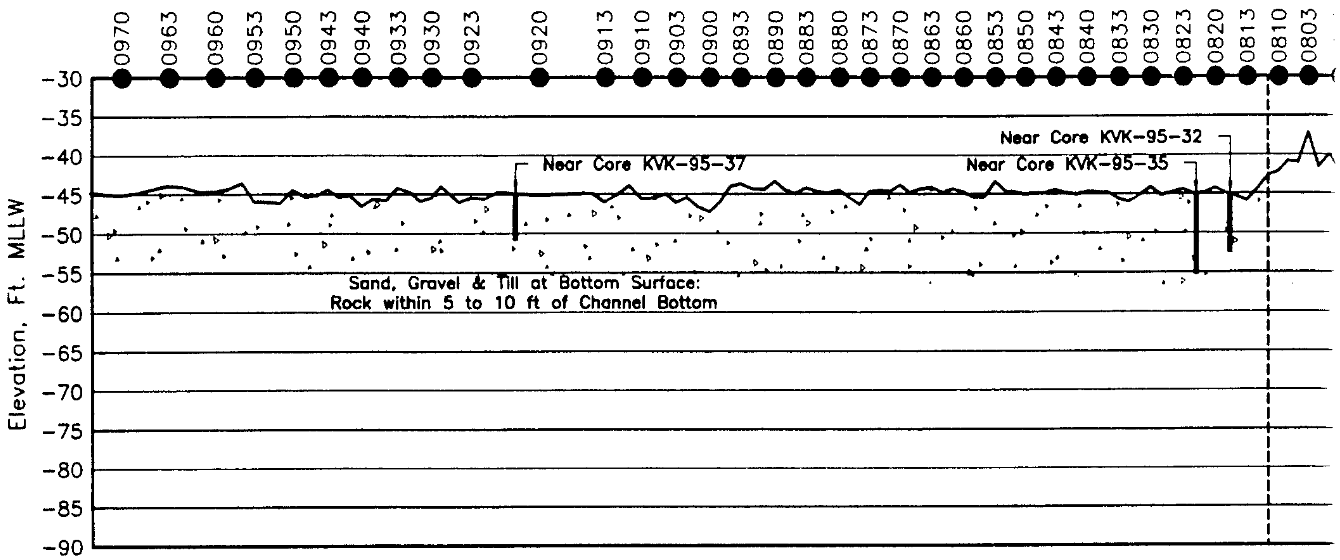
–Organic surface sediments. Gas bubbles or air pockets created by decaying material or biologic activity reflect most of the seismic energy back to the surface. This effect limits energy penetration into the subbottom causing poor definition of the subbottom interfaces or masks the interfaces altogether.

–Organically–rich silt and clay sediments

–Sediments primarily characterized as clays, silts, silty sands, fine sands, or combinations of each. These sediments maybe intermixed with coarse sands and gravels. Material densities are typically less than 1.90 g/cm^3.

–Sediments interpreted as coarse sands, gravels, cobbles, glacial till, or broken rock. These sediments may be intermixed with silts and clays or thin layers and lenses of fine–grained sediments. Layering within the coarse grained sediment is detected but definition is poor due to scattering of the seismic energy. Energy penetration is typically 10 to 15 feet.

–Rock. The rock may be fractured, broken, or weathered. The rock interface is interpreted as being highly irregular. In some areas, especially in Kill Van Kull and southern Newark Bay, the rock interface is difficult to define because of the irregular nature of the surface and small impedance contrast between the rock and overlying material.



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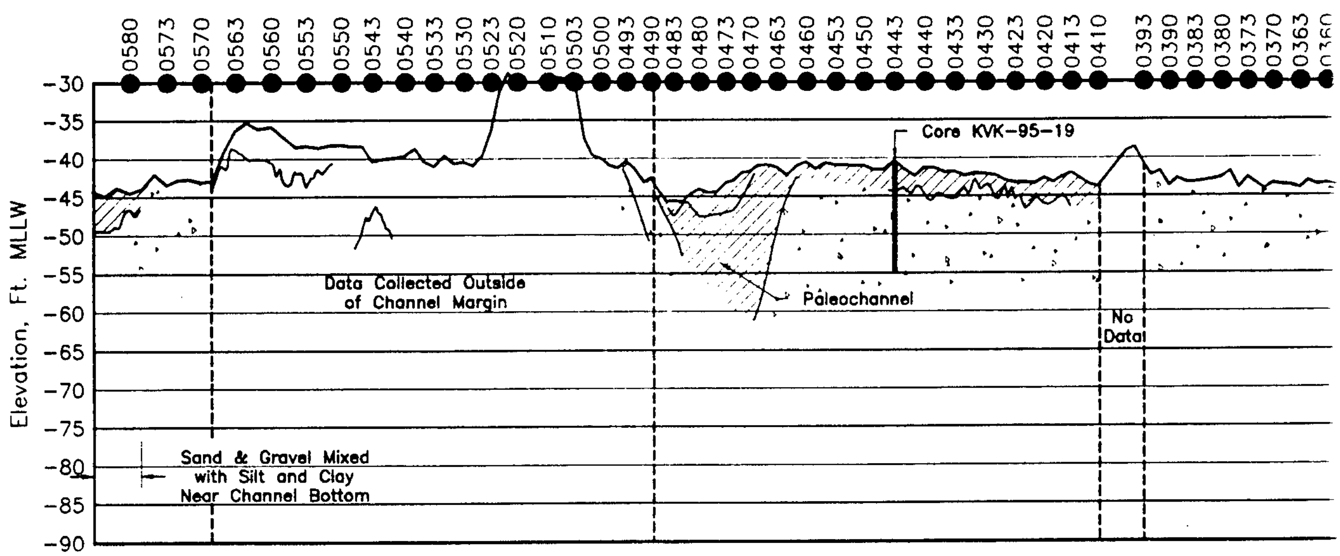
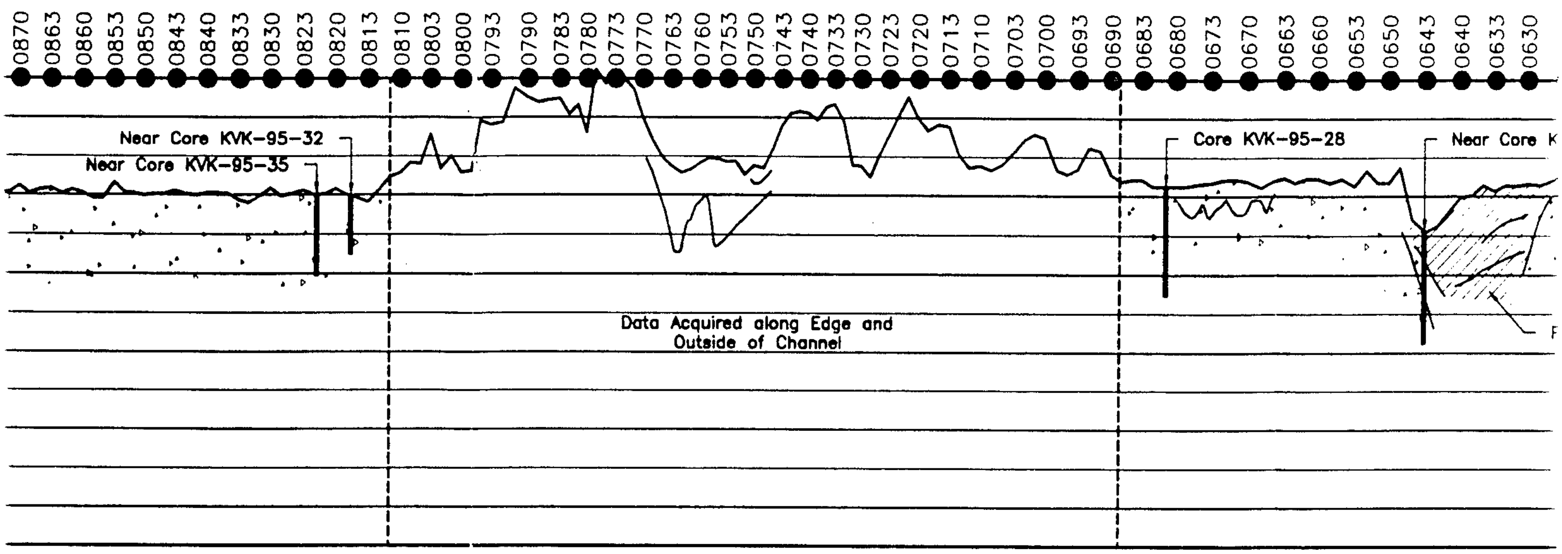


WES SURVEY LINE

PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHANNE



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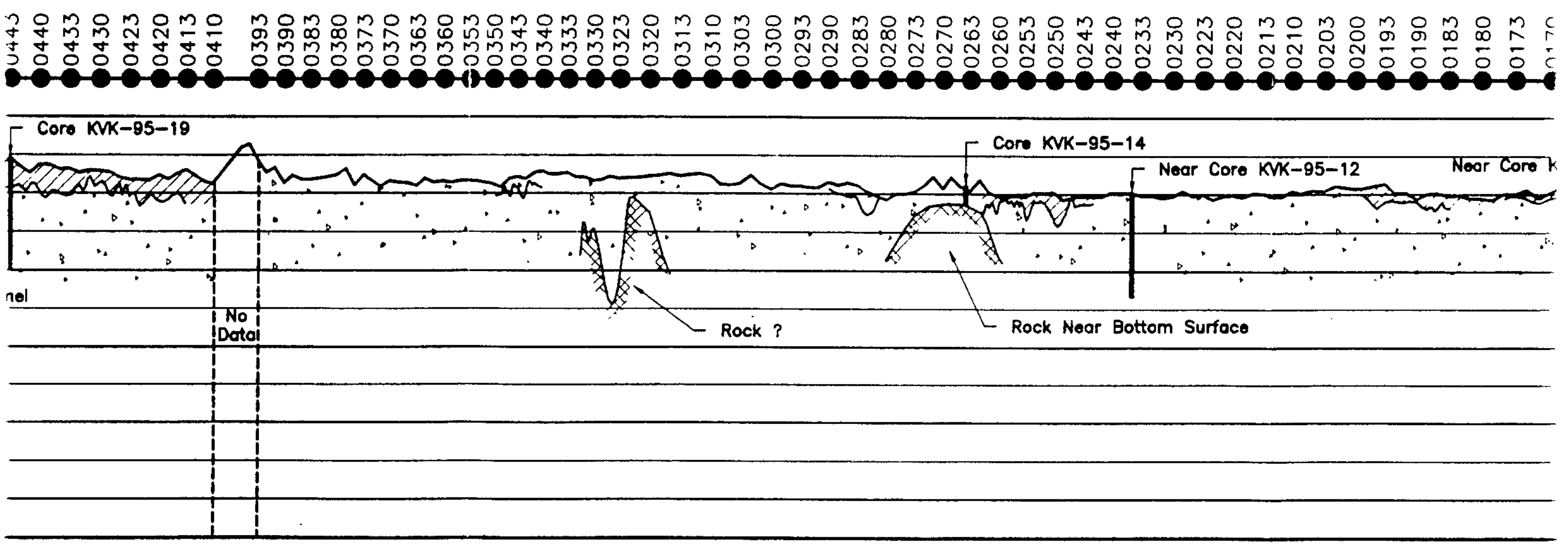

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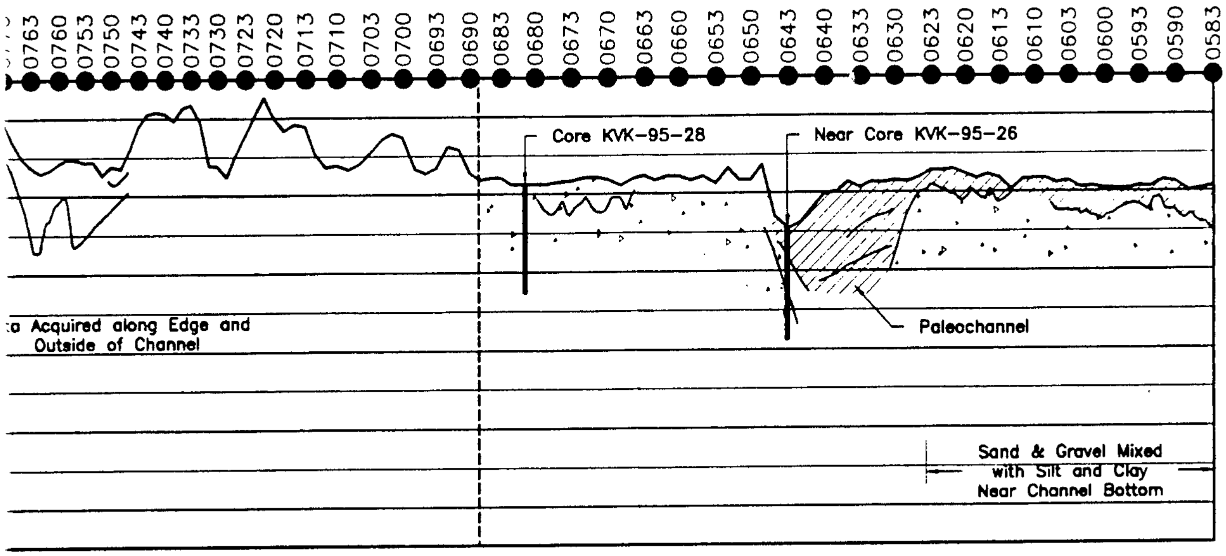

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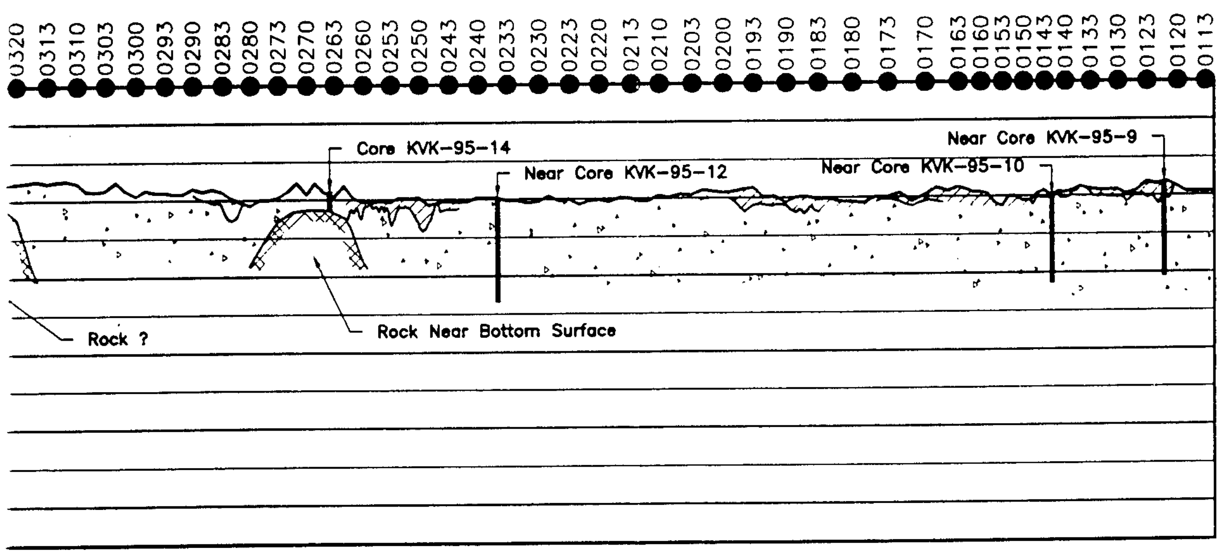

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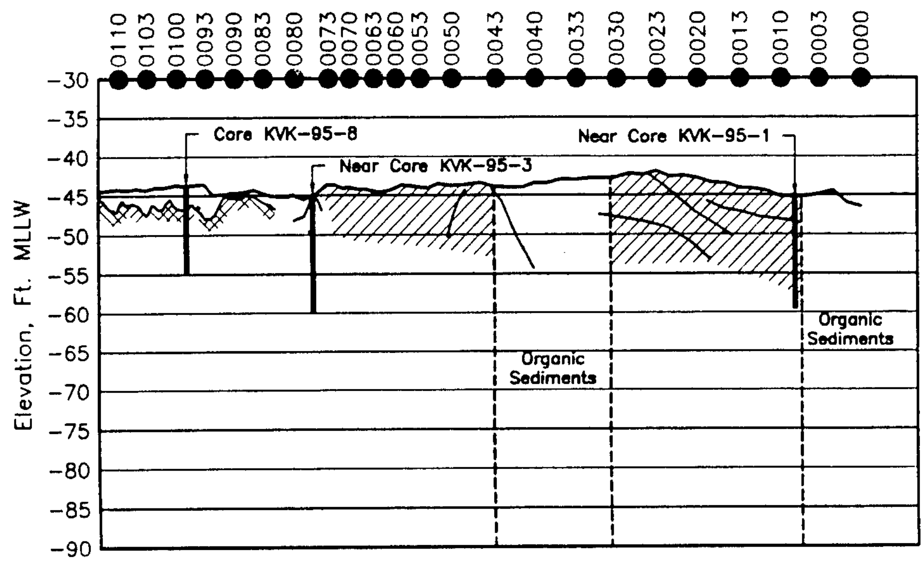

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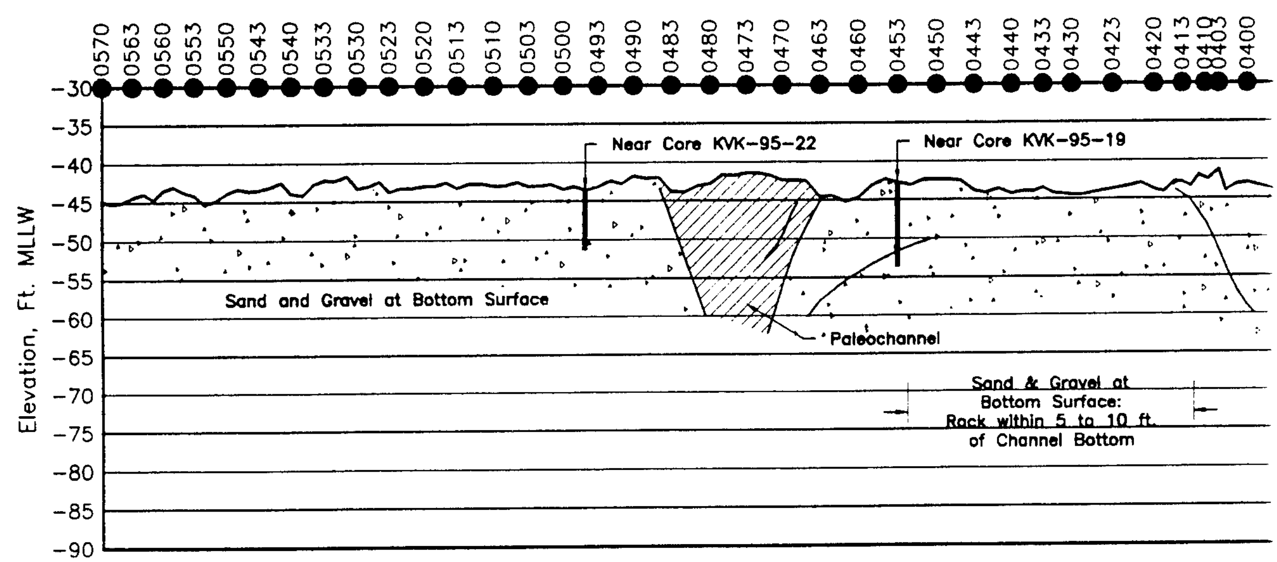

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PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHA

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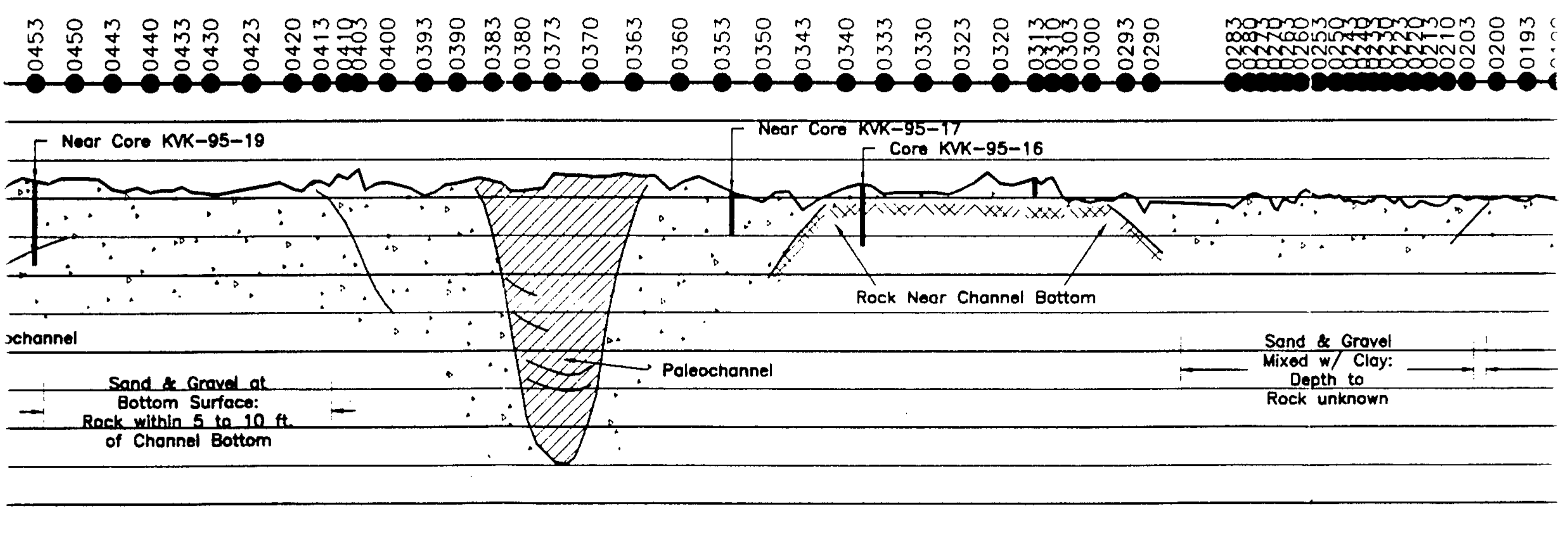

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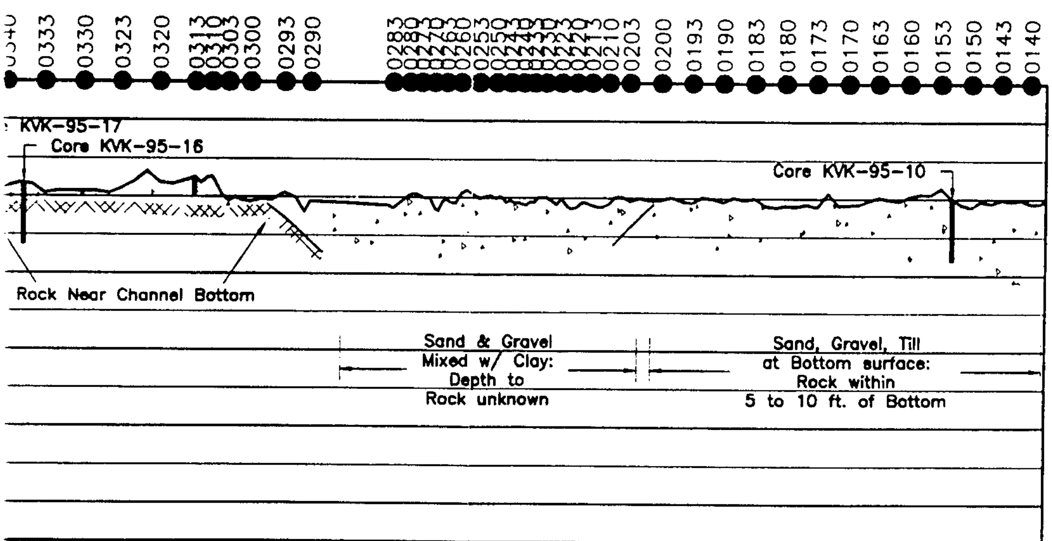

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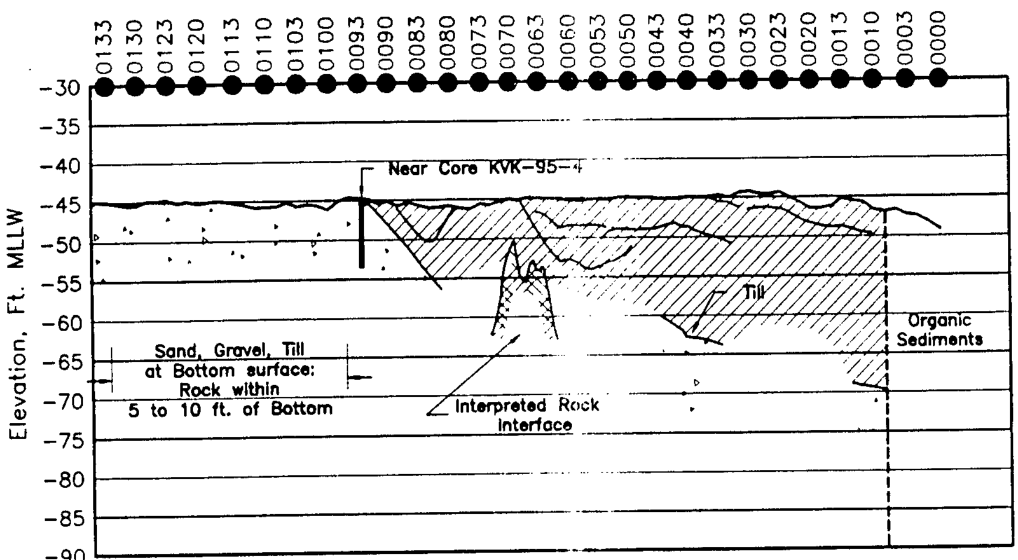

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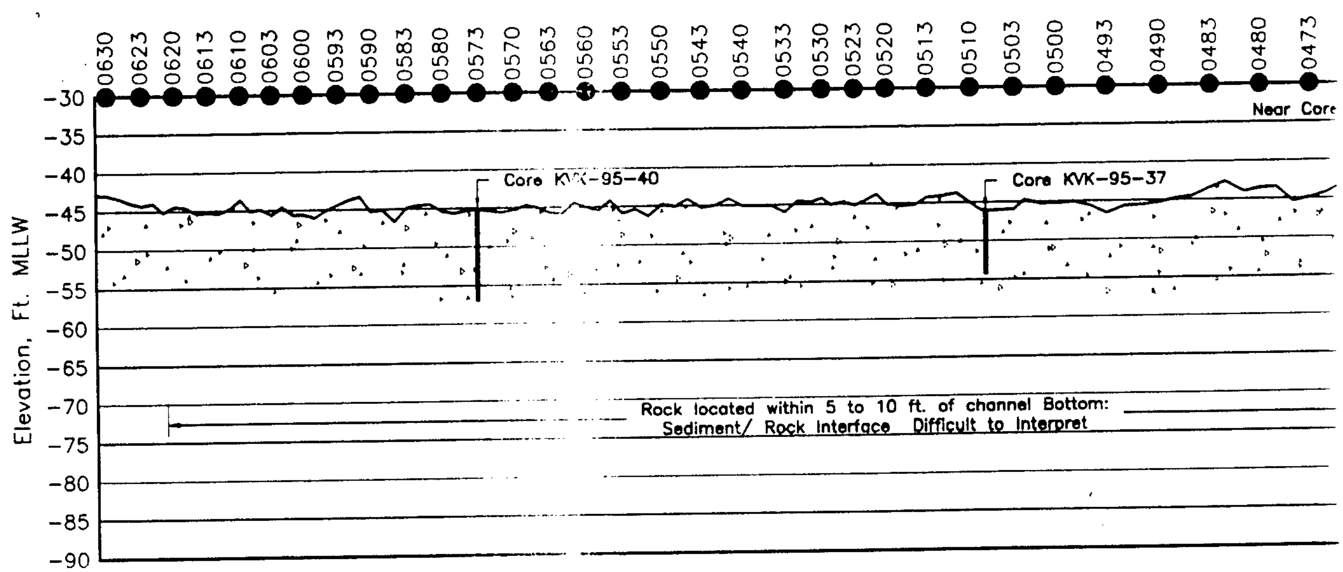

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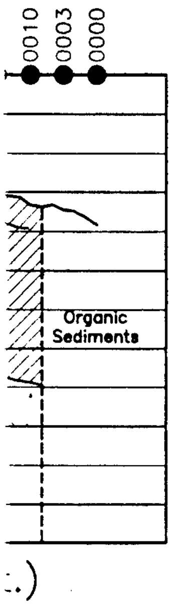
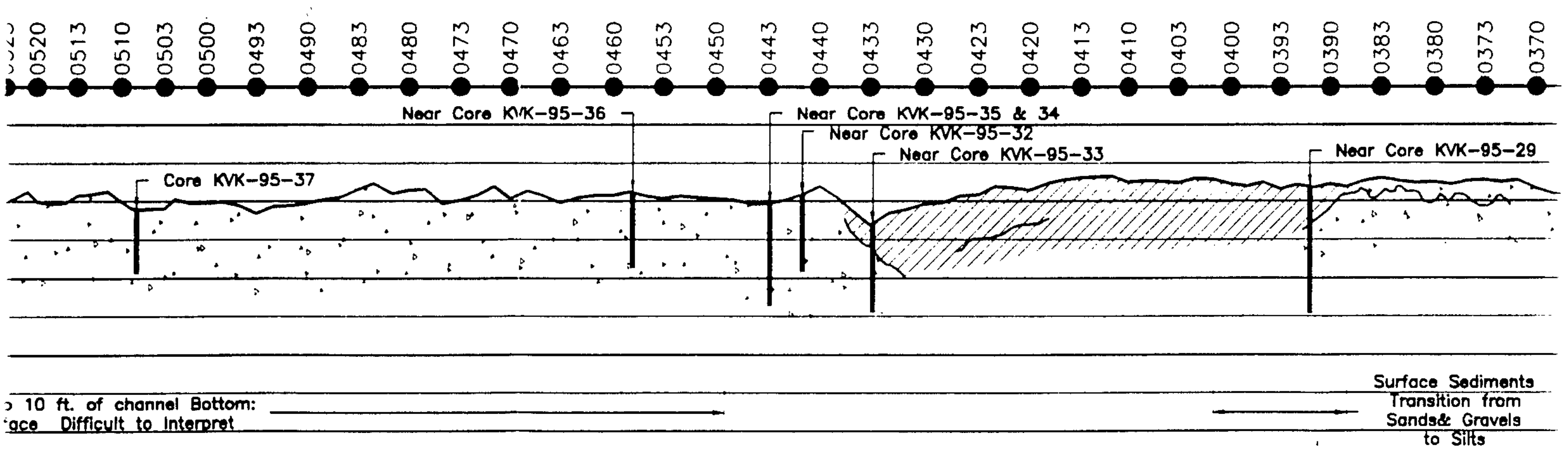
PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHANNE





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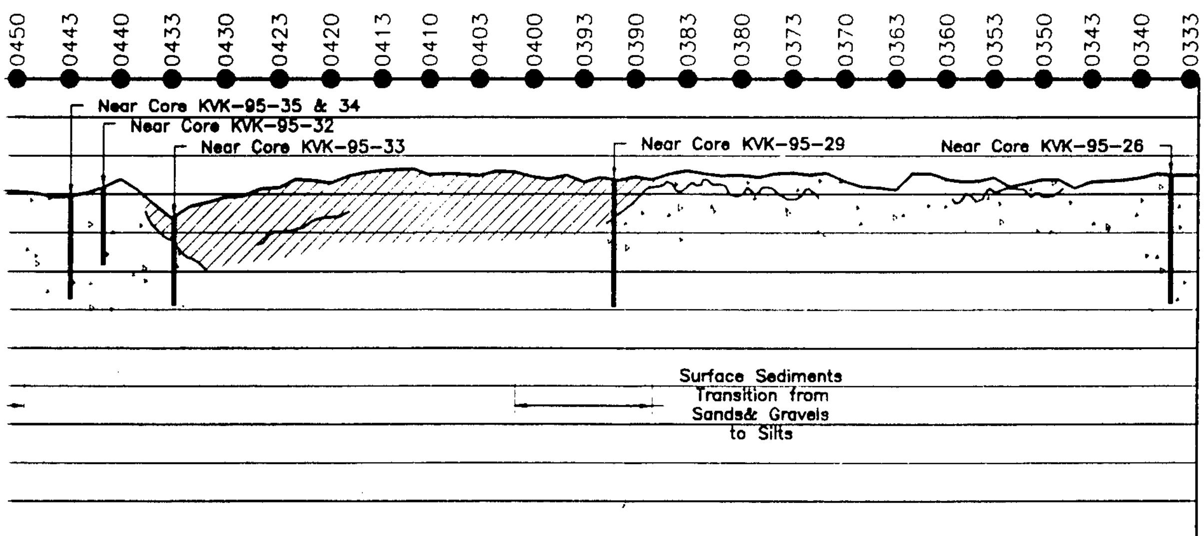
& NEW JERSEY CHANNELS PLATE # 03 SCALE: 1"=250'



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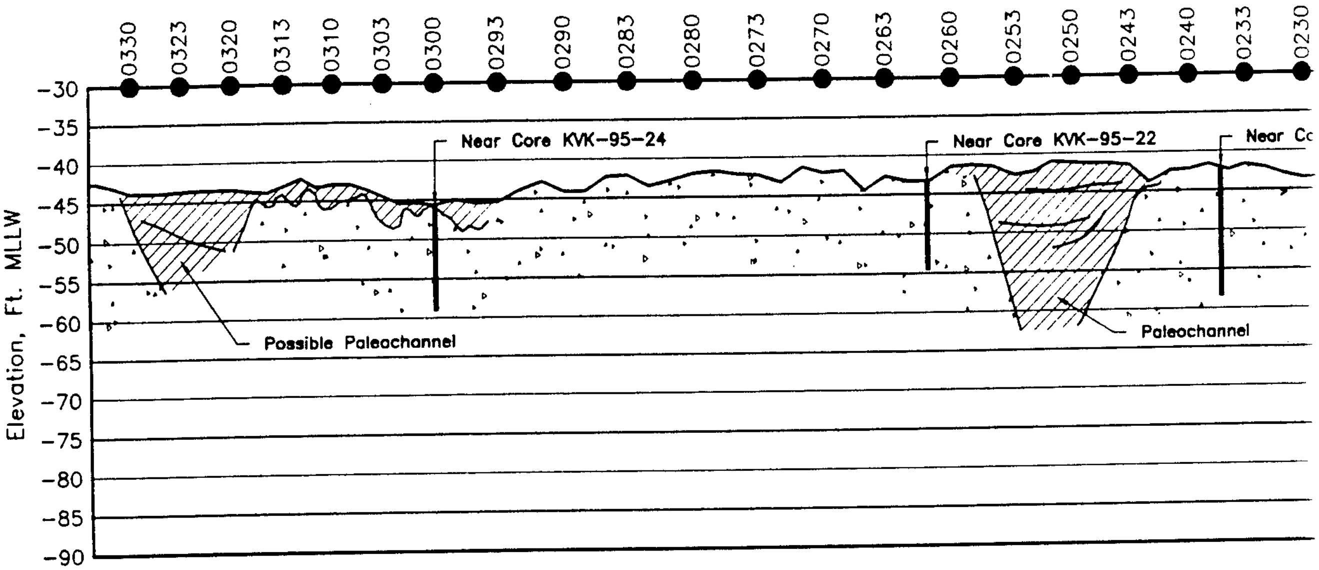

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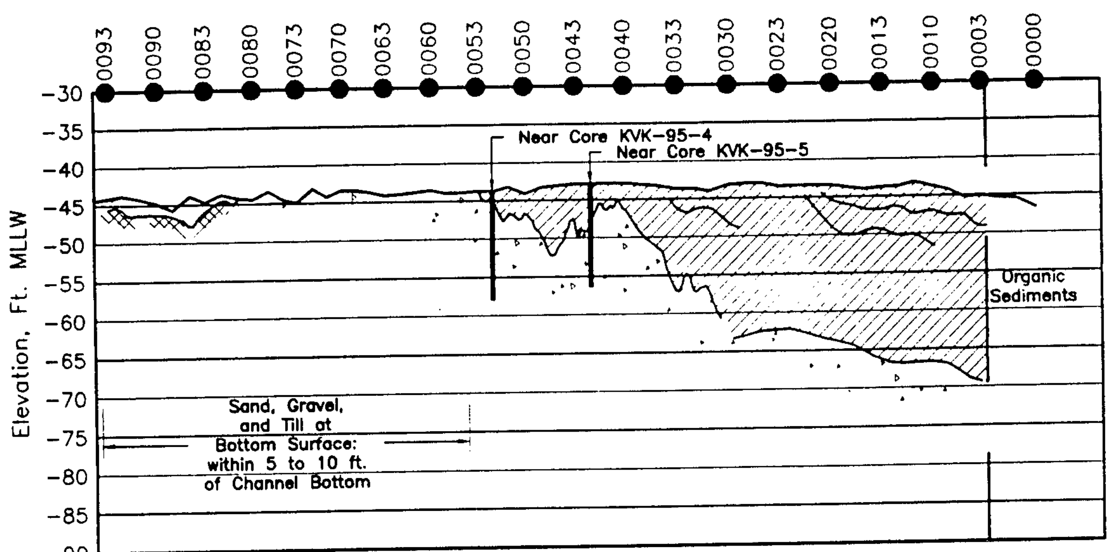

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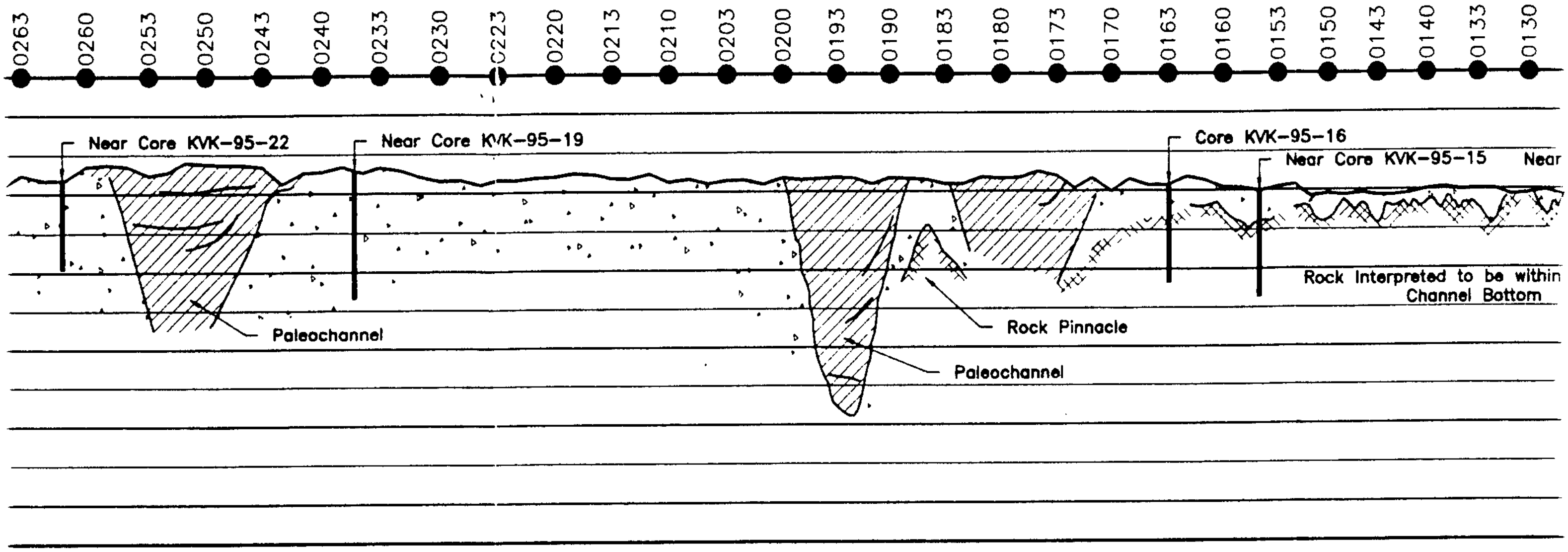
PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHANN



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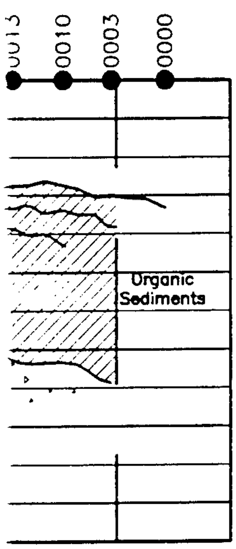

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& NEW JERSEY CHANNELS PLATE # 04 SCALE: 1"=250' 1C

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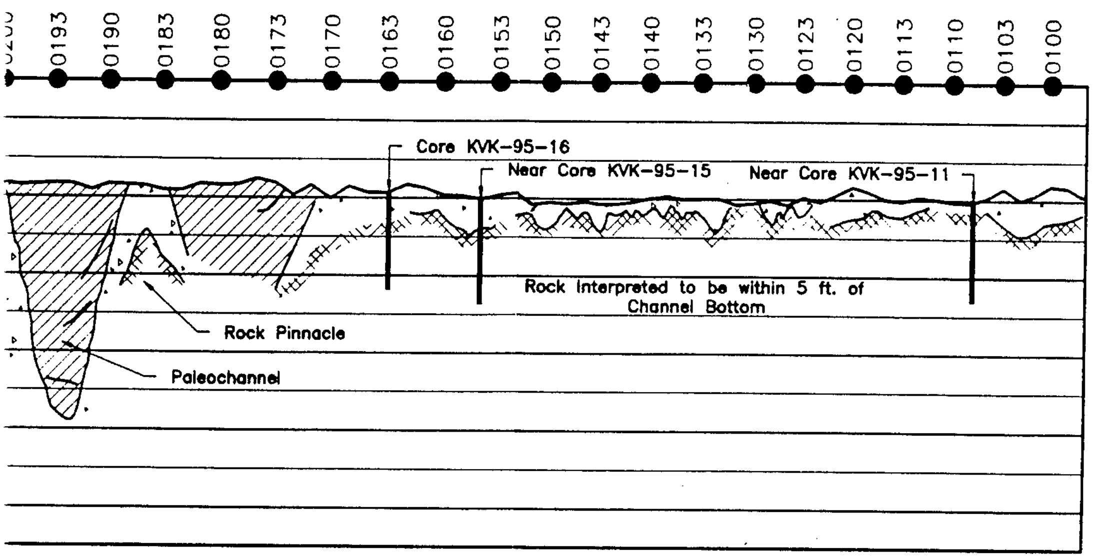

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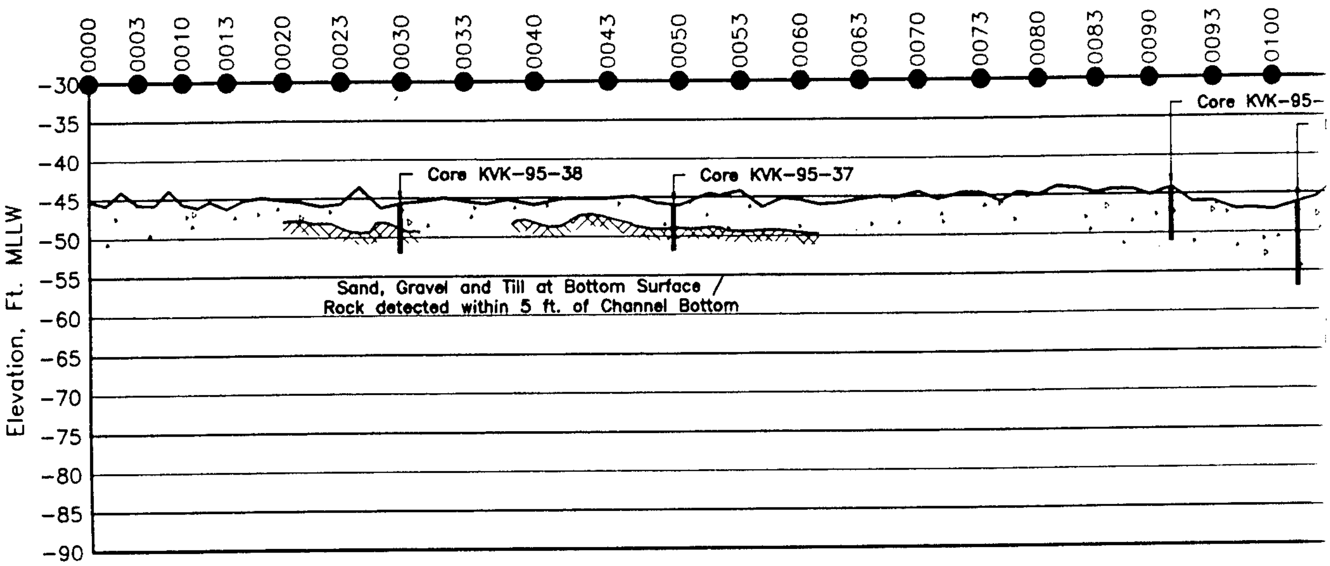

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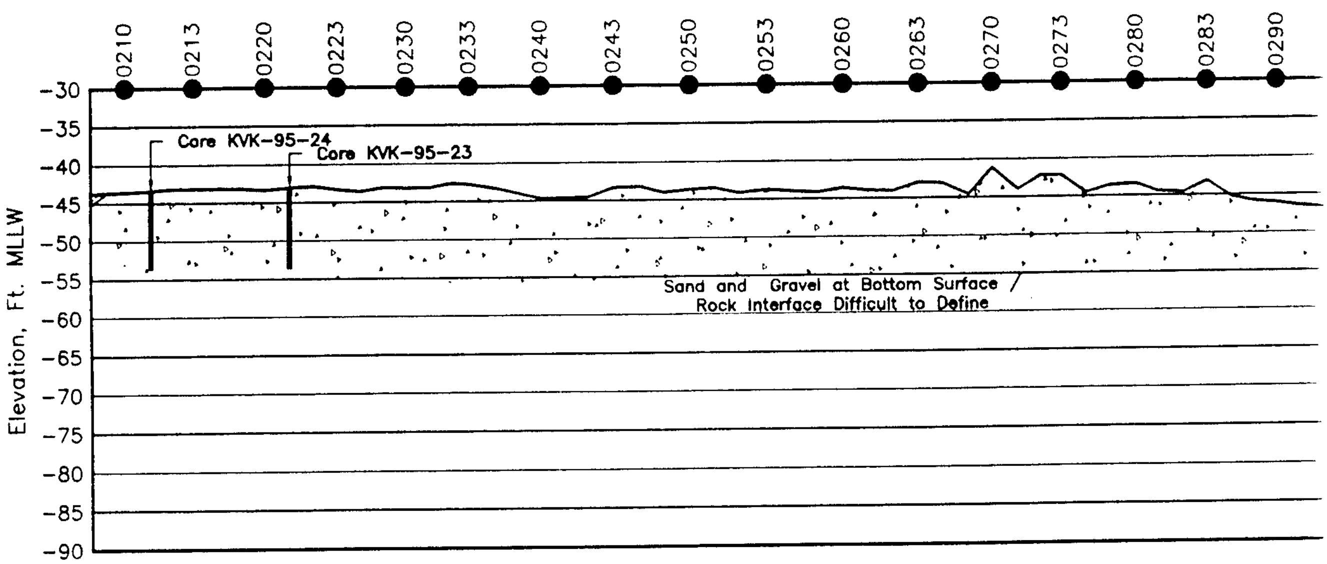

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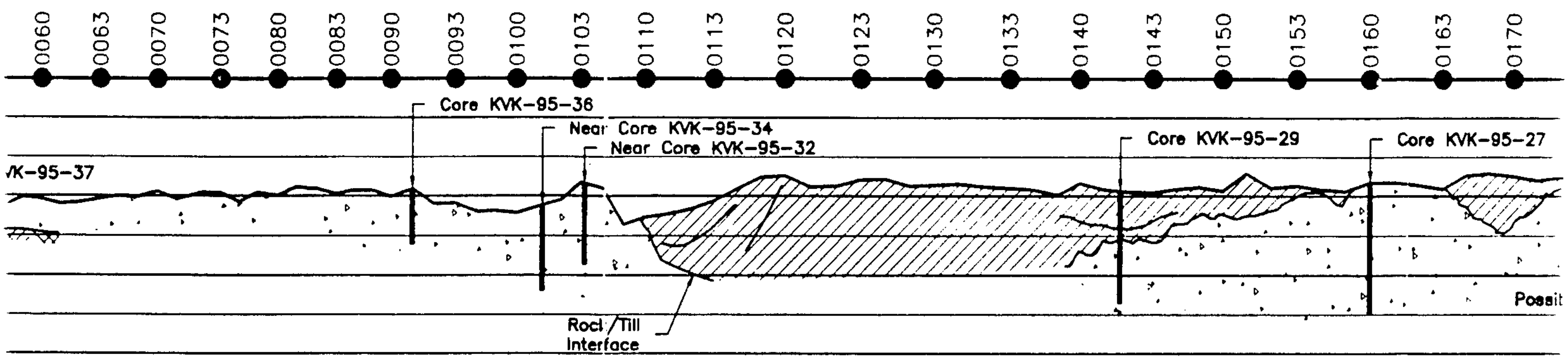
PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHANNE



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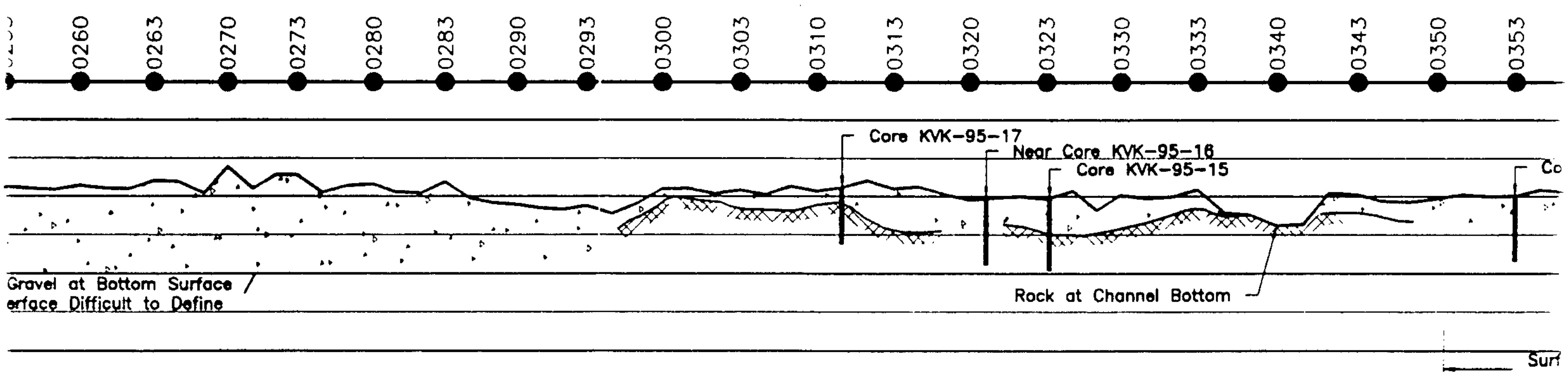

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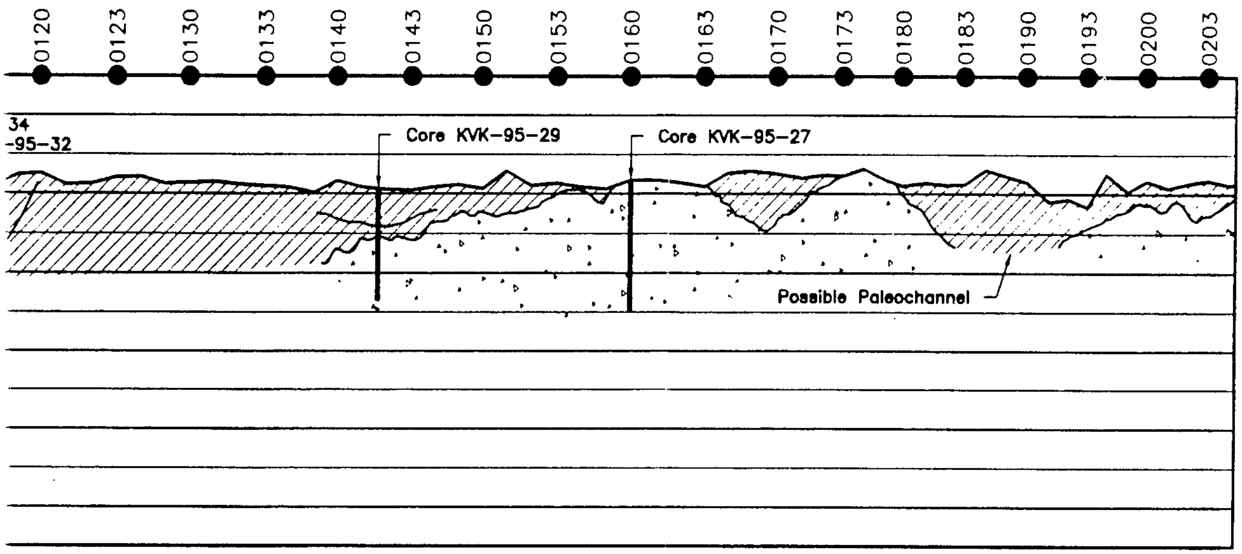
'ORK & NEW JERSEY CHANNELS PLATE # 05 SCALE: 1"=250'



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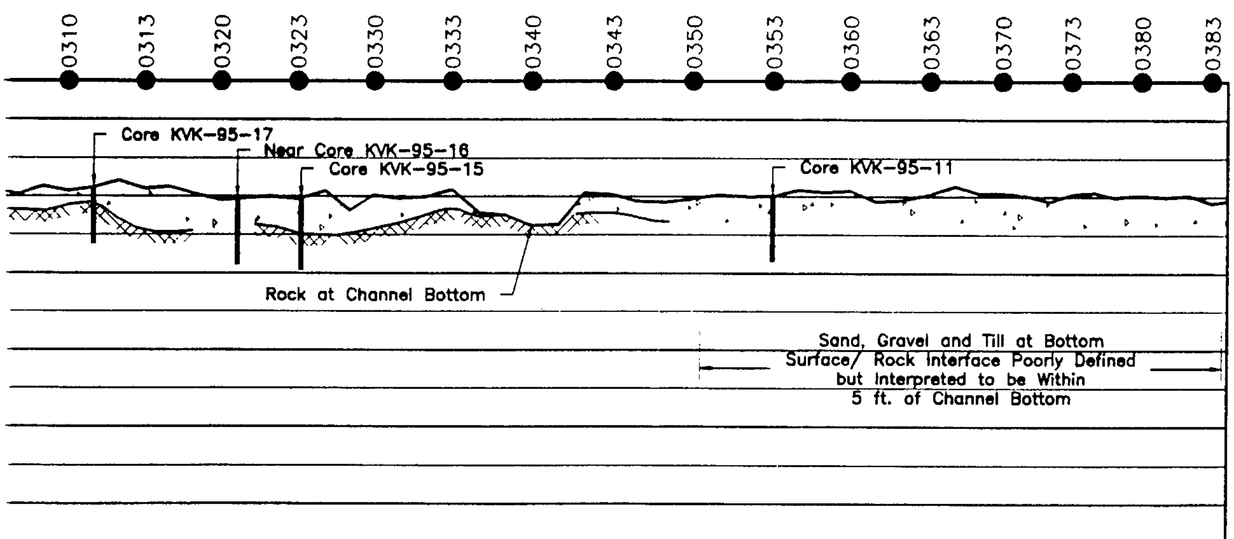

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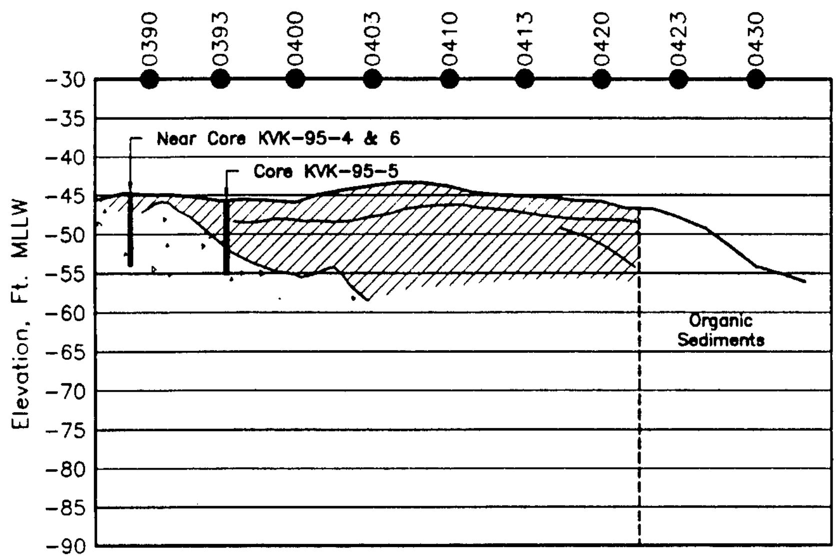

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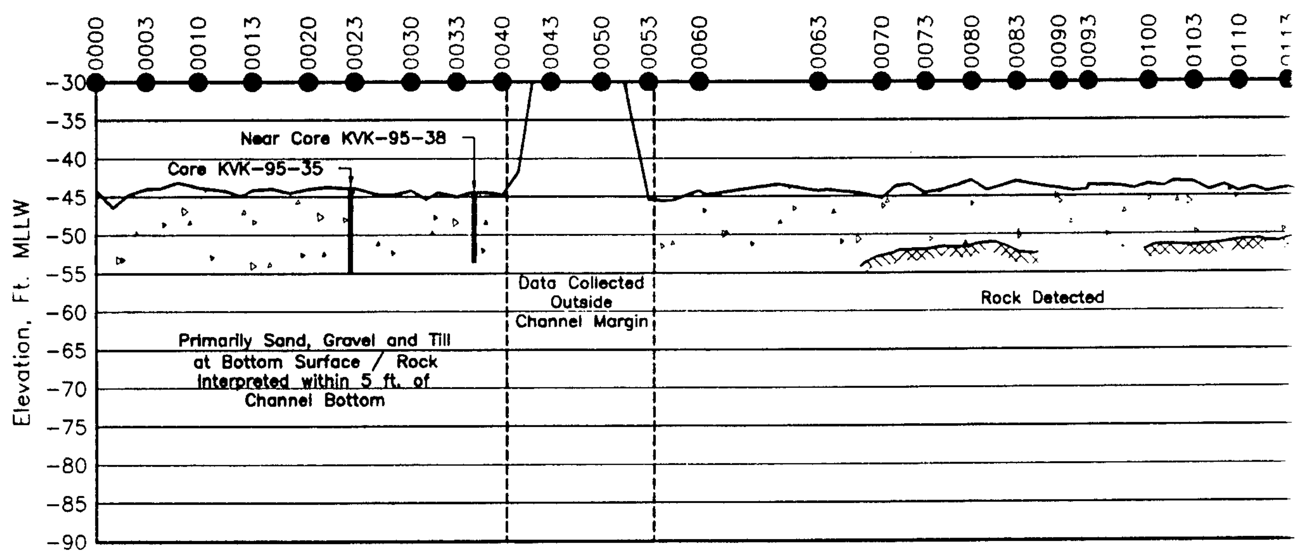

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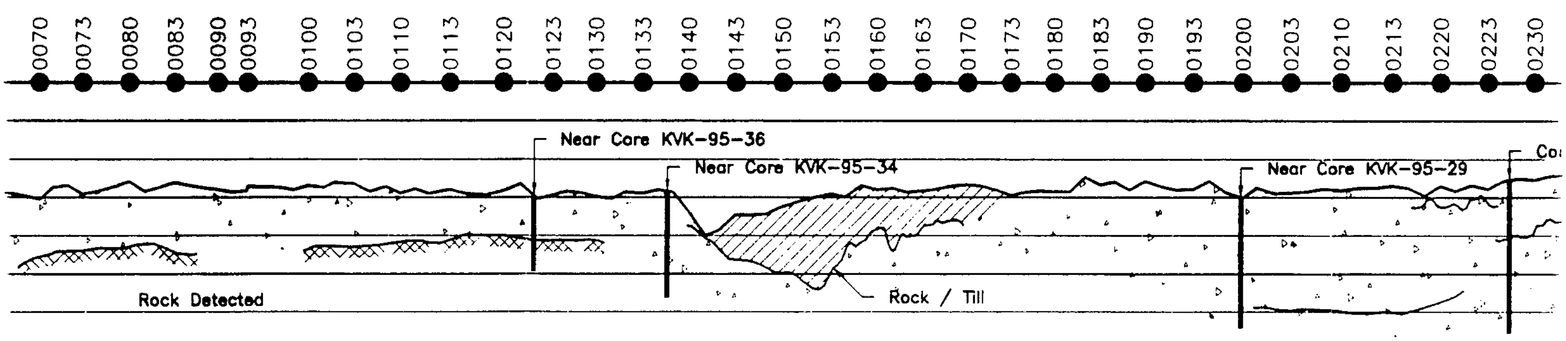
PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHAN



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< & NEW JERSEY CHANNELS PLATE # 06 SCALE: 1"=250'

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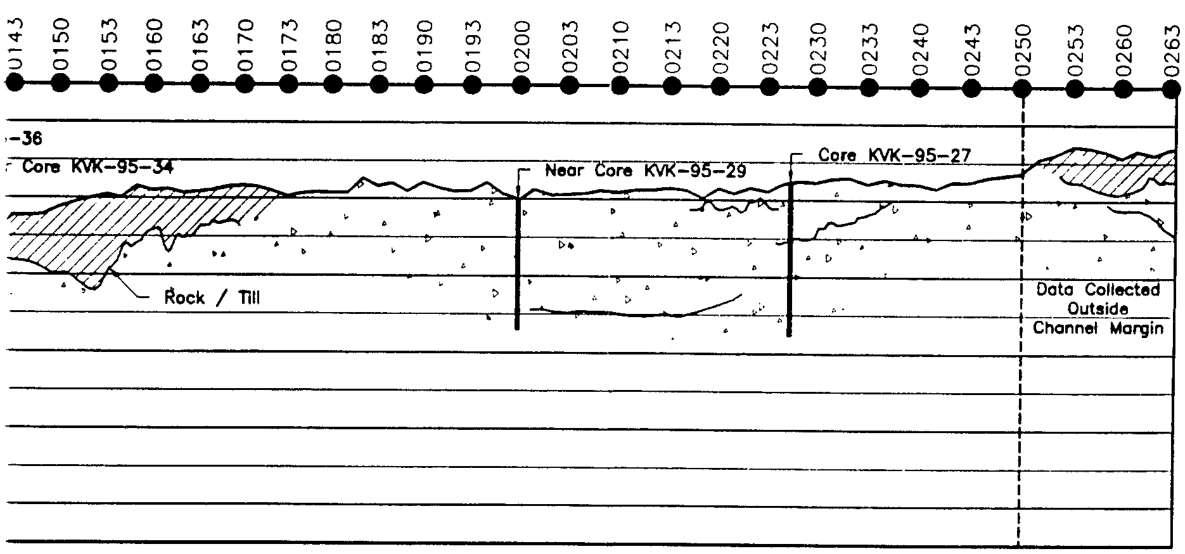

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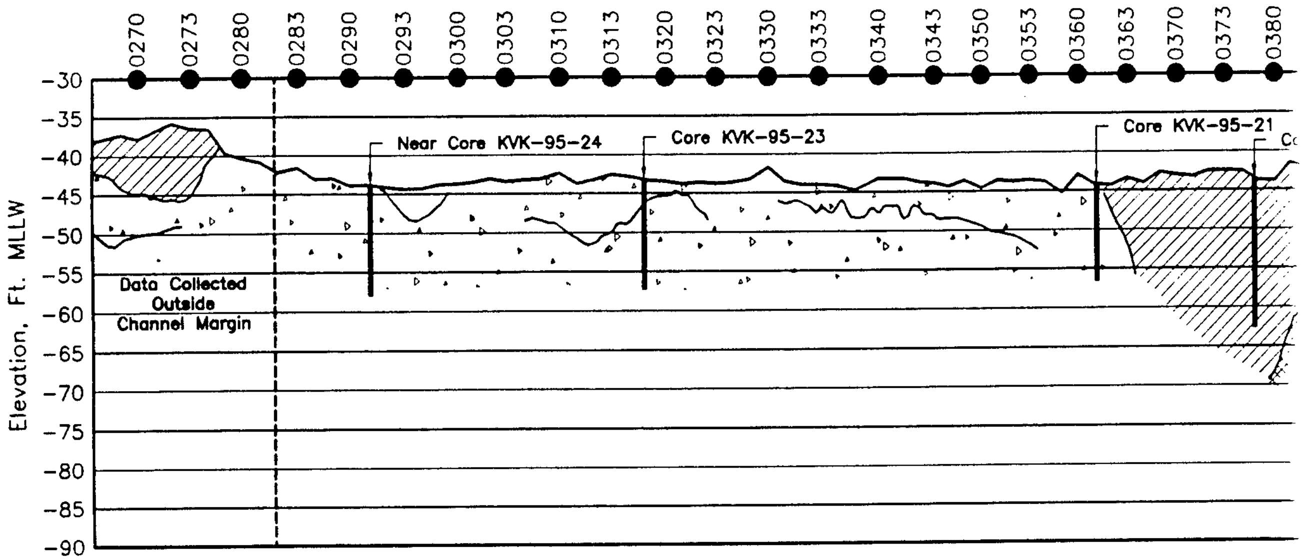

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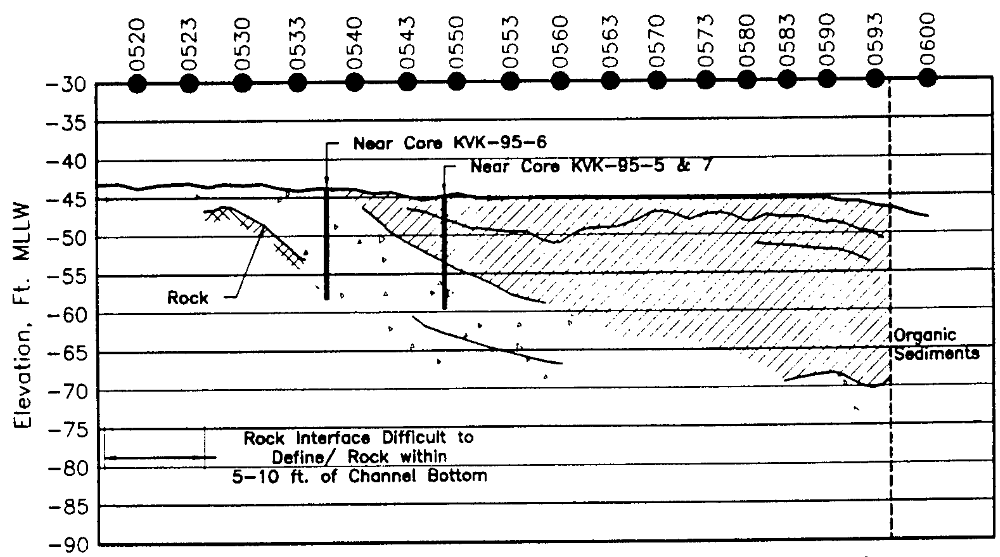

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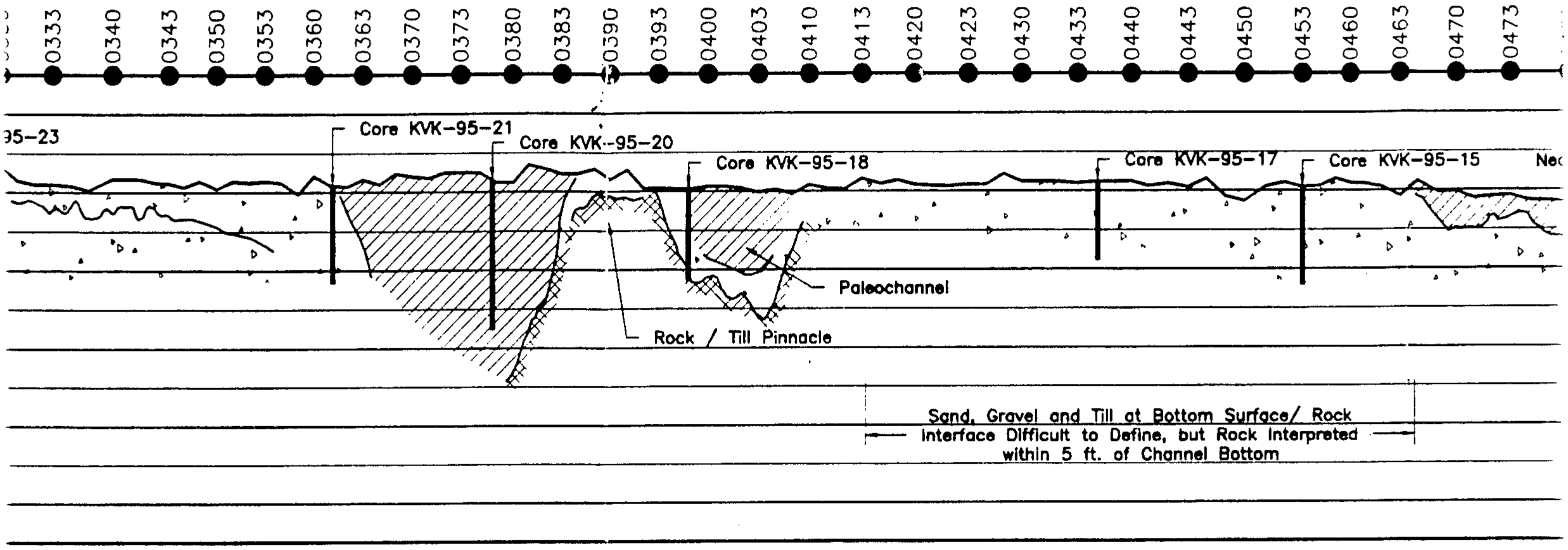
PROJECT AREA: KILL VAN KULL, NEW YORK & NEW JERSEY CHAN



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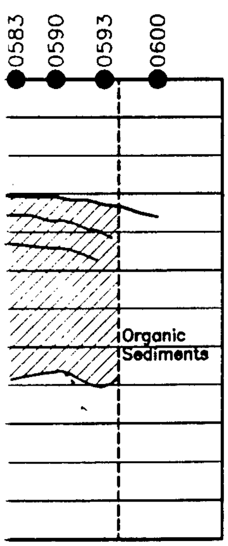

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'ORK & NEW JERSEY CHANNELS PLATE # 07 SCALE: 1"=250'

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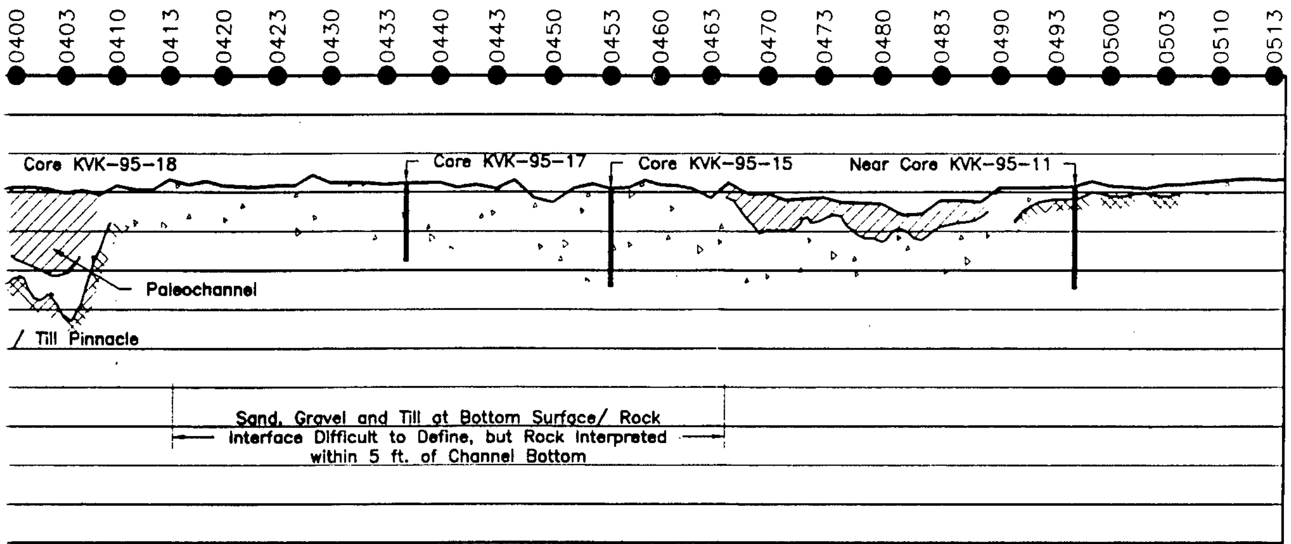

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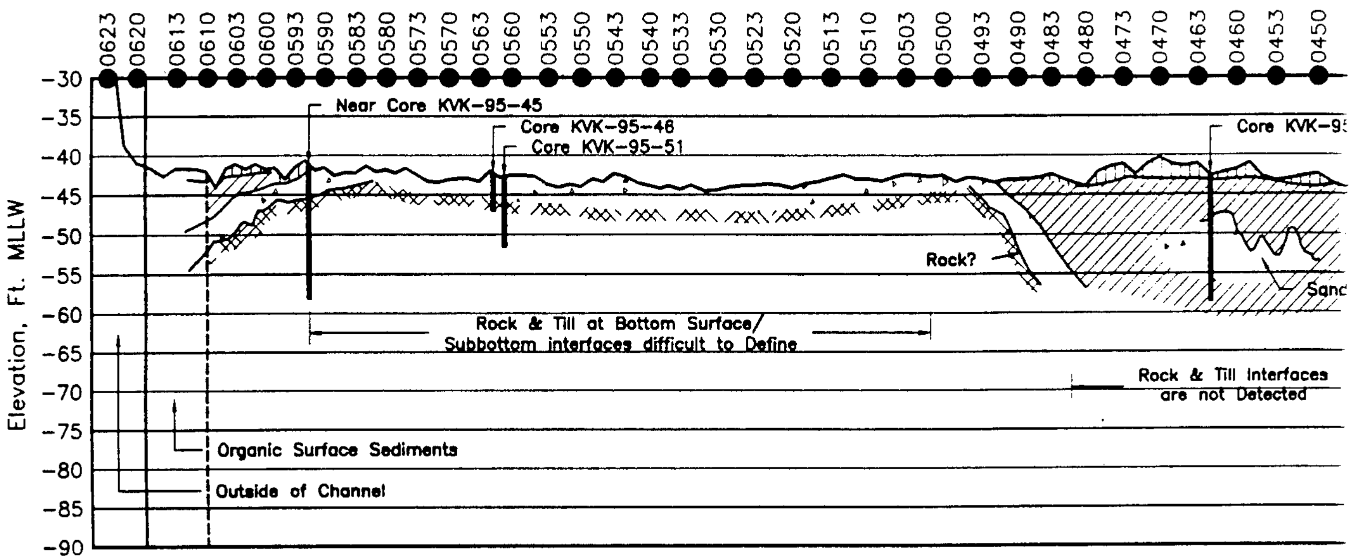

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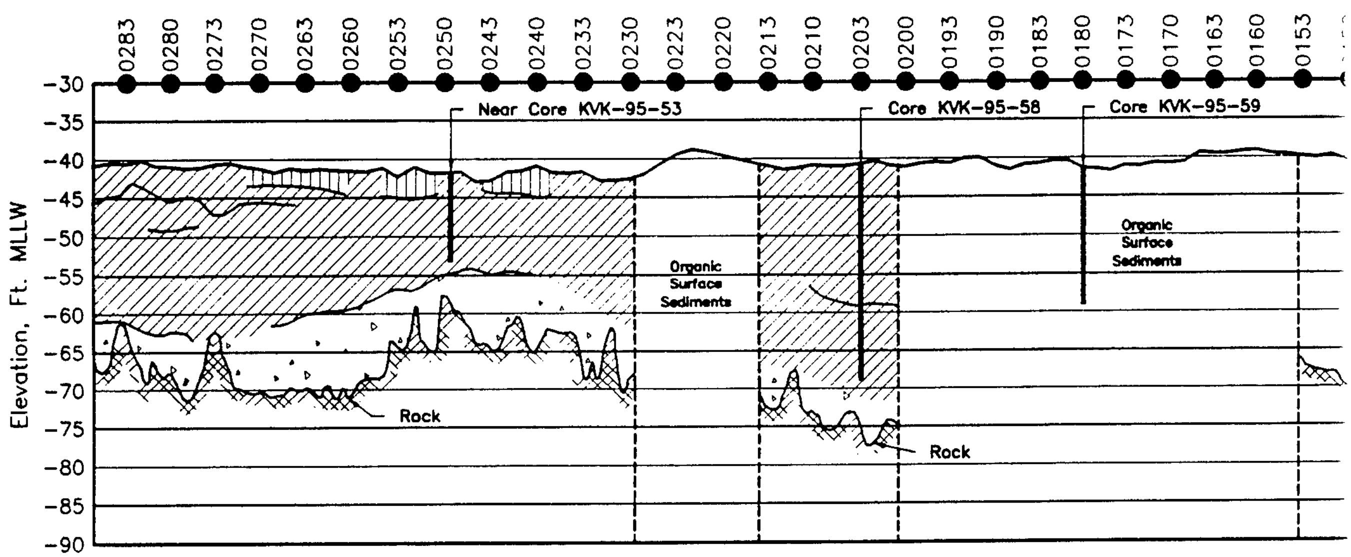

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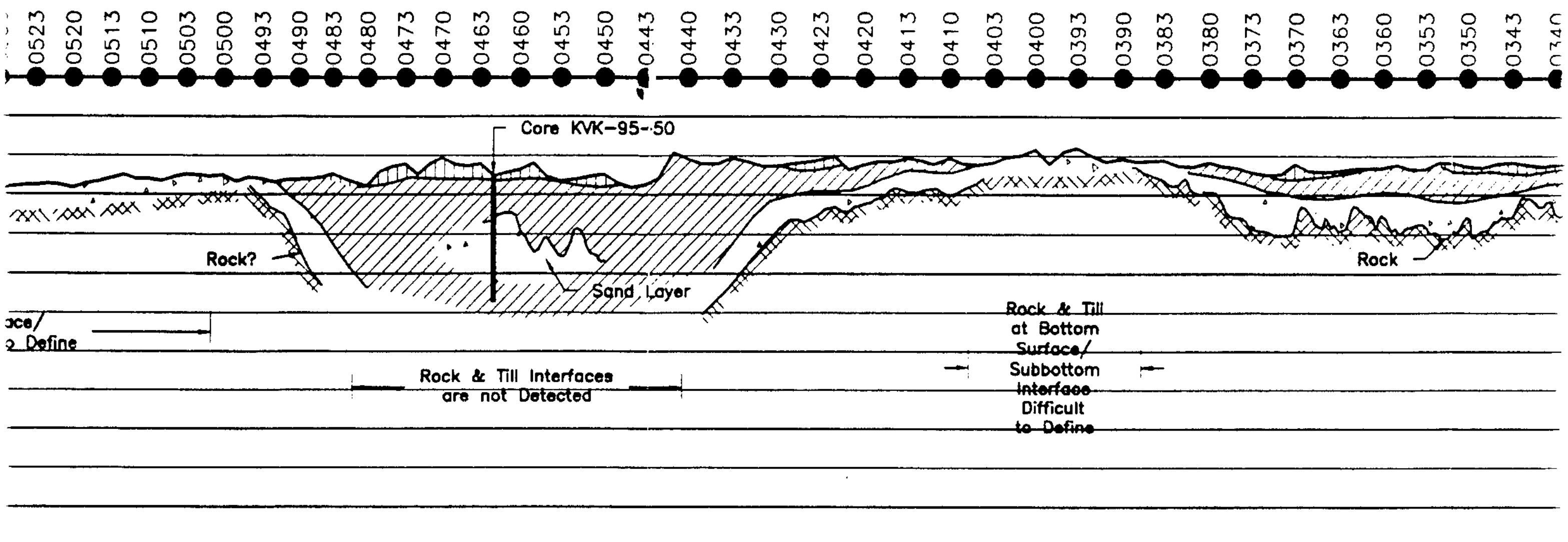
PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS



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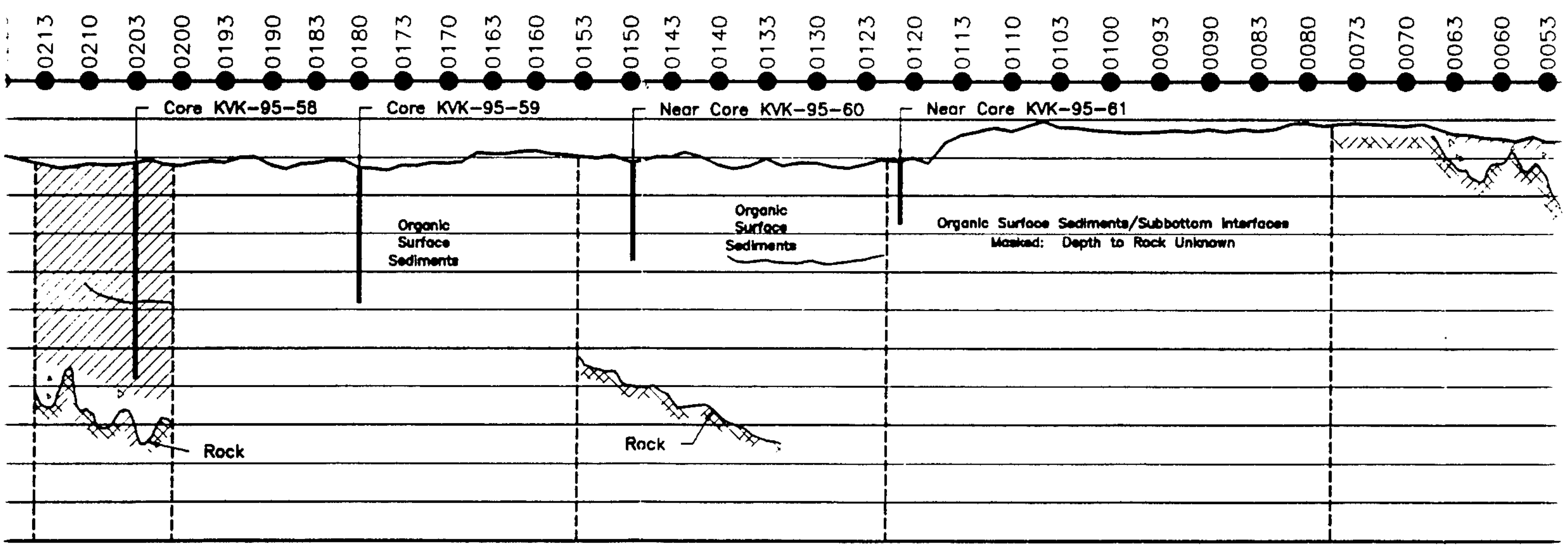

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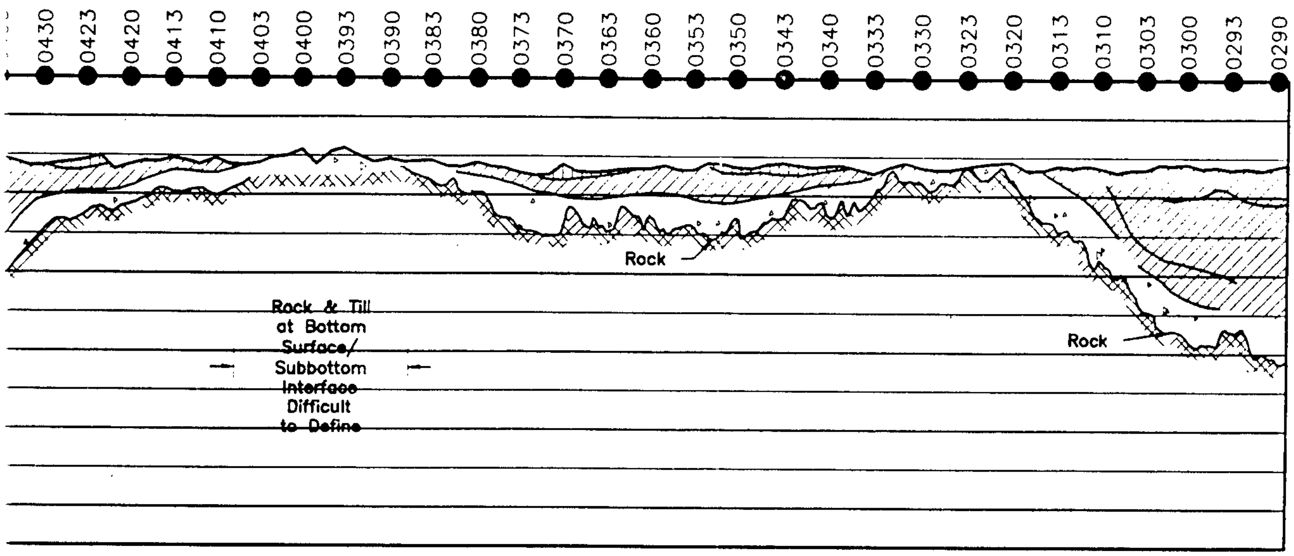
'ORK & NEW JERSEY CHANNELS PLATE # 08 SCALE: 1"=250



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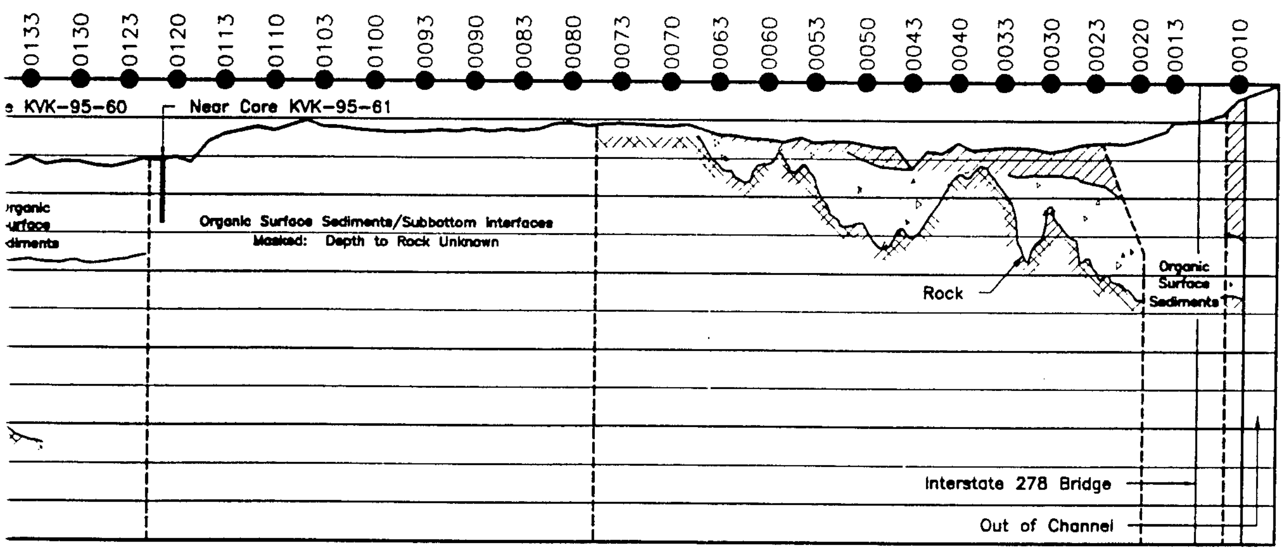

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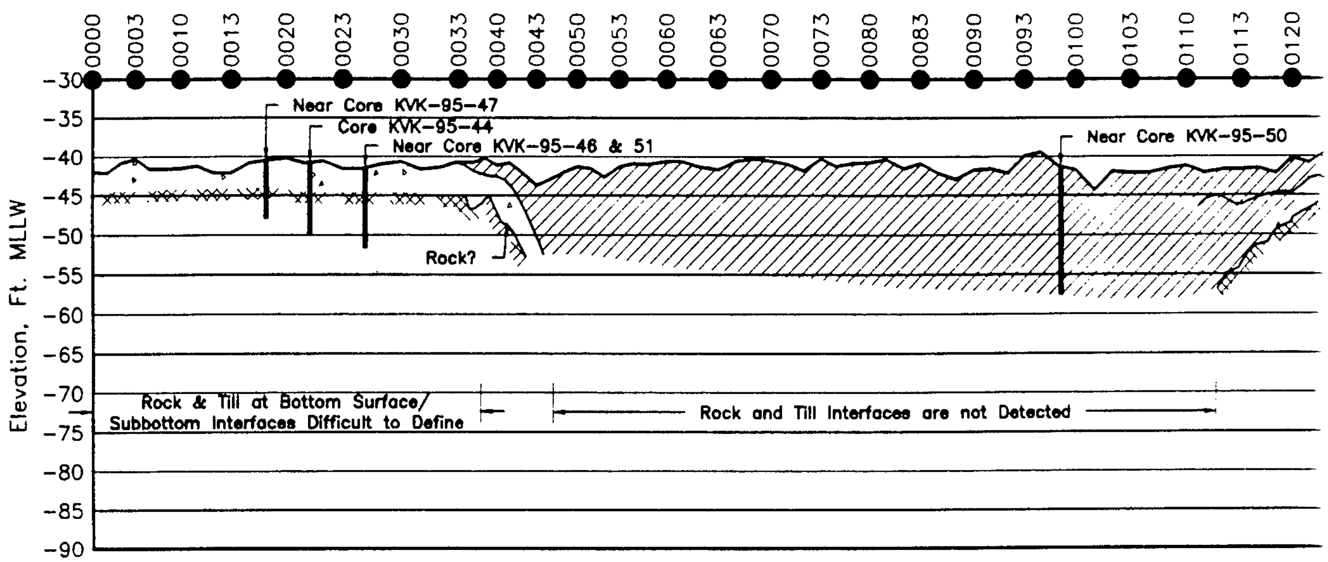

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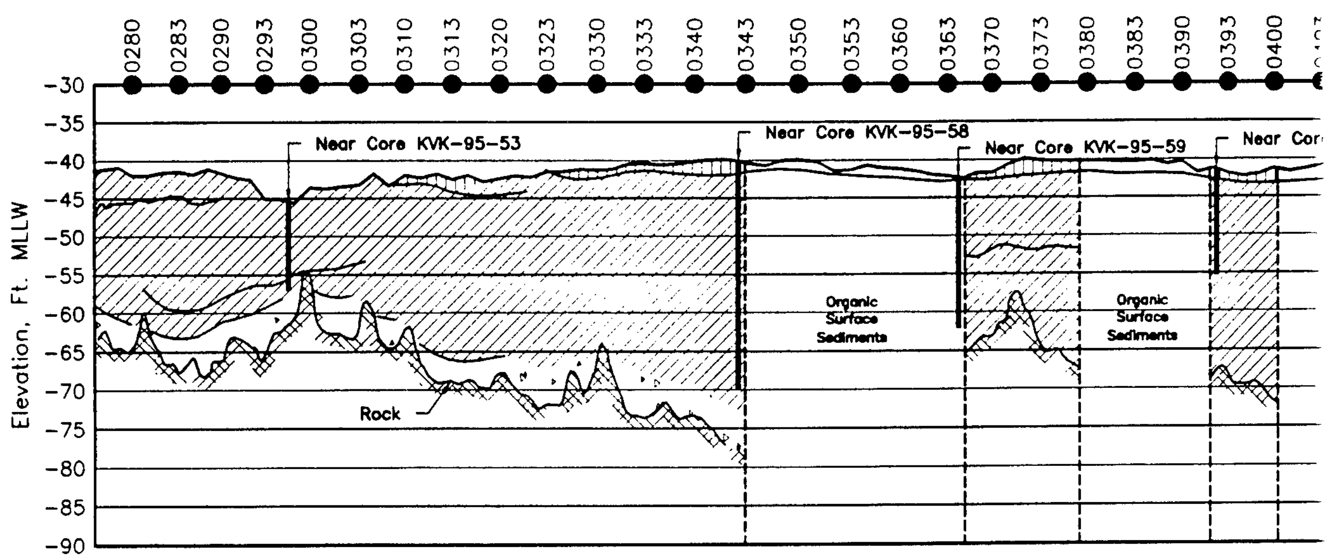

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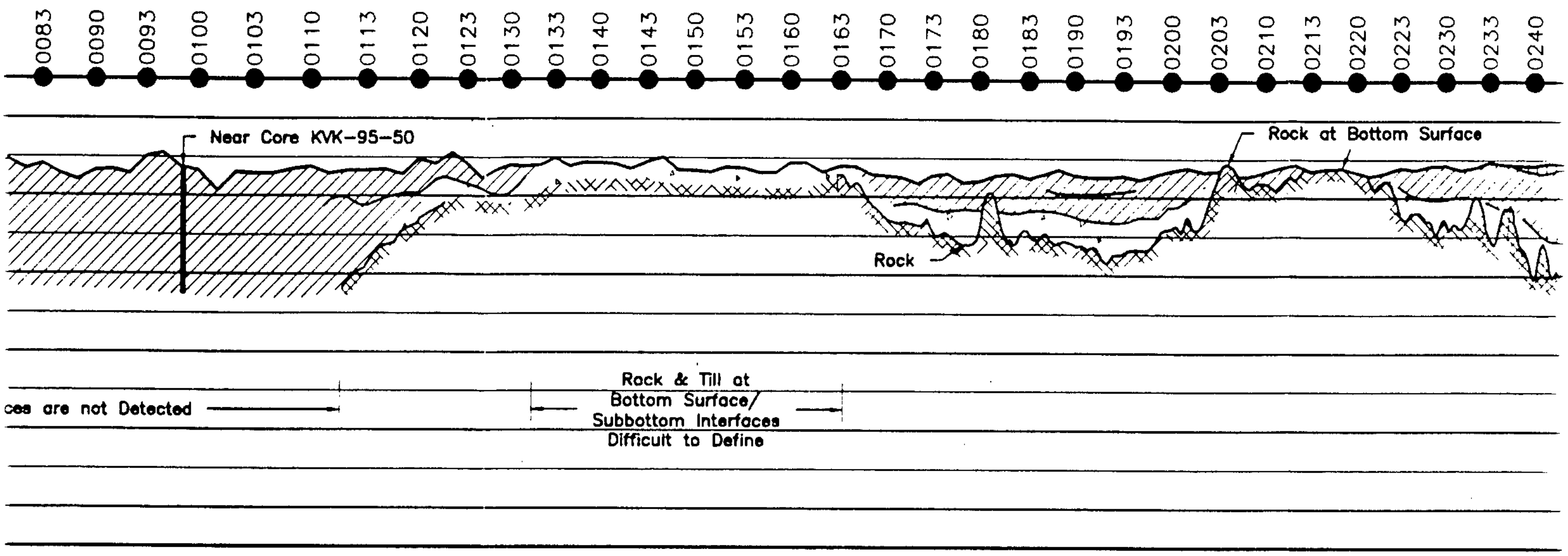
PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS



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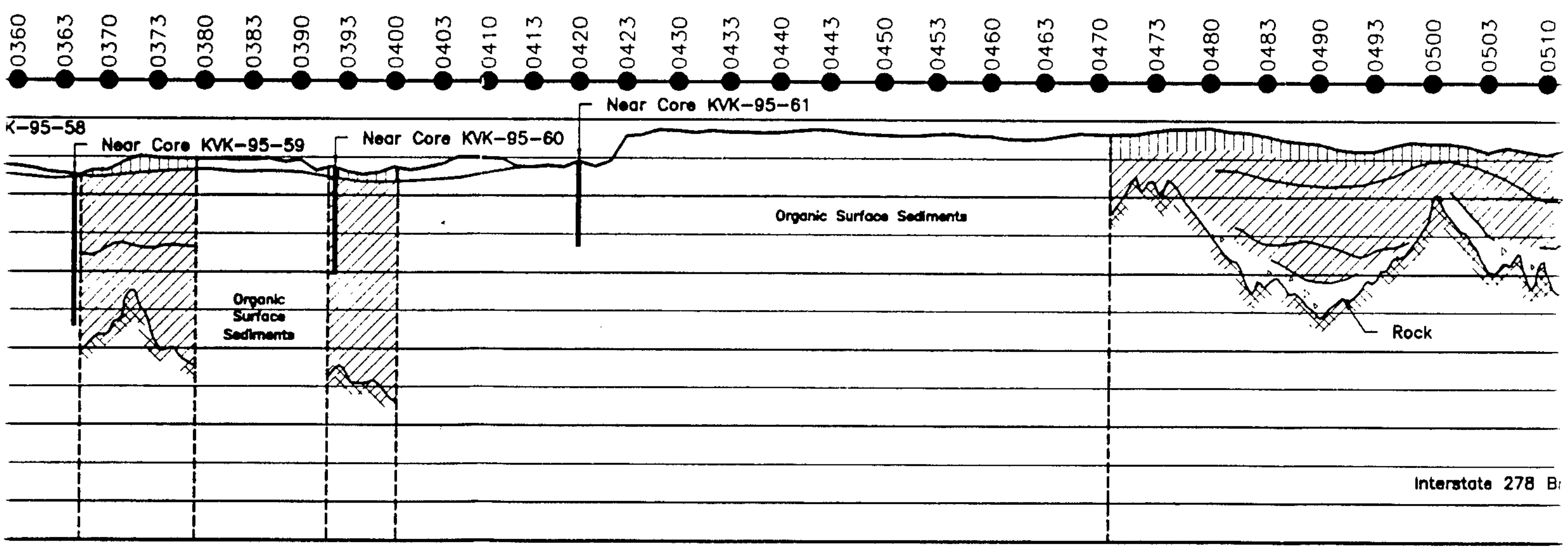

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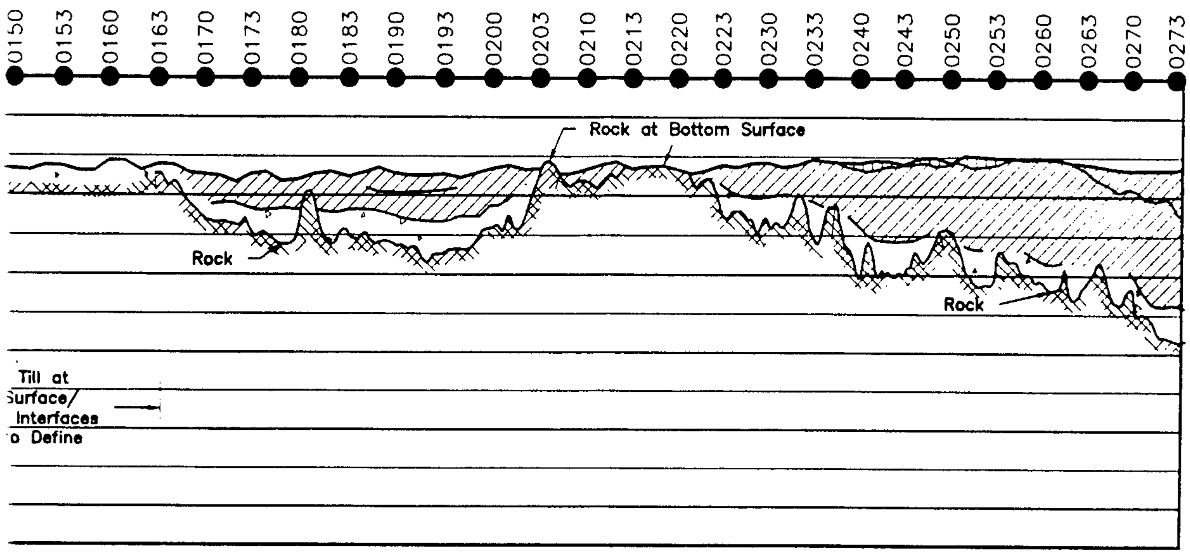

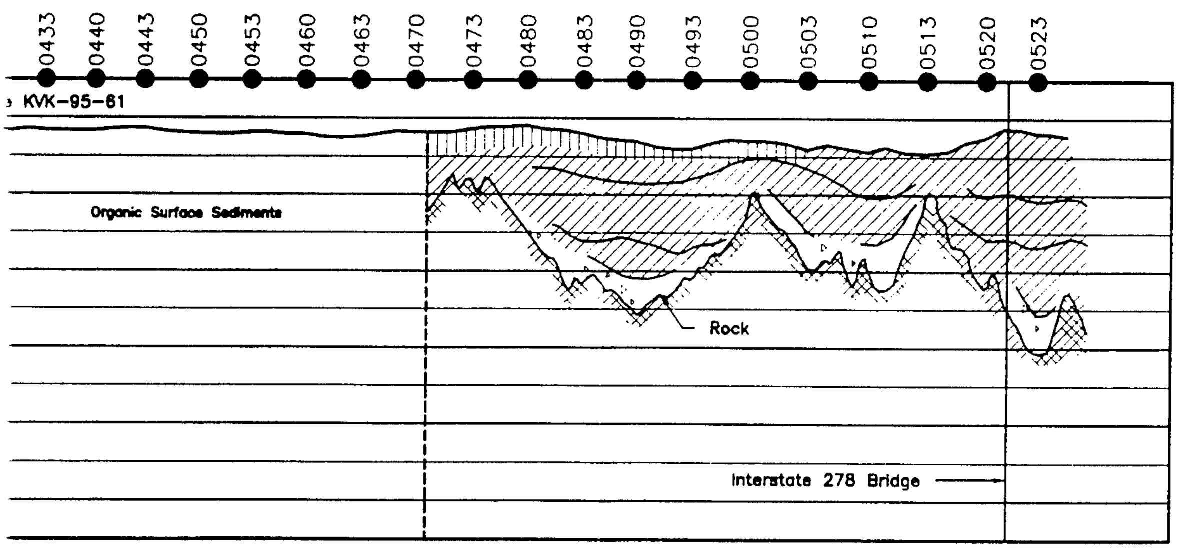

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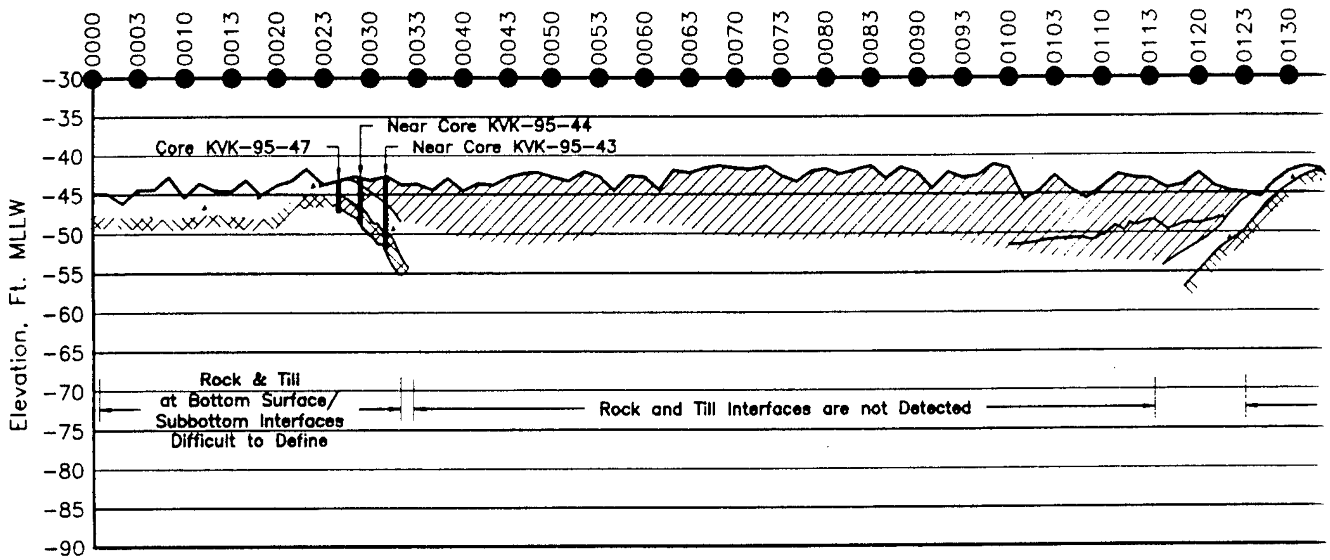

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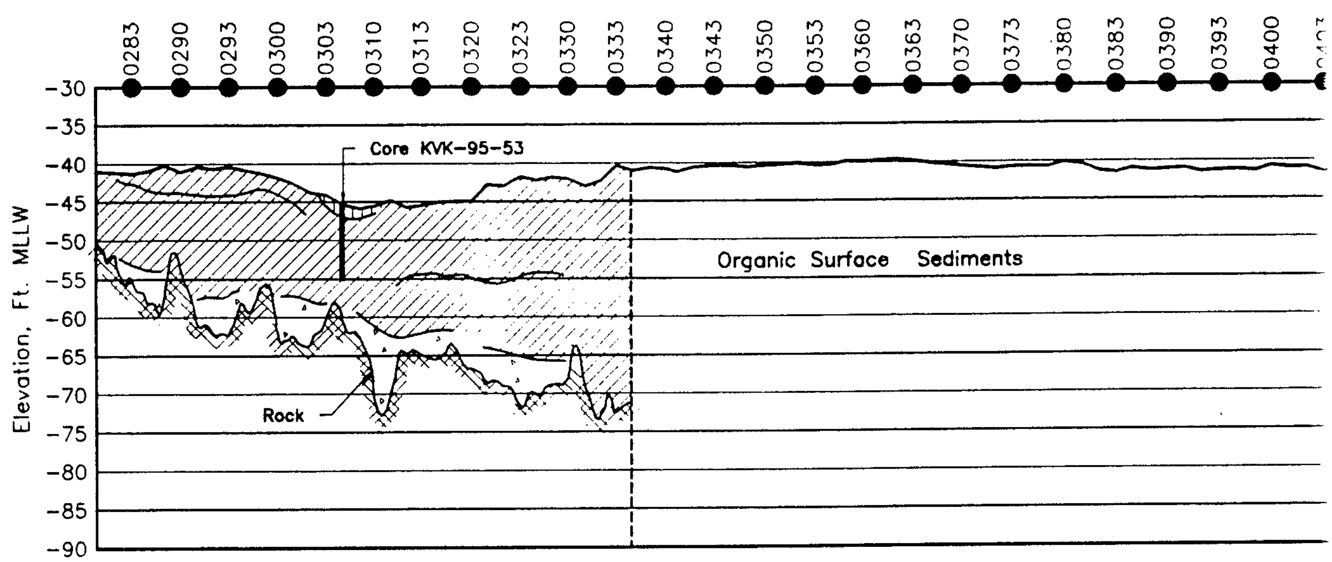

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PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS

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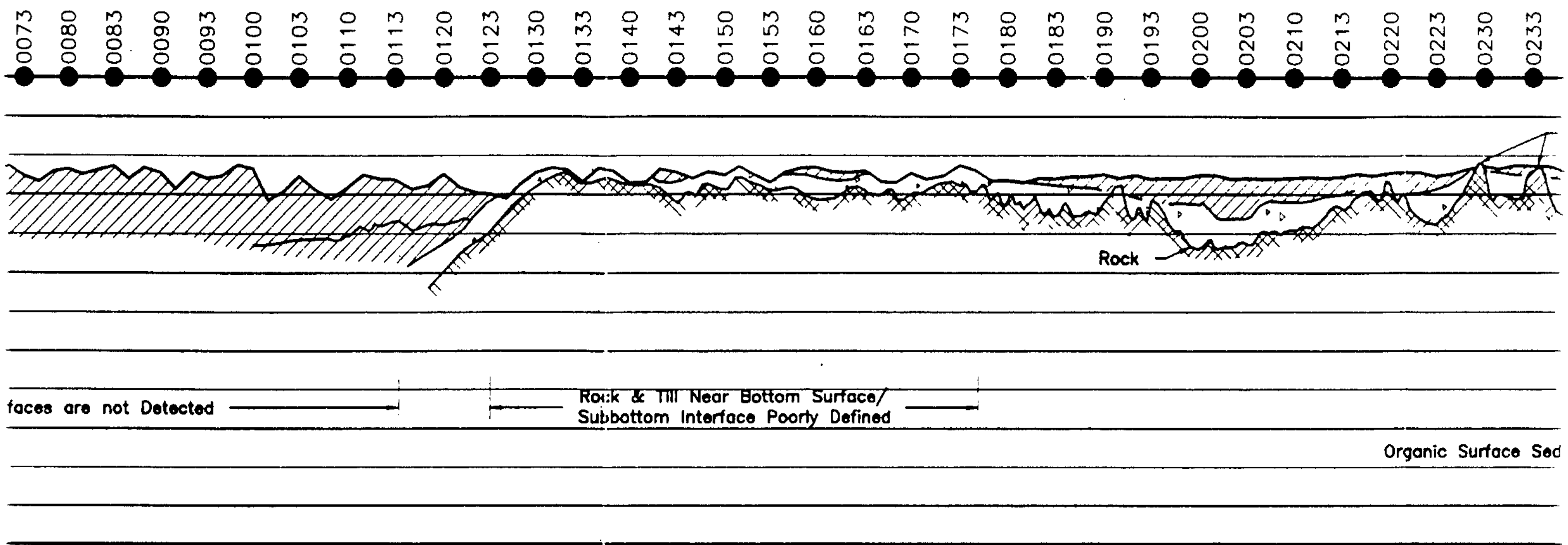

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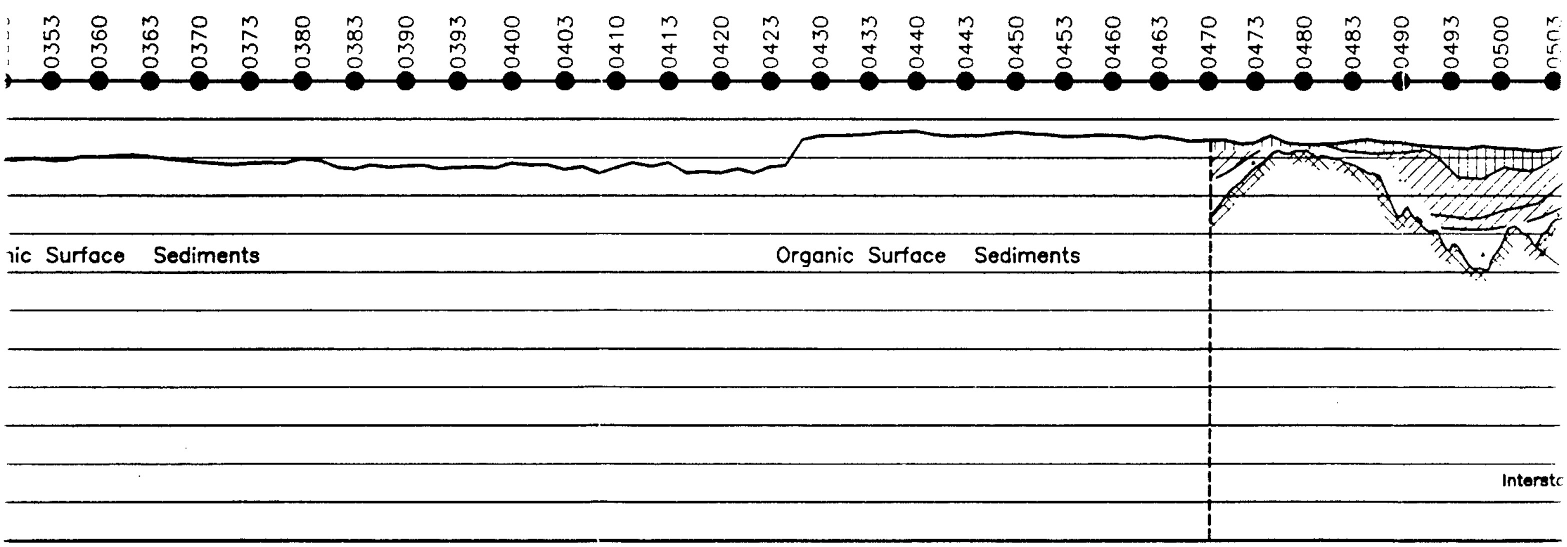

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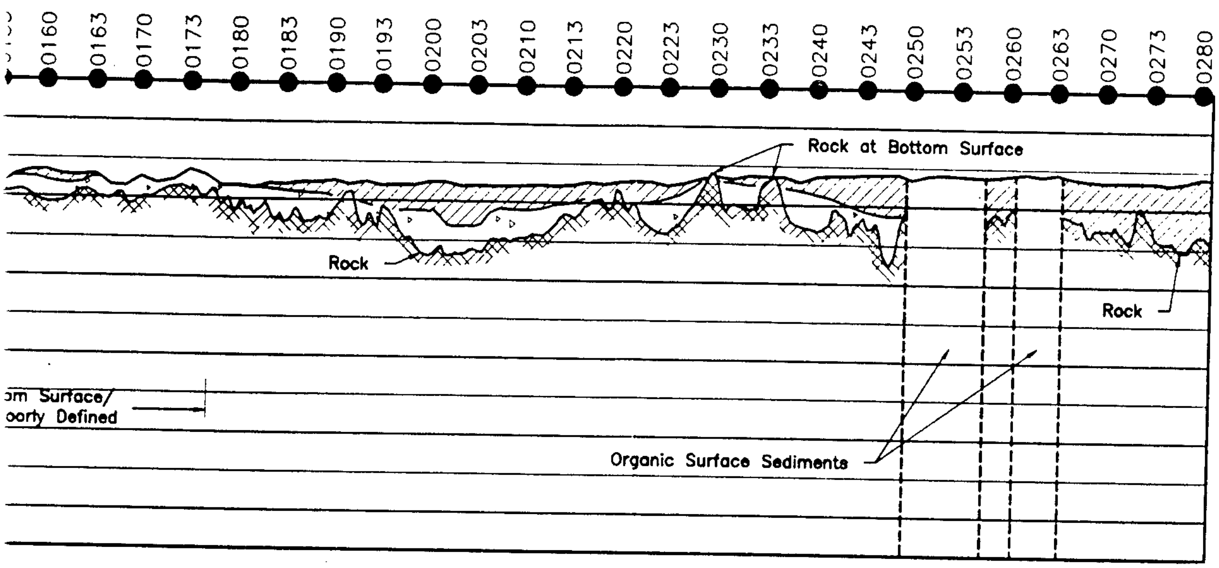
RK & NEW JERSEY CHANNELS PLATE # 10 SCALE: 1"=250'



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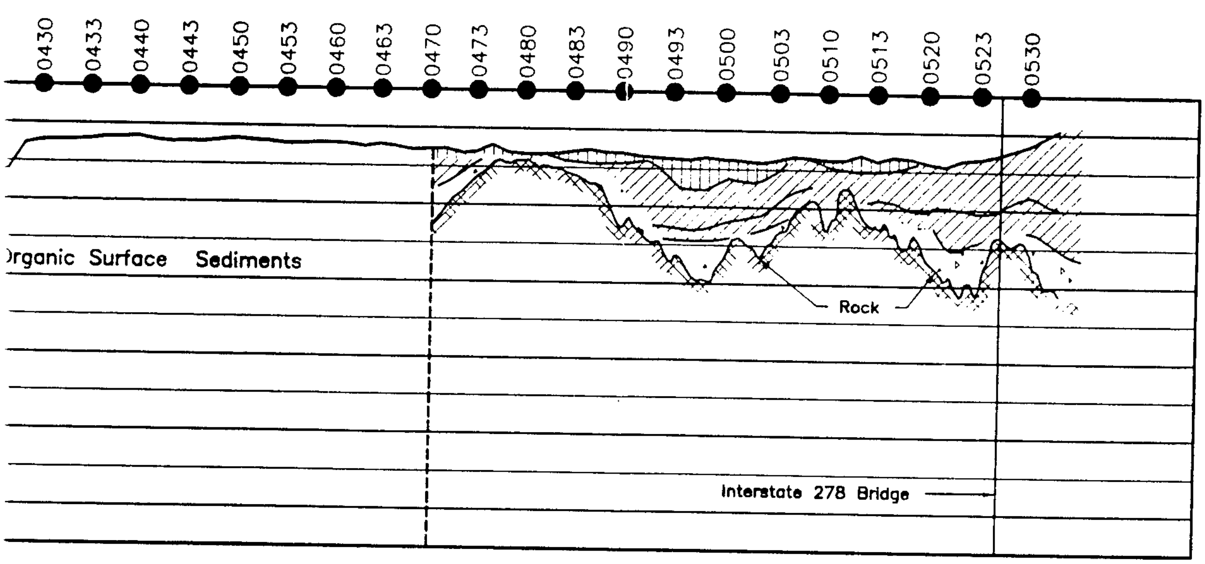

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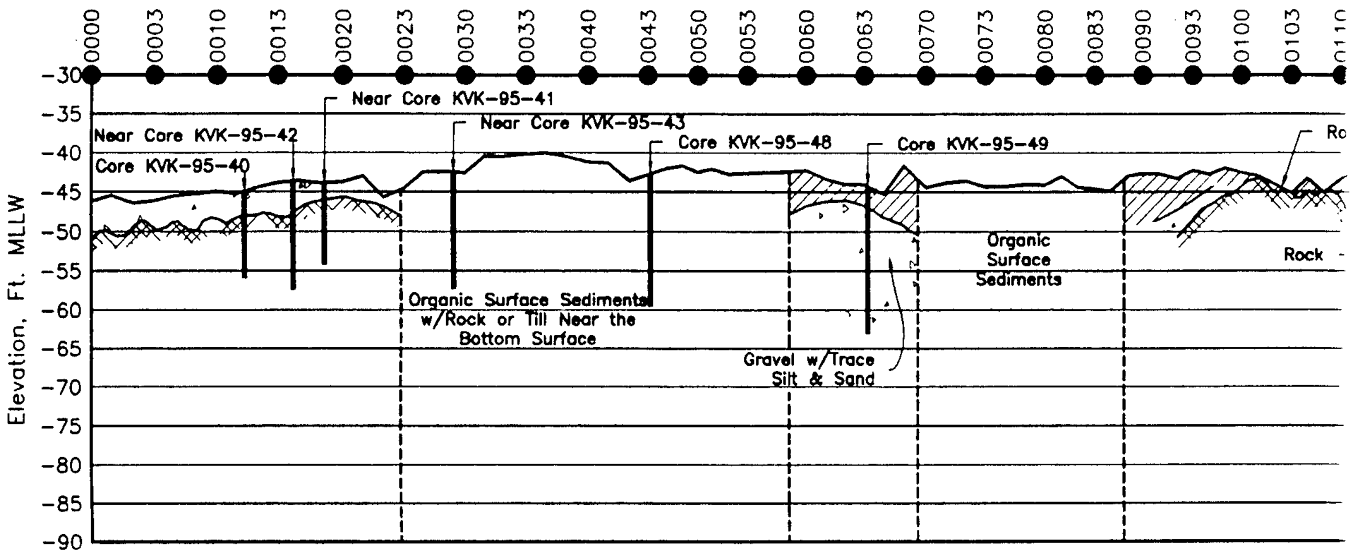
PLATE # 10 SCALE: 1"=250' 10 OCTOBER 1996



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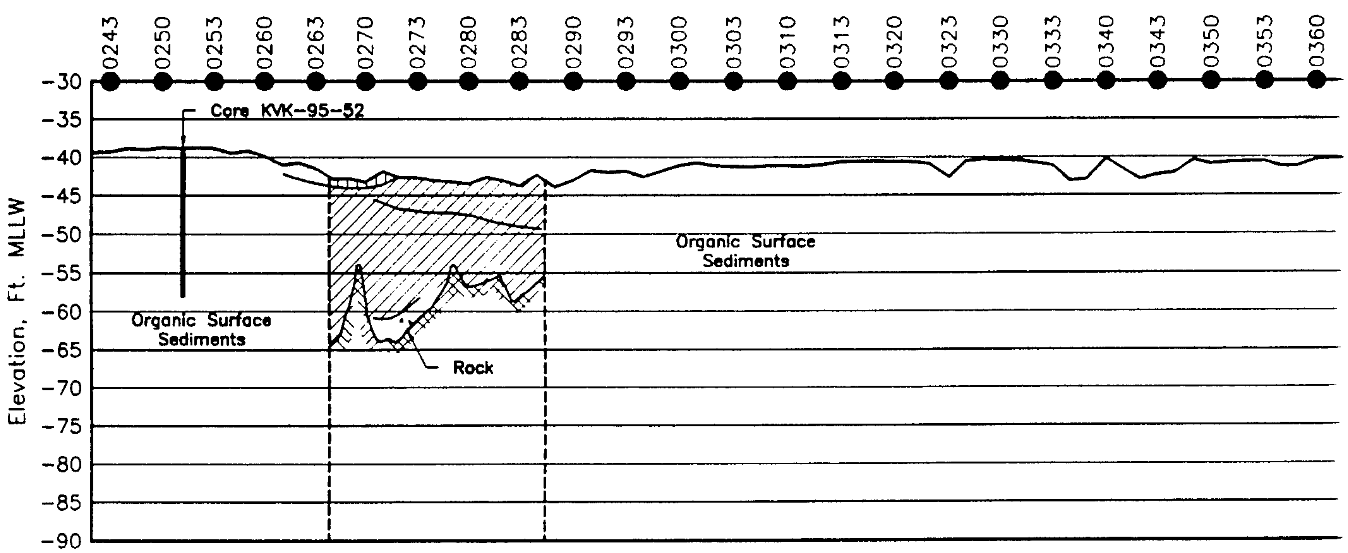

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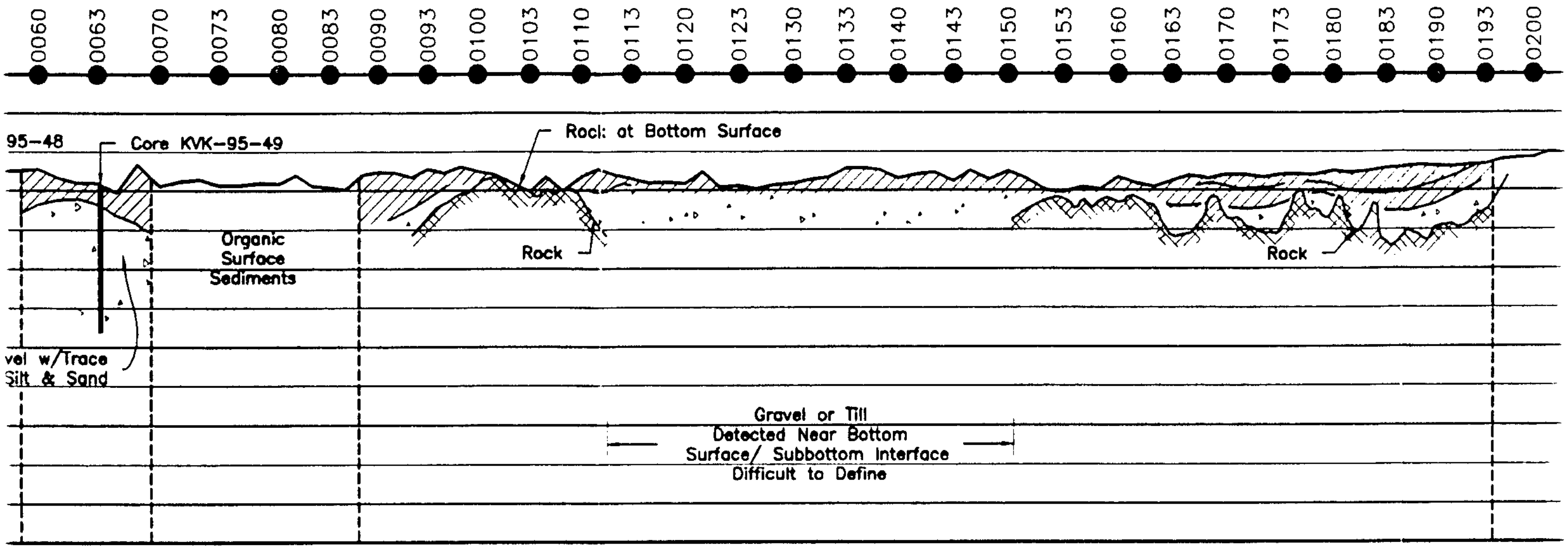
PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS



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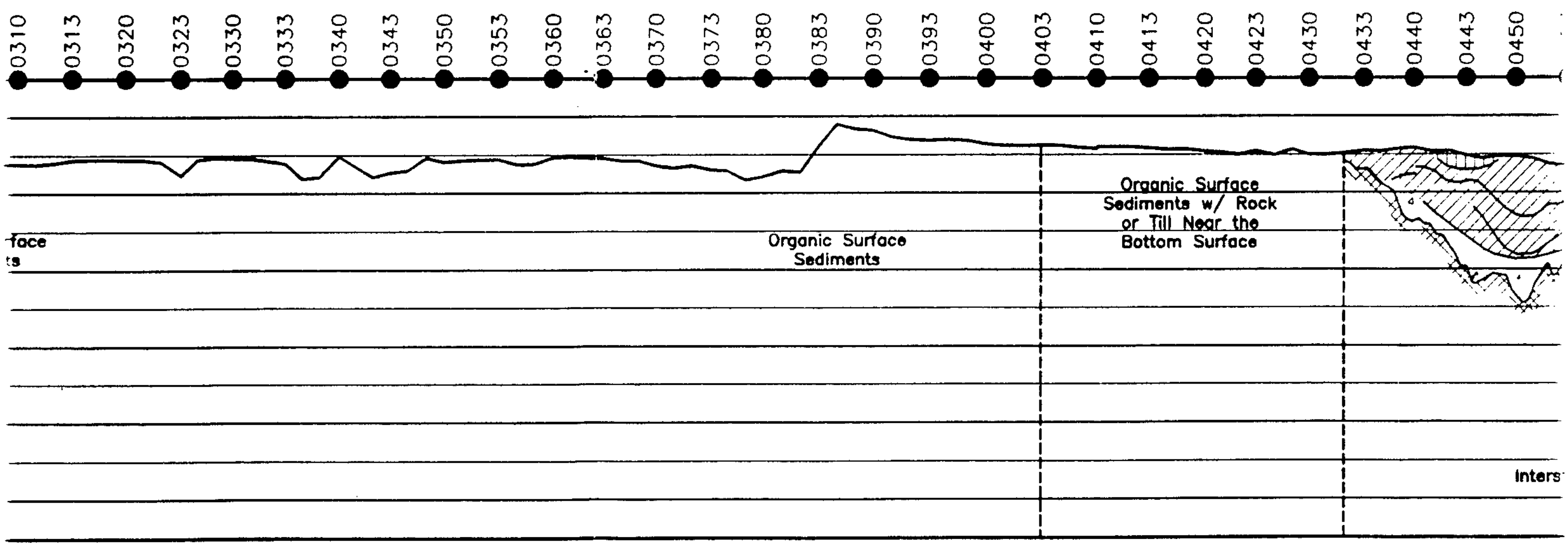

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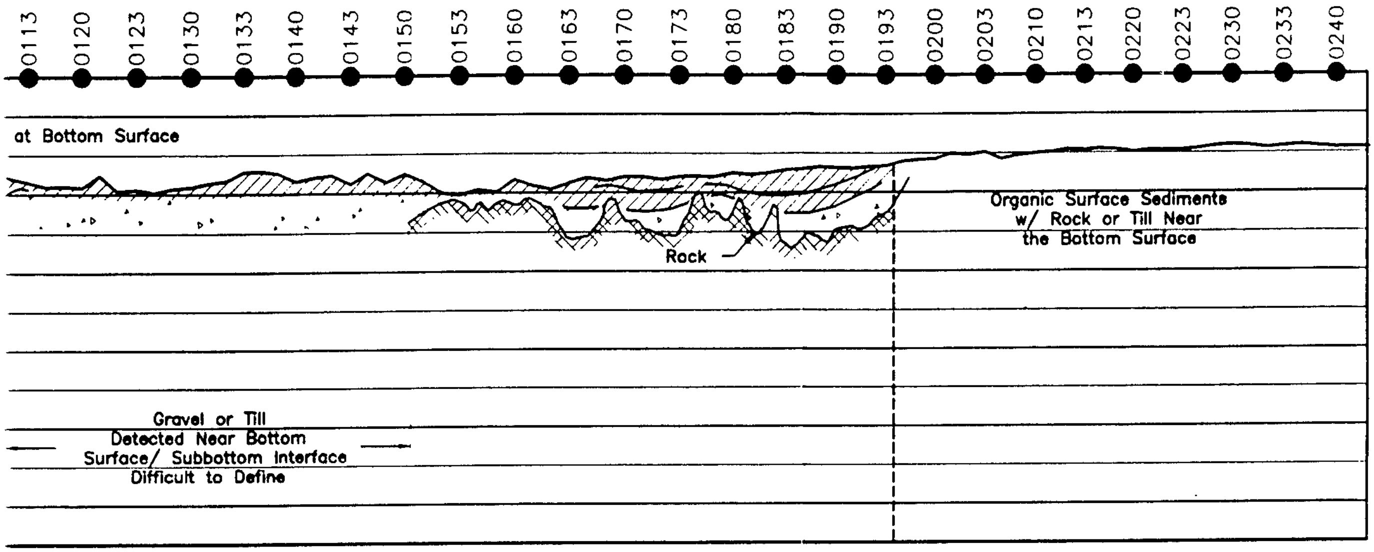
RK & NEW JERSEY CHANNELS PLATE # 11 SCALE: 1"=250'



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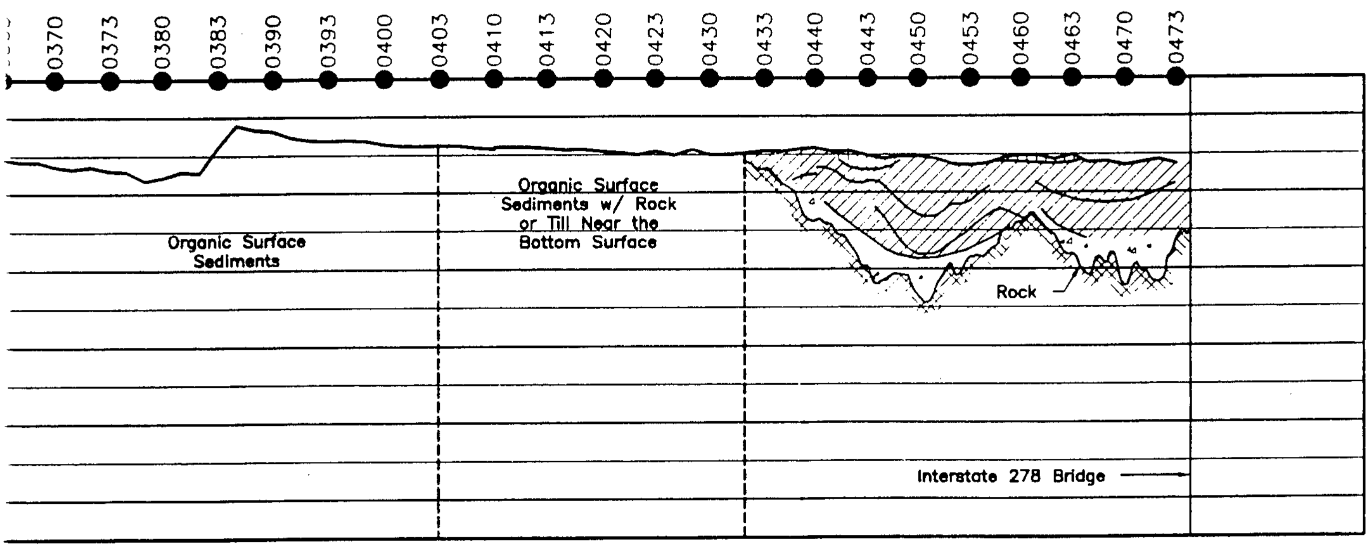

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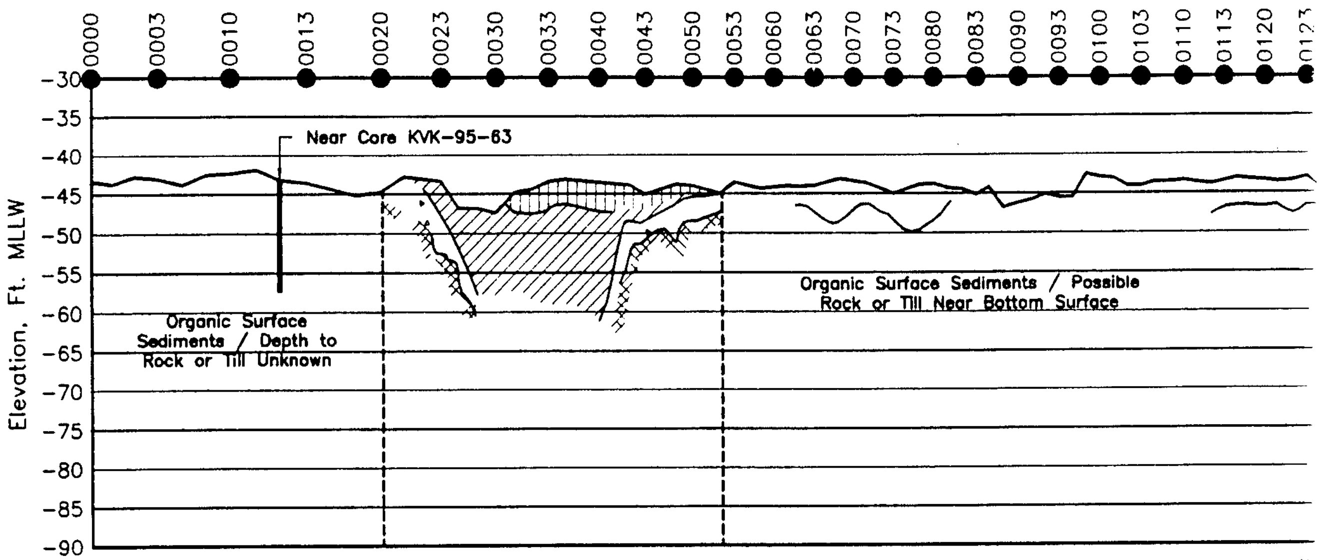

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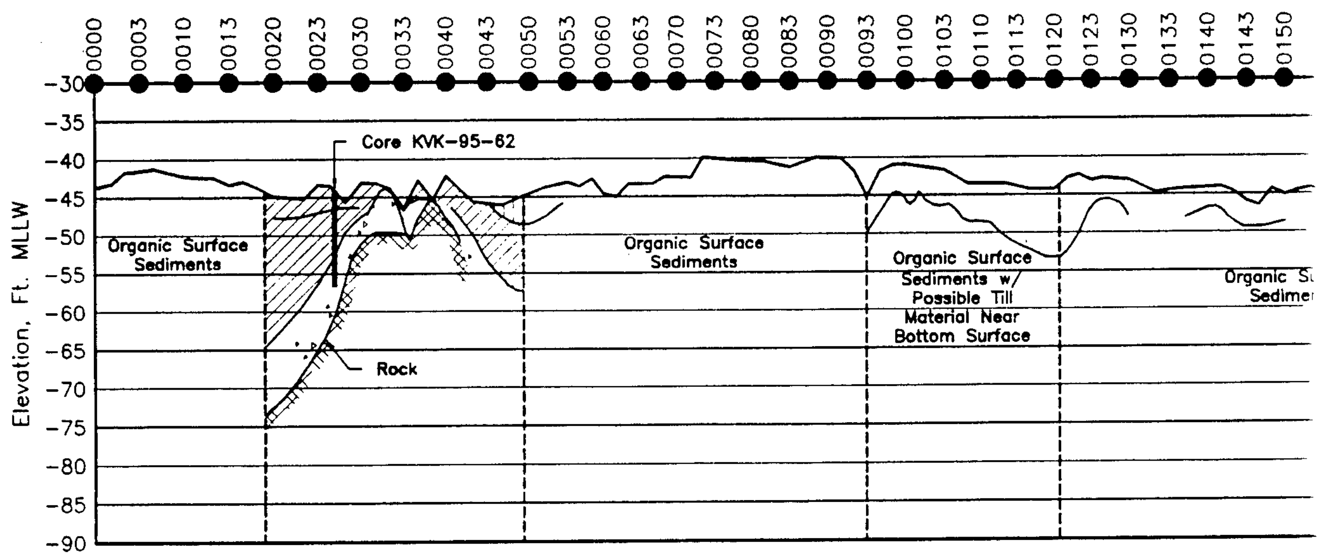

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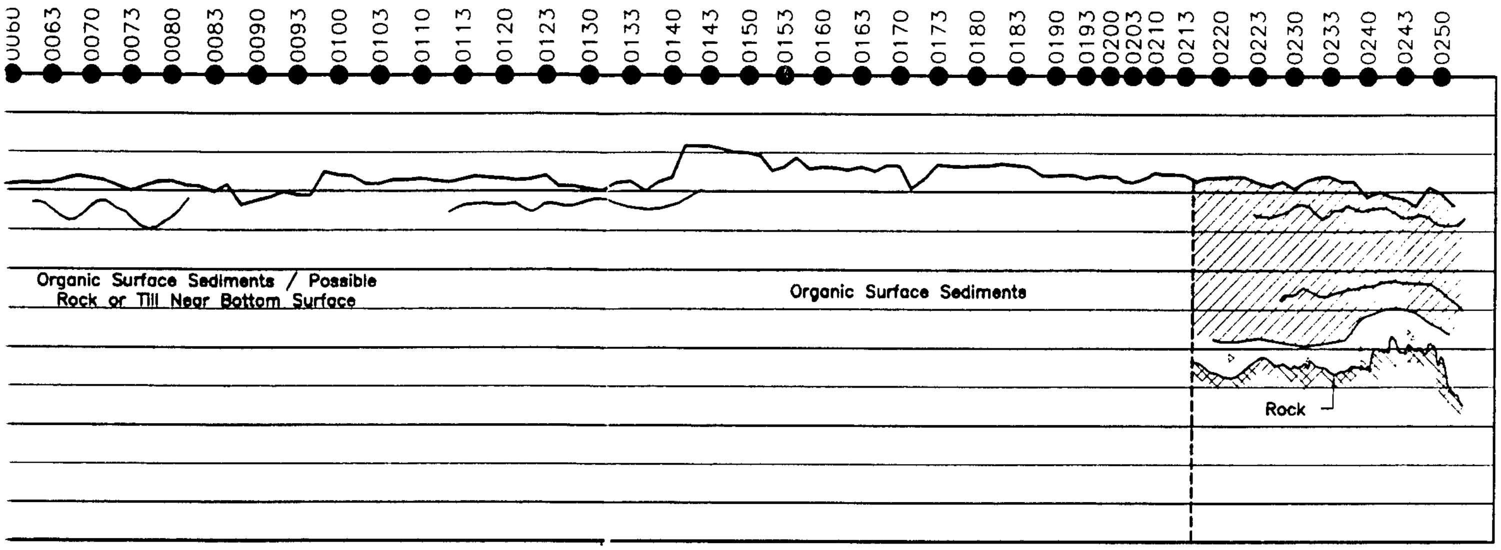
PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNEL



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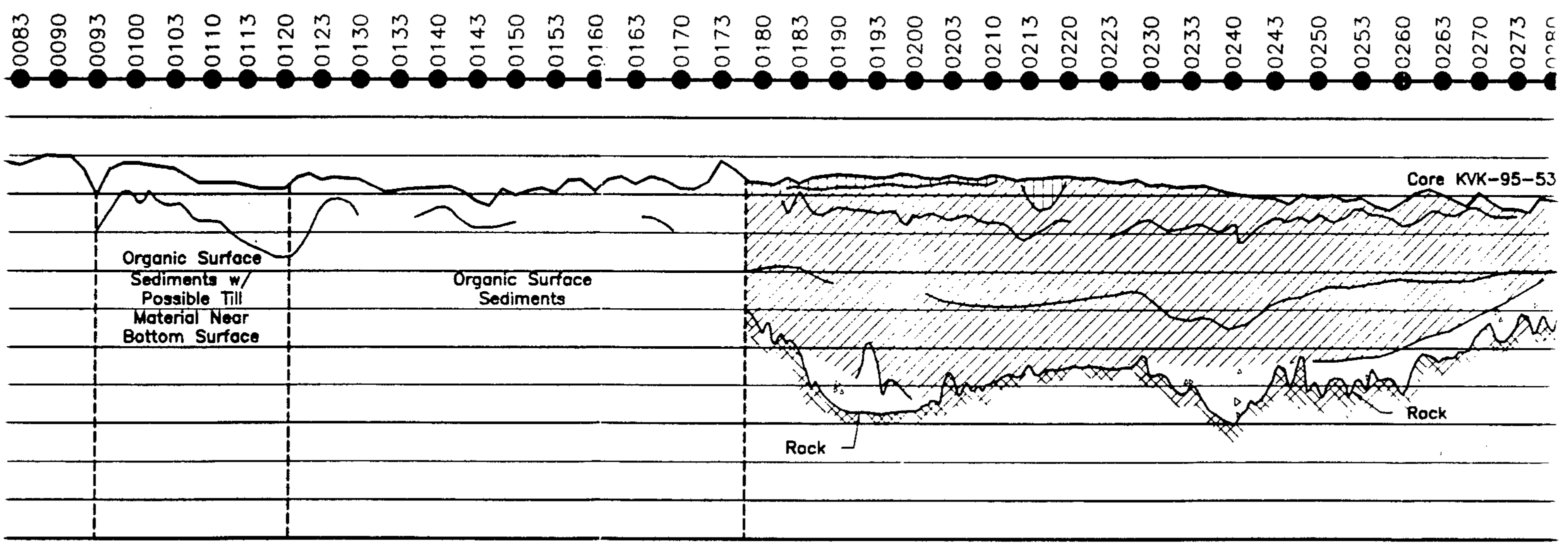

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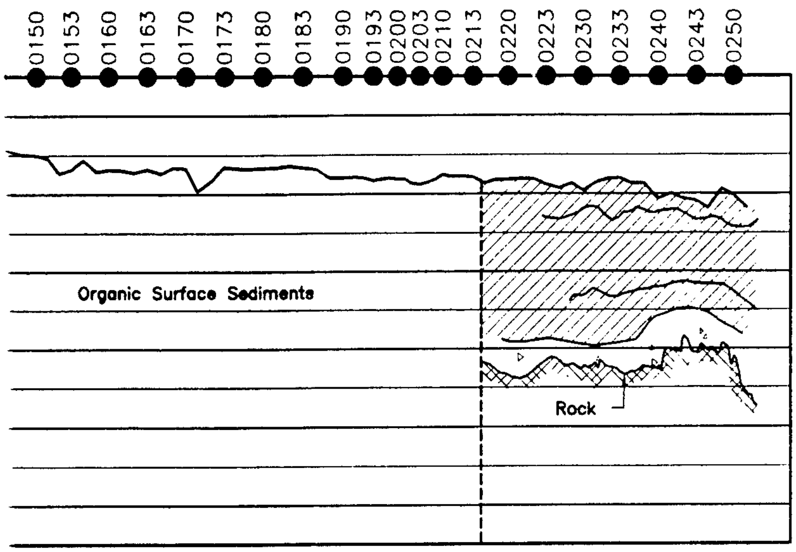

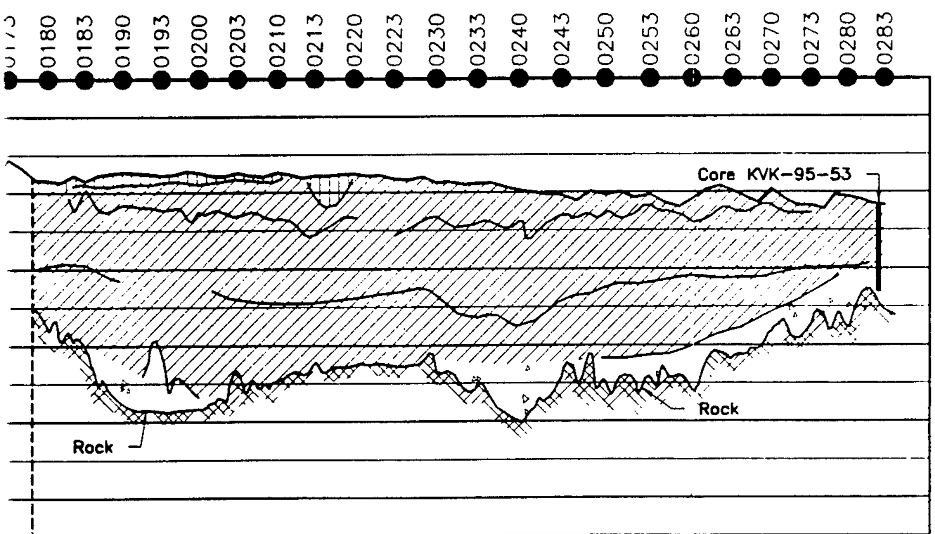

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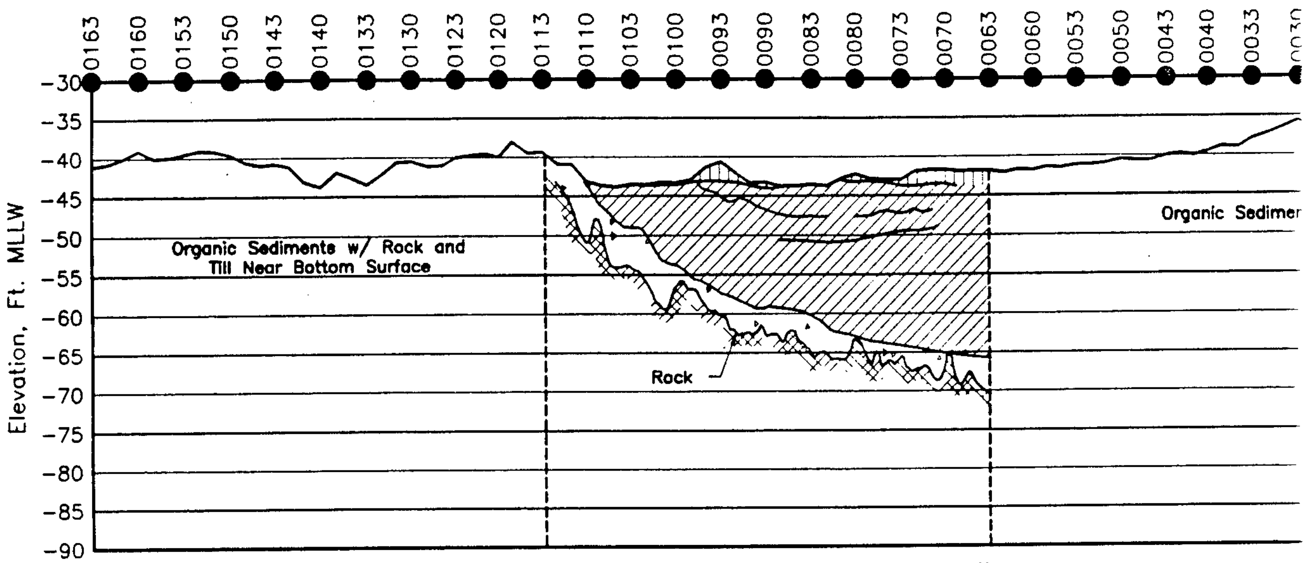
PLATE # 12 SCALE: 1"=250' 10 OCTOBER 1996



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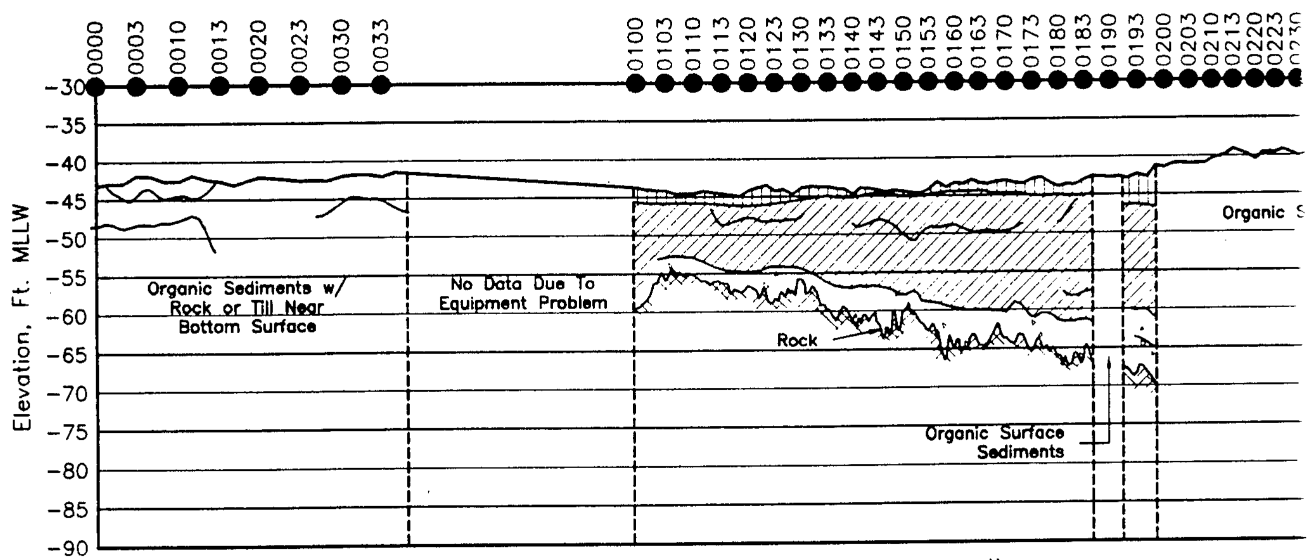

WES SURVEY LINE # PN05

PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNEl

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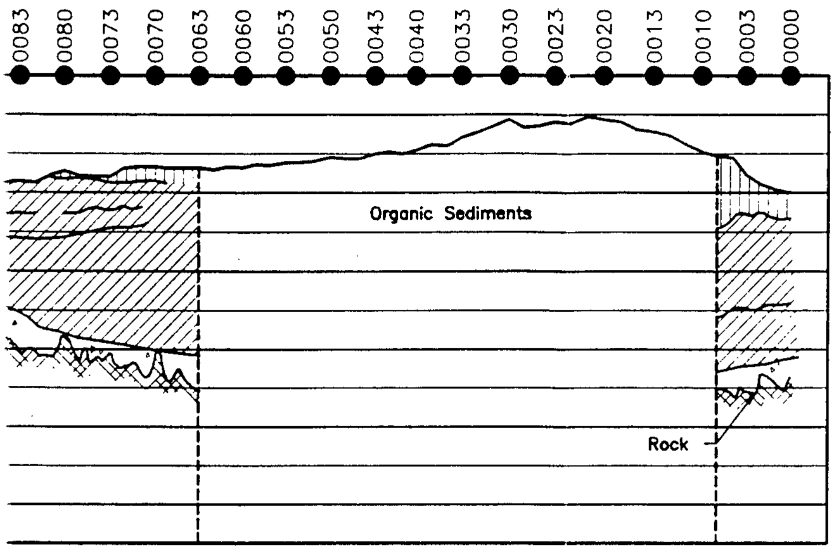

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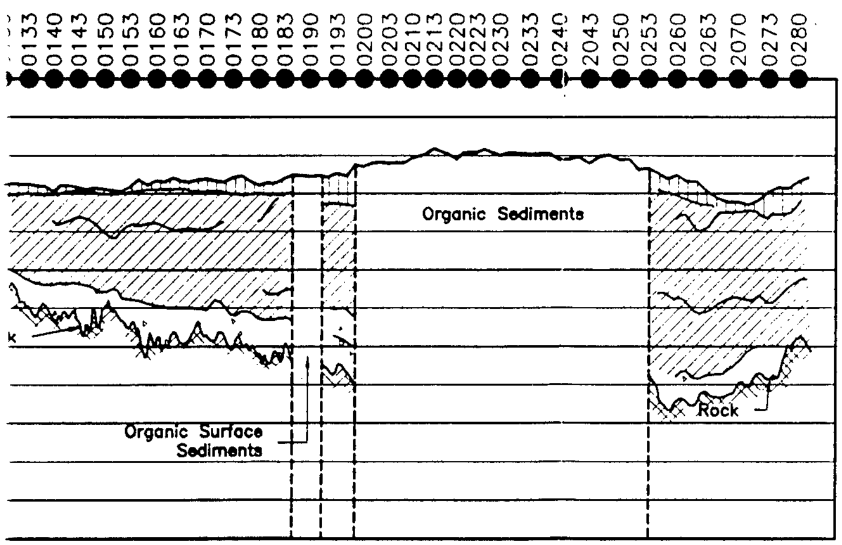
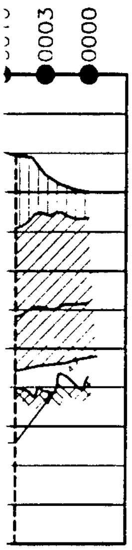


'EY LINE # PN05

& NEW JERSEY CHANNELS	PLATE # 13	SCALE: 1"=250'



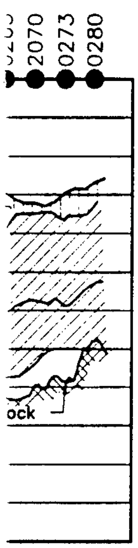
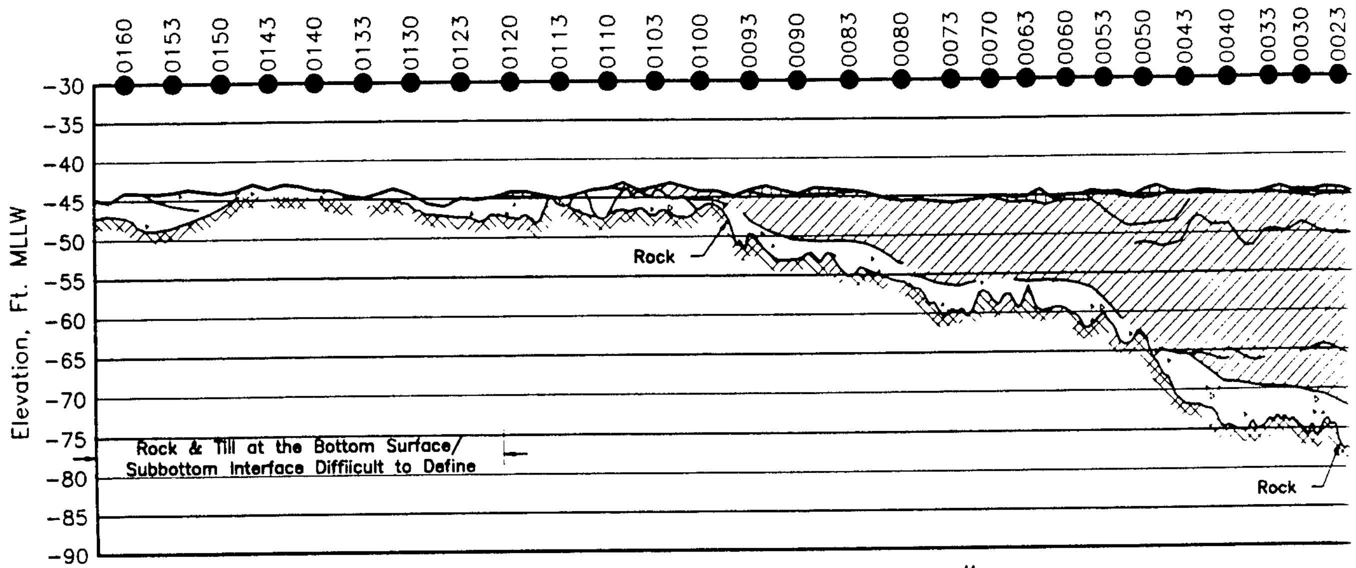


PLATE # 13 SCALE: 1"=250' 10 OCTOBER 1996



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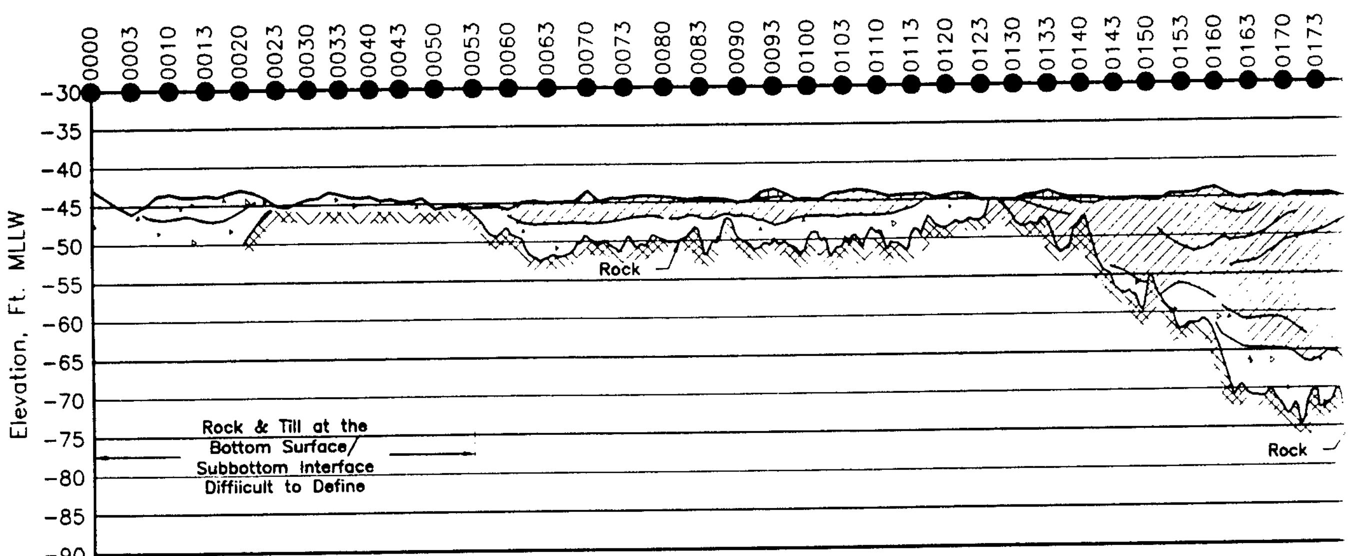

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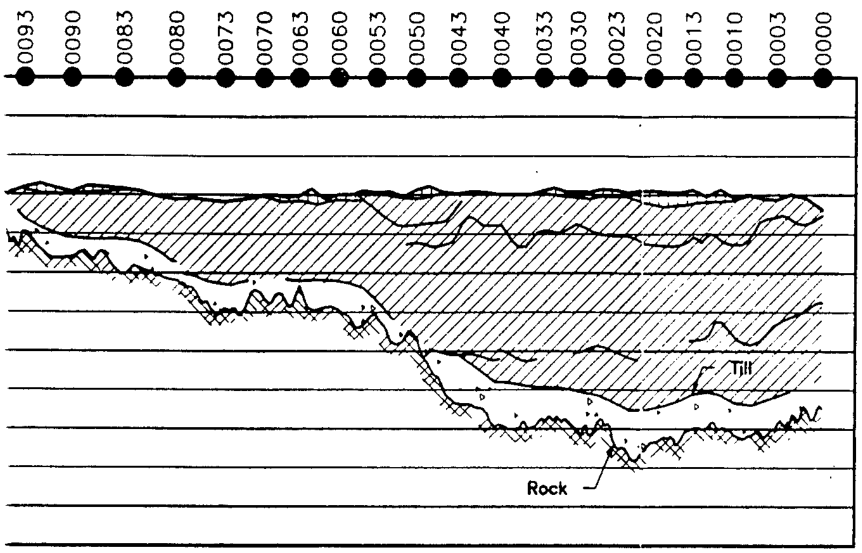
PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS



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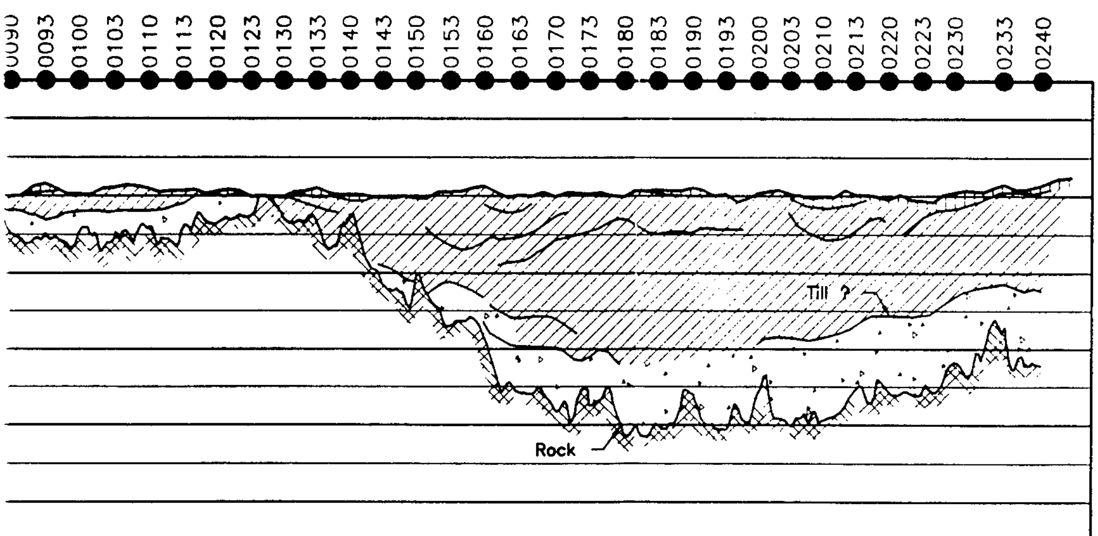

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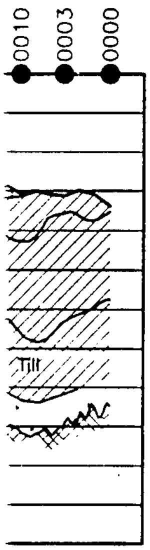

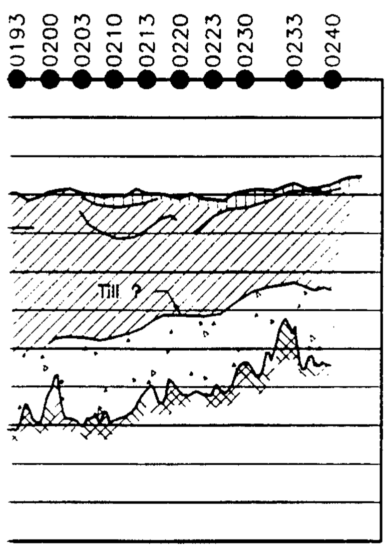

PLATE # 14 SCALE: 1"=250' 10 OCTOBER 1996

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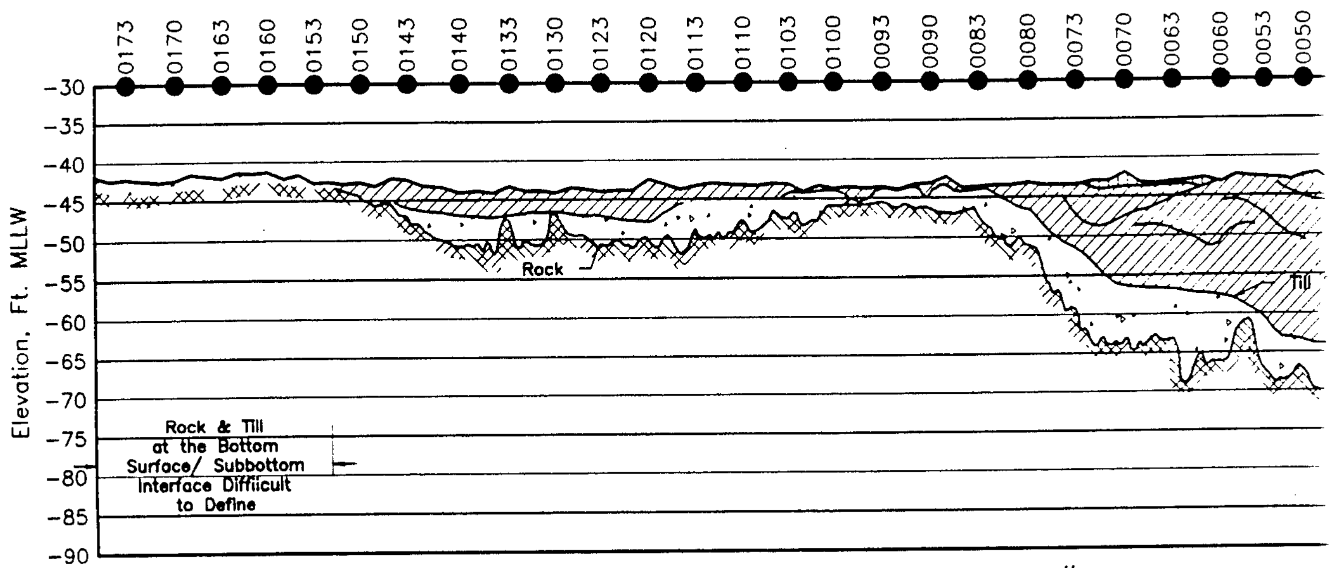
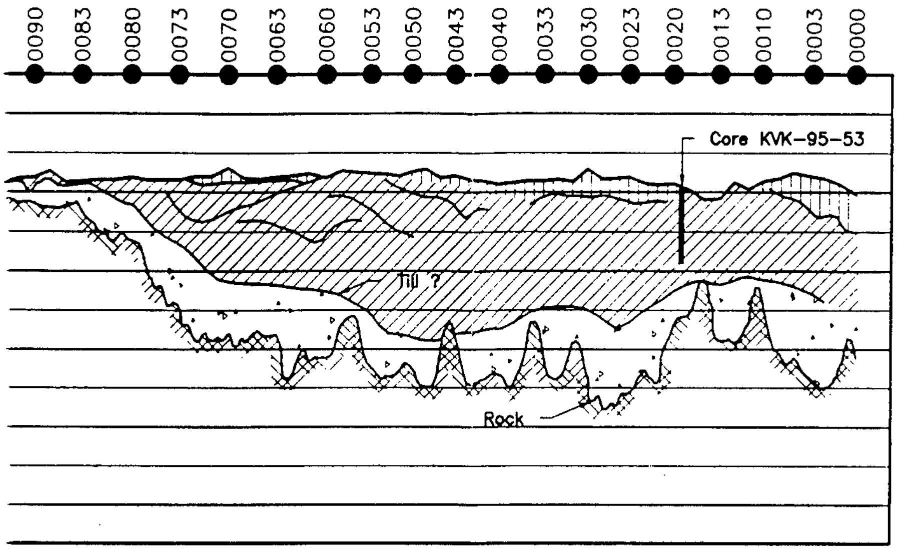


WES SURVEY LINE # PN08

PROJECT AREA: NEWARK BAY, NEW YORK & NEW JERSEY CHANNELS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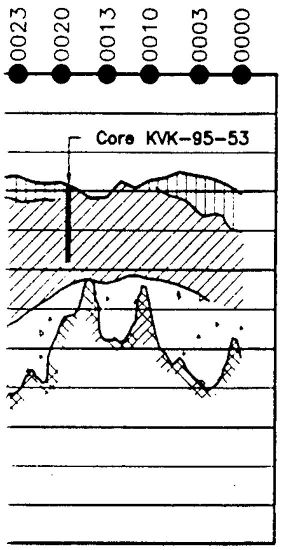

PLATE # 15 SCALE: 1"=250' 10 OCTOBER 1996

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REPORT DOCUMENTATION PAGE

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5. FUNDING NUMBERS	
6. AUTHOR(S)	Keith J. Sjostrom, Rodney L. Leist
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road, Vicksburg, MS 39180-6199
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13. ABSTRACT ***(Maximum 200 words)***

A high-resolution seismic reflection and side scan sonar survey was performed in Kill Van Kull and Newark Bay, NY/NJ. The geophysical data are intended to delineate the subbottom sediment and rock interfaces and provide a general interpretation of the bottom and subbottom sediments to elevations of -47 ft MLLW; approximately 5 ft below the current channel bottom. The geoacoustic data are correlated with available core information. The results are intended to supplement previously obtained corings by providing continuous profile line coverage of the bottom and subbottom lithology along the length of each project area. Two high-resolution subbottom profiling systems and a side scan sonar system were used to collect the geophysical data. The results are illustrated in geologic cross sections and referenced to UTM NAD 1983 Zone 18 positioning coordinates.

14. SUBJECT TERMS	Geophysics Kill Van Kull Newark Bay New York Harbor Seismic reflection
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