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1990 GROUNDWATER FLOW RATE AND DIRECTION DETERMINATION REPORT FOR THE INDUSTRIAL WASTEWATER TREATMENT PLANT, NAVAL AIR STATION, PENSACOLA, FLORIDA

July 1991

Prepared for:

DEPARTMENT OF THE NAVY
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive, P.O. Box 10068
Charleston, South Carolina 29411-0068

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ecology and environment, inc.
316 SOUTH BAYLEN STREET, PENSACOLA, FLORIDA 32501, TEL. (904)
International Specialists in the Environment

recycled paper

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1. INTRODUCTION

The purpose of this report is to present the procedures, methodologies, and results of the Annual Groundwater Plow Rate and Direction Determination study conducted by Ecology and Environment, Inc. (E & E) at the Industrial Wastewater Treatment Plant (IWTP), Naval Air Station (NAS) Pensacola. This report satisfies the requirements of *40* CFR 264.99(e) for Resource Compensation and Recovery Act (RCRA) permitted facilities and has been prepared by E 6 E for the Southern Division, U.S. Navy, Naval Facilities Engineering Command, under Contract No. N62467-88-C-0200. The report contains a summary and analysis of water level measurements and aquifer testing conducted by E 6 E during the period March 23, 1990 through March 27, 1990,

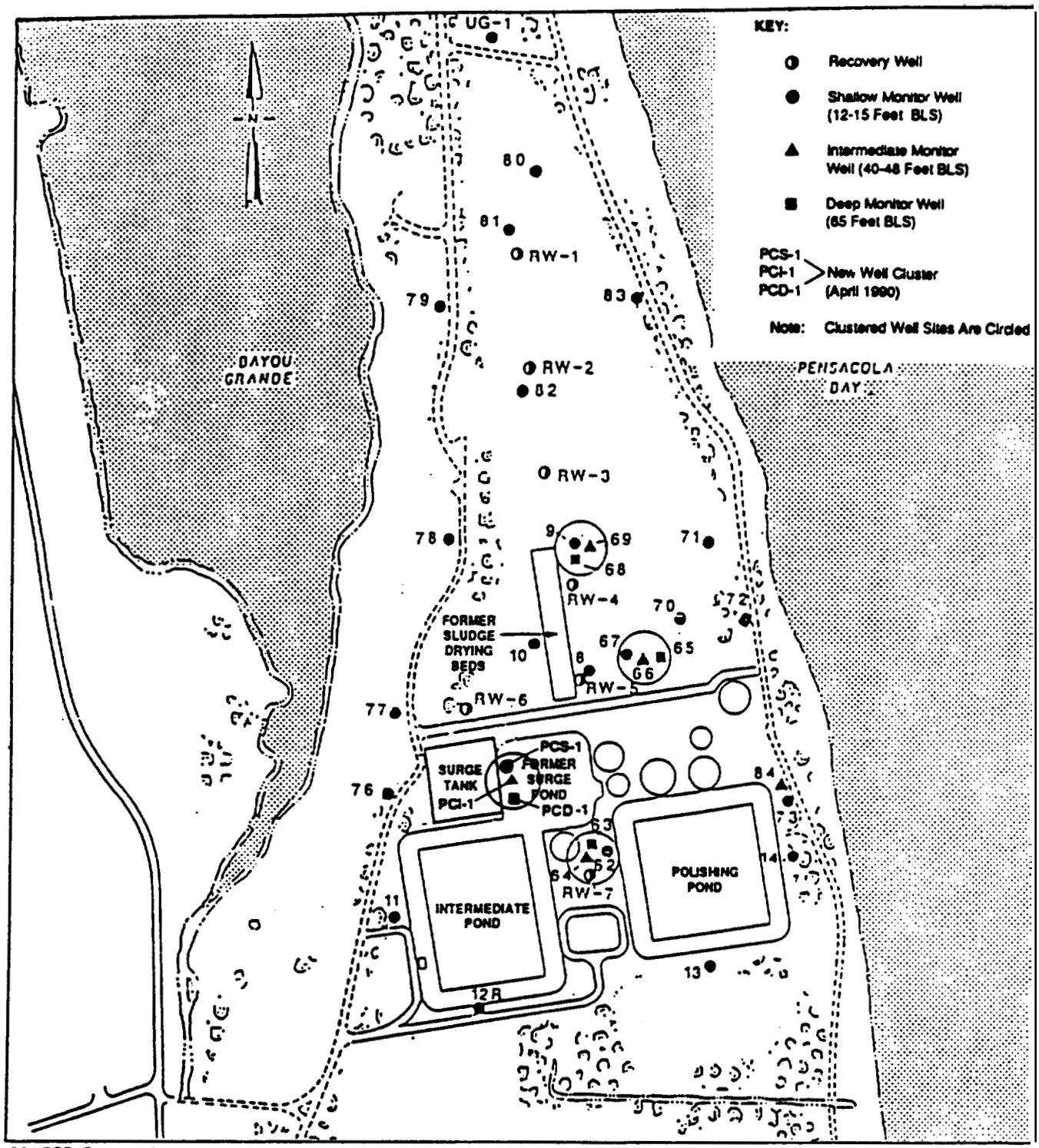
2. WATER LEVELS AND GROUNDWATER FLOW

21 HYDROGEOLOGY

The hydrogeologic sequence underlying the Industrial Wastewater Treatment Plant (IWTP) is, in descending order, the Sand-and-Gravel Aquifer, the Pensacola Clay, and the Floridan Aquifer. Because of its overall thickness (approximately 380 feet) and the fact that it is the main source of potable water in the Pensacola area, the Sand-and-Gravel Aquifer is the most important hydrogeologic unit at NAS Pensacola.

In the vicinity of the IWTP, the upper portion of the Sand-and-Gravel Aquifer is comprised of, in descending order, a shallov surficial zone, a low permeability zone, and a main producing zone. The surficial zone extends from land surface to depth of 40 feet, and is composed of fine- to medium-grained quartz sand. The low permeability zone is approximately 15 feet thick, and is composed of a blue-gray, plastic clay with some shell fragments. The low permeability zone functions as confining/semi-confining unit and retards the exchange of groundwater between the surficial zone and the underlying main producing zone. The main producing zone extends from the base of the low permeability zone to depth of approximately 380 feet, and is composed of a mosaic of sands, gravels, and discontinuous clay lenses. At the IWTP, the shallov monitoring wells (15 feet deep) are open to the uppermost surficial zone, the intermediate monitoring wells (40 feet deep) are open to the lowermost surficial zone, and the deep monitoring wells (65 feet deep) are open to uppermost main producing zone. Por the remainder of this report, these monitored depth intervals will be referred to as the shallow zone, intermediate zone, and deep zone.

As part of the well sampling activities during the March 1990, groundwater sampling event, water levels were measured in all the IWTP monitoring wells from which a sample vas collected. Figure 2-1 shovs



SOURCE: Geraghty & Miller, Inc. 1988

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Figure 2-1
LOCATIONS OF MONITORING AND RECOVERY WELLS AT NAS PENSACOLA WASTEWATER TREATMENT PLANT

the locations of the monitoring wells used for water level measurements. The results of the vater level measurements are given in Table 2-1. The following sections discuss and interpret the collected water level data and present groundwater flov directions for each of the monitored zones.

It should be noted that the recovery wells at the IWTP are open only to the shallov and intermediate zones. During the water level survey, only recovery well RU-7 was actively pumping and the discharge rate was very low (approximately 1 gallon per minute).

2.2 SHALLOW ZONE

Figure 2-2 shows the vater level elevations for the shallov zone of the Sand-and-Gravel Aquifer underlying the IWTP. The map indicates that the predominant feature influencing the groundwater flov in this zone is a flow divide vhich medially separates the small peninsula where the IWTP is located. Thus, groundwater flows away from the central area of the peninsula tovards the west, north, and east. The groundwater elevations mimic the peninsular topography, and flov occurs from areas of higher elevation toward areas of lover elevation. Due to the presence of the confining/semi-confining unit at 40 feet below land surface, the majority of the groundwater vithin the shallov zone probably discharges into Bayou Grande on the vest and Pensacola Bay on the east.

The horizontal hydraulic gradient in the shallov zone is 0.00037 along the north-south axis of the peninsula (based on head differences between vells GM-12R and UG-1), 0.0014 in an east-northeast direction (based on head differences between vells GM-12R and GM-13), and .0009 in a northvest direction (based on head differences betveen GX-12R and GM-11). This difference in flov gradients is a reflection of a lover topographic slope in a north-south direction and the closer proximity of discharge areas to the east and vest. There vas no observable influence from pumping recovery well RW-7 on water level elevations or flov directions in the shallow zone. In addition, previous vater level elevations collected when the recovery well system vas fully operational (e.g., August 1989) also shoved little, if any, effect of the groundvater recovery on shallov vater levels.

Table 2-1

WATER LEVEL ELEVATIONS
(Measured 3/23/90)

Well Number	Well Depth	TOC Elevation	Depth To Water	Water Level Elevation
Shallow Zone				
UG-1	15.0	8.48	6.38	2.10
GM-8	12.0	6.12	3.62	2.50
GM-9	11.8	5.65	3.14	2.51
GM-10	12.0	5.83	3.13	2.70
GM-11	11.8	6.00	3.51	2.49
GM-12R	11.3	9.83	7.01	2.82
GM-13	12.0	5.09	3.15	1.94
GM-14	11.4	4.56	3.20	1.36
Gn-62	15.0	7.11	4.40	2.71
GM-67	15.0	6.38	4.10	2.28
GM-71	12.5	6.76	5.10	1.66
at72	12.5	7.61	6.15	1.46
GM-76	13.5	7.88	6.00	1.88
GM-77	13.5	4.71	2.78	1.93
GM-78	13.0	7.02	4.63	2.39
GM-79	12.5	4.65	2.61	2.04
at83	12.5	4.84	3.77	1.07
Intermediate Zone				
GM-64	40.0	6.26	3.73	2.5
GM-66	40.0	7.48	5.75	1.73
GM-69	40.0	7.85	5.62	2.23
GM-84	40.0	11.84	10.81	1.03
Deep Zone				
GM-63	65.0	6.97	4.75	2.22
GM-65	65.0	6.67	4.34	2.33
GM-68	65.0	7.00	4.64	2.36

NOTE: Well depths are in feet below land surface. Elevations are in feet above mean sea level. Depths to water are in feet below top of well casing (TOC).

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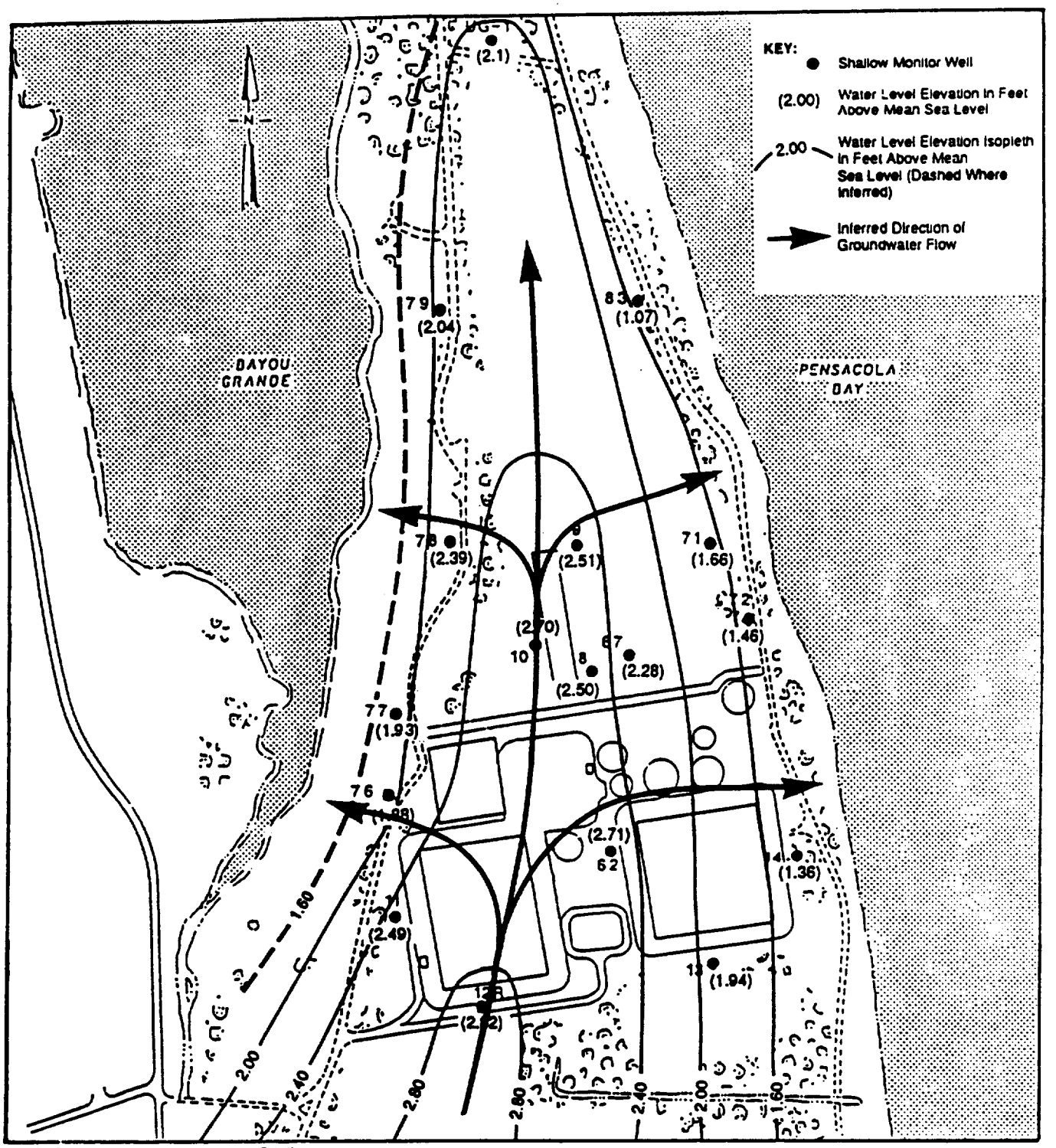

SOURCE: Geraghty & Miller, Inc. 1988; E & E, 1990

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Figure 2-2
WATER LEVEL ELEVATION MAP FOR THE SHALLOW ZONE, 3/23/90

2.3 INTERMEDIATE ZONE

Figure 2-3 shows the water level elevations for the intermediate zone of the Sand-and-Gravel Aquifer at the IWTP. For the area immediately underlying the facility, the map indicates that groundwater in this zone flows towards the east-northeast. Due to the presence of the confining/semi-confining unit at 40 feet below land surface, the majority of groundwater in the intermediate zone probably discharges into Pensacola Bay.

The horizontal hydraulic gradient, calculated using the head differences between wells GX-64 and GX-84, is 0.0025.

2.4 DEEP ZONE

Figure 2-4 shovs the water level elevations for the deep zone of the Sand-and-Gravel Aquifer underlying the IWTP. Although only three monitoring wells exist that are open to the deep zone, the water level elevations suggest that the groundwater in this zone flows toward the south. Thus, it is probable that flow from this zone discharges into Pensacola Bay or, depending on the lateral extent of the low permeability zone, the Gulf of Xexico. Given that this zone is below the low permeability zone, this flow direction is probably reflective of more regional factors (i.e., recharge to the north on the mainland and discharge into Pensacola Bay and/or the Gulf of Xexico to the south).

The horizontal hydraulic gradient, calculated using the head differences between GX-68 and GX-63, is 0.00018.

2.5 VERTICAL HYDRAULIC GRADIENTS

At the IWTP site, the presence of clustered wells allows the calculation of vertical hydraulic gradients between the shallow, intermediate, and deep zones of the Sand-and-Gravel Aquifer. Table 2-2 shovs the calculated vertical hydraulic gradients between these zones.

At well cluster GM-62, 63, 64 there is a potential for downvard groundwater flow to occur from the shallov to the intermediate and deep zones. The potential also exists for downward groundwater flow to occur from the intermediate to the deep zone.

At well cluster GM-65, 66, 67 there is a potential for downward groundwater flov to occur from the shallov to the intermediate zone.

Table 2-2

VERTICAL HYDRAULIC GRADIENTS
(Measured 3/23/90)

Well Cluster	Well Depth	Water Level Elevation	Hydraulic Gradient		
			S -> I	S -> D	I -> D
GM-62 (S)	15	2.71			
GM-64 (I)	40	2.53			
GM-63 (D)	65	2.22			
			0.0072	0.0098	0.0124
GM-67 (S)	15	2.28			
GM-66 (I)	40	1.73			
GM-65 (D)	65	2.33			
			0.0220	-0.0010	-0.0240
GM-9 (S)	11.8	2.51			
GM-69 (I)	40	2.23			
GM-68 (D)	65	2.36			
			0.0090	0.0020	-0.0050

S = Shallow Zone
I = Intermediate Zone
D = Deep Zone

NOTE: Well depths are in feet below land surface. Water level elevations are in feet above mean sea level. Vertical hydraulic gradients are dimensionless. Positive gradients indicate a potential for downward groundwater flow to occur between zones, while negative gradients indicate a potential for upward groundwater flow to occur between zones.

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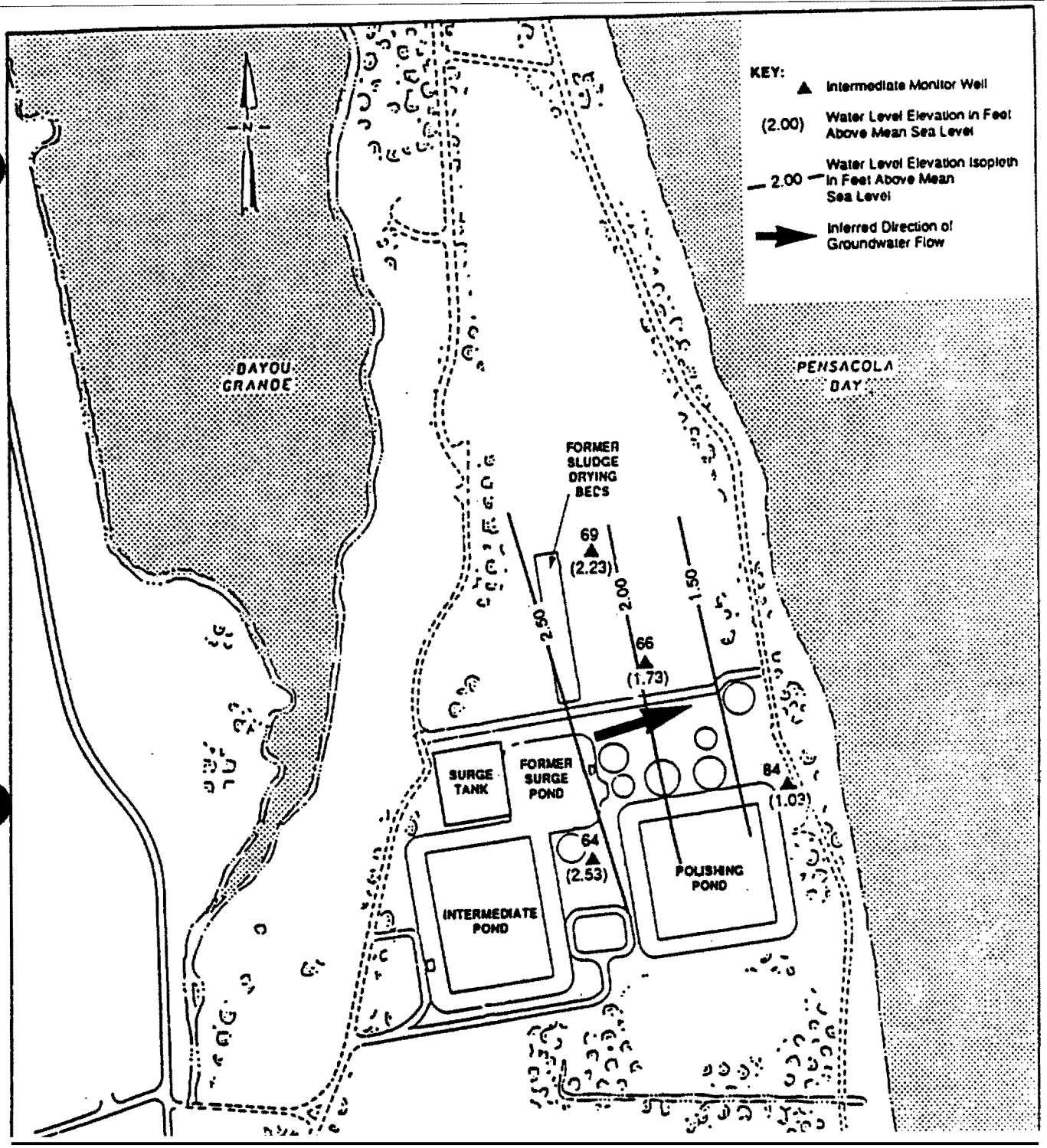

SOURCE: Geraghty & Miller, Inc. 1988

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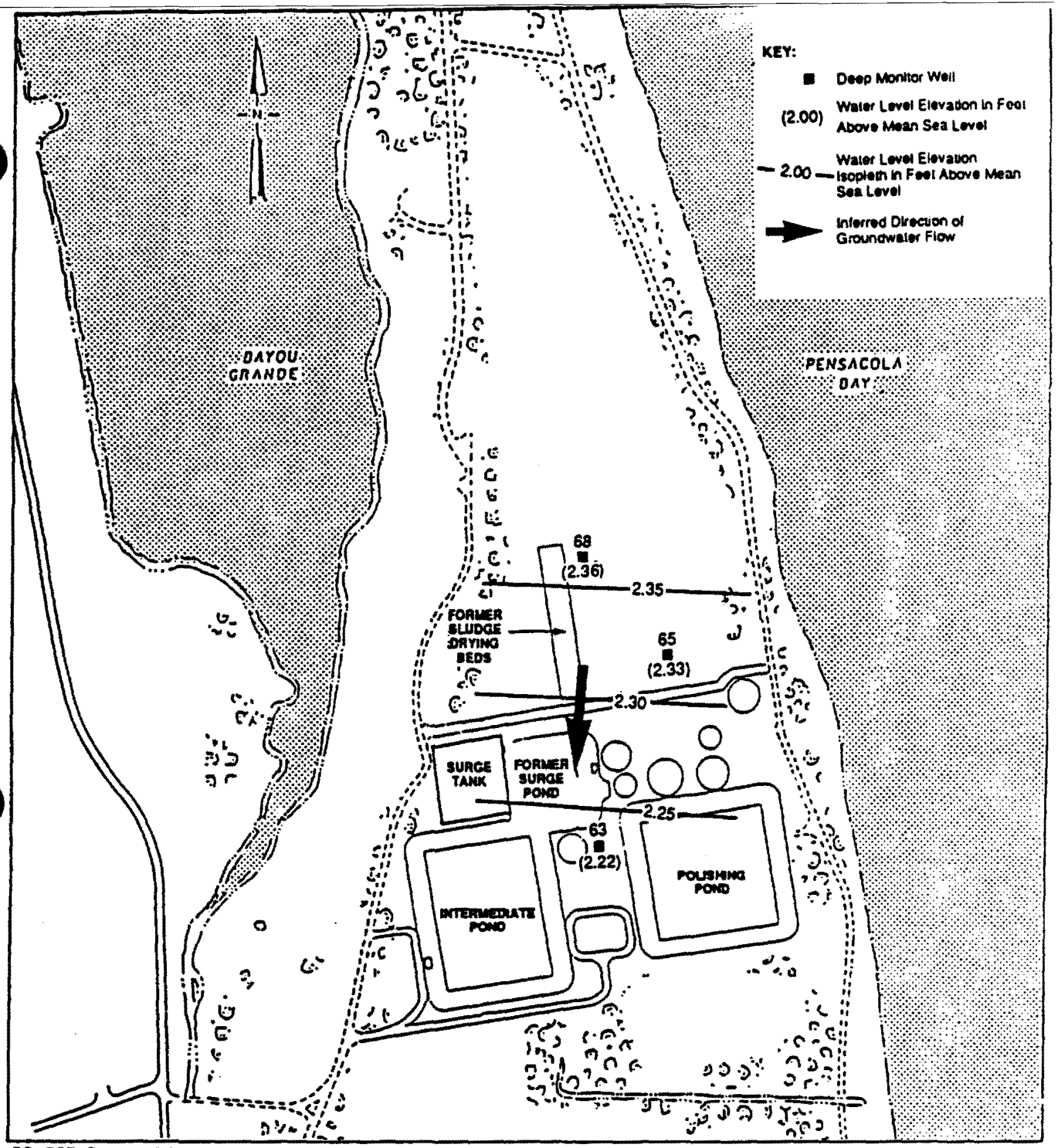
Figure 2-3
WATER LEVEL ELEVATION MAP FOR THE INTERMEDIATE ZONE, 3/23/90



SOURCE: Geraghty & Miller, Inc. 1988

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Figure 2-4
WATER LEVEL ELEVATION MAP FOR THE DEEP ZONE, 3/23/90

However, an upvard potential for groundwater flov exists from the deep zone to the intermediate and shallow zones.

At well cluster GM-9, 68, 69 there is a potential for downvard groundwater flow to occur from the shallow zone to the intermediate and deep zones. However, there is potential for upward groundwater flow from the deep zone to the intermediate zone.

3. AQUIFER TEST RESULTS AND GROUNDWATER FLOW RATES

On March 23, 26, and 27, 1990, E & E personnel conducted short-term aquifer tests at the IVTP. The purpose of the aquifer tests vas to determine the approximate hydraulic conductivity (K), transmissivity (T), and groundwater flow velocity (V) for each depth zone. The aquifer testing conducted consisted of "slug" tests and pumping tests. During the pumping tests at monitoring well clusters, the vater levels in wells at different depth intervals vere observed for changes to determine if there vas hydraulic connection between the monitored zones. The following sections discuss the methodology of these aquifer tests.

3.1 SLUG TESTS

Withdraval-type slug tests were conducted on shallow vells GX-9, 11, 62 and 67; intermediate vells GM-64, 66, and 69; and deep vells GM-63, 65, and 68. Figure 1-1 shows the locations of these monitoring vells.

The methodology of vithdraval-type slug tests involves quickly removing a known volume of vater from the well and recording the water level changes over tine vith a pressure transducer and digital data recorder until equilibration is achieved. The method used to calculate K and T from the slug test data is based on a technique for determining these parameters from partially penetrating vells in unconfined and confined aquifers (Bouwer and Rice, 1976; Cooper, et. al., 1967). For this procedure, semi-logarithmic graphs are prepared of the vater level and time data. In the unconfined solution, values from the straight-line portion of the graph are used for obtaining K and T values (based on equations given by Bouver and Rice 1976) using AOTESOLV, a commercially available computer program. In the confined solution, the graphed data is "fit" to a type curve using AQTESOLV based on equations given by Cooper et. al. (1967). Appendix A giver the analytical

solutions used in both methods.

Because the slug testing procedure evaluates only an area within a short radial distance of the well, values may not be representative of the whole aquifer zone. In addition, this procedure assumes that: the test has no significant effect on the water table; flow above the water table (in the capillary fringe) can be ignored; head losses as water enters the well are negligible (i.e., the well screen does not impede water movement); and the aquifer is homogeneous and isotropic.

The resultant parameter from this method for unconfined aquifers is hydraulic conductivity (K), and for confined aquifers is transmissivity (T). Because slug testing involves a relatively small volume of water displacement in the aquifer and is a short duration aquifer test, the area of influence during the test is small. Slug tests basically only evaluate the section of the aquifer immediately adjacent to the well screen. Because of this, for unconfined solutions, the values of transmissivity (T) can be calculated by multiplying the hydraulic conductivity (K) by the length of the screened interval (2.5 feet for IWTP monitoring wells). Conversely, for confined solutions, values of (K) can be calculated by dividing the resultant (T) by the length of the screened interval.

3.2 PUMPING TESTS

Pumping tests were conducted on shallow zone monitoring wells GH-9, 11, and 62; and on deep zone monitoring wells GM-63 and 68. Figure 2-1 shovs the location of these monitoring wells.

The pumping test methodology involved discharging groundwater from a production well at a known rate. When the production well was located at a well cluster, the drawdowns in water levels in this well and the two other wells were monitored with either a water level indicator or a pressure transducer and data logger. Vhen the pumping water level had stabilized in all the valls, the pump was shut off and water level recoveries were recorded until equilibration was achieved. When a shallow well vas used as the production well, the observation wells vere the adjacent intermediate and deep wells. When a deep well was used as the production well, the observation wells were the adjacent shallow and intermediate vells.

The resultant aquifer parameter calculated using pumping test recovery data is T. The analytical method is based on equations presented by Theis (1935), and is a variation of the method developed by Jacobs (1963). In this method, the vater level recovery data in the production well is plotted against time on semi-logarithmic graph paper, and a straight line is fit to the data points through one log cycle. T is then calculated using the following equation:

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

where: T = transmissivity (feet squared per minute [ft^2/min])
Q = discharge (feet cubed per minute [ft^3/min])
As = change in drawdown over one log cycle

To obtain T in ft^2/day, the equation is further derived (Heath, 1987):

$$T = \frac{350}{\Delta s}$$

where: T = transmissivity (ft^2/day)
Q = discharge (gallons per minute)

The Jacobs method is applicable to analyzing the dravdovn in a well if steady-state conditions are achieved. Given that the pumps in the production wells were not shut down until the pumping vater levels had stabilized, for practical purposes it can be assumed that steady-state conditions did exitt.

Because of the short duration of the recovery phase on these wells (less than 10 minutes), it is reasonable to assume that the flov of groundwater into the well was essentially radial and that vertical flow vas negligible. Therefore, these recovery tests evaluated only that portion of the aquifer adjacent to the well screen. Consequently, the values of K shown for the pumping tests were derived by dividing the calculated T values by the length of the well screen (2.S feet).

The resultant values of hydraulic conductivity obtained during aquifer testing represent the hydraulic conductivity of the aquifer media principally in the horizontal direction. Values in the vertical direction vould presumably be less (Freeze and Cherry, 1979).

3.3 GROUNDWATER FLOW VELOCITY

The horizontal groundwater flow velocity (V) was determined using the calculated K values and a derivation of Darcy's Law:

$$V = \frac{KI}{n_e}$$

where:
- V = velocity
- K = hydraulic conductivity
- I = horizontal hydraulic gradient
- n_e = affective porosity.

The effective porosity for these for these calculations vas estimated at 28 percent, a value typical of unconsolidated, medium-grained sands (Heath, 1987).

3.4 AQUIFER TEST RESULTS

Table 3-1 presents the results of the aquifer testing. Appendix B contains the slug test data and analyses, and Appendix C contains the pumping test data and analyses.

For the slug testing, all wells except GX-62 were analyzed using the unconfined solution. Well GX-62 required the confined solution because the data could not be "fit" to a straight-line plot.

The intermediate wells GX-64, 66, and 69 were not pump tested because the vells could not yield enough vater to sustain a prolonged flow. The shallow zone well GM-67, and the deep zone well GX-65 were not successfully pump tested because of difficulty in stabilizing the groundwater discharge rates.

Observation of different depth interval wells during the pumping tests indicated that: a) there vas no significant drawdown in intermediate or deep wells during the pumping of shallow wells, and b) there vas no significant drawdown in shallow or intermediate wells during the pumping of deep wells. These results indicate that no apparent hydraulic connection exists between these zones under short-term, low discharge rate (1 to 2 gallons per minute) aquifer stressing.

The slug test results shown in Table 3-1 are consistently higher than the pumping test results. The exact reason for this is unknown and is probably a function of the different tests and/or analytical methods

AQUIFER TEST RESULTS

Well Depth	Estimated[a] Hydraulic Conductivity (Ft/day)	Estimated[a] Transmissivity (Ft sq/day)	Estimated[b] Hydraulic Conductivity (Ft/day)	Estimated[b] Transmissivity (Ft sq/day)	Average[c] Estimated Hydraulic Conductivity (Ft/day)	Average[c] Estimated Transmissivity (Ft sq/day)	Estimated Average Groundwater[d] Flow Rate (Ft/day)	Estimated Average Groundwater[d] Flow Rate (Ft/yr)
Shallow Zone								
GM-9	31.06	77.65	17.50	43.75				
GM-11	6.95	17.39	4.17	10.44				
GM-62	44.36	110.90	13.92	34.00				
GM-67	44.13	110.34	(NS)	(NS)				
					23.15	57.07	0.116	42.34
Intermediate Zone								
GM-64	0.20	0.52	(NT)	(NT)				
GM-66	0.45	1.12	(NT)	(NT)				
GM-69	0.06	2.15	(NT)	(NT)				
					0.50	1.26	0.005	1.03
Deep Zone								
GM-63	4.56	11.40	2.74	6.06				
GM-65	24.06	62.17	(NS)	(NS)				
GM-68	20.34	50.86	15.10	37.76				
					13.52	33.80	0.009	3.29

[a] Parameters estimated using slug test results

[b] Parameters estimated using pumping test results

[c] Averages calculated using slug and pumping test results

[d] Flow rates calculated using average estimated hydraulic conductivities

(NS) Groundwater discharge rate not stabilized

(NT) Well not tested using this method

NOTE: Horizontal hydraulic gradients used for groundwater flow rate calculations: Shallow Zone - 0.0014, Intermediate Zone - 0.0025, Deep Zone - 0.00018.

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used. In general, however, the slug and pumping test results are in agreement within reasonable limits.

Aquifer test results shown in Table 3-1 for wells open to the shallow zone indicate that this zone is moderately permeable. Eydraulic conductivities range from 4.17 to 44.36 ft/day, and average 23.15 ft/day. The average horizontal flov velocity for this zone is 0.116 ft/day (42.34 ft/yr).

Aquifer test results for wells open to the intermediate zone indicate that this zone is characterized by low permeabilities. Hydraulic conductivities range from 0.20 to 0.86 ft/day, and average 0.50 ft/day. The average horizontal flow velocity for this zone is 0.005 ft/day (1.68 ft/yr).

Aquifer test results for wells open to the deep zone indicate that this zone is moderately permeable. Hydraulic conductivities range from 2.74 to 24.86 ft/day, and average 13.52 ft/day. The average horizontal flov velocity for this zone is 0.009 ft/day (3.29 ft/yr).

4. CONCLUSIONS

4.1 GROUNDWATER FLOW DIRECTION

Groundwater elevations in the shallow zone of the Sand-and-Gravel Aquifer underlying the IVTP mimic the peninsular topography, and groundwater flov occurs from the central portion of the site (i.e. the highest elevation) to the east, north, and vest (i.e. the lowest elevations). Groundwater flow in the intermediate zone flows to the east from the eastern side of the IVTP, and may possess a westerly component which flows from the western side of the facility. Based on subsurface lithologies, calculated flow directions, and the proximity of surface water bodies with a lover head, the majority of the groundwater in both of these zones probably discharges into Bayou Grande and Pensacola Bay. There vas no observable effect on the water level elevations in the shallow and intermediate wells due to the pumping of groundwater from recovery well RW-7.

Groundwater in the deep zone of the Sand-and-Gravel Aquifer underlying the IVTP appears to flow to the south, discharging into Pensacola Bay and/or the Gulf of Mexico.

12 GROUNDWATER FLOW RATES

The shallow zone of the Sand-and-Gravel Aquifer underlying the IWTP is characterized by a moderate permeability. The average estimated rate of groundwater flow in this zone is 0.116 ft/day (42.34 ft/yr).

The intermediate zone of the Sand-and-Gravel Aquifer underlying the IWTP possesses low permeabilities. Consequently, the average estimate rate of groundwater flov in this zone is also low at 0.005 ft/day (1.83 ft/yr).

The deep zone of the Sand-and-Gravel Aquifer underlying the IVTP is characterized by a moderate permeability. However, the horizontal

hydraulic gradient in this zone is lov. Therefore, the average estimated rate of groundvater flov in this zone is lov at 0.009 ft/day (3.29 ft/yr).

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6. FLORIDA PROFESSIONAL GEOLOGIST SBAL

I hereby affix my seal to the 1990 Groundwater Plov Rate and Direction Determination Report for the Industrial Wastewater Treatment Plant, Naval Air Station, Pcnsacola, Florida, in accordance vith Chapter 492 of the Florida Statutes and applicable rules and regulations developed pursuant thereto:

Name:	John D. Barksdale
License Number:	P.G. No. 1150
State:	Florida
Expiration Date:	July 31, 1992

John D. Barksdale

John D. Barksdale

7-2-91

Date

APPENDIX A

SLUG TEST ANALYTICAL SOLUTIONS

SLUG TEST METHOD FOR UNCONFINED AQUIFERS

REFERENCE: Bouwer, H. and R. C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

SOLUTION:

$$\ln s_0 - \ln s_t = \frac{2 K L t}{r_c^2 \ln(r_e/r_w)}$$

where:

s_0 = initial drawdown in well due to instantaneous removal of water from well [L]

s_t = drawdown in well at time t [L]

L = length of well screen [L]

r_c = radius of well casing [L]

$\ln(r_e/r_w)$ = empirical "shape factor" determined from tables provided in Bouwer and Rice *(1976)*

r_e = equivalent radius over which head loss occurs [L]

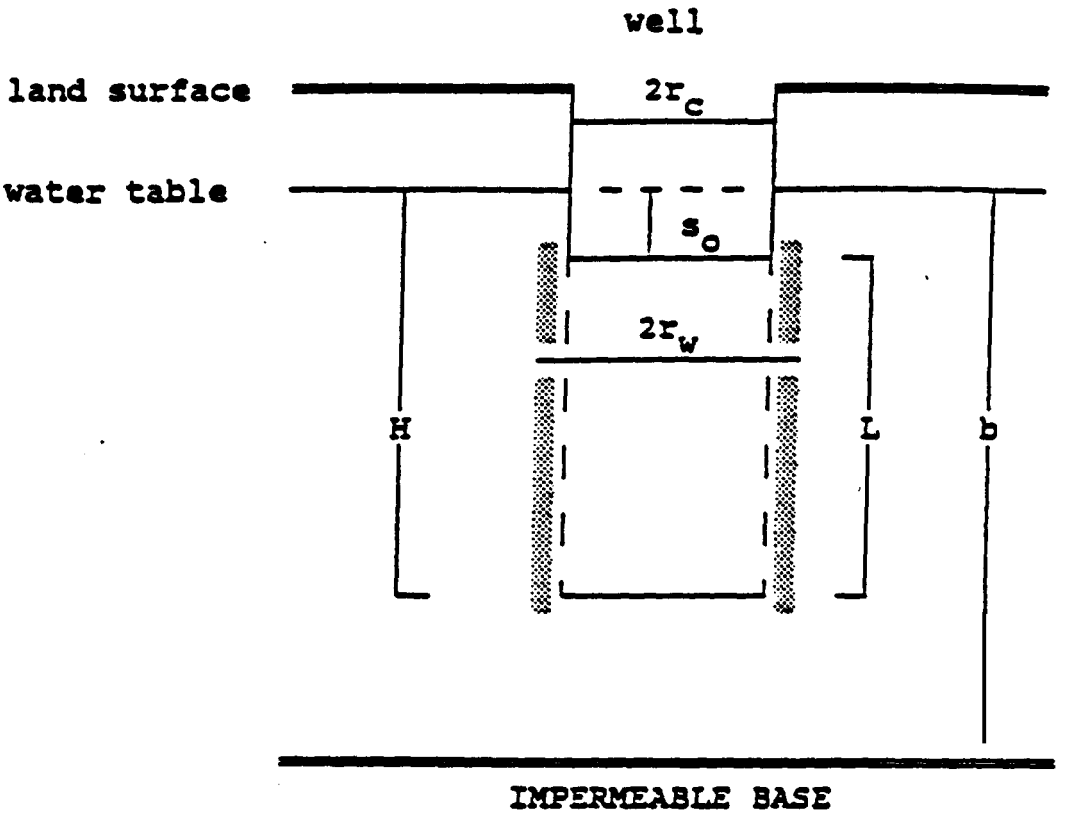
r_w = radius of well (including gravel pack) [L]

H = static height of water in well [L]

b = saturated thickness of aquifer

SLUG TEST METHOD FOR UNCONFINED AQUIFERS (continued)

DEFINITION OF TERMS:



SLUG TEST FOR CONFINED AQUIFERS

REFERENCE: Cooper, H. H., J. D. Bredehoeft, and S. S. Papadopulos, (1967) response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263-269.

ASSUMPTIONS:
aquifer has infinite areal extent
aquifer is homogeneous, isotropic, and of uniform thickness
aquifer potentiometric surface is initially horizontal
a volume of water, V, is injected into or discharged from the well instantaneously
pumping well is fully penetrating
flow to pumping well is horizontal
aquifer is confined
flow is unsteady
water is released instantaneously from storage with decline of hydraulic head
diameter of pumping well is *very* small so that storage in the well can be neglected

SOLUTION:

Integral solution for dimensionless drawdown in well:

$$H/H_0 = \frac{8\alpha}{\pi^2} \int_0^\infty \frac{e^{-\beta u^2/\alpha}}{u \cdot \{[uJ_0(u)-2\alpha J_1(u)]^2 + [uY_0-2\alpha Y_1(u)]^2\}} \, du$$

Laplace solution for response in well:

$$\bar{h} = \frac{r_w S H_0 K_0(rq)}{T q [r_w q K_0(r_w q) + 2\alpha K_1(r_w q)]}$$

$$q = (pS/T)^{1/2}$$

p = Laplace transform variable

where:

H = head in well at time t [L]

H_0 = initial head in well well due to slug injection or extraction [L]

a = $r_w^2 S/r_c^2$ [dimensionless]

SLUG TEST FOR CONFINED AQUIFERS (continued)

r_w = effective radius of well [L]

r_c = internal radius of well casing [L]

β = Tt/r_c^2

J_0 = Bessel function of first kind, zero order

J_1 = Bessel function of first kind, first order

Y_0 = Bessel function of second kind, zero order

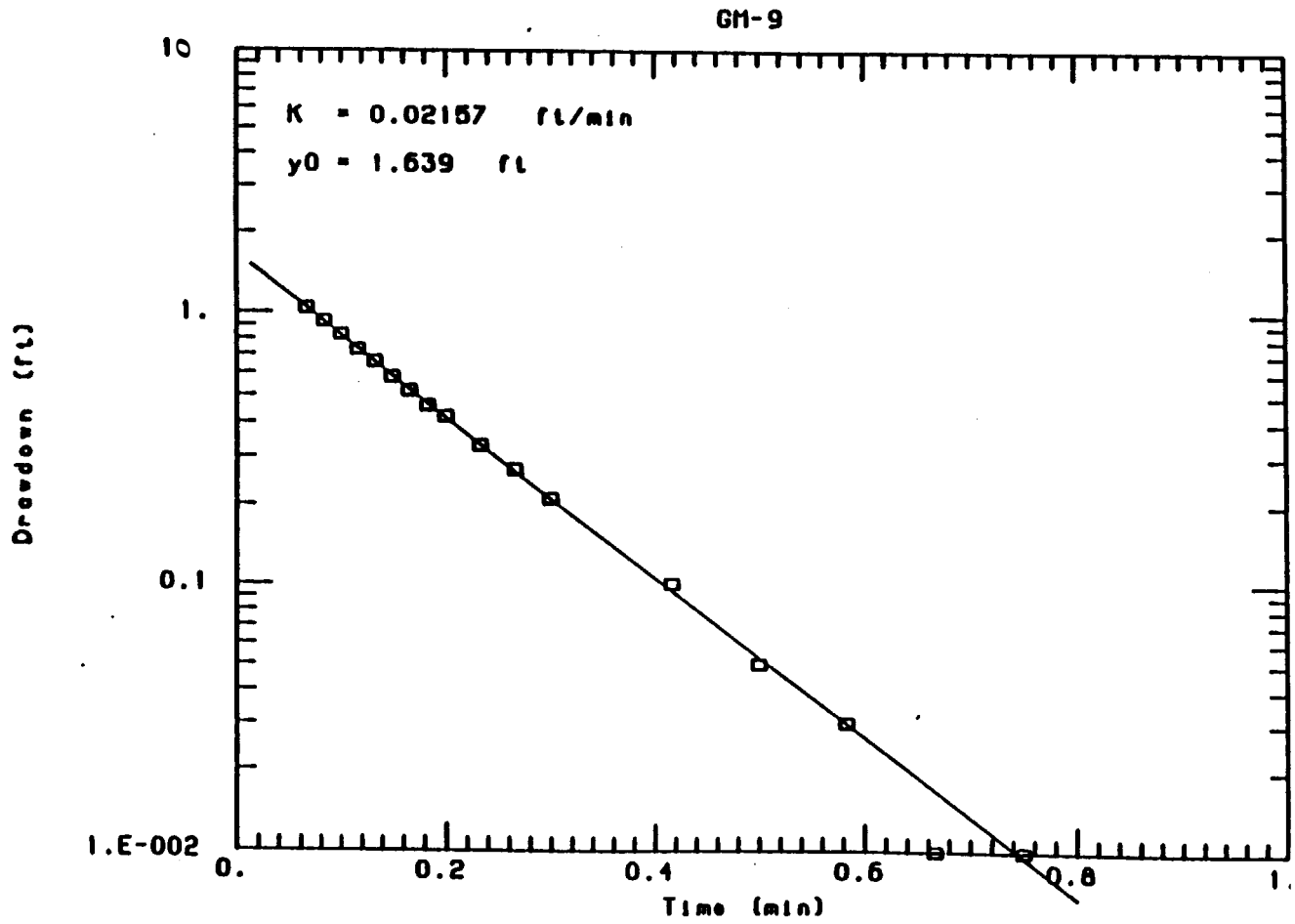
Y_1 = Bessel function of second kind, first order

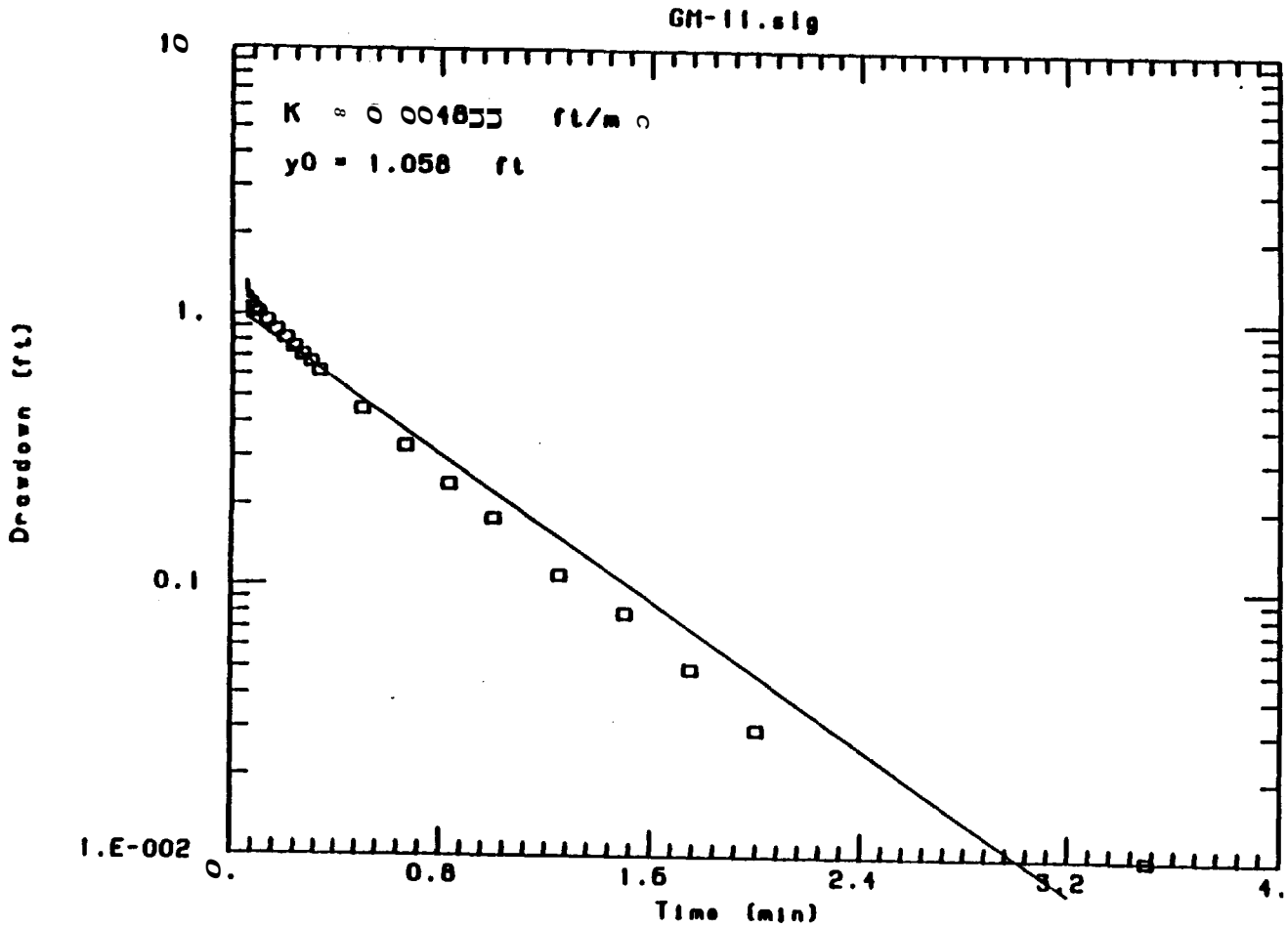
K_0 = modified Bessel function of second kind, zero order

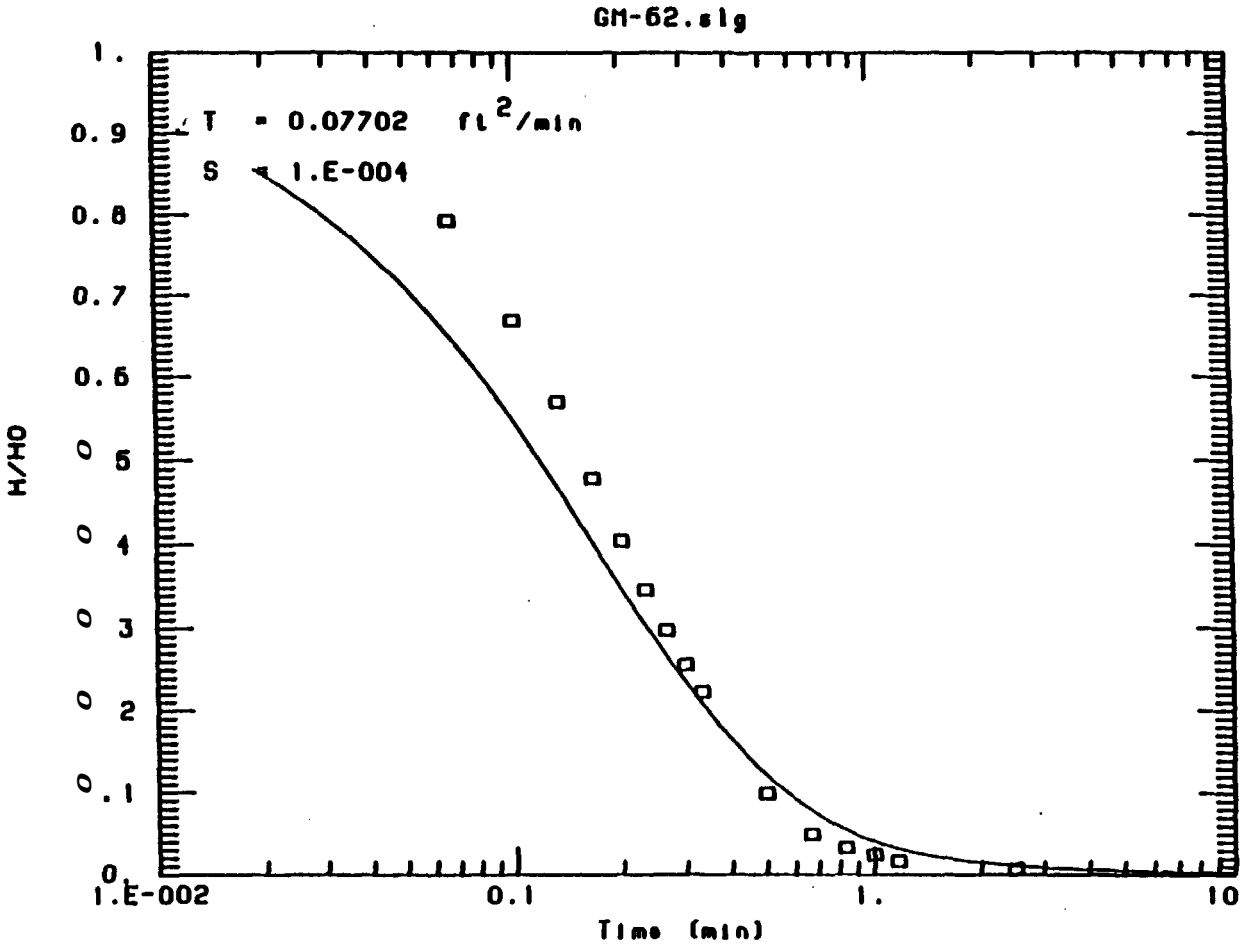
K_1 = modified Bessel function of second kind, first order

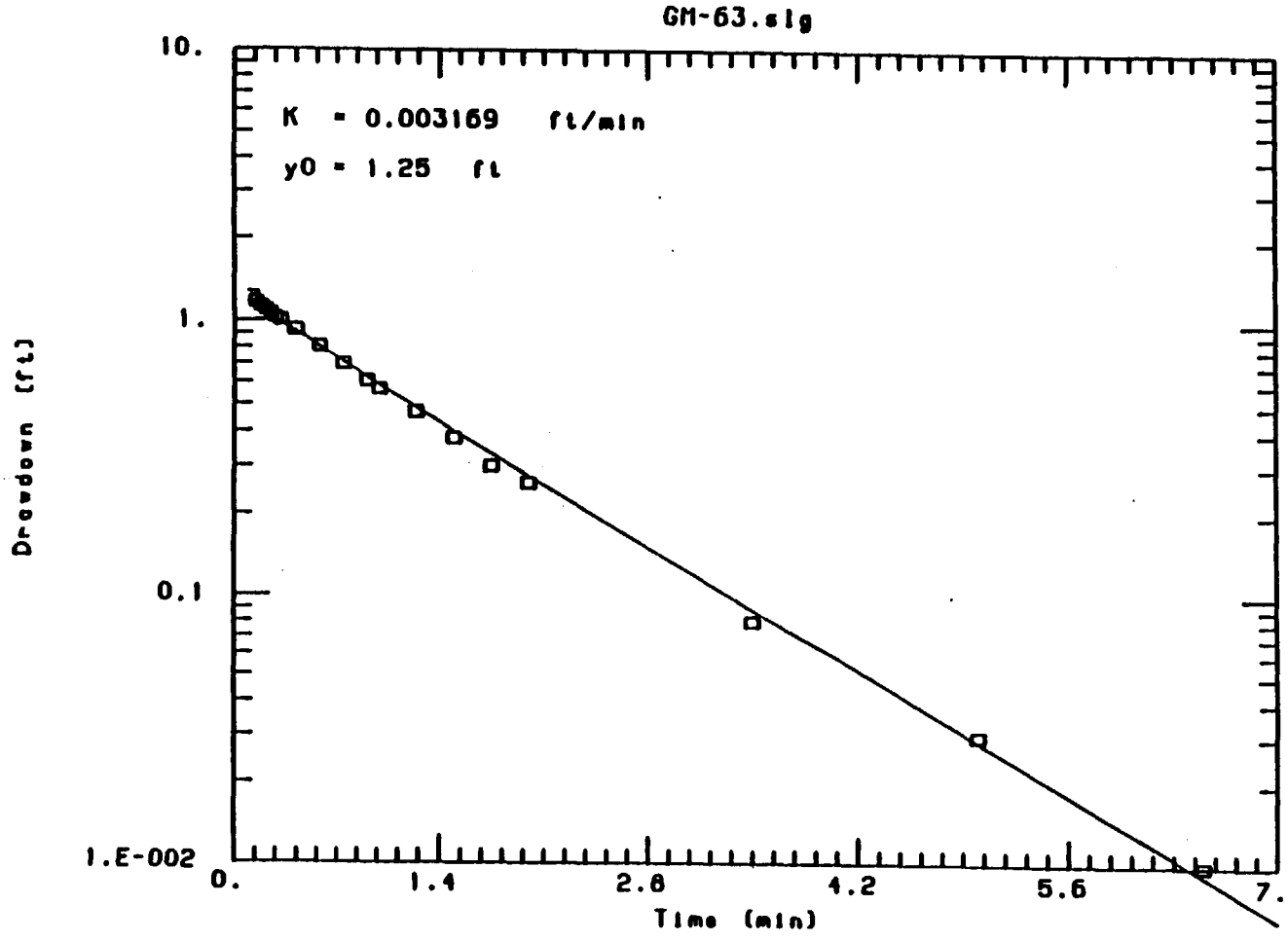
APPENDIX B

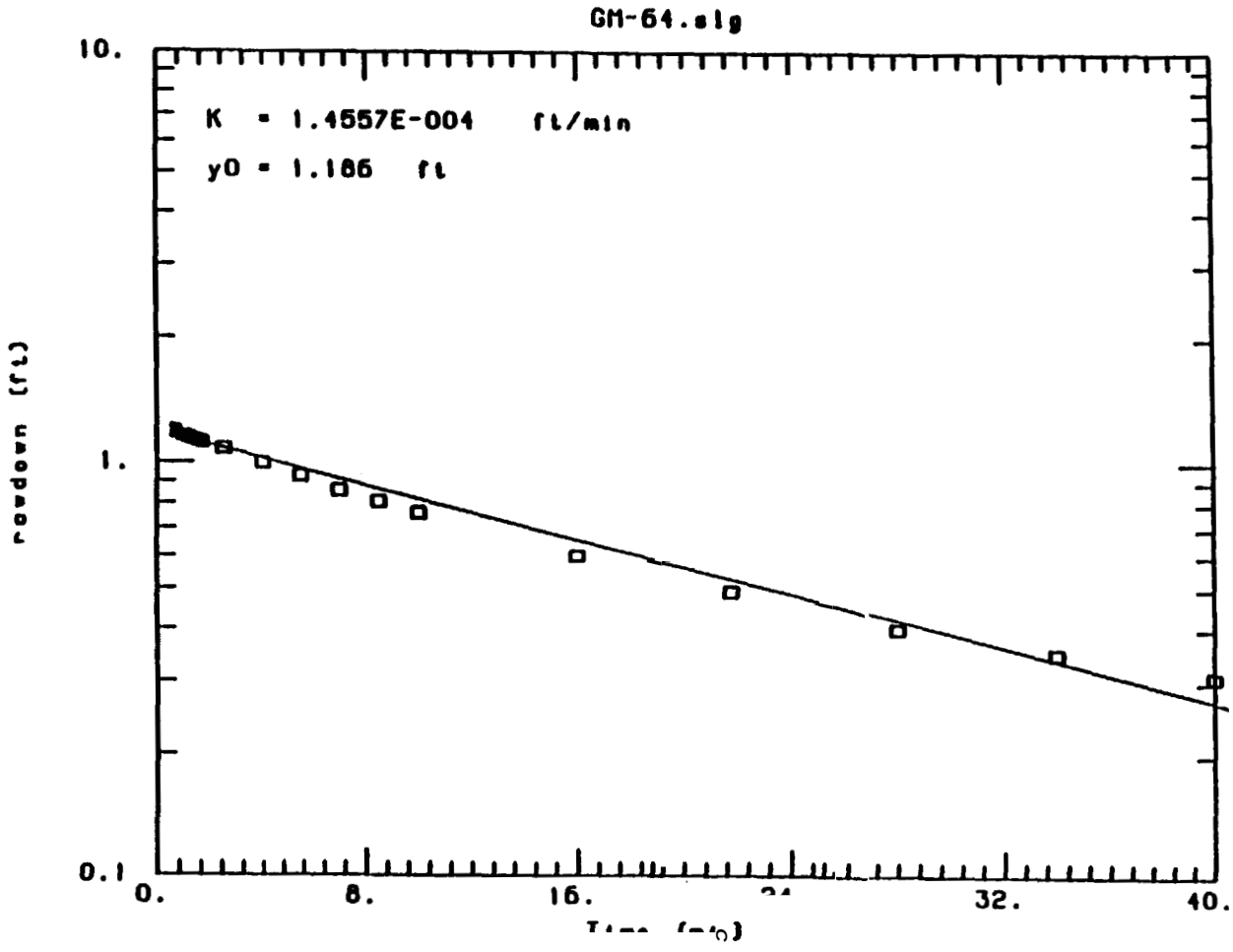
SLUG TEST DATA AND ANALYSES

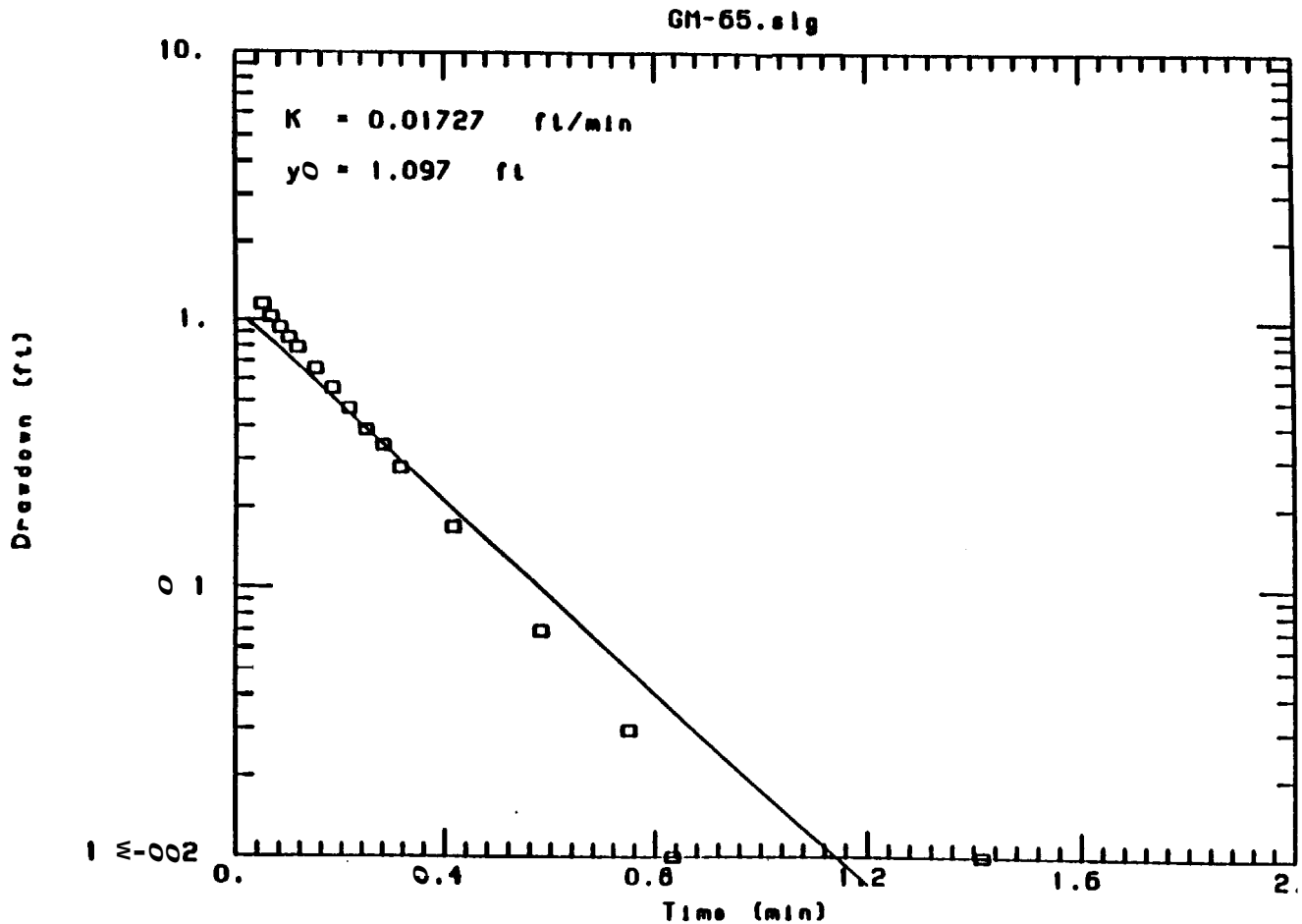

GM-9
K = 0.02157 ft/min
y0 = 1.639 ft
10
1.
0.1
1.E-002
Drawdown (ft)
0.
0.2
0.4
0.6
0.8
1.
Time (min)

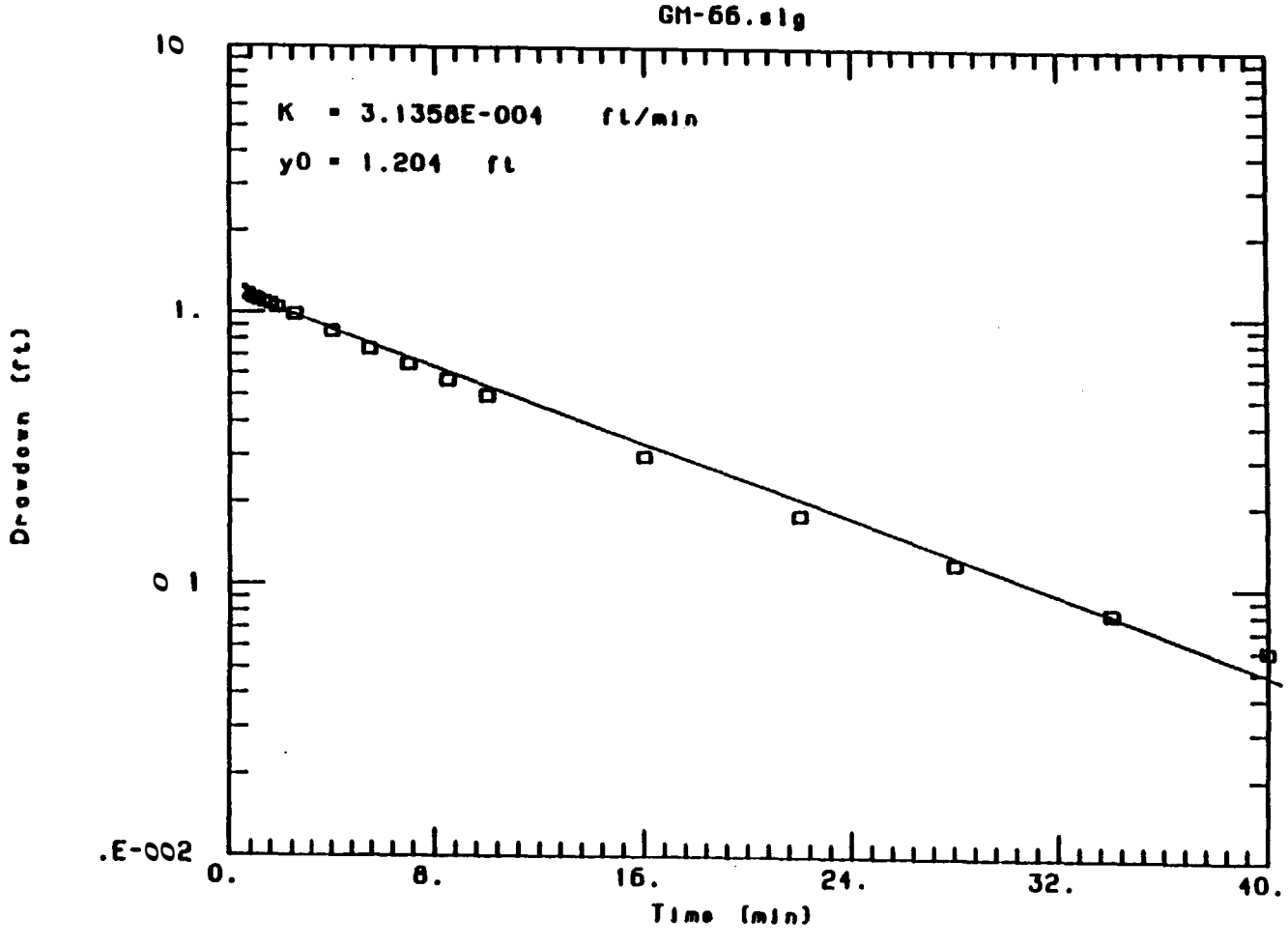

GM-11.slg
K = 0.004833 ft/min
y0 = 1.058 ft
10
1.
0.1
1.E-002
Drawdown (ft)
0.
0.8
1.6
2.4
3.2
4.
Time (min)

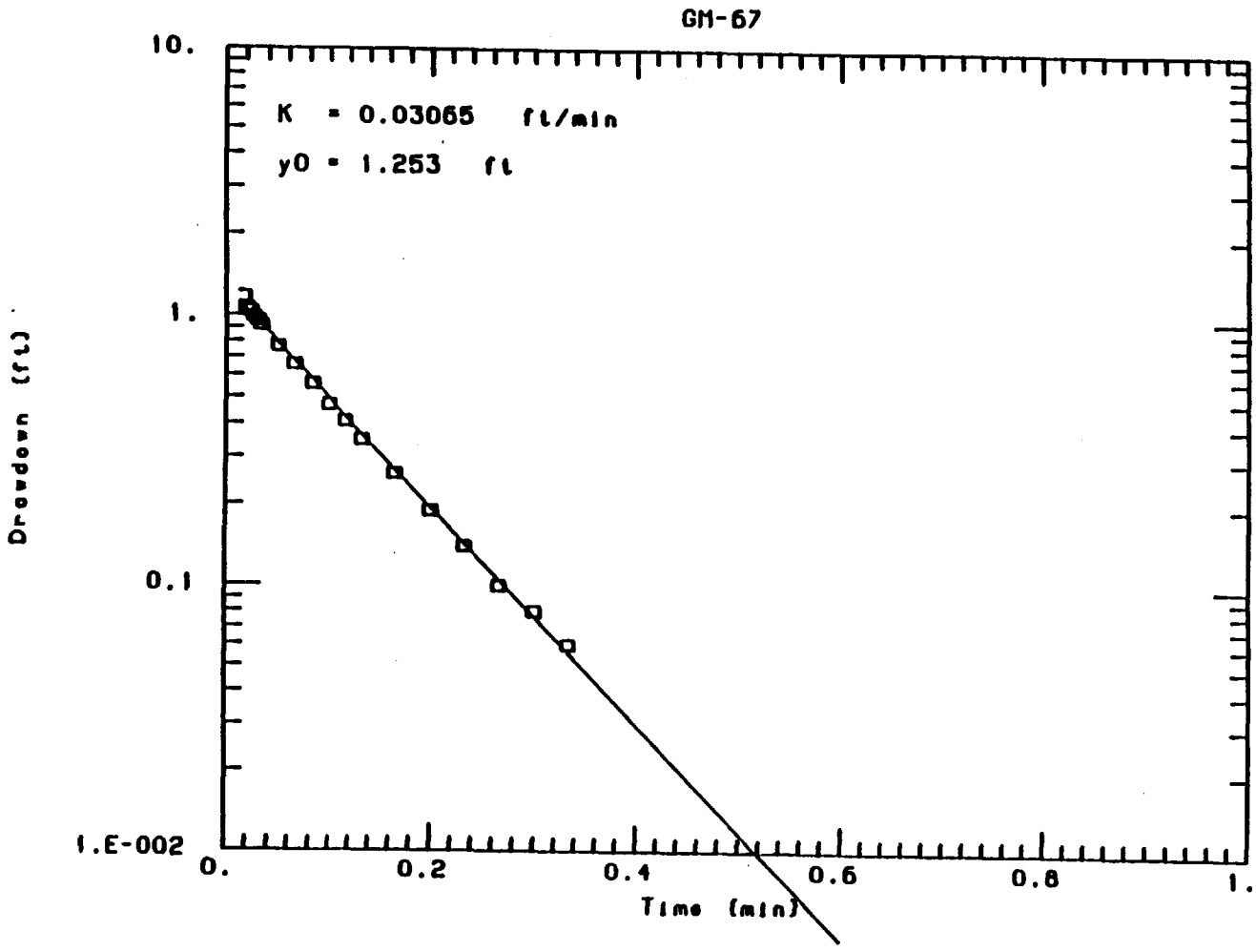

GM-62.slg
T = 0.07702 ft²/min
S = 1.E-004
H/HO
1.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
1.E-002
0.1
1.
10
Time (min)

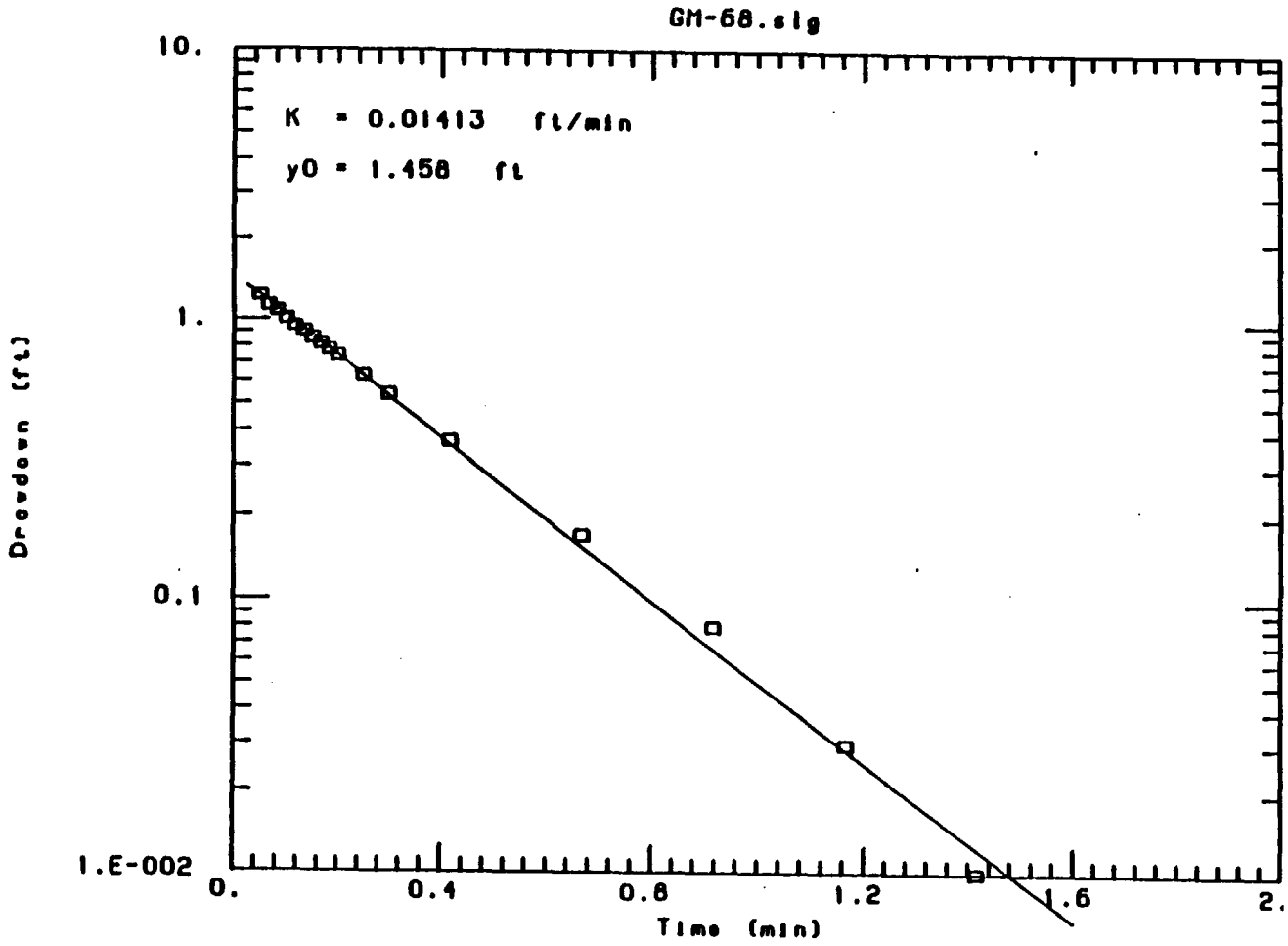

GM-63.slg
K = 0.003169 ft/min
y0 = 1.25 ft
10.
1.
0.1
1.E-002
Drawdown (ft)
0.
1.4
2.8
4.2
5.6
7.
Time (min)

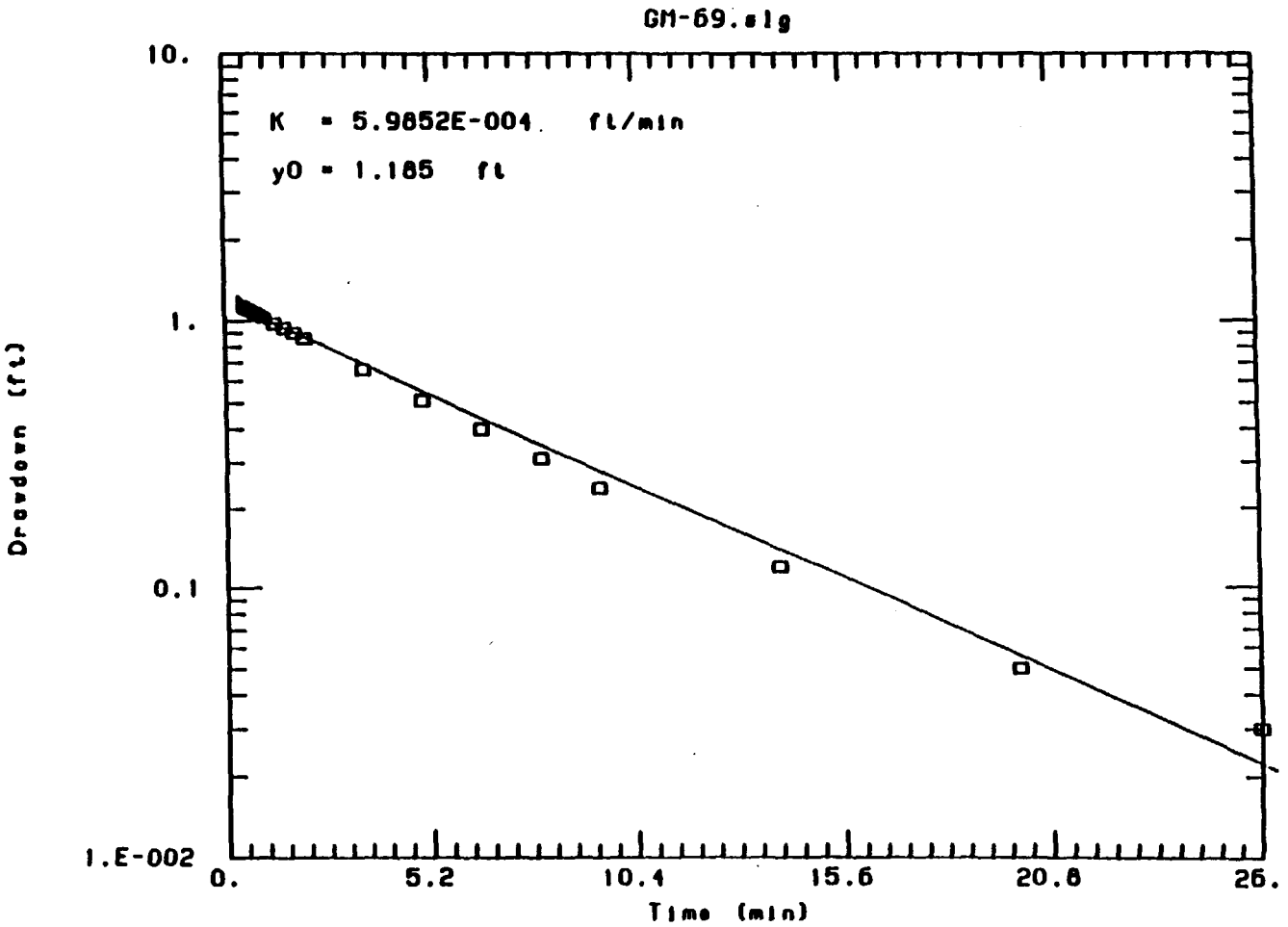

GM-64.slg
K = 1.4557E-004 ft/min
y0 = 1.186 ft
10.
1.
0.1
0.
8.
16.
32.
40.


GM-65.slg
K = 0.01727 ft/min
y0 = 1.097 ft
10.
1.
0.1
1.E-002
Drawdown (ft)
0.
0.4
0.8
1.2
1.6
2.
Time (min)


GM-66.slg
K = 3.1358E-004 ft/min
y0 = 1.204 ft
10
1.
0.1
.E-002
0.
8.
16.
24.
32.
40.
Drawdown (ft)
Time (min)


GM-67
K = 0.03065 ft/min
y0 = 1.253 ft
10.
1.
0.1
1.E-002
Drawdown (ft)
0.
0.2
0.4
0.6
0.8
1.
Time (min)

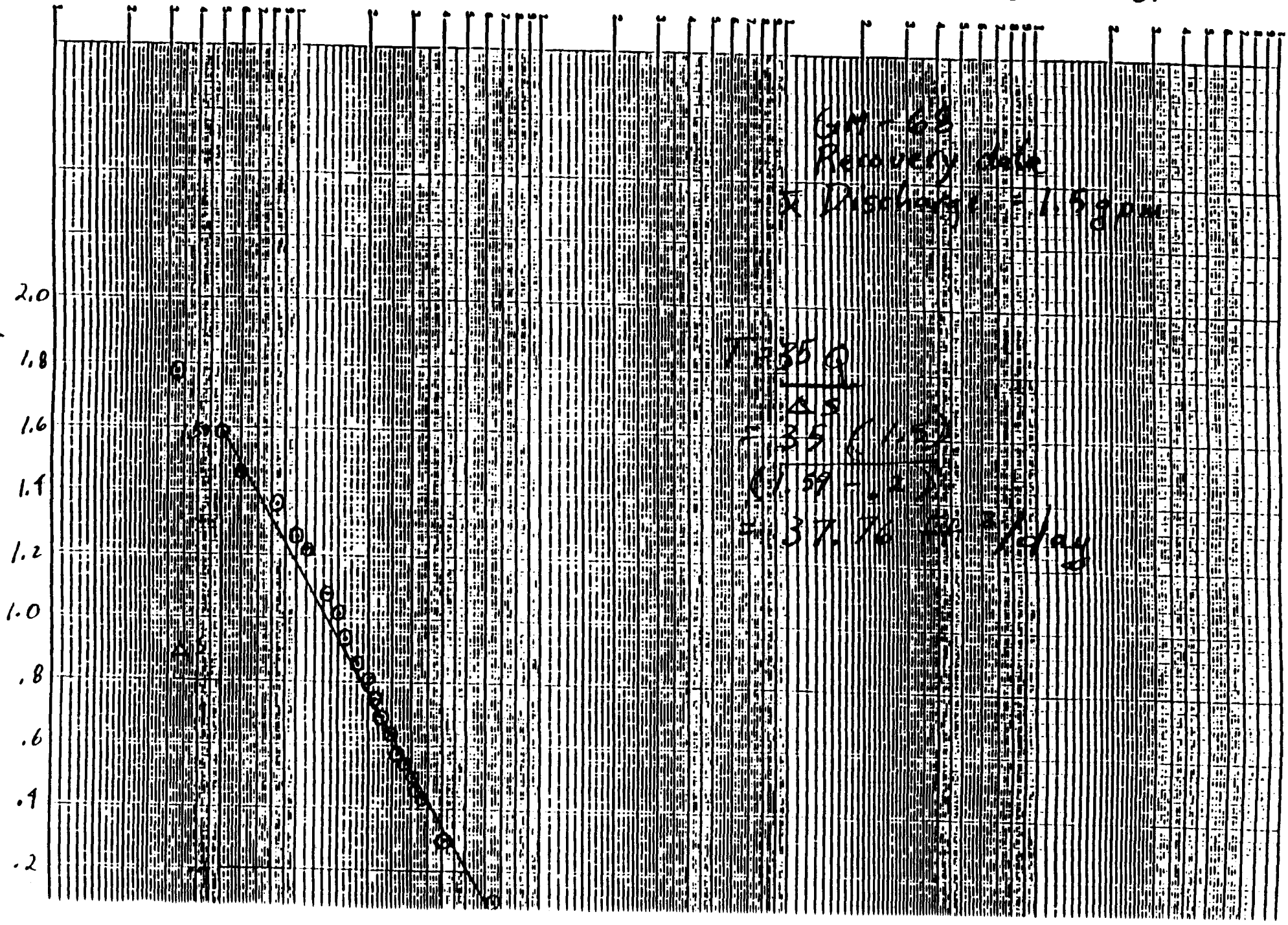

GM-68.slg
K = 0.01413 ft/min
y0 = 1.458 ft
10.
1.
0.1
1.E-002
Drawdown (ft)
0.
0.4
0.8
1.2
1.6
2.
Time (min)


GM-69.slg
K = 5.9852E-004 ft/min
y0 = 1.185 ft
10.
1.
0.1
1.E-002
Drawdown (ft)
0.
5.2
10.4
15.6
20.8
26.
Time (min)

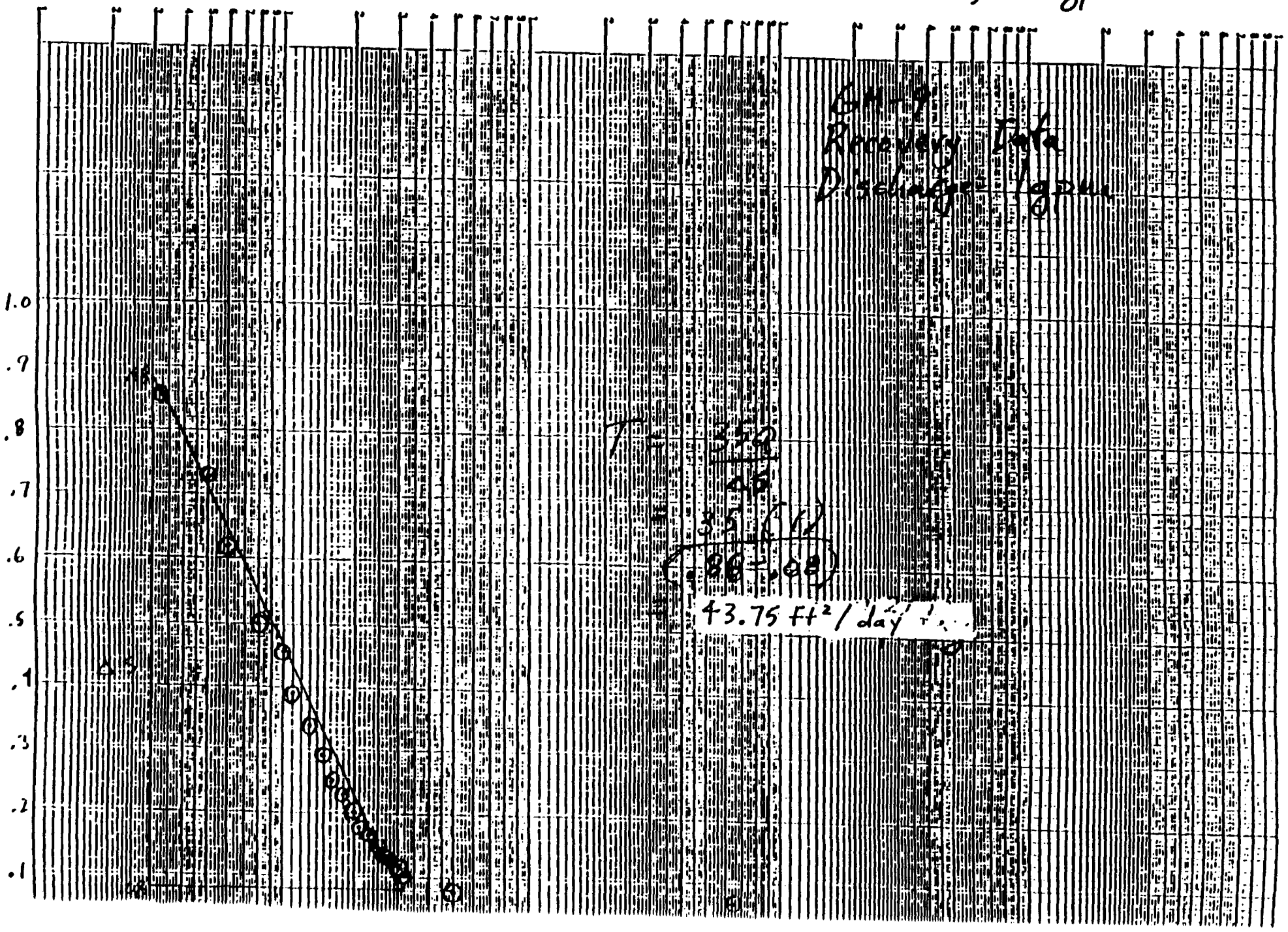
APPENDIX C

PUMPING TEST DATA AND ANALYSES

601-68
Recovery Data
Discharge: 1.5 gpm

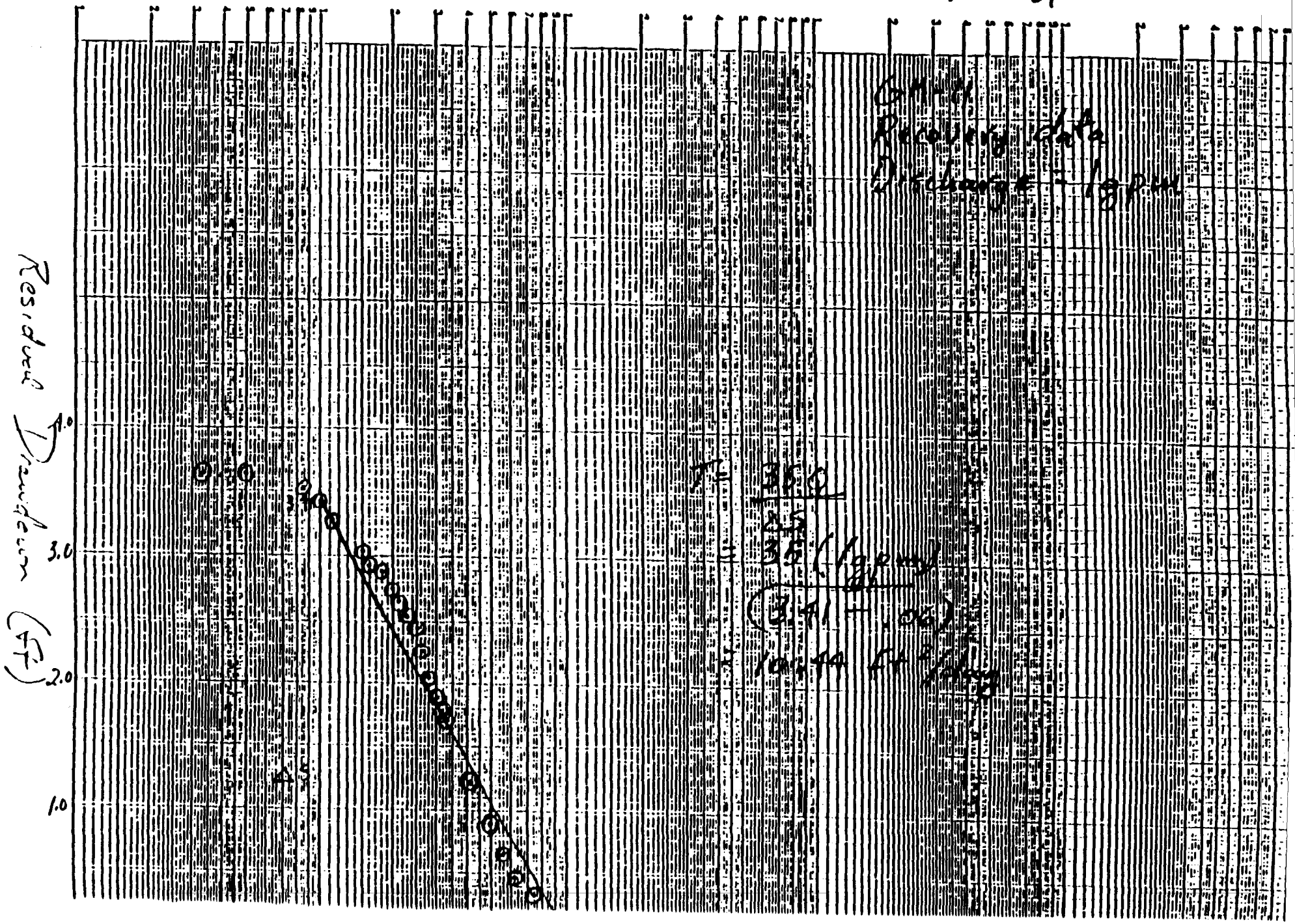


GM-4
Recovery Data.
Discharge = 1gpm



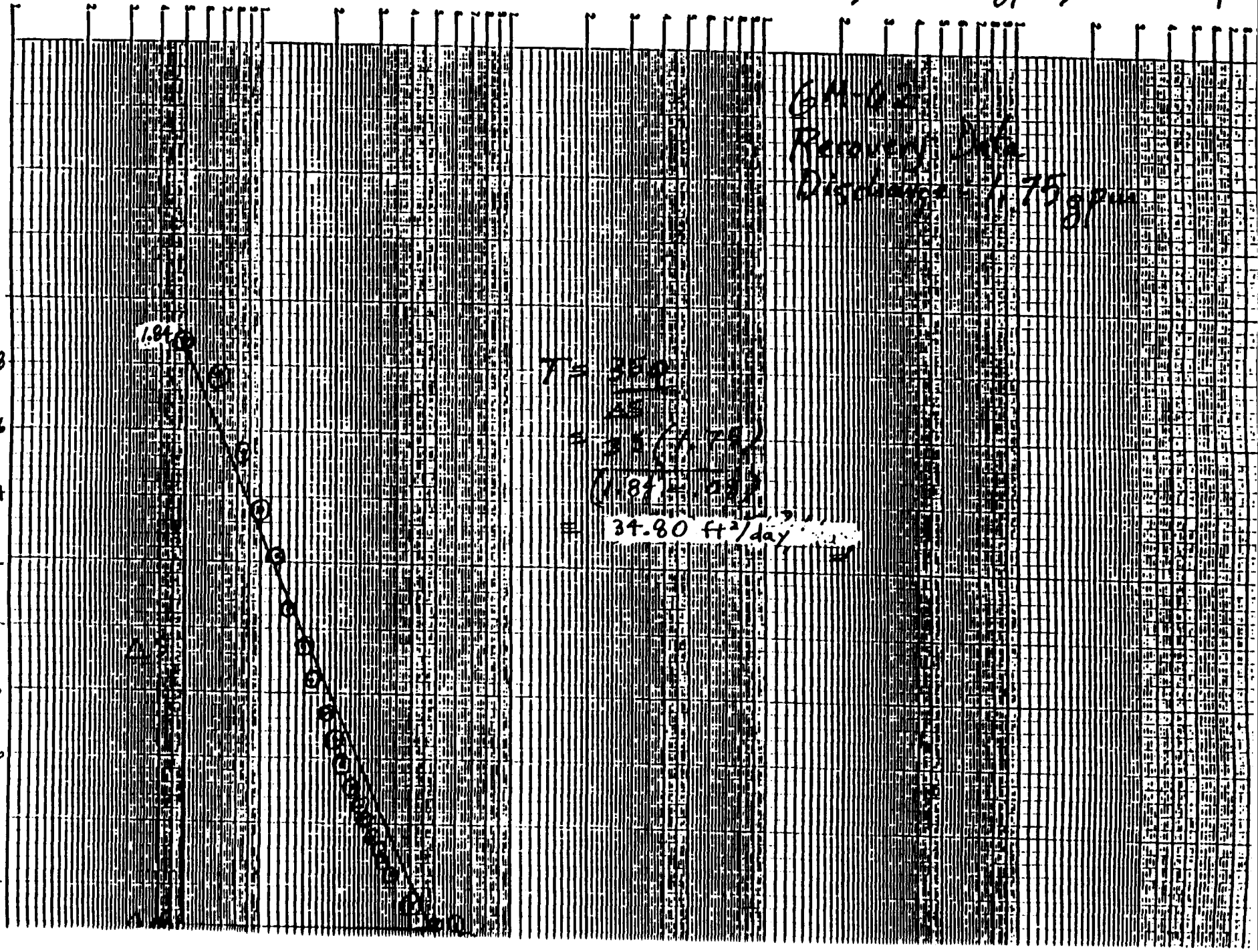
K+E SEMI-LOGARITHMIC 358-91
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

GM-11
Recovery data
Discharge: 1gpm

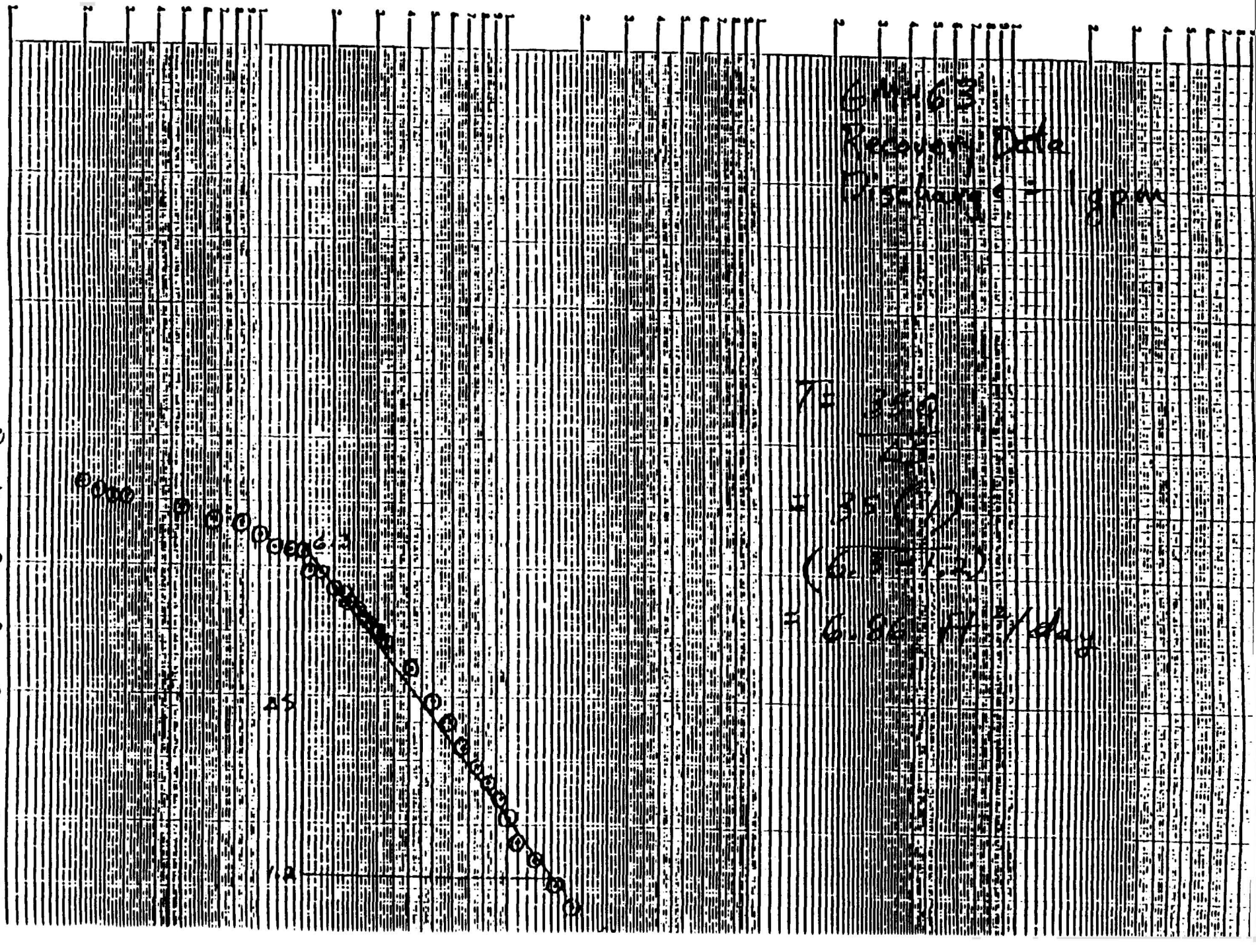


K+E SEMI-LOGARITHMIC 358-91
KEUFFEL & ESSER CO. MADE IN U.S.A.
5 CYCLES X 70 DIVISIONS

GM-62
Recovery Data
Discharge = 1.75 gpm, 34 mins pum



K+E SEMI-LOGARITHMIC 358-91
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS



APPENDIX D

FIELD LOG

3-23-90 MWSP

Water level Measurements

Well	Time	Depth from TOC (c
UG-1	1336	6.38
GM8	1453	3.62
GM9	1446	3.14
GM10	1449	3.13
GM11	1358	3.51
GM12R	1404	7.01
GM13	1413	3.15
GM14	1409	3.20
GM62	1514	4.40
GM63	1513	4.75
GM64	1510	3.73
GM65	1502	4.34
GM66	1501	5.75
GM67	1458	4.10
GM68	1443	4.64
GM69	1520	5.62
GM71	1437	5.10
GM72	1431	6.15
GM76	1354	6.00
GM77	1351	2.78
GM78	1347	4.63
GM79	1343	3.61
GM83	1331	3.77
GM84	1426	10.81

BEC

Slug Test : GM-69

1410 - Set probe @ 10.00 feet / inserted slug /
Took ~20 mins to equilibrate.
Will take rate at 15 secs. w/ REF
@ 0.00.

1435 - Began Slug Test 0 / Test run for
26 mins. / on data review it
looks good / REF = 0.00 at T=0
and XD was 0.02 at T: 26 mins.

Slug Test : GM-66
1530 - After cleaning probe and slug,
inserted slug into well w/
probe at 9.96. Took ~30 mins
for reequilibration.
1600 - Began Slug Test 1 / REF = 0.00
1625 - Caldwell decided to run
Slug Test 1 again because of
negative nos. at top of test.
1630 - Re-inserted slug into well
with probe at 9.88. Reequilibrated
to 9.98
1700 - Started Test 1 / REF = 0.00
Ran Test for 40 mins /
looks good / REF = 0.00 at T=0.0
and XD was 0.06 at T=40 mins
1715 - Removed / moved to GM-64.
BEC

1755 - Inserted slug into GM-64 w/ pr
at 10.07 / will remove: ~30.
Will set rate @ 15 secs and REF
Test will be Slug Test 2.

1825 - Start up Test 2 / REF = 0.00
Ran Test 2 for 40 mins — recov
only to .32 / Start looks
good w/ REF = 0 @ T = 0.00.
Going w/ this as total Δ
was 1.22; recovery to .32
represents a 75% recovery, w
should be enough to curve

1920 - Stickland + Caldwell off sit

BEC

26 MAR 90

0700 - STRICKLAND + CALDWELL IN OFFICE / PAPERWORK

0870 - LEAVE OFFICE / get gas / get DI

0900 - ARRIVE ON SITE / STRICKLAND BEGINS DECON FOR PUMP HOSE + CALDWELL MOVES TO GM-9 AND GM-68 TO SET UP DATA LOGGER (WILL SET UP 2 PROBES — ONE IN SHALLOW + ONE DEEP — WILL PUMP TEST MONITORING BOTH WELLS FOR EACH TEST (i.e. SHALLOW + DEEP).

0952 - CALDWELL HAS INSERTED BOTH PROBES: GM-9 @ 8.65
GM-68 @ 20.08
- STRICKLAND CONTINUING DECON.

1000 - CALDWELL OFFSITE TO CALL TALL. OFFICE + PENS. OFFICE

1026 Strickland finishes decon + sets up discharge hose from GM-9 & GM 68 to recovery system @ 450' from monitoring wells

1045 - CALDWELL BACK ON SITE PREPARE FOR PUMP TEST 3

Pump test on GM-68

#3 PRODUCTION OBS. HF

GM-68 GM-9
H_o (20.14) 0.00 (8.5) 0.00
H_f ABORTED BZC

		H_o	H_f
(3)	GM-69	5.74	
	GM-68	20.20	
	GM-9	8.69	

ABORTED

ABORTED DUE TO LOSS OF PUMP SUCTION (W.L. BELOW INTAKE)
- RESET PROBE / INSERTED ~30' INTAKE / CUT THROUGH

(4)	GM-69	5.74	(MEASURED w/ TAPE)
	GM-68	38.87	(CH. 1)
	GM-9	8.81	(CH. 2)

1120. DISCHARGE - UNSTEADY AT FIRST, THEN 1 GAL/
1130: 68 - -17.05 / 9 = -.35 / 69 = 5.74
1136: 68 = -17.04 / 9 = -.26 / 69 = 5.74
PUMP IS LABORING, MAY BE REACHING ITS CAPACITY - DISCHARGE 1 GAL/38 SECS
1143: 68 = -16.87 / 9 = -.24 / 69 = 5.74
1150 68 = -16.83 / 9 = -.15 / 69 - 5.74
1152 68 = -16.93 / 9 = -.13 / 69 = 5.74 - 1 GAL/4
Average discharge was ~1 GAL / 38 secs

(4) RECOVERY DATA ★ NEW 0.00 REF STATIC PUMPING LEVEL.

1154: GM-69 5.74
GM-68 (37.08)
GM-9 (8.67)

1206 ~~GM-69~~
~~GM-68~~
~~GM-9~~

68 - -18.67 / 9 = -.08 / 69 = 5.74

1215 68 - -18.67 / 9 = -.13 / 69 = 5.74
TERMINATED TEST 4.

★ I DON'T KNOW WHY THE READINGS WERE NEGATIVE REF at T=0 WAS NOT 0 ON PRNOUT — HOW THE ΔS APPEARS TO BE INTACT + USEABLE — BZC —

- DRAWDOWN IN PROD WELL (GM-68) - 1.88'
" " OBS WELL (GM-9) - .12
" " OBS WELL (GM-69) - .00

Pump Test on GM-9

TEST (5) H6 HF
GM-68 (CH. 1) (18.81)
GM-69 (hand) 5.74
GM-9 (CH. 2) (8.80)

TEST STARTED ~ 1240, PUMP CUT OFF ~ 2 MINS INTO TEST / TRIED AGAIN @ FULL THROTTLE, PUMPED DRY / TRIED AGAIN @ 1250 w/ 1/2 THROTTLE, LOOKS GOOD. DISCHARGE RATE - 1 gal/18 sec

1302: 68 - 0.00 / GM-9 .51 / 69: 5.74
DISCHARGE: 1 GAL / 1 MIN 20 SECS

1310: 68 0.00 / GM-9 .65 / 69: 5.74
1321: 68 0.00 / GM-9 .82 / 69: 5.74
DISCHARGE: 1 GAL / 63 SECS
1326: 68 0.00 / GM-9 .81 / 69: 5.74
DISCHARGE: 1 GAL / 63 SECS.
* DISCHARGE IS VARIABLE BUT AVGS. ~1 GAL/MIN
1332: 68 0.00 / GM-9 .80

TEST (6)
1334: RECOVERY OF TEST 5

1400
1420 - STRICKLAND DECONNECT CALDWELL COVER LOGGER TO GM-65 and GM-67
DEEP SHALLOW

(7) GM-65 H6 ~~(15.77)~~ 17.02 HF ~~29.~~
GM-67 ~~(8.65)~~ 9.65
~~BH~~

1430 - START UP / DISCHARGE: 16/3 min
1438 - STEPPED UP TO
1445 aborted pump test due to inadequate pumpage
1455 Caldwell call John B. to confirm to do slug test
1515 Caldwell off-site to get slug + string, Strickland removes intake hose from well and rolls up discharge hoses.
1600 - Caldwell back on site; set up slug test
(7) Slug Test on GM 67

(8) GM-65 (1) H6 (15.82) Pump test on GM-6
GM-67 (2) (9.64)
1642: Discharge ~ 1 gal / 45 secs after 1 +
1655: 65 - .88 / 67 - .00 From .86 1.03
Readings are fluctuating - pump disch is variable, but is X ~ 1 gal/
1700 - End of Test (8); Don't know if I would trust the average discharge
(9) Recovery Test on Test (8).
1701 - Start up
1719 - End of Test

1731: Pump test on GM-67

Test #7 Drawdown on GM-67

GM-65 (1) 15.48

GM-67 (2) 9.65

- Test started slowly — Discharge

after 3 mins = fed / 90 secs

after 5.5 mins = fed / 35 secs

1745: 65: 0.00

67 1.12

Discharge 1 gal / 30 sec secs — quite variable.

1750 65: 0.00

67: .85

Discharge 1 gal / 45 secs — quite variable

A check at 1755 indicated same rhys as at 1750 — Caldwell ended Test 7.

($\bar{x}_1$ = 1.6 gpm)

1755: Test #8 Recovery Data on GM-67

Test #7.

Test Terminated approx. 1810.

1755 - 1825: Site stabilization

1825 - Strickland + Caldwell off site

BZC

27 March 90

0120 - Caldwell + Berksdale on site

0120 -

0810 - Decon hose + probes

0810 - Move to GM-11

0850 - GM-11 H_o - 9.16 H

0851 - Start up of Test 7

0850 - End of Test 7 (pumped a total of 28 gallons (7 g

0900 0915 - Caldwell deconned slug + slugged GM

0916 0938 - Slug Test 4 on GM-11 / Berksdale off-

0938 - 0950 - Site stabilization / Caldwell to dec area.

0950 - Layne arrives on site

0956 - ~~[illegible]~~ Discussion w/ Layne;

1010 will Try RW5 first / they will pump pump w/ ½ horse sub, and we will ch w.v. before and after redevelopment.

1010 - Caldwell decons probes / Berksdale back on

1010 - Decon / set up for pumping on GM-

1050 G2(S) and G3(D)

1070 - 1115 - Set up pump test on G2 + G3

1115 - Test 5 H_o

G4 - 4.13 (Lower)

G3 - 23.93 (1)

G2 - 12.05 (2)

★ RW-7 ... close prox ... will pump constantly, ... not affect t

Pump test on GM-63

1120 - Start up

1122 - Cut Pump in — Discharge = 1 gal/min (3.5 3 ...

1138 - G4 - 4.13 / G3 - 6.91 / G2 - .14