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SUMMARY - 1985

INTERIM REMEDIAL INVESTIGATIONS REPORT

Freeman Chemical Corporation
Saukville, Wisconsin

Prepared by

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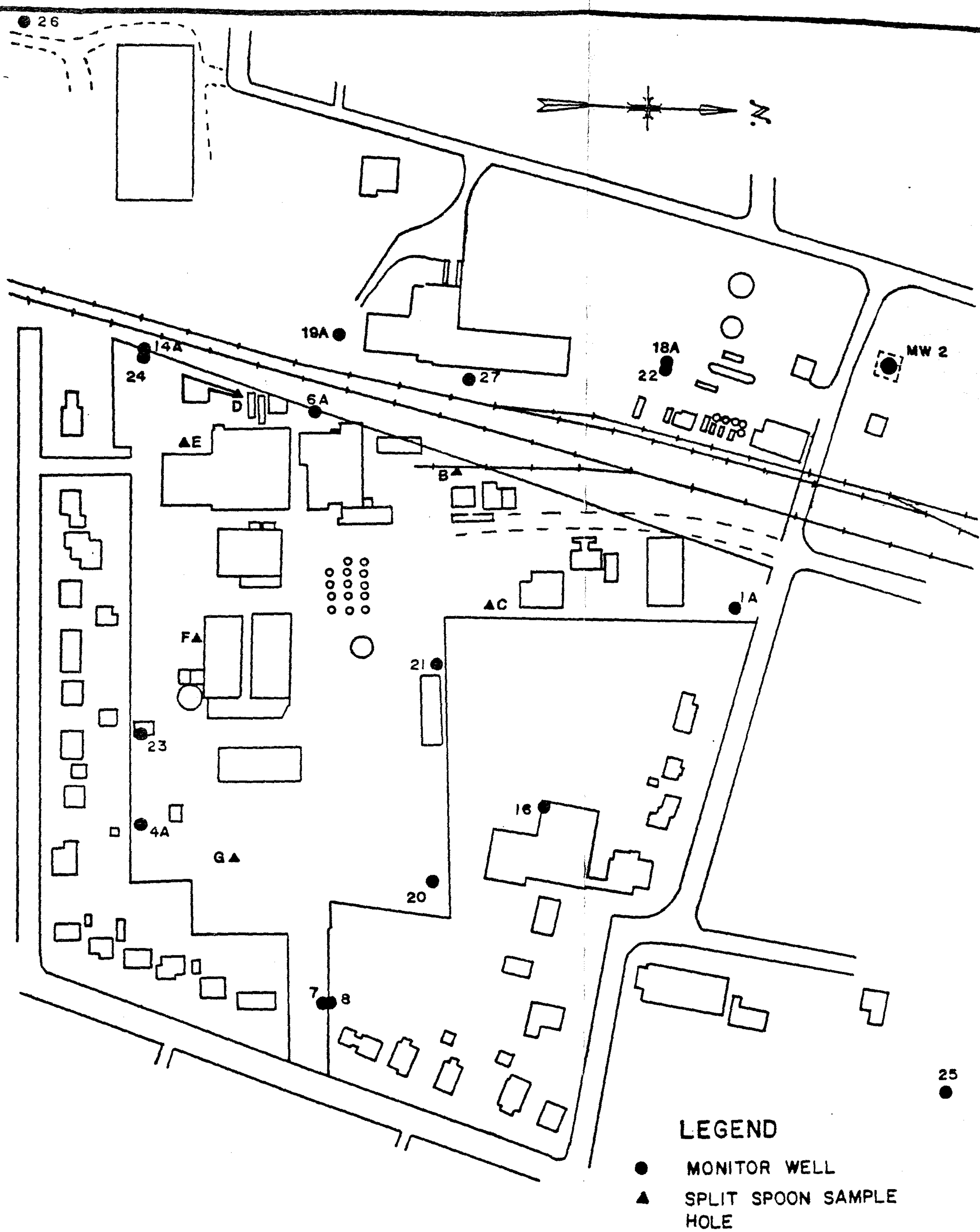
Hatcher Incorporated
Job No. 0001-003

February 28, 1986



r Incorporated	Date: February 1986	Monitor Well Location Map August 1985
MOND, VIRGINIA	Scale: 1" = 200'	Drawing No.: / Figure No.: 4

	PCE	TCE	1,2-DCE	1,1-DCE	vy chl	PCA	TCA	Me-chl	benzene	ET-benzene	toluene	m-xylene	o,p-xylene	trichloro-fluoro methane
W-21														
11/85								35	300	4000	340			
W-22														
11/85														
W-23														
11/85			2.7		3.7			4.4						
W-24														
11/85			180		35								5.7	
W-25														
11/85											8.2			
FB-1														
2/85								3.2			2.6			
5/85														
11/85														
FB-2														
2/85								1.9	1.0		3.7	1.3	1.2	
5/85														
11/85								3.5						
Trip Blank														
2/85														
5/85														
11/85														

	PCE	TCE	1,2-DCE	1,1-DCE	Vy. chl	PCA	TCA	Me-Cl	benzene	ET-benzene	toluene	m-xylene	o,p-xylene	trichloro-fluro methane
PZ-13														
2/85														
5/85								1.0						
PZ-14														
2/85					2.7							47	250	
5/85			2.9		1.8			1.0					100	
PZ-14A														
11/85										9500		13,000	9700	
PZ-16														
2/85														
5/85								1.4						
11/85														
PZ-17														
2/85								2.7						
5/85														
PZ-18														
2/85														
5/85														
PZ-18A														
11/85								5.0						
PZ-19														
2/85		1.1			1.2									
5/85		1.8	2.8											
PZ-19A														
11/85		4200	280	4.1	28									chlorobenzene- 1.7
PZ-20														
11/85								1.2						
PZ-26														
11/86														
PZ-27														
11/86		350	98				3.8	1.5						

	PCE	TCE	1,2-DCE	1,1-DCE	Vy chl.	PCA	TCA	Me-Cl	Benzene	ethyl benzene	toluene	m-xylene	o,p-xylene	trichloro-fluoro methane
PZ-1														
2/85														1.3
5/85														1.4
PZ-1A														
11/85								7.8		1.2				1.5
PZ-3														
2/85									30	2200	130	8700	7400	
5/85	15		5.1			5.1		11	290	3200	15,000	5300	4200	
PZ-4														
2/85								2.1						
5/85								1.7						
PZ-4A														
11/85								1.8						
PZ-5														
2/85			2900		230				4600	30,000	23,000	23,000	21,000	
5/85	210	370	42,000	58	1800	54	45	79	17,000	110,000	130,000	73,000	54,000	
PZ-6														
5/85		42	400		81			80	150	650	1600	1300	1000	
PZ-6A														
11/85			1200					600	2600	22,000	130,000			
PZ-7														
11/85								2.5						
PZ-8														
2/85														
5/85								1.8						
11/85														
PZ-9														
2/85													18	
PZ-11														
2/85														
5/85								1.8						
PZ-12														
2/85														
5/85			1.2					1.7						

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Freeman Chemical Company - Water Quality Results

Well #	PCE	TCE	1,2-DCE	1,1-DCE	vinyl chloride	tetrachloroethane	1,1,1-TCA	methylene chloride	benzene	ethylbenzene	toluene	m-xylene	o,p xylene	trichlorofluoromethane
MW-1														
2/85														
5/85														
11/85														
MW-2														
2/85							1.0							
5/85							2.0	1.0						
11/85							2.4							
MW-3														
2/85														
5/85							2.0							
11/85														
MW-4														
2/85							3.2							
5/85														
11/85														
PW-3														
2/85	1.2	4.0					4.6				170	120		
5/85							3.2		14	5.0	11	9.2		
11/85									1.4	2.8	52	39		
PW-6														
2/85														
5/85		12												
11/85		3.2												
PW-8 (Laubenstein Well)														
2/85	950	100		1.6										
5/85	6600	120				9.5								
11/85	2000	130		1.2			1.5	31				1.0		

1.0 INTRODUCTION

This report summarizes the results of field investigations made during 1985 by Hatcher Incorporated at the Saukville, Wisconsin, plant site of Freeman Chemical Corporation. These investigations were designed specifically to acquire additional data needed to select appropriate remedial solutions to contaminated soil and groundwater problems at this plant site.

1.1 Previous Investigations

Investigations at this site began in 1983 by Olver, Inc., with a two-phased investigation of the site hydrology and geology. The installation of monitoring wells and development of an understanding of the interaction between the shallow and deep aquifer were emphasized.

An interim report on the progress of Phases I and II was issued by Olver on June 20, 1984, detailing the results of the geotechnical investigations, piezometer installations, groundwater level monitoring, and groundwater collection and analysis activities. In addition, preliminary assessments of the hydrologic regime at Saukville were made. Soil boring and piezometer installation logs, chemical analyses, and groundwater hydrographs were included. A pump test program, designed to determine hydrologic characteristics (transmissivity, storage, and leakage) of the Dolomite Aquifer and the interrelationship of the shallow and Dolomite Aquifers, was conducted using the Saukville municipal wells, the Laubenstein well, and site piezometers.

Details of the pump test program, data analysis procedures, data evaluation, and aquifer characteristics were presented in a subsequent report by Olver issued January 10, 1985.

Results of the 1984 pump tests demonstrated that the

SUMMARY - 1985

INTERIM REMEDIAL INVESTIGATIONS
REPORT

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FIGURES (Continued)

Dolomite Aquifer is semi-confined by the surficial glacial materials and that recharge to the dolomite (probably from the Milwaukee River) occurs during pumpage.

The aquifer tests of the Saukville municipal wells in the Dolomite Aquifer also demonstrated a considerable local variability in yield. This yield variability is probably related to differences in fracture frequency, solutioning, and recharge opportunity at each well site. Transmissivity and storage coefficient values calculated from the test analyses also reflect aquifer anisotrophy; i.e., aquifer transmissivity and storage differ depending on the direction of the observation well(s) used in the test analyses from the pumped well. Transmissivity of the Dolomite Aquifer apparently ranges from 140 to 4,450 ft^2/day.

The rapid response of the old, deep well in the warehouse on the property just west of the Freeman Chemical site, hereafter referred to as the Laubenstein well, and the smaller delayed response of the site piezometers to pumping in nearby municipal wells indicated that the Laubenstein well and the site is at least partially in the drawdown cone of influence of those municipal wells. Thus, any pollutants in the dolomite in this drawdown cone can potentially move toward the pumped municipal wells.

Results of chemical analyses from the periodic sampling of the shallow piezometers indicated that organic solvents and phenols were present in the shallow aquifer. Although the data were not sufficiently detailed to be contourable, the higher concentrations tended to occur in the vicinity of the Freeman and Laubenstein warehouse sites. Analyses of water from the Laubenstein well pump test indicated contamination of the Dolomite Aquifer at that point. With regard to chlorinated solvents, the GC/MS analyses to date have indicated that dichloroethylene occurs beneath the Freeman site. Trichloroethylene has been identified in the Laubenstein well and in MW-2.

1.2 Summary of 1985 Activities

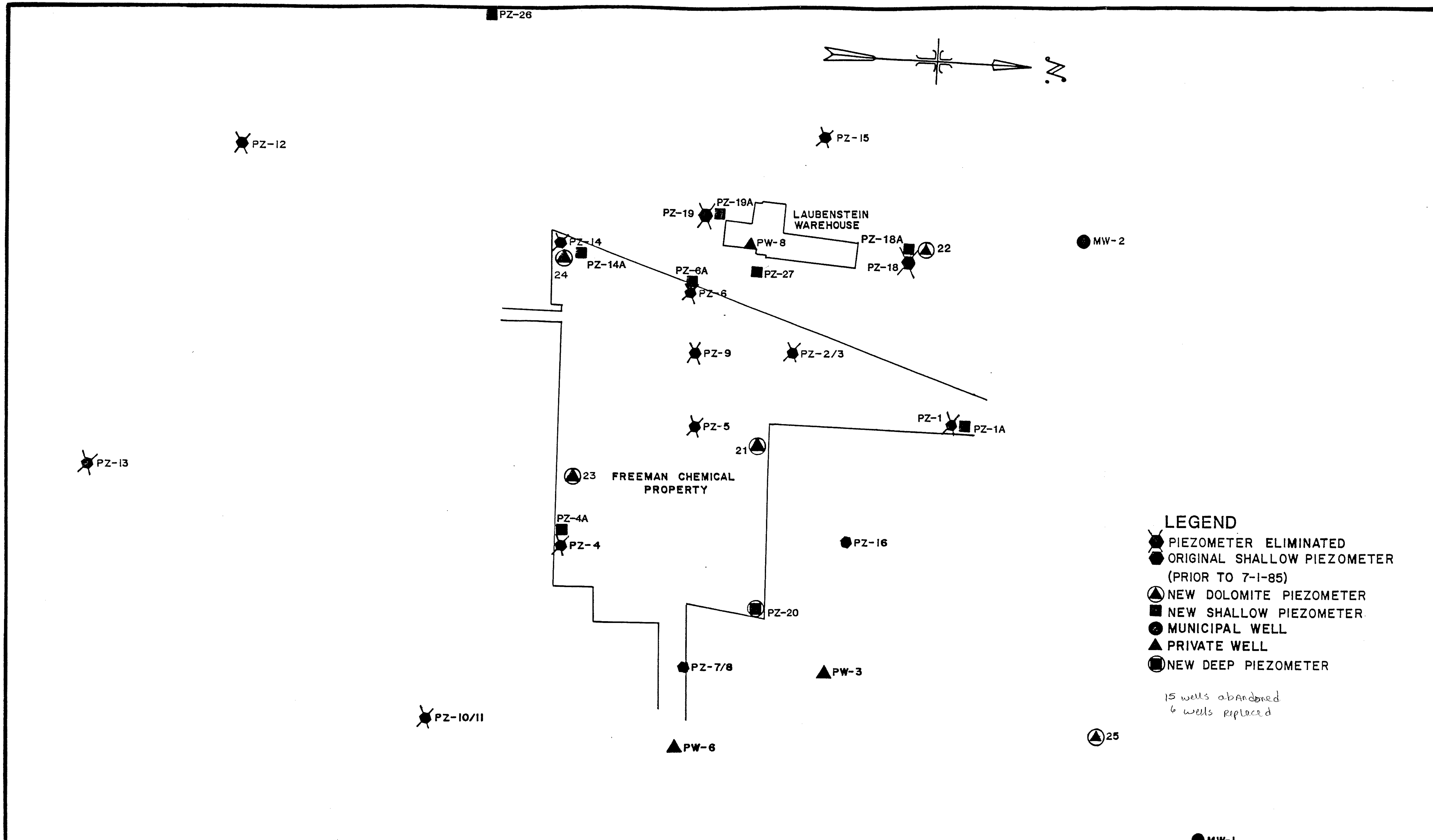
The field program conducted during the 1985 season was essentially the "Recommended Scope of Work" proposed by Hatcher Incorporated in their January 1985 report entitled "Summary - Hydrologic Assessment Activities, Wisconsin".

The 1985, fieldwork was initiated with a EM survey of the site and immediately surrounding area to determine possible conductivity or resistivity anomalies related to contaminant plume geometry. The Geonics 34-XL was used with both antenna orientations on 10 and 20 meter spacing. Useable data was acquired outside the plant site; however, the concentration of on-site metallic buildings, power lines, and buried pipes made on-site data interpretation problematical.

Subsequently, a very successful, shallow seismic refraction survey was run to determine depth to dolomite on, and immediately surrounding, the Saukville plant site. In addition to better definition of the dolomite upper surface, a good quality top of the saturated glacial materials was derived from the "first arrival" data.

Following evaluation of the seismic refraction data and comparison with existing geohydrologic data, new locations were selected for dolomite aquifer and overburden (surficial glacial) monitor/piezometer wells. Likewise, wells constructed across the dolomite-glacial overburden contact were selected for decomissioning and plugging. Finally, for a more comprehensive coverage of the site, additional strategic locations for split spoon sampling for lab permeability analysis were selected.

In all, 8 new monitoring wells were installed: 2 in glacial overburden, 1 in glacial sinkhole infill, and 5 in Silurian dolomite. ~~Three~~ existing piezometers were decommissioned; 3 were kept as is; and 6 were redone. See Figure 1. Short bailing and recovery tests were made on the new monitoring wells to estimate the hydrologic character of the glacial overburden materials.



	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Location Of Decommissioned And Other Monitoring Wells
			Scale: 1" = 200'	Drawing No.: / Figure No.: 1

At the initiation of the drilling and augering program by Canonie Construction Co., a borehole geophysical survey of most of the existing and a few of the new monitoring wells was made by BPB Surveys. Where possible, natural gamma-gamma density, neutron, gamma, acoustic, temperature, and caliper logs were run to determine individual well site construction, geology, and hydrologic character.

The Laubenstein well was test-pumped and sampled during the 1985 field season to determine the effect of longer term pumping on the concentration of trichloroethylene. Water from the upper 100 feet of this well was excluded from the test by installation of an inflatable packer.

At the end of the field season, 2 pilot groundwater dewatering schemes were installed in the glacial overburden: 1) a ±30-foot trench, representing a section of a Ranney collector, installed north of the tank farm and 2) a large-diameter, shallow well installed west of Building 5 near the former "dry well."

2.0 HATCHER INVESTIGATIONS

2.1 Seismic Refraction Profiling

A seismic refraction survey of the plant site and environs was made in June 1985, as part of the overall effort to acquire a more detailed map of the upper surface of the Silurian dolomite. The survey was conducted by Bison Instruments, Inc., and supervised by Hatcher Incorporated.

The Bison GeoPro 8012A Signal Processing Enhancement Seismograph was used, with 12 geophones and a sledge-hammer source. Hard copy records of the seismic waveform data were created. The sledge-hammer was struck against the ground surface, sending energy through the ground. The energy was reflected from different depths and received by the geophone array which sent a signal to the GeoPro for recording. Successive strikes in the same location reinforced or "stacked" the signal, thereby eliminating background noise and the need for large or explosive energy sources.

An array 120 feet in length was employed to assure that several refractions from the depth of interest were received. A 10-foot takeout (distance between geophones) and a 10-foot offset (distance between geophone one and the hammer position) was adopted for this study.

The hammer was impacted at both ends of the geophone array so true velocities and depths could be computed. Most of the 82 traverses were overlapped by 50 percent (see Figure 2 for locations of individual traverses).

Each set of waveforms was analyzed to determine the first arrival (initial seismic wave) at each geophone. The time of the first arrival was plotted against the source-to-geophone distance to yield time-distance graphs. The slopes (layer velocities) and time intercepts of the lines formed by the time-distance data were checked for inconsistancies and then reduced to depth to each refractor.

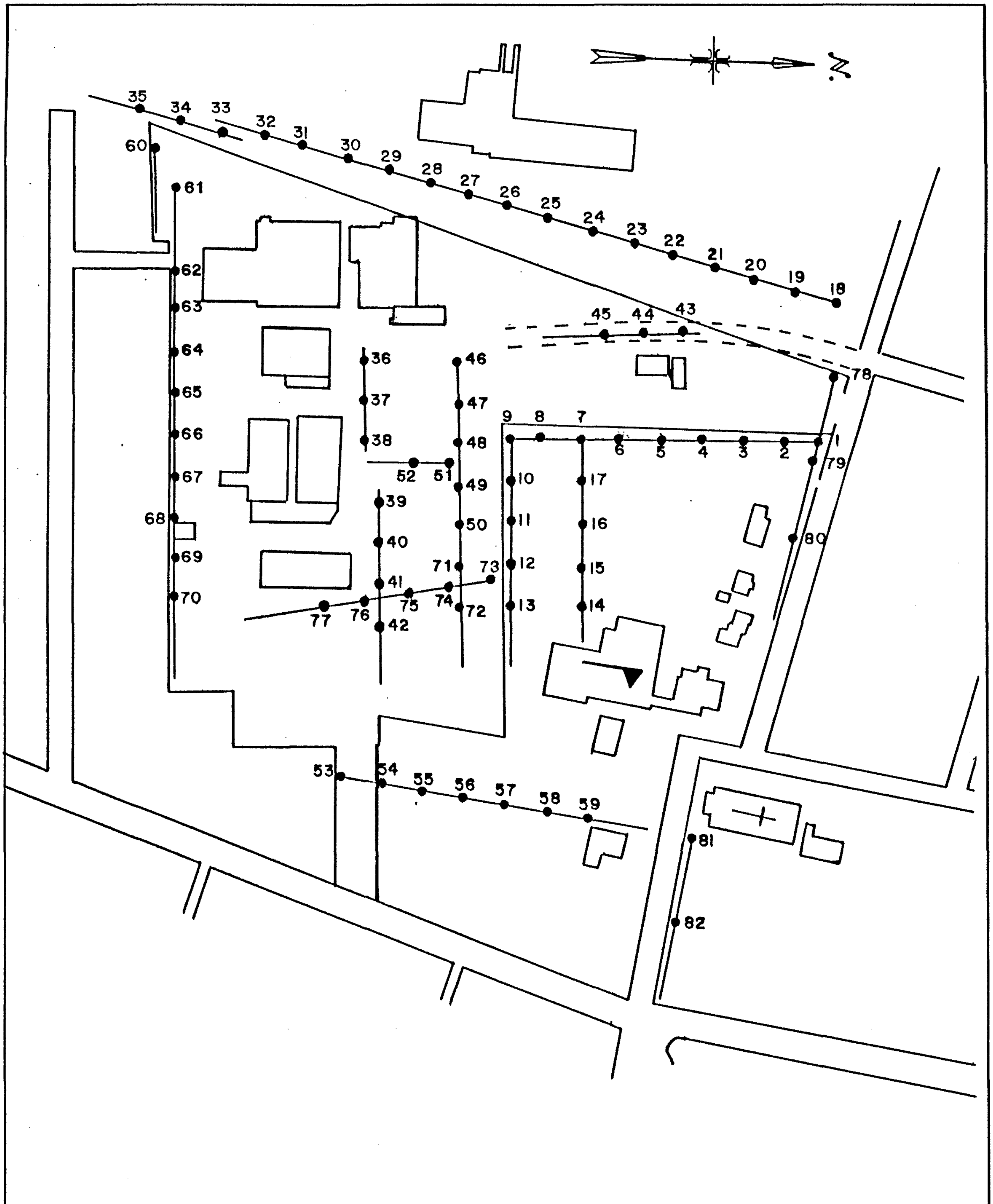


FIGURE 2

SEISMIC REFRACTION PROFILE LOCATION MAP

1" = 200'

Hatcher Incorporated

The seismic refractors have been plotted below their respective array position (Figures 3A and 3B) to create a series of seismic profiles. These profiles demonstrate: 1) that the dolomite upper surface is in places extensively pinnacled, with relief being as great as 20 ft./60 ft.; 2) that sink holes and/or channels exist; and 3) that first returns are apparently coincident with the top of saturated soil.

2.2 Terrane Conductivity Mapping – No results shown

An earth electromagnetic (EM) conductivity survey was made at the beginning of the field season to determine the applicability of this geophysical method for mapping contaminant dispersion. The Geonics 34-XL instrument was used for profiles on-site, along the railroad tracks west of the site, in the Immaculate Conception School ballfield north of the site, and in two large fields on the Logemann Co. property west and southwest of the site.

Conductivity readings at all the locations mentioned above were taken at 10-meter station spacings for both the vertical and horizontal antenna orientations. Additional readings at 20-meter station spacings were taken on most of the Logemann property.

Plotted conductivities for station locations off-site are contourable and apparently meaningful, except at an old trash dump on the southwest end of the Logemann property. There, high and reversed (negative) readings indicate the probable presence of metallic trash. Contoured conductivities in the school ballfield define a slightly elevated conductivity anomaly trending northeast from and downwind of the incinerator area. This anomaly may indicate depth to bedrock or reflect the downwind fallout plume of the incinerator. On-site, higher conductivities were found at places where no other data indicated subsurface contamination, such as along the south fence. There is little doubt that the on-site readings are heavily influenced

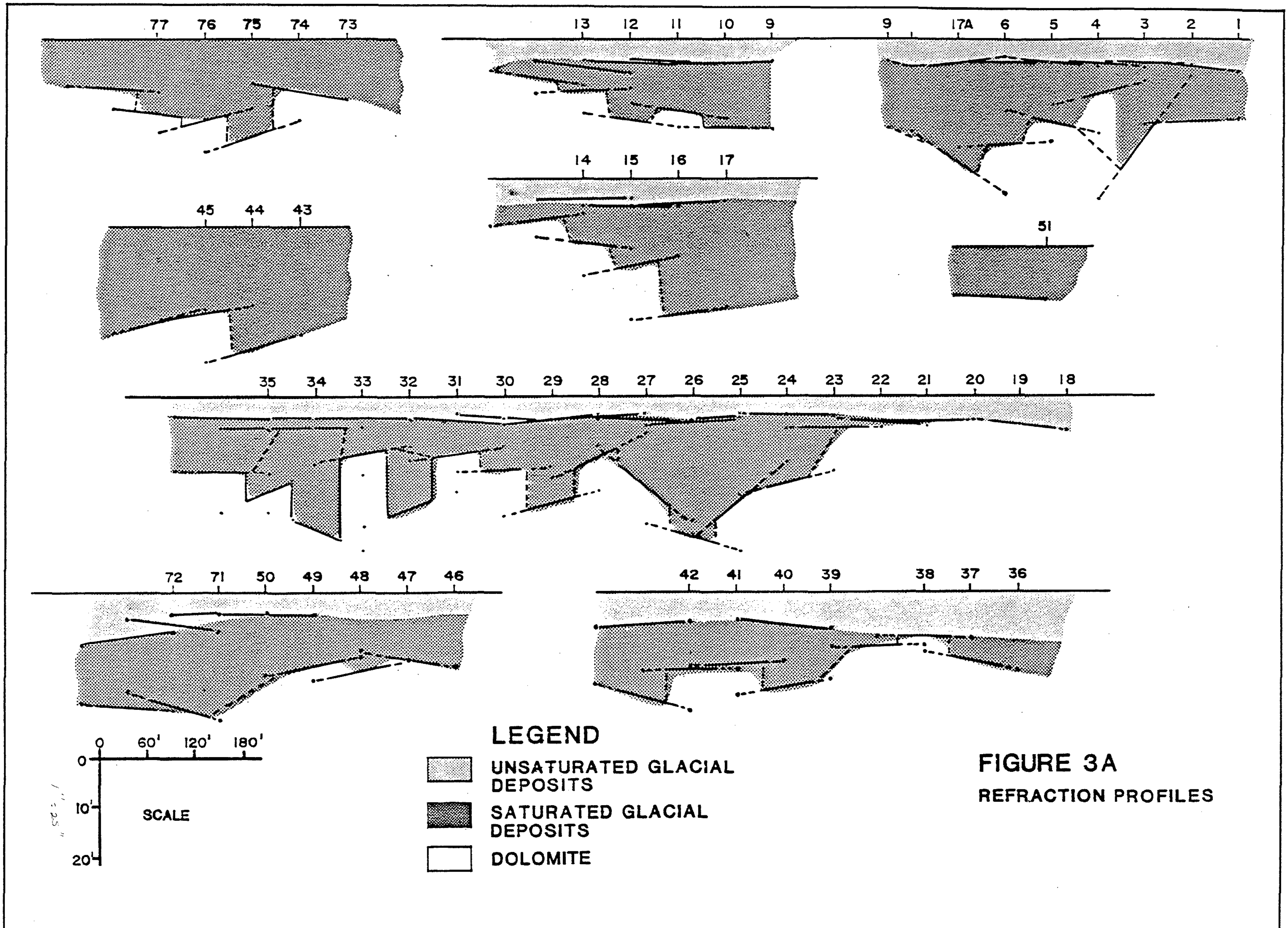


FIGURE 3A

REFRACTION PROFILES

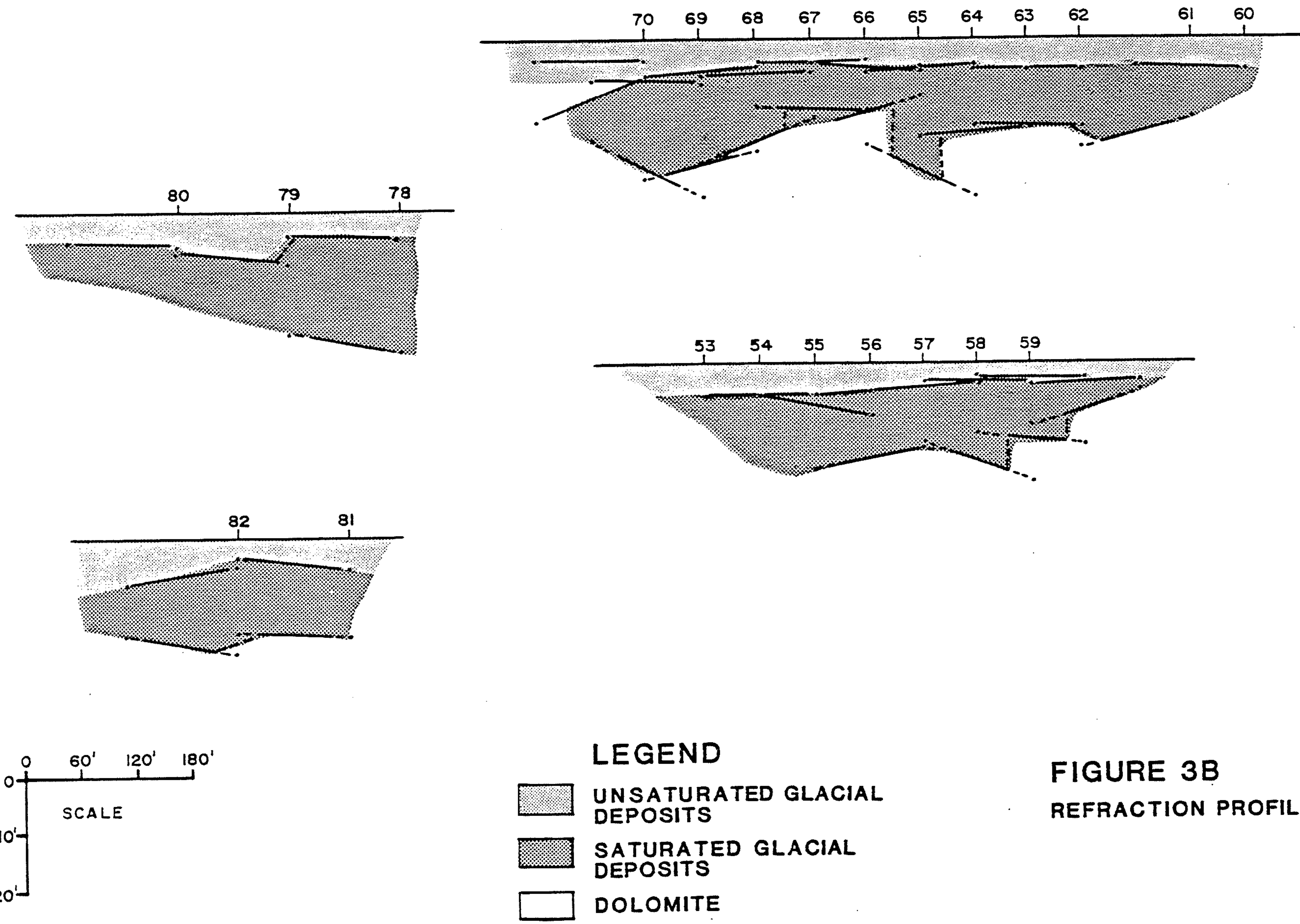


FIGURE 3B
REFRACTION PROFILES

by buried and overhead sources of "conductive noise."

2.3 Exploratory Augering

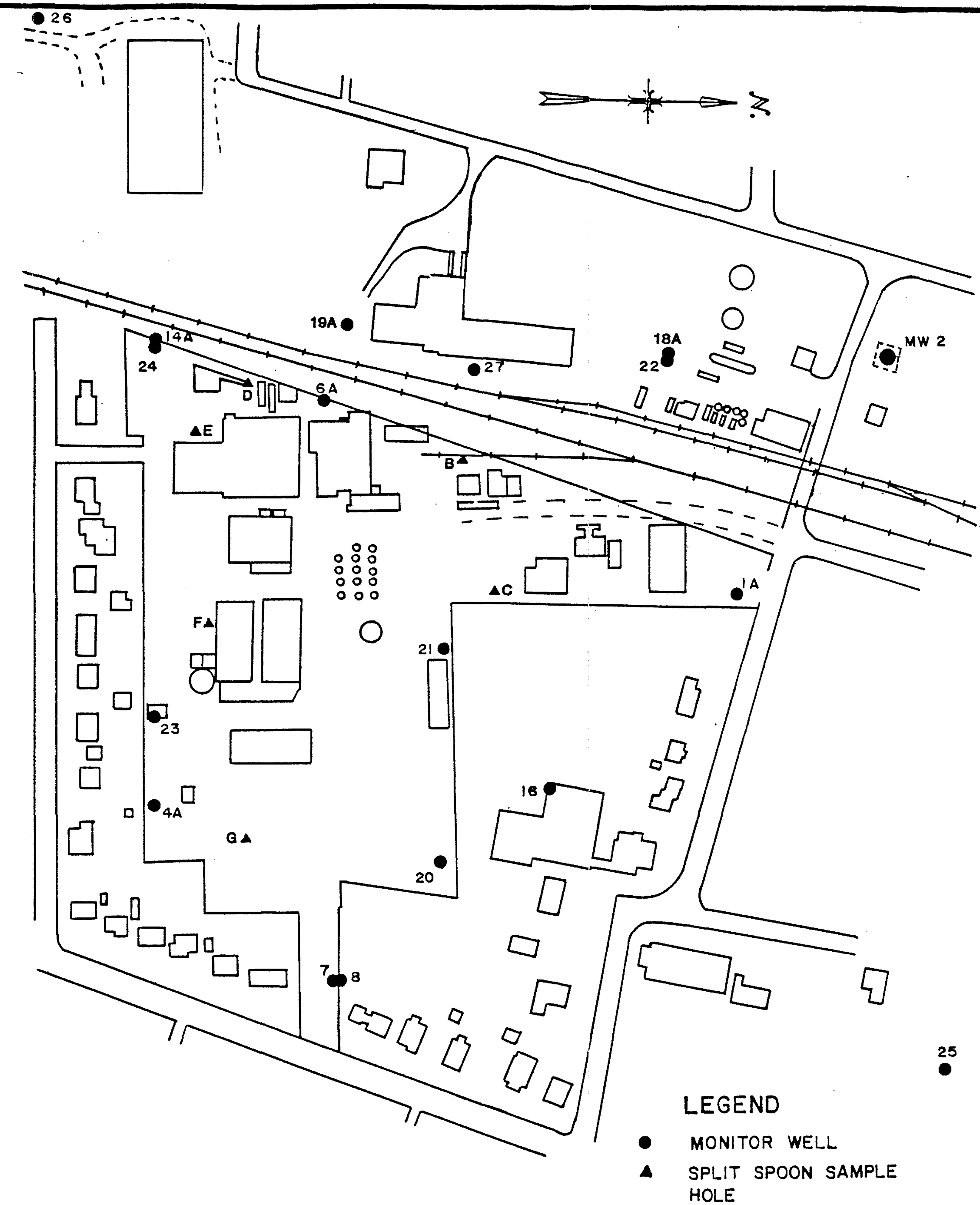
Exploratory augering and split spoon sampling were conducted during the monitoring well installation phase. Continuous split spoon samples were taken at PZ-6A and 14A and at SP-B, SP-C, SP-D, SP-E, SP-F and SP-G at locations shown on Figure 4. These locations were selected to provide more comprehensive subsurface coverage of the site.

Samples were taken with an 18-inch long NX core barrel through a 6-inch hollow stem auger. A representative part (6 inches) of each 18-inch sample was collected, bottled, and labeled. From these, appropriate samples were selected and submitted for laboratory permeability analyses.

When it was impossible to advance the auger, such as sometimes occurred in till and boulder zones, the hole was deepened with a rotary tri-cone. At the termination of each hole, the hole was sealed with a portland cement/ bentonite grout mixture pumped from the bottom of the hole until the grout reached the surface. All augers, pipe, and sampling equipment and the drilling rig were steamed cleaned between each auger hole or monitor well installation.

2.4 Monitor Well/Piezometer Program

The prior monitor well network contained a number of wells screened across the interface between the overlying glacial sediments and the underlying weathered upper surface of the dolomite. Such construction provided a potential pathway for contaminant leakage from the glacial overburden into the Dolomite Aquifer. Also, the groundwater head probably represents a composite shallow groundwater Dolomite Aquifer head. Lastly, the prior construction (5-foot screen at bottom of well) provided no opportunity to sample any



Job No.: 0001-003	**Hatcher Incorporated** RICHMOND, VIRGINIA	Date: February 1986	Monitor Well Location Map August 1985
		Scale: 1" = 200'	Drawing No.: / Figure No.: 4

solvents or hydrocarbons that might float on the groundwater.

Consequently, all monitor wells screened across the glacial-dolomite contact were decommissioned, except PZ-16. PZ-16 will be decommissioned when the soil in the ballfield will provide support for drilling equipment. These wells were replaced with monitor wells which were open only to the Dolomite Aquifer or screened through the saturated part of the glacial sediments. In addition, some new monitor wells were installed to obtain better chemical sampling and hydraulic head coverage of the site area. See Figure 1 for locations of new, replaced, and decommissioned wells.

Dolomite monitoring wells were constructed by mud rotary drilling into the top of the weathered dolomite and setting 4-inch O.D., schedule 80, PVC casing. The PVC casing was grouted in place by pumping a portland cement/ bentonite grout mixture into the bottom of the well and up around the outside of the casing until the grout appeared at the surface. Following curing, the dolomite holes were drilled out and advanced by coring a 2-inch continuous core, followed by reaming to a 3-5/8-inch hole size.

Existing 2-inch monitor wells screened across the glacial sediment/dolomite contact were decommissioned by: 1) drilling or driving through the bottom plug of the PVC screen, 2) pumping grout through the open end of the screen, 3) pulling the drill rods, PVC screen, and riser pipe. As in all individual auger hole and monitor well operations, the rig and all equipment were steamed cleaned between wells. New 2-inch PVC shallow monitoring wells were installed by: 1) augering to the target depth with a 6-inch hollow stem auger, 2) installing PVC screen of sufficient length to be open through the saturated section, and then 3) filling the annulus with filter material while removing the auger sections. Typical new monitor well construction at the Saukville site is shown by Figures 5 and 6. Logs for new wells?

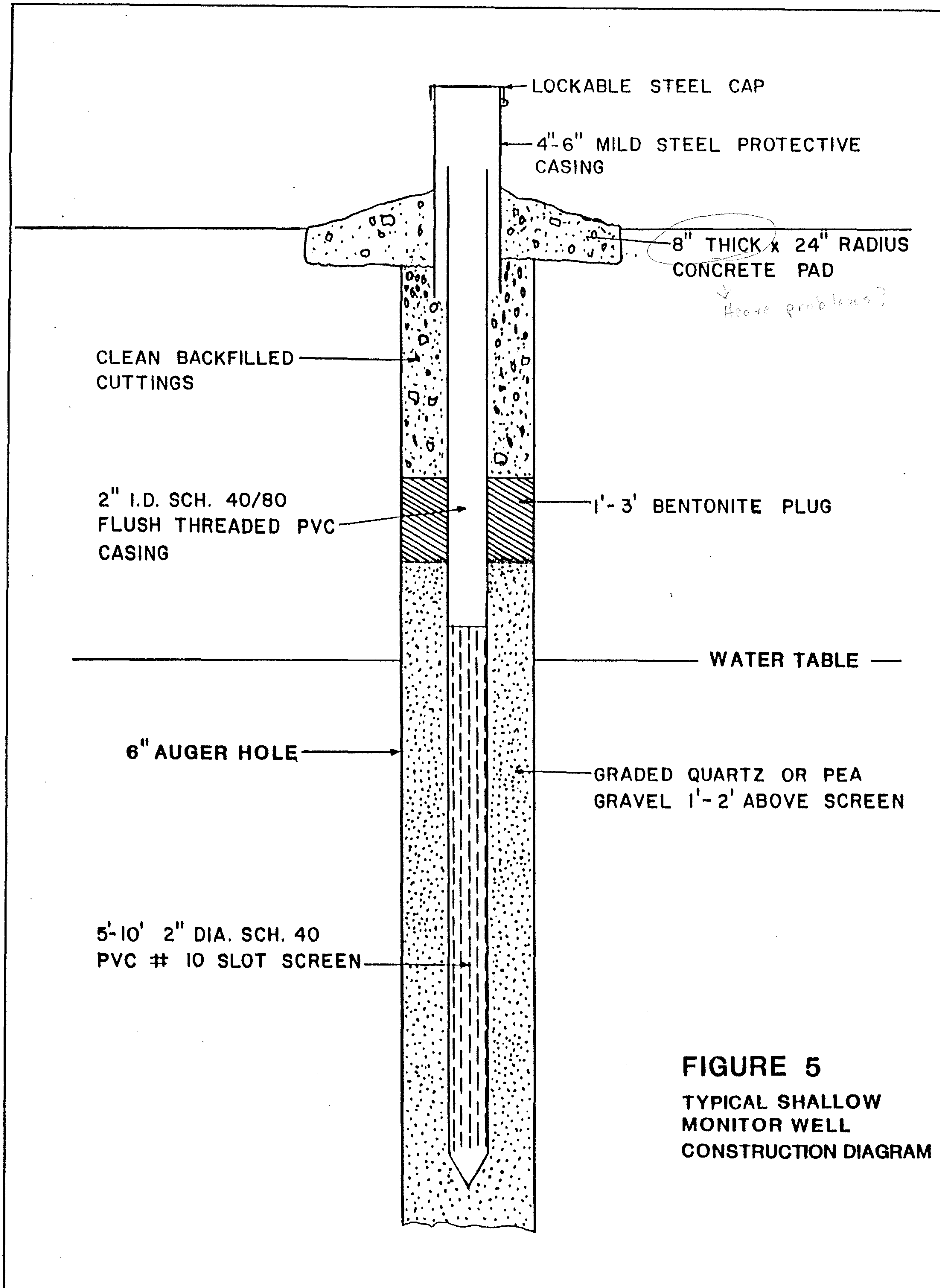


FIGURE 5

TYPICAL SHALLOW MONITOR WELL CONSTRUCTION DIAGRAM

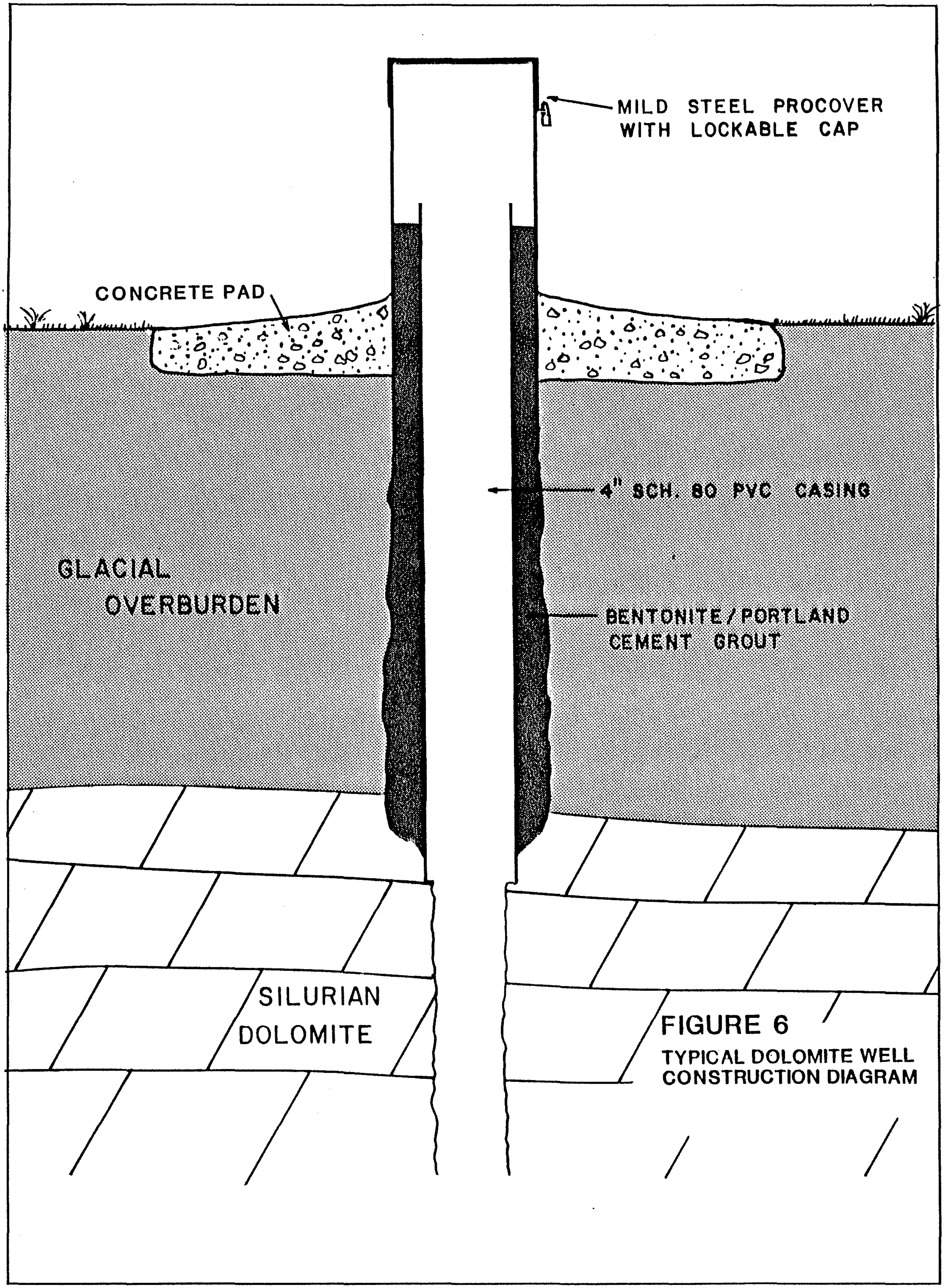


FIGURE 6
TYPICAL DOLOMITE WELL
CONSTRUCTION DIAGRAM

2.5 Borehole Geophysical Logging

A majority of the monitoring wells, the Laubenstein well (PW-8), new dolomite wells (W-23 and W-24), and the sinkhole well (W-20) were logged by BPB Instruments, Inc. Where possible natural gamma, caliper, temperature, neutron, gamma-gamma density, and acoustic logs were run to obtain as much data as possible on the physical construction of the monitor wells and the geophysical character, hydrology, and stratigraphy of all well sites mentioned above. These logs are found in Appendix I.

The caliper logs show PVC pipe joints and the top of the screen for almost all of the 2-inch PVC monitor wells. Individual vugs (small cavities), washouts, fractures, and other changes in hole diameter are especially evident on the caliper log of the Laubenstein well. The Laubenstein caliper log shows a large (4-5 feet) "washout" at the end of the 8-5/8-inch casing. Smaller but significant hole enlargements are evident to about 125 feet, between 308 and 330 feet, and below 422 feet.

The temperature logs give an accurate depth-to-water level in every instance by a sharp negative (colder) kick at the water-air interface. The negative temperature excursion at 17 feet in well 7 indicates colder ground water is entering the well bore at that point (top of screen). This is also the elevation of the top of the dolomite at this well site.

The temperature log of the Laubenstein well demonstrates that there are several points within the well where groundwater is entering or leaving the well bore. Although, normally, well bore temperatures gradually increase with depth, well bore temperature in this well decreases (gets colder) to the 450 feet depth indicating that colder water from shallower depths may be moving down the well bore to that depth. The water level of 38 feet, as indicated by the temperature log, suggests that nearby Municipal Well 2 was being pumped on this logging day. A well-bore, current-meter survey to determine direction and rate of water movement within the well bore of the Laubenstein well has not been run.

The temperature logs of those monitoring wells having screens across the dolomite-glacial sediment contact do not indicate significant vertical movement of water.

The gamma-gamma density logs give a high-amplitude, low-density kick (to the left) opposite the location of bentonite plugs in the monitoring well annulus. Most all bentonite plugs are shown to be actually within 1 foot of their reported locations. Otherwise, the gamma-gamma logs demonstrate that the least dense materials are generally within the upper 10-12 feet in the shallow monitoring wells. The gamma-gamma log for the Laubenstein well shows good correlation with the caliper log, having obvious, low-density kicks opposite higher diameter anomalies are shown on the caliper survey. The density logs also demonstrate that the density tool was probably more proficient at locating fractures and vugs than the caliper tool used on this survey. For example, low-density anomalies were located at 63.5 feet, 116 feet, and 428 feet. The large, low-density anomaly at 19 feet looks like a hole in the casing; however, if so, it was not detected by the caliper log.

The sonic survey of the Laubenstein well verifies the low-density and caliper anomalies, which are probably solution cavities in the dolomite. However, the low-density kick at 63.5 feet is not confirmed by the acoustic log, which may mean that it is clay filled or contains some low density mineral filling. Significantly, the acoustic log also identifies the upper temperature anomaly at ±375 feet to be opposite a large (±3-foot) opening in the dolomite.

The acoustic log of W-24 was run in the drill rod and is therefore useless.

The sonic log of PZ-20 was run in an open, mud-filled hole in glacial till, clay, and silt in a dolomite sinkhole. Comparison with the caliper log indicates that the sonic log anomalies are principally related to hole size changes.

The acoustic log of W-23 does not correlate with the gamma-gamma or the caliper log. The poor definition of the gamma-gamma log may indicate an electronic problem with the equipment when the logs for W-23 were made. Conversely, the neutron log for this well appears to be normal.

The neutron log, which is a measure of the relative abundance of hydrogen ions, was used at Saukville to indicate the presence of water and, therefore, higher permeability zones. The top of the saturated section on these logs is identified by the large negative shift (greater attenuation of neutron particles by hydrogen ions) and correlates well with the negative temperature anomalies. In general, they indicate that water in the glacial sediments decreases significantly with depth. Exceptions to this generality are PZ-19 and W-23, which indicate that more water exists toward the bottom of the glacial deposits at these two points. Likewise, PZ-20 (in the dolomite sinkhole) shows water to a depth of about 33 feet.

The neutron log of the Laubenstein well shows poor correlation with the temperature log, but fair correlation with the density and caliper logs. That is, higher hydrogen ion anomalies tend to match low-density, larger hole excursion anomalies.

2.6 Hydrologic tests

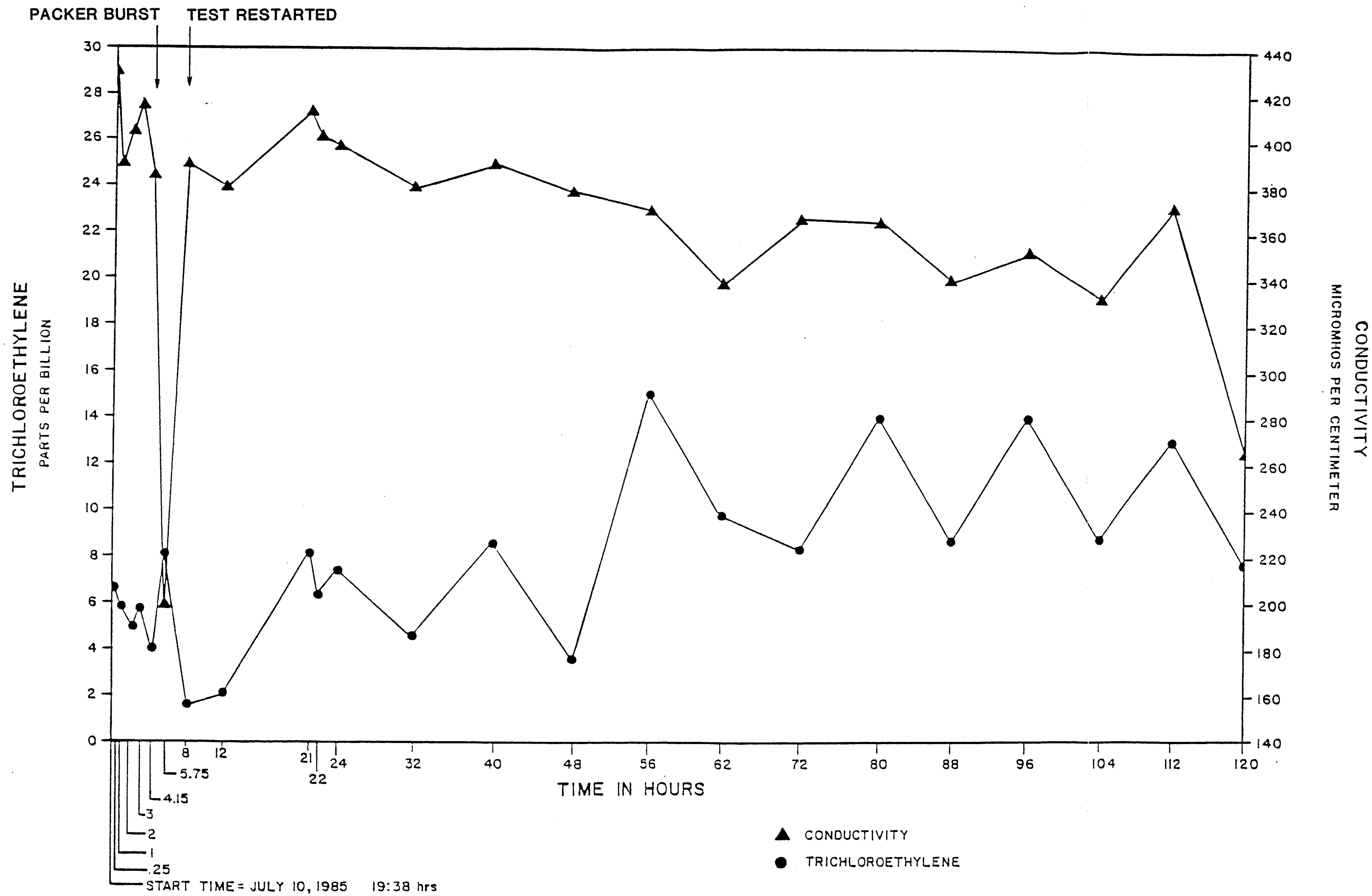
The absolute need to prevent cross contamination of wells and introduction of foreign water and contaminants into the monitoring wells severely limited the kinds of equipment that could be used and the types of hydrologic testing that could be done. Short bailing tests, followed by notation of recovery rate versus time, were made in all newly installed 2-inch-diameter, shallow monitoring wells. The large diameter pilot well was dewatered several times with a pump, and the rate of recovery was observed.

→ near PZ-6A

The dolomite wells were bailed by the drilling contractor to clean the wells of mud and cuttings, but recovery or bailing rates were not recorded. The water level of the pilot Ranney collector ditch was monitored over several days to document the rate of filling. (Evaluation of these tests is presently incomplete.)

The Laubenstein well was pumped at 50 gpm over a period of one week. This was not designed strictly as a controlled hydrologic test, but to determine the change of trichloroethylene with time. The results of this test are presented in Figure 7.

During the course of the exploratory augering, continuous split-spoon samples were collected. From these, representative samples of the tills and silty clays were selected for lab permeability analyses. Water for saturating the samples and running these tests was collected from a shallow on-site well. These tests are being run, but the results are incomplete at this date. Longer than anticipated saturation times, caused by the extreme "tightness" of these materials, has delayed the timely completion of these analyses.



Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986 Scale: None	Laubenstein Warehouse Well Pump Test Drawing No.: Figure No.: 7

3.0 GEOHYDROLOGIC SUMMARY

3.1 Geology

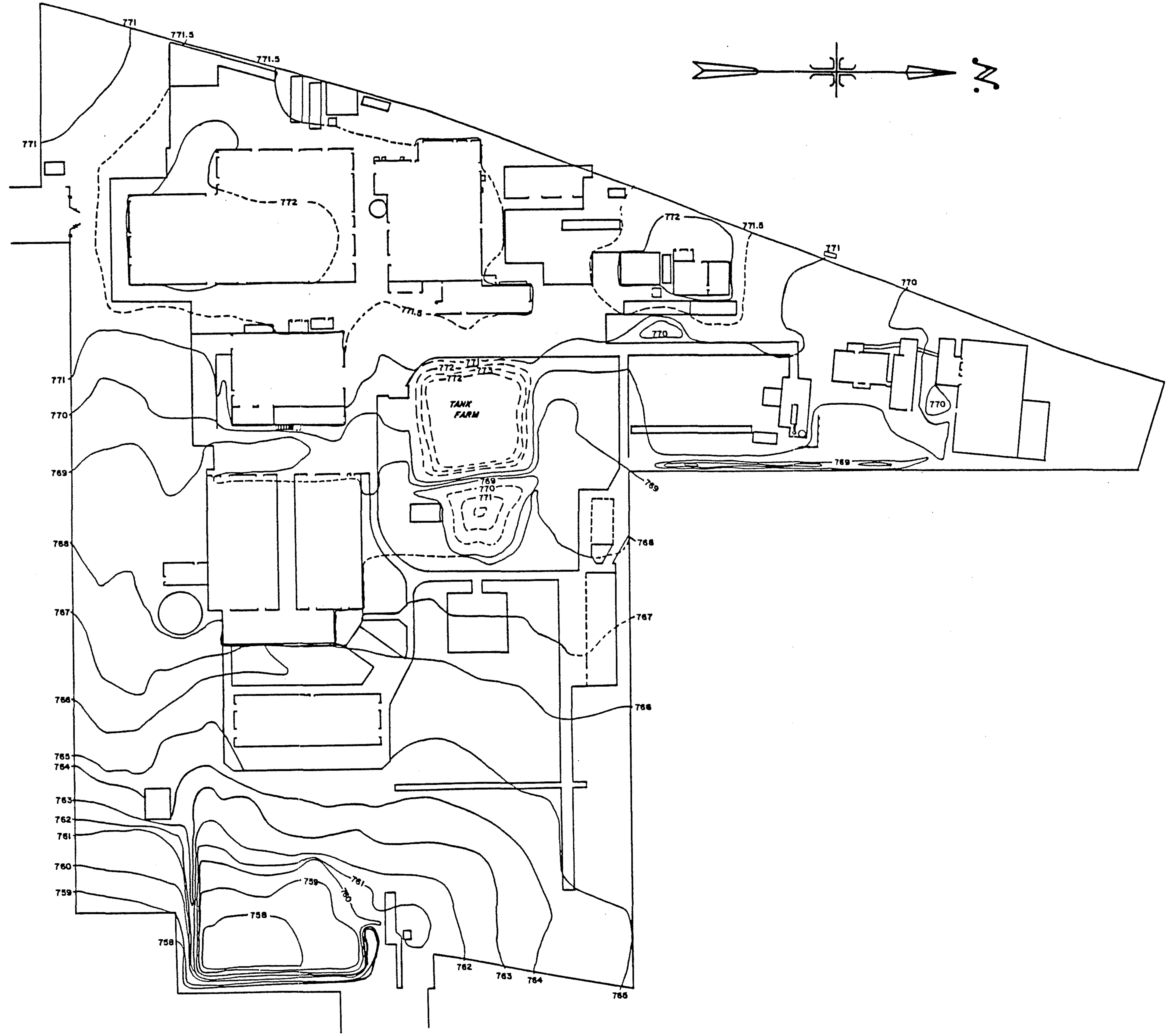
The field investigations conducted during 1985 have provided additional data concerning the geology of the Freeman Chemical Saukville site as discussed in the following paragraphs.

3.1.1 Top of Dolomite

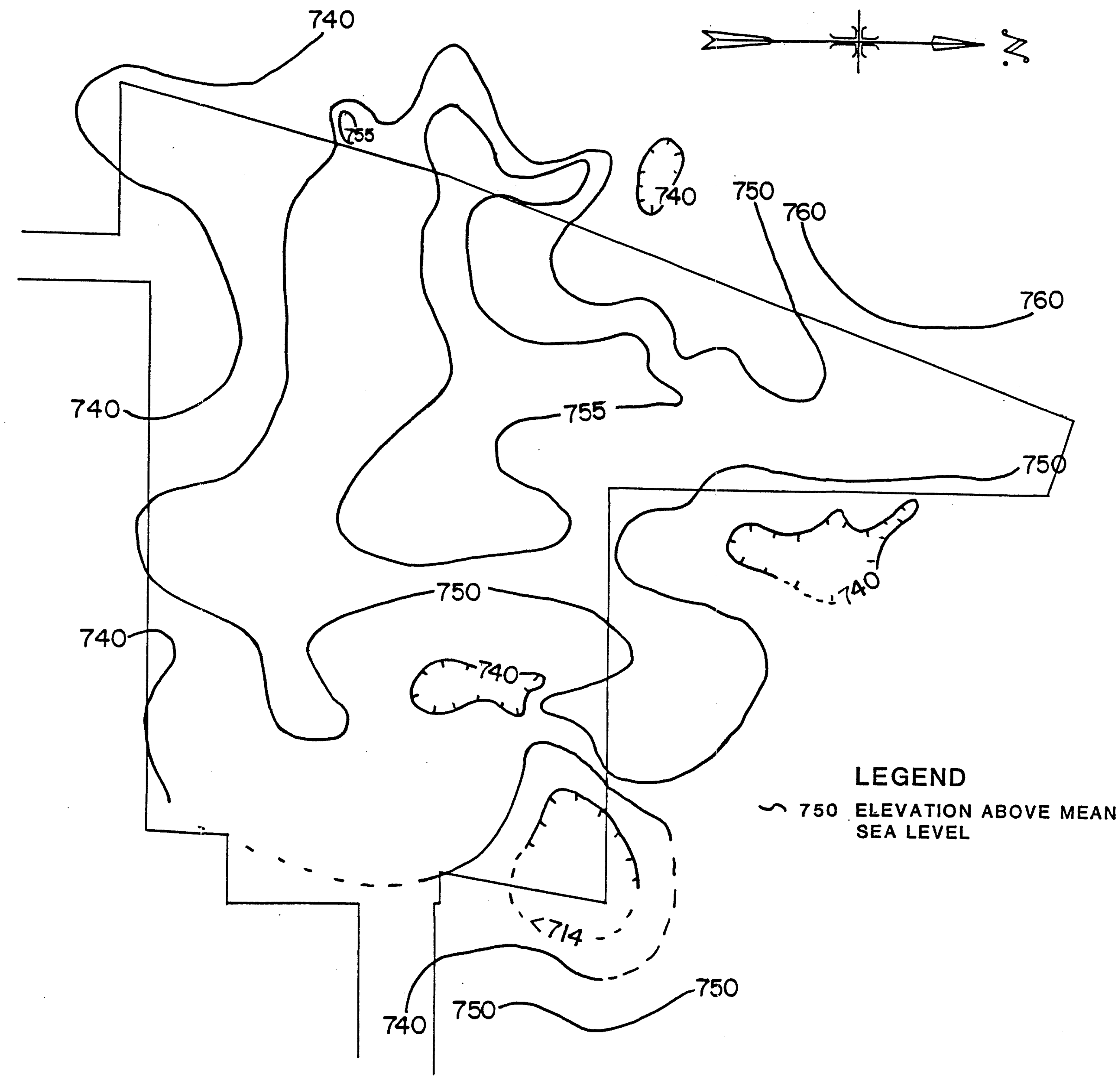
The seismic refraction data, the depths to the top of dolomite from construction of the present and prior monitoring well network, and the depths obtained from the present and prior exploratory augering have provided control for a more detailed, top-of-dolomite contour map. A recently completed, more detailed (1-foot contour interval) site topographic map has also permitted increased top-of-dolomite elevation accuracy (see Figures 8 and 9, respectively).

This dolomite topographic map, when compared with Figure 1 of the January 1985 report, demonstrates that the site is indeed dominated by a local bedrock high. However, additional control has changed its shape significantly. In fact, increased drill and auger data confirm what is indicated by the seismic refraction profiling; i.e., the dolomite surface is highly pinnacled and contains deep, narrow, irregular channels or, more likely, sink holes.

Closed depressions, interpreted as sink holes are still indicated in the vicinity of the Laubenstein well, in the southwest corner of the Immaculate Conception School ballfield, in the tanker parking area just north of Building 45, and in the extreme northeastern corner of the site where well PZ-20 was drilled to a depth of 190 feet through till, clay, and silty sand without obtaining bedrock.



Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Site Topographic Map	
		Scale: 1"=100'	Drawing No.:	Figure No.: 8



Job No.: 0001-003	Hatcher Incorporated	Date: February 1986	Top Of Dolomite Contour Map	
	RICHMOND, VIRGINIA	Scale: 1" = ± 140'	Drawing No.:	Figure No.: 9

An alternate interpretation is that the latter depression may be a filled river channel.

The new dolomite monitoring wells were cored from top of bedrock to a depth ranging from 65-85 feet. Well logs for these wells are presented in Appendix II. The 2-inch cores of these wells reveal that the upper surface is severely solutioned. Some large vugs are sand and/or clay filled and there is some evidence that the largest contain till and boulders. The core is also highly fractured, tending to come out of the core barrel in fragments. Opening size and fracture frequency decrease with depth, but the bottoms of all the drilled shallow dolomite wells were still quite open and permeable.

The dolomite surface is usually immediately overlain by a thin (less than 1 foot), fine to medium, usually clean sand, below which a few inches of blue clay from the weathered dolomite is sometimes present.

The surficial glacial materials blanketing the dolomite at this site consist of till, loess or varved lacustrine clay, and fluvial sands and gravels. The most common section consists, from the top down, of:

1. soil and/or fill
2. silty sand, plastic clay, or till
3. dense, varved, argillaceous clay
4. very dense till.

A few very thin, usually dry sand seams are present in the clay. The tills appear to be totally unsorted and are very difficult to penetrate. The glacial materials along the southern edge of the site contain a greater abundance of stream transported sediment than elsewhere on the site. See logs of SP-E, PZ-26, and 14A in Appendix II, for example.

3.1.2 Glacial Overburden Thickness

The top-of-dolomite elevation map and the new site topographic contour map were used to produce an overburden thickness map, Figure 10. This map was constructed by contouring thickness data from the auger hole and monitoring well logs and from differences in elevation at the points where contours of the topographic and top-of-dolomite maps intersected. The resulting map consists of isopleths of equal overburden thickness and should not be confused with a topographic map.

This thickness isopleth map shows that the glacial sediment cover blanketing the site is thinnest in the western central portion of the site beneath the main group of buildings and the tank farm. Off-site, sediment cover is thinnest just off the northwestern corner and beneath the Saukville Feed Company property (also to the northwest). Sediment cover is thickest, of course, at the locations of the supposed sinkholes.

3.1.3 Geologic Cross Sections

Geologic cross sections (Figure 12) have been constructed from the well and auger hole logs along lines shown on Figure 11. These generalized geologic sections illustrate the character, thickness, and lateral continuity of the strata immediately underlying the Saukville site.

The topography of the bedrock floor (top of dolomite) is dominated by a low, centrally located knoll sloping away in all directions. Smooth lines were drawn between well or auger hole data points, therefore, the bedrock floor in these sections appears smoother than the seismic refraction profiles suggest is the actual case. Greater relief in the bedrock floor is also suggested by those places on these sections where 2 or more wells are close together, such as at P-14, W-24, and P-14A on Section BM

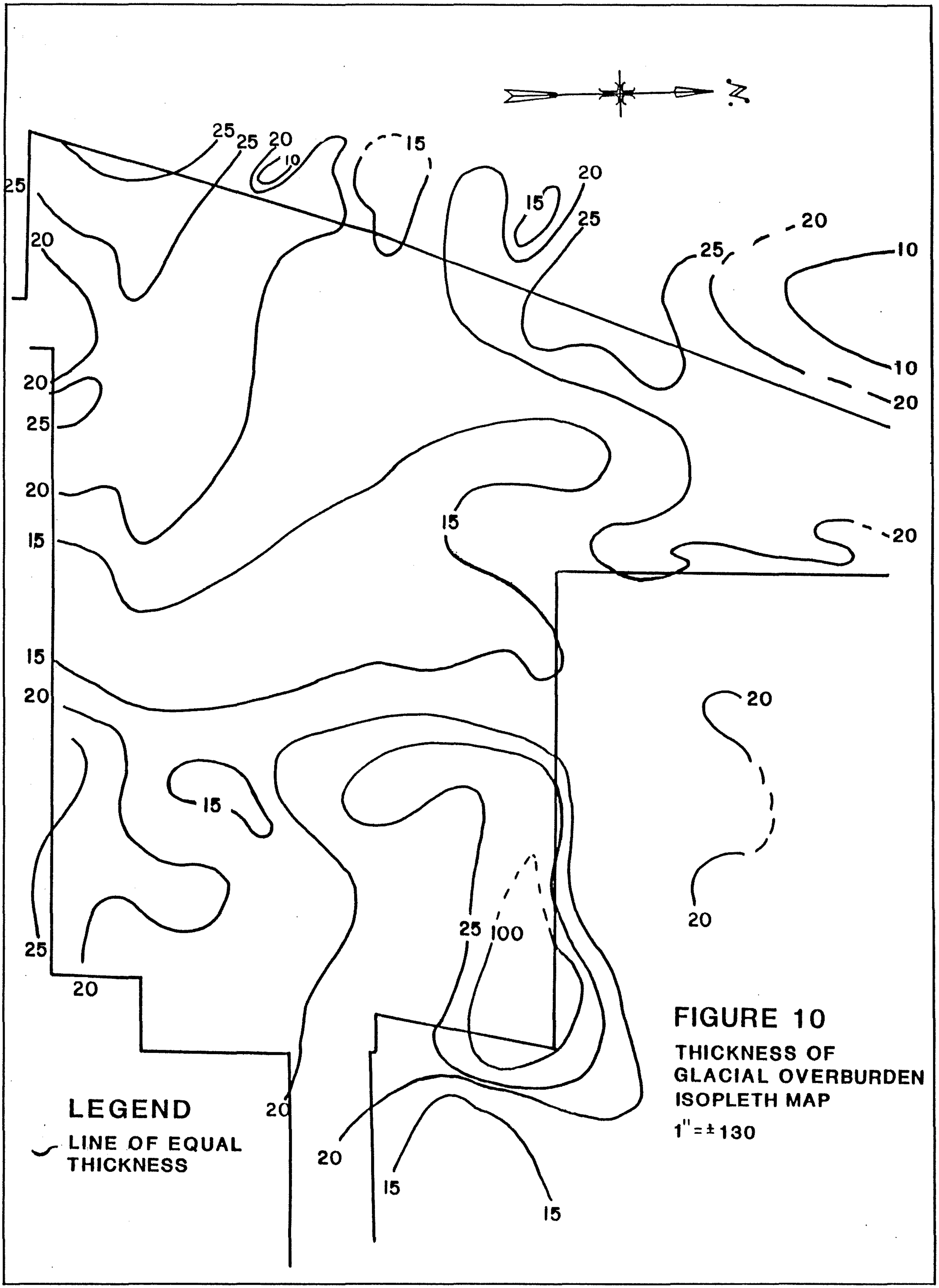


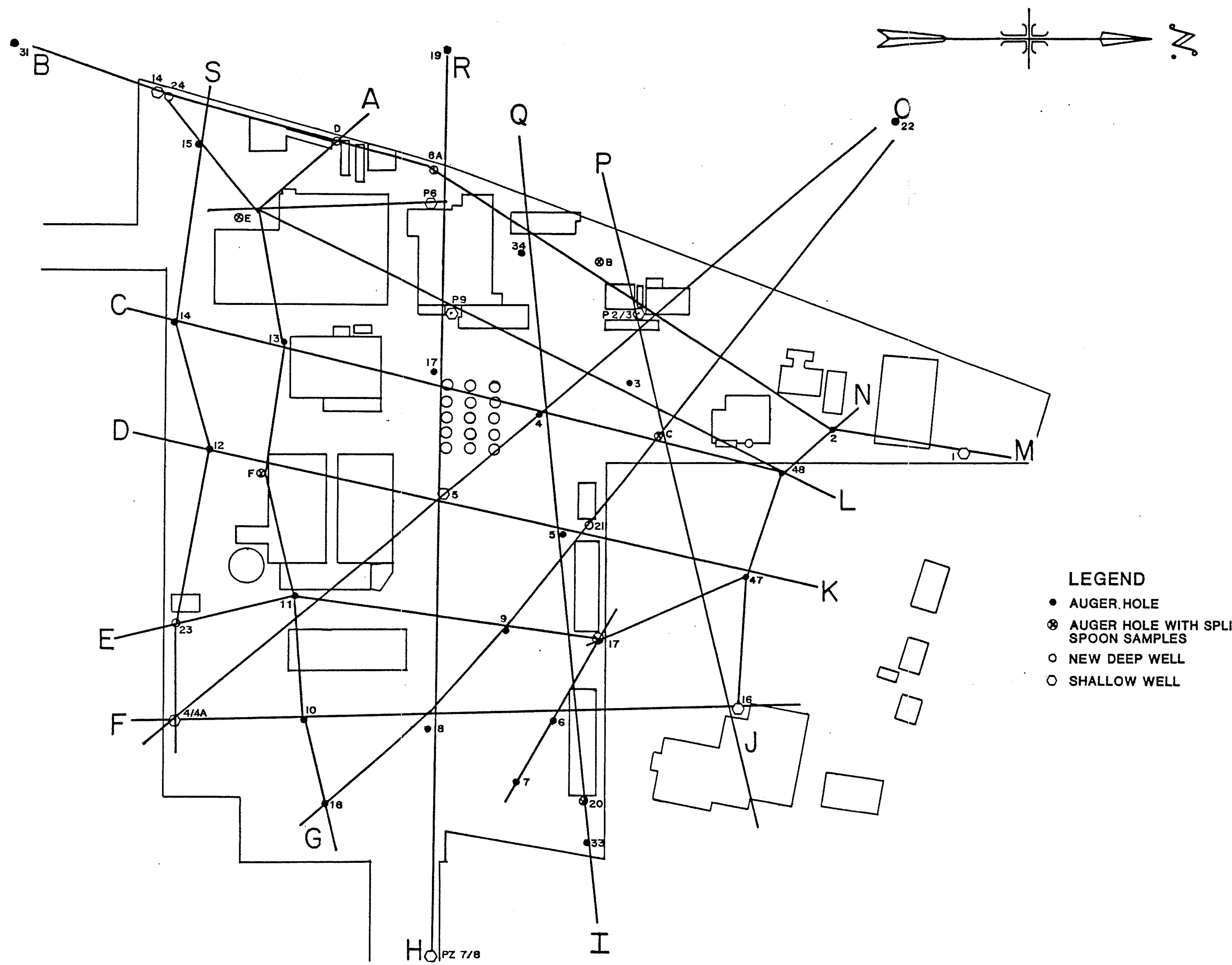
FIGURE 10

THICKNESS OF GLACIAL OVERBURDEN ISOPLETH MAP

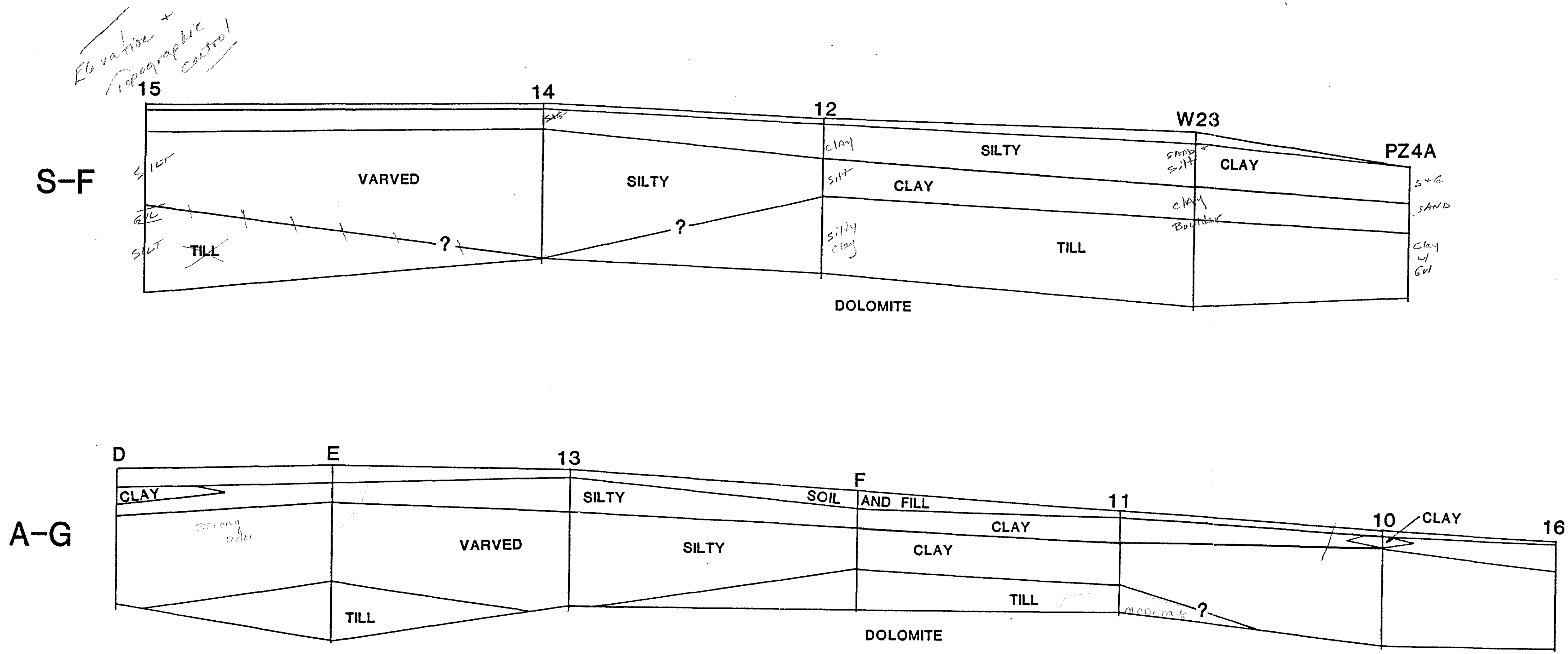
1" = ± 130

LEGEND

LINE OF EQUAL THICKNESS

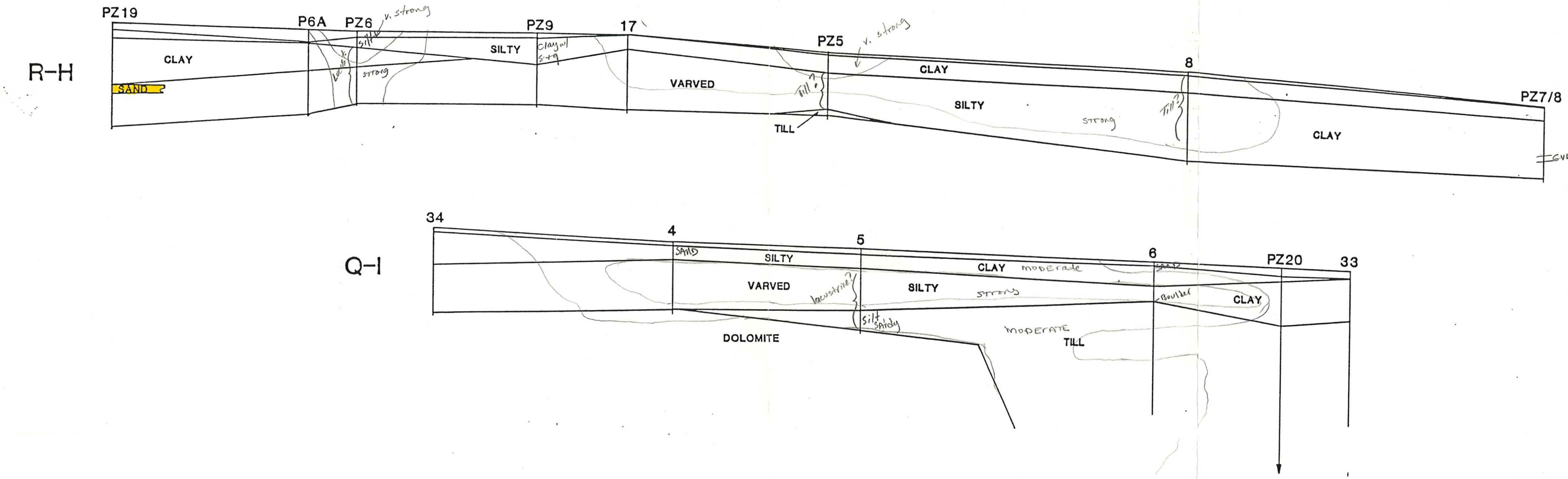


Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Cross Section Location Map
		Scale: 1" = ± 135'	Drawing No.: / Figure No.: 11



SEE FIGURE 11 FOR SECTION LOCATIONS.

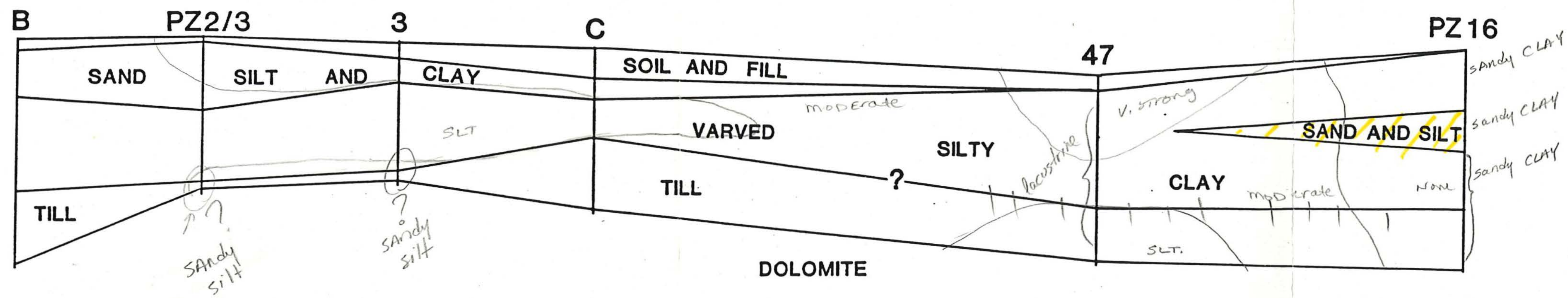
Note: Horizontal Scale: 1"=±50' Vertical Scale: 1"=±18'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Geologic Cross Sections S-F And A-G
			Scale: See Note	Drawing No.: / Figure No.: 12A



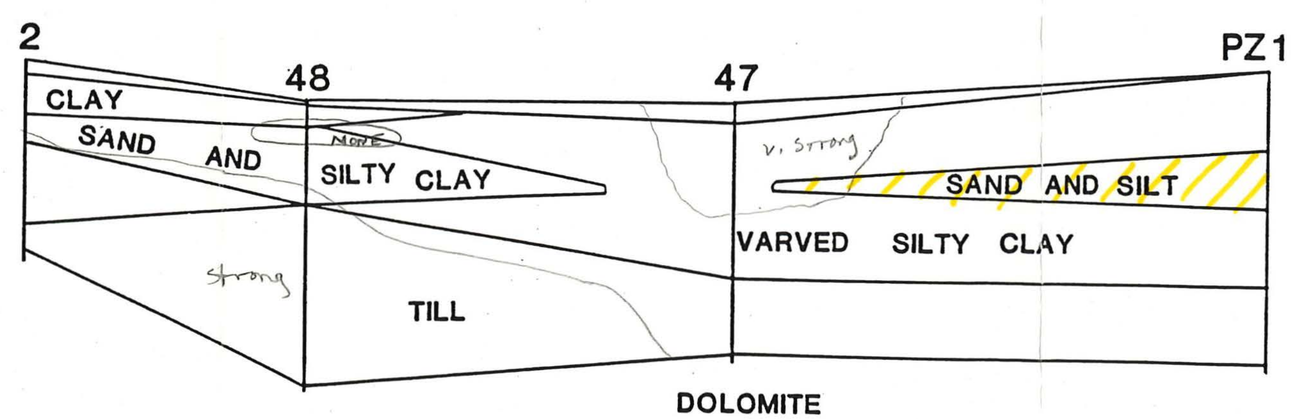
SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1" = ±100' Vertical Scale: 1" = ±26'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986 Scale: See Note	Geologic Cross Sections R-H And Q-I Drawing No.: Figure No.: 12B

P–J

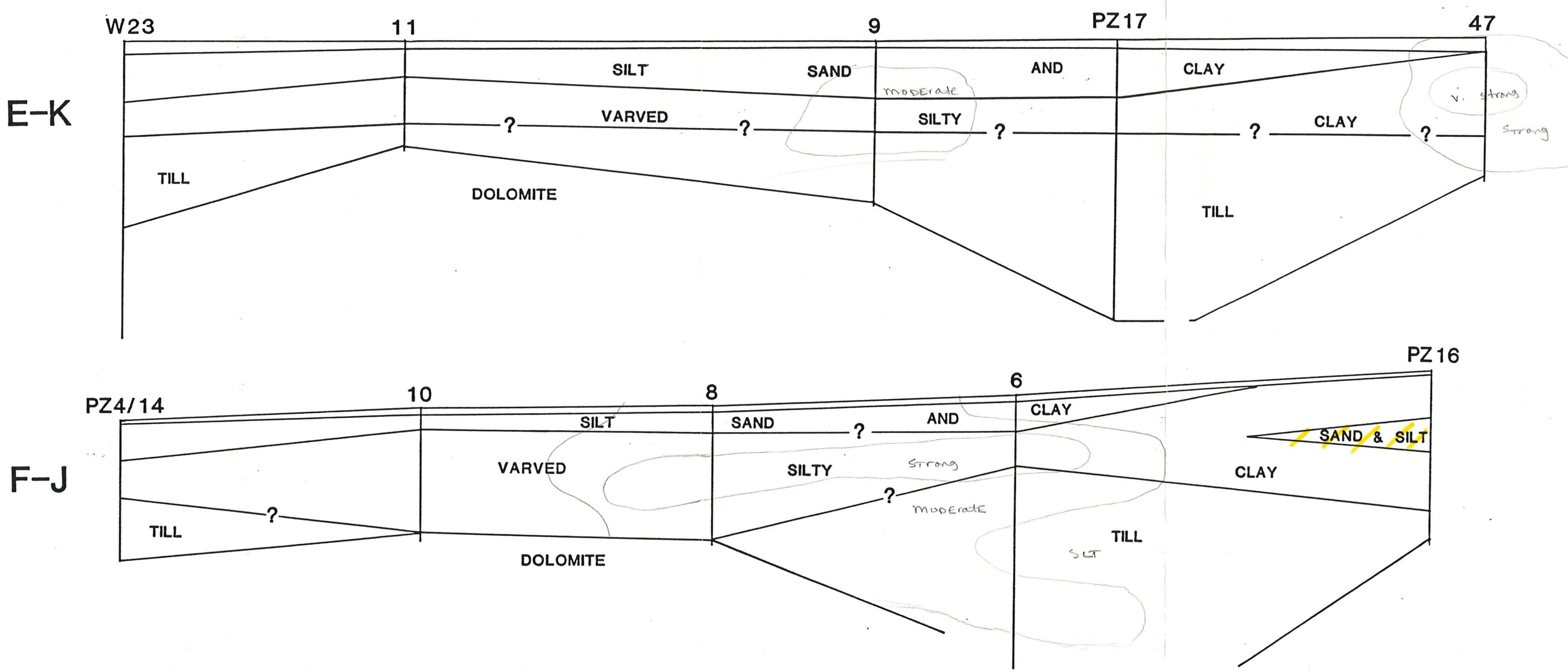


N–J



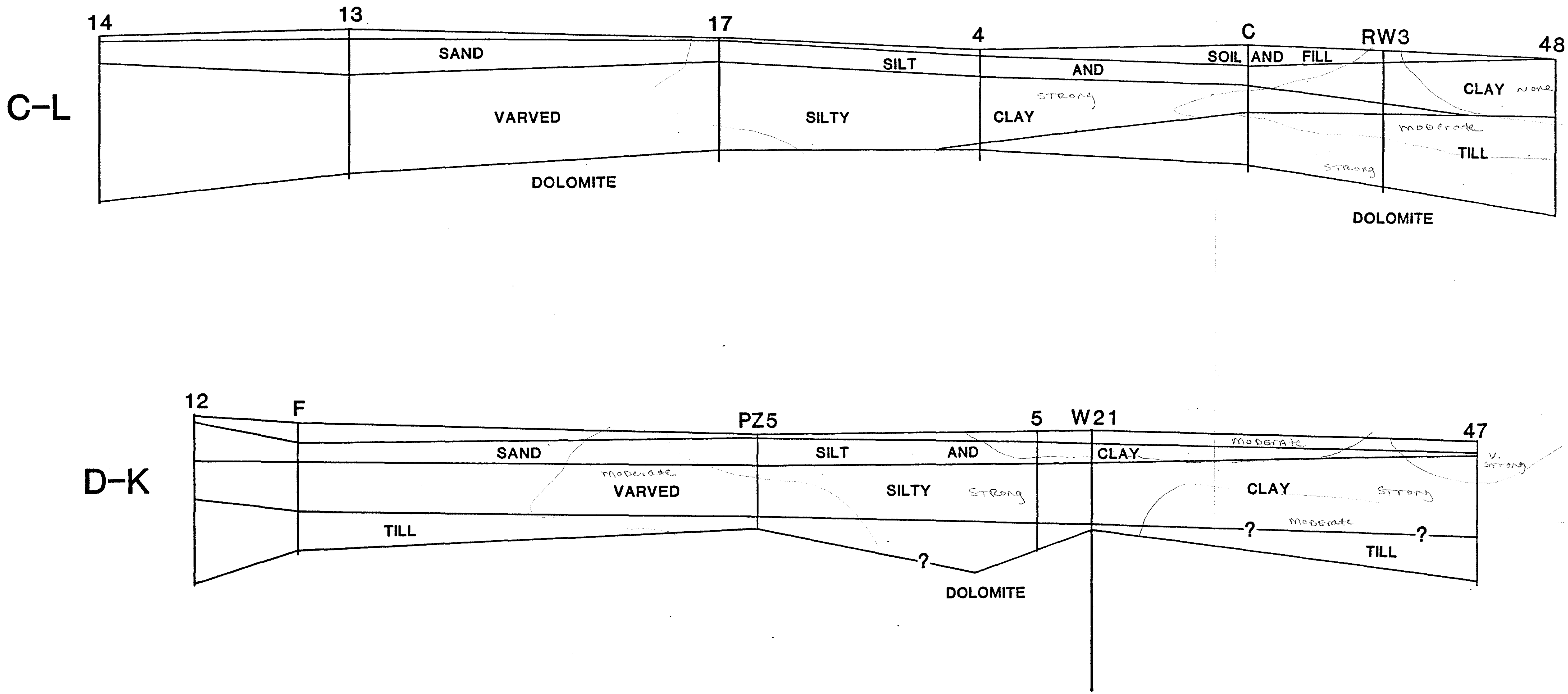
SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1" = ±50' Vertical Scale: 1" = ±19'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Geologic Cross Sections P–J And N–J
			Scale: See Note	Drawing No.: / Figure No.: 12C



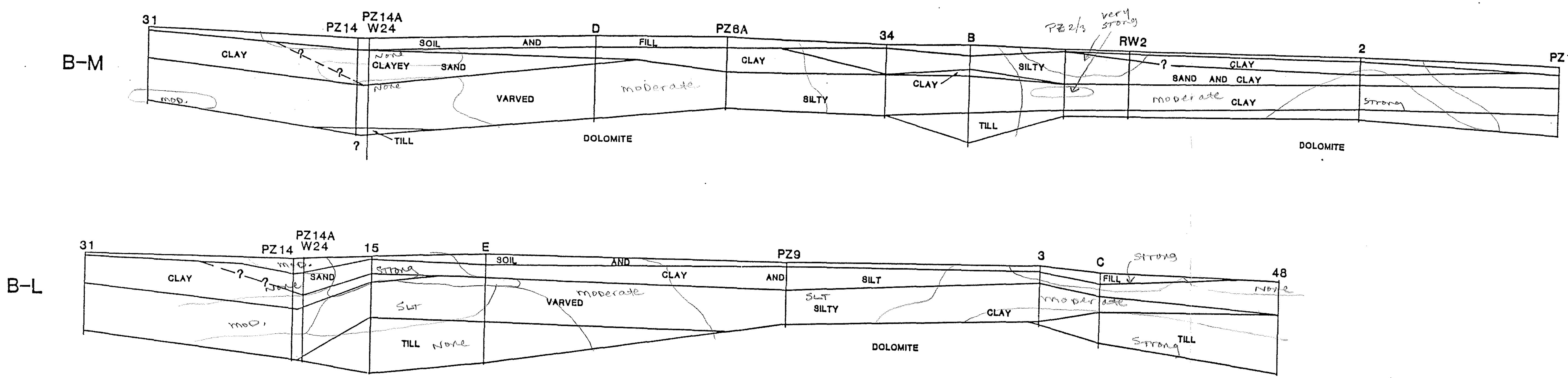
SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1"=±50' Vertical Scale: 1"=±18'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Geologic Cross Sections E-K And F-J
			Scale: See Note	Drawing No.: / Figure No.: 12D



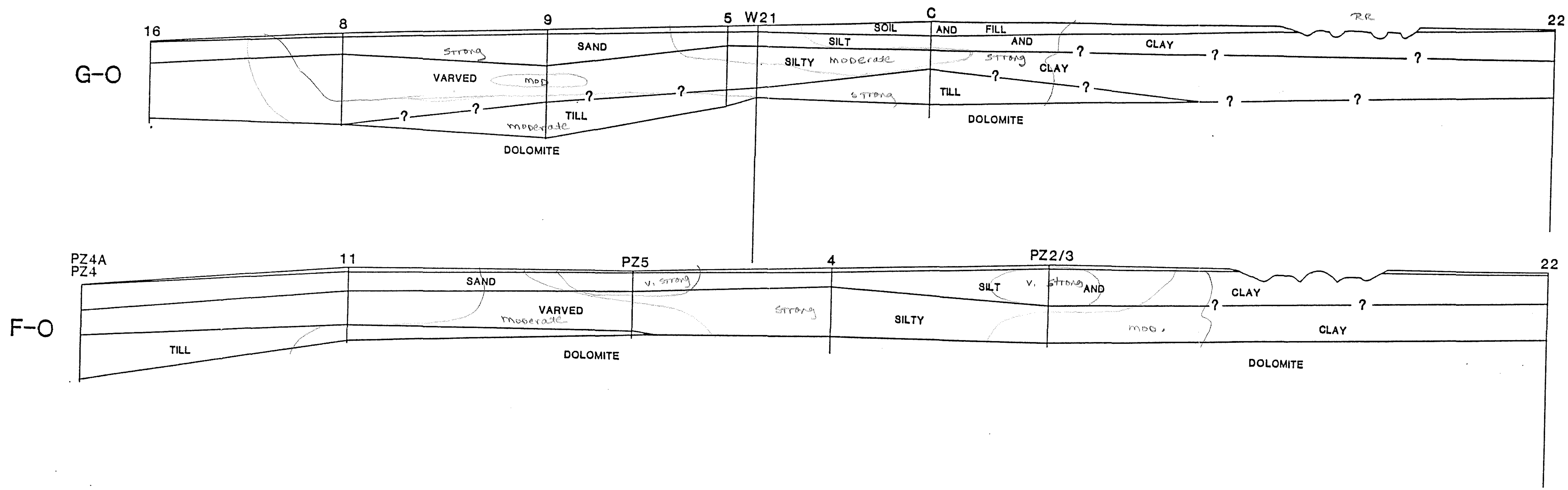
SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1" = ± 50' Vertical Scale: 1" = ± 18'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986 Scale: See Note	Geologic Cross Sections C-L And D-K Drawing No.: Figure No.: 12E



SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1" = ± 88' Vertical Scale: 1" = ± 30'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986 Scale: See Note	Geologic Cross Sections B-M And B-L Drawing No.: Figure No.: 12F



SEE FIGURE 11 FOR SECTION LOCATIONS.

Note: Horizontal Scale: 1" = ± 216' Vertical Scale: 1" = ± 24'	Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Geologic Cross Sections G-O And F-O
			Scale: See Note	Drawing No.: Figure No.:12G

or at 5 and W-21 on Section DK. Section QI shows that a sediment filled sinkhole or old river channel is present in the northeast corner of the site.

These sections illustrate that the top of the dolomite is blanketed by glacial outwash materials consisting of either very dense, unsorted till (hardpan of local usage) or varved, gray, argillaceous, usually dry lake clay. The lake clays are latteraly continuous over all of the site; the till less so. As shown, interbedded sand, silty and sandy clays, clay, and minor occurrences of till overlie the dense lake clays. The uppermost unit consists of thin soil and fill.

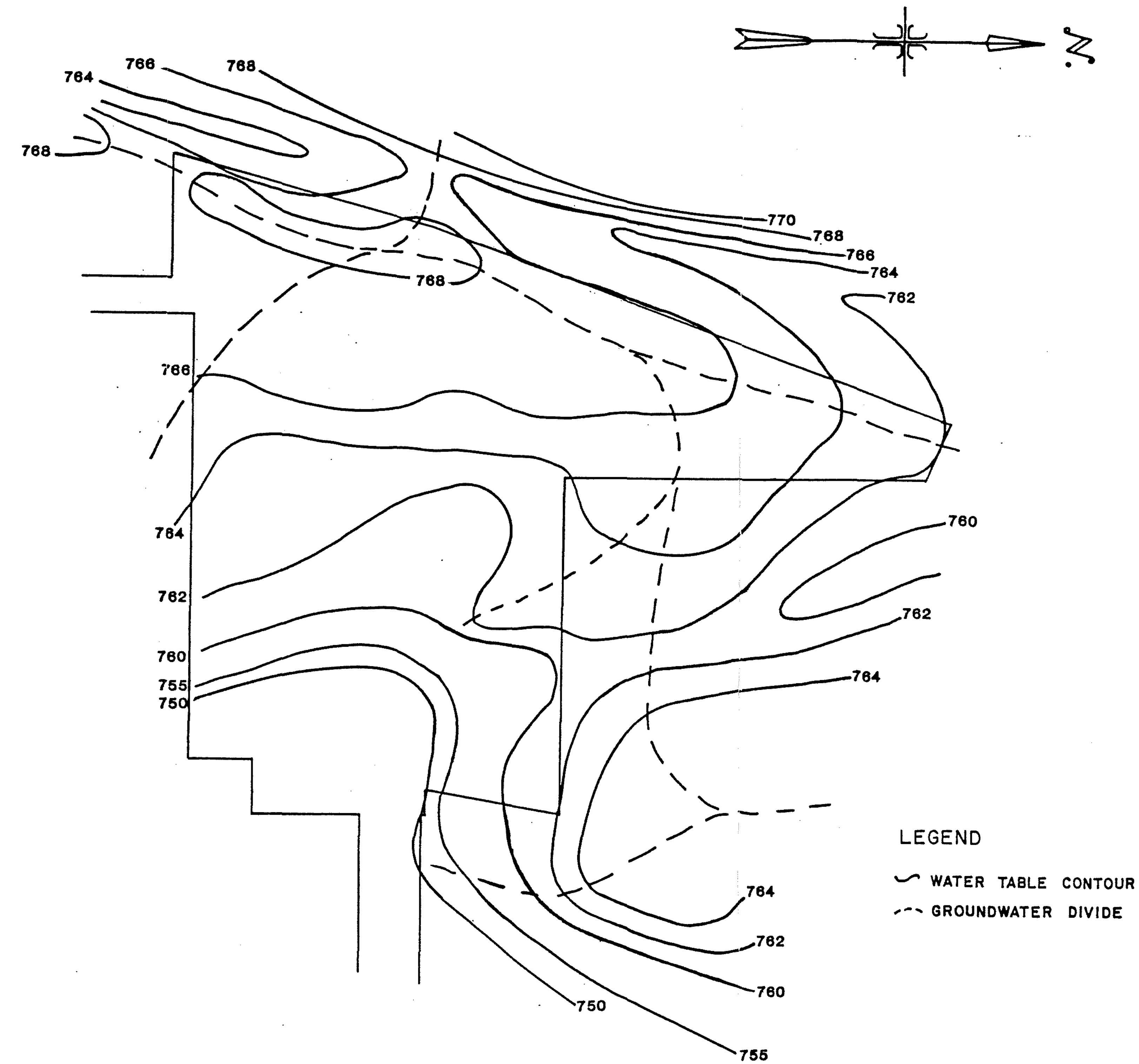
3.2 Hydrology

The 1985 field investigations have provided additional hydrologic data pertinent to the Freeman Chemical Saukville site as discussed in the following paragraphs.

3.2.1 Water Table Map

Water levels measured in the new shallow piezometers and first returns from the seismic refraction survey have been combined to produce a more highly detailed water table map of the site and surrounding local area. See Figure 13. As is typical, this map looks much like the configuration of the site topographic map. Water levels are highest along the western edge of the site and at the Immaculate Conception Church/School property.

Groundwater drainage divides have been superimposed on this figure to indicate general direction of water-table flow from the site. Most shallow groundwater flows to the lower southeastern part of the plant site (as does most surface water). All shallow groundwater along the western edge of the site flows to the railroad track area. Figure 13 also suggests that groundwater flows onto the



Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986 Scale: 1" = ± 182'	Water Table Map Summer 1985 Drawing No.: Figure No.: 13

site from the Immaculate Conception Church/School property and, possibly from the western Linden Street area.

Water table levels are shallow. They range from about 4 feet along the western edge of the property to approximately 13 feet at the eastern edge.

3.2.2 Dolomite Water Level Map

Water levels measured in the 5 new dolomite monitoring wells, the Laubenstein well, and PZ-7 have been used as a basis for this map. Figure 14 represents one interpretation of the semi-piezometric surface of the Dolomite Aquifer. However, during the course of this year's investigation, it became evident from development of the water table map described above and shown in Figure 13, that water levels in the prior piezometers, screened opposite the glacial sediment/dolomite contact, represented head of the top of dolomite rather than of the overburden. This conclusion is supported by the extremely low permeability of the dense glacial clays and the higher head differences between the top and bottom of the glacial overburden.

Consequently, water levels measured in the decommissioned wells have been used to augment water-level data used to construct Figure 14 to produce the more accurate dolomite semi-piezometric map shown in Figure 15. Because of the placement of W-22 between the Laubenstein well and MW-2, we are now able to document that the Laubenstein well has developed its own drawdown cone, even though it is unpumped. This is shown by both Figures 14 and 15. The latter figure indicates that a local groundwater high exists in the dolomite in the west central part of the Saukville site from which groundwater flows in almost every direction, except possibly to the southwest at the head of Linden Street.

Groundwater divides superimposed on Figure 15 indicate

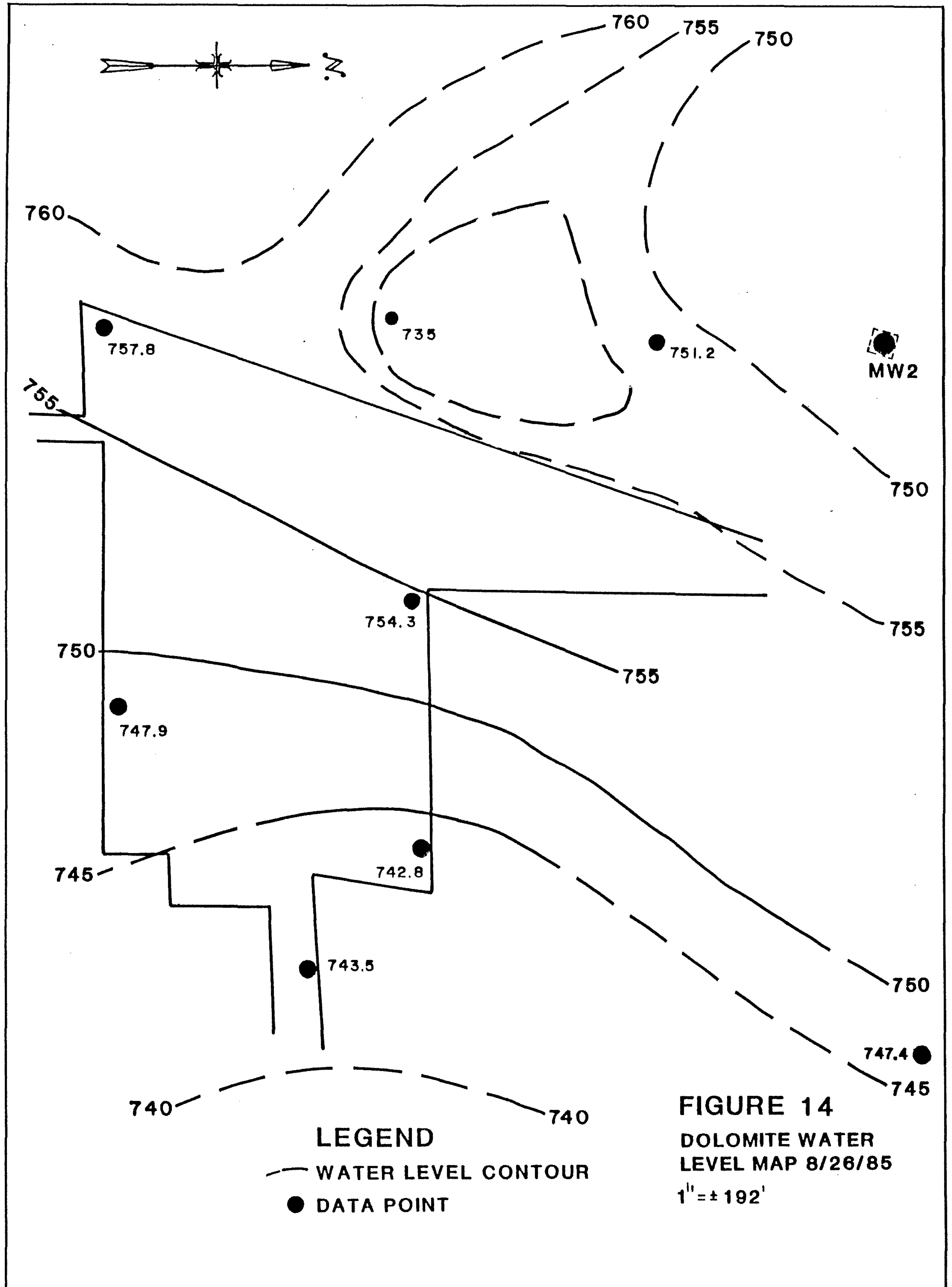
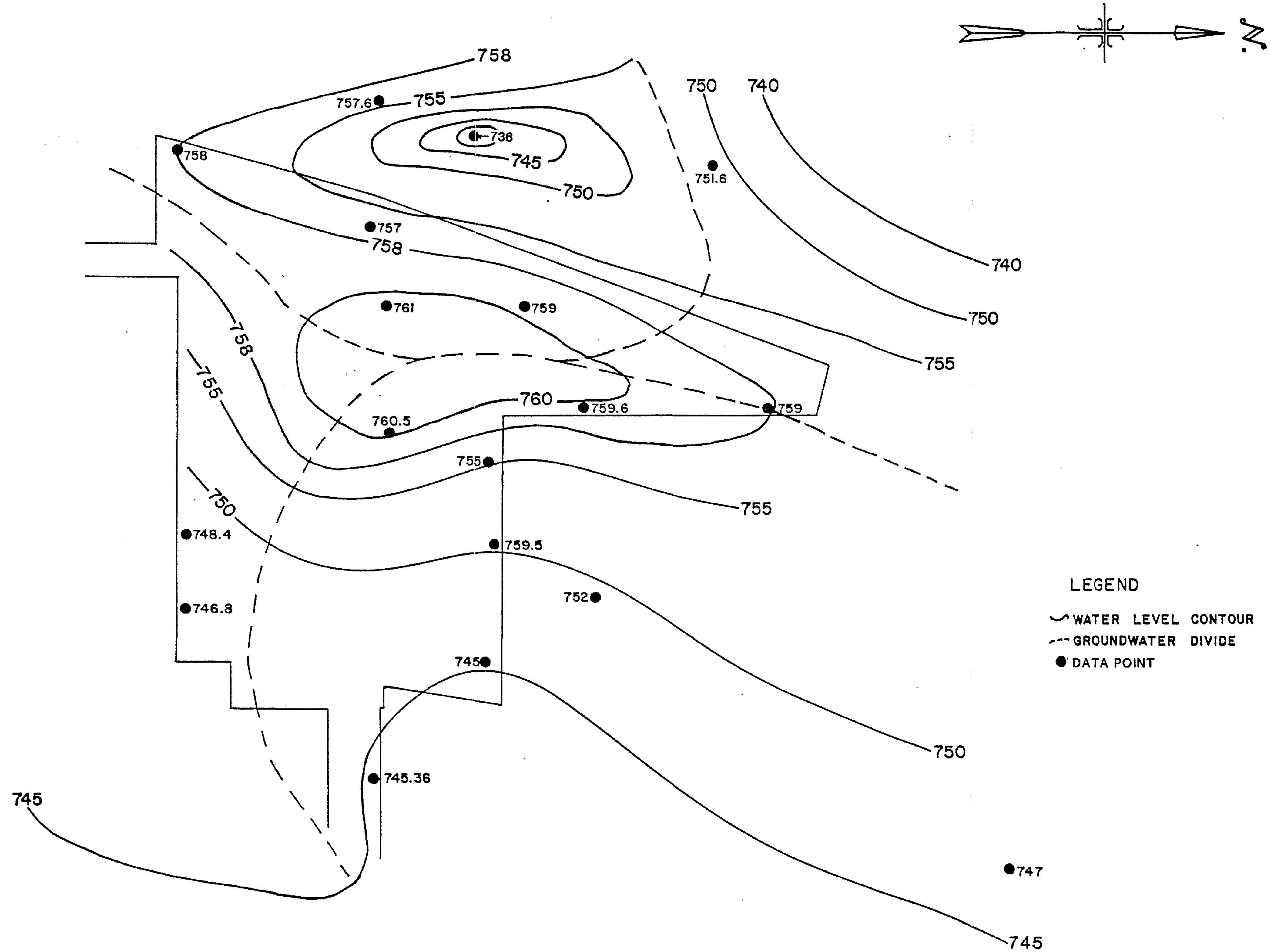


FIGURE 14
DOLOMITE WATER LEVEL MAP 8/26/85
1" = ± 192'



Job No.: 0001-003	Hatcher Incorporated	Date: February 1986	DOLOMITE CONSOLIDATED WATER LEVEL MAP-SUMMER 1985	
	RICHMOND, VIRGINIA	Scale: 1" = ± 182'	Drawing No.:	Figure No.: 15

that water in the upper part of the dolomite flows off-site from about the western 35 percent of the site along two paths: 1) directly toward the drawdown cone of MW-2 and 2) toward the drawdown cone of the unpumped Laubenstein well (PW-8), and thence to MW-2 through subsurface solution channels. Water from about 25 percent of the site is flowing southward and ultimately to the Milwaukee River. Water in the dolomite from about 50 percent of the site is flowing northeastward to the River and, perhaps to some extent, to MW-1.

Regardless of the direction of groundwater flow, it is apparent that the local groundwater high in the west central part of the site results from local, on-site recharge.

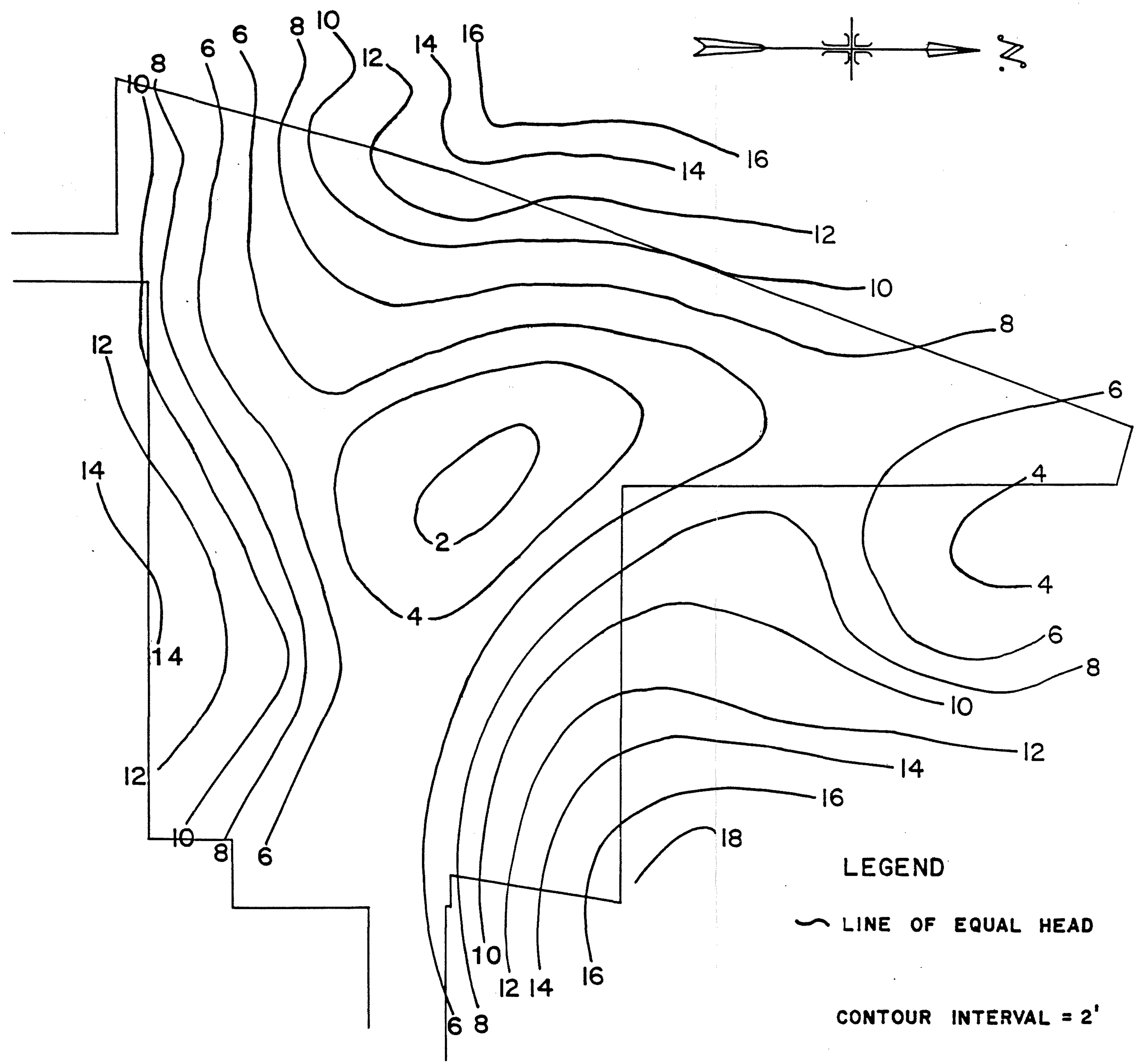
3.2.3 Head Difference Map

The water table map (Figure 13) and the dolomite semi-piezometric map (Figure 15) have been used to construct an isopleth map of the difference in head between the top and bottom of the glacial sediment overburden, Figure 16. Figure 16 indicates that the top of the dolomite and the glacial sediment are at or near the same head at the center of the site and at the extreme northern corner. These two locations also coincide with points where overburden thickness is least. Data from the head difference map combined with the thickness of overburden, isopleth data (Figure 10) and the permeability data was used(?) to calculate leakage rates through the glacial cover into the underlying dolomite.

3.2.4 Contaminant Dispersion

Probable Contaminant Sources

Accidental spillage of raw materials, resins, and by-products have occurred at the Saukville plant site in



Job No.: 0001-003	Hatcher Incorporated RICHMOND, VIRGINIA	Date: February 1986	Difference In Head Between Water Table And Dolomite Aquifer	
		Scale: 1" =± 130'	Drawing No.:	Figure No.: 16

the normal, daily manufacturing process since the plant's inception in 1949. Controlled seepage of reaction water to the glacial sediment occurred throughout a number of years through a "dry well" licensed by the Wisconsin DNR. This "dry well" may have been, in fact, constructed into the top of the dolomite. Reaction water has been accidently spilled both at the incinerator location and through at least one underground pipeline leak.

Small leakage has occurred over the years from barrel storage areas, such as in the far southwest corner, and in an area east of the scales along the ballfield fence presently used for tanker parking. Apparently, large volumes of barrels were stored at one time in the old barn formerly located just west of Building 45A. P2-14

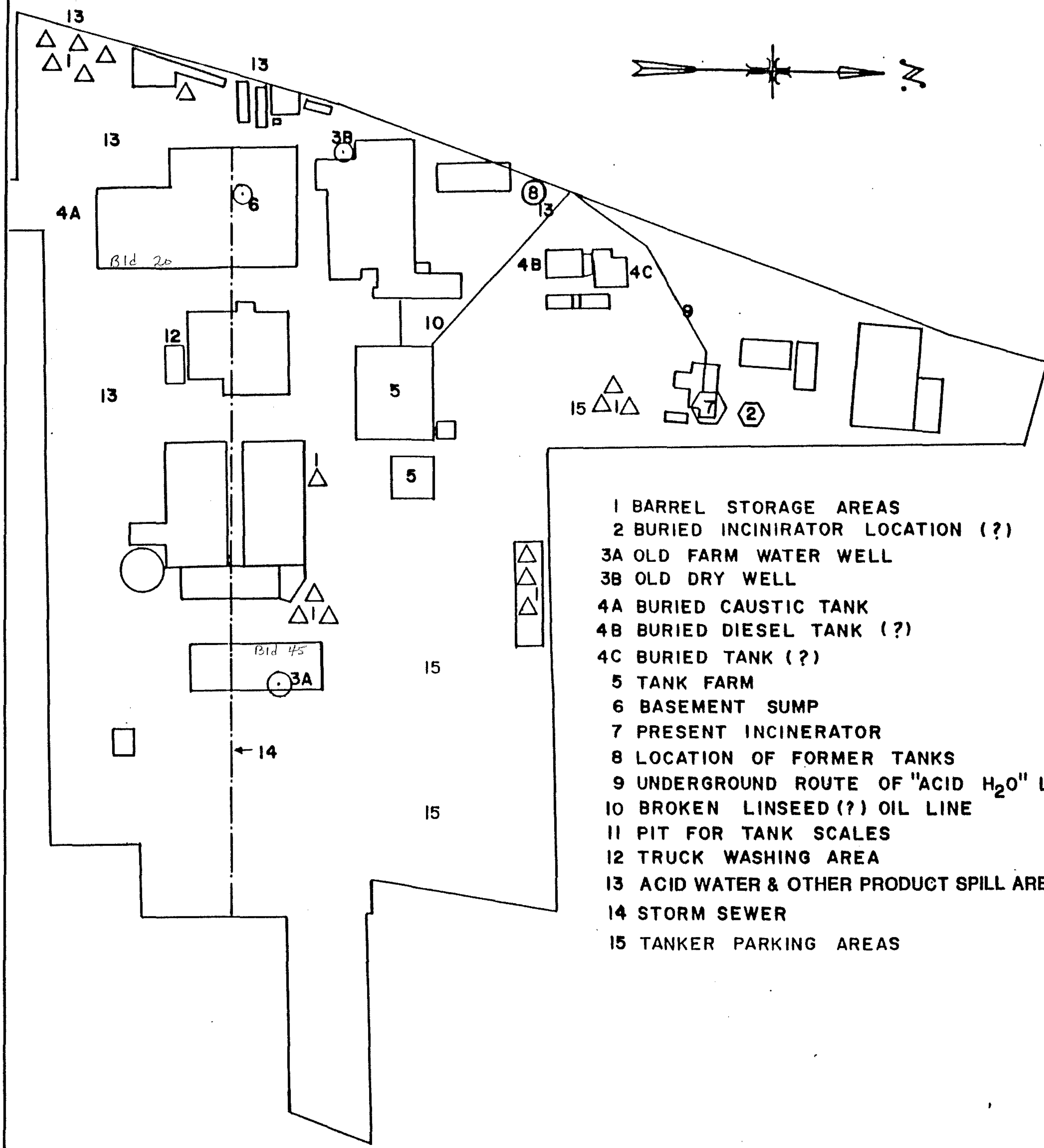
Accidental spillage of raw materials apparently occurred at the railroad siding during normal unloading of raw materials. Some raw materials were piped from that area to their point of use and/or storage, providing opportunity for leakage from ruptured raw material lines.

The bottom of a sump in at least one of the basements (e.g., Building 20) is constructed at or very close to the projected elevation of the top of dolomite. If so, this sump, and others like it, provide direct access to the dolomite from occasional spills from the kettles. The present tank farm is also sited in an area having thin cover over the dolomite.

Gasoline, diesel fuel, and "caustic" have been stored in underground tanks in the past. Figure 17 shows the locations of pipelines and other utilities in relationship to buildings and the possible location of contaminant sources.

Chemical Odor Distribution

Although the soil and rock obtained from the exploratory augering, split-spoon sampling, and coring have not been



1 BARREL STORAGE AREAS
2 BURIED INCINIRATOR LOCATION (?)
3A OLD FARM WATER WELL
3B OLD DRY WELL
4A BURIED CAUSTIC TANK
4B BURIED DIESEL TANK (?)
4C BURIED TANK (?)
5 TANK FARM
6 BASEMENT SUMP
7 PRESENT INCINERATOR
8 LOCATION OF FORMER TANKS
9 UNDERGROUND ROUTE OF "ACID H_2O" LINE
10 BROKEN LINSEED (?) OIL LINE
11 PIT FOR TANK SCALES
12 TRUCK WASHING AREA
13 ACID WATER & OTHER PRODUCT SPILL AREAS
14 STORM SEWER
15 TANKER PARKING AREAS

FIGURE 17

SOME POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION

1" = ± 145'

systematically sampled for contaminant level analysis, the presence or absence of VOC's in the collected samples has been documented by simply noting the presence or absence of odor at the time of collection.

These qualitative odor data are used in two ways in this report. First, their total absence in some holes gives good control of the lateral limit of contaminant dispersion from the site. This criterion is supported by past chemical analyses of groundwater from these holes; i.e., where no odor is present there is no contamination. Figure 18 shows the probable present-day limits of the site contaminant plume within the glacial overburden. Comparison with the water table map (Figure 13) shows that plume shape is consistant with expected flow direction.

Secondly, the odor data (from both the present and prior well and exploratory hole data) have been qualitatively divided into very strong, strong, moderate, and slight odor and have been used to illustrate the plume's 3-dimensional character. Therefore, Figure 18 is also a "birds eye" view of the distribution of different levels of odor concentration. The areas of strongest odor are located: 1) downslope from the tank farm and just north of Building 45A, 2) on the southwest corner of the Immaculate Conception Church ballfield (these two locations are at or near points underlain by probable sink holes), 3) west and southwest of Buildings 20 and 5 along the western fence, 4) at the tank farm proper, and 5) at Building 33 north of the scales. It is also noteworthy that an area of low odor concentration exists in the west central part of the site coincident with the water table divide.

Diagramatic cross sections have been drawn through the plant site to show the vertical and lateral distribution of different levels of odor concentration relative to site facilities. See Figure 11 for the locations and Figure 19, Sheets 1-3 for these cross sections. These cross sections are drawn at a vertical exaggeration of 2.5 times the

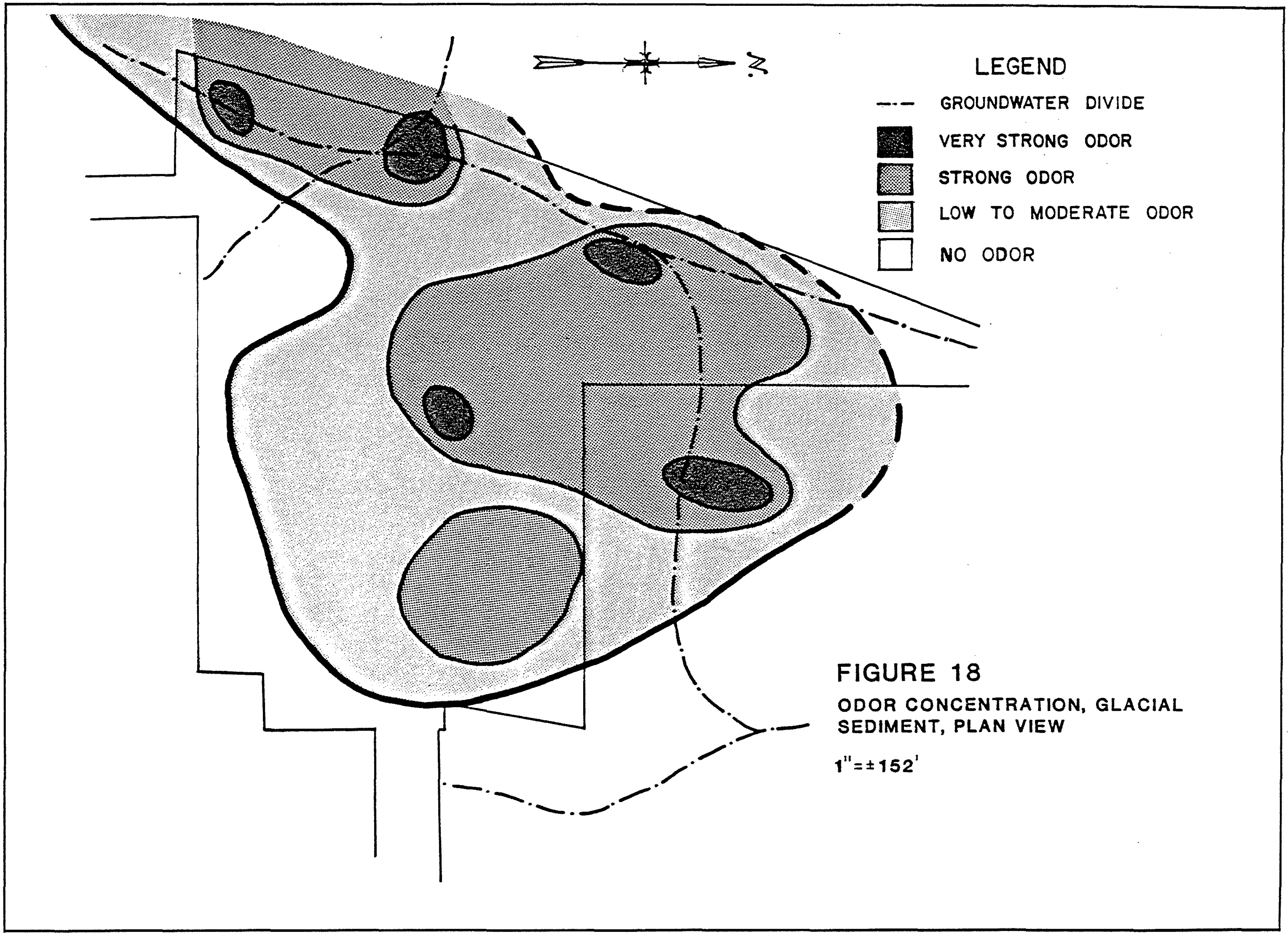


FIGURE 18

ODOR CONCENTRATION, GLACIAL SEDIMENT, PLAN VIEW

1"=±152'

Odor Cross-sections

horizontal. They illustrate: 1) the thinness of glacial cover at critical points, 2) the vertical and horizontal distribution of odor concentration, 3) the presence of probable sink holes, 4) the real or near juxtaposition of the bottom of the sump in Building 20 with the top of dolomite, and 5) the unknown extent of contaminates southward along the railroad tracks. Drawing 19A

3.2.5 Leakage to Dolomite Aquifer

The "thickness of overburden" and the "head difference" maps (Figures 10 and 16) were used in conjunction with lab permeability measurements to calculate the probable quantity of contaminated groundwater leaking from the saturated clay and clayey tills into the underlying dolomite. Laboratory permeability analyses of soil samples from the surficial glacial deposits ranged from 1.2×10^{-8} to 5.5×10^{-8} cm/sec.

Leakage rates for the three different classes of strength-of-odor areas shown on Figure 18 were calculated by determining area, average depth of confining layer and average head difference (Δh) for each individual area of each odor class. A slightly more conservative permeability value of 1×10^{-7} cm/sec was then used in the following modified form of the Darcy equation:

$Q = PIA = P \, {}^{\Delta h}/_{m} \, A \quad \therefore \quad P = Q\left({}^{m}/_{\Delta h}\right)\left({}^{1}/_{A}\right)$

$$P = Q\, m/\Delta hA$$

Where P is the permeability of the confining layer;

Q is the leakage;

Δh is the difference in lead across the confining layer;

A is the area of the confining layer;

M is the thickness of the confining layer.

zone lies west of piezometers 4A, 7, 8, and 16, and to the south of 1A. A line drawn to connect these locations would be beyond the border of the plume since these piezometers are essentially free of organic contamination (with a possible exception of trace quantities of methylene chloride). Piezometers in the known contaminated zones (i.e., 14A and 6A) show the presence of several volatile organics. Just west of the Freeman Chemical property, piezometers 19A and 27 show high concentrations of trichloroethylene, a compound not found on Freeman Chemical property, plus a few volatile organics that were found on the Freeman property. Piezometer 27, near and downgradient of the old air curtain incinerator, showed no signs of contamination. Only trace quantity of methylene chloride was detected in PZ-18A just north of the Laubenstein Warehouse.

Chemical data from the mid-depth zone (i.e., samples from private wells 3, 6, and 8; wells 21, 22, 23, 24, 25) all represent water from the upper dolomite. (The chemical analysis of PW-8 in Appendix III is an unpumped sample representative of the upper part of the Dolomite Aquifer.) Available data indicate volatile organic contamination in all but one of these (well 22). Generally, the contamination is low (less than 500 ppb) except for private well 8, which has high concentrations of trichloroethylene (2,000 ppb) and well 21, which is near the solvent storage tank and showed high concentrations of ethylbenzene, toulene, and methylene chloride. In summary, these data indicate that contamination in the top of the dolomite is more widespread but usually less concentrated than in the glacial overburden.

Samples from municipal wells 1, 2, 3, and 4 represent water from the deep Dolomite Aquifer. With the exception of trace quantities of methylene chloride in municipal well 2, no volatile organics were detected in the municipal well system. Another source of data on the deep aquifer is the pump test which was conducted in July of 1985 on PW-8. The summary of the data from this test are presented in Figure 7. This test indicated that trichlorethylene is present in the deep aquifer in the vicinity of private well 8 and that it persisted over the duration of the pump test (5 days).

Currently, the best researched standards to evaluate the quality implications of groundwater contamination in the Saukville area are the proposed Recommended Maximum Contaminant Levels (RMCL) and Maximum Contaminant Levels (MCL) (November, 1985 Federal Register). Because the Dolomite Aquifer affected by the contamination noted in this investigation is the sole source of drinking water for the Village of Saukville and because Saukville does not treat their groundwater, these standards are especially appropriate. The volatile organics detected in the Dolomite Aquifer and the proposed MCL or RMCL for these compounds are as follows:

Compounds	MCL	RMCL
Vinyl Chloride	0 ppb	--
Trans 1,2 Dichloroethylene	--	70 ppb
Trichloroethylene	0 ppb	--
Benzene	0 ppb	--
Toluene	--	2,000 ppb
Ethylbenzene	--	680 ppb
Xylene	--	440 ppb

Using this list as a guideline, private well 8 (the Laubenstein well) exceeds the standards for vinyl chloride, trans 1,2 dichloroethylene, and trichloroethylene; well 22 (near the present tank farm) exceeds the standards for benzene and trans 1,2 dichloroethylene; well 23 exceeds the proposed standards for vinyl chloride, and well 24 exceeds the proposed standards for vinyl chloride and trans 1, 2 dichloroethylene. In summary, dolomitic groundwater in the vicinity of Freeman Chemical Corporation and the adjacent property to the west will not comply with proposed groundwater standards for organic chemicals.

In conclusion, evaluating the qualitative groundwater data and other observations in this report, we note the following:

1. Quantitative data from the overburden piezometers support the proposed extent of groundwater predicted by qualitative odor data as presented in Figure 18.

2. The high levels of contaminant concentration in the glacial overburden compared to the much lower concentrations in the upper part of the dolomite indicate that the low calculated leakage value of 421 gpd (Section 3.2.5) is at least reasonable if not excessive. Dilution effects, etc. would have to support this statement w/ contamin. transp. model.

3. The levels and distribution of contaminants in the shallow dolomite is consistent with groundwater flow directions evident from Figure 14 of this report.

4. The water quality from a sustained pump test in PW-8 indicates a zone of probable deep dolomite contamination just west of the Freeman Chemical Corporation property.

5. The solvents used by Freeman and the trans 1,2 dichloroethylene once used on a limited basis seem to be found in most of the dolomite groundwater samples.

   However, trichlorethylene associated with a reported spill from another industry is not found on Freeman property, but confined to two piezometers and the private well on the "Laubenstein Property",

4.0 PILOT REMEDIAL MEASURES CONSTRUCTION

A pilot section of a Ranney-type collector ditch and a large-diameter, shallow well were constructed at the Saukville Plant site to determine the cost, construction feasibility, and dewatering efficiency of these techniques in low permeable glacial sediments. Sufficient data were deemed already available on the probable performance and hydrology of a well point dewatering system from installation and testing of the existing monitor wells.

4.1 Pilot Ranney Collector Ditch

A section of a Ranney-type collector was constructed north of the tank farm in an area used for tanker truck parking. A test ditch approximately 3 feet wide, 30 feet long, and 15 feet deep was dug with a large backhoe. See Figure 20. The ditch was backfilled with clean pea gravel to a depth of 1 foot followed by installation of a 20-foot section of 4-inch, schedule 80 PVC screen laid horizontally and a 12-foot section of solid 4-inch PVC standpipe. The ditch was then backfilled to approximately 4 feet from the surface with pea gravel and the remainder with spoil from excavation of the ditch.

Water level rise in the collector ditch was monitored over a period of 5 days. The volume of the excavation and the probable porosity of the pea gravel was used to calculate rate of filling. Rate of water-level recovery versus time is plotted on Figure 21. Assuming a porosity of 0.20 for the pea gravel fill, this ±30-foot-long ditch has an approximate yield of 0.12 gpm or 0.006 gpm per foot of ditch.

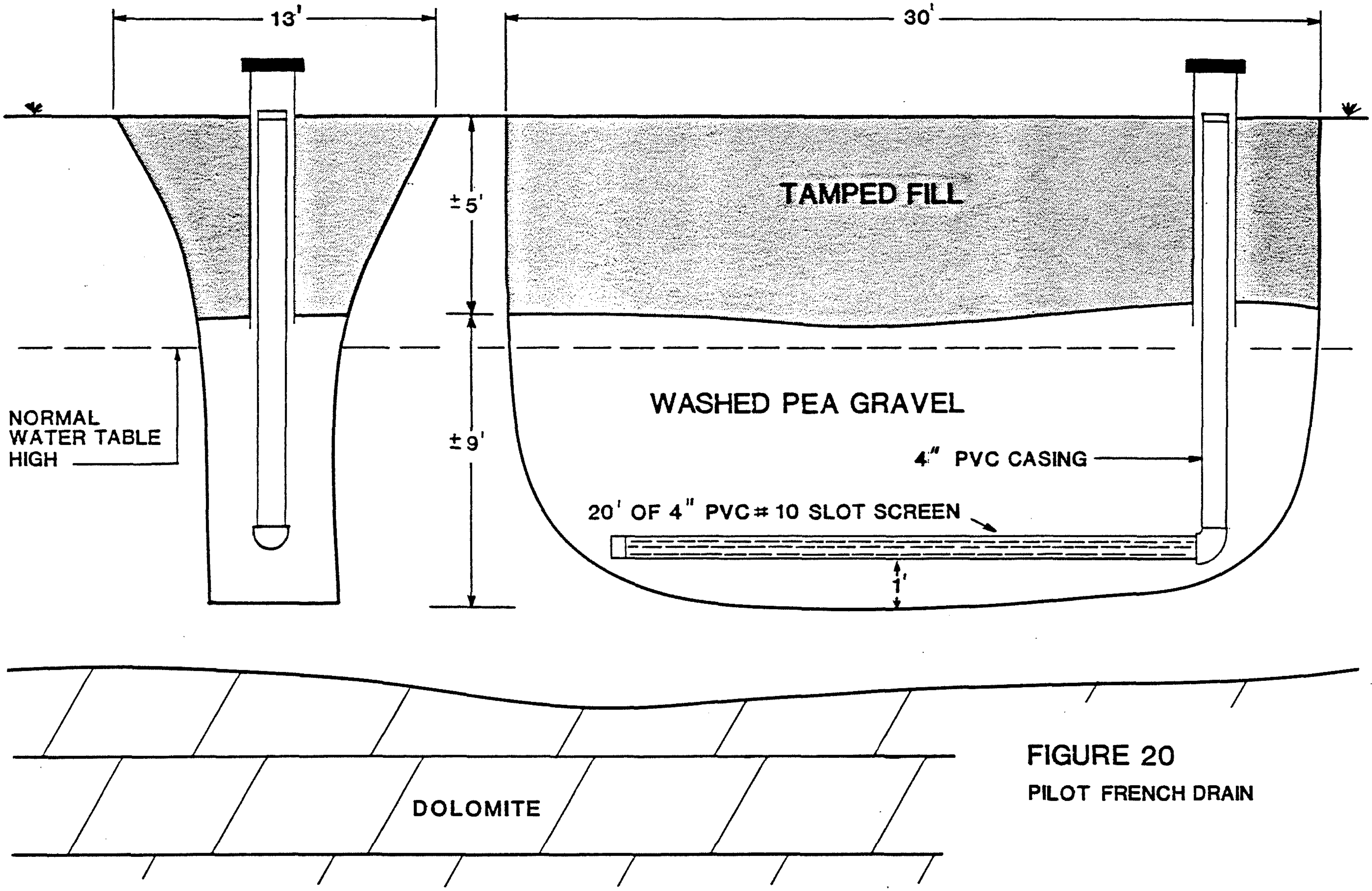


FIGURE 20
PILOT FRENCH DRAIN

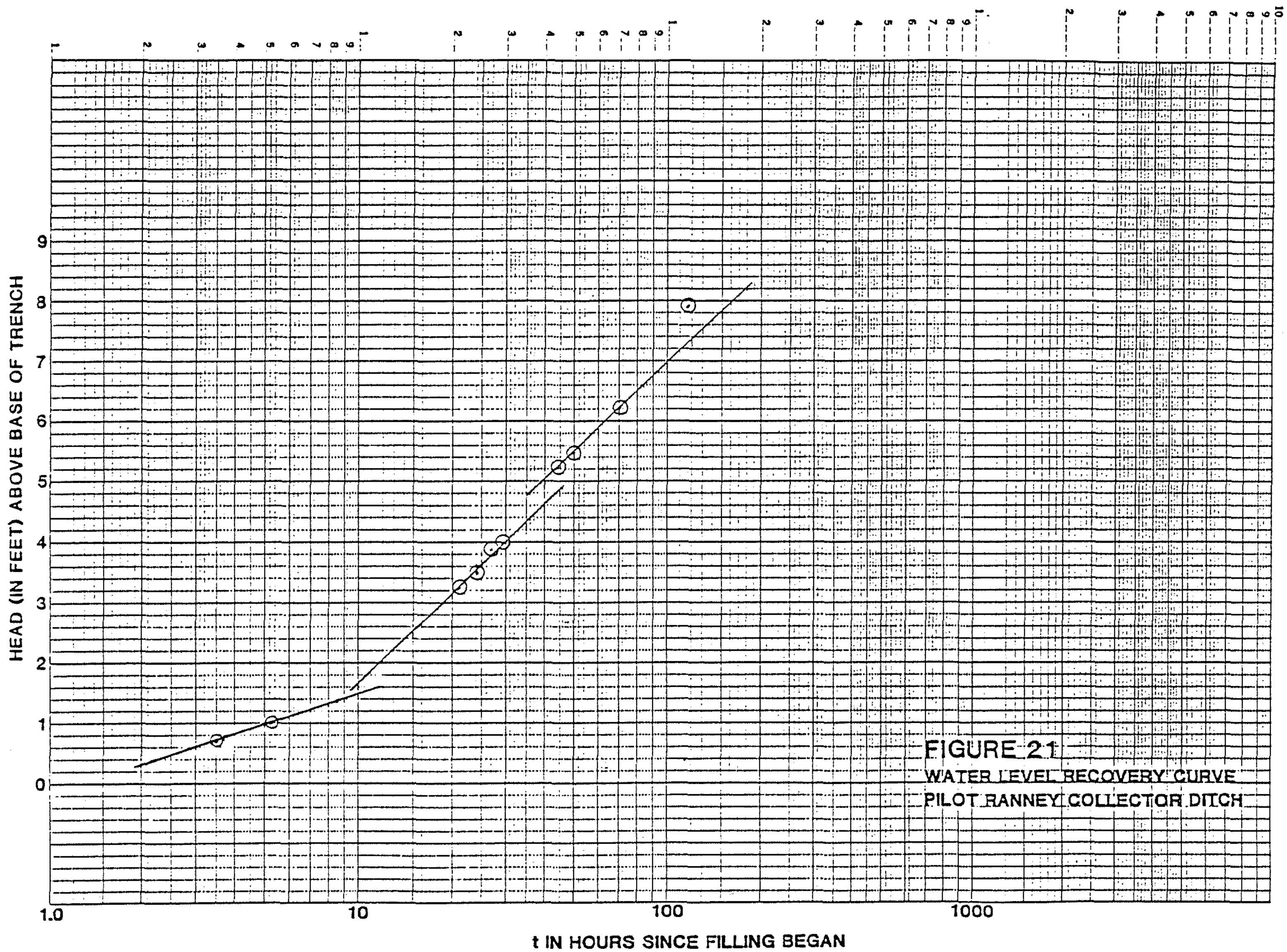


FIGURE 21
WATER LEVEL RECOVERY CURVE
PILOT RANNEY COLLECTOR DITCH

4.2 Shallow, Large-Diameter, Gravel-Packed Well

A 19-foot-deep, 16-inch-diameter, gravel-packed well was constructed in a 24-inch hole near PZ-6A west of Building 5 and in the vicinity of the reported "dry well." Figure 22 shows the construction details. This well, like the Ranney-type collector, was constructed to determine the construction cost, feasibility, and dewatering efficiency of such wells in glacial sediments of low permeability. The well was constructed and briefly tested during an extended rainstorm when groundwater level at the well was at the surface and surface water surrounded the well. Yield of this well was tested under these non-representative conditions at about 1.4 gpm over a period of approximately ½ hour. A 2-inch monitor well, approximately 15 feet south of this well, was tested at 0.44 gpm during dry weather.

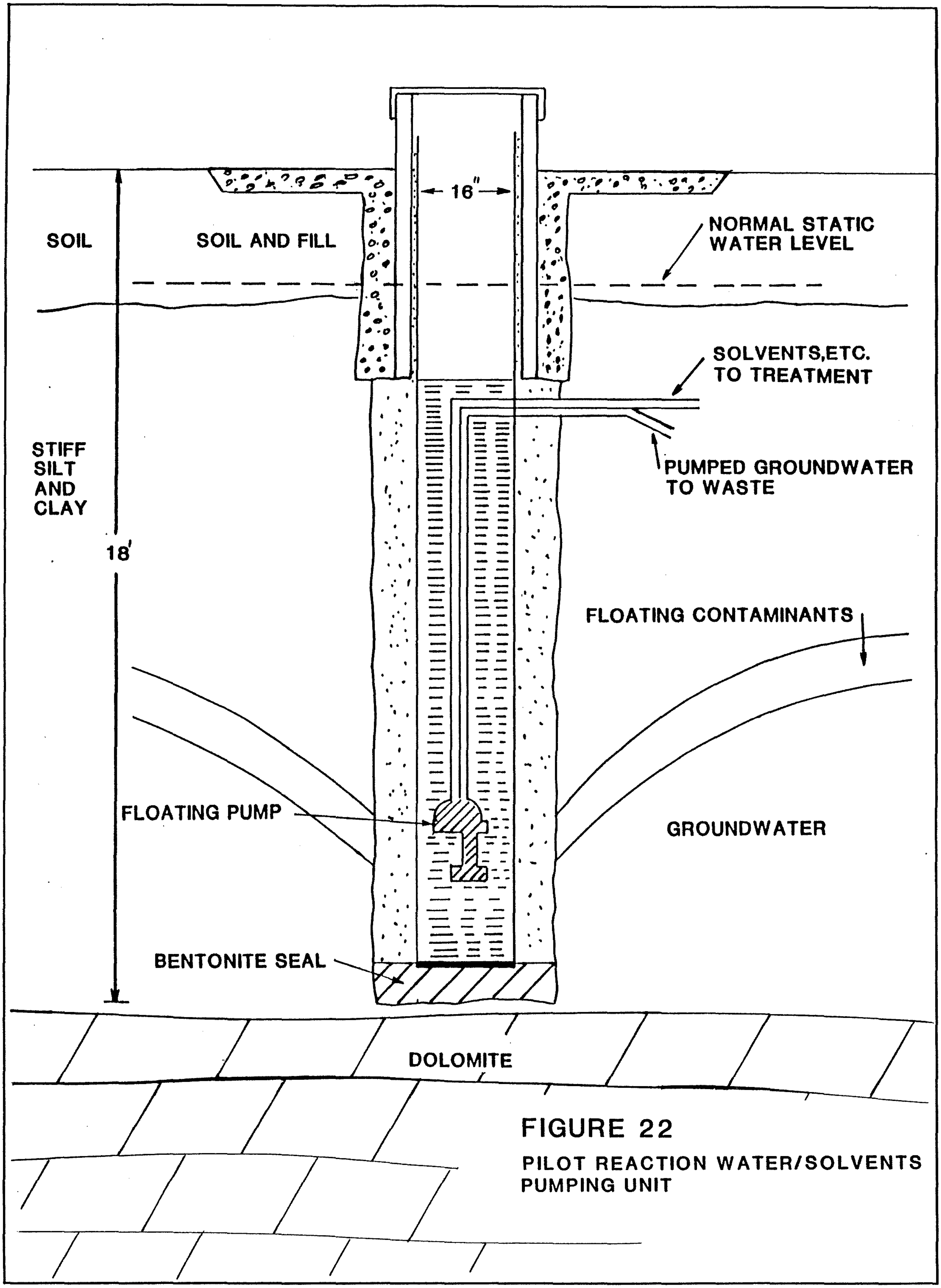


FIGURE 22

PILOT REACTION WATER/SOLVENTS PUMPING UNIT

5.0 CONCLUSIONS

5.1 Geologic

Data gathered during the 1985 field investigations, along with data from previous field work by Hatcher Incorporated and others, point to the following conclusions about the geology of the Saukville site.

- The fieldwork to date confirms that the Saukville Plant is sited on Silurian dolomite covered by a fairly thin veneer of Pleistocene glacial materials.

- The dolomite is highly solutioned and fractured at the top and has an irregular upper surface (karsted). Small pinnacles, depressions, and what are interpreted to be sediment filled sinkholes are common. At least one large sinkhole or filled river channel (thalweg) exists on the northeast edge of the site. The cores from construction of the dolomite monitoring wells show extensive solutioning of at least the top of the dolomite.

- The glacial overburden consists mostly of: 1) very dense tills and varved, lacustrine, silty clays that have very low permeabilities and 2) fluvial sands and gravels. These materials do not constitute a useable aquifer. The southern edge of the property contains a higher percentage of fluvial sands and gravels.

- The contact between the glacial sediments and the dolomite is usually marked by a thin, permeable sand.

- Glacial sediment cover is thinnest in the central part of the site.

5.2 Hydrologic

The data gathered to date point to the following conclusions concerning the hydrology of the Saukville site.

- The tight, glacial sediments are saturated, and the water table is shallow.

- The weathered top of the dolomite is the uppermost useable aquifer and is quite permeable. It is hydrologically connected to the overlying thin permeable sand.

- The Dolomite Aquifer is semi-confined at the site and is being slowly recharged through the overlying glacial materials.

- At the center of the site, the Dolomite Aquifer is essentially at water table head.

- Except at the solutioned and weathered surface, the hydrology of the dolomite is complex being related to the location, frequency, and size of solution channels and fractures.

- The immediate drawdown in the Laubenstein well in response to pumpage at MW-2 and the lack of response at dolomite well 22 located between them indicates that the Laubenstein well and MW-2 are probably connected by one or more solution channels. The density, sonic, and caliper surveys of the Laubenstein well indicate discrete enlargements of the hole at various depths. Also, the temperature logs indicate groundwater exit or entry at most of these points in the well bore giving further weight to this conclusion.

- The difference in head between the top and bottom of the saturated glacial sediments ranges from <2 to 20 feet in the site vicinity.

- Both the water table and the dolomite head maps indicate that a groundwater drainage divide exists across the western part of the site.

- The present position of the drainage divide across the site in the Dolomite Aquifer is controlled by pumpage of MW-2.

5.3 Contaminant Sources and Dispersion

Lastly, the field investigation data lead to the following conclusions concerning the sources and dispersion of contaminants at the Saukville site.

- The "tight" glacial sediments are saturated with contaminated groundwater having a strong and distinctive "reaction water" and/or solvent odor over approximately one third of the site.

- The above mentioned odor plume extends a short distance to the north into the adjacent ballfield of the Immaculate Conception Church and southward along the railroad tracks to an unknown distance, but less than the position of former PZ-12. The area of strong groundwater odor is surrounded by a "halo" of significantly less odor (low to moderate class on Figure 18), extending in all downgradient directions.

- Very strong odors occur:

    1. At the tank farm
    2. At Building 33

3. In the southwestern corner of the ballfield
4. West of Building 5 in the vicinity of the old "dry well"
5. In the extreme southwestern corner of the plant site
6. In an area just north of Building 45A.

- The distribution of the odor plume is consistent with the direction of groundwater flow from the site.

- The upper part of the dolomite contains contaminanted groundwater in at least the area north of the tank farm. Trans 1,2, Dichloroethylene has an apparent wider distribution in the top of the dolomite.

- The sump in the basement of Building 20 is at or very near the top of the dolomite. This sump, other similar sumps, building foundations, the old dry well, and tank excavations constructed into or nearly into the underlying dolomite are potential points of direct contaminant entry into the dolomite.

- Trichloroethylene is apparently confined to an off-site location at the Laubenstein Warehouse across the railroad on the west side of the Freeman property.

- The position of the dolomite groundwater divide across the western part of the site and the drawdown cone developed around the Laubenstein well when MW-2 is pumped, suggests that a logical contaminant path to MW-2 is radially from around the Laubenstein well, into the Laubenstin wellbore, and thence to MW-2 through subsurface fractures and/or solution channels.

6.0 PRELIMINARY REMEDIAL RECOMMENDATIONS

6.1 Technical Considerations

The glacial sediment cover over the karsted, pervious Upper Dolomite Aquifer has quite low permeability. However, because surface contamination has been going on for many years, the clays, silts, and tills over parts of the site are saturated with contaminants that continually and slowly recharge the Upper Dolomite Aquifer. Once in the Upper Dolomite Aquifer, the rate of contaminant movement may be at least one order of magnitude greater. Contaminated groundwater in the Upper Dolomite Aquifer, as demonstrated by the dolomite semi-piezometric map (Figure 14), flows both toward the river and toward the Laubenstein/MW-2 drawdown cone to the northwest.

This geohydrologic situation, plus the need to keep a manufacturing facility on line, limits the number and kind of practical and cost-effective remedial actions at the Saukville site to:

1. Control of present contaminant sources and elimination of contaminant pathways from the site to the surrounding environment.

2. Decontamination of the soil and groundwater by groundwater withdrawal and subsequent treatment or by some yet-to-be-developed in situ treatment process.

3. Use of groundwater management techniques that halt, if not reverse, the migration of contaminated groundwater off-site.

6.4 Control of Pollutant Migration in Dolomite Aquifer

Hatcher Incorporated proposes that the further spread of contamination in the upper Dolomite Aquifer be controlled by the use of a series of shallow, 4-6 inch diameter, open hole, scavanging wells placed in the upper surface of the dolomite. Some of the newly installed shallow dolomite monitoring wells may be used for this purpose.

Groundwater from the upper dolomite scavanging wells will be piped to a separate air stripper from the one used for water from the Ranney collector and thence to a reservoir. Water from the reservoir will be fed to the plant cooling water system to be mixed with cooling water from deep dolomite groundwater well(s). The rate of mixing will be determined by the relative groundwater chemistry of the two sources of cooling water and the established contaminant standards for discharge of cooling water effluent to the storm sewer. Proposed locations of upper dolomite scavanging wells are shown on Figure 23.

The groundwater flow toward MW-2 and the remainder of the municipal well system be reversed through a combination of the following practices:

1. Placing MW-1 and MW-2 out of service permanently or at least until the lower Dolomite Aquifer is flushed of contaminants.

2. Installation and pumpage of one or more deep dolomite water wells at sites shown on Figure 23. This well(s) will be used to provide cooling water to Freeman, thus replacing the water now coming from MW-2.

3. Recasing MW-3 to eliminate the existing sand problems, thus returning the well to service to replace the capacity lost by removing MW-1.

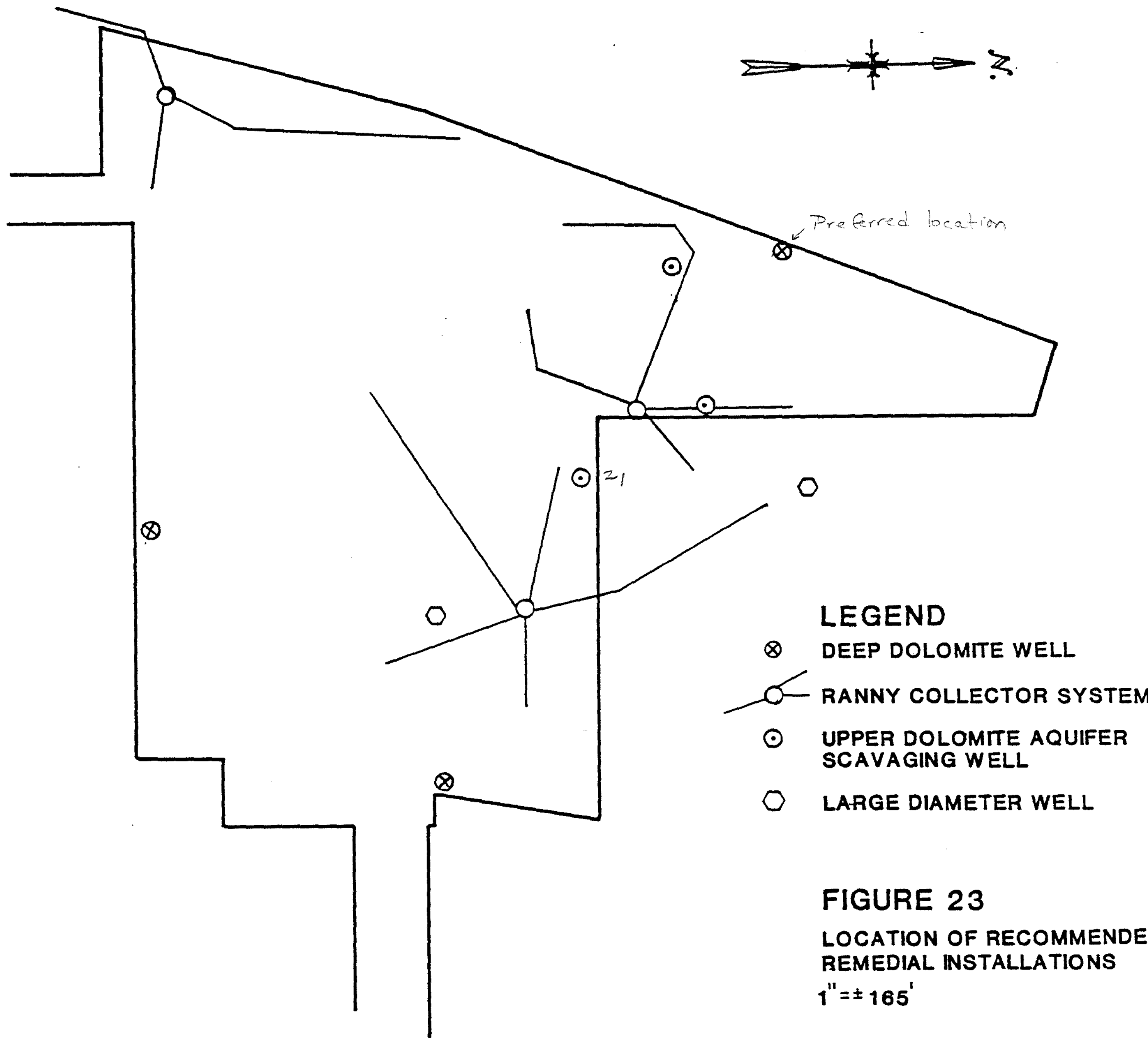


FIGURE 23

LOCATION OF RECOMMENDED REMEDIAL INSTALLATIONS

1" = ± 165'

The preferred location of the deep dolomite well is in the northwestern part of the site, between the center of the site and MW-2. This location is judged to be at a point where contaminant flow toward MW-2 resulting from pumpage at MW-2 can most efficiently be reversed.

From the standpoint of the most efficient subsurface dolomite flushing, it is desirable to repair and use the Laubenstein well (PW-8) as the deep dolomite well, especially since the most likely off-site pollution route to MW-2 is believed to be via the Laubenstein well. However, the use of this well is not proposed for two reasons:

1. Freeman does not own or control the property on which the well is located.

2. There is apparently a trichloroethylene spill associated with the property on which the well is located. Freeman proposed to take no actions affecting this spill clean-up.

(*) However, Freeman's pumpage will probably draw TCE onto their property + they'll end up cleaning up the TCE anyway, but less efficently.

Therefore, the northwestern deep well will be located as shown on Figure 23.

If additional cooling water is needed, other than that available from one deep dolomite well and that obtained from the upper Dolomite Aquifer scavanging wells, an additional well will be drilled at the northeastern corner location and then another, if needed, at a point along the southern property edge.

Water withdrawn from the deep well(s) will be air stripped and then used by Freeman Chemical as cooling water prior to discharge to the Milwaukee River. As described above, the water from the shallow dolomite will be mixed with this water. Freeman does have an existing WPDES permit for cooling water which will be modified to accept this change in water source.

Following the installation of the shallow and deep dolomite flow control system, water level information from appropriate monitoring locations, as well as, appropriate water quality data will be collected to verify the operating conditions (to be specified) are achieving the desired objectives of reversing the existing contaminant flow. Particular emphasis will be placed on observing the behavior of the groundwater during a range of operating conditions of the two municipal wells (MW-3 and MW-4), to assure that the contaminated groundwater is not flowing toward these wells.

Long-term monitoring of system.

Time table?

APPENDICES BOUND SEPARATELY