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Monitoring the Fixed FGD Sludge Landfill, Conesville, Ohio — Phase I

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Research Project 1406-2

Final Report, September 1979

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ABSTRACT

Stabilized flue gas desulfurization sludge, known as Poz-O-Tec^{R}, is being landfilled at the Conesville Power Station of the Columbus and Southern Ohio Electric Company. This is the first full-scale application of the IU Conversion Systems, Inc. fixation process for treating FGD sludge.

This study has consisted of the background information review and geohydrologic investigations necessary to formulate a long term monitoring program which will determine if full-scale application of the IUCS process (1) reflects laboratory and pilot scale results; (2) provides environmentally acceptable disposal methods; (3) causes operating problems; and (4) meets current and anticipated regulatory agency requirements.

Well monitoring to date has indicated that either the Poz-O-Tec or an adjacent emergency sludge retention pond is responsible for levels of conductivity, and concentrations of calcium, total dissolved solids, sulfate, and magnesium which are in excess of recommended drinking water standards. Additional monitoring is needed to accurately define the source.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

This final report is the first of a series of research reports under Research Project (RP) 1406 that evaluate the first full-scale system to utilize the disposal of sludge treated by the I.U. Conversion System (IUCS) process. This proprietary process has been heralded as one of the more promising disposal options involving chemical fixation and stabilization of the sludges prior to disposal in a landfill. Since this disposal facility at the Conesville Power Station of the Columbus and Southern Ohio Electric Company is a first-of-a-kind system, industry-sponsored surveillance was considered necessary.

This project has been divided into two successive phases. The purpose of Phase I was to obtain and evaluate background information on the disposal operation and hydrogeology and to plan a monitoring program based on that information. This final report documents the Phase I findings. Phase II entails the implementation of the monitoring program prepared in Phase I. The work program in both phases has been designed to be supportive to a related groundwater modeling effort conducted by Battelle, Pacific Northwest Laboratories, under RP1406-1.

PROJECT OBJECTIVES

This project has provided an opportunity to monitor one of only two commercial methods of sludge fixation available at a full-sized facility and to present an unbiased evaluation to the utility industry. Additionally, this study (Phases I and II) will provide a basis on which utilities can define and select cost-effective and workable environmental monitoring systems by verification of the predictive modeling developed by Battelle under RP1406-1. This Phase I study consisted of the background information collection and review, together with the geohydrologic investigations necessary to formulate a long-term monitoring program that will determine if full-scale application of the IUCS Poz-O-Tec® process (1) reflects laboratory and pilot-scale results, (2) provides environmentally acceptable disposal methods, (3) causes operating problems for the utility, and (4) meets current and anticipated regulatory agency requirements.

PROJECT RESULTS

Although laboratory tests show that the IUCS stabilization process decreases the permeability of the sludge to the range of 10^{-6} to 10^{-7} cm/sec, the field permeability at Conesville was measured to be ten times more permeable. Other physical laboratory test results conducted on Conesville sludge samples compared well with projected Poz-O-Tec® characteristics. From an operational standpoint, placement of the Poz-O-Tec® material is one of the major problems experienced thus far by the power station. The Poz-O-Tec® is initially too wet to handle and compact easily. Well monitoring during the Phase I investigation indicates some effect on groundwater quality in the vicinity of the disposal facilities. Unacceptable levels (with respect to drinking water standards) of calcium, pH, acidity, total dissolved solids, sulfates, and total iron were observed in the ash pond area. These abnormal levels are believed to be the result of leachate from either the Poz-O-Tec® or the emergency sludge pond. Additional monitoring during the Phase II study should resolve this question.

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ACKNOWLEDGMENTS

The authors would like to acknowledge the fine cooperation of the personnel of the Columbus and Southern Ohio Electric Company during these investigations. The authors would especially like to thank Harl A. Todd, supervisor - environmental, and Gary T. Sommerville, environmental specialist for C&SOE, for their patience and contributions of time and resources to supply valuable information.

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SUMMARY AND CONCLUSIONS

Stablized flue gas desulfurization sludge (Poz-O-Tec) is being landfilled at the Conesville Power Station of Columbus and Southern Ohio Electric Company located near the community of Conesville in central Ohio. This is the first full-scale application of the IU Conversion Systems, Inc. (IUCS) fixation process for treating FGD sludge and, as such, presents an excellent opportunity to evaluate the process under operating conditions. The purposes of this investigation have been to obtain and evaluate site specific background disposal operation and hydrogeologic information, and to develop a monitoring program which will determine the environmental effect of employing such a fixation process. This investigation consists of background literature and data review, aquifer testing, monitoring well installation, piezometric monitoring, groundwater sampling, and leachate quality and quantity prediction.

The sludge is deposited directly on thick deposits of glacial outwash comprised primarily of permeable sand and gravel. The disposal area is situated along the floodplain of the Muskingum River and is immediately adjacent to the station's ash sluice area. Groundwater levels in this area are generally 10 to 15 feet (3.05 to 4.57 m) below the ground surface. The direction of groundwater flow below the Poz-O-Tec area varies from slightly north of west to slightly south of west, toward the river. Under changing hydrogeologic conditions, the hydraulic gradient was observed to vary between a slope of 0.25% to 0.07% below the sludge disposal area and the area adjacent to the river. The gradient steepens significantly along the east perimeter of the sludge disposal area where the potentiometric surface falls from the level of pooled supernatant in the adjacent ash disposal area. Groundwater contamination is probable under these conditions (no liner or clay blanket, positive groundwater gradient,continual artifical recharge in ash sluice area) without appropriate preplanning and control of leachate movement.

Laboratory tests have reported that the IUCS stabilization process decreases the permeability of scrubber sludge to the range of 10^{-6} to 10^{-7} cm/s. A permeability of 9.3×10^{-7} cm/s was determined for a sample of Poz-O-Tec from Conesville by an independent testing laboratory for IUCS in late 1978. A permeability of 2.5×10^{-5} cm/s was determed by Battelle Pacific Northwest Laboratories for a core sample of cured Conesville Poz-O-Tec obtained during this investigation. Leaching tests of Poz-O-Tec conducted during other studies indicate the fixation process can decrease the concentration of total dissolved solids and other major chemical constituents to less than half that produced by unfixed sludges or the original scrubber slurry. Leachate test results for the sludge produced at Conesville could not be acquired for review as part of this investigation and will have to be developed during subsequent study.

If surface water is prevented from impounding on the Poz-O-Tec fill and groundwater levels are below the fill, IUCS contends that leachate can be discounted because of the reduction of the quantity of water for permeation. IUCS also indicates that permeation can be neglected when permeabilities are less than 10^{-6} cm/s because years of travel time will be required for water to pass through a few feet of fixed sludge. This situation generally exists at the Conesville site with the exception of the area of a pond in a portion of the northern end of the disposal area. Seasonal groundwater recharge feeds this pond which is low in elevation with respect to the Muskingum River. Poz-O-Tec has not yet been placed in this area.

The maximum amount of potential leachate from permeation of the present Poz-O-Tec landfill which covers 20.7 acres (8.38 ha) would be approximately 17,400 gpd (7.6×10^{-4} m^3/s) assuming continual saturation and a permeability of 9.3×10^{-7} cm/s. A more realistic estimate can be calculated by assuming that saturation takes place one-third of the time or less. Leachate quantity under these conditions, from the present fill, would be approximately 0 - 5800 gpd (0 to 2.5×10^{-4} m^3/s). A continual supply of water is available in the ash pond for leachate formation. The estimated total quantity of leachate due to permeation of the ash is 2,400,000 gpd (0.105 m^3/s).

Physical laboratory testing was conducted on month old samples of Poz-O-Tec from Conesville during late 1978 for IUCS. The results compared well with projected Poz-O-Tec characteristics with only minor exceptions. The tests results are as follows:

- Unconfined Compressive Strength - 30 to 60 psi (2.11 to 4.21 Kg/cm^2)
- Compressibility - Very small to negligible
- Stability of 3:1 Slope (Failure in Poz-O-Tec) - Factor of safety above 3.0
- Bearing Capacity for Shallow Foundations - Above 6000 psf (29,000 Kg/m^2)
- Average Density - 95 pcf (1537 Kg/m^3)

Placement is one of the major problems experienced thus far by the power station. The Poz-O-Tec at Conesville is initially too wet to handle and compact easily. After leaving the conveyors from the fixation plant, the sludge must cure undisturbed for a period of a few days to improve the handling characteristics. A pay loader moves the sludge from these stockpiles to benches which are extended a width equal to the reach of the pay loader. Once spread, the Poz-O-Tec must cure an additional six days before this freshly placed material is strong enough to support the pay loader for placement of more material on the bench.

Well monitoring during this investigation indicates that the ash pond has had the greatest overall effect on groundwater quality in the vicinity of the disposal facilities. Unacceptable levels (with respect to drinking water standards) of calcium, pH, acidity, total dissolved solids, sulfate, and total iron were noted at two monitoring wells in the ash pond area. All of the monitoring wells situated potentiometrically down-gradient of the ash pond and the Poz-O-Tec disposal area have contaminate levels equal to or slightly less than that of the ash pond area. Contaminate levels in two wells, MB-14 and MB-15, are much higher than those in any of the other monitoring wells.

The contaminate levels observed in wells MB-14 and MB-15 are believed to be the result of leachate from either the Poz-O-Tec or the emergency sludge pond which is situated at the south end of the sludge disposal area. With available information a further differentiation of the specific source cannot be made. Additional monitoring will be necessary to resolve this question.

Section 1

INTRODUCTION

Section 1

INTRODUCTION

The Clean Air Act Amendments of 1977 resulted in much stricter control of the flue gas emissions from power stations and will essentially guarantee the widespread use of flue gas desulfurization systems throughout the United States. These FGD systems will be primarily lime or limestone based scrubbers for at least the next few years and will produce large volumes of sludge. The disposal of these wastes, some of which may be considered hazardous by U.S. EPA, will have to be in hazardous or special waste landfills.

One of the more promising disposal options involves chemical fixation or stabilization of the sludge prior to disposal in a landfill, using a proprietory process. The Columbus and Southern Ohio Electric Company's Conesville Station is the first full-scale application of the fixation process developed by IU Conversion Systems, Inc. Sludge disposal at this facility began in January, 1977. Since this is a first-of-a-kind, industry sponsored surveillance at this facility was considered necessary to determine the advisability (or necessity) of employing such a fixation process.

In situ monitoring was recommended as the best way to evaluate the process. The results of such an analysis would be invaluable to the entire electric utility industry. The intent of the program is:

- to determine if the actual sludge produced under full-scale conditions compares satisfactorily with laboratory and pilot scale observations.
- to determine if the method of disposal as conducted is environmentally acceptable (that is, to determine if there are detrimental leachate, runoff, or future land use problems).
- to determine what operating problems, if any, the sludge disposal method causes for the utility.
- to determine if the method of disposal will satisfy current and anticipated regulatory requirements.

This purpose of this initial phase of the investigation has been to obtain and evaluate site specific background disposal operation and hydrogeologic information.

Based on the results of this analysis a three-year monitoring scheme has been formulated which can supply the additional information necessary to address the primary issues at hand.

Section 2

SLUDGE DISPOSAL

Section 2

SLUDGE DISPOSAL

DISPOSAL AREA

Disposal of stabilized flue gas desulfurization sludge, known as Poz-O-Tec, started at the Conesville Plant in January, 1977. The sludge disposal area is located in the western third of the original ash sluice pond. The total Poz-O-Tec area available is approximately 50 acres (20 hectares). The existing ash pond occupies an area of about 85 acres (34.5 hectares). The two areas were separated by the construction of a dike which was built primarily from bottom ash and fly ash excavated from the present sludge disposal area. Figure 2-1 shows the locations of these site features.

The bottom or base material in the Poz-O-Tec disposal area is primarily glacial sand and gravel outwash and some bottom or "cyclone" ash and fly ash. Near surface silts which overlie the sand and gravel deposits were almost totally removed within the disposal area and used for dike construction. This base was graded generally from the south-southwestern part of the waste disposal area to the north-northeastern end to promote drainage of runoff due to direct precipitation. Bottom ash was used where necessary to eliminate surface irregularities and to stabilize soft areas where heavy equipment could not operate (1). The base of the Poz-O-Tec disposal area ranges from approximately elevation 735± in the southern end of the sludge area to 726± in the northern corner according to available information.

SLUDGE GENERATION AND CHARACTERISTICS

The Conesville Plant utilizes electrostatic precipitators and Thiosorbic® lime based Flue Gas Desulfurization (FGD) systems to control particulate and SO_2 emissions from Units #5 and #6. The FGD sludge originates as bleed from the FGD system recycle slurry. The slurry is composed of approximately 5-12% solids and is routed to a thickener where the bleed is concentrated to approximately 30% solids. The reported composition of solids is approximately 80% calcium sulfite and 20% calcium sulfate. Underflow from a primary thickener is pumped to the IU Conversion Systems, Inc. (IUCS) stabilization system surge tank. The sludge then undergoes either direct vacuum filtration or secondary thickening and filtration to compose a filter cake of approximately 60% solids. The filter cake is blended with a substantial quantity of dry fly ash (2/3 of the weight of the dry filter cake) and a small percentage of lime to result in the stabilized waste known as Poz-O-Tec. This fixed sludge is then conveyed to the disposal area for landfill type disposal on two radial arm conveyors. Figure 2-2 illustrates this system. It is estimated by C&SOE personnel that 300,000 tons of dry sludge solids have been stabilized and landfilled during 1977 and 1978.

Permeability and Potential Leachate

The fixation process of IUCS reportedly renders the FGD wastes effectively impervious. Freshly placed Poz-O-Tec mixtures are reported to have permeabilities in the range of 10^{-6} cm/s while material which has cured for 14 to 28 days can develop permeabilities reaching 10^{-7} cm/s (2). In comparison, untreated FGD sludges and fly ashes typically have permeabilities in the range of 10^{-4} to 10^{-5} cm/s (3). Therefore, Poz-O-Tec is expected to be 100 to 1000 times less permeable than both untreated FGD sludge and fly ash.

During late 1978, actual permeability testing of a sample of Poz-O-Tec from the Conesville site for IUCS resulted in a calculated permeability of 9.3×10^{-7} cm/s (4). In comparison, a permeability of 2.5×10^{-5} cm/s was determined for a core sample obtained during this investigation by Battelle Pacific Northwest Laboratories. These limited results are inconclusive considering their variation, but indicate a fairly low permeability.

In addition to the reduction in permeability due to fixation, Aerospace Corporation has noted that the concentration of total dissolved solids and other major chemical species in leachate from fixed FGD sludges is less than half that produced by unfixed sludges or the original scrubber slurry (3). Combined with the reduction in permeability, this means that 0.5% to 0.05% of the leachate expected from unfixed sludge should result with the use of the IUCS process.

The chemistry of the sludge and resulting potential leachate are controlled by many factors including the original coal quality (and ultimately the fly ash and bottom ash produced), the quality of make-up waters for the scrubbing operations, the quality of the scrubber liquor, and the type of lime used in the scrubber and as an additive during fixation. Operating conditions vary from site to site and large variations are not uncommon at a single facility due to changes in operating efficiency

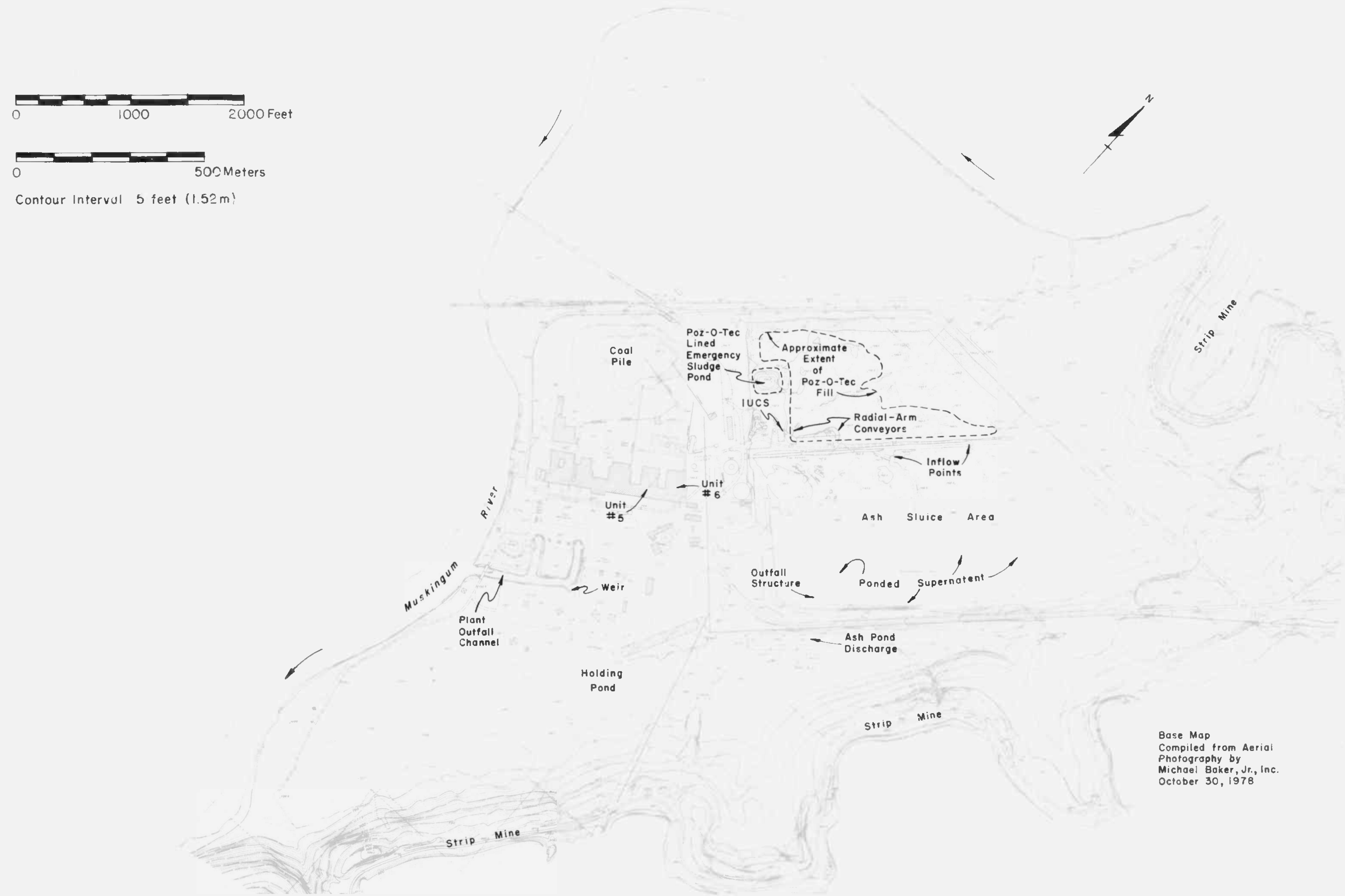

Figure 2-1. General Site Features - Conesville Power Station, Columbus and Southern Ohio Electric Company

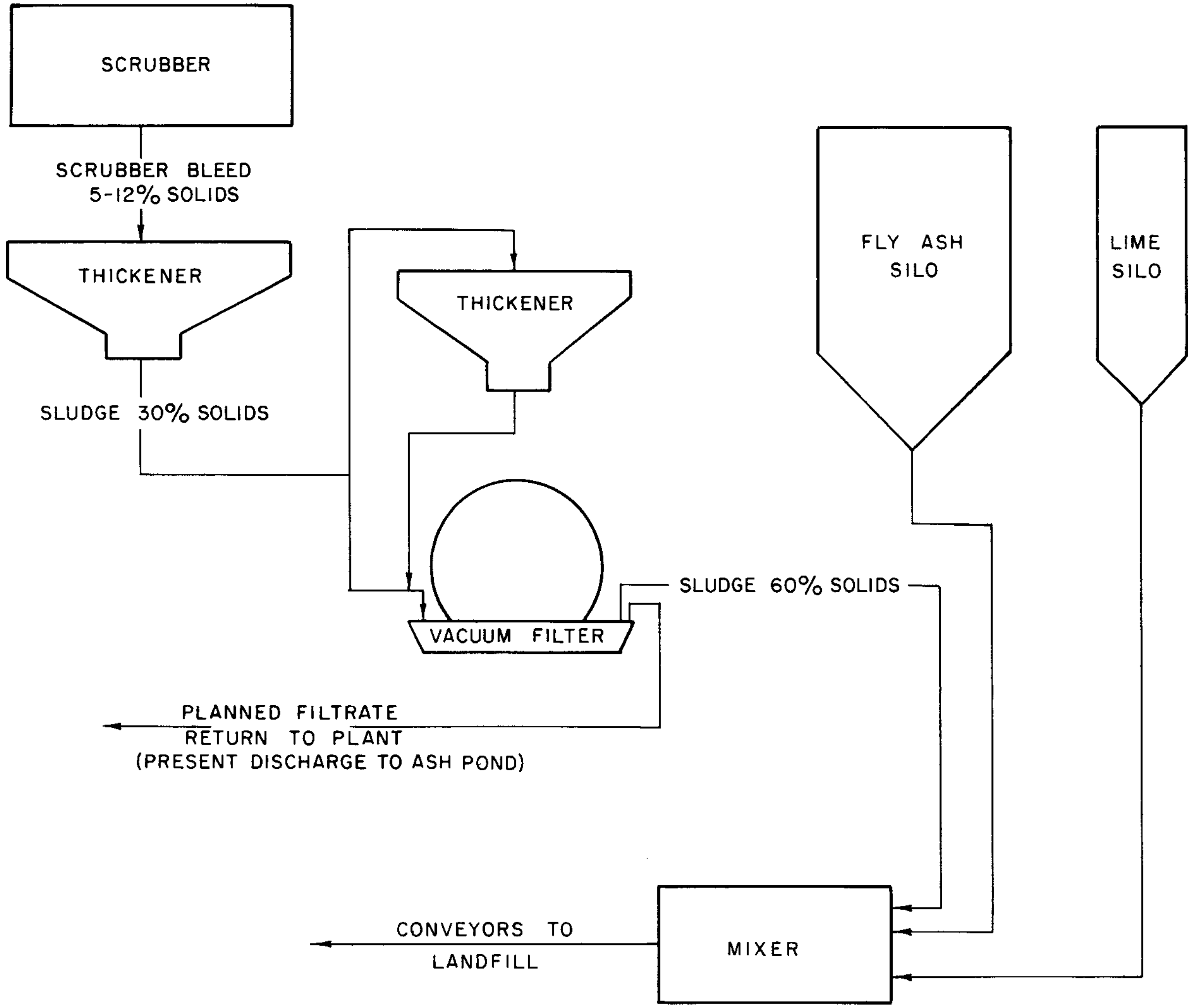

Figure 2-2. Sludge Fixation Scheme

and many other variables. Specific chemical data for the fixed sludge at Conesville could not be obtained for this phase of the monitoring project. However, some related information was acquired which gives an indication of potential leachate characteristics.

Coal burned in Units #5 and #6 is reported by C&SOE personnel to contain 4.5% sulfur and 18% ash. The electrostatic precipitators are designed to remove 99.65% of the fly ash in the flue gas while 89.7% of the sulfur dioxide should be removed by the scrubbing system. Leachate tests of the fly ash at Conesville were conducted during 1977 and are summarized in Table 2-1. These tests were not conducted according to the RCRA Draft Toxicant Extraction Procedure of 1978. The chemical characteristics of the fly ash are important with respect to the Poz-O-Tec because large quantities are utilized in the sludge fixation process. Fly ash is reported to be a primary contributor of trace metals. Fly ash not used for fixation is sluiced to the ash disposal pond. The supernatant from this pond drains to a holding pond located on the southern end of the plant property. Some of the holding pond water is released to the Muskingum River, some is recirculated as make-up waters for the scrubbers on Units #5 and #6 and ash sluice water. The resulting recycle loop through the ash pond and the holding pond may concentrate chemical species in the waters that might, in turn, be incorporated in the sludge bled from the scrubber vessels. Table 2-2 summarizes some past water quality information for the Conesville ash pond. Table 2-3 lists past water quality for the holding pond and more recent data acquired in 1976.

High levels of iron, copper, lead, dissolved solids, sulfate and low pH were noted as a result of the above fly ash leachate tests, as compared to combined recommended drinking water limits of the U.S. Public Health Service, the World Health Organization and the Environmental Protection Agency National Interim Primary Drinking Water Regulations. The levels of iron, lead and total dissolved solids are considered toxic according to the EPA definition (greater than 10 times the maximum recommended concentration) contained in the RCRA draft. However, as explained above, the leachate generation procedure used is not the recommended EPA method. In addition, concentrations of arsenic, zinc and calcium approximately twice the maximum allowable resulted. However, under operating ash pond conditions of 1974, pH, iron, copper, and arsenic levels were well within acceptable ranges in the outfall at all times. During 1973 and 1974 average concentrations of calcium and sulfate just slightly in excess of the maximums allowable occurred at the inlet and outfall of the plant holding pond. An iron concentration ten times the EPA limit occurred at the inlet for the holding pond,

Table 2-1

FLY ASH LEACHATE
CONESVILLE POWER STATION

Constituent[a]	Ash Leachate Analysis	
	Ten Minutes	Five Days
Acidity, Free ($CaCO_3$)	456	51
Acidity, Total ($CaCO_3$)	1579	467
Alkalinity, M.O. ($CaCO_3$)	0	0
Alkalinity, Pht. ($CaCO_3$)	0	0
Arsenic (As)	0.09	<0.01
Calcium (Ca)	640	500
Chloride (Cl)	35	32
Copper (Cu)	5.7	2.5
Iron (Fe)	150	84
Lead (Pb)	0.50	0.25
Mercury (Hg), µg/l	<0.2	<0.2
Nickel (Ni)	1.8	1.8
pH (standard units)	2.8	4.0
Silica	54	57
Dissolved Solids	6396	4861
Sulfate (SO_4)	1220	851
Zinc (Zn)	8.6	7.1
Boron (B)	36	47

Source: Columbus and Southern Ohio Electric Company-Tests conducted by NUS Corp.

Notes: Leaching procedure--

1. Add equivalent of 500 grams dry ash per 2000 ml deionized water to five, one-quart sample bottles.
2. Agitate bottles.
3. At prescribed intervals, remove successive bottles from agitation, filter through 0.45 micron filter, and analyze.

[a]All results are in mg/l unless otherwise specified.

but this condition was not evident at the outfall. During 1976 only iron and manganese concentrations were noted as being above EPA limits at the holding pond outfall. The mercury limit was seven times the EPA maximum allowable on one of the two reporting dates for 1976.

Table 2-2

ASH POND WATER QUALITY
CONESVILLE POWER STATION

	Period of Record 3/29/74 to 5/2/74			
	Inlet		Outfall	
Constituent	Range	Average	Range	Average
pH (standard units)	4.41 to 8.22	6.61	6.69 to 8.35	7.40
Iron (ppm)	0 to 10.2	1.23	0 to 0.75	0.18
Copper (ppb)	0 to 208	43.2	2 to 85	11.8
Arsenic (ppb)	0 to 60	9.4	0 to 17	7

Source: Raw Data supplied by Columbus and Southern Ohio Electric Company.

The specific chemical characteristics of the scrubber liquor, which is also significant to the type of potential leachate produced by the Poz-O-Tec (the FGD sludge is not totally dewatered and some liquor is incorporated in the Poz-O-Tec), was not available for the Conesville plant. Table 2-4 summarizes typical ranges for important chemical species which have been noted in other scrubber liquors. Many of the concentrations listed on Table 2-4 are well over recommended limits for safe drinking water.

Physical Properties

The IUCS fixation process produces an initial material much like silty clay which, upon curing, gains strength and forms a brittle concrete-like material. At the Conesville plant, the fixed sludge is initially too wet to handle and compact easily. After leaving the radial-arm conveyors, the sludge is generally allowed to cure undisturbed for a period of a few days which improves the handling characteristics. The resulting material is much like a sandy silt which can be easily moved to the ultimate disposal area. The placed Poz-O-Tec is unprotected from rainfall, but shows no substantial tendency to reslurry due to precipitation and/or heavy equipment traffic after approximately a week of undisturbed curing.

Table 2-3

HOLDING POND WATER QUALITY
CONESVILLE POWER STATION

Constituent[a]	Period of Record 1/4/73 to 5/9/74: Inlet[b] Range	Inlet[b] Average	Outfall Range	Outfall Average	9/13/76 and 9/17/76: Outfall Range	Outfall Average
Calcium	225 to 450	312	258 to 480	342	100	
Magnesium	18 to 170	91	85 to 210	127	22 to 23	23
Sodium	0 to 355	154	11 to 282	107	71 to 98	85
Bicarbonate	0 to 163	55	33 to 161	77	64 to 96	80
Carbonate	0	0	0	0	<2	
Hydroxide	0	0	0	0		
Sulfate	157 to 622	337	203 to 479	315	73 to 74	74
Chloride	70 to 317	154	92 to 458	187	140 to 180	160
T. Hardness	284 to 464	403	345 to 660	469		
Phenol. Alk.	0	0	0	0	<2	
M.O. Alk.	0 to 163	55	33 to 161	73	64 to 96	80
Free Carbon Dioxide	9 to 10	10	7 to 10	8		
Conductivity (μmhos/cm)			1180			
Silica	2.5 to 9	5	2.5 to 7.4	5		
Phosphate			0.5			
Iron	3		0 to 1.2	0.31	0.6 to 1.4	1
pH (standard units)	3.35 to 7.26	6.64	6.58 to 8.31	7.37		
COD			41			
Arsenic (μg/l)			0 to 15	5	2 to 3	3
Cadmium (μg/l)			<10		<10	
Chromium (μg/l)			<30		40 to 50	45
Copper (μg/l)			4.7 to 56	19	20 to 50	35
Lead (μg/l)			<5		<50	
Mercury (μg/l)			<0.2		0.1 to 15	8
Nickel (μg/l)			<40			

Table 2-3

HOLDING POND WATER QUALITY
CONESVILLE POWER STATION
(Continued)

Constituent[a]	Period of Record 1/4/73 to 5/9/74: Inlet[b] Range	Inlet[b] Average	Outfall Range	Outfall Average	9/13/76 and 9/17/76: Outfall Range	Outfall Average
Selenium (μg/l)			3		<2	
Zinc (μg/l)			85		20 to 40	30
Manganese (μg/l)					90 to 100	95
Barium (μg/l)					<500	

Sources: Data Summary Sheet, prepared by U.S. EPA-Indiana District, May 1 and 2, 1974.
Report of Effluent Analysis, prepared by Nalco Chemical Company, September 13 and 19, 1976.
Raw Data supplied by Columbus and Southern Ohio Electric Company.

[a]Results in mg/l unless otherwise specified.

[b]Discharge from ash pond.

Table 2-4

RANGE OF CONCENTRATION OF
CONSTITUENTS IN SCRUBBER LIQUORS

Constituent	Range of Concentration at Potential Discharge Point (mg/l)		
Aluminum (Al)	0.03	to	0.3
Antimony (Sb)	0.09	to	2.3
Arsenic (As)	< 0.004	to	0.3
Beryllium (Be)	< 0.0005	to	0.14
Boron (B)	0.9	to	46.
Cadmium (Cd)	0.002	to	0.11
Calcium (Ca)	420.	to	∼45,000.
Chromium (Cr)	0.001	to	0.5
Cobalt (Co)	< 0.002	to	0.7
Copper (Cu)	< 0.002	to	0.6
Iron (Fe)	0.02	to	8.1
Lead (Pb)	0.0014	to	0.55
Magnesium (Mg)	3.0	to	2750.
Manganese (Mn)	0.007	to	9.0
Mercury (Hg)	0.0004	to	0.07
Molybdenum (Mo)	0.07	to	6.3
Nickel (Ni)	0.005	to	1.5
Potassium (K)	5.9	to	32.
Selenium (Se)	< 0.001	to	2.2
Silver (Ag)	0.005	to	0.6
Sodium (Na)	14.0	to	20,000.
Tin (Sn)	3.1	to	3.5
Vanadium (V)	< 0.001	to	0.67
Zinc (Zn)	0.01	to	27.
Chloride (Cl)	470.	to	43,000.
Fluoride (F)	0.7	to	70.
Sulfite (SO_3)	0.08	to	3500.
Sulfate (SO_4)	720.	to	30,000.
Chemical Oxygen Demand	60.	to	390.
TDS	3200.	to	95,000.
Total Alkalinity (as $CaCO_3$)	41.	to	150.
Conductance, mho/cm	0.003	to	0.015
Turbidity, Jackson units	< 3.	to	< 10.
pH	2.8	to	12.8

Source: Michael Baker, Jr., Inc., FGD Sludge Disposal Manual. Palo Alto, Cal.: Electric Power Research Institute, 1979, EPRI FP-977, pp. 7-8 and 7-9.

A&H Corporation conducted laboratory tests and analysis of samples of Poz-O-Tec obtained from the Conesville facility during 1978 for IUCS. A summary of their test results is as follows (4):

- Unconfined Compressive Strength - 30 to 60 psi (2.11 to 4.21 Kg/cm^2)
- Compressibility - Very small to negligible
- Stability of 3:1 Slope (Failure in Poz-O-Tec) - Factor of safety above 3.0
- Bearing Capacity for Shallow Foundations - Above 6000 psf (29,000 Kg/m^2)
- Average Density - 95 pcf (1537 Kg/m^3)

The above strengths were obtained on samples which cured for approximately one month. The results of the tests compare well with projected Poz-O-Tec characteristics with only minor exceptions.

DISPOSAL OPERATIONS

The general operations scheme for the sludge disposal area initially calls for the extension of a Poz-O-Tec dike along the entire east side of the sludge area abuting the existing ash dike which separates the sludge area from the ash pond. The intent of this scheme is to further extend a long conveyor, which is presently situated on this partly completed dike, to minimize subsequent sludge haulage distances. The Poz-O-Tec dike should also seal off minor seepage occurring through the ash dike and originating from the ash pond. This seepage mainly occurs in the eastern corner of the Poz-O-Tec area. Depending on weather conditions and sludge availability, material will be moved into the disposal area and spread over suitably pre-graded areas to complete a 3 feet (0.9 m) liner over the entire disposal area bottom (1). Figure 2-1 illustrates the extent of the Poz-O-Tec fill as of October 30, 1978 when the area was photographed by Michael Baker, Jr., Inc. At that date the liner was incomplete and, as of April, 1979, the areal extent of the liner remained essentially the same.

The liner was incomplete because disposal operations in the northern end of the sludge disposal area have been hindered by the presence of a small pond. The base elevation (726±) is low in this area. With seasonally high levels in the adjacent Muskingum River, groundwater apparently recharges this pond. Runoff from the Poz-O-Tec area feeds this pond to a lesser extent. With a sufficient drop in river level and a respective lowering of ground-water levels the liner may be completed during the summer of 1979.

Present landfill materials in the Poz-O-Tec disposal area are placed in benches. Fill placement starts from the southern and southwestern end of the sludge disposal area and extends northeastward. A large capacity, rubber-tired pay loader moves the sludge from stockpiles at the base of the two radial-arm conveyors to the northeastern front of a bench. The material is extended laterally a width equal to the reach of the pay loader such that the loader does not drive onto the soft, freshly placed material (see Figure 2-3). A bulldozer spreads the freshly placed Poz-O-Tec. When the front of one bench has been completed, operations shift to another bench. The freshly placed Poz-O-Tec on the previous bench is allowed to cure for approximately six days according to the equipment operators. After six days, the Poz-O-Tec can support the loader and additional Poz-O-Tec is placed on the front of the original bench. When the front of the benches are extended the activities of the loader and dozer compact the partly aged fill. Benches are approximately 3 to 4 feet (0.9 to 1.2 m) thick. Present total thicknesses of Poz-O-Tec over the disposal area range from about 10 feet (3 m) at the southern end of the sludge area to the northernmost lift which is approximately 3 feet (0.9 m) thick.

When the liner of Poz-O-Tec in the disposal area is completed, the IUCS management plan recommends a sump pump(s) to remove runoff collected at the northern end of the disposal area. This water will be discharged into the adjacent ash sluice pond. Disposal will continue from south to north with controlled runoff at all times. The dikes will act as runoff control berms when the fill is below approximately elevation 770. Above elevation 770, the plan requires terraces 20 feet (6 m) high with 3:1 side slopes and a 50 foot (15 m) bench between the top of the slope of the lower terrace and the toe of the slope of a new terrace. These benches will slope toward the interior of the fill to a swale collection system for runoff. The management plan recommends a minimum 18 inch (0.46 m) seeded earth cover on finished benches, side slopes, and other completed fill surfaces for erosion control.

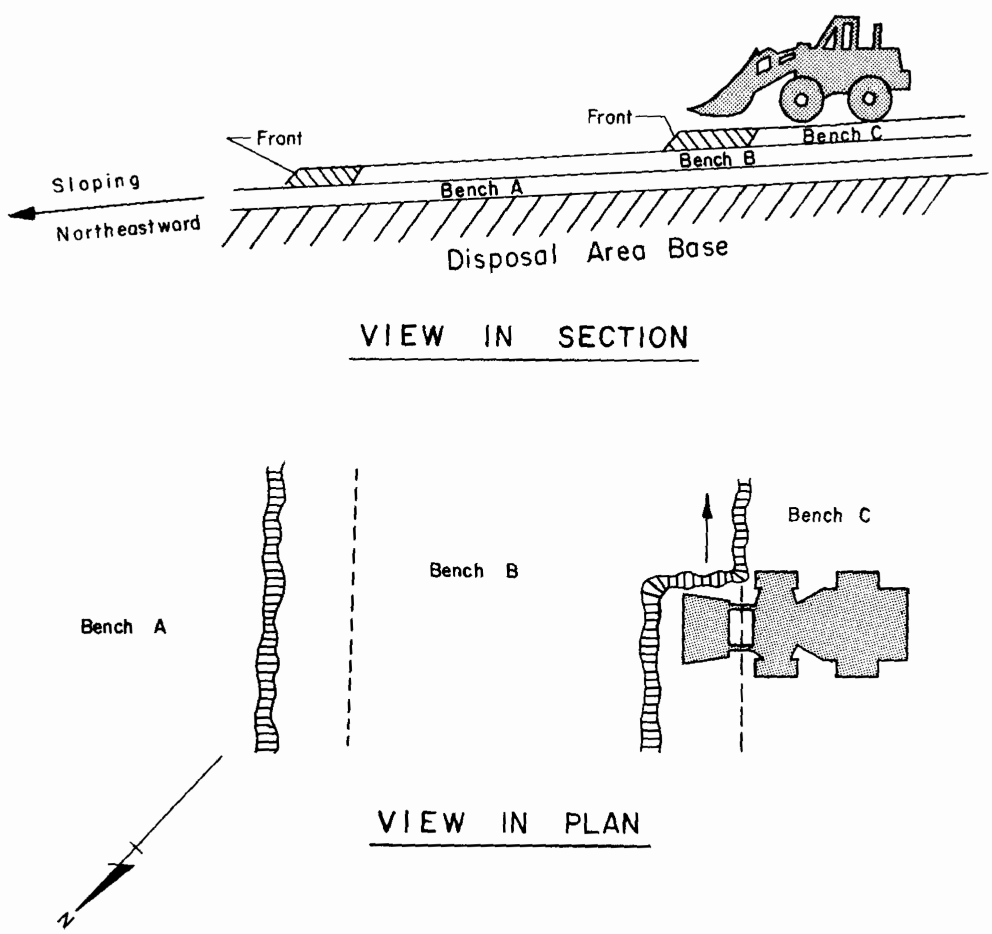

Figure 2-3. Poz-O-Tec Placement

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3. P.P. Leo and J. Rossoff. Control of Waste and Water Pollution from Power Plant Flue Gas Cleaning Systems; First Annual R&D Report. Cincinnati, Ohio: U.S. Environmental Protection Agency, 1976, EPA 600/7-76-018.

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Section 3

SITE GEOLOGY AND AQUIFERS

Section 3

SITE GEOLOGY AND AQUIFERS

GLACIAL INFLUENCES

The Conesville Power Station is situated along the floodplain of the Muskingum River in Coshocton County, Ohio. From available geologic evidence this area was not directly glaciated, however, the Illinoian and Wisconsin ice advances of the middle and late Pleistocene Epoch are thought to have extended into the western and northern tips of Coshocton County, respectively. As such, the Conesville vicinity has been affected by vast quantities of glacial meltwater and outwash which have both aggraded and degraded the present Muskingum River Valley (1).

Prior to the Illinoian ice advance glacial ice is postulated to have advanced far enough into western Ohio to block the old Teays valley. As a result, northward flowing drainage systems were blocked and impounded. Many of these impounded drainage systems overflowed the drainage divides on their southern borders. Excessive quantities of runoff were diverted to other southward draining systems during an erosional interglacial stage called Deep Stage drainage. The present Muskingum River valley, known as the Cambridge River valley during pre-glacial time and the Newark River valley during the Deep Stage, was reportedly deepened by as much as 200 feet (61 m) below the Teays level or approximately 160 feet (49 m) below the present valley floor elevation. Regional uplift of the land surface with respect to sea level may have also contributed to the overdeepening of the valley. The downcutting was so rapid that lateral valleys were only moderately affected and the uplands were only slightly reduced (1).

Outwash was concentrated in the deeply intrenched ancestral valleys of the Muskingum River as a result of the Illinoian ice advance and partially removed during the Sangamon interglacial stage. The Wisconsin glacial advance yielded another flood of debris, again concentrating in the partially eroded Muskingum valley.

Illinoian terrace deposits with an upper surface at an elevation of approximately 850 to 860 occur one-half mile (0.8 kilometer) west of the community of Conesville.

These deposits are 50 to 60 feet (15 to 18 m) higher than broad Wisconsin terraces which can be observed extending northwest from Conesville varying in elevation from 770 to 800. The primary streams in this area have reportedly degraded their channels by as much as 70 to 80 feet (21 to 24 m) below the level of the prominent gravel terraces of Wisconsin age.

The Wisconsin terraces in the immediate vicinity of the Conesville Power Station have mostly been degraded to elevation 730 to 740. A few small patches of higher remnants may still be present along the steep hillside bordering the northern and eastern perimeter of the plant, however, topographic expression indicates these deposits generally pinch out by approximately elevation 750. Illinoian terrace deposits are described by Lamborn (1954) as occurring in the upper part of the small stream valley, located immediately to the north of the power station, at elevation 860 to 870. Wisconsin terrace remnants may border the lower end of the small stream valley up to approximately elevation 800.

Exploratory drilling, often through the entire thickness of outwash, had been conducted as part of the planning for the Conesville Power Station. The locations of these previous borings are illustrated on Figure 3-1. Simplified plots of many of the logs for these borings are included in Appendix A. From the deep boring information, a primary site aquifer has been identified and its base contoured. Figure 3-2 shows the approximate contours as well as the estimated areal limit of the outwash aquifer. A cross section has been developed along the line indicated on Figure 3-1 and Figure 3-2 to show general subsurface conditions. This cross section is included as Figure 3-3.

The general subsurface conditions consist of a near surface relatively thin alluvial silt horizon which persists to an average elevation of 726. This horizon is underlain by a thick deposit of glacial outwash sand and gravel and/or sand, considered to be the primary site aquifer of interest for this investigation, which extends to an average elevation of 620. The base of this aquifer unit typically lies on much less permeable material such as sandy or clayey silt, silty clay, or fine silty sand. This latter material overlies bedrock encountered during drilling at elevation 593, the lowest point in the vicinity of the power station.

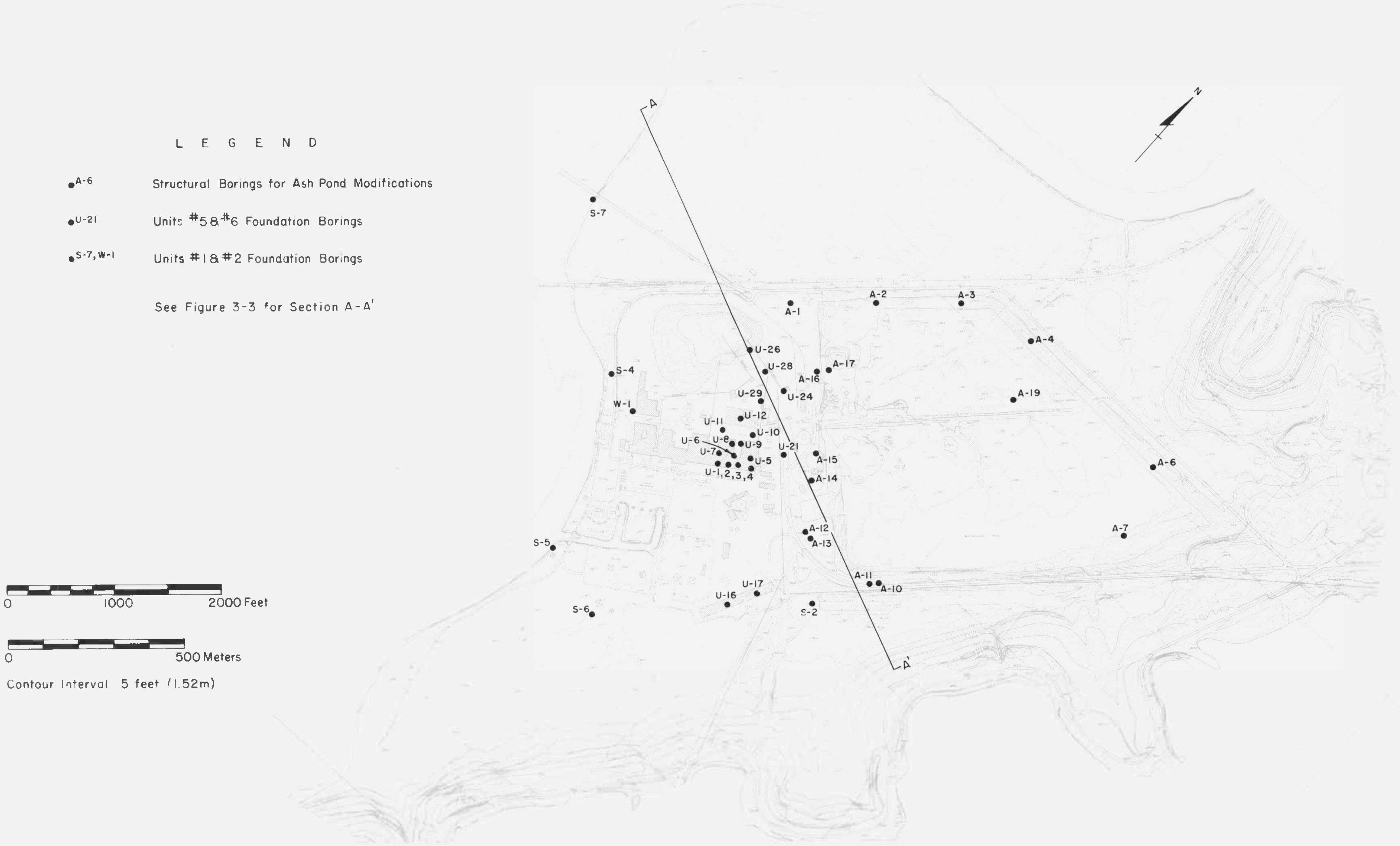

Figure 3-1. Locations of Drill Holes From Past Subsurface Investigations

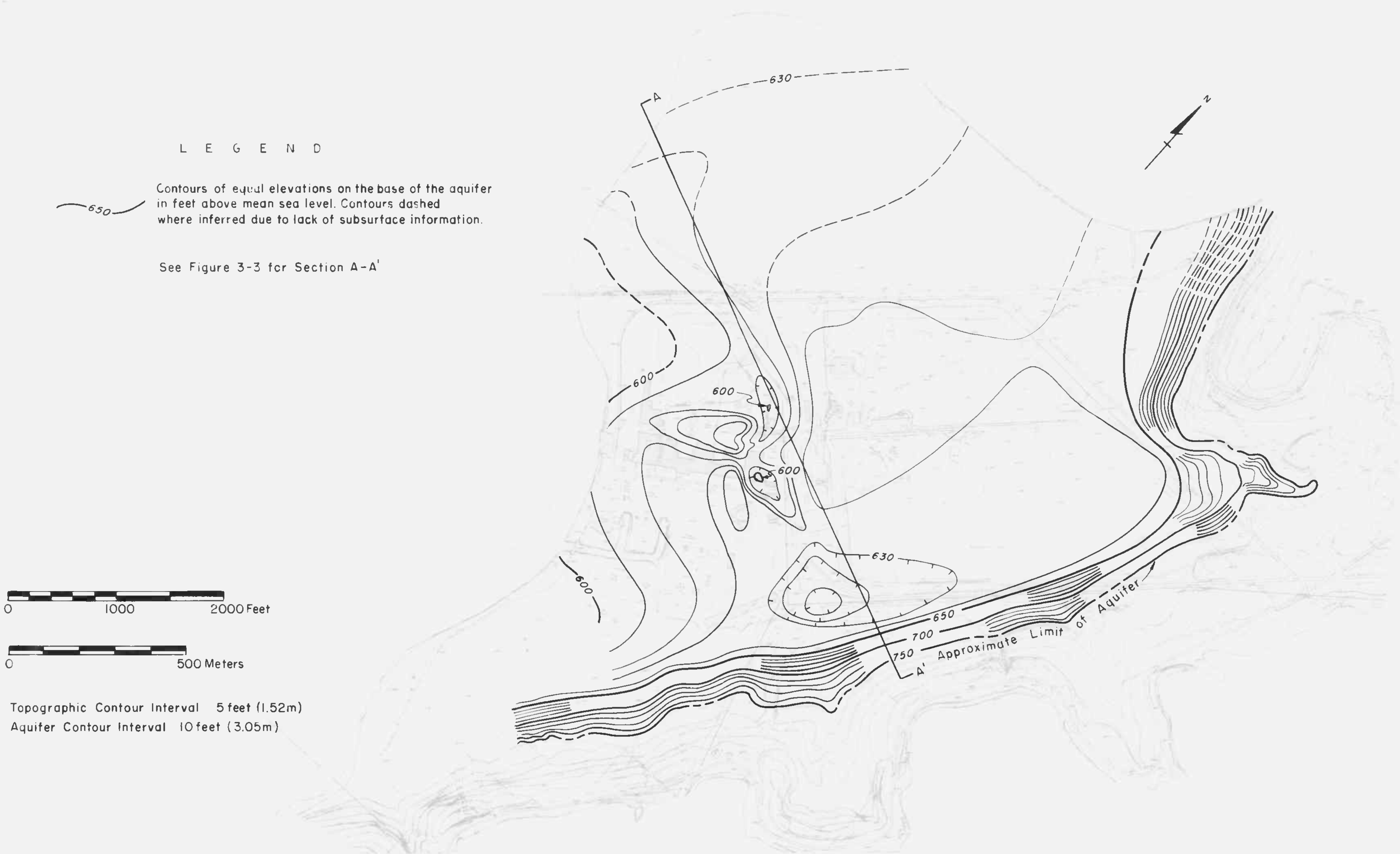

Figure 3-2. Base and Aerial Extent of Site Aquifer

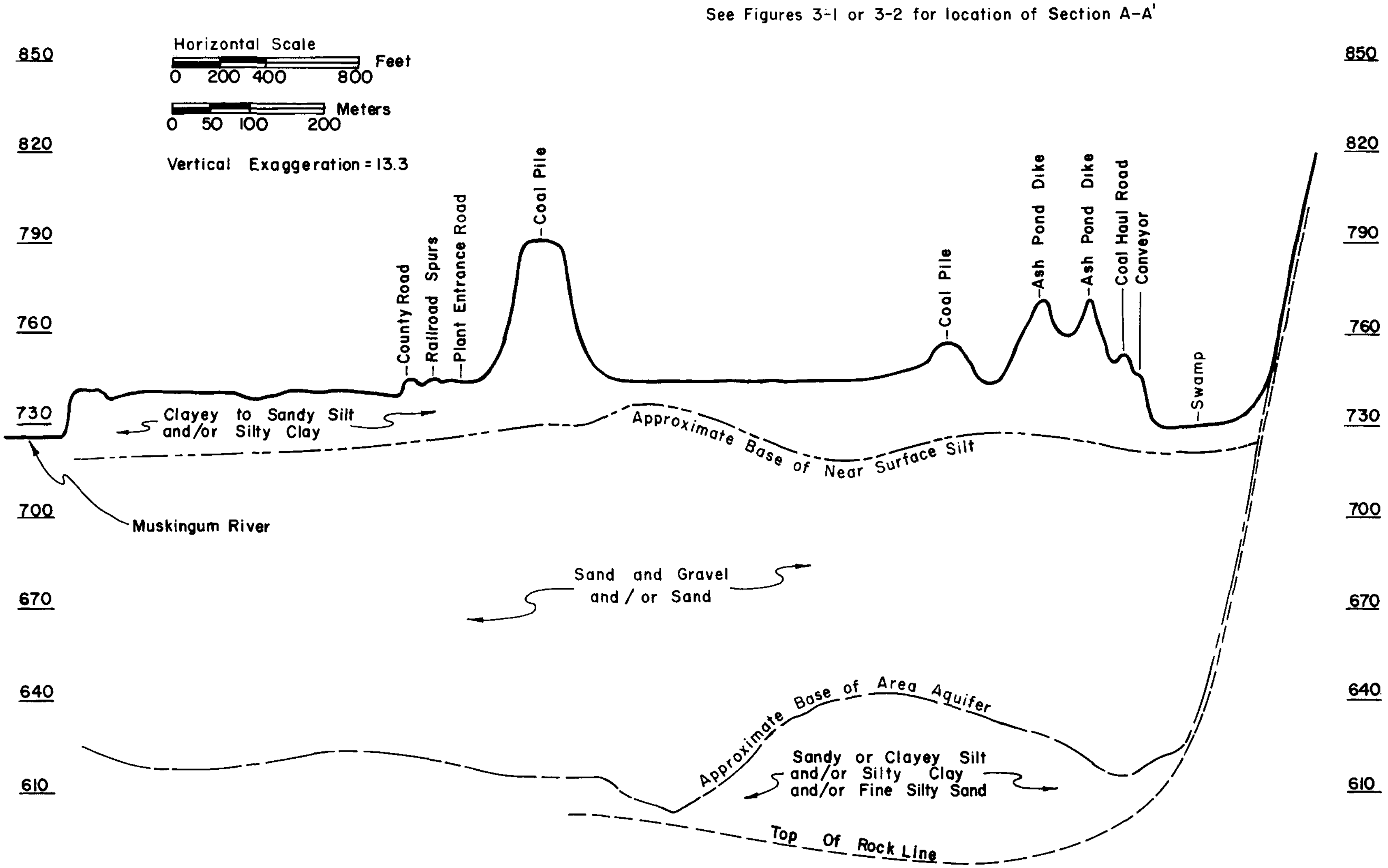

Figure 3-3. Cross section A-A' showing general subsurface conditions.

The permeable sand and gravel deposits adjacent to the Muskingum River are known to yield as much as 1000, or more, gallons per minute (0.063 m^3/s) from properly constructed wells (2).

BEDROCK GEOLOGY

Bedrock in the vicinity of the Conesville Power Station consists of the Conemaugh and Allegheny Series of the Pennsylvanian System which lie above drainage. The Middle Kittanning Coal of the Allegheny Series constitutes an important economic resource in this immediate area and outcrops at approximately elevation 860. The Pottsville Series of the Mississippian System contacts the Allegheny Series at approximately elevation 786 and extends below drainage to about elevation 597, coinciding closely with the deepest part of the ancestral Muskingum River valley. The Pottsville is locally comprised primarily of interbedded shale, clay, and thin coals and limestones. Table 3-1 summarizes the average Pottsville stratigraphic section which occurs in Coshocton County. Approximate elevations have been added to this section based on available drilling information and the local outcrop of the Middle Kittanning Coal. Recognized aquifers of the Pottsville Series in ascending order include the Sharon conglomerate, the Massillon sandstone, and the Homewood sandstone. When well developed, the Massillon sandstone is reported to be one of the best water bearing strata in the entire Pennsylvanian System. Fine wells in the Massillon have been developed in the past in the vicinities of Coshocton and Zanesville located upstream and downstream of Conesville, respectively (3). However, the Sharon conglomerate is not developed in Coshocton County, the Homewood sandstone is reported to be generally replaced by shale, and the Massillon sandstone is generally persistent but may be replaced by shale, according to the average stratigraphic section.

Typical predicted well yields for wells drilled to local bedrock aquifers are in the range of less than 5 gpm (3×10^{-4} m^3/s) to 25 gpm (1.6×10^{-3} m^3/s) (2). Because this range of expected yield is less than 3% of that for the area sand and gravel aquifer, no consideration of the bedrock aquifers has been pursued during this investigation.

Table 3-1

AVERAGE POTTSVILLE SECTION IN COCHOCTON COUNTY, OHIO

Member	Strata	Thickness	Approximate Top Elevation
Brookville	Clay-gray, plastic	5 ft 2 in (1.58 m)	786
Homewood	Sandstone-generally replaced by shale	16 ft 1 in (4.90 m)	781
Tionesta or No. 3b	Coal-shaly, local	6 in (0.15 m)	
Tionesta or No. 3b	Clay-gray, plastic	3 ft 10 in (1.17 m)	
	Shale-gray, sandy	13 ft 11 in (4.25 m)	
Upper Mercer	Ore-generally wanting	2 in (0.05 m)	
	Shale-dark	2 ft (0.61 m)	
Upper Mercer	Limestone-black, fossiliferous	3 ft (0.92 m)	744
	Shale-dark, carbonaceous	2 in (0.05 m)	
Bedford	Coal-shaly, persistent	1 ft 5 in (0.43 m)	
Bedford	Clay-gray, plastic	4 ft 10 in (1.47 m)	
	Shale	2 ft 10 in (0.86 m)	
Upper Mercer or No. 3	Coal-thin, local	11 in (0.28 m)	
Upper Mercer or No. 3	Clay-gray, plastic	2 ft 8 in (0.81 m)	
	Shale-bluish gray	12 ft 10 in (3.91 m)	
Lower Mercer	Ore-generally wanting	--	
Lower Mercer	Limestone-gray to gray black, fossiliferous	2 ft 6 in (0.76 m)	716
	Shale-dark, clayey	6 in (0.15 m)	
Middle Mercer	Coal-shaly and carb. shale	1 ft 4 in (0.41 m)	
Middle Mercer	Clay-gray, lower part sandy	5 ft 6 in (1.68 m)	
	Shale-gray to dark, sandy	3 ft 5 in (1.04 m)	
Flint Ridge	Coal-shaly, and carb shale, local	1 ft 5 in (0.43 m)	
Flint Ridge	Clay-gray, plastic	4 ft 6 in (1.37 m)	
	Shale-sandy	12 ft 7 in (3.84 m)	
Boggs	Sandy bed-ferruginous, calcareous, fossiliferous	6 in (0.15 m)	
	Shale-dark, sandy	2 ft (0.61 m)	
Lower Mercer or No. 3	Coal-shaly, local	3 in (0.08 m)	
Lower Mercer or No. 3	Clay-gray, plastic	1 ft 7 in (0.48 m)	
	Shale-often replaced by sandstone	23 ft (7.01 m)	
Lowellville	Limestone-dark, ferruginous	3 in (0.08 m)	657

Table 3-1

AVERAGE POTTSVILLE SECTION IN COCHOCTON COUNTY, OHIO
(Continued)

Member	Strata	Thickness	Approximate Top Elevation
	Shale-light to dark	10 in (0.25 m)	
Vandusen	Coal and Carb. Shale, local	4 in (0.10 m)	
Vandusen	Clay-local	2 ft 11 in (0.89 m)	
	Shale-sandy, often replaced by sandstone	5 ft 8 in (1.73 m)	
Bear Run	Coal and Carb. Shale-local	5 in (0.13 m)	
Bear Run	Clay-gray, local	2 ft 2 in (0.66 m)	
Massillon	Sandstone-generally persistent, locally replaced by shale	19 ft (5.80 m)	644
Quakertown or No. 2	Coal-generally thin, locally wanting	1 ft (0.31 m)	
Quakertown or No. 2	Clay-dark	1 ft 9 in (0.53 m)	
	Shale-blush	9 ft 5 in (2.87 m)	
Anthony	Coal and Black Shale-local	2 in (0.05 m)	
Sciotoville	Clay-gray	3 ft (0.92 m)	
	Sandstone-light gray, v. local	--	
	Shale-dark	11 ft 6 in (3.51 m)	
Sharon	Coal-v. local	--	
Harrison	Brecciated Conglomeratic Layer	9 in (0.23 m)	599

Source: Lamborn. Geology of Coshocton County. Columbus, Ohio: Ohio Division of Geological Survey, 1954, Bulletin 53, pp. 36-37.

REFERENCES

1. Raymond E. Lamborn. Geology of Coshocton County. Columbus, Ohio: Ohio Division of Geological Survey, 1954, Bulletin 53.

2. Ohio Division of Water. Water Inventory of the Muskingum River Basin. Columbus, Ohio, 1968, Ohio Water Plan Inventory Report No. 21.

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Section 4

FIELD INVESTIGATIONS

Section 4

FIELD INVESTIGATIONS

MONITORING WELLS

Monitoring well locations to detect potential leachate produced by the Poz-O-Tec landfill at the Conesville facility were selected according to three basic criteria: 1) a review of previous drilling information (included in Appendix A), 2) consideration of the probable groundwater mounding effects and water quality interference due to the ash disposal pond, and 3) the probable southwestward component of groundwater flow due to the effects of the Muskingum River. Anticipated problems of leachate detection due to water quality interference associated with the coal pile, holding pond, and the plant outfall area were avoided by keeping monitoring wells upgradient of the influence of these features with respect to the anticipated groundwater surface.

The basic approach taken in setting up the monitoring network followed EPA guidelines for monitoring groundwater at solid waste disposal facilities (1). Three basic well types were used which are illustrated on Figure 4-1. The basic well types consisted of wells for background water quality, wells for the purpose of determining worst case conditions, and wells to detect migrating leachate.

Seventeen monitoring wells were installed during January and February, 1979 as part of the field activities for this project. Thirteen of these wells, MB-1 and MB-4 through MB-15, were designed for water quality and aquifer potential monitoring. The four remaining wells, MB-2, MB-3, MB-16, and MB-17, were installed primarily as observation wells for drawdown measurements during pump tests, but were also monitored later for groundwater levels. Wells MB-1 and MB-15 served dual purposes in that they were used initially during pump tests for drawdown measurements, but were designed to be principally used for water quality and aquifer potential monitoring.

Well installations were accomplished by drilling with hollow stem augers having an inner diameter of approximately 4 inches (0.1 m). The hollow stem augers were first

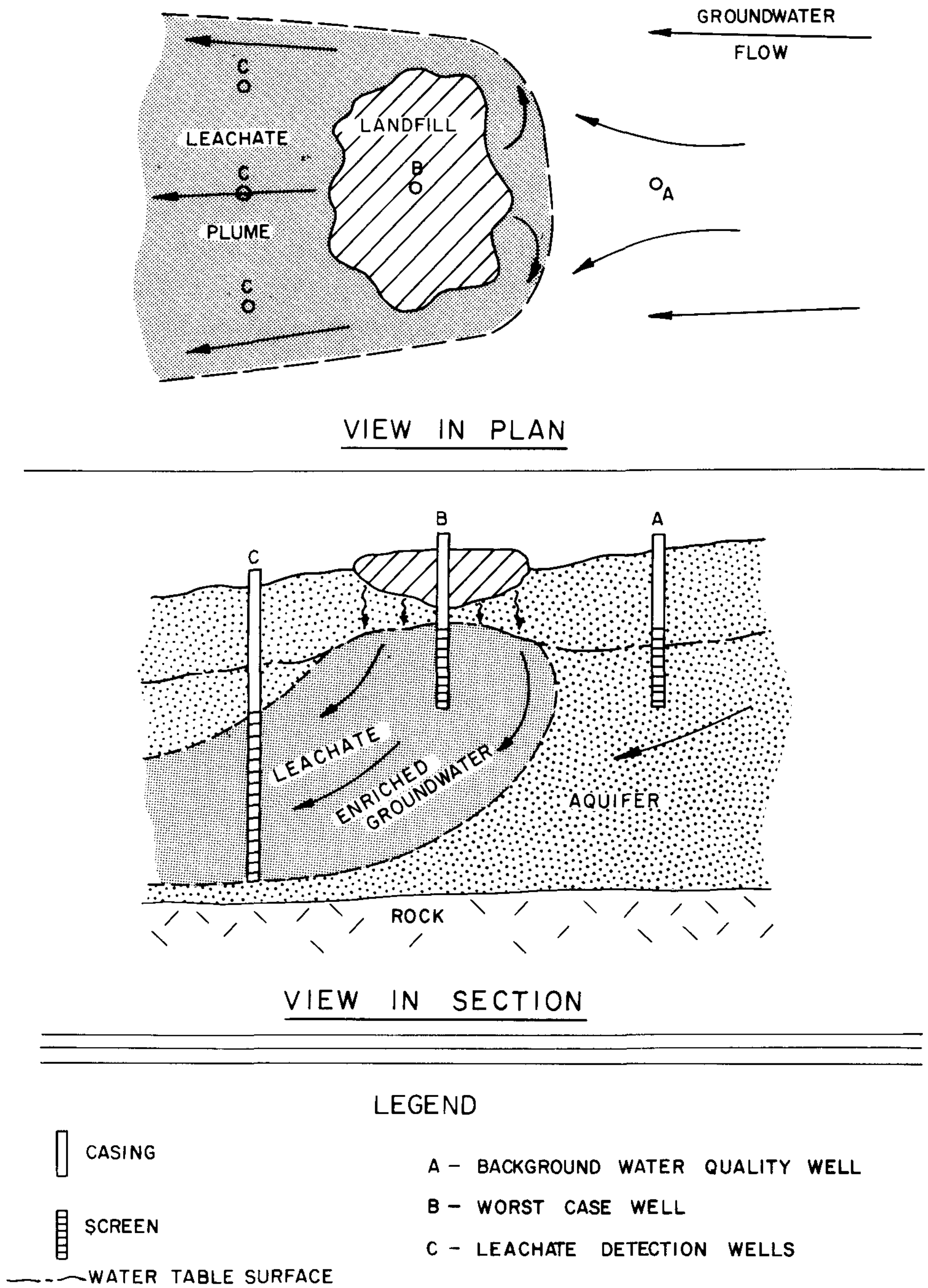


Figure 4-1. Basic Monitoring System

advanced to the desired depth of the well and then washed out with clean water to the bottom of the hole. After washing, polyvinyl chloride pipe having an inner diameter of 1.93 inches (0.05 m), a plugged bottom, and slotted section was lowered into the hollow stem augers. The hollow stem augers were then gradually pulled while pea gravel was added to the space between the inside of the hollow stems and the outside of the casing to form a gravel pack around the slotted casing or screen. A bentonite seal in the form of a slurry was placed through the hollow stems typically above the backfilled slotted section. The hole above the bentonite seal was backfilled with native sand and gravel auger cuttings with the exception of the top few feet which was sealed well with bentonite to prevent surface water infiltration.

The locations of the wells are shown on Figure 4-2. Figures 4-3 through 4-8 summarize the subsurface materials encountered during the drilling of these wells and the piezometer details with relation to the groundwater table.

Monitoring wells MB-1 and MB-6 were positioned to act as background water quality wells. It was believed that these wells would not be affected by either the ash pond or the Poz-O-Tec disposal area. MB-1 was situated such that it should indicate the water quality influence of the Muskingum River while MB-6 should indicate the typical groundwater quality from the adjacent hills, possibly influenced by nearby strip mining.

A large water quality influence was expected from the ash sluice pond considering its proximity to the sludge disposal area and its unlined condition. For this reason, the well cluster consisting of wells MB-12 and MB-13 was installed within the confines of the ash pond to also provide background water quality information. Well MB-12 was slotted in the sand and gravel just underlying the ash. Well MB-13 was situated immediately southwest of Well MB-12 and was slotted 10 feet (3.05 m) deeper to acquire information about attenuation and/or dilution with increasing depth.

A monitoring well cluster comprised of wells MB-10 and MB-11 was situated within the sludge disposal area. Well MB-10 was provided to supply water quality information indicative of worst case leachate conditions produced by the Poz-O-Tec, if any. Well MB-10 just penetrated the groundwater surface while well MB-11, located immediately southwest of well MB-10, was slotted 10 feet (3.05 m) deeper. It was believed that water quality from well MB-11 would be indicative of any leachate produced by the Poz-O-Tec after mixing with dilute leachate associated with the ash pond.

The additional clusters of wells consisting of MB-4 and MB-5 located immediately northwest of the sludge disposal area, MB-7, MB-8 and MB-9 located west of the center of the Poz-O-Tec area, and MB-14 and MB-15 located to the southwest, were established to detect potential leachate from the Poz-O-Tec. The depth to which a leachate plume might sink in the groundwater table was not known. However, it has been stated that thicker aquifers, 100 to 200 feet (30 to 60 m), tend to have more pronounced shallow and deep flow systems and that the leachate plume might remain in the shallow flow system (1). Therefore, each well cluster consisted of a shallow well which just intercepted the groundwater table and a well which was slotted 10 feet (3.05 m) deeper. The exception to this rule was well MB-9 which was drilled and screened near the base of the aquifer as a check against the shallow flow system premise.

AQUIFER TESTS

Two aquifer evaluation pumping tests were performed during February, 1979 near the disposal site. These tests were carried out as part of the development of site specific hydrogeologic information for determining the hydraulic properties of the glacial outwash aquifer underlying the site. The results of the tests were used to compute values of transmissivity, hydraulic conductivity, and storage coefficient for the glacial outwash.

An aquifer test is a controlled field experiment made to determine the hydraulic properties of water-bearing soils and rocks. The test is made by observing the groundwater flow produced by a known hydraulic gradient. The most usual kind of test is performed by pumping a well at a known rate while recording the drawdown in that well and the drawdown caused by this pumping in nearby observation wells. The resulting data is then analyzed using the theory of well hydraulics as developed by Theis, Jacobs, and others. Because aquifer tests determine the permeabilities of large masses of aquifer in situ, they represent the best method available for characterizing the hydraulic properties of the glacial outwash underlying the disposal area. The testing and analytical procedures described in the following sections are based on information from Davis and DeWiest (1966), and Edward E. Johnson, Inc., (1966).

Methods and Equipment

The pump wells, P-1 and P-2, were located 10 feet (3.05 m) southwest of monitoring wells MB-3 and MB-17, respectively (see Figure 4-2).

Figure 4-2. Locations of Site Monitoring Points

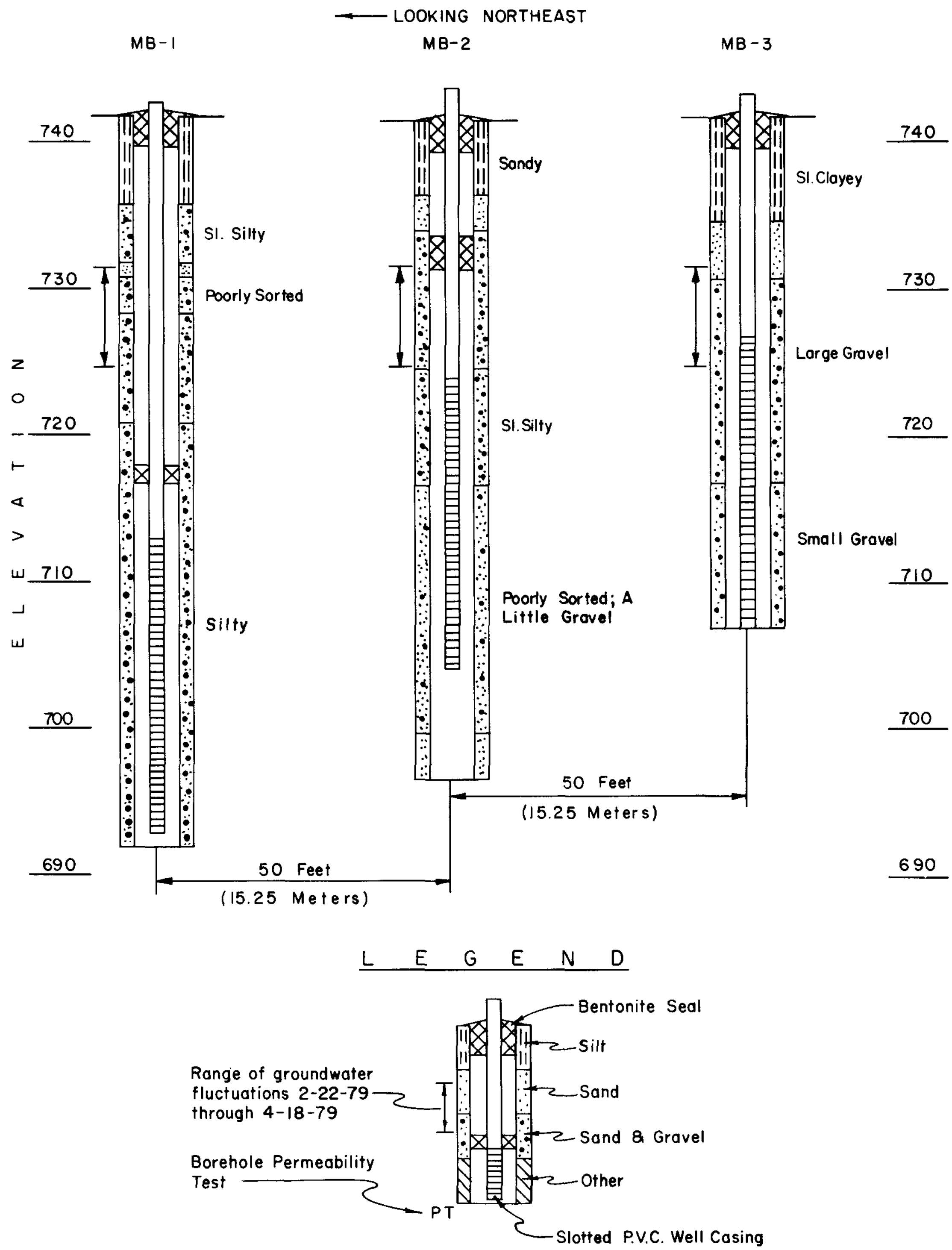


Figure 4-3. Installation Details - Monitoring Well MB-1, Observation Wells MB-2 and MB-3

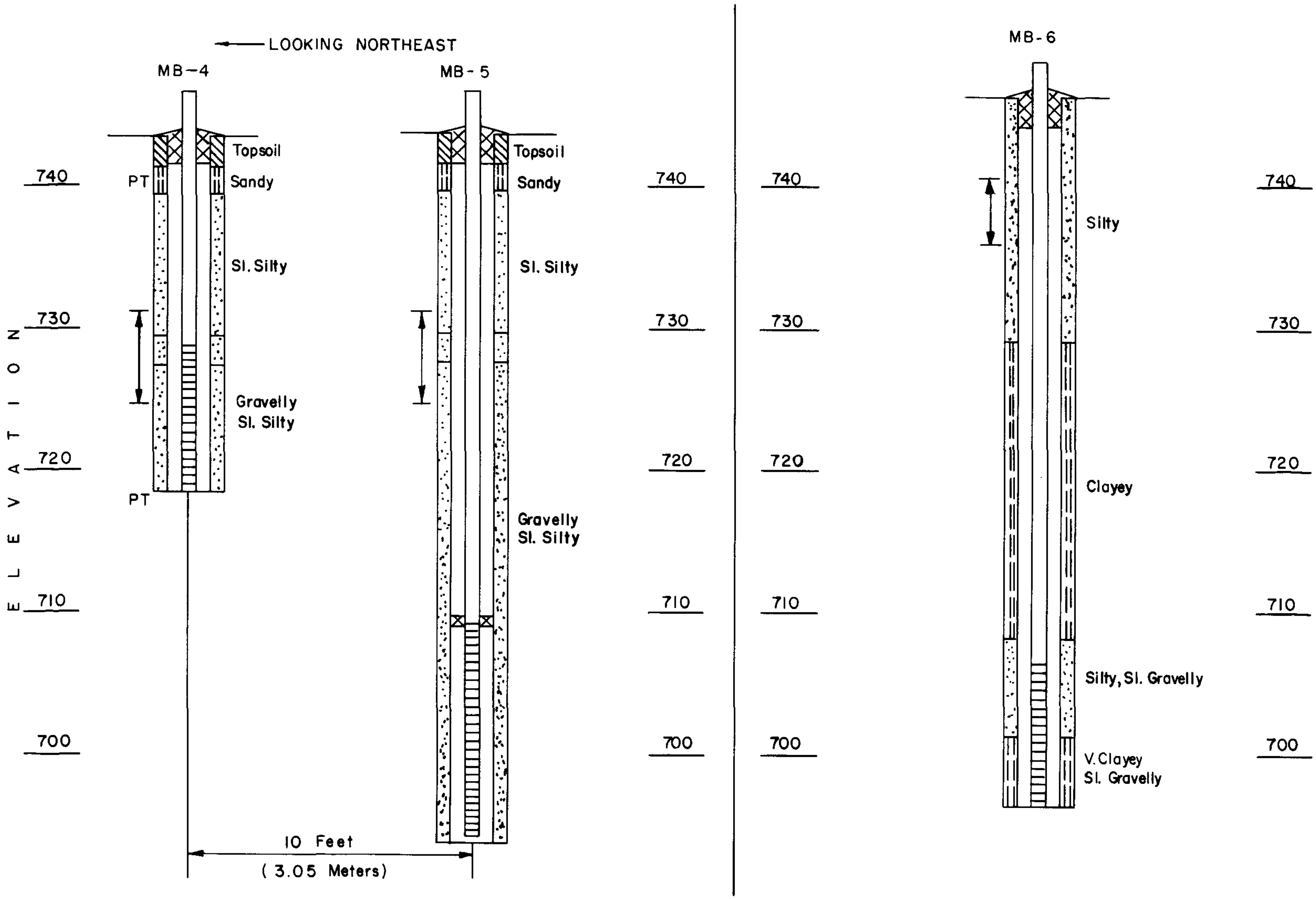


Figure 4-4. Installation Details - Monitoring Well Cluster MB-4 and MB-5, Monitoring Well MB-6

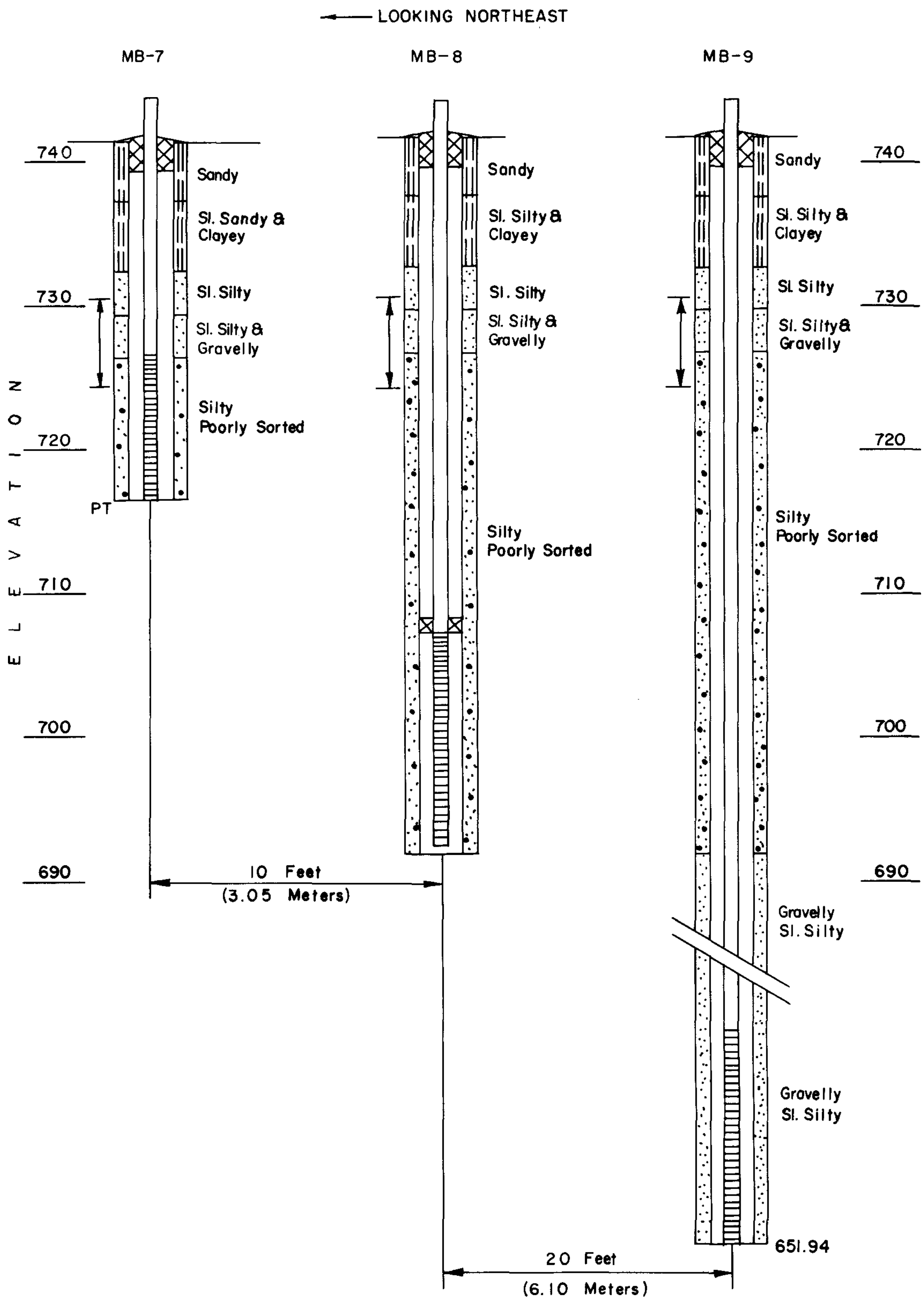


Figure 4-5. Installation Details - Monitoring Well Cluster MB-7, MB-8, and MB-9

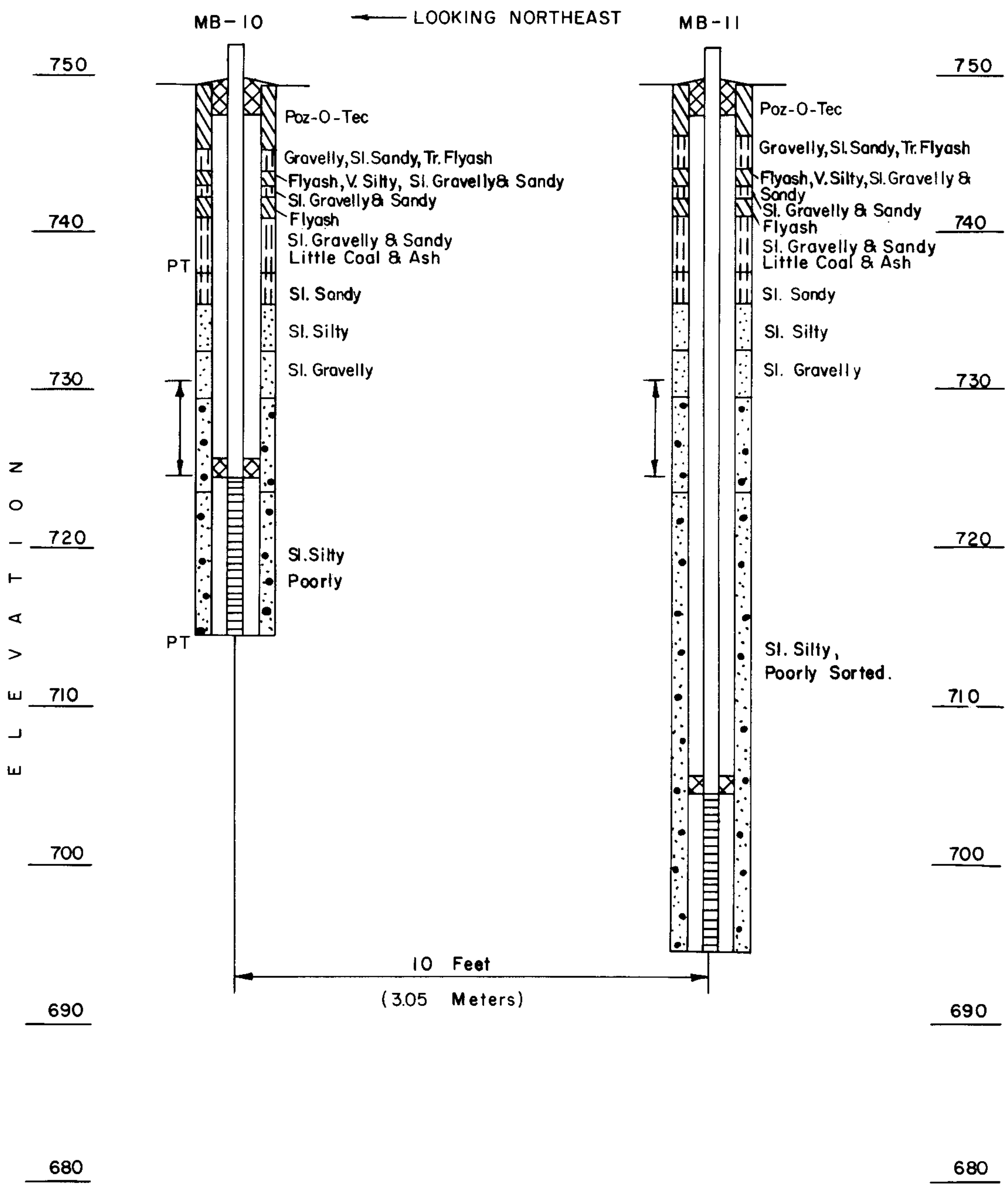
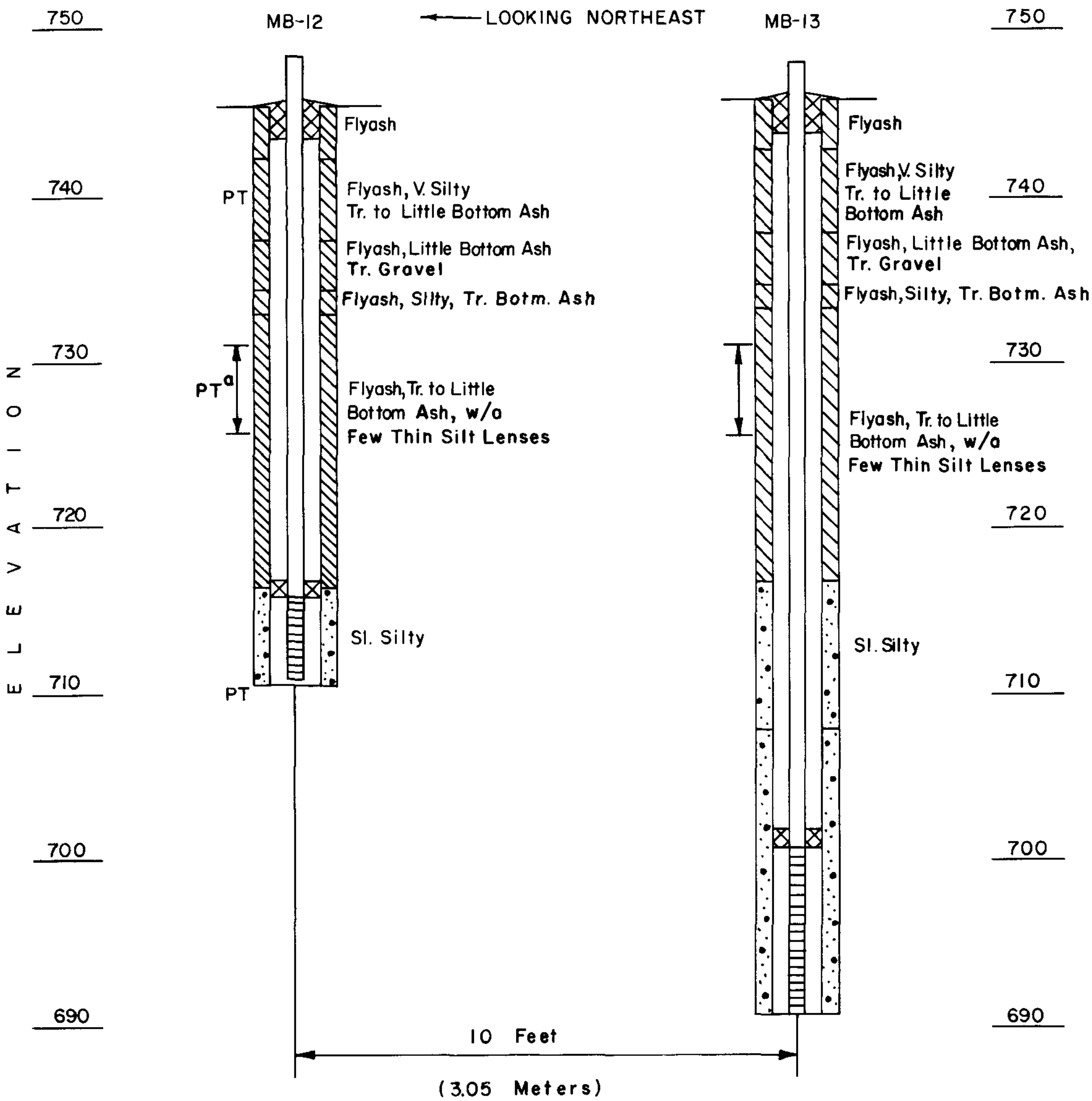


Figure 4-6. Installation Details - Monitoring Well Cluster MB-10 and MB-11



[a] Permeability test conducted in hole MB-12A located immediately adjacent to well MB-12

Figure 4-7. Installation Details - Monitoring Well Cluster MB-12 and MB-13

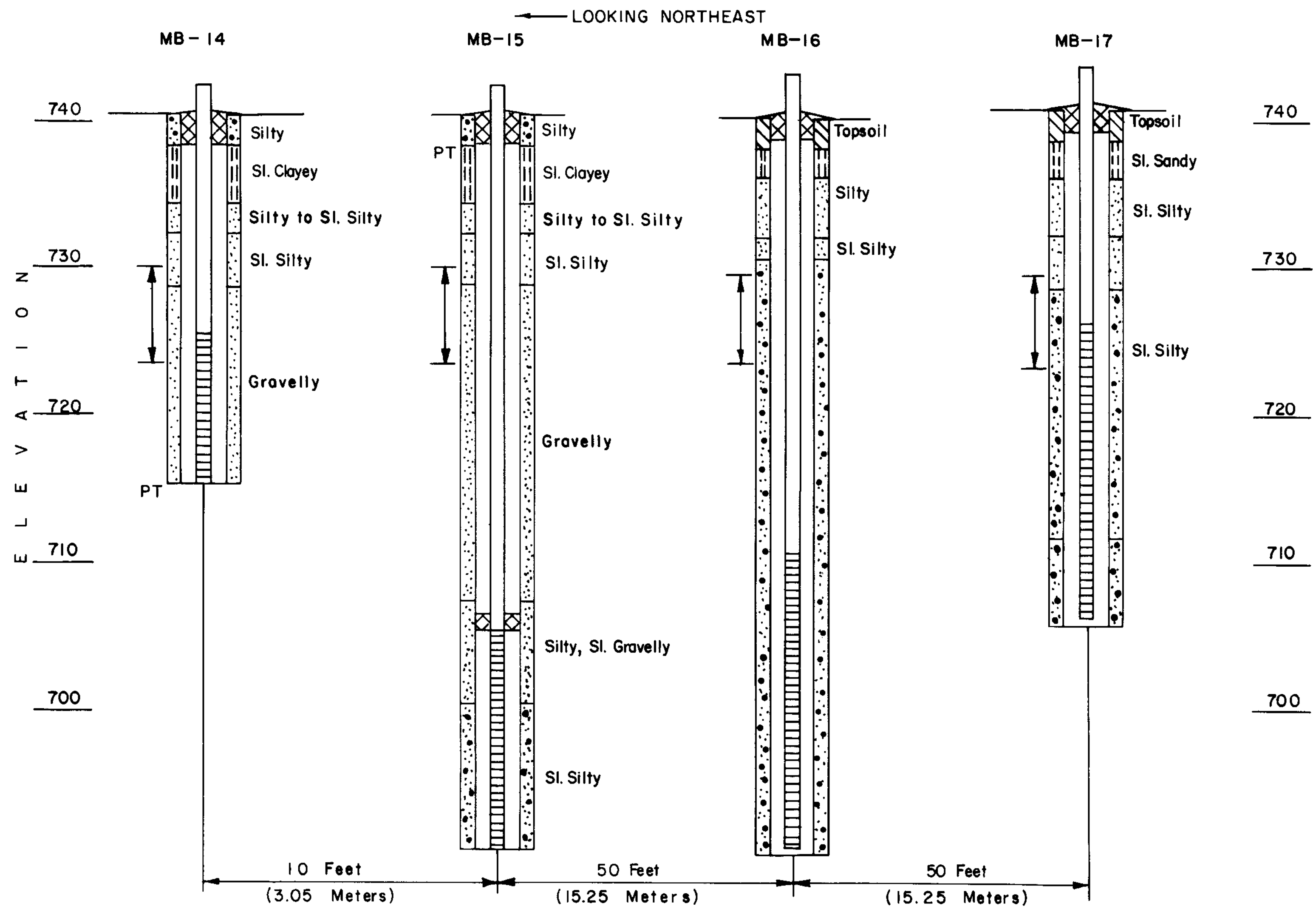


Figure 4-8. Installation Details - Monitoring Well Cluster MB-14 and MB-15, Observation Wells MB-16 and MB-17

Wells P-1 and P-2 were drilled 95 feet (29 m) and 102 feet (31 m), respectively, through the glacial outwash to the approximate base of the aquifer. Both wells were constructed of 8 inch (0.2 m) diameter steel casing. The bottom 40 foot (12 m) section of casing in each well was slotted with a cutting torch to act as a well screen. The wells were drilled by a cable tool rig.

During each test, water levels were measured in three observation wells located at distances of 10, 60, and 110 feet (3.05, 18.28, and 33.51 m) from the pumped well. The observation wells measured during Test No. 1 were MB-3, 2 and 1, while MB-17, 16, and 15 were used in the second test, located at the above respective distances from the pump wells and in straight lines. Details of monitoring well construction are summarized on Figures 4-3 through 4-8.

The test wells were pumped with a vertical turbine pump powered by diesel engine. The bottom of the pump was set at a depth of 50 feet (15.23 m) below the ground surface. Since the static water levels in the test wells were about 20 feet (6.09 m) below the surface in each case, approximately 30 feet (10.94 m) of available drawdown existed between the static water level and the bottom of the pump for both tests.

Based on the results of well development pumping, a rate of 400 gpm (0.025 m^3/s) was used in each test. This rate was chosen in order to produce drawdown in the observation wells while maintaining the water in the test well above the pumping level. During the course of each test, the pumping rate never varied significantly from 400 gpm (0.025 m^3/s).

The discharge rate of pumped water was measured by use of a circular orifice meter located near the discharge end of the outflow hose. Once the outflow stabilized at the proper rate during the initial part of testing, the rate was measured at least once every hour. Adjustments of the discharge rate were made by either adjusting the pump throttle or by turning a valve located in the discharge line near the pump. In each test, the outflow was conducted from the test site to areas draining away from the wells. The outflow points were at least 100 feet (31 m) away from the closest monitoring well. Also, the ground surface was frozen during the pump tests making interference from infiltration unlikely.

Water levels were measured in the observation wells to an accuracy of 0.01 foot (0.003 m) using electric depth gauges. Levels in the test well were attempted but could not be measured during the tests because the annular space between the pump and casing was too small to allow passage of the probe or a chalked tape. Readings were generally concentrated in the nearest observation wells (MB-3 and MB-17) during the first ten minutes of the two tests, with measurements taken every one to two minutes. After ten minutes, readings were taken in all of the wells with the interval between readings increasing in stages from 7 minutes to 20 minutes. After two hours measurements were made periodically at monitoring well MB-11 (location shown on Figure 4-2) in order to identify any long term fluctuations in ground water levels possibly taking place during the test.

The tests were planned to last for 24 hours each in order that steady state conditions of drawdown would be reached. Aquifer Test No. 1, however, was stopped after 17 hours of pumping due to a mechanical problem with the pump. Although the results of this test were unaffected since steady conditions had been reached, measurements of water level recovery could not be made after pumping had ended. However, recovery measurements were made during Test No. 2 for several hours after the end of pumping.

Test Analyses

Aquifer Test No. 1. During Test No. 1, water levels declined at approximately the same rate in all three observation wells. A drawdown of about 0.1 foot (0.03 m) occurred quickly after the start of pumping and water levels continued to decline slowly for the next six hours when maximum drawdown of about 0.25 foot (0.08 m) was measured. Water levels then began to rise for the remaining eleven hours of the test until a final drawdown of about 0.16 foot (0.05 m) was reached in each of the wells. While this water level rise during pumping is unexplained, it may have been the result of either natural recharge to the aquifer or artificial recharge created by seepage of discharged water back into the aquifer.

The data from the initial six hours of the test were sufficient to make calculations of the aquifer transmissivity. Among the analytical methods used were the Jacobs time-drawdown method and the Theis curve matching method. In addition, the Jacobs distance-drawdown method, was used, however, the results were unsatisfactory due to a lack of sufficient distance-drawdown data. Since the time-drawdown data for the three observation wells were so similar, the data from MB-3, located 10 feet (3.05 m) from the pumped well, were chosen for a representative analysis. Drawdown curves and calculations are included in Appendix B.

Results of the aquifer tests are summarized in Table 4-1. Aquifer Test No. 1 indicated a transmissivity of 880,000 gpd/ft (0.127 m^2/s) using the Jacobs time drawdown method, and about 2,200,000 gpd/ft (0.312 m^2/s) using the Theis method. The computed storage coefficients were both greater than 1.0, much higher than the normal upper limit of feasibility of 0.3. These high storage coefficient values are unexplained but may have been the result of high recharge rates to the aquifer.

Aquifer Test No. 2. The data obtained in the second test were similar to those from the first, with somewhat greater drawdowns. The greatest recorded drawdown was 0.56 feet (0.17 m) measured in well MB-17, a distance of 10 feet (3.05 m) from pump well P-2, near the end of pumping. Water levels in all three wells declined continuously for the first 12 hours of pumping then seemed to reach a steady state condition. However, water levels in monitoring well MB-11, located 1115 feet (340 m) from the test well, showed a continuous decline for the duration of pumping.

During the recovery period following pumping, water levels in the observation wells showed only a partial return to their original positions. Theoretically, the recovery should have been complete. After four hours of recovery, levels had risen to within 0.12 to 0.16 feet (0.037 to 0.049 m) of the initial levels. Readings taken 24 hours after pumping showed that the recovery had reversed to a further decline with water levels dropping 0.05 feet (0.015 m). During the recovery period MB-11 initially recovered 0.01 feet (0.003 m) then slowly declined 0.09 feet (0.027 m) during the next 24 hours. Figure 4-9 compares the water level behavior of MB-11 with one of the observation wells, MB-15. MB-11 indicates very little effect from pumping since only slight recovery occurred. Instead, the decline in MB-11 probably represents a long term fluctuation independent of pumping.

In order to account for the long term change in water levels, the data for Test No. 2 were adjusted by assuming that the magnitude of change was constant from MB-11 to the other wells. The values of decline in MB-11 were subtracted from the corresponding time drawdown data of MB-15, MB-16, and MB-17. As an example, Figure 4-9 includes the adjusted data for MB-15.

The test data were analyzed using the Jacobs time drawdown method, the Theis curve matching method, and the Theis recovery method. The resulting drawdown curves and calculations are included in Appendix B. Both the unadjusted and adjusted data were plotted; the curves show that the adjusted data follow more exactly the expected logarithmic drawdown pattern.

Table 4-1

AQUIFER PUMP TEST RESULTS

	Observation Well Data Used	Method of Calculation	T (Transmissivity)	K (Permeability)	S (Storage Coefficient)
TEST NO. 1 (Pump Well P-1)	MB-3	Jacobs Time-Drawdown	8.8×10^5 gpd/ft ($0.127\ m^2/s$)	11,600 gpd/ft^2 (0.546 cm/s)	4.22
		Theis Method	2.2×10^6 gpd/ft ($0.312\ m^2/s$)	28,900 gpd/ft^2 (1.36 cm/s)	2.63
TEST NO. 2 (Pump Well P-2)	MB-15	Jacobs Time-Drawdown	8.00×10^5 gpd/ft ($0.115\ m^2/s$)	9300 gpd/ft^2 (0.439 cm/s)	0.010
		Theis Method	8.20×10^5 gpd/ft ($0.118\ m^2/s$)	9530 gpd/ft^2 (0.451 cm/s)	0.0078
		Theis Recovery	7.49×10^5 gpd/ft ($0.108\ m^2/s$)	8710 gpd/ft^2 (0.412 cm/s)	------
	MB-16	Jacobs Time-Drawdown	7.71×10^5 gpd/ft ($0.111\ m^2/s$)	9070 gpd/ft^2 (0.428 cm/s)	0.020
		Theis Method	8.11×10^5 gpd/ft ($0.117\ m^2/s$)	9540 gpd/ft^2 (0.450 cm/s)	0.0176
		Theis Recovery	7.44×10^5 gpd/ft ($0.107\ m^2/s$)	8750 gpd/ft^2 (0.413 cm/s)	------
	MB-17	Jacobs Time-Drawdown	6.86×10^5 gpd/ft ($0.099\ m^2/s$)	8140 gpd/ft^2 (0.383 cm/s)	1.29
		Theis Method	1.02×10^6 gpd/ft ($0.147\ m^2/s$)	12,100 gpd/ft^2 (0.571 cm/s)	0.508
		Theis Recovery	6.10×10^5 gpd/ft ($0.088\ m^2/s$)	7240 gpd/ft^2 (0.341 cm/s)	------

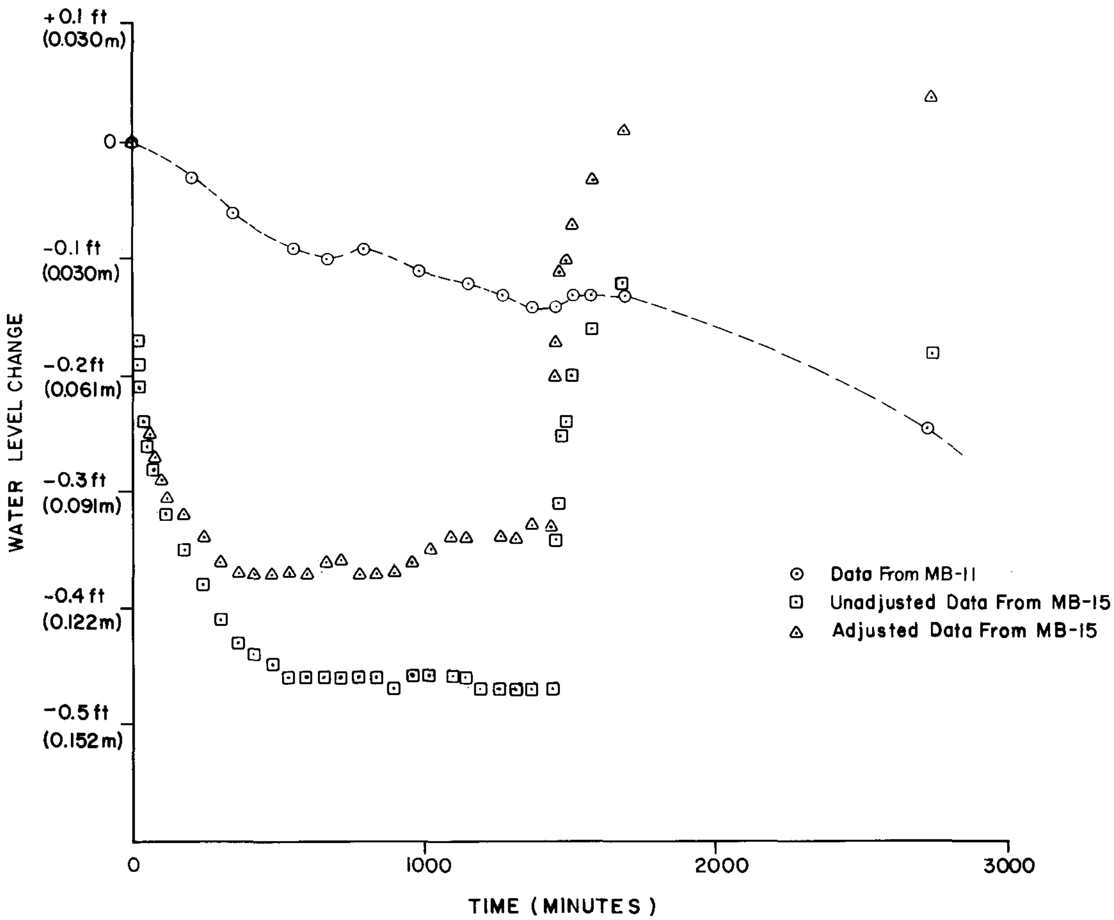


Figure 4-9. Adjustment of drawdown data for long-term water level changes.

Aquifer Test No. 2 proved to be more successful than Test No. 1 as a result of the accumulation of better quality data including the recovery data. Values of transmissivity are similar to those from the first test. The Jacobs time-drawdown method and the recovery method show a transmissivity for the aquifer of 600,000 to 800,000 gpd/ft (0.088 to 0.115 m^2/s). The Theis method produced similar transmissivity values in the range of 800,000 to 1,000,000 gpd/ft (0.118 to 0.147 m^2/s). The most consistent values computed for the storage coefficient are in the range of 0.01 to 0.02 as shown by the results for wells MB-15 and MB-16.

Overall, the results seem to indicate a transmissivity for the glacial outwash aquifer of between 600,000 to 1,000,000 gpd/ft (0.088 to 0.147 m^2/s). Based on the thickness of saturated aquifer at each test site, the permeability of the outwash is in the range of 7,000 to 12,000 gpd/ft^2, or 0.33 to 0.57 cm/s. The most consistent value is about 9,000 gpd/ft^2, or 0.43 cm/s. It is difficult to estimate an average value of storage coefficient for the outwash based on the results. The expected value would be approximately 0.1 assuming unconfined conditions. However, the most consistent result of 0.01 to 0.02 would seem to indicate semi-confined conditions rather than unconfined. This is a possibility in some areas of the aquifer since low permeability material for the most part overlies the aquifer.

BOREHOLE PERMEABILITY TESTS

Several borehole permeability tests were performed to estimate the permeabilities of various subsurface materials at the Conesville site. Borehole tests are somewhat similar to aquifer pumping tests with the major difference that water levels are measured only in the test well and observation wells are not needed. In addition, these tests are only representative of smaller portions of an aquifer. The tests at Conesville were performed during the installation of the monitoring wells in January and February, 1979. Figures 4-3 through 4-8 show the locations of the tests, the material tested, and the position with relation to the groundwater table.

Two methods of testing were used at Conesville. The first method was performed in silty soils and fly ash above the water table. Borehole casing was seated in the soil scheduled for testing and the casing was cleaned out completely by washing with water. The borehole casing was then filled with water to the top and free flow of water out of the open end of casing into the soil was allowed. After an initial saturation period, a constant head of water was maintained by adding just enough water to the hole to keep the water level at the casing top. By recording the rate at which water was added to the hole, the flow rate of water into the soil from the borehole under the constant head was determined. The soil permeability was then calculated using the following formula (2):

$$K = Q/5.5\ r\ H$$

where:

K = permeability in cm/s (ft/min),
Q = constant rate of flow into the hole in cm^3/s,
r = internal radius of casing in cm, and
H = constant head of water in hole in cm.

The second method was used in soils below the water table, primarily in the sand and gravel and basically gave results indicative of vertical permeabilities. Borehole casing was seated as before, but the soils were not washed from the bottom of the casing. This method also involved filling the cased borehole with water. However, rather than continuing to add water during the test to maintain a constant head, the water level was allowed to fall in the hole while recording the rate of fall. The following formula was then used to compute the soil permeability (3):

$$K = \frac{2\ \pi\ R + 11\ L}{11\ (t_2 - t_1)} \ln \frac{h_1}{h_2}$$

where:

K = permeability in ft/min (cm/s),
R = radius of the casing in ft,
L = thickness of soil in bottom of casing in ft,
t = time in min,
h_1 = differential head between water level in hole and water table for $t = t_1$ in ft,
h_2 = differential head for $t = t_2$ in ft.

Data plots and computations for all borehole tests are included in Appendix C.

A summary of the permeabilities as calculated from the borehole tests is shown in Table 4-2. As seen from the table, permeabilities were determined for the outwash sands and gravels, surface silt which covers a large part of the area surrounding

Table 4-2

RESULTS OF BOREHOLE PERMEABILITY TESTS

Well	Test Depth	Permeability									
		Sand & Gravel		Surface Silt		Fill		Fly ash & Silt		Fly ash	
		cm/s	ft/min	cm/s	ft/min	cm/s	ft/min	cm/s	ft/min	cm/s	ft/min
MB-4	3 ft (0.914 m)			1.95×10^{-5}	3.8×10^{-5}						
MB-4	25-26 ft (7.62-7.92 m)	3.7×10^{-3}	7.2×10^{-3}								
MB-7	25-26 ft (7.62-7.92 m)	4×10^{-3}	7.9×10^{-3}								
MB-10	11.5 ft (3.5 m)					5.6×10^{-4}	1.1×10^{-3}				
MB-10	35-36 ft (10.66-10.97 m)	2.8×10^{-3}	5.5×10^{-3}								
MB-12	5-6 ft (1.52-1.83 m)							3×10^{-5}	6×10^{-5}		
MB-12	35-36 ft (10.66-10.97 m)	1.4×10^{-2}	2.8×10^{-2}								
MB-12A	16.5-17.5 ft (5.03-5.33 m)									1.8×10^{-4}	3.6×10^{-4}
MB-15	3 ft (0.914 m)			1.7×10^{-4}	3.4×10^{-4}						
MB-14	25-26 ft (7.62-7.92 m)	1.9×10^{-3}	3.8×10^{-3}								

Note: Results for deep test at MB-12 and test in MB-15 are questionable.

the disposal site, fill material underlying the Poz-O-Tec, fly ash, and a fly ash-silt mixture found in parts of the ash disposal area. With the exception of the sand and gravel results, the tests indicate permeabilities which are consistent with the type of material. The tests performed in sand and gravel resulted in significantly lower permeabilities than the aquifer tests described in the previous section. There are at least two explanations for this difference. First, while aquifer tests primarily measure horizontal permeability, the borehole tests as performed in this study are more indicative of vertical permeability. Most layered soils such as the sand and gravel tend to have a lower permeability in the vertical direction. Second, there may be clogging effects due to sloughage of fines in a borehole test which may reduce the measured permeability. Aquifer test results are not affected by clogging at the borehole since observation wells are used for measurement. In actuality, the differences in measured permeability are probably the result of a combination of these factors.

WELL SAMPLING AND FIELD OBSERVATIONS

Beginning in late February, 1979 until mid April, 1979, water samples were acquired from wells MB-1 and MB-4 through MB-15 on a bi-weekly basis. Measurements of groundwater levels were taken weekly during this period. Water sampling was preceded by bailing each well to remove stagnant water which may have accumulated in the well, as recommended by the EPA (1). Once the well had been satisfactorily bailed, water samples were obtained from the shallow monitoring wells (those wells in which the groundwater surface was situated within the slotted casing interval) by simply using the bailer. In those wells where the slotted casing was significantly deeper than the groundwater surface, samples were obtained with the use of a 1-5/8 inch (0.04 m) Kemmerer style well sampler. This sampler was lowered into the well on a nylon line until the sampler was positioned within the slotted well casing. The sampler was then closed when triggered by way of a messenger (a weight with a hole in the middle for the nylon line) dropped from the ground surface. This method obtained a sample of water from within the slotted well casing at the desired sampling depth and prevented the influence of stagnant water that had not been removed by bailing prior to sampling.

Potential measurements in the monitoring wells were obtained with the use of an electric meter. Measurements were always taken prior to bailing for water sampling. In addition to potential measurements in the wells specifically installed for this investigation, elevations were continually noted at three points along the Muskingum River. The elevations of pooled water in the ash pond, holding pond, the plant outfall, and the water levels in the power station's Well 2 and Well 3 were also continually observed. The locations of the reference points for these measurements are illustrated on Figure 4-2. These data were collected for later geohydrologic interpretations including potentiometric surface contour maps to delineate the probable direction of leachate migration.

The results of the water quality analyses and respective interpretations are described in subsequent sections of this report. Figures 4-10 through 4-12 illustrate the potentiometric fluctuations noted in the monitoring wells as compared to the various river levels. Also shown on these figures are the observed surface water levels of the additional reference points monitored.

The graph of fluctations at monitoring well MB-1, shown on Figure 4-10, also represents the fluctuations which occurred at wells MB-2, MB-3, and P-2. The potentiometric levels in these four wells never varied by more than 0.1 foot (0.030 m). Similarly, the data for monitoring well MB-4 represents that of well MB-5 and the graphs for the fluctuations in wells MB-7, MB-10, MB-12, and MB-14 represent the fluctuations of the other wells in the same cluster. A summary of the actual potential elevations for all points monitored is included in Appendix D. These data, combined with observations during installation of the monitoring wells, indicate that perched water conditions do not occur in the vicinity of the study site.

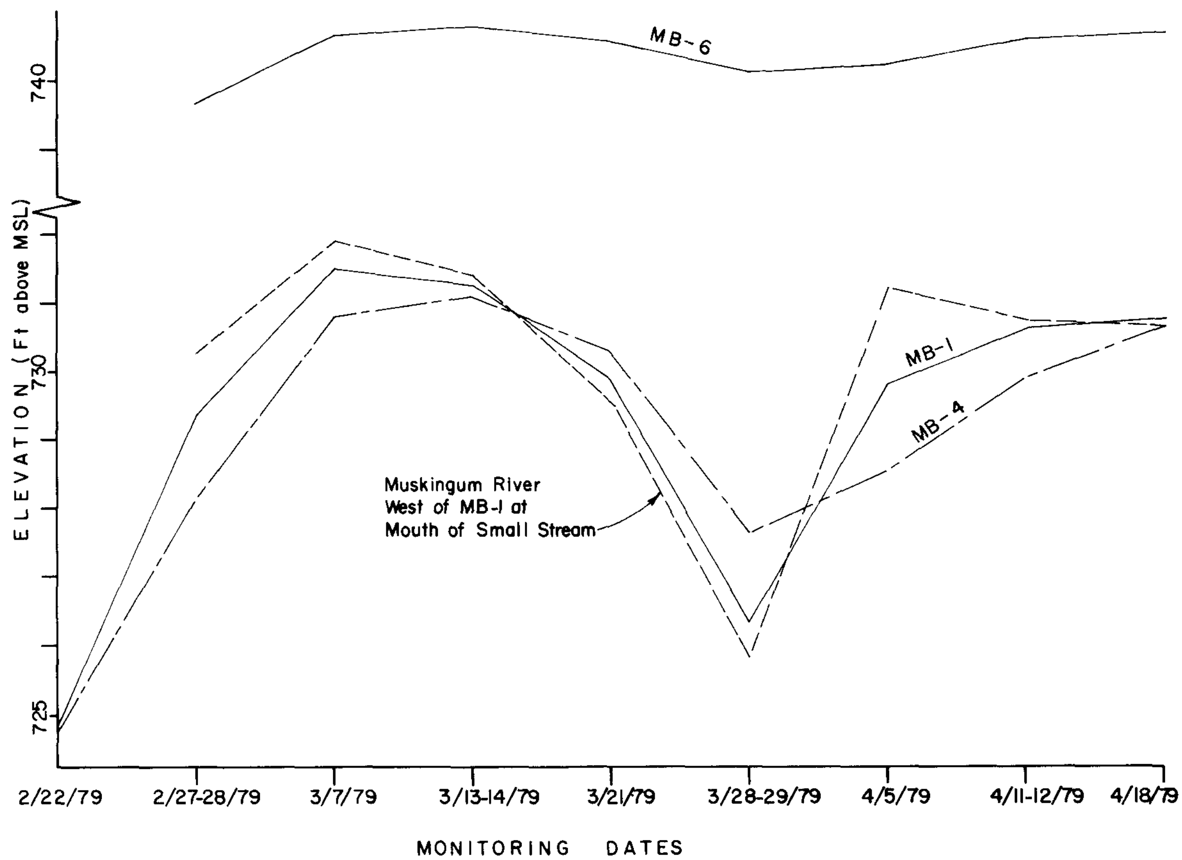


Figure 4-10. Observed Water Level Fluctuations - Northern Plant Area

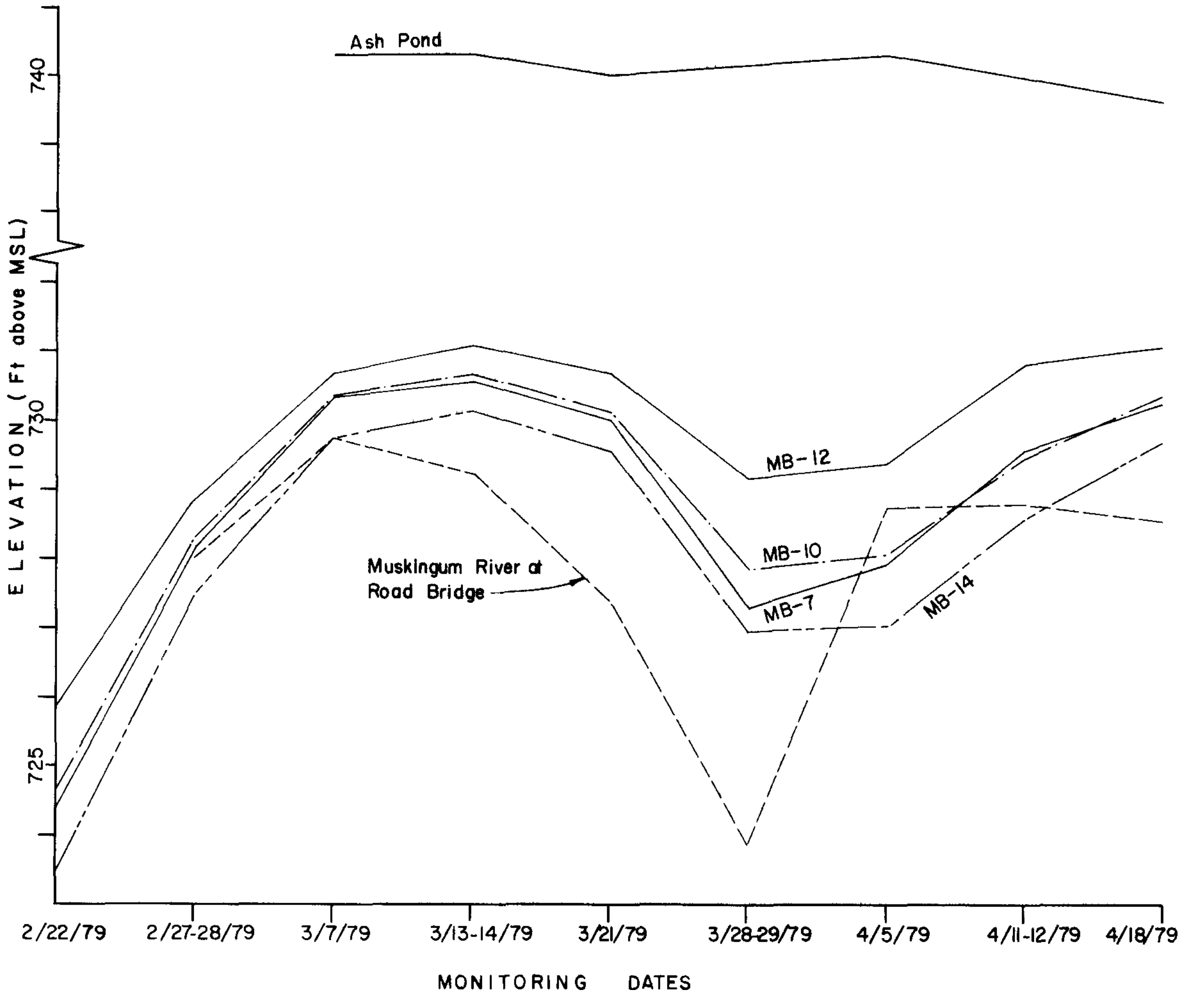


Figure 4-11. Observed Water Level Fluctuations - Central Plant Area

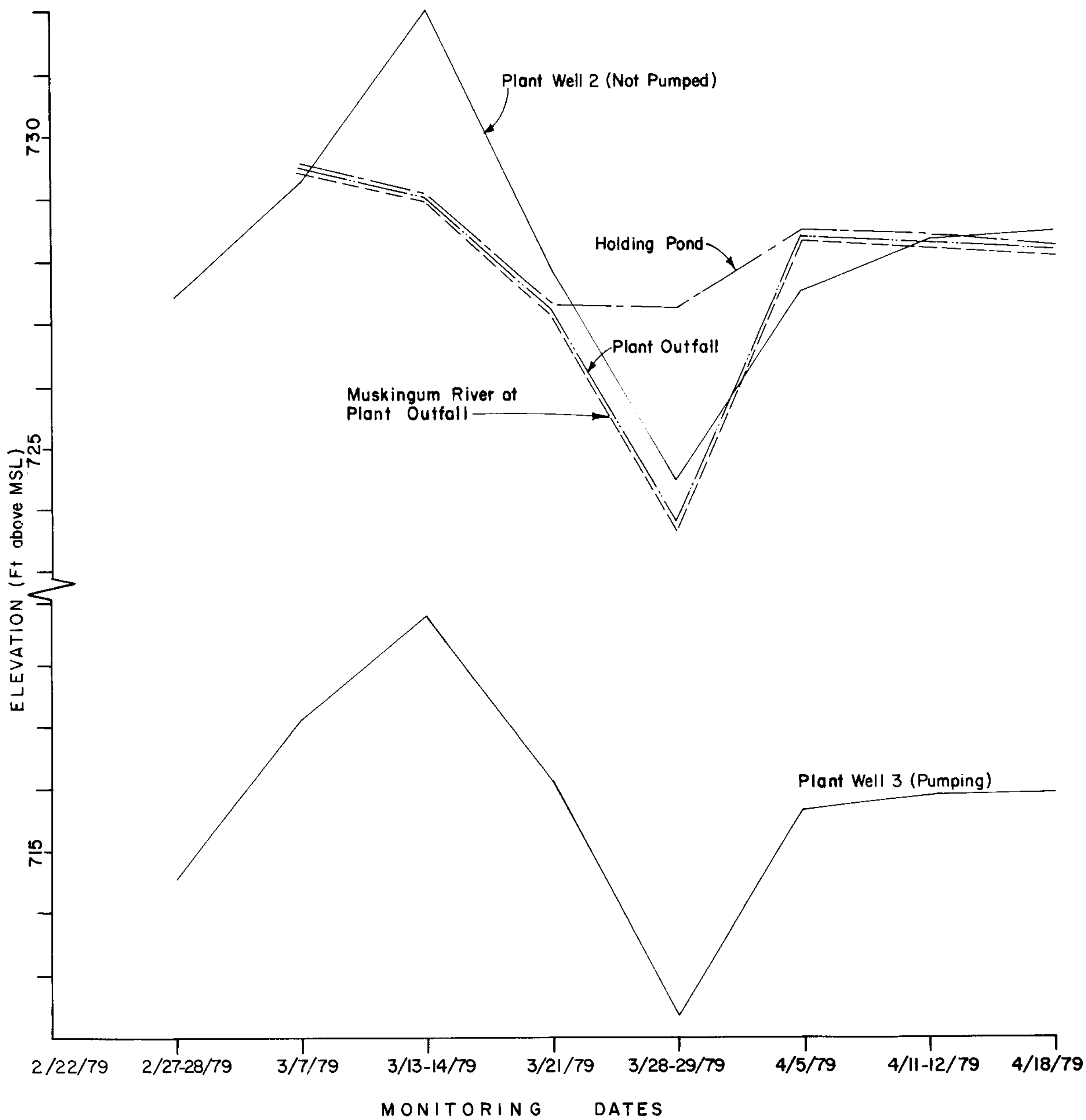


Figure 4-12. Observed Water Level Fluctuations - Southern Plant Area

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2. U.S. Department of the Interior. Bureau of Reclamation. Earth Manual. Washinton, D.C.: Government Printing Office, 1974, pp. 573-575.

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Section 5

GEOHYDROLOGIC INTERPRETATIONS

Section 5

GEOHYDROLOGIC INTERPRETATIONS

POTENTIOMETRIC SURFACE CONFIGURATION AND FLUCTUATION

The Muskingum River is the primary influence on the groundwater levels in the vicinity of the study area. It is also a primary source of recharge to the valley outwash groundwater system. This relationship is shown by Figures 4-10 through 4-12. All of the monitoring well fluctuations mirror respective river changes in at least a subdued manner. The least effects were observed at well MB-6 and the monitoring wells in the ash pond due to a combination of factors. With increased distance from the river, as compared to the other observation wells, there is a respective lag in response to river level changes. Also, significant secondary recharge points exist in the vicinities of these wells. Recharge in the vicinity of well MB-6 is due to the stream which drains the watershed north of the disposal areas. Because of the constant inflow of water, the ash pond serves as another groundwater recharge area.

Flow in the stream above well MB-6 was measured on one occasion during April, 1979 as being approximately 1370 gpm (0.087 m^3/s). Groundwater recharge along this stream course should be substantial from percolation through the anticipated terrace sand and gravel deposits. Estimates of water loss in the ash pond were attempted on three occasions. During the first attempt, no water loss was detected. Water losses of 1650 and 3003 gpm (0.104 and 0.19 m^3/s) over the entire pond were estimated during the subsequent measurements which must be attributed to combined evaporation and infiltration. The annual evaporation rate of water from open water surfaces around Conesville is estimated as 32.5 inches (0.825 m) (1). For the area of pooled water in the ash disposal facility, approximately 32 acres (13 hectares), the average evaporation rate calculates as only 53 gpm (0.003 m^3/s).

From the start of this investigation, local groundwater mounding was expected in the areas of these secondary sources of recharge. Other assumed controls of groundwater levels are the swamp just to the south of the ash disposal area, the holding pond, and the plant outfall channel. Groundwater levels in the immediate vicinities of these surface water features probably correspond with their respective water surfaces, considering the large volumes of water which continually run through these areas.

An average 11,000 gpm (0.7 m^3s) of water was measured discharging from the ash-pond into the swamp during the measurements to determine water loss in the ash pond. This water flows into the holding pond and is in turn released to the plant outfall channel or recirculated.

During the field monitoring period, the Muskingum River fluctuated by 5.96 feet (1.82 m) in the vicinity of the power station outfall to 6.37 feet (1.94 m) near the mouth of the small stream situated west of well MB-1. The lowest river level measured was elevation 723.44 near the power station outfall in late March, 1979. From general observation, this level is expected to only drop an additional 5 feet (1.52 m) maximum, which should correspond with the low flow along the Muskingum. The highest river level measured was elevation 731.99 at the northern river reference point during early March, 1979. According to the Huntingdon District Corps of Engineers, the maximum flood on record occurred in March, 1913 reaching an elevation of 746.2 in the approximate area where the county road bridge crosses the Muskingum River. More than a dozen flood control dams, now located in the Muskingum River system upstream of Conesville, insure that such a flood should not occur again. Considering these known fluctuations, groundwater levels close to the river should not drop below approximately elevation 718 during low flow periods. High groundwater levels near the river will correspond with the high river levels which are controlled by the flood control facilities located upstream.

Prior to the completion of the monitoring activities, hand auger holes were drilled within the ash disposal area to check the premise that the potentiometric surface mounded significantly beneath the ash pond. Excessive mounding seemed unlikely because the ash permeability was low in comparison to the underlying aquifer, according to the borehole permeability test results (see Table 4-2). This consideration was important because the configuration and extent of the resulting mound was expected to be a controlling factor in the direction of potential leachate migration from the adjacent Poz-O-Tec area. Figure 5-1 illustrates the positions of hand auger holes which were drilled in a line extending northwestward from the edge of water near the ash pond reference point and respective water levels noted. Additional holes drilled north of the ash pond reference point revealed saturated conditions very close to the surface which was expected considering the locations of the ash pond inflow points. The data obtained by drilling these auger holes confirms that mounding occurs. The surrounding potentiometric surface rises gradually to a zone approximately 15 feet (4.57 m) outside of the edge of pooled water or saturated areas.

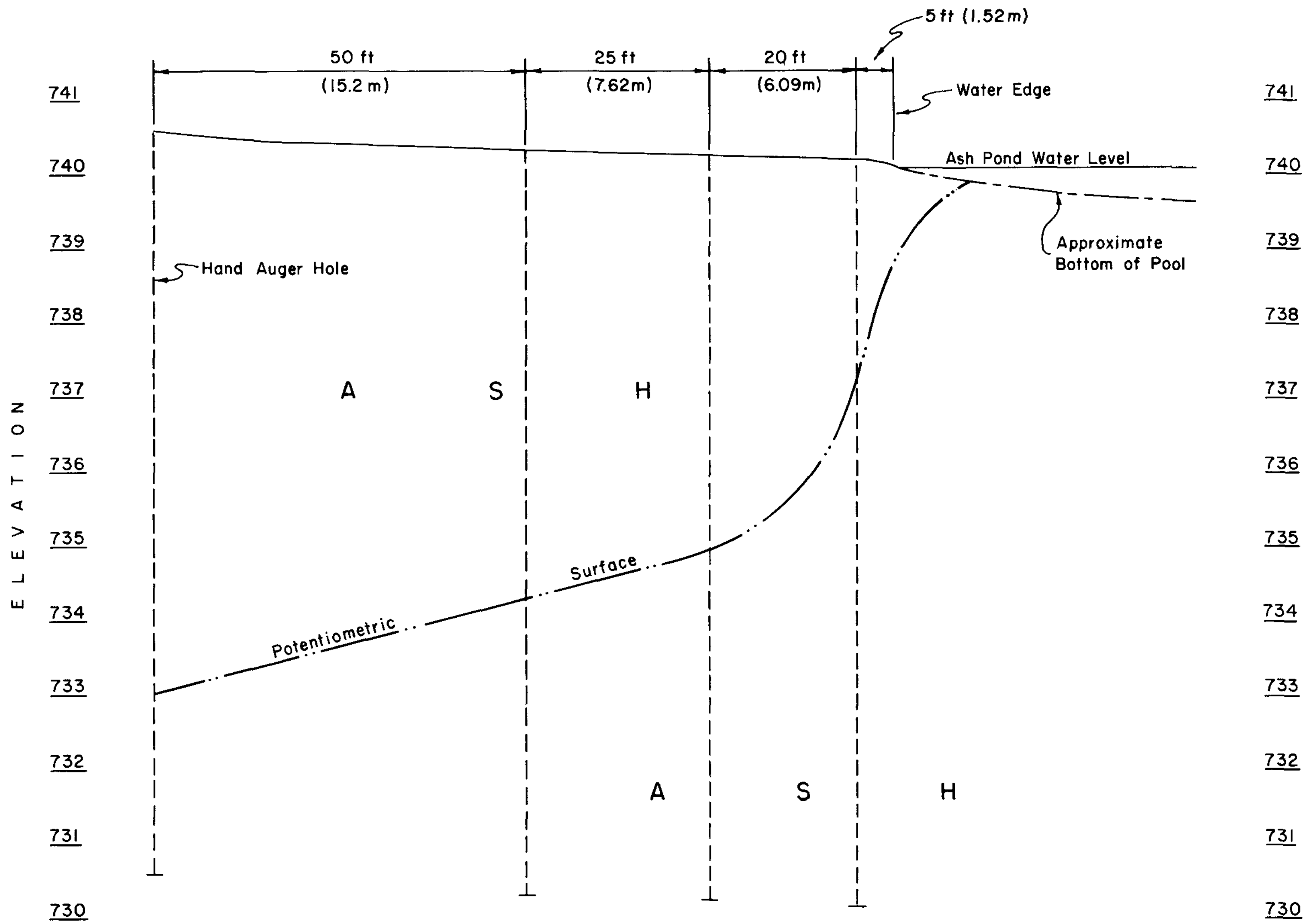


Figure 5-1. Potentiometric surface in the immediate vicinity of the ash pond.

Within this zone, the potentiometric surface steepens significantly and extends to the approximate surface of pooled water which generally is maintained at about elevation 740±. The elevation of this pool is the maximum groundwater level which can occur close to the Poz-O-Tec disposal area.

A contour map of the potentiometric surface for the groundwater levels observed on April 18, 1979 is included as Figure 5-2. This contour plot is typical of seasonally high groundwater conditions. The groundwater levels for this date are not the highest observed during the monitoring period, however, this set of data is the most complete and provided the best control for contouring. A cross section has been developed through the disposal areas along the line indicated on Figure 5-2 and is included as Figure 5-3. This cross section illustrates the estimated subsurface details below the sludge disposal and ash sluice areas, and the potentiometric surface at the time of the April 18 measurements. The absence of the alluvial surface silt, which is typically present about the site, is shown. As explained earlier in the report, this material was used as borrow for the construction of the disposal area dikes. The potentiometric surface is expected to remain essentially the same year round on the eastern side of the ash pond. To the west of the pond, groundwater levels were measured 5.3 feet (1.6 m) lower at well MB-13 and 5.8 feet (1.8 m) lower at well MB-11. Regardless of the fluctuations which occur at these two wells, controlled primarily by the Muskingum River, the potentiometric surface likely always rises to the level of ponded supernatent. Figure 5-4 is a contour plot of the estimated potentiometric surface compiled from the data of February 22, 1979, when the area groundwater levels were at their measured lowest.

The observed fluctuation of groundwater levels appears to make little difference in the direction of groundwater flow beneath the Poz-O-Tec area. The predominant direction of flow is westward, turning slightly northwest near the north end of the Poz-O-Tec area to slightly southwest at the south end.

ANTICIPATED LEACHATE QUANTITY AND CHARACTERISTICS

Quantity

The formation of leachate from a waste material is dependent upon the amount of water in contact with the waste. According to recent investigations (2), since Poz-O-Tec is placed in a relatively dry condition, the only mechanisms which bring water into contact with Poz-O-Tec are permeation, surface runoff, and groundwater contact. The Poz-O-Tec landfill lies largely above the existing groundwater table with the

Figure 5-2. Approximate potentiometric surface during typical seasonally high conditions

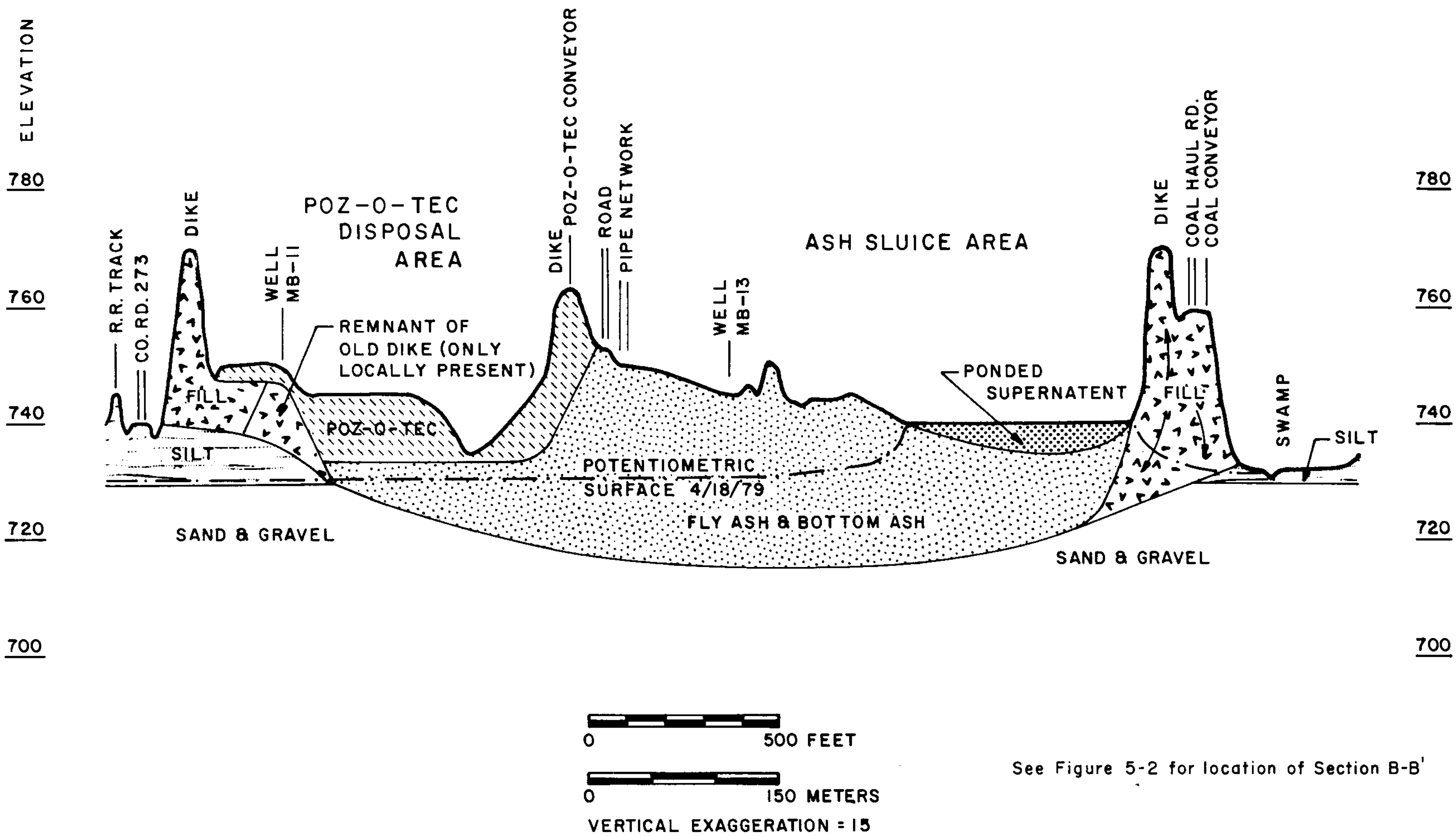
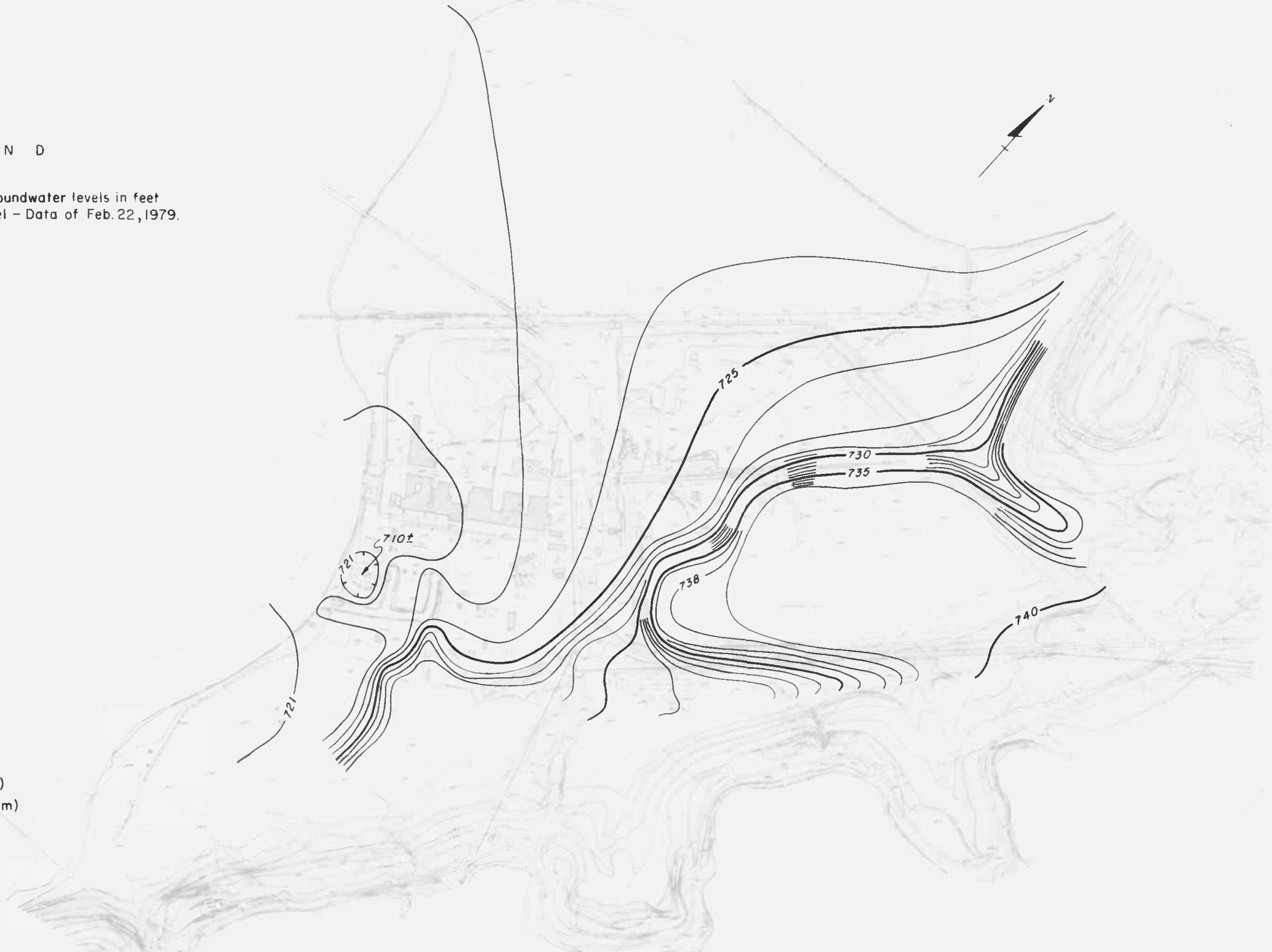


Figure 5-3. Cross Section B-B' Through Disposal Areas

exception of the northern area where the intermittent pond results with high river levels. Thus, only permeation and runoff need be considered in predicting leachate volume. Figure 5-5 is a schematic diagram of the Poz-O-Tec disposal site showing the processes by which Poz-O-Tec leachate is produced.

The relative volumes of permeation leachate and runoff leachate produced by the average annual rainfall (40 in/yr (1.02 m/yr)) will depend upon a number of factors including the permeability of the Poz-O-Tec. According to laboratory tests performed by an independent testing firm for IUCS (2), the Conesville Poz-O-Tec has a permeability of 9.3×10^{-7} cm/s. Theoretically, given this permeability, if the Poz-O-Tec were completely saturated throughout the year, the rate of permeation would be approximately 840 gpd (3.7×10^{-5} m^3/s) per acre (0.4 hectare) as shown in Figure 5-6. This is the maximum rate allowed by the Poz-O-Tec considering this permeability. The actual rate of permeation through the Poz-O-Tec is probably much lower. A rough estimate of the actual rate can be obtained by assuming 120 days of rainfall per year during which saturation of the Poz-O-Tec can take place. The effective permeation rate would thus be decreased by approximately two-thirds to 280 gpd (1.2×10^{-5} m^3/s) per acre (0.4 hectare), corresponding to about 10% of the annual precipitation as shown in Figure 5-6. This rate, in fact, is probably still too high since work by IUCS indicates permeation can be neglected for permeabilities less than 10^{-6} cm/s, the reason being that many years of travel time are required for water to pass through even a few feet of such a low permeability material. The actual rate of permeation should be between 0 and 280 gpd per acre. Taken over 20.7 acres (8.38 hectares) of Poz-O-Tec as estimated from the site map, the total volume of leachate produced from permeation is between 0 and 5800 gpd (0 to 2.5×10^{-4} m^3/s).

Most of the remaining portion of annual rainfall will become surface runoff leachate and eventually seep through exposed sand and gravel at the north end of the disposal area until the Poz-O-Tec liner has been completed. Although evaporation will remove part of the runoff, this may be neglected since the remaining leachate is concentrated by evaporation. Thus, assuming 90% of the annual precipitation becomes runoff, the volume of runoff leachate produced is about 2500 gpd (1.1×10^{-4} m^3/s) per acre (0.4 hectare) of Poz-O-Tec. Taken over 20.7 acres (8.38 hectares) of Poz-O-Tec and assuming surface inflow from outside the Poz-O-Tec area is minimal, the total rate of leachate production from runoff is 52,000 gpd (2.3×10^{-3} m^3/s). When the Poz-O-Tec liner in the disposal area is completed, sump pumps will be installed which will collect the runoff that will then be discharged into the ash pond.



L E G E N D

725 Contour of equal groundwater levels in feet above mean sea level – Data of Feb. 22, 1979.

0 1000 2000 Feet

0 500 Meters

Topographic Contour Interval 5 feet (1.52m)
Groundwater Contour Interval 1 foot (0.305m)

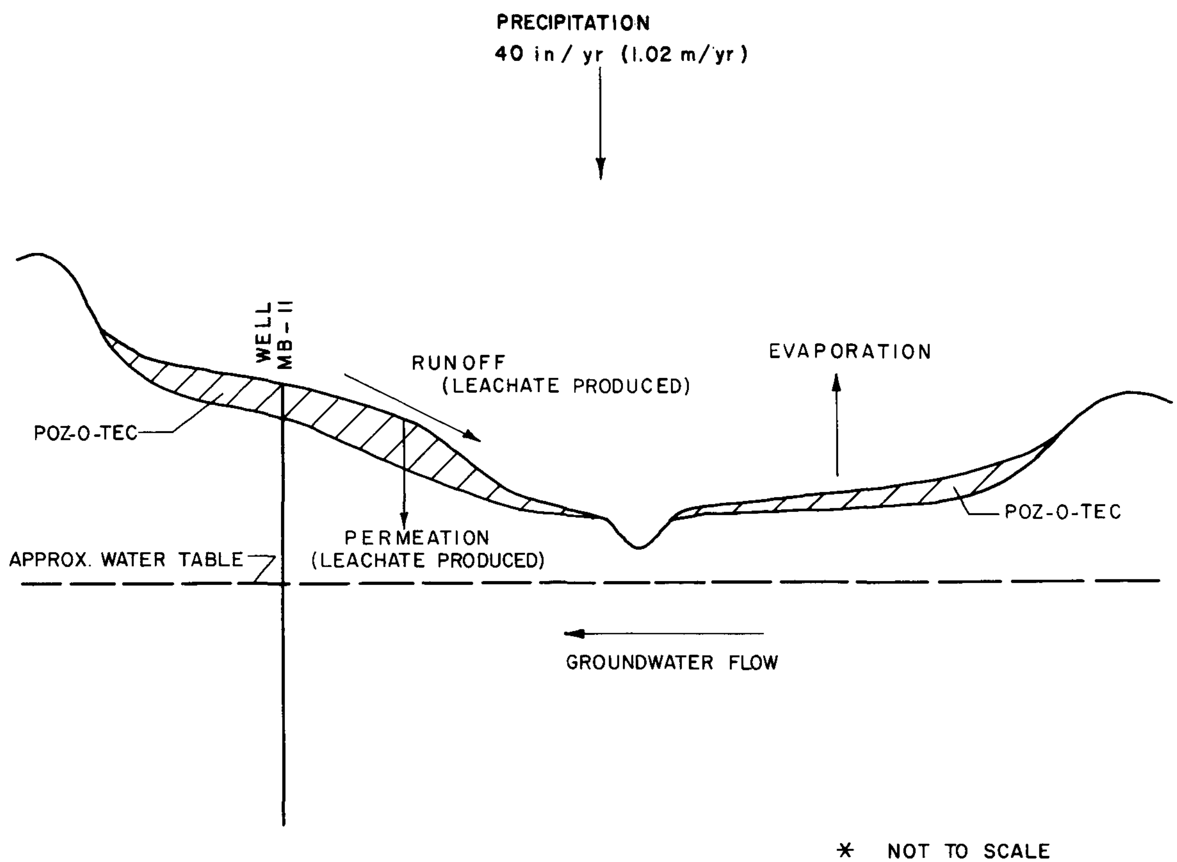


Figure 5-5. Schematic diagram of the Poz-O-Tec area showing pertinent hydrologic processes.

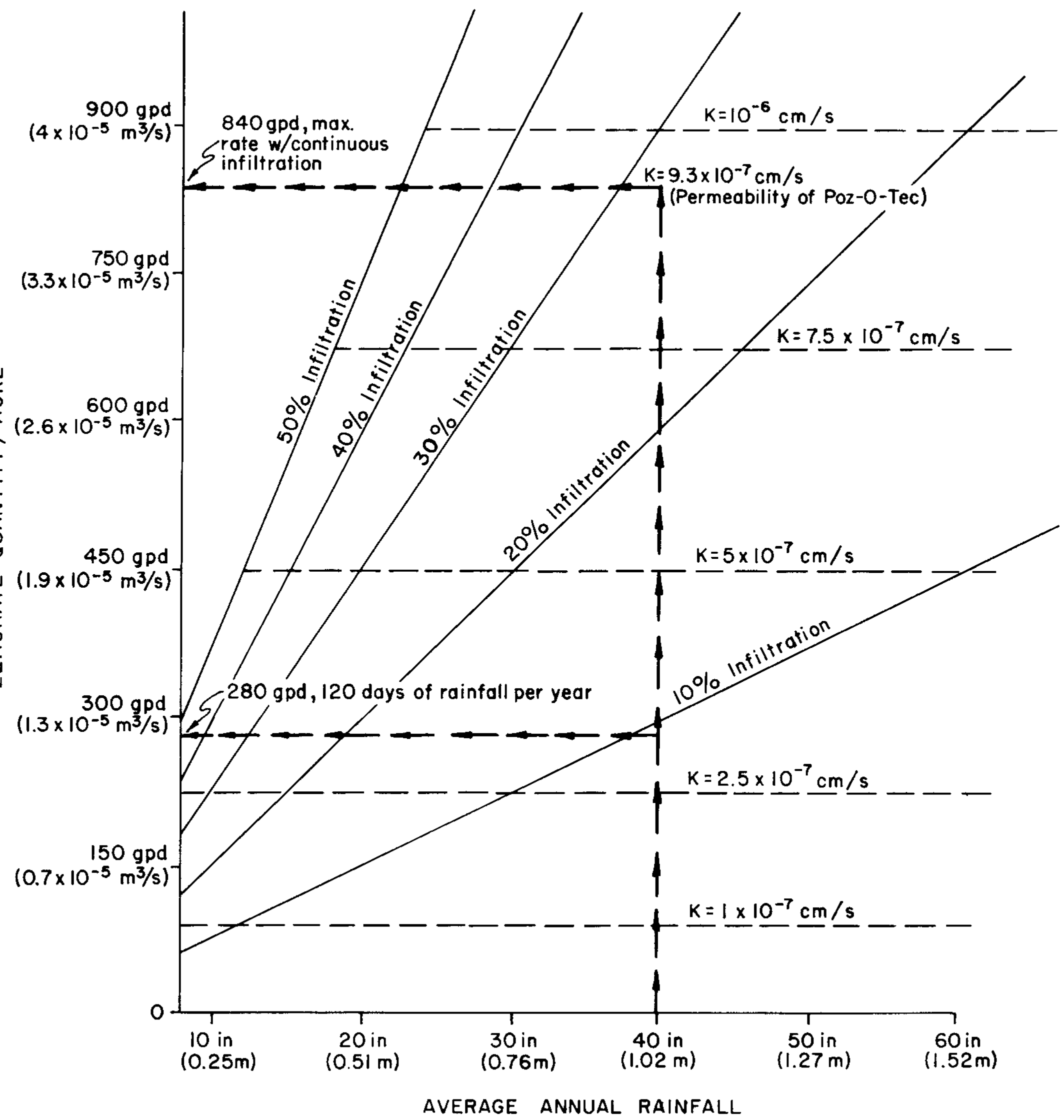


Figure 5-6. Quantity of leachate as a result of Poz-O-Tec permeation.

In addition to the Poz-O-Tec, leachate must also be considered from the ash disposal area. Ash leachate is produced by infiltration of precipitation, by surface runoff from the portions of the ash disposal area situated above drainage, and by permeation of runoff and supernatent pooled in portions of the ash pond. The permeation of ponded water is by far the most significant of these three sources, and consequently the other two will be neglected.

Since a continuous supply of water is available in the ash pond for leaching, the rate of leachate production will depend on the permeability of the ash underlying the pond along with the hydraulic head forcing water through the ash. Thus, Darcy's Law may be used to estimate the flow of leachate from the ash pond. Darcy's Law states that:

$$Q = K\ (\Delta h/\Delta L)A$$

where, in the case of the simplified ash pond of Figure 5-7,

Q = rate of leachate production in cm^3/s (m^3/s) (gpd),
K = permeability of the fly ash in cm/s,
$\Delta h/\Delta L = i$ = hydraulic gradient in cm/cm,
A = area of the ash pond in cm^2.

In using this formula, it is assumed that flow through the ash is both saturated and vertical.

Figure 5-7 illustrates the calculation of leachate production using Darcy's Law. The fly ash permeability, 10^{-4} cm/s, is known from borehole tests as described in Section 4. The area of the ash pond, 32 acres (12.96 hectares), where water is impounded was estimated from the site map. The values of Δh and ΔL are less easily defined, however, it is apparent from Figure 5-7 that if the pond depth is small compared to the ash thickness, the gradient $\Delta h/\Delta L$ will be close to 1. The average water depth is believed to be only a few feet, whereas, 29 feet (8.8 m) of fly ash was encountered during the drilling of well MB-13.

If a gradient of 1 is assumed, the rate of leachate production from the ash pond can be obtained from Figure 5-8. As seen from the chart, a permeability of 10^{-4} cm/s and a gradient of 1 corresponds to a leachate volume of 75,000 gpd (3.3×10^{-3} m^3/s) per acre (0.4 hectare) of pond. The water loss measurements described in the

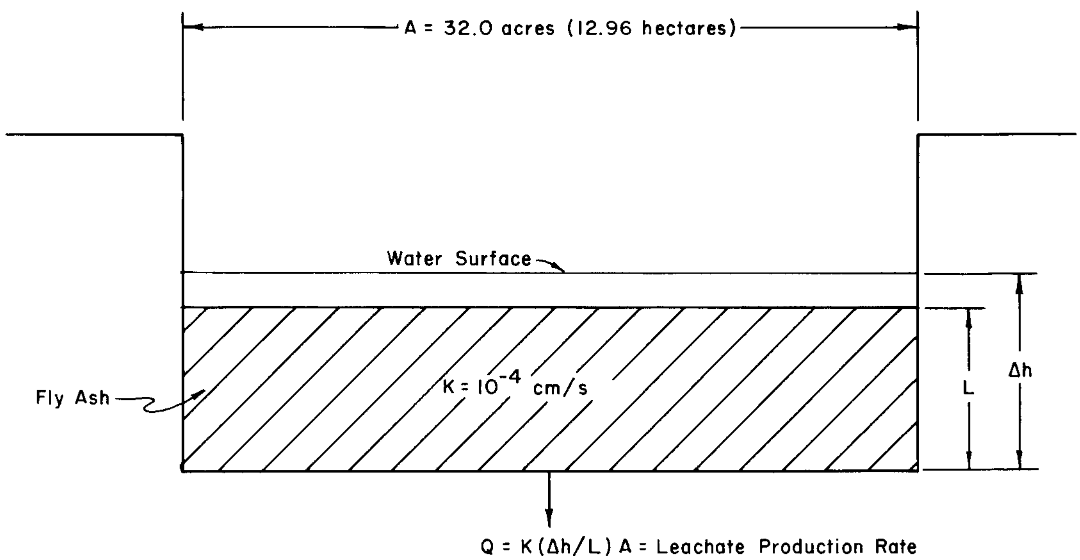


Figure 5-7. Computation of leachate production from ash pond permeation using Darcy's Law.

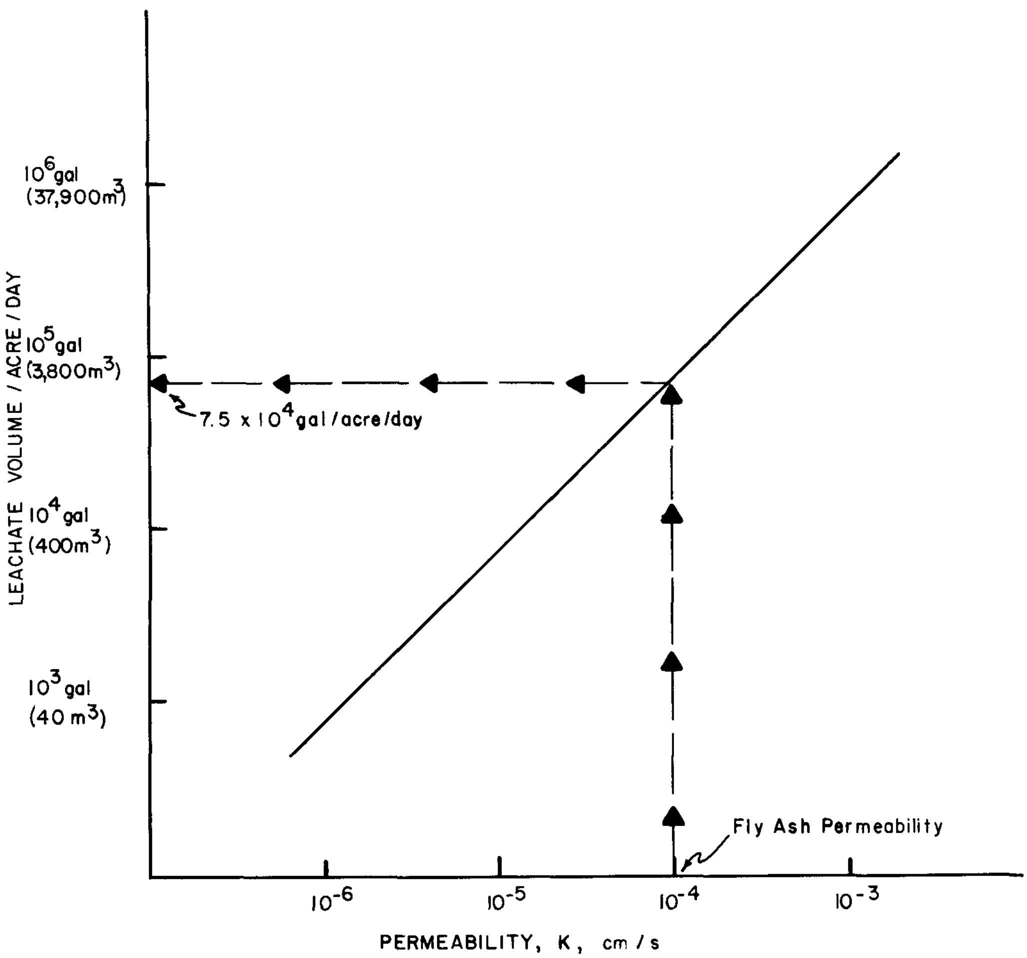


Figure 5-8. Effect of permeability on the volume of leachate from a pond.

beginning of Section 5 for the ash pond area would result in leachate volumes of 72,000 to 133,000 gpd (3.2 to 5.8 x 10^{-3} m^3/s) per acre (0.4 hectare) which shows that this estimate is in fair agreement. Considering the pond covers roughly 32 acres (12.96 hectares), the total estimated rate of ash leachate production is 2,400,000 gpd (0.105 m^3/s). This quantity is actually minimal compared to the amount of contaminated water which discharges through the ash pond outfall to the adjacent swamp to the east, then to the holding pond, and into the plant outfall channel. This quantity is approximately 15.8 million gallons per day (0.69 m^3/s). A fair proportion of this water can be expected to be lost through permeation. Table 5-1 compares leachate quantities estimated for the Poz-O-Tec and the ash pond.

Table 5-1

ESTIMATED LEACHATE PRODUCTION FROM
POZ-O-TEC AND THE ASH POND

Source	Production Per Acre	No. of Acres	Total Production
Poz-O-Tec:			
Permeation	0-280 gpd (0-1.2 x 10^{-5} m^3/s)	20.7 (8.38 ha)	0-5800 gpd (0-2.5 x 10^{-4} m^3/s)
Surface Runoff	2500 gpd (1.1 x 10^{-4} m^3/s)	20.7 (8.38 ha)	52,000 gpd (2.3 x 10^{-3} m^3/s)
Ash Pond:	75,000 gpd (3.3 x 10^{-3} m^3/s)	32.0 (12.96 ha)	2,400,000 gpd (0.105 m^3/s)

Quality

A complete discussion of the Poz-O-Tec process and the contributing factors for potential leachate is provided in Section 2. The quality of Conesville leachate is not specifically known since no tests have yet been performed. However, the potential leachate quality can be roughly estimated from background data including the reported range of concentrations of constituents in scrubber sludge liquors (Table 2-4), the quality measured for Conesville fly ash leachate (Table 2-1), and the Conesville ash pond and holding pond water qualities (Tables 2-2 and 2-3). At present, insufficient documentation supports an arbitrary halving of the concentrations of major constituents produced by these sources to predict leachate quality after fixation, as might be considered in light of observations by Aerospace Corporation explained in Section 2.

Table 5-2 summarizes runoff test results conducted by IUCS on Poz-O-Tec samples (not Conesville samples). These runoff tests are considered by IUCS to be more representative of expectable leachates than tests where forced leaching is done. All chemical constituents tested during these runoff tests are within recommended drinking water limits. Additional laboratory testing has been conducted by IUCS, including shake tests and runoff tests (Tables 5-3 and 5-4), in which much higher concentrations of total dissolved solids were noted from fresh Poz-O-Tec samples. The highest level reported was 2240 ppm which dropped significantly with increasing sample age (3).

From the above sources, it is apparent that the major constituents of Conesville leachate are most likely calcium, sulfate, sulfite, chloride, sodium, and magnesium. Trace metals in the leachate, which are contributed primarily from fly ash, could consist of elevated concentrations of iron, boron, copper, lead, zinc, nickel, and arsenic as shown from the fly ash leachate results. Although the Conesville fly ash produces a leachate with a low pH, an alkaline pH probably results from Conesville Poz-O-Tec because the FGD scrubber liquor should be alkaline. In addition, lime is added during the IUCS fixation process. Table 5-2 shows that runoff tests on Poz-O-Tec (non-Conesville) performed by IUCS resulted in leachates with pH from 7.4 to 9.8.

Leachates produced by the Poz-O-Tec at Conesville from infiltration and from surface runoff should be chemically similar but different in concentration. Tables 5-2, 5-3 and 5-4 show results from runoff tests and shake tests performed on Poz-O-Tec by IUCS. The shake test results (Table 5-3) show that as surface salts are dissolved by repeated washings, an equilibrium quality of about 200 ppm of total dissolved solids is produced (4). The runoff results shown in Table 5-2 and Table 5-4 also indicate qualities within this range of total dissolved solids for tests performed on aged samples. On the other hand, the leachate derived from infiltration should be much more concentrated. In fact, since the time of contact between the leachate water and the Poz-O-Tec is probably many years, the leachate most likely reaches the solubility limit of Poz-O-Tec. IUCS reports that the limit of solubility of Poz-O-Tec (non-Conesville) was about 5000 ppm of total dissolved solids as determined from shake tests (4). Of course, Conesville leachate probably differs from this somewhat since Poz-O-Tec chemistry varies according to the specific operation.

Table 5-2

RESULTS OF RUNOFF TESTS ON TWO STABILIZED
SLUDGE SAMPLES SHOWING IMPROVEMENT AS THE RESULT OF AGING

Volume Equivalent to Two Inch Rainfall in 60 Minutes
(all results except pH in ppm)

Constituent	Immediate		14 Days	
	Sample A	Sample B	Sample A	Sample B
pH	8.6	9.8	7.4	7.6
p'thn. Alkalinity	10.	10.	0.	0.
MO Alkalinity (Total)	230.	150.	30.	20.
Hardness	260.	250.	120.	20.
SO_3	10.	30.	5.	5.
SO_4	117.	196.	27.	16.
Cl	276.	10.	66.	6.
Total Dissolved Solids (Meter)	420.	330.	220.	60.
Al	.2	3.	--	< .1
As	< .002	.035	--	< .002
Ca	100.	100.	44.	8.5
Cd	< .01	.005	< .01	< .01
Cr	< .05	< .05	--	< .05
Cu	.03	< .02	--	.07
Fe	< .1	< .1	< .1	< .1
Hg	--	--	--	--
K	3.1	.20	3.8	.74
Mg	.05	.08	.06	.04
Mn	< .02	< .02	--	< .02
Na	7.2	1.00	3.7	.63
Pb	< .05	< .05	< .05	< .05
Sn	< 1.	< 1.	--	< 1.
Ti	< 1.	< 1.	--	< 1.
Zn	< .05	< .02	--	< .05
Total Solids	440.	400.	200.	110.

Source: IU Conversion Systems Laboratory Data.

Table 5-3

POZ-O-TEC LEACHATE FROM SUCCESSIVE SHAKE TESTS

TDS (ppm)	Grams Leached	Grams/in^2
974	1.948	0.046
338	0.676	0.015
268	0.536	0.012
194	0.388	0.009
214	0.428	0.010

Surface area = 42.4 in^2 (0.027 m^2)
Dilution ration (in^2/L) = 21.2:1

Source: H. Mullen, L. Ruggiano, and S. Taub. "Converting Scrubber Sludge and Fly-ash into Landfill Material." Pollution Engineering, May 1978, pp. 71-74.

Table 5-4

RUNOFF RESULTS FROM POZ-O-TEC SAMPLES

Age of Poz-O-Tec	TDS (ppm)
Immediate	2240
7 Days	588
28 Days	439

Source: H. Mullen, L. Ruggiano, and S. Taub. "Converting Scrubber Sludge and Flyash into Landfill Material." Pollution Engineering, May 1978, pp. 71-74.

RESULTS OF WATER QUALITY ANALYSES

Figures 5-9 through 5-25 have been compiled to facilitate comparisons of the actual groundwater quality determined for the various monitoring wells as a result of the short term monitoring program. The figures illustrate the consistency of the data and show trends in water quality. Existing or recommended drinking water concentration limits are included on the figures for comparison. The specific laboratory data is included in Appendix E for reference.

As anticipated, groundwater contamination has not occurred in the area of background well MB-1 (refer to Figure 4-2 for monitoring locations). Of the chemical constituents tested, all concentrations are within the existing or proposed limits for drinking water quality. Water quality at well MB-6 is largely the same, however, on one occasion the total iron concentration was 19 times higher than the proposed EPA limit, the mercury level was 1.4 times the EPA maximum allowable, and the selenium concentration was 6 times the recommended level. It is believed that this low level contamination may be related to strip mining which has occurred in the small watershed north of the disposal area.

The ash pond has had the greatest overall effect on general groundwater quality in the vicinity of the disposal facilities at Conesville (see Figure 2-1 for site features). Unacceptable levels (with respect to WHO, USPHS, and/or EPA standards) of calcium, pH, acidity, total dissolved solids, sulfate, and total iron were noted at monitoring wells MB-12 and MB-13 which are situated directly within the ash sluice area. These concentrations are significantly higher than the background levels at monitoring wells MB-1 and MB-6. Contaminants have apparently migrated westward from the ash pond and are affecting the Poz-O-Tec wells (MB-10 and MB-11) and all of the monitoring wells which are located west of the Poz-O-Tec disposal area. Some attenuation or dilution of the contaminate levels occurs during migration because the concentrations of chemical constituents are generally lower in all but wells MB-14 and MB-15. However, the reduced concentrations are still in excess of recommended drinking water standards.

The monitoring wells situated within the Poz-O-Tec area, MB-10 and MB-11, do not indicate that leachate is being produced by the fixed FGD sludge. The levels of chemical constituents noted in these wells were consistently equal to or lower than the respective levels caused by and emmanating from the ash pond. However, Poz-O-Tec was not deposited in the vicinities of wells MB-10 and MB-11 until relatively

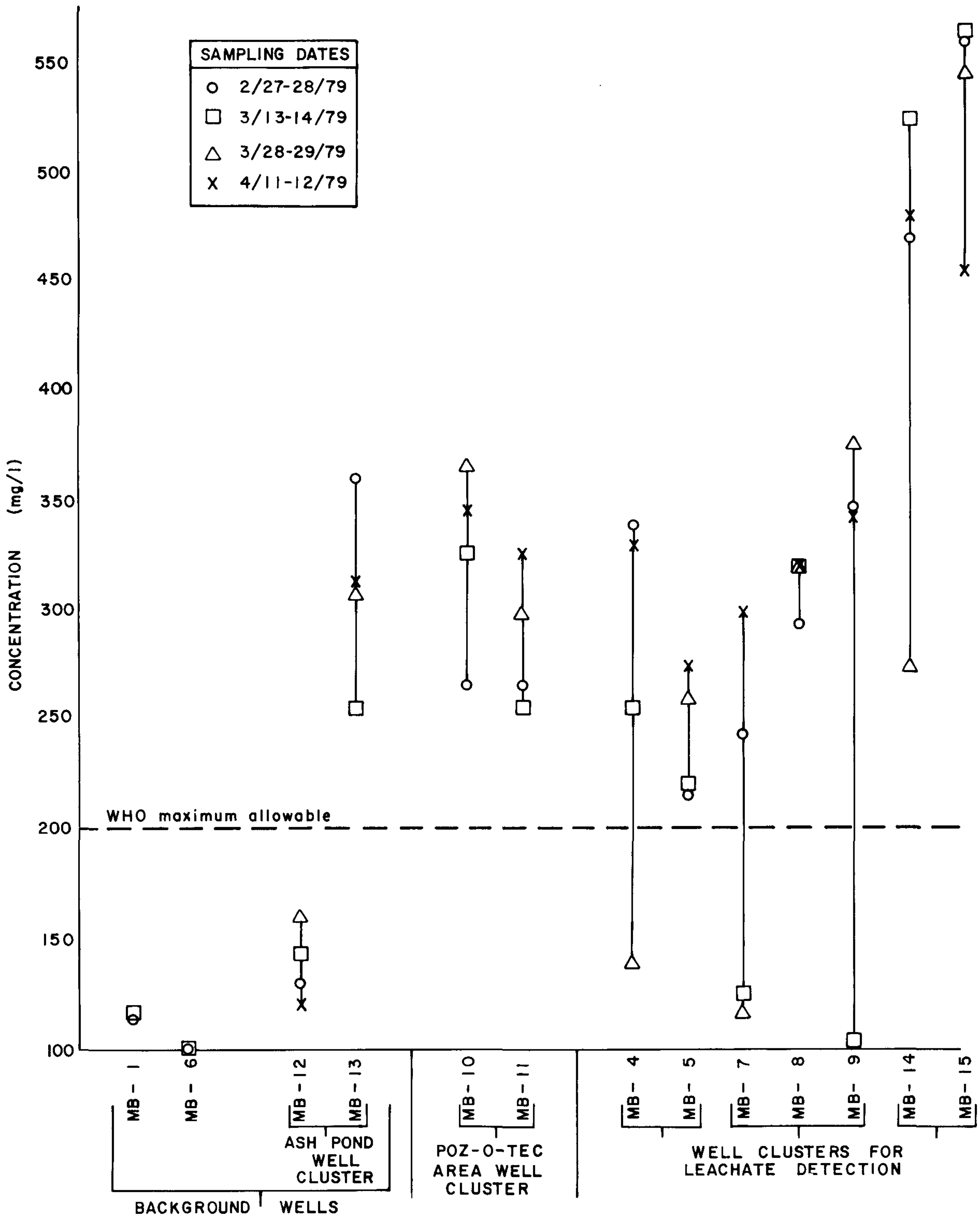


Figure 5-9. Observed Calcium Concentrations

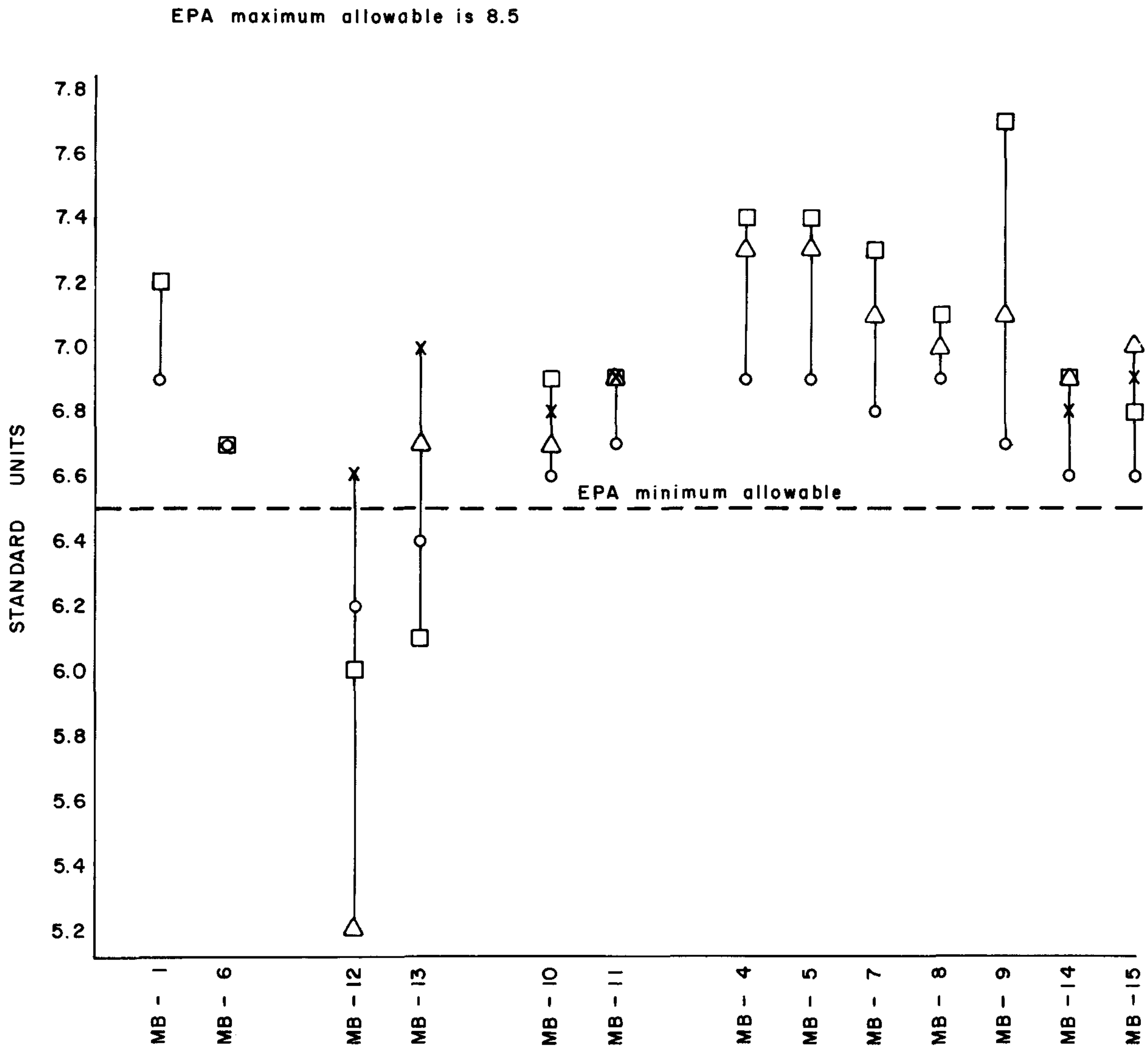


Figure 5-10. Observed Field pH

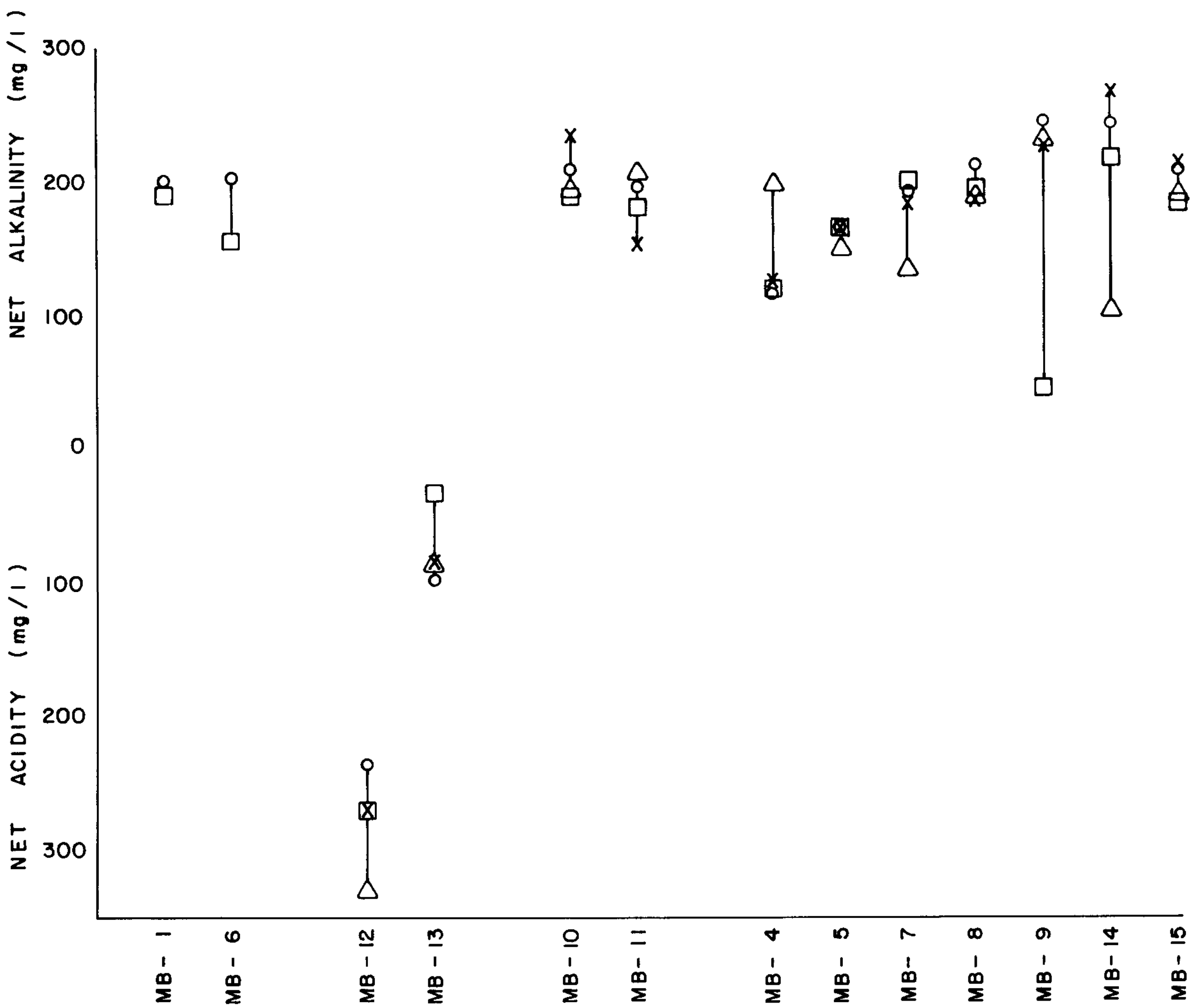


Figure 5-11. Observed Net Alkalinity/Acidity

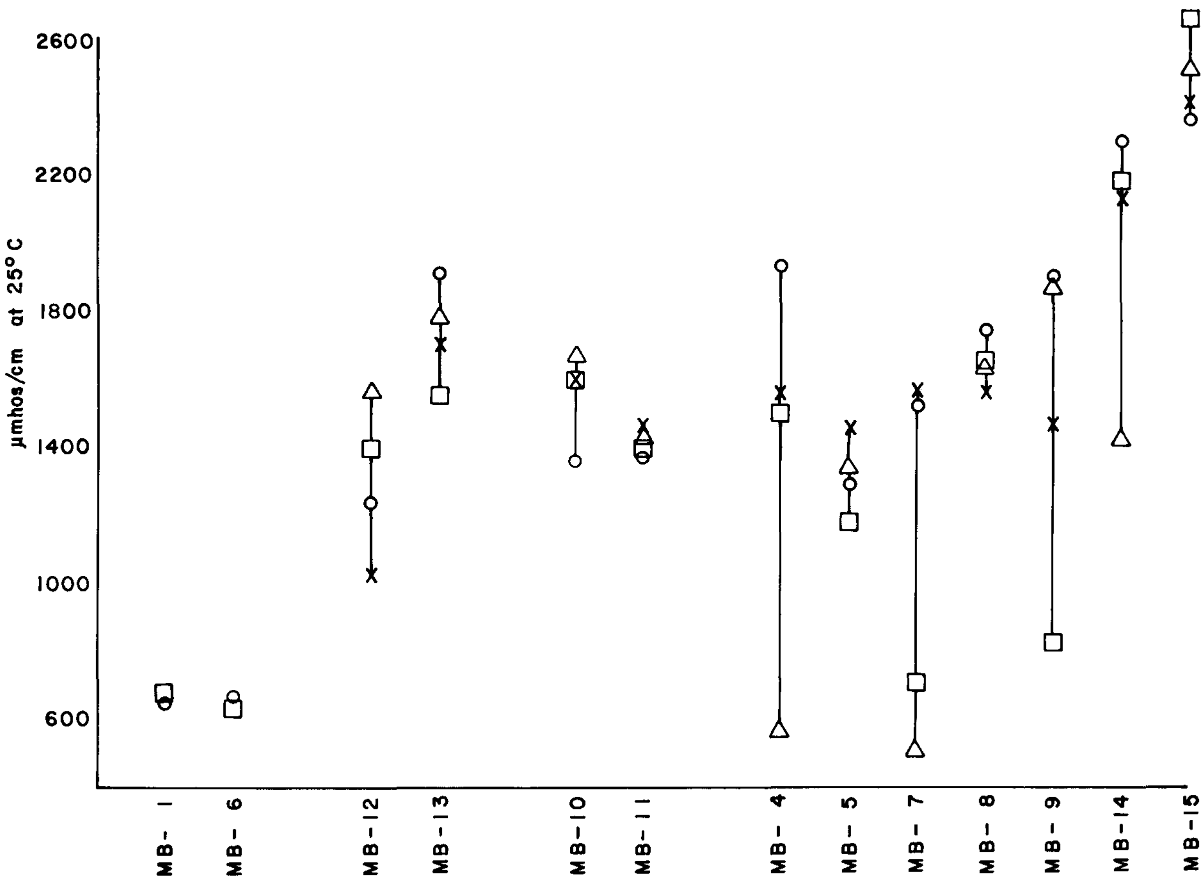


Figure 5-12. Observed Conductance

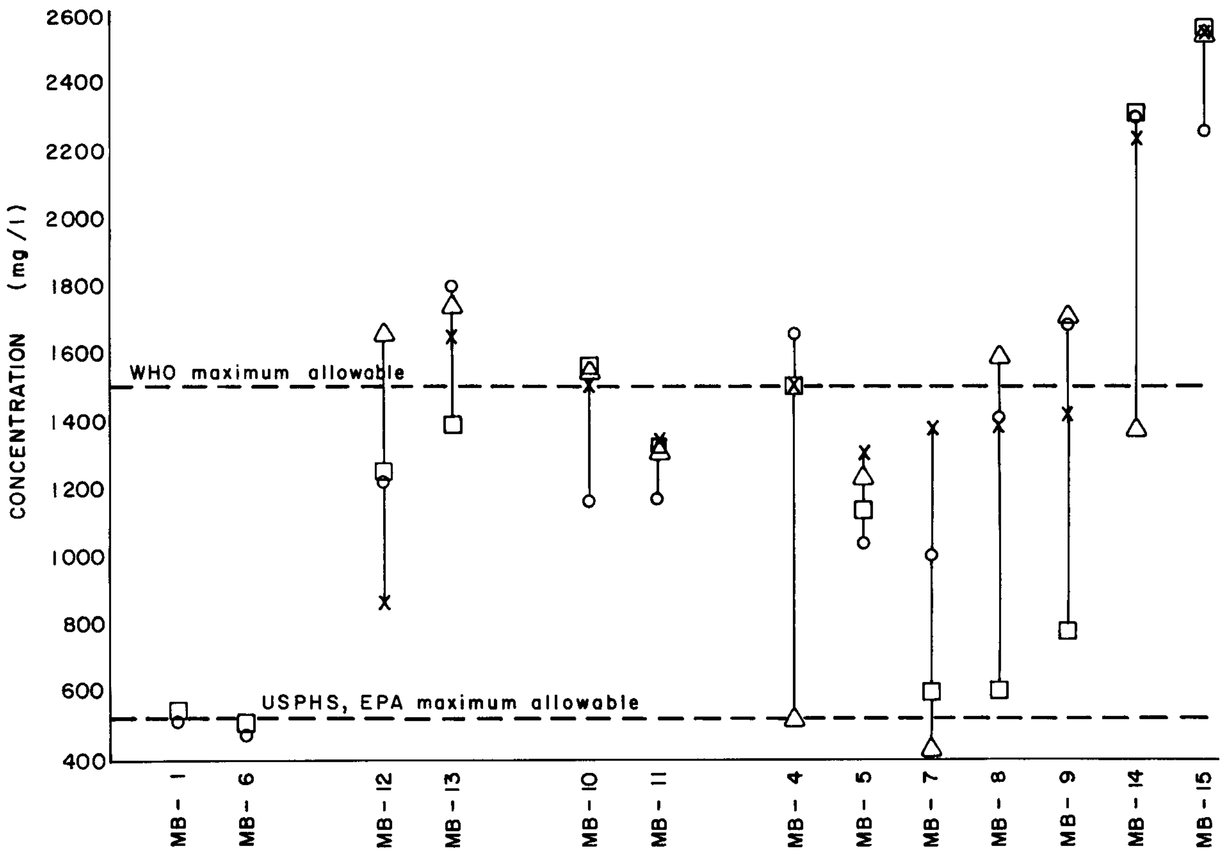


Figure 5-13. Observed Concentrations of Total Dissolved Solids

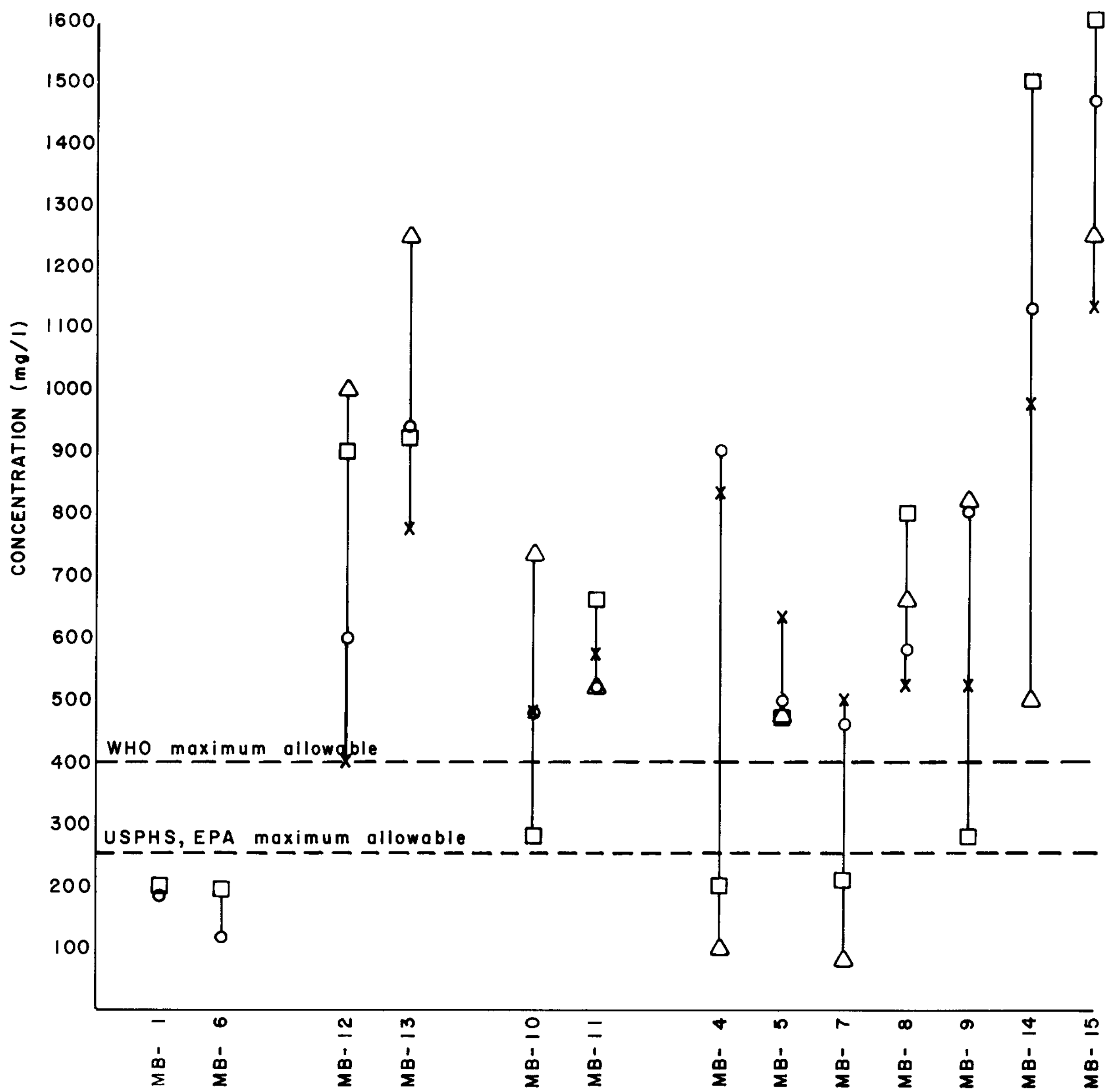


Figure 5-14. Observed Sulfate Concentrations

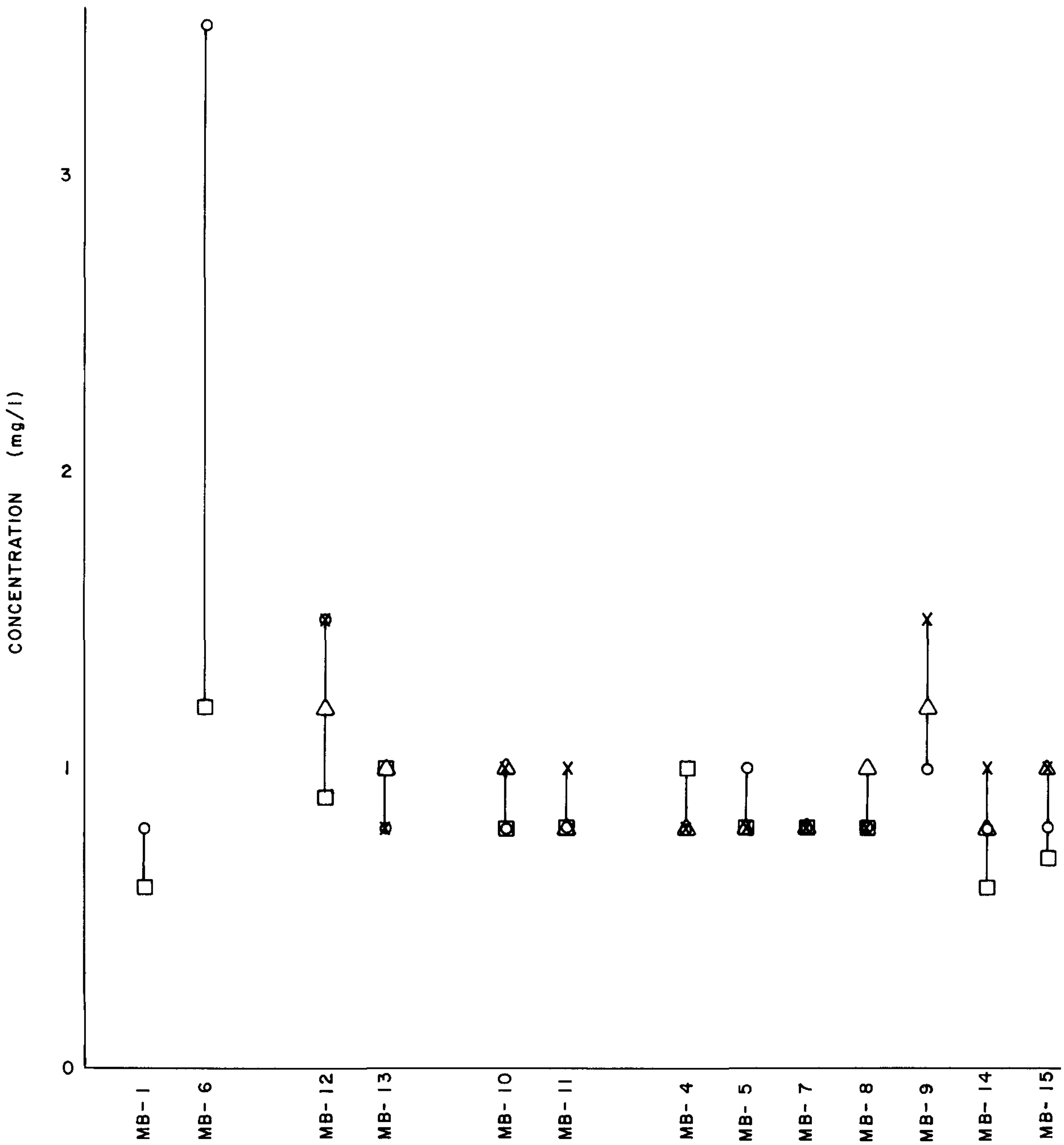


Figure 5-15. Observed Sulfite Concentrations

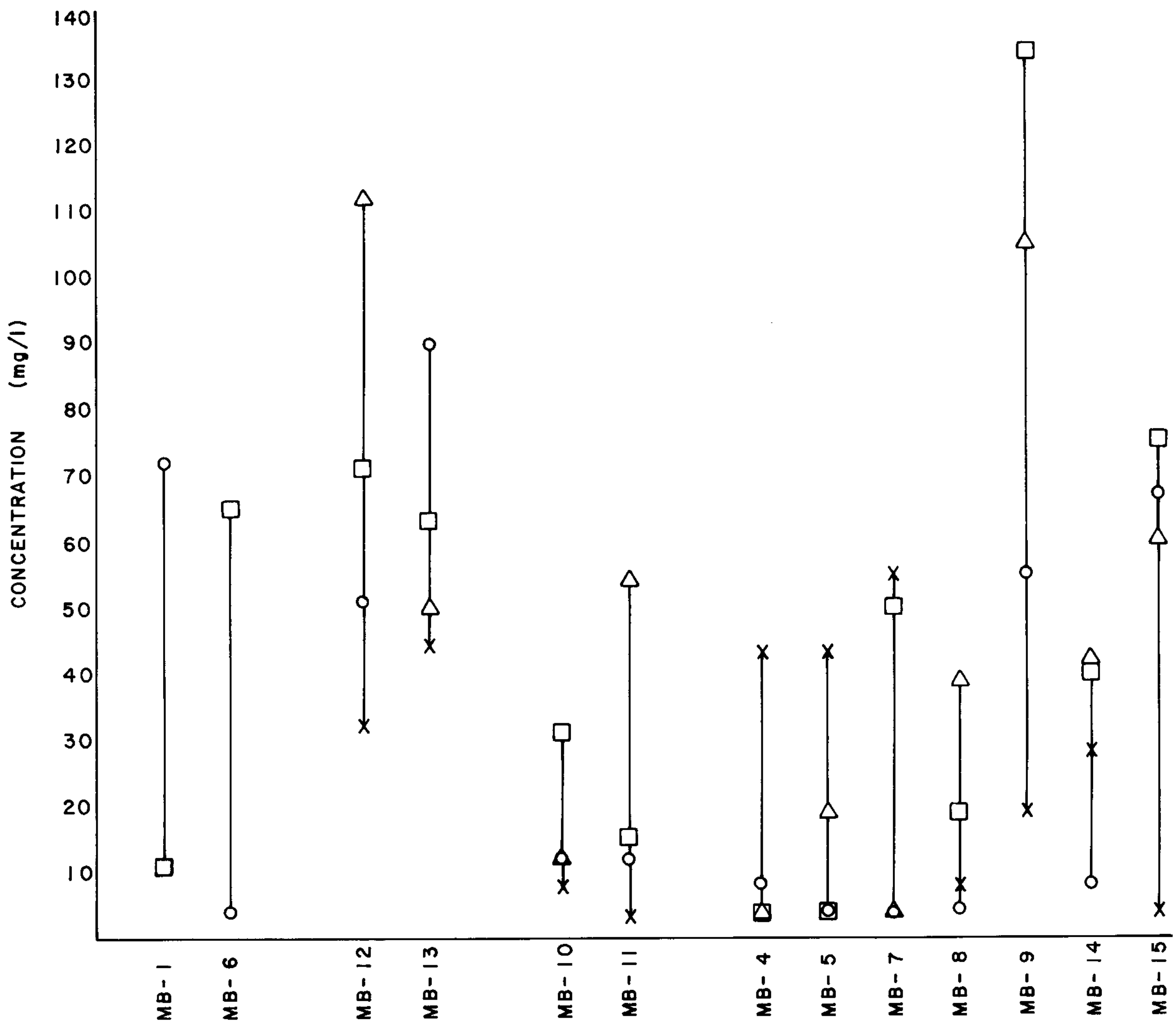


Figure 5-16. Observed COD

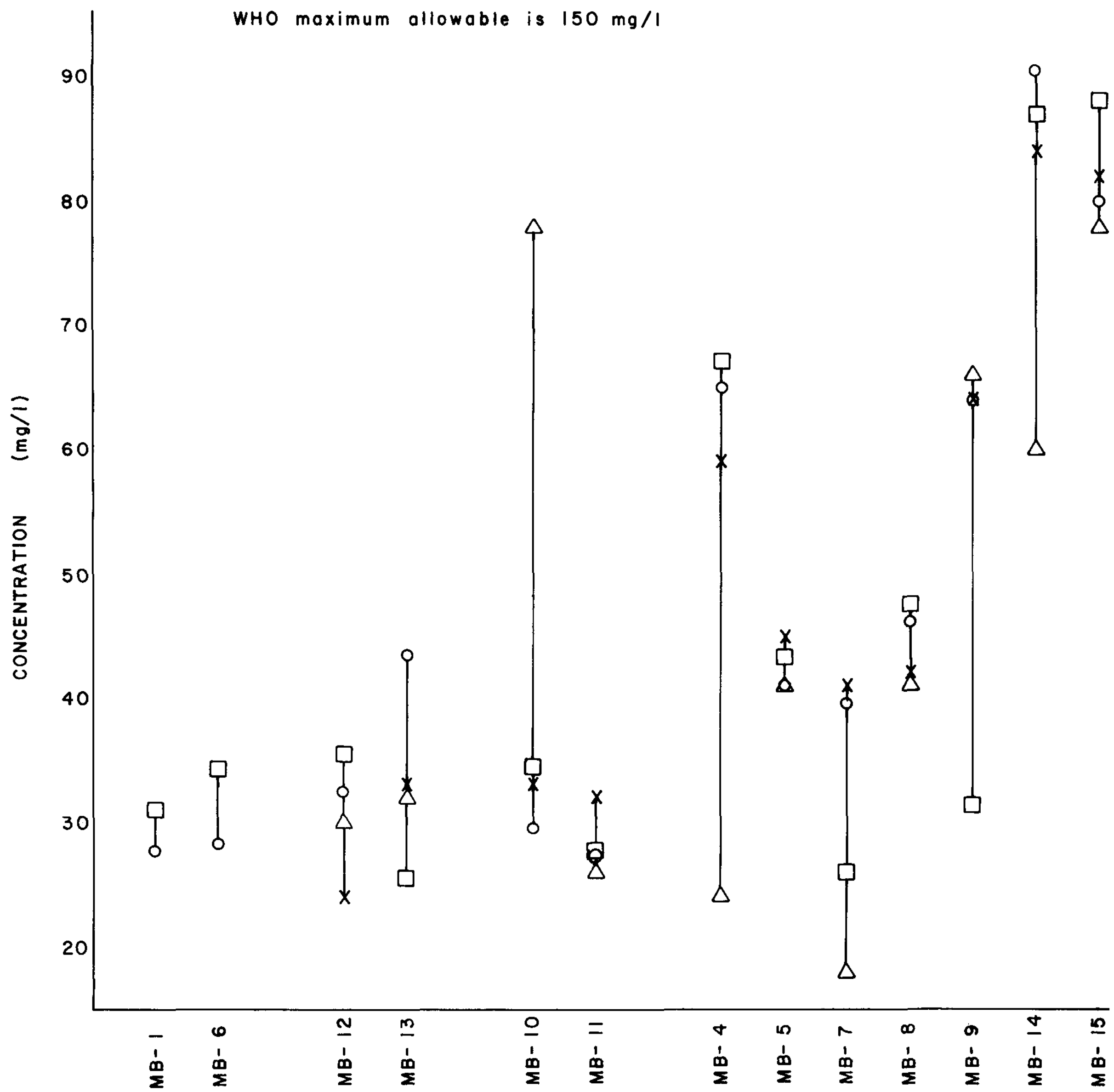


Figure 5-17. Observed Magnesium Concentrations

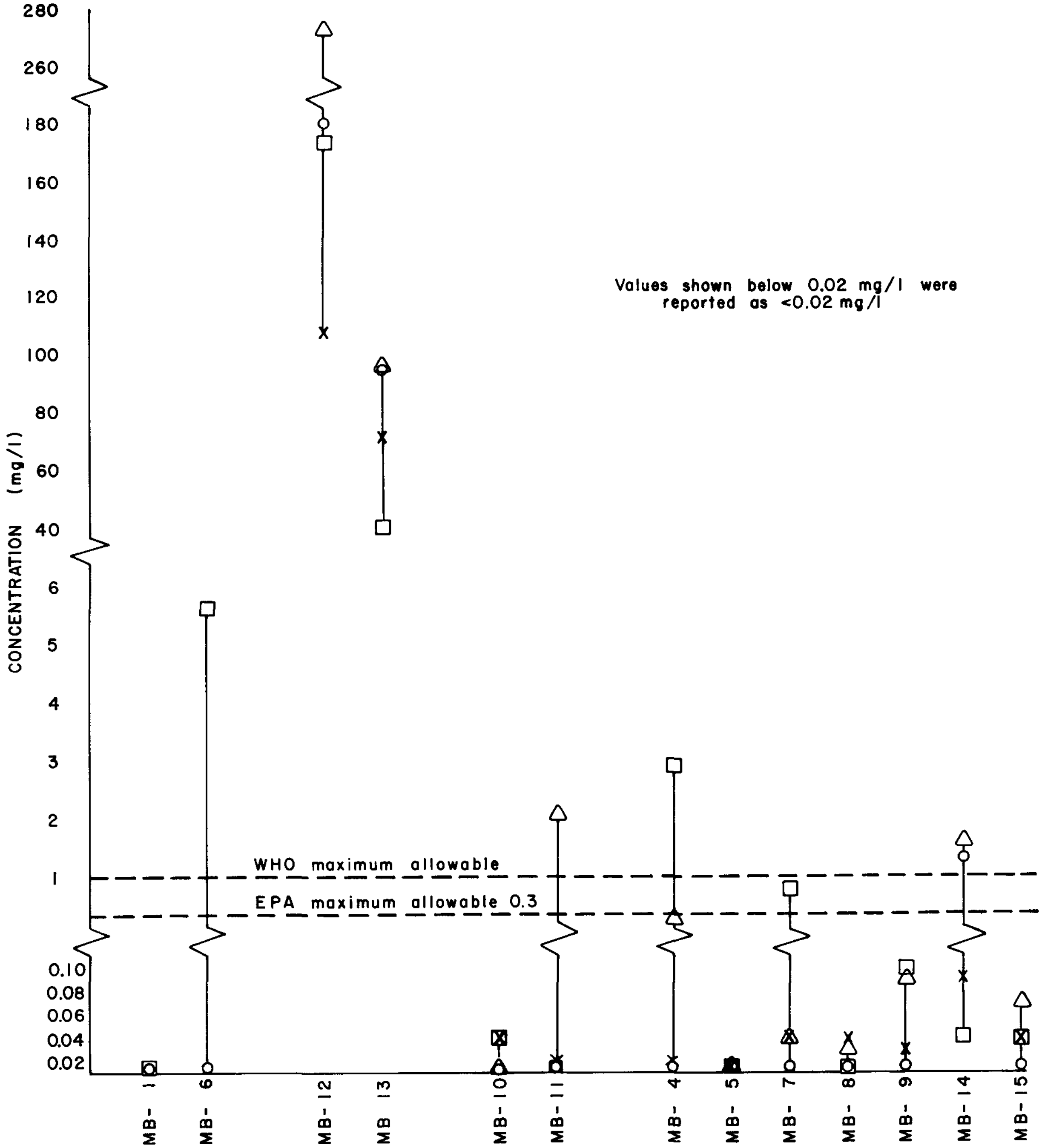


Figure 5-18. Observed Total Iron Concentrations

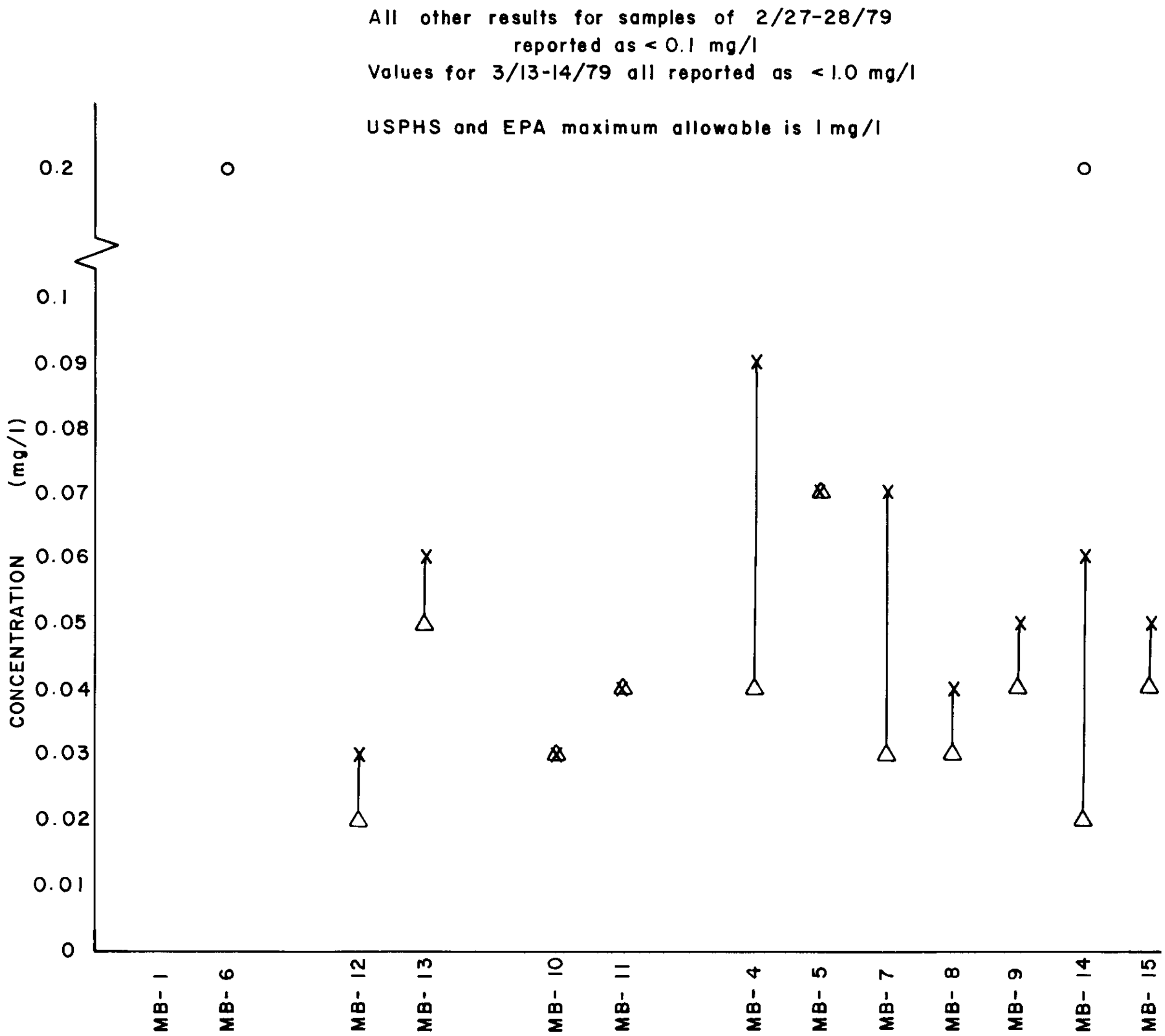


Figure 5-19. Observed Barium Concentrations

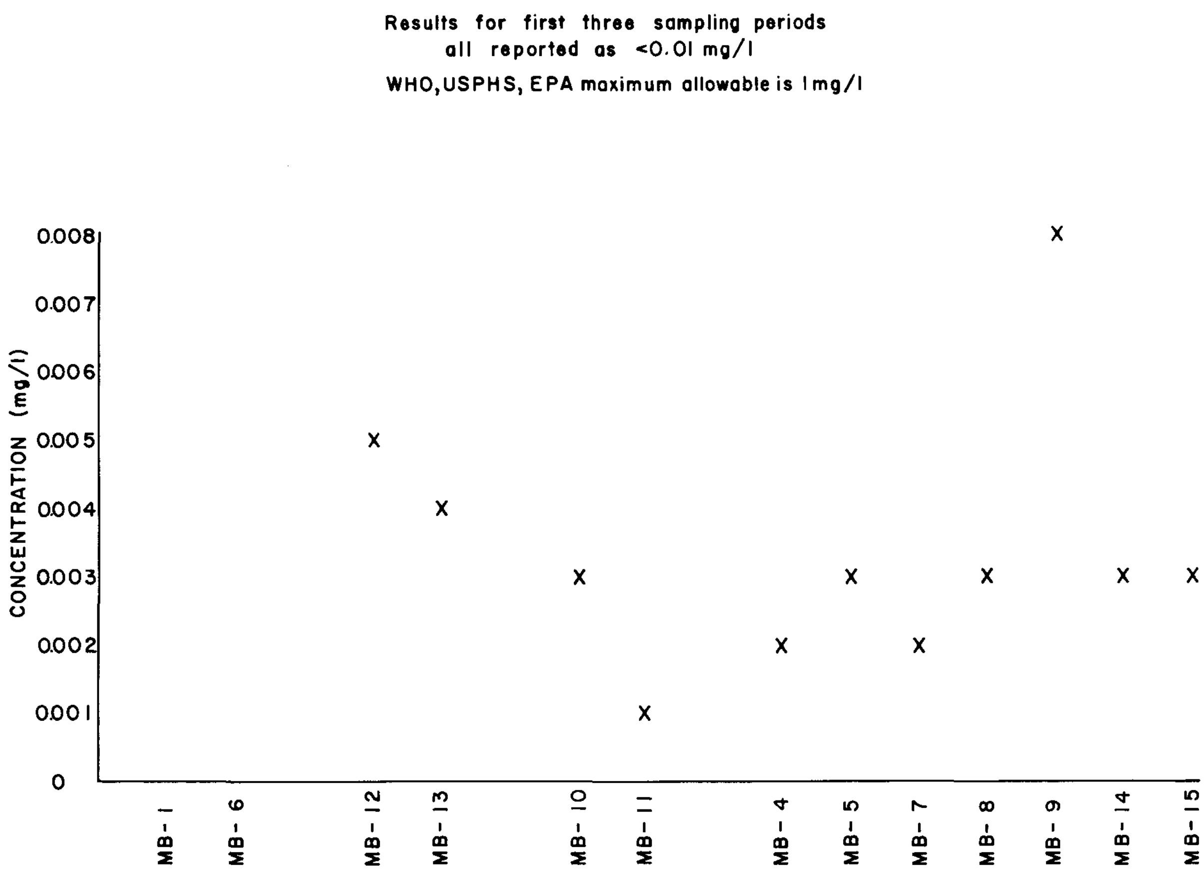


Figure 5-20. Observed Cadmium Concentrations

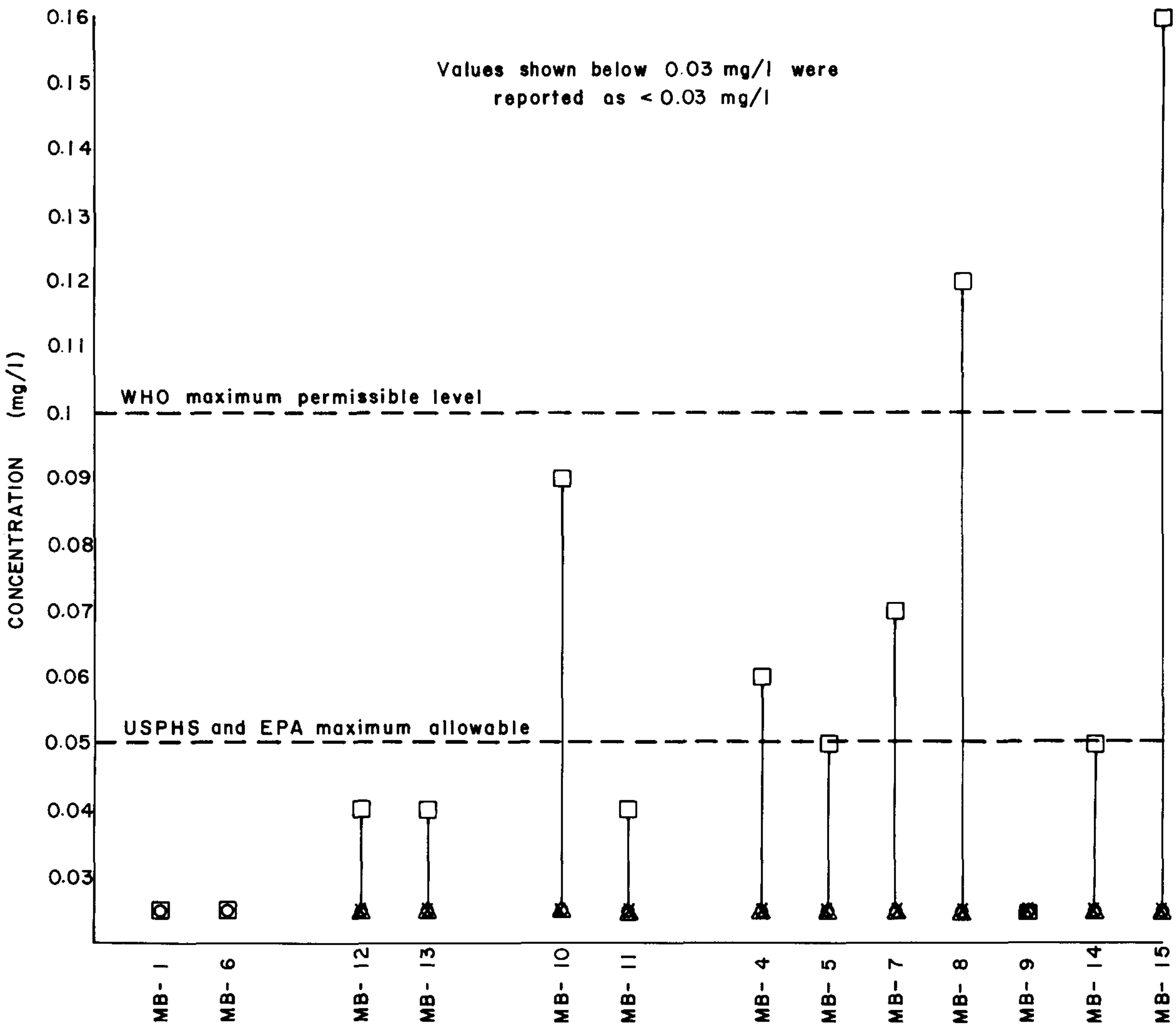


Figure 5-21. Observed Lead Concentrations

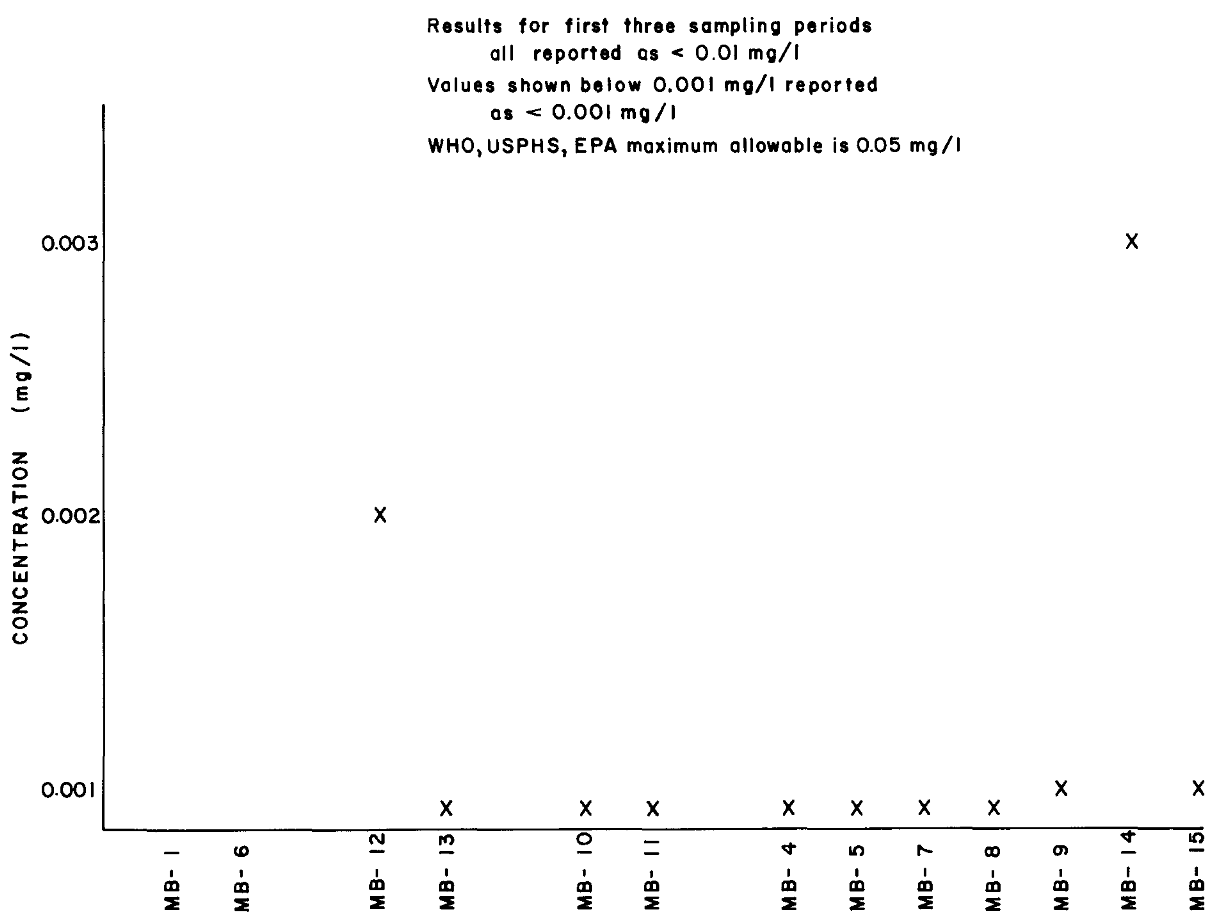


Figure 5-22. Observed Chromium Concentrations

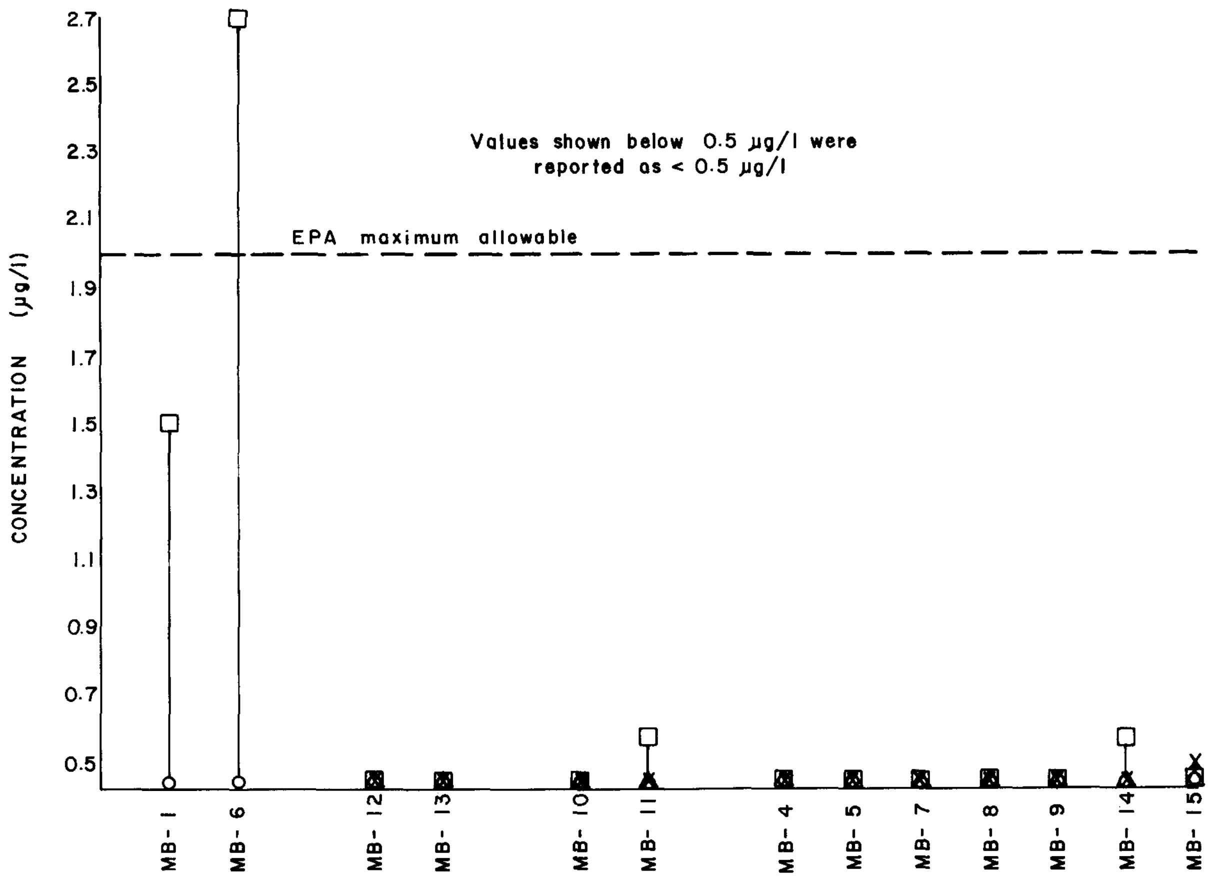


Figure 5-23. Observed Mercury Concentrations

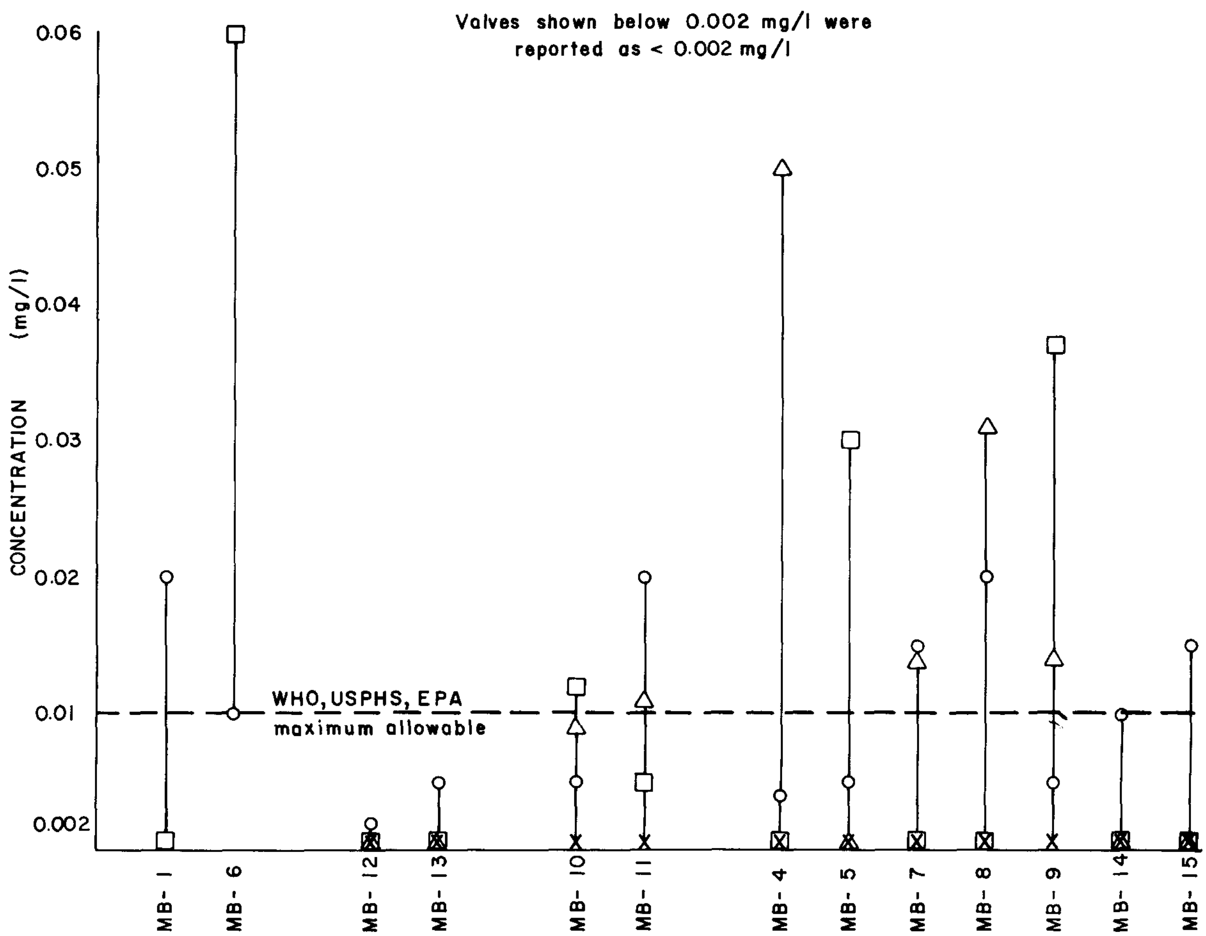


Figure 5-24. Observed Selenium Concentrations

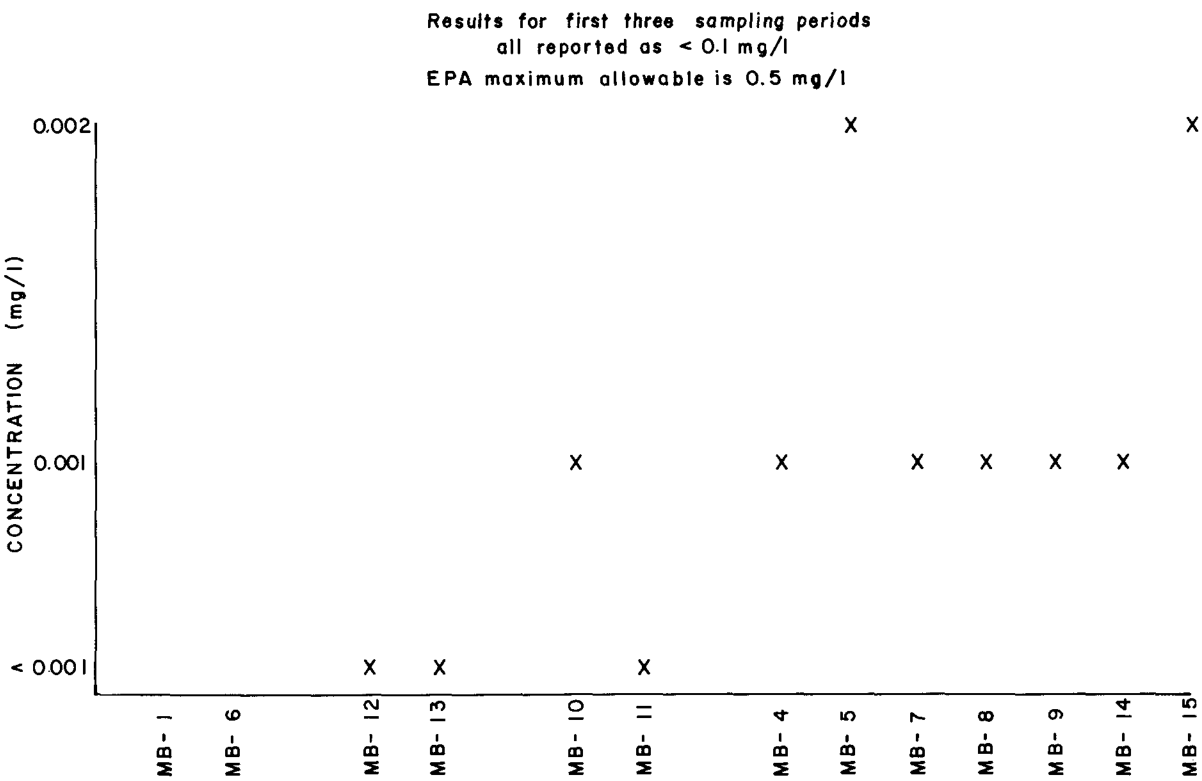


Figure 5-25. Observed Silver Concentrations

recently. The majority of Poz-O-Tec landfilled to date is concentrated in the southern corner of the sludge disposal area near the radial-arm conveyors. It is possible that any leachate which has been produced by the Poz-O-Tec has been directed toward the west to southwest and has bypassed wells MB-10 and MB-11. Figures 5-2 and 5-4, showing the configuration of the area potentiometric surface, support this premise.

Conductivity and concentrations of calcium, total dissolved solids, and sulfate are excessive in wells MB-14 and MB-15. It was originally believed that these impaired water quality levels might result because of the influence of the coal pile which is located immediately south of these wells. However, the high calcium concentrations are not likely to be associated with coal pile leachate. The high levels of calcium could originate from the ash pond (see Table 2-1), but similarly elevated concentrations should exist in all of the monitoring wells affected by the ash pond. Monitoring wells MB-14 and MB-15 are situated directly down gradient, with respect to the local potentiometric surface, from the greatest accumulation of Poz-O-Tec in the sludge disposal area. The emergency sludge pond (see Figure 2-1) is also situated up-gradient of these wells. Both the thickened unfixed FGD sludge, which is intermittently stored in the emergency pond, and the Poz-O-Tec can potentially produce leachates with the concentrations of chemical constituents occurring at wells MB-14 and MB-15. Supervising personnel at Conesville report that the emergency sludge pond was not lined until September 1978. Prior to this date, leachate could easily migrate into the underlying outwash provided the natural surface silt had also been removed from this segment of the sludge disposal area.

The groundwater quality impairment indicated at monitoring wells MB-14 and MB-15 is considered to be produced by leachate from the emergency sludge pond and/or the existing Poz-O-Tec landfill. With available information, however, a distinction as to the primary source cannot be made. The results of the trace metal analyses obtained during these investigations are generally inconclusive. The majority of the concentrations detected are well within recommended limits for drinking water quality. Lead concentrations were found to be in excess of drinking water standards at many of the observation wells on one occasion. This condition would appear to be a direct result of leachate from the Poz-O-Tec, but this assumption cannot be supported because this trend did not prevail over the monitoring period. Selenium concentrations were found to be above desired levels, however, this is apparently a background condition.

Additional groundwater monitoring will be necessary to facilitate an accurate evaluation of the effectiveness of the IUCS sludge fixation process for preventing leachate formation. As the Poz-O-Tec landfill is extended northeastward, wells MB-4, MB-5, MB-7 through MB-9, MB-10 and MB-11 should detect any leachate which might be produced by the Poz-O-Tec without interference from the emergency sludge pond.

REFERENCES

1. James J. Geraghty et al. Water Atlas of the United States. Port Washington, New York: Water Information Center, Inc., 1973.
2. Subsurface Investigation and Analysis: Poz-O-Tec Material Conesville Generating Station Conesville, Ohio. Columbus, Ohio: A & H Corporation, November, 1978, A & H #07-8511.
3. H. Mullen, L. Ruggiano, and S. Taub. "Converting Scrubber Sludge and Fly Ash into Landfill Material." Pollution Engineering, May 1978, pp. 71-74.
4. H. Mullen, L. Ruggiano, and S. Taub. "Converting Scrubber Sludge and Flyash into Landfill Material." Pollution Engineering, May 1978, pp. 71-74.

Section 6

LONG TERM MONITORING PROGRAM

Section 6

LONG TERM MONITORING PROGRAM

NEED FOR ADDITIONAL MONITORING

Contaminate levels at monitoring wells MB-14 and MB-15 may be due to either the emergency sludge pond in the Poz-O-Tec disposal area or the Poz-O-Tec itself. However, a further differentiation as to the most likely source cannot be made with available information. The information generated thus far also does not provide a sufficient data base to permit (1) delineation of the areal extent of aquifer affected by the pollution detected in the study area, (2) identification of the depth to which pollutants have migrated or (3) analyses of the capability of the aquifer for pollution attenuation.

Additional monitoring is necessary to evaluate the effectiveness of the IUCS sludge fixation technique. Both groundwater monitoring and surface water monitoring should be conducted. Runoff originating from the existing Poz-O-Tec landfill seeps directly into the ground through the small pond at the north end of the Poz-O-Tec disposal area. From the water quality observations at monitoring wells MB-4 and MB-5 it is uncertain if this infiltration has had any effect on groundwater quality. However, slightly elevated levels of calcium, conductance, total dissolved solids, sulfate, magnesium, total iron, barium and selenium were noted at monitoring well MB-4 as compared to many of the other wells. IUCS and C&SOE plan to pump this runoff into the adjacent ash pond when the Poz-O-Tec liner is completed in the north end of the disposal area. Ash pond water is channeled to the holding pond and then into the plant outfall channel which discharges into the Muskingum River.

In order to establish Poz-O-Tec performance is consistent with small-scale pilot studies, it is necessary to continue sampling at the existing monitoring network. If the Poz-O-Tec produces leachate, these constituents should affect wells MB-10, MB-11, MB-4, MB-5, and MB-7 through MB-9 as the Poz-O-Tec fill is extended further to the northeast. The emergency sludge pond cannot affect these wells due to the direction of groundwater flow.

Additional monitoring well clusters should be installed as shown on Figure 6-1 at greater distances from the Poz-O-Tec disposal area. These well clusters should consist of 3 wells for reliable sampling of groundwater at various depths, such as the well cluster comprised of wells MB-7, MB-8 and MB-9 (see Figure 4-5). Deep wells capable of sampling groundwater near the base of the aquifer should be added to the existing well clusters MB-10 and MB-11, and MB-12 and MB-13. The additional wells will permit observations concerning pollution migration and attenuation.

Surface runoff samples from the Poz-O-Tec should be collected whenever possible so that the potential impacts can be assessed. These waters will be pumped into the ash pond which discharges indirectly to surface water courses, according to present plans.

Periodic core samples of Poz-O-Tec should be acquired within the disposal area for physical testing including:

- unconfined compression
- permeability
- leachability (ASTM or PA methods)
- triaxial testing
- bulk density
- moisture content

Recently placed material as well as Poz-O-Tec which has cured for extended periods of time should be acquired to develop comparisons of change in characteristics versus time.

PROPOSED PHASE 2 PROGRAM

A Phase 2 monitoring program entails the implementation of the information prepared in Phase 1. The work program is also designed to be supportive to a related groundwater modeling effort conducted by Battelle Pacific Northwest Laboratories, Richland, Washington. When available, the information developed will be provided to Battelle. Close coordination will be maintained with Battelle to maximize efficiency of data collection and interpretation.

Based on the information that is available from the Phase 1 work, a Phase 2 monitoring program has been outlined. The Phase 2 program would consist of the following tasks:

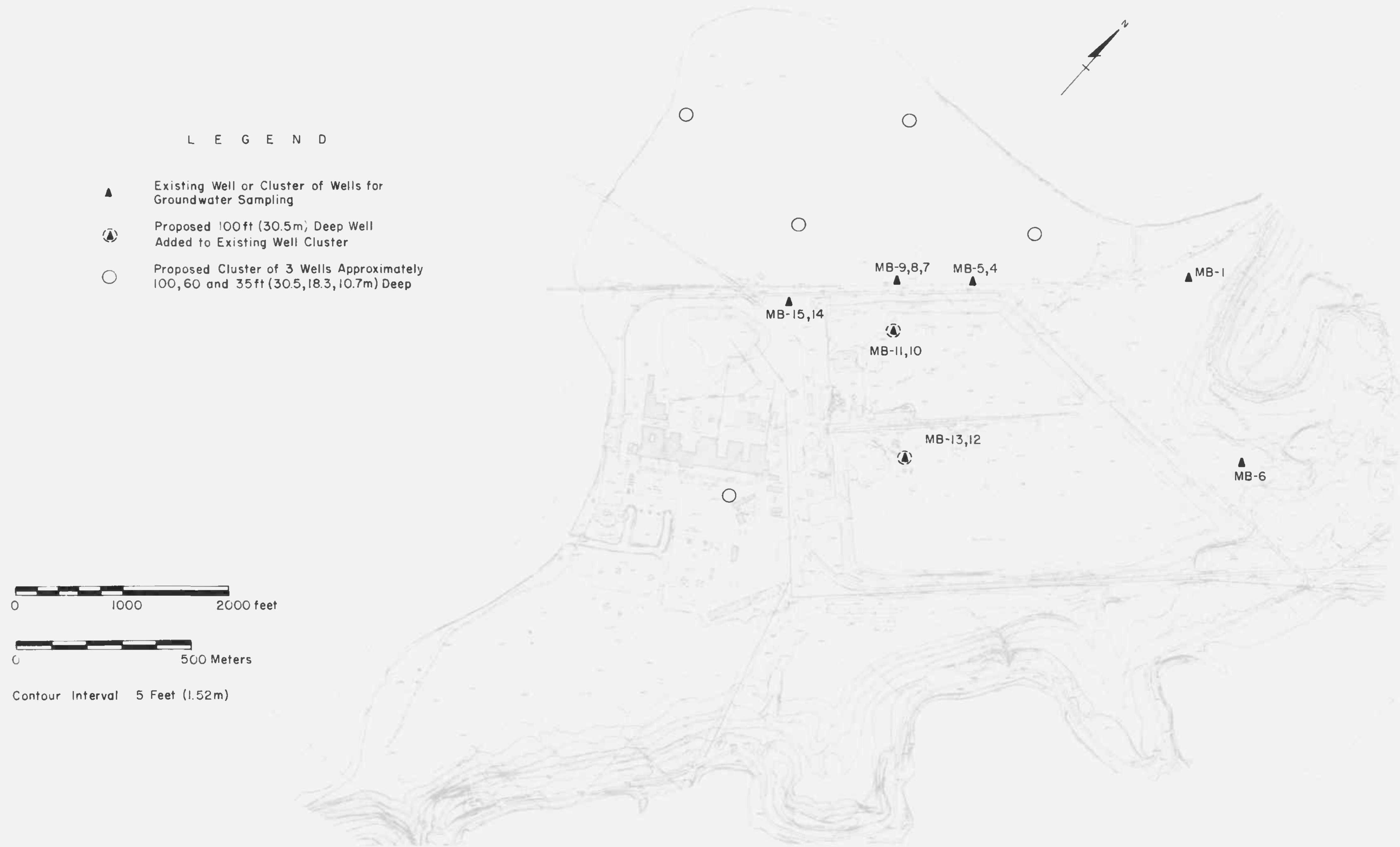


Figure 5-4. Approximate potentiometric surface during observed low conditions

Task 1 - Conduct Core Sampling

Approximately three (3) sets of core samples from the disposal area are needed: one (1) at the start of Phase 2 of the program and one (1) each year for the two succeeding years. The number of cores will depend upon the area to be covered, but should include both newly-placed material as well as that which has cured for varying periods. Tests will be performed as soon as possible after coring and will include those listed in the previous discussion.

The location of each core will be mapped and related to sludge thickness and the overall disposal operation. Each core hole will be backfilled with cement grout when completed. An area map will also be developed showing surface contours and fill progress, being updated when cores are taken. In each year, additional sludge and soil sampling and aquifer testing will be conducted as necessary to be supportive to the modeling work conducted by Battelle.

Task 2 - Conduct Groundwater Quality Monitoring

Additional monitoring wells are necessary at selected points as determined in Phase 1. (An estimated seventeen (17) wells will be installed in Phase 2.) The new wells will be added to the thirteen (13) wells installed in Phase 1. Samples will be collected from these wells quarterly and the samples analyzed for:

pH	chemical oxygen demand
conductivity	arsenic
alkalinity	barium
acidity	cadmium
iron	chromium
calcium	lead
magnesium	mercury
sulfate	selenium
sulfite	silver
total dissolved solids	

These analyses may be subject to modification as dictated by the EPA designation of hazardous substances or other current findings and developments. Consideration is being given to testing for boron since it is present in fly ash leachates and scrubber liquors and may serve as a tracer. However, the level of accuracy for boron detection is known to drop considerably as hardness levels in water samples increase above 100 mg/l. Most of the Conesville water samples had calcium concentrations many times greater than this level.

Geophysical logging is proposed to determine concentrations of dissolved solids within the stratification of the aquifer surrounding the wells. An electric log consists of a record of conductivities and aquifer permeabilities of the subsurface formations. By conducting an electric log quarterly in each well, changes in conductivity and aquifer characteristics can be compared with possible changes in water quality data to monitor leachate migration.

Task 3 - Conduct Surface Water Monitoring

In a manner similar to Task 2, surface runoff from the site will be analyzed quarterly for the parameters listed. Sampling stations will be obtained by arrangement with station personnel to maintain diversion channels. An estimated two (2) samples per quarter will be taken.

Task 4 - Monitor Disposal Operations

Quarterly visits to the station are necessary to observe current sludge disposal operating procedures, review the disposal operating log, and discuss disposal operation problems and solutions with the station and IUCS personnel. A running log of events will detail activities at the processing facility and disposal site, note unusual occurrences, list inspections and reports by regulatory agencies, record quantities of sludge disposed, equipment used, and note any operating or maintenance problems.

Task 5 - Prepare Annual Report

At the end of each year, a report which summarizes, integrates and interprets the results of the year-long monitoring activities in light of objectives of the study should be prepared. The results of the current year will be compared to those of preceding years in order to establish trends. Activities and unusual events for the year will be summarized and discussed and an overall assessment of the processing and disposal operations will be given.

Task 6 - Final Report

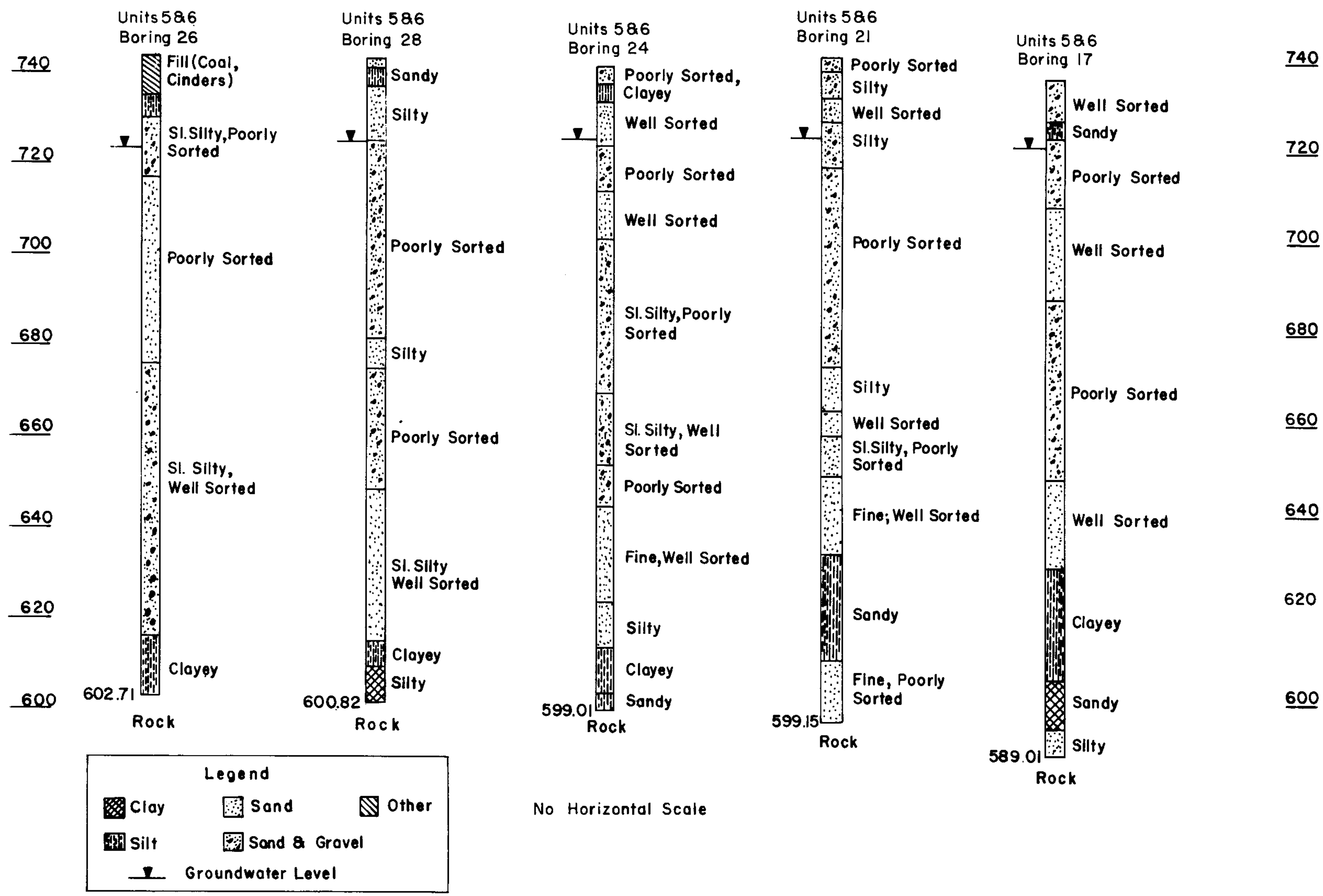
At the end of the three-year monitoring program, a final report should be prepared which details all the test results and interpretations. Based on Phase 1 and 2 work and on close contact with the utility personnel, the sludge disposal operation will be evaluated according to the four original study objectives:

- to determine if the type of fixed sludge processed and placed in a full-scale disposal operation reflects laboratory and limited field trial results

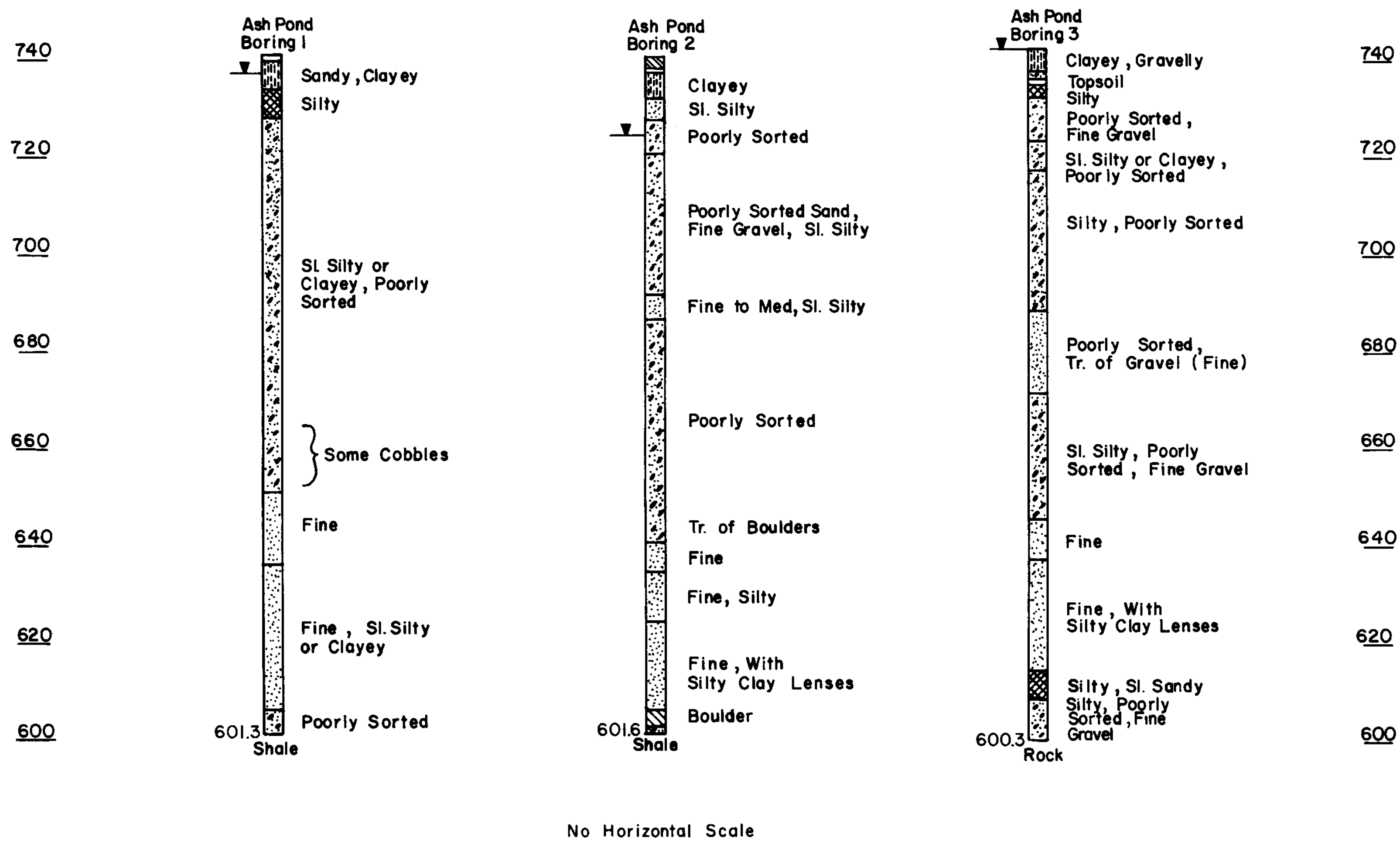
- to determine if the method of disposal as conducted is environmentally acceptable (that is, to determine if there are detrimental leachate, runoff, or future land-use problems)
- to determine what operating problems if any, the sludge disposal method causes for the utility
- to determine if the method of disposal will meet current and anticipated future regulatory requirements.

Appendix A

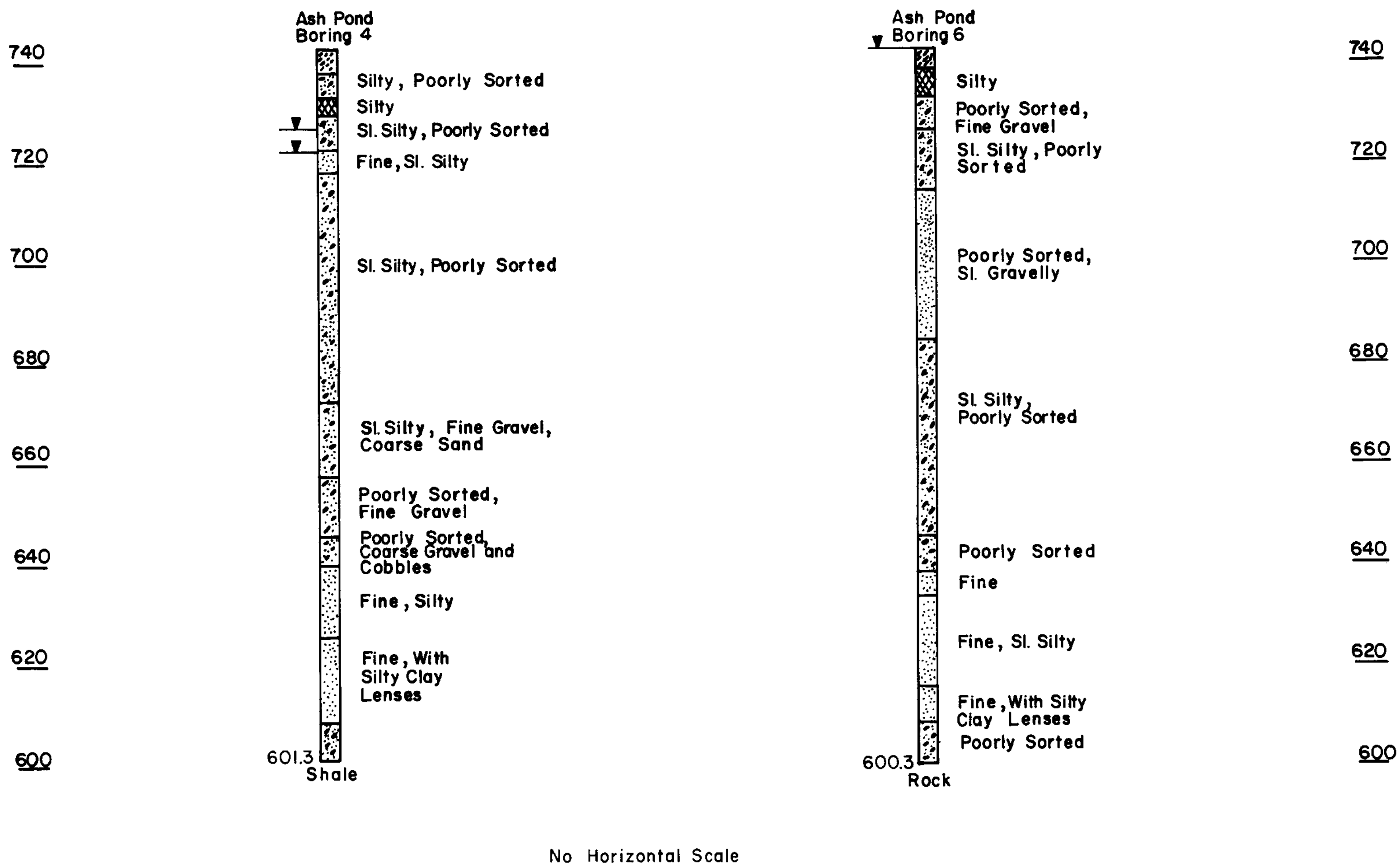
SUBSURFACE INFORMATION FROM PREVIOUS INVESTIGATIONS



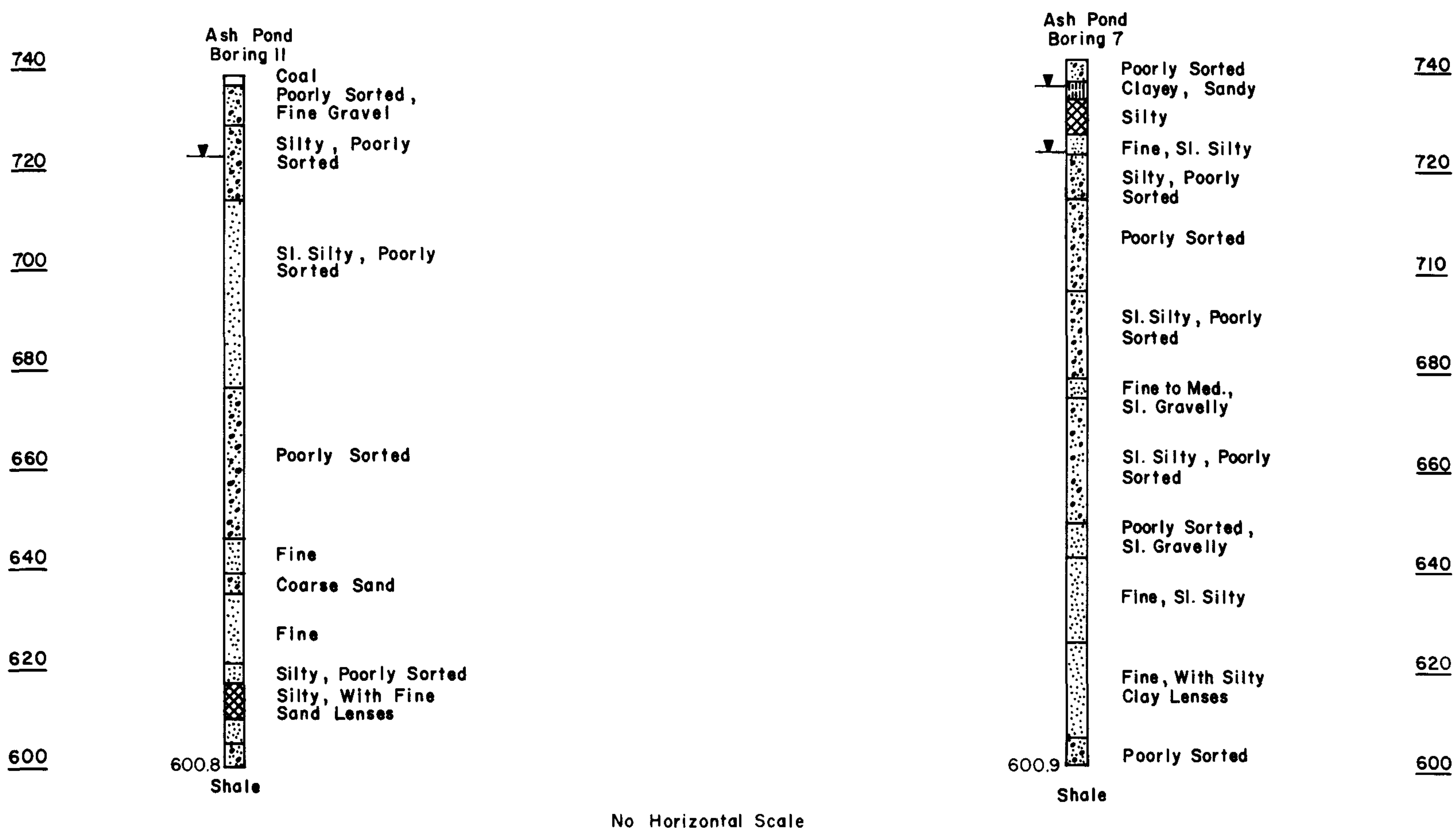
Simplified Plots of Units #5 & #6 Foundation Borings



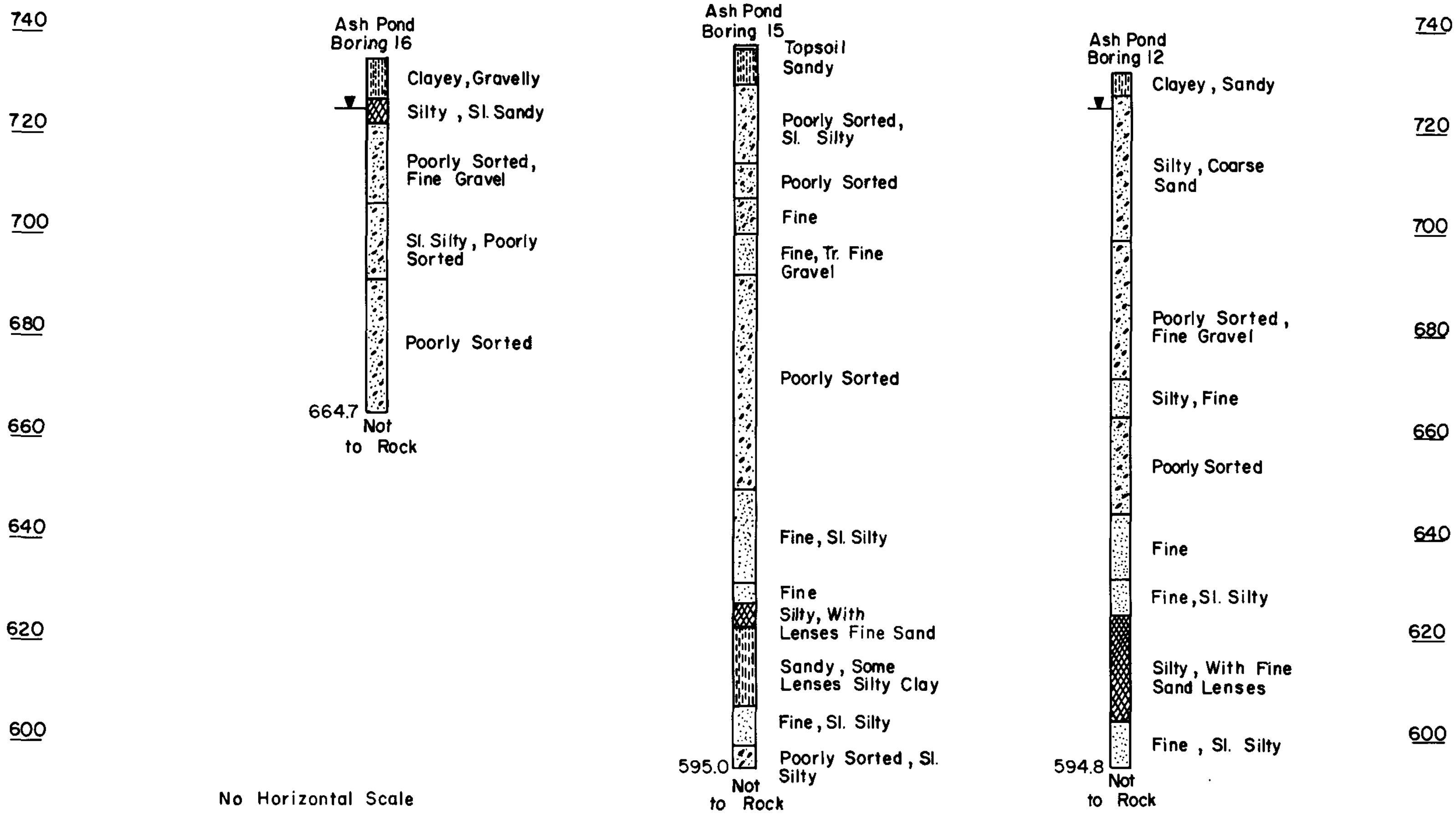
Simplified Plots of Structural Borings for Ash Pond Modifications



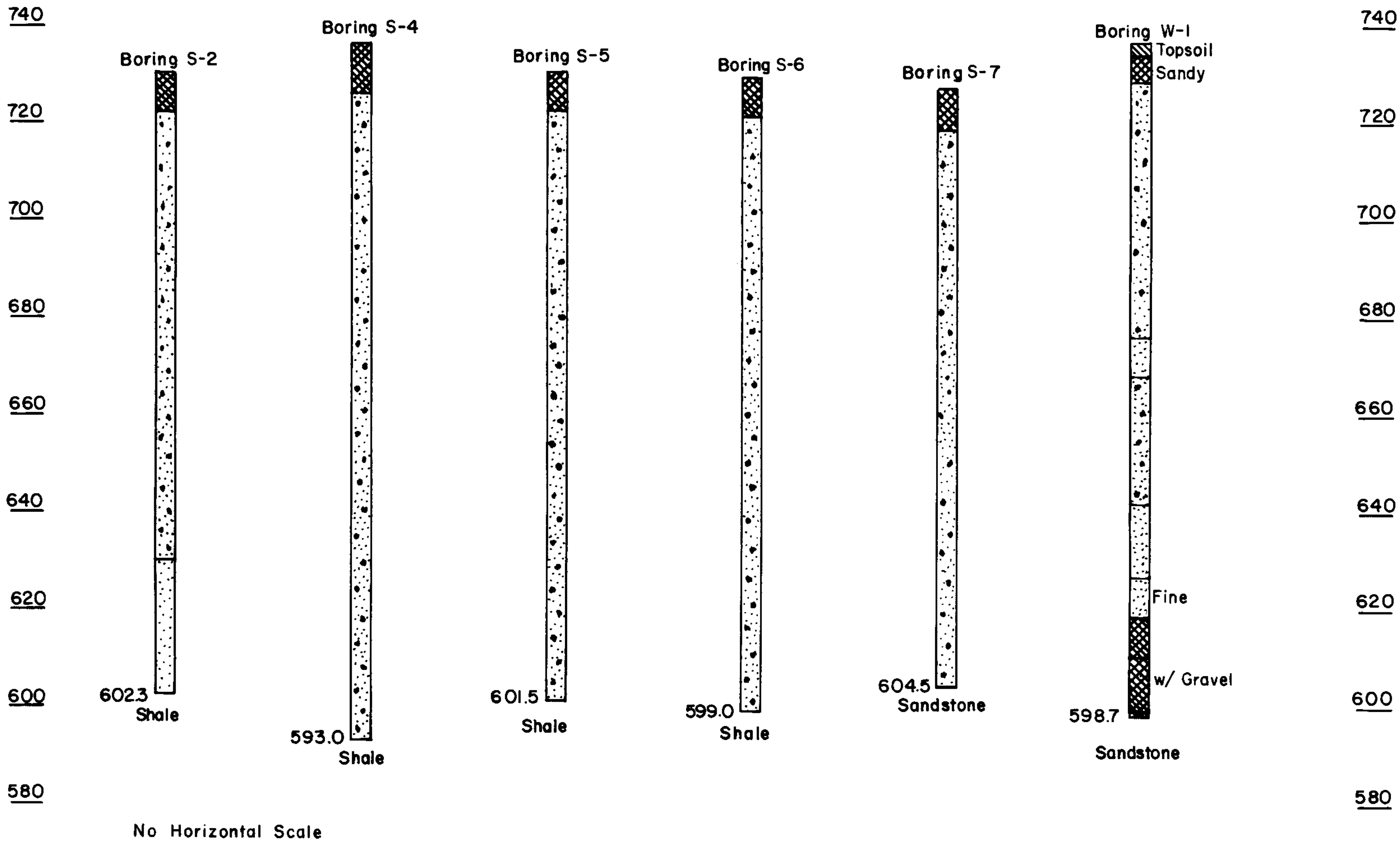
Simplified Plots of Structural Borings for Ash Pond Modifications



Simplified Plots of Structural Borings for Ash Pond Modifications



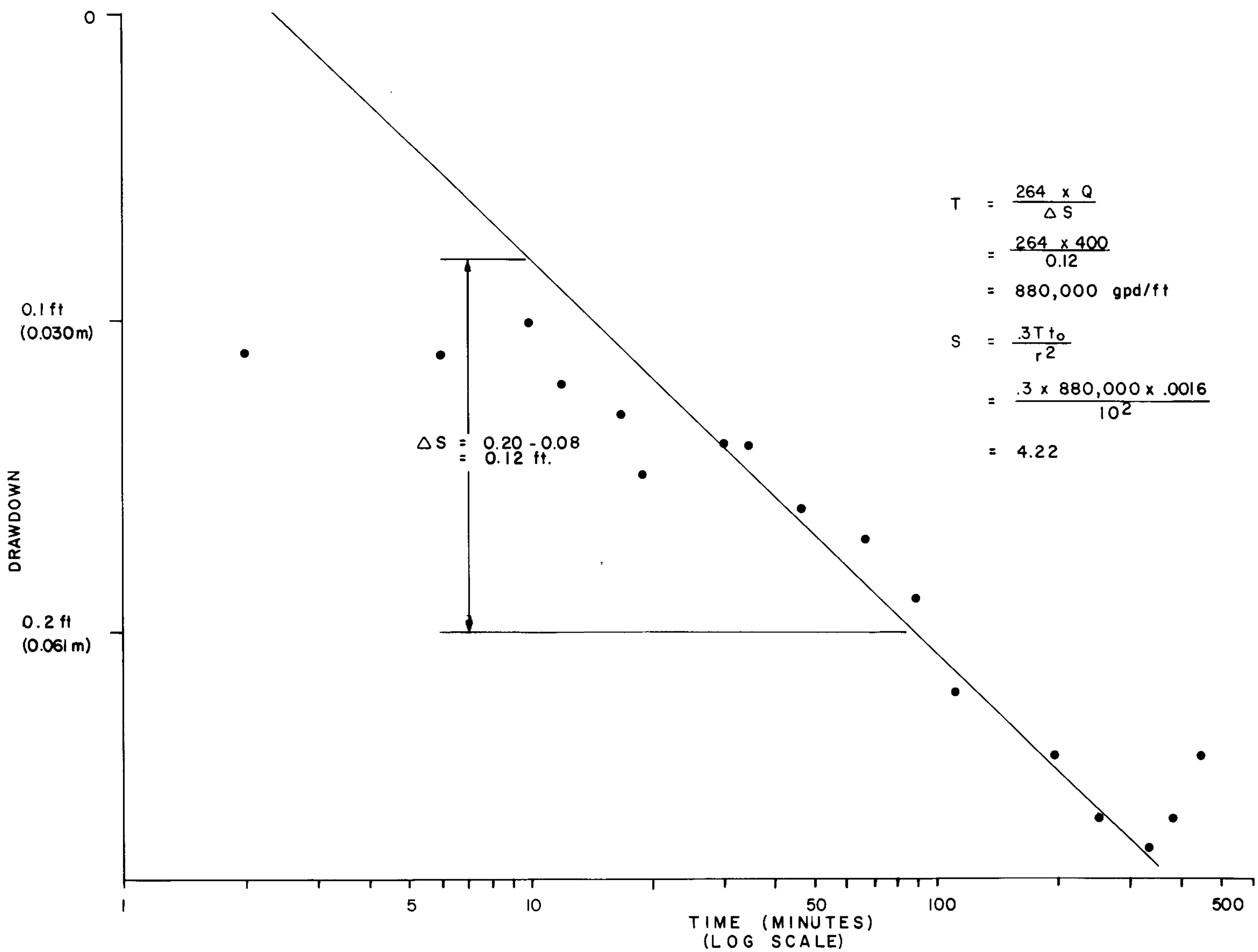
Simplified Plots of Structural Borings for Ash Pond Modifications



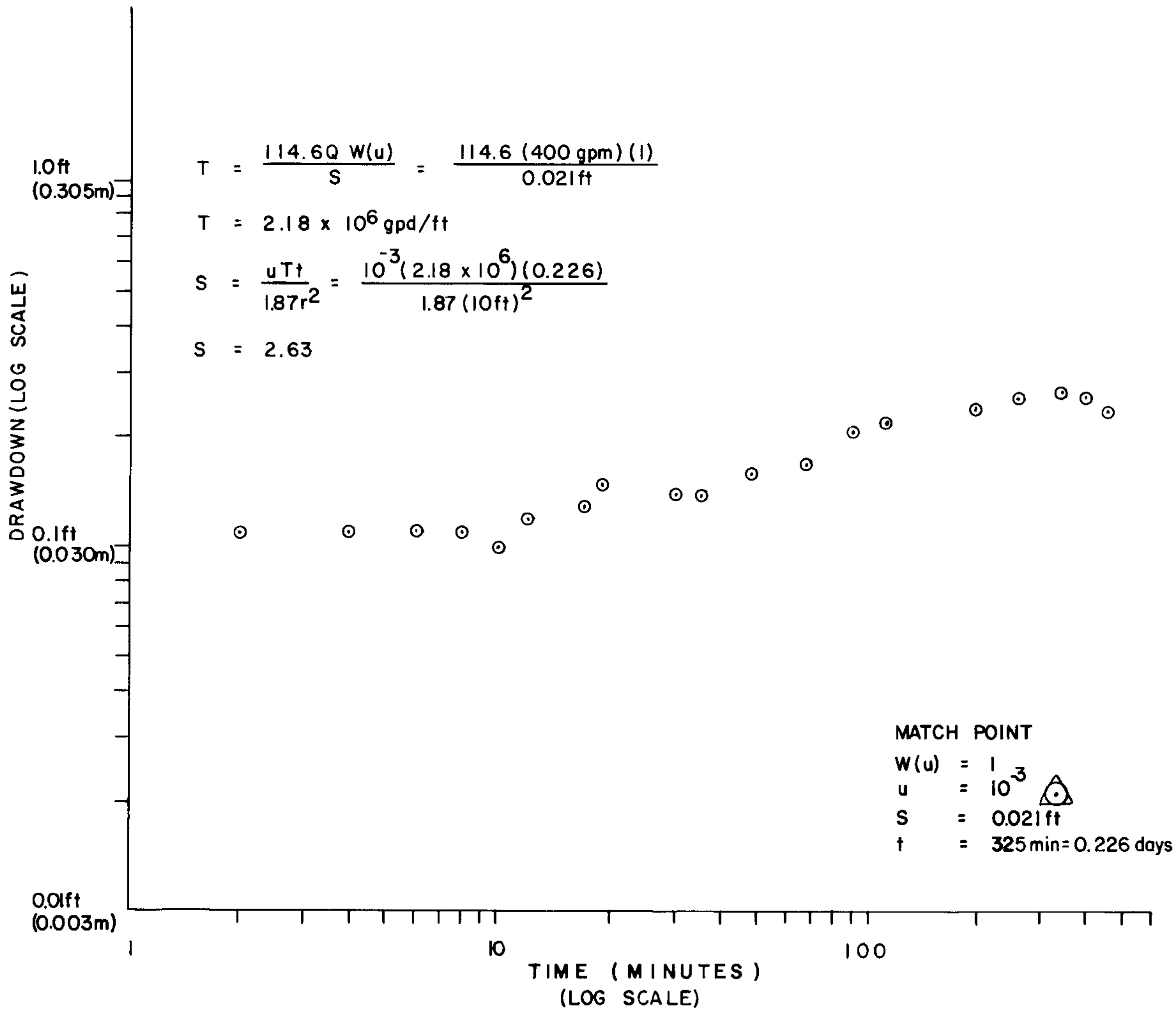
Simplified Plots of Units #1 & #2 Foundation Borings

Appendix B

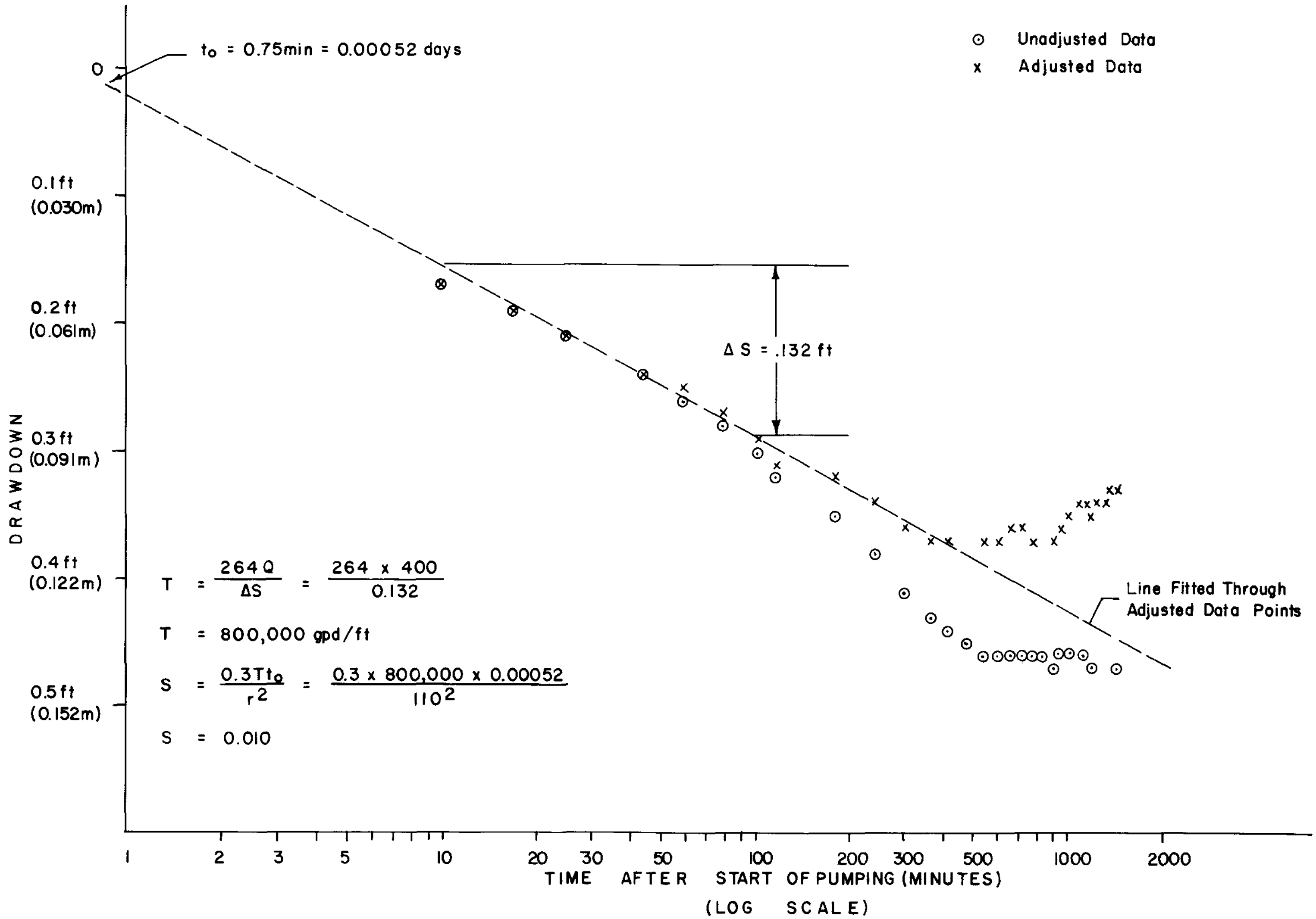
AQUIFER PUMP TEST DRAWDOWN CURVES AND CALCULATIONS



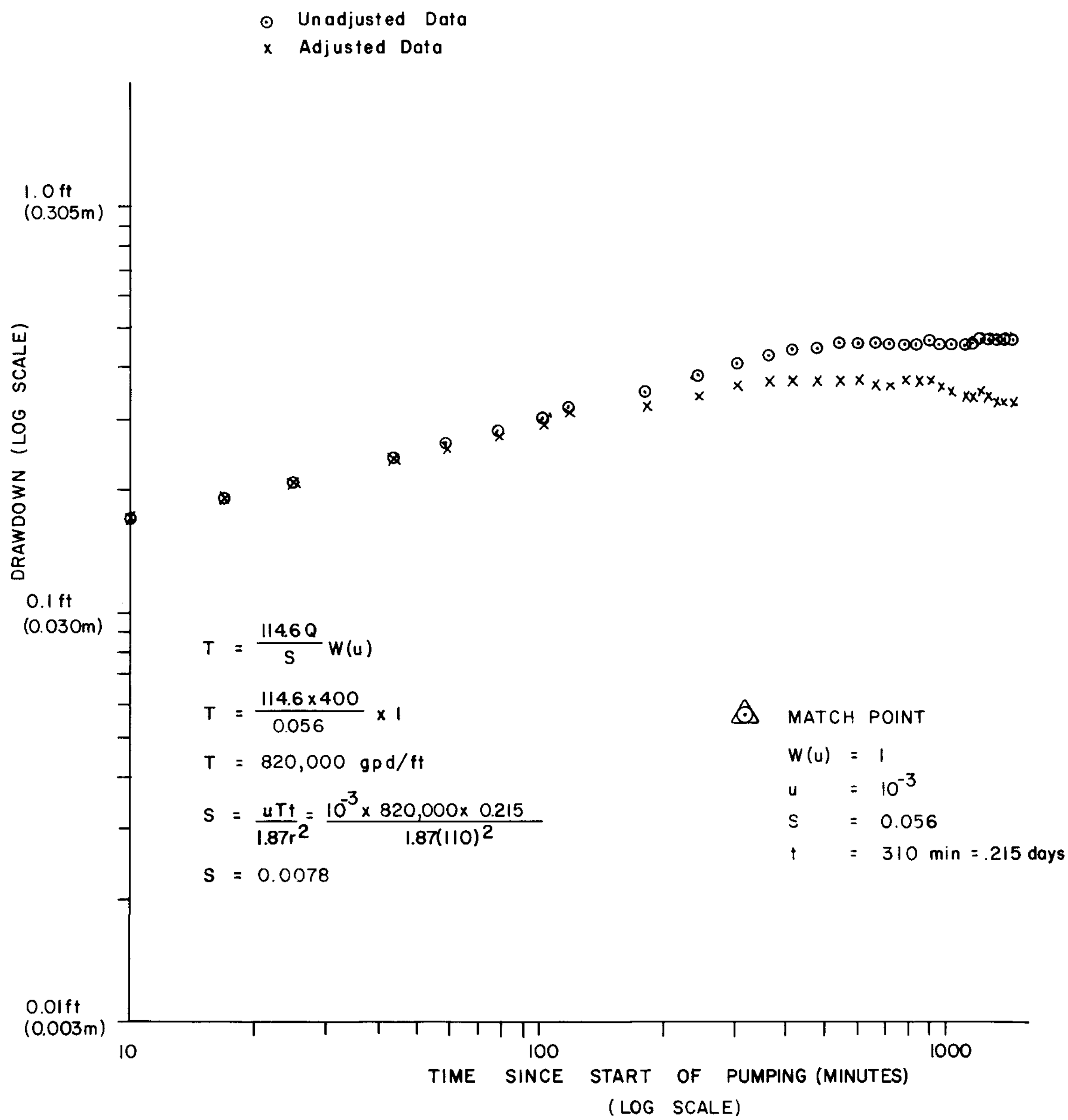
Pump Test No. 1 - Drawdown Data of Well MB-3
Jacobs Time - Drawdown Calculations



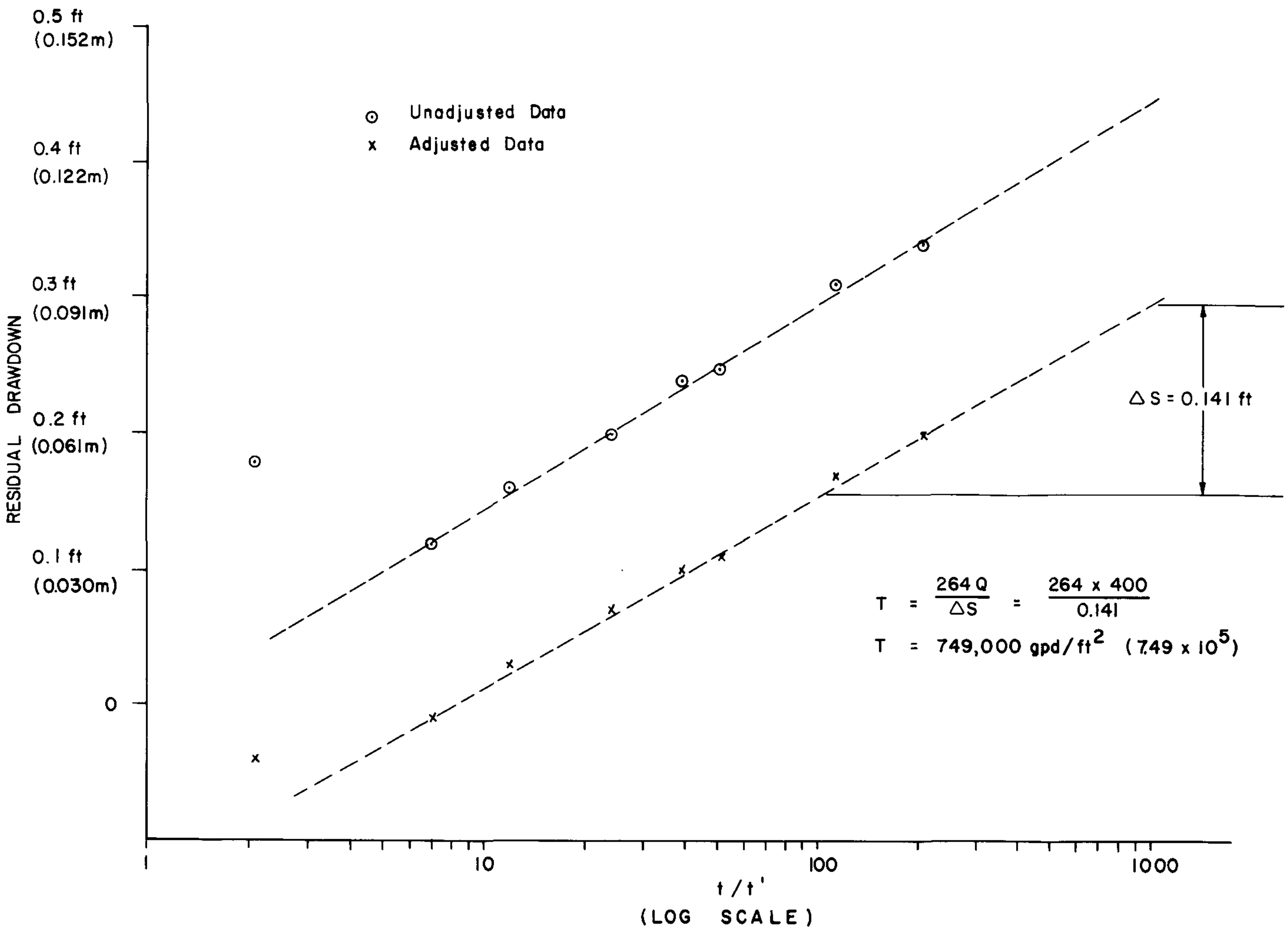
Pump Test No. 1 - Drawdown Data of Well MB-3
Theis Method Calculations



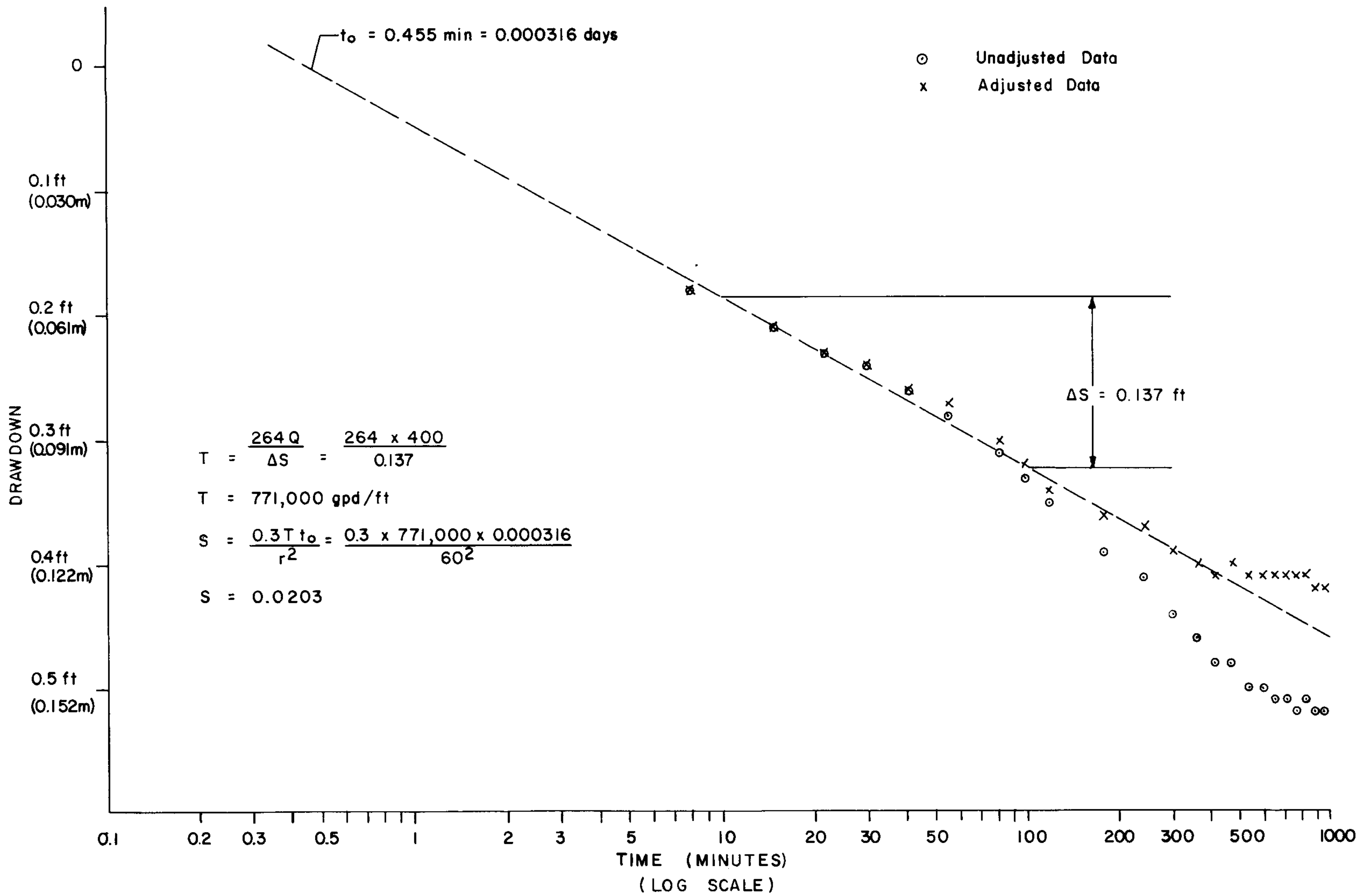
Pump Test No. 2 - Drawdown Data of Well MB-15
Jacobs Time - Drawdown Calculations



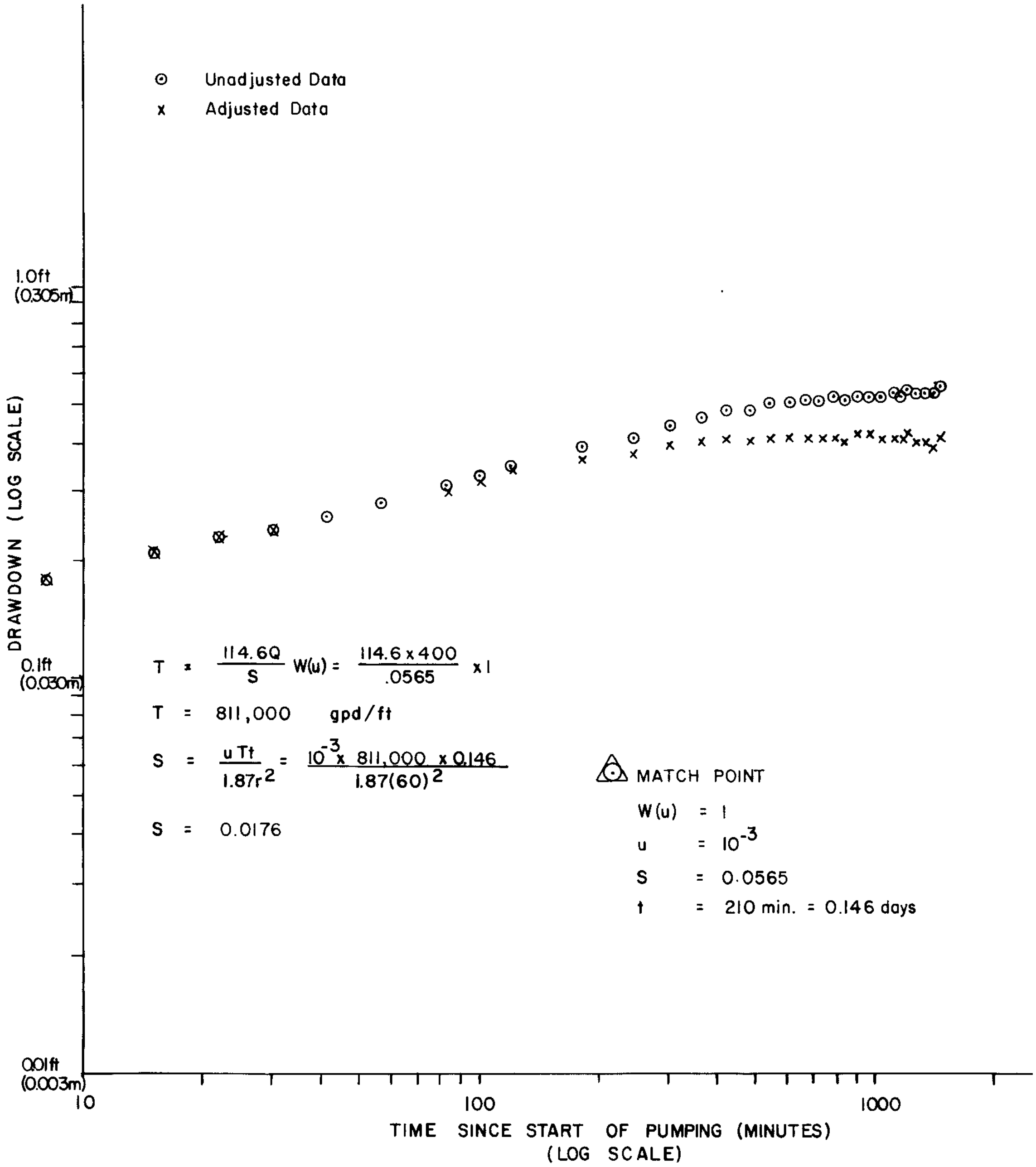
Pump Test No. 2 - Drawdown Data of Well MB-15
Theis Method Calculations



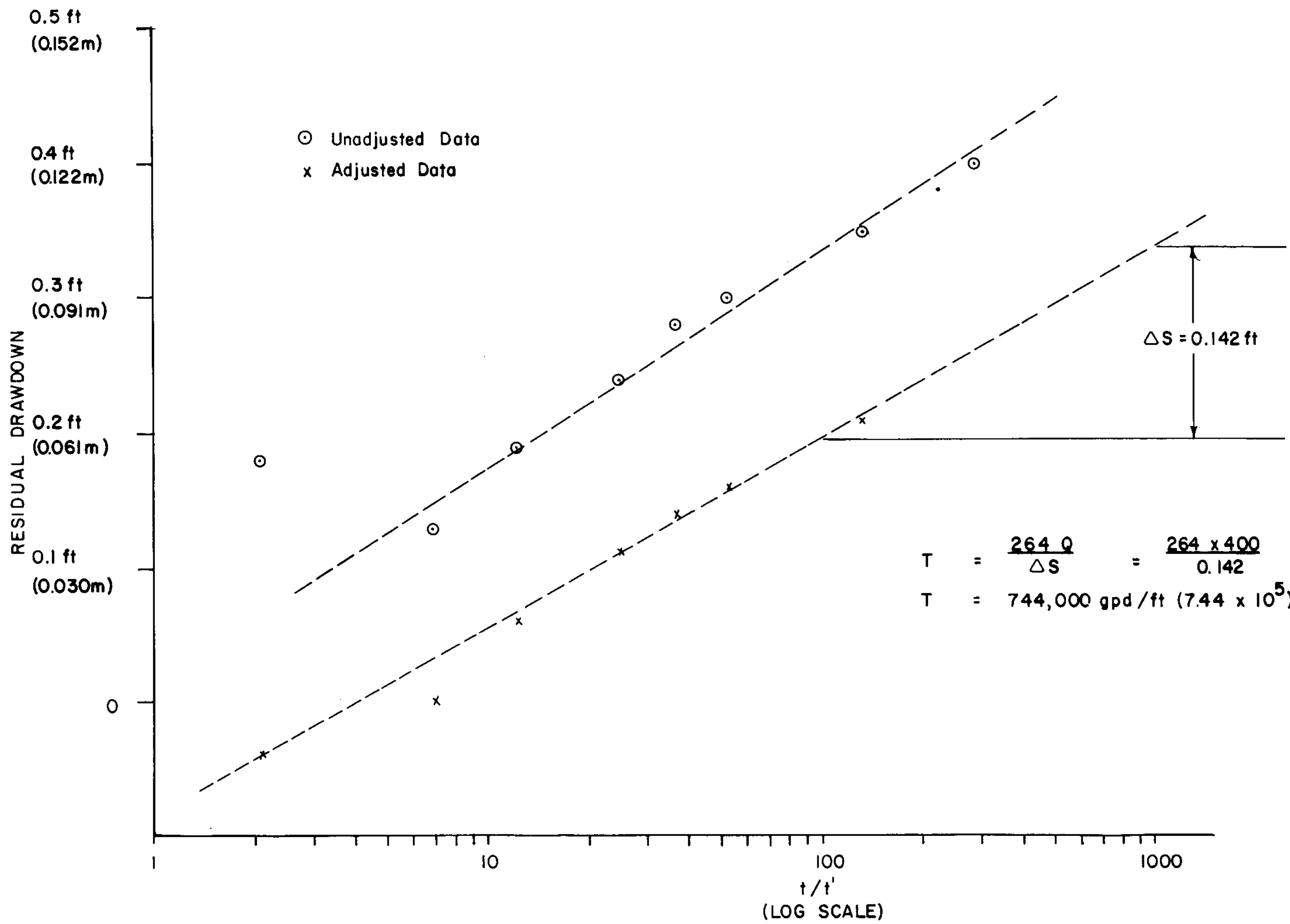
Pump Test No. 2 - Drawdown Data of Well MB-15
Theis Recovery Calculations



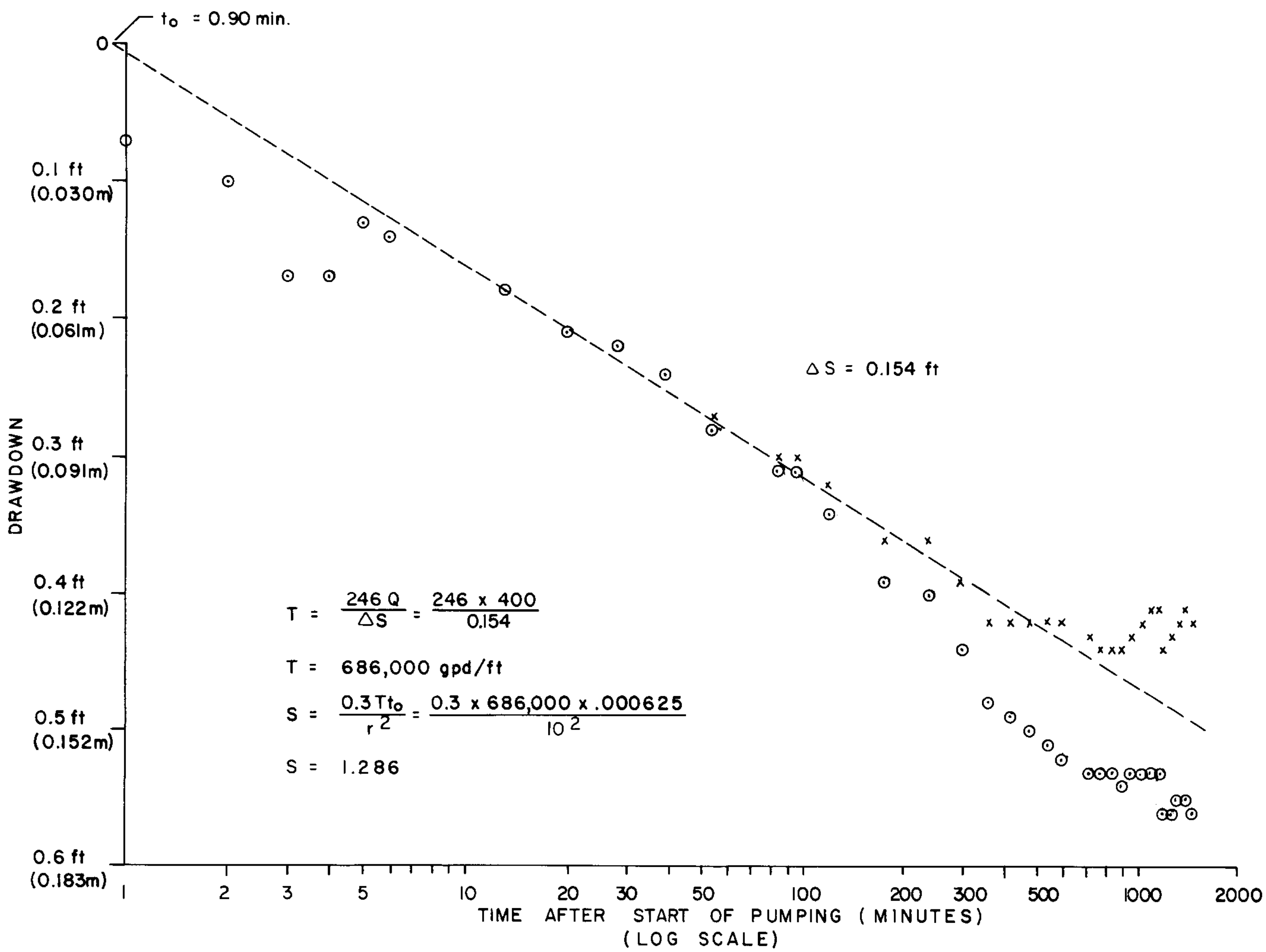
Pump Test No. 2 - Drawdown Data of Well MB-16
Jacobs Time - Drawdown Calculations



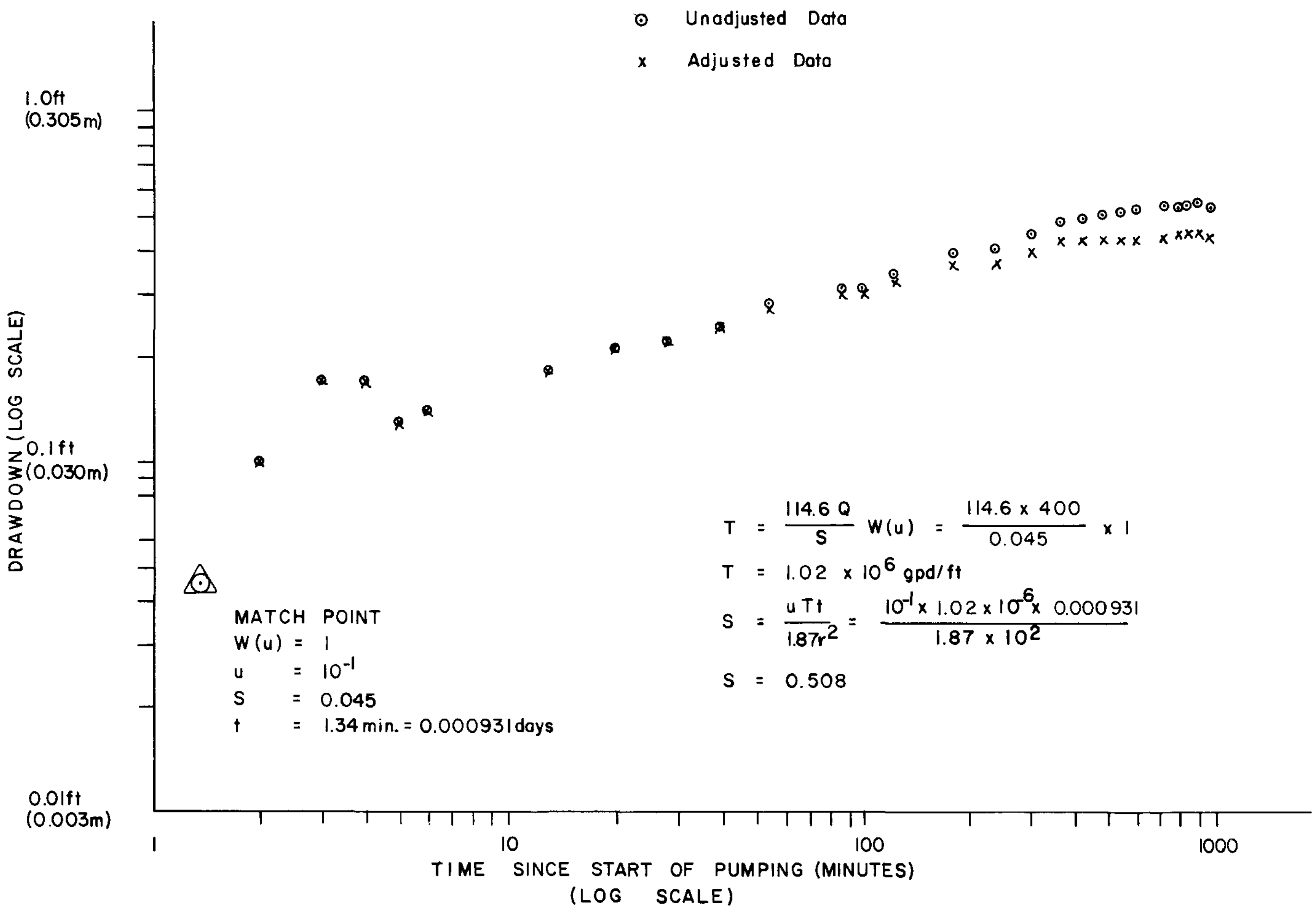
Pump Test No. 2 - Drawdown Data of Well MB-16
Theis Method Calculations



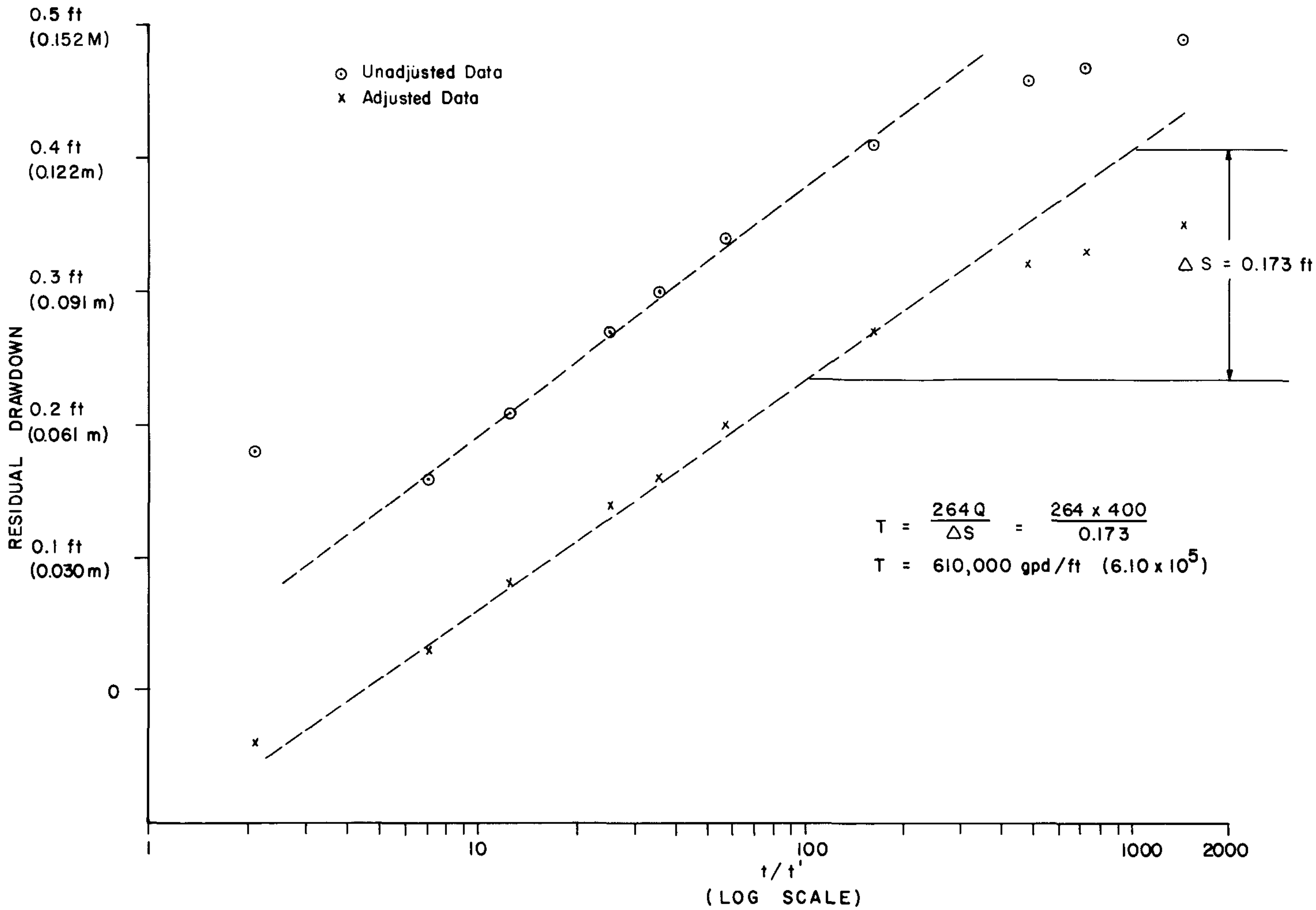
Pump Test No. 2 - Drawdown Data of Well MB-16
Theis Recovery Calculations



Pump Test No. 2 - Drawdown Data of Well MB-17
Jacobs Time - Drawdown Calculations



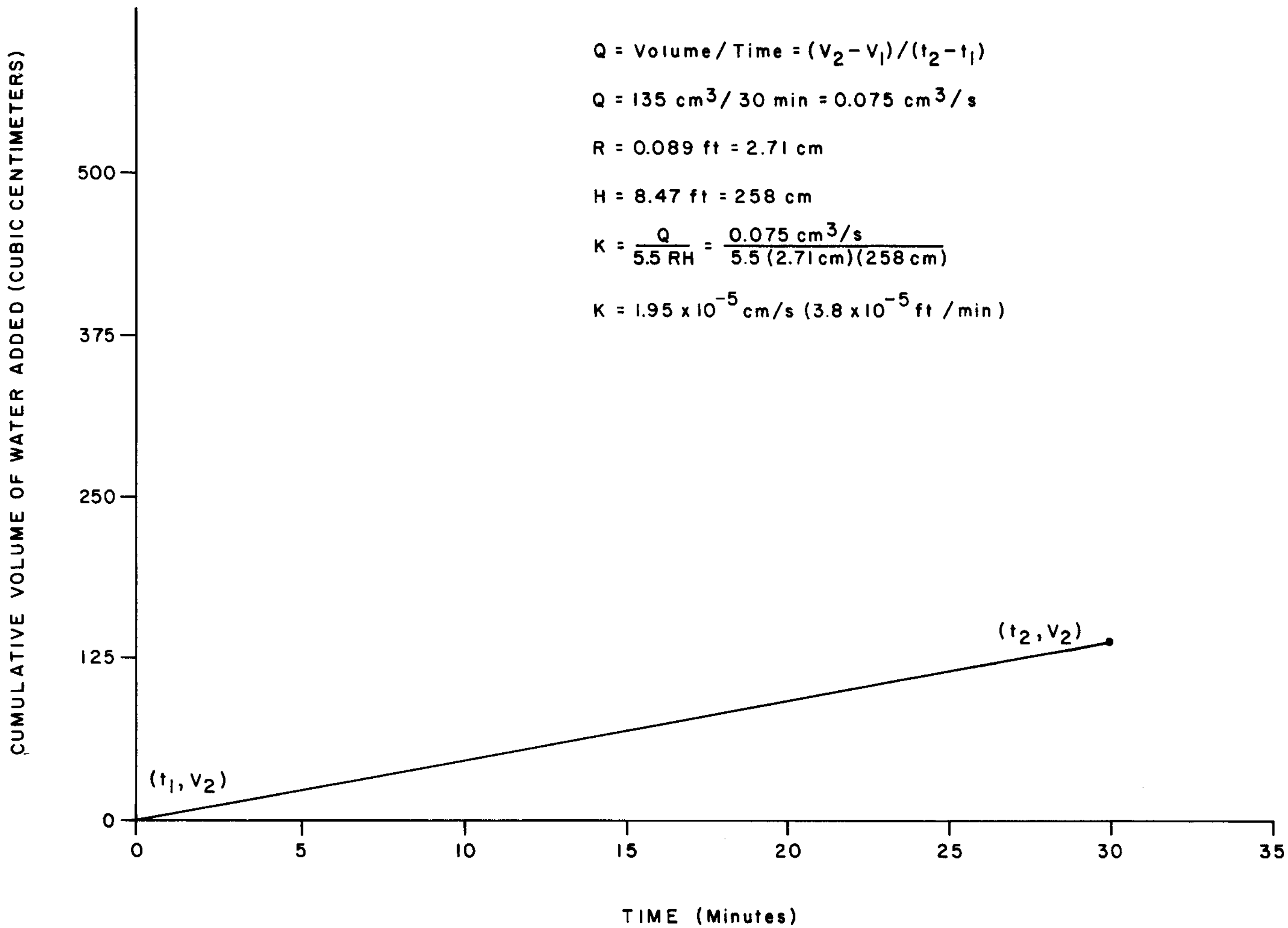
Pump Test No. 2 - Drawdown Data of Well MB-17
Theis Method Calculations



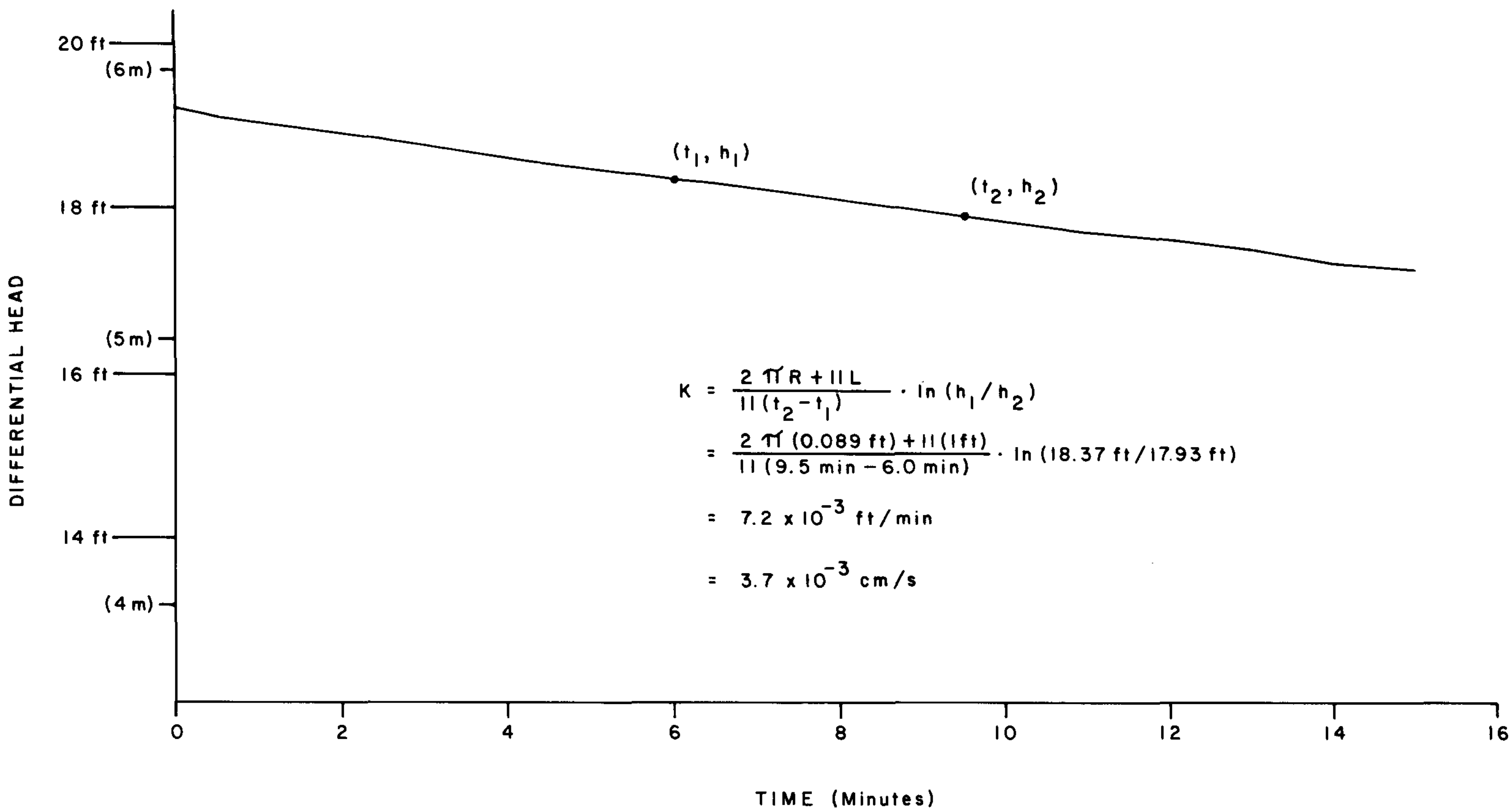
Pump Test No. 2 - Drawdown Data of Well MB-17
Theis Recovery Calculations

Appendix C

BOREHOLE PERMEABILITY TEST DATA PLOTS AND CALCULATIONS



Constant Head Permeability Test - Plot and Calculations
Surface Silt at Well MB-4



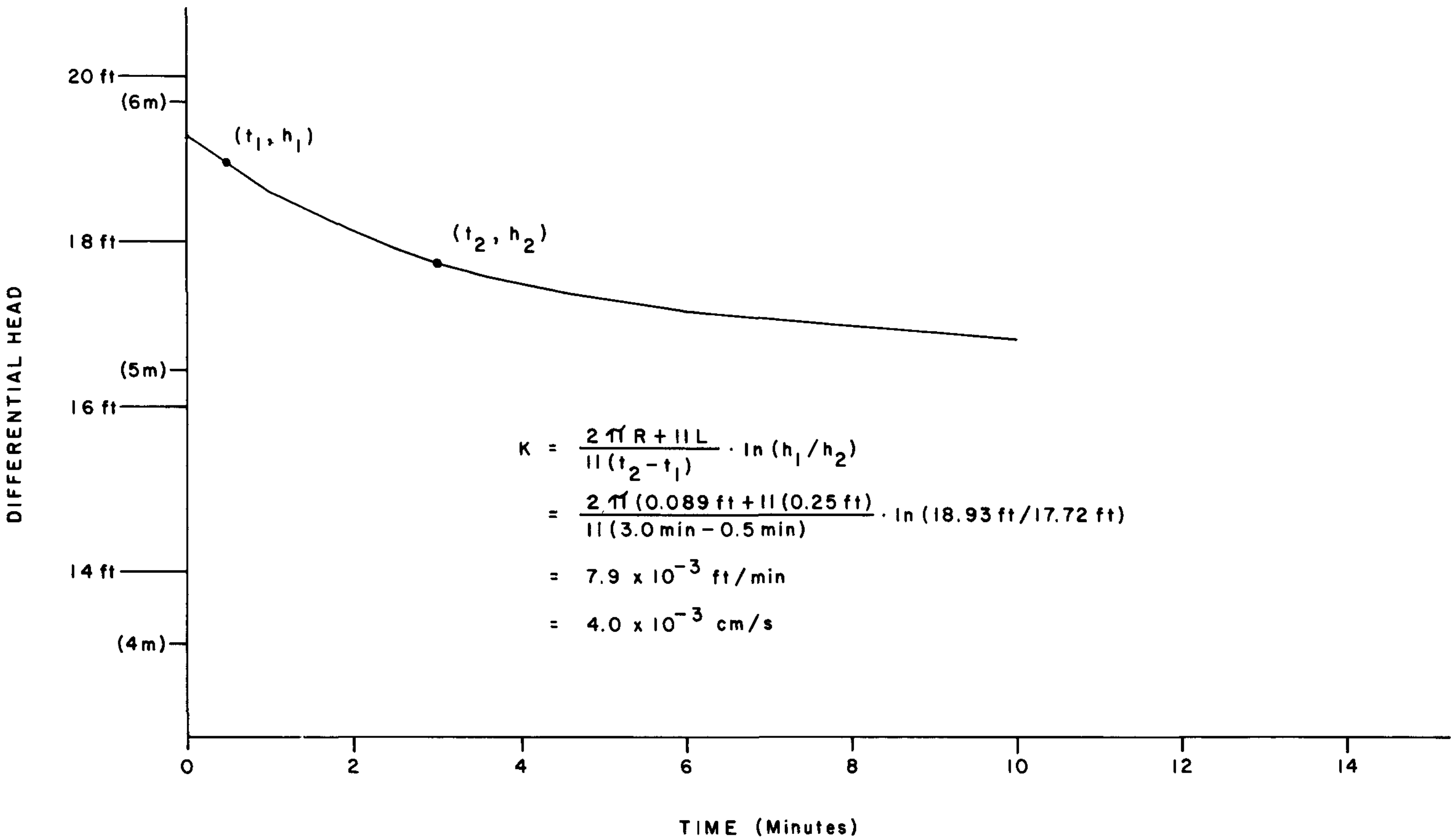
$$K = \frac{2\pi R + 11L}{11(t_2 - t_1)} \cdot \ln(h_1/h_2)$$

$$= \frac{2\pi(0.089\ \text{ft}) + 11(1\ \text{ft})}{11(9.5\ \text{min} - 6.0\ \text{min})} \cdot \ln(18.37\ \text{ft}/17.93\ \text{ft})$$

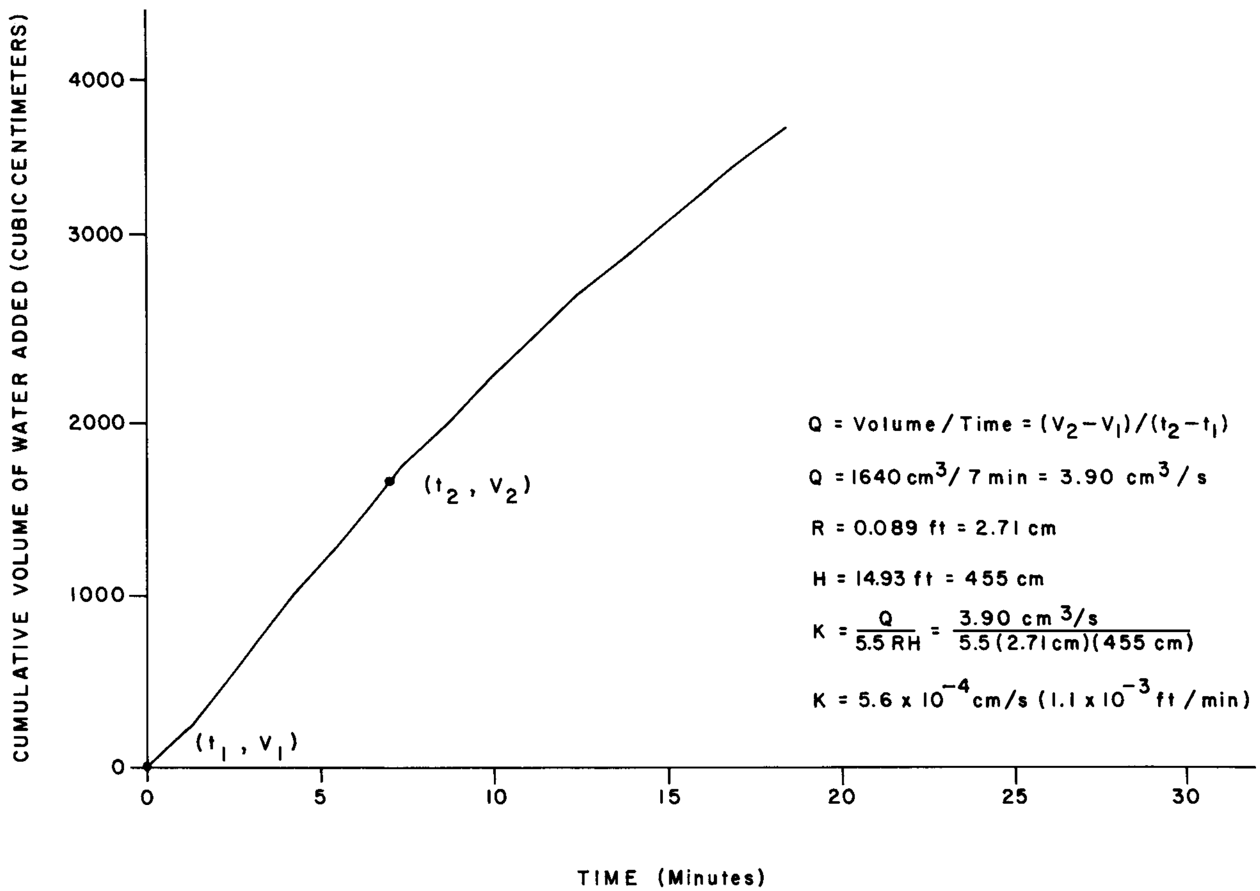
$$= 7.2 \times 10^{-3}\ \text{ft/min}$$

$$= 3.7 \times 10^{-3}\ \text{cm/s}$$

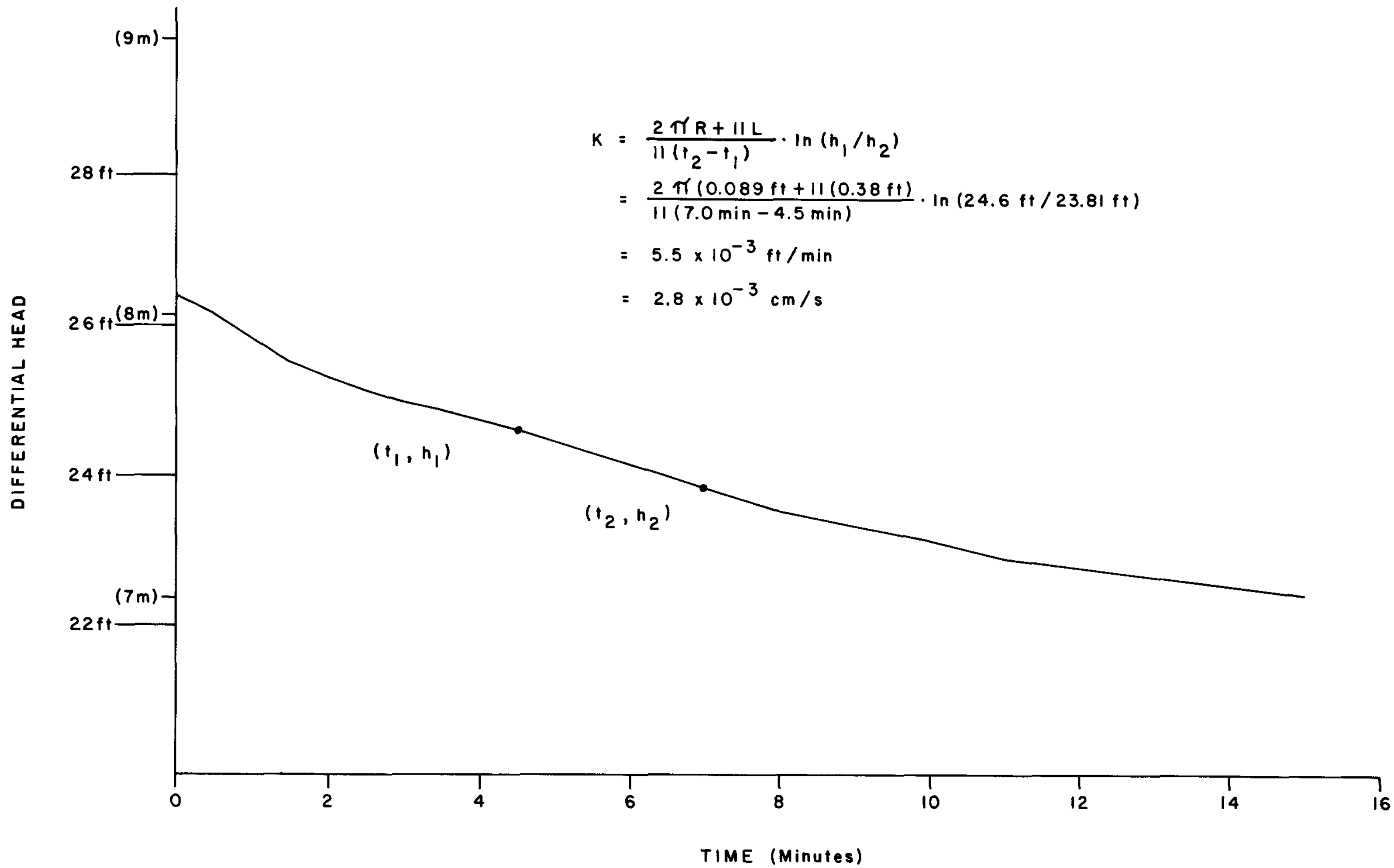
Falling Head Permeability Test - Plot and Calculations
Sand and Gravel at Well MB-4



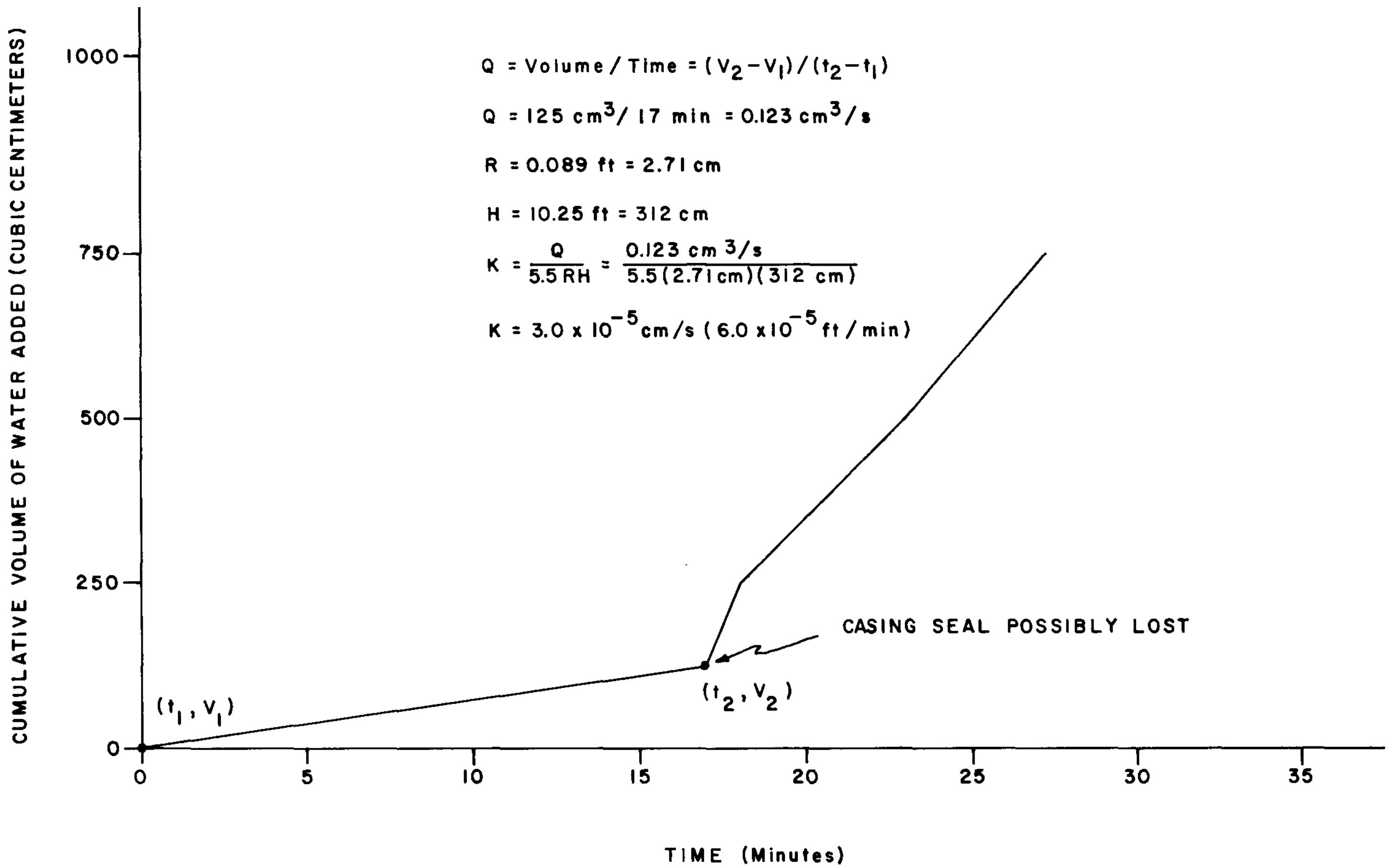
Falling Head Permeability Test - Plot and Calculations
Sand and Gravel at Well MB-7



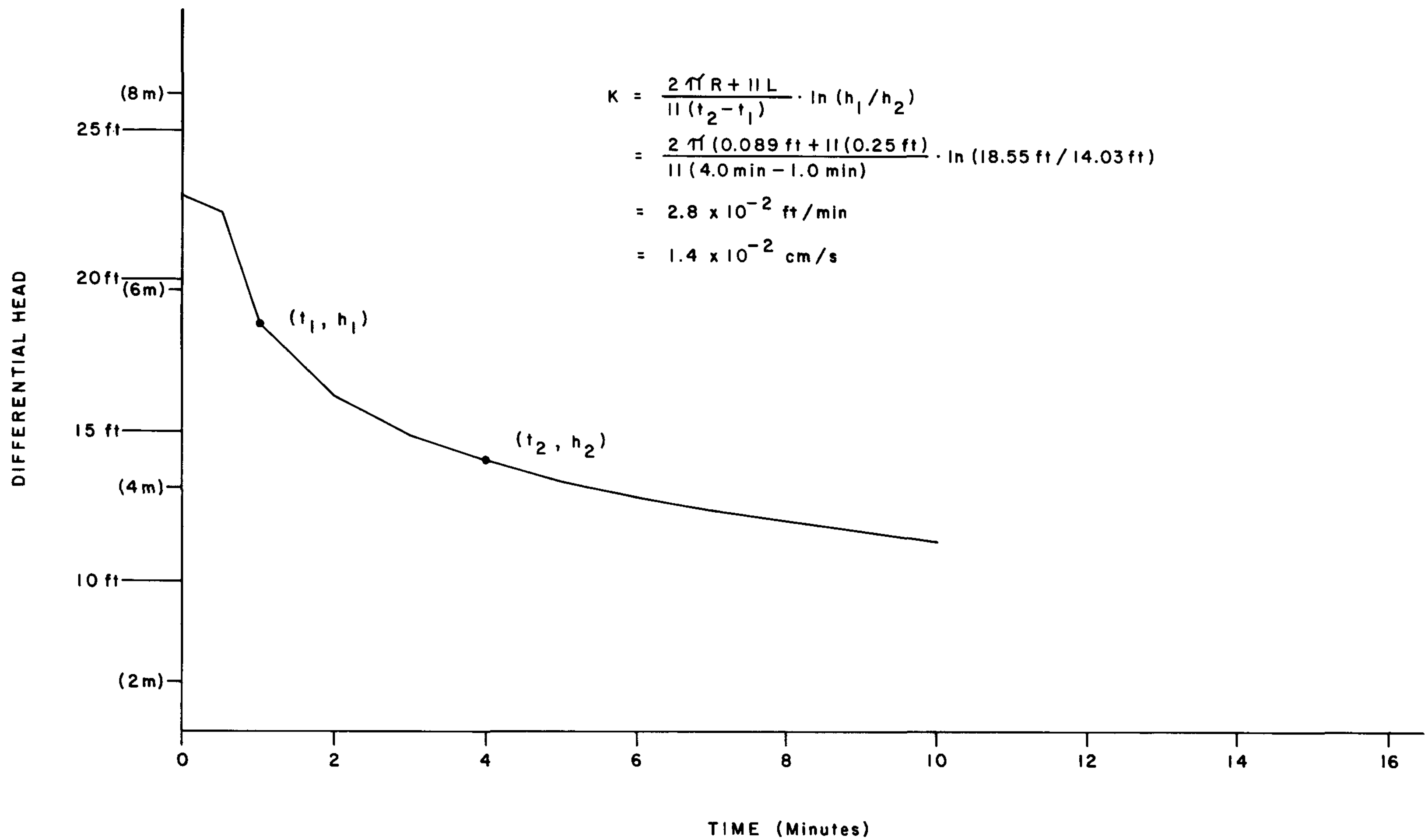
Constant Head Permeability Test - Plot and Calculations
Fill at Well MB-10



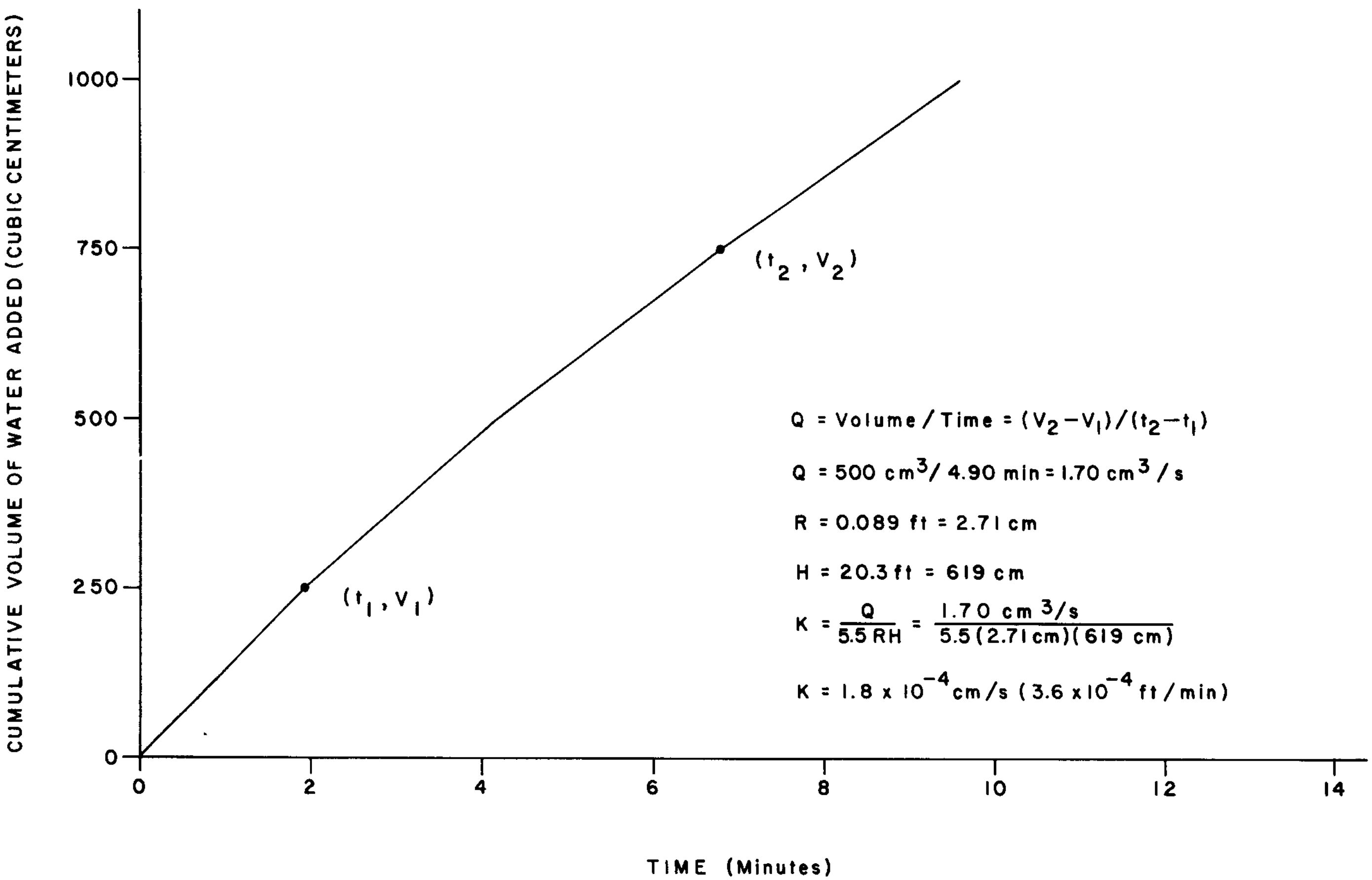
Falling Head Permeability Test - Plot and Calculations
Sand and Gravel at Well MB-10



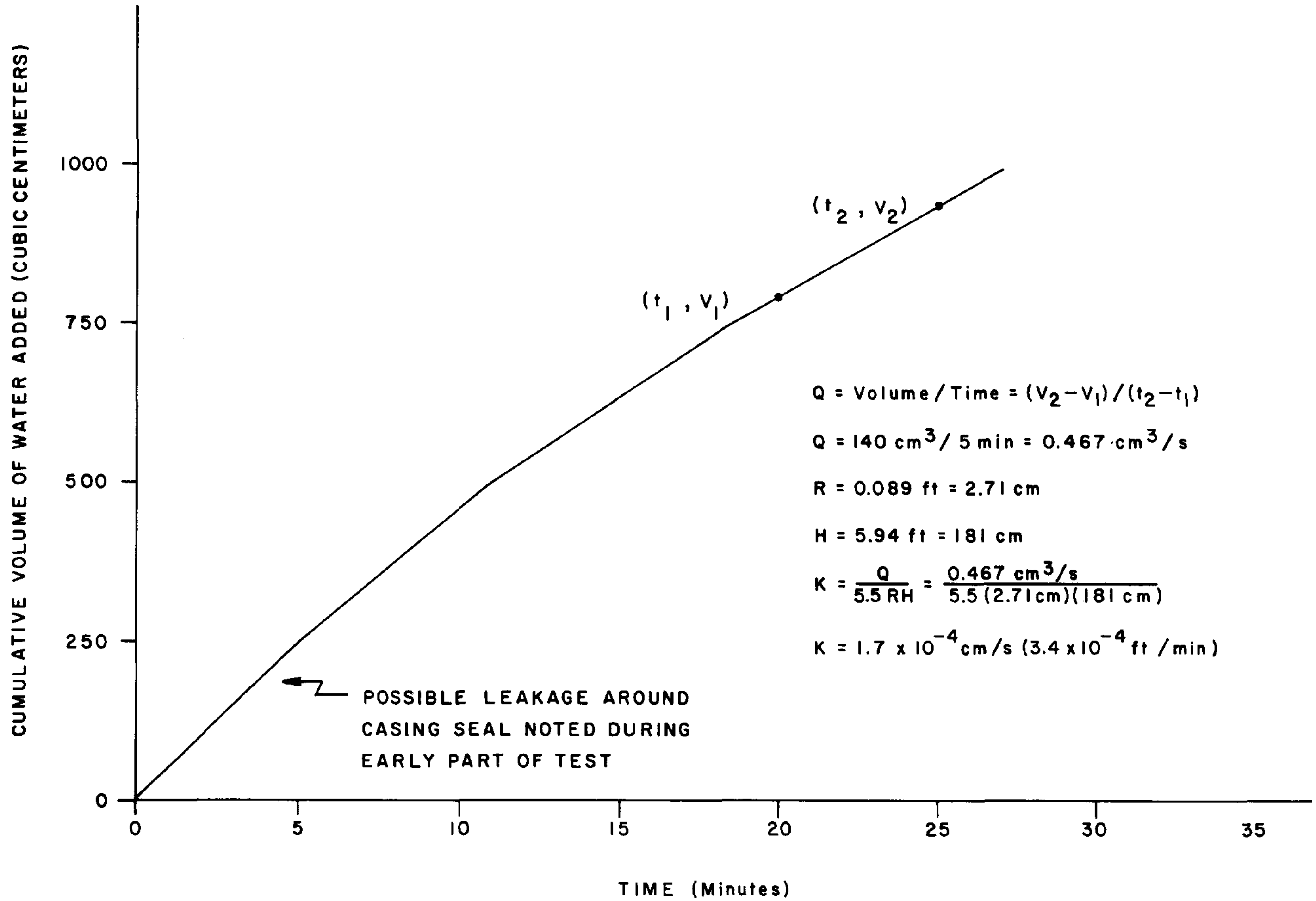
Constant Head Permeability Test - Plot and Calculations
Fly Ash and Silt at Well MB-12



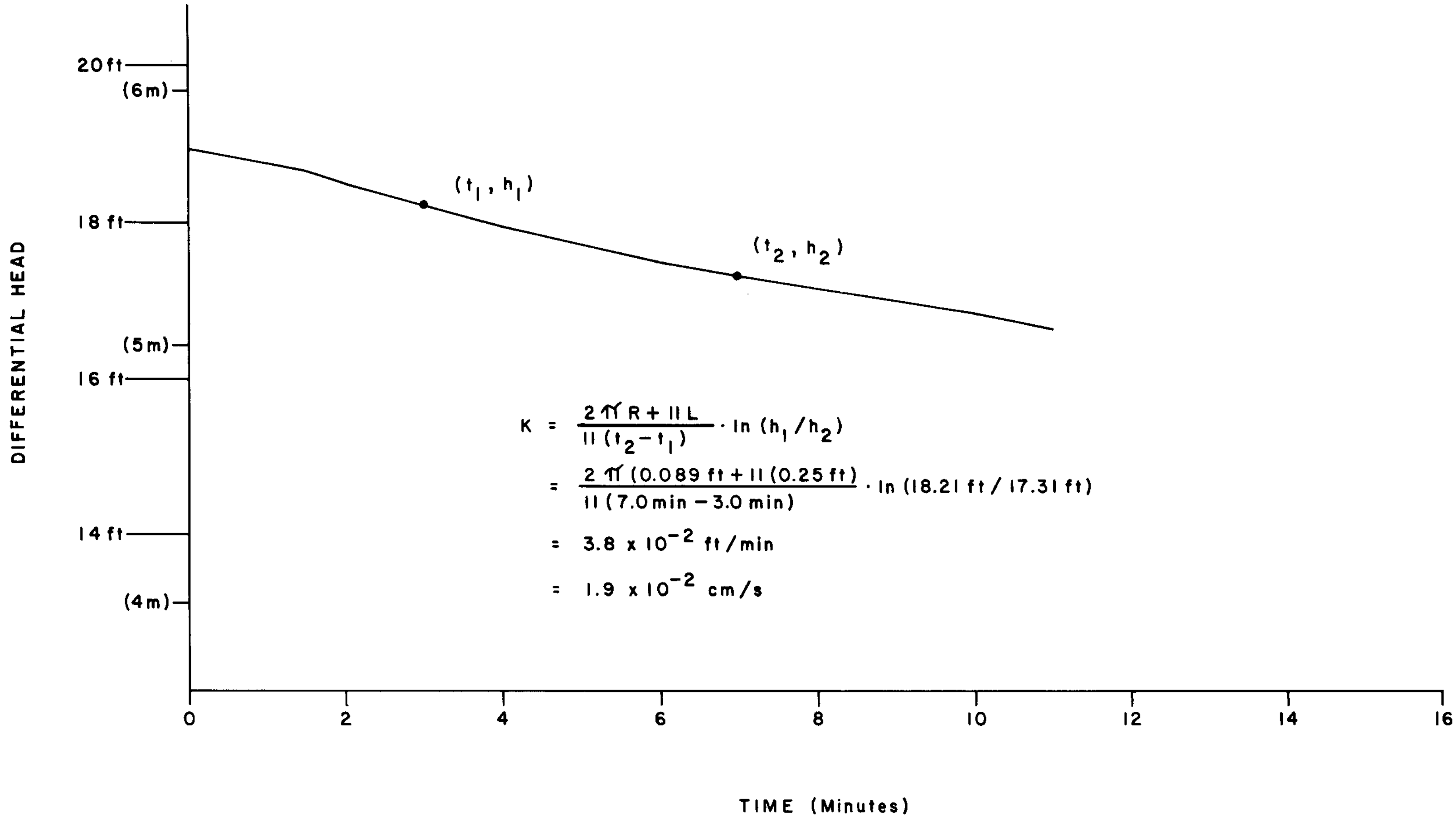
Falling Head Permeability Test - Plot and Calculations
Sand and Gravel at Well MB-12



Constant Head Permeability Test - Plot and Calculations
Fly Ash at Well MB-12A



Constant Head Permeability Test - Plot and Calculations
Surface Silt at Well MB-15



Falling Head Permeability Test - Plot and Calculations
Sand and Gravel at Well MB-14

Appendix D

RECORD OF OBSERVED GROUNDWATER AND SURFACE WATER LEVELS

MEASURED GROUNDWATER LEVELS

Monitoring Point	Elevation Top Casing Or Reference	First Sampling Period 2/22/79	First Sampling Period 2/27/79	First Sampling Period 2/28/79	Second Sampling Period 3/7/79	Third Sampling Period 3/13/79	Third Sampling Period 3/14/79	Fourth Sampling Period 3/21/79	Fifth Sampling Period 3/28/79	Fifth Sampling Period 3/29/79	Sixth Sampling Period 4/5/79	Seventh Sampling Period 4/11/79	Seventh Sampling Period 4/12/79	Eighth Sampling Period 4/18/79
MB-1	742.70	724.85	729.37	729.79	731.49	731.25	--	729.90	--	726.34	729.82	--	730.63	730.75
MB-2	743.66	724.83	729.38	--	731.49	--	--	729.89	--	726.41	729.78	--	730.59	730.78
MB-3	743.16	724.82	729.33	--	731.45	--	--	729.89	--	726.44	729.74	--	730.63	730.75
P-1	742.71	--	--	--	731.51	--	--	729.88	--	726.41	729.92	--	730.66	--
MB-4	746.52	724.77	--	728.11	730.81	731.09	--	730.29	727.63	--	728.55	729.92	--	730.67
MB-5	746.66	724.80	--	728.75	730.84	731.10	--	730.30	727.62	--	728.6	729.96	--	730.67
MB-6	748.89	Approx. 736	739.67	--	740.64	--	740.77	740.56	--	740.11	740.24	--	740.61	740.69
MB-7	744.35	724.35	--	728.16	730.33	730.57	--	729.99	--	727.3	727.92	--	729.54	730.26
MB-8	744.35	724.29	--	728.15	730.28	730.64	--	729.93	--	727.22	727.89	--	729.51	730.21
MB-9	744.44	724.36	--	728.23	730.38	730.72	730.61	729.99	--	727.26	727.94	--	729.54	730.23
MB-10	751.93	724.59	--	728.26	730.33	--	730.64	730.11	727.85	--	728.05	729.43	--	730.35
MB-11	751.95	724.63	--	728.32	730.35	--	730.69	730.13	727.88	--	728.11	729.48	--	730.38
MB-12	748.41	725.81	--	728.83	730.66	--	731.07	730.66	729.16	--	729.37	730.78	--	731.04
MB-13	747.78	725.55	--	728.77	730.66	--	731.01	730.06	728.62	--	728.78	730.08	--	730.80
MB-14	742.24	723.45	--	727.47	729.73	--	730.13	729.55	726.95	--	727.03	728.55	--	729.68
MB-15	742.31	723.43	--	727.46	729.72	--	730.09	729.53	726.91	--	727.01	728.53	--	729.64
MB-16	743.15	723.43	--	--	729.69	--	--	729.48	726.92	--	727.03	728.56	--	729.6
MB-17	743.91	723.37	--	--	729.66	--	--	729.45	726.88	--	726.99	728.52	--	729.55
P-2	742.13	--	--	--	729.55?	--	--	729.25?	--	--	--	--	--	--
River @ Bridge Ref.	745.61	--	727.29 727.09	727.99 728.59	729.73 729.79	--	729.26	727.39	723.94 723.86	723.7	728.69 728.88	728.86 728.79	728.66	728.52 728.39
River W. of MB-1 Ref.	731.77	--	729.27	730.27 730.79	731.91 731.99	--	731.41 731.42	729.58	725.89	725.62	731.19	--	730.77	730.67
River Near Outfall Ref.	732.98	--	--	--	729.40	--	728.95	727.11	723.67	723.44	728.33	--	728.22	728.09
Plant Well 2 Ref.	747.33	--	--	727.41	729.27	--	732.01?	727.88	--	724.45	727.52	--	728.33	728.48
Plant Well 3 Ref.	747.20	--	--	714.53	717.08	--	718.77	716.07	--	712.3	715.65	--	715.85	715.91
Ash Pond Ref.	742.43	--	--	--	740.28	--	740.29	739.98	740.13	--	740.29	739.93	--	739.61 740.11
Holding Pond Ref.	731.45	--	--	--	729.54	--	729.07	727.32	--	727.25	728.48	--	728.4	728.27
Outfall Ref.	733.99	--	--	--	729.45	--	729.0	727.19	--	723.75	728.4	--	728.28	728.16
Poz-O-Tec Pond		--	--	--	--	--	--	--	--	--	--	--	--	730.58

MEASURED GROUNDWATER LEVELS

Monitoring Point	Elevation Top Casing Or Reference	First Sampling Period			Second Sampling Period	Third Sampling Period		Fourth Sampling Period	Fifth Sampling Period		Sixth Sampling Period	Seventh Sampling Period		Eighth Sampling Period
		2/22/79	2/27/79	2/28/79	3/7/79	3/13/79	3/14/79	3/21/79	3/28/79	3/29/79	4/5/79	4/11/79	4/12/79	4/18/79
MB-1	742.70	724.85	729.37	729.79	731.49	731.25	--	729.90	--	726.34	729.82	--	730.63	730.75
MB-2	743.66	724.83	729.38	--	731.49	--	--	729.89	--	726.41	729.78	--	730.59	730.78
MB-3	743.16	724.82	729.33	--	731.45	--	--	729.89	--	726.44	729.74	--	730.63	730.75
P-1	742.71	--	--	--	731.51	--	--	729.88	--	726.41	729.92	--	730.66	--
MB-4	746.52	724.77	--	728.11	730.81	731.09	--	730.29	727.63	--	728.55	729.92	--	730.67
MB-5	746.66	724.80	--	728.75	730.84	731.10	--	730.30	727.62	--	728.6	729.96	--	730.67
MB-6	748.89	Approx. 736	739.67	--	740.64	--	740.77	740.56	--	740.11	740.24	--	740.61	740.69
MB-7	744.35	724.35	--	728.16	730.33	730.57	--	729.99	--	727.3	727.92	--	729.54	730.26
MB-8	744.35	724.29	--	728.15	730.28	730.64	--	729.93	--	727.22	727.89	--	729.51	730.21
MB-9	744.44	724.36	--	728.23	730.38	730.72	730.61	729.99	--	727.26	727.94	--	729.54	730.23
MB-10	751.93	724.59	--	728.26	730.33	--	730.64	730.11	727.85	--	728.05	729.43	--	730.35
MB-11	751.95	724.63	--	728.32	730.35	--	730.69	730.13	727.88	--	728.11	729.48	--	730.38
MB-12	748.41	725.81	--	728.83	730.66	--	731.07	730.66	729.16	--	729.37	730.78	--	731.04
MB-13	747.78	725.55	--	728.77	730.66	--	731.01	730.06	728.62	--	728.78	730.08	--	730.80
MB-14	742.24	723.45	--	727.47	729.73	--	730.13	729.55	726.95	--	727.03	728.55	--	729.68
MB-15	742.31	723.43	--	727.46	729.72	--	730.09	729.53	726.91	--	727.01	728.53	--	729.64
MB-16	743.15	723.43	--	--	729.69	--	--	729.48	726.92	--	727.03	728.56	--	729.6
MB-17	743.91	723.37	--	--	729.66	--	--	729.45	726.88	--	726.99	728.52	--	729.55
P-2	742.13	--	--	--	729.55?	--	--	729.25?	--	--	--	--	--	--
River @ Bridge Ref.	745.61	--	727.29 727.09	727.99 728.59	729.73 729.79	--	729.26	727.39	723.94 723.86	723.7	728.69 728.88	728.86 728.79	728.66	728.52 728.39
River W. of MB-1 Ref.	731.77	--	729.27	730.27 730.79	731.91 731.99	--	731.41 731.42	729.58	725.89	725.62	731.19	--	730.77	730.67
River Near Outfall Ref.	732.98	--	--	--	729.40	--	728.95	727.11	723.67	723.44	728.33	--	728.22	728.09
Plant Well 2 Ref.	747.33	--	--	727.41	729.27	--	732.01?	727.88	--	724.45	727.52	--	728.33	728.48
Plant Well 3 Ref.	747.20	--	--	714.53	717.08	--	718.77	716.07	--	712.3	715.65	--	715.85	715.91
Ash Pond Ref.	742.43	--	--	--	740.28	--	740.29	739.98	740.13	--	740.29	739.93	--	739.61 740.11
Holding Pond Ref.	731.45	--	--	--	729.54	--	729.07	727.32	--	727.25	728.48	--	728.4	728.27
Outfall Ref.	733.99	--	--	--	729.45	--	729.0	727.19	--	723.75	728.4	--	728.28	728.16
Poz-O-Tec Pond		--	--	--	--	--	--	--	--	--	--	--	--	730.58

Appendix E

LABORATORY WATER QUALITY ANALYSES

WATER QUALITY ANALYSES FOR SAMPLES COLLECTED FEBRUARY 27-28, 1979

	MB-1	MB-4	MB-5	MB-6	MB-7	MB-8	MB-9	MB-10	MB-11	MB-12	MB-13	MB-14	MB-15
pH (field)	6.9	6.9	6.9	6.7	6.8	6.9	6.7	6.6	6.7	6.2	6.4	6.6	6.6
pH (lab 3/1/79)	7.5	7.3	7.4	7.0	7.1	7.2	7.2	7.2	7.1	6.3	7.0	7.0	7.0
Total alkalinity, mg/1 $CaCO_3$	216	131	176	210	213	231	268	236	212	32	113	291	245
Total acidity, mg/1	14	14	10	7	21	19	23	26	15	269	212	48	37
Conductance, 25°C µmhos	650	1930	1290	670	1520	1740	1900	1360	1375	1240	1910	2300	2360
COD, mg/1	72	8	4	4	4	4	55	12	12	51	90	8	67
Sulfate, mg/1	188	900	500	120	460	580	800	480	520	600	940	1130	1470
Sulfite, mg/1	0.8	0.8	1.0	3.5	0.8	0.8	1.0	0.8	0.8	1.5	0.8	0.8	0.8
Total Dissolved Solids, mg/1	510	1655	1040	470	1000	1410	1685	1160	1170	1220	1800	2300	2260
Total iron, mg/1	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	180	95	1.3	<.02
Calcium, mg/1	114	339	215	100	243	294	347	265	265	130	360	470	560
Magnesium, mg/1	27.8	65.0	40.9	28.3	39.5	46.1	64.0	29.5	27.3	32.2	43.7	91	80
Arsenic, mg/1	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Barium, mg/1	<.10	<.10	<.10	0.20	<.10	<.10	<.10	<.10	<.10	<.10	<.10	0.20	0.10
Cadmium, mg/1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<0.01
Chromium, mg/1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	< 0.01
Lead, mg/1	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<0.03
Mercury, µg/1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Selenium, mg/1	0.020	.004	.005	.010	.015	.020	.005	.005	.020	.002	.005	.010	.015
Silver, mg/1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

WATER QUALITY ANALYSES FOR SAMPLES COLLECTED MARCH 13-14, 1979

	MB-1	MB-4	MB-5	MB-6	MB-7	MB-8	MB-9	MB-10	MB-11	MB-12	MB-13	MB-14	MB-15
pH (field)	7.2	7.4	7.4	6.7	7.3	7.1	7.7	6.9	6.9	6.0	6.1	6.9	6.8
pH (lab 3/15/79)	7.6	7.8	7.8	7.0	7.2	7.3	7.4	7.1	7.1	6.0	6.3	7.2	7.0
Total Alkalinity, mg/l $CaCO_3$	214	148	171	171	214	208	71	225	206	30	88	234	218
Total Acidity, mg/l $CaCO_3$	23	28	6	14	14	14	25	36	26	301	121	16	34
Conductance, 25°C μmhos	670	1500	1180	635	707	1650	828	1600	1400	1395	1550	2380	2660
COD, mg/l	11	4	4	65	50	19	134	31	15	71	63	40	75
Sulfate, mg/l	200	900	467	193	210	800	280	280	660	900	920	1500	1600
Sulfite, mg/l	0.6	1.0	0.8	1.2	0.8	0.8	---	0.8	0.8	0.9	1.0	0.6	0.7
Total Dissolved Solids, mg/l	542	1500	1136	507	596	604	777	1560	1323	1244	1394	2310	2561
Total Iron, mg/l	<.02	2.9	<.02	5.6	0.78	<.02	0.10	0.04	<.02	173	40	0.04	0.04
Calcium, mg/l	117	255	218	100	125	321	103	326	255	143	255	525	565
Magnesium, mg/l	31.0	67.0	43.2	34.2	26.0	47.4	31.2	34.5	27.5	35.4	25.4	87	88
Arsenic, mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Barium, mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium, mg/l	<.01	<.01	.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<0.01	<0.01	<0.01
Chromium, mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Lead, mg/l	<.03	.06	.05	<.03	.07	0.12	<.03	.09	.04	.04	.04	.05	.16
Mercury, μg/l	1.5	<0.5	<0.5	2.7	<0.5	<0.5	<0.5	<0.5	0.57	<0.5	<0.5	0.57	0.57
Selenium, mg/l	<.002	<.002	.030	.060	<.002	<.002	.037	.012	.005	<.002	<.002	<.002	<.002
Silver, mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

WATER QUALITY ANALYSES FOR SAMPLES COLLECTED MARCH 28-29, 1979

	MB-4	MB-5	MB-7	MB-8	MB-9	MB-10	MB-11	MB-12	MB-13	MB-14	MB-15
pH (field)	7.3	7.3	7.1	7.0	7.1	6.7	6.9	5.2	6.7	6.9	7.0
pH (lab 3/30/79)	7.5	7.4	7.1	7.6	7.3	7.0	7.3	5.3	6.3	7.0	7.6
Total Alkalinity, mg/l $CaCO_3$	210	163	142	213	260	234	231	10	63	149	226
Total Acidity, mg/l $CaCO_3$	11	13	9	23	29	40	24	340	151	45	36
Conductance, 25°C μmhos	560	1340	505	1640	1865	1670	1440	1560	1780	1420	2510
COD, mg/l	4	19	4	39	105	12	54	112	50	42	60
Sulfate mg/l	100	467	80	660	820	733	520	1000	1250	500	1250
Sulfite, mg/l	0.8	0.8	0.8	1.0	1.2	1.0	0.8	1.2	1.0	0.8	1.0
Total Dissolved Solids, mg/l	510	1230	430	1590	1710	1550	1305	1661	1740	1368	2544
Total Iron, mg/l	0.27	<.02	0.04	0.03	0.09	<.02	2.05	273	96	1.58	0.07
Calcium, mg/l	138	259	116	321	376	366	297	160	307	273	546
Magnesium, mg/l	24.0	41.0	18.0	41.0	66.0	78.0	26.0	30.0	32.0	60.0	78.0
Arsenic, mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Barium, mg/l	.04	.07	.03	.03	.04	.03	.04	.02	.05	.02	.04
Cadmium, mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	0.01	<.01	0.01
Chromium, mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	0.01	<.01	<.01
Lead, mg/l	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
Mercury, μg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Selenium, mg/l	.050	<.002	.014	.031	.014	.009	.011	<.002	<.002	<.002	<.002
Silver, mg/l	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

WATER QUALITY ANALYSES FOR SAMPLES COLLECTED APRIL 11-12, 1979

	MB-4	MB-5	MB-7	MB-8	MB-9	MB-10	MB-11	MB-12	MB-13	MB-14	MB-15
pH (field)	---	---	---	---	---	6.8	6.9	6.6	7.0	6.8	6.9
pH (lab 3/13/79)	7.6	7.6	7.2	7.5	7.5	7.4	7.3	5.5	6.5	7.1	7.1
Total Alkalinity, mg/l $CaCO_3$	142	184	206	211	250	264	173	10	100	307	260
Total Acidiy, mg/l $CaCO_3$	17	16	22	23	23	27	20	279	183	38	47
Conductance, 25°C μmhos	1560	1460	1563	1558	1465	1610	1463	1020	1700	2125	2418
COD, mg/l	43	43	55	8	19	8	<4	32	44	28	4
Sulfate, mg/l	833	633	500	525	525	475	575	400	775	975	1133
Sulfite, mg/l	0.8	0.8	0.8	0.8	1.5	1.0	1.0	1.5	0.8	1.0	1.0
Total Dissolved Solids, mg/l	1512	1309	1379	1387	1420	1513	1343	861	1651	2244	2549
Total Iron, mg/l	0.02	<.02	0.04	0.04	0.03	0.04	0.02	107	72	0.09	0.04
Calcium, mg/l	330	274	300	320	344	345	326	121	313	480	454
Magnesium, mg/l	59.0	45.0	41.0	42.0	64.0	33.0	32.0	24.0	33.0	84.0	82.0
Arsenic, mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Barium, mg/l	.09	.07	.07	.04	.05	.03	.04	.03	.06	.06	0.05
Cadmium, mg/l	.002	.003	.002	.003	.008	.003	.001	.005	.004	.003	.003
Chromium, mg/l	<.001	<.001	<.001	<.001	.001	<.001	<.001	.002	<.001	.003	.001
Lead, mg/l	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
Mercury, μg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Selenium, mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Silver, mg/l	.001	.002	.001	.001	.001	.001	<.001	<.001	<.001	.001	.002