GROUNDWATER EXPLORATION PROJECT NEAR FOX CREEK, ALBERTA - PHASE TWO

by: A. VandenBerg

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Phase Two

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PHASE TWO

A. van den Berg, 1969.

INTRODUCTION

This report describes the second phase of an investigation into the groundwater resources of an area adjacent to the proposed site of the Hudson's Bay Oil and Gas Company's gas plant, located two and one-half miles southwest of the town of Fox Creek, Alberta (Fig. 1). The first phase, conducted by R. J. Clissold, consisted of field mapping of surficial groundwater phenomena, collection of water samples for chemical analysis, and the drilling and bail testing of three deep test holes, W.T.H. No. 1, W.T.H. No. 2, and W.T.H. No. 3A (Fig. 2). The findings of this study have been reported in detail (Clissold, 1968) and indicate excellent prospects of developing the required supply of groundwater - 1000 igpm (imperial gallons per minute) for a period of 20 years - from an area within a two mile-radius of the plant and from depths of less than 500 feet.

The objective of the second phase of the investigation was to obtain more precise production test data at the sites of the three test holes and, if necessary, to advise on the construction and testing of production wells at these sites. The first step was to conduct a constant rate pump test of several days on W.T.H. No. 1 and No. 3A, the site of W.T.H. No 2 being inaccessible during the summer months. During the drilling of an observation well - W.T.H. No. 1A -, 200 feet west of W.T.H. No. 1, it appeared that the same zones which were highly productive in W.T.H. No. 1, had only very low transmissibility at the second site. Therefore, it was considered doubtful whether sufficient production could be obtained from this site, and W.T.H. No. 1 was temporarily abondoned.

At the site of W.T.H. No. 3A, results were more encouraging; as in W.T.H. No. 3A, two productive zones were encountered in W.T.H. No. 3B, offset 200 feet to the east, which had transmissibilities similar to the corresponding zones in W.T.H. No. 3A. Both productive zones were pump tested, and their combined production was estimated at 410 igpm. Later, Production Well No. 3 was constructed at this site.

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* W.T.H. = water test hole

The failure of W.T.H. No. 1A as a producer necessitated the drilling of additional exploratory holes. Four more test holes were drilled - W.T.H. No. 4, No. 5, No. 6 and No. 7 - to depths varying between 240 and 600 feet (Fig 2). Of these, W.T.H. No. 4 and W.T.H. No. 5 proved economically productive, as established from constant rate pump tests, and Production Wells No. 2 and No. 1 were respectively constructed at these sites. The safe production rates are estimated at 425 igpm for Production Well No. 1 and 235 igpm for Production Well No. 2.

GEOLOGY

The geology of the area has been described by Clissold (1968), and additional information obtained from W.T.H. Nos 4-7 is given in the drillers' logs (Appendix A) and figure 3.

Surficial deposits: Two types of surficial deposits were encountered during the test drilling: sand and till. The sand occurs in the valley of the creek which runs through the area in a northwesterly direction and discharges in Smoke Lake (Fig. 2). The sand was encountered in W.T.H. No. 3 and No. 5. W.T.H. No. 4 encountered 130 feet of till underlain by 5 feet of gravel. W.T.H. No. 6 and No. 7 encountered thin clay and sandy clay overlying bedrock.

Bedrock deposits: The bedrock sediments are composed of lensing beds of bentonitic shales, siltstones, and sandstones. Coal occurs in thin layers throughout. Some of the thicker sandstones can be correlated between test holes (Fig. 3) but there is no consistant marker in the section above the Ardley coal zone, which was not penetrated during the second phase of the project.

WELL AND AQUIFER EVALUATION

Water Test Hole No. 1A (200' west of #1)

The electric logs and sample logs from W.T.H. No. 1 indicated that the uppermost water producing zone is the interval between 280 and 325 feet below surface. When a depth of 325 feet was reached during drilling of W.T.H. No. 1A, a bail test was first made on the open interval from 226 to 330 feet. The test was run for 50 minutes at the rate of one bailer of 37 ig (Imperial gallons) per minute. Both drawdown and recovery measurements were taken, and the safe production rate is estimated at 12 igpm (Fig. 4).

Drilling was continued and bail tests made at intervals (Figs. 5 to 10); a summary of the results of these tests is given in Table 1. Down to a depth of 450 feet, the estimated safe yield varies between 12 and 36 igpm, values of transmissability are in the 200 to 300 igpd/ft (imperial gallons per day per foot) range, and the average permeability of the open interval varies between 1.0 and 2.3 igpd/ft^2 (imperial gallons per day per square foot). The comparable values from W.T.H. No. 1 (Clissold, 1968, page 25) for the interval from 197-440 feet are: 20-year safe yield - 855 igpm; transmissibility - 13,200 igpd/ft; average permeability - 55 igpd/ft^2.

Table 1

Water Test Hole No. 1A: Summary of Bail Tests

Bail Test No.	Open Interval (ft)	Transmissability (igpd/ft)	Average Permeability (igpd/ft^2)	20-year safe yield (igpm)
1	226 - 330	200 (drawdown)	1.9	12
1	226 - 330	105 (recovery)	1.0	
2	226 - 360	210	1.6	22
3	226 - 375	349	2.3	36
4	226 - 400	215	1.2	24
5	226 - 421	238	1.2	26
6	226 - 435	292	1.4	31
7	226 - 450	223	1.0	24
8	450 - 580	212 (recovery)	1.7	
8	450 - 580	266 (drawdown)	2.0	89

The interval from 450 to 580 feet was tested separately and the results (Fig. 11) are of the same order as for the interval from 226-450 feet. The 20-year safe yield is slightly higher due to the higher available drawdown.

Water Test Hole No. 3A and 3B, Production Well No. 3.

A constant-rate pump test of 7 days was conducted on W.T.H. No. 3A, at the end of which time the casing,(all of which was slotted) had been pulled back to 400 feet below surface. The hole had caved in below a depth of 400 feet. Although the drawdown curve (Fig. 12) indicates a high transmissibility of 59,400 igpd/ft, there is a sharp increase in the rate of drawdown at t(=time since pumping started) = 500 minutes. The estimated drawdown after 20 years, obtained by extrapolating the last observed trend of 4.9 ft. per log cycle, therefore is high and the safe production rate low (88 igpm).

However, it was felt that this low estimate in part could be caused by poor well performance, and a new test hole was drilled (W.T.H. No. 3B). Two separate pump tests and one bail test were made in this hole, the first pump test being on the open interval from 30-65 feet below ground level, in the sandstone directly underlying the surficial deposits (Fig. 3). The drawdown curve for this test (Fig. 13) is completely different from the curve for W.T.H. No. 3A; in Figure 13 the initial drawdown trend is quite steep, giving a low transmissibility value of 3400 igpd/ft., which trend suddenly decreases in slope at t=20 minutes. Extrapolation of the last established drawdown trend gives a 20-year safe yield of 225 igpm.

The shallow aquifer was then cased off, and drilling continued to a depth of 250 feet. The second water-yielding zone, a sandstone between depths of 133 and 236 feet was first bail tested (Fig. 14) and then pump tested (Fig 15). The transmissibility values derived from the recovery of the bail test, the drawdown during the pump test, and the recovery of the pump test are in reasonable agreement - 14,300, 13,900 and 12,800 igpd/ft, respectively - and, furthermore, no change in slope of the drawdown trend due to boundaries or inhomogeneities occured during the 3000 minutes duration of the pump test. The 20-year safe yield was estimated as 285 igpm.

Production Well No. 3 was drilled at this site; it encountered soft sandstone from 33-61 feet and alternating beds of hard and soft sandstone from 163-215 feet. Completion details are given in Appendix E. At the time of the writing of this report, no production test has been conducted on this well.

Water Test Hole No. 4 - Production Well No. 2

During drilling of this hole, the first large influx of water was encountered in the interval from 155-240 feet which consists of sandstone, argillaceous sandstone, and coal. An initial bail test (Fig. 16) indicates a transmissibility of approximately 25,000 igpd/ft and a 20-year safe yield of 760 igpm.

A subsequent pump test on the same open interval (Fig. 17) indicates a transmissibility of 14,400 igpd/ft (recovery data) or 21,700 igpd (drawdown data). The 20-year safe yield is estimated at 390 igpm, but because of large fluctuations in the water level during the pumping test, values of transmissibility and the estimated 20-year safe yield are subject to appreciable error.

Drilling was continued to a depth of 650 feet to test for the presence of deeper sandstone beds as encountered in W.T.H. No. 3A and No. 3B. Both the sandstones at 2250 and 2450 feet above sea level were encountered but, neither of these yielded appreciable water, as shown by bail test No. 2 (Fig. 18), which was conducted on the open interval from 138-650 feet, including the zone tested previously. The drawdown trend does not indicate an increase in the safe production rate.

Consequently, Production Well No. 2 was drilled at this location and completed with a screen and gravel pack from 156-240 feet.

A pump test was conducted after development of the well by surging, the results of which are shown in figure 19. An observation hole was drilled 200 feet away from the Production Well, but failed to respond to the pumping because excessive caving occurred before casing could be installed, which completely blocked off the producing zone. During the early part of the pump test, some difficulty was encountered with large amounts of sand and clay in the water. The water became fairly clear after 1 hour, but a sudden increase in clay and sand content occurred between 60 and 85 minutes after the pump was started. At the same time there was a noticable decrease in the rate of drawdown, which lasted for approximately 2 hours, after which drawdown continued to increase at the previous rate of approximately 4.6 feet per log cycle. The graph beyond $t \cong 500$ minutes seems to indicate a stable well; at t=1000 minutes an increase in the rate of drawdown to 8.6 feet per log cycle occurred. The scatter of the points near the end of the pump test is caused by a decrease in the pumping rate from 310 igpm to 265 igpm.

A transmissibility of 17,800 igpd/ft is indicated on the early part of the drawdown curve.

To establish the well-loss coefficients of the completed Production Well, two step-drawdown tests were conducted (Appendix D). In the first test the rate of discharge was varied stepwise between 240 and 310 igpm (Fig. 20), and in the second test between 159 and 217 igpm (Fig. 21). In both tests the duration of each step at constant discharge rate was 50 minutes. Another datum used in the analysis is the drawdown at 50 minutes during the constant rate test at 310 igpm. Values of Q and s/Q, where s = drawdown (ft.) after 50 minutes and Q = the pumping rate in igpm, is given in table 2.

Table 2

Production Well No. 2: Summary of step-down tests

Step-drawdown Test No.	Step	Q	s/Q
2	1	159	0.051
2	2	179	0.054
2	3	198	0.058
2	4	217	0.062
1	4	240	0.079
1	3	260	0.078
1	2	275	0.078
1	1	310	0.075
constant rate rest	-	310	0.082

The data from the second test and the constant rate test together give a consistent trend of increasing specific drawdown with increasing pumping rate. The data from the first test, however, does not fit on this trend; in themselves they would indicate a specific drawdown of 0.0775 ft/igpm (average), irrespective of the pumping rate. The data in figures 20 and 21 show that the extrapolation of the first three steps to 100 minutes, needed in the analysis, is straightforward for the second test, but is subject to different interpretations for the first test. The data in the first test, therefore, are considered less reliable and omitted from the analysis. If it is assumed that s_{50}, the drawdown at 50 minutes after pumping started, is a function of Q of the form

$$s_{50} = B_t Q + CQ^P \quad \text{----------} \quad (1)$$

where B_t = the specific formation loss after 50 minutes pumping and
CQ^P = the well loss for pumping rate Q,

the constants B_t, C and P are found by using Rorabaughs method (Fig. 22).

A reasonable fit to the five values of s/Q is obtained with $B_t = 0.03$, $C = 0.00002$ and $P = 2.37$. If the values for C and P are used, the well-loss at Q = 310 is calculated as 16.05 feet from eq. (1). From the constant-rate test, the formation loss at 20 years is the estimated drawdown after 20 years minus the well loss = 66.20 - 16.05 = 50.15 feet, and the specific formation loss at 20 years = $\frac{50.15}{310} = 0.162$ feet. The complete equation for the drawdown after 20 years then becomes

$$s_{20\ yr} = 0.162Q + 0.00002Q^{2.37} \quad \text{----------} \quad (2)$$

Some values of s vs. Q are given in table 3. Given the available drawdown of 156 (top of screen) - 94 = 62 feet, the safe yield can be estimated at 295 igpm.

Table 3
Drawdown after 20 years pumping

Q (igpm)	Drawdown (feet)
280	57.97
285	59.32
290	60.68
295	62.06
300	63.45

Water Test Hole No. 5 and Production Well No. 1

At this site two water-yielding zones were tested: (1) sandstone from 43-70 feet below surface, overlain by 28 feet of sand: and (2) sandstone from 185-240 feet below surface. The latter zone was bail-tested (Fig. 23 and Appendix C), the results indicating a transmissibility of 1060 igpd/ft and a 20-year safe yield of 35 igpm.

The upper zone was pump-tested at a constant rate of 345 igpm for 13,000 minutes (9 days). The plot of drawdown versus time (Fig. 24) indicates a transmissibility of 142,000 igpd/ft. A gradual increase in the rate of drawdown occurs at approximately 500 minutes. Towards the end of the test the rate of drawdown reached a value of 6.71 feet/log cycle, indicating limited areal extent of the aquifer; the 20-year safe yield was estimated at 370 igpm.

Subsequently, Production Well No. 1 was drilled at this site and completed with a 29-foot section of 9" O.D., 60 slot screen, packed with No. 8-12 frac. sand. However, the 16" O.D. surface casing was not set far enough in the sandstone, allowing loose fine surficial sand to move through the pack and screen into the well, causing excessive cavitation (Fig. 25). Therefore, the well had to be abandoned and a new well successfully completed nearby.

Throughout the construction and development of this well, specific drawdown after 30 minutes pumping was measured by means of short pump tests. The results of these tests are shown in figure 26. The first of these tests was conducted on the open hole and gave a specific drawdown of 0.0149 ft/igpm; on introduction of the screen and pack - No. 8-12 frac sand -, this increased to 0.0535 ft/igpm. As it is believed that this poor result was caused by too fine a pack material, the screen was pulled, the frac sand bailed out, and the screen replaced and packed with 3/8" pea gravel. Completed in this manner, the well had a specific drawdown of 0.0424 ft/igpm, a slight improvement over the previous test. Subsequent development of the well, however, had a much greater beneficial effect on its performance, finally reducing the specific drawdown to 0.0101 ft/igpm, or slightly less than for the undeveloped open hole.

To evaluate the well loss in the completed Production Well, a step-drawdown test was carried out (Appendix D) in which the pumping rate was varied between 240 and 437 igpm in four steps. The observed drawdowns are plotted in figure 27, and calculated values of s/Q for the different pumping rates are given in table 4.

Table 4

Production Well No. 1

Specific drawdown after 50 minutes

Q	s/Q
240	0.0106
285	0.0106
365	0.0108
395	0.0106 - (from constant rate test No. 2)
437	0.0112

Table 4 indicates that the specific drawdown is constant up to a pumping rate of at least 395 igpm; the higher value for Q = 437 igpm cannot be entirely due to error because the increase of 0.0006 ft/igpm from the value at 395 igpm represents a drawdown difference of approximately 0.25 ft. Because only two points of the curve $s/Q = B_t + CQ^{P-1}$ are known (at Q = 395 igpm and at Q = 437 igpm), only two equations in the three unknowns B_t, C and P are available; therefore it is arbitrarily assumed that, for pumping rates larger than 395 igpm, P has the value of two, that is, the well-loss is proportional to the square of the pumping rate. Thus, from the relation

$$s/Q = B_t + CQ \quad \text{----------} \quad (3)$$

and substituting values of s/Q and Q for Q = 395 igpm and Q - 437 igpm, the coefficients B_t and C are found to be 0.005 and 1.43×10^{-5}, respectively.

An observation well, W.T.H. No. 5B, was drilled 160 feet south of Production Well No. 1; a constant rate pump test was run on June 15, 1968, but the pump failed after approximately 2000 minutes. Because the exact time of the pump failure is not known, the recovery measurements could not be used. Moreover, the recovery data for the observation well shows either incomplete recovery of the observation well to nonpumping level at the time the test began, or large natural fluctuations; consequently, the data from the observation well can not be used to determine the aquifer constants. The drawdown in the pumped well indicates a transmissibility of 213,000 igpd/ft (Fig. 28). Pump test No. 2 ran for 6270 minutes at a rate of 395 igpm. The nonpumping level was

again lower than during the first test, both in the production well and the observation well. However, the level had been stable for some days, and both wells had recovered from the step drawdown test on the previous day to within 0.05 feet of their nonpumping level before the step drawdown test.

Figure 29 shows the drawdown curve for the production well; the initial rate of drawdown indicates a transmissibility of 1,490,000 igpd/ft. The rate of drawdown increases steadily towards the end of the test; a comparison with the pump test on W.T.H. No. 5 at the same site, which lasted 13,120 minutes, indicates furthermore that an additional increase can be expected for t between 6000 and 13,000 minutes. Therefore, in order to calculate the safe yield for a 20-year period, the final trend of the drawdown of pump test No. 1, W.T.H. No. 5, was adjusted to the pumping rate of the present test, giving a slope of 7.06 ft/log cycle. This slope was then used to extrapolate the drawdown graph to 10^7 minutes. Therefore, total drawdown at the pumping rate of 395 igpm should be, after 20 years, 28.5 ft. Of this, 2.23 ft. is well loss, as calculated with the approximate formula, well loss = $CQ^2 = 1.43 \times 10^{-5} Q^2$ and the formation loss becomes 28.5 - 2.23 = 26.2 feet. The complete formula for the 20-year drawdown as a function of pumping rate is then:

$$s = 0.0663Q + 1,43 \times 10^{-5} Q^2 \quad \text{----------} \quad (4)$$

If the available drawdown is taken as the difference between the depth of the top of the screen and the nonpumping level previous to pump test No. 2 = 51 - 11.5 = 39.5 feet, the 20-year safe yield can be computed as 535 igpm.

The drawdowns measured in Observation Well No. 5B are shown in figure 30. If the early part of the drawdown curve is used, values of 870,000 igpd/ft and 8.2×10^{-3} are obtained for transmissibility and storage coefficient, respectively. The deviation of the drawdown curve from the type curve after only 16 minutes indicates inhomogeneities in, or impermeable boundaries to, the aquifer in the immediate vicinity of both wells. If the latter part of the drawdown curve is used only to calculate aquifer coefficients, the transmissibility is found to be 94,000 igpd/ft and the storage coefficient 0.106; these values may be more characteristic of the average values over a large area of the aquifer. If these latter values for transmissibility and storage coefficient and an effective well radius of 8 inches - the radius of the outside of the gravel pack - are used, the specific drawdown after 20 years of production can be calculated as 0.0272 ft/igm, only 40 percent of the value of 0.0663 ft/igpm found previously from the step-drawdown test data.

Water Test Hole No. 6

Two prospective zones were tested at this site:

(1) a sandstone bed from 80-100 feet below surface;

(2) a sandstone bed from 240-250 feet below surface.

The upper zone was first bail-tested at a rate of 30 igpm (Fig.31). The early part of the drawdown curve and the recovery curve indicate a transmissibility of 1800 igpd/ft. After the first 20 minutes the drawdown stabilized at approximately 10 ft. from both the drawdown and the recovery curve (Fig.32). Although a decrease in the rate of drawdown occurred, the expected 20-year safe yield is only 46 igpm, due to the high initial rate of drawdown. The decrease in the rate of drawdown at an early time seems to indicate that the aquifer has higher transmissibility at a short distance away from the well. The deeper zone was bail-tested at a rate of 37 igpm. The drawdown curve is shown in Figure 33. The transmissibility is in the range from 135 igpd/ft (recovery curve) to 200 igpd/ft (drawdown curve). The 20-year safe yield is 22 igpm.

Water Test Hole No. 7

The first aquifer encountered during the drilling of W.T.H. No. 7 is a sandstone from 59-95 feet below surface. Pump test No. 1, conducted on this interval at a rate of 220 igpm, gave a transmissibility of 5500 igpd/ft and an estimated 20-year safe yield of 37 igpm (Fig.34).

A bail test on the second zone, a sandstone from 133-222 feet below surface, was first conducted at a rate of 37 igpm from which the transmissibility was estimated at 3900 igpd/ft and the 20-year safe yield at 65 igpm (Fig.35). A subsequent pump test, (Fig. 36), indicated a transmissibility of 20,7000 igpd/ft (drawdown curve) or 6700 igpd/ft (recovery curve). The estimated 20-year safe yield is 100 igpm.

SUMMARY AND CONCLUSIONS

Table 5 summarizes the results of the bail and pump tests; the total recommended production from the three production wells is 1070 igpm, which figure includes a safety factor of 0.8.

No economically productive zones were encountered below a depth of 250 feet; although thick sandstone beds were encountered below this depth, estimates of 20-year production capacity were below 100 igpm, which was considered too low for economical production.

Transmissibilities of the economically productive zones range from 3,400 to 142,000 igpd/ft., and permeabilities range from 97 to 5700 igpd/ft^2. The high permeabilities are almost certainly due to fracturing which seems to occur at relatively shallow depths only.

The evidence from test holes No. 1 and No. 1A indicates that abrupt lateral changes in transmissibility occur; as no major lithologic differences exist between these two test holes, the differences in permeabilities of the formation must be due to differences in the extent of fracturing at the two locations.

Local variations in the extent of fracturing as well as lensing of the strata also accounts for the time-variation of the rate of drawdown evident in most of the pump tests and in some of the bail tests. Especially noteworthy in this respect is the pump test on W.T.H. No. 6 (Fig. 32) which indicates that, although the sandstone from which the test hole is producing has a low permeability of only 50 igpd/ft^2, the cone of depression soon expanded into a high permeability area, as indicated by the strongly decreased rate of drawdown after approximately 30 minutes pumping. It is therefore quite likely that an economically productive well could be obtained in the immediate vicinity of W.T.H. No. 6.

For the production of groundwater the surficial sand deposits in the area are of almost equal importance to the fractured bedrock sandstones. Production Wells No. 1 and No. 3, although the screens are set in sandstone, undoubtedly obtain a large fraction of the water from the sand directly overlying the screened zone.

Not enough data are available to outline the areas in which fractured-bedrock or surficial sand occurs: the sand is probably limited to the drainage channels, where it must have been deposited in pre-Pleistocene or Pleistocene time, as it is overlain by boulder clay in W.T.H. No. 5.

Fracturing of the bedrock may well be caused by preglacial landsliding and therefore may occur primarily along the flanks of the preglacial valleys which are incised in the bedrock, as suggested by Toth (1966).

Aquifer and well evaluation in the area are hindered by the inhomogeneous nature of the sediments, and there is no assurance that drawdown trends established during relatively short pump tests will be valid for prolonged periods. A complete evaluation of the groundwater resources of the area would be possible only after considerably more reconnaissance drilling, preferably with rotary equipment, and one or more major pump tests, during which waterlevels should be recorded in a sufficient number of observation wells to observe the shape of the developing cone of depression.

The recommended maximum pumping rates in table 5 are believed to be reliable and the best evaluation possible from the available data, however, caution is indicated for the reasons given earlier; it is especially recommended that precise records of production rates be kept on all producing wells and weekly measurements of water levels be made throughout the producing life of the wells.

Edmonton, May 1, 1969 A. Vandenberg

References

1. Clissold, R.J. (1968): Groundwater exploration project near Fox Creek, Alberta; Res. Coun. Alberta unpublished report, 72 pages.

2. Toth, J. (1966): Groundwater geology, movement, chemistry, and resources near Olds, Alberta; Rex. Coun. Alberta Bulletin 17, 126 pages.

Table 5

Summary of results of production tests

Well or testhole	Depth interval (feet)	Transmis-sibility (igpd/ft)	Average permeability of open interval (igpd/ft^2)	Permeability of aquifer (igpd/ft^2)	Production capacity for 20 years (igpm)	Recommended maximum pumping rate = 80% of production capacity (ipgm)	
WTH No. 1A	226-450	230 av.	1.5	-	26	20	95 igpm
WTH No. 1A	450-580	240	-	8	89	75	
WTH No. 3B	30- 65	3,400	-	97	225	180	410 igpm
WTH No. 3B	153-236	13,300	-	100	285	230	
WTH No. 4, PW No. 2	157-240	18,000	217	-	295	235	
WTH No. 5, PW No. 1	43- 70	142,000	-	5700	535	425 *	
WTH No. 6	80-100	1,000	-	50	46	36	
WTH No. 7	59- 95	5,500	-	150	37	30	110 igpm
WTH No. 7	133-222	20,700	-	230	100	80	

APPENDIX A: DRILLERS LOGS

TEST hole No. 4

Interval (feet)	Description
0-105	Clay
105-130	Clay, hard
130-135	Gravel
135-140	Shale, sandy
140-145	Shale, sticky
145-150	Shale, sandy, hard
150-155	Shale, sandy
155-170	Sandstone
175-245	Sandstone, shale and coal
245-275	Shale
275-280	Shale and coal
280-320	Shale
320-325	Shale, hard
325-335	Sandstone, hard
335-340	Sandstone and shale
340-350	Shale
350-369	Shale and coal
369-400	Shale
400-410	Shale, hard
410-420	Shale and coal
420-435	Shale
435-440	Shale, hard
440-445	Shale, hard and sandstone
445-495	Shale, hard
495-505	Shale and coal

Interval (feet)	Description
505-511	Shale
511-515	Shale and sandstone
515-525	Sandstone
525-532	Sandstone, hard
532-545	Sandstone
545-550	Shale and coal
550-585	Shale, sticky
585-595	Shale, hard
595-600	Shale and coal
600-615	Shale, sticky
615-620	Shale and coal

Test hole No. 5

Interval (feet)	Description
0- 8	Clay and boulders
8- 15	Clay, sandy
15- 43	Sand
43- 70	Sandstone, light grey, medium size, silty
70- 75	Sandstone, clayey
75- 80	Shale
80- 85	Sandstone, very silty and clayey, grading to sandy shale
85- 90	Shale, in part silty and sandy
90-130	Shale
130-140	Siltstone, light grey
140-145	Shale
145-150	No sample
150-155	Shale

Interval (feet)	Description
155-160	Shale, dark brown, waxy
160-165	Sandstone, grey, medium size
165-170	Sandstone, light grey, very fine
170-175	Shale, dark grey, minor sandstone
175-180	Sandstone, light grey, fine, clayey
180-185	Sandstone, light grey, very fine, silty
185-205	Sandstone, light grey, medium size
205-210	Sandstone, light grey, fine
210-240	Sandstone, light grey, medium size
240-260	No sample
260-265	Shale
265-270	Shale and coal
270-275	Shale
275-280	No sample
280-285	Shale, brown grey, trace coal
285-290	No sample
290-300	Shale, dark brown, and coal
300-305	Shale, dark brown, carbonaceous
305-310	No sample
310-315	Shale
315-320	Coal and carbonaceous shale
320-340	Shale
340-350	No sample
350-355	Shale

Test hole No. 6

Interval (feet)	Description
25- 40	Sandstone, light brown, medium size
40- 45	Sandstone, light brownish grey, fine

Interval (feet)	Descritpion
45- 55	Sandstone, light brownish grey, fine, clayey
55- 65	Shale, very sandy
65- 75	Sandstone, light grey, medium size
75- 80	Shale, very sandy
80-100	Sandstone, light grey, medium size
100-140	Shale, sandy
140-170	Shale
170-175	Sandstone, light grey, fine
175-180	Sandstone, light grey, fine, clayey
180-190	Shale, sandy
190-195	Shale, dark brown, carbonaceous
195-210	Shale, greenish grey
210-235	Shale and bentonite
235-240	Shale, sandy
240-245	Sandstone, grey, hard
245-335	Sandstone, grey, alternating soft and hard
335-347	Sandstone and coal stringers
347-350	Shale
350-368	Shale, bentonitic, hard
368-371	Shale and coal
371-381	Shale and bentonite
381-385	Shale and coal
385-387	Shale, hard

Test hole No. 7

Interval (feet)	Description
0- 7	Clay, sandy
7- 42	Sand
42- 59	Shale
59- 81	Sandstone
81- 84	Shale
84-103	Sandstone
103-133	Shale
133-222	Sandstone
222-249	Shale and bentonite
249-254	Shale, hard, and coal
254-270	Coal
270-276	Coal and shale

APPENDIX B: PUMP TEST DATA

T.H. No. 3A, pump test No. 1: drawdown in pumped well

)ate :Feb. 13-20, 1968

nping rate :180 i gpm

)pen interval :perforated 0-400 ft.

tic level :5.31 ft. below top of casing

ıe since nping started (minutes)	Drawdown	Time since pumping started (minutes)	Drawdown (feet)
1	10.00	480	12.16
2	10.37	540	12.22
3	10.54	600	12.38
4	10.66	720	12.45
5	10.73	840	12.53
6	10.79	960	12.71
7	10.84	1200	12.99
9	10.92	1440	13.40
10	10.95	1620	14.10
12	11.01	1800	14.40
14	11.01	2100	14.76
16	11.03	2520	15.63
18	11.07	3000	15.80
20	11.09	3480	15.82
25	11.09	3960	15.82
30	11.09	4560	16.53
40	11.09	5220	17.09
50	11.68	5820	16.20
60	11.70	6420	16.24
120	11.83	7020	16.31
180	11.93	7980	16.70
240	12.01	9060	17.08
300	12.05	10260	17.36
360	12.10	10320	no measurement
420	12.14		

T.H. No. 3A pump test No. 1 :recovery of pumped well.

me since oing started (minutes)	Time since pumping started / Time since pumping stopped	Residual drawdown (feet)
321	10321	17.37
2	5161	14.05
323	3441	11.75
324	2581	10.90
325	2065	9.05

.H. No. 3B, pump test No. 1: drawdown in pumped well

	:March 1 - 4, 1968
ing rate	:235 igpm
interval	:30 - 65 ft.
vation well	:W.T.H. No. 3A, 200 ft. from pumping well.

ce g started tes)	Drawdown (feet)	Time since pumping started (minutes)	Drawdown (feet)	Time since pumping started (minutes)	Drawdown (feet)
)	0	30	25.39	870	25.13
	10.01	40	25.44	990	25.77
	15.15	60	24.67	1110	25.70
	18.40	90	24.52	1230	25.14
	19.47	120	24.66	1410	25.94
	20.59	150	24.27	1590	25.64
	21.36	180	24.21	1890	25.01
	21.81	210	24.14	2190	25.08
	22.52	270	23.94	2490	26.29
	22.82	330	23.93	2790	26.64
	23.17	390	23.27	2970	26.68
	23.78	450	23.54	3210	26.48
	24.25	510	23.69	3630	26.37
	24.66	570	24.62	3990	26.29
	24.98	630	25.69	4329	26.29
	25.25	750	25.14		

T. No. 3B, pump test No. 1: recovery of pumping well.

t/t' ;)	Drawdown (feet)	t (minutes)	t/t' .	Drawdown (feet)
4330	11.62	4354	174	2.48
2165	8.37	4359	145	2.36
1444	6.68	4364	124	2.23
1083	5.65	4369	109	2.16
867	4.93	4379	87	2.06
722	4.36	4389	73	1.95
620	4.11	4399	63	1.87
542	3.89	4409	55	1.77
482	3.60	4420	49	1.73
434	3.47	4430	45	1.64
395	3.29	4470	32	1.43
362	3.16	4590	17.8	1.05
289	2.88	5100	6.6	0.26
217	2.62	5500		flowing

t = time since pumping started
t' = time since pumping stopped

W.T.H. No. 3B, pump test No. 1 :drawdown in observation well W.T.H. No. 3A
Static level: 7.38 ft. below top of casing.

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
0.22	180	1.66	1500	3.11
0.52	210	1.72	1620	3.18
0.65	340	1.92	1740	3.20
0.86	370	1.97	1860	3.28
0.97	400	2.02	1980	3.36
1.07	430	2.08	2100	3.40
1.24	460	2.10	2375	3.50
1.25	490	2.14	2440	3.65
1.26	520	2.20	2560	3.72
1.26	535	2.21	2680	3.80
1.30	600	2.32	2800	3.84
1.36	660	2.41	3040	3.93
1.40	780	2.51	3280	3.99
1.42	900	2.64	3520	4.05
1.46	1020	2.76	3760	4.14
1.55	1140	2.85	4000	4.23
1.61	1260	2.90	4240	4.27
	1380	3.03	4329	4.27

W.T.H. No. 3B, pump test No. 2

Date :March 23-26, 1968
Pumping Rate :250 igpm.
Open interval :123-250 feet
Observation well: W.T.H. No. 3A, 200 feet from pumping well

Drawdown in pumped well (static level = 88.65 ft. below t.o.c.)

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
23.39	25	29.73	660	36.53
25.20	30	30.03	720	36.79
25.75	40	30.62	780	36.98
26.31	50	31.06	900	37.33
26.67	60	31.48	1020	37.48
27.22	120	32.97	1260	37.99
27.46	180	34.06	1380	38.18
27.74	240	34.48	1500	38.31
27.92	300	34.94	1680	38.41
28.29	360	35.42	1800	38.51
28.56	420	35.58	2040	38.94
28.75	480	35.78	2400	39.27
28.97	540	35.94	2700	39.53
29.18	600	36.38	3060	39.66

W.T.H. No. 3B, pump test No. 2

Recovery of pumped well

t/t'	drawdown (feet)	t (min)	t/t'	drawdown (feet)	t (min)	t/t'	drawdown (feet)
3061	19.29	3074	219	14.25	3300	13.8	7.35
1531	18.12	3076	205	14.25	3420	9.5	6.73
1021	17.45	3078	171	13.65	3540	7.4	6.17
766	16.85	3080	154	13.42	3660	6.1	5.79
613	16.45	3085	123	12.89	3780	5.2	5.49
511	16.04	3090	104	12.45	3900	4.6	5.21
438	15.71	3100	78	11.74	4020	4.2	4.98
383	15.44	3110	62	10.45	4140	3.8	4.78
341	15.21	3120	52	10.09	4260	3.6	4.59
307	14.98	3180	26.5	8.92	4380	3.3	4.45
256	14.59	3240	18	8.15	4500	3.1	4.30

. T. H. No. 3B, pump test No. 2

Drawdown in observation well

(static level 5.80 ft.)
(below top of casing)

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
0.02	467	0.23	1650	0.39	3450	0.51
0.05	587	0.24	2042	0.40	3600	0.53
0.09	633	0.27	2220	0.44	3860	0.54
0.11	708	0.28	2415	0.46	4120	0.55
0.14	800	0.29	2510	0.47	4480	0.58
0.16	930	0.30	2730	0.48	5040	0.59
0.18	1050	0.33	3030	0.49	5820	0.65
0.19	1260	0.34	3230	0.50		
0.21						

/.T.H. No. 4, pump test No. 1

ate :March 11, 1968
umping rate :235 Imperial gallons per minute
Open interval :138-245 feet
Aquifer :Sandstone, 155-240 feet
tatic level :94.85 feet below top of casing

Drawdown, pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
15.65	14	19.37	150	21.46	870	24.45
17.33	16	19.42	180	24.20	990	24.31
17.83	18	19.42	210	24.32	1170	24.83
17.97	20	19.59	240	25.13	1290	24.42
18.35	25	20.45	270	24.62	1530	24.17
18.23	30	20.48	300	24.46	1770	24.23
18.48	40	21.81	360	24.30	2010	24.73
18.73	50	22.36	420	23.93	2370	25.33
18.77	60	22.70	510	25.13	2790	25.47
18.86	90	23.68	630	24.77	3270	26.96
19.27	120	24.96	750	24.58	3590	27.00

Recovery, pumped well

t/t'	drawdown (feet)	t (min)	t/t'	drawdown (feet)	t (min)	t/t'	drawdown (min)
1796	11.01	3602	300	10.13	3650	61	8.97
1178	10.57	3604	257	10.11	3680	41	8.50
898	10.51	3606	225	10.05	3710	31	8.14
719	10.47	3608	200	9.95	3770	21	7.53
599	10.43	3610	181	9.89	3800	18.1	7.06
514	10.38	3615	145	9.75	3830	16	6.87
450	10.31	3620	121	9.61	3860	14.3	6.68
400	10.30	3630	91	9.34	3890	13	6.51
360	10.35	3640	73	9.14	3920	11.9	6.35

W T.H. No. 5, pump test No. 1

Date :April 16-25, 1968
Pumping rate :~~45-80 feet below ground level~~ 345 gpm
Open interval :45-80 feet below ground level
Aquifer :Sandstone, from 45 - 70 feet below ground level, overlain by sand.
Static level :12.28 feet below ground level.

Drawdown in pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
4.18	20	6.44	630	7.52	4050	8.80
5.91	25	6.48	690	7.56	4590	8.97
6.00	30	6.53	810	7.65	5010	9.08
6.12	40	6.60	930	7.72	5190	9.08
6.16	50	6.74	1050	7.79	7410	9.71
6.17	60	6.81	1290	7.92	8010	9.91
6.18	90	6.97	1530	8.00	8670	10.07
6.20	150	7.13	1830	8.10	9030	10.21
6.24	210	7.21	2010	8.09	9810	10.39
6.26	270	7.23	2310	8.22	10530	10.60
6.32	330	7.27	2610	8.30	11490	10.81
6.34	390	7.33	2910	8.42	2030	10.93
6.37	450	7.46	3270	8.49	12910	11.22
6.40	510	7.43	3690	8.61		

Recovery in pumped well

t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)
12911	3.50	12926	808	2.88
6456	3.44	12928	718	2.85
4304	3.33	12930	647	2.82
3228	3.19	12935	517	2.79
2583	3.12	12940	431	2.79
2152	3.08	12950	323	2.68
1845	3.06	12960	259	2.62
1614	3.02	12970	216	2.55
1435	3.00	13000	144	2.29
1292	2.98	13060	88	1.73
1080	2.97	13120	62	1.35
923	2.92			

V.T.H. No. 6, pump test No. 1

Date :April 10-13. 1968
umping rate :126 Imperial gallons per minute
)pen interval :83-153 feet below top of casing
quifer :Sandstone, from 80-100 feet below top of casing
tatic level :58.51 feet below top of casing

Drawdown of pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
16.86	20	48.71	330	50.87	1140	53.39
25.51	25	49.26	360	50.71	1260	53.39
32.73	30	49.63	390	51.07	1380	53.52
35.63	40	49.81	420	51.31	1500	53.72
38.11	50	50.22	450	51.50	1740	54.22
39.45	60	50.36	480	52.32	1980	53.92
41.03	90	50.54	540	52.83	2280	54.00
43.05	120	50.30	600	52.53	2700	53.98
43.98	150	50.37	660	52.68	3000	53.86
44.85	180	50.71	720	52.84	3300	53.92
46.17	210	51.33	780	52.92	3600	53.70
47.04	240	51.14	840	53.15	3900	53.86
47.96	270	51.07	900	53.13	4200	54.01
48.43	300	50.79	1020	53.36	4440	53.70

Recovery of pumped well

t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)
4441	39.00	4530	50	2.90
2221	24.86	4560	38	2.68
1481	20.48	4590	31	2.49
1111	15.06	4620	26	2.30
889	11.92	4650	22	2.18
741	9.48	4680	19.5	2.08
635	7.91	4740	15.8	1.92
556	6.82	4770	14.5	1.85
494	6.17	4800	13.3	1.82
445	5.83	4830	12.5	1.79
318	4.80	4850	11.5	1.76
279	4.48	4880	10.9	1.72
248	4.19	4910	10.3	1.69
223	3.99	4970	9.2	1.63
179	3.77	5030	8.4	1.56
149	3.62	5090	7.7	1.49
112	3.47	5150	7.2	1.43
90	3.34			

t = time since pumping started

W.T.H. No. 7, pump test No. 1

ate : May 22, 1968
mping rate :235 igpm, dropped to 220 igpm after 4 hrs. and to 200 igpm at end of test
pen interval :47-110 feet below top of casing
quifer :Sandstone, from 59-95 feet below top of casing
Static level :3.25 feet below top of casing

Drawdown of pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
28.25	12	49.36	120	59.22	720	81.87
41.14	14	49.55	180	61.70	780	84.13
42.77	16	50.56	240	64.05	840	85.38
45.28	18	50.70	300	66.56	900	87.23
46.32	20	50.98	360	68.54	960	91.09
47.73	25	51.28	420	69.96	1020	91.75
48.16	30	51.97	480	72.94	1080	93.05
48.56	40	53.34	540	74.19	1150	98.00
48.85	50	54.87	600	77.95		
48.94	60	55.59	660	80.69		

Recovery of pumped well

t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)
1151	63.98	1160	116	40.99	1190	30	36.54
576	52.58	1162	97	39.81	1195	26	36.00
384	46.63	1164	83	39.49	1200	24	35.60
289	43.36	1166	73	39.10	1210	20	33.66
231	42.71	1168	65	38.89	1240	13.7	30.41
193	42.39	1170	58	38.59	1270	10.5	28.15
165	41.94	1175	47	37.89			
145	41.65	1180	39	37.46			
129	41.40	1185	34	36.66			

W T.H. No. 7, pump test No. 2.

Date :June 3 - 5, 1968
Pumping rate :165 igpm
Open interval :127 - 276 feet below top of casing
Aquifer :Sandstone, from 133 - 222 feet below top of casing
Static level :95.02 feet below top of casing.

Drawdown of pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
45.43	16	49.50	360	51.83	1200	52.77
48.23	18	49.53	420	51.98	1380	52.87
48.24	20	49.55	480	52.11	1620	52.93
48.25	25	49.58	540	52.18	1800	53.01
48.28	30	49.70	600	52.21	2100	53.25
48.30	40	49.94	660	52.34	2520	53.58
48.30	50	49.96	720	52.39	3000	53.80
48.88	60	49.96	780	52.45	3540	54.10
48.98	120	51.20	840	52.47	4000	54.26
49.00	180	51.28	900	52.50	4480	54.50
49.21	240	51.48	960	52.64		
49.38	300	51.75	1020	52.67		

Recovery of pumped well

t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)	t (min)	t/t'	res. drawdown (feet)
4481	54.43	4494	321	15.86	4660	26.0	6.23
2241	53.29	4496	281	14.65	4720	19.7	5.74
1494	53.31	4498	249	13.40	4780	15.9	4.70
1121	48.59	4500	225	12.02	4840	13.4	4.30
897	28.94	4505	180	11.64	4900	11.7	3.92
748	22.45	4510	150	10.50	4960	10.3	3.46
641	21.28	4520	113	9.96	5020	9.3	2.90
561	20.92	4530	91	9.69	5080	8.5	2.52
449	18.82	4540	76	8.85	5140	7.9	1.96
374	17.92	4600	38	7.12			

= time since pumping started
' = time since pumping stopped

Production Well No. 1, pump test No. 1

Date :June 15 - 16, 1968
Pumping rate :460 igpm
Open interval :43 - 73 feet below fround level : No. 60 slot screen, 8" O.D., and packed with No. 8-16 sand.
Aquifer :45 - 70 feet, sandstone.
Static level :9.83 feet below ground level.

Drawdown of pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
5.09	12	5.59	120	6.09	900	7.19
5.15	14	5.65	180	6.27	1020	7.23
5.21	16	5.73	240	6.42	1200	7.27
5.25	18	5.82	300	6.63	1380	7.34
5.32	20	5.79	360	6.79	1500	7.38
5.34	25	5.82	420	6.88	1620	7.41
5.38	30	5.84	480	6.92	1800	7.46
5.44	40	5.90	600	6.98	1980	7.50
5.50	50	5.92	720	7.07		
5.55	60	5.96	840	7.15		

Recovery of pumped well

Because the exact time when the pump failed is not known, the recovery measurements are useless.

Drawdown and recovery of observation well (static level : 25.42)

drawdown		recovery		
drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
0.02	540	0.80	2130	-0.23
0.02	660	0.83	2190	-0.23
0.02	780	0.87	2250	-0.30
0.03	900	0.91	2310	-0.32
0.03	1020	0.98	2370	-0.36
0.11	1260	1.08	2790	-0.36
0.14	1500	1.14		
0.20	1740	1.20		
0.39	1980	1.29		
0.75				
0.77				

t = time since pumping started

Production Well No 1, pump test No. 2

Date : July 25 - 29, 1968
Pumping rate :395 igpm
Open interval :43-73 feet : No. 60 slot screen, 8" O.D., packed with No. 8-16 sand.
Aquifer :45-70 feet, sandstone
Static level :11.46 feet below top of casing.
Observation well :#5B, 160 feet from pumping well.

Drawdown in pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
3.91	16	4.02	330	4.79	1890	5.46
3.94	18	4.03	390	4.83	2190	5.50
3.96	20	4.04	450	4.85	2490	5.56
3.96	25	4.06	510	4.90	2790	5.62
3.95	30	4.08	630	4.97	3090	5.66
3.96	40	4.16	690	5.00	3390	5.71
3.97	50	4.20	810	5.07	3810	5.79
3.97	60	4.20	930	5.12	4230	5.85
3.97	90	4.31	1050	5.17	4830	5.97
3.98	150	4.57	1230	5.23	5310	6.00
3.99	210	4.63	1410	5.29	5790	6.08
4.00	270	4.67	1650	5.38	6270	6.10

Drawdown in observation well No. 5B

Static level : 25.62 feet below top of casing

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
0.03	16	0.17	330	0.71	1890	1.34
0.05	18	0.18	390	0.75	2190	1.39
0.07	20	0.19	450	0.77	2490	1.44
0.08	25	0.21	510	0.82	2790	1.48
0.08	30	0.22	630	0.88	3090	1.54
0.08	40	0.26	690	0.92	3390	1.58
0.09	50	0.31	810	0.99	3810	1.63
0.10	60	0.32	930	1.03	4230	1.70
0.11	90	0.40	1050	1.05	4830	1.80
0.11	150	0.41	1230	1.14	5310	1.86
0.13	210	0.61	1410	1.22	5790	1.90
0.15	270	0.69	1650	1.28	6270	1.95

t = time since pumping started.

Production Well No. 2, pump test No. 1

Date :August 15-18, 1968.
Pumping rate :310 igpm, dropped to 275 igpm at 3000 min. to 270 igpm at 3960 min., to 265 at 4680 min.
Open interval :8" O.D., No. 60 slot screen, packed with 1/4" gravel from 160-240 ft.
Aquifer :Sandstone and shale between 155 feet and 245 feet.
Static level :93.92 feet below top of casing.
Observation well :Well No. 4A did not respond to pumping.

Drawdown in pumped well

drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	drawdown (feet)
16.90	16	23.41	210	27.60	1500	33.33
19.63	18	23.74	240	27.83	1800	34.03
20.09	20	23.96	300	28.63	2040	34.68
20.71	25	24.42	360	29.48	2280	34.95
21.23	30	24.49	420	29.63	2520	35.28
21.68	40	25.08	480	29.98	2760	35.51
21.98	50	25.43	540	30.34	3000	35.88
22.03	60	25.78	600	30.58	3480	35.08
22.31	90	25.84	720	31.04	3720	35.71
22.68	120	26.13	840	31.41	3960	35.40
23.16	150	26.90	1020	31.88	4440	35.41
23.20	180	27.39	1260	32.42	4680	36.06

APPENDIX C : BAIL TEST-DATA

./.T.H. No. 1, bail test No. 1

ate :Feb 12, 1968
ailing rate :One bailer of 37 Imperial gallons per minute
Open interval :226-330 feet
atic level :62.50 feet below top of casing.

Drawdown		Recovery		
	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
	14.65	52	26	71.85
	20.15	54	13.5	62.06
	28.68	56	9.3	52.92
	34.26	58	7.3	43.24
	38.54	60	6.0	36.69
	46.18	65	4.3	22.76
	54.76	70	3.5	12.16
	63.48	75	3.0	5.21
	66.20	80	2.7	0.87
	71.71	85	2.4	-1.67
	79.90			
	80.94			
	87.22			

T.H. No. 1A, bail test No. 2

e :Feb. 13, 1968
ling rate :One bailer of 37 Imperial gallons per minute
Open interval :226-360 feet
tatic level :58.26 feet below top of casing

Drawdown		Recovery		
	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
	14.74	16	8	31.61
	20.76	18	4.5	20.86
	26.87	20	3.3	14.70
	32.06	22	2.7	10.15
	37.01	24	2.4	6.11
	39.76	26	2.2	4.42
	42.55	28	2.0	2.82
		30	1.9	1.73

time since bailing started
' = time since bailing stopped

W.T.H. No. 1A, bail test No. 3

Date :Feb. 14, 1968
Bailing rate :One bailer (37 Imperial gallons) per minute
Open interval :226 - 375 feet
Static level :58.30 feet below top of casing

Drawdown		Recovery		
r-	drawdown	t	t/t'	residual drawdown
in)	(feet)	(min)		(feet)
	16.60	52	26	47.45
	20.52	54	13.5	34.33
	25.45	56	9.33	27.80
	29.40	58	7.25	25.17
	31.91	60	6.0	20.26
	34.00	62	5.2	14.56
	36.72	64	4.6	9.34
	39.52	66	4.1	6.29
	38.63	68	3.8	4.20
	39.74	70	3.5	3.20
	41.16	75	3.0	0.87
	44.28	80	2.7	0.25
	47.11			
	48.45			
	51.03			
	51.24			

W.T.H. No. 1A, bail test No. 4

Date :Feb 15, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :226-400 feet
Static level :58.26 feet below top of casing

Drawdown		Recovery		
drawdown		t	t/t'	residual drawdown
(feet)		(min)		(feet)
10.26		47	23.5	43.14
15.82		49	12.3	33.04
19.55		51	8.5	24.04
20.06		53	6.6	17.42
24.45		55	5.5	12.25
28.58		57	4.8	8.39
31.06		59	4.2	5.47
33.70		61	3.8	3.69
36.46		63	3.5	2.38
38.84		65	3.3	1.50
42.36				
45.58				

W.T.H. No. 1A, bail test No. 5

Date :Feb. 16, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :226-421 feet
Static level :58.65 feet below top of casing

Drawdown		Recovery		
t	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
2	10.47	37	18.5	39.38
4	17.26	39	9.75	28.83
	21.75	41	7.0	20.69
8	24.97	43	5.4	14.53
	28.19	45	4.5	9.90
	30.26	47	4.0	6.43
4	30.58	49	3.5	4.10
	33.40	51	3.2	2.65
	35.16	53	3.0	1.50
	37.57	55	2.75	0.79
	43.31			
	46.32			
	48.38			

W.T.H. No. 1A, bail test No. 6

Date :Feb. 17, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :226-435 feet
Static level :57.38 feet below top of casing

Drawdown		Recovery		
drawdown (feet)	t (min)	t/t'	residual drawdown (feet)	
10.54	42	21	37.19	
16.67	44	11	27.16	
22.43	46	7.7	19.22	
25.72	48	6	13.24	
27.72	50	5	8.91	
30.85	52	4.3	6.24	
32.58	54	3.9	3.96	
35.52	56	3.5	3.32	
36.40	58	3.2	1.87	
38.05				
41.97				
44.12				
48.08				

t = time since bailing started
t' = time since bailing stopped

W.T. H. No. 1A, bail test No. 7

Date :Feb 19, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :226-450 feet
Static level :56.95 feet below top of casing

Drawdown		Recovery		
t (min)	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
	12.57	32	16	39.80
	17.97	34	8.5	29.51
	22.29	36	6	21.45
	25.61	38	4.8	15.35
	29.28	40	4	11.00
	32.29	42	3.5	7.63
	35.01	44	3.1	5.43
	39.18	46	2.9	3.87
	41.35			
	43.30			
	48.11			
	50.56			

W.T.H. No. 1A, bail test No. 8

Date :Feb. 22, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :450-580 feet
Static level :61.85 feet below top of casing

Drawdown		Recovery		
	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
	12.30	52	26	28.69
	23.69	54	13.5	15.95
	29.67	56	9.3	7.90
	31.31	58	7.3	3.27
	33.17	60	6	0.79
	34.75			
	35.53			
	35.75			
	35.09			
	35.91			
	33.99			
	35.31			
	36.51			
	37.87			
	40.51			
	42.40			

t = time since bailing started
t' = time since bailing stopped

W.T.H. No. 3B, bail test No. 1

Date :March 19, 1968
Bailing rate :One bailer of 35 Imperial gallons per minute
Open interval :123-250 feet
Static level :88.26 feet below top of surface casing

	Drawdown		Recovery	
t)	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
2	0.76	122	61	0.93
4	0.84	124	31	0.81
	1.00	126	21	0.65
)	0.95	128	16	0.57
2	0.95	130	13	0.51
4	0.98	132	11	0.45
6	1.08	134	9	0.41
	1.24	136	8.5	0.39
	1.08	138	7.6	0.38
5	1.15	140	7	0.36
	1.13			
3	1.26			
)	1.15			
5	1.26			
	1.34			
	1.36			
)	1.36			
)	1.16			
)	1.19			
)	1.19			

W.T.H. No. 4, bail test No. 1

Date :March 9, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
Open interval :138-245
Aquifer :Sandstone, from 155 to 240 feet
Static level :93.48 feet below top of casing

	Drawdown		Recovery	
)	drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
	0.74	122	61	0.69
	1.05	124	31	0.59
	0.55	126	21	0.60
	0.22	128	16	0.47
)	0.96	130	13	0.41
	1.05	132	11	0.40
	1.02			
	1.04			
	1.03			
	0.96			
	0.96			

. . No. 4, bail test No. 1 - con't

drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
0.96			
1.02			
0.95			
0.98			
0.97			
0.96			
0.93			
0.82			
0.90			

W.T.H. No. 4, bail test No. 2

Date :March 26, 1968
Bailing rate :One bailer of 35 Imperial gallons per minute
Open interval:138-650 feet
Static level :98.20 feet below top of casing

Drawdown			Recovery
drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
0.47	122	61	0.59
0.01	124	31	0.40
0.60	126	21	0.35
0.35	128	16	0.30
0.73	130	13	0.26
0.43	132	11	0.23
0.69	134	9.6	0.21
0.33	136	8.5	0.17
0.80	138	7.7	0.15
1.22	140	7.0	0.12
0.79	145	5.8	0.10
0.87	150	5.0	0.08
0.88	155	4.4	0.06
0.90			
0.87			
0.91			
0.85			
0.91			
1.02			

t time since bailing started
t' time since bailing stopped

W T.H. No. 5, bail test No. 1

Date:
Bailing rate :One bailer of 45 Imperial gallons per minute
Open interval :200-375 feet below top of casing
Aquifer :Sandstone, from 185-240 feet below top of casing
Static level :20.15 feet below top of casing

	Drawdown					Recovery			
in)	drawdown (feet)	t (min)	drawdown (feet)	t (min)	t/t'	res. drwdwn (feet)	t (min)	t/t'	res. drwdwn. (feet)
	13.75	14	22.81	121	121	40.88	136	8.5	13.67
	14.99	16	23.08	122	61	37.32	138	7.7	12.85
3	16.61	18	23.43	123	41	32.85	140	7	12.36
	16.65	20	23.56	124	31	28.98	145	5.8	11.06
	16.83	25	23.85	125	25	25.89	150	5	10.35
	17.07	30	24.03	126	21	23.44	160	4	9.36
	18.45	40	25.47	127	18	21.45	170	3.4	8.70
	18.59	50	29.97	128	16	20.59	180	3	8.29
	19.90	60	37.00	129	14.3	19.14	200	2.5	7.42
	21.83	80	38.64	130	13	17.97	220	2.2	7.17
	22.52	100	40.63	132	11	16.15	240	2	6.97
	22.57	120	43.81	134	9.6	14.75			

time since pumping started
= time since pumping stopped

W.T.H. No. 6, bail test No. 1

Date :April 8, 1968
Bailing rate :One bailer of 30 Imperial gallons per minute
Open interval :25-150 feet below top of surface casing
Aquifer :Sandstone from 80-100 feet below top of casing
Static level :57.62 feet below top of surface casing

Drawdown				Recovery		
drawdown (feet)	t (min)	drawdown (feet)	t (min)	t/t'	res. drawdown (feet)	
5.35	30	9.56	122	61	4.44	
6.60	40	9.03	124	31	2.65	
7.82	50	9.70	126	21	1.92	
7.89	60	10.01	128	16	1.52	
8.52	70	9.74	130	13	1.27	
8.70	80	9.67				
8.68	90	9.92				
8.80	100	9.68				
8.84	110	9.64				
8.95	120	9.54				
9.32						

W.T.H. No. 6, bail test No. 2

ate :May 10, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
pen interval :240-290 feet below top of surface casing
quifer :Sandstone from 240-250 feet below top of surface casing
Static level :90.55 feet below top of surface casing

Drawdown		Recovery			
drawdown (feet)	t (min)	drawdown (feet)	t (min)	t/t'	res. drawdown (feet)
7.78	30	61.99	122	61	71.01
14.25	35	64.12	124	31	67.03
25.04	40	66.64	126	21	65.85
25.04	45	68.77	128	16	60.93
28.82	50	70.55	130	13	57.39
32.88	55	71.70	132	11	53.13
37.48	60	73.55	134	9.6	49.55
40.25	80	78.75	136	8.5	45.65
43.66	100	78.79	138	7.7	42.54
45.78	120	88.45	140	7.0	40.72
58.04			145	5.8	33.44
			150	5	28.75
			155	4.4	24.44
			160	4	21.39
			170	3.4	16.11
			180	3	12.82
			220	2.2	8.01
			240	2	6.25

t = tiie since pumping started
t' = time since pumping stopped

W:T.H. No. 7, bail test No. 1

ate :June 3, 1968
Bailing rate :One bailer of 37 Imperial gallons per minute
pen interval:127-276 feet below top of casing
quifer :Sandstone, from 133-222 feet below top of casing
Static level :93.22 feet below top of casing

Drawdown		Recovery	
drawdown (feet)	t (min)	t/t'	residual drawdown (feet)
4.89	122	61	3.49
4.98	124	31	2.51
5.80	126	21	2.19
7.65	128	16	1.97
7.81	130	13	1.75
7.87	132	11	1.44
8.74	134	9.6	1.29
8.81	138	7.7	0.98
8.85	140	7	0.89
8.85	145	5.8	0.70
8.85	150	5	0.56
8.86	160	4	0.40
8.87	170	3.4	0.26
9.72	180	3	0.19
9.78			
9.79			
9.78			
9.78			

APPENDIX D

STEP-DRAWDOWN TEST DATA

roduction Well No. 1, step-drawdown test No. 1

Date :July 24, 1968
tatic level :11.42 feet below top of casing

in)	Drawdown (feet)			
	step 1 Q=437 igpm	step 2 Q=365 igpm	step 3 Q=285 igpm	step 4 Q=240 igpm
	2.29	4.06	3.18	2.70
	4.43	4.04	3.14	2.70
	4.50	4.02	3.13	2.66
	4.58	4.02	3.12	2.66
	4.58	4.01	3.10	2.66
	4.58	4.00	3.10	2.66
	4.60	4.00	3.10	2.66
	4.61	4.00	3.10	2.65
	4.62	4.00	3.10	2.65
	4.64	4.00	3.10	2.64
	4.66	4.00	3.09	2.64
	4.68	4.01	3.08	2.64
	4.70	4.01	3.08	2.64
	4.73	4.01	3.08	2.64
	4.75	4.01	3.08	2.64
	4.79	3.99	3.09	2.64
	4.81	4.00	3.08	2.64
	4.83	4.02	-	-
	4.87	4.03	3.09	2.64
	4.89	4.02	-	-
	4.91	4.02	3.10	2.64

t" = time since the step began

Production Well No. 2, step-drawdown test No. 1 Date: August 19, 1968

Static level: 101.63'

t")	Drawdown (feet)			
	step 1 Q=310 igpm	step 2 Q=275 igpm	step 3 Q=260 igpm	step 4 Q=240 igpm
	--	22.07	21.67	20.86
	16.41	21.84	21.63	20.67
	17.67	21.88	21.59	20.60
	18.23	21.85	21.52	20.49
	18.87	21.82	21.55	20.52
	19.18	21.75	21.49	20.49
	19.50	21.74	21.51	20.49
	19.95	21.87	21.57	20.39
	19.96	21.86	21.87	20.42
	20.44	21.86	21.62	20.44
	20.87	21.94	21.52	20.40
	21.14	21.89	21.58	20.42
	21.37	21.98	21.55	20.54
	21.66	21.90	21.62	20.54
	21.92	21.96	21.62	20.54
	22.36	21.97	21.78	20.57
	22.42	22.10	21.72	20.54
	22.89	22.24	21.86	20.57
	23.19	22.45	21.91	20.67

Production Well, No. 2, step-drawdown test No. 2 Date: August 23, (static level :106.98)

	Drawdown (feet)			
	step 1 Q=159 igpm	step 2 Q=178 igpm	step 3 Q=198 igpm	step 4 Q=127 igpm
	3.05	9.07	11.42	13.65
	4.91	9.22	11.58	13.80
	5.45	9.35	11.65	13.87
	5.74	9.42	11.71	13.96
	5.91	9.45	11.75	14.03
	6.04	9.50	11.79	14.09
	6.17	9.53	11.84	14.15
	6.31	9.56	11.87	14.16
	6.41	9.60	11.91	14.14
	6.53	9.64	11.96	14.19
	6.70	9.69	12.01	14.22
	6.90	9.74	12.06	14.27
	7.03	9.78	12.13	14.39
	7.14	9.81	12.16	14.35
	7.25	9.85	12.20	14.37
	7.56	9.99	12.26	14.49
	7.76	10.11	12.34	14.63
	7.95	10.23	12.50	14.73
	8.14	10.34	12.58	14.87

t" = time since the beginning of the step

APPENDIX E

Completion Details of Production Wells

Production well No. 1

Casing:	16" O.D. from 0 - 40 feet
	8 5/8" O.D. from 0 - 51 feet
Screen:	9" O.D., No. 60 slot, from 51 - 80 feet
Pack:	1/4" pea gravel, from 49 - 80 feet.

Production well No. 2

Casing:	16" O.D. from 0 - 117 feet
	8 5/8" O.D. from 0 - 156 8/12 feet
	125/8" O.D. from 0 - 159 feet
Screen:	9" O.D., No. 60 slot from 156 8/12 - 240 feet
Pack:	1/4" pea gravel from 68 - 240 feet.

Production well No. 3

Casing:	20" O.D. from 0 - 20 feet
	16" O.D. from 0 - 30 feet
	8 5/8" O.D. from 0 - 35 feet
	8 5/8" O.D. from 55 - 195 feet
Screen:	9" O.D., No. 40 slot, from 35 - 55 feet
	9" O.D., No. 60 slot, from 195 - 215 feet
Pack:	No. 8-16 frac sand from 30 - 60 feet
	1/4" pea gravel from 60 - 215 feet.

Production well No. 4

Casing:	16" O.D. from 0 - 15 feet
	8 5/8" O.D. from 0 - 30 feet
	8 5/8" O.D. from 40 - 50 feet
Screen:	9" O.D., No. 60 slot, from 30 - 40 feet
	9" O.D., No. 60 slot, from 50 - 80 feet
Pack:	1/4" pea gravel from 18 - 80 feet.

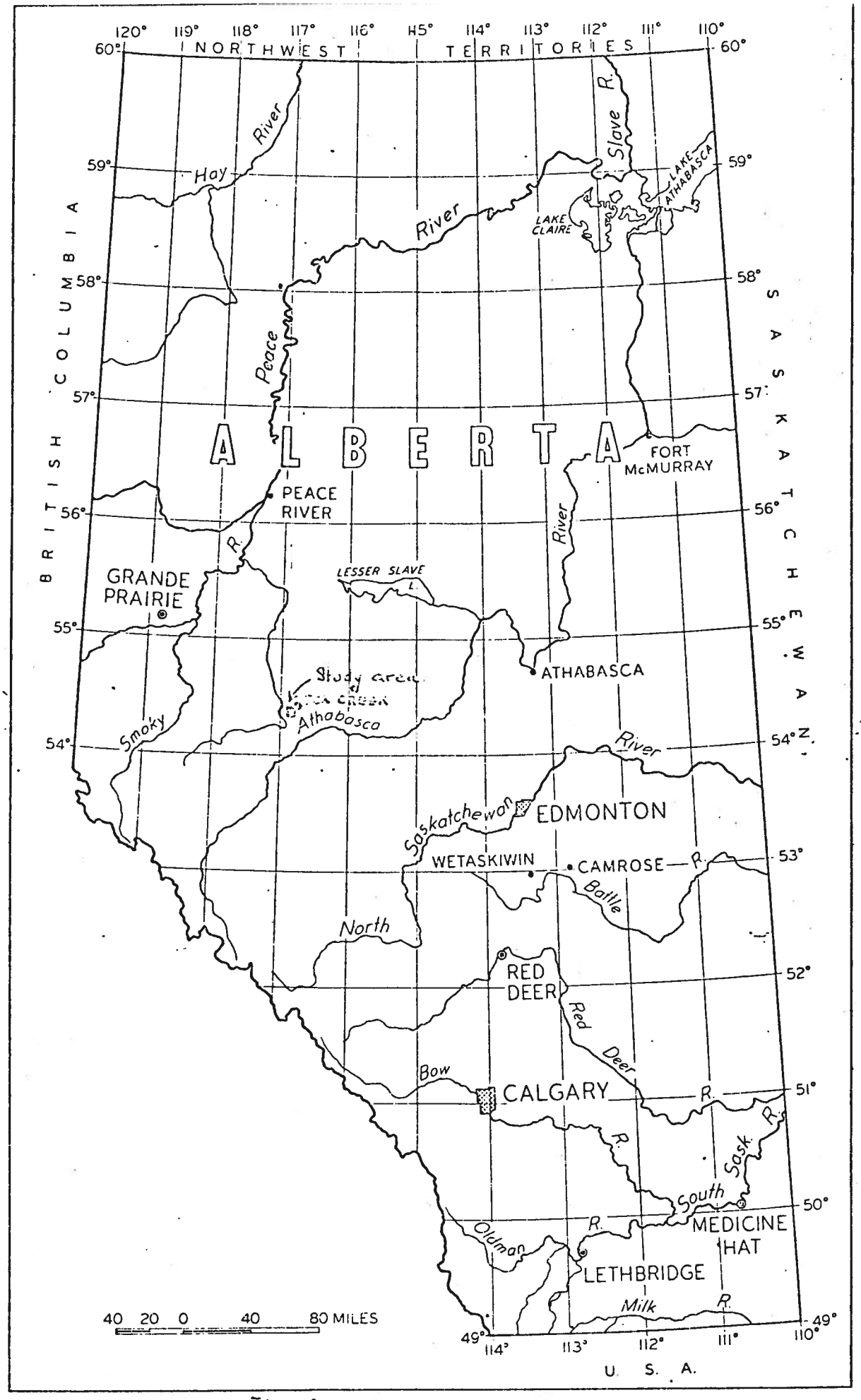


FIGURE 1

Index map of Alberta showing location of study area.

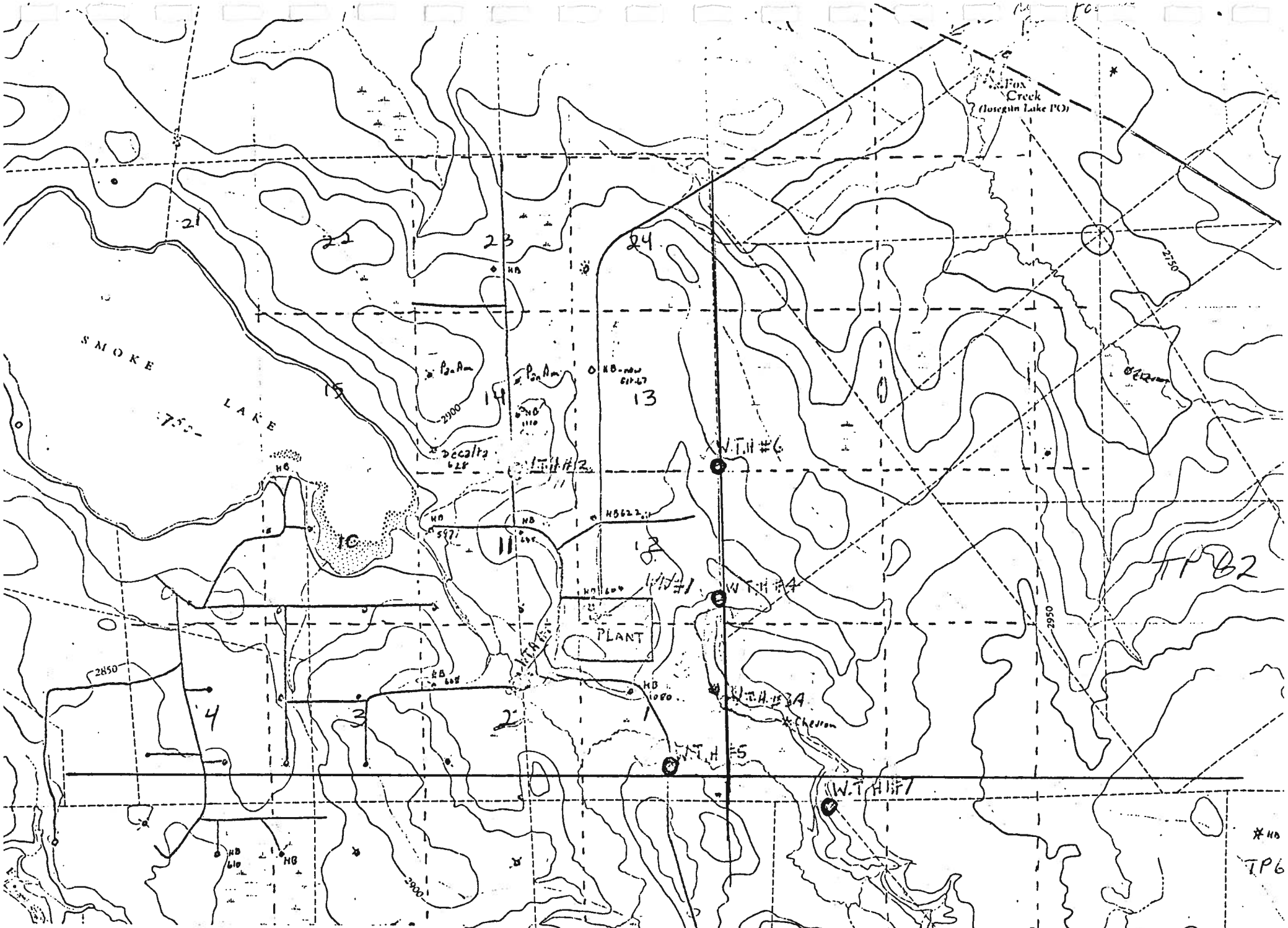
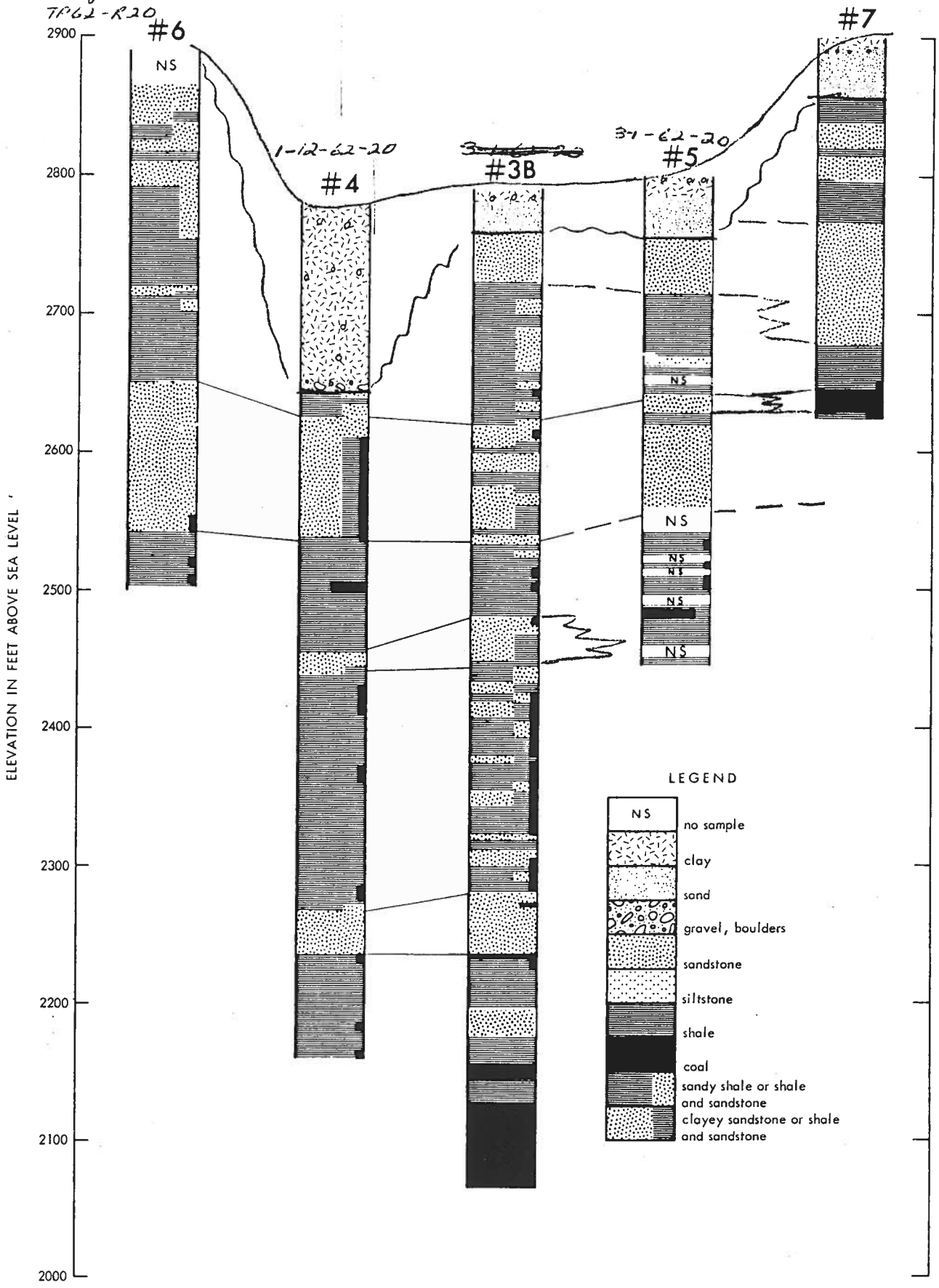

Fox Creek
(Joseph Lake PO)
SMOKE LAKE
W.T.H #6
W.T.H #2
W.T.H #4
W.T.H #1
W.T.H #3A
W.T.H #5
W.T.H #7
PLANT
TP82
TP6
R6 23 W5
R 19

FIGURE 2

NEC of Sec 12
TP62-R20

15-31-61-19

FIGURE 3: DRILLER'S LOGS



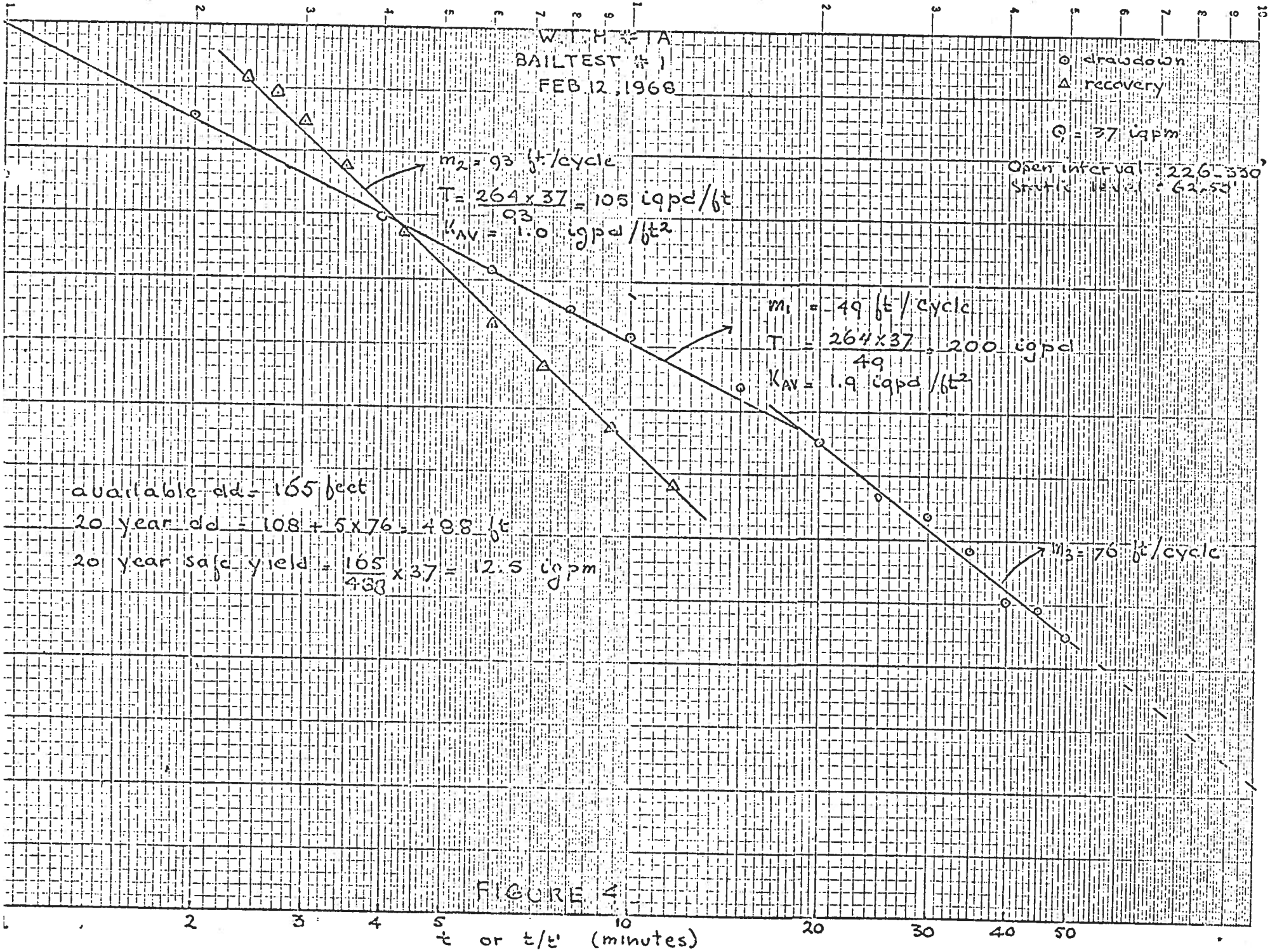

W.T.H. #1A
BAILTEST #1
FEB. 12, 1968
o drawdown
Δ recovery
Q = 37 igpm
Open interval: 226-330'
Static lev.: 62.5'
m_2 = 93 ft/cycle
$T = \frac{264 \times 37}{93} = 105$ igpd/ft
$K_{AV} = 1.0$ igpd/ft²
m_1 = 49 ft/cycle
$T = \frac{264 \times 37}{49} = 200$ igpd
$K_{AV} = 1.9$ igpd/ft²
available dd = 165 feet
20 year dd = 108 + 5 x 76 = 488 ft
20 year safe yield = $\frac{165}{488} \times 37 = 12.5$ igpm
m_3 = 76 ft/cycle
t or t/t' (minutes)

FIGURE 4

Feb. 13/68

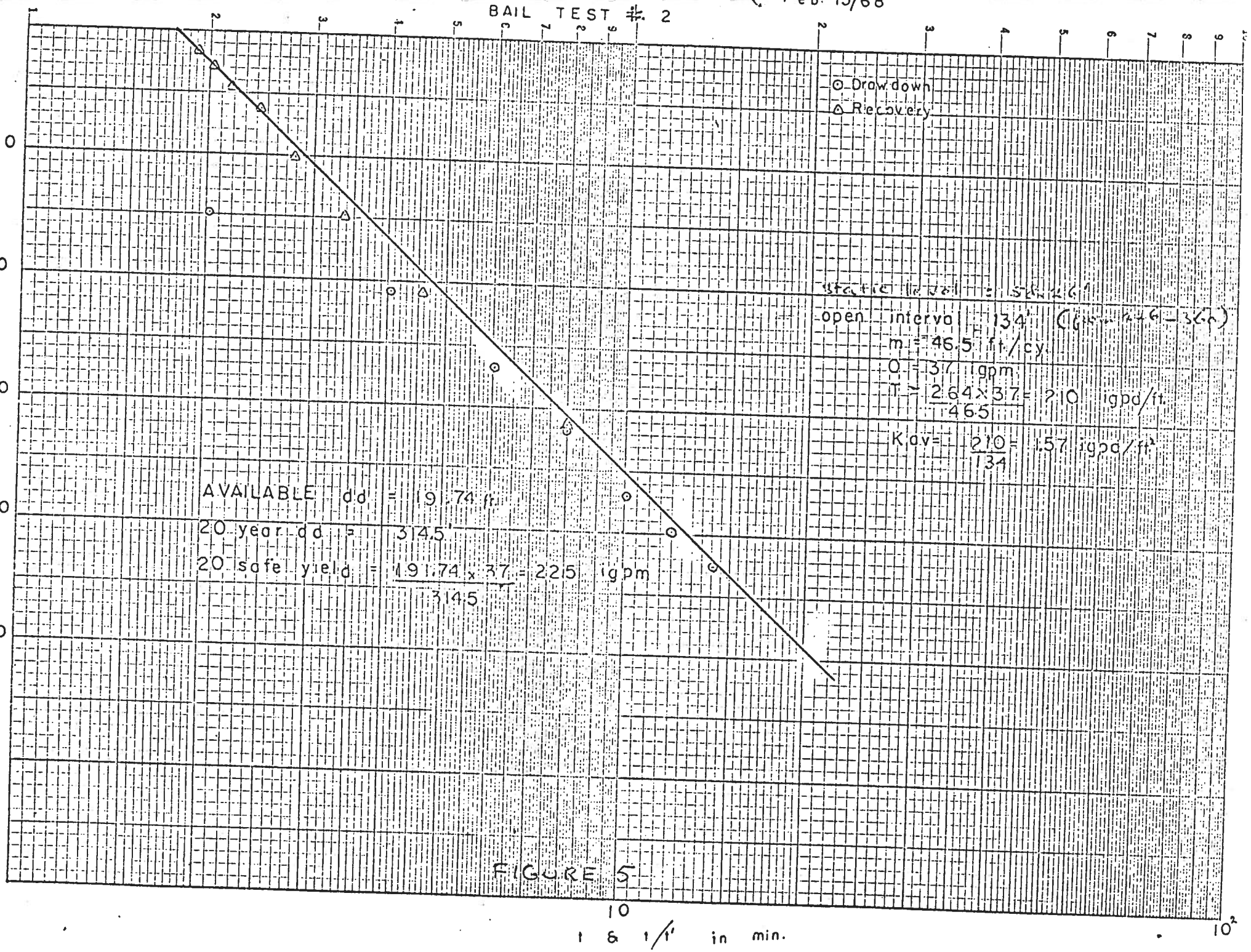


FIGURE 5

KEUFFEL & ESSER CO.

SM L

W.T.H. 1-A

BAIL TEST 3

Feb. 14/68

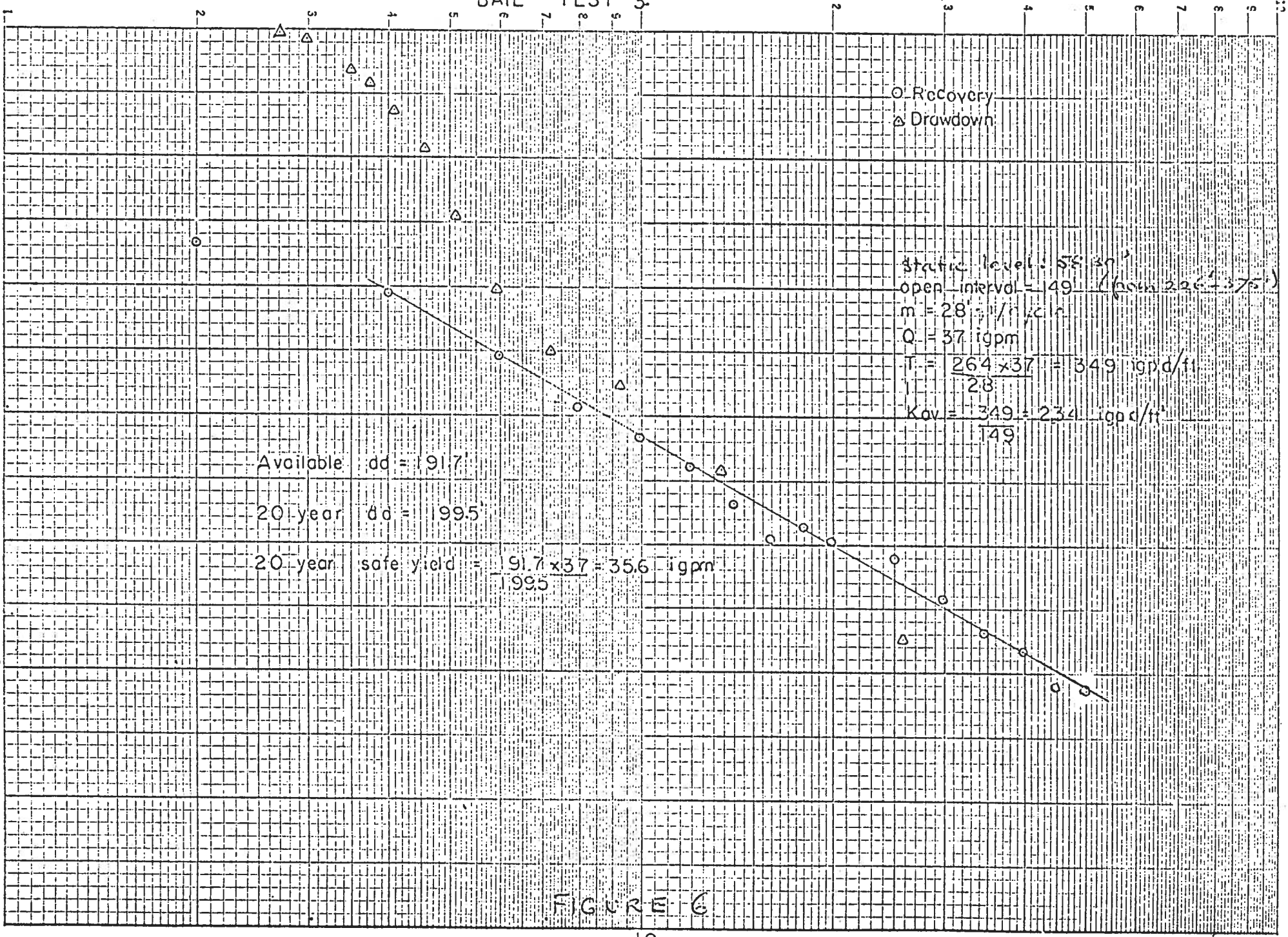


FIGURE 6

KEUFFEL & ESSER CO.

W.T.H. I-A

SMOKE L

BAIL TEST 4

Feb. 15/68

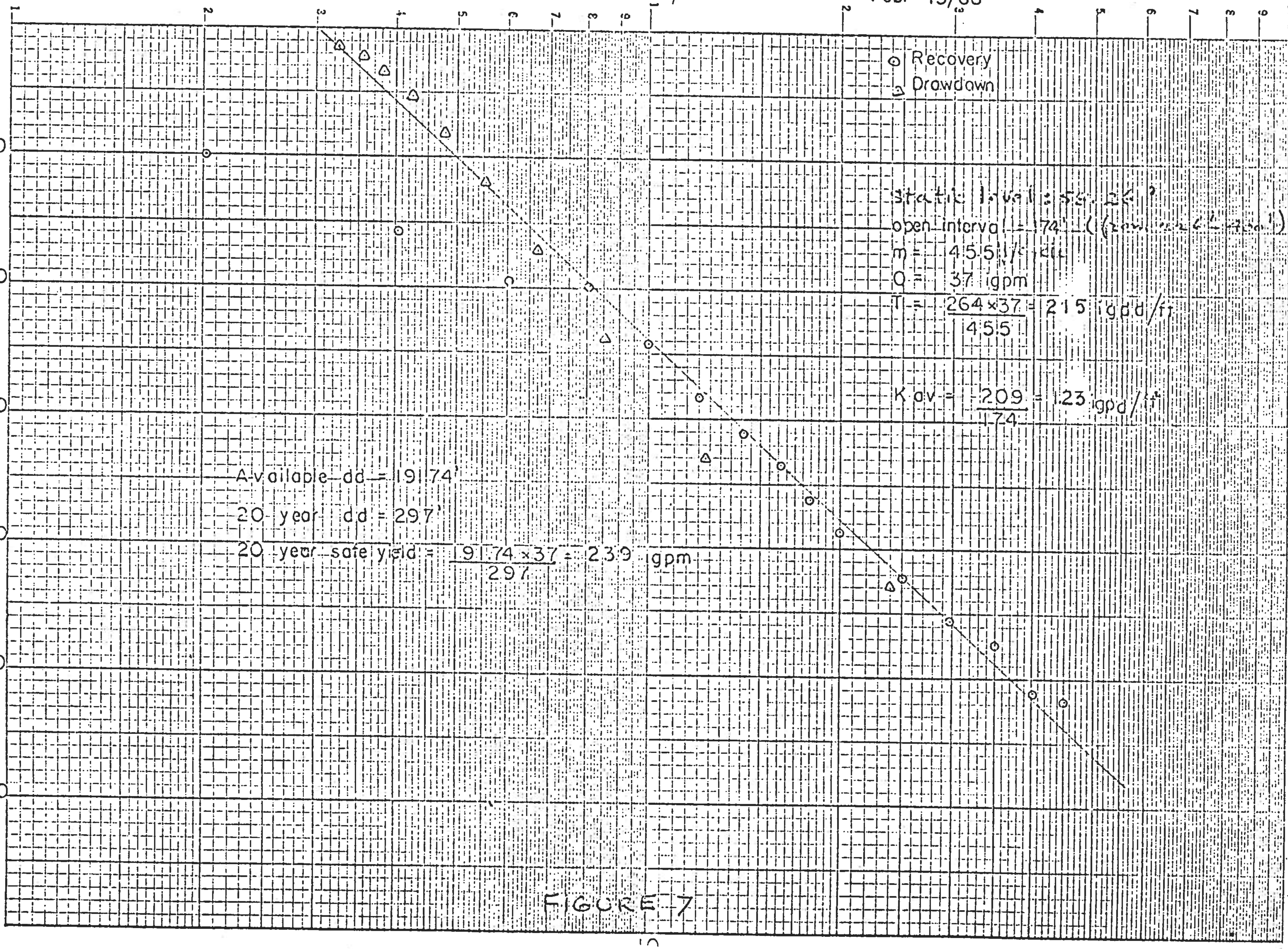
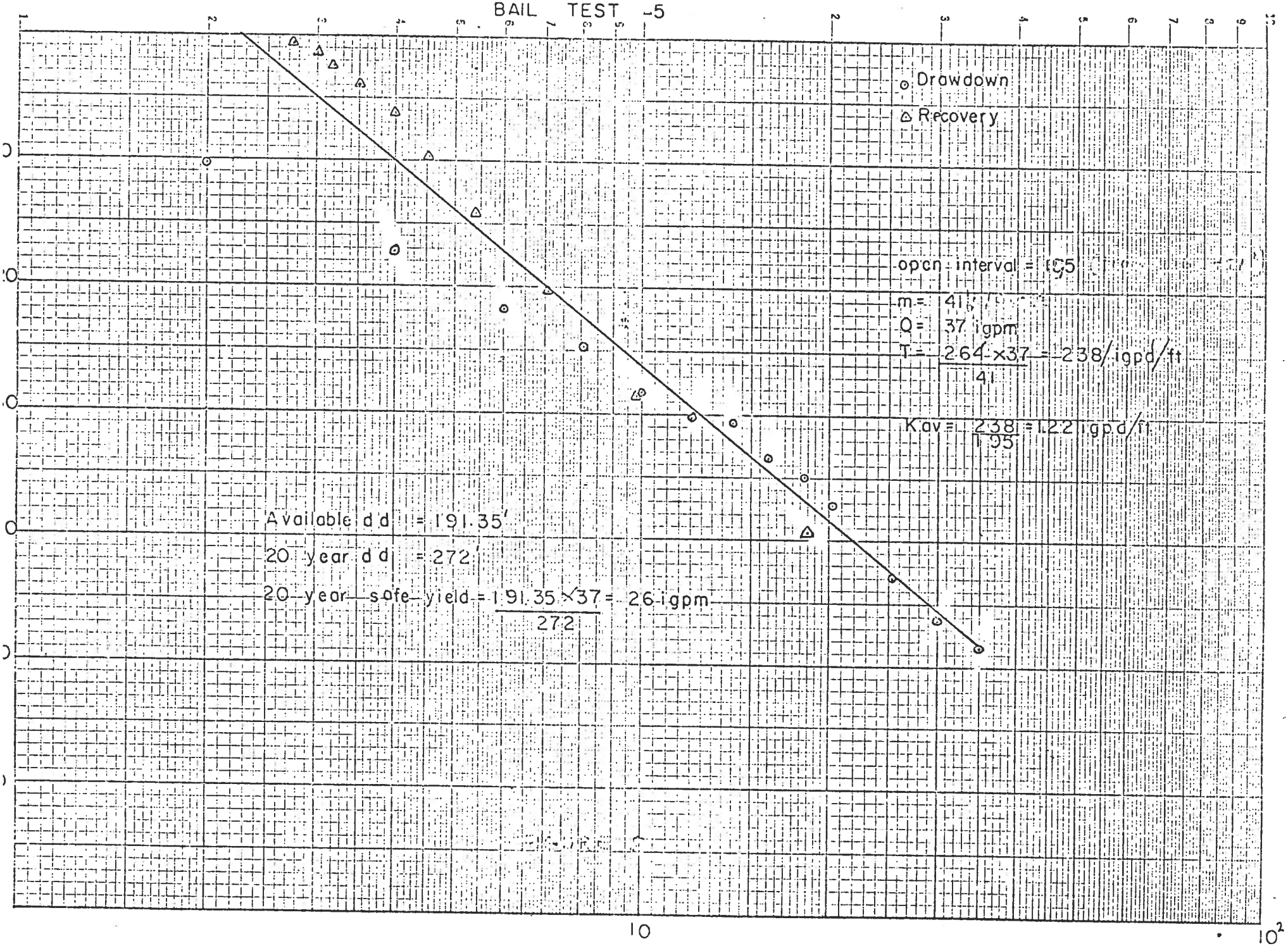


FIGURE 7

W.T.H. 1A

BAIL TEST -5



SK KE L.

Feb. 17/68

W.T.H. I-A

BAIL TEST 6

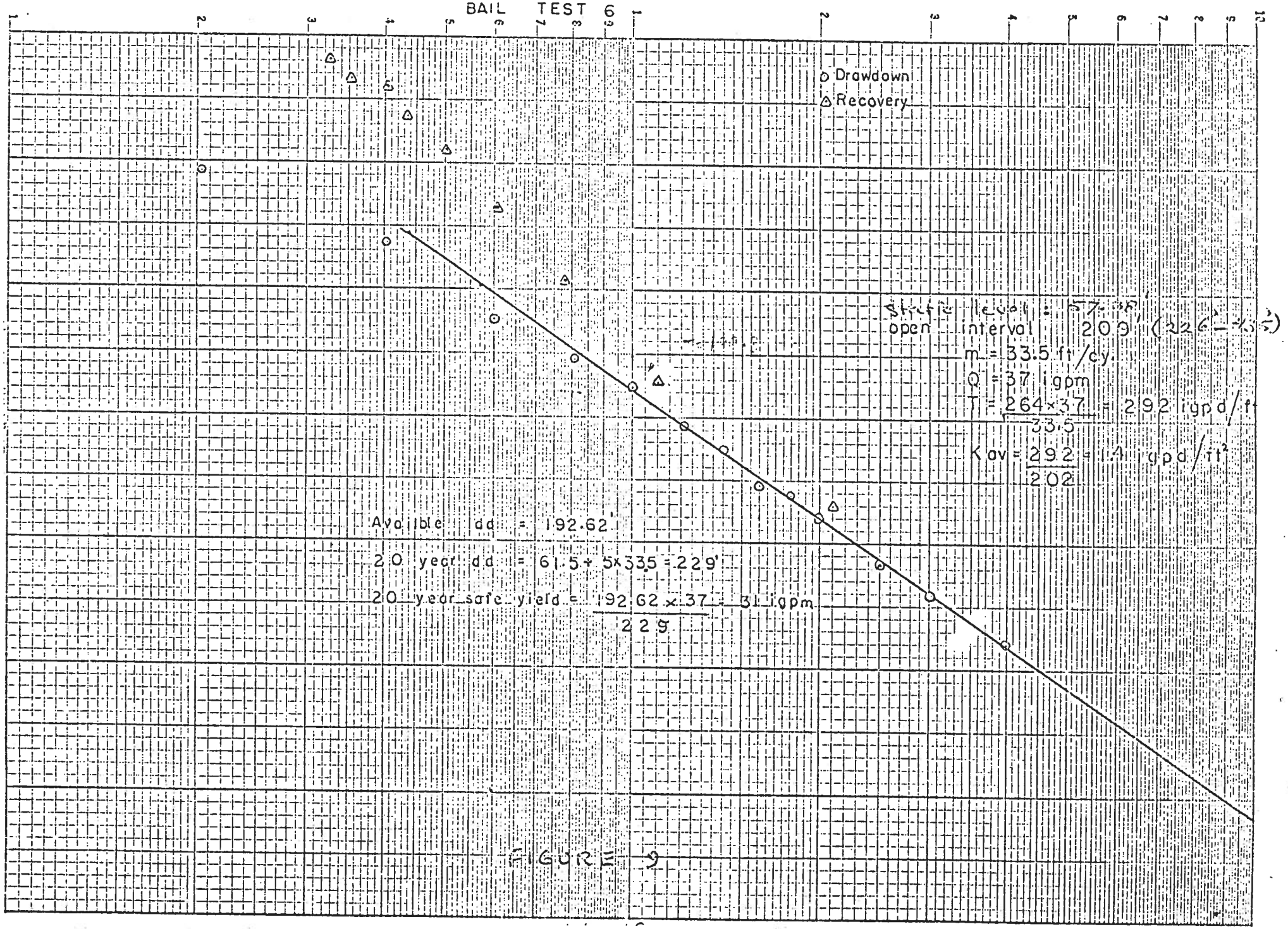


FIGURE 9

W.T 1A

BAIL TEST 7

Feb 19/68

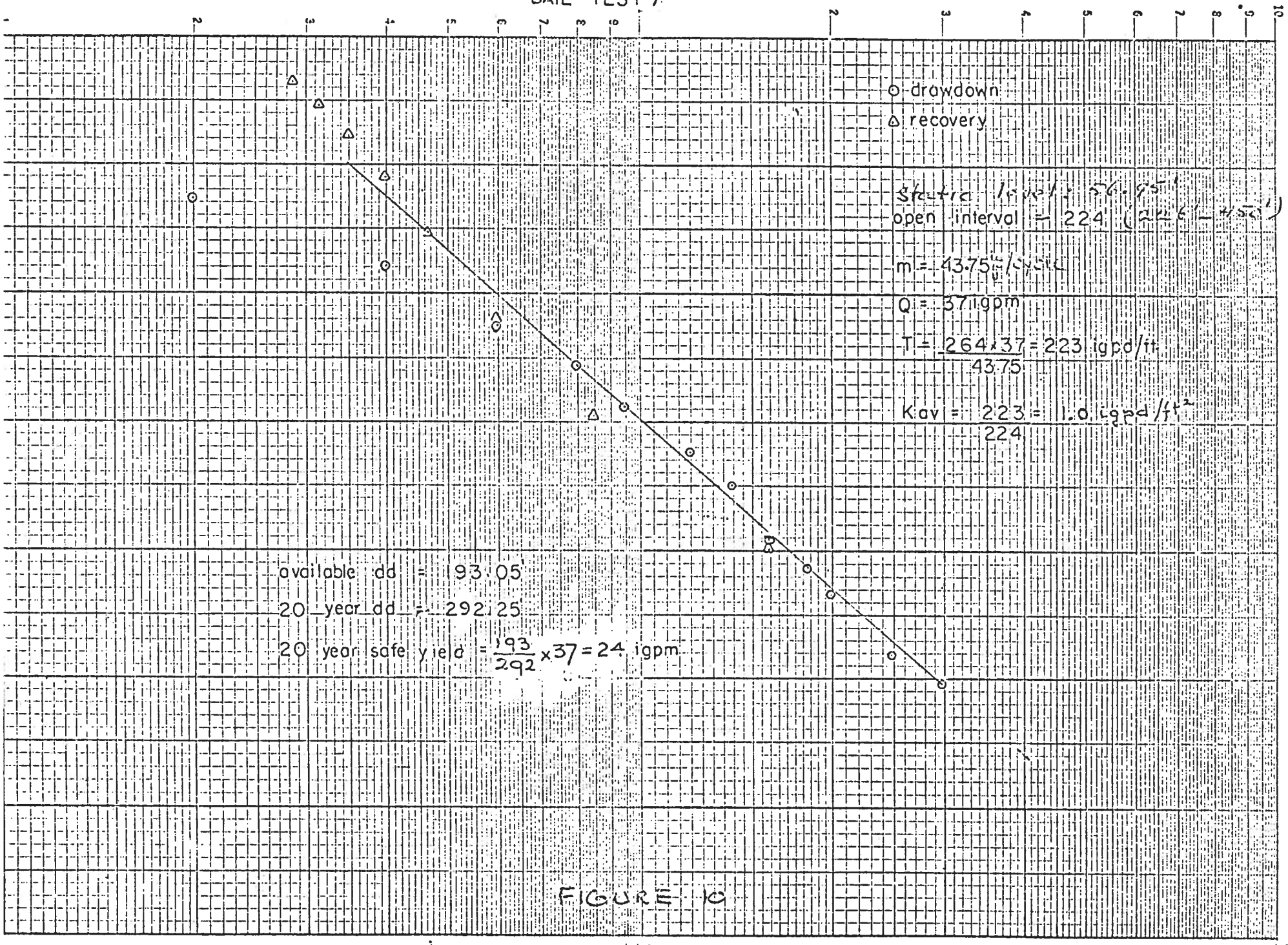


FIGURE 10

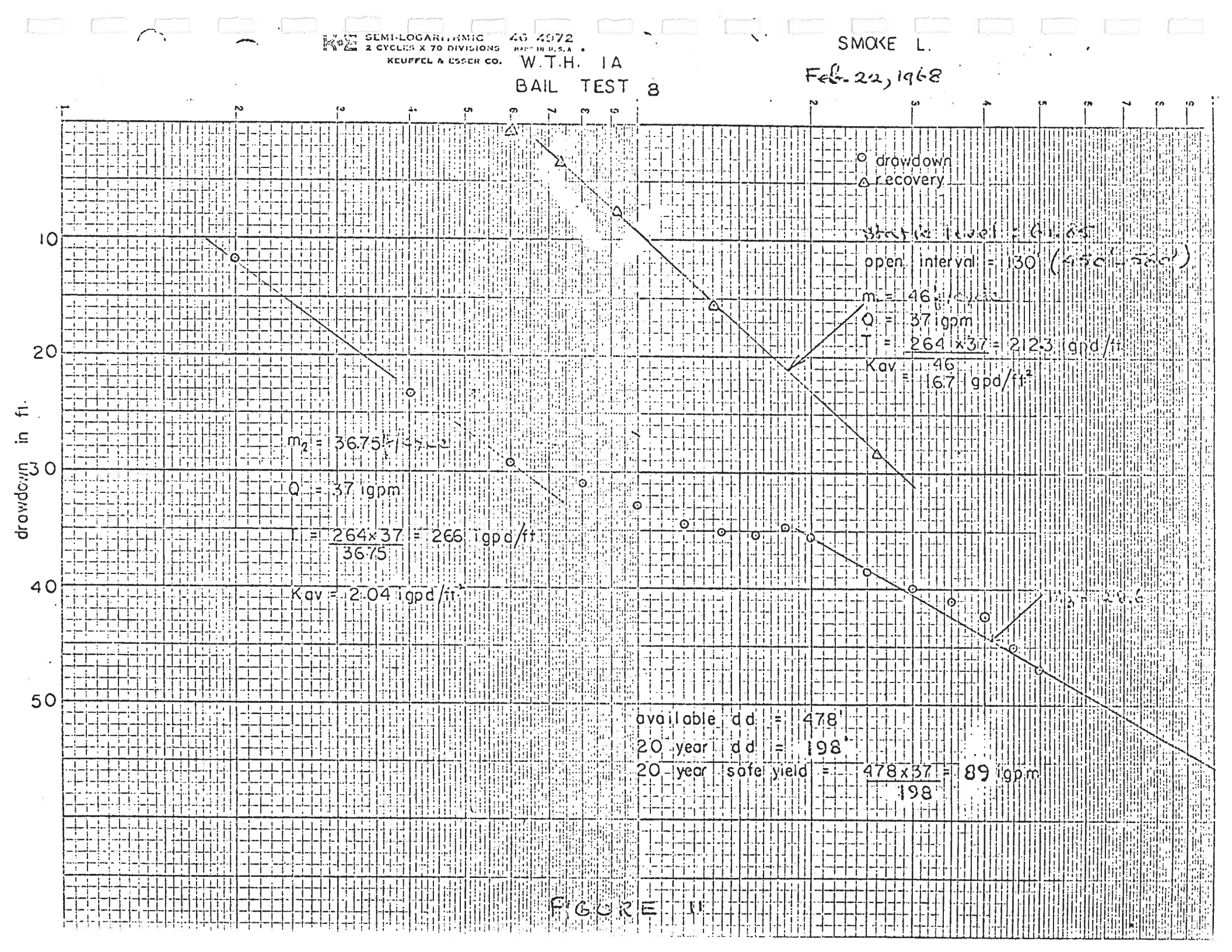

SEMI-LOGARITHMIC 46 4972
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.
W.T.H. IA
BAIL TEST 8
SMOKE L.
Feb. 22, 1968
drowdown in ft.
10
20
30
40
50
drowdown
recovery
open interval = 130
m = 46
Q = 37 igpm
T = 264 x 37 / 46 = 212.3 igpd/ft
Kav = 167 igpd/ft²
m₂ = 36.75
Q = 37 igpm
T = 264x37 / 36.75 = 266 igpd/ft
Kav = 2.04 igpd/ft²
available dd = 478'
20 year dd = 198'
20-year safe yield = 478x37 / 198 = 89 igpm

FIGURE 11

W.T. H 3A Pump test 1

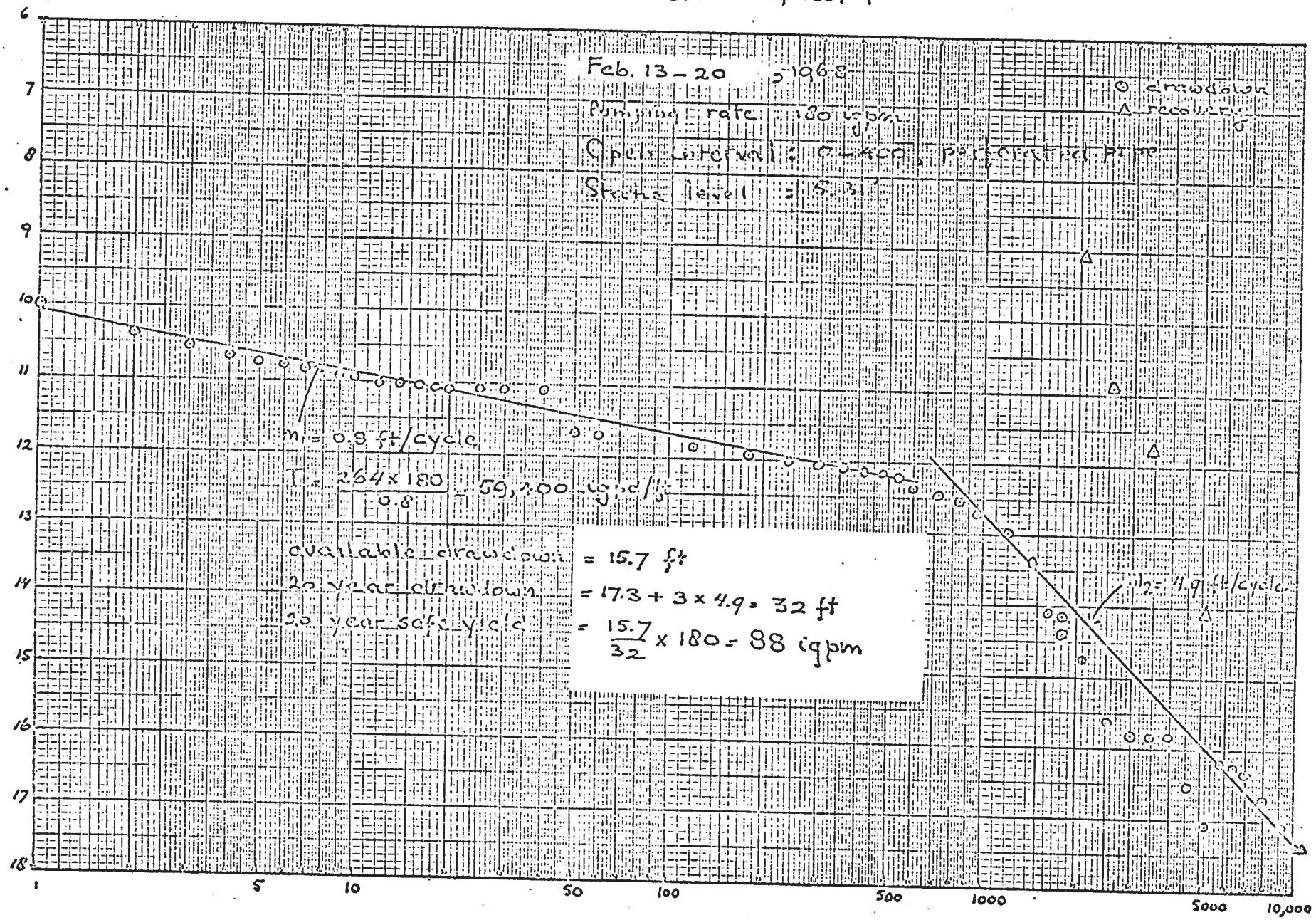
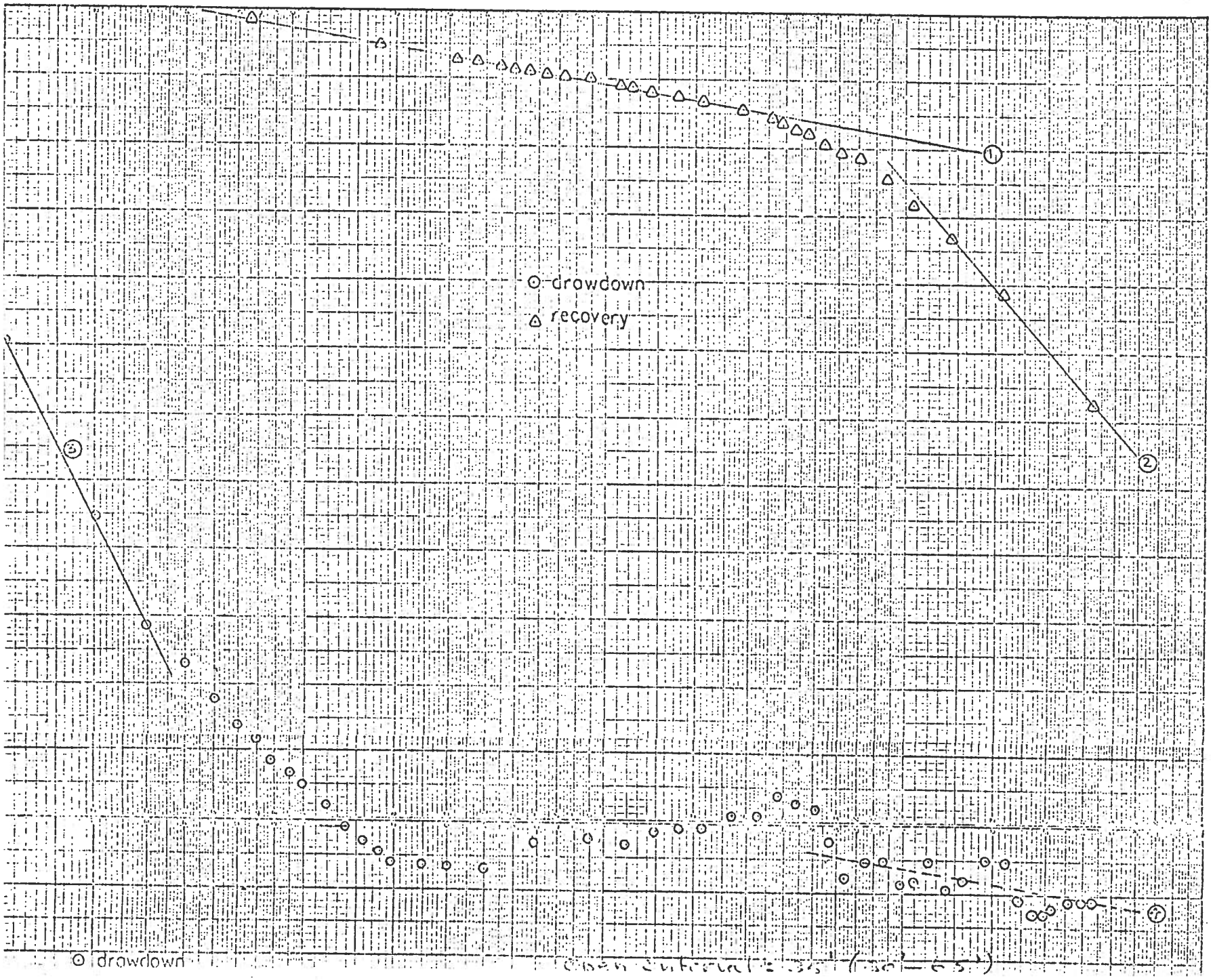


FIGURE 12.

SM[illegible] L.
March 1-4/68



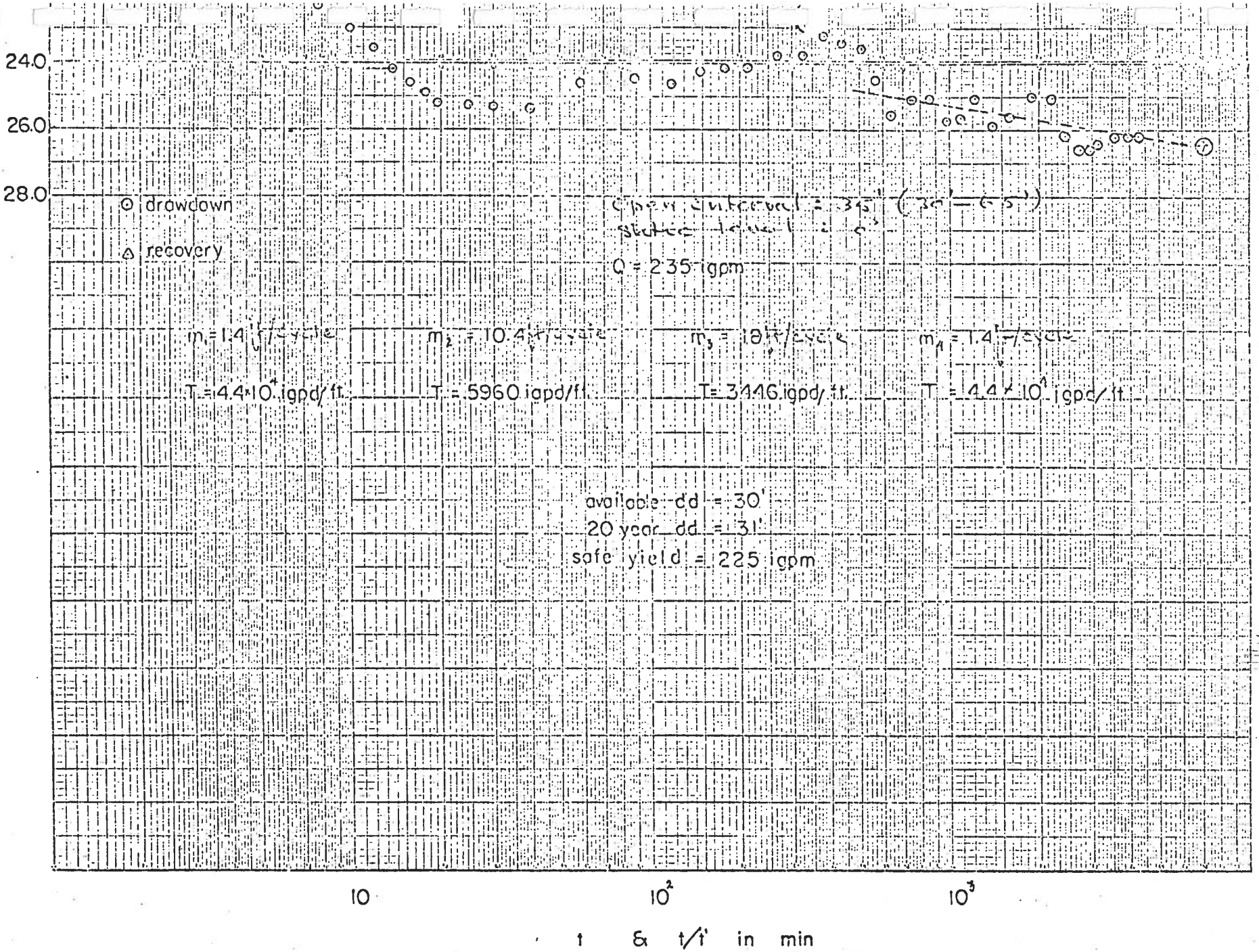

24.0
26.0
28.0
drawdown
recovery
Q = 235 igpm
m_1 = 1.4 ft/cycle
T_1 = 4.4×10⁴ igpd/ft
m_2 = 10.4 ft/cycle
T = 5960 igpd/ft
m_3 = 18 ft/cycle
T = 3446 igpd/ft
m_4 = 1.4 ft/cycle
T_4 = 4.4×10⁴ igpd/ft
available dd = 30'
20 year dd = 31'
safe yield = 225 igpm
10
10²
10³
t & t/r' in min

FIGURE 13.

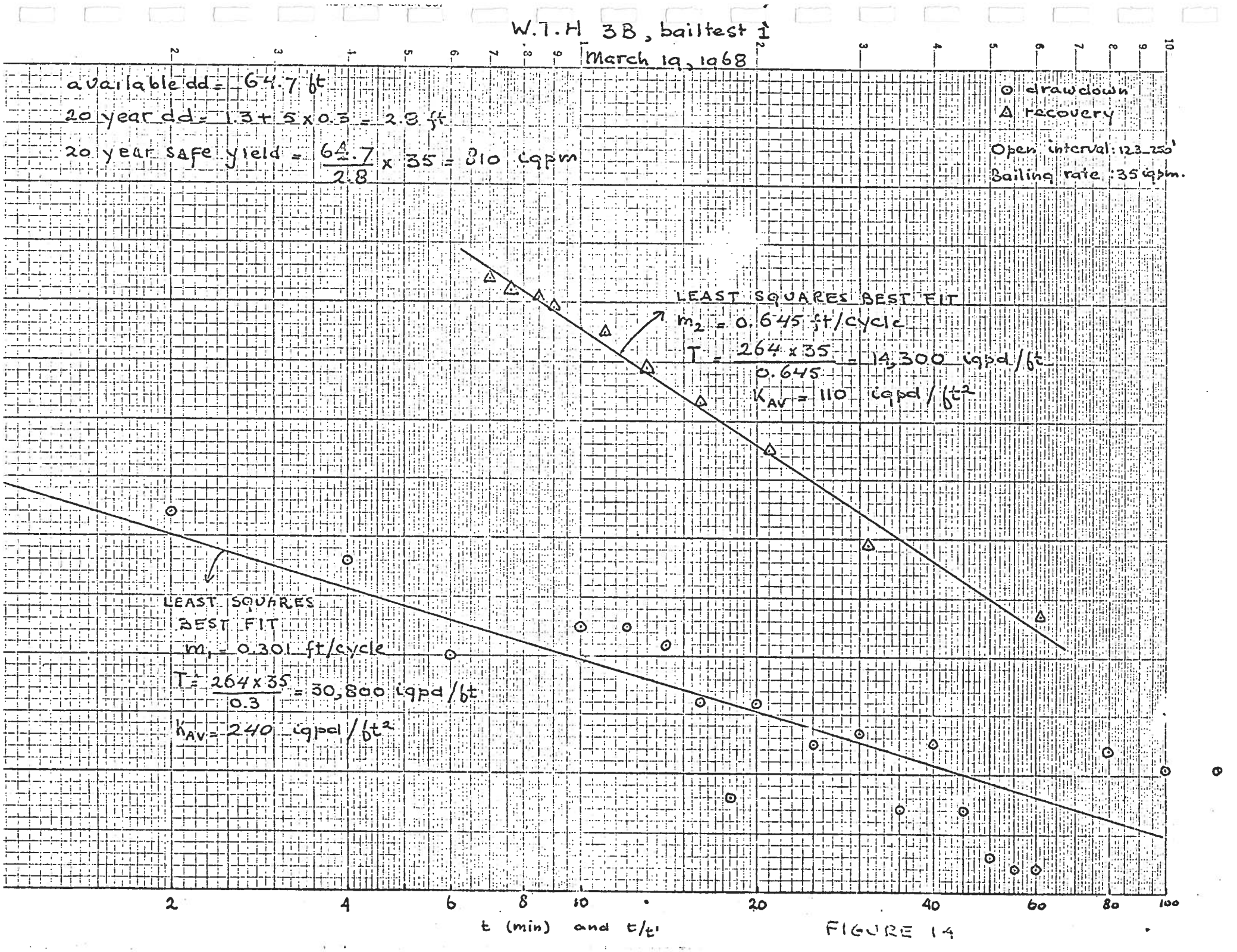
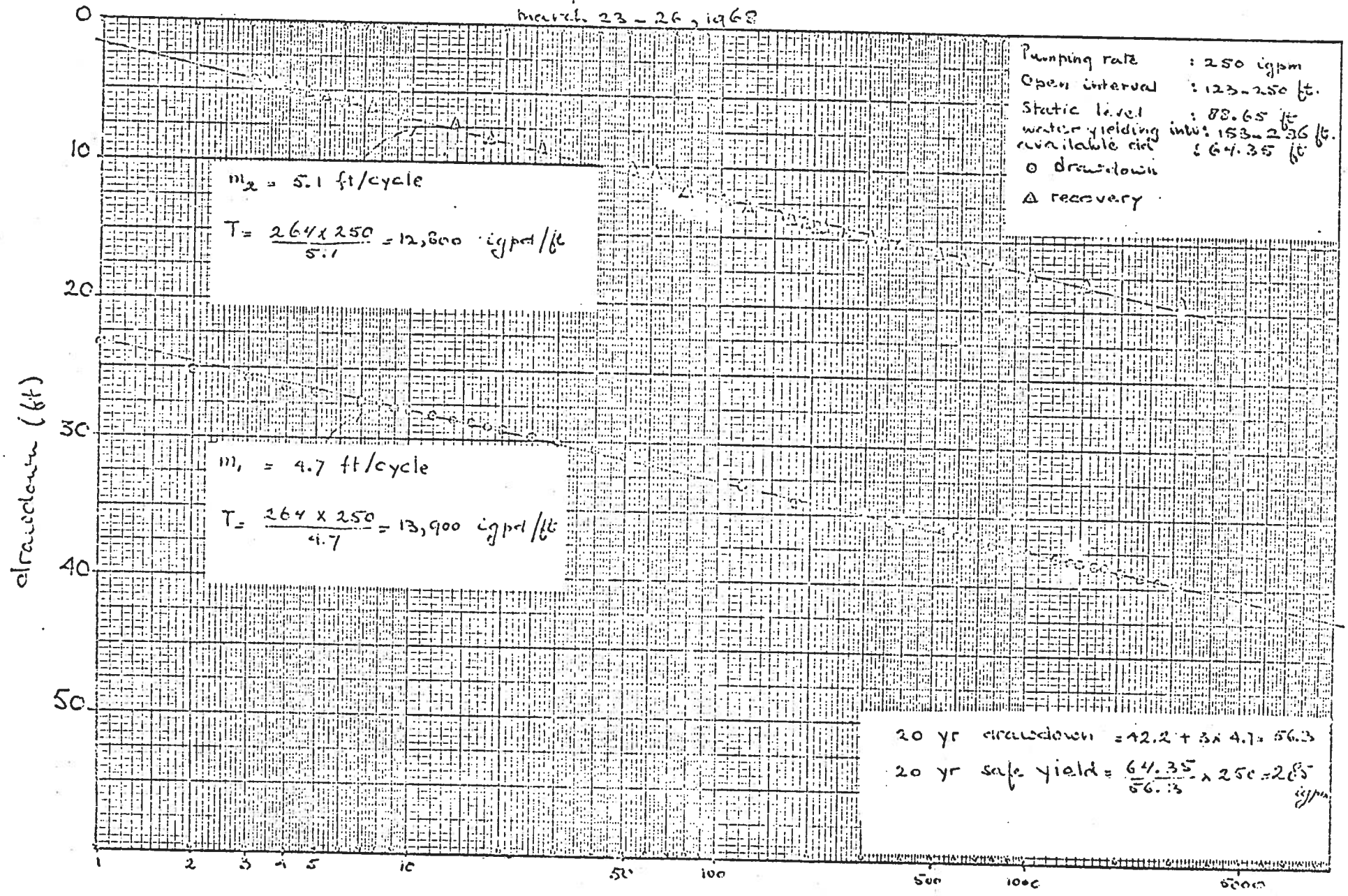

W.T.H 3B, bailtest 1
March 19, 1968
available dd = 64.7 ft
20 year dd = 1.3 + 5 x 0.5 = 2.8 ft
20 year safe yield = 64.7/2.8 x 35 = 810 igpm
o drawdown
Δ recovery
Open interval: 123-250'
Bailing rate: 35 igpm.
LEAST SQUARES BEST FIT
m2 = 0.645 ft/cycle
T = 264 x 35 / 0.645 = 14,300 igpd/ft
KAV = 110 igpd/ft2
LEAST SQUARES BEST FIT
m1 = 0.301 ft/cycle
T = 264 x 35 / 0.3 = 30,800 igpd/ft
KAV = 240 igpd/ft2
2 4 6 8 10 20 40 60 80 100
t (min) and t/t'

FIGURE 14

W.T.H # 3B

Pump test # 2

March 23 – 26, 1968



WELL 4

BAIL TEST 1

March 9, 1960

Open interval : 138 – 245'
Static level : 93.5'
Available dd. : 61.5
Aquifer : 155 – 240', sandstone

20 yr. dd. = 1.0 + 5 × 0.39 = 2.95'

estimated safe yield = $\frac{61.5}{2.95} \times 37 = 760$ igpm

⊙ drawdown
△ recovery
---- stabilized dd

$m_1 = 39'$
Q = 37 igpm
$T = \frac{264 \times 37}{39} = 25{,}000$ igpd/ft

$m_2 = 104$
Q = 37 igpm
$T = \frac{264 \times 37}{104} = 9400$ igpd/ft

FIGURE 16

10

10^2

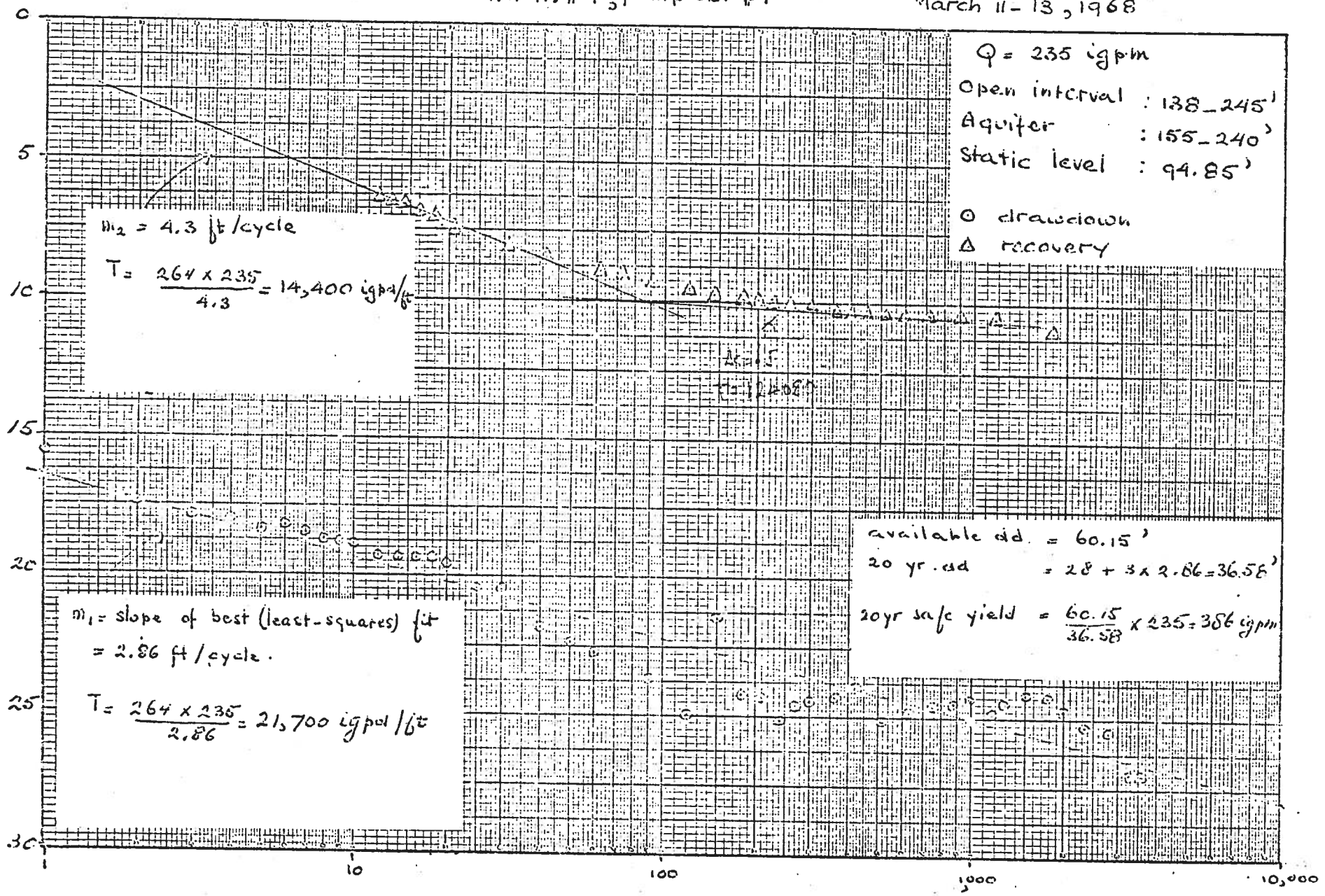
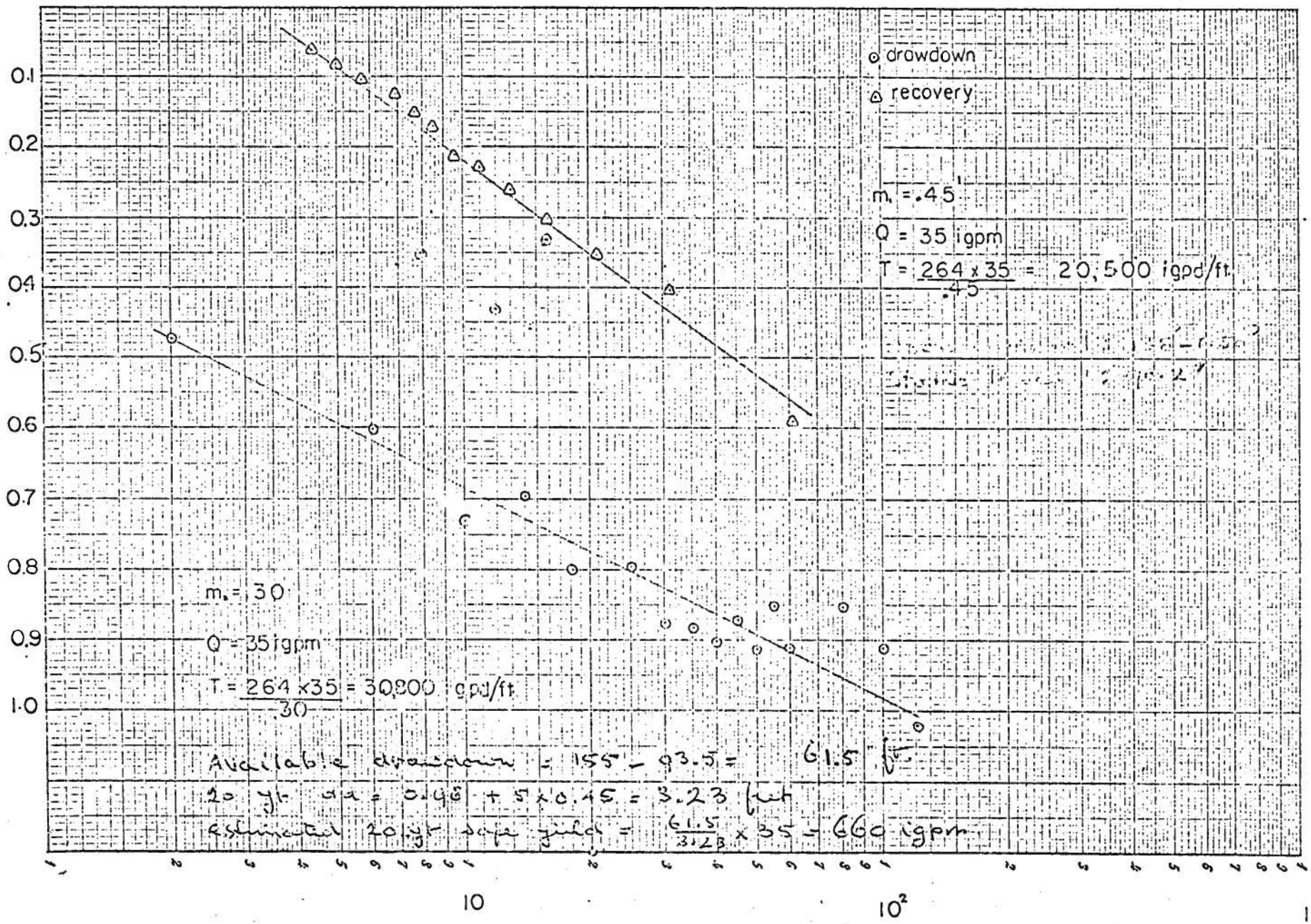

W.T.H. #4, pumptest #1
March 11 - 13, 1968
Q = 235 igpm
Open interval : 138_245'
Aquifer : 155_240'
Static level : 94.85'
○ drawdown
△ recovery
m_2 = 4.3 ft/cycle
$T = \frac{264 \times 235}{4.3} = 14{,}400$ igpd/ft
available dd. = 60.15'
20 yr. dd = 28 + 3 x 2.86 = 36.58'
20yr safe yield = $\frac{60.15}{36.58} \times 235 = 386$ igpm
m_1 = slope of best (least-squares) fit
= 2.86 ft/cycle.
$T = \frac{264 \times 235}{2.86} = 21{,}700$ igpd/ft
0
5
10
15
20
25
30
1
10
100
1000
10,000
t (min) and t/t'

FIGURE 17

W.T.H 4 March 26/68

BAIL TEST #2



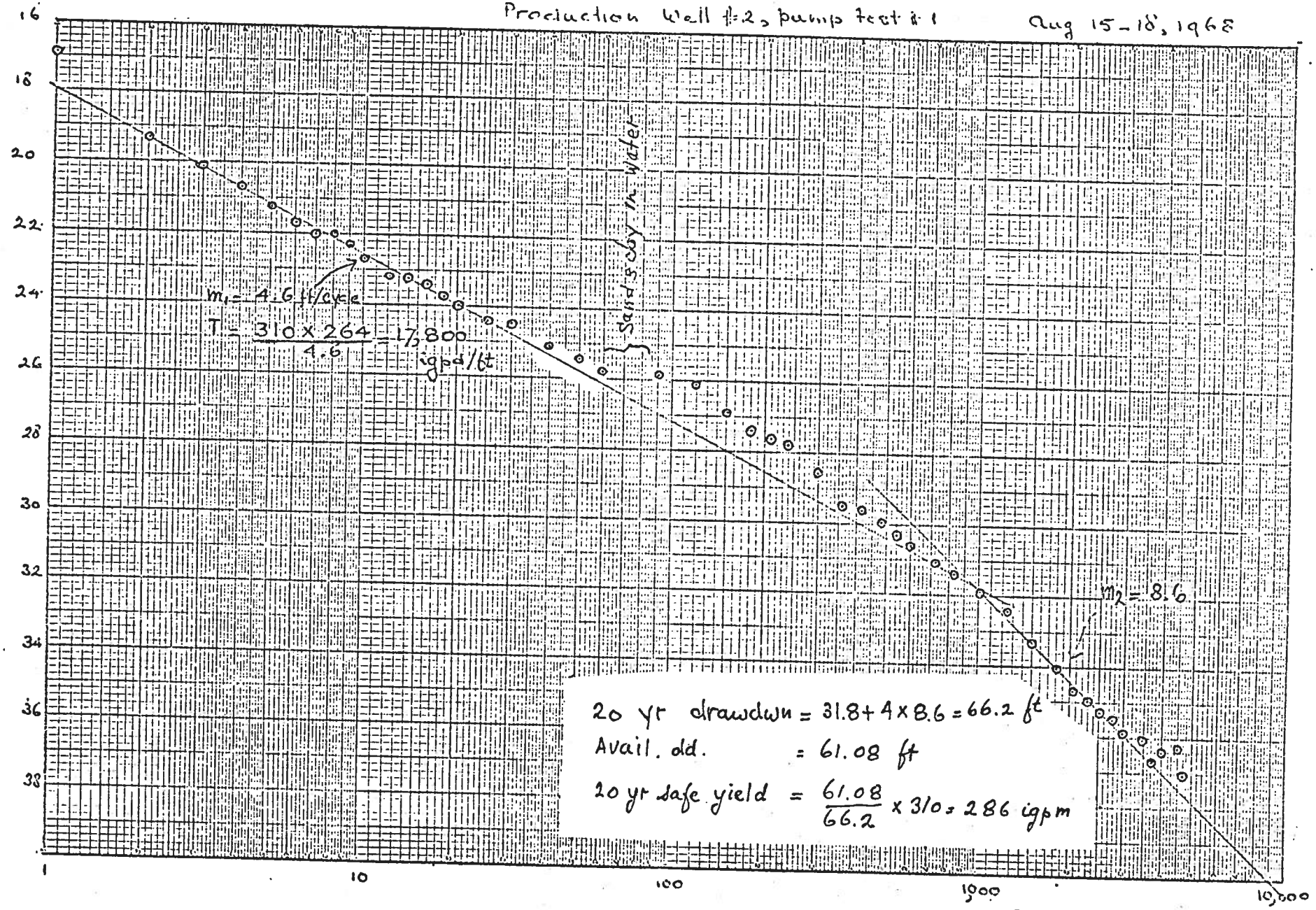

Production Well #2, pump test #1
Aug 15-18, 1968
drawdown (feet)
16
18
20
22
24
26
28
30
32
34
36
38
m_1 = 4.6 ft/cycle
$T = \frac{310 \times 264}{4.6} = 17{,}800$ gpd/ft
Sand & clay in water
m_2 = 8.6
20 yr drawdown = 31.8 + 4 × 8.6 = 66.2 ft
Avail. dd. = 61.08 ft
20 yr safe yield = $\frac{61.08}{66.2} \times 310 = 286$ igpm
1
10
100
1000
10,000
t (min)

FIGURE 19

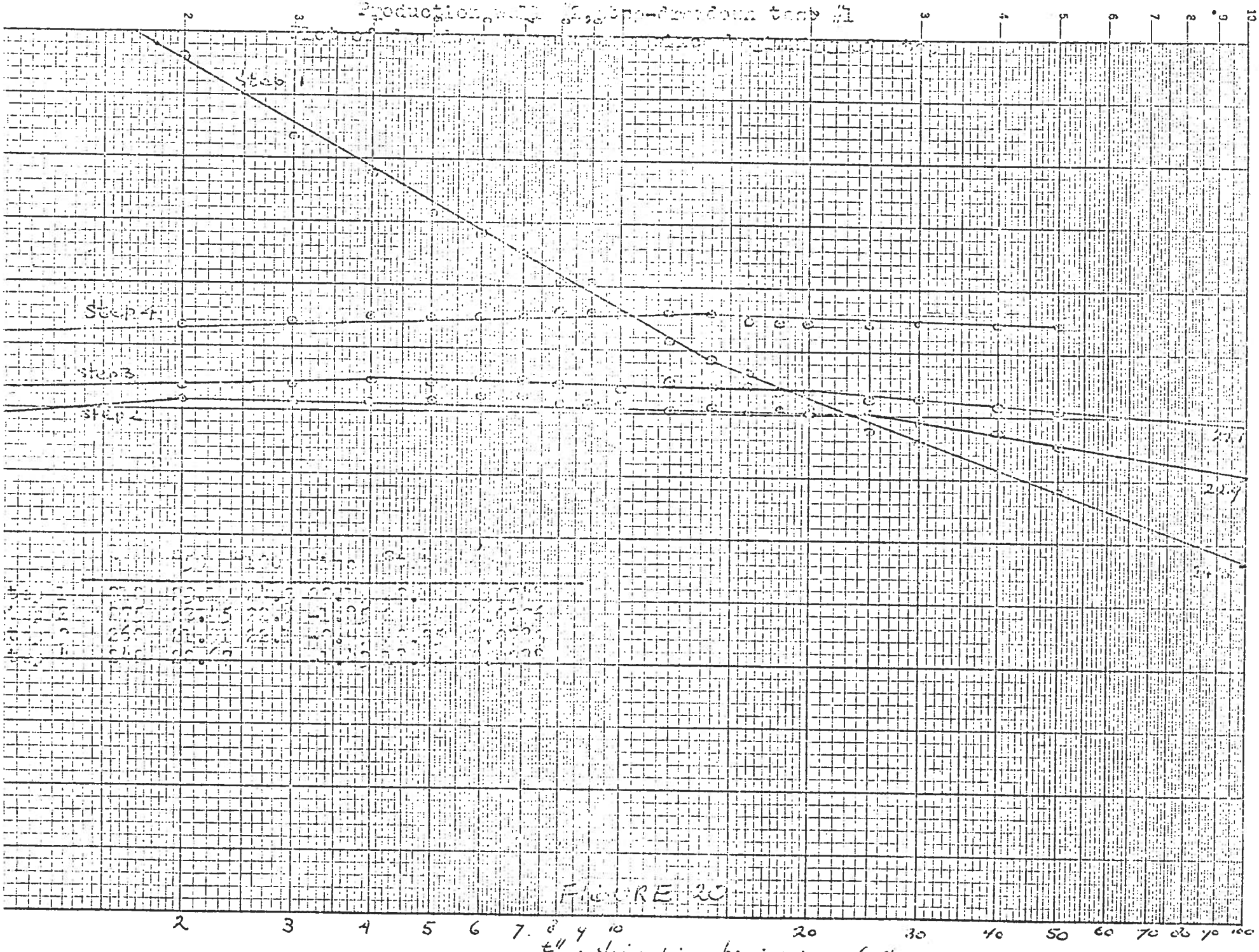
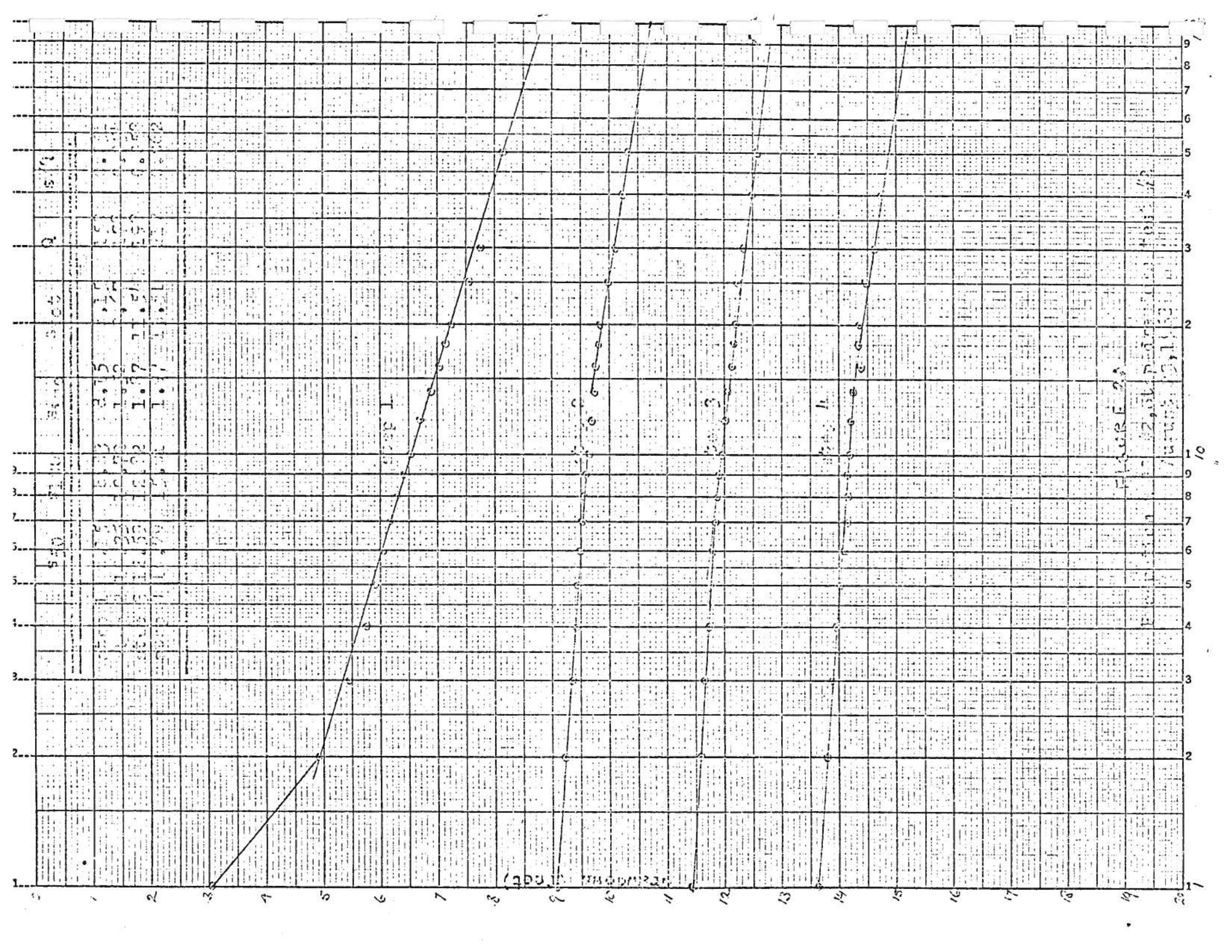

Production rate decline curve #1
Step 1
Step 2
Step 3
Step 4
2.7
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
t'', time since beginning of step

FIGURE 20



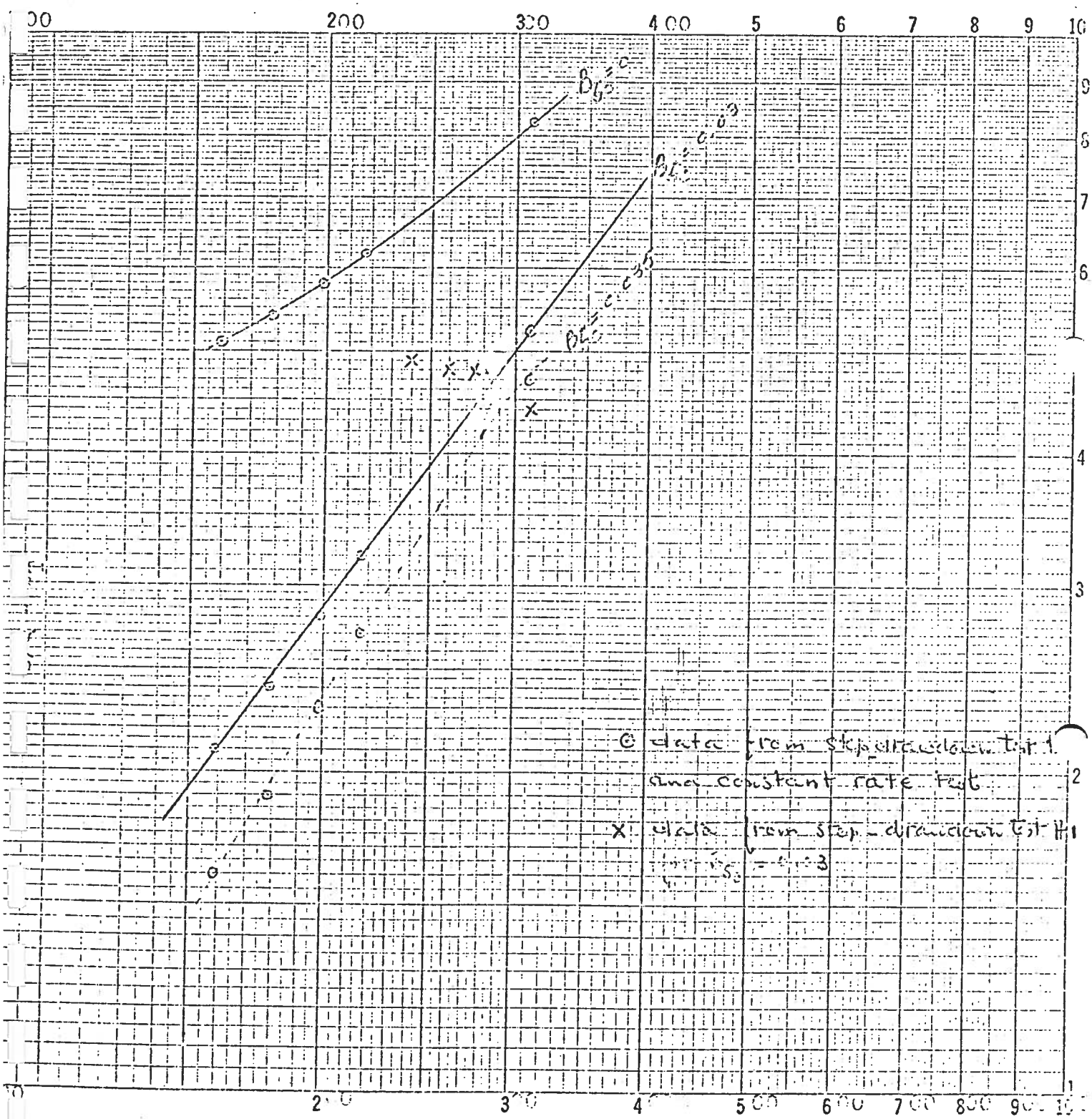


Figure 22. Production well #2, step-drawdown test #2, plot of $s/Q - B_{50}$ versus Q.

T. 5 SMOKE L.

BAIL TEST

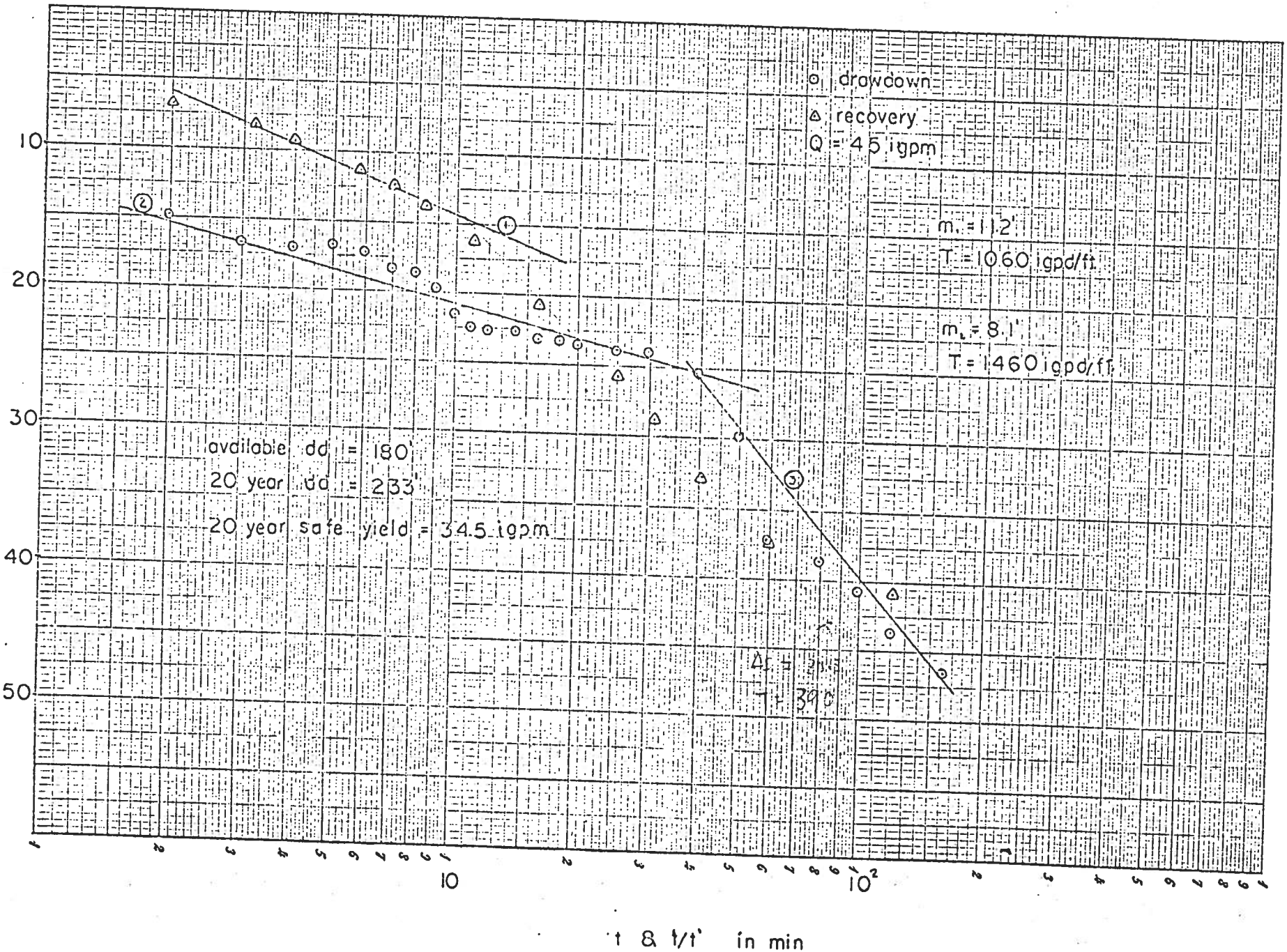


FIG. 24

W.T.H. #5, pump Test #1

drawdown and recovery of pumped well. April 16–25, 1968

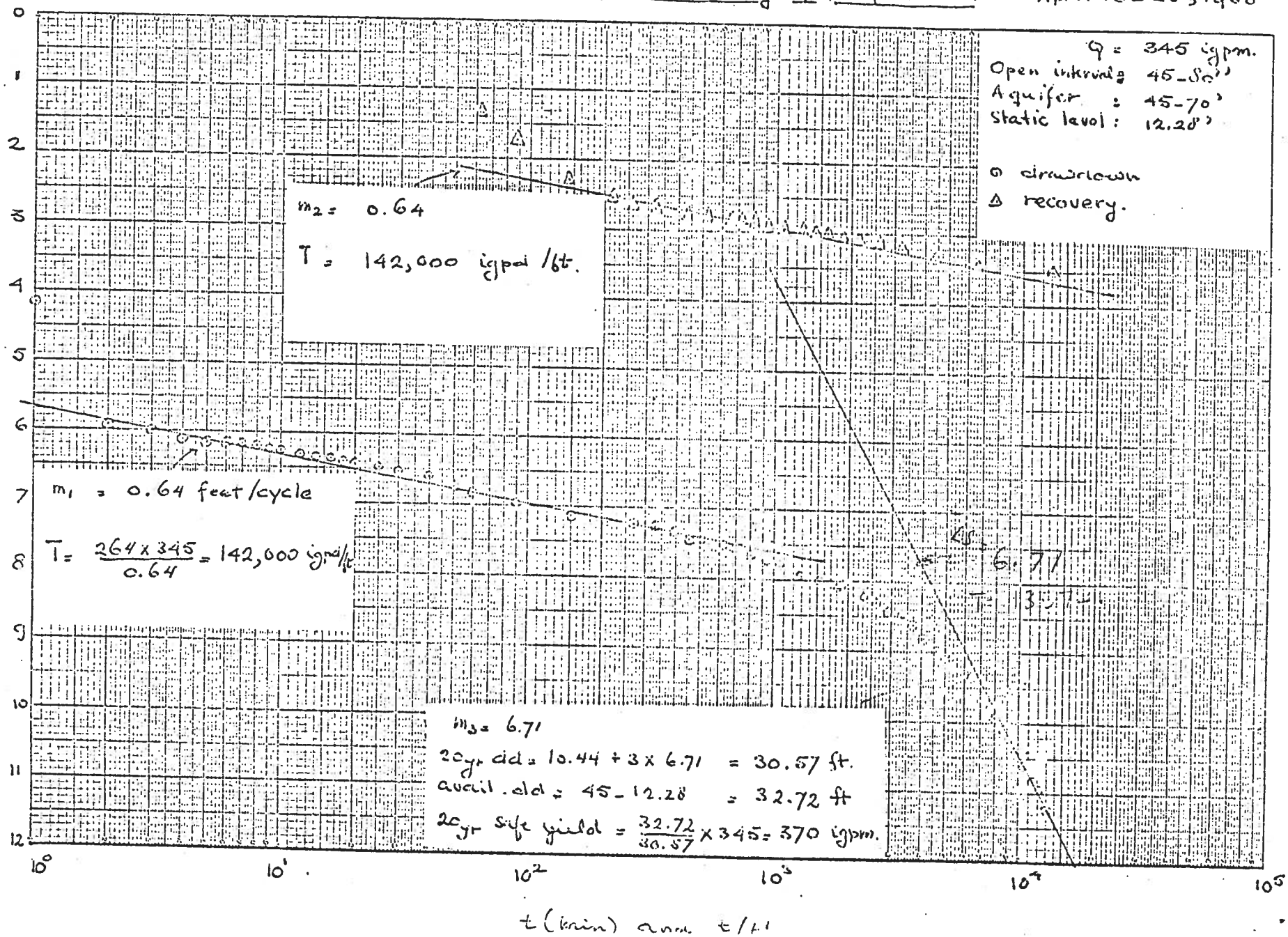


FIGURE 25

CAVING OF PRODUCTION WELL #1

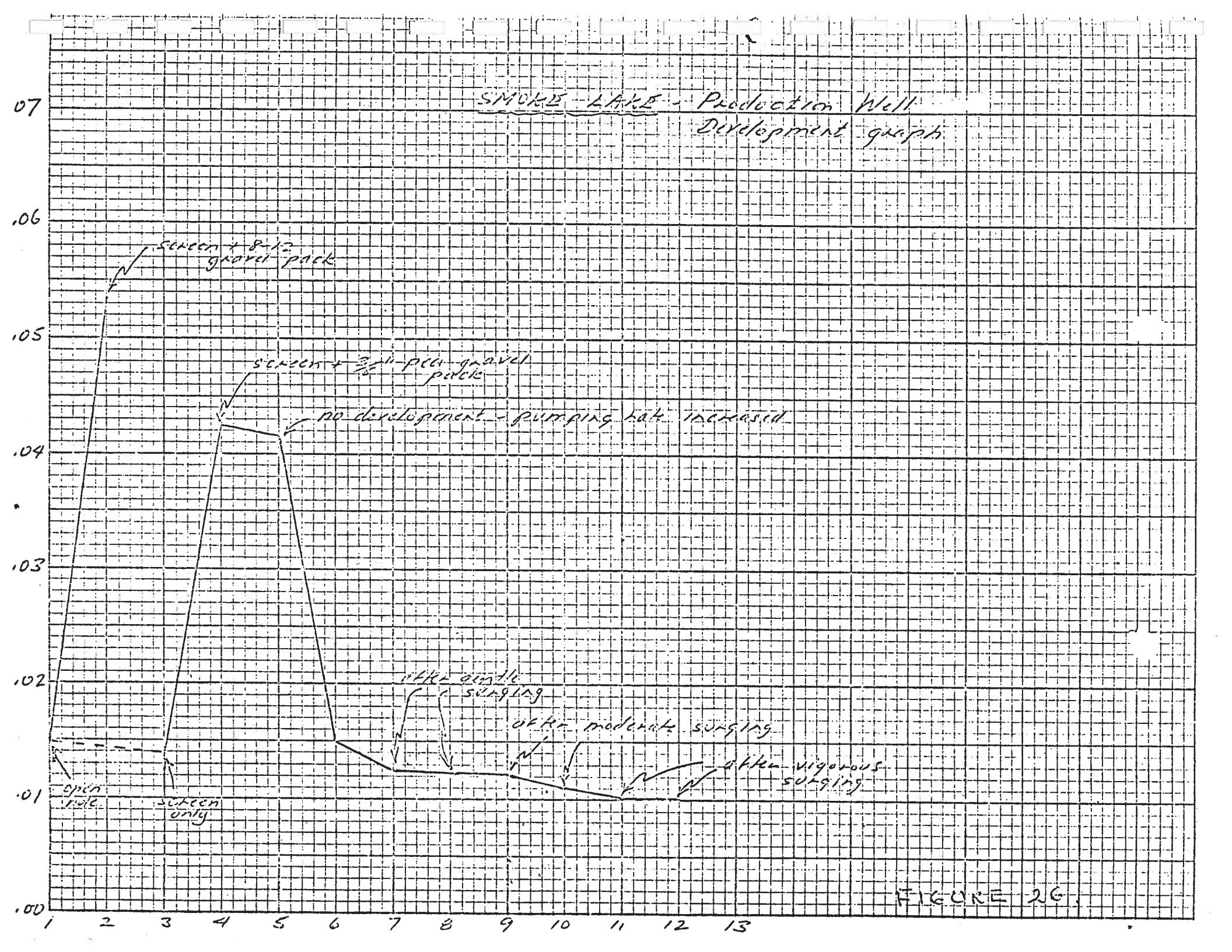
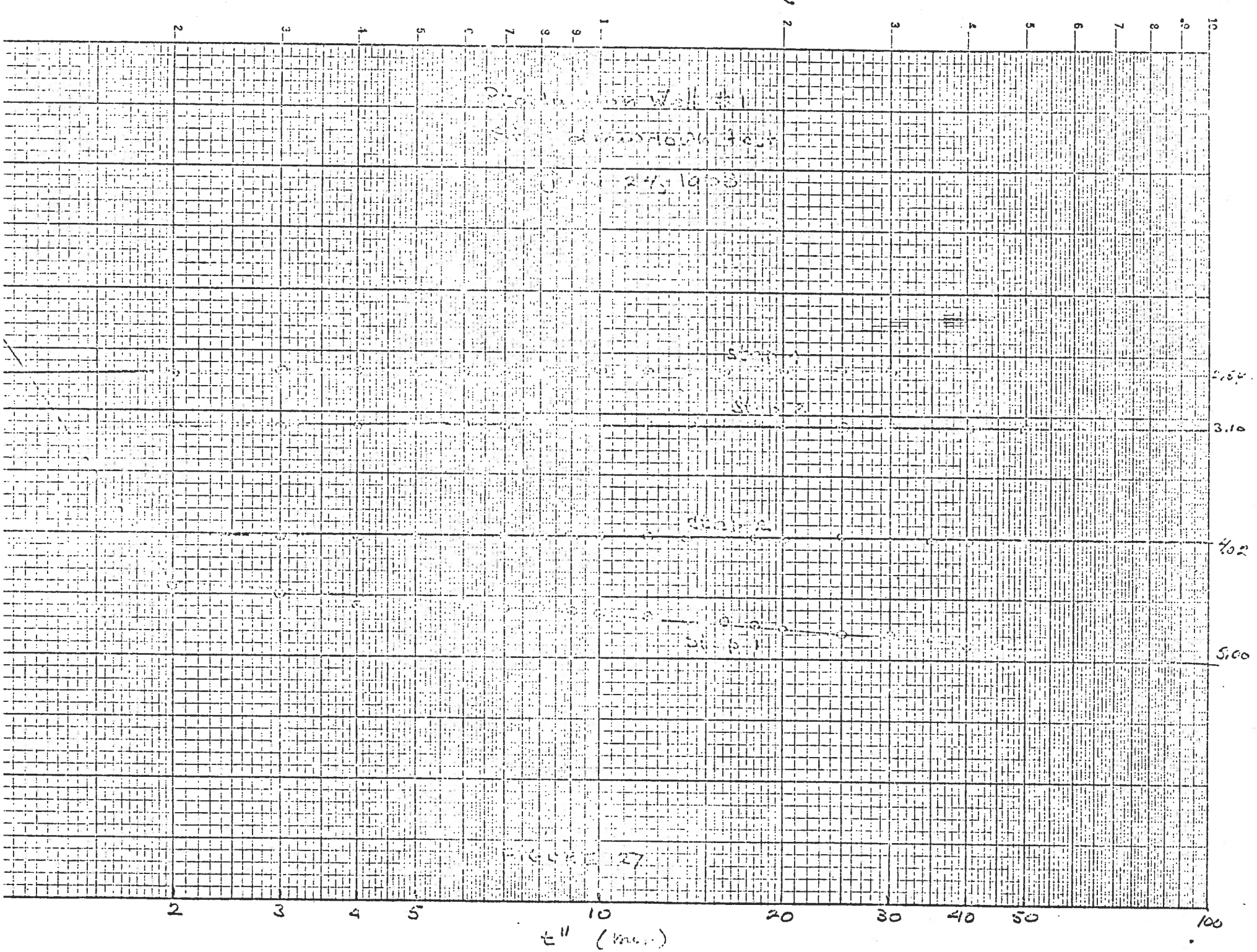

SMOKE LAKE - Production Well
Development graph
.07
.06
.05
.04
.03
.02
.01
.00
1
2
3
4
5
6
7
8
9
10
11
12
13
screen + 8-12 gravel pack
screen + 3/4" pea gravel pack
no development - pumping lift increased
open hole
screen only
after gentle surging
after moderate surging
after vigorous surging

FIGURE 26.


2
3
4
5
10
20
30
40
50
100
3.10
4.02
5.00

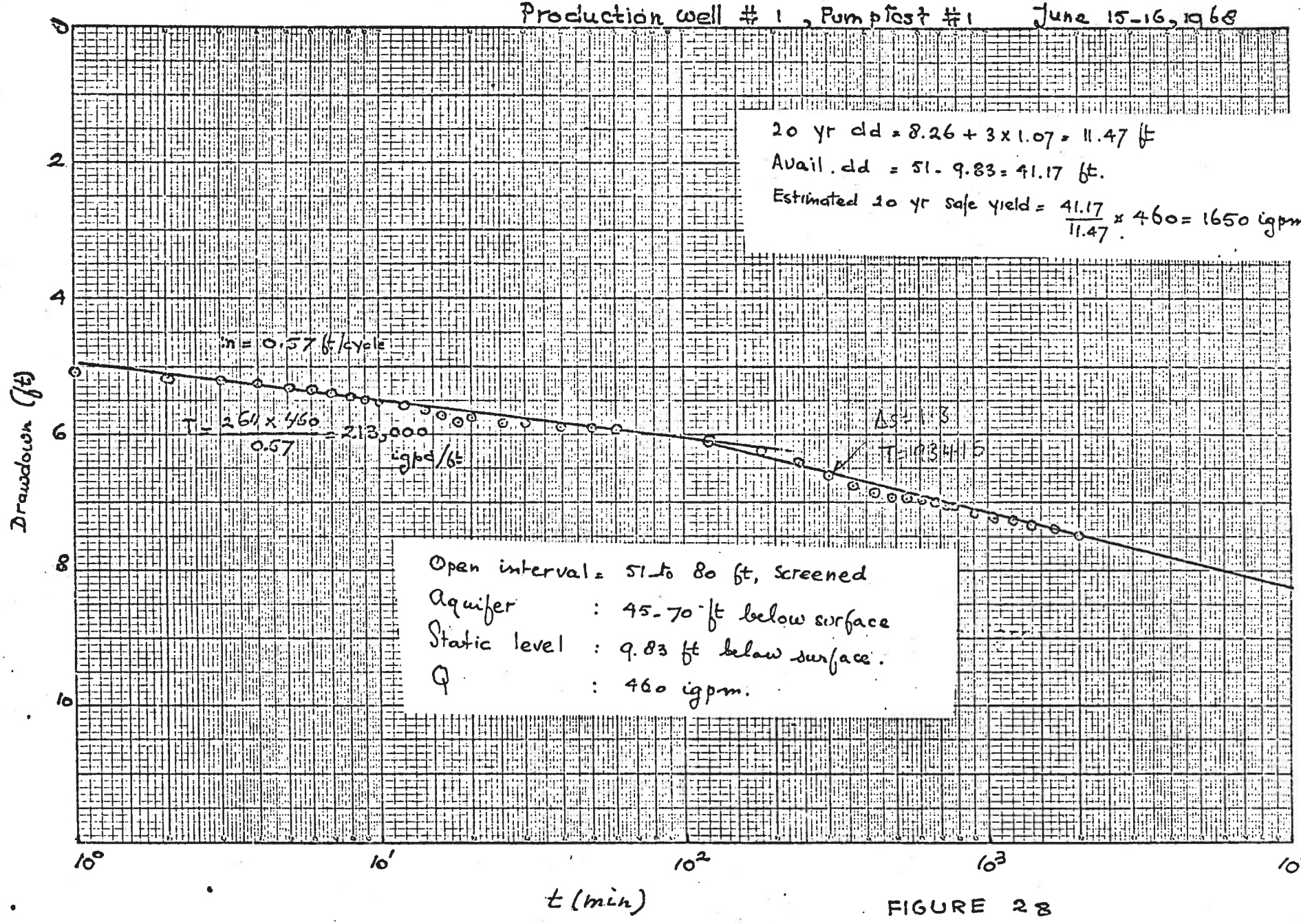

Production well # 1 , Pumptest #1 June 15-16, 1968
20 yr dd = 8.26 + 3 x 1.07 = 11.47 ft
Avail. dd = 51 - 9.83 = 41.17 ft.
Estimated 10 yr safe yield = 41.17/11.47 x 460 = 1650 igpm
n = 0.57 ft/cycle
T = 261 x 460 / 0.57 = 213,000 igpd/ft
Δs = 1.3
T = 193 x 460 / 1.3 = 68,300 igpd/ft
Open interval = 51 to 80 ft, Screened
Aquifer : 45-70 ft below surface
Static level : 9.83 ft below surface.
Q : 460 igpm.
Drawdown (ft)
0
2
4
6
8
10
10^0
10^1
10^2
10^3
10^4
t (min)

FIGURE 28

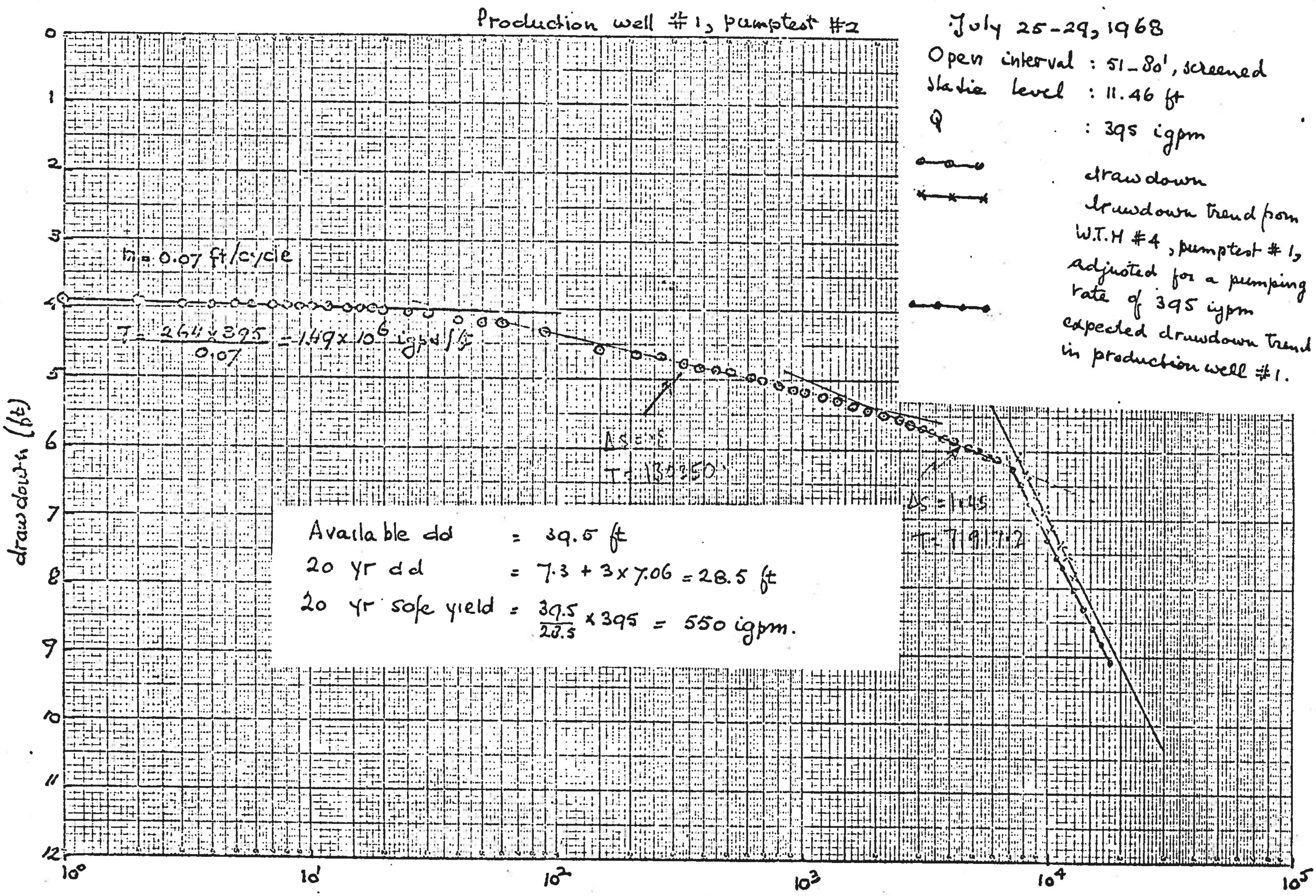

Production well #1, pumptest #2
July 25-29, 1968
Open interval : 51-80', screened
Static level : 11.46 ft
Q : 395 igpm
drawdown
drawdown trend from W.T.H #4, pumptest #1, adjusted for a pumping rate of 395 igpm
expected drawdown trend in production well #1.
m = 0.07 ft/cycle
T = 264 x 395 / 0.07 = 1.49 x 10^6 igpd/ft
ΔS = .78
T = 133,350
ΔS = 1.45
T = 71,912
Available dd = 39.5 ft
20 yr dd = 7.3 + 3 x 7.06 = 28.5 ft
20 yr safe yield = 39.5 / 28.5 x 395 = 550 igpm.
drawdown (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
10^0
10^1
10^2
10^3
10^4
10^5
t (min)

FIGURE 29.

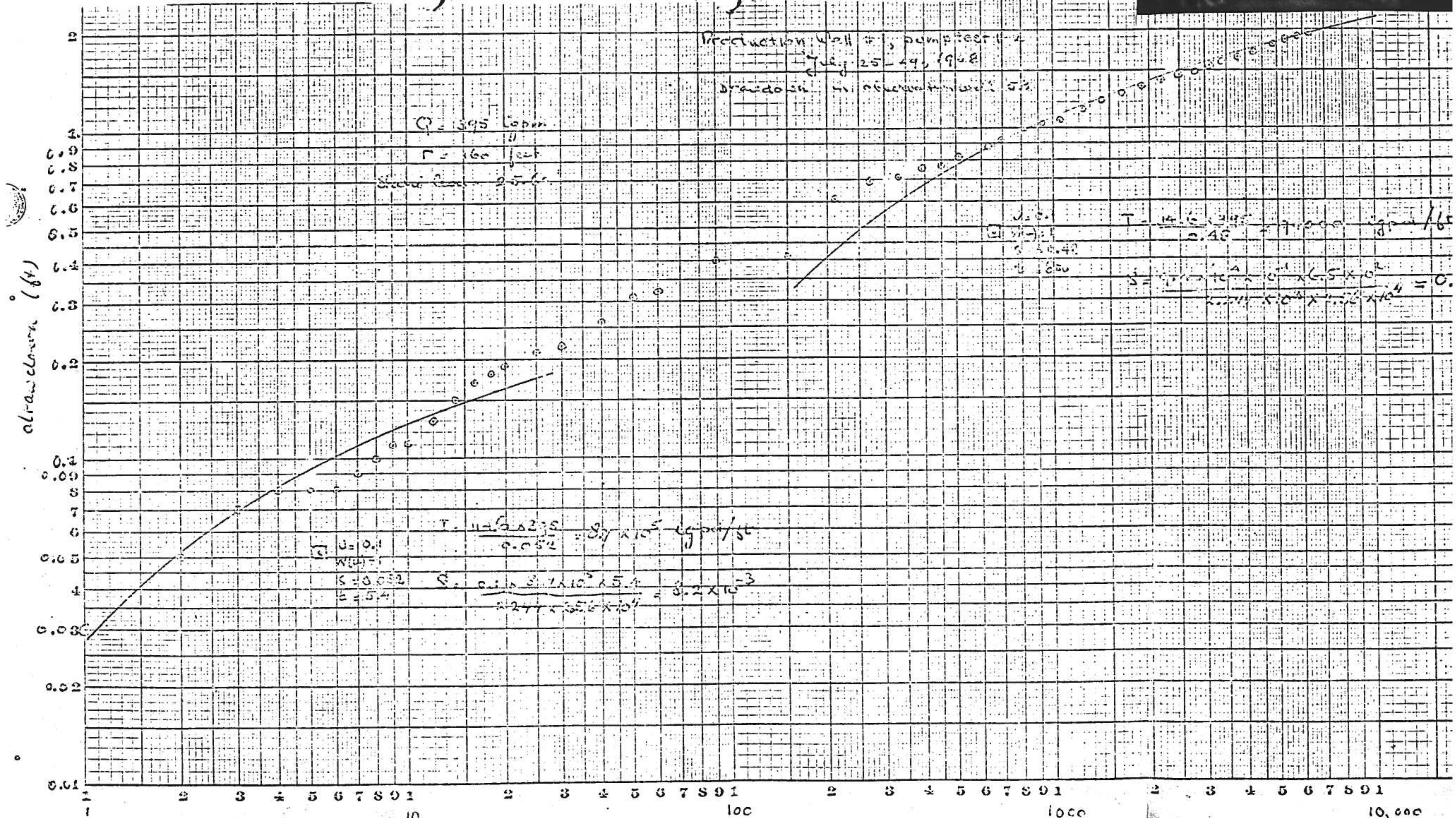
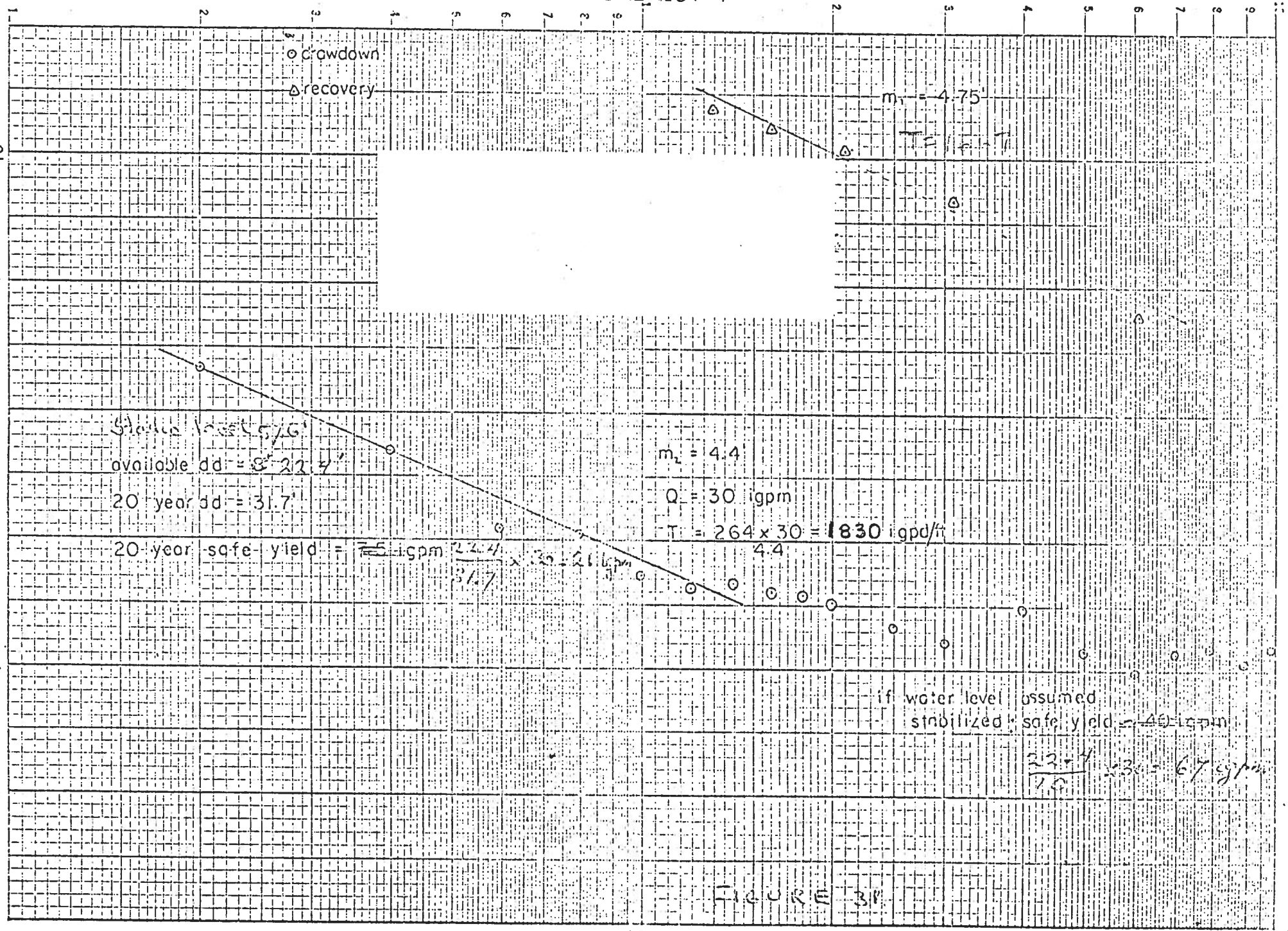

drawdown (ft)
Production Well #1, pump test 1-4
Q = 395 gpm
r = 160 feet
10
100
1000
10,000

FIG. 30

KEUFFEL & ESSER CO.

W.T.H. 6 BAIL TEST 1 SMOKE L.



W. T. H # 6, bail test # 2 May 10, 1968

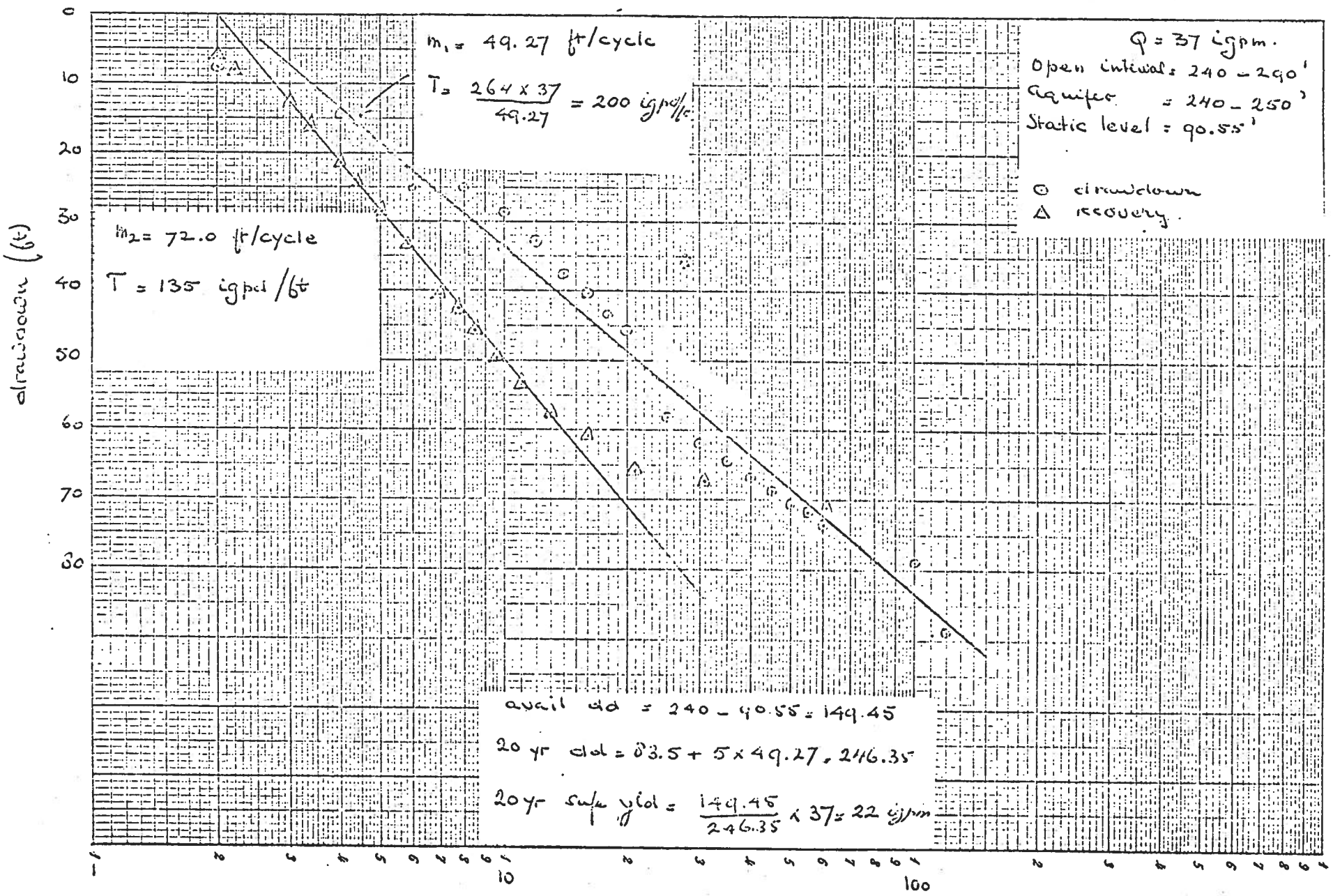


FIGURE 33

SMOKE L

Pump Test #1 > W T H #7 May 22/68

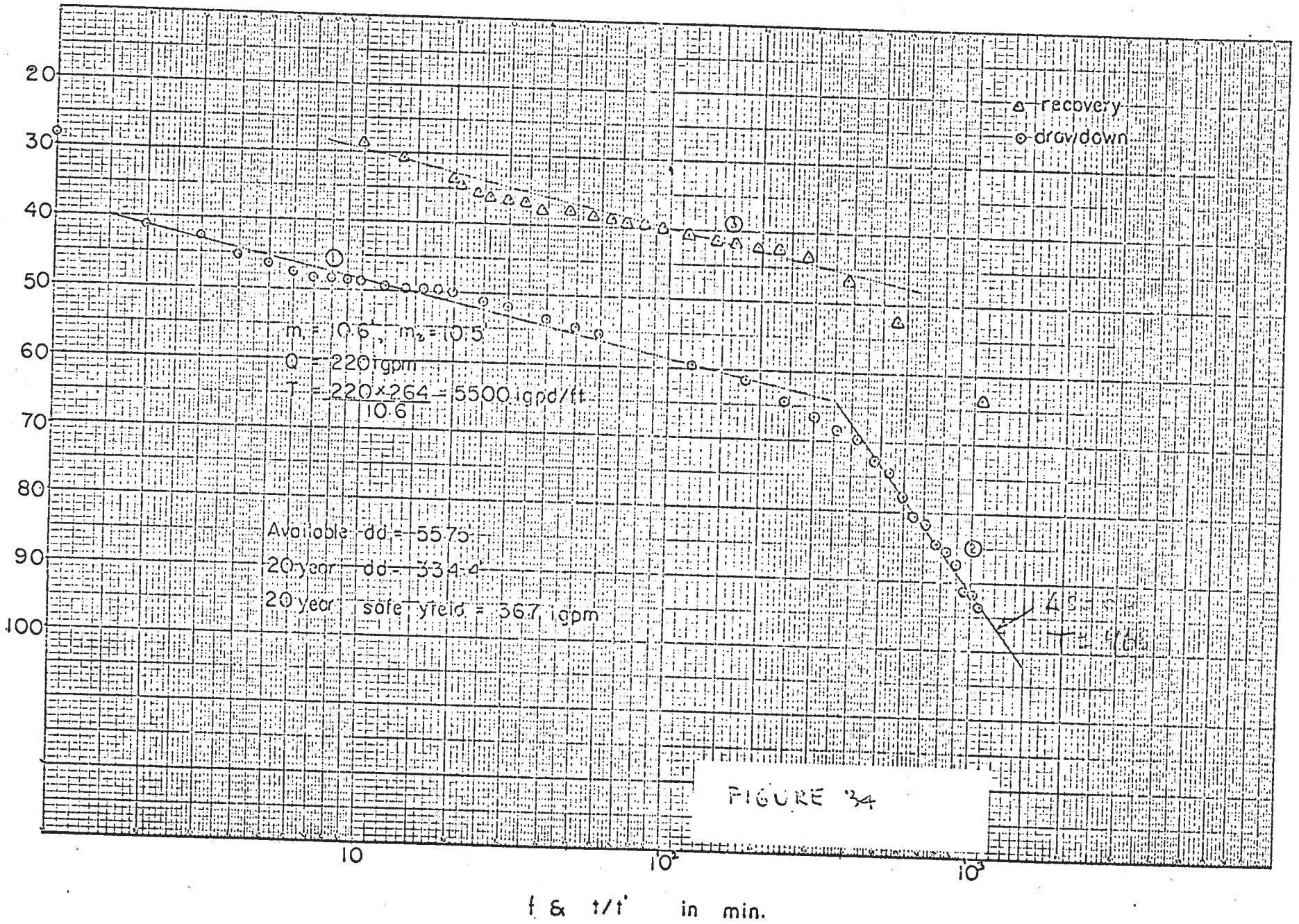


FIGURE 34

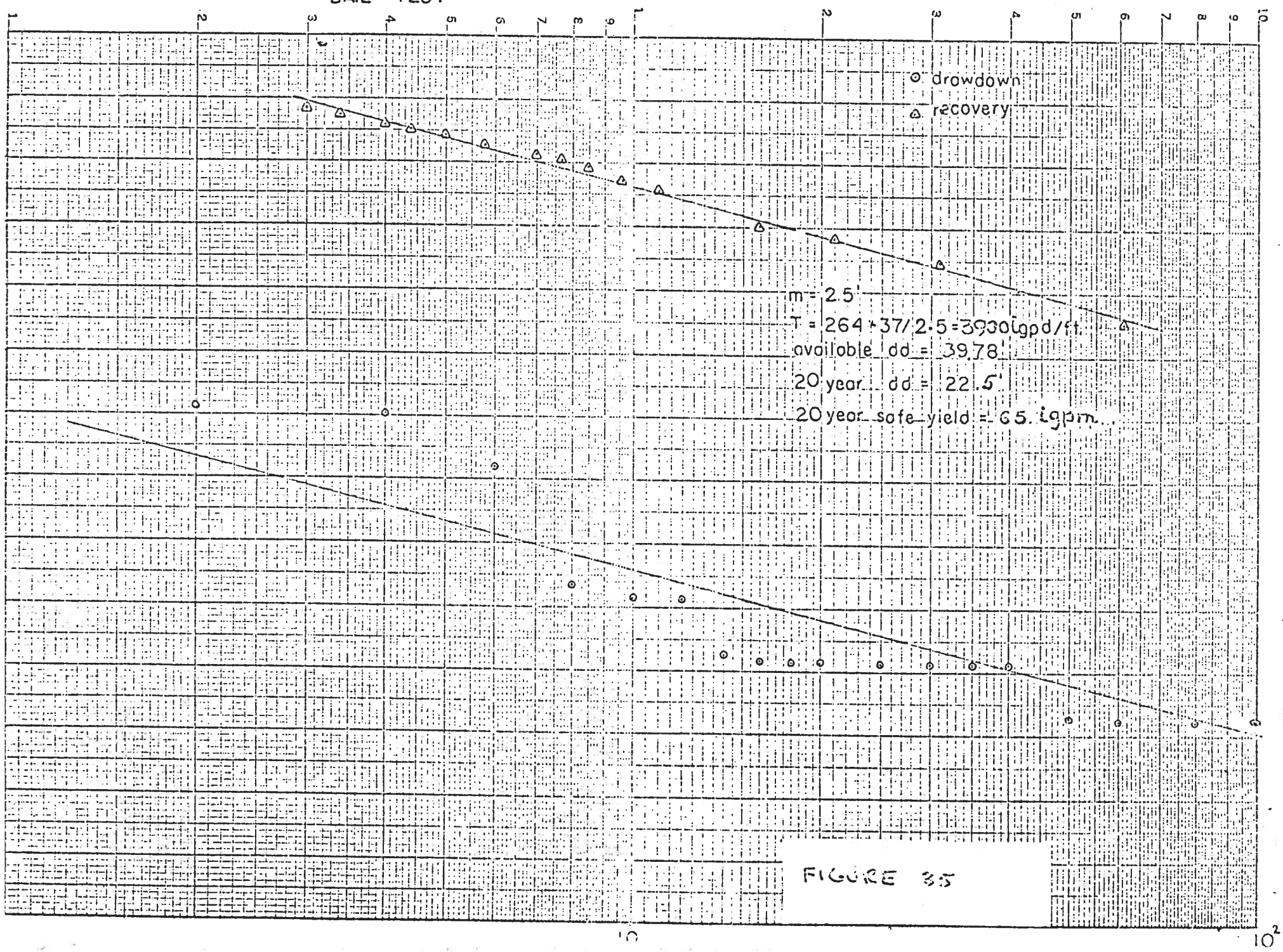

BAIL TEST
WTH 7
SMOKE L.
June 3/68
drowdown
recovery
m = 2.5'
T = 264 * 37/2.5 = 3930 igpd/ft.
available dd = 39.78'
20 year dd = 22.5'
20 year safe yield = 65. igpm.

FIGURE 35

W.T.H #7, pumptest #2

June 3-5, 1968

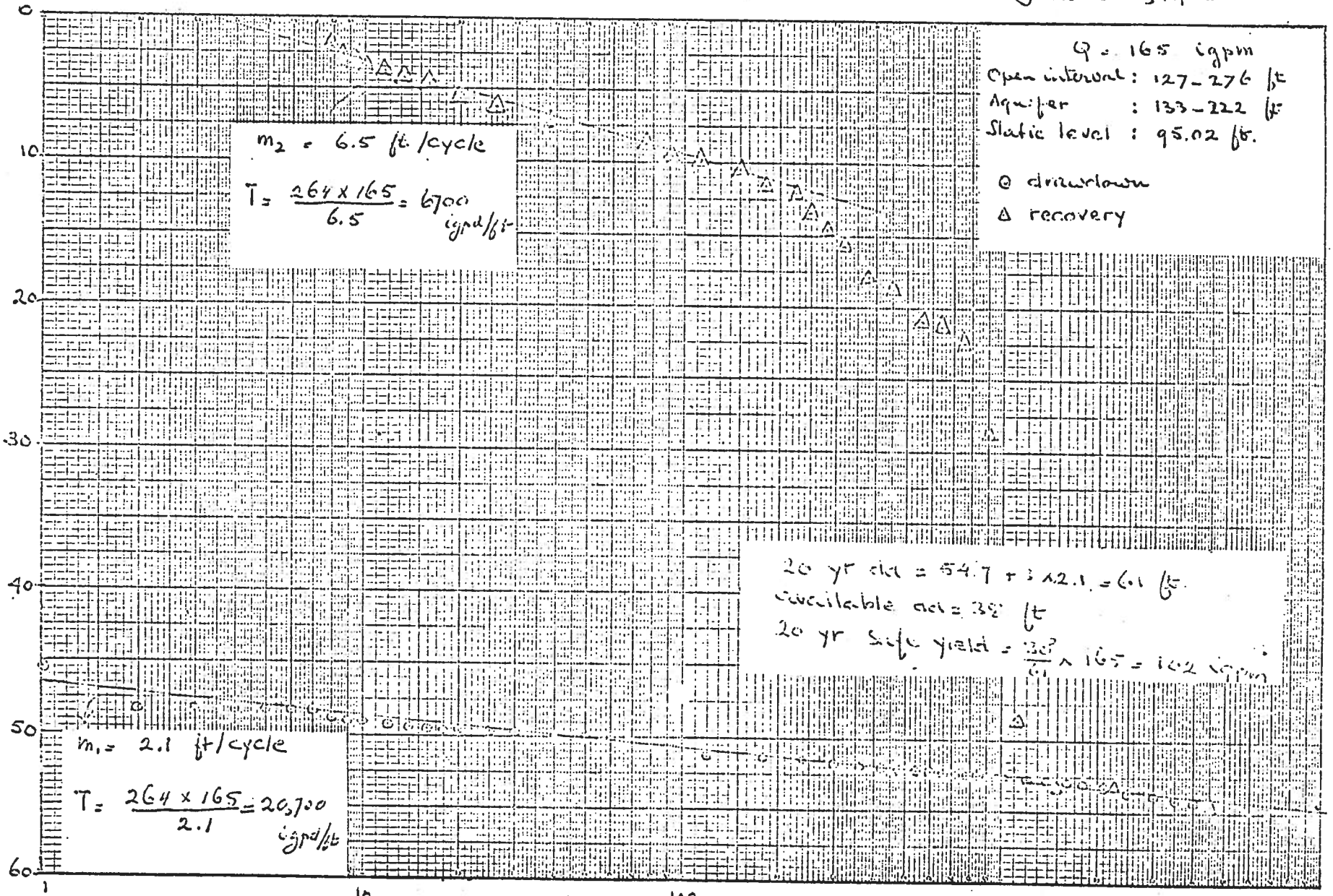


FIGURE 36