PUMP TEST AND AQUIFER ANALYSIS

UNDERGROUND STORAGE TANK INVESTIGATION

General Motors Corporation - Fisher Guide Division
Tenton, New Jersey

November 1989

WESTON
MANAGERS DESIGNERS/CONSULTANTS

PUMPING TEST AND AQUIFER ANALYSIS

UNDERGROUND STORAGE TANK INVESTIGATION

Prepared for
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Fisher Guide Division
Trenton, New Jersey

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By

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SECTION 1

INTRODUCTION

During the week of 9 October 1989 Roy F. Weston, Inc. (WESTON) conducted a pumping test at the GMC Inland Fisher Guide plant in Trenton, New Jersey. This work was conducted in accordance with recommendations of the Phase III Underground Storage Tank Investigation Report and the 3 August 1989 letter from WESTON to Eric Kinsel of the New Jersey Department of Environmental Protection (NJDEP).

The pumping test activities were divided into four phases: measurement of background static water levels for a period of 37 hours, completion of a step-drawdown test, completion of a constant rate pumping test, and completion of a recovery test.

The information obtained from the pumping test and subsequent data analysis provided in this report will be used to design a groundwater recovery system as described in the Phase III Underground Storage Tank Report (May 1989). This information will also be used in support of the groundwater recovery and treatment activities outlined in the Groundwater Remediation Plan (June 1989) requested by the NJDEP.

SECTION 2

PUMPING TEST METHODS

2.1 GENERAL OVERVIEW

Monitoring well UST-2 was chosen as the test well based on its location (e.g., downgradient of the contaminant source), depth (40 feet below grade), and performance during past sampling activities. UST-2 is completed within the upper Stockton Formation. The well is cased to a depth of 25 feet below grade. The remaining 15 feet of the well is an open hole. Water-producing fractures were encountered at 31 and 37 feet below grade during the drilling of this well. Five observation wells were chosen to monitor water levels in the upper Stockton Formation during all test activities: UST-3, UST-4, UST-6, UST-8, and UST-9. Figure 2-1 indicates the location of each of the observation wells in relation to the pumping well. Wells UST-3, UST-4, UST-8, and UST-9 are completed within the upper member of the Stockton Formation. Well UST-6, adjacent to the test well, was completed at the contact between the overburden material and the top of the Stockton. The depth of the bedrock wells varies, based on the depth at which the first water producing fracture was encountered. The observation wells were chosen based on their location and depth. With the exception of UST-9, the water levels in the observation wells were recorded using an electronic data logger (In Situ SE-2000). Water levels in UST-2 and UST-9 were measured to the nearest hundredth of an inch manually using an electronic water level indicator.

2.2 FIELD PROCEDURES

The pumping test activities were conducted in four phases: background water level measurement, a step-drawdown test, constant rate pumping test, and recovery test. Background water level measurements were collected from wells UST-3, UST-4, UST-6, and UST-8. These measurements were collected at 15 minute intervals for a period of 2,265 minutes (37.75 hours). Manual measurements were also collected from wells UST-2 and UST-9 at random intervals during this period.

A step-drawdown test was conducted subsequent to collection of the background data. This test involved the pumping of UST-2 at three different rates (steps). The test began with a pumping rate of 5 gallons per minute (gpm). The test was run at this discharge rate for one hour. The pumping rate was then increased to 10 gpm for the second step (one hour in

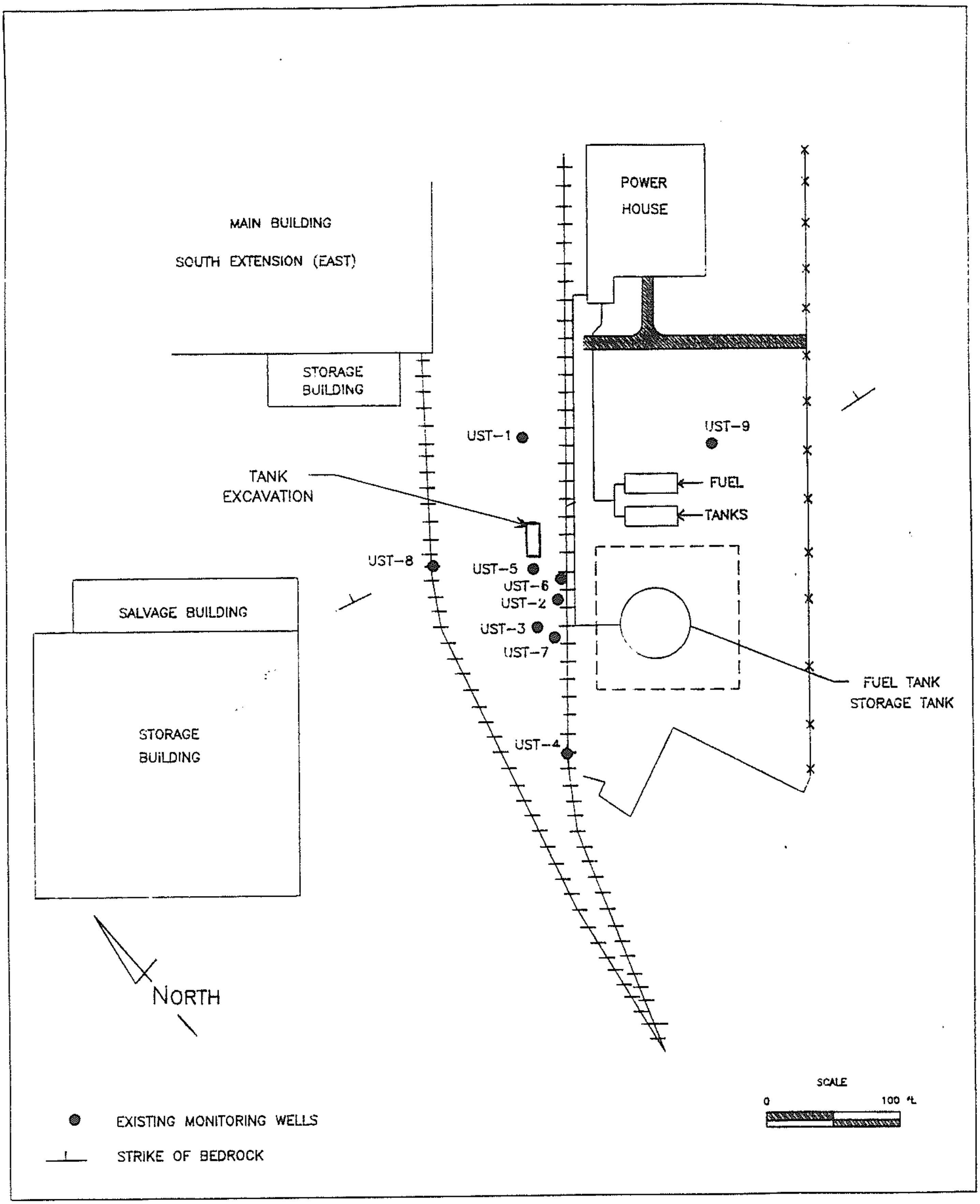


FIGURE 2-1
UNDERGROUND STORAGE TANK
MONITORING WELL LOCATIONS

duration). The third step was conducted at 15 gpm. Upon completion of the step-drawdown test, all wells were allowed to recover until they had returned to within 3 percent of static levels prior to initiating the pump test.

The constant rate pumping test was initiated at 2:45 pm on 11 October 1989. This test was conducted for 1440 minutes (24 hours). At 300 minutes (5 hours) into the test, the pumping well was fairly stable with approximately 0.7 feet of drawdown per hour. The depth to water at 300 minutes was 24.93 feet below grade. However, between 300 and 550 minutes (9.16 hours) into the test, the water level in the pumping well dropped 9.5 feet to 34.50 feet below grade. In response to this unexpected drop in the water level, the pumping rate was reduced to 8.5 gpm. Within 40 minutes of reducing the pumping rate, the water level in UST-2 returned to approximately 26 feet below grade. The pumping test was terminated at 1440 minutes in conjunction with the initiation of the recovery test. Manual measurements of the depth to water were collected in UST-2 at 30 second intervals for 20 minutes into the recovery test, 1 minute intervals for 15 minutes, 5 minute intervals for 25 minutes, and 10 minute intervals thereafter. The depth to the water table was recorded in wells UST-3, UST-4, UST-6, and UST-8 using the electronic data logger.

SECTION 3

PUMPING TEST RESULTS

The objective of the pumping test was to evaluate the hydraulic characteristics of the upper Stockton Formation. This information will be used to design a groundwater remediation system for use at the facility. The hydraulic characteristics necessary to design such a system include both transmissivity and storativity.

3.1 DATA OVERVIEW

Background static water levels were recorded in the observation wells for 2265 minutes (37.75 hours). This data is graphically presented in Appendix A for each of the observation wells. Data from wells UST-3 and UST-4 indicate a gradual rise in the water level during the background period (0.15 feet and 0.13 feet, respectively) while UST-6 showed a drop (0.38 feet) in the water level. The water level in well UST-8 fluctuated throughout the background period with no apparent trends (maximum fluctuation of 0.98 feet). The drop in the water level in well UST-6, and corresponding rise in UST-3 and UST-4, appears to be the result of natural drainage of the overburden material and the corresponding recharge of the bedrock aquifer. Graphs of the depth-to-water versus time for the observations well are presented in Appendix A.

The optimum pumping rate for the constant rate pumping test was determined from the results of the step-drawdown test. This test involved pumping UST-2 at three different pumping rates (steps). Each step was conducted for one hour at which time the pumping rate was increased 5.0 gpm. The first step was conducted at 5.0 gpm. During this step the pumping water level dropped 2.7 feet, stabilizing at 18.51 feet below grade. The water was turbid at the initiation of the test, however, it cleared up within 5 minutes of pumping. Step 2 was conducted at 10.0 gpm for one hour. The water level dropped an additional 4.79 feet, stabilizing at 23.30 feet below grade. The third step was conducted at 15.0 gpm for 12 minutes. At this time the water level had dropped to a level equivalent to the pump intake. Thus, the well could not sustain a flow rate of 15.0 gpm. The maximum depth to water during this step was 37.65 feet below grade. Upon completion of the step-drawdown test the depth to water was monitored for a period of 55 minutes. At this time the depth to water had returned to 16.25 feet below grade in the pumping well (97 % recovery to static conditions).

The constant rate pumping test was initiated 180 minutes (3 hours) after completion of the step-drawdown test. The pumping well (UST-2) had recovered to 98 % of static conditions at the initiation of the test. Based on the data collected during the step-drawdown test, the pumping rate was set at 10 gpm.

The depth to water in the pumping well dropped an average of 0.7 feet per hour during the constant rate test. Between 300 and 550 minutes (5.0 and 9.16 hours, respectively) into the test, the water level in the pumping well dropped 9.5 feet from 24.93 to 34.50 feet below grade. The pumping rate was decreased to 8.5 gpm to prevent the complete dewatering of the pumping well. Within 40 minutes of reducing the pumping rate, the water level in UST-2 returned to approximately 26 feet below grade. Based on the lithologic and structural nature of the aquifer (i.e., fine grained and fractured), it is likely that the sudden drop in the water level is the result of dewatering the fractures intercepted by UST-2. Therefore, the test results suggest that the optimum long term pumping rate for UST-2 is actually less than 10 gpm, at approximately 8.5 gpm.

With the exception of wells UST-6 and UST-8, the depth to water in the observation wells showed little change during the test (less than 0.3 feet). This indicates that there is poor communication between the fractures intercepted by these wells and the pumping well. Graphs of depth-to-water versus time for observation wells UST-3, UST-4, and UST-9 are provided in Appendix B.

The test was terminated at 1440 minutes in conjunction with the initiation of the recovery test. The water level in wells UST-2 and UST-8 steadily rose towards their static conditions. However, the water level in wells UST-3 and UST-4 remained stable for the duration of the recovery test. The depth to water in UST-6 remained stable for approximately 300 minutes, then began to increase for the remainder of the recovery test. Graphs of the recovery data are presented in Appendix B.

3.2 ANALYSIS OF TEST WELL DATA

The data obtained from the test well during the pumping and recovery tests was used to determine the transmissivity of the upper member of the Stockton Formation. Due to the fine grained nature of the formation, water is primarily transmitted and stored in fractures, joints, and parted bedding planes (secondary permeability features). Groundwater stored within the pores of the rock itself (primary permeability) is poorly transmitted. Therefore, transmissivity is largely controlled by the size and extent of the secondary permeability features. Storativity can not be reliably determined from the pumping well.

The straight line method of Cooper and Jacob (1946) was used to determine the transmissivity. This method involves the plotting of drawdown (or depth to water) versus time on semi-log paper (see Figure 3-1). Drawdown is plotted on the linear scale (vertical axis) while time is plotted on the logarithmic scale (horizontal axis). The change in drawdown (Δs) over one log cycle (taken from the graph) along with the pumping rate of the test well is used to calculate the transmissivity (T) of the aquifer using the following equation:

$$T = \frac{2.30\ Q}{4\ \pi \Delta s}$$

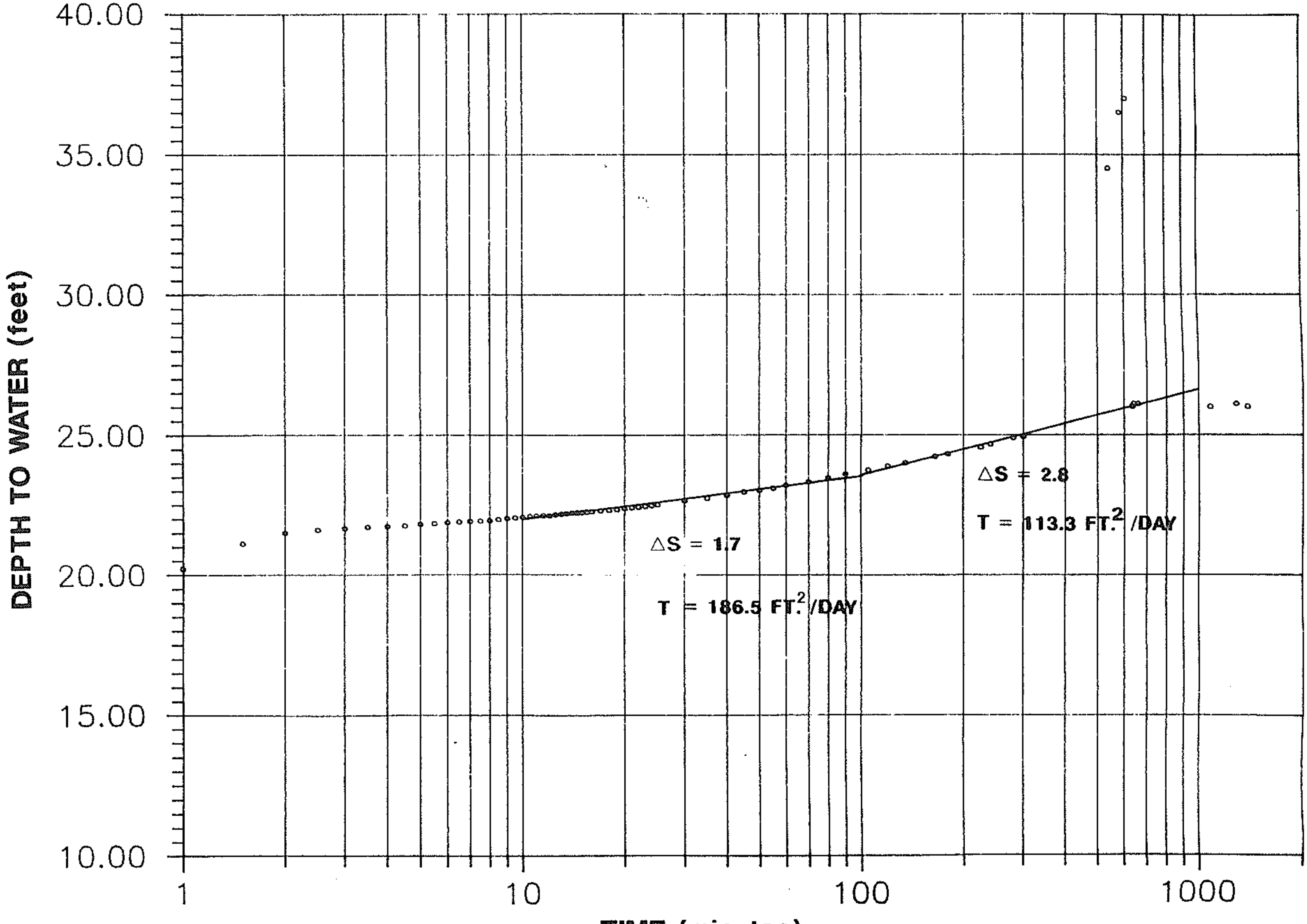
Q = pumping rate
Δs = change in drawdown

Transmissivity was calculated from data collected between 10 and 100 minutes and 100 and 1000 minutes into the test. The sudden increase of the depth to water between 300 and 550 minutes was not considered when evaluating the late pump test data (see Figure 3-1). Transmissivity ranged from 113 to 186 ft^2/day, the late pump test data yielding the lower transmissivity value.

The data obtained during recovery of the pumping well was also evaluated using the method developed by Cooper and Jacob. Transmissivity is calculated by plotting residual drawdown (or depth to water) versus the ratio of time since pumping started (t) to the time since pumping stopped (t^1). This graph is presented in Figure 3-2. The value of t/t^1 decreases as the length of recovery of the test well increases. The change in drawdown is calculated over one log cycle, as with the evaluation of the drawdown data (see Figure 3-2). Transmissivity is calculated using the following equation:

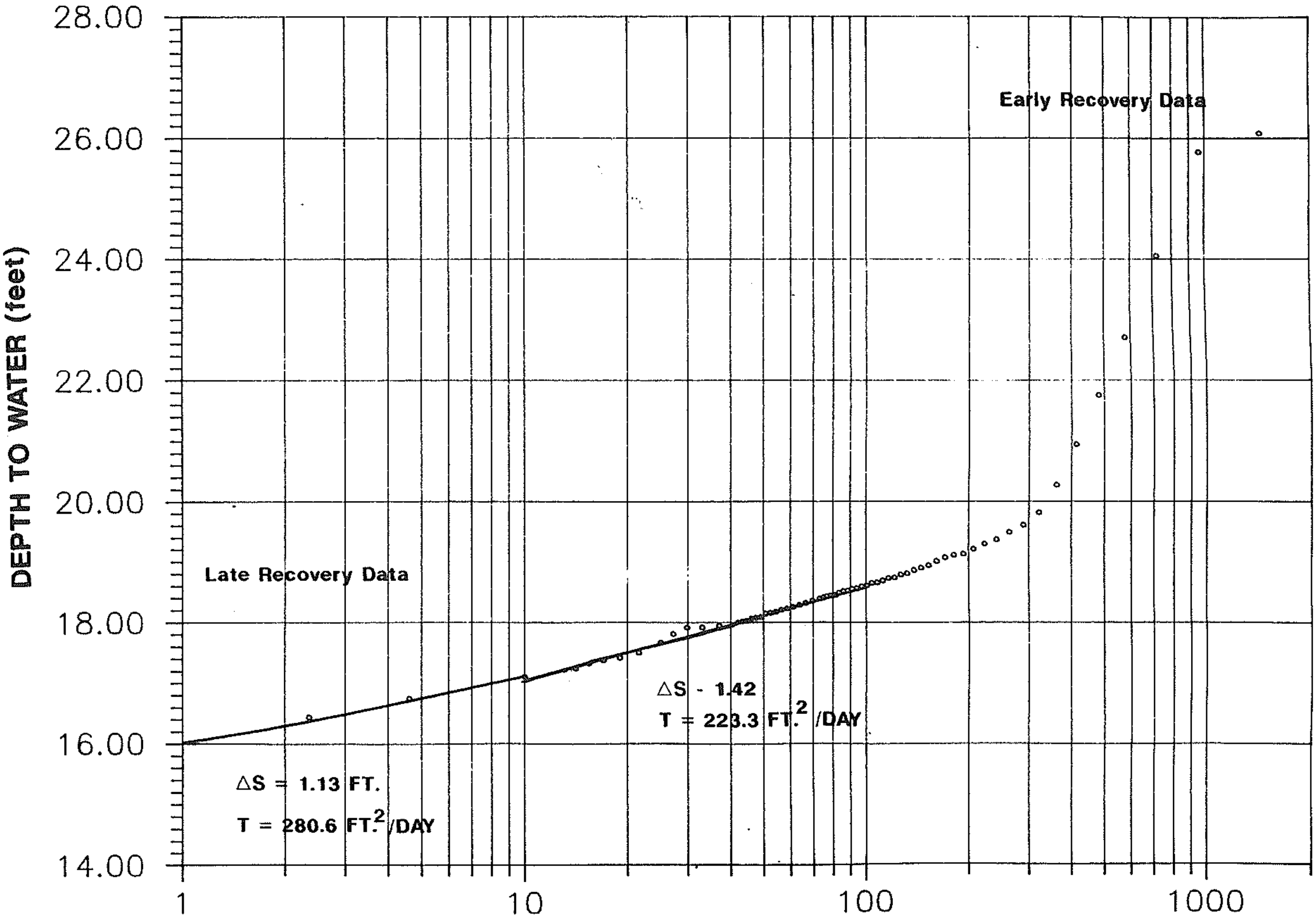
$$T = \frac{2.30\ Q}{4\ \pi\ \Delta s^1}$$

Transmissivity ranged from 223.3 to 280.6 ft^2/day using this method. The higher transmissivity value was calculated from the late recovery data.



40.00
35.00
30.00
25.00
20.00
15.00
10.00
DEPTH TO WATER (feet)
1
10
100
1000
TIME (minutes)
ΔS = 1.7
T = 186.5 FT.² /DAY
ΔS = 2.8
T = 113.3 FT.² /DAY

FIGURE 3-1


DEPTH TO WATER (feet)
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
1
10
100
1000
TIME (minutes)
Early Recovery Data
Late Recovery Data
ΔS - 1.42
T = 223.3 FT.2 /DAY
ΔS = 1.13 FT.
T = 280.6 FT.2 /DAY
FIGURE 3-2

3.3 ANALYSIS OF OBSERVATION WELL DATA

The depth to water in each observation well remained fairly stable during the pumping test with the exception of UST-6 and UST-8. Transmissivity and storativity were calculated from the observation well data using the Cooper and Jacob method. The data collected during the pumping phase is plotted on a graph of depth to water versus time. Due to the relatively poor response to pumping by wells UST-3, UST-4, and UST-9, only UST-8 was evaluated. Data from well UST-6 was not considered since this well is screened at the overburden/bedrock contact. Test data collected from UST-8 is presented in Figure 3-3. Transmissivity is calculated in the same manner for the observation wells as in the test well. Analysis of the observation well data yielded a transmissivity value of 417.2 ft^2/day. Storativity (S) is calculated using the following equation:

$$S = \frac{2.25\ Tt_o}{r^2}$$

T = transmissivity

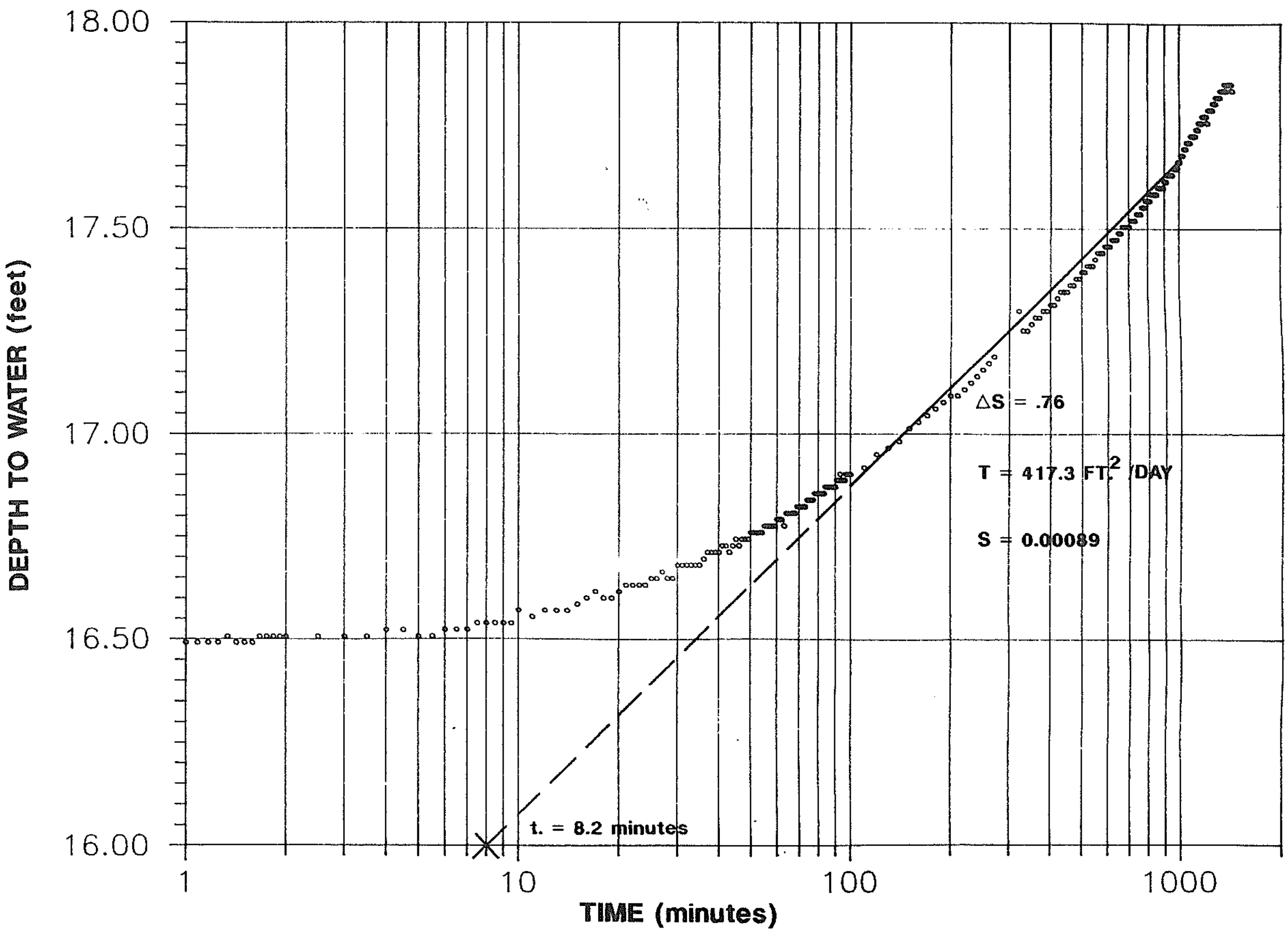
t_o = time at the point where the straight line intersects the zero-drawdown line

r = distance from the test well to the observation well

The value of t_o is obtained by extrapolating the straight line over one log-cycle to the x axis (see Figure 3-3). The intersection point is considered t_o. Storativity was calculated at 0.00089 from the late drawdown data.

The recovery data for the observation wells, with the exception of UST-8, shows a continued increase in the depth to water throughout the recovery period (see graphs in Appendix B). Therefore, this data is inappropriate for use in evaluating transmissivity and storativity. Data collected from UST-8 during the recovery test has been plotted on a graph of depth to water versus t/t^1 for evaluation (see Figure 3-4). Transmissivity was calculated in this observation well similarly to the test well evaluation. Using this method, transmissivity was calculated at 466.4 ft^2/day. Storativity must be calculated using a different equation than previously used for evaluating the test well.

$$S = \frac{2.25\ T\ t^1/r^2}{\log^{-1}[(S_p-S^1)/\Delta(S_p-S^1)]}$$



18.00
17.50
17.00
16.50
16.00
DEPTH TO WATER (feet)
1
10
100
1000
TIME (minutes)
ΔS = .76
T = 417.3 FT.^{2} /DAY
S = 0.00089
t. = 8.2 minutes

FIGURE 3-3

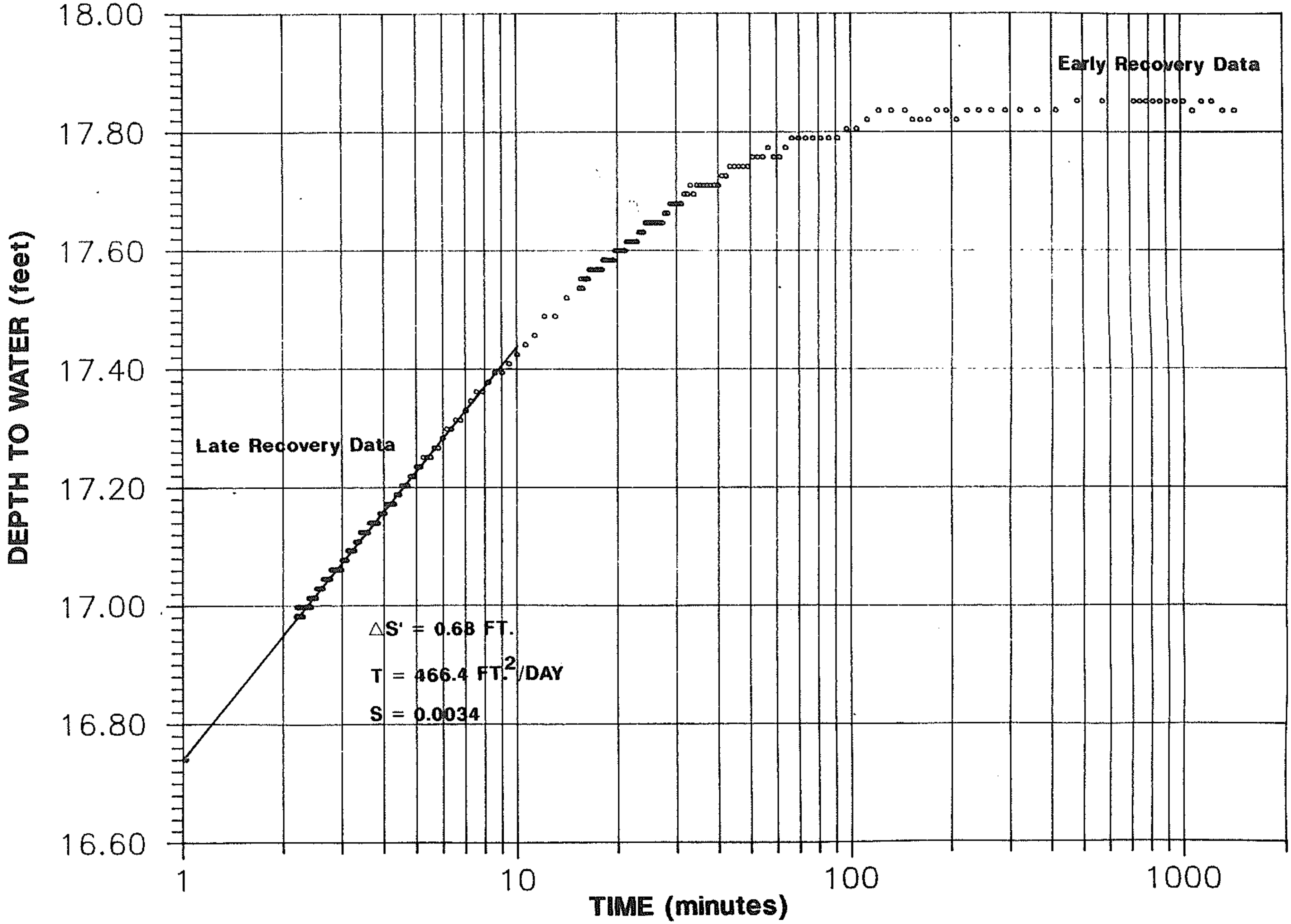


FIGURE 3-4
RECOVERY TEST DATA - OBSERVATION WELL UST-8

t^1 = time since pumping stopped
S_p = pumping period drawdown projected to time t^1
S^1 = residual drawdown at t^1
(S_p-S^1) = recovery at t^1

Using the depth to water/time graph of pump test data from this well (Figure 3-3), the values of (S_p-S^1) were estimated at 1.92 and $\Delta(S_p-S^1)$ at 1.17. Combined with the graph of the recovery data, a storativity of 0.0034 was obtained.

The data collected in each well during the pump test was also used to compile a distance-drawdown graph (see Appendix C) which was evaluated according to the Jacob method (1950). This method involves the use of simultaneous measurements of drawdown in the observation wells plotted against the distance of the observation well from the test well. Due to considerable scatter of the data on this graph the Jacob method could not be used to evaluate transmissivity.

3.4 CAPTURE ZONE ANALYSIS

During the Phase III UST Investigation, WESTON conducted a preliminary capture zone analysis using regional aquifer characteristics ($T = 70\ ft^2/day$, $S = 0.0002$). A pumping rate of 20 gpm and gradient of 0.05 was used to approximate the stagnation point and capture zone if UST-2 was used as a recovery well. The results of this preliminary capture zone analysis indicated that pumping UST-2 at 20 gpm would result in complete containment of the groundwater contamination originating from the UST in question (see Figure 3-5).

The capture zone analysis was re-evaluated using site-specific transmissivity and storativity values. This re-evaluation yielded the following results:

- Using the range of transmissivity and storativity values obtained from the aquifer analysis, the maximum stagnation point and capture zone width obtainable is 44 and 278 feet, respectively (See Figure 3-6). The minimum stagnation point and capture zone width obtained from site specific data was 22 and 139 feet, respectively.

- The maximum stagnation point given the site-specific conditions will not result in the withdrawal of all groundwater contamination which originated from the UST (See Figure 3-6).

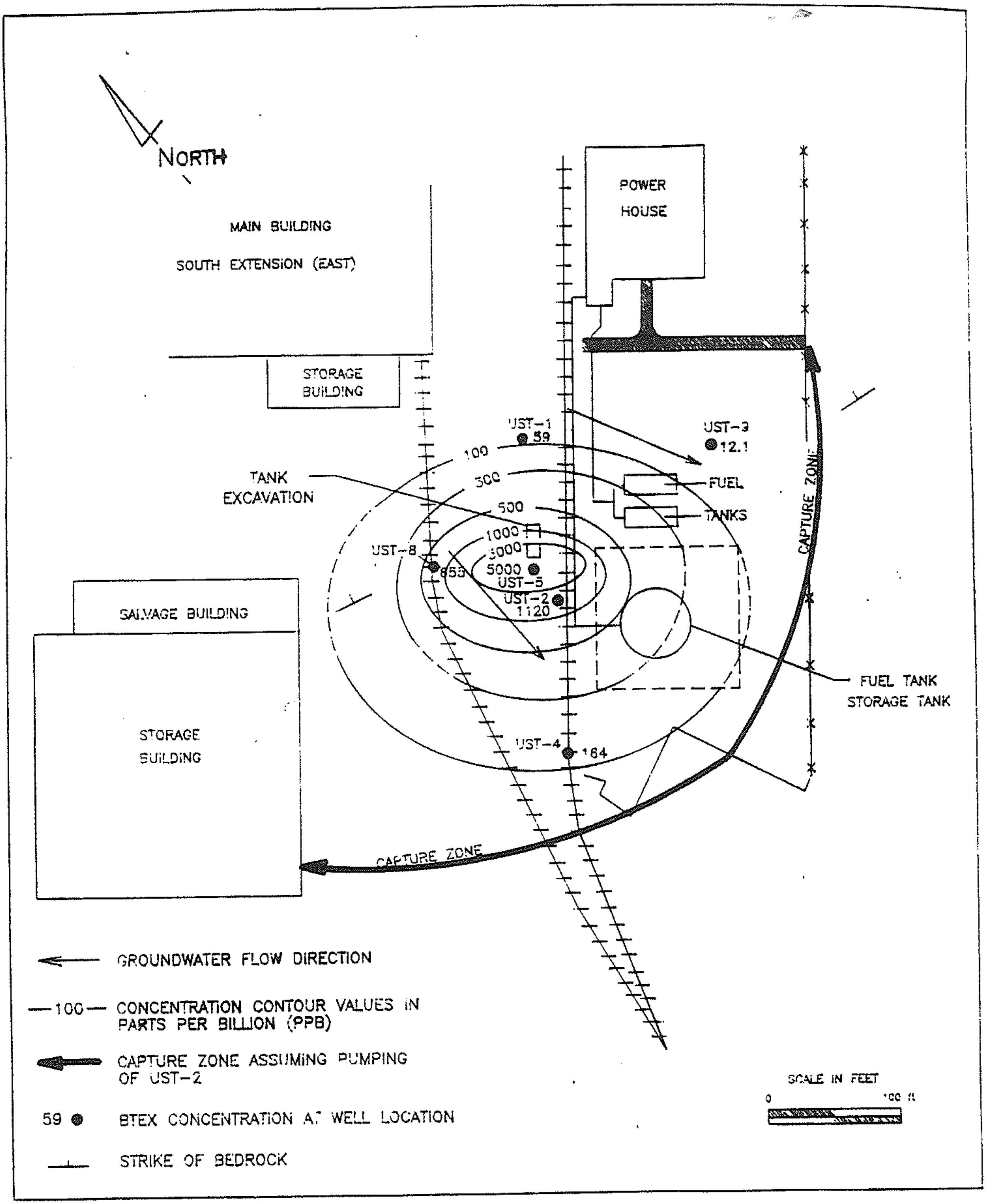


FIGURE 3-5 EXTENT OF MODELED CAPTURE ZONE - PRELIMINARY

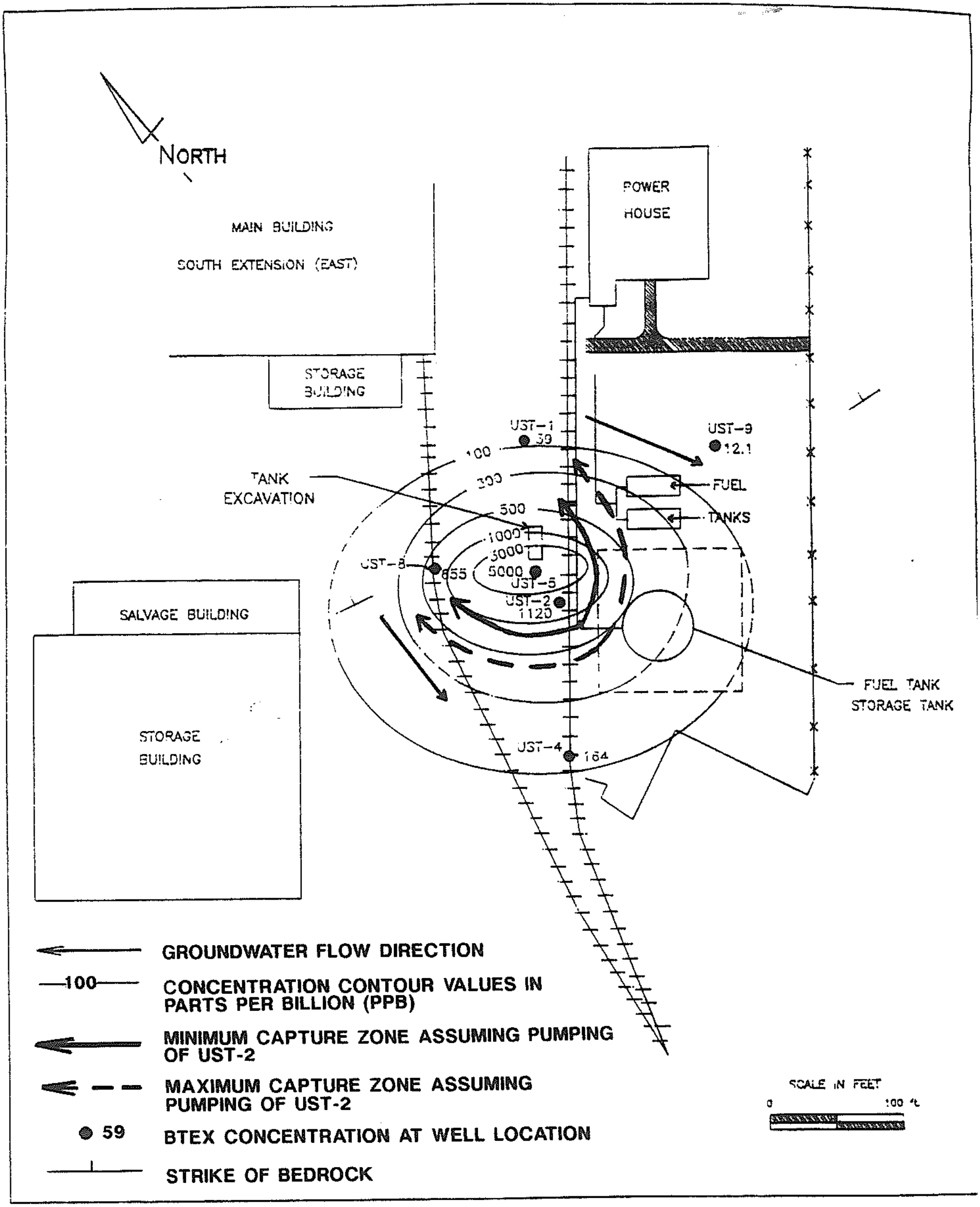


FIGURE 3-6 EXTENT OF MODELED CAPTURE ZONE - REVISED

- A 35 percent increase in the test well (UST-2) performance will result in a sufficient increase in the maximum stagnation point to capture the contaminants of concern.

3.5 SUMMARY AND DISCUSSION

With the exception of well UST-6, all of the observation wells are completed within the Stockton Formation. The wells are all cased to a depth of 20 feet, 10 feet into competent rock. The depth of all the bedrock wells is generally 40 to 50 feet below grade with the exception of UST-3 which is 61 feet in depth. These wells have intercepted fractures at a variety of depths, some of which produced water during drilling. As discussed in the previous subsections, well UST-8 was affected most by the pumping of well UST-2. Therefore, the fractures intercepted by UST-2 and UST-8 appear well connected. The water level data from wells UST-3 and UST-4 indicate that after approximately 500 minutes of pumping, the water level in the observation wells began to drop. UST-3 is 27 feet from the test well and UST-4 is 117 feet. The proximity of UST-3 to the test well suggests that the fractures intercepted by each well are poorly connected.

Transmissivity and storativity were determined using two different methods; the Cooper and Jacob (1946) method for pumping and recovery data from both test and observation wells and the Jacob (1950) for evaluating distance-drawdown graphs. Storativity was calculated only from the data collected from observation wells. Transmissivity values ranged from 113 to 466 ft^2/day. Storativity values ranged from 0.00089 to 0.0034 percent.

Based on the results of the pumping test and aquifer and capture zone analysis, monitoring well UST-2 is not capable, given its current construction, of terminating future downgradient migration of contaminants which originated from the UST in question.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

The pumping test and aquifer analysis was completed to calculate transmissivity and storativity of the upper Stockton Formation underlying the GMC Inland Fisher Guide plant. Transmissivity and storativity were used to calculate the maximum stagnation point and capture zone generated by the pumping of UST-2 at 8.5 gpm given the site-specific aquifer characteristics. Based on this information the following recommendations are made:

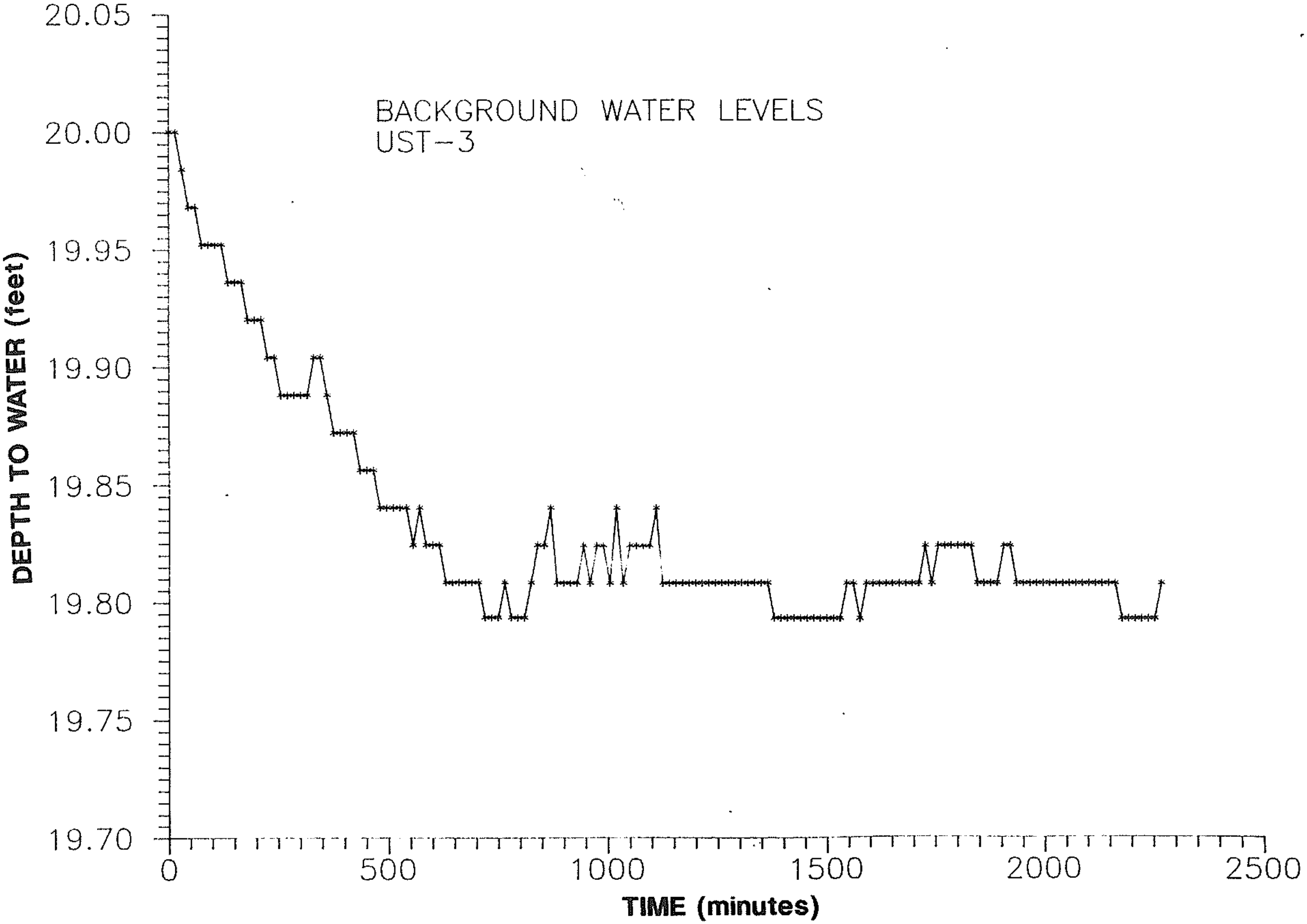
- Well UST-2 is acceptable for use as an extraction well for the remediation of groundwater contaminated by the removed UST with some modifications. The recommended alternative includes deepening the well to approximately 80 feet below grade. Deepening this well should increase the available drawdown and well yield as several additional water producing fractures are intercepted.

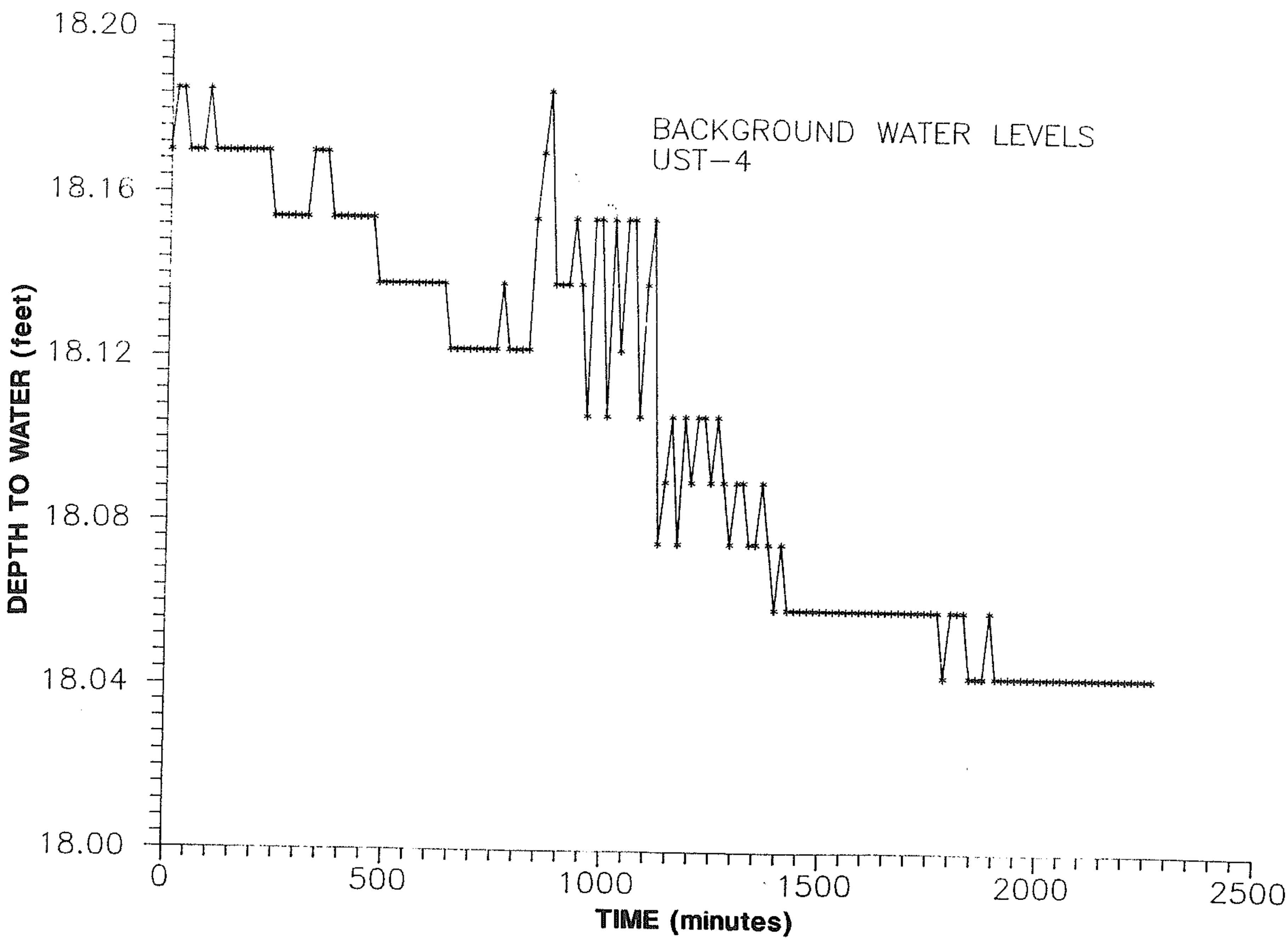
- Based on the flow conditions and levels of contamination, the treatment system should consist of an air stripping unit capable of reducing the concentration of total volatile organic compounds to a level below the current facility NJPDES permit limits.

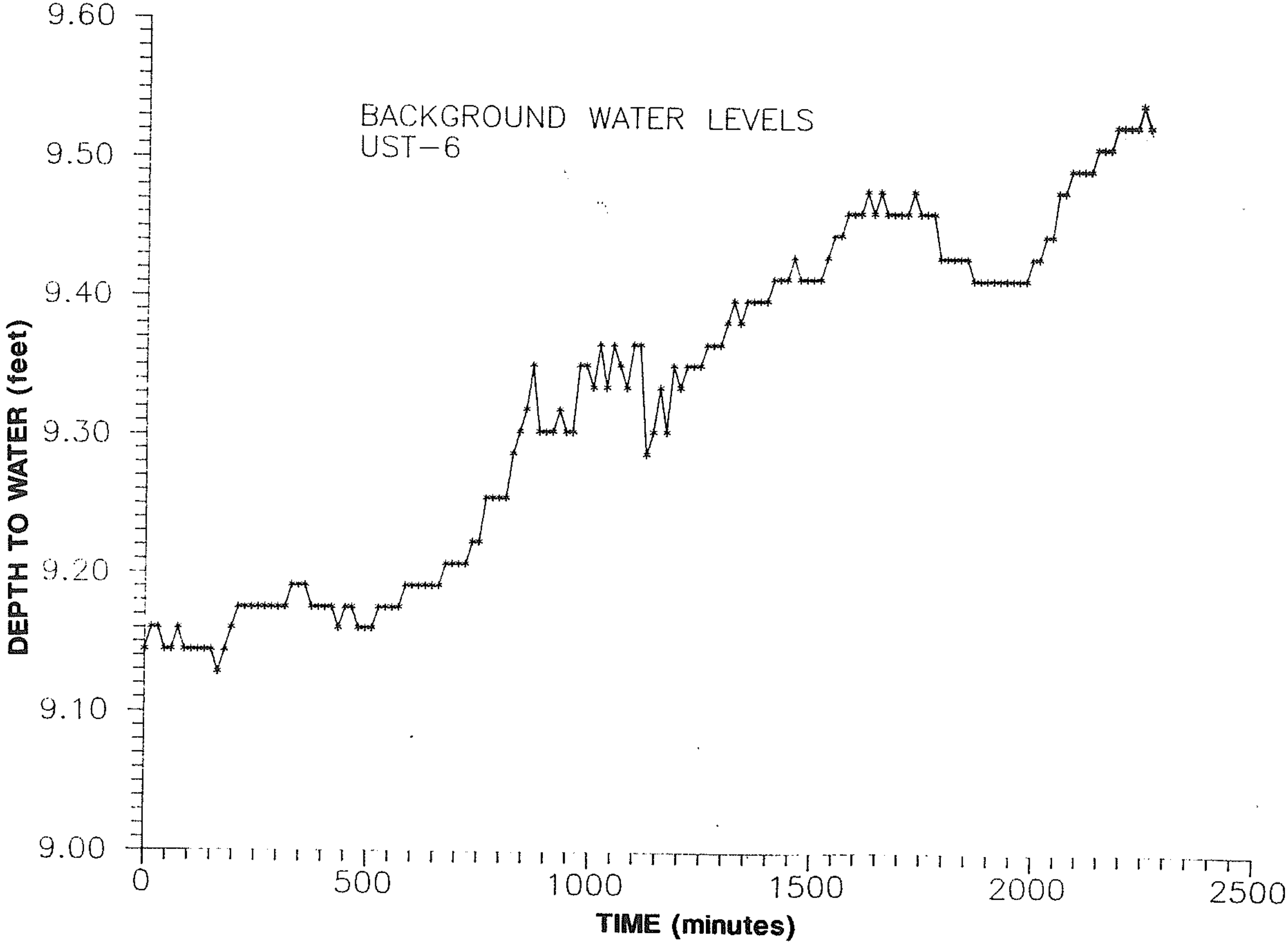
- A performance test should be conducted upon completion of the system installation to assure the treatment system is operating at maximum capacity and efficiency. Time series sampling should be conducted at regular intervals to evaluate the effectiveness of the recovery system.

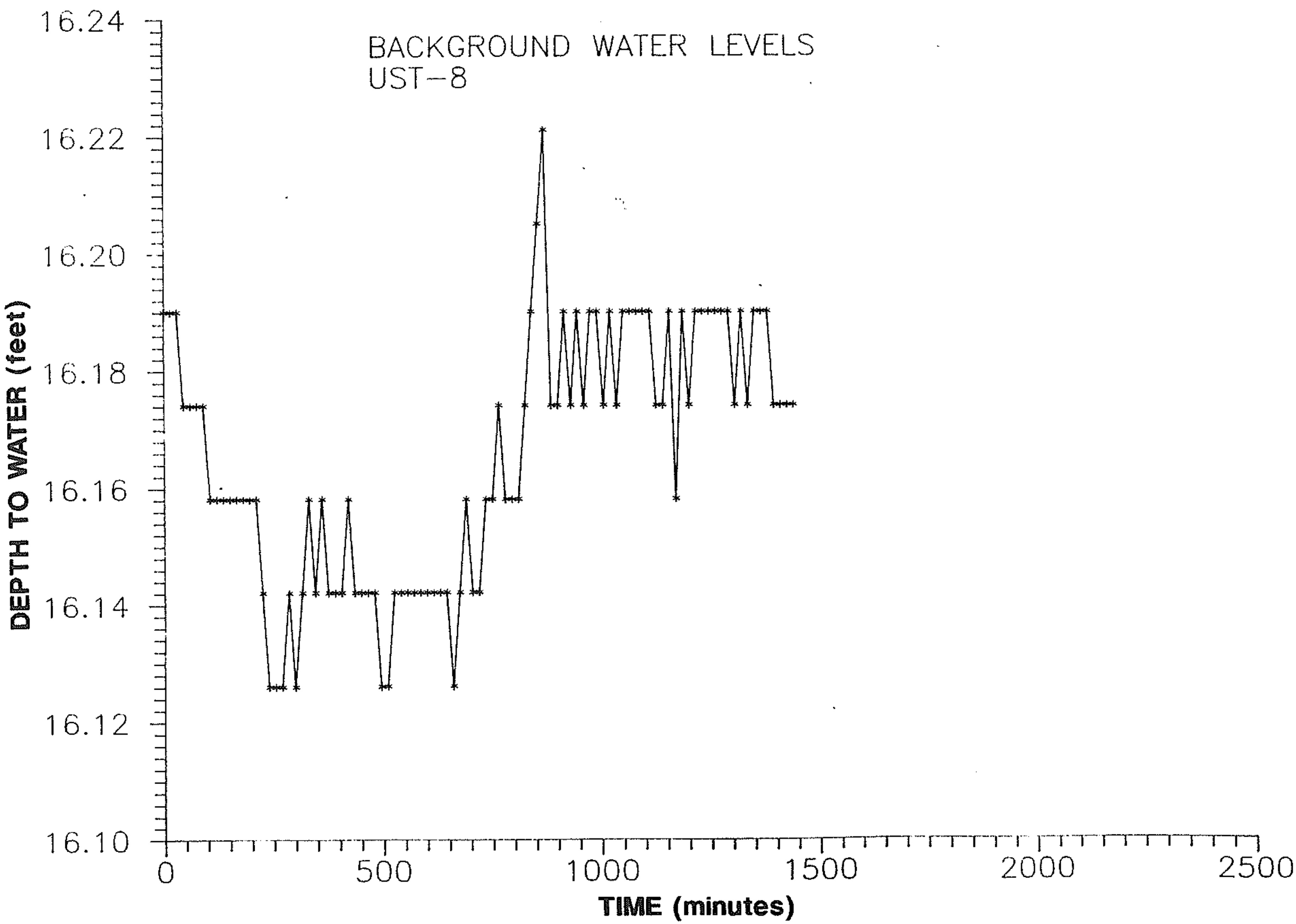
APPENDIX A

BACKGROUND WATER LEVEL MEASUREMENTS

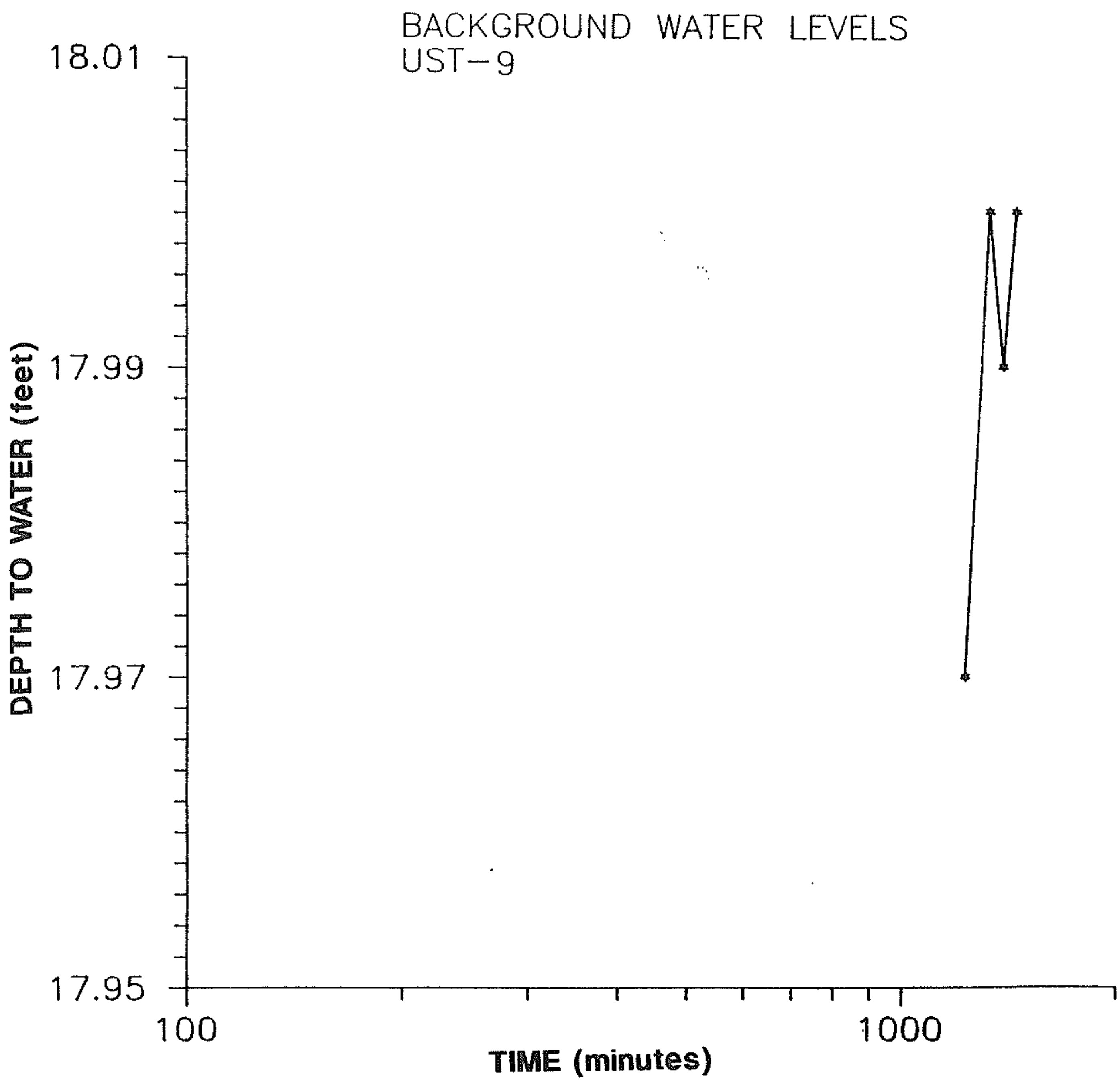

BACKGROUND WATER LEVELS
UST-3
DEPTH TO WATER (feet)
20.05
20.00
19.95
19.90
19.85
19.80
19.75
19.70
0
500
1000
1500
2000
2500
TIME (minutes)


BACKGROUND WATER LEVELS
UST-4
DEPTH TO WATER (feet)
18.20
18.16
18.12
18.08
18.04
18.00
0
500
1000
1500
2000
2500
TIME (minutes)


BACKGROUND WATER LEVELS
UST-6
DEPTH TO WATER (feet)
9.60
9.50
9.40
9.30
9.20
9.10
9.00
0
500
1000
1500
2000
2500
TIME (minutes)

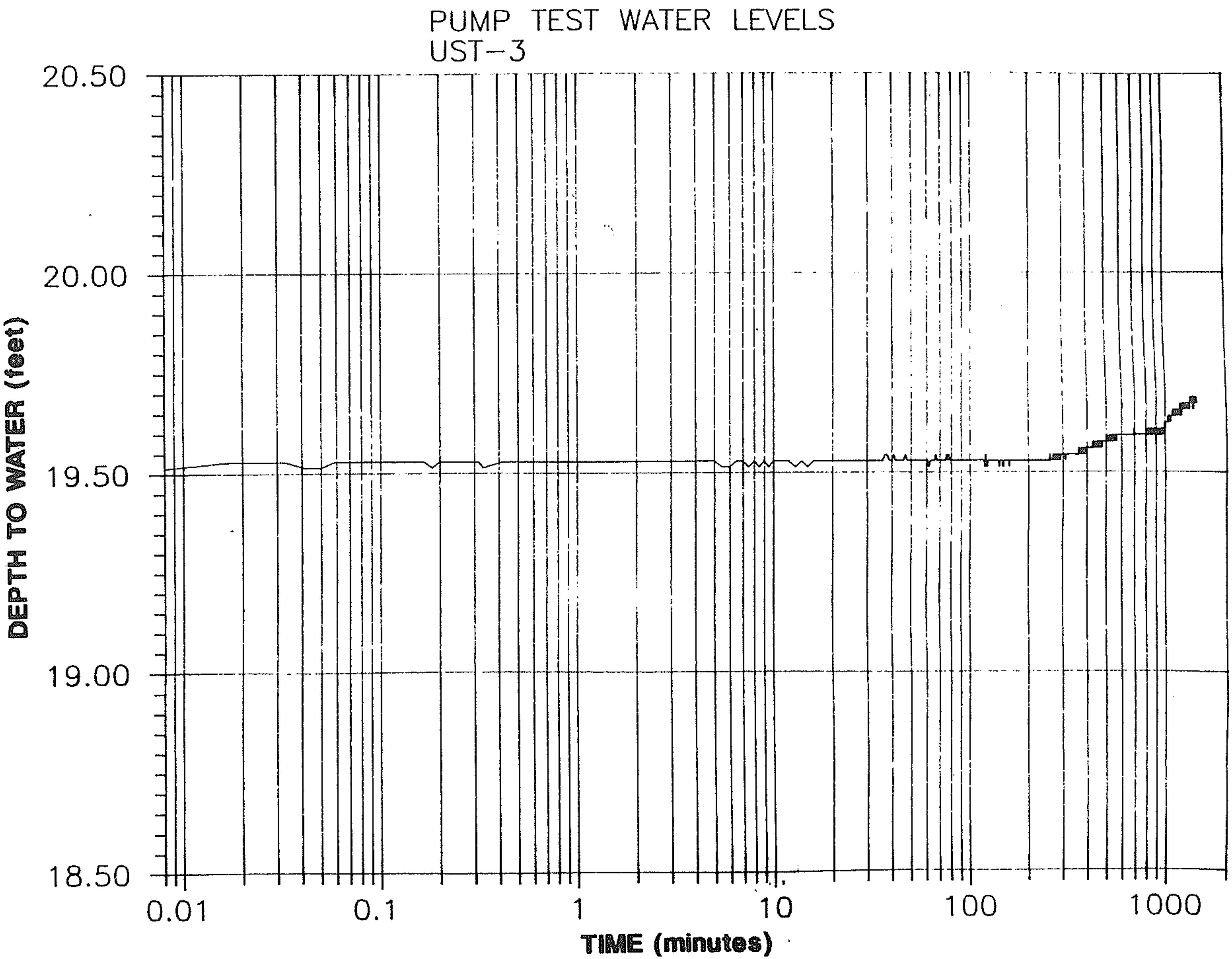


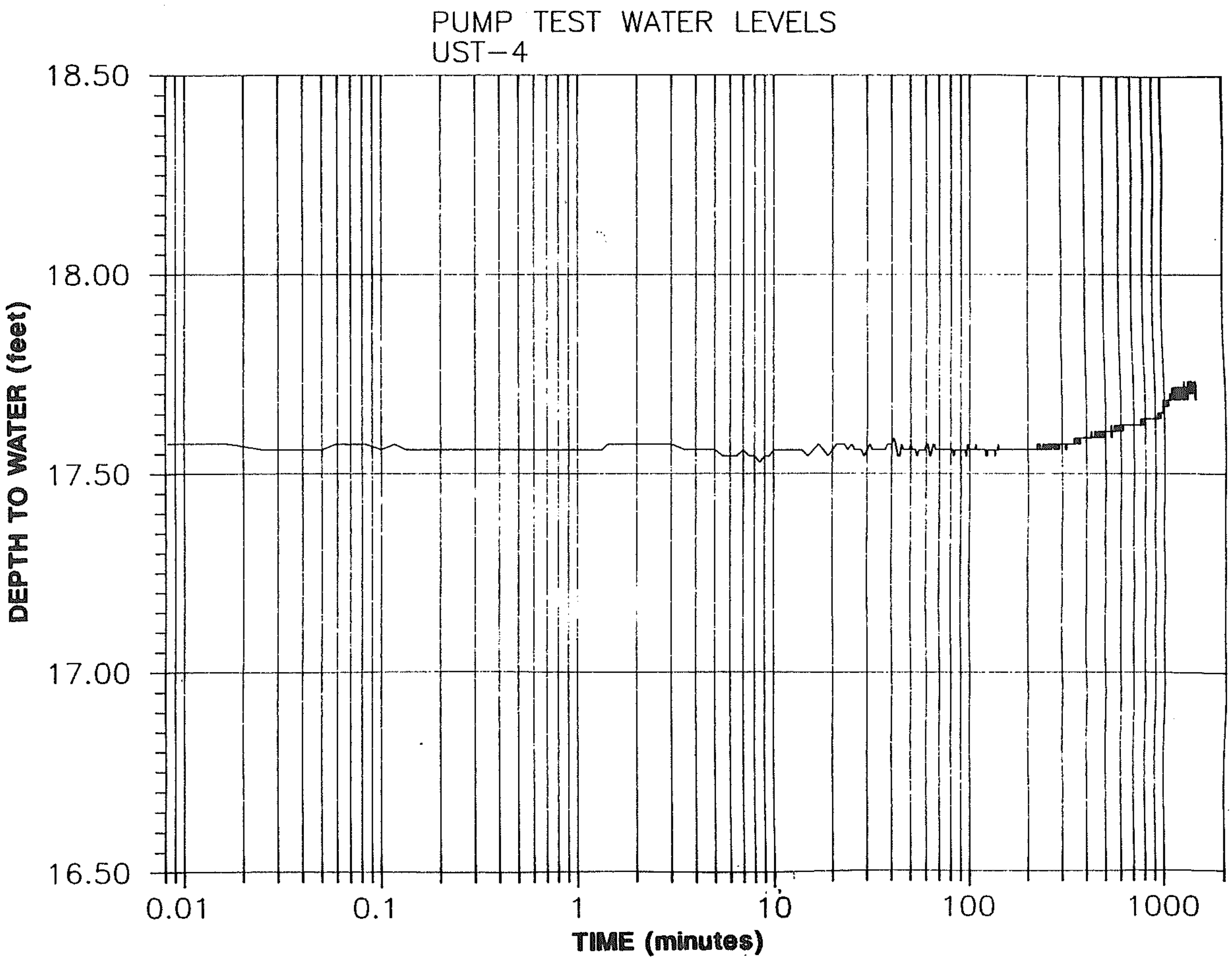
BACKGROUND WATER LEVELS
UST-8
16.24
16.22
16.20
16.18
16.16
16.14
16.12
16.10
DEPTH TO WATER (feet)
0
500
1000
1500
2000
2500
TIME (minutes)


BACKGROUND WATER LEVELS
UST-9
18.01
17.99
17.97
17.95
DEPTH TO WATER (feet)
100
1000
TIME (minutes)

APPENDIX B

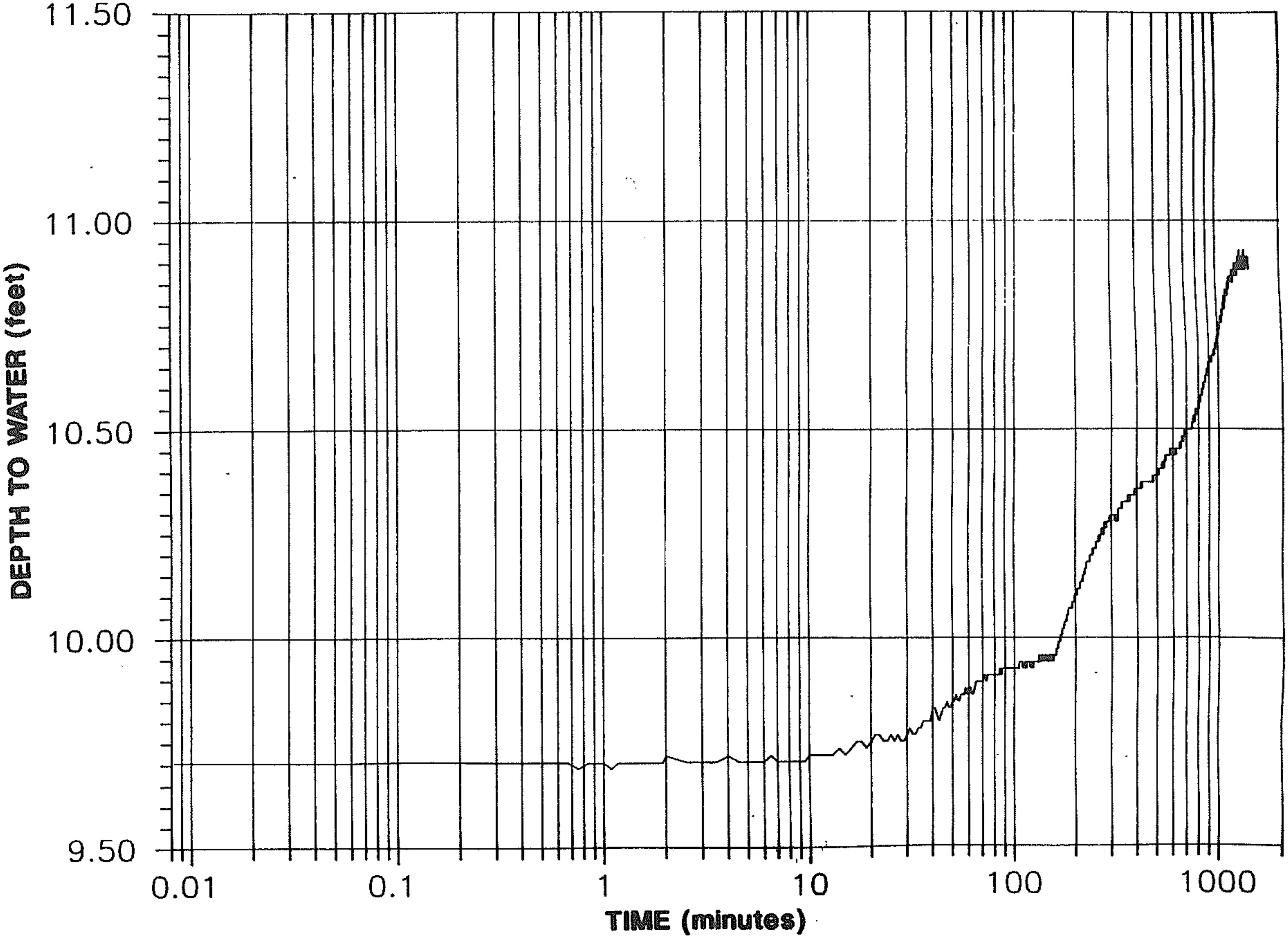
PUMP AND RECOVERY TEST RESULTS - OBSERVATIONS WELLS UST-3, UST-4, UST-6 AND UST-9

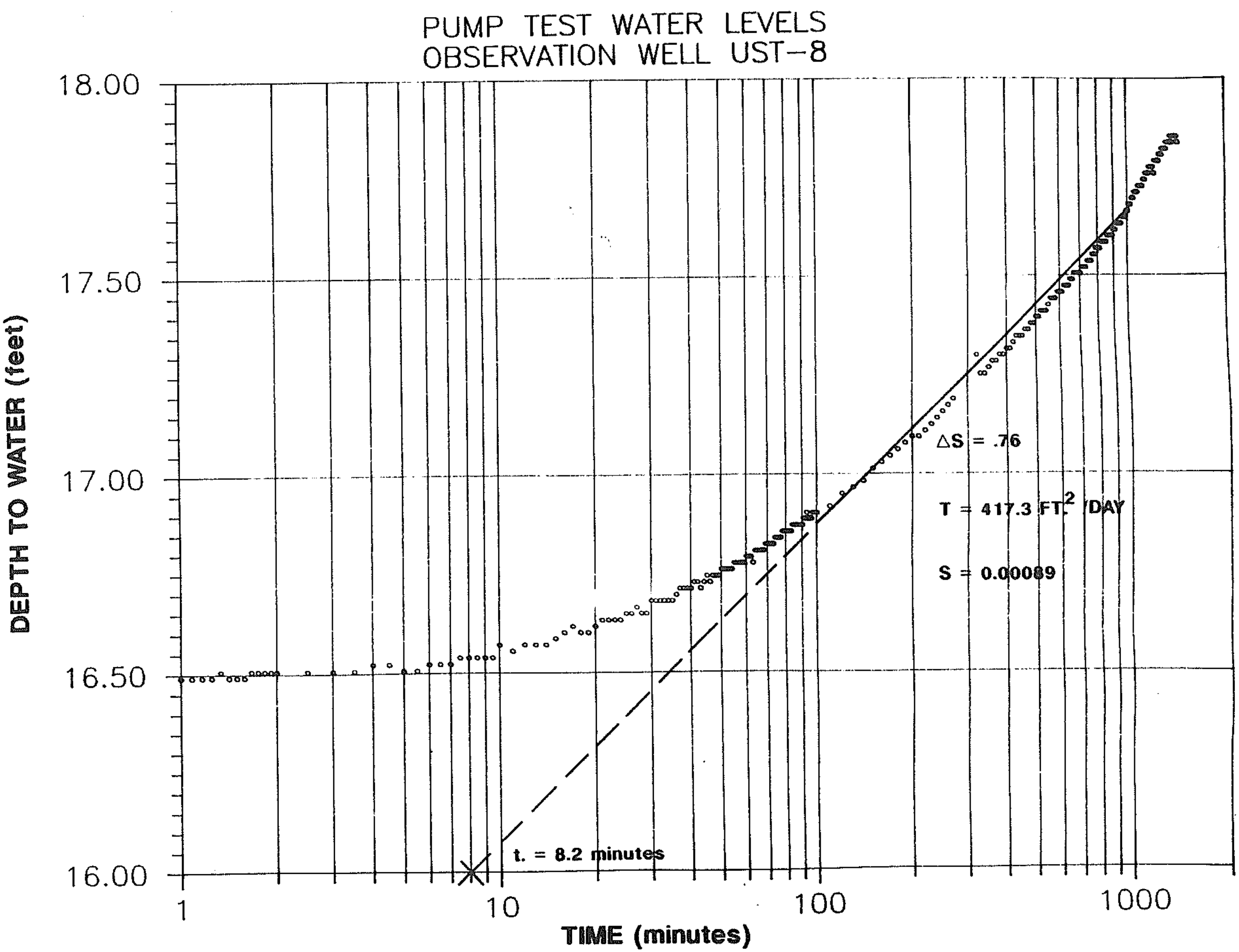

PUMP TEST WATER LEVELS
UST-3
DEPTH TO WATER (feet)
20.50
20.00
19.50
19.00
18.50
TIME (minutes)
0.01
0.1
1
10
100
1000



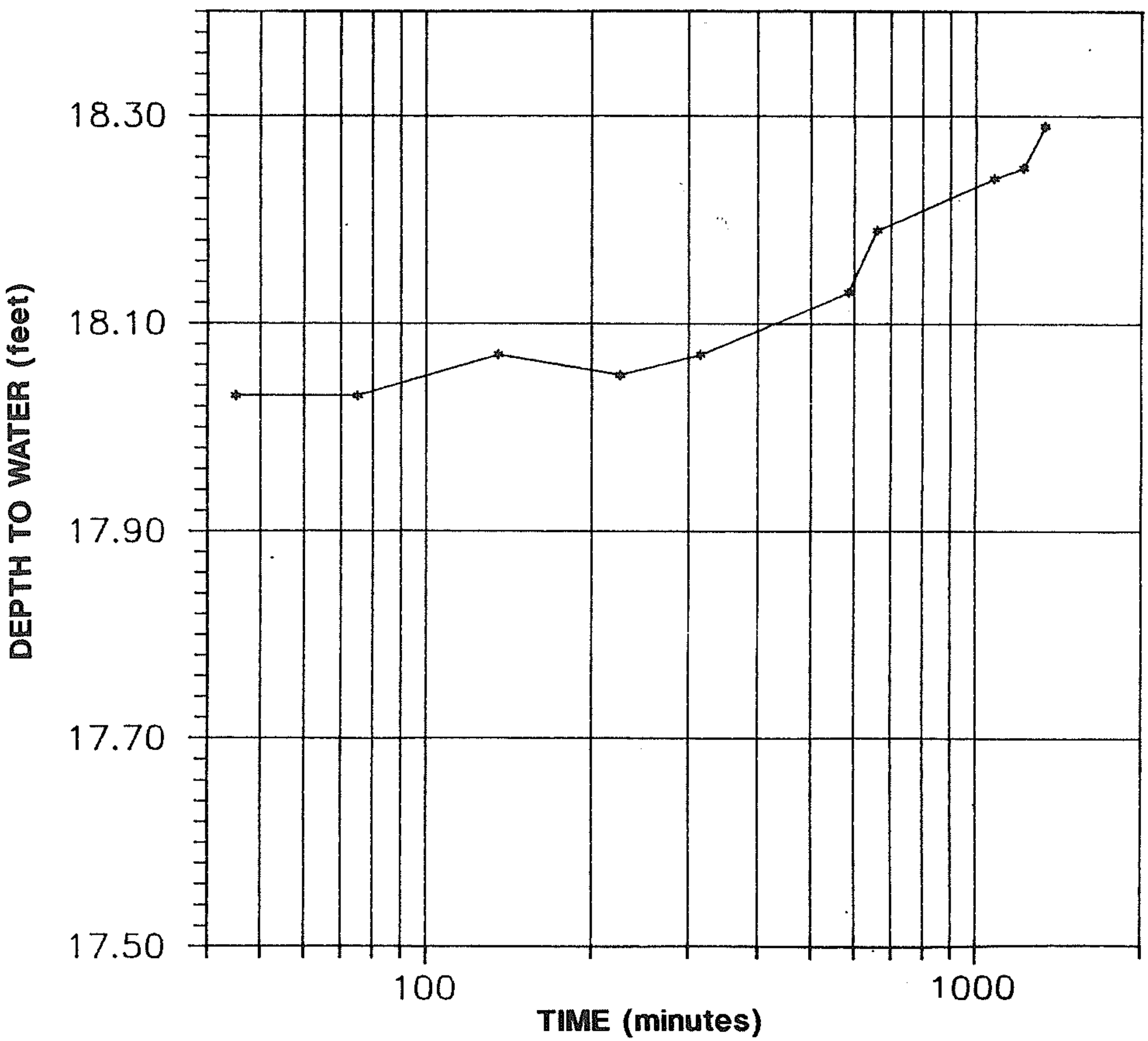
PUMP TEST WATER LEVELS
UST-4
DEPTH TO WATER (feet)
18.50
18.00
17.50
17.00
16.50
0.01
0.1
1
10
100
1000
TIME (minutes)

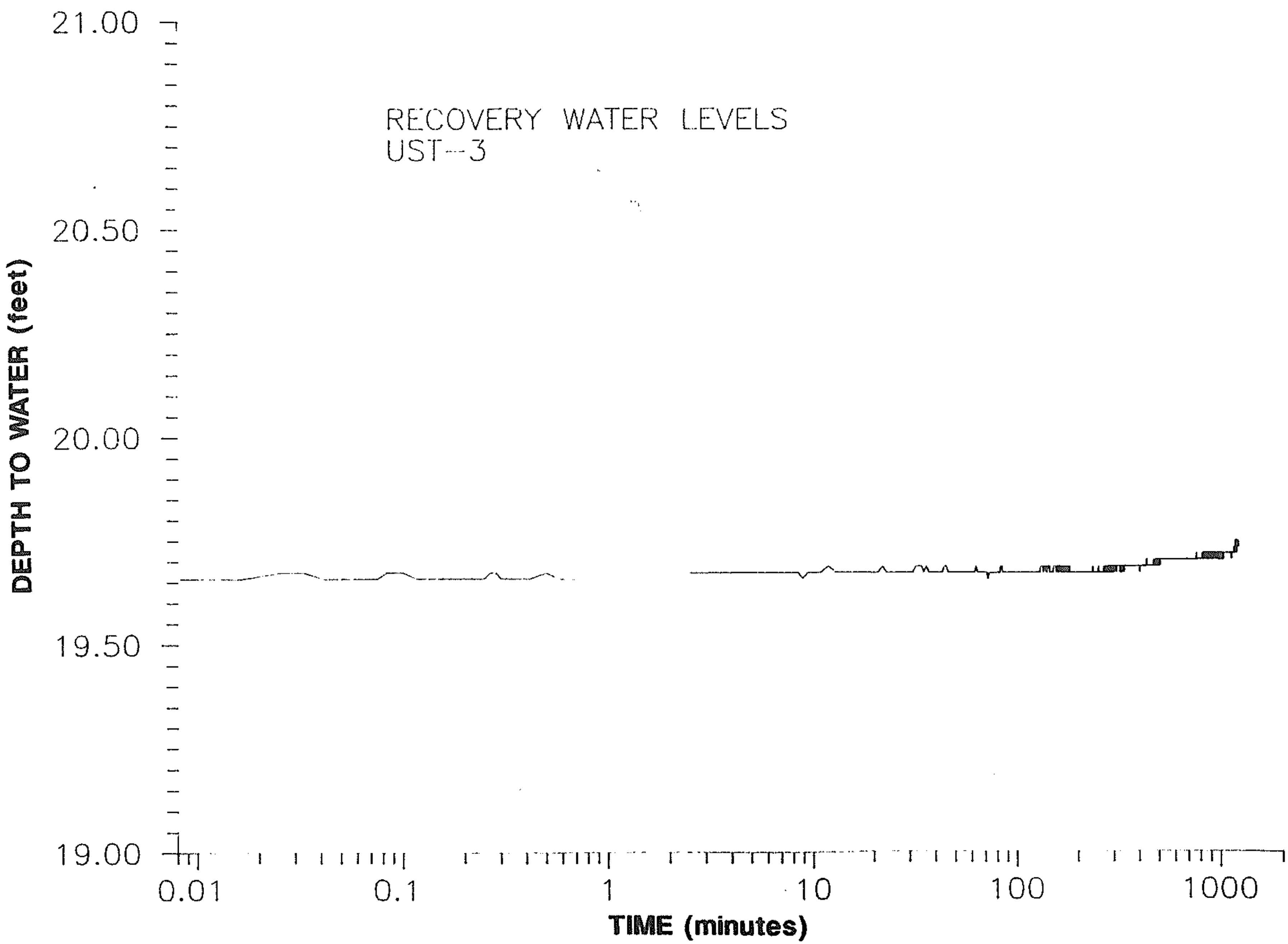
PUMP TEST WATER LEVELS
UST–6

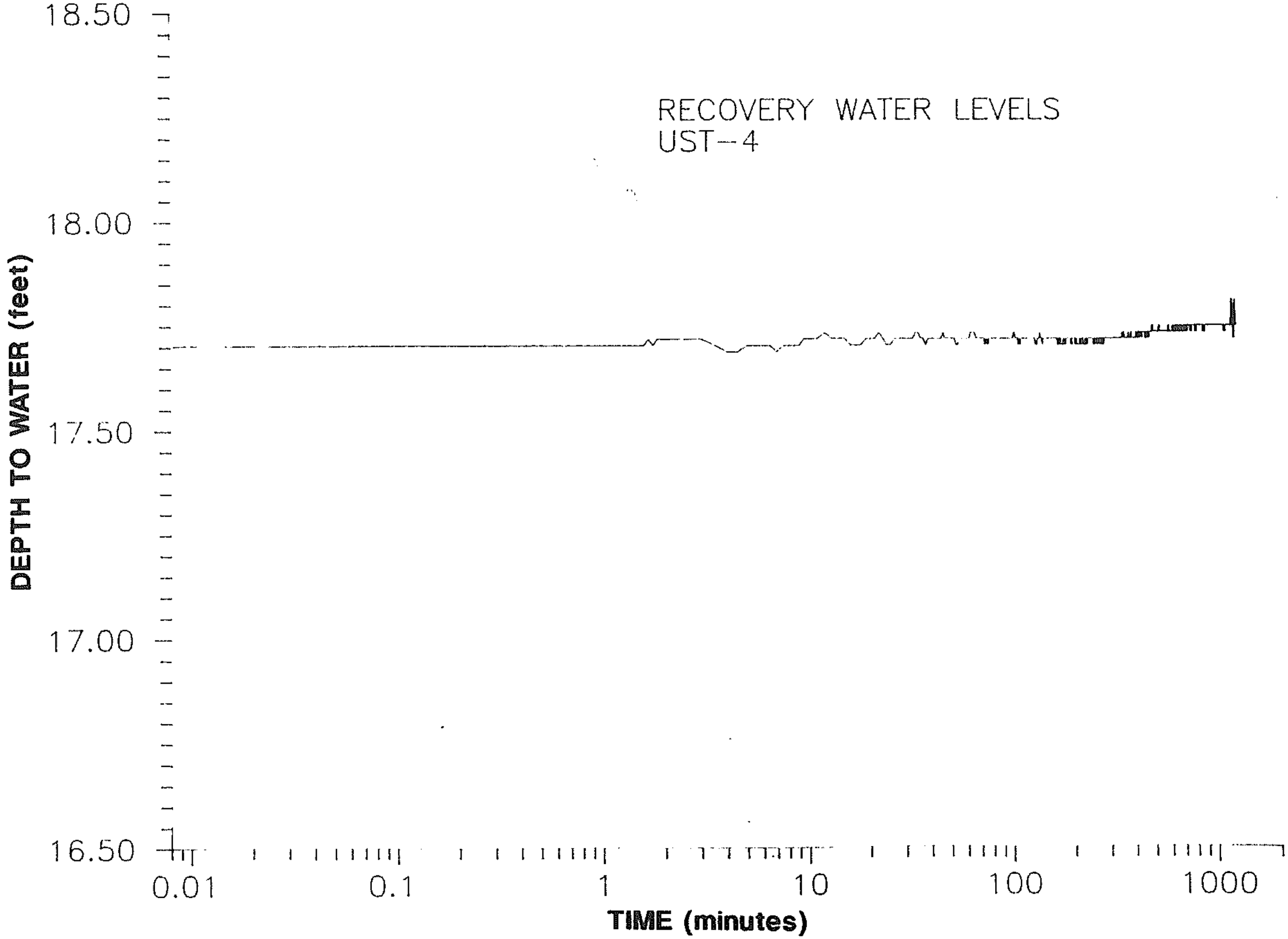



PUMP TEST WATER LEVELS
OBSERVATION WELL UST-8
DEPTH TO WATER (feet)
18.00
17.50
17.00
16.50
16.00
TIME (minutes)
1
10
100
1000
ΔS = .76
T = 417.3 FT.² /DAY
S = 0.00089
t. = 8.2 minutes

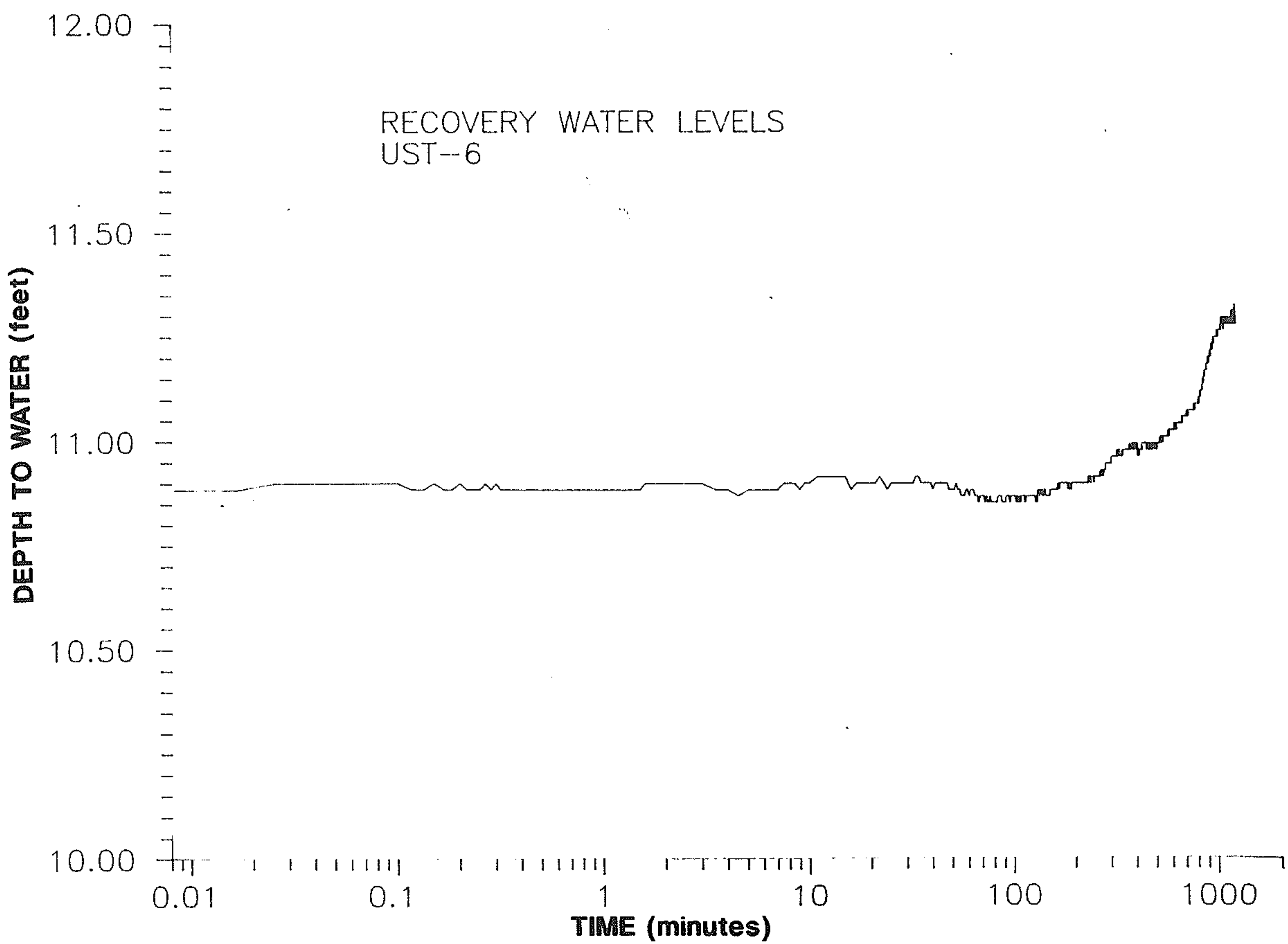
PUMP TEST WATER LEVELS
UST-9

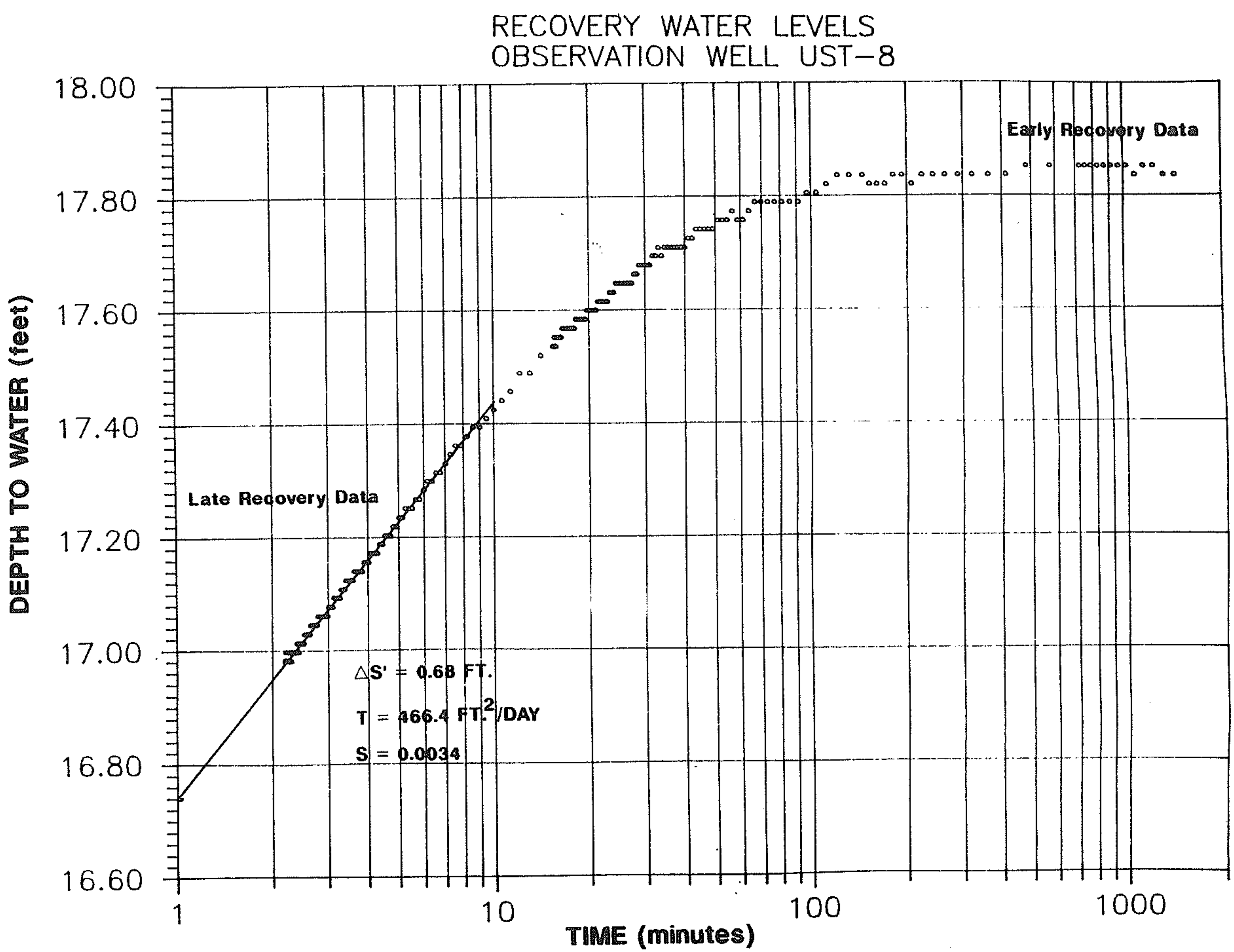



RECOVERY WATER LEVELS
UST--3
DEPTH TO WATER (feet)
21.00
20.50
20.00
19.50
19.00
0.01
0.1
1
10
100
1000
TIME (minutes)

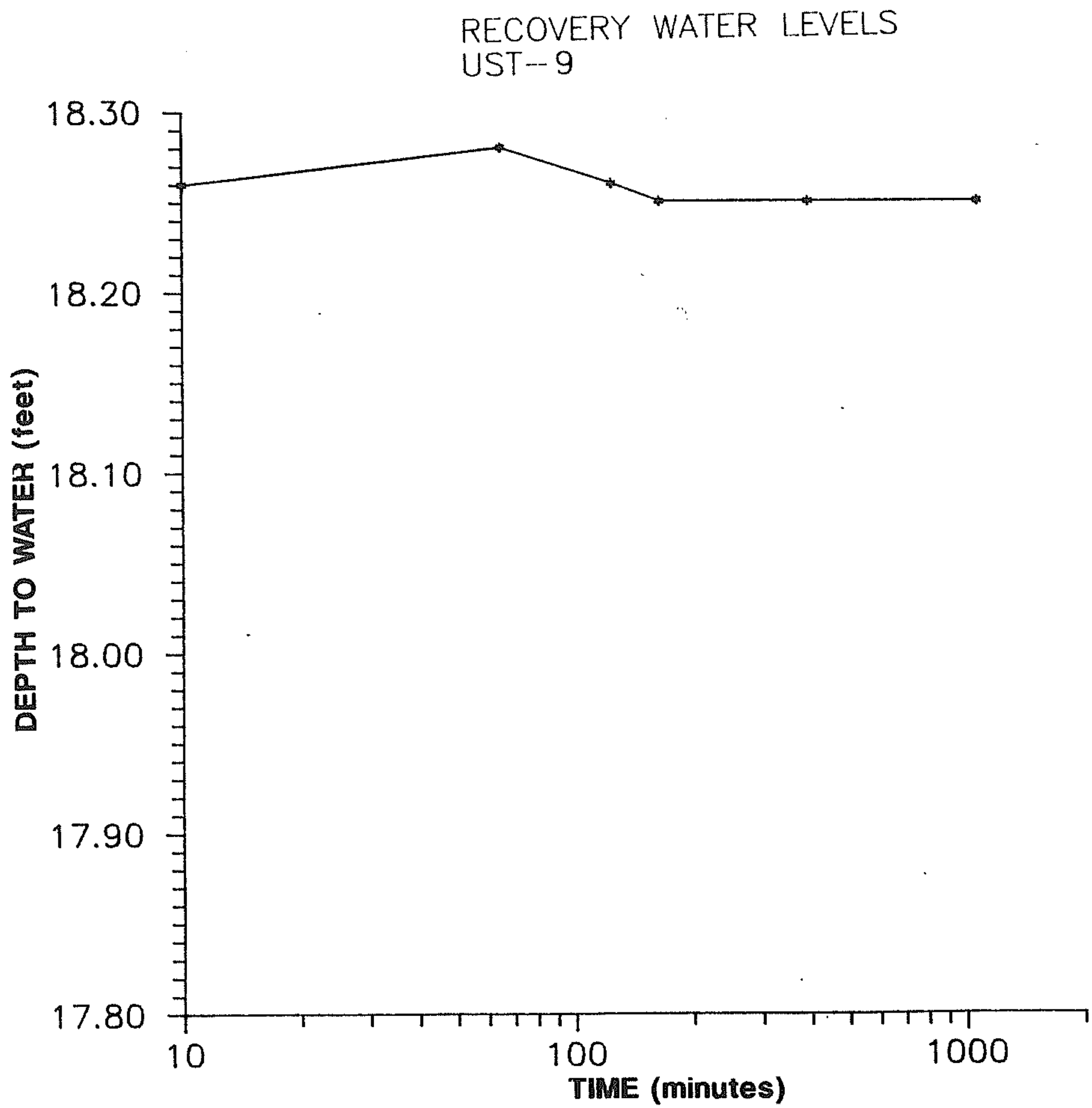


RECOVERY WATER LEVELS
UST-4
DEPTH TO WATER (feet)
18.50
18.00
17.50
17.00
16.50
TIME (minutes)
0.01
0.1
1
10
100
1000


RECOVERY WATER LEVELS
UST--6
DEPTH TO WATER (feet)
12.00
11.50
11.00
10.50
10.00
0.01
0.1
1
10
100
1000
TIME (minutes)

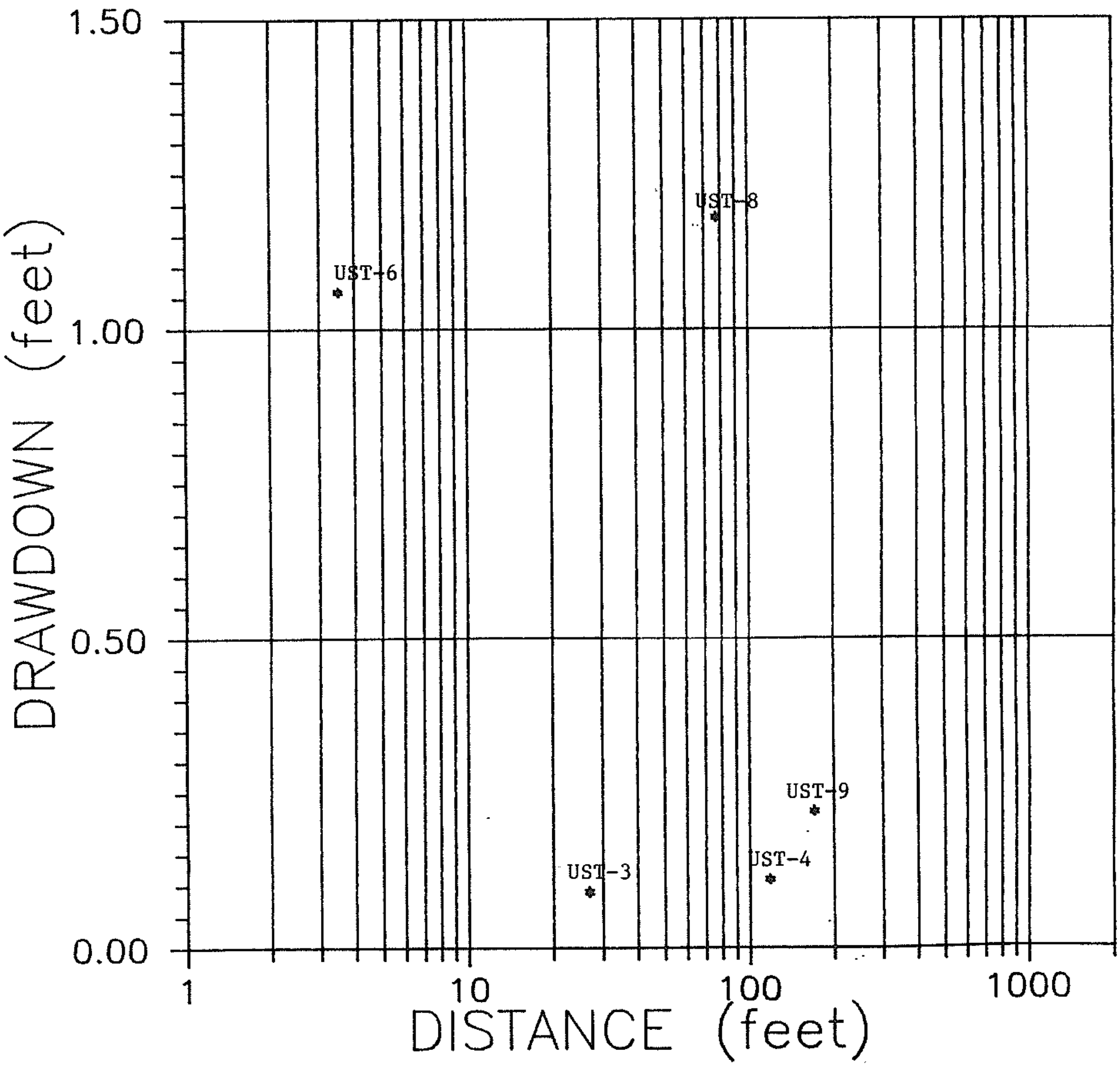


RECOVERY WATER LEVELS
OBSERVATION WELL UST-8
Early Recovery Data
Late Recovery Data
ΔS' = 0.68 FT.
T = 466.4 FT.2/DAY
S = 0.0034
DEPTH TO WATER (feet)
18.00
17.80
17.60
17.40
17.20
17.00
16.80
16.60
TIME (minutes)
1
10
100
1000


RECOVERY WATER LEVELS
UST--9
18.30
18.20
18.10
18.00
17.90
17.80
DEPTH TO WATER (feet)
10
100
1000
TIME (minutes)

APPENDIX C

DISTANCE VERSUS DRAWDOWN GRAPH OF OBSERVATION WELL DATA



1.50
1.00
0.50
0.00
DRAWDOWN (feet)
1
10
100
1000
DISTANCE (feet)
UST-6
UST-8
UST-3
UST-4
UST-9