HYDROLOGIC REPORT
LONGORIA LEASE AREA II
DUVAL COUNTY, TEXAS

Prepared For
URANIUM RESOURCES, INC.

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HYDROLOGIC REPORT

LONGORIA LEASE AREA II

DUVAL COUNTY, TEXAS

Prepared For

URANIUM RESOURCES, INC.

Richardson, Texas

ED L. REED AND ASSOCIATES, INC.
Consulting Hydrologists

Midland and San Angelo, Texas

December 1978

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HYDROLOGIC REPORT
LONGORIA LEASE AREA II
DUVAL COUNTY, TEXAS

INTRODUCTION

This report presents the hydrologic results of a detailed pump test conducted by Uranium Resources personnel on August 4, 1978. The Longoria Lease Area II was tested by pumping Well No. U-237 at an average rate of 37.9 gallons per minute. Twenty five ore zone wells and three shallow wells were monitored throughout the test. Continuous recorders were placed on four ore zone wells and one shallow monitor well.

The pump failed after 1065 minutes (almost 18 hours). The results of the testing are given below.

HYDROLOGIC CONCLUSIONS

The aquifer parameters of transmissivity and storage coefficient were determined for the 28 wells which were monitored. All of the ore zone wells responded to the pumpage and the shallow monitor wells likewise declined in response to the pumping of U-237.

Ore Zone Wells

The wells in the ore zone with six exceptions appear to have normal Theis drawdown curves. The exceptions were wells No. MW-1, MW-7, U-242, U-243, U-244 and U-246.

Wells No. U-242, 243, 244 and 246 demonstrated transmissivities one-third to one-half lower during the first 50 to 75 minutes than during the remainder of the test (Fig. 1). The average transmissivity for the early part of the test for these four wells is 1567 gal/day/ft. The later segments of the drawdown

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curves produced transmissivities very close to the surrounding area wells.

Well MW-7 differed in that the last 300 minutes of data indicate a response to a negative boundary. Well No. MW-1 reflects an excessively high transmissivity for the first 60 to 75 minutes before establishing a drawdown curve representative of the average transmissivity in the area.

The average transmissivity for the 25 ore zone wells monitored is 3700 gal/day/ft. The highest transmissivities are found to the southwest and northwest of the pattern area (Figure 1). A band of lower transmissivity extends east and west through the northern part of the pattern.

Shallow Monitor Wells

Three shallow monitor wells were observed during this test. All three wells showed early response to pumpage and continued to decline throughout the test. MS-1 and 2 showed a slight flattening of the Theis curve after several hours of pumping but then tended to remain parallel to the original curve previously established. The fact that all three shallow wells responded to the pumping of the ore zone well is indicative of hydraulic continuity between the ore zone and the shallow aquifer by some natural or man-made cause (Fig. 2).

It will therefore be necessary to model the ore zone aquifer and calculate the operational parameters of production, injection and bleed which will at all times and at all places impose a slight negative head on the ore zone. This negative head will cause the shallow zone to leak at a small rate into the ore zone and prevent excursion of the leachate from the ore zone upward to the shallow zone.

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Ground Water Movement

Based upon the average aquifer thickness of 31 feet in the ore zone, a porosity of 28% (obtained from exploration coring), a natural hydraulic gradient of 14.9 feet per mile, and a 25-well average transmissivity of 3700 gal/day/ft, we have estimated that the permeability of the ore zone is 120 gal/day/ft^2 and that the rate of natural ground water movement is about 0.20 feet per day.

The natural hydraulic gradient of the ore zone aquifer is east to southeast across the leach mine area (Fig. 3).

Please advise us if we can be of further assistance on this project.

Very tr , yours,

ED L. REED & ASSOCIATES, INC.

A. Joseph Reed

AJR:lb

COMPUTER DATA SHEETS

DEEP MINE WELLS

Obs. Well Number............ U 2[illegible]
Pumped Well Number.......... U 237

Time Test Started............ 900
Time Test Stopped............ 900
Static Water Level........... 75.68

Time	Wtr Level	Cum T	t/t'	Drawdown
0904	103.82	4	361.00	28.14
0905	92.79	5	289.00	17.11
0906	90.11	6	241.00	14.43
0907	88.55	7	206.71	1[illegible].87
0908	87.20	8	181.00	11.52
0909	86.43	9	161.00	10.75
0910	85.70	10	145.00	10.02
0911	85.12	11	131.91	9.44
0912	84.69	12	121.00	9.01
0913	84.26	13	111.77	8.58
0914	83.88	14	103.86	8.20
0915	83.57	15	97.00	7.89
0920	82.33	20	73.00	6.65
0925	81.62	25	58.60	5.94
0930	80.94	30	49.00	5.26
0935	80.50	35	42.14	4.82
0940	80.24	40	37.00	4.56
0945	79.90	45	33.00	4.22
0950	79.75	50	29.80	4.07
1000	79.41	60	25.00	3.73
1010	79.15	70	21.57	3.47
1020	78.96	80	19.00	3.28
1030	78.84	90	17.00	3.16
1053	78.60	113	13.74	2.92
1122	78.28	142	11.14	2.60
1223	77.90	203	8.09	2.22
1321	77.77	261	6.52	2.09
1424	77.65	324	5.44	1.97
1508	77.52	368	4.91	1.84
1600	77.42	420	4.43	1.74
1700	77.30	480	4.00	1.62
1757	77.10	537	3.68	1.42
1957	77.00	657	3.19	1.32
2303	76.84	843	2.71	1.16
0301	76.67	1081	2.33	0.99
0500	76.62	1200	2.20	0.94
0702	76.45	1322	2.09	0.77
0901	76.47	14[illegible]1	2.00	0.79
1100	75.75	1[illegible]60	1.92	0.07

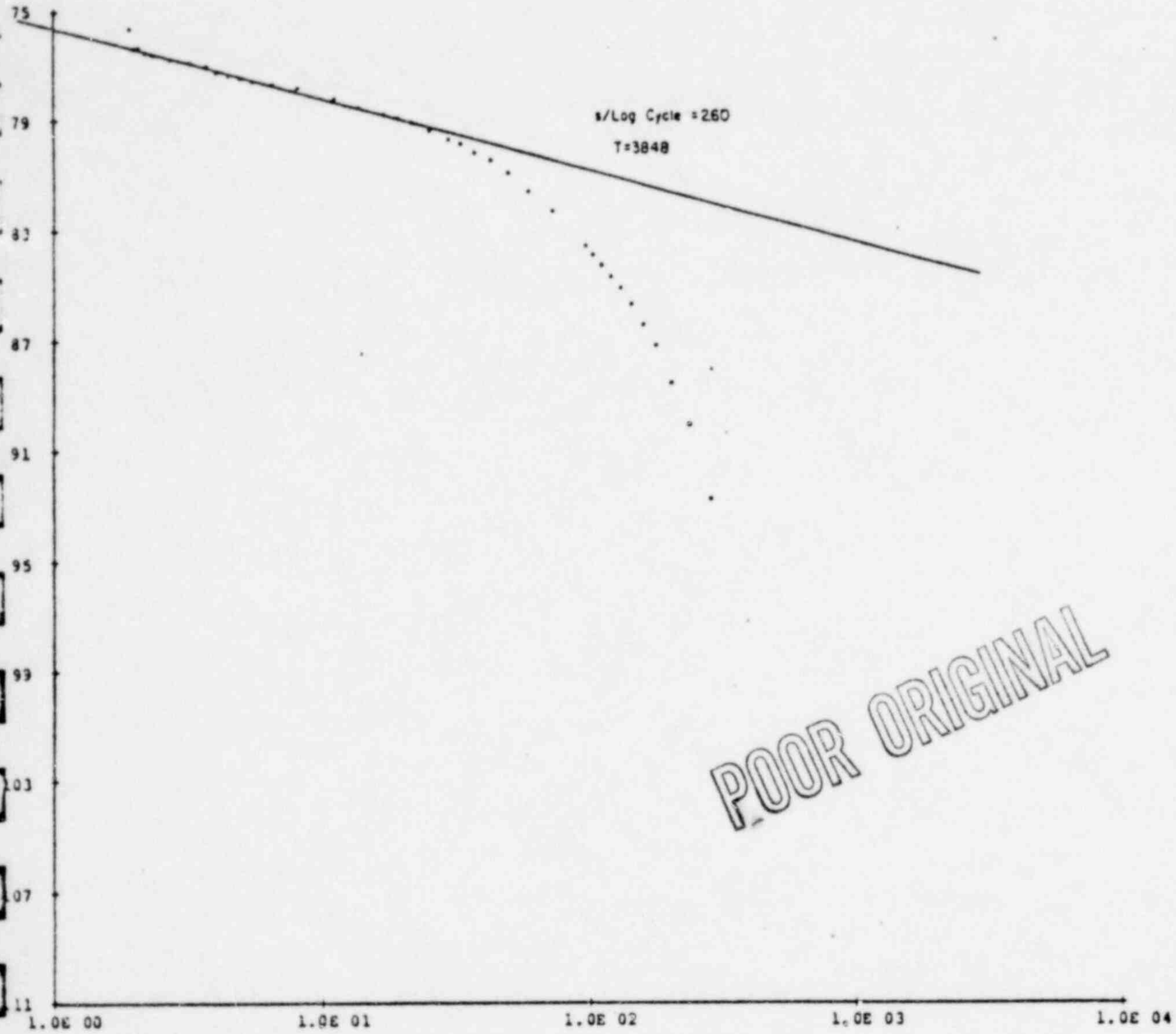
Duval County, Texas
URANIUM RESOURCES, INC.

Longoria Hydrologic Test
Recovery Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

Obs. Well Number............ U 237
Pumped Well Number.......... U 237
Time Test Started........... 900
Time Test Stopped........... 900
Static Water Level.......... 75.68



Abscissa is time in minutes from start of test
divided by time in minutes since pumping stopped.
Ordinate is depth to water from land surface datum.

Duval County, Texas
URANIUM RESOURCES, INC.

Longoria Hydrologic Test
Recovery Curve

August 4, 1976

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

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Obs. Well Number............ U 237
Pumped Well Number........... U 237

Time Test Started........... 900
Static Water Level........... 75.68

Time	Wtr Level	Cum T	Drawdown
0902	152.77	2	77.09
0903	166.47	3	90.79
0904	173.34	4	97.66
0905	178.76	5	103.08
0906	181.15	6	105.47
0907	183.32	7	107.64
0908	184.40	8	108.72
0909	185.37	9	109.69
0910	186.08	10	110.40
0911	186.81	11	111.13
0912	187.32	12	111.64
0913	187.69	13	112.01
0914	187.85	14	112.17
0915	188.20	15	112.52
0916	188.50	16	112.82
0917	188.77	17	113.09
0918	188.97	18	113.29
0919	189.20	19	113.52
0920	189.34	20	113.66
0921	189.25	21	113.57
0922	189.18	22	113.50
0925	189.36	25	113.68
0930	189.60	30	113.92
0935	190.33	35	114.65
0947	189.53	47	113.85
1000	190.23	60	114.55
1010	190.72	70	115.04
1020	191.00	80	115.32
1030	190.65	90	114.97
1045	190.30	105	114.62
1100	191.70	120	116.02
1116	191.46	136	115.78
1130	191.61	150	115.93
1146	191.65	166	115.97
1200	191.48	180	115.80
1218	190.90	198	115.22
1230	190.62	210	114.94
1245	191.00	225	115.32
1300	190.13	240	114.45
1333	190.71	273	115.03
1402	188.84	302	113.16
1430	188.88	330	113.20
1501	188.46	361	112.78
1600	188.66	420	112.98
1703	188.73	483	113.05
1803	189.06	543	113.38
1900	189.25	600	113.57
2000	188.25	660	112.57
2100	188.31	720	112.63
0104	189.63	964	113.95
0400	187.09	1140	111.41

POOR ORIGINAL

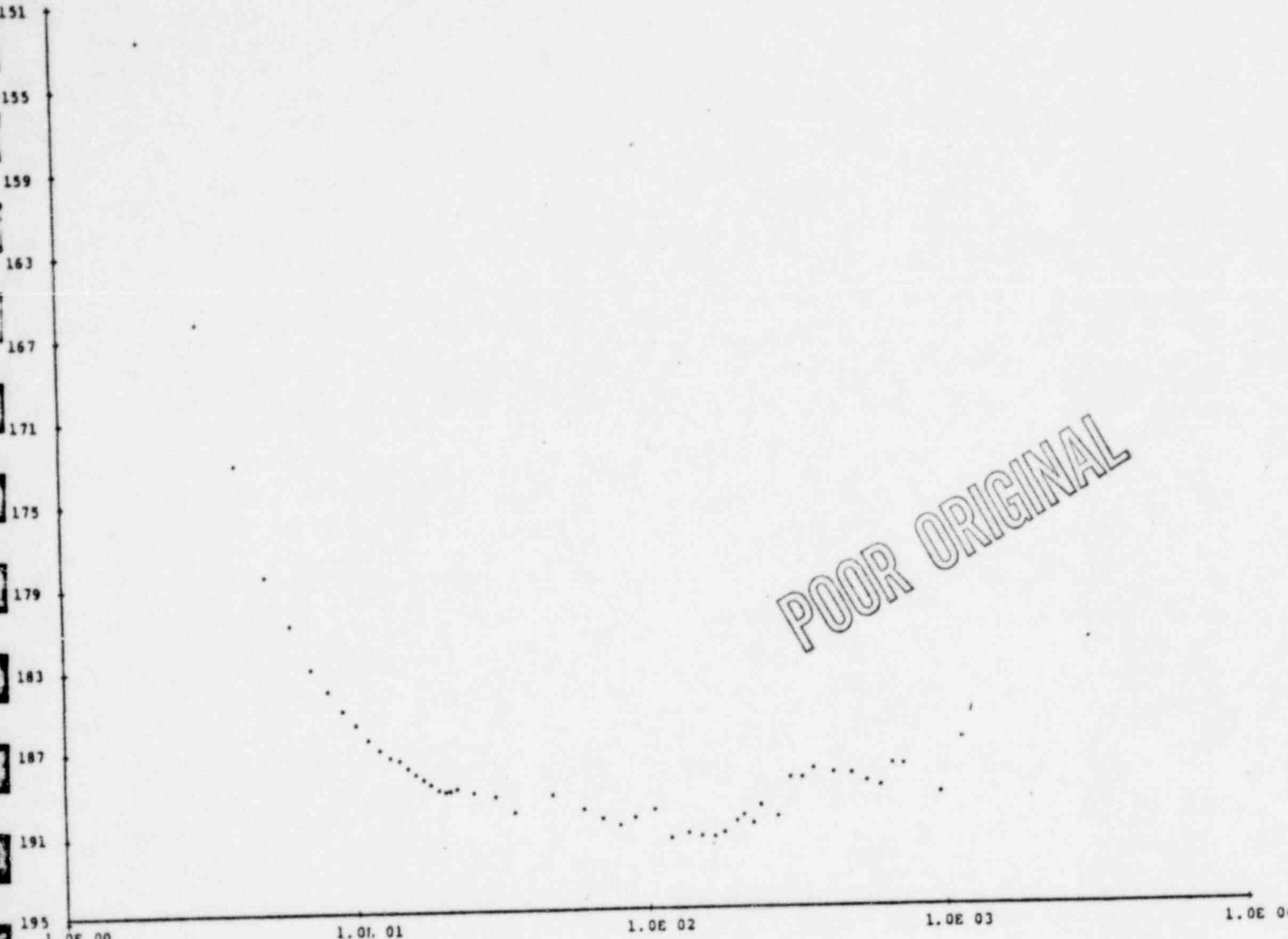
Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown of Pumped Well No. U 237

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

Obs. Well Number............ U 237
Pumped Well Number.......... U 237
Time Test Started.......... 900
Static Water Level.......... 75.68



Abscissa is time in minutes from start of test.
Ordinate is depth to water from land surface datum.

Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown of Pumped Well No. U 237

August 4, 1978

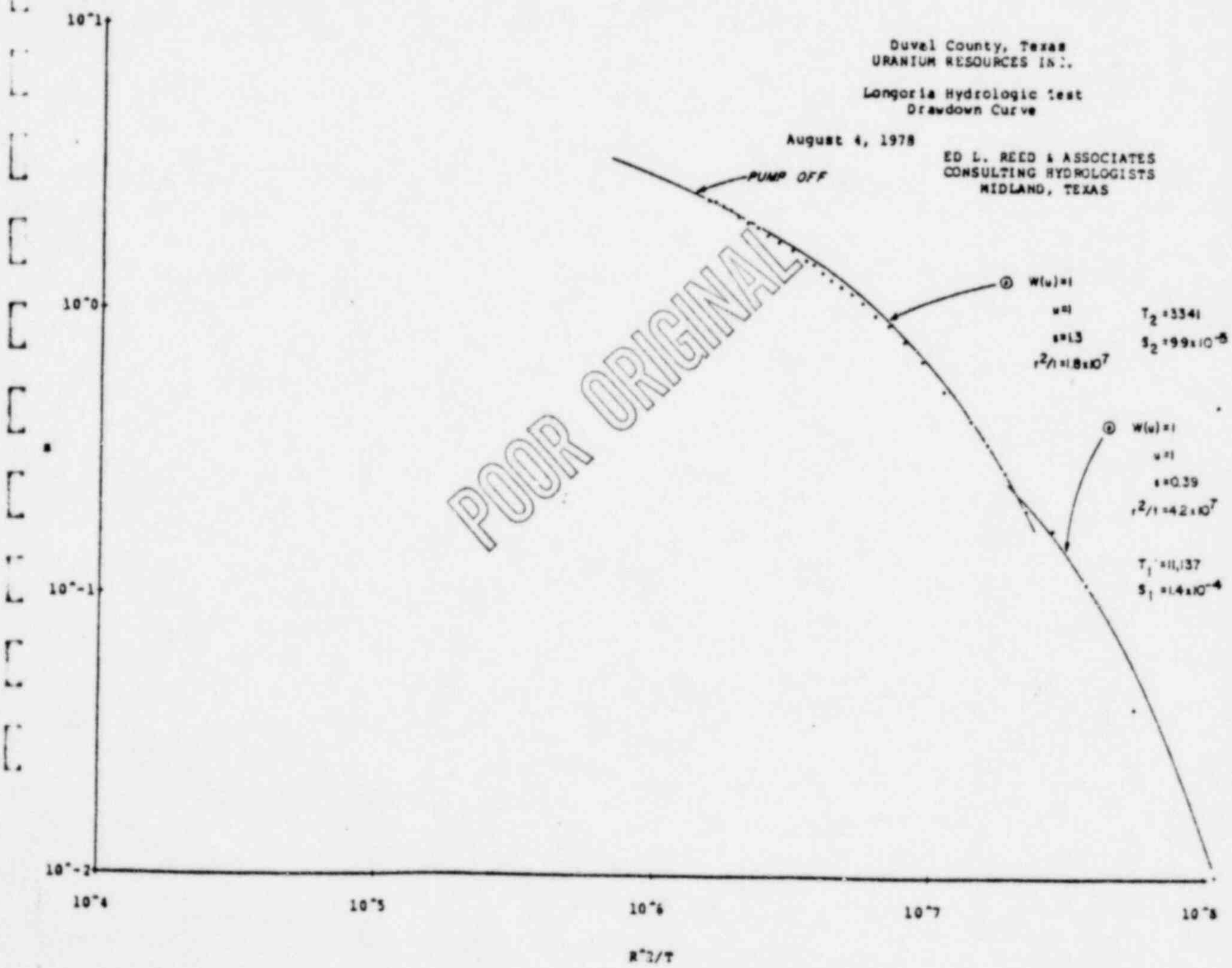
ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

Obs. Well Number............ MW-1

Pumped Well Number.......... U 237

Radius from Pumped Well..... 1065.00
Time Test Started........... 900
Static Water Level.......... 70.09

Time	Wtr Level	Cum T	R^2/T	Drawdown
0915	70.10	15	1.09E 08	0.01
0930	70.13	30	5.44E 07	0.04
0945	70.20	45	3.63E 07	0.11
1000	70.26	60	2.72E 07	0.17
1015	70.29	75	2.18E 07	0.20
1030	70.36	90	1.81E 07	0.27
1045	70.43	105	1.56E 07	0.34
1100	70.50	120	1.36E 07	0.41
1130	70.61	150	1.09E 07	0.52
1200	70.75	180	9.07E 06	0.66
1230	.87	210	7.78E 06	0.78
1300	70.97	240	6.81E 06	0.88
1330	71.05	270	6.05E 06	0.96
1400	71.15	300	5.44E 06	1.06
1430	71.23	330	4.95E 06	1.14
1500	71.30	360	4.54E 06	1.21
1530	71.37	390	4.19E 06	1.28
1600	71.44	420	3.89E 06	1.35
1630	71.54	450	3.63E 06	1.45
1700	71.59	480	3.40E 06	1.50
1800	71.73	540	3.02E 06	1.64
1900	71.84	600	2.72E 06	1.75
2000	71.94	660	2.47E 06	1.85
2100	72.05	720	2.27E 06	1.96
2200	72.13	780	2.09E 06	2.04
2300	72.23	840	1.94E 06	2.14
2400	72.34	900	1.81E 06	2.25
0100	72.41	960	1.70E 06	2.32
0200	72.49	1020	1.60E 06	2.40
0300	72.53	1080	1.51E 06	2.44



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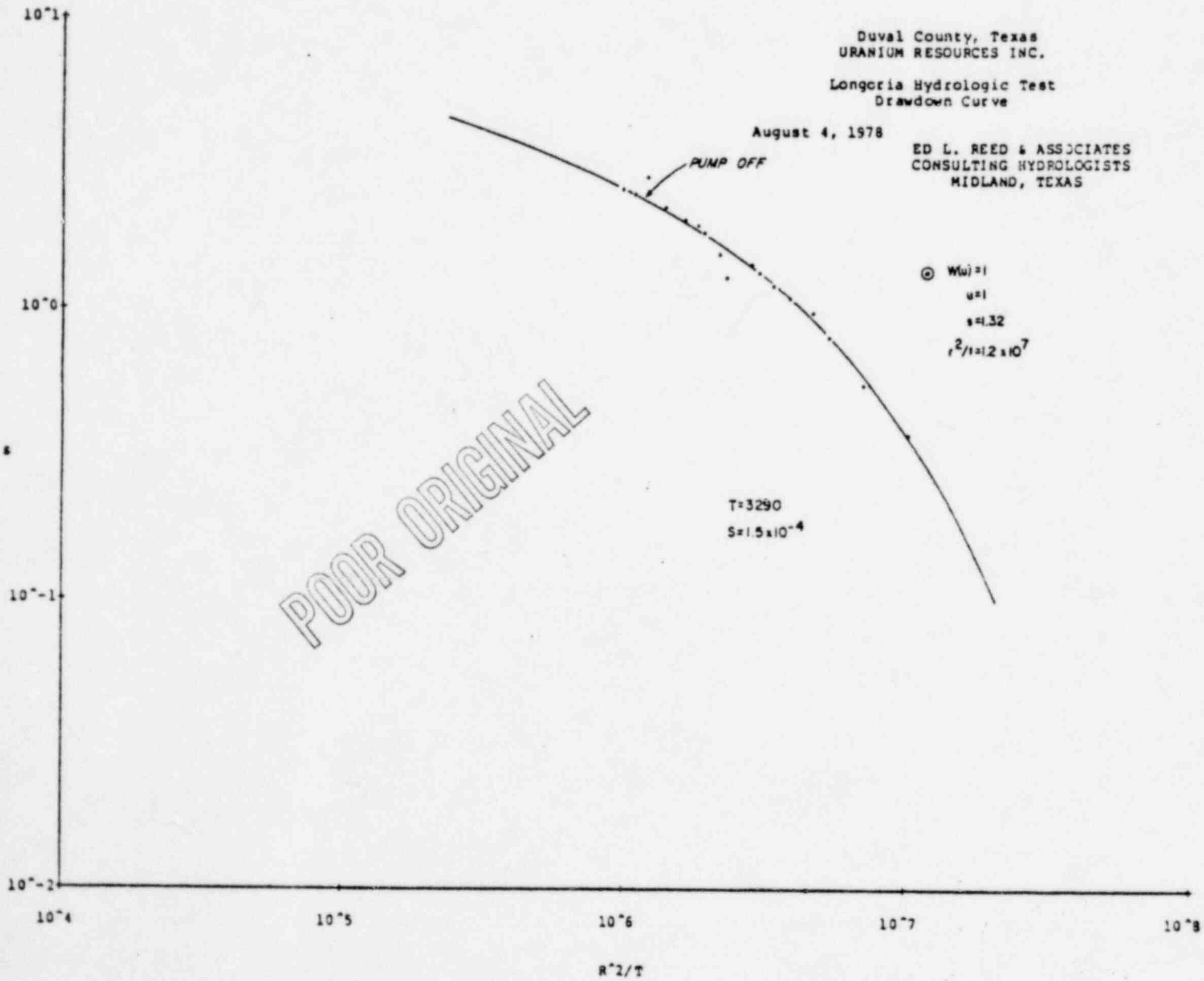
Obs. Well Number............ MW-2

Pumped Well Number.......... U 237

Radius from Pumped Well..... 928.00
Time Test Started........... 900
Static Water Level.......... 69.59

Time	Wtr Level	Cum T	R^2/T	Drawdown
1100	69.95	120	1.03E 07	0.36
1154	70.13	174	7.13E 06	0.54
1251	70.37	231	5.37E 06	0.78
1324	70.54	264	4.70E 06	0.95
1421	70.66	321	3.86E 06	1.07
1504	70.77	364	3.41E 06	1.18
1550	70.90	410	3.02E 06	1.31
1617	70.98	437	2.84E 06	1.39
1752	70.85	532	2.33E 06	1.26
1823	71.10	563	2.20E 06	1.51
1938	71.37	538	1.94E 06	1.78
2014	71.48	674	1.[illegible] 06	1.89
2128	71.57	748	1.66E 06	1.[illegible]
2336	71.77	876	1.42E 06	2.[illegible]8
0152	72.37	1012	1.23E 06	2.[illegible]8
0336	72.01	1116	1.11E 06	2.42
0534	72.10	1234	1.00E 06	2.51

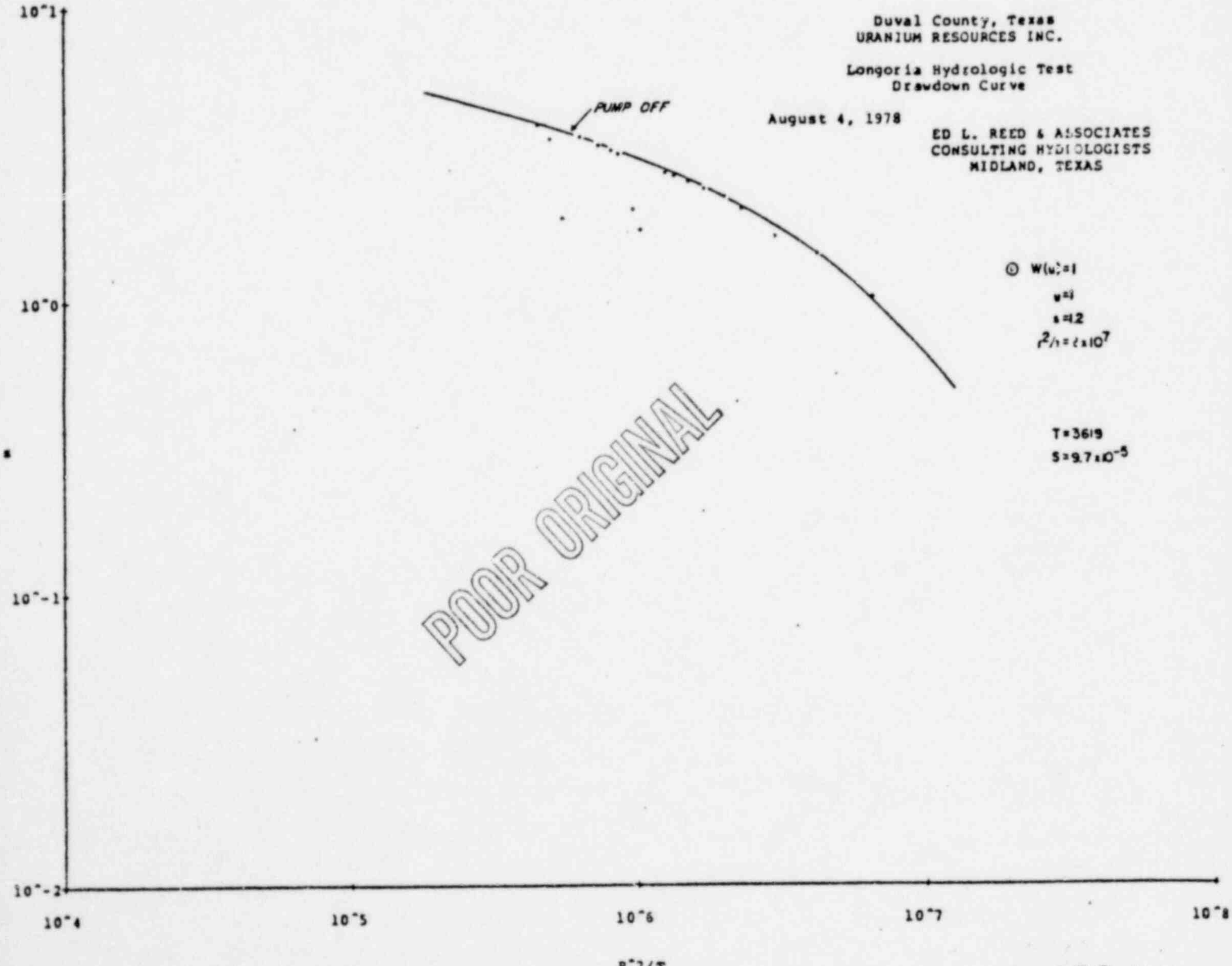


Obs. Well Number............ MW-3

Pumped Well Number.......... U 237

Radius from Pumped Well..... 618.00
Time Test Started........... 900
Static Water Level.......... 74.00

Time	Wtr Level	Cum T	R^2/T	Drawdown
1024	75.00	84	6.55E 06	1.00
1112	75.40	132	4.17E 06	1.40
1203	75.61	183	3.01E 06	1.61
1300	76.00	240	2.29E 06	2.00
1335	76.20	275	2.00E 06	2.20
1426	76.35	326	1.69E 06	2.35
1512	76.48	372	1.48E 06	[illegible].48
1555	76.60	415	1.33E 06	2.60
1623	76.66	443	1.24E 06	2.66
1758	75.70	538	1.02E 06	1.70
1830	76.00	570	9.65E 05	2.00
1945	77.07	645	8.53E 05	3.07
2020	77.18	680	8.09E 05	3.18
2134	77.31	754	7.29E 05	3.31
2342	77.53	882	6.24E 05	3.53
0156	75.86	1016	5.41E 05	1.86
0343	77.47	1123	4.90E 05	3.47
0540	77.88	1240	4.44E 05	3.88



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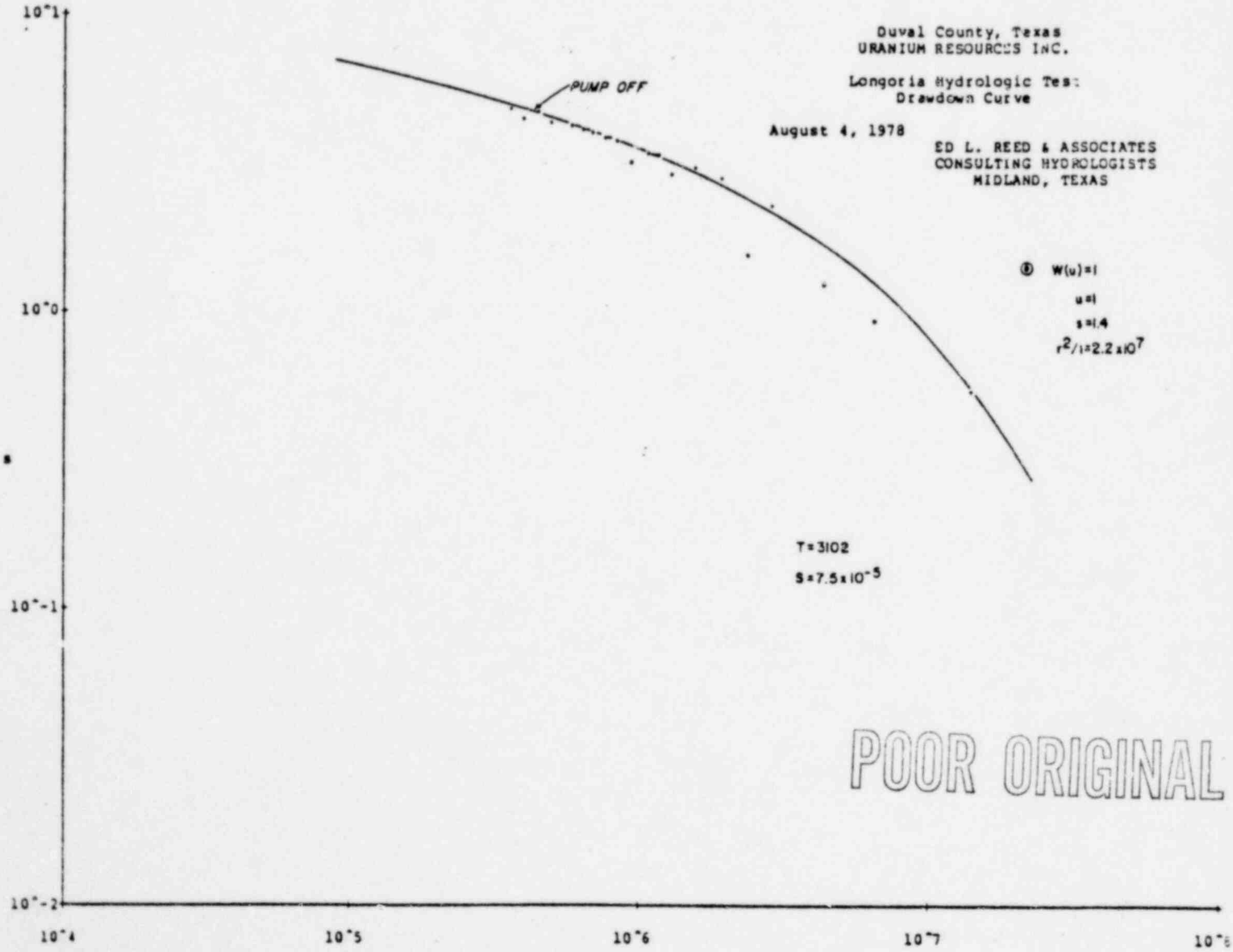
Obs. Well Number............ MW-4

Pumped Well Number.......... U 237

Radius from Pumped Well..... 553.00
Time Test Started........... 900
Static Water Level.......... 78.25

Time	Wtr Level	Cum T	R^2/T	Drawdown
0931	78.78	31	1.42E 07	0.53
1008	79.16	68	6.48E 06	0.91
1040	79.45	100	4.40E 06	1.20
1131	80.47	151	2.92E 06	2.22
1203	79.76	183	2.41E 06	1.51
1245	80.99	225	1.96E 06	2.74
1338	81.23	278	1.58E 06	2.98
1435	81.09	335	1.31E 06	2.84
1511	81.53	371	1.19E 06	3.28
1545	81.57	405	1.09E 06	3.32
1641	81.34	461	9.55E 05	3.09
1739	81.93	519	8.48E 05	3.68
1826	82.00	566	7.78E 05	3.75
1928	82.15	628	7.01E 05	3.90
2024	82.25	684	6.44E 05	4.00
2127	82.38	747	5.90E 05	4.13
2345	82.50	885	4.98E 05	4.25
0122	82.82	982	4.48E 05	4.57
0333	82.60	1113	3.96E 05	4.35
0523	82.95	1223	3.60E 05	4.70



POOR ORIGINAL

1214 333

Obs. Well Number............ Mw 5

Pumped Well Number.......... U 237

Radius from Pumped Well..... 655.00
Time Test Started........... 900
Static Water Level.......... 79.42

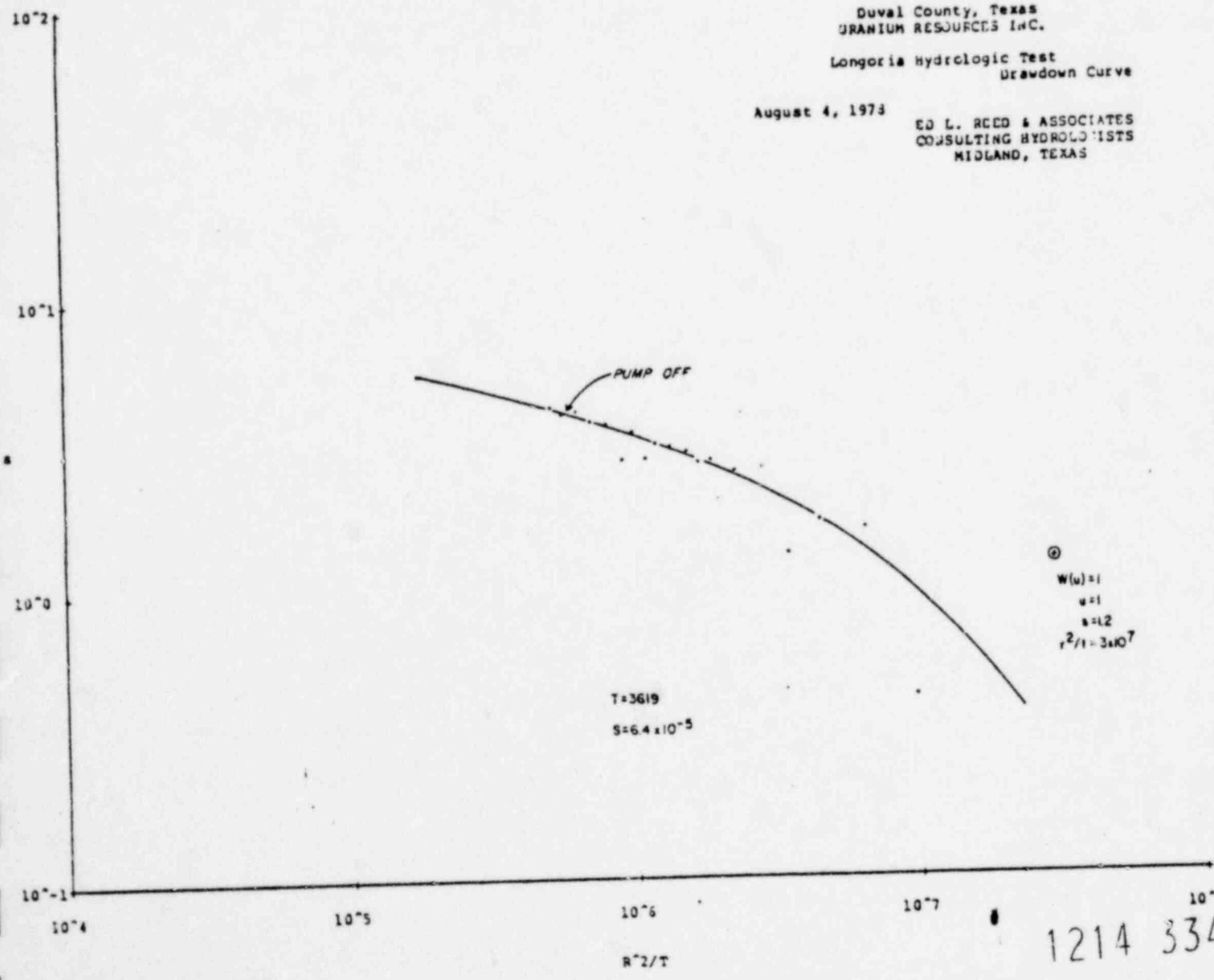
Time	Wtr Level	Cum T	R^2/T	Drawdown
1003	79.83	63	9.81E 06	0.41
1035	80.95	95	6.50E 06	1.53
1118	81.05	138	4.48E 06	1.63
1158	80.69	178	3.67E 06	1.27
1239	81.91	219	2.82E 06	2.49
1333	81.85	273	2.26E 06	2.43
1431	82.08	331	1.87E 06	2.66
1504	82.05	364	1.70E 06	2.63
1540	82.28	400	1.54E 06	2.86
1637	82.40	457	1.35E 06	2.98
1735	82.46	515	1.20E 06	3.04
1821	82.13	561	1.10E 06	2.71
1922	82.77	622	9.93E 05	3.35
2019	82.10	679	9.10E 05	2.68
2145	83.00	765	8.08E 05	3.58
2332	83.30	872	7.08E 05	3.66
0115	83.40	975	6.34E 05	3.98
0320	83.30	1100	5.62E 05	3.88
0516	83.51	1216	5.08E 05	4.09

Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS



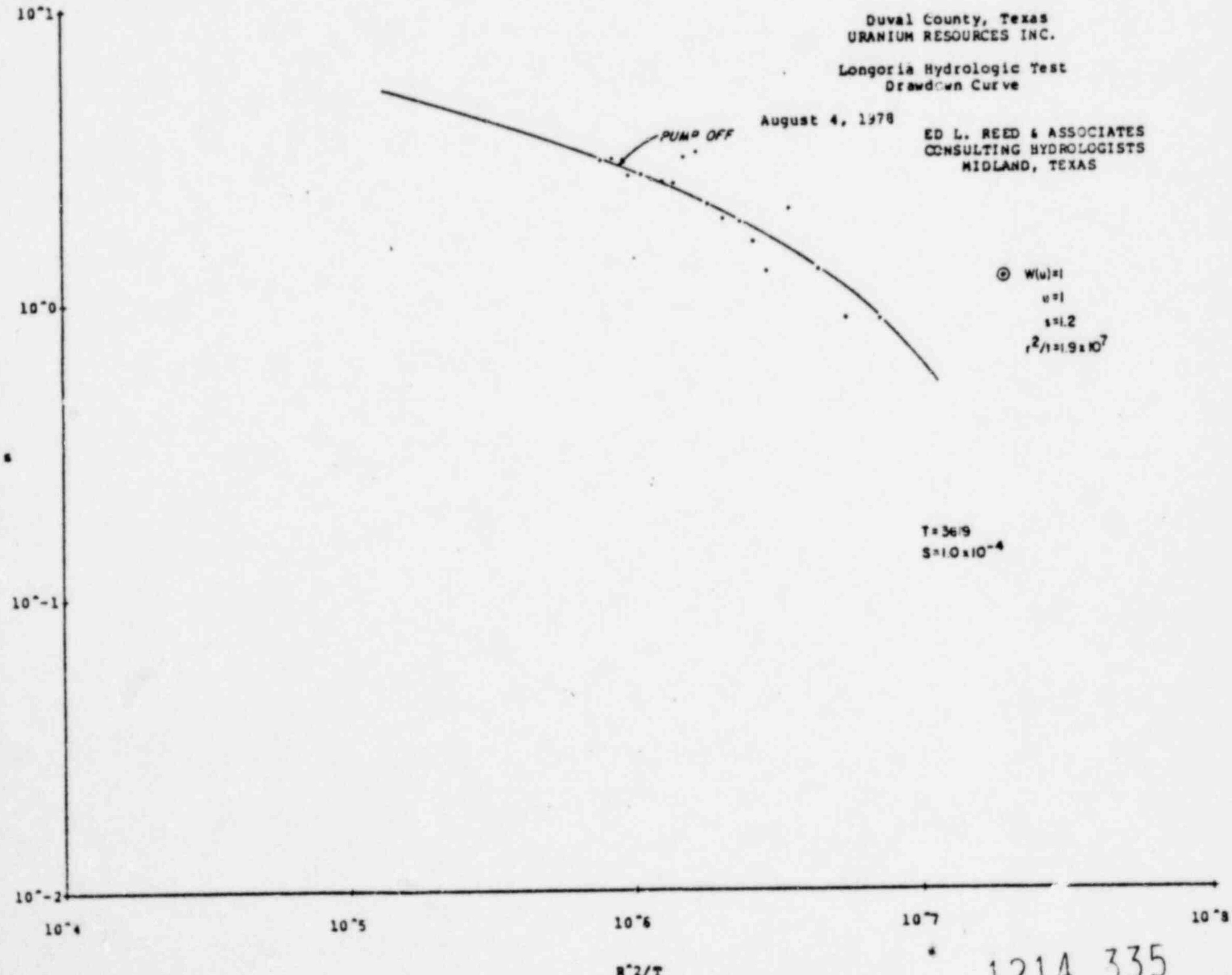
1214 334

Obs. Well Number............ MW-6

Pumped Well Number.......... U 237

Radius from Pumped Well..... 811.00
Time Test Started........... 900
Static Water Level.......... 76.93

Time	Wtr Level	Cum T	R^2/T	Drawdown
1111	77.77	131	7.23E 06	0.84
1152	77.78	172	5.51E 06	0.85
1233	78.18	213	4.45E 06	1.25
1327	78.94	267	3.55E 06	2.01
1422	78.17	322	2.94E 06	1.24
1458	78.49	358	2.65E 06	1.56
1536	78.76	396	2.39E 06	1.83
1632	78.80	452	2.10E 06	1.87
1731	79.03	511	1.85E 06	2.10
1817	80.10	557	1.70E 06	[illegible]
1918	79.98	618	1.53E 06	3.05
2014	79.40	674	1.41E 06	2.47
2113	79.44	733	1.29E 06	2.51
2331	79.60	871	1.09E 06	2.67
0108	79.58	968	9.78E 05	2.65
0318	79.96	1098	8.63E 05	3.03
0510	79.90	1210	7.83E 05	2.97



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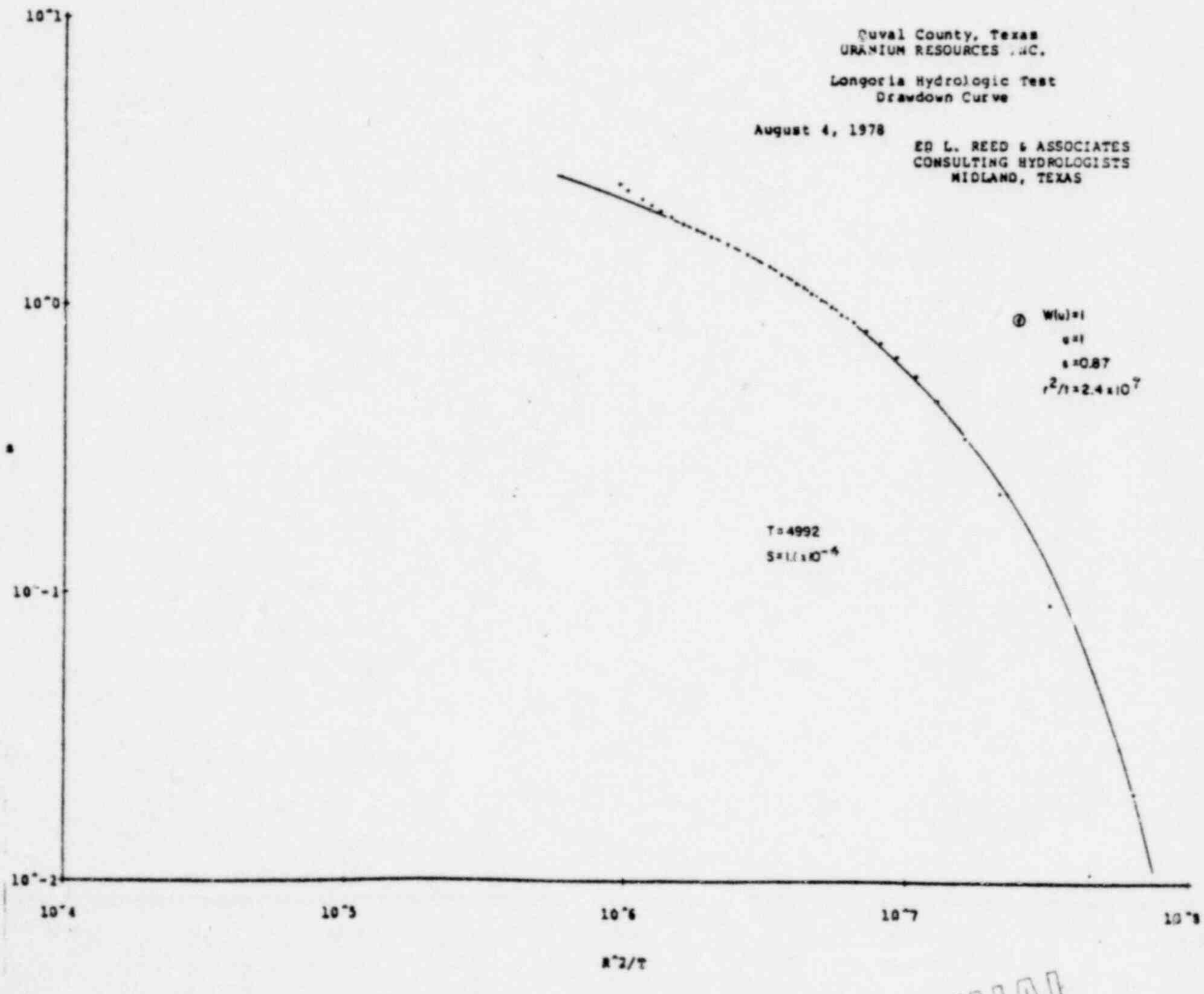
Obs. Well Number............ MW-7

Pumped Well Number.......... U 23,

Radius from Pumped Well..... 820.00
Time Test Started........... 900
Static Water Level.......... 78.34

Time	Wtr Level	Cum T	R^2/T	Drawdown
0915	78.36	15	6.46E 0'	0.02
0930	78.43	30	3.23E 07	0.09
0945	78.56	45	2.15E 07	0.22
1000	78.68	60	1.61E 07	0.34
1015	78.80	75	1.29E 07	0.46
1030	78.90	90	1.08E 07	0.56
1045	78.99	105	9.22E 06	0.65
1100	79.07	120	8.07E 06	0.73
1115	79.14	135	7.17E 06	0.80
1130	79.20	150	6.46E 06	0.86
1145	79.25	165	5.87E 06	0.91
1200	79.31	180	5.38E 06	0.97
1215	79.37	195	4.97E 06	1.03
1230	79.42	210	4.61E 06	1.08
1245	79.47	225	4.30E 06	1.13
1300	79.51	240	4.03E 06	1.17
1330	79.60	270	3.59E 06	1.26
1400	79.68	300	3.23E 0F	1.34
1500	79.81	360	2.69E 0,	1.47
1600	79.93	420	2.31E 06	1.59
1700	80.03	480	2.02E 06	1.69
1800	80.13	540	1.79E 06	1.79
1900	80.22	600	1.61E 06	1.88
2000	80.32	660	1.47E 06	1.98
2100	80.42	720	1.34E 06	2.08
2200	80.52	780	1.24E 06	2.18
2300	80.62	840	1.15E 06	2.28
0100	80.80	960	1.01E 06	2.46
0200	80.92	1020	9.49E 05	2.58



POOR ORIGINAL

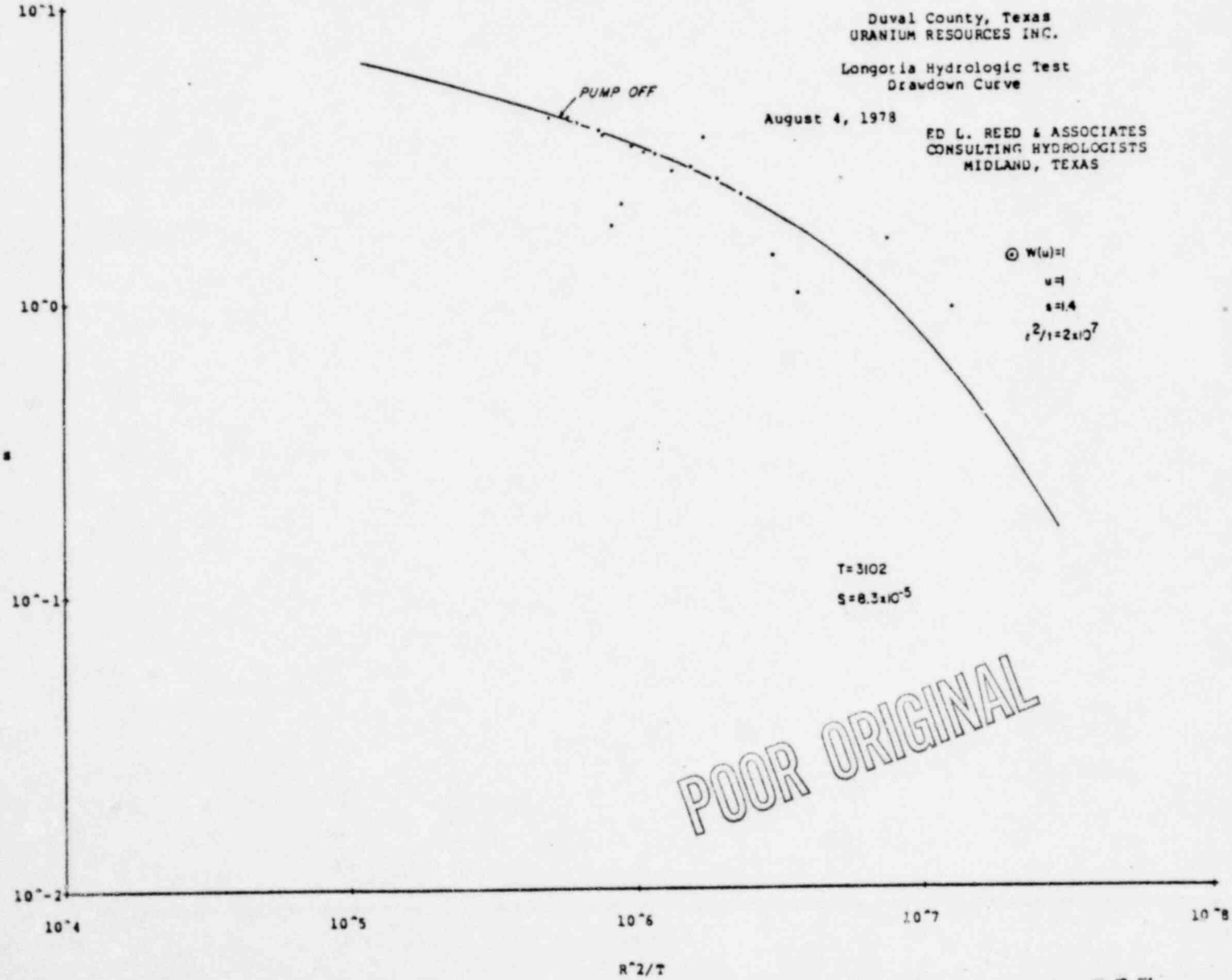
1214 336

Obs. Well Number............ MW-8

Pumped Well Number.......... U 237

Radius from Pumped Well..... 646.00
Time Test Started........... 900
Static Water Level.......... 77.42

Time	Wtr Level	Cum T	R^2/T	Drawdown
0905	78.29	5	1.20E 08	0.8[illegible]
0947	78.34	47	1.28E 07	0.92
1019	78.98	79	7.61E 06	1.56
1055	79.91	115	5.23E 06	2.49
1142	78.45	162	3.71E 06	1.03
1220	78.79	200	3.00E 06	1.37
1316	79.65	256	2.35E 06	2.23
1410	79.93	310	1.94E 06	2.51
1446	80.91	346	1.74E 06	3.49
1523	80.20	383	1.57E 06	2.78
1624	80.10	444	1.35E 06	2.68
1727	80.50	507	1.19E 06	3.08
1813	80.54	553	1.09E 06	3.12
1913	80.70	613	9.80E 05	3.28
2007	79.50	667	9.01E 05	2.0[illegible]
2104	79.16	724	8.30E 05	1.7[illegible]
2156	81.00	776	7.74E 05	3.5[illegible]
2217	81.16	797	7.54E 05	3.7[illegible]
0057	81.37	957	6.28E 05	3.95
0210	81.55	1030	5.83E 05	4.13
0505	81.52	1205	4.99E 05	4.10



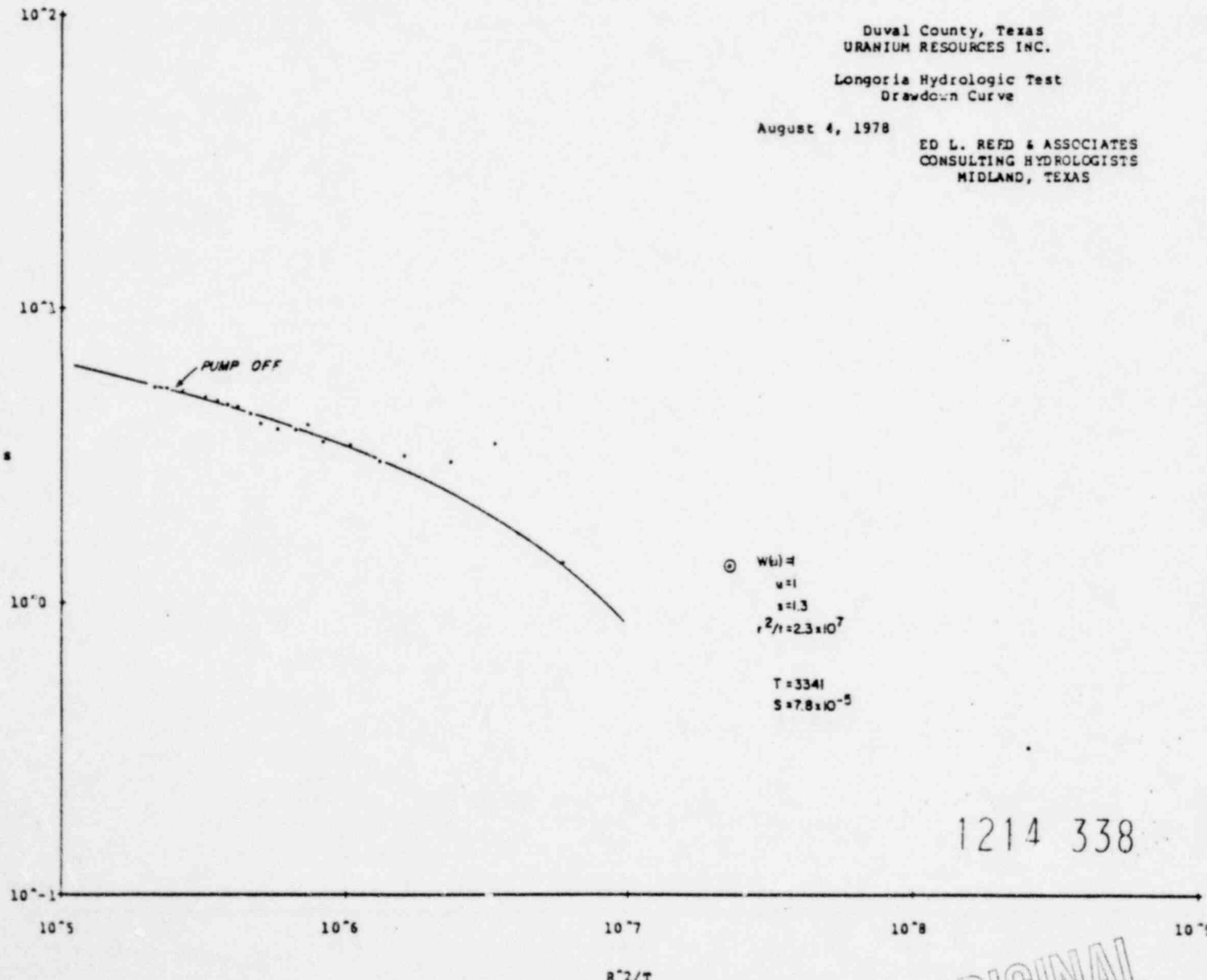
1214 337

Obs. We:l Number............ MW-9

Pumped Well Number.......... U 237

Radius from Pumped Well..... 420.00
Time Test Started........... 900
Static Water Level.......... 77.54

Time	Wtr Level	Cum T	R^2/T	Drawdown
0901	77.85	1	2.54E 08	0.31
0943	78.87	43	5.91E 06	1.33
1015	80.91	75	3.39E 06	3.37
1048	80.45	108	2.35E 06	2.91
1138	80.59	158	1.61E 06	3.05
1212	80.47	192	1.32E 06	2.93
1303	80.88	243	1.05E 06	3.34
1405	80.94	305	8.33E 05	3.40
1441	81.46	341	7.45E 05	3.92
1519	81.29	379	6.70E 05	3.75
1621	81.32	441	5.76E 05	3.78
1724	81.48	504	5.04E 05	3.94
1810	81.81	550	4.62E 05	4.27
1907	82.05	607	4.18E 05	4.51
2003	82.13	663	3.83E 05	4.59
2058	82.28	718	3.54E 05	4.74
2210	82.44	790	3.22E 05	4.90
0053	82.67	953	2.67E 05	5.13
0302	82.79	1082	7.35E 05	5.25
0500	82.83	1200	2.12E 05	5.29



1214 338

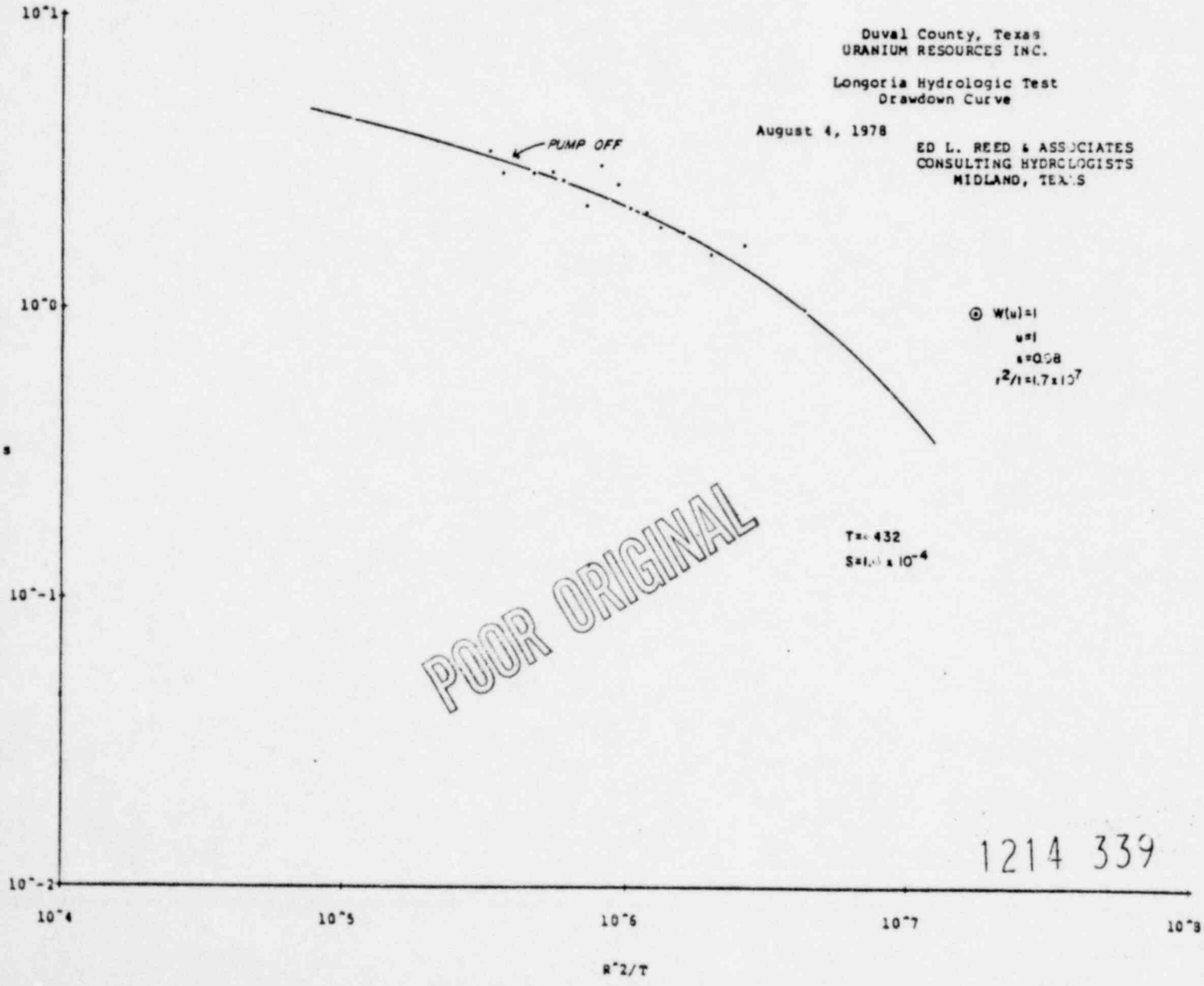
POOR ORIGINAL

Obs. Well Number............ MW-10

Pumped Well Number.......... U 237

Radius from Pumped Well..... 520.00
Time Test Started........... 900
Static Water Level.......... 77.02

Time	Wtr Level	Cum T	R^2/T	Drawdown
1031	77.99	91	4.28E 06	0.97
1130	78.63	150	2.60E 06	1.61
1216	78.52	196	1.99E 06	1.50
1306	78.79	246	1.58E 06	1.77
1358	78.86	298	1.31E 06	1.84
1433	79.10	333	1.17E 06	2.08
1520	79.17	380	1.02E 06	2.15
1600	79.60	420	9.27E 05	2.58
1705	80.03	485	8.03E 05	3.01
1805	79.20	545	7.14E 05	2.18
2000	79.69	660	5.90E 05	2.67
2103	79.86	723	5.39E 05	2.84
2303	79.83	843	4.62E 05	2.[illegible]1
0105	80.23	965	4.03E 05	3.[illegible]1
0303	79.84	1083	3.60E 05	2.82
0503	80.37	1203	3.24E 05	3.[illegible]5

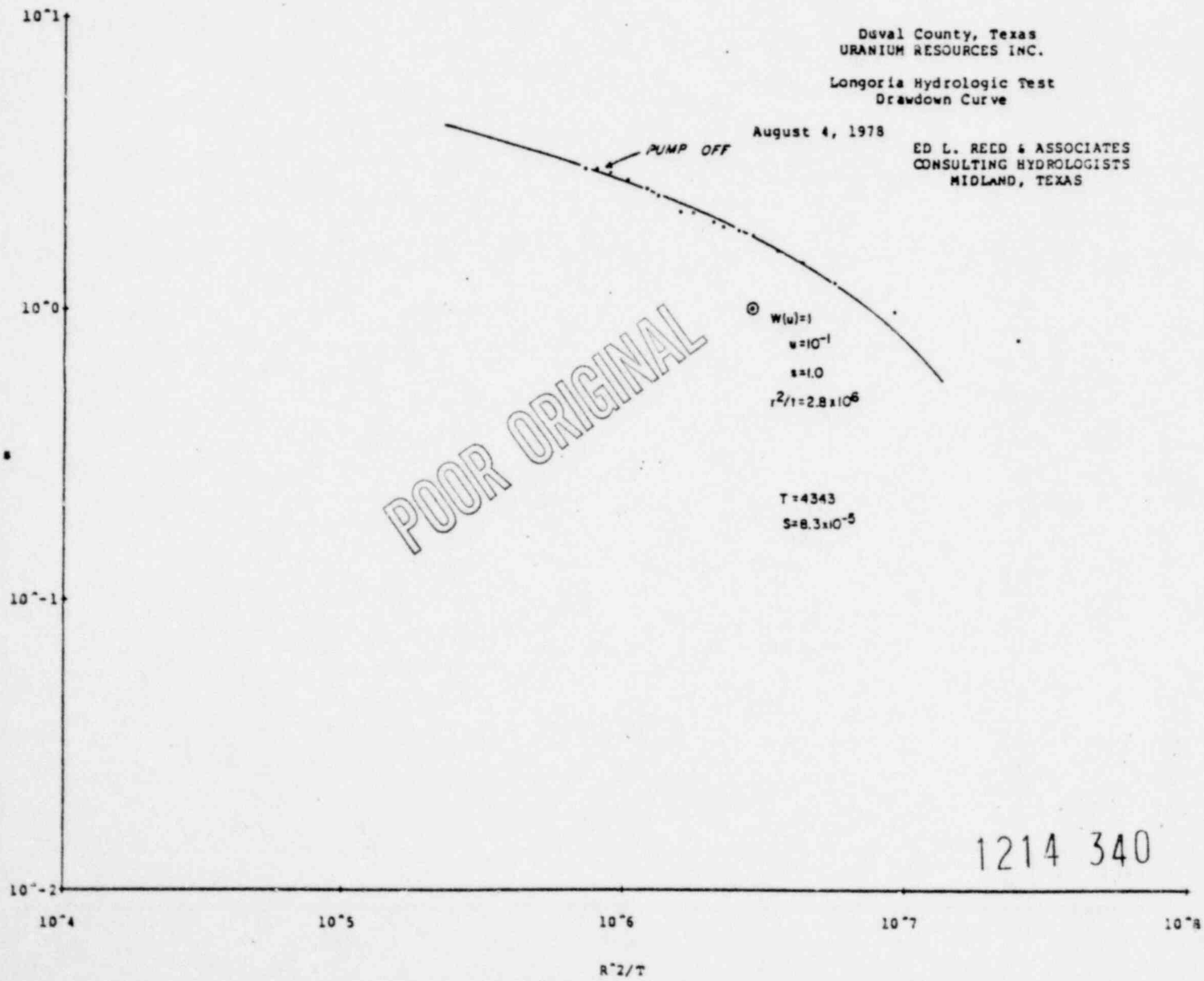


Obs. Well Number............ MW-11

Pumped Well Number.......... U 237

Radius from Pumped Well..... 780.00
Time Test Started........... 900
Static Water Level.......... 77.24

Time	Wtr Level	Cum T	R^2/T	Drawdown
0935	78.00	35	2.50E 07	0.76
1037	78.19	97	9.03E 06	0.95
1137	78.44	157	5.58E 06	1.20
1224	78.65	204	4.29E 06	1.41
1313	78.79	253	3.46E 06	1.55
1405	78.98	305	2.87E 06	1.74
1443	79.06	343	2.55E 06	1.82
1529	79.11	389	2.25E 06	1.87
1605	79.19	425	2.06E 06	1.95
1719	79.34	499	1.76E 06	2.10
1811	79.35	551	1.59E 06	2.11
2003	79.64	663	1.32E 06	2.40
2107	79.77	727	1.21E 06	2.53
2308	79.96	848	1.03E 06	2.72
0117	80.12	977	8.97E 05	2.88
0311	80.21	1091	8.03E 05	2.97
0505	80.23	1205	7.27E 05	2.99



Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

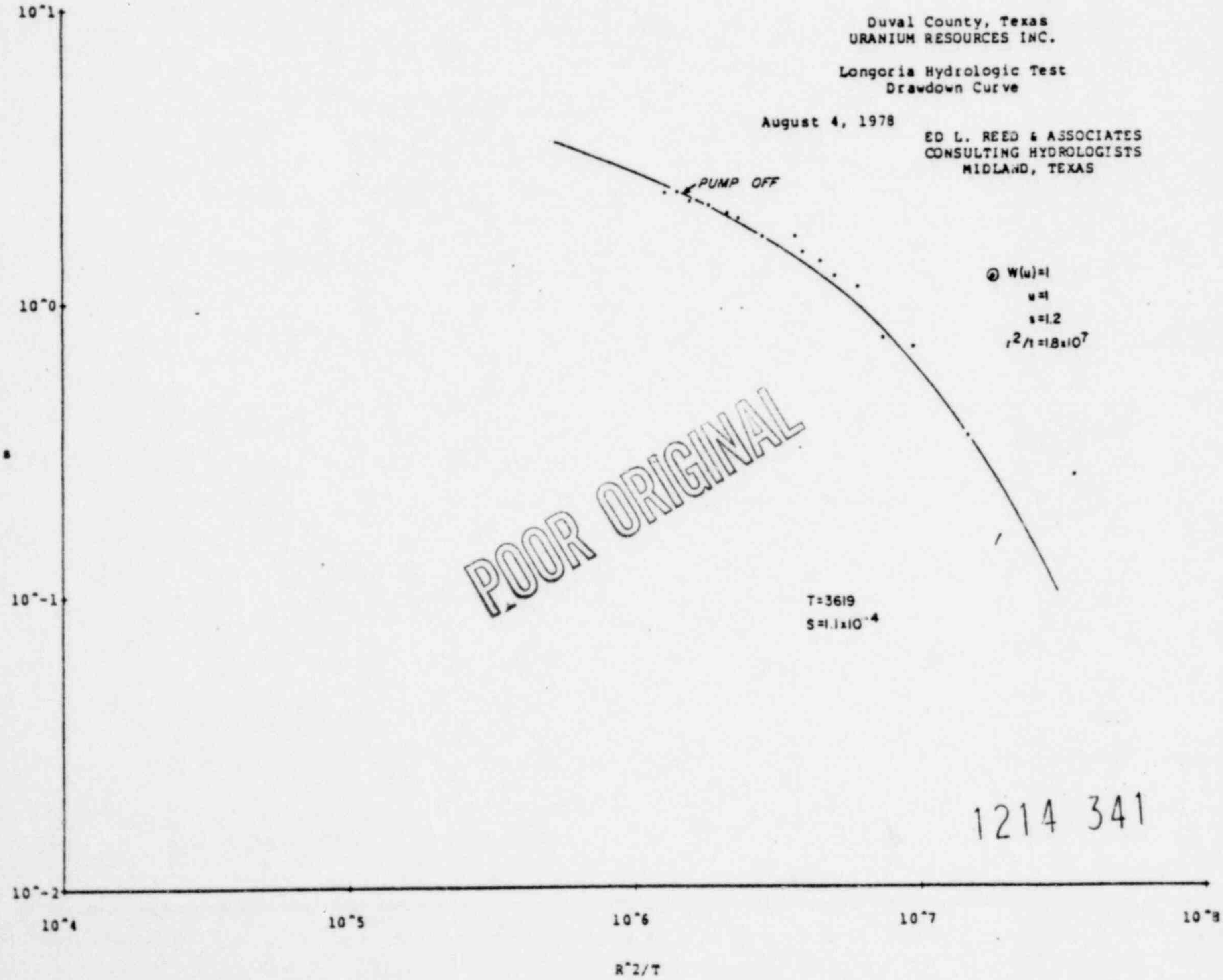
1214 340

Obs. Well Number............ MW-12

Pumped Well Number.......... U 237

Radius from Pumped Well..... 1046.00
Time Test Started........... 900
Static Water Level.......... 72.36

Time	Wtr Level	Cum T	R^2/T	Drawdown
0945	72.61	45	3.50E 07	0.25
1047	72.70	107	1.47E 07	0.34
1145	73.05	165	9.55E 06	0.69
1232	73.10	212	7.43E 06	0.74
1320	73.45	260	6.06E 06	1.09
1411	73.55	311	5.07E 06	1.19
1450	73.70	350	4.50E 06	1.34
1541	73.80	401	3.93E 06	1.44
1609	74.00	429	3.67E 06	1.64
1816	74.00	556	2.83E 06	1.64
2010	74.25	670	2.35E 06	1.8[illegible]
2112	74.33	732	2.15E 06	1.97
2315	74.46	855	1.84E 06	2.10
0138	74.53	998	1.58E 06	2.17
0318	74.68	1098	1.43E 06	2.32
0517	74.67	1217	1.29E 06	2.31



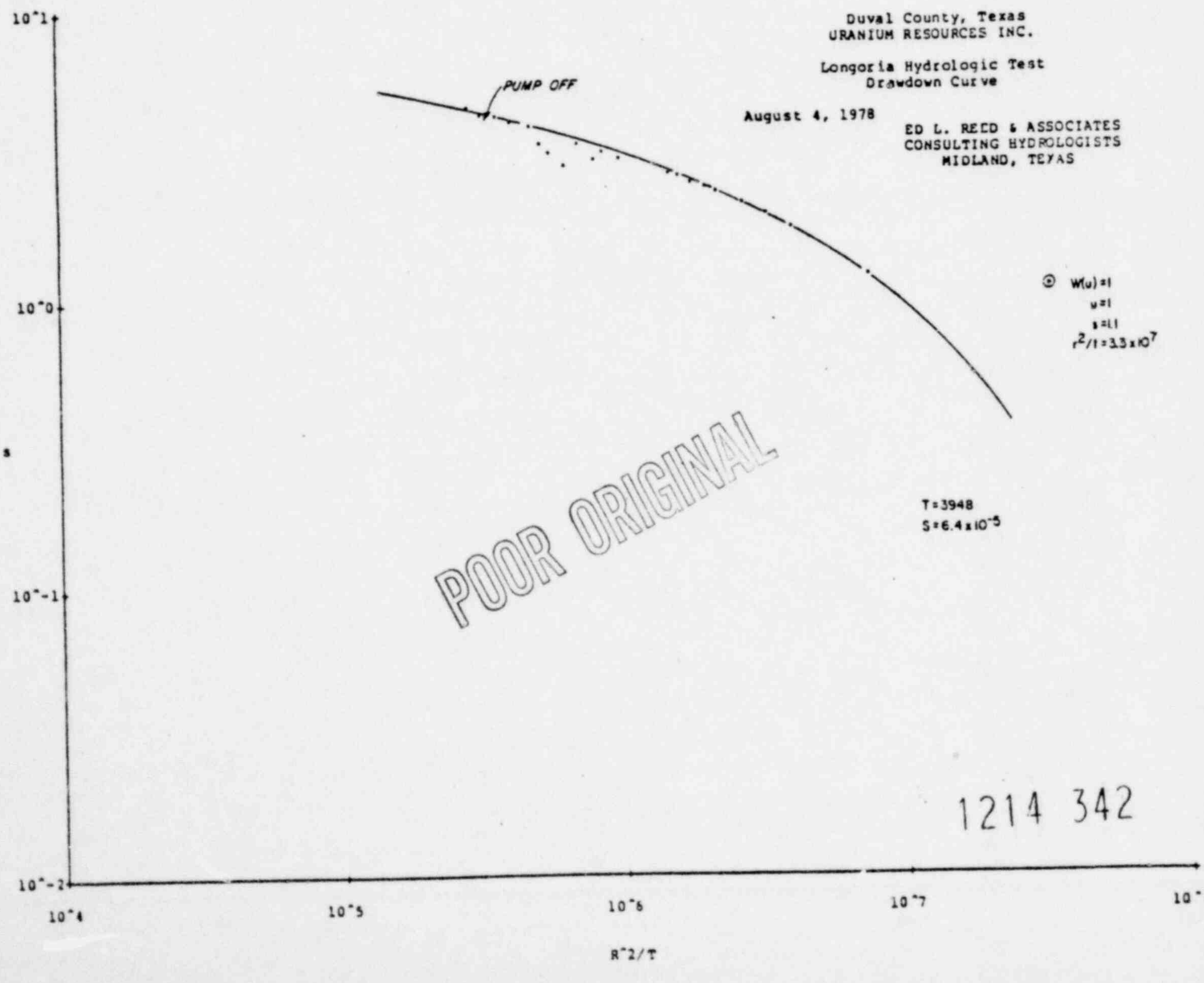
1214 341

Obs. Well Number............ U-226

Pumped Well Number.......... U 237

Radius from Pumped Well..... 497.00
Time Test Started........... 900
Static Water Level.......... 75.20

Time	Wtr Level	Cum T	R^2/T	Drawdown
0947	76.36	47	7.57E 06	1.16
1028	76.89	88	4.04E 06	1.69
1048	77.09	108	3.29E 06	1.89
1110	77.26	130	2.74E 06	2.06
1140	77.45	160	2.22E 06	2.25
1156	77.54	176	2.02E 06	2.34
1218	77.62	198	1.80E 06	2.42
1240	77.75	220	1.62E 06	2.55
1255	77.79	235	1.51E 06	2.59
1450	78.14	350	1.02E 06	2.94
1542	78.31	402	8.85E 05	3.11
1613	78.10	433	8.21E 05	2.90
1716	78.50	496	7.17E 05	3.30
1811	77.97	551	6.46E 05	2.77
1926	78.27	626	5.68E 05	3.(7
2012	78.50	672	5.29E 05	3.30
2112	79.01	732	4.86E 05	3.81
2316	79.13	856	4.16E 05	3.53
0110	79.34	970	3.67E 05	4.14
0312	79.37	1092	3.26E 05	4.17
0513	79.65	1213	2.93E 05	4./5



1214 342

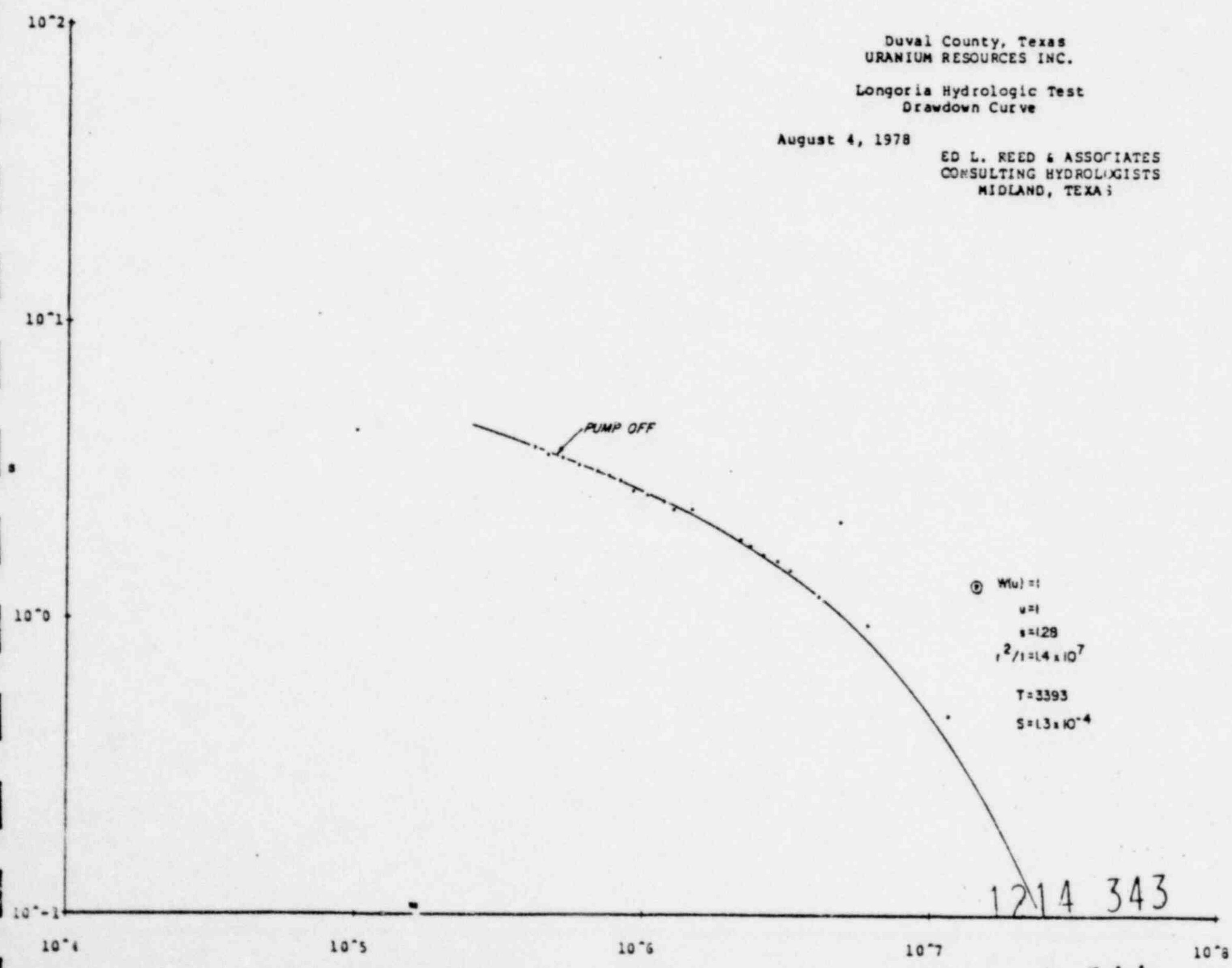
Obs. Well Number............ U-227

Pumped Well Number.......... U 237

Radius from Pumped Well..... 593.00
Time Test Started........... 900
Static Water Level.......... 73.63

Time	Wtr Level	Cum T	R^2/T	Drawdown
0924	73.74	24	2.11E 07	0.11
0944	74.09	44	1.15E 07	0.46
1024	74.56	84	6.03E 06	0.93
1045	75.70	105	4.82E 06	2.07
1104	74.79	124	4.08E 06	1.16
1137	75.05	157	3.23E 06	1.42
1153	75.15	173	2.93E 06	1.52
1213	75.23	193	2.62E 06	1.60
1234	75.35	214	2.37E 06	1.72
1253	75.43	233	2.17E 06	1.80
1445	75.90	345	1.47E 06	2.27
1538	75.90	398	1.27E 06	2.27
1610	76.04	430	1.18E 0[illegible]	2.41
1712	76.17	492	1.03E 06	2.5[illegible]
1808	76.26	548	9.24E 05	2.6[illegible]
1911	76.47	611	8.29E 05	2.84
2008	76.58	668	7.58E 05	2.9[illegible]
2110	76.67	730	6.94E 05	3.04
2312	76.84	852	5.94E 05	3.21
0107	77.02	967	5.24E 05	3.39
0309	77.09	1089	4.65E 05	3.4[illegible]
0510	77.30	1210	4.18E 05	3.6[illegible]

POOR ORIGINAL



1214 343

~~1214 344~~

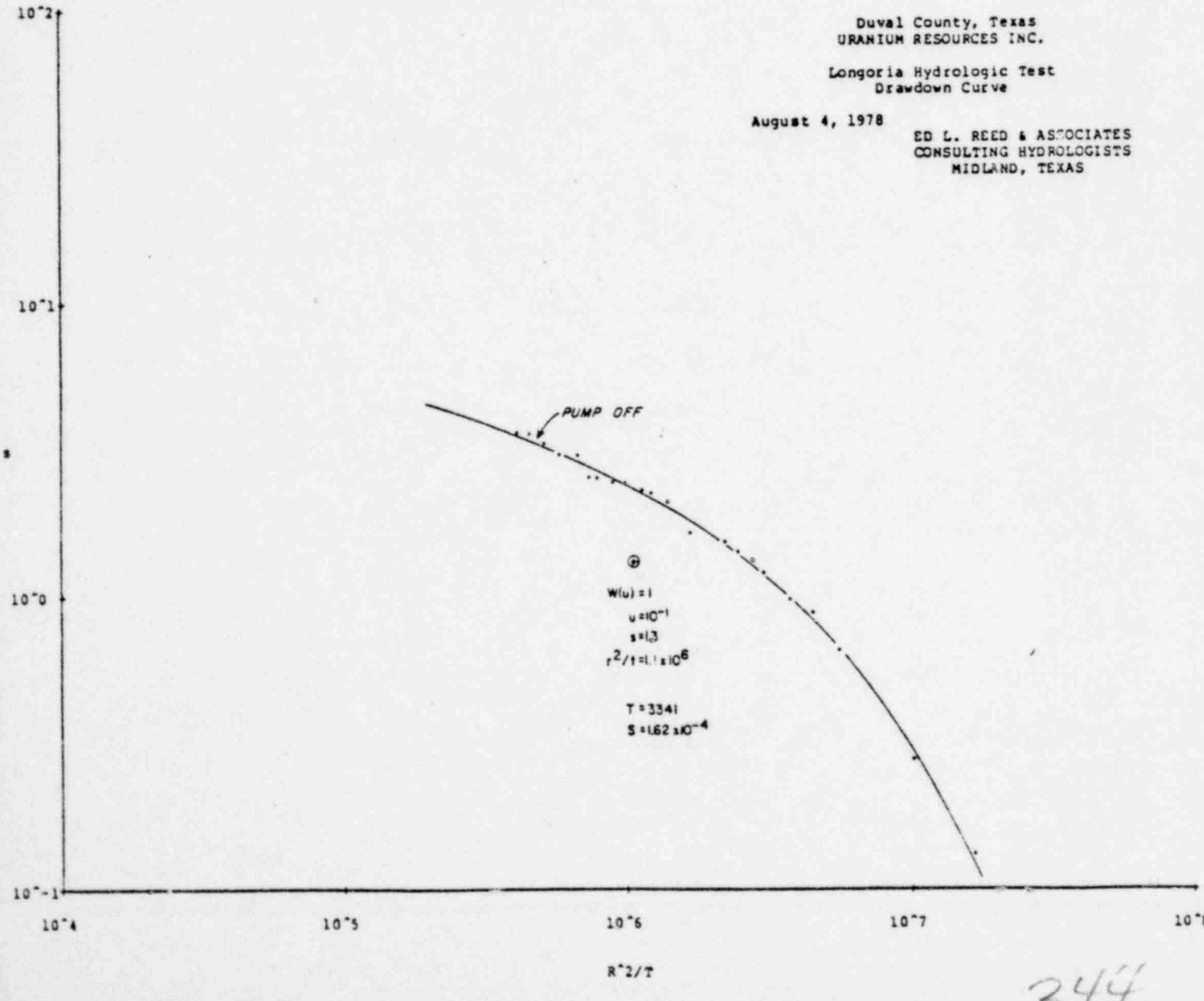
Obs. Well Number............ MW-15(MS-3)

Pumped Well Number.......... U 237

Radius from Pumped Well..... 590.00
Time Test Started........... 900
Static Water Level.......... 75.10

Time	Wtr Level	Cum T	R^2/T	Drawdown
0930	75.23	30	1.67E 07	0.13
0949	75.37	49	1.02E 07	0.27
1030	75.74	90	5.57E 06	0.64
1051	75.96	111	4.52E 06	0.86
1113	76.06	133	3.77E 06	0.96
1143	76.28	163	3.08E 06	1.18
1158	76.40	178	2.82E 06	1.30
1272	76.48	202	2.48E 06	1.38
1243	76.60	223	2.25E 06	1.50
1358	76.71	298	1.68E 06	1.61
1455	77.14	355	1.41E 06	2.04
1546	77.29	406	1.23E 06	2.19
1617	77.35	437	1.15E 06	2.[illegible]
1719	77.50	499	1.00E 06	2.40
1812	77.50	552	9.08E 05	2.40
1930	77.58	630	7.96E 05	2.48
2016	77.60	676	7.42E 05	2.50
2119	78.06	739	6.78E 05	2.96
2321	78.09	861	5.82E 05	2.99
0114	78.35	974	5.15E 05	3.25
0316	78.59	1096	4.57E 05	3.49
0517	78.62	1217	4.12E 05	3.52

POOR ORIGINAL



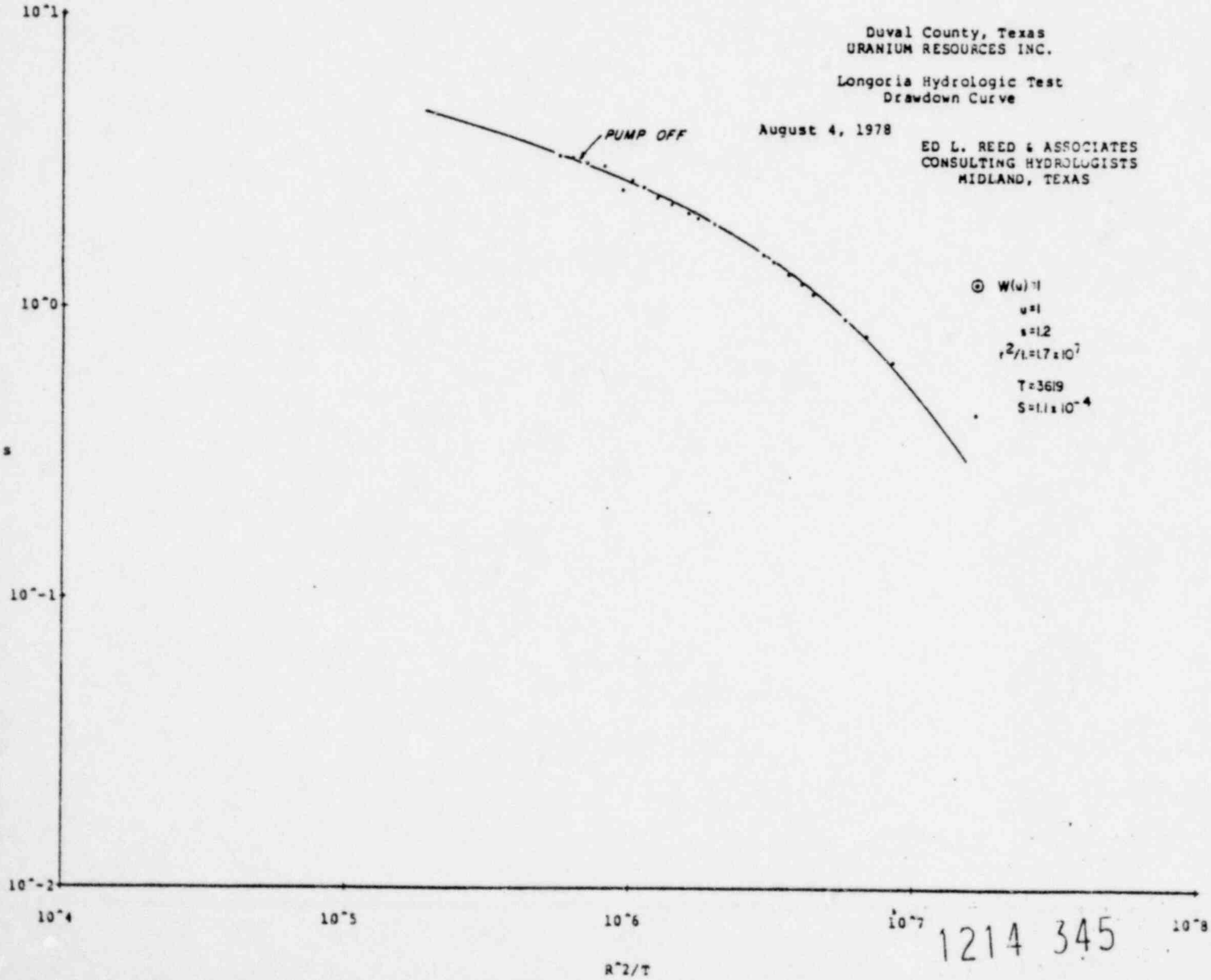
344

Obs. Well Number............ U-228

Pumped Well Number.......... U 237

Radius from Pumped Well..... 690.00
Time Test Started........... 900
Static Water Level.......... 72.68

Time	Wtr Level	Cum T	R^2/T	Drawdown
0941	73.10	41	1.67E 07	0.42
1021	73.31	81	8.46E 06	0.63
1041	73.46	101	6.79E 06	0.78
1100	73.57	120	5.71E 06	0.89
1135	73.77	155	4.42E 06	1.09
1150	73.86	170	4.03E 06	1.18
1209	73.95	189	3.63E 06	1.27
1232	74.07	212	3.23E 06	1.39
1250	74.15	230	2.98E 06	1.47
1442	74.57	342	2.00E 06	1.89
1534	74.64	394	1.74C 06	1.96
1607	74.72	427	1.61E 06	2.04
1707	74.87	487	1.41E 06	2.19
1805	75.00	545	1.26E 06	2.32
1908	75.19	608	1.13E 06	2.51
2005	75.35	665	1.03E 06	2.67
2106	75.14	726	9.44E 05	2.46
2304	75.65	844	8.12E 05	2.97
0104	75.72	964	7.11E 05	3.04
0305	75.85	1085	6.32E 05	3.1[illegible]
0506	75.90	1206	5.68E 05	3.22



1214 345

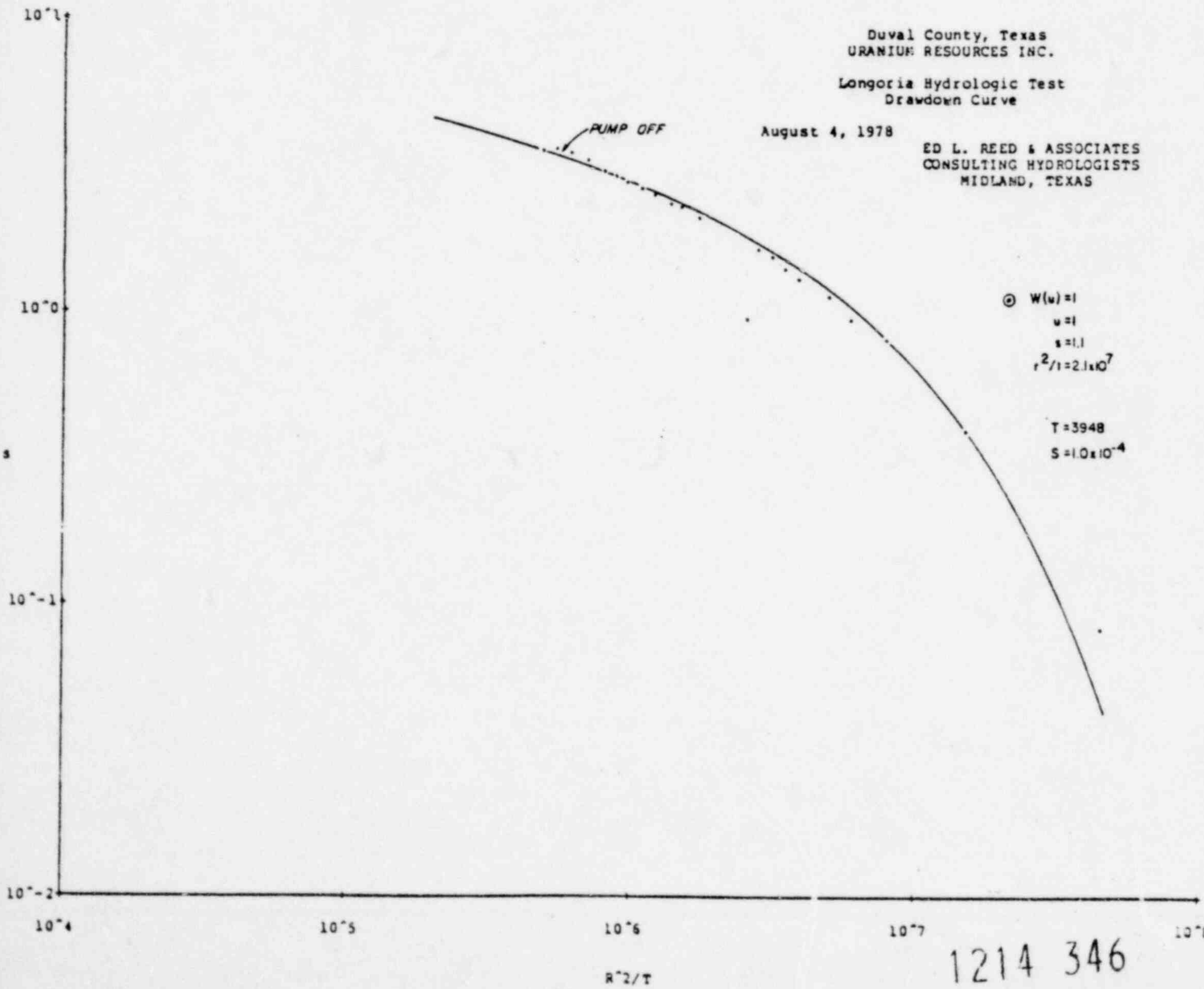
Obs. Well Number............ U-230

Pumped Well Number.......... U 237

Radius from Pumped Well..... 638.00
Time Test Started........... 900
Static Water Level.......... 73.33

Time	Wtr Level	Cum T	R^2/T	Drawdown
0913	73.41	13	4.51E 07	0.08
0939	73.71	39	1.50E 07	0.38
1014	74.11	74	7.92E 06	0.78
1039	74.24	99	5.92E 06	0.91
1058	74.43	118	4.97E 06	1.10
1131	74.59	151	3.88E 06	1.26
1148	74.68	168	3.49E 06	1.35
1206	74.82	186	3.15E 06	1.49
1229	74.90	209	2.80E 06	1.57
1248	74.25	228	2.57E 06	0.92
1438	75.35	338	1.73E 06	2.02
1531	75.52	391	1.50E 06	2.19
1604	75.59	424	1.38E 06	2.26
1704	75.74	484	1.21E 06	2.41
1802	75.87	542	1.08E 06	2.5[illegible]
1906	75.99	606	9.67E 05	2.66
2004	76.13	664	8.83E 05	2.80
2104	76.23	724	8.10E 05	2.90
2301	76.51	841	6.97E 05	3.18
0103	76.68	963	6.09E 05	3.35
0303	76.80	1083	5.41E 05	3.47
0502	76.73	1202	4.88E 05	3.40

POOR ORIGINAL



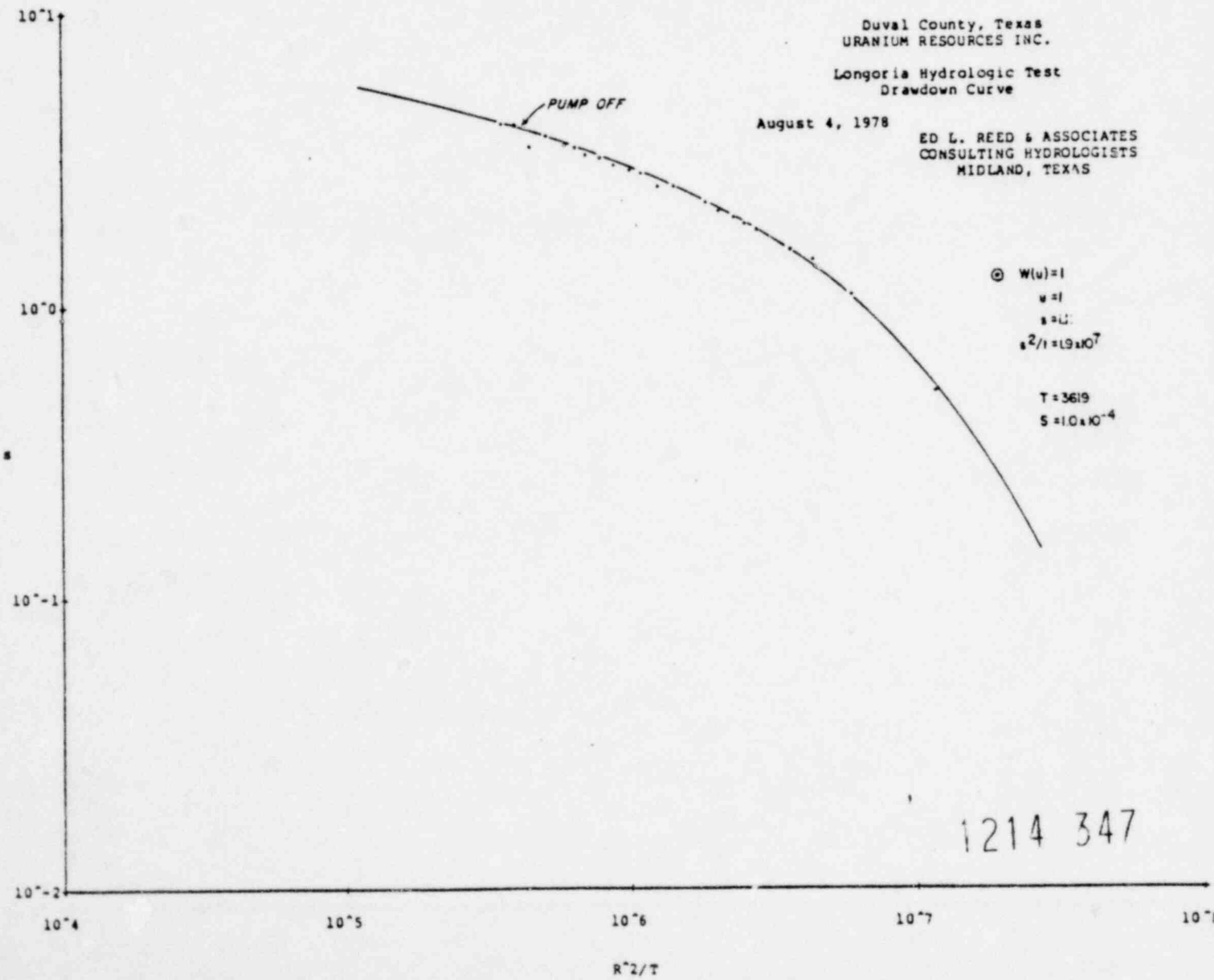
1214 346

Obs. Well Number............ U-231

Pumped Well Number.......... U 237

Radius from Pumped Well..... 544.50
Time Test Started........... 900
Static Water Level.......... 73.20

Time	Wtr Level	Cum T	R^2/T	Drawdown
0936	73.69	36	1.19E 07	0.49
1011	74.25	71	6.01E 06	1.05
1037	74.57	97	4.40E 06	1.37
1056	74.69	116	3.68E 06	1.49
1132	74.94	152	2.81E 06	1.74
1147	75.03	167	2.56E 06	1.83
1202	75.14	182	2.35E 06	1.94
1227	75.23	207	2.06E 06	2.03
1247	75.36	227	1.88E 06	2.16
1358	75.66	298	1.43E 06	2.46
1435	75.66	335	1.27E 06	2.46
1526	75.92	386	1.11E 06	2.72
1602	76.00	422	1.01E 06	2.80
1702	76.10	482	8.86E 05	2.90
1800	76.28	540	7.91E 05	3.08
1904	76.35	604	7.07E 05	3.15
2001	76.54	661	6.46E 05	3.34
2101	76.62	721	5.92E 05	3.42
2300	76.86	840	5.08E 05	3.66
0101	76.57	961	4.44E 05	3.37
0301	77.19	1081	3.95E 05	3.99
0500	77.25	1200	3.56E 05	4.05



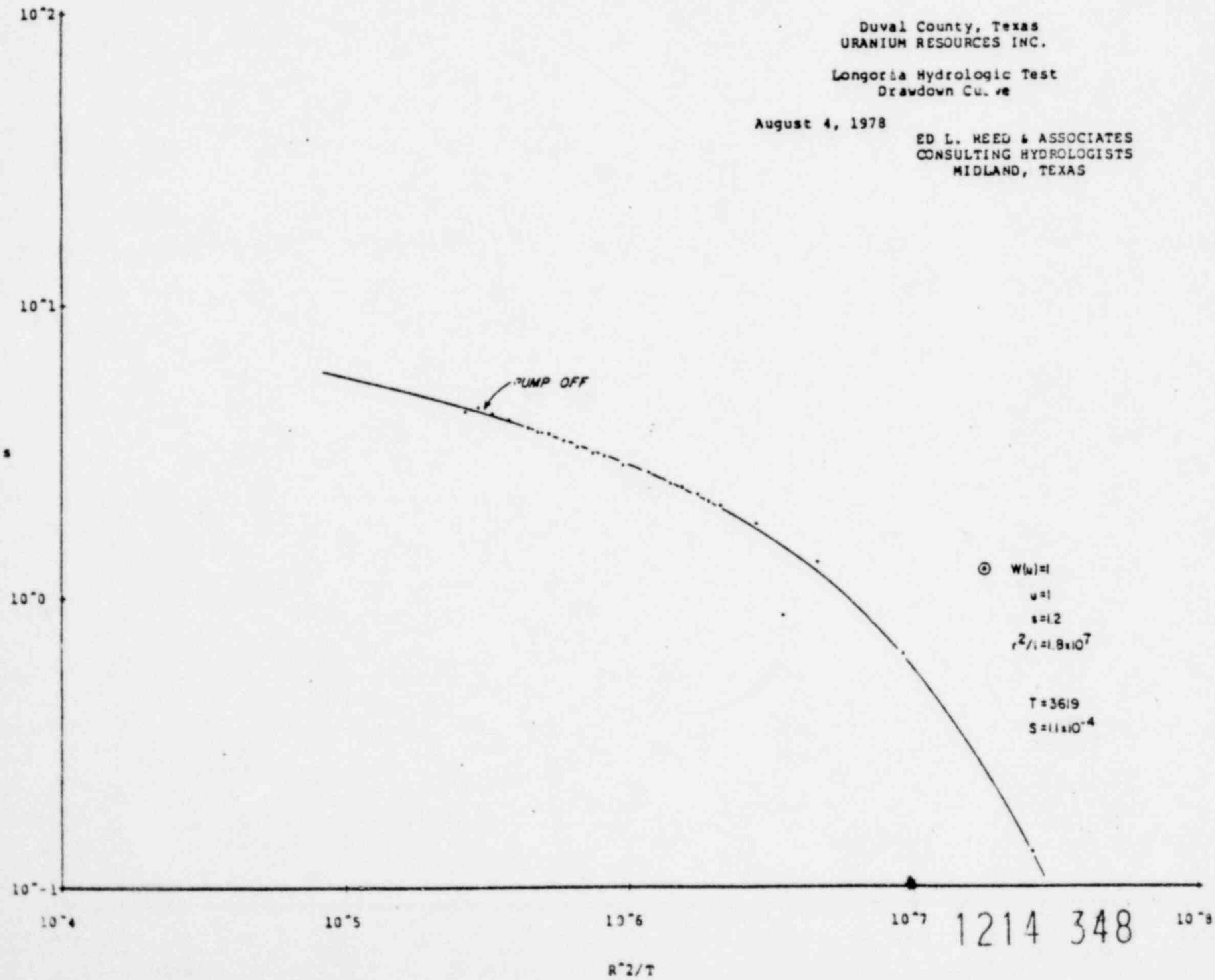
1214 347

Obs. Well Number............ U-232

Pumped Well Number.......... U 237

Radius from Pumped Well..... 469.00
Time Test Started........... 900
Static Water Level.......... 73.41

Time	Wtr Level	Cum T	R^2/T	Drawdown
0912	73.54	12	2.64E 07	0.13
0934	74.03	34	9.32E 06	0.62
1008	74.69	68	4.66E 06	1.28
1030	74.25	90	3.52E 06	0.84
1052	75.14	112	2.83E 06	1.73
1129	75.41	149	2.13E 06	2.00
1144	75.48	164	1.93E 06	2.07
1200	75.59	180	1.76E 06	2.18
1224	75.72	204	1.55E 06	2.31
1245	75.80	225	1.41E 06	2.39
1327	76.02	267	1.19E 06	2.61
1430	76.17	330	9.60E 05	2.76
1522	76.36	382	8.29E 05	2.95
1558	76.43	418	7.58E 05	3.02
1700	76.58	480	6.60E 05	3.17
1755	76.73	535	5.92E 05	3.32
1900	76.92	600	5.28E 05	3.51
2000	77.00	660	4.80E 05	3.59
2058	77.10	718	4.41E 05	3.69
2254	77.34	834	3.80E 05	3.93
0100	77.54	960	3.30E 05	4.13
0256	77.75	1076	2.94E 05	4.34
0456	77.60	1196	2.65E 05	4.19



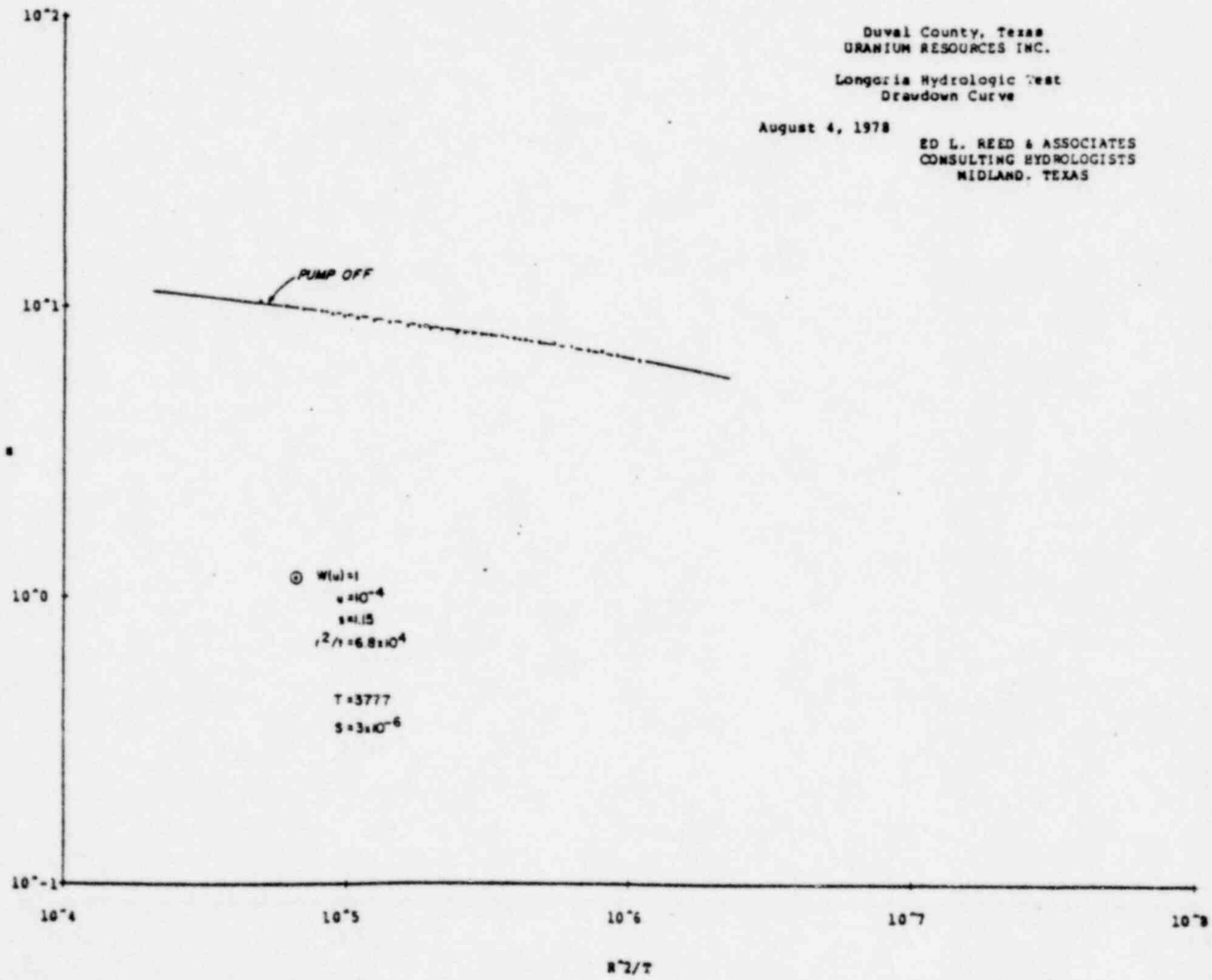
1214 348

Obs. Well Number............ U-234

Pumped Well Number.......... U 237

Radius from Pumped Well..... 204.00
Time Test Started........... 900
Static Water Level.......... 74.93

Time	Wtr Level	Cum T	R^2/T	Drawdown
0955	81.25	55	1.09E 06	6.32
1006	81.51	66	9.08E 05	6.58
1015	81.69	75	7.99E 05	6.76
1025	81.78	85	7.05E 05	6.85
1037	81.98	97	6.18E 05	7.05
1052	82.19	112	5.35E 05	7.26
1106	82.25	126	4.76E 05	7.32
1121	82.36	141	4.25E 05	7.43
1135	82.46	155	3.[illegible]7E 05	7.53
1151	82.57	171	3.50E 05	7.64
1205	82.64	185	3.24E 05	7.71
1222	82.69	202	2.97E 05	7.76
1235	82.78	215	2.79E 05	7.85
1249	82.84	229	2.62E 05	7.91
1305	82.77	245	2.45E 05	7.84
1338	83.02	278	2.16E 05	8.09
1405	83.10	305	1.96E 05	8.17
1434	83.19	334	1.79E 05	8.26
1506	83.29	366	1.64E 05	8.36
1605	83.47	425	1.41E 05	8.54
1700	83.61	480	1.[illegible]5E 05	8.68
1807	83.76	547	1.10E 05	8.83
1906	83.91	606	9.89E 04	8.98
2005	84.02	665	9.01E 04	9.09
2110	84.30	730	8.21E 04	9.37
2306	84.45	846	7.08E 04	[illegible].52
0110	84.64	970	6.18E 04	9.71
0507	85.04	1207	4.96E 04	10.11



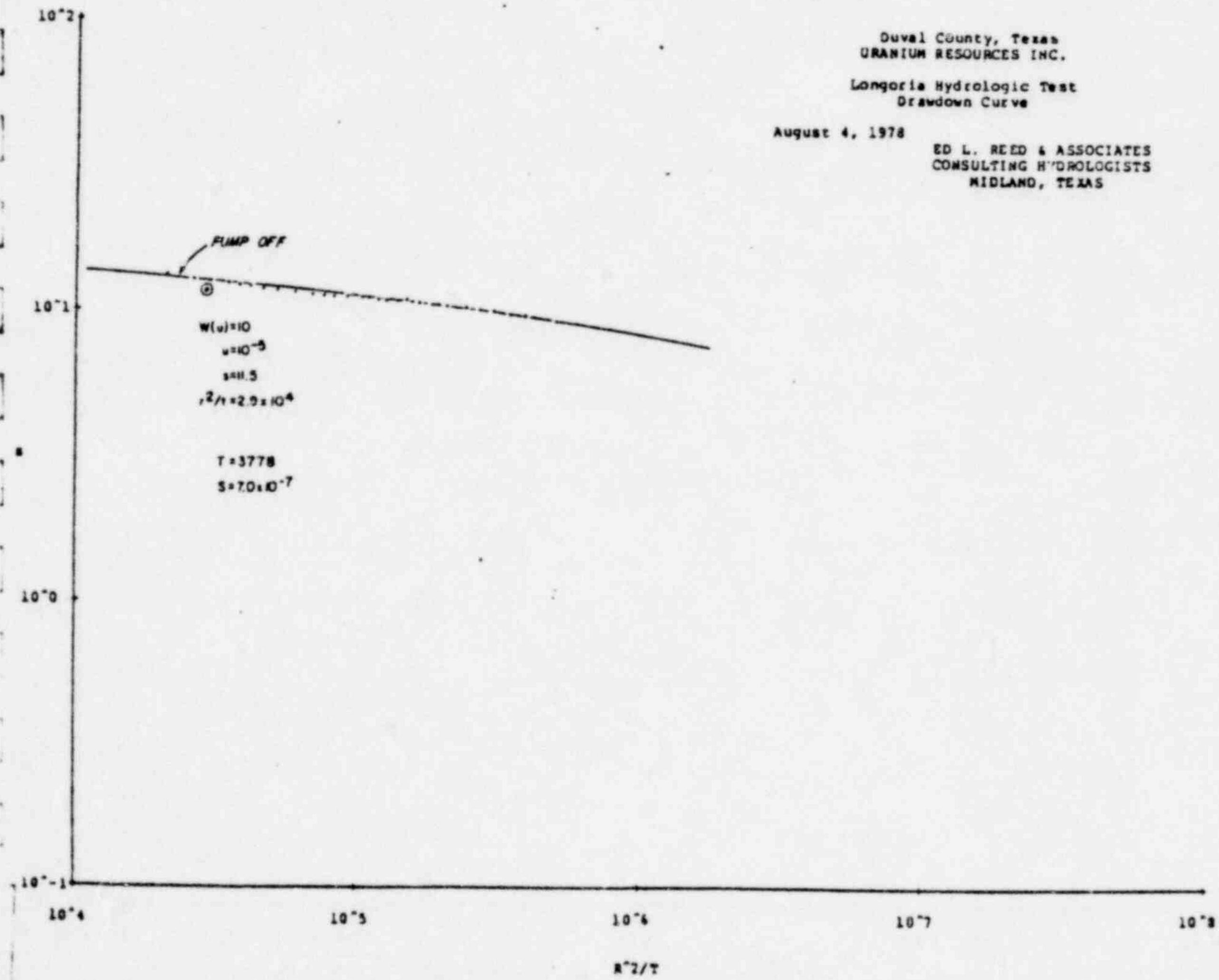
POOR ORIGINAL

1214 349

Pumped Well Number........... U 237

Radius from Pumped Well..... 132.00
Time Test Started. 900
Static Water Level.......... 75.19

Time	Wtr Level	Cum T	R^2/T	Drawdown
0950	83.99	50	5.02E 05	8.80
1004	84.36	64	3.92E 05	9.17
1013	84.55	73	3.44E 05	9.36
1023	84.77	83	3.02E 05	9.58
1034	84.87	94	2.67E 05	9.68
1044	85.04	104	2.41E 05	9.85
1102	85.15	122	2.06E 05	9.96
1118	85.25	138	1.82E 05	10.06
1133	85.37	153	1.64E 05	10.18
1149	85.66	169	1.48E 05	10.47
1203	85.53	183	1.37E 05	10.34
1220	85.59	200	1.25E 05	10.40
1233	85.64	213	1.18E 05	10.45
1248	85.77	228	1.10E 05	10.58
1303	85.77	243	1.03E 05	10.58
1336	85.89	276	9.09E 04	10.70
1404	85.91	304	8.25E 04	10.72
1432	85.99	332	7.56E 04	10.80
1504	86.09	364	6.89E 04	10.90
1603	86.28	423	[illegible]	11.09
1706	86.43	[illegible]	[illegible]	11.24
1805	86.55	54[illegible]	4.8[illegible] 04	11.36
1904	86.78	604	4.15E 04	11.59
2003	86.88	663	3.78E 04	11.69
2106	87.10	726	3.46E 04	11.91
2302	87.25	842	2.98E 04	12.06
0107	87.41	967	2.59E 04	12.22
0504	87.96	1204	2.08E 04	12.77



Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

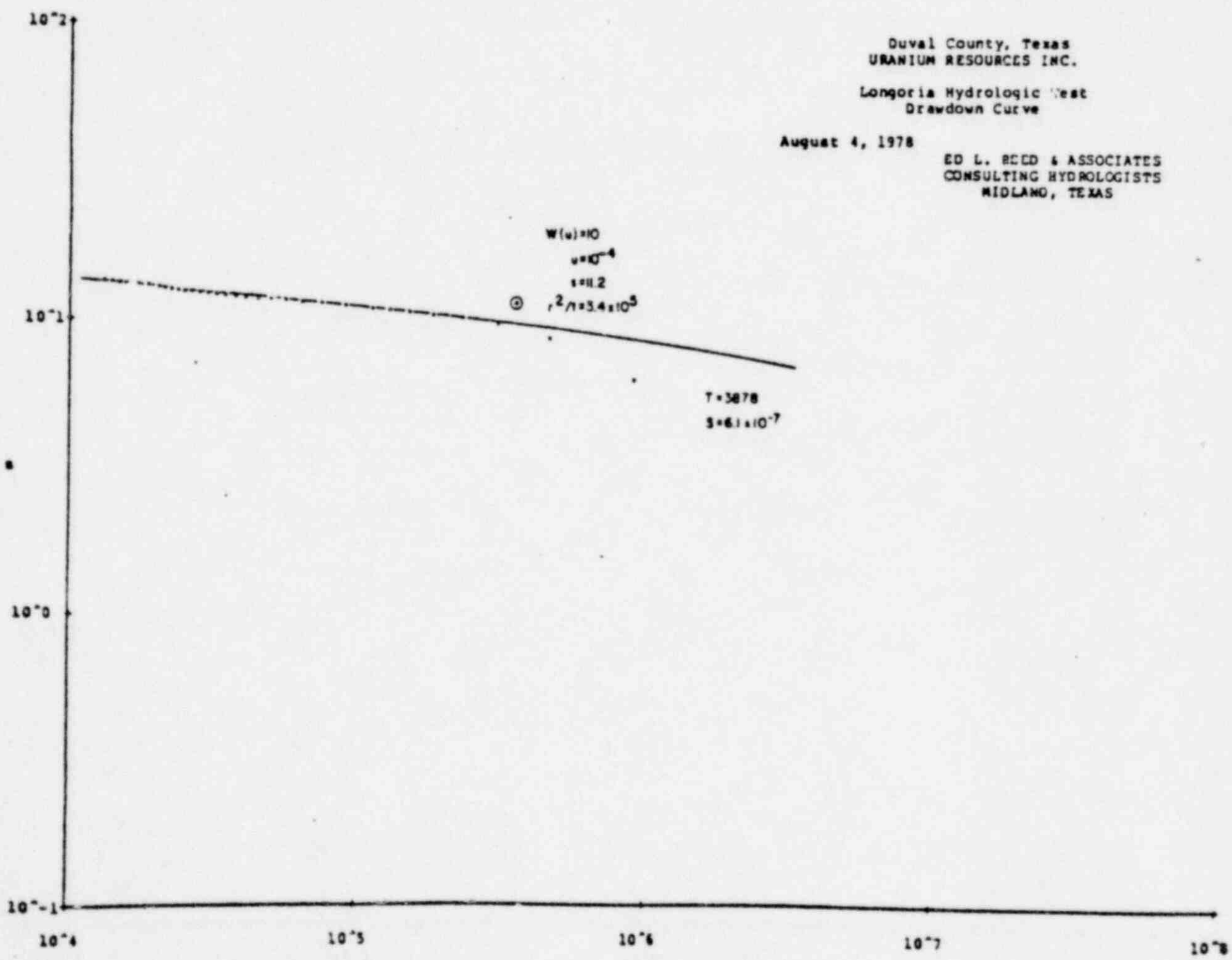
ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

Obs. Well Number............ U-236

Pumped Well Number.......... U 237

Radius from Pumped Well..... 97.00
Time Test Started........... 900
Static Water Level.......... 76.36

Time	Wtr Level	Cum T	R^2/T	Drawdown
0915	82.54	15	9.03E 05	6.18
0930	84.84	30	4.52E 05	8.48
0945	85.82	45	3.01E 05	9.46
1000	86.30	60	2.26E 05	9.94
1015	86.58	75	1.81E 05	10.22
1030	86.78	90	1.51E 05	10.42
1045	86.94	105	1.29E 05	10.58
1100	87.07	120	1.13E 05	10.71
1130	87.28	150	9.03E 04	10.92
1200	87.46	180	7.53E 04	11.10
1230	87.59	210	6.45E 04	11.23
1300	87.73	240	5.65E 04	11.37
1330	87.85	270	5.02E 04	11.49
1400	87.87	300	4.52E 04	11.51
1430	87.96	3[illegible]	4.11E 04	11.60
1500	88.06	3[illegible]	[illegible].76E 04	11.70
1530	88.14	3[illegible]0	[illegible].47E 04	11.78
1600	88.27	420	3.23E 04	11.91
1630	88.36	450	3.01E 04	12.00
1700	88.43	480	2.82E 04	12.07
1730	88.50	510	2.66E 04	12.14
1800	88.56	540	2.51E 04	12.20
1830	88.64	570	2.38E 04	12.28
1900	88.73	600	2.26E 04	12.37
1930	88.81	630	2.15E 04	12.45
2000	88.90	660	2.05E 04	12.54
2100	89.10	720	1.88E 04	12.74
2200	89.18	780	1.74E 04	12.82
2300	89.30	840	1.61E 04	12.94
2400	89.36	900	1.51E 04	13.00
0100	89.46	960	1.41E 04	13.10
0200	89.56	1020	1.33E 04	13.20



Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

POOR ORIGINAL

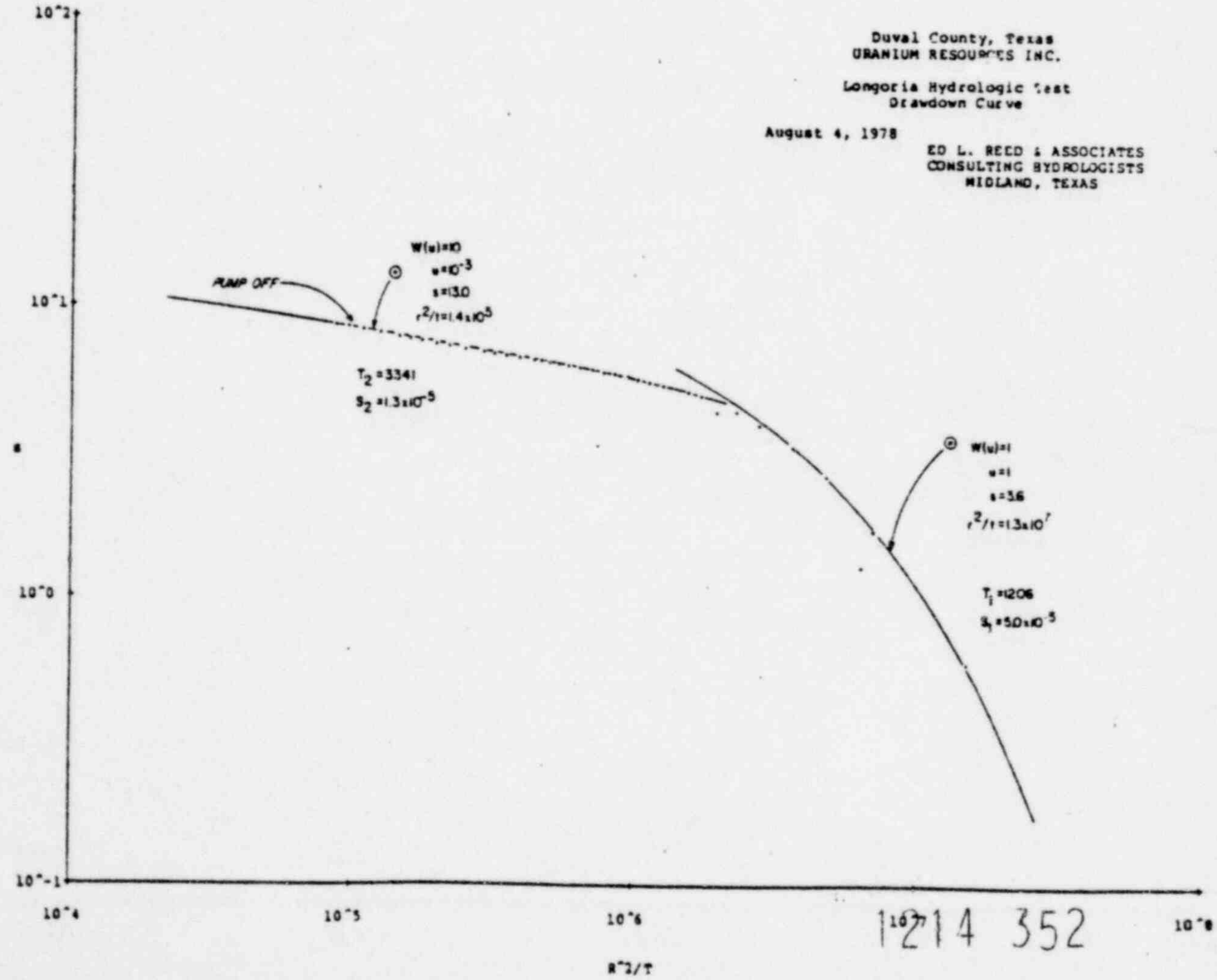
1214 351

Obs. Well Number............ U-242

Pumped Well Number.......... U 237

Radius from Pumped Well..... 271.00
Time Test Started........... 900
Static Water Level.......... 76.54

Time	Wtr Level	Cum T	R^2/T	Drawdown
0907	77.12	7	1.51E 07	0.58
0915	78.21	15	7.05E 06	1.67
0922	79.11	22	4.81E 06	2.57
0929	79.79	29	3.65E 06	3.25
0938	80.40	38	2.78E 06	3.86
0946	80.81	46	2.30E 06	4.27
0954	80.79	54	1.96E 06	4.25
1001	81.34	61	1.73E 06	4.80
1008	81.49	68	1.56E 06	4.95
1023	81.74	83	1.27E 06	5.20
1033	81.89	93	1.14E 06	5.35
1042	82.00	102	1.04E 06	5.46
1051	82.13	111	9.53E 05	5.59
1104	82.26	124	8.53E 05	5.72
1115	82.34	135	7.83E 05	5.80
1129	82.44	149	7.10E 05	5.90
1145	82.56	165	6.41E 05	6.02
1200	82.65	180	5.88E 05	6.11
1215	82.73	195	5.42E 05	6.19
1230	82.82	210	5.04E 05	6.28
1245	82.89	225	4.70E 05	6.35
1300	82.96	240	4.41E 05	6.42
1330	83.08	270	3.92E 05	6.54
1400	83.18	300	3.53E 05	6.64
1430	83.27	330	3.20E 05	6.73
1500	83.37	360	2.94E 05	6.83
1600	83.54	420	2.52E 05	7.00
1700	83.73	480	2.20E 05	7.19
[illegible]	83.84	540	1.96E 05	7.30
190[illegible]	84.01	605	1.75E 05	7.47
2001	84.13	661	1.60E 05	7.59
2102	84.24	722	1.46E 05	7.70
2300	84.48	840	1.26E 05	7.94
0102	84.70	962	1.10E 05	8.16
0300	84.87	1080	9.79E 04	8.33
0501	84.97	1201	8.81E 04	8.43



1214 352

POOR ORIGINAL

COMPUTER DATA SHEETS

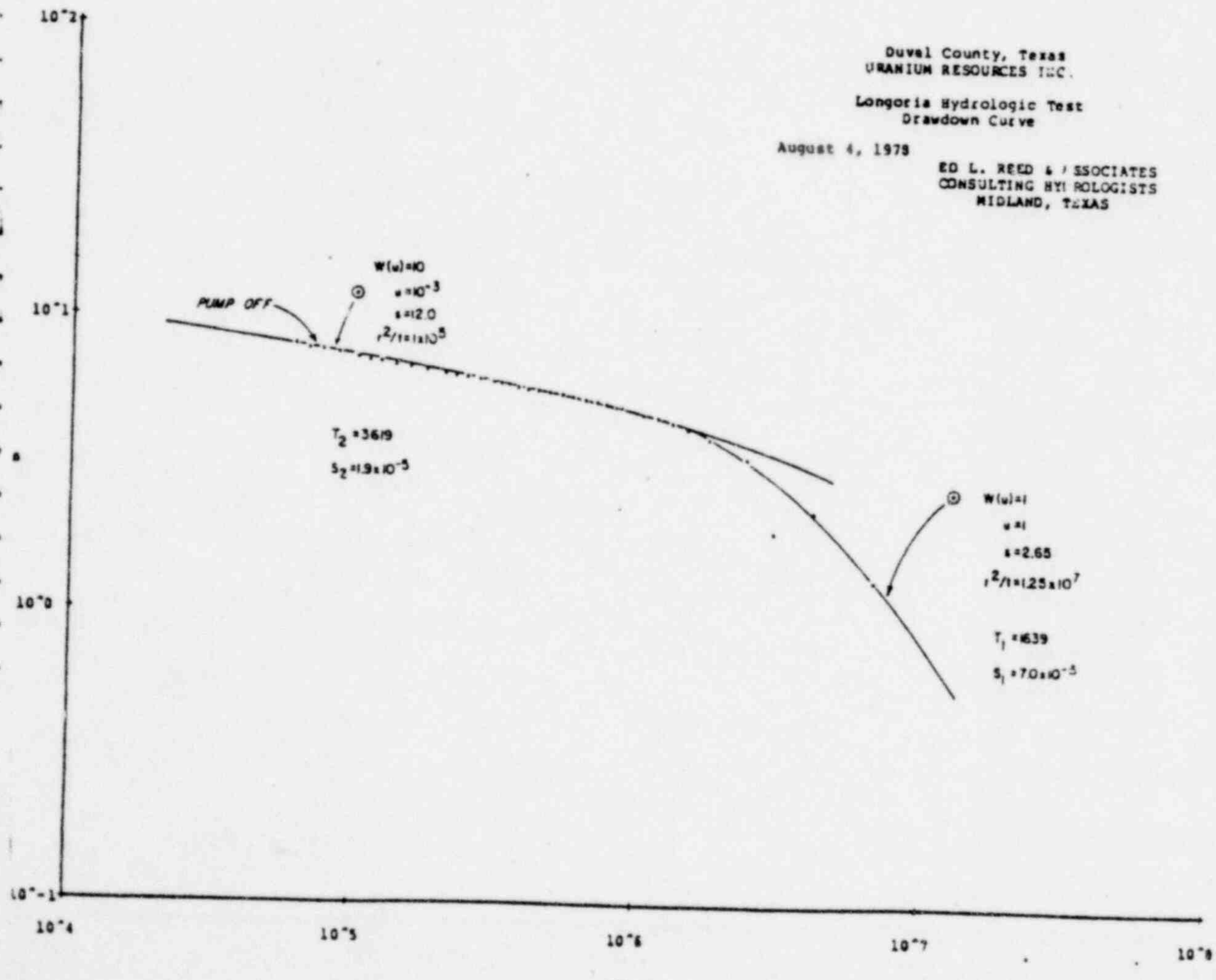
SHALLOW MONITOR WELLS

Obs. Well Number............ U-243

Pumped Well Number.......... U 237

Radius from Pumped Well..... 227.00
Time Test Started........... 900
Static Water Level.......... 77.19

Time	Wtr Level	Cum T	R^2/T	Drawdown
0903	77.26	3	2.47E 07	0.07
0911	78.50	11	6.75E 06	1.31
0918	79.41	18	4.12E 06	2.22
0925	79.06	25	2.97E 06	1.87
0931	80.54	31	2.39E 06	3.35
0942	81.11	42	1.77E 06	3.92
0950	81.38	50	1.48E 06	4.19
0957	81.61	57	1.30E 06	4.42
1004	81.78	64	1.16E 06	4.59
1012	81.87	72	1.03E 06	4.68
1027	82.16	87	8.53E 05	4.97
1038	82.26	98	7.57E 05	5.07
1045	82.36	105	7.07E 05	5.17
1056	82.46	116	6.40E 05	5.27
1108	82.58	128	5.80E 05	5.39
1118	82.64	138	5.38E 05	5.45
1133	82.74	153	4.85E 05	5.55
1149	82.83	169	4.39E 05	5.64
1203	82.89	183	4.05E 05	5.70
1218	82.95	198	3.75E 05	5.76
1234	83.09	214	3.47E 05	5.90
1248	83.15	228	3.25E 05	5.96
1303	83.20	243	3.05E 05	6.01
1334	83.34	274	2.71E 05	6.15
1404	83.43	304	2.44E 05	6.24
1433	83.49	333	2.23E 05	6.30
1504	83.61	364	2.04E 05	6.42
1604	83.75	424	1.75E 05	6.56
1703	83.91	483	1.54E 05	6.72
1803	84.02	543	1.37E 05	6.83
1911	84.17	611	1.21E 05	6.98
2006	84.28	666	1.11E 05	7.09
2109	84.42	729	1.02E 05	7.23
2310	84.67	850	8.73E 04	7.48
0109	84.83	969	7.66E 04	7.64
0306	84.88	1086	6.83E 04	7.69
0509	85.17	1209	6.14E 04	7.98



Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

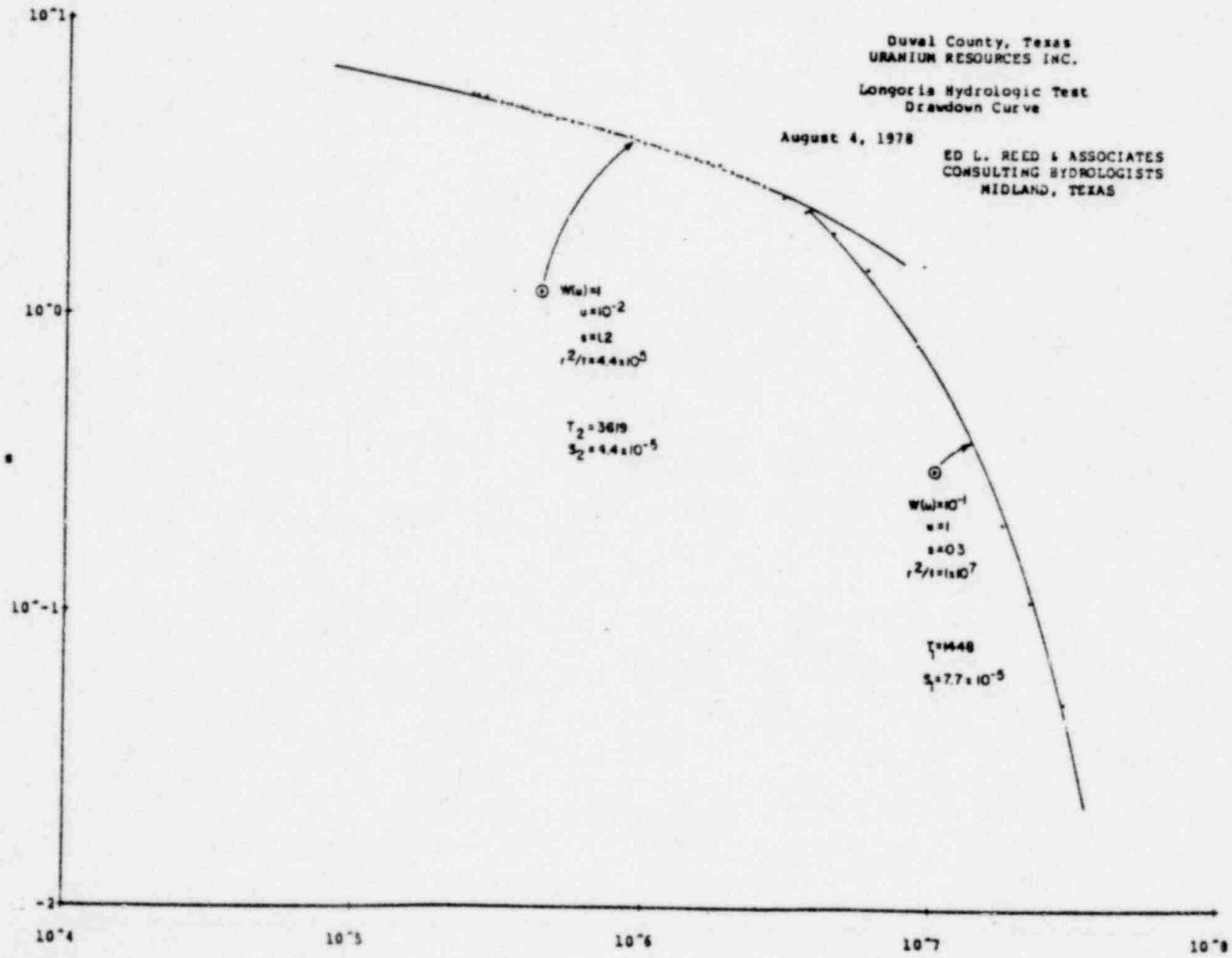
August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

Pumped Well Number.......... U 237

Radius from Pumped Well..... 428.00
Time Test Started........... 900
Static Water Level.......... 76.80

Time	Wtr Level	Cum T	R^2/T	Drawdown
0909	76.85	9	2.93E 07	0.05
0912	76.91	12	2.20E 07	0.11
0915	77.00	15	1.76E 07	0.20
0930	77.60	30	8.79E 06	0.80
0945	78.24	45	5.86E 06	1.44
1000	/8.72	60	4.40E 06	1.92
1015	79.07	75	3.52E 06	2.27
1030	79.32	90	2.93E 06	2.52
1045	79.53	105	2.51E 06	2.73
1100	79.69	120	2.20E 06	2.89
1115	79.83	135	1.95E 06	3.03
1130	79.99	150	1.76E 06	3.19
1145	80.09	165	1.60E 06	3.29
1200	80.17	180	1.47E 06	3.37
1215	80.25	195	1.35E 06	3.45
1230	80.32	210	1.26E 06	3.52
1300	80.46	240	1.10E 06	3.66
1330	80.59	270	9.77E 05	3.79
1400	80.76	300	8.79E 05	3.96
1500	80.93	360	7.33E 05	4.13
1600	81.12	420	6.28E 05	4.32
1700	81.26	480	5.50E 05	4.46
1800	81.[illegible]	540	4.88E 05	4.57
1900	81.49	600	4.40E 05	4.69
2000	81.62	660	4.00E 05	4.82
2100	81.76	720	3.66E 05	4.96
2200	81.87	780	3.38E 05	5.07
2300	81.96	840	3.14E 05	5.16
0100	82.18	960	2.75E 05	5.38
0200	82.29	1020	2.59E 05	5.49
0245	82.32	1065	2.48E 05	5.52



1214 355

Obs. Well Number............ U-246

Pumped Well Number.......... U 237

Radius from Pumped Well..... 354.00
Time Test Started........... 900
Static Water Level.......... 77.28

Time	Wtr Level	Cum T	R^2/T	Drawdown
0904	77.33	4	4.51E 07	0.05
0912	77.78	12	1.50E 07	0.50
0920	78.29	20	9.02E 06	1.01
0926	78.77	26	6.94E 06	1.49
0933	79.07	33	5.47E 06	1.79
0943	79.50	43	4.20E 06	2.22
0951	79.74	51	3.54E 06	2.46
1000	79.88	60	3.01E 06	2.60
1006	80.08	66	2.73E 06	2.80
1013	80.20	73	2.47E 06	2.92
1030	80.44	90	2.01E 06	3.16
1039	80.55	99	1.82E 06	3.27
1049	80.65	109	1.66E 06	3.37
1057	80.74	117	1.54E 06	3.46
1109	80.84	129	1.40E 06	3.56
1120	80.87	140	1.29E 06	3.59
1135	81.02	155	1.16E 06	3.74
1151	81.12	171	1.06E 06	3.84
1206	81.20	186	9.70E 05	3.92
1220	81.28	200	9.02E 05	4.00
1236	81.37	216	8.35E 05	4.09
1250	81.42	230	7.85E 05	4.14
1304	81.49	244	7.40E 05	4.21
1335	81.62	275	6.56E 05	4.34
1406	81.71	306	5.90E 05	4.43
1435	81.80	335	5.39E 05	4.52
1507	81.89	367	4.92E 05	4.61
1606	82.05	426	4.24E 05	4.77
1705	82.22	485	3.72E 05	4.94
1806	82.32	546	3.31E 05	5.04
1914	82.45	614	2.94E 05	5.17
2008	82.59	668	2.70E 05	5.31
2112	82.70	732	2.47E 05	5.42
2314	82.80	854	2.11E 05	5.52
0112	83.10	[illegible]	1.86E 05	5.82
0312	82.90	109[illegible]	1.65E 05	5.62
0511	83.27	1211	1.49E 05	5.99

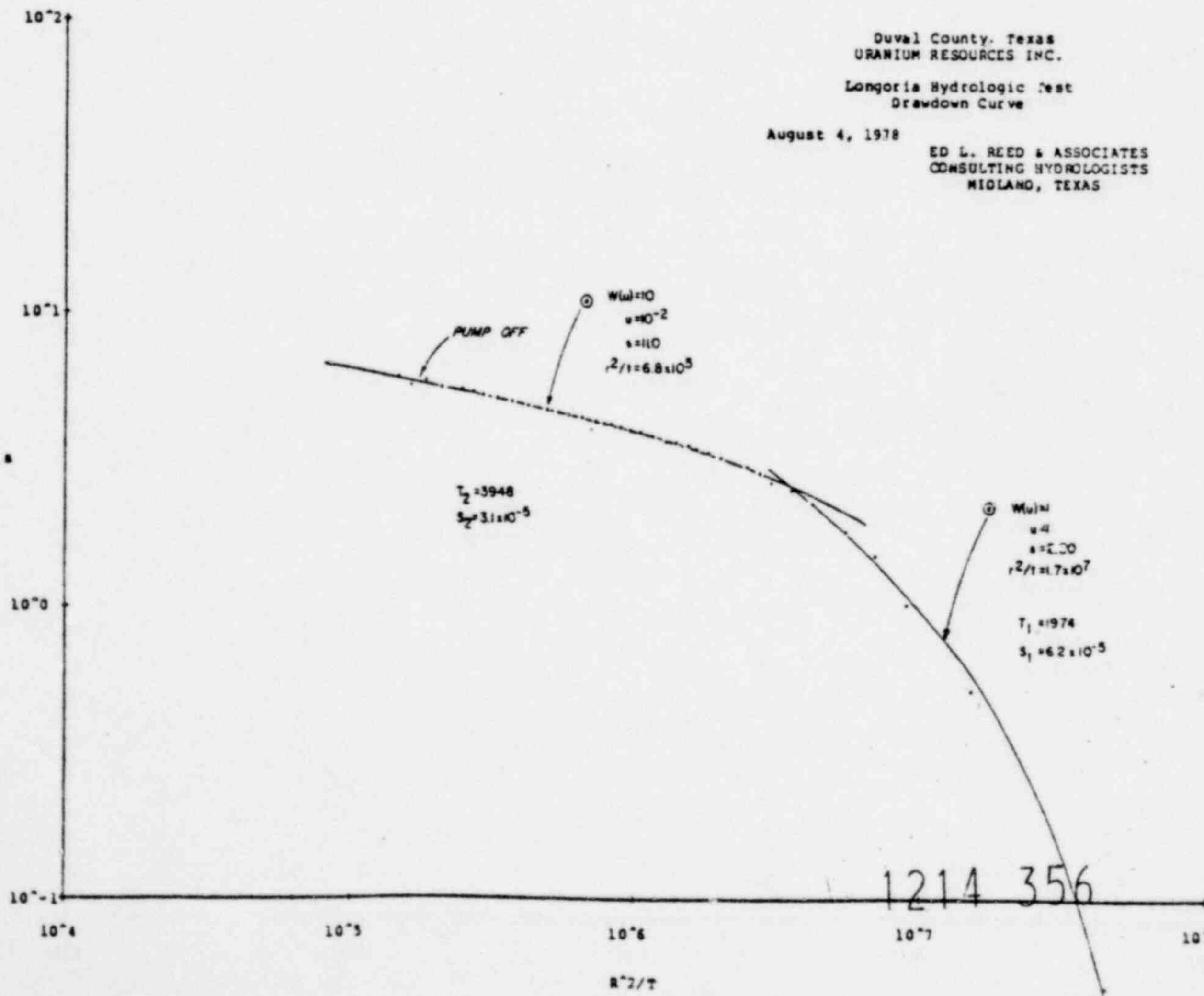
POOR ORIGINAL

Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS



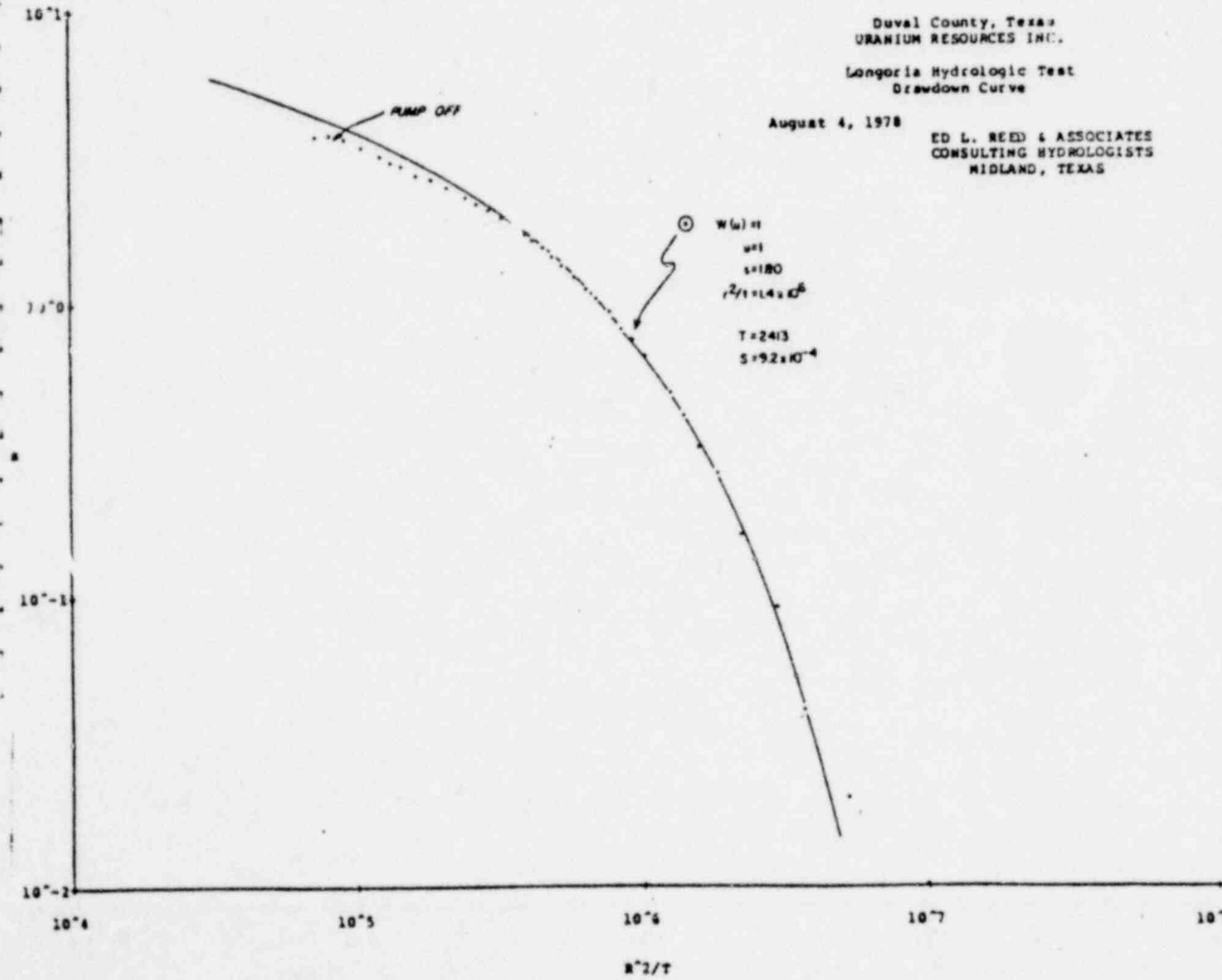
1214 356

Obs. Well Number............ MW-13-(MS-1)

Pumped Well Number.......... U 237

Radius from Pumped Well..... 248.00
Time Test Started............ 900
Static Water Level.......... 77.08

Time	Wtr Level	Cum T	R^2/T	Drawdown
0909	77.09	9	9.84E 06	0.01
0917	77.10	17	5.21E 06	0.02
0924	77.12	24	3.69E 06	0.04
0930	77.17	30	2.95E 06	0.09
0940	77.24	40	2.21E 06	0.16
0948	77.34	48	1.85E 06	0.26
0956	77.40	56	1.58E 06	0.32
1003	77.49	63	1.41E 06	0.41
1010	77.57	70	1.27E 06	0.49
1026	77.73	86	1.03E 06	0.65
1035	77.82	95	9.32E 05	0.74
1044	77.88	104	8.52E 05	0.80
1053	78.00	113	7.84E 05	0.92
1106	78.10	126	7.03E 05	1.02
1117	78.18	137	6.46E 05	1.10
1131	78.29	151	5.87E 05	1.21
1147	78.40	167	[illegible].30E 05	1.32
1202	78.50	182	4.87E 05	1.42
1217	78.60	197	4.50E 05	1.52
1233	78.69	213	4.16E 05	1.61
1247	78.75	227	3.90E 05	1.67
1301	78.85	241	3.67E 05	1.77
1332	79.00	272	3.26E 05	1.92
1402	79.12	302	2.93E 05	2.04
1432	79.23	332	2.67E 05	2.15
1502	79.33	362	2.45E 05	2.25
1602	79.52	422	2.10E 05	2.44
1701	79.67	481	1.84E 05	2.59
1801	79.77	541	1.64E 05	2.69
1908	79.97	608	1.46E 05	2.89
2003	80.06	663	1.34E 05	2.98
2105	80.20	725	1.22E 05	3.12
2301	80.43	841	1.05E 05	3.35
0106	80.66	966	9.17E 04	3.58
0304	80.79	1084	8.17E 04	3.71
0505	80.74	1205	7.35E 04	3.66



Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS

1214 357

Obs. Well Number............ MW-14(MS-2)

Pumped Well Number.......... U 237

Radius from Pumped Well..... 162.00
Time Test Started........... 900
Static Water Level.......... 75.11

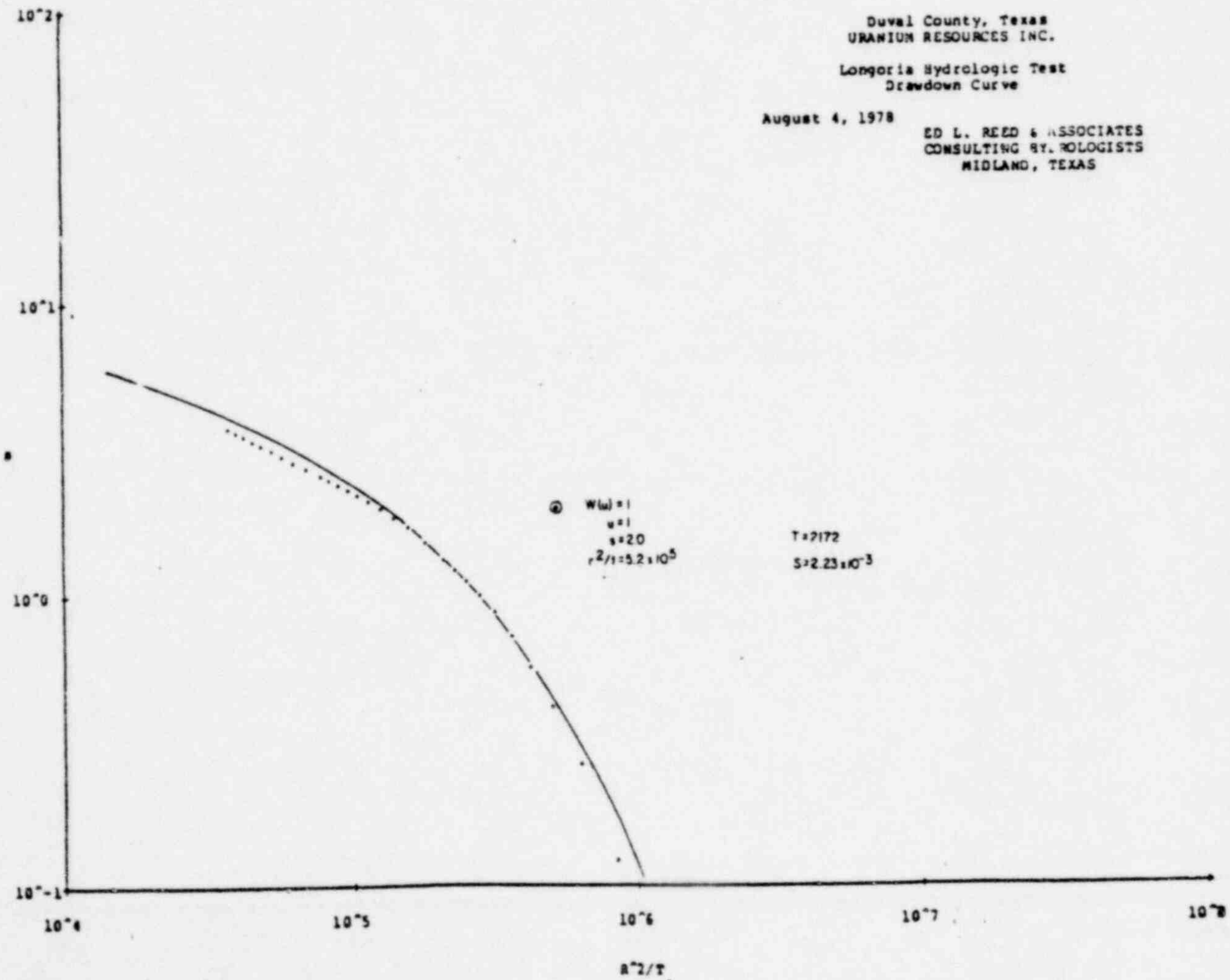
Time	Wtr Level	Cum T	R^2/T	Drawdown
0930	75.12	30	1.26E 06	0.01
0945	75.23	45	8.40E 05	0.12
1000	75.37	60	6.30E 05	0.26
1015	75.52	75	5.04E 05	0.41
1030	75.67	90	4.20E 05	0.56
1045	75.82	105	3.60E 05	0.71
1100	75.97	120	3.15E 05	0.86
1115	76.09	135	2.80E 05	0.98
1130	76.21	150	2.52E 05	1.10
1145	76.31	165	2.29E 05	1.20
1200	76.41	180	2.10E 05	1.30
1230	76.60	210	1.80E 05	1.49
1300	76.78	240	1.57E 05	1.67
1330	76.91	270	1.40E 05	1.80
1400	77.04	300	1.26E 05	1.93
1430	77.15	330	1.15E 05	2.04
1500	77.26	360	1.05E 05	2.15
1530	77.35	390	9.69E 04	2.24
1600	77.44	420	9.00E 04	2.33
1630	77.52	450	8.40E 04	2.41
1700	77.60	480	7.87E 04	2.49
1800	77.75	540	7.00E 04	2.64
1900	77.88	600	6.30E 04	2.77
2000	78.01	660	5.73E 04	2.90
2100	78.15	720	5.25E 04	3.04
2200	78.28	780	4.85E 04	3.17
2300	78.39	840	4.50E 04	3.28
2400	78.52	900	4.20E 04	3.41
0100	78.63	960	3.94E 04	3.52
0200	78.74	1020	3.71E 04	3.63

Duval County, Texas
URANIUM RESOURCES INC.

Longoria Hydrologic Test
Drawdown Curve

August 4, 1978

ED L. REED & ASSOCIATES
CONSULTING HYDROLOGISTS
MIDLAND, TEXAS



1214 358

FIGURES

1214 359

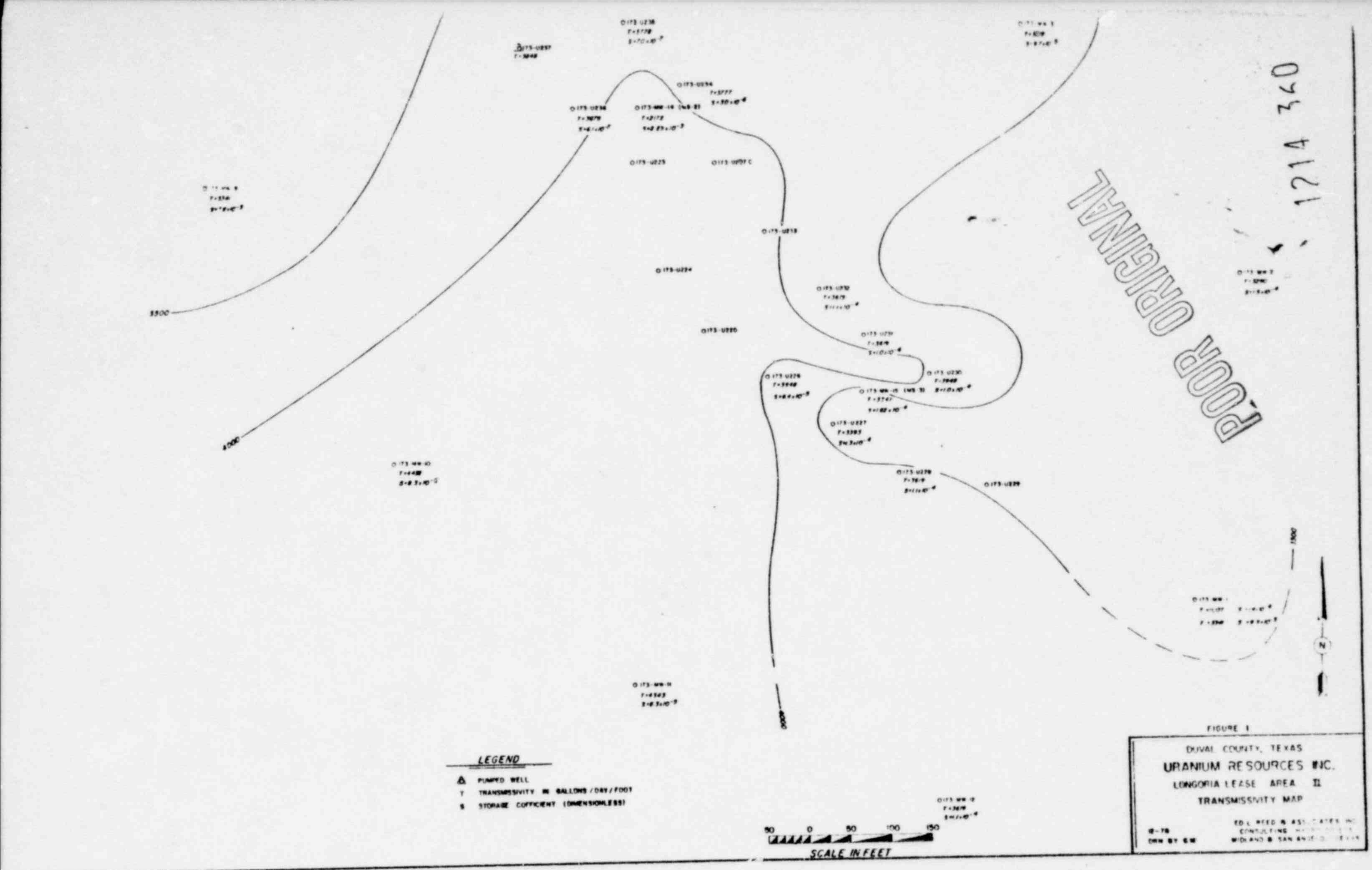
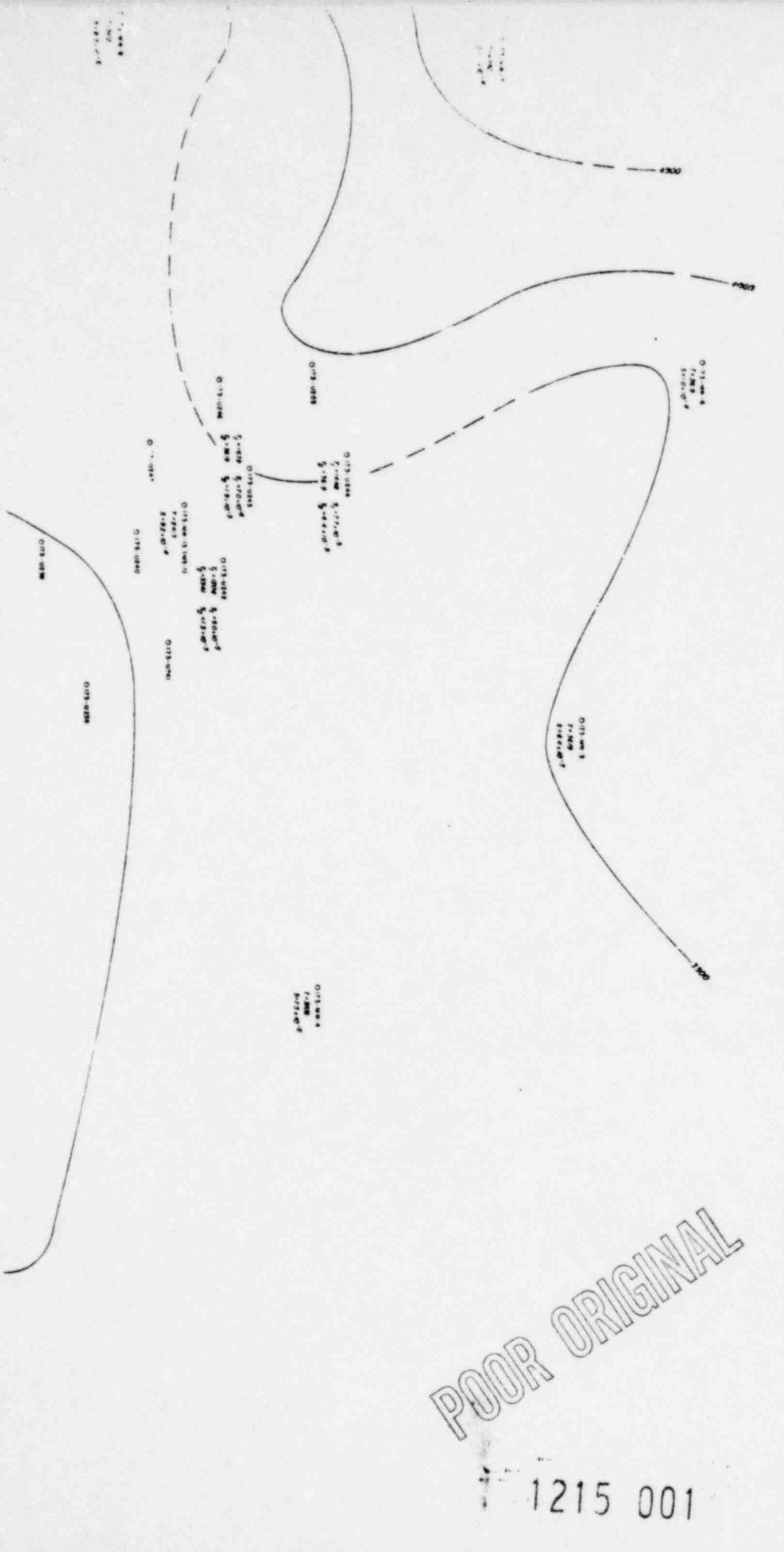
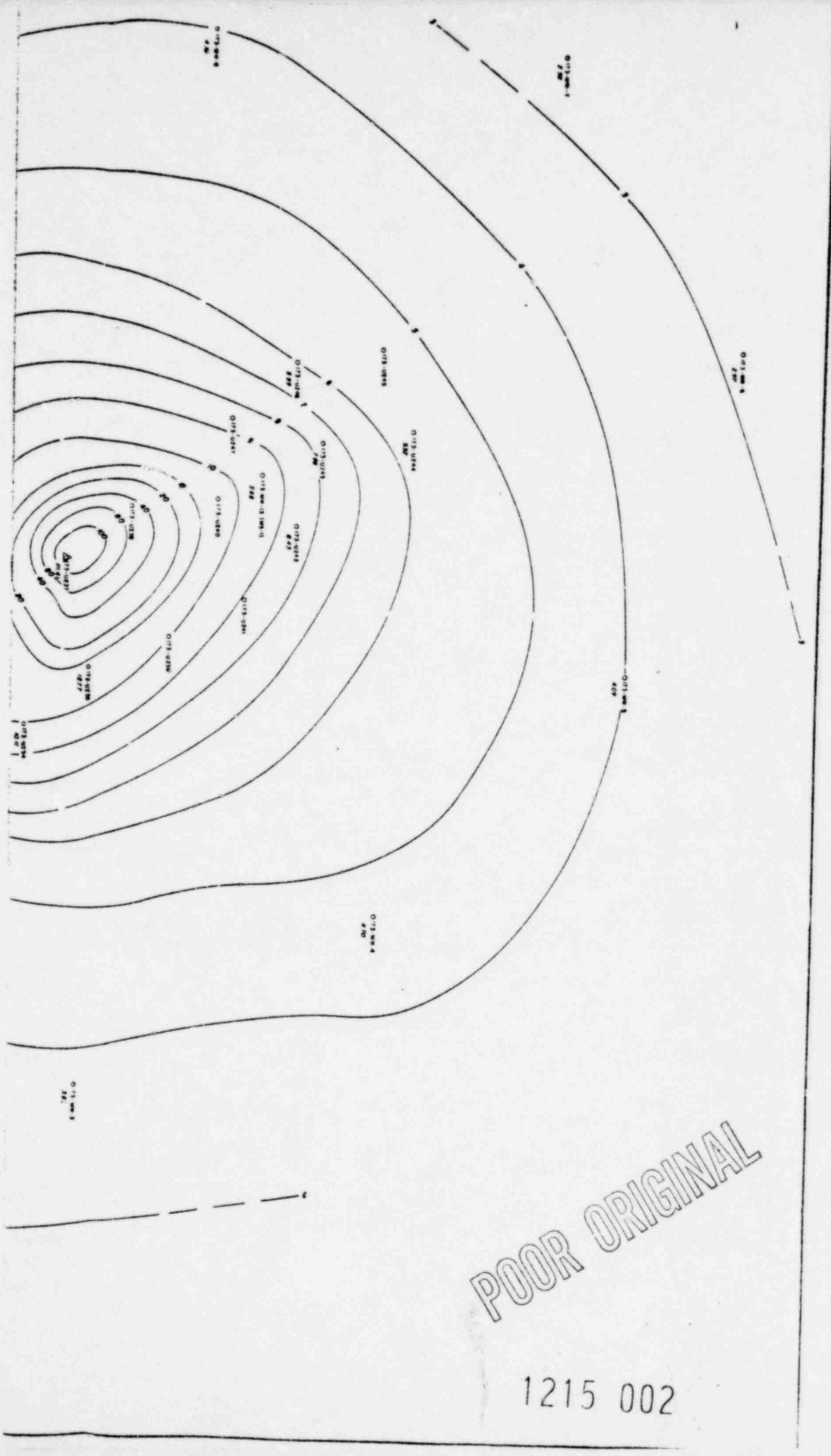

LEGEND
PUMPED WELL
T TRANSMISSIVITY IN GALLONS / DAY / FOOT
S STORAGE COEFFICIENT (DIMENSIONLESS)
50 0 50 100 150
SCALE IN FEET
FIGURE 1
DUVAL COUNTY, TEXAS
URANIUM RESOURCES INC.
LONGORIA LEASE AREA II
TRANSMISSIVITY MAP
DRN BY GM
POOR ORIGINAL
1214 340

IMAGE EVALUATION TEST TARGET (MT-3)

6"

IMAGE EVALUATION
TEST TARGET (MT-3)





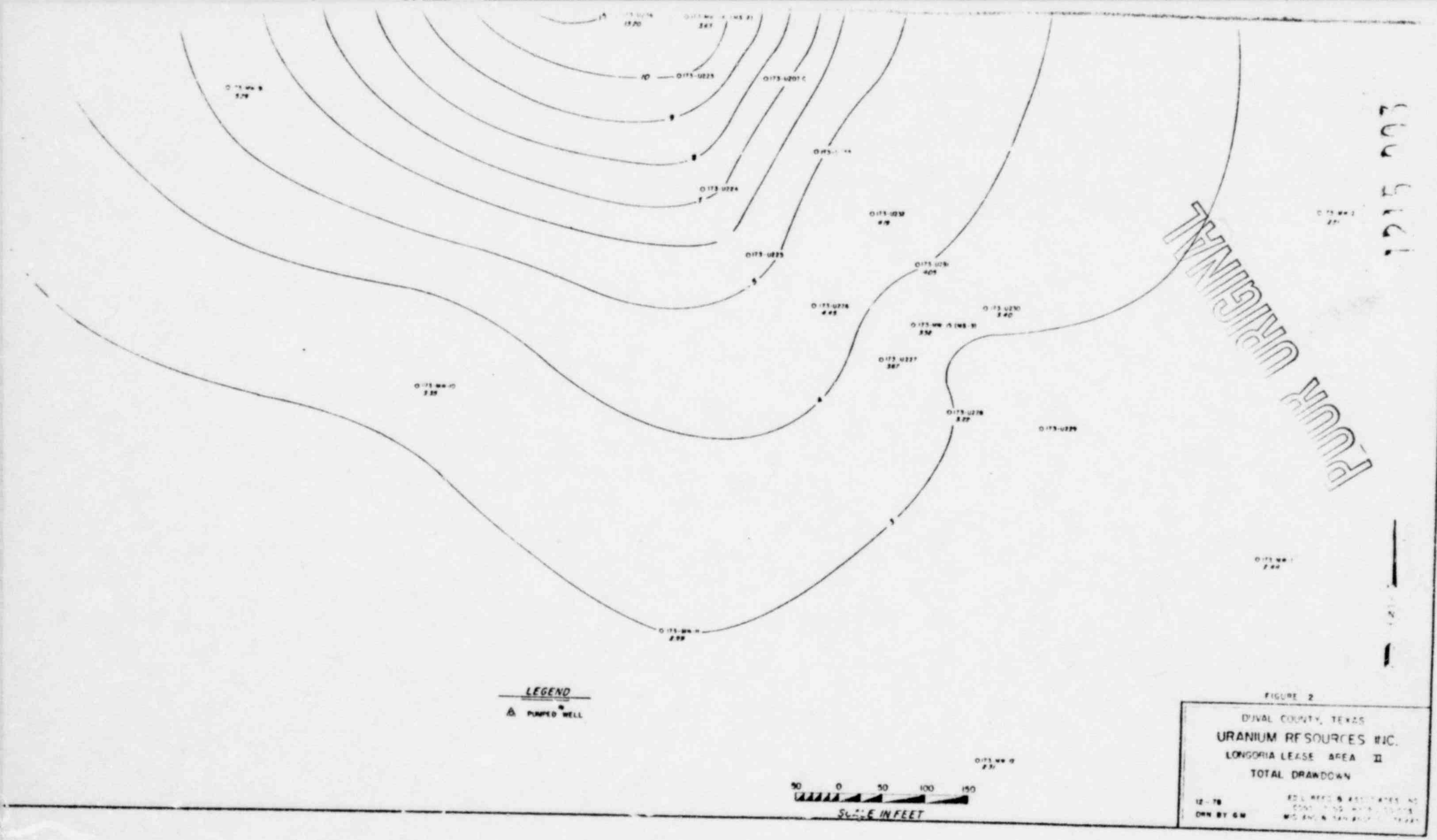
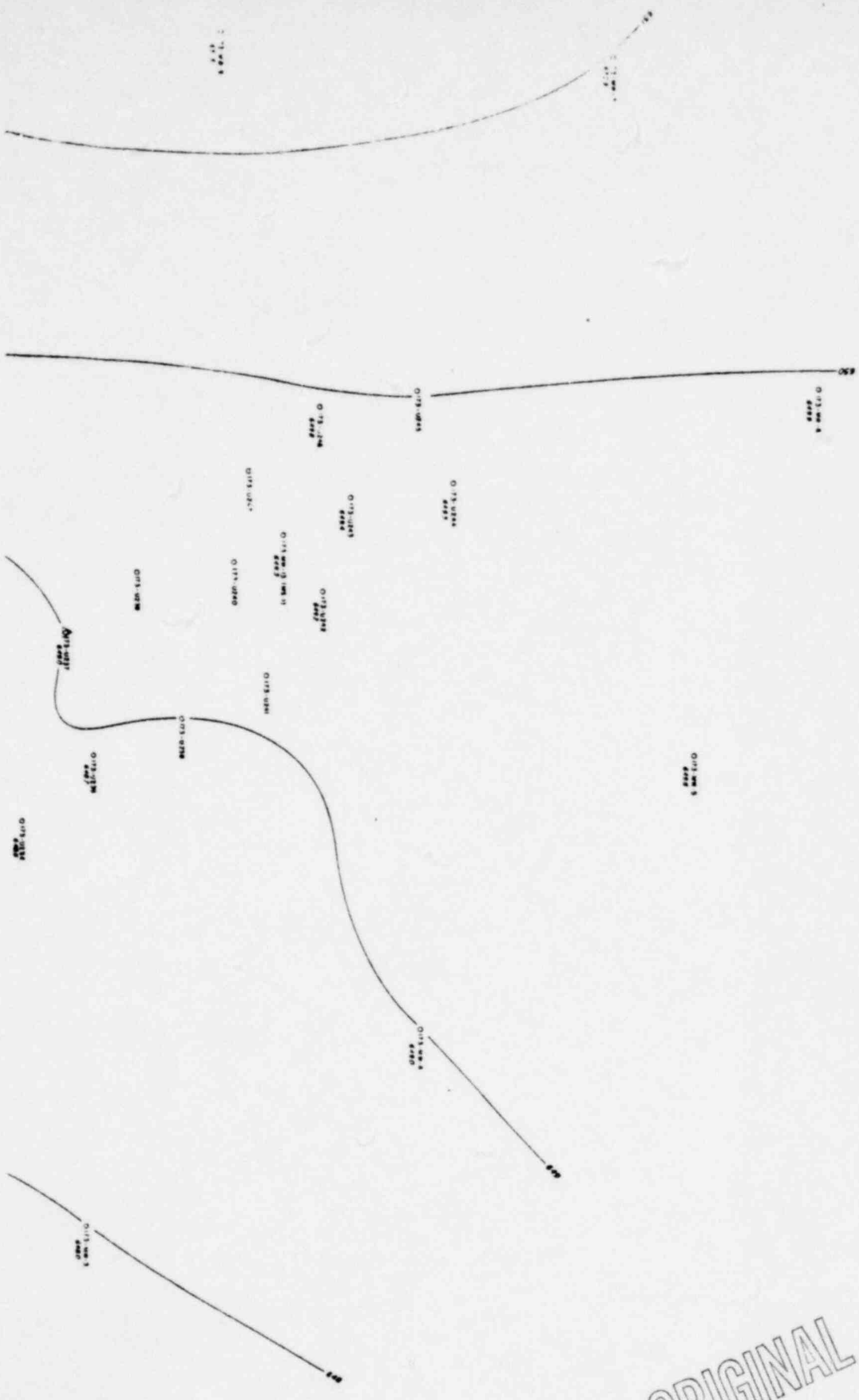


FIGURE 2

DUVAL COUNTY, TEXAS
URANIUM RESOURCES INC.
LONGORIA LEASE AREA II
TOTAL DRAWDOWN

12-78
DRN BY G M

1215 003



1215 004

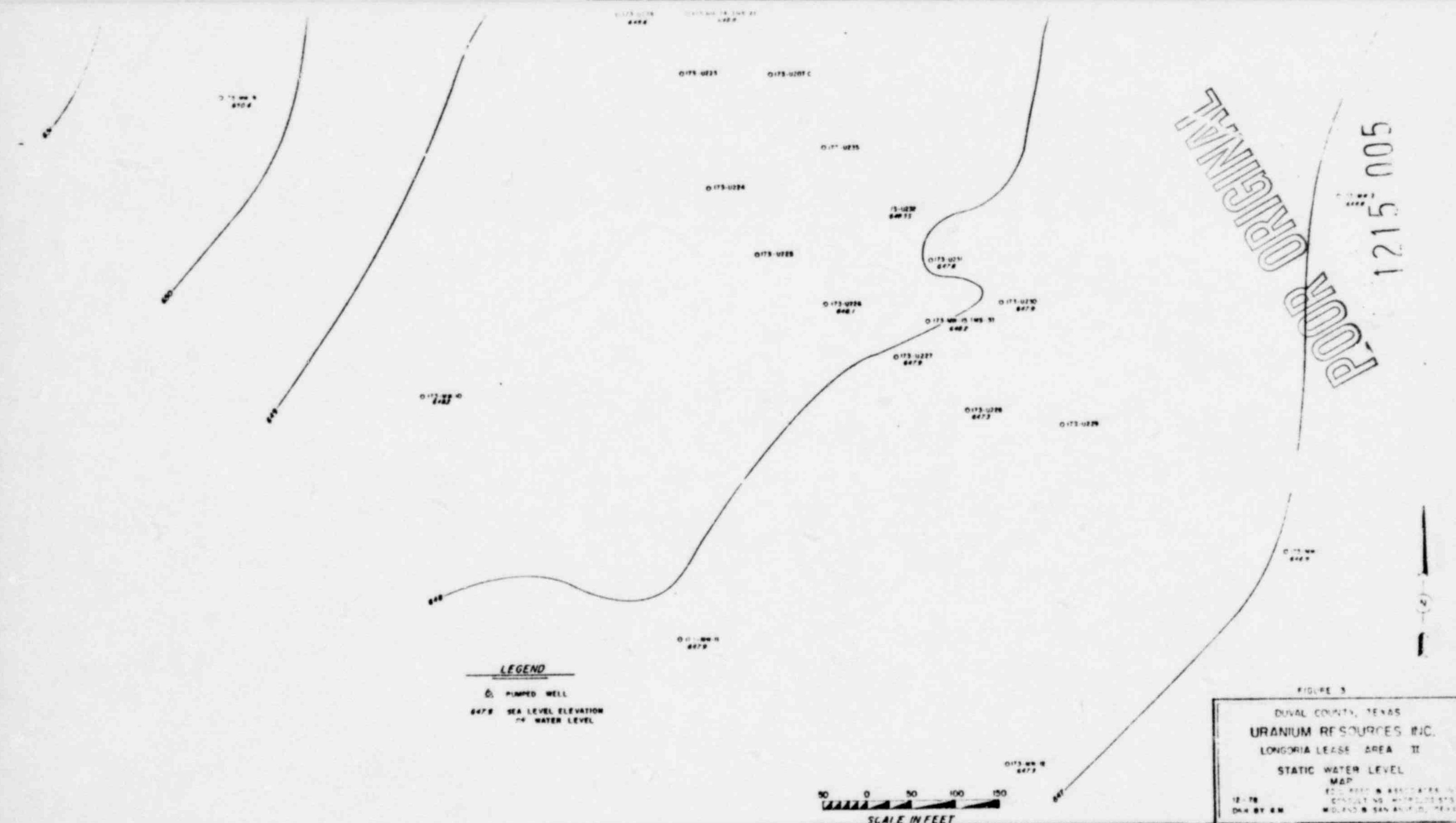


FIGURE 3

DUVAL COUNTY, TEXAS

URANIUM RESOURCES INC.

LONGORIA LEASE AREA II

STATIC WATER LEVEL MAP

POOR ORIGINAL

1215 005

TEXAS DEPARTMENT OF WATER RESOURCES
1700 N. Congress Avenue
Austin, Texas

SUBSURFACE WASTE DISPOSAL IN TEXAS

Agency Publication No. 72-05, prepared by the Texas Water Quality Board on Subsurface Waste Disposal in Texas, is out of print. The publication is currently under review and a revised edition will be published at a later date. Attached is a copy of a portion of the publication. Additional information concerning subsurface disposal can be obtained from the Geological Services Section of the Texas Department of Water Resources.

14311

Subsurface Waste Disposal in Texas

By Robert Hill

PURPOSE OF THE REPORT

This report on subsurface waste disposal is to inform the general public of the practice and nature of the method. It is designed to foster a better understanding of the discipline, and the role of the Texas Water Quality Board in protecting the quality of the water resources of the State, and to dispel fears of the public that are based on ignorance of the science. The report is also to be used as a general guide for persons considering or planning a subsurface waste disposal project.

INTRODUCTION

Subsurface or underground waste disposal, in the broad interpretation, is the placing of waste substances beneath the surface of the ground and includes sanitary landfills, septic tank lateral lines, injection wells and other methods. This paper discusses only subsurface disposal through injection wells which is the more common, although restricted, connotation of the term.

By means of a well, aqueous and gaseous fluids are injected into the subsurface strata. Solids other than those of minute size are usually not injected into the subsurface through a well. The receiving stratum usually is an aquifer containing highly mineralized water.

The year that disposal of liquid waste into subsurface strata began in Texas is not known. The first major and cooperative project began in the East Texas oil field in the year 1938. Salt water produced in conjunction with oil from the Woodbine Formation was returned to the lower part (i.e. downdip) of the formation with favorable results. Today millions of barrels of salt water are being returned to the formation from which the water originated.

In the early 1950's, the Railroad Commission of Texas began issuing permits for disposal of salt water into subsurface strata nonproductive of oil or gas. By this time, if not earlier, domestic waste was being disposed of in the subsurface. In 1961, the State Legislature adopted a Statute regulating injection of all wastes into the subsurface. By 1961, the use of this disposal method had become a common practice. The Statute was known as the Injection Well Act, and it required that any person seeking to dispose of waste into the subsurface must secure a permit from the Railroad Commission of Texas for all waste arising out of the production of oil and gas, and a permit from the Texas Board of Water Engineers for all other types of waste. The Act was amended in 1965 and again in 1969, resulting in transfer of the regulatory function of the Board of Engineers and its successors to the Texas Water Quality Board. In 1971, the 62nd Legislature in regular session passed the Texas Water Code which incorporated and revised the Injection Well Act. The Act became known as the Disposal Well Act and is now Chapter 22 of the Texas Water Code (Appendix). Should the waste to be injected contain radioactive materials, the applicant would have to obtain a license from the Texas State Department of Health in accordance with the Texas Radiation Control Act.

There has been an unusual amount of detrimental publicity on the use (or more appropriately misuse) of injection wells. This publicity has understandably concerned injection well failures. After all, a successful disposal well is seldom newsworthy.

Such publicity tends to alarm the public. Generally, the uninformed person has two fears, namely, that the waste may be injected into freshwater-bearing strata, or that the waste will migrate into these strata, and that the injection operation may cause earthquakes or a similar castastrophe.

The primary purpose of the Disposal Well Act is to protect the quality of the State's water resources and to protect the rights of the public. The Texas Water Quality Board and the Railroad Commission of Texas are charged with responsibility for administering the Act. As detailed later in this report, the Texas Water Quality Board staff has the function of reviewing an injection well application, conducting investigations and making recommendations to the Board for approval or refusal of the issuance of a waste control order, and the staff has responsibility of monitoring the disposal well operation after an order is granted.

If injection of waste is confined to suitable reservoirs, the well is properly designed and operated, and injection pressures are maintained below certain limits, there should be no hazards of earthquakes or spectacular well failures.

There have been 105 permits or waste control orders granted by the Texas Water Quality Board and its predecessors, and subsequently, 14 have been cancelled. About 350 million barrels of combined municipal and industrial waste is being injected annually in Texas.

GEOHYDROLOGY

A knowledge of the subsurface geology is the most essential aspect of a proposed subsurface disposal project. Suitable reservoirs must be available before a disposal operation can be given serious consideration.

The stratigraphy, structure, and occurrence of groundwater in an area has to be determined and evaluated prior to the use of an injection well.

Stratigraphy

Most of the rocks exposed at the surface in Texas are of sedimentary origin. These sedimentary rocks often extend several thousand feet beneath the land surface. They were deposited in stratified layers, and are generally composed of sand, silt, clay, shale, gravel, and limestone.

The ages of the rock units composing disposal zones utilized in Texas range in age from Permian to Quaternary. More wells utilize strata of the Miocene Series for waste injection than any other age because a preponderance of the chemical and petrochemical industries are located in areas of Miocene sediments that constitute excellent waste storage reservoirs. The majority of the disposal operations are into sand strata; however, limestone, dolomite and salt-dome caprocks are utilized. No waste disposal permit has been issued for the utilization of fractured shale nor igneous or metamorphic rocks in this State.

Hundreds of thousands of oil and gas exploratory tests have been drilled in Texas during the last 70 years. From this activity of the petroleum industry, an abundance of information is available concerning subsurface geology. Electrical logs, in particular, have furnished sufficient data for detailed mapping of the subsurface geology. Figure 1 is a generalized map of Texas indicating the suitability of the subsurface strata for disposal.

Structure

The structural geology or tectonic framework of an area is always important. Areas that exhibit high structural deformation are generally to be avoided for disposal operations. Also, highly faulted areas, particularly where the strata is composed of consolidated rocks, are not suitable for safe injection. Piercement-type salt domes, which cause considerable deformation, must receive a thorough evaluation prior to their utilization for subsurface disposal.

The stru[illegible]s most favorable for subsurface disposal are gently dipping monoclines, basins, and shelves or platforms. These structural types are the dominant geologic features in Texas.

<u>Groundwater</u>

The primary purpose of the Disposal Well Act is to protect both ground and surface fresh water from contamination. The occurrence and quality of groundwater in the State is fairly well known at this time. The groundwater availability programs of the Texas Water Development Board and the United States Geological Survey have resulted in numerous publications on the occurrence of usable-quality water in the shallow aquifers throughout the State. Also, a significant contribution by the petroleum industry and related service companies have been the publications on subsurface geology and resistivity of formation waters. Various types of electrical log surveys, of which hundreds of thousands have been conducted on exploratory wells in Texas, allow for reliable calculations of water quality.

Classification of water generally depends upon its use; however, a literature survey indicates a lack of uniformity in the definitions. For purpose of this report, groundwater is divided into three categories based upon mineralization, as follows:

Fresh water - water containing a total dissolved mineral concentration of 3,000 parts per million or less. This type of water usually, although not always, can be consumed by humans if aseptic and the mineralization is by natural occurring salts.

Potentially beneficial water - water containing a total dissolved mineral concentration between 3,000 and 10,000 parts per million. This type of water can be used for irrigation and stock watering under certain conditions, and is potentially useful for desaltination purposes.

Saline or salt water - water containing a total dissolved mineral concentration greater than 10,000 parts per million.

Texans are very dependent upon groundwater as a source of water supply. With the increase in population and productivity demands, the usage of groundwater is on the increase. Groundwater of usable quality commonly occurs throughout the State, with the notable exception being Northcentral Texas. Here rocks of the Permian and Pennsylvanian Systems seldom are freshwater-bearing. The depths from which groundwater is produced in Texas ranges from a few feet in alluvial deposits up to several thousand feet in Gulf Coast aquifers.

RESERVOIR CHARACTERISTICS

Physical characteristics of a reservoir that must be considered in determining the suitability of the strata for disposal are porosity, permeability, and volume. The chemi-physical aspect to consider in injection is the compatibility of the receiving stratum and its natural fluid with the wastewater.

Porosity

Porosity is the percentage of void space not occupied by the rock matrix. It may be intergranular, solution channels, fractures, etc. If a reservoir has a low porosity percentage, it is not a likely candidate for receiving waste. Porosities of the reservoirs presently receiving waste in Texas may range from a low of 10 percent to as much as 35 percent. In the Gulf Coast province, porosities of 30 to 35 percent are very common; in West Texas, the Panhandle, and East Texas, a few suitable reservoirs have porosities ranging from 20 to 30 percent. In North Texas, suitable reservoirs have porosities in the range of 10 to 22 percent. There are reservoirs that may be suitable for disposal in all areas that do not fall in the above ranges of porosity.

Permeability

Permeability is a measure of the formation's capacity to transmit a liquid or fluid. All substances have permeability, although in the case of granite or cement it may be so low as to be difficult to measure under a normal pressure differental.

A reservoir considered for injection must have sufficient permeability to allow the fluid to penetrate into the void spaces (porosity) without the need for undue pressure. Compacted clays, commonly described as impermeable or impervious, usually have low coefficients of permeability. Waste can be injected into clays (or shales) only at an extremely slow rate, thus clays are not suitable for waste disposal. By contrast sands, gravels, and vugular or fractured limestones may have high permeabilities and are usually given consideration as disposal reservoirs.

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Permeability may be measured in many different units such as darcys, Meinzer units, etc. The darcy is equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having an area cross-section of one square centimeter and length of one centimeter. The Meinzer unit of the coefficient of permeability, P, is the rate of flow of water in gallons per day through a cross-sectional area of one square foot under a hydraulic gradient of 1 foot per foot at 60°F. The Meinzer unit is usually used in hydrology, but other coefficients are also in common usage.

Theis[1] introduced the term coefficient of transmissibility, T, in 1935 and it is expressed as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide and extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. Thus the term coefficient of transmissibility is applied to an aquifer by multiplying the coefficient of permeability by the thickness, in feet, of the aquifer. Within the last few years, the term "transmissibility" has been changed to "transmissivity".

Volume

The thickness and areal development of a potential disposal reservoir are extremely important, for these are the parameters that determine not only

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[1] Theis, C.V., 1935, "Relation Between the Lowering of the Piezometric Surface and The Rate and Duration of Discharge of a Well Using Ground Water Storage", American Geophysical Union Trans., pt. 2, pp. 519-524.

the total pore volume of the reservoir, but also the volume of the fluid that is available for compression. This latter factor will be discussed under the heading of Hydraulics of Injection. For most injection operations, the reservoir should be large enough to be considered as having infinite lateral boundaries. If a reservoir has finite and known boundaries, it may also be suitable for a calculable amount of waste disposal.

Compatibility

Fluids that are injected into the subsurfaces have to be compatible with the rock matrix and the formation water. Compatibility tests are conducted by the applicant to assure that the injection operation will be successful. Some problems encountered are:

1) Acidic waste reacting with the carbonate material of the receiving stratum and causing a precipitate.
2) Alkaline waste reacting with the clay of the stratum and causing swelling of the clay.

Most compatibility tests are carried out in the laboratory prior to drilling a well; however, many tests can only be approximated prior to an actual injectivity test. Compatibility problems that arise after the well is drilled usually can be corrected by additional treating (i.e. filtering, pH adjustment, etc.) or by the injection of a buffer fluid to maintain separation of the waste and the formation water. If the waste is not compatible with the formation water, a buffer zone of compatible fluid sometimes can be injected ahead of the wastewater to prevent contact of the formation water and the noncompatible waste.

HYDRAULICS OF INJECTION

Radial Dispersion

Where the porosity, permeability and thickness are uniform in a horizontal stratum, the distribution of injected wastewater will be in a radial direction. Dip of the receiving bed which influences the pressure gradient can often be ignored when calculating the effluent distribution, if the dip of the beds is of a low order. Assuming uniformity in a bed that is receiving a fluid, the radial distance of distribution can be calculated by the formula.

$$r = \sqrt{\frac{Q}{\pi h \phi}}$$

where:

Q = quantity of fluid in cubic feet per unit of time
ϕ = porosity of receiving formation
h = thickness of formation in feet

For illustration, assume an injection operation as follows:

500 gallons per minute
200 feet, sand thickness
30 percent porosity

Find radius of displacement after 20 years of injection.

SOLUTION:

500 gpm = 619,810,000 cu. ft. in 20 years

$$r = \sqrt{\frac{619,810,000}{3.1416\ (200)\ 0.30}} = 1,790 \text{ feet}$$

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As can be observed in this example, injection at a large rate for a score of years results in the fluid moving approximately 3/10 of a mile radially from the wellbore. Radial displacement cannot always be expected to be uniform in all directions.

The question is often asked, "What happens to the waste after injection ceases?" The waste will move in the downdip direction of the regional hydraulic gradient. The direction is usually, but not necessarily, the same as that of the regional dip of the strata. The rate of movement is determined by the gradient differential and the permeability of the receiving strata. Commonly, the natural rate of water movement in salt water aquifers ranges from 5 to 50 feet per year. To illustrate the distance of travel based on an average rate of 26 feet a year, the waste would move only one mile in two centuries.

Obviously, the waste cannot continue to move in a down gradient direction indefinitely. The waste, along with the formation water, will eventually move upward through the overlying sediments even though the sediments may be less permeable than the disposal reservoir. This movement through the overlying clay and shales ranges from .01 to 0.2 feet per year; therefore, it would take several millennia for the flow to reach the surface. There is some evidence that the compressed clays may act like membranes resulting in some infiltration of the wastewater as it migrates upward.

Pressure Increase

The pressure increase on the fluid of a formation is a significant part of the injection operation and should be evaluated in all subsurface disposal projects. To understand the effect of subsurface disposal upon an aquifer, a knowledge of certain functions is essential.

The hydrostatic pressure on the formation causes the fluid to rise in an open borehole. If the fluid level rises above the top of the formation, the fluid is under artesian conditions. The plane to which this water would rise if unconfined is known as the potentiometric surface.

Upon injecting liquid into a subsurface zone under artesian conditions, a cone of impression is developed on the potentiometric plane i.e., a rise of the potentiometric level around the well. Conversely, the withdrawal of liquid from an artesian aquifer causes a cone of depression to develop around the wellbore. A typical cone of impression is shown in Figure 2. It can be observed that any point on the potentiometric surface is correlative with the pressure of the fluid within the formation immediately below the point. Thus the pressure in the formation can be calculated by meauring the fluid level in a monitoring well, open to the formation, provided the specific gravity of the fluid is known. A cone of impression will occur on the water surface by injection into an aquifer under water table conditions. Injection or withdrawal increases or decreases the natural hydraulic gradient around the wellbore.

Stated briefly, storage coefficient is the volume of water that is released or taken into storage per unit surface area of an aquifer per unit change in the component of head, normal to that surface. Stated another way, it is the amount of water released or stored in an aquifer by compression or expansion of the water and the aquifer skeleton. The latter measurement is often referred to as the bulk modulus of compression or elasticity. The storage coefficient is a significant measurement in calculating yield or storage in an artesian aquifer.

Generalizing, the formula for the coefficient of storage is:

$$S = f w \phi m \left(a + \frac{B}{\phi}\right) \text{ (modified after Jacobs}^{2}\text{)}$$

where:

- f = weight of 1 cubic inch of formation water at stated temperature in pounds
- ϕ = porosity of aquifer
- m = thickness of saturated aquifer in inches
- B = bulk of modulus of compression or elasticity of aquifer skeleton
- a = bulk modulus of compression of aquifer water

The coefficient of storage of an aquifer can be determined from pumping tests in an aquifer, if there are one or more observations wells to measure the rise or fall of the potentiometric surface over a period of time, and provided the pumping rate is constant. The transmissivity can also be obtained by measuring the change in the water level under controlled conditions.

In lieu of conducting pumping or flow tests to determine the coefficient of storage, it can be calculated with a few assumptions. Given the aquifer thickness and areal distribution, with a knowledge of the area, an empirical if not an exact storage coefficient may be derived. This method is normally used where a monitor well would be impractical.

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[2]Jacobs, C.E., 1950, "Flow of Ground Water", Chapter 5 in Rouse, Hunter, Engineering Hydraulics: John Wiley & Sons

A great store of information is available, much of it from the petroleum industry, on the porosity and permeability of the formations and the resistivity of the formation water. The information is obtained from sonic logs, core analysis, direct measurements, published data, etc. From this type of readily available information, the parameters of most formations in Texas can be determined with good accuracy.

To illustrate the derivation of the coefficient of storage, a typical Gulf Coast Frio sand is utilized:

Sand thickness	200 feet	(From various types of logs)
Formation water	1.068 sp. gr.	(From published information or calculations of water resistivity from logs)
Porosity	30 percent	(Very common for clean sands)
Water Compressibility	3.3×10^{-6} lb/in^2	(Standard for water at 60°F.)
Rock Compressibility	3.6×10^{-6} lb/in^2	(See discussion)

$$S = 0.039\ (0.30)\ 2400\ \left(3.3 \times 10^{-6} + \frac{3.6 \times 10^{-6}}{0.30}\right) =$$

$$4.24 \times 10^{-4}\ \text{lb/in}^2$$

Generally, water is considered as a noncompressible fluid; however, water is slightly compressible. Average compressibility of groundwater is 3.3×10^{-6} lb/in^2 at 60°F. Although higher temperatures are encountered at the usual subsurface depths of disposal, this increase can be largely ignored in this type problem because of the very small change that would occur.

When fluids are injected into the subsurface, displacement and compression occur with a resulting pressure increase with the formation. As pointed out in the preceding section, the size of the receiving reservoir is important to disposal operations. The distribution of a liquid injected into a formation is controlled by the thickness, porosity, permeability and coefficient of compressibility or storage coefficient.

The vertical compressibility of the aquifer skeleton is influenced by the weight of overburden; hence the depth, the lithology and the consolidation of the sediments are all important factors. The average range for matrix compressibility is from 2×10^{-6} to 2×10^{-5} lbs/in^2 or one magnitude for porous sedimentary rocks at average disposal depths in Texas. The selection of the matrix compressibility measurement for solution of the formula is one of empirical judgment based on published data relative to formation pressure, depth, etc. It is acknowledged that there is a certain amount of error in choosing this value, but it has small to negligible influence in the formula except in cases of extremely thin aquifers.

Nonequilibrium method

There are several methods and formulas utilized for computing injection pressures, reservoir yield, etc. Since we are aware that there is a rise in the potentiometric surface with injection at certain radii from the well within the influence of the cone of impression, a formula is needed that includes this concept of change with injection. Such a formula is utilized in the nonequilibrium method.

In 1935, Dr. C.V. Theis[1] derived the nonequilibrium formula from the analogy between the hydraulic conditions in an aquifer and the thermal conductions in similar thermal systems. In essence the method presents a means for calculating the water level changes that occur when water is being discharged from an aquifer. The method is based on the following assumptions:

1) the aquifer is homogeneous and isotropic
2) the aquifer is of infinite areal extent and constant thickness
3) the discharging well has a small diameter and completely penetrates the aquifer
4) water taken from storage in the aquifer is discharged instantaneously with the decline in head

An aquifer that would fit this idealized situation does not exist in nature; however, these theoretical restrictions do not preclude the use of the method where an aquifer approaches these parameters. Thousands of water well aquifer tests have proven the method to be reliable although not exact. For a detailed discussion of the method and original formula, refer to Theis' paper. The formula as modified by Wenzel[3] to simplify the calculation is:

$$\Delta s = \frac{114.6\ Q}{T}\ W(\mu)$$

Δs is the change of head in feet of the potentiometric surface or water table.

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[1]Theis (1935)

[3]Wenzel, L.K., 1942, "Methods for Determining Permeability of Water Bearing Materials, etc.", U.S. Geol. Surv. Water Supply Paper 887

Q = quantity in gallons per minute
T = transmissivity

The value of $W(\mu)$ is obtained by integration from Theis' formula; however, Wenzel tabulated the values of $W(\mu)$ for corresponding values of μ which simplifies the calculations. (For copy of the tables, refer to Wenzel's paper or other publications of the chart.)

The formula for obtaining μ is:

$$\mu = 1.87\ r^2\ S/Tt$$

where:

r = radius from injection well, in feet
S = coefficient of storage
t = time, in days

Although the method was developed through discharging wells, the same method can be applied to wells receiving fluids. Like all formulas, it can be used to determine any parameter. If the transmissivity and the coefficient of storage are known, the water level rise or fall (pressure change) may be computed for any point on the cone of depression or impression. If the formation pressure change is known, the transmissivity and storage coefficients can be determined assuming the lithologic boundaries are also known. The former method is most often used for predicting pressure buildup in an injection well operation because of the general lack of monitoring wells to conduct actual measurements.

Now that transmissivity, coefficient of storage, and the nonequilibrium formula have been discussed, a typical case will be taken to illustrate the solving for the potentiometric or water level change (Δs).

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A well is used for injection of 300 gallons per minute of waste in an areally extensive sand with a thickness of 200 feet, at a depth of 5,000 feet. The average porosity of the sand has been determined to be 30 percent and average permeability to be 0.5 darcy (laboratory) as in the previous example. Assume the sand to be uniform and 100 percent saturated with saline water. What will be the rise, in 10 years, on the potentiometric surface at a distance of 10,000 feet from the well if the waste has the same density as in the previous example?

The permeability, K, in darcys can be converted into Meinzer units where the viscosity of the fluid at formation temperature is determined. For purpose of the example, the assumed conversion factor will be 20.5 or approximately that of water at 68°F. Therefore, T = 0.5 x 20.5 x 200 = 2,050 (or rounded off = 2,000).

$$S = 4.28 \times 10^{-4} \text{ (from previous example)}$$

therefore:

$$u\ 10\ yr. = \frac{1.87\ (10{,}000)^2\ 4.28 \times 10^{-4}}{2{,}000 \times 3{,}650}$$

$$= 1.10 \times 10^{-2}$$

$$W(u) = 1.74 \text{ (from Wenzel's tabulations)}$$

$$\Delta s = 114.6 \left(\frac{300}{2000}\right) 1.74$$

$$= 29.8 \text{ feet}$$

This amounts to an increase of 13 pounds per square inch at a distance of 10,000 feet or 0.0026 pounds per foot of depth. From the example, it can be observed that the nonequilibrium method has many advantages over other methods in computing water level drawdown or buildup in artesian aquifers. It is, of course, important to determine or assume relatively correct values for transmissivity and storage.

The method has been purposely simplified for clarity in explanation, thus critics probably will question why such items as dissolved gases in disposal zones, permeability differences between fresh water and mineralized wastewater, temperature of injected fluid, effect of pressure on fluid compressibility, etc. have been ignored. Where these measurements are known and could be important, they are taken into consideration and utilized in the formula. However, they often can be ignored because of their insignificant effect on the total pressure change. It is not uncommon to find the total result of ignoring these minor corrections is to create a small safety factor (i.e. the pressure buildup may be overestimated). In summary, the three most important parameters, where reliable data is needed, are permeability, porosity, and thickness of an infinite aquifer.

The nonequilibrium method is based on the assumption that the hydraulic system does not reach a state of equilibrium. However, with long distances from the well and/or extended time periods, the nonequilibrium method approaches that of a hydraulic system in equilibrium. The nonequilibrium method is an excellent method for overall accuracy in computing expected pressure increases.

APPLICATION FOR SUBSURFACE WASTE CONTROL ORDER

An application to the Texas Water Quality Board for a subsurface waste control order must be on forms supplied by the Agency and accompanied by a $25.00 fee (see Appendix: Disposal Well Act). The application must include data on treatability studies conducted on alternate methods of waste disposal. The studies should indicate that the proposed subsurface disposal has less impact on the environment than the alternate methods.

A technical report on the proposed operation is required before the application can be processed (Figure 3). This comprehensive report includes such items as composition of the waste, data on well construction, geology of area, etc.

The Act does not require a public hearing on the application, but the Texas Water Quality Board, in adopting rules and regulations for administering the Act, deemed it in the public interest and made a public hearing mandatory for all applications. Notice of the public hearing must be published in a local newspaper of general distribution, by the applicant, at least 20 days prior to the date of the hearing. The purpose of the public hearing is to inform the public of the proposed operation and allow opportunity for comment on the project.

The technical staff of the Board reviews the submitted report on the proposed operation and the data developed in the public hearing. Included in the evaluation are: the determination of the regional structural geology and the lithology of the receiving stratum, the influence of the waste dispersion, pressure increase of the disposal zone, the presence of potential hazards to groundwater quality, producing oil and gas wells, etc. and proper well construction.

Upon completion of the review, the staff prepares a technical report for the Executive Director of the Board that includes staff recommendations on the application.

A waste control order may be granted by the Executive Director, or the Board, when it is determined that both groundwater and surface waters will be protected from pollution. The waste control order will contain provisions and requirements to assure proper monitoring and operation of the disposal well. The staff observes certain aspects of the drilling and completion of the disposal well, and monitors the disposal operation.

The holder of the waste control order is required to submit periodic reports on the injection operation. The holder must fulfill all provisions of the waste control order, and the Board may cancel the order for noncompliance or other good cause. The Act provides for a penalty fine not to exceed $1,000 for each day of noncompliance with provisions of the Act or waste control order.

INJECTION WELL DESIGN

The type of construction for injection wells is quite variable because of the different compositions and volumes of waste injected. The Board has not adopted standards on well construction, but prefers to consider each proposal on an individual basis. The construction of the well must be such that the potentially usable-quality water resources are adequately protected and the injected fluid is confined to the permitted disposal zone. A typical well would be completed as shown in Figure 4. The surface casing is set from the surface to a depth below strata containing potentially beneficial water, and then cemented back to the surface by the pump and plug method. The long string casing or protection casing is set from the surface to either the top or through the entire disposal zone. This casing is usually cemented to the surface by circulating cement from total depth, or by cementing the upper

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part by circulating through a multiple-stage cementing tool installed in the casing below the base of fresh water strata. The casing is pressure tested to assure that there are no leaks.

Two strings of cemented casing placed through the fresh water zone gives added strength to the casing and extra protection to the fresh water resources. The protection casing is usually made of carbon steel, but may be of a special alloy that is not affected by the corrosive nature of the waste.

Injection of waste as shown in Figure 4 is confined to the tubing, set or sealed in a packer. The injection tubing is made of a material that will not be affected by the injected waste. Materials commonly used in the construction of the tubing are carbon steel, internally plastic coated steel, fiberglass, and stainless steel. Screens, if utilized, are usually made of stainless steel.

The materials used in the well construction must be new and meet either American Petroleum Institute, American Society for Testing and Materials, or comparable nationally recognized standards.

The Agency usually requires that a pressure gauge be installed on the wellhead for monitoring the pressure on the annulus between the injection tubing and the protection casing. Should a leak occur in the tubing or the packer seat, a pressure increase on the annulus during injection would be indicated by the gauge, and remedial action can be initiated to correct the malfunction. A gauge on the injection tubing is also required to monitor the surface injection pressure.

Common methods of oil field construction and completion are utilized in the disposal wells. The specific method used in well design and construction depends more on past experience of the consulting engineer or geologist than on any trends or practice in an area. Stimulation of the disposal zone by acid and surging is common, and seems to be necessary in many instances. In fact, many wells are "acidized" each time the injection pressure increases significantly above the expected norm.

ABANDONING AND PLUGGING OF INJECTION WELLS

A well that is abandoned after use as an injection well must be plugged with cement in conformity with Board policy. The procedure for plugging the well involves approval of the proposed plugging operation by the Board prior to the permittee undertaking the operation. The purpose of plugging the well is to confine the disposed waste to the injection zone and to prevent future clandestine disposal.

Obviously, a standard method of well plugging cannot be adopted because of the different types of well construction utilized. Nevertheless, certain guidelines encompassing minimum criteria have been formulated. Basically, three cement plugs should be placed in each well previously used for disposal. First, a plug should be placed across the injection zone to seal it and prevent backflow. A second plug should be placed across the base of the surface casing to extend above and below the casing shoe approximately 50 feet. This plug affords protection from upward flow of fluid from any lower zone into the casing opposite the usable quality water zone. If the protection string casing has been cemented to the surface during installation, then this plug should be placed in the protection string casing at the same place as above to give added protection from upward movement of fluid in the event of casing collapse at a lower depth. In the event the protection string has not been cemented to the surface (i.e.

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an older well where cement did not reach the surface), that portion uncemented should be removed from the well prior to plugging. The third plug is placed in the top of the cased well and should extend 10 to 30 feet below the ground.

Other zones that must be sealed off by a cement plug are strata productive of oil and gas and any known high pressure salt water zones. An emergency procedure is utilized by the Board should a well be abandoned during the initial drilling and completion operations. Where a drilling rig is on location and can be used for plugging, the Board's staff can verbally approve a plugging procedure. This method would be utilized in the event drilling tools were lost in the well, similar problems encountered preventing further drilling, or the proposed injection stratum was unsatisfactory for disposal.

Upon completion of the plugging, a complete record of the operation is filed with the Board. A cementing affidavit from the service company that performed the cementing must accompany the plugging report.

CONCLUSION

The ultimate repository for all waste is either the atmosphere, the oceans, or the lithosphere. Wastes permanently disposed of in the atmosphere are limited to gases, although particulate matter is often discharged with the gaseous waste but of necessity must return to the surface.

The fate of the waste deposited in the oceans is generally unknown. However, we have become aware that some waste such as insecticides, lead, and mercury are entering the food chain and as such are polluting the food supply. The oceans have been utilized simply because their enormous volumes allow for dilution.

The advantages of underground disposal of waste are: (1) the fate of the waste is, in general, known and understood; (2) the waste is contained and can be isolated from man's food, water, air and activity; and (3) the waste can be recovered if the need arises.

The State of Texas realizes that there must be control over the disposition of waste in the subsurface. Accordingly, the Disposal Well Act was adopted to assure that these controls are forthcoming. The Texas Water Quality Board, in administering the Act, holds that disposal of waste in the subsurface is a practical and feasible method when properly designed and engineered. The Board also recognizes that, unlike stream disposal, subsurface disposal has volume limitations. Therefore, as technology of waste treatment advances, disposal of waste in the subsurface should be restricted to radioactive, and to refractory, and malodorous wastes.

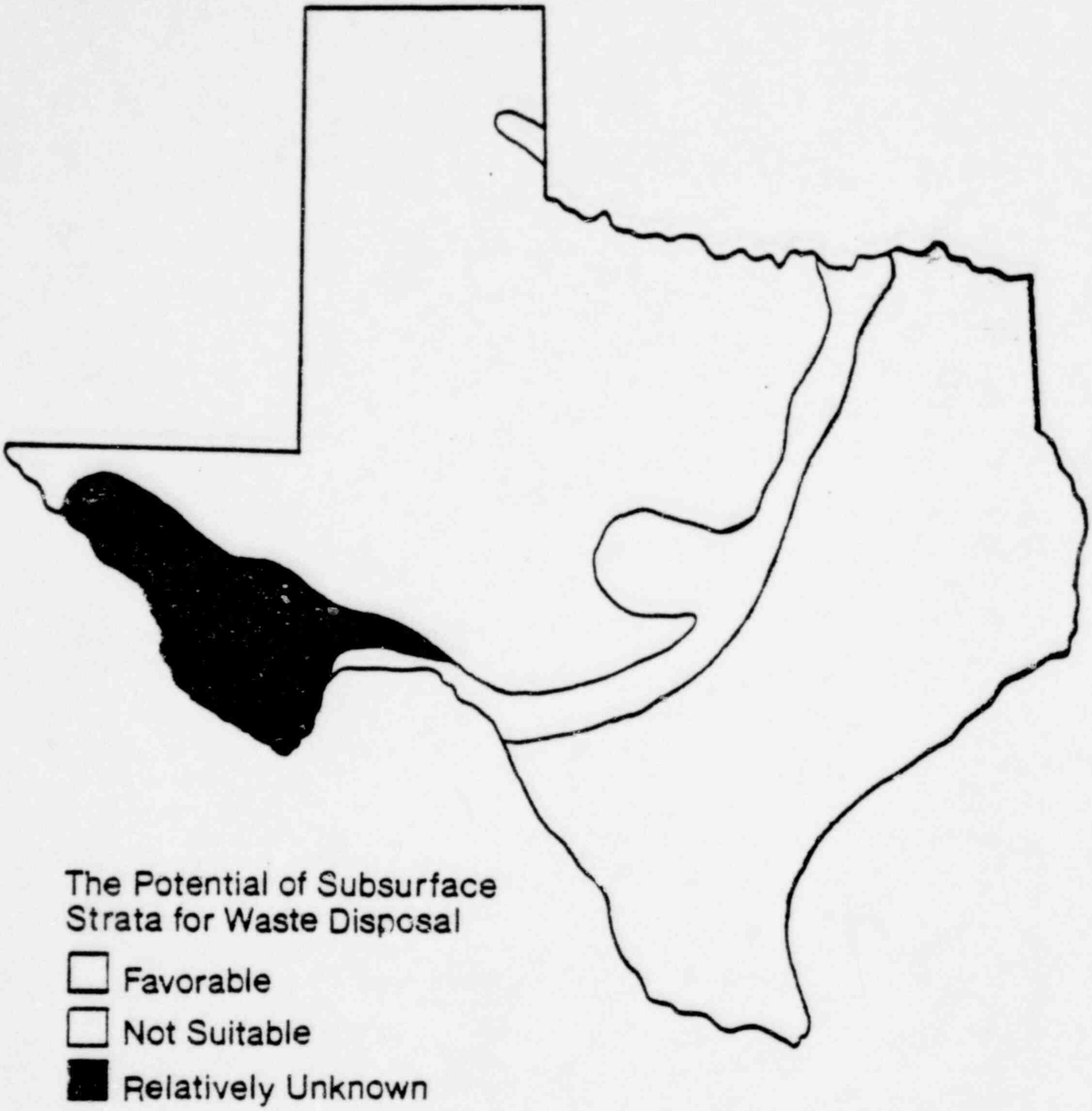
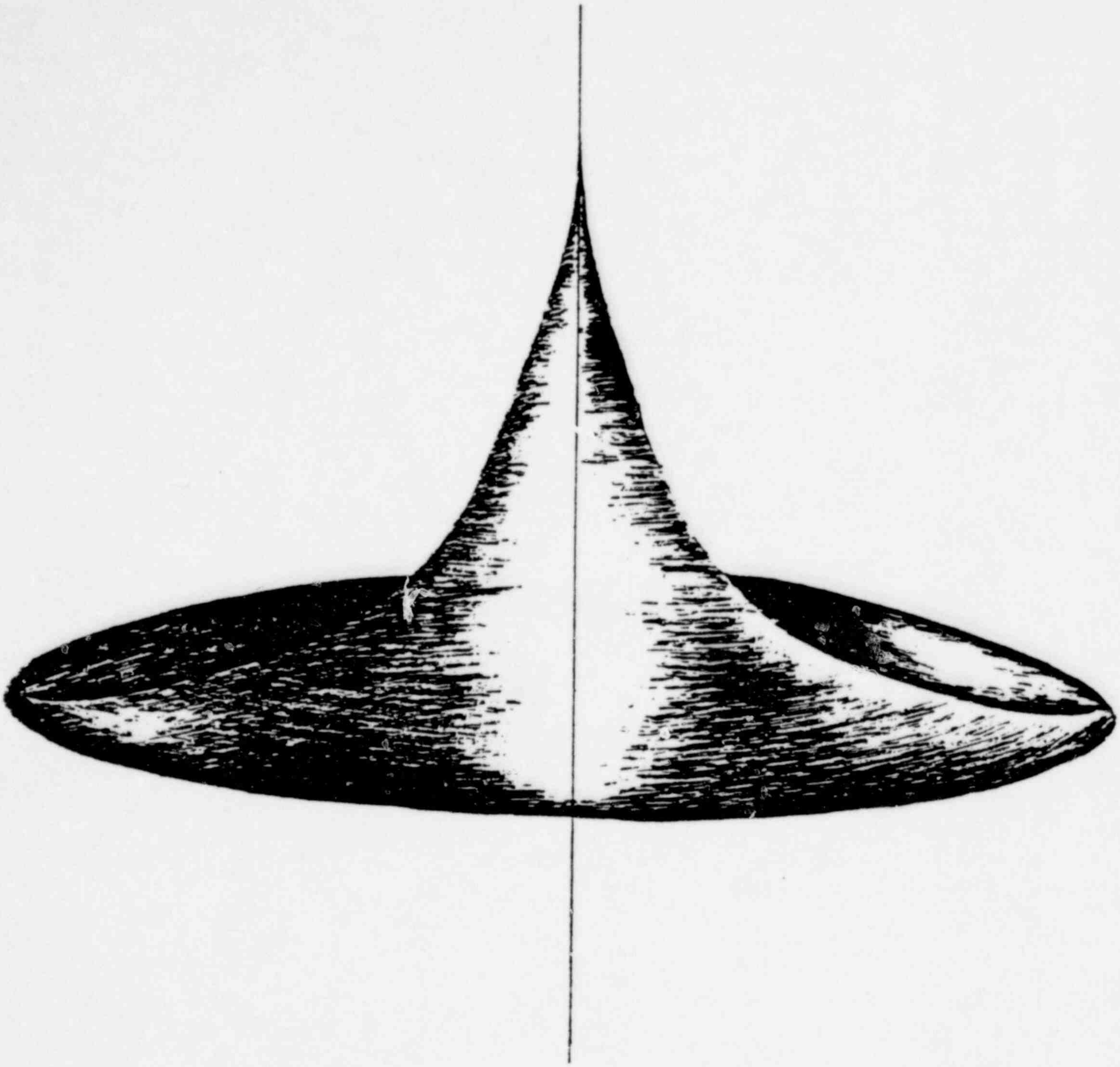

The Potential of Subsurface Strata for Waste Disposal
Favorable
Not Suitable
Relatively Unknown

Figure 1



Schematic Cone of Impression Around Wellbore

Figure 2

INSTRUCTIONS

1. Application form in quintuplicate, all accompanying data, and the required $25.00 filing fee shall be sent to the Texas Water Quality Board, P.O. Box 13246 Capitol Station, Austin, Texas 78711. The Board's staff is available for consultation should questions arise in completing the application.

2. Justification for subsurface disposal must accompany the application by submitting treatability studies of alternate methods of waste disposal. Explain in detail why each method is considered to be less satisfactory in terms of environmental protection than the proposed subsurface disposal method. Indicate whether this waste is presently being produced, and if so, what method is used in disposal. Briefly describe the manufacturing process(es) and product(s) from which waste will arise.

3. A technical report is required before an application can be processed. This report should include, but not necessarily be limited to the following information:

   a. An accurate plat showing location of proposed injection well relative to both state land survey and plant boundaries.

   b. A map indicating location and depth of water wells on and adjacent to plant property. This map or a supplementary map must show location of all artificial penetrations (oil and gas wells, exploratory tests, etc.) of the uppermost proposed injection interval(s) withn 2½ miles of the injection well site. (The technical staff may adjust this distance as the situation warrants.)

   c. Description of local topography and geology pertinent to injection program. Depth of deepest strata containing fresh water or water of suitable quality for potential beneficial development as determined by well development and or electrical logs.

   d. A detailed description of the chemical and physical characteristics of the waste to be injected. Complete chemical analyses of all inorganic constituents should be reported in ppm or mg l. If organic fractions are present, all such constituents should be reported in ppm or mg l. as individual percentages by weight, or in other appropriate terms. Give analysis of each waste stream and its percentage of total waste.

   e. The anticipated average and maximum rate of injection in gallons per minute. Estimated yearly volume of injected waste and anticipated life of project.

   f. Data on construction, completion and operation of proposed injection well.

      (1) Total depth

      (2) Casing—size, grade, type, weight and setting depth of all strings; size and type of tubing; name, model, and depth of tubing packer setting.

      (3) Cement—type and volume of cement to be used on each casing string and calculated top of cement behind each string. Describe and give percent of all cement additives.

      (4) Proposed injection interval(s) and perforations or screen setting depths. This should include the interval(s) to be utilized initially and the entire zone requested for future development.

      (5) Diagramatic sketch of proposed wells including the wellhead.

      (6) Anticipated maximum and average wellhead injection pressures.

      (7) Description of possible hydraulic fracturing and or acidizing programs, if anticipated.

      (8) Description of proposed injectivity tests.

      (9) Proposed logging, bottom-hole testing, coring, etc.

   g. Characteristics of injection interval(s):

      (1) Lithology, porosity, permeability, temperature.

      (2) Natural reservoir fluid pressure or hydrostatic head; fluid saturation and chemical characteristics; and fracture gradient or critical input pressure.

   h. Compatibility of injected waste and formation fluids.

   i. Calculated formation pressure increase by injected waste and directions of dispersion.

   j. Surface installations.

      (1) Detailed description of pretreatment process and facilities to be used (include flow diagram).

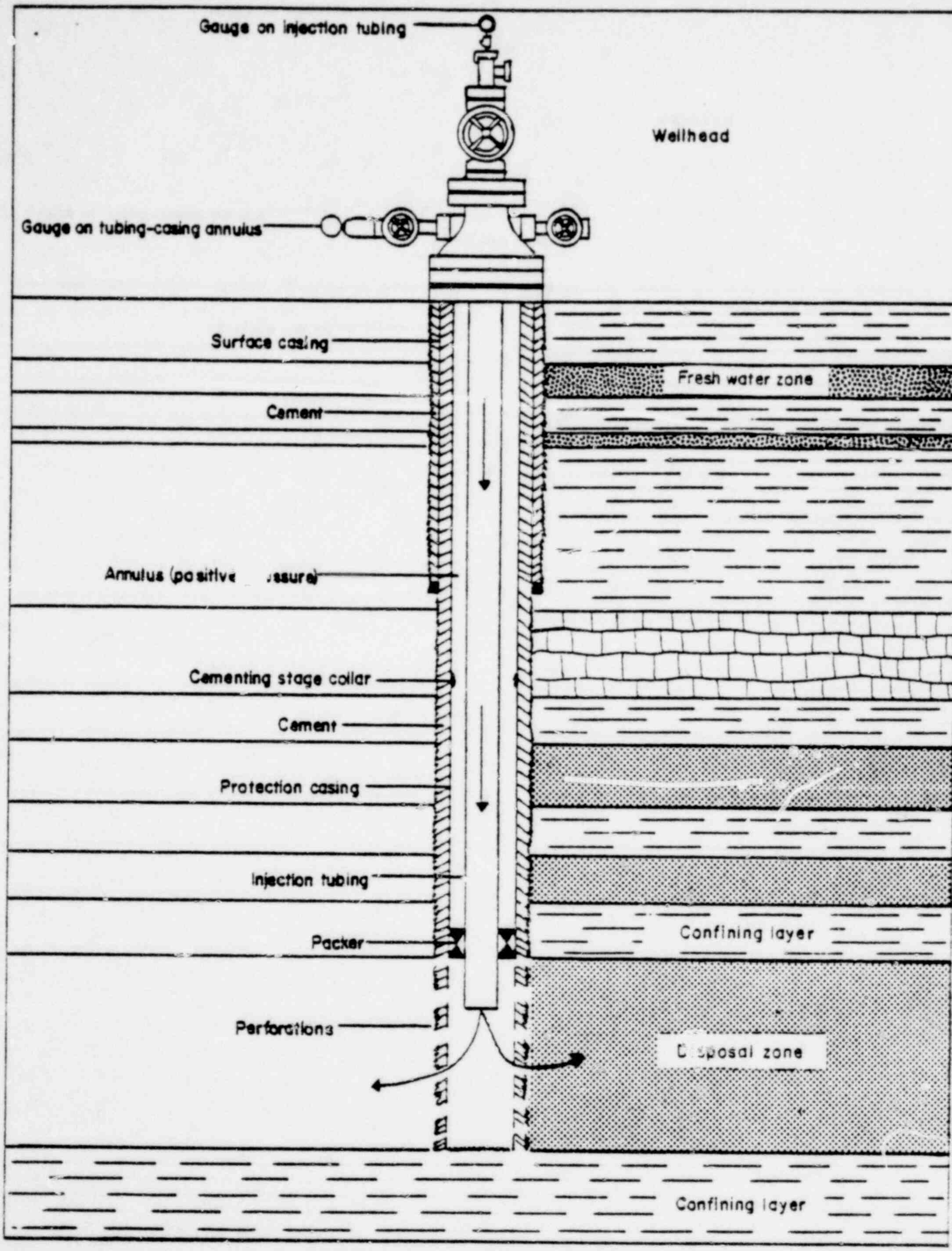
      (2) Description of type of materials to be used in pretreatment facilities and transmission lines.

      (3) Description and location of all waste retention facilities, if such are to be used in conjunction with the injection well.

4. In the event an existing well is to be converted to an injection well, applicant should submit a complete electrical log, all other logs or surveys performed on the well, and complete casing and cementing data.

5. Submit a list of adjacent landowners, their addresses, and a map indicating location of their property. (See Rules and Regulations, TWQB, Rule 305.1 (d))

Figure 3



Typical Industrial Waste Disposal Well

Figure 4

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TEXAS DEPARTMENT OF WATER RESOURCES

INSTRUCTIONS AND PROCEDURAL INFORMATION

For Filing an Application For a Permit To Dispose of Waste by Well Injection

PART ONE
GENERAL INSTRUCTIONS

1. No person may begin drilling a disposal well or converting an existing well into a disposal well to dispose of industrial and municipal waste without first obtaining a permit pursuant to the Texas Water Code. In applying to the Texas Department of Water Resources, hereafter referred to as the Department, the applicant shall follow the procedures outlined below on the application form and in the Rules of the Department.

2. Five copies of the application, two copies of the technical report and a $25.00 filing fee shall be mailed to:

   Executive Director
   TEXAS DEPARTMENT OF WATER RESOURCES
   P.O. Box 13087, Capitol Station
   Austin, Texas 78711

   An application will not be processed until all information required to properly consider the application has been received.

3. A person making application to the Department for a permit shall submit with the application, a letter from the Railroad Commission stating that drilling the disposal well and injecting industrial or municipal waste into the subsurface stratum will not endanger or injure any oil or gas formation.

   A copy of the application and technical report should be submitted to:

   RAILROAD COMMISSION OF TEXAS
   Attn: Oil & Gas Division
   P.O. Drawer 12967, Capitol Station
   Austin, Texas

4. An application which involves the disposal of a defined waste containing radioactive materials shall be accompanied by a letter or other instrument in writing from the Texas Department of Health, stating either that the applicant has a license from the Department of Health governing the disposal of radioactive materials; or that the applicant does not need such a license.

   A copy of the application should be submitted to:

2. By the Texas Water Commission

The Commission will notify the applicant of any hearing on the application. The Commission will mail notice of the hearing at which the application is to be considered to landowners, certain governmental entities and other parties who may be affected by the proposed waste injection. This notice will be mailed not less than twenty (20) days prior to the date set for the hearing.

After the hearing, if all necessary information has been available for discussion, a report, which will contain the recommendations concerning the applications will be prepared. The report will be sent to the applicant and other interested parties prior to the decision of the Texas Water Commission. The permit will be mailed to the applicant if granted by the Commission.

TEXAS DEPARTMENT OF WATER RESOURCES

1700 North Congress
Stephen F. Austin Building
P.O. Box 13087, Capitol Station
Austin, Texas 78711

FOR DEPARTMENT USE ONLY	
Application No.	
County-District	
Receipt Acknowledged	
Filing Fee Receipt Mailed	
Adm. Review By	
Administratively Complete	
Copies Sent: RRC, TDH, TWWDB, Dist. _____	

APPLICATION FOR PERMIT TO DISPOSE OF WASTE BY WELL INJECTION

1. Applicant ______________________________

   Plant Name ______________________________

   Address ______________________________

   City ______________________ Zip Code __________

   Telephone No. ______________________________

2. List those persons or firms authorized to act for the applicant during the processing of the permit application.

3. Type of permit: Original (_____) Amendment to Permit No. __________________

4. List any other permits, existing or pending, which pertain to pollution control acitivities conducted by the plant or at this location.

5. Nature and Status of Activity

   A. Type of operation or process: (for example sulphuric acid plant, petro-chemical plant, sewage treatment plant, etc.)

   B. Current methods of waste disposal:

6. Location of Proposed Injection Well

County________________________Lease______________________Well No.______________

Section__________________________________TWP-RGE or Block No._____________________________

Survey____________________________________Abstract______________________________

Name and address of surface owner____

____

Distance (in feet) and direction from two adjacent survey lines

____

____

7. Proposed Injection Program

A. New Well____________________ (Yes or No) Convert existing well_________________________ (Yes or No)

B. Type of waste____

____

C. Depth of well________________________________D. Depth(s) and geologic name of injection interval(s)____

8. Submit with Application

A. $25.00 Fee (Please remit by Check or Money Order)

B. Technical Report (see attached instructions)

C. Letter from the Railroad Commission (see attached instructions)

I, (name)____,(title)_____________________
(Company Representative)
state that I have knowledge of the facts herein set forth and that the same are true and correct to the best of my knowledge and belief. I further state than to the best of my knowledge and belief, the project for which application is made will not in any way violate any law, rule, ordinance, or decree of any duly authorized governmental entity having jurisdiction.

Date________________________________Signature____

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TECHNICAL REPORT

FOR

DISPOSAL WELL APPLICATIONS

Information shall be furnished in the form of a technical or engineering report prepared under the direction of a professional engineer or geologist.

Justification for subsurface disposal must accompany the application by submitting treatability studies of alternate methods of waste disposal. Explain in detail why each method is considered to be less satisfactory in terms of environmental protection than the proposed subsurface disposal method. Indicate whether this waste is presently being produced, and if so, what method is used in disposal. Describe in detail the manufacturing process(es) and product(s) from which waste will arise. Applicants should consult with the staff prior to completing the application to determine if the waste would be a candidate for subsurface disposal.

The applicant is advised to review the information to be developed in detail with the Department staff prior to beginning to collect the information indicated because certain conditions or data may require additional or different information than that listed below. Adjustments in the fol ing requirements may be made by the technical staff upon a showing of good cause that the situation warrants.

1. *[illegible] application map or maps similar to the map on Page 4 of Instructions. More than one map may be used to show the required information. Maps should be on sheets 8½x11 inches or folded to that size, and must include the following information:*
   - A. *The approximate boundaries of the tract of land on which the waste disposal activity is or will be conducted.*
   - B. *The location of disposal well as related to plant boundaries and two adjacent survey lines.*
   - C. *The general character of the areas adjacent to the place or places of disposal such as residential, commercial, recreational, agricultural, undeveloped, etc.*
   - D. *The boundaries and ownerships of the surface and subsurface rights of the tracts of land adjacent to the plant boundaries.*
   - E. *The names and addresses (including zip code) of the owners of the surface and subsurface rights of the tracts of land properly cross-referenced to the map.*

     Note: The applicant, unless otherwise approved by the Department, must own the surface and subsurface rights or have long-term leases for both surface and subsurface rights to an area required to contain the calculated waste movement over the life of the project.

2. *A USGS topographic map (1:24,000 scale, if available) indicating the plant boundaries and well location.*

3. *A map indicating location of all water wells on and adjacent to plant property and selected wells in a 2 1/2-mile radius of the proposed well, and a tabulation of depth, owner, chemical analysis, and other pertinent data keyed to the map.*

4. *A map showing the location of all artificial penetrations (oil and gas wells, exploratory test, disposal wells, etc.) within a 2 1/2-mile radius of the proposed disposal well. (Note: Scale of maps in 3 & 4 shall be the same.)*

5. A tabulation of all penetrations requested under (4) above of operator; lease or owner; well number; casing size; setting depth and cementing data for surface; intermediate and long string casings; and plugging data for the abandoned wells. In addition to this information, copies of available casing and cementing records for those wells which penetrate the uppermost proposed injection interval shall be submitted including but not limited to the following RRC forms: 1, 2, 2a, and 4, and cementing affidavits (RRC Form W-15). Tabulation shall be keyed to map in 4. above.

6. Description of local topography and geology pertinent to injection program. This information shall include but is not limited to:

   (A) Surface geologic map, cross-sections and structural contour map on a scale necessary to depict the regional geology of the area.

   (B) Two cross-sections perpendicular to each other crossing at the proposed injection well location. Those cross-sections will include, at a minimum, available log control, geologic units and lithology indicated from the surface to the lower confining bed below the injection zone, or if a major structure exists below the injection zone, to as deep as necessary to show the structure. All aquifers and their quality should be identified. (These maps will be to the necessary scale to detail the local geology -2½ mile radius of well minimum.)

   (C) Structural contour map on the top of the proposed injection zone.

   (D) Isopach map of the injection zone. (Between major confining zones.)

      1. Isopach of sand thickness in injection zone.
      2. If more than one zone is being requested, isopachs of each sand or porous zone.

   (E) Description of faulting and fracturing or lineations in the area (an aerial photo with lineation interpretations is suggested).

   (F) Depositional, structural and tectonic (seismic) history of the area including lithology and hydrologic properties of all units penetrated by the proposed well.

7. Piezometric surface map of the major aquifer in the area containing water with less than 10,000 mg/l TDS.

8. A detailed description of the chemical and physical characteristics of the waste to be injected. Complete chemical analyses of all inorganic constituents should be reported in ppm or mg/l. If organic fractions are present, all such constituents should be reported in ppm or mg/l, as individual percentages be weight, or in other appropriate terms. Give analysis of each individual waste stream and its percentage of total waste volume. Toxicity and degradability rates and levels are required on final waste stream.

9. The anticipated average and maximum rate of injection in gallons per minute. Estimate the yearly volume of injected waste and the anticipated life of the project. Also include the anticipated maximum injection pressure required.

10. Data on construction and completion of the proposed injection well (all new materials required unless otherwise approved by the Department):

A. Total depth of well.

B. Type of completion: perforation, open hole, screen, etc.

C. Type, size, weight, grade and setting depth of all casing strings. (API standards)

D. Proposed cementing procedures and type of cements including volumes, additives, slurry weight, etc. (Sufficient cement shall be used to circulate to the surface). Submit service company recommendations along with studies to determine the suitability of the selected cements.

E. Cementing technique and equipment: guide shoe, float collar, plugs, baskets, DV tools, etc. (Casing should be reciprocated or rotated during cementing.)

F. Proposed injection interval(s) and perforating or screen setting depths. This should include the interval(s) to be utilized initially and the entire zone requested for future development.

G. Number and location and spacing of centralizers, wall scratchers, etc.

H. Size and type of tubing, name, model, and proposed setting depth of tubing packer.

I. Description of filters, type, name and model, capacity.

J. Injection pumps, type, name and model, capacity.

K. Description of pressure and volume monitoring systems.

L. Diagramatic sketch of well including well head facilities.

M. Proposed well stimulation program, acidizing, etc.

N. Description of proposed injectivity tests. (i.e., permeability, reservoir limits, reservoir type, etc.)

O. Proposed logging, bottom-hole testing, coring, etc. Minimum requirements below may be adjusted by technical staff.

(1) Surface Hole
- a. Spontaneous Potential and Resistivity Log
- b. Caliper Log

(2) Bottom of Surface Casing to TD
- a. Spontaneous Potential and Resistivity Log
- b. Gamma Ray (full hole)
- c. Porosity Log
- d. Fracture Finder (at discretion of the staff)
- e. Cement Bond Log
- f. Directional Survey

(3) Injection Zone
a. Side walls at a minimum, full hole cores recommended
b. Bottom Hole pressure & Temperature Logs

11. Characteristics of Injection Interval (give sources of information).

A. Geologic name(s)

B. Depth and thickness and areal development

C. Lithology, porosity, permeability, and temperature (sources of information)

D. Natural reservoir fluid pressure (bottom-hole pressure) or hydrostatic head; fluid saturation and chemical characteristics of formation and formation fluids.

E. Location, extent, and effects of known or suspected faulting, fracturing and/or formation solution channels.

F. Fracture gradient or critical input pressure.

G. Piezometric surface map of receiving strata or if insufficient data is available, expected static fluid level and regional gradient.

12. Nature and extent of upper and lower confining strata. (lithology, permeability, etc.)

13. Compatibility of proposed injection fluid and formation and formation fluids (detailed testing required) at expected pressures and temperatures.

14. Corrosion Test on all facilities which will be in contact with the waste stream and long string casing.

15. Expected changes in pressure, formation fluid displacement, and direction(s) of dispersion of injected fluids.

16. Contingency plan and description of facilities to cope with well failures or shut-in. (A two well system is recommended). 90-day minimum emergency facilities unless two wells are to be used or operation can be closed.

17. Surface Installations

A. Detailed description of pretreatment process and facilities. Include flow diagram with waste streams identified (pits, ponds and lagoons are not recommended).

B. A plat of the plant showing all waste flow lines, and pretreatment system.

C. Plans for disposal of solid or semi-solid waste from pretreatment.

18. Other subsurface disposal operations in the area.

A. Discussion of industrial and municipal waste and saltwater disposal well *operations in the area, including names, distance from the proposed well, and the injection interval.*

B. *Hydrologic implications of proposed well as related to the existing injection operations.*

19. *Describe provisions for continuing activities necessary for proper well operation and qualifications of personnel who will operate and supervise the injection well and related facilities.*

CONSULTANTS FOR DESIGN OF WASTE DISPOSAL WELLS

To assist individuals and industries in contacting persons who design wells for subsurface disposal, the following list of consultants and consulting firms has been prepared. The TDWR acknowledges that the list may be incomplete, and additions to the list will be considered when called to our attention. The list is given in alphabetical order.

CLEMCO
120 South College Street
Tyler, Texas 75701

D'Appolonia Consulting Engineers, Inc.
10 Duff Road
Pittsburgh, Pennsylvania 15235

Ken E. Davis and Associates
Post Office Box 30296
Lafayette, Louisiana 70503
or
Post Office Box 42808
Houston, Texas 77042

Geraghty and Miller, Inc.
44 Sintsink Drive East
Port Washington, New York 11050

Godsey-Earlougher, Inc.
600 Copper Oaks Building
7030 South Yale
Tulsa, Oklahoma 74136

Golden Engineering, Inc.
1100 Milam Building
Suite 2000
Houston, Texas 77002

William F. Guyton and Associates
Consulting Ground Water Hydrologists
415 First Federal Plaza Building
Austin, Texas 78701

Hydrosciences, Inc.
2611 South Interlocken Drive
Evergreen, Colorado 80439
303/674-6400

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Layne Texas Company, Inc.
5402 Lawndale
Post Office Box 9469
Houston, Texas 77011

Pollution Control and Waste Disposal, Inc.
Suite 1408
3500 N. Causeway Boulevard
Metairie, Louisiana 70002

C. M. "Son" Pumphrey, Jr. and Associates
Post Office Drawer "D"
Lane City, Texas 77453
713/532-5189

Ed L. Reed and Associates
1109 N. Big Spring
Midland, Texas 79701

Resources Services, Inc.
Post Office Box 526
Worthington, Ohio 43085

Subsurface Disposal Corporation
5555 West Loop South
Suite 646
Bellaire, Texas 77401

Turke, Kehle and Associates
326 Chevy Chase III
313 E. Anderson Lane
Austin, Texas 78752

Williams Brothers Process Services, Inc.
Resource Sciences Center
6600 South Yale Avenue
Tulsa, Oklahoma 74136
918/496-5000

Underground Resource Management
202 San Jacinto Building
Austin, Texas 78701
512/478-2339

List of Consultants (Con't.)

J-W Operating Company
10120 Northwest Freeway
Suite 106
Houston, Texas 77092
713/688-7291

Sources of additional information:

Director, Consulting Engineers Council
of Texas, Inc.
302 International Life Building
Austin, Texas

Yellow Pages of the Telephone Directory in major cities under Consulting Geologist and Consulting Engineers.

4/19/79

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GENERAL PROVISIONS
156.25.01.001-.006

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. DEFINITIONS.

(a) "Defined Waste" means all wastes subject to the jurisdiction of the Department and includes waste, sewage, industrial waste, municipal waste, recreational waste, agricultural waste, or other waste, all as defined in Section 26.001, and industrial and municipal waste, other than salt water or other waste arising out of or incidental to the drilling for or the production of oil and gas, as defined in Section 27.002.

(b) "Radioactive Material" means any material, whether solid, liquid, or gas, which emits ionizing radiation. Ionizing radiation includes: gamma rays and x-rays; alpha and beta particles, high-speed electrons, neutrons, protons, and other nuclear particles; but not sound or radio waves, or visible, infrared, or ultraviolet light.

(c) "Outfall" means the point or location where waterborne defined waste discharges from a sewer system, treatment facility, or disposal system into or adjacent to the water in the state.

or pattern of discharge of certain prescribed types of defined waste into or adjacent to the water in the state which was occupying on or was established, in the judgment of the Texas Water Pollution Control Board or the Executive Secretary of the Board, within a reasonable time prior to November 7, 1961, the effective date of the State Water Pollution Control Act.**

(h) "Disposal Well Permit" means a waste discharge permit which authorizes the use of a disposal well for the subsurface disposal of certain prescribed types of defined waste, issued under the Disposal Well Act, Chapter 27 of the Texas Water Code, by the Commission or its predecessors, the State Board of Water Engineers, and Texas Water Commission (which became the Texas Water Rights Commission), the Texas Water Development Board, and the Texas Water Quality Board.

.002. STATUTORY DEFINITIONS. Definitions contained in Sections 26.001 and 27.002 shall apply to this Chapter.

.003. POLICIES FOR THE ADMINISTRATION OF WASTE DISCHARGES.

(a) The Department administers Chapters 26 and 27 of the Texas Water Code relating to the discharge of wastes

**The deadline for filing an application for a statutory permit was November 7, 1962.

.004. PROHIBITION AGAINST UNAUTHORIZED WASTE DISPOSAL.

(a) Except as enumerated in subsection (b) of this rule, no person may discharge, deposit, inject, or otherwise dispose of any defined waste unless the disposal is authorized by and conducted in compliance with a waste discharge permit, rule, or other order of the Department.

(b) The following activities under the conditions stated ordinarily do not need to be covered by a waste discharge permit. However, nothing herein limits the authority of the Commission to require a waste discharge permit to abate and prevent water pollution resulting from the disposal of any defined waste.

(1) Disposing of sewage from a private dwelling by means other than a disposal well. However, if the disposal is made in an area covered:

a. by an order regulating the use of private sewage facilities entered by the Commission under Section 26.031 or by a County Commissioners Court under Section 26.032;

b. by a rule or order entered under Section 27.019 controlling the use in a given area of disposal wells for the subsurface disposal of sewage; or

c. by any other order or rule of the Department;

the disposal shall be made in compliance with the rule or order.

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(5) Disposing of waste resulting from activities associated with the exploration, development or production of oil and gas. This includes the hauling by a salt water hauler of water containing salt or other mineralized substances produced in the drilling or operation of an oil and gas well for disposal in an approved salt water disposal system pursuant to a permit issued by the Texas Railroad Commission.

.005. WASTE DISCHARGE PERMIT.

(a) In general, a waste discharge permit authorizes:

(1) the disposal of a defined waste into or adjacent to the water in the state; or

(2) the disposal of a defined waste by disposal well.

(b) Although a waste disposal activity involving industrial solid waste may be subject to authorization under a waste discharge permit, the Commission may require the person owning or conducting the activity to comply with the rules of the Board contained in Chapter 22 related to the management of industrial solid waste.

(c) The Board may also adopt rules governing particular waste disposal activities otherwise subject to authorization under a waste discharge permit, as provided in Section 26.040. To the extent that the

PROCEDURE FOR OBTAINING WASTE DISCHARGE PERMITS
156.25.05.001-.016

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. GENERAL APPLICATION PROCEDURES.

(a) A waste discharge permit authorizes the disposal of a defined waste into or adjacent to the water in the state, or the disposal of a defined waste by disposal well. The forms for applying for a waste discharge permit or an amendment to a waste discharge permit shall be furnished or approved by the Executive Director. The Executive Director is available to confer with the applicant on any questions concerning the preparation of the application. It is strongly recommended that the applicant confer with the Executive Director before preparing design plans and specifications for sewer systems, treatment facilities, disposal systems, disposal well systems, and any other proposed collection, transportation, treatment, or disposal facilities involved in the application so that the applicant can be informed in advance of any requirements of the Department which are applicable to the proposed system or facility, or to the area in which it is to be located, such as recommended

(b) A letter from the Texas Railroad Commission stating that the drilling of the disposal well and the injection of the defined waste into the subsurface stratum selected for disposal will not endanger or injure any oil or gas formation.

.003. MAP REQUIRED. The application shall be accompanied by an application map and, if needed as explained below, a supplemental map. Maps must be of material suitable for a permanent record, and shall be on sheets 8-1/2 inches by 14 inches or folded to that size, and shall be on a scale of not less than 1 inch equals 1 mile. The application map should be an ownership map, if available*, or it may be a county highway map** or a map prepared by a registered professional engineer or a registered surveyor. The map shall show the approximate boundaries of the tract of land owned or used by the applicant on which the waste disposal activity is or will be conducted. The applicant shall locate on the map, each outfall, disposal well, place of deposit, and other place of disposal used or to be used by the applicant for the disposal of any defined waste. The map shall also show known geographic features, such as public roads, towns, streams, and watercourses; the general character of the areas adjacent to the place or places of disposal, such as residential, commercial, recreational, agricultural,

*Ownership maps may usually be obtained from commercial map companies, some county offices, and some abstract companies.
**County highways maps may be ordered either through the State Department of Highways and Public Transportation, Austin, Texas, or through the State District Highway Engineer for the county.

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(1) A general description of the facilities and systems used for the collection, transportation, treatment, and disposal of the waste or used in connection with the waste disposal activity.

(2) For each outfall, disposal well, place of deposit, or other place of disposal:

a. the volume and rate of disposal of the defined waste, including daily and yearly averages, the maximum rates of disposal over representative periods of time, and detailed information regarding patterns of disposal; and

b. the physical and chemical properties of the defined waste; the characteristics of the waste (chemical, physical, thermal, organic, bacteriological, or radioactive), as applicable, should be described in enough detail to allow evaluation of the water and environmental quality considerations involved.

(3) Such other information as may be reasonably required for an adequate understanding of the project or operation.

.005. WASTE CONTAINING RADIOACTIVE MATERIALS. An application which involves the disposal of a defined waste containing radioactive materials shall be accompanied by a letter or other instrument in application for a disposal well permit to determine the local conditions and the probable effect of the disposal well.

(b) Based on the inspection and other relevant information, the Executive Director shall make recommendations to the Commission concerning the requirements for setting casing based on the factors contained in Section 27.056.

(c) If the Executive Director recommends that a permit be issued by the Commission, the Executive Director shall prepare a proposed permit and findings consistent with the requirements of Section 27.051.

.009. NOTICE OF APPLICATION FOR DISPOSAL WELL. When an application for a disposal well is in proper form, the Executive Director shall submit copies of the application to:

(a) Texas Department of Health;

(b) Water Well Drillers Board; and

(c) Texas Railroad Commission.

.010. PUBLIC HEARING REQUIRED. A public hearing shall be held on every application for a waste discharge permit before it is acted on by the Commission.

.011. APPLICATION FORWARDED TO COMMISSION. When an application for a waste discharge permit is in proper form, the

(3) the county judge and health authorities of the county in which the waste is or will be disposed of;

(4) the Texas Department of Health;

(5) the Texas Parks and Wildlife Department;

(6) the Texas Railroad Commission; and

(7) the Texas Water Well Drillers Board when the application involves an injection well.

.013. CONTENTS OF WASTE DISCHARGE PERMIT. A waste discharge permit issued by the Commission shall:

(a) State the name and address of the holder of the permit;

(b) State the duration of the permit;

(c) Describe the location of each authorized point or place of discharge, injection, deposit, or disposal; in the case of disposal by injection, the permit shall also identify the stratum or strata which may be used for disposal and the disposal zone;

(d) Specify the maximum quantity of the defined waste that may be disposed of under the permit at any time and from time to time at each authorized point or place of discharge, injection, deposit, or disposal;

(e) Specify the character and quality of the defined waste which may be disposed of under the permit at each authorized point or place of discharge, injection, deposit, or disposal;

of time, to the extent applicable to the waste discharge of the defined waste in question, may be used in ascertaining the quantity of the discharge, unless some other method is specified.

(a) Average or Monthly Average. The quantity of a discharge of a defined waste stated as an average, not to exceed an average, or monthly average in gallons or other units of measurement per day, means and is determined by deriving the arithmetic average of the total of all daily discharges of the defined waste over a period of thirty (30) consecutive days. However, for monitoring and reporting purposes only, the monthly average quantity may be derived on a calendar month basis or on such other basis as may be agreed upon between the person making the discharge and the Executive Director unless specified in the waste discharge permit, rule, or other order.

(b) Daily Quantity. The quantity of the discharge of a defined waste stated so as not to exceed a specific maximum number of gallons or other units of measurement per day, means and is determined by deriving the total volume of the discharge of the defined waste over twenty-four (24) consecutive hours. For self-reporting purposes only, the twenty-four (24) hour reporting period may start and end at such times as may be established and used by the person making the discharge.

otherwise specified in the permit, rule, or other order, or agreed to by the Executive Director. In the computation, each analytical value from an individual sample shall be weighted according to the flow at the time of sampling. However, for monitoring and reporting purposes only, the monthly average quality may be derived on a calendar month basis or on such other basis as may be agreed upon between the person making the discharge and the Executive Director, unless specified in the permit, rule, or other order.

(b) 24-Hour Composite Quality. 24-hour composite quality means the quality determined by measuring the concentration in milligrams per liter, parts per million, or other appropriate units of measurement in a combination of grab samples of the discharge of a defined waste taken at selected, representative intervals over a period of twenty-four (24) consecutive hours. The volume of each sample in the composite shall be proportional to the flow at the time of sampling. For monitoring and reporting purposes only, the twenty-four (24) hour reporting period may start and end at such times as may be estimated and used by the person making the discharge.

(c) Individual or Grab Sample Quality. Individual or grab sample quality means the quality determined by measuring

REVOCATION, SUSPENSION AND AMENDMENT
OF WASTE DISCHARGE PERMITS
156.25.10.001-.006

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. WASTE DISPOSAL AUTHORITY SUBJECT TO REVOCATION, SUSPENSION, AND AMENDMENT.

(a) A waste discharge permit does not become a vested right in the holder of the permit. The permit may be revoked or suspended by the Commission for good cause, however, a public hearing shall first be held, notice of which shall be given to the holder of the waste discharge permit, and the revocation or suspension must be based on one of the following grounds:

(1) The holder has failed or is failing to comply with the conditions of the permit;

(2) The permit or the operations thereunder, have been abandoned;

(3) The permit is no longer needed by the holder;

(4) The authority to discharge defined waste into or adjacent to the water in the state under a waste discharge permit is subject to cancellation or suspension under Section 26.084.

(b) The Commission may amend waste discharge permits to require the holder of a waste discharge permit to conform is not required. The Executive Director shall forward the waiver to the Commission for consideration and action by the Commission at a regular meeting. A copy of the order entered is sent by mail to the holder of the waste discharge permit.

.003. AMENDMENT WITH CONSENT.

(a) The holder of a waste discharge permit on his own initiative or upon request of the Executive Director may file an application to amend the permit in any particular. The written request for amendment is prepared setting forth the modifications desired. The holder of a waste discharge permit may use the form of an application for a permit and indicate thereon the amendments requested.

(b) A public hearing shall be held on every application for amendment filed under this rule unless the modifications will amend the waste discharge permit to improve the quality of the defined waste authorized to be disposed of; and if the applicant does not seek to increase significantly the quantity of defined waste authorized to be disposed of, or to change materially the pattern or place of disposal. At the time the application is submitted to the Commission for consideration and action, the Executive Director will recommend whether a public hearing should be required.

(b) Notice of the date, time, place and purpose of the public hearing shall be personally served on the holder of the waste discharge permit or be sent by mail to the holder at his last known address as shown by the records of the Department, not less than twenty (20) days prior to the date of the hearing. Notice shall also be published at least once not less than twenty (20) days before the date for the hearing in a newspaper regularly published or circulated in each county where the Commission or the Executive Director has reason to believe persons reside who may be affected. The Commission will pay the publication cost and be responsible for proper publication. Notice shall be mailed to the mayor and health authorities of the city or town and to the county judge and health authorities of the county in which the defined waste is discharged or disposed of.

(c) After the hearing has been concluded, the Commission may revoke the waste discharge permit in whole or in part, amend it in any particular, suspend the authority to operate the waste disposal activity or dispose of defined waste for a specified period of time, dismiss the proceedings, or take any other action as may be appropriate.

(d) If the Commission in its order directs a person to perform or refrain from performing a certain act or

(c) After the hearing has been concluded, the Commission may impose new or additional conditions on the holder of the waste discharge permit, or dismiss the proceedings, or take any other action as may be appropriate.

(d) If the Commission in its order directs a person to perform or refrain from performing a certain act or activity, there shall be set forth in the order the findings on which the directive is based. A copy of every order of the Commission entered in the proceedings will be sent by mail to the holder of the waste discharge permit.

(e) The holder of the waste discharge permit shall have a reasonable time as specified in the order to conform to the new or additional conditions imposed by the Commission.

.006. EXTENSIONS OF TIME TO COMPLY WITH REVOCATION, SUSPENSION, OR NEW CONDITIONS.

(a) Upon application by the holder of a waste discharge permit or other order, the Commission may grant an additional period of time beyond that specified in the permit or order in which to terminate or suspend the disposal of waste or to conform to the additional conditions, through an amendment or temporary order issued in accordance with the procedures of the Chapter.

CORRECTIONS AND TRANSFERS OF
WASTE DISCHARGE PERMITS
156.25.15.001-.002

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. CORRECTIONS. The Commission may make corrections to waste discharge permits, either by reissuing the permit or by issuing an endorsement to the permit, without the necessity of observing the formal amendment procedures prescribed in this chapter:

(a) To correct a clerical or typographical error;

(b) To describe more accurately the location of the authorized point or place of discharge, injection, deposit, or disposal of any defined waste, or the route which any defined waste follows along the watercourses in the state after being discharged;

(c) To describe more accurately the character, quality or quantity of any defined waste authorized to be disposed of;

(d) To describe more accurately the pattern of discharge or disposal of any defined waste authorized to be disposed of; or

(e) To state more accurately any provisions in a permit but without changing the substance of any such provision.

RENEWALS
156.25.20.001-.004

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. DURATION. The Commission may issue waste discharge permits for specific periods of time. The waste discharge permit will terminate at the expiration of the period of time specified in the waste discharge permit except as provided in this subchapter.

.002. APPLICATION FOR RENEWAL. The Executive Director on his own motion or the holder of a waste discharge permit may initiate renewal procedures by the filing of an application for renewal prior to the expiration date. The application for renewal shall be filed with the Executive Director.

(a) The application for renewal may be in the same form as an application for a waste discharge permit. In preparing the application for renewal, the applicant shall specify that the applicant requests the continuation of the same requirements and conditions of the expiring waste discharge permit.

(b) If the applicant for renewal is in fact petitioning the Commission for a modification of the requirements and conditions of the expiring waste discharge permit, the

Director may be affected not less than thirty (30) days in advance of Commission consideration of the application for renewal.

(c) The Commission may require the applicant for renewal to be responsible for causing notice to be properly published or served in accordance with Commission instructions and to pay for all or part of the costs of the publication or service of notice.

.004. ACTION ON APPLICATION FOR RENEWAL.

(a) In considering the application for renewal, the Commission may take into account the following factors:

(1) Whether the permit holder has maintained compliance with the requirements and conditions of the expiring waste discharge permit;

(2) Whether the operations or facilities authorized by the waste discharge permit have been abandoned;

(3) Whether the waste discharge permit is no longer needed;

(4) Whether a change in conditions requires the discontinuation of the discharge; and

(5) Whether maintenance of the water quality consistent with the objectives of Chapter 26 of the Texas Water Code requires the discontinuation of the discharge.

EMERGENCY ORDERS
156.25.25.001-.005

These rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. EMERGENCY ORDER TERMINATING DISCHARGES. If the Executive Director determines there is good reason to believe that a discharge or proposed discharge of defined waste into or adjacent to any water in the state, whether the discharge is covered by a waste discharge permit or not, is creating or will cause extensive or severe property damage or economic loss to others, and that other procedures available to the Department to remedy the situation or prevent the situation from occurring will result in unreasonable delay, the Executive Director may request the Commission to issue a temporary order to the person responsible for or exercising control over the discharge or proposed discharge, directing that the discharge be discontinued, modified, or not made, or that other appropriate remedial or preventive measures be taken. The order may be issued without notice and hearing, or with such notice and hearing as the Commission deems practicable under the circumstances. The temporary order shall be complied with immediately upon its receipt by the person to whom it is directed.

supply additional information as may be reasonably required to assist the Commission in making the necessary findings set out in subsection (a) of this rule.

(d) The Executive Director shall forward the request for a temporary order accompanied by a proposed agenda item and notices of hearing, if appropriate, as well as the Executive Director's recommendation, including any proposed temporary orders and findings.

.003. NOTICE AND HEARING.

(a) If the Commission deems it practicable to do so, it shall call a public hearing before issuing an emergency or temporary order as authorized by this subchapter. If the Commission issues an emergency or temporary order without a hearing before the Commission, the Commission in its order shall call and set a time and place for a hearing to be held before the Commission as soon after the emergency or temporary order is issued as is practicable. At the hearing, the Commission shall consider whether to affirm, modify, or set aside the emergency or temporary order.

(b) For any hearing called as provided in subsection (a) of this rule, it is not necessary to give notice in accordance with the requirements of Section 26.022. However, such appropriate remedial or preventive measures be taken ; authorized under rule .001 of this subchapter, the person to whom the order is directed shall immediately comply with the order according to its terms as soon as he receives it, regardless of how he initially receives it. If the order is issued pursuant to rule .002 of this subchapter and authorizes a discharge, the person to whom the order is issued may not make any discharge under the order except in strict compliance with its terms and conditions.

at the hearing, compel the attendance of witnesses, and make findings of fact and conclusions of law.

.003. LEGAL PROCEEDINGS. The Executive Director is authorized to institute or cause to be instituted, in courts of competent jurisdiction, legal proceedings to enforce and compel compliance with the provisions of the Texas Water Code administered by the Department and the waste discharge permits, rules, decisions, determinations, and other orders of the Department.

Clarification of Permit Requirements

1. Drilling and construction supervision:
   Supervised by a qualified drilling engineer. who has the authority to act for the company on matters concerning drilling. Must be on the site during most of the drilling and during logging. testing. casings, cementing operations.

2. Drillers log or record of strata requested. (Constructed from cutting samples)

3. Casing testing:
   Must be witnessed by consulting engineer or company representative.

4. Collection of formation fluid:
   Must pump, jet, swab, backflow or otherwise produce the well until a representative sample of formation fluid can be obtained. It is suggested that conductivity or some other parameter be measured until it stabilizes, then several gallons or preferably barrels collected. The fluid should be analyzed for a minimum of the following:

Silica	Potassium
Calcium	Manganese
Magnesium	Barium
Sodium	Boron
Carbonate	Strontium
Bicarbonate	Cadmium
Sulfate	Iron
Chloride	pH
Floride	Dissolved Oxygen
Nitrate	Hydrocarbons
Viscosity	Specific Gravity
Conductivity	Temperature
Total Dissolved Solids	H_2S

5. Cores and core testing:
   Sidewall cores are required at a minimum full hole cores recommended.

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Cores will be analyzed for:

Permeability
Porosity
% Saturation of each fluid
Sample description
Sieve analysis of sand
Compatability testing of cores with waste stream for permeability reduction

6. Compatibility testing of formation fluids, waste streams and cores should be conducted or simulated at reservoir pressure and temperature.

7. Completion Report should consist of the following:

I. Drilling and Completion Records

1. Daily Reports
2. Drillers Log or Record of Strata
3. Casing and Tubing Records: pipetallys
4. Detailed Screen and Liner Setting
5. Cementing Records
6. Details of Centralizers, Scratchers, etc.
7. Engineering Drawings of:
   a. Well completion
   b. Packer assembly and setting
   c. Wellhead, parts list, etc.

II. Geophysical Logs

1. Final Prints of all Logs run on the Well
2. Interpretations of Logs by Qualified Persons
3. Directional or Inclinational Survey

III. Testing Records

A. Well Testing
1. Static Fluid Level

2. Bottom hole Temperature
3. Bottom hole Pressure
4. Injectivity Test Results, i.e., Permeability Determination, Reservoir Limits, Storage Coefficient
5. Spinner or Tracer Surveys
6. Casing Testing Results

B. Lab Testing
1. Cores for Permeability
2. Cores for Compatibility
3. Cores for Porosity
4. Complete analysis of formation water
5. Compatibility of formation water and wastewater
6. Descriptive core analysis and/or sieve analysis

IV. Other

1. New cross-sections, if required
2. New pressure increases, if required
3. Summary Data Sheet
4. Letter indicating Local Health Department furnished a copy of the Permit
5. Photo of Wellhead

8. Injectivity Testing

Testing must include pressure/time relationships to determine permeability, transmissivity and reservoir limits if any. Pressure recordings can be by bottom hole bomb, or quartz guage in the case of wells which operate on a vacuum. Testing can be pressure build-up or pressure fall off type.

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REVIEW OF ARTIFICIAL PENETRATIONS

Improperly plugged or completed wells which penetrate the injection zone pose a serious constraint to injection operations. The determination of what constitutes an improperly completed or plugged well is a difficult problem. Among the many variables are geology, completion methods, plugging methods, expected reservoir conditions, etc.

There are several schools of thought concerning the radius of investigation for artificial penetrations. This Agency has used as a rule of thumb, a 2½-mile radius. This is not an absolute requirement. The distance can be adjusted as the circumstances require. For example, after making Reservoir pressure calculations, it may be determined that a 3-mile review is required because of a large pressure increase at 2½ miles. On the other hand, low volumes in a thick reservoir may result in an insignificant pressure at 1 mile. However, later requests for volume increases can result in a second record search. In order to maintain a uniform approach to the radius of review, all applicants should submit data for 2½-miles with the application. Additional data can be submitted if needed after an evaluation is made.

Generally speaking, dry holes on the Texas Gulf Coast were abandoned without long string casing left in the hole. Surface casing was generally set and cemented at the base of fresh water and no long string was set. A plug is normally set at the base of the surface casing and at the top. The hole and the casing between plugs is usually filled with drilling muds. Due to the unconsolidated nature of the Gulf Coast Sediments and the plastic nature of most tertiary shales, abandoned well bores probably do not remain open for long periods of time.

In the west and north central part of the State, injection zones, confining beds and most of the overburdened strata are competent, indurated rocks. Well bores remain open for indefinite periods of time, and frequently drilling fluids and cement may not be in the well bore because of lost circulation zones.

A well which has been properly abandoned is one where interformational transfer of fluids does not occur or will not occur as a result of injection. Although our primary concern is protection of ground-water resources, oil or gas formations, or other mineral bearing zones may be affected, i.e., magnesium is produced from the Yates Formation and other commercial brines probably exist in the State.

Probably the greatest danger from artificial penetrations occurs in the West Texas area. Most reports of flowing abandoned wells or ground-water contamination from oil field brines is from this area. There are several possible causes for this, but it is primarily the

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result of well bores, which do not collapse around casing or do not close after casing is removed, or the fact that lost circulation zones are common and the hole may be unintentionally abandoned or completed without adequate mud or cement. Another problem common to all areas of the State is some wells are temporarily abandoned with casing in the hole and then forgotten.

Often the information submitted with an application is inadequate, incomplete or in error. For example, many tabulations indicate that the well is a producing well, however, the well may not have produced in many years and is temporarily abandoned. In order to check the status, the Railroad Commission records must be reviewed. Form W-10, semi-annual well status reports and Rule 14B(2) (plugging) exceptions are two methods of establishing well status. Additionally, the "Well Schedule" is a computer print-out of all active wells and is updated motnhly. There are separate schedules for oil and gas and are filed by district.

Additionally, all of the penetration in the area may not be tabulated or listed by the applicant. The General Land Office maintains up-to-date records on oil and gas well locations as does the Railroad Commission. The RRC also maintains reproducable field maps which have generally been updated within the past year.

After all the data has been assimilated, a determination must be made if a hazard exists. Using all the data available, some conflicting conclusions can be made. There are no unique solutions to the problem and a value judgement may be required.

There are several rules of thumb which can be applied. None are absolute and the reviewer should use individual knowledge and experience to supplement these ideas.

(1) In the Texas Gulf Coast area, the bore holes normally do not remain open for a long period of time. The weight of the drilling fluid (if the hole remains open) or the collapsed sediments should prevent any upward migration of native fluids if reservoir pressures are not significantly increased. A rule of thumb has been a pressure increase of 15 psi/1,000 feet of depth. This is based on the pressure differential of a 9.5 lb. mud, normal Gulf Coast reservoir pressures, and a considerable safety factor.

(2) In West Texas area, uncemented well bores can result in vertical avenues of escape. Generally, wells which penetrate the injection zone should have cement across the injection interval to prevent corrosion, casing failure and escape of fluids or contamination of produced fluids.

(3) It is not uncommon to find wells which have been abandoned with long string casing still in the hole and the well has not been plugged. Therefore, if no information concerning the well can be found, we should proceed as if it is not plugged and has long string casing in the hole. This is probably one of the most dangerous situations which can exist.

In summary, artificial penetrations, which are through the confining beds is one of the most serious problems in any injection operation. Each application for a well must be thoroughly evaluated in terms of reservoir pressure increase and artificial penetration in the area.

In order to review the surrounding penetration and to determine if a hazard exists, an accurate picture of the well and well status is necessary.

The attached review sheet has been compiled to facilitate this review.

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INJECTION WELL APPLICATION
REVIEW CHECKLIST

Application #______________________________

Applicant__________________________________

County_____________________________________

Reviewed by________________________________

Date_______________________________________

I. Justification

____ 1. Treatibility studies
____ 2. Current method of disposal
____ 3. Manufacturing processes
____ 4. Products

II. Well Location

____ 1. Plant location map
____ 2. Well location in relation to plant and survey lines
____ 3. Surface & ownership maps
____ 4. USGS Topo map
____ 5. Does applicant own surface and subsurface rights

III. Geology

A. Region

____ 1. Surface map
____ 2. Cross-sections
____ 3. Structural contour

B. Local

____ 1. Cross-sections
____ 2. Structural contour
____ 3. Isopach
____ 4. Description of faulting and fracturing
____ 5. Aerial photo
____ 6. Depositional, structural and tectonic history of the area

IV. Ground Water

____ 1. Map of area water wells

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____ 2. Depth, owner and chemical analysis from wells
____ 3. Piezometric surface map
____ 4. Base of usable water

V. Other Penetrations In The Area

____ 1. Map of penetrations within 2 1/2 mile radius
____ 2. Tabulations of penetrations
____ 3. Casing, cementing and P&A records

VI. Characteristics of Disposal Zone

____ 1. Lithology
____ 2. Areal development
____ 3. Porosity
____ 4. Permeability
____ 5. Expected temperature
____ 6. Natural reservoir pressure and static fluid level
____ 7. Fluid saturation
____ 8. Chemical characteristics
____ 9. Fracture gradient

VII. Proposed Well Completion

____ 1. Total Depth
____ 2. Injection interval
____ 3. Surface casing: size, type, weight, setting depth, guide/float equipment, centralizers, scratchers, etc.
____ 4. Surface casing cement data and service company recommendations
____ 5. Intermediate string and cementing data
____ 6. Protection or long string: size, type, weight, setting depth, guide/float equipment, DV Tool, centralizers, scratchers, etc.
____ 7. Protection string cement data and service company recommendations, cement compatibility data
____ 8. Packer: type and setting depth
____ 9. Description of annulus monitoring system, including type fluid and proposed pressure
____10. Type completion

____ a. Open hole
____ b. Perforated long string: where and how many
____ c. Screen and blank liner: size, setting depth, type
____ d. Underream and/or gravel pack
____ e. Other

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____11. Diagramatic sketch of well
____12. Diagramatic sketch of well head and complete description

VIII. Reservoir Stimulation and Testing

____ 1. Description of proposed injectivity tests
____ 2. Well stimulation: acidizing, etc.
____ 3. Description of logging program
____ 4. Description of coring program and laboratory testing

IX. Waste Characteristics

A. Nature of the waste
____ 1. Description of physical and chemical characteristics
____ 2. Analysis of final waste stream
____ 3. Analysis of individual waste streams
____ 4. Toxicity of final waste stream
____ 5. Degradability rate of final waste stream
____ 6. Compatibility of waste and native formation fluid
____ 7. Corrosion characteristics of waste

B. Volume of the waste
____ 1. Percentage of each stream to total effluent
____ 2. Average and maximum injection rates
____ 3. Monthly or yearly volume
____ 4. Anticipated life of the project

X. Waste Pretreatment Facilities

____ 1. Existing facilities
____ 2. Proposed facilities
____ 3. Flow diagram with waste streams identified
____ 4. Plat of plants showing all waste flow times
____ 5. Plans for emergency storage or treatment in case of well failure
____ 6. Pond or lagoons proposed or in use
____ 7. Filters types and location
____ 8. Injection pumps and location
____ 9. Disposal of sludges or solids

XI. Injection Well Operation

____ 1. Expected maximum and average injection pressure
____ 2. Formation pressure increase calculations
____ 3. Minimum fluid front calculations

XII. Remarks:

WELL DATA REPORT FOR INDUSTRIAL AND MUNICIPAL INJECTION WELLS

Operating Company Name and Address:

____

____

____

____

Telephone No. ______________________________

Individual Responsible for Well ______________________________

I. General Identification Data

1. Permit No. WDW-______________

2. Plant Well No. ______________________________

3. Latitude and Longitude ______________________________

4. Well Location (Legal Description) ______________________________

____

____

____

5. County ______________________________

6. Location to Nearest Town ______________________________

II. General Data on Well Site

1. Generalized Description of Waste Stream Injected ______________

____

____

____

____

______________(attach complete chemical analysis to this form).

2. Date Well Permitted __ ______(Day) __________(Month) __________(Year)

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3. Date Well Put Into Service ______(Day) ______(Month) ______(Year)
4. Maximum Injection Rate ____________gpm __________gallons/month
5. Average Injection Rate ____________gpm __________gallons/month
6. Maximum Injection pressure ______________________________psig
7. List All Special Provisions of the TWQB Permit not Covered Above:

____
____
____
____
____
____
____
____
____

8. Total Depth of Well ____________________________________
9. Name and Depth of Injection Zone __________________________

III. Geologic Information

1. Lithology and Stratigraphy

A. Geologic Description of Rock Units Penetrated by Well

(a) Name	(b) Age	(c) Depth	(d) Thickness	(e) Lithology

B. Description of Injection Unit

Injection Zone

(1) Name(s) ______________________

(2) Depth (drill) ______________________

(3) Thickness ______________________

(4) Formation Fluid Pressure ______________________

(5) Lithostatic Pressure ______________________

(6) Hydro Fracture Pressure ______________________

(7) Age of Unit ______________________

(8) Porosity (avg.) ______________________

(9) Permeability (Millidarcies) ______________________

(10) Bottom Hole Temperature ______________________

(11) Lithology ______________________

(12) BHP (original) ______________________

(13) BHP (present) ______________________

C. Chemical Characteristics of Formation Fluid ______________________

____

______________________ (attach complete chemical analysis)

D. Description of Hydrology of Fresh Water and other Potentially Beneficial Aquifers.

(1) Depth to Base of Usable Quality Water (3000 mg/l)

______________ feet

(2) Depth to Base of Potentially Usable Water (10,000 mg/l)

______________ feet

(3) Geologic Description of Aquifer Units

(a) Name	(b) Age	(c) Depth	(d) Thickness	(e) Lithology	(f) TDS (avg)

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(3) Geologic Description (continued)

(a) Name	(b) Age	(c) Depth	(d) Thickness	(e) Lithology	(f) TDS (avg.)
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______

(4) Number of Wells within 2½ mile radius that penetrate the injection interval ______

(5) Number of item (4) wells above that are plugged and abandoned ______

6) Number of item (4) wells above that are still producing ______

(7) Number of water wells with a 2½ mile radius ______

(8) Attach complete chemical analysis.

IV. Waste Characteristics

1. N mber of Waste Streams to Form Composite Injection Stream ______
2. Plant Products Manufactured and process or operation which result in waste being injected ______
3. Physical/Chemical Description (taken from complete chemical analysis attachment)
   - A. TDS ______
   - B. Specific Gravity ______
   - C. pH ______
   - D. Temperature ______
   - E. Degradability Level and Rate ______
4. Toxicity ______

5. Corrosion Reactivity

A. Surface Facilities ____________________

____

____

B. Injection Well Tubing ____________________

____

____

C. Long String Casing ____________________

____

____

6. Degradability Level and Rate ____________________

____

7. Biological Level at Injection ____________________

____

8. Pre-injection Waste Treatment Description ____________________

____

____

____

____

____

____

____

V. Well Design and Construction

1. Casing

Casing	Size, Weight, Grade	Depth Set
A. Surface Casing	____________	________
	____________	________
	____________	________
	____________	________

V. Well Design and Construction (Cont'd)

1. Casing

Casing	Size,weight,grade	Depth Set
B. Intermediate Casing	___	___
	___	___
	___	___
	___	___
C. Long String Casing	___	___
	___	___
	___	___
D. Injection Tubing	___	___
	___	___
	___	___

2. Cement Data

	Type/class	Additives	Amount	Circulated
A. Surface Casing	___	___	___	___
	___	___	___	___
B. Intermediate	___	___	___	___
	___	___	___	___
	___	___	___	___
	___	___	___	___
C. Long String	___	___	___	___
	___	___	___	___
	___	___	___	___

D. DV Tool (stage cementing)

Setting depth ______________________(if applicable)

3. Packer

A. Type ______________________

B. Name & Model ______________________

C. Setting Depth ______________________

3. Packer (cont'd)

   D. Type Annular Fluid Used ______________________

   ____

4. Centralizers: number and approximate depths

   ____

   ____

   ____

   ____

   ____

5. Bottom Hole Completion

   ____

   ____

   ____

   ____

   ____

6. Well Stimulation Programs

   ____

   ____

   ____

   ____

   ____

VI. Description of Surface Equipment

1. Holding Tanks and Flow Lines ______________________

   ____

   ____

   ____

   ____

   ____

   ____

2. Filters

   A. Type ______________________________

   B. Name & Model ______________________________

   C. Capacity ______________________________

3. Injection pumps

   A. Type ______________________________

   B. Name & Model ______________________________

   C. Capacity ______________________________

VII. Monitoring Systems

1. Injection Pressure Gauges (Non-Recording)

(a) Location	(b) Name & Model

2. Injection Pressure Gauges (Continuous Recording)

(a) Location	(b) Name & Model	(c) Mechanical	(d) Electrical

3. Casing-Tubing Annulus Pressure Gauges (Non-Recording)

(a) Location	(b) Name & Model

4. Casing-Tubing Annulus Pressure Gauges (Continuous Recording)

(a) Location	(b) Name & Model	(c) Mechanical	(d) Electrical

5. Injection Rate Meters (Non Recording)

(a) Location	(b) Name & Model

6. Injection Rate Meters (Continuous Recording)

(a) Location	(b) Name & Model	(c) Mechanical	(d) Electrical

7. pH Recording Devices

(a) Location	(b) Name & Model	(c) Continuous Recrd.	(d) Noncontinuous Recording

8. Temperature

(a) Location	(b) Name & Model	(c) Continuous Recrd.	(d) Noncontinuous Recording

9. Sampling Frequency and Water Quality Parameter Measures ____________________

10. Frequency of Measuring:

Water Levels ____________________

Bottom Hole Pressure ____________________

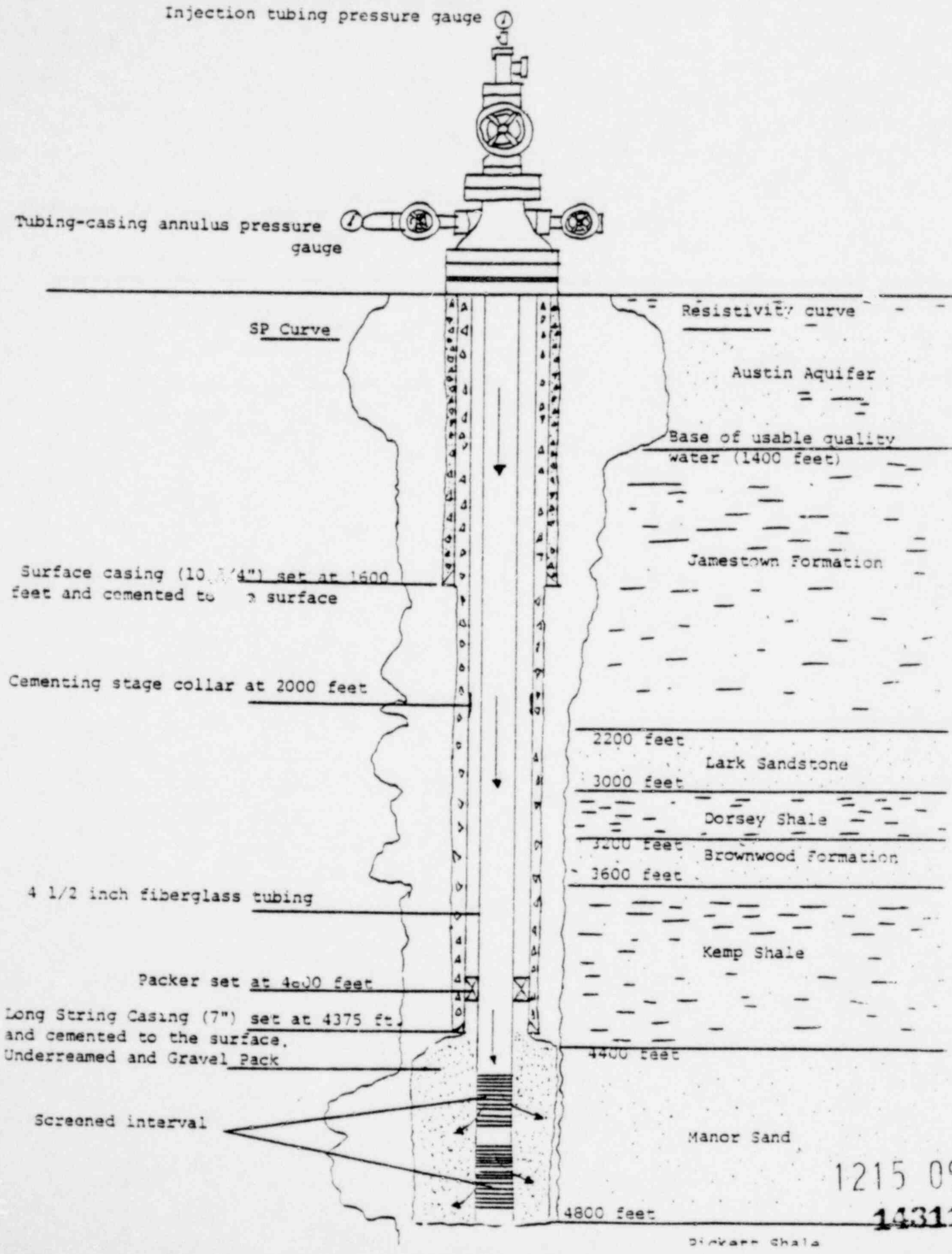
11. Contingency Plan for Well Failure During Operation ____________________

VIII. <u>Logging Program</u>

Surface TD	Long string TD
1. ____	1. ____
2. ____	2. ____
3. ____	3. ____
4. ____	4. ____

IX. Chronological listing of all wor' ı ərs and well malfunctions and brief description of reasons fo ·ll failure.

X. Diagramatic sketch of injection well showing casing, cement, tubing, packer, etc. with proper setting depths. Sketch should include well head and gauges. Geologic units penetrated by the well should be indicated as well as electric log of the well. 8½ x 11 paper is preferred. An example of the type sketch desired is attached.



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