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Occidental Chemical Corporation

DETERMINATION OF APPROPRIATE MONITORING INTERVALS

BEDROCK MONITORING WELL NESTS

BUFFALO AVENUE PLANT
SUPPLEMENTAL DATA COLLECTION PROGRAM

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BUFFALO AVENUE PLANT SUPPLEMENTAL DATA COLLECTION PROGRAM

January 1989
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CONESTOGA-ROVERS & ASSOCIATES

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1.0 INTRODUCTION

The Supplemental Data Collection Program (SDCP) requires the installation of sixteen bedrock monitoring well nests as located on Figure 1. The Site Operations Plan (SOP), which is included as Appendix A of the SDCP, specifies that each bedrock well nest will consist of four installations as follows:

a) one well to screen the upper weathered rock, which is estimated to be 15 feet thick;

b) one well to screen from the mid-section of the Gasport to the top of the Rochester Shale; and

c) two wells to monitor all of the waterbearing zones between (a) and (b).

Based upon the information obtained during the S-Area Bedrock Survey and confirmed during the initial injection testing performed on the deep SDCP bedrock wells, Occidental Chemical Corporation (OCC) believes that the bedrock interval extending from the mid-section of the Gasport to the top of the Rochester Shale is typically not a waterbearing zone. Therefore, the installation of a monitoring well into this unit is generally not necessary. OCC believes that the need for a well in this unit should be evaluated on an individual basis at each bedrock well nest. OCC also believes that it is appropriate at this point to review the installation procedures for the deep bedrock wells to make use of this identified and confirmed hydraulic condition in the interest of expediting future installations.

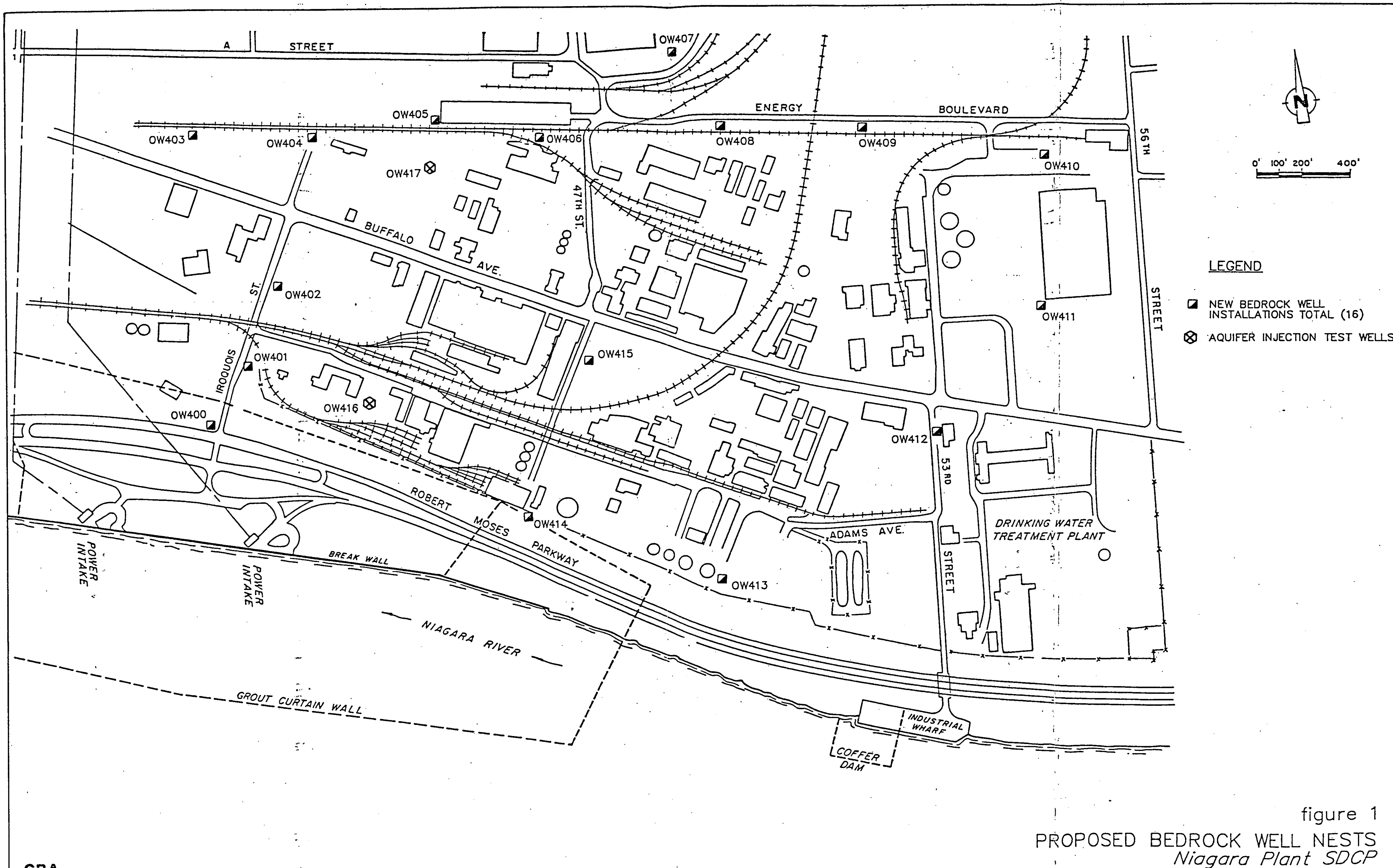

figure 1
PROPOSED BEDROCK WELL NESTS
Niagara Plant SDCP

2583-20/01/89-4-D-0

The purposes of this report are to:

- present an appropriate definition of a waterbearing interval;
- present the injection test data collected to date which shows that the Gasport/Decew Formation is not a waterbearing unit;
- recommend a procedural change to expedite the drilling/well installation program; and
- recommend appropriate bedrock monitoring intervals for the four locations where the deep bedrock well has been completed.

It is anticipated that discussions presented in this report will also be appropriate for subsequent bedrock installations and thereby expedite the selection of monitoring intervals at these installations as they are completed.

2.0 BACKGROUND INFORMATION

During the S-Area Remedial Program, twenty deep bedrock survey wells were installed to the top of the Rochester Formation. As part of the installation procedure, a series of one-hour pump tests were conducted for each 15-foot bedrock interval encountered. The subsequent data from these pump tests was used to evaluate the waterbearing characteristics of each 15-foot bedrock interval. A 15-foot interval was defined as being waterbearing where such an interval was capable of providing at least 0.5 gallons per minute for a 5-inch diameter borehole or an equivalent thereof.

Table 1 summarizes the waterbearing characteristics versus the stratigraphy in which the test was conducted. Although waterbearing intervals were encountered in virtually all bedrock formations present, there appears to be three distinct strata with a high frequency of waterbearing occurrence. These strata are:

i) the top 30 feet of the bedrock which was waterbearing 95 to 100 percent of the time;

ii) the bedrock intervals 60 to 75 and 75 to 90 feet below the top of the bedrock which were waterbearing 70 and 45 percent of the time respectively; and

iii) the Goat Island Formation which was waterbearing 86 percent of the time.

Oak Orchard ← Top of Rock
Eramosa
Goat Island
Gasport
Decew
Rochester

TABLE 1

BEDROCK WATERBEARING CHARACTERISTICS
STRATIGRAPHIC BREAKDOWN
S-AREA REMEDIAL PROGRAM

BEDROCK INTERVAL DESCRIPTION	*NO. OF TESTS CONDUCTED*	*WATERBEARING INTERVAL*	
		NUMBER	*% OF TESTS*
All tests conducted	226	101	45
Top of 15.0 ft of bedrock	20	20	100
Bedrock interval 15.0-30.0 ft from top of bedrock	20	19	95
Bedrock interval 30.0-45.0 ft from top of bedrock	20	11	55
Bedrock interval 45.0-60.0 ft from top of bedrock	20	4	20
Bedrock interval 60.0-75.0 ft from top of bedrock	20	14	70
Bedrock interval 75.9-90.0 ft from top of bedrock	20	9	45
Intervals straddling Eramosa/Oak Orchard Contact	18	2	11
Intervals conducted in Eramosa Formation	4	1	25
Intervals straddling Eramosa/Goat Island	18	5	28
Intervals conducted in Goat Island Formation	7	6	86
Intervals straddling Goat Island/Gasport	18	5	28
Intervals conducted in Gasport Formation	16	3	19
Intervals straddling Gasport/Decew Contract and Decew/Rochester Contact	28	2	7

Initially, the S-Area deep bedrock wells were intended to monitor the waterbearing zone in the Gasport/Decew Formation above the top of the Rochester Formation. Referring to Table 1, it can be seen that only five of the 44 tested intervals (11 percent) in the Gasport and Decew Formations were waterbearing. After several deep wells were installed in non-waterbearing intervals in the Gasport and Decew Formations, modifications were made to the well installation procedures. The well casings were installed at shallower depths to attempt to ensure that a waterbearing zone (generally in the Goat Island Formation) was actually being monitored by the deep well installation.

As a result of the initial premise that the wells would monitor the Gasport Formation, seven of the twenty S-Area deep bedrock wells have been closed by grouting to the land surface since the monitored zone was non-waterbearing. Only five of the S-Area deep bedrock wells monitor a waterbearing interval contained in the Gasport or Decew Formations while three other wells have waterbearing intervals straddling the Goat Island and Gasport Formation contact. It should also be noted that two of the Gasport/Decew wells have been postulated to be monitoring an artificially created waterbearing zone. A large gas pocket was encountered during the drilling at OW203 and following gas venting, the static water level dropped significantly. It appears that the water at this depth was introduced into the gas pocket during drilling. The waterbearing zone at OW202 appears to be connected to the zone at OW203 since it exhibits the same characteristics. Consequently, it is likely that only three of the deep bedrock wells monitoring the ~~Gasport/Decew Formations~~ are actually monitoring a waterbearing interval.

3.0 WORK COMPLETED TO DATE

At the time of the writing of this report, two deep SDCP bedrock wells (OW404A and OW411A) have been completed to the top of the Rochester Formation. Injection testing has been performed over the entire bedrock strata from the top of bedrock to the top of the Rochester Formation. In both of these wells, the bedrock interval extending from the middle of the Gasport Formation to the bottom of the Decew Formation was non-waterbearing.

In addition, at two other deep bedrock wells (OW402A and OW410A), injection testing has been completed to the mid-section of the Gasport Formation. Injection testing of the lower Gasport Formation and Decew Formation will take place following enlargement of the NX corehole and installation of a four-inch diameter steel casing in each well. See Figure 2 for the locations of these four wells.

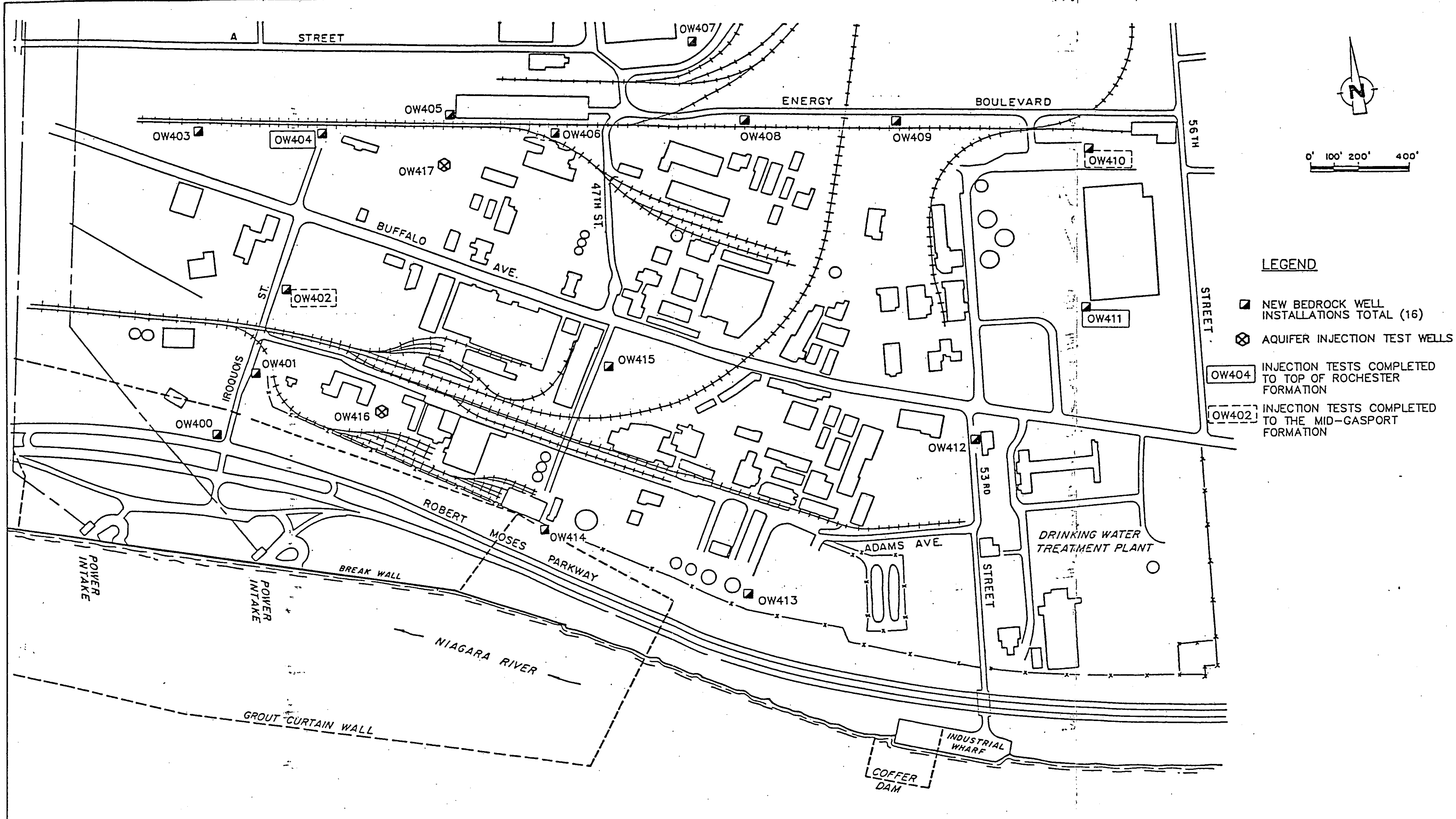

figure 2

COMPLETED INJECTION TEST LOCATIONS
Niagara Plant SDCP

CRA

2583-20/01/89-4-D-0

OCC PLANT SITE. 1/89

$$K = \frac{Q}{LH_o}\left[\frac{1}{2\pi}\ln\left(\frac{R}{r_o}\right)\right]$$

$L = 15'$

$\frac{R}{r_o} = 10$

$H_o = 10'$

Q .3 gpm

~~r_o 3"~~

$= \frac{.3\ gpm}{15' \times 10'} \times \frac{1}{2(\pi)} \ln(10)$

$= \frac{.3\ gpm}{150\ ft^2} \times \frac{.1}{6.28}$ 1

gpm x m/d

$= .002 \times .159 \times .1$

$= 3.1 \times 10^{-4}\ gpm/ft^2 \times 1440\ min/d = \frac{4.46 \times 10^{-1}\ gpd/ft^2}{21,203}$

$= 2.1 \times 10^{-5}$ cm/sec

(1 cm/sec = 21,203 gpd/ft²)

$\frac{1\ gpm}{6.3^{-5}\ m^3/sec} = \frac{.3\ gpm}{X}$

$\frac{6.3}{1} = \frac{x}{.3} = \frac{1.89}{1} = x$ $1.89 \times 10^{-5}\ m^3/sec$

1,000,000 cm² = 1 m³

4.0 DEFINITION OF A WATERBEARING INTERVAL

The SOP defines a waterbearing interval as "a layer of rock up to 15 feet thick which does yield, or could yield, groundwater to an appropriately constructed well at a rate which is the equivalent of 0.5 gallons or more per minute to a 5-inch diameter well or 0.3 gallons or more per minute to a 3-inch diameter well".

One aspect that the SOP definition does not consider is the effect that pressure head/drawdown has on the flow rate to the well. For example, during a pump test program, one 15-foot interval could supply 0.5 gpm with only five feet of drawdown while another 15-foot interval supplying 0.5 gpm may require 50 feet of drawdown. Although both intervals supplied 0.5 gpm, there is an obvious difference in the waterbearing characteristics of the two intervals.

The injection tests conducted for the SDCP take into account the effect that pressure head has on the flow rate to the well. Calculations were made using Hvorslev's equation which is as follows:

$$K = \frac{Q}{L H_o} \left[\frac{1}{2\pi} \ln \left(\frac{R}{r_o} \right) \right]$$

where K = hydraulic conductivity
- Q = flow rate
- L = length of test interval
- H_o = pressure head
- R = radius of influence
- r_o = radius of borehole

Substituting into the above equation some known and assumed values, one can calculate the hydraulic conductivity (K) which is then a function of both the flow rate (Q) and the pressure head (H_o). Using a test interval length of 15 feet, an assumed $\frac{R}{r_o}$ of 10 and a nominal pressure head of 10 feet, a flow rate of 0.3 gpm for a 3-inch diameter borehole is equivalent to a hydraulic conductivity of 5×10^{-5} cm/sec. From the equation it can be seen that any change in the pressure head would result in an inverse change in the hydraulic conductivity (i.e. doubling H_o would reduce K by half).

In summary, the definition of waterbearing status should not be based solely on the flow rate but on the hydraulic conductivity which considers both the flow rate and the pressure head. Therefore, for a 3-inch diameter borehole (which is the diameter of the NX corehole for all the injection tests), any interval which has a hydraulic conductivity greater than 5×10^{-5} cm/sec should be considered waterbearing. If the hydraulic conductivity is less than the 5×10^{-5} cm/sec value, that interval should be considered non-waterbearing. Through a comparison of the hydraulic conductivity data with the measured water levels of the specific test intervals, it is possible to determine which of the intervals are hydraulically connected and would therefore be expected to have similar chemical characteristics. Thus the hydraulic information will be used to determine which 15-foot waterbearing intervals should be included in a specific monitoring interval for which an individual well is required.

It should also be noted at this time that the grouting of casings and bedrock formations is presently being conducted to a

1×10^{-5} cm/sec standard. This further justifies the hydraulic conductivity standard of 5×10^{-5} cm/sec to determine waterbearing status.

5.0 DISCUSSION OF INJECTION TEST DATA

As mentioned earlier in Section 3, injection tests have been conducted at four bedrock installations. The results of the injection tests for each of the four deep bedrock wells are presented on Tables 2 through 5. The overall results indicate a wide range of hydraulic conductivities over the depth of each well as follows:

OW404A 2.0×10^{-7} to 7.0×10^{-1} cm/sec

OW411A 5.0×10^{-7} to 5.4×10^{-2} cm/sec

OW402A 3.9×10^{-6} to 6.7×10^{-1} cm/sec

OW410A 2.1×10^{-6} to 9.4×10^{-3} cm/sec

Following the previous discussions regarding the definition of waterbearing, a more complete representation of the hydraulic characteristics of a bedrock interval is its hydraulic conductivity. Based on the injection test results, the calculations in Section 4 and the S-Area bedrock survey information, it is suggested that a waterbearing unit be defined as a unit with a hydraulic conductivity of 5×10^{-5} cm/sec. The length of the test (for 3" φ bore) interval is not specifically included in this new definition, as Hvorslev's formula includes this factor in the calculations of hydraulic conductivity.

To illustrate the appropriateness of the 5×10^{-5} cm/sec guideline for waterbearing status, one can refer to Tables 2 through 5. Of the 39 intervals listed, 26 would be considered waterbearing and only 13 are therefore non-waterbearing. As a reference point to evaluate the appropriateness of the assumption in the calculations, Table 1 indicates that during the S-Area pump testing program, only 45 percent of the tested

TABLE 2

HYDRAULIC CONDUCTIVITY
(cm/sec)
OW404A

INTERVAL	*FEET BELOW GROUND SURFACE*	*FEET BELOW TOP BEDROCK*	*HYDRAULIC[1] CONDUCTIVITY (cm/sec)*	*DEPTH TO STATIC WATER LEVEL (ft.BGS)*	*DATE*
A	21.5 - 36.5	0 - 15.0	water meter inoperable[3]		
B	36.4 - 51.7	14.9 - 30.2	9.8×10^{-4} - 1.8×10^{-3}	22.16	11/29/88
B-C	42.7 - 58.0	21.2 - 36.5	9.1×10^{-4} - 1.8×10^{-3}	23.26	11/29/88
C-D	57.7 - 73.0	36.2 - 51.5	9.7×10^{-4} - 1.2×10^{-3}	23.29	11/28/88
D-E	72.7 - 88.0	51.2 - 66.5	6.0×10^{-2} - 1.0×10^{-1}	23.75	11/28/88
E-F	87.7 - 103.0	66.2 - 81.5	1.7×10^{-1} - 7.0×10^{-1}	23.55	11/28/88
F-G	102.7 - 118.0	81.2 - 96.5	5.7×10^{-2} - 7.1×10^{-2}	21.74	11/23/88
G-H	117.7 - 133.0	96.2 - 111.5	2.0×10^{-7} - 7.9×10^{-7}	10.45*	11/23/88
			(6.4×10^{-6} hydrofracture)[2]		
H-I	132.7 - 148.0	111.2 - 126.5	1.0×10^{-5} - 3.2×10^{-5}	20.18	11/23/88
I-J	147.6 - 166.3	126.1 - 144.8	5.6×10^{-6} - 2.1×10^{-5}	23.33	11/08/88
			(5.5×10^{-5} - 7.8×10^{-5} hydrofracture)[2]		
J-K	166.5 - 186.5	145.0 - 165.0	3.1×10^{-5} - 4.9×10^{-5}**	11.44**	12/14/88

(~200 gallons returned to surface at completion of test when packer was released. 398.5 gallons were injected during entire test).

* Water level may not have reached static conditions after packer inflation due to low hydraulic conductivity.
** Hydraulic conductivity estimates do not account for water returned to surface.
1 Hydraulic characteristics calculated assuming $R/r_o = 10$
2 Injection pressures caused fractures in rock to expand, thereby increasing magnitude of hydraulic conductivity estimates.
3 Interval will be tested in an adjacent corehole.

TABLE 3

HYDRAULIC CONDUCTIVITY
(cm/sec)
OW411A

INTERVAL	*FEET BELOW GROUND SURFACE*	*FEET BELOW TOP BEDROCK*	*HYDRAULIC[1] CONDUCTIVITY (cm/sec)*	*DEPTH TO STATIC WATER LEVEL (ft.BGS)*	*DATE*
A	26.1 - 44.0	0 - 17.9	Not Tested[2]		
B	44.0 - 59.3	17.9 - 33.2	1.4×10^{-3} - 1.6×10^{-3}	22.84	12/09/88
C	59.0 - 74.3	32.9 - 48.2	3.2×10^{-5} - 4.2×10^{-5}	19.69	12/08/88
D	74.0 - 89.3	47.9 - 63.2	1.1×10^{-4} - 2.1×10^{-4}	19.83	12/08/88
E	89.0 - 104.3	62.9 - 78.2	1.2×10^{-2} - 5.4×10^{-2}	21.44	12/08/88
F	104.0 - 119.3	77.9 - 93.2	1.7×10^{-5} - 2.9×10^{-5}	21.45	12/07/88
G	119.0 - 134.3	92.9 - 108.2	1.2×10^{-3} - 1.6×10^{-3}	23.68	12/07/88
H	134.0 - 149.3	107.9 - 123.2	1.0×10^{-3} - 1.2×10^{-3}	27.44	12/07/88
I-J	149.0 - 167.6	122.9 - 141.5	1.2×10^{-4} - 1.4×10^{-4}	23.53	12/09/88
J-K-L	167.6 - 199.6	141.5 - 173.5	5.0×10^{-7} - 1.0×10^{-6}	-3.84*	12/21/88

* Water level may not have reached static conditions after packer inflation due to hydraulic conductivity.
1 Hydraulic conductivities calculated assuming $R/r_o = 10$.
2 Appropriate testing equipment was not available at time of injection testing. Interval will be tested in an adjacent corehole.

TABLE 4

HYDRAULIC CONDUCTIVITY
(cm/sec)
OW402A

INTERVAL	*FEET BELOW GROUND SURFACE*	*FEET BELOW TOP BEDROCK*	*HYDRAULIC[1] CONDUCTIVITY (cm/sec)*	*DEPTH TO STATIC WATER LEVEL (ft.BGS)*	*DATE*
A	24.6 - 40.0	4.2 - 19.6	2.7×10^{-4} - 3.7×10^{-4}	19.20	03/01/89
B	35.8 - 51.1	15.4 - 30.7	2.3×10^{-4} - 3.0×10^{-4}	15.48	01/12/89
C	50.8 - 66.1	30.4 - 45.7	1.9×10^{-5} - 2.8×10^{-5}	15.60	01/12/89
D	65.8 - 81.1	45.4 - 60.7	3.9×10^{-6}*	15.42	01/12/89
E	80.8 - 96.1	60.4 - 75.7	5.2×10^{-2} - 6.7×10^{-1}	17.38	01/11/89
F	95.8 - 111.1	75.4 - 90.7	1.6×10^{-4} - 2.8×10^{-4}	13.06	01/11/89
G	110.8 - 126.1	90.4 - 105.7	1.1×10^{-4} - 1.2×10^{-4}	14.76	01/11/89
H	125.8 - 141.1	105.4 - 120.7	1.7×10^{-4} - 2.4×10^{-4}	12.31	01/10/89
I	141.1 - 159.7	120.7 - 139.3	3.9×10^{-5} - 5.2×10^{-5}	13.81	01/10/89

1 Hydraulic conductivities calculated assuming $R/r_0 = 10$

* Flow was only measurable at maximum injection pressure therefore only one hydraulic conductivity estimate was calculated.

TABLE 5

HYDRAULIC CONDUCTIVITY
(cm/sec)
OW410A

INTERVAL	*FEET BELOW GROUND SURFACE*	*FEET BELOW TOP BEDROCK*	*HYDRAULIC[1] CONDUCTIVITY (cm/sec)*	*DEPTH TO STATIC WATER LEVEL (ft.BGS)*	*DATE*
A	25.7 - 40.7	0 - 15.0	9.3×10^{-5} - 1.5×10^{-4}	17.84	12/21/89
B	41.3 - 56.6	15.6 - 30.9	2.5×10^{-4} - 3.7×10^{-4}	-5.47	01/17/89
C	56.3 - 71.6	30.6 - 45.9	3.9×10^{-6}*	35.87	01/17/89
D	71.3 - 86.6	45.6 - 60.9	5.0×10^{-6} - 9.3×10^{-6}	32.21	01/17/89
E	86.3 - 101.6	60.6- 75.9	5.1×10^{-3} - 9.4×10^{-3}**	39.85	01/17/89
F	101.3 - 116.6	75.6 - 90.9	2.1×10^{-6} - 4.6×10^{-6}	30.22	01/17/89
G	116.3 - 131.6	90.6- 105.9	5.2×10^{-6} - 6.4×10^{-6}	24.41	01/16/89
H	131.3 - 146.6	105.6 - 120.9	9.9×10^{-5} - 2.0×10^{-4}	28.09	01/16/89
I	146.4 - 165.0	120.7 - 139.3	2.1×10^{-4} - 2.8×10^{-4}	52.27***	01/16/89

1 Hydraulic conductivities calculated assuming $R/r_0 = 10$

* At minimum flow rate from injection equipment, transducer pressure was at maximum allowable downhole pressure. Therefore only one value was obtained.

** During injection at intermediate injection rates, transducer pressure fell below initial transducer reading obtained after packer inflation and prior to initiation of injection.

*** Data logger checked prior to start of tests on 01-16-89. Reading of 11.37 p.s.i. was too low. Raised transducer 10 feet. Transducer read change correctly. Similar situation for all tests conducted on 01/16/89 and 01/17/89. Therefore water level data is inaccurate however since transducer read incremental change correctly, the hydraulic conductivity estimates are valid.

intervals were deemed waterbearing. Therefore a criteria which indicates that 67 percent of the bedrock tested to date is waterbearing would seem conservative. In addition, the volume of water available from the 36 percent with hydraulic conductivities less than 5×10^{-5} cm/sec is very small compared to the water available from the intervals with hydraulic conductivities ranging from 5×10^{-5} to 7×10^{-1} cm/sec.

Using this new waterbearing definition, one can now refer to Tables 2 through 5 and delineate the waterbearing intervals. These are as follows:

OW404A - All test intervals from 0 to 96.2 feet below top of bedrock indicate a hydraulic conductivity greater than 5×10^{-5} cm/sec. All the remaining test intervals from 96.2 feet to the top of the Rochester Formation have hydraulic conductivities less than 5×10^{-5} cm/sec.

OW411A - The data indicates three zones with hydraulic conductivities in excess of 5×10^{-5} cm/sec (0 - 32.9, 48.2 - 77.9 and 93.2 - 141.5 feet below the top of bedrock). These waterbearing zones are separated by zones with hydraulic conductivities less than 5×10^{-5} cm/sec at 32.9 - 48.2, 77.9 - 93.2 and 141.5 - 173.5 feet below the top of bedrock.

OW402A - The data indicates that the bedrock zones from 0 to 30.4 and 60.7 to 120.7 feet below the top of bedrock have hydraulic conductivities greater than 5×10^{-5} cm/sec and are thus considered waterbearing. The remaining test intervals from

30.4 - 60.7 feet below the top of bedrock exhibit hydraulic conductivities less than 5×10^{-5} cm/sec. The lower portion of the Gasport Formation has not yet been tested as the drilling is not complete.

OW410A - This installation appears to contain three distinct waterbearing zones with hydraulic conductivities in excess of 5×10^{-5} cm/sec (0 -30.6, 60.9 -75.6, and 105.9 - 139.3 feet below top of bedrock). The zones between these depths (30.6 - 60.9 and 75.6 - 105.9 feet below top of bedrock) have markedly different hydraulic conductivities (less than 5×10^{-5} cm/sec), resulting in their definition as non-waterbearing. The lower portion of the Gasport Formation has again not yet been tested.

The distinction between waterbearing and non-waterbearing zones were made strictly on the hydraulic conductivities of each test interval. In most cases, these distinctions can be verified by comparing the static water levels of each test interval. Waterbearing zone test intervals which are hydraulically connected are expected to have similar static water levels. Many times, the subsequent non-waterbearing zones and next waterbearing zones indicate different static water levels. When using the static water level data, attention should be paid to the date of data collection.

6.0 RECOMMENDATIONS FOR MONITORING INTERVALS

To determine the appropriate intervals to be monitored at each bedrock well nest, the previous discussions regarding the waterbearing zones will be the primary source of information. To aid in the decision process, Table 6 presents the presently available bedrock stratigraphic information for each well. This will help to correlate the choice of waterbearing zones to the S-Area information presented in Section 2 which indicated three distinct waterbearing strata. The recommended monitoring intervals also need to address the intent of the criteria set out in the SOP as presented in Section 1.

The stratigraphic and hydraulic information collected to date from wells OW404A and OW411A make it very clear that similar conditions as those encountered during the S-Area Bedrock Survey will be encountered across the Niagara Plant Site. The one common factor that most affects the SDCP is the prevalence of non-waterbearing intervals in the Gasport and Decew Formations. At both OW404A and OW411A, the deep well installed monitors the lower Gasport/Decew Formation directly above the top of the Rochester Formation. But in both cases, the tested intervals below the bottom of the installed 4-inch diameter casings indicated hydraulic conductivities less than 5×10^{-5} cm/sec by one to two orders of magnitude. These units are definitely non-waterbearing and installation of wells into these units for hydraulic and chemical data collection is not useful. These results substantiate the S-Area data as presented in Table 1, which indicates that the probability of encountering a waterbearing unit in the Gasport and Decew Formations is very low.

TABLE 6

BEDROCK STRATIGRAPHIC SUMMARY
NIAGARA PLANT SDCP

FORMATION	*DEPTHS BELOW TOP OF BEDROCK (feet)*			
	OW404A	*OW411A*	*OW402A*	*OW410A*
Oak Orchard	0-88.4	0-92.4	N/A	0-90.4
Eramosa	88.4-104.9	92.4-116.0	N/A	90.4-108.1
Goat Island	104.9-123.2	116.0-134.1	N/A	108.1-125.0
Gasport	123.2-148.7	134.1-160.8	N/A	N/A
Decew	148.7-156.0	160.8-169.0	N/A	N/A
Rochester	156.0	169.0	N/A	N/A

N/A: The bedrock stratigraphy for wells OW402A and OW410A has not been completed as of the date of this report.

In order to avoid installing additional wells into non-waterbearing formations and to increase the probability of encountering a waterbearing interval at the deepest well in each bedrock well nest, it is proposed that the depth at which the 4-inch diameter casing is set be modified. The 4-inch diameter steel casing should be installed approximately at the depth of the bottom of the Eramosa and top of the Goat Island Formations. This will most likely allow for the monitoring of the waterbearing unit which is generally present in the Goat Island Formation. This modification is similar to the one implemented during the S-Area Remedial Program which resulted in all of the remaining wells becoming operable. This modification will eliminate the well in the Gasport/Decew Formation thus reducing the number of bedrock wells in a nest from four to three.

It is recognized that as a result of the implementation of the above modification, it is possible that two separate waterbearing units may be identified by the injection testing to be present below the bottom of the casing (i.e. a test interval with a hydraulic conductivity exceeding 5×10^{-5} cm/sec is found in both the Goat Island and Gasport/Decew Formations). In such a case, two wells will be installed; one to monitor each of the identified waterbearing intervals in the Goat Island and Gasport/Decew Formations. Consequently, where the Gasport/Decew Formation is waterbearing, a well nest will consist of four wells.

Using the criteria established herein, it is now possible to determine the appropriate intervals to be monitored in the four well nests currently underway. These intervals are discussed in the following subsections.

6.1 WELL NEST OW404

For well nest OW404, the recommended monitoring intervals are as follows:

D well:	0 - 51.2 ft. below top of bedrock
C well:	51.2 - 96.2 ft. below top of bedrock
B well:	not required
A well:	already installed but non-waterbearing (well to be grouted to ground surface)

The SOP specifies that one well be installed to monitor the upper weathered rock. Although the document estimates this depth to be 15 feet, Table 1 shows that in 19 of the 20 S-Area deep bedrock wells, the B zone (15-30 feet below the top of bedrock) was waterbearing and that in 11 of the 20 wells, the C zone (30-45 feet below the top of bedrock) was also waterbearing. In addition, the water quality of waterbearing intervals in the upper 30 - 45 feet of bedrock was also chemically similar in most cases. Since the first three test intervals at OW404A indicate markedly similar hydraulic conductivities, it appears that these three intervals constitute the uppermost waterbearing unit.

The SOP also specifies the monitoring of the lower portion of the Gasport Formation as well as the Decew Formation. Well

OW404A is presently installed to this depth but the monitored zone is non-waterbearing. Therefore this well serves no useful purpose and will be grouted to the ground surface using positive displacement techniques.

Finally, the SOP specifies two wells to monitor all the waterbearing zones between the upper weathered bedrock zone and the lower Gasport/Decew zone. From the injection test data at OW404A, only one waterbearing zone is present between the A and D zones (the exact bedrock depth associated with each zone are presented in Table 2). No non-waterbearing interval was found between the uppermost waterbearing unit (0 - 51.2 feet below the top of bedrock) and the second waterbearing unit (51.2 to 96.2 feet below the top of bedrock). The non-waterbearing unit may have been in the D interval but the testing procedures may have overlapped this interval with the tests performed in the C-D or D-E intervals.

The interval from 51.2 to 96.2 feet below the top of bedrock appears to be one unit as all three test intervals indicate similar hydraulic conductivities. There is no reason to divide this unit into two monitoring wells as the bedrock exhibits similar hydraulic characteristics and is all part of the lower Oak Orchard Formation (see Table 6). By monitoring this interval as one unit, no further waterbearing intervals are present below this depth. The S-Area study indicated that a third waterbearing unit was present in the Goat Island Formation 86 percent of the time. From Table 6, it can be seen that the Goat Island Formation at OW404A is present from 104.9 to 123.2 feet below the top of the bedrock. As the test intervals encompassing these depths indicate hydraulic conductivities less than 5×10^{-5} cm/sec, it is recommended that the B zone well not be installed since the unit is non-waterbearing.

6.2 WELL NEST OW411

For well nest OW411, the recommended monitoring intervals are as follows:

D well:	0 - 32.9 ft. below top of bedrock
C well:	48.2 - 77.9 ft. below top of bedrock
B well:	93.2 - 141.5 ft. below top of bedrock
A well:	already installed but non-waterbearing (well to be grouted to ground surface)

The uppermost waterbearing unit is straight forward encompassing the first two tested intervals (assuming the A interval {see Table 3} will be waterbearing). The monitoring well in the lower Gasport/Decew Formation is already in place but the monitored zone is again non-waterbearing. Therefore, this well serves no useful purpose and will also be grouted to the ground surface.

At this location, the specified two wells between the upper weathered zone and the lower Gasport/Decew zone is straightforward. The two zones listed at the start of this sub-section have similar hydraulic characteristics with non-waterbearing intervals separating them from each other as well as from the other monitored zones. When referring to the bedrock stratigraphy as presented in Table 6, it can be seen that these two waterbearing units are present in the lower Oak Orchard Formation and the Goat Island Formation with the non-waterbearing units in the middle Oak Orchard, the Eramosa and the Gasport/Decew Formations. These results correspond exactly with the generalized waterbearing strata found during the S-Area Remedial Program.

6.3 WELL NEST OW402

For well nest OW402, the recommended monitoring intervals are as follows:

D well: 0 - 30.4 ft. below top of bedrock

C well: 60.7 - 75.4 ft. below top of bedrock

B well: 75.4 - 139.3 ft. below top of bedrock

A well: to be installed following reaming of NX corehole and casing installation.

As at well nest OW411, the uppermost waterbearing unit is again straight forward encompassing the first two tested intervals. The hydraulic conductivities of these two intervals are practically identical justifying the assumption that these two intervals are part of one waterbearing unit. The monitoring well in the lower Gasport/Decew Formation is presently being installed so the hydraulic conductivity is as yet unknown.

The required two wells to monitor the waterbearing unit (s) between the upper weathered zone and the lower Gasport/Decew Formation are determined at this time based on the hydraulic conductivity data. Although the five tested intervals between 60.7 and 139.3 feet below the top of bedrock are all waterbearing, the hydraulic conductivity of the interval located 60.4 to 75.7 feet below the top of bedrock (E interval {see Table 4}) is 2 to 3 orders of magnitude greater than the values for the other three intervals. One of the two monitoring wells should therefore monitor the E interval while the second well encompasses the four remaining waterbearing intervals. Although the bedrock stratigraphy of this well nest has not yet been delineated, these waterbearing units appear to approximately conform to the S-Area results.

6.4 WELL NEST OW410

For well nest OW410, the recommended monitoring intervals are as follows:

D well:	0 - 30.6 ft. below top of bedrock
C well:	60.6 - 75.6 ft. below top of bedrock
B well:	105.6 - 139.3 ft. below top of bedrock
A well:	to be installed following reaming of NX corehole and casing installation.

Again, the D zone (see Table 5) well would monitor the upper two tested intervals as both have similar hydraulic conductivities. As with well nest OW402, the monitoring well in the lower Gasport/Decew Formation will be injection tested following its completion.

The two middle zones to be monitored are again well defined by the hydraulic conductivity data. Both zones are separated from other waterbearing units by zones of low hydraulic conductivity, typically in the 10^{-6} cm/sec range. The full bedrock stratigraphy is currently not completed, but the C well is definitely in the lower Oak Orchard Formation while the B well is anticipated to be in the Goat Island Formation. This again corresponds with the results of the S-Area pump testing program.

7.0 RECOMMENDATIONS FOR REMAINING WELL INSTALLATIONS

For the four well nests which are discussed in Section 6, the proposed monitoring intervals are presented for State concurrence. Following agreement, the remaining wells in each nest will be installed.

For the remaining 12 well nests, data is not yet available as the deep well at each location is not yet installed. Due to the fact that time is a critical issue for the SDCP work, it is imperative that prompt State discussion and concurrence be obtained for each well nest as the injection test data becomes available. It is anticipated that this report will ease the decision making process for the determination of monitoring intervals at the remaining well nests.

In an effort to efficiently make further selections of appropriate monitoring intervals, it is suggested that the following procedures be initiated by the OCC and State Field Representatives.

i) Following the completion of the injection testing procedures for the last interval of each deep bedrock well, the OCC Field Representative will spend the remainder of that working day reducing the data and preparing a recommendation for the appropriate monitoring intervals.

ii) The following morning, the available data will be hand delivered to the State Field Representatives.

iii) That afternoon, a field meeting will be held between OCC and State Field Representatives to discuss and finalize the selection of the monitoring intervals. While this scheduling criteria is not a critical issue for these initial well nest installations, it will be for subsequent installations. It is therefore imperative that in order for the drilling contractor to complete all of the work in the specified time period, all decisions must be made promptly.