SITE CHARACTERIZATION REPORT - REVISED GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION

HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

VOLUME 1 - TEXT, FIGURES, TABLES

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February 15, 2002

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Re: Hyde Park Remedial Program
Site Characterization Report

Dear Ms. Sosa and Mr. Jackson:

Enclosed you will find the "Site Characterization Report – Revised Geologic and Hydrologic Characterization" submitted as part of the Hyde Park remedial program. This report caps the tremendous effort made during 2001 to fully recharacterize the site and has identified the need for an ongoing hydrogeologic characterization (Section 5.0); this work will be carried out in the first half of 2002.

We appreciate the input EPA, DEC and their consultants have provided during the 2001 remedial program field work and evaluation. If, after reviewing this report, you would like to schedule a group meeting for presentation or discussion, we are available after March 4th. Please feel free to contact any member of the group, including SSPA, SEDA and CRA, should you have further questions.

Sincerely,

George W. Luxbacher, P.E., Ph.D.

Encl.

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TABLE OF CONTENTS

LIST OF FIGURES

(Following Text)

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The *Site Characterization Report – Revised Geologic and Hydrogeologic Characterization*, presents a refinement to the current characterization of hydrogeologic conditions at the Hyde Park Landfill Site. The report provides descriptions of a historical data review, an intensive field investigation completed in 2001, and the evaluation of these data.

The Hyde Park Landfill Site in the Town of Niagara, New York, is a former Hooker Chemical Corporation disposal facility that operated from 1953 to 1975. During the period of operation, the Landfill received approximately 80,000 tons of chemical waste, including non-aqueous phase liquids (NAPL). The chemical wastes were primarily chlorinated organic compounds and phenols.

The Landfill was closed by Occidental Chemical Corporation (OCC) in 1975 and in 1978 was covered with a clay cap. Several remedial systems have been installed to control the flow of groundwater. The first wells of the bedrock groundwater extraction system, collectively designated the NAPL Containment System, were installed in 1993 and 1994, to control the migration of NAPL and groundwater affected by NAPL. This system has been operational since 1994, and has been modified and augmented since that time. It has removed a significant mass of pure phase and dissolved chemicals, and reduced the loading to the Niagara River Gorge.

A hydraulic monitoring network was installed to evaluate the performance of the NAPL Containment System. Performance monitoring requirements were defined for the network in a *Stipulation on Requisite Remedial Technology Program* (RRT). To date, the NAPL Containment System has satisfied the remedial objectives of the RRT in all but the northwestern portion of the Site.

In response to difficulties in demonstrating hydraulic containment in the northwestern portion of the Site, Miller Springs Remediation Management, Inc. (MSRM) commissioned a modeling study of the bedrock aquifer, a review of historical data, and an assessment of the hydraulic monitoring network. These efforts were completed in 2000. The results suggested that the difficulties in satisfying the performance monitoring requirements might be related to the design of the monitoring network and the conceptual hydrogeologic model of the Site, and not necessarily a failure of the NAPL Containment System to achieve the performance objectives. Based on these findings, an extensive investigation effort was proposed for 2001. The objective of the 2001 investigations was to refine, and if necessary revise the Site geologic and hydrogeologic characterization. These investigations included:

- a borehole geophysical logging program;
- a borehole camera logging program;
- a borehole flowmeter profiling program;
- the lithologic and stratigraphic re-logging of existing drill core;
- mapping of outcrops; and
- the determination of the physical properties of selected intact drill core.

The results from these studies have been interpreted by the MSRM Technical Team and are presented in this report.

The geologic studies demonstrate that the geology of the Lockport Group at the Site is consistent with the regional geologic conditions described in publications of the United States Geological Survey and the New York State Geological Survey. The Site geologic characterization has been revised to conform to the current USGS geologic nomenclature presented in Brett et al. (1995). The Site geology is generally characterized as nearly flat-lying planar beds of dolomite with shaly intervals. The geologic strata are generally continuous over the Niagara region. Geologic bedding at the Site dips to the south-southeast at approximately 40 feet per mile, consistent with regional studies.

The revised hydrogeologic characterization presents a refined conceptual model of the groundwater system. The refined conceptualization is a framework to support evaluation and monitoring of the groundwater system. The revised hydrogeologic characterization integrates Site conditions with the regional conceptualizations developed by Johnston (1964) and Yager (1995). Johnston and Yager identified a combined total of eleven, bedding-parallel, flow zones in the region. The eleven regional flow zones have been identified at the Site. Horizontal groundwater flow occurs primarily within these flow zones. The flow zones are separated by aquitards. Groundwater flows vertically downwards through vertical fractures in the aquitards.

The revised hydraulic characterization described here represents a significant refinement of the existing Site characterization that conceived of Upper, Middle, and Lower bedrock monitoring intervals. The refined characterization demonstrates that the existing bedrock monitoring wells intercept multiple flow zones. This is particularly the case for the Upper bedrock monitoring wells; for many of these wells, the open intervals intersect different flow zones at different wells. The water levels in these wells provide weighted-averages of conditions in multiple flow zones, and are not reliable data for the demonstration of hydraulic containment as mandated in the RRT.

The refined hydrogeologic characterization highlights the limitations of the existing monitoring well network. However, further studies are required to complete the Site characterization. The hydrogeologic framework is defined in this report. Additional water level data from piezometers monitoring discrete flow zones are needed to fully assess groundwater flow. Additional detailed monitoring and hydraulic testing will be performed to complete the Site characterization. Using the new framework and the additional data collected, a groundwater flow model will be developed. The interpretations of the additional data and the model analyses will support the development of a performance-monitoring program for the NAPL Containment System that is capable of demonstrating the achievement of the remedial objectives for the Site.

1.0 INTRODUCTION

1.1 PURPOSE

Miller Springs Remediation Management, Inc. (MRSM) and Glenn Springs Holdings, Inc. (GSHI), have prepared the following Site Characterization Report (SCR) - Revised Geologic and Hydrogeologic Characterization for the Hyde Park Landfill Site. The report is a joint effort of a Technical Team comprising MSRM and GSHI, Conestoga-Rovers & Associates (CRA), Sayko Environmental Data Analysis (SEDA), and S. S. Papadopulos & Associates, Inc. (SSP&A). The report has been prepared to present the results of the additional Site geologic and hydrogeologic characterization activities undertaken since June 2001; and, to provide a revised hydrogeologic characterization. This additional work consisted of:

- drilling and geologic logging of 15 new monitoring wells and 5 new purge wells;
- geophysical logging of 117 monitoring wells and 17 purge wells;
- borehole camera logging of 24 monitoring wells;
- borehole flowmeter logging of 44 monitoring wells;
- local outcrop mapping; and
- petrophysical testing of samples of intact rock.

The findings of these recent investigations, and the revised hydrogeologic characterization, are consistent with the regional conceptualization of groundwater flow presented by others (e.g., Yager, 1996). The refined conceptual hydrogeologic characterization will guide the design of an appropriate water level monitoring network, the formulation of a new groundwater flow model, the development of a new NAPL Plume Containment System monitoring program, and, as necessary, modification of the bedrock NAPL Plume Containment System.

1.2 BACKGROUND

The Hyde Park Landfill Site (Site) is a former Hooker Chemical Corporation disposal facility that operated from 1953 to 1975. Occidental Chemical Corporation (OCC) closed the facility in 1975. The Site occupies approximately 25 acres in the northwest portion of the Town of Niagara, New York. Figure 1.1 presents the Site location and nearby major structures. Figure 1.2 presents a detailed Site plan, indicating the locations of the monitoring and purge wells.

During the period of operation the Landfill received approximately 80,000 tons of chemical waste, including non-aqueous phase liquids (NAPL) (Interagency Task Force on Hazardous Wastes, 1979). The chemical wastes consisted predominately of chlorinated organics including hexachloropentadiene, chlorinated acids, chlorinated toluenes, benzenes, and phenols. The Landfill was closed in 1975 and a clay cap was installed in 1978.

On April 30, 1982, the United States District Court (Court) approved a "Stipulation and Judgement Approving Settlement Agreement" (Settlement Agreement) between OCC and the United States Environmental Protection Agency (USEPA) and New York State Department of Environmental Conservation (NYSDEC). Subsurface investigations were performed at the Site under the Settlement Agreement. The geologic and hydrogeologic characteristics of the Site were originally evaluated in a series of investigations conducted by CRA between 1983 and 1986 (CRA, 1983a; 1984). The initial subsurface investigations also identified significant chemical migration through the overburden into the underlying bedrock, including the presence of NAPL.

The requirements for remediation at the Site were presented in the *Stipulation on Requisite Remedial Technology (RRT) Program* (RRT Stipulation), which was approved by the Court on August 11, 1986. The remedial systems specified in the RRT Stipulation included the bedrock NAPL Containment System. The purpose of the bedrock NAPL Containment System was to contain, to the extent practicable, the NAPL and impacted groundwater within the NAPL plume boundary. The performance of the bedrock NAPL containment system was based on the achievement of inward horizontal hydraulic head differentials across the NAPL plume boundary.

The bedrock NAPL containment system commenced operation in 1994. The system has undergone a number of improvements since that time, including the installation of additional bedrock purge wells and the recently completed upgrade of the groundwater treatment plant. However, demonstrating hydraulic containment in the northwestern portion of the Site with the inward horizontal head differential criterion has been problematic.

In 2000, MRSM and GSHI retained SSP&A to quantitatively analyze groundwater flow conditions at the Site. SSP&A reviewed Site data and developed a numerical groundwater model, documenting the results of their study in three reports (SSP&A, 2000; 2001a; 2001b). MSRM and GSHI also retained SEDA as a senior peer reviewer for the modeling, and to provide technical oversight of the field studies. SEDA also evaluated the existing monitoring well network and water level database. SEDA (2001) identified wells that may provide water level data that are not representative of the bedrock units.

The USEPA and NYSDEC reviewed the groundwater modeling and non-representative well reports. They generally agreed that the groundwater flow model was reasonably consistent with available data and simulated general flow directions at the Site; however, they questioned the utility of the model to predict the capture zones of the purge wells. The concern was not based on the groundwater modeling efforts, but on the characterization of the Site. The Agencies believed that use of the Upper, Middle and Lower bedrock monitoring wells did not provide information on the discrete bedding-parallel flow zones that were identified in regional studies (i.e., Johnston, 1964; Miller and Kappel, 1987; Yager and Kappel, 1987; Yager, 1996). The work presented here is intended to address these concerns. MSRM and GSHI intend to develop a refined groundwater flow model based on this Site characterization as presented in this report.

1.3 REPORT ORGANIZATION

The SCR is organized as follows:

Section 1.0	Introduction - presents the purpose of the report and the background information that led to the development of the revised conceptual hydrogeologic characterization for the Site.
Section 2.0	Sources of Information - identifies the sources of data used to develop the revised conceptual hydrogeologic characterization.
Section 3.0	Geologic Characterization - presents a description of the regional and Site stratigraphy, lithology, and geologic structure.
Section 4.0	Hydrogeologic Characterization - presents a summary of the regional flow zones and the Site flow zones identified from the characterization data.
Section 5.0	Completion of the Hydrogeologic Characterization - presents the scope of work required to complete the characterization with respect to the direction of groundwater flow and physical properties of the bedrock flow zones.
Section 6.0	References.

Figures and Tables

Appendices

2.0 SOURCES OF INFORMATION

Numerous sources of information have been reviewed to develop the revised geologic and hydrogeologic characterization for the Site. These information sources are listed below:

- USGS and NYSGS Publications;
- graduate theses;
- communications from the USGS;
- consultant reports; and
- Site studies described here.

A complete list of references is provided in Section 6.0. This report and the appendices to this report provide details of the Site studies.

3.0 GEOLOGIC CHARACTERIZATION

3.1 INTRODUCTION

The geologic characterization presents a summary of published regional geologic studies, historical Site data, and the results of geophysical/Site investigations completed in 2001. Contour maps and cross-sections describing the stratigraphy in the vicinity of the Site are included, as well as an analysis of the vertical distribution of fractures.

The objectives of the geologic characterization are to document the current understanding of geologic conditions at the Site, and to make the Site geologic nomenclature consistent with the currently accepted USGS nomenclature.

3.2 REGIONAL GEOLOGY

Several regional geological and hydrogeological studies have been conducted in the Niagara region. These studies have focused on two major aspects: the geology - stratigraphy and depositional environments; and the hydrogeology - movement of groundwater in the bedrock.

The most current stratigraphic nomenclature and lithologic descriptions for the Niagara region are presented in a USGS publication (Brett et al., 1995). Brett et al. (1990) also described the depositional environments and erosional surfaces relative to sea levels for the Niagaran series of rocks.

The geology of the Niagara region consists of a generally thin blanket of unconsolidated Wisconsin-age glacial sediments overlying Silurian-age bedrock. The major water-bearing units in the Niagara region are in the bedrock above the Burleigh Hill member of the Rochester Shale. In the vicinity of the Site, this interval includes the rocks of the Lockport Group and the DeCew Formation of the Clinton Group. Figure 3.1 presents a stratigraphic column for these geologic units.

The bedrock sequence above the Rochester Shale consists of a series of stratigraphic units composed of dolomite, argillaceous dolomite, and dolomitic shale, forming a series of tabular units that dip generally southward at about 30 feet per mile.

3.2.1 STRATIGRAPHIC NOMENCLATURE AND LITHOLOGY

The bedrock exposed in the Niagara Falls area and the Niagara Gorge have been described by numerous authors, using several different nomenclature systems. The review of nomenclature presented here is confined to the more recent work conducted by the NYSGS and the USGS.

The most recent nomenclature systems are those presented by Zenger (1965), Rickard (1975), and Brett et al. (1995). Brett et al. (1995) significantly revised the nomenclature system for the Niagara region, building upon regional stratigraphic correlations and formalizing informal unit names. The nomenclature of Brett et al. (1995) has been officially recognized by the NYSGS, and has been adopted for use at the Site. The nomenclature used in previous Site reports is compared to the nomenclature of Brett et al. (1995) in Appendix B.

Lithologic descriptions of the stratigraphic units defined in Brett et al. (1995), are summarized on Table 3.1. Only those stratigraphic units relevant to the Site are presented. The descriptions presented on Table 3.1 are also representative of the bedrock in the vicinity of the Site.

The proper names of the stratigraphic units have been shortened in this report as follows:

Formal Name	*Short Name*
Eramosa Formation	Eramosa
Vinemount Member of the Goat Island Formation	Vinemount
Ancaster Member of the Goat Island Formation	Ancaster
Niagara Falls Member of the Goat Island Formation	Niagara Falls
Pekin Member of the Gasport Formation	Pekin
Gothic Hill Member of the Gasport Formation	Gothic Hill
DeCew Formation	DeCew
Burleigh Hill Member of the Rochester Shale	Rochester Shale

3.2.2 DEPOSITIONAL ENVIRONMENTS

Brett et al. (1990) described the depositional environments of the Niagaran Series (i.e., Medina, Clinton, and Lockport Groups) in western New York. The following summary, adapted from Brett et al. (1990), is provided to aid in understanding the local stratigraphy. The reader is referred to Brett et al. (1990) for additional information.

The Niagaran Series of bedrock was deposited in the northwestern portion of the Appalachian Basin. The resulting lithology is reflective of changes in water depth. In general, fine-grained materials were deposited in deeper, quiet water settings. Coarse-grained materials were deposited in shallower water settings. The relationships between relative water depth and the regional bedrock stratigraphy and lithology, as defined by Brett et al. (1990), are presented on Figure 3.1.

Figure 3.1 indicates that most of the stratigraphic units were deposited in pelagic (deep water) settings. This resulted in a stratigraphic sequence consisting of uniform, regionally-extensive, horizontally continuous, and, for the most part, conformable strata. The sedimentary rocks are essential flat-lying, planar, and gently dipping (less than 1°).

3.2.3 REGIONAL FRACTURES

Several investigators have mapped regional fractures. Johnston (1964) noted that bedding-plane fractures were most significant with respect to groundwater flow, and in some cases were noted to be extensive. IJC (1974) noted open bedding fractures at several stratigraphic intervals along the face of the American Falls, in particular within the upper third of the Ancaster/Niagara Falls, near the Ancaster/Vinemount contact, and at the Vinemount/Eramosa contact.

The orientations of the vertical joints mapped in the various investigations are shown on Figure 3.2. The primary orientations of the regional vertical joints are:

- N.30°E. to N.50°E.;
- N.70°E. to N.90°E.; and
- N.20°W. to N.30°W.

Isachsen and McKendree (1977) reviewed published mapping of brittle geologic structures in the Niagara region. They did not identify any fault structures.

The regional vertical fracture orientations are approximately parallel and perpendicular to the current regional stress field indicated by Tepper et al. (1990). Sheeting joints, that is, vertical joints formed locally from the lateral stress relief (exfoliation), were noted in the Rochester near the American Falls. The sheeting joints in the Rochester Shale are related to localized stress fields caused by erosion and rock falls at the American Falls, and the Rochester Shale is essentially intact away from the face of the American Falls (IJC, 1974).

Various investigators have noted that bedding-plane fractures and vertical joint sets are concentrated in the shallow portion of the bedrock, irrespective of the stratigraphic unit (Johnston, 1964; IJC, 1974; and Tepper et al., 1990). Generally, fractures or joints do not extend into or through the Rochester Shale (IJC, 1974).

3.3 SITE INVESTIGATIONS

3.3.1 PRE-2001 INVESTIGATIONS

Numerous investigations have been conducted at the Site since 1979.

The *Hyde Park-Bloody Run Aquifer Survey* (CRA, 1983a) presented information gathered from the core drilling and testing of 50 bedrock wells along eight vectors that radiate from the Site. These original vector wells were open across the full thickness of the Lockport to the top of the Rochester Shale. They have been abandoned, grouted, and replaced with the current Upper, Middle, and Lower bedrock vector monitoring wells.

The *Lockport Formation Investigation* (CRA, 1983b) presented the results of outcrop mapping of fracture and joint orientations along the NYPA access road west of the Site. The primary observations were that fractures were more frequent in the upper part of the bedrock, and that fractures were vertical or near-vertical.

Between 1983 and 1992, bedrock investigations and construction activities were focused on meeting the requirements of the RRT Stipulation. These activities included the installation of a community early warning monitoring network, and the construction of a bedrock NAPL Plume Containment System and monitoring network. The results of these investigation and construction activities were reported in a sequence of reports and technical memoranda.

In 1993, the document Identification of Major Hydraulic Units of the Lockport Formation was submitted as Appendix B of the Drilling Summary Report, RRT Well Installations (CRA, 1993). The document, dated April 16, 1991, provided a conceptual hydrogeologic framework for the bedrock at the Site. The bedrock above the Rochester Shale was subdivided into three monitoring intervals, the Upper, Middle, and Lower bedrock. The approximately 170 existing monitoring wells at the Site have been completed and named following that subdivision. The monitoring interval is indicated by the letter U, M, or L at the end of the well identifier, e.g., B1U, B1M, and B1L.

Between 1993 and 2001, additional bedrock investigations and construction activities focused primarily on augmenting the bedrock NAPL Plume Containment purge and monitoring well network, and the installation of the APL Plume Containment System. The construction activities were conducted in phases; the results of the activities were presented in a sequence of annual reports, quarterly monitoring reports, and technical memoranda.

3.3.2 SUMMARY OF 2001 INVESTIGATIONS

During 2001, MSRM completed several tasks to improve the geologic and hydrogeologic characterization of the Site. These tasks completed during 2001 included:

- a borehole geophysical logging program;
- a borehole camera logging program;
- a borehole flowmeter profiling program;
- the drilling and geologic logging of new monitoring and purge wells;
- the lithologic and stratigraphic relogging of existing drill core;
- mapping of outcrops; and
- the determination of physical properties of selected samples of drill core.

Each of these tasks is discussed briefly below.

Borehole Geophysical Logging Program

The principal objective of the borehole geophysical logging program was to locate water-bearing features in the bedrock at the Site. American and Canadian researchers with the USGS and National Water Research Institute (NWRI) previously used borehole geophysics in the Niagara region to aid in the identification of bedrock fractures (Kappel and Tepper, 1992; Novakowski and Lapcevic, 1988).

The 2001 Site borehole geophysical logging program consisted of:

- geophysical logging of 134 wells;
- geophysical relogging of eight wells with the nearby purge wells not operating; and
- geophysical logging of eight off-Site monitoring wells at a nearby site north of the forebay canal.

The wells north of the forebay canal were logged to aid in the assessment of the regional extent of fractures. However, since there was no drill core available to ascertain the stratigraphic contact elevations, the data were not used for fracture analysis.

MSRM retained Century Geophysical Corporation (Century) to complete the geophysical program. The geophysical logging conducted by Century included:

- caliper logging;
- natural gamma logging;
- spontaneous potential logging;
- fluid resistivity logging;
- 16-N and 64-N resistivity logging;
- lateral resistivity logging;
- single point resistivity logging;
- fluid temperature and delta temperature logging;
- P-wave sonic logging; and
- acoustic televiewer logging.

The acoustic televiewer used by Century was too narrow for logging in the purge wells (nominal diameter of 12 inches). Occidental Oil and Gas Company (OOGC) personnel suggested that Formation Micro Imager (FMI) logging could be performed on the larger diameter purge wells to provide similar data to the acoustic televiewer (Mike Metz, personal communication). MSRM retained Schlumberger Limited (Schlumberger) to complete the FMI logging. Due to the size of the FMI logging tool (approximately 40 feet long), only three purge wells had sufficient saturated intervals to complete logging (PW-1L, PW-2M, and PW-8M). A section of the PW-2M FMI log with the interpretation of fractures is provided on Figure A.4 of Appendix A.

The complete details of the borehole geophysical logging program, and 2-page summary logs, are presented in Appendix A.

Borehole Camera Logging

MSRM is conducting ongoing logging of monitoring wells with a downhole camera. The camera is a GeoVision Micro M3 Color Camera, with video logged via a Sony Super 8 Video Camera Recorder at ground surface. Twenty-four (24) wells in ten clusters have currently been logged with the camera. The downhole camera provides a detailed visual impression of conditions along a borehole. The video records for 11 wells have been examined in detail to obtain visual confirmation of the fractures identified with the geophysical logs and flowmeter profiles.

Borehole Flowmeter Profiling

MSRM retained Quantum Engineering Corporation (Quantum) to complete an electromagnetic borehole flowmeter profiling program. The flowmeter data were used to locate water-bearing features. The borehole flowmeter measures vertical flow within the well bore. The measurements may be made under ambient conditions to identify where flow may enter the well, flow vertically (generally downward), and exit the well. Water can be added to the well during the profiling, to enhance the identification of location(s) where the injected water exits the well. The flowmeter has a lower limit of flow detection that precludes the detection of very low flows. Wells with very low permeability do not have detectable flow under ambient or injection conditions.

The borehole flowmeter was the only instrument that demonstrated directly the presence of a transmissive fracture in the wells. The geophysical testing described above provided only indirect evidence of water-bearing zones.

The borehole flowmeter program consisted of profiling 44 monitoring wells, under ambient and injection conditions. The Quantum report is presented in Appendix C. The borehole flowmeter data are included on the 2-page geophysical summary logs in Appendix A. Discussions of the results are included in Section 4.0.

Drilling and Logging of New Monitoring and Purge Wells

During 2001, additional drilling and logging was conducted at the Site. The work consisted of drilling of new monitoring wells for general monitoring, and drilling of new purge wells and related monitoring wells to enhance the bedrock containment system.

Monitoring well clusters J5 and AB1 were installed following the 2001 system shutdown for general water level monitoring. Their locations were selected to supplement the observation well network north of the Landfill. An Upper, Middle, and Lower bedrock monitoring well were installed at each location. The locations of these monitoring wells are shown on Figure 1.2. Well completion details are summarized on Table 3.2.

During 2001, 5 new purge wells were installed at the Site: four Upper bedrock wells PW-7U (retrofit of an existing NAPL recovery well), PW-8U, PW-9U, PW-10U; and one Middle bedrock well, PW-8M. Nine additional monitoring wells were installed close to the new purge wells as follow:

- MW1-2001 to MW7-2001 for monitoring drawdown response to pumping purge wells PW-8U, PW-9U, and PW-10U; and
- CD-5U and CD-6U for use as injection wells to complete a future tracer study with PW-7U.

The locations of these new monitoring and purge wells are shown on Figure 1.2.

The Stratigraphic and Instrumentation Logs for the new monitoring and purge wells are provided in Appendix D.

Lithologic Logging Program

The lithologic logging program consisted of the relogging of available drill core from 62 existing boreholes, as well as the new purge and monitoring well cores. The cores were relogged to update the Site geologic data to the stratigraphic nomenclature of Brett et al. (1995), and to check apparent outlier values for contact elevations in the original core logging data. The Site-specific lithologic descriptions are discussed in Section 3.4.1 and are presented in Appendix B.

Outcrop Mapping

In September 2001, personnel from the Technical Team performed a limited survey of outcrops along the NYPA access road and the Niagara Gorge (Figure 1.2). The mapping was undertaken to identify vertical fractures and joints where groundwater seepage was observed, or where it appeared that significant groundwater seepage might have occurred in the recent past. The results of the mapping are summarized in Appendix E.1, and discussed in Section 3.4.6.

Physical Properties Testing

At the suggestion of Occidental Oil and Gas Corporation (OOGC), selected representative samples of bedrock drill core from the J5 well cluster were tested to determine petrophysical properties, including:

- porosity;
- permeability;
- grain density;
- bulk density; and
- compressional and shear acoustic velocity.

Core Laboratories (Core) in Houston, Texas performed the petrophysical testing. The results of the petrophysical analyses are presented in Appendix F and are discussed in Section 3.4.5.

3.4 SITE GEOLOGY

3.4.1 SITE LITHOLOGIC DESCRIPTIONS

Lithologic descriptions of the regional stratigraphic units are summarized on Table 3.1. Appendix B provides a detailed discussion of each stratigraphic unit of interest at the Site, the unit contacts, and photographs of local outcrops and selected drill core. The lithology observed at the Site is consistent with the regional descriptions. Table 3.3 presents a summary of published data on unit thicknesses for the Niagara region, and of the data collected at the Site. In general, the unit thicknesses observed at the Site are similar to regional observations. The thickness values presented on Table 3.3 should be considered with the recognition that there may be a relatively large uncertainty associated with the identification and measurement of unit contacts. The uncertainty is discussed in detail in Appendix G.

3.4.2 INTERPRETATION OF DATA

The interpretation of the data collected during the 2001 Site investigations for geologic characterization included:

- contouring of the lithologic contacts;
- comparing the gamma logs with the lithology; and
- evaluation of the distribution of fractures.

During the evaluation of the lithologic contact data, a number of outlier points were identified in the original data. Comparison of the original data with the results of the geophysical logs suggested that the vertical location of the contacts in a number of wells had either been picked or recorded incorrectly, had significant measurement error, or all three.

In response to the identification of outlier data, all available drill cores were lithologically relogged. Table 3.4 presents a list of the wells that were relogged and the elevations of the tops of the stratigraphic units. Only the data from relogged cores were used in the interpretation of the lithologic contacts presented here.

The identification of a lithologic contact has a subjective component. The subjective nature of the contact reflects the following:

- there are several potential criteria for picking a contact;
- many of the contacts are gradational in nature; and
- the stratigraphic units are lithologically similar.

There is also uncertainty in the measurement related to the survey of grade (the elevation datum). Based on an analysis presented in Appendix G, it was concluded that the accuracy of the contact picks appears to be about ±3 feet, and potentially as large as ±5 feet. As a result, some of the bends in the top of unit contours presented in the following section may be related to unavoidable uncertainties in picking the contact elevation rather than a true variation in the contoured surface. In general, observations of stratigraphic units in the outcrops along the NYPA access road and the Niagara River Gorge suggest that the units are approximately flat-lying, planar, and uniformly thick.

3.4.3 CONTOURS OF THE LITHOLOGIC CONTACTS

Figures 3.3, 3.4, and 3.5 present the elevations of the top of the following:

- bedrock;
- Vinemount; and
- Ancaster.

Figure 3.3 presents the elevation of the bedrock surface. The uppermost bedrock units have been affected by glacial and pre-glacial erosion. Over most of the Site, the uppermost bedrock unit is the Eramosa. Along the northwestern side of the Site, the Eramosa is truncated and the Vinemount forms the uppermost bedrock unit. Near monitoring wells ABP-8 and APW-2, localized erosion has removed the Vinemount and most of the Ancaster/Niagara Falls. The bedrock low identified at ABP-8 and APW-2 is not apparent along the NYPA access road adjacent to these wells.

Figure 3.4 presents the elevation of the top of the Vinemount. Along the northwestern portion of the Site, the upper surface of the Vinemount is eroded, and the contours of the top of the unit are not presented.

Figure 3.5 presents the elevation of the top of the Ancaster. Along a small area near the Niagara Gorge, the upper surface of the Ancaster is also eroded, and the contours of the top of the unit are not presented.

Figures 3.6, 3.7, 3.8, and 3.9 present the elevations of the top of the following units:

- Pekin;
- Gothic Hill;
- DeCew; and
- Rochester Shale.

The full thicknesses of the Pekin, Gothic Hill, and DeCew appear to be present over the Site area. At the Site, it appears that these units have not been eroded since lithification. The top of the DeCew has been reported to represent a regional, erosional unconformity (Brett et al., 1995). However, no erosional features have been observed in the cores or outcrops, or are suggested from the contours presented on Figure 3.8.

The lithologic contacts at the Site may be characterized, within the margin of measurement error, as uniformly planar and parallel to the overlying and underlying units. Apparent deviations from an ideal plane surface are attributed to uncertainties in determining stratigraphic contact elevations (as discussed in Appendix G) and to depositional variations. The contact surfaces strike approximately N.70°E. and dip to the south-southeast at approximately 40 feet/mile.

3.4.4 GEOLOGIC CROSS-SECTIONS

A three-dimensional geologic model has been created for the Site using the Environmental Visualization System (EVS). The three-dimensional model is included on a compact disc (CD) enclosed with the report. The model is in a format that is compatible with the freeware 4-D Interactive Model Viewer, which is included on the CD. Using the 4-D Interactive Model Viewer, the model can be rotated in any direction, zoomed into or out of, and changed from orthographic to perspective view. Instructions on how to use the Interactive Viewer are also included on the CD.

EVS has been used to create two sections for the report, one along strike and one along dip. The cross-section locations are shown on Figure 3.10. Cross-section A-A', Figure 3.11, is along strike. This cross-section shows the limited extent of the Eramosa Formation. As well, the planar nature of the complete stratigraphic section is apparent. Cross-section B-B', Figure 3.12, is along dip.

3.4.5 PROPERTIES OF THE INTACT ROCK

Petrophysical testing of drill core samples was conducted to determine the physical properties of the intact rock. These tests included porosity, permeability, grain density, bulk density, and compressional and shear acoustic velocity. Details of the tests and additional discussion of results are presented in Appendix F.

The porosity values determined for the intact bedrock ranged from 3.5 to 7.6 percent. These values are consistent with published values for limestone and dolomite (Table 2.4, Freeze and Cherry, 1979). The grain densities range from 2.83 to 2.85 g/cm^3, values consistent with the density for the mineral dolomite, 2.85 g/cm^3 (Deer et al., 1966). The bulk densities of the bedrock samples ranged from 2.71 to 2.73 g/cm^3, consistent with a total porosity of 4 to 5 percent.

The laboratory determined hydraulic conductivities ranged from 4.3×10^{-7} to 4.2×10^{-10} cm/sec. These values are consistent with values for intact dolomite (Table 2.2, Freeze and Cherry, 1979). They are several orders of magnitude lower than the slug test and packer test results for the Site (summarized in Appendix H and further discussed in Section 4.0). The difference is attributed to the presence of fractures in the rock mass tested *in situ*; these fractures are absent from the intact core sample analyzed in the laboratory.

The petrophysical testing results were sent to OOGC to aid in the determination of porosity from the P-wave sonic geophysical logs run on 74 boreholes. The laboratory determined acoustic velocity was used by OOGC to calibrate P-wave sonic (sonic) logs. OOGC used the following equation to determine porosity from the sonic logs:

$$\text{Porosity} = \frac{\Delta T\text{-}\Delta T_{MA}}{\Delta T_F\text{-}\Delta T_{MA}} \frac{1}{CP} \tag{1}$$

Where:
ΔT = Sonic log travel time;
ΔT_{MA} = matrix travel time (μsec/ft);
ΔT_F = Fluid travel time (μsec/ft); and
CP = Compaction factor.

Typical values for ΔT_{MA} for dolomite and ΔT_F for water are 44 μsec/ft and 189 μsec/ft, respectively (Schlumberger, 1987). By calibrating observed and predicted porosities of core samples, OOGC determined that a value for CP of 1.45 was appropriate to calculate porosity from the sonic logs. The log processing software Powerlog was used to solve equation 1 with the above-noted parameter values. The calculated porosity values were similar to those determined in the laboratory.

The results of the petrophysical testing suggest that the hydraulic conductivity of the intact rock at the Site is very low. The hydraulic conductivities estimated from the laboratory measurements are much lower than those estimated from single-well response tests at the Site (summarized in Appendix H), suggesting that groundwater flow at the Site is controlled by the secondary porosity of the rock, in particular, bedding-plane fractures. The inference that groundwater flow occurs primarily in the secondary porosity of the rock, and in particular, discrete bedding-related features, is consistent with the conceptual hydrogeologic models formulated by Johnston (1964) and Yager (1996). Yager (1996) indicated that the rock matrix transmits negligible amounts of groundwater because of the low primary porosity. Based on the porosity results discussed in Section 3.4.6, the rock matrix porosity is in the range of 5 percent. Although Yager (1996) is correct that the rock matrix transmits negligible groundwater, the reason is more likely due to the low conductivity of the intact material rather than low porosity.

3.4.6 FRACTURES AND JOINTING

Based on inspection of local outcrops and review of the 2001 Site investigation data, three categories of fractures have been defined at the Site:

- near-horizontal;
- dipping fractures; and
- near-vertical fractures.

The near-horizontal fractures are bedding-related; for the purposes of this study they have been defined as fractures having a dip of less than 5°. The dipping fractures are defined here as having a dip between 5° and 75°. "Near-vertical" is taken here to mean having a dip greater than 75°.

All three categories of fractures have been observed in outcrops near the Site. At the outcrops, the orientation of the near-vertical fractures were measured and documented. In boreholes, all three categories were documented. The elevations of fractures observed in the boreholes have been tabulated, as well as the strike and dip of the dipping fractures. The orientations of the dipping fractures were determined from analysis of the acoustic televiewer images. This information is included on tables in Appendices A and B.

Yager (1996) reports that the upper 10 to 25 feet of bedrock is weathered, and that this weathered zone contains many closely spaced horizontal (bedding-plane) fractures that are interconnected by high-angle (near-vertical) fractures. Regionally, those observations may be correct. However, based on inspection of the cores collected at the Site, the weathering zone in the vicinity of the Site is limited to only the first 2 feet of the bedrock. Visual inspection of the geophysical logs suggests that the intensity of fracturing near the top of bedrock is commonly more intense than at depth. However, this appears to be related to the type of bedrock rather than the depth below top of bedrock.

The preceding observations are based on visual inspection of geophysical logs and rock core; therefore, they reflect a subjective rather than quantitative analysis. The following discussion presents quantitative analyses of the measurements collected in outcrops near the Site, and from the geophysical logs. These analyses provide fracture elevations and orientations. However, there is no assessment of the hydraulic properties, e.g., aperture, of the fractures.

3.4.6.1 FRACTURES DETECTED IN OUTCROP

Bedding-plane fractures were commonly observed in outcrops near the Site, along the NYPA access road and the Niagara River gorge. These are typically continuous along the outcrop, and are generally associated with shaly intervals. The shaly intervals are more susceptible to weathering than the dolomite, and differential weathering has accentuated the fractures within the shaly intervals. Dipping fractures were not commonly observed in outcrops near the Site, and those that were observed were typically not continuous along dip for a significant stratigraphic interval. Differential weathering has not accentuated these fractures.

In September 2001, members of the Technical Team mapped selected vertical fractures along the NYPA access road to the Robert Moses Power Plant, and along the face of the Niagara Gorge near the Site. Only those fractures that appeared to conduct water were mapped. The results of this mapping are reported in a memorandum presented in Appendix E.1. The general orientations (apparent strikes) of the mapped fractures were:

- N.90°E., or
- N.55°E.

Bedrock outcrops to the west of the Site along the NYPA access road were also previously mapped and reported in Appendix J of the report *Pump Well Installation and Pump Test Results*, CRA (1983). This appendix has been reproduced here as Appendix E.2. It should be noted that all large, accessible fractures, including blast-induced fractures from the construction of the NYPA access road, were mapped during this investigation. The major orientations of the mapped fractures were:

- N.30°E. to N.80°E.; and
- N.170°E. to N.180°E.

Other more randomly oriented fractures were also noted.

The orientations of the fractures mapped in outcrop near the Site are presented on Figure 3.13 along with the regional data previously presented on Figure 3.1. The vertical fracture and joint orientations are similar to the regional trends discussed in Section 3.2.4, with a predominant orientation approximately parallel to the regional stress orientation (northeast).

3.4.6.2 FRACTURES DETECTED IN BOREHOLES

Fractures were identified in boreholes through the geophysical logging program and the examination of rock core. The types of fractures identified included:

- near-horizontal fractures (bedding-parallel, with a dip of less than 5°);
- dipping fractures (i.e., dips between 5° and 75°); and
- near-vertical fractures (dips exceeding 75°).

Geophysical logs, primarily the caliper and acoustic televiewer logs, were used to identify the presence of near-horizontal, bedding-related fractures. Dipping fractures were identified from the acoustic televiewer and FMI logs. Both near-horizontal and dipping fractures were observed in drill core. However, the near-horizontal and dipping fractures observed in the drill core may be related to breakage during core handling and drying of the core, rather than to *in situ* fracture partings. Therefore, the core was not used for the identification of near-horizontal and dipping fractures.

Near-vertical fractures were not readily detected by borehole geophysical methods, and were determined through an examination of rock core or noted from a review of 11 borehole video logs. It is unlikely that many of the near-vertical fractures identified in drill core resulted from core handling or the desiccation of drill core because the primary planes of weakness, the shale partings and shale beds, are horizontal.

A total of 782 fractures were identified from Site borehole geophysical logs, examination of drill core, and inspection of the borehole video logs. The fractures were identified from 59 Upper wells, 32 Middle, and 35 Lower bedrock wells. Of the total number of fractures identified, 691 were near-horizontal bedding-plane fractures (Table A.2), 28 were dipping fractures (Table A.3), and 63 were near-vertical fractures (Table B.2).

The fracture data were analyzed to estimate fracture frequency. With respect to the hydrogeologic characterization, it is important to determine consistent patterns of bedrock fracturing. In particular, it is essential to determine whether the frequency of fracturing depends on depth or lithology. In conducting this evaluation, average fracture frequencies were determined for different depths and lithologies. The results are expressed as the number of fractures per 100 feet of log/core inspected.

Figure 3.14A presents a histogram of the distribution of caliper log footage versus depth below top of bedrock. The histogram "bins" represent 10-foot intervals starting at the top of bedrock. The results shown on Figure 3.14A show that there is a gradual decline in the footage of caliper logged with depth below top of rock. Figure 3.14B presents a histogram of the distribution of acoustic televiewer footage logged versus depth below bedrock. This figure shows a similar pattern to the caliper logs.

Figure 3.14C presents a histogram of distribution of drill core by length versus depth below top of bedrock. The figure shows that the footage of core is greatest for shallow depths, and declines with depth. This is consistent with the results shown on Figures 3.14A and 3.14B. This distribution was considered in the evaluation of the presence of near-vertical fractures determined from drill core.

Bedding-Plane Fractures

Approximately 90 percent (691 of 782) of the fractures identified are near-horizontal. Table A.2 provides a listing of the near-horizontal fractures, identified by inspection of the caliper, acoustic televiewer (saturated intervals only), and the FMI logs (PW-1L, PW-2M, and PW-8M; saturated intervals only).

Figure 3.15A presents a histogram of the frequency of bedding-plane fractures versus depth below the bedrock surface. The histogram "bins" represent 10-foot intervals beginning at the top of bedrock. The frequency is calculated by dividing the number of fractures observed in each 10-foot interval by the total number of feet of caliper log in that 10-foot interval. This provides an average value of fractures per foot value for each interval. The average value was converted to number of fractures per 100 feet of caliper logging for convenience.

Figure 3.15A shows that, relative to the top of bedrock, the frequency of fractures tends to decrease with depth. However, the decrease is relatively gradual, as opposed to a rapid drop in the fracture frequency at some fixed depth below the top of bedrock. This interpretation is important to the Site characterization, as the highly transmissive zone identified in the upper 15 feet of bedrock by Johnston (1964) and subsequent investigators, is not supported by the vertical distribution of bedding-related fractures at the Site. This analysis does not account for fracture apertures that influence fracture transmissivity.

Figure 3.15B presents a histogram of the bedding-plane fractures versus stratigraphic unit. These are the same data presented in Figure 3.15A, but the histogram "bins" represent stratigraphic units rather than depth below top of bedrock. These results indicate that the frequency of near-horizontal fractures is greatest in the Eramosa, Vinemount, Ancaster/Niagara Falls, and Pekin (approximately 20 per 100 feet of caliper logging). This distribution is generally consistent with visual observations of local outcrops. The frequency of bedding-plane fractures is much lower in the Gothic Hill, DeCew and Rochester Shale (approximately 10 per 100 feet of caliper logging). The distribution of bedding-plane fractures is consistent with the lithology. For example, the Gothic Hill is a thick- to massive-bedded, coarse-grained dolomite. This unit has fewer open bedding-plane fractures than the more thinly-bedded units such as the Vinemount and the Pekin.

Dipping Fractures

Approximately 4 percent (28 of 782) of the fractures identified in the boreholes are dipping fractures, that is, the dips are between 5° and 75°. Dips of less than 5° could not distinguished from bedding-plane fractures, and the maximum dip observed was 31°. Dipping fractures were identified using the acoustic televiewer geophysical logging tool in the saturated portion of the open boreholes. Table A.3 provides a summary of the locations and orientations of identified dipping fractures, which range in dip from 6 to 31 degrees.

Figure 3.16A presents a histogram of the number of dipping fractures versus depth below the top of bedrock. The number of dipping fractures is limited compared to bedding-plane fractures; therefore, the histogram bins were increased to 30 feet. The number of fractures observed in the depth interval was divided by the total footage of acoustic televiewer logged in the depth interval. The results show very small fracture frequencies in all depth intervals (ranging from 0.5 to 3.5 fractures per 100 feet of logging). The greatest frequency was observed in the 120- to 140-foot interval below the bedrock surface. The apparently high fracture frequency is likely a statistical artifact associated with the limited length of geophysical logs over this interval.

Figure 3.16B presents a histogram of the frequency of dipping fractures versus stratigraphic unit. The figure shows that there is no apparent pattern to the distribution of the dipping fractures other than the highest frequency (approximately 2.5 per 100 feet of acoustic televiewer logging) in the Eramosa, Pekin and DeCew.

Figure 3.17 presents a stereonet analysis of the orientation of dipping fractures. The dip of the fractures is between 6 and 31 degrees. Examination of this figure shows that there is no significant clustering of fracture dip directions.

No spatial patterns in the distribution of dipping fractures were identified.

Near-Vertical Fractures

Approximately 8 percent (63 of 782) of the fractures identified are near-vertical (dips exceeding 75°). Near-vertical fractures have been logged in available drill core. In addition, three near-vertical fractures were noted on the 11 borehole video logs. The depths of near-vertical fractures are presented on Table B.2.

Figure 3.18A presents a histogram of the frequency of near-vertical fractures versus depth below bedrock. The results shown on Figure 3.18A indicate that there is a general decline in the occurrence of near-vertical fractures with depth.

Figure 3.18B presents a histogram of the distribution of near-vertical fractures versus stratigraphic unit. The greatest fracture frequency occurs in the Eramosa and then declines with depth to the DeCew. No near-vertical fractures were observed in the Rochester Shale, consistent with regional observations presented in Section 3.2.3.

No spatial patterns in the distribution of near-vertical fractures were identified.

3.5 SUMMARY

The following observations summarize the revised geologic characterization of the Site:

1. The Site stratigraphy is generally consistent in lithology, thickness, and orientation with published regional geologic information from USGS, NYSGS, and others.
2. The stratigraphic nomenclature of Brett et al. (1995) for the Lockport Group has been adopted for the Site, to be consistent with regional studies.
3. In the vicinity of the site, bedding strike is approximately N.70°E. and dips to the southeast at approximately 40 feet per mile.
4. Petrophysical testing of drill core samples indicates that the Site-specific bedrock properties are consistent with published values for dolomite bedrock. The low hydraulic conductivities of the intact samples suggest that groundwater flow occurs only in the connected fractures in the rock.
5. Fractures within the bedrock sequence have been identified through borehole geophysical logging, core logging, and outcrop mapping. The fractures consist of near-horizontal bedding-plane fractures, dipping fractures, and near-vertical fractures. The fracture identification was a simple true/false analysis and did not consider fracture aperture or hydraulic properties. In general, the average number of fractures per vertical foot of bedrock appears to decrease gradually with depth below top of bedrock. This observation appears to conflict with published reports that suggest that fracturing occurs primarily within the top 15 feet of bedrock.
6. Approximately 90 percent of the fractures identified have been classified as near-horizontal bedding-plane fractures. Bedding-plane fractures are evenly distributed within the Eramosa, Vinemount, Ancaster/Niagara Falls, and Pekin.
7. Approximately 4 percent of the fractures are detected with dipping fractures (6 to 31 degrees). There was no dominant orientation in dip direction. Dipping fractures were found most frequently in the Eramosa, Pekin, and DeCew.
8. Approximately 10 percent of the fractures identified are near-vertical fractures. These fractures were encountered most frequently in the Eramosa. Near-vertical fractures were not observed in the Rochester Shale, consistent with regional observations.

4.0 HYDROGEOLOGIC CHARACTERIZATION

4.1 INTRODUCTION

4.1.1 OBJECTIVE

The objective of the investigations performed by MSRM in 2001 has been to refine the understanding of the Site geology and hydrogeology. The hydrogeologic characterization is a conceptual model that represents a simplification of a complex groundwater system. This simplification is required to establish a tractable framework for evaluating and monitoring the groundwater system. The characterization developed in this section will be used to refine the groundwater-monitoring network, develop a new groundwater flow model, and ultimately, to define an effective and practical monitoring program for the bedrock NAPL Plume Containment System.

The hydrogeologic characterization developed here is intended to refine the characterization presented initially in the Stipulation on the RRT (United States District Court for the Western District of New York, 1986). In the Stipulation on the RRT, groundwater was conceived as flowing in the Lockport Dolomite, and eventually discharging at the gorge of the Niagara River. The characterization presented here refines the understanding of the structure of the bedrock, and in particular identifies discrete flow zones at the Site. The higher resolution of bedrock flow processes will provide the basis for a new groundwater flow model for the Site.

This section of the report presents a hydrogeologic framework, but no interpretations of groundwater flow. Although there is an extensive database of groundwater levels, the existing monitoring network does not monitor the hydrogeologic framework described here. To the extent practical, the existing water levels were reviewed with respect to the revised hydrogeologic framework. No reliable interpretation of groundwater flow could be developed.

4.1.2 REGIONAL HYDROGEOLOGIC CONCEPTUALIZATION

Johnston (1964) proposed that groundwater flow in the Lockport Group occurs primarily in discrete, bedding-parallel flow zones. The flow zones were separated by layers of typically more massive rock that acted as aquitards. Johnston's conceptual model of layered flow zones and aquitards was based largely on observations made during construction of the New York Power Authority (NYPA) Niagara Project conduits. Figure 4.1 shows the flow zones identified by Johnston (1964) along the rock-cut created for construction of the conduits linking the upper Niagara River to the NYPA forebay. Johnston marked his flow zones with a relative estimate of the flow within them, with "**XXX**" indicating the greatest flow, and "**X**" indicating the least.

Geologists and hydrologists of the USGS conducted extensive research that supported Johnston's conceptualization of groundwater flow zones in the Niagara region. The USGS expanded on Johnston's work to include a greater vertical section of the Lockport Group, and traced the flow zones laterally across the Niagara region. Progress on the conceptualization of flow zones was presented in Yager and Kappel (1987), Kappel and Tepper (1992), and Yager (1996). The work of the USGS demonstrated that the locations of the flow zones and aquitards within the stratigraphic sequence could be correlated regionally.

Yager (1996) presented the most recent USGS conceptual model of the regional hydrogeology. The USGS idealization of the bedrock hydrogeology was formulated to support the development of a numerical model of groundwater flow in the Niagara region. The USGS identified nine regionally extensive flow zones in the Lockport Group. Figure 4.2 presents a comparison of Johnston's 1964 mapping and the USGS interpretation. Johnston's stratigraphic column C reproduced on Figure 4.2 was developed from the conduit excavation located near the confluence of the NYPA conduits and the NYPA forebay. The USGS column is from well Lewiston-1 (LW-1) located along the south berm of the Lewiston Reservoir, about 3,800 feet east of Johnston's stratigraphic column. Johnston (1964) identified two lower flow zones that are not included in the Yager (1996) model. Yager (1996) identified five flow zones not included in Johnston's mapping, indicated as I-V on Figure 4.2. A synthesis of the flow zone mapping of Johnston (1964) and Yager (1996) therefore comprises 11 flow zones.

Figure 4.3 presents the USGS log of LW-1. The log presents the core breaks that indicate the locations of fractures or weakness in the rock. It can be seen that the core breaks do not always correlate with the flow zones, and some flow zones do not occur at core breaks. This suggests that the USGS recognized implicitly that only a subset of the bedrock fractures is significant for groundwater flow. The lack of core breaks at flow zones II, VI, and VIII, suggests that the USGS conceptualized flow zones as regional features that are not transmissive everywhere in the Niagara region.

4.1.3 SITE HYDROGEOLOGIC CONCEPTUALIZATION

As discussed in Section 3.4.5, the hydraulic conductivity of the intact rock at the Site is very low. Our review of Site data indicates that groundwater flow at the Site is controlled by bedding-plane fractures.

On the basis of the extensive geophysical and borehole flowmeter investigations conducted at the Site in 2001, the Technical Team has concluded that the combined total of 11 flow zones identified by Yager and Johnston are present at the Site. The eight deepest flow zones have been identified positively at the Site. The three shallow flow zones appear to be present; however, they are difficult to identify with certainty. The three uppermost flow zones occur in the Eramosa. As indicated on Figure 3.3, the Eramosa is eroded such that these flow zones subcrop beneath the Landfill.

Visual evidence of the existence of flow zones in the vicinity of the Site is presented on Figure 4.4. This figure presents a photograph of the gorge of the Niagara River viewed from the Canadian side of the river, in November 2001. Groundwater seepage is visible discharging from a horizontal, bedding-parallel zone along the northwestern-facing wall of the gorge. This seep is located near the AFW-2 well cluster. The seep occurs just above the contact between the Vinemount and Ancaster; this location coincides with the USGS-designated flow zone VI.

The flow zones at the Site are idealized as essentially parallel, planar features. On the scale of the Site, the idealization of flow zones as parallel, planar features is consistent with the inferred nature of the geologic units presented in Section 3.5. The idealization is also consistent with observations from outcrops. Figure 4.5, a panoramic photograph taken from the Butterfly Conservatory in Canada, shows planar bedding along an approximately 1/2-mile section of the Niagara River gorge. Site-related features are labeled for reference. No significant bedding parallel seeps directly downgradient from the Site are visible on Figure 4.5. The absence of local seeps is likely due to pumping by the bedrock purge wells.

4.2 BASIS FOR THE EXISTING SITE HYDROGEOLOGIC CHARACTERIZATION

The previous hydrogeologic conceptualization of the Site defined three bedrock monitoring intervals, the Upper (U), Middle (M), and Lower (L) bedrock. This characterization was presented in the *Drilling Summary Report, RRT Well Installations* (CRA, 1993). The basis for the characterization was packer testing described in *Identification of Major Hydraulic Units of the Lockport Formation*, dated April 16, 1991. This technical note was included as Appendix B of the *Drilling Summary Report.*

The results of the packer testing were used to divide the bedrock above the Rochester Shale into the Upper, Middle, and Lower monitoring intervals. The criteria that defined these intervals are summarized below.

Upper wells

The open intervals for the Upper wells were specified according to two criteria:

- the "minimum depth of Upper well installation shall be 25 feet below top of bedrock"; and
- the "maximum depth shall be approximately halfway through the first non-water-bearing interval or the top of the Eramosa (approximate maximum depth is 70 feet below top of bedrock)." [According to the stratigraphic nomenclature of Brett et al. (1995), the Eramosa is now referred to as the Vinemount.]

Lower wells

The Lower wells were open "from approximately 1 - foot below the top of Gasport Formation to the top of the Rochester Formation". According to the stratigraphic nomenclature of Brett et al. (1995), the specified open intervals for the Lower wells corresponded to the Gothic Hill of the Gasport Dolomite and the DeCew.

Middle wells

According to the *Identification of Major Hydraulic Units of the Lockport Formation*, the "delineation of the middle monitoring interval is left to whatever units are identified between the upper and lower intervals."

The existing bedrock monitoring wells were installed and are classified according to the Upper, Middle, and Lower classifications.

4.3 2001 INVESTIGATION ACTIVITIES FOR REFINEMENT OF THE HYDROGEOLOGIC CONCEPTUALIZATION

The data collected during the 2001 Site investigations that are the foundation of the revised hydrogeologic characterization are the geophysical and borehole flowmeter logs. The discrete vertical geophysical profiles were correlated across the Site, making use of the work of previous investigators. The important findings of the previous investigators are:

- groundwater flow zones are parallel to bedding;
- groundwater flow zones are regionally continuous; and
- there are eleven defined flow zones.

The evaluation presented here begins with the assumption that the previous investigators made reasonable interpretations of the data available to them.

4.3.1 FRAME OF REFERENCE FOR FLOW ZONES IDENTIFIED FROM THE GEOPHYSICAL AND BOREHOLE FLOWMETER INVESTIGATIONS

Our analysis of the results of the geophysical investigation has revealed that the gamma logs provide important insights into the structure of the groundwater system. In particular, the gamma logs provide a reliable and relatively precise basis for determining the orientation of bedding at the Site. The gamma logs provide an indirect measure of the clay content of the rock, and therefore can be used to identify distinct shaly intervals within the bedrock. Figure 4.6 presents the second page of the 2-page summary for well clusters F2 and H2. The gamma signature from the F2 cluster is typical of the Site. A comparison of the gamma signatures between wells and well clusters at the Site demonstrates a consistent signature from the bottom of the Eramosa down through the Pekin. Specific peaks in the gamma logs, indicative of shaly intervals, can be correlated across the Site.

The 2-page summary logs for all of the wells geophysically logged are included in Appendix A. Several clear overlays of the 2-page summary logs are also provided in Appendix A, to facilitate independent review of our correlations.

Figure 4.7 shows the gamma peaks visible in the logs for well F2U, F2M, F2L, H2U, H2M, and H2L. The peaks labeled on Figure 4.7, and others, can be traced across the Site. Key gamma peaks have been identified in the logs for all wells that were logged. The gamma peaks have been labeled for two reasons:

- to provide a reference for tracking the bedding across the Site; and
- to provide a reference for locating flow zones.

The key peaks are special only in that they are more prominent, and can be identified clearly. There are no other criteria for their selection.

The USGS did not use gamma peaks as a reference, presumably because the peaks are more difficult to correlate on a regional scale. However, on the Site scale the gamma signatures are clear and unique. The distinctiveness of the gamma signatures makes the gamma peaks an excellent reference system for identifying the vertical locations of the flow zones. There is evidence that this distinctiveness extends beyond the immediate vicinity of the Site. Figure 4.8 presents a comparison of the gamma signature for USGS well LW-1, presented by Brett et al. (1995), and the gamma signatures from the AGW-2 cluster. Well LW-1 is located on the berm of the Lewiston Reservoir, approximately one mile northeast of the Site. The gamma signature for LW-1 is nearly identical to the gamma signatures from Site wells. Some peaks, particularly gamma peak E (GP-E), are clearly evident on a regional scale.

For the Site, gamma peaks rather than lithologic contacts are used to trace bedding, and ultimately flow zones. As discussed in Section 3.0 and Appendix G, the identification of lithologic or formation contacts is somewhat subjective. There may be several, potentially conflicting, criteria defined to identify a contact. As demonstrated in Appendix G, use of the criteria established by Brett et al. (1995) to pick the contacts has led the same geologist, inspecting the same core at two different times, to identify picks that differ by as much as 5 feet. The gamma peaks constitute a more precise set of markers for referencing the locations of bedding-parallel flow zones than do the lithologic contacts.

The purpose of identifying and labeling key gamma peaks has been to establish a common reference for the bedding. This purpose can be accomplished by identifying any of the obvious, traceable peaks. It is not necessary to either identify or follow every gamma peak across the Site to understand the bedding. Therefore, not every gamma peak has been labeled. The labels begin at "E", near the top of the Vinemount. Although there appear to be traceable peaks in the overlying Eramosa, there are fewer data in the Eramosa than in other units, as the thickness of the Eramosa over large portions of the Site has been reduced by erosion. Labels "A" to "D" are reserved for possible later use in the Eramosa. There are also gamma peaks located between the labeled peaks that can be traced across the Site.

Table 4.1 presents a list of the elevations of the gamma peaks identified from the 2-page summary logs presented in Appendix A.1. The elevations of peaks are measured to the nearest foot. As discussed in Appendix G, the potential measurement error associated with the elevation of the gamma peaks is approximately ±2 feet.

4.3.2 INTERPRETATION OF GAMMA PEAKS AS PLANES

The locations of the gamma peaks presented on Table 4.1 have been plotted in three dimensions, and inspected to evaluate the nature of bedding beneath the Site. Figures 4.9A, B, and C present side views of these gamma peak picks. The gamma peaks have been color-coded, with a common color assigned to the same gamma peak identified in each log. As shown on Figure 4.9A, when viewed from an arbitrary angle, the locations of peaks appear to be essentially random. However, as the view is rotated, the gamma peak data begin to align. Figure 4.9B, which presents a view rotated 90° with respect to Figure 4.9A, shows a more systematic arrangement of the gamma peaks. An analysis of the spatial distribution of the gamma logs has determined that the direction of strike of the bedding is N.69°E. Figure 4.9C shows that the gamma peaks when viewed along bedding strike (strike is into and out of the page, dip is parallel to the page). The gamma peak data form essentially parallel lines (actually planes) striking N.69°E. and dipping N.159°E. at 39 feet per mile.

The surfaces containing each gamma peak on Figure 4.9C appear to be planar. Furthermore, these planes appear to be parallel. These observations suggest that bedding is planar and parallel at the Site. This characterization of the bedding is consistent with the regional mapping described in Section 3.0 and with visual observations from outcrops near the Site (cf. Figure 4.5).

A set of parallel planes has been fit to gamma peaks GP-E through GP-N. Figure 4.10 presents the three-dimensional plot of all of the gamma peak picks and the best-fit planes. The figure presents the same side view as Figure 4.9C, that is, looking along strike. The bedding-parallel planes match closely all of the gamma peaks. Figure 4.11 presents cross-section B-B′ showing the gamma logs for selected wells and the traces of the best-fit planes, along strike. The location of the cross section is shown on Figure 3.10. The section is similar to Figure 4.10, and shows the relation between the gamma signatures and the best-fit planes.

Figures 4.10 and 4.11 depict qualitatively the match between the gamma peaks and the mathematical best-fit planes. Figure 4.12 presents a probability plot of the differences between the best-fit planes and the gamma peaks listed on Table 4.1. The differences are referred to as residuals. The probability plot includes the residuals for all of data from GP-E through GP-N. Based on the discussion of measurement errors presented in Appendix G, the measurement error associated with any pick from the gamma logs is about ±2 feet. This measurement error is depicted on the probability plot.

Approximately 90 percent of the residuals are within the potential measurement error of ±2 feet. Of the residuals greater than ±2 feet, some appear to be related to survey/zero datum issues. For example, at well H2M, every residual is between -1.9 feet and -3.0 feet; i.e., every gamma peak, not just one or two, is 2 to 3 feet lower than predicted with the best-fit planes. Similarly, every one of the residuals from AGW-2M is between +2.0 feet and +2.8 feet. A geologic condition that causes a uniform offset of every gamma peak from the top of the Vinemount through the Pekin Member seems unlikely. It seems more likely that there is a survey error, or that the geophysical survey zero datum was incorrectly referenced. If the geophysical survey had been referenced to the top of the well casing at H2M instead of ground surface, the error would cause every gamma peak to appear approximately 2 feet low, i.e., the residuals would all be -2 feet. Regardless of the explanation for the residuals greater than ±2 feet, none are more than 1 foot greater than the potential measurement error.

The uncertainties in the elevations of the gamma peaks discussed above are not great enough to affect the interpretations in this report. The characterization is intended to identify Site-wide features, and is relatively insensitive to minor uncertainties smaller than 2 or 3 feet.

The conceptualization of bedding defined by parallel planes is a simplifying assumption that is mathematically and conceptually reasonable. The conceptualization is consistent with the depositional environment in which the beds were formed. This conceptualization is carried through the definition of flow zones.

4.3.3 INTERPRETATION OF WATER-BEARING FEATURES FROM GEOPHYSICAL DATA

The significance of the different borehole logging tools is discussed in Appendix A. Based on our review of the data, four of the geophysical tools provided information that was useful for identifying fractures: three-arm caliper; temperature (and delta temperature); fluid resistivity; and acoustic televiewer. These tools provided indirect indications of inflows along the open intervals, or in the case of the acoustic televiewer, indications of changes in the properties at the surface of the borehole wall. As indicated previously, the natural gamma log also provided crucial information for this investigation. Review of the gamma signatures for the wells revealed that particular peaks in the gamma response could be used as a yardstick for vertical referencing.

Only one of the borehole tools, the borehole flowmeter, provides definitive evidence that a permeable zone exists. The borehole flowmeter measures vertical flow within a borehole, under either ambient or injection conditions. Water is added to enhance the vertical flow and potentially improve the detection of water-bearing features. The QEC report on the borehole flowmeter testing is included as Appendix C.

All other geophysical measurements provide indirect evidence of a water-bearing feature. In interpreting the geophysical data, water-bearing features have been identified where the results of the borehole flowmeter profiling demonstrate that a permeable feature is present, or where one or more of the geophysical measurements strongly indicates that a water-bearing feature is present. An example interpretation is provided on Figure 4.13. Figure 4.13 presents the geophysical log for the B2 well cluster. At approximately 554 feet above mean sea level (ft AMSL), the borehole flowmeter data ("fluid flow") demonstrates the presence of a water-bearing zone (the red line shows flow under injection conditions). At 549 ft AMSL, an offset in temperature and fluid resistivity indicates another water-bearing feature. Green lines on Figure 4.13 indicate the 549 and 554 ft AMSL levels.

The interpretation of water-bearing features discussed above seems simple and was initially undertaken on a quantitative level. However, the interpretation quickly became subjective. A subjective interpretation was necessary due to several factors. Three of these factors are discussed below.

- Except for the borehole flowmeter, the geophysical measurements are indirect indicators of a water-bearing feature;
- There is some uncertainty associated with the elevation of a selected water-bearing feature due to the potential offset between the actual location of the feature and its appearance on the geophysical signal. For example, a conductivity shift occurs where water of a different conductivity enters the borehole. Depending on the rate of flow into the well, the magnitude of vertical flow at that point of entry, and the conductivity of the incoming water, the conductivity shift will be offset from the point where groundwater enters the borehole; and
- There is a balance between picking every feature that possibly indicates flow and picking only those that are unequivocal. Only the significant features need to be captured to define a conceptual model. Our experience demonstrated that identifying every detail confounds the identification of the flow zones. Studying minute detail also increases the number of incorrect picks, further confounding the characterization.

Several guidelines were developed during the review of the geophysical logs to assist in the identification of water-bearing features. These guidelines are described below.

1. Confidence in the pick should be high.
2. Data near the water surface, and at the bottom of the well casing, often appear to be unreliable. An example of noisy, unreliable data at the water surface may be seen in the log for well B1M at 527 ft AMSL. The data may be disturbed by vertical flow around the casing and/or the introduction of the tool into the water column.
3. Changes in the specific conductance (the inverse of fluid resistivity) in the Lower wells may not be indicative of groundwater flow. A layer of high conductance water is frequently observed in the Lower wells, including the Lower wells with essentially zero transmissivity and therefore, no groundwater flow. The high conductance layer is more likely related to diffusion of salt from the brine known to be present in the Rochester Shale, than to water-bearing features.
4. Some of the temperature changes are so small as to have questionable validity. Even if the changes are accurate, the flow is so small that the actual groundwater temperature is not offset, and the magnitude of the flow is likely insignificant. This general observation is tempered by the observation that the transmissivity in many Lower bedrock wells is so low that small temperature spikes may indeed be a significant indicator of groundwater flow.
5. The temperature and fluid resistivity data from re-logged wells may not be equally reliable. Pumping was stopped temporarily at some purge wells to allow for water levels in the Middle bedrock monitoring wells to recover. Under pumping conditions, the water level in many Middle wells is within the open interval. The acoustic televiewer does not work unless submerged, and in those wells with the water level in the open interval, the acoustic televiewer only recorded a portion of the open interval. Pumping was temporarily stopped at selected purge wells to allow water levels to recover, and eight Middle bedrock monitoring wells were re-logged with the acoustic televiewer. The multi-parameter tool described in Appendix A was also run after recovery to provide quality control. However, because these wells had recently refilled, the temperature and fluid resistivity profiles may have shifted and not had sufficient time to equilibrate.

Occasionally, two different measurements indicating a water-bearing feature occur at slightly different elevations. The difference in elevation may be as much as 2 or 3 feet. If these measurements are judged to represent the same feature, the water-bearing feature may be picked at an average elevation; or possibly at either extreme, based on the reviewer's judgment. Figure 4.13 shows that at B2M, the caliper and acoustic televiewer logs indicate a feature at 520 ft AMSL. The borehole fluid flow measurement shows water entering the formation between 521 and 522 ft AMSL. In this case, the water-bearing feature is picked at the midpoint in the data, 521 ft AMSL. This level is indicated by a green line on Figure 4.13.

The uncertainties in the elevations of the water-bearing features discussed above are not great enough to affect the interpretations in this report. The characterization is intended to identify Site-wide flow zones, and is relatively insensitive to minor uncertainties smaller than 2 or 3 feet.

The water-bearing features identified by inspection of the 2-page summary logs are presented on Table 4.2. As noted above, only features considered significant are identified on the table. The picks represent an attempt to balance between too fine and too coarse an interpretation of the data.

The water-bearing features can also be observed in the borehole videos being collected by MSRM. The geophysical logs generally provide more quantitative evidence of flow than do the video logs. In contrast, the video logs provide a better "feel" for what the water-bearing features look like.

4.3.4 GROUPING OF WATER-BEARING FEATURES INTO FLOW ZONES

Not all of the water-bearing features identified on Table 4.2 are flow zones. They may be points within a flow zone. However, water-bearing features will exist between flow zones. Flow zones are identified by the consistent occurrence of water-bearing features aligned along bedding.

The water-bearing features are grouped into flow zones using the conceptualization that bedding is aligned with the parallel planes fit to the gamma peaks, that the flow zones are parallel to these planes, and that water-bearing features will be observed more frequently at flow zones than between flow zones. The evaluation of flow zones was initiated by defining the plane fit to gamma peak "E" (GP-E) as a datum. This peak has been used because it is the most prominent peak in the gamma signature, it can be seen in almost every well at the Site, and it is regionally identifiable.

All points in a flow zone parallel to the GP-E plane will be offset by the same vertical distance from the GP-E plane. The vertical distances between the GP-E plane and each water-bearing feature have been calculated and are listed on Table 4.2. These distances have been inspected for clustering.

Figure 4.14 presents the results of the clustering analysis. The distances between the water-bearing feature and GP-E are sorted from smallest to largest, and plotted with a uniform spacing along the x-axis. If the water-bearing features are all from one flow zone, the data points will fall along a single horizontal line, representing a particular vertical distance from GP-E. If the features are distributed randomly, the data will fall on a single sloping line. Multiple flow zones will appear as steps on the plot. Ideally, the data for a single flow zone lie at a common distance from the GP-E plane, followed by a vertical step to the position of the next flow zone. Measurement error and the failure of nature to conform to mathematically-perfect planes, results in some deviation from the ideal horizontal line at one elevation.

The clustering of water-bearing features around common positions is clearly evident on Figure 4.14. The flow zones are identified on Figure 4.15. The discussion of flow zones presented here follows the numbering system adopted by the USGS (Yager, 1996), with the modification of Roman numerals to conventional Arabic numerals. Flow zones 4 to 9 are the same as zones IV to IX identified by the USGS and presented in Yager (1996). Johnston (1964) identified the same flow zones as Yager, as well as two deeper flow zones, one at the Gothic Hill/DeCew contact, and one at the DeCew/Rochester Shale contact. These flow zones are present at the Site, and have been numbered 10 and 11.

Figure 4.16 presents gamma logs for well clusters F2 and H2. The gamma log is annotated with the gamma peak labels and the flow zones. Based on the analyses presented above and inspection of the geophysical data, the correlations between the flow zone locations and the gamma peaks or unit contacts are:

Flow Zone	*Gamma Peak or unit contact*
1	Estimated to be 47 feet above GP-E
2	Estimated to be 26 feet above GP-E
3	Estimated to be 17 feet above GP-E
4	10 to 14 feet above GP-E
5	0 to 5 feet above GP-E
6	From GP-G to GP-H
7	Around GP-K
8	Just above GP-L
9	Between GP-L and GP-M
10	Middle to lower Gothic Hill
11	Bottom of DeCew

Where gamma logs are available, identification of the gamma peaks allows determination of the positions of the flow zones. If gamma logs are not available, or are inconclusive, the elevation of the flow zones can be estimated from the following equation:

$$\text{Elevation of flow zone} = C_x\,\text{Esp} + C_y\,\text{Nsp} + \textit{Constant}$$

where:

C_x, C_y, and *Constant* are constants determined by the fitting of bedding-parallel planes through the center of the flow zones. Esp and Nsp are Easting and Northing coordinates in the NYS 1983 state-plane coordinate system, Western zone. In this equation, flow zone elevations are referenced with respect to the NAD83 datum.

The equations for each flow zone are tabulated below.

Flow Zone	C_x	C_y	*Constant (ft)*
1	-0.002660558	0.006826912	-4454.1
2	-0.002660558	0.006826912	-4475.1
3	-0.002660558	0.006826912	-4484.1
4	-0.002660558	0.006826912	-4490.1
5	-0.002660558	0.006826912	-4498.6
6	-0.002660558	0.006826912	-4515.1
7	-0.002660558	0.006826912	-4535.1
8	-0.002660558	0.006826912	-4540.1
9	-0.002660558	0.006826912	-4544.1
10	-0.002660558	0.006826912	-4558.6
11	-0.002660558	0.006826912	-4573.1

It is important to retain all of the decimal places for C_x and C_y since they are used in conjunction with the state plane coordinates. The calculated elevations from these equations will generally be within 3 feet of the actual location for flow zones 4 to 11. Flow zones 1, 2, and 3 are estimates based on limited data and the accuracy of the mathematical planes for these zones cannot be reliably assessed at this time.

4.4 CHARACTERISTICS OF THE HYDROGEOLOGIC SYSTEM

The hydrogeologic characterization described in this section summarizes our interpretation of the studies completed at the Site, both past and present, the published reports from the USGS and NYSGS, and the experience and expertise of the Technical Team. The characterization focuses on the spatial configuration of the flow zones. Quantitative assessment of the spatial hydraulic properties has been deliberately excluded. A discussion of the reason for not including more quantitative results is presented in Section 4.4.2.

The characterization developed here is sufficient to guide the evaluation and possible refinement of the current monitoring network to more accurately reflect hydrogeologic conditions at the Site.

4.4.1 GENERAL DESCRIPTION OF THE HYDROGEOLOGIC SYSTEM

The results of the regional and Site-specific groundwater investigations demonstrate that there are zones of enhanced permeability parallel to bedding. These zones are defined as flow zones and have been recognized in numerous publications. Horizontal groundwater flow is concentrated in the flow zones. The hydraulic properties of the flow zones are spatially variable, as indicated in the summary of results of past slug and packer testing presented in Appendix H.

The flow zones are separated by aquitards. Figure 4.15, the cluster analysis presented in Section 4.3.4, shows that there are water-bearing features within the aquitards. However, the density of water-bearing features is low within the aquitards as compared to the adjacent flow zones. Like flow zones, the hydraulic properties of the aquitards are spatially variable. Between flow zones 9 and 10, there are very few water-bearing features, suggesting that the hydraulic conductivity of this aquitard is probably low compared to the aquitard between flow zones 5 and 6, where there are many water-bearing features.

Although flow zones are the focus of the evaluation presented here, the aquitards are equally important, as it is the layering and contrasting hydraulic properties that comprise the hydrogeologic system. The aquitards will be addressed with equal consideration in future groundwater modeling efforts.

Johnston (1964) suggested that most of the groundwater flow occurs within flow zones. This suggestion must be interpreted carefully. Groundwater flow occurs throughout the bedrock system. The groundwater system is recharged by the infiltration of precipitation. It is more reasonable to conceive of recharge flowing vertically downwards through the overburden and vertical fractures in the aquitards, to replenish the flow zones. Horizontal groundwater flow occurs primarily within the flow zones.

Johnston (1964) suggested that the recharge to the flow zones occurs in the outcrop area of the flow zones, north of the Site. Kappel and Tepper (1992) added the qualification that this applies "in areas undisturbed by natural or manmade structures." When the planes defining the flow zones at the Site are extended they are truncated by both natural and manmade structures: the NYPA forebay, NYPA conduits, and the gorge of the Niagara River.

Previous investigations have indicated that the Rochester Shale forms an impermeable bottom to the shallow bedrock groundwater system at the Site. Kappel and Tepper (1992) concluded that at the regional scale, "Ground water is prevented from flowing below the Lockport Group by the low permeability of the underlying Rochester Shale." Away from the Niagara River, groundwater flow across the Rochester Shale is further limited by overpressurization of the natural-gas reservoir within and below the Rochester Shale. The data from the Intermediate Formation Wells (IFWs) installed at the Site confirm that there is no hydraulic communication across the Rochester Shale to deeper formations.

4.4.2 DETAILS OF THE HYDROGEOLOGIC SYSTEM

The refinement of the hydrogeologic characterization presented in Section 4.0 has provided the location of flow zones. The elevations of the flow zones can be estimated using the equations presented in Section 4.3.4. As indicated previously, the frame of reference defined by the peaks of the gamma responses has been crucial in the synthesis of the results from the geophysical and borehole flowmeter investigations. To confirm that this frame of reference is reliable, the predicted elevations of the flow zones have been mapped back to the summaries of the geophysical logs, and in particular to the gamma logs. Two examples of this mapping, for well clusters F2 and H2, are shown on Figure 4.16. The results shown on Figure 4.16 illustrate the relations between the flow zones and the gamma peaks, and demonstrate the consistency of those relations across the Site.

The flow zones identified in this report have been numbered following the convention set by the USGS, as described in Yager (1996). Flow zone 7 in this report is equivalent to Yager's flow zone VII. Yager identified nine flow zones, the lowest located in the Pekin Member of the Gasport Formation. Johnston identified two flow zones below Yager's flow zone IX, one at the top of the DeCew, and one at the DeCew/Rochester Shale contact. These have been identified as flow zones 10 and 11.

Flow Zones 4 Through 11

Eight of the flow zones (4 through 11) have been clearly identified from the data collected during the 2001 Site investigations, as described in Section 4.4.4. Flow zones 4 through 9 correspond to six of the flow zones incorporated in the regional model of Yager (1996), flow zones IV to IX. Flow zones 10 and 11 correspond to the two lowest flow zones identified by Johnston (1964). The three flow zones that have not been clearly identified at the Site are Yager's uppermost flow zones I, II, and III. As indicated previously, these three flow zones are located in the Eramosa where the thickness may have been reduced by erosion. Identification of discrete flow zones at the top of the Eramosa may also be confounded by the relatively higher intensity of fracturing due to weathering.

Flow Zones 1, 2, and 3

The cluster analysis does not provide clear evidence of any flow zones above flow zone 4. Flow zones 1, 2, and 3 are likely present at the Site; however, the greater density of fractures in the Eramosa than the underlying units obscures their identification. Since reliable identification of key water-bearing features above flow zone 4 is not possible from the cluster analysis, the flow zones above flow zone 4 were estimated by more subjective interpretation of the data on water-bearing features, and by estimating the probable vertical position from the USGS flow zone picks at well LW-1, shown on Figure 4.2. The borehole flowmeter data suggest that a transmissive zone has been observed in two wells, F3U and J1U, approximately 26 feet above GP-E. This position coincides with the elevation of Yager (1996) flow zone II.

The cluster analysis also shows an absence of water-bearing features between about 31 and 44 ft above GP-E. This is indicative of an aquitard. Four water-bearing features are identified between 45 and 49 ft above GP-E. There are few points here because this is approaching the highest elevation in the bedrock in the vicinity of the Site. Although the data are sparse, a critical feature implicit in the identification of a flow zone is the presence of an underlying aquitard. The water-bearing features between 45 and 49 feet above GP-E are assumed to represent a flow zone, coinciding approximately with Yager's flow zone I. A small cluster of data likely indicates flow zone 3, centered approximately 17 feet above GP-E.

Dominant Flow Zones

Based on the frequency of occurrence of water-bearing features, Johnston's "**XX**" flow classification, and results of the borehole flowmeter testing, flow zones 5, 6, and 9 appear to be the most transmissive. This observation is very preliminary.

No detailed investigation of the hydraulic properties of individual flow zones has been conducted. The results of the packer tests conducted at the Site in 1991 have been inspected to assess the transmissivity of individual flow zones. These data are inconclusive, as the 15-foot packer spacing for these tests precludes isolation of the individual flow zones. The performance data from the purge wells have also been examined to assess the transmissivity of the individual flow zones. However, no conclusions can be drawn from these data either, as the open intervals of the purge wells also intercept multiple flow zones.

Additional evaluation of the relative transmissivity of the flow zones will be important for future modeling as well as monitoring.

Comparison of the Flow Zones and Stratigraphic Units

Figure 4.17 presents the flow zones identified above, overlain on the cross-section B-B′ that was presented on Figure 3.12. The flow zones are shown as black lines representing the parallel planes given by the equations in Section 4.3.4. Several concepts are presented in this figure.

- The geology discussed in Section 3.0 uses the best-estimate elevations of the stratigraphic contacts, determined by inspection of drill cores. This is standard practice in the industry. The flow zones are idealized plane surfaces. The goal of the hydrogeologic characterization has been to revise the description of the subsurface so that it is consistent with regional characterizations formulated in terms of flow zone concepts. Based on the discussion of data accuracy presented in Appendix C, both approaches are valid interpretations.
- The dips of the flow zone planes are parallel to the stratigraphic contacts and the gamma planes.
- The locations of the flow zones defined at the Site conform to the location of the flow zones defined regionally by Johnston (1964) and Yager (1996) and referenced to stratigraphy.
- Flow zones 1 through 6 are truncated on Site due to erosion of the bedrock prior to intersecting the Niagara Gorge.

Overburden and Upper 15 Feet of Bedrock

Two features of the hydrogeologic system that have not yet been addressed are the overburden sediments and the first 15 feet of bedrock. The overburden consists of lacustrine silts and clays overlying glacial till. The results of single-well response tests at the Site indicate that the silts and clays have limited transmissivity (CRA, 1983a; CRA, 1984). The results from the single-well response tests are consistent with the very low yields of the monitoring wells and extraction wells/trenches located in these materials. The basal till immediately overlying the bedrock was characterized as being connected directly to the top of rock (CRA, 1983a; CRA, 1984). Groundwater flow in the overburden is therefore most likely downwards, replenishing the bedrock aquifer.

The upper 15 feet of bedrock has been characterized by Johnston (1964), Kappel and Tepper (1992), and Yager (1996), as a "highly-fractured weathered zone..." that is very transmissive. We believe that Kappel and Tepper (1992) and Yager (1996) presented the 15-foot depth as a 'carry-over' from Johnston (1964). Although it is reasonable to expect that fractures will be most open at the top of bedrock, and will tend to close deeper in the bedrock due to lithostatic pressure, the 15-foot depth described by Johnston (1964) does not appear to be an appropriate generalization for the Site.

As shown on the cross-sections (Figures 3.11 and 3.12), the upper 15 feet of bedrock generally includes the Eramosa and the Vinemount. Visual inspection of the geophysical logs for signs of fracturing (principally caliper logs, acoustic televiewer, and temperature) suggests that fracturing in the shallow bedrock is highly variable. At AGW-2, 30 feet of the Eramosa appears to be intensely fractured, while at AGW-3U, a similar section of the Eramosa appears to be sparsely fractured. At wells B1U and B2U, where the Eramosa has been eroded and the Vinemount is the uppermost bedrock unit, there does not appear to be any intense fracturing of the shallow bedrock at these wells. In general, inspection of the geophysical data suggests that the depth and intensity of fracturing is highly variable across the Site.

Section 3.0 presents an evaluation of the frequency of fractures with respect to depth below top of bedrock, and by stratigraphic unit. The results of that analysis indicate that the number of fractures gradually decreases with depth below the top of bedrock, and that the frequency of fractures is dependent on the lithology. There is no indication of a rapid change in the frequency of fractures at a specific depth. Although the evaluation does not consider fracture apertures, the results suggest that an assumed 15-foot zone of weathering/more intense fracturing is not necessarily appropriate for the Site.

4.4.3 IMPLICATIONS OF THE REVISED HYDROGEOLOGIC CHARACTERIZATION

The revised hydrogeologic characterization described above satisfies the objective defined for this study; it provides a tractable framework for evaluating groundwater flow, and APL and NAPL migration. It also leads to a conclusion that the existing monitoring network may require revision for detailed groundwater flow analysis, and in particular, the evaluation of hydraulic containment.

Figure 4.18 presents a view along strike of the flow zones and open intervals of the existing bedrock monitoring wells. The view is similar to Figures 4.11 and 4.17. The flow zones are truncated at the top of bedrock and the Niagara River gorge. The Upper, Middle, and Lower bedrock wells are designated by color. The figure shows that the open intervals of the monitoring wells intersect multiple flow zones. The water level in a well that spans multiple flow zones represents a weighted average of the water levels in the individual flow zones. The average water level is a function of the hydraulic head in each flow zone intercepted, weighted by the local transmissivity of each flow zone. The transmissivity of the flow zones is spatially variable; two nearby wells that are open across the same flow zones may have water levels that represent averages with significantly different transmissivity weighting, resulting in different water levels in the wells.

Figure 4.19 is identical to Figure 4.18, with the exception that the open intervals of the monitoring wells have been replaced by the open intervals of the purge wells. This figure shows that the existing purge wells also intercept multiple flow zones. This construction allows the purge wells to contain multiple flow zones. However, it complicates the analysis of pumping test data.

Figure 4.20 presents a plan view of the Site showing the subcrop of the aquitards separating the eleven flow zones identified. The color bands represent the subcrop of the bedrock aquitards (the intersection of the top of bedrock with the aquitard). The contacts between aquitards are the flow zone subcrops (assuming that flow zones are very thin planes). Figure 4.20 demonstrates an interesting result of the revised hydrogeologic characterization. Although eleven flow zones are identified, flow zones 1 through 5 subcrop before reaching the gorge face. The point of potential exposure is at the gorge face. Therefore, only flow zones 6 to 11 represent the potential exposure pathways. Flow zone 1 does not even reach the downgradient (northwest) portion of the Landfill. The truncation of flow zones has important implications for monitoring conditions at the Site, and these will be examined in detail as our understanding of the groundwater flow system evolves. Here, the figure is presented as a conceptual/working tool.

Figures 4.18, 4.19, and 4.20 were created from a three-dimensional EVS model. The three-dimensional model is included on a compact disc (CD) enclosed with the report. The model is in a format that is compatible with the freeware 4-D Interactive Model Viewer included on the CD. Using the 4-D Interactive Model Viewer, the model can be rotated in any direction, zoomed into or out of, and changed from orthographic to perspective view. The CD includes instructions on viewing the EVS model.

4.5 SUMMARY

The following observations summarize the revised hydrogeologic characterization of the Site:

1. The previous hydrogeologic characterization of the Hyde Park Landfill Site defined three bedrock monitoring intervals: Upper, Middle, and Lower. The monitoring intervals were based on the criteria defined in the *Drilling Summary Report, RRT Well Installations* (CRA, 1993).

2. The revised hydrogeologic characterization developed here represents a refinement of the previous characterization.

3. The revised hydrogeologic characterization defines discrete flow zones that transmit groundwater in the horizontal direction. The primary characteristics of the flow zones are:
   - they are parallel to bedding; and
   - they are regionally continuous.

4. The combined total of 11 regional flow zones identified by previous investigators are present at the Site. The eight, deepest flow zones have been identified positively at the Site. The three shallow flow zones appear to be present, but are based on a very limited data set. The three uppermost flow zones occur in the Eramosa.

5. Northwest of the Landfill, in the downgradient direction of groundwater flow, flow zones 1 through 5 subcrop before reaching the gorge face. The point of potential exposure is at the gorge face. Therefore, only flow zones 6 to 11 represent the potential exposure pathways. The truncation of flow zones has important implications for monitoring conditions at the Site.

6. Based on the frequency of occurrence of water-bearing features, Johnston's "**XX**" flow classification, and results of the borehole flowmeter testing, flow zones 5, 6, and 9 appear to be the most transmissive. This observation is very preliminary.

7. Although flow zones are the focus of the evaluation presented here, the aquitards are equally important, as it is the layering and contrasting hydraulic properties that comprise the hydrogeologic system. The aquitards will be addressed with equal consideration in future groundwater modeling efforts.

8. No detailed investigation of the hydraulic properties of individual flow zones has been conducted. Additional evaluation of the relative transmissivity of the flow zones will be important for future modeling as well as monitoring.

9. The revised hydrogeologic characterization described above satisfies the objective defined for this study; it provides a tractable framework for evaluating groundwater flow, and APL and NAPL migration. It also leads to a conclusion that the existing monitoring network may require revision for detailed groundwater flow analysis, and in particular, the evaluation of hydraulic containment.

5.0 ONGOING HYDROGEOLOGIC CHARACTERIZATION

The existing numerical groundwater models of the region Yager (1996), and of the Site (SSP&A, 2001a) simulate the general groundwater flow directions, however, neither of these models simulate the 11 discrete flow zones. The existing monitoring wells provides water levels that are averages of the multiple flow zones intercepted. These water level data are useful for evaluating the general direction of groundwater flow. However, they are not useful for the calibration of a model simulating 11 discrete flow zones, or for the precise hydraulic monitoring required in the RRT.

While the characterization presented here provides a tractable hydrogeologic framework for the Site, an interpretation of the groundwater flow within individual flow zones cannot be determined. Thus, it is the opinion of the Technical Team that the hydrogeologic characterization is a continuing effort. Three steps remain to complete the characterization of the Site.

1. Installation of multi-level piezometers to monitor water levels in flow zones.
2. Monitoring the multi-level piezometers to assess both pumping and non-pumping conditions.
3. Mathematical modeling of groundwater flow.

Installation of Multi-level Piezometers

Monitoring groundwater levels in individual flow zones is necessary to complete and validate the revised hydrogeologic characterization. The objective of the multi-level monitoring will be to determine the groundwater flow conditions in each flow zone, and to assess the significance of individual flow zones. The data will also provide a calibration reference for the groundwater flow model.

Multi-level monitoring devices must be installed at select locations across the Site. The design of the multi-level monitoring network is currently being evaluated. The feasibility of retrofitting existing wells versus installing new borings for monitoring is also being reviewed. Potential multi-level piezometer designs include:

- conventional small-diameter, short-screen piezometers;
- multiple transducers in a single borehole; and
- commercial multi-level monitoring devices such as those available from Solinst Canada, Ltd., and Westbay Instruments, Inc.

<u>Monitoring and Reporting</u>

The multi-level piezometers will be distributed across the site to assess Site-wide groundwater flow conditions. A monitoring program will be developed for the new piezometers. It is anticipated that select piezometers will be monitored continuously with data loggers, and periodic monitoring of piezometers that are not instrumented will be performed. Both pumping and non-pumping conditions will need to be monitored, as well as the transient response when changing from pumping to non-pumping conditions. At least one pumping test at PW-2M will be performed.

The results of the multi-level piezometer monitoring will be compiled, evaluated, and presented in a report. The report will provide contour maps of the potentiometric surface for each of the significant flow zones that can be monitored independently, and estimates of the spatial properties of the flow zones. This report will represent the completion of the revised hydrogeologic characterization.

<u>Groundwater Flow Modeling</u>

The MSRM Technical Team will complete a model that is consistent with the revised conceptualization presented here, and that is capable of accurately simulating the groundwater flow and purge well containment system. The groundwater levels and spatial hydraulic properties of the flow zones developed during the installation and monitoring of the multi-level piezometers will be incorporated into the new Site groundwater flow model. The model will be used to evaluate the flow directions as well as the significance of individual flow zones (with respect to the proportion of groundwater flow carried). A report describing the modeling will be prepared.

Performance monitoring for the NAPL Plume Containment System

The revised site characterization described in this report has been undertaken to resolve the inability to satisfy all of the requirements for demonstration of containment of the NAPL plume mandated in the RRT. As discussed previously, the inability to satisfy the RRT requirements is not necessarily an indication of failure of the NAPL Plume Containment System. Rather, the existing monitoring network does not provide sufficient precision to demonstrate achievement of the RRT requirements.

An alternative performance monitoring program must be developed for the Site. The hydrogeologic characterization presented here represents a significant refinement of the previous characterization. There are presently no groundwater level data available to evaluate the reliability of the revised hydrogeologic characterization. The results of additional monitoring, testing, and modeling described above must be completed and evaluated prior to developing a monitoring program that is capable of providing a reliable demonstration of the achievement of the remedial objectives of the RRT.

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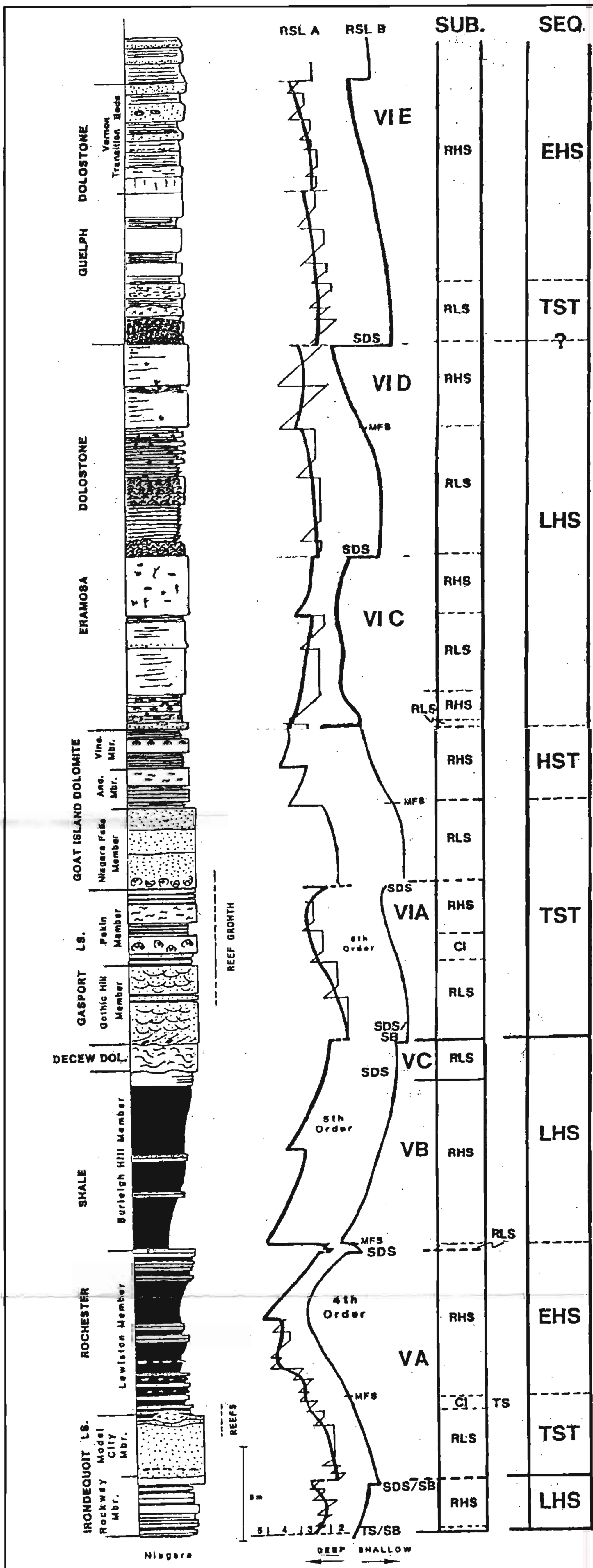
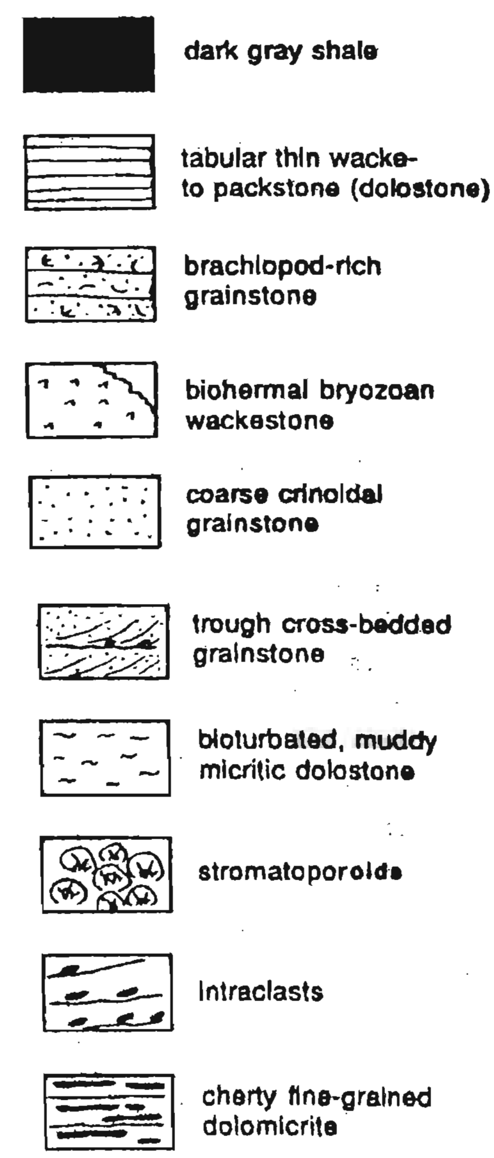


LEGEND



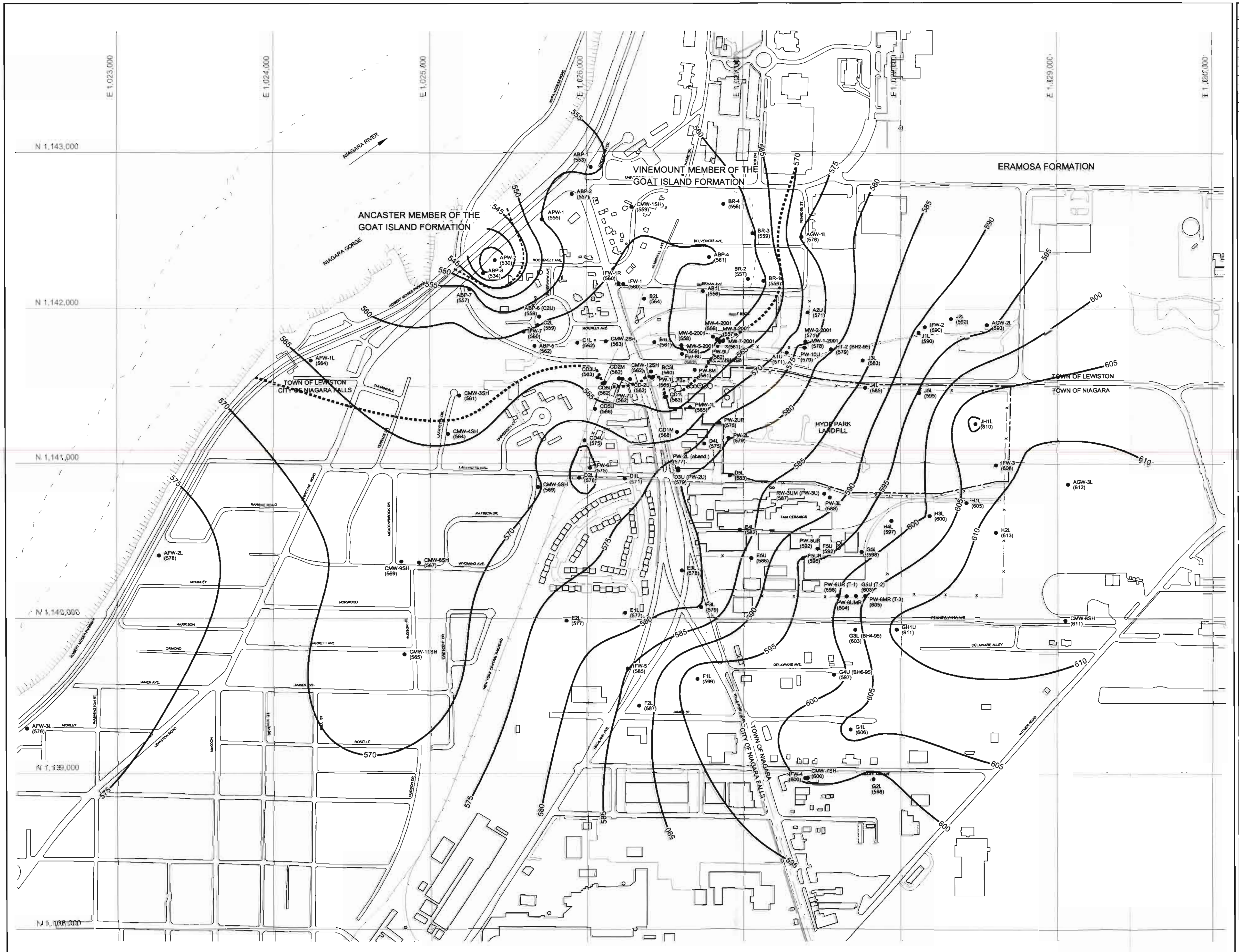
RSL	RELATIVE SEA LEVEL
RLS	RELATIVE LOWSTAND
RHS	RELATIVE HIGHSTAND
MFS	MARINE FLOODING SURFACE
CI	CONDENSED INTERVAL
TS	TRANSGRESSIVE SURFACE
SDS	SEA LEVEL DROP SURFACE
SB	SEQUENCE BOUNDARY
TST	TRANSGRESSIVE SYSTEMS TRACT
LHS	LATE HIGHSTAND
EHS	EARLY HIGHSTAND
LHS	LATE HIGHSTAND
HST	HIGHSTAND
SUB.	SUBSEQUENCE
SEQ.	SEQUENCE
VA,VIC	SEQUENCE (V,VI) / SUBSEQUENCE (A,C)

SOURCE: BRETT, ET AL., (1990)(FIGURES 15 AND 16)

figure 3.1

SEQUENCE STRATIGRAPHIC RELATIONSHIPS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA012 FEB 12/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

DITCH
POWER TOWER
MUNICIPAL BOUNDARY
RAILWAY
FENCE
EDGE OF NIAGARA GORGE
540 TOP OF BEDROCK CONTOUR
TOP OF ANCASTER MEMBER OR VINEMOUNT MEMBER SUBCROP
AGW-2L (593) BOREHOLE LOCATION WITH TOP OF BEDROCK ELEVATION (ft AMSL)

NOTE

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF BEDROCK ELEVATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
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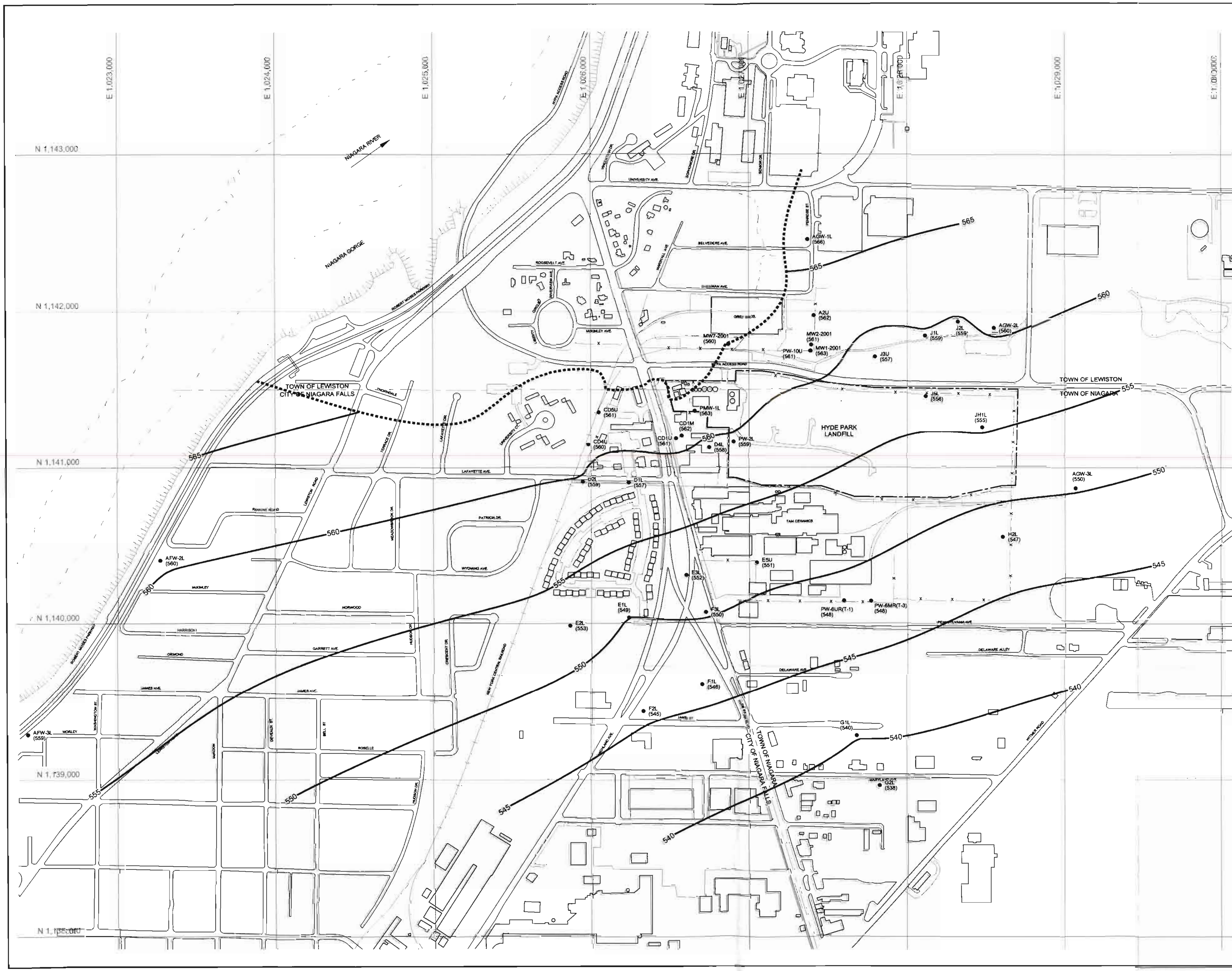
01069-30(299)GN-WA034 JAN 23/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

DITCH

POWER TOWER

MUNICIPAL BOUNDARY

RAILWAY

FENCE

EDGE OF NIAGARA GORGE

560 TOP OF VINEMOUNT MEMBER CONTOUR

TOP OF VINEMOUNT MEMBER SUBCROP

AGW-2L (560) BOREHOLE LOCATION WITH TOP OF VINEMOUNT MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF VINEMOUNT MEMBER OF THE GOAT ISLAND FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
1 = 300'	01069-30	299	3.4

01069-30(299)GN-WA028 JAN 23/2002

Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF ANCASTER MEMBER CONTOUR
- TOP OF ANCASTER MEMBER SUBCROP
- AGW-2L (540) BOREHOLE LOCATION WITH TOP OF ANCASTER MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF ANCASTER MEMBER OF THE GOAT ISLAND FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
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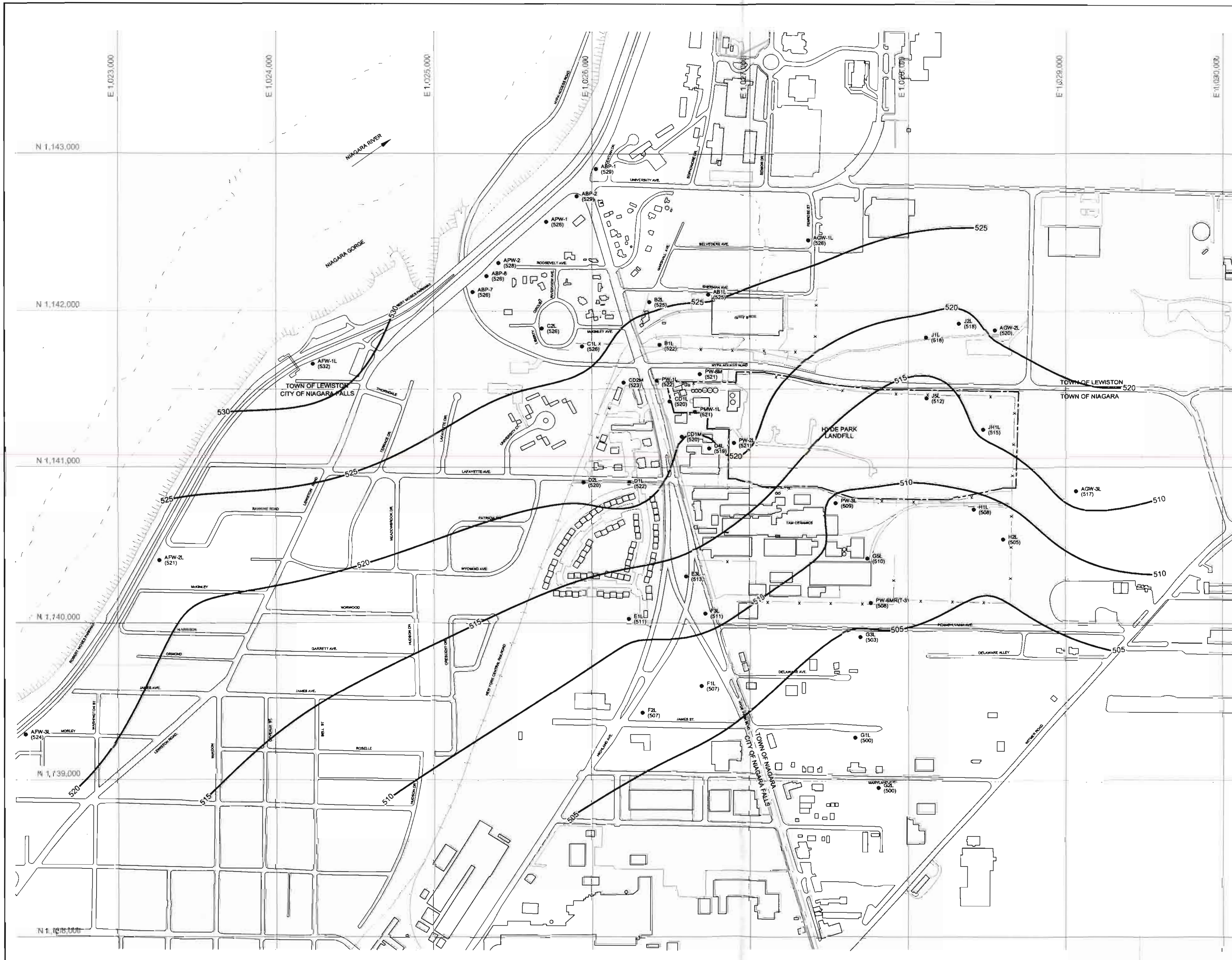
01069-30(299)GN-WA029 JAN 18/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 TOP OF PEKIN MEMBER CONTOUR
- AGW-2L (520) BOREHOLE LOCATION WITH TOP OF PEKIN MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL. ELEVATION = 612.77. DATUM NOT VERIFIED

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF PEKIN MEMBER OF THE GASPORT FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:
COORDINATE SYSTEM: CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
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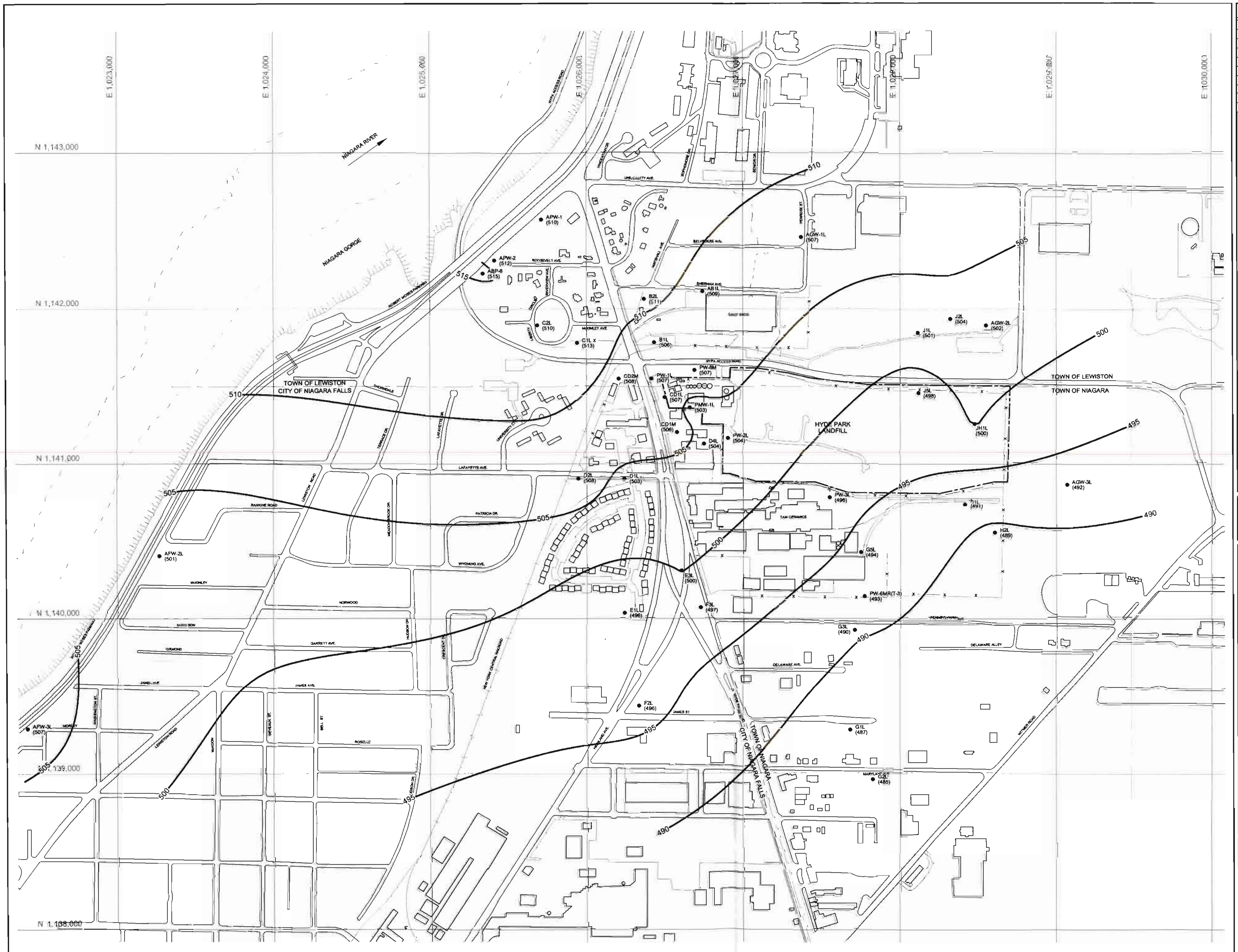


Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 TOP OF GOTHIC HILL MEMBER CONTOUR
- AGW-2L (502) BOREHOLE LOCATION WITH TOP OF GOTHIC HILL MEMBER ELEVATION (ft AMSL)

NOTE:
1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF GOTHIC HILL MEMBER OF THE GASPORT FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:
COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager: MM	Reviewed By: BT	Date: NOVEMBER 2001	
Scale: 1" = 300'	Project Nº: 01069-30	Report Nº: 299	Drawing Nº: 3.7

01069-30(299)GN-WA031 JAN 18/2002

Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 TOP OF DECEW FORMATION CONTOUR
- AGW-2L (498) BOREHOLE LOCATION WITH TOP OF DECEW FORMATION ELEVATION (ft AMSL)

NOTE:
1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 812.77 DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

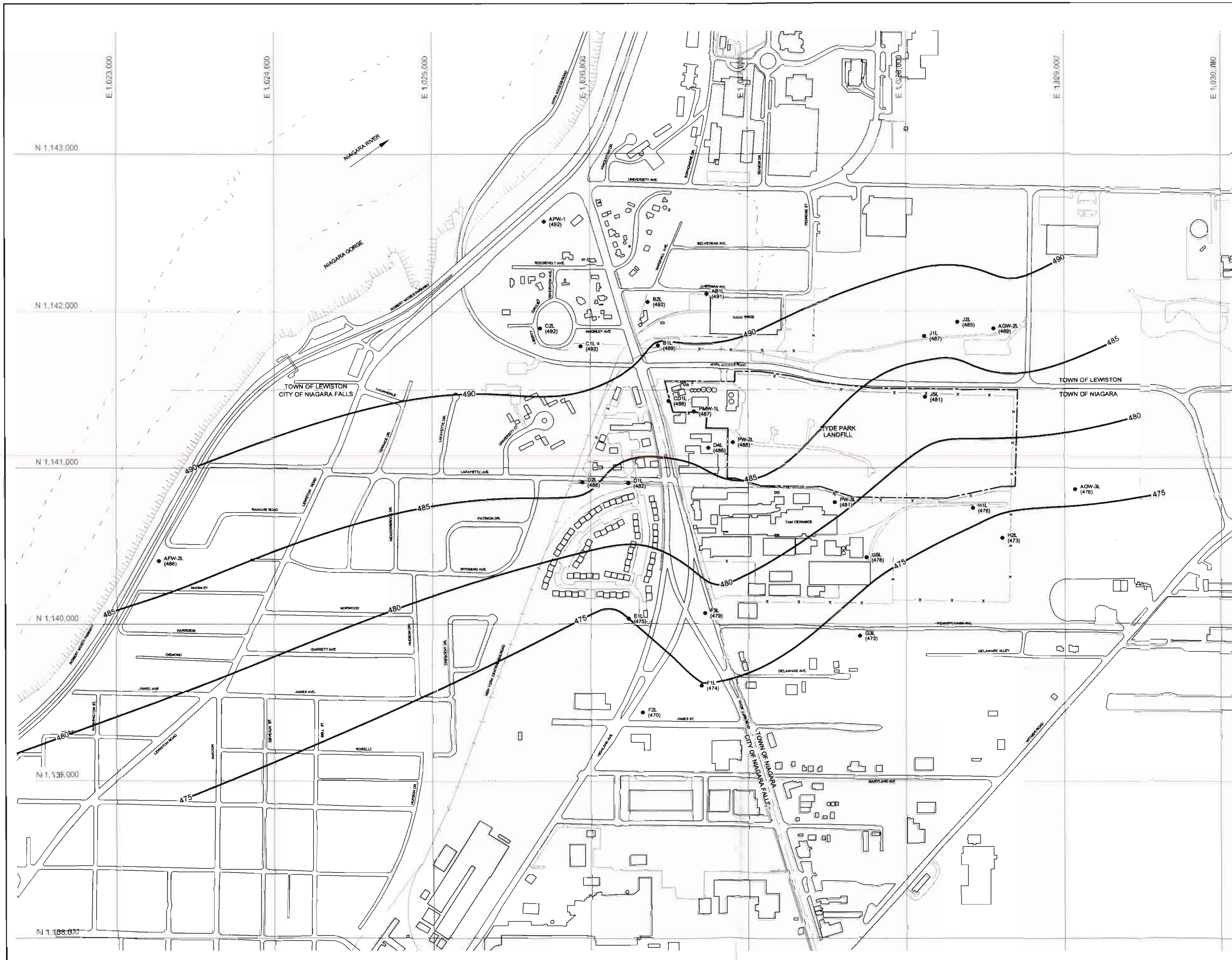
TOP OF DECEW FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:
COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager: MM	Reviewed By: BT	Date: NOVEMBER 2001	
Scale: 1 = 300'	Project Nº: 01069-30	Report Nº: 299	Drawing Nº: 3.8

01069-30(299)GN-WA032 JAN 18/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF ROCHESTER SHALE CONTOUR
- AGW-2L (489) — BOREHOLE LOCATION WITH TOP OF ROCHESTER SHALE ELEVATION (ft AMSL)

NOTE:
1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF ROCHESTER SHALE

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:
COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1996

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
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01069-30(299)GN-WA033 JAN 18/2002

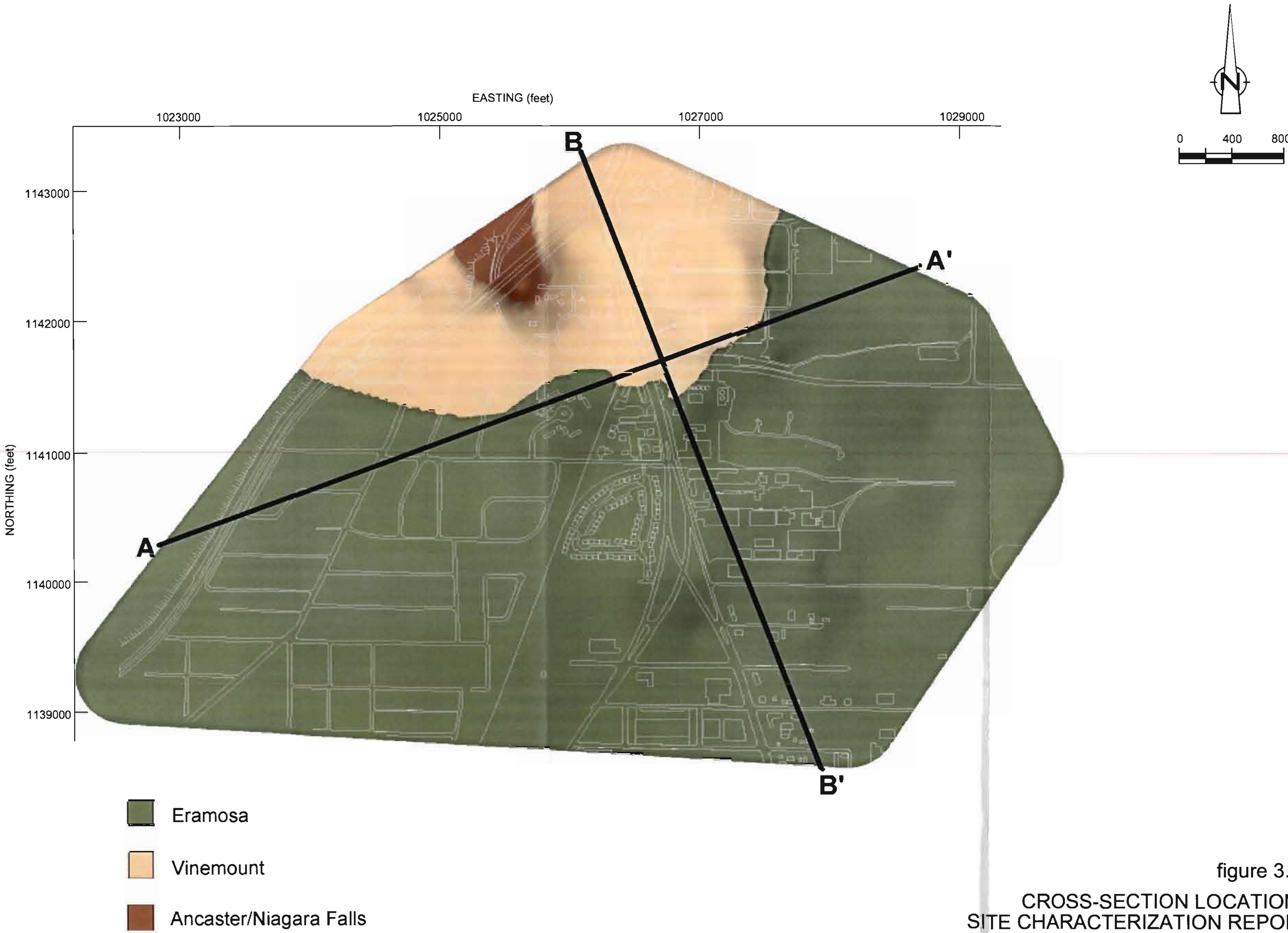
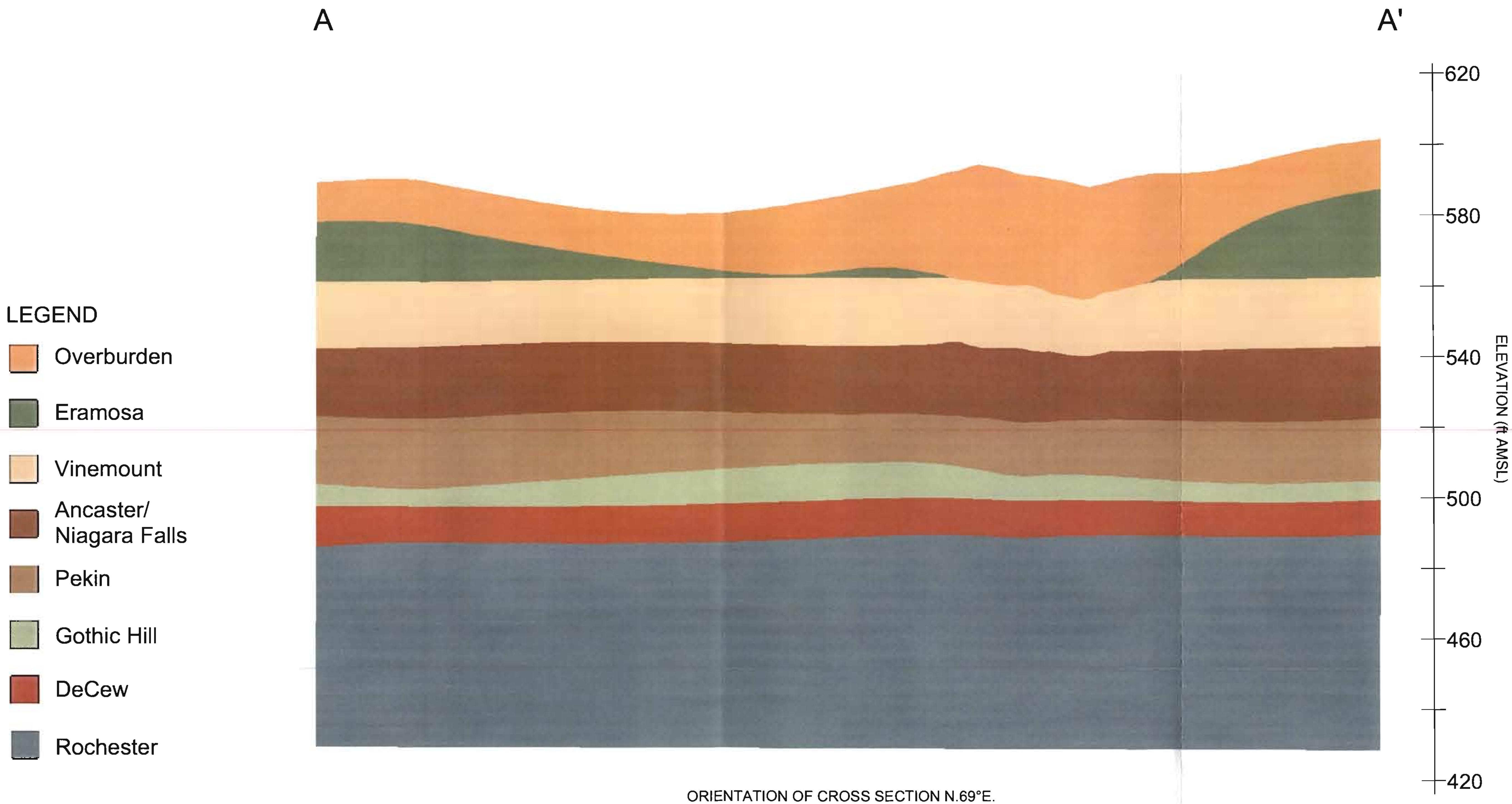


figure 3.10

CROSS-SECTION LOCATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA037 JAN 18/2002



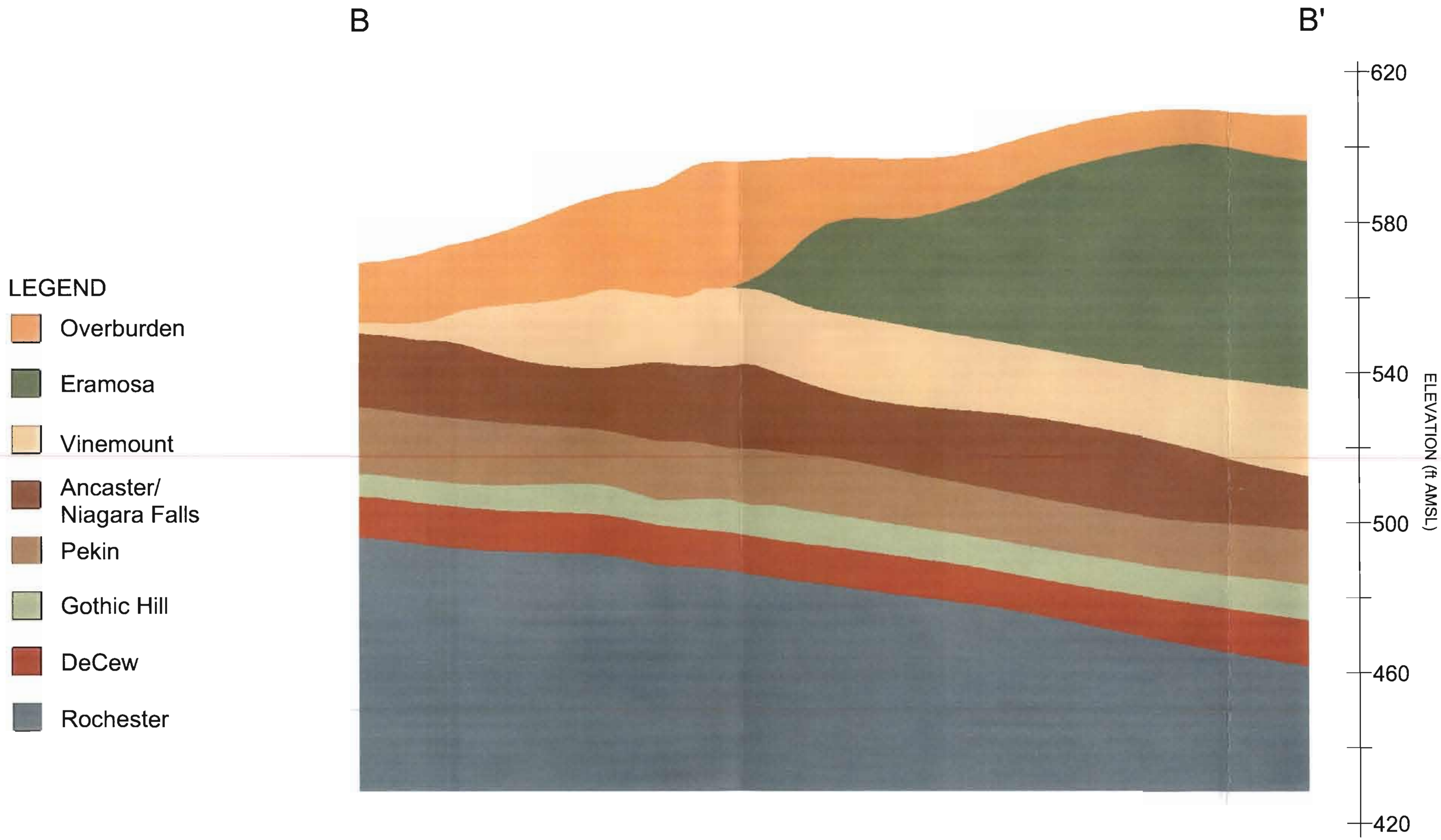
SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

figure 3.11

SCHEMATIC CROSS-SECTION A-A' (ALONG STRIKE)
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA035 FEB 13/2002



ORIENTATION OF CROSS SECTION N.159°E.

SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

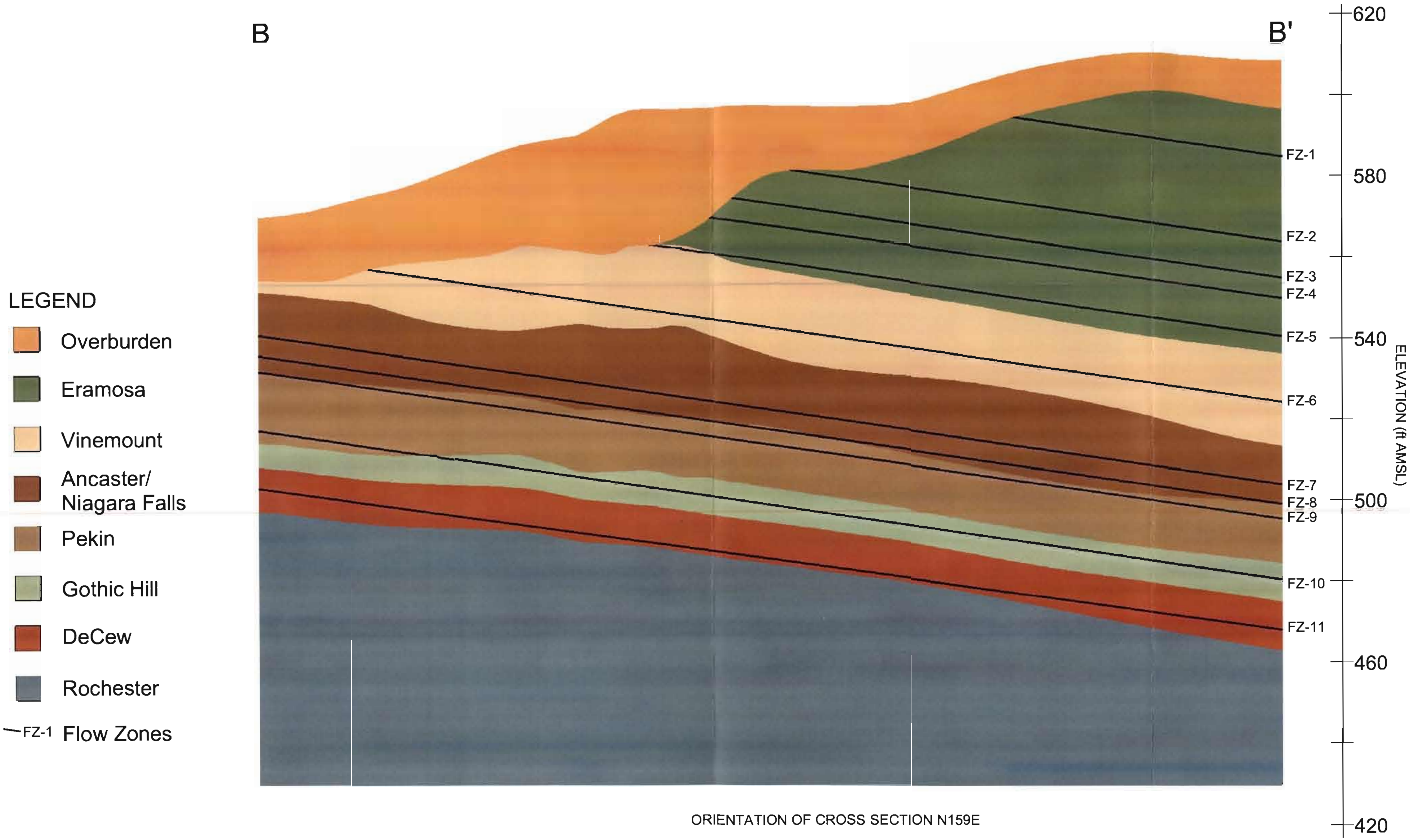
figure 3.12

SCHEMATIC CROSS-SECTION B-B' (ALONG DIP)
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA036 FEB 13/2002

Figure 4.5 View of the Niagara River Gorge from Canada



SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

figure 4.17

NORTH TO SOUTH SCHEMATIC CROSS-SECTION B-B' WITH FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA038 FEB 14/2002

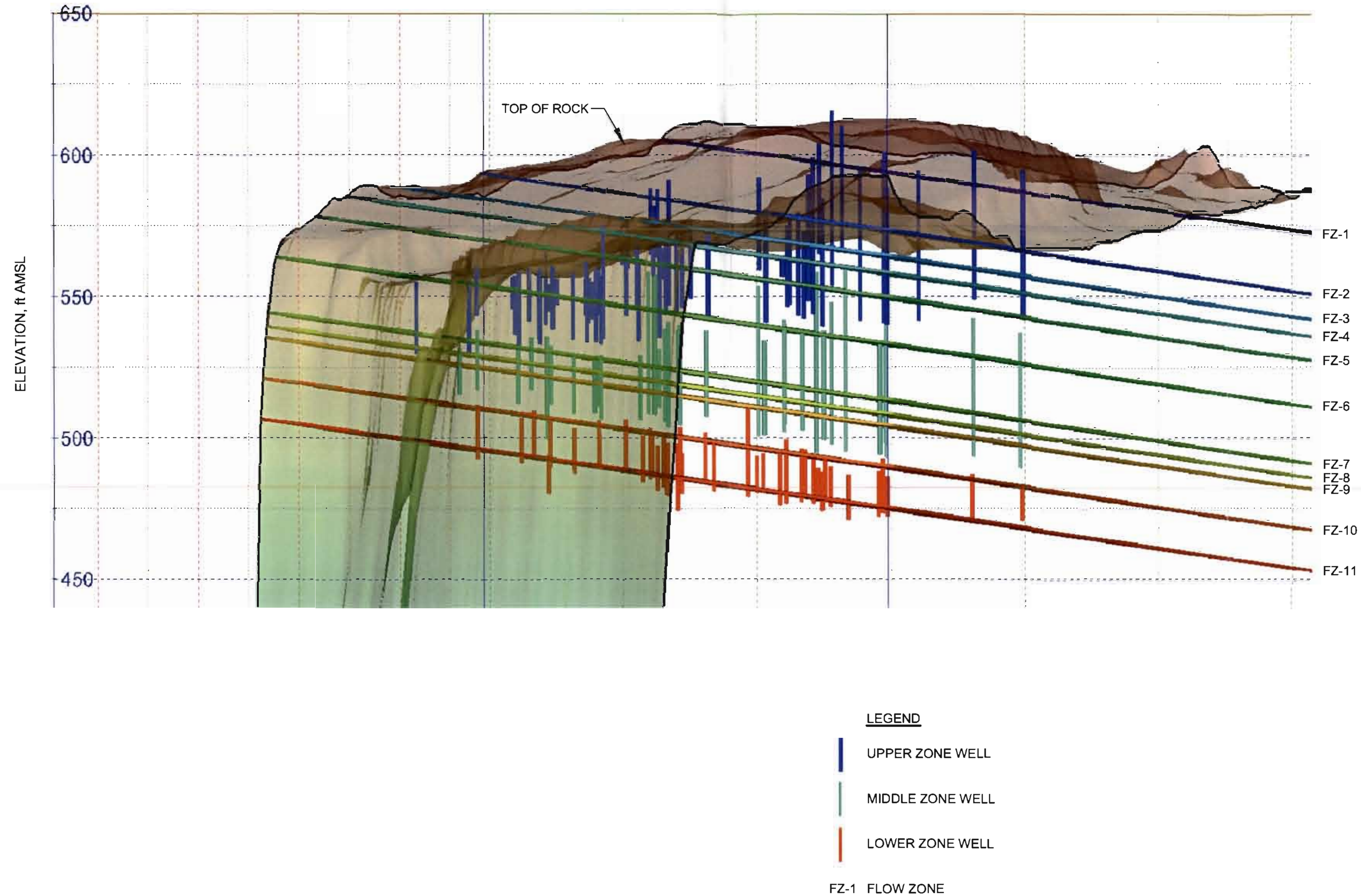


figure 4.18

VIEW LOOKING ALONG STRIKE (N.69° E.) OF MONITORING WELL INTERVALS AND FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

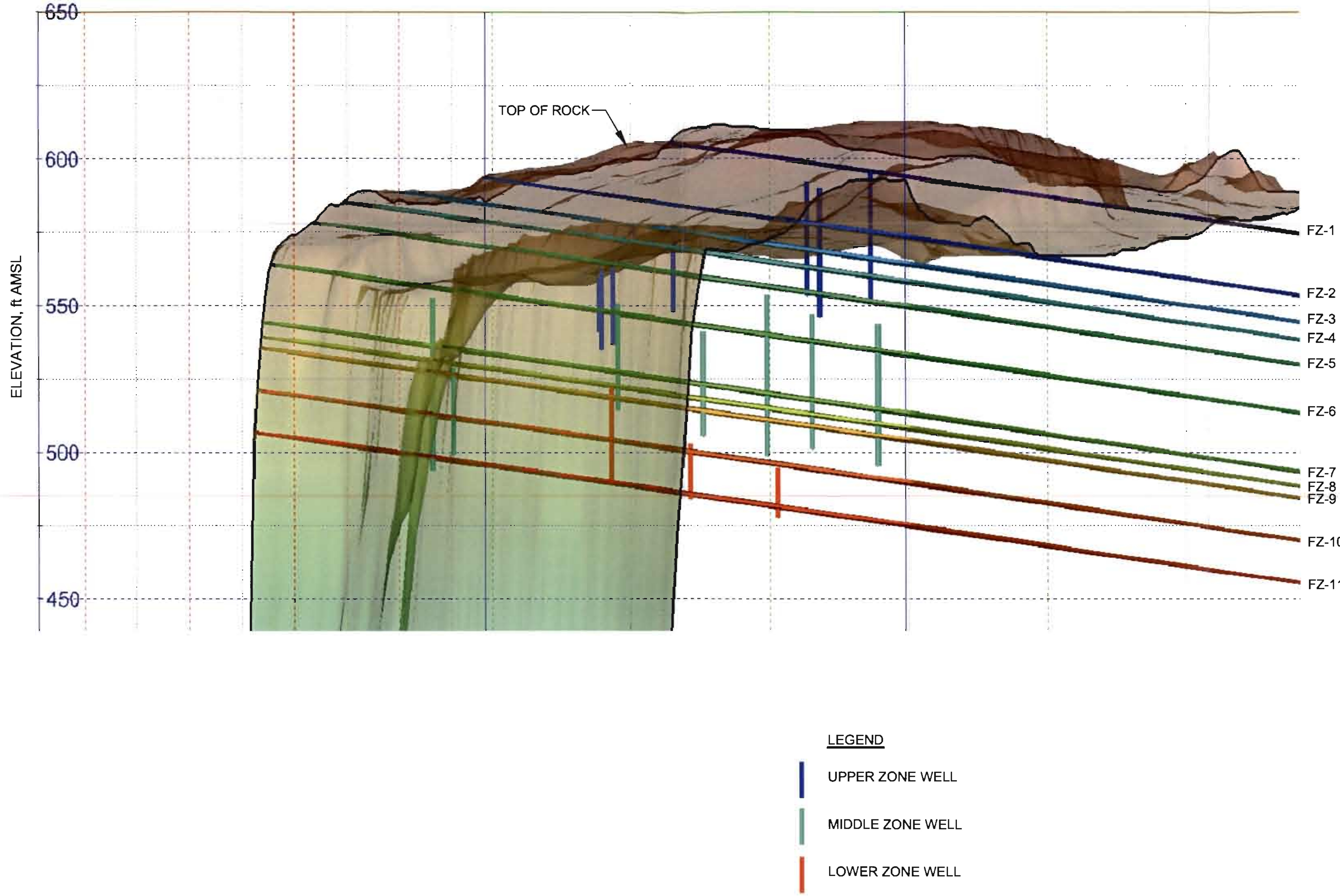


figure 4.19

VIEW LOOKING ALONG STRIKE (N.69° E.) OF PURGE WELL INTERVALS AND FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

CRA

01069-30(299)GN-WA041 FEB 14/2002

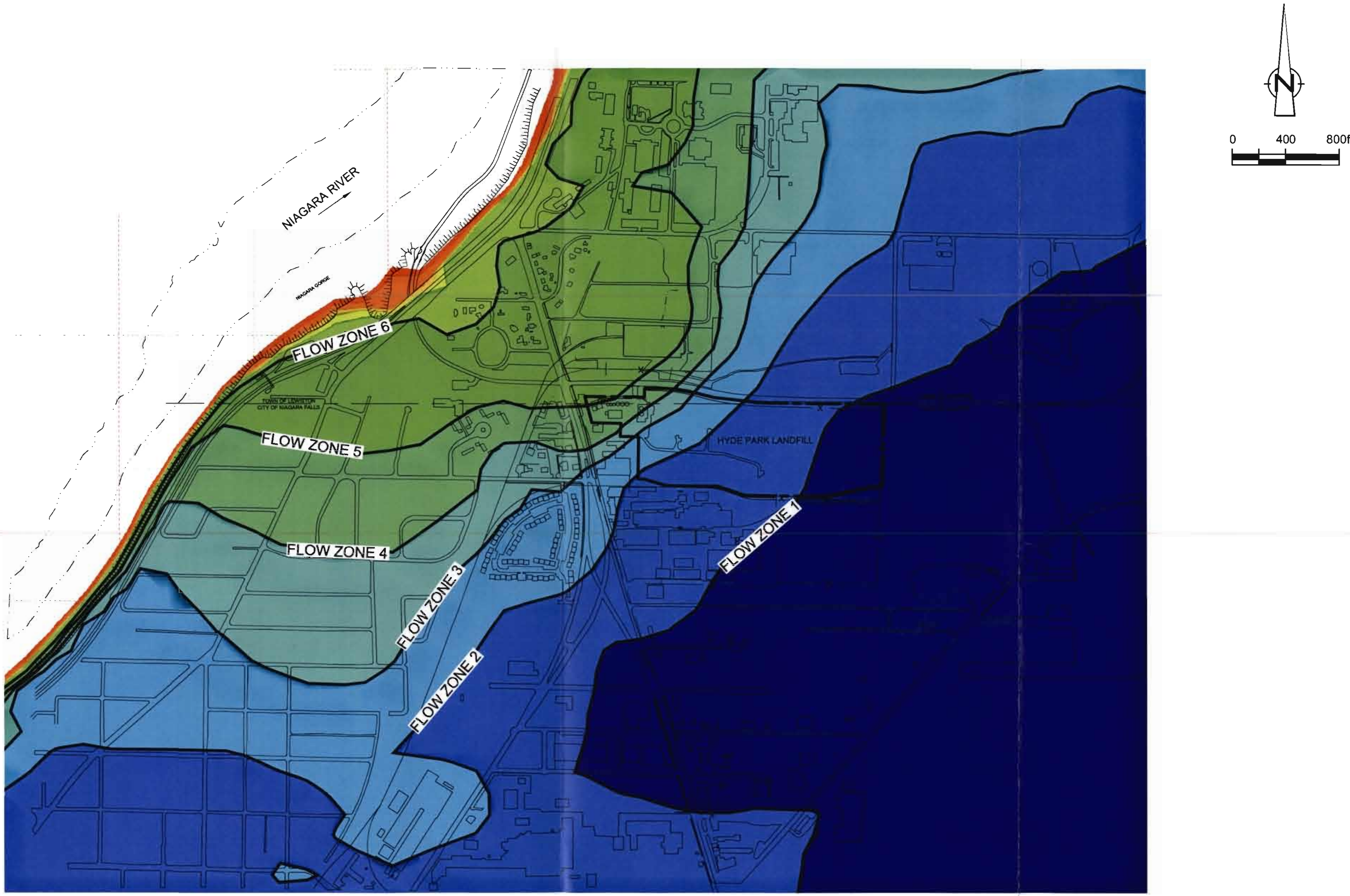
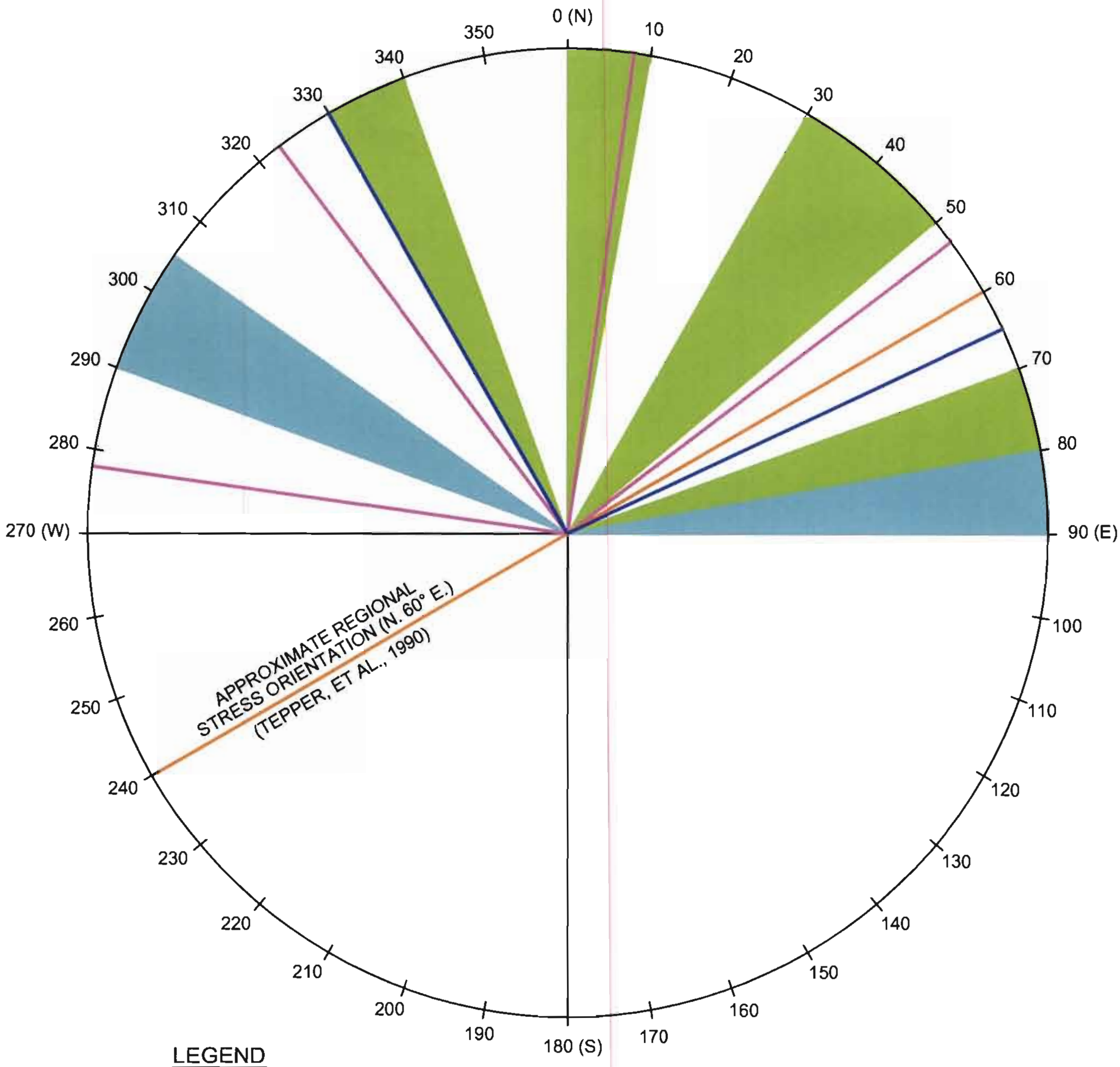


figure 4.20

PLAN VIEW OF AQUITARD SUBCROPS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA042 FEB 14/2002



LEGEND

IJC (1974)
N. 70° E. - N. 80° E.
N. - N. 10° E.
N. 30° E. - N. 50° E.
N. 20° W. - N. 30° W.

TEPPER, ET AL. (1990)
N. 55° W. - N. 70° W.
N. 80° E. - N. 90° E.

JOHNSTON (1964)
N. 65° E.
N. 30° W.

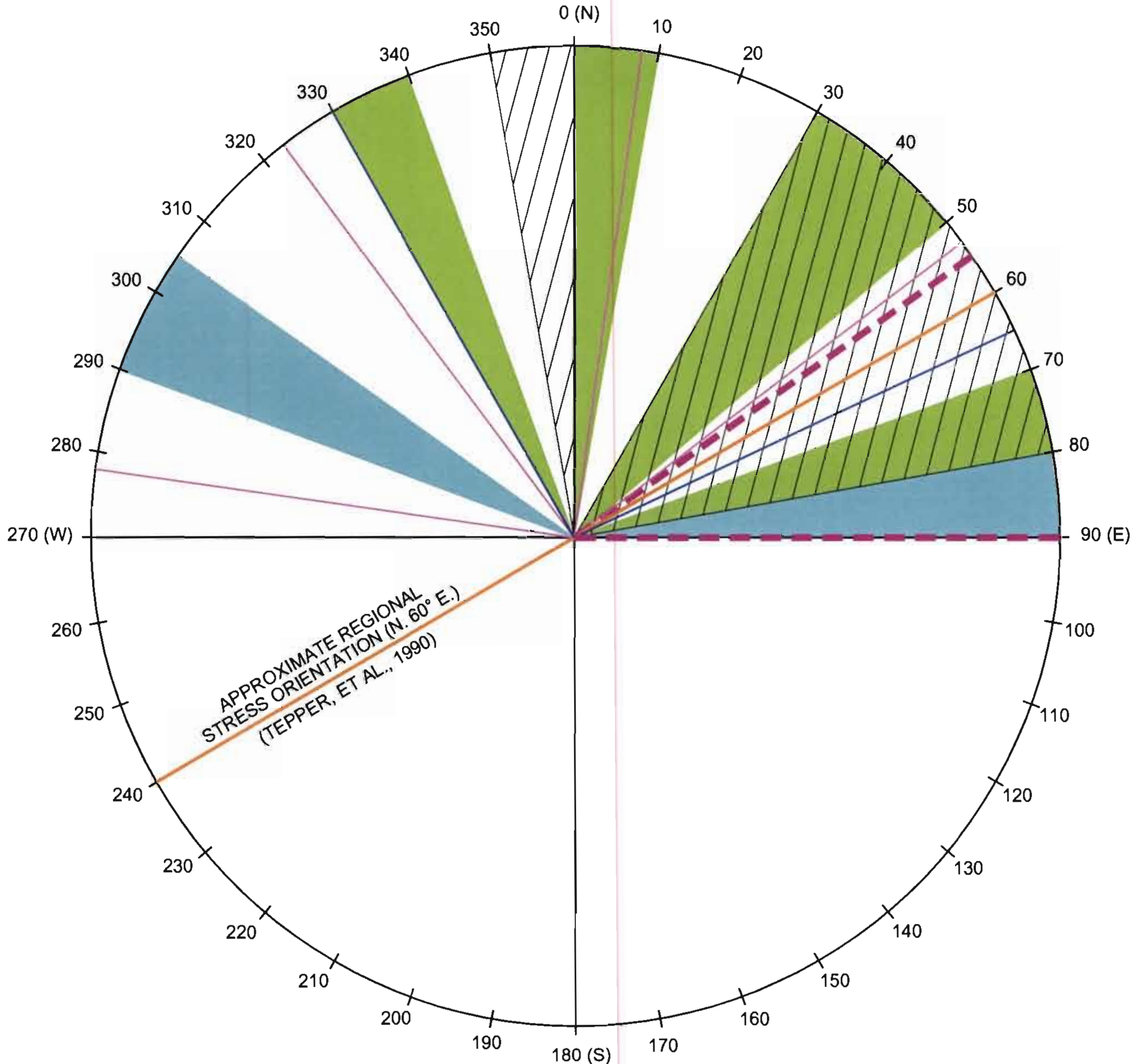
MEMARIAN (1975)
N. 8° E.
N. 53° E.
N. 82° W.
N. 37° W.

figure 3.2

SUMMARY OF REGIONAL NEAR-VERTICAL JOINT TRENDS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

CRA

01069-30(299)GN-WA002 JAN 29/2002



LEGEND

IJC (1974)
N. 70° E. - N. 80° E.
N. - N. 10° E.
N. 30° E. - N. 50° E.
N. 20° W. - N. 30° W.

TEPPER, ET AL. (1990)
N. 55° W. - N. 70° W.
N. 80° E. - N. 90° E.

MEMARIAN (1975)
N. 8° E.
N. 53° E.
N. 82° W.
N. 37° W.

LOCKPORT FORMATION INVESTIGATION (CRA, 1990)
N. 30° E - N. 80° E.
N. 10° W. - N.

OUTCROP MAPPING (CRA, SSP&A, MSRM, 2001)
N. 90° E.
N. 55° E.

JOHNSTON (1964)
N. 65° E.
N. 30° W.

figure 3.13

SITE AND REGIONAL NEAR-VERTICAL JOINT ORIENTATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

CRA

01069-30(299)GN-WA002 JAN 23/2002

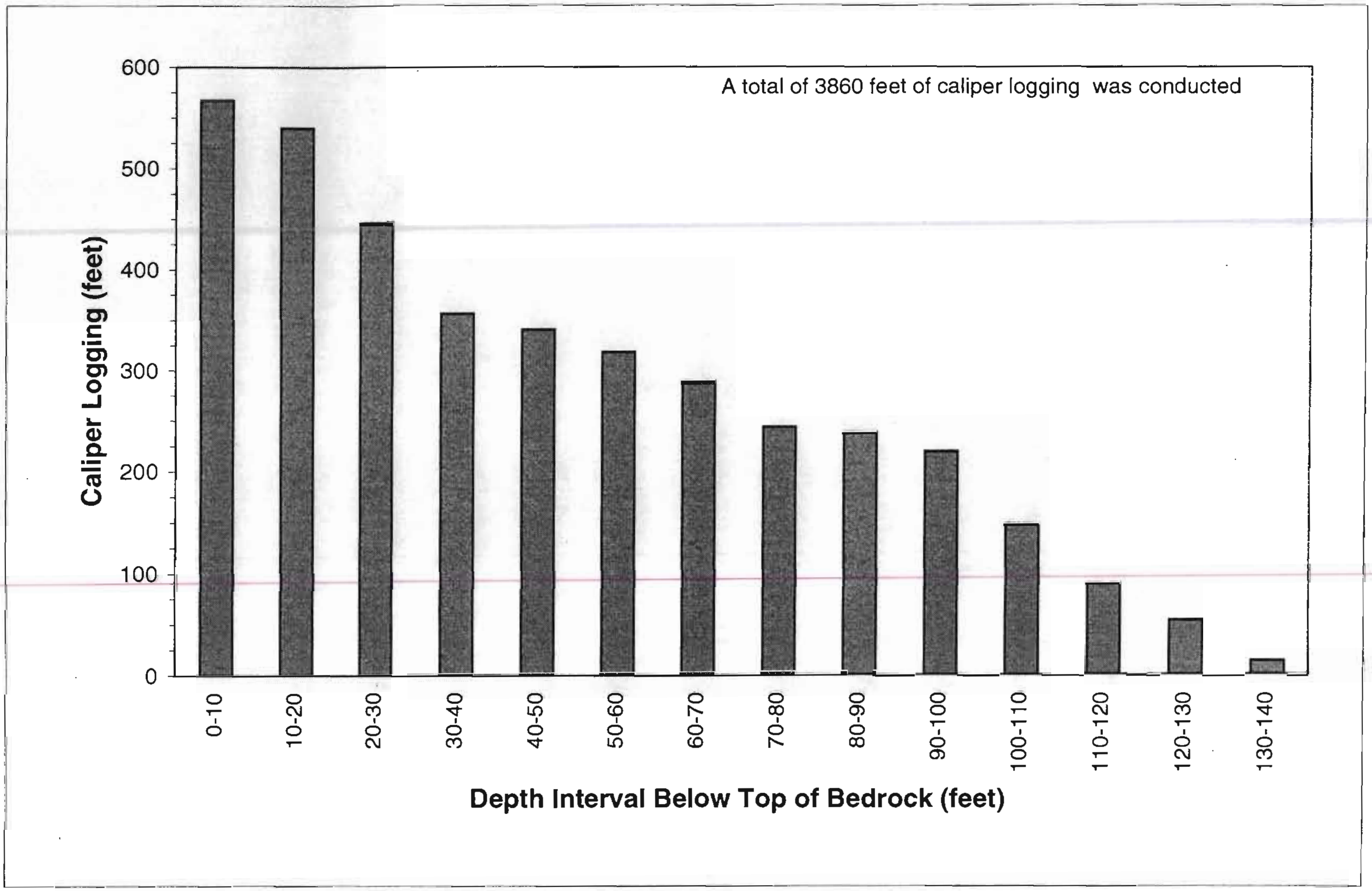


figure 3.14A
NUMBER OF FEET CALIPER LOGGED VERSUS DEPTH
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

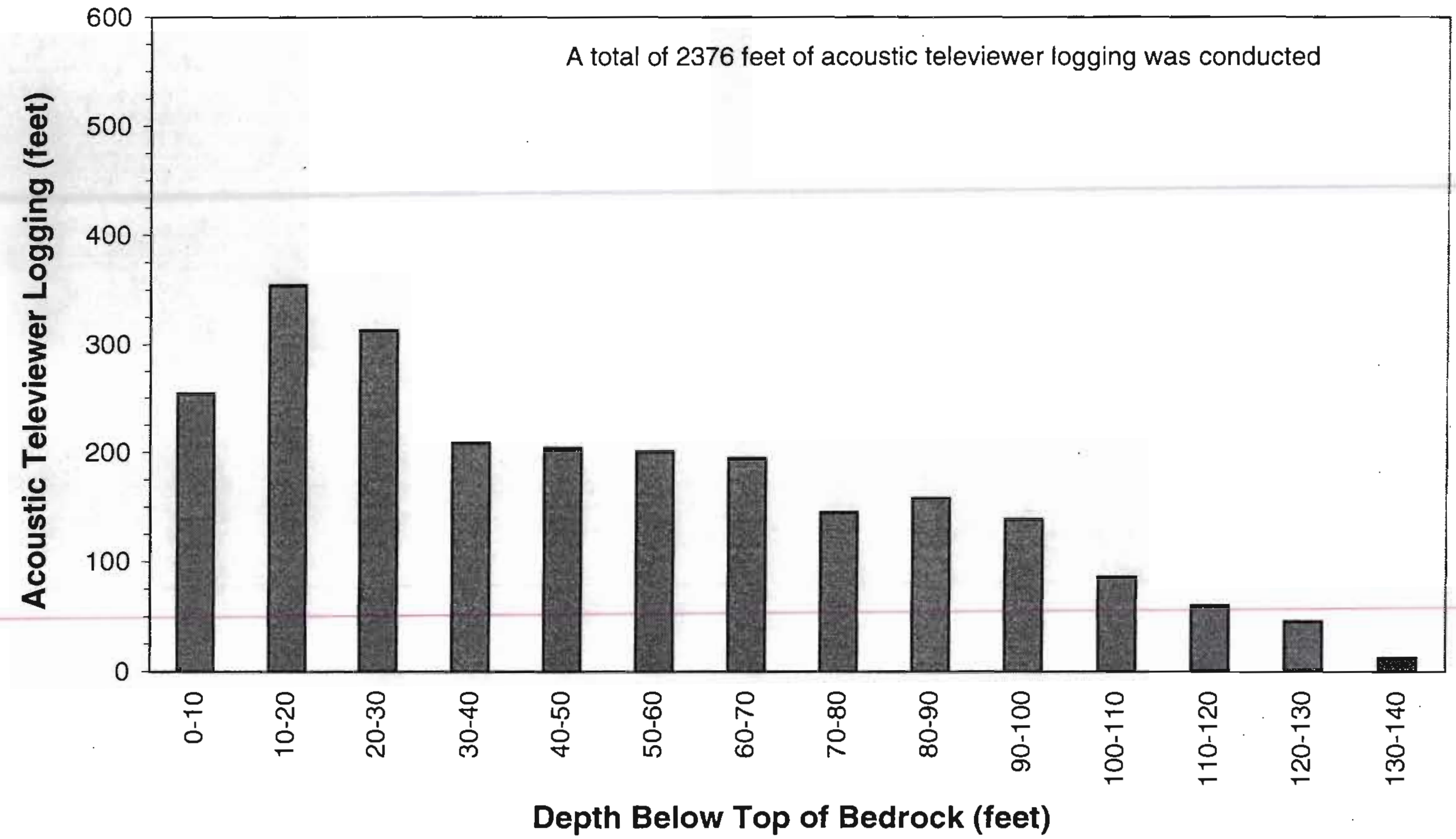


figure 3.14B

NUMBER OF FEET ACOUSTIC TELEVIEWER LOGGED VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

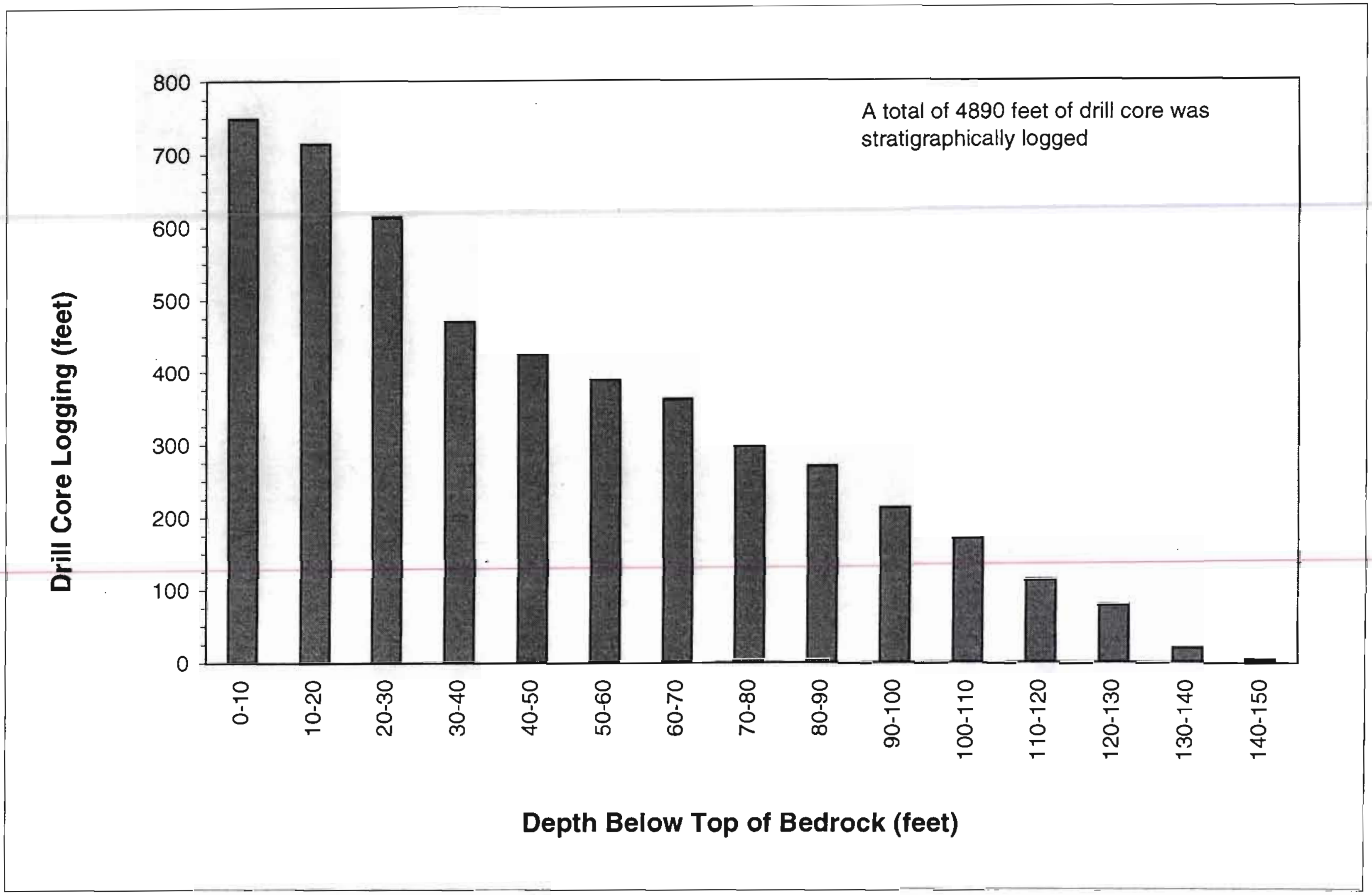
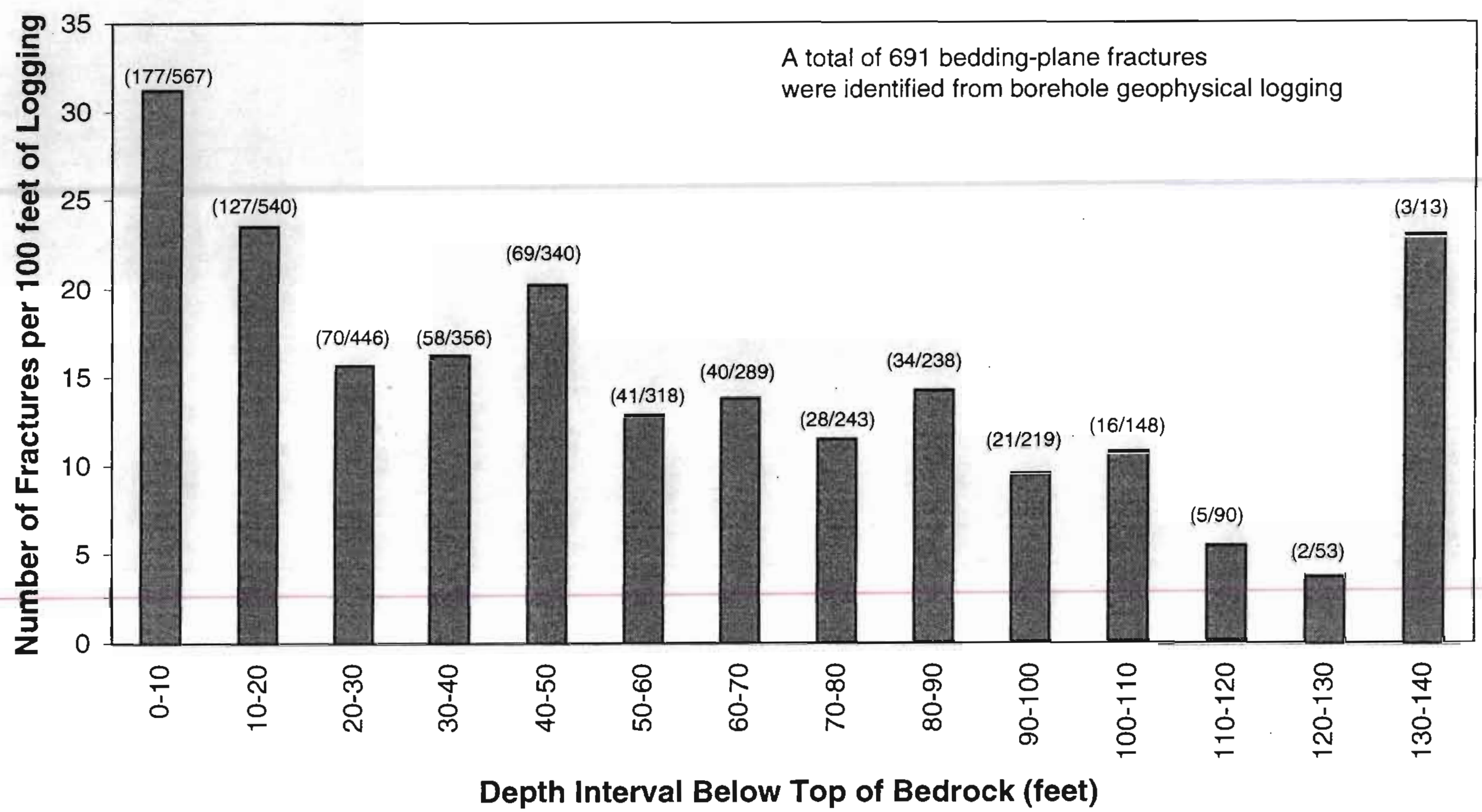


figure 3.14C
NUMBER OF FEET OF DRILL CORE LOGGED VERSUS DEPTH
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

CRA



Legend

(177/567) = number of bedding-plane fractures identified in the 10 foot interval/
number of feet of caliper logging in the 10 foot interval.

figure 3.15A

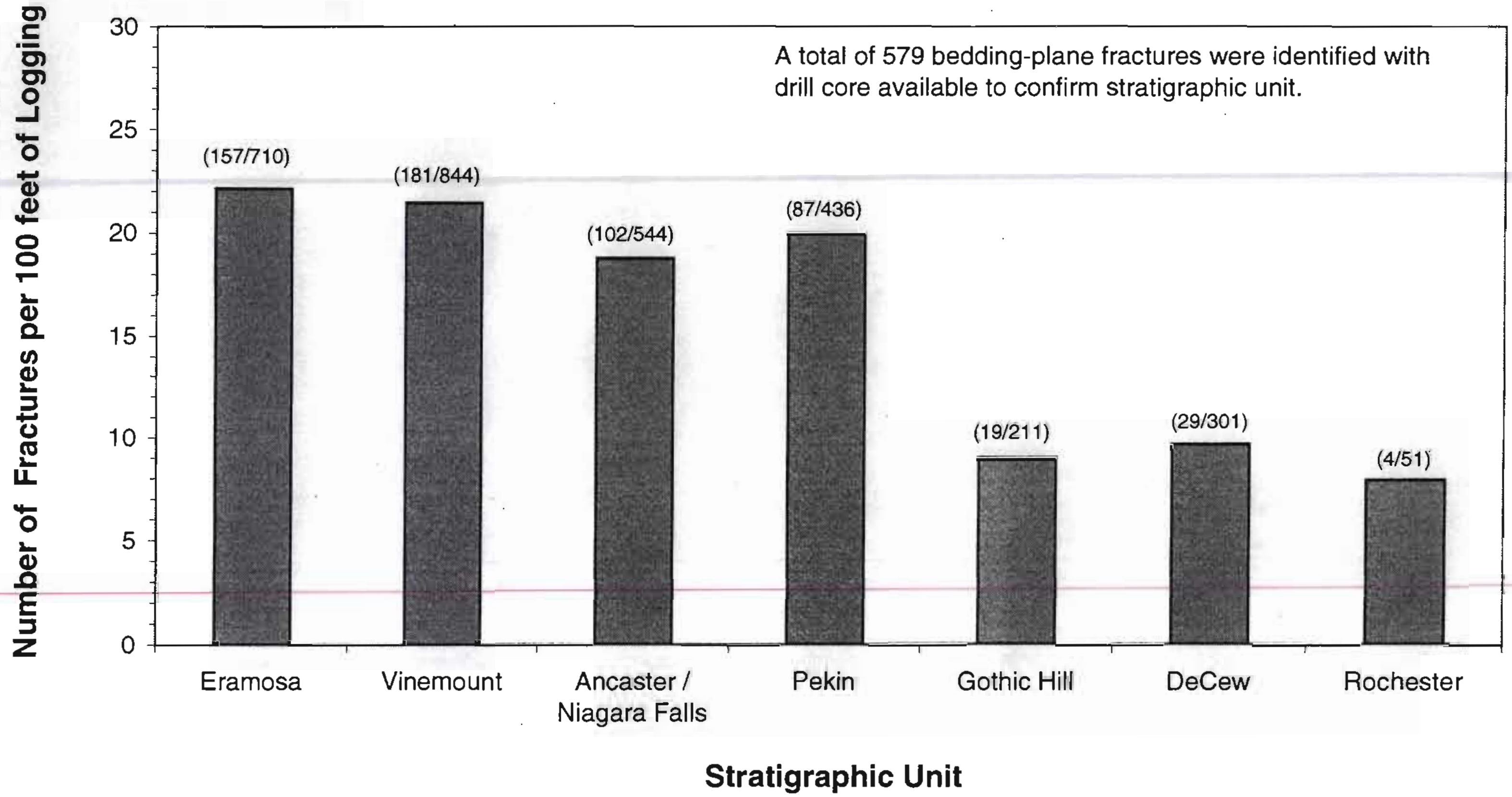
DISTRIBUTION OF BEDDING-PLANE FRACTURES VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

CRA 1069-30(299) I:\HG\1069\Site Char Rpt\Figure 3.14 - 18 histograms.xls Fig3.15A h f vs depth



Legend
(157/710) = number of bedding-plane fractures identified per stratigraphic interval/number of feet of caliper logging per stratigraphic interval

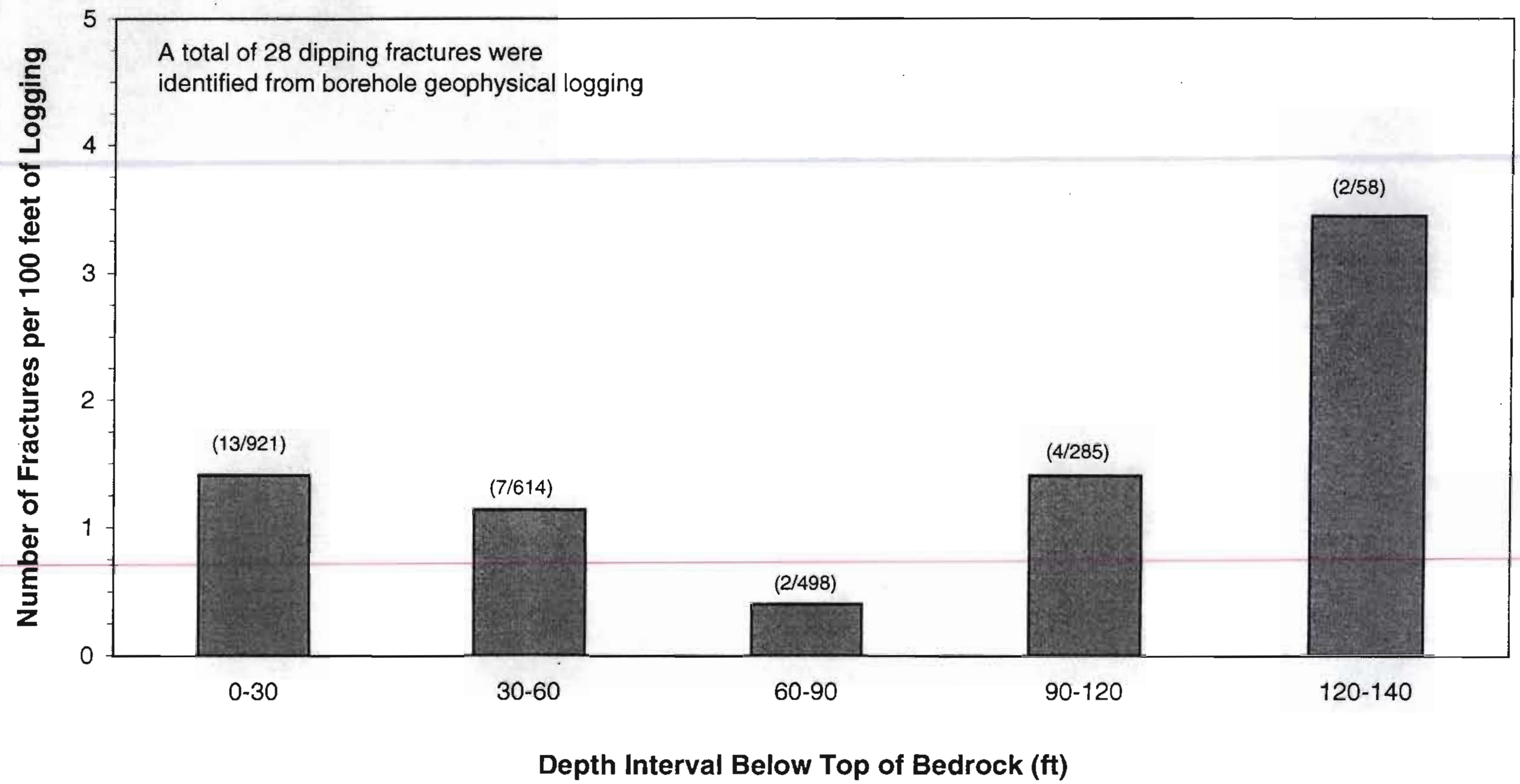
figure 3.15B

DISTRIBUTION OF BEDDING-PLANE FRACTURES VERSUS STRATIGRAPHIC UNIT

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



Legend
(13/921) = number of dipping fractures identified in the 30 foot interval/ number of feet of acoustic televiewer logging in the 30 foot interval.

figure 3.16A
DISTRIBUTION OF DIPPING FRACTURES VERSUS DEPTH
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

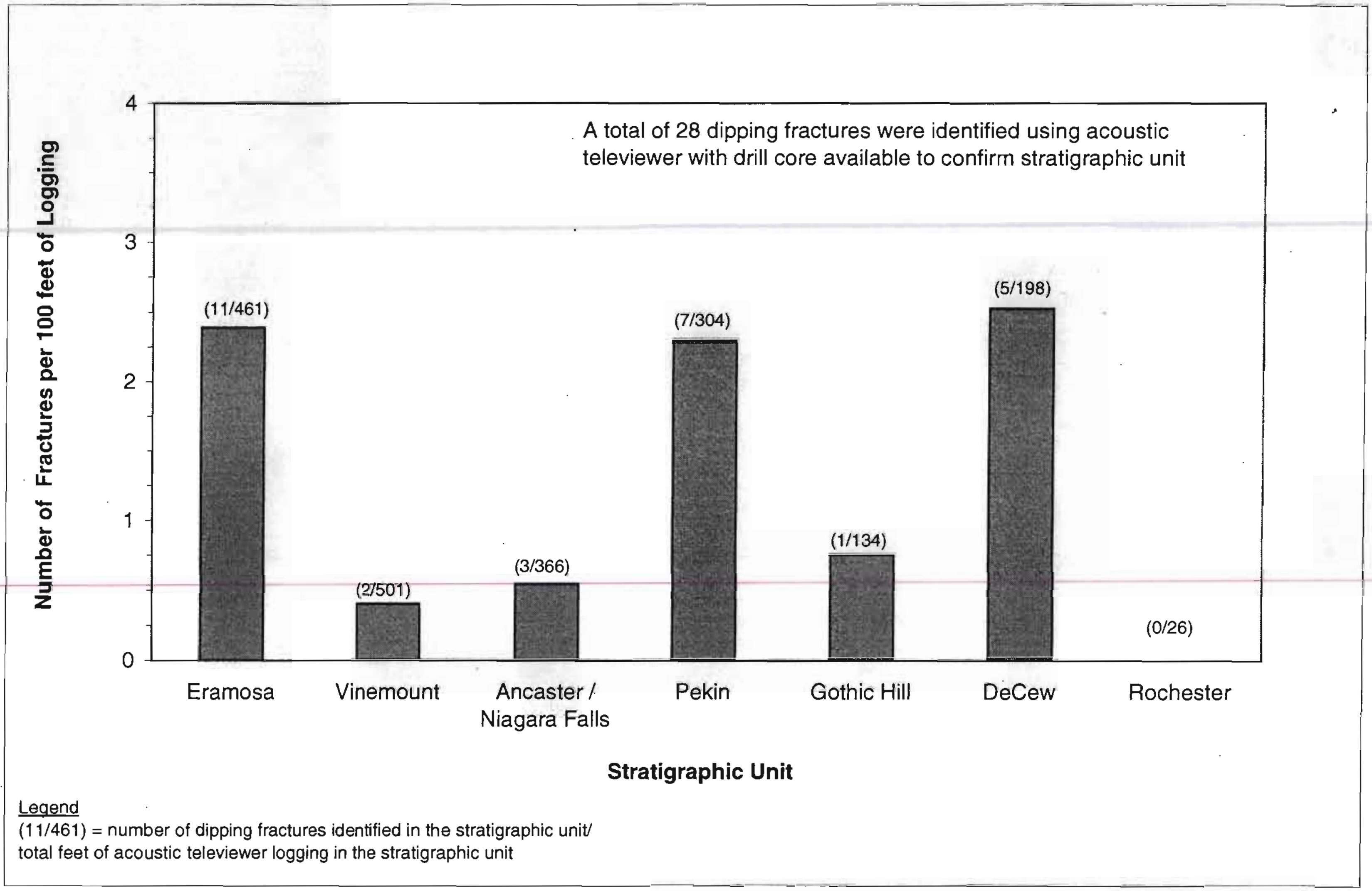


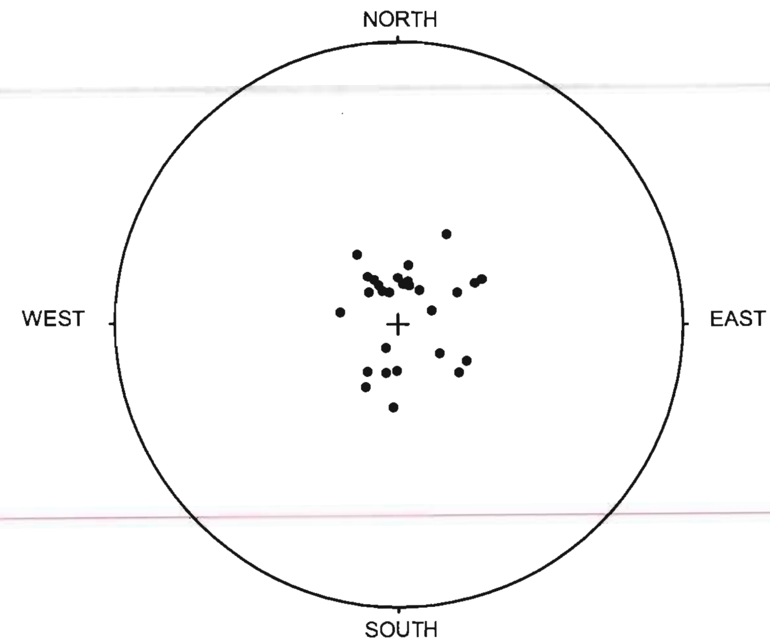
figure 3.16B

DISTRIBUTION OF DIPPING FRACTURES VERSUS STRATIGRAPHIC UNIT

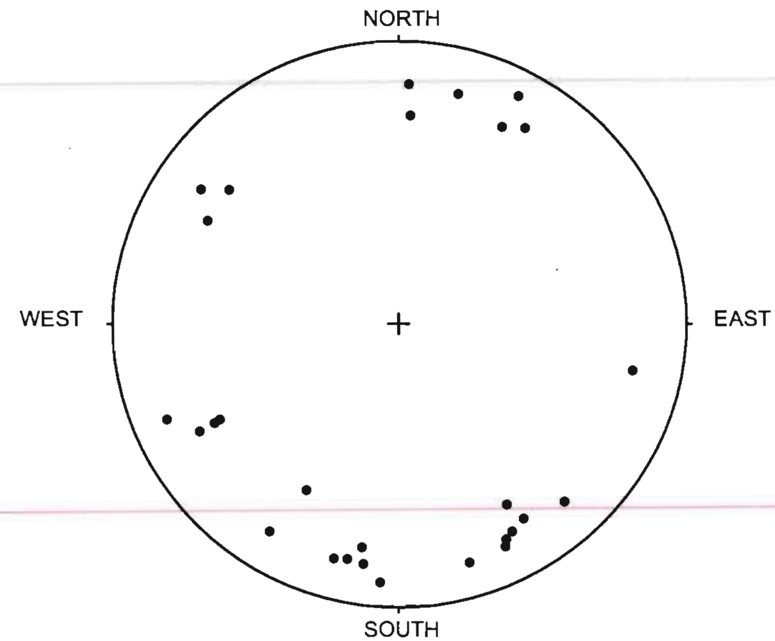
SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



ORIENTATION OF POLES TO THE FRACTURE PLANES
PROJECTION: SCHMIDT NET



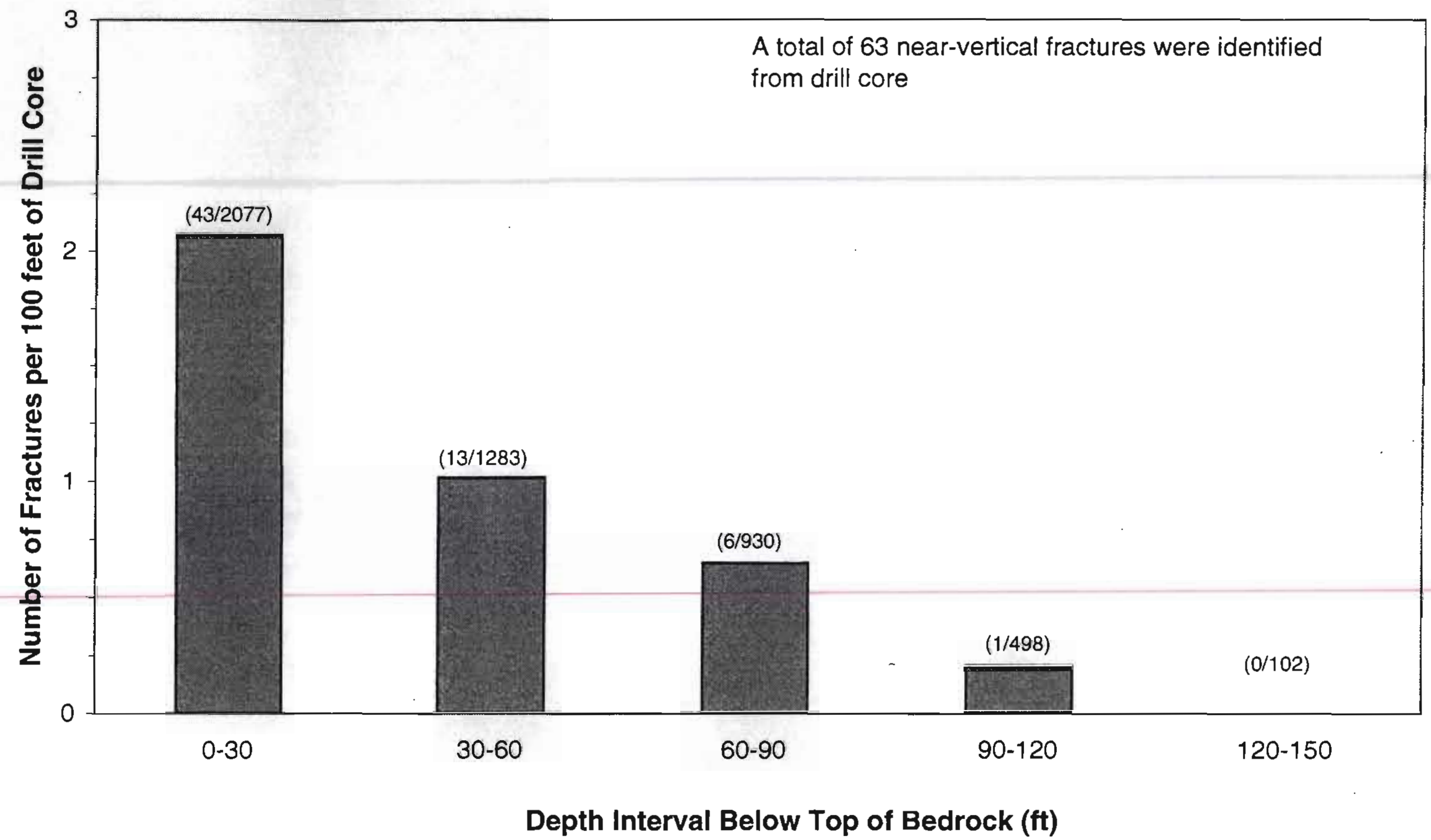
DIP DIRECTION AND DIP OF FRACTURE PLANES
PROJECTION: SCHMIDT NET

n = 28 DIPPING FRACTURES
DOES NOT INCLUDE OFFSITE WELLS

figure 3.17

ORIENTATION OF DIPPING FRACTURES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA039 FEB 13/2002



Legend

(43/2077) = number of near-vertical fractures identified in 30-foot interval/total length of drill core logged in the 30 foot interval

figure 3.18A

DISTRIBUTION OF NEAR-VERTICAL FRACTURES VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

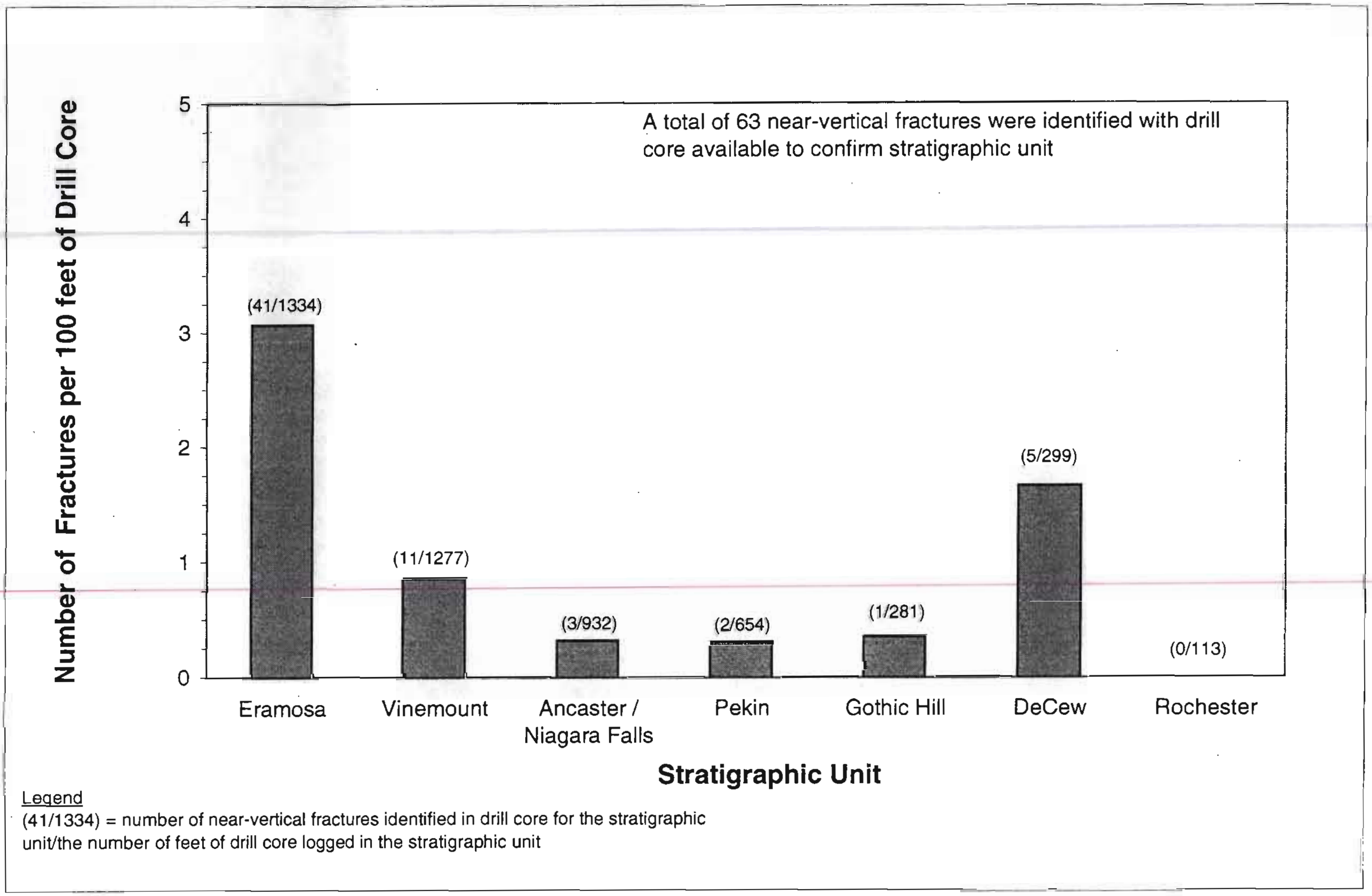


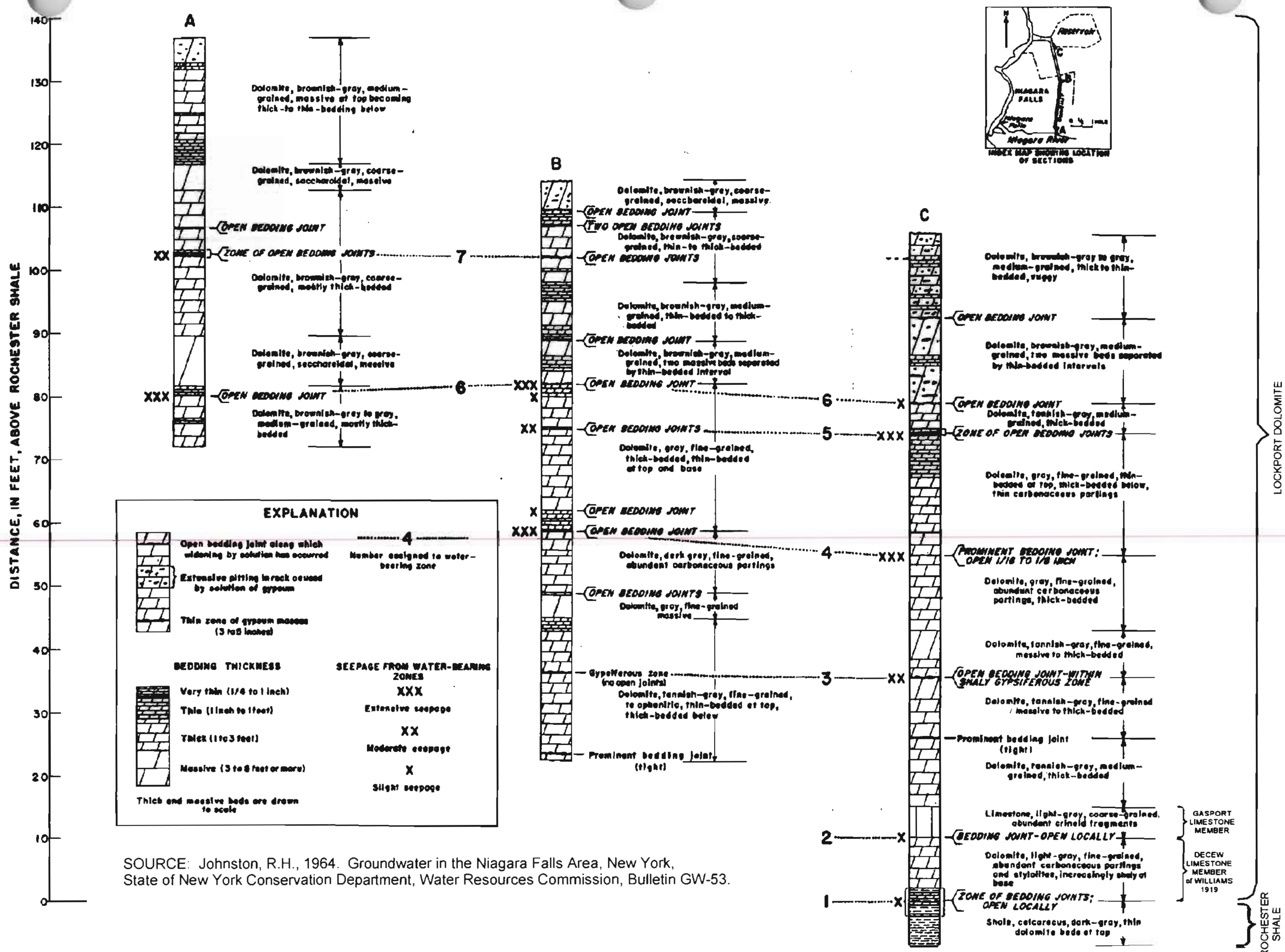
figure 3.18B

DISTRIBUTION OF NEAR-VERTICAL FRACTURES VERSUS STRATIGRAPHIC UNIT

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



SOURCE: Johnston, R.H., 1964. Groundwater in the Niagara Falls Area, New York, State of New York Conservation Department, Water Resources Commission, Bulletin GW-53.

Figure 4.1 - Flow Zones Identified by Johnston (1964)

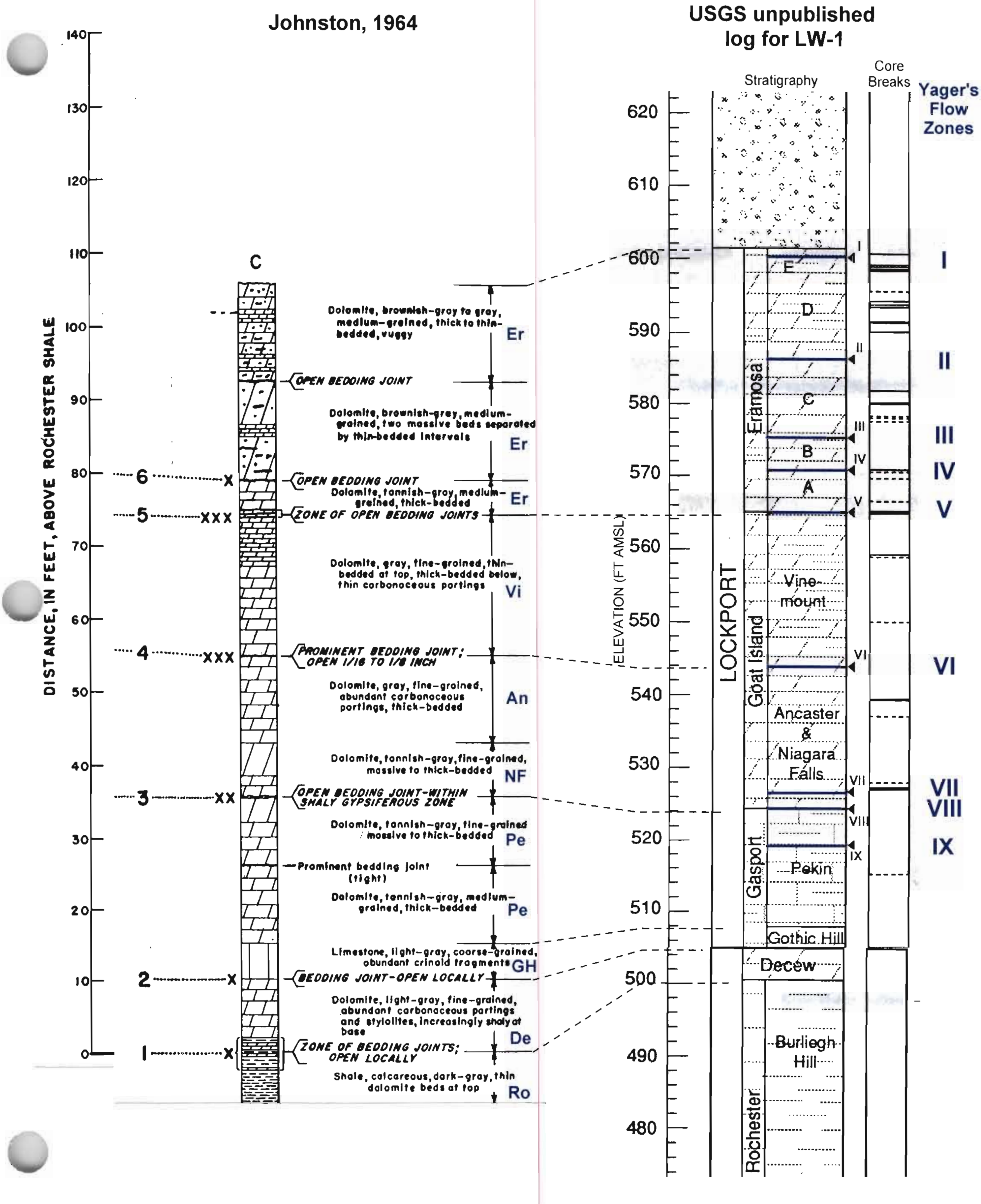


Figure 4.2 - Comparison of Johnston (1964) and USGS (Yager, 1996) flow zones

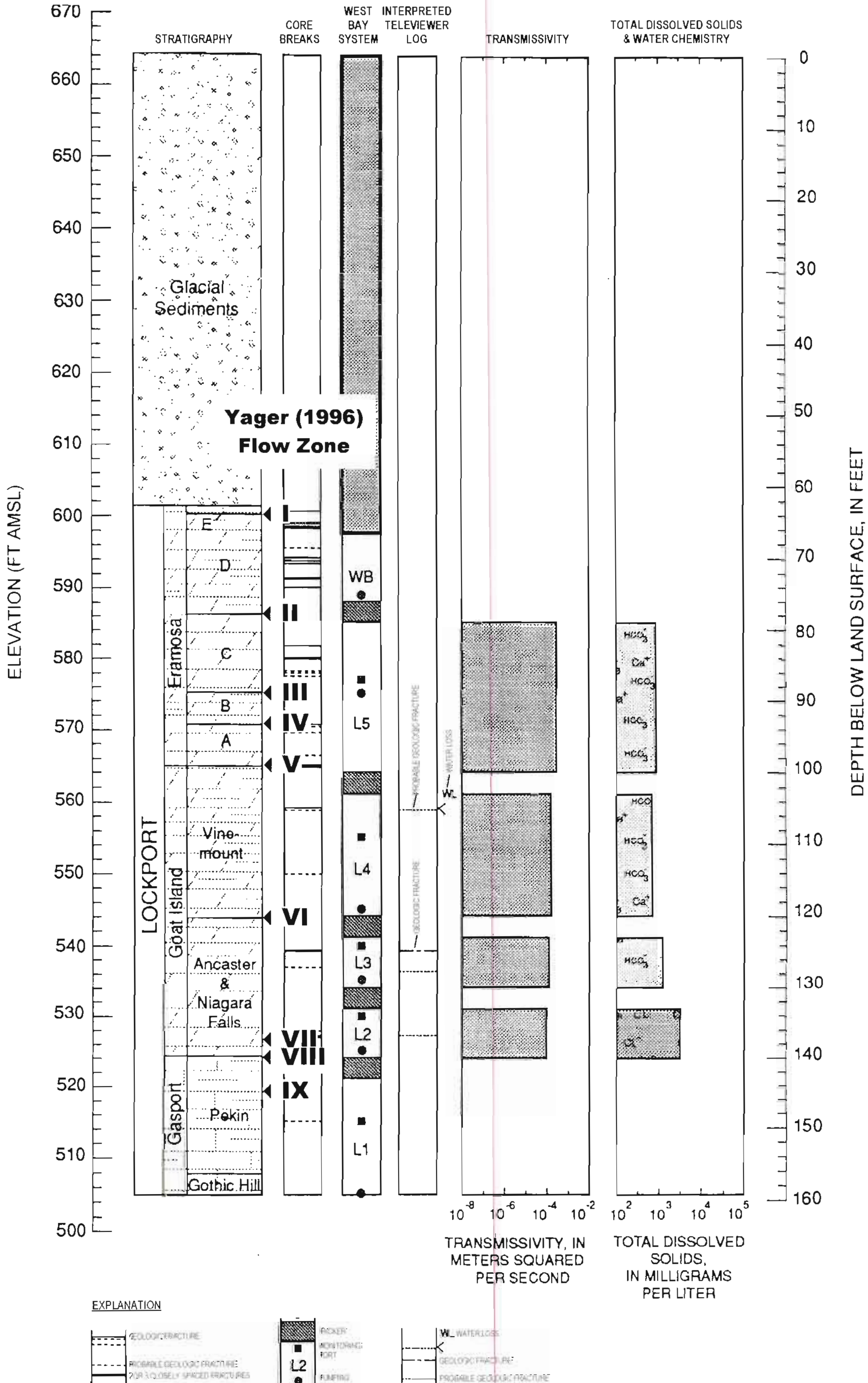


Figure 4.3 - Additional Details of the USGS Log of LW-1

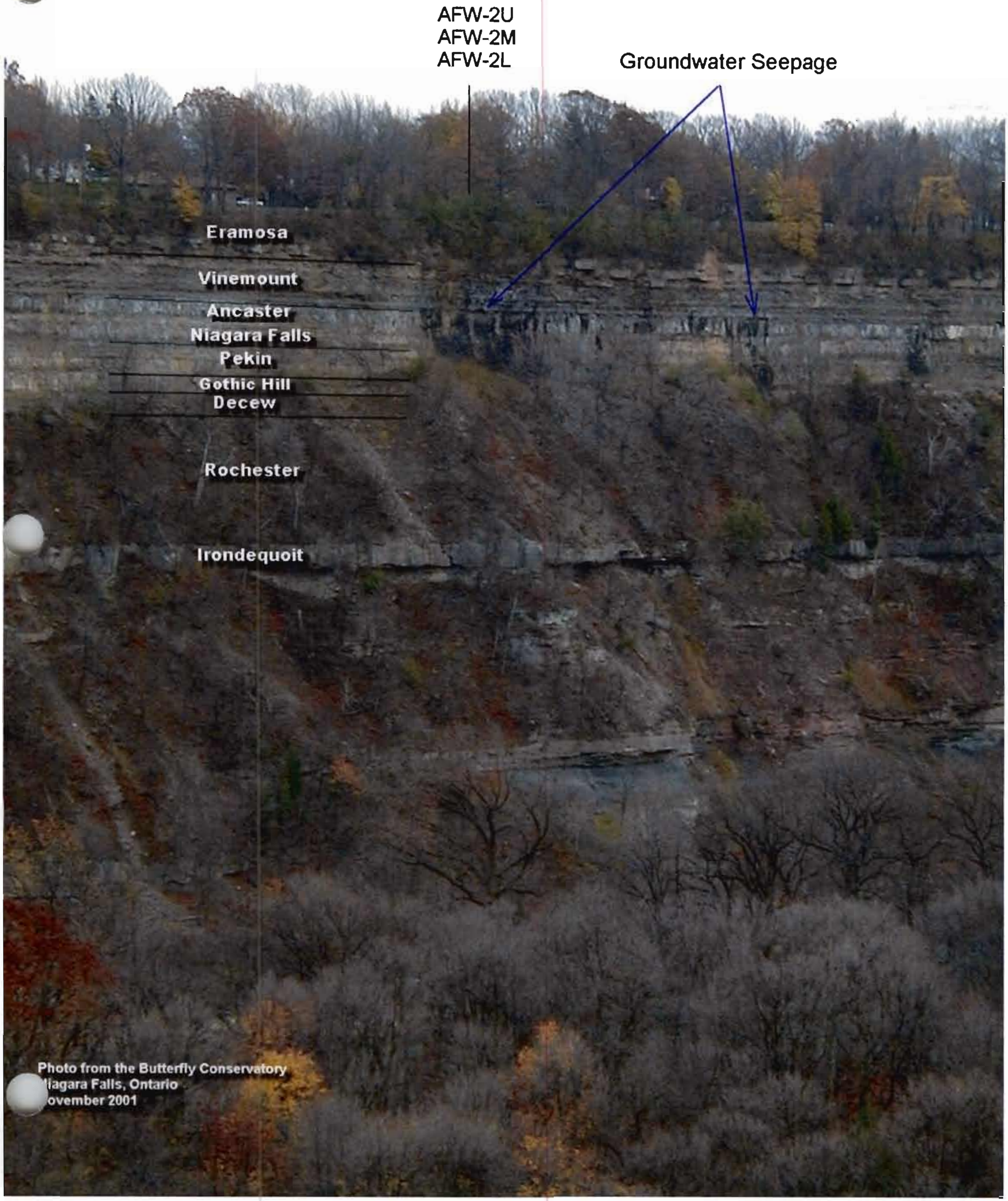


Figure 4.4 Groundwater Seepage Along Bedding

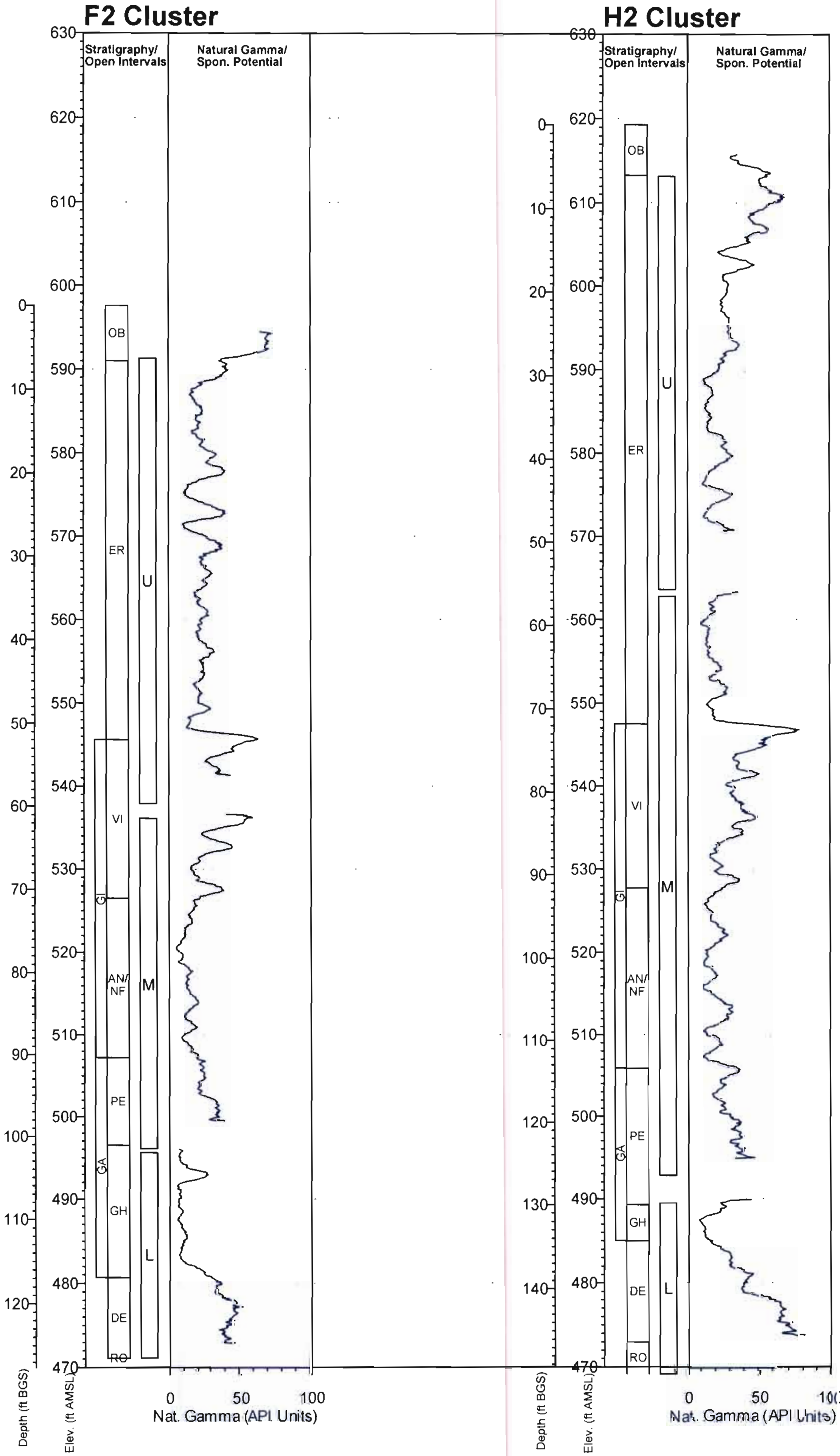


Figure 4.6 Example of Typical Gamma Signatures

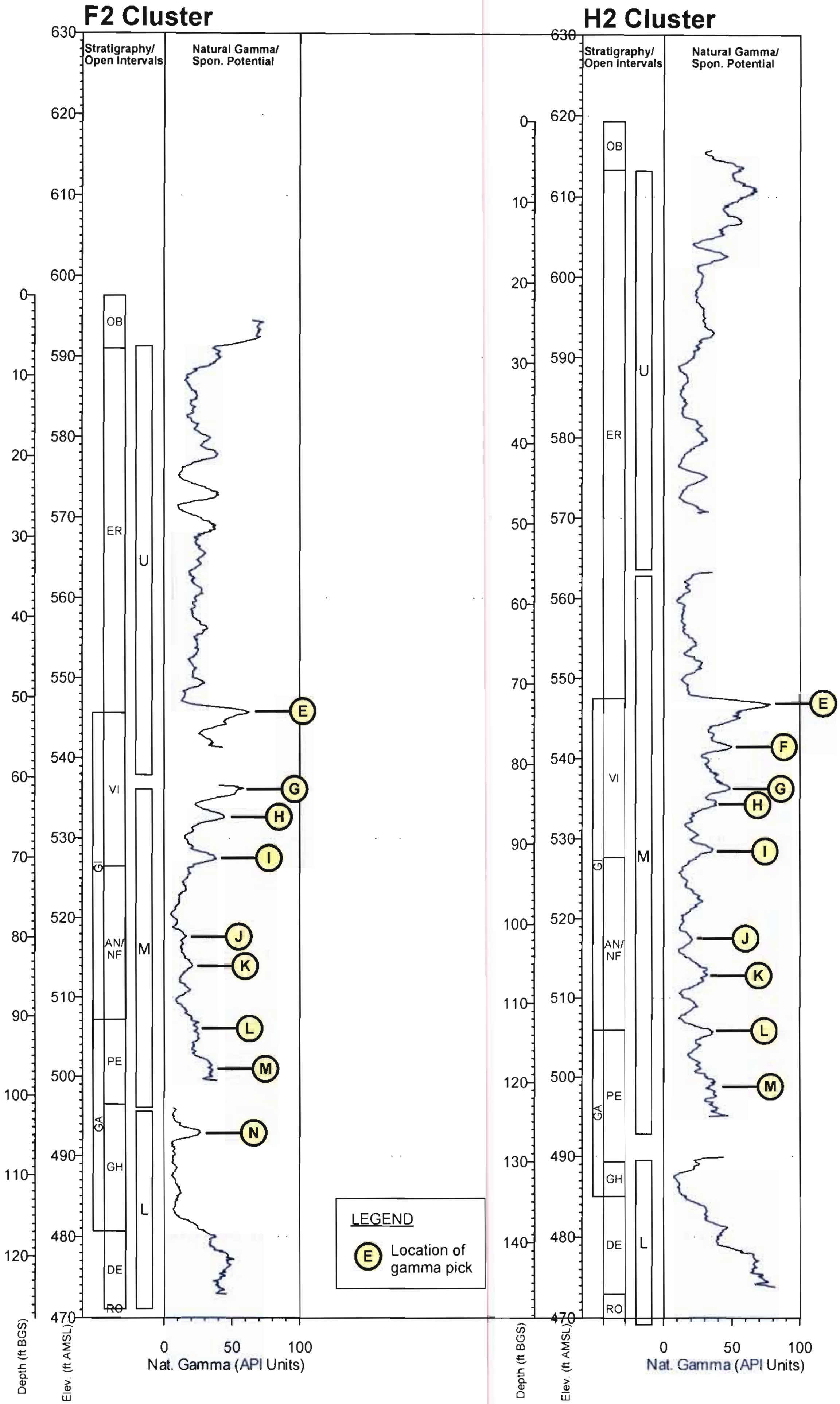


Figure 4.7 F2 and H2 Gamma Signatures With Key Peaks Labeled

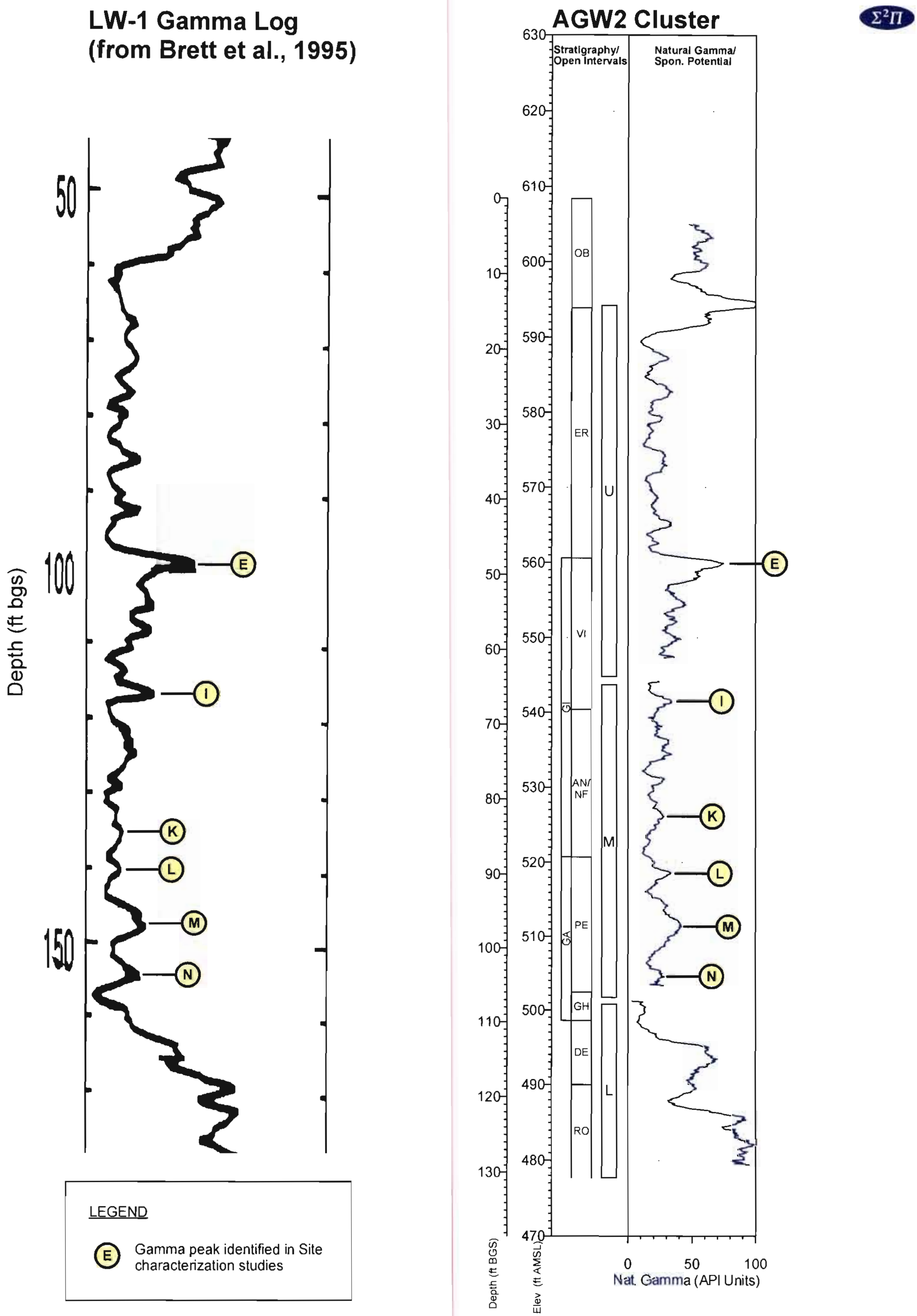


Figure 4.8 Comparison of AGW-2 Gamma Signatures with LW-1 Gamma Signature from Brett et al. (1995)

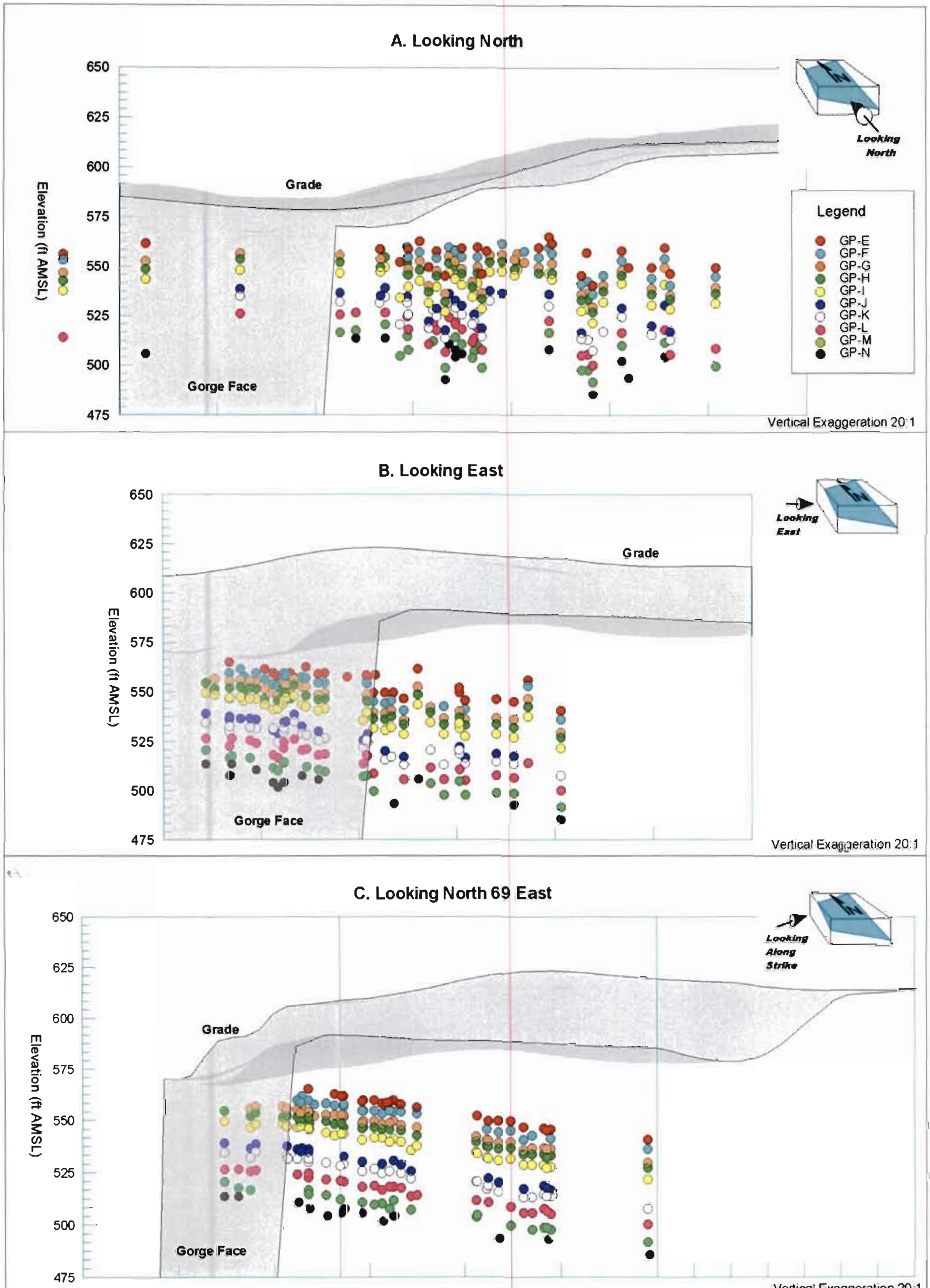


Figure 4.9 Inspection of the Gamma Peak Picks in 3-Dimensions

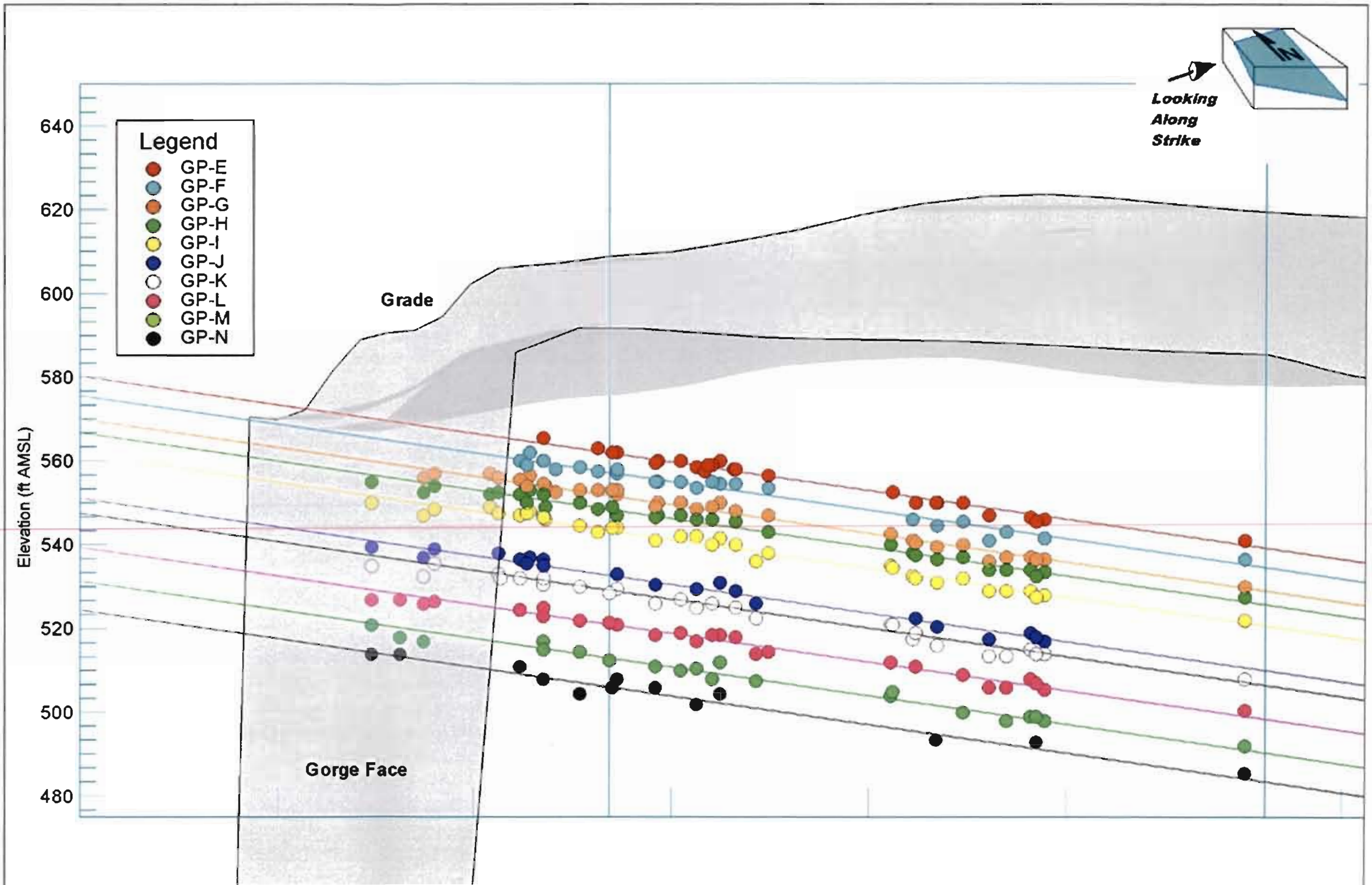
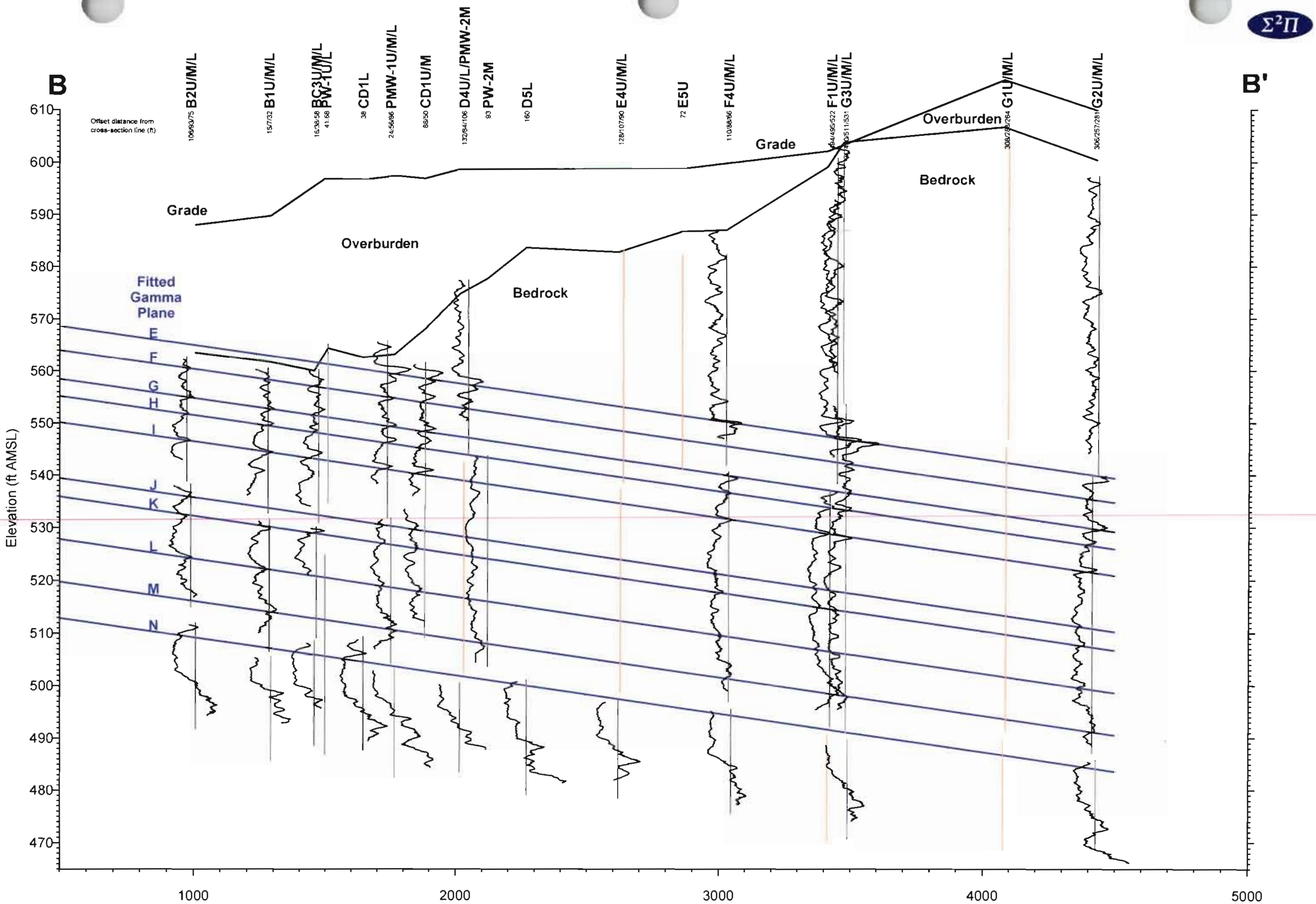


Figure 4.10 Comparison of Gamma Pick and Best-fit Planes. Looking along Strike.

View looking North 69 East
Vertical Exaggeration 20:1

SEDA



Exaggeration=20:1.
Refer to Figure 3.10 for cross-section location.

Figure 4.11 Natural Gamma Signals Along Dip (looking along strike)

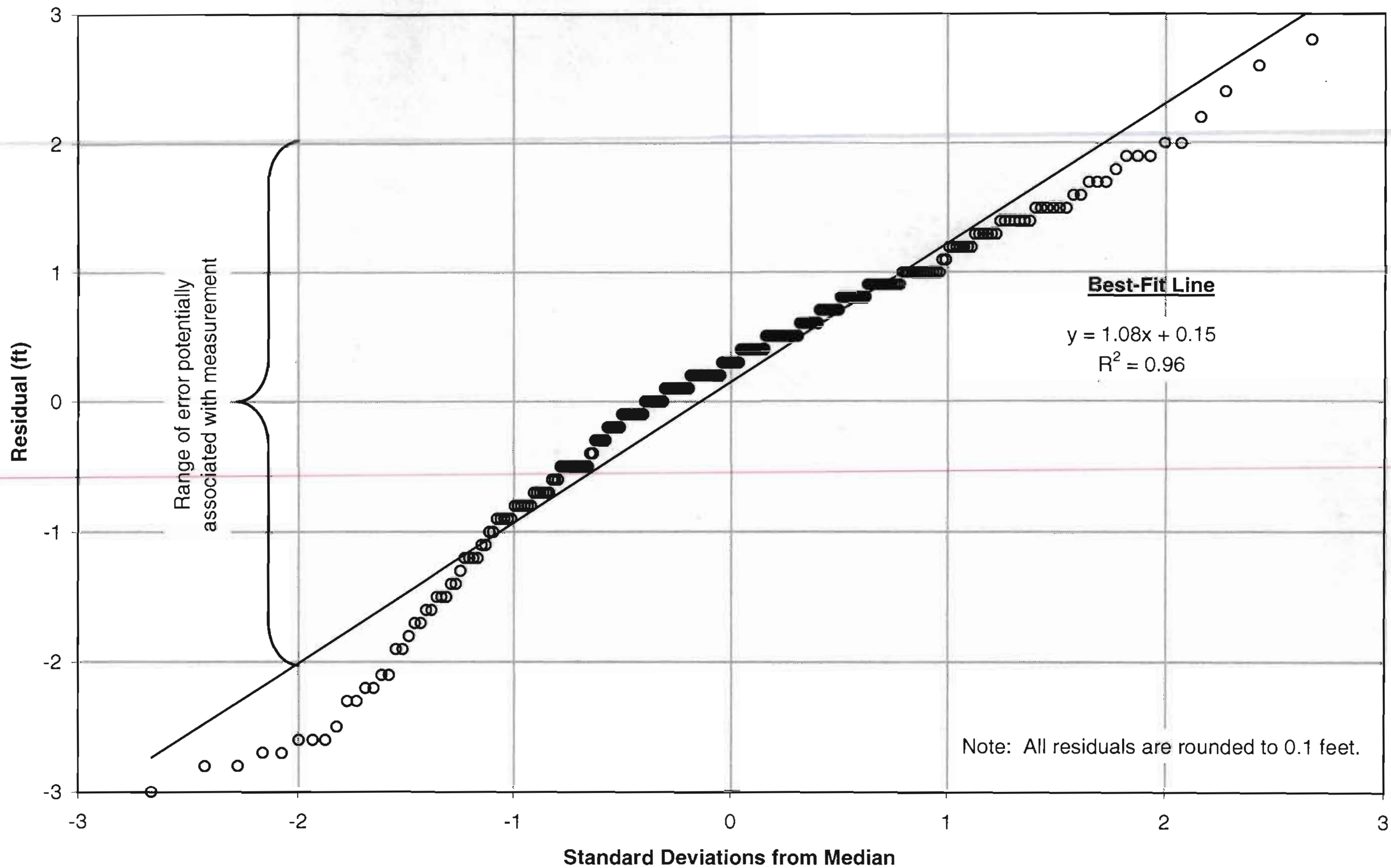


Figure 4.12 Probability Plot of Residuals for Gamma Best Fit Planes

B2 Cluster Page 1 of 2

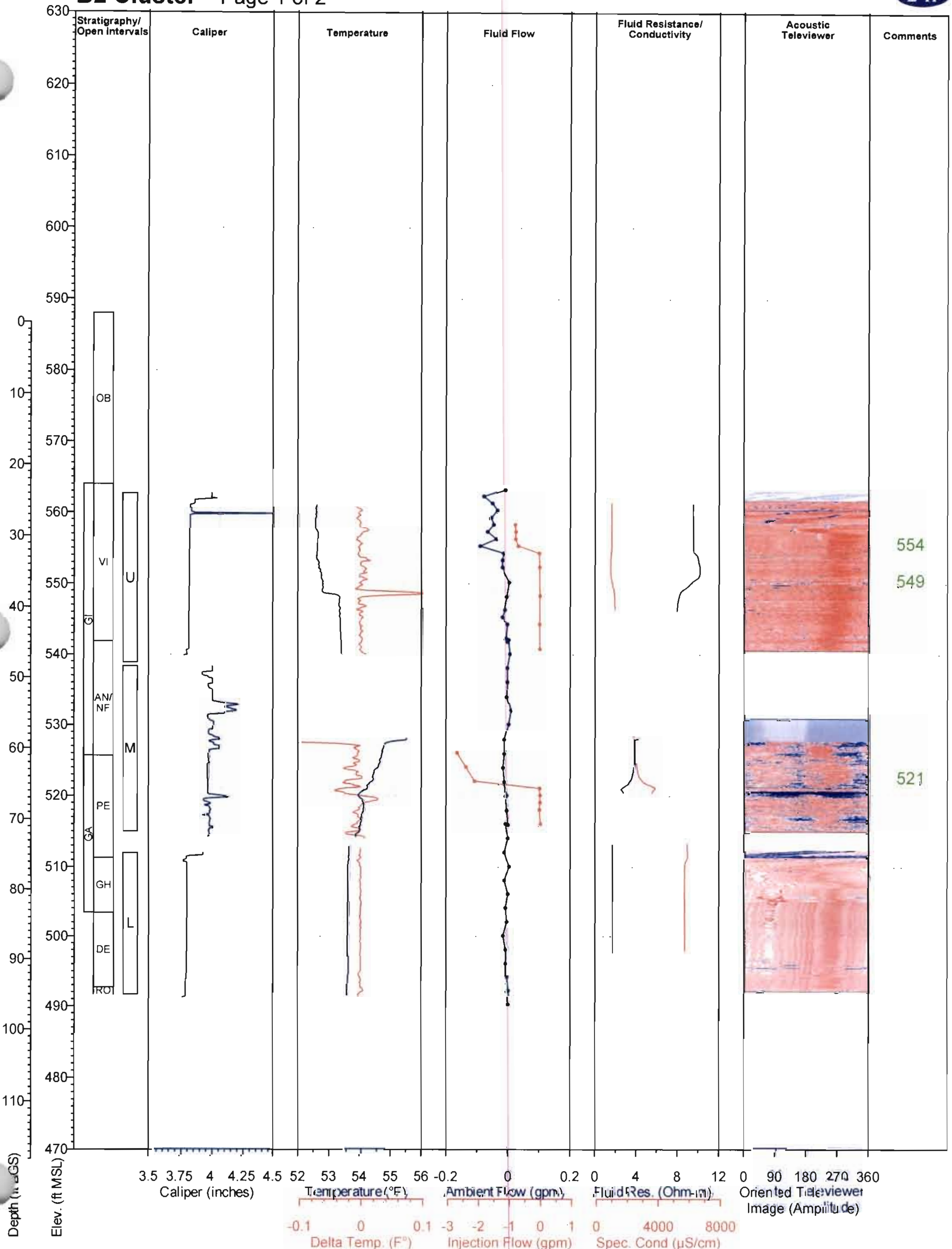


Figure 4.13 Geophysical Log for the B2 Well Cluster

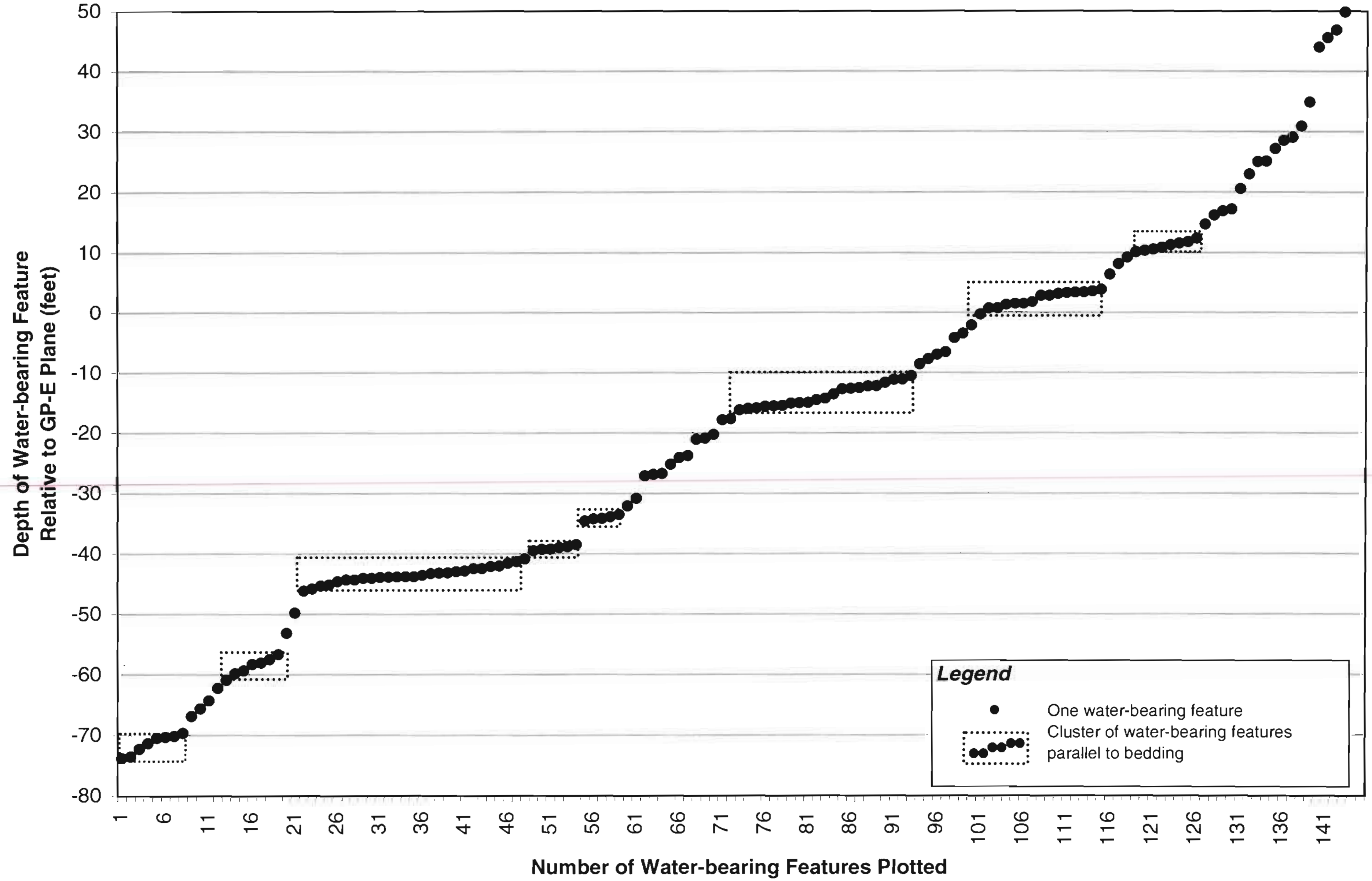


Figure 4.14 Cluster Analysis For Identification of Flow Zones

Filename: SEDA Fig 4.__15.xls
Date Printed: 2/14/2002

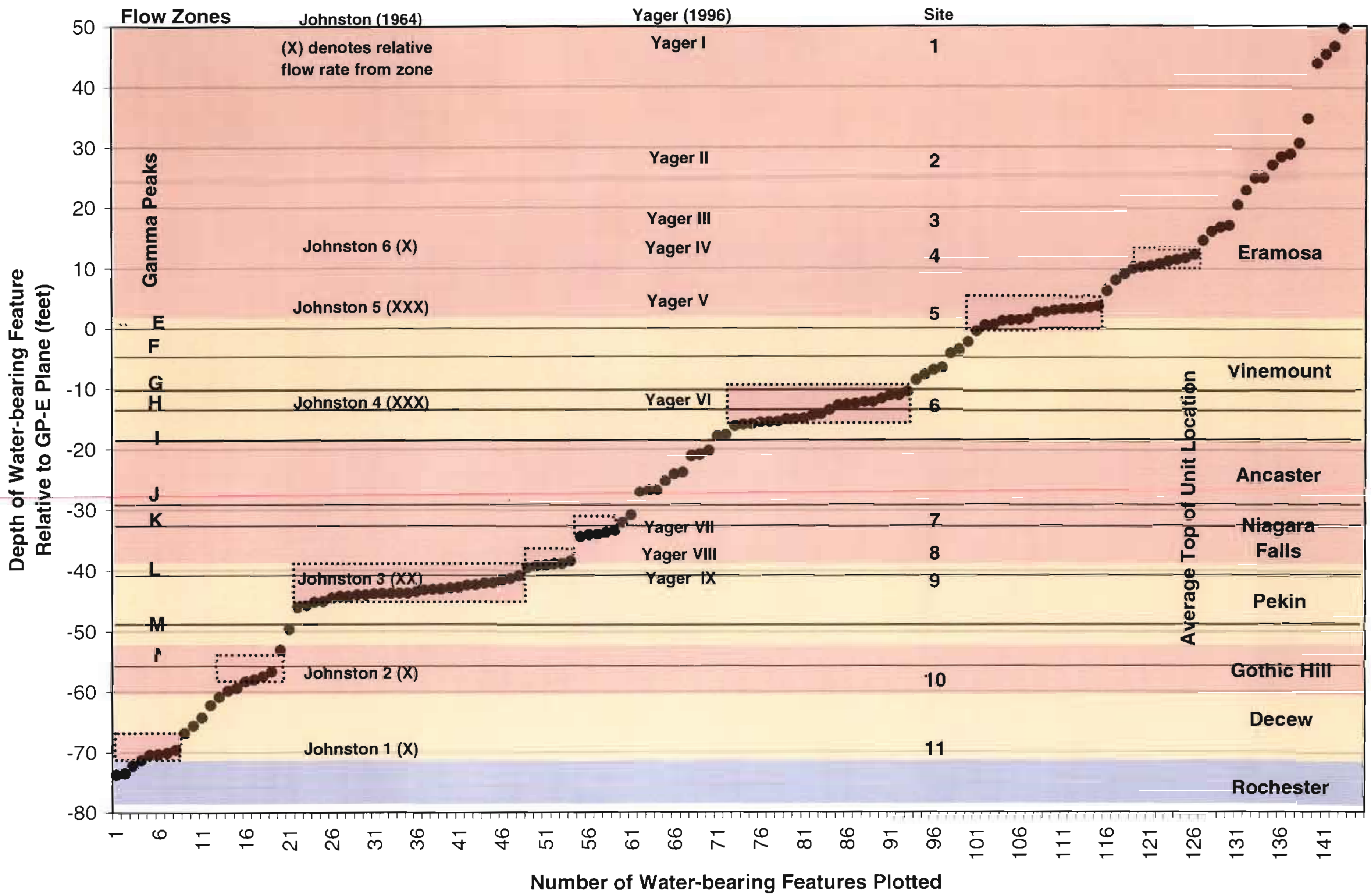


Figure 4.15 Comparison of Water-Bearing Clusters with Published Flow Zones, Stratigraphy, and Gamma Peaks

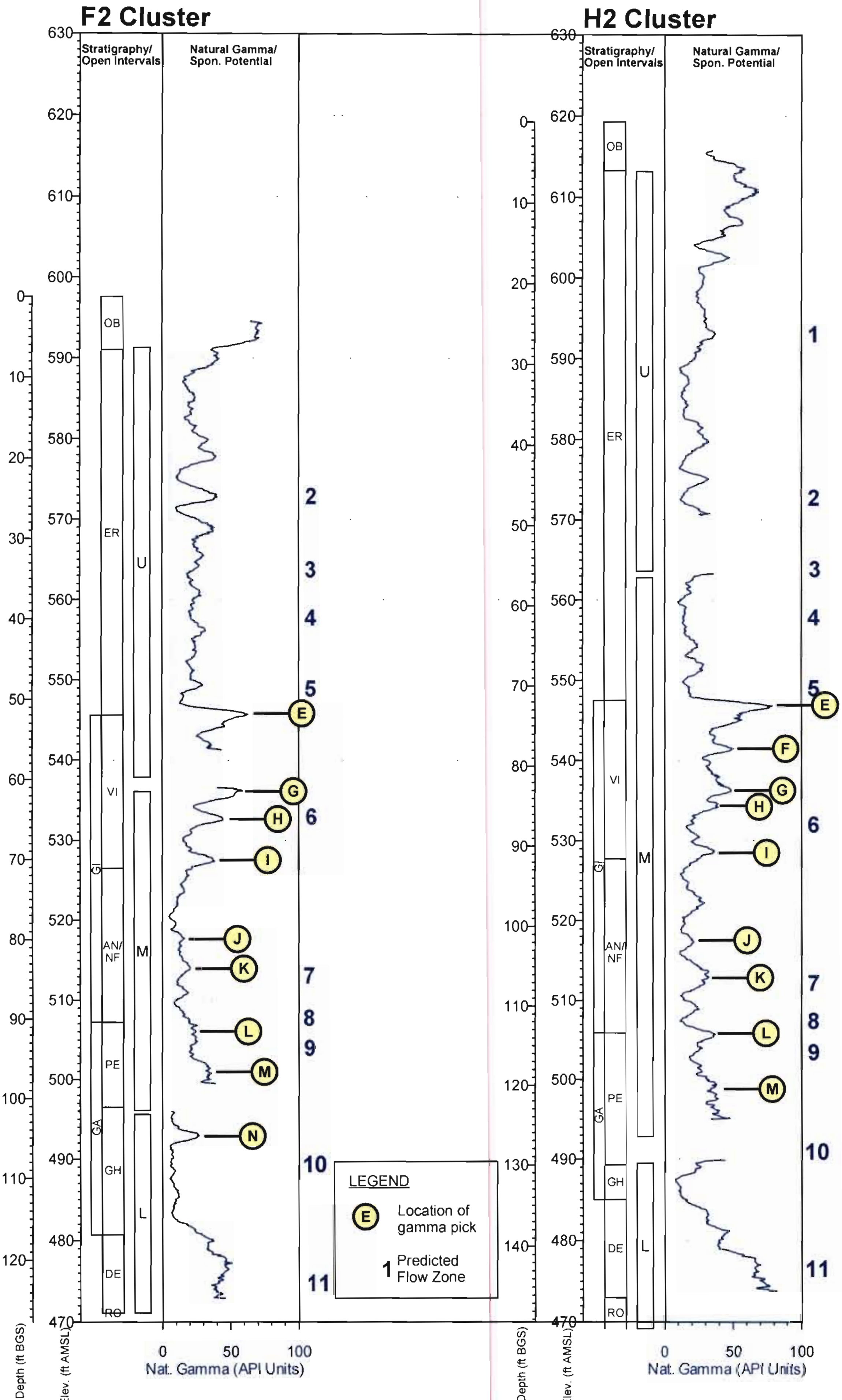


Figure 4.16 Locations of Flow Zones Referenced to the Gamma Peaks

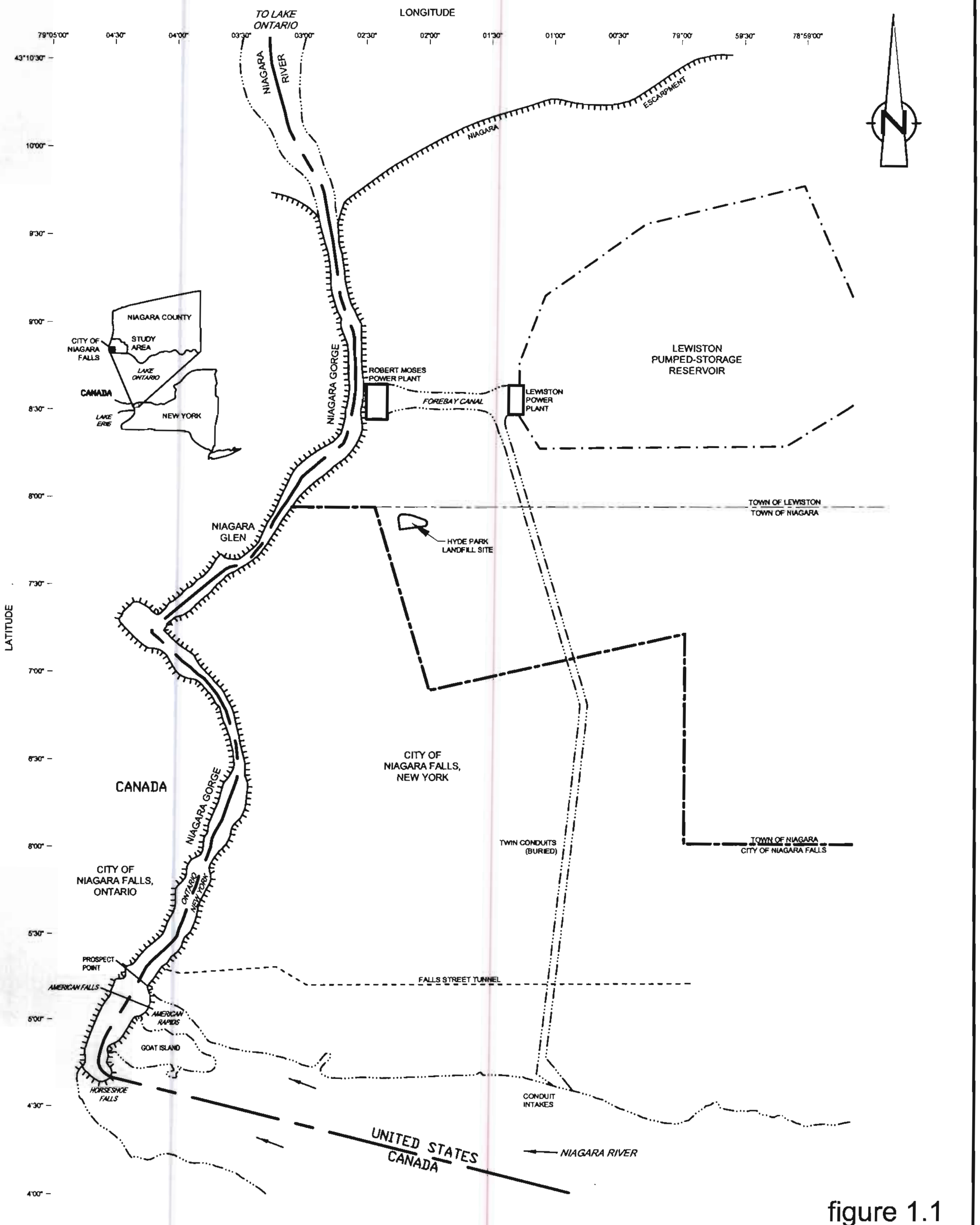


figure 1.1

SITE LOCATION
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

SOURCE: MILLER, KAPPEL, 1987

01069-30(299)GN-WA013 JAN 23/2002

TABLE 3.1

REGIONAL LITHOLOGIC DESCRIPTIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK
(Brett et al., 1995)

	Lithologic Description	Unit Thickness	Contact With Overlying Unit
Eramosa Formation	Dark brownish-gray, thin to thick bedded, bituminous dolomite, commonly vuggy	38 to 50 feet	Typically sharp, occurs at the basal stromatolitic marker bed of the Guelph Dolomite
Vinemount Member of the Goat Island Formation	Light to dark gray, medium to thin bedded, very fine-grained, argillaceous, bituminous, dolomite with thin shale partings	17 to 20 feet, anomalously thin (9 to 10 feet thick) at two locations in the Niagara region	Commonly gradational, but often sharp where the overlying unit is thick-bedded
Ancaster Member of the Goat Island Formation	Medium ash-gray, thin to medium bedded, fine grained dolomite with abundant chert nodules	2 to 25 feet. The thickness tends to be compensatory, such that the Ancaster Member is thick where the Niagara Falls Member is thin and vice versa	Abrupt and often demarcated by a 1- to 2-inch thick black shale, also described for the Niagara Falls area as being gradational and difficult to establish
Niagara Falls Member of the Goat Island Formation	Light olive to brownish-gray, sucrosic, medium grained, thick to massive bedded, porous and vuggy dolomite, containing stromatoporoids	3 to 15 feet	Sharp but conformable, color and texture typically change from dark and medium-grained below the contact to pale buff and finer-grained above.
Pekin Member of the Gasport Formation	Argillaceous, dark gray, fine-grained, thin to medium bedded, dolomicrite with local bioherms and flanking fossiliferous facies	Up to 33 feet but was noted to vary significantly	Varies from gradational to sharp
Gothic Hill Member of the Gasport Formation	Thick to massive bedded, dark olive gray to light pink, crinoidal grainstone and crinoidal dolomite	3 to 21 feet	Sharp and conformable, obvious due to the distinctive lithological change
DeCew Formation	Dark gray to olive gray, argillaceous to sandy, fine-grained dolomite with stringers of crinoid ossicles, internal soft sediment deformation structures	4.5 to 11.8 feet	Sharp and unconformable
Burleigh Hill Member of the Rochester Shale	Dark to medium gray, highly calcareous to dolomitic mudstone	30 feet near Lewiston to 23 feet thick at the Niagara Falls	Gradational and often difficult to establish in the Niagara region

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval	
				Start Depth	End Depth
Monitoring Wells					
A1U	598.0	600.35	26.0	27	57
A2U	593.5	593.51	22.0	22	52
AB1L	588.0	590.05	27.3	79	98
AB1M	588.0	589.44	22.6	44	86
AB1U	587.9	589.53	28.5	31	45
ABP-1	571.9	571.68	18.0	32 (2)	47 (2)
ABP-2	574.9	576.00	17.2	33 (2)	48 (2)
ABP-3 (1)	591.1 (1)	592.41 (1)	28.5	29	60
ABP-4	588.1	589.41	27.0	27	59
ABP-5	589.3	590.44	28.0	28	57
ABP-6 (C2U)	590.4	590.08	30.6	35 (2)	55 (2)
ABP-7	574.4	575.61	8.0	8	61
ABP-8	575.1	576.43	41.0	41	62
AFW-1L	570.9	570.61	8.0	56	81
AFW-1M	570.6	570.33	7.3	30	55
AFW-1U	570.3	569.84	7.5	8	29
AFW-2L	592.2	591.83	13.4	89	105
AFW-2M	592.2	591.73	13.6	61	88
AFW-2U	592.4	610.94	14.8	15	60
AFW-3L	589.3	588.73	12.4	85	106
AFW-3M	589.0	588.66	15.5	49	84
AFW-3U	588.4	588.10	13.2	14	48
AGW-1L	591.4	592.94	15.2	95	113
AGW-1M	591.4	593.56	14.6	53	94
AGW-1U	590.2	593.52	22.0	22	52
AGW-2L	608.4	611.24	15.3	108	131
AGW-2M	608.7	610.39	14.2	65	107
AGW-2U	608.8	610.94	14.6	15	64
AGW-3L	628.3	628.15	16.1	136	155
AGW-3M	627.8	627.41	8.6	77	132
AGW-3U	627.1	626.64	8.7	9	75
B1L	589.7	592.24	28.0	84	104
B1M	589.5	591.31	28.4	58	83
B1U	589.8	592.40	29.3	29	57
B2L	588.0	590.08	24.5	76	96
B2M	587.9	589.96	26.0	50	73
B2U	587.9	590.17	25.2	25	49
BC3L	595.0	594.70	35.0	87	107
BC3M	595.1	596.55	35.0	65	86
BC3U	595.2	594.93	35.0	35	64
BR-1	582.6	583.35	23.5	24	38
BR-2	581.6	582.07	24.5	25	39
BR-3	582.0	582.55	23.0	23	38
BR-4	583.5	583.84	26.8	27	42
C1L	591.4	593.16	29.5	82	104
C1M	591.5	594.04	29.6	57	82
C1U	591.6	593.66	28.5	29	56
C2L	590.2	589.69	30.6	81	101

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval Start Depth	End Depth
C2M	590.1	589.90	24.8	57	80
C2U (ABP-6)	590.1	590.08	30.6	31	56
CD1L	596.8	596.63	34.0	87	109
CD1M	597.1	596.83	28.8	63	88
CD1U	597.0	596.86	23.6	35	64
CD2M	596.1	598.30	33.0	65	90
CD3U	593.4	595.41	30.0	32	62
CD4U	588.0	588.85	12.0	14	44
CD5U	588.2	588.38	20.0	22	51
CD6U	588.6	588.71	24.5	27	56
CMW-1SH	577.3	576.68	17.7	18	33
CMW-2SH	591.2	589.73	28.0	28	43
CMW-3SH	583.5	582.74	22.3	22	37
CMW-4SH	575.6	574.97	11.2	11	26
CMW-5SH	584.7	584.13	15.3	15	30
CMW-6SH	573.3	572.68	5.4	5	20
CMW-7SH	612.1	611.16	11.8	12	27
CMW-8SH	617.3	617.01	5.9	6	21
CMW-9SH	572.8	572.59	3.5	4	14
CMW-11SH	574.0	573.86	8.5	9	19
CMW-12SH	595.5	597.65	33.0	34	49
D1L	592.7	592.37	21.0	87	110
D1M	592.9	592.53	25.0	52	86
D1U	593.2	592.89	19.1	19	51
D2L	589.4	589.92	13.0	87	109
D2M	589.6	589.40	13.8	49	86
D2U	589.8	589.51	13.3	13	48
D3U (PW-2U)	600.0	600.02	20.1	20	52
D4L	598.6	600.09	23.8	98	115
D4M (PMW-2M)	598.0	598.00	22.1	61 (2)	96 (2)
D4U (PMW-2U)	598.4	598.09	21.0	21	55
D5L	599.1	598.81	15.5	98	120
E1L	594.0	596.59	17.5	95	121
E1M	594.3	596.25	16.7	54	94
E1U	594.4	596.57	18.9	19	54
E2L	591.3	592.36	15.0	90	117
E2M	591.2	593.70	13.5	48	89
E2U	591.7	592.46	14.0	14	48
E3L	593.1	592.90	15.1	96	119
E3M	593.8	593.70	14.0	49	94
E3U (PW-5U)	595.0	591.61	15.3	15	50
E4L	598.2	597.64	15.5	101	120
E4M	598.3	597.98	15.3	61	100
E4U	598.5	598.23	15.3	15	60
E5U	598.6	598.27	12.0	16	57
F1L	602.0	604.32	3.0	111	132
F1M	602.6	602.38	3.0	66•	111
F1U	603.4	603.11	2.8	3	65
F2L	597.6	597.63	10.5	102	127

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval Start Depth	Open Borehole or Screened Interval End Depth
F2M	597.6	597.32	7.2	62	102
F2U	598.4	598.27	7.1	7	61
F3L	597.6	597.41	17.9	106	120
F3U (PW-6U)	610.6	609.76	8.1	8	60
F4L (1)	601.0 (1)	600.3	18.5	106	126
F4M (1)	600.9 (1)	600.41	18.6	60	104
F4U (1)	601.1 (1)	600.65	18.8	19	59
F5U	604.8	595.03	12.0	12	61
F5UR	604.9	604.63	9.0	9	59
G1L	615.6	617.53	9.0	126	147
G1M	615.3	617.78	9.5	70	124
G1U	615.8	618.33	11.0	11	69
G2L	609.8	609.55	9.5	124	141
G2M	610.1	609.87	11.2	70	123
G2U	609.1	608.87	11.8	12	69
G3L (BH4-95)	617.7	620.67	14.0	128	147
G3M	617.0	618.76	12.0	64	126
G3U	616.7	619.23	13.0	13	63
G4U (BH6-95)	610.6	620.31	13.3	13	72
G5L	605.5	605.46	7.5	115	134
G5U (T-2)	610.6	613.10	13.3	13	72
GH1U	619.5	620.51	8.2	8	59
H1L	618.9	620.84	13.0	128	143
H1M	619.4	621.74	12.8	58	127
H1U	619.8	621.53	13.0	13	57
H2L	619.3	621.57	6.0	130	150
H2M	619.8	621.77	6.0	57	127
H2U	619.6	621.70	6.2	6	56
H3L	612.9	614.95	12.8	118	138
H3U	613.7	615.05	11.8	12	72
H4L	611.2	613.82	13.5	113	133
HT-2 (BH2-95)	600.2	602.2	20.5	21	38
IFW-1	586.2	585.27	25.4	152	177
IFW-1R	586.2	584.96	25.4	152	177
IFW-2	607.3	610.56	16.5	180	205
IFW-3	619.3	622.14	11.3	200	227
IFW-4	612.2	611.78	11.8	206	230
IFW-5	596.1	596.43	11.1	177	207
IFW-6	592.3	592.05	16.7	164	191
IFW-7	590.0	592.27	29.8	156	180
J1L	606.8	609.78	16.0	103	123
J1M	606.9	609.09	15.5	46	100
J1U	606.9	608.86	16.1	16	45
J2L	608.0	610.53	15.3	102	125
J2M	607.4	609.58	18.8	46	101
J2U	607.9	610.18	17.1	17	45
J3L	600.2	602.71	16.4	101	121
J3U (BH1-95)	600.3	603.10	15.2	15	45
J4L	599.9	600.69	14.0	103	122

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval Start Depth	End Depth
J5L	606.1	607.79	11.5	99	126
J5M	604.6	606.37	12.0	61	101
J5U	604.5	606.10	13.5	14	61
JH1L	624.4	626.43	14.2	111	147
MW1-2001	595.4	597.16	18.5	17	38
MW2-2001	594.4	596.04	21.5	23	35
MW3-2001	589.8	591.26	30.0	32	50
MW4-2001	588.8	590.90	30.0	32	50
MW5-2001	591.7	593.11	32.5	35	50
MW6-2001	591.2	592.66	32.5	35	50
MW7-2001	590.3	591.86	29.0	29	56
PMW-1L	597.4	597.37	34.2	94	115
PMW-1M	597.7	597.21	30.3	66	94
PMW-1U	596.9	596.66	31.0	31	65
PMW-3L	604.6	606.51	14.9	108	126
PMW-3M	605.1	607.47	10.6	49	107
PMW-3U	604.9	607.30	9.9	10	48
Purge Wells					
APW-1	569.0	565.53	13.6	14	77
APW-2	574.0	570.55	42.6	43	77
PW-1L	596.8	593.55	15.9	72	110
PW-1U	596.7	593.55	32.3	32	62
PW-2L	600.0	597.53	20.1	95	118
PW-2L (aband.)	598.0	598.00	20.5	20	120
PW-2M (1)	597.6 (1)	596.94 (1)	19.9	54	94
PW-2UR	597.9	598.14	22.0	22	52
PW-3L	602.8	599.35	14.5	106	127
PW-3M	601.4	598.17	13.5	45	105
PW-4M	610.3	607.22	11.8	61	112
PW-4U	607.5	605.23	9.0	13	57
PW-5UR	604.8	595.03	12.0	12	61
PW-6MR (T-3)	612.1	611.09	7.1	66	119
PW-6UMR	612.2	615.51	7.8	8	120
PW-6UR (T-1)	611.3	608.95	12.5	13	63
PW-7U (CD-2U)	596.7	592.98	34.0	32	64
PW-8M	597.0	593.18	36.0	44	86 (3)
PW-8U	593.7	589.78	31.0	31	56
PW-9U	591.8	588.00	29.5	29	55
PW-10U	597.8	594.01	18.5	19	31 (4)
RW-3UM (PW-3U) (1)	602.1 (1)	593.93 (1)	14.4	15	44

Notes:
(1) Survey Elevation uncertain.
(2) Screened interval.
(3) Original pilot hole extended to 89.8 feet bgs.
(4) Original pilot hole extended to 40.5 feet bgs.

TABLE 3.3

SYMMARY OF UNIT THICKNESSES REPORTED IN PUBLICATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Unit Name: Zenger (1965)/Rickard (1975)	Unit Name: Brett, et al. (1995)	Zenger (1965)	IJC (1974)	Novakowski and Lapcevic (1998)	Kappel and Tepper (1992)	Blair and McFarland (1992)	Brett, et al. (1995)	Hyde Park Landfill Site (4)
Upper Oak Orchard Member / Upper Guelph Formation	Guelph Dolomite (1)	> 120 feet	> 70 feet	120 feet	33 feet	16 - 46 feet	36-37 (3)	--
Lower Oak Orchard Member (1) / Lower Guelph Formation	Eramosa Dolomite (1)				52 feet		38 - 50 feet	0 - 67 feet
Eramosa Member / Eramosa Formation	Vinemount Member of the Goat Island Formation	16 - 18 feet	14 feet	10 - 33 feet	41 feet	69 - 85 feet (2)	17-20 feet	18 - 24 feet
Goat Island Member / Goat Island Formation	Ancaster Member of the Goat Island Formation	19 - 25 feet	26 feet	16 - 26 feet		20 - 33 feet	2-25 feet	13 - 24 feet
	Niagara Falls Member of the Goat Island Formation						3 - 15 feet	
Gasport Member / Gasport Formation	Pekin Member of the Gasport Formation	15 - 23 feet	18 feet	44 feet	33 feet	36 - 46 feet	Varies significantly, 23 feet average	11 - 24 feet
	Gothic Hill Member of the Gasport Formation						3 - 21 feet	4 - 16 feet
Decew Member / DeCew Formation	DeCew Dolomite	8 - 12 feet	10 feet	11 feet	NR	7 - 9 feet	8-12 feet	8 - 13 feet
Rochester Shale	Rochester Shale	NR	~60 feet	55 feet	NR	57 - 61 feet	58 - 65 feet	56 - 63 feet

Notes: NR - Not Reported.
(1) These units are commonly surficial units and tend to be erosionally truncated
(2) These values (21 - 26 meters) do not correspond to other researchers and are suspect. These values may reflect thicknesses reported further north of the Niagara Falls area.
(3) Thickness based on two USGS drill cores.
(4) Based on lithologic logging of available drill core.

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster/ Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
A1U	598.0	571 (1)	561	542	--	--	--	--
A2U	593.5	572 (1)	563	542	--	--	--	--
AB1L	588.0	drilled out without coring to near bottom elevation of AB1M					502	492
AB1M	588.0	drilled out without coring to near bottom elevation of AB1U			525	510		
AB1U	587.9	--	559 (2)	546				
ABP-1	571.9	--	554 (2)	549	529	--	--	--
ABP-2	574.9	--	558 (2)	550	529	--	--	--
ABP-3 (4)	591.1 (4)	--	563 (2) (4)	546 (4)	--	--	--	--
ABP-4	588.1	--	561 (2)	538	--	--	--	--
ABP-5	589.3	--	562 (2)	546	--	--	--	--
ABP-7	574.4	--	558 (2)	547	527	--	--	--
ABP-8	575.1	--	--	534 (3)	527	516	--	--
AFW-1L	570.9	--	565 (2)	551	533	core lost during storage		
AFW-2L	592.2	579 (1)	560	542	521	501	497	487
AFW-3L	589.3	577 (1)	560	539	524	507	496	--
AGW-1L	591.4	576 (1)	567	547	527	508	core lost during storage	
AGW-2L	608.4	594 (1)	561	540	521	502	499	490
AGW-3L	628.3	612 (1)	550	531	517	493	487	476
APW-1	569.0	--	556 (2)	544	527	510	504	492
APW-2	574.0	--	--	531 (3)	528	512	504	--
B1L	589.7	--	562 (2)	544	522	507	500	490
B2L	588.0	--	564 (2)	542	526	511	503	493
BR-1	582.6	--	559 (2)	--	--	--	--	--
BR-2	581.6	--	557 (2)	--	--	--	--	--
BR-3	582.0	--	559 (2)	--	--	--	--	--
BR-4	583.5	--	557 (2)	--	--	--	--	--
C1L	591.4	--	563 (2)	543	526	513	503	492
C2L	590.2	--	560 (2)	542	526	511	502	492
CD1L	596.8	--	563 (2)	542	521	508	499	489
CD1M	597.1	568 (1)	562	541	520	507	--	--
CD1U	597.0	573 (1)	562	541	--	--	--	--
CD2M	596.1	--	563 (2)	544	523	509	--	--

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster/ Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
CD3U	593.4	--	564 (2)	545	--	--	--	--
CD4U	588.0	575 (1)	560	--	--	--	--	--
CD5U	588.2	566 (1)	562	542	--	--	--	--
CD6U	588.6	--	562 (2)	549	--	--	--	--
D1L	592.7	572 (1)	558	535	522	504	494	483
D2L	589.4	576 (1)	560	536	521	508	497	486
D4L	598.6	576 (1)	558	539	519	504	496	486
E1L	594.0	577 (1)	550	528	511	496	487	475
E2L	591.3	578 (1)	553	534	core lost during storage			
E3L	593.1	578 (1)	553	531	514	500	490	--
E5U	598.6	587 (1)	551	--	--	--	--	--
F1L	602.0	594 (1)	546	528	508	core lost during storage	483	475
F2L	597.6	578 (1)	546	527	507	497	481	471
F3L	597.6	580 (1)	550	531	511	497	489	479
G1L	615.6	607 (1)	540	522	501	487	481	--
G2L	609.8	599 (1)	539	515	501	486	478	--
G3L (BH4-95)	617.7	drilled out to 114' bgs before beginning coring			504	491	484	473
G4U	610.6	597 (1)	--	--	--	--	--	--
G5L	605.5	598 (1)	552	531	510	494	487	476
G5U (T-2)	610.6	603 (1)	548	--	--	--	--	--
H1L	618.9	606 (1)	549	530	508	492	486	476
H2L	619.3	613 (1)	548	528	506	489	485	473
HT2	600.2	580 (1)	--	--	--	--	--	--
J1L	606.8	591 (1)	560	539	519	502	497	487
J2L	608.0	593 (1)	560	540	519	504	497	486
J3U	600.3	583 (1)	558	--	--	--	--	--
J5L	606.1	drilled out without coring to near bottom elevation of J5M				498	494	481
J5M	604.6	drilled out without coring to near bottom of J5U		533	513			
J5U	604.5	594 (1)	556					
JH1L	624.4	610 (1)	555	537	516	500	496	--
MW1-2001	595.4	578 (1)	563	--	--	--	--	--
MW2-2001	594.4	572 (1)	562	--	--	--	--	--

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster/ Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
MW3-2001	589.8	--	558 (2)	542	--	--	--	--
MW4-2001	588.8	--	557 (2)	540	--	--	--	--
MW5-2001	591.7	--	559 (2)	542	--	--	--	--
MW6-2001	591.2	--	559 (2)	543	--	--	--	--
MW7-2001	590.3	561 (1)	561	542	--	--	--	--
PMW-1L	597.4	566 (1)	564	546	521	504	498	488
PMW-3L (4)	604.6 (4)	590 (1)(4)	549 (4)	531 (4)	510 (4)	495 (4)	488 (4)	477 (4)
PW-1L	596.8	--	565 (2)	543	523	508	499	--
PW-2L	600.0	580 (1)	560	537	522	505	498	488
PW-3L	602.8	588 (1)	554 (2)	530	509	496	492	481
PW-4M (4)	610.3 (4)	601 (1)(4)	555 (4)	536 (4)	520 (4)	502 (4)	--	--
PW-6UR(T-1)	611.3	599 (1)	549	--	--	--	--	--
PW-6MR(T-3)	612.1	605 (1)	548	529	509	493	--	--
PW-7U (CD-2U)	596.7	--	562 (2)	543	--	--	--	--
PW-8U	593.7	--	563 (2)	539	--	--	--	--
PW-8M	597.0	--	561 (2)	542	522	508	--	--
PW-9U	591.8	--	562 (2)	539	--	--	--	--
PW-10U	597.8	580 (1)	561	--	--	--	--	--

Notes:
ft AMSL - feet Above Mean Sea Level.
The top of the drill core begins at or below the overburden/bedrock interface, depending on the depth of installation of surface casing.
-- Not present or not present in currently available drill core.
Due to the gradational nature of many unit contacts and lithologic similarity of many units, and the resultant difficulties in establishing exact unit contacts, all point should be considered approximate.
1) The Eramosa Formation is the uppermost bedrock unit and the elevation given is for the top of the drill core.
2) The Vinemount Member is the uppermost bedrock unit over part of the site and the elevation given is for the top of the drill core.
3) The Ancaster Member is the uppermost bedrock unit over part of the site and the elevation given is for the top of the drill core.
4) The original ground surface elevation is uncertain, therefore all contact elevations are estimated.

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
A1U	E	560
A1U	F	555
A1U	G	550
A1U	H	547
A2U	E	562
A2U	F	557
A2U	G	552
A2U	H	547
A2U	I	544
ABP-3	F	561
ABP-3	H	553
ABP-3	I	547
ABP-3	J	537
ABP-4	G	556
ABP-4	H	552
ABP-4	I	547
ABP-4	J	538
ABP-4	K	533
ABP-5	F	559
ABP-5	G	554
ABP-5	H	550
ABP-5	I	547
ABP-5	J	536
ABP-7	G	556
ABP-7	H	553
ABP-7	I	547
ABP-7	J	537
ABP-7	K	533
ABP-7	L	526
ABP-7	M	517
AFW-1U	G	557
AFW-1U	H	554
AFW-1U	I	549
AFW-1M	J	539
AFW-1M	K	535
AFW-1M	L	527
AFW-2U	E	562
AFW-2U	G	553
AFW-2U	H	549

Well	Gamma Peak	Elevation (ft msl)
CMW-5SH	E	559
D1U	E	558
D1U	F	554
D1U	G	548
D1U	H	545
D1M	I	540
D1M	J	529
D1M	K	525
D1M	L	518
D2U	E	559
D2U	F	555
D2U	G	549
D2U	H	546
D2M	I	540
D2M	K	526
D2M	L	518
D2M	M	508
D3U	E	555
D4U	E	558
E1U	E	550
E1M	G	540
E1M	H	537
E1M	I	532
E1M	J	522
E1M	K	519
E1M	L	511
E1L	L	504
E2U	E	553
E2M	I	535
E2M	K	521
E2M	M	505
E3M	G	543
E3M	H	540
E3M	I	535
E3M	K	521
E3M	L	512
E3M	M	504
F1U	E	547
F1M	G	537

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
AFW-2U	I	544
AFW-2L	N	506
AFW-3U	E	557
AFW-3U	F	553
AFW-3U	G	547
AFW-3U	H	543
AFW-3M	I	538
AFW-3M	L	514
AGW-1U	E	565
AGW-1U	F	560
AGW-1U	I	547
AGW-1M	J	536
AGW-1M	K	531
AGW-1M	L	523
AGW-1M	M	517
AGW-1M	N	508
AGW-2U	E	559
AGW-2U	F	554
AGW-2U	G	549
AGW-2M	I	542
AGW-2M	J	531
AGW-2M	L	519
AGW-2M	M	512
AGW-2M	N	505
AGW-3M	E	550
AGW-3M	F	545
AGW-3M	G	540
AGW-3M	H	537
AGW-3M	I	532
AGW-3M	L	509
AGW-3M	M	500
APW-1	H	555
APW-1	I	550
APW-1	J	539
APW-1	K	535
APW-1	L	527
APW-1	M	520
APW-1	N	513
APW-2	L	527

Well	Gamma Peak	Elevation (ft msl)
F1M	H	534
F1M	I	529
F1M	J	519
F1M	K	515
F1M	L	508
F1M	M	499
F2U	E	546
F2M	G	537
F2M	H	533
F2M	I	528
F2M	J	518
F2M	K	514
F2M	L	507
F2M	M	499
F2L	N	493
F4U	E	550
F4M	G	540
F4M	H	537
F4M	I	532
F4M	K	518
F4M	L	510
F4M	M	503
G2M	E	541
G2M	F	536
G2M	G	530
G2M	H	527
G2M	I	522
G2M	K	508
G2M	L	500
G2M	M	492
G2L	N	485
G3M	E	546
G3M	F	542
G3M	G	537
G3M	H	534
G3M	I	528
G3M	J	517
G3M	K	514
G3M	L	506

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
APW-2	M	518
APW-2	N	514
B1U	F	559
B1U	G	553
B1U	H	550
B1U	I	545
B1M	K	530
B1M	L	522
B1M	M	515
B1L	N	505
B2U	F	560
B2U	G	555
B2U	H	552
B2U	I	547
B2M	J	536
B2M	K	532
B2M	L	524
B2L	N	511
BC3U	F	558
BC3U	G	553
BC3U	I	544
BC3M	J	533
BC3M	K	529
BC3M	L	521
BC3L	N	508
BR-1	F	558
BR-1	G	553
BR-2	G	554
BR-2	H	549
BR-2	I	546
BR-3	G	557
BR-3	H	552
BR-3	I	549
C1U	F	560
C1U	G	554
C1U	H	552
C1U	I	546
C1M	J	535
C1M	K	532

Well	Gamma Peak	Elevation (ft msl)
G3M	M	498
H1M	E	550
H1M	F	545
H1M	G	540
H1M	H	537
H1M	I	531
H1M	J	521
H1M	K	516
H2M	E	546
H2M	F	541
H2M	G	536
H2M	H	533
H2M	I	528
H2M	J	517
H2M	K	513
H2M	L	506
H3L	N	494
H3U	E	550
J1M	E	559
J1M	F	554
J1M	G	549
J1M	H	546
J1M	I	542
J1M	J	530
J1M	K	525
J1M	L	517
J1M	M	510
J1L	N	502
J3U	E	558
PMW-1U	E	560
PMW-1U	F	555
PMW-1U	G	550
PMW-1U	H	547
PMW-1M	I	542
PMW-1M	K	527
PMW-1M	L	519
PMW-1M	M	510
PW-2M	I	538
PW-2M	J	528

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
C1M	L	525
C1M	M	515
C2M	K	532
C2M	L	525
C2M	M	517
CD1U	E	559
CD1U	F	555
CD1U	G	549
CD1U	H	546
CD1U	I	541
CD1M	J	530
CD1M	K	526
CD1M	L	518
CD1M	M	511
CD1L	N	506
CD2M	K	529
CD2M	L	521
CD2M	M	513
CD3U	E	563
CD3U	F	558
CD3U	G	553
CD3U	H	549
CD3U	I	543

Well	Gamma Peak	Elevation (ft msl)
PW-2M	K	525
PW-2M	L	516
PW-2M	M	508
PW-4M	F	546
PW-4M	G	541
PW-4M	H	538
PW-4M	I	533
PW-4M	K	518
PW-6MR	F	543
PW-6MR	G	537
PW-6MR	H	534
PW-6MR	I	529
PW-6MR	K	514
PW-6MR	L	506
PW-6MR	M	498
PW-4M	K	518
PW-6MR	F	543
PW-6MR	G	537
PW-6MR	H	534
PW-6MR	I	529
PW-6MR	K	514
PW-6MR	L	506
PW-6MR	M	498

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
A1U	563	CR	560.1	2.9
A1U	549	CR	560.1	-11.1
A2U	565	CRV	561.6	3.4
A2U	551	CT	561.6	-10.6
ABP-3	562	CSR	564.6	-2.6
ABP-3	558	RT	564.6	-6.6
ABP-3	549	CSR	564.6	-15.6
ABP-4	555	T	565.7	-10.7
ABP-4	553	TRV	565.7	-12.7
ABP-4	539	S	565.7	-26.7
ABP-5	560	CS	564.7	-4.7
ABP-5	557	R	564.7	-7.7
ABP-5	552	T	564.7	-12.7
ABP-5	547	CS	564.7	-17.7
ABP-5	544	T	564.7	-20.7
ABP-5	538	CTR	564.7	-26.7
ABP-7	524	SR	568.3	-44.3
ABP-7	524	SC	568.3	-44.3
ABP-7	521	S	568.3	-47.3
ABP-8	520	S	568.8	-48.8
AFW-1U	548	S	568.0	-20.0
AFW-1U	547	S	568.0	-21.0
AFW-1U	542	S	568.0	-26.0
AFW-1M	520	CS	568.0	-48.0
AFW-1M	516	S	568.0	-52.0
AFW-2L	495	S	561.9	-66.9
AFW-2U	572	TRV	561.7	10.3
AFW-2U	565	RAV	561.7	3.3
AFW-2U	550	T	561.7	-11.7
AFW-2U	544	RV	561.7	-17.7
AFW-3U	560	CT	556.4	3.6
AFW-3U	557	CSR	556.4	0.6
AFW-3U	554	TRV	556.4	-2.4
AFW-3M	514	SR	556.5	-42.5
AGW-1U	567	CSR	564.3	2.7
AGW-1U	560	CT	564.3	-4.3
AGW-1U	552	T	564.3	-12.3
AGW-1M	537	SR	564.2	-27.2
AGW-1M	520	R	564.2	-44.2
AGW-1M	519	CTR	564.2	-45.2
AGW-1M	513	R	564.2	-51.2
AGW-1L	490	SR	564.1	-74.1
AGW-2U	591	CSR	557.8	33.2
AGW-2U	585	CSR	557.8	27.2
AGW-2U	575	RSC	557.8	17.2
AGW-2U	566	CS	557.8	8.2
AGW-2U	561	CS	557.8	3.2
AGW-2U	554	CS	557.8	-3.8
AGW-2M	542	CS	557.9	-15.9

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
AGW-2M	540	CS	557.9	-17.9
AGW-2M	537	CSR	557.9	-20.9
AGW-2M	531	SR	557.9	-26.9
AGW-2M	524	TRC	557.9	-33.9
AGW-2M	519	CR	557.9	-38.9
AGW-2M	517	S	557.9	-40.9
AGW-2M	515	CR	557.9	-42.9
AGW-2L	497	S	557.9	-60.9
AGW-3U	600	CT	549.4	50.6
AGW-3U	595	R	549.4	45.6
AGW-3M	551	CSR	549.5	1.5
AGW-3M	534	R	549.5	-15.5
AGW-3M	511	RT	549.5	-38.5
APW-1	536	TR	570.2	-34.2
APW-1	527	T	570.2	-43.2
APW-1	516	S	570.2	-54.2
APW-2	523	CSR	569.2	-46.2
APW-2	516	SR	569.2	-53.2
APW-2	513	CT	569.2	-56.2
B1U	560	TRV	563.0	-3.0
B1U	547	TR	563.0	-16.0
B1M	529	CF	562.9	-33.9
B1M	525	S	562.9	-37.9
B1M	519	TF	562.9	-43.9
B1L	503	T	562.9	-59.9
B2U	560	CF	565.2	-5.2
B2U	554	FR	565.2	-11.2
B2U	549	TR	565.2	-16.2
B2M	533	CV	565.1	-32.1
B2M	527	CT	565.1	-38.1
B2M	521	TFR	565.1	-44.1
BC3U	558	TR	561.5	-3.5
BC3U	551	CR	561.5	-10.5
BC3U	549	R	561.5	-12.5
BC3M	526	SR	561.6	-35.6
BC3M	519	CT	561.6	-42.6
BR-1	556	CS	563.7	-7.7
BR-2	552	SR	564.0	-12.0
BR-3	557	CR	566.0	-9.0
BR-3	551	SR	566.0	-15.0
BR-4	556	CS	567.8	-11.8
C1U	562	CSR	564.0	-2.0
C1U	557	RT	564.0	-7.0
C1U	549	CS	564.0	-15.0
C1M	524	CR	564.1	-40.1
C1M	520	CRV	564.1	-44.1
C1L	508	TR	564.1	-56.1
C1L	494	CT	564.1	-70.1
C2M	530	CR	565.8	-35.8

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
C2M	525	CSR	565.8	-40.8
C2M	522	CRV	565.8	-43.8
C2L	508	CR	565.6	-57.6
C2L	496	CT	565.6	-69.6
CD1U	561	CSR	558.5	2.5
CD1U	544	CTR	558.5	-14.5
CD1M	525	SR	558.5	-33.5
CD1M	519	T	558.5	-39.5
CD1L	508	CS	560.3	-52.3
CD1L	502	R	560.3	-58.3
CD1L	498	CT	560.3	-62.3
CD1L	489	CT	560.3	-71.3
CD2M	518	CTRV	561.9	-43.9
CD3U	560	CR	562.3	-2.3
CD3U	556	S	562.3	-6.3
CD3U	548	TR	562.3	-14.3
CD3U	541	S	562.3	-21.3
CD4U	572	TR	559.7	12.3
CD4U	560	R	559.7	0.3
CD4U	555	SR	559.7	-4.7
D1U	570	FR	557.6	12.4
D1U	564	FR	557.6	6.4
D1U	559	CFV	557.6	1.4
D1U	543	CS	557.6	-14.6
D1M	514	CFV	557.6	-43.6
D1L	499	S	557.5	-58.5
D2U	570	CFR	558.2	11.8
D2U	560	CFR	558.2	1.8
D2U	555	CSR	558.2	-3.2
D2U	546	FR	558.2	-12.2
D2M	525	T	558.3	-33.3
D2M	519	R	558.3	-39.3
D2M	515	CF	558.3	-43.3
D2L	494	S	558.3	-64.3
D2L	488	S	558.3	-70.3
D3U	565	TC	556.9	8.1
D4U	572	RC	557.3	14.7
D4U	558	TRC	557.3	0.7
D5L	499	R	555.7	-56.7
E1U	568	R	551.1	16.9
E1U	562	FV	551.1	10.9
E1U	554	T	551.1	2.9
E1U	549	TR	551.1	-2.1
E1L	495	S	551.3	-56.3
E2L	494	S	552.1	-58.1
E3M	525	TR	552.1	-27.1
E3M	510	CSR	552.1	-42.1
E3L	494	SR	552.3	-58.3
E3L	481	CR	552.3	-71.3

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
F1U	570	CT	547.0	23.0
F1M	522	R	547.2	-25.2
F1M	513	R	547.2	-34.2
F1M	508	TV	547.2	-39.2
F1M	504	CTV	547.2	-43.2
F2U	572	FTRC	546.9	25.1
F2U	557	FRC	546.9	10.1
F2M	504	FC	547.0	-43.0
F3L	490	CR	550.4	-60.4
F4U	585	CTR	550.1	34.9
F4U	554	CSR	550.1	3.9
F4M	526	CTR	550.1	-24.1
F4M	508	CTRV	550.1	-42.1
G2U	556	CTR	539.8	16.2
G2M	525	TC	540.0	-15.0
G2M	501	TCR	540.0	-39.0
G2L	484	CR	539.9	-55.9
G3M	503	CTR	546.8	-43.8
G3L	473	F	546.8	-73.8
G5U	579	TR	548.1	30.9
G5L	484	R	550.1	-66.1
H1U	600	CF	550.1	49.9
H1U	597	CF	550.1	46.9
H1M	550	CTR	550.3	-0.3
H1M	512	CFR	550.3	-38.3
H1M	509	FRC	550.3	-41.3
H1M	505	FC	550.3	-45.3
H1M	505	CF	550.3	-45.3
H1L	480	CSF	550.5	-70.5
H2U	603	CTR	549.0	54.0
H2U	593	CR	549.0	44.0
H2U	578	CR	549.0	29.0
H2M	558	R	548.8	9.2
H2M	531	SR	548.8	-17.8
H2M	518	CRT	548.8	-30.8
H2M	503	CR	548.8	-45.8
H2L	483	S	548.7	-65.7
H3U	552	TCR	550.5	1.5
H3L	493	T	550.5	-57.5
H3L	481	CTR	550.5	-69.5
J1U	587	FR	558.5	28.5
J1U	569	CT	558.5	10.5
J1M	550	R	558.6	-8.6
J1M	545	V	558.6	-13.6
J1M	524	CF	558.6	-34.6
J1M	517	F	558.6	-41.6
J1M	514	CFRV	558.6	-44.6
J3U	570	CTR	558.7	11.3
J3L	485	F	558.5	-73.5

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
J4L	485	F	557.3	-72.3
JH1L	510	TR	553.8	-43.8
PMW-1U	563	R	559.6	3.4
PMW-1U	549	R	559.6	-10.6
PMW-1U	544	T	559.6	-15.6
PMW-1M	517	CR	559.5	-42.5
PMW-1L	500	R	559.4	-59.4
PMW-1L	489	CS	559.4	-70.4
PW-1U	562	CR	561.3	0.7
PW-1U	541	T	561.3	-20.3
PW-2M	533	TR	556.8	-23.8
PW-2M	507	T	556.8	-49.8
PW-3M	527	SR	553.6	-26.6
PW-3M	515	S	553.6	-38.6
PW-3L	495	R	553.0	-58.0
PW-3L	490	S	553.0	-63.0
PW-5UR	576	CTR	551.0	25.0
PW-6UR	569	T	548.5	20.5
PW-6UR	560	T	548.5	11.5
PW-6MR	533	T	548.1	-15.1
PW-6MR	527	TR	548.1	-21.1

Column Headings

Elevation (ft msl)
Elevation of feature picked from 2-page geophysical summaries

Selection Basis
T - temperature offset
S - spike in delta temperature
R - offset in fluid resistivity
C - opening based on caliper log
V - P-sonic velocity increase
F - Borehole vertical flow meter

GP-E Elevation (ft msl)
Elevation of the GP-E plane at the well location

Depth Relative to GP-E (ft)
Depth of feature compared to the GP-E plane elevation