# APPENDIX B

# SITE-SPECIFIC LITHOLOGIC DESCRIPTIONS

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## 1.0 INTRODUCTION

The logging of drill core with respect to lithology and formation contacts for the bedrock sequence in the vicinity of the Site and the presence of vertical fractures are described in this Appendix. The stratigraphic nomenclature of Brett et al. (1995) is used. These lithologic descriptions are based on the logging of available drill core from boreholes installed from 1991 to the present. Lithologic descriptions are provided only for the units encountered at the Site, the Eramosa Formation, the Goat Island Formation, the Gasport Formation, the DeCew Formation, and the Rochester Shale. The lithology of the deeper stratigraphic units encountered during the drilling of the Intermediate Formation Wells (CRA, 1990) are not discussed in this Appendix.

## 2.0 LITHOLOGIC UNIT DESCRIPTIONS

The bedrock nomenclature system used in classifying the bedrock units at the Site during previous investigations was based on the nomenclature systems of Zenger (1965) and Rickard (1975). However, two Site-specific variations from these nomenclature systems were noted. Each unit name was essentially that of Rickard (1975), with the exception of the uppermost unit. Rickard (1975) named the uppermost unit the Guelph Formation for the Niagara region, the equivalent of the Oak Orchard Formation found further east in New York State. The nomenclature used at the Site retained the name Oak Orchard Formation for this unit (the previous Oak Orchard Member of Zenger, 1965) (Table B.1). The second variation was in the description and upper contact of the Gasport Formation. During early investigations at the Site, the upper portion of the Gasport Formation (the Pekin Member of Brett et al., 1995) was not recognized, because of the similar lithology to the overlying Goat Island Formation. The Gasport Formation, as defined during historical Site investigations and with concurrence of the NYSDEC, thus consisted only of the lower unit, composed of coarse crystalline, crinoidal dolostone (the Gothic Hill Member of Brett et al., 1995). Consequently, the upper portion of the Gasport Formation (the Pekin Member of Brett et al., 1995) was included in the overlying Goat Island Formation (Table B.1). The following descriptions utilize the nomenclature of Brett et al. (1995) with the previous nomenclature as used by CRA / NYSDEC (1979) in brackets.

The Stratigraphic and Instrumentation Logs from pre-2001 drilling programs utilize the historic nomenclature. The Stratigraphic and Instrumentation Logs for the 2001 drilling program, included in Appendix D, utilized the nomenclature of Brett et al. (1995).

Many of the unit contacts described below are more readily visible in nearby outcrops due to the scale of view and the weathering effects that may accentuate lithologic differences between units. The lack of weathering effects and smaller scale of view in drill core can make determination of unit contacts more difficult and subject to error. Due to the gradational nature of several unit contacts, the lithological similarities of many units, the subjective nature of picking unit contacts, and other potential errors described in Section 3.0 of the main report and in Appendix G, all stratigraphic contacts should be considered accurate to approximately ± 3 feet.

Photographs of nearby outcrops and drill core, referenced in the following discussion, are included in Attachment 1.

Eramosa Formation (Lower Oak Orchard Formation)

The Eramosa Formation is a thick- to thin-bedded, dark brownish-gray, bituminous dolomite that emits a petroliferous odor from fresh surfaces. Some horizons contain small white chert nodules. The Eramosa Formation contains continuous shale partings near the bottom and becomes alternating massive- and thin-bedded. The Eramosa Formation also contains small to large bioherms. The Eramosa Formation appears in outcrop as thick- to massive-bedded, separated by layers of thin-bedded material. The thickness of the Eramosa Formation varies from 0 to 67 feet at the Site and averages 30 feet thick. The Eramosa Formation is the uppermost bedrock unit across the Site, except where missing due to erosion. Thus a true unit thickness cannot be determined in the vicinity of the Site. The Eramosa Formation is not exposed in outcrops in the vicinity of the Site.

Eramosa Formation / Vinemount Member of Goat Island Formation Contact
(Oak Orchard Formation / Eramosa Formation Contact)

The contact between the Eramosa Formation and the Vinemount Member of the Goat Island Formation is generally sharp and easy to identify. The base of the Eramosa Formation becomes very fine-grained and contains numerous, closely spaced, deformed shale layers. Fossils are common within these shale layers. The Vinemount Member begins within the first fine-grained beds that do not contain fossils. There is sometimes a noticeable color change from dark gray to light gray. The Eramosa Formation / Vinemount Member contact is not exposed in outcrops in the vicinity of the Site.

Vinemount Member of the Goat Island Formation (Eramosa Formation)

The Vinemount Member of the Goat Island Formation is a light to dark gray, medium- to thin-bedded, fine-grained, argillaceous dolomite with thin shale partings. The Vinemount Member is commonly bituminous and emits a petroliferous odor from fresh surfaces. The Vinemount Member contains closely spaced shale partings covering approximately 1 foot vertically near the bottom of the unit. The Vinemount Member appears in outcrop near the Site as thin- to medium-bedded with irregular, discontinuous shale layers, and partings. The thickness of the Vinemount Member, where uneroded, ranges from 18 to 24 feet at the Site and averages 20 feet thick (Figure B.1). Across the western portion of the Site, the Vinemount Member forms the uppermost bedrock unit and is erosionally truncated. The bedding of the Vinemount Member is visible on Photograph 1 and the top portion of Photograph 13. The overall competent nature of the drill core is visible on Photographs 14, 15, and 16.

Vinemount Member / Ancaster Member Contact
(Eramosa Formation / Goat Island Formation Contact)

The contact between the Vinemount Member and the Ancaster Member of the Goat Island Formation is difficult to visually identify in drill core. The contact is conformable and gradational and generally there is no color change. At the base of the Vinemount Member, the shale layers become very closely spaced (<1/2 inch) over an approximate 1-foot interval. Just below these beds, the grain size of the rock starts to increase from fine-grained to medium-grained. Where the grain size becomes predominantly medium-grained, the Ancaster Member begins. The location of the grain size change beneath the lower shale layers varies across the Site from less than a few inches to greater than 2 feet. The contact between the Vinemount Member and the Ancaster Member is visible on Photograph 2. The contact in drill core is visible, but difficult to see, on Photograph 6.

Ancaster Member of the Goat Island Formation (Upper Goat Island Formation)

The Ancaster Member of the Goat Island Formation is a medium ash-gray, thin to medium-bedded, fine-grained dolomite. The unit weathers to light tan and regionally, contains nodules of distinctive pale, cream-colored chert (Brett et al., 1995). At the Site, chert is uncommonly encountered and was not observed in outcrop. In outcrop, the Ancaster Member appears regularly spaced and medium bedded. The Ancaster and the underlying Niagara Falls Members have previously been grouped together at the Site. The combined thickness of these two members at the Site ranges from 13 to 24 feet and averages 19 feet thick (Figure B.1). The bedding of the Ancaster Member is visible on Photographs 3 and 13. The overall competent nature of the drill core is visible on Photograph 16.

Ancaster Member / Niagara Falls Member Contact
(Upper Goat Island Formation / Lower Goat Island Formation Contact)

The contact between the Ancaster Member and Niagara Falls Member of the Goat Island Formation has not been discretely logged at the Hyde Park Landfill Site.

Niagara Falls Member of the Goat Island Formation (Lower Goat Island Formation)

The Niagara Falls Member of the Goat Island Formation is a light olive to brownish-gray, saccharoidal, medium-grained, thick- to massive-bedded, porous, and vuggy dolomite. The vugs and mineralization in the Niagara Falls Member noted in

Brett et al. (1995) to occur regionally are not commonly encountered in drill core at the Site. In outcrop, the Niagara Falls Member appears massive with few fractures. The bedding of the Niagara Falls Member is visible on Photographs 4 and 13. The overall competent nature of the drill core is visible on Photograph 17.

Niagara Falls Member / Pekin Member Contact
(Goat Island Formation / Gasport Formation Contact)

The contact between the Niagara Falls Member of the Goat Island Formation and the Pekin Member of the Gasport Formation is conformable but generally fairly easy to identify. Toward the base of the Niagara Falls Member the rock becomes very uniform in grain size and color (medium-grained and medium gray) and commonly breaks at stylolites spaced approximately 2 to 3 feet apart. At the top of the Pekin Member, a noticeable textural change in the rock occurs, from lack of structure to a very deformed structure, the color of the rock also becomes slightly darker. Within the first 2 to 3 feet of the Pekin Member, the bedding becomes thin and crinoid fossil fragments may be present. The contact between the Niagara Falls Member and the Pekin Member is visible on Photograph 4. The contact in drill core is visible on Photograph 17.

Pekin Member of the Gasport Formation (Gasport Formation)

The Pekin Member is an argillaceous, dark gray, fine-grained, thin- to medium-bedded dolomicrite. The Pekin Member was not officially recognized historically as part of the Gasport Formation at the Site. In outcrop, the Pekin Member displays deformed, irregular shale partings of limited lateral extent. The shale partings are often closely spaced in outcrop. The Pekin Member ranges in thickness from 11 to 24 feet and averages 16 feet thick at the Site (Figure B.1). The thick bedding is visible on Photographs 5, 6, 7, and the bottom of Photograph 13. The overall competent nature of the Pekin Member is visible in drill core on Photographs 17 and 18.

Pekin Member / Gothic Hill Member Contact
(Goat Island Formation / Gasport Formation Contact)

The contact between the Pekin Member and Gothic Hill Member of the Gasport Formation is generally sharp and easy to identify. The Gothic Hill Member is characterized as being a thick bedded crinoidal grainstone. The base of the Pekin Member often contains thin beds (approximately 4 inches thick) with crinoid fragments separated by thin beds of dolostone with shale layers. The contact between these two units is commonly marked by a shale parting. The contact between the Pekin Member and the Gothic Hill Member is visible on Photograph 7. The contact is visible in drill core on Photograph 20.

Gothic Hill Member of the Gasport Formation (Gasport Formation)

The Gothic Hill Member of the Gasport Formation is a thick- to massive-bedded, dark olive-gray to light pink, dolomitic limestone (primarily crinoidal grainstone and crinoidal dolomite). The Gothic Hill Member appears in outcrop as a massive unit, which is generally unfractured horizontally. Low-angle cross-stratification is apparent in outcrop and the fossil fragments are commonly visible in relief due to differential weathering. The Gothic Hill Member ranges in thickness from 4 to 16 feet and averages 7 feet thick at the Site (Figure B.1). The massive bedding of this unit and cross-stratification are visible on Photographs 7, 8, 9, and 10. The overall competent nature of the drill core is visible on Photograph 20.

Gothic Hill Member / DeCew Formation Contact
(Gasport Formation / DeCew Formation Contact)

The contact between the Gasport Formation and the DeCew Formation is sharp and easy to identify. This contact is marked by the loss of crinoid fragments and a change from medium- to coarse-grained to fine-grained. The contact between the Gothic Hill Member and the DeCew Formation is visible on Photographs 9 and 10.

DeCew Formation

The DeCew Formation is a variably bedded, dark-gray to olive-gray, argillaceous to sandy, fine-grained dolomite that locally contains shale partings and interbeds up to a few inches thick. It commonly shows contorted and enterolithic bedding. The contorted and enterolithic bedding was postulated by Brett et al. (1995) to be caused by a seismic disturbance. In outcrop, the contorted and enterolithic bedding weathers differentially, showing the bedding details in relief. In outcrop near the Site, the contorted and enterolithic bedding of the DeCew Formation occupies approximately the middle one-third of the unit. The top of the contorted and enterolithic bedding forms an irregular bedding plane surface overlain and draped by similar argillaceous to sandy dolomite with near-horizontal bedding. The DeCew Formation ranges in thickness from 8 to 13 feet and averages 11 feet thick at the Site (Figure B.1). The variations in bedding within the DeCew Formation is readily apparent on Photographs 9, 11, and 12. The upper portion of the DeCew Formation is visible in drill core on Photograph 20. There is no apparent erosion or weathering on the top of the DeCew Formation, at the shale parting that forms the contact with the overlying Gothic Hill Member, although this contact is considered to be a regional unconformity (Brett et al., 1995). The rust staining visible in drill core on Photograph 20 is caused by oxidation of the core box metallic hardware.

DeCew Formation / Rochester Shale Contact

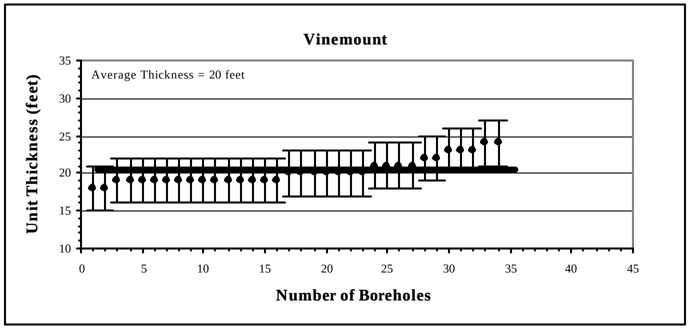
The contact between the DeCew Formation and Rochester Shale is conformable and somewhat difficult to visually identify in drill core. The contact is determined by the flatness of the bedding, the first horizontal bedding marks the top of the Rochester Shale. In addition, the Rochester Shale becomes significantly softer below the DeCew Formation / Rochester Shale contact. The contact between the DeCew Formation and the Rochester Shale is visible on Photograph 12.

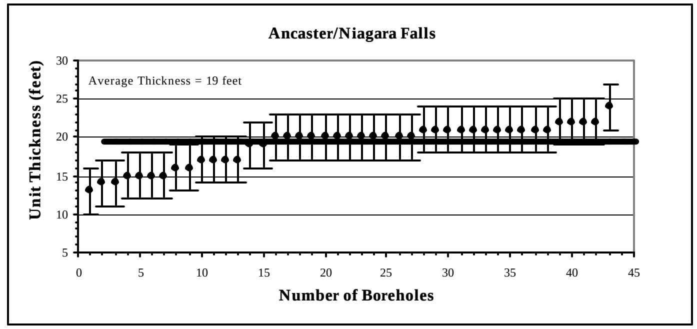
Rochester Shale

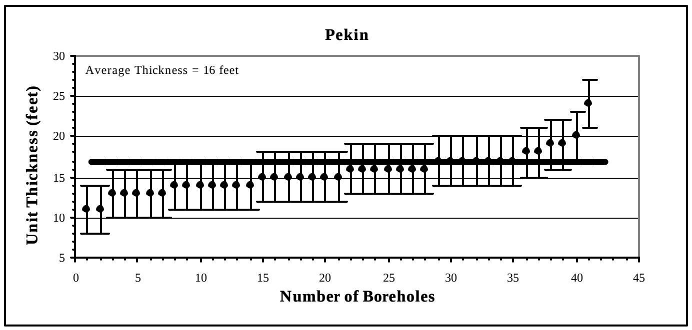
The Rochester Shale is a medium-gray to black calcareous mudstone with thin interbeds of calcareous to dolomitic calcisiltite and calcarenite. In outcrop, the upper portion of the Rochester Shale weathers rapidly to a crumbly texture of small shale fragments partially covered by light colored evaporative mineral coatings. The full thickness of the Rochester Shale was penetrated during the installation of the Intermediate Formation Wells (IFW). The Rochester Shale ranges in thickness from 56 to 63 feet and averages 59 feet based on these seven IFW monitoring wells. The bedding and rapid weathering of this unit are apparent on the lower portion of Photograph 12.

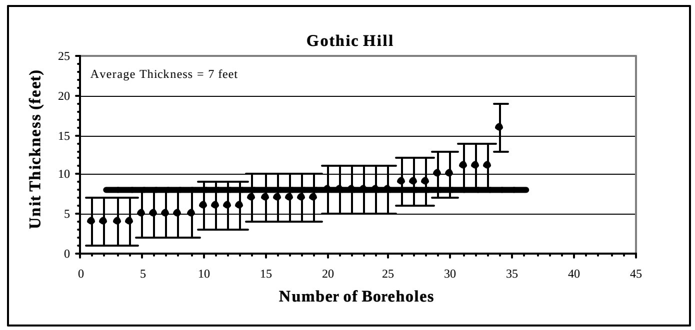
## 3.0 NEAR-VERTICAL FRACTURES

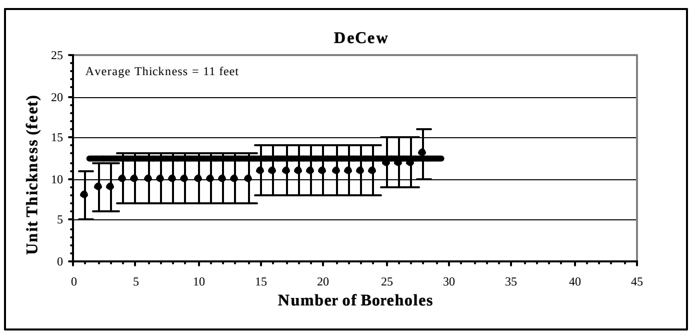
Near-vertical fractures were encountered in available drill core and were logged during the lithologic logging process. The depths of these vertical fractures from ground surface are presented in Table B.2. As well, this table includes three near-vertical fractures visible from borehole video logging (C1U, C2M) that were not noted to be present in the drill core.




Note: Error bars represent ± 3 feet.

**figure B.1**

**STRATIGRAPHIC UNIT THICKNESSES**

**SITE CHARACTERIZATION REPORT**

**HYDE PARK LANDFILL SITE**

***Town of Niagara, New York***

**TABLE B.1**

**STRATIGRAPHIC NOMENCLATURE COMPARISON**
**SITE CHARACTERIZATION REPORT**
**HYDE PARK LANDFILL SITE**
**TOWN OF NIAGARA, NEW YORK**

**Zenger (1965) (NY Bull.404)**

| | |
|---|---|
| Lockport Formation | Oak Orchard Member |
| | Eramosa Member |
| | Goat Island member |
| | Gasport Member |
| | DeCew Member |
| Clinton Group | Rochester Shale |

**Rickard (1975) (NY Map Series 24)**

| | |
|---|---|
| Lockport Group | Guelph Dolomite |
| | Eramosa Formation |
| | Goat Island Formation |
| | Gasport Formation |
| Clinton Group | DeCew Dolomite |
| | Rochester Shale |

**CRA/ NYSDEC (1979)**

| | |
|---|---|
| Lockport Group | Oak Orchard Formation |
| | Eramosa Formation |
| | Goat Island Formation |
| | Gasport Formation |
| | DeCew Formation |
| Clinton Group | Rochester Shale |

**Brett, et al. (1995) (USGS Bull.2086)**

| | | |
|---|---|---|
| Lockport Group | Guelph Dolomite | |
| | Eramosa Dolomite | |
| | Goat Island Dolomite | Vinemount Member |
| | | Ancaster Member |
| | | Niagara Falls Member |
| | Gasport Dolomite | Pekin Member |
| | | Gothic Hill Member |
| Clinton Group | DeCew Dolomite | |
| | Rochester Shale | Burleigh Hill Member |
| | | Lewiston Member |

Note: The Gasport Formation as used by CRA at the Site is composed of the Gothic Hill Member only.
The Pekin Member of the Gasport Formation was historically included in the overlying Goat Island Dolomite.

**TABLE B.2**

**NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES**
**SITE CHARACTERIZATION REPORT**
**HYDE PARK LANDFILL SITE**
**TOWN OF NIAGARA, NEW YORK**

| Well Location | Ground Surface Elevation (ft. AMSL) | Top of Bedrock Elevation (ft. AMSL) | Fracture 1 (Depth ft. bgs) Top | Fracture 1 Bottom | Fracture 2 (Depth ft. bgs) Top | Fracture 2 Bottom | Fracture 3 (Depth ft. bgs) Top | Fracture 3 Bottom | Fracture 4 (Depth ft. bgs) Top | Fracture 4 Bottom |
|---|---|---|---|---|---|---|---|---|---|---|
| A1U | 598.0 | 571 | No Vertical Fracturing Noted | | | | | | | |
| A2U | 593.5 | 572 | 30.8 | 31.0 | | | | | | |
| AB1L | 588.0 | 561 | No Vertical Fracturing Noted | | | | | | | |
| AB1M | 588.0 | 565 | No Vertical Fracturing Noted | | | | | | | |
| AB1U | 587.9 | 559 | No Vertical Fracturing Noted | | | | | | | |
| ABP-1 | 571.9 | 554 | No Vertical Fracturing Noted | | | | | | | |
| ABP-2 | 574.9 | 558 | No Vertical Fracturing Noted | | | | | | | |
| ABP-3 (1) | 591.1 (1) | 562 (1) | No Vertical Fracturing Noted | | | | | | | |
| ABP-4 | 588.1 | 561 | No Vertical Fracturing Noted | | | | | | | |
| ABP-5 | 589.3 | 561 | No Vertical Fracturing Noted | | | | | | | |
| ABP-7 | 574.4 | 566 | No Vertical Fracturing Noted | | | | | | | |
| ABP-8 | 575.1 | 534 | No Vertical Fracturing Noted | | | | | | | |
| AFW-1L | 570.9 | 565 | 57.0 | 61.0 | | | | | | |
| AFW-2L | 592.2 | 579 | 15.2 | 15.6 | 17.5 | 19.5 | 21.5 | 22.5 | | |
| AFW-3L | 589.3 | 577 | 12.5 | 13.2 | 17.0 | 18.0 | | | | |
| AGW-1L | 591.4 | 576 | 19.5 | 21.5 | 23.6 | 23.8 | | | | |
| AGW-2L | 608.4 | 593 | 16.0 | 17.5 | 31.5 | 32.0 | | | | |
| AGW-3L | 628.3 | 612 | 38.4 | 38.6 | 51.8 | 52.1 | 56.6 | 56.8 | 86.5 | 89.8 |
| APW-1 | 569.0 | 555 | No Vertical Fracturing Noted | | | | | | | |
| APW-2 | 574.0 | 531 | No Vertical Fracturing Noted | | | | | | | |
| B1L | 589.7 | 562 | 28.0 | 29.0 | | | | | | |
| B2L | 588.0 | 564 | 55.9 | 56.0 | | | | | | |
| BR-1 | 582.6 | 559 | 23.6 | 23.8 | | | | | | |
| BR-2 | 581.6 | 557 | No Vertical Fracturing Noted | | | | | | | |
| BR-3 | 582.0 | 559 | 24.4 | 24.5 | | | | | | |
| BR-4 | 583.5 | 557 | No Vertical Fracturing Noted | | | | | | | |
| C1U | 591.6 | 562 | 30.5 (1) | 32.5 (1) | | | | | | |
| C1L | 591.4 | 562 | 91.0 | 93.0 | 95.0 | 97.0 | | | | |
| C2M | 590.1 | 560 | 59 (1) | 63 (1) | 71 (1) | 79 (1) | | | | |

**TABLE B.2**

**NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES**
**SITE CHARACTERIZATION REPORT**
**HYDE PARK LANDFILL SITE**
**TOWN OF NIAGARA, NEW YORK**

| Well Location | Ground Surface Elevation (ft. AMSL) | Top of Bedrock Elevation (ft. AMSL) | Fracture 1 (Depth ft. bgs) Top | Fracture 1 (Depth ft. bgs) Bottom | Fracture 2 (Depth ft. bgs) Top | Fracture 2 (Depth ft. bgs) Bottom | Fracture 3 (Depth ft. bgs) Top | Fracture 3 (Depth ft. bgs) Bottom | Fracture 4 (Depth ft. bgs) Top | Fracture 4 (Depth ft. bgs) Bottom |
|---|---|---|---|---|---|---|---|---|---|---|
| C2L | 590.2 | 560 | 59.0 | 63.0 | 71.0 | 76.0 | | | | |
| CD1L | 596.6 | 563 | 36.5 | 37.4 | | | | | | |
| CD1M | 596.8 | 568 | No Vertical Fracturing Noted | | | | | | | |
| CD1U | 596.9 | 573 | 33.3 | 38.1 | 52.7 | 52.8 | | | | |
| CD2M | 596.1 | 563 | No Vertical Fracturing Noted | | | | | | | |
| CD3U | 593.4 | 562 | 31.1 | 31.4 | | | | | | |
| CD4U | 588.9 | 574 | 13.7 | 16.5 | | | | | | |
| CD5U | 588.2 | 566 | No Vertical Fracturing Noted | | | | | | | |
| CD6U | 588.6 | 562 | No Vertical Fracturing Noted | | | | | | | |
| D1L | 592.7 | 572 | 23.6 | 24.2 | | | | | | |
| D2L | 589.4 | 576 | No Vertical Fracturing Noted | | | | | | | |
| D4L | 598.6 | 575 | No Vertical Fracturing Noted | | | | | | | |
| E1L | 594.0 | 577 | 21.0 | 21.5 | | | | | | |
| E2L | 591.3 | 576 | No Vertical Fracturing Noted | | | | | | | |
| E3L | 593.1 | 578 | 23.7 | 23.8 | | | | | | |
| E5U | 598.6 | 587 | No Vertical Fracturing Noted | | | | | | | |
| F1L | 602.0 | 599 | 44.2 | 44.8 | | | | | | |
| F2L | 597.6 | 587 | 29.2 | 29.4 | 34.8 | 35.0 | | | | |
| F3L | 597.6 | 580 | No Vertical Fracturing Noted | | | | | | | |
| G1L | 615.6 | 607 | 9.5 | 10.5 | 13.2 | 16.0 | | | | |
| G2L | 609.8 | 600 | 45.2 | 45.8 | 51.5 | 53.4 | | | | |
| G3L (BH4-95) | 617.7 | 60604 | No Vertical Fracturing Noted | | | | | | | |
| G4U | 610.6 | 597 | No Vertical Fracturing Noted | | | | | | | |
| G5L | 605.5 | 598 | 126.5 | 126.8 | | | | | | |
| G5U (T-2) | 610.6 | 603 | 8.2 | 8.5 | 14.5 | 14.8 | 49.9 | 50.2 | | |
| H1L | 618.9 | 606 | No Vertical Fracturing Noted | | | | | | | |
| H2L | 619.3 | 613 | 14.3 | 14.5 | | | | | | |
| HT-2 (BH2-95) | 600.2 | 579 | No Vertical Fracturing Noted | | | | | | | |
| J1L | 606.8 | 591 | 18.2 | 18.4 | 30.2 | 30.4 | | | | |

**TABLE B.2**

**NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES**
**SITE CHARACTERIZATION REPORT**
**HYDE PARK LANDFILL SITE**
**TOWN OF NIAGARA, NEW YORK**

| Well Location | Ground Surface Elevation (ft. AMSL) | Top of Bedrock Elevation (ft. AMSL) | Fracture 1 (Depth ft. bgs) | | Fracture 2 (Depth ft. bgs) | | Fracture 3 (Depth ft. bgs) | | Fracture 4 (Depth ft. bgs) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Top | Bottom | Top | Bottom | Top | Bottom | Top | Bottom |
| J2L | 608.0 | 593 | 24.2 | 24.8 | 33.0 | 33.2 | | | | |
| J3L | 600.2 | 584 | No Vertical Fracturing Noted | | | | | | | |
| J5L | 606.1 | 591 | No Vertical Fracturing Noted | | | | | | | |
| J5M | 604.6 | 593 | No Vertical Fracturing Noted | | | | | | | |
| J5U | 604.5 | 591 | No Vertical Fracturing Noted | | | | | | | |
| JH1L | 624.4 | 610 | No Vertical Fracturing Noted | | | | | | | |
| MW1-2001 | 595.4 | 577 | 18.0 | 20.0 | | | | | | |
| MW2-2001 | 594.4 | 573 | No Vertical Fracturing Noted | | | | | | | |
| MW3-2001 | 589.8 | 560 | No Vertical Fracturing Noted | | | | | | | |
| MW4-2001 | 588.8 | 559 | No Vertical Fracturing Noted | | | | | | | |
| MW5-2001 | 591.7 | 559 | No Vertical Fracturing Noted | | | | | | | |
| MW6-2001 | 591.2 | 559 | No Vertical Fracturing Noted | | | | | | | |
| MW7-2001 | 590.3 | 561 | No Vertical Fracturing Noted | | | | | | | |
| PMW-1L | 597.4 | 563 | 100.5 | 100.8 | 102.6 | 102.9 | | | | |
| PMW-3L | 604.6 | 590 | No Vertical Fracturing Noted | | | | | | | |
| PW-1L | 596.8 | 581 | No Vertical Fracturing Noted | | | | | | | |
| PW-2L | 600.0 | 580 | No Vertical Fracturing Noted | | | | | | | |
| PW-3L | 602.8 | 588 | No Vertical Fracturing Noted | | | | | | | |
| PW-4M | 610.3 | 599 | 11.2 | 11.5 | 30.9 | 31.1 | 35.8 | 36.0 | 39.7 | 40.0 |
| PW-6UR(T-1) | 611.3 | 604 | No Vertical Fracturing Noted | | | | | | | |
| PW-6MR(T-3) | 612.1 | 605 | 8.1 | 8.5 | 12.5 | 12.7 | 45.8 | 46.2 | 67.5 | 67.6 |
| PW-7U (CD-2U) | 596.7 | 563 | No Vertical Fracturing Noted | | | | | | | |
| PW-8U | 593.7 | 563 | No Vertical Fracturing Noted | | | | | | | |
| PW-8M | 597.0 | 561 | No Vertical Fracturing Noted | | | | | | | |
| PW-9U | 591.8 | 562 | No Vertical Fracturing Noted | | | | | | | |
| PW-10U | 597.8 | 579 | 19.0 | 19.5 | 26.2 | 26.5 | | | | |

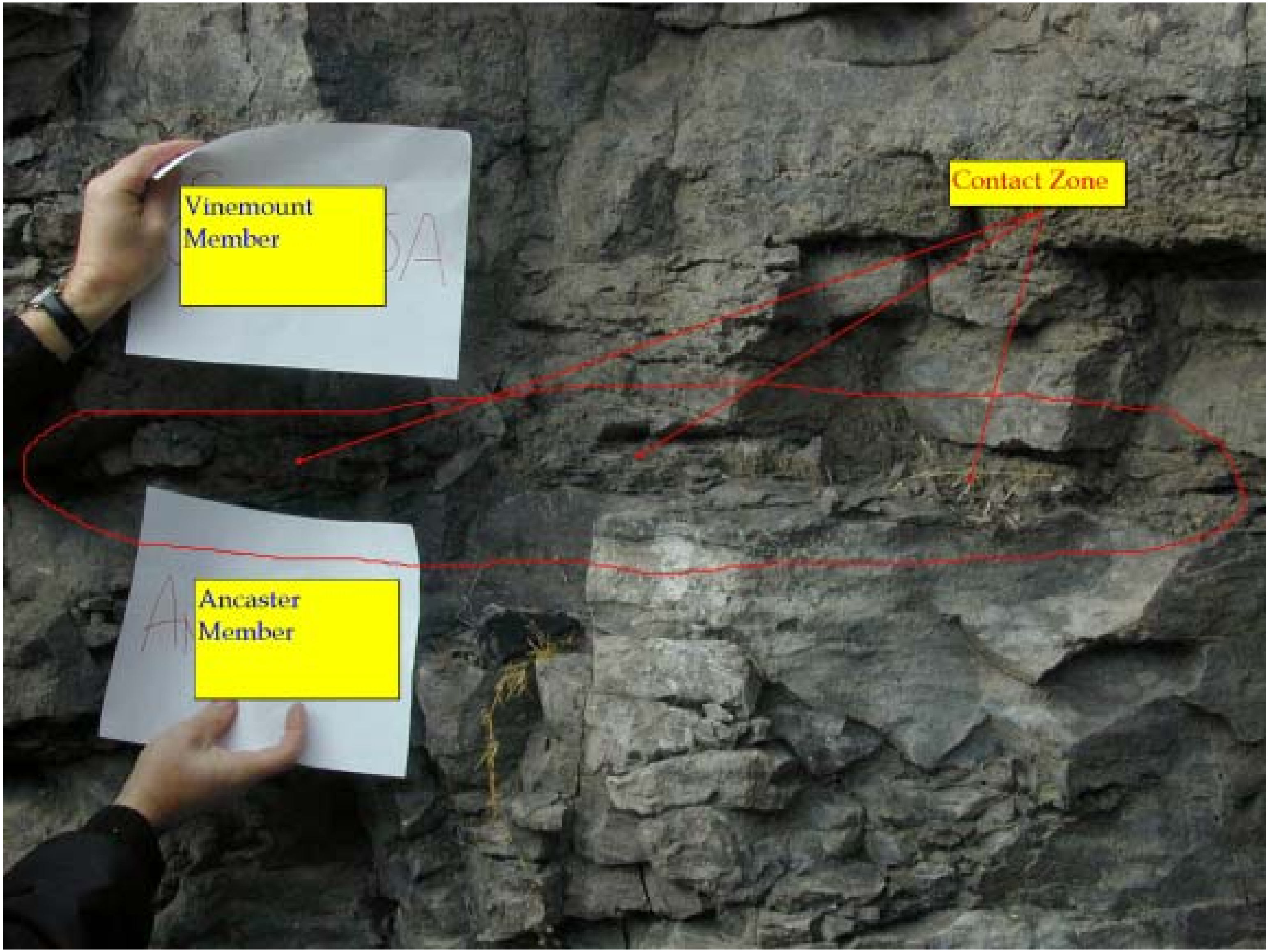
Notes:

ft. AMSL - feet Above Mean Sea Level.
ft. bgs - feet below ground surface
Only boreholes for which drill core was available are listed.
(1) Fracture identified from borehole video log.

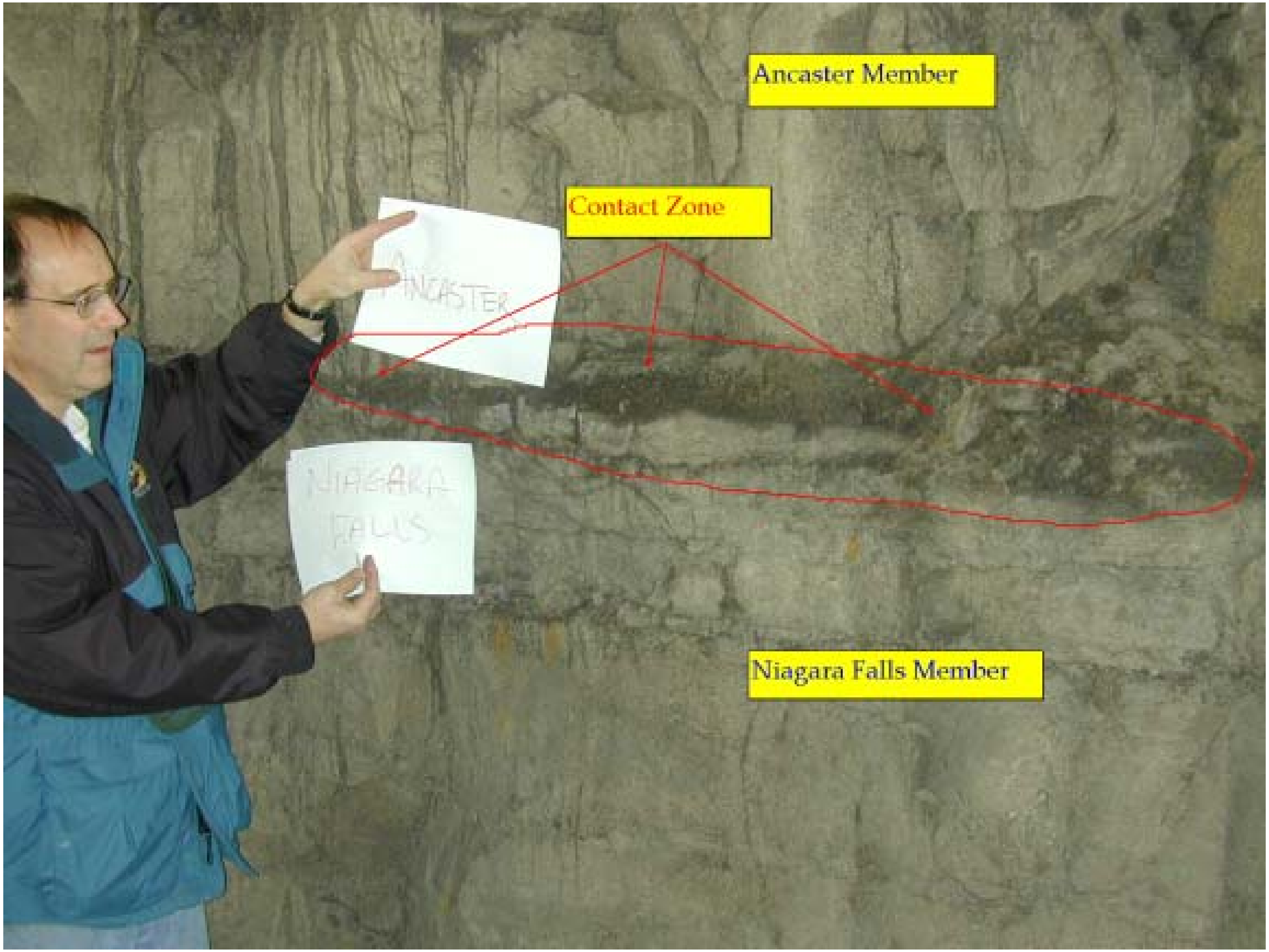
# ATTACHMENT 1

# PHOTOGRAPHS OF NEARBY OUTCROPS AND DRILL CORE

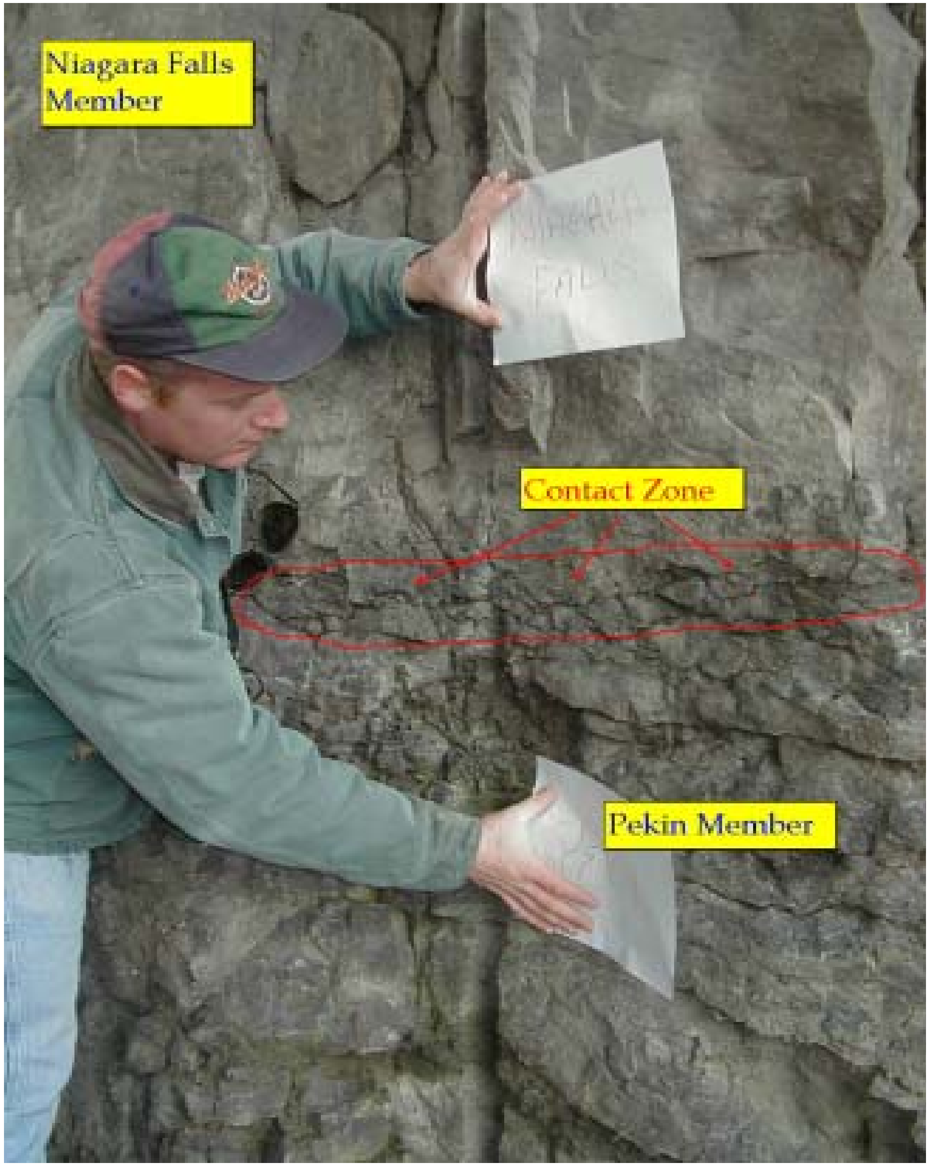

Photograph 1. Horizontal bedding, bedding plane fractures, and vertical fractures in the Vinemount Member of the Goat Island Formation. NYPA Access Road.



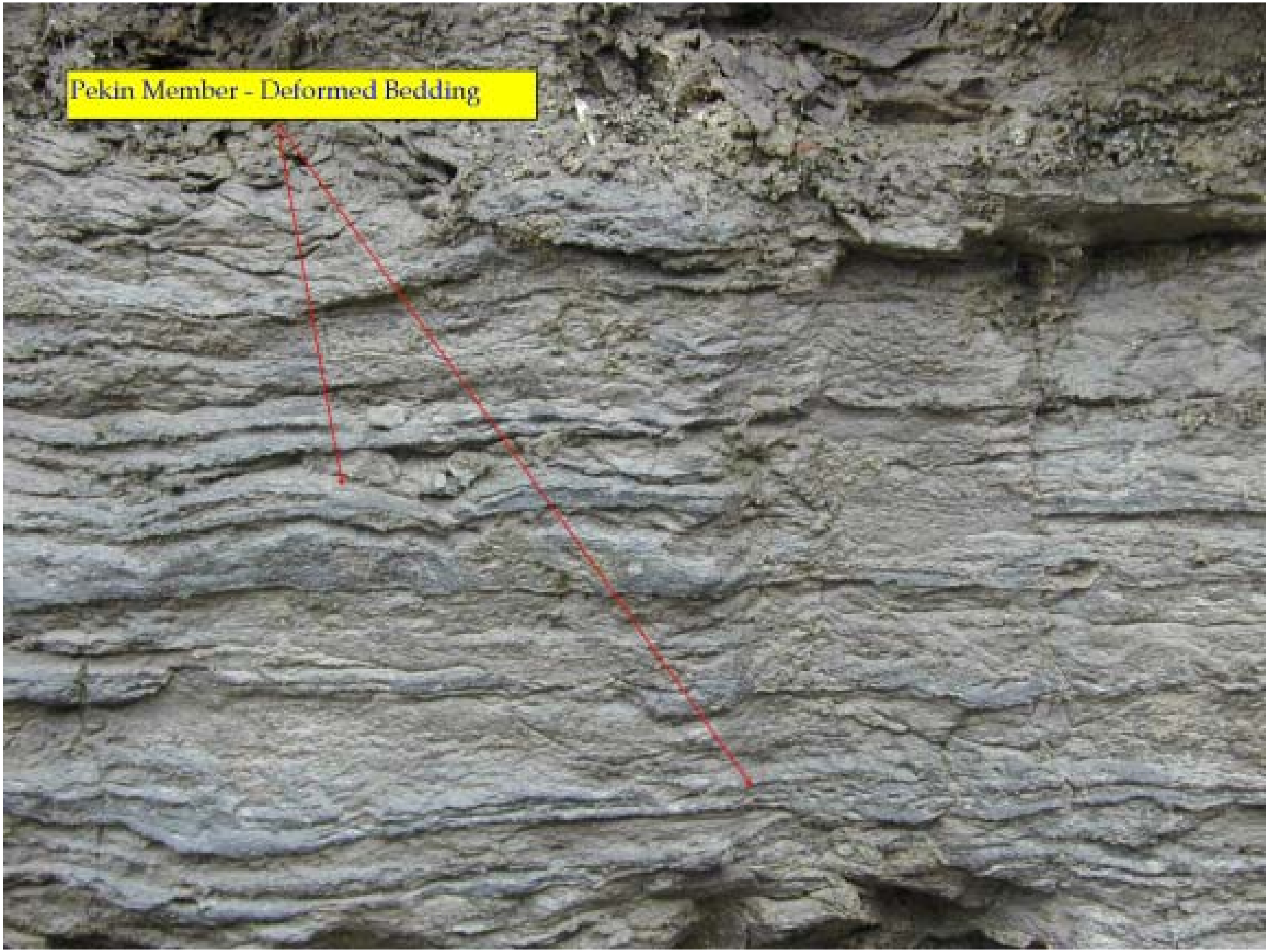

Photograph 2. Contact between the Vinemount Member and the Ancaster Member of the Goat Island Formation. NYPA Access Road.



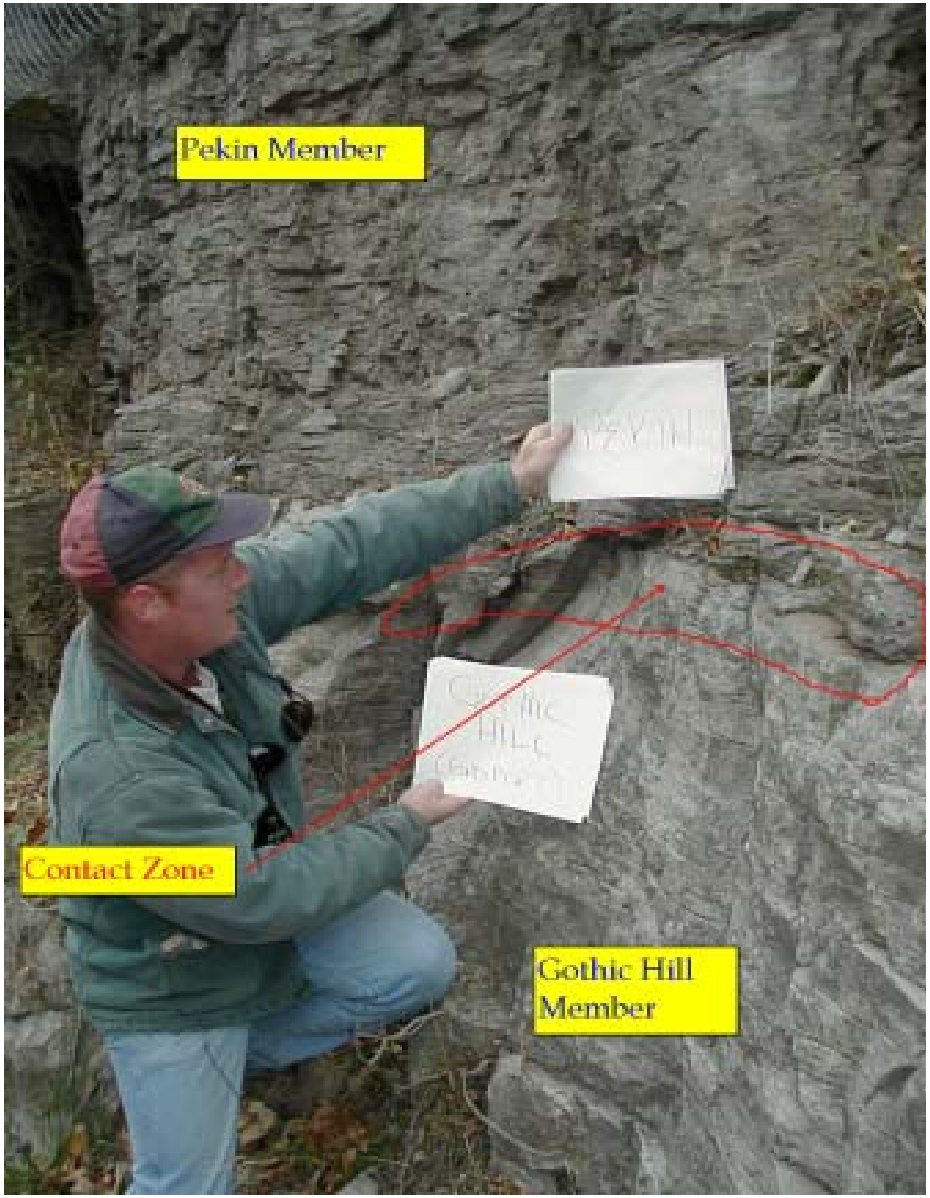

Photograph 3. Contact between the Ancaster Member and the Niagara Falls Member of the Goat Island Formation. Note the thick to massive bedding in each member. NYPA Access Road.



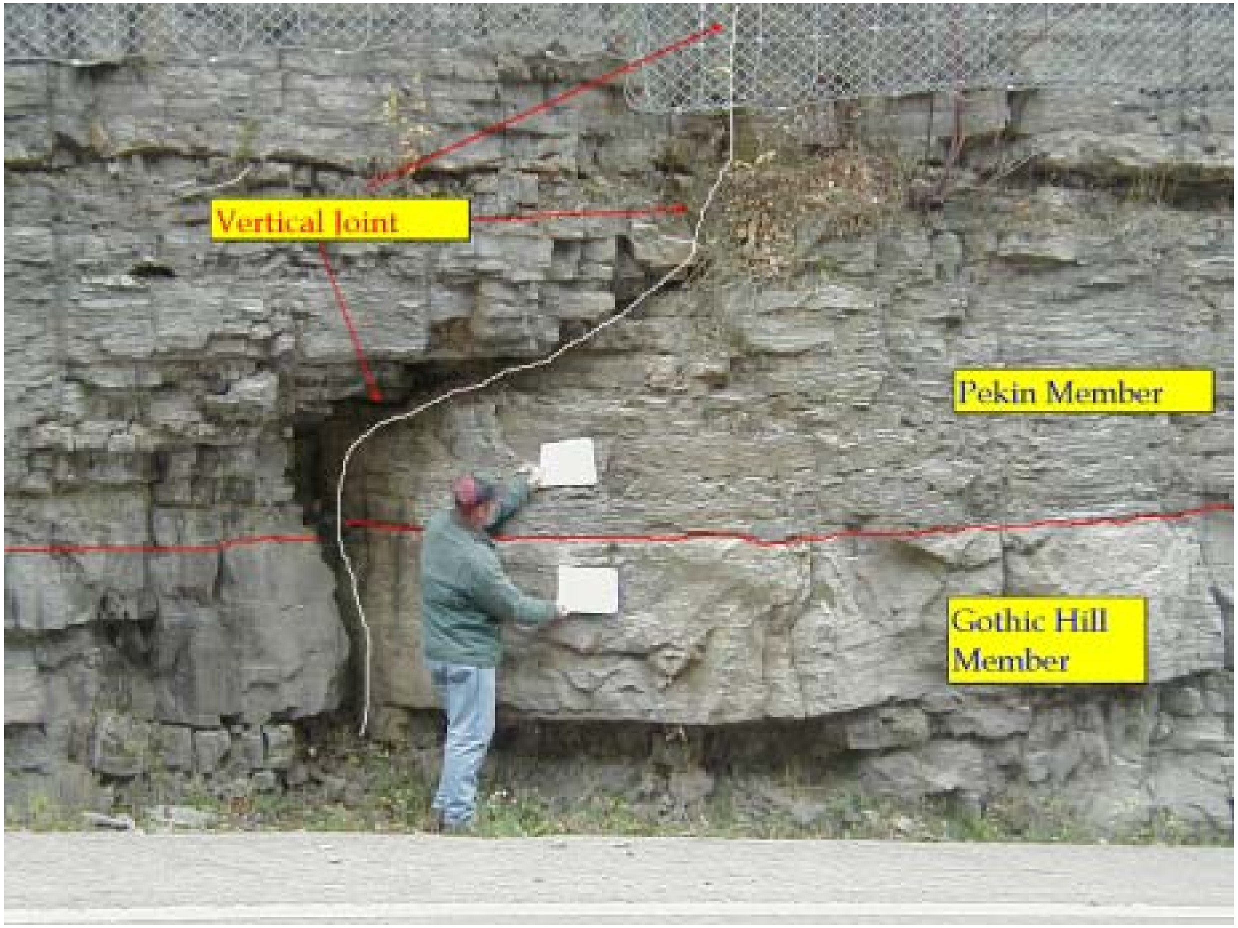

Photograph 4. Contact between Niagara Falls Member of the Goat Island Formation and the Pekin Member of the Gasport Formation. NYPA Access Road.




Photograph 5. Deformed bedding of the Pekin Member of the Gasport Formation, probably caused by stromatolites. NYPA Access Road.

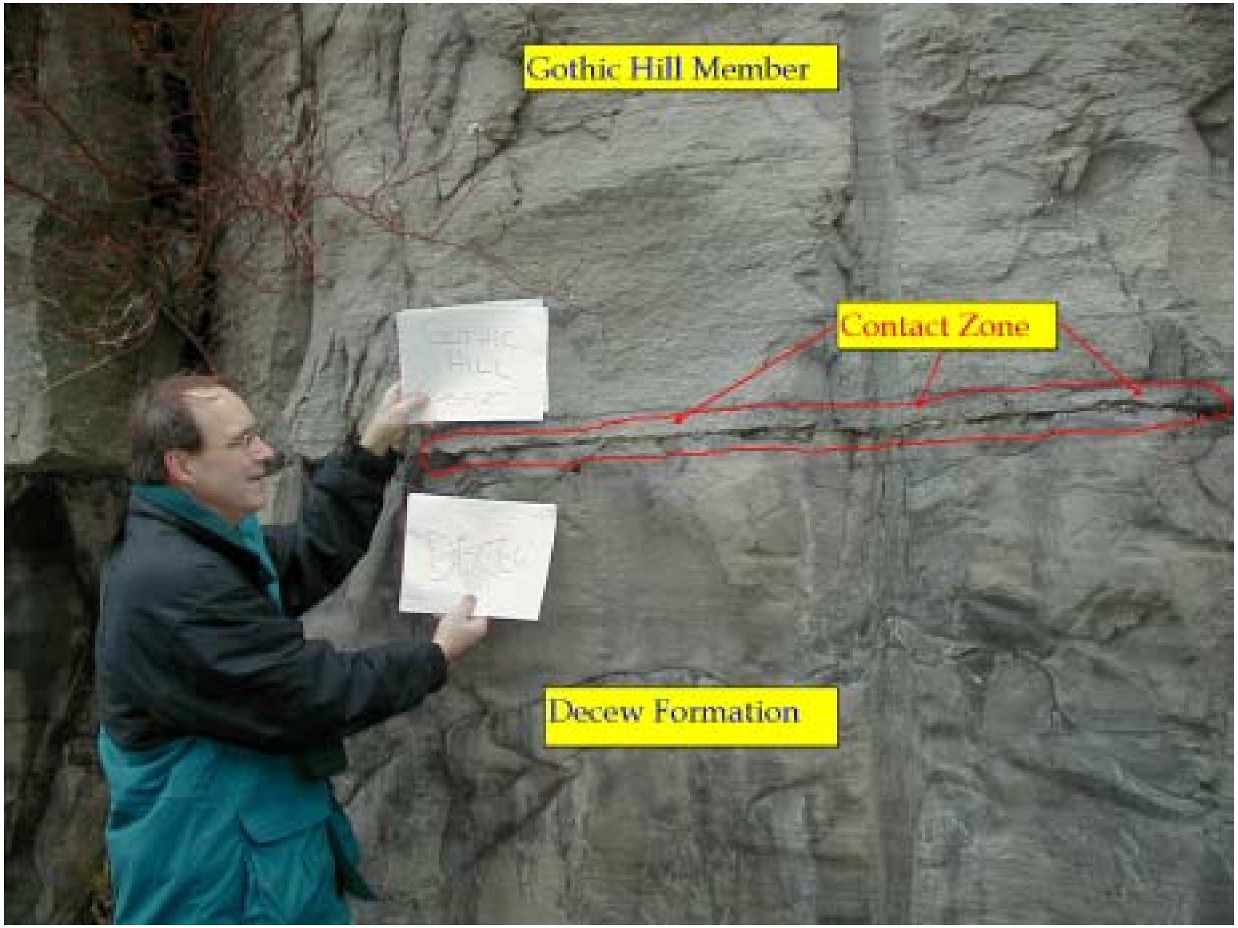



Photograph 6. Contact between the Pekin Member and the Gothic Hill Member of the Gasport Formation. NYPA Access Road.

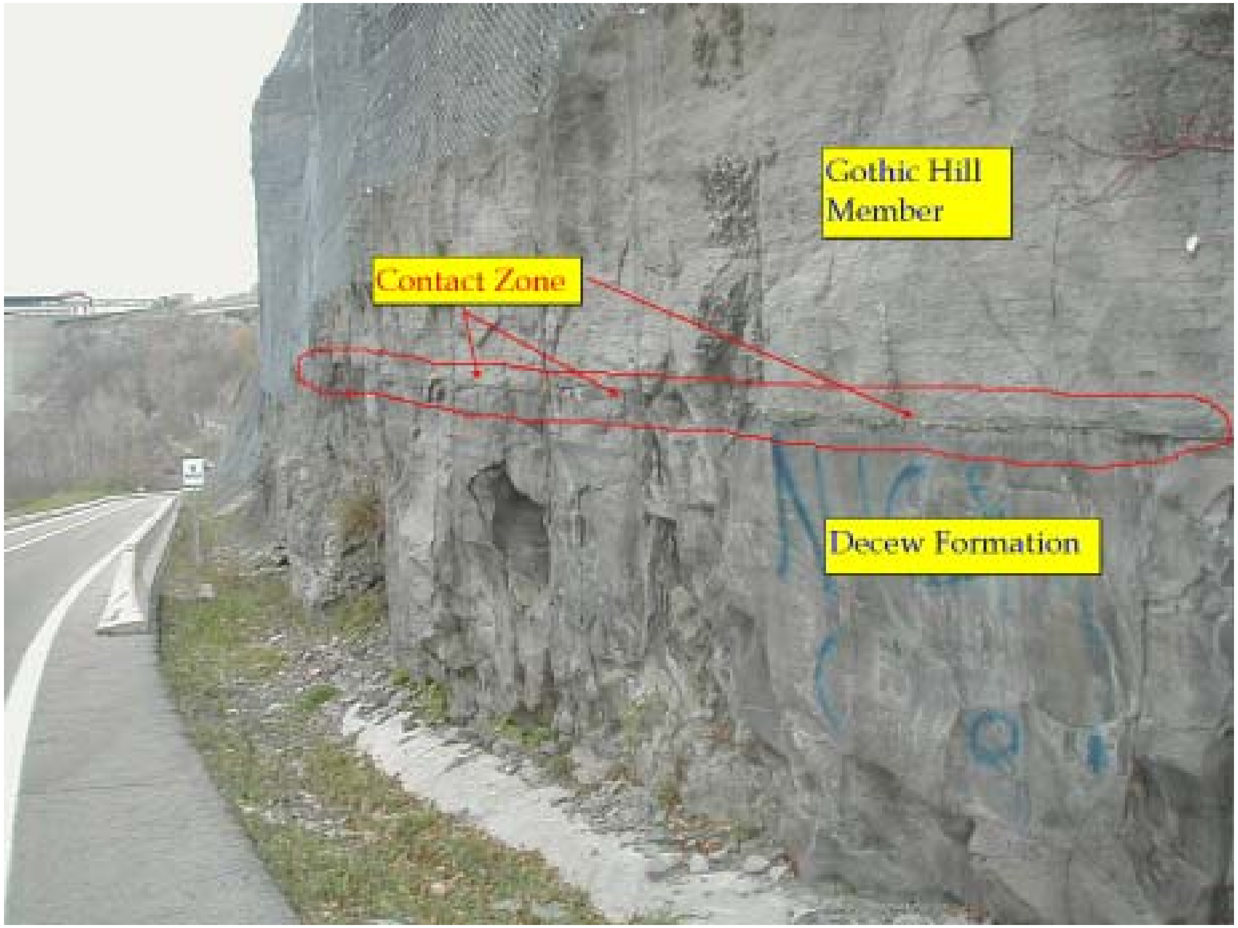



Photograph 7. Contact between the Pekin Member and the Gothic Hill Member of the Gasport Formation. Note the large vertical joint (steeply dipping in the center of the photograph) within the Pekin Member. NYPA Access Road.

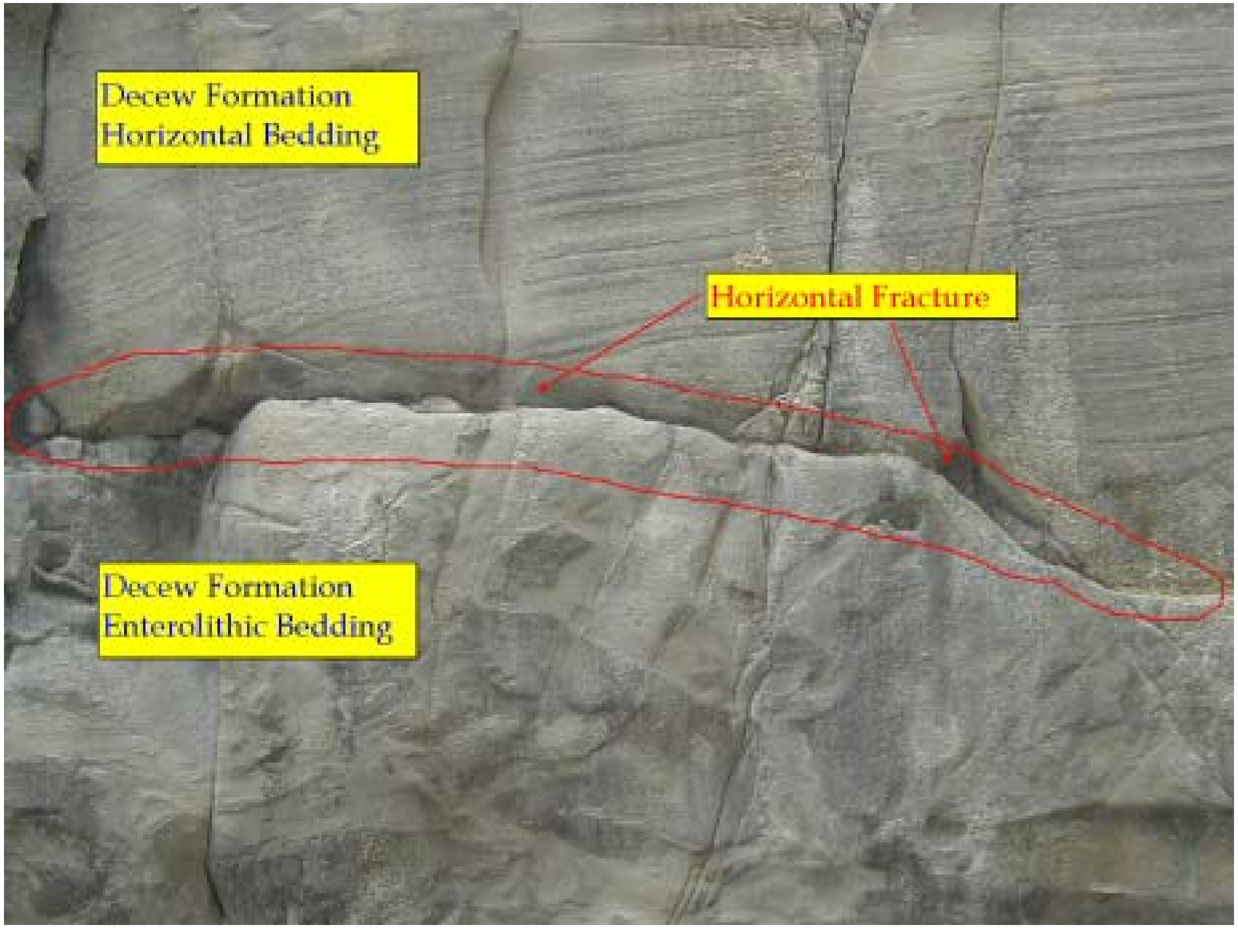

Photograph 8. Cross-bedding within the coarse-grained Gothic Hill Member of the Gasport Formation.  Note the vertical joint and lack of bedding plane fractures. NYPA Access Road.



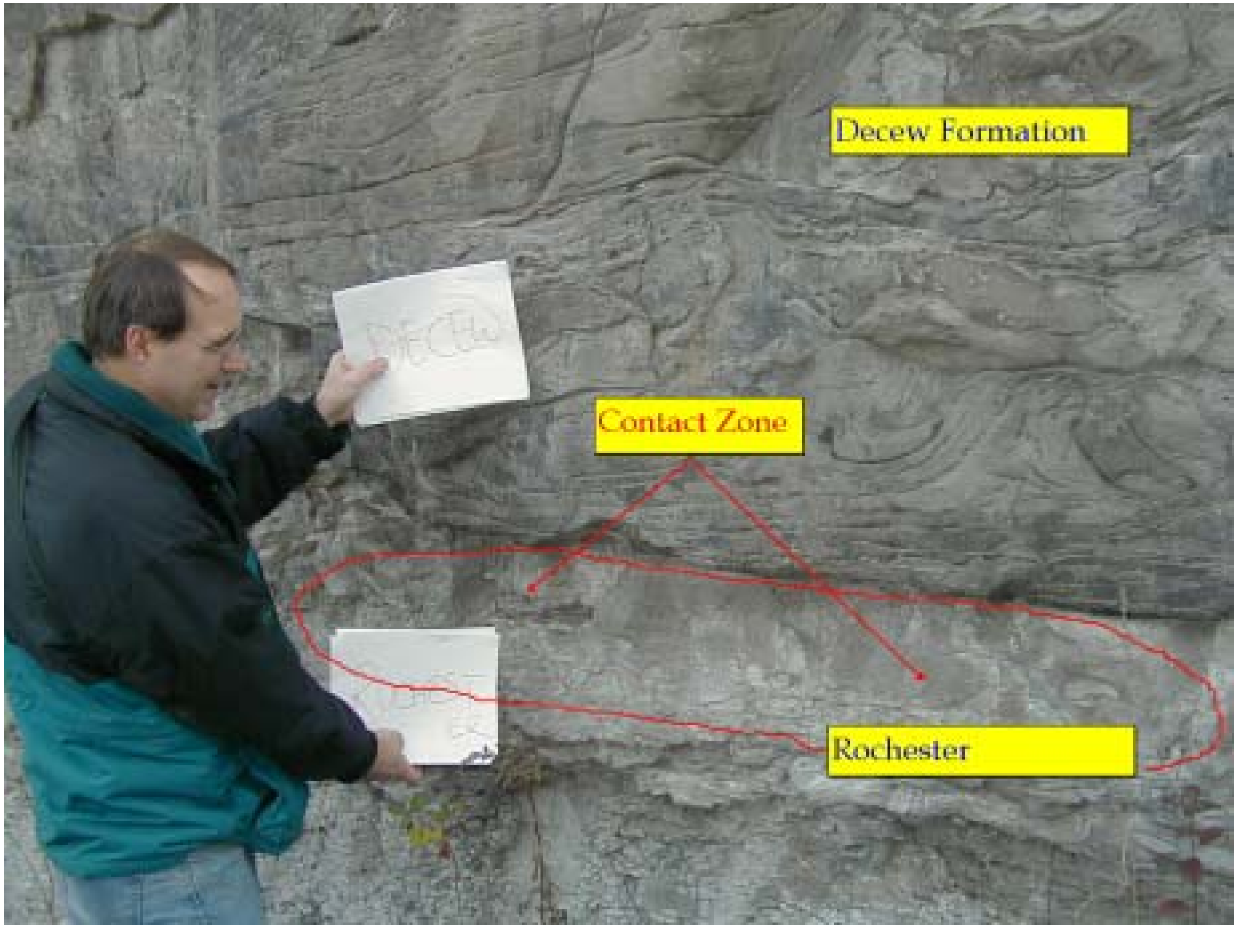

Photograph 9. Contact between the Gothic Hill Member of the Gasport Formation and the DeCew Formation.  Note large vertical joint on left side of photograph. NYPA Access Road.



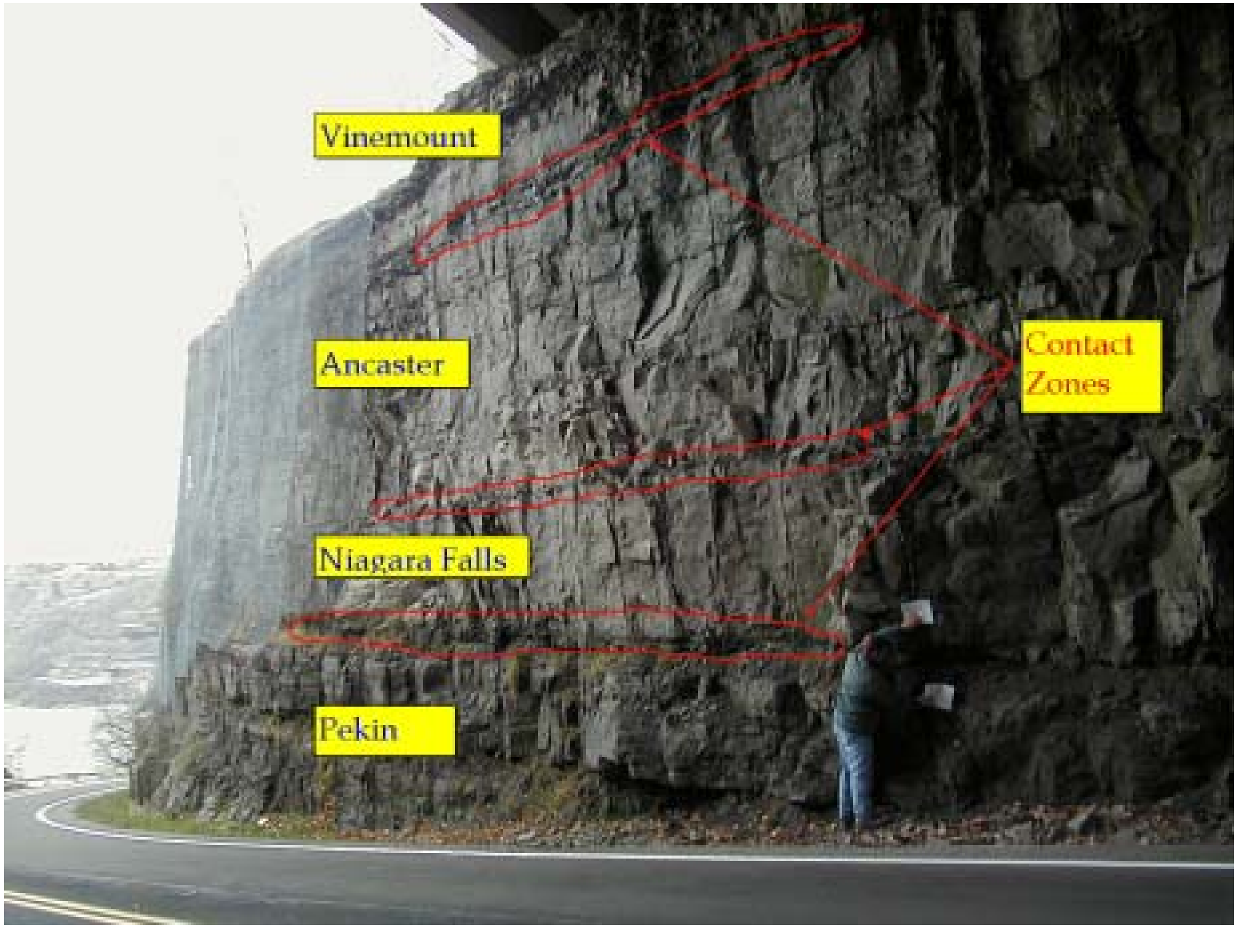

Photograph 10. Contact between Gothic Hill Member of the Gasport Formation and the DeCew Formation. Note the massive nature of each unit and overall lack of bedding plane fractures. NYPA Access Road.




Photograph 11. Bedding plane contact between near-horizontal bedding and enterolithic bedding within the DeCew Formation. NYPA Access Road.




Photograph 12. Contact between the DeCew Formation and the Rochester Shale. Note the enterolithic bedding in the DeCew Formation near the "Contact Zone" label and overlying near-horizontal bedding near the "DeCew Formation" label. NYPA Access Road.




Photograph 13. Stratigraphic section and contact zones, Goat Island Formation and Pekin Member of the Gasport Formation. NYPA Access Road.


Photograph 14. B2L core showing Vinemount Member of Goat Island Formation.

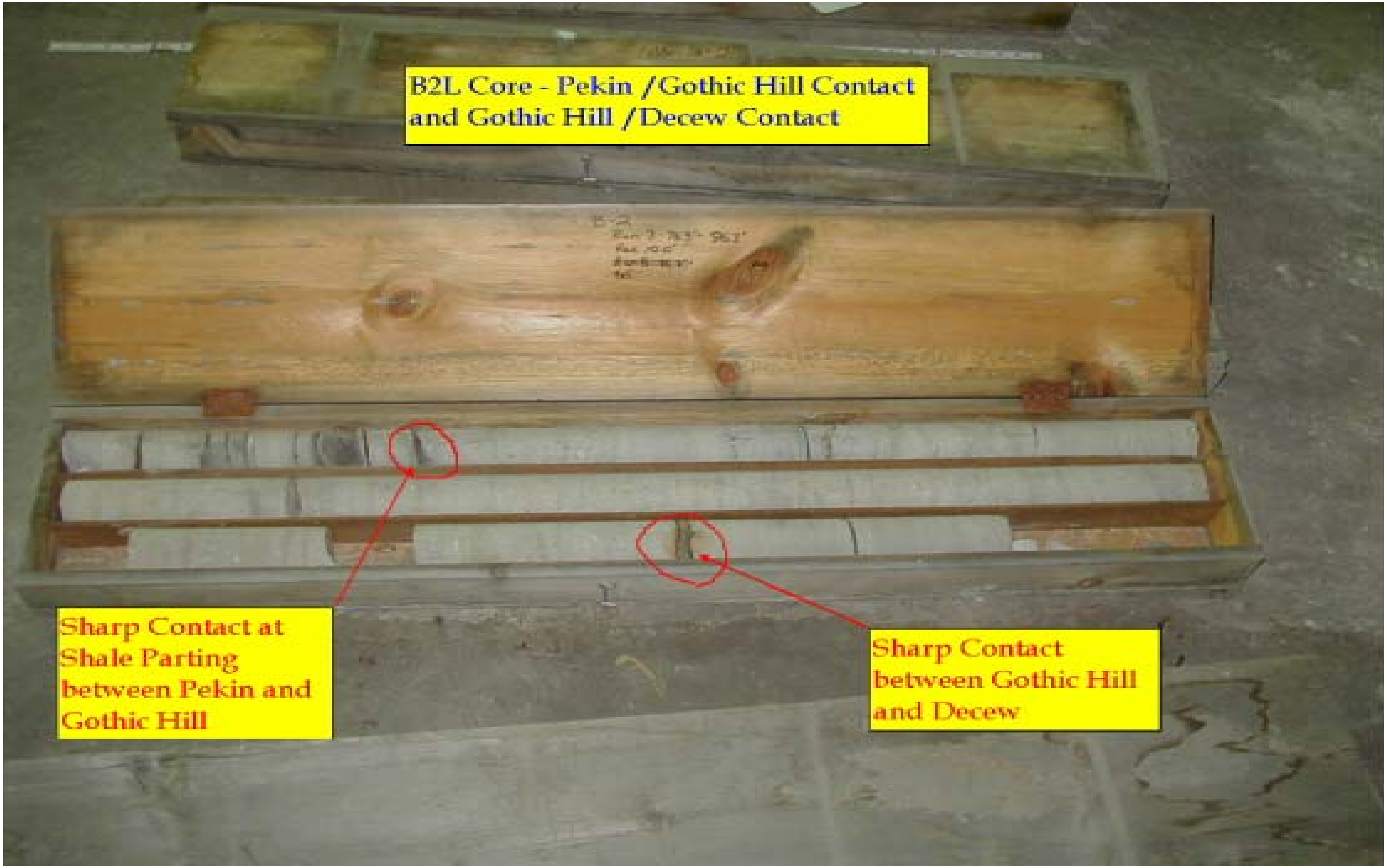

Photograph 15. B1L core showing Vinemount Member of Goat Island Formation.


Photograph 16. B1L core showing Vinemount Member / Ancaster Member contact.


Photograph 17. B2L core showing Niagara Falls Member / Pekin Member contact.


Photograph 18. B1L core showing Pekin Member of Gasport Formation.


Photograph 19. Close-up of C1L core showing Pekin Member of Gasport Formation.




Photograph 20. B2L core showing Pekin Member / Gothic Hill Member contact and Gothic Hill Member / DeCew Formation contact.

# APPENDIX C

# QUANTUM ENGINEERING CORPORATION ELECTROMAGNETIC BOREHOLE FLOWMETER TESTING REPORT

QEC

QEC - T - 142

# Results of Field Tests with the Electromagnetic Borehole Flowmeter At the Hyde Park Landfill Site Niagara Falls, NY

**by**

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**November 2001**

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# Introduction

Quantum Engineering Corporation (QEC) conducted flowmeter tests at the Hyde Park Landfill in Niagara Falls, New York. The tests were performed under subcontract to Conestoga-Rovers & Associates, Inc. (CRA) of Niagara Falls, New York. The instrument system used, the Electromagnetic Borehole Flowmeter (EBF), was designed expressly for such tests as performed at the Hyde Park Landfill (Young and Waldrop, 1989). Data from this procedure provide a cost-effective method to define a profile of hydraulic conductivity throughout the screened or uncased portion of the saturated zone. It also provides the hydrogeologic flow conditions occurring naturally in each well. The QEC team that performs EBF tests are inventors of the instrument system. They have conducted similar tests for a wide range of geohydrology throughout the United States.

Field data were collected at 44 wells at the site during an 11-day period in August 2001. The tests were conducted according to a scope of work developed jointly by staff of QEC, CRA and S.S. Papadopulos & Associates, Inc. (SSP&A). This report presents results from the field tests as well as describes the test protocol and the EBF system used.

## The Borehole Flowmeter Method

The flowmeter method represents a reasonably simple approach for assessing the relative hydraulic conductivity in porous media or flow through fractured rock at discrete positions in a screened well or uncased borehole. This method is equally effective for evaluating the direction of ambient flow caused by vertical hydrostatic pressure gradients throughout the depth of a borehole. The technique involves measuring at arbitrarily selected intervals as water is transmitted through a well under ambient and induced pumping conditions.

In principal, the flowmeter method is very straightforward. Consider the test setup for the well shown in Figure 1. When water is pumped into or from the well at a constant rate for an extended time (i.e. typically about 10 minutes), then the water surface level inside the well will adjust until it reaches equilibrium. At that time, water is being induced into (or from) the well at the same rate as that being pumped near the surface. Water is entering or exiting the well horizontally throughout the screened or open interval of the well and flowing vertically within the well. The objective is to measure the vertical distribution of the horizontal flow into or from the well. The horizontal flow rate at each stratum is indicative of the hydraulic conductivity of those strata as discussed by Molz, et.-al. (1990).

Under ideal conditions, the probe is sealed to the wall such that any vertical flow must pass through the recording zone of the meter. Then the flow into or from the well below the meter is recorded as it flows vertically in the well. For some applications, it is not possible to effect a complete seal with the wall and prevent bypass flow. For such cases, it is often desirable, but not essential, to determine the percentage of flow rate bypassing the recording section of the probe and correct the probe readings accordingly.

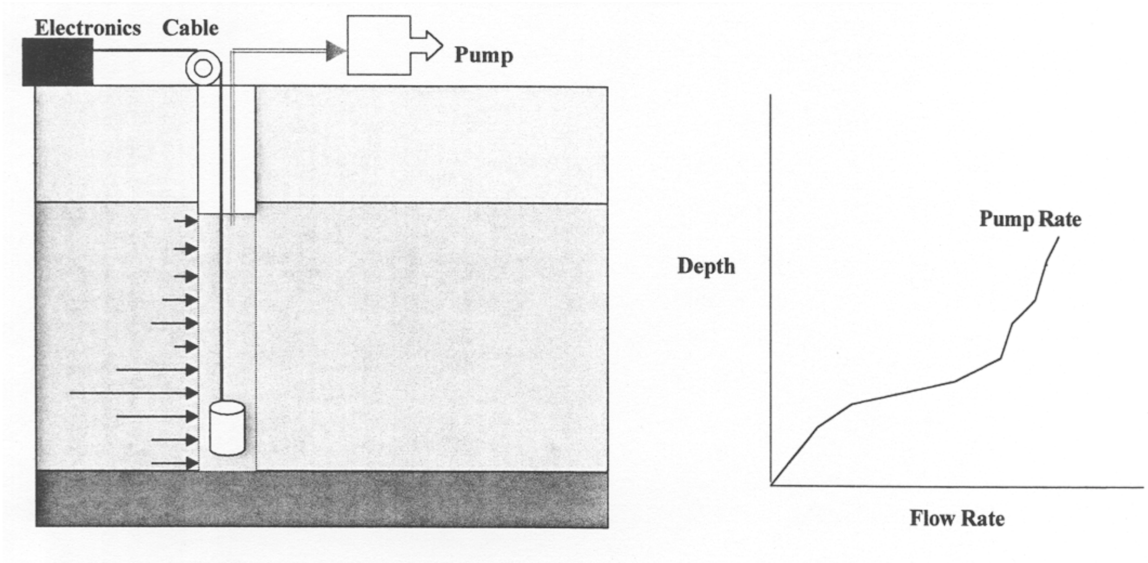


**Figure 1. Apparatus and Geometry of a Borehole Flowmeter Test**

A flowmeter test for a well is initiated by measuring for ambient flow throughout the screened or uncased section of the well. This is typically initiated with the flowmeter at the bottom of the screen where flow rates should be zero. The probe is then raised one increment. After any flow disturbance caused by the probe movement has subsided, the vertical flow at that station is recorded. This process is repeated throughout the entire screened or uncased region. These ambient flows reveal the presence of vertical pressure gradients, positive or negative, between strata, and provide a baseline for analyzing induced flow into the well during pumping.

Once the ambient flow pattern has been recorded, the induced flow test is initiated by pumping into or from the well at a constant rate. The water surface is monitored to determine when equilibrium conditions have been achieved. At that time, the probe is systematically moved vertically with flow rates recorded at predetermined intervals throughout the well screen or uncased region. Data at each depth are displayed on a digital readout and stored in a data file of a portable computer. These tests can be performed with equal accuracy by injecting flow into the well at a constant rate instead of pumping.

Data analysis is also relatively simple. The lateral inflow from each stratum is calculated by successively subtracting the cumulative flow measured at those strata from the cumulative flow recorded at the level immediately below. Hydraulic conductivity can be calculated for those strata by using the Cooper-Jacob formula for horizontal flow to a well. The ratio of local hydraulic conductivity $K_i$ to average $K_{ave}$ for each well is computed using Equation 7 from Molz and Young (1993),

$$K_i / K_{ave} = ((\text{Delta } Q_i - \text{Delta } q_i) / \text{Delta } z) / (Q_{pump} / b) \; ; i= 1,2, \ldots n$$

where

Delta $Q_i$ = Flow from the ith layer in the well;

Delta $q_i$ = Ambient flow from the ith layer of the well;

Delta z = ith layer thickness;

$Q_{pump}$ = Flow rate pumped from the well during the induced flow test; and

b = Aquifer thickness.

Additional details are presented in Molz, et. al., (1994).

## The Electromagnetic Borehole Flowmeter

The EBF measures flow using Faraday's Law of Induction.  This principal states that the voltage induced by a conductor moving at right angles through a magnetic field is directly proportional to the velocity of the conductor through the field.  The flowing water is the conductor, the electromagnet generates the magnetic field, and the electrodes measure the induced voltage.  The electronics attached to the electrodes transmit a voltage directly proportional to the velocity of the water flowing through the interior of the probe.  The voltage produced by the water movement through the probe is insensitive to the conductivity of the water as long as the water is conductive.

This method of measuring velocity provides essentially an instantaneous response to changes in flow rates.   Data are typically recorded and averaged over 60 seconds for each data point during a static test of a particular stratum.  The total time required to position the probe to a desired depth, allow the flow to settle from the disturbance of movement, record a data point, and document notes is about five minutes.

The external dimension of the downhole probe is designed to fit snugly into a Schedule 40 two-inch diameter pipe.  Two probes are available - one with a half-inch inside throat diameter and another with a one-inch throat diameter.  The performance specifications of both probes are presented in Table 1.

### Table 1: Performance Specifications of the EBF Probes

| | **1/2 Inch id Probe** | **1 Inch id Probe** |
|---|---|---|
| Minimum Flow | 10 mL/min (0.0026 gpm) | 40 mL/min (0.011 gpm) |
| Minimum Velocity | 0.131 cm/sec (0.0043 fps) | 0.131 cm/sec (0.0043 fps) |
| Maximum Flow | 10 L/min (2.64 gpm) | 40 L/min (10.6 gpm) |
| Maximum Velocity | 131 cm/sec (4.3 fps) | 131 cm/sec (4.3 fps) |

Both probes are designed such that the electromagnets, electrodes and electronic components are fixed in place, tested and then potted with a watertight epoxy.  The probes have no moving parts and have smooth exterior surfaces for easy cleaning.

Because the EBF can accurately record extremely low flow rates, it is possible to record ambient flow rates occurring naturally in wells, as well as the influx of flows during pumping. The flowmeter measures flow in either direction with equal accuracy.

This new instrument system has proved to be useful in support of environmental groundwater investigations throughout the USA during the seven years that it has been produced commercially.  The publications by Young, et al (1998), Molz, et al (1994), Hutchins and Acree (2000) and Molz and Young (1993) provide examples of results from several such applications available in the scientific literature.  Examples of data and analysis methods are also presented in the QEC web site at www.qec-ebf.com.

The downhole probe, cable, and aboveground electronics box is shown in Figure 2.  The compactness of the system makes it easy to transport, ship and handle in the field.

**Figure 2: The Electromagnetic Borehole Flowmeter System**

## Test Results

Hubert Pearson of QEC, a member of the invention team and experienced in conducting EBF tests, served as test engineer. Staff of CRA and SSP&A assisted throughout in conducting these tests. Jon Williams of CRA and Christopher Neville of SSP&A provided guidance for test objectives to assure that test data would be consistent with their needs for defining the hydrogeology at this site.

The flowmeter test was performed with the QEC EBF system using the one-inch inside diameter (i.d.) probe. A one-half inch diameter probe was available, but was not used. Although the one-half inch probe provides better resolution for ambient flow, it was found in the field that the larger i.d. probe is more effective in uncased boreholes where it is sometimes not possible to achieve a complete seal to the walls. The impact of the coarser resolution of the larger i.d. probe on the identification of flow zones was considered to be negligible. This was because the primary results used for the identification of the flow zones were obtained under injection conditions. The injection testing was conducted at rates that were much higher than the 0.011 gpm lower flow limit for the one-inch probe.

Calibration of the EBF system was checked prior to the initial test, but no adjustments were required. Experience has shown that the EBF system is not subject to calibration drift. This is attributable to the design features of the electronics and the fabrication method by which the electronics of the probe are encased in watertight epoxy. The calibration curve for the EBF system used is presented in Figure 3.

The EBF system produced a linear signal throughout the range of flows tested. Upward flows were designated as positive as the sign convention used throughout all testing. QEC furnished the EBF system, and a water level measuring device. CRA provided a portable generator and a potable water supply used for injection during the test.

The wells were drilled to a pre-determined depth before solid steel casings were installed in the upper portion of each well. The EBF tests were performed in the lower uncased

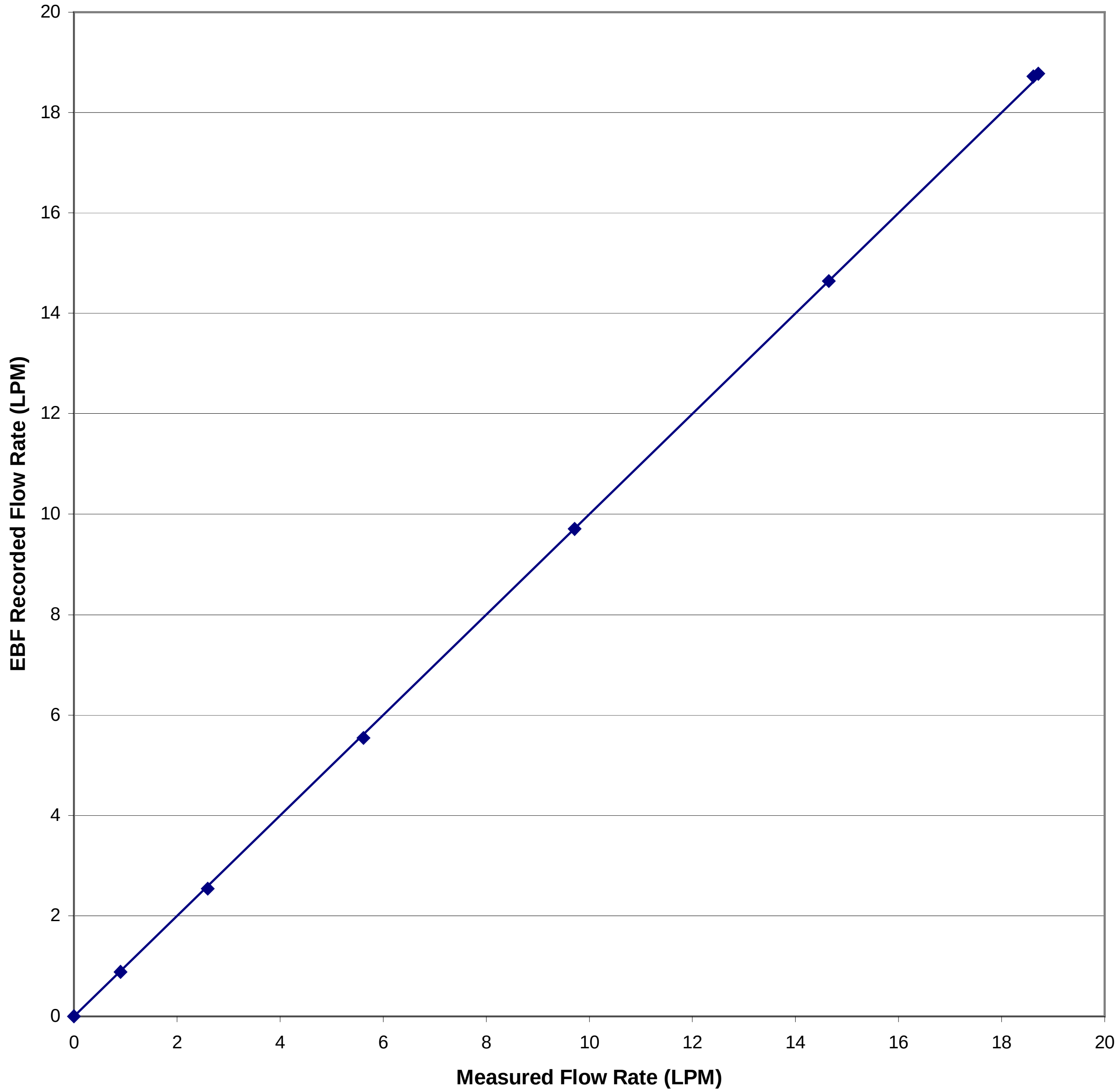


**Figure 3: Calibration Curve for the One Inch EBF System**

portion of rock. The wells tested fell into three classes depending upon the depth of each well. Wells were labeled U, M, and L denoting the uncased portion in the Upper, Middle, and Lower zones, respectively. The uncased portion of the wells of the Upper zone typically extended between depths of 25 and 50 feet below grade, the Middle zone between 50 and 80 feet, and the Lower zone between 80 and 110 feet, depending on the depth of the overburden. Five new monitoring wells, with depths of up to 50 feet, were also tested. The locations of all wells tested relative to the Hyde Park Landfill are shown in Figures 4 through 6.

The solid casings of the wells were nominally 3 7/8 inches in diameter. This precluded use of the inflatable packer since this is slightly less than the outside diameter of the inflatable packer for the EBF downhole probe. Instead of using the packer to prevent bypass flow around the exterior of the probe, a collar with a hard rubber outer ring cut to the approximate size of the uncased borehole was used to restrict vertical flow around the probe. This collar restricted much of the vertical flow, but being of a fixed diameter in an uncased hole, the seal was sometimes incomplete. Nevertheless, this approach was usually adequate for isolating flow rates into or from major fractures during ambient and injection testing. Since the objective of the flowmeter testing was to identify flow zones, no attempt was made to correct probe readings to account for leakage around the probe.

The test for each well was initiated with a test of ambient flow in the well. This was followed by an induced flow test. Water was injected at a constant rate instead of pumping for the induced flow test. Equilibrium conditions were established by injecting water into the well for about 10 minutes at a low sustained flow rate of about 1.0 gpm or less. This provided a vertical profile of flow rate throughout the uncased interval of the well. Well parameters including the effect on water surface due to injecting water are shown in Table 2. The vertical profile of flow rate combined with the ambient flow rate for each well provided the location and relative importance of fractures throughout the uncased portion of each well. The engineers also attempted to test well J1L, but the test was aborted when they encountered an obstruction at a depth of 95 feet. However, a slug test conducted at the time indicated that this well was very tight.

A discrepancy exists between the recorded injection flow rate and the maximum flow rate recorded by the flowmeter at the uppermost test measurement for several wells. This was the case for four of the five monitoring wells tested. This discrepancy is likely caused by an incomplete seal with the wall to prevent bypass flow. As long as the percentage of bypass flow was reasonably consistent, then the recorded flow profile is adequate for predicting the location of significant fractures. An abrupt change in the flow rate recorded between different depths indicates that flow has entered or exited the well. Bypass flow may affect the magnitude of the recorded flow rate, but not the percentage change between stations. However, in such cases, some discretion is advised when interpreting results.

Graphs of the vertical profile of induced and ambient flow rates for each well are presented in Appendix A. The profiles of ambient and induced flow rates were plotted as recorded. Whenever ambient flow rates were considered significant, a profile of Net Induced Flow Rate was computed by subtracting ambient flow rate from the induced flow at corresponding depths. Each graph also contained an additional profile that included QEC's interpretation of the data. This profile is intended to eliminate such effects as variations in cross-sectional diameter of the uncased borehole and other data anomalies. The Interpreted profile reflects an intended correction to the Net Induced profile.

Each graph also includes notation based on the authors' interpretation of fracture locations, explanation of unusual data, or other information noted while conducting the test or analyzing the data. Much of this information is based on the experience of the authors, but is obviously open to different interpretations of others. It is included to assist those using these data in conjunction with results from other geophysical tests. Combining results from the EBF tests with those from geophysical tests should provide hydrogeologists with a reasonable understanding of the hydrogeology in the vicinity of each well.

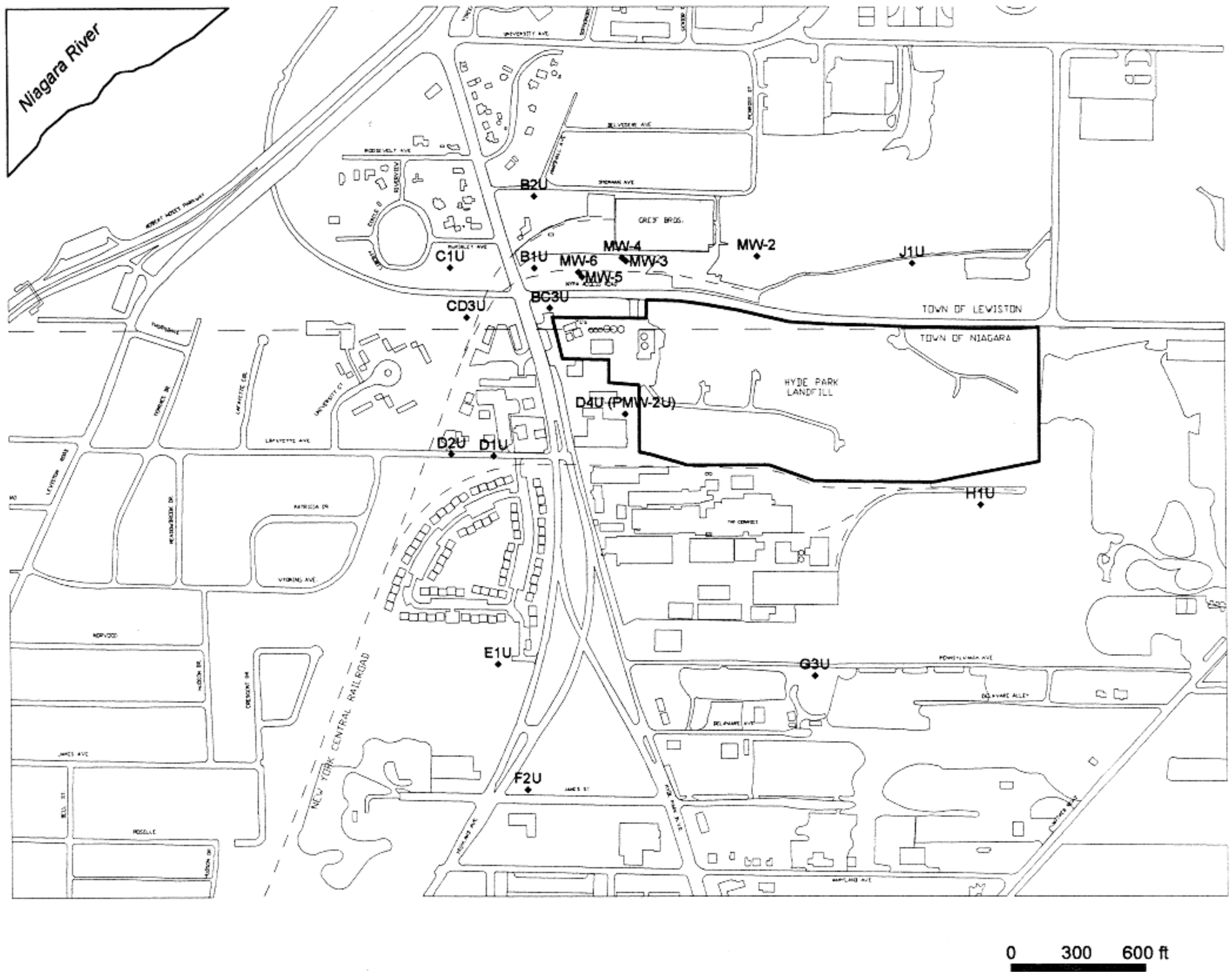


**Figure 4: Location of Upper Zone Wells Tested**

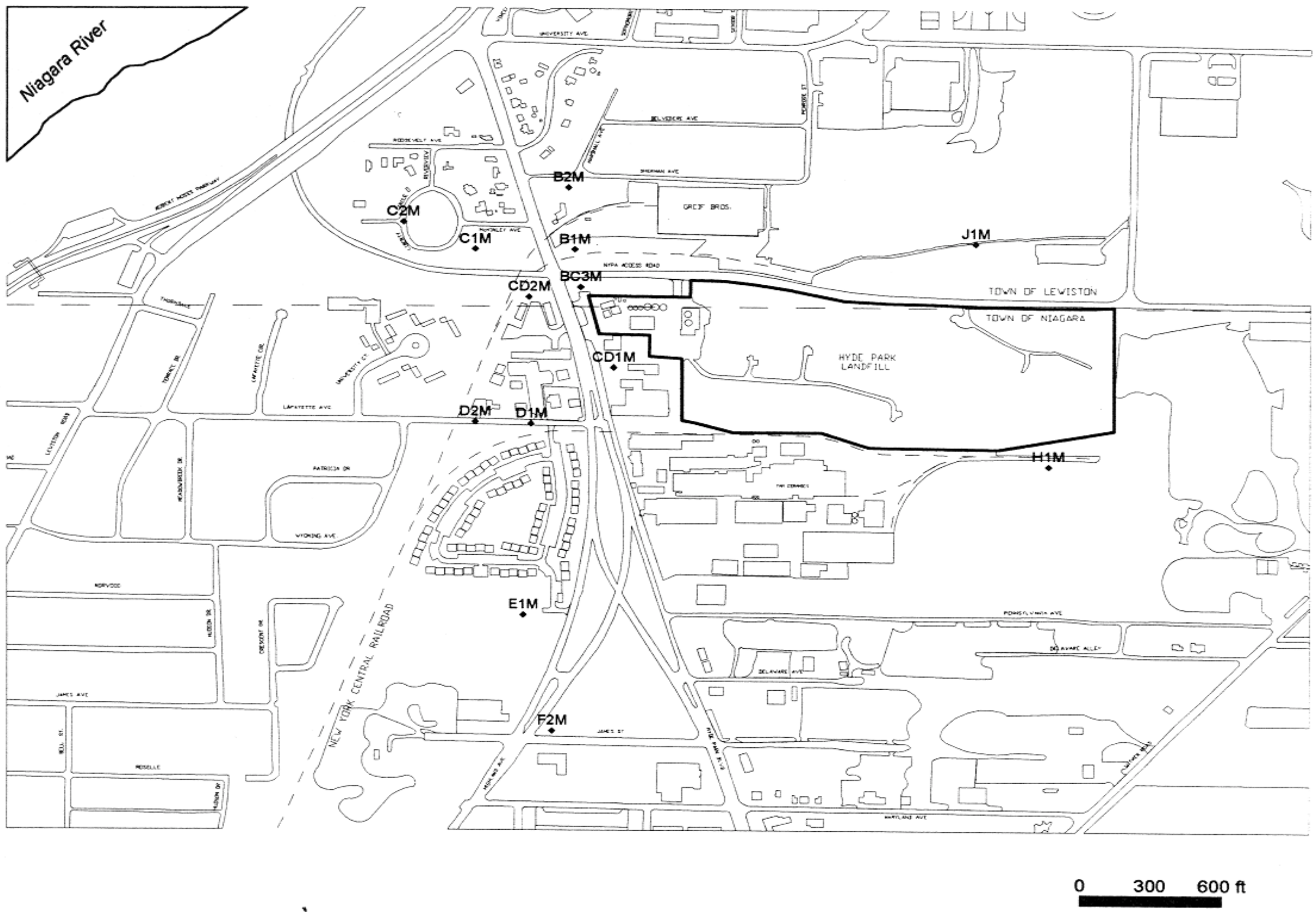


**Figure 5: Location of Medium Zone Wells Tested**

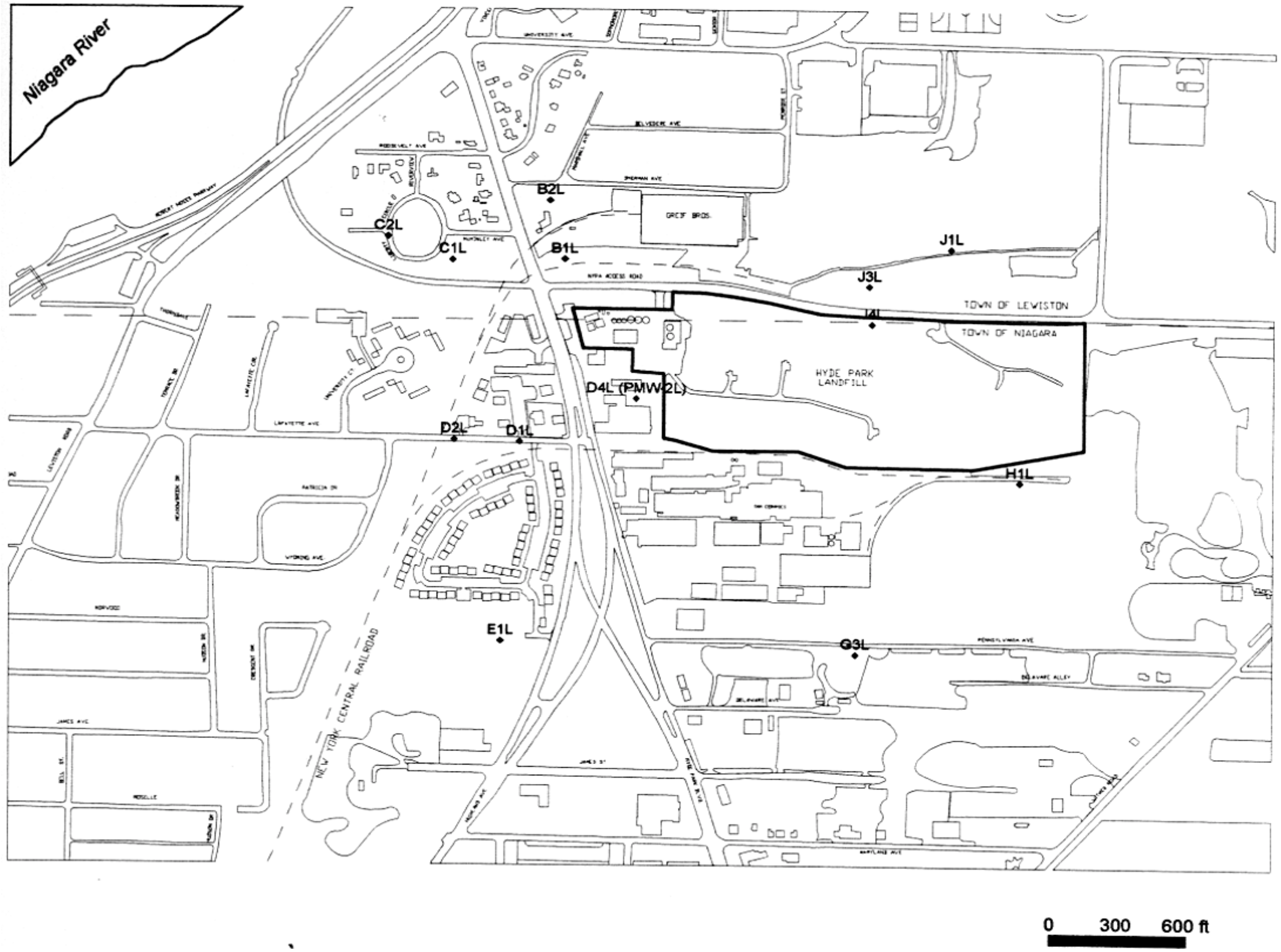


**Figure 6: Location of Lower Zone Wells Tested**

## Table 2: Parameters of Wells Tested

| Well No. | Bottom of Casing (Note 1) (ft.) | Bottom of Well (Note 1) (ft.) | Ambient Flow Direction | Injection Test Successful (Note 2) | Static Depth to Water (ft.) | Injected Depth to Water (ft.) | Injection Rate (gpm) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| B1L | 87 | 107 | Negligible | No | 49.05 | - | - |
| B1M | 60 | 85 | Negligible | Yes | 43.40 | 42.90 | 0.87 |
| B1U | 32 | 60 | Negligible | Yes | 25.63 | 24.30 | 1.90 |
| B2L | 78 | 98 | Negligible | No | 48.70 | - | - |
| B2M | 52 | 75 | Negligible | Yes | | 42.60 | 2.85 |
| B2U | 27 | 51 | Down | Yes | 26.95 | 20.85 | 0.80 |
| BC3M | 66 | 87 | Negligible | Yes | 52.14 | 49.60 | 0.34 |
| BC3U | 35 | 62 | Negligible | No | 29.08 | - | - |
| | | | | | | | |
| C1L | 85 | 103 | Negligible | Yes | 55.00 | 53.20 | 3.4 |
| C1M | 59 | 81 | Negligible | Yes | 49.15 | 48.55 | 3.4 |
| C1U | 31 | 58 | Down | Yes | 28.60 | 28.60 | 1.8 |
| C2L | 80 | 101 | Negligible | Yes | 49.40 | 38.30 | 0.30 |
| C2M | 56 | 80 | Negligible | Yes | 44.24 | 29.60 | 0.20 |
| CD1M | 64 | 88 | Negligible | Yes | 52.08 | 51.70 | 0.33 |
| CD2M | 64 | 90 | Negligible | Yes | 53.45 | 53.45 | 0.34 |
| CD3U | 28 | 60 | Negligible | Yes | 28.33 | 13.35 | 0.35 |
| | | | | | | | |
| D1L | 86 | 110 | Negligible | No | 61.00 | 11.88 | 0.1 |
| D1M | 50 | 86 | Negligible | Yes | 47.08 | 46.83 | 5.9 |
| D1U | 20 | 50 | Down | Yes | 15.58 | 3.40 | 5.9 |
| D2L | 88 | 110 | Negligible | No | 55.70 | - | - |
| D2M | 48 | 87 | Up | Yes | 43.78 | 43.53 | 0.34 |
| D2U | 13 | 48 | Down | Yes | 13.30 | 12.05 | 0.30 |
| D4L | 98 | 128 | Negligible | No | 61.94 | N/A | 0.30 |
| D4U | 21 | 55 | Negligible | Uncertain | 17.28 | 16.85 | 0.52 |
| | | | | | | | |
| E1L | 98 | 121 | Negligible | No | 46.29 | 28.40 | 0.24 |
| E1M | 56 | 96 | Negligible | No | 49.91 | - | 0.27 |
| E1U | 21 | 56 | Down | Yes | 20.24 | 19.33 | 3.8 |
| | | | | | | | |
| F2L | 102 | 126 | Negligible | No | 40.95 | - | - |
| F2M | 61 | 99 | Negligible | Yes | 52.12 | 51.65 | 0.29 |
| F2U | 7 | 57 | Down/Up | Yes | 22.40 | 22.11 | 0.32 |
| | | | | | | | |
| G3L | 131 | 150 | Negligible | Yes | 37.15 | 36.85 | 0.34 |
| G3U | 15 | 66 | Down | Yes | 28.95 | 27.85 | 0.48 |

## Table 2: Parameters of Wells Tested (Continued)

| Well No. | Bottom of Casing (Note 1) (ft.) | Bottom of Well (Note 1) (ft.) | Ambient Flow Direction | Injection Test Successful (Note 2) | Static Depth to Water (ft.) | Injected Depth to Water (ft.) | Injection Rate (gpm) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| H1L | 130 | 145 | Negligible | Yes | 62.90 | 49.00 | 0.16 |
| H1M | 60 | 129 | Negligible | Yes | 65.28 | 63.10 | 1.30 |
| H1U | 15 | 59 | Negligible | Yes | 16.73 | 14.78 | 1.40 |
| | | | | | | | |
| J1M | 50 | 101 | Up | Yes | 51.03 | 50.10 | 5.1 |
| J1U | 18 | 47 | Down | Yes | | 16.32 | 0.39 |
| J3L | 103 | 123 | Down | Yes | 44.99 | 42.15 | 0.33 |
| J4L | 103 | 122 | Negligible | Yes | 41.84 | 41.10 | 0.30 |
| | | | | | | | |
| MW 2 | 23 | 35 | Down | Yes | 23.90 | 34.0 | 1.13 |
| MW 3 | 35 | 51 | Down | Yes | 35.75 | 33.6 | 0.75 |
| MW 4 | 34 | 50 | Negligible | Yes | 36.60 | 34.0 | 0.30 |
| MW 5 | 37 | 52 | Down | Yes | 40.40 | 38.7 | 1.76 |
| MW 6 | 37 | 52 | Negligible | Yes | 39.55 | 31.2 | 2.30 |

1) Well depths shown are approximate based on measurements from the top of casing during EBF tests.
2) An unsuccessful injection test usually indicates the well would not accept water at a sustained rate. See notes on graphs of the profile of flow rates in Appendix A for an explanation for individual wells.

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# Appendix A

# Profiles of Ambient and Induced Flow Rates

**Figure A-1: Profile of Flow Rate in Well B1L**

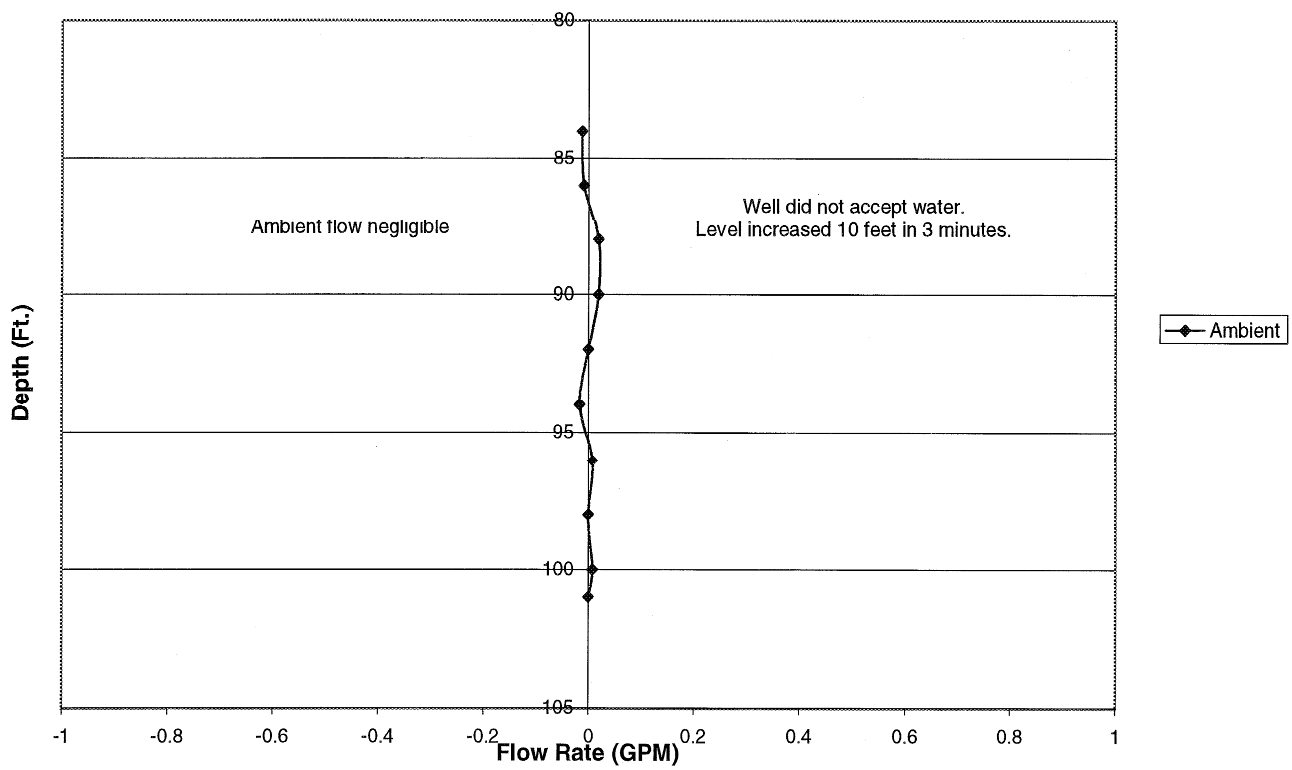
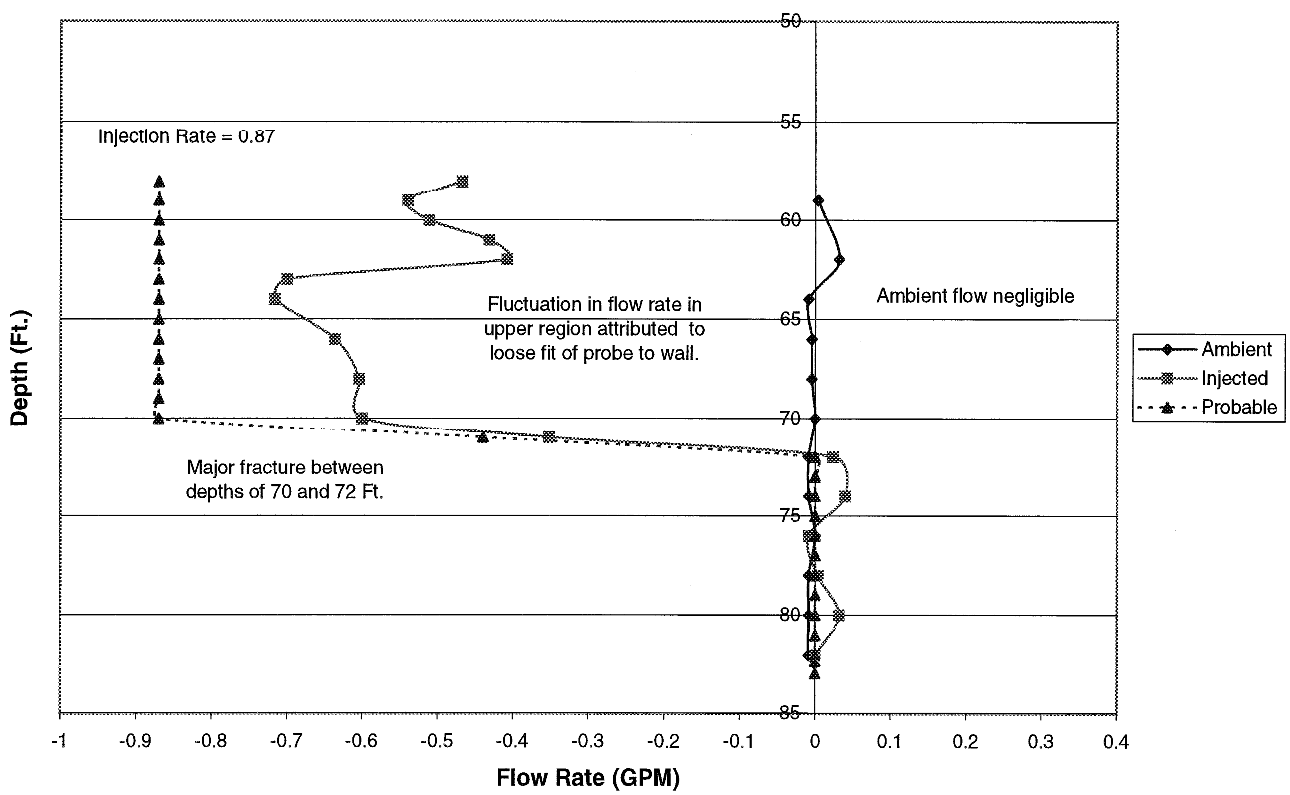


**Figure A-2: Profile of Flow Rates in Well B1M**



## Figure A-3: Profile of Flow Rates in Well B1U

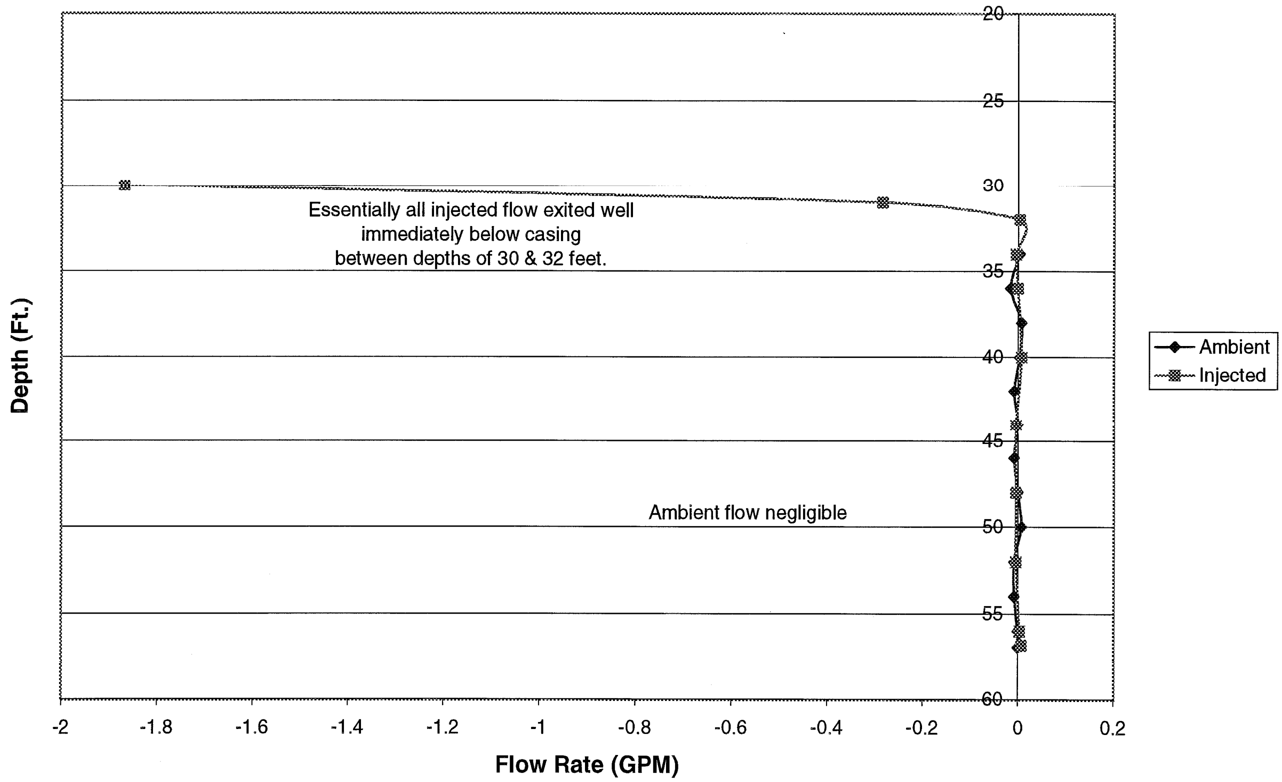
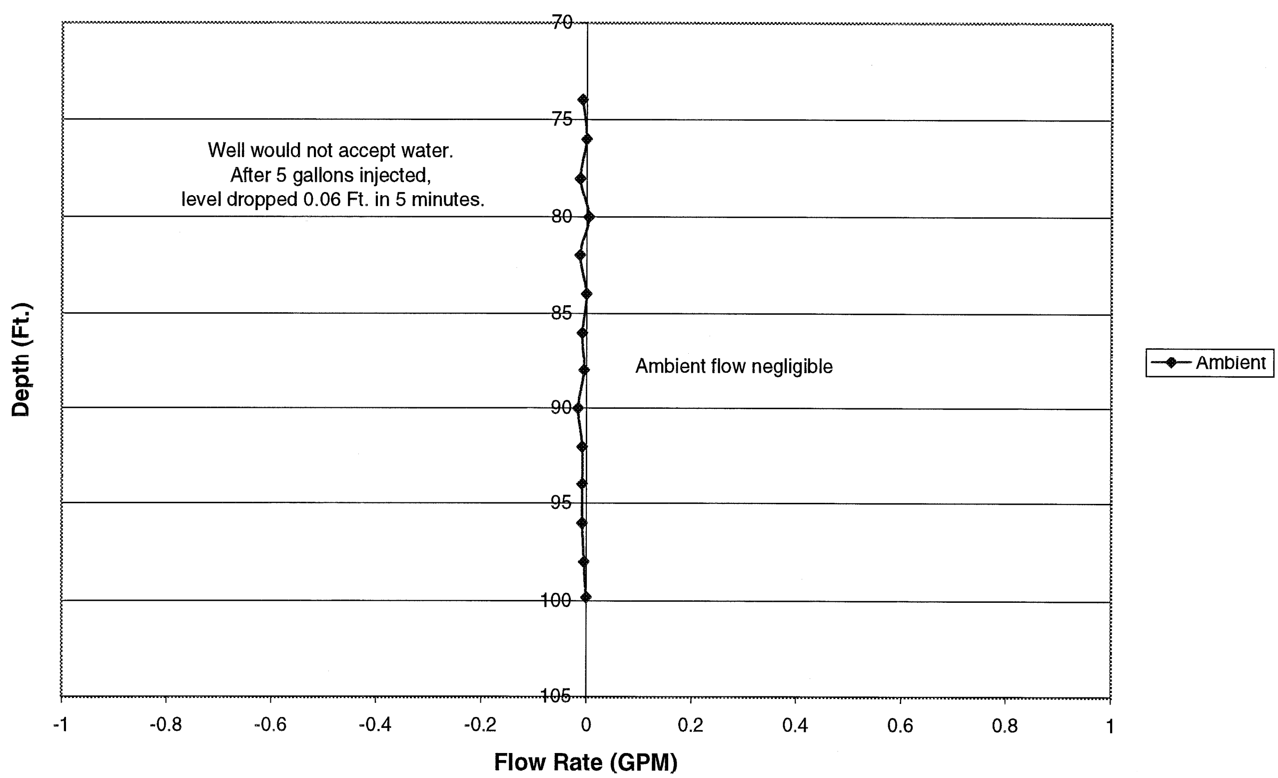


**Figure A-4: Profile of Flow Rates In Well B2L**



## Figure A-5: Profile of Flow Rates in Well B2M

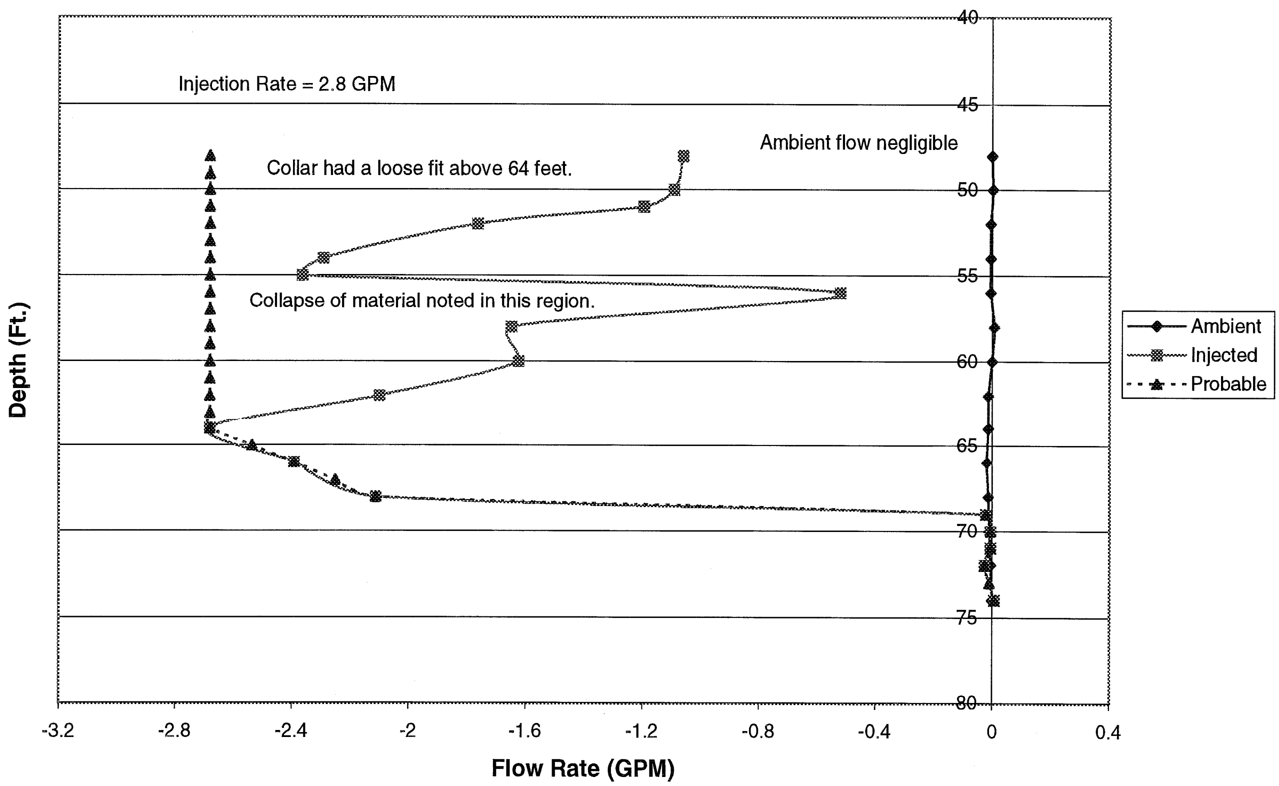
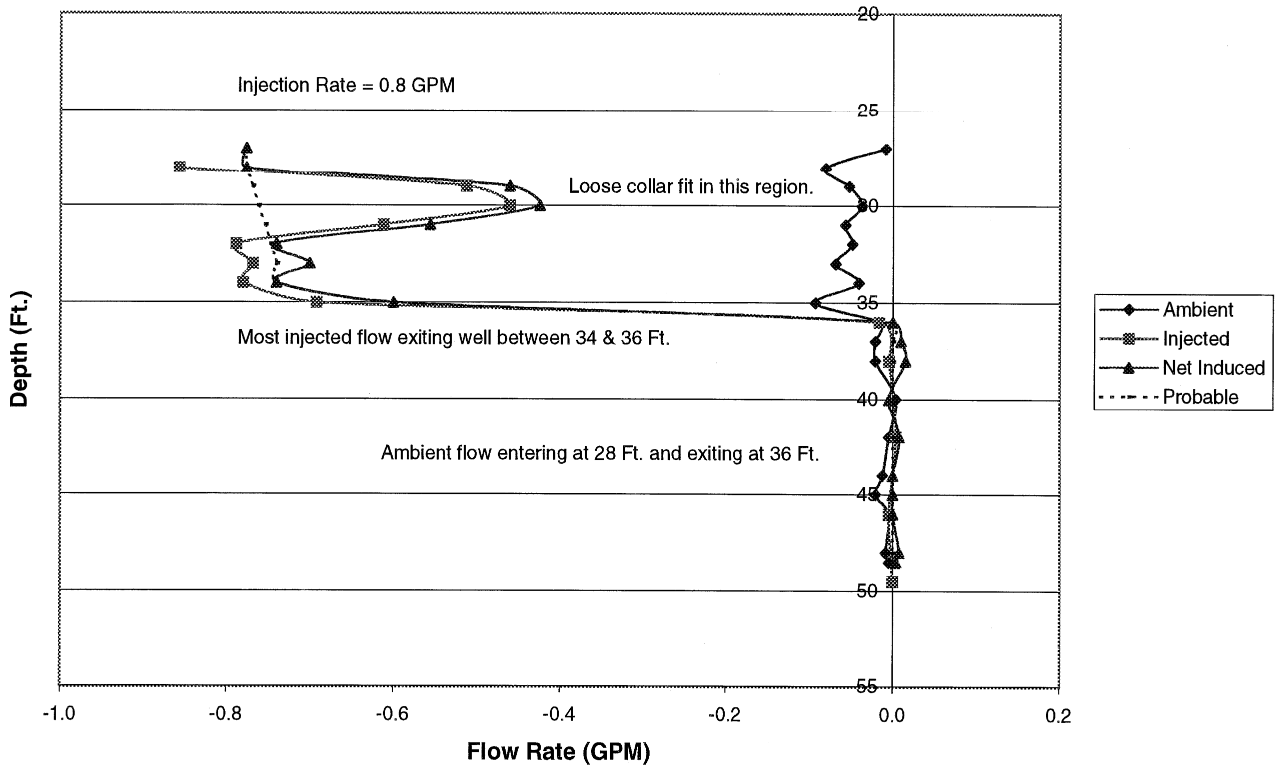
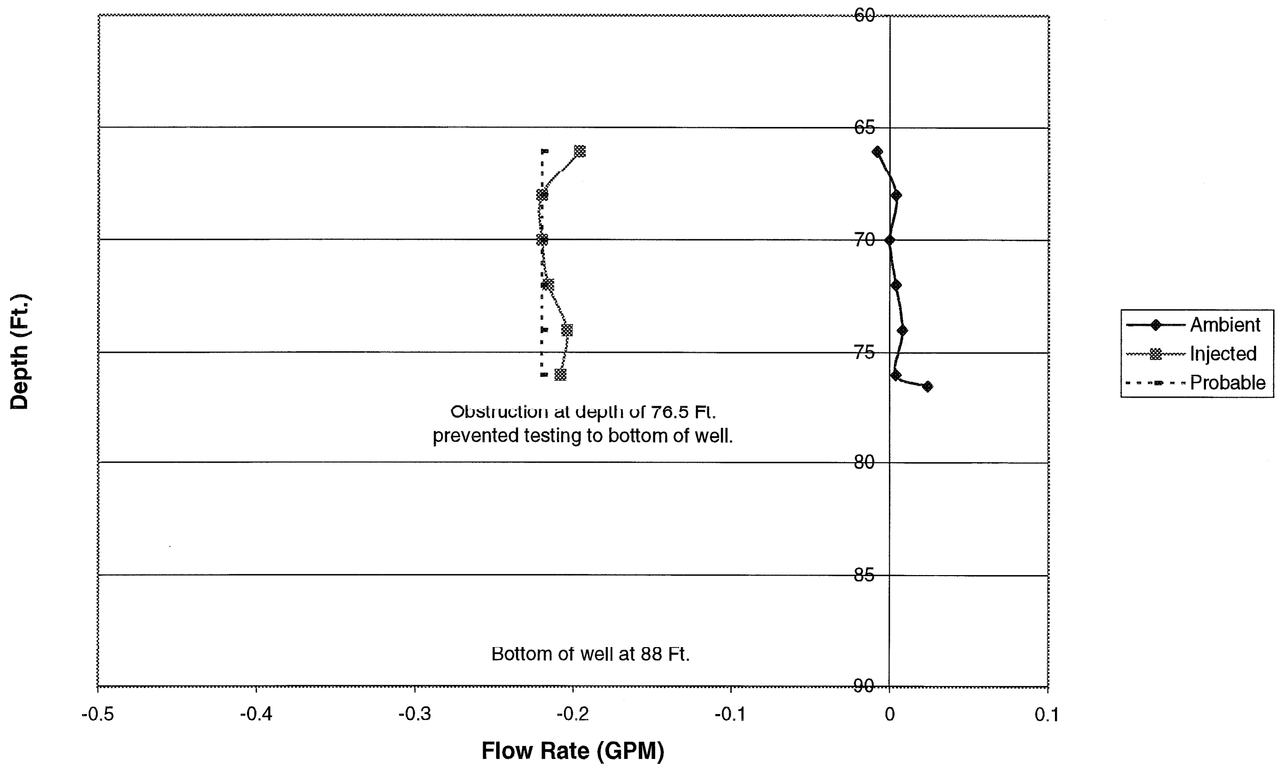


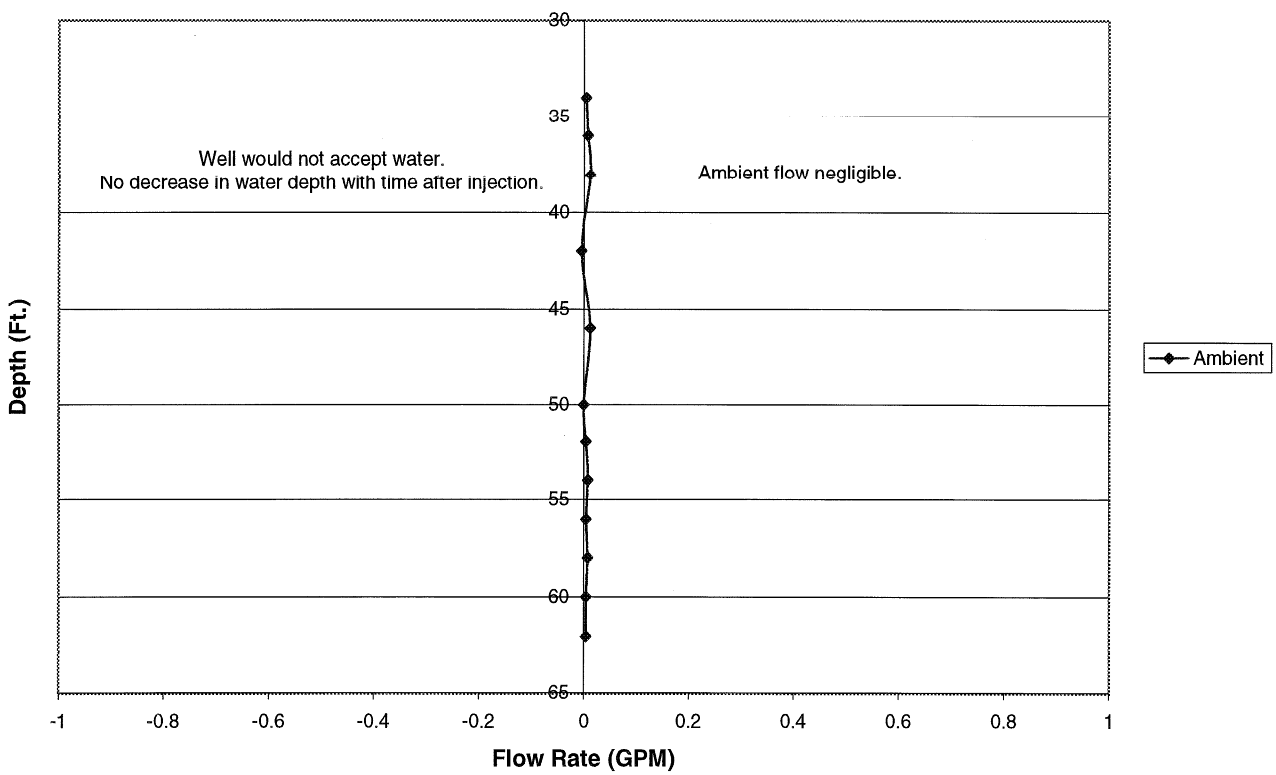
**Figure A-6: Profile of Flow Rates in Well B2U**



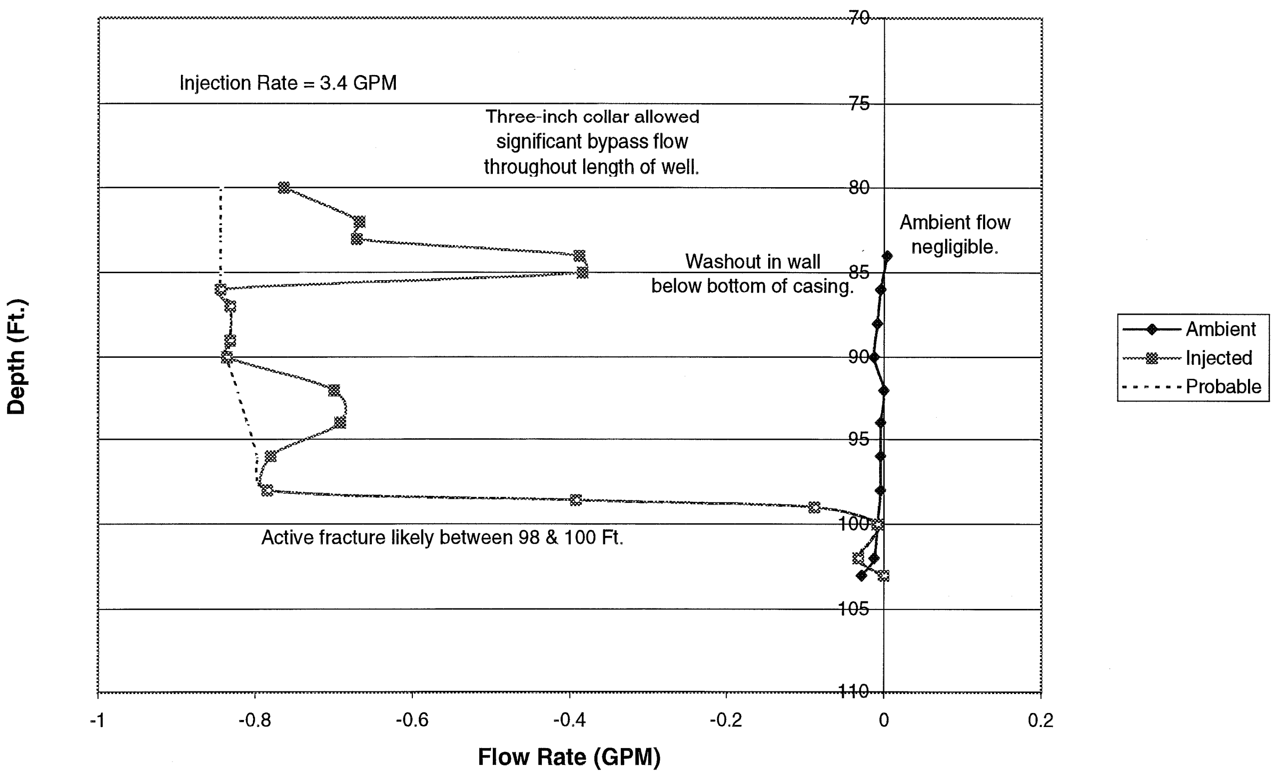
## Figure A-7: Profile of Flow Rates in Well BC3M



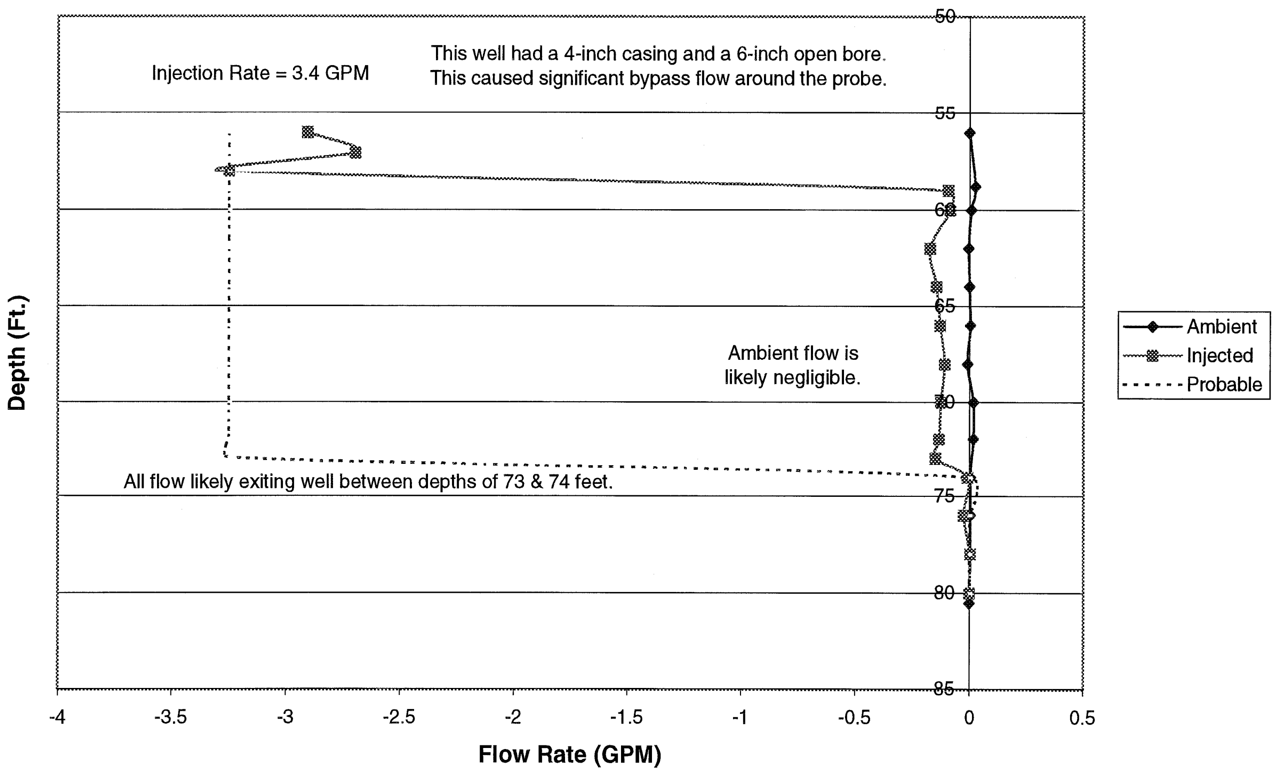
## Figure A-8: Profile of Flow Rate in Well BC3U



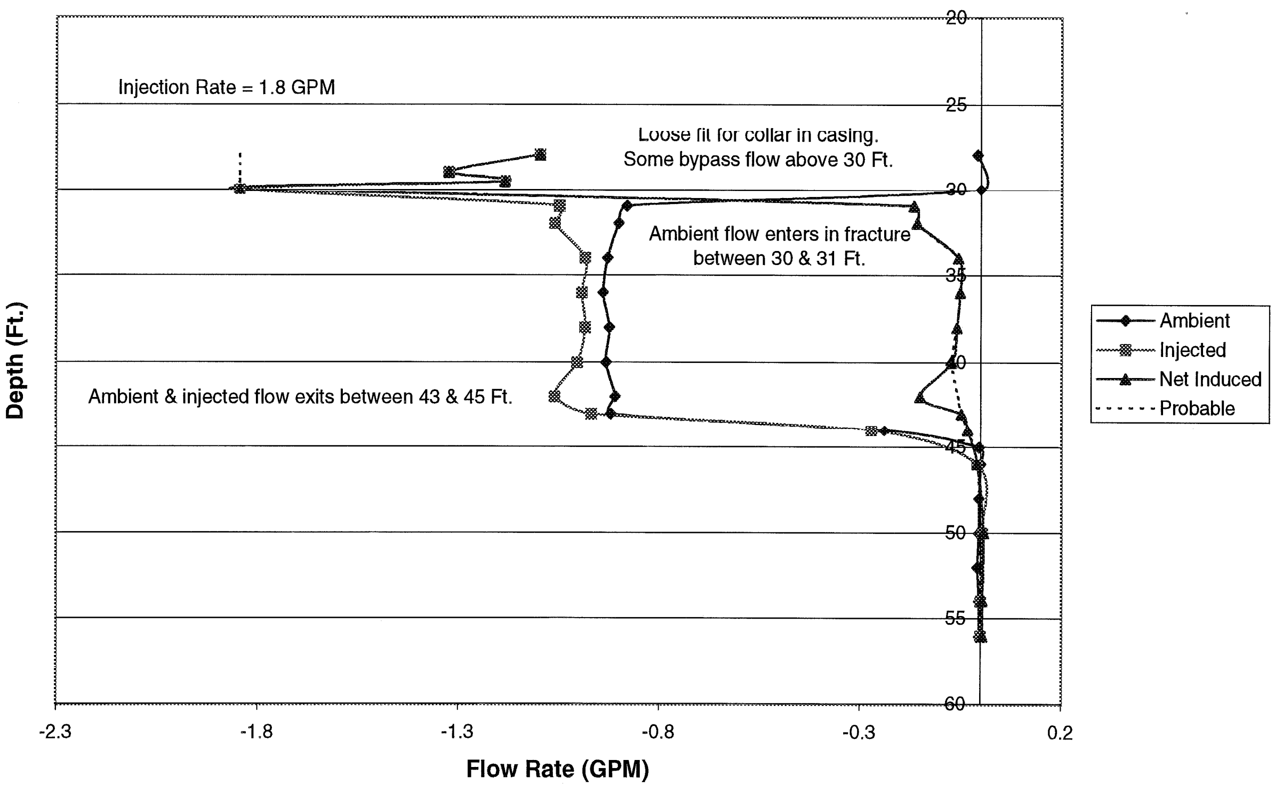
## Figure A-9: Profile of Flow Rates in Well C1L



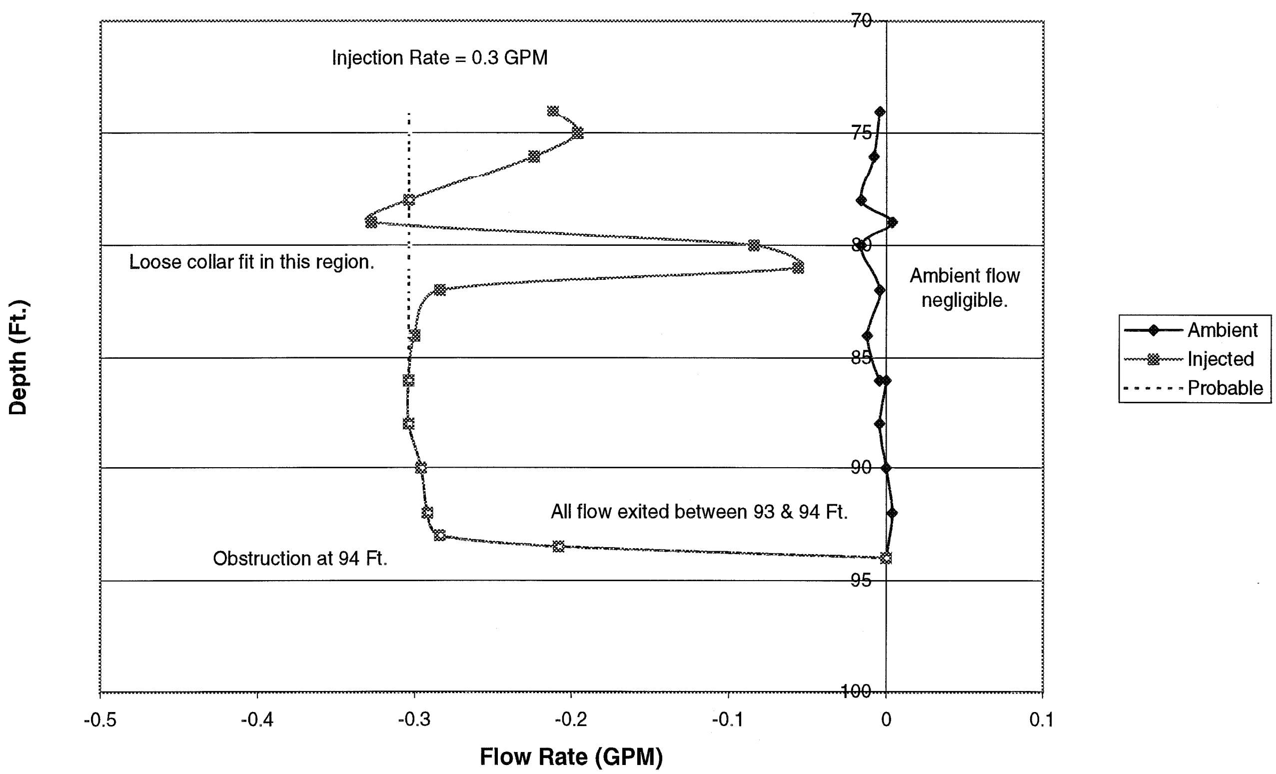
## Figure A-10: Profile of Flow Rates in Well C1M



## Figure A-11: Profile of Flow Rates in Well C1U



## Figure A-12: Profile of Flow Rates in Well C2L



## Figure A-13: Profile of Flow Rates in Well C2M

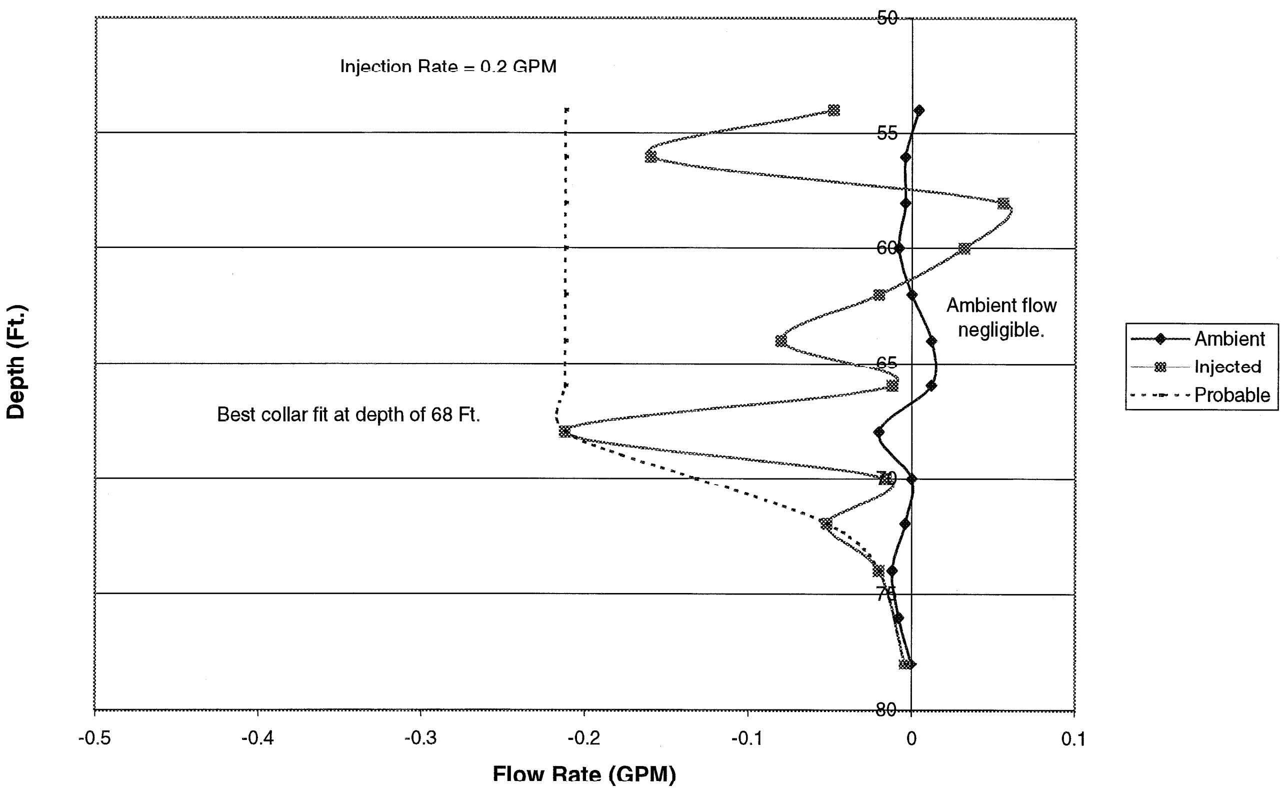


**Figure A-14: Profile of Flow Rates in Well CD1M**

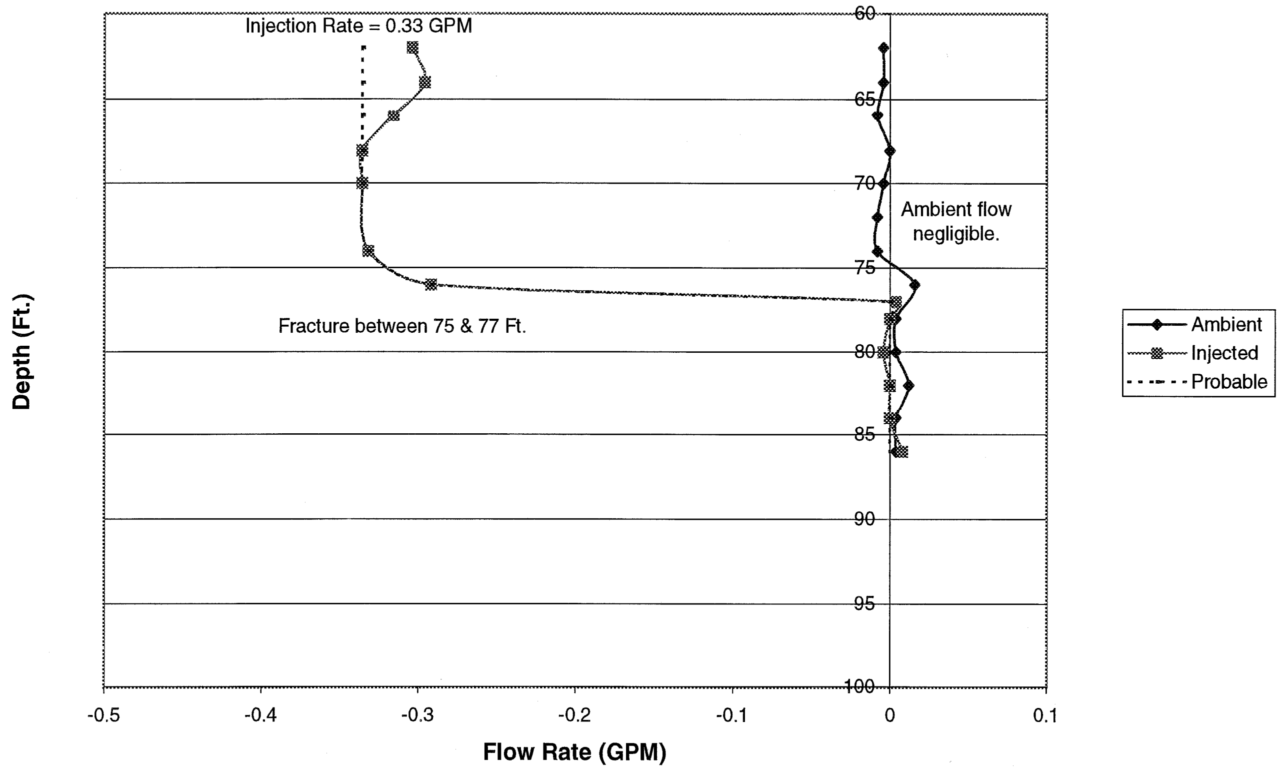
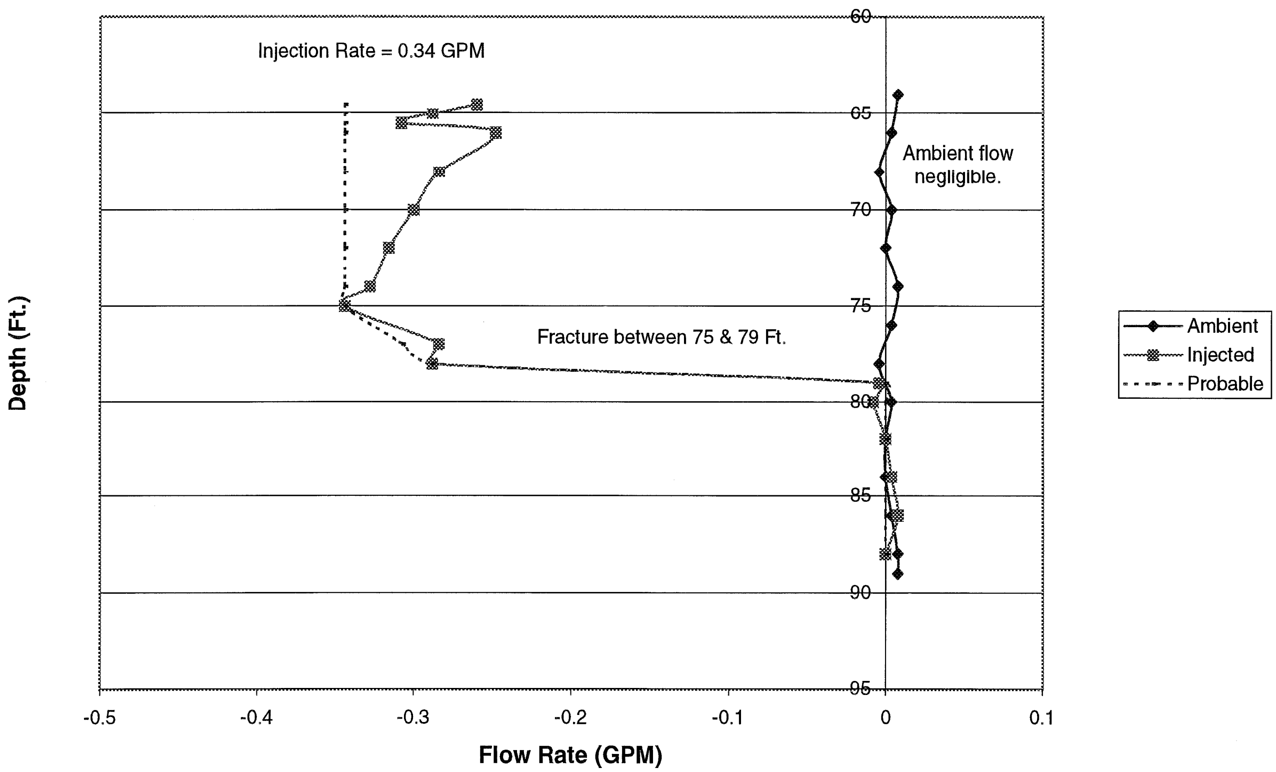
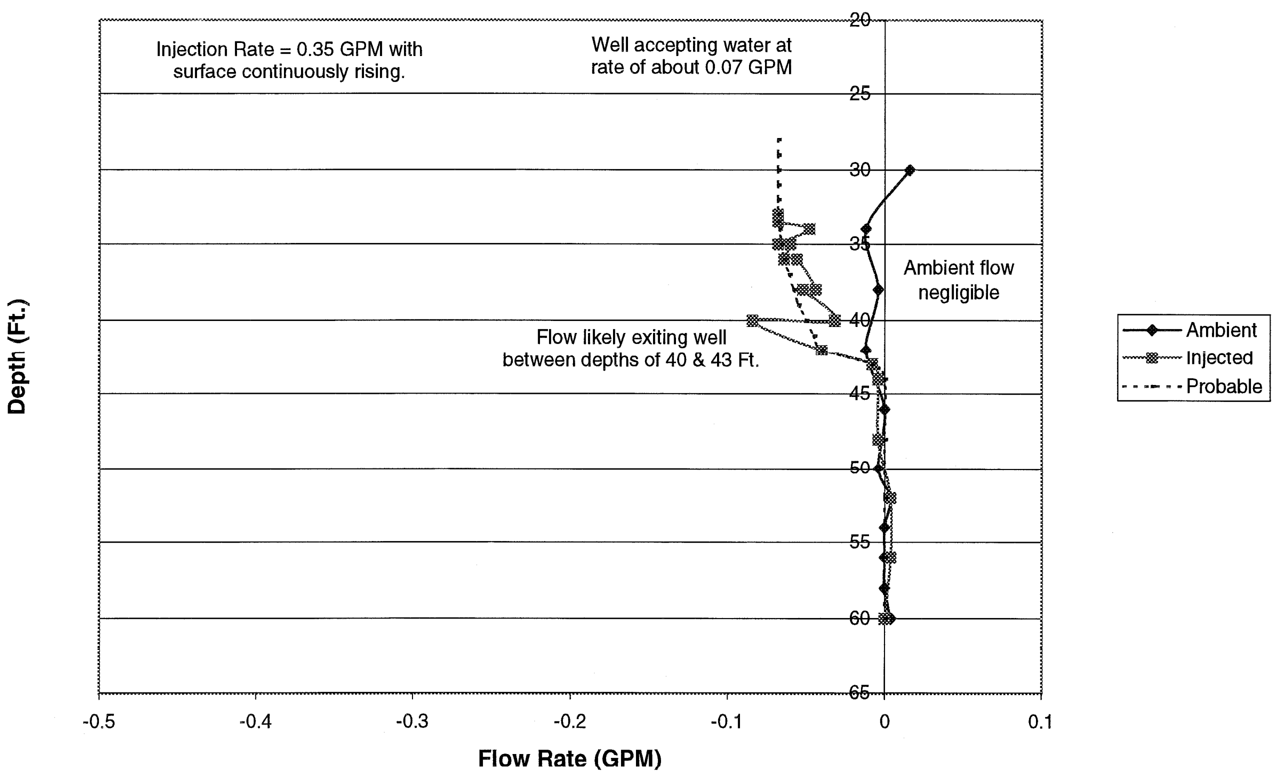


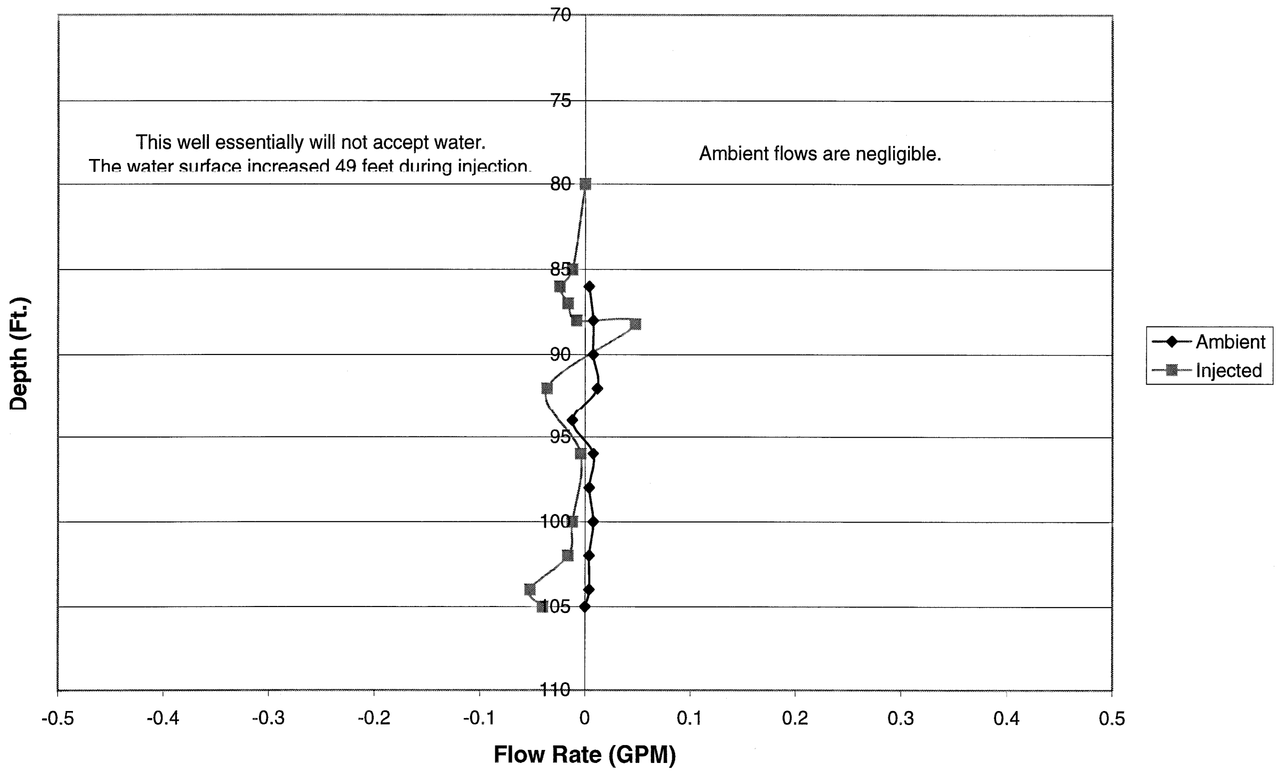
**Figure A-15: Profile of Flow Rates in Well CD2M**



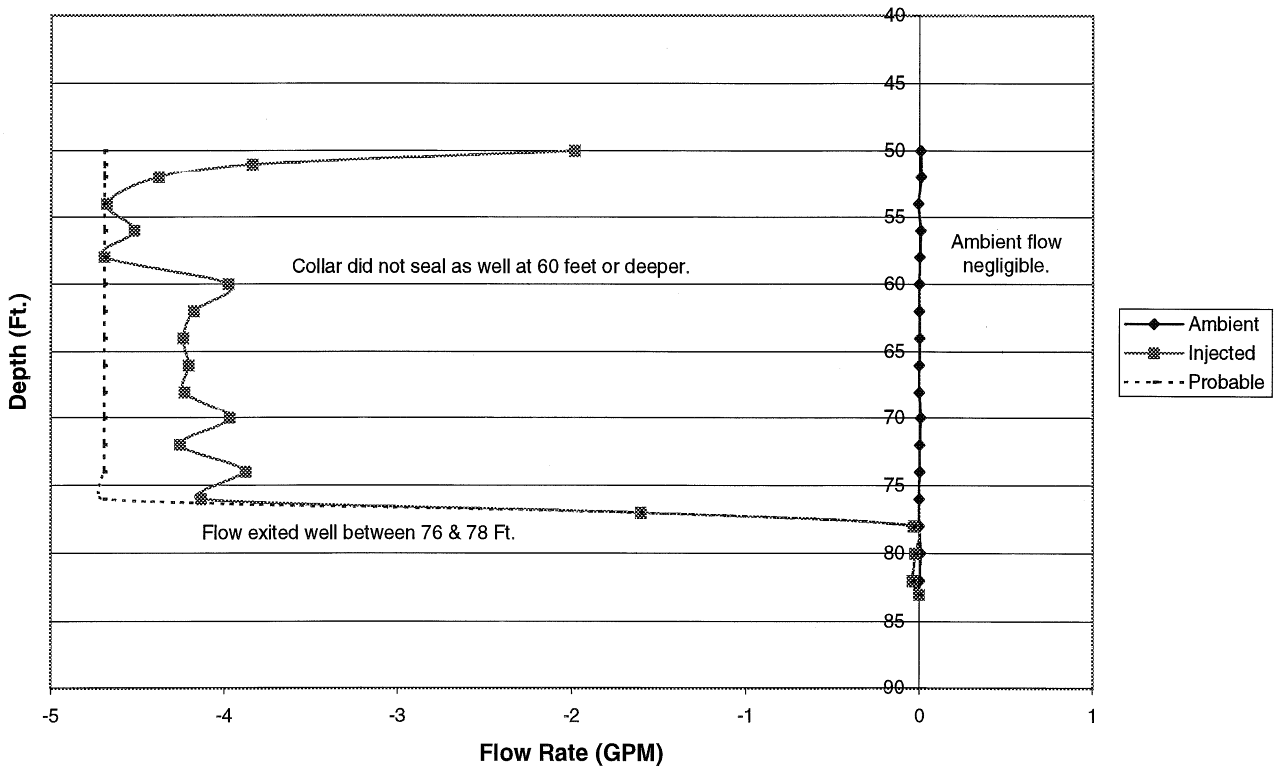
## Figure A-16: Profile of Flow Rates in Well CD3U



## Figure A-17: Profile of Flow Rates in Well D1L



## Figure A-18: Profile of Flow Rates in Well D1M



## Figure A-19: Profile of Flow Rates in Well D1U

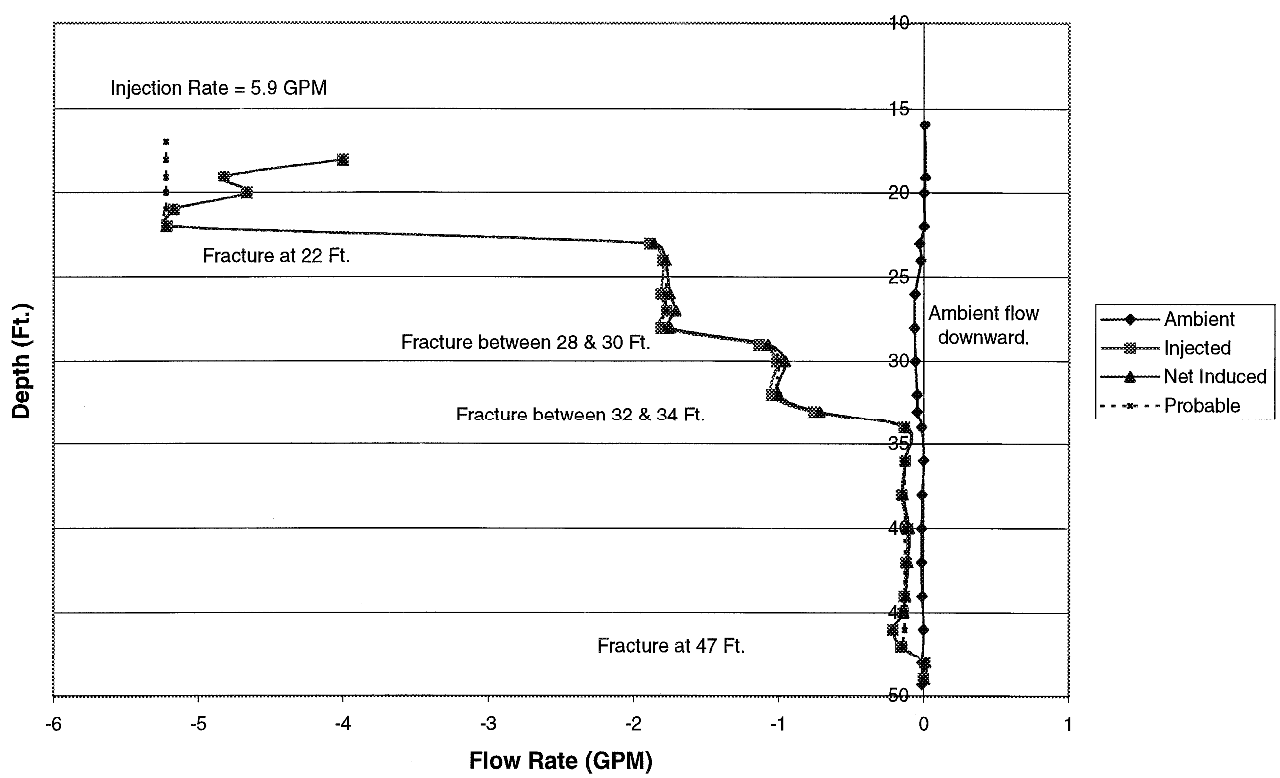
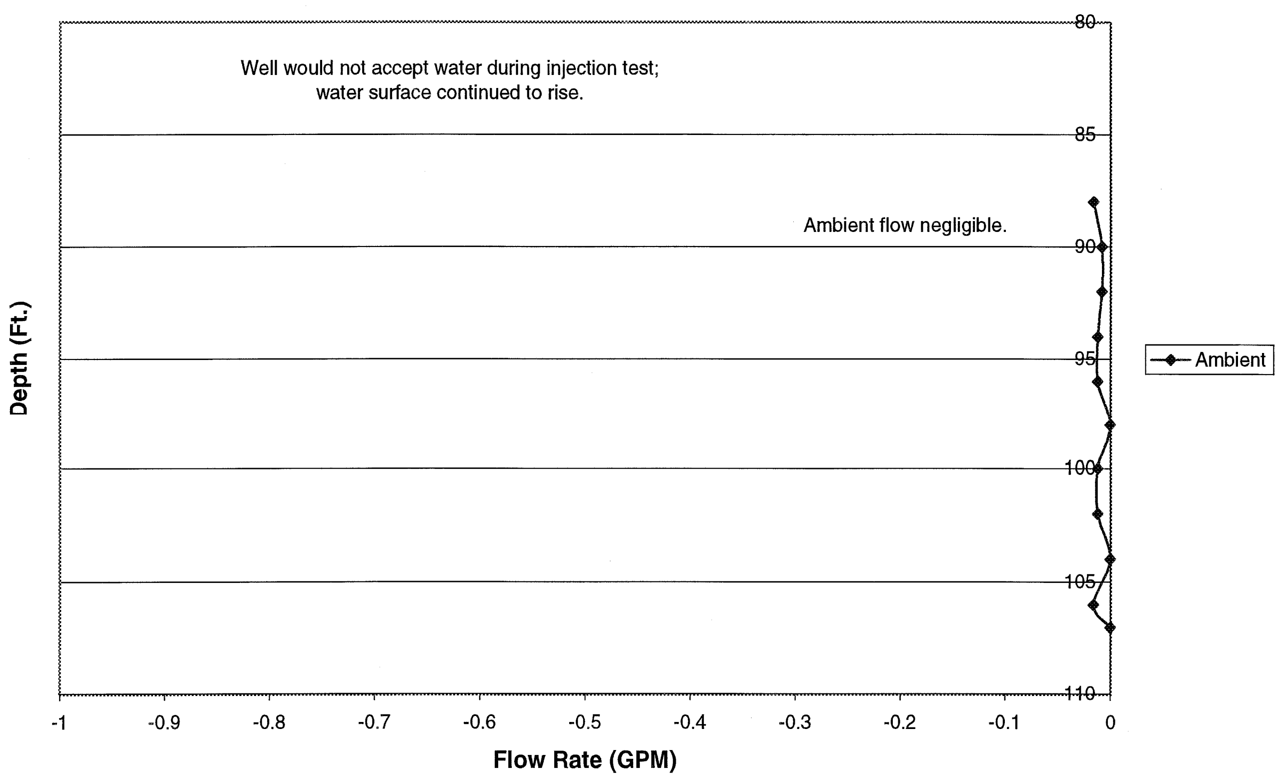
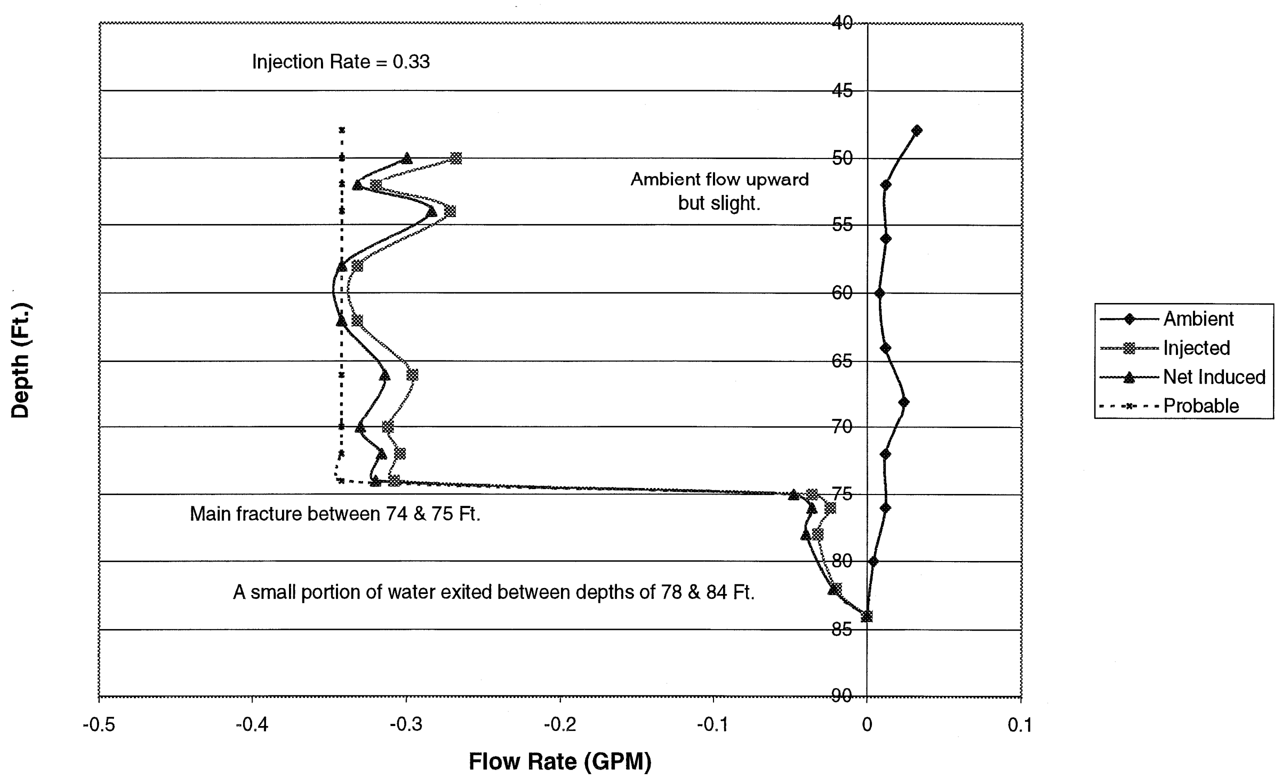


**Figure A-20: Profile of Flow Rate in Well D2L**



## Figure A-21: Profile of Flow Rates in Well D2M



## Figure A-22: Profile of Flow Rates in Well D2U

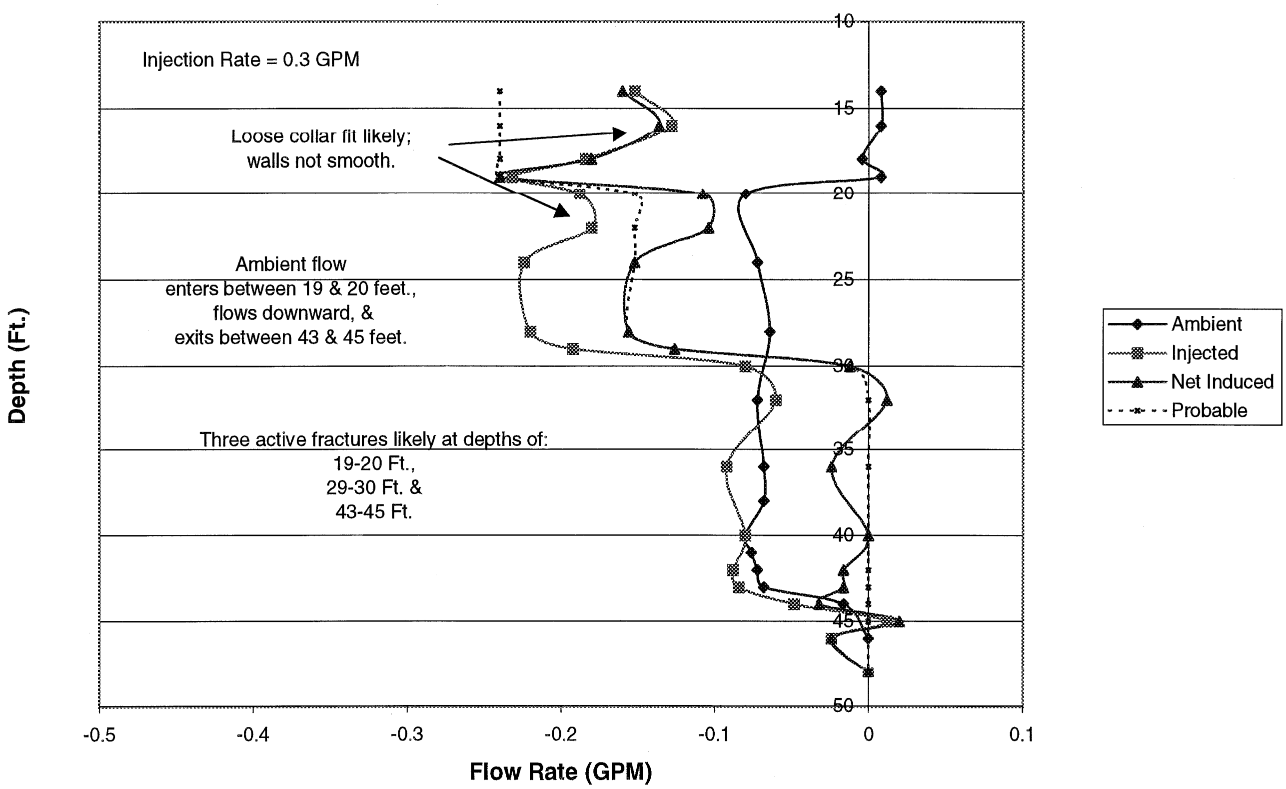
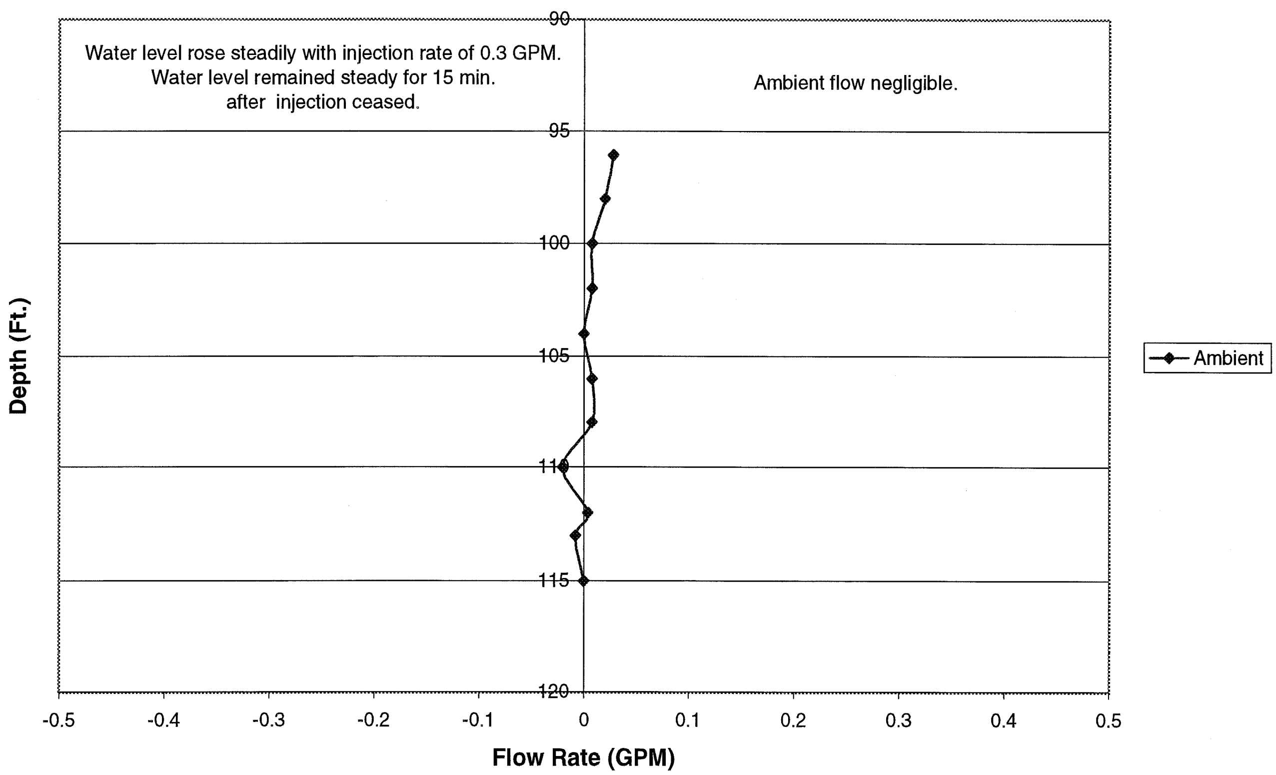
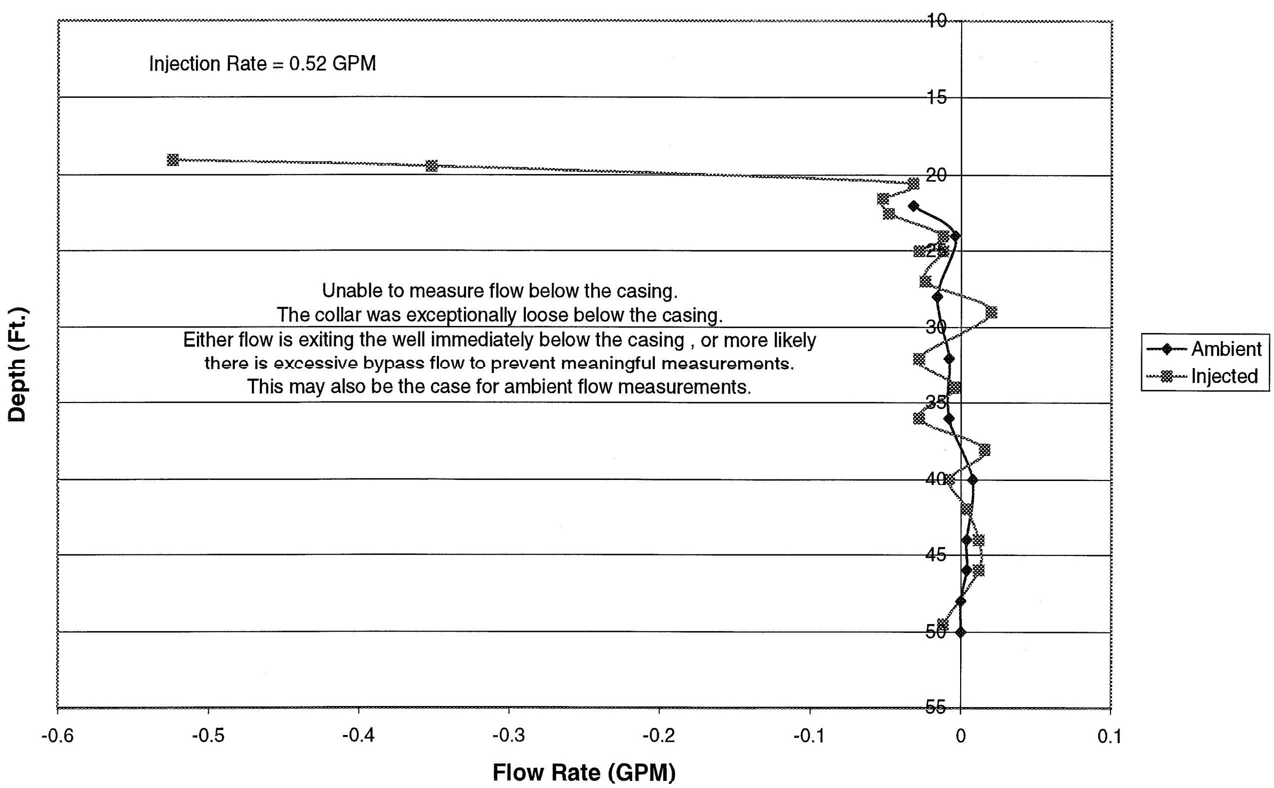


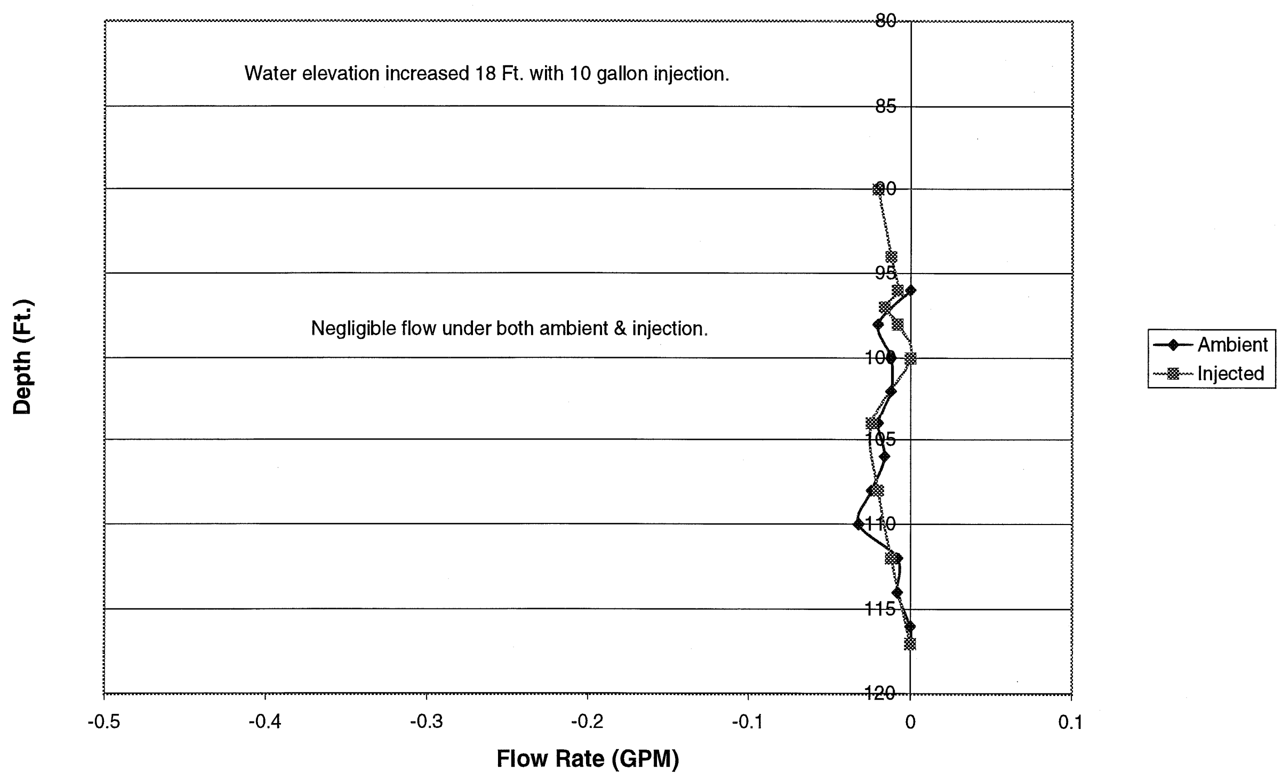
**Figure A-23: Profile of Flow Rate in Well D4L**



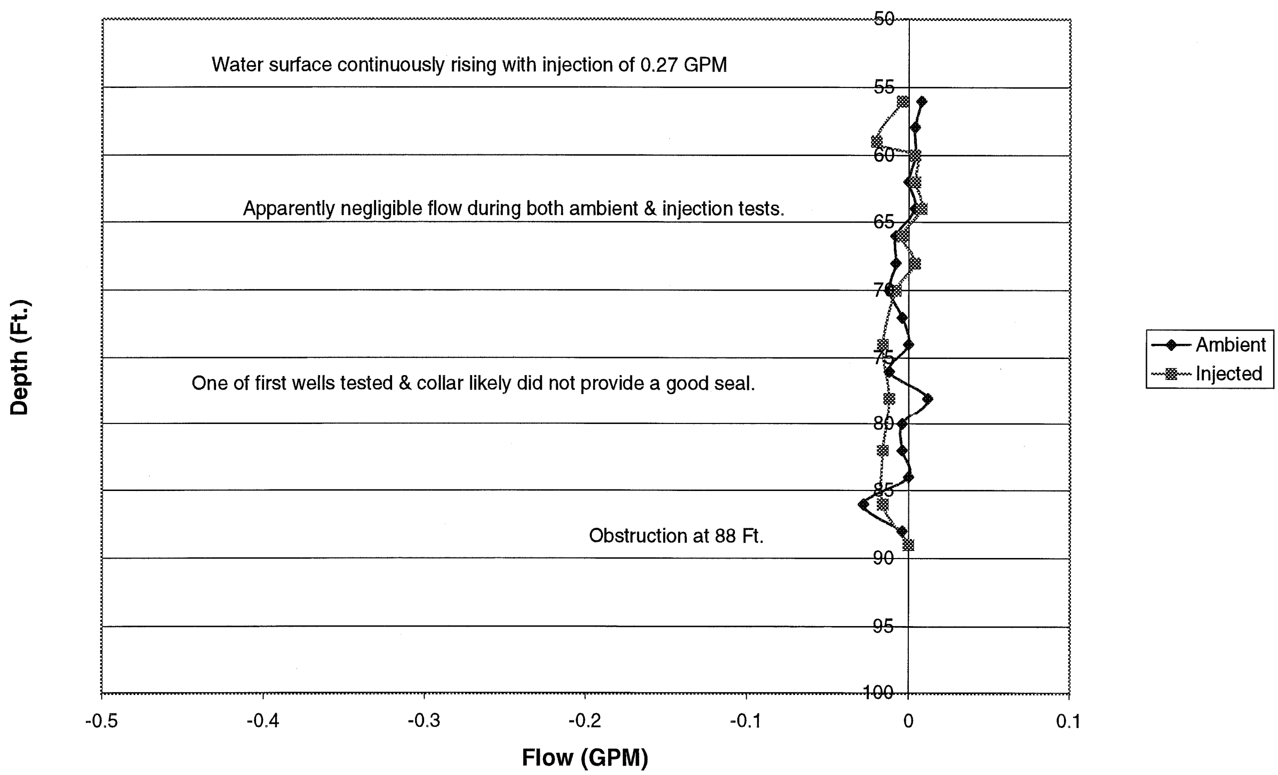
## Figure A-24: Profile of Flow Rates in Well D4U



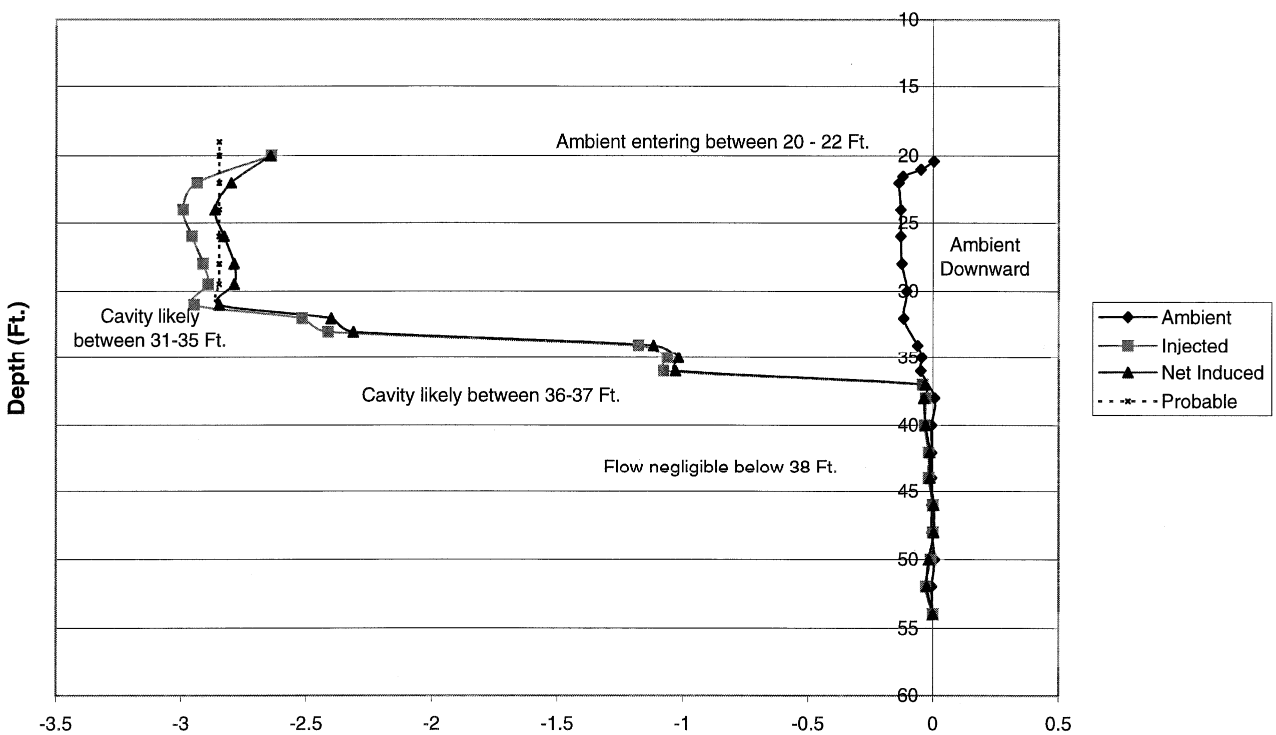
## Figure A-25: Profile of Flow Rates in Well E1L



## Figure A-26: Profile of Flows in Well E1M

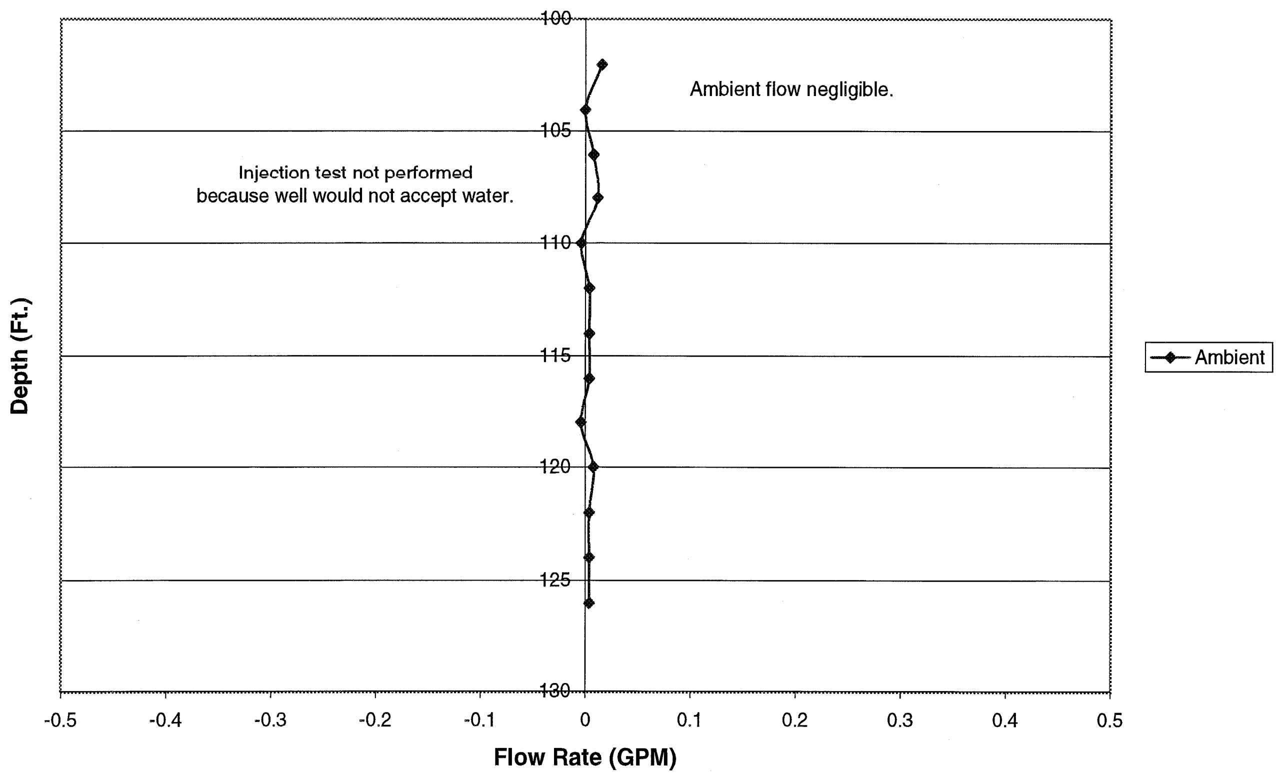


## Figure A-27: Profile of Flow Rates in Well E1U

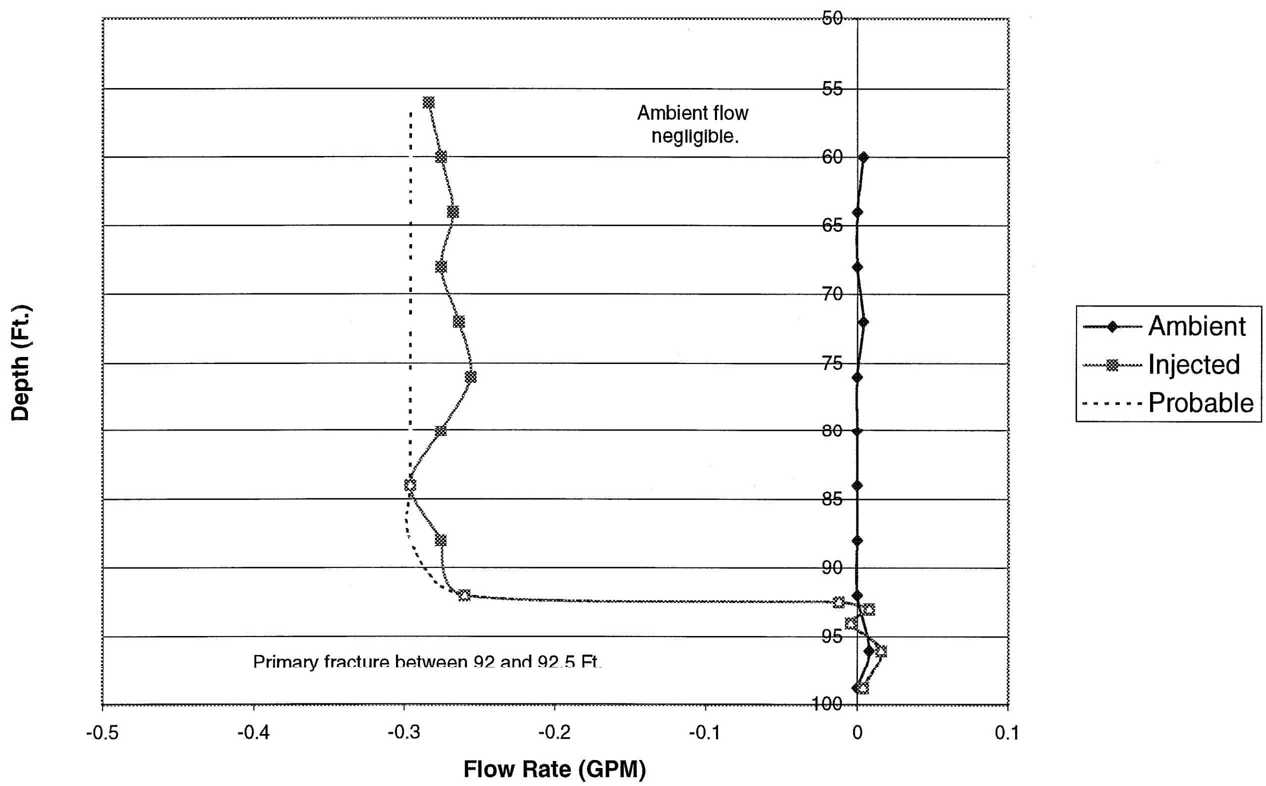



Flow Rate (GPM)

**Figure A-28: Profile of Ambient Flow in Well F2L**



## Figure A-29: Profile of Flow Rates in Well F2M



## Figure A-30: Profile of Flow Rates in Well F2U

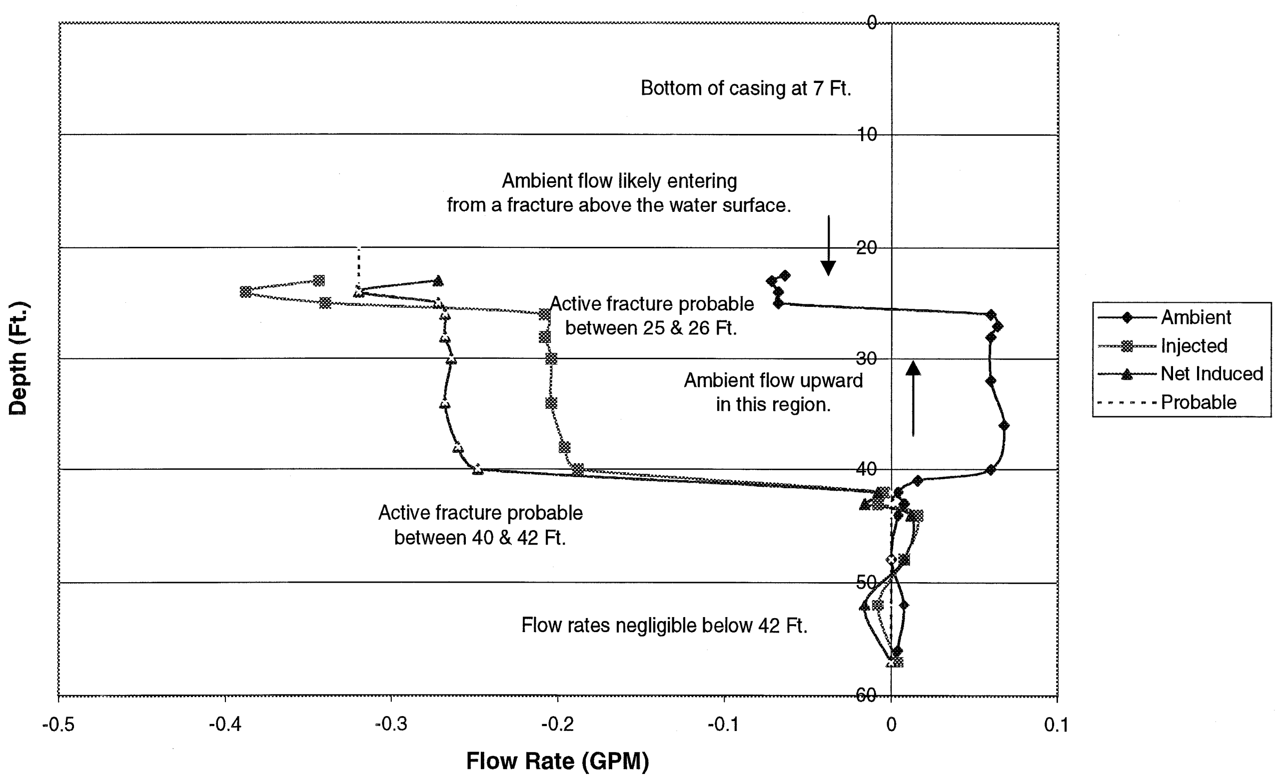
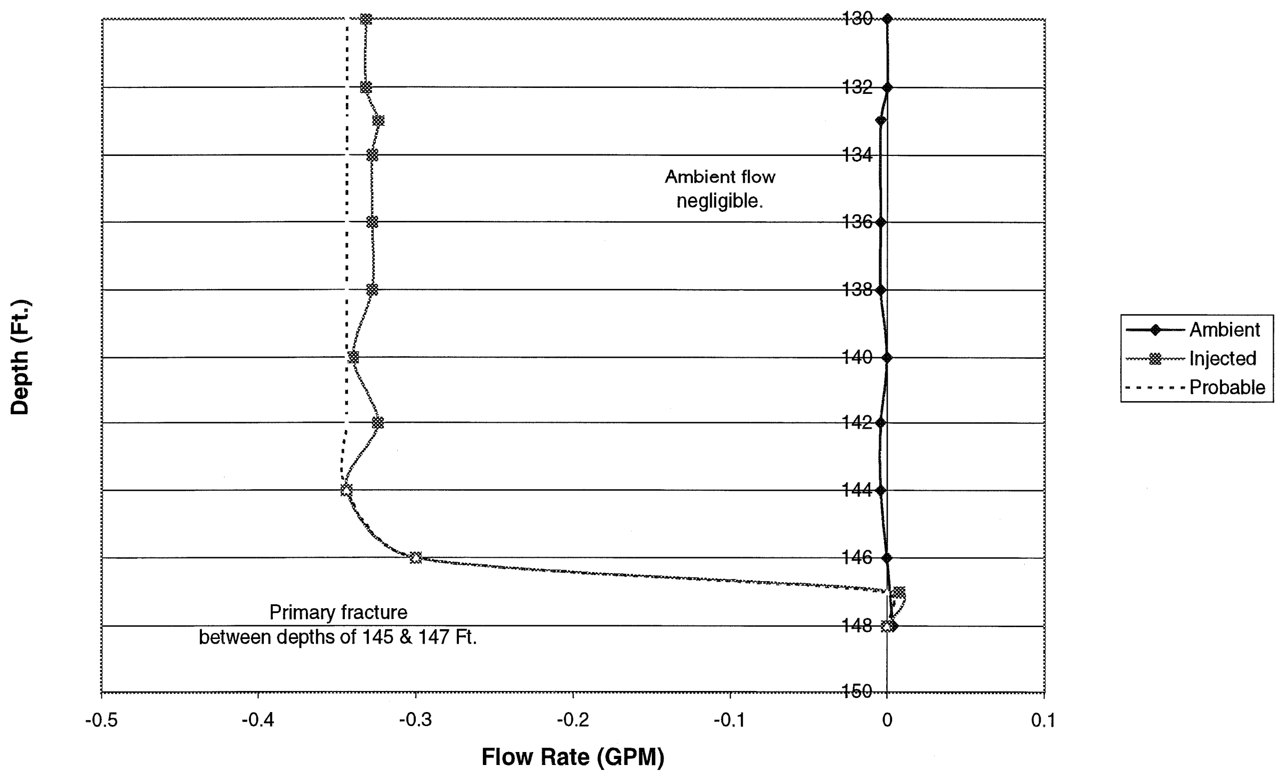
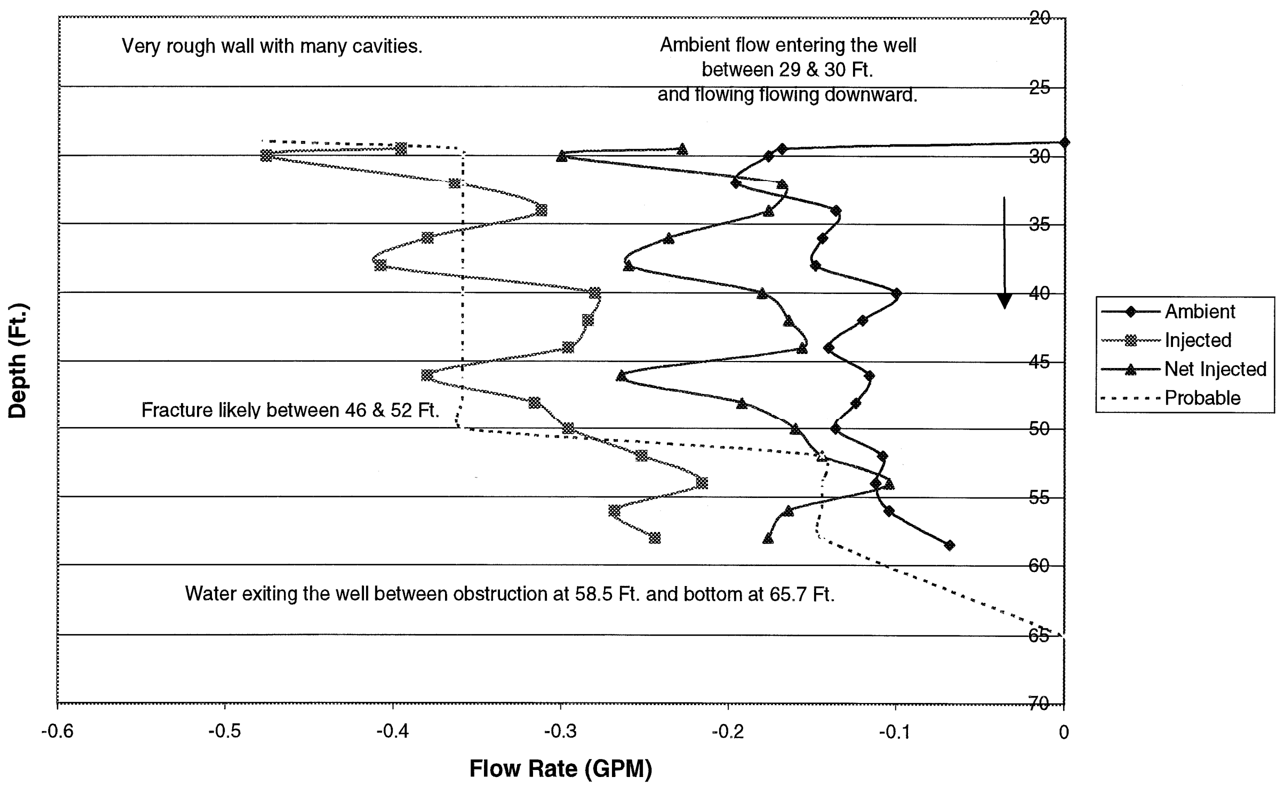


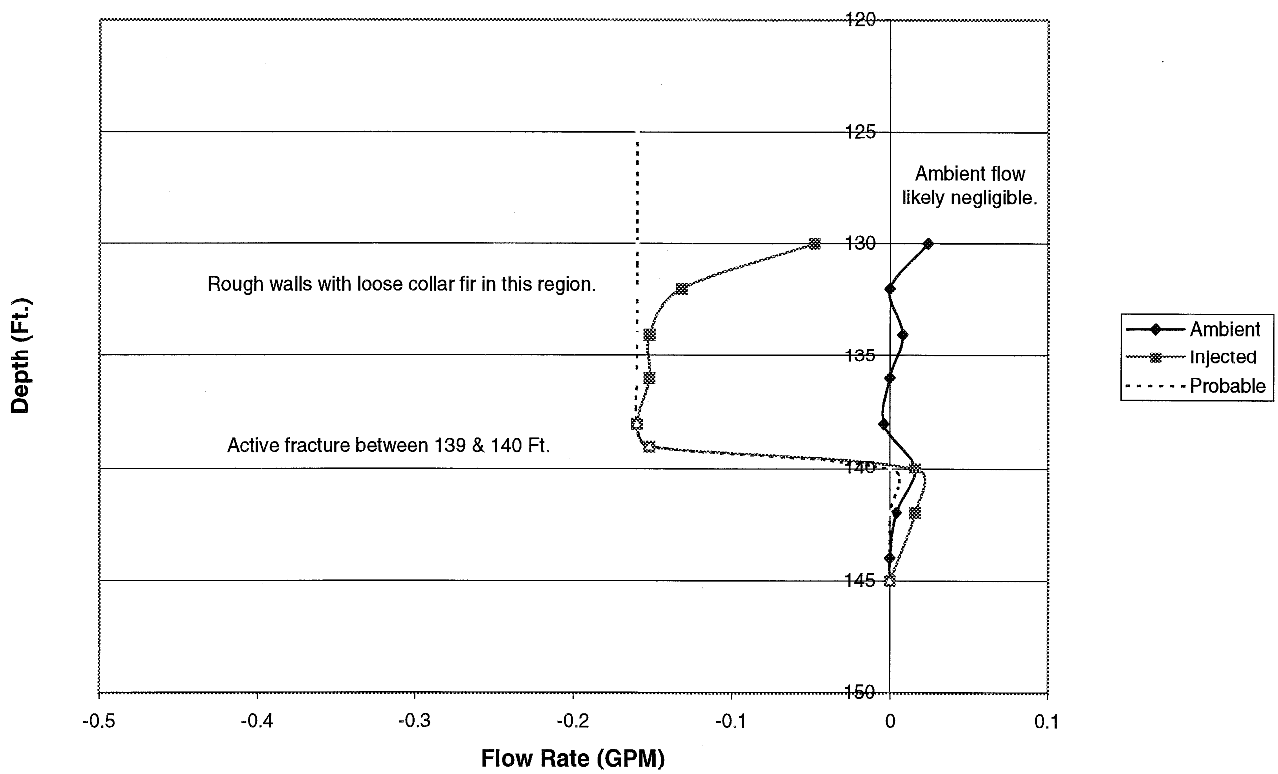
**Figure A-31: Profile of Flow Rates in Well G3L**



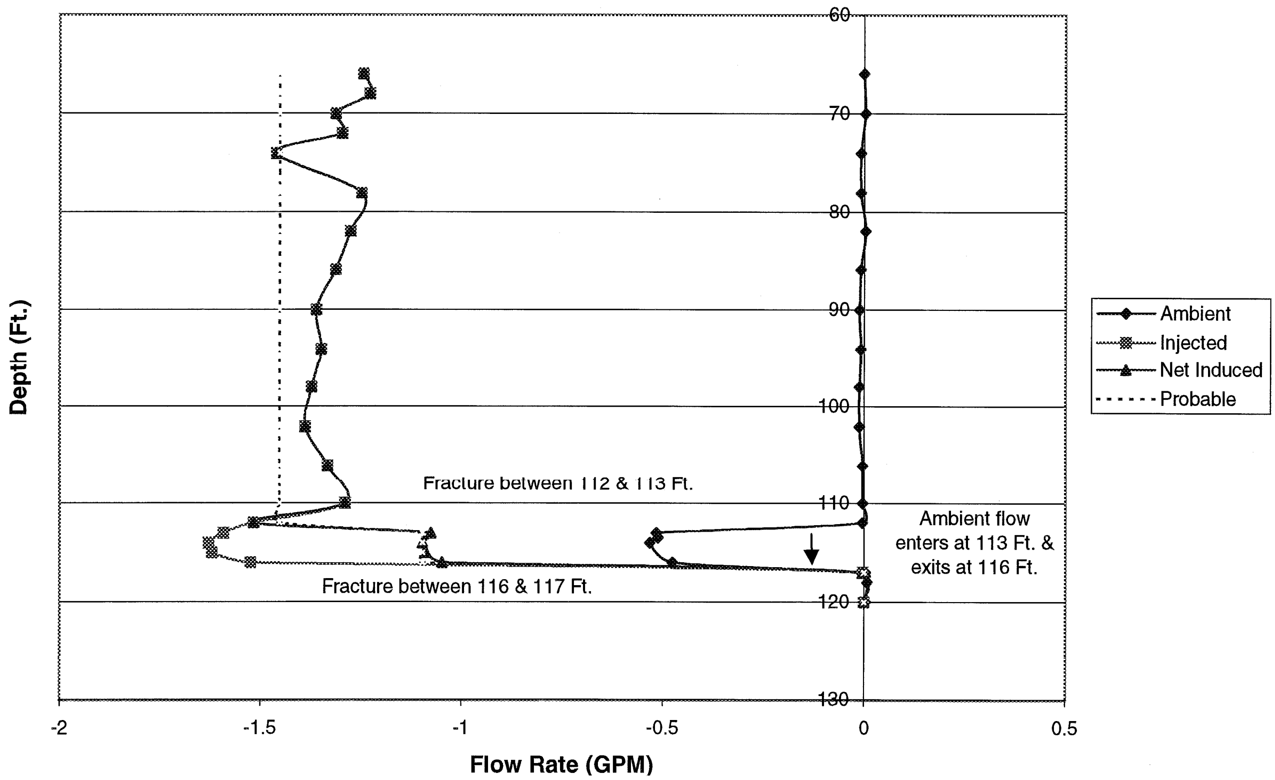
## Figure A-32: Profile of Flow Rates in Well G3U



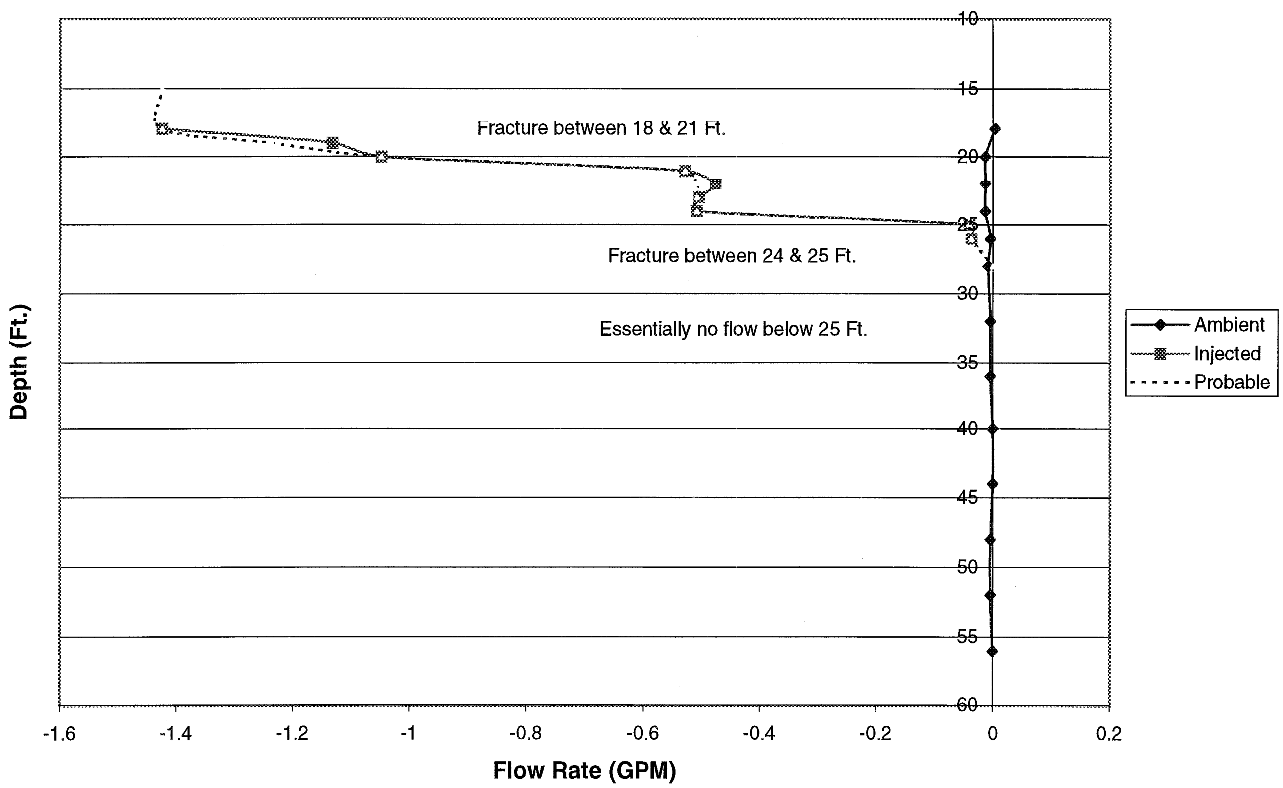
## Figure A-33: Profile of Flow Rates in Well H1L



## Figure A-34: Profile of Flow Rates in Well H1M



## Figure A-35: Profile of Flow Rate in Well H1U



## Figure A-36: Profile of Flow Rates in Well J1M

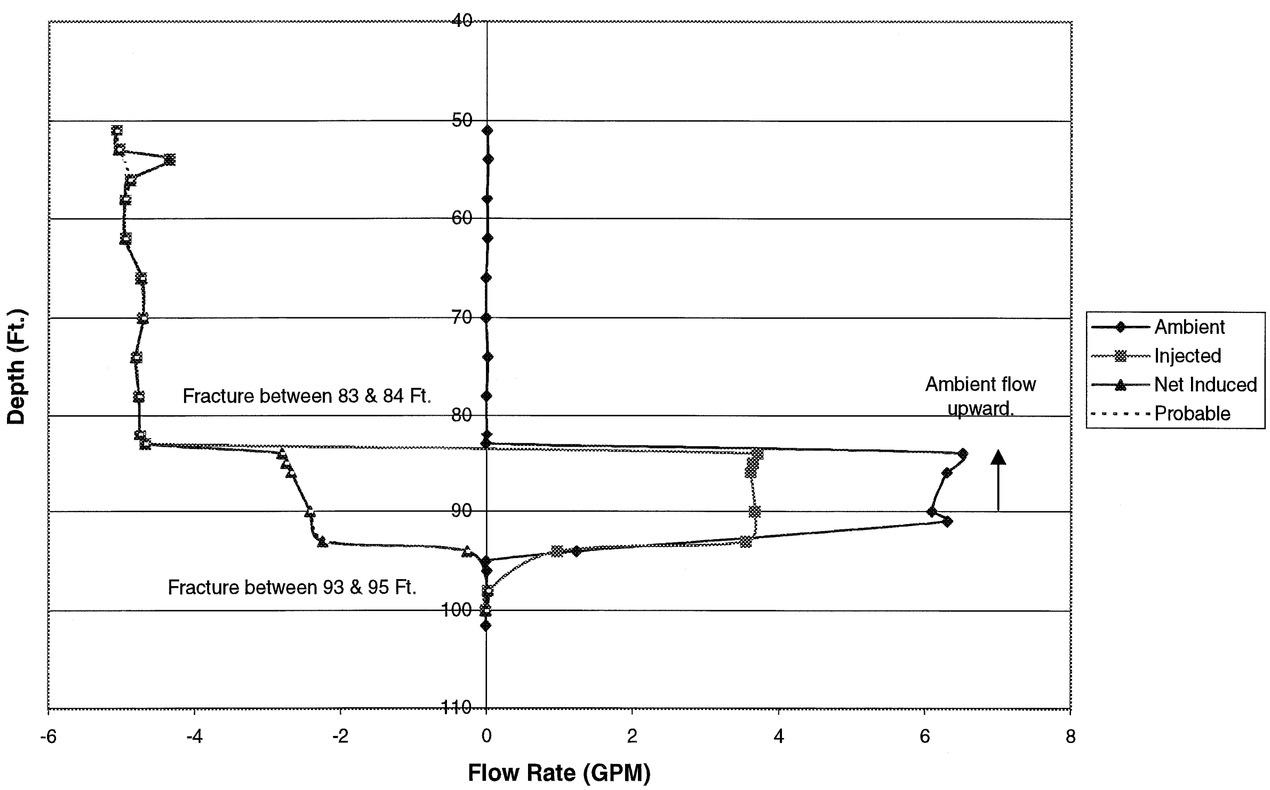


**Figure A-37: Profile of Flow Rates in Well J1U**

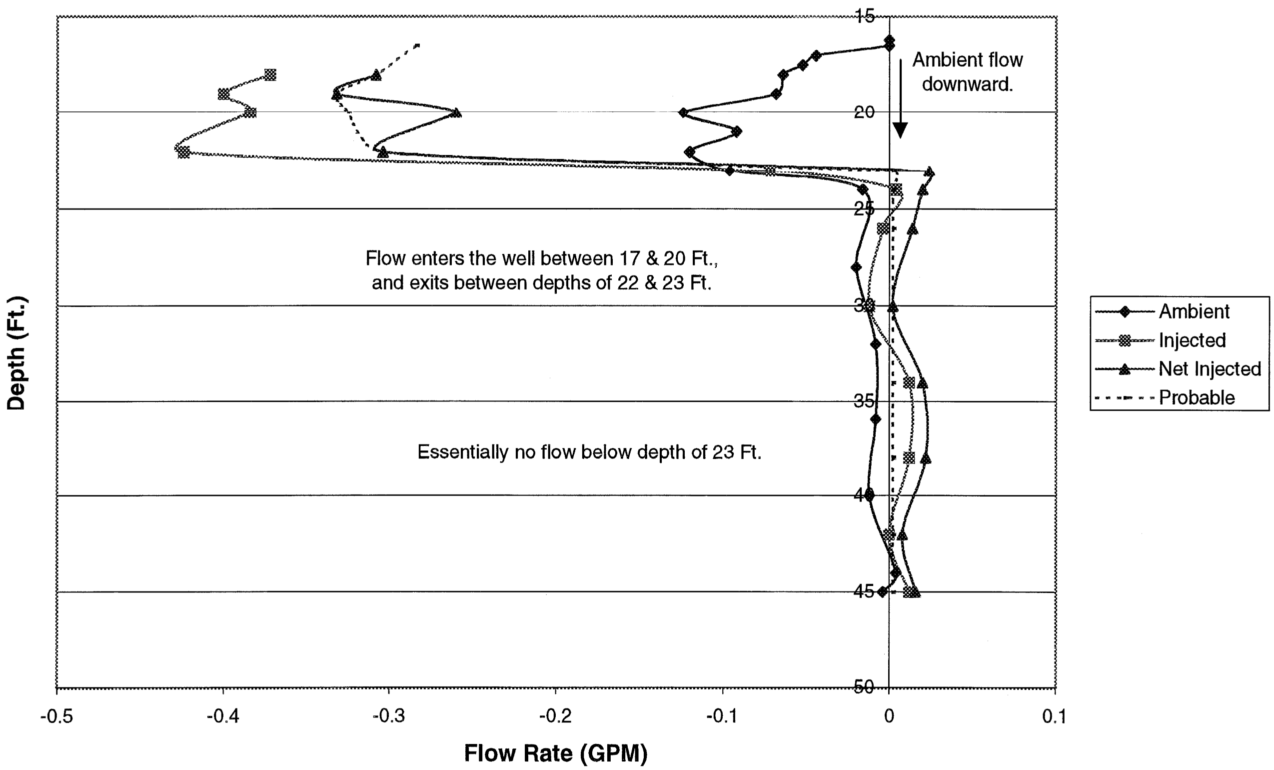
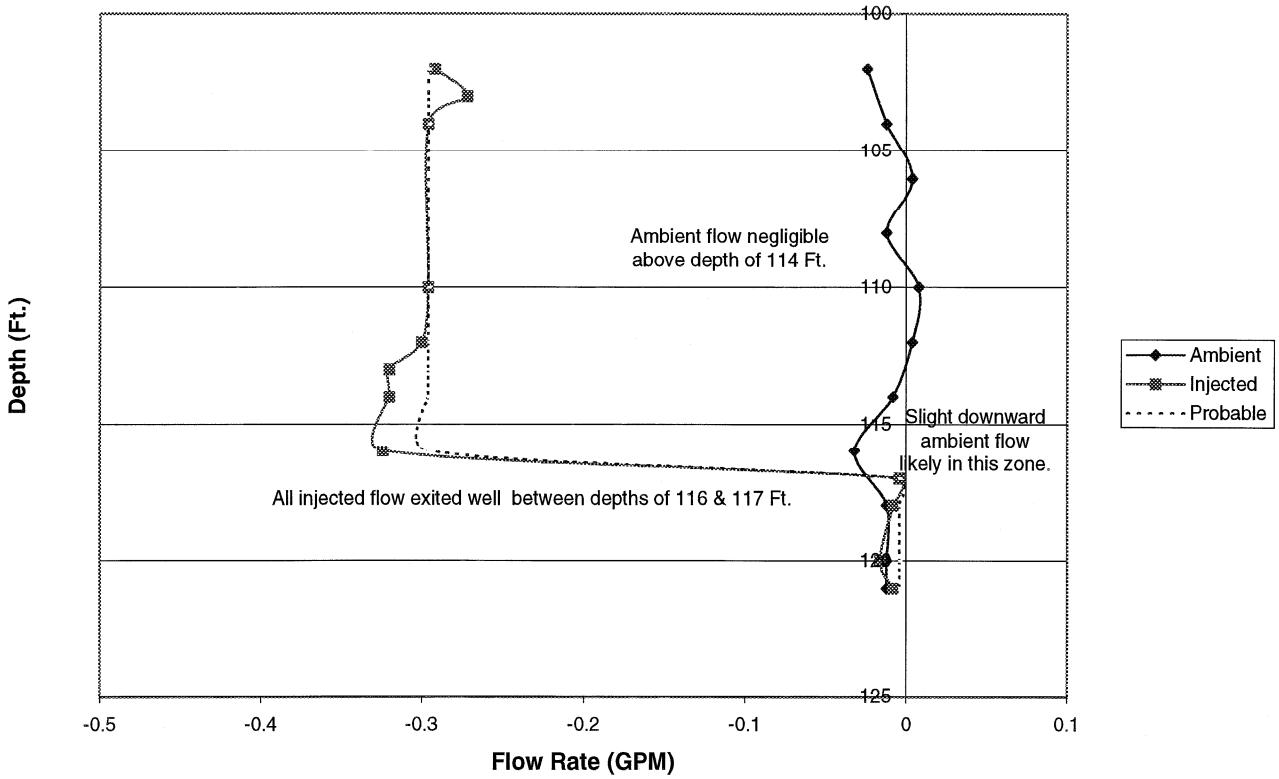


**Figure A-38: Profile of Flow Rates in Well J3L**



## Figure A-39: Profile of Flow Rates in Well J4L

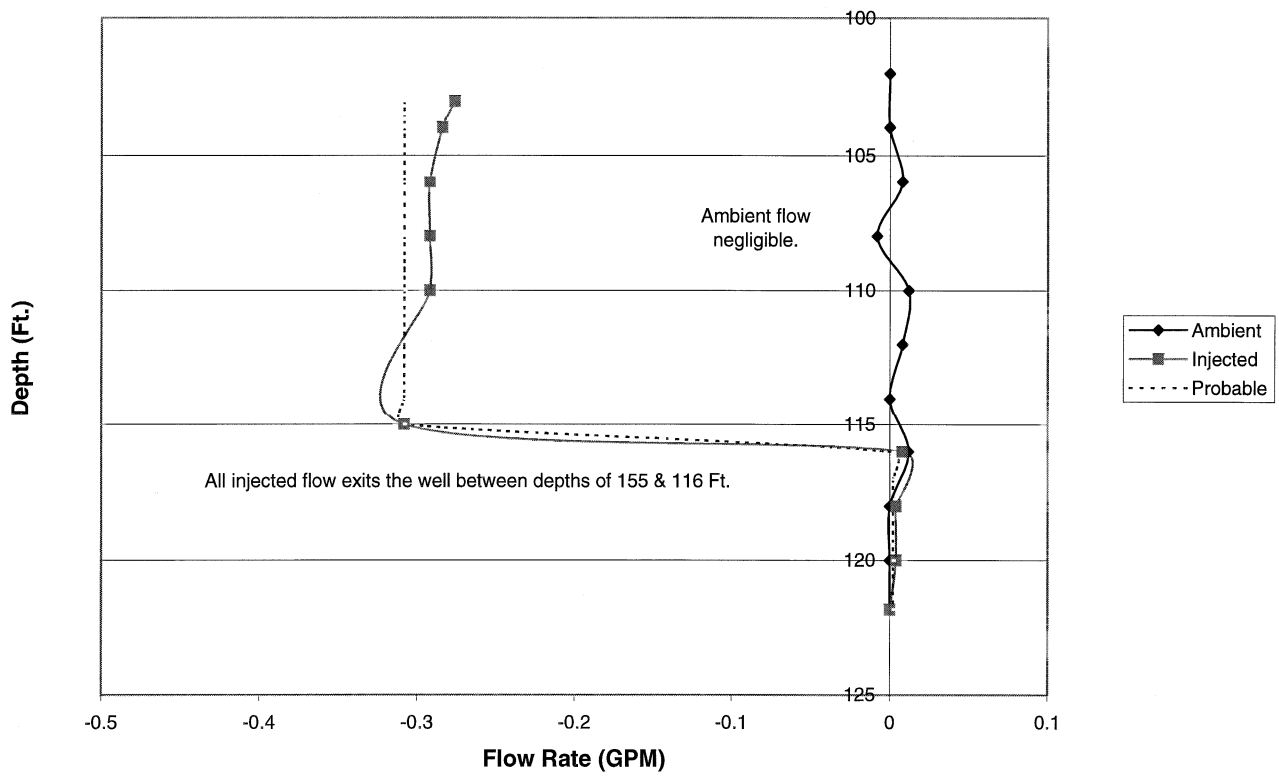


**Figure A-40: Profile of Flow Rates in Well MW 2**

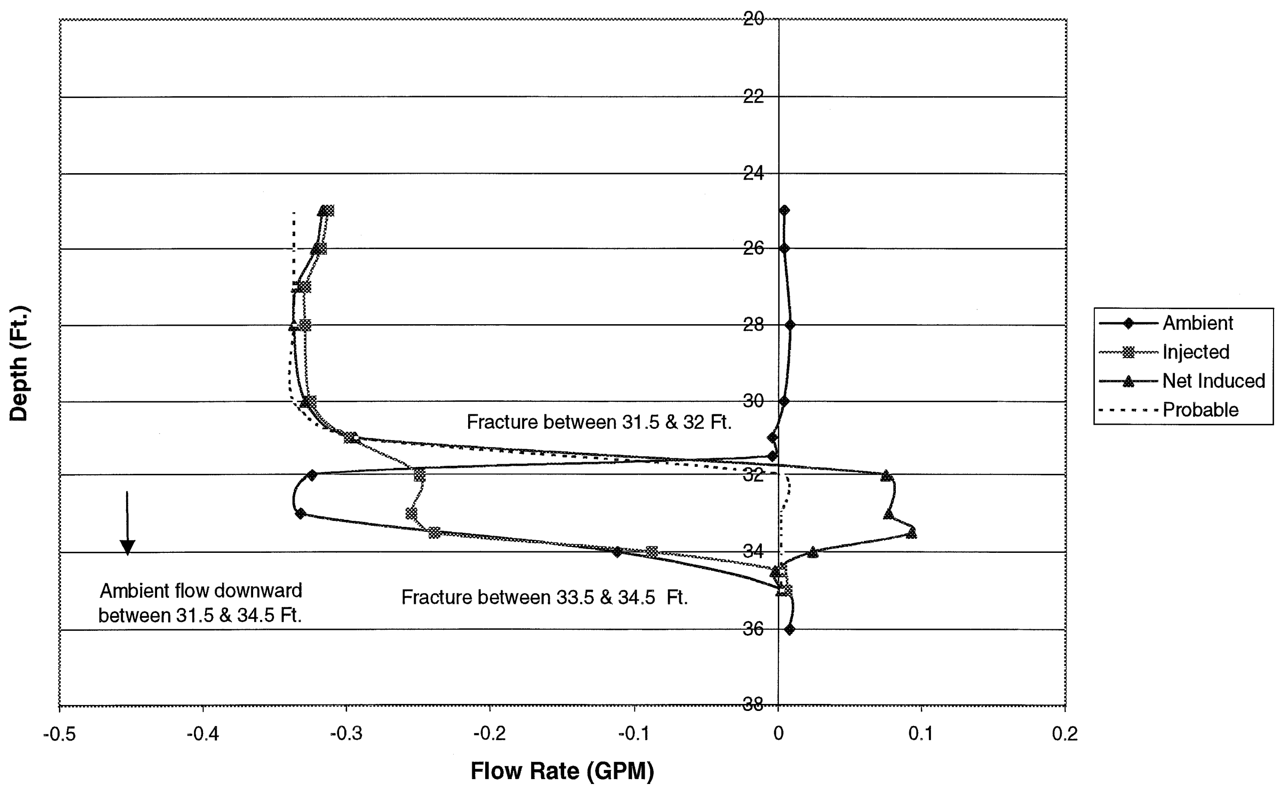


**Figure A-41: Profile of Flow Rates in Well MW 3**

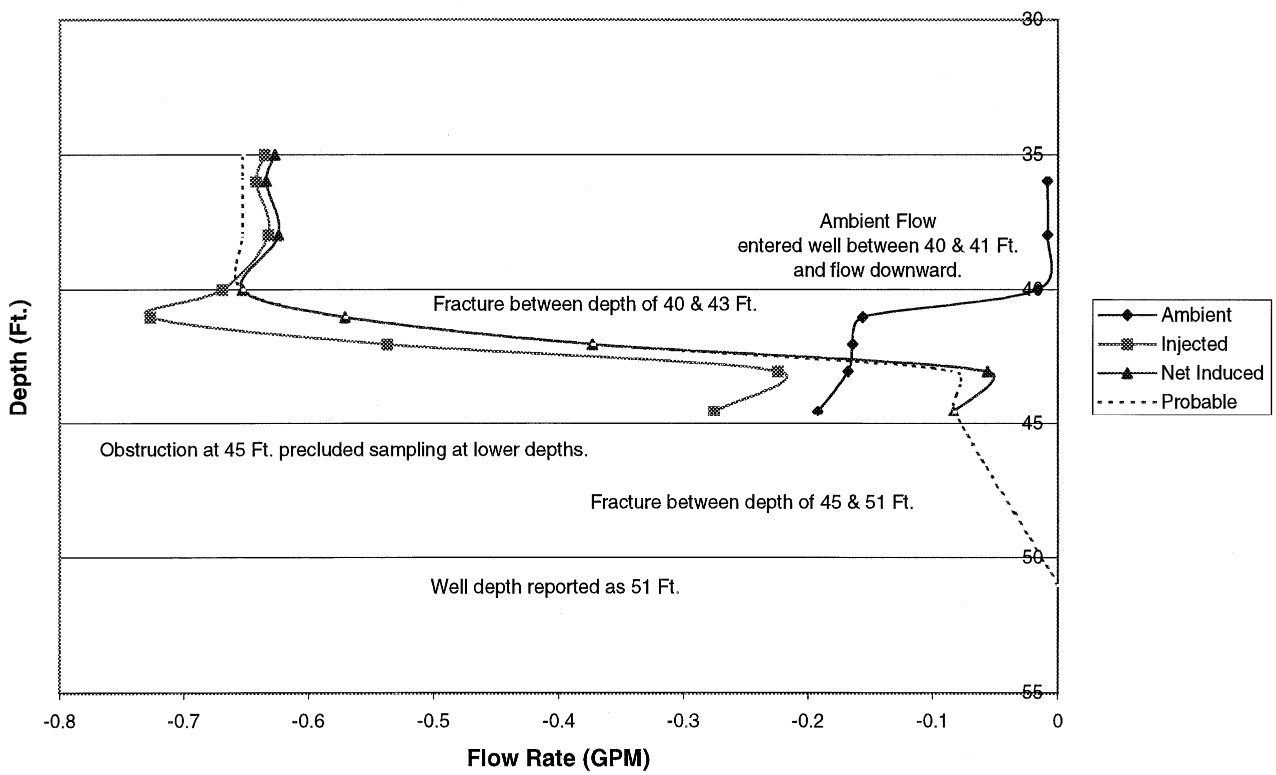


**Figure A-42: Profile of Flow Rates in Well MW 4**

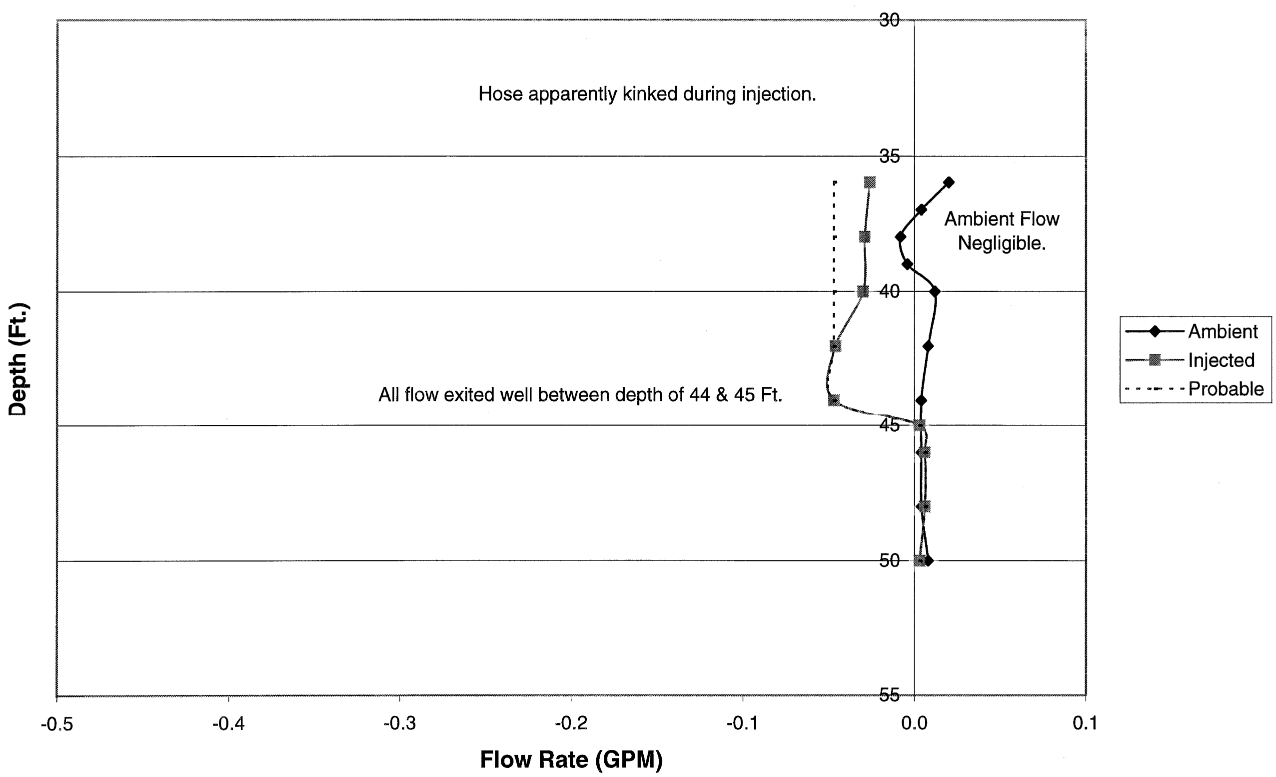
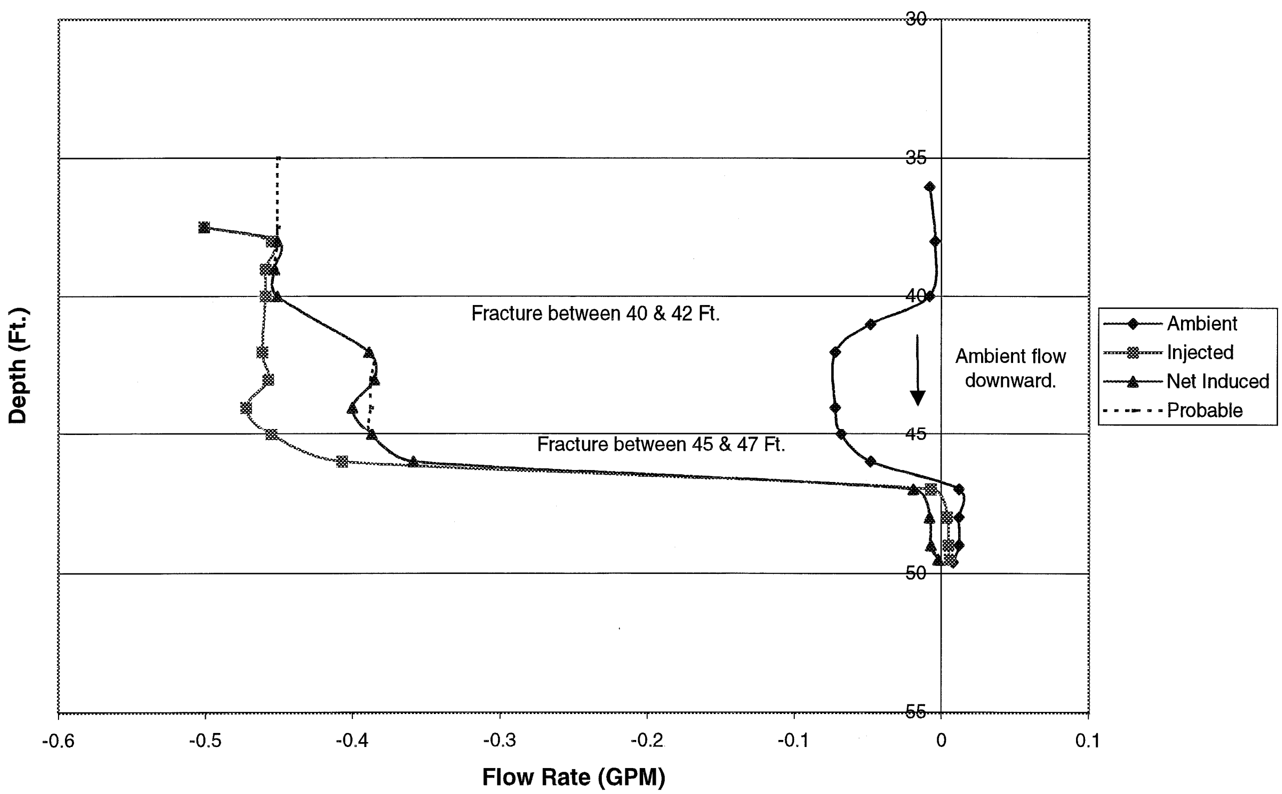
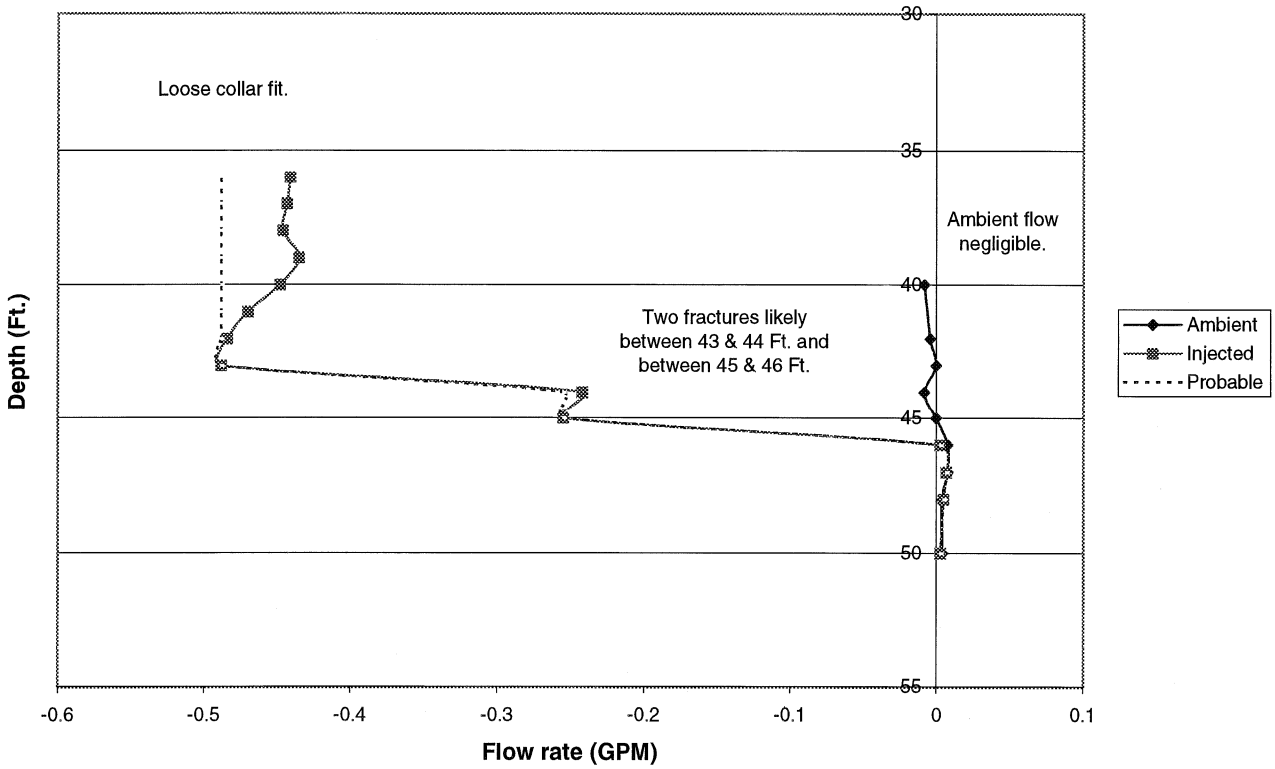


**Figure A-43: Profile of Flow Rates in Well MW 5**



## Figure A-44: Profile of Flow Rates in Well MW 6



# APPENDIX D

# STRATIGRAPHIC AND INSTRUMENTATION LOGS

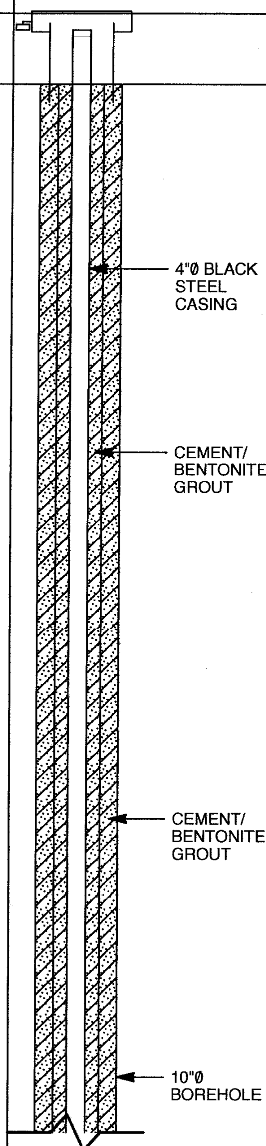
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1U
DATE COMPLETED: September 12, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1142098.7 TOP OF RISER | 589.53 | | | | | |
| | EASTING: 1026699.49 GROUND SURFACE | 587.86 | | | | | |
| 0–28.5 | OVERBURDEN (not sampled)<br>(see overburden stratigraphy for well AB1L) | | | | | | |
| 28.5 | END OF OVERBURDEN HOLE @ 28.5ft BGS | | | | | | |

Depth scale (ft BGS): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1U
DATE COMPLETED: September 12, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 28 | | | 10"Ø BOREHOLE | | | | |
| | BEDROCK (not sampled) | 559.36 | CEMENT/ BENTONITE GROUT; 6"Ø BOREHOLE | | | | |
| 30 | - mechanical breaks: 30.8 and 34.6 ft BGS | 557.36 | | | | | |
| 32–36 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- shaley partings: 31.4, 31.9, 32.0, 32.4, 32.9, 33.1, 33.4, 33.8, 34.3, and 35.5 ft BGS<br>- vugs: 38.4 and 35.1 ft BGS | | | 1 | 92 | 67 | 100 |
| 36–42 | - shaley partings: 35.6, 36.2, 36.6, 37.2, and 38.0 ft BGS<br>- closed horizontal fracture, gypsum coated @ 38.2 ft BGS<br>- vugs: 38.4 and 40.0 ft BGS<br>- mechanical breaks: 39.0, 39.7, 39.9, and 40.1 ft BGS<br>- shaley partings: 41.3, 41.6, 41.7, 42.2, 42.8, and 42.9 ft BGS | | HQ COREHOLE | 2 | 100 | 86 | 80 |
| 42 | - closed horizontal fracture coated with gypsum and sphalerite @ 42.6 ft BGS | 545.46 | | | | | |
| 44 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert | 542.86 | | | | | |
| 46 | END OF BOREHOLE @ 45.0ft BGS | | | | | | |
| 48–60 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

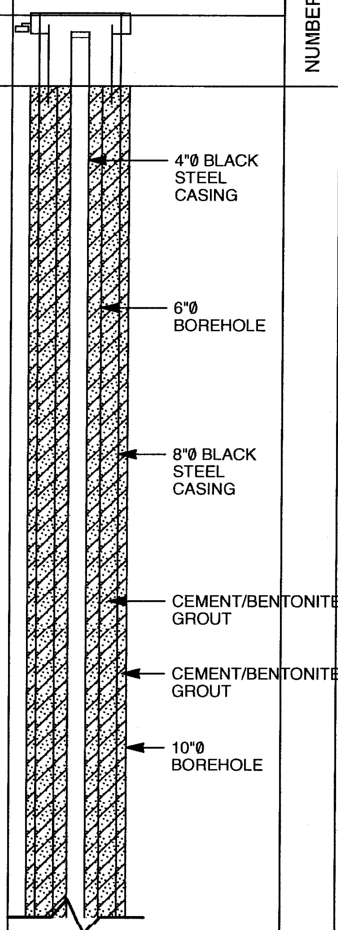


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1142105.06 / TOP OF RISER | 589.44 | | | | | |
| | EASTING: 1026719.93 / GROUND SURFACE | 588.02 | | | | | |
| 0–22.6 | OVERBURDEN (not sampled)<br>(see overburden for well AB1U) | | | | | | |
| 22.6 | END OF OVERBURDEN HOLE @ 22.6ft BGS | | | | | | |

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

OVERBURDEN LOG 01069NEW.GPJ CRA_CORP.GDT 2/13/02

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 22.9 | BEDROCK (not sampled)<br>(see bedrock for well AB1U) | 565.42 | 4"Ø BLACK STEEL CASING<br>CEMENT/BENTONITE GROUT | | | | |
| 43.8 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert | 544.52 | HQ COREHOLE | 1 | 100 | | 100 |
| | - mechanical breaks: 43.9, 45.0, 45.5, 47.4, 48.0, 50.8, 54.3, 56.2, 57.1, 57.9 (shaley), 58.5 (shaley), 60.1, 61.6, 62.6, 63.1, 64.9, 65.2, 65.4, 67.8, 68.0, 68.8, 69.3, 69.7, 70.7, 71.0, 71.6, 72.3, 73.2, 73.6, 74.3, 74.6, 76.3, 77.0, 77.6, 77.8, and 78.3 ft BGS | | | 2 | 100 | 80 | 100 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 56 | | | | | | | |
| 58 | | | | | | | |
| 60 | | | | 3 | 99 | 92 | 75 |
| 62 | | 525.42 | | | | | |
| 64 | DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous<br>-abundance of crinoids at Goat Island/Gasport contact<br>- slightly weathered horizontal fractures: 64.1 and 64.2 ft BGS<br>- very broken and fractured, slightly weathered between 64.5 and 64.7 ft BGS | | | | | | |
| 66 | | | | | | | |
| 68 | | | | | | | |
| 70 | | | HQ COREHOLE | 4 | 93 | 81 | 50 |
| 72 | | | | | | | |
| 74 | | | | | | | |
| 76 | | | | | | | |
| 78 | - gypsum-lined closed fracture @ 77.2 ft BGS | 509.62 | | | | | |
| 80 | DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite<br>- mechanical breaks: 79.0, 80.4, 80.5, 81.8, and 83.5 ft BGS | | | 5 | 100 | 93 | 50 |
| 82 | | | | | | | |
| 84 | | | | | | | |
| 86 | END OF BOREHOLE @ 85.5ft BGS | 502.52 | | | | | |
| 88 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|---|---|---|---|
| | NORTHING: 1142109.27 EASTING: 1026737.66 TOP OF RISER / GROUND SURFACE | 590.05 / 587.97 | | | | | | |
| | ASPHALT | 587.77 | | | | | | |
| | GW-GRAVEL, fill | | | SS1 | | 0.8 | 19 | 0 |
| 2 | CL-CLAY, some silt, yellowish-orange, dry, slight plasticity, dense | 585.97 | 4"Ø BLACK STEEL CASING | SS2 | | 1.7 | 15 | 0 |
| 4 | | | | SS3 | | 1.4 | 13 | 0 |
| 6 | | | | SS4 | | 1.3 | 26 | 0 |
| 8 | | | | SS5 | | 1.9 | 20 | 0 |
| 10 | | | 8"Ø BLACK STEEL CASING | SS6 | | 1.5 | 7 | 0 |
| 12 | | | | SS7 | | 2.0 | 22 | 0 |
| 14 | | | CEMENT/BENTONITE GROUT | SS8 | | 2.0 | 9 | 0 |
| 16 | - moist below 17 ft BGS | | CEMENT/BENTONITE GROUT | SS9 | | 2.0 | 19 | 0 |
| 18 | | | 10"Ø BOREHOLE | SS10 | | 2.0 | WH | 0 |
| 20 | - wet below 20 ft BGS | | | SS11 | | 2.0 | WH | 0 |
| 22 | | | | SS12 | | 2.0 | 4 | 0 |
| 24 | | | | SS13 | | 1.7 | 1 | 0 |
| 26 | | | | SS14 | | 1.3 | >50 | 0 |
| 28 | END OF OVERBURDEN HOLE @ 27.3ft BGS | | | | | | | |
| 30 | | | | | | | | |
| 32 | | | | | | | | |
| 34 | | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 28 | BEDROCK (not sampled) (see bedrock stratigraphy for well AB1U and AB1M) | 560.67 | | | | | |
| 30 | | | | | | | |
| 32 | | | 4"Ø BLACK STEEL CASING | | | | |
| 34 | | | | | | | |
| 36 | | | | | | | |
| 38 | | | CEMENT/BENTONITE GROUT | | | | |
| 40 | | | | | | | |
| 42 | | | | | | | |
| 44 | | | 6"Ø BOREHOLE | | | | |
| 46 | | | | | | | |
| 48 | | | | | | | |
| 50 | | | | | | | |
| 52 | | | | | | | |
| 54 | | | | | | | |
| 56 | | | | | | | |
| 58 | | | | | | | |
| 60 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

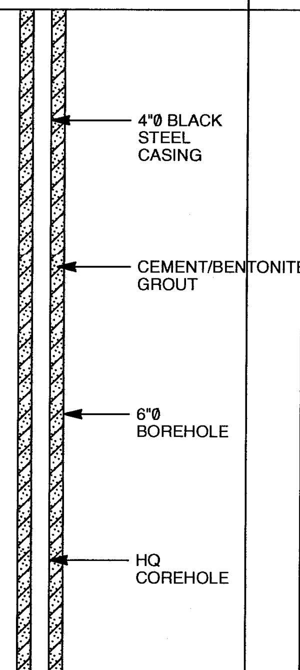
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 62–78 | | | | | | | |
| 79.1 | DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite<br>- mechanical breaks: 79.9, 83.7, and 85.1 ft BGS<br>- shaley partings: 79.6 and 80.1 ft BGS | 508.97 | | 1 | 100 | 80 | 100 |
| | | | | 2 | 100 | 95 | 100 |
| 86.4 | DOLOMITE (Decew Formation): medium-grey, fine-grained, thin to thick-bedded, argillaceous<br>- mechanical breaks: 87.5, 88.5, 90.1, 90.6, 93.1, 93.7, 94.0, 94.3, and 94.5 ft BGS<br>- shaley parting @ 95.1 ft BGS | 501.67 | | | | | |
| | | 492.47 | | 3 | 97 | 90 | 100 |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | SHALE (Rochester Shale Formation): dark-grey to black, massively bedded, dolomitic | 490.47 | | | | | |
| 98 | - shaley parting @ 97.1 ft BGS | | | | | | |
| | END OF BOREHOLE @ 97.5ft BGS | | | | | | |
| 100 | | | | | | | |
| 102 | | | | | | | |
| 104 | | | | | | | |
| 106 | | | | | | | |
| 108 | | | | | | | |
| 110 | | | | | | | |
| 112 | | | | | | | |
| 114 | | | | | | | |
| 116 | | | | | | | |
| 118 | | | | | | | |
| 120 | | | | | | | |
| 122 | | | | | | | |
| 124 | | | | | | | |
| 126 | | | | | | | |
| 128 | | | | | | | |
| 130 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
# (OVERBURDEN)

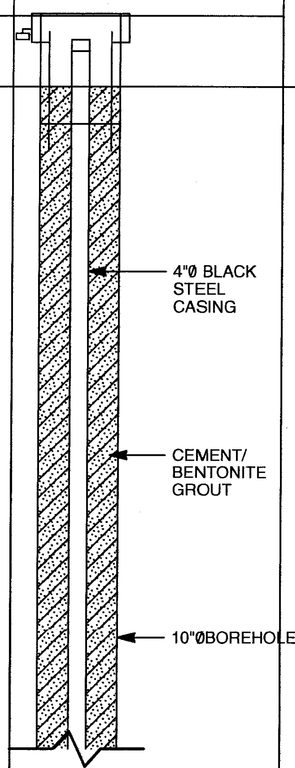


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-5U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141348.77 / TOP OF RISER | 588.38 | | | | | |
| | EASTING: 1026048.56 / GROUND SURFACE | 588.17 | | | | | |
| | OVERBURDEN (not sampled) | | | | | | |
| 18 | END OF OVERBURDEN HOLE @ 18.0ft BGS | | | | | | |

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-5U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 18 | BEDROCK (not sampled) | 570.17 | | | | | |
| 22 | DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules<br>- fractures: 22.6, 22.8, and 23.4 ft BGS<br>- mechanical break @ 24.8 ft BGS<br>- shaley parting @ 26.4 ft BGS | 566.17 | | 1 | 85 | 50 | 0 |
| 26.6 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 25.9, 26.0, 28.1, 28.2, 28.3, 28.7, 29.5, 34.1, 34.5, 36.1, 37.2, 37.7, 37.8, 38.8, 39.4, 40.0, 40.4, 42.2, and 42.25 ft BGS<br>- shaley partings: 26.6, 26.65, 27.2, 27.3, 27.5, 27.7, 30.3, 35.3, 41.2, 41.7, 43.1, 43.3, 44.8, 45.1, and 45.3 ft BGS<br>- faractures: 38.0 (with mineralization) and 46.1 ft BGS | 561.57 | HQ COREHOLE | 2 | 96 | 66 | 0 |
| | | | | 3 | 100 | 92 | 0 |
| 46 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- fractures: 46.4 and 48.2 ft BGS<br>- mechanical breaks: 48.6, 49.6, 49.8, and 49.9 ft BGS | 542.47 | | 4 | 100 | 87 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
HOLE DESIGNATION: CD-5U
PROJECT NUMBER: 01069-30
DATE COMPLETED:
CLIENT: MSRM
DRILLING METHOD: HSA/Wet Rotary
LOCATION: Niagara Falls, NY
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | END OF BOREHOLE @ 51.0ft BGS | 537.17 | | | | | |
| 52 | | | | | | | |
| 54 | | | | | | | |
| 56 | | | | | | | |
| 58 | | | | | | | |
| 60 | | | | | | | |
| 62 | | | | | | | |
| 64 | | | | | | | |
| 66 | | | | | | | |
| 68 | | | | | | | |
| 70 | | | | | | | |
| 72 | | | | | | | |
| 74 | | | | | | | |
| 76 | | | | | | | |
| 78 | | | | | | | |
| 80 | | | | | | | |
| 82 | | | | | | | |
| 84 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

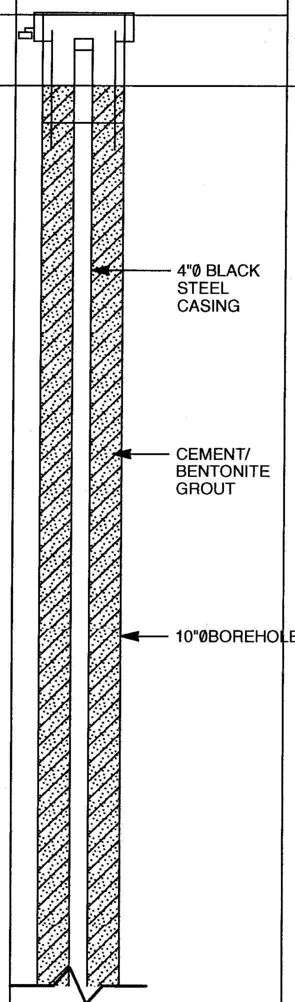
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-6U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141518.27 / EASTING: 1026111.43 — TOP OF RISER / GROUND SURFACE | 588.71 / 588.61 | | | | | |
| 0–24.5 | OVERBURDEN (not sampled) | | | | | | |
| 24.5 | END OF OVERBURDEN HOLE @ 24.5ft BGS | | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

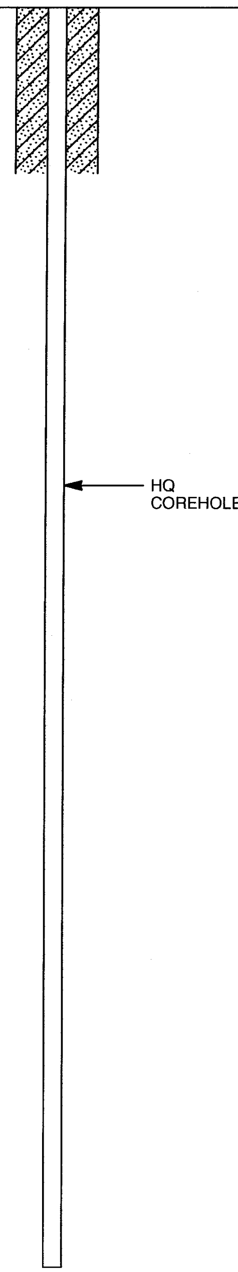


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-6U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| 24.0–26.0 | BEDROCK (not sampled) | 564.11 |
| 26.0–40.0 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 26.6, 26.7, 26.8, 26.9, 27.05, 27.1, 27.7, 28.3, 29.0, 29.2, 29.5, 29.7, 29.8, 30.2, 30.4, 32.6, 34.4, 34.65, 35.5, 35.7, 38.7, 38.0, 39.6, 40.8, and 43.2 ft BGS<br>- fractures: 32.2 and 36.6 ft BGS<br>- shaley partings: 30.7, 33.5, 33.55, 34.6, 38.4, and 39.8 ft BGS | 562.11 |
| 40.0–56.2 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- fracture @ 41.9 ft BGS<br>- mechanical breaks: 44.9, 46.0, 48.0, 48.9, 49.9, 50.6, 52.8, 52.9, 54.4, and 54.9 ft BGS<br>- shaley partings: 43.7, 43.8, 45.0, 46.8, 48.6, and 50.8 ft BGS | 548.51 |
| 56.2 | END OF BOREHOLE @ 56.2ft BGS | 532.41 |

MONITOR INSTALLATION




| RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|
| 1 | 100 | 46 | 100 |
| 2 | 99 | 80 | 90 |
| 3 | 100 | 90 | 90 |
| 4 | 98 | 96 | 80 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)

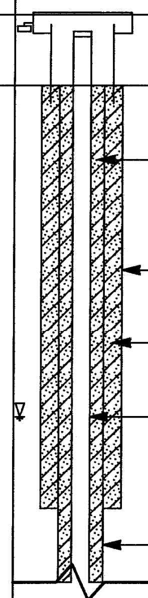
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

NORTHING: 1141499.79 — TOP OF RISER: 606.10
EASTING: 1028119.09 — GROUND SURFACE: 604.52

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| 0–1 | Not sampled. | 603.52 |
| 1–3 | OH-SILT and CLAY (TOPSOIL), gravel | 601.52 |
| 3–5 | ML/CL-SILT and CLAY | 599.52 |
| 5–9 | ML/CL-CLAY and SILT, brown, dry | 595.52 |
| 9–11 | ML-SILT (TILL), some gravel, brown, wet | 593.52 |
| 11–13.5 | Weathered Bedrock | |
| 13.5 | END OF OVERBURDEN HOLE @ 13.5ft BGS | |

MONITOR INSTALLATION




SAMPLE

| NUMBER | INTERVAL | REC (ft) | 'N' VALUE |
|---|---|---|---|
| SS1 | X | | 32 |
| SS2 | X | | 33 |
| SS3 | X | | 19 |
| SS4 | X | | 34 |
| SS5 | X | | 45 |
| SS6 | X | | - |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | | | 6"Ø BOREHOLE | | | | |
| 14 | DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules | 591.02 | | 1 | 60 | 0 | 50 |
| 16 | | | | | | | |
| 18 | - fractures with iron staining (possible overburden washing down into fracture): 17.8 and 18.2 ft BGS | | | | | | |
| 20 | - fractures: 13.8, 14.0, 14.1, 14.3, 14.5, 14.6, 20.2 (broken along plane of calcite-filled vugs), 22.7, and 32.3 ft BGS | | | 2 | 100 | 73 | 20 |
| 22 | | | | | | | |
| 24 | - mechanical breaks: 15.0, 15.8, 16.1, 16.4, 16.7, 17.7, 18.9, 19.2, 19.8, 21.4, 21.85, 21.9, 22.5, 24.0, 26.1, 28.0, 28.9, 29.55, 30.3, 30.4, 31.7, 36.3, 37.0, 37.3, 37.4, 38.3, 39.2, 41.0, and 44.3 ft BGS | | HQ COREHOLE | | | | |
| 26 | | | | | | | |
| 28 | - shaley partings: 15.9, 17.2, 17.35, 22.3, 25.6, 25.9, 27.2, 27.5, and 43.5 ft BGS | | | | | | |
| 30 | - fracture with extensive mineralization (gypsum, calcite, and very small amounts of shpalerite and galena) @ 30.0 ft BGS | | | 3 | 97 | 78 | 0 |
| 32 | - fracture with extensive mineralization (gypsum and calcite) @ 30.9 ft BGS<br>- abundant fossils (colonial corals) between 33.0 and 36.5 ft BGS | | | | | | |
| 34 | | | | | | | |
| 36 | - mineral partings: 24.5, 25.0, 44.9, and 45.0 ft BGS | | | | | | |
| 38 | | | | | | | |
| 40 | | | | 4 | 98 | 95 | 0 |
| 42 | - abundant vugs, partially/wholely infilled with gysum, samll vugs cotain visible calcite crystals between 42.0 and 47.0 ft BGS | | | | | | |
| 44 | - fractures with mineralization: 45.9, 46.0, 46.5, 47.2, 47.5, and 47.6 ft BGS | | | | | | |
| 46 | - mecahnical break @ 46.2 ft BGS | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 48–60.5 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mecahnical breaks: 48.3, 48.6, 49.1, 50.2, 50.7 (on small galena-filled vug), 52.5, 53.5, 53.9, 54.0, 54.3, 56.2, 56.8, and 60.3 ft BGS<br>- partings with gypsum-filled vugs: 50.5, 58.1, and 58.6 ft BGS<br>- shaley partings: 48.1, 51.7, and 54.7 (on vug with gypsum and calcite crystalization), 57.8, and 58.05 ft BGS<br>- fracture with gypsum @ 58.9 ft BGS | 556.42 | HQ COREHOLE | 5 | 100 | 81 | 0 |
| | | | | 6 | 100 | 96 | 0 |
| 60.5 | END OF BOREHOLE @ 60.5ft BGS | 544.02 | | | | | |

Depth scale: 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

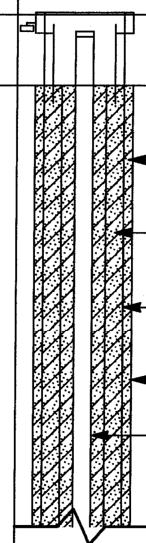
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141471.71 / EASTING: 1028121.17 / TOP OF RISER / GROUND SURFACE | 606.37 / 604.62 | | | | | |
| | OVERBURDEN (not sampled) (see overburden stratigraphy for well J5U) | | | | | | |
| 12 | END OF OVERBURDEN HOLE @ 12.0ft BGS | | | | | | |




Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

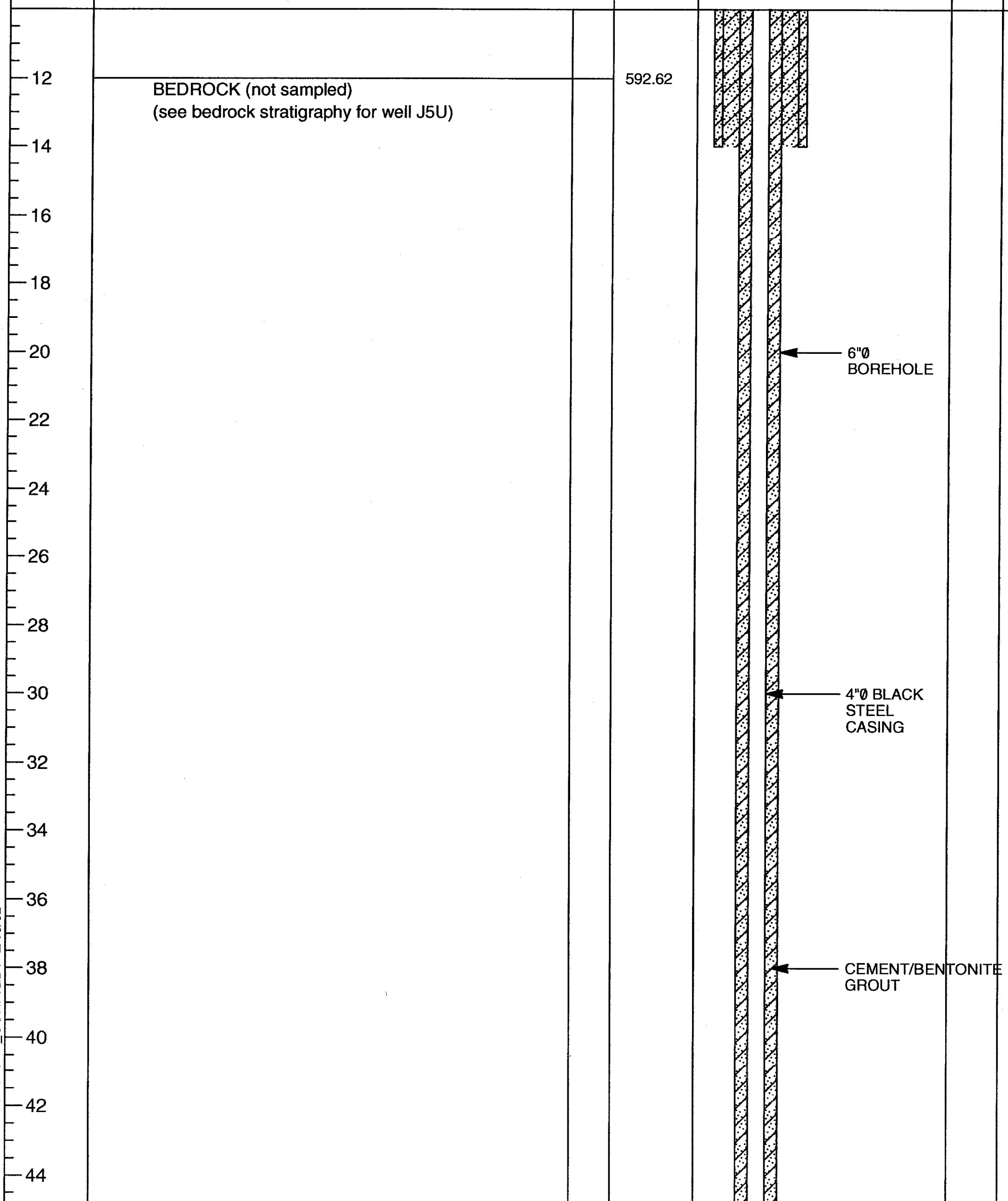
# STRATIGRAPHIC AND INSTRUMENTATION LOG
# (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 12 | BEDROCK (not sampled)<br>(see bedrock stratigraphy for well J5U) | 592.62 | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



| | |
|---|---|
| PROJECT NAME: Hyde Park RRT | HOLE DESIGNATION: J5M |
| PROJECT NUMBER: 01069-30 | DATE COMPLETED: August 30, 2001 |
| CLIENT: MSRM | DRILLING METHOD: HSA/Wet Rotary |
| LOCATION: Niagara Falls, NY | FIELD PERSONNEL: J. Raby, P. Kryger |

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 46–60 | - shaley partings: 60.0, 62.1, 66.4, and 67.0 ft BGS | | 4"Ø BLACK STEEL CASING; 6"Ø BOREHOLE; CEMENT/BENTONITE GROUT | | | | |
| 60.8 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 61.7, 61.9, 63.6, 65.6, 66.1, 68.8, 69.5, 70.8, and 70.9 ft BGS<br>- fractures: 62.8, 65.2, and 71.2 ft BGS | 544.12 | HQ COREHOLE | 1 | 97 | 94 | 100 |
| 71.6 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- mechanical breaks: 71.4, 72.4, 72.5, 73.2, 73.6, 74.6, 75.3, 76.6, 77.0, 77.5, 79.1, 80.6, 82.9, 84.3, 84.8, 87.1, 91.1, 92.3, 92.4, 93.2, 94.0, 97.2, and 98.7 ft BGS<br>- fractures: 71.7, 80.6, 82.8, 83.2 (with gypsum), 86.5 (with gypsum), 86.7 (with gypsum and sphalerite), 88.4, 90.2, 91.9 (very | 533.32 | | 2 | 100 | 85 | 90 |

Depth scale: 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

BEDROCK LOG 01069NEW.GPJ CRA_CORP.GDT 2/13/02

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | vuggy with gypsum mineralization) ft BGS | | | | | | |
| 82–90 | - shaley partings: 81.6, 89.7, 95.7, 99.0, and 99.05 ft BGS | | HQ COREHOLE (at 90) | 3 | 97 | 92 | 0 |
| 92 | DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous<br>-abundance of crinoids at Goat Island/Gasport contact | 512.52 | | 4 | 100 | 96 | 0 |
| 100.5 | END OF BOREHOLE @ 100.5ft BGS | 504.12 | | | | | |

Depth scale: 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

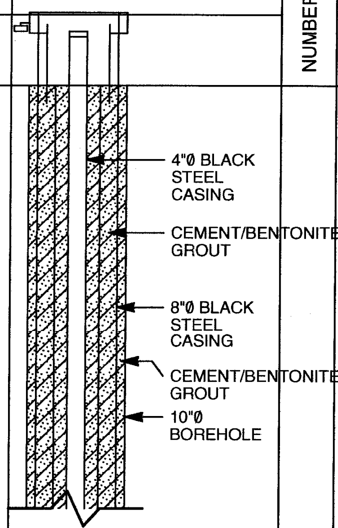
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141449.01 EASTING: 1028117.61 TOP OF RISER / GROUND SURFACE | 607.79 / 606.08 | | | | | |
| 0–11.5 | OVERBURDEN (not sampled) (see overburden stratigraphy for J5U) | | | | | | |
| 11.5 | END OF OVERBURDEN HOLE @ 11.5ft BGS | | | | | | |




Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

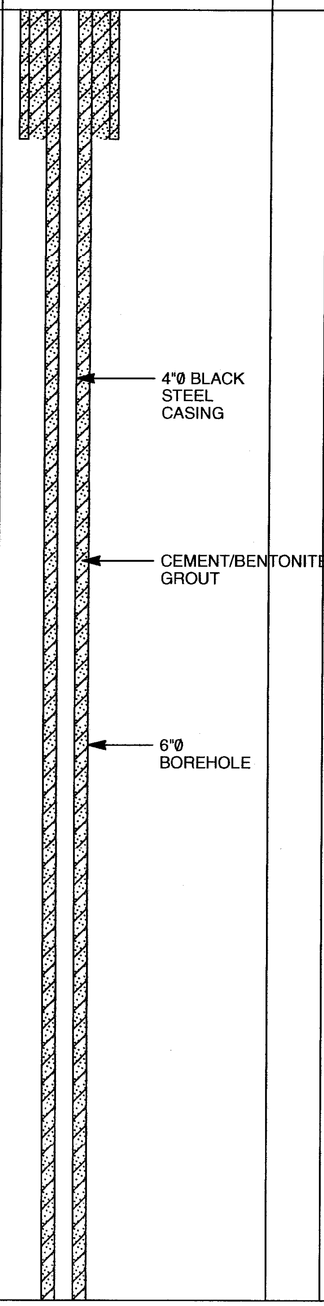
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | FQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 12 | BEDROCK (not sampled)<br>(see Bedrock stratigraphy for well J5M) | 594.58 | | | | | |




Depth scale: 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

BEDROCK LOG 01069NEW.GPJ CRA_CORP.GDT 2/13/02

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 46 | | | | | | | |
| 48 | | | | | | | |
| 50 | | | 6"Ø BOREHOLE | | | | |
| 52 | | | | | | | |
| 54 | | | | | | | |
| 56 | | | CEMENT/BENTONITE GROUT | | | | |
| 58 | | | | | | | |
| 60 | | | 4"Ø BLACK STEEL CASING | | | | |
| 62 | | | | | | | |
| 64 | | | | | | | |
| 66 | | | | | | | |
| 68 | | | | | | | |
| 70 | | | | | | | |
| 72 | | | | | | | |
| 74 | | | | | | | |
| 76 | | | | | | | |
| 78 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

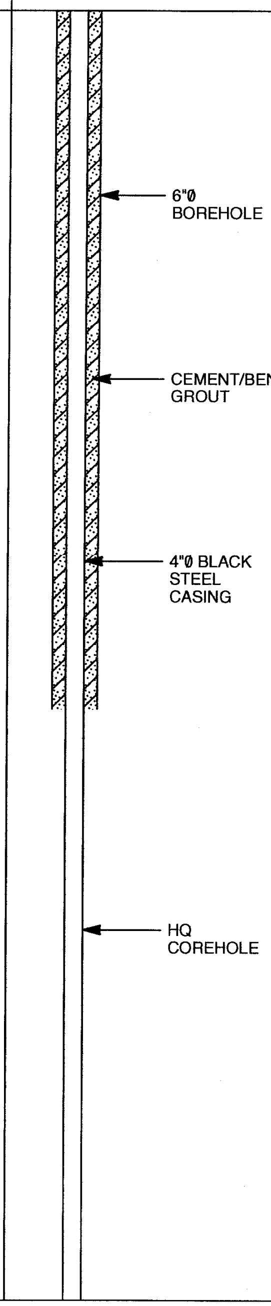
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 82–98 | | | | | | | |
| 99.6 | DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous<br>-abundance of crinoids at Goat Island/Gasport contact<br>- mechanical breaks: 99.6, 100.1, 101.6, 101.9, 102.1, 104.0, 104.6, 105.6, 106.6, 109.0, 110.1, and 110.8 ft BGS<br>- fractures: 104.3 and 107.6 ft BGS<br>- shaley partings: 103.8, 104.8, 107.5, and 114.3 ft BGS | 506.98 | | 1 | 100 | 100 | 100 |
| | | | | 2 | 100 | 58 | 100 |
| | | | | 3 | 100 | 91 | 100 |
| 108.5 | DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite | 498.08 | | | | | |
| 112.5 | DOLOMITE (Decew Formation): medium-grey, fine-grained, thin to thick-bedded, argillaceous | 494.08 | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 116–124 | - mechanical breaks: 113.8, 114.9, 116.5, 117.1, 118.9, 121.3, 122.8, 123.0, 125.2, 125.3, and 125.4 ft BGS<br>- shaley partings: 114.3, 118.7, and 119.7 ft BGS<br>- fractures: 120.0, 122.5, 123.9, and 124.1 ft BGS | | HQ COREHOLE | 4 | 100 | 94 | 100 |
| 124–126 | SHALE (Rochester Shale Formation): dark-grey to black, massively bedded, dolomitic | 481.48 | | 5 | 100 | 77 | 100 |
| 126 | END OF BOREHOLE @ 126.0ft BGS | 480.08 | | | | | |

Depth scale: 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

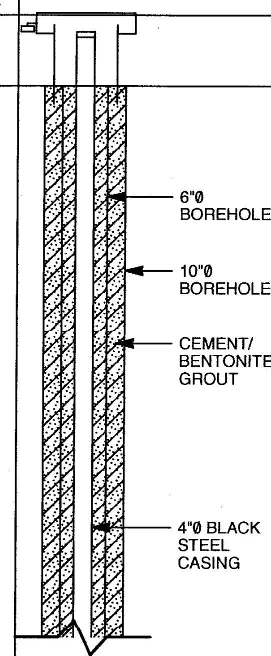
# STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW1-2001
DATE COMPLETED: July 18, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141743.95 TOP OF RISER | 597.16 | | | | | |
| | EASTING: 1027388.74 GROUND SURFACE | 595.41 | | | | | |
| 0–15 | OVERBURDEN<br>See stratigraphy for well PW-10U for Overburden. | | | | | | |
| 15.0 | END OF OVERBURDEN HOLE @ 15.0ft BGS | | | | | | |

Depth scale (ft BGS): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

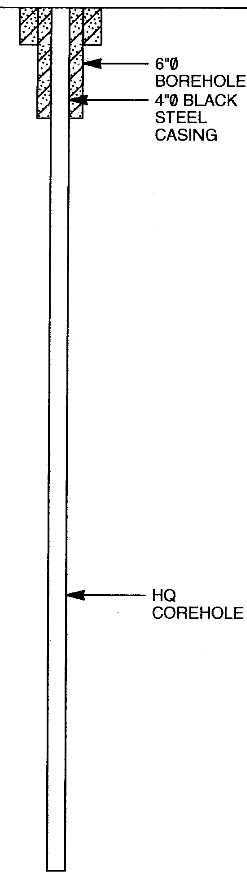


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW1-2001
DATE COMPLETED: July 18, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| 15.0 | BEDROCK (not sampled) | 580.41 |
| 17.0 | DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules<br>-extensive fracturing and weathering (vertical fracture from 17.2 to 19.5), small vugs, some colonial corals @ 17.0 to 19.5 ft BGS<br>- abundance of small vugs @ 19.5 to 21.3 ft BGS<br>- weathered fractures: 18.2, 19.0, 19.8, 20.8, 21.3, 29.5, 29.8, 30.6, 31.0, and 31.2 ft BGS<br>- no vugs, chert inclusions, higher shale content @ 21.3 to 23.9 ft BGS<br>- shaley partings: 22.0, 22.9, 27.5, and 28.2 ft BGS<br>- highly weathered fracture @ 23.8 ft BGS<br>- abundance of vugs (some with calcite of sphalerite crystals) and corals with some stylolites @ 23.9 to 31.0 ft BGS<br>- mechanical breaks: 25.8 and 31.5 ft BGS<br>- mineral parting @ 31.6 ft BGS<br>- small vein with calcite crystals on perimeter and sphalerite crystals on the inside @ 31.6 to 31.8 ft BGS | 578.41 |
| 32.2 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- shaly partings: 32.25, 32.5, 32.7, 32.8, 33.7, 34.5, 34.7, 35.0, 35.7, 36.3, and 37.1 ft BGS | 563.21 |
| 37.5 | END OF BOREHOLE @ 37.5ft BGS | 557.91 |

MONITOR INSTALLATION




| RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|
| 1 | 98 | 66 | 0 |
| 2 | 100 | 75 | 0 |
| 3 | 100 | 67 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

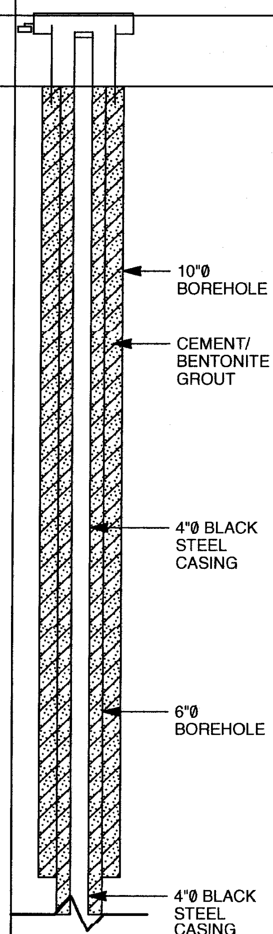
# STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW2-2001
DATE COMPLETED: July 19, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141782.65 TOP OF RISER | 596.04 | | | | | |
| | EASTING: 1027393.5 GROUND SURFACE | 594.42 | | | | | |
| | OVERBURDEN<br>See stratigraphy for well PW-10U for Overburden. | | | | | | |
| 22 | BEDROCK (not sampled) | 572.92 | | | | | |
| | END OF OVERBURDEN HOLE @ 22.5ft BGS | | | | | | |




Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW2-2001
DATE COMPLETED: July 19, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 22 | BEDROCK (not sampled) | 572.92 | 4"Ø BLACK STEEL CASING | | | | |
| 24 | DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules<br>- mechanical breaks: 26.7, 28.6, and 31.7 ft BGS | 571.92 | | 1 | 100 | 100 | 100 |
| 30 | | | HQ COREHOLE | 2 | 100 | 89 | 100 |
| 33 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 32.6, 32.8, 33.1, and 33.9 ft BGS | 561.92 | | | | | |
| 35 | END OF BOREHOLE @ 35.1ft BGS | 559.32 | | | | | |

Depth scale: 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

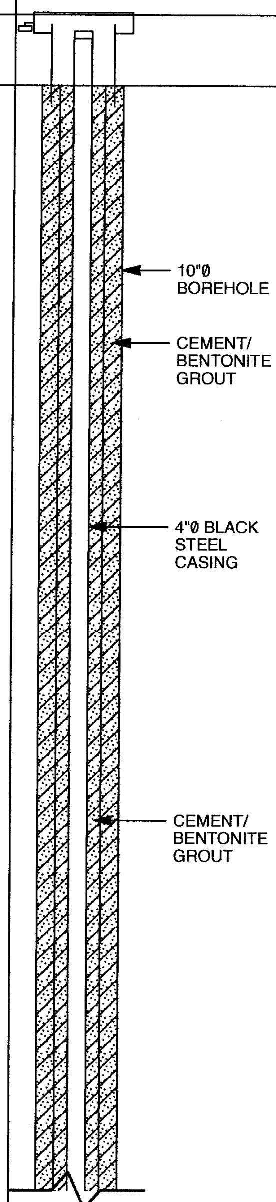
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW3-2001
DATE COMPLETED: July 26, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141799.31 TOP OF RISER | 591.26 | | | | | |
| | EASTING: 1026826.96 GROUND SURFACE | 589.76 | | | | | |
| | OVERBURDEN | | | | | | |
| 2 | See stratigraphy for well PW-9U for Overburden. | | | | | | |
| 4 | | | | | | | |
| 6 | | | | | | | |
| 8 | | | | | | | |
| 10 | | | | | | | |
| 12 | | | | | | | |
| 14 | | | | | | | |
| 16 | | | | | | | |
| 18 | | | | | | | |
| 20 | | | | | | | |
| 22 | | | | | | | |
| 24 | | | | | | | |
| 26 | | | | | | | |
| 28 | | | | | | | |
| 30 | END OF OVERBURDEN HOLE @ 30.0ft BGS | | | | | | |
| 32 | | | | | | | |
| 34 | | | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW3-2001
DATE COMPLETED: July 26, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | FQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 30 | BEDROCK (not sampled) | 559.76 | 6"Ø BOREHOLE; 4"Ø BLACK STEEL CASING | | | | |
| 32 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- shaly partings: 35.1, 36.2, 41.4, 41.5, 46.5, and 47.2 ft BGS<br>- mechanical breaks: 32.1 to 33.2, 34.3, 35.4, 36.7, 37.4, 38.6, 38.8, 38.95, 39.85, 40.2, 40.7, 41.0, and 43.0 ft BGS<br>- partially filled void/fracture @ 42.45 ft BGS<br>- vugs with mechanical breaks: 43.8 and 43.9 ft BGS<br>- vug @ 44.0 ft BGS<br>- partially filled fracture | 557.76 | HQ COREHOLE | 1 | 83 | 79 | 100 |
| | | | | 2 | 99 | 89 | 70 |
| 47.5 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- mechanical breaks: 48.0 and 48.2 ft BGS | 542.26 | | 3 | 91 | 86 | 70 |
| 50 | END OF BOREHOLE @ 50.0ft BGS | 539.76 | | | | | |

Depth scale (ft BGS): 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

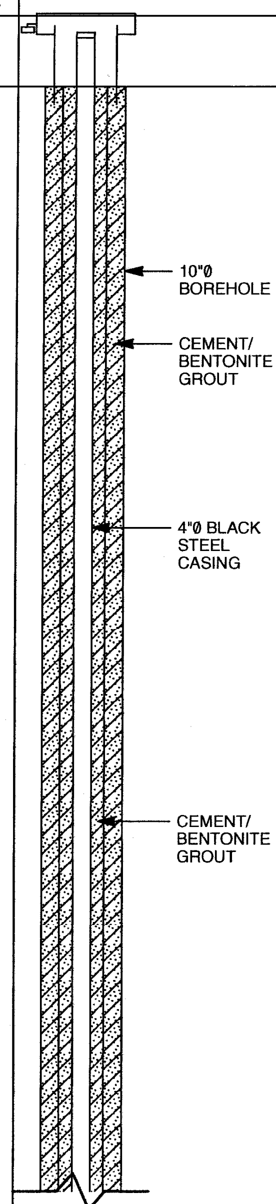


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW4-2001
DATE COMPLETED: July 27, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141816.56 / EASTING: 1026802.81 — TOP OF RISER / GROUND SURFACE | 590.90 / 588.82 | | | | | |
| | OVERBURDEN<br><br>See stratigraphy for well PW-9U for Overburden. | | | | | | |
| 30 | END OF OVERBURDEN HOLE @ 30.0ft BGS | | | | | | |

Depth scale (ft BGS): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW4-2001
DATE COMPLETED: July 27, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 30 | BEDROCK (not sampled) | 558.82 | 6"Ø BOREHOLE | | | | |
| 32 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces | 556.82 | 4"Ø BLACK STEEL CASING | | | | |
| 34 | | | | 1 | 71 | 66 | 100 |
| 36 | - mechanical break: 33.1, 33.5, 33.6, 34.5, 34.9, 35.4, 36.8, 38.4, 38.7, 39.1, 39.8, 40.6, 40.95, 42.4, 42.9, 43.6, 43.8, 44.25, 46.7, 47.7, 48.2, and 49.8 ft BGS | | | | | | |
| 38 | - shaly partings: 36.6, 37.8, 38.2, 38.8, 40.0, 41.0, and 43.5 ft BGS | | | | | | |
| 40 | | | | 2 | 100 | 85 | 75 |
| 44 | - partially infilled fracture @ 44.5 ft BGS | | HQ COREHOLE | | | | |
| 48 | - possible fracture with partial gypsum infilling @ 48.35 ft BGS | 540.32 | | 3 | 100 | 99 | 70 |
| 50 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert | 538.52 | | | | | |
| | END OF BOREHOLE @ 50.3ft BGS | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

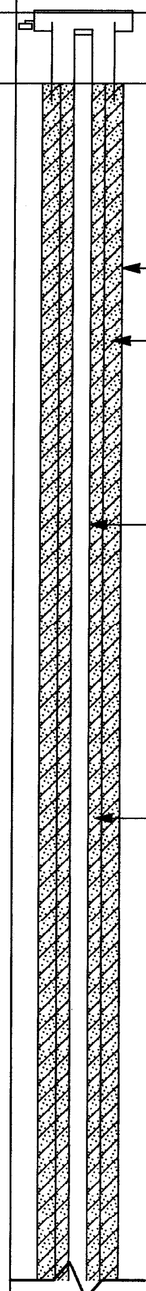
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
HOLE DESIGNATION: MW5-2001
PROJECT NUMBER: 01069-30
DATE COMPLETED: July 25, 2001
CLIENT: MSRM
DRILLING METHOD: HSA/Wet Rotary
LOCATION: Niagara Falls, NY
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141738.31 EASTING: 1026603.95 TOP OF RISER | 593.11 | | | | | |
| | GROUND SURFACE | 591.69 | | | | | |
| | OVERBURDEN<br>(See overburden stratigraphy for well PW-8U.) | | | | | | |
| 32.5 | END OF OVERBURDEN HOLE @ 32.5ft BGS | | | | | | |

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34



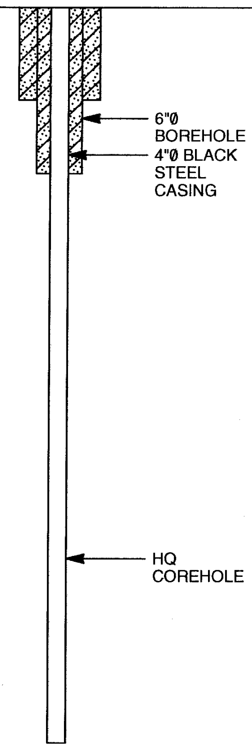

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



| | |
|---|---|
| PROJECT NAME: Hyde Park RRT | HOLE DESIGNATION: MW5-2001 |
| PROJECT NUMBER: 01069-30 | DATE COMPLETED: July 25, 2001 |
| CLIENT: MSRM | DRILLING METHOD: HSA/Wet Rotary |
| LOCATION: Niagara Falls, NY | FIELD PERSONNEL: J. Raby, P. Kryger |

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 32–34 | BEDROCK (not sampled) | 559.19 | | | | | |
| 34–50 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 33.1, 33.5, 35.9, 37.7, 38.2, 40.3, 41.47, 43.3, 47.6, and 47.9 ft BGS<br>- shaly partings: 33.8, 37.8, 39.0, 40.75, 41.3, 43.4, 43.75, 44.5, 45.5, 45.8, 46.5, 48.6, and 49.3 ft BGS<br>- fracture with gypsum mineralization @ 44.05 ft BGS<br>- vugs: 45.5 and 46.5 to 47.0 ft BGS<br>- fracture with extensive mineralization (probably plugged) | 557.19 | | 1 | 100 | 100 | 90-95 |
| | | | | 2 | 100 | 100 | 90-95 |
| | | | | 3 | 100 | 90 | 90-95 |
| 50 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>END OF BOREHOLE @ 50.0ft BGS | 542.19<br>541.69 | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

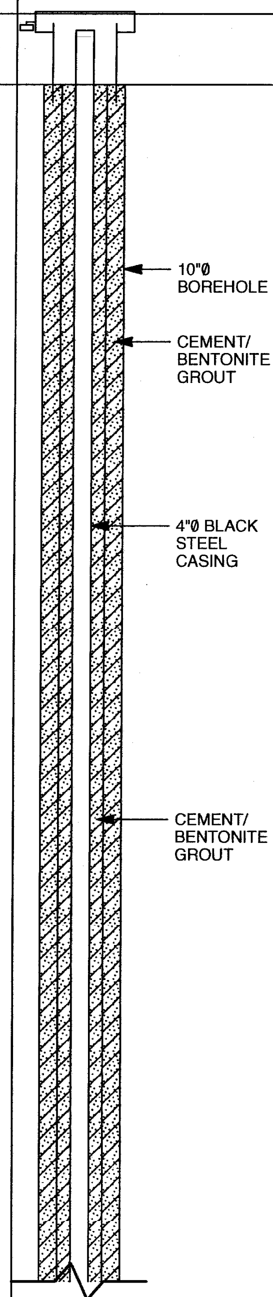


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW6-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141760.93 TOP OF RISER | 592.66 | | | | | |
| | EASTING: 1026600.12 GROUND SURFACE | 591.16 | | | | | |
| 0–32.5 | OVERBURDEN<br>(See stratigraphy for well PW-8U for Overburden.) | | | | | | |
| 32.5 | END OF OVERBURDEN HOLE @ 32.5ft BGS | | | | | | |

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

OVERBURDEN LOG 01069NEW.GPJ CRA_CORP.GDT 2/13/02

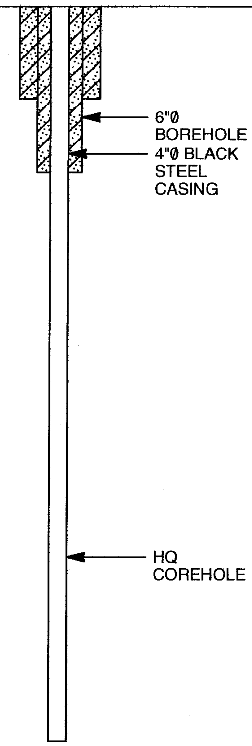
# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW6-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | FQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 32 | | | | | | | |
| 33 | BEDROCK (not sampled) | 558.66 | | | | | |
| 34 | | | | | | | |
| 35 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained. argillaceous. thin shale partings. commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- mechanical breaks: 33.1, 33.3, 33.7, 33.8, 35.8, 36.4, 36.5, 36.7, 38.3, 38.9, 40.0, 40.6, 43.0, and 49.4 ft BGS<br>- shaly partings: 35.6, 40.7, 42.5, 42.9, 48.1, 48.7, and 49.6 ft BGS<br>- large gypsum filled vugs @ 41 ft BGS<br>- gypsum filled fracture @ 41.1 ft BGS | 556.66 | | 1 | 100 | 100 | 90 |
| 36–44 | | | | 2 | 100 | 81 | 90 |
| 46 | - gypsum filled fracture @ 46.4 ft BGS | | | | | | |
| 48 | | | | 3 | 100 | 85 | 70-75 |
| 49 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- fracture and/or mechanical break with gypsum and sphalerite crystals @ 49.2 ft BGS | 542.56 | | | | | |
| 50 | END OF BOREHOLE @ 50.0ft BGS | 541.16 | | | | | |
| 52 | | | | | | | |
| 54 | | | | | | | |
| 56 | | | | | | | |
| 58 | | | | | | | |
| 60 | | | | | | | |
| 62 | | | | | | | |
| 64 | | | | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

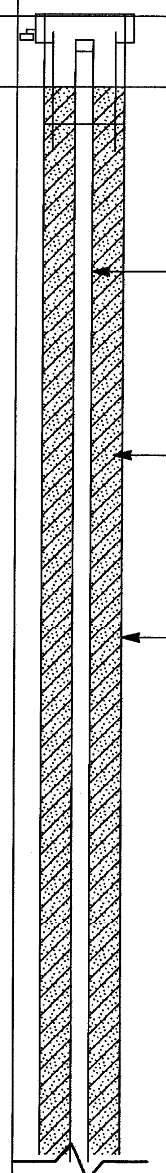


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW7-2001
DATE COMPLETED: July 3, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| | NORTHING: 1141787.34 — TOP OF RISER | 591.86 |
| | EASTING: 1026866.6 — GROUND SURFACE | 590.28 |
| | TOPSOIL | 589.68 |
| | CL-CLAY, trace medium sand, light brown, dry, medium plasticity with added moisture | |
| 12 | - moist below 12 ft BGS | |
| 24.5 | - wet below 24.5 ft BGS | |
| 26 | - Rock fragments | |
| 29.2 | END OF OVERBURDEN HOLE @ 29.2ft BGS | 561.28 |

MONITOR INSTALLATION




| SAMPLE NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|
| SS1 | X | 1.3 | 7 | 0 |
| SS2 | X | 0.7 | 19 | 0 |
| SS3 | X | 1.6 | 11 | 0 |
| SS4 | X | 0.8 | 14 | 0 |
| SS5 | X | 1.0 | 10 | 0 |
| SS6 | X | 1.6 | 10 | 0 |
| SS7 | X | 2.0 | 19 | 0 |
| SS8 | X | 2.0 | 12 | 0 |
| SS9 | X | 2.0 | 16 | 0 |
| SS10 | X | 1.7 | 8 | 0 |
| SS11 | X | 2.0 | 8 | 0 |
| SS12 | X | 2.0 | 9 | 0 |
| SS13 | X | 1.4 | 7 | 0 |
| SS14 | X | 1.7 | 43 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW7-2001
DATE COMPLETED: July 3, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | | 561.08 | | | | | |
| 30 | BEDROCK<br>DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules | 560.88 | | 1 | 100 | 33 | 100 |
| 32–48 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- fractures: 29.0-29.3, and 45.5 (fracture with open vug)<br>- Shaley parting: 29.55, 29.95, 30.75, 31.0, 32.35, 33.1, 33.5, 34.0, 34.4, 34.5, 38.7, 39.2, 39.9, 40.1, 40.2, 42.8, 43.8, 44.2, 47.3, and 47.9 ft BGS<br>- mechanical breaks: 29.7, 33.7, 36.6, 37.0, 37.6, 37.8, 39.6, 40.7, 42.0, 42.3, 42.4, 44.2, 45.2, 45.3, and 45.7 ft BGS | | HQ - COREHOLE | 2<br>3 | 94<br>100 | 75<br>88 | 100<br>100 |
| 48–55.5 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- Shaley parting: 50.8, 53.0, 53.55 ft BGS<br>- mechanical breaks: 48.9, 50.3, 51.3, 52.1, 53.9, and 54.5 ft BGS | 542.18 | | 4 | 100 | 96 | 80-90 |
| 55.5 | END OF BOREHOLE @ 55.5ft BGS | 534.78 | | | | | |

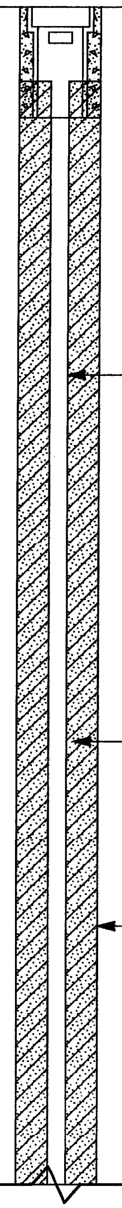
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | SAMPLE NUMBER | SAMPLE INTERVAL | SAMPLE REC (ft) | SAMPLE 'N' VALUE |
|---|---|---|---|---|---|---|---|
| | NORTHING: 1141543.65 GROUND SURFACE | 596.72 | | | | | |
| | EASTING: 1026223.72 TOP OF RISER | 592.98 | | | | | |
| 0–32 | OVERBURDEN (see overburden stratigraphy for well CD-2U) | |  | | | | |
| 32 | END OF OVERBURDEN HOLE @ 32.0ft BGS | | | | | | |



Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

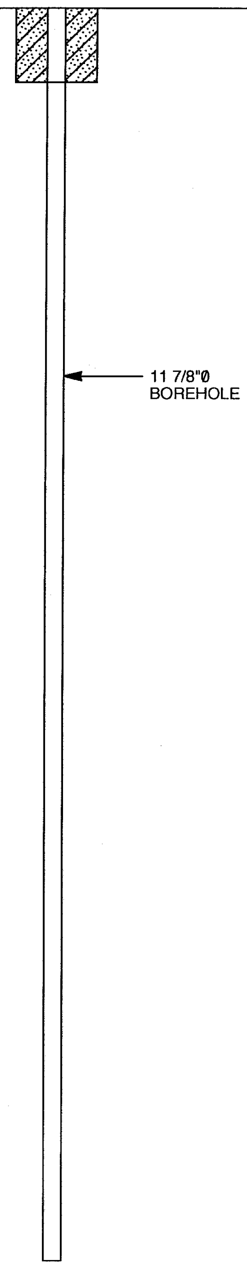
# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % |
|---|---|---|---|---|---|---|
| 32 | BEDROCK<br>(see bedrock stratigraphy for well CD-2U) | 564.72 | | | | |
| 34 | | | | | | |
| 36 | | | | | | |
| 38 | | | | | | |
| 40 | | | 11 7/8"Ø BOREHOLE | | | |
| 42 | | | | | | |
| 44 | | | | | | |
| 46 | | | | | | |
| 48 | | | | | | |
| 50 | | | | | | |
| 52 | | | | | | |
| 54 | | | | | | |
| 56 | | | | | | |
| 58 | | | | | | |
| 60 | | | | | | |
| 62 | | | | | | |
| 64 | | 532.72 | | | | |




NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | |
|---|---|---|---|---|---|---|---|
| | END OF BOREHOLE @ 65.0ft BGS | | | | | | |
| 66 | | | | | | | |
| 68 | | | | | | | |
| 70 | | | | | | | |
| 72 | | | | | | | |
| 74 | | | | | | | |
| 76 | | | | | | | |
| 78 | | | | | | | |
| 80 | | | | | | | |
| 82 | | | | | | | |
| 84 | | | | | | | |
| 86 | | | | | | | |
| 88 | | | | | | | |
| 90 | | | | | | | |
| 92 | | | | | | | |
| 94 | | | | | | | |
| 96 | | | | | | | |
| 98 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

# STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)



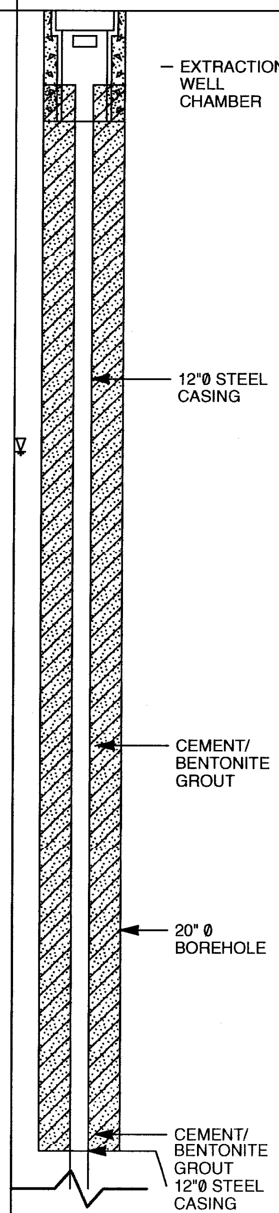
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8U
DATE COMPLETED: July 5, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

NORTHING: 1141704.94 — GROUND SURFACE: 593.65
EASTING: 1026603.26 — TOP OF RISER: 589.78

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| 0 | TOPSOIL | 593.45 |
| | CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense | |
| 4.5 | FILL, brick, cinders, black | 589.15 |
| 6.3 | CL-CLAY, trace medium grained sand, light-brown, dry, high plasticity, dense | 587.35 |
| 12 | - becomes moist | |
| 20 | - becomes wet | |
| 23 | - some rock fragments | |
| 30 | WEATHERED ROCK | 563.65 |
| 32 | END OF OVERBURDEN HOLE @ 32.0ft BGS | |

MONITOR INSTALLATION




SAMPLE

| NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|
| 1 | X | 0.8 | 17 | 0 |
| 2 | X | 1.0 | 28 | 0 |
| 3 | X | 0.4 | 17 | 0 |
| 4 | X | 1.8 | 15 | 0 |
| 5 | X | 1.5 | 13 | 0 |
| 6 | X | 1.1 | 11 | 0 |
| 7 | X | 2.0 | 15 | 0 |
| 8 | X | 2.0 | 12 | 0 |
| 9 | X | 2.0 | 12 | 0 |
| 10 | X | 2.0 | 5 | 0 |
| 11 | X | 2.0 | 4 | 0 |
| 12 | X | 2.0 | 6 | 0 |
| 13 | X | | WH | 0 |
| 14 | X | 2.0 | 14 | 0 |
| 15 | X | 0.9 | 9 | 0 |
| 16 | X | 0.7 | 9 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8U
DATE COMPLETED: July 5, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | FQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| | WEATHERED ROCK | 563.65 | CEMENT/ BENTONITE GROUT; 12"Ø STEEL CASING | | | | |
| 32 | BEDROCK<br>DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>-fractured @ 31.0 to 31.6 ft BGS<br>- gypsum and calcite filled vugs: 41.5, 42.1, 42.7, 44.0, 46.25<br>- shaley partings: 32.1, 34.0, 34.7, 37.4, 37.75, 39.5, 39.9, 40.4, 40.8, 43.25, 43.6, 45.45, 48.2, 48.8 ,49.9, 52.0, 53.8, and 54.5<br>- mechanical breaks: 33.7, 34.5, 35.6, 37.3, 38.6, 39.4, 40.6, 40.9, 45.7, 46.6, 50.5, 55.0 | 561.65 | | 1 | 60 | 70 | 100% |
| 34 | | | | 2 | 100 | 60 | 100% |
| 40 | | | 11 7/8"Ø BOREHOLE | 3 | 100 | 86 | ~100% |
| 42 | - fractures with small, well formed calcite crystals @ 42.8 ft BGS | | | | | | |
| 44 | - sphalerite filled vug | | | | | | |
| 50 | | | | 4 | 99 | 96 | 75 |
| 54 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abumdant nodules of distinctive pale, cream-colored chert | 539.25 | | | | | |
| 56 | | 538.15 | | | | | |
| 58 | END OF BOREHOLE @ 55.5ft BGS | | | | | | |

Depth scale: 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)

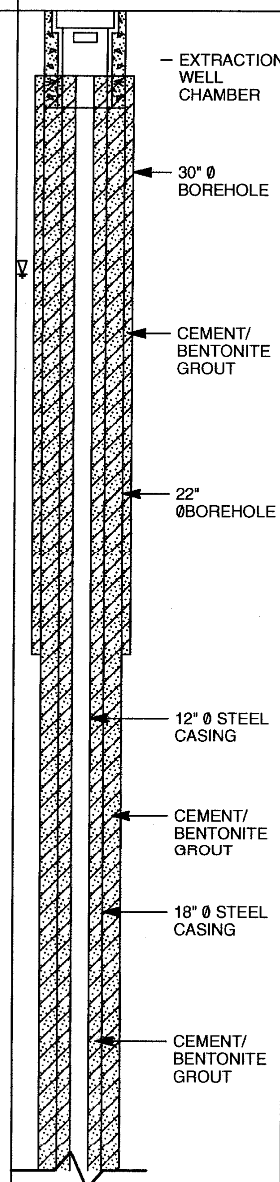


PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8M
DATE COMPLETED: June 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| | NORTHING: 1141602.21 / GROUND SURFACE | 597.01 |
| | EASTING: 1026685 / TOP OF RISER | 593.18 |
| | TOPSOIL | 596.41 |
| | CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense | |
| 6 | FILL, black ash, wood fragments, glass | 591.11 |
| 8 | ML-SILT, some clay, trace to little fine grained sand, light brown, moist, low plasticity | 588.81 |
| 14 | CL-CLAY, trace sand, light brown, dry, high plasticity, dense | 583.01 |
| 22 | - rock fragments | |
| 36 | END OF OVERBURDEN HOLE @ 36.0ft BGS | |

MONITOR INSTALLATION




SAMPLE

| NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|
| 1 | X | 1.2 | 18 | 0 |
| 2 | X | 0.9 | 21 | 0 |
| 3 | X | 1.5 | 39 | 0 |
| 4 | X | 1.3 | 22 | 0 |
| 5 | X | 0.9 | 17 | 0 |
| 6 | X | 1.1 | 26 | 0 |
| 7 | X | 1.1 | 37 | 0 |
| 8 | X | 1.2 | 13 | 0 |
| 9 | X | 2.0 | 21 | 0 |
| 10 | X | 1.2 | 16 | 0 |
| 11 | X | 0.5 | 19 | 0 |
| 12 | X | 1.0 | 18 | 0 |
| 13 | X | 2.0 | 16 | 0 |
| 14 | X | 2.0 | 9 | 0 |
| 15 | X | 1.9 | 7 | 0 |
| 16 | X | 2.0 | 4 | 0 |
| 17 | X | 2.0 | 11 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8M
DATE COMPLETED: June 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 36 | BEDROCK | 561.01 | | 1 | 100 | 0 | 90 |
| 38 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>-extremely weathered @ 36.0-37.5 ft BGS | 559.51 | CEMENT/ BENTONITE GROUT | 2 | 100 | 0 | 90 |
| 40 | | | 12" Ø STEEL CASING | | | | |
| 42 | not sampled due to low RQD (37.5-42.0 ft BGS) | 555.01 | 18" ØSTEEL CASING | | | | |
| 44–54 | DOLOSTONE (Goat Island Formation-Vinemount Member) (cont)<br>- shaly partings: 42.6, 42.85, 43.5, 44.8, 45.4, 45.90, 45.95, 46.2, 46.7, 48.25, 48.55, 48.60, 50.0, 50.2, and 50.4 ft BGS<br>- mechanical breaks: 43.0, 43.2, 44.0, 46.0, 45.7, 46.7 (with gypsum infilling), 47.6, 48.2, 50.4, 53.5, 54.2, 54.3, 54.5 ft BGS<br>- gypsum filled vugs: 47.9, 49.3, 49.6, and 52.2-52.3 ft BGS<br>- possible fracture with gypsum infilling: 46.8, 48.75, 48.95, 49.1, 49.75, 50.8, and 52.6 ft BGS | | | 3 | 100 | 86 | 90 |
| | | | | 4 | 100 | 75 | 50 |
| 55–72 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abumdant nodules of distinctive pale, cream-colored chert<br>- shaly partings: 55.8, 57.8, 60.6, 77.8, 78.7, 80.1, 84.3, and 88.2 ft BGS<br>- break along stylolite<br>- mechanical breaks: 55.2, 55.6 (with trace gypsum), 58.8, 60.3, 64.0, 64.6, 64.9, 69.2, 69.7, 70.1, 71.1, 72.3, 76.3, 78.4, 79.1, 80.6, 80.9, 81.1, 81.3, 84.5, 82.0, 82.1, 82.3, 82.6, 82.9, 83.6, 84.1, 85.1, 85.8, 86.6, 87.1 , and 89.2 ft BGS<br>- fractures: 57.5, 85.0 (with trace gypsum), 60.1, 76.8 (with gypsum), and 77.9 (with gypsum)<br>- abundance of stylolites @ 70-75 ft BGS | 542.21 | 11 7/8" Ø BOREHOLE | 5 | 100 | 85 | 25 |
| | | | | 6 | 97 | 97 | 25 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8M
DATE COMPLETED: June 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 76 | - fractured and weathered @ 75.5-76.0 ft BGS | 521.71 | 11 7/8" Ø BOREHOLE | | | | |
| 76–86 | DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous<br>- weathered fracture/parting @ 77.3-77.4 ft BGS | | | 7 | 98 | 71 | 25 |
| 86 | END OF BOREHOLE @ 86.0ft BGS | | HQ COREHOLE<br>CEMENT/ BENTONITE GROUT | 8 | 100 | 86 | 50 |
| 90 | DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite<br>-abundance of crinoids at Goat Island/Gasport contact | 507.51<br>507.21 | | | | | |

Depth scale: 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

# STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-9U
DATE COMPLETED: July 13, 2001
DRILLING METHOD: HSA
FIELD PERSONNEL: J. Raby

NORTHING: 1141789.33 — GROUND SURFACE 591.79
EASTING: 1026842.54 — TOP OF RISER 588.00

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION |
|---|---|---|---|
| | TOPSOIL | | |
| | CL-CLAY, trace medium grained sand, light brown, dry, high plasticity | 591.19 | EXTRACTION WELL CHAMBER |
| 10 | | | 12"Ø STEEL CASING |
| 12 | - moist | | |
| 20 | | | CEMENT/ BENTONITE GROUT |
| 24 | - wet | | 16" Ø BOREHOLE |
| 26 | - rock fragments | | |
| 29.5 | auger refusal @ 29.5 ft BGS | 562.59 | |
| | BEDROCK | 562.29 | |
| | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces | | |
| | END OF OVERBURDEN HOLE @ 31.5ft BGS | | |

SAMPLE

| NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|
| 1 | X | 1.3 | 7 | 0 |
| 2 | X | 0.7 | 19 | 0 |
| 3 | X | 1.6 | 11 | 0 |
| 4 | X | 0.8 | 13 | 0 |
| 5 | X | 1.0 | 10 | 0 |
| 6 | X | 1.6 | 10 | 0 |
| 7 | X | 2.0 | 19 | 0 |
| 8 | X | 2.0 | 12 | 0 |
| 9 | X | 2.0 | 16 | 0 |
| 10 | X | 1.7 | 8 | 0 |
| 11 | X | 2.0 | 8 | 0 |
| 12 | X | 2.0 | 9 | 0 |
| 13 | X | 1.4 | 7 | 0 |
| 14 | X | 1.7 | 43 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊽

# STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-9U
DATE COMPLETED: July 13, 2001
DRILLING METHOD: HSA
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL | MONITOR INSTALLATION | RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|---|---|---|---|
| 32 | | | | 1 | 100 | 70 | 100 |
| 34 | - shaly partings: 29.9, 31.3, 31.9, 32.7, 36.0, 37.75, 39.0, 40.4, 41.4, 41.7, 45.0, 46.6, 48.2, 49.8, 50.4, and 52.0 ft BGS | | | 2 | 100 | 100 | <100 |
| 36 | - fractures: 30.1-30.7 and 44.6 ft BGS (vug with a hollow cavity through the core) | | | | | | |
| 38 | - mechanical breaks: 34.0, 35.6, 36.7, 38.1, 38.75, 39.1, 41.0, 42.7, 43.1, 44.1, 44.2, 47.0, and 50.1 ft BGS | | | | | | |
| 40 | | | 11 7/8"Ø BOREHOLE | 3 | 100 | 76 | <100 |
| 42 | | | | | | | |
| 44 | | | | | | | |
| 46 | | | | | | | |
| 48 | - large vug with calcite on walls and gypsum in center @ 48 ft BGS | | | | | | |
| 50 | | | CEMENT/ BENTONITE GROUT | 4 | 100 | 96 | <100 |
| 52 | - stylolite parting, very jagged @ 51.3 ft BGS | | HQ COREHOLE | | | | |
| 53 | DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert<br>- shaly partings: 53.0 ft BGS | 539.19 | | | | | |
| 55 | END OF BOREHOLE @ 55.0ft BGS | 536.79 | | | | | |
| 56 | | | | | | | |
| 58 | | | | | | | |
| 60 | | | | | | | |
| 62 | | | | | | | |
| 64 | | | | | | | |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ▽

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (OVERBURDEN)



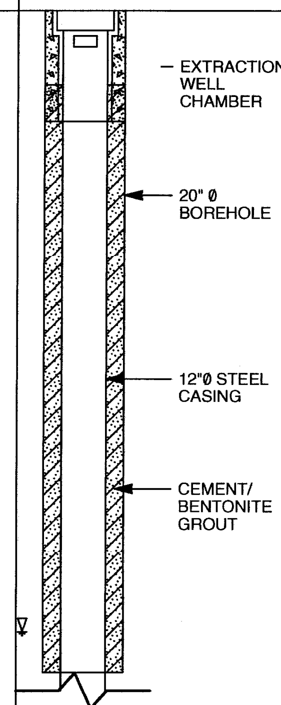
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-10U
DATE COMPLETED: July 2, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

NORTHING: 1141743.95 GROUND SURFACE 597.64
EASTING: 1027386.41 TOP OF RISER 594.01

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| 0 | TOPSOIL | 597.64 |
| | CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense | |
| | FILL, black, cinders, some glass | 592.84 |
| | CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense | 589.84 |
| | - wet | |
| | - some gravel, fractured rock | |
| 18.5 | END OF OVERBURDEN HOLE @ 18.5ft BGS | |

MONITOR INSTALLATION




SAMPLE

| NUMBER | INTERVAL | REC (ft) | 'N' VALUE | PID |
|---|---|---|---|---|
| 1 | X | 1.1 | 14 | 0 |
| 2 | X | 1.3 | 17 | 0 |
| 3 | X | 1.3 | 16 | 0 |
| 4 | X | 1.7 | 22 | 0 |
| 5 | X | 1.5 | 6 | 0 |
| 6 | X | 1.9 | 7 | 0 |
| 7 | X | 0.0 | 16 | NA |
| 8 | X | 1.6 | 7 | 0 |
| 9 | X | 0.3 | 21 | 0 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ▽

# STRATIGRAPHIC AND INSTRUMENTATION LOG
## (BEDROCK)



PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-10U
DATE COMPLETED: July 2, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

| DEPTH ft BGS | STRATIGRAPHIC DESCRIPTION & REMARKS | ELEV. ft AMSL |
|---|---|---|
| | - wet | |
| 18 | - some gravel, fractured rock | |
| | BEDROCK<br>DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules<br>- vugs @ 22.5 ft BGS<br>- fractures: 19.0-19.5, 19.75 (with iron staining), 20.5-20.8, 21.2-21.3, 23.65 (with gypsum and iron staining), 26.0-26.8, 37.85 (with gypsum and calcite), 34.8, and 35.6 ft BGS<br>- mechanical breaks: 18.7, 22.0, 25.55, 26.0, 31.5, 33.4, 34.5, and 35.4 ft BGS<br>- shaly partings: 32.1 ft BGS | 579.34 |
| 36 | DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces<br>- shaly partings: 36.3, 36.5, 36.8, 36.85, and 37.2 ft BGS<br>- mechanical breaks: 38.6, and 39.0 ft BGS | 561.94 |
| 40.5 | END OF BOREHOLE @ 40.5ft BGS | 557.34 |

MONITOR INSTALLATION: 11 7/8"Ø BOREHOLE; CEMENT/ BENTONITE GROUT; HQ COREHOLE

| RUN NUMBER | CORE RECOVERY % | RQD % | Water Return (%) |
|---|---|---|---|
| 1 | 88 | 60 | 100 |
| 2 | 95 | 72 | 100 |
| 3 | 100 | 100 | 100 |
| 4 | 99 | 77 | 100 |

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

APPENDIX E.1

MAPPING OF VERTICAL FRACTURES NEAR THE
HYDE PARK LANDFILL SITE

# Hyde Park Landfill Site
# Niagara Falls, New York

# Mapping of Vertical Fractures Near the Hyde Park Landfill Site

*Prepared For:*

**Miller Springs Remediation Management Inc. and**
**Glenn Springs Holdings, Inc.**

*Prepared By:*

**S.S. PAPADOPULOS & ASSOCIATES, INC.**
**Environmental & Water Resource Consultants**

**February 12, 2001**

**207 King Street South, Waterloo, Ontario N2J 1R1 (519) 579-2100**

# Table of Contents

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# List of Figures

# Section 1
# Introduction

On Thursday, September 6, Rick Passmore (GSHI), Jon Williams (CRA) and Chris Neville (SSP&A) examined the face of the Niagara River gorge close to the Hyde Park Landfill Site. This examination was intended to be a quick survey to identify major water-bearing vertical fractures, and thereby obtain additional basic data that might be useful in understanding the structure of the zones of different hydraulic response at the Site. If these fractures can be correlated to features at the Site, they may be incorporated in the revised characterization and groundwater model of the Site.

**Location of mapping**

The fracture mapping was conducted along the access road to the New York Power Authority (NYPA) Niagara Project. This is the same rock cut that was examined for the *Lockport Formation Investigation* in 1983, reported in CRA (1983).

The location of the mapping is shown on Figure 1. For this mapping, we examined the full length of the NYPA access road between the Robert Moses Parkway and the powerhouse. To obtain a better impression of fracture orientations, we examined vertical fractures along both faces of the rock cut, where possible. The western face of the rock cut drops off about 200 ft north of the Parkway, and along this side we examined the gorge face along a path that follows the river. Our walk along the path terminated back at the Limestone Cave.

**Geologic setting**

The cut for the NYPA access road exposes the rocks of the Lockport Dolomite, the Decew Dolomite and Rochester Shale of the Clinton Group, and units below the Rochester Shale. Although we observed a horizontal groundwater seep near the contact between the Decew Dolomite and the Rochester (indicated by wetness on the rock face and by a horizontal fringe of vegetation), we did not observe any vertical fractures that extended into the Rochester Shale.

Several stratigraphic nomenclatures have been adopted for the rocks of the Niagara region. These nomenclatures are summarized on Figure 2. In all previous investigations at the Site, the nomenclature of Zenger has been adopted (Zenger, 1962; Zenger, 1965; Zenger, 1966). The United States Geological Survey suggests that the most appropriate stratigraphic designations are described in Brett and others (1995).

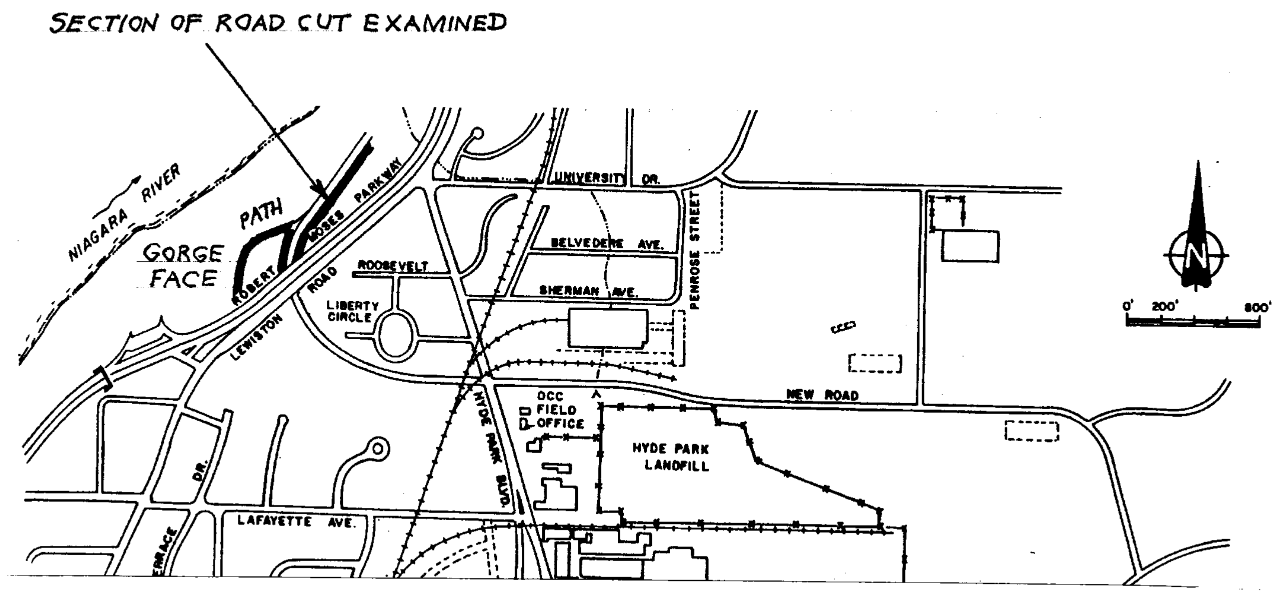


Figure 1. Location of vertical fracture mapping from exposed bedrock

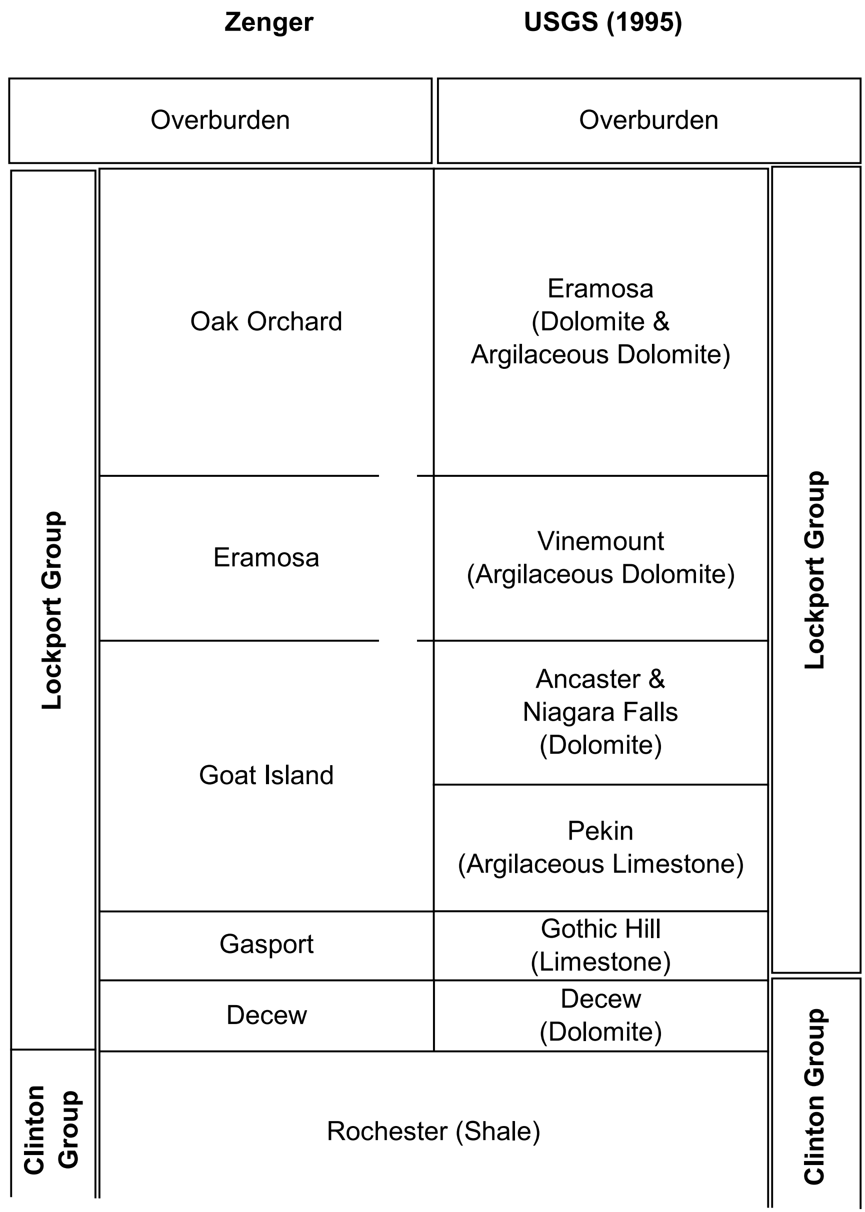


Figure 2. Summary of Lockport Group nomenclature at the Hyde Park Site

# Section 2
# Vertical Fracture Mapping

In this limited investigation, we attempted to identify accessible fractures that appeared to provide a significant vertical conduit to fluid flow near the Site. Our criteria included fracture length, visual evidence of flowing water, presence of vegetation, and where possible, continuity across both faces of the rock cut.

Table 1 lists the locations and orientations of the identified vertical fractures. The locations of the fractures were estimated in the field using a hand-held GPS unit. Field coordinates were converted from the reported latitude and longitude, based on the NAD 83 datum. Figure 3 shows the locations of the fractures. Our experience with this GPS unit at the Site suggests that its reported locations are correct within approximately ±150 ft. Where possible, the strike orientations of the fractures were also measured with a hand compass. The corrected strike orientations of the fractures are shown on Figure 4.

**Table 1. Fracture locations and orientations**

| Vertical fracture | Measurement Point | Latitude | Longitude | Strike angle, from true North |
|---|---|---|---|---|
| 1 | VF001 | 43.13445 | -79.04459 | 272 |
| | VF002 | 43.13449 | -79.04439 | 106 |
| 2 | VF003 | 43.13449 | -79.04429 | nm |
| | VF004 | 43.13467 | -79.04451 | nm |
| 3 | VF005 | 43.13475 | -79.04443 | nm |
| | VF006 | 43.13481 | -79.04425 | nm |
| 4 | VF007 | 43.13519 | -79.04405 | nm |
| 5 | VF008 | 43.13499 | -79.04446 | 220 |
| 6 | VF009 | 43.13483 | -79.04485 | 230 |
| 7 | VF010 | 43.13462 | -79.04495 | 272 |
| 8 | VF011 | 43.13454 | -79.04501 | 280 |
| 9 | VF012 | 43.13440 | -79.04510 | nm |
| 10 | VF013 | 43.13380 | -79.04527 | 268 |

Note: “nm” indicates that a bearing was not estimated.

**Observations on the individual fractures**

Ten vertical fractures were identified along our traverse of the NYPA access road and the path along the Niagara River gorge. Notes on the individual fractures are presented below.

1. Vertical Fracture 1 is located along the NYPA access road, below the Robert Moses Parkway. The fracture can be identified across both sides of the road. Measuring point VF001 is located on the western side of the road (that is, the side closest to the Niagara River), and VF002 is located on the eastern side of the road. The fracture extends from the top of rock (Eramosa) into the Gasport. The fracture is nearly vertical in the Eramosa and Goat Island; it angles off slightly after entering the Gasport.

2. Vertical Fracture 2 is located further down the NYPA access road. The fracture can be identified across both sides of the road. Measuring point VF003 is located on the eastern side of the road, and VF004 is located on the western side of the road. The fracture extends from the top of the Goat Island into the Gasport. The fracture was not accessible for measuring its orientation with a compass.

3. Vertical Fracture 3 is the third fracture encountered proceeding down the NYPA access road. The fracture can be identified across both sides of the road, and its position is determined by measuring points VF005 and VF006. The fracture extends from the top of the Goat Island through the Decew. The fracture is close to vertical – I estimated its inclination to be about 10° from the vertical. The fracture was not accessible for measuring its orientation with a compass.

4. Vertical Fracture 4 is the fourth fracture encountered proceeding down the NYPA access road. At this point, there is no longer a rock cut along the western side of the road. Its position is given by point VF007. The fracture extends from the top of rock (Eramosa) through the Decew to the top of the Rochester Fm. The fracture was not accessible for measuring its orientation with a compass.

5. Vertical Fracture 5 is the first fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF008. The fracture can be identified in the Gasport.

6. Vertical Fracture 6 is the second fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF009. It was possible to identify the fracture in the Gasport and Decew.

7. Vertical Fracture 7 is the third fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF010. It was possible to identify the fracture in the Gasport and Goat Island.

8. Vertical Fracture 8 is the fourth fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF011. It was possible to identify the fracture in the Gasport and Goat Island.

9. Vertical Fracture 9 is the fifth fracture encountered proceeding southwards along the path running along the gorge face. It is located in the crown on the Limestone Cave, and its position is given by point VF012. The fracture extended the full length of the cave. It was possible to identify the fracture in the Gasport and Goat Island.

10. Vertical Fracture 10 is the located along the stairs leading up from the Limestone Cave. Its position is given by point VF013. The fracture extends almost parallel to the face of the gorge. The fracture extends from the top of rock (at this location the Eramosa) to the Goat Island. Rick Passmore was able to determine its location at the sidewalk of the Robert Moses Parkway.

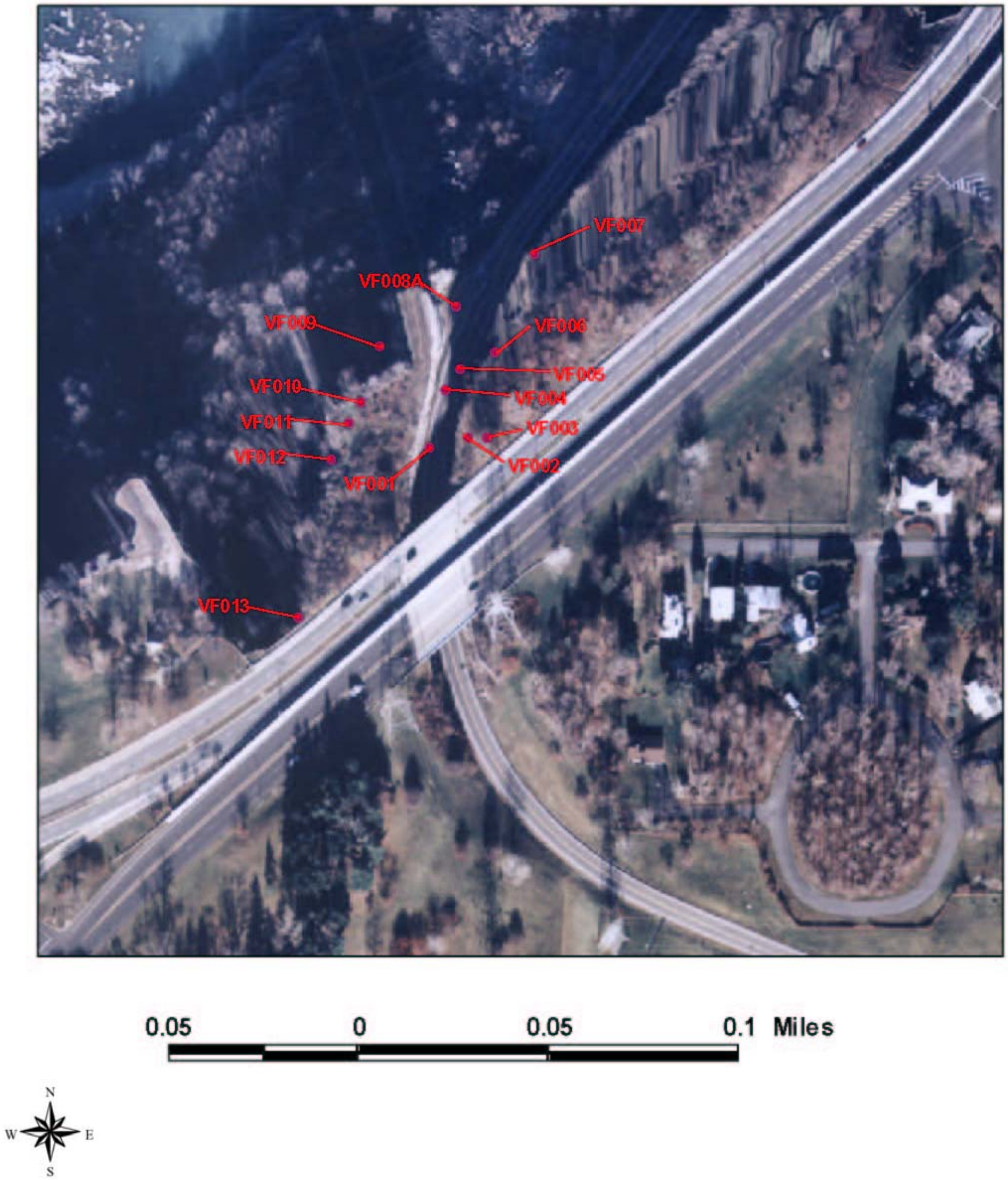


Figure 3. Locations of vertical fractures

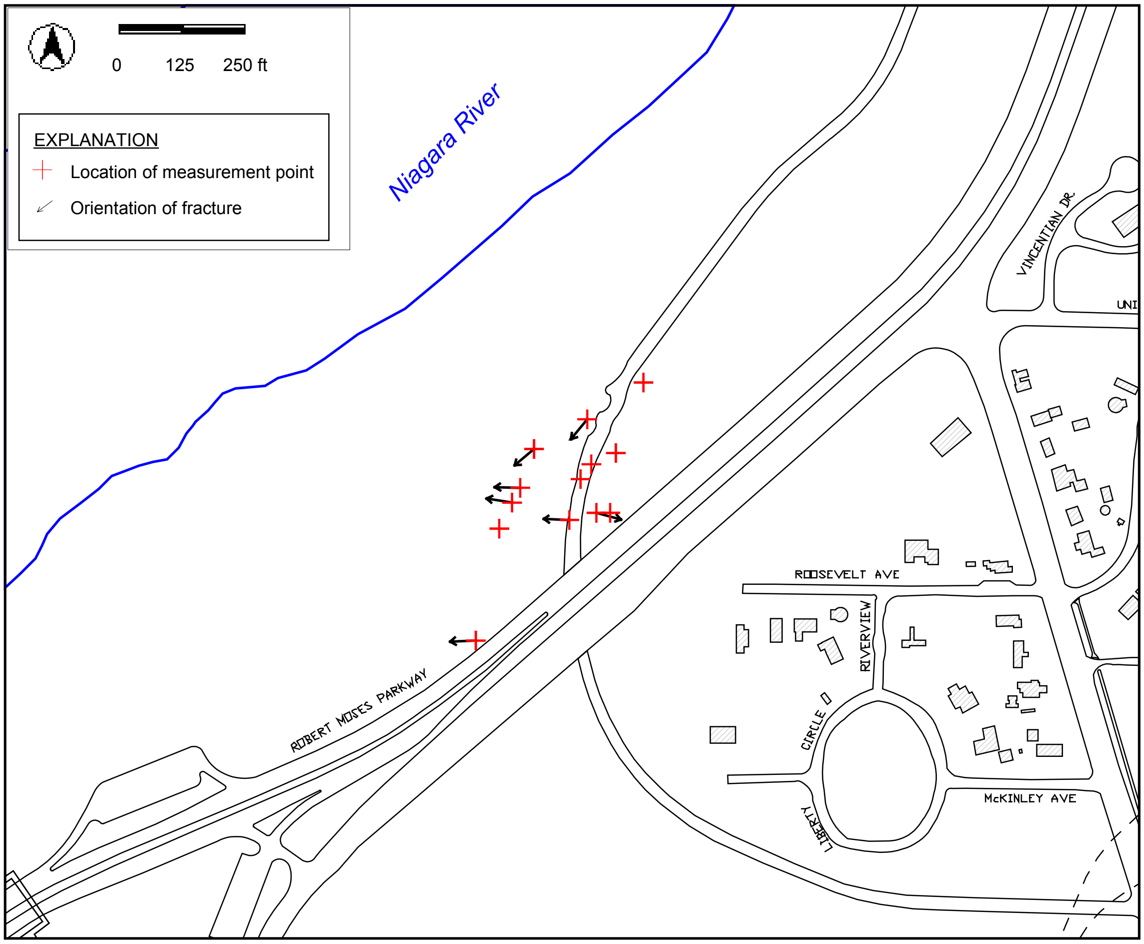


Figure 4. Locations and orientations of vertical fractures

# Section 3
# Interpretations

The investigation was intended as a quick survey of major water-bearing features close to the Site, rather than as a comprehensive study. A comprehensive study would consist of a survey of all outcrops in the vicinity of the Site, as well as lineament studies from topographic maps and air photos. Since only two outcrops at the gorge were examined in this study, there is not sufficient data to support definitive determination of fracture patterns at the gorge (or by extrapolation, at the Site). We can draw only some preliminary inferences from the mapping.

The mapping data suggest that there are two fracture sets in the vicinity of the gorge. The first set of fractures runs almost east-west, the strike of the second set is about 55° from north. The spacing between fractures in each set is between 50 and 100 ft. We have used the limited data to sketch "mean" vertical fracture orientations. The hypothesized distribution of fractures is shown on Figure 5.

We recognize that the fracture patterns shown on Figure 5 are speculative, being based only on the data available from a deliberately limited field examination. However, our interpretations are consistent with other data from regional geologic interpretations. Figure 6 shows the joint orientations identified by Williams and others (1985) in the Niagara region. Williams and others (1985) identified a dominant East-West fracture set with an orientation consistent with our mapping. Williams and others identified another fracture set with an orientation that is similar to the second set we show on Figure 6; however, this is not a dominant set.

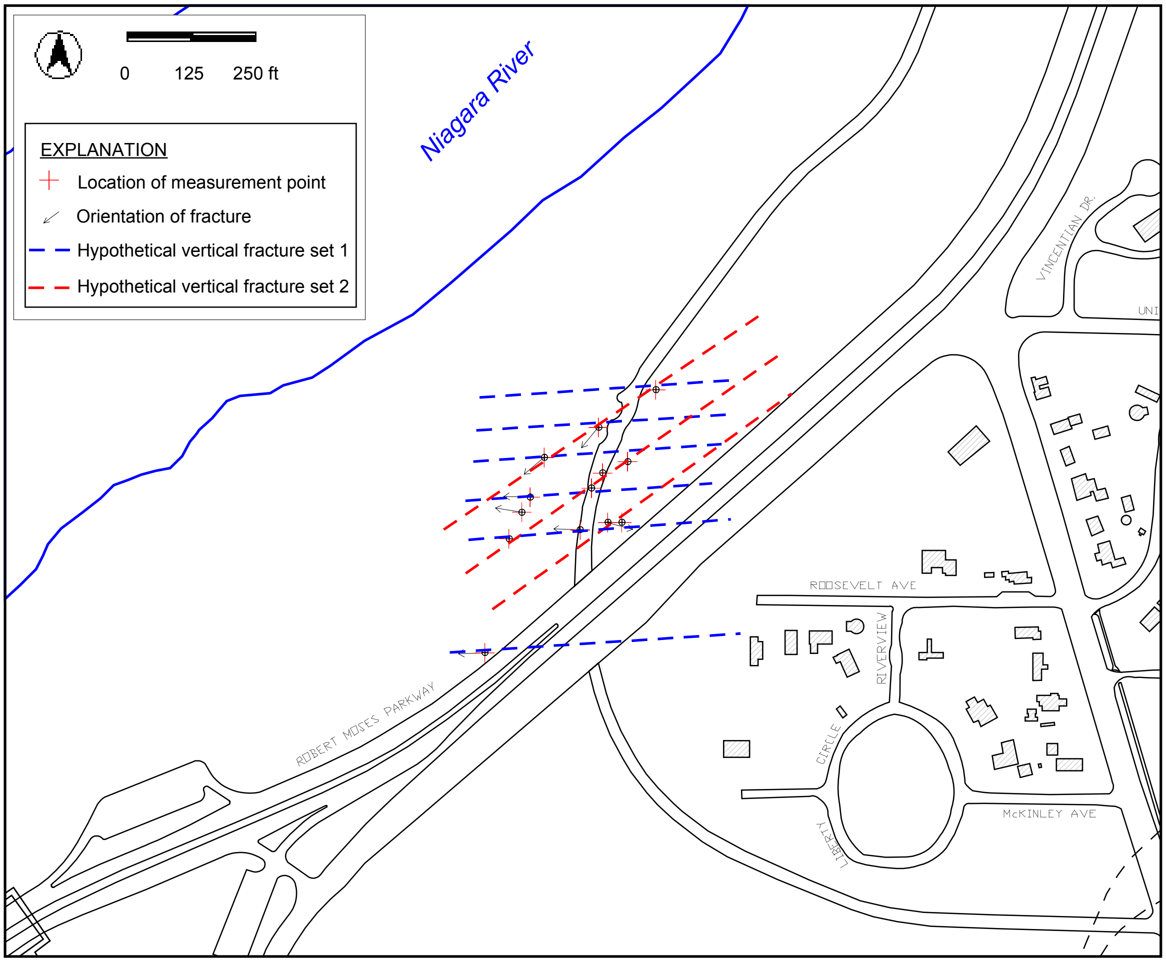


Figure 5. Hypothesized vertical fractures

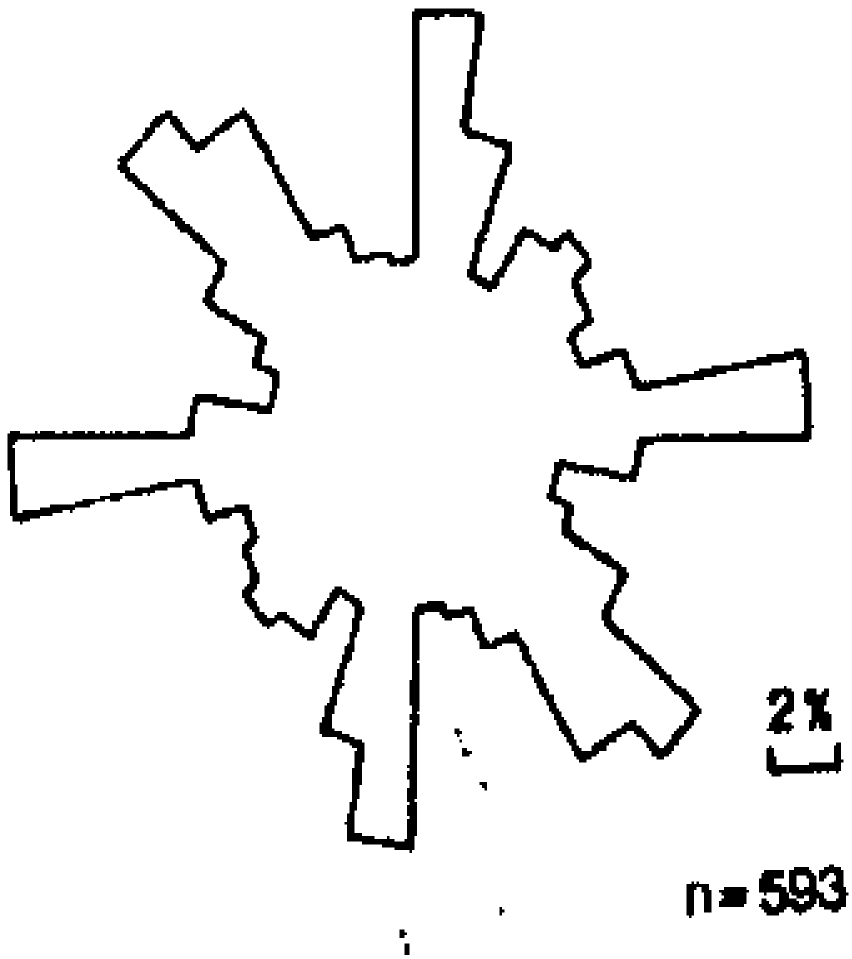


Figure 6. Joint orientations determined from Silurian and Devonian rocks in the Niagara Peninsula (after Williams and others, 1985)

# Section 4
# References

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# APPENDIX E.2

# LOCKPORT FORMATION INVESTIGATION (CRA, 1983)

# APPENDIX J

# LOCKPORT FORMATION INVESTIGATION

APPENDIX J

## LOCKPORT FORMATION INVESTIGATION

On August 25, 1983 the Lockport Formation was examined and the fractures were recorded with respect to frequency, aperature, length and orientation. This fracture mapping was conducted at the rock cut along New Road above the PASNY hydroelectric station in the Niagara Gorge shown on Figure 1. The general stratigraphy for the Lockport Formation is presented in Figure 2.

A representative area on the rock face was outlined for each Member of the Lockport Formation as the Members were encountered along New Road. The contacts between the Oak Orchard, Eramosa and Goat Island Members were inferred during the fracture mapping. However, the results of the mapping for these 3 Members were compiled as the precise contacts were too ambiguous to plot the data separately.

Many of the natural fractures throughout the Formation showed a distinct dark brown or gray staining along the fracture face. However, some of the fractures that appeared to be natural by their orientation and magnitude, did not exhibit any evidence of staining.

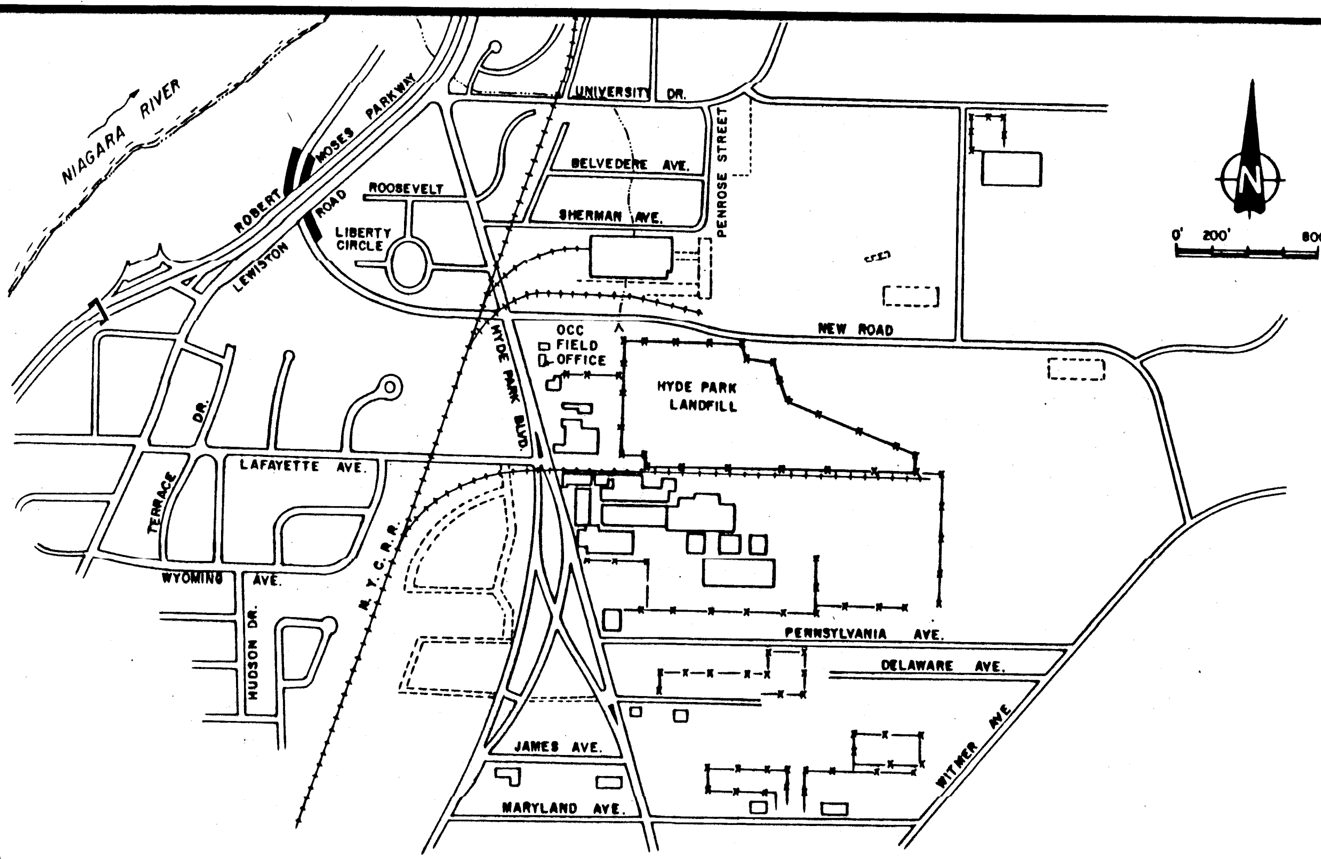



figure I

FRACTURE MAPPING FROM EXPOSED BEDROCK – LOCKPORT FORMATION HYDE PARK REMEDIAL PROGRAM

*Occidental Chemical Corporation*

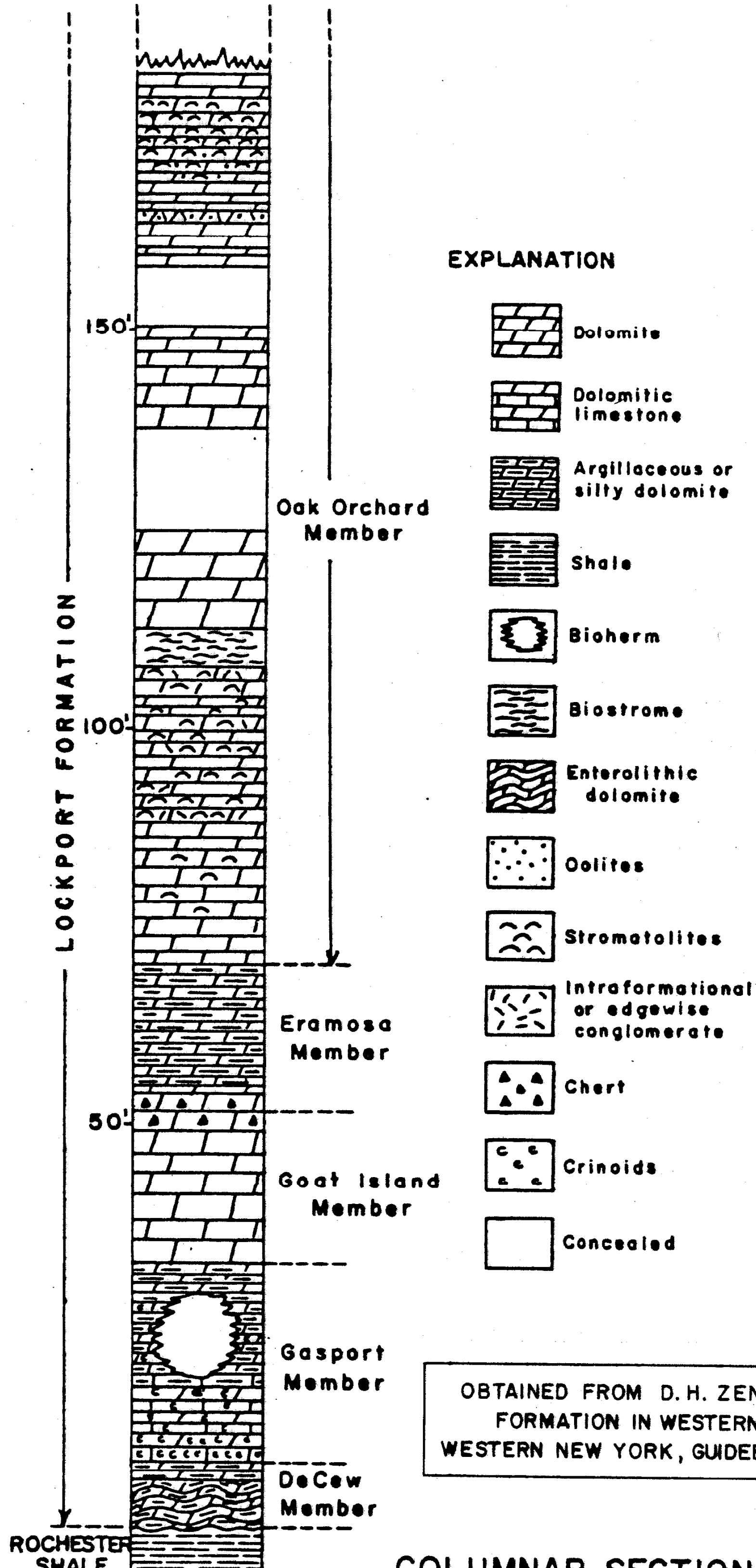
LEGEND

SECTION OF ROAD CUT EXAMINED

CRA

CRA 0008244

1069-24/11/83




CRA 0008245

OBTAINED FROM D. H. ZENGER, 1966, 'THE LOCKPORT FORMATION IN WESTERN NEW YORK' IN GEOLOGY OF WESTERN NEW YORK, GUIDEBOOK, E. J. BUEHLER ed. 115 p.

figure 2

COLUMNAR SECTION OF THE LOCKPORT FORMATION IN THE NIAGARA FALLS AREA
HYDE PARK REMEDIAL PROGRAM
*Occidental Chemical Corporation*

CRA

1069-24/11/83

Therefore, all of the fractures observed were recorded even though several fractures may have been the result of blasting during the excavation of the road cut. The natural fractures or joint sets are expected to represent a family of fractures along a distinct orientation, if the joints are well developed. The induced fractures are expected to represent a more random statistical variation. The fracture orientations were plotted with respect to true north.

The fractures were observed to be significantly more frequent in the upper part of the Formation, particularly the Oak Orchard, Eramosa and Goat Island Members. In general, the fractures were vertical to near vertical.

The frequency and orientation of the fractures are shown in Figure 3 for the upper 3 Members, in Figure 4 for the Gasport and Decew Members and in Figure 5 for all of the Lockport Formation. Generally, the fracture aperatures were less than 1/32" wide with irregular fracture surfaces. Fracture lengths were typically 0.5 to 2 feet long.

Figure 4 illustrates the low frequency of fractures in the lower portion of the Lockport Formation. The dimensions of the fractures in this section

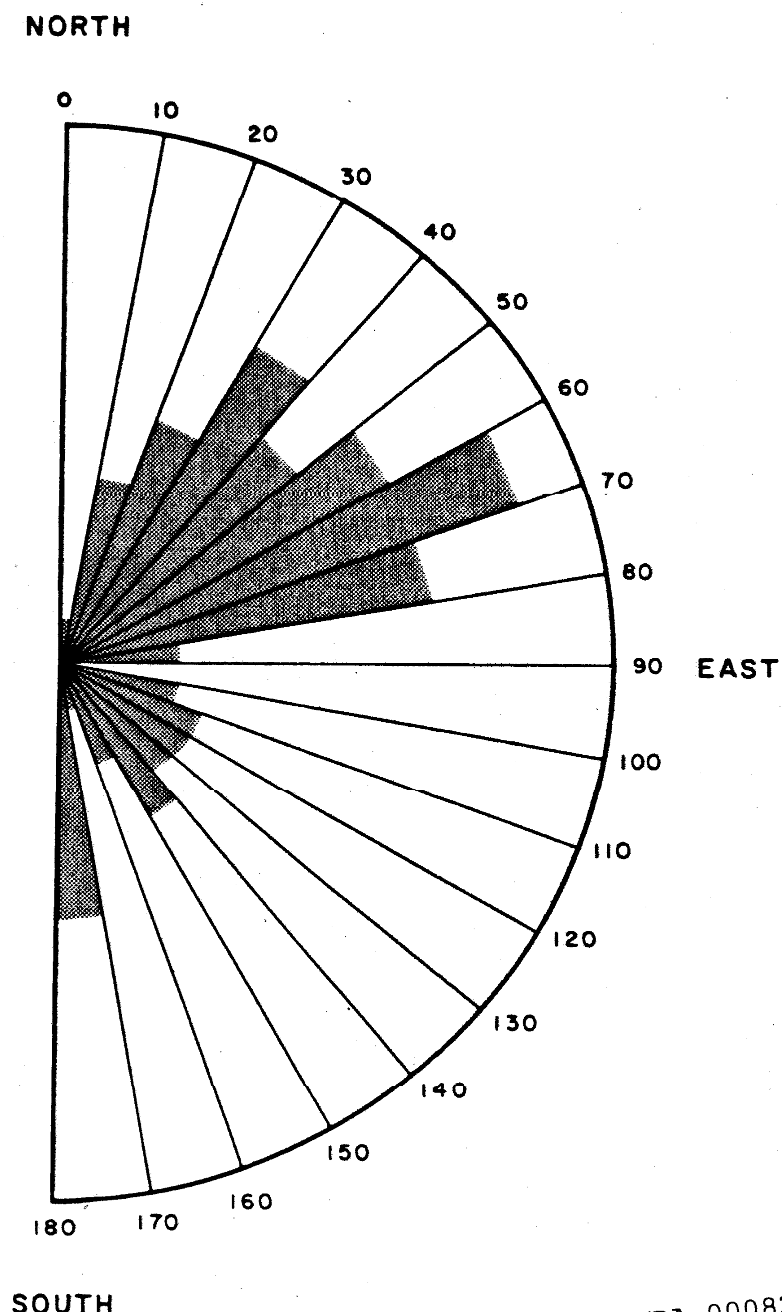



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figure 3

STRIKE OF JOINT SETS FOR OAK ORCHARD, ERAMOSA AND GOAT ISLAND MEMBERS FROM ROAD CUT IN NEW ROAD ABOVE P.A.S.N.Y. HYDROELECTRIC STATION

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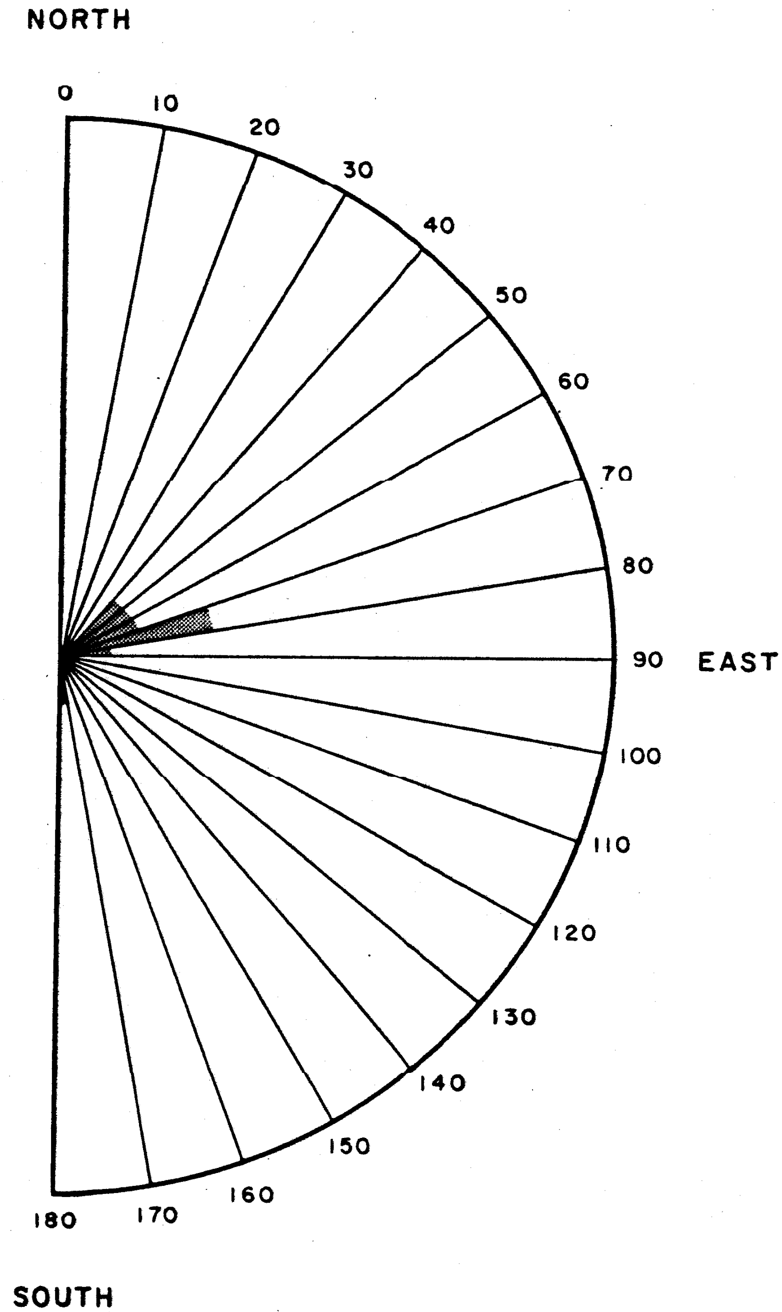


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figure 4

STRIKE OF JOINTS IN GASPORT AND DECEW MEMBERS FROM ROAD CUT IN NEW ROAD ABOVE P.A.S.N.Y. HYDROELECTRIC STATION

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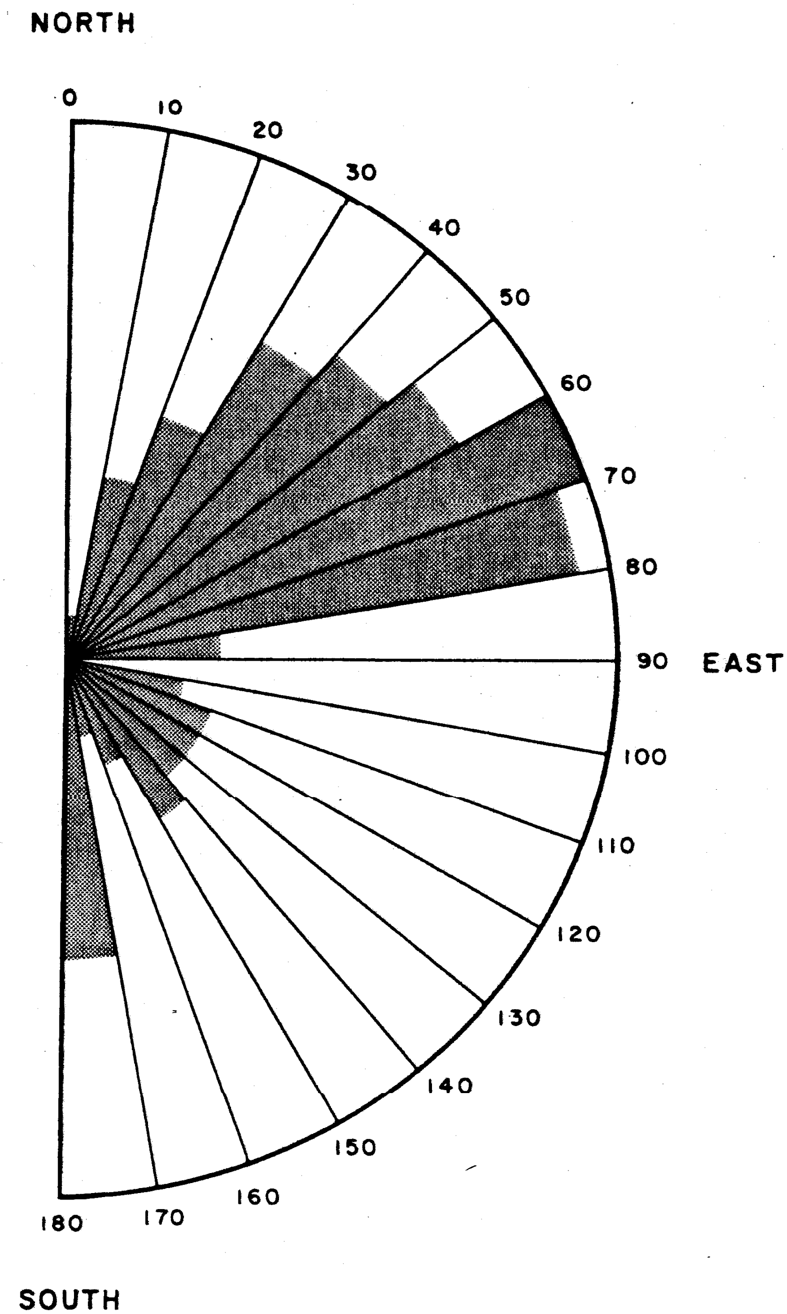


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figure 5

STRIKE OF JOINTS IN LOCKPORT FORMATION
FROM ROAD CUT IN NEW ROAD ABOVE
P.A.S.N.Y. HYDROELECTRIC STATION

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were much larger than those in the rest of the Formation. Five large fractures, with aperatures of <1/32" to 4" and extending from 15 to over 40 feet, were observed in the Gasport and Decew Members. The trend of these fractures is N68°E to N86°E.

Figure 5 shows a broad variation in the attitude of the main joint set with an average strike of N50°E. The secondary joint set trends N130°E. There is a tertiary joint set trending N.S.

# APPENDIX F

# PETROPHYSICAL TESTING RESULTS

# Hyde Park Landfill Site
# Niagara Falls, New York

# Report on the Results of Petrophysical Tests Conducted on Samples from the Hyde Park Landfill Site

*Prepared For:*

**Miller Springs Remediation Management Inc. and**
**Glenn Springs Holdings, Inc.**

*Prepared By:*


**S.S. PAPADOPULOS & ASSOCIATES, INC.**
**Environmental & Water Resource Consultants**


**February 12, 2002**


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# Table of Contents

**Page**

# Section 1
# Introduction

Core Laboratories in Houston, Texas conducted petrophysical tests on samples of bedrock drill core from the Site. The core testing was conducted to determine fundamental properties of the intact rock materials. The physical properties that were determined included:

- Bulk density;
- Porosity;
- Grain density;
- Permeability; and
- Acoustic velocity.

This memorandum documents the test methods, summarizes the results of the tests, and discusses the reliability of the results and their physical significance.

The petrophysical testing was undertaken at the suggestion and direction of Mr. Michael Metz, Chief Petrophysical Engineer, Occidental Oil and Gas Corporation (OOGC). The documentation of the petrophysical testing incorporates the technical contributions of several individuals. Staff of Core Laboratories provided details on the test methods (Art Curby, Di Jiao, and John Dacy), and Jon J. Williams, CRA, provided details on the rock sampling. Mr. Metz and members of the Hyde Park Technical Team have reviewed the final report.

# Section 2
# Core Samples

Core samples were obtained from the drilling of well cluster J5, installed in August 2001. The locations of the samples relative to the geologic contacts are shown on Figure 1. This figure incorporates the stratigraphic nomenclature of Brett et al. (1995), and the stratigraphic contacts developed for the revised Site characterization. The locations of the core samples were chosen to provide samples from each bedrock type at the Site, based on the previous stratigraphic model developed for the Site. According to the previous nomenclature for the Site, the sample locations correspond to:

- Samples 1 and 2: Oak Orchard Formation;
- Samples 3 and 4: Eramosa Formation;
- Samples 5 and 6: Goat Island Formation;
- Samples 7 and 8: Gasport Formation; and
- Samples 9 and 10: Decew Formation.

It was not possible to obtain an intact sample from the Rochester Shale.

The core samples were prepared following the instructions of Michael Metz (OOGC) and shipped to Core Laboratories. The samples consisted of intact rock, typically 0.5 feet long with a diameter of 3 inches.

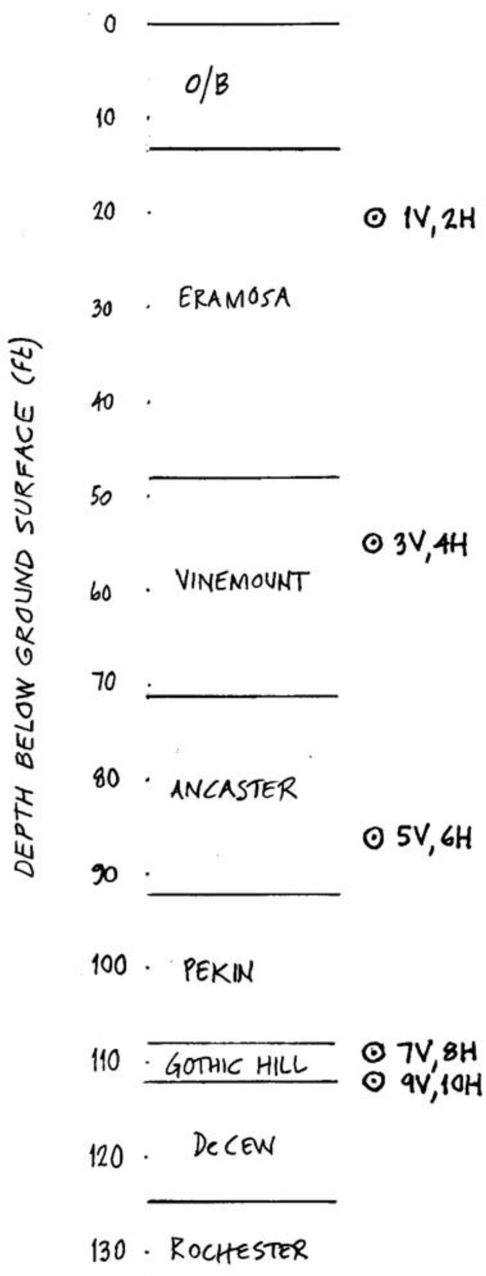


**Figure 1. Locations of J5 core samples**

# Section 2
# Results of the Petrophysical Tests

## 2.1 Summary of results

The results of the petrophysical tests are assembled on Table F.1. The upper portion of the table provides the results from the porosity, permeability, and grain density determinations. The quantities b(He), Beta, and Alpha are intermediate quantities for the determination of permeability. A total of 10 samples were tested from five locations; two samples from each sample were tested to obtain independent estimates of horizontal and vertical permeability.

The lower portion of Table F.1 provides the results from the bulk density determinations, and the results of the acoustic tests. The acoustic tests provided estimates of velocities, moduli and Poisson's ratios.

## 2.2 Bulk density

Bulk densities of five core samples were determined by estimating the volume of the samples, and measuring their mass under room temperature and pressure. The sample volumes were estimated from the average of five measurements of the diameter of each cylindrical sample. The bulk densities are summarized below.

| Sample | Bulk density ($g/cm^3$) |
|---|---|
| 1V | 2.73 |
| 3V | 2.73 |
| 5V | 2.76 |
| 7V | 2.71 |
| 9V | 2.71 |

The bulk density values are highly consistent, suggesting that the rocks of the Lockport Group have similar material properties.

## 2.3 Porosity and grain density

The porosity and grain density of ten core samples were determined at ambient conditions, using the Boyle's Law double-cell technique (American Petroleum Institute RP-40). With this technique, the porosity is calculated from:

**Porosity = Pore Volume / (Pore Volume + Grain Volume) X 100**

Grain volumes were determined using the double-cell technique with helium as the expansion gas (API RP-40, Sec 5.3.2.1). Pore volumes were determined with the double-cell technique at a net confining stress (NCS) of 800 psig, in a hydrostatic core holder (API RP-40, Sec 5.3.2.2). The final porosity and grain density determinations are summarized below.

| Sample | Porosity (%) | Grain density ($g/cm^3$) |
|---|---|---|
| 1V | 4.82 | 2.841 |
| 2H | 5.45 | 2.840 |
| 3V | 4.30 | 2.830 |
| 4H | 4.31 | 2.828 |
| 5V | 3.91 | 2.849 |
| 6H | 3.53 | 2.844 |
| 7V | 5.39 | 2.846 |
| 8H | 4.79 | 2.846 |
| 9V | 5.37 | 2.843 |
| 10H | 7.55 | 2.839 |

The reported porosities of the samples vary over a relatively narrow range, from about 3% to 8%. This range is consistent with the general range cited by Freeze and Cherry (1979) for limestone and dolomite of 0 to 20%. The reported grain densities of the samples also vary over a relatively narrow range, from about 2.828 to 2.849 $g/cm^3$. This range is consistent with the mineral density of dolomite, 2.85 $g/cm^3$. The mineral density of dolomite is slightly higher than the typical value of 2.65 $g/cm^3$ typically assumed for mineral soils (Freeze and Cherry, 1979). The value reported by Freeze and Cherry is representative of shales and quartz sands.

The narrow ranges of the reported porosities and grain densities again suggest that the rocks of the Lockport Group have similar material properties.

The internal consistency of the bulk density, porosity, and grain density measurements can be checked. If it is assumed that the samples are dry, then the bulk density can be calculated from:

$$\rho_b = (1-\phi)\,\rho_s$$

If it is assumed that the samples are saturated, the bulk density is given by:

$$\rho_b = \phi\rho_w + (1-\phi)\,\rho_s$$

In these relations, $\phi$ denotes the porosity, and $\rho_s$ and $\rho_b$ denote the grain and bulk density, respectively. The calculated bulk densities tabulated below have been determined by substituting the reported values of porosity and grain density into the two theoretical relations.

| Sample | Reported Bulk density ($g/cm^3$) | Calculated Bulk density-Dry ($g/cm^3$) | Calculated Bulk density-Wet ($g/cm^3$) |
|---|---|---|---|
| 1V | 2.73 | 2.704 | 2.752 |
| 3V | 2.73 | 2.685 | 2.751 |
| 5V | 2.76 | 2.708 | 2.777 |
| 7V | 2.71 | 2.693 | 2.747 |
| 9V | 2.71 | 2.690 | 2.744 |

The reported bulk densities generally lie between the two corresponding calculated values. This suggests that the samples underwent some drying before the bulk density determinations. The close agreement between values confirms the internal consistency of the reported measurements.

## 2.4 Permeability

Permeabilities were measured on ten samples, using methods described in Jones (1972, 1987, 1988) and Amaefule et al. (1988). The laboratory measurements were made by passing air through the samples. The measured permeability is "apparent", and must be corrected for the effects of gas slippage (the Klinkenberg effect). This "corrected" permeability is determined from:

$$k_{app} = k_{\infty}\left(1+\frac{b}{P}\right)$$

where $k_{app}$ is the measured permeability, and $k_{\infty}$ is the corrected permeability. In this relation, $b$ denotes the Klinkenberg factor, and $P$ denotes the mean air pressure at which the permeability was measured. The corrected permeability represents the apparent permeability extrapolated to infinite air pressure. The Core Labs results are tabulated below; these values represent the corrected permeability, the appropriate measure for subsequent estimation of the hydraulic conductivity.

| Sample | Reported Permeability (md) |
|---|---|
| 1V | 4.51E-03 |
| 2H | 5.50E-01 |
| 3V | 5.82E-04 |
| 4H | 5.31E-04 |
| 5V | 1.40E-03 |
| 6H | 1.11E-03 |
| 7V | 1.99E-03 |
| 8H | 2.45E-03 |
| 9V | 1.07E-03 |
| 10H | 2.44E-02 |

The analysis assumes that the samples are dry. The values have not been corrected for a possible reduction in permeability due to the presence of water in the pore spaces.

**Equivalent hydraulic conductivities**

The hydraulic conductivity ($K$) is related to the permeability ($k$) according to:

$$K = \frac{\rho g}{\mu} k$$

where $\rho$ is the density of water and $\mu$ is the dynamic viscosity of water, and $g$ is the acceleration due to gravity. The groundwater temperatures determined during the geophysical logs range from between 52°F and 56°F (11°C to 13°C). For an average temperature of 12°C, the density and dynamic viscosity of water are 999.5 kg/m$^3$ and 1.235 cP, respectively. To estimate the hydraulic conductivity in units of *cm/sec*, the reported permeabilities must be multiplied by a factor of $7.8388 \times 10^{-7}$. This factor incorporates the conversion from the oil-field units of millidarcies (md) defined in Muskat (1937). The estimated hydraulic conductivities are listed on the following table.

| Sample | Reported Permeability (md) | Hydraulic Conductivity (cm/sec) |
|---|---|---|
| 1V | 4.51E-03 | 3.53E-09 |
| 2H | 5.50E-01 | 4.31E-07 |
| 3V | 5.82E-04 | 4.56E-10 |
| 4H | 5.31E-04 | 4.16E-10 |
| 5V | 1.40E-03 | 1.10E-09 |
| 6H | 1.11E-03 | 8.70E-10 |
| 7V | 1.99E-03 | 1.56E-09 |
| 8H | 2.45E-03 | 1.92E-09 |
| 9V | 1.07E-03 | 8.39E-10 |
| 10H | 2.44E-02 | 1.91E-08 |

The hydraulic conductivities of the samples range from about $4 \times 10^{-10}$ to $4 \times 10^{-7}$ cm/sec. Figure 2 shows the envelope of reported values superimposed on the general ranges cited by Freeze and Cherry (1979). The plot shows that the hydraulic conductivities of the core samples are consistent with literature values for intact dolomites and shales. The measured values are several orders of magnitude lower than the values inferred from slug tests at the Site. This suggests that the permeability of the bedrock at the Site is controlled by fractures, and not by flow in the matrix.

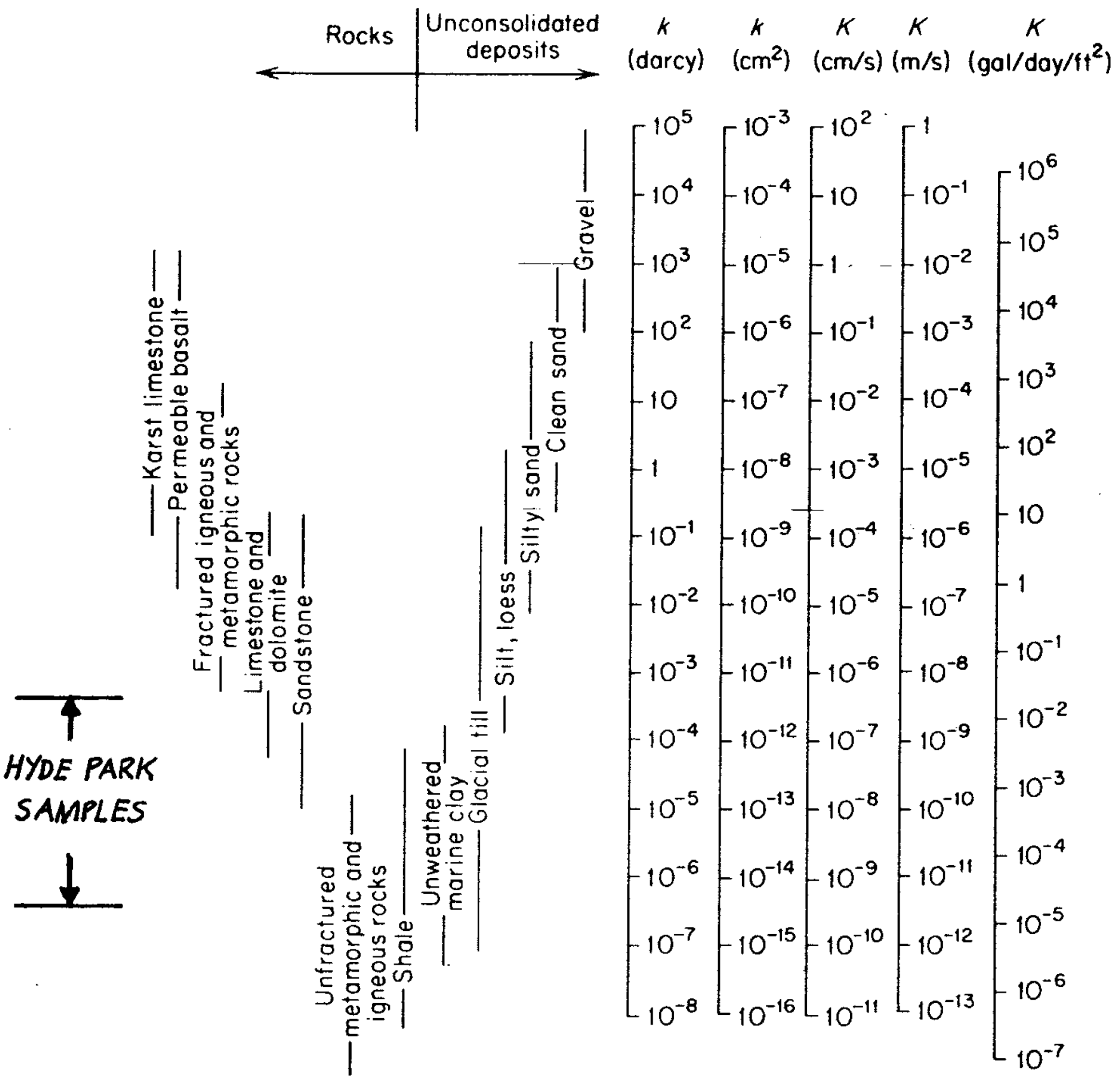


**Figure 2. Range of permeabilities for the Hyde Park Landfill samples (Adapted from Freeze and Cherry, 1979)**

## 2.5 Compressional velocity

Compressional velocities were measured on five samples, using laboratory techniques consistent with ASTM Standard D2845-1995 “Method for Laboratory Measurement of Pulsed Sonic Velocities and Ultrasonic Elastic Constants of Rock”. Ultrasonic waves are passed through the sample, and the waveforms stored for subsequent analysis of the compressional and shear wave velocities. The wave velocities are calculated using the arrival times of the P and S waves and length of the sample. The dynamic moduli and dynamic Poisson’s ratio are also calculated.

The compressional velocities have been used to calibrate the sonic geophysical logs used to estimate the rock porosity. The Core Labs results are tabulated below.

| Sample | Compressional velocity, *v* (ft/s) |
|---|---|
| 1V | 18,172 |
| 3V | 16,785 |
| 5V | 18,921 |
| 7V | 18,769 |
| 9V | 17,931 |

The reported compressional velocities represent the properties of the rock minerals (matrix) and pore space, and are consistent with typical values from other dolomite samples (M. Metz, OOGC, personal communication, January 2002). The difference between the measured compressional velocities and tabulated values for the matrix constitutes the basis for the estimation of porosity from the sonic logs. For the matrix alone, tabulated velocity values for dolomite range from 21,000 to 24,000 ft/s (Keys, 1989; Schlumberger, 1987). Century Geophysics assumed a value of 22,700 ft/s for the interpretation of the sonic logs.

# Section 3
# Summary of Findings

1. The bulk density values are highly consistent, suggesting that the rocks of the Lockport Group have similar material properties.

2. The narrow ranges of the reported porosities and grain densities again suggest that the rocks of the Lockport Group have similar material properties.

3. The reported bulk densities are internally consistent with the reported porosities and grain densities.

4. The hydraulic conductivities of the core samples are consistent with literature values for intact dolomites and shales. The measured values of hydraulic conductivity are several orders of magnitude lower than the values inferred from slug tests at the Site. This suggests that the permeability of the bedrock at the Site is controlled by fractures, and not by flow in the matrix.

5. The reported compressional velocities are consistent with typical values for dolomite.

# Section 4
# References

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Keys, W.S., 1989: **Borehole Geophysics Applied to Ground-Water Investigations**, National Water Well Association, Dublin, OH.

Muskat, M., 1937: **The Flow of Homogeneous Fluids through Porous Media**, McGraw-Hill Book Company, Inc., New York, NY.

Schlumberger, 1987: **Log Interpretation Principles/Applications**, Schlumberger Educational Services, Houston, TX.

**TABLE F.1**

**BEDROCK PHYSICAL PROPERTIES TEST RESULTS**
**SITE CHARACTERIZATION REPORT**
**HYDE PARK LANDFILL SITE**
**TOWN OF NIAGARA, NEW YORK**

| Sample Location | Depth (ft. bgs) | Unit | Test Orientation | Depth (ft) | Net Confining Stress (psig) | Porosity (%) | Permeability Klinkenberg (mD) | Permeability Klinkenberg ($cm^2$) | Permeability Kair (mD) | Permeability Kair ($cm^2$) | b(He) (psi) | Beta (per ft) | Alpha (microns) | Grain Density ($g/cm^3$) | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J5U | 20.17 - 21.05 | Eramosa Fm. | Vertical | 20.17 | 800 | 4.82 | 0.005 | 4.88E-09 | 0.010 | 1.09E-08 | 110.88 | 1.99E+16 | 2.77E+05 | 2.841 | Dol gry xln |
| J5U | 20.17 - 21.05 | | Horizontal | 20.50 | 800 | 5.45 | 0.550 | 5.95E-07 | 0.593 | 6.42E-07 | 5.14 | 6.79E+11 | 1.17E+03 | 2.840 | Dol gry xln svug |
| J5M | 54.95 - 55.5 | Vinemount | Vertical | 54.95 | 800 | 4.30 | 0.001 | 6.30E-10 | 0.002 | 1.71E-09 | 176.70 | 1.82E+16 | 3.82E+04 | 2.830 | Dol gry |
| J5M | 54.95 - 55.5 | Member | Horizontal | 55.35 | 800 | 4.31 | 0.001 | 5.74E-10 | 0.001 | 1.59E-09 | 182.28 | 2.32E+16 | 4.29E+04 | 2.828 | Dol gry |
| J5M | 86 - 86.5 | Niagara Falls | Vertical | 86.00 | 800 | 3.91 | 0.001 | 1.51E-09 | 0.003 | 3.74E-09 | 142.75 | 9.20E+16 | 4.59E+05 | 2.849 | Dol gry |
| J5M | 86 - 86.5 | Member | Horizontal | 86.35 | 800 | 3.53 | 0.001 | 1.20E-09 | 0.003 | 3.05E-09 | 152.60 | 1.95E+17 | 7.42E+05 | 2.844 | Dol gry |
| J5L | 109 - 109.6 | Gothic Hill | Vertical | 109.00 | 800 | 5.39 | 0.002 | 2.15E-09 | 0.005 | 5.15E-09 | 132.04 | 1.25E+17 | 8.58E+05 | 2.846 | Dol gry |
| J5L | 109 - 109.6 | Member | Horizontal | 109.30 | 800 | 4.79 | 0.002 | 2.65E-09 | 0.006 | 6.21E-09 | 125.48 | 1.50E+16 | 1.27E+05 | 2.846 | Dol gry |
| J5L | 112 - 112.65 | DeCew | Vertical | 112.00 | 800 | 5.37 | 0.001 | 1.16E-09 | 0.003 | 2.94E-09 | 150.64 | 5.30E+15 | 2.13E+04 | 2.843 | Dol gry styl |
| J5L | 112 - 112.65 | Formation | Horizontal | 112.40 | 800 | 7.55 | 0.024 | 2.64E-08 | 0.028 | 3.06E-08 | 12.77 | 8.35E+15 | 6.73E+05 | 2.839 | Dol gry |

| Sample Location | | | | Depth (ft) | Net Stress (psi) | Bulk Density, ($g/cm^3$) | Acoustic Velocity Compressional (ft/sec) | Acoustic Velocity Compressional (μs/ft) | Acoustic Velocity Shear (ft/sec) | Acoustic Velocity Shear (μs/ft) | Dynamic Bulk Modulus, 1.00E+06 | Dynamic Young's Modulus, 1.00E+06 | Dynamic Shear Modulus, 1.00E+06 | Dynamic Poisson's Ratio | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J5U | 20.17 - 21.05 | Eramosa Fm. | Vertical | 20.17 | 0 | 2.73 | 18172 | 55.0 | 10833 | 92.3 | 6.40 | 10.58 | 4.32 | 0.22 | Dol gry xln |
| J5M | 54.95 - 55.5 | Vinemount M. | Vertical | 54.95 | 0 | 2.73 | 16785 | 59.6 | 10259 | 97.5 | 5.20 | 9.30 | 3.87 | 0.20 | Dol gry |
| J5M | 86 - 86.5 | Niagara Falls M | Vertical | 86.00 | 0 | 2.76 | 18921 | 52.9 | 11095 | 90.1 | 7.22 | 11.35 | 4.58 | 0.24 | Dol gry |
| J5L | 109 - 109.6 | Gothic Hill M. | Vertical | 109.00 | 0 | 2.71 | 18769 | 53.3 | 10794 | 92.6 | 7.21 | 10.68 | 4.26 | 0.25 | Dol gry |
| J5L | 112 - 112.65 | DeCew Fm. | Vertical | 112.00 | 0 | 2.71 | 17931 | 55.8 | 10556 | 94.7 | 6.32 | 10.05 | 4.07 | 0.23 | Dol gry styl |

Notes:
Dol = dolomite
gry = gray
xln = crystalline
svug = small vugs
styl = stylolite

# APPENDIX G

# ACCURACY OF ELEVATION MEASUREMENTS

TABLE OF CONTENTS

## LIST OF FIGURES
(Following Text)

# 1.0 INTRODUCTION

Numerous elevation measurements are presented in this report, and correlations made across the Site based on these measurements. The accuracy of these measurements is an important consideration in the interpretation of data. This appendix presents an estimate of the uncertainty associated with certain measurements, and a discussion of how the uncertainty affects data interpretation.

Figure G.1 presents a hypothetical set of elevation measurements made along a cross section. For the purposes of this discussion, the measurements are assumed to represent the interpreted elevation of a peak on the gamma geophysical log. Each estimated elevation measurement is plotted as a dot with an associated measurement error, depicted by the error bars extending above and below the data points. Assuming that all measurements and reference points have been accurately documented, the actual elevation of the measurement is not the point, but is somewhere between the error bars. There are two key elements affecting measurement error:

- the surface elevation survey; and
- the accuracy of the downhole measuring tool (e.g., a tape along a core, a depth-to-water meter, or a geophysical instrument).

Figure G.2 presents three interpretations of the data plotted on Figure G.1:

- connects all of the reported values with straight lines;
- fits a smooth curve to the reported values; and
- provides a best-fit line to the reported values that falls within the error bars.

All three interpretations are equally valid, none are exactly right, and unless we know a-priori the actual line, there is no way to know which interpretation is the closest to being correct. In general, it is not possible to quantitatively establish the 'best' approach for presenting the relation between the data points because the shape of the surface containing them is unknown. However, it is possible to establish the most appropriate approach. According to the principle of parsimony (also referred to as Occam's Razor), if multiple hypotheses can explain the data, then the most appropriate hypothesis is the one that is simplest. Additional details can be found at http://pespmc1.vub.ac.be/OCCAMRAZ.html).

Regardless of which interpretation is presented, the accuracy of the measurements underlying the reported values must be understood to avoid over-interpreting the data.

## 1.1 MAGNITUDE OF THE MEASUREMENT ERROR

In the following discussion, the magnitude of the two error factors discussed above is estimated.

## 1.2 SURFACE ELEVATION SURVEY

During the evaluation of geophysical data for the Site Characterization Report, a number of potential outliers were identified. The investigation of these outliers included a resurvey of the grade elevation for the wells in question. Figure G.3 presents a summary of the difference between the original elevation and the December 2001 resurvey.

There are several sources for the errors in elevation plotted on Figure G.3. Three examples are described below:

- At ABP-3, the grade was lowered by 6 feet, and the well was cut down. The original grade was retained in the database, because the lithologic contacts are recorded in depth below grade at the time of drilling. Changing grade would result in calculation of incorrect contact elevations. However, the database grade elevation was used for the 2001 geophysical survey reference, resulting in an error in the calculation of elevations in the 2001 geophysical survey;
- There was no change in grade at the F4 well cluster. This 5-foot error is either related to an inaccurate survey, or an inaccurate transfer of the survey data into the database; and
- Well J5L was installed in 2001. The original elevation of the survey was determined upon completion of the well. The difference between the two values is 0.9 feet. Grade has probably not changed by 0.9 feet between the first survey and December 2001. The difference suggests that the survey accuracy, possibly the placement of the stadia rod, introduce an error close to 1 foot.

In this inspection of 21 resurvey measurements, there were five locations where the survey error was outside of the primary cluster of data. These five are considered to be "mistakes". That is, a transcription error or a change in grade that was not properly recorded. The remaining 16, clustered between –1 and 0 feet, are considered to reflect the precision of the measurement.

It is unusual that there were no errors between 0 and +1 feet. This may be because the wells selected for resurvey were identified as outliers, and were therefore a biased data set. It is also unlikely that the 'rate' of errors (5 mistakes in a sample of 21, or 24 percent), represents the general population. Based on the results of this error analysis, the error associated with grade survey is estimated to be ±1 foot.

## 1.3 ACCURACY OF THE DOWNHOLE ELEVATION MEASUREMENTS

The accuracy of a downhole elevation measurement, e.g., the elevation of a gamma peak, is difficult to quantify. It is typically assumed to be the equivalent to the measuring increments of the measuring tool. For example, depth-to-water meters are typically graduated in 0.01-foot increments. However, the water level data collected during the May/June shutdown of the bedrock purge well system demonstrated that the error associated with a carefully performed hand water level measurement is much greater than the 0.01-foot graduations on the tape. The analysis demonstrated that the hand measurement errors were normally distributed with a standard deviation of 0.08 feet; that is, 36 percent of the measurements made have an error >0.08 feet (data to be published in the May/June Shutdown Report). The analysis excluded mistakes, e.g., incorrectly recording numbers, gross errors, and does not account for error associated with the survey of the top of the well casing.

The analysis of water level errors was relatively easy to perform because water levels were collected both by hand and with electronic data loggers. In contrast, downhole measurements of a gamma response or other geophysical measurement only have one set of measurements.

A simple review of the data from one well cluster, AGW-1, provides insight into the elevation error associated with the geophysical measurements. Figure G.4 shows the gamma logs from AGW-1U, AGW-1M, and AGW-1L down to an elevation of 500 ft AMSL. The gamma signals for AGW-1U and AGW-1M are from the open interval of these wells. The AGW-1L signal is through the well casing. The gamma signal passes through the well casing although it is somewhat attenuated and slightly averaged. The gamma signals of AGW-1U and AGW-1M should overlay directly on the AGW-1L signal.

Well AGW-1L is 23 feet from AGW-1M and 58 feet from AGW-1U. Because the wells are not exactly on top of each other, the comparison is potentially flawed. Consider however, how data are interpreted. When data points separated by 500 feet or more are contoured, as is done for the Hyde Park data and at many other sites, there is an implicit assumption that the measurement taken at locations close together are very similar. This assumption is the basis of geostatistical kriging. Conceptually, the same measurement from three closely spaced wells may be interchanged, e.g., rather than using the three clustered data points, the data from any one well in the cluster will suffice. Alternatively, the mathematics of most contour routines effectively averages the values from clustered readings.

Recognizing the assumptions associated with the analysis, the comparison of the three gamma signals clearly suggests that there is an error. Two peaks are compared between AGW-1M and AGW-1L, and one between AWG-1U and AGW-1L. The peaks are offset by approximately 2 feet, 1 foot, and 1 foot, respectively. These differences appear to represent the combined error arising from a ±1-foot measurement error associated with the precision of the gamma tool and an offset associated with the zero-referencing of the log of the gamma tool.

This estimate of ±1 foot measurement error is consistent with the QA/QC discussion presented in Appendix A. The comparison of gamma logs collected in the same well on two different occasions (relogs of the well), concluded that there was approximately ± 0.6 feet of uncertainty associated with referencing the instrument to grade, and ± 0.6 feet of uncertainty in the vertical location of the gamma peak by the gamma tool. The total uncertainty estimated in Appendix A is ±1.2 feet.

## 2.0 ERRORS ASSOCIATED WITH THE IDENTIFICATION OF LITHOLOGIC CONTACTS

The previous discussion addressed errors associated with the physical downhole measurement. This section considers the uncertainty associated with the identification of a lithologic contact.

One reason for the uncertainty in the identification of a lithologic contact appears to be the description of the contact. Brett et al. (1995) refers to the Vinemount-Ancaster contact as having a "shaly interval" at the interface. Is the contact always at the lowest shaly marker, regardless of whether or not it is the same bed? Most frequently, the Vinemount-Ancaster contact is picked just below gamma peak I (GP-I) (see Section 4 of the Site Characterization Report for details). Brett et al. (1995) also state that, "a groundwater seepage zone is recognized at this contact in many outcrops." Our review has led us to the conclusion that GP-H, about 5 feet above GP-I, is where the flow zone occurs at the Site. Occasionally, the Vinemount-Ancaster has been picked at a shaly interval that appears as a gamma peak about 5 feet below GP-I (this gamma peak is not obvious in all gamma logs). Brett et al. also states that "one or more beds of coarse crinoidal debris are typically observed near the top of the Ancaster Member." The multiple criteria for the nature of a contact, and the potential for different interpretations of a contact, create a potential for different investigators, inspecting the same core or outcrop, to pick the contact at different elevations. The description of the Vinemount-Ancaster contact suggests the possibility of picking the contact ±5 feet from its true value, based on which description of the contact is given priority.

To assess the uncertainty at the Site, a comparison was made between the contact picks made when the cores collected at the Site were first inspected, right after installation, and when the cores were relogged in 2001. Obvious recording errors were not included in the comparison.

Figures G.5A, B, and C present probability plots of the change in elevation of the contact picks between the first and second logging of the cores. Changes of 4 to 5 feet may be observed. However, 2 to 3 feet of change appears to be a more typical range.

## 3.0 CONCLUSIONS

Three topics have been discussed in this appendix:

- Interpretation of data with errors;
- Measurement errors associated with downhole geophysics measurements; and
- Errors associated with the identification of lithologic contacts.

The discussion of the interpretation of data that contain errors demonstrates that there are multiple equally correct (or equally incorrect) ways of interpreting the same data set. It is impossible to know which method is the best. The straight line fit, being the simplest interpretation, would be selected based on the principle of parsimony. The example values presented were generated as a random error added to a straight line, and the straight line was in fact the closest to reality.

The evaluation of downhole measurement errors suggests that there is about 1 foot of error associated with the grade reference elevation, and ±1 foot of error associated with the precision of the geophysical measurement. No other factors were considered. Based on the two factors considered, any elevation measured from the geophysical tools has an error of approximately ±2 feet.

The review of errors associated with selection of a lithologic contact suggests that the ambiguity of the criteria used for picking a contact results in the potential for the contact to be identified at different elevations by different geologists. The graphical analysis presented compares the contact picks at two different times by the same geologist, likely reducing uncertainty. The graphical analysis suggests that the ±3 feet error is common and errors as large as 4 to 5 feet are occasionally observed.

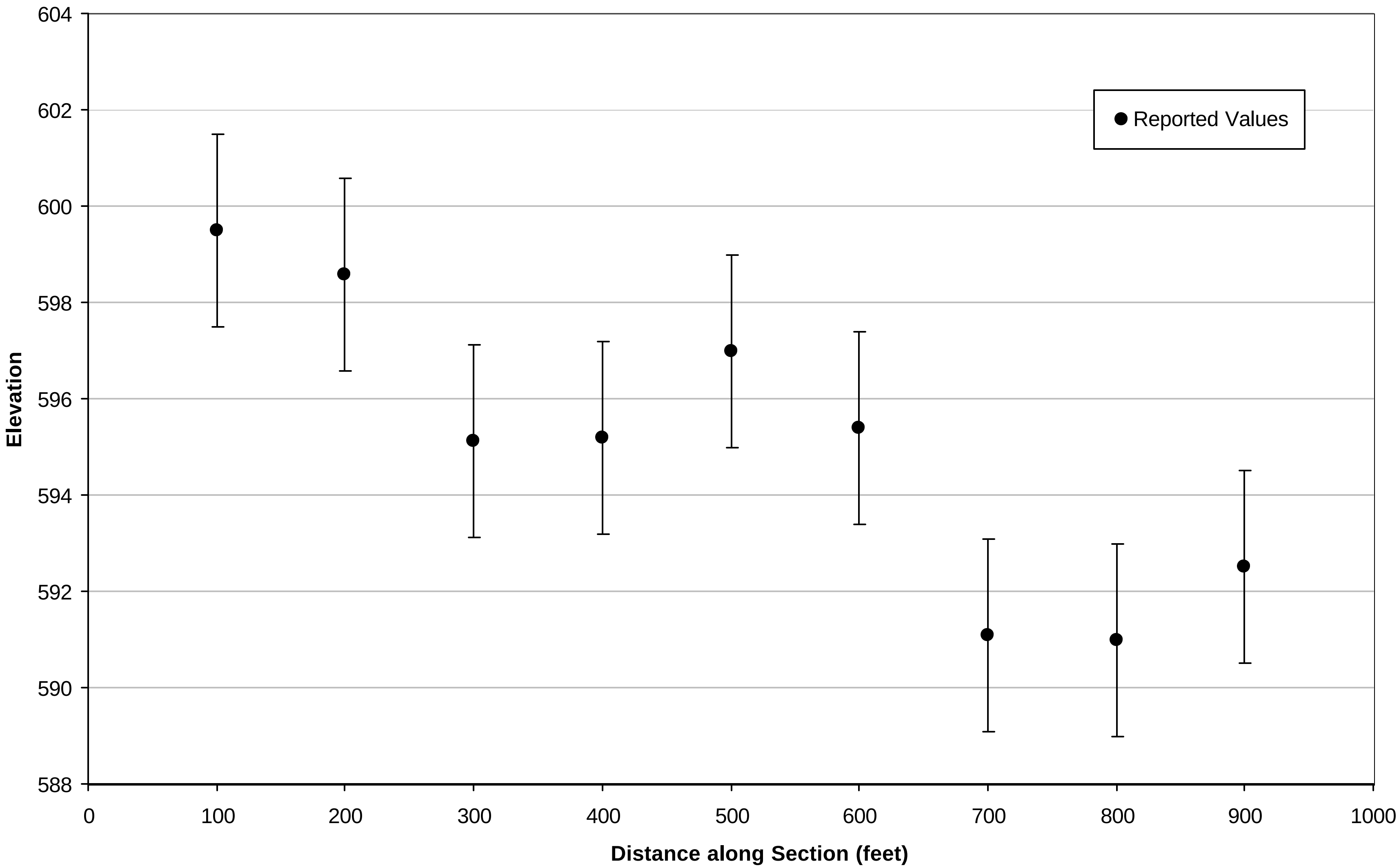



**Figure G.1 Data with Measurement Error Bars**

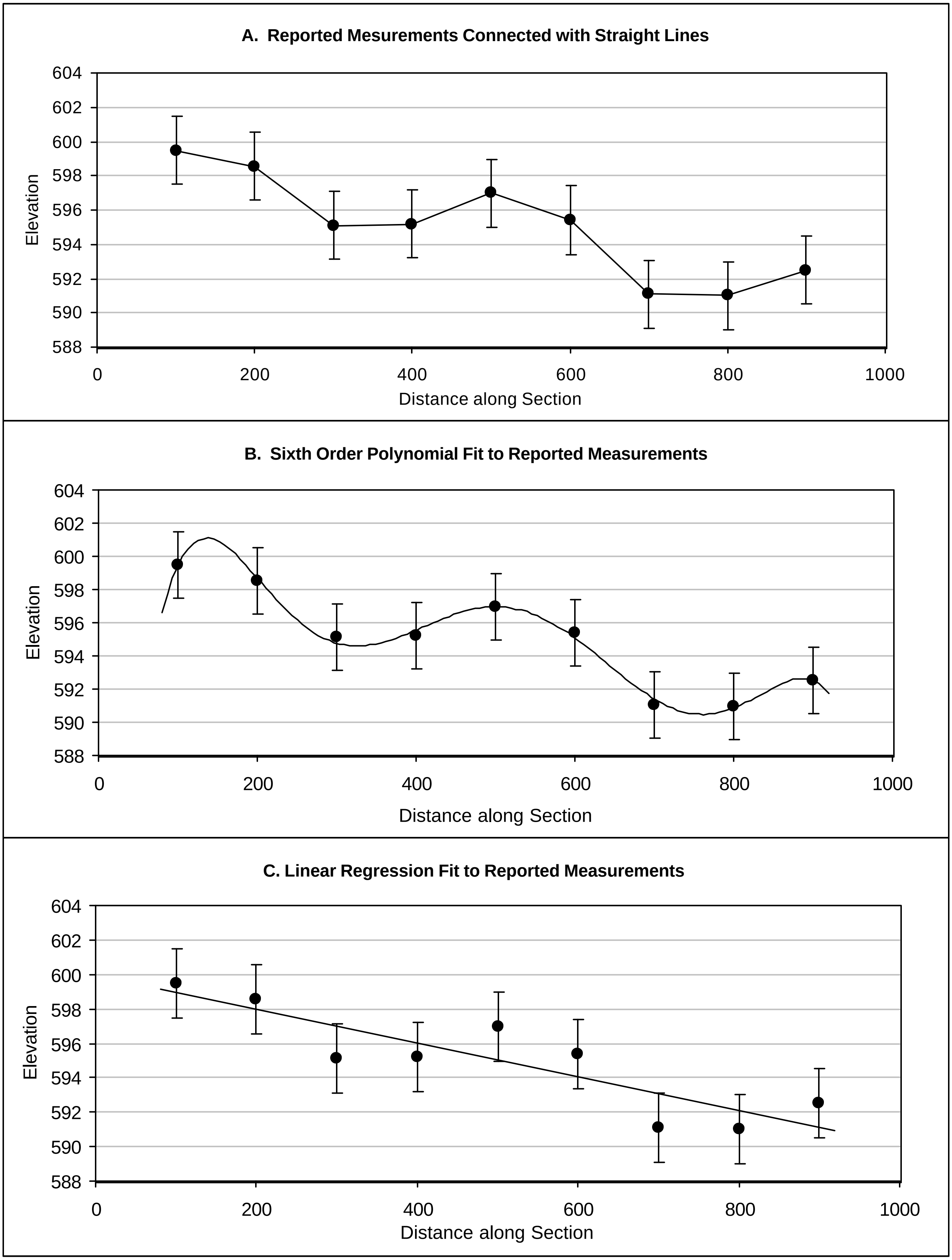



**Figure G.2 Interpretation of Data with Measurement Error**

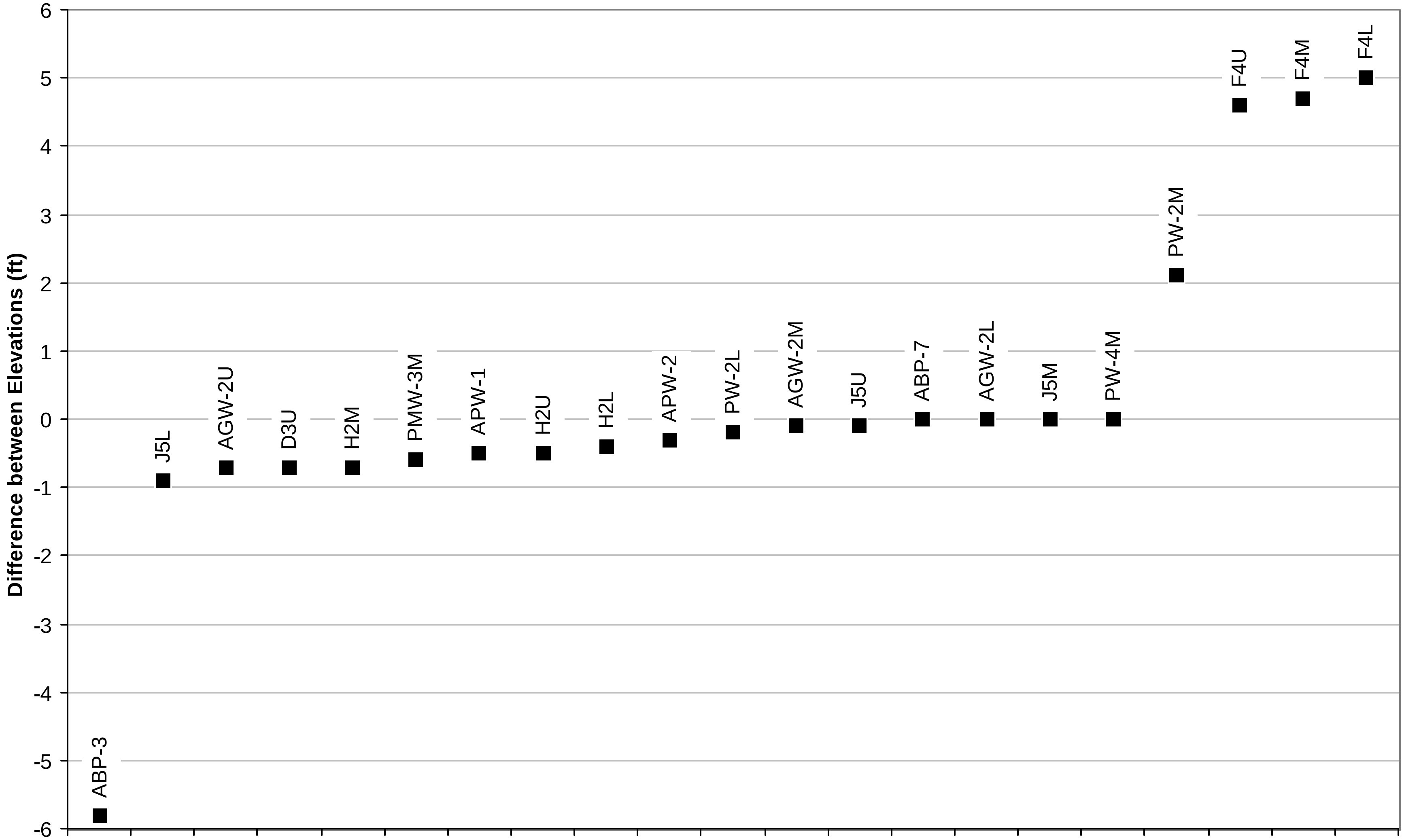
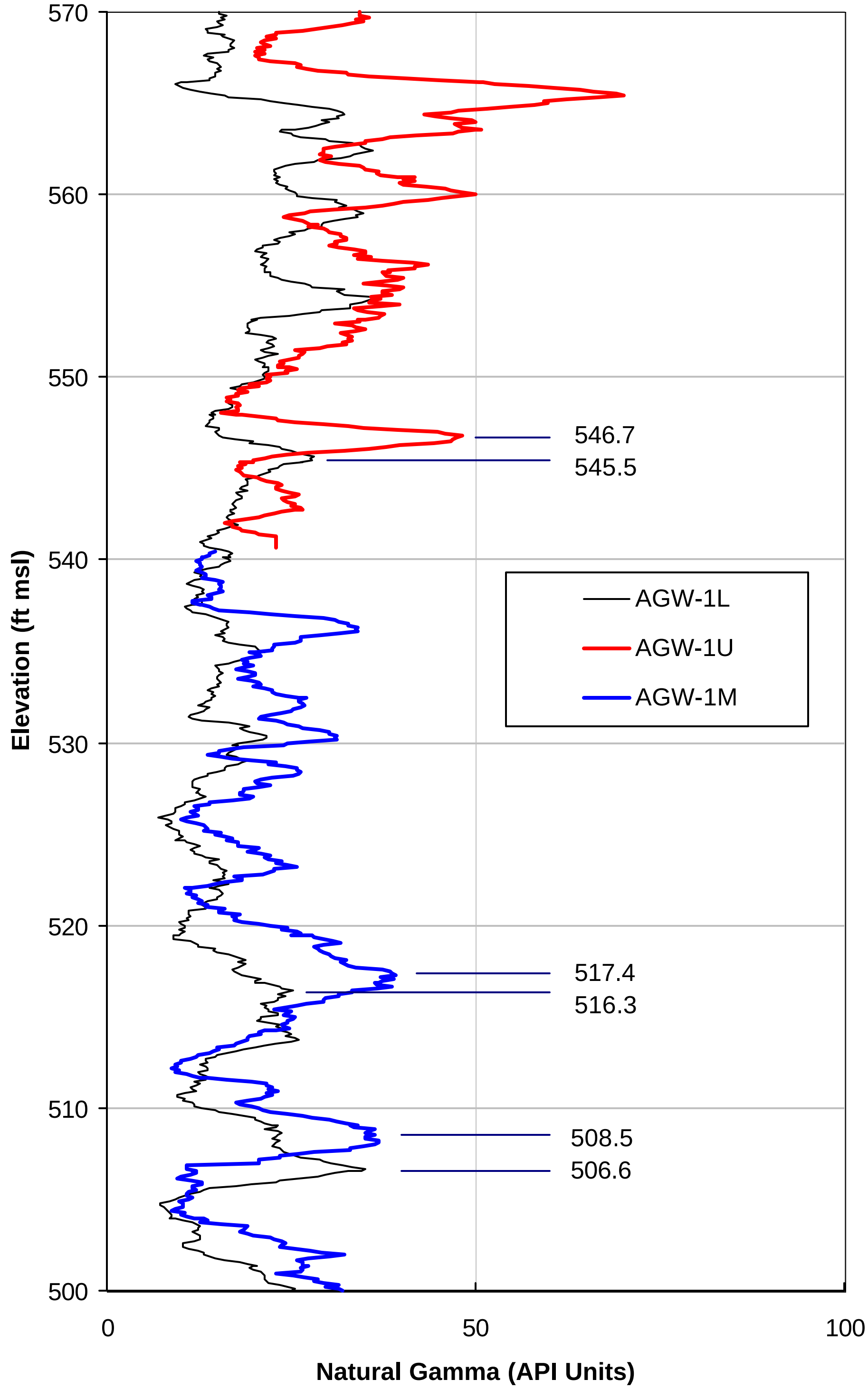



**Figure G.3 Difference between Grade Elevations in Site Database and 2001 Survey**




AGW-1

**Figure G.4 Comparison of Natural Gamma Signals From AGW-1U, AGW-1M, and AGW-1L**

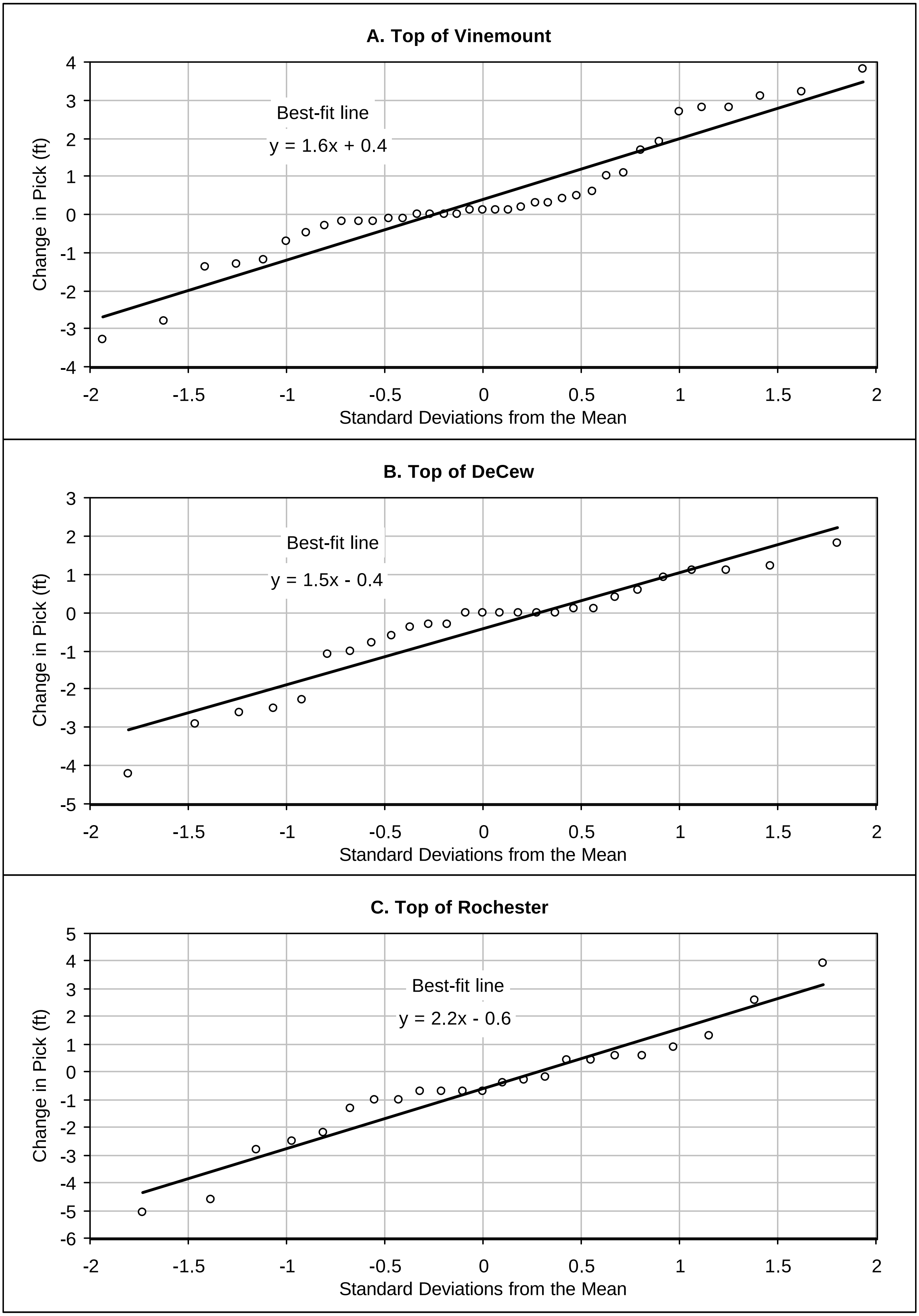



**Figure G.5 Change in Lithologic Contact Picks**

# APPENDIX H

# SUMMARY OF PACKER FLOW TESTS AND SINGLE WELL RESPONSE TESTS

S. S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

# Memorandum

Date: June 28, 2001

From: Christopher J. Neville and Mark A. Kuhl

To: File

SSPA Project: SSP-610

**Subject: Hyde Park Landfill: Single well response tests**

A relatively large number of single well response tests have been conducted at the Hyde Park Landfill Site. These tests include packer tests in boreholes and slug (recovery)/evacuation tests in completed wells. The results from the tests were not re-analyzed or used directly during the development of the Site groundwater model. The results from the single well tests were not used to assign hydraulic conductivity distributions. This was a deliberate decision based on our experience that single-well tests provide an impression of conditions only in very close proximity to the well being tested (a few well diameters). Research in settings similar to the Hyde Park Landfill has shown that interpretations are heavily weighted towards the source well (Novakowski, 1989).

Instead of using the single-well tests directly, the specifications of the bulk hydraulic properties of the bedrock were constrained by the results of the purge well tests. The constant-rate pumping tests with multiple observation wells yield better estimates of "effective" properties; however, they do not provide a detailed impression of local-scale heterogeneities. The review of the model by the USEPA and USGS provides us with an opportunity to take a closer look at all of the hydraulic conductivity data. In this memo we summarize the results of our re-examination of the results of the single well tests. Our specific objectives in re-examining the data are:

- to identify local variations in hydraulic conductivities in the bedrock zones;
- to check that the results of the packer tests are consistent with the slug test results; and
- to compare the results of the packer tests with the available hydrostratigraphic conceptualizations.

## I. Slug testing

Results of 64 slug tests conducted in active wells at the Site are available. Some wells have been tested more than once, and 5 of the responses were not interpretable. For wells that have been tested more than once, we use the geometric mean to assign a single well. A total of 51 wells can be assigned hydraulic conductivities from slug tests (17 Upper; 10 Middle; 24 Lower). The hydraulic conductivities estimated from slug tests are plotted on attached Figures 1, 2 and 3 for the Upper, Middle, and Lower zones, respectively.

Comments on the slug test results

1. The figures of hydraulic conductivities suggest that there is relatively good spatial coverage over the Site. The spatial coverage is least dense in the Middle zone, and most extensive in the Lower zone. Coverage is most complete immediately west and south of the Site.

2. The figures of hydraulic conductivities suggest that there is relatively good spatial coverage over the Site. The spatial coverage is least dense in the Middle zone, and most extensive in the Lower zone. Coverage is most complete immediately west and south of the Site, but there are relatively few results available for the areas north and northwest of the landfill.

3. The hydraulic conductivity values indicate that there is significant heterogeneity at the Site.
   - In the Upper zone, the slug test $K$ values range from $8 \times 10^{-7}$ to $3 \times 10^{-3}$ cm/sec.
   - In the Middle zone, the slug test $K$ values range from $4 \times 10^{-10}$ to $4 \times 10^{-3}$ cm/sec.
   - In the Lower zone, the slug test $K$ values range from $5 \times 10^{-8}$ to $2 \times 10^{-3}$ cm/sec.

4. The results from all slug tests close to the Niagara River gorge indicate low hydraulic conductivity ($10^{-10}$ to $10^{-6}$ cm/sec) across all three bedrock zones.

5. In the Upper zone, $K$ values vary abruptly across the Site. There are no obvious spatial trends. However, there does appear to be a band of relatively high conductivity connecting wells C1U, CD3U, D1U, and E5U.

   Figure 4 shows the Upper zone high transmissivity zones inferred during calibration of the groundwater flow model. There are no slug tests to confirm or refute our inference of a higher $T$ zone north of the Site. Two of the three slug tests conducted in wells that lie within the southern high $T$ zone have higher hydraulic conductivities (> $10^{-4}$ cm/sec).

5. In the Middle zone, there appears to be a band of high conductivity connecting wells B1M, BC3M, and CD1M. It is impossible to determine whether this is actually a zone of elevated permeability, because the test results at C1M, CD2M and D1M were not interpretable.

   Figure 5 shows the Middle bedrock high transmissivity zone inferred during model calibration. The high-*K* band lies within the high transmissivity zone, providing some independent suggestion of its existence.

6. In the Lower zone, *K* values vary abruptly over relatively small distances across the Site. The slug test *K* values suggest there is an area south and west of the zone that has low permeability. This area includes the gorge wells AFW-1L, AFW-2L and AFW-3L, and the off-Site wells D2L, E1L, E3L, F1L, and F2L. We have plotted this zone on Figure .

## II. Packer testing

Packer tests were carried out in 19 boreholes at the Hyde Park Landfill Site between January and September 1991. The test results were reported in the 1991 Drilling Summary Report (CRA, 1991). The average spacing between packers was 15 ft. Slug tests have been conducted in some of the wells that were installed subsequently. As far as I am aware, no attempt was ever made to display the packer test results graphically, or to compare the results of the packer and slug testing. Although they have not been examined in detail before, the packer test data provide valuable information on the distribution of horizontal hydraulic conductivity with depth. These data are an important addition to the Site characterization. The additional slug test results also provide an excellent opportunity to evaluate the consistency between parameter estimates derived from the packer and slug tests. An assessment of the consistency between test results will be important for anticipating the value of possible future packer testing at the Site.

The wells that were packer-tested are listed on the attached table. The table also indicates whether a slug test was conducted in the corresponding completed well. Profiles of the horizontal hydraulic conductivity distribution have been prepared for each well. The profiles also include the slug test estimate of $K$ where available. The profiles also show the "detection limit" of the packer tests. Our review of the data suggests that the lower limit on the packer-derived conductivities is $10^{-7}$ cm/sec, although in reality it may be an order of magnitude higher.

<u>Comments on the packer test results</u>

1. The packer test $K$ profiles confirm that the bedrock properties are heterogeneous at the Site. Hydraulic conductivities vary by orders of magnitude along each borehole, and at the same elevation at two boreholes.

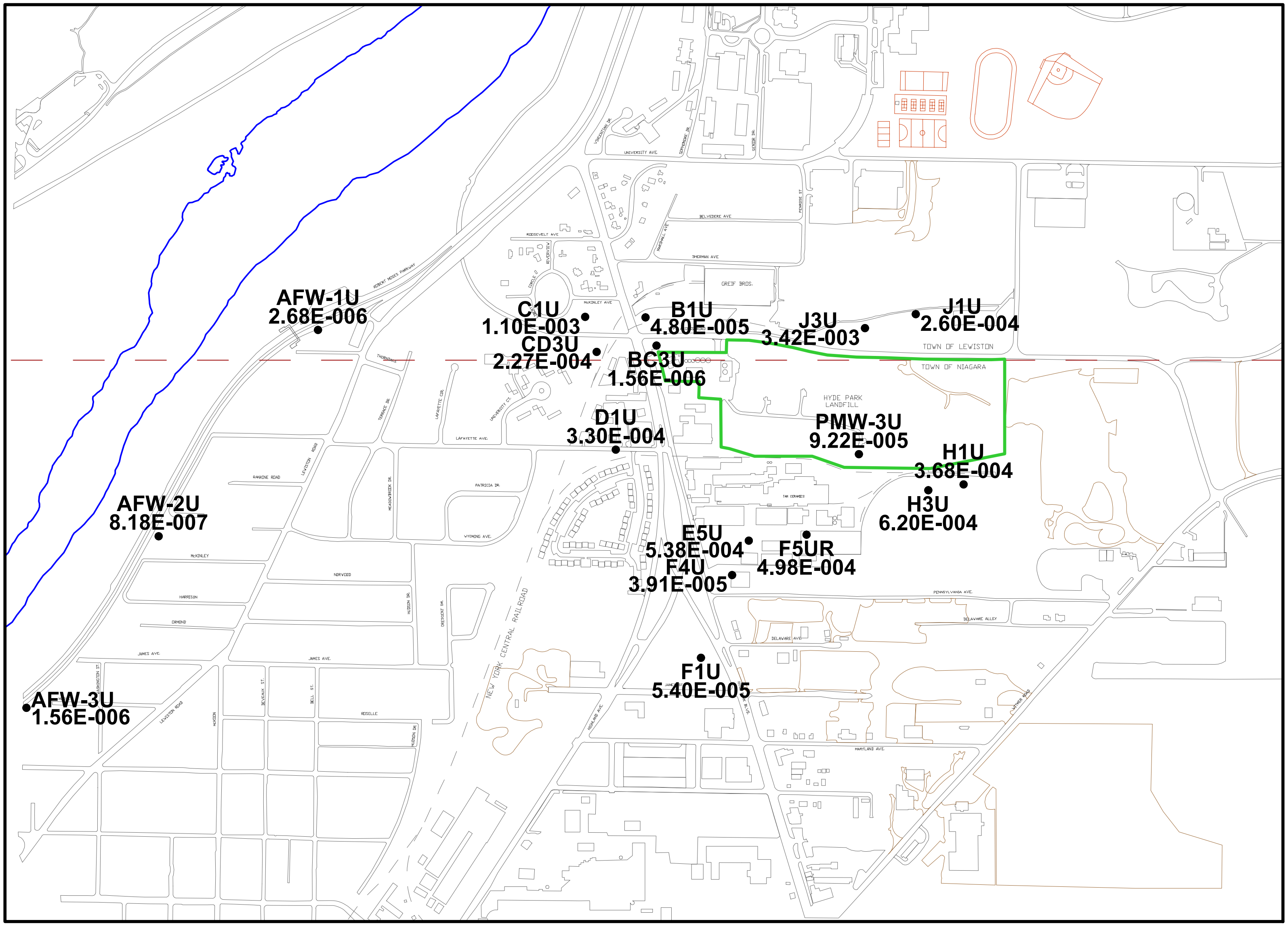
2. There appears to be only a weak Site-wide trend of hydraulic conductivity as a function of depth. In general, hydraulic conductivities tend to be higher at the top of the borehole. However, the variations in $K$ along each profile do not show a clear demarcation between Upper, Middle, and Lower bedrock zones.

3. In most wells, there is a relatively close correlation between packer and slug test derived estimates of hydraulic conductivity. This is an encouraging result because it suggests that the packer tests can be used to obtain a reliable estimate of the near-well conductivities.

**Listing of packer test profiles**

| Borehole | Slug tests |
|---|---|
| AFW-1L | AFW-1U, AFW-1M, AFW-1L |
| AFW-2L | AFW-2U, AFW-2M, AFW-2L |
| AFW-3L | AFW-3U, AFW-3M, AFW-3L |
| AGW-1L | |
| AGW-2L | |
| AGW-3L | |
| B1L | B1U, B1M, B1L |
| C1L | C1U, C1M (nir), C1L |
| D2L | D2L |
| E1L | E1L |
| F1L | F1L |
| G1L | G1L |
| H1L | H1U, H1M |
| J1L | J1U, J1L |
| PMW-1L | PMW-1L |
| PMW-2L | |
| PMW-3L | PMW-3U, PMW-3M |
| PW-2L | |
| PW-3L | |

Note: nir means "not an interpretable response"




EXPLANATION

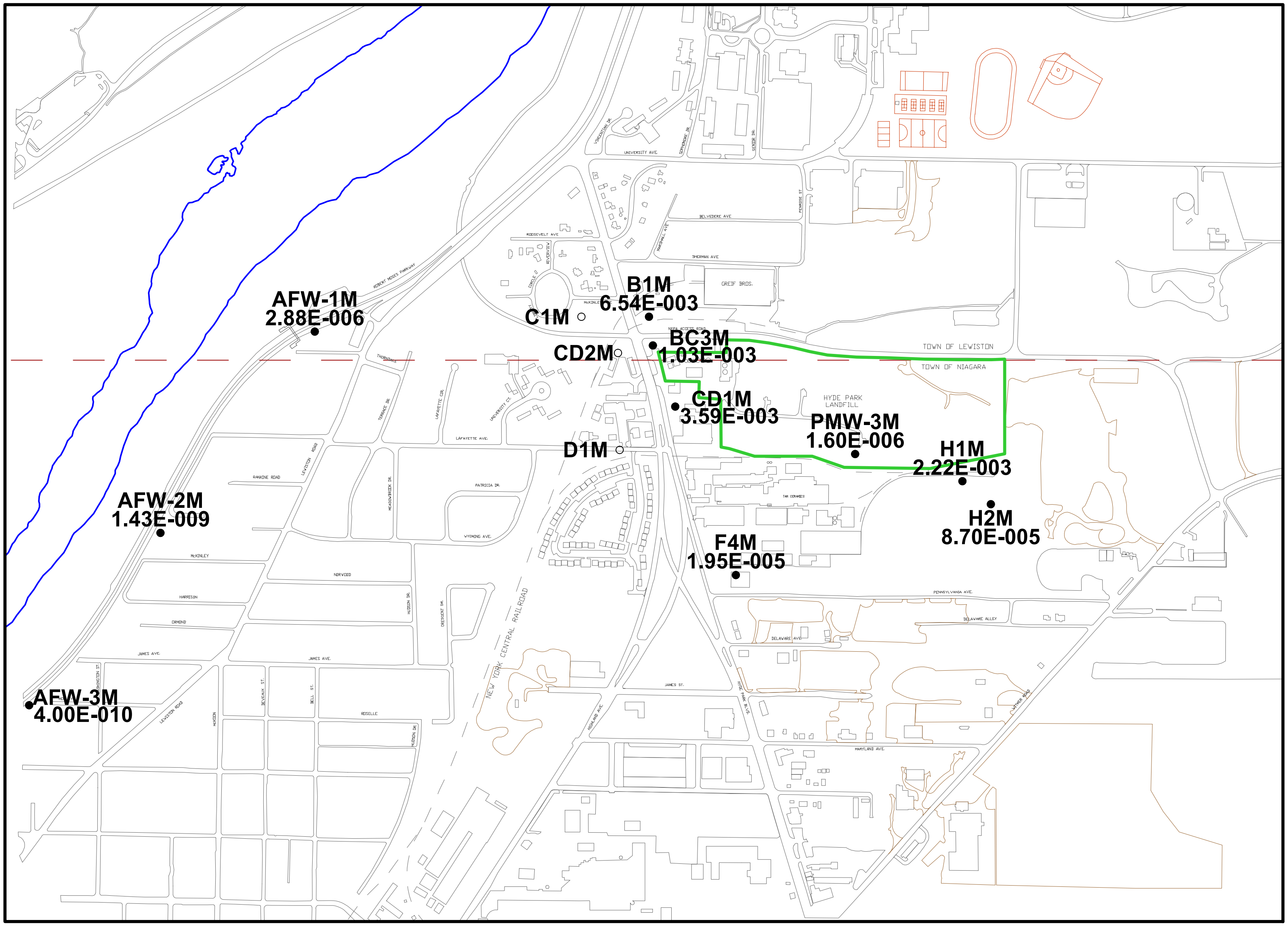
Site boundary

C1U
1.10E-003
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

**Figure 1** - Slug Test Hydraulic Conductivities - Upper Zone

28-Jun-2001




EXPLANATION

Site boundary

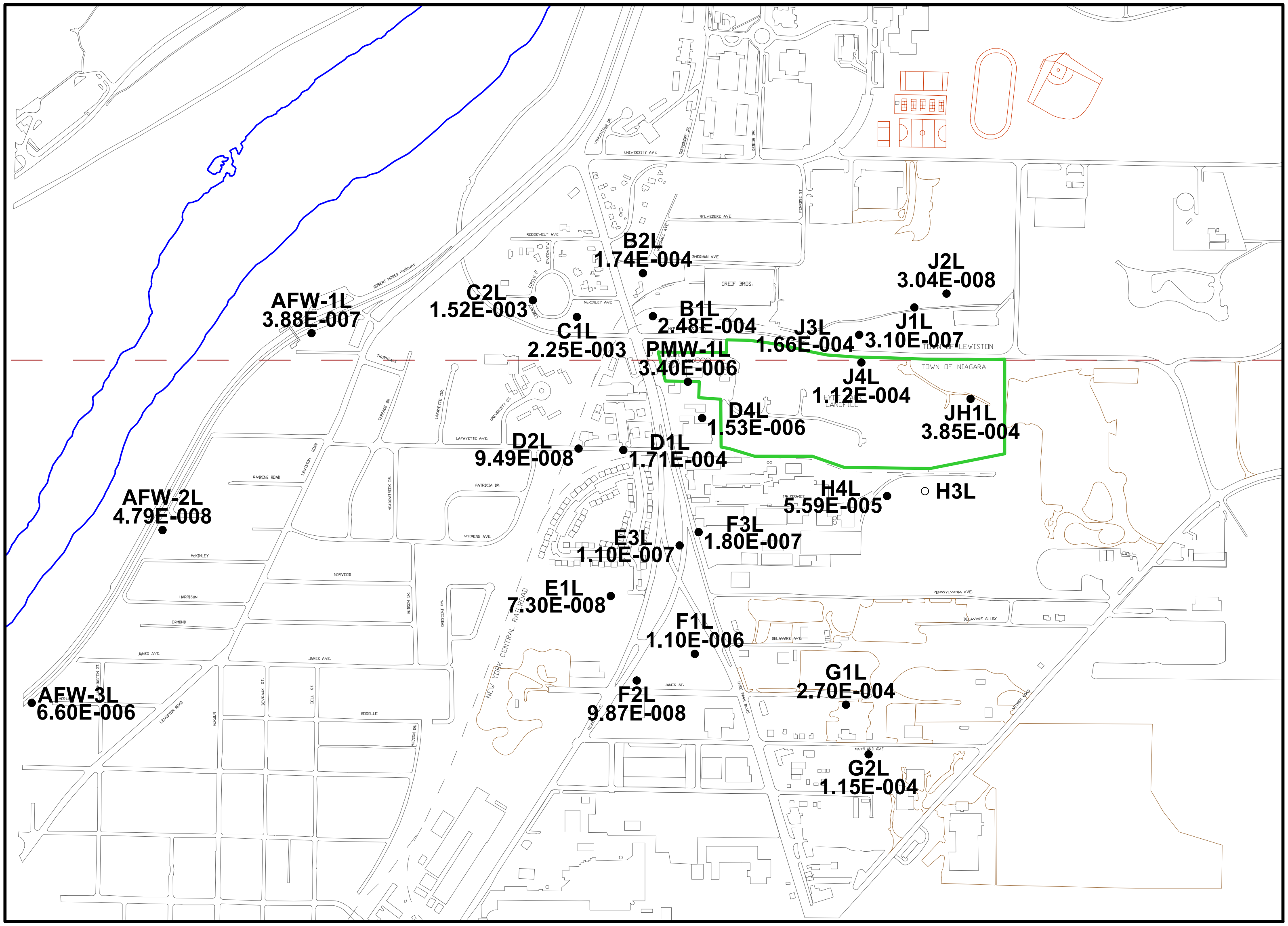
○ Well tested, response not interpretable

B1M
6.54E-003 Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

**Figure 2** - Slug Test Hydraulic Conductivities - Middle Zone

28-Jun-2001




EXPLANATION

Site boundary

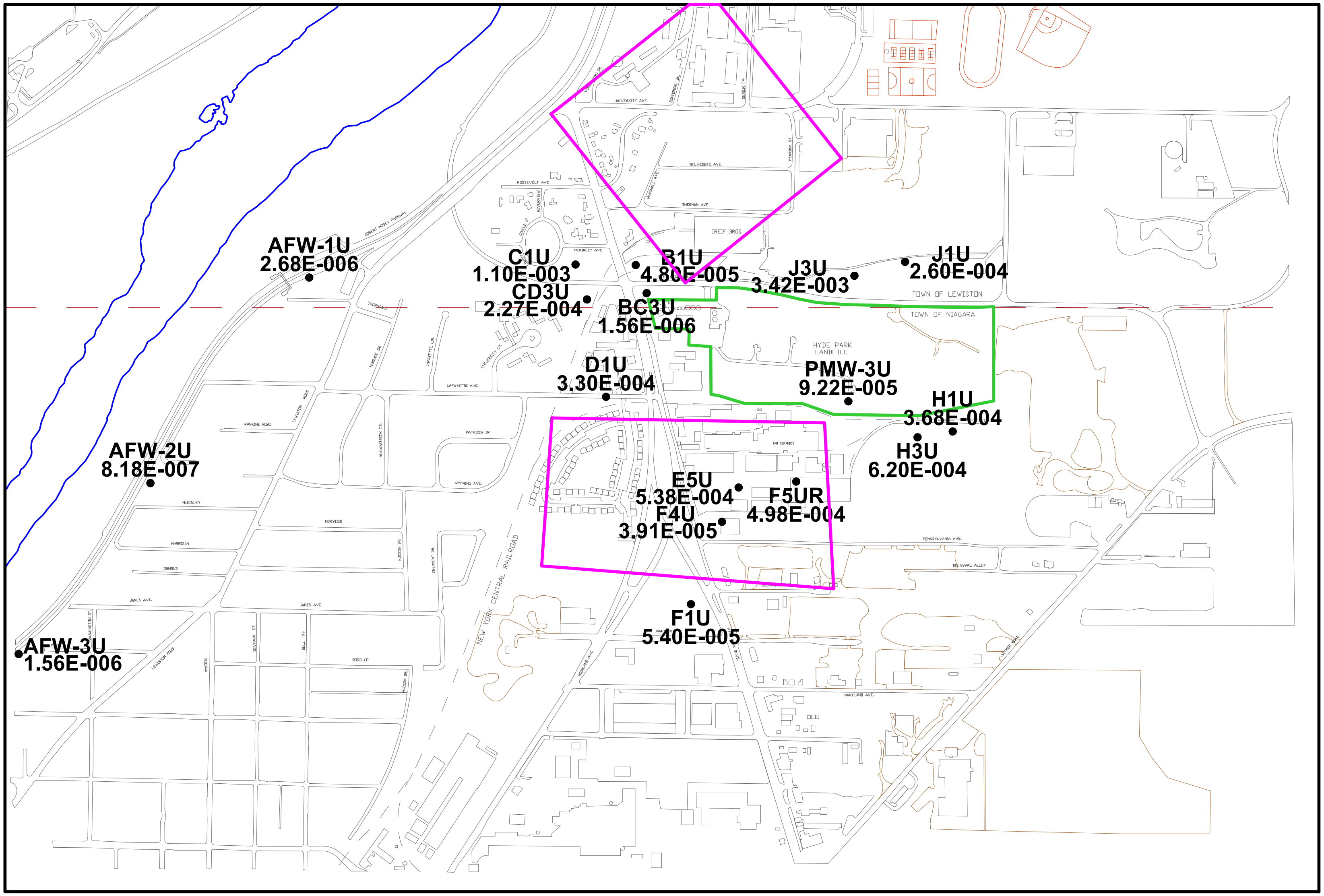
○ Well tested, response not interpretable

G2L
1.15E-004 Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

**Figure 3** - Slug Test Hydraulic Conductivities - Lower Zone

28-Jun-2001




EXPLANATION

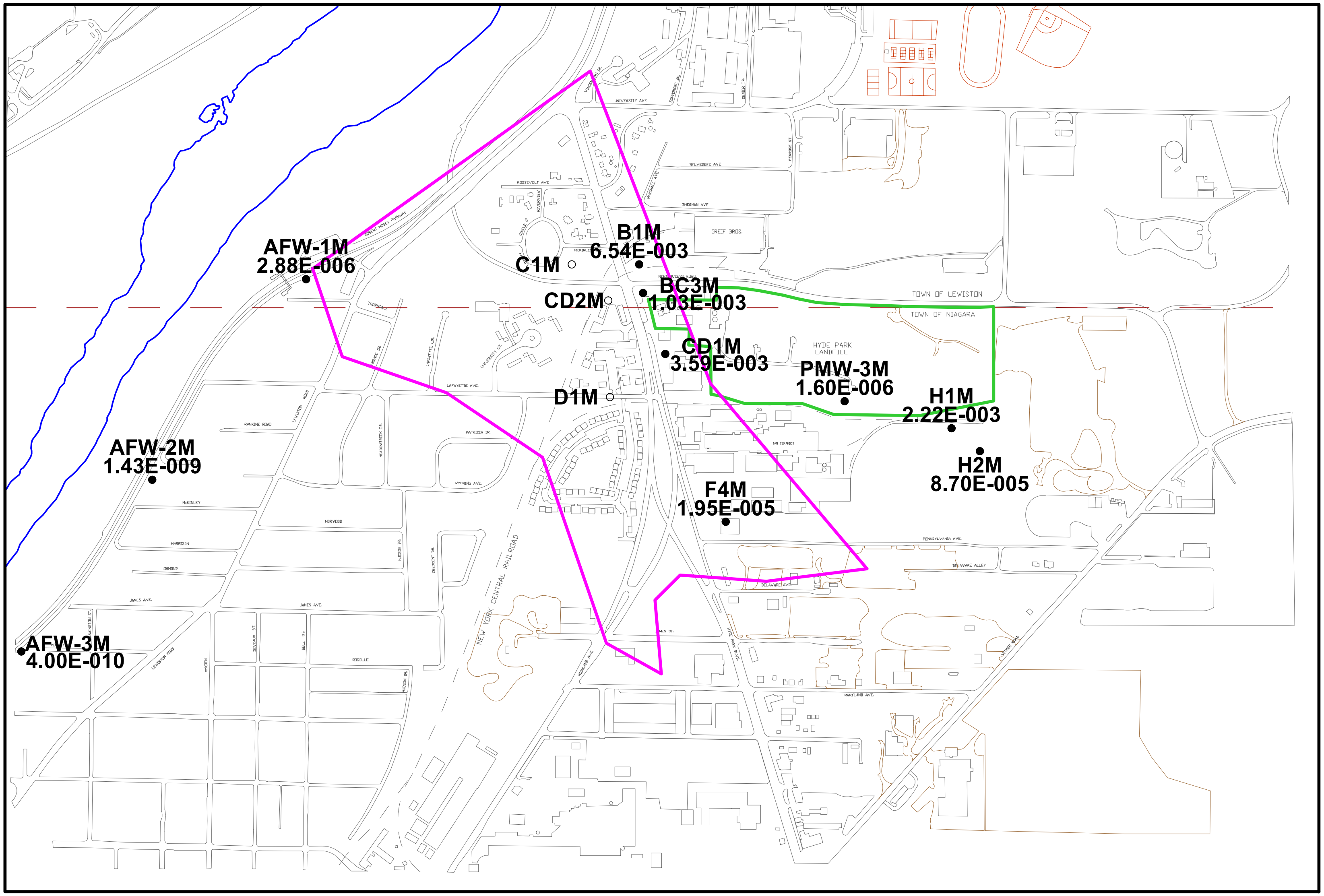
Site boundary

C1U
1.10E-003 Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

**Figure 4** - Slug Test Hydraulic Conductivities - Upper Zone

28-Jun-2001




EXPLANATION

Site boundary

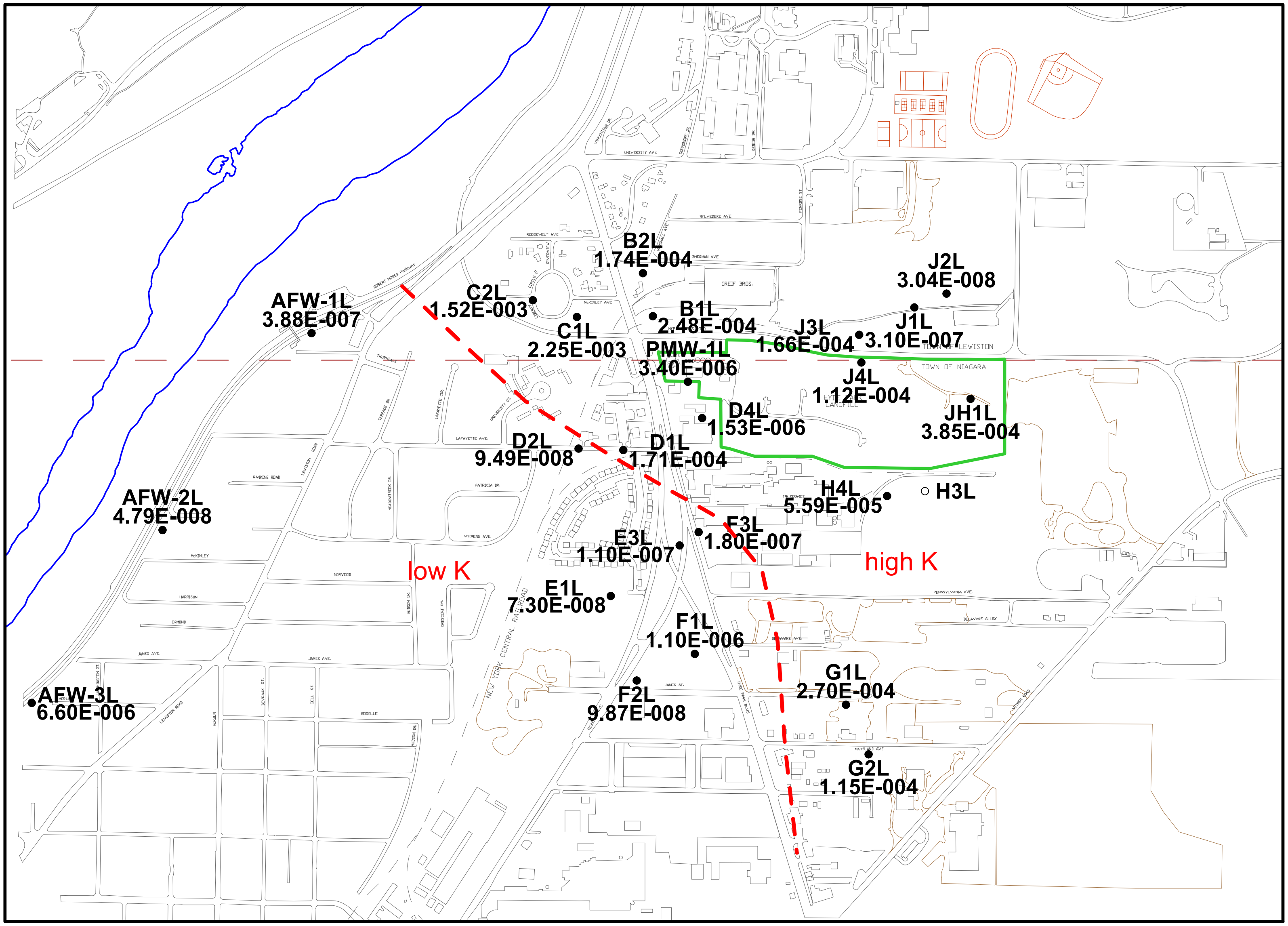
○ Well tested, response not interpretable

● B1M 6.54E-003 Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

**Figure 5** - Slug Test Hydraulic Conductivities - Middle Zone

28-Jun-2001




EXPLANATION

Site boundary

○ Well tested, response not interpretable

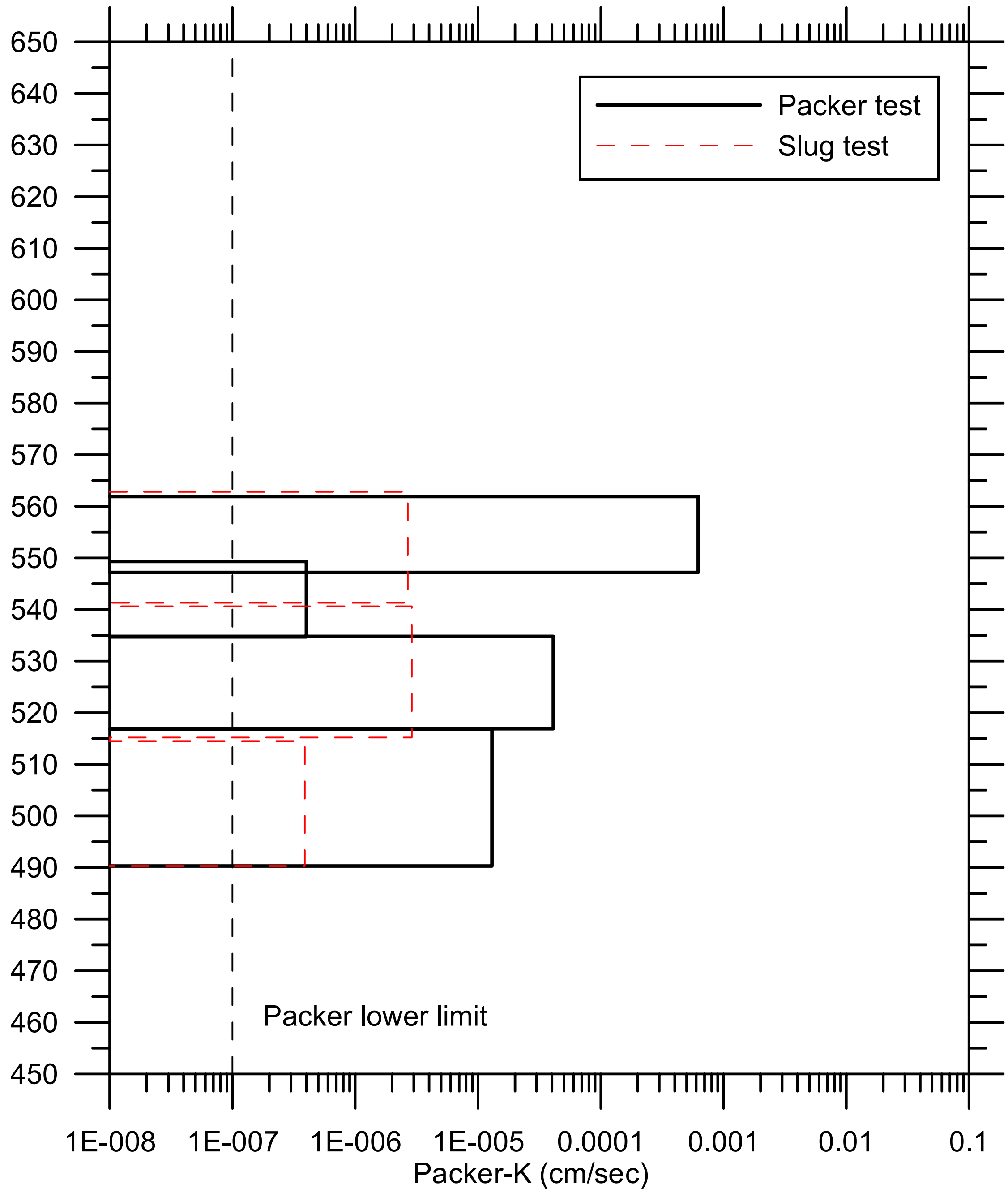
G2L 1.15E-004 Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

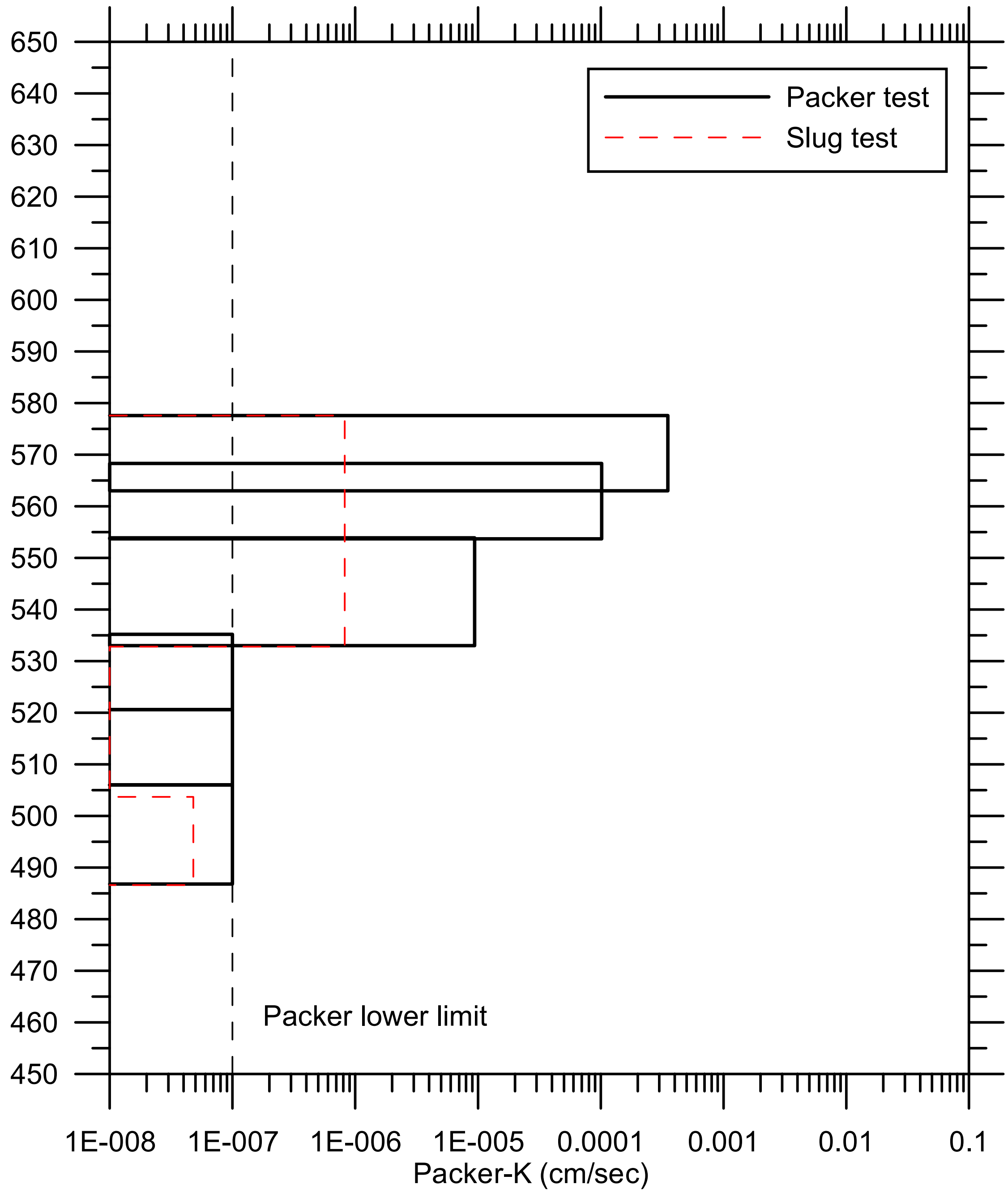
**Figure 6** - Slug Test Hydraulic Conductivities - Lower Zone

28-Jun-2001

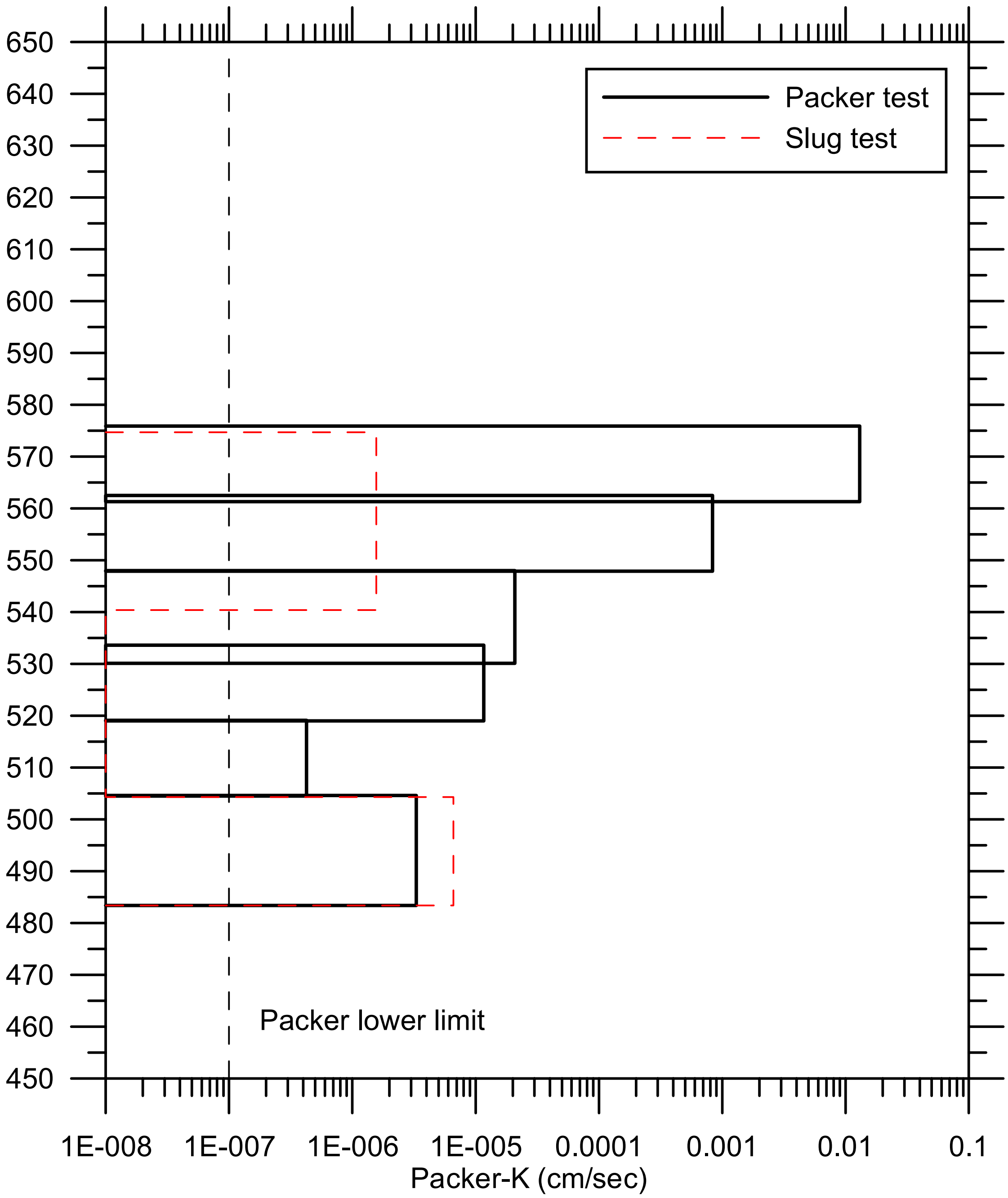
AFW-1 Packer testing, July 1991

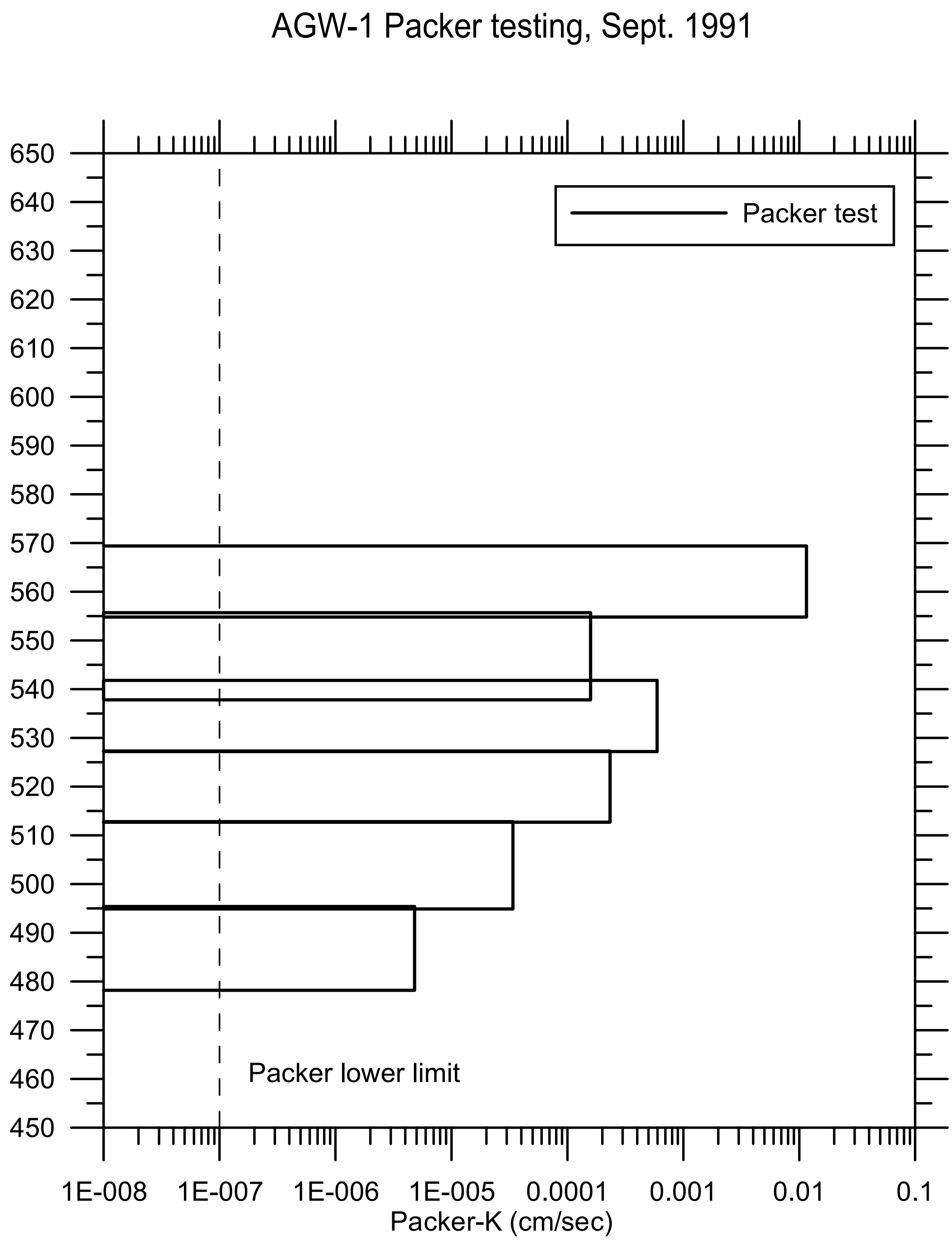


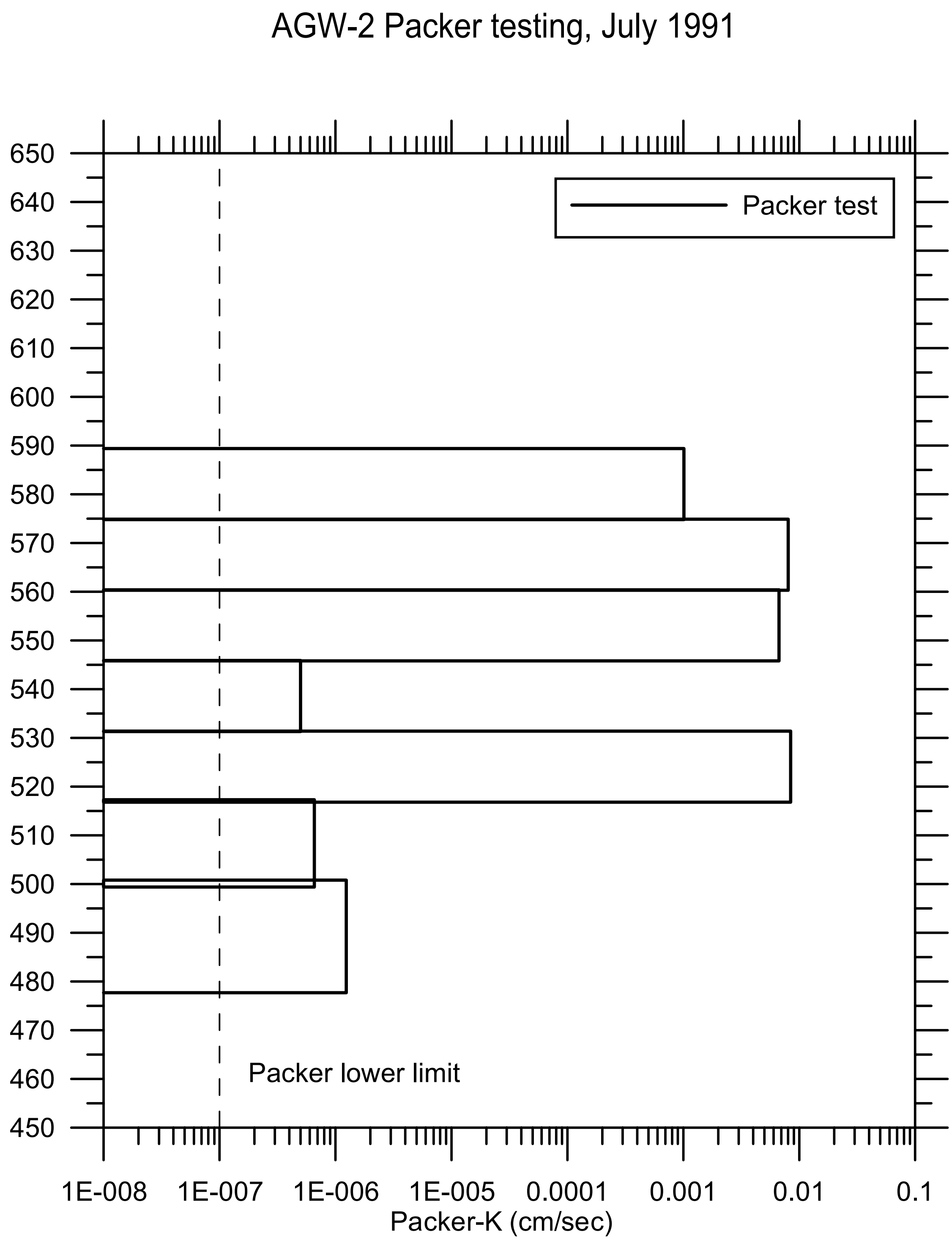
AFW-2 Packer testing, July 1991



# AFW-3 Packer testing, July 1991




AGW-1 Packer testing, Sept. 1991
Packer test
Packer lower limit
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)



AGW-2 Packer testing, July 1991
Packer test
Packer lower limit
650
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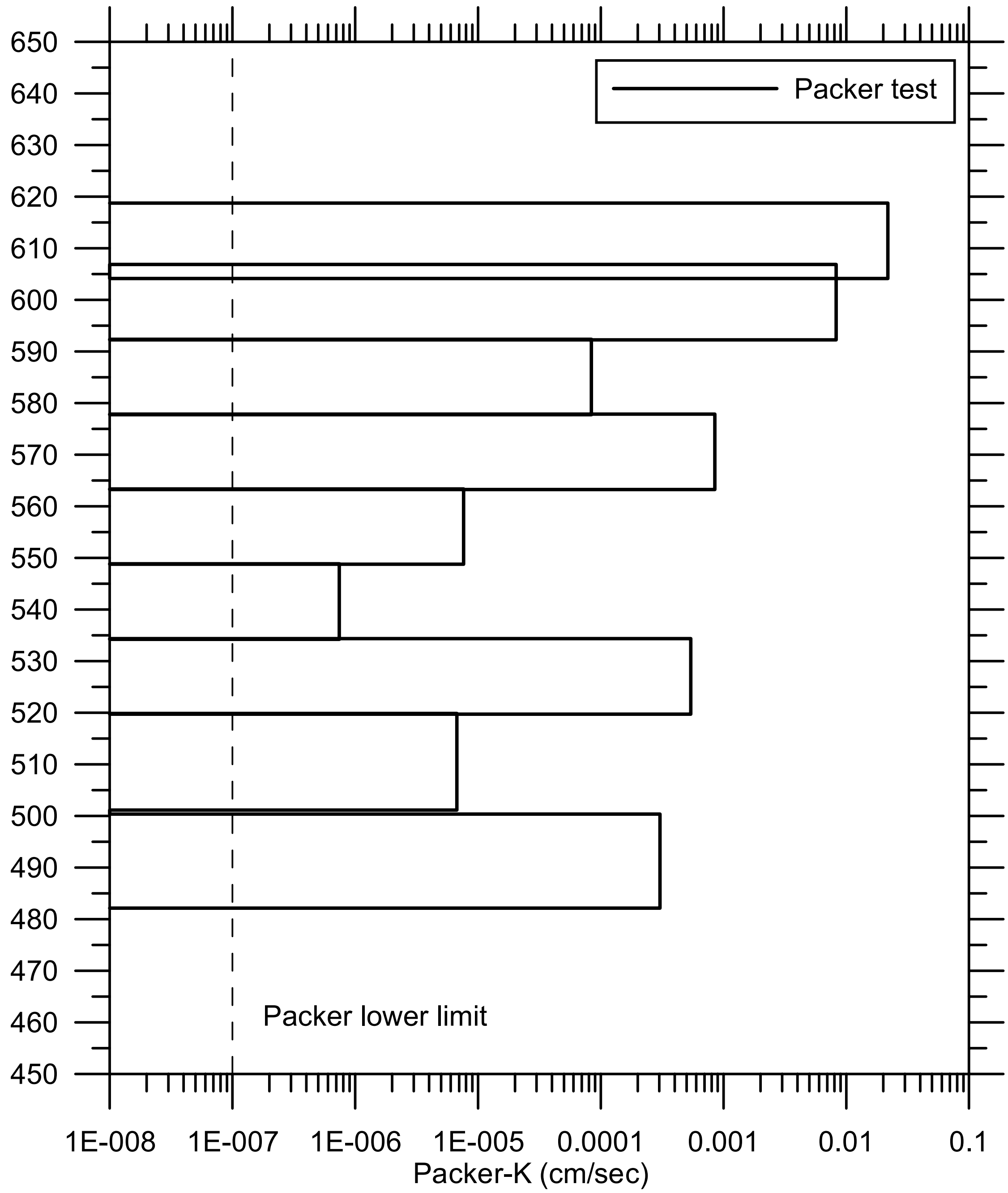
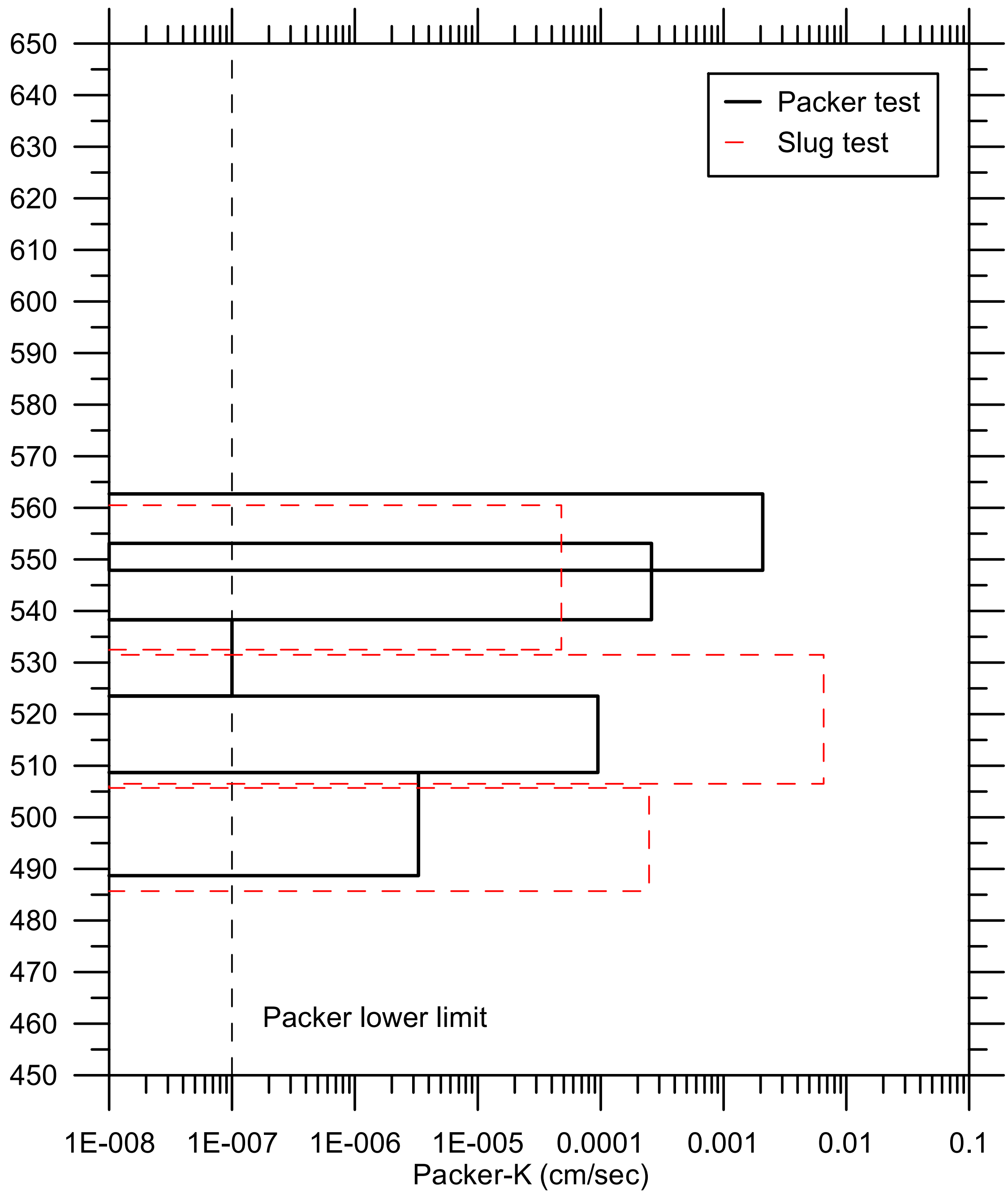
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)

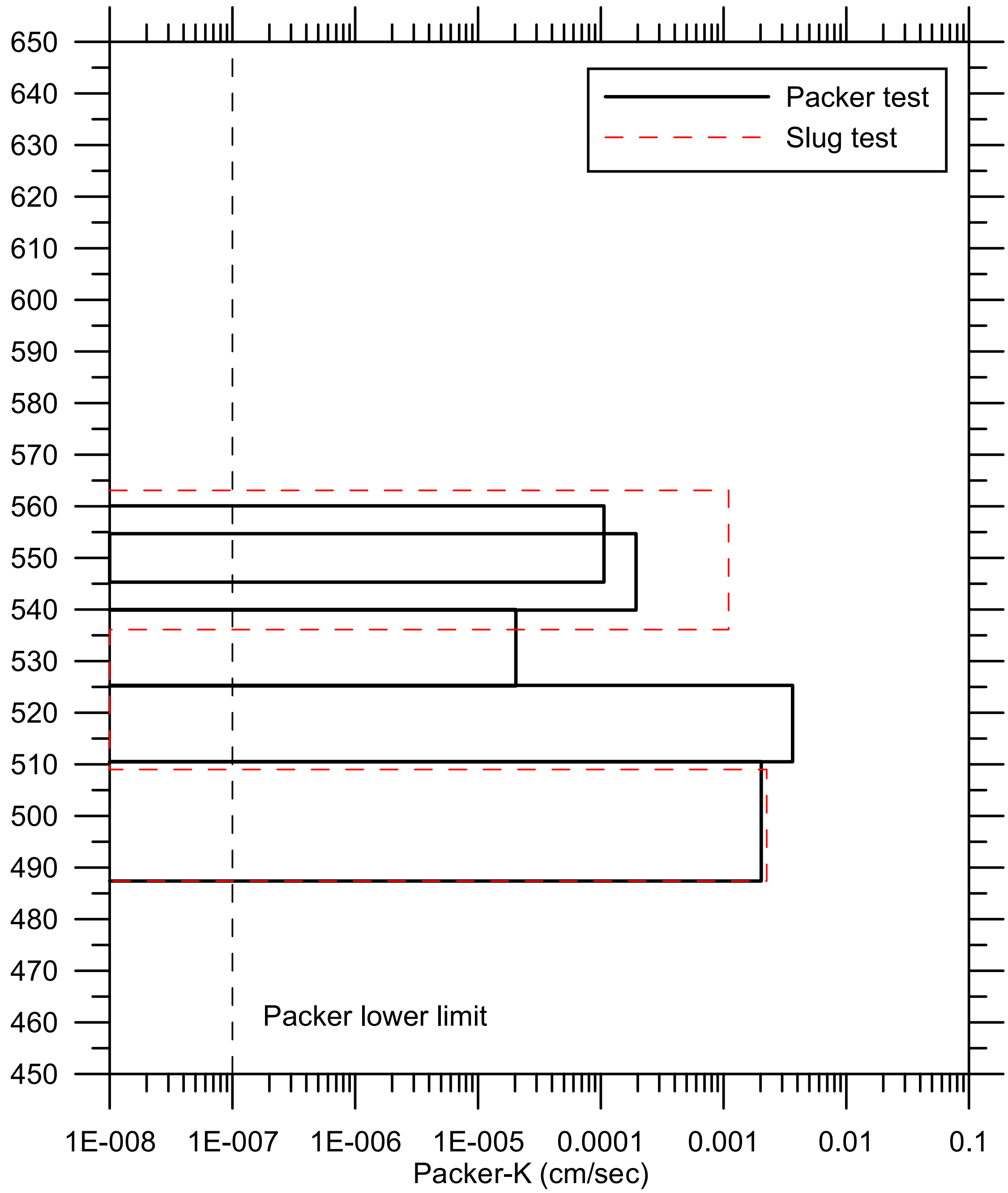
AGW-3 Packer testing, Sept. 1991



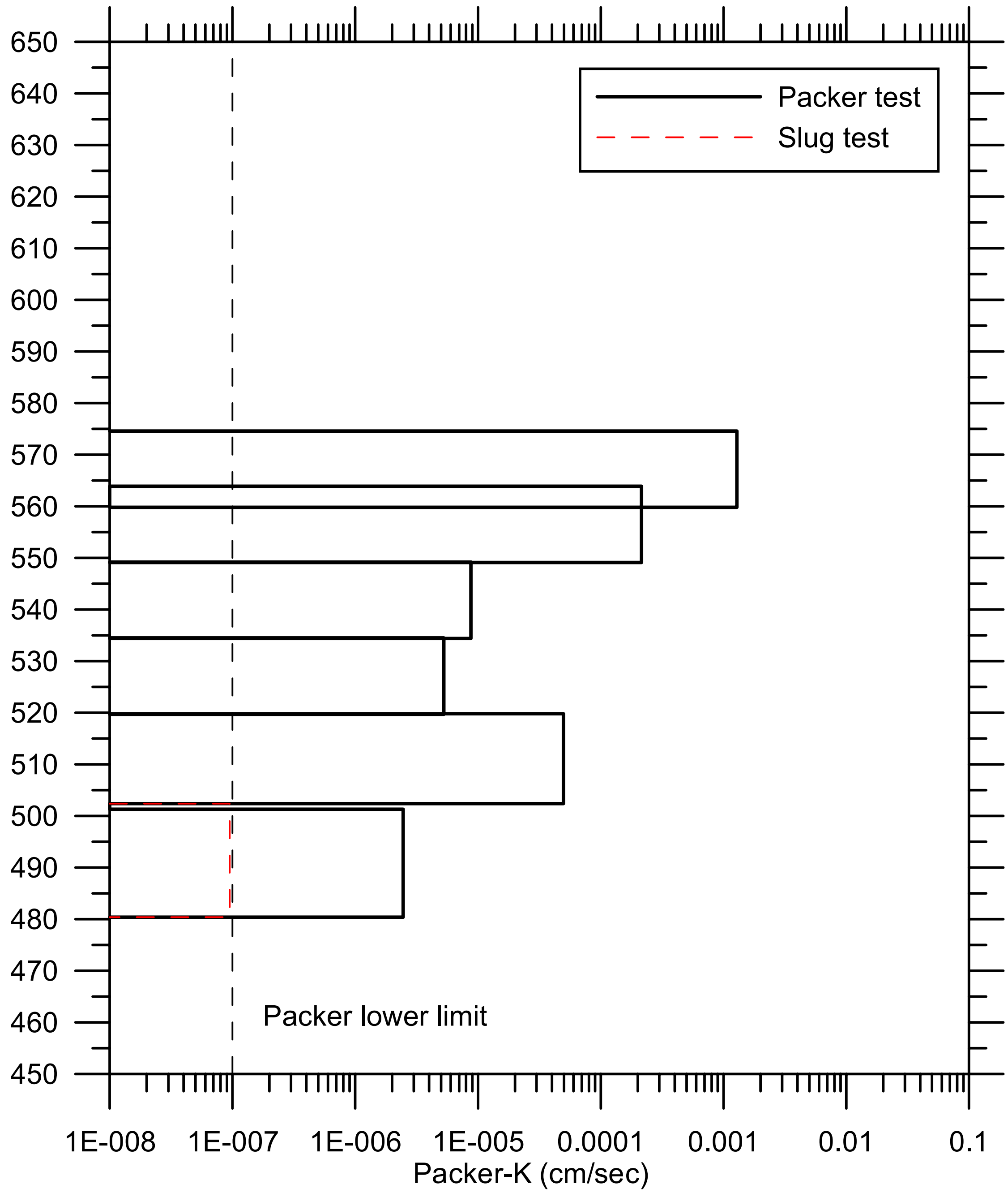
B1 Packer testing, March 1991

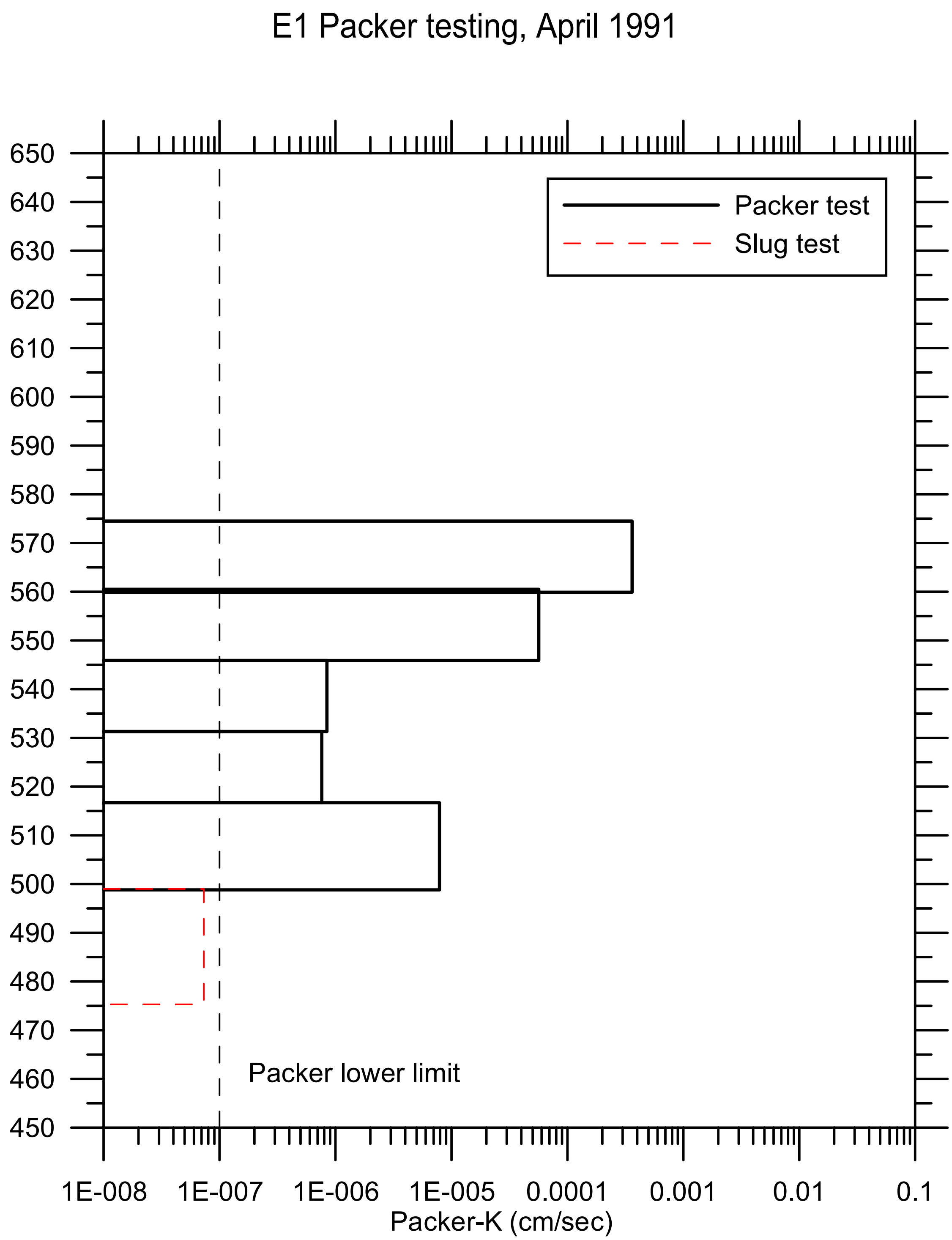


C1 Packer testing, Jan. 1991



D2 Packer testing, April 1991





E1 Packer testing, April 1991
650
640
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620
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600
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560
550
540
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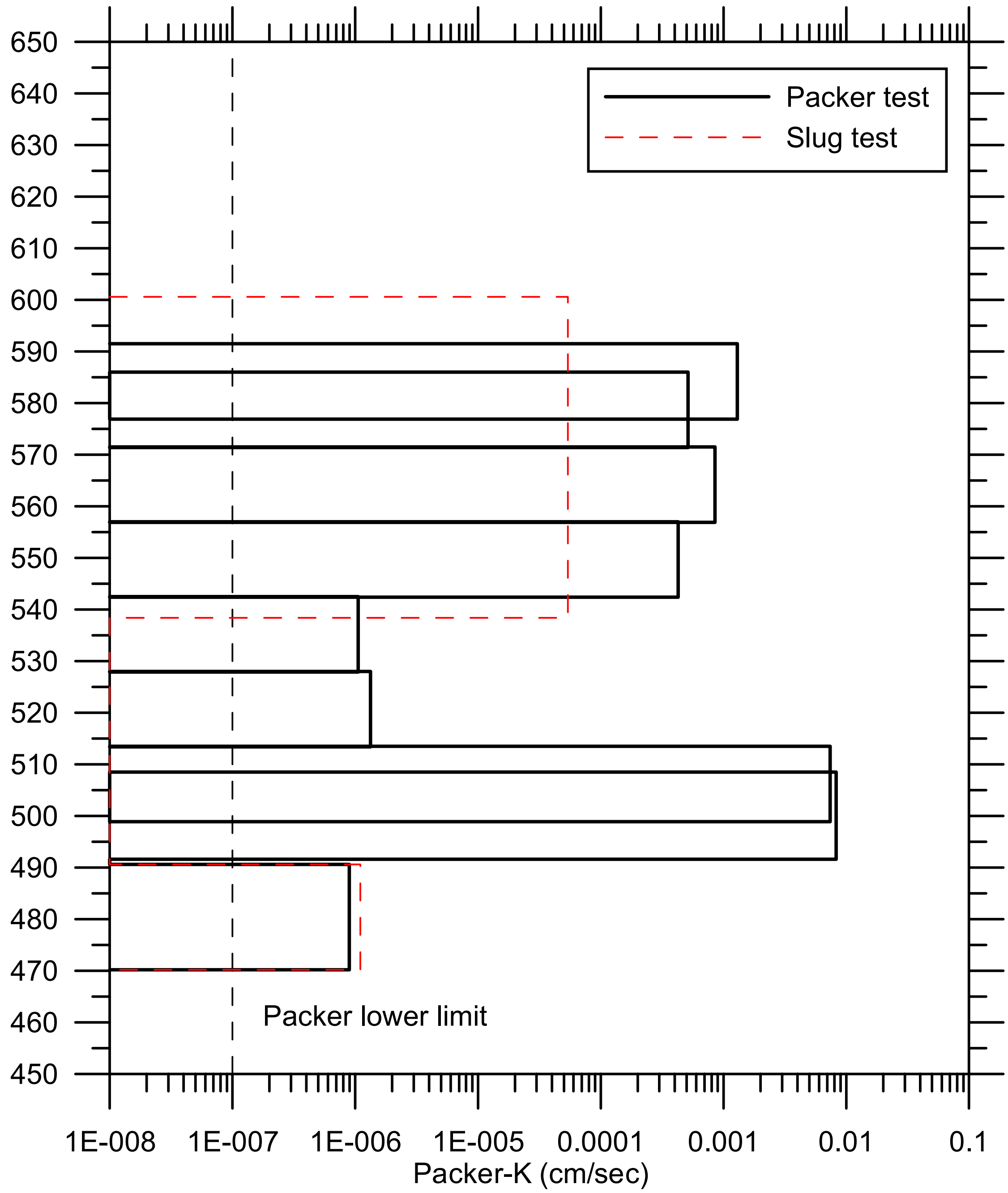
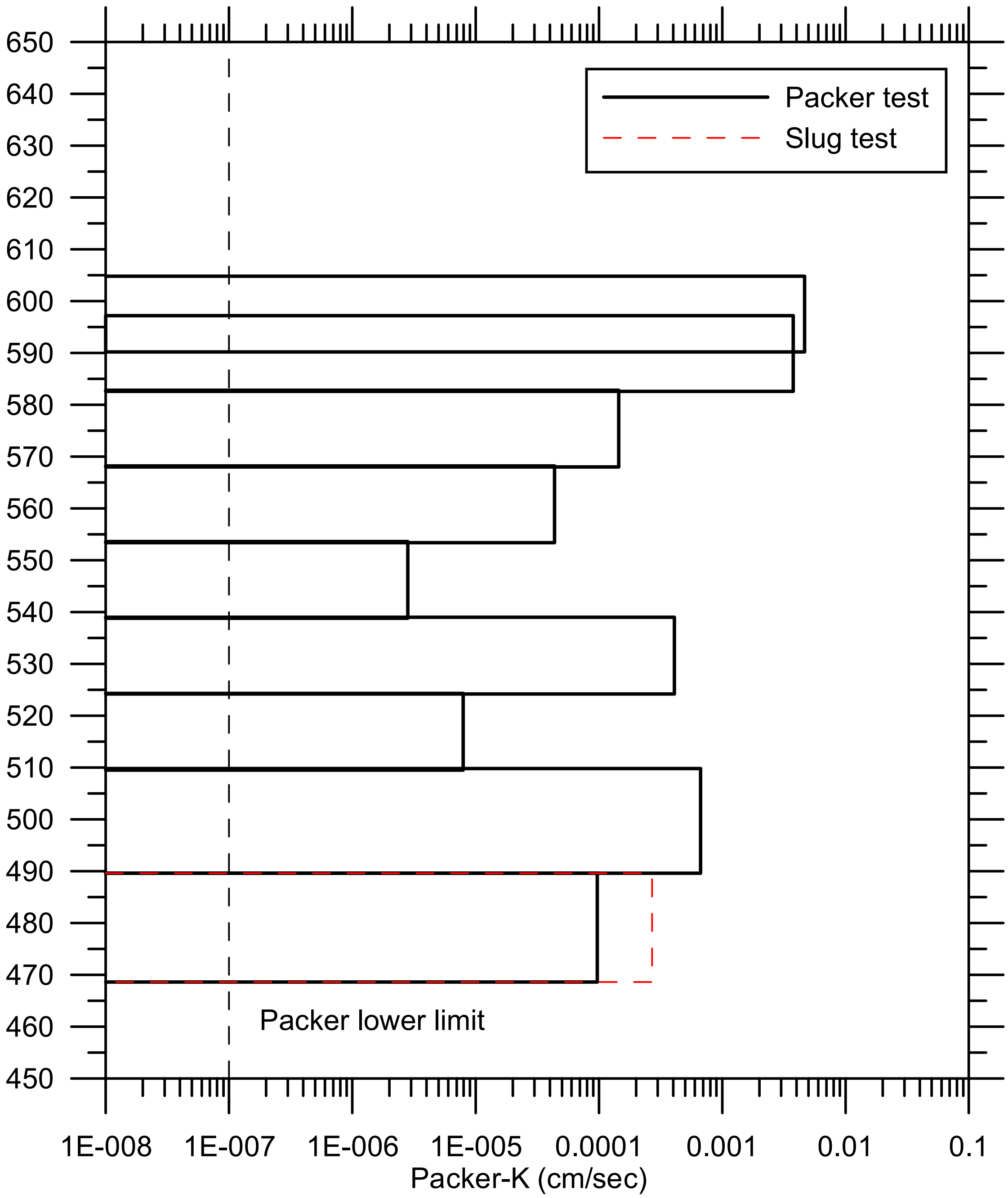
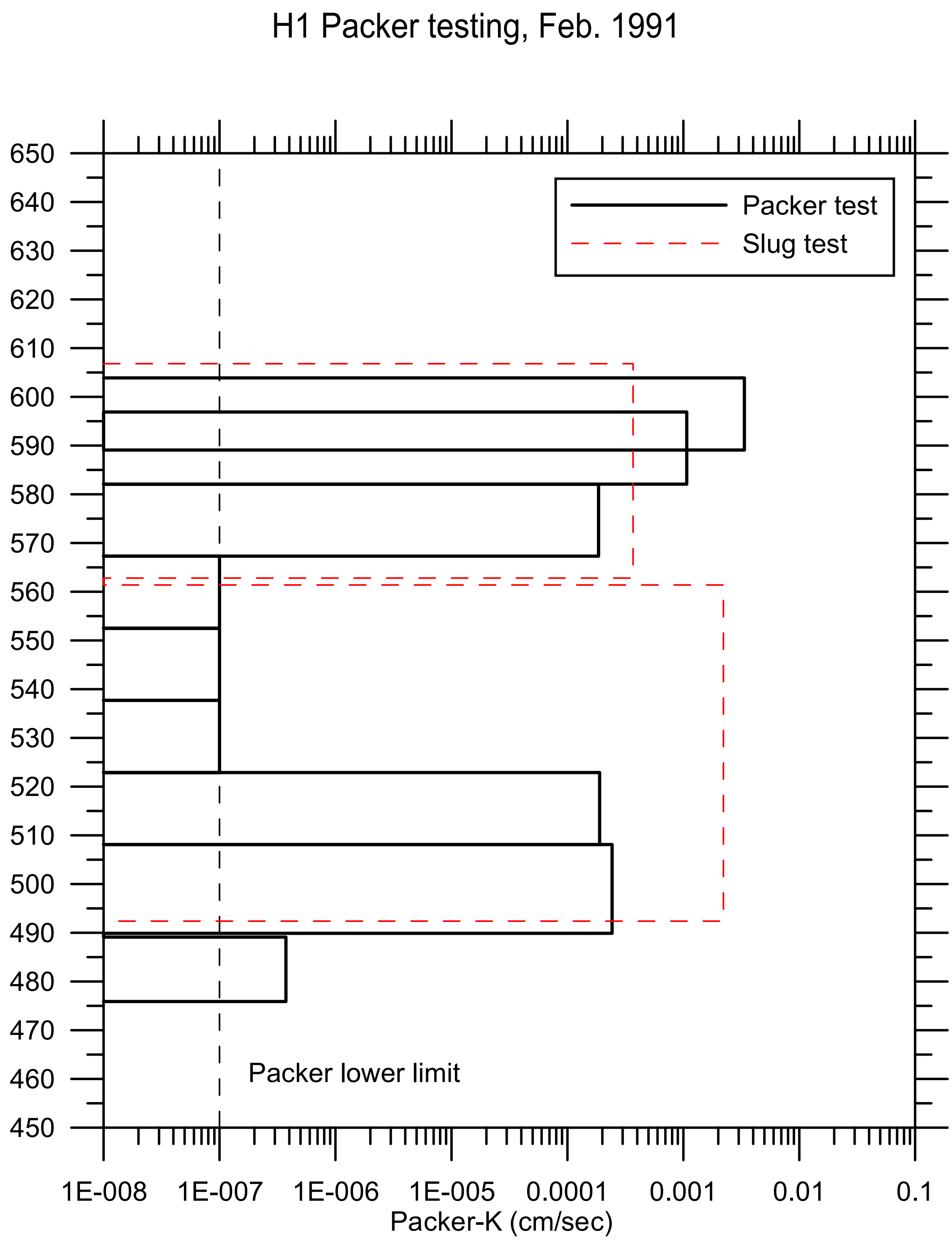
520
510
500
490
480
470
460
450
Packer test
Slug test
Packer lower limit
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)

F1 Packer testing, Aug. 1991



G1 Packer testing, Feb. 1991





H1 Packer testing, Feb. 1991
Packer test
Slug test
Packer lower limit
650
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560
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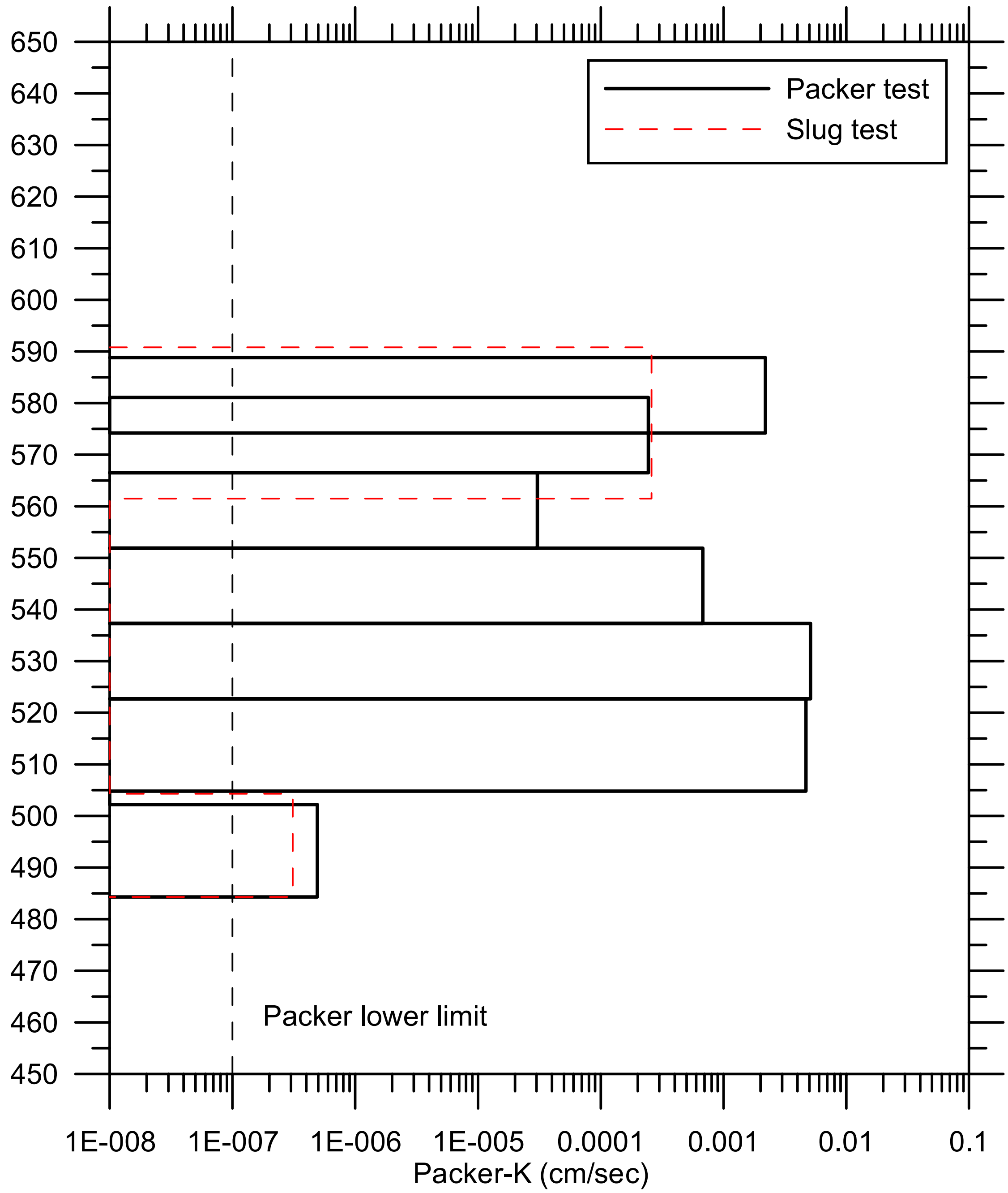
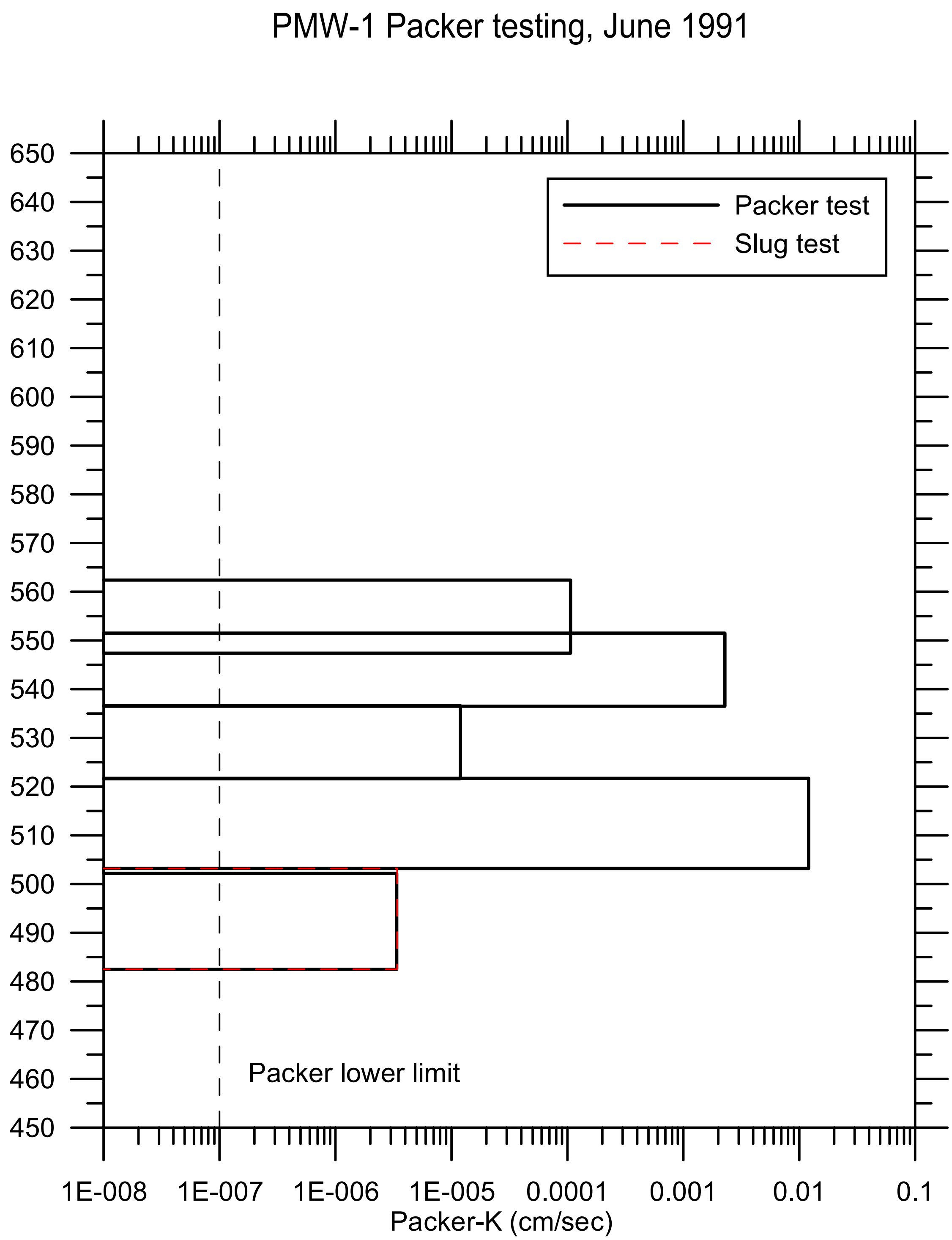
530
520
510
500
490
480
470
460
450
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)

J1 Packer testing, March 1991




PMW-1 Packer testing, June 1991
Packer test
Slug test
Packer lower limit
650
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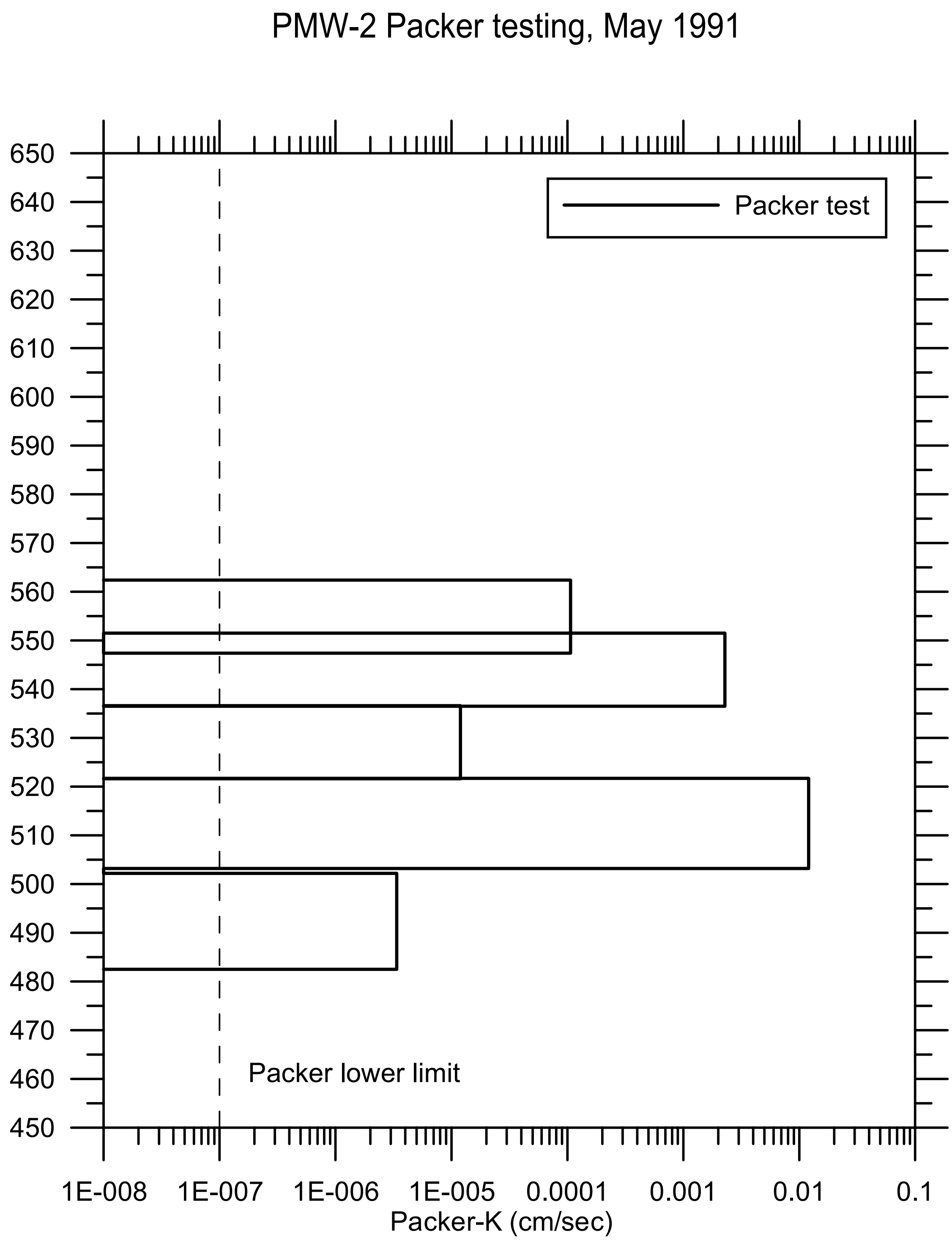
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)


PMW-2 Packer testing, May 1991
Packer test
Packer lower limit
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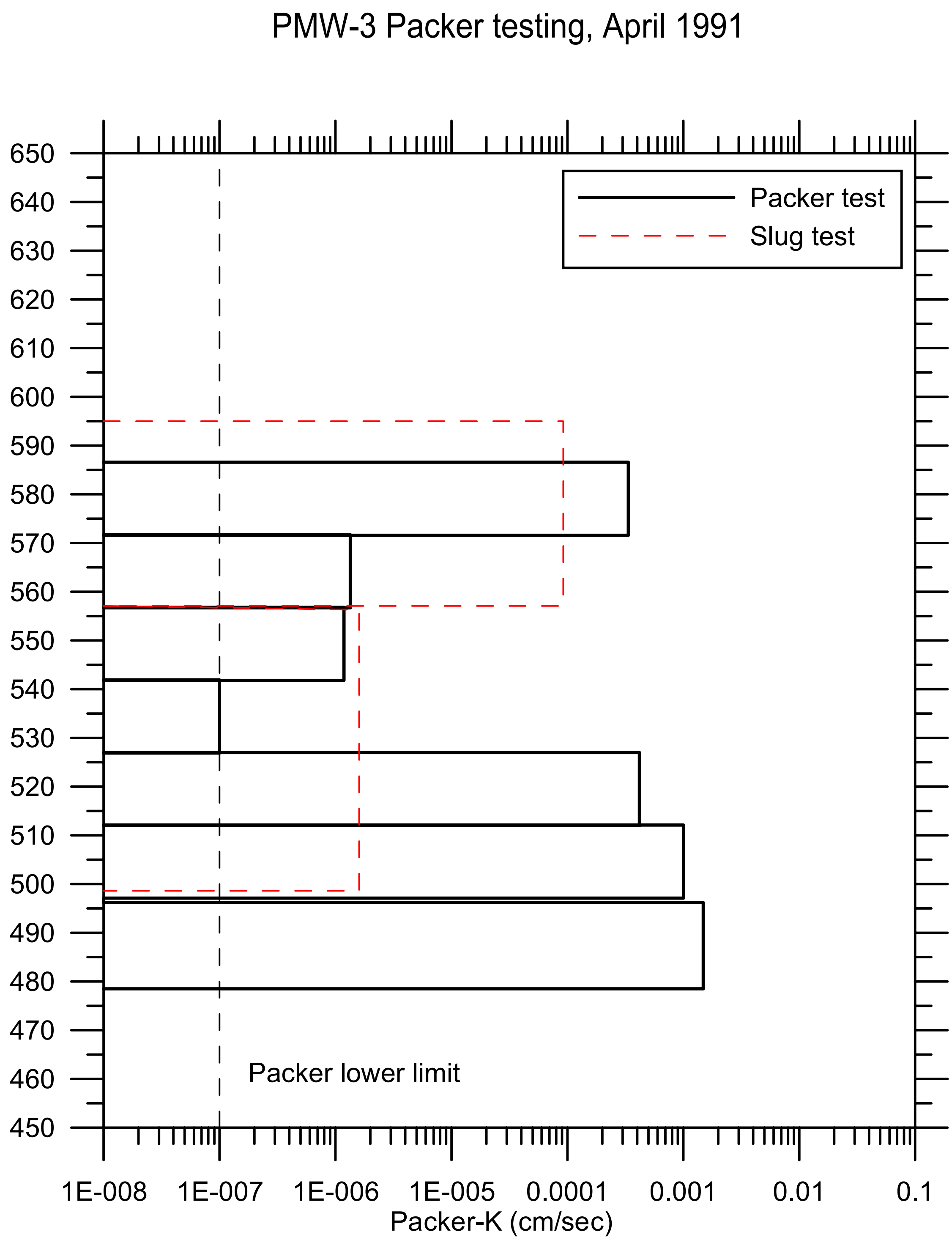
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)


PMW-3 Packer testing, April 1991
Packer test
Slug test
Packer lower limit
650
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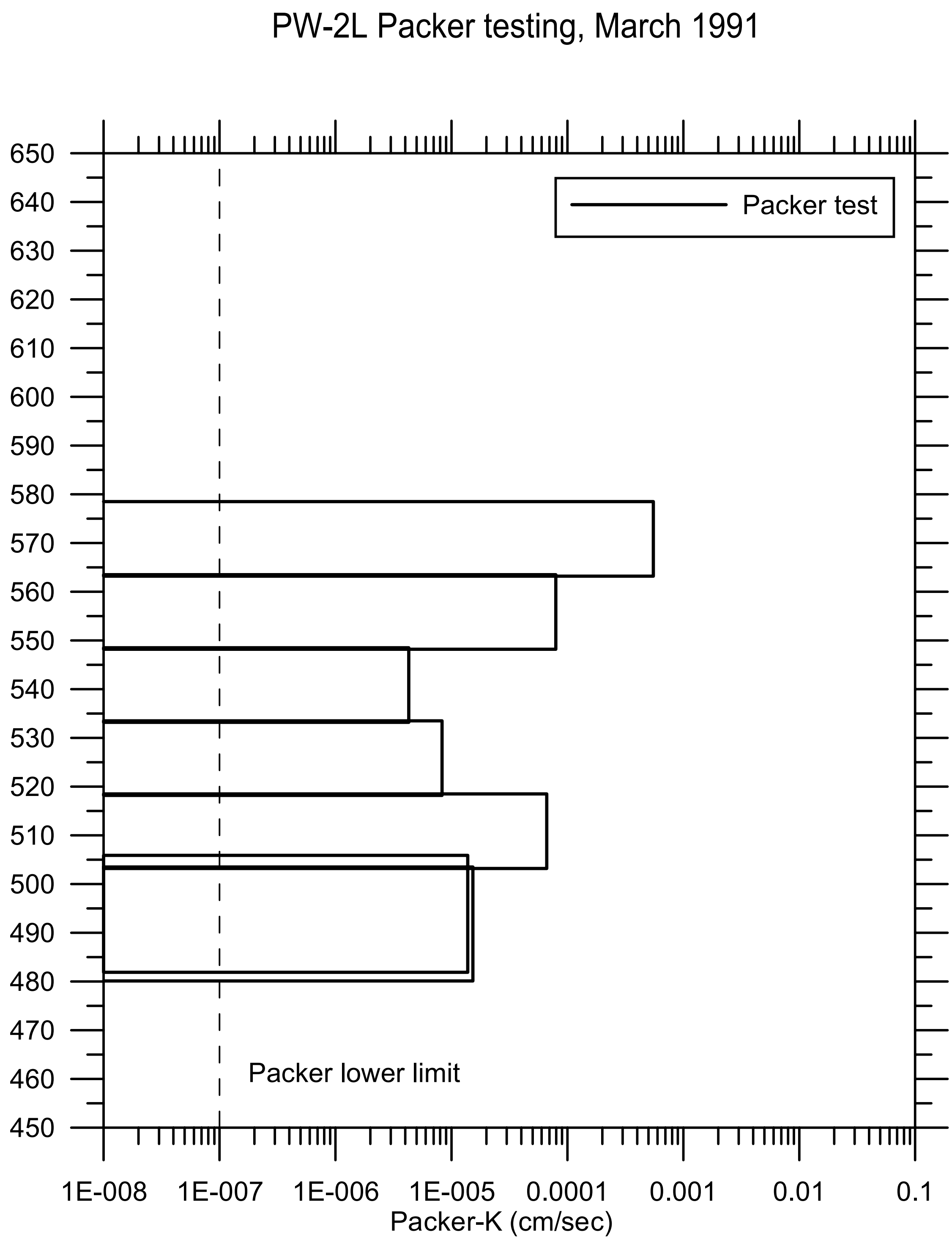
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)


PW-2L Packer testing, March 1991
Packer test
Packer lower limit
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490
480
470
460
450
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)

PW-3L Packer testing, Feb. 1991