2021 Hazardous Waste Scanning Project

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Volume I

Geologic Report
Necco Park
Niagara Falls, New York
July 1988

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists
5120 Butler Pike, Plymouth Meeting, Pennsylvania 19462

5120 Butler Pike
Plymouth Meeting
Pennsylvania 19462
215-825-3000
Telex 846-343

Woodward-Clyde Consultants

July 6, 1988
88C2137G-1

E. I. du Pont de Nemours and Company
Chemicals and Pigments
Buffalo Avenue and 26th Street
Niagara Falls, New York 14302

Attention: Mr. Bev Adams
Manager, Environmental Affairs

Re: Geologic Report, Necco Park
Niagara Falls, New York

Gentlemen:

In accordance with your request, Woodward-Clyde Consultants (WCC) is pleased to present the Geologic Report for Necco Park, Niagara Falls, New York. This report presents all the monitoring well, hydrogeologic, and geologic data collected during the drilling phase of the off-site investigation. These data were interpreted by WCC with respect to the geologic conditions within the study area. An interpretive report which will comprehensively characterize the geologic, hydrogeologic and contaminant conditions in the study area will be issued when sufficient groundwater chemistry data have been collected.

We appreciate the opportunity to work with Du Pont on the Necco Park Project.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

Andrew H. Leitzinger
Assistant Project Geologist

Kelly R. McIntosh
Project Scientist

AHL/KRM/kcs/WM-5T

cc: T. Fargo
W. Porter
F. Waller

GEOLOGIC REPORT

NECCO PARK
NIAGARA FALLS, NEW YORK

VOLUME I

Prepared for:

E. I. DU PONT DE NEMOURS AND COMPANY

Niagara Falls, New York

Prepared by:

WOODWARD-CLYDE CONSULTANTS

Plymouth Meeting, Pennsylvania

July 1988

EXECUTIVE SUMMARY

Du Pont is conducting an off-site investigation in the vicinity of Necco Park in accordance with the Necco Park Consent Decree (Appendix I, Section III, Installation of New Groundwater Monitoring Wells). During 1985 through 1987, seventy-eight monitoring wells were installed in the vicinity of Necco Park. These monitoring wells supplement over one-hundred monitoring wells previously installed at or near the site, expanding the boundaries of the Necco Park investigations. This report presents the data collected during the drilling phase of the off-site investigation and geologic interpretation of these data.

The following data are presented in this report:

- Monitoring Well Diagrams
- Monitoring Well Construction Details
- Survey Results
- Grout Seal Hydrostatic Head Test Results
- In Situ Hydraulic Conductivity Test Results
- Slug Test Hydraulic Conductivity Results
- Bedrock Core and Overburden Description Logs
- Geologic Data (Formation Thickness and Contact Elevations)
- Fracture Frequency Plots

The overburden in the study area consists of natural and man-emplaced material (fill). Much of the natural overburden, consisting of glacial till and glaciolacustrine sediments, has been disturbed or removed. Within the glaciolacustrine sediments an upper glaciolacustrine unit and a lower glaciolacustrine unit are distinguishable. In some locations, perched water was observed at the contact between these two units. Overburden generally thickens to the southeast in the study area, and thickness ranges from less than 2 feet to greater than 22 feet. The overburden saturated thickness has been designated the A-zone.

The top of the Lockport Formation is represented by the top of bedrock. Field observations indicate that the top of bedrock is not highly weathered within the study area, suggesting a substantial regolith zone does not exist in the area. Thickness of the Lockport

Formation in the study area averaged 147.6 feet, and ranged between 142 feet and 151 feet. The attitude of bedding, identified at all levels of the Lockport Formation, averaged 0.5 of a degree S45E, and was found to vary consistently from northwest to southeast across the site. Viewed areally, these variations in bedding dip attitude constitute an identifiable northeast trending structure affecting the bedrock within the study area.

Bedding plane fracture zones have been identified based on field observations during drilling, bedrock core examination and hydraulic conductivity test results. These fracture zones were found to have limited and definable areal extent within the study area and are designated the B- through G-zones. Bedding plane fracture zones B through F exist solely within the Oak Orchard Member of the Lockport Formation. The G-zone has been subdivided into three fracture zones. The G_1-zone is present in the Eramosa Member of the Lockport Formation. The G_2-zone and G_3-zone can be present in either the Goat Island Member or the Gasport member of the Lockport Formation. The contact between the Lockport Formation and the underlying Rochester Shale is designated the J-zone.

Vertical fracturing in the study area has been investigated. The principal joint fracture direction is approximately N65^{o}E - N75^{o}E based on bedrock exposure observations along the PASNY Conduits and along the recently constructed Niachlor Brine Pipeline. Secondary and tertiary joint fracture directionals have been identified.

The geologic study of the Necco Park area provides direct and indirect evidence for a N60^{o}E trending, high angle fault crossing the study area. The structure is believed to be related to a northeast trending zone of high transmissivity and increased vertical fracturing which was identified and studied by the US Geological Survey. Evidence identified includes breccia, slickensides and bedding offset. The fault may be represented in the study area by two or more parallel fault planes. Homoclinal folding is believed to have occurred as a result of the same compressional stress which caused the faulting. A degree of vertical fracturing higher than the regional average appears to be associated with this structure. The increased vertical fracturing may serve as a connection between the upper water-bearing zones of the Lockport Formation. The impact of the fault structure on groundwater flow in the D-zone and below could not be ascertained.

Regarding hydrogeology, WCC concludes the following: (1) circulation fluid losses during drilling were generally consistent with the results of hydraulic conductivity tests; (2) a drop in hydraulic conductivity of several orders of magnitude is apparent in the C-zone over a horizontal distance of approximately 300 feet near the south perimeter of Necco Park, and may be related to the fault structure (3) estimated G_2- and G_3-zone hydraulic conductivity values are relatively high within the apparent areal distribution of these zones; and (4) the J-zone was found to be impermeable (estimated hydraulic conductivity less than 1×10^{-4} cm/sec) throughout the study area.

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1.0 INTRODUCTION

Du Pont is conducting an off-site investigation in the vicinity of Necco Park in accordance with the Necco Park Consent Decree (Appendix I, Section III, Installation of New Groundwater Monitoring Wells). During 1985 through 1987 seventy-eight (78) additional monitoring wells were installed in the Necco Park area. These monitoring wells supplement over 100 previously installed monitoring wells at or near the site and expand the boundaries of the Necco Park study area. The installation of these monitoring wells represents the third phase of exploratory drilling since subsurface investigations began in 1982.

For the purposes of this report, the phase of drilling and monitoring well installation provided for under the Necco Park Consent Decree which spans the years 1985, 1986, and 1987, is referred to as the off-site investigation. Previous investigation phases conducted during 1983 and 1984 are referred to as the initial and supplemental investigation phases, respectively.

1.1 OBJECTIVE

The off-site investigation phase is ongoing. The purpose of this Geologic Report is to present all the monitoring well, hydrogeologic, and geologic data collected during the drilling phase of the off-site investigation, and to interpret these data with respect to the geologic conditions within the study area. An interpretive report which will comprehensively characterize the geologic, hydrogeologic, and contaminant conditions in the study area will be issued when sufficient groundwater chemistry and hydraulic data have been collected. The present report does not characterize groundwater flow, groundwater chemistry or contaminant transport.

1.2 BACKGROUND

The Du Pont Necco Park site, which encompasses about 24 acres, is bordered on the south by the CECOS Waste Management Facilities and to the north and east by BFI sanitary landfill operations (Figure 1). The property bordering on the west is the Conrail (Niagara Junction Railway Co.) right-of-way. The Necco Park site had been used for landfilling operations from the late 1930's until the landfill was closed in 1977. Deposited in this landfill were industrial wastes and large quantities of flyash, building and sodium cell rubble, and miscellaneous dismantlement waste (including segregated asbestos). The industrial wastes consist of material from processes operated at the Du Pont Niagara Plant during that period. The wastes included cell bath (barium, calcium and sodium chlorides), discarded cell rubble, chloromethane, chloroethane and adiponitrile process residues and tars, polyvinylacetate alcohol process residues and off-grade products, Terathane[R] process filter cloths with filter aid, polymer and calcium salts.

Beneath Necco Park there exist three geologic units which are of relevance to this study: namely, unconsolidated overburden, Lockport Formation and Rochester Shale Formation. The overburden consists primarily of natural glacial till, glaciolacustrine silts and clays and man-emplaced fill (Figure 2). The Lockport Formation consists of approximately 145 feet of relatively competent dolomite bedrock which is subdivided into five principal members: the Oak Orchard, Eramosa, Goat Island, Gasport and DeCew. Beneath the Lockport Formation lies the Rochester Shale. This unit consists of shale, dolomitic shale, and shaley limestone (Figure 3).

Hydrogeologic conditions at the site were evaluated in the initial and supplemental investigations. These investigations indicated that groundwater flow beneath the site occurs in the overburden under unconfined conditions, and in separate bedding plane fracture zones in the dolomite bedrock of the Lockport Formation. Letter designations assigned to these principal water-bearing zones are: A-zone for the saturated thickness of the overburden; and B-, C-, CD-, D-, E-, F-, and G-zones for the identified Lockport Formation bedding plane fracture zones. The DeCew/Rochester shale contact is designated the J-zone (Figure 4).

2.0 OFF-SITE MONITORING WELL INSTALLATION PROGRAM

Monitoring Wells Installed: As part of the off-site investigation phase, seventy-eight (78) additional VH-Series monitoring wells were installed between July of 1985 and July of 1987 (Table 1). The locations of these monitoring wells are presented on Figure 5 along with previously installed monitoring well locations. Monitoring well clusters were located as specified by agreement between the USEPA and Du Pont, based on access and monitoring considerations. The number and depths of monitoring wells installed at a given cluster location was determined based on the site-specific hydrogeologic conditions encountered during drilling.

Study Area Boundaries: The off-site investigation area is defined by the monitoring well distribution. Figure 1 shows the boundaries of the off-site investigation based on the monitoring well clusters installed. Pine Avenue forms the southern boundary, Interstate 190 forms the eastern boundary, an east-west line at approximately 600 feet north of the northern Necco Park perimeter forms the northern boundary and a north-south line originating at the intersection of Pine Avenue and Packard Road forms the western boundary. The area enclosed by these boundaries is referred to in this report as the study area.

Monitoring Well Installation Procedures: Monitoring wells were installed according to procedures developed by WCC and agreed upon by Du Pont and the USEPA. These procedures are provided in this report (Volume II, Appendix A, Necco Park Drilling Specifications, WCC, August 1986). Below is a general description of monitoring well installation procedures.

The monitoring wells at Necco Park were installed in the overburden and primary water-bearing fractures of the Lockport Formation. Hollow-stem auger, rotary drilling and NX coring techniques were used to install monitoring wells ranging in depth from less than 20 feet to greater than 170 feet. Water was the drilling fluid used during bedrock drilling and coring.

Overburden monitoring wells were installed through a hollow-stem auger or temporary casing. A 4-1/2 inch O.D., 20 slot stainless steel well screen and 4-1/2 inch O.D., carbon steel riser pipe were placed in each borehole. A sand pack was placed to one foot above the top of the screen. A one foot bentonite seal was placed above the sand pack. The remainder of the annulus was filled by tremie with a cement or cement/bentonite mixture.

Bedrock monitoring wells were installed using a 6-5/8 inch O.D. surface casing set into bedrock, and a 4-1/2 inch O.D. monitoring well casing set in a 5-5/8 inch to 6-1/4 inch hole extending down to the top of the monitored interval. Casing lengths were constructed of carbon steel and coupled typically with screw threads and occasionally with butt welds. Each casing was pressure grouted from the base of the casing unless conditions prevented this, in which case tremie grouting methods were used. If grout return was not achieved, then grout was applied to the annulus from the outside of the casing, as necessary. Grout mixtures were either neat cement or cement/bentonite. The majority of the monitoring wells were grouted using a neat cement mixture. After grout set was achieved, the well was extended below the monitoring well casing by coring and reaming to a 3-7/8 inch diameter.

Special procedures were developed and applied as amendments to the Necco Park Drilling Specifications as the program progressed. Procedures were developed for hydrostatic testing of grout seals during the installation process. The purpose of the hydrostatic tests was to evaluate the integrity of the seal between the bottom of the well casing and the grout. Test procedures were also developed for in-situ assessment of hydraulic conductivity of an interval of bedrock during the drilling process. These tests were conducted using constant pressure and/or constant head procedures. Results of all tests were recorded. Fluorescent tracer dye (Rhodamine WT) was used in an effort to track the influence of lost circulation fluid in the formation fractures. Drilling fluids spiked with Rhodamine WT to a concentration of 100 ppb were used during bedrock drilling after June of 1986. At each cluster location continuous bedrock core samples were obtained. Shortly after the beginning of the program, a mandatory two-foot overlap between cored intervals at different well locations in a cluster was implemented.

All monitoring wells were installed under the supervision of a qualified engineer/geologist. After installation, monitoring wells were developed according to the Necco Park Drilling Specifications. Geographic and vertical control was provided by a licensed surveyor. Most monitoring wells were subjected to single well hydraulic conductivity testing (slug tests) following well development.

3.0 METHODS OF GEOLOGIC DATA ACQUISITION AND DATA PRESENTATION

This section describes the methods used in the geologic investigation and presents the geologic data collected.

3.1 MONITORING WELL RECORDS

Records were kept by a qualified engineer/geologist of all relevant details of monitoring well construction. Records of monitoring well construction data are presented as Report of Monitoring Well Diagrams (Volume II, Appendix B). Measurements included as depths below ground surface in tenths of feet are: top of bedrock, bottom of surface casing, bottom of well casing, well bottom, top of screened interval and fracture zone. Casing diameters are presented in inches. All monitoring well construction details were converted to elevation above mean sea level using the USLS datum (Table 2). Survey results including top of casing elevations, ground surface elevations and coordinate locations are presented in Table 3. The results of final grout seal hydrostatic tests for bedrock wells are presented on Table 4.

3.2 IN SITU HYDRAULIC CONDUCTIVITY TESTS

As discussed previously, in situ hydraulic conductivity tests were often conducted after drilling cored intervals in which no circulation fluid loss was recorded. The results of these tests are listed in Table 5.

3.3 SINGLE WELL HYDRAULIC CONDUCTIVITY TESTS (Slug Tests)

After completion of well development at a monitoring well cluster, single well hydraulic conductivity tests were performed to provide additional information on bedrock hydraulic conductivity. The tests were conducted by applying or removing an instantaneous charge (head loss or gain) on a monitoring well and recording resultant drop or rise in hydrostatic head on a chart recorder. Data obtained in the field from these tests were used to estimate hydraulic conductivity values in cm/sec (Bouwer and Rice, 1976; Cooper et al (1967)). Nearly all monitoring wells were tested in this manner. The estimated hydraulic conductivity values were presented on Table 6.

3.4 GEOLOGIC RECORDS

Split-spoon samples of the overburden and continuous bedrock core samples were obtained from each drilling location and logged by a qualified geologist to provide a record of site geology. These logs are included in Volume II, Appendix C. Care was taken to insure that lithologic detail of bedrock was recorded. Standard logging procedures were modified to provide for accurate "formation specific" detail. Consistency and completeness in record taking were maintained throughout the logging program. The information on each log include:

- Core Run Designation
- Rock Quality Designation (RQD)
- Percent Run Recovery
- Stratigraphic Change Depths
- Formational and Member Contacts
- Rock Type Description
- Fracture Frequency
- Fracture Depth and Relative Dip
- Percentage Circulation Fluid Losses and Depth

For consistency, bedrock cores obtained from previously installed monitoring wells in expanded clusters were relogged as described above. New logs for old core from expanded monitoring well clusters VH-129, VH-130, VH-143, VH-145, and VH-146 and previously existing well clusters VH-112, VH-136, and VH-141 are also included in Volume II, Appendix C.

4.0 INTERPRETIVE GEOLOGIC DATA PRESENTATION

The geologic and hydrogeologic data presented in the previous section were used to construct maps, diagrams, plots and cross-sections for interpretation of the geology of the study area. The following key figures are presented in this section so that the reader may become familiar with them. Each figure will be referenced and discussed in detail in following sections.

Geologic Cross-Sections: Geologic cross-sections were constructed based on bedrock cores and overburden data converted from depth below ground surface to elevation. Ten cross-section lines (A-A' through J-J') transect the study area (Figure 6). Geologic cross-sections are presented in Figures 7 to 13. Cross-sections showing monitored interval and estimated hydraulic conductivity were also constructed (Figures 14 to 20).

Structure Contour Maps: Structure contour maps illustrate the upper surface of geologic features in map (plan) view. Structure contour maps were constructed of the top of bedrock, top of oolite bed (a marker horizon in the Oak Orchard Member), top of Eramosa Member, top of Goat Island Member, top of Gasport Member, top of DeCew Member and top of Rochester Shale (Figures 21 through 27). Structure contour maps or distribution maps were also constructed of the major bedding plane fracture zones (Figures 28 through 35).

Isopach Maps: Isopach maps (equal thickness maps) display contours of the thickness of a geologic structure or unit. Isopach maps of the overburden and Lockport Formation in the study area are presented on Figures 36 through 38.

Hydraulic Conductivity Contour Maps: Estimated hydraulic conductivity values derived from slug test data were plotted and/or contoured for most of the water-bearing zones within the study area. These maps show "water-bearing areas" based on the 1×10^{-4} cm/sec hydraulic conductivity criterion for water bearing intervals (Figures 39 to 54).

Fracture Frequency Plots: Fracture frequency per vertical foot was determined from inspection of bedrock core from each monitoring well cluster location. Fracture frequency plots for all new or expanded clusters installed during the off-site investigation are provided in Volume II, Appendix D.

5.0 REGIONAL GEOLOGY

The regional geology of the Niagara Falls area relevant to the Necco Park investigation is presented in this section. Descriptions of the overburden, Lockport Formation and Rochester Shale are included.

5.1 OVERBURDEN STRATIGRAPHY

The overburden materials in the Niagara Falls area consist of predominantly natural sands, silts and clays, and man-deposited miscellaneous fill. Figure 2 presents a typical section of overburden in the Niagara Falls area.

A one to five foot thickness of glacial till generally occurs at the base of the overburden. Glacial till contains very poorly sorted sands, silts, clays and gravels. The till in the Niagara Falls area was deposited near the end of the Wisconsinan Glaciation during the Pleistocene Epoch. The tills in the vicinity of Necco Park are characteristically stiff red clays with varying amounts of sand, silt and gravel. Above the till there is usually a variable thickness of glaciolacustrine lake sediments consisting of sand, silt and clay deposited about 12,000 years before present as the continental ice sheets retreated northward. These sediments, commonly represented as varved (banded) silts and clays, were deposited in temporary lakes which formed at the ice front (proglacial lakes). Additional sediments were later deposited when a large post-glacial lake formed on the flatland between the Niagara and Onondaga Escarpments. This lake (Lake Tonawanda) stretched for over fifty miles to the east of the Niagara Falls area (Tesmer 1981). A one to two foot thickness of topsoil overlies the glaciolacustrine sediments in undisturbed regions. Since much of the Niagara Falls area has been disturbed by human activities, many areas exist where sections of natural overburden have been removed and/or replaced with miscellaneous fill material.

5.2 LOCKPORT FORMATION STRATIGRAPHY

The Middle Silurian Lockport Formation[1], consisting of approximately 140 feet of relatively competent dolomite lies beneath the overburden in the Niagara Falls area. This unit thickens to the southeast and thins to the west towards the Niagara Gorge, and to the north towards the Niagara Escarpment. The Lockport Formation, which has also been referred to as the Lockport Dolomite (or Dolostone), can be subdivided into five principal members: the Oak Orchard, Eramosa, Goat Island, Gasport and DeCew Members (Zenger 1962). The Lockport Formation is primarily dolomitic and characterized generally by brownish-gray to dark gray color, medium granularity, medium to thick bedding, stylolites, carbonaceous partings, vugs and poorly preserved fossils. The Lockport is subdivided into its five principal members based on variations within this general description (Zenger 1962). A stratigraphic column showing the Lockport Formation is provided on Figure 3.

Oak Orchard Member: The Oak Orchard Member, the uppermost and thickest member of the Lockport Formation, ranges from approximately 80 feet to 120 feet in thickness in the Niagara Falls area. It is brownish-gray to dark gray, fine to medium grained, thin to thick bedded, saccharoidal, bituminous dolomite with stylolites, carbonaceous partings, vugs, minor occurrences of stromatolites, oolites and tabulate coral fossils. The Oak Orchard exhibits the greatest degree of variability of the Lockport Formation members being shaley and thin bedded in sections and massive in other sections.

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1 The thickness of dolomite, which in this report is referred to as the Lockport Formation, has been classified both as a formation and as a group. Tesmer (1981) uses nomenclature adopted by the New York State Geological Survey and defines the unit as a group consisting of four separate formations: The Oak Orchard, Eramosa, Goat Island and Gasport Formations. The DeCew dolostone (dolomite) is not grouped with the Lockport Group, on the basis that there exists a non-conformity at the top of the DeCew indicating a hiatus in sedimentation. Zenger (1962) classifies the Lockport as a formation with the Oak Orchard, Eramosa, Goat Island, Gasport and DeCew as principal members. Dr. Carlton Brett of the University of Rochester concurs with Zenger, however, he classifies the DeCew as a separate formation. Brett indicated that no official classification has been accepted and that either nomenclature may be used so long as references are cited (Telecon February 2, 1987). For the purposes of this study the stratigraphic classification for the Lockport Formation adopted by Zenger will be used.

Eramosa Member: The Eramosa Member, 16 to 18 feet thick in the Niagara Falls area, underlies the Oak Orchard Member. This unit is generally medium to dark-gray, fine grained, thin to medium bedded argillaceous and bituminous dolomite, with many shale partings, gypsum vugs, and some stylolites (Zenger, 1962). The contact between the Oak Orchard Member and the Eramosa member is characteristically sharp in the Niagara Falls area.

Goat Island Member: The Goat Island Member, occurring beneath the Eramosa, is generally 19 to 25 feet in thickness in the Niagara Falls area. Generally the Goat Island is light olive-gray to brownish-gray, medium-grained, thick-bedded, saccharoidal dolomite, with abundant chert nodules (near the top), stylolites, carbonaceous partings, and some vugs containing gypsum, calcite, and sphalerite (Zenger 1962). The contact between the Eramosa and the Goat Island is conformable and is characterized by gradual lightening in color over a two foot thickness.

Gasport Member: Below the Goat Island Member is the approximately 15 to 30 feet thick Gasport Member. Because the Gasport occurs as a complex of different facies, this member tends to exhibit a high degree of variability between geographic localities. The Gasport is predominantly olive-gray to brownish-gray, coarse grained, medium to thick bedded, fossil-fragmental, crinoidial limestone or dolomite (Zenger, 1962). However, due to localized facies changes, this member can appear as dark gray, fine grained argillaceous dolomite with sporadic crinoid fragments. The contact between the Goat Island and the Gasport Member is conformable (Zenger, 1962). However, because of local facies relationships between the top of the Gasport and the bottom of the Goat Island it is often difficult to identify. The combined thickness of the Goat Island and Gasport Members, however, is generally constant.

DeCew Member: The DeCew Member underlies the Gasport Member and overlies the Rochester Shale. The DeCew is described as medium-gray to medium dark-gray, fine-grained, thin-to thick-bedded and massive argillaceous dolomite. Thicknesses range from 8 to 10 feet in the Niagara Falls area. The contact between the DeCew and the Gasport Member is characteristically abrupt in the Niagara Falls area, and is marked by a change from the massive crinoidial basal conglomerate of the Gasport member to the fine-textured argillaceous dolomite of the DeCew (Zenger, 1962). Tesmer (1981) separates this unit from the Lockport Formation on the grounds that a non-conformity exists between the DeCew and the Gasport indicating a break in sedimentation. However, Zenger (1962) notes that the non-conformity occurs locally and that the contact between the DeCew and Gasport is conformable at other localities.

5.3 ROCHESTER SHALE STRATIGRAPHY

The Rochester Shale Formation lies below the DeCew Member and is typically 55 to 65 feet thick in the Niagara Falls area. It is described as dark bluish to brownish gray, calcareous shale with occasional argillaceous limestone layers. The upper Rochester Shale tends to be more dolomitic than the lower, especially at the contact with the DeCew. This contact, although gradational at most locations, tends to be more abrupt and undulating in the Niagara Falls area. This has been attributed to localized channeling at the top of Rochester Shale in the Niagara Falls area prior to the deposition of the DeCew Member (Tesmer 1981). The maximum depth of investigation for this study was limited to the top 10 feet of the Rochester Shale.

5.4 REGIONAL STRUCTURAL GEOLOGY

A south-dipping homocline, which affects the Paleozoic rocks of western and southern New York, is the dominant structural feature in the Lockport Formation, as well as in the sedimentary formations beneath it. Bedding dips are characteristically gentle. The dip has been calculated to be 29 feet per mile at Niagara Falls (Zenger, 1962).

Local deviations in the dominant regional structure do occur, and may be attributed to monoclinal flexures and faulting. A large scale, tectonically related, structural pattern is believed to affect the rocks of western New York (Yager and Kappel, 1987). The nature and significance of this pattern will be discussed in greater detail in Section 8.0.

Joints, high angle to vertical fractures related to regional stress patterns, are common in the Lockport Formation. These joints are probably most open or developed in the upper part of the Lockport Formation, where a relatively high degree of weathering has occurred (Johnston, 1964). Where dissolutioned, these joints may serve as conduits for vertical and horizontal movement of groundwater between bedding plane fractures. The prominent sets of vertical joints in the Niagara Falls area are oriented N65°E and N30°W (Johnston, 1964). Near the bedrock surface, joints tend to be open and well developed; however, they become relatively tight and poorly developed at depth (Miller and Kappel, 1987). The incidence or frequency of vertical fractures may vary with depth between areas. Studies conducted by the U.S. Geological Survey suggest that vertical fracture frequency may increase along regional structural lineaments (Yager and Kappel, 1987). These lineaments, are related to the large scale structural pattern mentioned above.

Bedding plane fractures, near horizontal fractures parallel to formation bedding, are distributed throughout the Lockport Formation. Bedding plane fracture zones are believed to transmit the majority of the groundwater flow in the Lockport Formation (Johnston, 1965, Miller and Kappel, 1987, Yager and Kappel, 1987). Several conditions are needed for a water-bearing bedding plane fracture zone to develop. First, variations in lithology must be present which facilitate differential responses to weathering, solutioning, stress and strain factors. Secondly, tectonic or isostatic rebound related stresses create breaks or fractures along the pre-determined zones of weakness. Thirdly, groundwater flowing through these fissures cause solutioning (i.e., widening) of the fractures until transmissivity becomes significant. In the Lockport Formation, horizontal bedding plane fracture zones tend to lie within particular stratigraphic intervals.

6.0 GEOLOGY OF THE STUDY AREA

A large amount of geologic data has been obtained during the off-site investigation at Necco Park. Over two thousand feet of bedrock core have been studied in detail to improve the understanding of the geology and hydrogeology of the study area. A detailed description, based on these data, of the lithology, stratigraphy, structure and fracture properties of the relevant geologic units within the study area is presented below.

6.1 OVERBURDEN

The overburden within the study area consists of natural and man-emplaced material (Figure 2). It was observed during drilling that much of the natural overburden within the study area has been disturbed or removed by human activity. Although natural overburden was observed, in general, fill has replaced much of the natural materials. Where fill materials occur, the thickness of natural material depends on the depth of excavation or disturbance prior to fill emplacement. No areas were observed where fill was emplaced directly on top of non-disturbed natural overburden. The depth and areal distribution of fill within the study area has not been accurately delineated. Geologic cross-sections A-A' through J-J' (Figures 7 through 13) include interpretations of overburden based on available data. Due to the variable nature of the overburden, adequate correlation of overburden lithology between observation points was not possible. It is likely that the quantity of fill and natural materials within the overburden varies considerably throughout the study area.

Based on sampling records, the natural overburden in the study area (excluding surficial soils), may be sub-divided into two primary units; glaciolacustrine and glacial till. The glaciolacustrine may be divided into two sub-units. The lower glaciolacustrine unit, consists primarily of compacted clays with fine silt interbeds or varves. The upper glaciolacustrine unit is typically orange to yellow clayey sandy silt. The interface between the lower and upper glaciolacustrine sub-units is often the site of perched water represented by a 1 to 1.5 foot saturated thickness.

The glacial till observed below the glaciolacustrine sediments in the study area is typically a red, silty, sandy, gravelly clay. The contact between the till and the lower glaciolacustrine unit is usually apparent when sand and gravel becomes mixed with the clay. In places, large boulders have been encountered (a few feet above the top of bedrock) while augering through the till.

Overburden thicknesses vary considerably within the boundaries of the study area. Thicknesses range from less than 2 feet in the southwest to greater than 22 feet in the southeast. An isopach map of the overburden (which does not include recently landfilled areas) shows general thickening occurs toward the southeast (Figures 36 and 37). Since the surface topography in the area is relatively flat, the thickening of the overburden corresponds to the dip of the bedrock surface.

6.2 LOCKPORT FORMATION

Stratigraphic and lithologic data from the study of bedrock core obtained during monitoring well installation revealed that all Lockport Formation members fit the general lithologic descriptions provided in Section 5.2 (Figure 3). The elevations of key marker horizons and the top of rock are provided in Tables 7 and 8. The Oak Orchard Member was studied in detail to characterize the relationship between bedding orientation, lithologic variation and major fracture zone positioning. The lithology of the Oak Orchard was found to vary from massive competent units 10 to 15 feet in thickness to thinly bedded argillaceous units 3 to 5 feet thick. The upper Oak Orchard (the upper 15 feet) was characteristically thinly bedded stromatolitic and oolitic dolomite while the lower Oak Orchard varied from massive to thinly bedded units. Of the lower four members of the Lockport Formation, the greatest degree of lithologic variability between drilling locations occurred in the Gasport Member. The upper half of the Gasport Member varied from light-gray, relatively massive, crinoidial dolomite to dark-gray, thinly bedded, argillaceous dolomite with very sporadic crinoid fossils. This variability can be attributed to relatively small scale facies changes between isolated reef structures.

Four key marker horizons were identified within the Lockport Formation. Marker horizons are widespread and identifiable stratigraphic beds selected for use in preparing structure contour maps or other maps which emphasize the nature or attitude of a plane or surface. Near the top of the Oak Orchard, an oolite bed was identified at all drilling locations. This horizon provides an indication of the upper Lockport Formation bedding orientation, and occurs within 1.5 feet above or below the B-zone fractures. Other marker horizons within the Lockport Formation which provide reliable bedding plane orientation data are the top of Eramosa, top of Goat Island and top of DeCew Members. The top of the Gasport Member is not considered a key marker horizon because of its high degree of variability. Detailed graphic representations of the lithology of the Lockport Formation within the study area are provided on Cross-Sections A-A' through J-J' (Figures 7 to 13).

The average thickness of the Lockport Formation within the study area based on available data is 148 feet (Table 9). Thicknesses (including the DeCew) range from 142 feet at location VH-112 to 151 feet at location VH-153. Generally, Lockport Formation thicknesses increase toward the southeast in the study area. However, locally increased thickening was observed in the area near location VH-147 and VH-148 (Figure 38). Thickness variations within the Lockport Formation are not unexpected and are most likely caused by a gain of upper Oak Orchard Member to the southeast and/or variations in the DeCew/Rochester Shale contact.

Lockport Formation member thicknesses were determined based on core inspection (Table 10). Oak Orchard Member thicknesses ranged between 74.1 to 80.5 feet and averaged 77.3 feet. The variation is primarily due to changes in the top of rock and thickening towards the southeast. Eramosa Member thicknesses ranged between 13.7 and 20.5 feet and averaged 16.5 feet. The Goat Island and Gasport Member thicknesses were more variable than other Lockport Formation Members. Generally where one member thickened, the other thinned and vice-versa. The combined thicknesses exhibited a much lower degree of variability. The Goat Island Member thicknesses ranged between 21.2 and 33.5 feet and averaged 26.8 feet. The Gasport Member thicknesses ranged between 9.1 and 25.4 feet and averaged 16.6 feet. However, the combined Goat Island/Gasport member thicknesses ranged between 42.1 and 47.3 feet and averaged 44.6 feet. DeCew Member thicknesses ranged between 8.1 and 12.5 feet and averaged 9.9 feet.

6.2.1 LOCKPORT FORMATION BEDDING STRUCTURE

Top of Lockport Formation (Top of Bedrock): The top of the Lockport Formation within the study area is represented by the top of bedrock. Part of the upper Oak Orchard Member has been removed by erosional processes, most recently by the scouring action of the Wisconsinan ice sheets during the Pleistocene epoch. The top of bedrock reflects the differential weathering which occurred during this period and also reflects the orientation of formation bedding.

The top of rock was usually identified by auger refusal during hollow stem auger drilling. At nearly every drilling location within the study area, the top of bedrock was relatively unweathered. Direct observations at the extensive Niachlor excavations within the study area confirmed these relatively intact conditions at the top of bedrock. These observations indicate that a substantial regolith zone does not exist at the top of rock in the Necco Park area. A structure contour map was constructed for the top of bedrock (Figure 21). In the northwest study area, the top of bedrock dips S60°E at approximately 0.7 degrees. In the southeast section of the study area, the top of rock dips 0.2 degrees towards the south. Apparent dips of top of rock are shown on cross-sections A-A' through J-J' (Figures 7 through 13).

Top of Members and Marker Horizons: Bedding plane structure and orientation of the Lockport Formation can be illustrated through structure contour maps of the key marker horizons previously discussed (Figures 22, 23, 24, and 26). The top of Gasport, not considered a good marker horizon, was mapped for completeness (Figure 25). Bedding plane orientation is generally characterized by gentle dip. Average dip angle and direction is approximately 0.5 of a degree in a S45°E direction. Bedding planes strike predominantly N60°E. Important variations exist on a smaller scale within the study area. Each structure contour map (excluding the top of Gasport map) may be sub-divided into three separate areas where bedding structure is similar. The northwestern area has a bedding dip angle of approximately 0.6 of a degree; the central area has a bedding dip angle of approximately 1.0 degree; and the southeastern area has a bedding dip angle of approximately 0.2 of a degree. The top of oolite bed structure contour map (Figure 22) provides evidence which suggests that bedding dip direction in the east section of the study area trends in a more southerly direction, than the rocks to the northwest.

It would appear, based on the structure contour maps alone, that the changes in dip angle represent a gentle fold structure. However, additional evidence, including identification of breccia, bedding offset and slickensides indicates that the structure is related to high angle faulting (see Figure 59). The evidence for the existence of faulting will be discussed in detail in Section 8.0. Apparent dips of the top of rock, oolite bed, and Lockport Formation members are shown on Cross-Sections A-A' through J-J' (Figures 7 to 13).

6.3 TOP OF ROCHESTER SHALE FORMATION

The Rochester Shale Formation, which underlies the Lockport Formation within the study area, was penetrated at thirteen drilling locations. The top of the Rochester Shale is considered to be the fifth principal marker horizon within the study area. The attitude of bedding of the Rochester Shale along Cross-Sections A-A' through J-J' are provided on Figures 7 to 13. Based on core inspection, the upper Rochester Shale consists predominantly of dolomitic shale in the study area. The contact between the DeCew Member and the Rochester Shale was observed as being either relatively abrupt or gradational. This variation is believed to be the result of localized channelization shortly after the time of deposition (Zenger, 1962). A structure contour map of the top of the Rochester Shale reveals that the bedding strike and dip conform with the attitude of the overlying Lockport Formation (Figure 27). This indicates that the structural deformation affecting the Lockport Formation also affects the Rochester Shale.

7.0 HYDROGEOLOGY OF THE STUDY AREA

This section discusses the relationship between the geology of the study area and groundwater flow.

7.1 FRACTURE ZONE CHARACTERIZATION

Groundwater flow through the Lockport Formation in the Necco Park study area occurs through horizontal water-bearing bedding plane fracture zones. This was reported by Johnston (1964) based on observations along the exposed walls of the NYPA Conduits which cut through the Lockport Formation west of the study area. Johnston identified seven water-bearing zones, each consisting of either a single open bedding plane or an interval of rock layers containing several open bedding planes. Although the concept of separate and hydrologically distinct fracture zones has been an issue of dispute in the past, the United States Geological Survey (USGS) concurs with Johnston (Miller and Kappel, 1987). A similar series of bedding plane fracture zones at Necco Park (Figure 4) was delineated by WCC in the initial and supplemental site investigations (WCC, 1984). The areal extent of each zone, the relationship of each zone to bedding, and the influence of vertical fractures are discussed below.

The identification of water-bearing fracture zones was based on field observations during drilling, bedrock core examination, and hydraulic conductivity test results. Circulation fluid losses (expressed as percent water loss) during drilling provided the initial qualitative data. Core observation was used to verify the depth of a fracture zone. Usually a weathered fracture or series of fractures was observed at approximately the same depth as the noted circulation fluid losses. Moderate to high hydraulic conductivity test results (greater than 1×10^{-4} cm/sec) usually corresponded to water-bearing fracture zones where water loss was observed. Low hydraulic conductivity values (less than or equal to 1×10^{-4} cm/sec) usually corresponded to intervals where no circulation loss was observed. The depth of occurrence of a certain fracture zone was predictable based on data obtained during the extensive drilling associated with the initial and supplemental investigations at Necco Park. The primary water-bearing fracture zones present in the study area, designated the B- through G-zones are discussed below.

B-ZONE: The uppermost water-bearing bedding plane fracture zone in the Lockport Formation within the study area is designated the B-zone. It generally exists approximately four feet below the top of rock and 10 feet above the C-zone. A fracture elevation contour map was constructed for the B-zone based on all data obtained to date (Figure 28). The B-zone dips mainly southeast at an average angle of 0.6 of a degree. Projections of this fracture zone to the northwest suggest that it sub-crops within the study area in the vicinity of VH-156 cluster. It is probable that this sub-crop area represents a groundwater recharge area for the B-zone. The B-zone is recharged elsewhere through vertical fractures. Similar sub-crop areas may exist for fracture zones C through F further northwest of the study area. The B-zone was not observed in the southeastern study area. This may be related to the fault structure, to be discussed in Section 8.0 of this report. A relationship between the B-zone and the oolite bed discussed in Section 6.2 is apparent. The B-zone usually occurs within 1.5 feet above or below the relatively porous oolite bed.

C-ZONE: The C-zone generally occurs approximately 10 feet below the B-zone. A structure contour map for the C-zone shows the apparent distribution of the C-zone based on previous and current hydrogeologic data (Figure 29). This zone dips to the southeast with bedding at an angle of approximately 0.7 of a degree. This zone was not observed within the southeastern half of the study area based on nine observation points. Low slug test hydraulic conductivity results support observations during drilling and core inspection. The distribution of the C-zone may be influenced by the fault structure.

CD-ZONE: The CD-zone occurs as a series of intermediate bedding plane fracture zones which occur between the C-zone and D-zone bedding plane fractures. In this study, all CD-zone fractures are considered a single zone, even though in some places two distinguishable CD fracture zones occur together. For example, at monitoring well cluster VH-136, CD_1 and CD_2 fractures were identified. CD-zone fractures appear to be concentrated in the northern half of the study area (Figure 30), and are mostly absent in the southern half of the study area. The greatest presence of CD-zone fractures is in the western Necco Park site area where monitoring wells VH-116 CD_1 and CD_2, VH-136CD_1 and CD_2, VH-137CD and VH-143CD have been installed. Cross section E-E' (Figure 11) indicates that a series of CD-zone fractures exist which descend in stair-step fashion towards the south.

WCC has concluded that CD-zone fractures are not areally extensive and are discontinuous within the study area. The fractures may serve as intermediate groundwater flow pathways between the C- and D-zones. The CD-zone fractures are generally present northwest of the fault structure.

D-ZONE: The D-zone generally occurs approximately 30 feet below the C-zone. The areal distribution of this fracture zone is illustrated on Figure 31. The D-zone is well represented in the northern half of the study area, but is poorly represented in the southern half. Approximate dip angle is 0.7 of a degree to the southeast. Since the D- and E-zones tend to be very close to one another (5 to 10 feet), discretion was used when assigning a zone designation to either of these fractures. In locations where both of these zones are present, indications are that they may be hydraulically connected based on proximity and similar hydraulic heads.

E-ZONE: The E-zone usually occurs 5 to 10 feet below the D-zone. The distribution for this zone is presented on Figure 32. The E-zone has not been observed in the southwestern corner of the study area and does not occur at other isolated locations (e.g., VH-129, VH-130, VH-143). It is inferred that the presence of this water-bearing zone, although widespread throughout the study area, tends to be locally discontinuous. The approximate dip angle of this fracture zone is 0.4 of a degree to the southeast.

F-ZONE: The F-zone occurs approximately 17 feet below the D-zone and/or 7 feet below the E-zone. The areal distribution for this fracture zone is presented on Figure 33. The F-zone dips towards the southeast at approximately 0.7 of a degree. The F-zone has not been observed in the southwest and southeast sections of the study area.

G-ZONE: Prior to the off-site investigation, a fracture zone (given the designation G-zone) was identified as existing approximately 60 feet below the F-zone and 30 feet above the top of the Rochester Shale. This zone was identified at cluster locations VH-136 and VH-141 during the supplemental site investigation. More recent data obtained during the off-site investigation indicates the existence of two water-bearing fracture zones in the Lockport Formation below the bottom of the Oak Orchard Member and above the top of the Rochester Shale. A third, much less continuous, fracture zone was identified at cluster locations VH-147 and VH-153.

As a result of new findings, the G-zone (defined in the context of this report as the water-bearing thickness of bedrock below the bottom of the Oak Orchard and above the top of the Rochester Shale) was sub-divided into three separate fracture zones, G_1, G_2, and G_3. The G_1 zone was identified in the Eramosa Member at locations VH-147 and VH-153 and occurred 20 and 26 feet above the G_2-zone respectively. This zone was not noted in other cluster locations and is not considered a major water-bearing zone.

The G_2-zone was encountered at seven monitoring well cluster locations within the study area. The G-zone fractures previously identified at VH-136 and VH-141 have been reclassified as G_2-zone fractures based on stratigraphic position relative to other newly identified G_2-zone fractures. The G_2-zone has the largest known distribution of the G-zone series (Figure 34), but still its distribution is limited. This zone appears to be absent in the southern study area (based on observations at locations VH-146, VH-148, and VH-150) and in the northwestern study area (based on VH-156 and VH-143). The G_2-zone generally dips toward the southeast at approximately 0.6 of a degree. In the east section of the study area, however, the G_2-zone appears to be dipping towards the north at approximately 0.3 of a degree. This fracture zone appears most commonly in the lower Goat Island Member or upper Gasport Member.

A third G-zone fracture, designated G_3, has been identified at approximately 14 feet below the G_2-zone at several drilling locations (VH-130, VH-145, VH-147 and VH-153). This zone is not represented in the northern and southern study areas based on data from eight drilling locations (Figure 35). The G_3-zone most commonly exists in the upper to middle Gasport Member. It dips at approximately 0.6 of a degree to the southeast in the western study area and approximately 0.2 of a degree to the north-northeast in the eastern study area.

The G^{-3} zone is the deepest water-bearing zone in the Lockport Formation encountered in the Necco Park investigations.

J-ZONE (Top of Rochester Shale): The J-zone is defined as the interface between the DeCew Member of the Lockport Formation and the Rochester Shale (Figure 27). The J-zone has been penetrated at 13 locations in the study area. It has been determined that the J-zone does not coincide with a major water-bearing fracture zone. The J-zone exhibited very low hydraulic conductivity test results and circulation water loss was not noted during drilling (with the exception of VH-143J where a 50 percent circulation fluid loss was noted).

VERTICAL FRACTURING: Vertical fracturing represents the least documented aspect of the structural geology of the study area. All drilling thus far at Necco Park has been vertical, therefore, the incidence of intersecting vertical or near-vertical fractures has been uncommon. Johnston (1964) identified the major joint fracture orientations in the area as N65°E and N30°W. These orientations were observed in rock exposures along the NYPA conduits. A study of bedrock exposures along Pine Avenue during the construction of the Niachlor Brine Pipeline in 1986 indicated a local principal joint fracture direction of N75°E, a secondary direction of N60°W, and a tertiary direction of N20°W (Volume II, Appendix E).

Vertical fractures are expected to be most developed or open within the upper 20 to 30 feet of bedrock. These fractures serve as vertical conduits of groundwater flow between water-bearing bedding plane fracture zones, and transmit water horizontally as well.

The incidence or frequency of vertical fractures within the study area is not well documented. However, locally higher vertical fracture frequency can be inferred along or near the fault structure mentioned in Section 6.2.1. This increased vertical fracturing is expressed by localized high hydraulic conductivity and apparent hydraulic connection between water-bearing zones. A further discussion of these phenomena is provided in Section 8.0.

FRACTURE FREQUENCY: Fracture frequency (number of fractures per vertical foot) was determined during inspection of bedrock core from each monitoring well cluster installed as part of the off-site investigation. Fracture frequencies were plotted versus depth below ground surface to compare changes in observed fracture frequency with changes in lithology and depth (Volume II, Appendix D). In this way the relationship between fracture frequency and the positioning of the major water-bearing bedding plane fractures was examined.

In general, there appears to be relatively high fracture frequencies at depths were circulation fluid losses were noted. However, there were a few instances where a fracture zone was represented by only one large open fracture. There were also instances where high observed fracture frequency coincided with no water-bearing fracture zone. Because of this inconsistency, observed fracture frequency is not the best indication of water-bearing characteristics or capabilities of bedrock intervals. Fractures observed in core represent a combination of open water-bearing fractures, tight argillaceous partings, joint fractures, and (if not recognized in the field) artificial breaks caused during the drilling process. For example, relatively impermeable areas which exhibit many argillaceous partings usually exhibit high observed fracture frequency, but do not coincide with water-bearing fractures.

7.2 HYDROLOGIC DATA

Hydrologic data including circulation water loss percentages and in-situ hydraulic conductivity test results were obtained during drilling operations. Hydraulic conductivity values were estimated from slug tests performed following well development. Hydraulic conductivities were estimated using the methods published by Bouwer and Rice (1976) and Cooper et al (1967). The thicknesses used in these calculations were the length of open hole (bedrock wells) or screened interval (overburden wells). Therefore resulting hydraulic conductivities for the bedrock wells are descriptive of an equivalent unit with a thickness equal to the open hole interval of the well. These data were used to identify water-bearing zones in conformance with the accepted criteria (estimated hydraulic conductivity greater than 1×10^{-4} cm/sec).

Circulation fluid loss percentages represent estimated values obtained under highly variable field and drilling conditions. Generally circulation fluid loss percentages correlate with a range of estimated hydraulic conductivity values. In monitoring wells where 100 percent circulation fluid losses were noted, estimated hydraulic conductivities ranged between 1×10^{-3} cm/sec and 1 cm/sec. Circulation fluid losses ranging from 50 to 90 percent corresponded to hydraulic conductivity values ranging between 1×10^{-4} cm/sec and 1×10^{-1} cm/sec. Circulation fluid losses ranging from 10 to 50 percent corresponded to a range of hydraulic conductivity values between 1×10^{-6} cm/sec and 1×10^{-4} cm/sec. At monitoring wells where no circulation fluid losses were noted, hydraulic conductivities were generally between 1×10^{-7} cm/sec and 1×10^{-4} cm/sec. In-situ hydraulic conductivity values compared favorably with slug test hydraulic conductivity values (Tables 5 and 6).

Monitored intervals in each new monitoring well installed as part of the off-site investigation were assigned water-bearing zone designations. These designations were based on the depth and positioning of the fracture or interval in relation to the positioning of established fracture zones in previously installed clusters. In monitoring wells where circulation fluid losses and relatively high hydraulic conductivities were noted, water-bearing zone designations were based on the stratigraphic position of the fracture relative to marker horizons and established fractures in nearby monitoring wells. Examination of geologic cross-sections aided in these determinations. In monitoring wells where no circulation fluid losses or fractures were noted, and results of hydraulic conductivity tests were low, zone designations were determined by comparing the open-hole interval to equivalent stratigraphic intervals established by cross-section analysis. As an example, the open interval in monitoring well VH-145F exhibited no circulation fluid loss, had no observed fracture zone and had a measured hydraulic conductivity of 3×10^{-5} cm/sec. This open interval is not water-bearing based on accepted criteria. Therefore, it was assigned a zone designation based on the equivalent stratigraphic interval spanned by the open-hole. In this case, the interval spanned is that in which the F-zone commonly occurs (e.g., at VH-112 and VH-141, cross-section F-F', Figures 11 and 18).

In this manner, water-bearing zone designations were made for monitoring wells not exhibiting water-bearing properties to maintain consistency in the monitoring program. Occasionally, open-hole intervals were found to overlap two equivalent stratigraphic intervals. These intervals usually exhibited low hydraulic conductivities and no circulation fluid losses. An example of this situation is monitoring well VH-152BC, which has an open-hole interval which covers the equivalent stratigraphic interval for the B-and C-zones. In another example, monitoring wells designated GJ cover both the stratigraphic equivalents of the G- and J-zones. Table 11 lists all Necco Park monitoring wells and corresponding monitored zones.

Hydraulic conductivity contour maps were constructed for zones A through J based primarily on slug test values. The purposes of constructing these maps were to illustrate hydraulic conductivity variation for each zone in the study area and to note any patterns. Segregations were made on most maps based on the 1×10^{-4} cm/sec hydraulic conductivity criterion for water-bearing zones. These segregations result in a simplified distribution pattern for the major water-bearing zones within the study area based solely on the accepted water-bearing criteria (Figures 39 to 54).

The A-zone hydraulic conductivities were contoured (Figure 39). However due to the highly variable nature of the overburden fill materials, segregations based on the hydraulic conductivity criterion are not appropriate. The B-zone is generally non water-bearing in the southern half of the study area and water-bearing in the northern half (Figures 40 and 41). The C-zone is not represented as a water-bearing zone in the south and east study area. C-zone estimated hydraulic conductivities are highest in the northern and western study area. There is an apparent drop in estimated hydraulic conductivity of several orders of magnitude in the C-zone over a horizontal distance of 300 to 400 feet near the southern perimeter of Necco Park (Figures 42 and 43). The possible significance of this change will be discussed in Section 8.0. The estimated hydraulic conductivities for the CD-zone (where present) are relatively high (Figure 44). Hydraulic conductivities in the D-zone exceed the 10^{-4} cm/sec criterion throughout much of the study area with the exception of the extreme southern boundary (Figures 45 and 46). The E-zone also exhibits hydraulic conductivities above the 10^{-4} cm/sec criteria throughout much of the study area. Low hydraulic conductivity regions in the E-zone exist along the southwest and northern borders of the study area (Figures 47 and 48). The F-zone appears to be water-bearing in the north, west, east and southeast study areas. A relatively impermeable area of the F-zone is indicated in the central and southern study areas (Figures 49 and 50). No hydraulic conductivity contour map was constructed for the G_1-zone. G_1 hydraulic conductivities of 2.5×10^{-2} and 4.8×10^{-4} cm/sec were obtained for monitoring wells VH-147G_1 and VH-153F/G_1 respectively (Figure 51). A permeable area in the G_2-zone trends northeast/southwest across the study area reflecting the distribution pattern for the G_2-zone. Non-permeable areas in the G_2-zone were found in the northwest and southeast study area (Figures 52 and 53). G_3-zone hydraulic conductivity contours were not constructed, however a hydraulic conductivity distribution for the G_3-zone is provided on Figure 51. Hydraulic conductivities for the G_3-zone ranged from 2.5×10^{-2} cm/sec to 7.0×10^{-1} cm/sec at VH-153G_3 and VH-147G_3, respectively.

A hydraulic conductivity distribution map for the J-zone was constructed (Figure 54). At no tested location within the study area were hydraulic conductivities for the

J-zone above the 10^{-4} cm/sec water-bearing criteria. Monitoring well VH-145J exhibited a slug test hydraulic conductivity value of 5.0×10^{-4} cm/sec, which can be attributed to a section of relatively permeable lower Gasport Member existing in the open hole. However, an in situ hydraulic conductivity test which isolated the J-zone in this monitoring well yielded a value of 7.5×10^{-6} cm/sec. Based on these data, the DeCew/Rochester Shale contact does not appear to represent a significant water-bearing zone in the study area.

8.0 FAULT CHARACTERIZATION

As a result of the geologic study at Necco Park, evidence has been gathered to delineate a fault related geologic structure in the bedrock beneath the Necco Park study area. The structure, identified based on inspection of bedrock core and cross-sectional analyses, is believed to be directly related to a northeast trending (N55°E) zone of high transmissivity identified by Johnston (USGS 1964) and studied more recently by Yager and Kappel (1987).

8.1 U.S. GEOLOGICAL SURVEY STUDIES

Richard H. Johnston (1964), studied the hydrogeology of the Lockport Dolomite during the construction of the NYPA conduits and noted that high yield production wells in the Niagara Falls area were isolated within a relatively narrow northeast trending band (Figure 55). Well yields cited by Johnston were as high as 2000 gpm from a formation (Lockport Dolomite) which was otherwise considered a minor aquifer. Well yields away from this band averaged approximately one order of magnitude less. Johnston suggested that this band of high yield wells represented a zone of high transmissivity associated with increased vertical fracturing.

The identified band of high yield wells intersects the NYPA conduits near Royal Avenue. At this location, an area of compound jointing (or vertical fracturing) was observed during construction. The vertical fracturing was observed on both sides of the conduit excavation. This became an area of trench wall failure. This was the only location where the excavation walls failed during construction. A high yield dewatering well installed at Royal Avenue was pumped for over one month before this area was dewatered, indicating very high transmissivity. (Telecon with Richard Yager, USGS, July 1, 1987.)

At the time of this writing the USGS is continuing their study of the lineament as part of an Interagency Agreement with the U.S. Environmental Protection Agency (USEPA) to investigate regional groundwater flow in the Niagara Falls area. Preliminary results of this study have been made available which provide more information on the nature of the lineament. A structure contour map of the base of the Rochester Shale south of Niagara Falls in Canada is provided which indicates a lineament trending northeast and intersecting Niagara Falls near the zone of high transmissivity noted by Johnston (Figure 56) (Yager and Kappel 1987). This structural lineament is believed to be related to a much larger scale structural system of lineaments which occurs throughout western Ontario and western New York (B.V. Sanford et. al. 1985) (Figure 57). These lineaments are interpreted to be faults with displacement ranging from 10 to 100 feet. The faults, assumed to be related to basement structures, dissect the rock mass into blocks which have been tilted in response to tectonic events. The faults are believed to have formed very long ago (as early as Silurian times); however the lineaments appear to be the loci of modern day stress relief in the form of seismic events. Seismic data recorded between 1970 and 1986 include five events with epicenters along the line of the projected lineament (Yager and Kappel 1987), (Figure 58).

The USGS has conducted surface resistivity surveys at two sites along the projected lineament northeast of the Niagara Falls airport. The results of the study suggest that there is a much higher incidence of vertical fracturing along the lineament. A drilling program was initiated by the USGS in the fall of 1987 to attempt to intersect the structure by bedrock core drilling at the site of the resistivity survey. The USGS have taken interest in the Necco Park study and were permitted to inspect Necco Park bedrock core. Preliminary results of the USGS drilling program indicate a high incidence of healed vertical fractures at the drilling locations along the lineament (Personal Correspondence, William Kappel 1988).

8.2 WOODWARD-CLYDE CONSULTANTS STUDIES

The zone of high transmissivity identified by Johnston and the projected lineament proposed by Yager and Kappel traverse the study area. Inspection of bedrock core and interpretation of cross-sections and structure contour maps indicate the presence of a geologic fault striking approximately N55^{o}-60^{o}E through the study area in the Lockport

Formation and Rochester Shale (Figure 59). The following sections present evidence for the fault, interpretations of fault position, geologic history and possible effect on the control of groundwater flow within the study area.

8.2.1 INDIRECT EVIDENCE

Structure contour maps of the five principal marker horizons discussed in Section 6.0 reveal a N60°E trending structure underneath the site area, which is represented by an apparent increase in formation bedding dip angle (Figures 22, 23, 24, 26, and 27). This structure can be described a monocline. The structure is parallel to the zone of high transmissivity and subparallel to the lineament recorded at the base of the Rochester Shale in Canada southwest of Niagara Falls, New York. The structure, if projected towards the southwest, intersects the NYPA conduits near the location of the Royal Avenue conduit trench failure and the high yield dewatering well. This structure when considered with supporting evidence is interpreted to be fault related.

Apparent bedding offset along the structure can be inferred through cross-section analysis. The offset is interpreted when bedding dip trends are projected toward the structure. This offset is inferred in four of the eight cross-sections which intersect the structure. The greatest degree of offset is seen on cross-section H to H' (Figure 12), approaching 7 to 10 feet at the Rochester Shale/Decew Contact. Offsets can be also inferred at the Decew/Gasport, Gasport/Goat Island, Goat Island/Eramosa, and Eramosa/Oak Orchard Member contacts on several cross-sections. The observed offset appears to form the border of two separate structural blocks. The northwestern block is interpreted to have moved upwards relative to the southeastern block.

8.2.2 DIRECT EVIDENCE

Direct observable evidence for faulting within the study area was found in bedrock core from monitoring well cluster locations VH-146 and VH-130, both located near the axis of the structure described above. At these two locations, intervals containing slickenside surfaces and/or breccia were observed. In VH-146D slickensides were observed at 52 feet and a brecciated zone was found between 54 feet and 58 feet. In core from VH-130G, at depths of approximately 125 feet and in the interval between 136 and 144 feet, five slickenside surfaces and a section of breccia were noted. The slickensides occurred most commonly on high angle fractures in close proximity to the brecciated sections. The breccia zones were characteristically healed with secondary mineralization of gypsum and calcite. The breccia zone observed at VH-146 occurred in the Oak Orchard Member and the breccia zone observed at VH-130 occurred in the Gasport Member.

At both locations, the breccia zones were markedly different from other core sections inspected. However, separate sections of breccia in core from VH-130G appear to have had different origins. Certain sections are most likely carbonate breccias of sedimentary origin, while other sections appear to have a tectonic overprint. It is not clear why the two types of breccia occur within such close stratigraphic proximity. Sanford et. al. has theorized that the fault lineaments of western New York and southwestern Ontario were active during deposition. These syndepositional tectonic movements may have contributed to the formation and position of pinnacle reef structures observed along similar lineaments (Figure 60) along the upthrust scarps at the edges of the faulted crustal blocks (Sanford et. al. 1985). This may explain the close proximity of fault related breccia and slickenside surfaces with carbonate breccia observed at VH-130G. It is unclear whether the breccia section observed in core from VH-146D is of tectonic or sedimentary origin.

In VH-130G the affected interval was accompanied by very high drilling fluid circulation losses and high estimated hydraulic conductivity. Slickensides were also found at monitoring locations VH-129D, VH-129J, VH-130J, and VH-151B. However, no evidence of breccia was observed at these locations. Well developed slickensides observed in core from VH-130J within the DeCew Member indicate reverse movement.

There was no conclusive evidence of repeated or missing stratigraphic sections in bedrock core from either VH-146 or VH-130, suggesting that these core sections are proximal to, but do not penetrate a major plane of bedding offset. However, it would be difficult to differentiate between sections within members of the Lockport Formation if a repeated section did occur.

8.3 INTERPRETATIONS OF FAULT POSITION

The position of faulting underneath the study area has been inferred largely based on observations described above. At least two interpretations are possible based on the available data. The faulting may be represented by one plane on which most of the observed offset has occurred, or by two or more closely spaced parallel or sub-parallel fault planes. In the first interpretation, a single fault plane is positioned just northwest of monitoring well clusters VH-130 and VH-146. The major fault plane is not intersected at either VH-130 or VH-146. A second interpretation is based on the concept of at least two fault planes at VH-146D and VH-130G (Figure 61).

It is possible that a fault system along a lineament of this magnitude is much more complicated than the relatively simple models which are presented here. The offset observed may be expressed in a series of smaller scale parallel faults which have not been intersected during drilling. It is probable, however, that the faulting occurs at or very near monitoring well clusters VH-130 and VH-146 and strikes in a N60°E direction.

Monoclinal folding is likely closely related to the faulting observed at Necco Park. Evaluations of structure contour maps suggest that downwarping of rock beds has occurred northwest of the fault. If a fold was the first expression of strain of the rock relative to compressional stress, faulting occurred later when a critical stress was reached. High angle reverse faulting of this nature is believed to begin at great depth, with fold deformation preceding faulting in an upwardly progressive manner. At a point, above which faulting no longer occurs, only a fold is represented. Offsets tend to be greatest at depth with the lowest amount of offset represented closer to the surface (Telecon Richard Yager, USGS) (Figure 62). The small amount of data available, the low degree of bedding offset and superimposed monoclinal folding have contributed to the difficulty involved with interpretation of the fault within the study area. Angled bedrock coring to be performed near the fault in 1988 should provide additional data on this feature.

Data suggest a high angle (75 to 95 degrees) northwest dipping fault plane. Fault dip angle and direction have not been quantified. The extent or existence of faulted bedrock beyond the boundaries of the study area can not be determined based on available data.

8.4 GEOLOGIC HISTORY OF FAULTING

There is evidence for at least three stages of deformation along the fault at Necco Park. The first stage, monoclinal folding, is represented by the apparent downwarping of rock beds northwest of the fault. A second stage involving the initial faulting episodes is represented by the healed fault breccia observed. The healed nature of the fault breccia suggests it occurred very long ago, possibly as early as the Silurian or Devonian periods. As discussed in Section 8.2, Sanford et. al. (1985) have hypothesized that syndepositional tectonic activity has occurred along many fracture lineaments in western New York and southwestern Ontario. A third stage of deformation is characterized by reactivation of the old fault plane as evidenced by brittle deformation features such as the slickensides observed. This later stage may have occurred in the recent geologic past. Seismic events along the lineament indicate that contemporary stress relief may be occurring.

8.5 EFFECTS OF FAULT ON VERTICAL FRACTURE FREQUENCY AND WATER-BEARING ZONE DISTRIBUTION

It is believed that the degree of vertical fracturing associated with the fault related lineament within the study area is higher than the regional average. The actual density and orientation of these fractures is not known, however vertical fractures oriented approximately N60°E would most likely be associated with the faulting. It is probable that this relatively high density of vertical fracturing associated with the fault provides vertical pathways through which the downward flow of groundwater can occur. As a result, the degree of hydraulic connection between certain water-bearing zones appears to be higher near the fault. For example, the C-zone and D-zone static water levels are similar in the vicinity of the fault.

The existence of increased vertical fracturing associated with the fault appears to have had an effect on the distribution of certain water-bearing bedding plane fracture zones within the study area; most notably the B- and C-zones. Neither of these zones is well represented southeast of the fault. The water-bearing C-zone is apparently discontinued at the approximate location of the fault. Southeast of this boundary, estimated hydraulic conductivities for the C-zone are on the average much lower (Figure 63).

In the B- and C-zones it is inferred that, although there was a lithologic and tectonic/isostatic predetermination for the formation of substantial C and B water-bearing fracture zones southeast of the fault boundary, these intervals were evidently isolated from the higher volume of groundwater flow from up-gradient recharge areas. This occurred through a combination of bedding offset, and a higher density vertical fracturing which allowed groundwater to move to successively lower fracture zones such as the D-zone. The apparent result is less solutioning of bedding plane fractures southeast of the fault. The impact of the fault on the areal extent of water-bearing capability for the deeper zones is not known.

Static water levels, obtained when the recovery system was temporarily shut down, indicate nonhomogeneity near the fault. Monthly groundwater measurements, normally obtained while the recovery system is operational, suggest anisotropy in the B- and C-zones. An anisotropic response to pumping from the recovery wells was also observed during aquifer tests conducted by WCC in 1984 and 1987. These tests showed that the drawdown response of the B- and C-zones to withdrawal from recovery well 52 was higher along the fault. This suggests a linear flow component near this structure (linear flow to a vertical planar groundwater sink).

9.0 ADDITIONAL STUDIES

This section discusses additional studies which were conducted as part of the off-site investigation.

9.1 BEDROCK THIN-SECTIONS

Bedrock thin-sections were made of selected bedrock intervals from core obtained at monitoring well cluster location VH-148. These sections were dyed to reveal porosity and calcite/dolomite ratios and were observed using a polarizing microscope. Presently, no conclusions have been drawn regarding this information, however; the sections will be available for future study if needed.

9.2 AERIAL SURVEY AND TOPOGRAPHIC MAPPING

In April 1986 an aerial survey was flown over the Necco Park/CECOS Area. From these photographs a detailed topographic map was constructed. This map includes relevant geographic features and ground surface elevation contours in one foot (where possible) intervals (Figure 65).

10.0 SUMMARY AND CONCLUSIONS

An off-site investigation was conducted in which seventy-eight (78) additional monitoring wells were installed in an expanded study area. Geologic and hydrogeologic data obtained during the investigation were used characterize the hydrogeologic and geologic conditions within the study area. Monitoring well records, in situ hydraulic conductivity test results, single well hydraulic conductivity tests results, and geologic records are presented and discussed in this report.

The overburden was found to consist of natural and man-emplaced material. The natural material consisted primarily of glacial till and glaciolacustrine sediments. The man-emplaced material consisted of a wide variety of materials. Much of the natural overburden had been disturbed, removed or altered. Overburden generally thickened to the southeast in the study area.

Generally, the Lockport Formation members and the top part of the Rochester Shale fit the descriptions given in the discussion of regional geology. However, key observations were noted. For example, marker horizons were identified in the Lockport Formation and at the Top of the Rochester Shale which gave reference points around which bedding structure and fracture positioning could be identified. Using this information detailed cross-sections and structure contour maps were constructed to illustrate these relationships. The attitude of bedding was identified at all levels of the Lockport Formation and was found to vary consistently from northwest to southeast across the site. Viewed areally, these variations in bedding dip attitude constitute an identifiable northeast trending structure affecting the bedrock within the study area.

Bedding plane fracture zones were identified from field observations during drilling, bedrock core examination and hydraulic conductivity test results. Circulation fluid losses were compared with estimated hydraulic conductivity values. A detailed description of the primary water-bearing fracture zones within the study area was presented. Bedding plane fracture zones B through F were found to exist solely within the Oak Orchard Member of the Lockport Formation. The B-zone was found to be closely related to the uppermost marker horizon, the oolite bed. The G-zone was subdivided into one intermediate, relatively discontinuous water-bearing fracture zone designated the G_1-zone, and two primary water-bearing bedding plane fracture zones designated the G_2- and G_3-zones.

Vertical fracturing and fracture frequency were discussed. The principal joint fracture direction was found to be approximately N65 - 75°E based on bedrock exposure observations along the NYPA Conduits and along the recently constructed Niachlor Brine Pipeline. Secondary and tertiary joint fracture directionals were also identified. Fracture frequency, as observed in bedrock core, was calculated per foot and plotted. These data were compared relative to the positioning of the major water-bearing fracture zones. Although good correlations were noted (i.e., water-bearing zones usually corresponded to increased observed fracture frequency) situations were observed which did not fit the general rule.

Hydrologic data obtained for monitored intervals during and after monitoring well installation were presented in detail. Hydraulic conductivity contour maps were constructed for water-bearing zones A through J to illustrate apparent hydraulic conductivity variation for each zone within the study area. WCC concludes the following from the hydrologic evaluation:

1) Generally circulation fluids loss percentages (during drilling) correspond to a range of estimated hydraulic conductivity values.

2) A four orders of magnitude drop in estimated hydraulic conductivity in the C-zone over a horizontal distance of 300 - 400 feet near the south perimeter of Necco Park was noted. This is possibly related to a northeast trending fault structure found to be crossing the study area.

3) Estimated G_2- and G_3-zone hydraulic conductivity values were relatively high within the known areal distribution of these zones.

4) The J-zone was found to be of low permeability throughout the study area. Estimated hydraulic conductivities were below the water-bearing criterion of 1×10^{-4} cm/sec.

As a result of the geologic study at Necco Park, evidence was identified which suggests a fault related geologic structure in the bedrock within the study area. The structure is believed to be directly related to a northeast trending zone of high transmissivity identified and studied by the USGS. The zone of high transmissivity is believed to be related to: a structural lineament identified in the Rochester Shale south of Niagara Falls in Canada; local seismic events; and a large scale structural system of basement faults which occurs throughout western Ontario, Canada and western New York State. Increased vertical fracturing is believed to be associated with the lineament.

Evidence used to identify faulting included slickensides, breccia and bedding offset. The fault may be represented by at least two parallel fault planes, which appear to affect the Lockport Formation and Rochester Shale. Monoclinal folding is believed to have occurred as a result of the same stress which caused the faulting. The fault appears to have had several generations of activity as evidenced by healed breccia and slickensides. A greater degree of vertical fracturing is believed to be associated with the fault as evidenced by the USGS findings, and various phenomena observed within the study area including hydraulic head similarities between zones near the fault, a linear N60°E nonhomogeneity in the piezometric surface of the B-zone and C-zone, and directional responses to pumping.

Vertical fracturing associated with the fault appears to have had an effect on the distribution of several of the major water-bearing fracture zones within the study area, most notably the B-zone and the C-zone. The increased vertical fracturing probably serves as a hydraulic connection between certain fracture zones. This has subsequently caused the hydraulic isolation of equivalent bedrock intervals southeast of the fault from natural upgradient recharge areas. The impact of the fault on groundwater flow in the D-zone and below remains largely unknown.

Additional studies were conducted as part of the off-site geologic investigation including thin section analysis, aerial photography and topographic mapping.

11.0 LIMITATIONS

The findings and conclusions presented in this report are based on interpretations developed from available geologic and hydrogeologic data. These findings and conclusions are subject to confirmation and/or revision when/if additional information becomes available. Best efforts were made to accurately delineate the geology within the study area and relate it to regional information.

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Tables

TABLE 1

MONITORING WELLS INSTALLED DURING OFF-SITE INVESTIGATION PHASE JULY 1985 - JULY 1987 Necco Park

VH-129D (New)
VH-129E
VH-129F
VH-129G
VH-129J

VH-130F
VH-130G
VH-130J

VH-143CD
VH-143D
VH-143F
VH-143G
VH-143J

VH-145A
VH-145B
VH-145E
VH-145F
VH-145G_2
VH-145G_3
VH-145J

VH-146A
VH-146F
VH-146GJ

VH-147B
VH-147C
VH-147D
VH-147F
VH-147G_1
VH-147G_2
VH-147G_3
VH-147J

VH-148B
VH-148C
VH-148D
VH-148F
VH-148G+

VH-149A
VH-149B
VH-149C
VH-149D

VH-150A
VH-150B
VH-150C
VH-150E+
VH-150F
VH-150GJ

VH-151A
VH-151B
VH-151C

VH-152A
VH-152BC
VH-152CD

VH-153A
VH-153B
VH-153C
VH-153D
VH-153E
VH-153F/G_1+
VH-153G_2
VH-153G_3
VH-153J

VH-154A
VH-154B+
VH-154D
VH-154E+

VH-155A
VH-155C+
VH-155CD
VH-155D
VH-155E+
VH-155E(R)+

VH-156A
VH-156C+
VH-156C (grouted)
VH-156D
VH-156E
VH-156F
VH-156G
VH-156J

\+ Well Renamed Since Installation.

TABLE 2
WELL CONSTRUCTION DETAILS
FOR MONITORING WELLS INSTALLED 1985-1987
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELLS	MONITORED ZONE	GROUND ELEVATION	TOP OF CASING ELEVATION	OVERBURDEN THICKNESS	TOP OF ROCK ELEVATION	OPEN HOLE ELEVATION	FRACTURE ELEVATION	BOTTOM ELEVATION	% LOST CIRCULATION
VH-129D(NEW)	D	577.23	580.47	21.50	555.73	518.03	513.23	508.23	50.00
VH-129E	E	577.49	580.42	21.00	556.49	508.99	508.49	496.49	50.00
VH-129F	F	577.81	580.19	21.50	556.31	596.81	494.21	584.21	20.00
VH-129G	G2	577.56	580.80	21.20	556.36	483.96	455.16/447.16	437.16	70.00
VH-129J	J	577.63	580.75	21.10	556.53	437.23	NF	401.23	0.00
VH-130F	F	577.23	580.82	16.50	560.73	512.73	NF	492.73	0.00
VH-130G	G2&G3	577.12	580.46	16.00	561.12	493.12	452.12/447.52*	433.12	100.00
VH-130J	J	576.99	580.65	17.00	560.99	431.99	NF	403.99	0.00
VH-143CD	CD1	584.40	587.59	6.50	577.90	561.40	557.40	553.40	100.00
VH-143D	D	583.80	587.25	7.70	576.10	552.80	538.60	534.60	100.00
VH-143F	F	583.90	587.21	8.30	575.60	529.70	521.70	514.10	100.00
VH-143G	G	583.90	587.37	9.50	574.40	485.40	NF	445.40	0.00
VH-143J	J	583.80	587.18	10.50	573.30	433.80	430.80	423.80	50.00
VH-145A	A	572.60	575.85	20.00	552.60	567.60	NA	552.60	NA
VH-145B	B	572.30	575.47	20.00	552.30	550.30	NF	542.30	0.00
VH-145E	E	572.80	575.94	20.00	552.80	510.30	505.80	500.80	80.00
VH-145F	F	573.00	576.06	21.00	552.00	501.00	NF	481.00	0.00
VH-145G2	G2	572.70	575.83	22.00	550.70	480.70	449.20	439.20	100.00
VH-145G3	G3	572.60	575.78	20.50	552.10	493.10	437.10	427.10	100.00
VH-145J	G&J	572.50	575.65	20.00	552.50	427.00	NF	397.00	10.00
VH-146A	A	572.65	576.12	12.00	560.65	565.65	NA	560.65	NA
VH-146F	F	572.75	575.78	12.70	560.05	512.55	506.46	496.46	80.00
VH-146GJ	GJ	572.76	575.98	12.60	560.16	496.32	NF	403.26	0.00
VH-147B	B	578.30	581.71	1.40	576.70	575.00	572.60	565.90	<10
VH-147C	C	578.50	581.88	1.80	576.70	565.40	563.70	559.00	100.00
VH-147D	D	578.00	581.46	1.30	576.70	553.50	531.50	526.00	<10
VH-147F	F	578.00	581.57	1.30	576.70	526.00	NF	496.00	0.00
VH-147G1	G1	577.90	581.55	1.40	576.50	495.90	487.40	477.40	100.00
VH-147G2	G2	578.30	581.60	1.60	576.70	477.80	466.80	457.80	50.00
VH-147G3	G3	578.00	581.42	1.50	576.50	457.80	453.30	441.80	100.00
VH-147J	J	578.10	581.33	2.10	576.00	441.60	NF	420.90	0.00
VH-148B	B	574.00	576.68	1.50	572.50	569.80	568.60	559.90	100.00
VH-148C	C	573.70	576.68	2.50	571.20	559.90	558.10	548.10	100.00
VH-148D	D	573.00	576.36	1.50	571.50	547.80	NF	522.80	0.00
VH-148F	F	572.80	576.24	1.50	571.30	520.50	NF	500.50	0.00
VH-148G†	G	573.50	576.55	2.60	570.90	500.80	NF	453.50	0.00
VH-149A	A	572.80	576.26	16.80	556.00	566.60	NA	556.60	NA
VH-149B	B	572.90	576.28	16.20	556.70	554.20	552.40	543.70	0.00
VH-149C	C	572.90	576.52	17.20	555.70	543.80	NF	513.80	0.00
VH-149D	D	572.90	576.46	17.20	555.70	514.00	513.30	503.80	0.00
VH-150A	A	572.89	575.70	16.40	556.49	568.49	NA	556.49	NA
VH-150B	B	572.88	576.11	17.20	555.68	553.68	553.18	548.18	60.00
VH-150C	C	573.02	576.19	17.20	555.82	548.32	NF	528.32	0.00

NA = NOT APPLICABLE
NF = NO FRACTURE
NM = NOT MENTIONED
ALL MEASUREMENTS IN FEET
* = ALSO FRACTURES AT 437.52 AND 435.62
† WELL RENAMED

TABLE 2 (CONT)
WELL CONSTRUCTION DETAILS
FOR MONITORING WELLS INSTALLED 1985-1987
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELLS	MONITORED ZONE	GROUND ELEVATION	TOP OF CASING ELEVATION	OVERBURDEN THICKNESS	TOP OF ROCK ELEVATION	OPEN HOLE ELEVATION	FRACTURE ELEVATION	BOTTOM ELEVATION	% LOST CIRCULATION
VH-150E+	E	573.06	576.31	17.20	555.86	528.36	512.36/510.76	506.36	20.00
VH-150F	F	572.67	575.99	16.50	556.17	505.97	501.57	485.97	5.00
VH-150GJ	GJ	573.29	576.63	17.30	555.99	486.59	NF	404.59	0.00
VH-151A	A	573.12	572.95	19.50	550.75	567.71	NA	553.71	NA
VH-151B	B	573.58	573.33	20.10	553.48	551.48	NF	543.48	0.00
VH-151C	C	573.35	573.18	22.60	550.75	543.25	537.35	525.75	<10
VH-152A	A	573.60	577.02	21.80	551.80	566.90	NA	551.90	NA
VH-152BC	BC	573.40	576.80	21.40	552.00	550.00	NF	532.00	0.00
VH-152CD	CD	573.20	576.70	20.80	552.40	532.40	NF	517.40	0.00
VH-153A	A	572.80	576.09	17.20	555.60	566.60	NA	555.60	NA
VH-153B	B	572.90	576.16	19.30	553.60	551.60	NF	532.40	<10
VH-153C	C	571.90	575.72	18.50	553.40	531.40	NF	511.40	0.00
VH-153D	D	572.70	576.41	19.00	553.70	512.20	504.70	499.20	100.00
VH-153E	E	572.90	576.43	19.50	553.40	499.40	498.40	492.40	100.00
VH-153F/G1+	F/G1	573.40	576.90	19.50	553.90	492.90	474.90	467.90	0.00
VH-153G2	G2	572.70	576.17	19.50	553.20	467.20	448.20	437.70	100.00
VH-153G3	G3	572.60	576.01	19.80	552.80	437.60	433.10	423.10	50.00
VH-153J	J	572.60	575.91	18.00	554.60	423.10	NF	396.90	0.00
VH-154A	A	572.60	576.45	15.30	557.30	567.30	NA	557.30	NA
VH-154B+	B	573.30	577.01	15.70	557.60	555.60	545.80	535.60	<10
VH-154D	D	573.00	576.46	15.60	557.40	535.30	NF	515.30	0.00
VH-154E+	E	572.70	576.42	16.00	556.70	515.30	500.40	495.40	90.00
VH-155A	A	571.70	574.79	14.40	557.30	562.30	NA	557.30	NA
VH-155C+	C	571.70	574.81	14.30	557.40	555.40	543.70	538.70	GAIN
VH-155CD	CD	571.60	574.81	14.40	557.20	538.50	NF	522.50	0.00
VH-155D	D	571.60	574.79	14.40	557.20	522.50	513.60	508.60	100.00
VH-155E+	E	571.60	574.90	14.50	557.10	508.60	506.4/500.7	488.60	100.00
VH-155ER+	E	571.80	574.99	14.80	557.00	508.50	NF	488.80	0.00
VH-156A	A	590.40	594.00	9.80	580.60	585.60	NA	580.60	NA
VH-156C+	C	590.80	594.24	9.80	581.00	579.50	573.10	568.00	100.00
VH-156D	D	591.30	594.69	10.80	580.50	553.50	538.70	534.30	100.00
VH-156E	E	591.40	594.87	10.00	581.40	534.40	531.70	526.70	70.00
VH-156F	F	591.30	594.79	10.40	580.90	526.60	522.80	511.60	50.00
VH-156G	G	591.30	594.70	7.40	583.90	511.60	NF	451.60	0.00
VH-156J	J	591.00	594.42	8.00	583.00	451.30	NF	432.00	0.00

NA = NOT APPLICABLE
NF = NO FRACTURE
NM = NOT MENTIONED
ALL MEASUREMENTS IN FEET
+ WELL RENAMED

Table 3
Elevations and Coordinates(1) for
Necco Park Monitoring Wells Installed
(1985-1987)
Necco Park, Niagara Falls, N.Y.

Well Number	Top Casing Elevation	Ground Elevation	North Coordinate	East Coordinate
VH-129D(NEW)	580.47	577.23	1500.80	3506.28
VH-129E	580.42	577.49	1500.56	3521.15
VH-129F	581.19	577.81	1498.87	3539.46
VH-129G	580.80	577.56	1498.35	3554.04
VH-129J	580.75	577.63	1498.38	3571.44
VH-130F	580.82	577.23	1571.63	3044.00
VH-130G	580.46	577.12	1573.54	3030.82
VH-130J	580.65	576.99	1577.43	3008.67
VH-143CD	587.59	584.40	2210.70	2188.12
VH-143D	587.25	583.80	2194.37	2187.20
VH-143F	587.21	583.90	2177.57	2187.00
VH-143G	587.37	583.90	2160.40	2186.23
VH-143J	587.18	583.80	2131.23	2183.21
VH-145A	575.85	572.60	761.60	3860.94
VH-145B	575.47	572.30	762.96	3752.65
VH-145E	575.94	572.80	762.76	3847.49
VH-145F	576.06	573.00	762.96	3828.09
VH-145G2	575.83	572.70	762.16	3808.96
VH-145G3	575.78	572.60	762.29	3790.16
VH-145J	575.65	572.50	762.50	3769.78
VH-146A	576.12	572.65	1003.67	2233.33
VH-146F	575.78	572.75	1002.23	2261.99
VH-146GJ	575.98	572.76	1002.85	2248.11
VH-147B	581.71	578.30	1123.23	470.19
VH-147C	581.88	578.50	1128.73	453.79
VH-147D	581.46	578.00	1117.55	485.33
VH-147F	581.57	578.00	1113.06	503.10
VH-147G1	581.55	577.90	1106.72	527.05
VH-147G2	581.60	578.30	1102.99	547.11
VH-147G3	581.42	578.00	1098.78	562.29
VH-147J	581.33	578.10	1092.31	579.08
VH-148B	576.68	574.00	927.51	1252.16
VH-148C	576.68	573.70	925.07	1270.83
VH-148D	576.36	573.00	941.82	1263.51
VH-148F	576.24	572.80	938.79	1285.83
VH-148G+	576.55	573.50	921.24	1295.96
VH-149A	576.26	572.80	575.49	2414.08
VH-149B	576.28	572.90	580.82	2426.37
VH-149C	576.52	572.90	594.18	2427.87
VH-149D	576.46	572.90	608.41	2429.39

(1) from Soderholm Engineering, 1987
(+) Well renamed

Table 3 (continued)

Well Number	Top Casing Elevation	Ground Elevation	North Coordinate	East Coordinate
VH-150A	575.70	572.89	893.03	2834.09
VH-150B	576.11	572.88	891.88	2848.66
VH-150C	576.19	573.02	890.74	2863.73
VH-150E+	576.31	573.06	889.30	2878.85
VH-150F	575.99	572.67	890.50	2895.26
VH-150GJ	576.63	573.29	886.56	2908.97
VH-151A	572.95	573.21	-26.21	3369.68
VH-151C	573.18	573.35	-24.40	3353.61
VH-152A	577.02	573.60	18.89	4703.34
VH-152BC	576.80	573.40	22.87	4687.20
VH-152CD	576.70	573.20	26.73	4669.87
VH-153A	576.09	572.80	830.88	5359.00
VH-153B	576.16	572.90	846.25	5376.41
VH-153C	575.72	571.90	829.07	5370.88
VH-153D	576.41	572.70	836.12	5379.47
VH-153E	576.43	572.90	838.38	5366.93
VH-153F/G1+	576.90	573.40	852.64	5384.36
VH-153G2	576.17	572.70	842.21	5386.83
VH-153G3	576.01	572.60	852.36	5397.97
VH-153J	575.91	572.60	861.38	5409.86
VH-154A	576.45	572.60	1212.98	5753.61
VH-154B+	577.01	573.30	1187.02	5736.19
VH-154D	576.46	573.00	1196.22	5741.79
VH-154E+	576.42	572.70	1204.42	5746.96
VH-155A	574.79	571.70	1873.62	6269.44
VH-155C+	574.81	571.70	1905.83	6296.22
VH-155CD	574.81	571.60	1896.82	6288.77
VH-155D	574.79	571.60	1890.23	6282.99
VH-155E+	574.90	571.60	1882.22	6276.87
VH-155E(R)+	574.99	571.80	1845.70	6248.74
VH-156A	594.00	590.40	2535.66	782.48
VH-156C+	594.24	590.80	2545.18	799.66
VH-156D	594.69	591.30	2559.10	823.90
VH-156E	594.87	591.40	2579.35	825.72
VH-156F	594.79	591.30	2572.96	844.22
VH-156G	594.70	591.30	2594.25	847.70
VH-156J	594.42	591.00	2587.36	867.23

(1) from Soderholm Engineering, 1987
(+) Well renamed

TABLE 4
GROUT SEAL PERMEABILITY (CM/SEC)
NECCO PARK
NIAGARA FALLS, NEW YORK

WELL NUMBER	7 INCH CASING	4 INCH CASING
VH-129D(new)	0.00	6.7E-6
VH-129E	0.00	0.00
VH-129F	0.00	0.00
VH-129G	0.00	0.00
VH-129J	0.00	8.0E-7
VH-130F	7.4E-6	0.00
VH-130G	0.00	0.00
VH-130J	0.00	0.00
VH-143CD	3.2E-5	1.2E-5
VH-143D	2.4E-5	8.9E-6
VH-143F	1.9E-6	5.1E-6
VH-143G	8.0E-6	8.9E-7
VH-143J	5.8E-6	3.5E-6
VH-145E	0.00	0.00
VH-145F	0.00	0.00
VH-145G2	0.00	0.00
VH-145G3	0.00	0.00
VH-145J	0.00	0.00
VH-145B	0.00	0.00
VH-146F	0.00	0.00
VH-146GJ	0.00	0.00
VH-147B	1.7E-5	2.8E-6
VH-147C	0.00	1.9E-6
VH-147D	5.7E-5	2.6E-5
VH-147F	3.3E-5	7.5E-5
VH-147G	1.1E-4	9.4E-7
VH-147J	2.0E-6	2.5E-6
VH-148B	0.00	0.00
VH-148C	0.00	0.00
VH-148D	6.2E-6	0.00
VH-148F	0.00	9.0E-6
VH-148G+	0.00	0.00
VH-149B	8.8E-6	3.2E-6
VH-149C	1.4E-6	1.2E-6
VH-149D	4.7E-6	1.0E-5
VH-150B	0.00	0.00
VH-150C	0.00	0.00
VH-150E+	0.00	0.00
VH-150F	0.00	0.00
VH-150GJ	0.00	5.7E-6
VH-151B	0.00	0.00
VH-151C	0.00	0.00
VH-152B	1.3E-5	8.5E-7
VH-152CD	2.4E-5	1.2E-5
VH-153B	3.9E-5	2.7E-6
VH-153C	1.2E-5	8.8E-6
VH-153D	0.00	6.2E-6
VH-153E	1.7E-5	1.5E-6
VH-153F/G1+	9.2E-5	5.9E-6
VH-153G2	1.3E-5	2.6E-5
VH-153G3	1.2E-5	3.9E-6
VH-153J	2.8E-5	4.0E-6
VH-154B+	0.00	0.00
VH-154C	0.00	1.0E-6
VH-154D	0.00	0.00
VH-155E(R)+	0.00	0.00
VH-156C+	3.9E-6	0.00
VH-156C	1.6E-6	0.00
VH-156D	0.00	0.00
VH-156E	0.00	0.00
VH-156F	0.00	0.00
VH-156G	0.00	0.00
VH-156J	0.00	0.00

+ WELL RENAMED

TABLE 5

INSITU PERMEABILITY TESTS
HYDROSTATIC HEAD METHOD
NECCO PARK
1987

WELL NUMBER	HYDRAULIC CONDUCTIVITY (CM/SEC)	INTERVAL TESTED (FEET)
VH-129D(NEW)	1.20E-3	9.8 (59.2' - 69.0')
VH-129E	5.10E-4	10 (68.5' - 78.5')
VH-129F	1.40E-4	9.9 (81.0' - 90.9')
VH-129G	1.20E-2	10 (93.6' - 103.6')
VH-129G	3.70E-8	20 (93.6' - 113.6')
VH-129G	4.20E-5	30 (93.6' - 123.6')
VH-129G	1.30E-4	40 (93.6' - 133.6')
VH-129J	1.40E-6	10 (140.4' - 150.4')
VH-129J	3.80E-7	20 (140.4' - 160.4')
VH-129J	5.00E-7	30 (140.4' - 170.4')
VH-130F	1.20E-6	10 (64.5' - 74.5')
VH-130F	4.10E-6	20 (64.5' - 84.5')
VH-130G	4.60E-7	10 (84.5' - 94.5')
VH-130G	8.00E-7	20 (84.5' - 104.5')
VH-130G	2.30E-6	30 (84.5' - 114.5')
VH-130G	2.70E-7	40 (84.5' - 124.5')
VH-130G	6.30E-4	50 (84.5' - 134.5')
VH-130J	2.30E-7	10 (145' - 155')
VH-130J	4.80E-6	20 (145' - 165')
VH-145F	4.40E-6	20 (72' - 92')
VH-145G2	6.10E-7	20 (92' - 112')
VH-145J	1.46E-4	20 (145.5' - 165.5')
VH-146GJ	9.00E-6	10 (76.2' - 86.2')
VH-146GJ	1.00E-6	20 (76.2' - 96.2')
VH-146GJ	3.70E-7	30 (76.2' - 106.2')
VH-146GJ	5.30E-7	40 (76.2' - 116.2')
VH-146GJ	9.20E-6	50 (76.2' - 126.2')
VH-146GJ	8.40E-7	60 (76.2' - 136.2')
VH-146GJ	1.30E-5	70 (76.2' - 146.2')
VH-146GJ	1.00E-5	80 (76.2' - 156.2')
VH-146GJ	2.50E-6	99.3 (76.2' - 169.5')
VH-147J	2.35E-6	42.8 (92' - 134.8')
VH-148D	4.10E-4	10 (25.2' - 35.2')
VH-148F	2.60E-6	20 (52.2' - 72.2')
VH-148G+	8.70E-7	20 (72.2' - 92.2')
VH-148G+	3.00E-6	40 (72.2' - 112.2')
VH-148G+	5.20E-6	60 (72.2' - 132.2')

+ WELL RENAMED

TABLE 5(CONTINUED)

INSITU PERMEABILITY TESTS
HYDROSTATIC HEAD METHOD (CONT.)
NECCO PARK
1987

WELL NUMBER	HYDRAULIC CONDUCTIVITY (CM/SEC)	INTERVAL TESTED (FEET)
VH-148G+	8.10E-6	80 (72.2' - 152.2')
VH-148G+	1.30E-5	85 (72.2' - 157.2')
VH-150C	6.40E-7	10 (24.7' - 34.7')
VH-150C	6.20E-5	20 (24.7' - 44.7')
VH-150E+	5.20E-6	10 (44.7' - 54.7')
VH-150E+	2.60E-4	20 (44.7' - 64.7')
VH-150F	4.60E-5	10 (66.7' - 76.7')
VH-150F	1.40E-5	20 (66.7' - 86.7')
VH-150GJ	8.20E-7	10 (86.7' - 96.7')
VH-150GJ	9.50E-7	20 (86.7' - 106.7')
VH-150GJ	5.70E-7	30 (86.7' - 116.7')
VH-150GJ	1.40E-6	40 (86.7' - 126.7')
VH-150GJ	2.90E-7	50 (86.7' - 136.7')
VH-150GJ	5.90E-7	60 (86.7' - 146.7')
VH-150GJ	4.29E-7	70 (86.7' - 156.7')
VH-150GJ	2.90E-7	80 (86.7' - 166.7')
VH-150GJ	2.30E-7	85 (86.7' - 171.7')
VH-151B	7.80E-6	8 (22.1' - 30.1')
VH-151C	6.90E-6	10 (30.1' - 40.1')
VH-151C	2.70E-6	10 (21.3' - 31.3')
VH-153B	3.05E-4	20 (21.3' - 41.3')
VH-153C	8.54E-5	20 (40.5' - 60.5')
VH-153F/G+	1.50E-4	20 (80.5' - 100.5')
VH-153J	2.75E-6	19.2 (149.5' - 168.7')
VH-154B+	2.66E-5	10 (37.4' - 47.7')
VH-154B+	2.42E-5	20 (37.4' - 57.7')
VH-154D	7.40E-4	10 (57.3' - 67.3')
VH-154D	1.50E-2	20 (57.3' - 77.3')
VH-155E+	8.70E-7	10 (63' - 83')
VH-155E(R)+	1.00E-4	11 (63.8' - 74.8')
VH-156C(GROUTED)	1.30E-6	15 (22.8' - 37.7')
VH-156G	1.00E-6	20 (79.7' - 99.7')
VH-156G	7.00E-5	40 (79.7' - 119.7')
VH-156G	2.00E-5	60 (79.7' -139.7')
VH-156J	1.90E-7	20 (139.7' -159.7')

+ WELL RENAMED

TABLE 5 (CONT.)
INSITU PERMEABILITY TESTS
PACKER METHOD
NECCO PARK
1987

WELL NUMBER	AVERAGE HYDRAULIC CONDUCTIVITY (CM/SEC)	INTERVAL TESTED (FEET)
VH-156C(GROUTED)	0.00	15
VH-156G	5.94E-6	40
VH-148G+	3.30E-7	20 (92.2' - 112')
VH-148G+	2.56E-5	21 (111.2' - 132.2')
VH-148G+	1.35E-7	20 (137.2' - 157.2')
VH-145J	0.00	12 (163.5' - 175.5')
VH-145J	1.67E-6	26 (149.5' - 175.5')
VH-145J	7.00E-6	30 (145.5' - 175.5')
VH-146GJ	8.40E-8	18.3 (96.2' - 114.5')
VH-146GJ	0.00	20 (114.5' - 134.5')
VH-146GJ	0.00	20 (134.5' - 154.5')
VH-146GJ	0.00	15 (154.5' - 169.5')
VH-130G	0.00	20 (104' - 124')
VH-129G	1.11E-3	10 (113.6' - 123.6')
VH-129G	7.04E-4	19 (113.6' - 132.6')
VH-129G	2.43E-6	7.8 (132.6' - 140.4')
VH-129J	5.40E-7	16 (160.4' - 176.4')
VH-130J	5.84E-7	10 (163' - 173')
VH-150GJ	1.30E-7	20 (106.7' - 126.7')
VH-150GJ	3.20E-7	20 (126.7' - 146.7')
VH-150GJ	0.00	20 (146.7' - 166.7')
VH-150GJ	0.00	10 (161.7' - 177.7')

+ WELL RENAMED

TABLE 6
SLUG TEST
HYDRAULIC CONDUCTIVITIES
FOR MONITORING WELLS INSTALLED
1985-1987

MONITORING WELL	HYDRAULIC CONDUCTIVITY	PERCENT DRILLING WATER LOSS
VH-129D(NEW)	4.1 x 10-3	50
VH-129E	3.8 x 10-4	50
VH-129F	< 1.0 x 10-6	20
VH-129G	9.3 x 10-3	70
VH-129J	1.7 x 10-5	0
VH-130F	< 1.0 x 10-6	0
VH-130G	> 1.0 x 10-0	100
VH-130J	4.4 x 10-6	0
VH-143CD	1.1 x 10-1	100
VH-143D	2.7 x 10-3	100
VH-143F	9.1 x 10-3	100
VH-143G	9.9 x 10-4	0
VH-143J	< 1.0 x 10-6	50
VH-145A	1.4 x 10-4	NA
VH-145B	< 1.0 x 10-6	0
VH-145E	1.5 x 10-3	80
VH-145F	3.3 x 10-5	0
VH-145G2	2.0 x 10-2	100
VH-145G3	> 1.0 x 10-0	100
VH-145J	5.0 x 10-4	10
VH-146A	< 1.0 x 10-6	NA
VH-146F	3.3 x 10-3	80
VH-146GJ	4.5 x 10-6	0
VH-147B	ND	<10
VH-147C	3.6 x 10-3	100
VH-147D	8.5 x 10-5	<10
VH-147F	4.1 x 10-4	0
VH-147G1	2.5 x 10-2	100
VH-147G2	8.6 x 10-3	50
VH-147G3	7.0 x 10-0	100
VH-147J	2.5 x 10-6	0
VH-148B	2.0 x 10-3	100
VH-148C	7.1 x 10-2	100
VH-148D	2.1 x 10-3	0
VH-148F	< 1.0 x 10-6	0
VH-148G+	9.0 x 10-4	0
VH-149A	1.4 x 10-4	NA
VH-149B	< 1.0 x 10-6	0
VH-149C	4.5 X 10-4	0
VH-149D	1.2 X 10-5	0

MONITORING WELL	HYDRAULIC CONDUCTIVITY	PERCENT DRILLING WATER LOSS
VH-150A	2.2 x 10-4	NA
VH-150B	7.9 x 10-2	60
VH-150C	2.3 x 10-5	0
VH-150E+	5.1 x 10-4	20
VH-150F	9.1 x 10-6	5
VH-150GJ	2.5 x 10-6	0
VH-151A	1.1 x 10-3	NA
VH-151B	< 1.0 x 10-6	0
VH-151C	1.3 x 10-3	<10
VH-152A	7.5 x 10-4	NA
VH-152BC	7.0 x 10-4	0
VH-152CD	< 1.0 x 10-6	0
VH-153A	2.6 X 10-4	NA
VH-153B	1.5 x 10-4	<10
VH-153C	2.4 x 10-5	0
VH-153D	1.9 x 10-1	100
VH-153E	4.0 x 10-0	100
VH-153F/G1+	4.8 x 10-4	0
VH-153G2	2.9 x 10-2	100
VH-153G3	2.5 x 10-2	50
VH-153J	2.8 x 10-6*	0
VH-154A	6.8 x 10-4	NA
VH-154B+	4.1 x 10-4	<10
VH-154D	7.4 x 10-5	0
VH-154E+	1.2 x 10-1	90
VH-155A	< 1.0 X 10-6	NA
VH-155C+	> 1.0 x 10-0	GAIN
VH-155CD	3.8 x 10-3	0
VH-155D	2.7 x 10-2	100
VH-155E+	< 1.0 x 10-6	100
VH-155ER+	5.3 x 10-4	0
VH-156A	ND	NA
VH-156C+	1.9 x 10-2	100
VH-156D	2.1 x 10-1	100
VH-156E	1.1 x 10-4	70
VH-156F	2.5 x 10-4	50
VH-156G	< 1.0 x 10-6	0
VH-156J	1.9 x 10-7*	0

(1) ALL HYDRAULIC CONDUCTIVITIES IN CM/SEC
* = INSITU HYDRAULIC CONDUCTIVITY
NA = NOT APPLICABLE
ND = NO DATA
+ = WELL RENAMED

TABLE 7
LOCKPORT FORMATION MEMBER CONTACT ELEVATIONS
GEOLOGIC REPORT
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELL CLUSTER	OO/ER	ER/GI	GI/GP	GP/DC	DC/RS
VH-112	479.40	ND	431.80	417.70	408.00
VH-129	479.76	461.96	436.96	418.83	407.53
VH-130	486.52	568.72	447.52	421.99	412.39
VH-136	496.30	479.50	451.00	435.40	425.20
VH-141	484.90	ND	432.10	423.90	414.20
VH-143	500.50	482.80	456.60	438.70	430.60
VH-145	474.90	461.20	433.60	413.70	404.70
VH-146	485.01	464.46	438.56	424.16	414.16
VH-147	497.90	481.30	459.80	435.90	425.90
VH-148	491.00	476.00	447.00	430.00	420.80
VH-150	477.99	461.29	435.59	416.89	407.49
VH-153	472.70	456.20	432.60	412.90	402.40
VH-156	509.30	494.80	461.30	449.00	436.50

OO/ER = OAK ORCHARD /ERAMOSA CONTACT
ER/GI = ERAMOSA / GOAT ISLAND CONTACT
GI/GP = GOAT ISLAND / GASPORT CONTACT
GP/DC = GASPORT / DECEW CONTACT
DC/RS = DECEW / ROCHESTER SHALE CONTACT
ALL MEASUREMENTS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL)
ND = NO DATA

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TABLE 8
TOP OF ROCK AND OOLITE BED ELEVATIONS
GEOLOGIC REPORT
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELL CLUSTER	TOP OF(1) ROCK	TOP OF OOLITE BED
VH-111	565.30	560.70
VH-112	556.00	550.60
VH-116	571.70	569.40
VH-127	559.70	556.94
VH-129	557.74	552.24
VH-130	561.20	555.30
VH-136	573.90	567.40
VH-137	564.30	560.20
VH-139	555.60	550.10
VH-141	558.60	556.10
VH-143	576.90	574.40
VH-145	551.30	544.30
VH-146	561.10	557.30
VH-147	576.80	569.30
VH-148	571.00	564.60
VH-149	556.00	550.90
VH-150	555.68	549.68
VH-151	553.48	543.08
VH-152	552.30	542.60
VH-153	553.40	542.90
VH-154	557.60	547.30
VH-155	557.40	549.70
VH-156	581.80	578.80

(1) SOME VALUES REPRESENT AVERAGES
ALL MEASUREMENTS IN FEET ABOVE MEAN SEA LEVEL (MSL)

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TABLE 9
LOCKPORT FORMATION THICKNESSES*
GEOLOGIC REPORT
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELL CLUSTER	THICKNESS (FEET)
VH-112	148.30
VH-129	149.70
VH-130	149.00
VH-136	147.70
VH-141	145.00
VH-143	142.60
VH-145	147.80
VH-146	146.00
VH-147	150.10
VH-148	150.10
VH-150	148.50
VH-153	152.20
VH-156	147.40
AVERAGE THICKNESS	147.60

* INCLUDES DECEW THICKNESS
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TABLE 10
LOCKPORT FORMATION MEMBER THICKNESSES
GEOLOGIC REPORT
NECCO PARK, NIAGARA FALLS, NEW YORK

MONITORING WELL	OAK ORCHARD	ERAMOSA	GOAT ISLAND	GASPORT	DECEW	GASPORT + GOAT ISLAND
VH-112	ND	ND	ND	14.10	9.70	ND
VH-129	77.80	16.80	25.00	18.20	12.00	43.40
VH-130	74.10	17.80	21.20	25.40	10.00	46.60
VH-136	75.70	16.80	28.50	15.10	10.40	43.60
VH-141	ND	ND	ND	9.10	9.70	ND
VH-143	77.90	17.75	26.15	17.80	8.10	43.50
VH-145	76.30	13.70	27.50	19.80	9.00	47.30
VH-146	75.70	20.50	26.50	15.60	9.00	42.10
VH-147	78.50	17.00	21.20	24.00	10.00	45.20
VH-148	80.50	15.00	29.00	17.00	10.20	46.00
VH-150	77.70	16.70	25.70	18.70	9.40	44.40
VH-153	80.50	16.50	23.50	19.70	10.50	43.20
VH-156	73.00	14.50	33.50	12.00	12.50	45.50
AVERAGE THICKNESS	77.30	16.50	26.80	16.60	9.90	44.60

ND=NO DATA
ALL MEASUREMENTS IN FEET

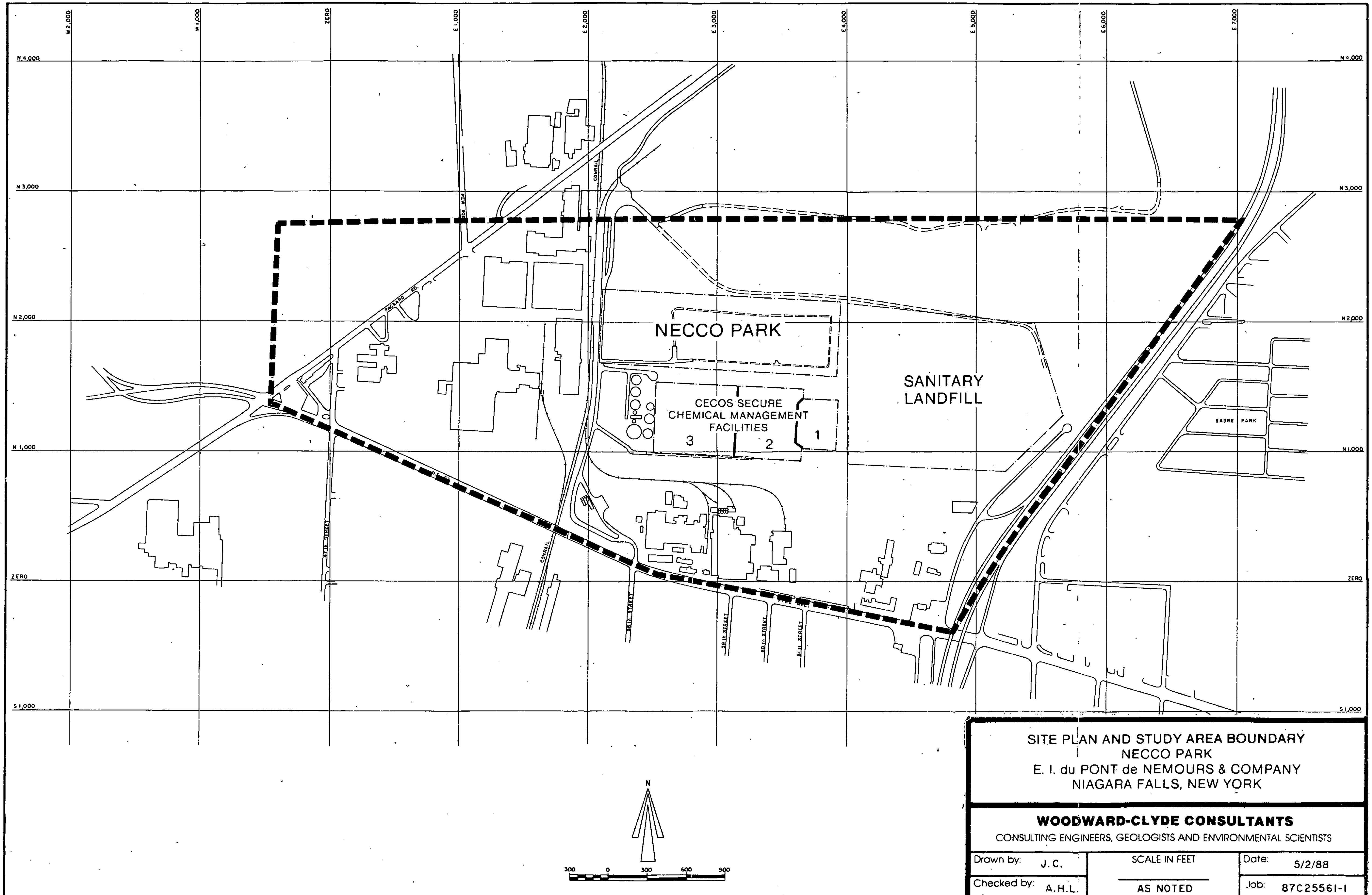
NECGEO2.SAV

TABLE 11
MONITORING WELLS AND MONITORED ZONE
NECCO PARK
NIAGARA FALLS, NEW YORK

MONITORING WELL	MONITORED ZONE	MONITORING WELL	MONITORED ZONE	MONITORING WELL	MONITORED ZONE	MONITORING WELL	MONITORED ZONE
WELL 52	B-C	VH-128A	A	VH-141E	E	VH-150A	A
WELL 53	A	VH-129B	B	VH-141F	F	VH-150B	B
D-3	A	VH-129C	C	VH-141G	G2	VH-150C	C(NF)
D-7	A	VH-129D	D	VH-141J	J	VH-150E+	E
D-8	A	VH-129D(NEW)	D	VH-142A	A	VH-150F	F
D-9	A	VH-129E	E	VH-142B	B	VH-150GJ	GJ(NF
D-10	B-C*	VH-129F	F	VH-142C	C	VH-151A	A
D-11	A	VH-129G	G2	VH-143A	A	VH-151B	B(NF)
D-12	B-C	VH-129J	J	VH-143B	B	VH-151C	C(NF)
D-13	A	VH-130B	B	VH-143C	C	VH-152A	A
D-14	B-C	VH-130C	C	VH-143CD	CD1	VH-152BC	BC(NF)
D-22	C	VH-130D	D	VH-143D	D	VH-152CD	CD(NF)
D-23	B	VH-130F	F(NF)	VH-143F	F	VH-153A	A
C-72	B-C?	VH-130G	G2&G3	VH-143G	G(NF)	VH-153B	B(NF)
C-83	B-C?	VH-130J	J	VH-143J	J	VH-153C	C(NF)
VH-102B	B	VH-131A	A	VH-145A	A	VH-153D	D
VH-105C+	C	VH-136B	B	VH-145B	B(NF)	VH-153E	E
VH-105CD+	CD1	VH-136C	C	VH-145C	C	VH-153F/G1+	F-G1(NF)
VH-105D	D	VH-136CD1	CD1	VH-145D	D	VH-153G2	G2
VH-111B	B	VH-136CD2	CD2	VH-145E	E	VH-153G3	G3
VH-111D	D	VH-136D	D	VH-145F	F(NF)	VH-153J	J
VH-112A	A	VH-136E	E	VH-145G2	G2	VH-154A	A
VH-112B	B	VH-136F	F	VH-145G3	G3	VH-154B+	B
VH-112C	C	VH-136G	G2	VH-145J	G&J(NF)	VH-154D	D(NF)
VH-112D	F	VH-136J	J	VH-146A	A	VH-154E+	E
VH-112F	F	VH-137A	A	VH-146C	C(NF)	VH-155A	A
VH-112J	GJ(NF)	VH-137B	B	VH-146E+	E	VH-155C+	C
VH-114B	B(NF)	VH-137C	C	VH-146F	F	VH-155CD	C-D(NF)
VH-115B	C	VH-137CD	CD1	VH-146GJ	GJ	VH-155D	D
VH-115C	C	VH-137D	D	VH-147B	B	VH-155E+	E
VH-115D	D	VH-138B	B	VH-147C	C	VH-155E+	E
VH-116B	B	VH-138C	C	VH-147D	D(NF)	VH-156A	A
VH-116CD1+	CD1	VH-139A	A**	VH-147F	F(NF)	VH-156C+	C
VH-116CD2+	CD2	VH-139B	B	VH-147G1	G1	VH-156D	D
VH-117A	A	VH-139C	C(NF)	VH-147G2	G2	VH-156E	E
VH-117C	C(NF)	VH-139D	D(NF)	VH-147G3	G3	VH-156F	F
VH-117E	E	VH-140A	A	VH-147J	J	VH-156G	G(NF)
VH-118B	B	VH-140B	B	VH-148B	B	VH-156J	J
VH-119B	B	VH-140C	C	VH-148C	C		
VH-120B	B	VH-140E+	E	VH-148D	D(NF)		
VH-123B	B	VH-141B	B	VH-148F	F(NF)		
VH-123C	C	VH-141C	C	VH-148G+	G(NF)		
VH-123D	D	VH-141CD	CD1	VH-149A	A		
VH-127C	C	VH-141D	D	VH-149B	B		
				VH-149C	C		
				VH-149D	D		

* WELL GROUTED TO BELOW B-ZONE
** TOP OF BEDROCK WELL
(NF) = NO FRACTURE
\+ WELL RENAMED

Figures

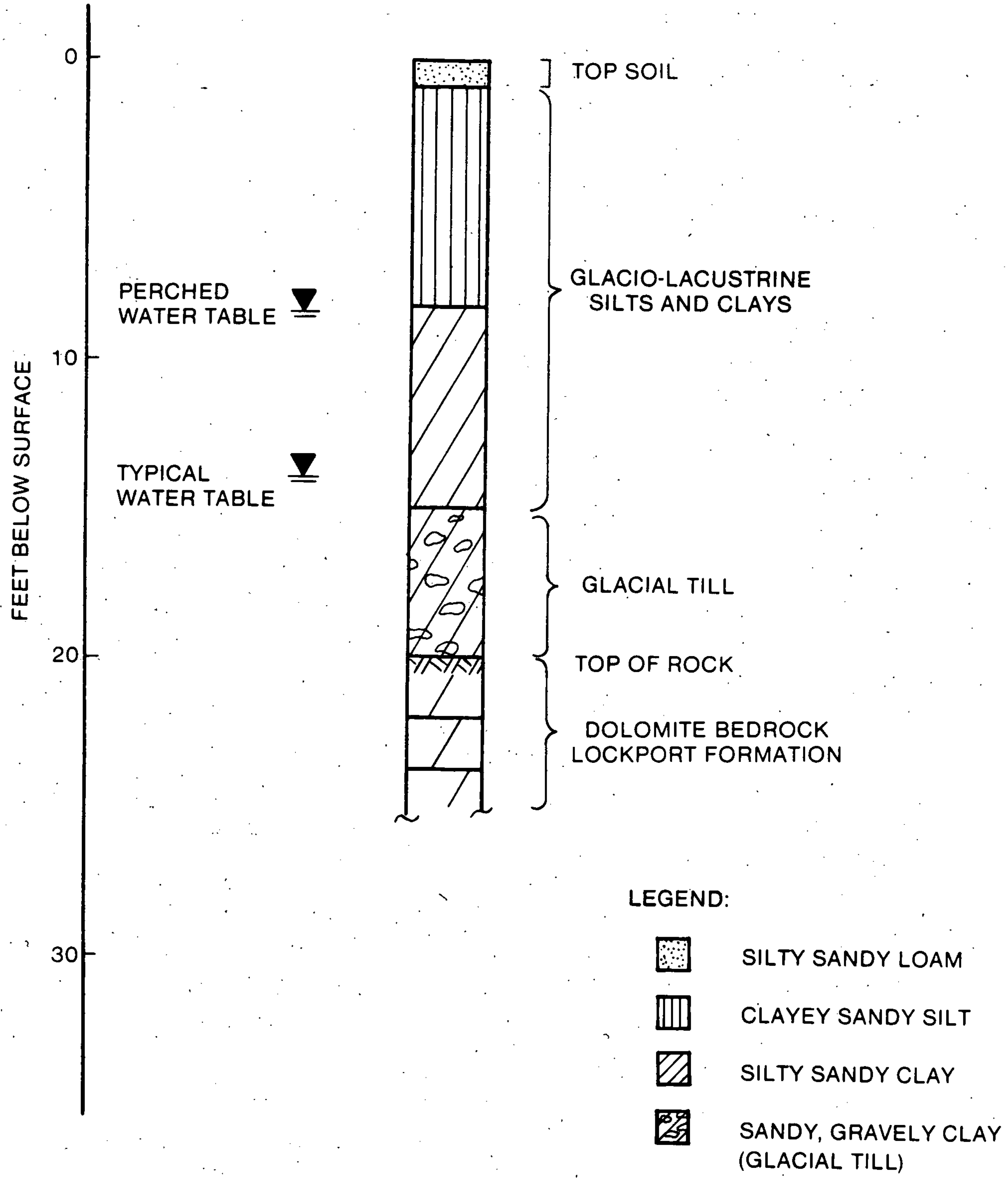


SITE PLAN AND STUDY AREA BOUNDARY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

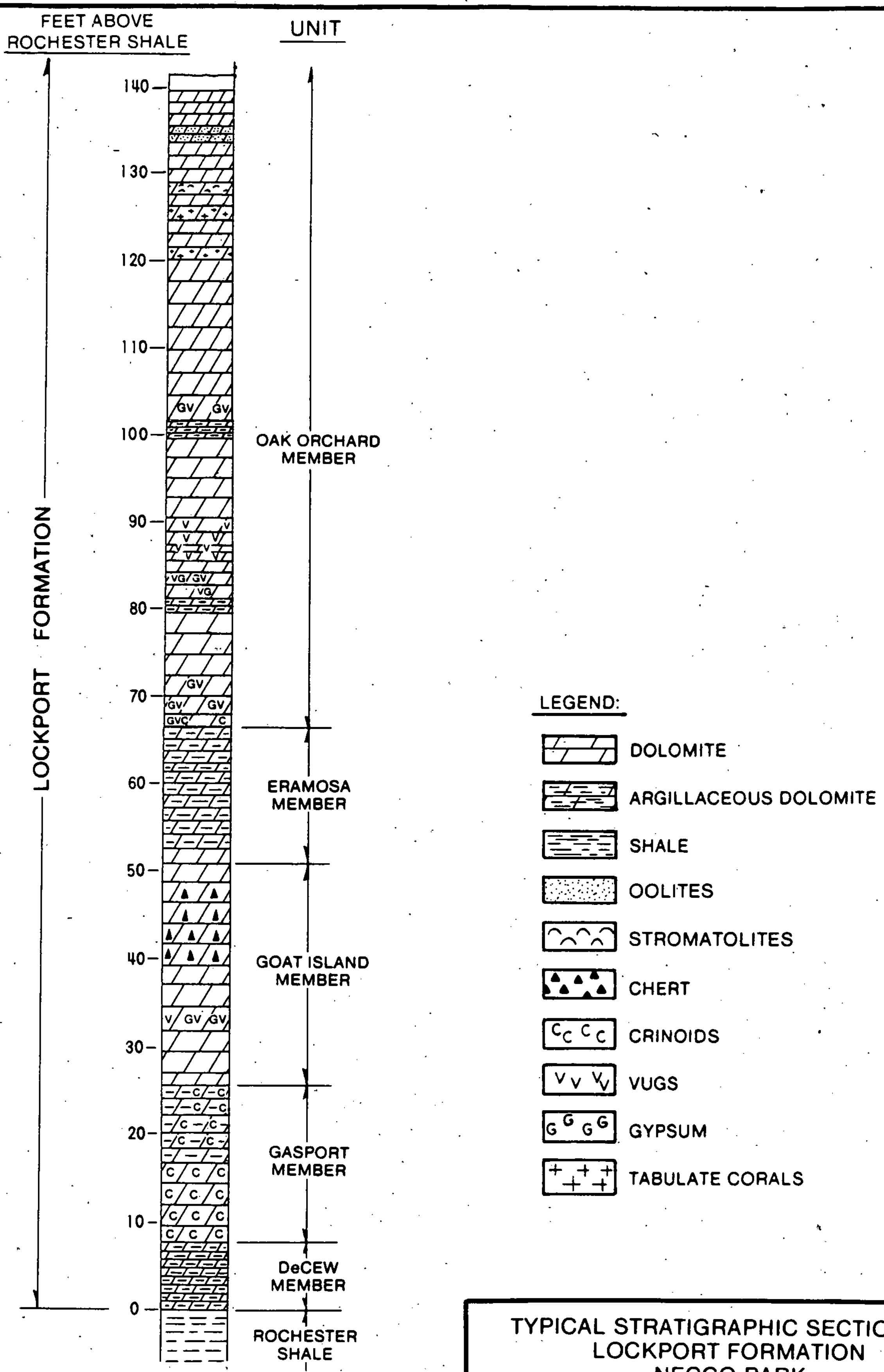
Drawn by: J. C.	SCALE IN FEET	Date:	5/2/88
Checked by: A.H.L.	AS NOTED	Job:	87C25561-I

FIGURE 1



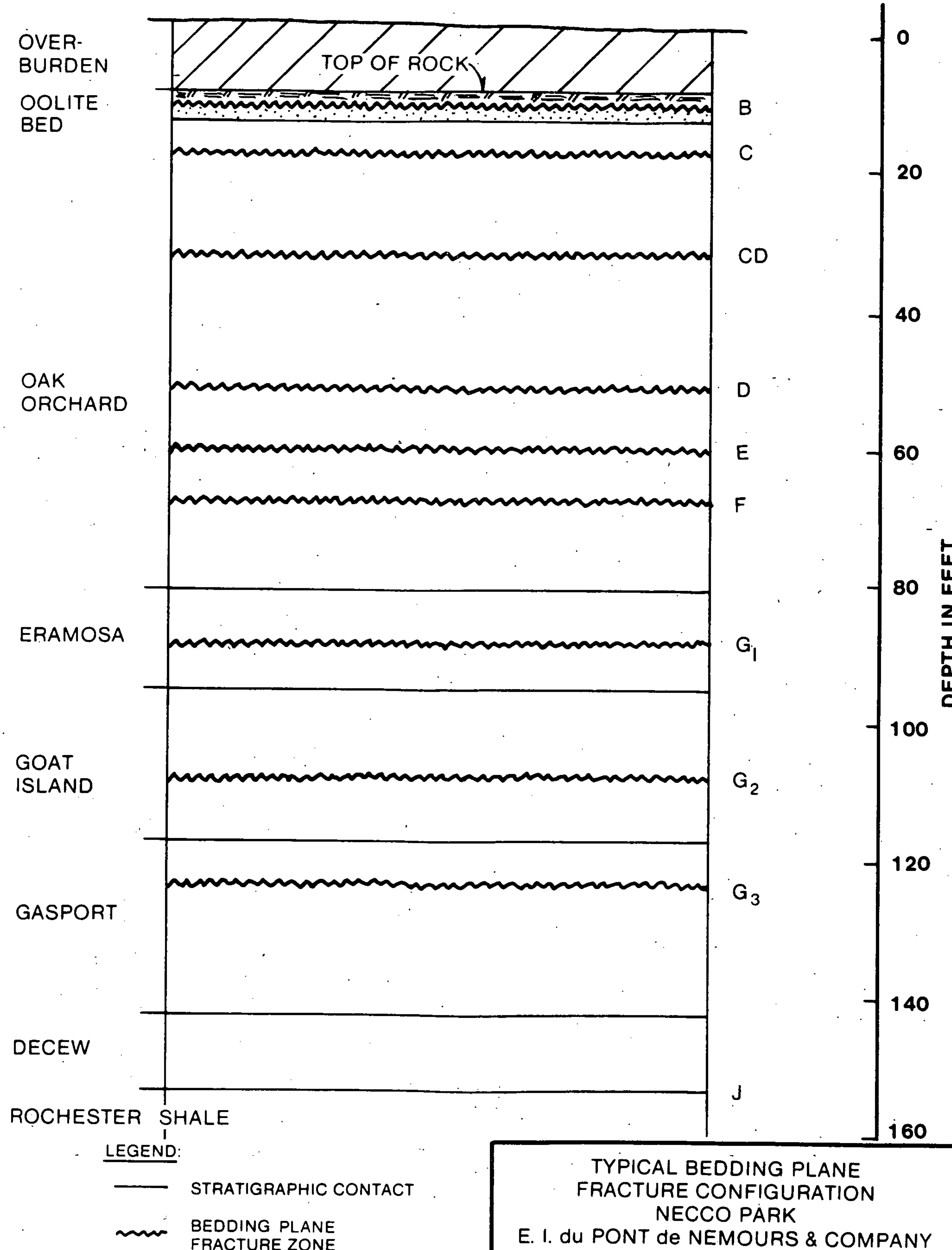
TYPICAL STRATIGRAPHIC SECTION OF
UNDISTURBED OVERBURDEN
GEOLOGY REPORT
NECCO PARK
NIAGARA FALLS, NEW YORK

FIGURE 2



TYPICAL STRATIGRAPHIC SECTION OF
LOCKPORT FORMATION
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

FIGURE 3



TYPICAL BEDDING PLANE
FRACTURE CONFIGURATION
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

FIGURE 4

LEGEND:

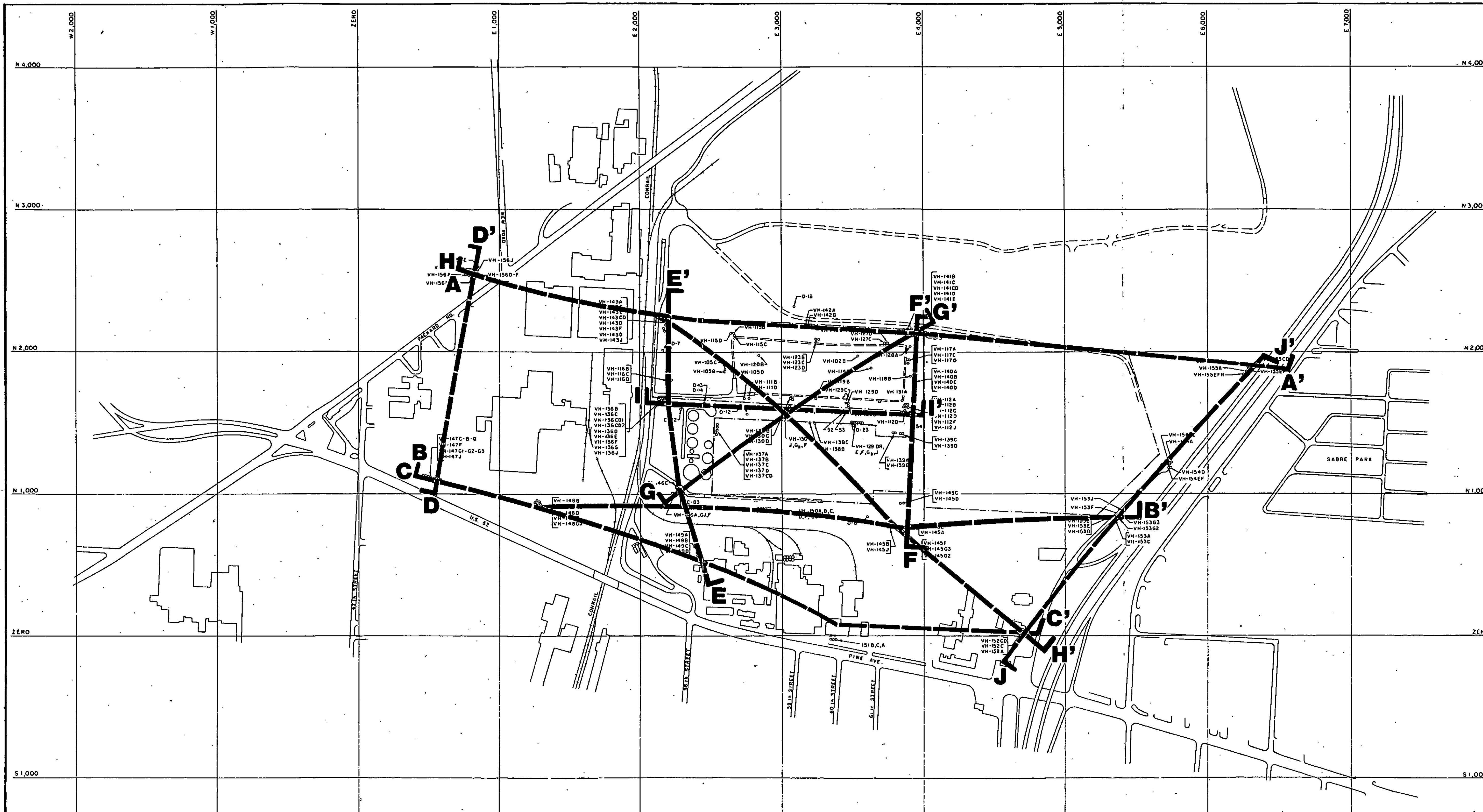
VH-157A ○ MONITORING WELL

† WELL RENAMED

300 0 300 600 900

MONITORING WELL LOCATION PLAN NECCO PARK E. I. du PONT de NEMOURS & CO. NIAGARA FALLS, NEW YORK			
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS			
DRAWN BY: J.C.	SCALE AS NOTED	DATE 9/9/87	
CHECKED BY: A.H.L.		JOB NO. 87C2556P-1	

FIGURE 5



LEGEND:

VH-157A O MONITORING WELL

A A' CROSS SECTION LINE

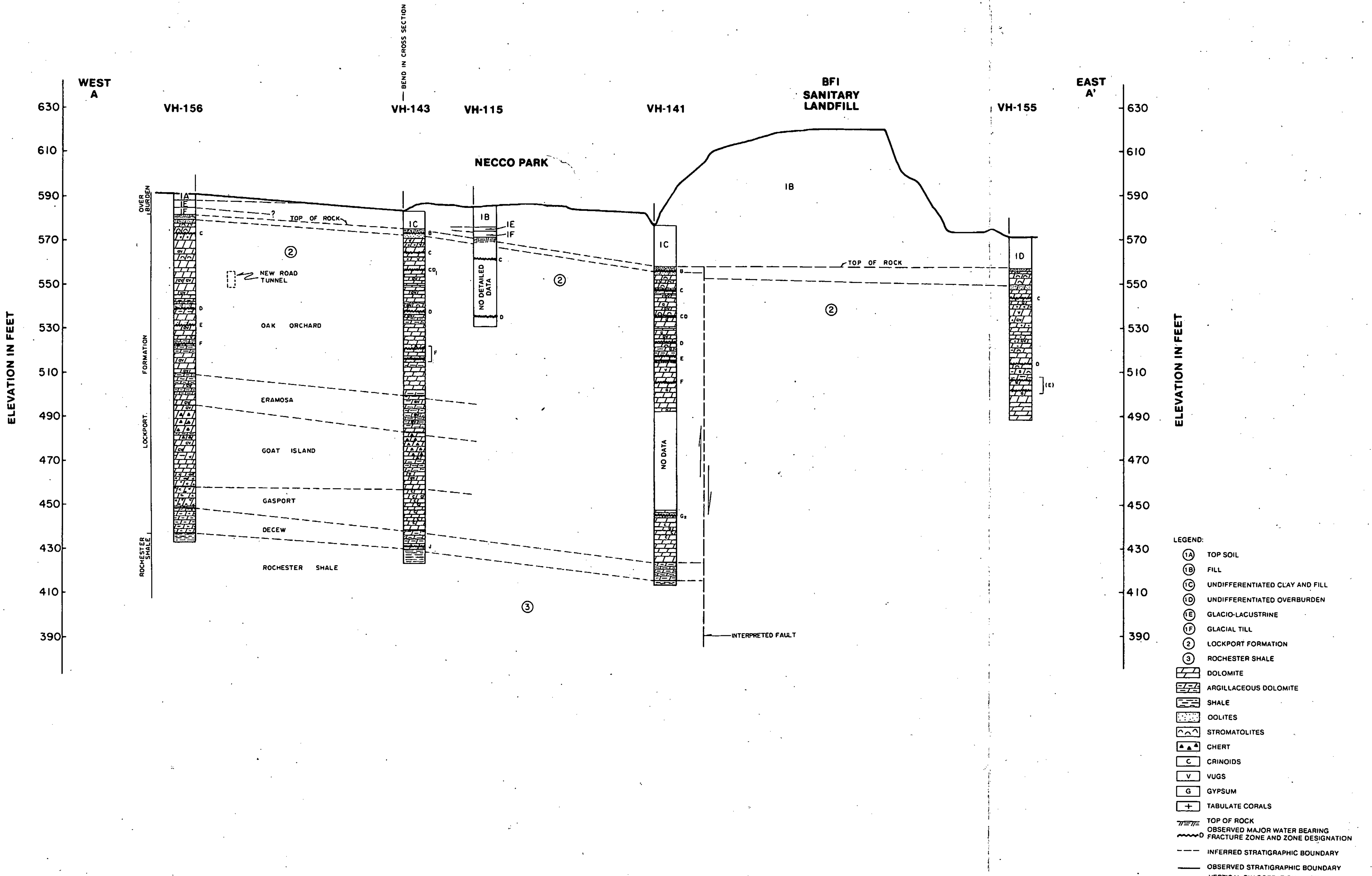
300 0 300 600 900

CROSS-SECTION LOCATION PLAN
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: D.E.G.	SCALE	DATE 12/3/87	
CHECKED BY: A.H.L.	AS NOTED	JOB NO. 87C2556 I-1	

FIGURE 6

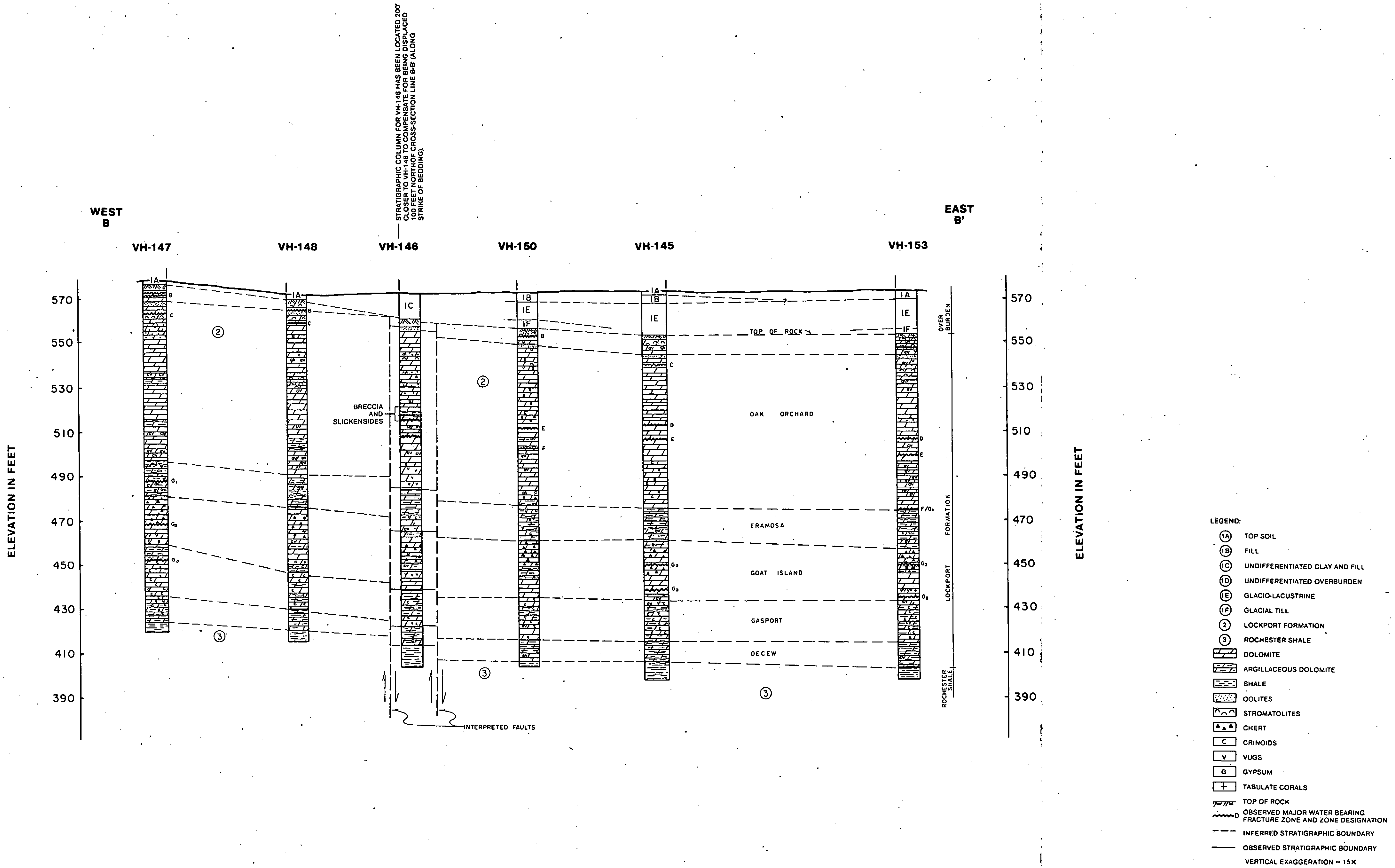


GEOLOGIC CROSS SECTION A-A'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/5/87
Checked by: A.H.L.		Job No.: 87C2556I-1

FIGURE 7

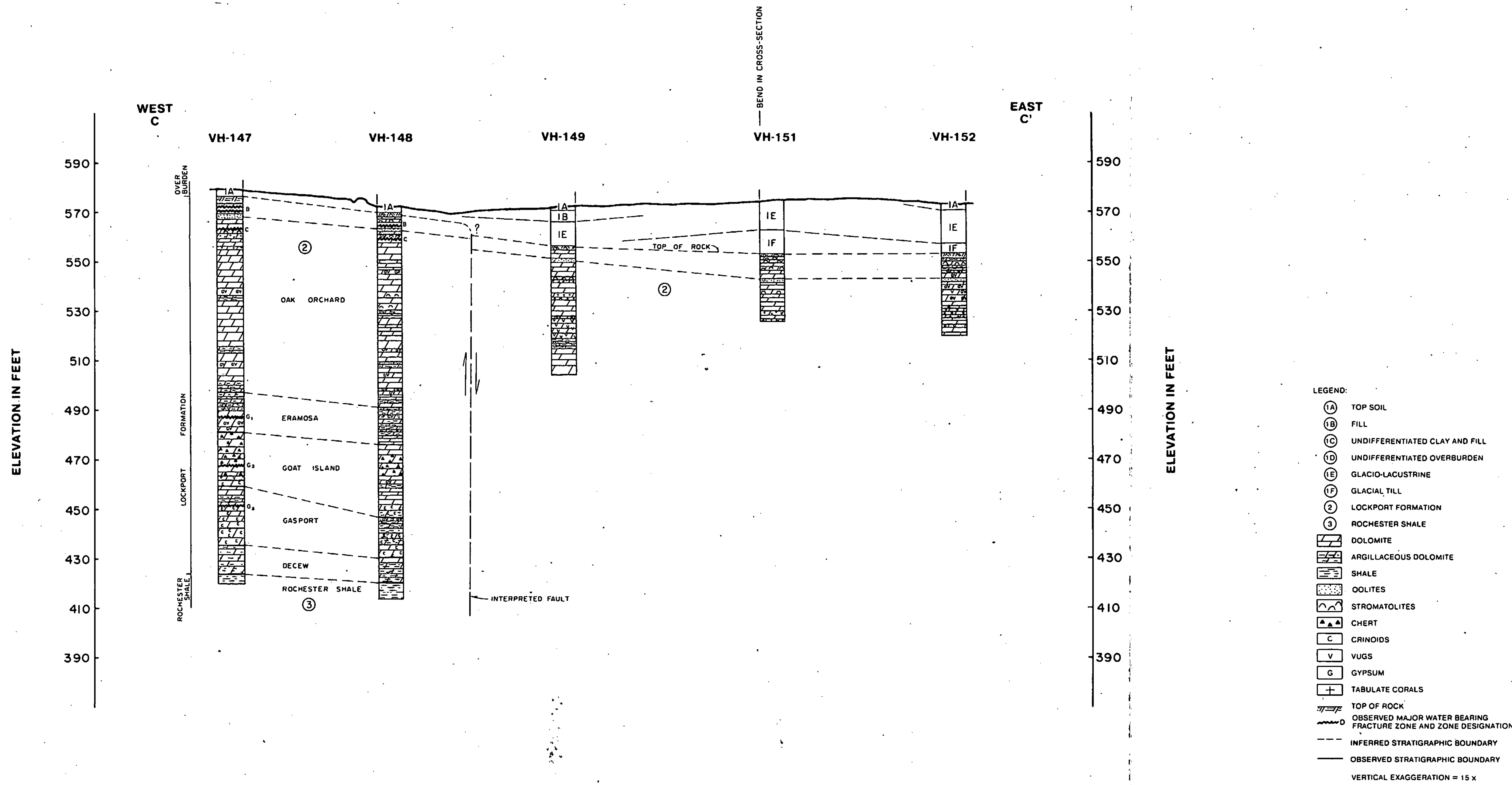


GEOLOGIC CROSS SECTION B-B'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/16/87
Checked by: A.H.L.		Job No.: 87C2556 I-1

FIGURE 8

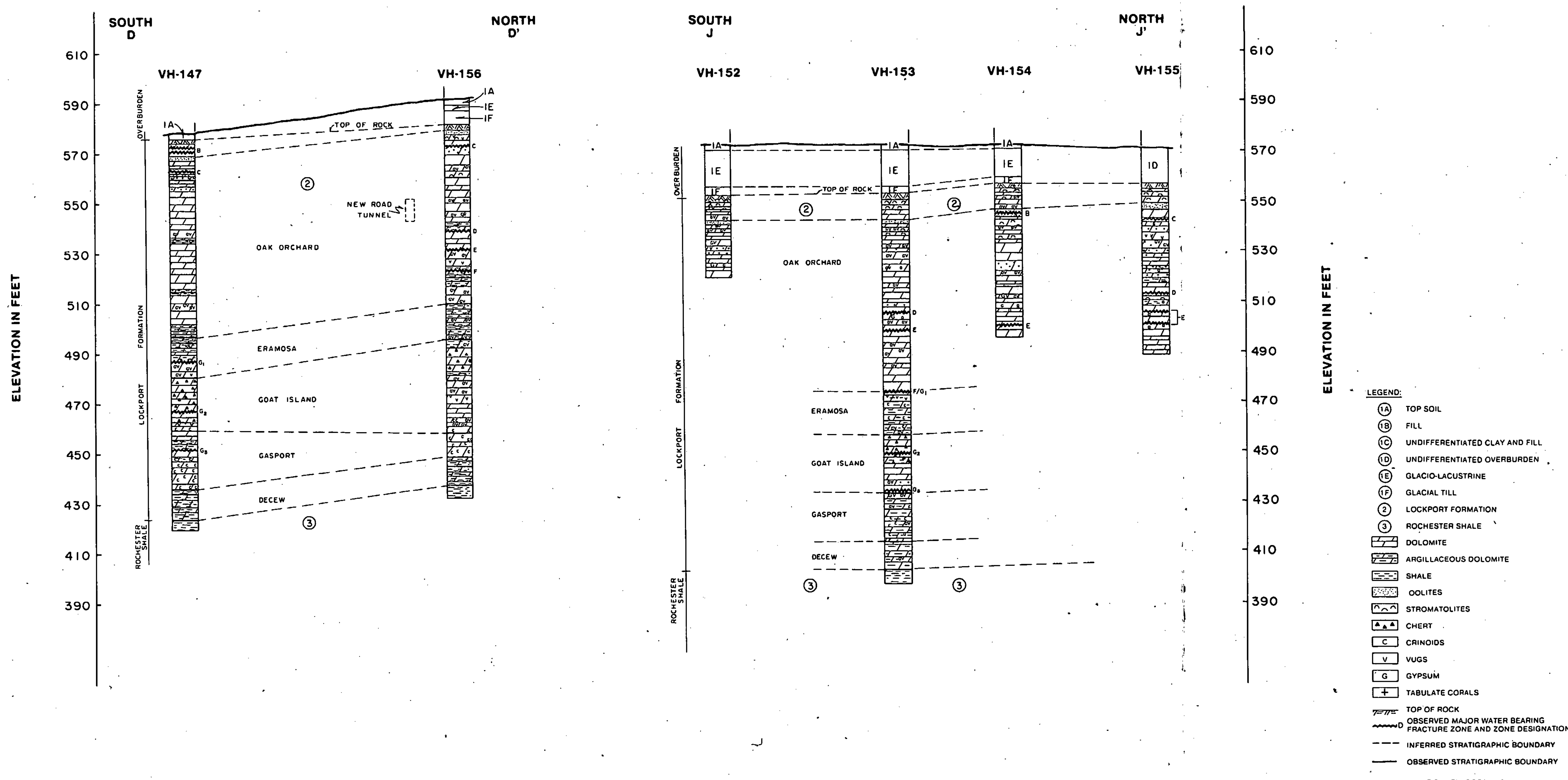


GEOLOGIC CROSS SECTION C-C'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/5/87
Checked by: A.H.L.		Job No.: 87C25561-1

FIGURE 9

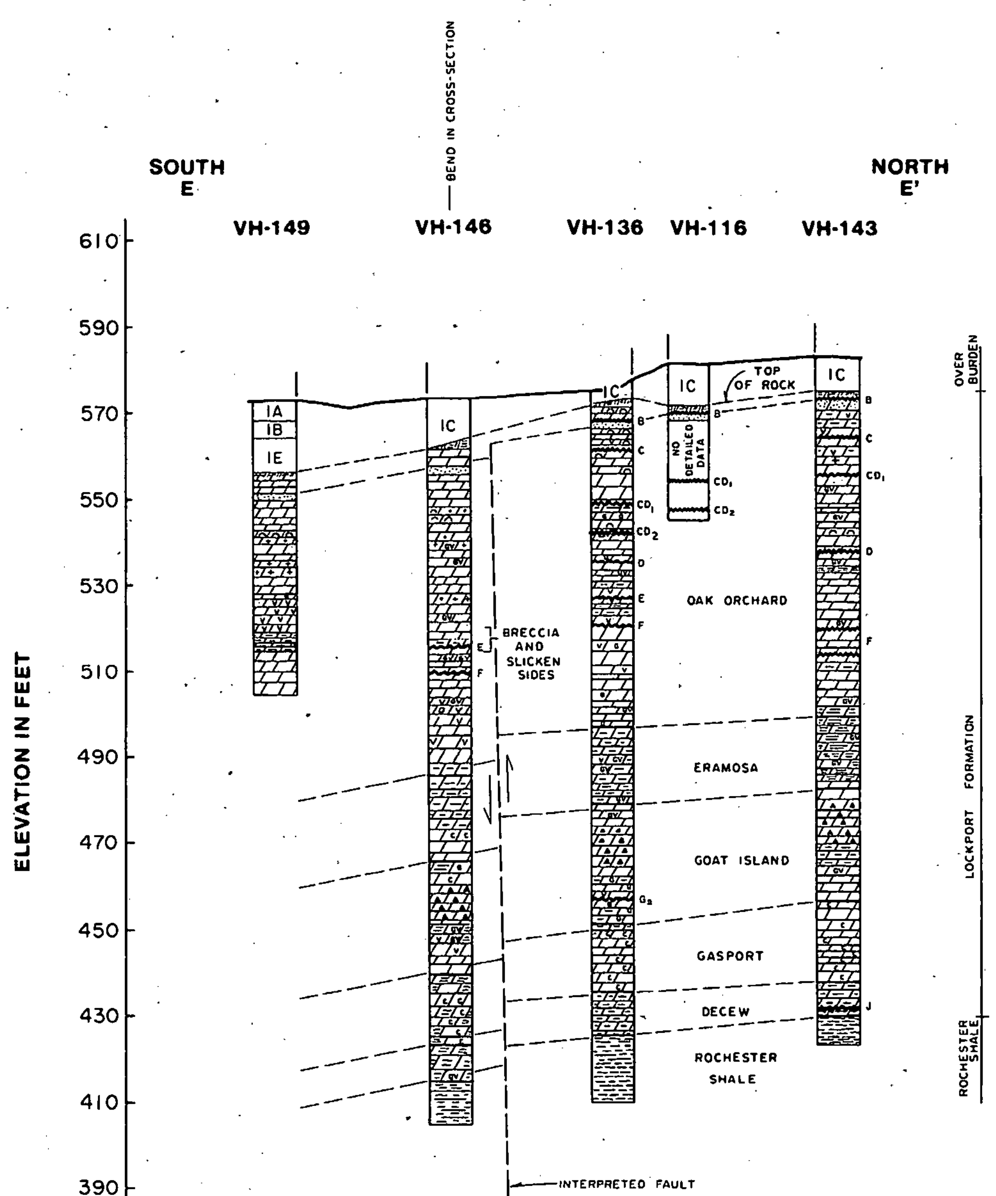


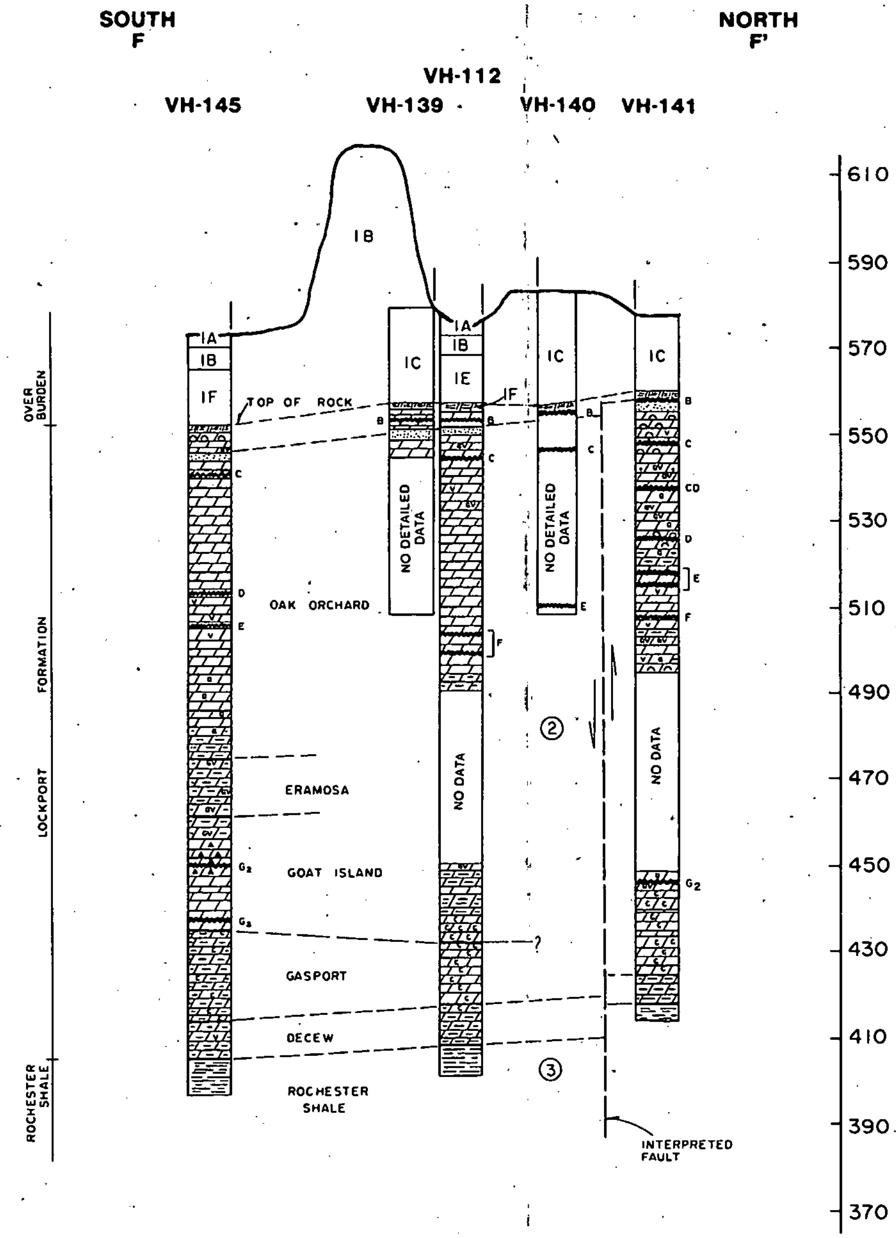
GEOLOGIC CROSS SECTIONS D-D' AND J-J'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/5/87
Checked by: A.H.L.		Job No.: 87C2556I-1

FIGURE 10





LEGEND:

- (1A) TOP SOIL
- (1B) FILL
- (1C) UNDIFFERENTIATED CLAY AND FILL
- (1D) UNDIFFERENTIATED OVERBURDEN
- (1E) GLACIO-LACUSTRINE
- (1F) GLACIAL TILL
- (2) LOCKPORT FORMATION
- (3) ROCHESTER SHALE
- DOLOMITE
- ARGILLACEOUS DOLOMITE
- SHALE
- OOLITES
- STROMATOLITES
- CHERT
- C CRINOIDS
- V VUGS
- G GYPSUM
- + TABULATE CORALS
- TOP OF ROCK
- D OBSERVED MAJOR WATER BEARING FRACTURE ZONE AND ZONE DESIGNATION
- INFERRED STRATIGRAPHIC BOUNDARY
- OBSERVED STRATIGRAPHIC BOUNDARY

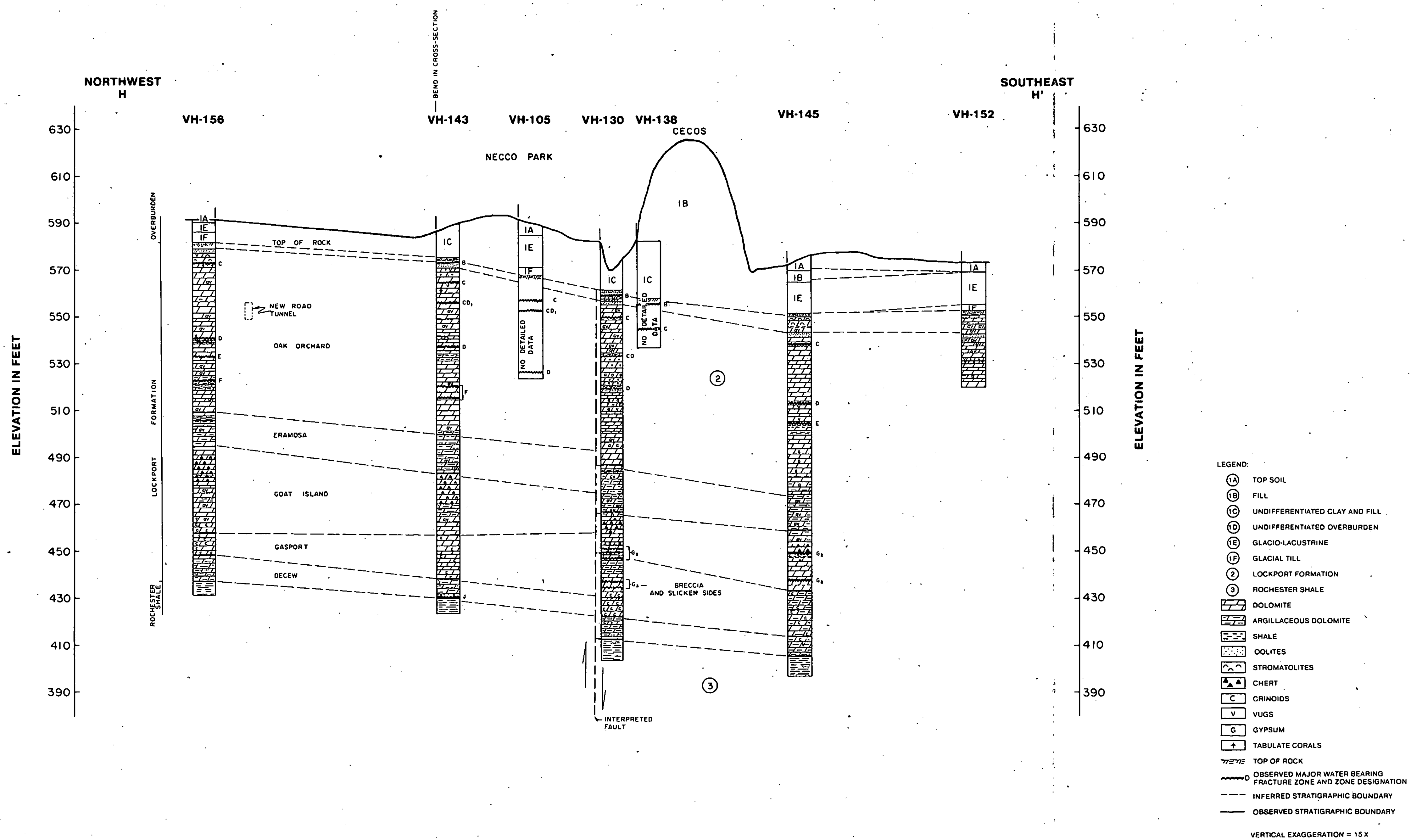
VERTICAL EXAGGERATION = 15 X

GEOLOGIC CROSS SECTIONS E-E' AND F-F'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: J.C.	Scale	Date: 11/5/87
Checked by: A.H.L.	0 150 300	Job No.: 87C2556I-1

FIGURE 11

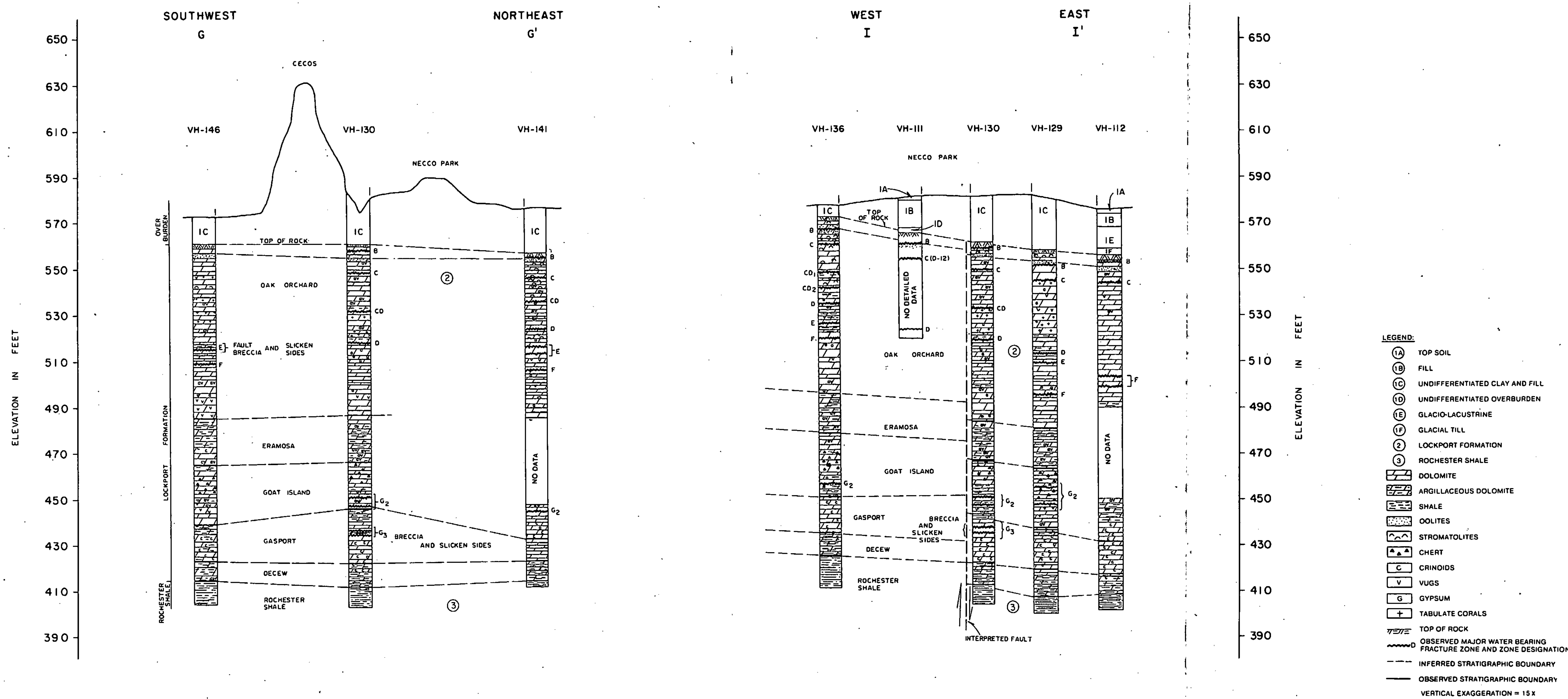


GEOLOGIC CROSS SECTION H-H'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/5/87
Checked by: A.H.L.		Job No.: 87C2556I-1

FIGURE 12

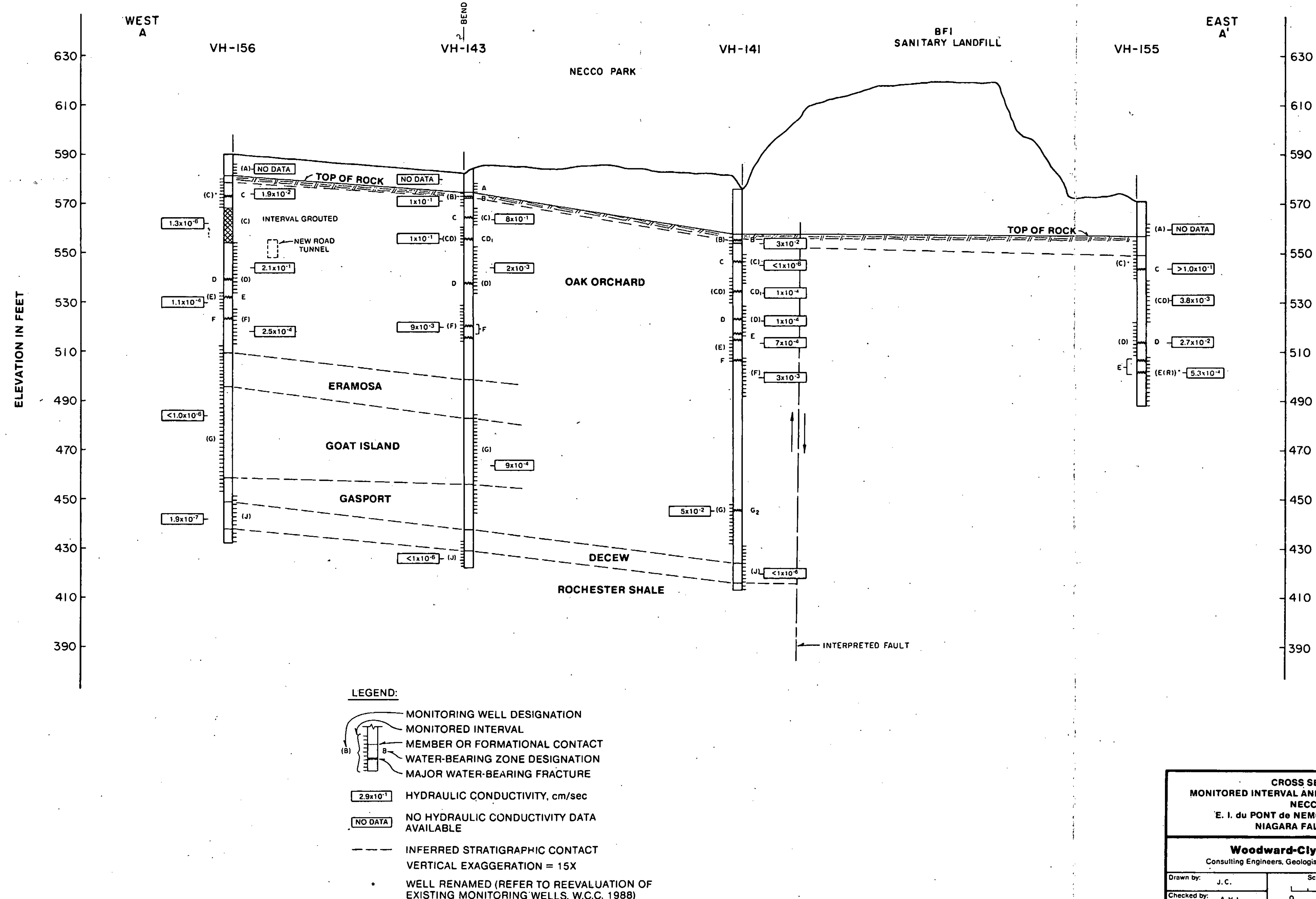


GEOLOGIC CROSS-SECTIONS G-G' AND I-I'
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: J.C.	Scale 0 150 300	Date: 11/5/87
Checked by: A.H.L.		Job No.: 87C2556I-1

FIGURE 13

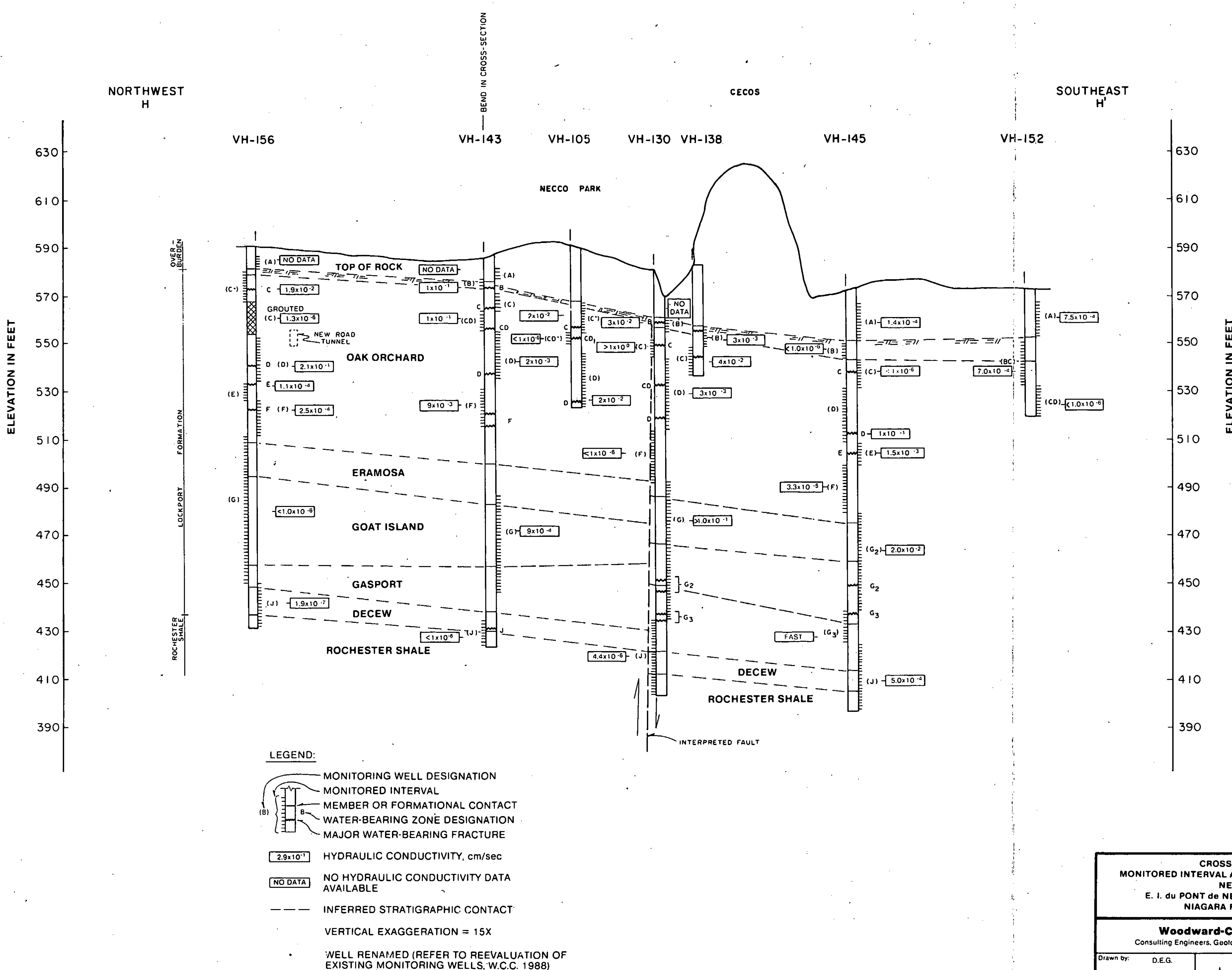


CROSS SECTION A-A'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: J.C.	Scale 0 300	Date: 11/11/87
Checked by: A.H.L.		Job No.: 87C25561-1

FIGURE 14

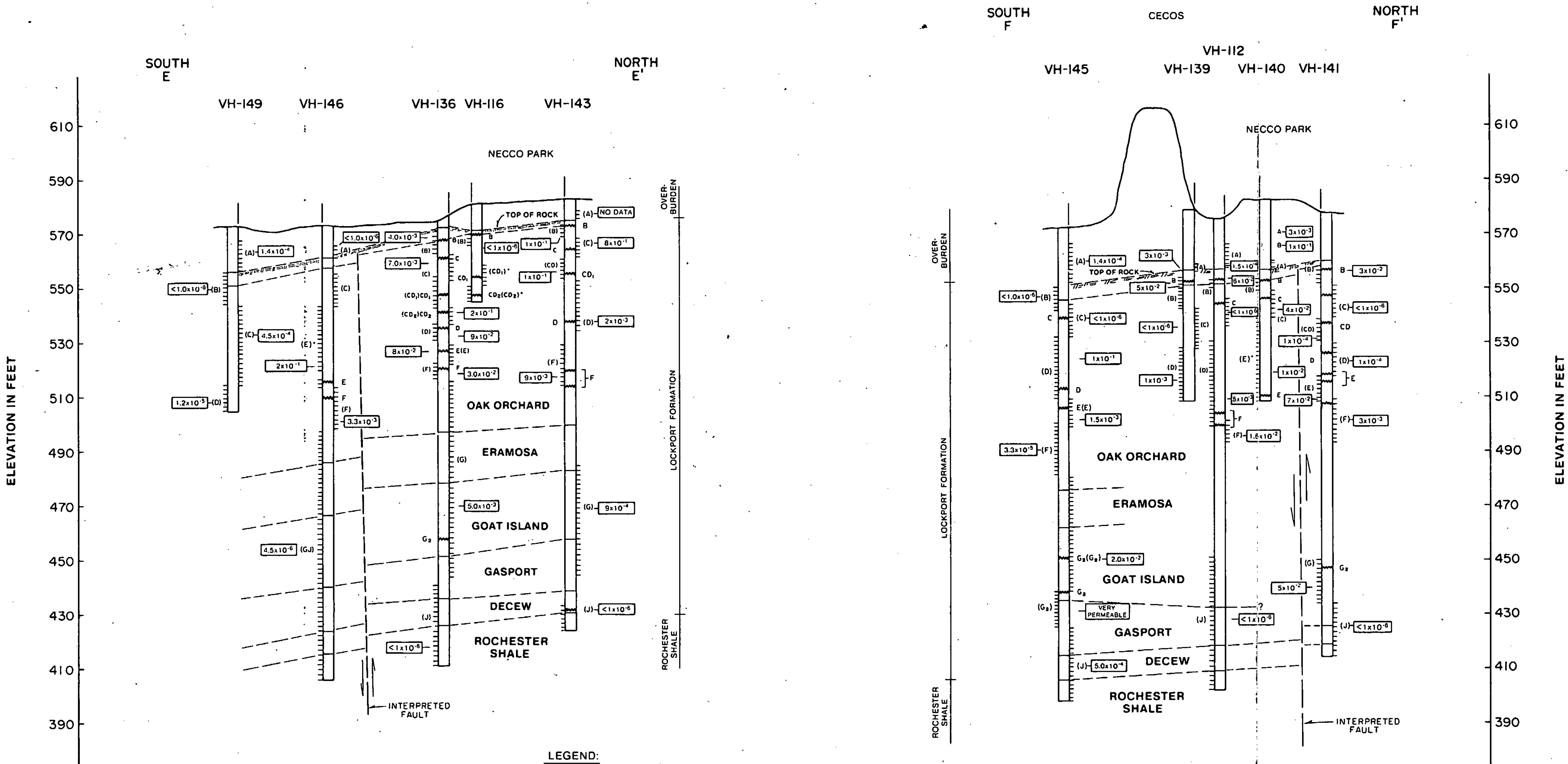


CROSS SECTION H-H'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 12/1/87	
Checked by: A.H.L.		Job No.: 87C2556 I-1	

FIGURE 19



LEGEND:

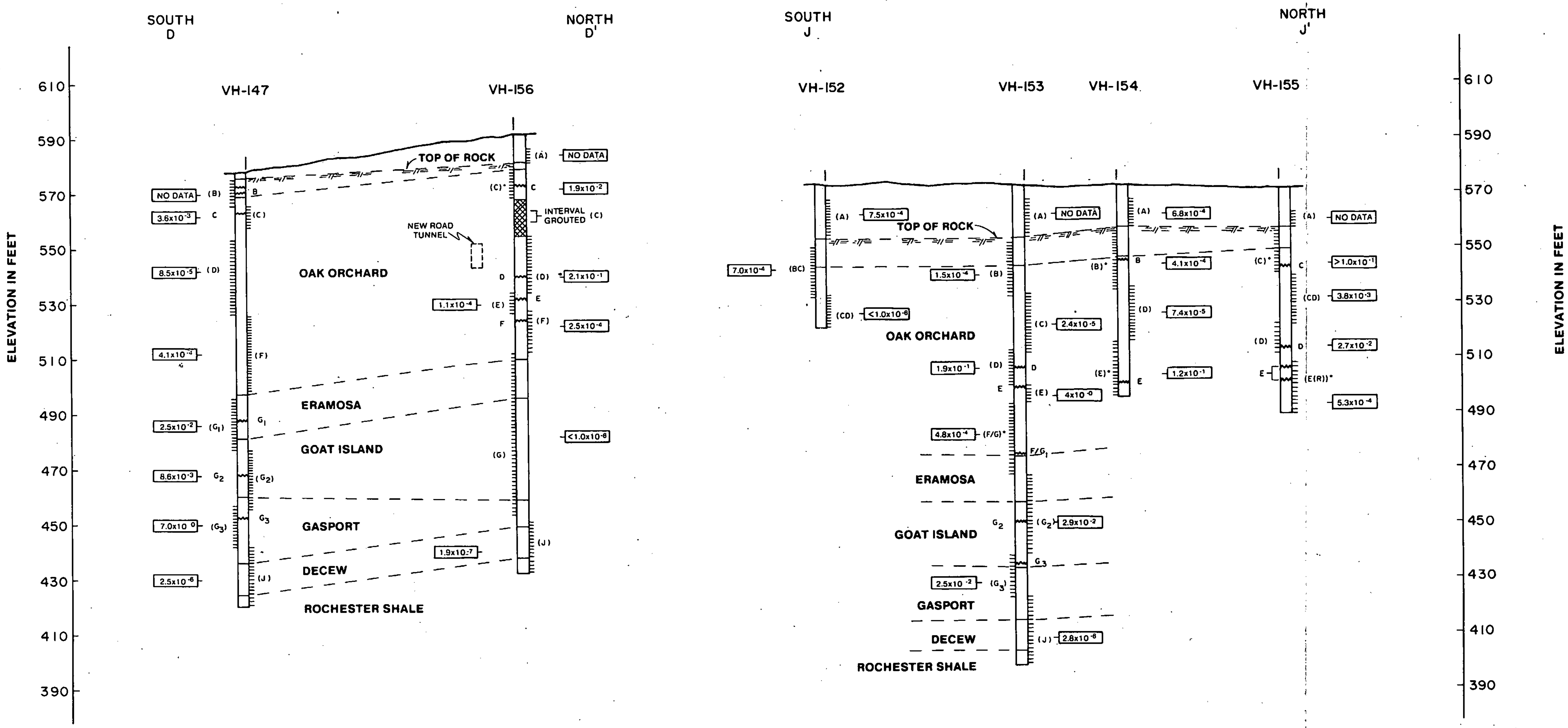
- MONITORING WELL DESIGNATION
- MONITORED INTERVAL
- MEMBER OR FORMATIONAL CONTACT
- WATER-BEARING ZONE DESIGNATION
- MAJOR WATER-BEARING FRACTURE
- 2.9x10⁻¹ — HYDRAULIC CONDUCTIVITY, cm/sec
- NO DATA — NO HYDRAULIC CONDUCTIVITY DATA AVAILABLE
- — — — INFERRED STRATIGRAPHIC CONTACT
- VERTICAL EXAGGERATION = 15X
- * WELL RENAMED (REFER TO REEVALUATION OF EXISTING MONITORING WELLS, W.C.C. 1988)

CROSS-SECTIONS E-E' AND F-F'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: J.C.	Scale 0 300'	Date: 12/2/87
Checked by: A.H.L.		Job No.: 87C255F I-I

FIGURE 18



LEGEND:

MONITORING WELL DESIGNATION
MONITORED INTERVAL
MEMBER OR FORMATIONAL CONTACT
WATER-BEARING ZONE DESIGNATION
MAJOR WATER-BEARING FRACTURE

2.9x10-1 HYDRAULIC CONDUCTIVITY, cm/sec

NO DATA NO HYDRAULIC CONDUCTIVITY DATA AVAILABLE

— — — INFERRED STRATIGRAPHIC CONTACT

VERTICAL EXAGGERATION = 15X

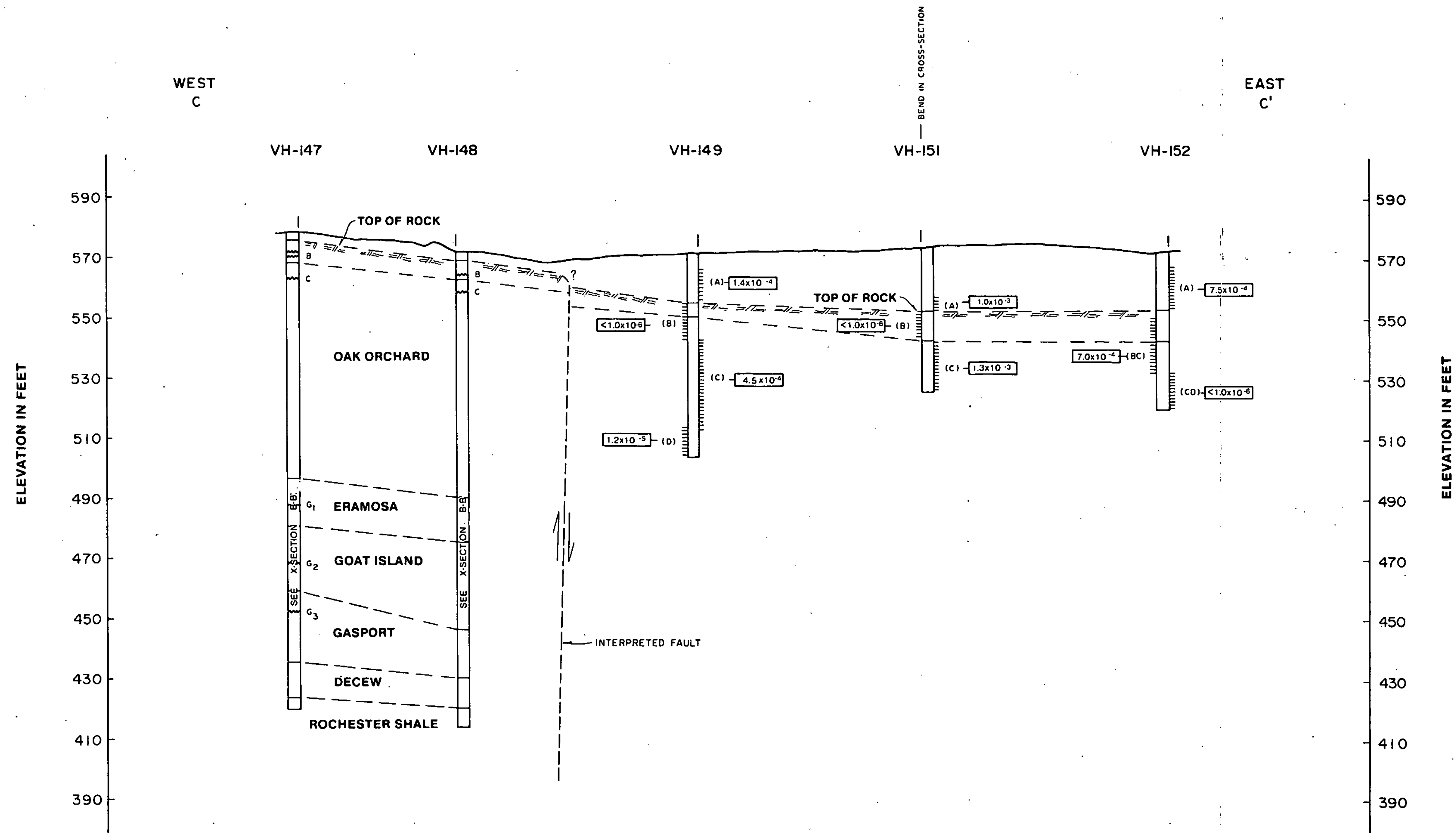
* WELL RENAMED (REFER TO REEVALUATION OF EXISTING MONITORING WELLS, W.C.C. 1988)

CROSS SECTION D-D' AND J-J'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/11/87	
Checked by: A.H.L.		Job No.: 87C2556 I-1	

FIGURE 17



LEGEND:

- MONITORING WELL DESIGNATION
- MONITORED INTERVAL
- MEMBER OR FORMATIONAL CONTACT
- (B) B WATER-BEARING ZONE DESIGNATION
- MAJOR WATER-BEARING FRACTURE

2.9x10^{-1} — HYDRAULIC CONDUCTIVITY, cm/sec

NO DATA — NO HYDRAULIC CONDUCTIVITY DATA AVAILABLE

--- INFERRED STRATIGRAPHIC CONTACT

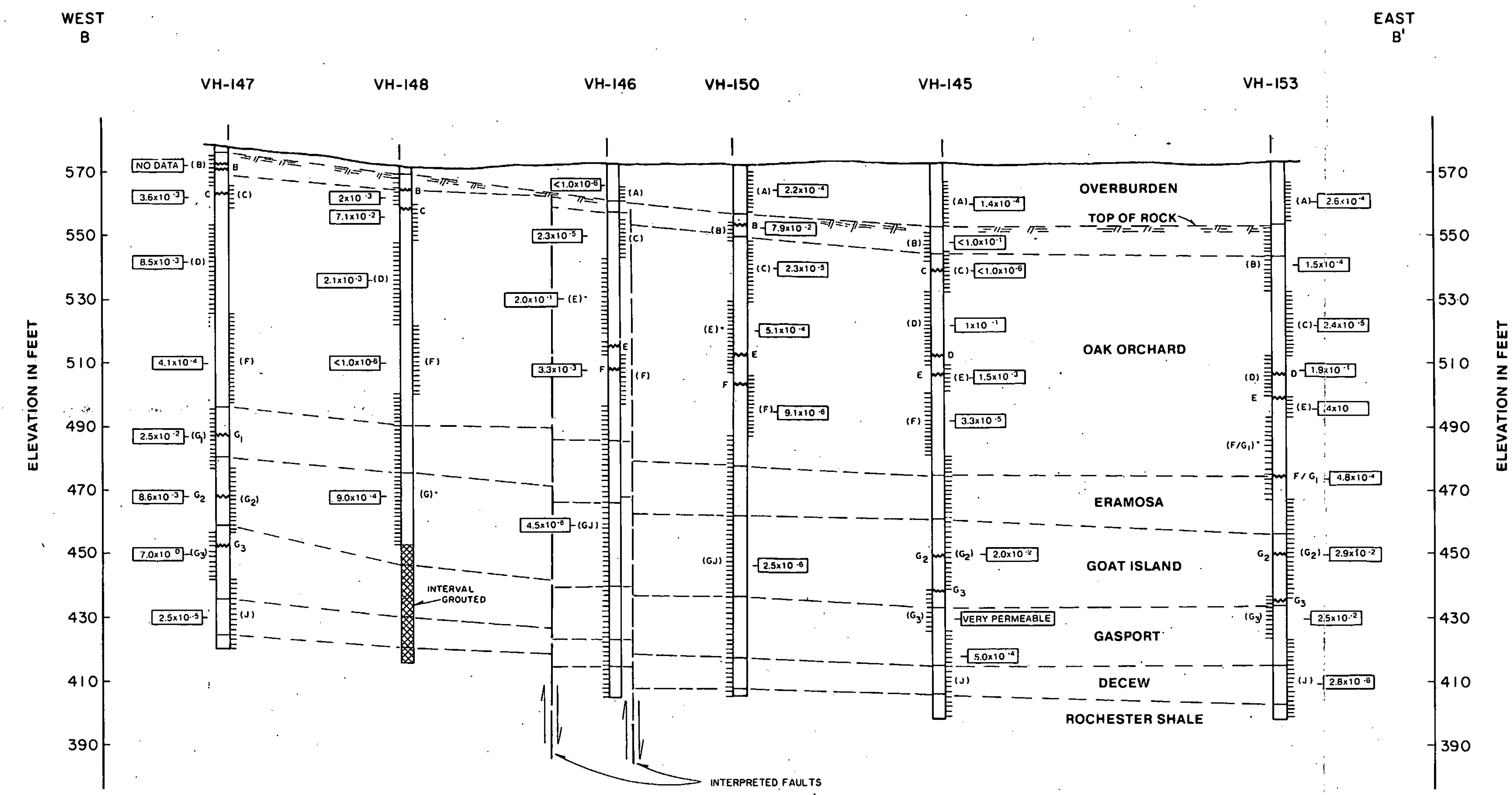
VERTICAL EXAGGERATION = 15X

CROSS SECTION C-C'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 11/11/87
Checked by: A.H.L.		Job No.: 87C2556 I-1

FIGURE 16



LEGEND:

- MONITORING WELL DESIGNATION
- MONITORED INTERVAL
- MEMBER OR FORMATIONAL CONTACT
- WATER-BEARING ZONE DESIGNATION
- MAJOR WATER-BEARING FRACTURE

2.9x10⁻¹ HYDRAULIC CONDUCTIVITY, cm/sec

NO DATA — NO HYDRAULIC CONDUCTIVITY DATA AVAILABLE

— — — INFERRED STRATIGRAPHIC CONTACT

VERTICAL EXAGGERATION = 15X

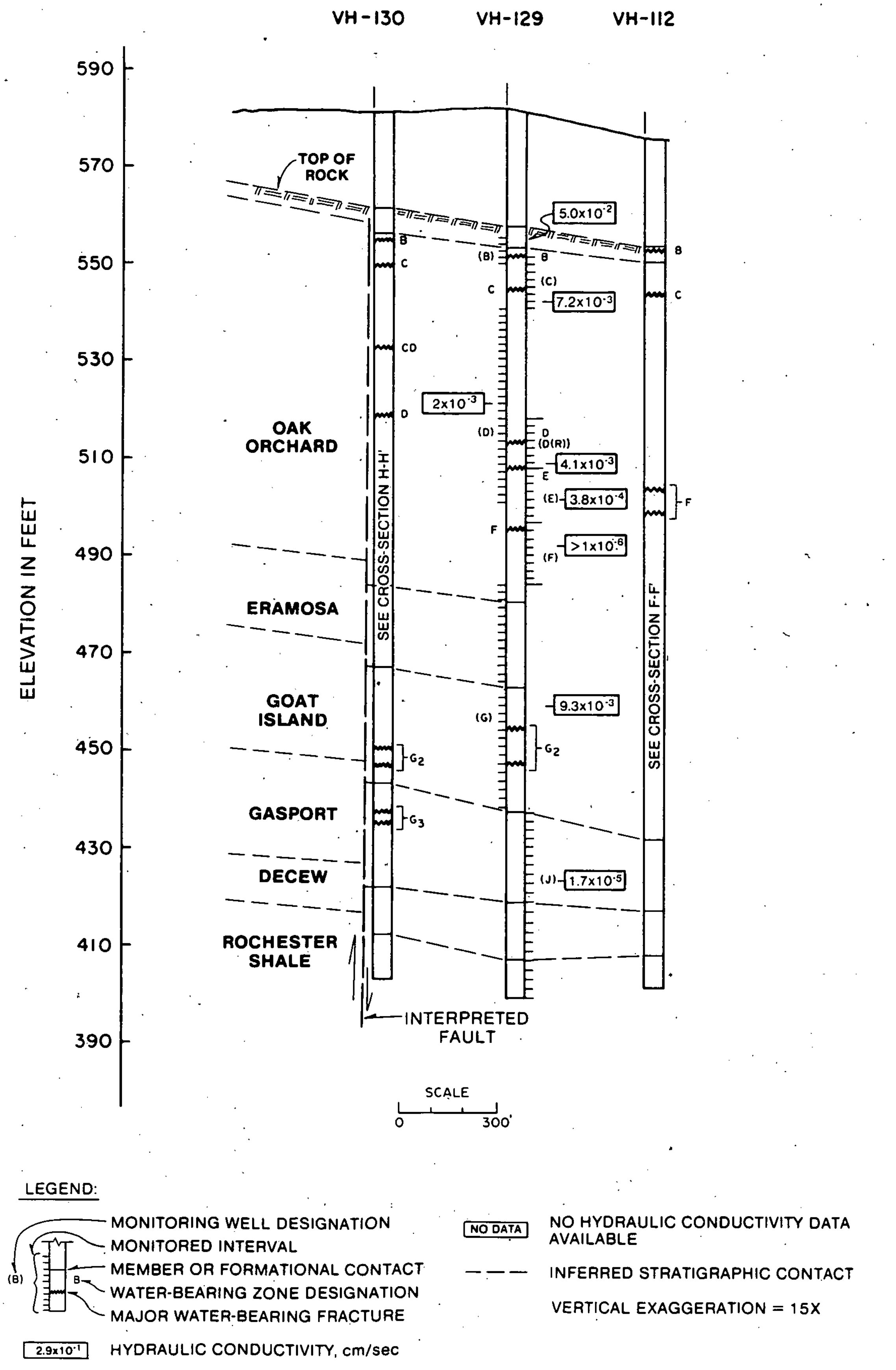
* WELL RENAMED (REFER TO REEVALUATION OF EXISTING MONITORING WELLS, W.C.C. 1988)

CROSS SECTION B-B'
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY, INC.
NIAGARA FALLS, NEW YORK

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: D.E.G.	Scale 0 150 300	Date: 12/ 2/87
Checked by: A.H.L.		Job No.: 87C2556-I-I

FIGURE 15



CROSS-SECTION J-J' (IN PART)
VH-129 CLUSTER
MONITORED INTERVAL AND HYDRAULIC CONDUCTIVITY
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

FIGURE 20

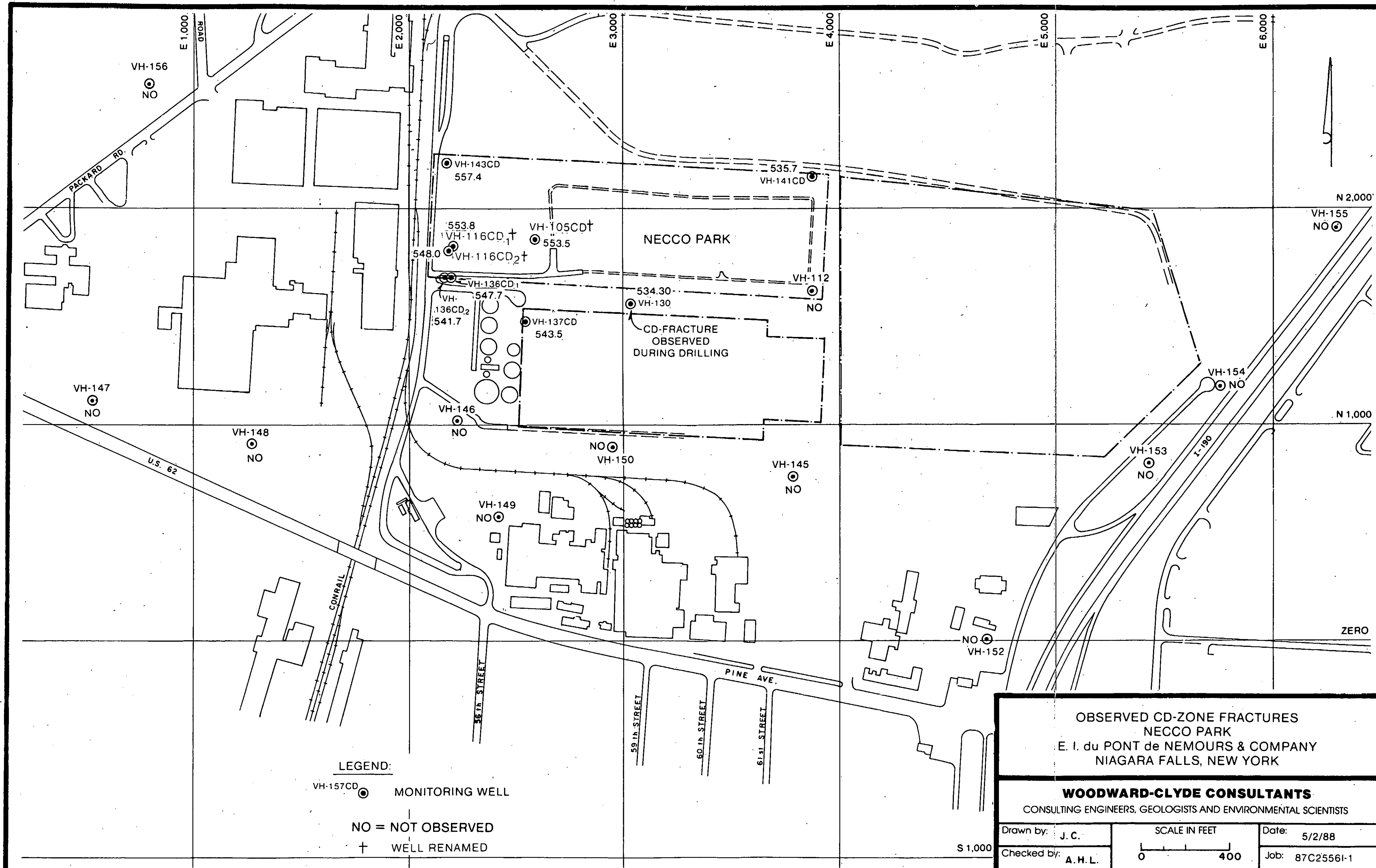
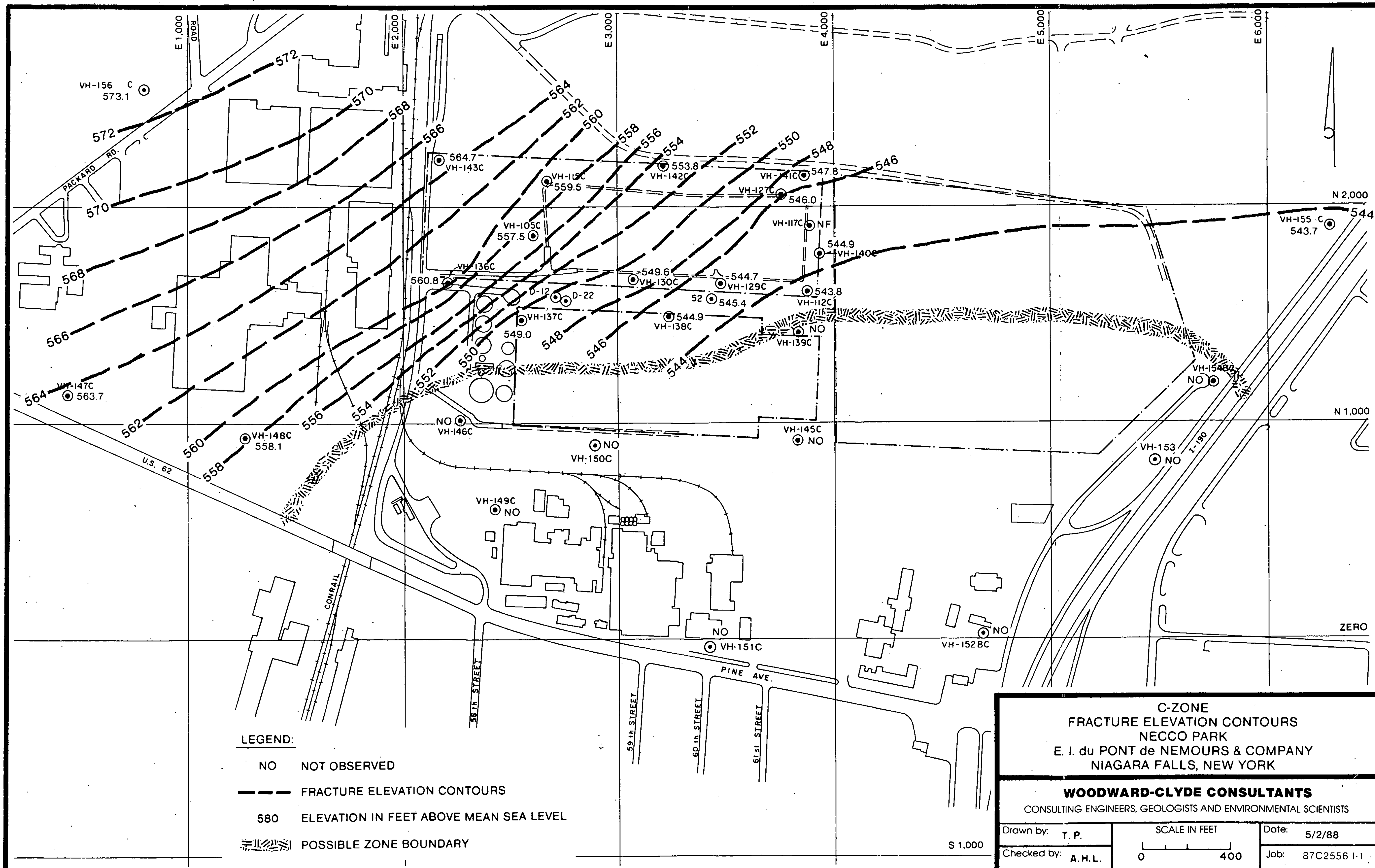

E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
NECCO PARK
VH-156 NO
VH-143CD 557.4
535.7 VH-141CD
553.8 VH-116CD1†
548.0 VH-116CD2†
VH-105CD† 553.5
VH-136CD1 547.7
VH-136CD2 541.7
534.30 VH-130
CD-FRACTURE OBSERVED DURING DRILLING
VH-137CD 543.5
VH-112 NO
VH-155 NO
VH-154 NO
VH-147 NO
VH-146 NO
VH-148 NO
NO VH-150
VH-145 NO
VH-153 NO
VH-149 NO
NO VH-152
LEGEND:
VH-157CD MONITORING WELL
NO = NOT OBSERVED
† WELL RENAMED
OBSERVED CD-ZONE FRACTURES
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A. H. L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C25561-1

FIGURE 30



LEGEND:

NO NOT OBSERVED

FRACTURE ELEVATION CONTOURS

580 ELEVATION IN FEET ABOVE MEAN SEA LEVEL

POSSIBLE ZONE BOUNDARY

C-ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
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WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: T. P.	SCALE IN FEET	Date: 5/2/88
Checked by: A.H.L.	0 400	Job: 87C2556 I-1

FIGURE 29

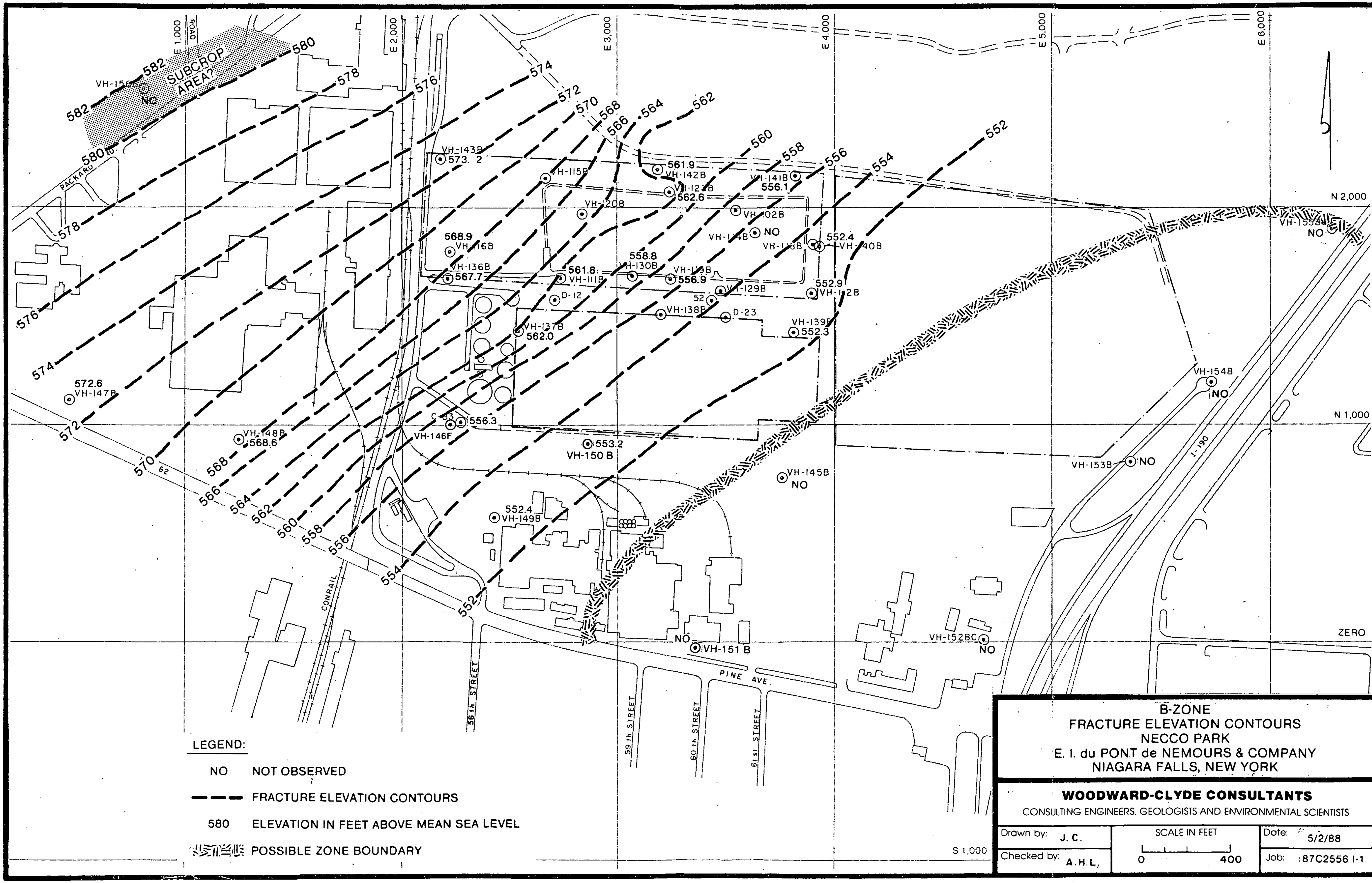

B-ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
NO NOT OBSERVED
FRACTURE ELEVATION CONTOURS
580 ELEVATION IN FEET ABOVE MEAN SEA LEVEL
POSSIBLE ZONE BOUNDARY
SUBCROP AREA?
PACKARD RD.
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
VH-143B 573.2
VH-115B
561.9 VH-142B
VH-141B 556.1
VH-127B 562.6
VH-120B
VH-102B
VH-114B NO
VH-113B 552.4 VH-140B
VH-155B NO
568.9 VH-116B
VH-136B 567.7
561.8 VH-111B
558.8 VH-130B
VH-119B 556.9
VH-129B
552.9 VH-112B
D-12
D-23
VH-138B
VH-139B 552.3
VH-137B 562.0
572.6 VH-147B
VH-154B NO
556.3
VH-146F
VH-148B 568.6
553.2 VH-150 B
VH-153B NO
VH-145B NO
552.4 VH-149B
NO VH-151 B
VH-152BC NO

FIGURE 28

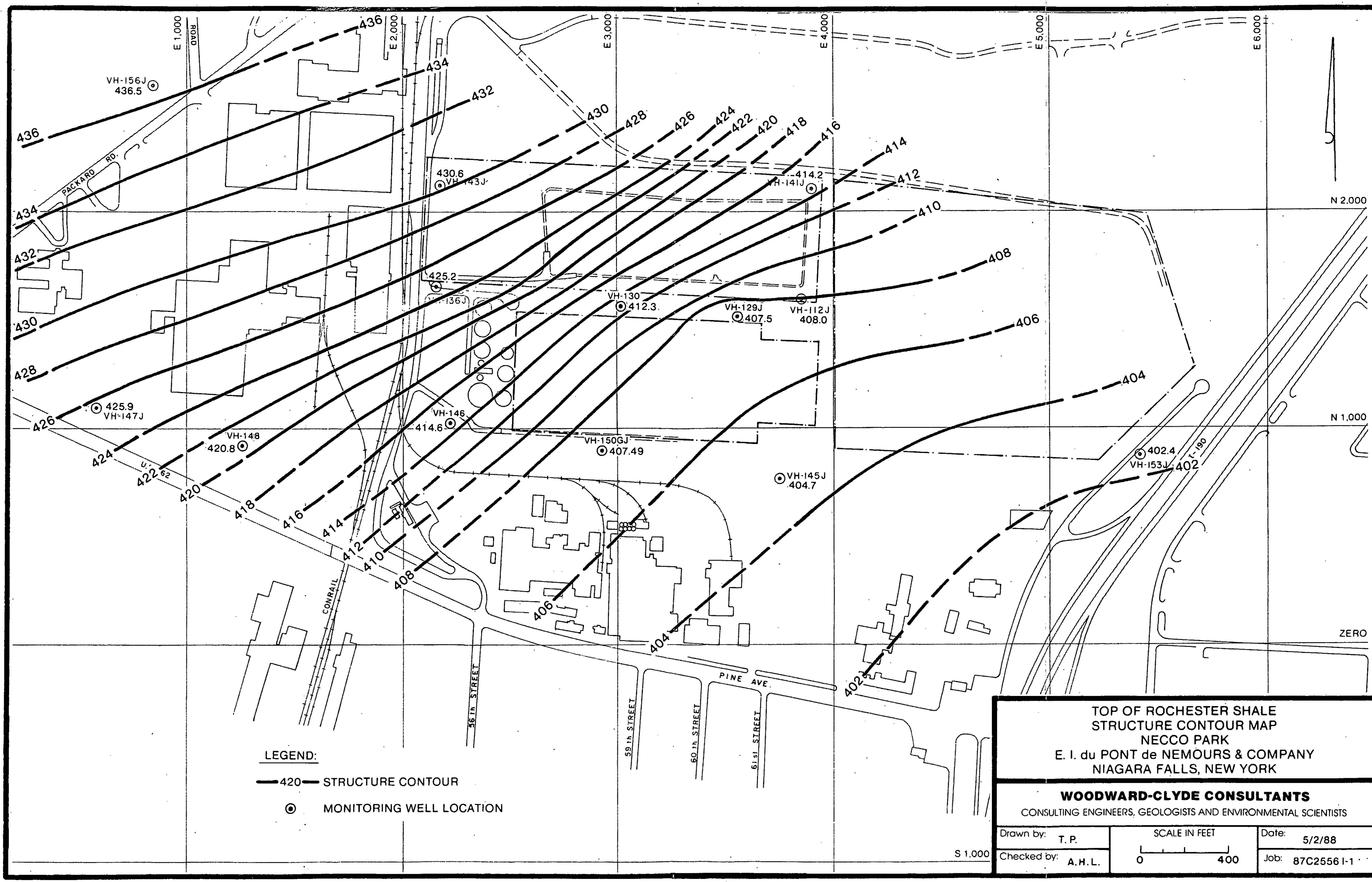

TOP OF ROCHESTER SHALE
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
420 STRUCTURE CONTOUR
MONITORING WELL LOCATION
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
U.S. 62
I-190
VH-156J 436.5
430.6 VH-143J
414.2 VH-141J
425.2
VH-136J
VH-130 412.3
VH-129J 407.5
VH-112J 408.0
425.9 VH-147J
VH-148 420.8
VH-146 414.6
VH-150GJ 407.49
VH-145J 404.7
402.4 VH-153J
436
434
432
430
428
426
424
422
420
418
416
414
412
410
408
406
404
402

FIGURE 27

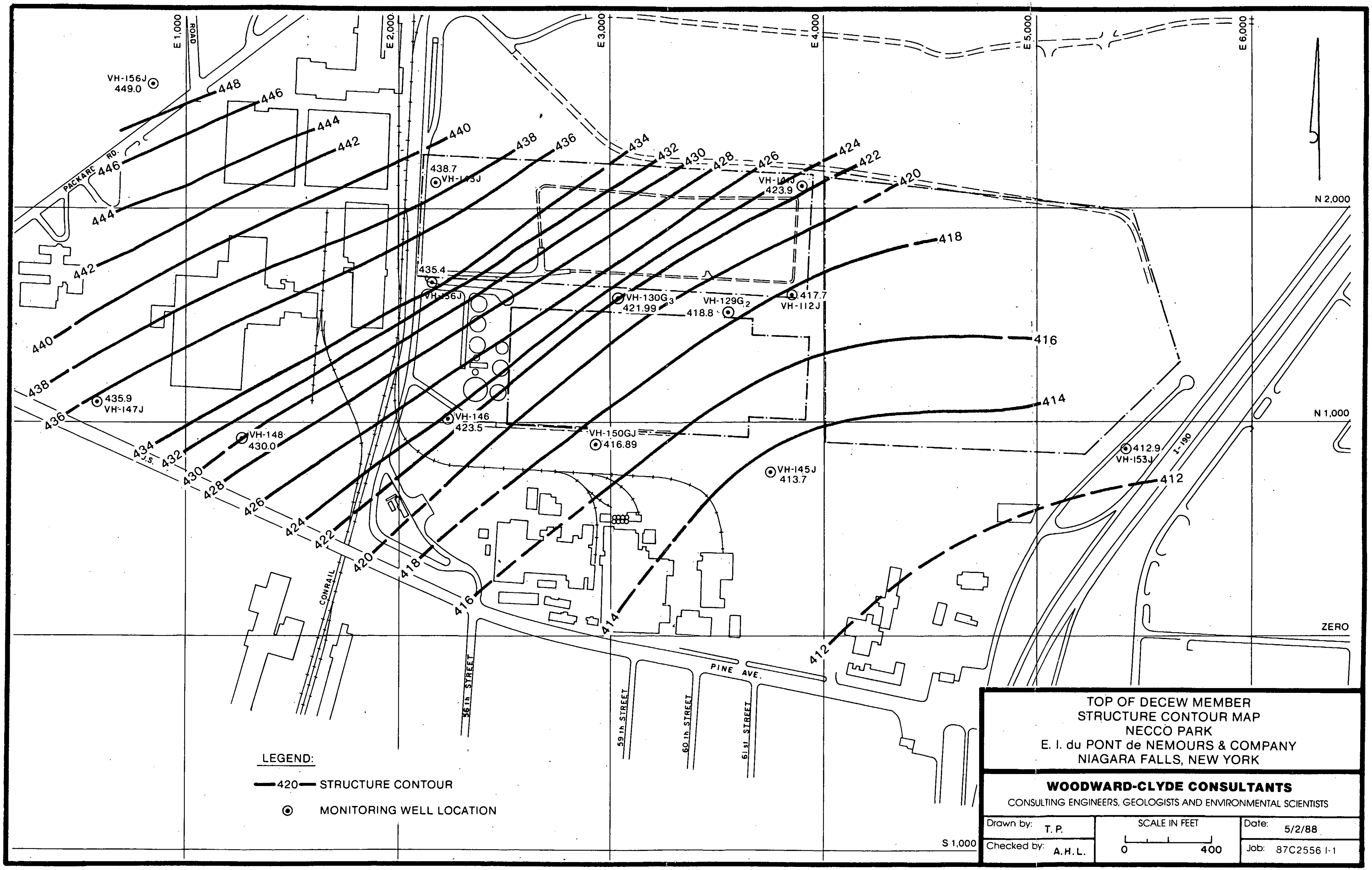
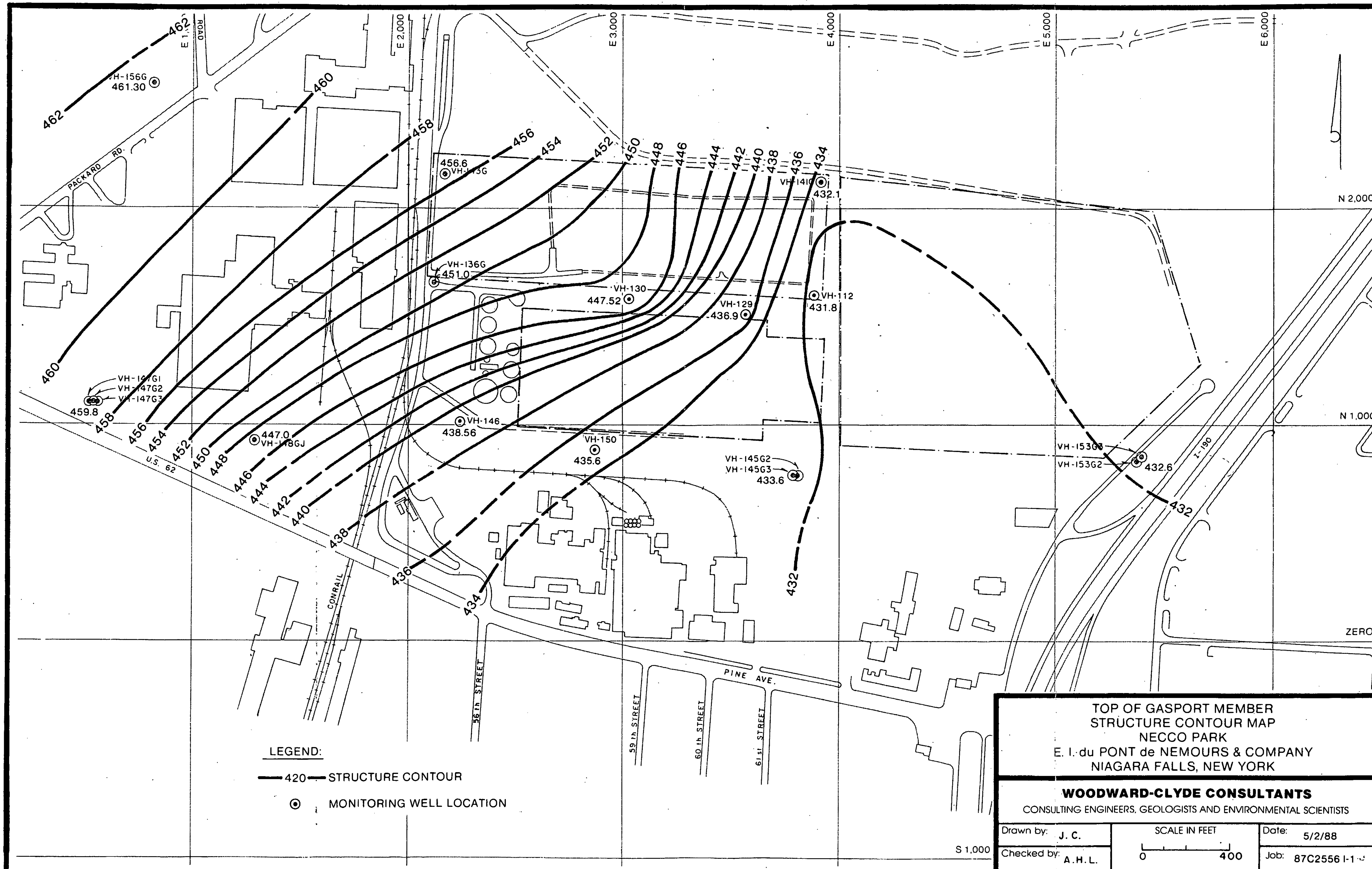

TOP OF DECEW MEMBER
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
420 STRUCTURE CONTOUR
MONITORING WELL LOCATION
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190
VH-156J 449.0
438.7 VH-143J
435.4
VH-136J
VH-141J 423.9
VH-130G3 421.99
VH-129G2 418.8
417.7 VH-112J
435.9 VH-147J
VH-146 423.5
VH-148 430.0
VH-150GJ 416.89
VH-145J 413.7
412.9 VH-153J
448
446
444
442
440
438
436
434
432
430
428
426
424
422
420
418
416
414
412

FIGURE 26



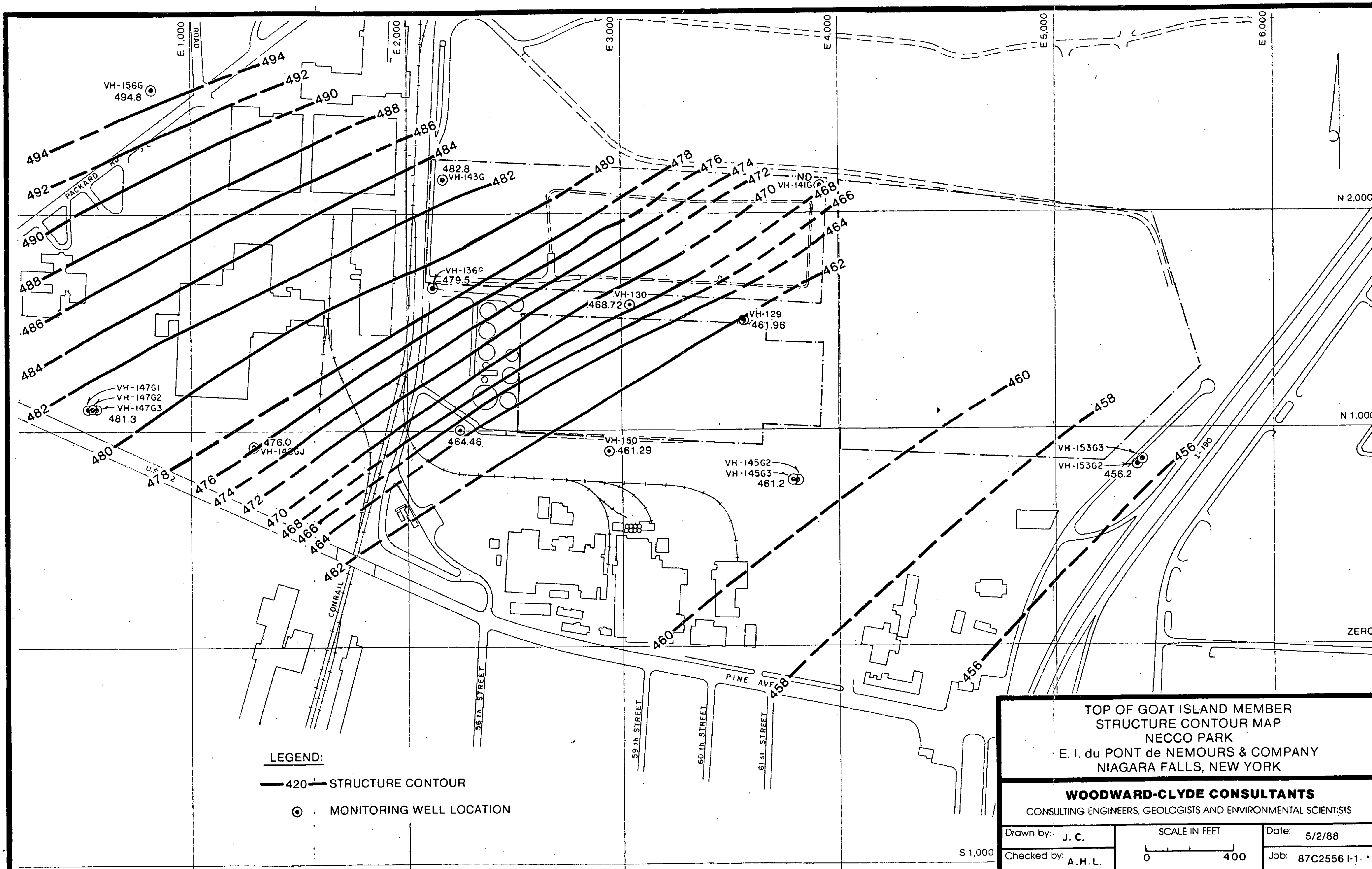
TOP OF GASPORT MEMBER
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET	Date: 5/2/88
Checked by: A.H.L.	0 400	Job: 87C2556 I-1

FIGURE 25



TOP OF GOAT ISLAND MEMBER
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET	Date: 5/2/88
Checked by: A.H.L.	0 400	Job: 87C2556 I-1

FIGURE 24

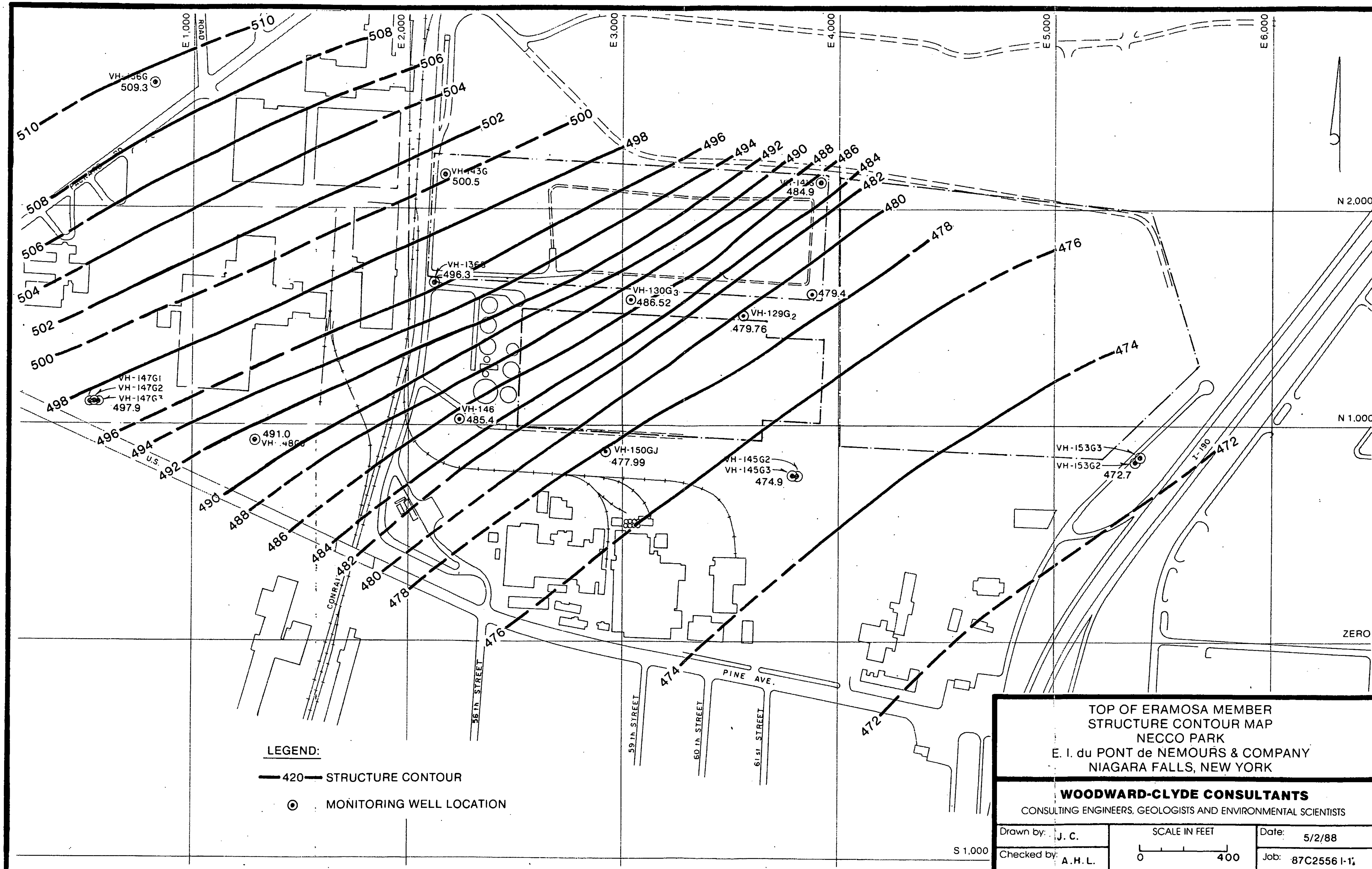
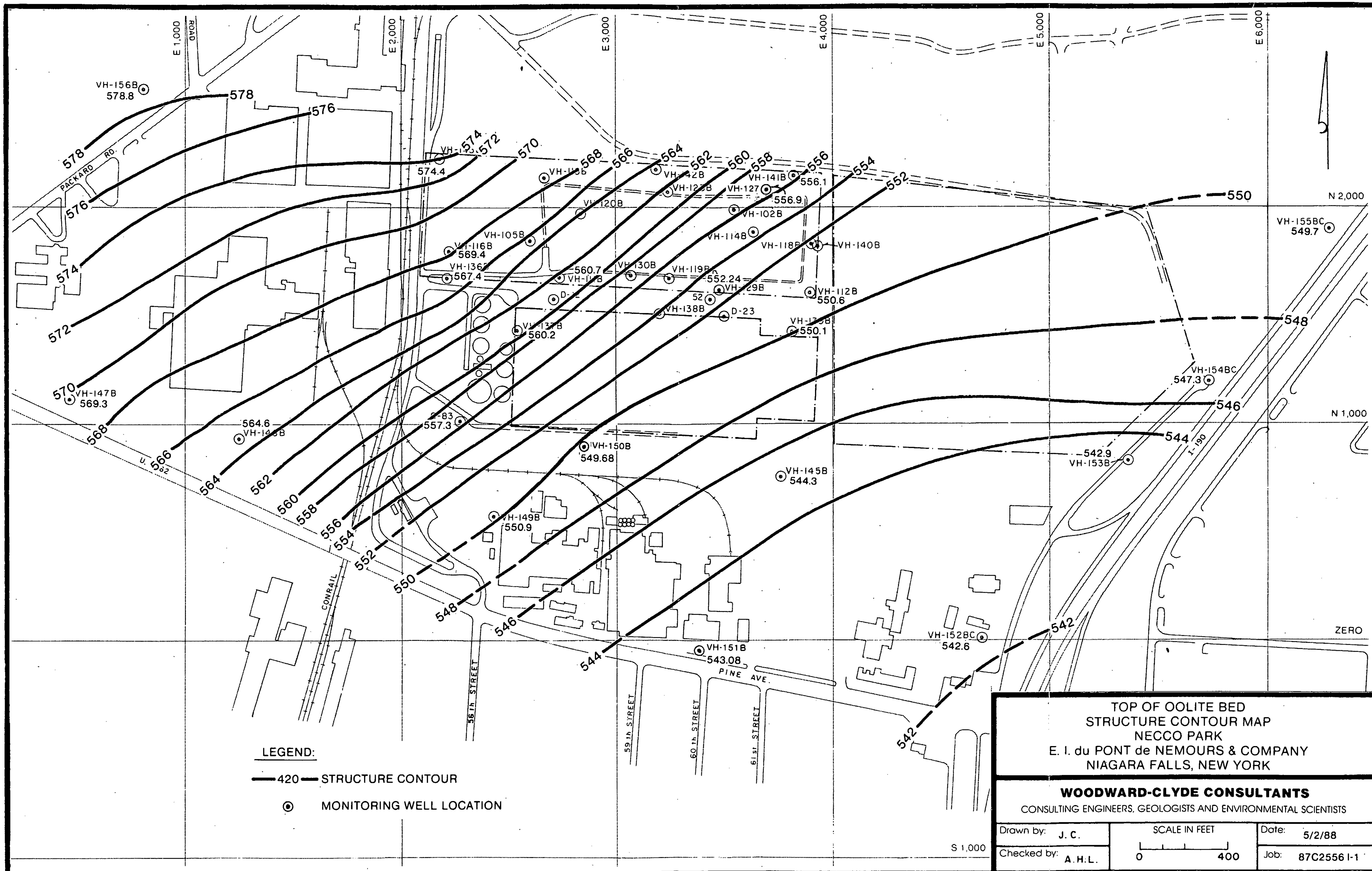

TOP OF ERAMOSA MEMBER
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
420 STRUCTURE CONTOUR
MONITORING WELL LOCATION
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
VH-143G
500.5
VH-136B
496.3
VH-130G3
486.52
VH-129G2
479.76
479.4
484.9
VH-147G1
VH-147G2
VH-147G3
497.9
491.0
VH-146
485.4
VH-150GJ
477.99
VH-145G2
VH-145G3
474.9
VH-153G3
VH-153G2
472.7
509.3
510
508
506
504
502
500
498
496
494
492
490
488
486
484
482
480
478
476
474
472
ROAD
CONRAIL
U.S.
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190

FIGURE 23



TOP OF OOLITE BED
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET	Date: 5/2/88
Checked by: A.H.L.	0 400	Job: 87C2556 I-1

FIGURE 22

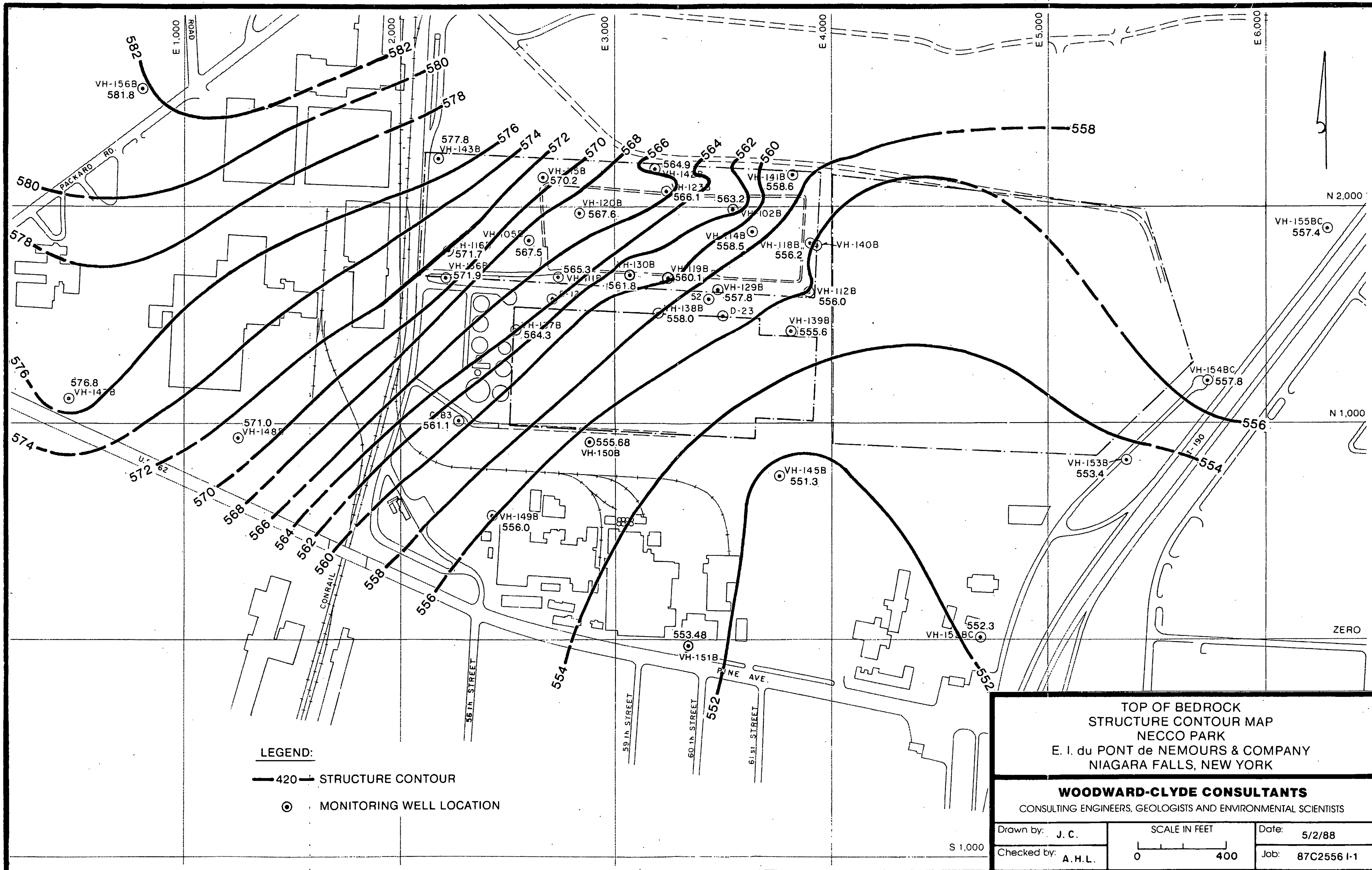
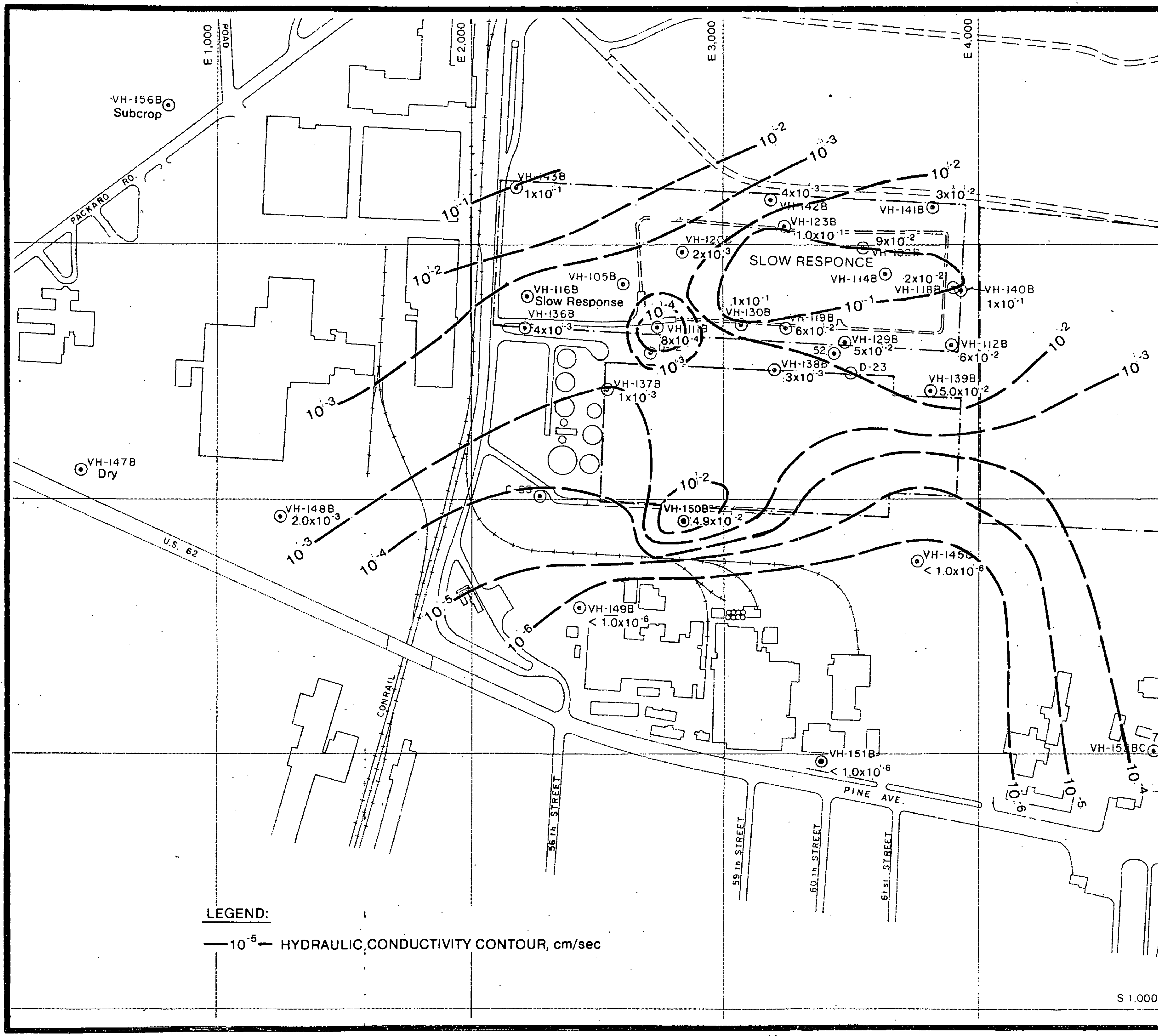

TOP OF BEDROCK
STRUCTURE CONTOUR MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
420 STRUCTURE CONTOUR
MONITORING WELL LOCATION
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190
VH-156B 581.8
577.8 VH-143B
VH-115B 570.2
564.9 VH-142B
VH-123B 566.1
563.2
VH-141B 558.6
VH-102B
VH-120B 567.6
VH-105B 567.5
VH-116B 571.7
VH-126B 571.9
565.3
VH-130B 561.8
VH-119B 560.1
VH-114B 558.5
VH-118B 556.2
VH-140B
VH-129B 557.8
VH-112B 556.0
VH-138B 558.0
D-23
VH-139B 555.6
VH-137B 564.3
576.8 VH-147B
571.0 VH-148B
D-83 561.1
555.68 VH-150B
VH-149B 556.0
VH-145B 551.3
553.48 VH-151B
552.3 VH-152BC
VH-153B 553.4
VH-154BC 557.8
VH-155BC 557.4
582
580
578
576
574
572
570
568
566
564
562
560
558
556
554
552

FIGURE 21



B-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET	Date:	10/30/87
Checked by: A.H.L.	0 — 400	Job:	87C25561-1

FIGURE 40

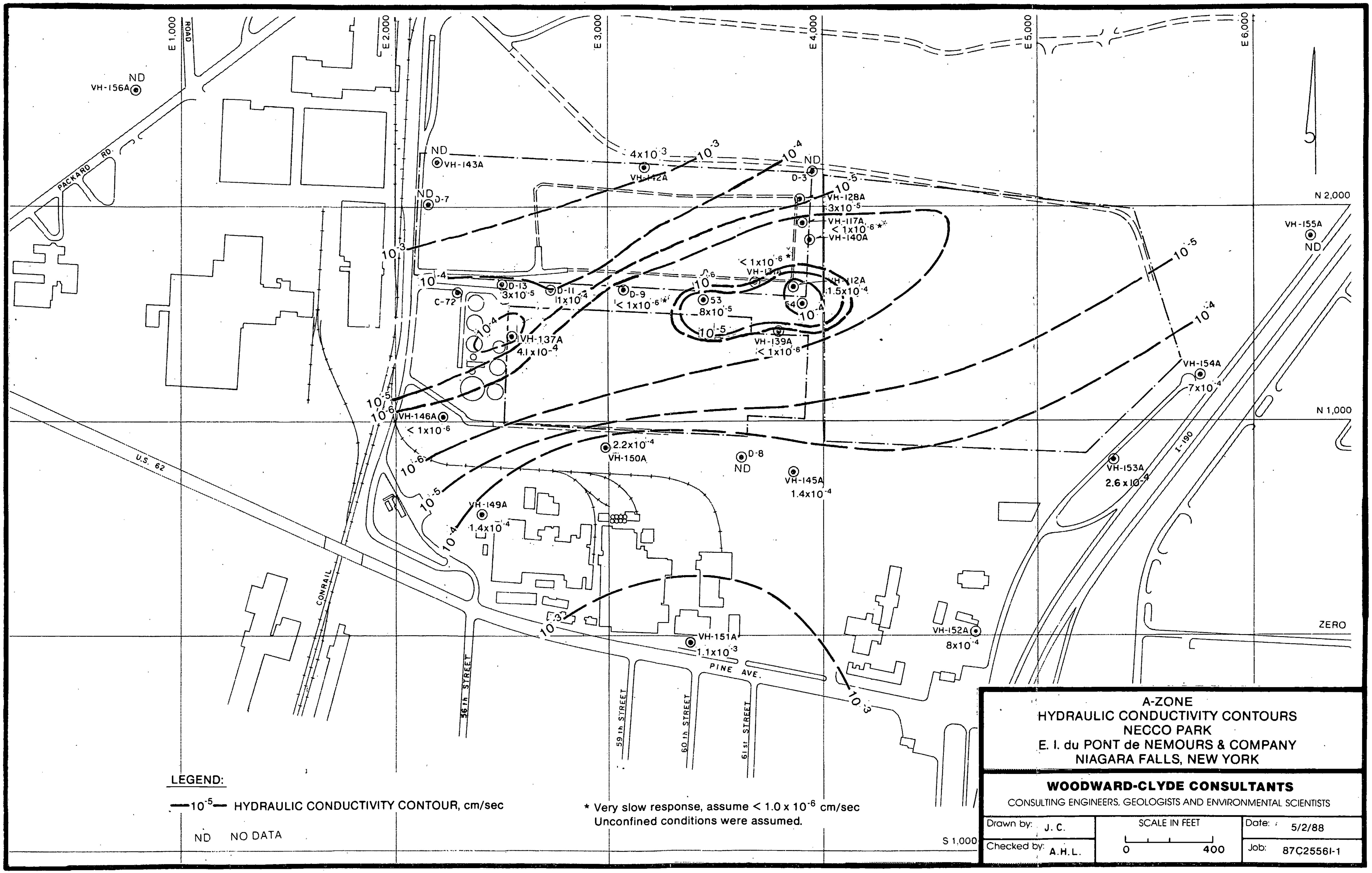

A-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
10⁻⁵ HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
ND NO DATA
* Very slow response, assume < 1.0 x 10⁻⁶ cm/sec
Unconfined conditions were assumed.
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
VH-156A ND
VH-143A ND
D-7 ND
VH-142A 4x10⁻³
D-3 ND
VH-128A 3x10⁻⁵
VH-117A < 1x10⁻⁶ *
VH-140A
VH-155A ND
VH-134A < 1x10⁻⁶ *
VH-112A 1.5x10⁻⁴
D-13 3x10⁻⁵
D-11 1x10⁻⁴
D-9 < 1x10⁻⁶ *
53 8x10⁻⁵
54 10⁻⁴
C-72
VH-137A 4.1x10⁻⁴
VH-139A < 1x10⁻⁶
VH-154A 7x10⁻⁴
VH-146A < 1x10⁻⁶
VH-150A 2.2x10⁻⁴
D-8 ND
VH-145A 1.4x10⁻⁴
VH-153A 2.6x10⁻⁴
VH-149A 1.4x10⁻⁴
VH-151A 1.1x10⁻³
VH-152A 8x10⁻⁴
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶

FIGURE 39

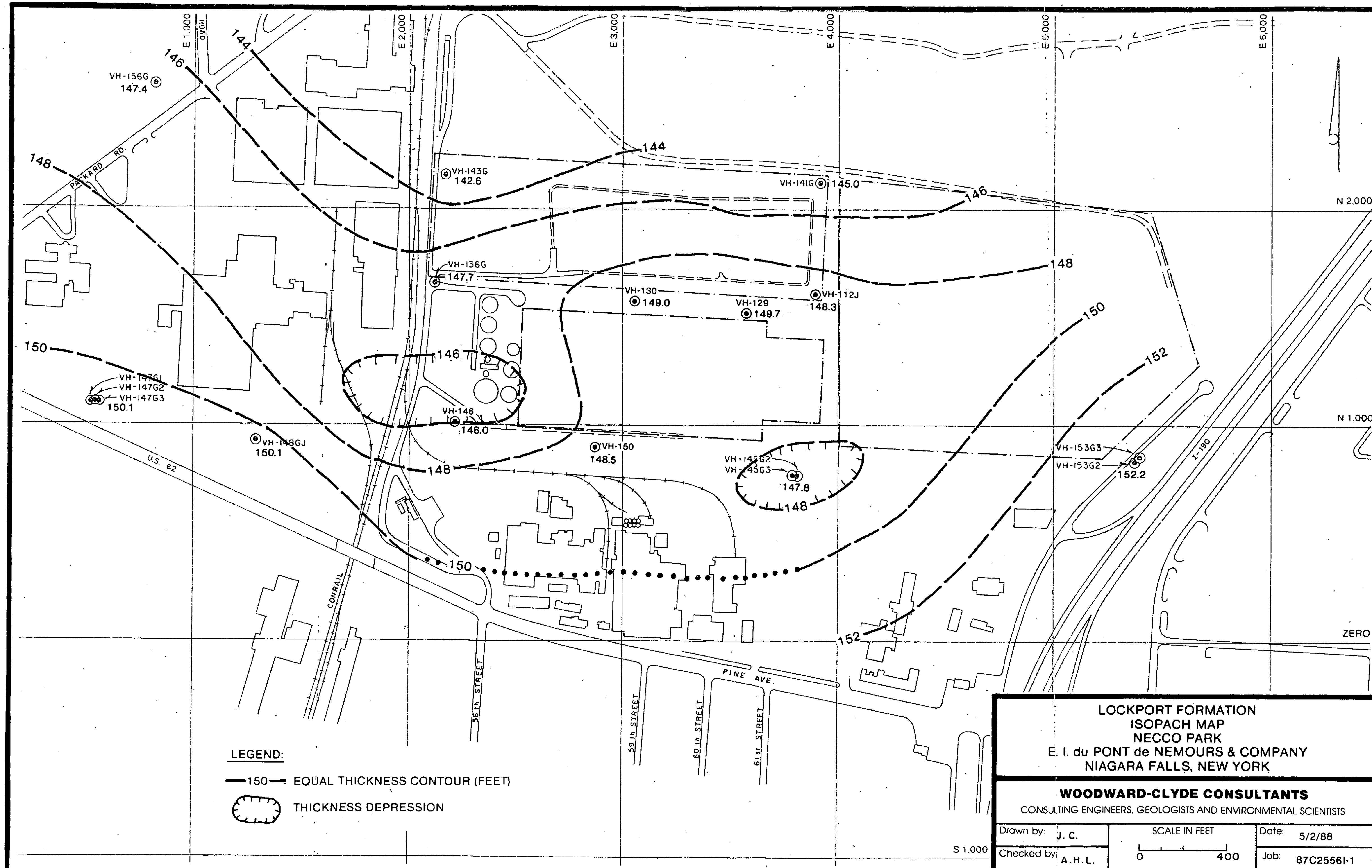
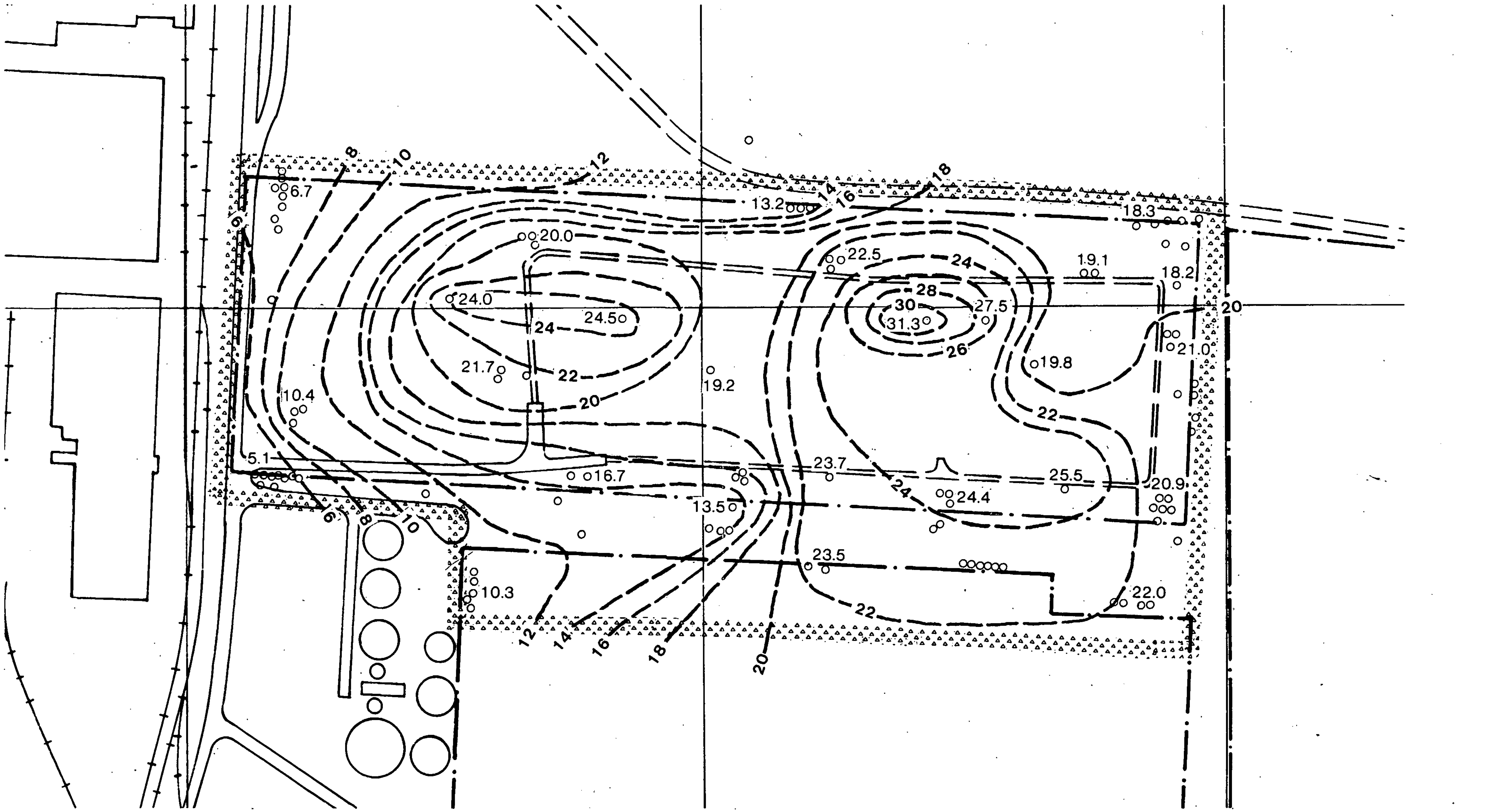

LOCKPORT FORMATION
ISOPACH MAP
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
150 EQUAL THICKNESS CONTOUR (FEET)
THICKNESS DEPRESSION
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
VH-156G 147.4
VH-143G 142.6
VH-141G 145.0
VH-136G 147.7
VH-130 149.0
VH-129 149.7
VH-112J 148.3
VH-147G1
VH-147G2
VH-147G3
150.1
VH-146 146.0
VH-148GJ 150.1
VH-150 148.5
VH-145G2
VH-145G3
147.8
VH-153G3
VH-153G2
152.2
144
146
148
150
152

FIGURE 38.



LEGEND:

—10— ISOPACH CONTOUR (FEET)

o MONITORING LOCATION (See Monitoring Well Location Plan for well designations).

OVERBURDEN
ISOPACH MAP
NECCO PARK AND IMMEDIATE VICINITY
E. I. du PONT de NEMOURS & COMPANY

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET 0 200	Date: 5/2/88
Checked by: A.H.L.		Job: 87C25561-1

FIGURE 37

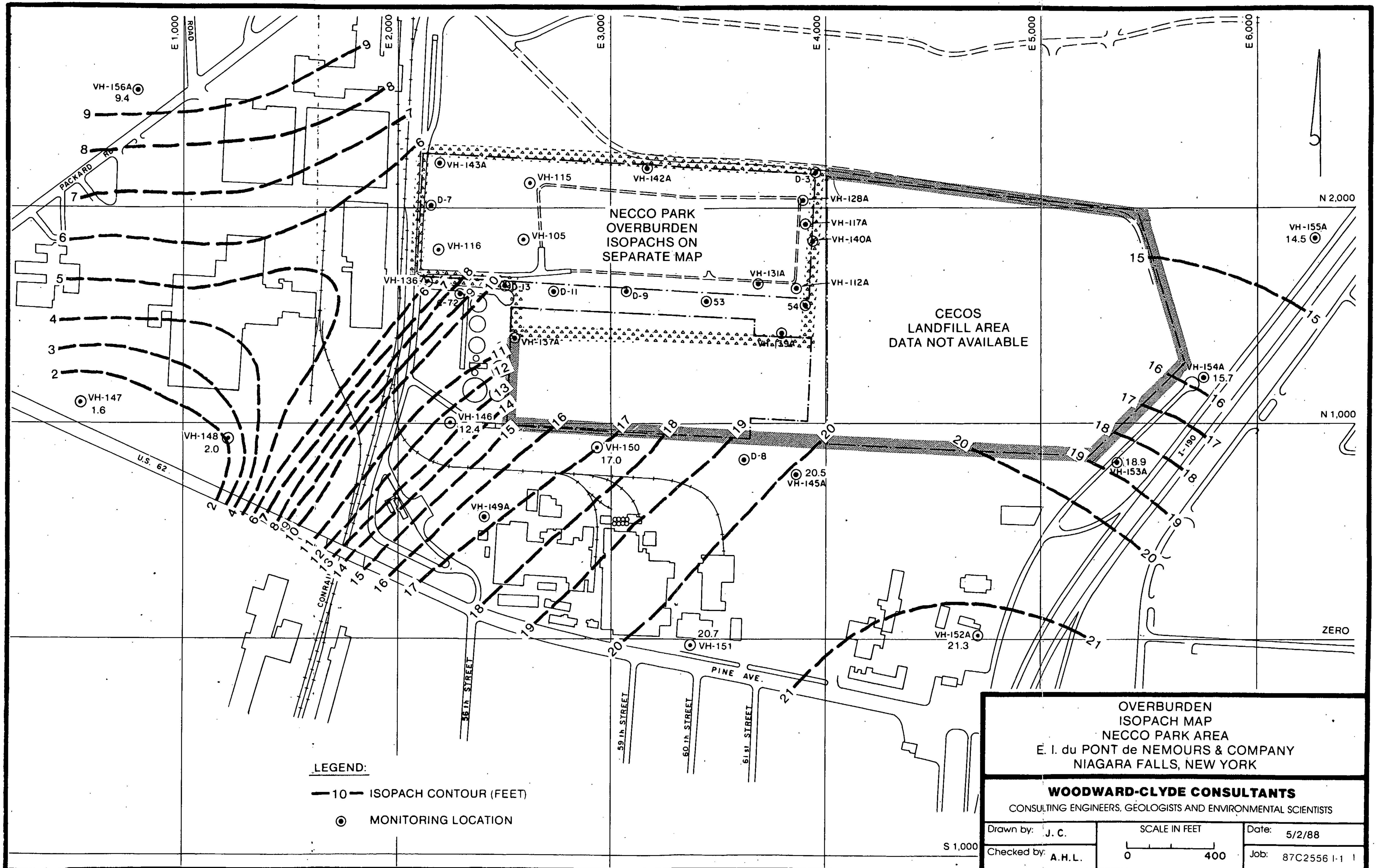

NECCO PARK OVERBURDEN ISOPACHS ON SEPARATE MAP
CECOS LANDFILL AREA DATA NOT AVAILABLE
LEGEND:
—10— ISOPACH CONTOUR (FEET)
MONITORING LOCATION
OVERBURDEN ISOPACH MAP NECCO PARK AREA
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1

FIGURE 36

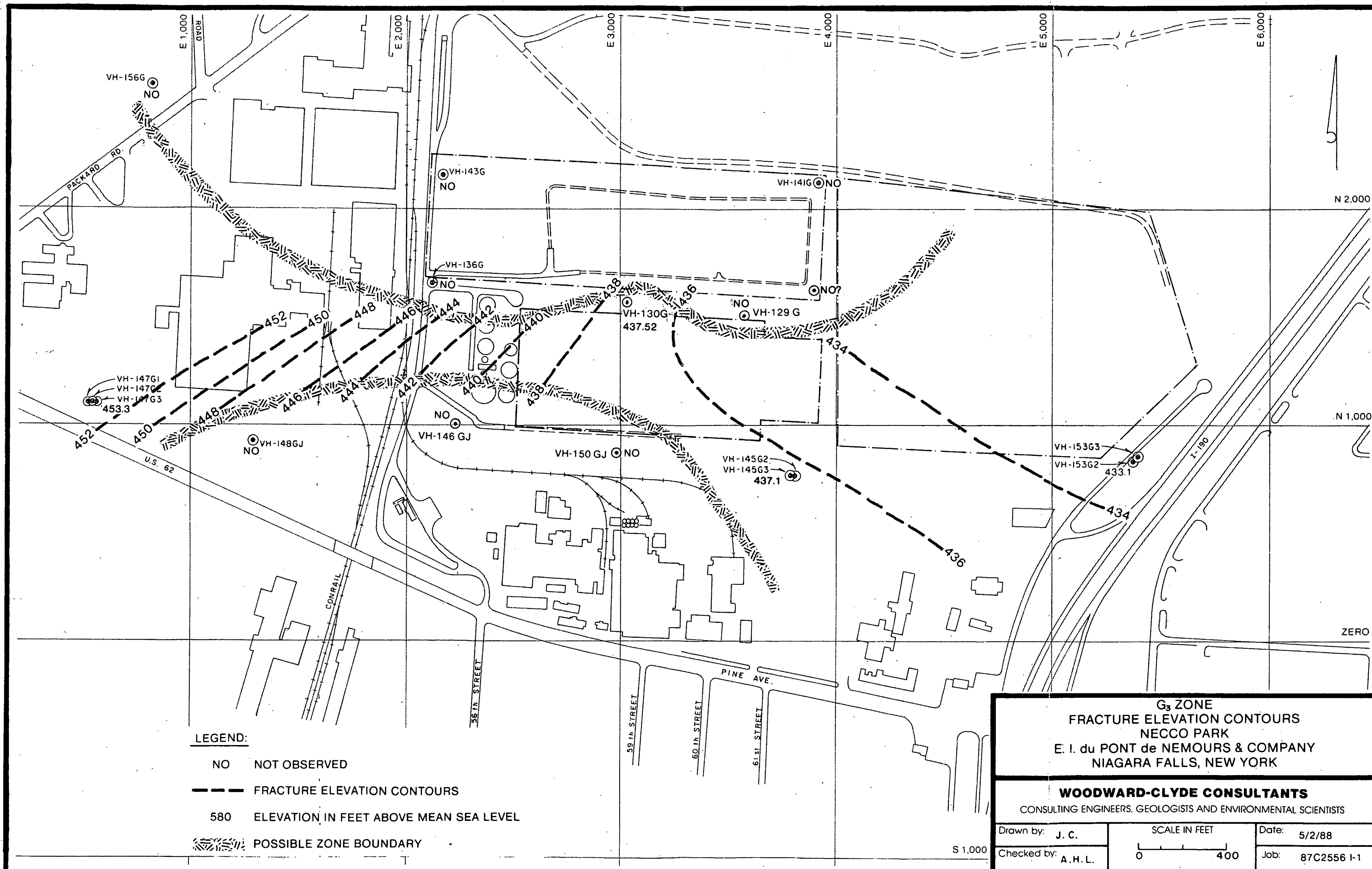

G3 ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
NO NOT OBSERVED
FRACTURE ELEVATION CONTOURS
580 ELEVATION IN FEET ABOVE MEAN SEA LEVEL
POSSIBLE ZONE BOUNDARY
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190
VH-156G NO
VH-143G NO
VH-141G NO
VH-136G NO
NO?
VH-130G 437.52
NO VH-129 G
VH-147G1
VH-147G2
VH-147G3
453.3
VH-148GJ NO
NO VH-146 GJ
VH-150 GJ NO
VH-145G2
VH-145G3
437.1
VH-153G3
VH-153G2
433.1
452
450
448
446
444
442
440
438
436
434

FIGURE 35

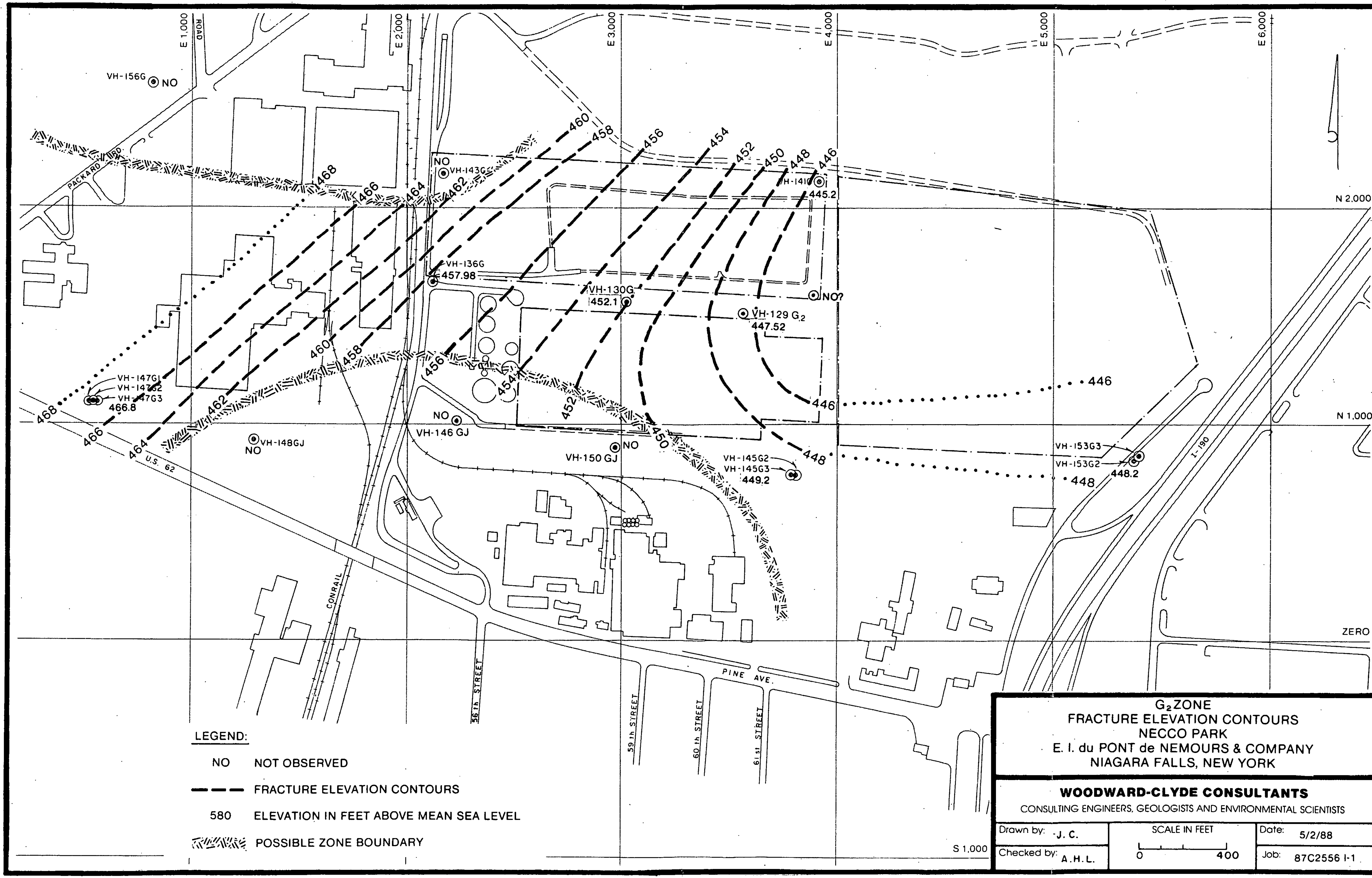
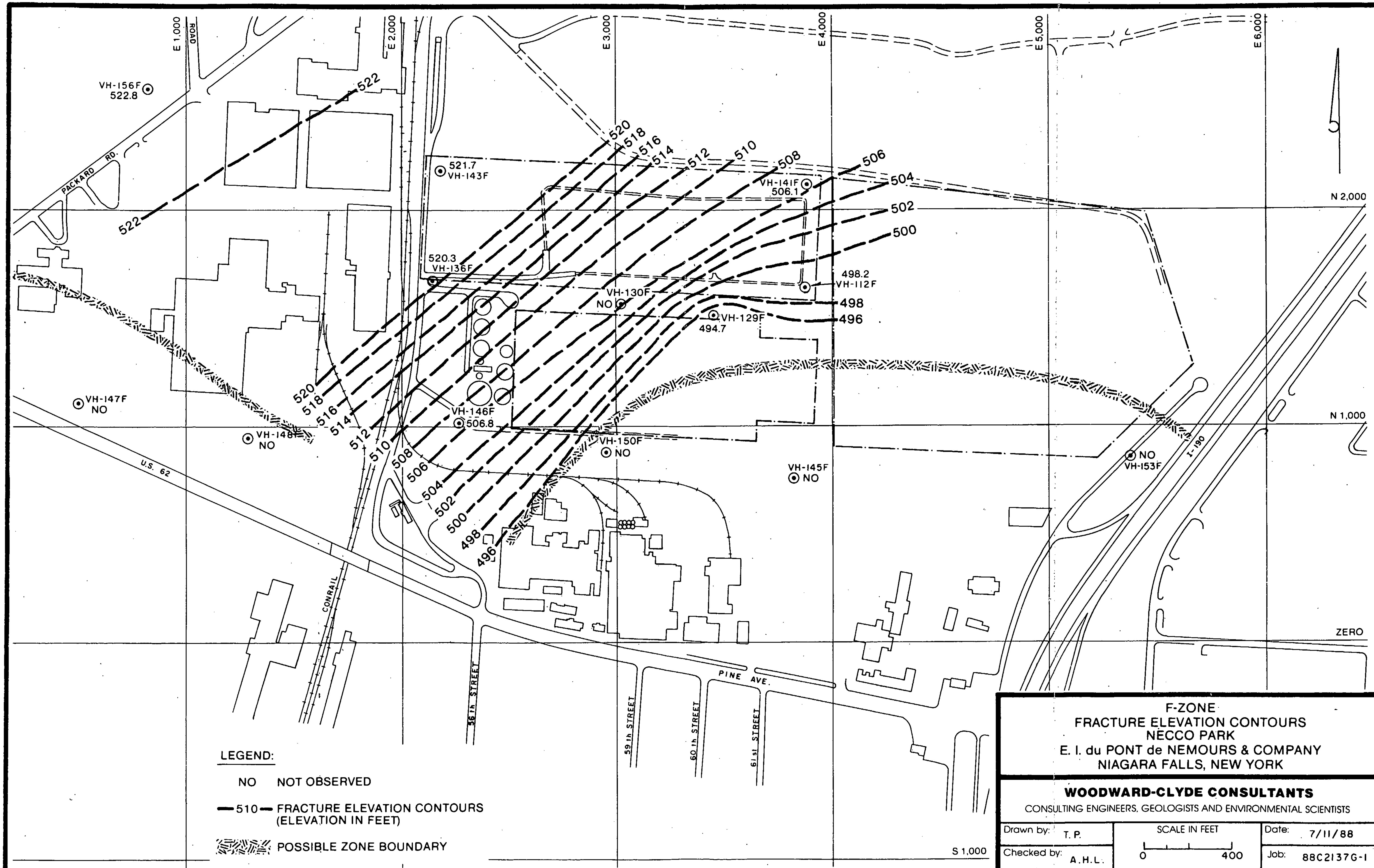

G2 ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
NO NOT OBSERVED
FRACTURE ELEVATION CONTOURS
580 ELEVATION IN FEET ABOVE MEAN SEA LEVEL
POSSIBLE ZONE BOUNDARY
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
PINE AVE.
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
I-190
VH-156G NO
VH-143G NO
VH-141G 445.2
VH-136G 457.98
VH-130G 452.1
NO?
VH-129 G2 447.52
VH-147G1
VH-147G2
VH-147G3
466.8
VH-146 GJ NO
VH-148GJ NO
VH-150 GJ NO
VH-145G2
VH-145G3
449.2
VH-153G3
VH-153G2
448.2
468
466
464
462
460
458
456
454
452
450
448
446

FIGURE 34



F-ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: T. P.	SCALE IN FEET 0 — 400	Date: 7/11/88
Checked by: A.H.L.		Job: 88C2137G-1

FIGURE 33

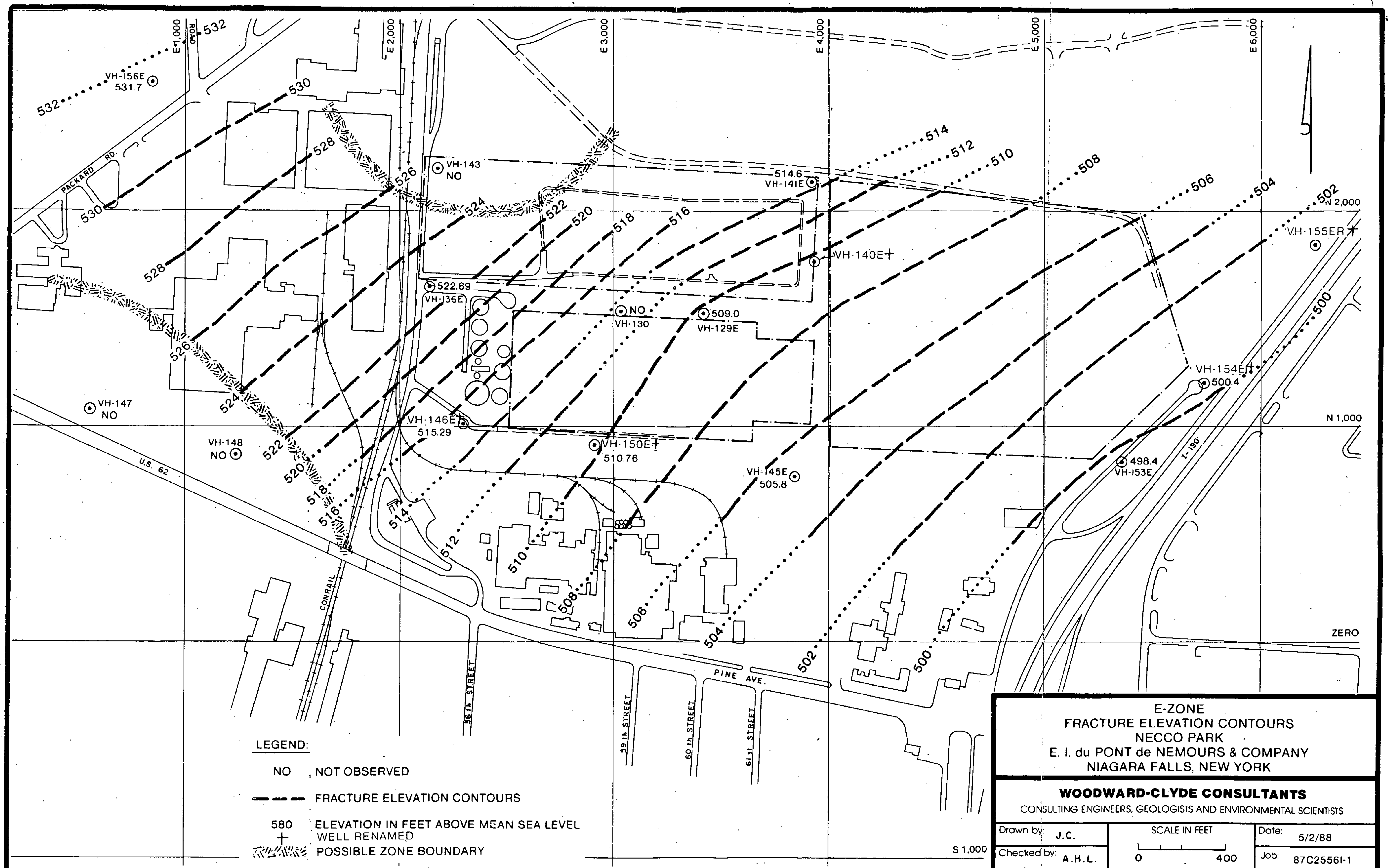
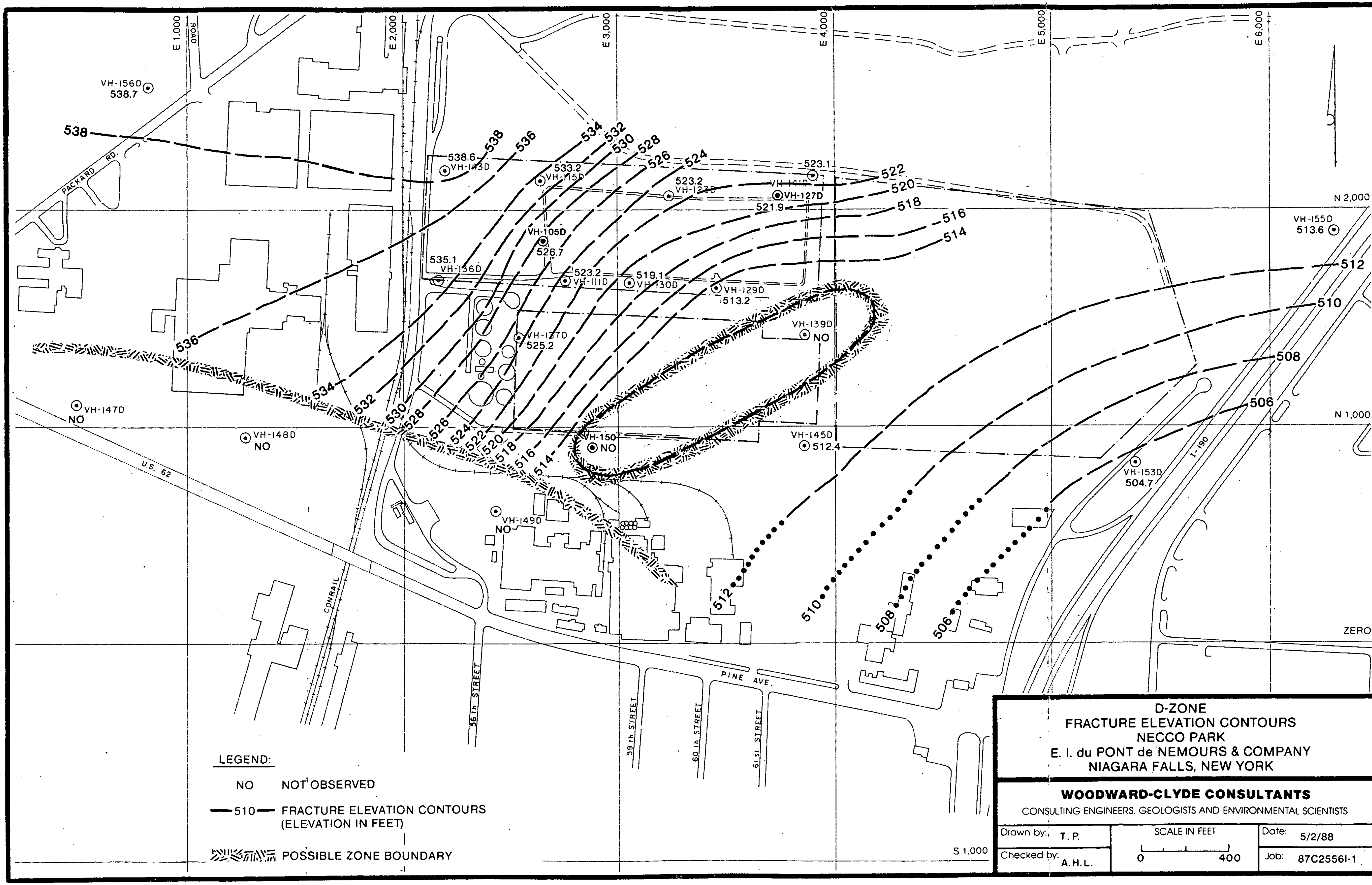
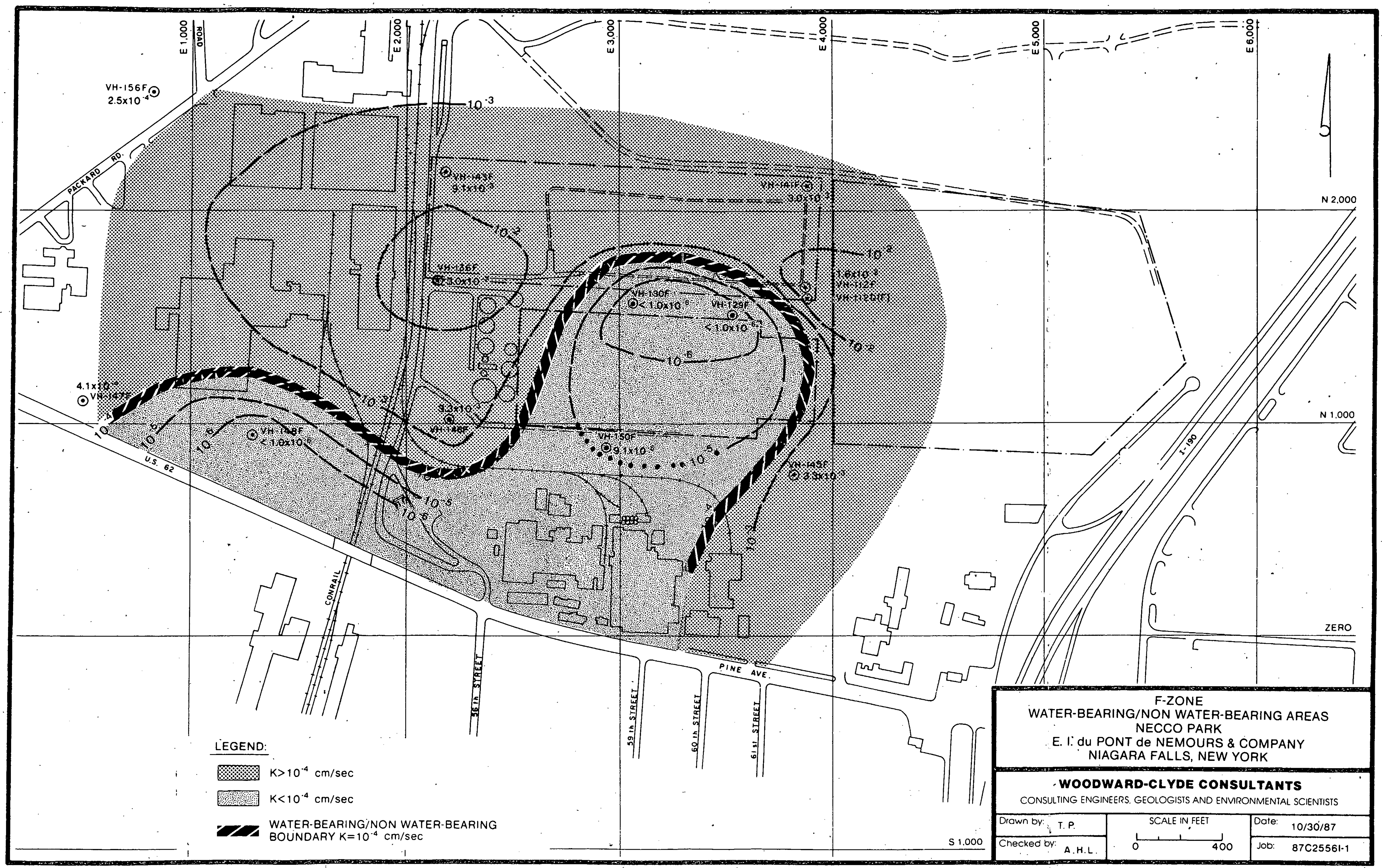

E-ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J.C.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
NO NOT OBSERVED
FRACTURE ELEVATION CONTOURS
580 ELEVATION IN FEET ABOVE MEAN SEA LEVEL
WELL RENAMED
POSSIBLE ZONE BOUNDARY
VH-156E 531.7
VH-143 NO
514.6 VH-141E
VH-140E
522.69 VH-136E
NO VH-130
509.0 VH-129E
VH-155ER
VH-154E
500.4
VH-147 NO
VH-148 NO
VH-146E 515.29
VH-150E 510.76
VH-145E 505.8
498.4 VH-153E
PACKARD RD.
ROAD
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
532
530
528
526
524
522
520
518
516
514
512
510
508
506
504
502
500

FIGURE 32


D-ZONE
FRACTURE ELEVATION CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A. H. L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
NO NOT OBSERVED
510 FRACTURE ELEVATION CONTOURS (ELEVATION IN FEET)
POSSIBLE ZONE BOUNDARY
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
PINE AVE.
56 th STREET
59 th STREET
60 th STREET
61 st STREET
I-190
VH-156D 538.7
538.6 VH-143D
533.2 VH-115D
523.2 VH-123D
523.1
VH-141D
VH-127D
521.9
VH-105D 526.7
535.1 VH-136D
523.2 VH-111D
519.1 VH-130D
VH-129D 513.2
VH-139D NO
VH-137D 525.2
VH-147D NO
VH-148D NO
VH-150 NO
VH-145D 512.4
VH-155D 513.6
VH-153D 504.7
VH-149D NO
538
536
534
532
530
528
526
524
522
520
518
516
514
512
510
508
506
FIGURE 31



E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
56 th STREET
59 th STREET
60 th STREET
61 st STREET
PINE AVE.
I-190
VH-156F
2.5x10-4
VH-143F
9.1x10-3
VH-141F
3.0x10-3
VH-136F
3.0x10-3
VH-190F
< 1.0x10-6
VH-129F
< 1.0x10-6
1.6x10-3
VH-112F
VH-112D(F)
4.1x10-4
VH-147F
3.3x10-3
VH-148F
VH-149F
< 1.0x10-6
VH-150F
9.1x10-6
VH-145F
3.3x10-3
LEGEND:
K>10-4 cm/sec
K<10-4 cm/sec
WATER-BEARING/NON WATER-BEARING
BOUNDARY K=10-4 cm/sec
F-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 10/30/87
Job: 87C25561-1

FIGURE 50

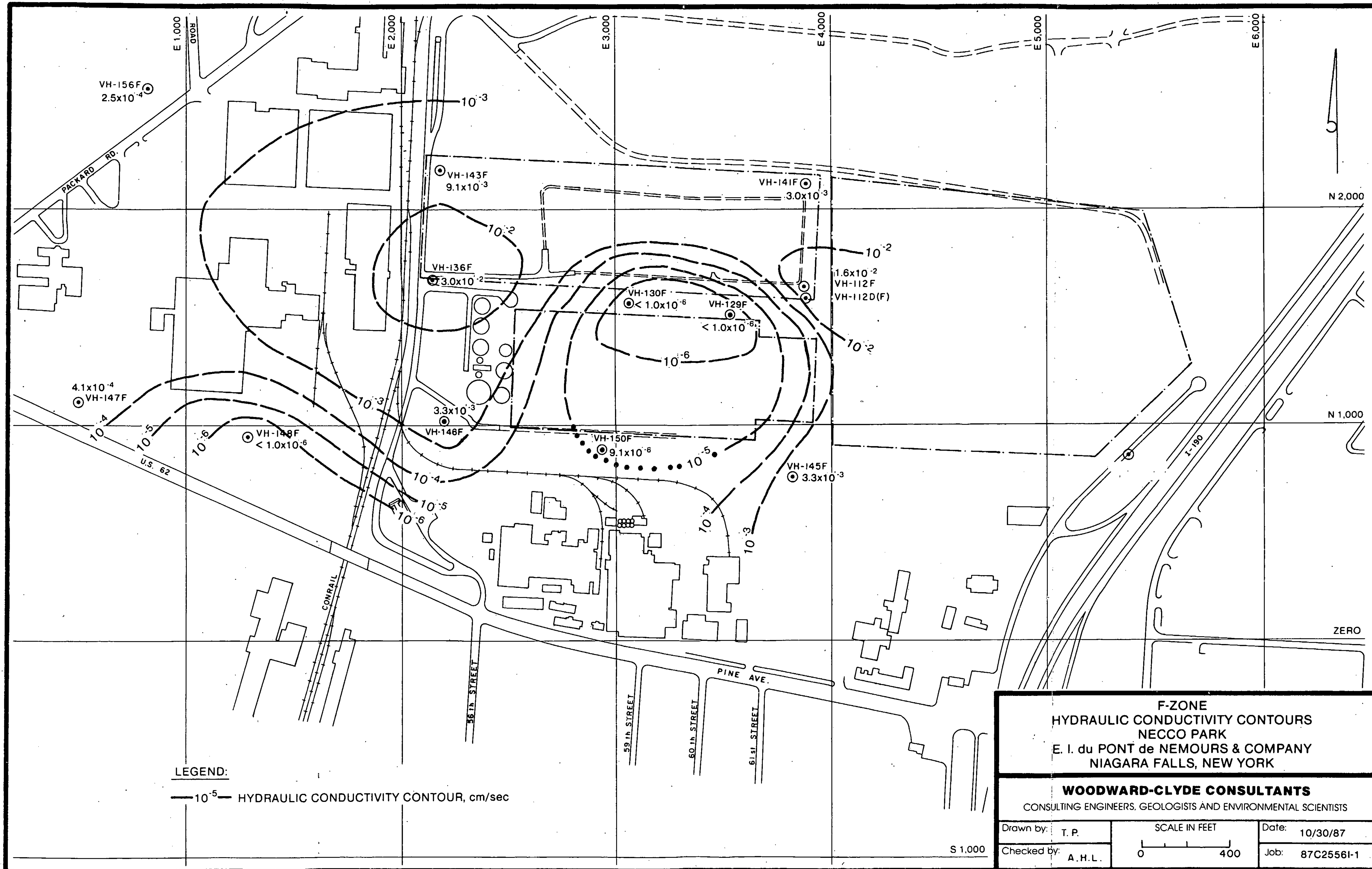
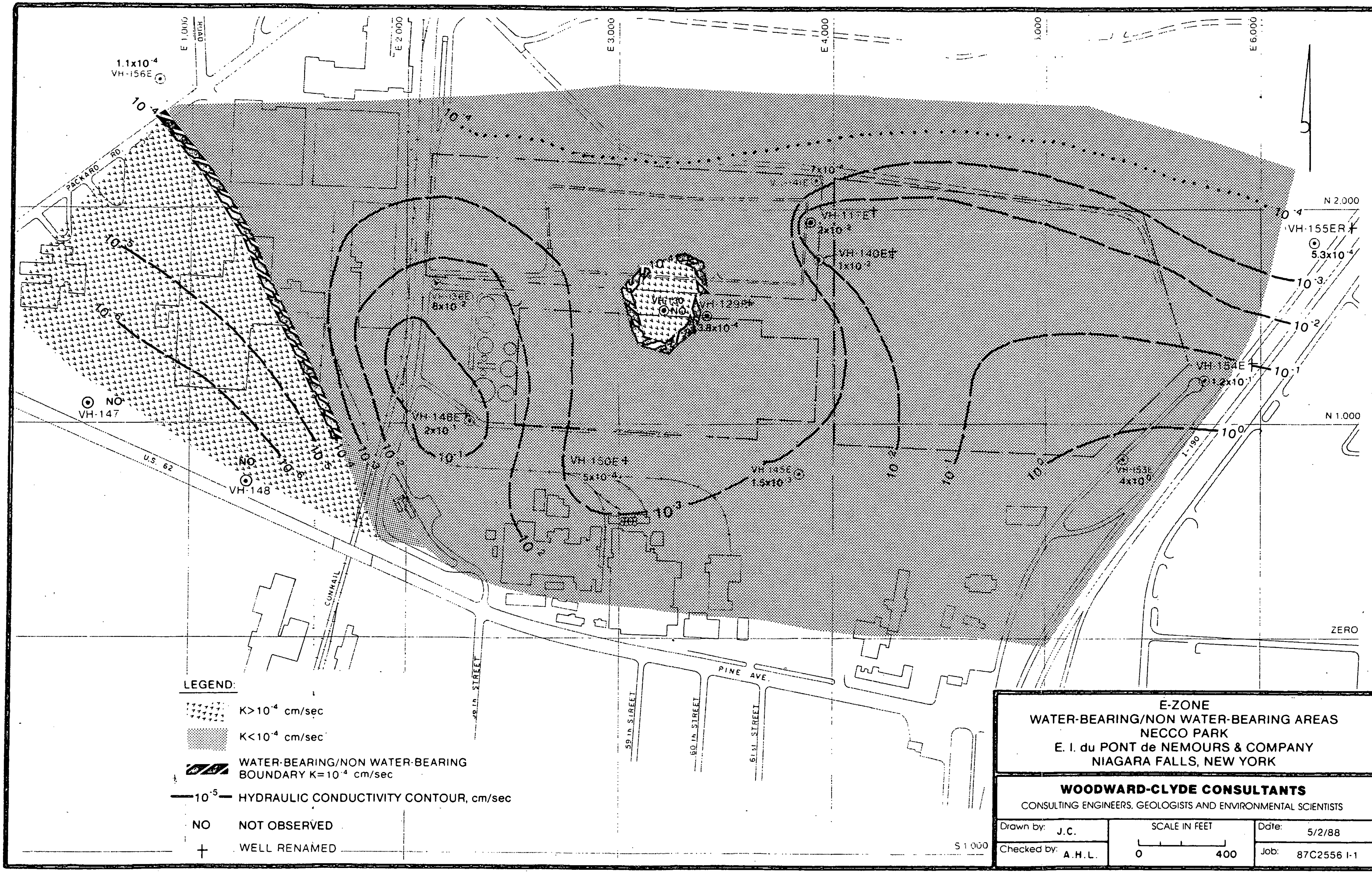
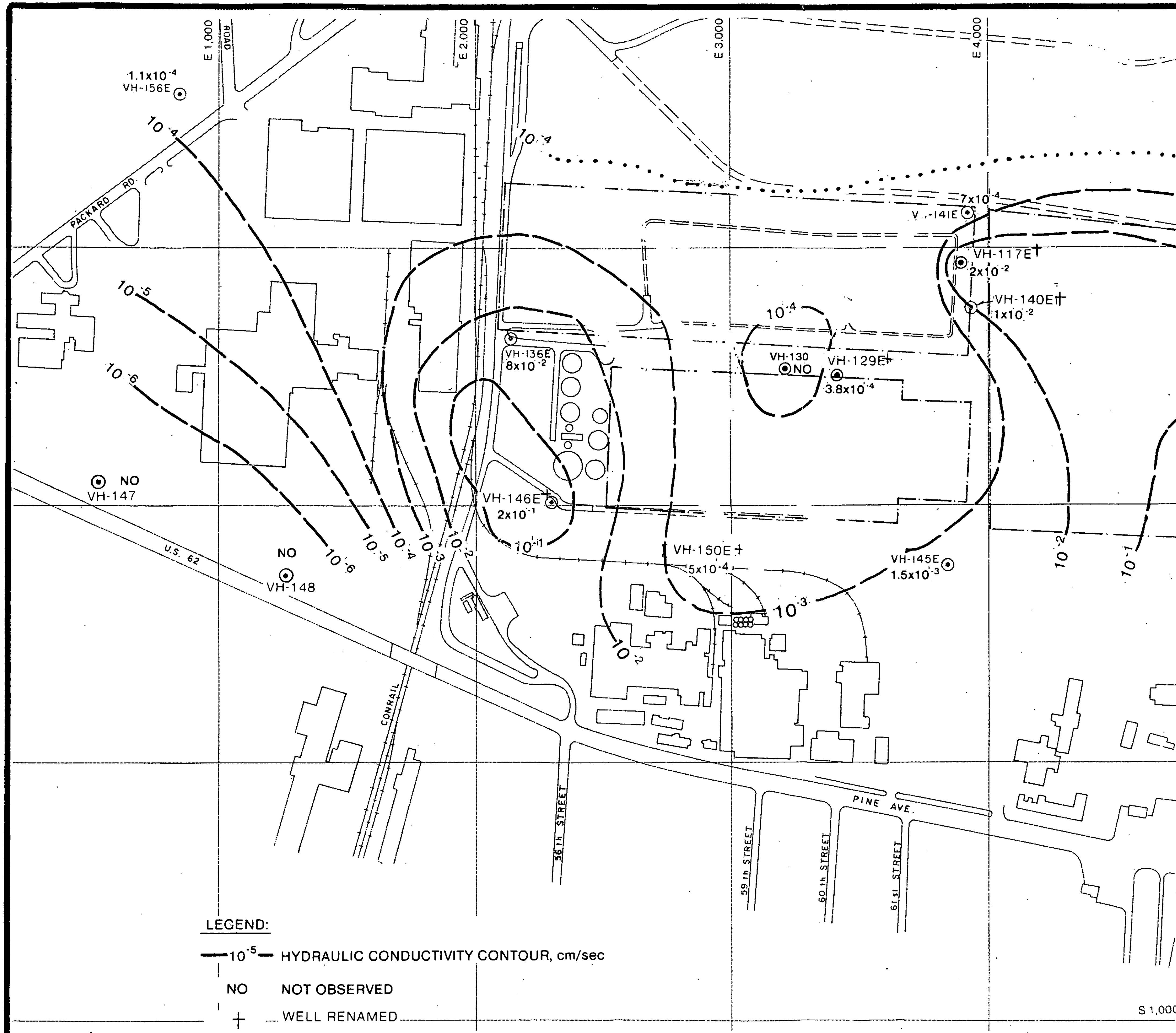

F-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 10/30/87
Job: 87C25561-1
LEGEND:
10⁻⁵ HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
VH-156F 2.5x10⁻⁴
VH-143F 9.1x10⁻³
VH-141F 3.0x10⁻³
VH-136F 3.0x10⁻²
VH-130F < 1.0x10⁻⁶
VH-129F < 1.0x10⁻⁶
1.6x10⁻² VH-112F
VH-112D(F)
4.1x10⁻⁴ VH-147F
3.3x10⁻³ VH-146F
VH-148F < 1.0x10⁻⁶
VH-150F 9.1x10⁻⁶
VH-145F 3.3x10⁻³
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190

FIGURE 49



LEGEND:
K>10⁻⁴ cm/sec
K<10⁻⁴ cm/sec
WATER-BEARING/NON WATER-BEARING BOUNDARY K=10⁻⁴ cm/sec
10⁻⁵ HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
NO NOT OBSERVED
+ WELL RENAMED
E-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J.C.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1
PACKARD RD.
U.S. 62
PINE AVE.
CONRAIL
59 th STREET
60 th STREET
61 st STREET
I-190
N 2,000
N 1,000
ZERO
S 1,000
E 1,000
E 2,000
E 3,000
E 4,000
E 6,000
VH-156E 1.1x10⁻⁴
VH-147 NO
VH-148 NO
VH-117E 2x10⁻²
VH-140E 1x10⁻²
VH-130 NO
VH-129E 3.8x10⁻⁴
VH-148E 2x10⁻¹
VH-150E 5x10⁻⁴
VH-145E 1.5x10⁻³
VH-155ER 5.3x10⁻⁴
VH-154E 1.2x10⁻¹
VH-153E 4x10⁰

FIGURE 48



E-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J.C.	SCALE IN FEET 0 400	Date: 5/2/88
Checked by: A.H.L.		Job: 87C2556 I-1

FIGURE 47

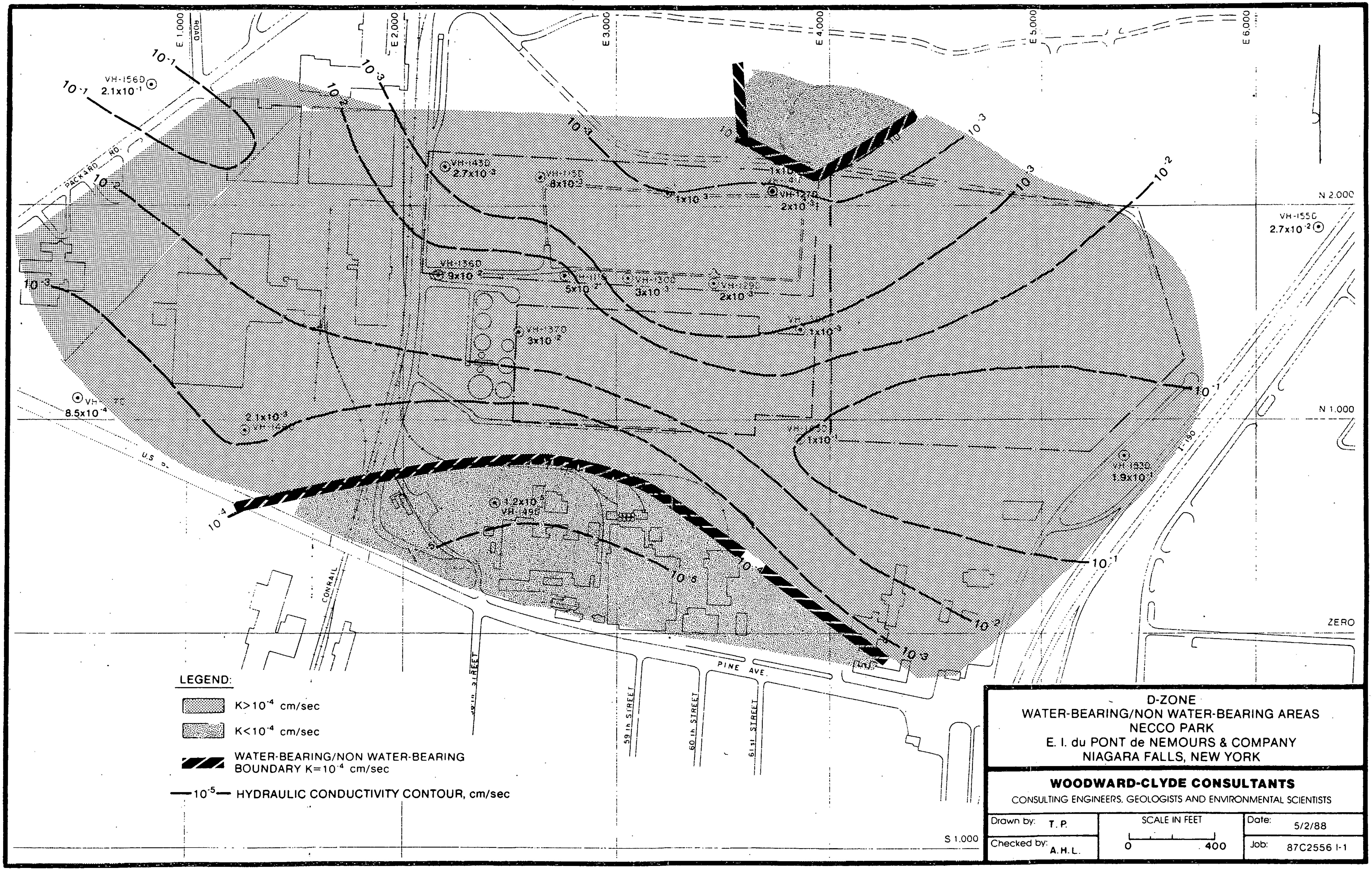
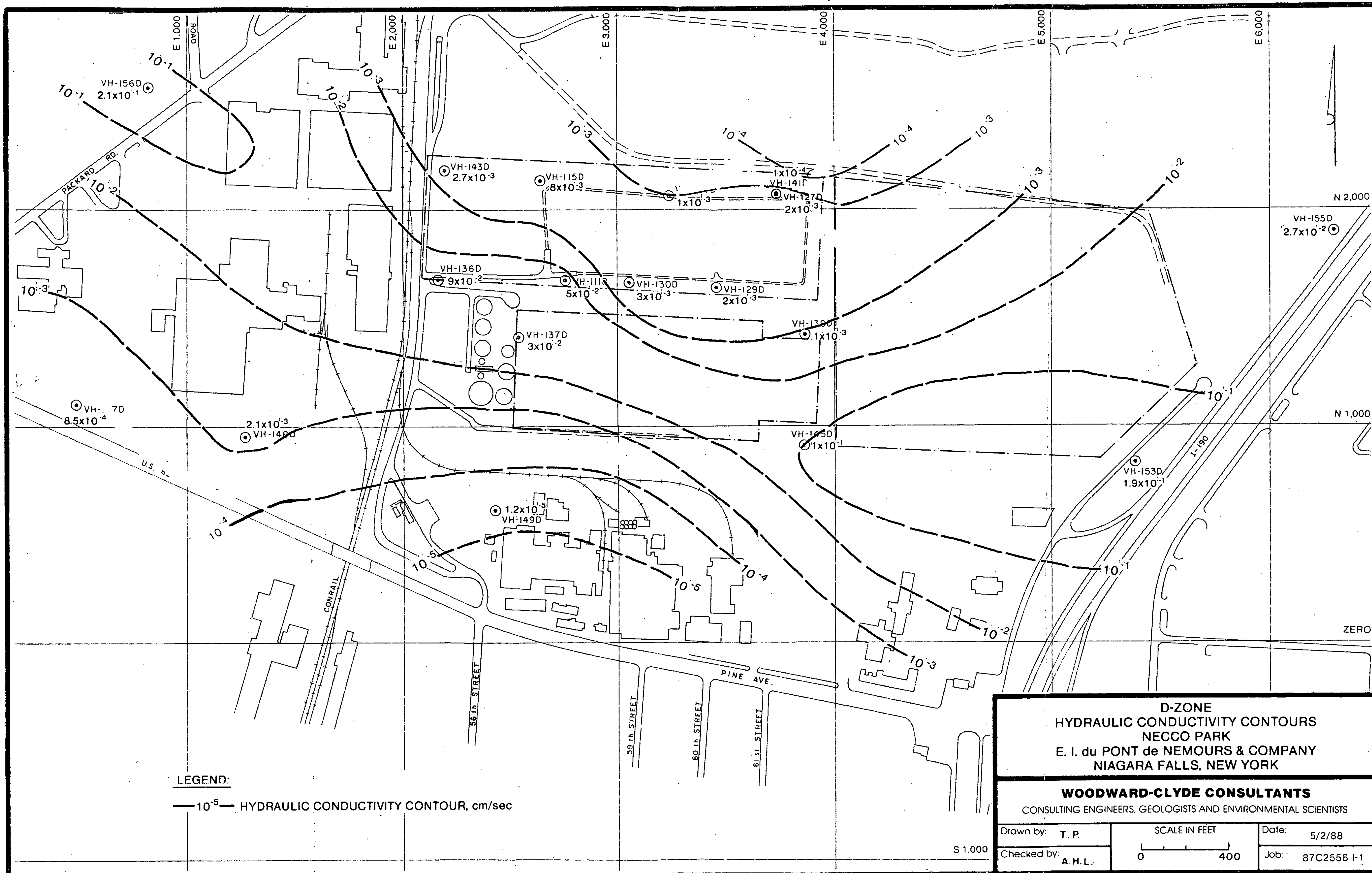

D-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
K>10-4 cm/sec
K<10-4 cm/sec
WATER-BEARING/NON WATER-BEARING BOUNDARY K=10-4 cm/sec
—10-5— HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
CONRAIL
PINE AVE.
59th STREET
60th STREET
61st STREET
I-190
VH-156D 2.1x10-1
VH-143D 2.7x10-3
VH-127D 2x10-3
VH-136D 9x10-2
VH-130D 3x10-3
VH-137D 3x10-2
VH-155D 2.7x10-2
VH-193D 1.9x10-1
VH-149D 1.2x10-5
8.5x10-4
2.1x10-3
1x10-3
1x10-1
5x10-2
2x10-3
.8x10-3

FIGURE 46



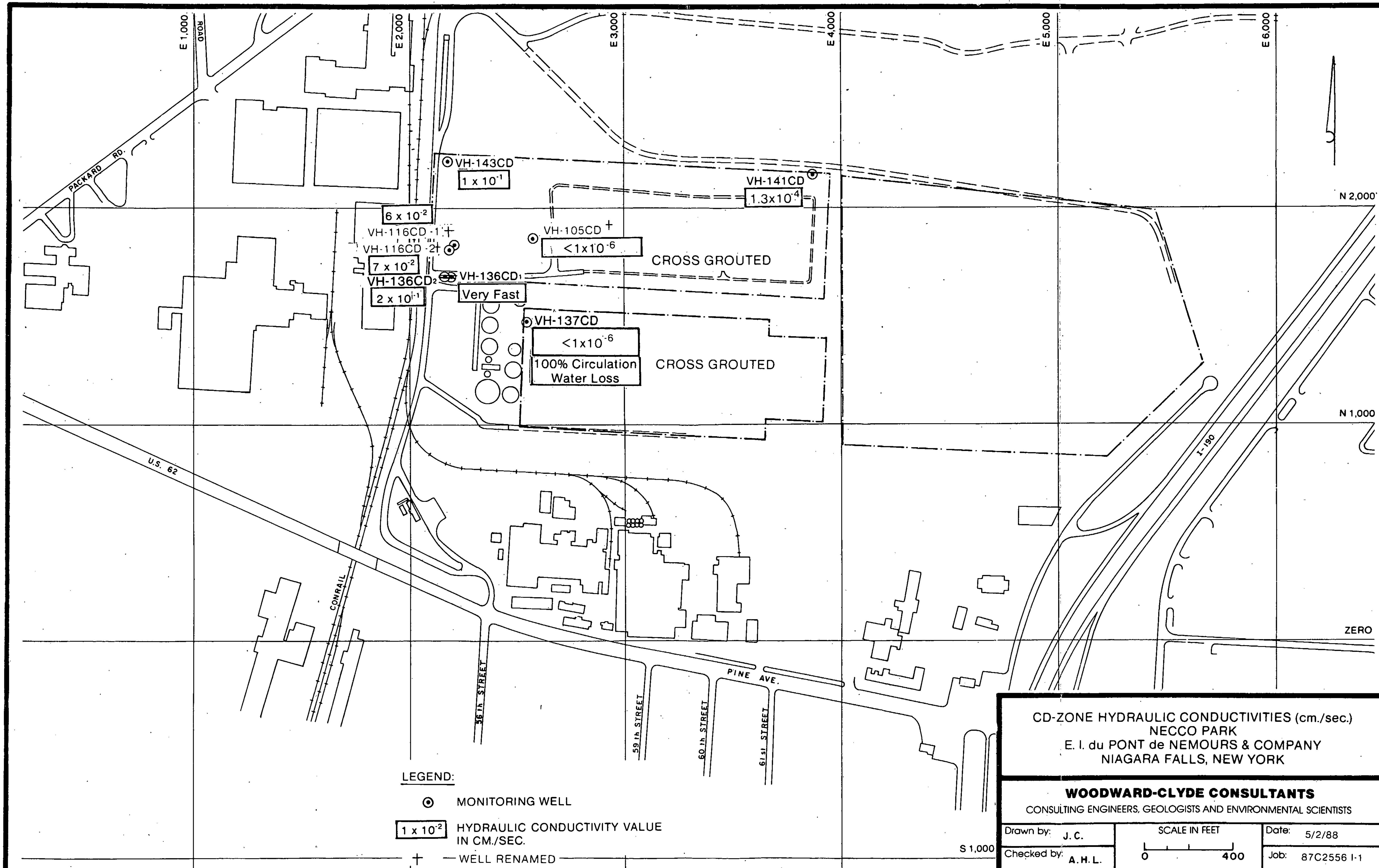
D-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: T. P.	SCALE IN FEET	Date: 5/2/88
Checked by: A. H. L.	0 400	Job: 87C2556 I-1

FIGURE 45



E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190
VH-143CD
1 x 10-1
VH-141CD
1.3x10-4
6 x 10-2
VH-116CD-1
VH-116CD-2
7 x 10-2
VH-105CD
<1x10-6
CROSS GROUTED
VH-136CD2
2 x 10-1
VH-136CD1
Very Fast
VH-137CD
<1x10-6
100% Circulation Water Loss
CROSS GROUTED
LEGEND:
MONITORING WELL
1 x 10-2 HYDRAULIC CONDUCTIVITY VALUE IN CM./SEC.
WELL RENAMED
CD-ZONE HYDRAULIC CONDUCTIVITIES (cm./sec.)
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
SCALE IN FEET
0 400
Date: 5/2/88
Checked by: A.H.L.
Job: 87C2556 I-1

FIGURE 44

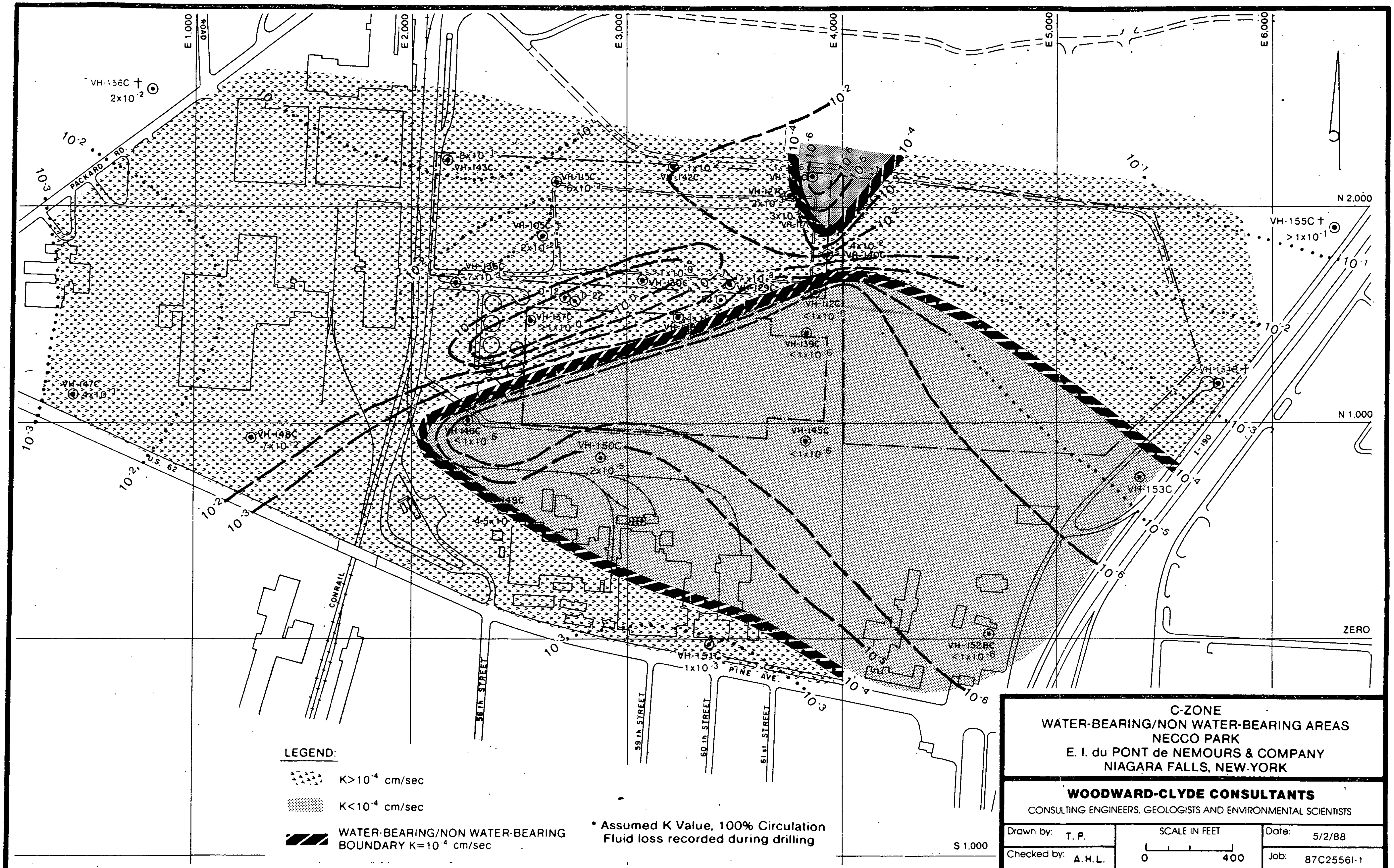

C-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
K>10^-4 cm/sec
K<10^-4 cm/sec
WATER-BEARING/NON WATER-BEARING BOUNDARY K=10^-4 cm/sec
* Assumed K Value, 100% Circulation Fluid loss recorded during drilling
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
I-190
VH-156C
2x10^-2
VH-143C
8x10^-3
VH-115C
VH-105C
2x10^-2
VH-142C
1x10^-3
VH-155C
>1x10^-1
VH-140C
4x10^-2
VH-136C
VH-130C
VH-129C
VH-112C
<1x10^-6
VH-137C
VH-139C
<1x10^-6
VH-147C
4x10^-3
VH-148C
7x10^-2
VH-146C
<1x10^-6
VH-145C
<1x10^-6
VH-150C
2x10^-5
VH-153C
VH-149C
VH-151C
1x10^-3
VH-152BC
<1x10^-6

FIGURE 43

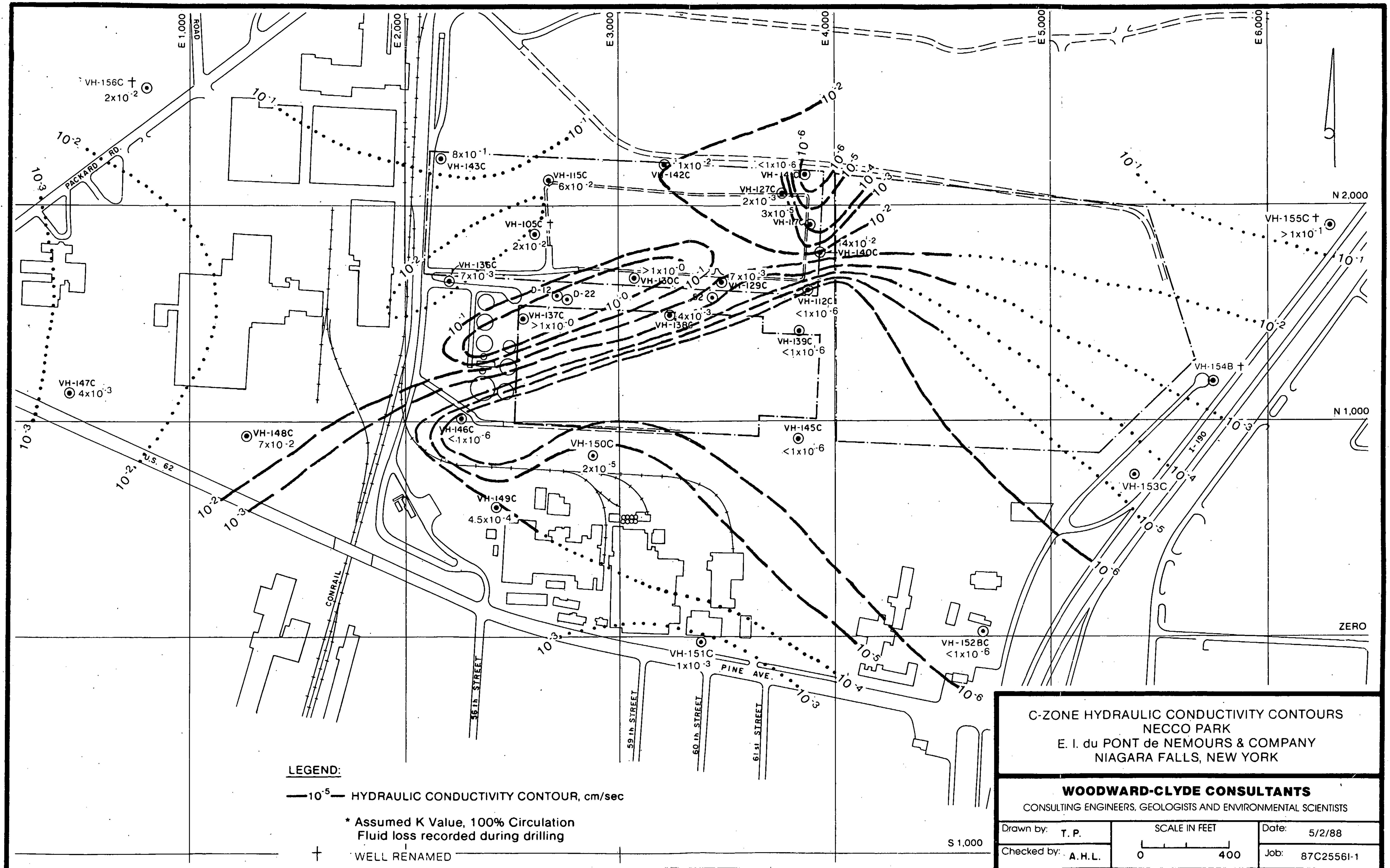

C-ZONE HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C25561-1
LEGEND:
—10^-5— HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
* Assumed K Value, 100% Circulation Fluid loss recorded during drilling
+ WELL RENAMED
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
VH-156C
VH-143C
VH-142C
VH-115C
VH-127C
VH-105C
VH-117C
VH-140C
VH-135C
VH-130C
VH-129C
VH-112C
VH-137C
VH-138C
VH-139C
VH-147C
VH-148C
VH-146C
VH-150C
VH-145C
VH-149C
VH-151C
VH-152BC
VH-153C
VH-154B
VH-155C
D-12
D-22
B2

FIGURE 42

LEGEND:

K>10-4 cm/sec

K<10-4 cm/sec

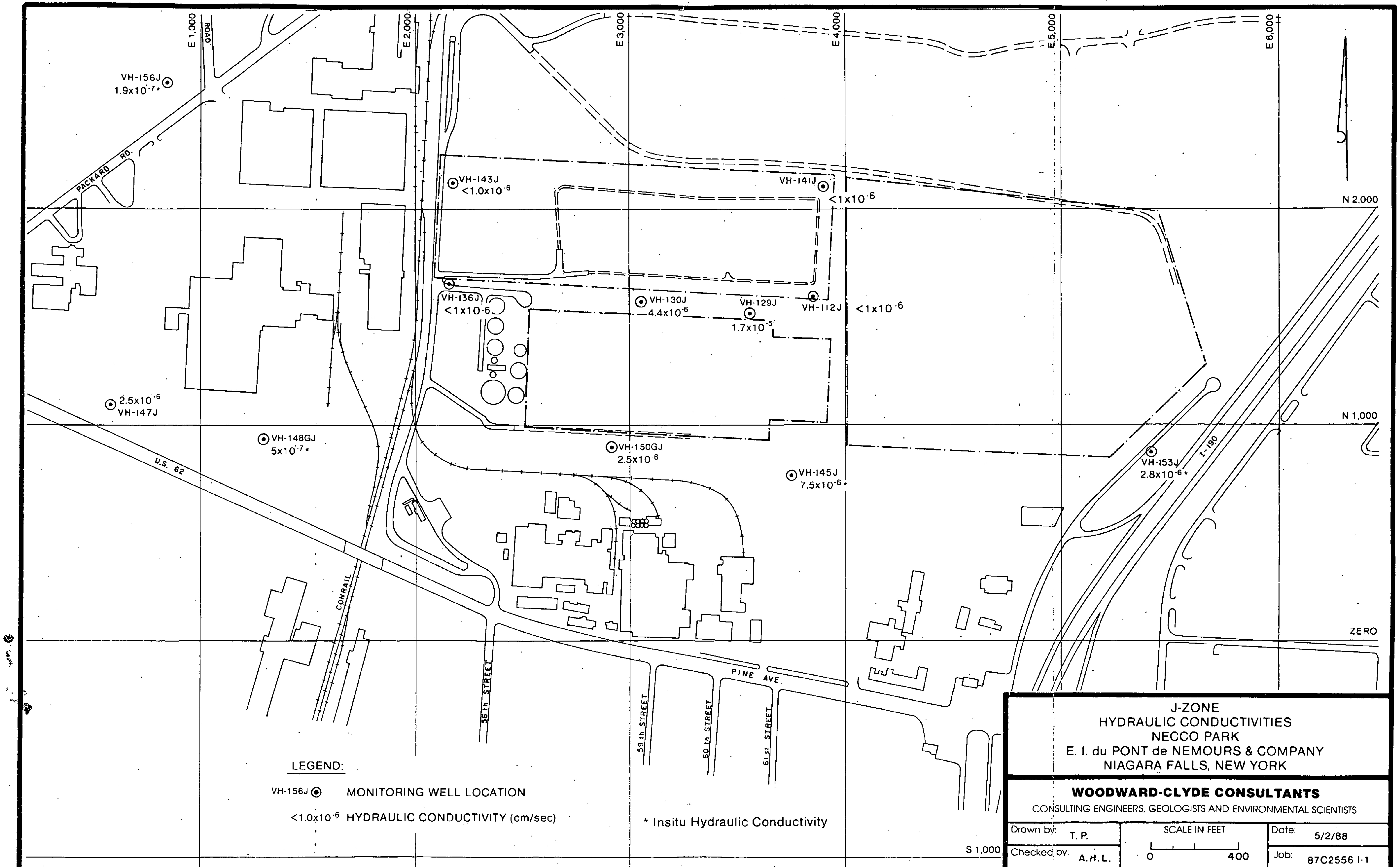
WATER-BEARING/NON WATER-BEARING BOUNDARY K=10-4 cm/sec

B-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

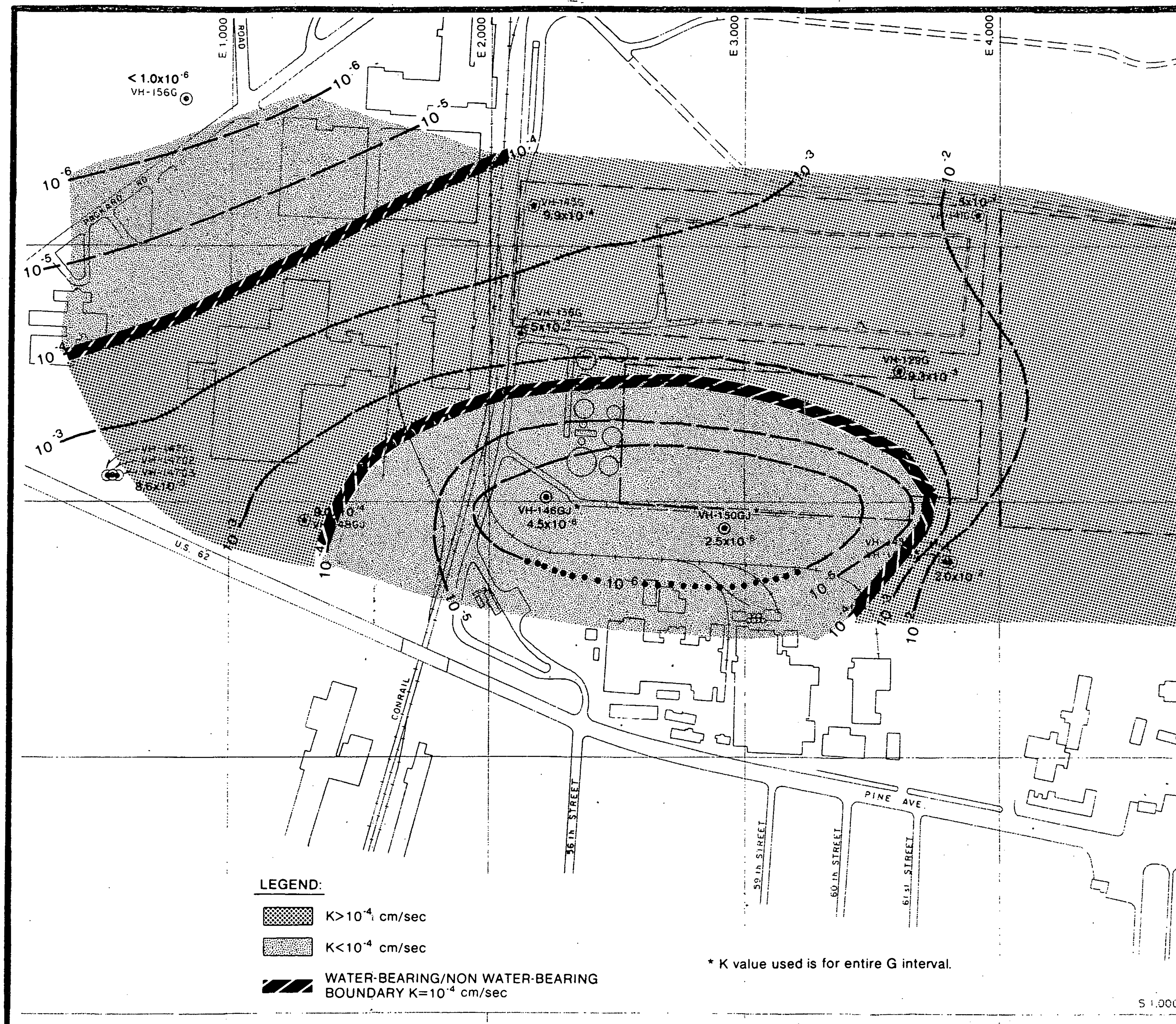
Drawn by: J. C.	SCALE IN FEET	Date:	10/30/87
Checked by: A.H.L.	0 400	Job:	87C25561-1

FIGURE 41



E 1,000
ROAD
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
U.S. 62
CONRAIL
56 th STREET
59 th STREET
60 th STREET
61 st STREET
PINE AVE.
I-190
VH-156J
1.9x10-7*
VH-143J
<1.0x10-6
VH-141J
<1x10-6
VH-136J
<1x10-6
VH-130J
4.4x10-6
VH-129J
1.7x10-5
VH-112J
<1x10-6
2.5x10-6
VH-147J
VH-148GJ
5x10-7*
VH-150GJ
2.5x10-6
VH-145J
7.5x10-6*
VH-153J
2.8x10-6*
LEGEND:
VH-156J MONITORING WELL LOCATION
<1.0x10-6 HYDRAULIC CONDUCTIVITY (cm/sec)
* Insitu Hydraulic Conductivity
J-ZONE
HYDRAULIC CONDUCTIVITIES
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C2556 I-1

FIGURE 54



LEGEND:

- K>10⁻⁴ cm/sec
- K<10⁻⁴ cm/sec
- WATER-BEARING/NON WATER-BEARING BOUNDARY K=10⁻⁴ cm/sec

* K value used is for entire G interval.

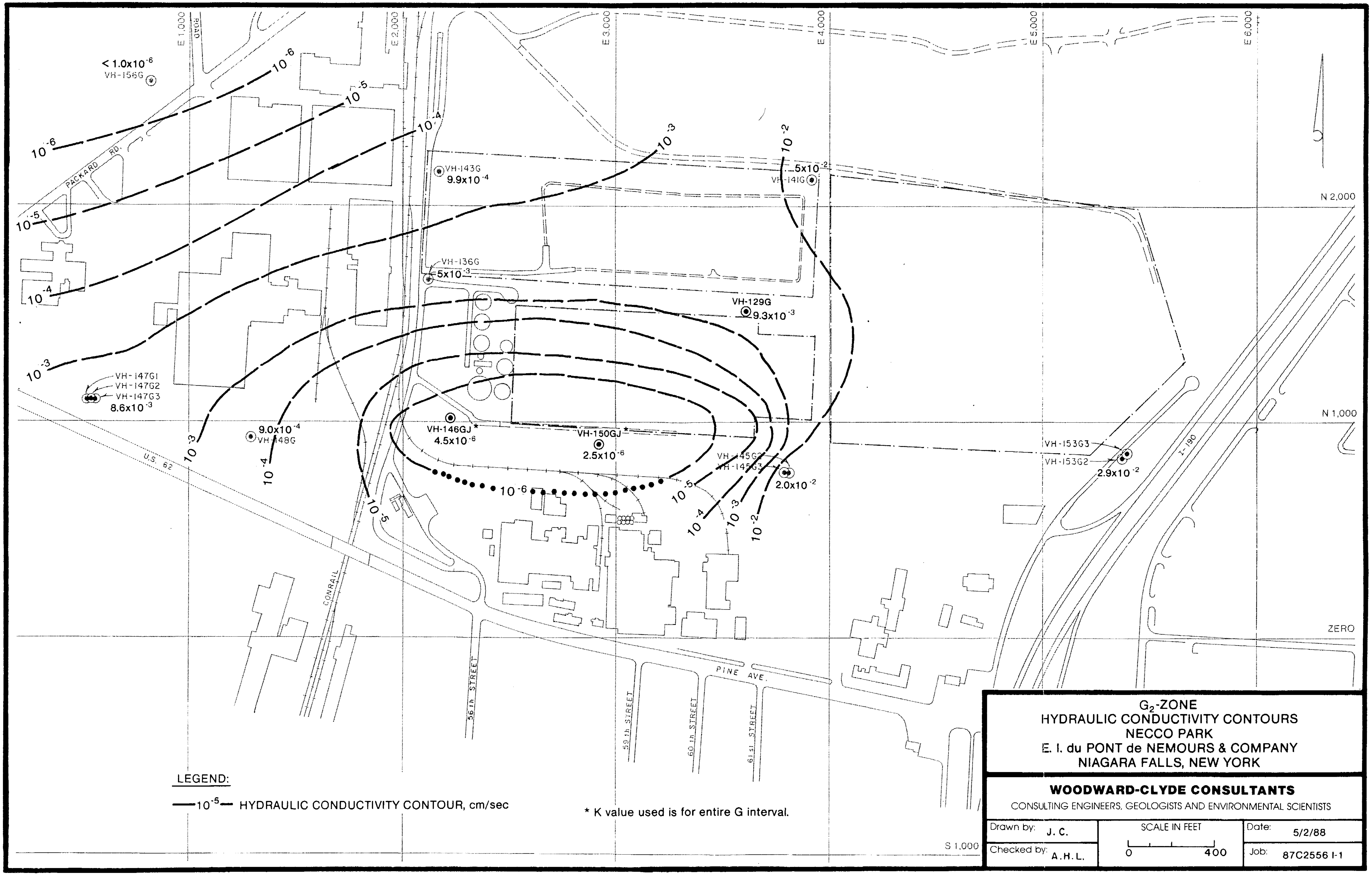
G_2-ZONE
WATER-BEARING/NON WATER-BEARING AREAS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET 0 400	Date: 5/2/88
Checked by: A.H.L.		Job: 87C2556 I-1

FIGURE 53



LEGEND:

—10-5— HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec

* K value used is for entire G interval.

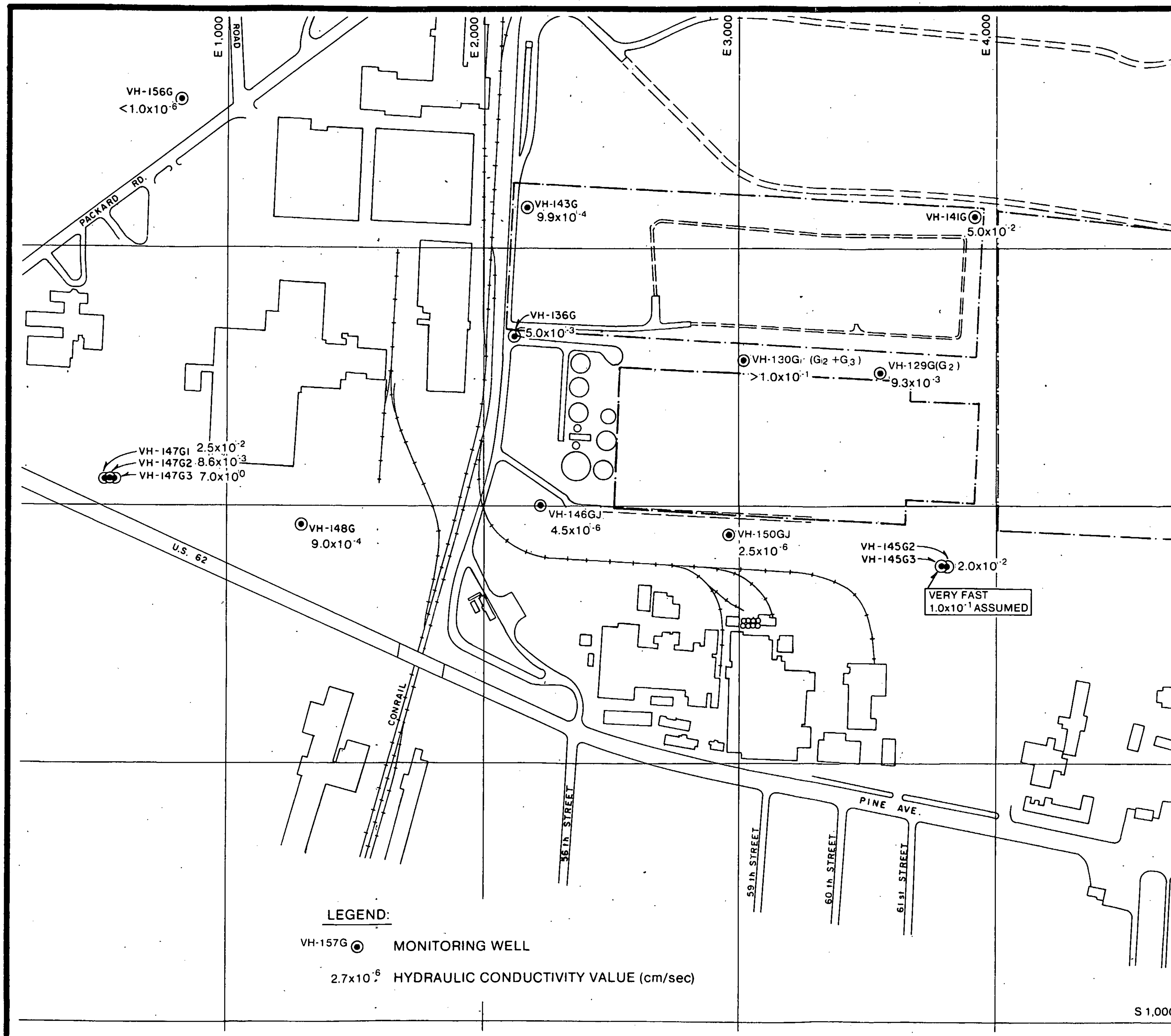
G_2-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET 0 400	Date: 5/2/88
Checked by: A.H.L.		Job: 87C2556 I-1

FIGURE 52

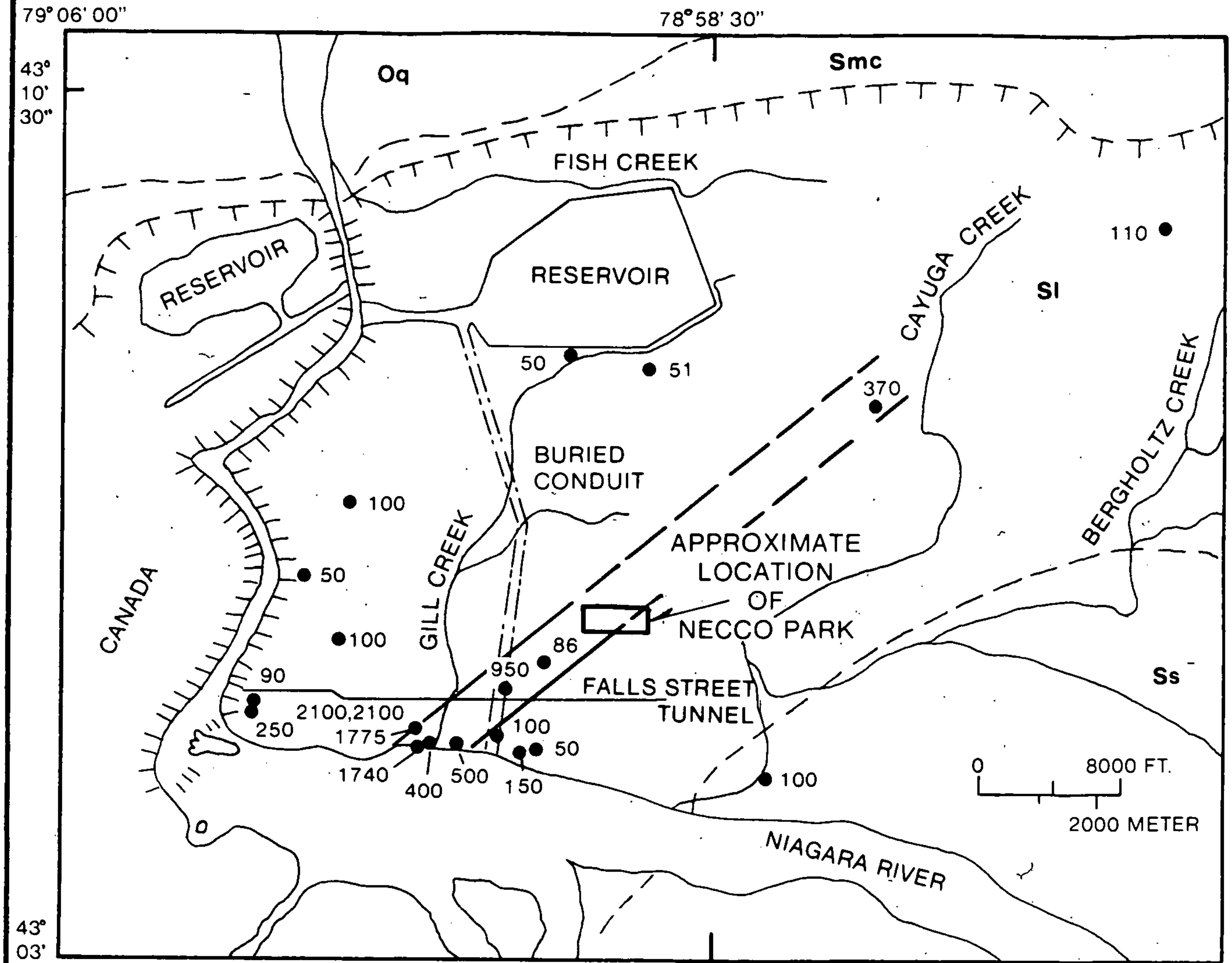


G-ZONE(G_1, G_2, G_3)
HYDRAULIC CONDUCTIVITIES
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by: J. C.	SCALE IN FEET 0 — 400	Date: 5/2/88
Checked by: A.H.L.		Job: 87C2556 I-1

FIGURE 51



Base from U.S. Geological Survey
Niagara Falls, 1948 and Tonowanda 1948, 1:62,500

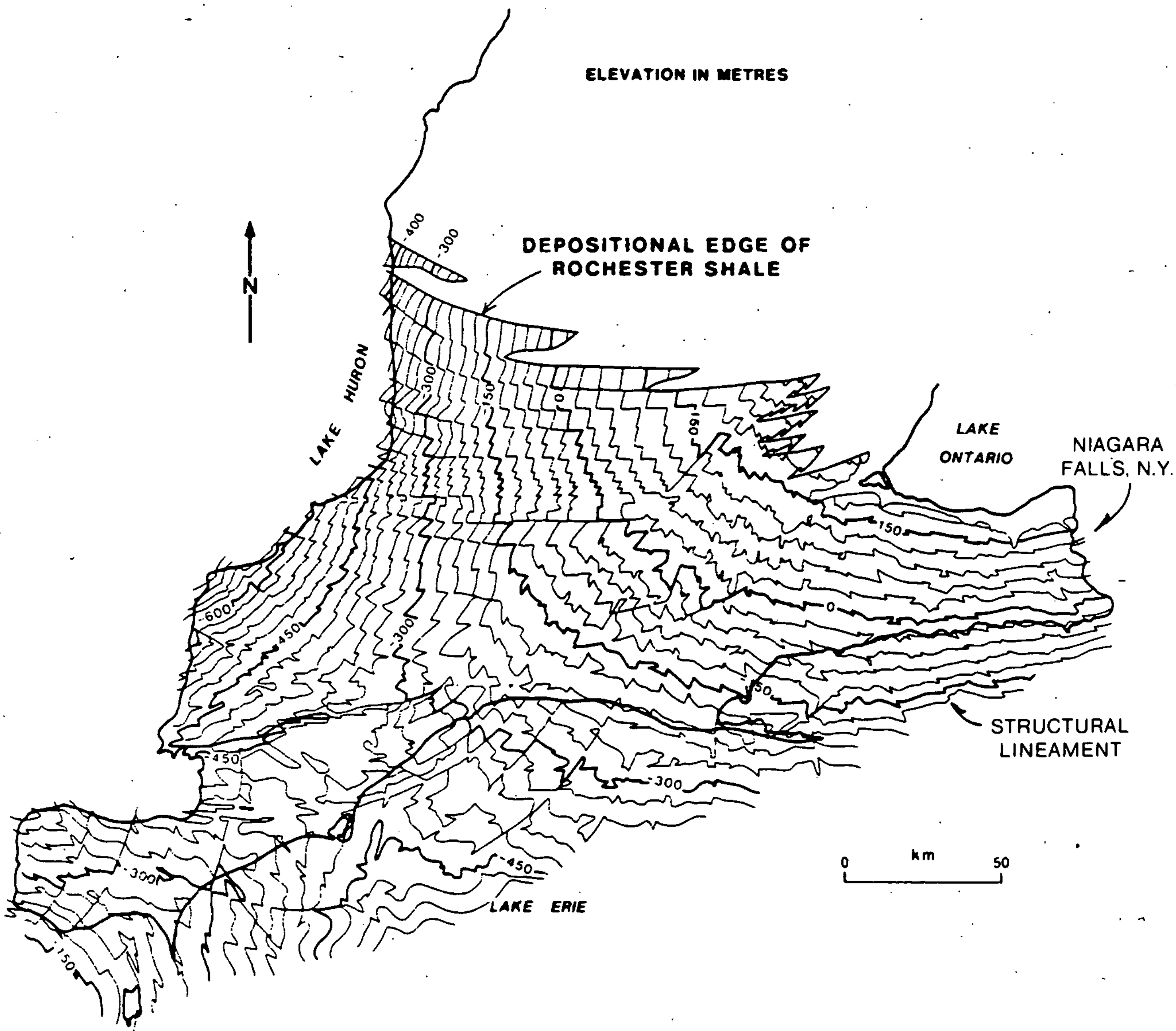
EXPLANATION

(double line symbol)	Zone of High Transmissivity identified by Johnston (1964) Dashed where extrapolated
●	50 Production Well--number is well yield, in gallons per minute
(escarpment symbol)	Niagara escarpment
(gorge symbol)	Niagara gorge
— — —	Contract between Geologic Formation or Group
Ss	Silurian Salina Group
Sl	Silurian Lockport Group
Smc	Silurian Medina and Clinton Groups
Oq	Ordovician Queenston Formation

(Adapted from Yager and Kappel, USGS 1987.)

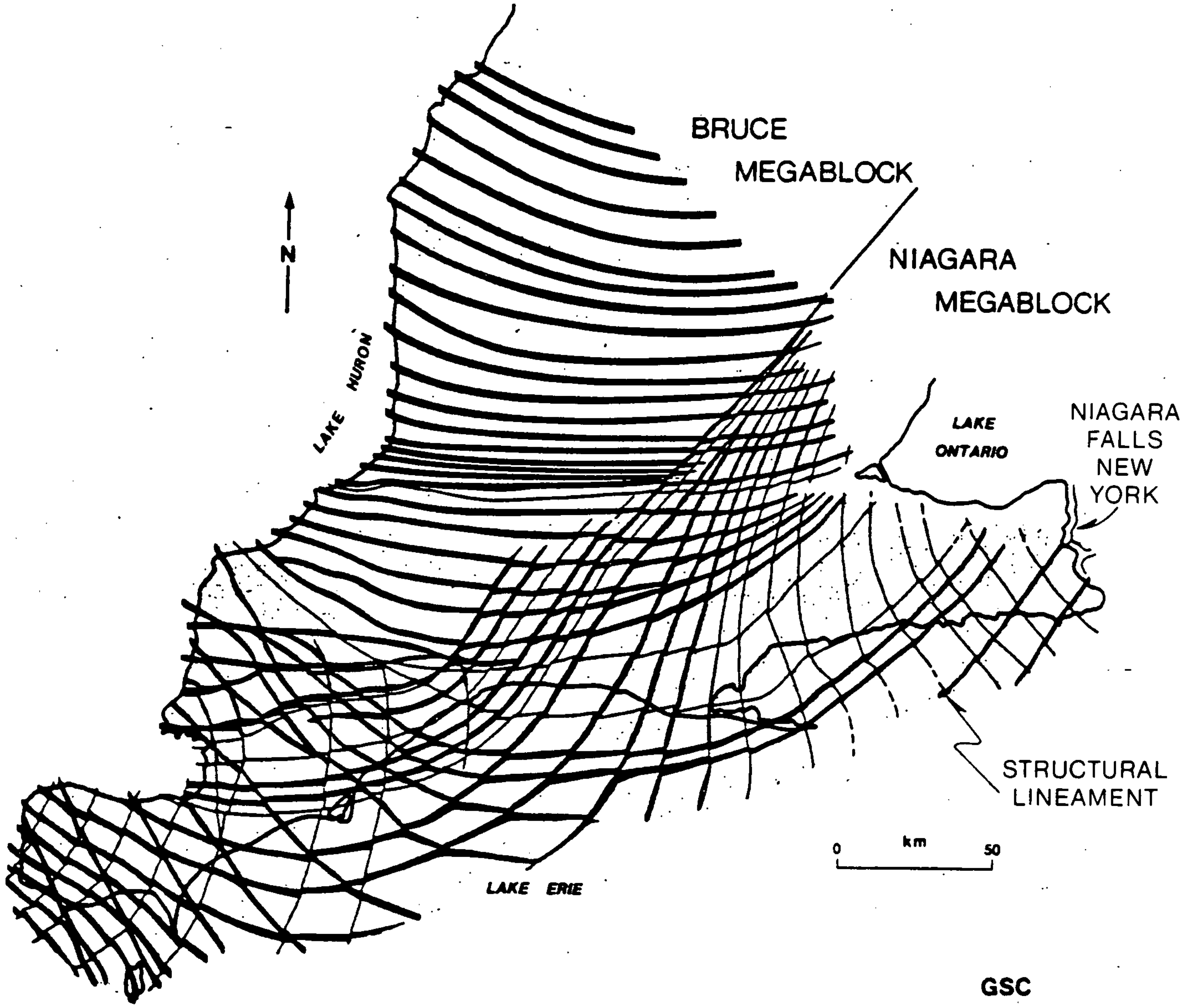
HIGH YIELD PRODUCTION WELLS
NIAGARA FALLS AREA
NEW YORK

FIGURE 55



(From B.V.Sanford et. al.,Bulletin of Canadian Petroleum Geology, March 1985)

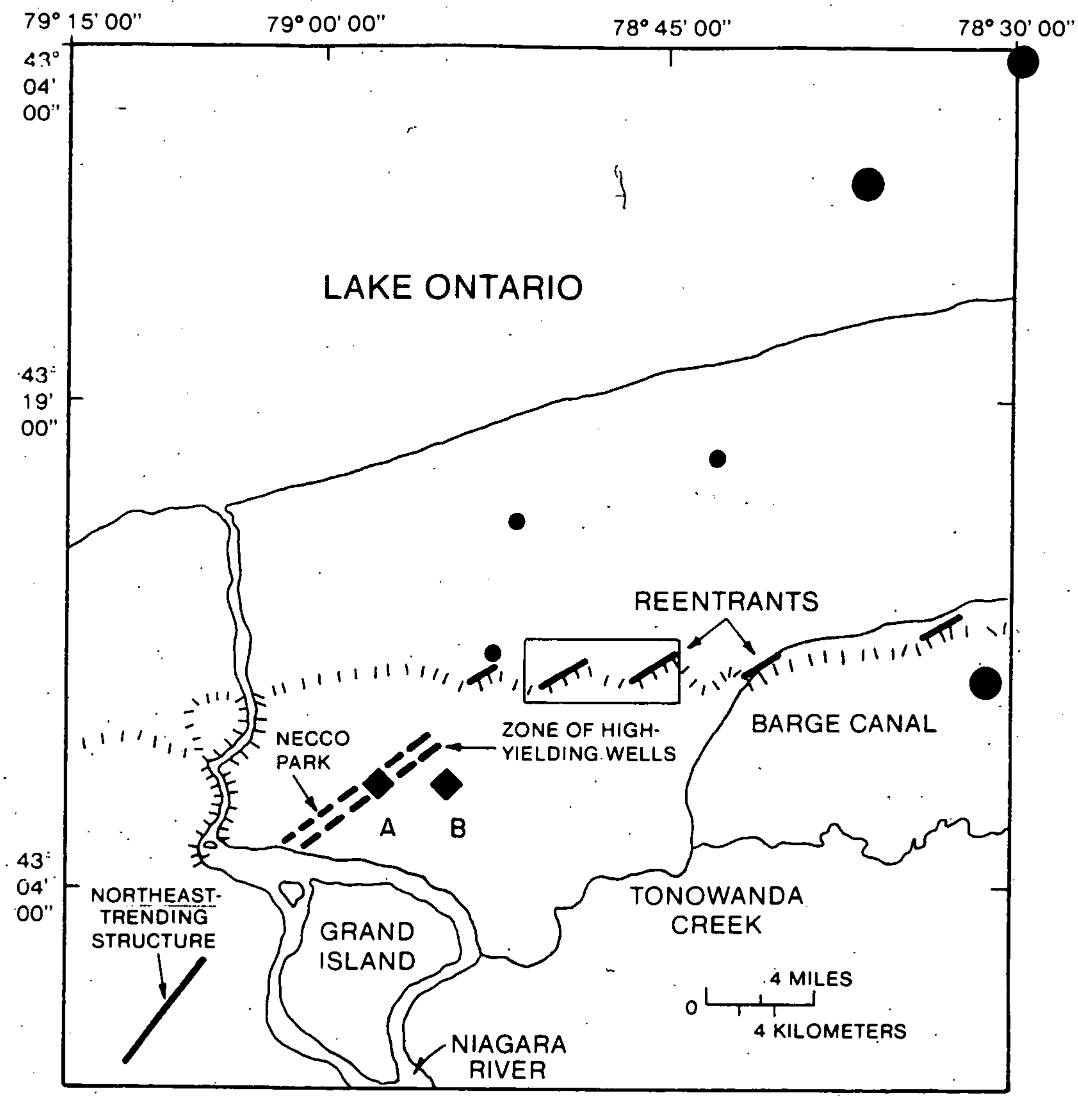
STRUCTURE CONTOURS ON ROCHESTER FORMATION, SOUTHWESTERN ONTARIO



(From B.V. SanFord, et.al., Bulletin
of Canadian Petroleum Geology March 1985).

CONCEPTUAL FRACTURE FRAMEWORK
SOUTHWESTERN ONTARIO

FIGURE 57



Base from U.S. Geological Survey
Toronto, 1962 1:250,000

EXPLANATION

I I I I I	Niagara Escarpment
TTTTT	Niagara Gorge
◆	Electromagnetic Survey Sites A and B
	Seismic Event--number indicates magnitude:
●	2.0 - 2.9
•	< 1.0

(From Yager and Kappel, U.S.G.S. 1987)

SEISMIC EVENTS
RECORDED BY LAMONT-DOHERTY
GEOLOGIC OBSERVATORY
NIAGARA FALLS AREA
1970-1986

FIGURE 58

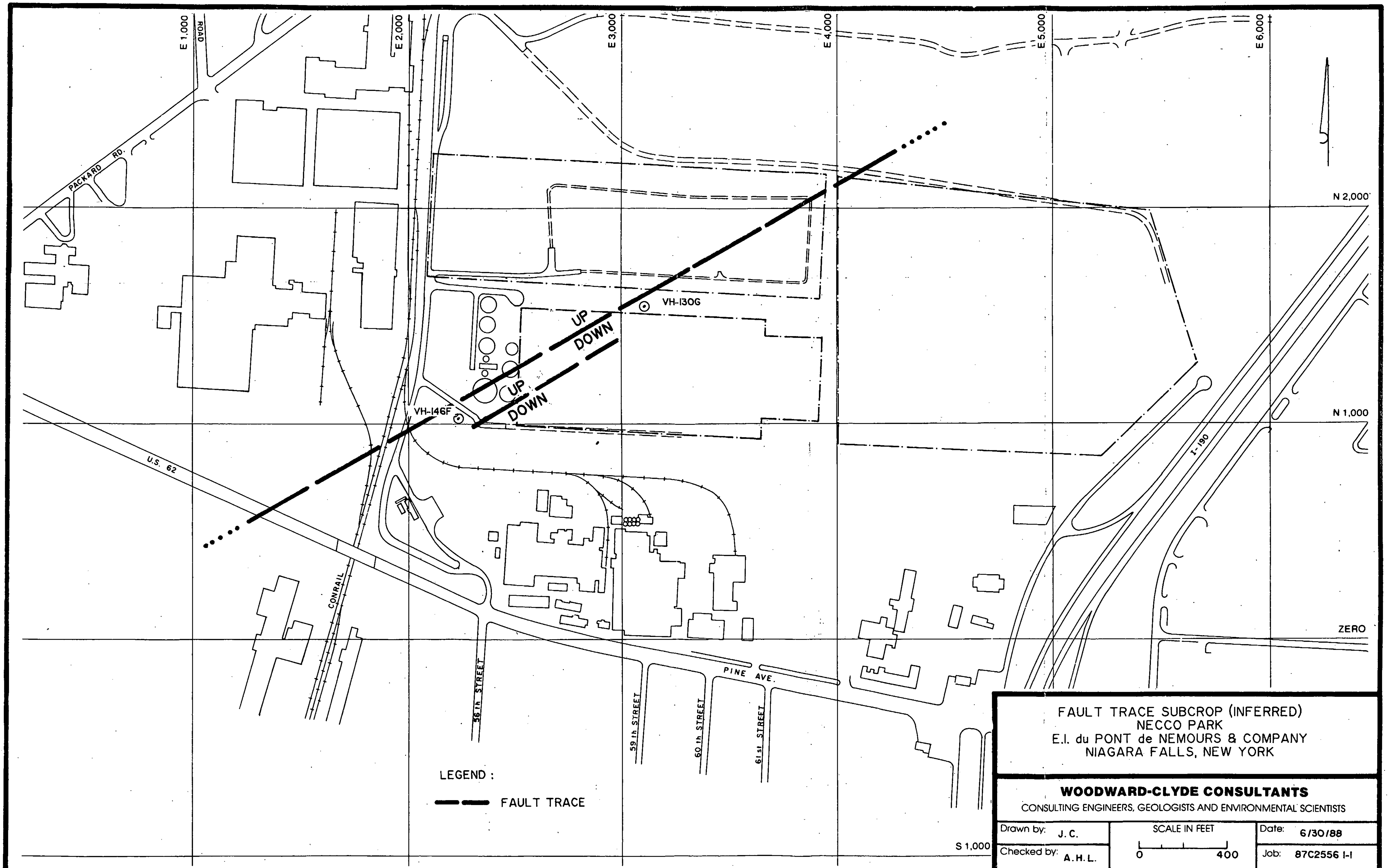
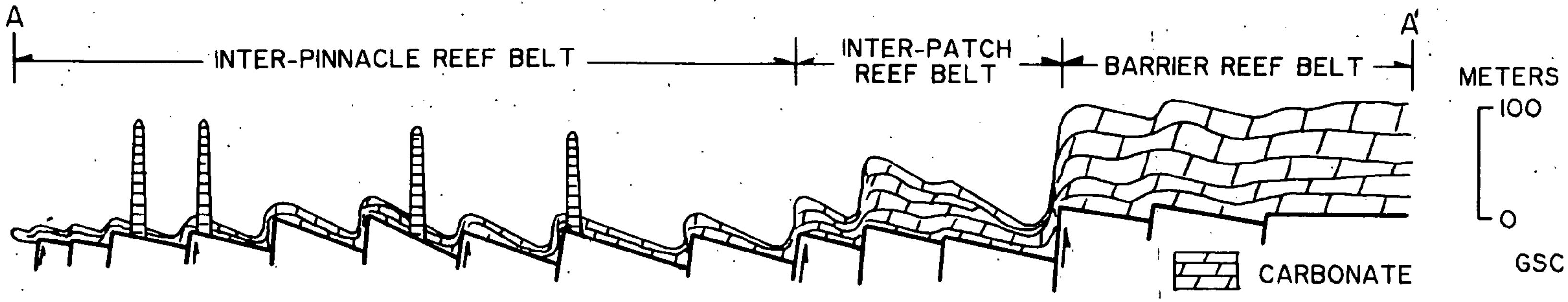

E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190
VH-130G
VH-146F
UP
DOWN
UP
DOWN
LEGEND :
FAULT TRACE
FAULT TRACE SUBCROP (INFERRED)
NECCO PARK
E.I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A.H.L.
SCALE IN FEET
0
400
Date: 6/30/88
Job: 87C2556 I-I

FIGURE 59

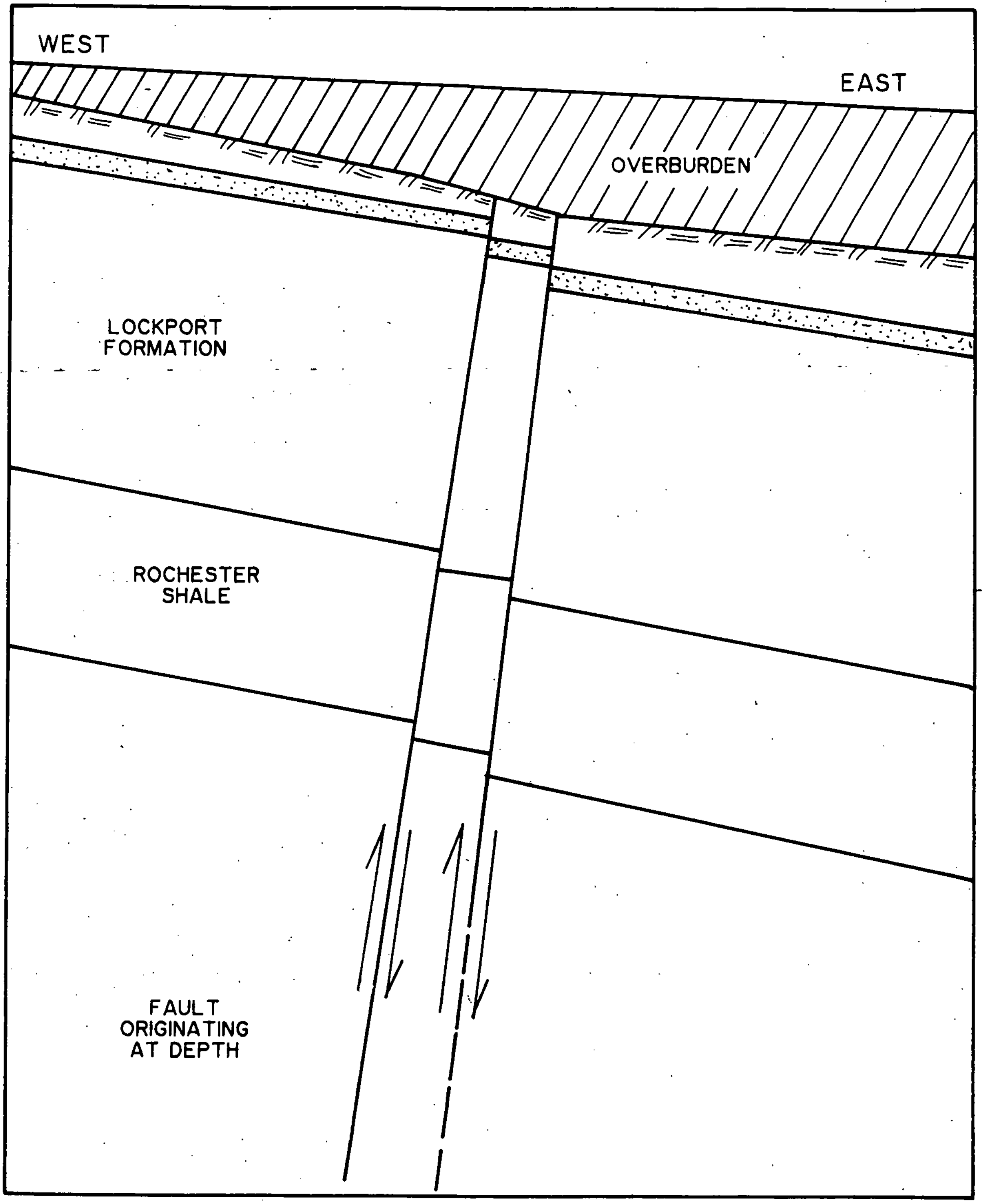


(From B.V.Sanford et. al., Bulletin of Canadian Petroleum Geology, March 1985)

Isopach and facies of Guelph carbonate, Huron area.

RELATIONSHIP OF PINNACLE REEFS AND FAULT SCARPS

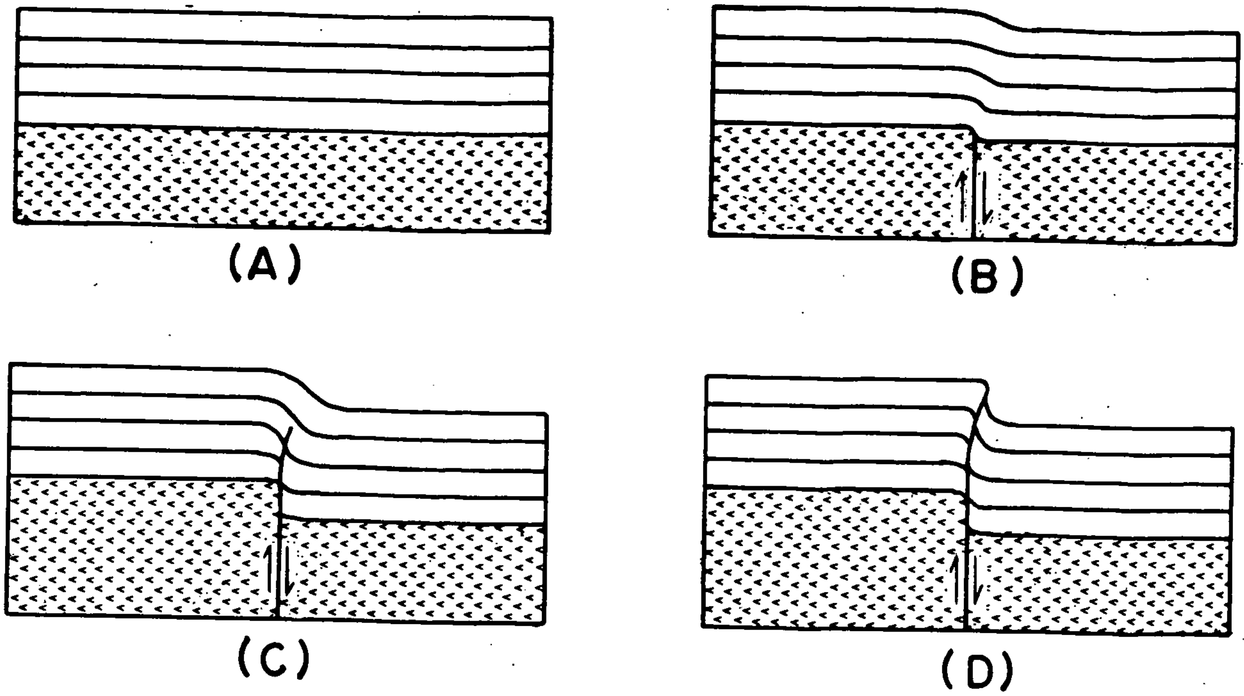
FIGURE 60



NOT TO SCALE

FAULT MODEL
NECCO PARK
E.I. du PONT de NEMOURS & CO.
NIAGARA FALLS, NEW YORK

FIGURE 61

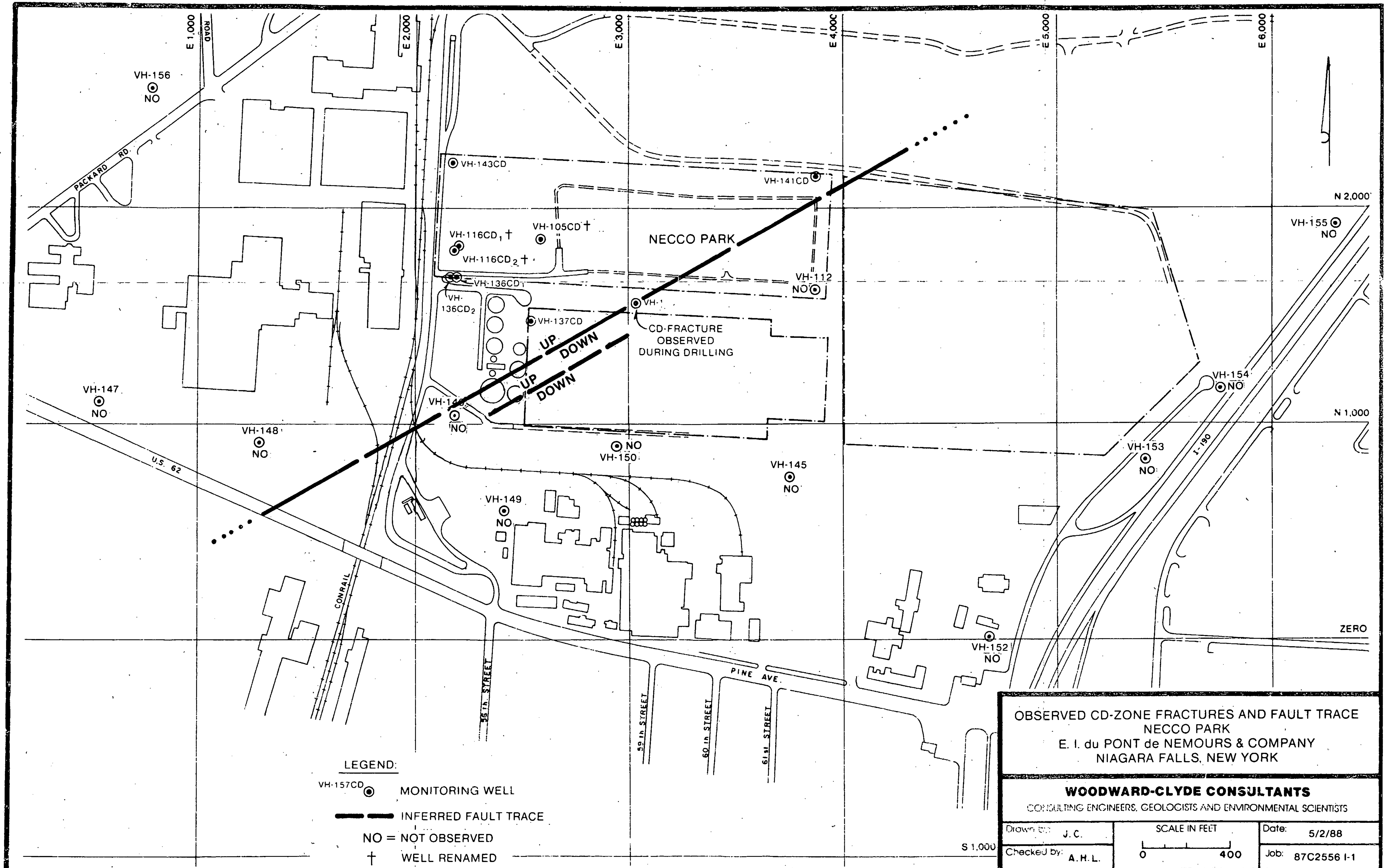


Postulated sequence in deformation of sedimentary rock beds overlying basement fault blocks. (A) Before faulting in basement. (B) Initial stage of faulting in basement. (C) Intermediate stage in basement faulting Lower sedimentary beds have exceeded critical degree of bending and are faulted; upper sedimentary beds are bent but not faulted. (D) Advanced stage of basement faulting. Faulting extends through sedimentary beds to surface. (From Prucha, Graham, and Nickelsen, 1965)

(Drawing from Spencer, 1977)

SEQUENCE OF BASEMENT FAULTING
IN OVERLYING SEDIMENTARY ROCKS
NECCO PARK
GEOLOGIC REPORT
NIAGARA FALLS, NEW YORK

FIGURE 62



OBSERVED CD-ZONE FRACTURES AND FAULT TRACE
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: J. C.
Checked by: A. H. L.
SCALE IN FEET
0
400
Date: 5/2/88
Job: 87C2556 I-1
LEGEND:
VH-157CD
MONITORING WELL
INFERRED FAULT TRACE
NO = NOT OBSERVED
WELL RENAMED
NECCO PARK
CD-FRACTURE
OBSERVED
DURING DRILLING
UP
DOWN
UP
DOWN
VH-156
NO
VH-143CD
VH-141CD
VH-116CD1 †
VH-116CD2 †
VH-105CD †
VH-136CD1
VH-136CD2
VH-137CD
VH-112
NO
VH-147
NO
VH-148
NO
NO
VH-150
VH-145
NO
VH-149
NO
VH-155
NO
VH-154
NO
VH-153
NO
VH-152
NO
E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
PACKARD RD.
ROAD
U.S. 62
CONRAIL
PINE AVE.
56th STREET
59th STREET
60th STREET
61st STREET
I-190

FIGURE 64

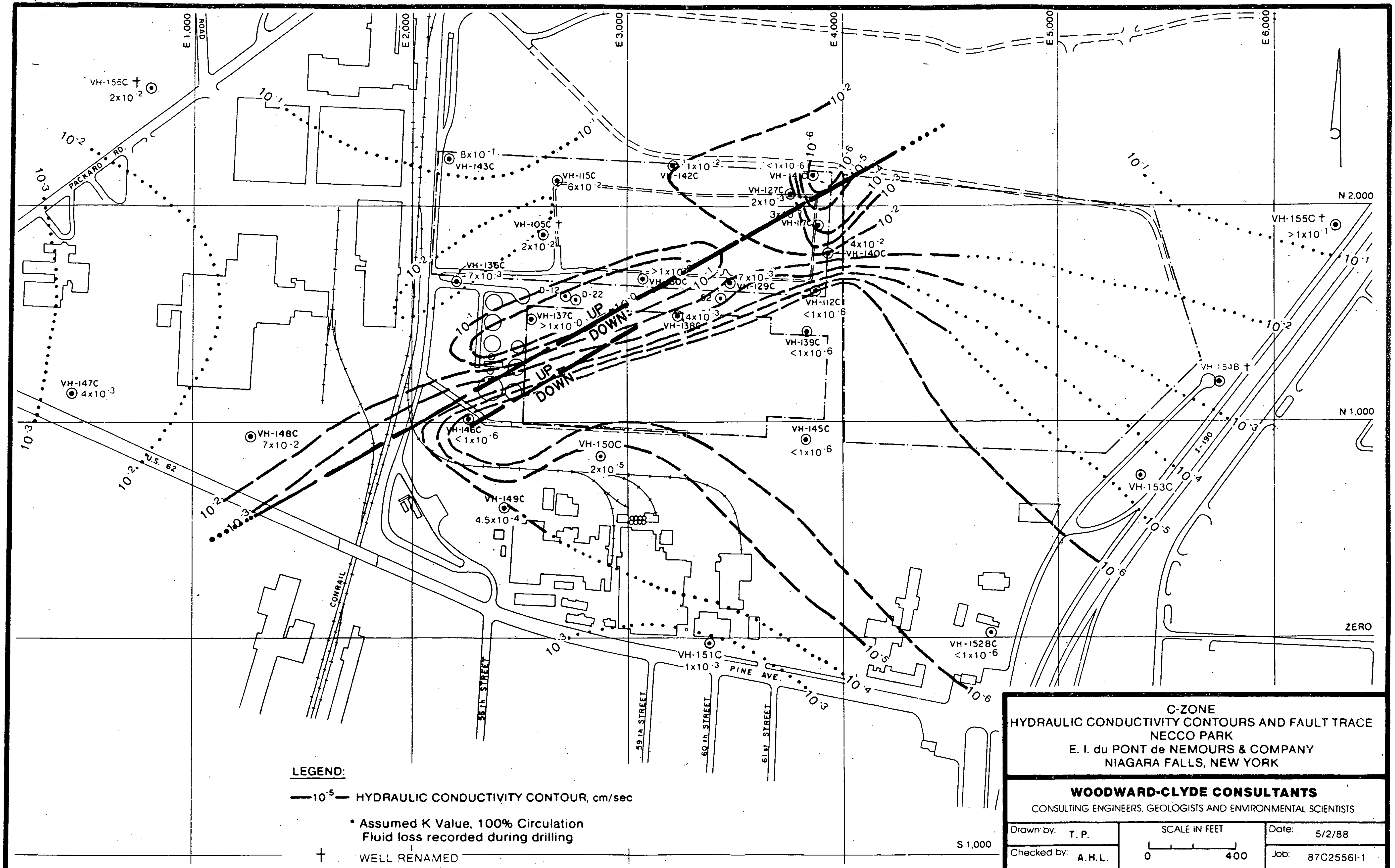
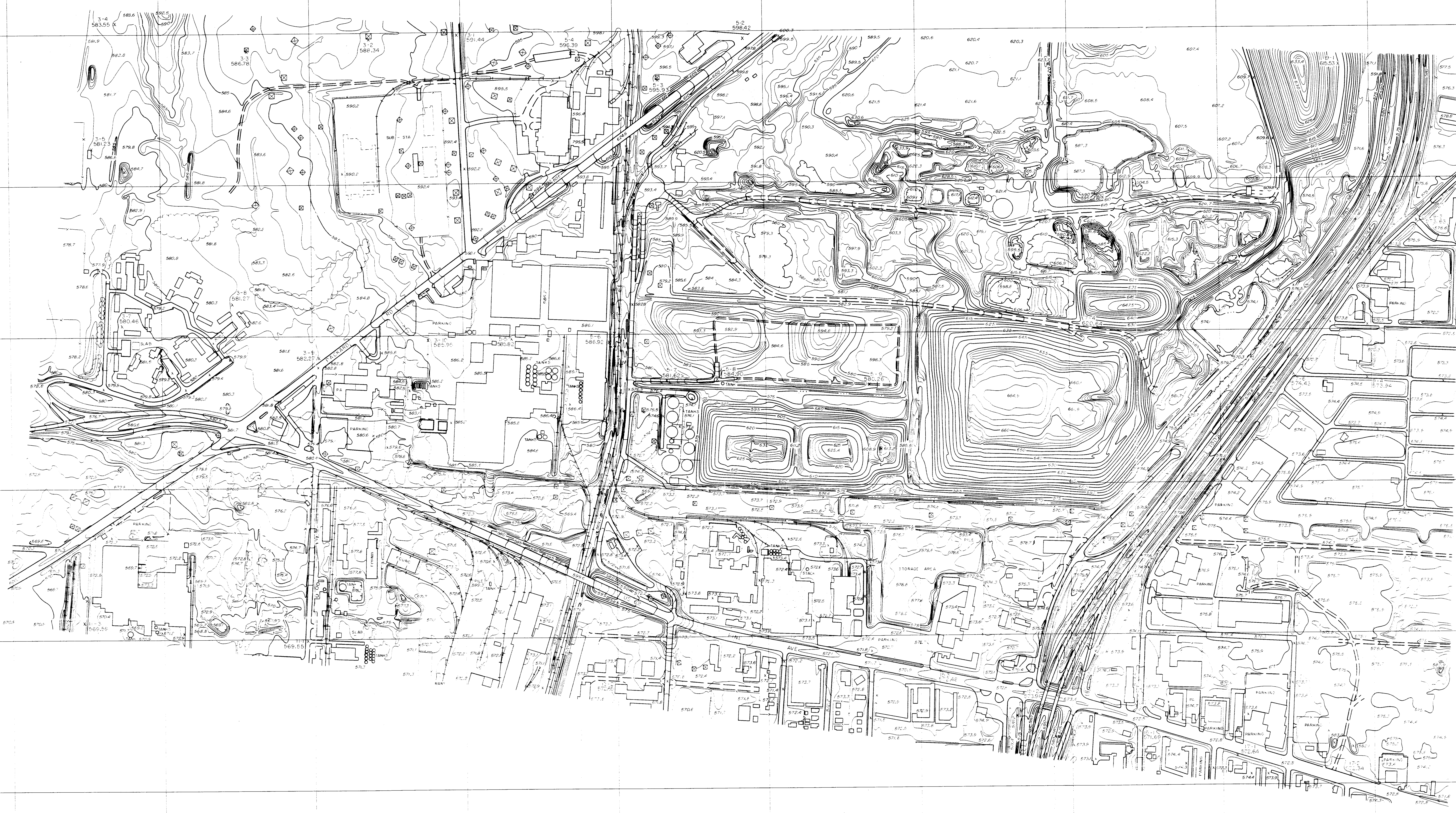

E 1,000
E 2,000
E 3,000
E 4,000
E 5,000
E 6,000
N 2,000
N 1,000
ZERO
S 1,000
ROAD
PACKARD RD.
U.S. 62
CONRAIL
I-190
56th STREET
59th STREET
60th STREET
61st STREET
PINE AVE.
VH-156C † 2x10^-2
VH-143C 8x10^-1
VH-115C 6x10^-2
VH-105C † 2x10^-2
VH-142C 1x10^-2
VH-141C <1x10^-6
VH-127C 2x10^-3
VH-117C 3x10^-3
VH-140C 4x10^-2
VH-136C 7x10^-3
VH-130C >1x10^-1
VH-129C 7x10^-3
VH-112C <1x10^-6
VH-137C >1x10^0
VH-138C 4x10^-3
VH-139C <1x10^-6
VH-147C 4x10^-3
VH-148C 7x10-2
VH-146C <1x10^-6
VH-150C 2x10^-5
VH-145C <1x10^-6
VH-149C 4.5x10^-4
VH-151C 1x10^-3
VH-152BC <1x10^-6
VH-153C
VH-154B †
VH-155C † >1x10^-1
D-12
D-22
D2
UP
DOWN
UP
DOWN
LEGEND:
—10^-5— HYDRAULIC CONDUCTIVITY CONTOUR, cm/sec
* Assumed K Value, 100% Circulation Fluid loss recorded during drilling
† WELL RENAMED
C-ZONE
HYDRAULIC CONDUCTIVITY CONTOURS AND FAULT TRACE
NECCO PARK
E. I. du PONT de NEMOURS & COMPANY
NIAGARA FALLS, NEW YORK
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
Drawn by: T. P.
Checked by: A.H.L.
SCALE IN FEET
0 400
Date: 5/2/88
Job: 87C25561-1

FIGURE 63



TOPOGRAPHIC MAP

OF

NECCO PARK AREA

NIAGARA FALLS, NEW YORK

FIGURE 65

300 0 300 600 900

SCALE 1" = 300'

CONTOUR INTERVAL 1'

DATE OF PHOTOGRAPHY APRIL 1986

DATE OF MAPPING OCTOBER 1986

ABRAMS

AERIAL SURVEY CORPORATION

124 N. LARCH ST., LANSING, MICHIGAN 48901

A.A.S.C. 20598