GEOTECHNICAL PRESENTATION TO THE NATIONAL ACADEMY OF SCIENCES NIAGARA FALLS STORAGE SITE SUBCOMMITTEE

JUNE 29-30, 1994

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(Continued) Graphic Index with Sources

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CONSIDERATIONS FOR LONG-TERM STORAGE OF RADIOACTIVE MATERIALS

- Structural stability
- Relationship of the facility to the 100-year floodplain
- Composition of the underlying materials
- Design of the facility
- Risk to drinking water aquifers

STRUCTURAL CONSIDERATIONS

- **Proximity to known and active faults**
  - — No active faults in proximity to NFSS
- **Karst formation (caverns)**
  - — No limestone units in proximity to NFSS
- **Stability of soils underlying the facility**
  - — Underlying soils are stable under the design load conditions

SURFACE WATER CONSIDERATIONS

- **The facility should not be located in a 100-year floodplain**
  - **— NFSS is not in a 100-year floodplain**

- **The facility should not pose a threat to a wetland in the event of a release**
  - **— NFSS is not located in a wetland and does not pose a threat to wetlands**

COMPOSITION OF UNDERLYING MATERIALS

- Geological materials underlying the facility should have the capacity to retard the movement of contaminants in the event of a release
- Predominantly unconsolidated clay units to bedrock
- Bedrock composed of shale
- Absence of limestone units in the area

DESIGN CONSIDERATIONS

- Contains and confines the waste
- Structurally stable
- Prevents inadvertent intrusion
- Inhibits migration of the waste
- Reduces surface water infiltration

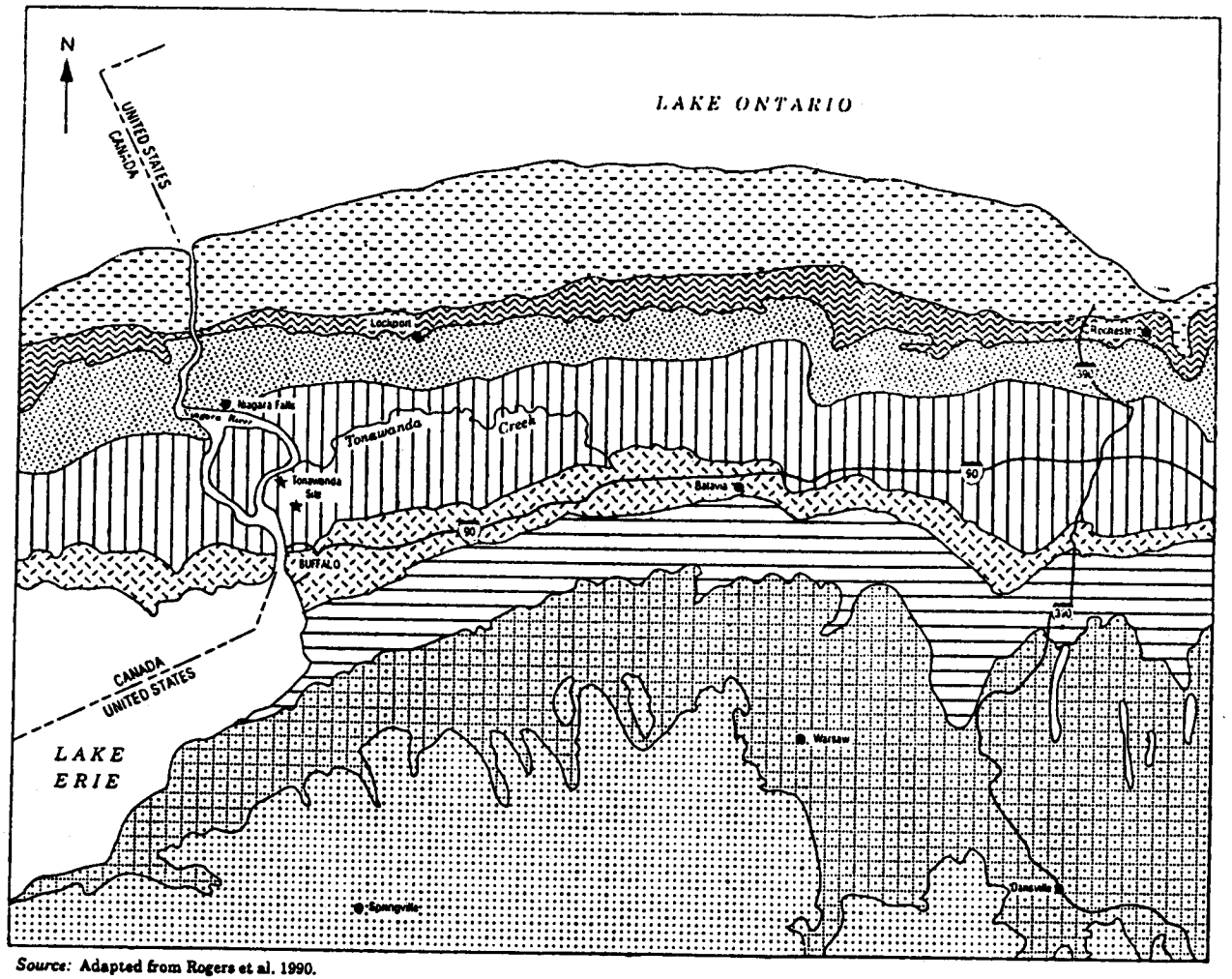
NFSS has a modified UMTRA cap design that achieves each of the listed objectives

GROUNDWATER CONSIDERATIONS

- The facility should not pose a threat to the local drinking water aquifers
  - No local drinking water aquifers underlay NFSS

REGIONAL GEOLOGIC STRUCTURE AND STRATIGRAPHY

- Bedrock dips to the south-southeast
- Clarendon-Linden structure
- Seismically stable
- Bedrock composed of Queenston shale
- Bedrock covered by a layer of unconsolidated materials composed primarily of lake clays



Source: Adapted from Rogers et al. 1990.

EXPLANATION

DEVONIAN

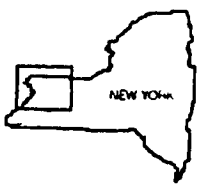
- Canadaway Group
- West Falls, Sonyea, and Genesee Groups and Tully Limestone
- Hamilton Group
- Onondaga Formation

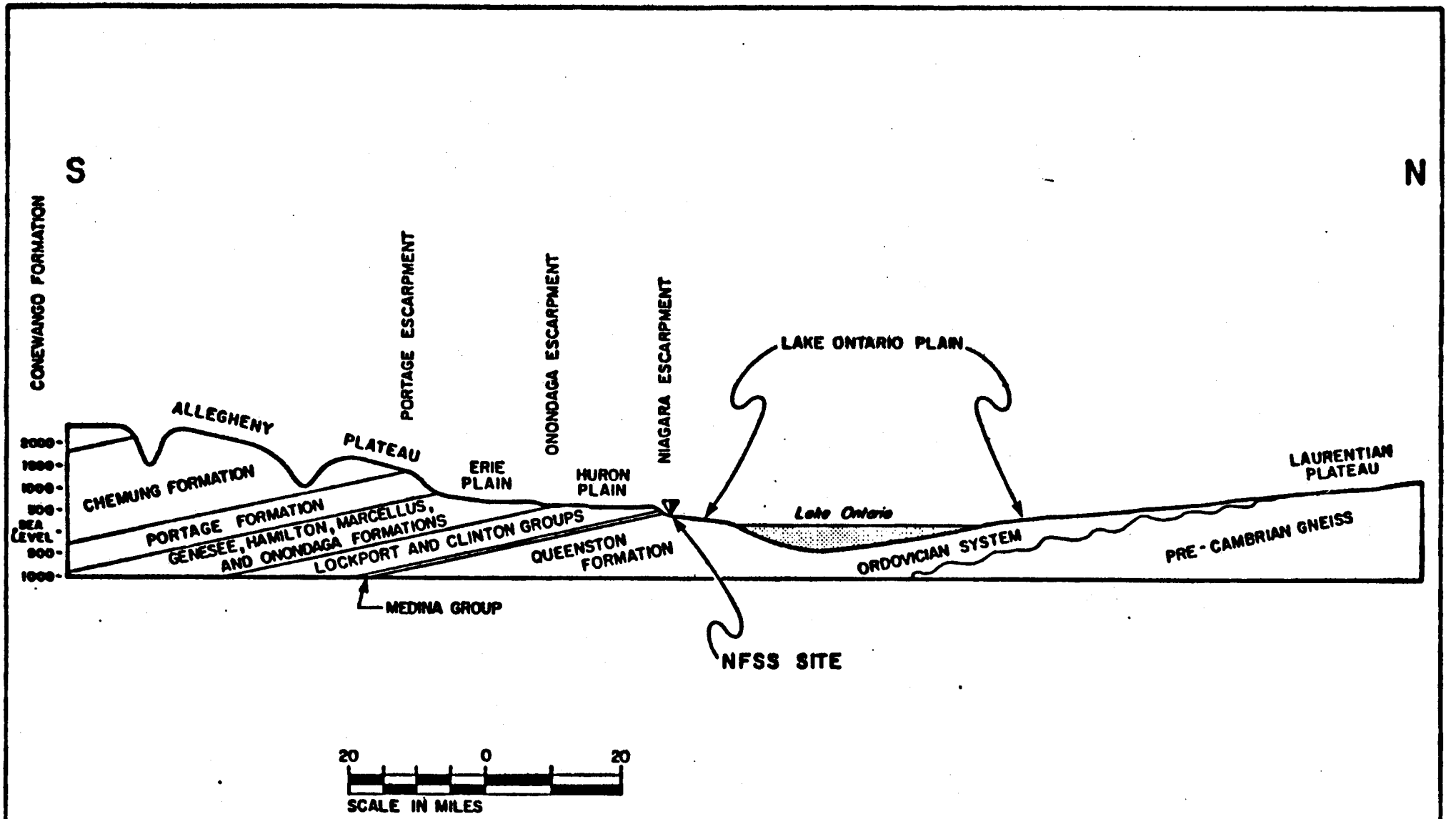
SILURIAN

- Salina Group
- Lockport Group
- Clinton and Medina Groups

ORDOVICIAN

- Queenston Shale

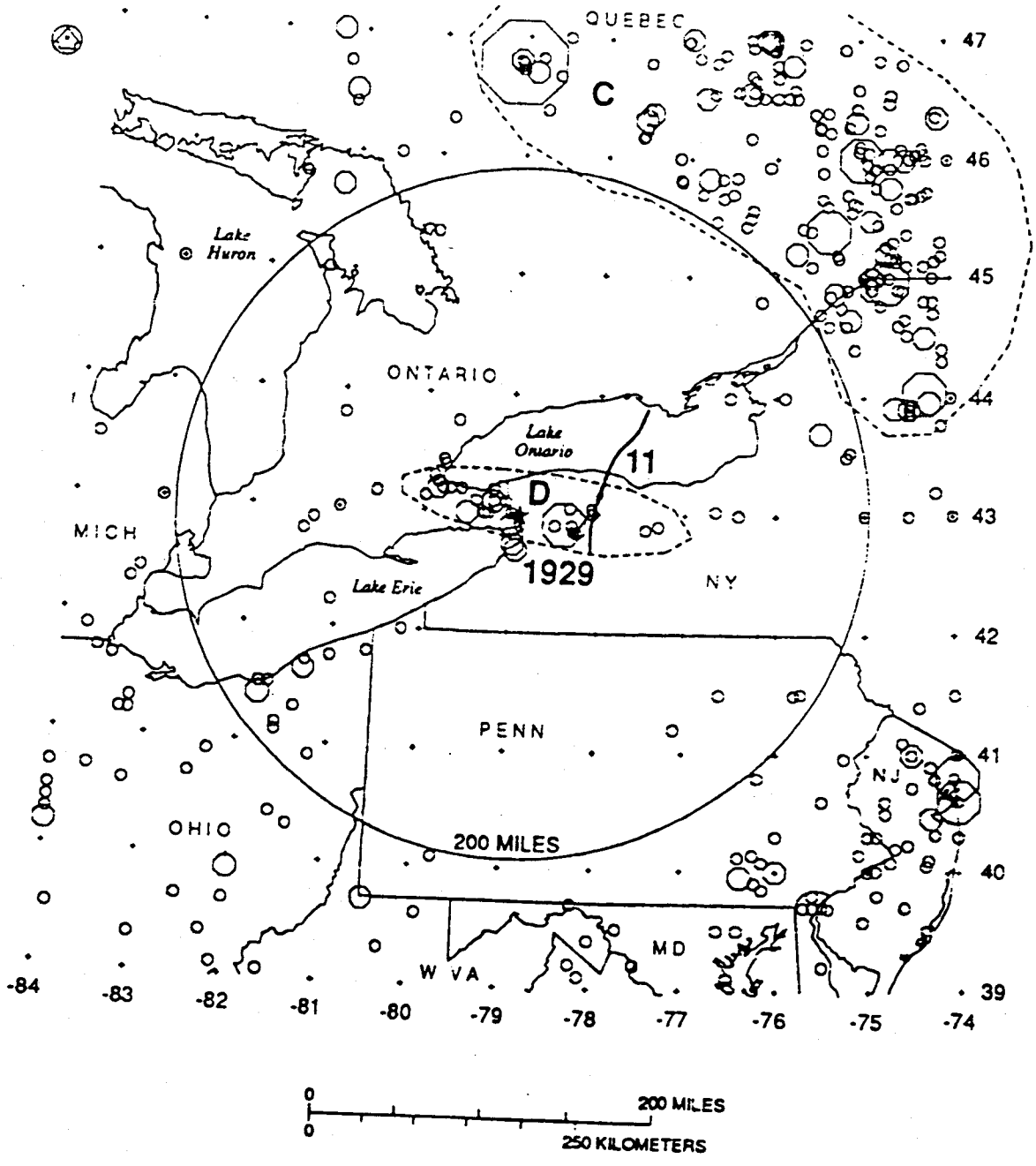




(MODIFIED FROM KINDLE AND TAYLOR, 1913)

ref. NFSS Geologic Report, 1984.

NIAGARA FALLS STORAGE SITE	BECHTEL
ALLEGHENY PLATEAU TO LAURENTIAN PLATEAU NORTH - SOUTH SECTION	JOB 14501
	FIGURE 3



EXPLANATION

Magnitude Scale

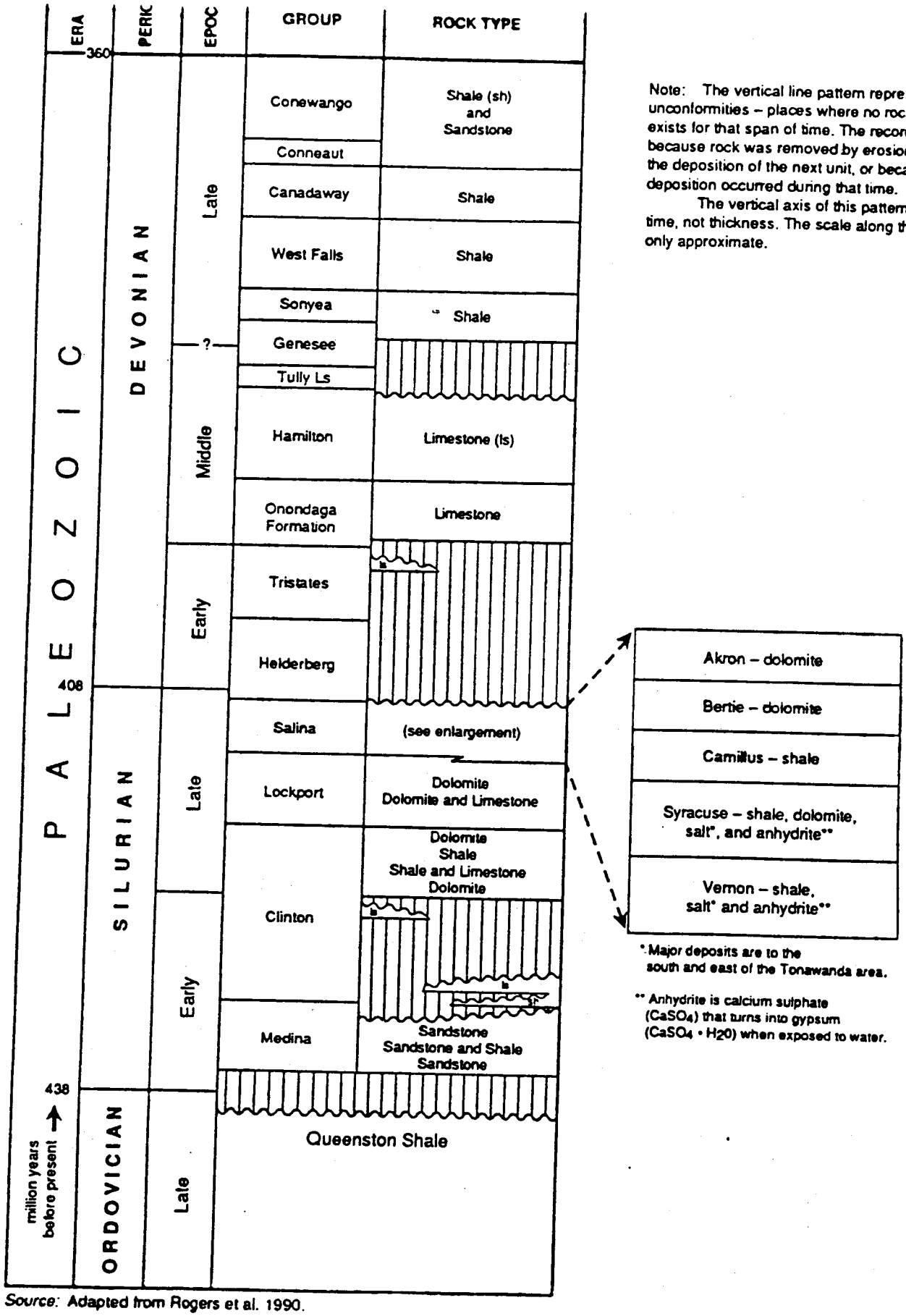
3.0-3.9 4.0-4.9 5.0-5.9 6.0-6.9

Earthquake locations and magnitude values are from Armbruster and Seeber (1992).

Seismic Source Zones (enclosed by dashed lines)
C = Western Quebec
D = Niagara
11 = Clarendon–Linden structure (bold line)

Data on seismic source zones C and D and structure 11 are from BNI (1986).

1929 = Location of Attica, New York, earthquake of August 12, 1929
★ = Tonawanda Site



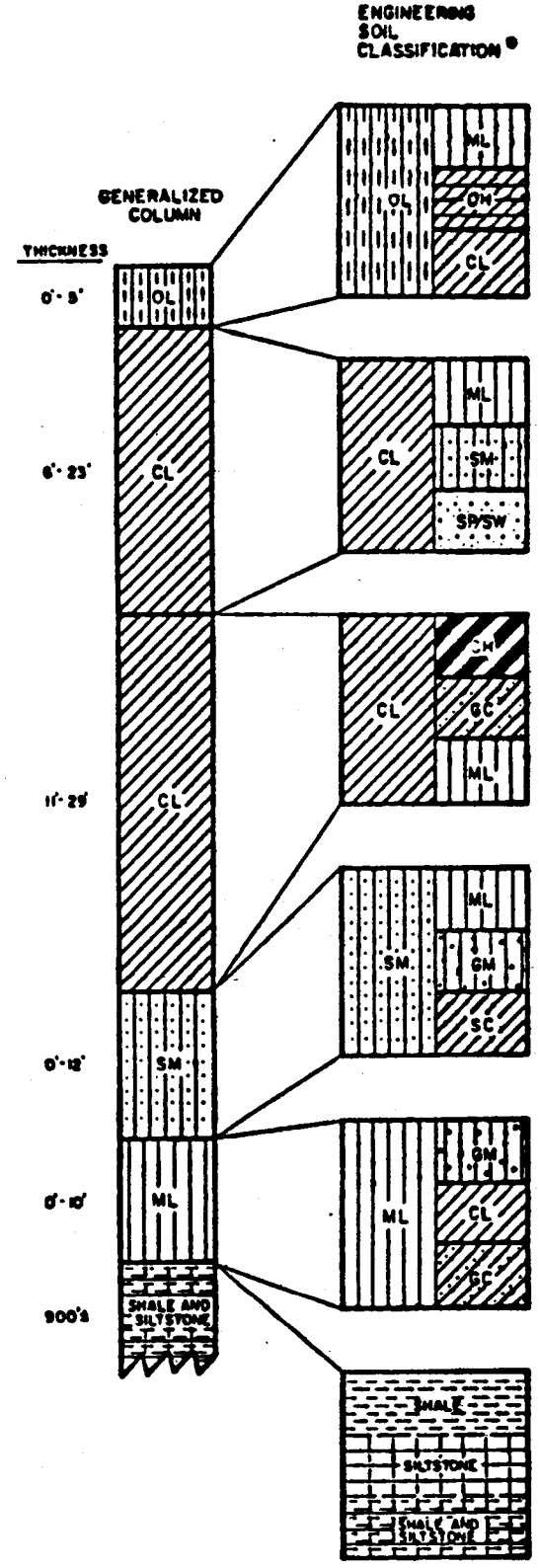
Note: The vertical line pattern represents unconformities – places where no rock record exists for that span of time. The record is missing because rock was removed by erosion before the deposition of the next unit, or because no deposition occurred during that time.

The vertical axis of this pattern represents time, not thickness. The scale along this axis is only approximate.

* Major deposits are to the south and east of the Tonawanda area.

** Anhydrite is calcium sulphate ($CaSO_4$) that turns into gypsum ($CaSO_4 \cdot H_2O$) when exposed to water.

Source: Adapted from Rogers et al. 1990.



SURFICIAL SOILS AND FILL

Brown or yellow-brown Silt with varying percentages of organics. In many areas, this unit is indistinguishable from the unit below it. Soil often contains sand and gravel. Generally dry and of loose to medium density.

BROWN CLAY UNIT

Predominantly brown to red-brown Clay containing significant amounts of silt and sand with lesser amounts of gravel. Portions of this unit are often clayey Silt. Occasionally entire unit is composed of clayey, silty Sands and/or Gravels, but these are generally restricted to the basal area. Soil is usually dry and of medium relative density.

GRAY CLAY UNIT

Gray or gray-brown Clay with varying amounts of silt and sand. Gravel is generally small in size and dispersed randomly. Occasionally the sand, silt, or gravel becomes the dominant constituent of the soil especially in the transitional zone at the base. Consistency is soft to medium. Unit is generally saturated and is slightly to moderately plastic.

SAND AND GRAVEL UNIT

Unit composed predominantly of gray or brown sandy Silt. Generally a transitional zone, it can range from almost clean sand to silty clay. Gravel quantities vary from absent to being over 50% of the unit. Zone is site continuous with rare, localized absences due to erosion. Unit is wet.

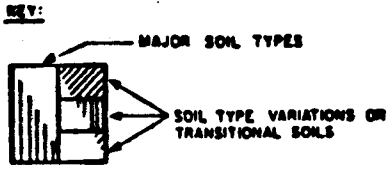
RED SILT UNIT

Red to red-brown clayey Silt. Gravel present throughout, occasionally in quantity. Unit is commonly present where bedrock is topographically depressed. Soil is generally dry and has a relative density classed as dense to very dense.

BEDROCK

Queenston Formation. Red to brown-red Shale and Siltstone. Occasional lenses of green siltstone are common. Bedding is thin and horizontal. Upper zone of rock is slightly to moderately weathered with some calcite replacement on the wider fractures. Clay is present on some weathered surfaces.

Reference report by Acres American Inc., 1981, Hydrologic Geologic Characterization of the DOE-Niagara Falls Storage Site.



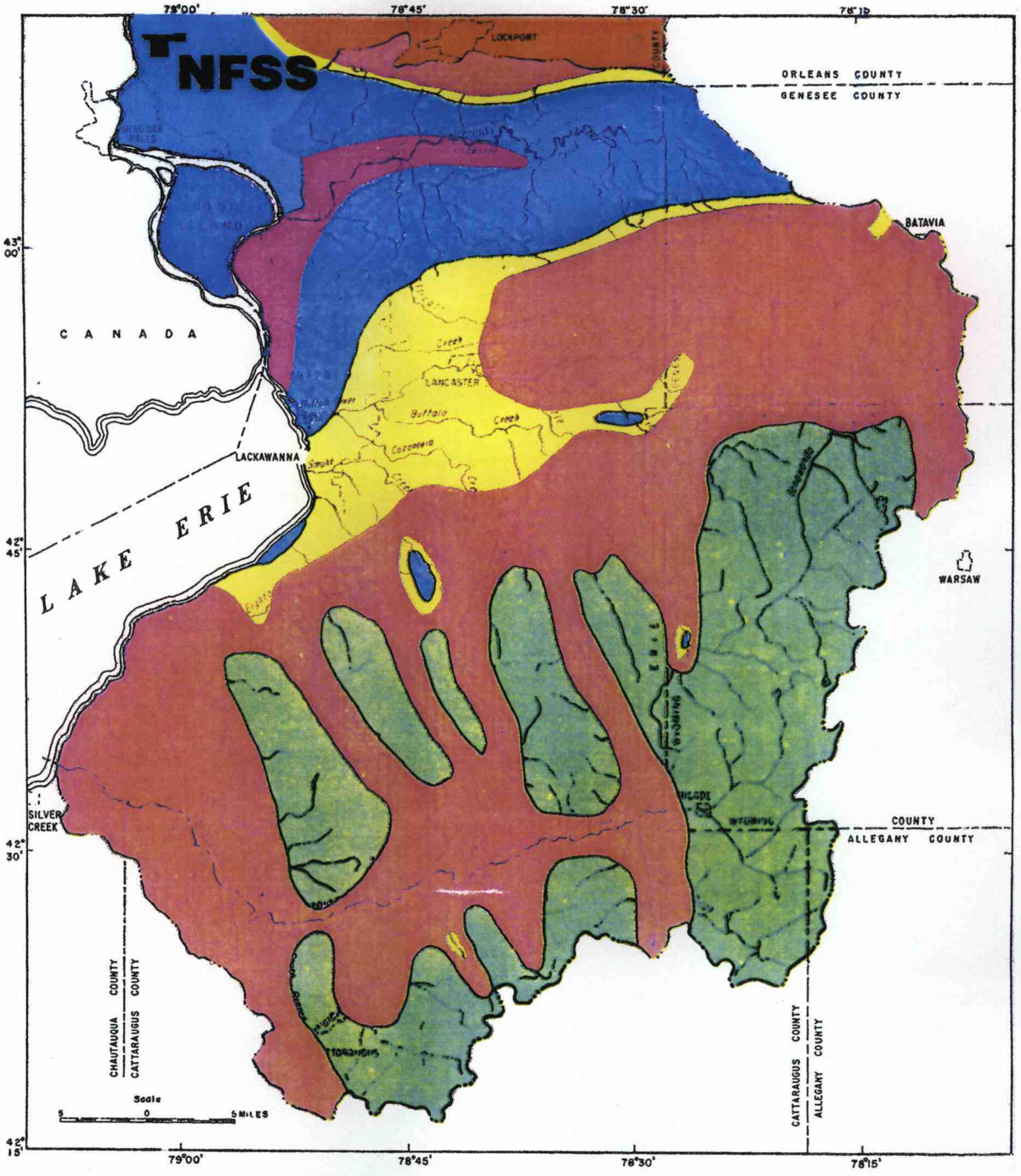
* SOIL CLASSIFICATION BASED ON THE "UNIFIED SOIL CLASSIFICATION SYSTEM" FIGURE 3.2.

ref. NFSS Geologic Report, 1984.

NIAGARA FALLS STORAGE SITE	BECHTEL
GENERALIZED GEOLOGIC COLUMN	JOB 14501
	FIGURE 4

REGIONAL GROUNDWATER ANALYSIS

- Water quality data
- Well canvas



EXPLANATION

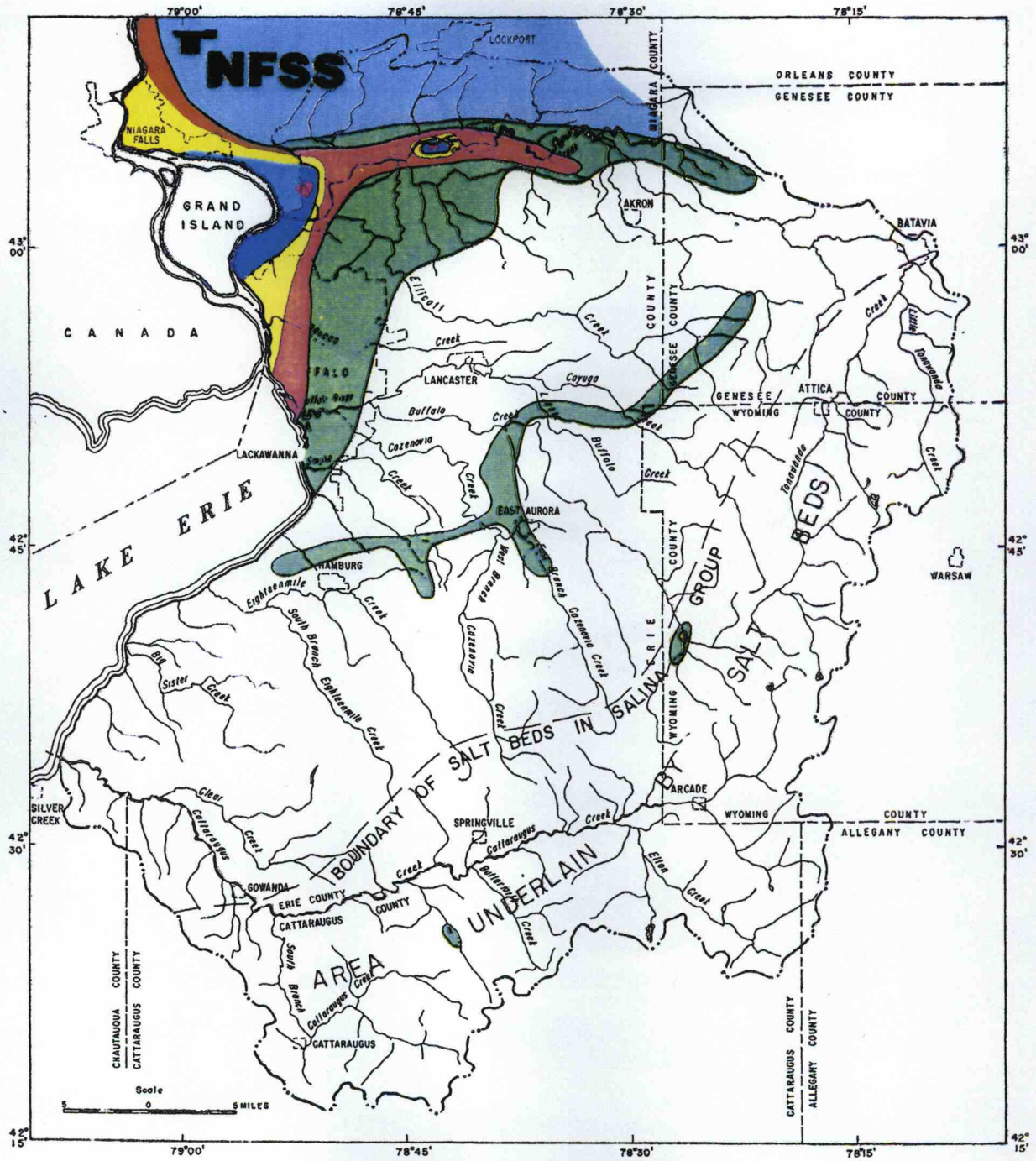
Specific conductance , in micromhos per centimeter at 25° C

< 500	500–1000	1000–1500	1500–3000	3000–9000

Basin boundary

Source: La Salla, 1968

Specific Conductance of Water in Bedrock



EXPLANATION

Chloride content , in parts per million

< 100	100–500	500–1000	1000–1500	1500–2000	2000–2500

Source: La Salla, 1988

Basin boundary

Chloride Content of Water in Bedrock

TABLE 4

GROUND-WATER QUALITY IN THE CONFINED ALLUVIAL AQUIFER AND FRACTURED SHALE/GLACIAL TILL WATER-BEARING ZONE ON AUGUST 24, 1977

PARAMETER	SAMPLING LOCATION							
	B-21	B-22	B-32	B-33	B-34	B-35	B-36	B-37
Formation	GT/FS	GT	GT	FS	AL	GT/FS	AL	AL
pH	8.6	8.6	8.2	7.7	8.3	7.8	8.1	8.3
Sp. Gr.	1.002	1.004	1.002	1.005	1.022	1.003	1.003	1.005
Conductivity (mhos)	730	3,350	840	4,400	850	1,900	370	710
TC (mg/l)	18	29	59	36	37	34	73	37
TIC (mg/l)	10	5	45	11	27	17	47	17
TOC (mg/l)	8	22	14	25	10	17	26	20
T.D.S. (mg/l)	552	2,842	818	4,920	882	1,820	376	540
COD (mg/l)	95.2	161.6	120	169.8	<40	89.9	140.8	171.8
Chloride (mg/l)	135	1,586	236	1,231	287	186	34	160
B (mg/l)	0.40	0.82	0.57	1.07	0.38	1.46	0.13	0.29
Cd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	<0.01	<0.01	0.02	0.03	0.01	0.03	0.02	<0.01
Cr (mg/l)	<0.01	0.03	0.01	<0.01	<0.01	0.01	0.03	0.01
Cu (mg/l)	0.44	0.70	0.63	1.2	<0.01	0.30	1.2	0.58
Fe (mg/l)	0.18	0.37	0.36	0.98	7.4	1.0	3.4	15.4
Ni (mg/l)	0.08	0.06	<0.01	0.14	0.07	<0.01	0.04	0.14
Mn (mg/l)	0.14	0.28	0.40	3.0	11.0	0.74	0.75	5.2
Zn (mg/l)	1.2	0.31	2.2	3.5	2.8	0.46	0.52	0.72
Se (mg/l)	0.009	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	0.005
As (mg/l)	0.003	0.004	0.003	<0.003	<0.003	0.003	0.005	<0.003
Hg (mg/l)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sulfate (mg/l)	-	-	-	-	-	1,025	-	-

FORMATIONS

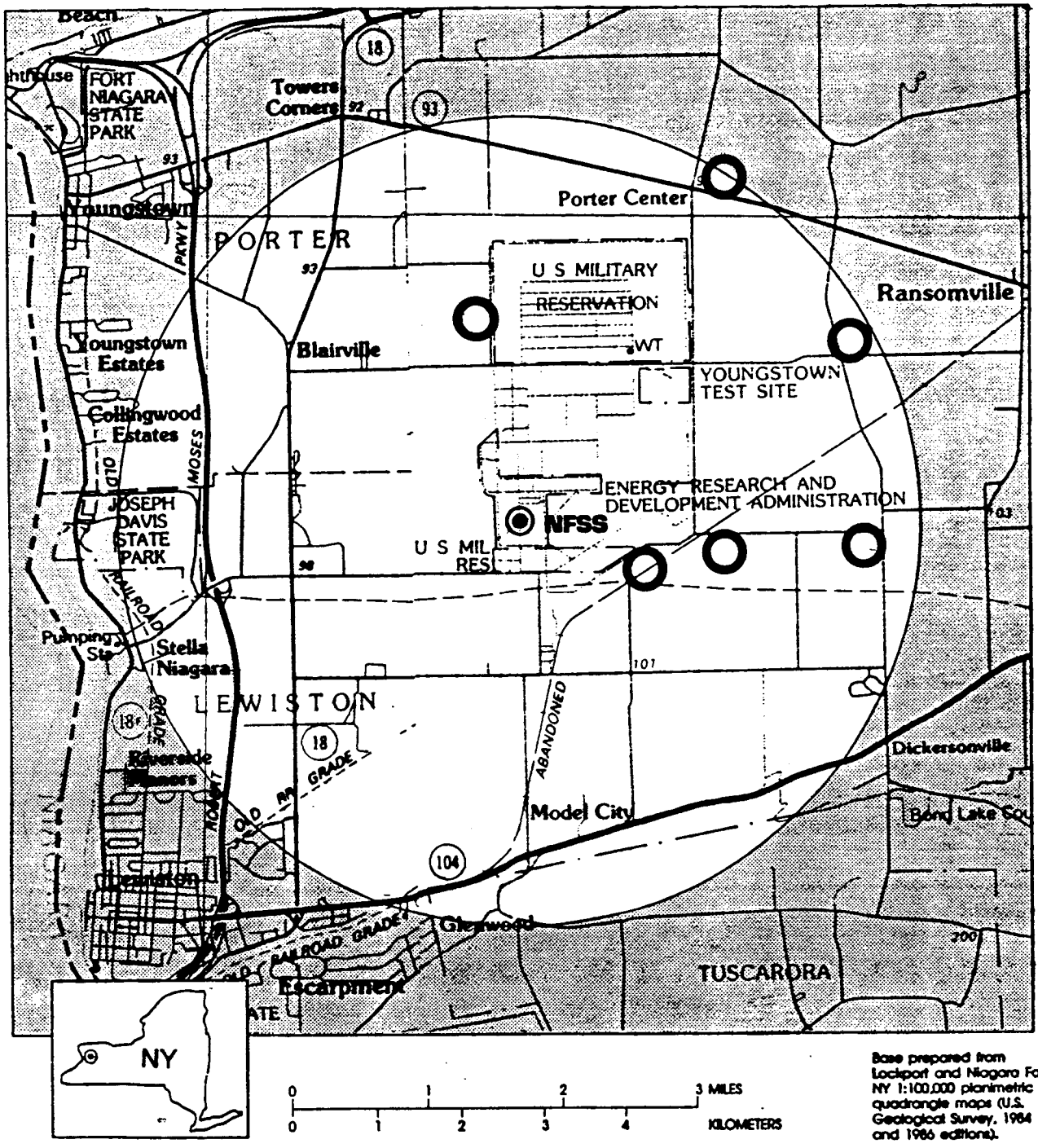
FS = Fractured Queenston Shale (only)
GT = Pre-Wisconsin Glacial Till
GT/FS = Combined Fractured Shale/ Pre-Wisconsin Glacial Till
AL = Alluvial Aquifer

TABLE 4 (Cont'd)

PARAMETER	SAMPLING LOCATION							
	B-38	B-39	B-40	B-41	B-42	B-43	B-44	B-45
Formations	AL	AL	AL	GT/FS	GT/FS	AL	AL	GT/FS
pH	8.0	7.7	8.0	8.0	8.3	7.8	8.0	7.8
Sp. Gr.	1.002	1.004	1.001	1.003	1.003	1.002	1.002	1.003
Conductivity (mhos)	490	2,000	910	1,280	1,140	1,650	1,450	2,300
TC (mg/l)	99	37	176	58	45	56	26	27
TIC (mg/l)	30	11	28	20	13	34	26	11
TOC (mg/l)	69	26	148	38	32	22	0	16
T.D.S. (mg/l)	420	2,662	692	694	2,564	1,550	1,264	2,274
COD (mg/l)	225.7	95.2	426.5	153.2	120.1	113.9	47.6	85.7
Chloride (mg/l)	93	186	211	262	149	270	230	358
B (mg/l)	0.25	0.93	0.30	0.67	0.66	0.57	0.90	0.75
Cd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	0.01	<0.01	0.01	<0.01	0.03	0.01	0.02	<0.01
Cr (mg/l)	<0.01	0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.01
Cu (mg/l)	0.12	0.14	0.27	0.23	0.08	0.19	0.10	0.72
Fe (mg/l)	0.14	0.28	0.35	0.21	0.34	0.60	0.64	0.57
Ni (mg/l)	0.15	0.04	0.06	0.07	0.06	0.08	0.02	<0.01
Mn (mg/l)	0.13	0.43	0.21	0.45	0.20	0.25	0.25	1.8
Zn (mg/l)	0.08	1.9	0.31	0.99	2.7	0.24	0.95	2.1
Se (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005
As (mg/l)	<0.003	0.003	<0.003	<0.003	<0.003	0.003	<0.003	<0.003
Hg (mg/l)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sulfate (mg/l)	-	1,060	-	625	625	475	650	1,000

TABLE 4 (Cont'd)

PARAMETER	SAMPLING LOCATION							Secondary Drinking Water Standards *
	B-46	B-48	B-49	WELL 1	WELL 2	WELL 3	WELL 5	
Formations	AL	GT/FS	GT/FS					
pH	7.7	7.9	8.4	7.4	6.8	7.0	7.7	
Sp. Gr.	1.004	1.003	1.002	1.003	1.003	1.003	1.002	
Conductivity (mhos)	3,100	1,850	650	2,000	1,220	1,110	710	
TC (mg/l)	42	27	22	11	9	11	58	
TIC (mg/l)	32	12	10	5	0	8	25	
TOC (mg/l)	10	15	12	6	9	3	33	
T.D.S. (mg/l)	3,546	1,614	518	2,082	1,276	1,104	620	500 *
COD (mg/l)	89.0	82.8	51.8	43.5	40	53.8	70.4	
Chloride (mg/l)	331	438	81	216	196	230	176	250 *
B (mg/l)	1.66	0.97	0.52	0.67	0.92	0.80	0.30	
Cd (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Co (mg/l)	<0.01	0.02	0.02	0.04	<0.01	<0.01	0.02	
Cr (mg/l)	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	
Cu (mg/l)	0.44	0.34	0.19	0.05	0.02	0.01	0.07	
Fe (mg/l)	1.8	0.36	1.1	9.4	20.8	5.6	0.23	
Ni (mg/l)	0.05	<0.01	<0.01	<0.01	0.06	0.03	0.05	
Mn (mg/l)	0.70	1.9	0.29	0.66	0.93	0.39	0.14	
Zn (mg/l)	2.8	0.13	0.60	0.10	0.06	0.04	0.28	
Se (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	
As (mg/l)	0.003	<0.003	0.003	<0.003	<0.003	<0.003	0.003	
Hg (mg/l)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Sulfate (mg/l)	1,000	800	-	600	1,200	620	-	

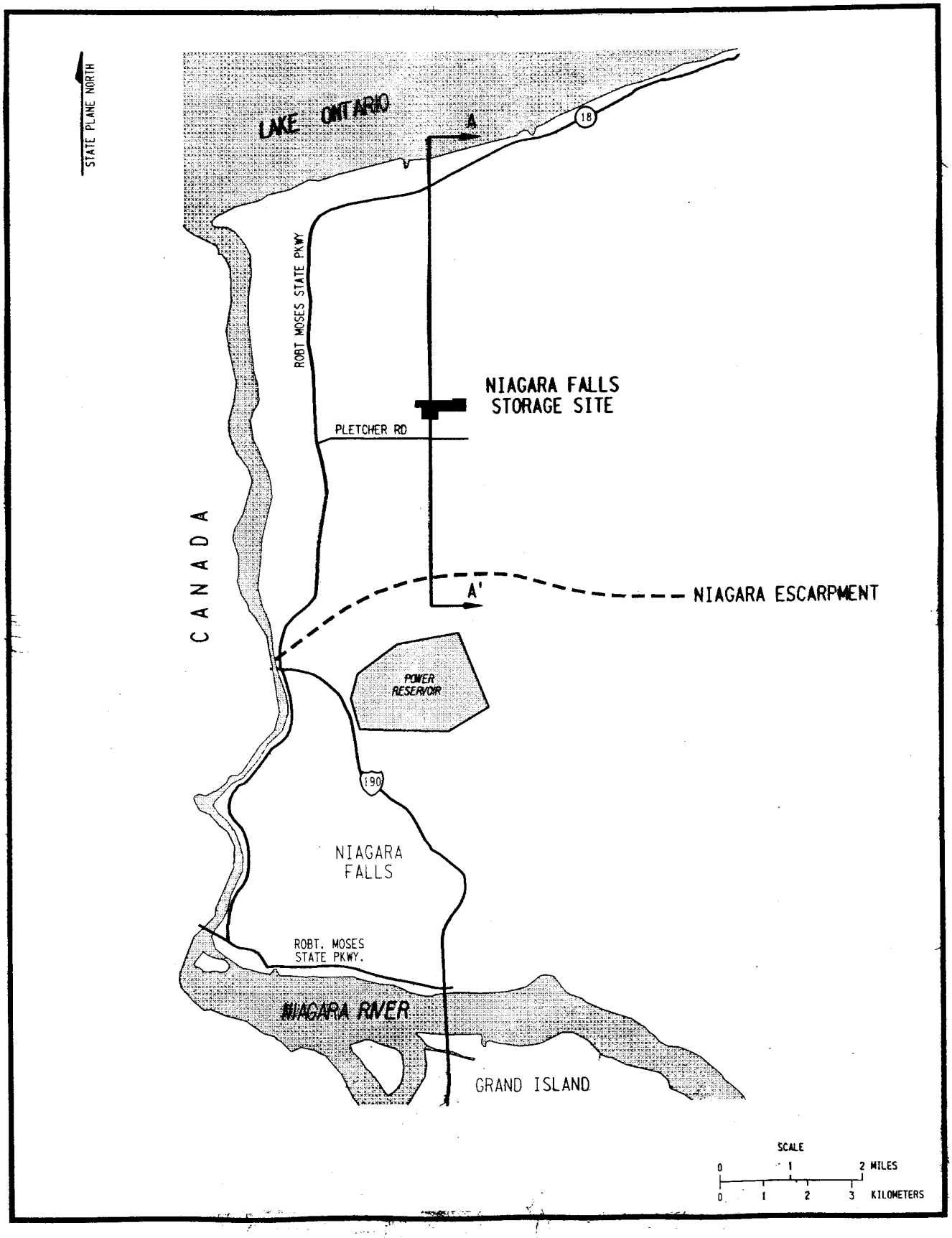


ref. Unpublished Well Canvass Update 1994.

SITE-SPECIFIC GEOLOGY

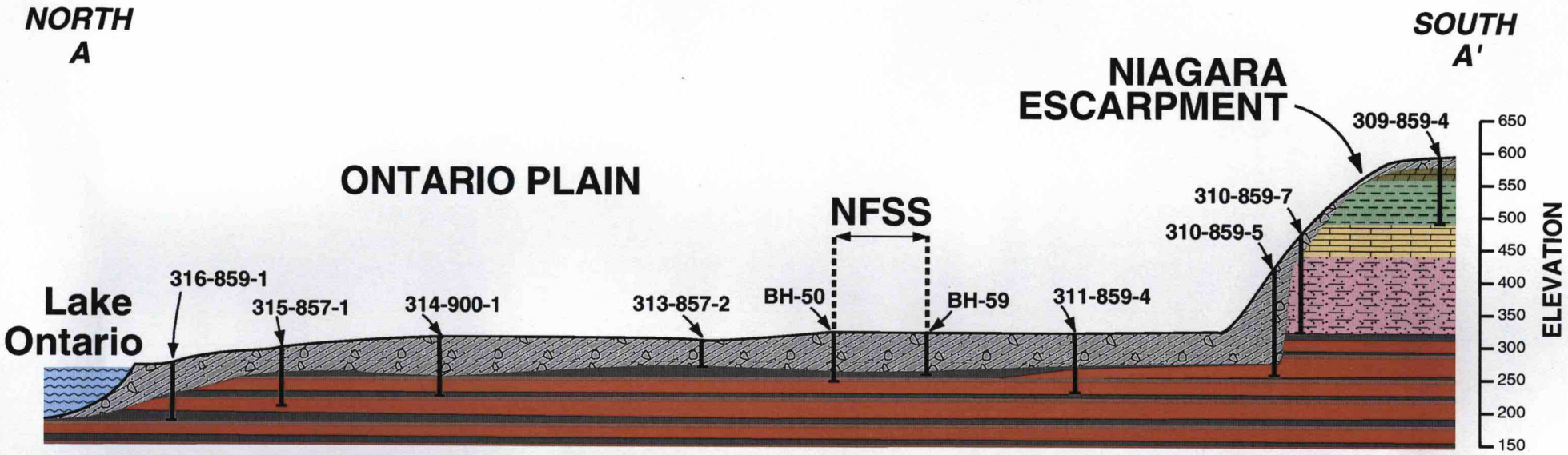
- Relation to the Niagara escarpment

- Stratigraphy



158F033.DGN

Location of Profile A - A'



EXPLANATION

313-857-2

Water well from: Johnson, "Ground Water in the Niagara Falls Area, New York," New York Conservation Dept., Water Resource Commission, Bulletin GW-53, 1964

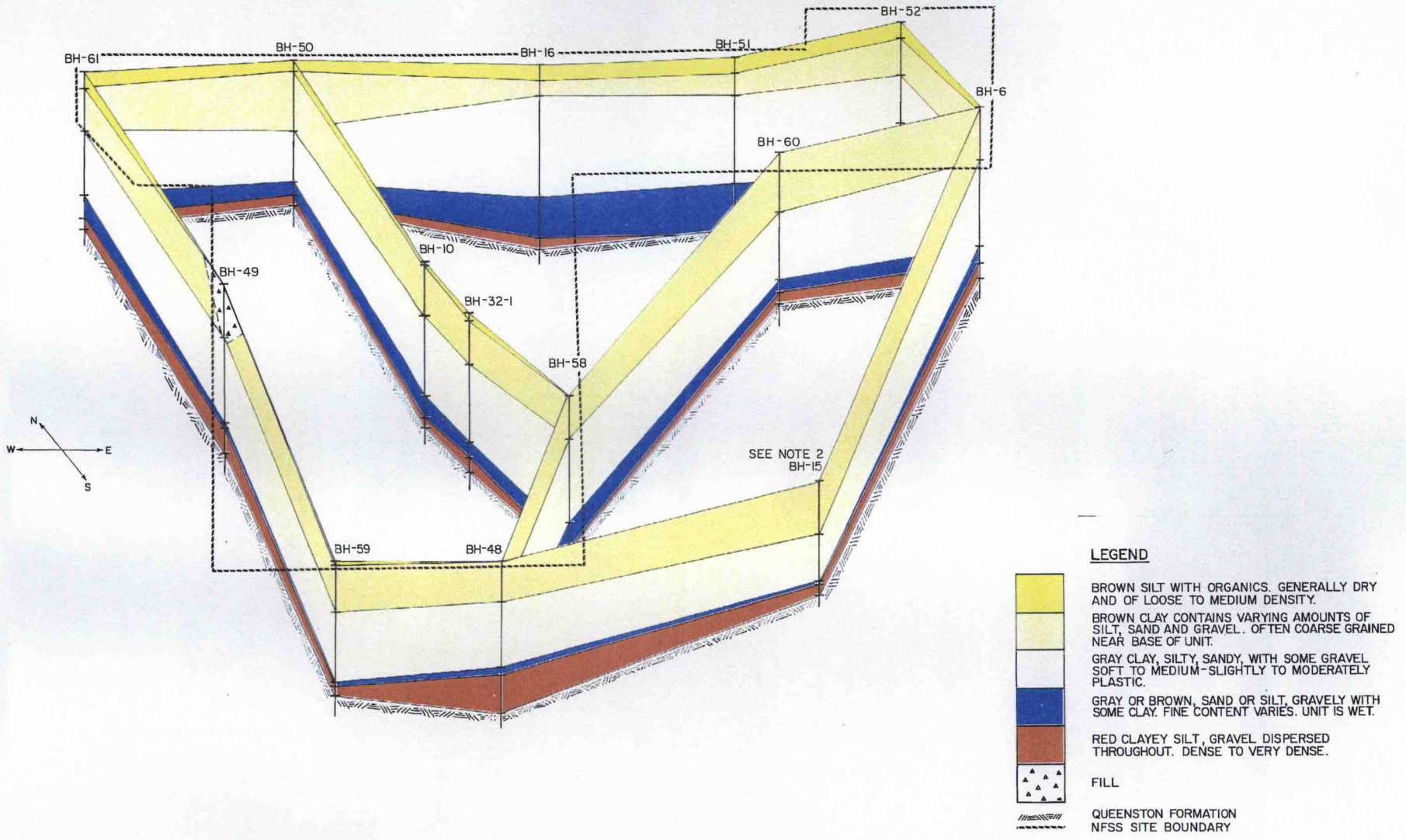
BH-50

Observation well from: Acres American, Inc., "Hydrologic and Geologic Characterization of the DOE - Storage Site Niagara Falls," prepared for NLO, Inc., Fernald, Ohio, Sept. 30, 1981

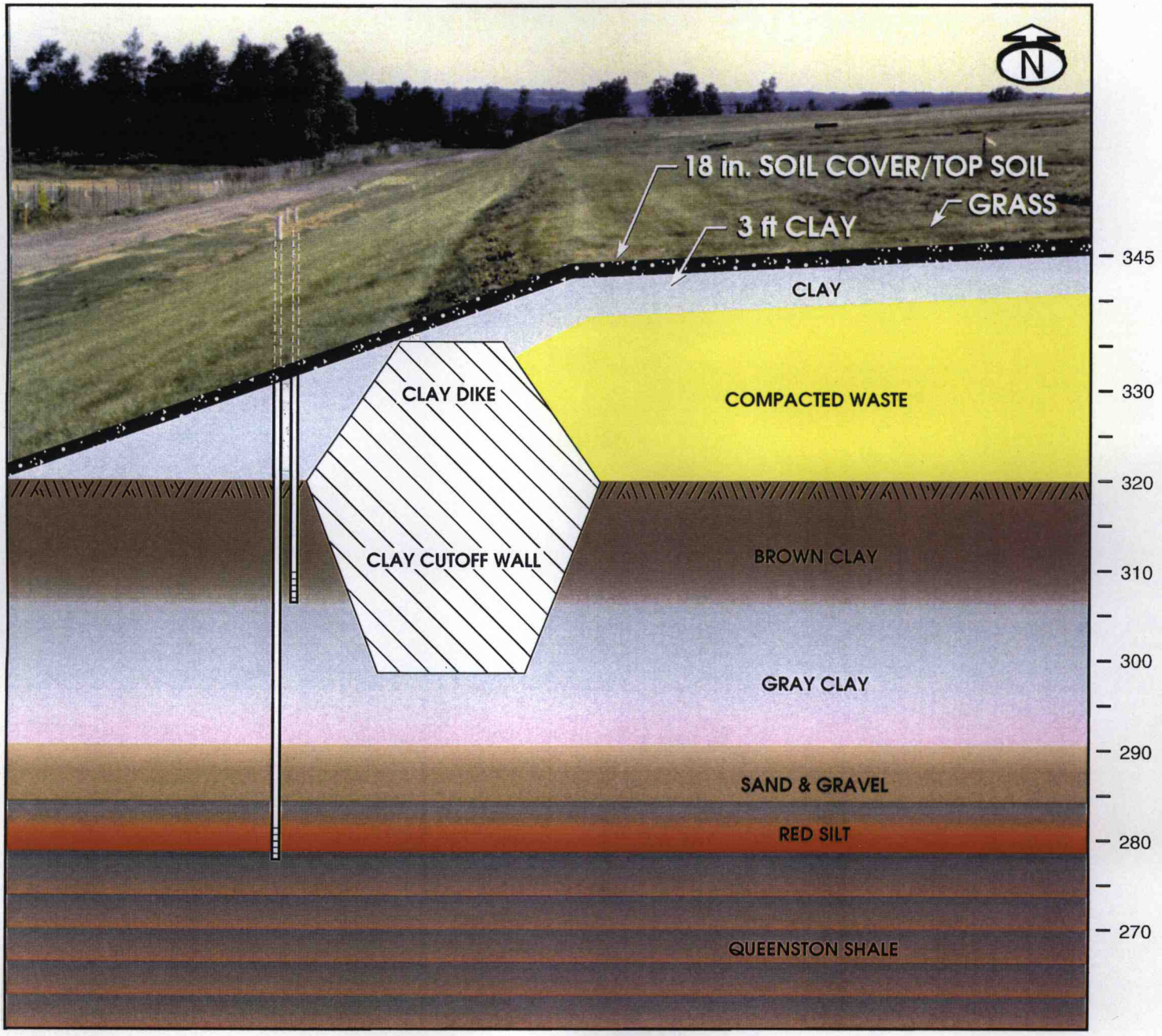
- Unconsolidated Lacustrine, Alluvial & Glacial Deposits
- Lockport Dolomite
- Rochester Shale
- Clinton Group
- Albion Sandstones and Shales
- Queenston Shale

Source: NFSS analysis of contaminant migration Phase 1 Report, 1982.

SQ4.12 4739.6



Source: Acres American, NFSS Geologic Report, 1981.



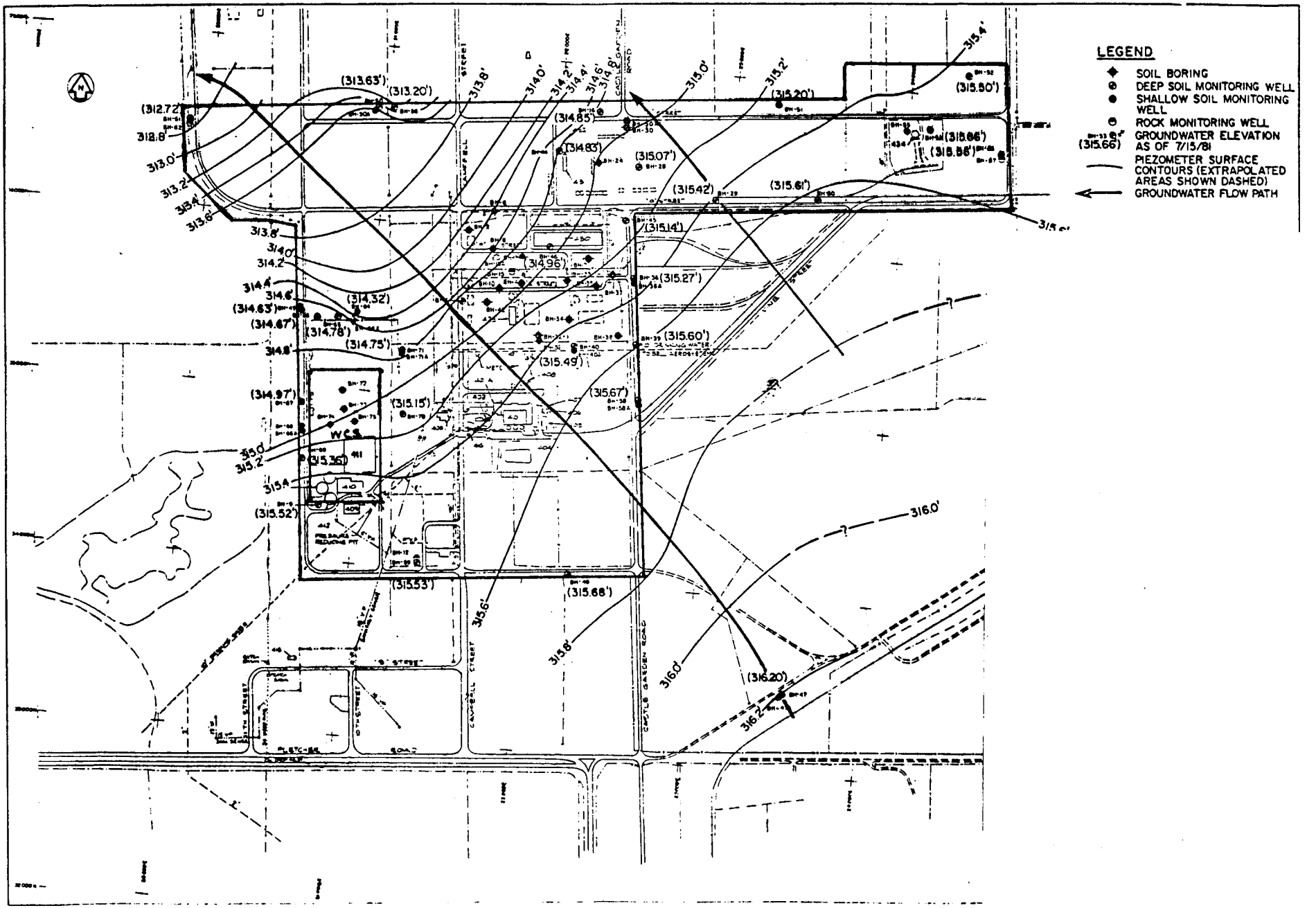
Note: Per Generalized Soil Column NFSS Geologic Report, 1984.

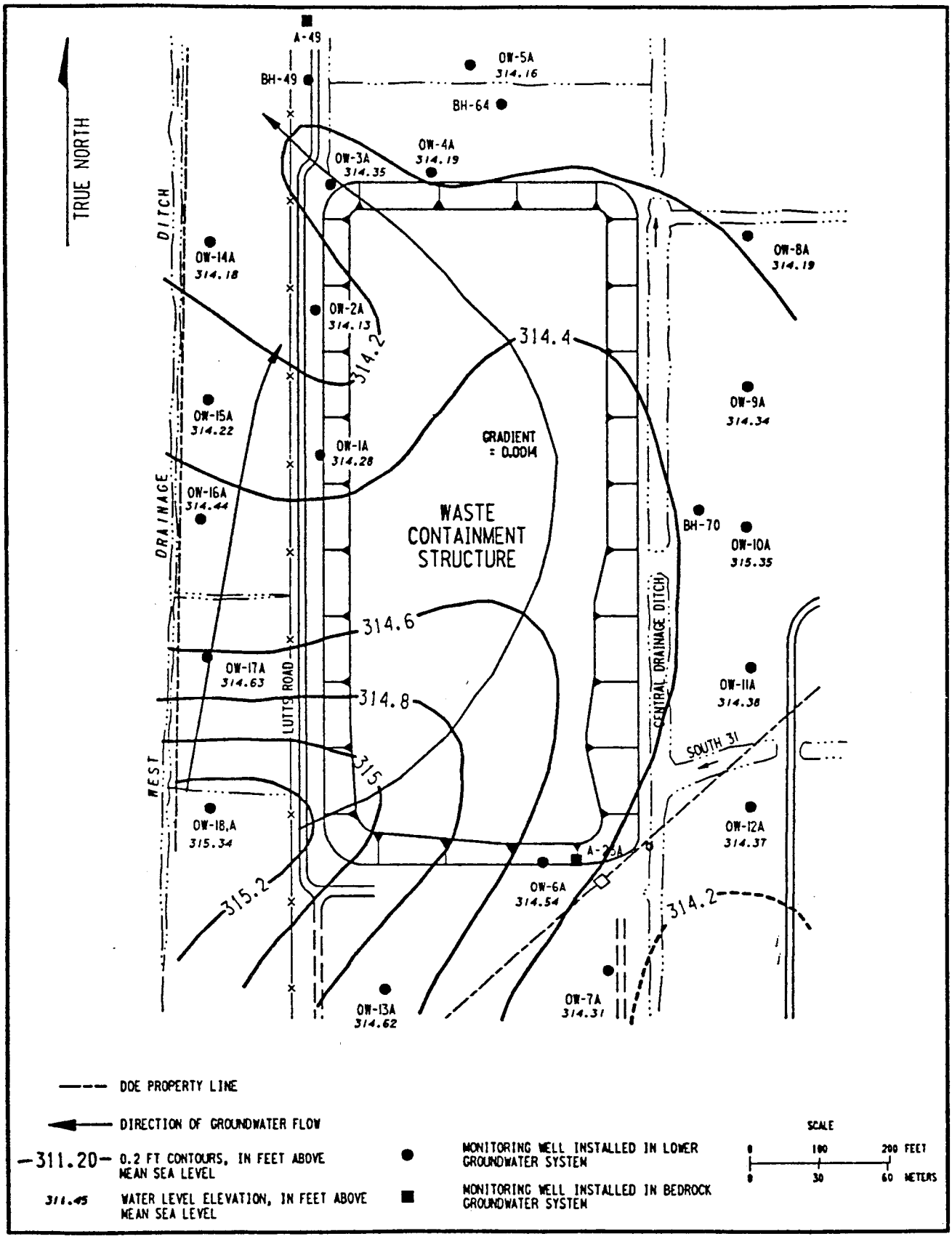
SITE—SPECIFIC HYDROGEOLOGY

- Bedrock gradient

PRECONSTRUCTION/POST—CONSTRUCTION OF THE INTERIM STORAGE CELL

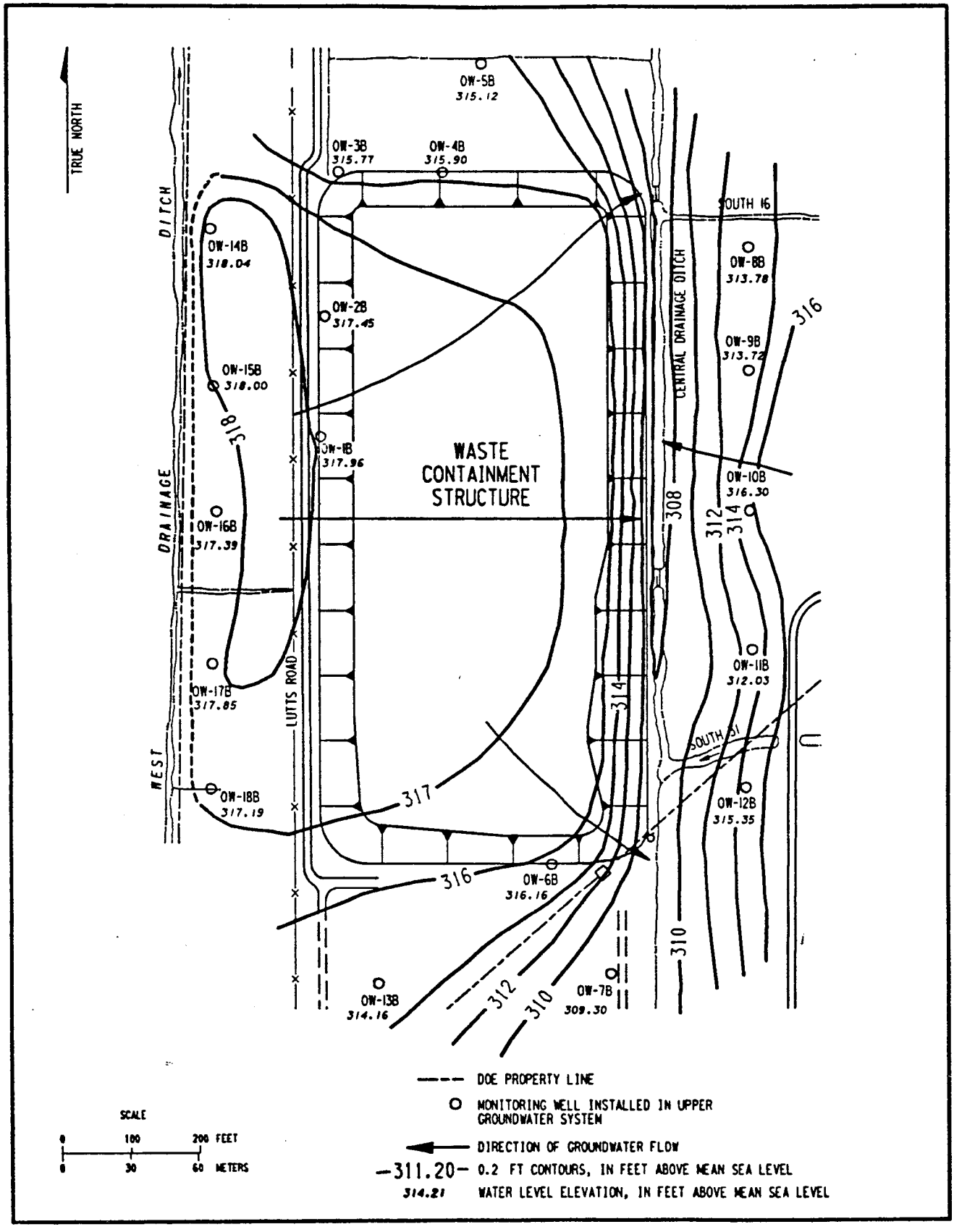
- Water table gradient
- Influence from modern landfill pumping operations


LEGEND
SOIL BORING
DEEP SOIL MONITORING WELL
SHALLOW SOIL MONITORING WELL
ROCK MONITORING WELL
(315.66) GROUNDWATER ELEVATION AS OF 7/15/81
PIEZOMETER SURFACE CONTOURS (EXTRAPOLATED AREAS SHOWN DASHED)
GROUNDWATER FLOW PATH
(313.63')
(313.20')
(312.72')
312.8'
313.0'
313.2'
313.4'
313.6'
313.8'
314.0'
314.2'
314.4'
314.6'
314.8'
315.0'
315.2'
315.4'
316.0'
316.2'
(314.85')
(314.83')
(315.07')
(315.42')
(315.20')
(315.50')
(315.86')
(315.88')
(315.61')
(315.14')
(314.96')
(315.27')
(314.32')
(314.63')
(314.67')
(314.78')
(314.75')
(315.60')
(315.49')
(315.67')
(314.97')
(315.15')
(315.36')
(315.52')
(315.53')
(315.68')
(316.20')
W.C.S.
CAMPBELL STREET
CASTLE GARDEN ROAD



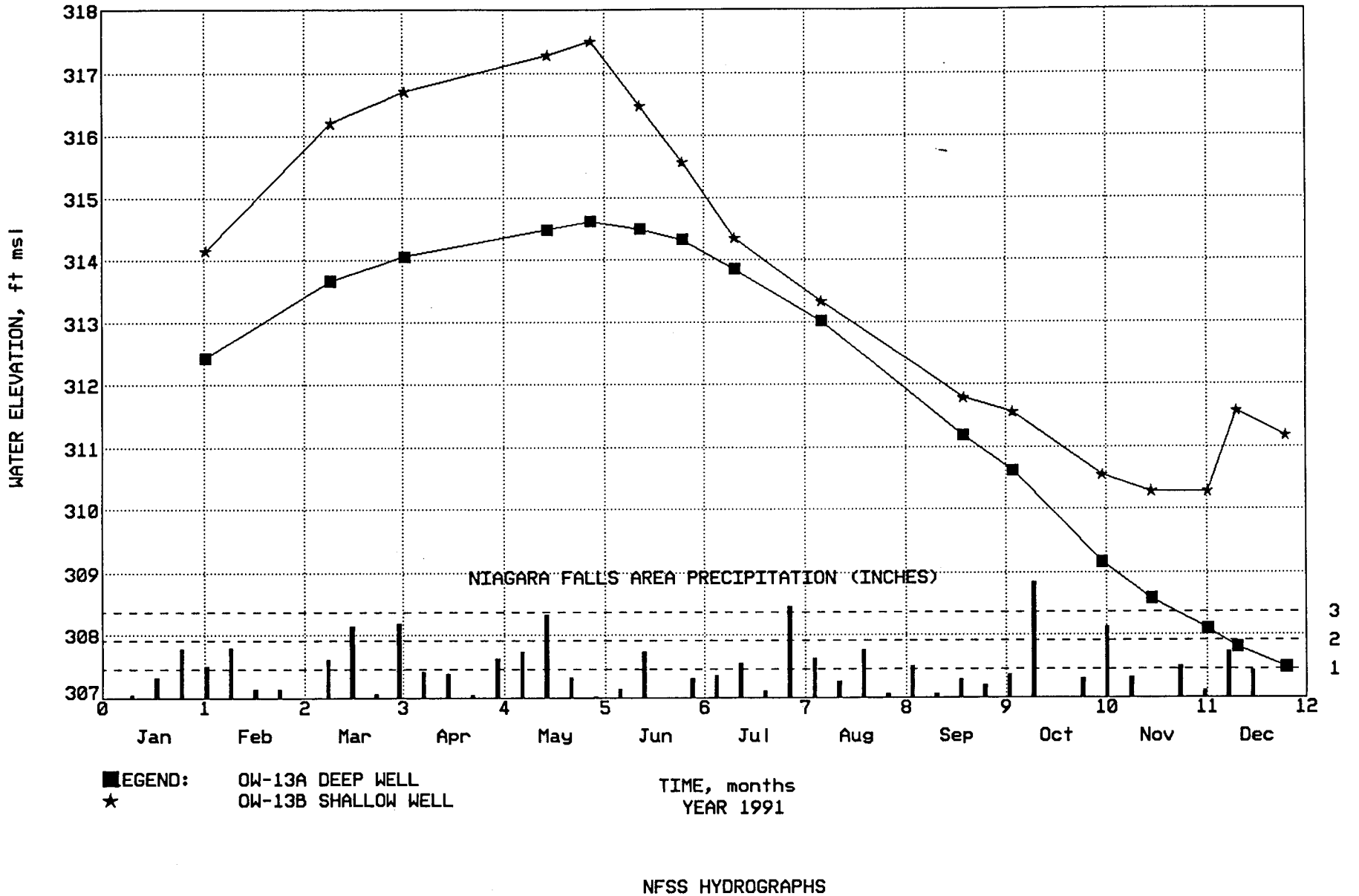
158 R1DF013.DGN

Potentiometric Map of Lower Groundwater System (5/29/91)

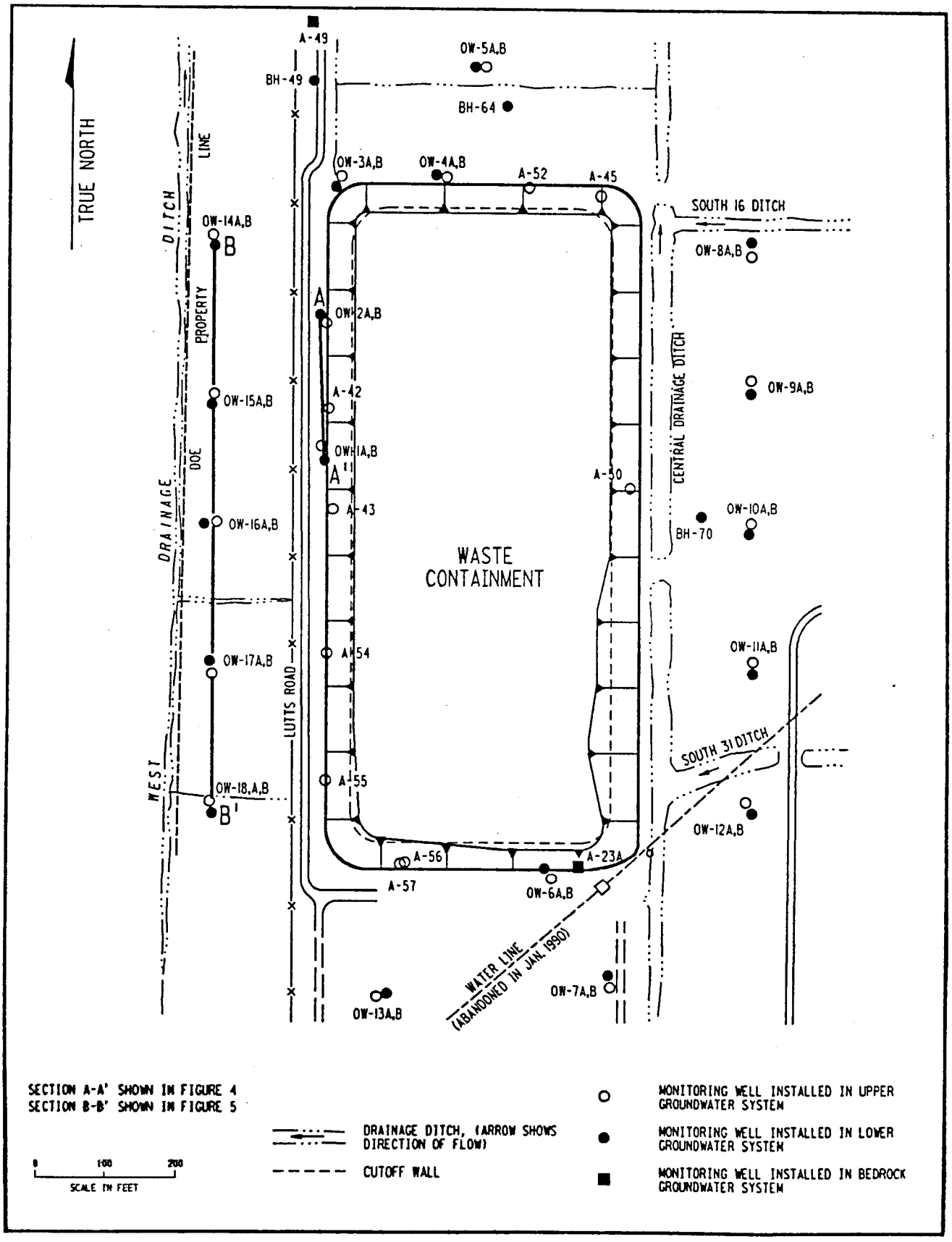


158 R10F007.DGN

Potentiometric Map of Upper Groundwater System (2/1/91)

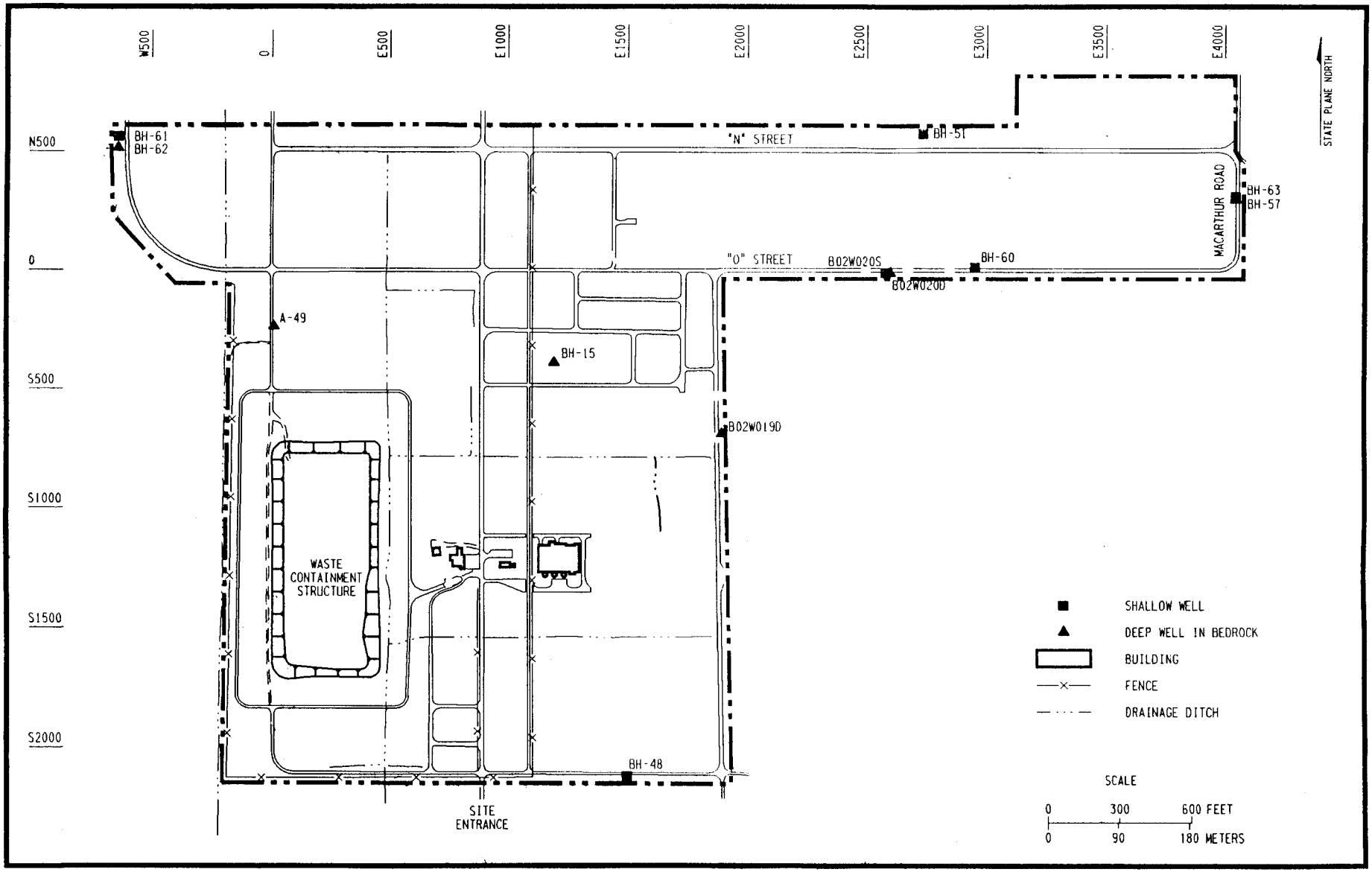


NFSS HYDROGRAPHS



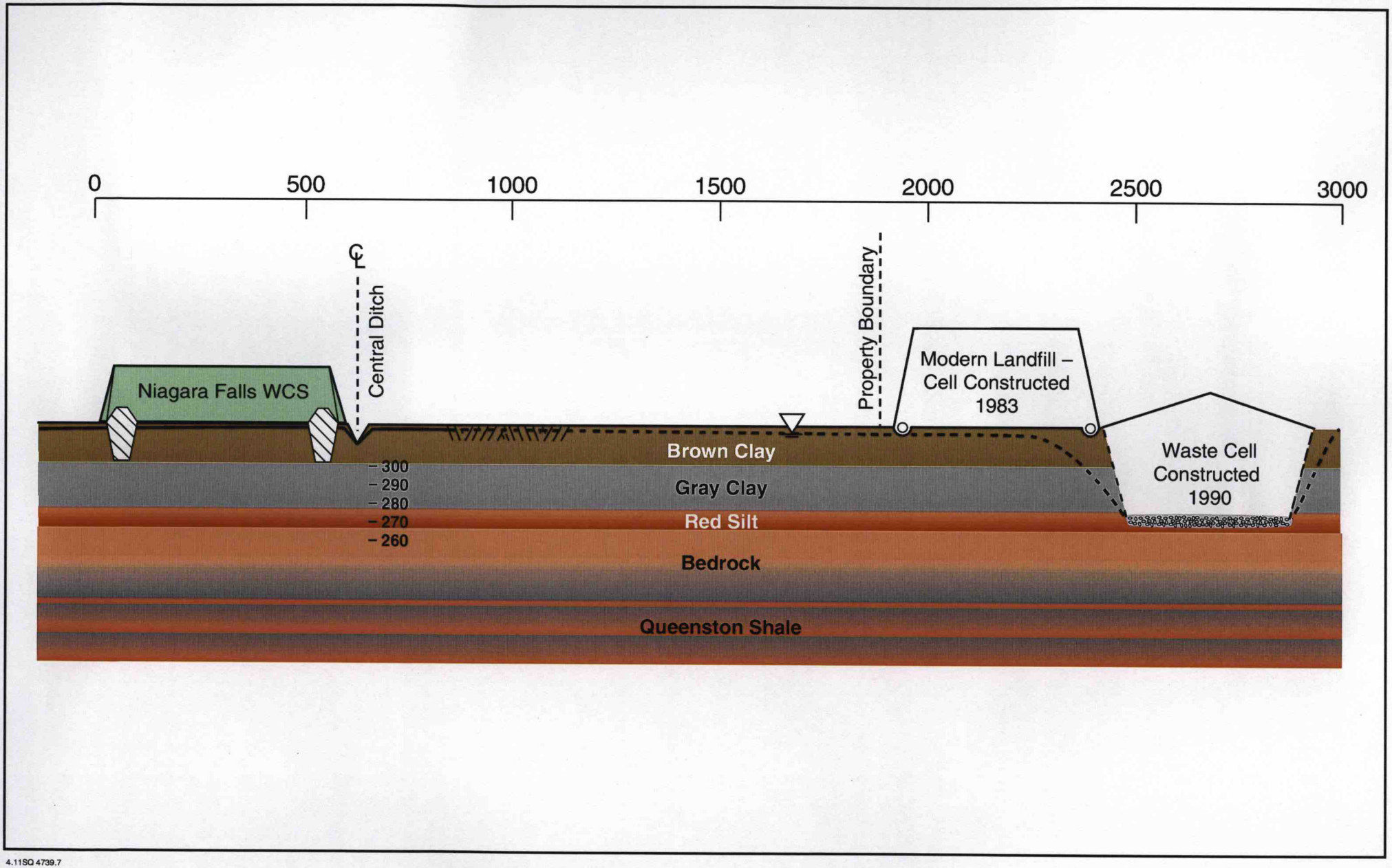
202F040.DGN F2

MONITORING WELL LOCATIONS



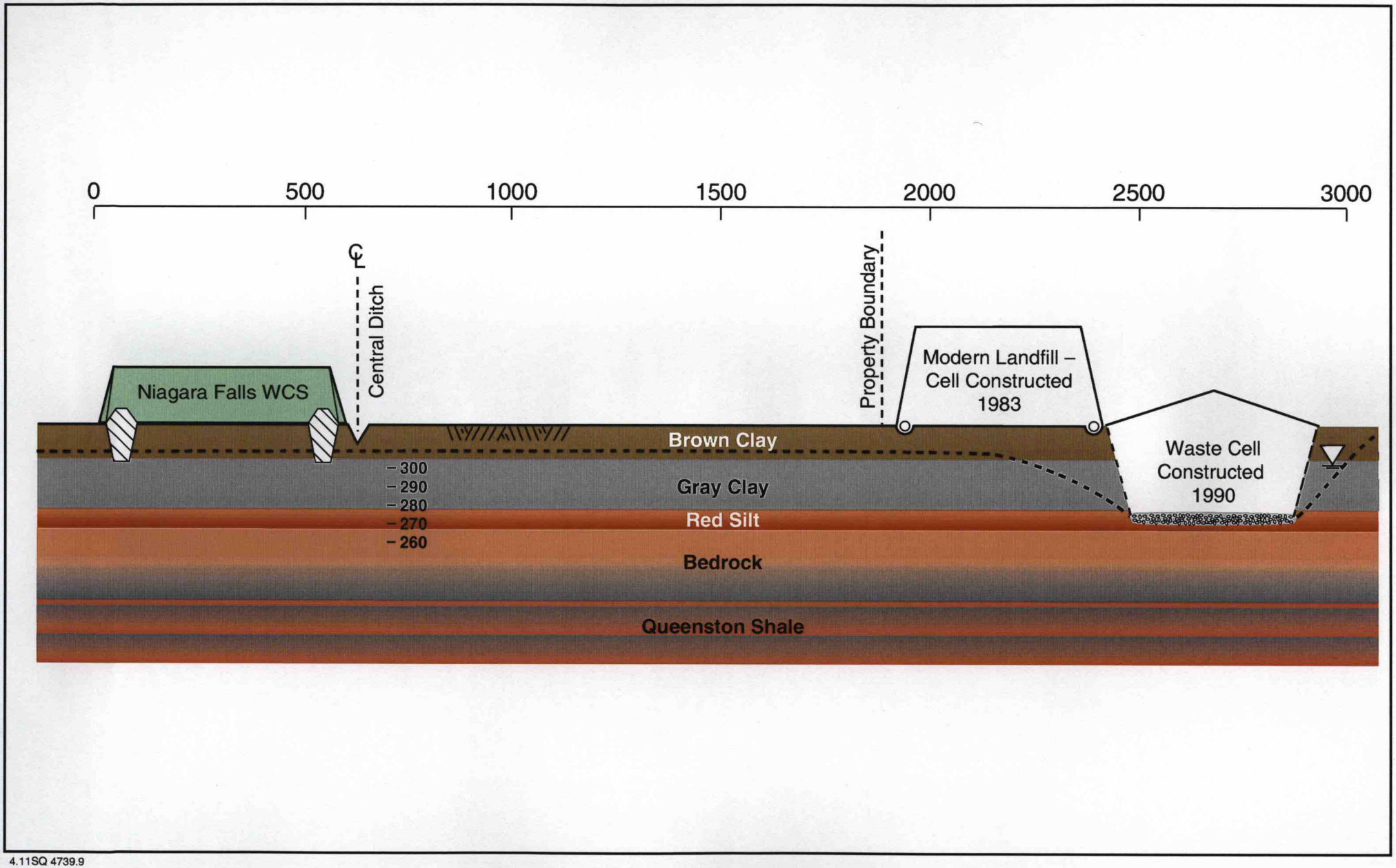
158F035.DGN

Monitoring Well Locations at the Niagara Falls Storage Site



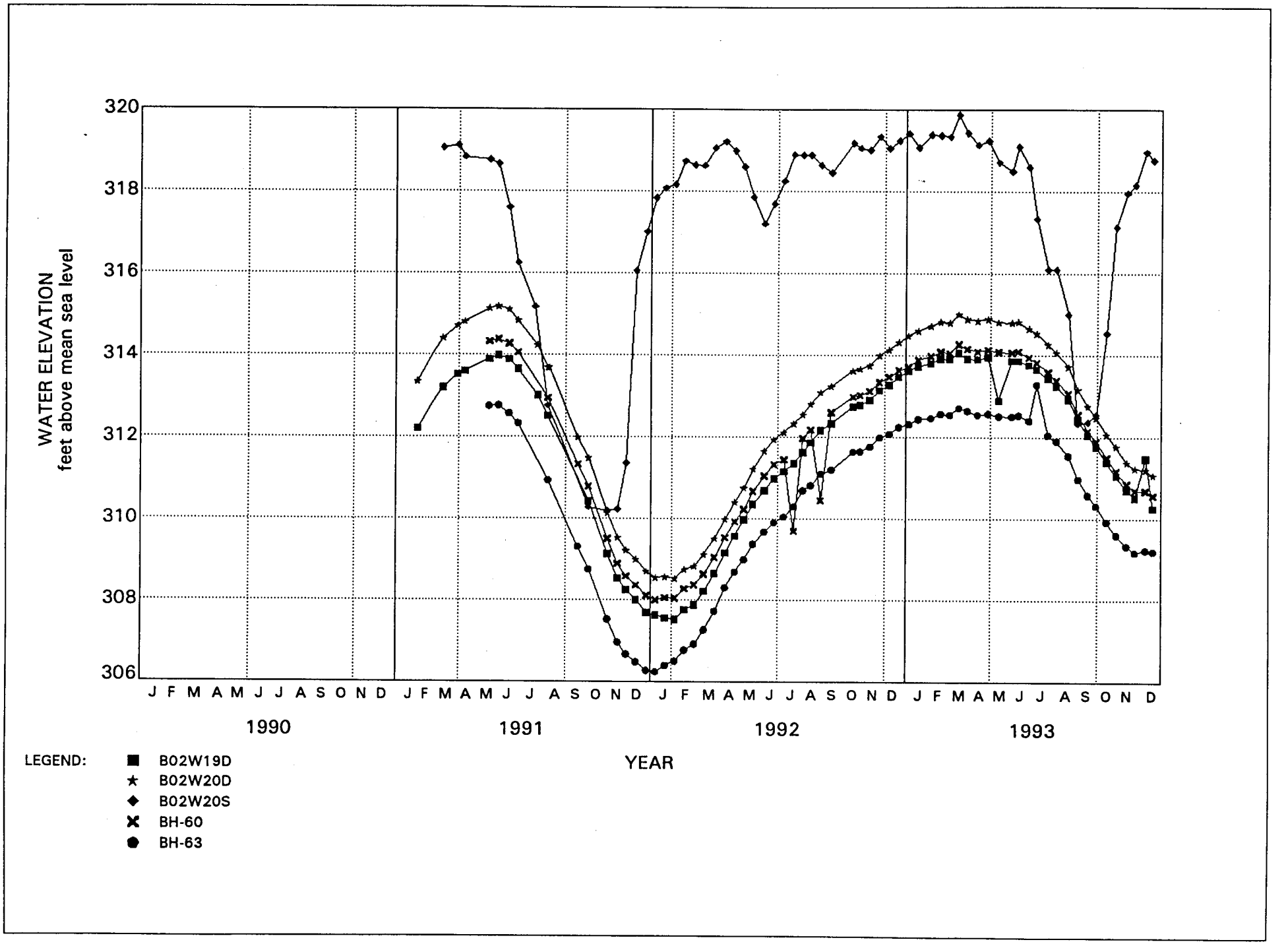
4.11SQ 4739.7

Water Table from West to East at NFSS



4.11SQ 4739.9

Water Level Profile for the Groundwater at the Top of Bedrock


WATER ELEVATION
feet above mean sea level
320
318
316
314
312
310
308
306
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1990
1991
1992
1993
YEAR
LEGEND:
B02W19D
B02W20D
B02W20S
BH-60
BH-63

FACILITY DESIGN

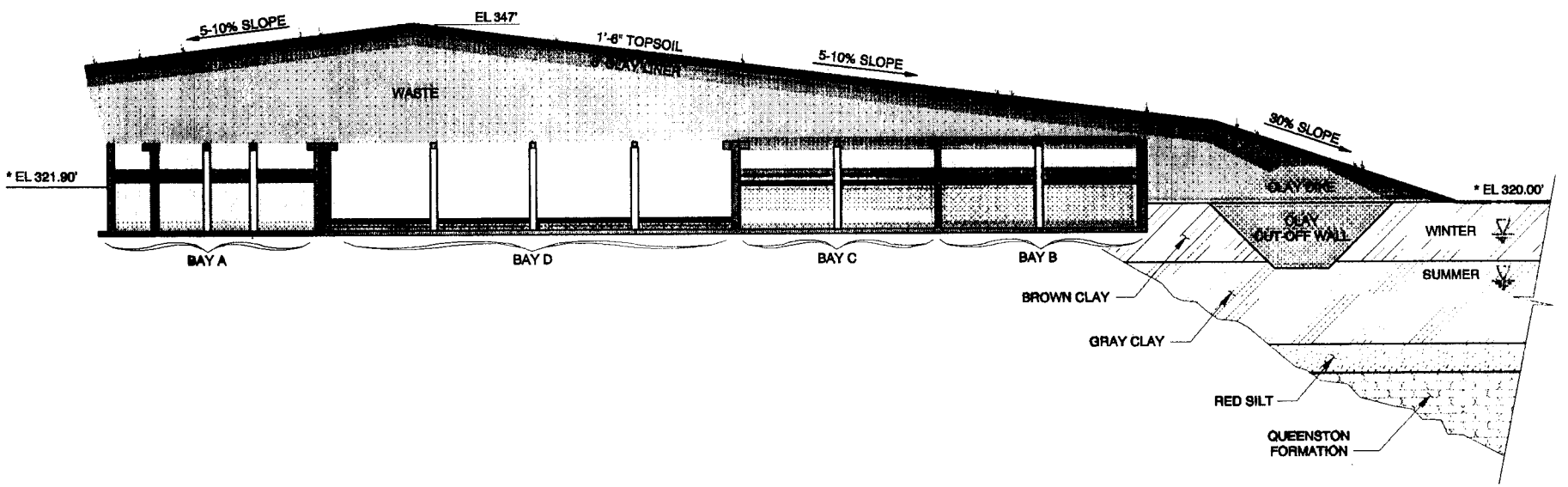
- Design criteria
- Interim cap design
- Final cap design
- Cutoff wall construction
- Monitoring systems and procedures
  - Monitoring wells outside the cutoff wall
  - VWPTs inside the pile
  - Annual walkover and inspection

DESIGN REQUIREMENTS FOR THE NFSS WASTE CONTAINMENT FACILITY

Item No.	Description	Existing Cap	Long-Term Cap	Dike and Cutoff Walls	Bottom	Remarks
1.	Design Service Life	25-50 years	200-1000 years	200-1000 years	200-1000 years	
2.	Safety Factor: Cutoff Walls Slope Stability					
	Static conditions	1.5	1.5	--	--	
	Earthquake	1.0	1.0	--	--	
3.	Surface Drainage Slope					
	Top Surface	5-10 %	5-10 %	--	--	
	Side Slopes	Max. 3H to 1V	Max. 5H to 1V	--	--	
4.	Surface Erosion Protection	Shallow-rooted grass	Shallow-rooted grass Riprap to elevation 98.4 m (323 ft)	--	--	
5.	Intrusion Barrier Required	No	Yes	--	--	
6.	Frost Penetration	48 in.	48 in.	--	--	Assume bare ground
7.	Radon Barrier Required	Yes (20 $pCi/m^2/s$)	Yes (20 $pCi/m^2/s$)	--	--	
8.	Radiation Barrier Required	Yes (100 mrem/yr)	Yes (100 mrem/yr)	--	--	
9.	Component Construction	Topsoil/clay	Topsoil/rock layer/clay	Clay	Natural clay strata	
10.	Clay Permeability	10^{-7} cm/s	10^{-7} cm/s	Approx. 10^{-7} cm/s	Approx. 10^{-7} cm/s	
11.	Clay Adsorption Coefficient					
	Natural Uranium	5 ml/g	5 ml/g	5 ml/g	5 ml/g	
	Radium-226	500 ml/g	500 ml/g	500 ml/g	500 ml/g	
12.	Inspection and Maintenance Required	Yes (design life)	Yes	No	No	
13.	Earthquake Pseudostatic Coefficient	0.1g	0.15g	0.15 g	--	

Item No.	Description	Existing Interim Cap	Long-Term Cap	Dike and Cutoff Walls	Bottom	Remarks
14.	DOE Concentration Guide for Radionuclide Migration (groundwater concentration, uncontrolled areas)	--	--			
	Natural Uranium	--	--	600 pCi/l	600 pCi/l	
	Radium-226, -228			30 pCi/l	30 pCi/l	
15.	Temperature Extremes	-29° to 34°C (-20° to 94°F)	-29° to 34°C (-20° to 94°F)	-29° to 34°C (-20° to 94°F)	—	
16.	Rainfall per Year	74 cm (29 in.)	74 cm (29 in.)	--	--	
17.	Wind Speed and Direction	(80 mph) southwest	(80 mph) southwest	--	--	
18.	Annual Deep-Infiltration Rate	2.54 cm (1.0 in.)	2.54 cm (1.0 in.)	--	--	
19.	Design Flood Plain Elevation	Elevation 96.6 m (317 ft) m.s.l. per 100 years	Probable Maximum Flood (PMF) 98.4 m (323 ft)	Probable Maximum Flood (PMF) 98.4 m (323 ft)		
20.	Groundwater Elevation (high)	--	--	--	Elevation 96 m (315 ft) m.s.l. (Exclusive of PMF)	
21.	Snowfall Per Year	2.4 m (93 in.)	2.4 m (93 in.)	--	—	
22.	Internal Cap Drainage Layer	None	Yes	--	--	
23.	Waste Containment Consolidation	Minimize settlement (95% compaction)	Minimize settlement (95% compaction)	95% compaction	--	
24.	Shrinkage, Swelling, and Frost Action Requirements	Yes (3 to 5% in volume expansion)	Yes (3 to 5% in volume expansion)	Yes (3 to 5% in volume expansion)	No	
25.	Migration Limits	Not to exceed EPA primary drinking water standards in off-site groundwater	Not to exceed EPA primary drinking water standards in off-site groundwater	Not to exceed EPA primary drinking water standards in off-site groundwater	Not to exceed EPA primary drinking water standards in off-site groundwater	
26.	Buffer Zone (measured from lateral limit of waste)	30.5 m (100 ft)	30.5 m (100 ft)	--	--	
27.	Groundwater Hydraulic Gradient (saturated zone)	--	--	--	0.0015	

NIAGARA FALLS STORAGE SITE
CROSS SECTION OF INTERIM WASTE CONTAINMENT STRUCTURE AND BUILDING 411



CONTAMINATED SOIL FILL

INITIAL UNCOMPACTED SOIL FILL

COMPACTED CLAY COVER

EXISTING SAND FILTER

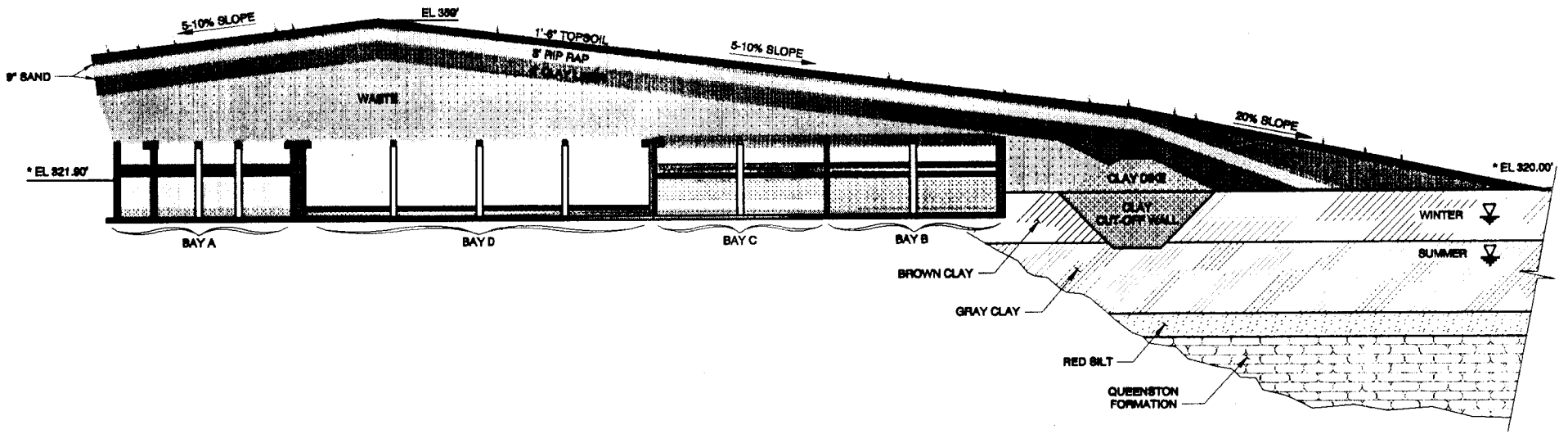
SAND LAYER

EXISTING L-30 AND F-32 RESIDUES

EXISTING K-65 RESIDUES

GEOTEXTILE FABRIC

NIAGARA FALLS STORAGE SITE
CROSS SECTION OF FINAL WASTE CONTAINMENT STRUCTURE AND BUILDING 411



CONTAMINATED SOIL FILL

INITIAL UNCOMPACTED SOIL FILL

COMPACTED CLAY COVER

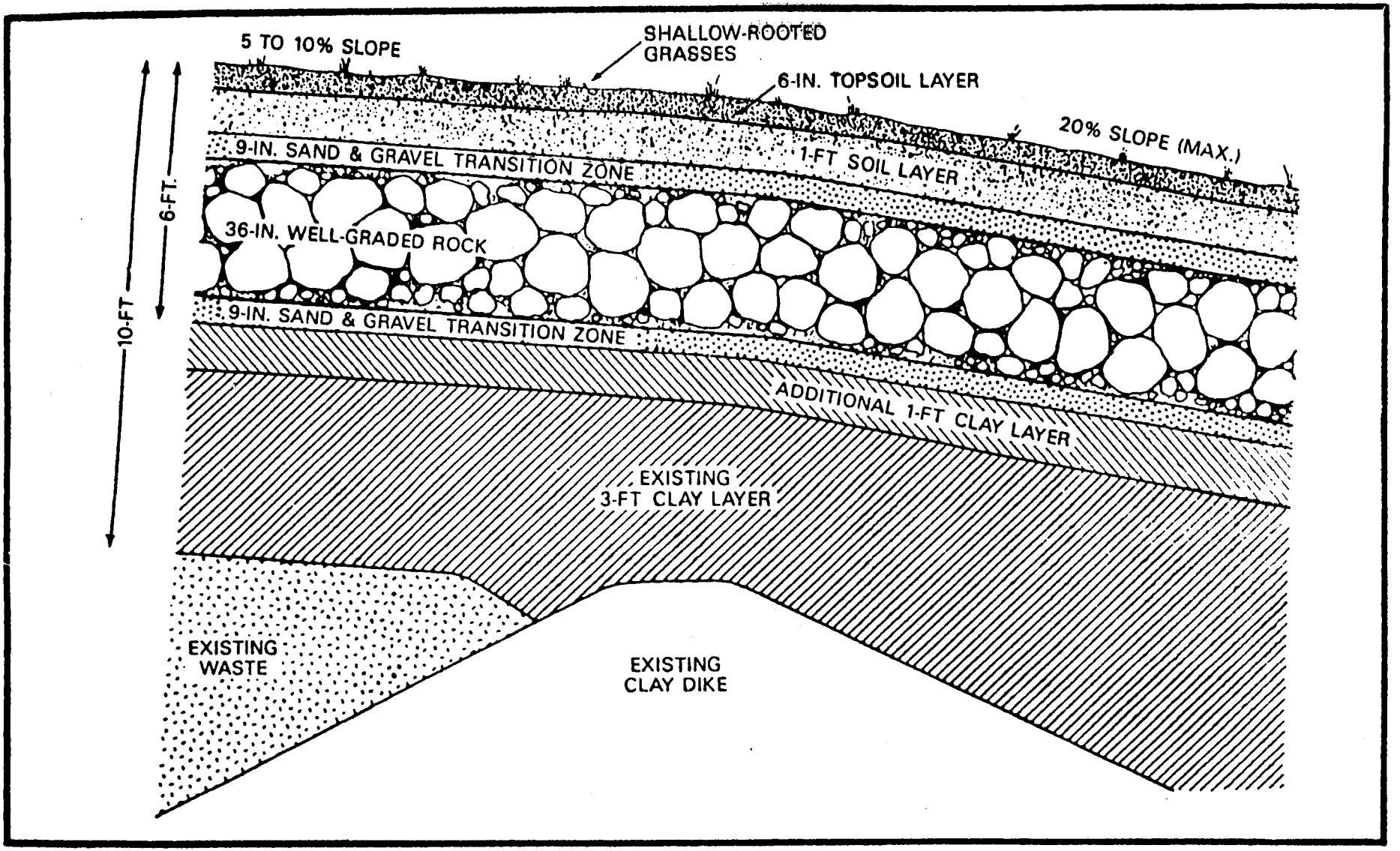
EXISTING SAND FILTER

SAND LAYER

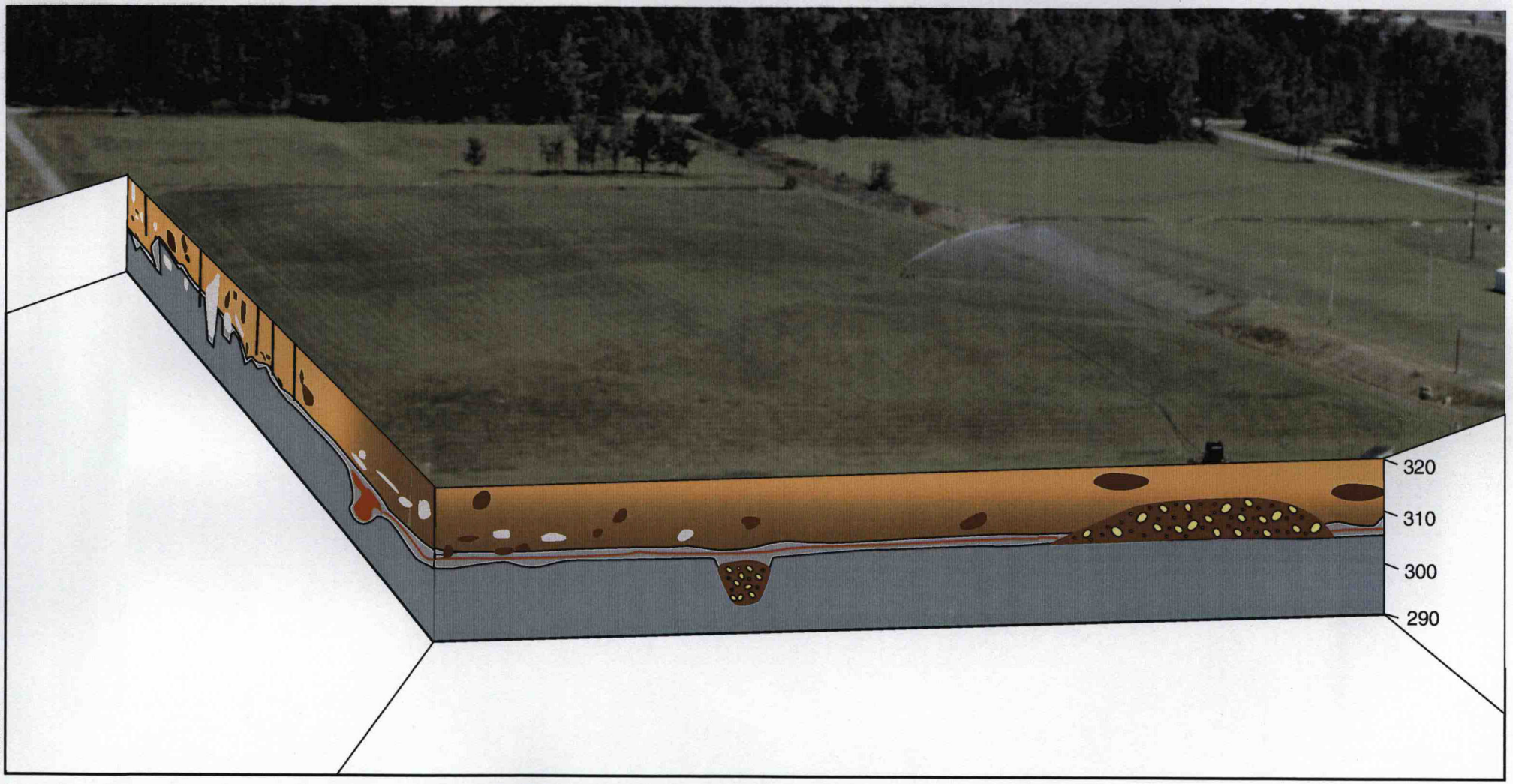
EXISTING L-30 AND F-32 RESIDUES

EXISTING K-65 RESIDUES

GEOTEXTILE FABRIC

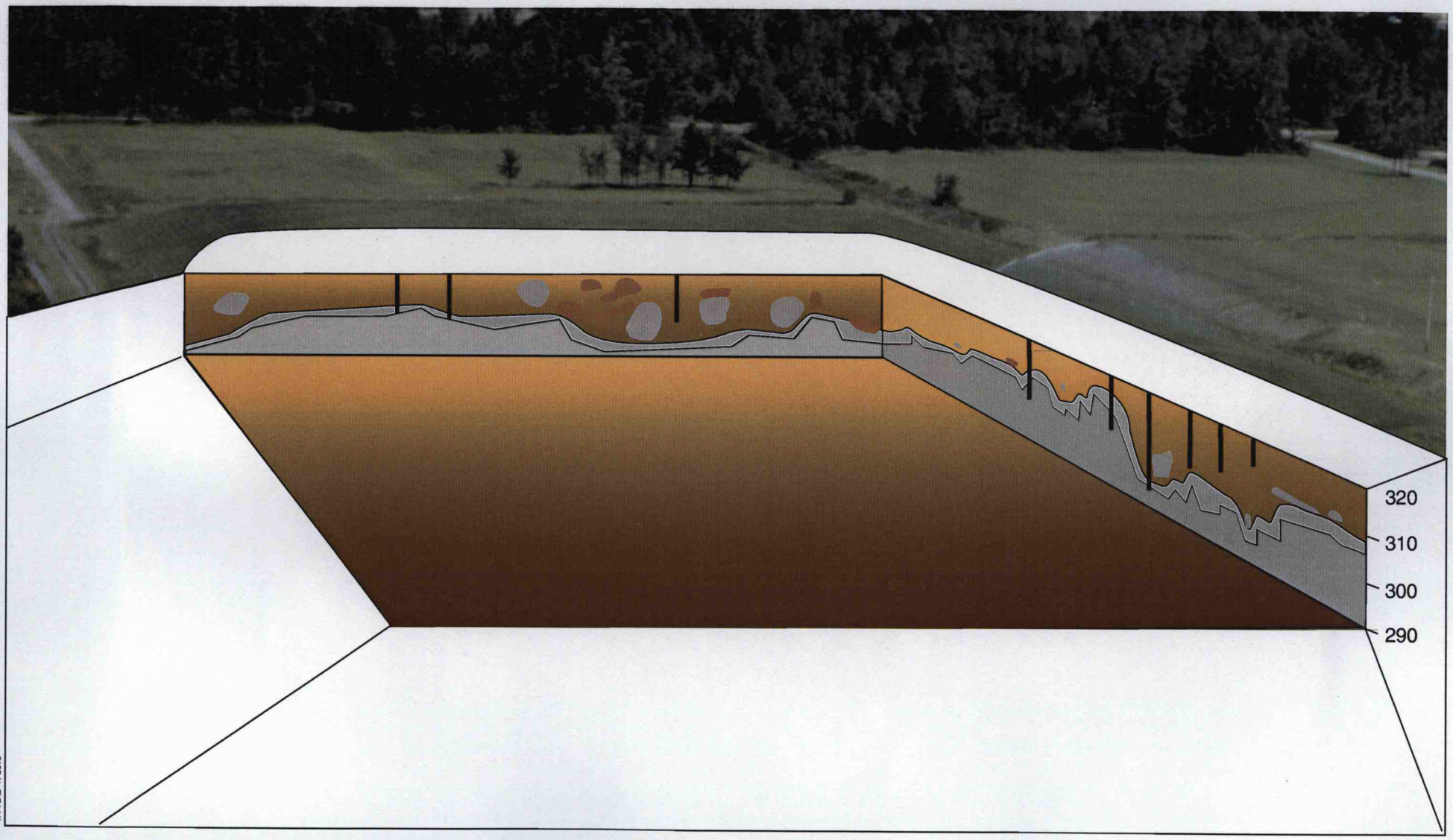


NFSS LONG-TERM COVER LAYERS



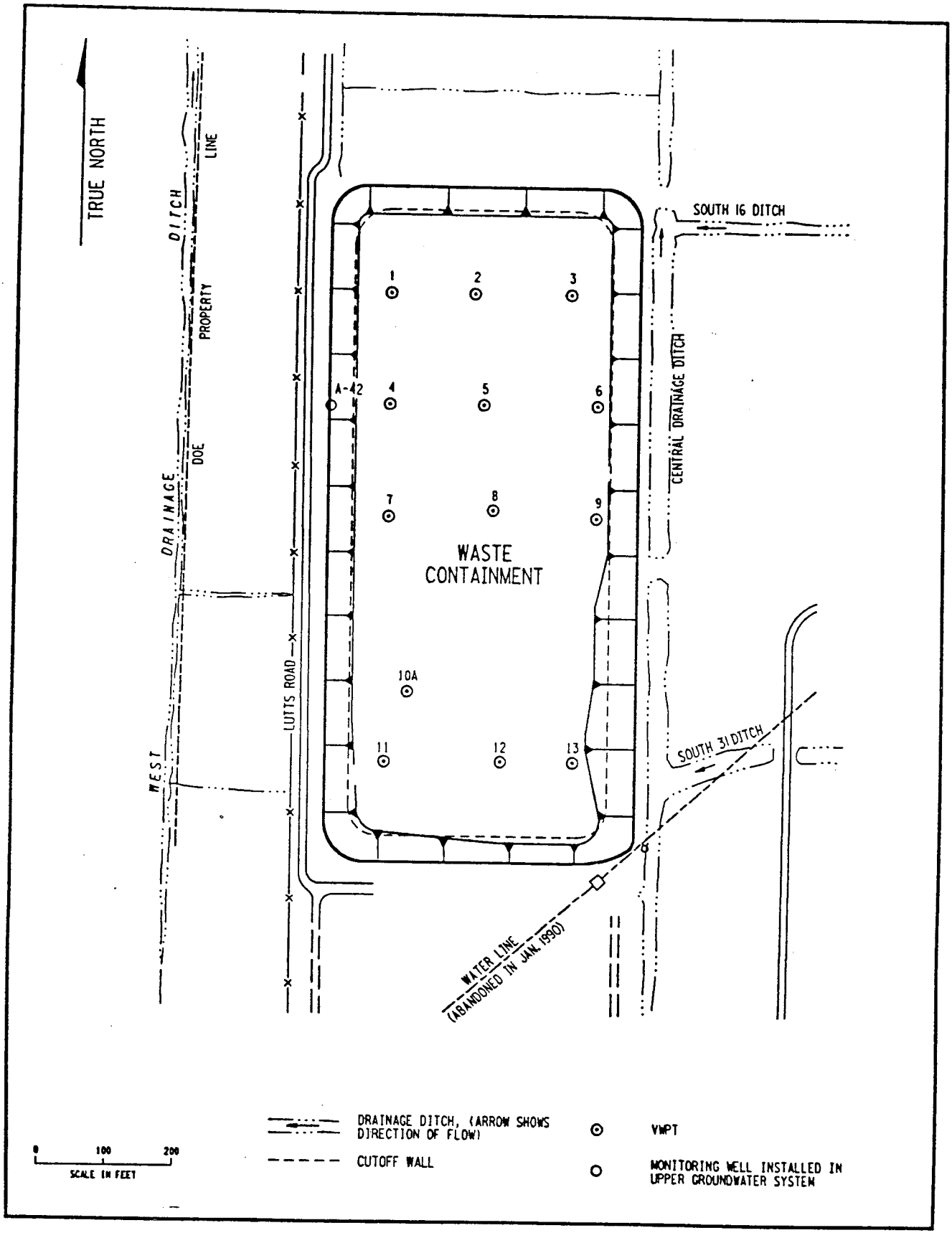
4.11SQ 4739.4

Ref. Geotechnical Post-Construction Report, 1986
NFSS Geologic Report, 1984



4.11SQ 4739.5

Ref. Geotechnical Post-Construction Report, 1986
NFSS Geologic Report, 1984



VWPT LOCATIONS

VERIFICATION OF GEOTECHNICAL INPUT PARAMETERS FROM NFSS EIS

	EIS PARAMETERS	VERIFICATION
Erosion rate	0.0 m/yr	0.00008 m/yr
Density c2	1.8 g/cc	1.8 g/cc
Density s2	1.7 g/cc	1.7 g/cc
Well intake	4 or 10 gal/min	10 gal/min
Effective porosity	0.1	0.1
Porosity	0.4	0.4
ET coefficient	0.85	0.85
K saturation	0.14 m/yr	0.14 m/yr
Gradient	0.0016 or 0.001	0.0016
Precipitation	0.89 m/yr	0.89 m/yr
K unsaturated	0.14 m/yr	0.14 m/yr
T unsaturated	9 m	-
Effective Porosity	0.2	0.2
Kd Cs-137	2	-
U-234	16	16
U-236	16	-
U-238	16	16
Ra-226	-	500
Pb-210	-	100
Th-230	-	6,000
Infiltration	0.107	0.107
Runoff	0.2	0.2

Both models assume no dispersion or diffusion