DOCUMENTATION OF ENVIRONMENTAL INDICATOR DETERMINATION

RCRA Corrective Action
Environmental Indicator (EI) RCRIS code (CA725)

Current Human Exposures Under Control

Facility Name:	**IBM - Thomas J. Watson Research Center**
Facility Address:	**Yorktown Heights, NY 10598**
Facility EPA ID #:	**NYD084006741**

1. Has **all** available relevant/significant information on known and reasonably suspected releases to soil, groundwater, surface water/sediments, and air, subject to RCRA Corrective Action (e.g., from Solid Waste Management Units (SWMU), Regulated Units (RU), and Areas of Concern (AOC)), been **considered** in this EI determination?

   __X__ If yes - check here and continue with #2 below.

   _____ If no - re-evaluate existing data, or

   _____ if data are not available skip to #6 and enter"IN" (more information needed) status code.

BACKGROUND

Definition of Environmental Indicators (for the RCRA Corrective Action)

Environmental Indicators (EI) are measures being used by the RCRA Corrective Action program to go beyond programmatic activity measures (e.g., reports received and approved, etc.) to track changes in the quality of the environment. The two EI developed to-date indicate the quality of the environment in relation to current human exposures to contamination and the migration of contaminated groundwater. An EI for non-human (ecological) receptors is intended to be developed in the future.

Definition of "Current Human Exposures Under Control" EI

A positive "Current Human Exposures Under Control" EI determination ("YE" status code) indicates that there are no "unacceptable" human exposures to "contamination" (i.e., contaminants in concentrations in excess of appropriate risk-based levels) that can be reasonably expected under current land- and groundwater-use conditions (for all "contamination" subject to RCRA corrective action at or from the identified facility (i.e., site-wide)).

Relationship of EI to Final Remedies

While Final remedies remain the long-term objective of the RCRA Corrective Action program the EI are near-term objectives which are currently being used as Program measures for the Government Performance and Results Act of 1993, GPRA). The "Current Human Exposures Under Control" EI are for reasonably expected human exposures under current land- and groundwater-use conditions ONLY, and do not consider potential future land- or groundwater-use conditions or ecological receptors. The RCRA Corrective Action program's overall mission to protect human health and the environment requires that Final remedies address these issues (i.e., potential future human exposure scenarios, future land and groundwater uses, and ecological receptors).

Duration / Applicability of EI Determinations

EI Determinations status codes should remain in RCRIS national database ONLY as long as they remain true (i.e., RCRIS status codes must be changed when the regulatory authorities become aware of contrary information).

2. Are groundwater, soil, surface water, sediments, or air **media** known or reasonably suspected to be **"contaminated"**[1] above appropriately protective risk-based "levels" (applicable promulgated standards, as well as other appropriate standards, guidelines, guidance, or criteria) from releases subject to RCRA Corrective Action (from SWMUs, RUs or AOCs)?

	Yes	No	?	Rationale / Key Contaminants
Groundwater	X			Based upon groundwater monitoring results- Key contaminants; Freon and TCE.
Air (indoors)[2]		X		Soil gas sampling for Freon and TCE.
Surface Soil (e.g., <2 ft)		X		All contaminated surface soil was excavated.
Surface Water		X		Sampling of the stream which runs through the site shows no contamination is present.
Sediment		X		Sediment samples from the stream which runs through the site shows no contamination.
Subsurf. Soil (e.g., >2 ft)		X		Sampling showed deep unsaturated soils not contaminated.
Air (outdoors)		X		No significant sources.

____ If no (for all media) - skip to #6, and enter "YE," status code after providing or citing appropriate "levels," and referencing sufficient supporting documentation demonstrating that these "levels" are not exceeded.

__X__ If yes (for any media) - continue after identifying key contaminants in each "contaminated" medium, citing appropriate "levels" (or provide an explanation for the determination that the medium could pose an unacceptable risk), and referencing supporting documentation.

____ If unknown (for any media) - skip to #6 and enter "IN" status code.

Rationale and Reference(s):

Facility and Release Sources.

IBM Yorktown is a research laboratory occupying an area of approximately 219 acres. Research activities involve wet chemical operations carried-out in Building 801 which is laid out in an arc. There are separate buildings onsite for wastewater treatment, maintenance and administration. The facility has a RCRA permit that addresses: (1) the storage and management of hazardous waste; (2) the operation and maintenance of a final corrective measures pump and treat system for remediating contaminated groundwater; and (3) the monitoring of the corrective action groundwater well network to assess the remedy's performance. Figures 1 and 2 show the facility location and the layout of the site.

In 1988, IBM expanded its groundwater monitoring program to determine the effects of suspected releases from their old laboratory underground wastewater piping system. Investigations determined that releases of dilute laboratory wastewater from isolated sections of the old piping system had contaminated on-site groundwater and soils surrounding the pipeline with volatile organic constituents (VOCs). Low concentrations of metals were also detected in the soil where leaks occurred, but did not contribute to the groundwater contamination. The layout of the underground piping system subject to excavation is depicted in Figure 3. Soil gas analysis showed that the most significant releases from the underground piping system occurred in the vicinity of Core areas 5 and 6 with less significant releases occurring in the vicinity of Core area 3. Refer to Figures 4 and 5 that illustrate soil gas concentration contours of Freon 113 at four and twelve foot depths below the Building 801.

Geology and Hydrology.
The complexity of the bedrock formations existing in the vicinity of this facility is illustrated in Figure 13. The entire site is underlain by metamorphic bedrock consisting primarily of garnet and quartz-rich biotite schist and was encountered at a depth as low as 78 feet below the surface. Structurally, bedrock under the site is dominated by foliation striking northeast-southwest and dipping to the south between 60 and 90 degrees with joints generally orienting and dipping in the same direction. Fractures are opened and concentrated in zones with many filled with quartz. Two bedrock ridges cross the site from northeast to southwest and are separated by a bedrock valley that widens and becomes lower in elevation to the northeast. A saddle-like feature exists in the southernmost bedrock ridge at the east end of Building 801. A number of metals, including chromium, copper, lead, nickel and zinc occur naturally in the rock. Therefore, weathering products of these rocks could be expected to impact natural concentrations of some or all of these metals to groundwater flowing through them. The site's schist bedrock is covered by variable unconsolidated units that include glacial deposits and weathered bedrock. Figures 14 and 15 depict the cross section of the geology existing along the front of Building 801 and through that Building 801respectively and illustrates the typical depth of the unconsolidated units.

Overburden soil groundwater is found in unconsolidated deposits consisting of sand and till lying above weathered bedrock, with the water table being about 10 feet below the surface near the building in the vicinity of the significant releases. The water table elevation deepens and the thickness of the unconsolidated deposits increase from 40 to 80 feet when moving north from the building. Figure 16 is the elevation contour map for the soil water table that shows the general direction of soil groundwater flow during the RFI and prior to implementing corrective measures. Flow is generally to the north and northwest beneath Building 801. Vertical downward gradients were found to exist between the soil unit and the underlying bedrock at MW-104 and 107 that would cause the deeper soil groundwater at Building 801 to migrate to the shallow bedrock flow system moving away from this building. Further to the north at MW-147 a net upward vertical flow moves the shallow bedrock groundwater into the deeper soil groundwater. Figure 17, a north-south cross section running through Building 801, illustrates this vertical flow.

Figure 18 shows the bedrock potentiometric surface identified during the RFI. The presence of zones of high fracture connectivity is the primary control on hydraulic conductivity distribution. Since the primary orientation of hydraulic conductivity is not parallel to the apparent hydraulic gradient, groundwater flow paths are not perpendicular to the potentiometric surface contours shown in the figure. With the implementation of the bedrock groundwater extraction system the potentiometric surface has changed as illustrated in Figure 19.

Contamination.

In 1989 the old laboratory piping system was completely replaced by an updated double walled underground piping system monitored by a leak detection system. Also, all contaminated soil surrounding the old pipeline exhibiting contamination above cleanup criteria was removed and shipped off-site for disposal. Residual metal contamination in the soil was reduced to background levels by the removal action. Several VOCs were detected in the soil, however, Acetone was at the highest concentrations which ranged from 12 to 360 parts per billion (ppb). Therefore, Acetone was established as the indicator contaminant with a cleanup level of 100 ppb, a level that is considered protective for all human exposure pathways and that would result in the removal of all the other VOCs.

Both the overburden soil groundwater and underlying bedrock groundwater contain VOC plumes with Freon 113 and Trichloroethylene (TCE) having the highest concentrations and being considered the target contaminants. From the RFI Report Figures 6 and 7 presents the average TCE and Freon 113 detected in the soil groundwater. Whereas Figures 8 and 9 present average concentrations for TCE and Freon 113 in the bedrock groundwater. In 1990 a sophisticated bedrock groundwater "pump and treat" system was installed to pump bedrock groundwater from several production wells. This extraction system is responsible for containing and reducing in size the contaminant plumes both in the bedrock and soil groundwater. The latest annual groundwater monitoring report dated February 28, 2000 and covering the four quarters in 1999 reported mostly non-detects in both the soil and bedrock monitoring wells. The maximum concentrations of Freon 113 and TCE were detected in the soil groundwater at 2.0 and 9.5 ppb respectively. This observation occurred in a well approximately 50 feet north from the main building. Maximum concentrations of Freon 113, Freon 123a, and TCE were detected in the bedrock groundwater at 31J, 6.4 and 7.5J ppb respectively where the J represents an estimated value. This observation occurred in a well located inside the main building. Each constituent has as its cleanup level the New York State Groundwater Protection Standard of 5.0 ppb.

Releases of VOCs had occurred at several locations from the underground laboratory wastewater sewer lines that run under the main building. Although the groundwater extraction system has been successful in significantly reducing the concentrations of VOCs in both the soil and bedrock groundwater, recent groundwater monitoring data is still detecting low residual levels of VOCs in the bedrock groundwater beneath the building near Core 6 and in soil groundwater approximately 50 feet from Core 3 in the main building. The continued presence of these VOCs in groundwater might suggest that this contamination could be a potential source for indoor air contamination.

Soil gas studies conducted in 1988, when groundwater contamination was at its maximum, detected maximum gas concentrations of Freon 113 at 170 ug/l or 170 mg/cubic meter and TCE at 0.68 ug/l or 0.68 mg/cubic meter under the building at a depth of four feet in the vicinity of Cores 5 and 6 where the most significant releases occurred.. Since then corrective measures has been successful in significantly reducing groundwater contaminant concentrations under and adjacent to the building from their previous maximum levels (i.e., Freon 113 at 3,000 ug/l and TCE at 420 ug/l in the soil groundwater and Freon 113 at 1400 ug/l and TCE at 27 in the bedrock groundwater). The lower residual groundwater contaminant concentrations currently being detected in the same vicinity where these maximum levels were observed would be expected to cause soil gas concentrations to decrease dramatically from the levels previously identified during the 1988 soil gas studies.

References:

1. Annual and Semiannual Corrective Action Status Reports
2. RFI Report, dated February 1, 1991
3. Statement of Basis, NYSDEC, dated October 1995
4. Approved Groundwater Monitoring Plan.

Footnotes:

[1] "Contamination" and "contaminated" describes media containing contaminants (in any form, NAPL and/or dissolved, vapors, or solids, that are subject to RCRA) in concentrations in excess of appropriately protective risk-based "levels" (for the media, that identify risks within the acceptable risk range).

[2] Recent evidence (from the Colorado Dept. of Public Health and Environment, and others) suggest that unacceptable indoor air concentrations are more common in structures above groundwater with volatile contaminants than previously believed. This is a rapidly developing field and reviewers are encouraged to look to the latest guidance for the appropriate methods and scale of demonstration necessary to be reasonably certain that indoor air (in structures located above (and adjacent to) groundwater with volatile contaminants) does not present unacceptable risks.

3. Are there **complete pathways** between "contamination" and human receptors such that exposures can be reasonably expected under the current (land- and groundwater-use) conditions?

Summary Exposure Pathway Evaluation Table

	Potential **Human Receptors** (Under Current Conditions)						
"Contaminated" Media	Residents	Workers	Day-Care	Construction	Trespassers	Recreation	Food[3]
Groundwater	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Air (indoors)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
~~Soil (surface, e.g., <2 ft)~~							
~~Surface Water~~							
~~Sediment~~							
~~Soil (subsurface e.g., >2 ft)~~							
~~Air (outdoors)~~							

Instructions for Summary Exposure Pathway Evaluation Table:

1. Strike-out specific Media including Human Receptors' spaces for Media which are not "contaminated") as identified in #2 above.
2. enter "yes" or "no" for potential "completeness" under each "Contaminated" Media -- Human Receptor combination (Pathway).

Note: In order to focus the evaluation to the most probable combinations some potential "Contaminated" Media - Human Receptor combinations (Pathways) do not have check spaces ("___"). While these combinations may not be probable in most situations they may be possible in some settings and should be added as necessary.

__X__ If no (pathways are not complete for any contaminated media-receptor combination) - skip to #6, and enter "YE" status code, after explaining and/or referencing condition(s) in-place, whether natural or man-made, preventing a complete exposure pathway from each contaminated medium (e.g., use optional Pathway Evaluation Work Sheet to analyze major pathways).

_____ If yes (pathways are complete for any "Contaminated" Media - Human Receptor combination) - continue after providing supporting explanation.

_____ If unknown (for any "Contaminated" Media - Human Receptor combination) - skip to #6 and enter "IN" status code

Rationale and Reference(s):

Groundwater.

Using the groundwater monitoring data reported during the RFI and presented in Figures 6, 7, 8, and 9 as a benchmark, it's concluded that the implemented pump and treat corrective measures has been successful. It has dramatically reduced both the soil and bedrock groundwater plumes in size and in contaminant concentrations as illustrated in Figure 10 , 11, and 12. From the RFI monitoring data it was concluded that the groundwater plumes never did not migrate off-site to impact residences.

There are no known direct pathways between the residual groundwater contamination and human receptors. The stream flowing through the property, No Name Creek, has not been impacted by the contaminated groundwater as demonstrated by groundwater monitoring and sampling of the Creek. Therefore, the stream's water and sediment would not serve as an indirect pathway between human receptors, using the stream for recreational purposes, and the contaminated groundwater.

All the groundwater pumped from the subsurface is treated to meet the State's Groundwater Protection Standards. Approximately 85% of the treated water is reused in onsite cooling towers. Although contaminants could remain in the treated water at very low residual levels of 5.0 ppb their releases from the cooling tower are controlled by an air emissions permit issued by the State to assure the protection of public health and the environment. The fence around the wastewater treatment area prevents trespassers from gaining access to any exposed contaminated wastewater.

Groundwater at this site was not and is not used as a source of drinking water for the facility or as a watering source for growing food. Workers sampling contaminated groundwater or working construction in the vicinity of contaminated groundwater would be protected by following the appropriate facility health and safety plan. Also, day care services are not provided at this site.

Air.

Several factors suggest that indoor air is not a pathway of concern. First; soil gas studies conducted in 1988, when groundwater contamination was at its maximum, detected maximum gas concentrations of Freon 113 at 170 ug/l or 170 mg/cubic meters and TCE at 0.68 ug/l or 0.68 mg/cubic meters under the building at a depth of four feet in the vicinity of Cores 5 and 6 where releases were significant. Gas phase concentration were an order of magnitude lower for the Freon and non-detect at 0.38 mg/cubic meters for TCE at other sampling locations beneath the building. All soil gas phase concentrations detected were significantly lower than OSHA exposure limits for workers; 9,500 mg/cubic meters for Freon 113 and 270 mg/cubic meters for TCE. Second; the building sits on a concrete slab which serves as a barrier limiting contaminated vapors from entering the building. And third; being the building houses laboratories that utilize volatile chemicals the indoor air is exchanged frequently to assure that the workers are adequately protected. This high air exchange rate would keep any VOC vapors that might find there way into the building from concentrating.

Refer to the references listed under paragraph 2 for further details.

Footnotes:

[3] Indirect Pathway/Receptor (e.g., vegetables, fruits, crops, meat and dairy products, fish, shellfish, etc.)

4. Can the **exposures** from any of the complete pathways identified in #3 be reasonably expected to be **"significant"**[4] (i.e., potentially "unacceptable" because exposures can be reasonably expected to be: 1) greater in magnitude (intensity, frequency and/or duration) than assumed in the derivation of the acceptable "levels" (used to identify the "contamination"); or 2) the combination of exposure magnitude (perhaps even though low) and contaminant concentrations (which may be substantially above the acceptable "levels") could result in greater than acceptable risks)?

____ If no (exposures can not be reasonably expected to be significant (i.e., potentially "unacceptable") for any complete exposure pathway) - skip to #6 and enter "YE" status code after explaining and/or referencing documentation justifying why the exposures (from each of the complete pathways) to "contamination" (identified in #3) are not expected to be "significant."

____ If yes (exposures could be reasonably expected to be "significant" (i.e., potentially "unacceptable") for any complete exposure pathway) - continue after providing a description (of each potentially "unacceptable" exposure pathway) and explaining and/or referencing documentation justifying why the exposures (from each of the remaining complete pathways) to "contamination" (identified in #3) are not expected to be "significant."

____ If unknown (for any complete pathway) - skip to #6 and enter "IN" status code

Rationale and Reference(s):

Footnotes:

[4] If there is any question on whether the identified exposures are "significant" (i.e., potentially "unacceptable") consult a human health Risk Assessment specialist with appropriate education, training and experience.

5. Can the "significant" **exposures** (identified in #4) be shown to be within **acceptable** limits?

_____ If yes (all "significant" exposures have been shown to be within acceptable limits) - continue and enter "YE" after summarizing and referencing documentation justifying why all "significant" exposures to "contamination" are within acceptable limits (e.g., a site-specific Human Health Risk Assessment).

_____ If no (there are current exposures that can be reasonably expected to be "unacceptable")- continue and enter "NO" status code after providing a description of each potentially "unacceptable" exposure.

_____ If unknown (for any potentially "unacceptable" exposure) - continue and enter "IN" status code

Rationale and Reference(s):

6. Check the appropriate RCRIS status codes for the Current Human Exposures Under Control EI event code (CA725), and obtain Supervisor (or appropriate Manager) signature and date on the EI determination below (and attach appropriate supporting documentation as well as a map of the facility):

X YE - Yes, "Current Human Exposures Under Control" has been verified. Based on a review of the information contained in this EI Determination, "Current Human Exposures" are expected to be "Under Control" at the **IBM - Thomas J. Watson Research Center** facility, EPA ID #**NYD084006741**, located in **Yorktown Heights, NY** under current and reasonably expected conditions. This determination will be re-evaluated when the Agency/State becomes aware of significant changes at the facility.

_____ NO - "Current Human Exposures" are NOT "Under Control."

_____ IN - More information is needed to make a determination.

Completed by: [signature] Date: March 27, 2000

James R. Meacham
Project Engineer
New York State Department of Environmental Conservation (NYSDEC)

And

[signature] Date: March 27, 2000

Steve Kaminski
Chief, Eastern Engineering
NYSDEC

Supervisor: [signature] Date: March 28, 2000

Paul J. Merges
Director, Bureau of Radiation and Hazardous Site Management
NYSDEC

Locations where References may be found:

NYSDEC
Division of Solid and Hazardous Materials
50 Wolf Road
Albany, NY 12233-7252

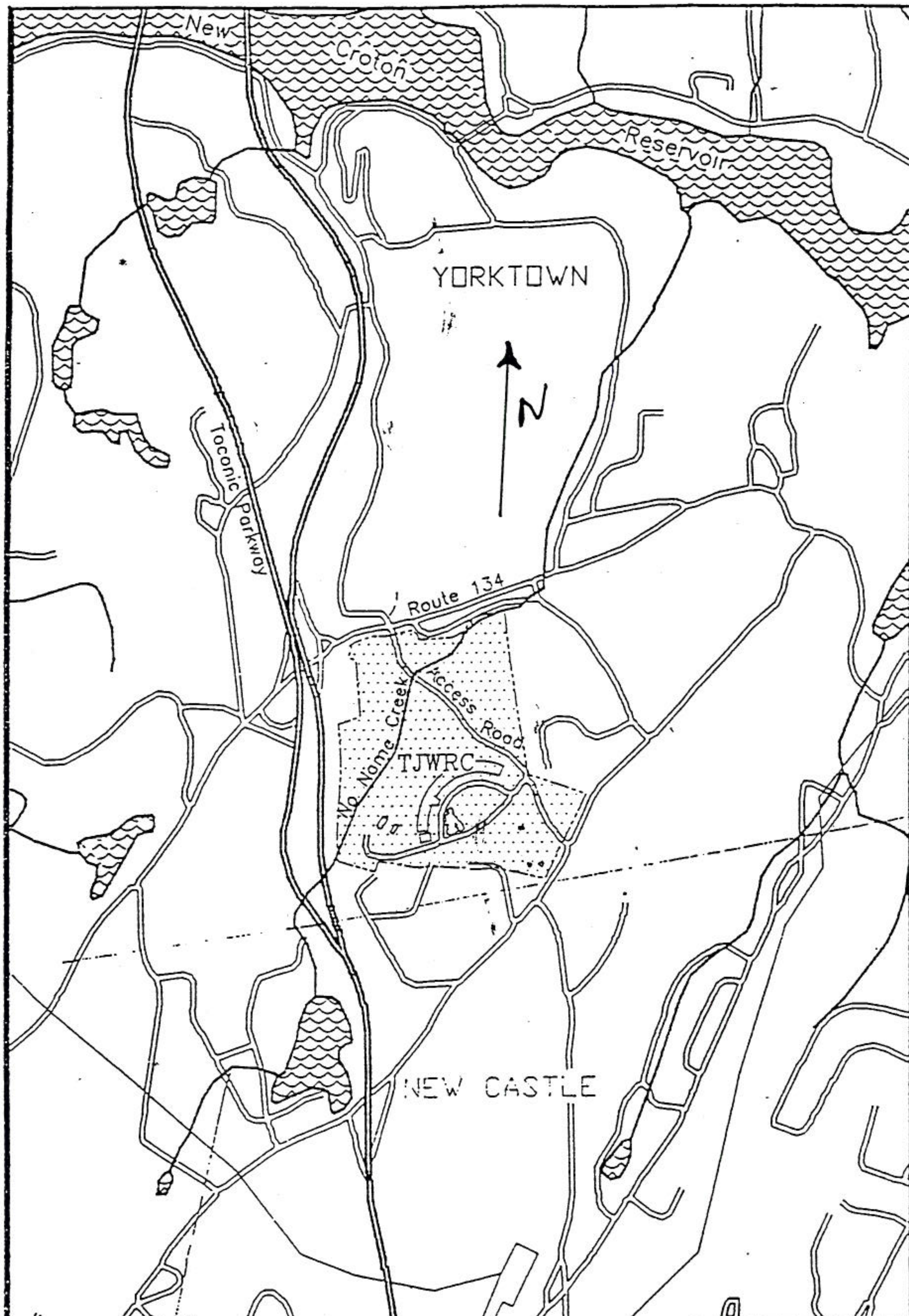
Contact telephone and e-mail numbers

James Meacham
(518)457-9255
E-Mail: jrmeacha@gw.dec.state.ny.us

FINAL NOTE: THE HUMAN EXPOSURES EI IS A QUALITATIVE SCREENING OF EXPOSURES AND THE DETERMINATIONS WITHIN THIS DOCUMENT SHOULD NOT BE USED AS THE SOLE BASIS FOR RESTRICTING THE SCOPE OF MORE DETAILED (E.G., SITE-SPECIFIC) ASSESSMENTS OF RISK.

FIGURE 1

FACILITY LOCATION



Scale: 1" = 2000'

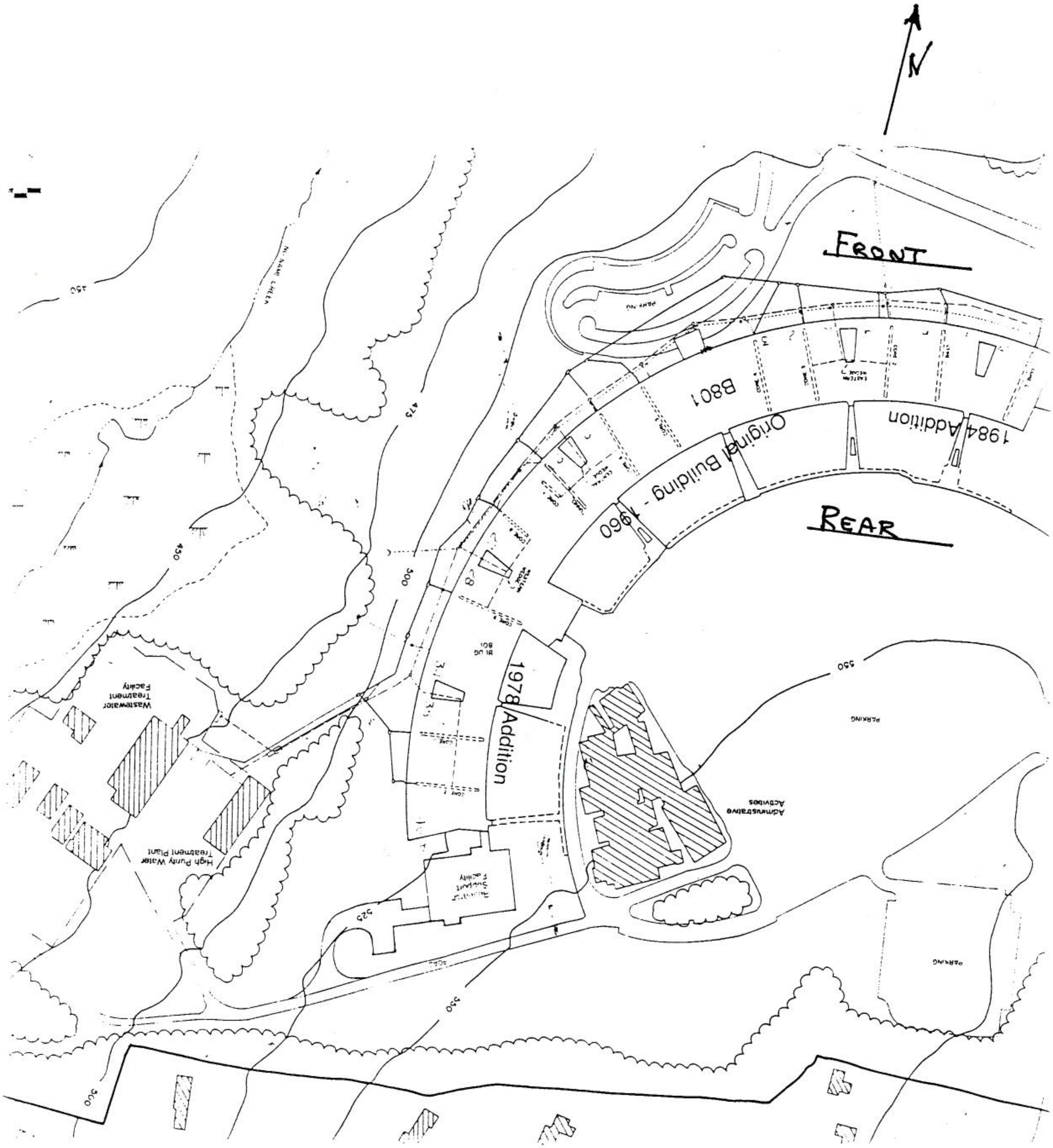


FIGURE 2
SITE LAYOUT

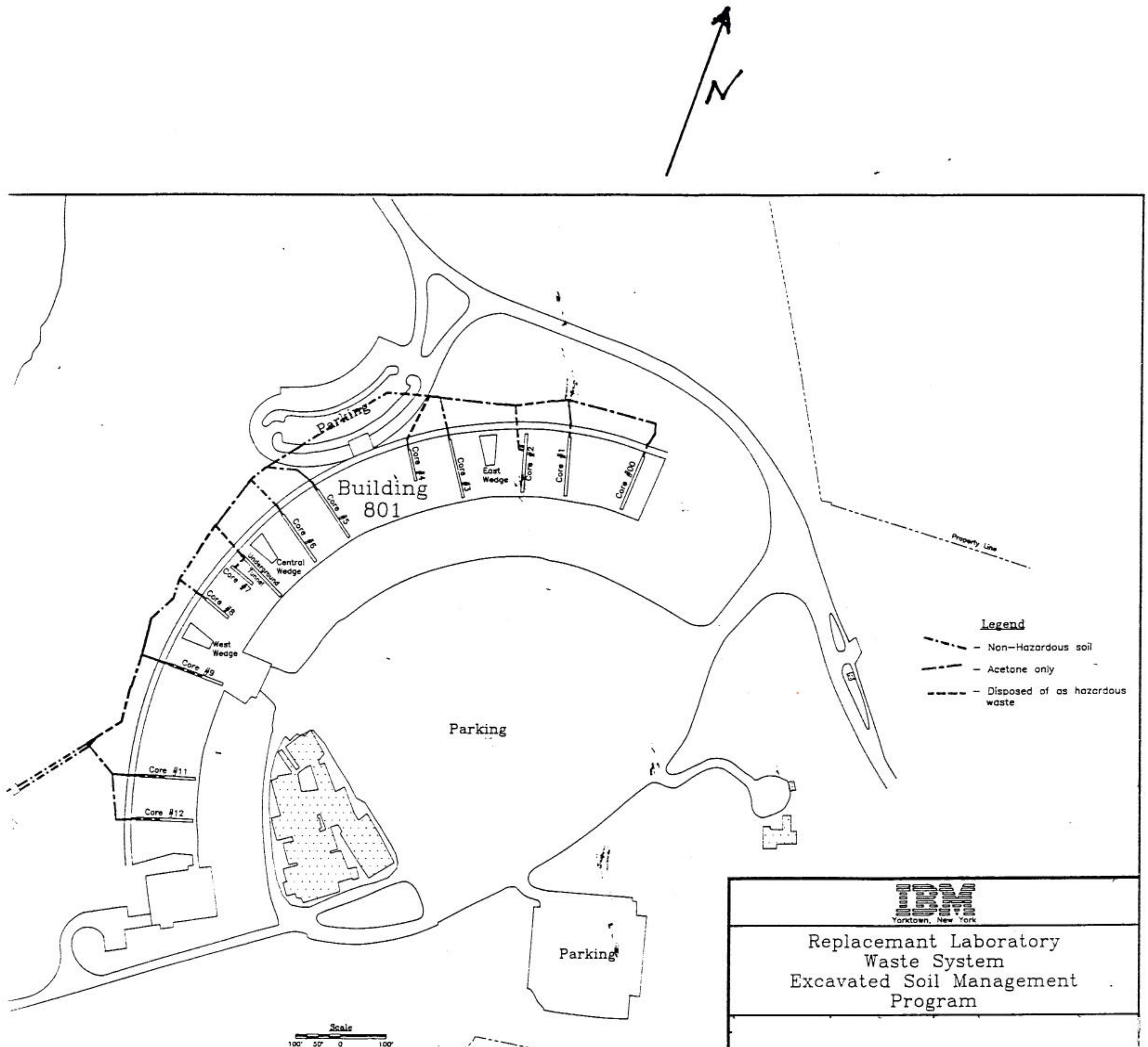
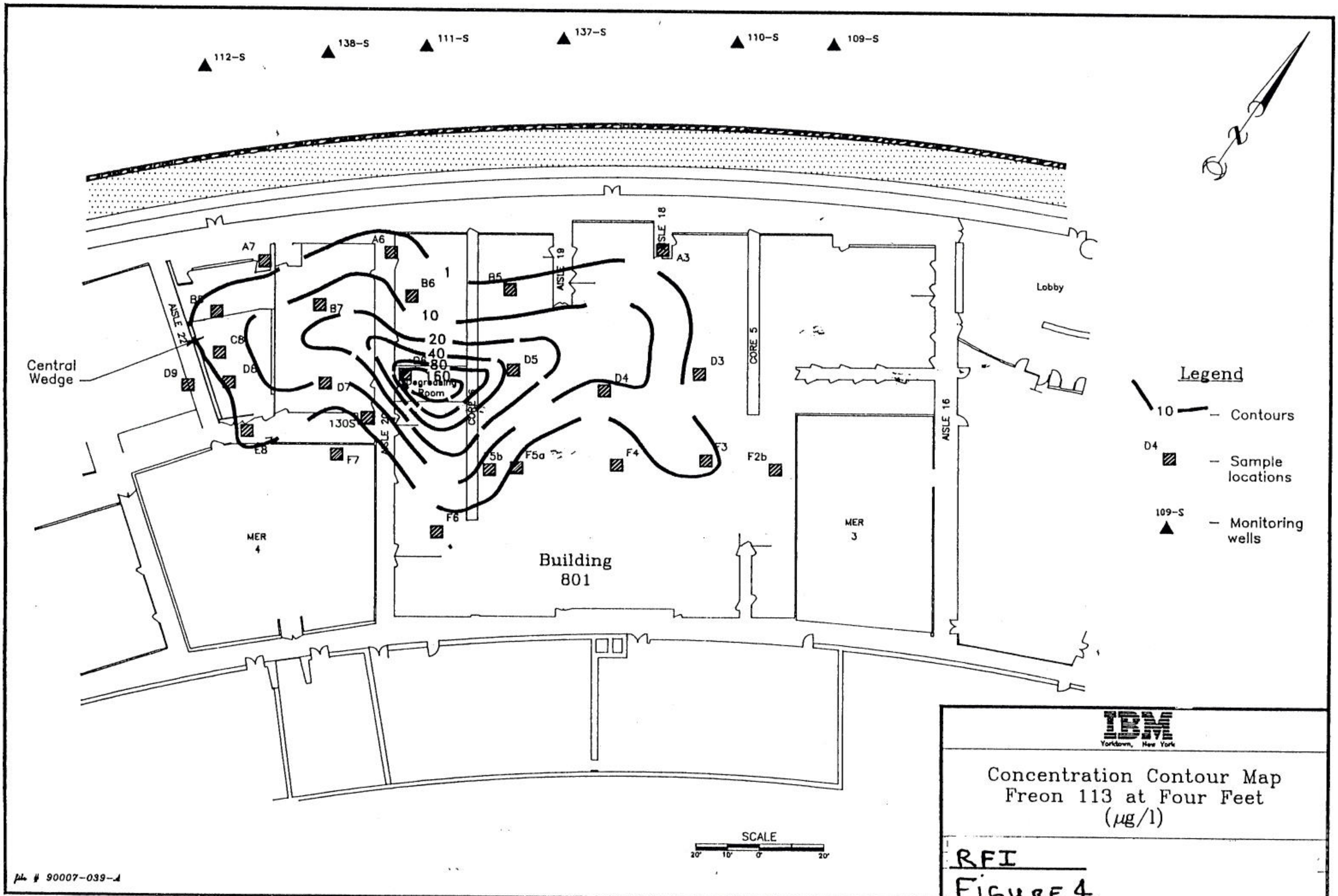

N
Parking
Building
801
Core #4
Core #3
East Wedge
Core #2
Core #1
Core #00
Core #5
Core #6
Central Wedge
Underground Tunnel
Core #7
Core #8
West Wedge
Core #9
Core #11
Core #12
Parking
Parking
Property Line
Legend
- Non-Hazardous soil
- Acetone only
- Disposed of as hazardous waste
IBM
Yorktown, New York
Replacemant Laboratory
Waste System
Excavated Soil Management
Program
Scale
100' 50' 0 100'
Property Line

FIGURE 3.



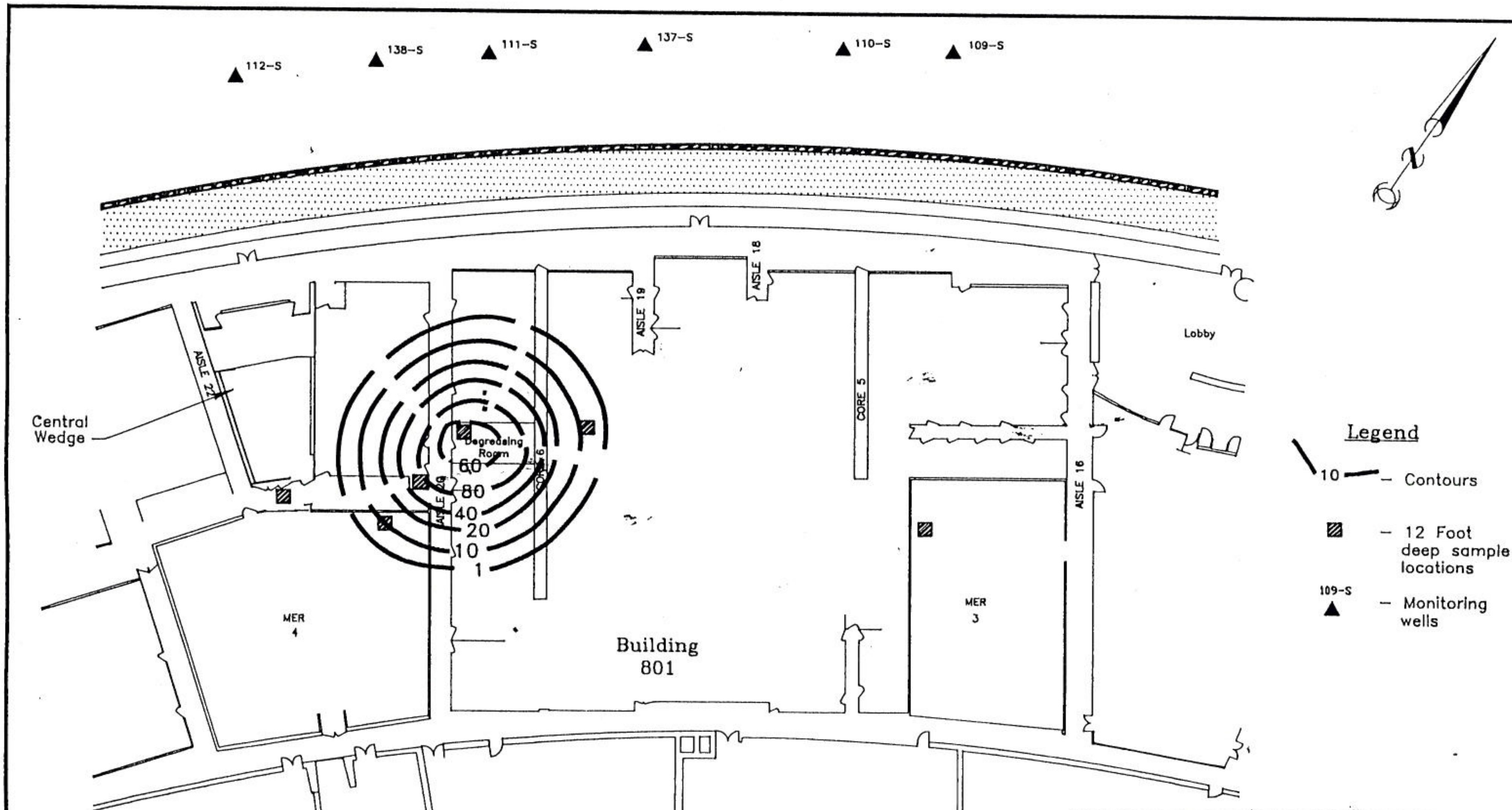
IBM Yorktown, New York

Concentration Contour Map
Freon 113 at Four Feet
($\mu g/l$)

RFI

FIGURE 4.

File # 90007-039-A



IBM Yorktown, New York

Concentration Contour Map
Freon 113 at Twelve Feet
($\mu g/l$)

RFI

FIGURE 5.

file # 90007-040-A

Figure 6. RFI
Average TCE Soil Groundwater Concentrations (ug/l)

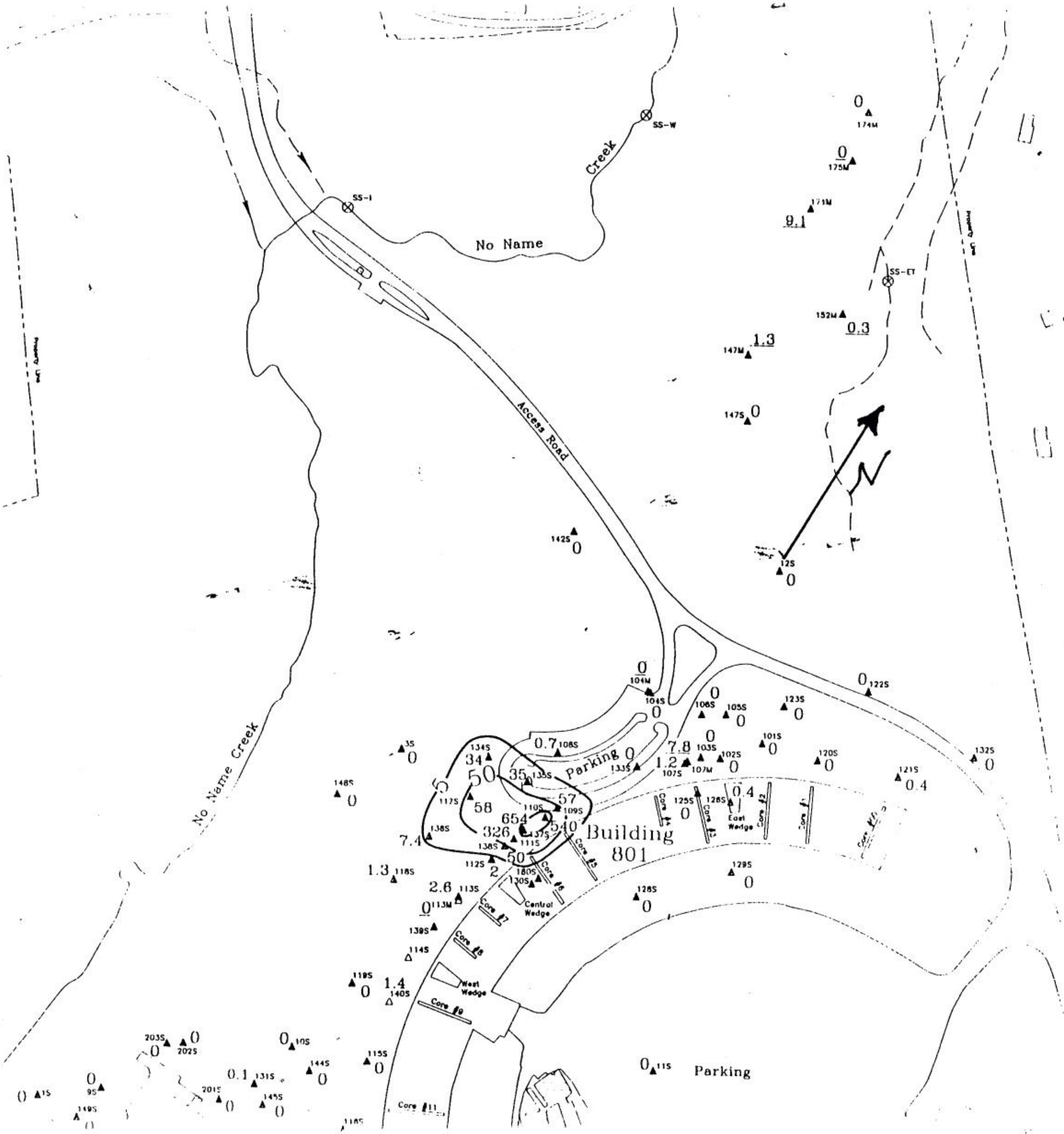


FIGURE 7. RFI
AVERAGE FREON 113 SOIL GROUNDWATER
CONCENTRATIONS (mg/l)

Figure 8. RFI
Average TCE Bedrock
Groundwater Concentrations (ug/L)

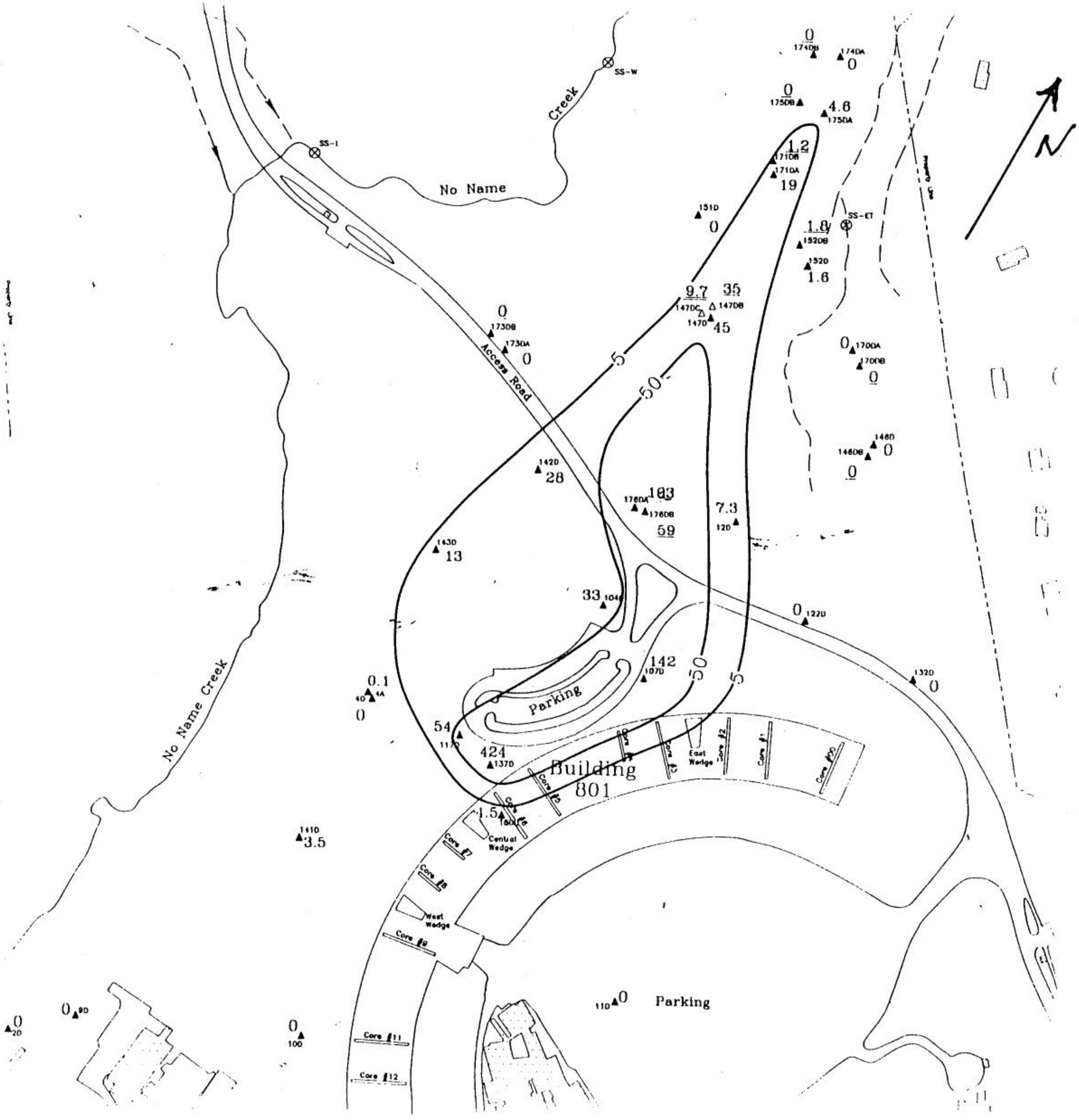


FIGURE 9 RFI
AVERAGE FREON 113 BEDROCK
GROUNDWATER CONCENTRATIONS (µg/l)

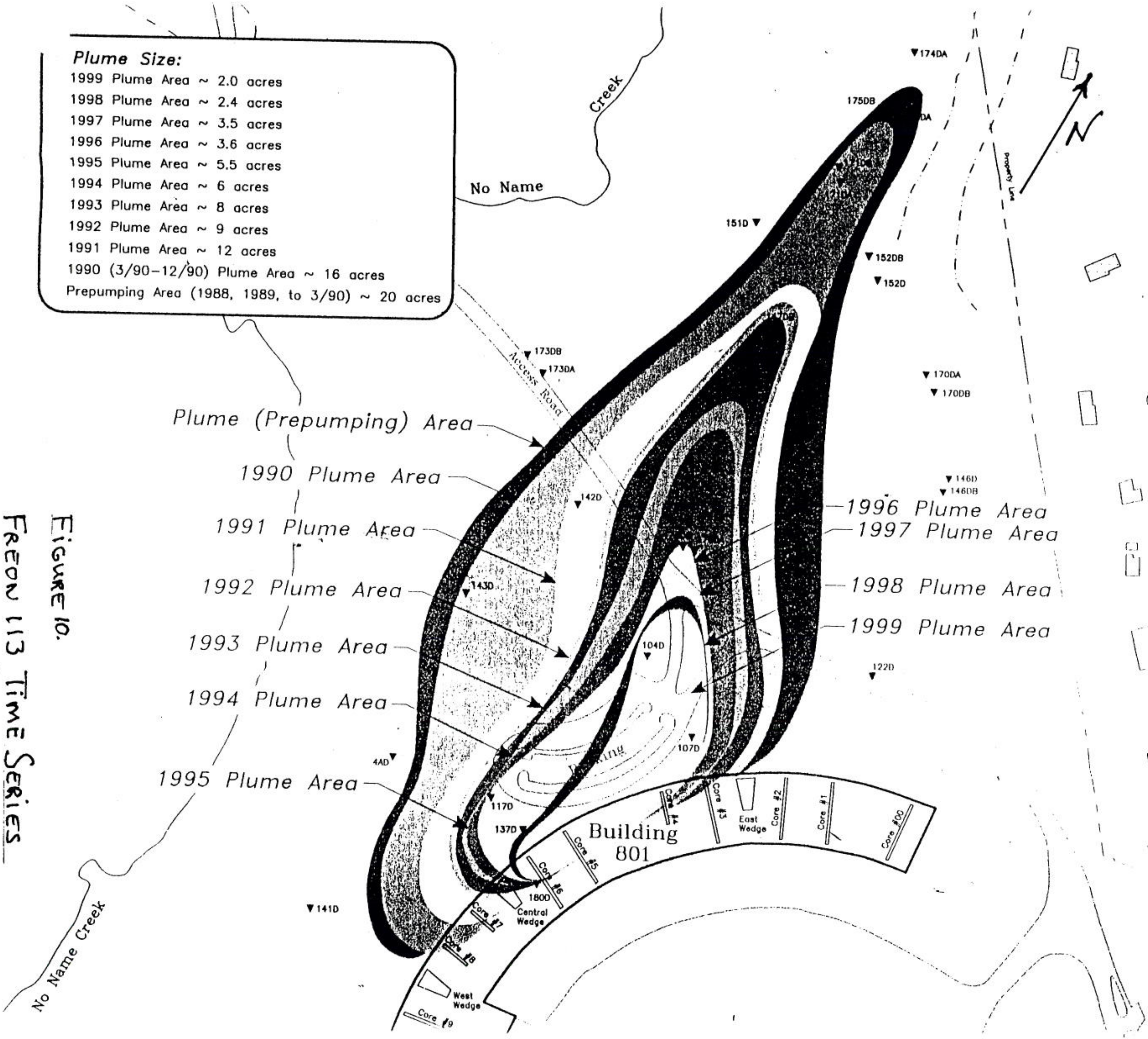


Figure 10. Freon 113 Time Series Bedrock Groundwater Isoconcentrations

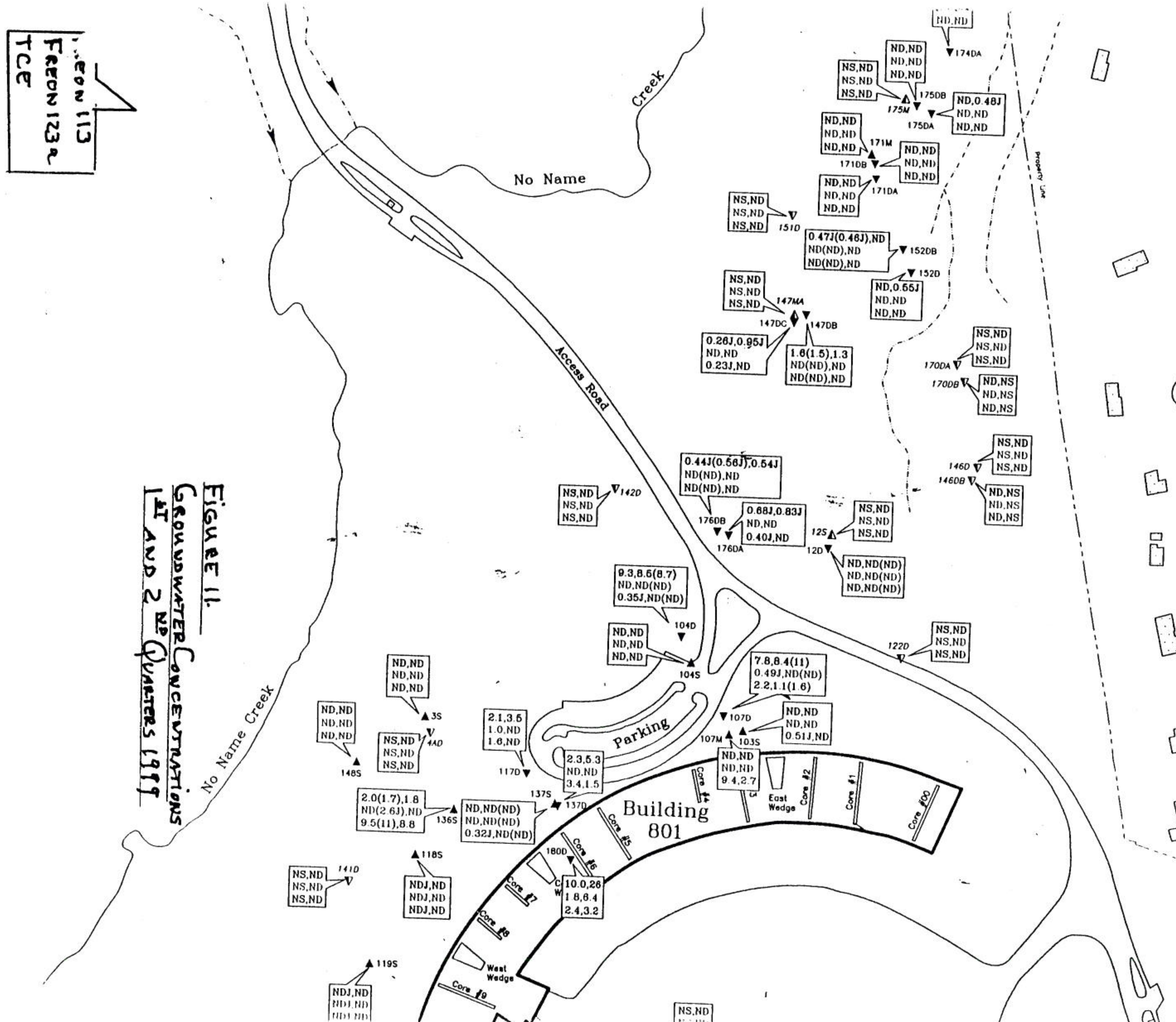


FIGURE 11. GROUNDWATER CONCENTRATIONS 1ST AND 2ND QUARTERS 1999

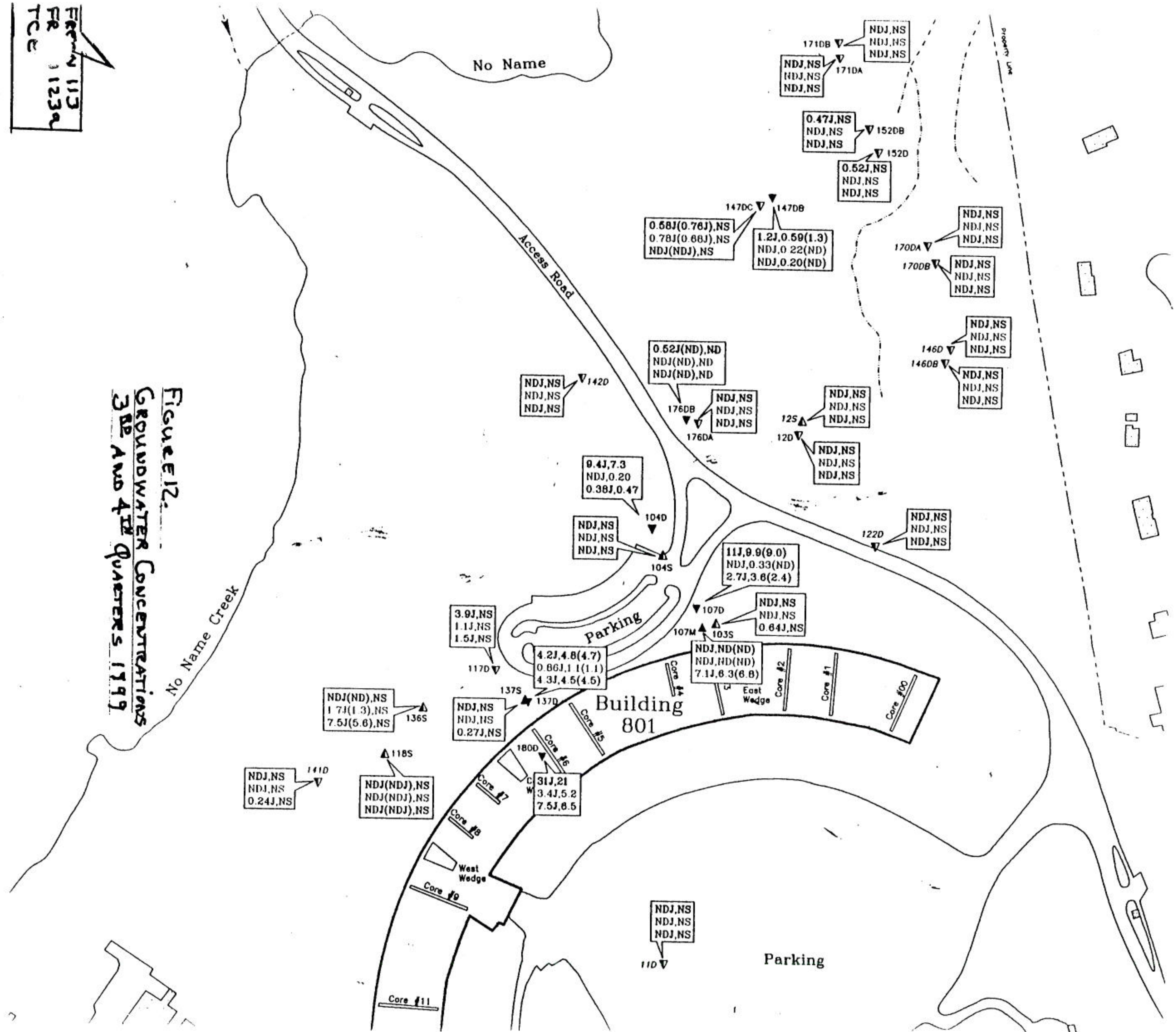


Figure 12.
Groundwater Concentrations
3rd and 4th Quarters 1999
TCE
No Name
No Name Creek
Access Road
Parking
Building 801
Parking
Core #00
Core #1
Core #2
Core #4
Core #5
Core #6
Core #7
Core #8
Core #9
Core #11
East Wedge
West Wedge
171DB
NDJ,NS
NDJ,NS
NDJ,NS
171DA
NDJ,NS
NDJ,NS
NDJ,NS
152DB
0.47J,NS
NDJ,NS
NDJ,NS
152D
0.52J,NS
NDJ,NS
NDJ,NS
147DC
0.58J(0.76J),NS
0.78J(0.68J),NS
NDJ(NDJ),NS
147DB
1.2J,0.59(1.3)
NDJ,0.22(ND)
NDJ,0.20(ND)
170DA
NDJ,NS
NDJ,NS
NDJ,NS
170DB
NDJ,NS
NDJ,NS
NDJ,NS
146D
NDJ,NS
NDJ,NS
NDJ,NS
146DB
NDJ,NS
NDJ,NS
NDJ,NS
142D
NDJ,NS
NDJ,NS
NDJ,NS
176DB
0.52J(ND),ND
NDJ(ND),ND
NDJ(ND),ND
176DA
NDJ,NS
NDJ,NS
NDJ,NS
12S
NDJ,NS
NDJ,NS
NDJ,NS
12D
NDJ,NS
NDJ,NS
NDJ,NS
104D
9.4J,7.3
NDJ,0.20
0.38J,0.47
104S
NDJ,NS
NDJ,NS
NDJ,NS
122D
NDJ,NS
NDJ,NS
NDJ,NS
107D
11J,9.9(9.0)
NDJ,0.33(ND)
2.7J,3.6(2.4)
103S
NDJ,NS
NDJ,NS
0.64J,NS
107M
NDJ,ND(ND)
NDJ,ND(ND)
7.1J,6.3(6.8)
117D
3.9J,NS
1.1J,NS
1.5J,NS
137S
137D
4.2J,4.8(4.7)
0.86J,1.1(1.1)
4.3J,4.5(4.5)
NDJ,NS
NDJ,NS
0.27J,NS
136S
NDJ(ND),NS
1.7J(1.3),NS
7.5J(5.6),NS
118S
NDJ(NDJ),NS
NDJ(NDJ),NS
NDJ(NDJ),NS
141D
NDJ,NS
NDJ,NS
0.24J,NS
180D
31J,21
3.4J,5.2
7.5J,6.5
11D
NDJ,NS
NDJ,NS
NDJ,NS

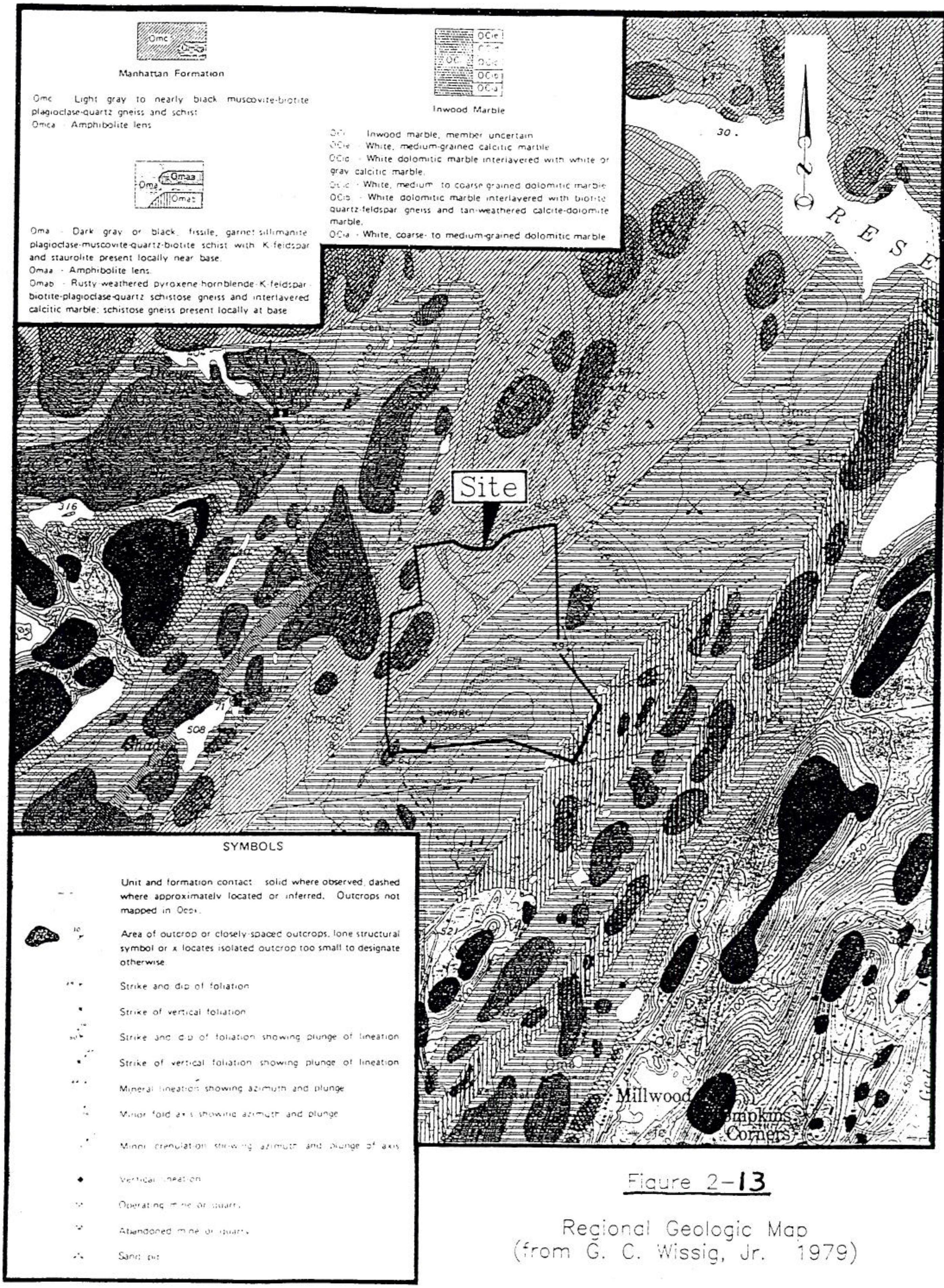


Figure 2-13

Regional Geologic Map
(from G. C. Wissig, Jr. 1979)

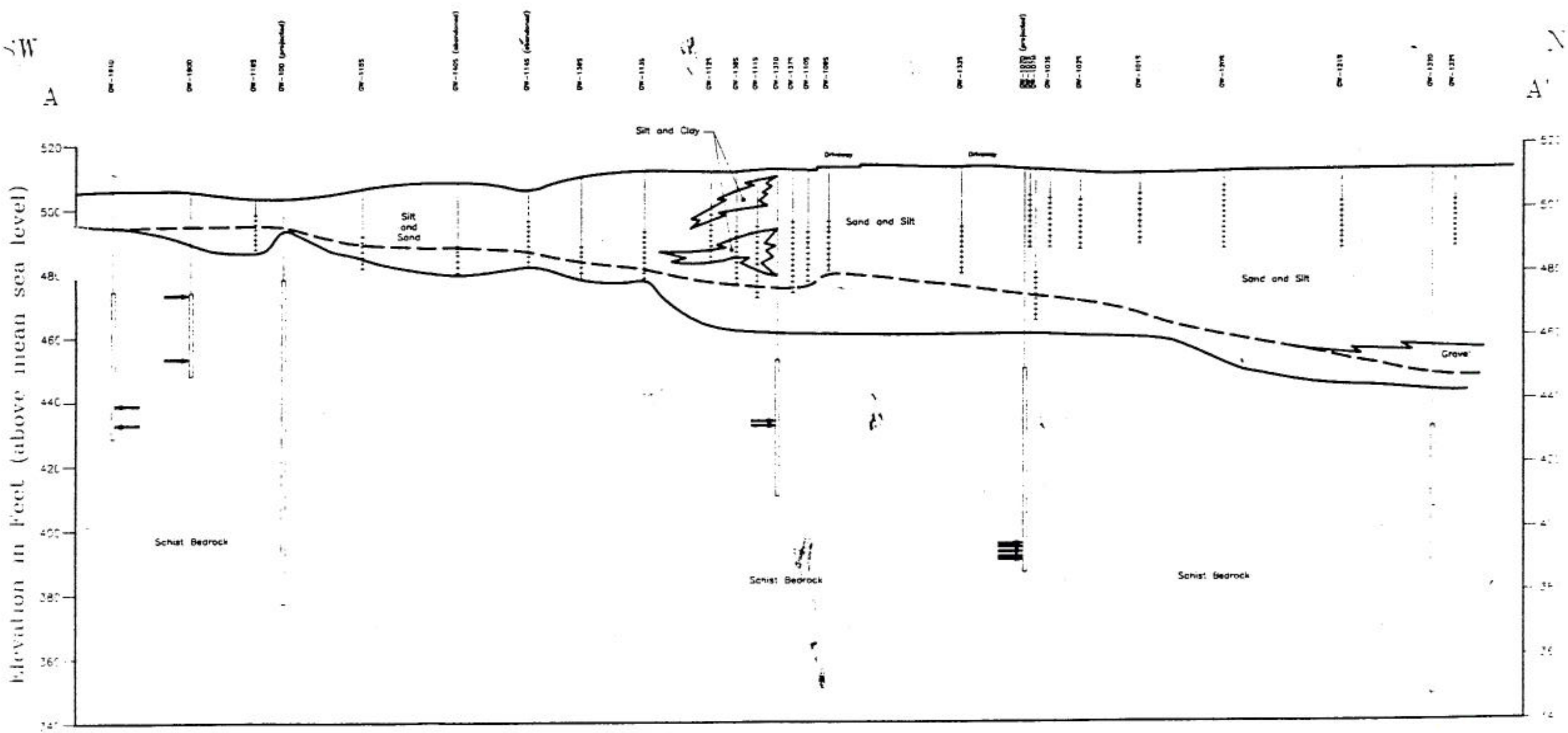


FIGURE 14

CROSS SECTION ALONG FRONT OF BUILDING 801

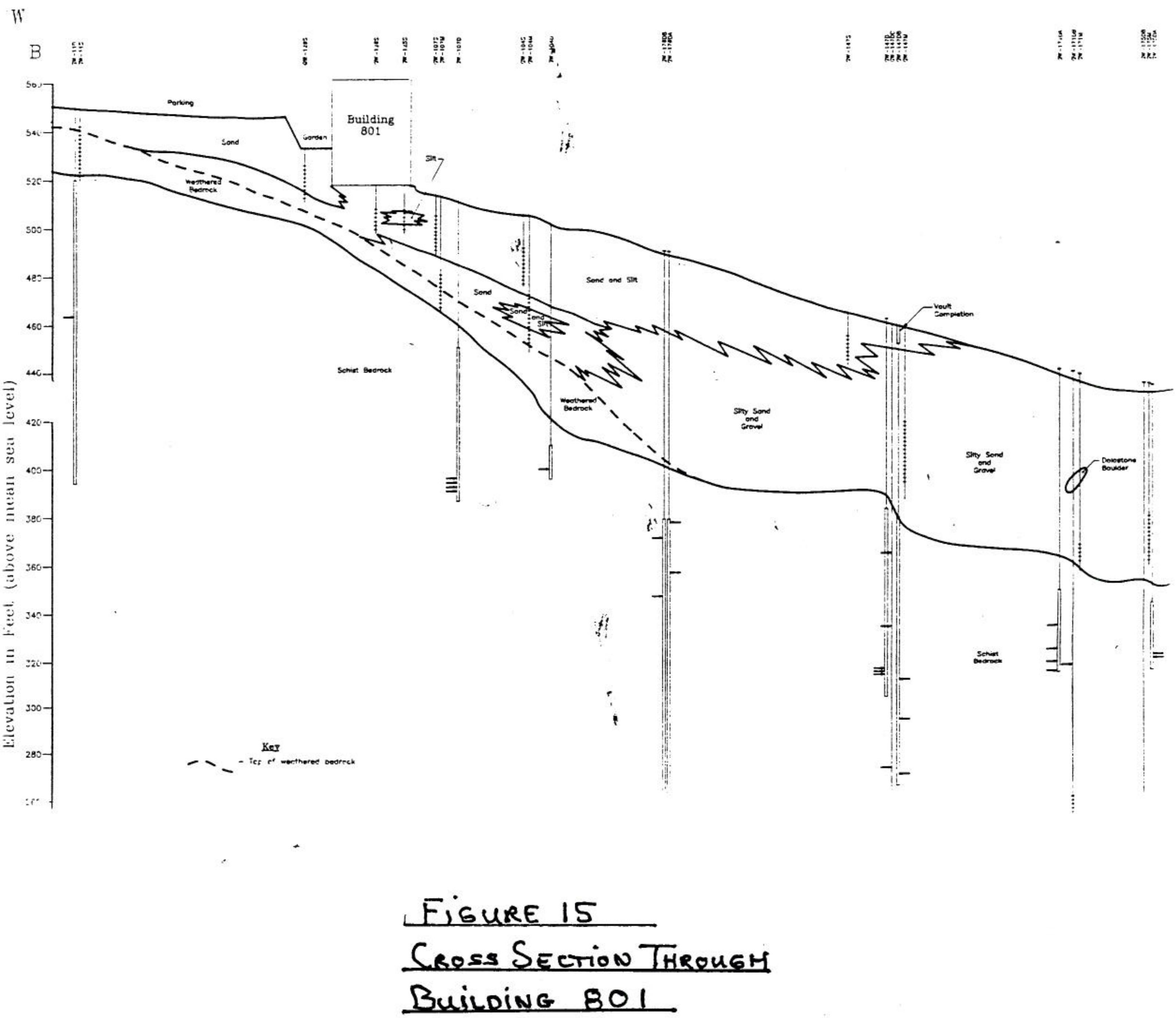


FIGURE 15
CROSS SECTION THROUGH
BUILDING 801

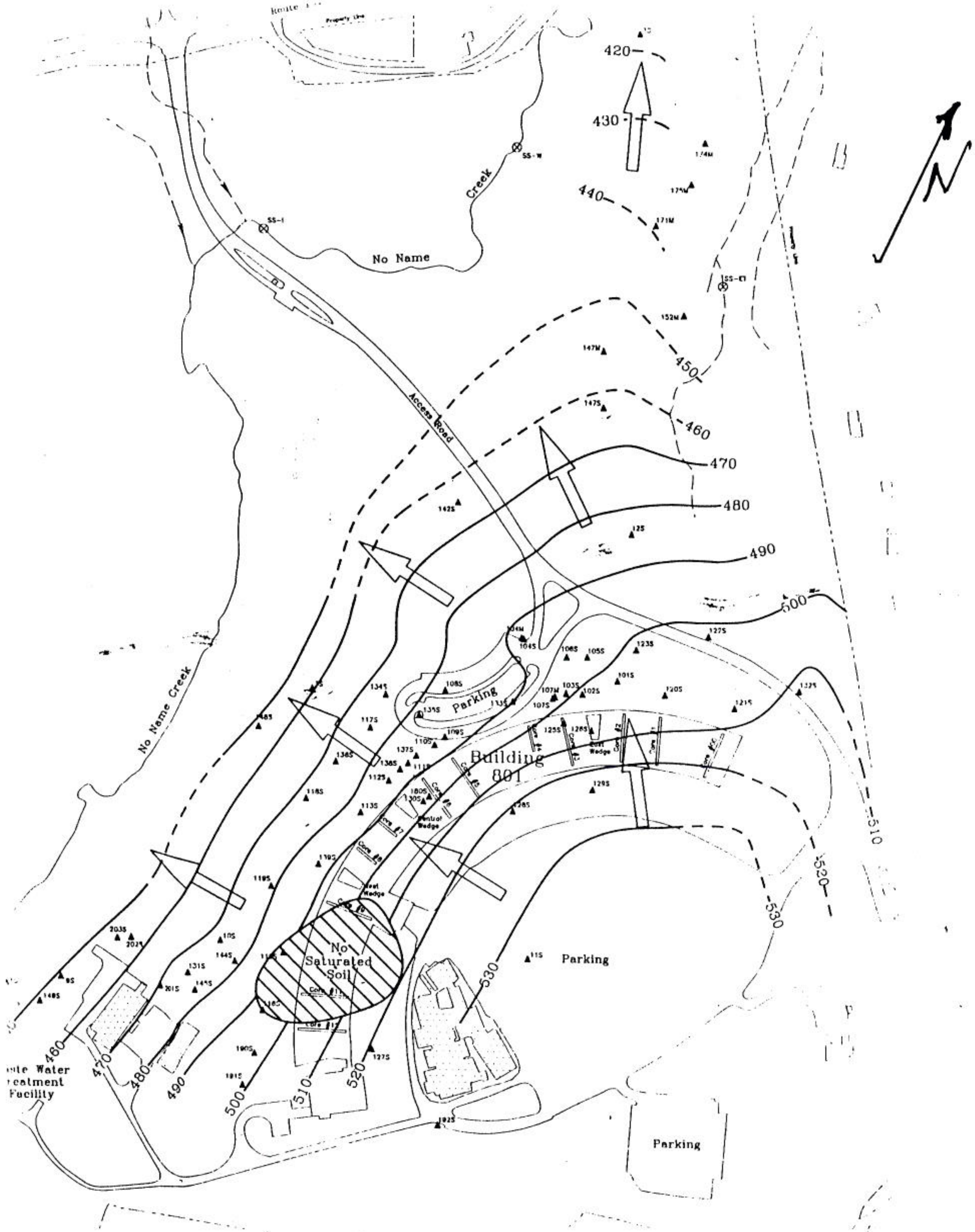


FIGURE 16 RFI
SOIL GROUNDWATER TABLE
ELEVATION CONTOURS

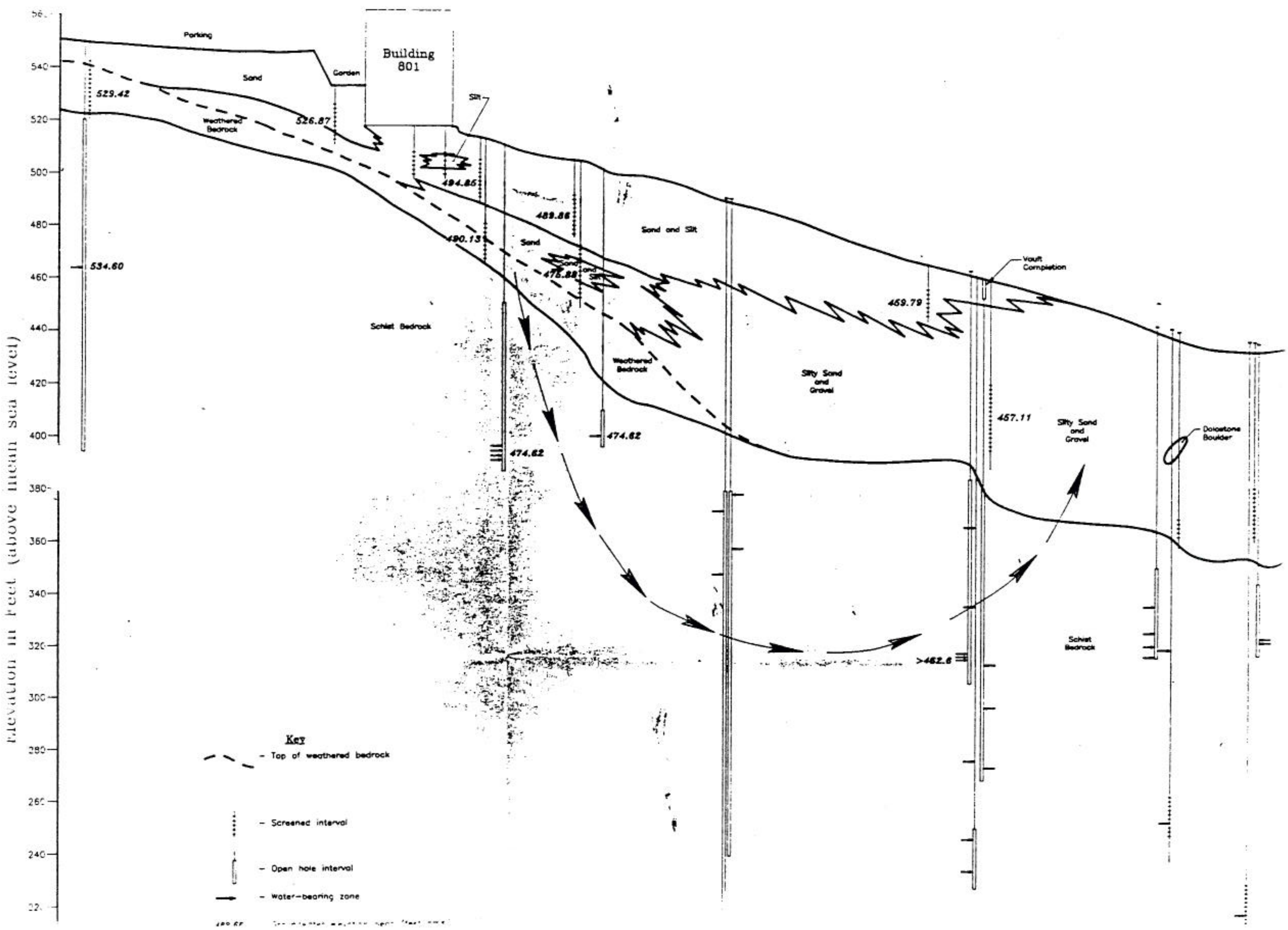


FIGURE 17 RFI
VERTICAL GROUNDWATER FLOW

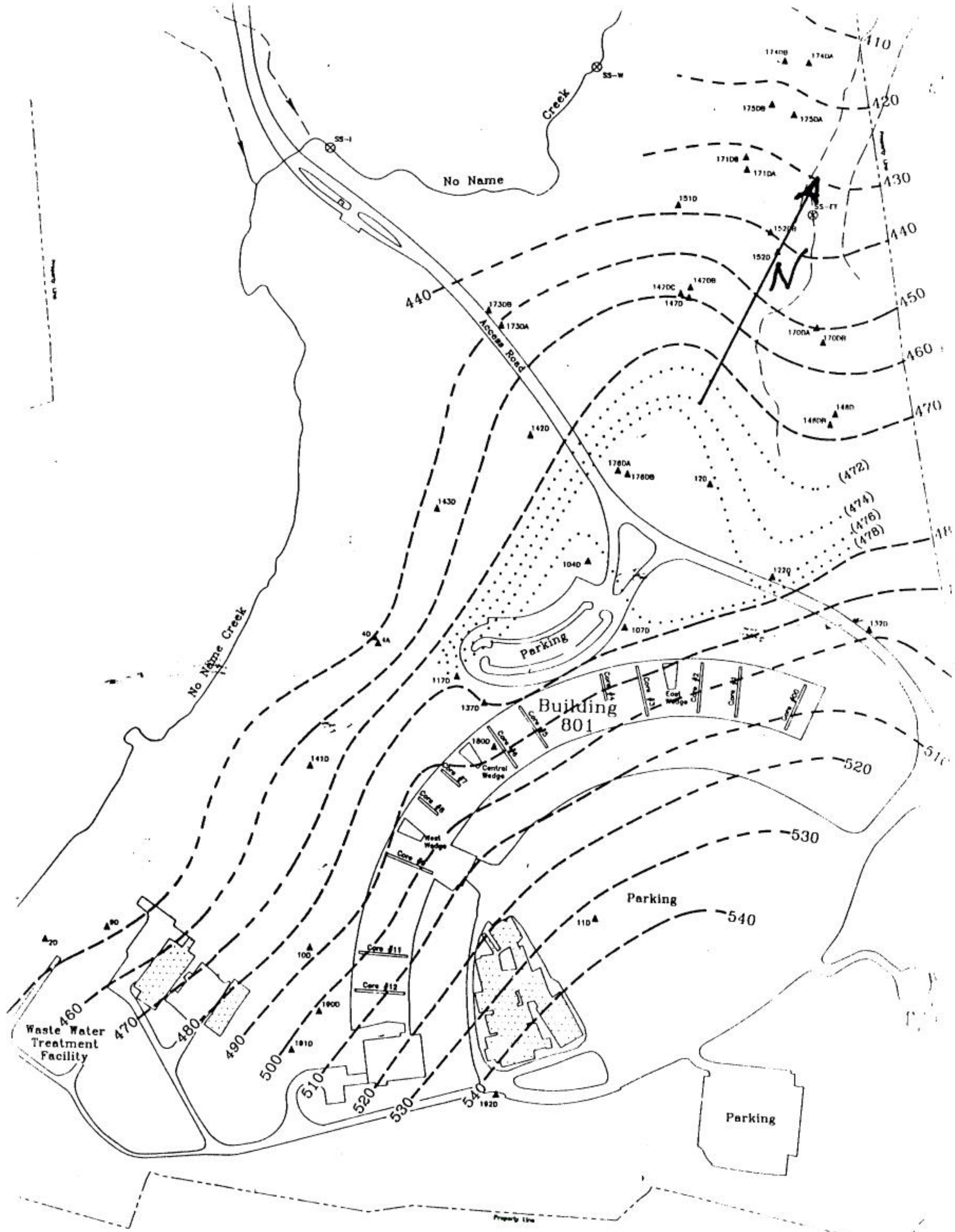
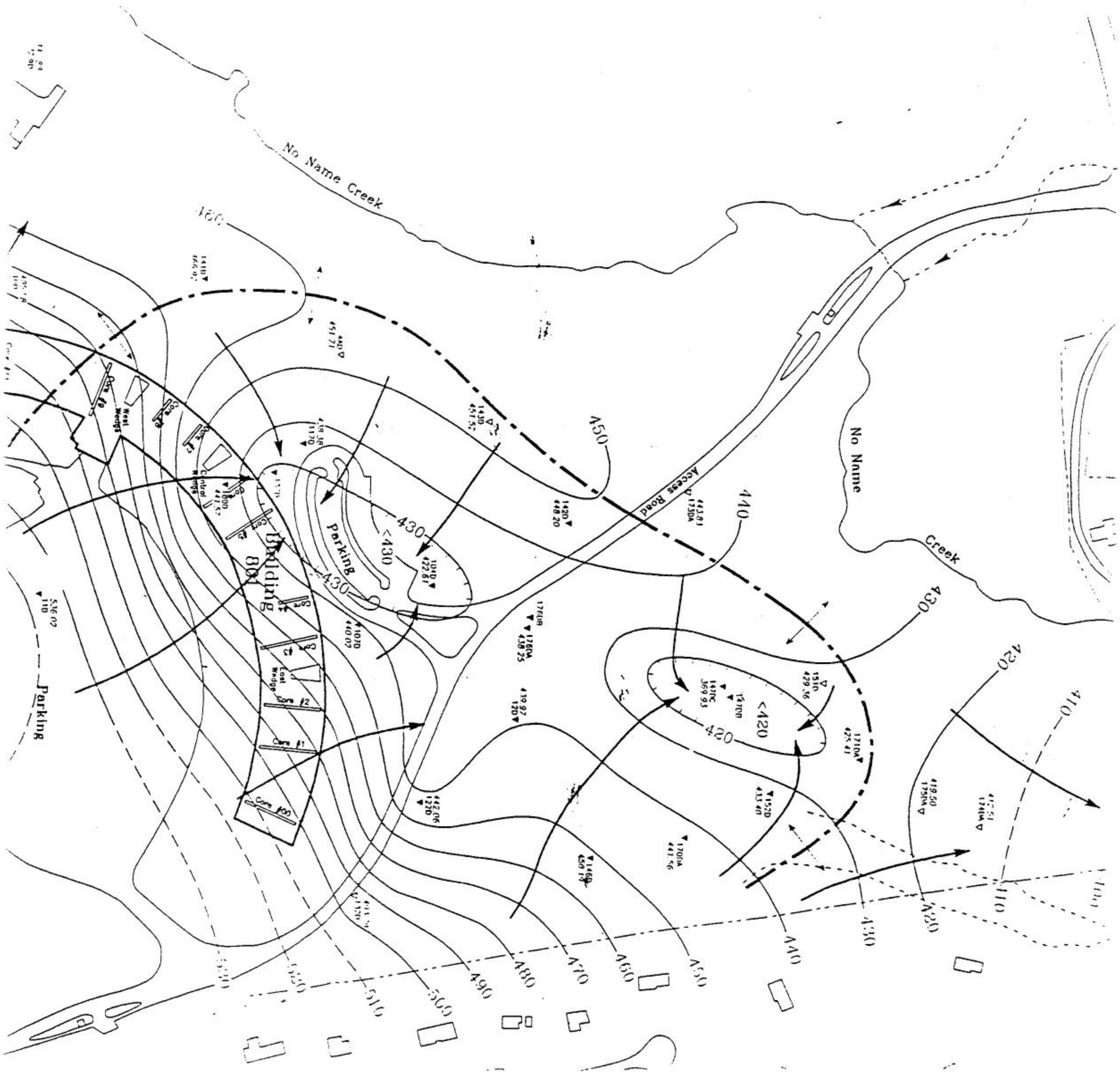


FIGURE 18 RFI
BEDROCK
POTENTIOMETRIC
SURFACE



GENERALIZED
BEDROCK GROUNDWATER
FLOW DIRECTION

LIMIT OF
BEDROCK GROUNDWATER
CAPTURE

FIGURE 19
BEDROCK POTENTIOMETRIC SURFACE
AFTER PUMPING BEGAN