HYDROGEOLOGIC INVESTIGATION OF
HARBOUR RIDGE LIMTED
ST. LUCIE COUNTY, FLORIDA

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Geraghty & Miller, Inc.

HYDROGEOLOGIC INVESTIGATION OF HARBOUR RIDGE LIMTED ST. LUCIE COUNTY, FLORIDA

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TABLE OF CONTENTS

TABLES

FIGURES

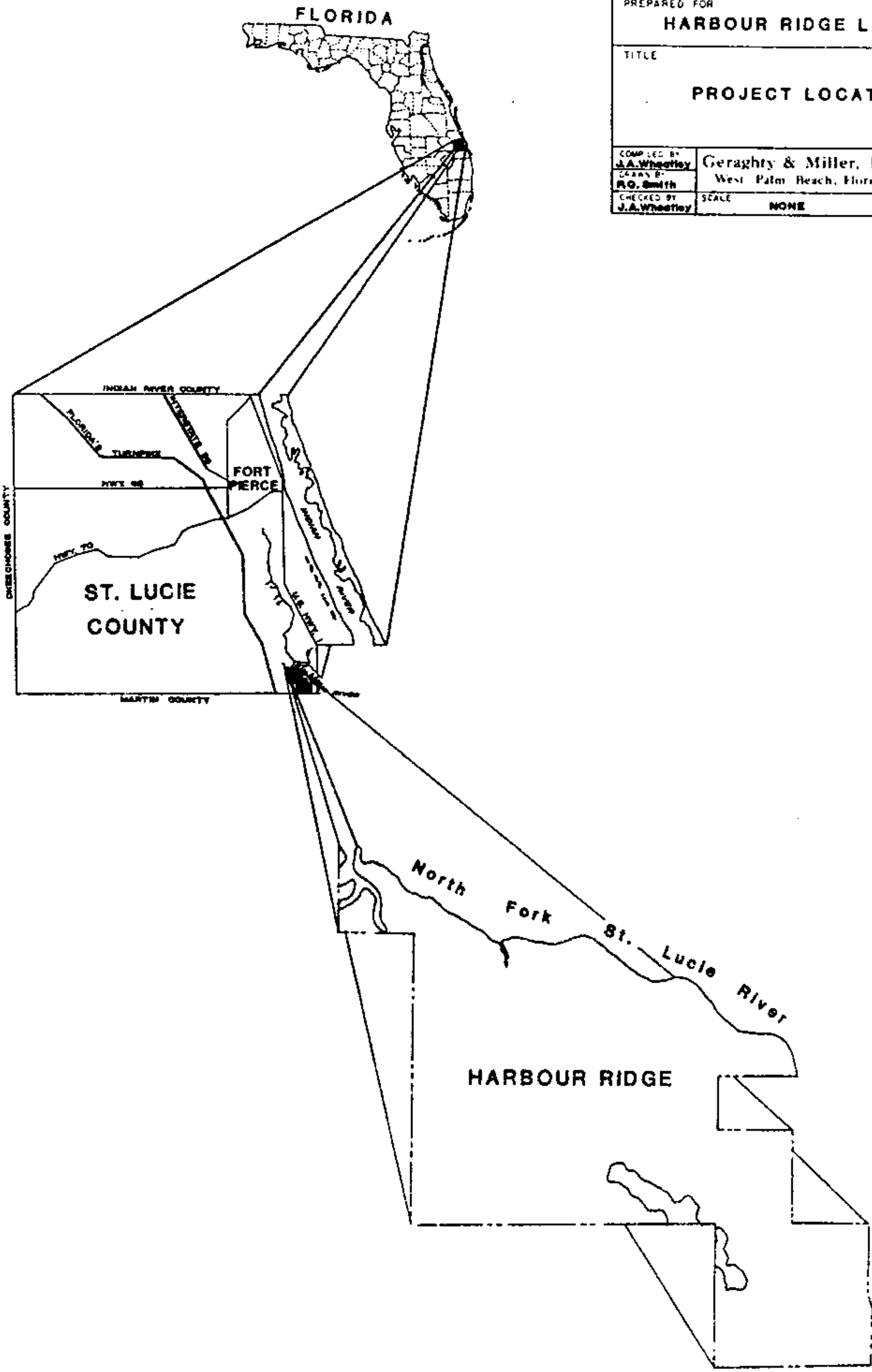
HYDROGEOLOGIC INVESTIGATION OF
HARBOUR RIDGE LIMITED
ST. LUCIE COUNTY, FLORIDA

INTRODUCTION

In 1981, Harbour Ridge Limited, contracted Geraghty & Miller, Inc., to conduct a hydrogeologic investigation of its St. Lucie County property, the location of which is shown in Figure 1.

The first phase of the investigation consisted of the installation of six two-inch-diameter test wells to obtain initial on-site hydrogeologic data. From the data obtained in Phase I, locations were selected for Phase II, a more detailed testing program consisting of one test-production well, three observation wells, and three salt-water monitoring wells. After the installation of all wells in Phase II, a 72-hour constant-rate pumping test was conducted.

This report contains a summary of all data obtained in the testing programs, a description of the hydrogeologic system that occurs at the site, an analysis of the hydrologic coefficients derived, and a model of the impacts of a proposed well field.



PREPARED FOR	HARBOUR RIDGE LIMITED
TITLE	PROJECT LOCATION

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DRAWN BY R.O. Smith		REVISED
CHECKED BY J.A.Wheatley	SCALE NONE	FIGURE I

FINDINGS

1. The water-table zone of the shallow aquifer extends from 20 feet to 60 feet below land surface. The water-table aquifer consists predominantly of fine-grained sand with traces of clay. Below the water-table zone, a layer of sandy clay occurs with a thickness of 6 to 11 feet. The production zone of the shallow aquifer exists below the clay to a depth of 129 to 150 feet below land surface.

2. The production zone in the shallow aquifer is 80 to 110 feet below land surface.

3. The ground-water quality in the Harbour Ridge area is generally good. The water is treatable and a potable product could be delivered.

4. In the vicinity of Harbour Ridge, the production zone of the shallow aquifer responds to pumping as a leaky artesian one, with recharge by vertical leakage downward through a confining bed consisting of sandy clay.

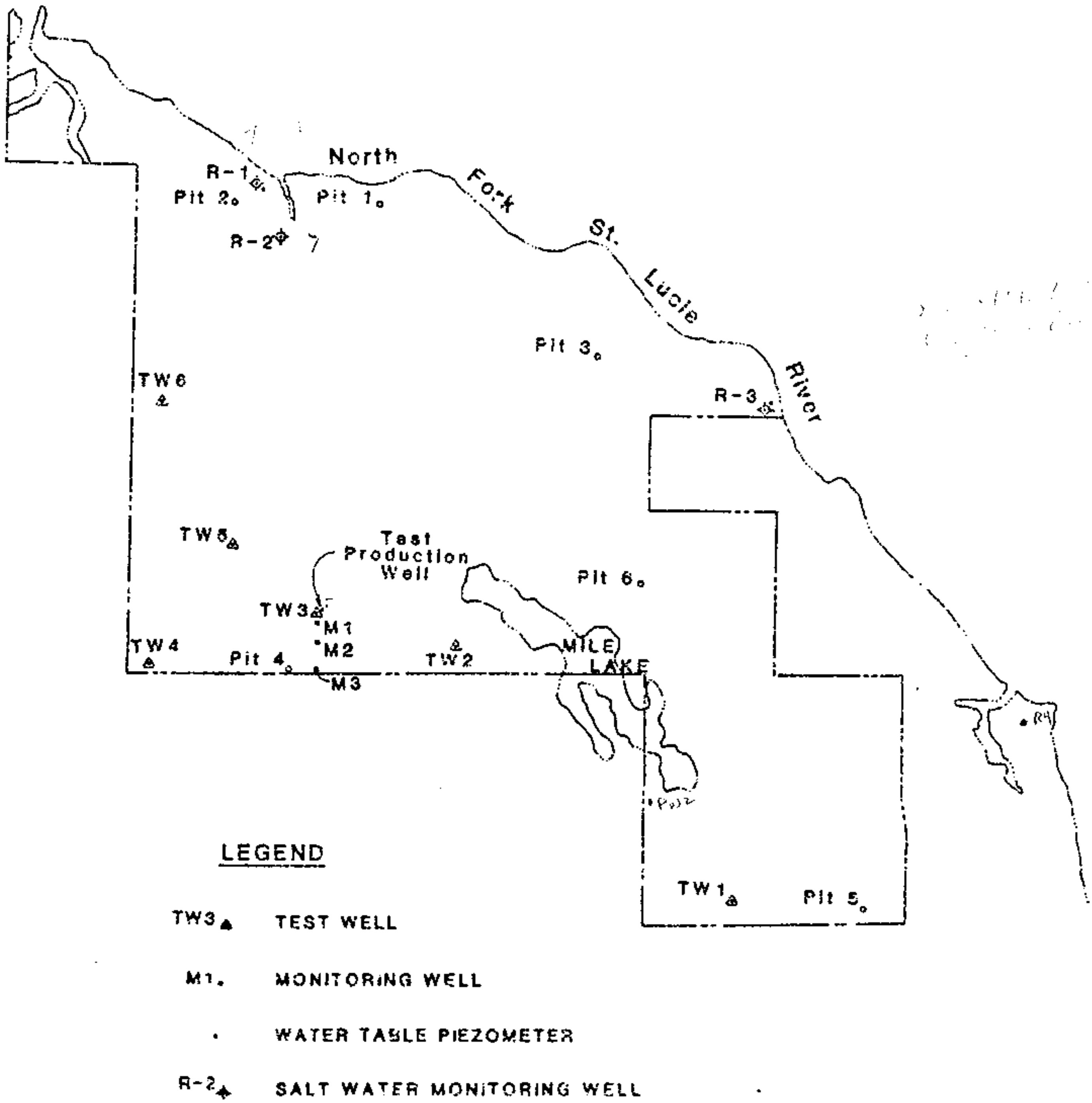
5. The aquifer coefficients are estimated as follows:

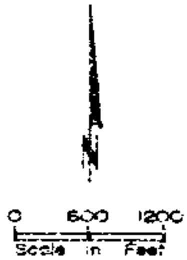
Transmissivity =	100,000 gpd/ft
Storage Coefficient =	.0002
Leakange =	.002 gpd/cu.ft.

6. A diversion of 0.644 mgd can be obtained from the shallow aquifer without causing adverse impacts.

WELL CONSTRUCTION METHODOLOGY

To determine geologic and hydrologic conditions in the project area, a total of 16 wells and 6 test pits were installed during 1981. All wells were installed by Maxson Well Drilling, Inc., of Lake Worth, Florida, under the direction of Geraghty & Miller, Inc., hydrogeologists. Except for the test-production well which was installed by the cable-tool method, all wells were installed by the drive-wash method. The six test pits were installed by Harbour Ridge during their investigation into fill material available beneath the site and were constructed to a depth of two to three feet below the water table. In addition to the wells and test pits, three water-table piezometers were installed adjacent to Wells R1, R2, and TPW1. Locations of wells, piezometers, and test pits are given on Figure 2. All wells were left in place for future monitoring use.





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LOCATION MAP
OF WELLS AND TEST PITS

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Except for the test-production well, all wells were constructed with 2-inch-diameter steel casings and PVC screens. The test-production well was gravel-packed and constructed with a 16-inch-diameter outer casing. The inner casing was an 8-inch-diameter steel pipe attached to a 30-foot-long stainless steel screen. The test-production well complies with the rules of the Florida Department of Environmental Regulation (DER), chapter 17-21, Water Wells in Florida; and chapter 17-22, Water Supplies; and was permitted by DER. Construction details, depths, and screen intervals of all wells are shown in Figure 3.

The salt-water monitor wells were constructed to determine variations of ground-water quality with respect to depth in the vicinity of the North Fork of the St. Lucie River. The wells were installed by the drive-wash method to facilitate water sampling. Two-inch-diameter, open-ended, galvanized casing was driven in 21-foot sections. After each section was driven, the formation samples were collected by washing; and a water sample was collected by air-lift pumping. Upon completion, all wells were surveyed to determine their elevations referenced to NGVD.

WELL NUMBER	DEPTH (feet)	SCREEN INTERVAL (feet)
TW1	125	85-105
TW2	140	80-100
TW3	126	85-110
TW4	138	113-138
TW5	126	85-105
TW6	126	75-95
R1	149	146-149
R2	149	146-149
R3	129	126-129
TPW	110	80-110
M1	110	80-110
M2	110	80-110
M3	110	80-110

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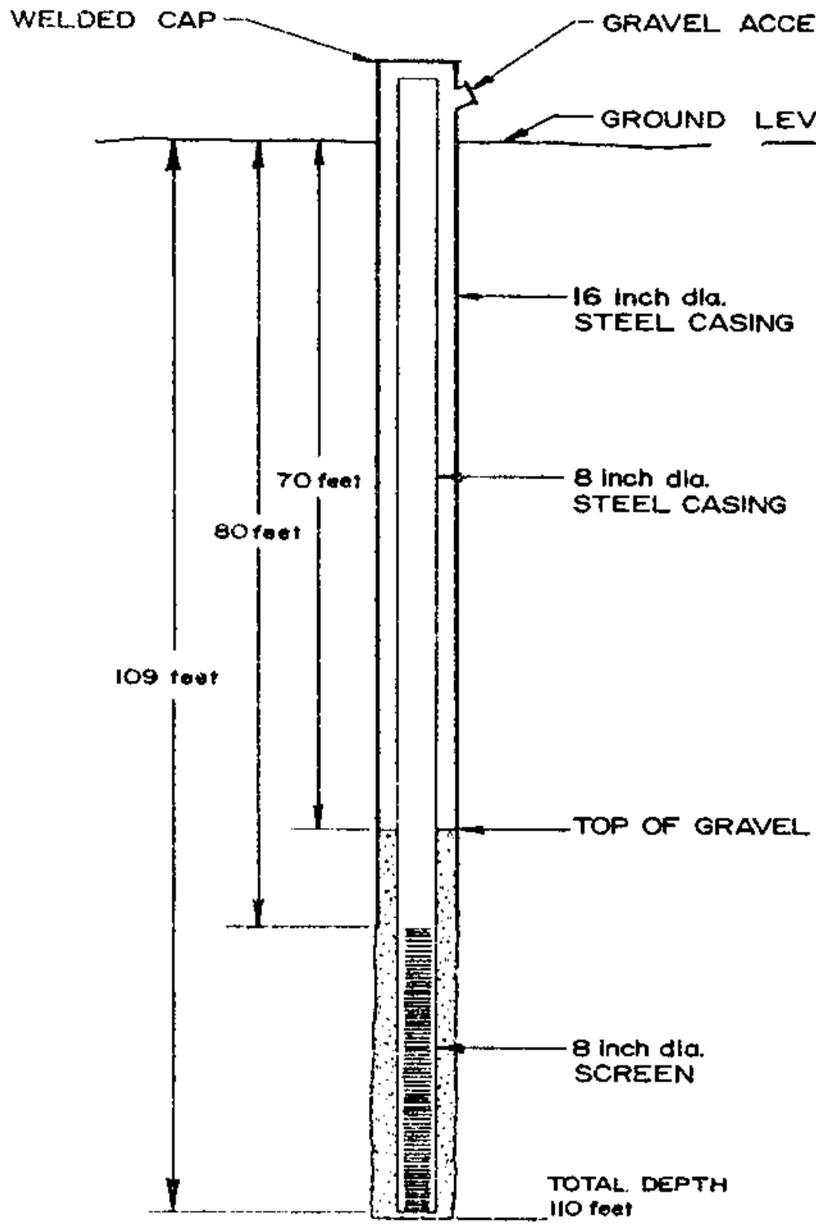
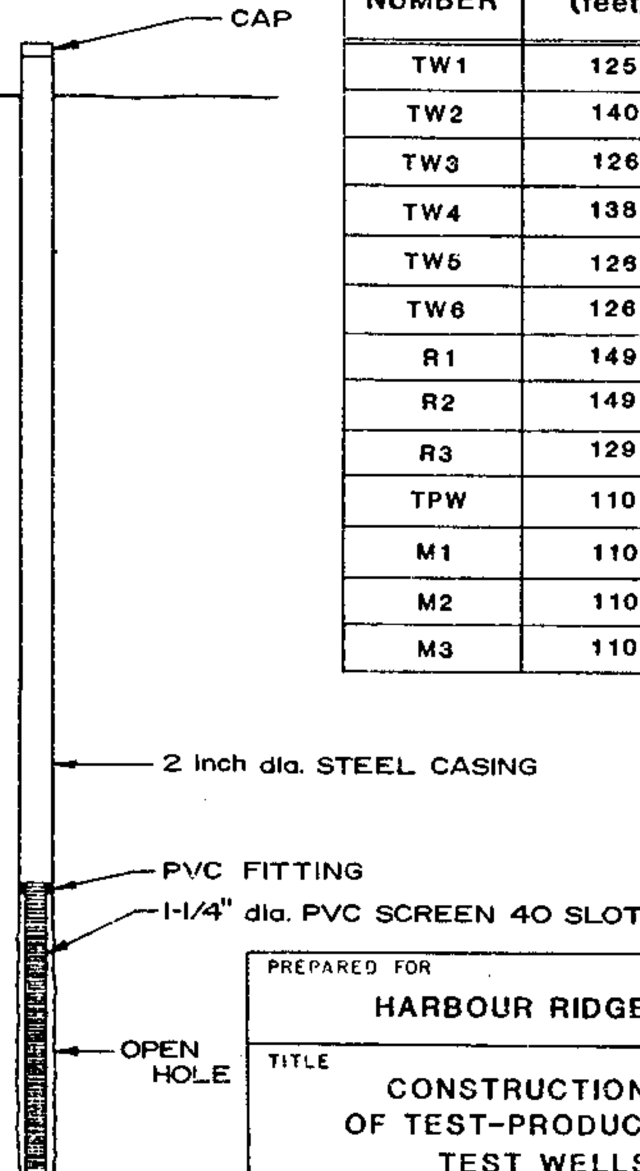


PRODUCTION WELL



TYPICAL
2 inch dia. WELL

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CONSTRUCTION DETAILS OF TEST-PRODUCTION WELL, TEST WELLS AND MONITORING WELLS

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CHECKED BY J.A. Wheatley	SCALE NONE	FIGURE 3

HYDROGEOLOGIC CONDITIONS

Shallow Aquifer

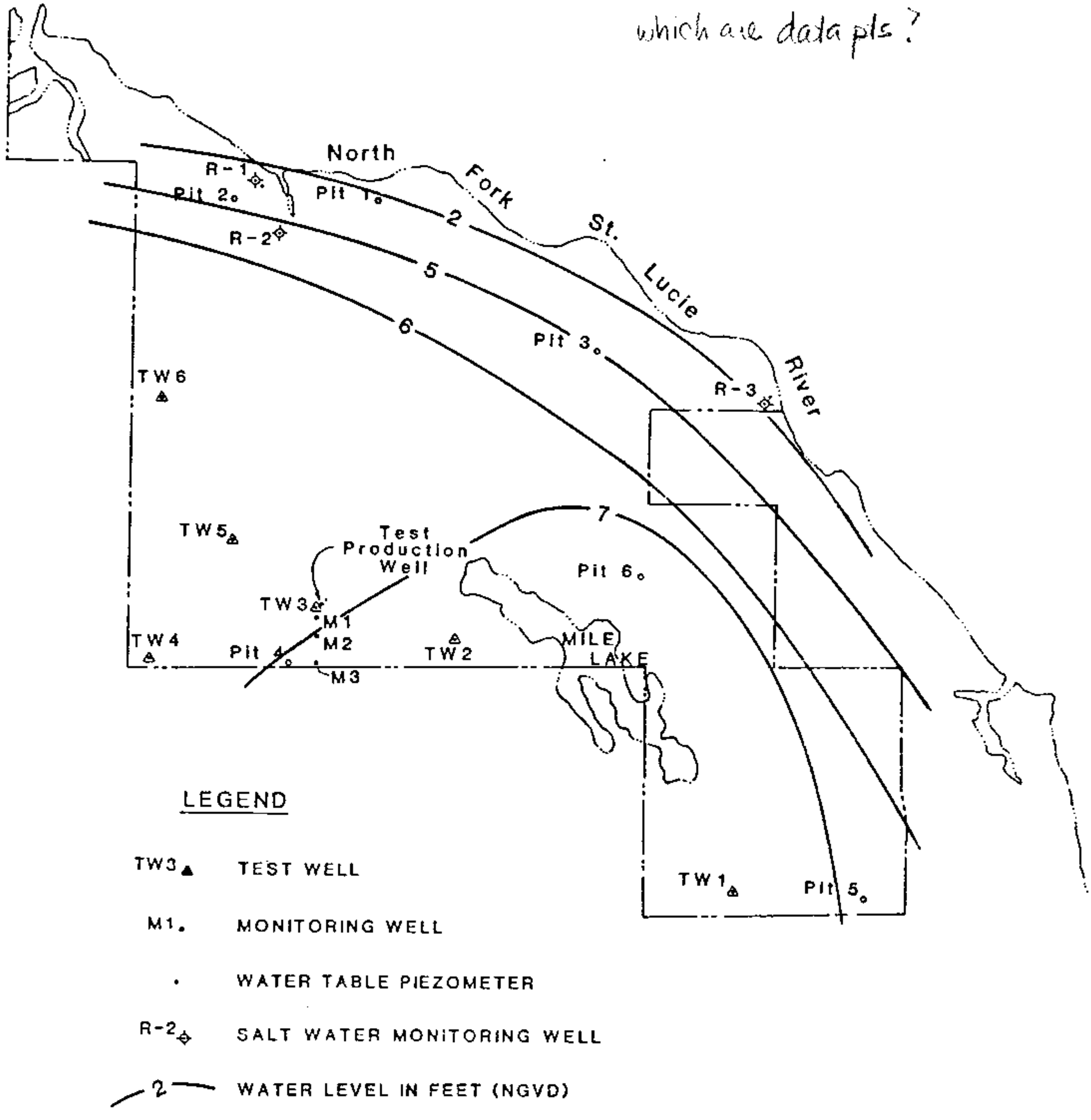
The drilling of sixteen wells and the installation of six test pits on the Harbour Ridge property generated a substantial amount of site-specific hydrogeologic data. Geologic logs of wells are given in Appendix A. The data reveal that from present land surface to depths of 20 to 60 feet below land surface, the formation consists predominantly of fine-grained sand with small amounts of clay. Ground water is encountered a few feet below land surface in this zone at the water table. The land saturated section of these suficial sands is the water-table portion of the shallow aquifer. In this interval, the overall water-yielding capacity of the material is fairly low; high-capacity wells cannot be completed in this section. Below the surficial sands, the formation becomes finer and consists of a sandy clay. The clay, which varies in thickness from 6 to 11 feet, acts as a confining layer between the water-table and production zone of the shallow aquifer. The most permeable section of the production zone occurs between 80 and 110 feet below land surface and consists of medium- to coarse-grained, partly-cemented sand, and limestone. Where it occurs, this section can yield large quantities of water to production wells. Below this unit, at a depth from 129 to 150 feet below land surface, the formation is a very fine-grained sand that grades downward to a grayish-olive clay. This clay marks the base of the shallow aquifer. The water-table zone, confining bed, and production zone are the major components of the shallow aquifer.

Water-level elevations were measured in all wells and test pits during January 1982. From these data, contour maps of water levels in the water table and production zone were constructed and are shown on Figures 4 and 5. From these two maps (Figures 4 and 5), it can be seen that the natural directions of ground-water flow in both the water table and the production zone are from the southwest to the northeast towards the North Fork of the St. Lucie River. These two contour maps also show that the water levels at the water table are 1 to 2 feet higher than the heads in the production zone.

Floridan Aquifer

The Floridan aquifer consists of a series of soft limestone formations interbedded with dense dolomite and occasional clays. The aquifer is over 1,000 feet thick with the top occurring between 300 feet and 450 feet below land surface. Within the limestone, extensive solution channeling has occurred, creating a high secondary permeability which accounts for the large yields obtainable from the aquifer. Overlying this limestone is a confining layer known as the Hawthorn Formation, consisting primarily of impermeable sand clays.

which are data pts?



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CONTOURS OF WATER LEVELS
AT THE WATER TABLE
JANUARY 4th & 5th, 1982

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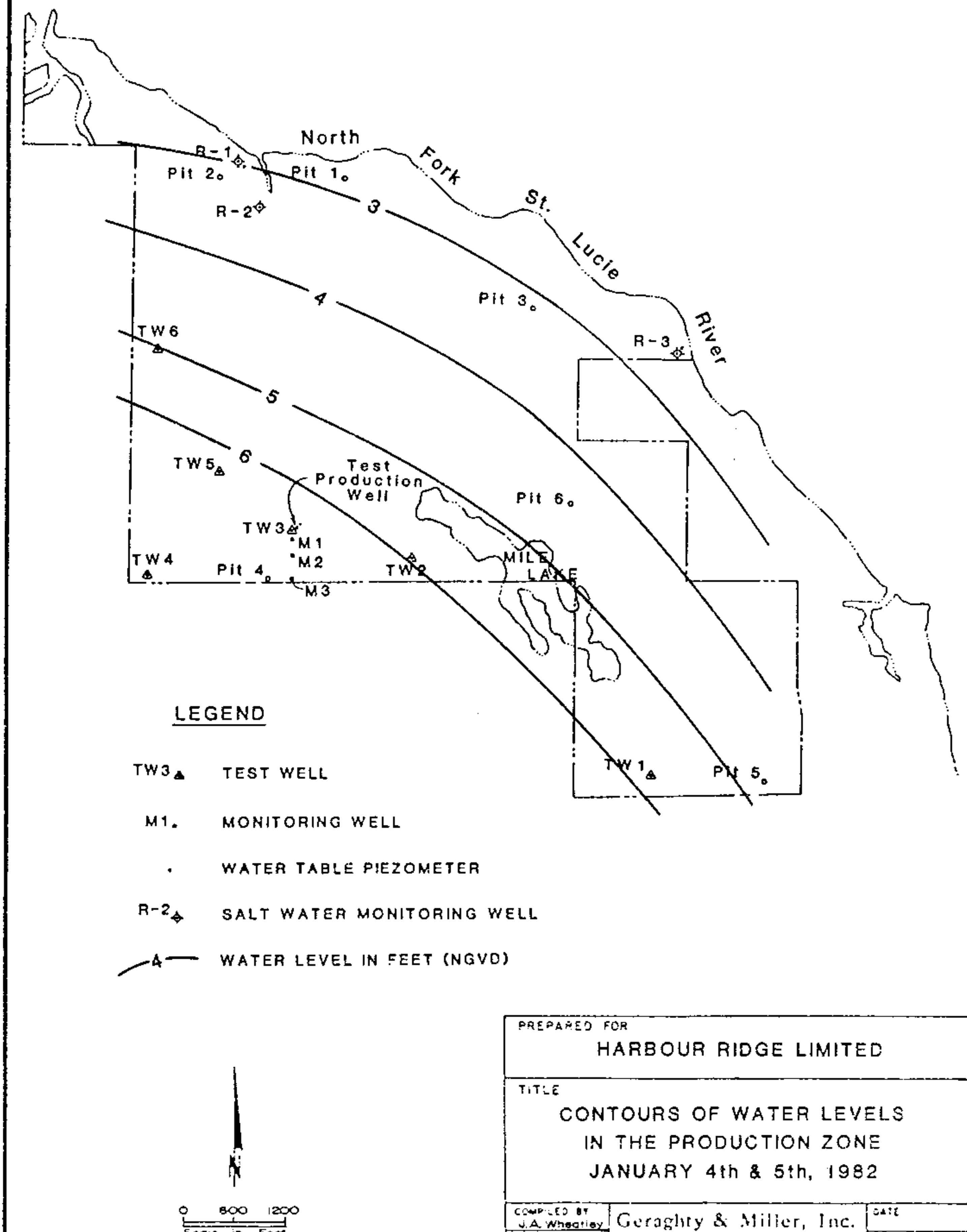
DRAWN BY P.Q. Smith		REV. SEC.
CHECKED BY J.A. Wheatley	SCALE As Shown	FIGURE 4



PREPARED FOR HARBOUR RIDGE LIMITED		
TITLE CONTOURS OF WATER LEVELS IN THE PRODUCTION ZONE JANUARY 4th & 5th, 1982		
COMPILED BY J.A. Wheatley	Geraghty & Miller, Inc. West Palm Beach, Florida	DATE
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CHECKED BY J.A. Wheatley	SCALE As Shown	FIGURE 5

The principal use of water from the Floridan aquifer in St. Lucie County is for irrigation. Users obtain their water from individual wells that are allowed to flow freely into ditches for irrigation. The excess water is transported to the St. Lucie River by means of drainage canals.

WATER QUALITY

Shallow Aquifer

To determine if water quality in the shallow aquifer in the area of Harbour Ridge was such that a potable product could be delivered with conventional treatment methods, water samples were collected and analysed from the test-production well and the salt-water monitoring wells.

Test Production Well—The analysis of the water sample collected from the test-production well is presented in Appendix B. The sample was obtained on December 5, 1981, after approximately 72 hours of continuous pumping. The water is of good quality. The chloride concentration of 25 mg/l falls well within the recommended limit of 250 mg/l for public water supply. Total dissolved solids of 558 mg/l are what one might expect for this area. The iron concentration, although above recommended DER limit for public supplies, is not excessive and can be treated so that a potable product can be delivered to consumers.

Salt-Water Monitoring Wells—To determine the potential for salt-water intrusion into the ground-water system from the North Fork of the St. Lucie River, three salt-water monitoring wells (R1, R2, and R3) were installed on Harbour Ridge property adjacent to the River (see Figure 2). Water samples were collected approximately every 20 feet during the drilling and analyzed for chloride content by field methods. The results of these analyses are given in Table 1.

As can be seen from the Table 1, chloride concentrations in the shallow aquifer at the locations of Wells R2 and R3 are less than 115 mg/l and it is likely that no saline water occurs within the water-table zone or production zone in those areas. At the location of Well R1, saline water is present in both the water-table and production zone. The highest chloride concentrations occur in the production zone of the shallow aquifer.

Floridan Aquifer

Detailed water-quality data on the Floridan aquifer are very limited and are reported in the literature only as general trends. Because the Floridan aquifer is principally used for irrigation and because chloride

TABLE 1

SALT-WATER MONITORING WELLS,
RESULTS OF CHLORIDE ANALYSIS
HARBOUR RIDGE, ST. LUCIE COUNTY, FLORIDA

Interval Sampled (Depth Below Land Surface in Feet)	Well R1	Well R2	Well R3
21- 24	[1]1,400	50	[2]N/S
42- 45	2,500	62	100
63- 66	11,000	62	75
84- 87	20,000	N/S	100
105-108	26,000	62	112
126-130	N/S	N/S	[3]425
146-149	4,000	100	N/S

Notes: 1 All results are reported in milligrams per liter as Cl^-.

2 N/S = No sample obtained.

3 The base of shallow aquifer was 129 feet below land surface at this location.

concentrations are a major concern in the irrigation water, water-quality data most often record chlorides only. The range of chloride concentration in water from this aquifer in St. Lucie County, as reported by the SFWMD in selected wells from 1977 to 1979, range from 280 mg/l (milligrams per liter) to 1250 mg/l (Reece, D. E., et al, 1980). Progressively higher chloride concentrations generally occur at greater depths. In isolated instances, however, higher chloride concentrations occur at shallower depths than would normally be expected. This phenomenon is thought to be due to localized withdrawals, allowing water of poorer quality from the deeper zones to move upward. The potential for degradation must be considered in the planning of any diversion from the Floridan aquifer.

Ranges in the quality of water in the Floridan aquifer in the vicinity of Harbour Ridge are shown on Table 2. This table was compiled from numerous analyses performed on two wells by the South Florida Water Management District from 1977 to 1979.

To the east of St. Lucie County, a transition zone exists between the relatively fresh water in the Floridan aquifer and salt water. The location of this contact (salt-water interface) is presently unknown, but presumably occurs seaward of the barrier beach where water quality is still similar to that in interior parts of the County.

TABLE 2

RANGES IN CONCENTRATIONS OF
CHEMICAL CONSTITUENTS IN WATER
SAMPLES FROM FLORIDAN AQUIFER WELLS
IN THE VICINITY OF HARBOUR RIDGE
(Reece, D. E., et al, 1980)

Total Dissolved Solids	2090 - 2940 mg/l
Alkalinity, as $CaCO_3$	146 - 160 mg/l
Chloride, as Cl	920 - 1300 mg/l
Sulfate, as SO_4	170 - 210 mg/l
Strontium, as Sr	6.6 - 12.0 mg/l
Sodium, as Na	490 - 790 mg/l
Potassium, as K	14 - 25 mg/l
Calcium, as Ca	100 - 130 mg/l
Magnesium, as Mg	68 - 120 mg/l
pH	7.2 - 7.6
Specific Conductance	3270 - 4640 micromhos
Temperature	27.7 - 30.7 °C

PUMPING TESTS

A step-drawdown pumping test and a constant-rate pumping test were conducted on the test-production well at Harbour Ridge. Both tests were conducted with the same test arrangement.

A right-angle drive, gasoline-powered vertical turbine pump was installed in the well, and a six-inch-diameter PVC discharge line was run approximately 300 feet to a nearby shallow pond in a closed depression. The pumping rate was controlled by a gate valve located close to the pump, and a six-inch totalizing flow meter was installed in the discharge pipe so that the pumping rate could be determined. An access for water-level measurements (which were made with an electric probe) was made available between the inner well casing and the pump column.

Step-Drawdown Pumping Test

A step-drawdown pumping test was conducted on the test production well (TPW1) on December 1, 1981. The step-drawdown test was conducted for the following purposes:

1. To establish pumping levels at various production rates to aid in determining the design of a permanent pump,

2. to determine the magnitude of water-level response in nearby monitoring wells to pumping stress so that the proper water-level responses in the constant-rate pumping test could be anticipated,

3. to set the gate valve and motor speed to a suitable pumping rate for the constant-rate test, and

4. to establish a baseline for future performance tests of the well and permanent pump.

Pumping steps were 30 minutes in length and were followed by 30-minute recovery steps. The test data are shown in Table 3. These data indicated that a rate approximately equal to that in the first step would be most useful for the 72-hour constant-rate pumping test.

Interpretation of step-drawdown data by the method of Rorabaugh ("Graphical and Theoretical Analysis of Step-Drawdown Test of Artesian Well," American Society of Civil Engineers, December 1953) shows that the equation: $s = 0.022\ Q + 0.01396\ Q^{1.08}$ can be used to predict drawdown in TPW1 after 30 minutes, and: $s = 0.025\ Q + 0.01396\ Q^{1.08}$

TABLE 3

DATA FROM STEP-DRAWDOWN PUMPING
TEST OF TEST-PRODUCTION WELL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Step	Pumping Rate (gpm)	Initial Depth to Water (feet)	Final Depth to Water (feet)
1	400	6.23	24.10
2	305	6.45	20.00
3	200	6.29	15.50

Note: All depths referenced to measuring point 1.35 feet above land surface.

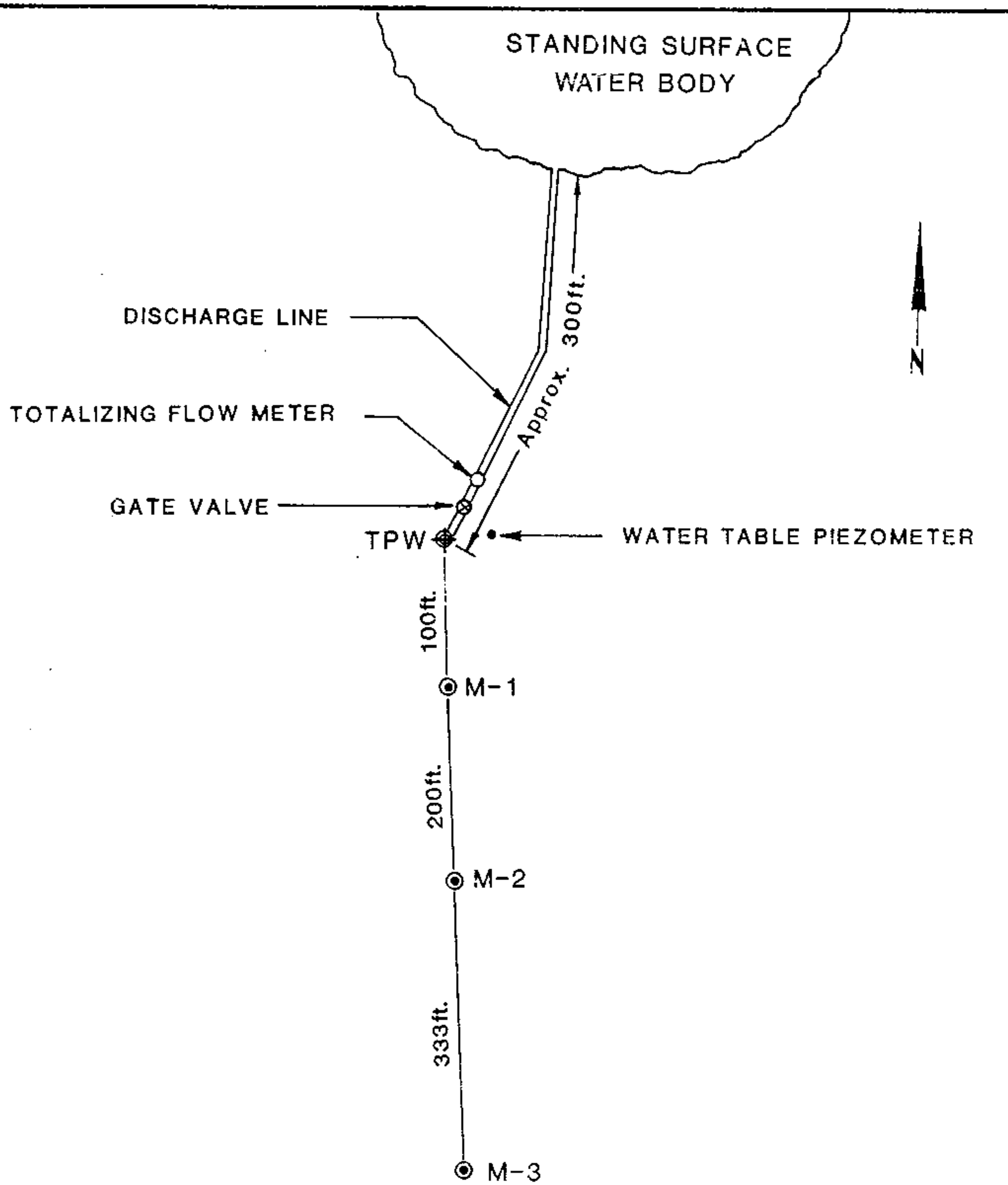
has been generated using data from the constant-rate pumping test and can be used to predict drawdown at stabilization.

Constant-Rate Pumping Test

A constant rate pumping test was begun on December 2, 1981. Water levels were measured in TPW1 by means of an electric probe, and in monitoring wells by hand-held wet tapes. A layout of the pumping test is shown in Figure 6. Water levels were measured periodically in TPW1 and the monitoring wells in the hour prior to the test. Water levels were stable in all wells during this period.

The test began at 9:00 a.m. on December 2, 1981. The pumping rate varied between 390 and 400 gpm (gallons per minute) in the first 2 minutes of the pumping before it was stabilized at 400 gpm. Pumping continued for 72 hours at this rate (+/- 0.5%). Water levels were measured frequently (each minute or more frequently during the first 20 minutes of pumping) in TPW1, M-1, M-2, M-3 and the piezometer adjacent to TPW1. After 72 hours, the pump was shut off and the recovery of water levels were measured for three hours in all wells.

When Test Production Well 1 was turned on, the water levels in all wells monitoring the production zone declined--rapidly at first, and later at



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PREPARED FOR HARBOUR RIDGE LIMITED		
TITLE PUMPING TEST LAYOUT HARBOUR RIDGE ST. LUCIE COUNTY, FLORIDA		
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a continually decreasing rate. The largest decline occurred in the pumped well; drawdown was progressively smaller at increasing radial distances from the pumped well. After about one day of pumping, water levels appeared to stabilize in the monitoring wells.

No change in the water level in the piezometer adjacent to TPW1 was observed during the test other than normal daily fluctuations. Due to this and the fact that the shallow pond has bottom peat accummulations from 1 to 3 feet, it does not appear that any substantial amount of water was released into the shallow aquifer during the pumping test.

At the completion of pumping, recovering water levels were measured in several monitoring wells. Their responses mirrored those during the pumping phase; recovery was initially rapid, but slowed at a continually decreasing rate. Measurements of recovering water levels were discontinued before the levels had recovered to the pre-test levels.

When pumped, the aquifer responded as a leaky artesian one. The fine-grained sand, shells, and clay above the production zone appear to act as a leaky confining bed. Below the production zone, the formation contains clay units of very low permeability—so low that this lower confining bed may be assumed to be impermeable.

Drawdown and recovery data from individual monitoring wells and TPW1 were plotted on semi-logarithmic or double-logarithmic graph paper, or both. Two methods of analysis are appropriate in determining aquifer coefficients from these test data. For data graphed on double-logarithmic paper, a method described by Walton ("Selected Analytical Methods for Well and Aquifer Evaluation," W. C. Walton, McGraw-Hill Publishing Company, 1962) has been applied. For data graphed on semi-logarithmic paper, the Hantush I method described by Kruseman and DeRidder ("Analysis and Evaluation of Pumping Test Data," G. P. Kruseman and N. S. DeRidder, International Institute for Land Reclamation and Improvement, 1976) has been used. As noted previously, pre-pumping and pre-recovery water-level trends were small and have been disregarded. Normal daily water-level fluctuations were small enough so that the effect on test data is not significant; they also were disregarded.

The two methods of analysis complement each other although the assumptions made about the ground-water system are the same for each method. In the Walton method, the most critical data are collected in the first few minutes of the test, and the data are visually matched to a type curve. Matching is often somewhat arbitrary depending on the skill of the analyst. Conversely, the critical data in the Hantush I method are collected after the first few minutes of testing and until stabilization. Interpretation is based on determining or estimating the value of stabilized water level and on fitting a straight line to the data collected in the middle portion of the test. The data and interpretations from representative wells are shown in Appendix C.

One additional check can be made on the accuracy of the aquifer coefficients interpreted by these two methods. Jacob's modification of the Theis equation ("A Generalized Graphic Method for Evaluating Formation Constants and Summarizing Well-Field History," H. H. Cooper and C. E. Jacob, American Geophysical Union Transactions, vol. 27, 1946) can be applied to data after the first few minutes of pumping or recovery and before stabilization. Although the major assumption upon which this method is based (that the system is a non-leaky artesian aquifer) is not valid at Harbour Ridge, leakage has only a small effect on the shape of the data curve before stabilization. Analysis of transmissivity at the pumped well by Jacob's modified method should produce an approximation of transmissivity obtained by other methods. Storage coefficient and leakance cannot be calculated by this method at any well or for the pumped well because the radius of measurement (effective radius of the pumped well) is unknown. Table 4 summarizes aquifer coefficients determined by the various methods. Values of 100,000 gpd/ft for transmissivity, .002 gpd/cu.ft. for leakance and .0002 for a storage coefficient are considered to be representative of this aquifer.

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TABLE 4
AQUIFER COEFFICIENTS DETERMINED
FOR INDIVIDUAL WELLS AS A RESULT OF
CONSTANT-RATE TEST OF TEST-PRODUCTION WELL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Well No.	Method Used*/ Data Used	Transmissivity (gpd/ft)	Storage Coefficient (dimensionless)	Leakance (gpd/ft^3)
M-1	H/Drawdown	99,800	2×10^{-4}	1×10^{-3}
M-2	CJ/Drawdown	69,500	4×10^{-4}	1×10^{-3}
	H/Drawdown	96,300	3×10^{-4}	2×10^{-3}
M-3	CJ/Drawdown	99,700	2×10^{-4}	1×10^{-3}
	H/Drawdown	126,300	2×10^{-4}	4×10^{-4}
TPW-1	JM/Recovery	97,800	Not Available	Not Available

*Methods of Analysis Used - Hantush I (H), Cooper-Jacob (CJ), or Jacob Modification (JM).

IMPACT OF PROPOSED WITHDRAWAL FROM SHALLOW AQUIFER

The potential amount of water available from the shallow aquifer at the Harbour Ridge site is the amount of fresh water that can be pumped from the aquifer on a sustained basis without causing adverse impacts. At Harbour Ridge, the greatest concern is the potential for salt-water intrusion from the North Fork. The possibility of adverse impacts at Harbour Ridge is real because the property is not large enough for production wells to be located more than a few thousand feet from the North Fork of the St. Lucie River. It is necessary, therefore, to estimate how far in the coastal direction the impacts of the proposed diversions will ultimately extend.

The limit of the catchment area surrounding the well is established by the ground-water divide that develops when drawdowns produced by pumping form a cone of depression around a well. The ground-water divide is where flow in the aquifer changes from towards the river to towards the well, and is marked by a limiting flow line and by zero hydraulic gradient on the aquifer's potentiometric surface.

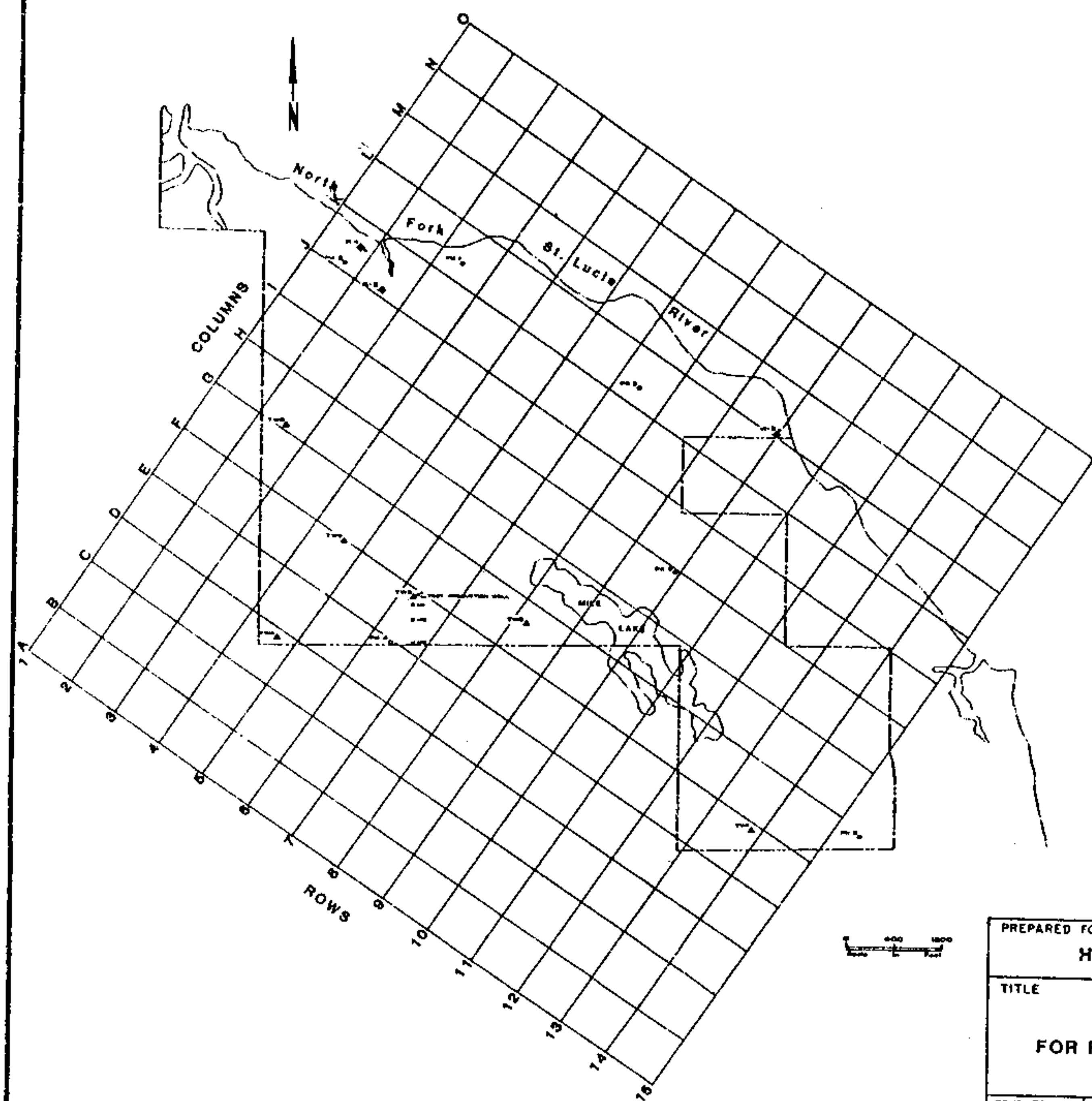
The catchment area could be approximated from a cone of depression based on drawdowns calculated by appropriate mathematical formulas. These formulas are derived on the basis of simplifying assumptions about the ground-water flow system. For example, an appropriate formula for the flow system at Harbour Ridge would be the leaky artesian aquifer equation developed by Jacob and Hantush for steady-state flow. The field situation at Harbour Ridge is such that the formula's assumption that the only water available to the well is vertical leakage through the confining bed induced by the cone of depression that is developed is overly conservative. Other factors that can be considered, which are not taken into account in the Jacob and Hantush analytical formulas, are lateral inflow from outside the area of influence of the pumping wells (natural gradient) and natural vertical leakage which occurred even before pumping began. Therefore, the catchment area needed to achieve the desired diversion and consequently, the distance to the ground-water divide will be less in practice than is predicted by the analytical formulas.

Mathematical Simulation

A more accurate mathematical simulation is needed to estimate how far the ground-water divide will ultimately extend towards the areas of brackish ground water occurring along the North Fork of the St. Lucie River. This can be achieved by more realistically simulating field conditions at Harbour Ridge, particularly the areal distribution of inflow and leakage occurring before pumpage starts. This can be done by subdividing the flow system into discrete volume elements and using numerical approximation methods to solve the resulting finite difference equations. Relevant parameters controlling flow in a leaky artesian aquifer system such as water-level altitudes, soil permeability, and thickness are built into the equations on a volume-element by volume-element basis. Because of the large number of volume elements needed to represent differences in water-level altitude in sufficient detail, and the large number of calculations that must be made upon each element, digital computers are used to solve the finite difference equations. This results in a flow-system model in which differences that occur from one place to another can be accounted for.

The supply source at Harbour Ridge is a leaky artesian aquifer. About 200 volume elements are used to simulate the aquifer being pumped and an equal number volume elements to simulate the leaky confining bed, over a two-square-mile-area (Figure 7). Because no water will be supplied from aquifer storage under steady-state conditions, it is only necessary to use the volume elements to define the geometry of the flow system, the hydraulic coefficients of the aquifer and confining bed, and conditions (heads or flows) at the boundaries of the flow system and the well.

The computer is programmed to achieve an iterative solution of the resulting system of equations by using the method of successive over-relaxation. The correct solution is achieved when successive iterations result in negligible changes in calculated water-level altitudes at all volume elements. As a check on the validity of the iterative solution, the computer is also programmed to calculate a mass balance to be sure that under the resulting head distribution the sum of



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VOLUME ELEMENTS FOR FINITE-DIFFERENCE MODEL

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CHECKED BY J.A. Wheatley	SCALE As Shown	FIGURE 7

all computed inflows equals the sum of all computed outflows, which must prevail under steady-state flow.

Description of the Model

The geometry of the flow system in the vicinity of the proposed wells, and the node-centered volume elements used to model it are shown in Figure 7. Each element is 754 feet on a side (except where they are bisected by boundaries). Along the lateral boundaries of the model (rows 1 and 15), no flow occurs. Flow of fresh water is simulated as perpendicular to, and toward the river, where the outflow boundary occurs. This outflow is approximated to occur along a straight line lying on the average a short distance off-shore (column o). The production wells that will intercept some of this flow during pumping are located at elements F6 and E13.

The lateral boundaries (rows 1 and 15), are maintained as no-flow boundaries even though some flow across them to the well will occur when pumpage starts. This is done to simplify the model, although it also leads to a conservative estimate, because the effect of assuming no flow across lateral boundaries is to exaggerate the growth of the wells' catchment area toward the area of brackish ground water.

Another boundary on the model shown in Figure 7 is where inflow occurs across the model's southwestern limit (column A) from upland areas. This boundary is simulated by flows calculated from potentiometric head and transmissivity data. However, the potentiometric heads beneath up-gradient areas to the west can only be estimated because no observation wells are located off-site. As topographic maps show that the land surface is about +16 feet NGVD (National Geodetic Vertical Datum) in areas far enough to the west, say 3,000 feet, to not be significantly effected by pumpage, and available data suggest that potentiometric heads are about six feet below land surface, the potentiometric heads in this area are estimated to be at +10 feet NGVD. Therefore, this boundary is simulated by using inflows calculated on the presumption that potentiometric heads will remain constant at about ten feet NGVD in the source area. what about 600 pumpage This inflow is not fixed but will increase as water levels are drawn down by the pumpage along the site's southwestern boundary. It is modeled by using an expression of Darcy's Law for the flow term in the finite difference equation at the volume elements along this boundary.

Before the model can be completed, one must also define conditions along the boundary receiving precipitation recharge, which is the upper limit of the flow system. This flow boundary is not shown in Figure 7 because it affects every volume element. In a leaky artesian aquifer, this can be done by specifying the average water-level distribution through the overlying water table, which is the source of leakage supplying the pumped wells. These water levels can be presumed to be constant in the model, because any leakage-induced drawdown of the water table will be offset by a resulting increase in net recharge. This is because the accompanying increase in the depth to the water table, which is close to the surface in many areas, will reduce the natural evaporative loss of ground water. what about wetlands? This reduction in discharge will be larger relative to the leakage, because evaporative losses from the shallow water-table are high.

In on-shore areas the water table or its outcropping such as lakes is the upper boundary. Along the North Fork of the St. Lucie River where outflow by vertical leakage must occur, the heads along the upper limit of the flow system are those in the St. Lucie River which are taken as 0 feet NGVD. The water-table elevations used to define this boundary on the model are shown in Table 5. They are derived from the measurements made in the water table observation wells and pits during the field investigation (Figure 4).

The other flow limit boundary, the bottom of the shallow aquifer, is implicitly modeled by the inclusion of aquifer thickness in the definition of transmissivity. The lower confining bed is assumed to be impermeable.

Table 6 shows the model input data for each square volume element needed to define the hydraulic characteristics of the aquifer system at the

TABLE 5

WATER-TABLE ELEVATIONS USED IN
FINITE-DIFFERENCE MODEL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

COLUMNS

ROWS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	8.3	8.3	8.3	7.7	7	6.8	6.6	6.4	6.2	4	0	0	0	0	0
2	8.3	8.3	8.2	7	6.9	6.8	6.6	6.5	6.3	5.3	2	0	0	0	0
3	8.3	8.2	8.1	6.9	6.8	6.7	6.5	6.3	6.1	5.8	3.5	0	0	0	0
4	8.2	8.1	8	6.9	6.8	6.7	6.5	6.3	6.1	6	5	1.8	0	0	0
5	8.2	8.1	8	6.9	6.8	6.7	6.6	6.5	6.3	6.1	5.1	2	0	0	0
6	8.2	8.1	8	7.3	7	6.8	6.8	6.8	6.4	6.1	5.3	2.1	0	0	0
7	8.2	8.1	8	7.7	7.5	7.2	7	6.8	6.5	6.1	5.5	2.2	0	0	0
8	8.2	8.1	8	7.8	7.6	7.5	9.25	9.25	7	6.2	5.3	2.3	0	0	0
9	8.2	8.1	8	7.8	7.6	7	9.25	9.25	7.2	6.3	5.2	2.1	0	0	0
10	8.2	8.1	8	7.8	7.6	7.5	9.25	9.25	7.3	6	5.1	2	0	0	0
11	8.2	8.1	7.9	7.8	7.6	7.5	9.25	9.25	7.2	5.9	5	2	0	0	0
12	8.2	8.1	7.9	7.8	7.6	7.5	9.25	7.5	7	5.6	4	0	0	0	0
13	8.1	8	7.8	7.8	7.6	7.5	7.3	7.2	6	5.3	2.5	0	0	0	0
14	8.1	7.9	7.8	7.8	7.6	7.5	7.5	7	5.8	5	2	0	0	0	0
15	8	7.9	7.8	7.8	7.6	7.5	7.5	6.2	5.8	4	0	0	0	0	0

Note: Locations of columns and rows shown on Figure 7.

TABLE 6

AQUIFER SYSTEM COEFFICIENTS IN CONSISTENT UNITS HARBOUR RIDGE ST. LUCIE COUNTY, FLORIDA

Mapped Coefficient		Model Input	
Transmissivity	Leakance	Transmissivity	Leakance Factor
100,000	0.002	13,369	152
gal/day/ft	gal/day/ft^3	sq./ft/day	sq./ft/day

site, as determined by the field studies, in the consistent units required by the finite difference equations.

The model is not complete until discharge at the offshore outflow boundary is accounted for. However, there are no data defining the discharge-controlling parameters, water levels in the production zone, or confining bed characteristics in this offshore area. The outflow boundary condition is established by extrapolation of present day on-shore water levels and by assuming that they will not be drawn down significantly by pumping because the wells are nearly a mile away.

Calibration

As some of the boundary condition data had to be estimated, it is necessary to check the model's accuracy. Because the model calculates internal heads, a check can be made by determining whether it can duplicate the water levels in the production zone under non-pumping conditions. Table 7 shows the results of this calculation. It agrees closely with the observed water levels (Figure 5) so no adjustment was made in the model input data that had to be estimated. Table 8 gives the flows into and out of each volume element of the production zone under non-pumping conditions.

TABLE 7

WATER LEVELS IN PRODUCTION ZONE UNDER NON-PUMPING CONDITIONS
AS CALCULATED BY FINITE-DIFFERENCE MODEL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

COLUMNS

ROWS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	7.97	7.61	7.25	6.88	6.50	6.11	5.72	5.31	4.89	4.44	3.98	3.54	3.13	2.75	2.4
2	7.97	7.61	7.25	6.88	6.50	6.12	5.72	5.32	4.89	4.45	3.99	3.55	3.13	2.75	2.4
3	7.97	7.61	7.25	6.88	6.50	6.12	5.73	5.32	4.90	4.47	4.01	3.56	3.14	2.76	2.4
4	7.97	7.62	7.26	6.88	6.51	6.13	5.74	5.34	4.92	4.48	4.03	3.58	3.15	2.76	2.4
5	7.97	7.62	7.26	6.89	6.52	6.14	5.75	5.35	4.93	4.50	4.05	3.60	3.16	2.76	2.4
6	7.98	7.63	7.27	6.91	6.54	6.16	5.77	5.37	4.95	4.52	4.07	3.61	3.17	2.77	2.4
7	7.98	7.63	7.28	6.92	6.55	6.18	5.79	5.39	4.97	4.53	4.08	3.62	3.17	2.77	2.4
8	7.99	7.64	7.29	6.93	6.57	6.20	5.82	5.42	4.99	4.54	4.09	3.62	3.18	2.77	2.4
9	7.99	7.65	7.30	6.94	6.58	6.21	5.84	5.43	5.00	4.55	4.09	3.62	3.18	2.77	2.4
10	8.00	7.65	7.30	6.95	6.58	6.22	5.84	5.44	5.00	4.55	4.08	3.62	3.17	2.77	2.4
11	8.00	7.65	7.30	6.95	6.59	6.22	5.84	5.43	4.99	4.54	4.07	3.61	3.17	2.77	2.4
12	8.00	7.65	7.30	6.95	6.58	6.21	5.83	5.41	4.98	4.52	4.05	3.59	3.16	2.76	2.4
13	8.00	7.65	7.30	6.95	6.58	6.21	5.81	5.40	4.96	4.50	4.03	3.57	3.15	2.76	2.4
14	8.00	7.65	7.30	6.94	6.58	6.20	5.81	5.39	4.94	4.48	4.01	3.56	3.14	2.76	2.4
15	8.00	7.65	7.30	6.94	6.58	6.20	5.80	5.38	4.94	4.48	4.00	3.56	3.14	2.76	2.4

Note: Locations of columns and rows shown on Figure 7.

TABLE 8

MASS BALANCE OF INFLOWS AND OUTFLOWS
PRODUCTION ZONE UNDER NON-PUMPING CONDITIONS
AS CALCULATED BY FINITE-DIFFERENCE MODEL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

COLUMNS

ROWS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	2366	52.3	79.8	62.5	38.1	52.1	66.8	82.6	99.7	-33.	-302	-269	-238	-209	-2E3
2	4731	105.	144.	18.8	60.9	104.	133.	180.	214.	129.	-303	-539	-476	-418	-5E3
3	4729	89.2	129.	3.27	45.2	88.1	117.	148.	182.	203.	-78.	-541	-477	-419	-5E3
4	4716	73.6	113.	2.46	44.1	86.8	116.	147.	180.	230.	147.	-271	-479	-420	-5E3
5	4708	72.9	112.	1.11	42.5	84.9	129.	175.	208.	243.	159.	-243	-480	-420	-5E3
6	4697	71.9	111.	60.0	70.6	97.5	156.	217.	220.	240.	187.	-229	-482	-421	-5E3
7	4685	70.8	109.	119.	144.	155.	183.	214.	232.	238.	216.	-215	-482	-421	-5E3
8	4673	69.8	108.	132.	157.	198.	521.	582.	306.	252.	184.	-201	-483	-421	-5E3
9	4664	69.0	107.	131.	155.	120.	519.	580.	335.	266.	169.	-231	-483	-421	-5E3
10	4657	68.4	106.	130.	154.	195.	518.	579.	350.	221.	155.	-246	-482	-421	-5E3
11	4653	68.1	90.9	130.	154.	195.	518.	580.	336.	207.	141.	-244	-481	-421	-5E3
12	4652	68.0	90.8	130.	154.	196.	520.	317.	308.	164.	-7.7	-545	-480	-420	-5E3
13	4646	52.9	75.8	130.	155.	197.	226.	274.	158.	122.	-232	-543	-478	-419	-5E3
14	4647	37.9	75.9	130.	155.	197.	258.	245.	130.	78.3	-306	-541	-478	-419	-5E3
16	2320	19.0	38.0	65.0	77.7	98.9	129.	62.3	65.5	-36.	-304	-270	-239	-209	-2E3

Note: Locations of columns and rows shown on Figure 7.

It can be seen that there is somewhat more discharge to the St. Lucie River than inflow from upland areas, with the difference supplied by downward leakage through the confining bed. It can also be seen that the production zone is receiving more recharge from leakage in the area of Mile Lake where the water table is highest.

Results of Impact Analysis

After calibration, the ultimate effect of continuously pumping two wells at a combined rate of 86,296 cu.ft./day (0.644 MGD) was determined. Table 9 shows how pumping changes the flow distribution. It can be seen by comparison with Table 8 that most of the water pumped will be supplied by an increase in inflow from upland areas and a decrease in discharge to the River, with some also being supplied by a net increase in downward leakage through the confining bed.

Table 10 and Figure 8 shows the new water levels in the production zone calculated by the model as a result of two wells continuously pumping at a combined rate of 0.644 mgd, and the position of the resulting ground-water divide. It can be seen that none of the water within about 3000 feet of the St. Lucie River should move into the well. A comparison of Figure 5 and Figure 8 shows that water levels in the production zone along the North Fork of the St. Lucie River will be slightly lower but the magnitude of the natural gradient towards the

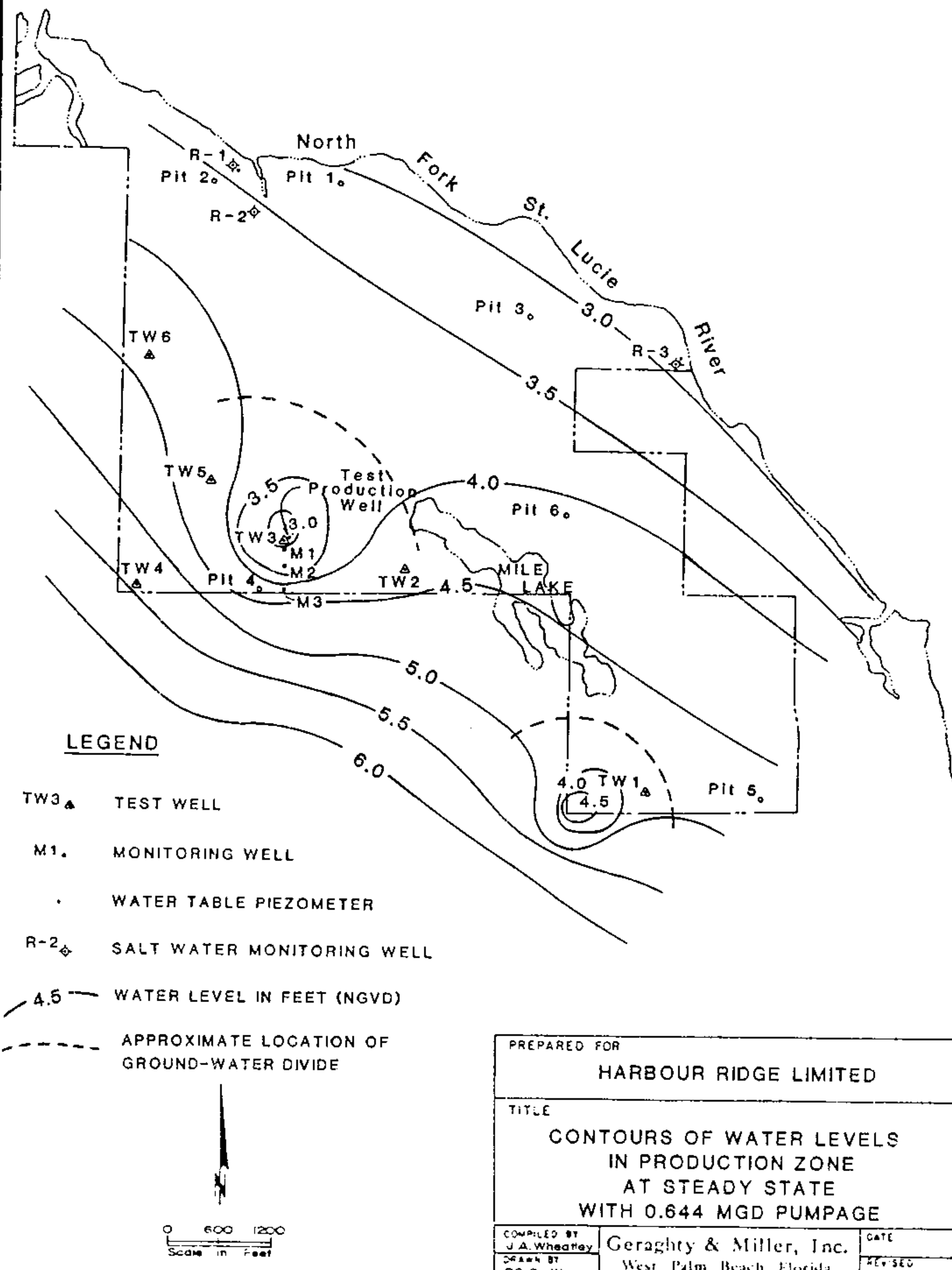
TABLE 9

MASS BALANCE OF INFLOWS AND OUTFLOWS
PRODUCTION ZONE UNDER STEADY-STATE CONDITIONS WITH
0.644 MGD PUMPAGE AS CALCULATED BY FINITE-DIFFERENCE MODEL
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

COLUMNS

ROWS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	3295	130.	166.	156.	137.	151.	162.	170.	176.	31.0	-251	-230	-212	-196	-1E3
2	6608	261.	320.	211.	263.	309.	329.	358.	370.	260.	-198	-461	-425	-393	-2E3
3	6659	251.	312.	207.	264.	312.	330.	338.	345.	337.	28.6	-462	-425	-393	-2E3
4	6717	242.	307.	224.	293.	350.	357.	354.	353.	370.	256.	-190	-426	-393	-3E3
5	6770	248.	318.	245.	336.	427.	415.	404.	391.	388.	271.	-161	-427	-394	-3E3
6	6783	249.	322.	319.	413.	-7E4	491.	461.	408.	387.	299.	-148	-429	-395	-3E3
7	6739	245.	314.	362.	436.	495.	467.	441.	413.	381.	325.	-136	-430	-395	-3E3
8	6657	237.	301.	352.	403.	458.	759.	785.	474.	387.	289.	-124	-432	-396	-3E3
9	6568	229.	288.	332.	371.	340.	725.	762.	489.	393.	269.	-157	-434	-397	-3E3
10	6497	222.	279.	319.	354.	394.	705.	747.	494.	340.	249.	-175	-436	-398	-3E3
11	6455	219.	261.	316.	351.	386.	695.	738.	472.	321.	232.	-176	-436	-398	-3E3
12	6440	218.	262.	322.	365.	391.	694.	470.	439.	274.	79.6	-480	-436	-398	-3E3
13	6430	203.	249.	335.	-2E4	402.	401.	425.	287.	228.	-147	-479	-436	-398	-3E3
14	6423	187.	247.	323.	366.	391.	428.	394.	257.	183.	-222	-478	-436	-398	-3E3
15	3206	93.2	122.	159.	177.	193.	213.	136.	128.	16.1	-263	-239	-218	-199	-1E3

Note: Locations of columns and rows shown on Figure 7.



PREPARED FOR

HARBOUR RIDGE LIMITED

TITLE

CONTOURS OF WATER LEVELS IN PRODUCTION ZONE AT STEADY STATE WITH 0.644 MGD PUMPAGE

COMPILED BY J.A. Wheatley	Geraghty & Miller, Inc. West Palm Beach, Florida		DATE
DRAWN BY P.Q. Smith			REVISED
CHECKED BY J.A. Wheatley	SCALE	As Shown	FIGURE 8

TABLE 10

WATER LEVELS IN PRODUCTION ZONE UNDER STEADY-STATE
CONDITIONS WITH 0.644 MGD PUMPAGE
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

ROWS	COLUMNS														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	7.08	6.59	6.11	5.64	5.20	4.81	4.47	4.16	3.88	3.59	3.30	3.03	2.79	2.58	2.4
2	7.07	6.58	6.10	5.62	5.17	4.77	4.43	4.14	3.87	3.59	3.31	3.03	2.79	2.58	2.4
3	7.04	6.55	6.05	5.54	5.06	4.65	4.33	4.08	3.83	3.58	3.31	3.04	2.80	2.58	2.4
4	7.01	6.51	5.98	5.42	4.87	4.40	4.15	3.97	3.78	3.56	3.32	3.05	2.80	2.59	2.4
5	6.99	6.47	5.91	5.29	4.59	3.89	3.87	3.84	3.73	3.55	3.32	3.06	2.81	2.59	2.4
6	6.98	6.46	5.88	5.20	4.28	2.68	3.57	3.76	3.71	3.56	3.33	3.07	2.82	2.60	2.4
7	7.00	6.49	5.93	5.32	4.63	3.94	3.93	3.90	3.78	3.59	3.36	3.09	2.83	2.60	2.4
8	7.04	6.54	6.02	5.48	4.95	4.49	4.26	4.08	3.88	3.65	3.40	3.12	2.84	2.61	2.4
9	7.08	6.60	6.10	5.62	5.16	4.77	4.48	4.24	3.98	3.71	3.43	3.14	2.86	2.61	2.4
10	7.12	6.64	6.16	5.70	5.27	4.91	4.61	4.34	4.05	3.76	3.46	3.15	2.87	2.62	2.4
11	7.14	6.66	6.19	5.72	5.29	4.96	4.68	4.39	4.10	3.79	3.48	3.16	2.87	2.62	2.4
12	7.15	6.67	6.18	5.68	5.20	4.93	4.68	4.41	4.11	3.80	3.48	3.16	2.87	2.62	2.4
13	7.15	6.66	6.16	5.60	4.86	4.85	4.66	4.41	4.11	3.80	3.47	3.15	2.87	2.62	2.4
14	7.15	6.67	6.18	5.67	5.19	4.93	4.68	4.41	4.11	3.79	3.46	3.15	2.87	2.62	2.4
15	7.15	6.67	6.19	5.71	5.27	4.96	4.69	4.41	4.11	3.79	3.45	3.15	2.87	2.62	2.4

Note: Locations of columns and rows shown on Figure 7.

River will remain the same. From these results, it can be seen that a diversion of 0.644 mgd from the shallow aquifer can be maintained on the Harbour Ridge property without causing adverse impacts.

Respectfully submitted,
GERAGHTY & MILLER, INC.

James A. Wheatley
Staff Scientist

Boris J. Bermes
Senior Scientist

APPENDIX A

GEOLOGIC LOGS

GEOLOGIC LOG OF
TEST WELL HR-1
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, light gray, fine- to medium-grained; Organics, trace.	0- 5	5
SAND - Sand, 90%, light brown, fine- to medium-grained; Clay, 10%, brown.	5- 15	10
SAND - Sand, 85%, white, fine- to medium-grained; Clay, 15%, light brown to brown.	15- 25	10
SAND - Sand, 90%, gray, very fine-grained; Clay, 10%, gray.	25- 31	6
SAND - Sand, 90%, gray, medium-grained; Clay, 10%, dark gray.	31- 36	5
SHELLY SAND - Sand, 75%, light gray, fine- to medium-grained; Shell fragments, 20%; Clay, 5%, dark gray.	36- 42	6
SAND AND CLAY - Sand, 70%, gray, medium-grained; Clay, 25%, gray and black; Shell fragments, 5%.	42- 50	8
SAND - Sand, 90%, gray, very fine-grained; Shell fragments, 5%; Clay, 5%, gray.	50- 56	6
SHELLY SAND - Sand, 70%, gray, medium-grained; Shell fragments, 30%.	56- 63	7
SAND - Sand, 90%, gray, very fine- to fine-grained; Shell fragments, 5%; Clay, 5%, gray.	63- 80	17

Sample Description	Depth Interval (feet)	Thickness (feet)
SANDSTONE - Sandstone, 90%, gray, fair cementation; Sand, 10%, very fine-grained.	80- 90	10
LIMESTONE - Limestone, 95%, tan, soft; Sand and Shell fragements, 5%.	90- 97	7
SANDSTONE AND LIMESTONE - Sandstone, 80%, gray, fair cementation; Limestone, 10%, tan, soft.	97-105	8
SAND - Sand, 95%, gray, very fine- to medium-grained; Shell fragments, 5%; Clay, trace.	105-125	20+
TOTAL DEPTH:	125	

GEOLOGIC LOG OF
TEST WELL HR-2
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - white, medium- to fine-grained; Organics, trace.	0- 5	5
SAND - Sand, 90%, white, medium- to fine-grained; Clay, 10%, tan to brown.	5- 30	25
SANDY SHELL - Sand, 60%, gray, fine-grained; Shell fragments, 30%, fine; Clay, 10%, gray to black.	30- 32	2
CLAY AND SAND - Sand, 70%, gray, fine-grained; Clay, 20%, gray; Shell fragments, 10%, fine.	32- 35	3
CLAY - Clay, 90%, gray; Shell fragments, 10%.	35- 43	8
SANDY CLAY - Clay, 70%, gray; Sand, 20%, fine-to meduium-grained; Shell fragments, 10%.	43- 48	5
SHELL - Shell fragments, 90%, fine; Sand, 10%, fine-grained, green.	48- 51	3
SHELL - Shell fragments, 80%; Sand, 20%, medium- to fine-grained, gray, loose cementation.	51- 58	7
SAND - Sand, 90%, gray, very fine-grained; Shell fragments, 10%, fine.	58- 60	2
SANDSTONE AND SHELL - Sandstone, 60%, medium- to coarse-grained, good cementation; Shell fragments, 20%, coarse; Sand, 10%, fine- to medium-grained.	60- 80	20

Sample Description	Depth Interval (feet)	Thickness (feet)
CLAY AND SHELL - Shell fragments, 60%; Clay, 40%, gray.	80- 82	2
SANDY LIMESTONE - Sand, 60%, cream, medium-grained; Limestone, 30%, cream, granular; Shell fragments, 10%.	82-100	18
SHELL - Shell fragments, 90%, fine; Sand, 10%, gray, fine-grained.	100-140	40+
CLAY - olive green.		
TOTAL DEPTH:	140	

GEOLOGIC LOG OF
TEST WELL HR-3
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, tan, fine- to medium-grained; Organics, trace.	0- 5	5
SAND - Sand, 90%, light brown, medium-grained; Clay, 10%, gray.	5- 10	5
SAND - Sand, 85%, tan, medium-grained; Clay, 15%, gray.	10- 25	15
SAND AND CLAY - Sand, 70%, gray, fine- to medium-grained; Clay, 30%, gray, sandy.	25- 35	10
SANDY SHELL - Sand, 40%, fine-grained, gray; Shell fragments, 40%; Clay, 20%, gray.	35- 53	18
SANDSTONE - Sandstone, 80%, fine-grained; Shell fragments, 20%.	53- 65	12
SAND - Sand, 90%, gray, fine-grained; Shell fragments, 10%.	65- 75	10
SHELLY SAND - Sand, 70%, gray, fine-grained; Shell fragments, 30%.	75- 80	5
SANDY SHELL - Shell fragments, 60%, Sand, 40%, gray, medium-grained.	80- 85	5
SHELLY SAND - Sand, 80%, gray, medium- to fine-grained; Shell fragments, 20%.	85- 95	10
SHELLY SAND - Sand, 75%, gray, medium- to coarse-grained; Shell fragments, 25%.	95-110	~~10~~ 15

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, gray, medium-grained; Shell fragments, trace.	110-120	10
SAND - Sand, 95%, gray, medium-grained; Clay, 5%, gray.	120-126	6+
TOTAL DEPTH:	126	

GEOLOGIC LOG OF
TEST WELL HR-4
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, tan, medium- to fine-grained; Organics, trace.	0- 5	5
SAND - Sand, 85%, light brown, fine-grained; Clay, 15%, light brown.	5- 20	20
SAND - Sand, tan, fine- to medium-grained; Clay, trace, black; Shell fragments, trace.	20- 30	10
SHELLY SAND - Sand, 70%, tan, medium- to coarse-grained; Shell fragments, 30%, Clay, trace, black.	30- 39	9
SANDSTONE - Sandstone, 90%, gray, good cementation; Shell fragments, 10%.	39- 45	6
SAND - Sand, gray, fine-grained, some cementation.	45- 50	5
SHELLY SAND - Sand, 80%, gray fine- to medium-grained, some cementation; Shell fragments, 20%.	50- 60	10
SAND - Sand, 85%, gray, medium-grained; Shell fragments, 15%.	60- 95	20
SAND - Sand, 90%, gray, medium- to coarse-grained, some cementation; Shell fragments, 10%.	95-138	44+
TOTAL DEPTH:	138	

GEOLOGIC LOG OF
TEST WELL HR-6
HARBOUR RIDGE
ST. LUCIE COUNTY, FLORIDA

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, white, fine- to medium-grained; Organics, trace.	0- 12	12
SANDY CLAY - Clay, 80%, light brown; Sand, 20%, light brown fine-grained.	12- 15	3
CLAYEY SAND - Sand, 85%, white, fine-grained; Clay, 15%, black.	15- 20	5
CLAYEY SAND - Sand, 85%, light brown, very fine-grained; Clay, 15%, gray to black.	20- 30	10
SAND - Sand, gray to black, medium- to coarse-grained; Clay, trace, black.	30- 35	5
SAND - Sand, light brown, medium-grained; Shell fragments, trace; Clay, trace.	35- 42	7
SHELLY SAND - Sand, 70%, light gray, fine- to medium-grained; Shell fragments, 20%; Sandstone, 10%.	42- 45	3
SANDSTONE - Sandstone, 90%, gray, good cementation; Sand, 10%, gray, fine-grained.	45- 52	7
SAND - Sand, 90%, light brown, fine-grained; Sandstone, 5%, gray, good cementation; Shell fragments, 5%.	52- 60	8
SHELLY SAND - Sand, 80%, light gray, fine- to medium-grained, some cementation; Shell fragments, 20%.	60- 95	35
SHELLY SAND - Sand, 90%, light gray, fine- to medium-grained, some cementation; Shell fragments, 10%.	95-126	31+
TOTAL DEPTH:	126	

GEOLOGIC LOG OF
WELL NUMBER R-1
HARBOUR RIDGE

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 90%, clear, very fine- to fine-grained, angular, quartz; Silt, 10%, dark yellowish brown; Organics, trace.	0- 7	7
SAND - Sand, 95%, very fine- to fine-grained, clear, angular, quartz; Silt, 5%, brownish gray.	7- 14	7
SAND - Sand, 90%, very fine- to fine-grained, clear, angular, quartz; Silt, 5%, brownish gray.	14- 21	7
SAND - Sand, 90%, very fine- to fine-grained, clear, angular, quartz; Silt, 5%, brownish gray.	21- 28	7
CLAYEY SAND - Sand, 70%, clear, very fine- to fine-grained, angular, quartz; Clay, 30%, dusky brown to dusky yellowish brown.	28- 35	7
SAND - Sand, 70%, very fine- to fine-grained, clear, angular, quartz; Shell, 10%, white, fine fragments; Silt, 10%, dusky yellowish brown; Clay, 10%, dusky yellowish brown; Wood fragments, trace, moderate reddish brown.	35- 42	7
SHELLY SANDSTONE - Sand, 65%, very fine- to fine-grained, clear, quartz; Shell, 30%, white to moderate brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	42- 49	7

Geologic Log of
Well Number R-1
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SHELLY SANDSTONE - Sand, 65%, very fine- to fine-grained, clear, quartz; Shell, 30%, white to moderate brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	49- 56	7
SANDSTONE - Sand, 75%, very fine to fine-grained, clear, quartz; Shell, 20%, white to moderate brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	56- 63	7
SANDSTONE - Sand, 80%, very fine to fine-grained, clear, quartz; Shell, 10%, white to pinkish gray, fine to med. fragments; Silt, 10%, light olive gray; Phosphorite, trace.	63- 70	7
SANDSTONE - Sand, 75%, very fine to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	70- 77	7
SANDSTONE - Sand, 75%, very fine to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	77- 84	7
SANDSTONE - Sand, 90%, very fine to fine-grained, clear, sub-angular, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	84- 91	7

Geologic Log of
Well Number R-1
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 90%, very fine to fine-grained, clear, sub-angular, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	84- 91	7
SANDSTONE - Sand, 80%, very fine to medium-grained, clear, sub-angular to sub-rounded, quartz; Shell, 15%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	91- 98	7
SANDSTONE - Sand, 80%, very fine to medium-grained, clear, sub-angular to sub-rounded, quartz; Shell, 15%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Clay, trace, grayish yellow green; Phosphorite, trace.	98-105	7
SAND - Sand, 85%, very fine to medium-grained, clear, quartz, sub-angular to sub-rounded; Shell, 10%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	105-112	7
SAND - Sand, 85%, very fine to medium-grained, clear, quartz, sub-angular to sub-rounded; Shell, 10%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	112-119	7
SAND - Sand, 90%, very fine to fine-grained, sub-angular, clear, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light gray; Phosphorite, trace.	119-126	7

Geologic Log of
Well Number R-1
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 90%, very fine to fine-grained, sub-angular, clear, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light gray; Phosphorite, trace.	126-133	7
SAND - Sand, 90%, very fine to fine-grained, sub-angular, clear, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light gray; Phosphorite, trace.	133-140	7
SAND - Sand, 95%, very fine to fine-grained, sub-angular, clear, quartz; Shell, 2.5%, white to yellowish gray, fine fragments; Silt, 2.5%, light gray; Phosphorite, trace.	140-147	7
SAND - Sand, 90%, very fine grained, sub-angular, clear, quartz; Shell, 5%, white to yellowish gray; Silt, 5%, light olive gray; Sandstone, trace, light olive gray; Clay, trace, light gray; Phosphorite, trace.	147-150	7+
TOTAL DEPTH:	150	

GEOLOGIC LOG OF
WELL NUMBER R-2
HARBOUR RIDGE

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 85%, very fine to fine grained, clear, quartz; Silt, 15%, pale yellowish brown; Wood fragments, trace.	0- 7	7
SAND - Sand, 80%, very fine to fine grained, clear, quartz; Silt, 20%, pale yellowish brown; Clay, trace, very light gray.	7- 14	7
SAND - Sand, 80%, very fine to fine grained, clear, quartz; Silt, 20%, pale yellowish brown, Clay, trace, very light gray.	14- 21	7
SAND - Sand, 80%, very fine to fine grained, clear, quartz; Clay, 20%, olive black.	21- 28	7
CLAYEY SAND - Sand, 65%, very fine to fine grained, clear, quartz; Clay, 35%, olive black; Shell, trace, fine to medium fragments, white.	28- 35	7
SAND - Sand, 80%, very fine to fine grained, clear, angular to sub-rounded, quartz; Silt, 15%, light olive gray; Shell, 5%, fine to medium fragments, white to light brown; Phosphorite, trace.	35- 42	7
SHELL - Shell, 80%, white to light brown, fine to coarse fragments; Sand, 15%, very fine grained, clear, quartz; Silt, 5%, light olive gray; Phosphorite, trace.	42- 49	7

Geologic Log of
Well Number R-2
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 70%, very fine to fine grained, clear, quartz; Shell, 25%, fine to coarse fragments, white to light brown; Silt, 5%, light olive gray; Phosphorite, trace.	49- 56	7
SHELLY SANDSTONE - Sand, 65%, fine to fine grained, clear, quartz; Shell, 30%, fine to coarse fragments, white to light brown; Silt, 5%, light olive gray; Phosphorite, trace.	56- 63	7
SAND - Sand, 90%, very fine grained, clear, quartz; Silt, 5%, light olive gray; Shell, 5%, fine fragments, white to pinkish gray; Phosphorite, trace.	63- 70	7
SHELLY SANDSTONE - Sand, 65%, fine to fine grained, clear, quartz; Shell, 30%, fine to coarse fragments, white to light brown; Silt, 5%, light olive gray; Phosphorite, trace.	70- 77	7
SANDSTONE - Sand, 70%, very fine to fine grained, clear, quartz, subrounded; Shell, 25%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	77- 84	7
SAND - Sand, 90%, very fine grained, clear, quartz; Silt, 5%, light olive gray; Shell, 5%, fine fragments, white to pinkish gray; Phosphorite, trace.	84- 91	7

Geologic Log of
Well Number R-2
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 85%, very fine to fine grained, clear, quartz; Shell, 10%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	91- 98	7
SANDSTONE - Sand, 85%, very fine to medium grained, clear, angular to subrounded, quartz; Shell, 10%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	98-105	7
SAND - Sand, 90%, very fine to fine grained, clear, angular to subrounded, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	105-112	7
SAND - Sand, 80%, very fine to fine grained, clear, angular to subrounded, quartz; Shell, 15%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray; Phosphorite, trace.	112-119	7
SAND - Sand, 90%, very fine to fine grained, clear, angular to subrounded, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace; Clay, trace, light olive gray.	119-126	7
SAND - Sand, 90%, very fine to fine grained, clear, angular to subrounded, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace; Clay, trace, light olive gray.	126-133	7

Geologic Log of
Well Number R-2
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 90%, very fine to fine grained, clear, angular to sub-rounded, quartz; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace; Clay, trace, light olive gray.	133-140	7
SAND - Sand, 90%, very fine to fine grained, clear, angular to sub-rounded, quartz; Shell, 5%, white to yellowish gray, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	140-147	7
SAND - Sand, 90%, very fine to fine grained, clear, angular to sub-rounded, quartz; Shell, 5%, white to yellowish gray, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	147-150	3+

TOTAL DEPTH: 150 Ft.

GEOLOGIC LOG OF
WELL NUMBER R-3
HARBOUR RIDGE

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 80%, very fine- to fine-grained, clear, quartz; Silt, 20%, grayish brown.	0- 7	7
NO SAMPLE	7- 14	7
NO SAMPLE	14- 21	7
CLAYEY SAND - Sand, 60%, very fine- to fine-grained, clear, quartz; Clay, 40%, dark yellowish brown.	21- 28	7
SAND - Sand, 80%, very fine- to fine-grained, clear, quartz; Clay, 20%, light brownish gray.	21- 28	7
NO SAMPLE	35- 42	7
SHELLY SAND - Sand, 65%, very fine- to medium-grained, sub-angular to sub-rounded, clear, quartz; Shell, 30%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	42- 49	7
SAND - Sand, 80%, very fine- to fine-grained, clear, quartz; Shell, 10%, white to light brown, fine fragments; Silt, 10%, light olive gray.	49- 56	7
SANDSTONE - Sand, 70%, very fine- to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	56- 63	7

Geologic Log of
Well Number R-3
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 70%, very fine- to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	63- 70	7
SANDSTONE - Sand, 75%, very fine- to fine-grained, sub-angular to sub-rounded; Shell, 15%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	70- 77	7
SANDSTONE - Sand, 80%, very fine- to fine-grained, sub-angular to sub-rounded, clear, quartz; Shell, 10%, white to light brown, fine fragments; Silt, 10%, light olive gray; Clay, trace, light gray; Phosphorite, trace.	77- 84	7
SAND - Sand, 8-%, very fine- to fine-grained, sub-angular to sub-rounded, clear, quartz; Shell, 10%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, 5%, black.	84- 91	7
SAND - Sand, 80%, very fine- to fine-grained, clear, quartz; Shell, 10%, white to light brown, fine to coarse valves and fragments; Silt, 5%, light olive gray; Phosphorite, 5%, black.	91- 98	7

Geologic Log of
Well Number R-3
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 80%, very fine- to fine-grained, clear, quartz; Shell, 10%, white to pinkish gray, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	98-105	7
SAND - Sand, 80%, very fine- to fine-grained, clear, quartz; Shell, 15%, white to pinkish gray, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	105-112	7
SAND - Sand, 85%, very fine- to fine-grained, clear, quartz; Shell, 10%, white to pinkish gray, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	112-119	7
CLAY - Clay, 80%, grayish olive; Sand, 20%, quartz, very fine-grained; Phosphorite, trace.	119-126	7
CLAY - Clay, 90%, grayish olive; Sand, 10%, very fine-grained, quartz; Phosphorite, trace.	126-133	7
CLAY - Clay, 90%, grayish olive; Sand, 10%, very fine-grained, quartz; Phosphorite, trace.	133-140	7
CLAY - Clay, 90%, grayish olive; Sand, 10%, very fine-grained, quartz; Phosphorite, trace.	140-147	7+

TOTAL DEPTH: 147

GEOLOGIC LOG OF
TEST PRODUCTION WELL #1
HARBOUR RIDGE

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, 75%, clear, very fine- to fine-grained, angular, quartz; Silt, 25%, grayish brown.	0- 5	5
SILTY SAND - Sand, 70%, clear, very fine- to fine-grained, angular, quartz; Silt, 30%, dark yellowish brown.	5- 10	5
SILTY SAND - Sand, 60%, clear, very fine- to fine-grained, angular, quartz; Silt, 35%, dark yellowish brown; Clay, 5%, very light gray.	10- 15	5
SAND - Sand, 80%, very fine- to fine-grained, clear, angular to sub-rounded, quartz; Silt, 20%, pale yellowish brown.	15- 20	5
SAND - Sand, 80%, very fine- to fine-grained, clear, angular to sub-rounded, quartz; Silt, 20%, pale yellowish brown.	20- 25	5
SAND - Sand, 80%, very fine- to fine-grained, clear, sub-angular to sub-rounded, quartz; Silt, 20%, pale yellowish brown.	25- 29	4
CLAYEY SAND - Sand, 70%, fine-grained, clear, quartz; Clay, 30%, olive gray.	29- 35	6
CLAY - Clay, 80%, olive black; Sand, 20%, fine-grained, clear, quartz.	35- 40	5

Geologic Log of
Test Production Well #1
Harbour Ridge

Sample Description	Depth Interval (feet)	Thickness (feet)
SHELLY SAND - Sand, 50%, clear, fine-grained, quartz; Shell, 30%, white to yellowish gray, fine to coarse fragments; Clay, 20%, olive gray.	40- 45	5
SANDSTONE - Sand, 80%, fine-grained, clear to medium dark gray, quartz; Shell, 20%, white to yellowish gray, fine to coarse fragments.	45- 50	5
SANDSTONE - Sand, 80%, fine-grained, clear, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 10%, white to yellowish gray, fine to coarse fragments.	50- 55	5
SANDSTONE - Sand, 80%, fine-grained, clear, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 10%, white to yellowish gray, fine to coarse fragments.	55- 60	5
SANDSTONE - Sand, 80%, fine- to medium-grained, clear, rounded to sub-angular, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 10%, white to yellowish gray, fine to medium fragments; Phosphorite.	60- 65	5
SANDSTONE - Sand, 75%, fine-grained, clear, rounded to sub-angular, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 5%, white to yellowish gray, fine to medium fragments; Phosphorite, trace.	65- 70	5

Geologic Log Of
Test Production Well #1
Harbour Ridge

Sample Description	Depth Interval (feet)	Thickness (feet)
SANDSTONE - Sand, 75%, very fine- to fine-grained, clear, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 15%, white to yellowish gray, fine to medium fragments; Phosphorite, trace.	70- 75	5
SANDSTONE - Sand, 75%, very fine- to fine-grained, clear, quartz; Silt, 10%, dusky yellow green to medium dark gray; Shell, 15%, white to yellowish gray, fine to medium fragments; Phosphorite, trace.	75- 80	5
SHELLY SANDSTONE - Sand, 50%, fine-grained, clear, rounded, quartz; Shell, 30%, medium to very coarse fragments, white to yellowish brown; Silt, 20%, light to olive gray to dark gray; Phosphorite, trace.	80- 85	5
SHELLY SANDSTONE - Sand, 60%, fine-grained, clear, rounded, quartz; Shell, 30%, fine to coarse fragments; white to yellowish brown; Silt, 10%, light olive gray to dark gray; Phosphorite, trace.	85- 90	5
SHELLY SANDSTONE - Sand, 60%, fine-grained, clear, rounded, quartz; Shell, 30%, fine to coarse fragments, white to yellowish brown; Silt, 10%, light olive gray to dark gray; Phosphorite, trace.	90- 95	5
SANDSTONE - Sand, 70%, fine-grained, clear, rounded, quartz; Shell, 20%, fine to medium fragments, white to yellowish brown; Silt, 10%, light olive gray; Phosphorite, trace.	95-100	5

Geologic Log Of
Test Production Well #1
Harbour Ridge

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, 75%, clear, fine- to medium-grained, angular to sub-rounded, quartz; Shell, 20%, fine to coarse fragments, white to yellowish brown; Silt, 5%, light olive gray; Phosphorite, trace.	100-105	5
SAND - Sand, 75%, clear, very fine- to medium-grained, angular to sub-rounded, quartz; Shell, 20%, fine to coarse fragments, white to yellowish brown; Silt, 5%, light olive gray; Phosphorite, trace.	105-110	5+
TOTAL DEPTH:	110 Ft.	

GEOLOGIC LOG OF
WELL NUMBER M-1
HARBOUR RIDGE

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 95%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Clay, 5%, dark yellowish brown.	20- 21	1
SAND - Sand, 65%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 20%, fine fragments, white to light brown; Clay, 15%, light olive gray.	41- 42	1
SHELLY SANDSTONE - Sand, 60%, very fine- to fine-grained, clear, quartz; Shell, 35%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray.	42- 49	7
SANDSTONE - Sand, 80%, clear, very fine- to fine-grained, quartz, Shell, 10%, white to light brown fine fragments; Silt, 10%, light gray; Phosphorite, trace.	49- 56	7
SANDSTONE - Sand, 70%, clear, very fine- to fine-grained, quartz, Silt, 20%, light olive gray; Shell 10%, white to light brown, fine fragments, Phosphorite, trace.	56- 63	7
SAND - Sand, 70%, clear, very fine- to fine-grained, Shell, 20%, white to light brown, fine fragments; Silt, 10%, light olive gray; Phosphorite, trace.	63- 70	7
SAND - Sand, 70%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Phosphatic sand, 20%, black fine-grained; Shell, 10%, white to light brown, fine fragments.	70-77	7

Geologic Log of
Well Number M-1
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 70%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 25%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray; Phosphorite, trace.	77- 84	7
SANDSTONE - Sand, 70%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 25%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray; Phosphorite, trace.	84- 91	7
SANDSTONE - Sand, 75%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 15%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	91- 98	7
SANDSTONE - Sand, 75%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 15%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	98-105	7
SAND - Sand, 85%, clear, very fine- to fine-grained, angular to sub-rounded, quartz; Shell, 10%, white to light yellowish brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	105-	5+
TOTAL DEPTH:	110	

GEOLOGIC LOG OF
WELL NUMBER M-2
HARBOUR RIDGE

Sample Description	Depth Interval	Thickness (feet)
SAND - Sand, 90%, very fine- to fine-grained, angular, clear, quartz; Silt, 10%, pale yellowish brown.	10- 21	11
SAND - Sand, 80%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Silt, 15%, light olive gray; Shell, 5%, pinkish gray, fine to medium fragments; Phosphorite, trace.	21- 28	7
CLAYEY SAND - Sand, 60%, very fine- to fine-grained, clear, quartz; Clay, 30%, olive gray; Shell, 10%, white to light brown, fine to coarse fragments.	28- 35	7
SANDSTONE - Sand, 75%, very fine- to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray; Phosphorite, trace.	35- 42	7
SANDSTONE - Sand, 75%, very fine- to fine-grained, clear, quartz; Shell, 20%, white to light brown, fine fragments; Silt, 5%, light gray, Phosphorite, trace.	42- 49	7
SANDSTONE - Sand, 90%, fine-grained, clear, rounded to sub-angular, quartz; Shell, 5%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	49- 56	7

Geologic Log of
Well Number M-2
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE, Sand, 90%, fine-grained, clear, rounded to sub-angular, quartz; Shell, 5%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	56- 63	7
SAND - Sand, 80%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Shell, 15%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	63- 70	7
SAND - Sand, 70%, fine-grained, angular to sub-rounded, clear, quartz; Shell, 15%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	70- 77	7
SANDSTONE - Sand, 80%, very fine-grained, clear, quartz; Shell, 15%, white to light brown, fine to medium fragments; Silt, 5%, light olive gray; Phosphorite, trace.	77- 84	7
SAND - Sand, 85%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Shell, 10%, white to light brown, fine fragments; Silt, 5%, light olive gray; Phosphorite, trace.	84- 91	7
SANDSTONE - Sand, 80%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Shell, 15%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	91- 98	7

Geologic Log of
Well Number M-2
Harbour Ridge

Sample Description	Depth Interval	Thickness (feet)
SANDSTONE - Sand, 80%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Shell, 15%, white to light brown, fine to coarse fragments; Silt, 5%, light olive gray; Phosphorite, trace.	98-105	7
SAND - Sand, 95%, fine- to medium-grained, angular to sub-rounded, clear, quartz; Shell, 5%, white to light brown, fine fragments; Silt, trace, light gray; Phosphorite, trace.	105	5+
TOTAL DEPTH:	110	

GEOLOGIC LOG OF
WELL NUMBER M-3
HARBOUR RIDGE

Sample Description	Depth Interval (feet)	Thickness (feet)
SAND - Sand, 80%, very fine- to fine-grained, clear, angular, quartz; Silt, 20%, dusky brown.	0- 7	7
SAND - Sand, 80%, very fine- to fine-grained, clear, angular, quartz; Clay, 20%, very light gray.	7- 14	7
SAND - Sand, 90%, very fine- to fine-grained, clear, angular, quartz; Clay, 10%, very light gray to pale yellowish brown.	14- 21	7
CLAYEY SAND - Sand, 70%, very fine- to fine-grained, clear, angular, quartz; Clay, 30%, olive gray.	21- 28	7
SAND - Sand, 75%, very fine- to fine-grained, clear, angular, quartz; Clay, 15%, very light olive gray; Shell, 10%, white to light brown, fine fragments.	28- 35	7
SANDY CLAY - Clay, 60%, very light gray to olive gray; Sand, 30%, very fine- to fine-grained, quartz; Shell, 10%, white to light brown, fine to coarse fragments.	35- 42	7
SANDSTONE - Sand, 80%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Shell, 10%, white to light brown, fine to medium fragments; Silt, 10%, light olive gray; Phosphorite, trace.	42- 49	7

Geologic Log of
Well Number M-3
Harbour Ridge

Sample Description	Depth Interval (feet)	Thickness (feet)
SANDSTONE - Sand, 65%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Silt, 20%, light gray; Shell, 15%, white to light brown, fine to medium fragments; Phosphorite, trace.	56- 63	7
SANDSTONE - Sand, 65%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Silt, 20%, light gray; Shell, 15%, white to light brown, fine to medium fragments; Phosphorite, trace.	63- 70	7
SAND - Sand, 75%, very fine- to fine-grained, angular to sub-rounded, clear, quartz; Phosphatic Sand, 15%, black, sub-rounded; Shell, 5%, white to light brown, fine fragments; Silt, 5%, light olive gray.	70- 77	7
SANDSTONE - Sand, 75%, very fine- to fine-grained, clear, quartz; Silt, 20%, light gray to dusky yellow green; Shell, 5%, white to light brown, fine to medium fragments, Phosphorite, trace.	77- 84	7
SANDSTONE - Sand, 80%, very fine- to fine-grained, clear, angular to sub-rounded, quartz; Silt, 10%, light gray to light olive gray; Shell, 10%, white to light brown, fine fragments; Phosphorite, trace.	84- 91	7
SANDSTONE - Sand, 80%, very fine- to fine-grained, clear, angular to sub-rounded, quartz; Silt, 10%, light gray to light olive gray; Shell, 10%, white to light brown, fine fragments; Phosphorite, trace.	91- 98	7

Geologic Log Of
Well Number M-3
Harbour Ridge

Sample Description	Depth Interval (feet)	Thickness (feet)
SANDSTONE - Sand, 80%, very fine- to fine-grained, clear, angular to sub-rounded, quartz; Silt, 10%, light gray to light olive gray; Shell, 10%, white to light brown, fine fragments; Phosphorite, trace.	98-105	7+
TOTAL DEPTH:	105	

APPENDIX B

WATER QUALITY ANALYSIS OF TEST PRODUCTION WELL

GEOTEC, INC
1602 CLARE AVENUE
WEST PALM BEACH, FL 33401

LAB ID 86122

SECONDARY
WATER ANALYSIS

SAMPLE NO. 112-788

DATE REC'D 12/5/81

TIME REC'D

PROJECT NO.

Geraghty & Miller, Inc.
Forum III - Suite 604
1665 Palm Beach Lakes Blvd.
West Palm Beach, FL 33401

DATE COLLECTED BY client TIME

LOCATION JOB # P528DB1 PURPOSE

	page*	DATE	BY	NBR	FOUND, mg/L
ALKALINITY as $CaCO_3$	3	12/31	ms	23-377	250
CALCIUM	103	12/8	bm	38-288	121
CHLORIDE	29	12/22	ce	44-24	25
COLOR	36	12/6	bm	23-367	> 70
COPPER	108	12/7	bm	38-287	< 0.001
FOAMING AGENTS	157				
HYDROGEN SULFIDE	284	1/11	jp	20-360	.05
IRON	110	12/16	bm	39=209	1.48
MAGNESIUM	114	12/10	bm	38-288	7
MANGANESE	116	12/10	bm	38-289	<0.0001
ODOR	287	12/6	bm	23-367	1
pH	239	12/11	ce	47-21	7.0
SODIUM	147	12/8	bm	38-288	23
SULFATE	277	1/4	ce	47-27	11
TOTAL DISSOLVED SOLIDS	270	12/16	ms	23-370	558
TOTAL HARDNESS as $CaCO_3$	68	12/31	ms	23-376	91
ZINC	155	12/28	bm	38-299	< 0.01
MBAS		12/9	jp	20-32	0.06

* Methods for Chemical Analysis of Water and Wastes, US EPA

5-79

DATE January 11, 1982 BY [signature]

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

LAB ID 86122

PRIMARY
WATER ANALYSIS

SAMPLE NO. 112-788

Geraghty & Miller, Inc.
Forum III - Suite 604
1665 Palm Beach Lakes Blvd.
West Palm Beach, FL 33401

DATE REC'D 12/5/81

TIME REC'D

PROJECT NO.

DATE COLLECTED BY client TIME

LOCATION JOB # P528DB1 PURPOSE

	STORET #	DATE	BY	NBR	MCL, mg/L	FOUND mg/L
ARSENIC	01002	12/30	bm	38-300	0.05	0.008
BARIUM	01007	12/8	bm	28-288	1.	0.06
CADMIUM	01027	12/11	bm	28-289	0.010	< 0.001
CHROMIUM	01034	12/11	bm	38-289	0.05	< 0.001
LEAD	01051	12/12/	bm	38-293	0.05	< 0.001
MERCURY	71900	12/11	bm	38-292	0.002	< 0.0001
SELENIUM	01147	12/17	bm	38-294	0.01 0.	0.002
SILVER	01077	12-6	bm	38-287	0.05	< 0.001
FLUORIDE	00951	12/15	bm	23-369		0.13
NITRATE-N	00630	12/8	ce	47-20	10.	.04
TURBIDITY	00076	12/6	bm	22-367	1 NTU	13
TOTAL COLIFORM					<1/100 mL	

DATE >α January 11,1982

BY [signature]

8-81

EVERGLADES LABORATORIES, INC. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-4200

LAB ID 86109

PRIMARY ORGANICS

GERAGHTY & MILLER

SAMPLE NO. 975

DATE REC'D 12-5-81

PROJECT NO. ______

DATE COLL ______

BY ______ TIME ______ LOCATION JOB # P528DB1

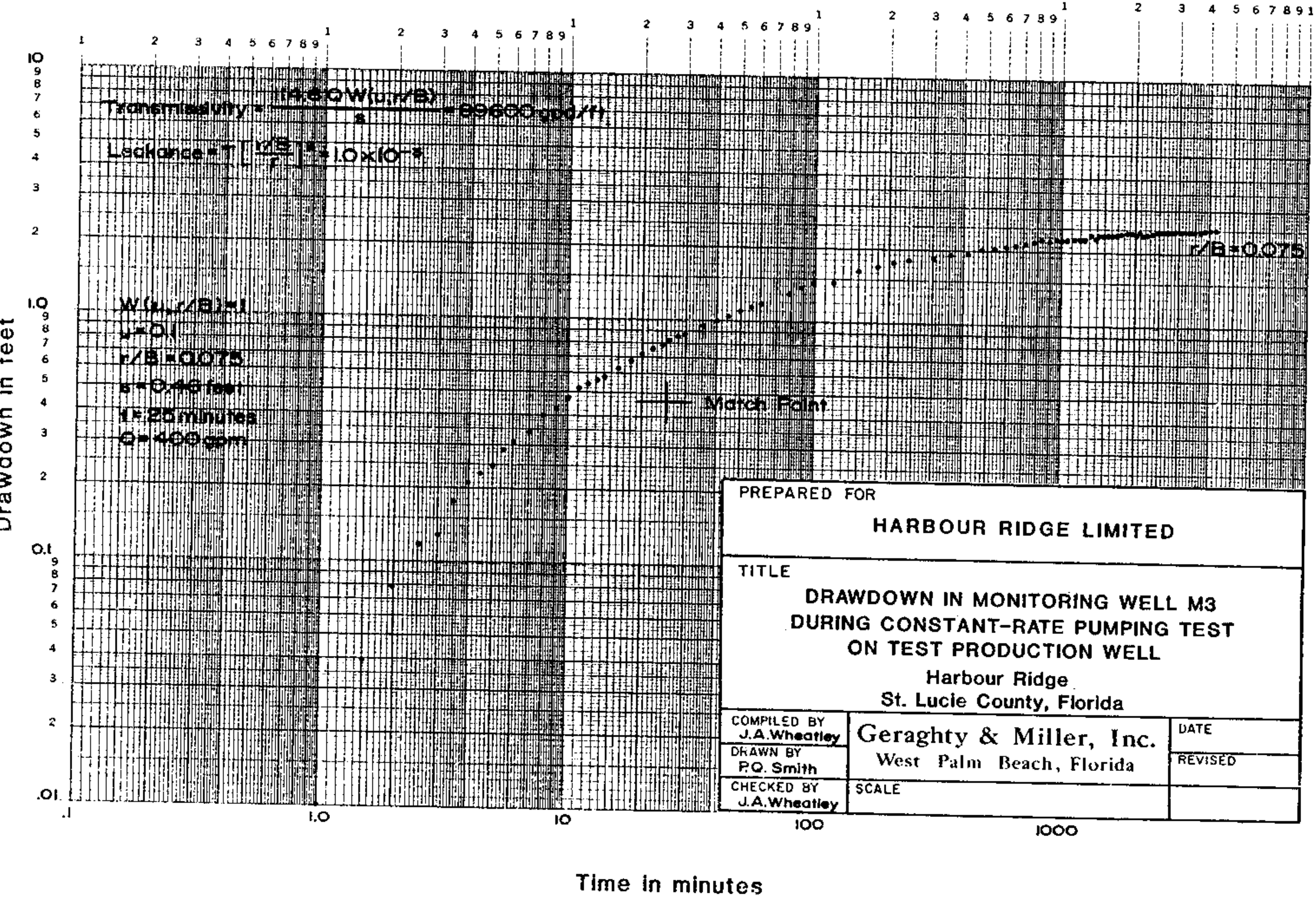
	STORET NO.	METHOD CODE	MCL µg/L	FOUND µg/L	FOUND mg/L
ENDRIN	39390	1	0.2	<0.004	<0.000004
LINDANE	39782	1	4	<0.01	<0.00001
METHOXYCHLOR	39480	1	100	<0.1	<0.0001
TOXAPHENE	39400	1	5	<0.7	<0.0007
2,4-D		2	100	<0.08	<0.00008
2,4,5-TP	39760	2	10	<0.01	<0.00001

METHODS:
1. METHOD FOR ORGANOCHLORINE PESTICIDES IN INDUSTRIAL EFFLUENTS. EPA 1973
2. METHOD FOR CHLORINATED PHENOXY ACID HERBICIDES IN INDUSTRIAL EFFLUENTS, EPA 1973
3. METHOD 608, ORGANOCHLORINE PESTICIDES AND PCBs FEDERAL REGISTER VO. 44 DEC. 3, 1979
4. OTHER:

______ DATE 12-26-81

APPENDIX C

REPRESENTATIVE DRAWDOWN DATA AND INTERPRETATION



PREPARED FOR

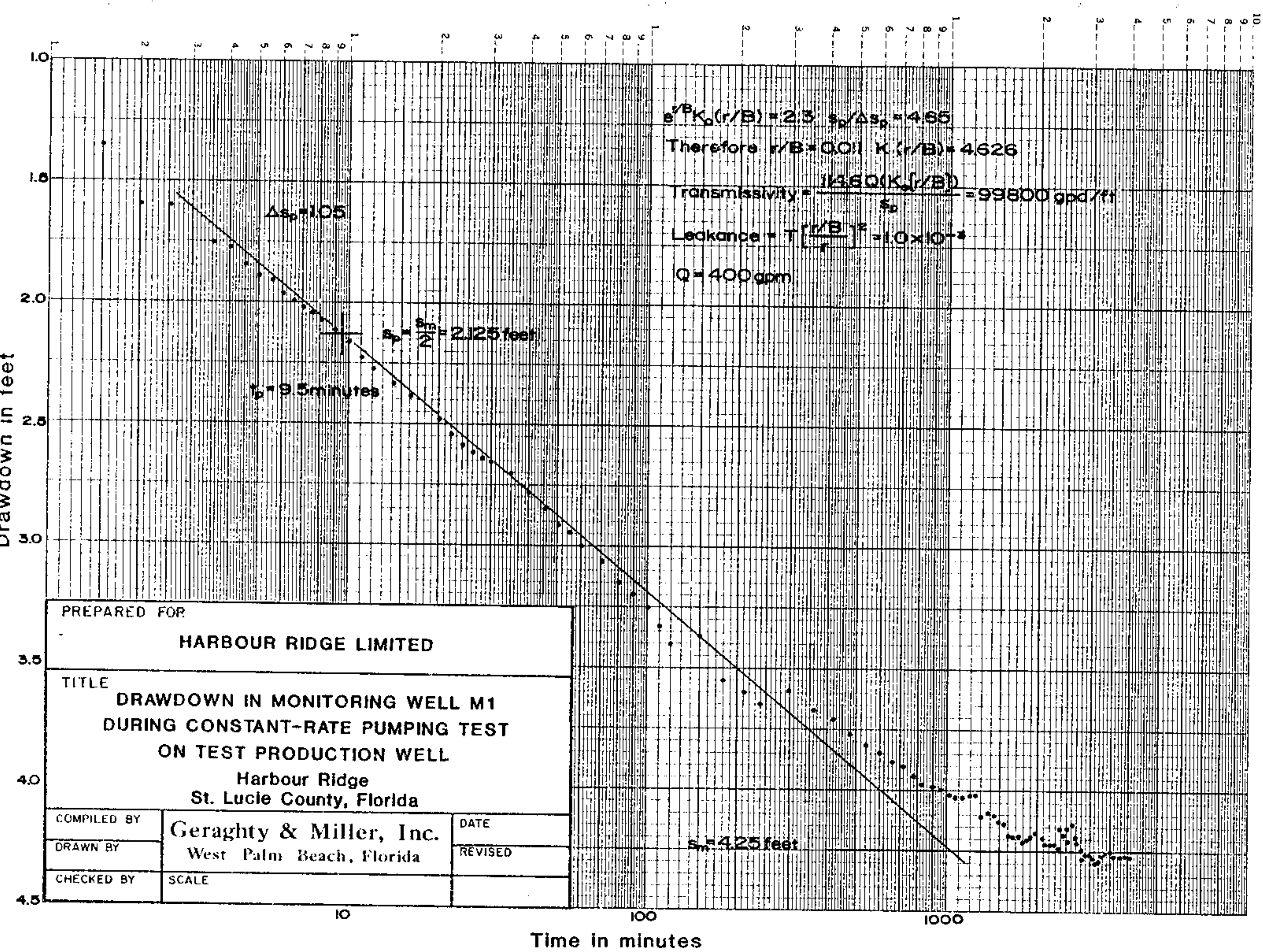
HARBOUR RIDGE LIMITED

TITLE

DRAWDOWN IN MONITORING WELL M3 DURING CONSTANT-RATE PUMPING TEST ON TEST PRODUCTION WELL

Harbour Ridge
St. Lucie County, Florida

COMPILED BY J.A.Wheatley	Geraghty & Miller, Inc.	DATE
DRAWN BY P.Q. Smith	West Palm Beach, Florida	REVISED
CHECKED BY J.A.Wheatley	SCALE	



Drawdown in feet
Time in minutes
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
10
100
1000
$e^{r/B}K_o(r/B) = 2.3 \; s_p/\Delta s_p = 4.65$
Therefore $r/B = 0.011 \; K_o(r/B) = 4.626$
Transmissivity $= \frac{114.6Q(K_o[r/B])}{s_p} = 99800$ gpd/ft
Leakance $= T\left[\frac{r/B}{r}\right]^2 = 1.0 \times 10^{-3}$
Q = 400 gpm
$\Delta s_p = 1.05$
$s_p = \frac{s_m}{2} = 2.125$ feet
$t_p = 9.5$ minutes
$s_m = 4.25$ feet
PREPARED FOR
HARBOUR RIDGE LIMITED
TITLE
DRAWDOWN IN MONITORING WELL M1
DURING CONSTANT-RATE PUMPING TEST
ON TEST PRODUCTION WELL
Harbour Ridge
St. Lucie County, Florida
COMPILED BY
DRAWN BY
CHECKED BY
Geraghty & Miller, Inc.
West Palm Beach, Florida
SCALE
DATE
REVISED

Method	Wells	Transmissivity (gpd/ft)	Storativity	Leakance (gpd/ft³)
Hantush I	M1	100,100	1.6×10^{-4}	8.5×10^{-4}
"	M2	89,100	2.7×10^{-4}	2.3×10^{-3}
"	M3	96,800	2.6×10^{-4}	1.4×10^{-3}
Hantush II	M 1,2,3	97,900	—	4.8×10^{-4}
Hantush-Jacob	M1,2,3	83,500	—	3.2×10^{-3}
Distance-Drawdown	M1,2,3	89,500	4.3×10^{-4}	—
Hantush Image	M 1,2,&3	35,200	.36	—
Hantush W/ Storage	M1	66,400	3×10^{-4}	—
Walton	M1	91,700	2.4×10^{-4}	9.2×10^{-6}
	M2	99,600	.33	1×10^{-3}
	M3	8,800	3×10^{-5}	2.9×10^{-4}

METHOD	WELLS USED	T (gpd/ft)	S	Leakance (gpd/ft³)
HANTUSH I	M-1	100,160	1.6 x 10^{-4}	3.9 x $10^{[illegible]}$
"	M-2	89,136	2.65 x 10^{-4}	7.1 x $10^{[illegible]}$
"	M-3	94,982	2.61 x 10^{-4}	7.0 x $10^{[illegible]}$
HANTUSH-JACOB	M1, M2, M3	83,552	can't derive	1.5 x 10^{-2}
DISTANCE-DRAWDOWN	M1, M2, M3	89,496	4.27 x 10^{-4}	can't derive
HANTUSH IMAGE	M_1, M_2, M_3	35,200	.136	
[illegible] Jacob	M1	91,700	2.3 x 10^{-4}	9.2 x 10^{-6}
	M3	99,600	.33	1 x $10^{[illegible]}$
	M2	8,800	3 x 10^{-5}	2.4 x 10^{-4}
Hantush II	M1, M2, M3	97,900	—	2.3 x $10^{[illegible]}$
Ave		92,500	3 x 10^{-4}	8 x $10^{[illegible]}$
Hantush w/ Storage in confining layer	M1	66,400	3 x 10^{-4}	—

(4)

$Q = 2126\ m^3/day$

$\Delta S_{m\beta} = 1.77\ (m)$

$\Delta S_{mx} = -9.6 \times 10^{-3}$

$z = -3$

(76) $\Delta S_{m\beta} = \frac{2.30\,Q}{2\pi\,kD} \therefore kD = \frac{2.3\,Q}{2\pi\,\Delta S_{m\beta}} = \frac{2.3(2126)}{2\pi\,(1.77)} = 440\ m^2/day$

(75) $\Delta S_{mx} = \frac{QSz}{4\pi(kD)^2} \therefore S = \frac{4\pi(T)^2\,\Delta S_{mx}}{Qz} = \frac{4\pi(440)^2 - 9.6\times10^{-3}}{2126(-3)} = .37$

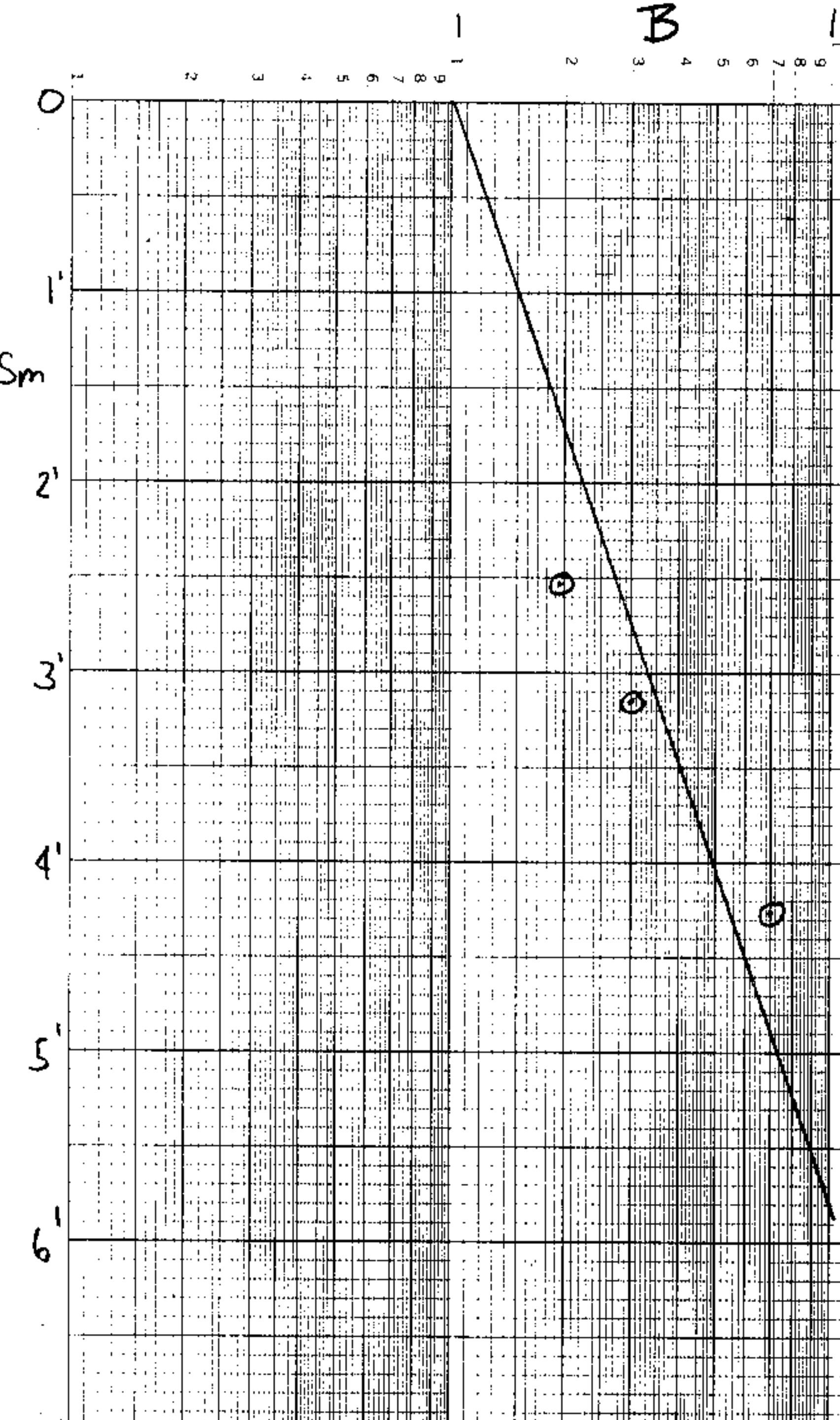
$T = 440\ m^2/day \times 80.52 = $ **35,400 gpd/ft**

$S = .37$?

Recharge Boundary is 300' from production well

Hantush Image Well Method   Harbour Ridge DRI

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.   46 6210



M1 $B = \frac{r_i}{r_r}$ $r_r = \sqrt{1^2 + 0^2} = 1$

$r_i = \sqrt{(2(-3) - 1)^2 + 0^2} = 7$

$B = 7$

M2 $r_i = \sqrt{(2(-3) - 3)^2 + 0} = 9$

$r_r = \sqrt{3^2 + 0} = 3$

$B = 3$

M3 $r_i = \sqrt{(2(-3) - 6.33)^2 + 0} = 12.33$

$r_r = \sqrt{6.33^2 + 0} = 6.33$

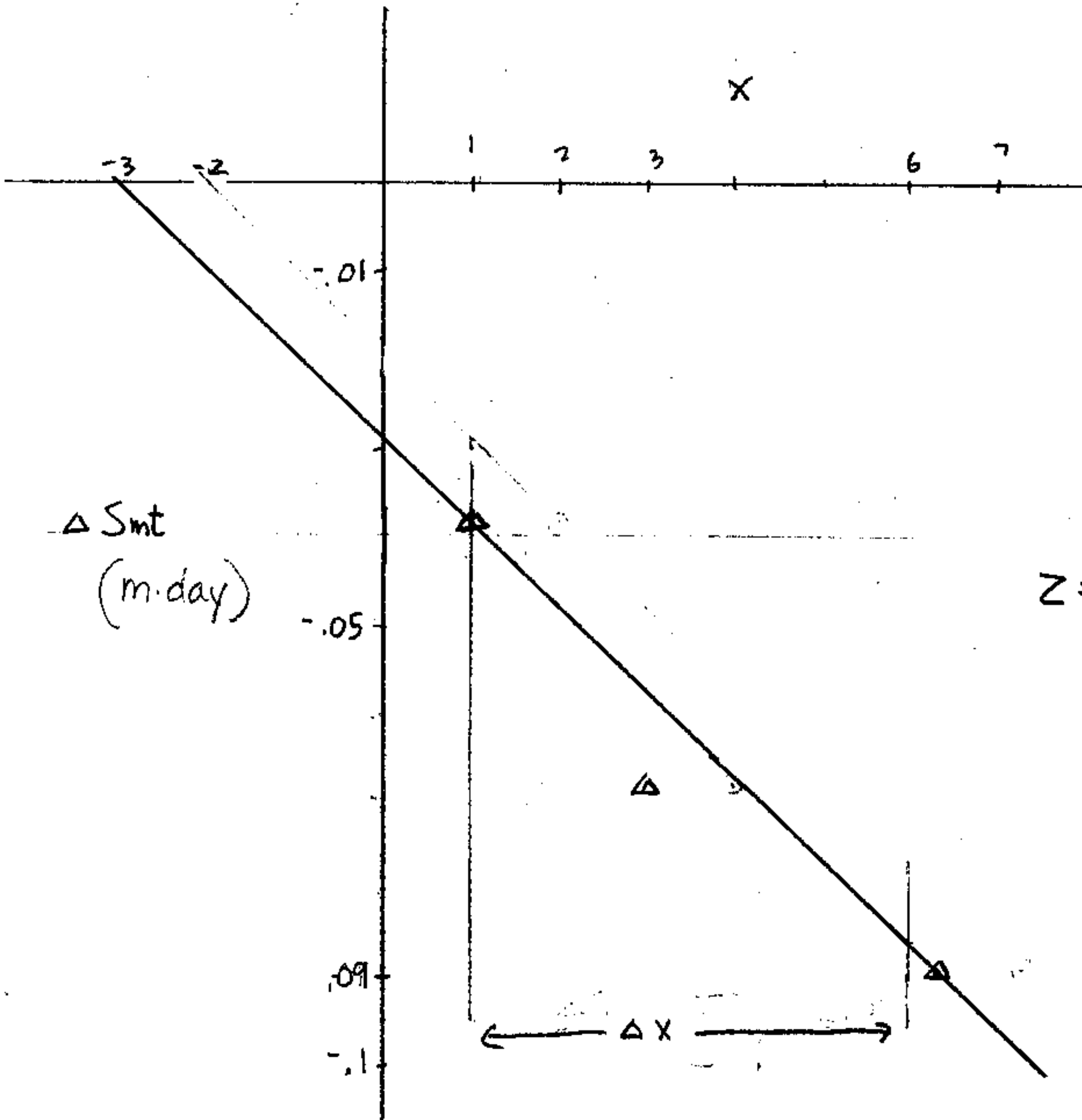
$B = 1.95$

	B	Sm'	Sm (m)
M1	7	4.27	1.30
M2	3	3.15	0.96
M3	1.95	2.51	0.77

$\Delta S_{mB} = 5.8' \times .3048 = 1.77$ (m)

Harbour Ridge DRI

Hantush Image Method



	X	ΔSmt
M1	1	-.038
M2	3	-.068
M3	6.3	-.089

$\Delta S_{mx} = {}^{-}9.6 \times 10^{-3}$

Z = -3 = effective distance to line of recharge

$$\frac{\Delta(\Delta S_{mt})}{\Delta x} \quad \frac{.086 - .038}{6 - 1} = -9.6 \times 10^{-3} = \Delta S_{mx}$$

m-1 Hantussh Image Method Harbour Ridge DR1

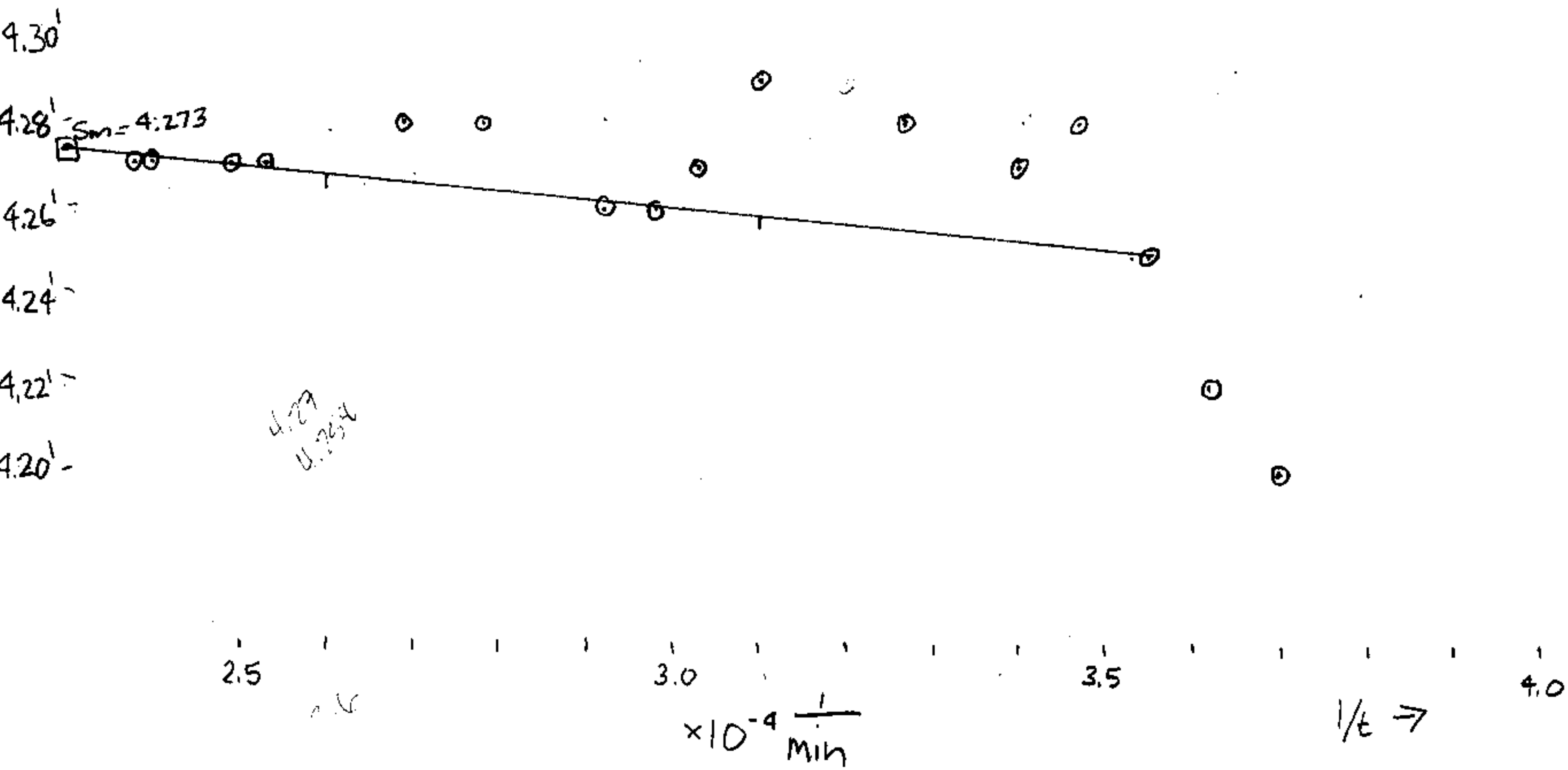
$r = 100'$

$\Delta s = .012$

$\Delta^1/_t = 5 \times 10^{-5}$

$\Delta S_{mt} = \frac{.012}{5 \times 10^{-5}} = 2.4 \times 10^{2}$

$$\frac{\Delta DD}{\Delta^1/t} = \frac{9 \times 10^{-3}}{5 \times 10^{-5}} = 1.8 \times 10^{-2} = \Delta S_{mt} = 3.8 \times 10^{-2} \text{ (m·day)}$$

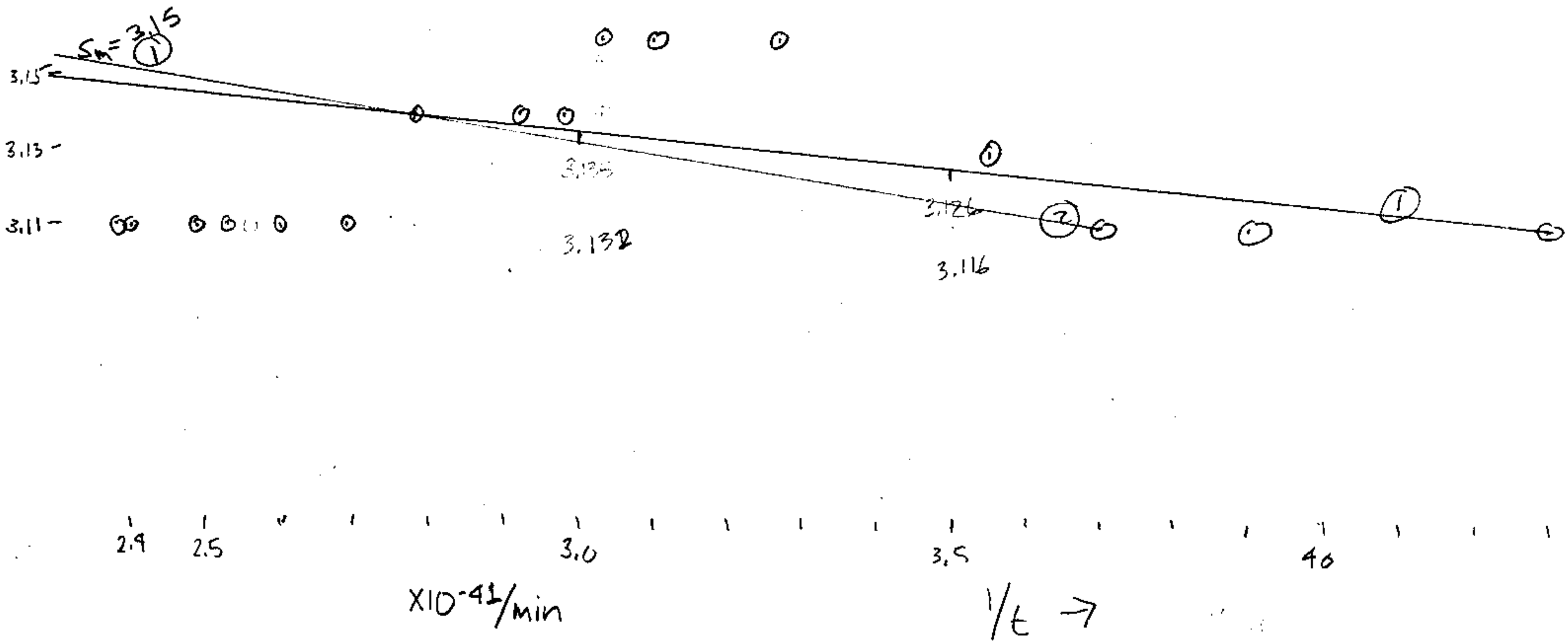


OBS. WELL #M-2   Harbour Ridge DRI   Hantush Image Method

r = 300

(1) $\frac{\Delta DD}{\Delta 1/t} = \frac{9\times10^{-3}}{5\times10^{-5}} = 1.8\times10^{2} = \Delta S_{mt}$

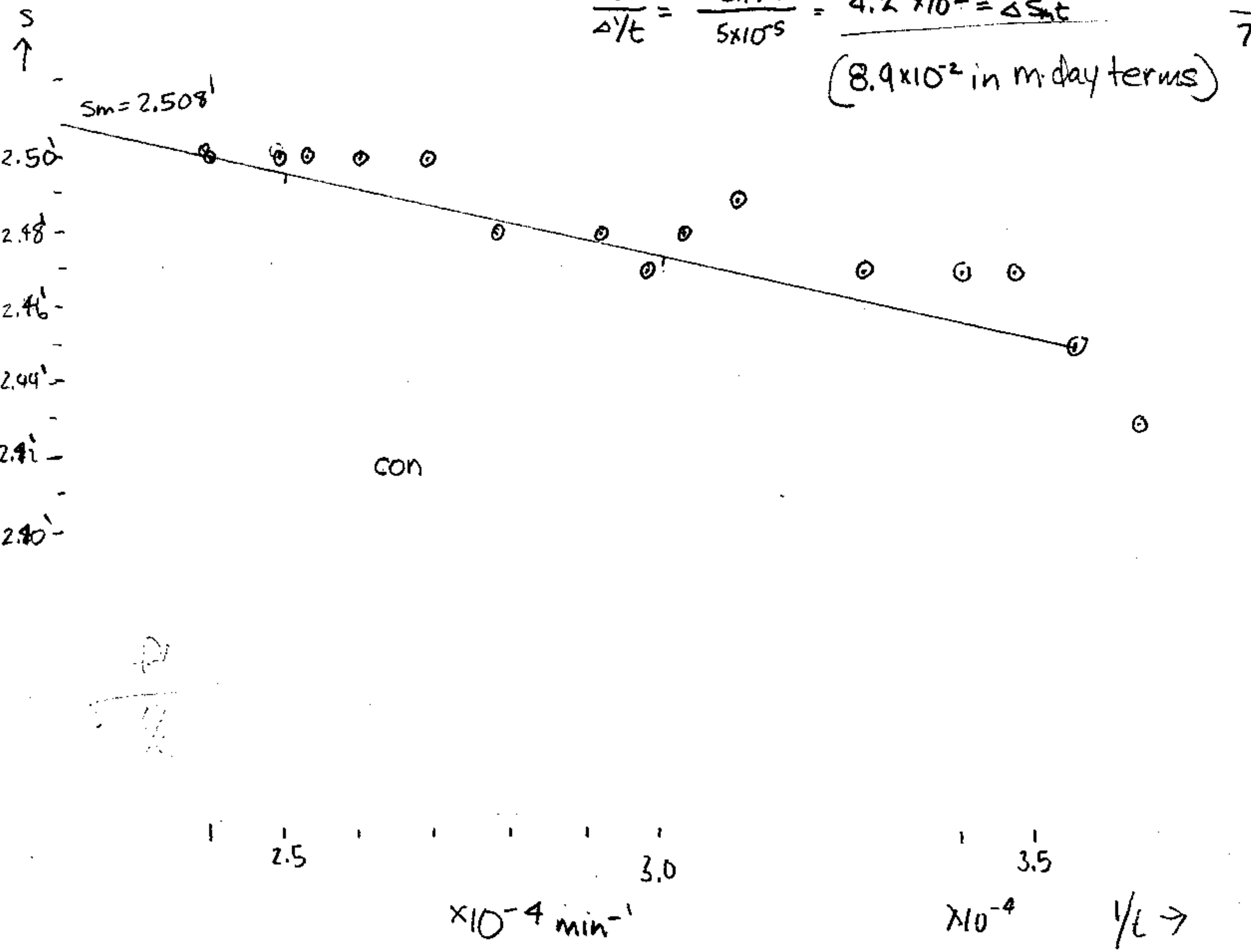
(2) $\frac{\Delta DD}{\Delta 1/t} = \frac{1.6\times10^{-2}}{5\times10^{-5}} = 320 = \Delta S_{mt} = 6.8\times10^{-2}$ (m·day)



OBS. WELL #M-3 Harbour Ridge DRI Hantush Image Method

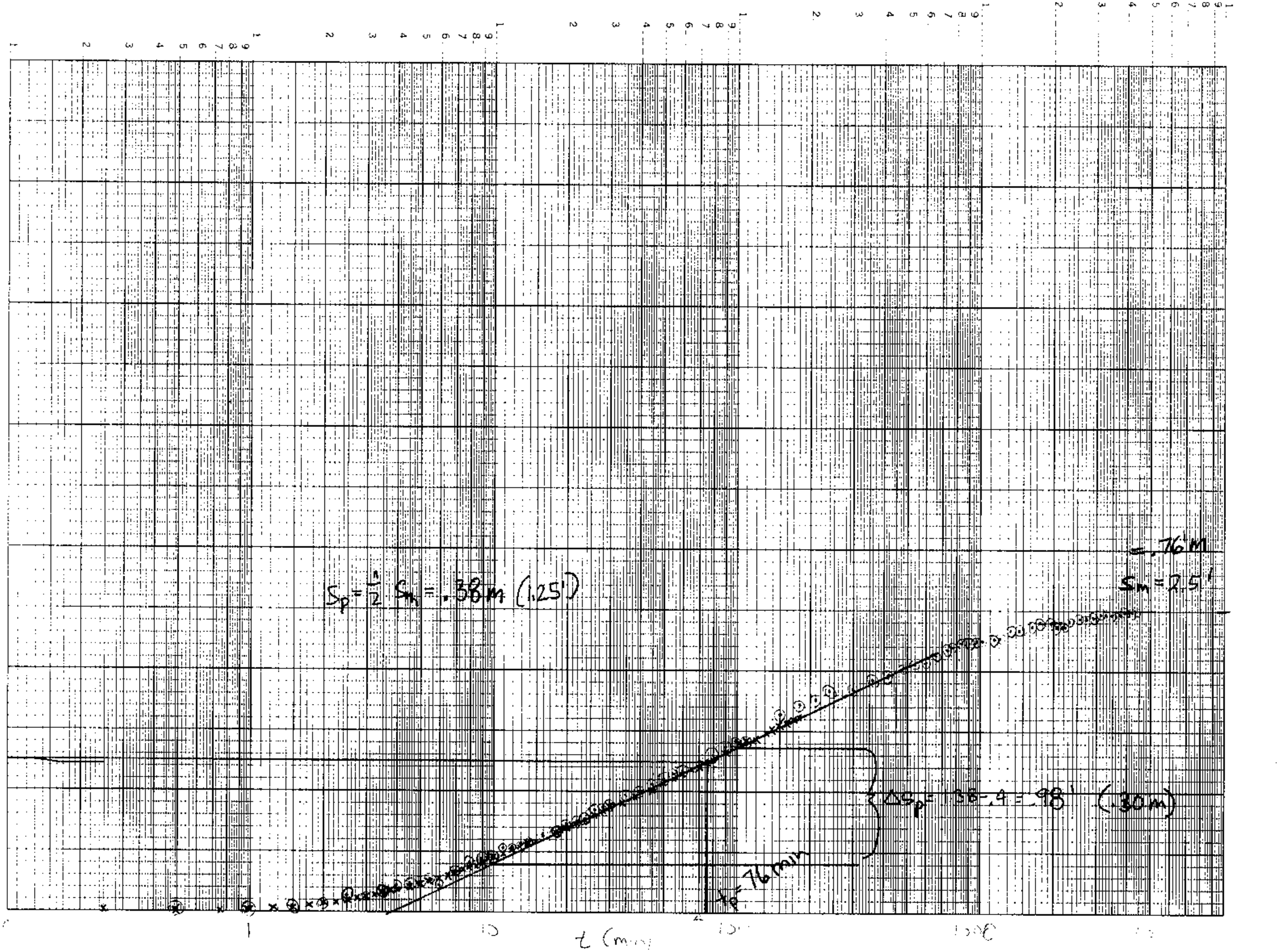
r=633

$$\frac{\Delta DD}{\Delta^1/t} = \frac{2.1\times10^{-2}}{5\times10^{-5}} = \frac{4.2\times10^{2} = \Delta S_{mt}}{(8.9\times10^{-2} \text{ in m·day terms})} \qquad \frac{6.4\times10^{-2}(m)}{7.2\times10^{-2}(day^{-1})} = 8.9\times10^{-2}$$



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



$S_m = 4.28'$

$r = 100' = 30.5\,m'$

$Q = 2126\ m^3/day$

$S_p = \frac{1}{2}(S_m) = 2.14' \times .3048 = .65\,m$

$t_p = 9.5\ min \times 6.944\times10^{-4} = 6.6\times10^{-3}\ days$

$\Delta S_p = 3.18 - 2.16 = 1.02\ feet \times .3048 = .31\,m$

(33) $2.30 \frac{S_p}{\Delta S_p} = e^{r/L} K_0(r/L)$

$2.30 \frac{.65}{.31} = 2.30(2.097) = 4.82 = e^{r/L} K_0(r/L)$

from Annex III $X = 0.009 = r/L$

$r = 30.5 \quad \therefore \quad L = \frac{30.5}{.009} = 3389 \cong$ **3300 m**

(31) $\Delta S_p = \frac{2.30\,Q}{4\pi kD} e^{-r/L} \qquad e^{-r/L} = .991$

$kD = \frac{2.30\,Q}{4\pi\,\Delta S_p} e^{-r/L} = \frac{2.3(2126)}{4\pi(.31)}(.991) = 1244\ m^2/day$

$1244\ m^2/day \times 80.52 =$ **100,160 gpd/ft**

(30) $\frac{r}{2L} = \frac{r^2 S}{4kDt_p}$

$S = \frac{4\,kD\,t_p\,r}{r^2\,2L} = \frac{4(1244)(6.6\times10^{-3})(30.5)}{(30.5)^2\ 2\ (3300)} =$ **1.6×10^{-4}**

$c = L^2/kD = (3300)^2/1244 =$ **8754 days**

~~Leakance (gpd/ft³) = 1/c = 1.1×10⁻⁴~~

Leakance = $1/c \times 7.48\ gpd/ft^3 =$ **8.5×10^{-4}**

Check on Hantush I M1

at t = 0.1

(28) $u = \frac{r^2 S}{4kDt} = \frac{(30.5)^2 (1.6\times10^{-4})}{4(1244).1} = 2.99\times10^{-4}$

$W(u, r/L) = 7.5$

(27) $s = \frac{Q}{4\pi kD} W(u, r/L) = \frac{2126 (7.5)}{4\pi (1244)} = 1.02\,m \times 3.28 = 3.34'$

✓ checks

Hantush I | M_2 r=300 | Harbour Ridge

$S_m = 3.15'$

$S_p = 1.575 \times .3048 = .48$ m

$t_p = 30$ min $\times 6.944 \times 10^{-4} = 2.083 \times 10^{-2}$ days

$\Delta s_p = \Delta s$ per log cycle $= 2.15 - 1.05 = 1.1' \times .3048 = .335$ m

eq 33: $2.3\ s_p/\Delta s_p = e^{r/L} K_0(r/L)$

$(2.3)(.48/.335) = 3.30 = e^{r/L} K_0(r/L)$

for $e^{r/L} K_0(r/L) = 3.3$, $x = .048 = r/L$

$r = 91.44$ m $\Rightarrow L =$ **1905 m**

$r/L = .048$

$e^{-.048} = .953$

$\Delta s_p = .335$
$Q = 2126$
$e^{-r/L} = .953$

eq 31: $\Delta s_p = 2.30Q/4\pi KD\ e^{-r/L}$

$KD = (2.3)(2126)(.953)/4\pi(.335) = 1107$ m²/day

$(1107)(80.52) =$ **89,136 gpd/ft = T**

eq. 30: $r/2L = r^2S/4KDt_p \Rightarrow S = \frac{4KD(t_p)(r)}{r^2 2L} = \frac{4KDt_p}{r2L}$

$S = \frac{(4)(1107)(2.083 \times 10^{-2})}{(91.44)(2)(1905)} =$ **$2.65 \times 10^{-4} = S$**

$c = L^2/KD = (1905)^2/1107 = 3278$ days

Leakance = ~~$1/c = 3.05 \times 10^{-4}$~~

$= 1/c$ * 7.48 gpd/ft³ = **2.3×10^{-3}**

* I did not check this

Hantush I	M-3	Harbour Ridge

$S_m = 2.5'$

$S_p = 1.25' \times .3048 = .381\ m$

$t_p = 75\ min = 5.208 \times 10^{-2}$ days

$\Delta S_p = 1.0' = .3048\ m$

$r = 633' = 193\ m$

$Q = 2126\ m^3/day$

eq 33: $(2.3)(.381)/.3048 = 2.875 = e^{r/L} K_0(r/L)$

for $e^{r/L} K_0(r/L) = 2.875$, $X = .079 = r/L$ $(r = 193\ m)$

$L = 193/.079 = \boxed{2443\ m}$

$r/L = .079 \Rightarrow e^{-r/L} = .924$

eq 31: $KD = (2.30)(2126)(.924)/4\pi(.3048) = \left[\frac{2.3\ Q}{4\pi \Delta S_p}(e^{-r/L})\right]$

$KD = 1180\ m^2/day = \boxed{94{,}982\ gpd/ft = T}$

eq 30: $S = 4KDt_p / r2L$

$= (4)(1180)(5.208 \times 10^{-2}) / (193)(2)(2443)$

$= \boxed{2.61 \times 10^{-4} = S}$

$c = L^2/KD = (2443)^2/1180 = 5058$ days

Leakance = ~~$1/c = 1.98 \times 10^{-4}$~~

$= 1/c \times 7.48 \frac{gpd}{ft^3} = 1.5 \times 10^{-3}$

* No checkee

Hantush I	M3 Harbour Ridge	r=633' (193m)

$S_m = 2.5$ feet (.76m)
$S_p = 1.25$ feet (.38m)
$t_p = 76$ min (
$\Delta S_p = .98$ (ft) (.3m)

33) $2.30\ S_p/\Delta S_p = e^{r/L} K_o(r/L)$

$2.3\ .38/.3 = e^{r/L} K_o(r/L)$

$2.9 = e^{r/L} K_o(r/L)$

$r/L = .076 \qquad L = r/.076 = 2539$ m

31) $\Delta s_p = \frac{2.3Q}{4\pi kD} e^{-r/L} \qquad kd = \frac{2.3Q}{4\pi \Delta S_p} e^{-r/L} \qquad Q = 2126 \quad e^{-r/L} = .927$

$T = \frac{2.3(2126)}{4\pi(.3)} .927 = 1202$ m²/day × 80.52 = **96,800 gpd/ft**

30) $S = \frac{\cancel{r}\ 4kDt_p}{2Lr^{\cancel{2}}} = \frac{4(1202)(.053)}{2(2539)193} =$ **$2.6\times10^{-4} = S$**

$C = L^2/T = 2539^2/1202 = 5363$

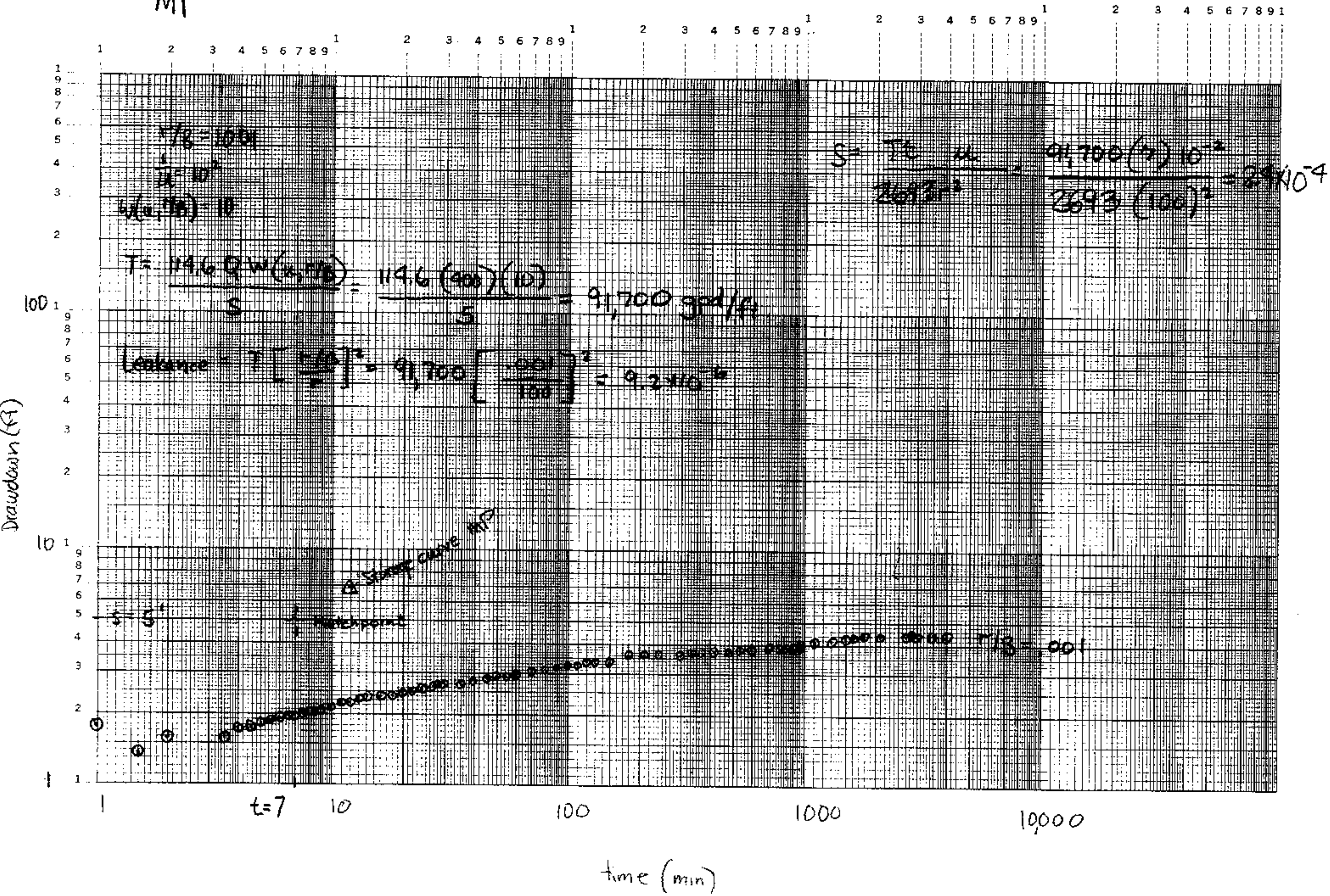
~~Leakance = 6.6×10^{-3} gpd/ft³~~

Leakance = $1/c \times 7.48$ gpd/ft³ = **1.4×10^{-3}**

3.281 ft/m

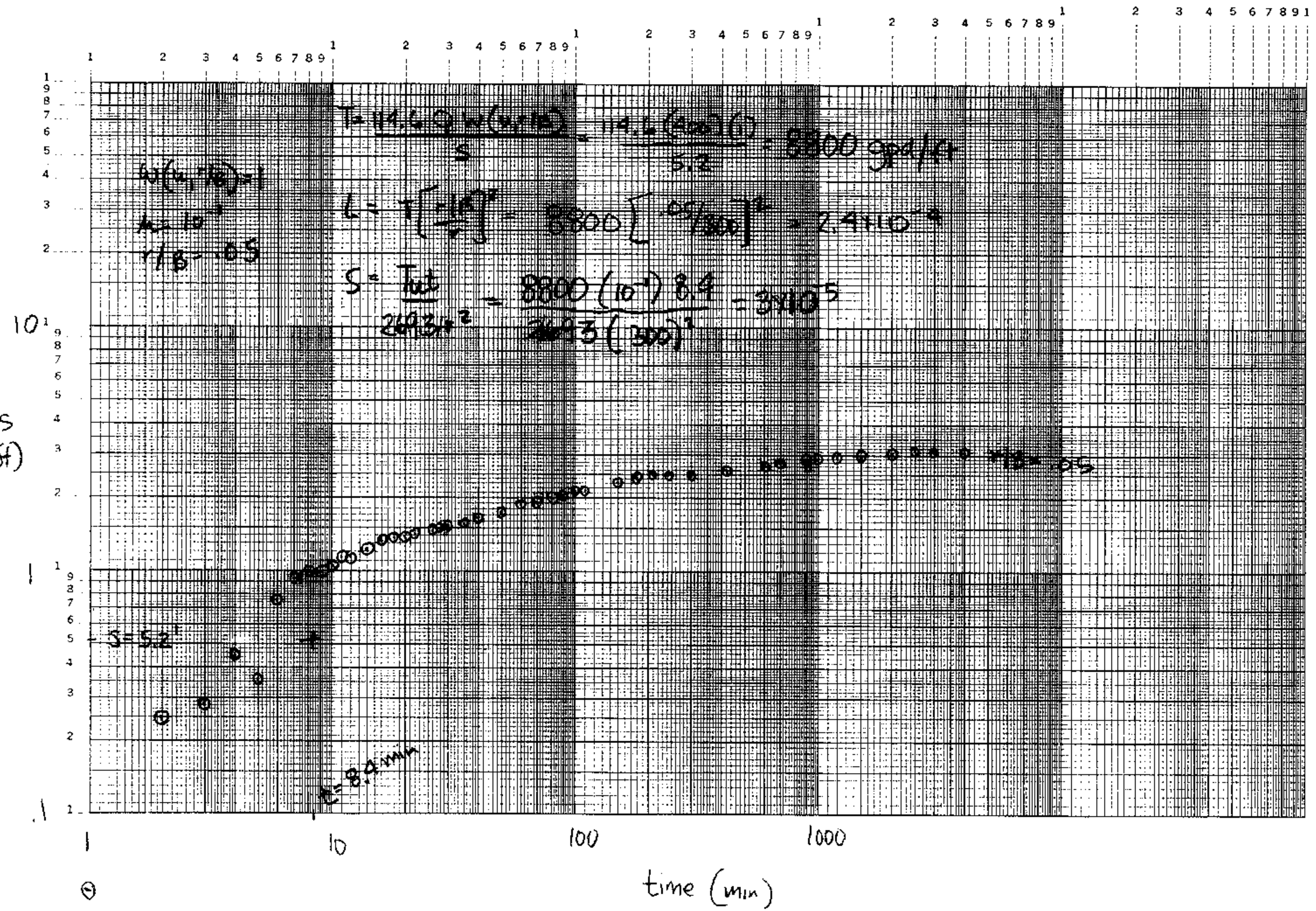
Walton's Method

M1



46 7522

M2 Harbour Ridge DR1



Harbour Ridge   Well M.1

Hantush Leaky Artesian Aquifer w/ Storage in the Confining Layer

$u = 10^{-2}$ $Q = 400$ gpm   p284 Fetter

$W(u,\beta) = 10$ $r = 100'$ p220 Walton

$t = 12$ min $\beta = 5.0 \times 10^{-2}$

$s = 6.9$ feet $b' = 10$ feet

$T = 114.6\, Q\, W(u,\beta) / s$

$= 114.6\,(400)\,10 / 6.9 = \boxed{66{,}435 \text{ gpd/ft}}$

$S' = Tut / 2693 r^2$

$= 66{,}435\,(.01)(12) / 2693\,(100)^2$

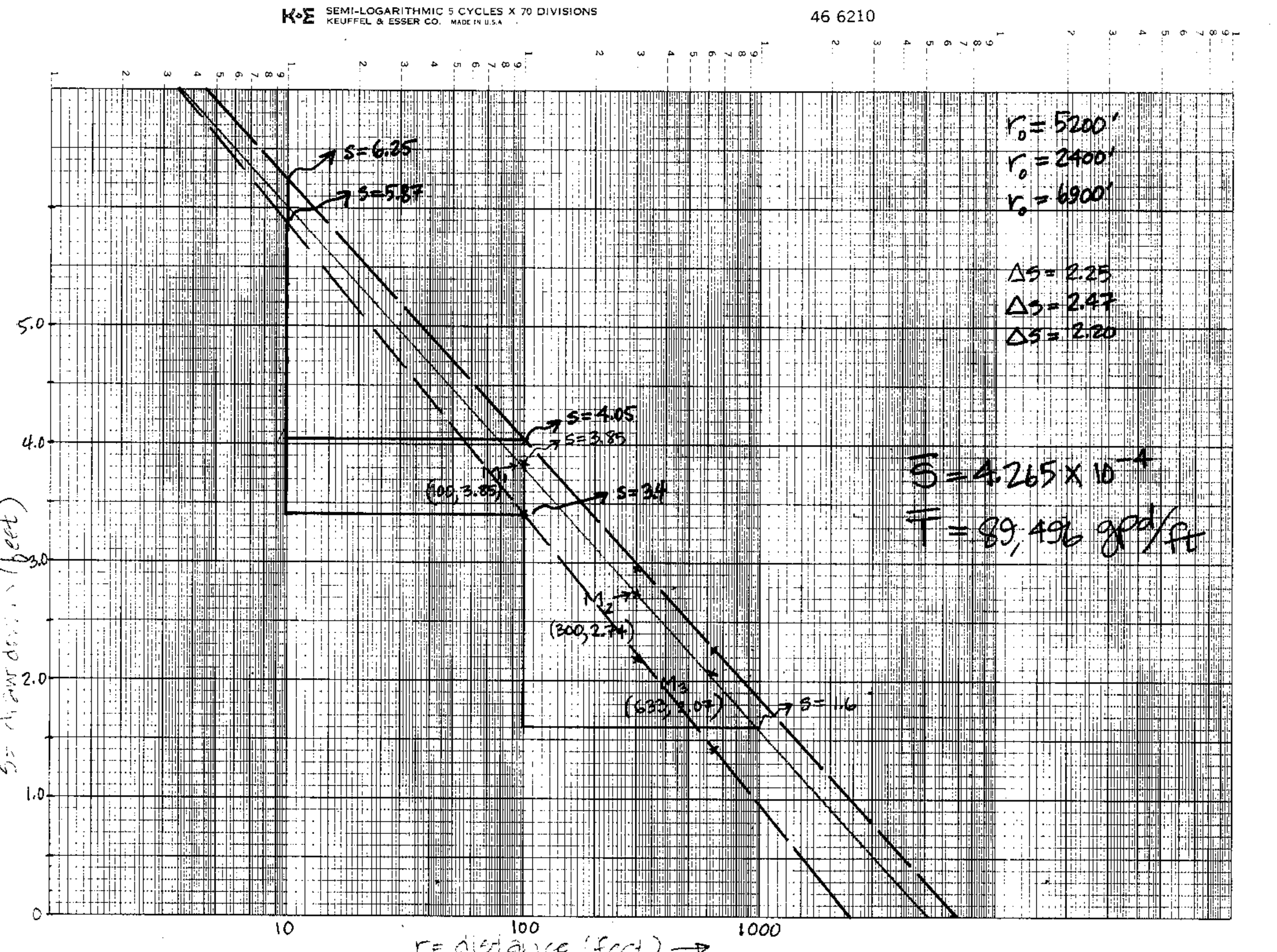
$= \boxed{3 \times 10^{-4}}$

$K' = 16 \beta^2 T b' S / r^2 S'$

$= 16\,(.05)^2\, 66{,}435\,(10)(.0003) / 100^2\,(.0003)$

$K' = 2.66\; S/S'$ gpd/ft²

DISTANCE-DRAWDOWN FOR t = 600 min t=120 min t=1200 min HARBOUR RIDGE



$\Delta s = 2.25 \quad r_0 = 5200 \quad t = 600$

$$T = \frac{(528)(390)}{2.25} = 91{,}520 \text{ gpd/ft}$$

$$S = \frac{(91520)(600)}{(4790)(5200)^2} = 4.24 \times 10^{-4}$$

$\Delta s = 2.20 \quad r_0 = 6900 \quad t = 1200$

$$T = \frac{(528)(390)}{2.20} = 93{,}600 \text{ gpd/ft}$$

$$S = \frac{(93{,}600)(1200)}{(4790)(6900)^2} = 4.93 \times 10^{-4}$$

$\Delta s = 2.47 \quad r_0 = 2400 \quad t = 120$

$$T = \frac{(528)(390)}{2.47} = 83{,}368 \text{ gpd/ft}$$

$$S = \frac{(83{,}368)(120)}{(4790)(2400)^2} = 3.63 \times 10^{-4}$$

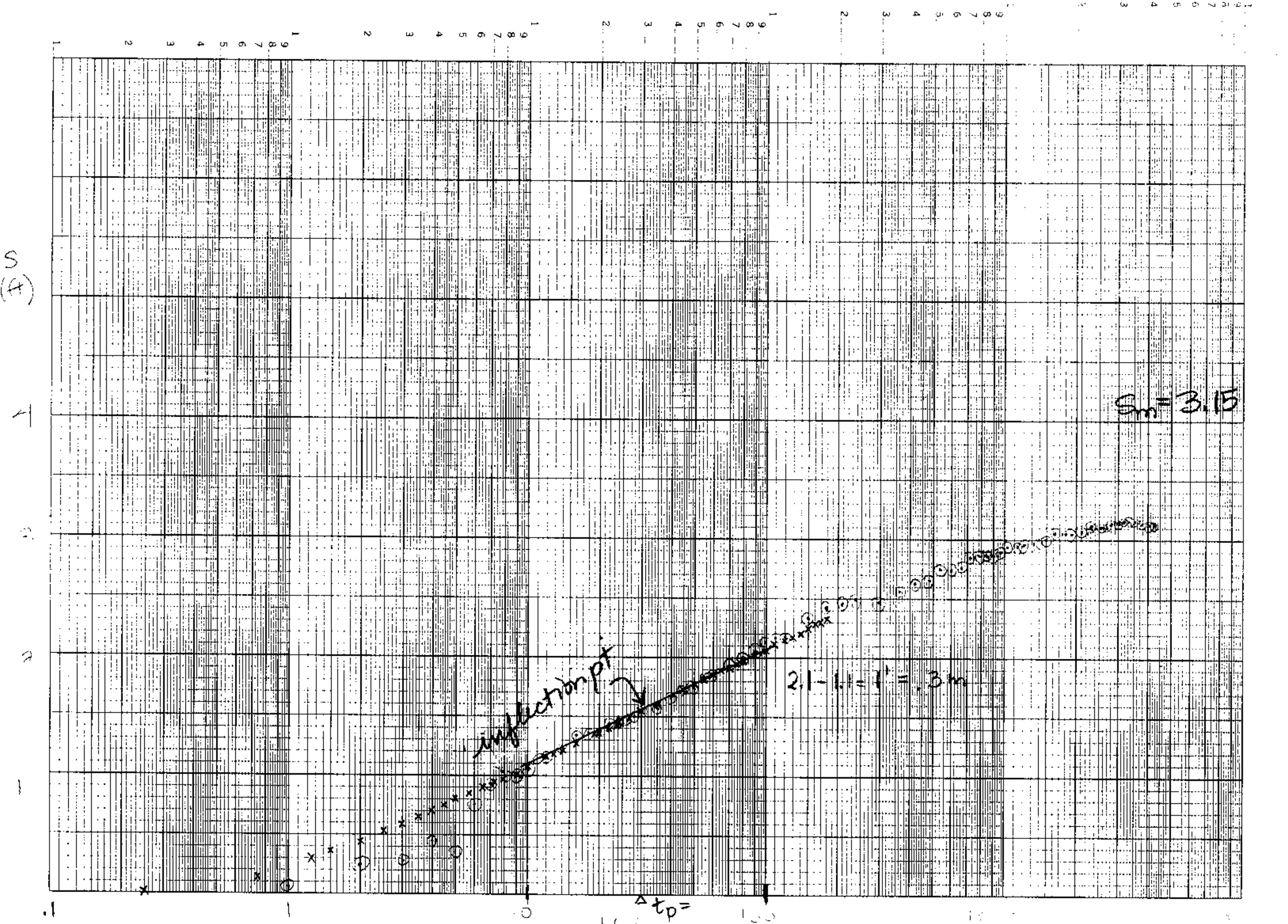
$$\overline{S} = 4.265 \times 10^{-4}$$

$$\overline{T} = 89{,}496 \text{ gpd/ft}$$

M-2

K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



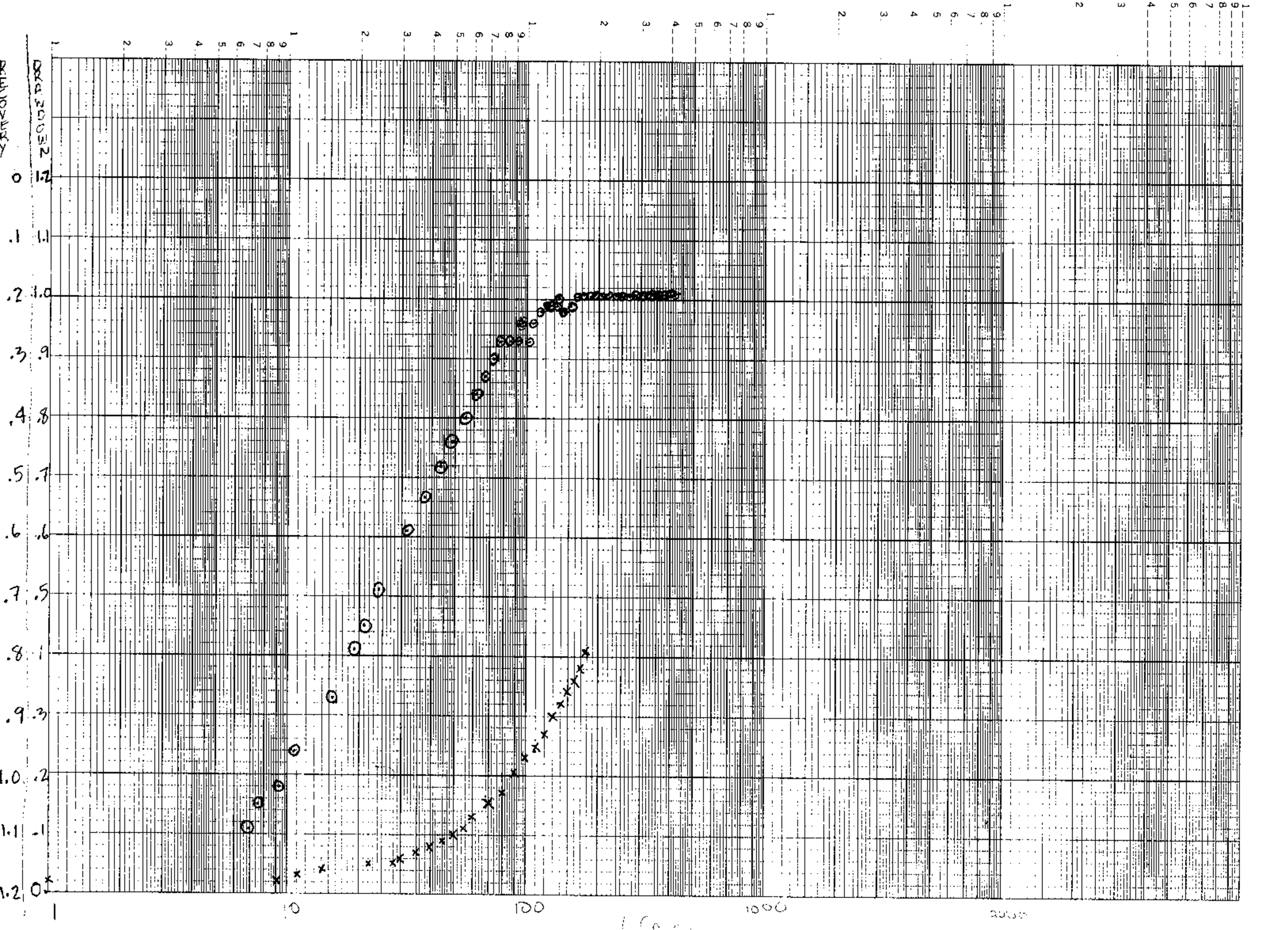
Pumping TEST

Water Well Harbour

⊙ drawdown
x recovery

K•Σ SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



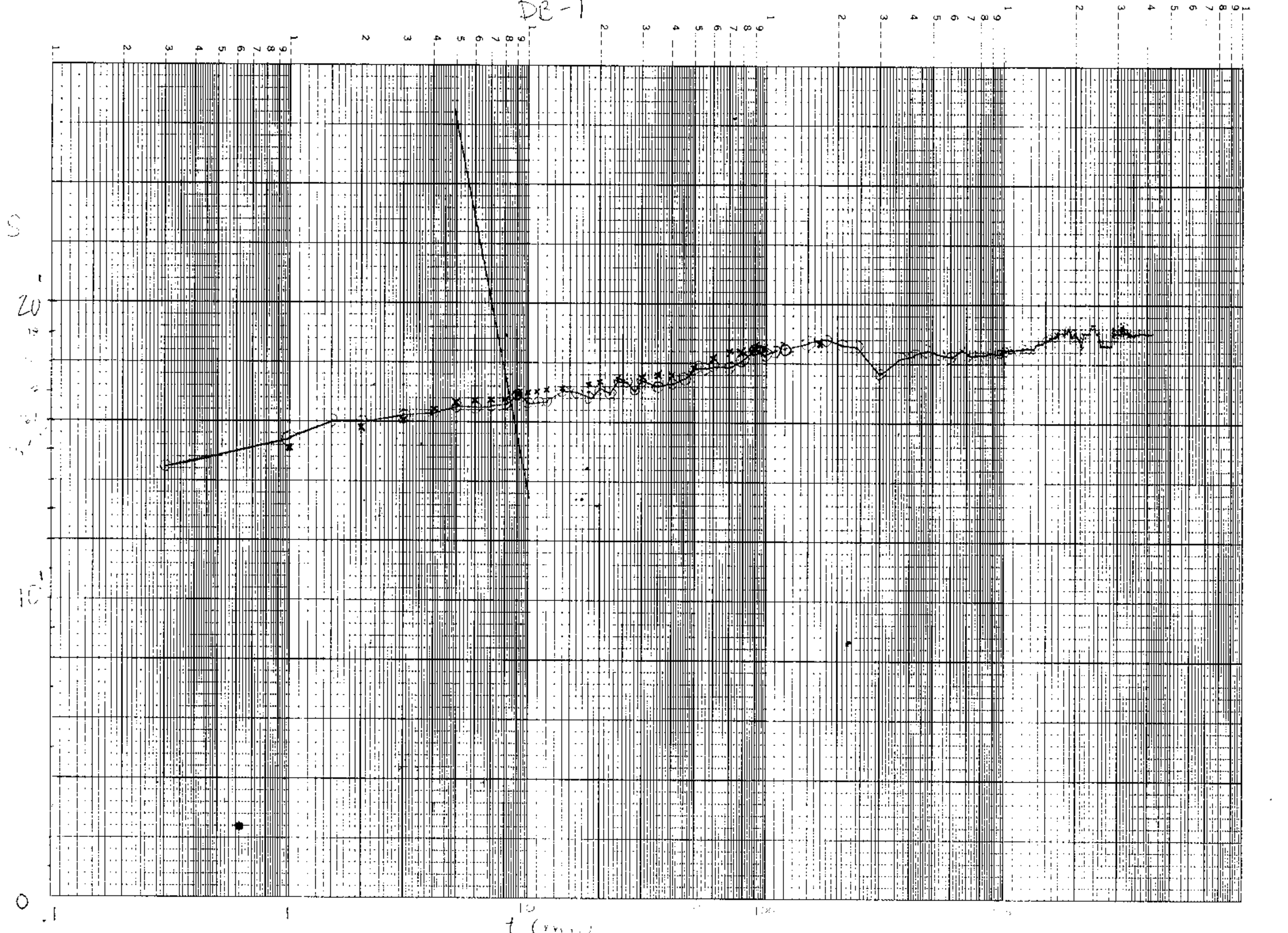
Pumping TEST

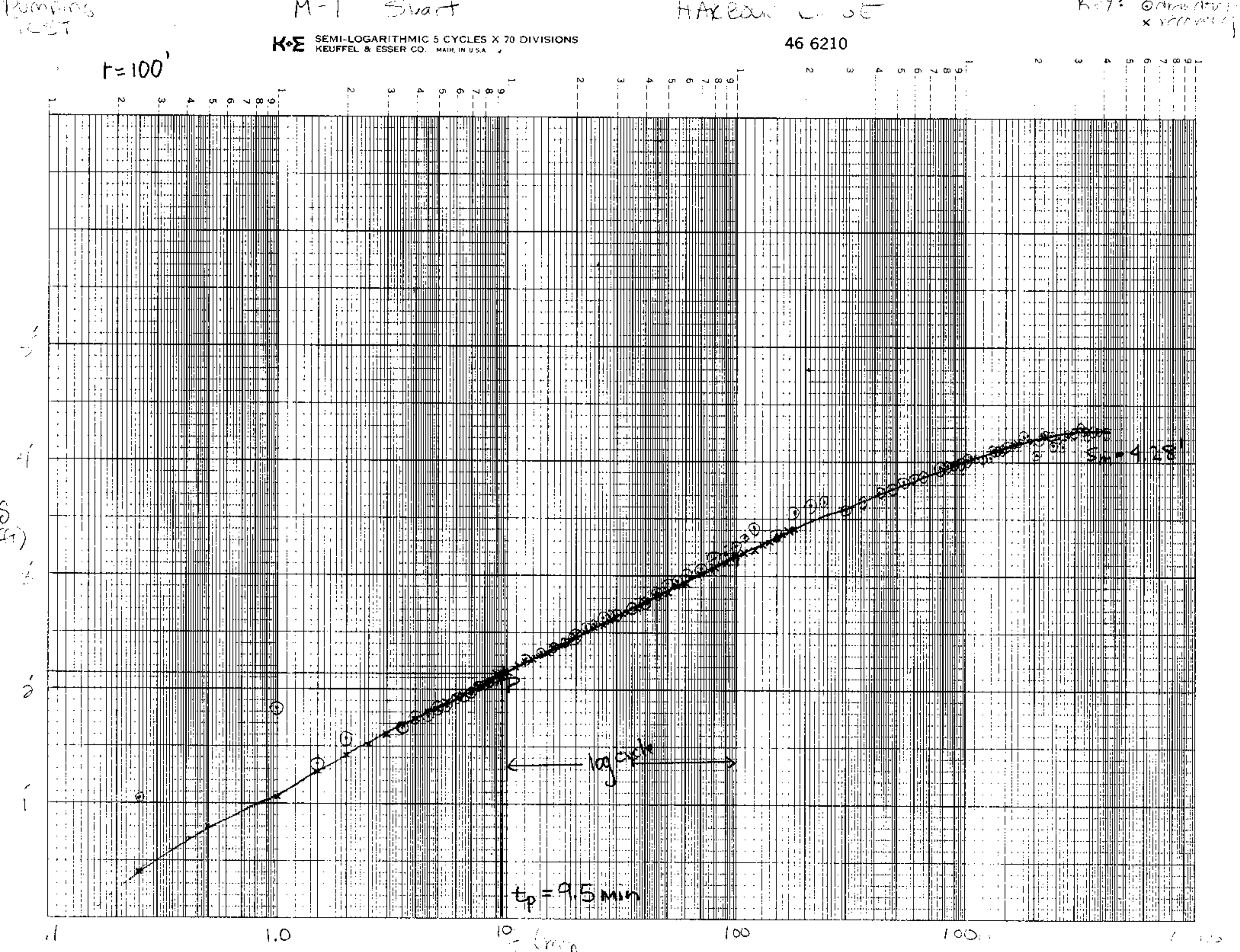
TEST PRODUCTION WELL - HARBOUR RIDGE 12-2-82

K·E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210

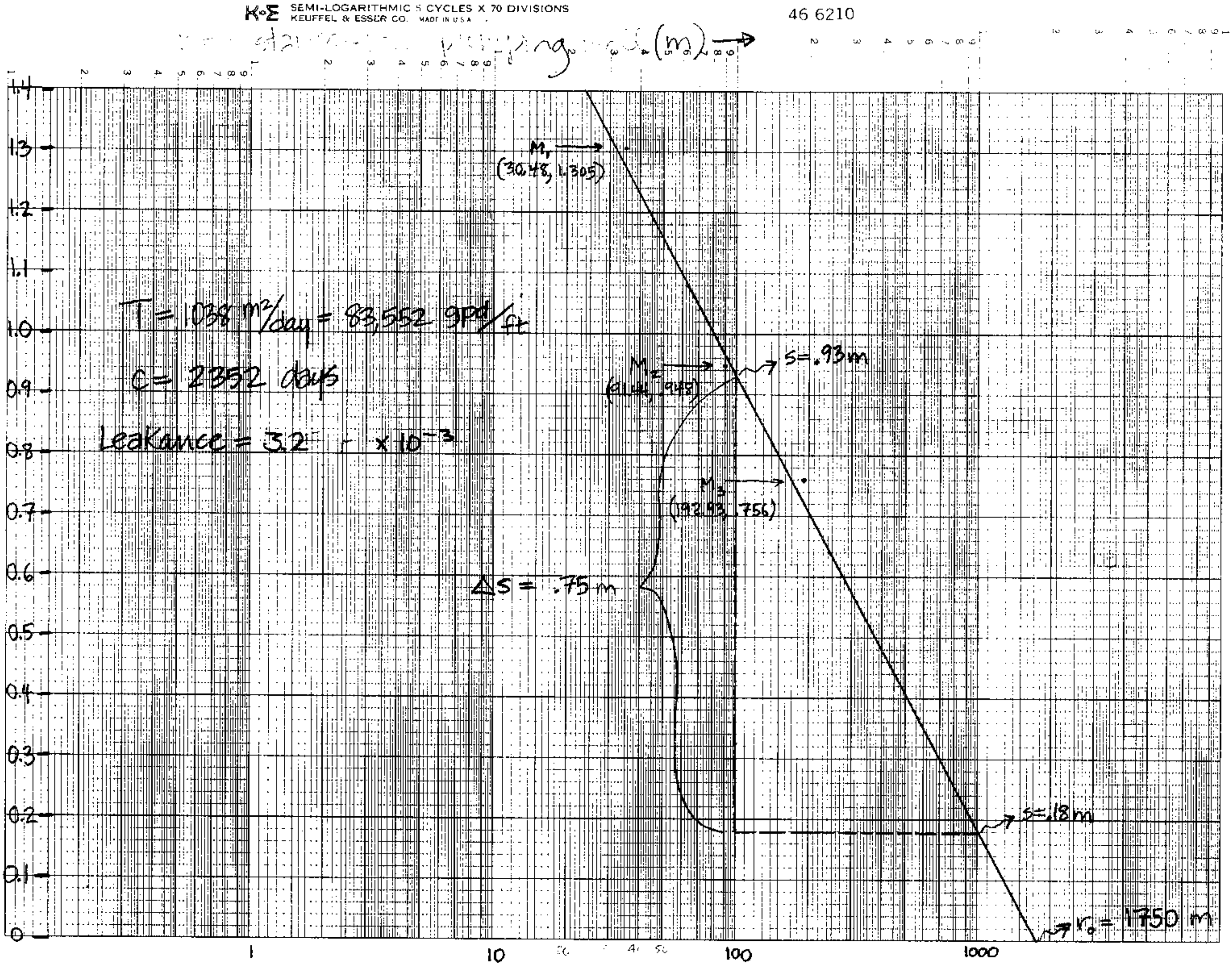
DB-1





Pumping Test
M-1 Start
K&E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6210
r = 100'
S_m = 4.28'
log cycle
t_p = 9.5 min
.1
1.0
10
100
1000

HARBOUR RIDGE



$Q = 390$ gpm $=$ 2126 m^3/day $\Delta s = .75 m$ $r_0 = 1750 m$

$$\Delta s = 2.3Q / 2\pi KD \Longrightarrow KD = 2.3Q / 2\pi \Delta s$$

$$KD = \frac{(2.3)(2126)}{2\pi(.75)} = 1037.65 \ m^2/day = \text{transmissivity}$$

$$= 83,552 \ gpd/ft$$

$$C = \frac{(r_0/1.12)^2}{KD}$$

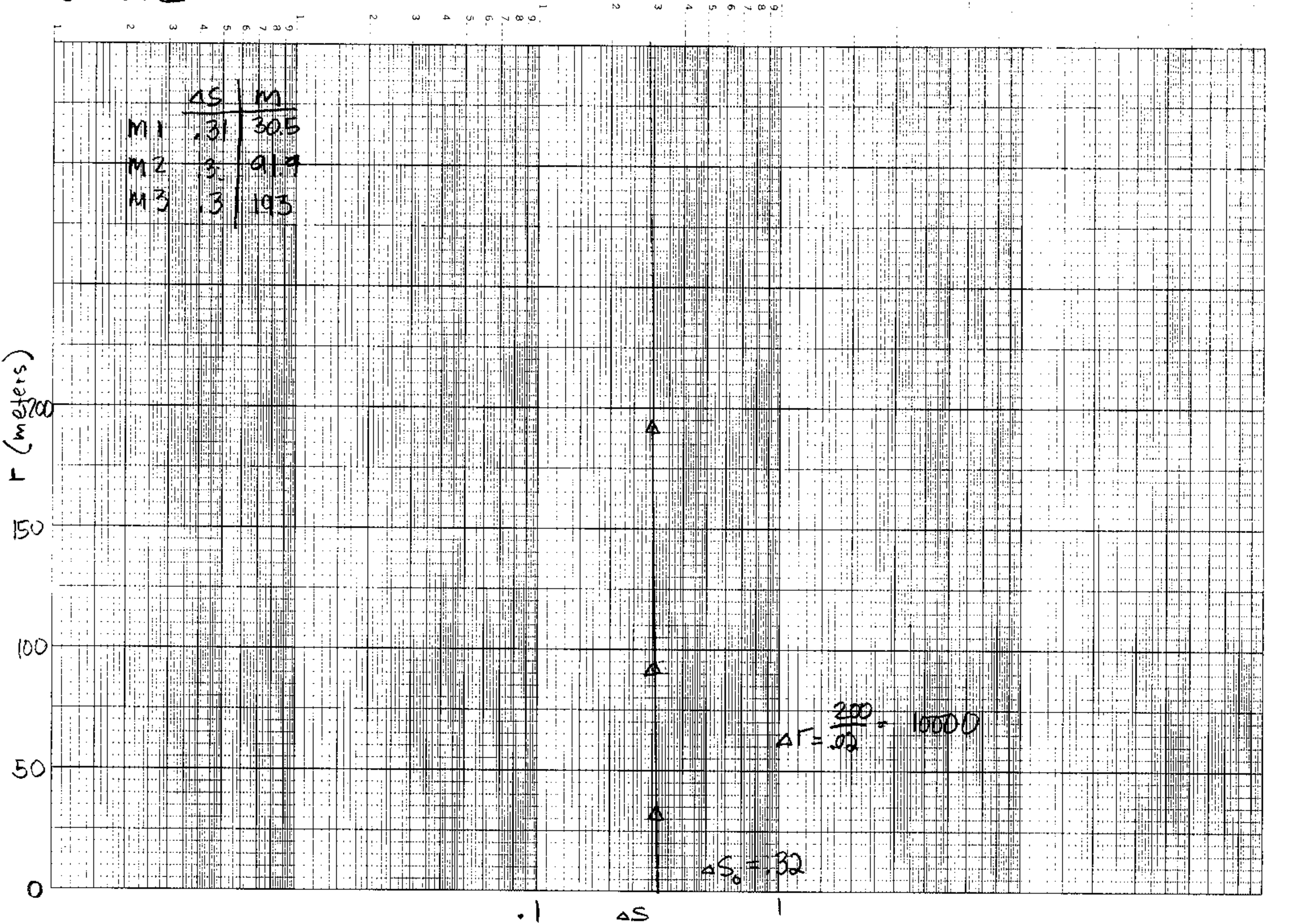
$$C = \frac{(1750/1.12)^2}{1038} = 2352 \text{ days}$$

$$\text{Leakance} = 1/C \times 7.48 = 3.2 \times 10^{-3}$$

Hantush II

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



Hantush II

$L = 1/2.3\ \Delta r = 1/2.3 \times 10{,}000 = 4348$

$c = L^2/kD \qquad kD = 2.3\ Q/4\pi\ (\Delta s)_0$

$T = 2.3\ (2126)/4\pi(.32) = 1216 = 97{,}900\ gpd/ft^2$

$C = 4348^2/1216 = 15547$

$\text{Leakance} = 1/c \times 7.48 = 4.8 \times 10^{-4}\ gpd/ft^3$

	r	r/L	K_0	Sp	tp	Sm
M1	30.5	.007	off (5)			
M2	91.4	.021	3.98	.55		
M3	193	.044	3.241	.45	120 min	

(29) $s_p = Q/4\pi kD \times K_0(\frac{r}{L})$ -

M1 $s_p = 2126/4\pi(1216) \times 5$

M2 $s_p = \frac{2126 \times 3.98}{4\pi(1216)} = .55$

M3 $s_p = \frac{2126 \times 3.24}{4\pi(1216)} = .45$