December 15, 1978

Mr. Peter J. Murphy
Utah Geological and Mineral Survey
606 Blackhawk Way
Salt Lake City, UT 84108

Dear Peter:

The results of the November 7, 1978 pump test of the flowing geothermal well near Crystal Hot Springs are encouraging. The aquifer can probably support several more low-capacity wells without diminishing the natural discharge to the ponds at Crystal Hot Springs.

The alluvial aquifer is tight, and large diameter wells may not be able to produce more water than smaller, less costly wells. All wells should be completed in bedrock.

I believe that the fractured quartzite is leaking hot water to the overlying alluvial aquifer. An observation well and an additional pump test will be needed to assess this inferred leakage and the accompanying vertical movement of water and delayed yield from storage.

A thin hole within 30 feet of the flowing well, similar to the temperature gradient holes but with perforated PVC casing, would be an adequate observation well, which might later be adaptable to production.

Sincerely,

Christian Smith

Christian Smith

CS/smk

encl.

cc: P.M. Wright
D. Foley
S.H. Ward
L.L. Mink

CRYSTAL HOT SPRINGS PUMP TEST ANALYSIS

The flowing geothermal well on the grounds of the Utah State Prison near Crystal Hot Springs, Jordan Narrows Quadrangle, Utah, was pumped at an average rate of 30 gpm for more than six hours on November 7, 1978. This report summarizes the data and results of this short-term pump test.

Figure 1 is a sketch of the well and the geologic units it penetrates. The well diameter is 6 in, its total depth 285 ft; it is cased to the bottom of the hole. Torch-cut slots in the bottom 110 ft of the casing were used to complete the well. The artesian head is inferred to be 9 ft above ground level; artesian flow is about 8 gpm at 180°F. The 195 ft thick, fine-grained alluvial aquifer is confined above by approximately 90 ft of clay and below by pervasively fractured quartzite bedrock. While it is not known whether the quartzite yields water directly to the well, all evidence indicates that it does leak hot water to Crystal Hot Springs, a few hundred feet to the south.

The pump test was designed to be, but did not satisfy the strict requirements for, a step-drawdown test and numerical analysis. Attempts to apply the step-drawdown analysis suggest well-losses are minimal and that the well is efficient. Completion of the well may even have improved the transmissivity of the aquifer within a short distance of the well.

The raw pump test data are plotted in Figure 2. Discharge, Q, in gallons per minute and drawdown (the increasing depth to water), s, in feet are plotted against the logarithm of time. A nearly constant rate of discharge at 30 gpm was sustained for 288 minutes. During most of this interval the drawdown was also nearly constant at 57 feet. Drawdown increased to 93 ft only when discharge exceeded 30 gpm between 183 and 188 minutes. These observations indicate that there is a source of hot water near the well capable of supplying about 30 gpm instantaneously to the aquifer. The constant drawdown (136 ft) during the final pumping interval indicates that the source of hot water may be capable of supplying as much as 35 gpm.

The source of hot water also fills the ponds at Crystal Hot Springs. It is possible but unlikely that the well is pumping water that would otherwise rise to these ponds. It is also possible that the quartzite is leaking water directly to the well. In either case, pumping 30 gpm should have no observable effect upon the natural regime of the ponds.

Since no observation wells were available, the log-log type curve solution for transmissivity, T, and storage, S, cannot be found. To estimate T, the 'Harrill time', t_H, was used in a conventional straight-line analysis of the recovery data (Fig. 3). This value compensates for the changes in discharge and the nonequal periods of pumping at the different discharges recorded during the test (Harrill, 1970). Two straight-line segments emerged, an 'early' segment and a 'late' segment, from which the corresponding transmissivities T_e and T_l can be computed.

$$T_e = 34.4 \text{ ft}^2/\text{day}$$

$$T_l = 18.7 \text{ ft}^2/\text{day}$$

These values are low but are typical of tight, fine-grained artesian aquifers.

The two estimates of T are sufficiently low to limit the rate at which the aquifer can deliver water to the well. When pumped at a rate less than it can deliver, an aquifer with a low T and a nearby source of water is likely to sustain a constant drawdown. The response in an artesian system may be instantaneous: an increased discharge can cause the water level to drop immediately. If the pumping rate is again dropped to the lower rate, the water level will again remain constant, but at a lower level. This is thought to be what happened during the pump test at Crystal Hot Springs.

Given an estimate of T and the pump-test data, it is possible to estimate the value of storage, S. The well was pumped for 0.26 days at an average discharge of 30 gpm; the total drawdown was 135 ft. The results are:

$$T_e = 34.4 \text{ ft}^2/\text{day} \qquad S = 0.001$$

$$T_l = 18.7 \text{ ft}^2/\text{day} \qquad S = 0.05$$

The solutions are not strictly valid for reasons discussed below. Figure 4 is a graph of drawdown as a function of the logarithm of distance from the pumping well for these two solutions. Tables 1 and 2 are the values plotted in Figure 4. Data from an observation well within 30 ft of the pumping well would discriminate between these two solutions. Both values of S are high for artesian systems; the value of S = 0.05 is so high that the T_l solution is less likely.

The Theis equation has been used to predict the effects of continued pumping on the aquifer (Theis, 1935), This general equation assumes an infinite isotropic aquifer with no recharge areas near the pumping well, conditions violated at Crystal Hot Springs. Since a recharge area is present, the Theis equation will predict drawdowns greater than those that will probably be observed. The drawdowns listed in Tables 3a-d and 4a-d and shown in Figures 5 and 6 may be excessive and the values of S maybe too great.

Figures 5 and 6 plot the drawdown as a function of the logarithm of distance from a well pumping 10 gpm for periods of one day, one month, one year, and ten years. It can be seen that continued pumping of the present well is predicted to have little effect on the Crystal Hot Springs area. The aquifer may be able to support several properly spaced small-diameter wells pumping 10 gpm in a well field.

Before production is contemplated, an observation well should be drilled near the present well and a flow test run. The leaky confined aquifer equation of Hantush (1959) could then be used to refine the conclusions presented here.

REFERENCES

Harrill, J. R., 1970, Determining transmissivity from water-level recovery of a step-drawdown test: U.S. Geol. Survey Prof. Paper 700-C, p. C212-C213.

Hantush, M. D., 1959, Nonsteady flow to flowing wells in leaky aquifers: Jour. Geophys. Research, v. 64, no. 8, p. 1043-1052.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Amer. Geophys. Union Trans. pt. 2, p. 517-524

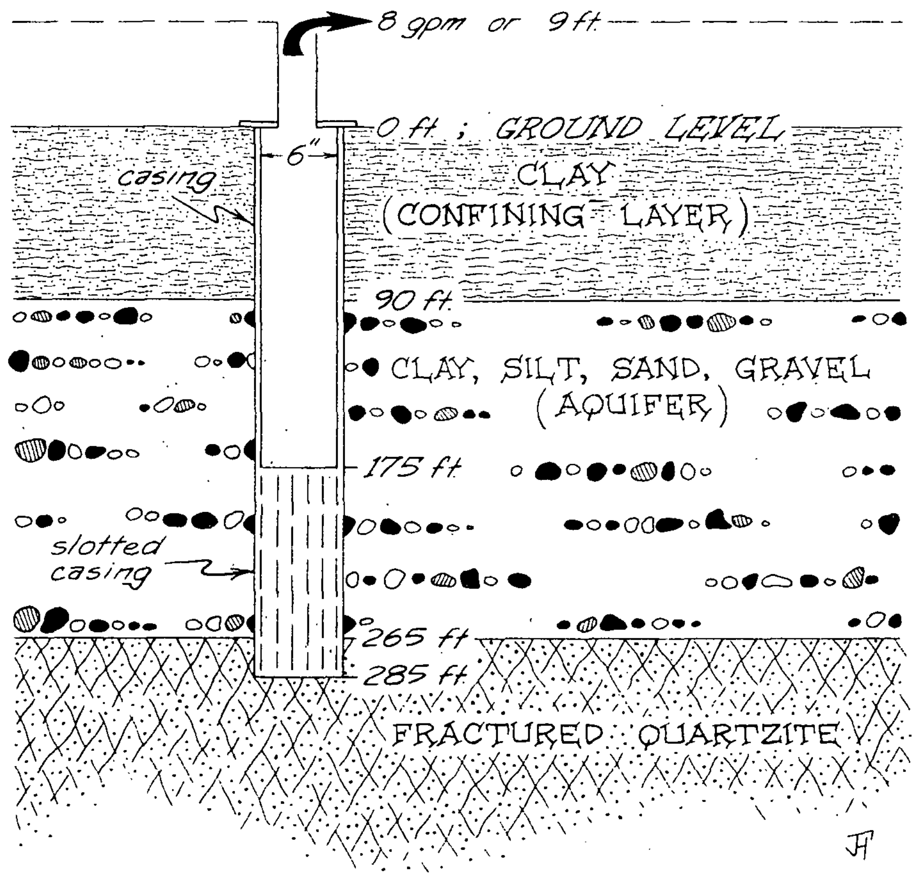


FIGURE 1. DIAGRAMMATIC SKETCH OF CRYSTAL SPRINGS/UTAH STATE PRISON FLOWING GEOTHERMAL WELL

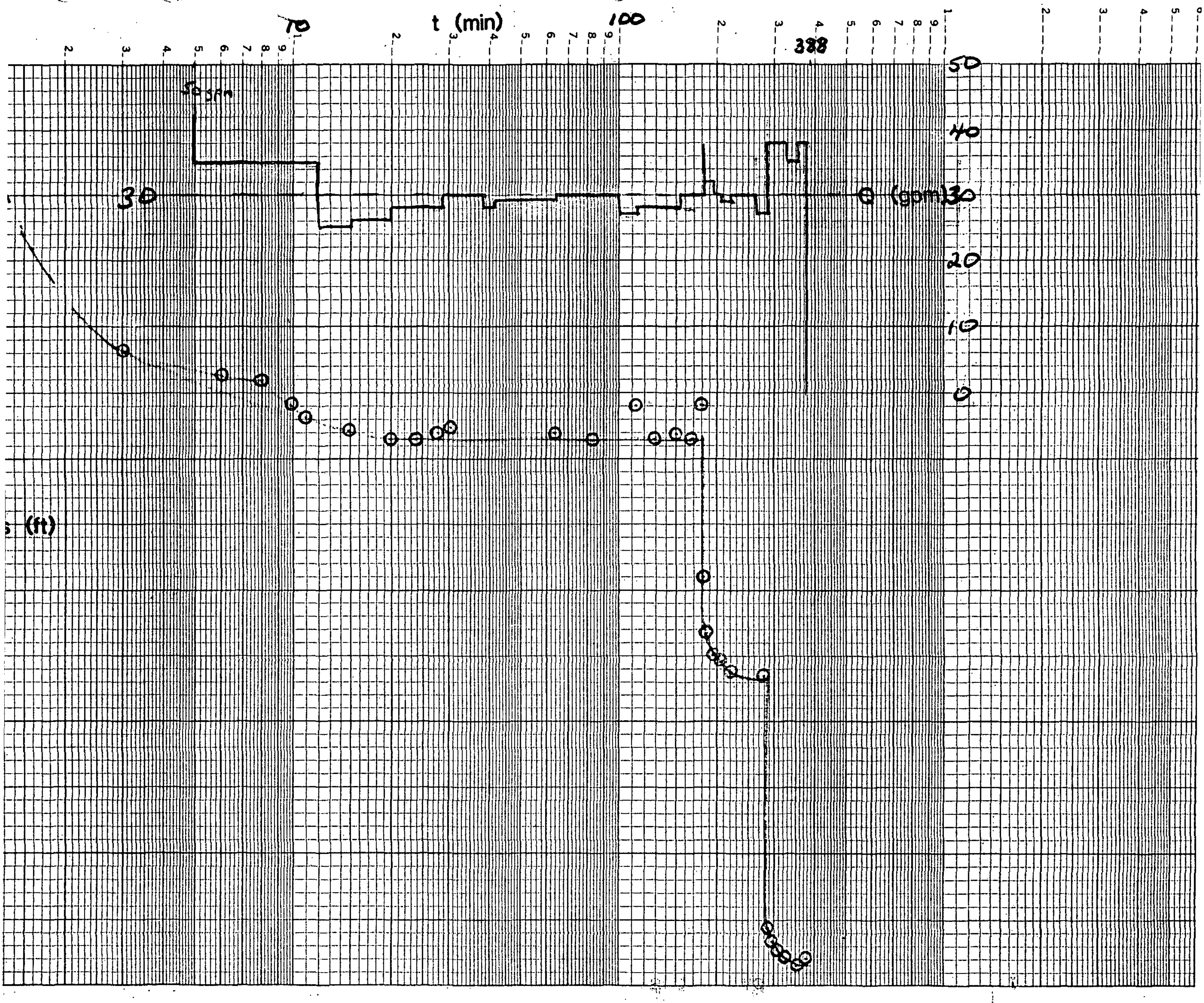


Fig 2 Pump-test data - Discharge, Q, and drawdown, s, vs. log time, t

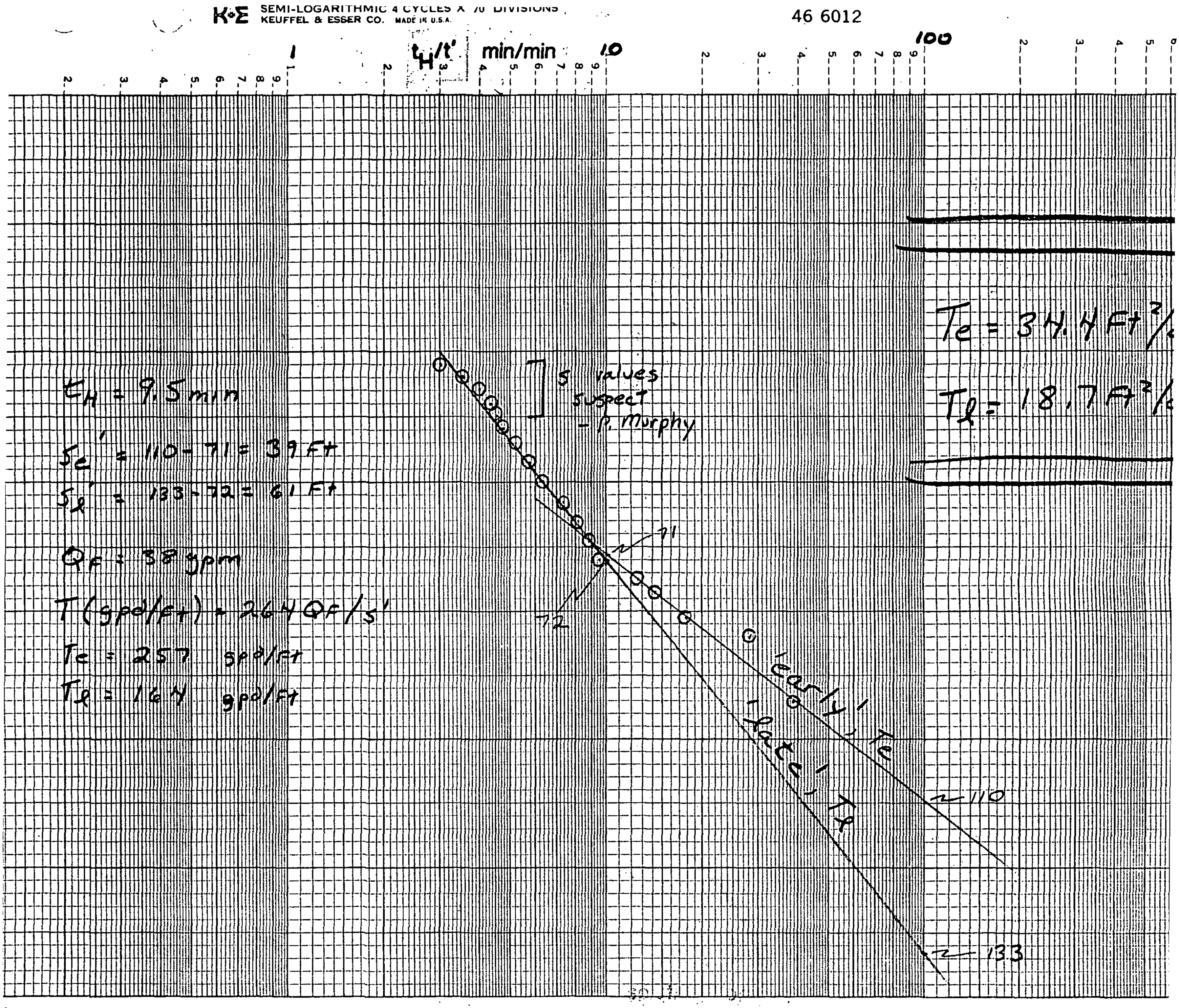
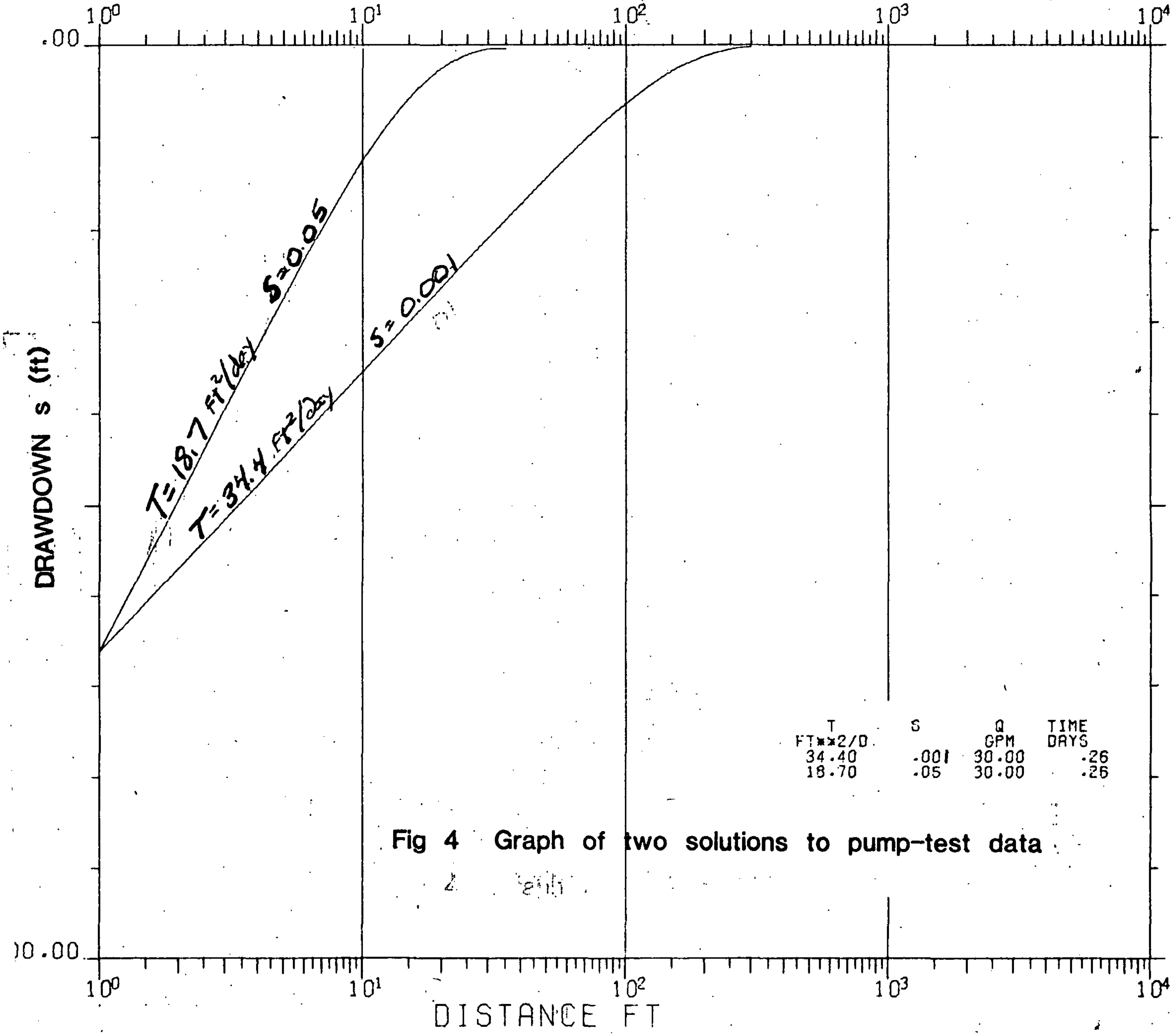


Fig 3 Straight-line solution for transmissivity, T



T FT**2/D	S	Q GPM	TIME DAYS
34.40	.001	30.00	.26
18.70	.05	30.00	.26

Fig 4 Graph of two solutions to pump-test data

T= [illegible] S= .0010 Q= [illegible] TIME= [illegible]

#	DISTANCE	DRAWDOWN
1	1,0000	132,361
2	1,2000	127.490
3	1,4000	123.372
4	1,6000	119.804
5	1,8000	116.657
6	2,0000	113.843
7	2,2000	111,296
8	2,4000	108,972
9	2,6000	106.834
10	2,8000	104.854
11	3,0000	103.011
12	3,5000	98.894
13	4,0000	95,327
14	4,5000	92.182
15	5,0000	89.369
16	5,5000	86.824
17	6,0000	84.501
18	6,5000	82.365
19	7,0000	80,387
20	8,0000	76.825
21	9,0000	73.685
22	10,0000	70.877
23	12,0000	66.022
24	14,0000	61.922
25	16,0000	58,377
26	18,0000	55,255
27	20,0000	52.468
28	22,0000	49,953
29	24,0000	47.662
30	26,0000	45.561
31	28,0000	43.621
32	30,0000	41.820
33	35,0000	37.821
34	40,0000	34,391
35	45,0000	31.398
36	50,0000	28.755
37	55,0000	26.397
38	60,0000	24.277
39	65,0000	22.360
40	70,0000	20.617
41	80,0000	17.567
42	90,0000	14.995
43	100,0000	12.806
44	120,0000	9.327
45	140,0000	6.755
46	160,0000	4.849
47	180,0000	3.442
48	200,0000	2.413
49	220,0000	1,669
50	240,0000	1.138
51	260,0000	.768
52	280,0000	.521
53	300,0000	.379

Table 2 Solution to pump-test data, TI

DRAWDOWN # 2
T= 18.7000 S= .0500 Q= 30.0000TIME= .2600

#	DISTANCE	DRAWDOWN
1	1.0000	132.432
2	1.2000	123.499
3	1.4000	115.955
4	1.6000	109.429
5	1.8000	103.683
6	2.0000	98.552
7	2.2000	93.921
8	2.4000	89.702
9	2.6000	85.830
10	2.8000	82.255
11	3.0000	78.937
12	3.5000	71.563
13	4.0000	65.232
14	4.5000	59.706
15	5.0000	54.819
16	5.5000	50.454
17	6.0000	46.526
18	6.5000	42.967
19	7.0000	39.727
20	8.0000	34.046
21	9.0000	29.237
22	10.0000	25.130
23	12.0000	18.555
24	14.0000	13.641
25	16.0000	9.954
26	18.0000	7.194
27	20.0000	5.142
28	22.0000	3.631
29	24.0000	2.531
30	26.0000	1.743
31	28.0000	1.193
32	30.0000	.835
33	35.0000	.825

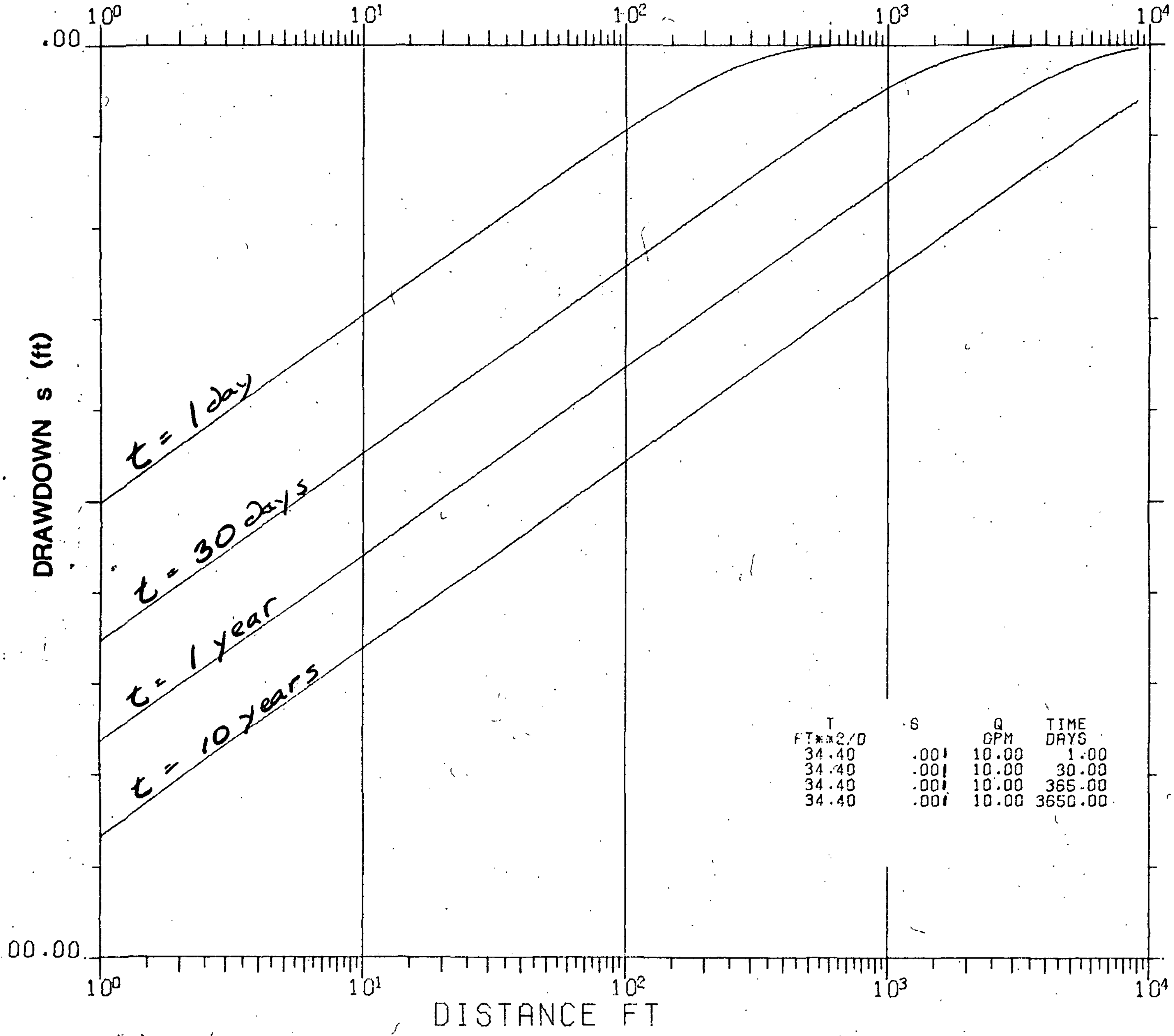


Fig 5 Graph of predicted effects of continued pumping, Te

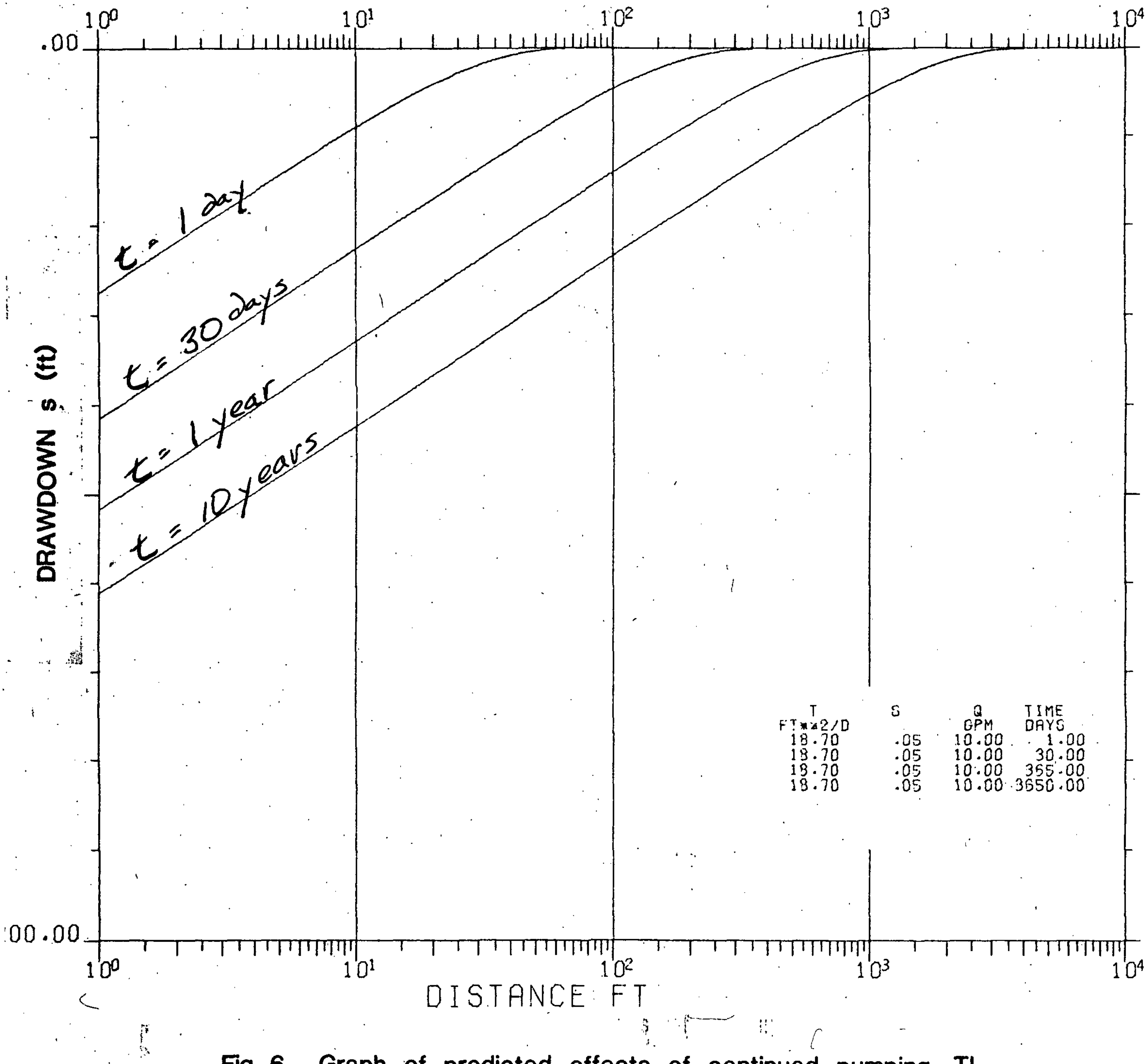


Fig 6 Graph of predicted effects of continued pumping, TI

10	2,8000	40,949
11	3,0000	40,335
12	3,5000	38,962
13	4,0000	37,773
14	4,5000	36,724
15	5,0000	35,786
16	5,5000	34,937
17	6,0000	34,162
18	6,5000	33,450
19	7,0000	32,790
20	8,0000	31,601
21	9,0000	30,553
22	10,0000	29,615
23	12,0000	27,993
24	14,0000	26,621
25	16,0000	25,434
26	18,0000	24,387
27	20,0000	23,451
28	22,0000	22,605
29	24,0000	21,833
30	26,0000	21,124
31	28,0000	20,467
32	30,0000	19,856
33	35,0000	18,494
34	40,0000	17,317
35	45,0000	16,281
36	50,0000	15,358
37	55,0000	14,526
38	60,0000	13,770
39	65,0000	13,077
40	70,0000	12,438
41	80,0000	11,297
42	90,0000	10,301
43	100,0000	9,422
44	120,0000	7,935
45	140,0000	6,720
46	160,0000	5,710
47	180,0000	4,860
48	200,0000	4,137
49	220,0000	3,521
50	240,0000	2,993
51	260,0000	2,540
52	280,0000	2,152
53	300,0000	1,818
54	350,0000	1,178
55	400,0000	,748
56	450,0000	,465
57	500,0000	,283
58	550,0000	,172
59	600,0000	,119

a - 1 day

10	2,8000	56.095
11	3,0000	55.480
12	3,5000	54.107
13	4,0000	52.918
14	4,5000	51.869
15	5,0000	50.931
16	5,5000	50.082
17	6,0000	49.307
18	6,5000	48.594
19	7,0000	47.934
20	8,0000	46.745
21	9,0000	45.696
22	10,0000	44.758
23	12,0000	43.134
24	14,0000	41.761
25	16,0000	40.572
26	18,0000	39.523
27	20,0000	38.585
28	22,0000	37.736
29	24,0000	36.961
30	26,0000	36.248
31	28,0000	35.588
32	30,0000	34.974
33	35,0000	33.602
34	40,0000	32.413
35	45,0000	31.364
36	50,0000	30.426
37	55,0000	29.578
38	60,0000	28.804
39	65,0000	28.092
40	70,0000	27.432
41	80,0000	26.245
42	90,0000	25.197
43	100,0000	24.261
44	120,0000	22.642
45	140,0000	21.275
46	160,0000	20.092
47	180,0000	19.050
48	200,0000	18.120
49	220,0000	17.280
50	240,0000	16.515
51	260,0000	15.813
52	280,0000	15.165
53	300,0000	14.562
54	350.0000	13.224
55	400.0000	12.075
56	450,0000	11.071
57	500,0000	10.182
58	550,0000	9.388
59	600,0000	8.673
60	650,0000	8.024
61	700,0000	7.433
62	800,0000	6.395
63	900,0000	5.514
64	1000,0000	4.760
65	1200,0000	3.547
66	1400,0000	2.634
67	1600,0000	1.943
68	1800,0000	1.422
69	2000,0000	1.029
70	2200,0000	.737
71	2400,0000	.521
72	2600,0000	.364
73	2800,0000	.253
74	3000,0000	.176
75	3500,0000	.124

b - 1 month

Table 3 Predicted drawdown, Te

[illegible]	[illegible]	68.595
9	2,6000	67.882
10	2,6000	67.222
11	3,0000	66.607
12	3,5000	65.234
13	4,0000	64.045
14	4,5000	62.996
15	5,0000	62.058
16	5,5000	61.209
17	6,0000	60.434
18	6,5000	59.721
19	7,0000	59.061
20	8,0000	57.872
21	9,0000	56.823
22	10,0000	55.884
23	12,0000	54.261
24	14,0000	52.888
25	16,0000	51.699
26	18,0000	50.650
27	20,0000	49.711
28	22,0000	48.862
29	24,0000	48.087
30	26,0000	47.375
31	28,0000	46.715
32	30,0000	46.100
33	35,0000	44.727
34	40,0000	43.538
35	45,0000	42.489
36	50,0000	41.551
37	55,0000	40.702
38	60,0000	39.927
39	65,0000	39.214
40	70,0000	38.554
41	80,0000	37.365
42	90,0000	36.316
43	100,0000	35.378
44	120,0000	33.755
45	140,0000	32.382
46	160,0000	31.194
47	180,0000	30.145
48	200,0000	29.208
49	220,0000	28.359
50	240,0000	27.585
51	260,0000	26.873
52	280,0000	26.214
53	300,0000	25.601
54	350.0000	24.231
55	400,0000	23.045
56	450,0000	22.000
57	500,0000	21.065
58	550,0000	20.221
59	600,0000	19.451
60	650,0000	18.744
61	700,0000	18.090
62	800,0000	16.914
63	900,0000	15.880
64	1000,0000	14.958
65	1200,0000	13.373
66	1400,0000	12.045
67	1600,0000	10.908
68	1800,0000	9.918
69	2000,0000	9.045
70	2200,0000	8.267
71	2400,0000	7.569
72	2600,0000	6.940
73	2600,0000	6.369
74	3000,0000	5.849
75	3500,0000	4.736
76	4000,0000	3.837
77	4500,0000	3.104
78	5000,0000	2.508
79	5500,0000	2.014
80	6000,0000	1.612
81	6500,0000	1.285
82	7000,0000	1.018
83	8000,0000	.628
84	9000,0000	.378

c - 1 year

[illegible]	[illegible]	79.623
8	2,4000	78.848
9	2,6000	78.135
10	2,8000	77.475
11	3,0000	76.861
12	3,5000	75.488
13	4,0000	74.299
14	4,5000	73.250
15	5,0000	72.311
16	5,5000	71.462
17	6,0000	70.688
18	6,5000	69.975
19	7,0000	69.315
20	8,0000	68.125
21	9,0000	67.076
22	10,0000	66.138
23	12,0000	64.514
24	14,0000	63.141
25	16,0000	61.952
26	18,0000	60.903
27	20,0000	59.965
28	22,0000	59.116
29	24,0000	58.341
30	26,0000	57.628
31	28,0000	56.968
32	30,0000	56.354
33	35,0000	54.981
34	40,0000	53.792
35	45,0000	52.743
36	50,0000	51.804
37	55,0000	50.955
38	60,0000	50.180
39	65,0000	49.468
40	70,0000	48.808
41	80,0000	47.618
42	90,0000	46.569
43	100,0000	45.631
44	120,0000	44.007
45	140,0000	42.634
46	160,0000	41.445
47	180,0000	40.396
48	200,0000	39.458
49	220,0000	38.609
50	240,0000	37.834
51	260,0000	37.122
52	280,0000	36.462
53	300,0000	35.847
54	350.0000	34.475
55	400,0000	33.286
56	450,0000	32.237
57	500,0000	31.299
58	550,0000	30.451
59	600,0000	29.676
60	650,0000	28.964
61	700,0000	28.305
62	800,0000	27.117
63	900,0000	26.069
64	1000,0000	25.133
65	1200,0000	23.513
66	1400,0000	22.144
67	1600,0000	20.960
68	1800,0000	19.917
69	2000,0000	18.986
70	2200,0000	18.144
71	2400,0000	17.378
72	2600,0000	16.673
73	2800,0000	16.023
74	3000,0000	15.419
75	3500,0000	14.074
76	4000,0000	12.918
77	4500,0000	11.906
78	5000,0000	11.009
79	5500,0000	10.205
80	6000,0000	9.480
81	6500,0000	8.820
82	7000,0000	8.217
83	8000,0000	7.154
84	9000,0000	6.245

d - 10 years

[illegible]	[illegible]	[illegible]
11	3,0000	37.208
12	3,5000	34.700
13	4,0000	32.533
14	4,5000	30.626
15	5,0000	28.926
16	5,5000	27.393
17	6,0000	25.998
18	6,5000	24.721
19	7,0000	23.543
20	8,0000	21.436
21	9,0000	19.597
22	10,0000	17.972
23	12,0000	15.216
24	14,0000	12.960
25	16,0000	11.077
26	18,0000	9.486
27	20,0000	8.129
28	22,0000	6.966
29	24,0000	5.965
30	26,0000	5.101
31	28,0000	4.355
32	30,0000	3.710
33	35,0000	2.459
34	40,0000	1.601
35	45,0000	1.022
36	50,0000	.639
37	55,0000	.394
38	60,0000	.254
39	65,0000	.214

a - 1 day

10	2,5000	66.152
11	3,0000	65.022
12	3,5000	62.497
13	4,0000	60.310
14	4,5000	58.381
15	5,0000	56.656
16	5,5000	55.095
17	6,0000	53.671
18	6,5000	52.361
19	7,0000	51.148
20	8,0000	48.963
21	9,0000	47.036
22	10,0000	45.313
23	12,0000	42.334
24	14,0000	39.818
25	16,0000	37.642
26	18,0000	35.724
27	20,0000	34.012
28	22,0000	32.466
29	24,0000	31.057
30	26,0000	29.764
31	28,0000	28.569
32	30,0000	27.460
33	35,0000	24.993
34	40,0000	22.872
35	45,0000	21.019
36	50,0000	19.377
37	55,0000	17.908
38	60,0000	16.584
39	65,0000	15.382
40	70,0000	14.285
41	80,0000	12.354
42	90,0000	10.711
43	100,0000	9.299
44	120,0000	7.015
45	140,0000	5.280
46	160,0000	3.953
47	180,0000	2.938
48	200,0000	2.164
49	220,0000	1.578
50	240,0000	1.139
51	260,0000	.812
52	280,0000	.574
53	300,0000	.403
54	350,0000	.213

b - 1 month

Table 4 Predicted drawdown, TI

10	2,0000	86.620
11	3,0000	85.489
12	3,5000	82.964
13	4,0000	80.776
14	4,5000	78.847
15	5,0000	77.121
16	5,5000	75.559
17	6,0000	74.134
18	6,5000	72.822
19	7,0000	71.608
20	8,0000	69.421
21	9,0000	67.491
22	10,0000	65.765
23	12,0000	62.779
24	14,0000	60.254
25	16,0000	58.068
26	18,0000	56.139
27	20,0000	54.414
28	22,0000	52.854
29	24,0000	51.429
30	26,0000	50.119
31	28,0000	48.907
32	30,0000	47.778
33	35,0000	45.258
34	40,0000	43.076
35	45,0000	41.152
36	50,0000	39.433
37	55,0000	37.880
38	60,0000	36.463
39	65,0000	35.161
40	70,0000	33.956
41	80,0000	31.791
42	90,0000	29.887
43	100,0000	28.189
44	120,0000	25.267
45	140,0000	22.818
46	160,0000	20.719
47	180,0000	18.888
48	200,0000	17.273
49	220,0000	15.832
50	240,0000	14.538
51	260,0000	13.368
52	280,0000	12.306
53	300,0000	11.337
54	350,0000	9.254
55	400,0000	7.562
56	450,0000	6.175
57	500,0000	5.033
58	550,0000	4.089
59	600,0000	3.311
60	650,0000	2.669
61	700,0000	2.141
62	800,0000	1.357
63	900,0000	.840
64	1000,0000	.510
65	1200,0000	.217

c - 1 year

10	2,0000	105.482
11	3,0000	104.352
12	3,5000	101.826
13	4,0000	99.638
14	4,5000	97.709
15	5,0000	95.982
16	5,5000	94.421
17	6,0000	92.995
18	6,5000	91.684
19	7,0000	90.470
20	8,0000	88.282
21	9,0000	86.353
22	10,0000	84.626
23	12,0000	81.639
24	14,0000	79.114
25	16,0000	76.926
26	18,0000	74.997
27	20,0000	73.271
28	22,0000	71.709
29	24,0000	70.284
30	26,0000	68.973
31	28,0000	67.759
32	30,0000	66.628
33	35,0000	64.103
34	40,0000	61.916
35	45,0000	59.987
36	50,0000	58.262
37	55,0000	56.701
38	60,0000	55.276
39	65,0000	53.966
40	70,0000	52.753
41	80,0000	50.567
42	90,0000	48.640
43	100,0000	46.917
44	120,0000	43.936
45	140,0000	41.419
46	160,0000	39.240
47	180,0000	37.320
48	200,0000	35.605
49	220,0000	34.056
50	240,0000	32.645
51	260,0000	31.348
52	280,0000	30.150
53	300,0000	29.037
54	350,0000	26.560
55	400,0000	24.428
56	450,0000	22.561
57	500,0000	20.904
58	550,0000	19.420
59	600,0000	18.078
60	650,0000	16.857
61	700,0000	15.740
62	800,0000	13.766
63	900,0000	12.075
64	1000,0000	10.612
65	1200,0000	8.216
66	1400,0000	6.361
67	1600,0000	4.910
68	1800,0000	3.772
69	2000,0000	2.880
70	2200,0000	2.182
71	2400,0000	1.641
72	2600,0000	1.222
73	2800,0000	.902
74	3000,0000	.660
75	3500,0000	.301
76	4000,0000	.223

d - 10 years