Water and Wastewater Comprehensive Plan

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TABLE OF CONTENTS

			PAGE NO.
	EXECUTIVE SUMMARY		
1.	INTRODUCTION		1
2.	POPULATION, WATER AND WASTEWATER USE		2
	2.1	Historical and Projected Population	2
	2.2	Historical Water Use	4
	2.3	Project Water Use	5
		2.3.1 Projected Municipal Water Needs	5
		2.3.2 Projected Other Municipal Use	6
		2.3.3 Projected Industrial Sales	6
		2.3.4 Projected Vernon Total Requirements	7
		2.3.5 Projected Wilbarger County Requirements	8
	2.4	Wastewater Projections	10
		2.4.1 Industrial Wastewater Flows	10
		2.4.2 Domestic Wastewater Flows	12
		2.4.3 Infiltration and Inflows	13
		2.4.4 Total Wastewater System Flows	14
3.0	EVALUATION OF EXISTING GROUND WATER RESOURCES		15
	3.1	Odell-Winston Well Field	15
	3.2	Long-Term Availability of the Odell-Winston Well Field	16
	3.3	Round Timber Ranch Well Field	17
	3.4	Conclusions and Recommendations	18
4.0	COMPARISON OF SUPPLY AND DEMAND		20
5.0	SCREENING OF WATER SUPPLY ALTERNATIVES		22
	5.1	Alternatives Recommended for Further Analysis	24
	5.2	Alternatives Explored but Not Recommended	26
6.0	NITRATE REMOVAL EVALUATION		30
	6.1	Treatment Technologies for Nitrate Removal	30
	6.2	Alternatives Considered	32
	6.3	Cost Estimates	35
	6.4	Recommendations	35
7.0	ALTERNATIVES RETAINED FOR DETAILED ANALYSIS		38
	7.1	Description of Alternatives	38
	7.2	Estimated Costs	40
	7.3	Recommendations	41
8.0	WATER DISTRIBUTION SYSTEM		44
	8.1	Description of the Distribution System	44
	8.2	Distribution System Modeling	45

9.0 WASTEWATER SYSTEM . . . 47
9.1 Existing Collection System . . . 47
9.2 Wastewater Collection System Analysis . . . 47
9.2.1 Wastewater System Analysis Software . . . 47
9.2.2 Hydraulic Analysis 48
9.3 Wastewater Collection System Improvements for 2020 . . . 50

10.0 CONCLUSIONS AND RECOMMENDATIONS . . . 51
10.1 Recommendations . . . 52
10.1.1 Recommendations for Nitrate Removal System . . . 52
10.1.2 Recommendations for Pursuing Ground Water from Altus . . . 52
10.1.3 Recommendations for Existing Well Fields . . . 53

11.0 CAPITAL IMPROVEMENT PLAN . . . 54
11.1 Water Treatment . . . 54
11.2 Water Supply . . . 55
11.3 Water Distribution System . . . 58
11.4 Wastewater System . . . 59
11.5 Capital Improvements Schedule . . . 61
11.6 Potential Funding Sources for Capital Improvement Projects . . . 64

BIBLIOGRAPHY

LIST OF TABLES

Table 2-1 Historical and Projected Population 3
Table 2-2 Historical Water Use and Per Capita In-City Municipal Use 4
Table 2-3 TWDB Projected Per Capita Municipal Demand 5
Table 2-4 Projected Municipal In-City Use 6
Table 2-5 Projected Municipal Sales 7
Table 2-6 Projected Industrial Use 7
Table 2-7 Vernon Total Requirements 8
Table 2-8 Wilbarger County Projected Total Average-Day Needs Under Dry Conditions 8
Table 2-9 Historical Wastewater Flows 11
Table 2-10 Industrial and Commercial Wastewater Flows 12
Table 2-11 Infiltration/Inflow Associated with Major Storm Events 13
Table 2-12 Summary of Wastewater Design Flows 14
Table 5-1 Summary of Comparison of Alternatives 23
Table 6-1 Advantages and Disadvantages of Nitrate Removal Technologies 33
Table 6-2 Cost Evaluation for Nitrate Treatment Alternatives 37
Table 7-1 Advantages and Disadvantages of Retained Alternatives 42
Table 7-2 Summary of Cost Estimates 43
Table 8-1 Existing Pump Stations 44
Table 8-2 Water Demands 46
Table 9-1 Distribution of 1999 Wastewater Flows by Drainage Area 49
Table 9-2 Distribution of 2020 Wastewater Flows by Drainage Area 49

LIST OF TABLES (continued)

Table 11-1	Nitrate Removal Cost Estimate	55
Table 11-2	Water Supply Project Costs	57
Table 11-3	Water Distribution Project Costs	58
Table 11-4	Wastewater System Project Costs	60

LIST OF FIGURES

		PAGE
Figure 2-1	Historical and Projected City of Vernon Population	3
Figure 2-2	Historical and Projected Water Use City of Vernon	9
Figure 4-1	Comparison of Supply and Demand	21
Figure 7-1	Alternative 1: Treated Surface Water	after 38
Figure 7-2	Alternative 2: Raw Water from Lake Kickapoo	after 39
Figure 7-3	Alternative 3: Raw Surface Water with Desalination	after 39
Figure 7-4	Alternative 4: Ground Water - Round Timber Ranch	after 40
Figure 8-1	Location of Pressure Plane Boundary	after 45
Figure 11-1	Schematic Diagram - Ion Exchange Process	after 55
Figure 11-2	Proposed Treatment Plant Location	after 55
Figure 11-5	Schedule for Proposed Water Projects	62
Figure 11-6	Schedule for Proposed Wastewater Projects	63

Plate 1	Existing Water Distribution System
Plate 2	Proposed Water Distribution Improvements - 2020 Conditions
Plate 3	Existing Wastewater Collection System
Plate 4	2020 Modeled Wastewater Conditions
Plate 5	2020 Wastewater Improvements
Plate 6	Water Distribution Capital Improvement Projects
Plate 7	Wastewater System Capital Improvement Projects

APPENDIX A	List of meetings and presentations
APPENDIX B	Groundwater Resources Study for Odell-Winston and Round Timber Ranch Well Fields
APPENDIX C	Water Distribution Study Pressure Results

EXECUTIVE SUMMARY

In July 1997, the City of Vernon authorized Freese and Nichols, Inc. to conduct a water supply study to meet the City's growing demands through 2050, and evaluate the City's water distribution and wastewater system needs through 2020. This project was performed in conjunction with the Texas Water Development Board, under a water and wastewater regional grant. The purpose of the plan is to identify capital improvements to Vernon's water and wastewater systems that are needed to meet regulatory requirements and future demands.

The City of Vernon is the largest city in Wilbarger County, located in North Texas near the Texas-Oklahoma border. Vernon currently provides for most of the county's municipal and industrial water needs from wells located in the Seymour Aquifer. Previous studies have indicated that the long-term reliable supply from the City's existing well fields may not meet increasing demands. The well fields have consistently exceeded the U.S. EPA primary drinking water standard of 10 mg/l nitrate as nitrogen. The development of this Water and Wastewater Comprehensive Plan included evaluations of:

- Population, water and wastewater demands;
- Existing and potential ground water resources;
- Water supply alternatives;
- Nitrate removal alternatives;
- Water distribution system; and
- Wastewater treatment system.

The study concluded with the development of a Capital Improvement Plan.

Population and water demand projections used in this study are consistent with Senate Bill One planning. Water demands were developed for both drought of record conditions (Senate Bill One projections) and normal rainfall. The City of Vernon currently provides for all in-city water needs, the water needs of Box WSD, Hinds-Wildcat, Northside and Oklaunion water supply systems and a portion of Lockett's water supply needs. By the year 2010, Vernon may provide for all of Lockett's needs. Historically Vernon has provided for nearly all the industrial needs of Wilbarger County and this is expected to continue. As shown in Table ES-1, by 2050 the City of Vernon and its users are expected to require between 2.984 MGD of water for normal precipitation years and 3.753 MGD of water for dry conditions.

Table ES-1
Vernon Total Requirements

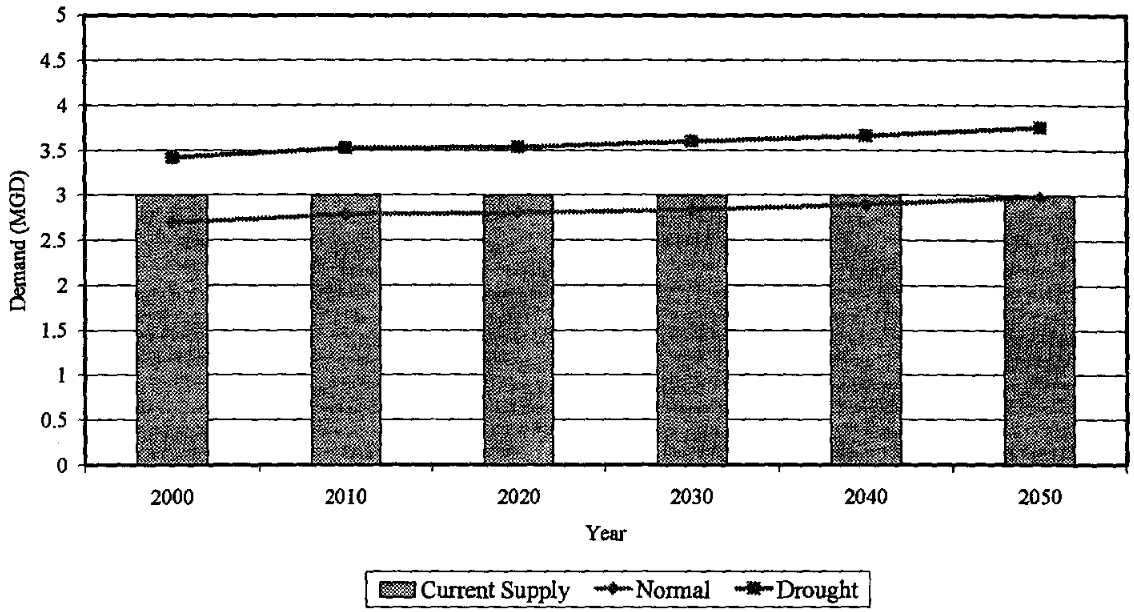
Year	In-City Normal (MGD)	Industrial Sales (MGD)	Normal Municipal Sales (MGD)	Normal Total (MGD)	Dry Year Extra In-City (MGD)	Dry Year Extra Municipal Sales (MGD)	Dry Year Total (MGD)
2000	1.914	0.660	0.114	2.688	0.686	0.041	3.415
2010	1.837	0.757	0.192	2.786	0.670	0.070	3.525
2020	1.810	0.806	0.182	2.799	0.669	0.067	3.535
2030	1.793	0.866	0.177	2.836	0.696	0.068	3.600
2040	1.750	0.970	0.172	2.892	0.700	0.069	3.661
2050	1.738	1.076	0.170	2.984	0.701	0.069	3.753

The main water supply for the City is ground water from two well fields, the Odell and Winston fields, located north of the City. The water produced by the Odell-Winston wells generally meets Texas Drinking Water Standards for total dissolved solids (TDS) but exceeds the limit for nitrate. During average precipitation periods the wells can sustain a water pumpage rate of approximately 2.5 MGD. This rate may increase or decrease, depending on rainfall conditions.

Figure ES-1 compares the City's existing supply to projected demand. Under normal precipitation conditions with conservation implemented, the City's existing supply will be adequate to meet 2050 demands. However during dry periods, shortages in supply are imminent and other supply sources will be needed. Several alternative supply sources were examined in this study including treated surface water from Wichita Falls, raw surface water from Wichita Falls, desalination of water from Lake Diversion, nitrate removal of current sources and ground water from Round Timber Ranch. Nitrate removal and ground water from Round Timber Ranch are the recommended supply alternatives.

Nitrate removal does not increase supply but can be used to bring the existing supply into compliance with drinking water standards. Several alternative nitrate

Figure ES-1
Comparison of Current Supply and Projected Demand



removal treatment methods were analyzed and an ion exchange process is recommended for the following reasons:

- Over the twenty year planning horizon, ion exchange is less costly;
- The ion exchange process produces a smaller waste stream which can be treated without requiring expansions at the wastewater treatment facility; and
- Based on preliminary discussions with the TNRCC, an ion exchange process would be approved for the City without expensive and time-consuming pilot plant testing.

The ion exchange process would treat about 2,280 gpm of well water that would be blended with 1,635 gpm of untreated well water to enable the City to meet the regulatory limits for nitrate.

The City of Altus, Oklahoma leases the well field from Round Timber Ranch but has not used this source for several years. The City of Altus may consider leasing their right to the City of Vernon. Available records indicate the Round Timber Ranch well field can produce approximately 1.2 MGD for a period exceeding five years, assuming average recharge conditions. However, before the City of Vernon enters into an agreement with the City of Altus, a detailed study of the well field would need to be performed.

The water distribution and wastewater systems were evaluated as part of this study. The water distribution system generally is capable of meeting the City's needs through the year 2020. The primary recommendation is the addition of two loop lines that are needed to better transport water from the booster pump stations to elevated storage tanks and to remedy future pressure problems in the southern and western portions of the City. Several improvements to the wastewater system are required for the City to meet its 2020 needs including expansion to the southwest to provide sewer service to residents currently using septic tanks, improvements to collection lines and maintenance of smaller lines.

The Capital Improvement Plan is organized into four areas: water treatment; water supply; water distribution; and wastewater system. For each area, a brief description of the projects, dates, and associated costs are listed.

- Water Treatment
  - Installation of an ion exchange facility for nitrate removal, 2000-2002, $4,513,691.
- Water Supply
  - Direct connection of in-city wells to the proposed treatment plant and Rhodia Industries to supply its manufacturing needs with untreated water, 2000-2001, $1,171,110.
  - Replace existing 150,000-gallon Odell Well Field Storage Tank to meet safety and sanitary requirements, 2000-2001, $222,600.
  - Lease and develop water supply from Round Timber Ranch to meet the City's projected demands through 2050, 2001-2005, $4,425,400.
  - Paint and upgrade 750,000-gallon Odell Well Field Storage Tank to meet requirements, 2003-2004, $276,000.
- Water Distribution System
  - Six line improvements, 2000-2010, $2,158,798.
  - Three storage tank improvements, 2001-2005, $1,443,250.
- Wastewater System
  - Five line extensions and improvements, 2000-2006, $3,802,872.
  - One lift station elimination, 2005-2006, $282,325.

1.0 INTRODUCTION

The City of Vernon is located in Wilbarger County in north Texas near the Texas/Oklahoma border. It is the largest city in the county with a population of about 12,500, which accounts for 80 percent of the total county population. As a result, the City of Vernon provides for a large portion of the county's municipal water needs and nearly all of the county's industrial water needs. Vernon currently obtains all of its water supply from wells in the Seymour Aquifer, mostly located north of the city. Average–day water use between 1980 and 1996 ranged from a low of 2.2 mgd (1990) to a high of 3.3 mgd (1991), with little indication of a trend in use. Previous studies have indicated that the long-term reliable supply from the City's existing well fields may not meet increasing demands. Also, water from the City's wells in the Seymour Aquifer has elevated nitrate levels, which is often slightly in excess of the U.S. EPA primary drinking water standard of 10 milligrams per liter (mg/l) of nitrate as nitrogen. In response to these concerns the City initiated the development of a Water and Wastewater Comprehensive Plan. As part of this plan, assessments of the City's water supply and wastewater systems were conducted, including evaluations of:

- Population, water and wastewater demands through 2050,
- Existing and potential ground water resources,
- Water supply alternatives,
- Nitrate removal alternatives,
- Water distribution system, and
- Wastewater treatment system.

Based on the findings of these evaluations, a Capital Improvement Plan was prepared and is presented in Section 11. A listing of the various meetings and presentations held during the development of the plan is included in Appendix A.

2.0 POPULATION, WATER AND WASTEWATER USE

In order to assess the ability of the City of Vernon's current water and wastewater systems to meet existing and future demands, an evaluation of the City's growth and water use demands was conducted. The City of Vernon currently provides water for in-city customers, surrounding communities (contract customers) and most of the county's industrial and manufacturing needs. It is anticipated that the City will continue to provide water to these entities. Vernon's wastewater system serves in-city municipal and commercial customers.

2.1 Historical and Projected Population

The historical and projected populations for the City of Vernon are based on data obtained from the Texas Water Development Board (TWDB), and are shown on Table 2-1. As part of the Senate Bill One regional water planning efforts, the projected populations for cities and counties were reviewed and modified if warranted. For the City of Vernon, there were no changes to projected population. However, there were significant changes to the rural county other population in Wilbarger County. For consistency with Senate Bill One planning, the Senate Bill One population projections are presented in this report.

Historical data from 1980 through 1996 indicate that the population of the City of Vernon decreased from 1986 through 1990, but increased slightly after 1990. Projections of future populations for the City of Vernon show a continuing growth trend. Figure 2-1 displays these historical and projected population trends for Vernon.

The projected population for Wilbarger County-Other is expected to increase from 2,925 in year 2000 to 3,527 in year 2050. The populations for Vernon's municipal customers are expected to remain approximately the same through the planning period.

Figure 2-1
Historical and Projected City of Vernon Population

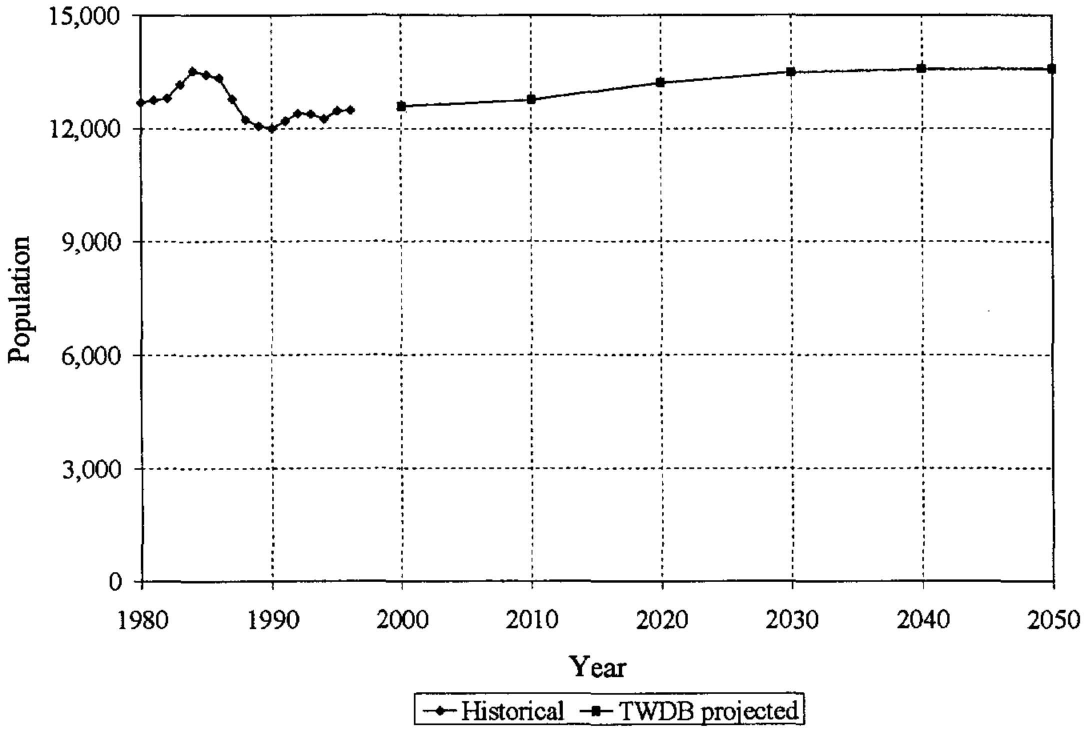


Table 2-1
Historical and Projected Population

Year	Historical Population	Year	Projected Population
1980	12,695	2000	12,590
1981	12,752	2010	12,755
1982	12,808	2020	13,215
1983	13,159	2030	13,480
1984	13,520	2040	13,568
1985	13,430	2050	13,576
1986	13,340		
1987	12,773		
1988	12,230		
1989	12,069		
1990	12,001		
1991	12,195		
1992	12,400		
1993	12,371		
1994	12,246		
1995	12,460		
1996	12,481		

Source: TWDB (1999) and Biggs and Mathews, Inc.et al (2000)

2.2 Historical Water Use

The historical annual water use for the City of Vernon from 1980 through 1996 is summarized on Table 2-2. The information in this table is from TWDB records based on data reported by Vernon. The industrial water use values represent sales of potable water for manufacturing purposes. Municipal sales are wholesale sales to other water suppliers. The in-city municipal use and in-city average per capita use values include all in-city use not counted as industrial sales. These values show that the water use has remained relatively steady over the period from 1980 through 1996.

Table 2-2

Historical Water Use and per Capita In-City Municipal Use

Year	Estimated Population	Water Use in MGD				In-City Municipal Gallons per Capita
		Total	Industrial Sales	Municipal Sales	In-City Municipal	
1980	12,695	3.047	0.653	0.168	2.227	175
1981	12,752	3.102	0.720	0.150	2.232	175
1982	12,808	2.987	0.413	0.186	2.388	186
1983	13,159	2.489	0.337	0.201	1.952	148
1984	13,520	2.765	0.420	0.217	2.128	157
1985	13,430	2.781	0.426	0.305	2.050	153
1986	13,340	2.388	0.374	0.192	1.822	137
1987	12,773	2.375	0.380	0.184	1.811	142
1988	12,230	2.512	0.351	0.174	1.987	162
1989	12,069	2.445	0.402	0.165	1.878	156
1990	12,001	2.211	0.581	0.134	1.496	125
1991	12,195	3.322	0.469	0.222	2.631	216
1992	12,400	2.669	0.567	0.103	1.999	161
1993	12,371	2.671	0.729	0.130	1.811	146
1994	12,246	2.675	0.600	0.162	1.912	156
1995	12,460	2.503	0.546	0.127	1.831	147
1996	12,481	2.843	0.607	0.113	2.122	170

2.3 Projected Water Use

2.3.1 Projected Municipal Water Needs

Municipal requirements are a function of population and per capita use. Table 2-3 shows the average per capita use (1987-1996) and Senate Bill One projected per capita use. TWDB "without conservation" values assume that normal per capita municipal demand will be constant at the average level experienced in recent years. The dry year "without conservation" value is based on the highest per capita use in recent years with a maximum value of 25 percent greater than the average use. This value is less than the actual recorded use of 216 gpcd in 1991. Therefore, the drought per capita values with conservation are based on an initial per capita of 216 gpcd, which reflects the per capita values used in the Senate Bill One planning.

Table 2-3
TWDB Projected per Capita Municipal Demand

Year	Historical per Capita per Day Use (Gallons)	TWDB Projected per Capita per Day Demand in Gallons			
		Without Conservation		With Conservation	
		Normal	Drought	Normal	Drought
Average 1987-1996	158				
2000		160	200	152	206
2010		160	200	144	196
2020		160	200	137	188
2030		160	200	133	185
2040		160	200	129	181
2050		160	200	128	180

Generally, the TWDB has assumed that projected per capita demands "with conservation" are more likely to occur. The projected demands allow for reductions due to additional conservation measures. The historical values for Vernon show no sign of decreasing, and significant reduction in water use through conservation may not be realized. However, for consistency with Senate Bill One planning the per capita demand with conservation values were used. Table 2-4 compares the normal year and dry year water use projections.

Table 2-4
Projected Municipal In-City Use

Year	Population	Per Capita Use (gpcd)	Normal Year Use (MGD)	Dry Year Additional (MGD)	Dry Year Use (MGD)
2000	12,590	152	1.914	0.686	2.600
2010	12,755	144	1.837	0.670	2.506
2020	13,215	137	1.810	0.669	2.479
2030	13,480	133	1.793	0.696	2.488
2040	13,568	129	1.750	0.700	2.450
2050	13,576	128	1.738	0.701	2.438

2.3.2 Projected Other Municipal Use

Table 2-5 displays the projected municipal sales by Vernon for other municipal use in Wilbarger County. The City of Vernon sells water to five water supply systems in the county: Box WSD, Hinds-Wildcat, Lockett, Northside and Oklaunion. Vernon generally provides for all these districts' water needs with the exception of Lockett. Currently, Vernon supplies only a small portion of Lockett's water supply, but it is projected that Vernon will provide for all of Lockett's needs by 2010. The projected populations and water use for these districts are expected to remain fairly constant through the planning period. Based on Senate Bill One population projections and Vernon's per capita water use, the projected municipal sales are summarized on Table 2-5.

2.3.3 Projected Industrial Sales

The City of Vernon provides industrial water to local users. Historically, Vernon has provided essentially all of the industrial use in the county, and this is expected to continue. Table 2-6 shows the projected county industrial sales based on Senate Bill One projections for Wilbarger County. The industrial water use is expected to increase steadily over the 50-year time frame. Recent discussions with local industries indicate that some growth may occur earlier than projected on Table 2-6. However, the total industrial growth over the planning period should remain the same.

Table 2-5
Projected Municipal Sales

Year	Normal Year		Dry Year Additional	
	(Acre-Feet)	(MGD)	(Acre-Feet)	(MGD)
2000	128	0.114	46.1	0.041
2010	215	0.192	78.3	0.070
2020	205	0.182	75.6	0.067
2030	199	0.177	76.8	0.068
2040	193	0.172	77.1	0.069
2050	191	0.170	77.1	0.069

Table 2-6
Projected Industrial Use

Year	Industrial Use (Acre-Feet)	Industrial Use (MGD)
2000	740	0.660
2010	849	0.757
2020	904	0.806
2030	971	0.866
2040	1,087	0.970
2050	1,206	1.076

Source: Biggs and Mathews, Inc. et al (2000)

2.3.4 Projected Vernon Total Requirements

Table 2-7 lists the projected water use for the City of Vernon. Municipal and industrial uses are included in the total water use. Figure 2-2 represents the historical and projected water use, for normal and dry conditions, for Vernon.

Table 2-7
Vernon Total Requirements

Year	In-City Normal (MGD)	Industrial Sales (MGD)	Normal Municipal Sales (MGD)	Normal Total (MGD)	Dry Year Extra In-City (MGD)	Dry Year Extra Municipal Sales (MGD)	Dry Year Total (MGD)
2000	1.914	0.660	0.114	2.688	0.686	0.041	3.415
2010	1.837	0.757	0.192	2.786	0.670	0.070	3.525
2020	1.810	0.806	0.182	2.799	0.669	0.067	3.535
2030	1.793	0.866	0.177	2.836	0.696	0.068	3.600
2040	1.750	0.970	0.172	2.892	0.700	0.069	3.661
2050	1.738	1.076	0.170	2.984	0.701	0.069	3.753

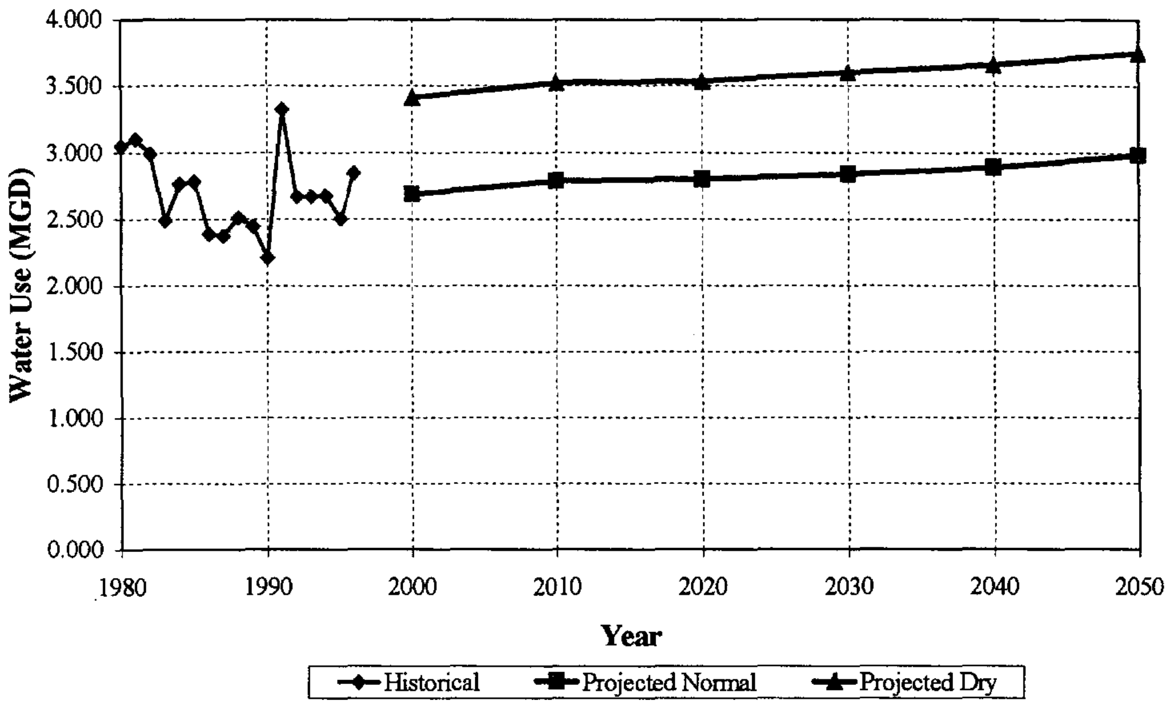
2.3.5 Projected Wilbarger County Requirements

Table 2-8 is the summary of the projected total average-day requirements by decade from 2000 through 2050 for Wilbarger County. The values shown in Table 2-8 are based on the Senate Bill One projections.

Table 2-8
Wilbarger County Projected Total Average-Day Needs Under Dry Conditions

Year	Projected Dry Year Average-Day Demand in MGD						Dry Year Total (MGD)
	Vernon Municipal	Other Municipal	Industrial	Irrigation	Steam Electric Power	Mining and Livestock	
2000	2.600	0.433	0.660	17.013	7.226	1.624	29.556
2010	2.506	0.457	0.757	16.502	10.705	1.624	32.551
2020	2.479	0.461	0.806	16.007	14.273	1.624	35.650
2030	2.488	0.464	0.866	15.527	17.841	1.624	38.810
2040	2.450	0.463	0.970	15.062	17.841	1.624	38.410
2050	2.438	0.478	1.076	14.609	17.841	1.624	38.066

Figure 2-2
Historical and Projected Water Use
City of Vernon



2.4 Wastewater Projections

The wastewater flows in a municipal collection system are quite variable, depending on time, wastewater discharge origin, and weather. To better identify the magnitude of these variations, the components of the wastewater flow were assessed separately using historical information and projected growth patterns. These components include base flow (domestic or industrial), time variations (peak hour and average day), and wet weather inflow/infiltration.

A detailed evaluation of the historic patterns and extent of the variation is required to establish a reliable basis for projecting future flow rates. Monthly average day and maximum day wastewater flows along with rainfall records for the years 1996 through 1998 are summarized in Table 2-9. The per capita wastewater flows were determined using the historical populations over the last three years. The monthly maximum day flows ranged from a low of 1.370 MGD in November 1998 to a high of 2.920 MGD in August 1996.

2.4.1 Industrial Wastewater Flows

In the City of Vernon, the industrial wastewater flows were estimated using a percentage return flow of the water used by these industrial and commercial customers. An approximate estimate of the wastewater flows is 75 percent of the water usage. The primary industrial wastewater customers are shown in Table 2-10 along with projected average and peak wastewater flows for the year 1999. A 2.0 peaking factor was used as an approximate estimate of the peak two-hour industrial flow for all industrial and commercial customers. These peaking factors should represent a conservative estimate of the total peak industrial flow for the City of Vernon. The future industrial wastewater flows were estimated as a 30 percent increase of the 1999 industrial wastewater flows. The 1999 peak two-hour industrial flow is estimated at 0.322 MGD. The projected 2020 peak two-hour industrial flow is 0.419 MGD.

Table 2-9
Historical Wastewater Flows

Month/Year	Population	Avg. Day Wastewater Flow (MGD)	Avg. Day Wastewater Flow (GPCD)	Max. Day Wastewater Flow (MGD)	Monthly Rainfall (Inches)	Rainfall on Max. Flow Day (Inches)
Jan., 1996	12,481	1.056	85	1.820	0.50	
Feb., 1996		1.131	91	1.940	0.00	
Mar., 1996		1.319	106	2.100	2.14	
Apr., 1996		1.177	94	1.990	0.35	
May, 1996		1.226	98	3.050	1.23	1.23
Jun., 1996		1.316	105	2.290	1.72	
Jul., 1996		1.308	105	2.070	1.93	
Aug., 1996		1.323	106	2.920	3.16	
Sep., 1996		1.445	116	2.041	3.42	1.5
Oct., 1996		1.426	114	2.110	0.13	
Nov., 1996		1.426	114	1.920	1.35	
Dec., 1996		1.410	113	1.940	0.00	
Average for Year		**1.297**	**104**	**2.183**	**1.33**	
Jan., 1997	12,500	1.401	112	1.567	0.30	
Feb., 1997		1.413	113	1.934	4.54	2.8
Mar., 1997		1.373	110	1.550	0.00	
Apr., 1997		1.495	120	2.276	5.64	2.96
May, 1997		1.514	121	1.763	2.51	0.05
Jun., 1997		1.531	122	1.793	4.84	1.66
Jul., 1997		1.433	115	1.761	0.37	0.2
Aug., 1997		1.391	111	1.596	2.57	1.2
Sep., 1997		1.435	115	2.861	7.40	5.4
Oct., 1997		1.465	117	1.808	1.76	0.08
Nov., 1997		1.489	119	1.654	0.80	
Dec., 1997		1.565	125	1.800	3.18	0.3
Average for Year		**1.459**	**117**	**1.864**	**2.83**	
Jan., 1998	12,515	1.598	128	1.761	1.96	0.47
Feb., 1998		1.617	129	1.807	3.43	
Mar., 1998		1.777	142	2.064	3.95	2.56
Apr., 1998		1.826	146	2.018	0.87	
May, 1998		1.605	128	1.840	0.54	
Jun., 1998		1.464	117	1.651	1.05	0.3
Jul., 1998		1.328	106	1.563	0.59	
Aug., 1998		1.281	102	1.414	0.59	0.1
Sep., 1998		1.266	101	1.515	0.18	
Oct., 1998		1.309	105	1.544	1.38	0.1
Nov., 1998		1.282	102	1.370		
Dec., 1998		1.327	106	1.563		
Average for Year		**1.473**	**118**	**1.676**	**1.45**	

Table 2-10
Industrial and Commercial Wastewater Flows

Customer	1999 Annual Average Water (gpd)	Estimated Annual Average Wastewater (gpd)	Estimated Peak Wastewater (gpd)	Estimated Peak Wastewater (MGD)
Wright Foods	165,528	123,316	246,632	0.247
Wilbarger Hospital	11,880	8,850	17,701	0.018
WTU	30,744	22,904	45,808	0.046
VRJC	7,776	5,793	11,586	0.012
TOTAL	**215,928**	**160,863**	**321,727**	**0.322**

Notes: The estimated wastewater flow was calculated as 75% of the water consumption.

Wastewater from Rhodia Industries is treated on-site at Rhodia's wastewater treatment plant. The City of Vernon does not receive wastewater from Rhodia.

2.4.2 Domestic Wastewater Flows

The average domestic wastewater flow was estimated from the meter records. Dry weather flow (base flow) was determined using average day wastewater flows that occurred at least five days after a storm event. For the metering area examined the overall average day dry weather flow was 1.487 MGD. After accounting for industrial flows, the average day domestic wastewater flow was calculated at 1.162 MGD. Using the 1999 projected population, the average day per capita domestic wastewater flow is estimated at 93 gallons per day.

Harmon's Equation was used to calculate a peaking factor to convert average day domestic wastewater flow to a peak domestic wastewater flow. The calculated Harmon's peaking factor using the 1999 population of 12,540 for the overall wastewater collection system is 2.81. Using this peaking factor, the 1999 peak two-hour domestic wastewater flow is projected at 3.265 MGD.

2.4.3 Infiltration and Inflows

The wet weather flow records were analyzed and compared to the dry weather periods to isolate the flow resulting from infiltration and inflow. Several significant storm events that have occurred over the last few years can be utilized for infiltration and inflow analysis. The quantity of wastewater flow resulting from infiltration and inflow was calculated by subtracting the average day dry weather flow from the peak wet weather wastewater flow for these specific storm events as shown in Table 2-11. Wastewater collection systems are typically designed to convey the peak infiltration and inflow resulting from a 5-year storm event. This provides a condition where all wastewater flows throughout the wastewater collection system are contributing to the peak two-hour design flow. A 2-hour duration five year storm event was chosen from the TP40 urban hydrology publication as the design storm. The 5-year 2-hour storm event for the City of Vernon is estimated at 3.0 inches . The averages of the rainfall and estimated infiltration and inflow are also shown in Table 2-11. Using a direct relationship between these averages and the 5-year 2-hour storm event, a peak infiltration and inflow of 0.847 MGD was calculated.

Table 2-11

Infiltration/Inflow Associated with Major Storm Events

Storm Event	Rainfall Amount (Inches)	Peak Wet Weather Wastewater Flow (MGD)	Avg. Dry Weather Flow Before Storm Event (MGD)	Estimated Infiltration & Inflow (MGD)
Sept. 4, 1996	1.5	2.041	1.445	0.596
April 25, 1997	2.96	2.276	1.36	0.916
Sept. 22, 1997	5.4	2.861	1.3	1.561
Mar. 15, 1998	2.56	2.064	1.63	0.434
Avg.	3.105			0.877

TP-40, 5-Year 2-Hour Storm Event for Vernon 3 Inches

Recommended Peak Infiltration & Inflow for 5-Year Storm Event 0.847 MGD

2.4.4 Total Wastewater System Flows

A summary of the wastewater design flows for the City of Vernon is presented in Table 2-12. These flows include average day and peak flows for domestic and industrial wastewater, and an estimate of the peak infiltration/inflow. The 1999 peak 2-hour design flow is 4.44 MGD, which is the sum of the peak domestic, peak industrial and peak infiltration/inflow. Accounting for population and industrial growth, the 2020 wastewater peak two-hour design flow is 4.75 MGD.

Table 2-12
Summary of Wastewater Design Flows

Wastewater Flow	1999	Projected 2020
Average Day Dry Weather	1.487 MGD	1.647 MGD
Average Day Industrial	0.161 MGD	0.209 MGD
Average Day Domestic	1.162 MGD	1.225 MGD
Average Day Domestic (per capita)	93 gpcd	93 gpcd
Peaking factor for 2-Hour Peak Domestic	2.81	2.81
Peak 2-Hour Domestic	3.27 MGD	3.44 MGD
Peaking factor for Industrial	2	2
Peak Industrial	0.322 MGD	0.419 MGD
Peak Infiltration/Inflow	0.847 MGD	0.893 MGD
Peak Infiltration/Inflow (per capita)	68 gpcd	68 gpcd
Peak 2-Hour Design Flow	4.44 MGD	4.75 MGD

3.0 EVALUATION OF EXISTING GROUND WATER RESOURCES

The City of Vernon currently uses ground water from two principal well fields, the Odell and Winston well fields. The Odell water supply wells are located approximately 12 miles north of the City and the Winston wells are located 2 miles north of the Odell field. Water from these wells is pumped to a central storage tank at the Odell field, then flows by gravity to the City for distribution. Since these well fields are operated as a single supply source, they are referred to collectively as the Odell-Winston well field. Additional water supply wells are located within the city limits. These city wells are only used as needed to meet peak demands in the summer.

As part of this study, the reliability and performance of the current water supply operations at the Odell-Winston well field and a potential new supply source at Round Timber Ranch were evaluated. Well data, historical pumping records and precipitation data were reviewed. The findings of this evaluation are detailed in the Ground Water Resources Study Report, included in Appendix B, and summarized below. A review of the wells within the City of Vernon was not included in this evaluation.

3.1 Odell-Winston Well Field

The Odell-Winston well field draws water from the Seymour Aquifer. The Seymour Formation consists of isolated areas of alluvium that vary in thickness from 70 to 110 feet in the area of the Odell-Winston well fields. The aquifer is relatively shallow and exists under water table conditions. The upper portion of the Seymour consists of fine-grained and cemented sediments. The basal portion of the formation has a consistent zone of sands, gravels and conglomerate that typically produces greater volumes of water.

Recharge to the Seymour is largely due to direct infiltration of precipitation over the outcrop area. The rate of recharge to the Seymour is probably greater in the Odell-Winston area since the topography is gently rolling and much of the surface is composed of highly permeable sands. Previous studies have indicated that the recharge rate is about 10 to 15 percent of the annual precipitation. Considering the sandy soils and small runoff in this area, the average annual recharge rate is likely to be closer to 15 percent of the precipitation. The average annual precipitation for Vernon is 26.7 inches per year for the period 1904 to 1997. Over the last decade, the average annual precipitation has been 31.7 inches. Therefore it is likely that recharge to the Seymour during the past 10 years has been greater than the historical average.

Water quality in the Seymour Aquifer is variable throughout the region, and generally ranges from fresh to slightly saline. Moderate to high nitrate concentrations occur in the Seymour over a wide area. These nitrate concentrations are most likely due to agricultural practices, and can be attributed to nitrogen fertilizer or leaching from areas formerly covered with nitrogen-fixing vegetation such as grasses or mesquite groves. Water quality sampling conducted as part of this study found that water from the Odell-Winston wells is considered fresh with moderate nitrate levels. The total dissolved solid (TDS) levels ranged from 300 to 800 mg/l, except for well WW #9 which produced water with 1,016 mg/l of TDS. Thus most of the wells produce water that meets the Texas Drinking Water Standard for TDS. However, nitrate levels in most wells exceeded the Drinking Water Standard of 10 mg/l. Although there does not appear to be a spatial trend in the concentration of nitrate in the water supply wells, the nitrate levels in the Winston wells are generally greater than in the Odell wells. Based on the limited available data shown in Tables 2-2 and 2-3 of the Ground Water Resources Report (Appendix B), no other constituent appears to exceed the Texas Drinking Water Standards.

There are 21 water supply wells in the Odell-Winston well field; fourteen are located in the Odell Well Field and seven are located in the Winston Well Field. In addition, a chlorine injection station and two above ground storage tanks exist at the Odell well field. All wells are equipped with submersible pumps which are routinely set at one foot above the bottom of the well. The pumps were automated in early 1998 so they can be controlled from the City of Vernon. A summary of the well data is included in Appendix B. Since 1960, the annual water supply volumes for the City indicate a general increasing trend, peaking in the mid 1980s. The average daily pumpage over the past ten years is about 2.9 mgd, with peak flow rates greater than 5 mgd. This pumpage includes water from the in-city wells.

3.2 Long-Term Availability of the Odell-Winston Well Field

The water supply availability of an aquifer is comprised of two parts: effective recharge and recoverable storage. For the Odell-Winston well field, the effective recharge was determined to be approximately 15 percent of the annual precipitation. Recoverable storage was estimated from aquifer characteristics, including saturated thickness, storage factor and permeability. Comparisons of well pumping rates to water levels and precipitation to water levels were also used to assess the long-term availability of the Odell-Winston field.

For the Odell Well Field, the saturated thickness of the Seymour Aquifer varies from 24 feet in the western portion of the field to 63 feet toward the south. The wells in the Winston Well Field generally have a greater saturated thickness than the Odell field, averaging about 60 feet. Based on these findings, the Seymour Aquifer has sufficient saturated thickness in most areas of the Odell-Winston Well Field to continue using the ground water as a long-term water supply. The wells with the greater saturated thickness should be used to provide the majority of water during drought or high demand conditions. The wells in the Odell field with the relatively smaller saturated thickness should not be relied upon for continuous water supply during an extended dry period when recharge is reduced.

Comparisons of precipitation to water levels and pumping rates to water levels over the past ten years showed an increasing trend in the water levels. This was attributed to a greater than average annual precipitation and slight decrease in pumping rates (average 2.8 MGD). However, during an extended dry period from 1960 to 1975, water levels showed a declining trend with a lower average pumpage rate (2.1 MGD). This indicates that recharge is a significant factor for determining water supply rates, and the greater than average precipitation during the last ten years has compensated for the larger annual pumping rates.

Based on these findings, it is likely that the Odell-Winston Well Field can sustain a water supply rate of approximately 2.5 MGD, assuming average rainfall rates and recharge conditions. This also assumes that demand for ground water from other users around the well fields will not increase. During a drought period when recharge is reduced, water levels will most likely decline if a pumping rate of 2.5 MGD is maintained. Ground water level declines during drought periods may further decrease the water supply rate of the well field. However, water levels should increase during extended periods of greater than average rainfall.

3.3 Round Timber Ranch Well Field

The Round Timber Ranch Well Field is located north of the Winston Well Field near the Texas - Oklahoma border. The well field consists of 16 water supply wells drilled in the Seymour Formation, varying in depth from 58 to 113 feet. Ground water from the Round Timber Ranch is leased to the City of Altus, Oklahoma, for water supply, but it has not been used since 1989.

The current condition of the well field is unknown. A previous survey in 1993 indicates the well pumps and conveyance system are in poor condition, and only two wells were operational at the time. Available records, generally from November 1978 to May 1986, indicate a slight declining trend in water levels with an average pumpage rate of 1.2 MGD. Since the well field has not been used for ten years it is likely that ground water levels have increased from 1986.

There are no recent water quality data available for the Round Timber Ranch Well Field. Discussions with the City of Altus indicate that the water is generally of good quality with nitrate levels about 8 mg/l during the operation of the well field. A recent sample collected from one of the wells at Round Timber Ranch had a reported nitrate concentration of 12 mg/l. Presently, the Round Timber Well Field is not recharged by the Red River due to a relatively high water table. However, excessive pumpage could reverse the water table gradient, which may result in high TDS water from the Red River recharging the well field.

Reviews of the saturated thickness of the aquifer, pumping rates and water levels indicate that if the Round Timber Ranch Well Field is rehabilitated, it could sustain an average water supply rate of 1.2 MGD for a period exceeding five years, assuming average recharge conditions. For an extended pumping period, ground water levels will most likely decline throughout the well field which could reduce sustainable pumping rates. Likewise, an extended drought will result in a decline of ground water levels. Therefore, if the Round Timber Ranch Well Field is used as a long-term water supply, sustainable pumping rates are likely to be less than 1.2 MGD. However, additional data are needed to better assess the long-term reliability of the well field.

3.4 Conclusions and Recommendations

Based on the available information, conclusions and recommendations regarding the Odell-Winston well field are as follows:

- The well field could likely sustain a pumping rate of approximately 2.5 MGD, assuming average rainfall and recharge rates.
- During an extended drought, ground water levels will decline, reducing sustainable pumping rates.
- Ground water supply rates could be increased with additional water supply wells installed outside the area of drawdown of the existing well field.
- Recharge rates could be increased at the existing well fields by building small dams and

infiltration wells in surface water drainages.

- The creation of a 1-mile buffer zone around the existing well field, within which groundwater use and agricultural activities would be restricted, would help protect the field's existing supply and potentially reduce future nitrate contamination.
- To reduce operation and maintenance costs and increase the system's reliability, it is recommended that the City develop a well field management plan that outlines regular maintenance, recommended pumping rates, and trigger conditions that warrant modifications to the operation (i.e., changing pump rates at different well fields, etc.).
- During drought periods, it is recommended that the Winston Well Field should be pumped at higher rates than the Odell Well Field due to the aquifer's greater saturated thickness in the vicinity of the Winston field.

For the Round Timber Ranch well field, it was concluded that:

- If the well field is rehabilitated, it is likely that it could sustain an average rate of 1.2 MGD for a period of at least five years, assuming average rainfall and recharge conditions.
- If the well field is to be used for a longer period than five years, the sustainable pumping rate may have to decrease from 1.2 MGD. Additional wells could be installed outside the influence of the existing well field, but additional data are needed to provide a more definitive estimate of the long-term sustainable pumping rate.

4.0 COMPARISON OF SUPPLY AND DEMAND

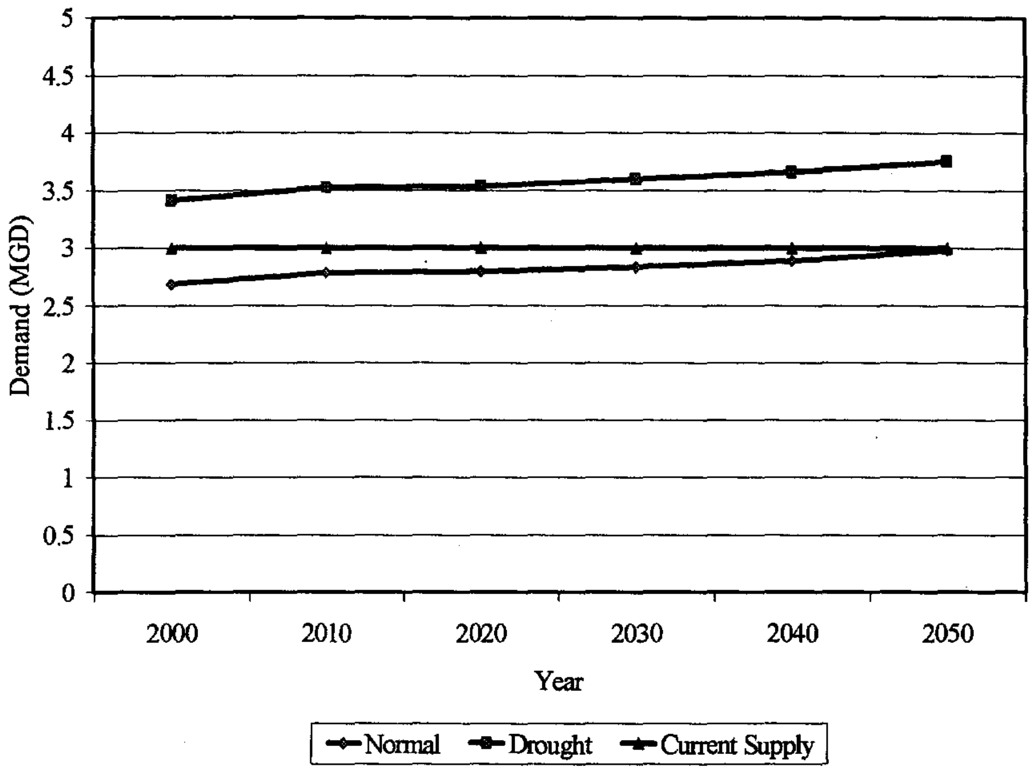
As discussed in Section 2, the projected population for the City of Vernon is expected to increase by 8 percent by 2050 and the per capita use is expected to slightly decrease through the planning period due to conservation. Municipal sales are projected to increase in 2010 when Lockett is expected to purchase additional supply from Vernon. After 2010, municipal sales slightly decrease, but industrial use is projected to steadily increase over the 50-year period. Based on these projections, the total water requirements for the City of Vernon during normal rainfall conditions are expected to increase by about 11 percent between 2000 and 2050, from 2.7 MGD to 3.0 MGD. During a dry year, the projected water demand in 2050 would be even higher (about 3.7 MGD) due to increased lawn irrigation.

The estimated reliable supply from the City's Odell-Winston Well Field is about 2.5 MGD. The in-City wells, which were not evaluated as part of this study, have historically produced approximately 0.5 MGD to meet peak demands. However, the long-term reliability of the in-City wells is unknown. In addition, water from each of the City's well fields has reported nitrate levels in excess of the regulatory limit of 10 mg/l. Generally, the nitrate levels in the in-City wells and the Winston Well field are higher than the Odell Well Field.

Assuming the in-City wells continue to produce 0.5 MGD, the total long-term supply available to the City of Vernon is about 3 MGD. Thus, there is a gap between the city's projected long-term water needs and the reliable supply from the current well fields. For normal rainfall conditions, the city has sufficient supply through 2050, provided conservation measures are implemented. For dry year conditions, the shortage is imminent. A comparison of water supply to projected demands is shown on Figure 4-1.

Figure 4-1

Comparison of Supply and Demand



5.0 SCREENING OF WATER SUPPLY ALTERNATIVES

Based on the supply and demand comparisons, a new water supply (or supplies) will be needed to provide additional water to meet the City's projected demands. In addition, the City also needs to consider alternatives that would provide good quality water such that the City can meet the water quality limits for nitrate. In consultation with city staff, fifteen sources of additional or improved water supply for the City of Vernon were considered:

- Treated surface water from
  - Altus, Oklahoma
  - Greenbelt Municipal & Industrial Water Authority
  - Wichita Falls
  - Frederick, Oklahoma
- Raw surface water from
  - Altus, Oklahoma
  - Witchita Falls
  - Frederick, Oklahoma
  - Santa Rosa Lake
  - A new dam on Beaver Creek
  - Lake Diversion (with desalination)
- Desalination of surface water
- Pease River chloride control project
- Additional groundwater from Round Timber Ranch well field (Altus, Oklahoma)
- Nitrate removal from groundwater
- Industrial reuse

The screening of alternatives was based on meetings with potential suppliers and review of existing data and reports. The criteria used were quantity available, quality, comparative cost, distance from Vernon, permitting complexities, institutional difficulties, and time of development. Based on this screening process, five alternatives were selected for more detailed analysis. The following describes the findings of the screening and the reasons for decisions on whether or not to pursue detailed analysis of each of the alternatives. A summary of screening process is presented on Table 5-1.

Table 5-1
Summary of Comparison of Alternatives

Alternative	Quantity	Comparative Quality	Comparative Cost	Distance (miles)	Permitting Complexity	Institutional Difficulty	Time of Development (years)	Detailed Study
Treated Surface Water								
Altus, Oklahoma	0	Good	High	35	Moderate	High	5	
Greenbelt MIWA	0	Good	Very High	110	Low	High	5	
Wichita Falls	**2**	**Good**	**High**	**50**	**Low**	**Moderate**	**5**	**Yes**
Frederick, OK.	1	Good	High	25	Moderate	High	5	
Raw Surface Water								
Altus, Oklahoma	0	Good	High	35	High	High	5	
Wichita Falls (Kickapoo)	**2**	**Good**	**High**	**45**	**Low**	**Moderate**	**5**	**Yes**
Frederick, OK.	1?	Good	High	25	High	High	5	
Santa Rosa Lake	0	Good?	High	10	Low	High	5	
Other Projects								
Beaver Creek Dam	3?	Fair	Very High	20±	High	High	15	
Lake Diversion/ Desalination	**3+**	**Good**	**Very High**	**30**	**Low**	**Moderate**	**5**	**Yes**
Surface Water Desalination	Variable	Good	Very High	10±	Low	Moderate	5	
Nitrate Removal	**0***	**Good**	**Moderate**	**0**	**Moderate**	**Low**	**3**	**Yes**
Pease River Chloride Control	0	Fair-Poor	High	0	Very High	Very High	25	
Industrial Reuse	?	Fair-Poor	Moderate	0	Moderate	High	5	
Round Timber Ranch	**1?**	**Fair**	**Low to Moderate**	**20**	**Low**	**Moderate**	**3**	**Yes**

5.1 Alternatives Recommended for Further Analysis

Treated Surface Water from Wichita Falls

Treated water from Wichita Falls could provide up to 2 million gallons per day (MGD) of good quality water for Vernon. The purchase cost would be low for treated water (about $0.95 per thousand gallons). However, the total cost would be high due to the 50 mile distance the water must be pumped from Wichita Falls, which results in high capital costs for transmission facilities and high operating costs. Wichita Falls is willing to discuss the sale of treated water from the Cypress Water Treatment Plant which is nearest to Vernon. Permitting complexity is expected to be minimal with only a moderate level of institutional difficulty. The time of development for this alternative would be approximately five years.

Raw Surface Water from Wichita Falls (Lake Kickapoo)

Raw surface water from Wichita Falls out of Lake Kickapoo could provide Vernon with up to 2 MGD of good quality water. The total cost would be high due to the need to transport the water 45 miles to Vernon and build a plant to treat it. The permitting complexity would be low with a moderate level of institutional difficulties. Wichita Falls currently sells raw water for $0.205 per thousand gallons. The time required for project development would be about five years.

Raw Surface Water from Lake Diversion with Desalination

The Red River Authority is interested in pursuing a regional water supply project using Lake Kemp/Lake Diversion water with desalination. Possible customers include Vernon, Electra, Seymour, and the water supply corporations in the area. This alternative could provide over 3 MGD of good quality water for the City of Vernon. However, the comparative cost is very high. Lake Diversion has a high total dissolved solids (TDS) concentration of 1,700-1,800 mg/l. The proposed Wichita River chloride control project may lower the salts in the lake. The approach RRA has considered in the past would be to purchase Lakes Kemp/Diversion water from Wichita Falls, use excess capacity in an existing West Texas Utilities (WTU) pipeline leading to the Oklaunion power plant, and treat the water by reverse osmosis to reduce the TDS. In exchange for use of its pipeline and space for the treatment facility, WTU requested that the blowdown water from the power plant be treated to reduce disposal. This would increase the TDS levels of the source water, which would increase the costs of treatment. Treated water would be purchased from RRA and transported 8 miles from the Oklaunion plant to Vernon. The permitting complexities of this alternative are low while the institutional difficulties are moderate. This option would take approximately 5 years to develop.

Additional Groundwater from Round Timber Ranch Well Field (Altus, Oklahoma)

The possibility of obtaining water for Vernon from the Round Timber Ranch was discussed with representatives of the city of Altus, Oklahoma. The City of Altus has a contract with the owner of the Round Timber Ranch (located on the south (Texas) bank of the Red River) allowing Altus to pump groundwater from the ranch as long as they make minimum payments and pay 2 cents for every 1,000 gallons they pump. Altus might be interested in leasing the right to pump water from Round Timber Ranch for 25 years if Altus can retain the right to make use of the supply in an emergency. Altus plans to study its projected needs before selling any of its water, and Vernon should perform a legal review of the Round Timber contract to make sure of the impact of any resale. The Round Timber wells have not been operated since 1991 or 1992. The well field has 16 wells, of which two have reverted ownership back to Round Timber Ranch and one has collapsed. Altus believes that the expected long-term yield is about 2 MGD. Woodward-Clyde estimates that the long-term sustainable supply from Round Timber Ranch is less than 1.2 mgd and recommends additional study to determine the reliable supply and the quality of the water. The comparative cost of this alternative is low to moderate as the water would only be transported 20 miles. Permitting complexity is low, and institutional difficulty is moderate. This alternative could probably be developed in three years.

Nitrate Removal from Groundwater

The nitrate removal option does not add water to the current water supply system, but it would improve the water quality of the existing supplies. The cost would be moderate with no additional piping necessary for transporting the water. The permitting complexity would be moderate, and the institutional difficulty would be low. Nitrate removal can be accomplished either using biological treatment or membrane treatment. The pros and cons of these methods are discussed in detail in Section 6. The nitrate removal project would take about 3 years to complete.

5.2 Alternatives Explored but Not Recommended

Treated Surface Water from Altus, Oklahoma

The City of Altus, Oklahoma, has good quality water, but the City does not want to sell any of its surface water from Tom Steed Reservoir. The City uses 5 of its permitted 7 MGD water from Tom Steed on an average day. Altus also does not want to commit limited treatment capacity to supply another city, and Altus is concerned about using old pipelines to transport water. The comparative cost of this source is high because the treated water would be expensive at Altus and would have to be transported approximately 35 miles and across the Red River. Permitting complexities are expected to be moderate. Institutional difficulty would be high because of issues with the interstate sale of water, and the time of development would be around 5 years. This alternative was eliminated because Altus is not interested in selling treated water to Vernon.

Treated Surface Water from Greenbelt Municipal & Industrial Water Authority (GMIWA)

Greenbelt MIWA has good quality water, but does not appear to have any available to sell to Vernon. The reaction of the GMIWA board to the idea of selling water to Vernon is uncertain, but it is unlikely that Vernon could become a member of the MIWA. Greenbelt's treatment plant is rated at 12 MGD, but it is difficult to get more than 8 MGD due to the Safe Drinking Water Act disinfection rules, and the plant is fully utilized in the summer. There is probably some capacity available in the Quanah pipeline. The comparative cost of this alternative is very high due to the transportation distance of 110 miles. The charge to non-member cities is $1.30 per 1,000 gallons of treated water, and transmission costs would be added to this. Permitting complexities are expected to be low, but the institutional difficulties would be high because of Greenbelt MIWA's reluctance to sell to Vernon. The expected time of development is 5 years. This alternative was eliminated because of the very high cost and the lack of water available for sale.

Treated Surface Water from Frederick, Oklahoma

The City of Frederick, Oklahoma, has 1 MGD of good quality treated surface water available for sale. The existing plant capacity is 2 MGD but can be expanded up to 6 MGD. Frederick has rights to 2 MGD from Lake Frederick and 1 MGD from Tom Steed Reservoir which has never been used. The comparative cost is high, and the pumping distance is 25 miles. Permitting complexities are expected to be moderate. The institutional difficulties are expected to be high because of the politics involved with water exportation. The time of development is estimated at 5 years. This alternative was eliminated because of uncertainty about institutional difficulties, limited supply, and high expense.

Raw Surface Water from Altus, Oklahoma

Altus, Oklahoma, has good quality raw water in Tom Steed Reservoir but does not want to sell any of it. Altus would prefer to sell water from the Round Timber Ranch well field, if they choose to sell at all. The City also has water in Altus Reservoir, but the quality is not suitable for municipal use. The comparative cost from Altus would be high, and the water transmission distance is 35 miles. Permitting complexities and institutional difficulties would be high because of interstate water issues. The expected time of development is five years. This alternative was eliminated because Altus does not want to sell suitable quality raw surface water.

Raw Surface Water from Frederick, Oklahoma

The City of Frederick, Oklahoma, has approximately 1 MGD of good quality raw water available to sell. Frederick has a right to 1 MGD of water from the Tom Steed Reservoir which it has not used to date. However, sale of water from Tom Steed Reservoir would trigger "right of first refusal" options for other participants in the project. Altus might exercise its right of first refusal on Tom Steed water if Frederick tries to sell to Vernon. The comparative cost of the raw water would be high as the distance for piping the water would be 25 miles. Permitting complexities are expected to be high, and Frederick is concerned about the politics of water exportation. The institutional difficulties would be high because of exportation issues. The time of development would be roughly five years. This alternative was eliminated because of the limited amount available and the likely institutional difficulties.

Raw Surface Water from Santa Rosa Lake

The Wagonner Estate owns Santa Rosa Lake, and representatives of the estate are not interested in selling Santa Rosa Lake water to Vernon. They are looking to buy water. Although the quality of the water is fairly good, Santa Rosa Lake has a history of low lake levels and high siltation. The lake went totally dry in 1971. The lake is used for irrigation and livestock supply, but it has not been used for potable supply since it went dry in 1971. The comparative cost of the water would be high, and the piping distance is approximately 10 miles. The permitting complexities are low, but the institutional difficulties are high because the Wagonner Estate does not want to sell to Vernon. The time of development would be five years. This alternative was eliminated because the W.T. Wagonner Estate does not want to sell water to Vernon and the source may not be reliable during a drought.

New Dam on Beaver Creek

Another possible source for potable water is to build a new dam on Beaver Creek. The dam could provide approximately 3 MGD of fair quality water. Building such an impoundment would be very expensive, and comparative cost of the supply would be very high. The water would have to be transported roughly 20 miles to reach Vernon. Permitting complexities would be high for a new reservoir, as would the institutional difficulties. Mr. Willingham of the W. T. Wagonner Estate stated that his initial response would be to oppose a reservoir on Beaver Creek. The time of development would be 15 years. This alternative was eliminated because of cost and institutional concerns.

Desalination of Surface Water

Desalination of existing surface water was another possibility that was examined. The amount of water that could be gained through this process is unclear, with little or no reliable supply. The quality would be good. Desalination is an expensive process, so the comparative cost of this supply is very high. The water would be transported about 10 miles. Permitting complexities would be low, and the institutional difficulties would be moderate. The time of development is estimated to be 5 years. This alternative was eliminated because of cost and uncertain supplies.

Pease River Chloride Control Project

The Pease River Chloride Control Project would not provide any additional water supply without additional work by Vernon to develop the supply, but it would improve the quality of the Pease River, which runs through Vernon. The water would be of fair to poor quality. The comparative cost is high, and the piping distance would be small. The permitting and institutional complexities are expected to be very high. The time of development is at least 25 years. This project was eliminated because of institutional complexities and uncertain supplies.

Industrial Reuse

Industrial reuse would add an uncertain amount of fair to poor quality water to the water supply. The comparative cost would be moderate with no additional piping distance. Permitting complexities are expected to be moderate while the institutional difficulties would be high. The expected time of development is five years. This alternative was eliminated because existing industries have indicated that they are not interested in reuse. The alternative should be re-examined if future industries are interested in this source of supply.

6.0 NITRATE REMOVAL EVALUATION

Nitrate is a stable and highly soluble ion with low potential for coprecipitation or adsorption. These properties make it difficult to remove using conventional water treatment processes such as coagulation, clarification and filtration. More sophisticated technologies such as ion exchange, reverse osmosis, electrodialysis and biological denitrification can be used to remove nitrates from drinking water. In the following sections, these treatment methods are discussed in detail.

6.1 Treatment Technologies for Nitrate Removal

Biological Denitrification

Biological denitrification is commonly used for the treatment of municipal and industrial wastewater. However, increasing knowledge and experience indicates that biological treatment may be effective for removing nitrates from drinking water. Biological denitrification has been studied both at laboratory- and full-scale plants in Europe and the process has been evaluated to a limited extent in the United States. The main reasons for the slow transfer of technology from wastewater to water treatment are the concerns over possible bacterial contamination of treated water, the presence of residual organics in treated water, and the possible increase in chlorine demand of treated water.

There have been numerous pilot and demonstration studies conducted on the biological treatment of nitrate laden ground water in the United States. Unfortunately, there are no full-scale biological nitrate removal facilities constructed for drinking water treatment. Recently, Nitrate Removal Technologies, LLC (NRT) is marketing a dentrification system which was originally developed by the University of Colorado. This denitification system, trade-named BioDen™, uses bacteria along with acetic acid (vinegar) to remove nitrate ions from water. The BioDen™ system is an anaerobic biological process in which nitrates are converted by bacteria into harmless nitrogen gas and carbon dioxide. The bacteria that are used in the BioDen™ process are naturally-occurring non-pathogenic bacteria that grow in plastic media packed in reactors. The BioDen™ system consists of three major system components: biological dentrification reactors, biological roughing filters and slow sand filters.

Electrodialysis Process (ED)

Electrodialysis (ED) is an electrochemical separation process in which ions such as nitrates and chlorides are transferred from a less concentrated to a more concentrated solution as a result of an applied direct electric current (DC) . ED treats water by selective removal of undesirable ions (nitrates) through a semi-permeable membrane. An electrodialysis system requires a supply of pressurized water (50 to 75 psi), a membrane stack and a DC power source. Electrodialysis Reversal (EDR) is the same process, with the exception that the polarity of the DC power is reversed two to four times per hour to alter the direction of ion movement for effective ion removal. The EDR process reduces scaling and chemical usage compared with conventional ED and has been used for the production of drinking water from brackish water and seawater.

Reverse Osmosis (RO)

In an RO process, ionic species in water (nitrates, sulfates, etc.) are removed by forcing the water across a semipermeable membrane and leaving nitrates and other ionic species behind. The membranes separate feed water into two effluent streams: the permeate (flow that passes through the membranes), and the concentrate (flow that retains the dissolved and suspended solids rejected by the membranes). Removal of nitrates is achieved by subjecting water in RO cells to pressures exceeding 300 psi. Membranes commonly used for nitrate removal are made of cellulose acetate, while membranes made of polyamides and composite membranes are also available. These membranes do not show preference for any ion, but the salt rejection (nitrates, sulfates, chlorides, etc.) is found to be proportional to the valence of ions present in the water. In addition to the nitrate removal, RO membranes produce water with very low mineral content (lower hardness). Common problems associated with RO membranes include fouling and deterioration of membranes with time. These problems result from the deposition of soluble materials, organic matter, suspended and colloidal particles and other contaminants. Another problem is the disposal of a high volume of wastewater generated by the process.

Ion Exchange (IX)

The ion exchange (IX) process involves passage of nitrate laden water through a resin bed containing strong base anions. The nitrate ions are exchanged for chloride or bicarbonate ions until the resin's exchange capacity is exhausted. Just prior to complete exhaustion of an exchange bed, the exchange bed is taken out of service, and the resin bed is either completely or partially regenerated with sodium chloride or sodium bicarbonate.

An ion exchange system is very similar to a water softening unit used in many residential households and is a proven technology. The process generates only a small amount of waste, but this wastestream has high concentrations of nitrate and salts. Additional problems, such as increased corrosiveness and negative health effects, are associated with the high chloride content of the product water. Sulfate in the raw water is troublesome because the standard anion resins that prefer sulfate to nitrate may not adequately reduce the nitrate concentrations.

6.2 Alternatives Considered

Four nitrate treatment options that appear to be feasible and consistent with the current available nitrate removal technologies were explored. Each of these options is described in the following paragraphs.

Alternative No.1: Construction of a BioDen™ Denitrification Facility

Under this alternative, the City would construct a BioDen™ denitrification facility to remove nitrate from groundwater. The facility would be designed to meet the City's peak water demand of 3,900 gpm. The BioDen™ facility consists of ten biological denitrification filters, biological roughing filters and slow sand filters, feed pumps, numerous flow control valves, chemical (vinegar) feed facility, instrumentation and control.

The BioDen™ process would not treat the entire flow. It would be designed to treat up to 2,950 gpm untreated water. The treated water from the BioDen™ plant would be blended with 950 gpm untreated (bypassed) water to obtain a finished water flow of 3,900 gpm. The nitrate level in the finished water would be less than 8 mg/L as nitrogen. Very little wastestream would be generated by this process.

The biological denitrification filters and biological roughing filters would have to be housed in a building. The slow sand filter could be constructed outdoors but covers are recommended.

Table 6-1
Advantages and Disadvantages of Nitrate Removal Technologies

Technology	Advantages	Disadvantages
Biological Denitrification	• Proven technology for nitrate removal in wastewater treatment field • No significant wastestream generated compared to other technologies • No capital costs for WWTP expansion	• High capital costs compared to other technologies • Longer start-up time • Requires long pilot testing for TNRCC approval • Requires close monitoring of process • Poor automatic process control • Poor performance in lower temperatures
Electrodialysis Process	• No pretreatment required • Treated water has low total dissolved solid (TDS) • No chemicals required in the process • Excellent automatic process control • Stable operation, requires less operator's attention • Quick start-up time	• Not proven in full-scale for nitrate removal • High capital costs compared to other technologies • High operating and maintenance costs • Requires pilot testing for TNRCC approval • Significant quantity of wastestream generated • Requires WWTP expansion or alternate disposal means
Reverse Osmosis	• Proven technology in full-scale • Low capital costs • Excellent automatic process control • Produces water with very low total dissolved solid (TDS) concentrations • Stable operation, requires less operator's attention • Quick start-up time	• High operating and maintenance costs • Significant quantity of wastestream generated • Pretreatment required • Scaling problems due to deposition of suspended and soluble materials • Requires disposal of wastestream high in TDS • Requires pilot testing for TNRCC approval • Requires WWTP expansion or alternate disposal means
Ion Exchange	• Proven technology • Moderate capital costs • Low operating and maintenance costs • Small wastestream generated by this process • No capital costs for WWTP expansion • Pilot testing not required for TNRCC approval • Excellent automatic process control. • Stable operation, requires less operator's attention • Quick start-up time	• Increase of TDS (salt) in product water • Requires disposal of wastestream high in nitrate and sodium chloride level • High sulfate levels may interfere with nitrate removal

Alternative No. 2: Installation of a EDR Facility

In Alternative No.2, the City would install an EDR plant to remove nitrate. The EDR plant would consist of three EDR units, booster feed pumps, prefilters (cartridge filters for pretreatment), flow control valves, instrumentation and control. The entire plant would be installed in a building.

The EDR plant would treat up to 3,850 gpm nitrate contaminated raw water. The treated water would be blended with 600 gpm untreated (bypassed) water to obtain 3,900 gpm finished water having a nitrate concentration less than 10 mg/L as nitrogen. A wastestream of 550 gpm would be generated by this process. The EDR wastestream would discharge to the sewer system and ultimately to the wastewater treatment plant (WWTP). Preliminary information indicates that the WWTP does not have enough capacity to handle the increased flow from the EDR plant. If this alternative was selected, the WWTP would require expansion or an alternate disposal facility would be needed.

Alternative No. 3: Installation of an RO Facility

Under this alternative, the City would install an RO plant to remove nitrate. The membranes used in the RO units are polyamide membranes which are chlorine tolerant. The RO plant consists of modular membrane units, booster feed pumps, low pressure PVC piping, high pressure stainless steel piping, prefilters (cartridge filters for pretreatment) and necessary instrumentation and control.

Since the RO plant would remove more than 90 percent of the nitrates, the entire flow would not require treatment to obtain a finished water nitrate level of 10 mg/L as nitrogen. The RO plant would be designed to treat up to 2,846 gpm of ground water, which would be blended with 1,755 gpm to produce 3,900 gpm of finished water. A reject wastestream of 707 gpm would be generated by this process. As previously discussed, the WWTP does not have enough capacity to handle this wastestream.

The RO plant would be housed in a building. The RO membranes require frequent acid washing to prevent precipitation of sulfate ions in membranes. Therefore, a sulfuric acid facility would have to be installed. The RO membranes would require replacement every three to five years.

Alternative No. 4 Installation of an Ion Exchange Facility

In this alternative, the City would install a continuous ion exchange system with multiple exchange beds. The continuous ion exchange system would employ anion exchange resin beds to exchange nitrate for chloride. A percentage of other anions, such as carbonate, would also be removed in this process, and the system would be designed to account for these species as well. The exhausted exchange beds would be regenerated with a sodium chloride solution.

The exchange system would treat up to 2,280 gpm of nitrate-contaminated water. The treated water would be blended with 1,635 gpm untreated water to produce 3,900 gpm total finished water with a nitrate concentration less than 10 mg/L (as nitrogen). The system's wastestream (up to 15 gpm) would be diverted to the sewer system, and ultimately to the wastewater treatment plant. In contrast to Alternatives 2 and 3, the WWTP has sufficient capacity to handle the small additional flow from this wastestream.

In addition to the ion exchange resin beds, the ion exchange system includes a nitrate monitor, flow controllers, booster pumps, brine pumps, brine tanks and PLC for automatic operation. The entire plant would be housed in a building, excluding the brine storage tank. The brine storage tank would be installed outside on a concrete pad. The exchange resins would be replaced every 5 to 10 years.

6.3 Cost Evaluation

A preliminary opinion of probable construction cost for each alternative is provided in Table 6-2. The annual operating and maintenance (O&M) cost for each alternative is also provided in the table. The capital costs are annualized over 20 years at an interest rate of 7 percent. The annualized capital cost for each alternative is added with its respective O&M cost to determine the total annual cost.

Among the four nitrate treatment technologies evaluated, the ion exchange alternative has the lowest total annualized costs even though it has higher capital cost than an RO plant. The higher annualized costs for the RO plant are due to higher O&M costs associated with the membrane technology. The capital costs for biological denitrification (Alternative No.1) and EDR (Alternative No.2) processes are both significantly higher than the other two alternatives. The cost for the RO plant and EDR system do not include costs associated with expansion of the WWTP or alternative disposal options. If these costs were included, the annual costs for these alternatives would be even higher.

6.4 Recommendations

Both RO and ion exchange processes are proven technologies for nitrate removal from ground water and would be feasible alternatives for the City of Vernon. However, it is recommended that ion exchange be implemented for nitrate removal for the City's system for the following reasons:

- Over a 20-year period, the ion exchange plant would be less costly than an RO facility.
- The ion exchange process would produce very little wastestream which could be treated by the existing WWTP without major plant expansion.
- The RO plant generates a large wastestream which would require WWTP expansion.
- Also, based on preliminary discussions with the TNRCC, an ion exchange process for nitrate removal would be approved for the City of Vernon without expensive pilot plant testing. On the other hand, pilot testing is mandatory for the approval of an RO process.
- High concentrations of TDS in the RO wastestream may cause biomonitoring test failure for the WWTP.

Table 6-2
Cost Evaluation for Nitrate Treatment Alternatives

Alt	Description	Item	Quantity		Unit Cost	Itemized Capital Cost	Itemized Annual Cost	Total Annual Cost
1	Install a biological denitrification facility to remove nitrate from groundwater. The facility consists of biological denitrification reactors, roughing filters, slow sand filters, feed pumps and process control equipment.	1) Equipment costs including feed pumps, instru. & control	1	ls	$6,603,516	$6,603,516		
		2) Building for denitrification & roughing filters	9980	sf	$85	$848,300		
		3) Slow sand filter construction	1	ls	$675,000	$675,000		
		4) Electrical	1	ls	$370,000	$370,000		
						$8,496,816	$802,039	
		5) Yearly O&M costs	794	MG	$.43/1000 gal.		$341,420	
								$1,143,439
2	Install an electro dialysis reversal (EDR) system to remove nitrate from groundwater. Approximately 3,850 gpm well-water will be treated with EDR and blended with 600 gpm untreated water. EDR system will produce about 550 gpm wastestream.	1) Equipment costs including feed pumps, instru. & control	1	ls	$4,528,125	$4,528,125		
		2) Building	6000	sf	$85	$510,000		
		3) Electrical (8% equip. costs)	1	ls	$360,000	$360,000		
						$5,398,125	$509,545	
		4) Yearly O&M costs	1051	MG	$0.46/1000 gal		$483,460	
								$943,005
3	Install a reverse osmosis (RO) plant to physically remove nitrate from ground water. Approximately 2,846 gpm water will be treated by RO units and blended with 1,755 gpm untreated water. RO units will produce about 707 gpm wastestream.	1) Equipment costs including booster pumps, instru. & control	1	ls	$2,354,625	$2,354,625		
		2) Building	7250	sf	$85	$616,250		
		3) Electrical (8% equip. costs)	1	ls	$230,000	$230,000		
						$3,070,875	$289,869	
		4) Yearly O &M costs	546	MG	$0.57/1000 gal.		$296,400	
								$601,089
4	Install ion exchange beds to remove nitrate. Approximately 2,280 gpm well-water will be treated with ion exchange beds and blended with 1,635 gpm untreated water. Ion exchange beds will produce only 15 gpm wastestream.	1) Equipment costs including feed pumps. & controls	1	ls	$2,716,875	$2,716,875		
		2) Building for ion exchange beds	2500	sf	$85	$212,500		
		3) Building for auxiliary skid	600	sf	$75	$45,000		
		4) Electrical	1	ls	$120,000	$120,000		
						$3,094,375	$292,087	
		5) Yearly O&M costs	610	MG	$0.25 /1000 gal.		$152,500	
								$444,587

* Total capital cost is amortized for 20 years at 7% interest rate.

ASSUMPTIONS

Design Flow = 5.88 MGD (3,875 gpm)
Average Flow = 2.88 MGD (2,000 gpm)
Maximum influent nitrate level = 18 mg/L as N
Effluent nitrate level = < 8 mg/L as N

7.0 ALTERNATIVES RETAINED FOR DETAILED ANALYSIS

Five alternatives were recommended for detailed analysis. These include:

1. Treated surface water from Wichita Falls,
2. Raw surface water from Wichita Falls (Lake Kickapoo),
3. Raw surface water from Lake Diversion with desalination,
4. Ground water from Round Timber Ranch well field, and
5. Nitrate removal from ground water.

A description of each alternative is presented below and the advantages and disadvantages are summarized on Table 7-1.

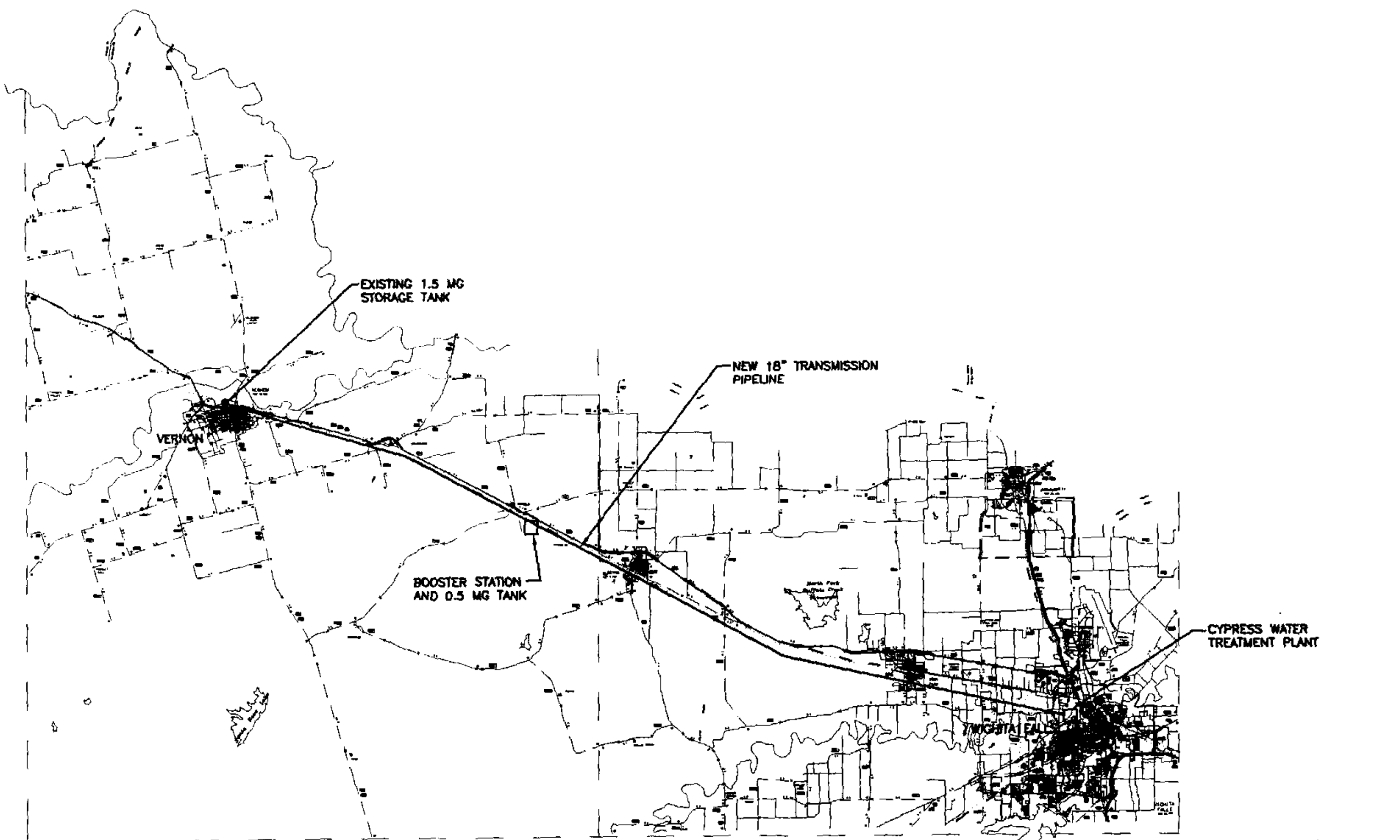
7.1 Description of Alternatives

Alternative 1: Treated surface water from Wichita Falls

The City of Vernon would purchase up to 2 MGD of treated water from the City of Wichita Falls. The estimated purchase cost would be about $0.95 per thousand gallons. Water would be pumped approximately 50 miles via an 18-inch pipeline from the Cypress Water Treatment plant in northwest Wichita Falls to the City's existing 1.5-MG central storage tanks. As shown on Figure 7-1, the transmission pipeline would generally follow the right-of-way for Highway 287, crossing approximately 8 major roads/highways. A new pump station (90 HP) with metering vault would be located at the Cypress plant. A booster station (140 HP) and 0.5-MG storage tank would be located along the route (approximately 30 miles west of Wichita Falls). This water would not require additional treatment.

Alternative 1A: Treated surface water from Wichita Falls, with shared supply to the City of Electra

This is a modification of Alternative 1 such that the pipeline from the City of Wichita Falls would also provide up to 1 MGD of treated water to the City of Electra. It is assumed that 3 MGD of water would be pumped via a 20-inch pipeline to a booster pump station (150 HP) and 0.5-MG storage tank located at Electra. One MGD would be diverted to the City of Electra. The other 2 MGD would be pumped via an 18-inch pipeline to the City of Vernon. It was assumed that the City of Electra



NOTE: FOR ALTERNATE 1A, THE BOOSTER STATION AND STORAGE TANK WOULD BE LOCATED AT THE CITY OF ELECTRA.

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FIGURE 7-1

ALTERNATIVE 1

TREATED SURFACE WATER

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would pay for one third of the pipeline and pumping costs associated with the 20-inch line. This alternative has not been presented to the City of Electra, but the City is actively pursuing new water supplies and may be interested.

Alternative 2: Raw surface water from Lake Kickapoo

The City of Vernon would purchase up to 2 MGD of raw surface water from the City of Wichita Falls. The estimated purchase cost would be about $0.21 per thousand gallons. Water would be pumped approximately 45 miles via an 18-inch pipeline from Lake Kickapoo to a new surface water treatment plant (Figure 7-2). The transmission pipeline would generally follow a rural route, crossing approximately 6 roads/highways and 1 railroad. This alternative would require the construction of an intake structure and a new pump station (90 HP) with metering vault at Lake Kickapoo, and a booster station (110 HP) with a 0.5-MG storage tank. It also would require constructing a new 2-MGD surface water treatment plant.

Alternative 3: Raw surface water from Lake Diversion with desalination

The Red River Authority in conjunction with West Texas Utilities is interested in pursuing a regional water supply project using Lake Kemp/Diversion water with desalination. Water from Lake Diversion would be pumped to the WTU Oklaunion power plant, using an existing pipeline. At Oklaunion, the water would be treated first by conventional surface water treatment, followed by reverse-osmosis. The City of Vernon would purchase up to 2 MGD of treated water from the Red River Authority (additional water may be available for purchase). The estimated purchase cost would be at a minimum about $3.00 per thousand gallons at the Oklaunion power plant. No firm costs for treated water has been established. As shown on Figure 7-3, water would be pumped approximately 8 miles via a 16-inch pipeline from the Oklaunion Water Treatment plant to the existing 1.5-MG storage tank in Vernon. The transmission pipeline would generally follow the right-of-way for Highway 287, crossing approximately 2 major roads/highways and 1 railroad. A new pump station (90 HP) with metering vault would be located at the Oklaunion plant. This water would not require additional treatment.

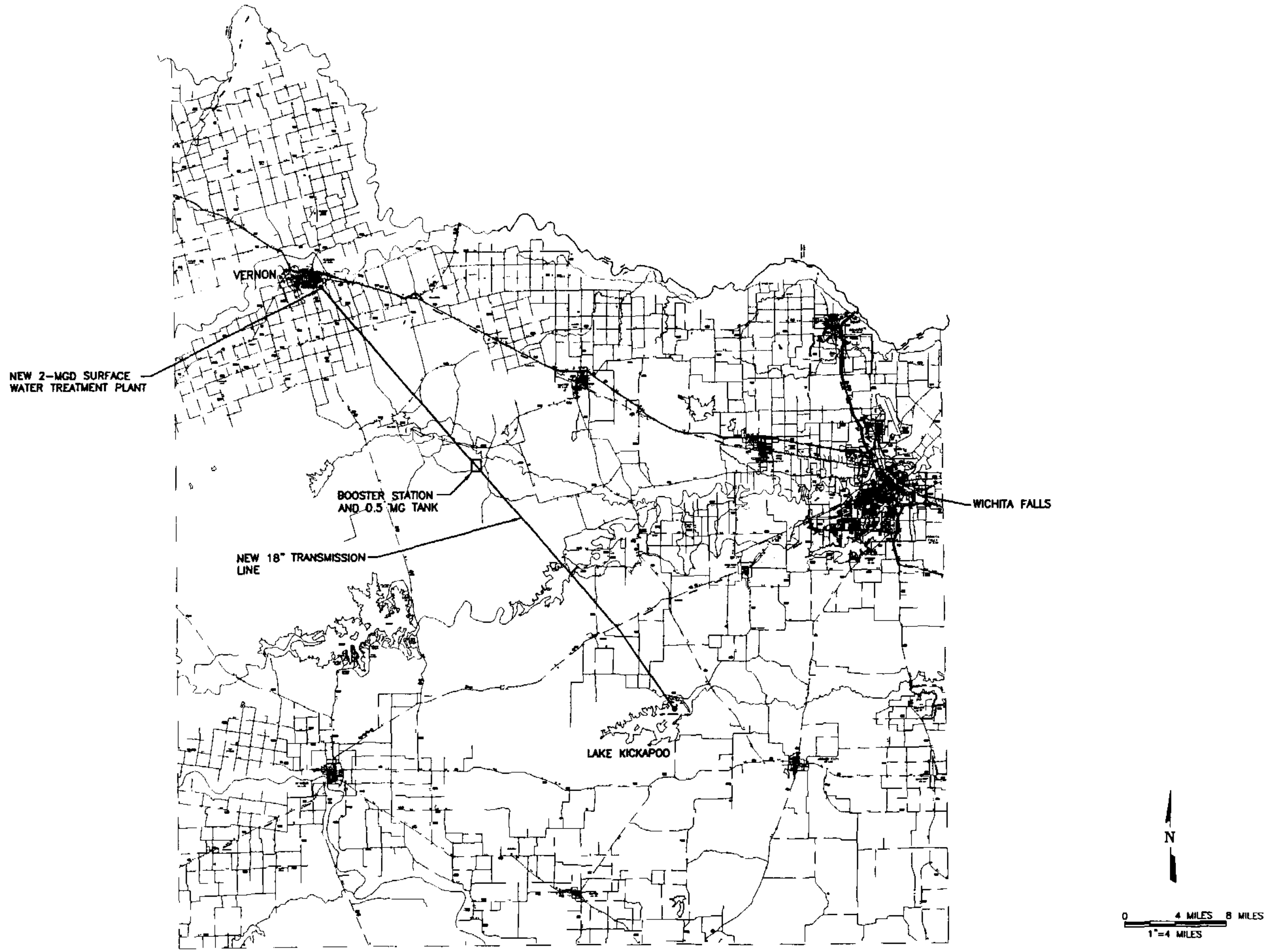

FIGURE 7-2

ALTERNATE 2
RAW WATER FROM LAKE KICKAPOO

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4055 International Plaza-Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

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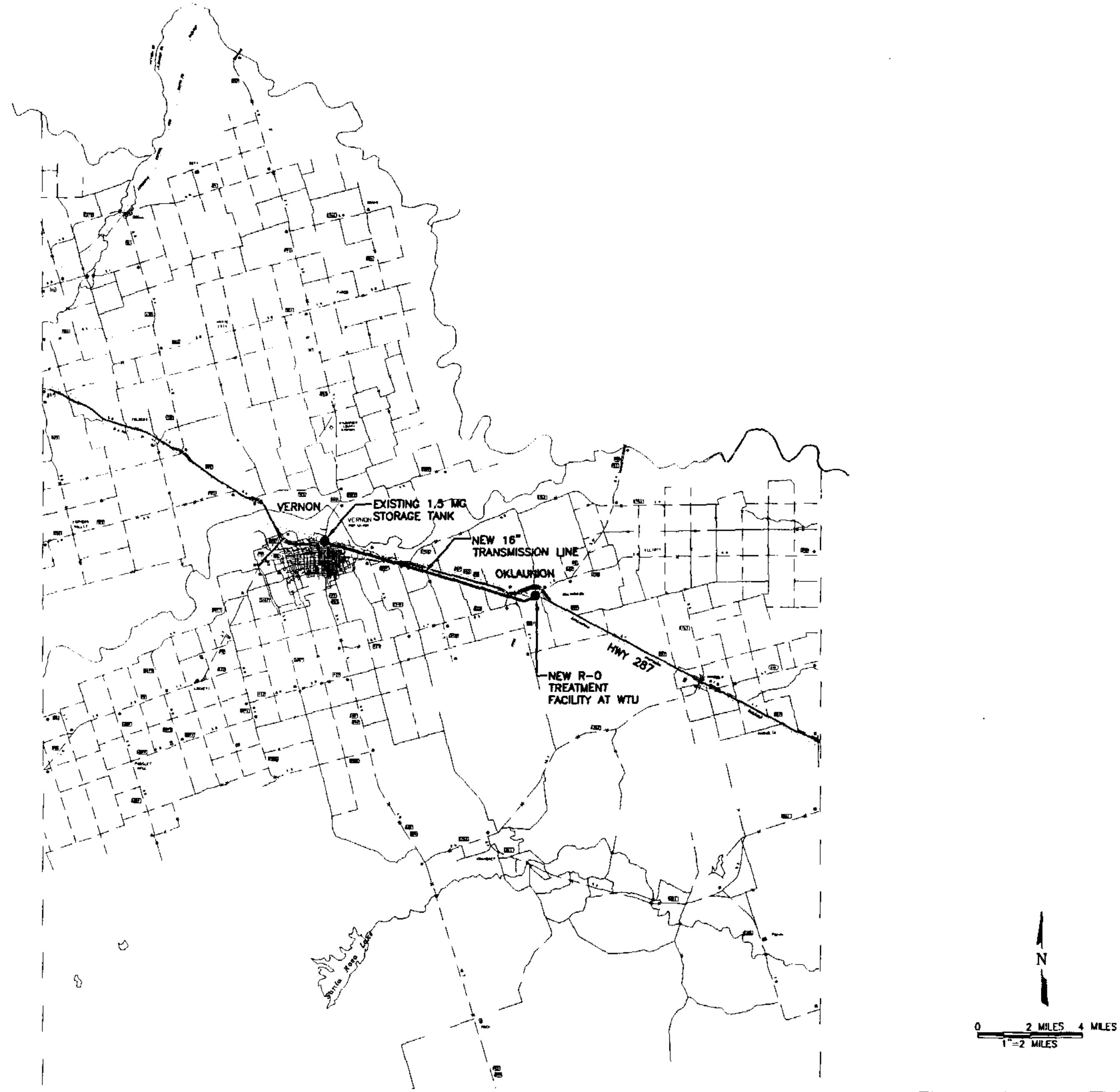

FIGURE 7-3

ALTERNATE 3

RAW SURFACE WATER WITH DESALINATION

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Alternative 4: Ground water from Round Timber Ranch well field

The City of Altus is considering leasing their right to pump water from the Round Timber Ranch to the City of Vernon. This option would include re-development of 13 existing water wells, new well controls and pumps, and a new pumping station (note: one water well that has collapsed would not be used and two wells have reverted ownership to Round Timber Ranch). The water would be pumped from the well field to a new 0.5-MG storage tank (an existing 1-MG tank may be used). From the tank the water would be pumped approximately 11.5 miles through a new 14-inch transmission line to the Odell-Winston storage tank (Figure 7-4). The ground water would then be transported to the City's treatment plant via an existing 21-inch pipeline. Previous water quality data indicate the Round Timber ground water has nitrate levels at or just below the 10 mg/l limit. No treatment of this water is assumed at this time.

Alternative 5: Nitrate removal treatment

This alternative does not provide additional quantities of ground water to the City of Vernon, but would improve the water quality of the existing supplies. This option would include an ion-exchange system to reduce the nitrate levels of the City's supply to below the regulatory limit of 10 mg/l. The ion-exchange beds would be housed in a 2,500 square-foot building. The system would be capable of treating approximately 2,280 gpm of well water. The treated water would then be blended with 1,635 gpm of untreated water. Based on current water quality data, this 58 percent ratio would produce a supply with nitrates at about 8 mg/l and a 15 gpm waste stream.

7.2 Estimated Costs

Table 7-2 summarizes the preliminary cost estimates that were prepared for these alternatives. Capital costs were estimated and amortized over a 30-year period at an interest rate of 6 percent, with the exception of the nitrate removal option. This option was amortized over a 20-year period, which is the life expectancy of the equipment. To account for uncertainties, a 25 percent contingency was included for all capital costs. Annual costs included operational costs associated with pumping, water treatment, water purchase, system maintenance, and capital bond debt. The total annual costs for each alternative is presented as cost per 1,000 gallons.

These estimated costs were used as a tool to assess the relative economic feasibility of these alternatives. Costs for mitigation and permitting the transmission pipelines were assumed to be 3

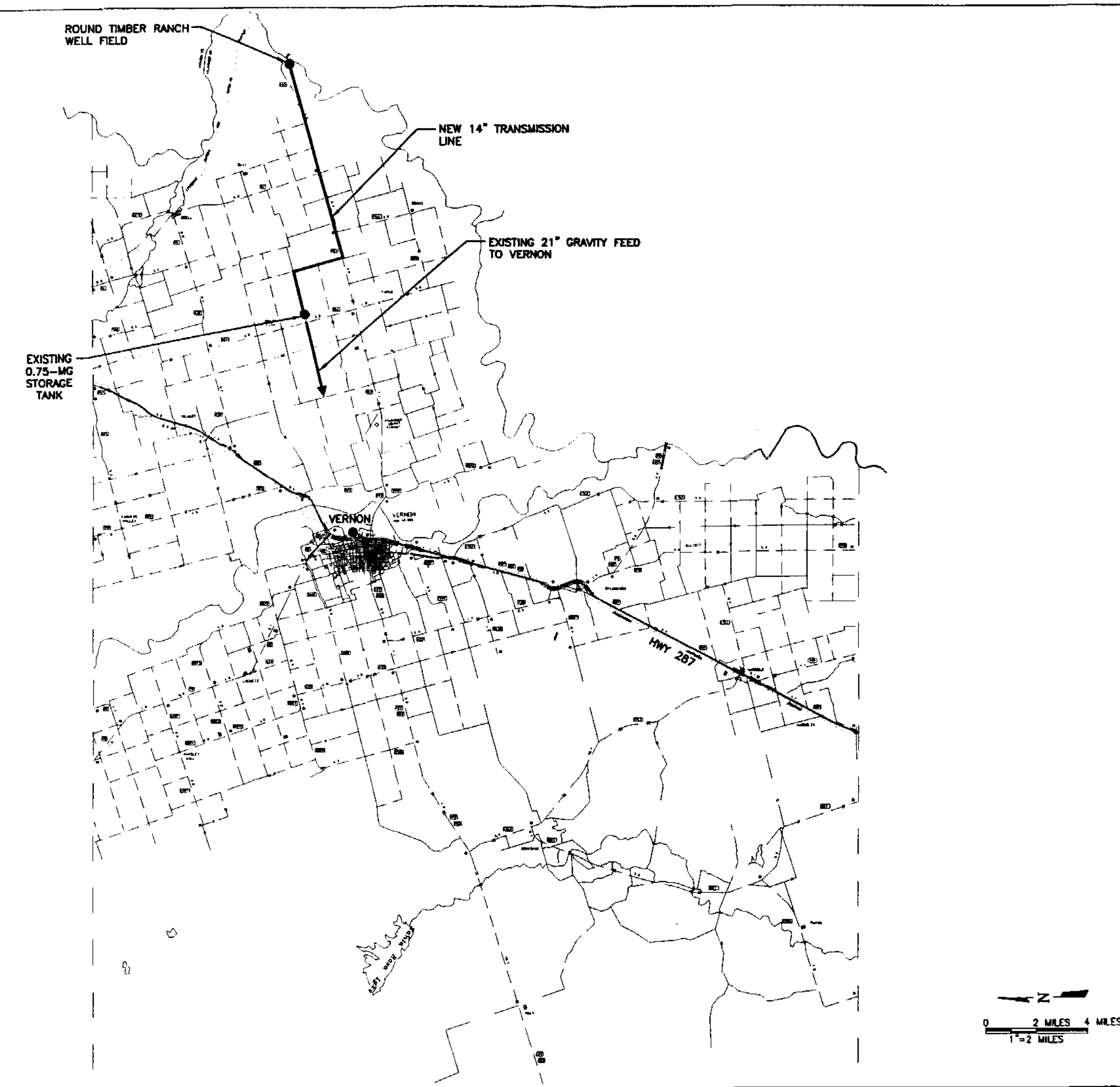

FIGURE 7-4

ALTERNATE 4

GROUND WATER-ROUND TIMBER RANCH

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percent of the construction costs. However, accurate mitigation costs require detailed environmental evaluations and coordination with the appropriate government agencies. Also, no dollar amounts were assigned to sales of surplus supply.

In light of these considerations, the different alternatives provide additional treated water at an estimated cost of $1.15 to $3.42 per 1,000 gallons. Treatment costs associated with nitrate removal for the City's existing supply is $0.53 per 1,000 gallons. The most economical source of new water is the Round Timber Ranch. The other alternatives are comparable in cost, ranging from $2.90 to $3.42 per 1,000 gallons.

7.3 Recommendations

The cost analyses indicate that Alternative 4: Round Timber Ranch is the most economical source of new water for the City. This water would not be a replacement supply, but can supplement the City's existing supply to meet the projected needs. A new water source that would significantly reduce the City's reliance on ground water, such as treated water from Oklaunion, is much more costly but would provide a larger reliable supply for future needs.

The scenario of additional water supply from the Round Timber Ranch with the implementation of a nitrate removal system would provide the additional water needed to meet the city's future needs and improve the water quality. Further cost evaluations indicate that implementation of this scenario would incur an additional annual debt service of $782,000. The annual operation and maintenance costs would be approximately $237,000, and water purchase costs are estimated at $55,000 per year. This corresponds to a total annual cost of $1,074,000 or an additional $0.84 per 1,000 gallons of total supply.

However, these costs are preliminary and include a moderate level of uncertainty, especially for the costs associated with supply from Round Timber Ranch. No purchase price for the water from the City of Altus has been established, which may have a significant effect on the total costs. For this estimate, it was assumed that water from Altus would be purchased at $0.15 per 1,000 gallons.

Table 7-1
Advantages and Disadvantages of Retained Alternatives

	Alternative	Advantages	Disadvantages
1	Treated Surface Water from Wichita Falls	• Does not require additional treatment by City. • Minimal permitting complexity. • Good quality water.	• Requires construction of 50-mile pipeline. • Costs are high due to capital costs of pipeline. • Would take 2 to 3 years to implement.
1A	Treated Surface Water from Wichita Falls (with Electra)	• Reduces debt service due to cost sharing of portion of capital costs with Electra. (see above)	• Requires coordination with another community. • City of Wichita Falls may not be willing to sell 3 MGD.
2	Raw Surface Water from Wichita Falls	• Good quality water. • Permitting complexity is low.	• Requires construction of 45-mile pipeline and treatment plant. • Costs are high due to capital costs and operation. • Requires additional City staffing. • Would take 5 years to implement.
3	Raw Surface Water from Lake Diversion with desalination	• Existing pipeline to Oklaunion in place. • Larger amount of available water (up to 3 MGD).	• Treatment system is not constructed. • Assumes participation of other communities. • Time to develop is dependent on other participants. • High costs due to desalination and conventional surface water treatment.
4	Ground water from Round Timber Ranch	• Existing well field. • Minimal treatment required. • Low to moderate costs. • Can utilize existing storage and conveyance system. Can be implemented within 2-3 years.	• Limited knowledge of capacity of well field. • Ground water may require nitrate removal treatment. • Higher level of uncertainty for capital expenses.
5	Nitrate Removal	• Would provide higher quality of existing supply. • Can be implemented within 2 years to meet EPA nitrate regulations. • Low costs.	• Does not increase supply amount, still requires supplemental source to meet future demands.

Table 7-2
Summary of Cost Estimates

				Annual Costs						
Alternative		Quantity (AF/Y)	Total Capital Costs	Annualized Capital	Pumping (electrical)	Treatment	Water Purchase	Transmission O&M[3]	Total	Cost/ 1,000 gal
1	Treated Surface Water from Wichita Falls	2,000	$16,332,000	$1,187,000	$122,000	$0	$619,000	$121,000	$2.049,000	$3.14
1A	Treated Surface Water from Wichita Falls (with Electra)	2,000	$14,455,000	$1,050,000	$115,000	$0	$619,000	$108,000	$1,892,000	$2.90
2	Raw Surface Water from Wichita Falls	2,000	$20,262,000	$1,472,000	$90,000	$424,000	$134,000	$110,000	$2,230,000	$3.42
3	Raw Surface Water from Lake Diversion with Desalination	2,000	$2,671,000	$194,000	$44,000	$0	$1,955,000[1]	$21,000	$2,214,000	$3.40
4	Ground Water from Round Timber Ranch	1,100	$4,222,000	$307,000	$25,000	$0	$55,000[2]	$29,000	$416,000	$1.15
5	Nitrate Removal	2,900	$4,177,000	$364,000	$0	$137,000	$0	$0	$501,000	$0.53

1. Water purchase costs from the Red River Authority was assumed at a minimum of $3.00/ 1,000 gallons. This cost has not been confirmed.
2. Water purchase costs from the City of Altus was assumed at $0.15/ 1,000 gallons. This cost has not been confirmed.
3. Transmission O&M was calculated at 1% of the pipe costs and 2.5% of the pump station cost.

8.0 WATER DISTRIBUTION SYSTEM

As part of the Comprehensive Water and Wastewater Plan, the water distribution system for the City of Vernon was evaluated for existing and proposed 2020 demands.

8.1 Description of the Distribution System

Vernon's water distribution system consists of four pump stations, ground storage tanks at each pump station, two elevated tanks, and water distribution mains ranging in size from 3/4-inch to 21 inches. The majority of the water mains are older lines, constructed prior to 1960 of cast iron and steel. Portions of the system installed between 1960 and 1980 used asbestos cement pipe. Currently, upgrades to the system are being made with PVC pipe. The major transmission line from the Odell-Winston well field is constructed of concrete steel cylinder pipe.

Four booster pump stations supply the distribution system with ground water from separate well fields. Each pump station has its own independent ground storage tank(s). Under normal conditions only the Big Tanks pump station, which receives water from the Odell-Winston well fields, is utilized. The other pump stations draw water from the in-city wells, which are not part of the long-term water supply strategy for Vernon. The pumping capacity at the booster stations are as follows:

Table 8-1
Existing Pump Stations

Pump Station	Number of Pumps	Design Capacity[1] (GPM)	Design Head (Ft)	Maximum Capacity (GPM)	Shutoff Head (Ft)	Storage Tank Capacity (gallons)
Old Warehouse	1	600	290	870	310	45,000
South Park	1 (west) 1 (east)	600 600	185 170	2,050 1,900	190 175	33,000
Schmokers	1 (south) 1 (north)	1,000 1,000	160 160	1,300 1,300	200 200	45,000
Big Tanks	4	1,500	188	2,025	210	750,000

1. If not specified individually, the capacities and head listed are for each pump at the respective pump station.

The City of Vernon uses two elevated storage tanks, both of which are 500,000 gallons in capacity. The west tank is located west of the intersection of Sand Road and Wichita Street. The south tank is located near Houston and Peter Cooper streets. The overflow elevation of both tanks is 1368 feet msl.

The growth of the City has historically been to the west and south, but no major line extensions have been constructed in these areas. Also, the topography of the area slopes upward to the southwest which results in a lower static pressure in those directions. The water distribution system is currently in one pressure plane. If the system is extended further to the southwest, an additional pressure plane may be required. Depending on future growth and the distribution of demands, an estimate of the existing pressure plane boundary in this area is shown on Figure 8-1. The existing water distribution system is shown on Plate 1.

8.2 Distribution System Modeling

The water distribution system was analyzed under various operating conditions to assess water pressures, pipe capacity limitations and pumping facilities. All 6-inch and larger water lines as provided by the City were included in the model. For modeling purposes, all booster pump stations were assumed to be off, except for the main Big Tanks Station. Four operating conditions were considered: peak day, peak hour, average day and peak day demands with fire flows. Each of these conditions were evaluated for the projected 2020 demands to assess future system improvements.

The distribution system was modeled using the CYBERNET 3.1 computer modeling program. The model was developed from the City of Vernon's existing system. Water demands were distributed throughout the system based on the location of major water users and a block by block meter count of the city. Calibration of the system was conducted for the existing system using the 1996 historical average day demands. Comparisons of recorded fire flow pressures to modeled results were also conducted and are included in Appendix C.

The increased demands for 2020 were distributed equally throughout the system. It was assumed that there were no new demand points. The demands used in the modeling are presented below.

MAY 09, 2000 10:45:19 A.M. LTS: 1.00 PSLTS: 1 TWIST: 0.0

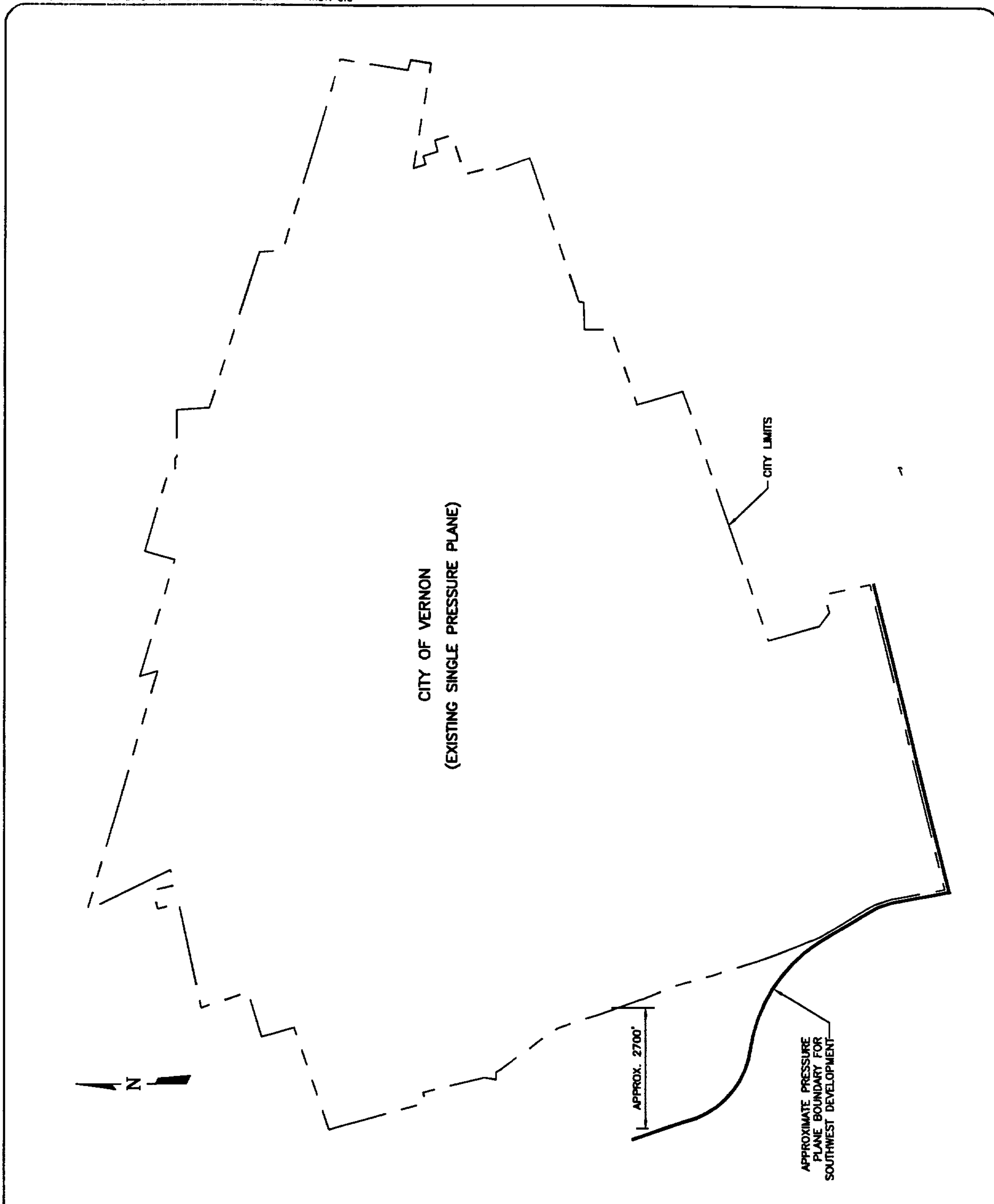


FIGURE 8-1

FREESE • NICHOLS
4055 International Plaza • Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

CITY OF VERNON
WATER AND WASTEWATER COMPREHENSIVE PLAN

LOCATION OF PRESSURE PLANE BOUNDARY

F&N JOB NO.	VRN97341A
FILE	FIG-8-1.DWG
DATE	MAY 2000
SCALE	N.T.S.
DESIGNED	SFK
DRAFTED	SB

Table 8-2

Water Demands

Demand Year	Average Day (mgd)	Peak Day (24-hr) (mgd)	Peak Day (18-hr) (mgd)	Peak Hour (mgd)
1996 (calibration)	2.83	4.86	6.48	12.59*
2020	3.627	6.17	8.23	12.59*

* Minimum requirement by the TNRCC for fire fighting capability.

With 2020 demands the pressures in the southern and western portions of the city were found to be very low. To alleviate this situation, two distribution loops were added to the model and are shown on Plate 2. The west loop is a combination of 12- and 16-inch water mains located on the far west side of the city. It is fed by a proposed 16-inch distribution line from the Big Tanks Pump Station. This loop has two interconnecting lines to the existing distribution system. The proposed south loop is completed by connecting a series of existing 10- and 12-inch water mains located in the southern portion of the city. This loop is also proposed to have two interconnections to the existing system.

Two other conditions in the existing system were modified in the computer model to meet the demand requirements. This included opening a 6-inch valve in Fifteenth Street to allow adequate fire flow, and opening the valve on a 10-inch line in Paradise Street to provide an interconnection to the west loop.

With these modifications, the water pressure in the system under 2020 peak hour demand conditions range from a low of 38 psi in the southwest corner of the city limits to a high of 72 psi in the northeast, which meets TNRCC minimum water pressure requirements. The overall system pressure varies from low to high pressure at a uniform rate across the city. The booster pump capacity was determined adequate for 2020 conditions, and no additional elevated storage was needed.

The only distribution needs identified from the modeling effort are the addition of two loop lines. These lines are needed to better transport water from the booster pump stations to the elevated storage tanks and to remedy future pressure problems in the southern and western parts of the city.

9.0 WASTEWATER SYSTEM

9.1 Existing Collection System

The City of Vernon's existing wastewater collection system is composed of collection lines ranging from 6-inch lateral collectors to 24-inch trunk interceptors. The wastewater collection system can be divided into 11 drainage areas. Plate 3 shows the primary wastewater collection lines, lift stations, and drainage areas for the City of Vernon. The location and depth of the wastewater lines are based on information received from the City with some field verification. Actual slopes and depths of pipe may vary slightly from the modeled system.

9.2 Wastewater Collection System Analysis

The Texas Natural Resources Conservation Commission (TNRCC) requires that municipal wastewater collection systems be designed for the two-hour peak flow. The two-hour peak flow is defined as the maximum amount of flow that can be expected over a two hour time period. The two-hour peak flow includes the peak industrial wastewater flow, peak wastewater domestic flow and peak infiltration and inflows. The projected two-hour peak design flows were compared to the existing maximum carrying capacities of the wastewater collection system to determine what improvements would be required.

9.2.1 Wastewater System Analysis Software

The City of Vernon's wastewater collection system was modeled using the HYDRA computer model. The HYDRA computer model utilizes computer mapping and flow data to simulate the operation of the collection system and pumping facilities at the various lift stations in the wastewater collection system. The model calculates available flow capacity within each line segment to determine if surcharging or overflowing conditions exist for a given planning period. Information on the existing wastewater collection lines for input to the computer model was obtained from mapping provided by the City of Vernon. In areas where information was not available from the detailed sewer maps, it was obtained by city staff or the slope of the line was assumed to meet the minimum design requirements as set forth by the TNRCC "Design Criteria for Sewer Systems." After review of the detailed sewer maps, the project was limited to the analysis of major sewer lines and several 6-inch lines because of service to large areas. The lines excluded from the analysis were principally subdivision laterals.

The industrial flows and infiltration/inflows were included in the Hydra computer model as constant peak point flows. The domestic wastewater flows were input into the model using a typical domestic diurnal curve. The diurnal curve peaks the domestic flows over a 24-hour time period. As discussed in Section 2.4, the wastewater peak two-hour design flow is the sum of the peak industrial flow, peak domestic wastewater flow and peak infiltration and inflow. The 1999 and 2020 peak two-hour wastewater design flows are 4.76 and 5.178 MGD. The distribution of the wastewater flows by drainage area for years 1999 and 2020 are shown on Tables 9-1 and 9-2.

9.2.2 Hydraulic Analysis

The City of Vernon's wastewater collection system contains different pipe materials that have different friction coefficients when new, but after years of service and solids buildup the friction coefficients tend to equalize. A coefficient of friction value (Manning's "n") of 0.013 was used in all cases for determining the pipe capacities. The maximum capacity of the gravity sewers was calculated using Manning's Equation. When the flow in a line segment exceeds the theoretical capacity as determined by Manning's equation, the line is considered to be surcharged. If a line segment is surcharged and the flow causes overflows to occur, the lines should be targeted for improvements. Additionally, acceptable minimum and maximum velocities in the sewer lines of 2.0 and 10.0 feet per second (fps) were used in evaluating the suitability of each line. Where the capacities are adequate but the velocity limits are exceeded, those lines should be monitored for settling solids or high turbulence, and necessary improvements made.

Table 9-1 Distribution of 1999 Wastewater Flows by Drainage Area

Drainage Area	Percent	Average Day Domestic Flow (MGD)	Average Day Domestic Flow (CFS)	Peak 2-Hour Domestic Flow (MGD)	Peak 2-Hour Domestic Flow (CFS)	Estimated Population	Peak Infiltration and Inflow (MGD)	Peak Infiltration and Inflow (CFS)	Peak Industrial Flow (MGD)	Peak Industrial Flow (CFS)	Peak 2-Hour Design Flow (MGD)	Peak 2-Hour Design Flow (CFS)
1	8.6%	0.100	0.154	0.280	0.433	1,075	0.073	0.112	0.604	0.934	0.956	1.480
2	14.8%	0.171	0.265	0.482	0.746	1,850	0.125	0.193			0.607	0.939
3	9.4%	0.110	0.170	0.309	0.478	1,185	0.080	0.124			0.389	0.601
4	3.9%	0.046	0.071	0.129	0.199	495	0.033	0.052			0.162	0.251
5	11.9%	0.138	0.214	0.388	0.600	1,490	0.101	0.156			0.489	0.756
6	11.5%	0.134	0.207	0.376	0.582	1,445	0.098	0.151			0.474	0.733
7	19.1%	0.222	0.344	0.625	0.967	2,400	0.162	0.251			0.787	1.218
8	1.0%	0.011	0.017	0.031	0.048	120	0.008	0.013			0.039	0.061
9	12.0%	0.139	0.215	0.391	0.604	1,500	0.101	0.157			0.492	0.761
10	1.4%	0.017	0.026	0.047	0.073	180	0.012	0.019	0.046	0.071	0.105	0.162
11	6.4%	0.074	0.115	0.208	0.322	800	0.054	0.084			0.262	0.406
TOTAL	100%	1.162	1.798	3.266	5.053	12,540	0.847	1.311	0.650	1.005	4.762	7.369

Table 9-2 Distribution of 2020 Wastewater Flows by Drainage Area

Drainage Area	Percent	Average Day Domestic Flow (MGD)	Average Day Domestic Flow (CFS)	Peak 2-Hour Domestic Flow (MGD)	Peak 2-Hour Domestic Flow (CFS)	Estimated Population	Peak Infiltration and Inflow (MGD)	Peak Infiltration and Inflow (CFS)	Peak Industrial Flow (MGD)	Peak Industrial Flow (CFS)	Peak 2-Hour Design Flow (MGD)	Peak 2-Hour Design Flow (CFS)
1	9.2%	0.113	0.174	0.316	0.490	1,215	0.082	0.127	0.718	1.111	1.116	1.727
2	14.8%	0.181	0.280	0.509	0.788	1,955	0.132	0.204	0.017	0.026	0.658	1.018
3	9.5%	0.117	0.181	0.328	0.508	1,260	0.085	0.132	0.008	0.012	0.421	0.652
4	3.7%	0.046	0.071	0.129	0.199	495	0.033	0.052			0.162	0.251
5	11.6%	0.142	0.219	0.398	0.617	1,530	0.103	0.160			0.502	0.776
6	11.7%	0.143	0.221	0.401	0.621	1,540	0.104	0.161			0.505	0.782
7	18.9%	0.231	0.358	0.650	1.005	2,495	0.169	0.261	0.016	0.025	0.834	1.291
8	1.0%	0.012	0.019	0.034	0.052	130	0.009	0.014			0.043	0.066
9	11.7%	0.144	0.222	0.404	0.625	1,550	0.105	0.162			0.508	0.787
10	1.4%	0.018	0.027	0.049	0.077	190	0.013	0.020	0.085	0.131	0.147	0.227
11	6.5%	0.079	0.123	0.223	0.345	855	0.058	0.089			0.280	0.434
TOTAL	100%	1.225	1.895	3.442	5.325	13,215	0.893	1.381	0.843	1.305	5.178	8.011

9.3 Wastewater Collection System Improvements for 2020

For the 2020 analysis, additional lines were included in the southwestern and western portion of the City. The southwestern lines are used to collect wastewater from an existing subdivision that currently is using septic tanks. Due to the length of this collection system and relatively little slope in elevation, two new lift stations are needed to tie into Vernon's existing system. The proposed western addition provides service to new residences and future growth.

Using the expanded service system, the hydraulic analysis indicated that several existing sewer lines are overloaded for the 2020 conditions. As shown on Plate 4, the 6-inch line running south to north in between Deaf Smith Street and Fannin Street and the 10-inch line running east along Wichita Street are overloaded from the southern and southwestern drainage areas. These two lines tie into the 18-inch interceptor, overloading the 18-inch line. To eliminate overloading the 18-inch interceptor it is recommended to transfer wastewater flows to the 24-inch interceptor in the northern drainage areas. This can be done by replacing the 6-inch line between Deaf Smith Street and Fannin Street with a 12-inch line, and continuing a new 15-inch line at Dawson Street that will tie into the 24-inch interceptor.

The second area shown to be overloaded is a 6-inch line along Dawson Street between Houston and Fannin Streets. It is recommended to replace the 6-inch line with a 12-inch line. The third area that is overloaded is a 12-inch line with a 6-inch and 10-inch segment that runs west along Bismark Street, north on Nabers Street, and continuing west along Wichita Street. The 6-inch segment on Bismark Street and the 10-inch segment on Wichita Street are both overloaded and should be replaced with a 12-inch line. A diversion structure that connects the existing 12-inch line on Wichita to an existing line between Houston and Lamar Streets would relieve some of the overloading on this section until all downstream improvements are completed. Other improvements that were studied were preliminary alternative routes to eliminate lift stations. These preliminary alternative routes could eliminate lift stations #1, #2, #4, #8, and #10. Before these preliminary routes can be designed, more surveyed topography will be required to verify the wastewater lines will meet the TNRCC minimum grades based upon a pipeline velocity of 2.0 feet per second (fps) with a Manning's roughness value of 0.013. These proposed improvements, along with the proposed expanded collection system, are shown on Plate 5.

10.0 CONCLUSIONS AND RECOMMENDATIONS

The City of Vernon has sufficient water supply to meet its needs through 2050 under normal rainfall conditions, provided conservation measures are implemented. Under drought conditions, the City may not be able to meet the increased demands using only its existing well fields. These supply concerns may be imminent, especially if weather conditions in north central Texas continue to be dry. But perhaps more pressing are the water quality issues associated with Vernon's water supply. The nitrate concentrations are often slightly in excess of the primary drinking water standard, and the City must implement a strategy to meet this standard in a timely manner.

Based on these findings and the evaluation of numerous water supply and treatment alternatives, it is recommended that the City of Vernon pursue:

- A nitrate removal system, employing ion exchange technology, and
- Additional water supply from the Round Timber Ranch site or equivalent new well field.

Nitrate removal and treatment is the least costly option to provide good quality water to Vernon and its customers. However, nitrate removal alone will not provide additional supply that may be needed for drought conditions. The City's existing well system may be able to meet dry year demands for a limited time, but it is unlikely that the system can sustain the projected long-term dry year demands. Additional ground water supply will meet the City's growing needs and complement its existing system.

To reduce its demand on the Odell-Winston well field, the City has begun to use local wells for irrigation of parks and golf courses. It is also proposing to directly connect Rhodia Industries to the City's existing in-city well field. The in-city wells have high nitrate levels, which are undesirable for municipal use but do not affect the manufacturing use for Rhodia. These modifications will reduce the amount of water that is required for treatment and help sustain the City's existing supply until a new source can be developed. A summary of recommendations specific to the nitrate treatment system and ground water supply is presented at the end of this section.

The analyses of the City's water distribution and wastewater systems indicated several improvements needed to adequately meet the projected demands in 2020. For the water distribution system, a proposed loop system on the west side of town should provide sufficient water pressure for new and existing customers. For the wastewater system, proposed expansions to the west and southwest would provide service to Vernon's growing population and existing residents currently on septic systems. Also several proposed improvements to collection lines in the center of town would relieve potential overloading and maintenance issues associated with the smaller lines. Details of these improvements are included in the Capital Improvement Plan (Section 11).

10.1 RECOMMENDATIONS

10.1.1 Recommendations for Nitrate Removal System

1. Pursue permitting requirements with TNRCC for an ion exchange system to treat water for Vernon and existing customers. (Assume municipal customers located up gradient of the treatment plant will not initially receive treated water.)
2. Utilize a modular treatment system that can be constructed in stages and expanded as needed.
3. Coordinate with the wastewater treatment plant for waste disposal.
4. Continue discussions with the municipal customers that would not initially receive treated water to develop a time frame for treated water service. (This includes the City of Lockett, and Hines-Wildcat and Northside water supply corporations.)

10.1.2 Recommendations for Pursuing Ground Water from Altus

1. Prior to leasing the Round Timber Ranch well field, it is recommended that a detailed study of well field be conducted to better assess the long-term supply (study costs are already included for this alternative). At a minimum, this study would include:
    - Initial static water level measurements
    - Well and pump condition assessment, including total well depth
    - Water quality sampling
    - Specific capacity of each well
    - A 24-hour pumping test
    - Development of a ground water flow model of the well field based on the data collected during the pumping test. This model will be used to assess the long-term reliability of the well field.
    - Summary report with the results and recommendations

2. Begin discussions with the City of Altus on lease agreements and purchase costs.

3. Continue to pursue negotiations with adjacent landowners and farmers regarding potential new well field sites. If a new site is considered, then a detailed study of the site will be required. This will include the drilling of pilot well(s) and well testing as described above for Altus.

10.1.3 Recommendations for Existing Well Fields

1. Develop a well field management plan that outlines regular maintenance, recommended pumping rates, trigger conditions that warrant modifications to the operation (i.e., changing pump rates at different well fields, etc.).

2. Conduct a sensitivity analysis of the production costs associated with the existing Odell-Winston well field to determine if an optimization study of Vernon's well system could potentially increase supply and/or reduce operation costs. If the sensitivity analysis indicates an optimization study is warranted, then ground water flow modeling would be conducted to analyze the major factors that control pumping costs. Consideration would be given to minimize electricity costs, transmission costs and pumping efficiency at each well.

3. Consider purchasing land around the Odell and Winston well fields to create a buffer zone. This buffer zone would help protect the field's existing supply and potentially reduce future nitrate contamination.

11.0 CAPITAL IMPROVEMENT PLAN

The Capital Improvement Plan for the City of Vernon is organized into four areas: 1) water treatment, 2) water supply, 3) water distribution, and 4) wastewater system. For each area, projects and associated costs have been identified.

The projects included in the Capital Improvements Plan were generally identified during this study. There are several water supply and distribution projects that were previously identified during a tank inspection study that was conducted by Freese and Nichols in 1999. Also, capital improvements identified by the City of Vernon have been incorporated into this plan. For scheduling and funding purposes, the water treatment, water supply and distribution projects were considered collectively. It was assumed that the wastewater projects would be funded from a separate source, and they were therefore considered separately during scheduling.

The costs generated for each project are preliminary budgeting costs and include contingencies of 20 to 25 percent, depending on the uncertainties. The projects were prioritized based on need, costs, construction sequencing, and input from the City. A brief description of the projects and associated costs for each area of improvement is presented below.

11.1 Water Treatment

There is only one recommended project for water treatment. This is the installation of an ion exchange treatment unit to remove nitrate from the City's existing water supply. This alternative is described in detail in Section 6. Initially it will be designed to serve the City of Vernon and the City's existing water customers with the exception of Northside and Hinds-Wildcat water supply corporations. These customers will continue to receive untreated water due to their location relative to the treatment plant and existing distribution system. The housing and design will allow for expansion of the treatment system in the future, if needed. A schematic of the ion exchange process and proposed treatment plant layout are shown on Figures 11-1 and 11-2, respectively. Costs for this project are presented in Table 11-1.

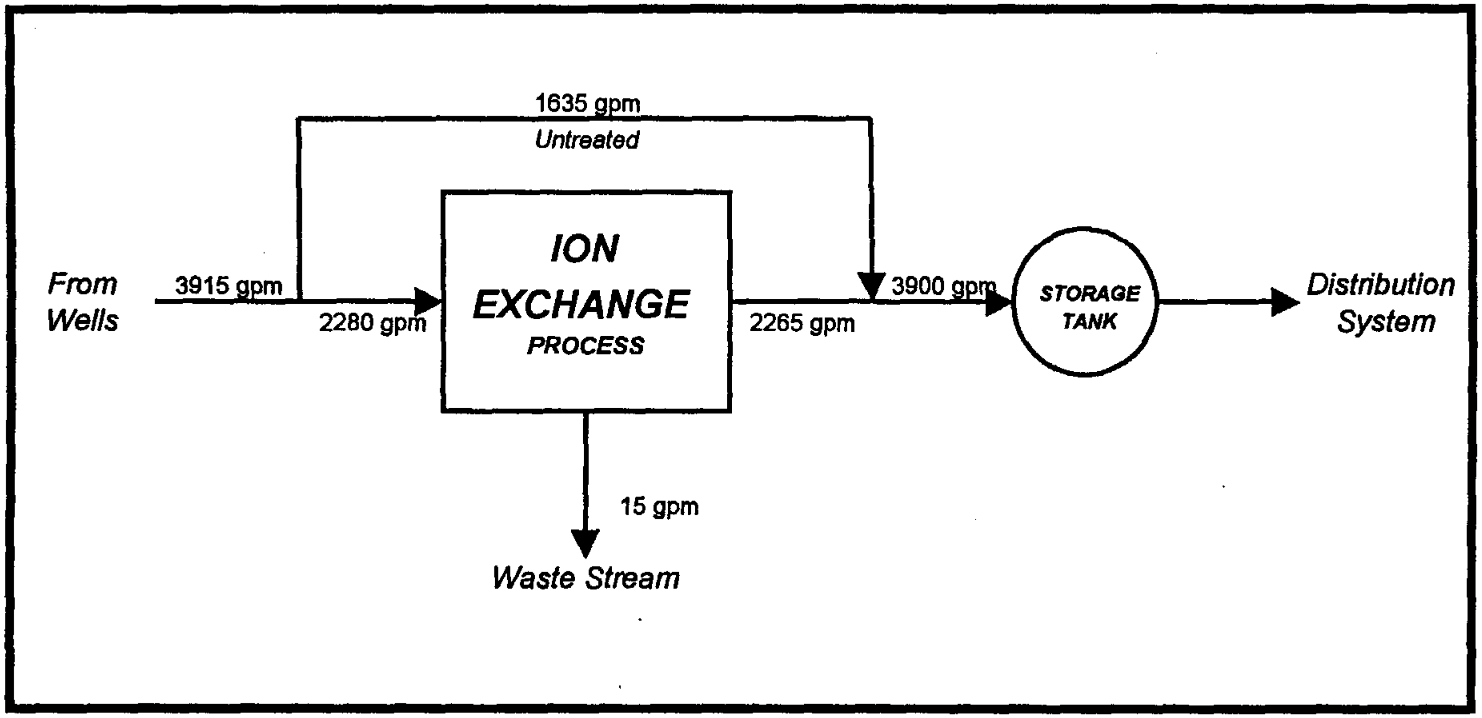
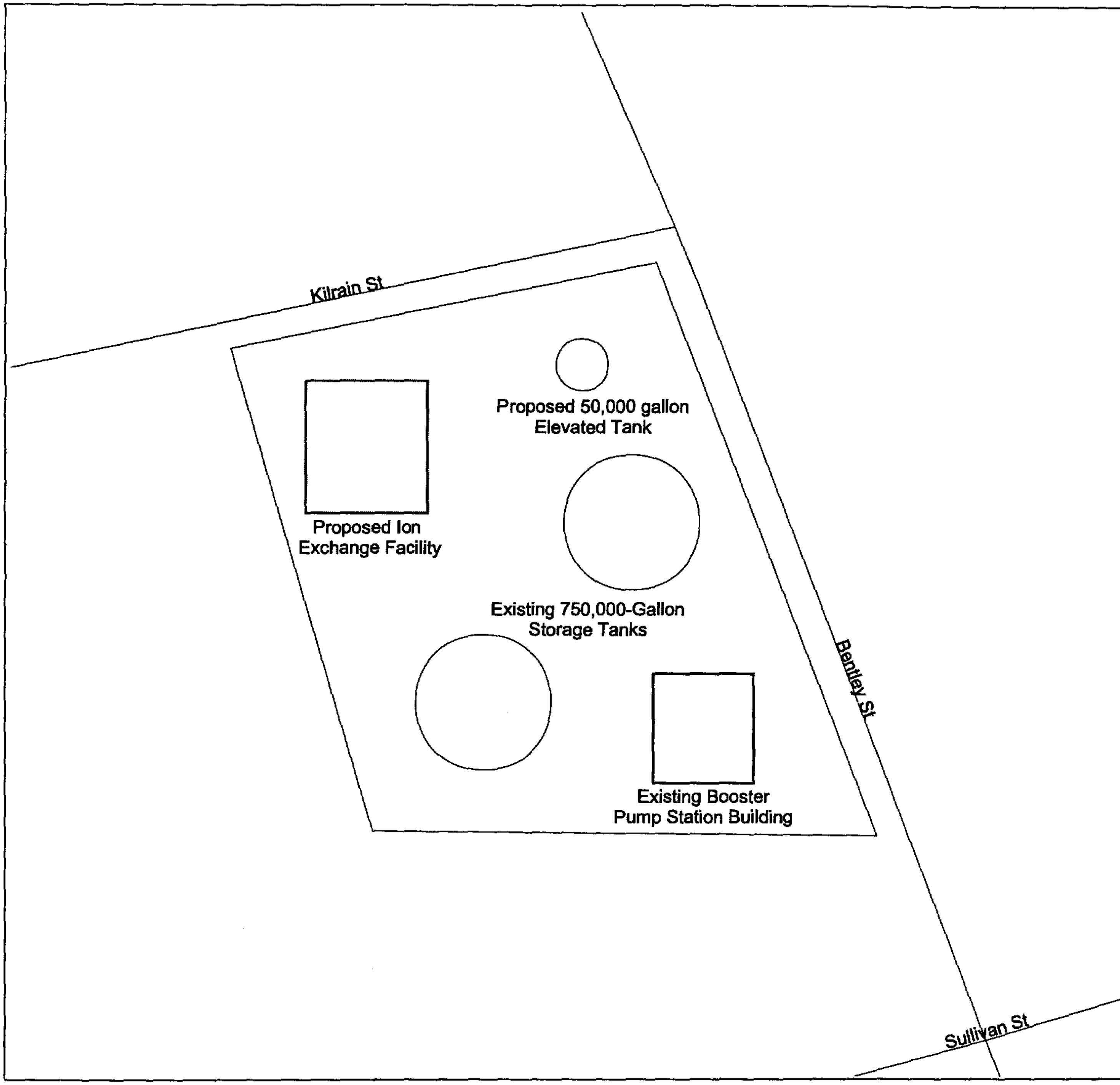


FIGURE - 11-1: SCHEMATIC DIAGRAM ION EXCHANGE PROCESS
CITY OF VERNON, TEXAS



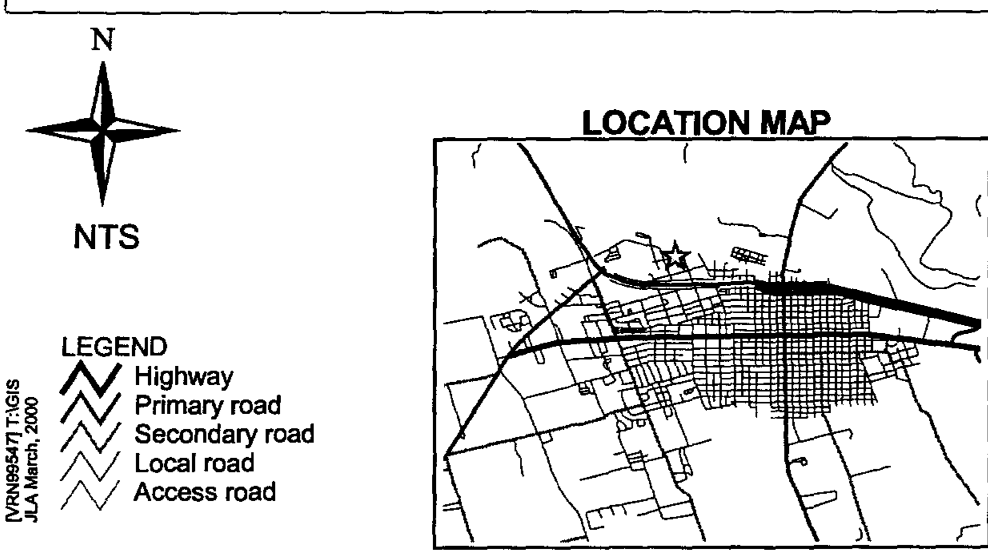


Figure 11-2
Proposed Treatment Plant Location

Table 11-1
Nitrate Removal Cost Estimate

Description		Cost
Ion Exchange Facility		$3,094,375
Engineering Fees		$563,025
Bond Issuance Costs		$76,009
Land, Easements or ROW		$28,000
	Subtotal	$3,761,409
Contingency (@20%)		$752,282
	Total Project Costs	*$4,513,691*

11.2 Water Supply

The recommended projects associated with water supply include:

1. Direct connection of in-city wells (Schmoker Well Field) to the proposed treatment plant and Rhodia Industries,
2. Replace existing 150,000 gallon Odell Well Field Storage Tank,
3. Lease and develop water supply from Round Timber Ranch, and
4. Paint and upgrade 750,000 gallon Odell Well Field Storage Tank.

Other recommendations associated with water supply include the development of a well field management plan and a sensitivity analysis for a well field optimization study. While these are recommended actions that may increase the production of the City's current water supply, they are generally operational and not considered capital improvements, and therefore are not included in the Capital Improvement Plan. The recommendation to purchase additional land around the existing well field may provide some additional protection of water supply, but there are many unknowns associated with existing leases or ownerships of the surrounding properties. This recommendation is also not included in the Capital Improvement Plan due to the high uncertainties of cost and availability. The four water supply projects listed above are viable capital improvement projects designed to increase the reliability of the City's supply. A brief summary of these projects is presented below and costs are outlined in Table 11-2.

Project 1: Schmoker Well Field Extension

A new water transmission line from the Schmoker Well Field to the proposed treatment plant will be constructed for back-up water supply. As part of this project, an extension from this line to Rhodia Industries will be laid to provide Rhodia's manufacturing water needs. This water will not be treated for nitrates. The City will continue to provide Rhodia with treated water for municipal uses. A new 100,000-gallon ground storage tank, 50,000-gallon elevated storage tank and pump station will also be required to complete this project. It is expected that this project will be constructed in conjunction with the treatment system.

Project 2: Replace Small Odell Storage Tank

During a recent tank inspection, it was recommended that the small Odell Well Field Storage Tank be replaced with a larger (250,000-gallon) tank. The interior of the existing 45-year old tank has severely corroded. The tank also has structural deficiencies and does not meet the current safety and sanitary requirements of the TNRCC and American Water Works Association (AWWA).

Project 3: Round Timber Ranch

Water supply from the Round Timber Ranch was discussed in detail in Section 7. This project will include additional well field studies, a pipeline to the existing Odell-Winston storage tanks, new pump station, and refurbishment or replacement of the existing wells, equipment and storage tanks. Due to the uncertainties associated with this project, contingencies were estimated at 25 percent.

Project 4: Upgrade Large Odell Storage Tank

As part of the tank inspection report, it was recommended that the 750,000-gallon Odell Storage Tank be re-painted and upgraded in accordance with existing TNRCC and AWWA standards.

Table 11-2
Water Supply Project Costs

	quantity	unit	unit cost	cost
Project 1: Schmoker Extension				
Schmoker Ground Storage Tank	1	ea	$85,000	$85,000
Schmoker Elevated Storage Tank	1	ea	$199,750	$199,750
8-inch Transmission Line	9,000	lf	$35	$315,000
Pump Station	1	ea	$212,500	$212,500
Engineering				$163,675
Subtotal				$975,925
Contingencies @ 20%				$195,185
Total Project Costs				*$1,171,110*
Project 2: Small Odell Storage Tank				
250,000-gal Storage Tank	1	ea	$161,500	$161,500
Engineering				$24,000
Contingencies @ 20%				$37,100
Total Project Costs				*$222,600*
Project 3: Round Timber Ranch				
Study of well field	1	ea	$150,000	$150,000
14" Pipeline	60,720	ft	$35	$2,125,200
ROW costs	11.5	mi	$9,700	$111,600
Pump Station	1	ea	$210,000	$210,000
Metering Vaults	1	ea	$16,000	$16,000
Highway crossings	4	ea	$18,000	$72,000
Tie to existing well field	1	ea	$25,000	$25,000
Refurbish well field	1	ea	$300,000	$300,000
0.5 MG Well field Storage Tank	1	ea	$200,000	$200,000
Subtotal Construction				$3,059,800
Mitigation & Permitting				$91,800
Engineering @ 15%				$458,900
Contingencies @ 25%				$764,900
Total Project Costs				*$4,425,400*
Project 4: Large Odell Storage Tank				
Repaint existing 750,000-gal tank	1	ea	$200,000	$200,000
Engineering				$36,000
Contingencies				$40,000
Total Project Costs				*$276,000*

11.3 Water Distribution System

Nine projects were identified for improvement to the water distribution system. The water line projects are discussed in Section 8 and shown on Plate 6. The main improvements to the system consist of two loops added to the western and southern portions of the system and several line replacements in the center of town. Refurbishing several water distribution tanks is also included. Costs for each of these projects are presented in the following table.

Table 11-3
Water Distribution Project Costs

	quantity	unit	unit cost	cost
Project 1: Houston Street				
12-in water line	700	lf	$45.00	$31,500
Asphalt Repair	700	lf	$15.00	$10,500
Valves/Hydrants/Misc (@ 20%)	1	ea		$6,300
Engineering				$10,000
Total Project Costs				*$58,300*
Project 2: Bowie Street				
10-in water line	5,600	lf	$40.00	$224,000
Asphalt Repair	5,600	lf	$15.00	$84,000
Valves/Hydrants/Misc (@ 10%)	1	ea	10% of line	$22,400
Engineering @ 15%				$49,560
Total Project Costs				*$379,960*
Project 3: Northwest Loop				
16-inch water line	3,550	lf	$70.00	$248,500
Bore under Highway	400	lf	$300.00	$120,000
12-inch water line	4,050	lf	$45.00	$182,250
Asphalt Repair	9,350	lf	$15.00	$114,000
Valves/Hydrants/Misc (@ 10%)	1	ea	10% of line	$43,073
Engineering @ 15%				$106,174
Total Project Costs				*$813,999*
Project 4: Tolar Street				
10-in water line	6,900	lf	$40.00	$276,000
Asphalt Repair	6,900	lf	$15.00	$103,500
Valves/Hydrants/Misc (@ 10%)	1	ea	10% of line	$27,600
Engineering @ 15%				$61,065
Total Project Costs				*$468,165*

Table 11-3
Water Distribution Project Costs (continued)

	quantity	unit	unit cost	cost
Project 5: Southwest Loop				
16-inch water line	2,500	lf	$70.00	$175,000
12-inch water line	23,750	lf	$45.00	$1,068,750
10-in water line	1,000	lf	$40.00	$40,000
Asphalt Repair	27,250	lf	$15.00	$408,750
Valves/Hydrants/Misc (@ 10%)	1	ea	10% of line	$128,375
Engineering @ 15%				$273,131
Total Project Costs				*$2,094,006*
Project 6: College/Center Streets				
12-inch water line	5,910	lf	$45.00	$265,950
Asphalt Repair	5,910	lf	$15.00	$88,650
Valves/Hydrants/Misc (@ 10%)	1	ea	10% of line	$26,595
Engineering @ 15%				$57,179
Total Project Costs				*$438,374*
Project 7: South Elevated Storage Tank				
Paint and Upgrade Tank	1	ea	$320,000	$320,000
Engineering @15%				$48,000
Total Project Costs				*$368,000*
Project 8: West Elevated Storage Tank				
Paint and Upgrade Tank	1	ea	$325,000	$325,000
Engineering @15%				$48,750
Total Project Costs				*$373,750*
Project 9: Northside Pump Station Ground Storage Tanks				
Paint and Upgrade Tank	1	ea	$610,000	$610,000
Engineering @15%				$91,500
Total Project Costs				*$701,500*

Note: Water line costs assume 3 ft of cover. All unit costs include a 20 % contingency

11.4 Wastewater System

The wastewater system capital improvement projects include a combination of service extensions to existing residents and line replacement of overloaded sewer lines. The proposed line improvements were identified into 6 separate projects that are shown on Plate 7. These projects are listed by priority number based on input from the City of Vernon and logical construction sequencing. A summary of the cost estimates for each project is presented in Table 11-4.

Table 11-4
Wastewater System Project Costs

	quantity	unit	unit cost	cost
Project 1: Southern Line Extension				
6-inch wastewater line	4,000	lf	$35.00	$140,000
8-inch wastewater line	9,300	lf	$45.00	$418,500
10-inch wastewater line	6,200	lf	$55.00	$341,000
Lift station	1	ea	$150,000	$150,000
Asphalt Repair	19,500	lf	$15.00	$292,500
Manholes	30	ea	$3,000.00	$90,000
Manhole Tie-in	1	ea	$1,500.00	$1,500
Engineering @ 15%				$215,025
Total Project Costs				*$1,648,525*
Project 2: Western Line Extension				
8-inch wastewater line	9,300	lf	$45.00	$418,500
12-inch wastewater line	3,200	lf	$65.00	$208,000
Lift Station	1	ea	$150,000	$150,000
Asphalt Repair	12,500	lf	$15.00	$187,500
Manholes	24	ea	$3,000.00	$72,000
Manhole Tie-in	1	ea	$1,500.00	$1,500
Engineering @ 15%				$155,625
Total Project Costs				*$1,193,125*
Project 3: Dawson/Harrold Street				
12-in wastewater line	700	lf	$65.00	$45,500
15-in wastewater line	2,550	lf	$80.00	$204,000
Bore under Highway	500	lf	$300.00	$150,000
Asphalt Repair	3,250	lf	$15.00	$48,750
Manholes	7	ea	$3,000.00	$21,000
Manhole Tie-in	2	ea	$1,500.00	$3,000
Engineering @ 15%				$70,838
Total Project Costs				*$543,088*
Project 4: Downtown Improvements				
12-in wastewater line	3,400	lf	$65.00	$221,000
Asphalt Repair	3,400	lf	$15.00	$51,000
Manholes	7	ea	$3,000.00	$22,100
Manhole Tie-in	2	ea	$1,500.00	$3,000
Engineering @ 15%				$44,565
Total Project Costs				*$341,665*

Note: Wastewater line costs assume an average depth of 12 ft. All unit costs include a 20 % contingency.

Table 11-4 (continued)

	quantity	unit	unit cost	cost
Project 5: Bismark Improvements				
12-inch wastewater line	630	lf	$65.00	$40,950
Diversion Structure	1	ea	$9,000	$9,000
Asphalt Repair	630	lf	$15.00	$9,450
Manholes	1	ea	$3,000.00	$4,095
Manhole Tie-in	2	ea	$1,500.00	$3,000
Engineering @ 15%				$9,974
Total Project Costs				*$76,469*
Project 6: Lift Station Eliminations				
6-inch wastewater line	5,000	lf	$35.00	$175,000
Asphalt Repair	2,500	lf	$15.00	$37,500
Manholes	11	ea	$3,000	$33,000
Engineering @ 15%				$36,825
Total Project Costs				*$282,325*

Note: *Wastewater line costs assume an average depth of 12 ft. All unit costs include a 20 % contingency.*

11.5 Capital Improvements Schedule

Proposed schedules for the water and wastewater projects identified in this capital improvement plan are presented on Figures 11-5 and 11-6, respectively. These schedules assume that the improvements are completed by 2010. However, since a debt analysis has not been completed to date, modification to this schedule may be needed to maintained a preferred debt level.

Based on discussions with the City of Vernon, the City's top priorities for their water supply are to reduce the nitrate concentrations in their water supply and better utilize the in-city wells for supplemental supply. The City also recognizes that further study of the Round Timber Ranch in the near future would provide the additional information needed for their long-term supply planning. The priorities for the water distribution system are based on pressure needs and existing demands. The water lines in the center of town and the connection of the Big Tanks Pump Station to the West Tank were given a higher priority than the southwest loop and the western extensions along Center and College Streets.

The wastewater projects were prioritized to meet the needs of the City's existing residents. Since Vernon is not experiencing serious wastewater overflows at this time, the new service extensions were given a higher priority than existing line replacements. For the line replacement projects, the down gradient segments were assumed to be upgraded first. This was to prevent possible bottlenecks within the system.

Figure 11-5

Schedule for Proposed Water Projects

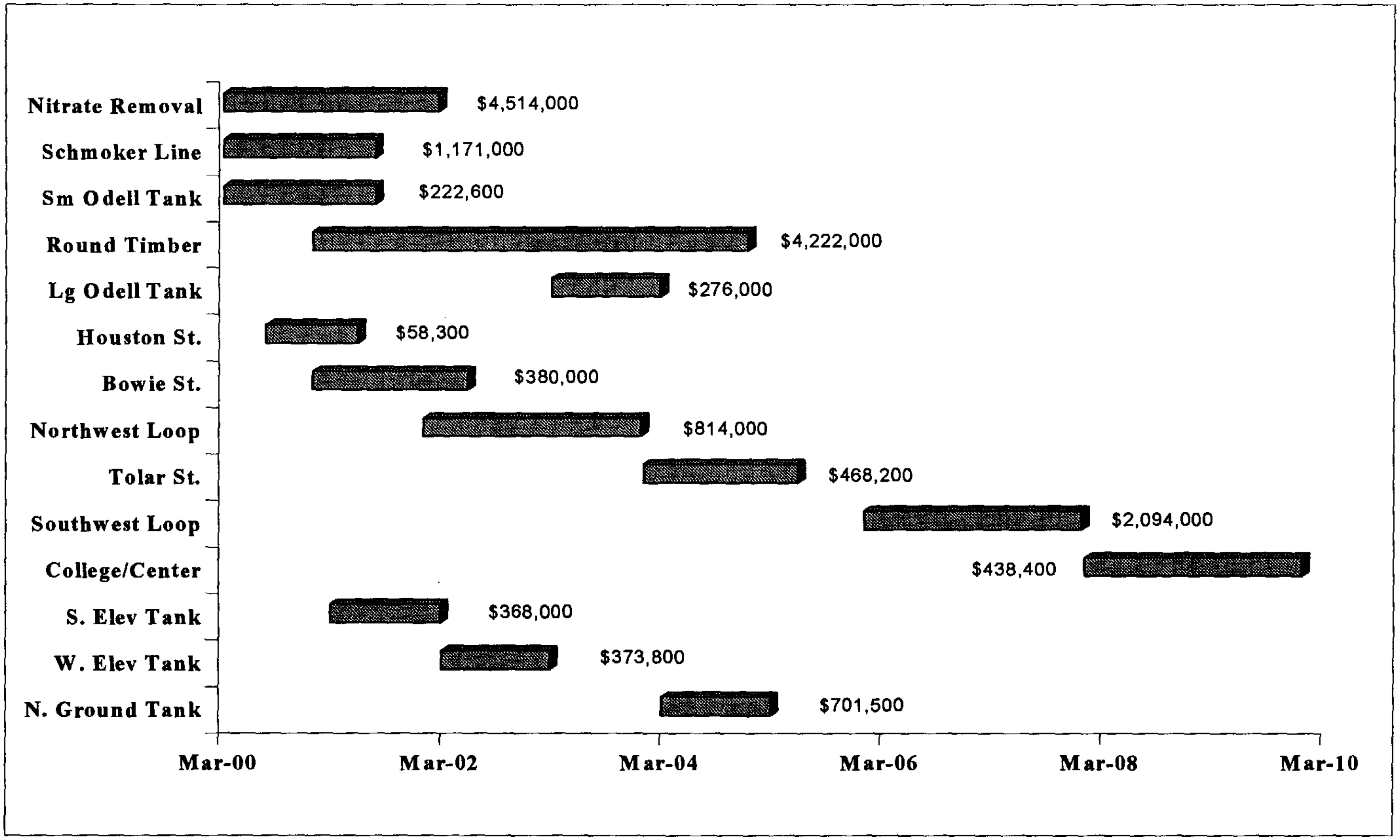
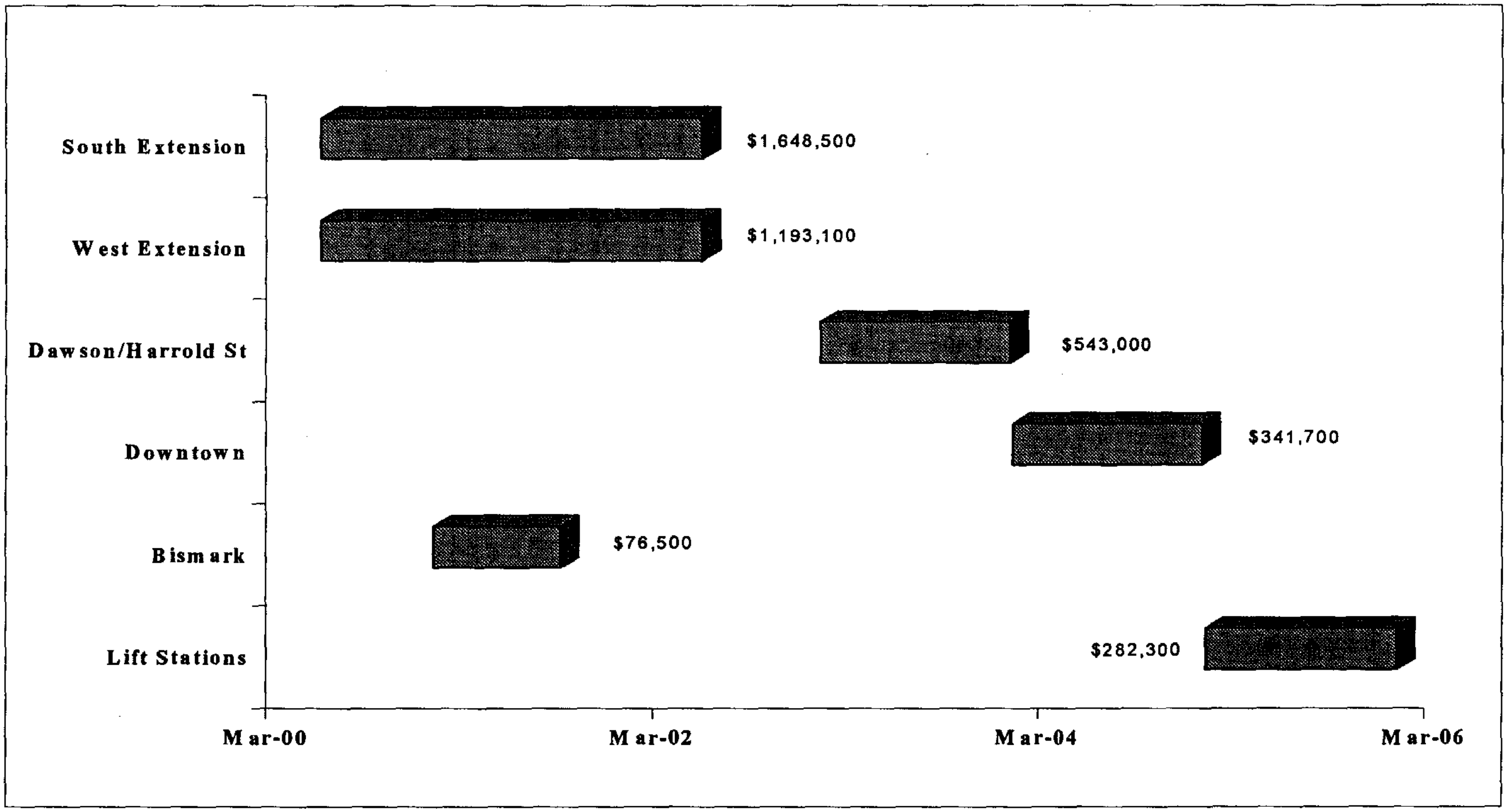


Figure 11-6

Schedule for Proposed Wastewater Projects



11.6 Potential Funding Sources for Capital Improvement Projects

Water System Improvements

Several sources of funding will be required to construct the proposed capital improvements. The City has already received approval of a loan from the Texas Safe Drinking Water State Revolving Fund for construction of the groundwater treatment facility and related work. Some remedial projects have been funded by the Community Development Block Grant program, and a few additional small projects may be eligible for funding under this program. Other small projects may be funded out of operating revenues. The remainder of the projects will likely require the sale of revenue bonds, either directly by the City of Vernon, or indirectly through a state program such as the Water Supply Loan program.

Wastewater System Improvements

A few small projects such as the lift station diversion projects may be funded either by funds remaining from a previous loan from the Texas Clean Water State Revolving Fund, or out of operating revenues. The remainder of the projects will likely require the sale of revenue bonds, either directly by the City of Vernon, or indirectly through additional loans from the State Revolving Fund.

BIBLIOGRAPHY

Biggs and Matthews, Inc. et al, "Draft Region B Water Plan", prepared in accordance with Senate Bill One, October 2000.

Clifford D. and Liu, X., " Ion exchange for nitrate removal.", Journal of American Water Works Association, May 1986.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting at Altus, 3/30/98," April 2, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch and Stephanie Griffin, "Historical and Projected Population and Water Use," December 22, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting with Red River Authority, 4/9/98," April 10, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting with Wichita Falls, 4/9/98," April 10, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting with Greenbelt Municipal and Industrial Water Authority, 4/9/98," April 10, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting at Frederick, 3/30/98," April 2, 1998.

Freese and Nichols, Inc.: Memorandum from Tom Gooch, "Meeting at W.T. Wagonner Estate Building, 3/30/98," April 2, 1998.

Gayle, B. P., Boardman, G. D., Sherrard, J. H., Benoit, R.E., "Biological Denitrification of Water.", Journal of Environmental Engineering, October, 1989.

Kapoor A. and Viraraghavan, T., " Nitrate removal from drinking water - review." Journal of Environmental Engineering, April 1997.

Liu, X and Clifford D., " Ion exchange with denitrified brine reuse.", Journal of American Water Works Association, November 1996.

Lauch, R. P. and Guter, G. A., " Ion exchange for the removal of nitrate from well water.", Journal of American Water Works Association, May 1986.

Sleight, S. D. and Atallah, O. A., "Reproduction in the guinea pig as affected by chronic administration of potassium nitrate and potassium nitrite.", Toxicology Applied Pharmacol, December 1968.

State Data Center, Historical Population for the City of Vernon - 1998, Austin, Texas, 1999.

TNRCC Design Criteria for Sewage Systems, 30 TAC Chapter 317, Austin, Texas.

TWDB, Historical and Projected Population and Water Use Data for Regional Planning Groups, Updated Version, 4/26/99, with 1997 Data Included, published as a CD, Austin, Texas, 1999.

University of Colorado, " Demonstration of Biological Denitrification of Drinking Water for Rural Communities.", Report published in September 1997.

Woodward-Clyde, "Final Report, Groundwater Resources Study for Odell-Winston and Round Timber Ranch Well Fields, City of Vernon", October 1, 1998.

APPENDIX A

List of Meetings and Presentations

LIST OF MEETINGS AND PRESENTATIONS

Date	Description
12/13/99	Presentation of Capital Improvement Plan to City of Vernon Commission
11/22/99	Presentation of Water Distribution Study & Wastewater Study to City of Vernon Commission
10/26/99	Presentation of Water Supply Study to City of Vernon Commission
4/29/99	Meeting with City of Altus regarding water supply alternatives
4/28/99	Meeting with Red River Authority regarding water supply alternatives
2/23/99	Submittal of Water Supply Screening Memorandum to Vernon.
4/9/98	Meeting with Greenbelt MIWA regarding water supply alternatives
4/9/98	Meeting with Red River Authority regarding water supply alternatives
4/9/98	Meeting with City of Wichita Falls regarding water supply alternatives
3/30/98	Meeting with City of Altus regarding water supply alternatives
3/30/98	Meeting with City of Frederick regarding water supply alternatives
3/30/98	Meeting with Wagonner Estate regarding water supply alternatives
3/16/98	Project Kick-off Meeting (minutes attached)

FREESE • NICHOLS

Simon W. Freese, P.E. 1900–1990
Marvin C. Nichols, P.E. 1896–1969

MEMORANDUM

To: File

From: David W. Sloan

Re: Vernon Water & Wastewater Comprehensive Plan
Kickoff Meeting Minutes - 3-11-98

Date: March 16, 1998

A kickoff meeting was held Wednesday, March 11, 1998 in Vernon for the Vernon Water & Wastewater Comprehensive planning efflort. The following were in attendance:

Jim Murray	City Manager	City of Vernon
Steve Ainsworth	Utilities Director	City of Vernon
Curtis Johnson	Contract Manager	TWDB
Curtis Campbell	Asst. General Manager	Red River Auth. of Texas
Dwight Brandt	Water Distrib. Task Mgr.	Brandt Engineers
Brett Roberts	Project Hydrogeologist	Woodward Clyde
Leonard Ripley	Project Manager	Freese & Nichols
Tom Gooch	Water Supply Task Mgr.	Freese & Nichols
David Sloan	Asst. Project Manager	Freese & Nichols

1. Leonard Ripley began by having each person introduce themselves and their role in the project. Handouts consisted of the meeting agenda, project directory and project schedule. He then gave a brief overview of the project, noting the three major elements of the study: water supply, water distribution, and wastewater collection. It was noted the project schedule is beginning approximately two months later than anticipated in the TWDB grant application.

2. Tom Gooch then discussed plans for the water supply study. It was agreed the TWDB population and water use projections would be the basis for the required supplies.

3. Tom reviewed the various water supply alternatives which had been previously listed. No new sources were proposed. Several of the sources are already considered to have a low probability of use, but will be included in the screening process. These include Wichita Falls (distant & expensive), desalination of alluvial groundwater or high chloride surface water (expensive), Greenbelt MIWA (distant & expensive) and construction of a new dam on

Beaver Creek (expensive & long lead time). It was agreed that meetings should be arranged with three of the alternative sources to determine their potential prior to the detailed analysis; they were: City of Altus, Oklahoma, City of Frederick, Oklahoma, and the Waggoner Ranch (Owners of Santa Rosa Lake). Jim Murray and Tom Gooch will arrange a trip to meet with each of these entities.

4. Curtis Campbell noted the chloride control projects which are proceeding should improve the quality of water in Lake Kemp and Lake Diversion over time (10-15 years). He also noted reverse osmosis energy recovery research being conducted by EPRI, and discussed possibility of including the WTU Oklaunion plant in their study.

5. Leonard noted denitrification for nitrate removal is looking much more promising than a year ago. Several pilot plants are now operating in the U.S. and this can now be considered a viable process, although there are still some regulatory obstacles to overcome.

6. Vernon's external customers were reviewed and are as follows:

   Oklaunion WSC — Northside WSC
   WTU — Texas Youth Commission
   Red River Authority Systems: Hinds, Lockett and Box WSCs

   With the exception of Lockett WSC, these systems use Vernon water exclusively for their potable supply. The Lockett system uses Vernon water to supplement local groundwater for peak demands.

7. Other communities interested in the study: Electra and Harrold. Electra is working with Jacobs and Martin and Don Rauschuber to find additional water supplies. Harrold is interested in participating in line from Frederick if that option is selected.

8. Jim Murray indicated there is support in the city for development of a reliable supply of water with acceptable quality. The city would also like a modest surplus available for industrial growth. A total supply of 4-5 MGD should meet anticipated needs. A representative peak day of 4.8 MGD was recorded in July 1996. The average demand that month was about 4.0 MGD and normal usage averages about 3 MGD.

9. Visits with potential industrial reuse/alternative supply customers will be arranged at a later date. Leonard noted the reuse concept was expanded to include sources such as high nitrate groundwater which may be more acceptable to food grade industries than reclaimed wastewater. Chris Bissett is the appropriate contact with WTU (Abilene office) for reuse discussions. New plant manager for Rhodia (formerly Rhone-Poulenc) is David Kramer.

10. Dwight Brandt discussed water distribution study and noted most information had been received from city. Steve Ainsworth noted the electronic mapping should be checked against

the most recent hard copies to verify information. City will provide recent subdivisions for update information. Leonard noted the future improvements for the water system could not be determined until the planned source of water was known.

11. David Sloan and Steve Ainsworth discussed wastewater collection system. City is consolidating requested information and will be able to provide most of the desired data. FN will determine which lines are appropriate for additional work by city crews to determine line sizes and invert elevations.

12. Curtis Johnson stressed importance of submitting subcontract agreements for TWDB review.

After the meeting adjourned, Brett Roberts and Tom Gooch visited well fields with Steve Ainsworth.

APPENDIX B

Groundwater Resources Study for Odell-Winston and Round Timber Ranch Well Fields

FINAL REPORT

GROUNDWATER RESOURCES STUDY FOR ODELL-WINSTON AND ROUND TIMBER RANCH WELL FIELDS, CITY OF VERNON

Prepared for
Freese and Nichols, Inc.
Fort Worth, Texas

October 1, 1998

Woodward-Clyde

Woodward-Clyde
Stanford Place 3, Suite 1000
4582 South Ulster Street
Denver, CO 80237

Project No. 24614

TABLE OF CONTENTS

Section 1 Introduction 1-1

1.1 Background 1-1
1.2 Objectives 1-1
1.3 Data Sources 1-2

Section 2 Review of Odell-Winston Well Field 2-1

2.1 Geology 2-1
2.2 Hydrology 2-1
2.3 Water Supply Wells 2-1
2.4 Other Users of the Seymour Aquifer 2-2
2.5 Condition of Water Supply Wells 2-2
2.6 Water Table 2-3
2.7 Pumping Rates 2-4
2.8 Water Quality 2-4
2.9 Pumping Costs 2-5

Section 3 Long-Term Availability of Groundwater From Odell-Winston Well Field 3-1

3.1 Saturated Thickness of Aquifer 3-1
3.2 Precipitation Rates Compared to Water Levels 3-1
3.3 Pumping Rates Compared to Water Levels 3-2
3.4 Influence of Other Users 3-2
3.5 Summary of Long-Term Availability of Water Resources 3-3

Section 4 Review of Round Timber Ranch Well Field 4-1

4.1 Geology 4-1
4.2 Hydrology 4-1
4.3 Water Supply Well Construction 4-1
4.4 Other Users of Seymour Aquifer 4-1
4.5 Condition of Water Supply Wells 4-2
4.6 Water Table 4-2
4.7 Pumping Rates 4-2
4.8 Water Quality 4-2

Section 5 Long-Term Availability of Groundwater From Round Timber Well Field 5-1

5.1 Saturated Thickness of Aquifer 5-1
5.2 Precipitation Rates Compared to Water Levels 5-1
5.3 Pumping Rates Compared to Water Levels 5-1
5.4 Summary of Long-Term Availability of Groundwater 5-2

TABLE OF CONTENTS

Section 6 Conclusions and Recommendations 6-1

6.1 Long-Term Pumping Rates 6-1
6.2 Well Field Management 6-1
6.3 Cost Savings and Well Field Protection 6-3

Section 7 References 7-1

List of Tables

Table 2-1 Odell-Winston Well Field Water Supply Wells

Table 2-2 Water Quality Data for Odell-Winston Well Field (August 1998)

Table 2-3 Water Quality Data for Odell-Winston Wells Collected by TWDB (March 1998)

List of Figures

Figure 2-1 Saturated Thickness of Aquifer Penetrated by Water Supply Wells, Odell-Winston Well Field

Figure 2-2 Odell-Winston Well WW-1 Hydrograph

Figure 2-3 Odell-Winston Well WW-2 Hydrograph

Figure 2-4 Odell-Winston Well WW-3 Hydrograph

Figure 2-5 Odell-Winston Well WW-4 Hydrograph

Figure 2-6 Odell-Winston Well WW-5 Hydrograph

Figure 2-7 Odell-Winston Well WW-6 Hydrograph

Figure 2-8 Odell-Winston Well WW-7 Hydrograph

Figure 2-9 Odell-Winston Well WW-8 Hydrograph

Figure 2-10 Odell-Winston Well WW-9 Hydrograph

Figure 2-11 Odell-Winston Well WW-10 Hydrograph

Figure 2-12 Odell-Winston Well WW-11 Hydrograph

Figure 2-13 Odell-Winston Well WW-12 Hydrograph

Figure 2-14 Odell-Winston Well WW-13 Hydrograph

Figure 2-15 Odell-Winston Well WW-14 Hydrograph

Figure 2-16 Odell-Winston Well WW-15 Hydrograph

Figure 2-17 Odell-Winston Well WW-16 Hydrograph

Figure 2-18 Odell-Winston Well WW-17 Hydrograph

TABLE OF CONTENTS

Figure 2-19 Odell-Winston Well WW-18 Hydrograph
Figure 2-20 Odell-Winston Well WW-19 Hydrograph
Figure 2-20 Odell-Winston Well WW-19 Hydrograph
Figure 2-21 Odell-Winston Well WW-20 Hydrograph
Figure 2-22 Odell-Winston Well WW-21 Hydrograph
Figure 2-23 Odell-Winston Well WW-22 Hydrograph
Figure 2-24 Hydrograph for State Observation Well #1346106
Figure 2-25 Hydrograph for State Observation Well #1346402
Figure 2-26 Hydrograph for State Observation Well #1346409
Figure 2-27 Hydrograph for State Observation Well #1346504
Figure 2-28 Hydrograph for State Observation Well #1346505
Figure 2-29 City of Vernon Annual Water Supply Volumes
Figure 2-30 Odell-Winston Well Field Daily Pumping Rates (April-June, 1998)
Figure 2-31 Concentration of Nitrate in Wells Versus Depth of the Aquifer the Well Penetrates
Figure 3-1 City of Vernon Annual Water Supply Volumes (1988 to 1997)
Figure 4-1 Hydrograph for Round Timber Ranch Well Field Observation Well #1
Figure 4-2 Hydrograph for Round Timber Ranch Well Field Observation Well #2
Figure 4-3 Hydrograph for Round Timber Ranch Well Field Observation Well #3
Figure 4-4 Hydrograph for Round Timber Ranch Well Field Observation Well #4
Figure 4-5 Hydrograph for Round Timber Ranch Well Field Observation Well #5
Figure 4-6 Hydrograph for Round Timber Ranch Well Field Observation Well #6
Figure 4-7 Hydrograph for Round Timber Ranch Well Field Observation Well #7
Figure 4-8 Round Timber Ranch Well Field Average Daily Pumping Rate Per Year
Figure 4-9 Round Timber Ranch Well Field Average Daily Pumping Rate Per Month

List of Appendices

Appendix A City Of Vernon Precipitation Data
Appendix B Odell-Winston Well Field Pumping Rate Data
Appendix C Round Timber Ranch Well Logs
Appendix D Round Timber Ranch Well Field Specific Capacity Data

This technical memorandum, which is prepared in support of the City of Vernon Water and Wastewater Comprehensive Plan, presents a review of the available groundwater resources and water quality for the Odell-Winston Well Field in Wilbarger County, Texas. The work was conducted by Woodward-Clyde under subcontract to Freese and Nichols Incorporated.

1.1 BACKGROUND

The current City of Vernon water supply needs are primarily met by groundwater withdrawn from the Odell-Winston Well Field. The Odell water supply wells are located approximately 12 miles north of the City of Vernon. The Winston water supply wells are located approximately 14 miles north of the City of Vernon. Additional water supply wells located within the City of Vernon are only used as backup during peak water demand periods. A review of the wells within the City of Vernon was not included within the scope of this study.

Concentrations of dissolved nitrate in the City of Vernon water supply have recently exceeded the Texas Department of Health (TDH) standard of 10 mg/l. The demand for water in the City of Vernon is projected to increase from the current level of approximately 2.7 MGD (3,100 acre-ft/year) in 1997 to approximately 3.5 MGD (3,900 acre-ft/year) in 2050. As a result of the issues associated with the water quality and the projected increase in demand for water, the City of Vernon wishes to investigate future water supply options. The Round Timber Ranch Well Field, located about 20 miles north of the City of Vernon has been identified as a potential alternative water supply. The Round Timber Ranch Well Field is leased by the City of Altus, but has not been used since 1989.

As part of the overall water supply study, this technical memorandum addresses the reliability and performance of the current water supply operations at the Odell-Winston Well Field and evaluates the potential for gaining additional water supply from the Round Timber Ranch Well Field. The remainder of Section 1 discusses the objectives of this study and the sources of data used for this study. Section 2 reviews the data available for the Odell-Winston Well Field. Estimates of the long-term availability of water in the Odell-Winston Well Field are made in Section 3. Available data for the Round Timber Ranch Well Field are reviewed in Section 4 and estimates of the available long-term water supply from the Round Timber Ranch Well Field are discussed in Section 5. Conclusions and recommendations are provided in Section 6.

1.2 OBJECTIVES

The overall objective of the Water Supply Plan for the City of Vernon is to develop up to three long-term water supply scenarios, with each scenario identifying the combination of sources to meet the water supply demands through 2050. The overall objective of this report is to support the development of the Water Supply Plan based on an evaluation of the existing Odell-Winston Well Field and a review of the available information for the Round Timber Ranch Well Field.

The specific objectives of this groundwater resources study are:

- Review the performance of the Odell-Winston Well Field
- Review the potential of the Round Timber Ranch Well Field as an additional water supply for the City of Vernon

- Estimate the long-term availability of groundwater from the Odell-Winston Well Field and Round Timber Ranch Well Field
- Recommend well field management practices to enhance and/or maintain long-term water supply from the Odell-Winston Well Field

1.3 DATA SOURCES

A variety of existing data were compiled to support this study, including reports of previous studies, City of Vernon and City of Altus water level records, pumping rate records, water quality records and drillers logs, and Texas Water Development Board monitoring well water level records. In addition, new water quality, pumping rate and water level data was generated for the Odell-Winston Well Field by the City of Vernon.

2.1 GEOLOGY

The Odell-Winston Well Field draws water from the Seymour Aquifer. The Seymour Formation consists of Quaternary Age semi-consolidated and unconsolidated alluvial deposits of clay, silt, sand, caliche, conglomerate and gravel. The Seymour Formation unconformably overlies rocks of Permian age and typically caps the interstream areas or divides between major streams. In some areas, particularly along the major streams, the Seymour Formation is overlain by unconsolidated Quaternary alluvium deposits. The thickness of the Seymour Formation is as much as 125 feet, but varies from approximately 70 to 110 feet in the area of the Odell-Winston Well Field . Although individual beds of the Seymour Formation are usually discontinuous, a fairly consistent zone of sand, gravel and conglomerate is usually present near its base. Texas Department of Water Resources (TDWR, 1979) notes that this basal unit is best developed in the Odell-Fargo area.

2.2 HYDROLOGY

The groundwater within the Seymour Aquifer is unconfined and therefore exists under water table conditions. The source of recharge to the Seymour aquifer is infiltration of precipitation falling directly on its outcrop area. The rate of recharge to the Seymour is probably greatest in the Odell-Fargo area as the topography is gently rolling and much of the surface is composed of highly permeable sand. Recharge to the Seymour Aquifer is estimated to be about 10 percent of annual precipitation (TDWR, 1979). The average annual precipitation for Vernon is 26.7 inches for the period 1904 to 1997. However, over the last decade (1988 to 1997), the average annual precipitation for Vernon has been 31.7 inches. Therefore it is likely that recharge to the Seymour Aquifer during the past 10 years has been slightly greater than the historical average. The rainfall data are provided in Appendix A.

Groundwater movement within the Seymour Aquifer in the Odell-Fargo area is generally from two groundwater highs located in the central part of the area towards the south, southwest, east, north, northwest and northeast. Directions of groundwater movement around the Odell-Winston Well Field is largely influenced by drawdown of the water table due to pumping of wells.

2.3 WATER SUPPLY WELLS

The Odell-Winston Well Field consists of 21 water supply wells varying in depth from 75 to 110 feet. Fourteen of the wells (wells WW-1, WW-3 to WW-15) are located in the Odell Well Field and seven of the wells (wells WW-16 to WW-22) are located in the Winston Well Field. In addition, a chlorine injection station and two above ground storage tanks exist at the Odell Well Field. Well WW-2 was originally installed in the Winston Well Field but was abandoned some time ago as it was not productive. Locations of the wells are shown on Figure 2-1.

Table 2-1 lists details of each well's construction and pump placement. In some cases, the original depths of the wells listed on the drillers logs are deeper than the currently measured depths. This is possibly due to infilling of the wells by sediments over time. The screen interval of the wells is taken from the drillers logs and ranges from 12 to 45 feet in length. The wells were initially installed with steel casings and screens varying in diameter from 10 to 16 inches. The

City of Vernon indicates that since their initial installation, wells WW-3, WW-4, WW-6, WW-9, WW-17, and WW-21 have had PVC casing and screen inserts installed inside the original casings. According to the City of Vernon, all wells are installed with submersible pumps which are routinely set at an elevation one foot from the bottom of the well. Although information on the original pumps installed in the wells is known, details of the current pump sizes were not available from the city of Vernon. The pumps were automated in early 1998 so that they can be switched on and off from the City of Vernon without having to visit each pump. In addition, totalizer flow meters were installed at each well to provide flow rate data for each well. This information was not previously available. The flow meters were also automated early in 1998 so that flow rate data for each well can be obtained from the City of Vernon.

2.4 OTHER USERS OF THE SEYMOUR AQUIFER

Groundwater in the Seymour Aquifer is used extensively for public water supply, irrigation, industrial, domestic and livestock purposes. Most of the groundwater pumped from the Seymour Aquifer in Wilbarger County is used for irrigation and public water supply. In the areas adjacent to the Odell-Winston Well Field a number of irrigation wells exist which can affect the saturated thickness of the Seymour Aquifer in the well field and reduce the efficiency of the City of Vernon water supply wells. TDWR (1979) noted that there were 173 irrigation wells in the Odell-Fargo area.

The City of Vernon leased the land for the chlorine station and storage tanks at the Odell Well Field in 1954 for $100 for a term of 99 years. The Winston Farm where the Winston Well Field is located was purchased by the City of Vernon in 1970. Therefore the City owns the land and all water rights for the Winston Well Field. This gives the City much more control over the use of water in the Winston area than it does around the Odell Well Field.

2.5 CONDITION OF WATER SUPPLY WELLS

The condition of each water supply well in the Odell-Winston Well Field is not known. However, discussions with the City of Vernon and the review of downhole television logs of five wells have provided some information on the condition of some of the wells. Based on this information, several historical well problems have been noted by the City. After the gravel pack for WW-4 collapsed, the gravel was bailed out and an 8 inch diameter PVC casing was inserted. This PVC insert does not go all the way to the bottom of this well. Nevertheless, Well WW-4 is still used. Well WW-3 routinely breaks suction because the pump is oversized. (At that time, the City was planning to replace this pump with a smaller one). For different periods during the first half of 1998, the pumps in wells WW-3, WW-6, WW-7, WW-10, WW-17, WW-19 and WW-21 had to be pulled out of the wells for repair or replacement. The City does not routinely maintain the pumps. Rather, they are removed and either replaced or repaired once they stop working.

The City recorded downhole television logs of five wells in 1996 and provided this video to Woodward-Clyde for review. The television logs from the five wells (WW-4, WW-6, WW-10, WW-17, and WW-21) showed the wells are generally in good condition. All wells were constructed with 8 inch PVC casing inserted inside the outer casing, except WW-10, which still used the original 10-inch steel casing. Well WW-10 showed some signs of corrosion, particularly the screen, while the other wells showed some signs of minor encrustation on the screens and clogging of the screens. In addition, wells WW-6, WW-17 and WW-21 showed a significant amount of sediment in the bottom of the well; the sediment covers the base of the screens. Other observations from the video logs include: the PVC insert did not extend to the bottom of WW-4 as noted above; WW-10 was slightly bent between the depths of 65 and 80 feet; Well WW-17 had a slotted section of pipe incorrectly installed between 18 and 25 feet depth; and WW-21 appeared to have a small hole in the casing at about 20 feet depth.

2.6 WATER TABLE

The depth to the static water table in the Odell-Winston Well Field ranges from approximately 20 to 80 feet below the ground surface. Static water level measurements have been made periodically for the water supply wells within the Odell-Winston Well Field since the 1950s. However, regular static water level measurements have only been made in the last decade. Figures 2-2 to 2-23 show the trends in the static water levels for the twenty-one wells in the Odell-Winston Well Field for the last decade. Most water supply wells show a relatively stable to slightly increasing static groundwater level during the last ten years. Specifically, WW-2, WW-3, WW-10, WW-14, WW-15, WW-16, WW-17, WW-18, WW-19, WW-20 and WW-22 show significantly increasing groundwater level elevations over the last decade. However, wells WW-11, WW-12 and WW-13 show a slight decline in static groundwater levels, particularly since 1992. Some wells (WW-1, WW-6, WW-15, WW-16, WW-17, WW-20 and WW-22) show a sharp decline in water level elevations for the 1998 summer months although the general trend over the last decade is either stable or increasing. These recent sharp declines are a result of the reduced recharge and increased demand for water during the dry and hot conditions that prevailed in the area during the summer of 1998. In addition, other users (especially irrigation wells) of the Seymour Aquifer in the areas of the Odell-Winston Well Field influence the water levels in the surrounding aquifer. For example, an irrigation well located close to WW-1 is only used by the farmer in dry periods; use of this well in the summer of 1998 caused a significant decline in the water level in WW-1.

Five State of Texas observation wells are located in the area of the Odell-Winston Well Field. Locations of these wells are shown on Figure 2-1. Water level data was obtained for each of these observation wells from the Texas Water Development Board. The hydrographs are shown in Figures 2-24 to 2-28. All five wells show a steady decline in water levels from when records were first collected in the early 1950's to the late 1980's. However, over the last decade all of the State observation wells show a steady increase in water levels. The water levels measured in early 1998 are back to water level elevations equivalent to the water levels measured in the 1970's. This steady increase in water levels during the late 1980's and 1990's is consistent with the steady to increasing static water levels observed in the City of Vernon water supply wells. The increasing water level elevations correspond with the higher than average rate of precipitation and hence recharge that has occurred over the last decade. For the period 1950 to 1987 when a decline in water levels was observed, average annual precipitation was slightly less than the historical average (25.7 inches versus 26.7 inches).

2.7 PUMPING RATES

After the automated flow meters were installed and operational in early 1998, the City of Vernon began recording average daily pumping rates for each water supply well. Prior to 1998, pumping rate data are available for the entire Odell-Winston Well Field for some months during years 1991, 1992 and 1993. However, total water supply volumes, including the wells used in the City of Vernon, are available for a much longer period (1960-1997). Figure 2-29 shows the annual water use volumes for the City of Vernon for the years of record. During the period 1960 to 1975 the annual water supply volumes show a general increasing trend, while for the period 1986 to 1997, the annual water supply volumes show a general decreasing trend. Between 1986 and 1997, the annual water use for the City of Vernon has ranged from approximately 914 million gallons in 1995 (2.5 MGD) to 1,281 million gallons in 1986 (3.5 MGD), with an average of approximately 1,046 million gallons (2.9 MGD). Between 1960 and 1985, the annual water use for the City of Vernon ranged from 522 million gallons in 1960 (1.4 MGD) to 1,264 million gallons in 1974 (3.5 MGD), with an average of approximately 878 million gallons (2.4 MGD).

Figure 2-30 shows the average daily pumping rates for the entire well field for the months of April, May and June, 1998. The peak daily flow during this period reached 5.4 MGD, while the daily averages were 2.7 MGD for April; 3.5 MGD for May; and 4.0 MGD for June. Average daily flows for each well for the period March 13 to May 10, 1998 is provided in Appendix B.

2.8 WATER QUALITY

The Odell-Winston water supply wells were sampled by the City of Vernon in August 1998. All wells were analyzed for total dissolved solids (TDS), chloride and nitrate. In addition, WW-19 was analyzed for alkalinity, sulfate, fluoride, hardness, sodium, calcium and magnesium. The TWDB sampled WW-11 and WW-14 in March 1998 for a range of major cations and anions, nitrogen compounds and metals. Tables 2-2 and 2-3 present the water quality data. Other water quality data available for each individual well within the Odell-Winston Well Field is limited to three samples in 1970 and one sample in 1980.

The TDS concentrations for the water samples collected in 1998 range from 270 mg/l for WW-1 to 1016 mg/l for WW-9. Most wells have TDS concentrations in the range of 300 to 500 mg/l. WW-9 has a TDS concentration greater than the Texas Drinking Water Standard of 1,000 mg/l. Chloride concentrations range from 7 mg/l for WW-12 and WW-13 to 283 mg/l for WW-9. No wells have concentrations of chloride greater than the Texas Drinking Water Standard of 300 mg/l. The concentrations of nitrate in the water samples collected by the City of Vernon in August 1998 range from 7.7 mg/l to 16.6 mg/l. Fourteen of the twenty-two wells have concentrations of nitrate greater than the Texas Drinking Water Standard of 10 mg/l. The concentrations of nitrate reported in the two samples collected by the TWDB in March 1998 (49.6 mg/l and 58.4 mg/l) are not considered realistic when compared with the nitrate plus nitrite concentrations for the same samples (11.2 mg/l and 13.2 mg/l). The concentrations of nitrate plus nitrite exceeds the Texas Drinking Water Standard of 10 mg/l in both samples. The concentrations of all other parameters in the two samples collected by TWDB are below the Texas Drinking Water maximum concentration limits.

Although there do not appear to be any spatial trends in the concentration of nitrate in the water supply wells, the concentration of nitrate in the Winston wells is generally greater than in the

Odell wells. However, there does appear to be a general trend in the concentration of nitrate compared to the saturated thickness of the aquifer, as shown on Figure 2-31. The wells that penetrate a greater saturated thickness of the aquifer generally have greater concentrations of nitrate. The reason for this relationship is not known, but it may be a reflection of higher nitrate concentrations in soils closer to the ground surface.

During the water quality sampling of the wells by the City of Vernon in August 1998, the amount of sand being pumped in the groundwater from each well was measured using an Imhoff cone. It is important to limit the sand being pumped because sand can be destructive to pumps and can accumulate in storage tanks, which reduces storage capacity. Large amounts of sand pumping can be indicative of a poor quality or an improperly designed well screen. If a screen shows signs of high sand pumping then it may have corroded and could eventually result in the screen collapsing. The measured concentration of sand being pumped from each well is presented in Table 2-2. The concentration of sand being pumped ranges from 0 to 0.1 ml of sand per 1,000 ml of water. Well WW-16 has the greatest concentration of sand (0.1 ml/1000 ml). Assuming a sand density of 2.65 g/cm^3 and a 50 percent porosity of sand in the Imhoff cone, 0.1 ml/1000 ml is approximately 133 mg of sand per liter of water. Driscoll (1995) recommends a maximum sand concentration of 20 mg/l to avoid downhole instability that could cause failure of the screen. Wells WW-5, WW-6, WW-7, WW-8, WW-15, WW-16, and WW-21 pump sand at concentrations greater than 20 mg/l. The City of Vernon observed an accumulation of over one-foot of sand in a storage tank at the Odell Well Field over a period of about ten years.

2.9 PUMPING COSTS

The City of Vernon has indicated that the cost of pumping groundwater from wells in the Odell-Winston Well Field averages approximately $1.08 per 1,000 gallons of water. This cost includes all electrical and labor costs for the City of Vernon water supply department.

TABLE 2-1
ODELL-WINSTON WELL FIELD WATER SUPPLY WELLS

Well No.	Ground Elevation(1) (feet MSL)	Measuring Point(1) (feet)	Well Depth(2) (feet)	Well Bottom Elevation (feet MSL)	Original Casing Diameter (inches)	Screen Interval(3) (feet)	Pump Elevation(4) (feet MSL)	Depth to Static Water Level 5/98(5) (feet)	Static Water Elevation (feet MSL)	Water in Well (feet)	Depth to Water During Pumping 5/98 (feet)	Water in Well During Pumping (feet)
1	1410	1.52	93	1318.52	10	65-95	1319.52	69	1342.52	24	82	11
2	1358	1.9	75	1284.9	NA	NA	1285.9	NA	NA	NA	NA	NA
3	1395	2.11	91	1306.11	10	42-82	1307.11	42	1355.11	49	NA	NA
4	1392.4	1.85	93	1301.25	10	52-92	1302.25	44	1350.25	49	76	17
5	1392.1	1.75	93	1300.85	10	50-90	1301.85	44	1349.85	49	54	39
6	1383.5	1.6	93	1292.1	10	40-85	1293.1	36	1349.1	57	NA	NA
7	1394.8	1.75	97	1299.55	10	43-98	1300.55	50	1346.55	47	NA	97
8	1394.3	0	97	1297.3	10	57-97	1298.3	54	1340.3	43	76	21
9	1399.7	1.25	110	1290.95	10	47-107	1291.95	75	1325.95	35	96	14
10	1399.4	1.4	99	1301.8	10	40-100	1302.8	36	1364.8	63	NA	NA
11	1408	1.6	104	1305.6	10	68'2"-98'2"	1306.6	75	1334.6	29	95	9
12	1421	1.7	108	1314.7	12	86-112	1315.7	78	1344.7	30	99	9
13	1410	1.45	98	1313.45	12	76.8-102.8	1314.45	66	1345.45	32	75	23
14	1397	0.54	108	1289.54	12	85-110	1290.54	68	1329.54	40	83	25
15	1384	0	96	1288	12	71-96	1289	55	1329	41	78	18
16	1354.5	2.5	93	1264	16	72-92	1265	27	1330	66	56	37
17	1355	2.35	85	1272.35	16	74-89	1273.35	22	1335.35	63	45	40
18	1357	2.35	85	1274.35	16	69-84	1275.35	29	1330.35	56	61	24
19	1350	1.05	76	1275.05	14	NA	1276.05	27	1324.05	49	NA	NA
20	1364	2.9	93	1273.9	14	102-114	1274.9	44	1322.9	49	58	35
21	1361	2.22	87	1276.22	14	72-86	1277.22	26	1337.22	61	NA	NA
22	1358	0.88	89	1269.88	12	NA	1270.88	27	1331.88	62	61	28

Note: (1) From Geraghty & Miller, 1992
(2) From City of Vernon Monthly Groundwater level measurements
(3) From drillers logs
(4) From City of Vernon Utilities Manager - "All pumps set 1 foot above base of well"
(5) All Static Water Levels are from May 1998 measurements except WW-3 (June 1998) and WW-10 (November 1997)
(6) NA indicates not available

TABLE 2-2
WATER QUALITY DATA FOR ODELL-WINSTON WELL FIELD (AUGUST 1998)

Parameter	WW-1	WW-3	WW-4	WW-5	WW-6	WW-7	WW-8	WW-9	WW-10	WW-11	WW-12	WW-13	WW-14
TDS (mg/l)	270	334	440	328	490	330	352	1016	454	390	348	294	776
Chloride (mg/l)	14	19	12	11	38	12	27	283	8	12	7	7	213
Nitrate (mg/l)	7.8	10.5	9.9	9.2	11.8	10.1	10.8	7.7	10.1	9.7	9.4	11.4	10.1
Alkalinity (mg/l)													
Sulfate (mg/l)													
Fluoride (mg/l)													
Hardness (as CaCO3) (mg/l)													
Total Sodium (mg/l)													
Calcium (Hardness as Ca) (mg/l)													
Magnesium(Hardness as Mg) (mg/l)													
Total Manganese (mg/l)													
Total Iron (mg/l)													
Total Potassium (mg/l)													
Sand (ml of sand/1000ml of water)	0	0	0	0.05	0.05	0.05	0.05	0	0	0	0	0	0

Note: All samples collected by City of Vernon in August 1998

TABLE 2-2
WATER QUALITY DATA FOR ODELL-WINSTON WELL FIELD (AUGUST 1998)

Parameter	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20	WW-21	WW-22	Texas Drinking Water Standards
TDS (mg/l)	394	482	542	416	286	380	384	396	1000
Chloride (mg/l)	8	15	27	66	12	17	41	31	300
Nitrate (mg/l)	11.7	13.6	14.7	10.8	8	11.3	16.6	14	10
Alkalinity (mg/l)					202				
Sulfate (mg/l)					26				300
Fluoride (mg/l)					0.47				2
Hardness (as CaCO3) (mg/l)					255				
Total Sodium (mg/l)					76.9				
Calcium (Hardness as Ca) (mg/l)					64				
Magnesium(Hardness as Mg) (mg/l)					23				
Total Manganese (mg/l)					<0.01				0.05
Total Iron (mg/l)					<0.03				0.3
Total Potassium (mg/l)					0.8				
Sand (ml of sand/1000ml of water)	0.05	0.1	0	0	0	0	0.05	0	

Note: All samples collected by City of Vernon in August 1998

TABLE 2-3
WATER QUALITY DATA FOR ODELL-WINSTON WELLS COLLECTED BY TWDB (MARCH 1998)

Parameter	WW-11	WW-14	Texas Drinking Water Standard
pH	7.83	7.65	7
Temperature (C)	19	20	
TDS (mg/l)	326	669	1000
Chloride (mg/l)	12	57	300
Nitrate (mg/l)	49.6	58.4	10
Alkalinity (mg/l)	207	443	
Sulfate (mg/l)	21	62	300
Fluoride (mg/l)	0.3	0.8	2
Hardness (as CaCO3) (mg/l)	217	468	
Total Sodium (mg/l)	22	57	
Calcium (Hardness as Ca) (mg/l)	64	91	
Magnesium(Hardness as Mg) (mg/l)	14	58	
Silica (mg/l)	25	29	
Strontium (mg/l)	0.3	1	
Carbonate (mg/l)	0	0	
Bicarbonate (mg/l)	239	516	
Conductivity	504	1061	
Aluminum, Dissolved (µg/l)	4.6	<4	50-200
Antimony, Dissolved (µg/l)	<1	<1	6
Arsenic, Dissolved (µg/l)	<5	<5	50
Barium, Dissolved (µg/l)	237	133	2000
Beryllium, Dissolved (µg/l)	<1	<1	4
Boron, Dissolved (µg/l)	70	198	
Bromide, Dissolved (mg/l)	0.11	<0.1	
Cadmium, Dissolved (µg/l)	<1	<1	5
Chromium, Dissolved (µg/l)	20.4	40.8	100
Cobalt, Dissolved (µg/l)	<1	<1	
Copper, Dissolved (µg/l)	<2	2.5	1000
Iron, Dissolved (µg/l)	<10	<10	300
Lead, Dissolved (µg/l)	<1	<1	
Lithium, Dissolved (µg/l)	9.8	28.6	
Manganese, Dissolved (µg/l)	<1	<1	50
Molybdenum, Dissolved (µg/l)	<1	1.1	
Nickel, Dissolved (µg/l)	2.9	4.7	100
Nitrite plus Nitrate, Dissolved (mg/l as N)	11.2	13.2	10
Nitrogen, Ammonia, Dissolved (mg/l as N)	<0.05	<0.05	
Nitrogen, Kjeldahl, Dissolved (mg/l as N)	<0.1	<0.1	
Oxidation Reduction Potential (millivolts)	54.6	104.1	
Phosphorus, Dissolved (mg/l)	<0.1	<0.1	
Selenium, Dissolved (µg/l)	<5	<5	50
Strontium, Dissolved (µg/l)	307	969	
Thallium, Dissolved (µg/l)	<1	<1	2
Vanadium, Dissolved (µg/l)	8.4	17.8	
Zinc, Dissolved (µg/l)	<4	50.9	

Figure 2-2
Odell-Winston Well WW-1 Hydrograph

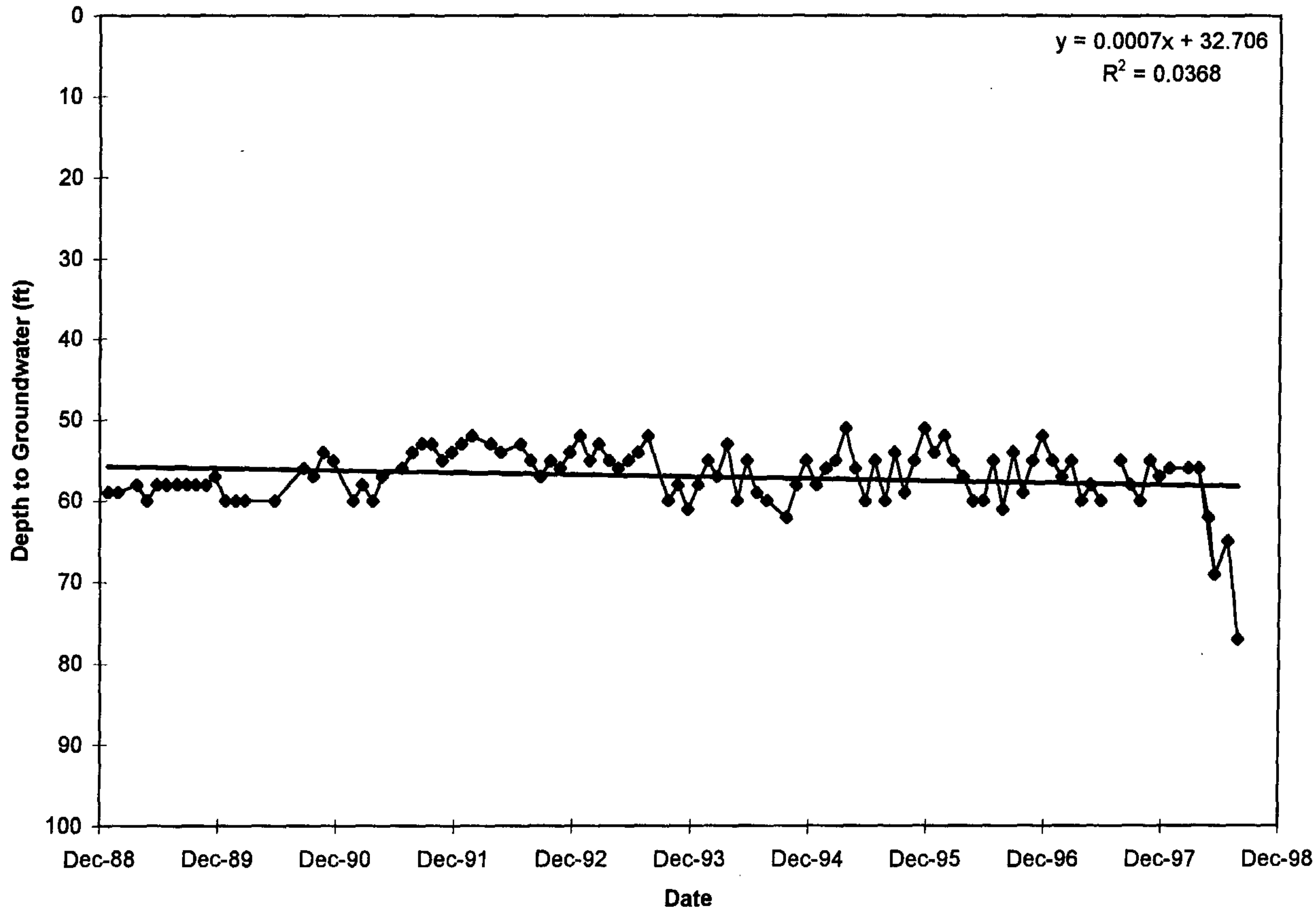


Figure 2-3
Odell-Winston Well WW-2 Hydrograph

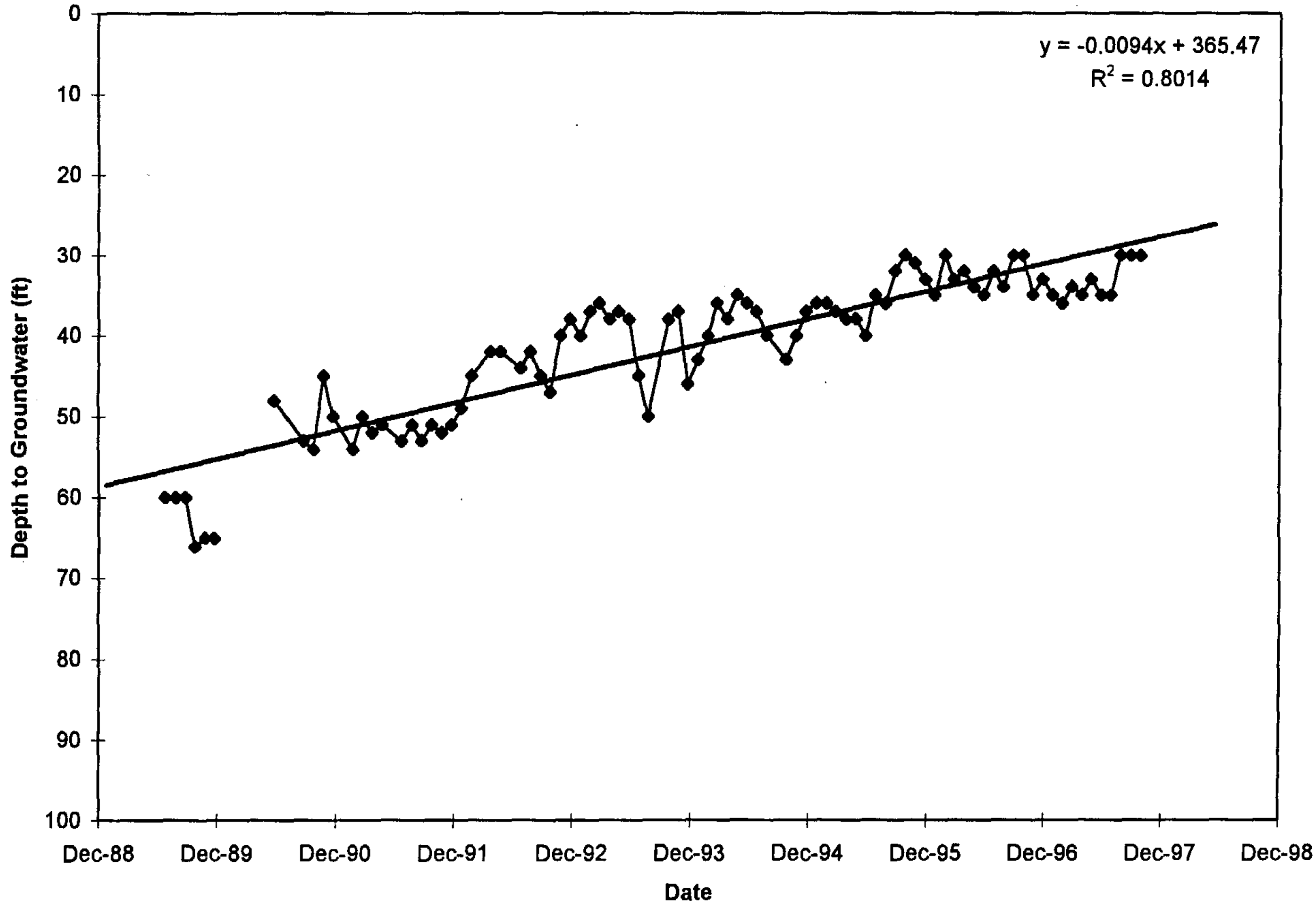


Figure 2-4
Odell-Winston Well WW-3 Hydrograph

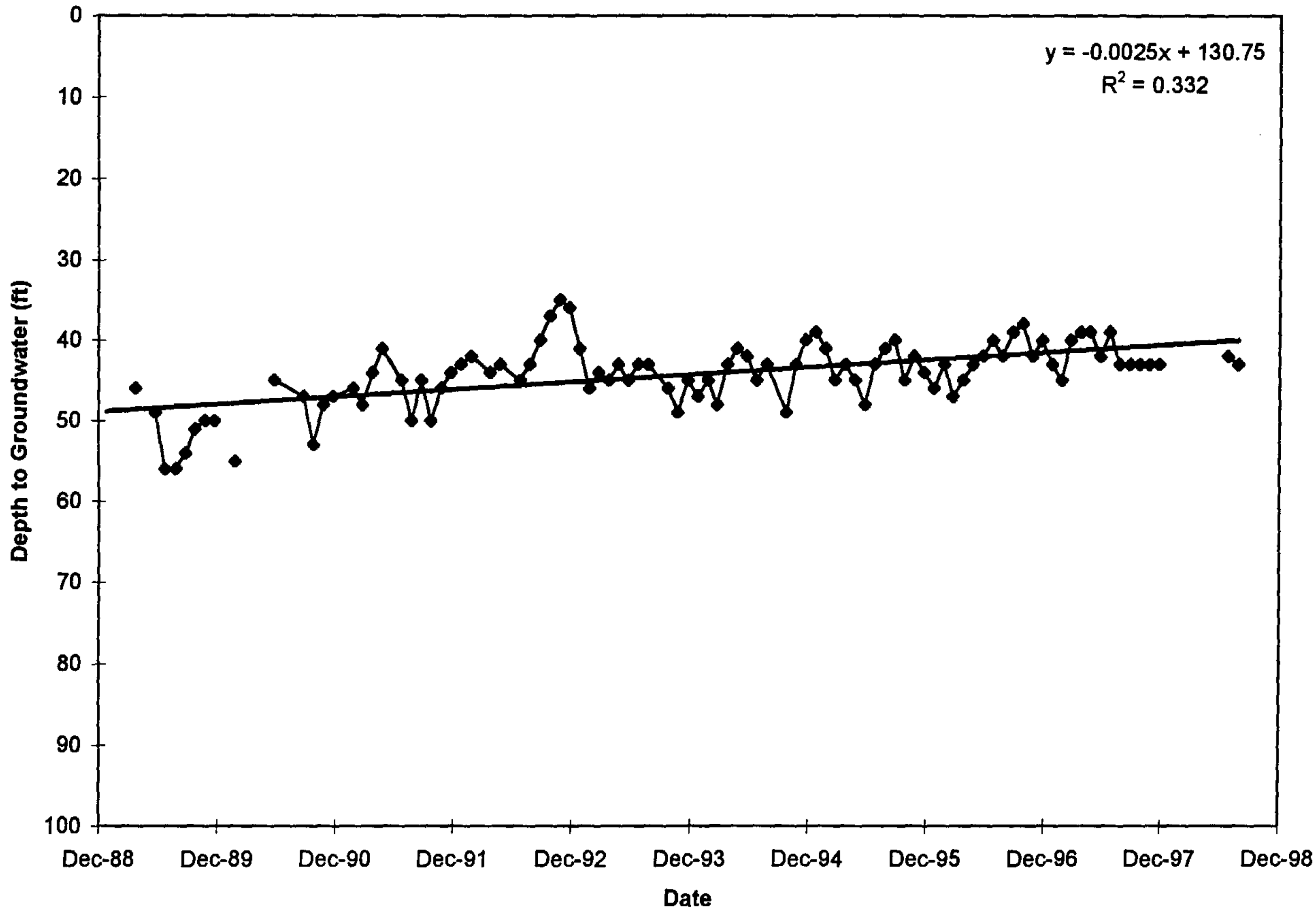


Figure 2-5
Odell-Winston Well WW-4 Hydrograph

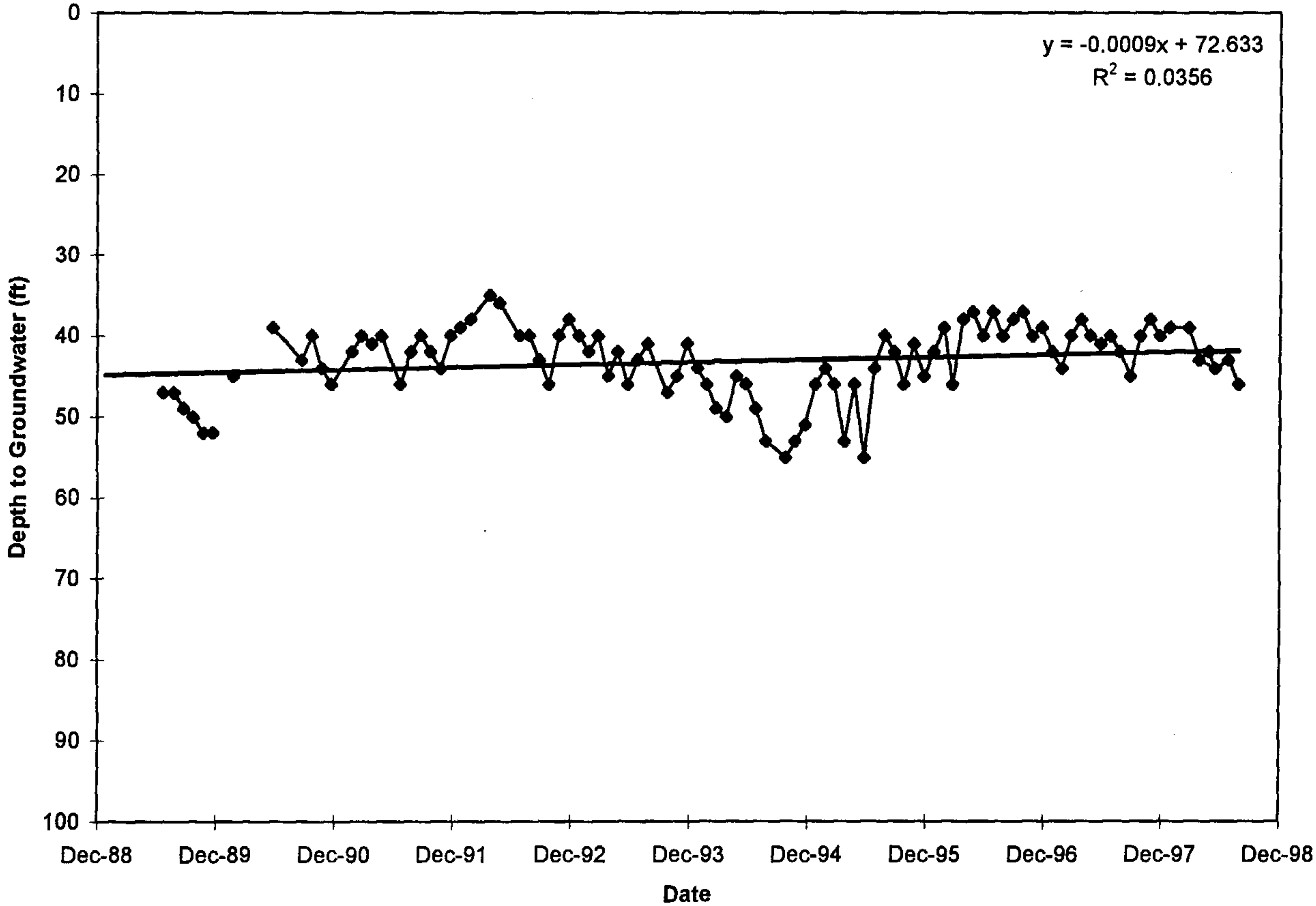


Figure 2-6
Odell-Winston Well WW-5 Hydrograph

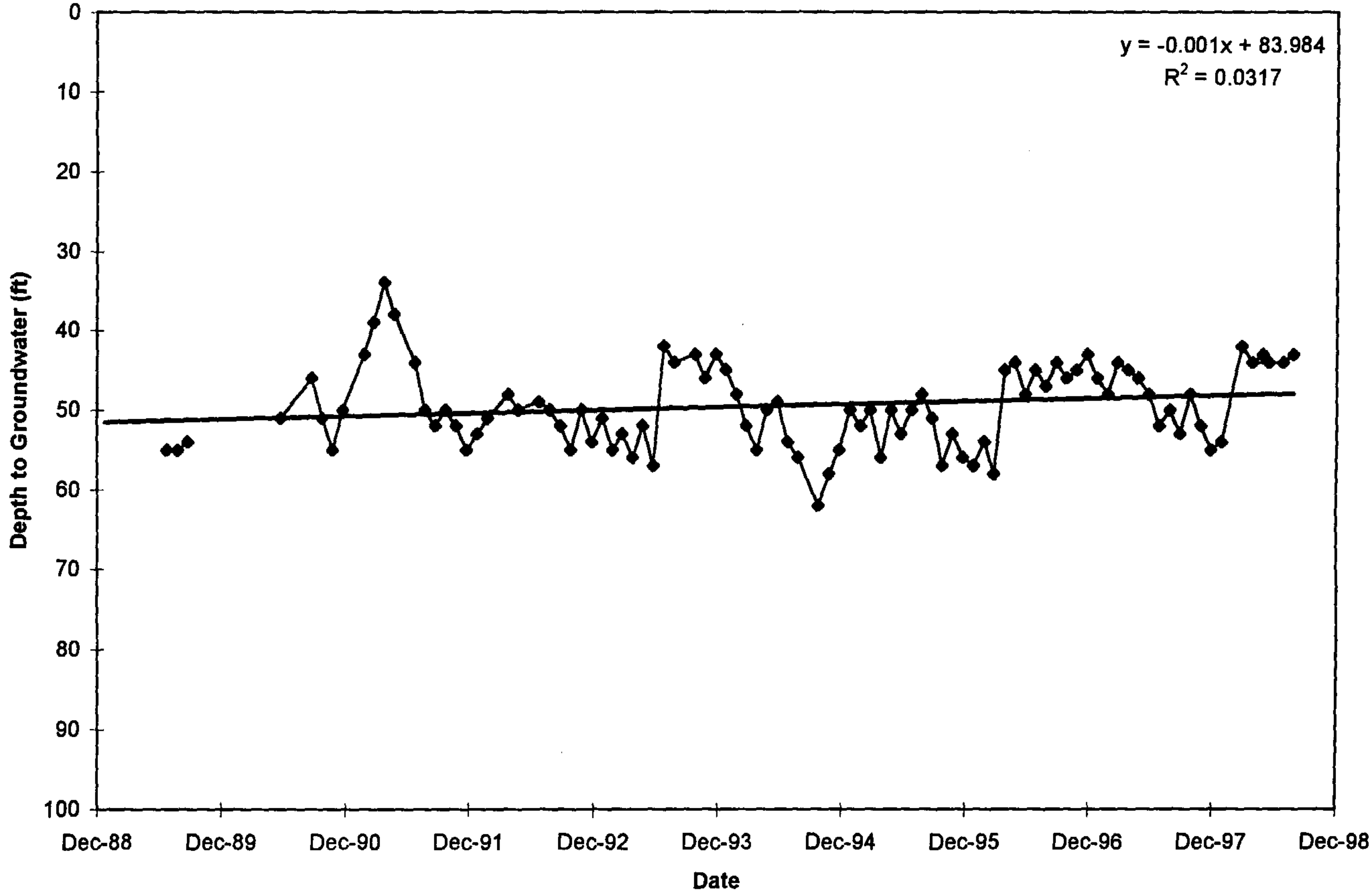


Figure 2-7
Odell-Winston Well WW-6 Hydrograph

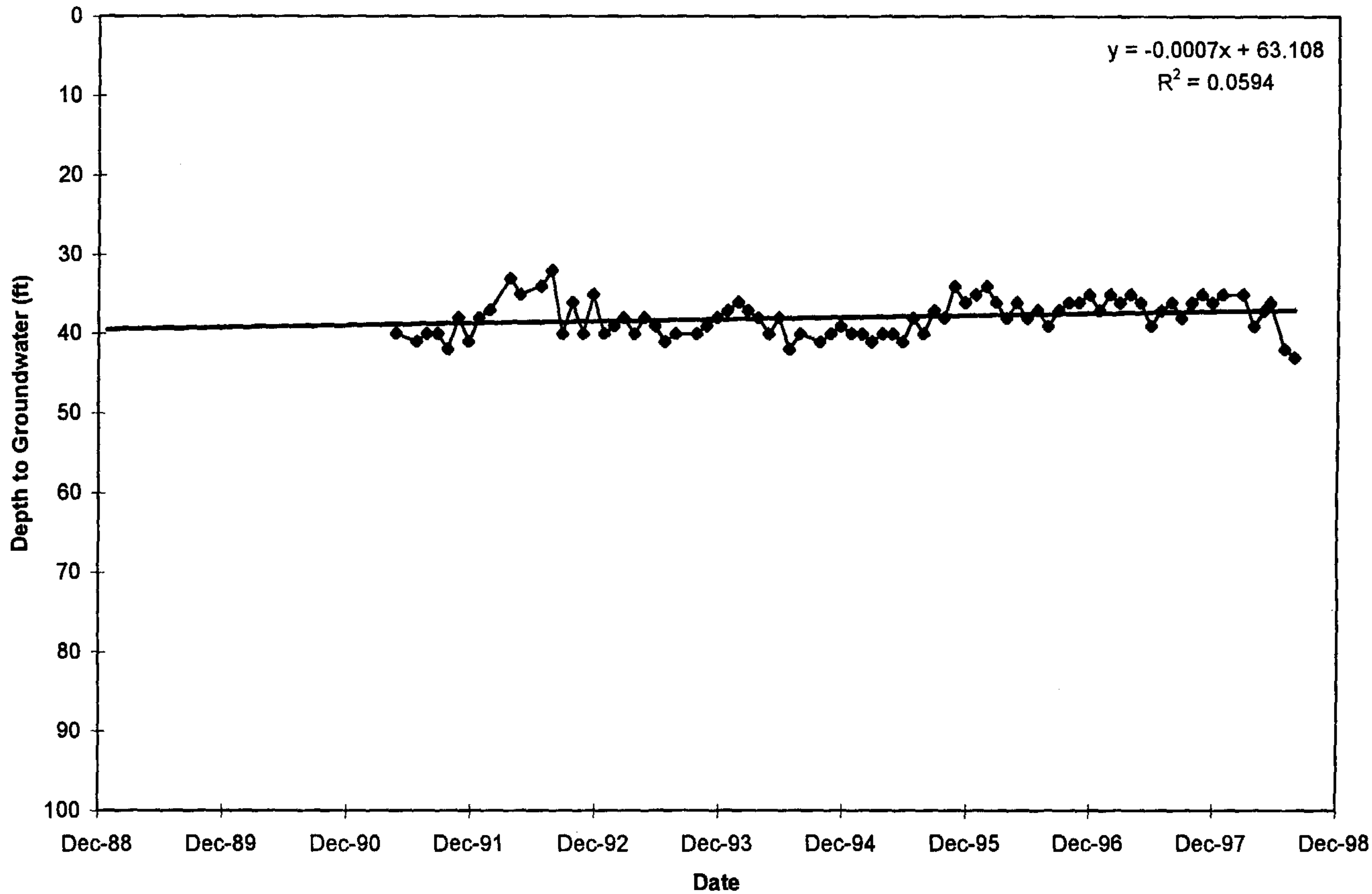


Figure 2-8
Odell-Winston Well WW-7 Hydrograph

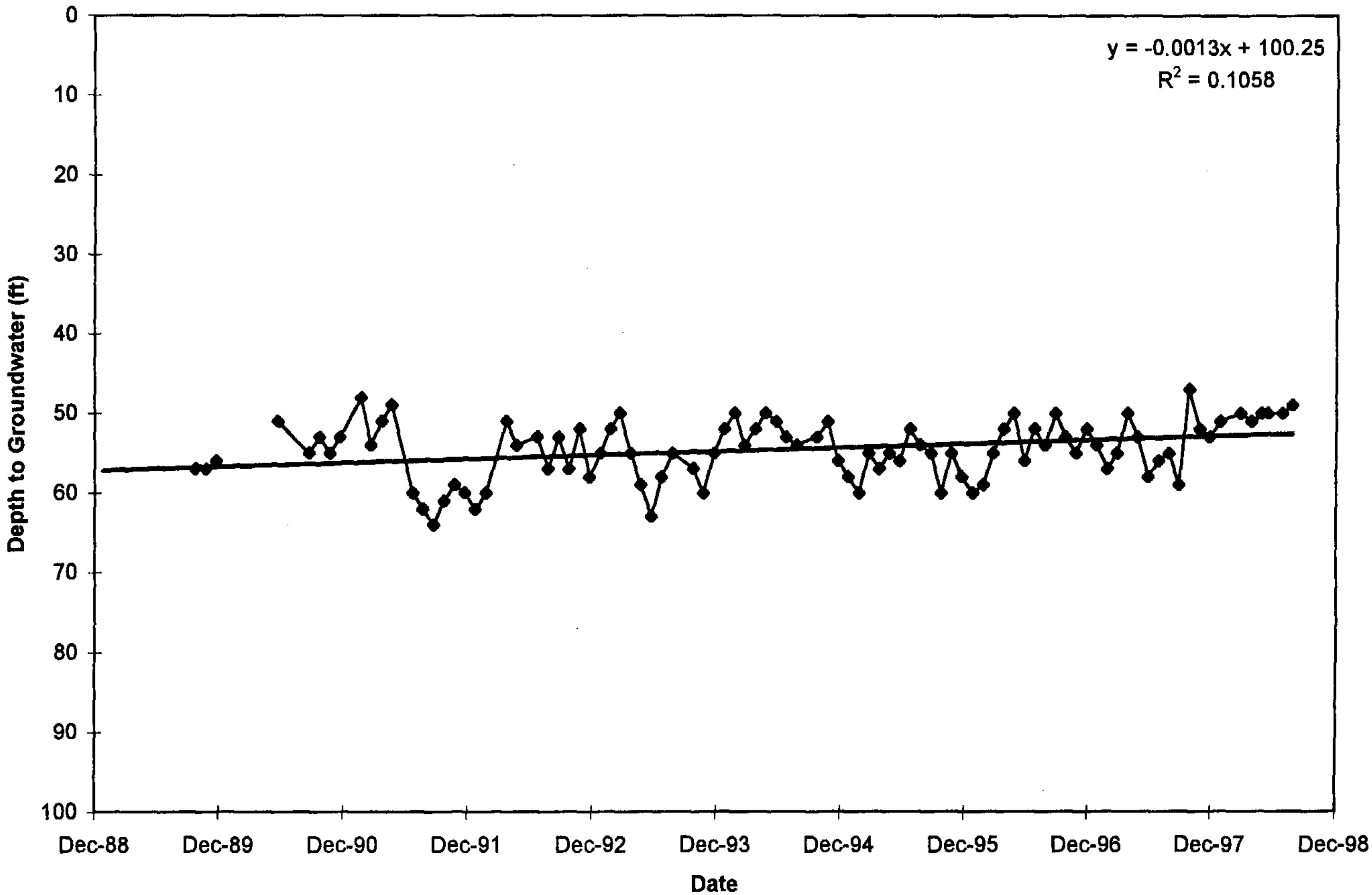


Figure 2-9
Odell-Winston Well WW-8 Hydrograph

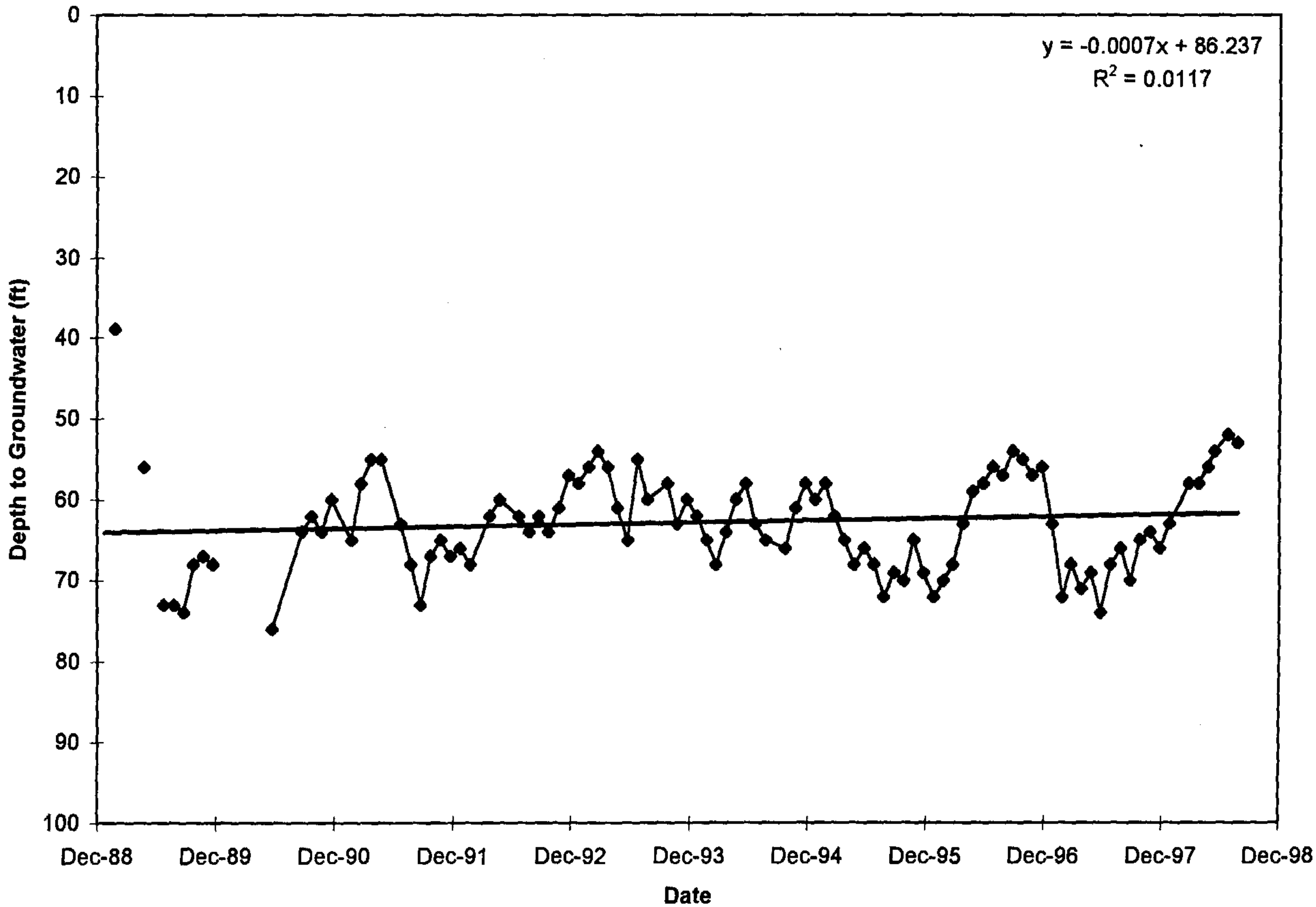


Figure 2-10
Odell-Winston Well WW-9 Hydrograph

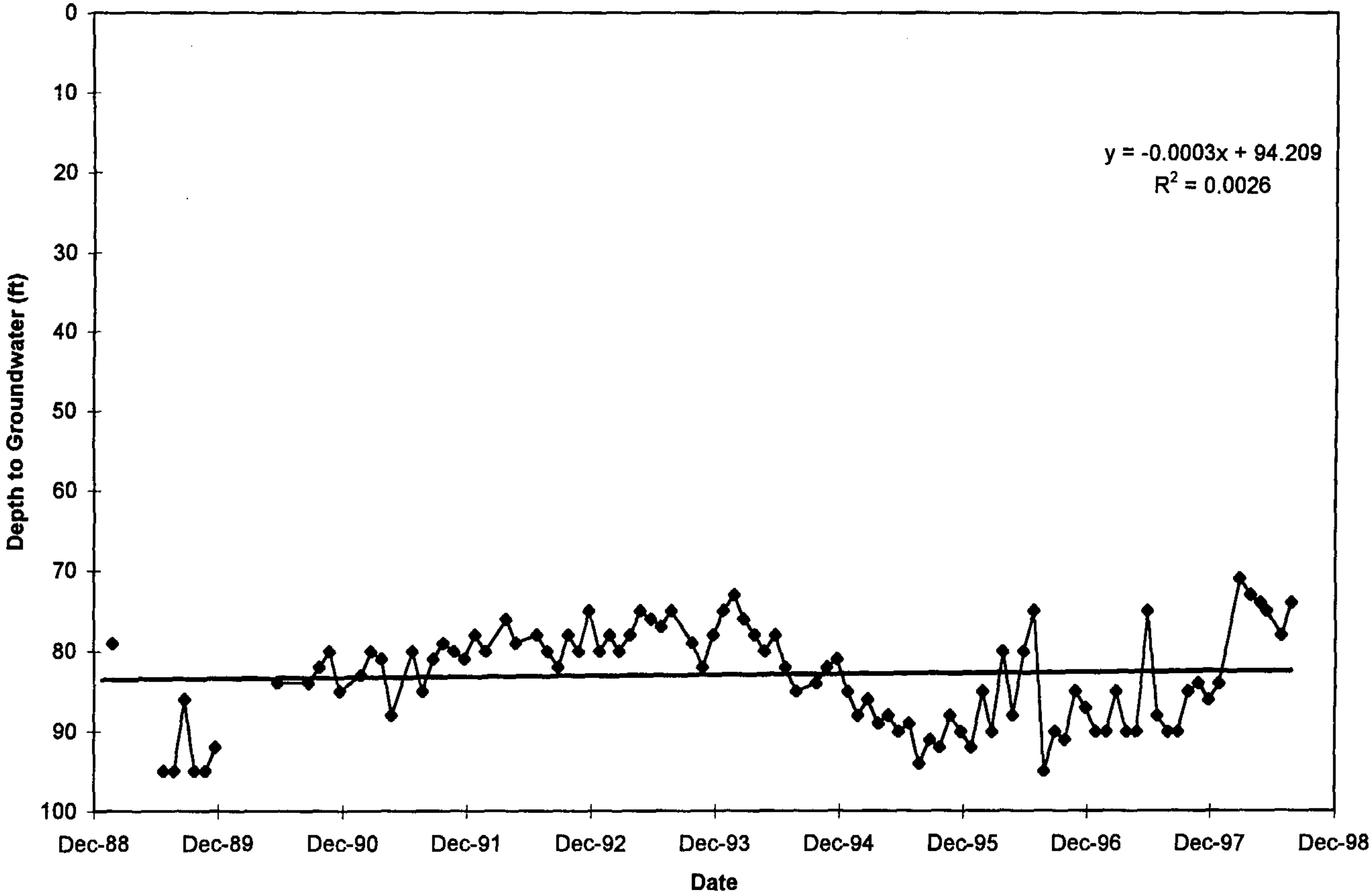


Figure 2-11
Odell-Winston Well WW-10 Hydrograph

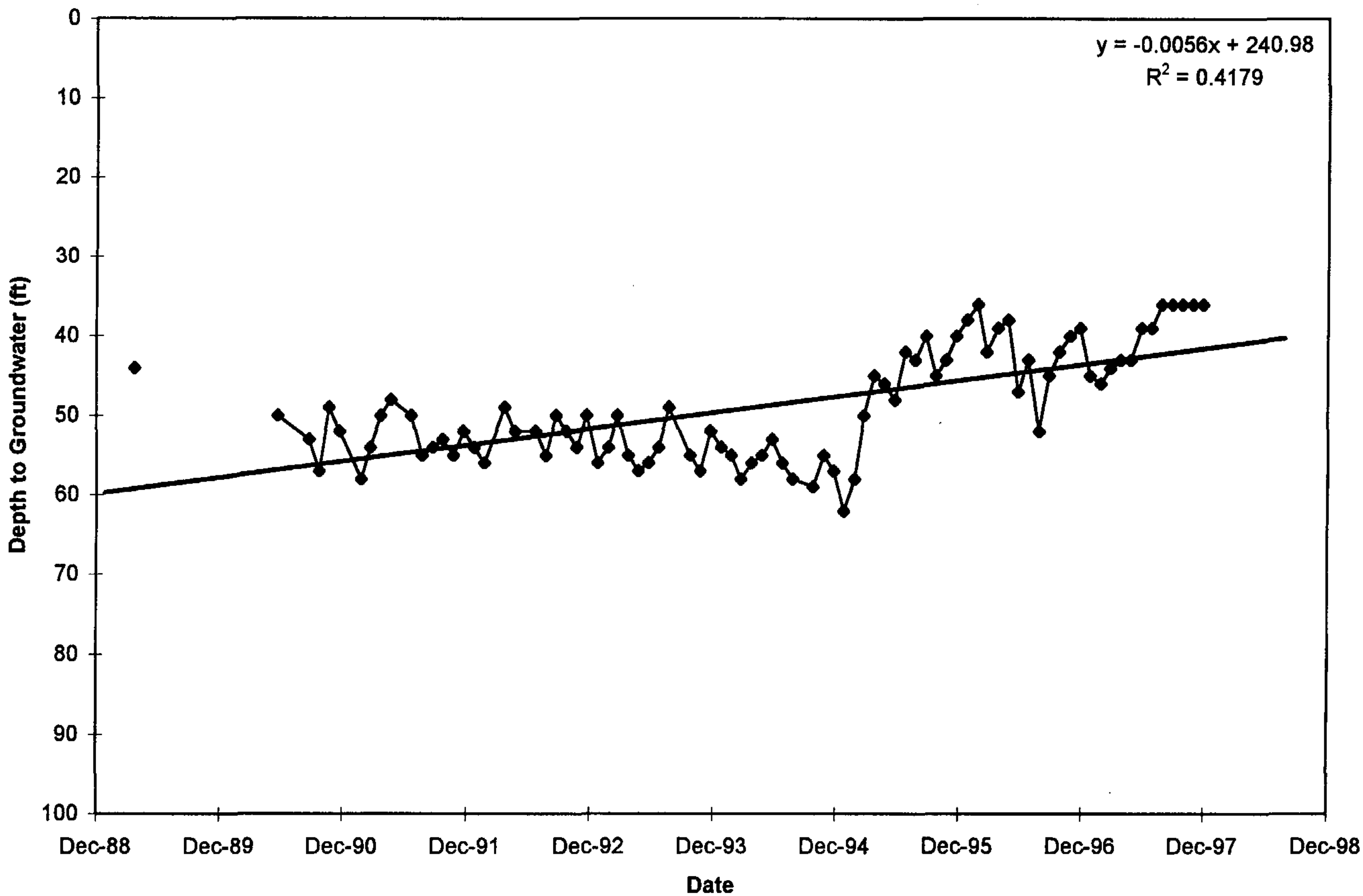


Figure 2-12
Odell-Winston Well WW-11 Hydrograph

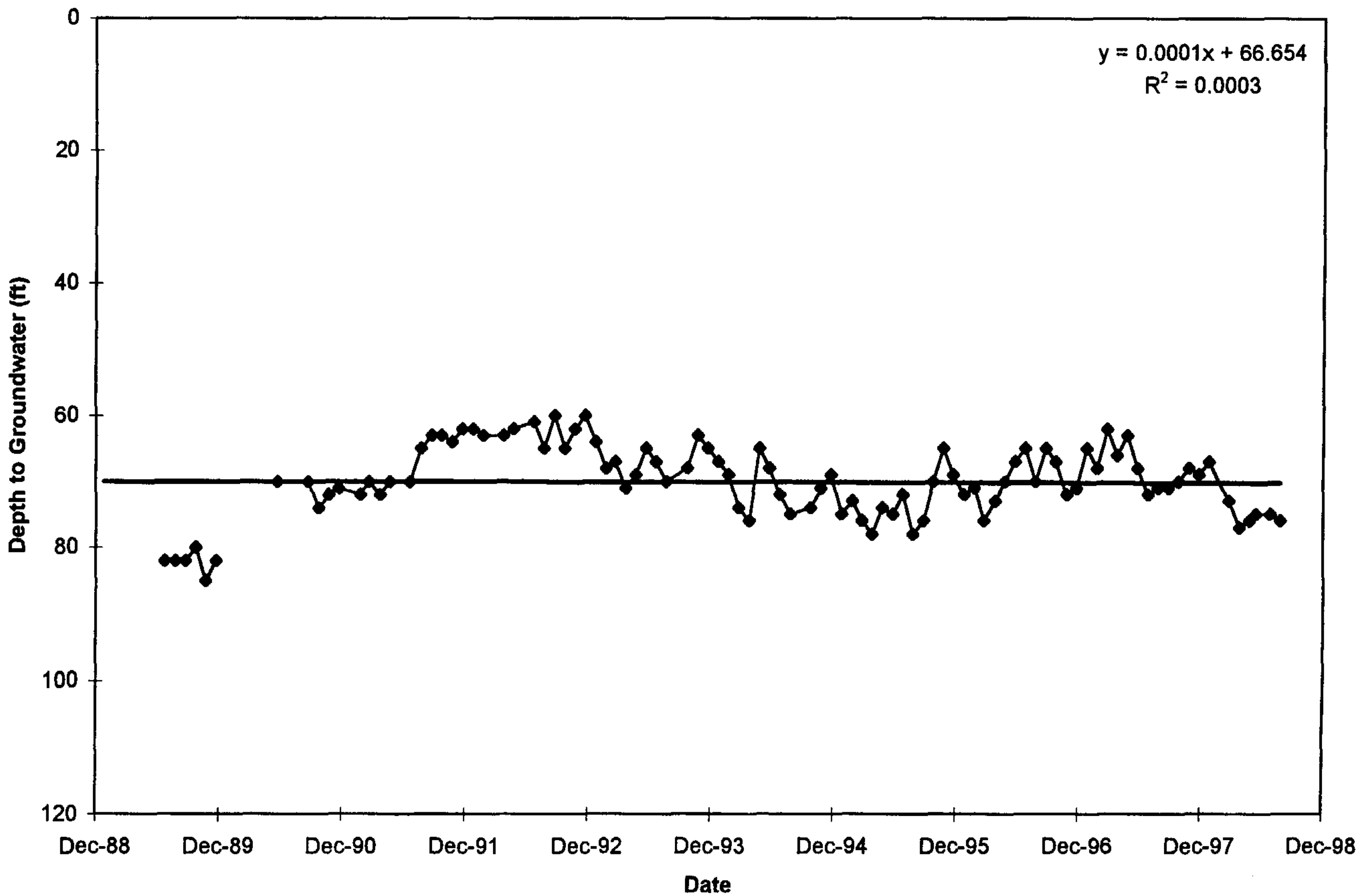


Figure 2-13
Odell-Winston Well WW-12 Hydrograph

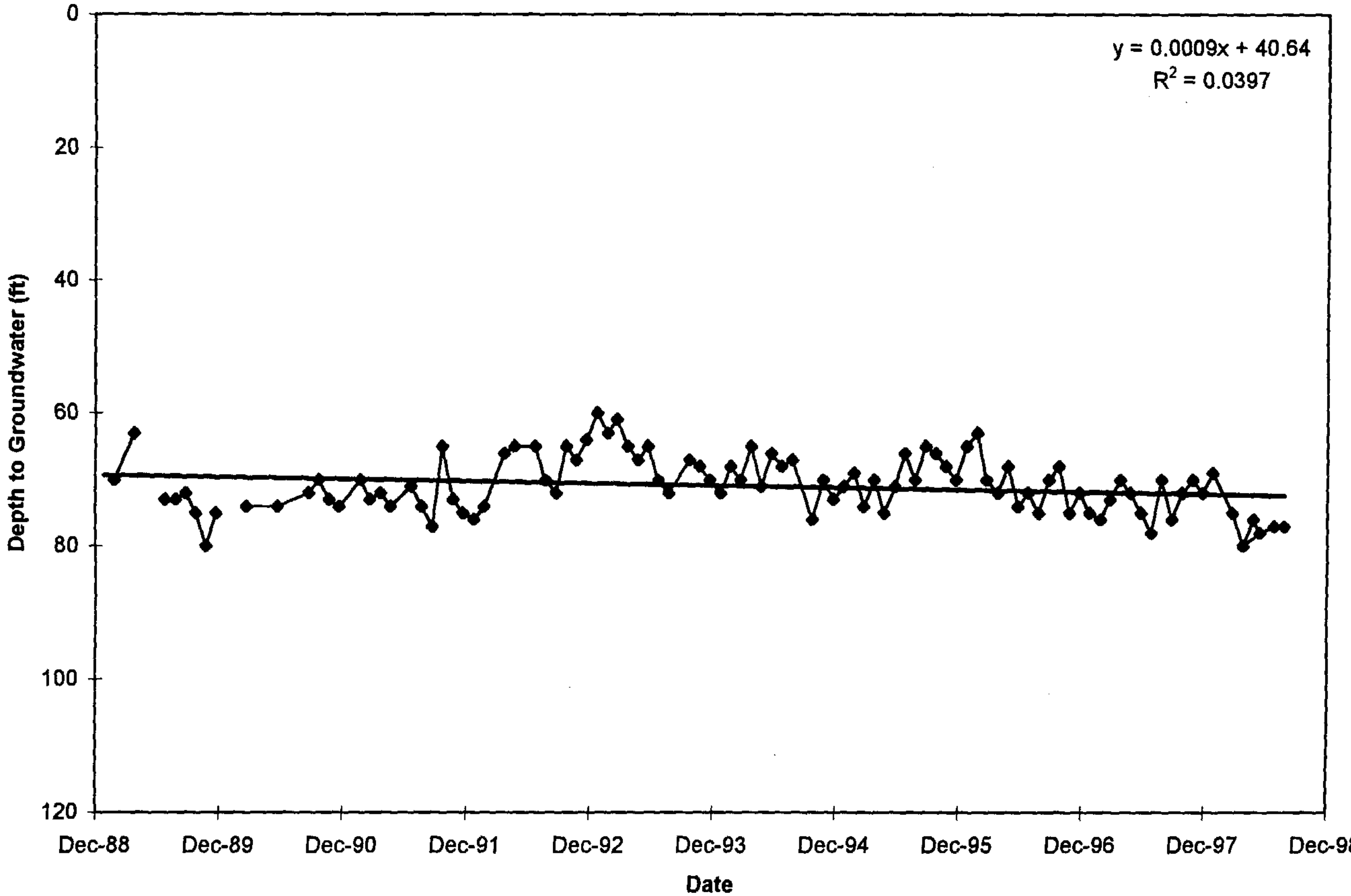


Figure 2-14
Odell-Winston Well WW-13 Hydrograph

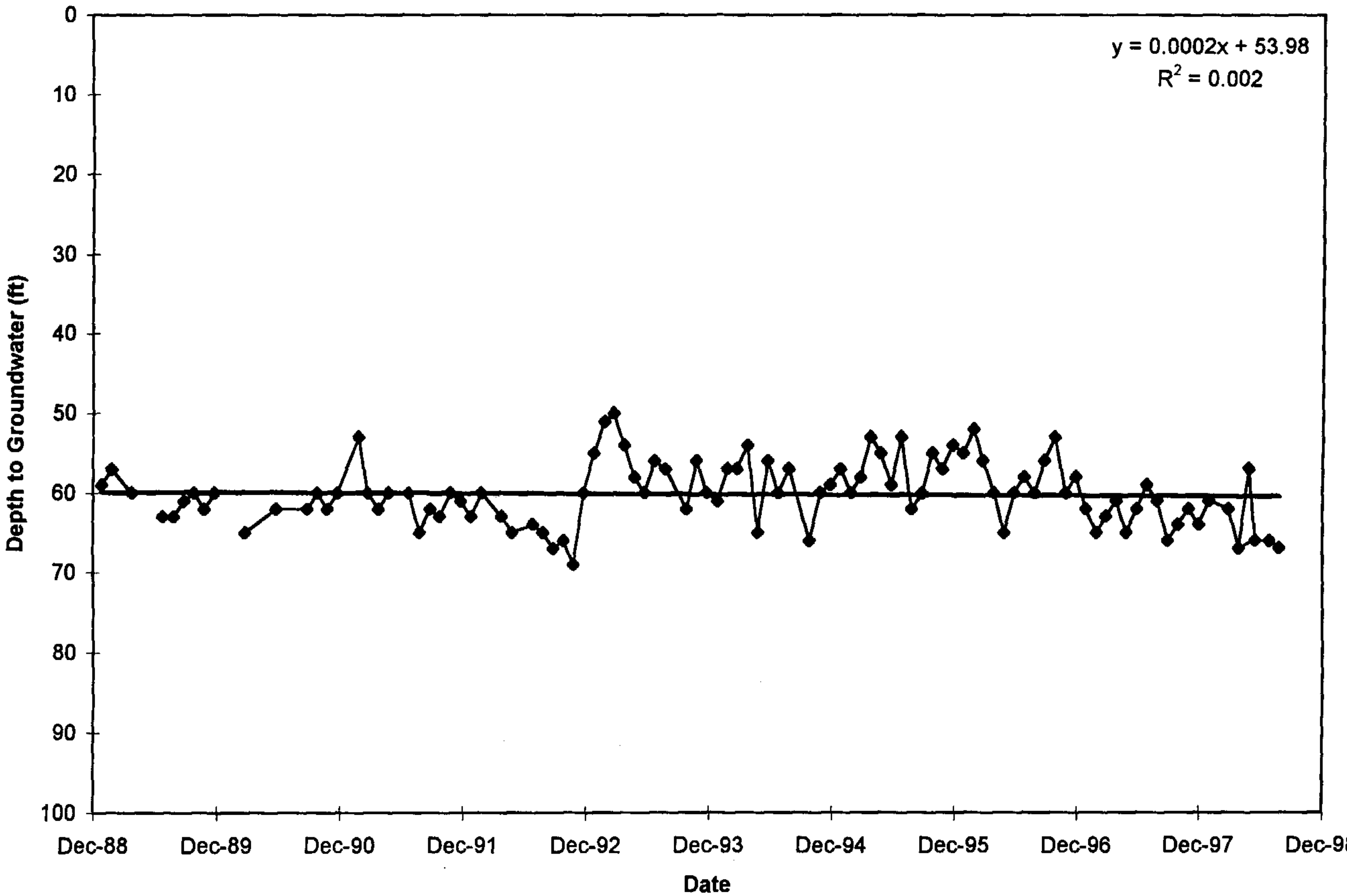


Figure 2-15
Odell-Winston Well WW-14 Hydrograph

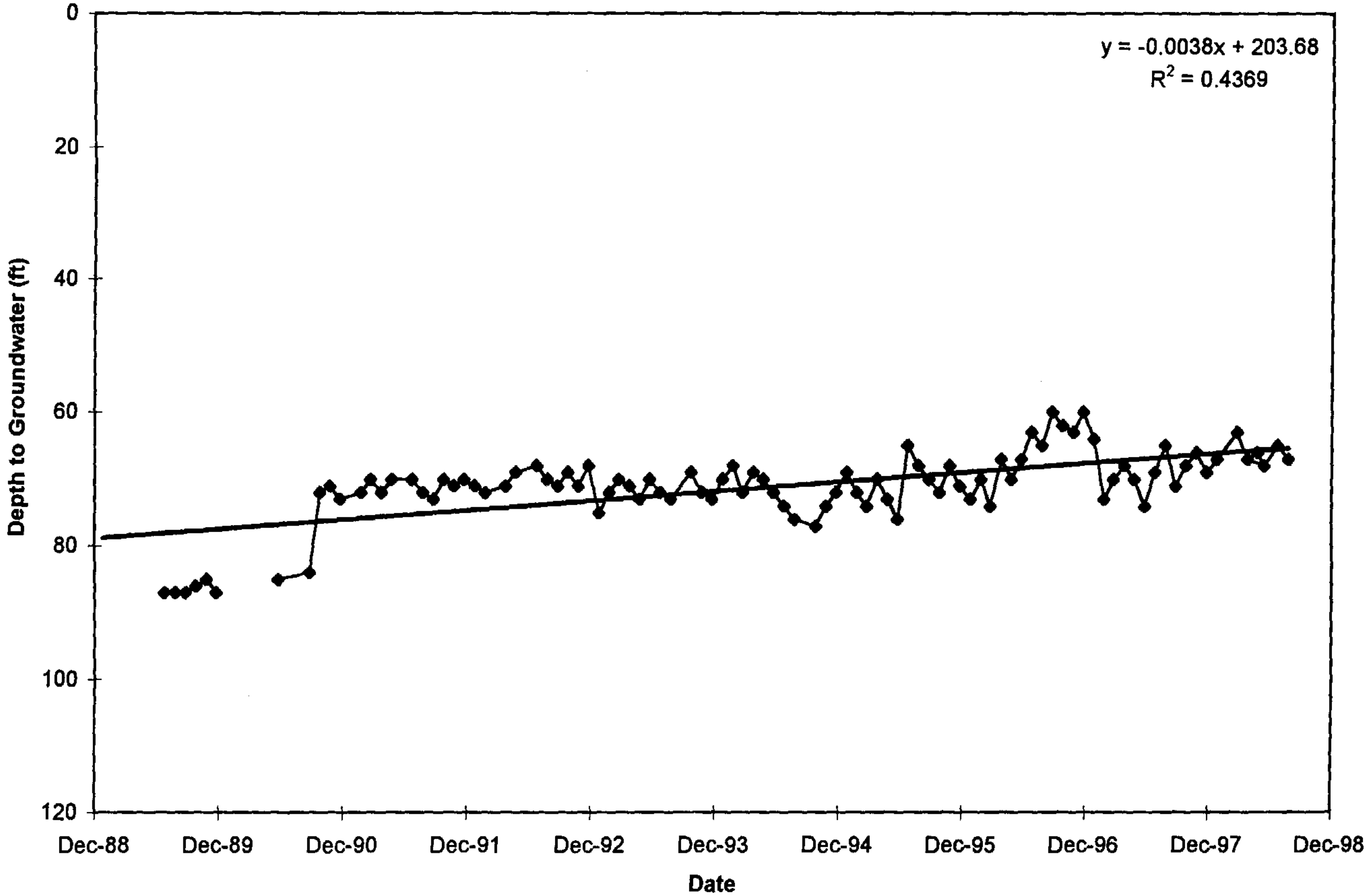


Figure 2-16
Odell-Winston Well WW-15 Hydrograph

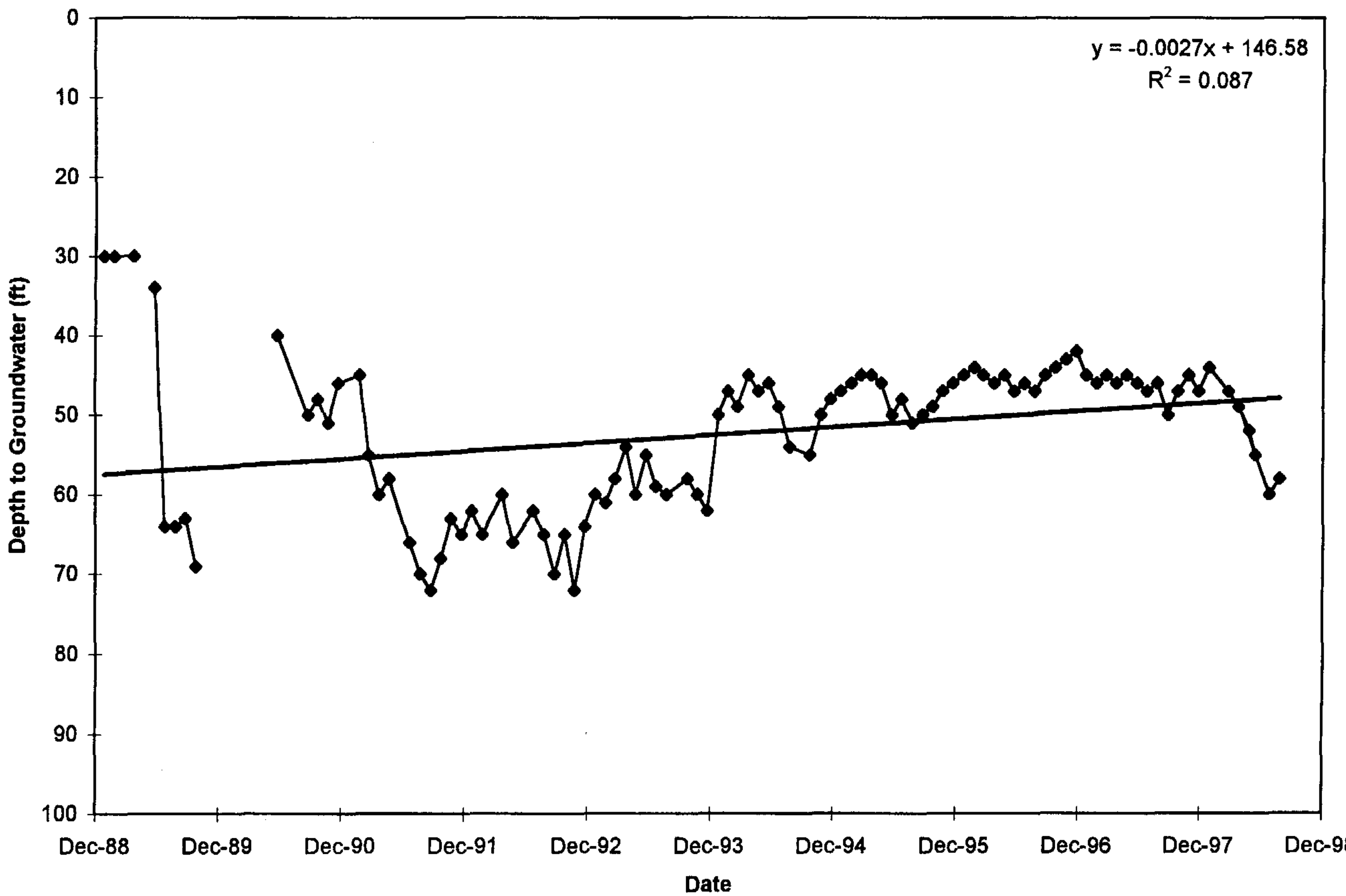


Figure 2-17
Odell-Winston Well WW-16 Hydrograph

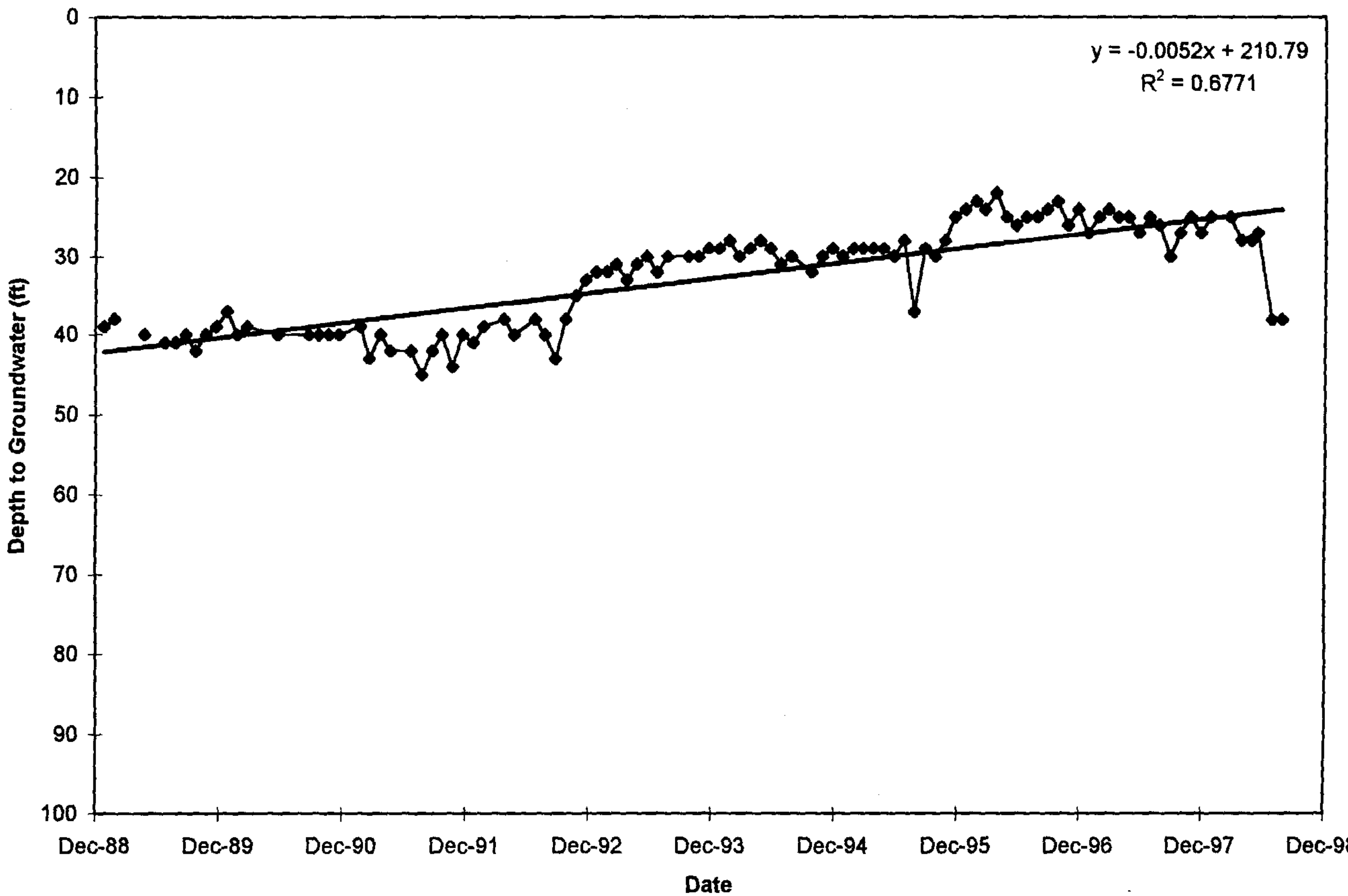


Figure 2-18
Odell-Winston Well WW-17 Hydrograph

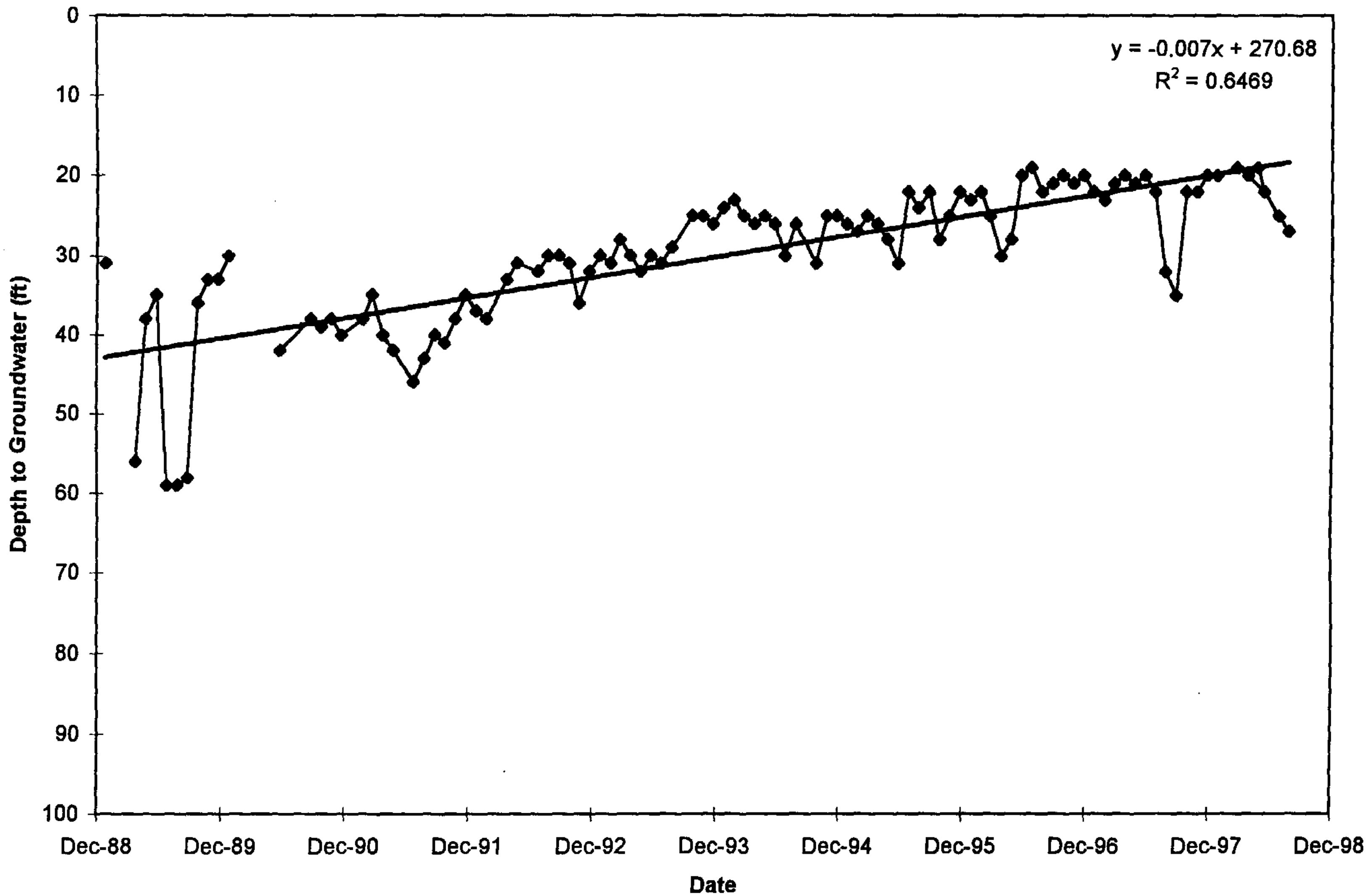


Figure 2-19
Odell-Winston Well WW-18 Hydrograph

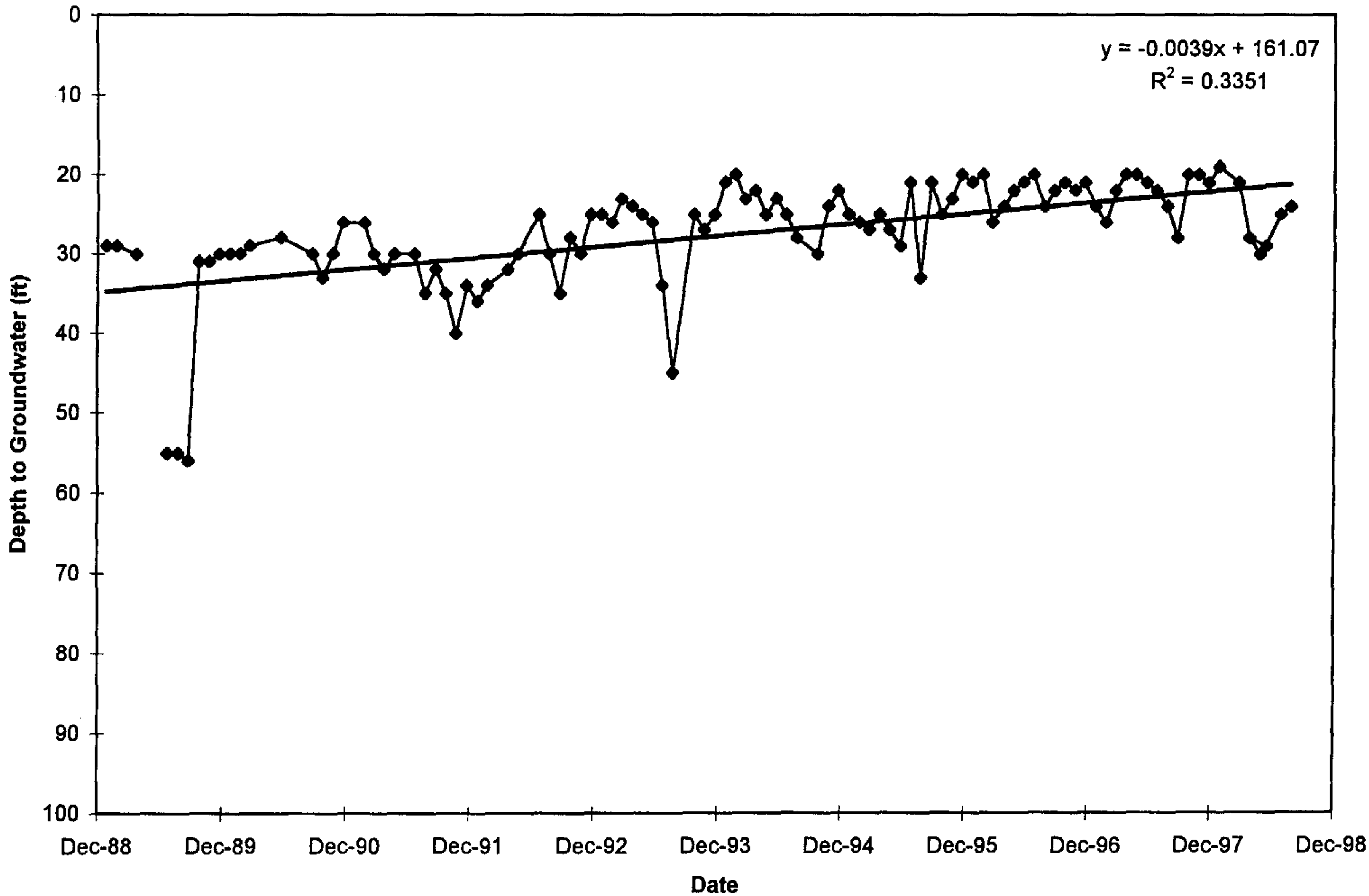


Figure 2-20
Odell-Winston Well WW-19 Hydrograph

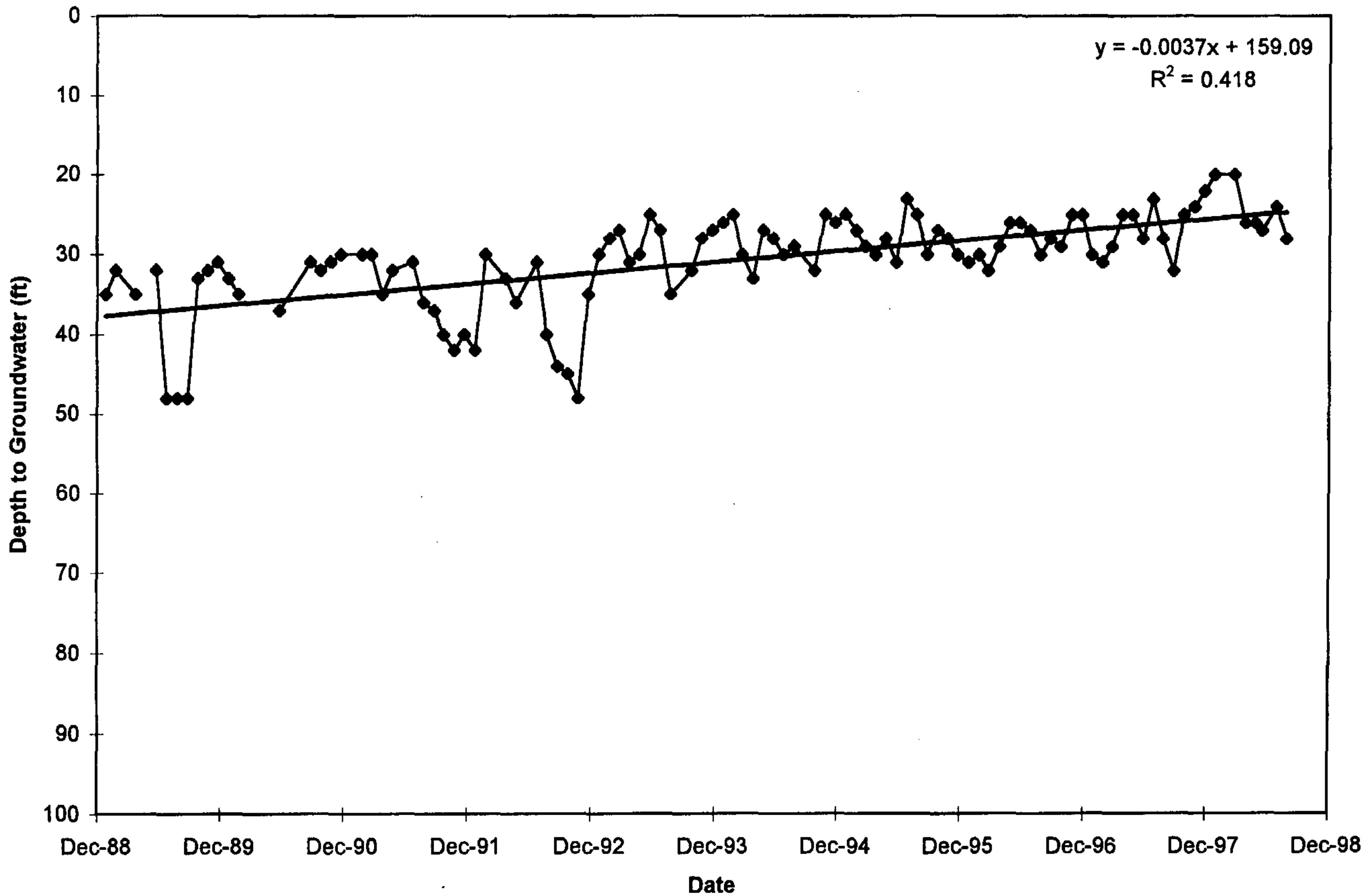


Figure 2-21
Odell-Winston Well WW-20 Hydrograph

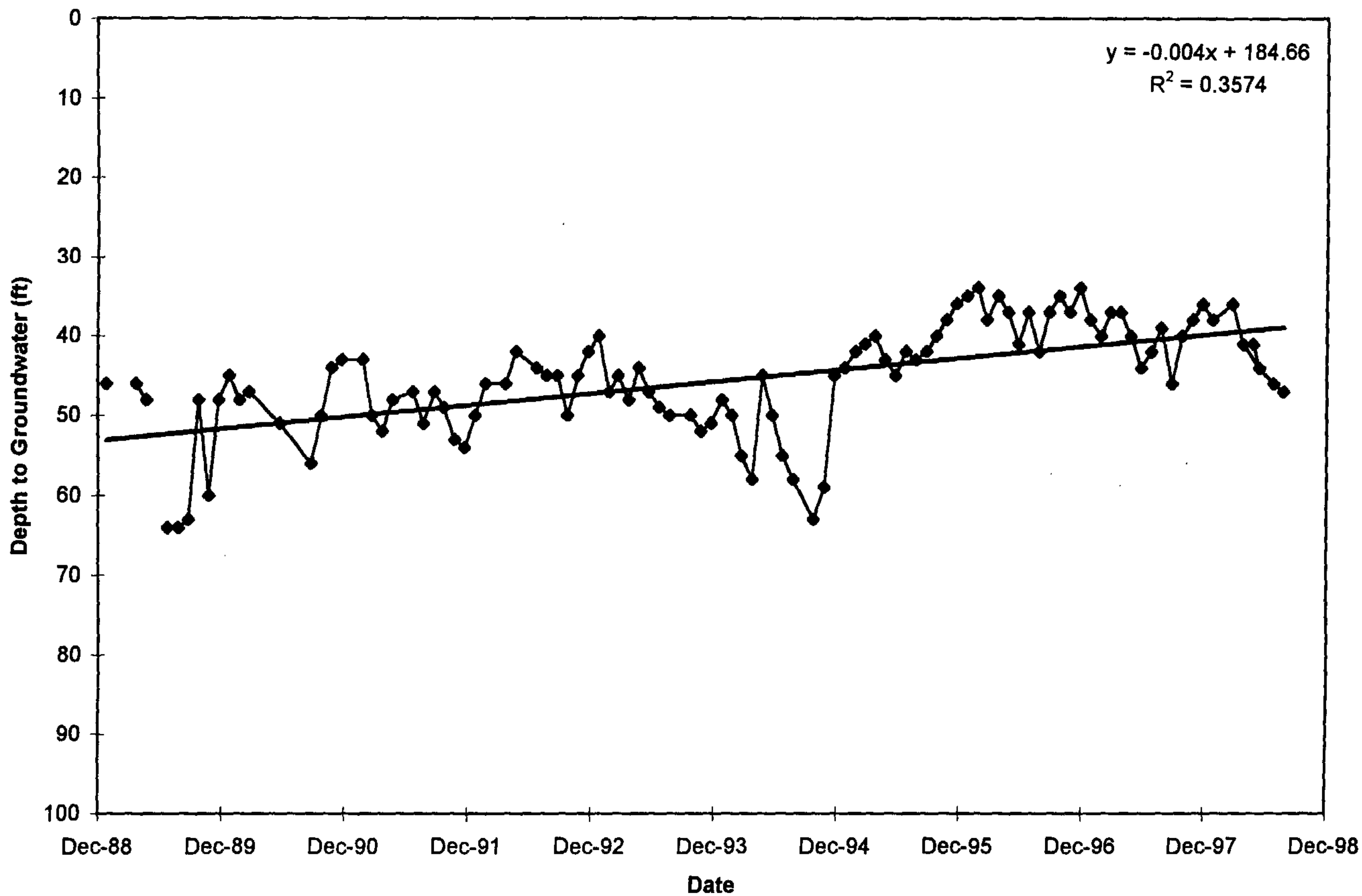


Figure 2-22
Odell-Winston Well WW-21 Hydrograph

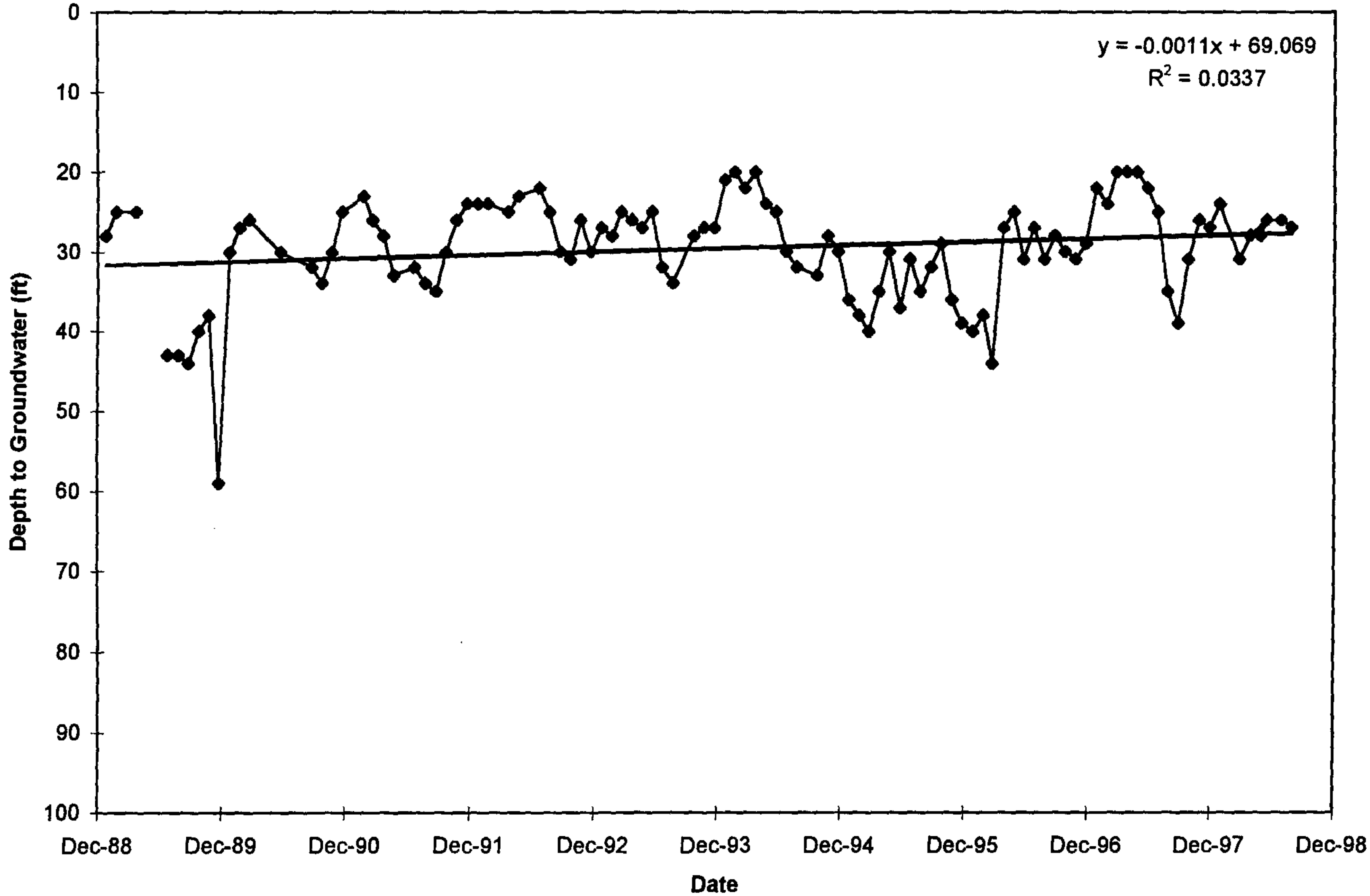


Figure 2-23
Odell-Winston Well WW-22 Hydrograph

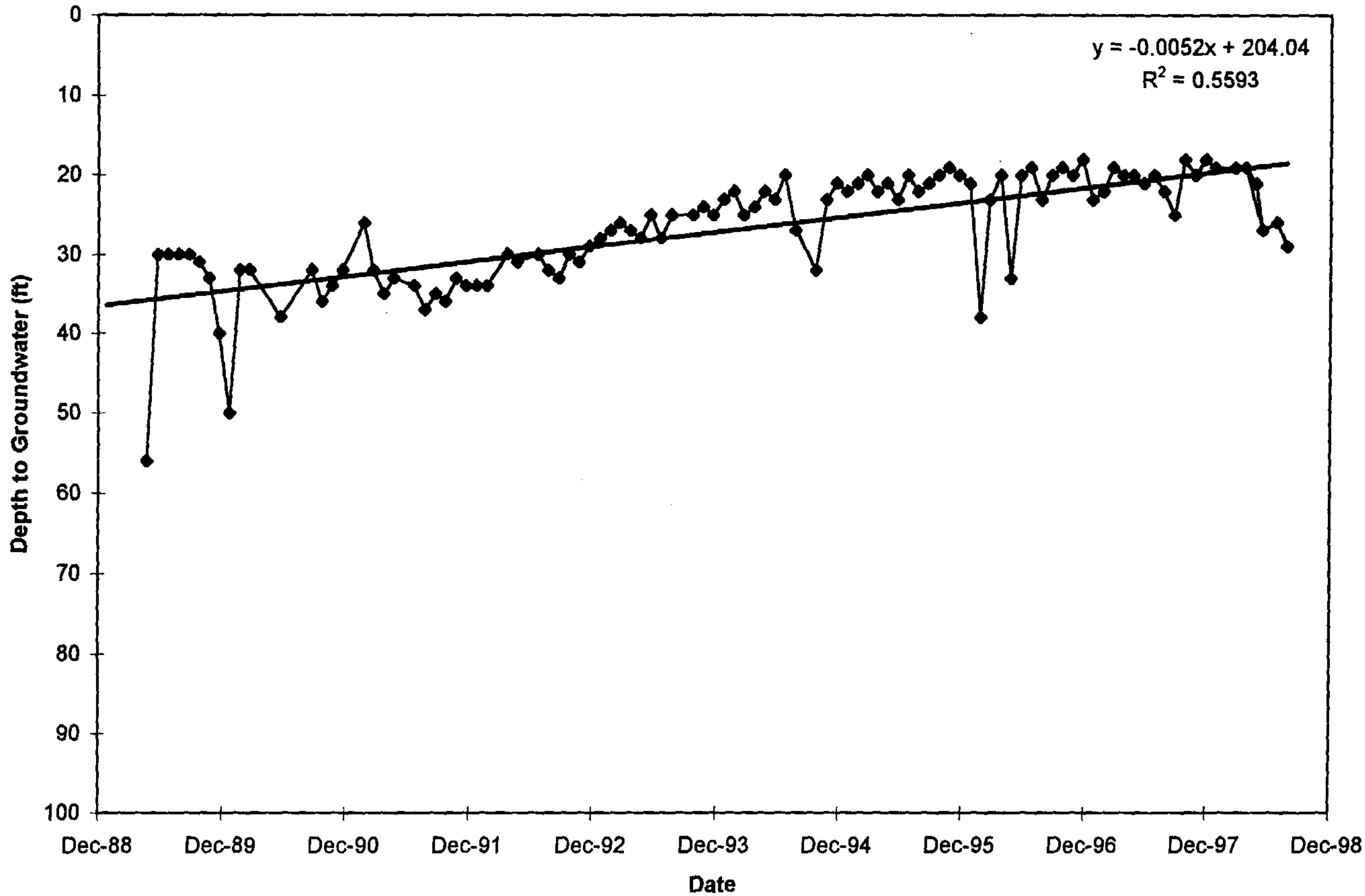


Figure 2-24
Hydrograph for State Observation Well #13 46 106

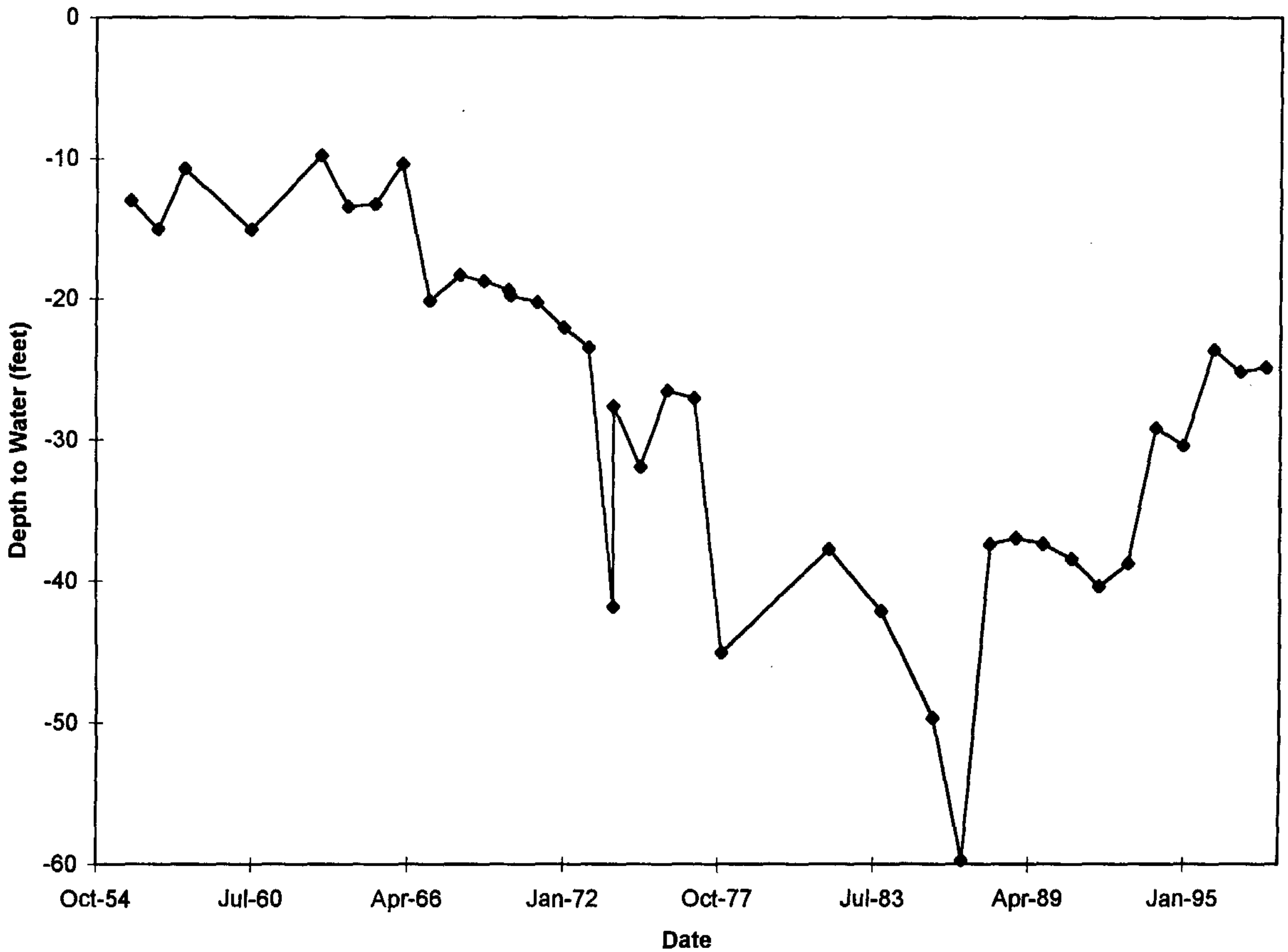


Figure 2-25
Hydrograph for State Observation Well #13 46 402

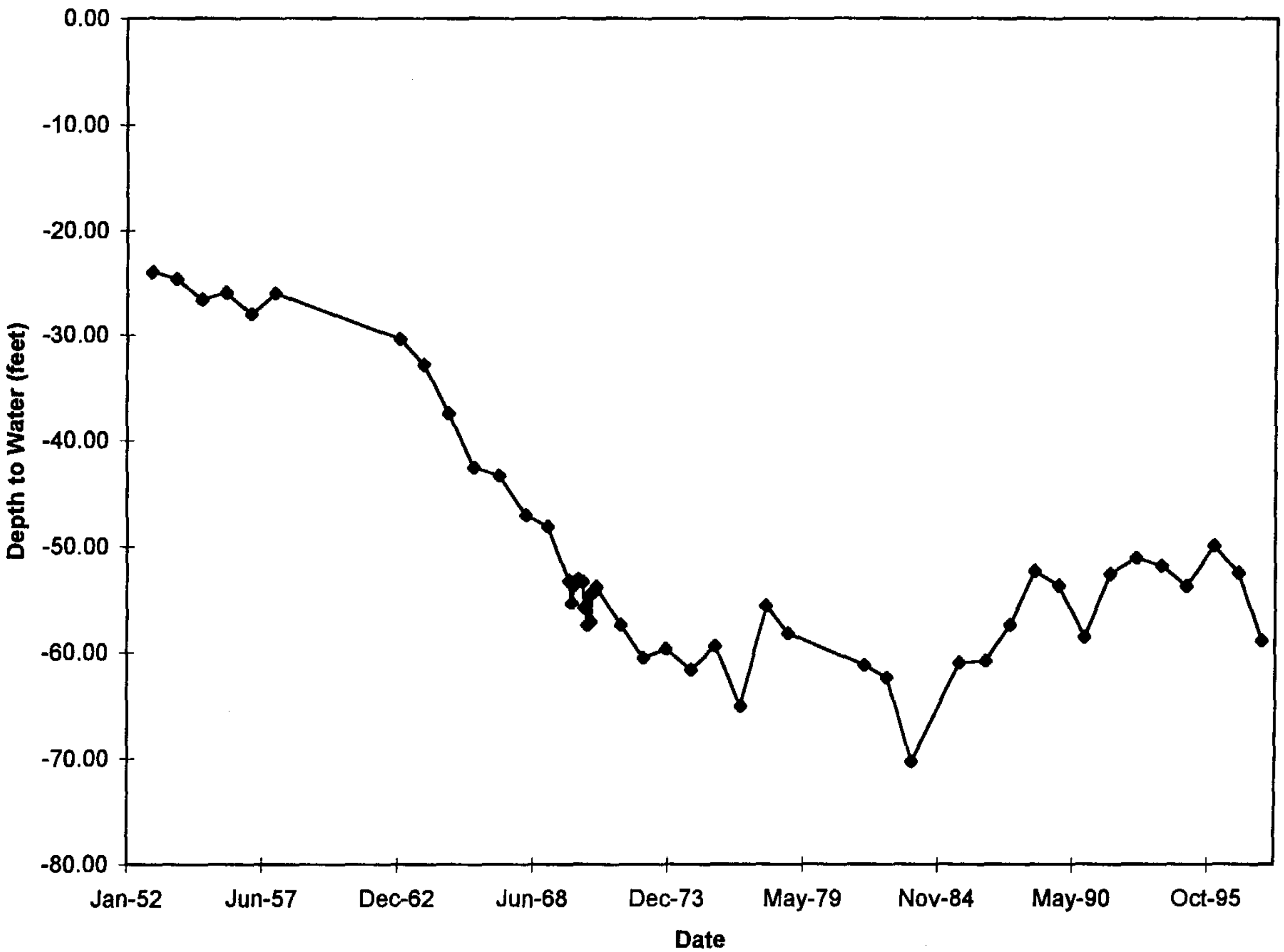


Figure 2-26
Hydrograph for State Observation Well #13 46 409

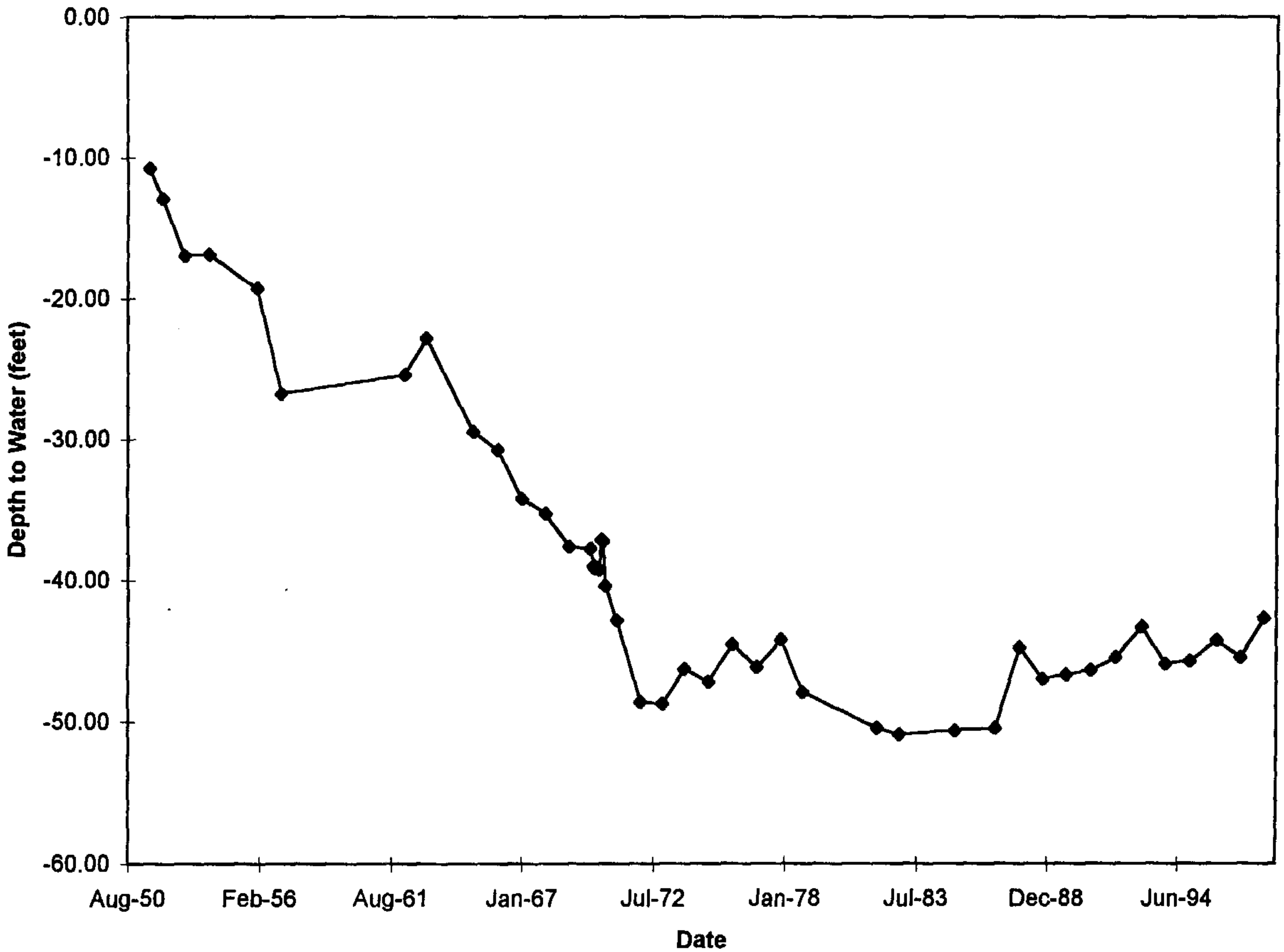


Figure 2-27
Hydrograph for State Observation Well #13 46 504

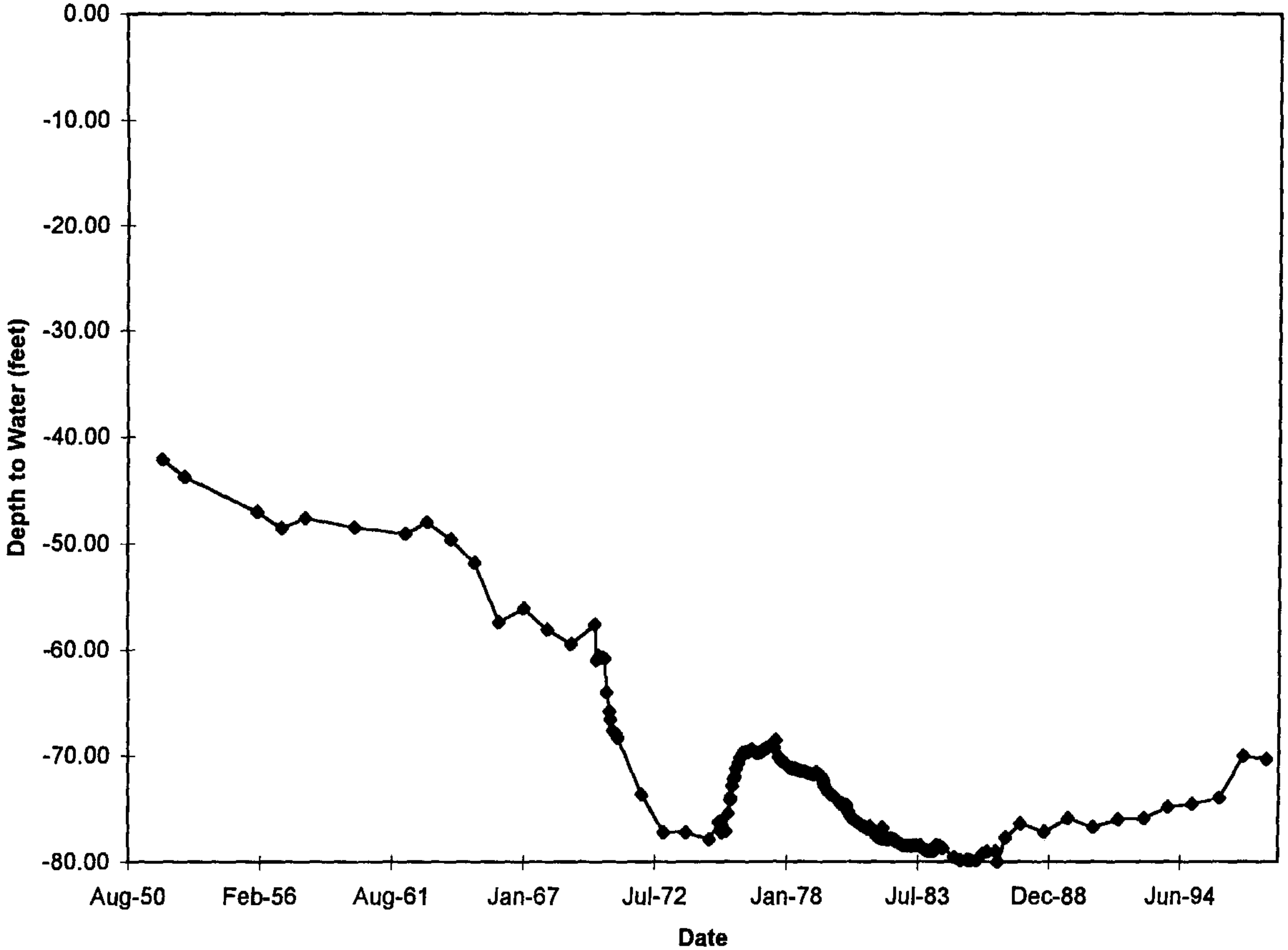


Figure 2-28
Hydrograph for State Observation Well #13 46 505

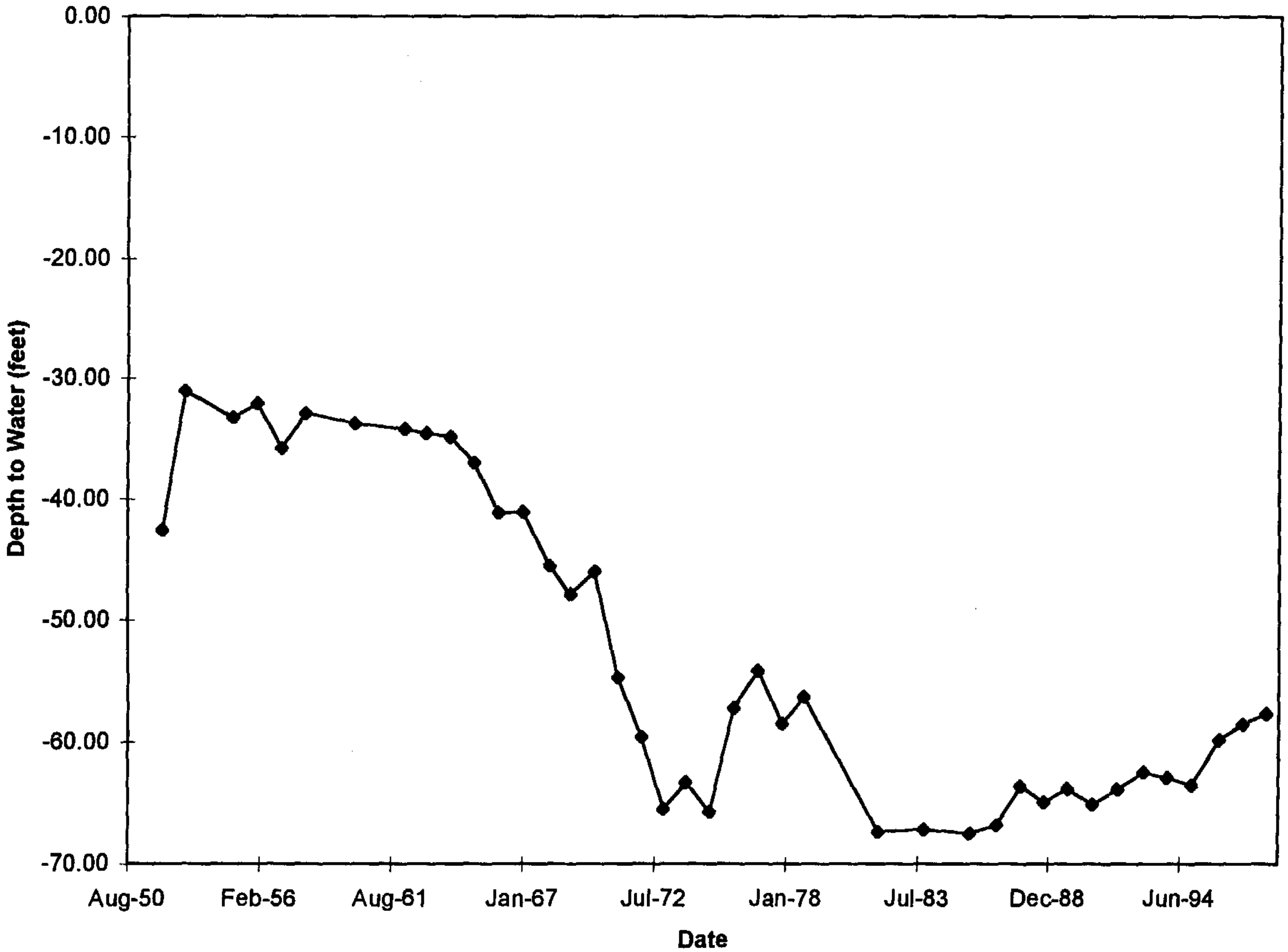


Figure 2-29
City of Vernon Annual Water Supply Volumes

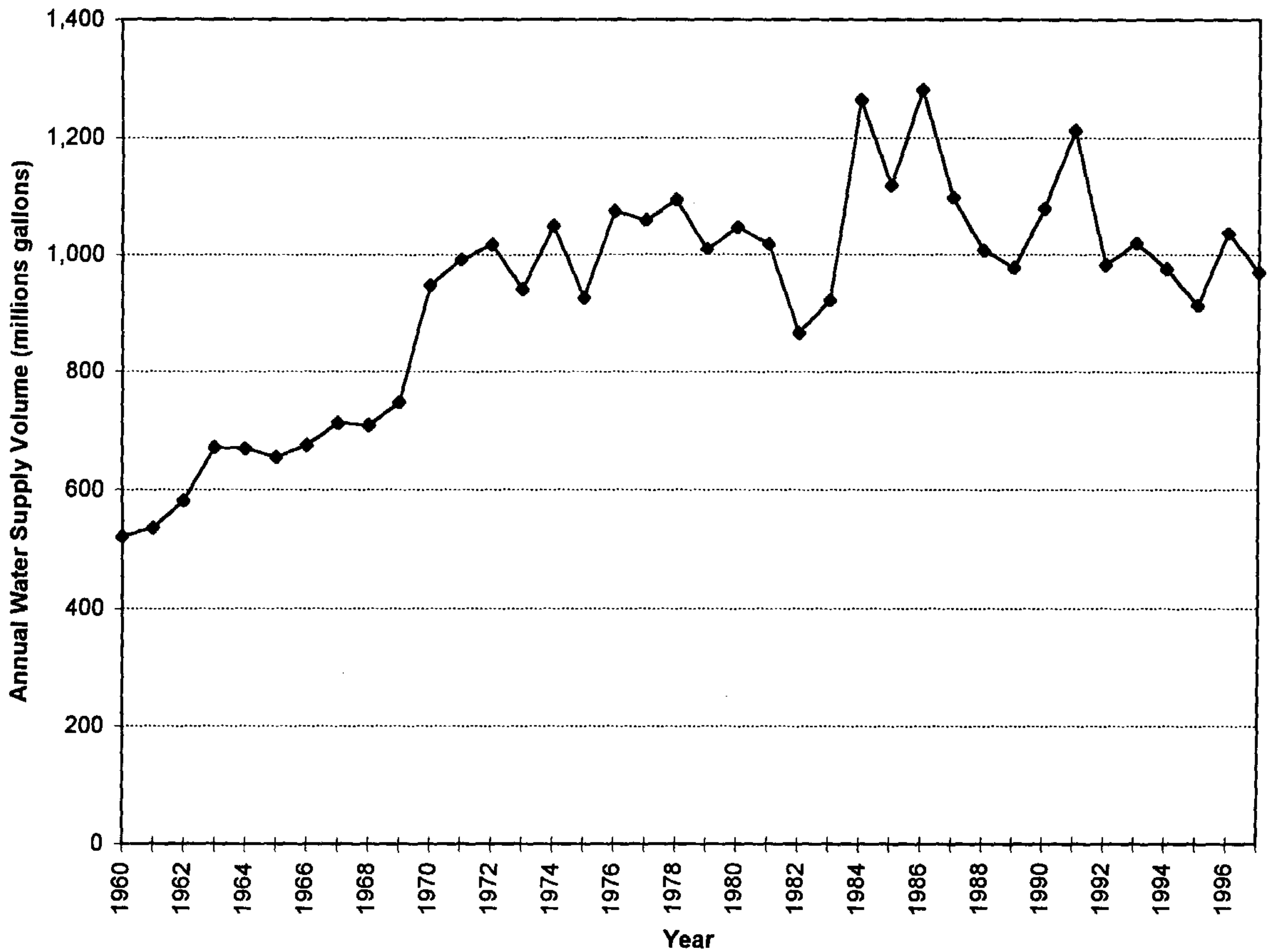


Figure 2-30
Odell-Winston Well Field Daily Pumping Rates (April - June, 1998)

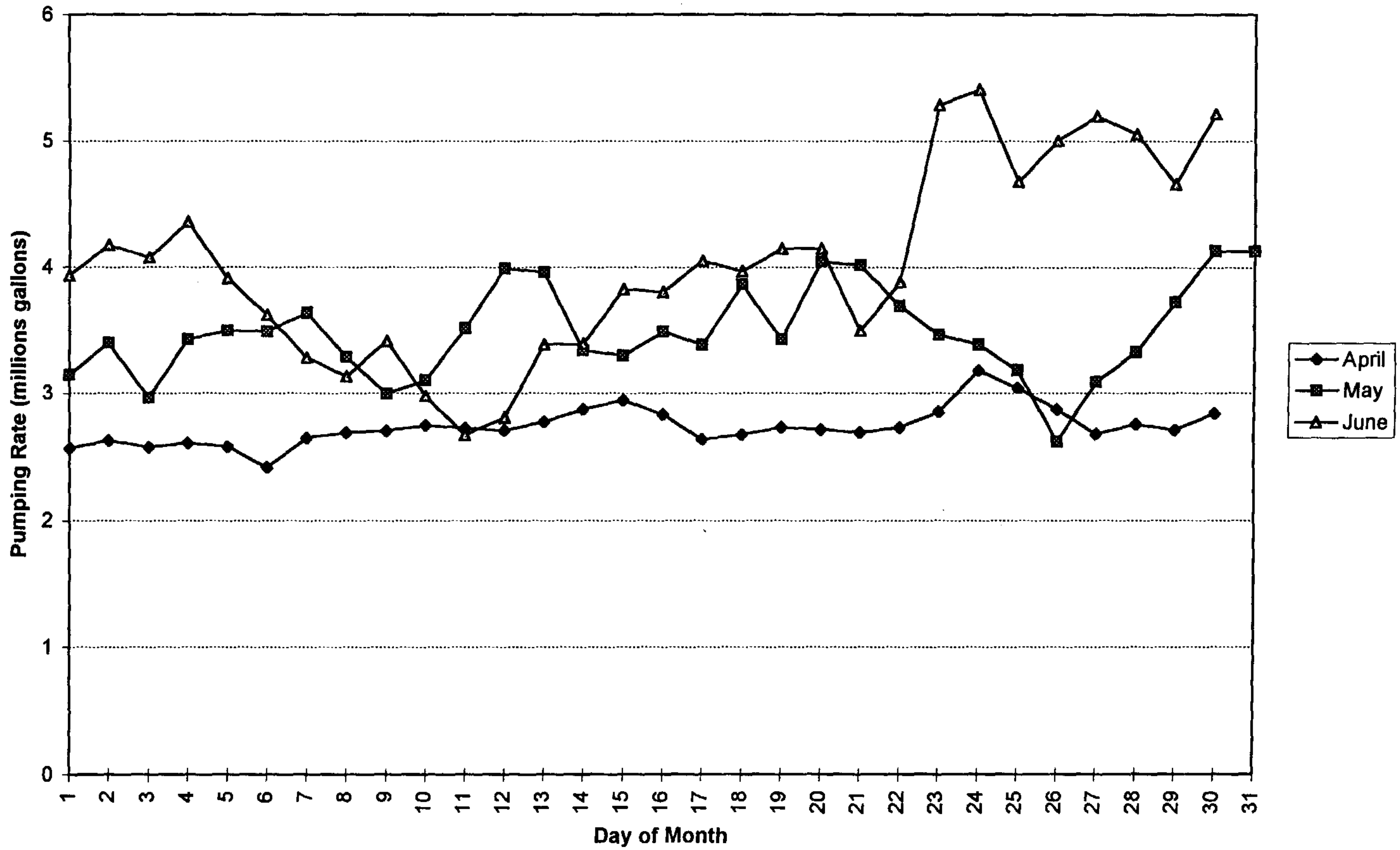
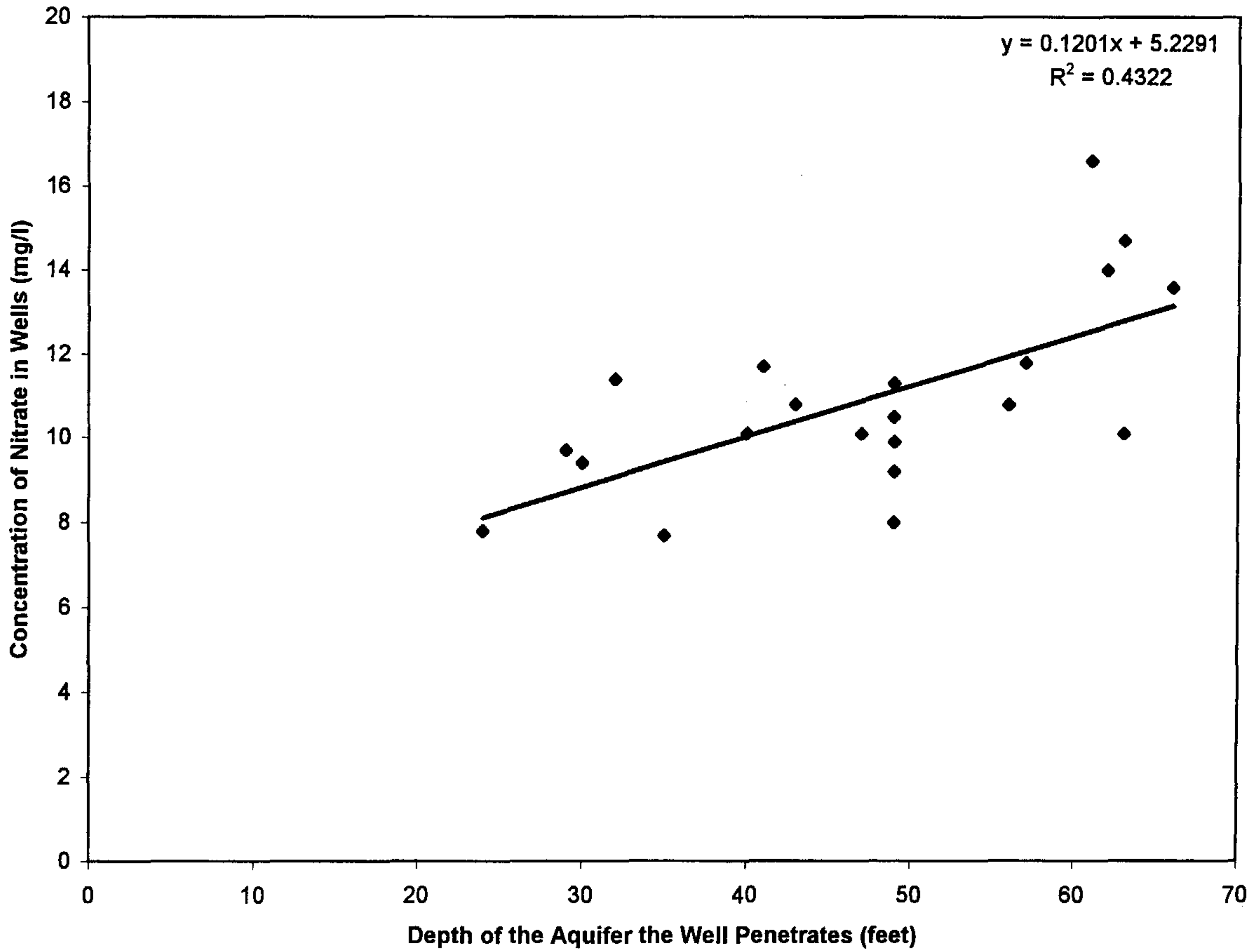


Figure 2-31
Concentration of Nitrate in Wells Versus Depth of the Aquifer the Well Penetrates



3.1 SATURATED THICKNESS OF AQUIFER

Static groundwater level measurements and total well depths were used to calculate the saturated thickness of the Seymour Aquifer penetrated by the Odell-Winston water supply wells. Groundwater level measurements made in May 1998 were used to calculate the saturated thickness for all wells except WW-3 (June, 1998) and WW-10 (November, 1997). The saturated thickness calculations were used as the basis for preparing a contour map of the aquifer's saturated thickness in the well field (Figure 2-1).

The saturated thickness of the aquifer penetrated by the Odell water supply wells varies from 24 feet to 63 feet. The western part of the Odell Well Field, which includes wells WW-1, WW-10, WW-11 and WW-12, has the least saturated thickness, while the area around WW-10 has the greatest saturated thickness. The water supply wells which penetrate the aquifer in the Winston Well Field generally have a greater saturated thickness than the Odell Well Field. Saturated thickness in the Winston Well Field varies from 49 feet to 66 feet. The least saturated thickness occurs in the north of the well field around WW-19 and WW-20, while the greatest thickness occurs in the area around WW-16.

Figure 2-1 indicates that the Seymour Aquifer has a sufficient saturated thickness in most areas of the Odell-Winston Well Field to continue using the groundwater as a long-term water supply. The generally greater saturated thickness in the Winston Well Field and central northern and southern parts of the Odell Well Field suggests wells in these areas should be used to provide the majority of the water during drought conditions and high demand periods. But, as noted earlier, wells in the Winston Well Field generally have greater concentrations of nitrate. The relatively small saturated thickness of the wells in the west of the Odell Well Field indicates that these wells should not be relied upon for a continuous water supply during an extended dry period where recharge is reduced and water demand is typically greater.

3.2 PRECIPITATION RATES COMPARED TO WATER LEVELS

For the period of groundwater level records presented in Figures 2-2 to 2-22 (1988 to 1998), average annual precipitation has been 5 inches above the historical average. To determine whether this extra precipitation alone can account for the increasing water levels in the Odell-Winston water supply wells during the last decade, the extra water levels likely to result from the higher recharge rate was estimated.

The average annual change in water levels for each water supply well in the Odell-Winston Well Field was estimated by fitting a linear trend line to the well hydrographs. The trend lines are shown on the hydrographs in Figures 2-2 to 2-22. The average annual changes in water levels for the entire well fields were estimated by averaging the annual change in water levels for each well. The resulting average increase in water levels for all wells in the Odell-Winston Well Field is estimated to be 0.95 ft/year (11.4 inches/year). For the wells in the Odell Well Field, the average annual increase in water levels is estimated to be 0.46 ft/year (5.5 inches/year). For the wells in the Winston Well Field, the average increase in water levels is estimated to be 1.8 ft/year (21.6 inches/year).

The TDWR (1979) estimates recharge to be 10 percent of annual precipitation, however Layne Western Co. (1964) estimate recharge to be approximately 15 percent of annual precipitation. It is our opinion, based on experience at other sites, the sandy nature of the surface and the small volumes of runoff that occur in the area, that recharge rates are more likely to be closer to 15 percent of annual precipitation. Therefore, the extra recharge to the Seymour Aquifer since 1988 compared to the historical average is estimated to be 0.75 inches/year. The extra 0.75 inches per year of precipitation will move through pores in the vadose zone and enter the saturated zone. Assuming a storativity value for the Seymour Aquifer of 0.14 (TDWR, 1979), the 0.75 inches/year average additional recharge is estimated to cause a 5.4 inches/year rise in the water table elevation.

Thus, the observed increase in water levels since 1988 in the Odell Well Field is likely attributable to the additional recharge since 1988. However, the observed increase in water levels since 1988 in the Winston Well Field is approximately 16 inches/year greater than the estimated increase in water levels caused by the additional recharge since 1988.

3.3 PUMPING RATES COMPARED TO WATER LEVELS

For the period of groundwater level records presented in Figures 2-2 to 2-22 (1988 to 1998), annual water supply rates have shown a slight decreasing trend, as shown on Figure 3-1. Insufficient information is available on individual wells to assess any changes in pumping rates of the Winston or Odell wells which may explain the different average rates of water level elevation increases over the last 10 years. However, the slight decreasing trend in water supply rates for the City of Vernon over the last 10 years has likely contributed to the observed average increase in water levels in the Odell-Winston Well Field over the past 10 years.

The water supply volumes produced from the well fields during the period 1988 to 1997 averages 1,018 million gallons per year (2.8 MGD). By comparison, the average water supply volume pumped during the period 1960 to 1975 is 772 million gallons per year (2.1 MGD). During the period 1960 to 1975, the state observation wells show a decreasing trend in water level elevations. During the period 1988 to 1997, the state observation wells and water supply wells show a stable to slightly increasing trend in groundwater levels. However, annual precipitation for the period 1960 to 1975 was 25.1 inches compared to 31.7 inches for 1988 to 1997. Thus, it is reasonable to conclude that greater than average groundwater recharge rates during the last ten years have compensated for the larger annual pumping rates. During the period 1960 to 1975, the declining groundwater levels indicate pumping rates during that period exceeded the recharge rates.

3.4 INFLUENCE OF OTHER USERS

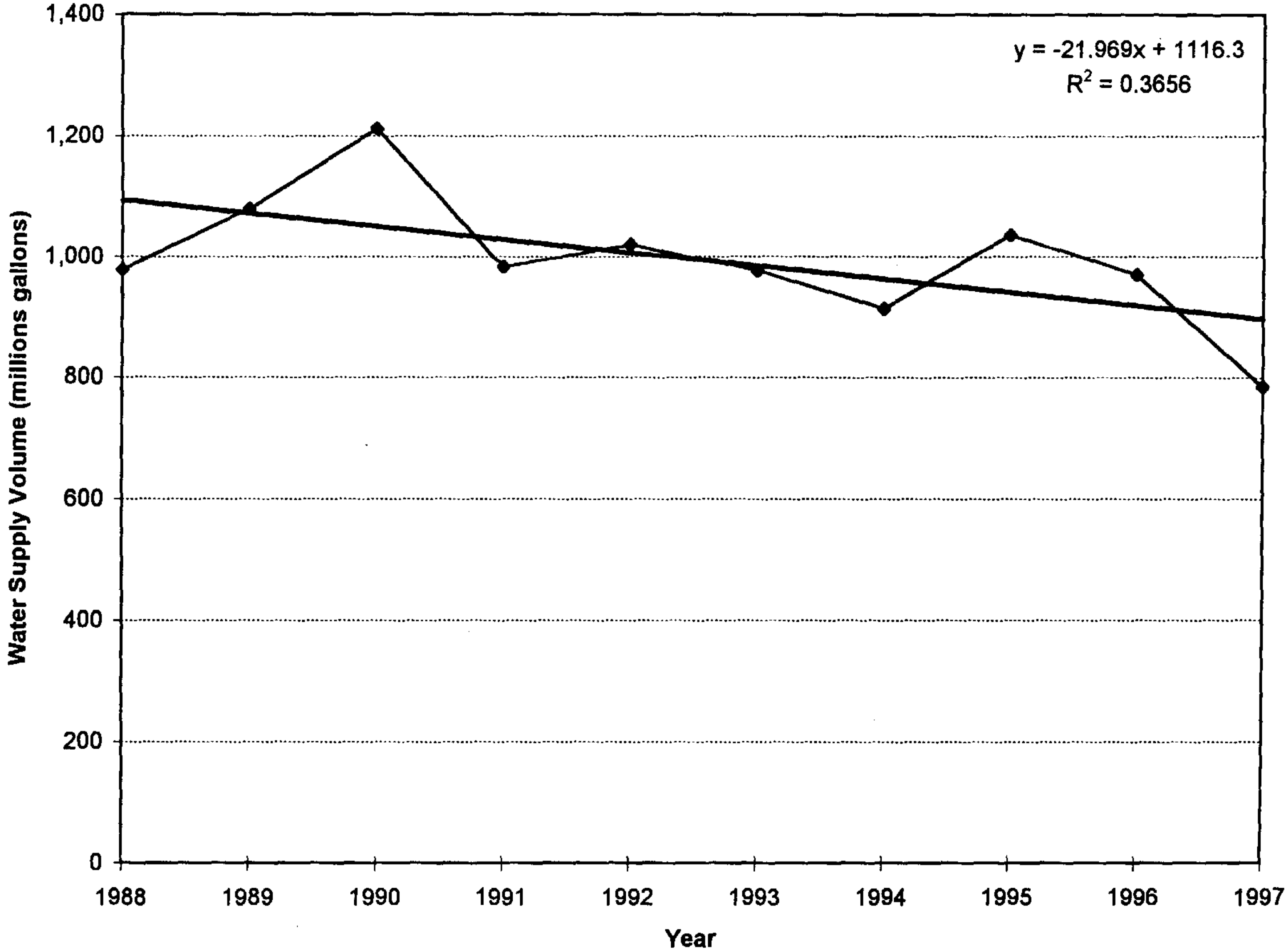
Possible reasons for the greater increase in water levels at the Winston Well Field compared to the Odell Well Field could include the lower demand for groundwater from the Seymour Aquifer close to the Winston Well Field compared to Odell Well Field. The City of Vernon owns the land around the Winston Well Field and therefore has a buffer zone around the wells, while in the Odell Well Field other wells are located close to the well field.

3.5 SUMMARY OF LONG-TERM AVAILABILITY OF WATER RESOURCES

Based on the above information, it is likely that the Odell-Winston Well field can sustain a water supply rate of approximately 900 million gallons per year (2.5 MGD), assuming average rainfall rates and recharge conditions will prevail. This also assumes that demand for groundwater from other users around the Odell-Winston Well Field will not increase. During a drought period when recharge rates are reduced, it is likely that water level elevations will decline if a pumping rate of 2.5 MGD is maintained. The Winston Well Field has a greater average saturated thickness than the Odell Well Field. Therefore, the Winston Wells should be pumped more heavily during drought and peak demand periods to prolong the life of the Odell Well Field. However, it should be noted that this would cause an increase in the concentration of nitrate in the water supply, as the concentration of nitrate in the Winston wells is generally greater than those in the Odell Well Field.

It is likely that groundwater supply from the Odell-Winston Well Field could be increased from the current pumping rates without significant impact on water level elevations by installing additional water supply wells outside of the area of the existing wells. However, it is anticipated that the water quality from any new wells will be similar to the concentrations of nitrate in existing wells, which is greater than the Texas Drinking Water Standard.

Figure 3-1
City of Vernon Annual Water Supply Volumes (1988 to 1997)



The Round Timber Ranch Well Field consists of 16 water supply wells varying in depth from 58 to 113 feet. Information on the location of all the wells is unavailable. The well field was last used during 1989.

4.1 GEOLOGY

The Round Timber Ranch Well Field draws water from the Seymour Aquifer. Drill hole logs indicate that the Seymour Formation in the area of Round Timber Ranch Well Field has a fairly consistent zone of coarser sand and gravel present near its base. The thickness of the Seymour Formation in the Round Timber Ranch area appears to range from 60 ft to about 115 feet, based on drill hole logs.

4.2 HYDROLOGY

The groundwater within the Seymour Aquifer at the Round Timber Ranch is unconfined and therefore exists under water table conditions. The source of recharge to Round Timber Ranch Well field is infiltration of precipitation falling directly on the Seymour Formation outcrop area. The rate of recharge to the Seymour Aquifer in the Round Timber Ranch area is probably similar to the Odell-Winston Well Field because the topography is gently rolling and much of the surface is composed of highly permeable sand. A report prepared for the City of Altus by Layne Western Company in 1964 suggests that recharge rates are greater than 10 percent of precipitation (2.5 inches/year) and probably more likely to be 4 inches per year. To further reduce surface water runoff and enhance recharge, four detention dams have been constructed on the Round Timber Ranch property.

Groundwater movement within the Seymour Aquifer in the Round Timber Ranch area is likely to be towards the Red River in the west, north and east. However, directions of groundwater movement around the Round Timber Ranch Well Field would be influenced by drawdown of the water table due to pumping of wells when the well field is operating.

4.3 WATER SUPPLY WELL CONSTRUCTION

Appendix C contains the drillers logs giving details of each wells construction. The screen interval of the wells ranges from 10 to 30 feet in length. The wells are all constructed with steel casings and stainless steel screens all with a diameter of 12 inches. Based on the information attached to the drillers logs, it appears that the wells were originally fitted with 3 to 7.5 HP turbine pumps.

4.4 OTHER USERS OF SEYMOUR AQUIFER

As noted in Section 2.4, groundwater in the Seymour Aquifer is used extensively for public water supply, irrigation, industrial, domestic and livestock purposes. Other users of groundwater close to the Round Timber Ranch Well Field is unknown, however it is likely that other wells are present in the area.

The City of Altus leases the water rights, wells and land required for the extraction, conveyance and storage of water from the Mock and Holloway properties.

4.5 CONDITION OF WATER SUPPLY WELLS

The condition of each water supply well or well casing in the Round Timber Ranch Well Field is unknown. However, a survey of the well field by the City of Altus in 1993, 33 months after the well field was shut down, indicates that the well pumps and water conveying facilities are generally in poor condition, with only two wells (17, 18) operational at the time of the survey. It was noted that the 24 volt control system (wiring) had deteriorated beyond repair, approximately 15 feet of pipe line was washed out, Well #1 casing had collapsed and the well "sanded in", and the pumps were removed from some wells.

4.6 WATER TABLE

Seven observation wells exist in the Round Timber Ranch Well Field. Records of groundwater water levels measured in these wells are available from November 1978 to May 1986. The depth to the static water table measured in the observation wells ranged from 13 to 77 feet below the ground surface in May 1986. Since the well field has not been used since 1989, it is likely that groundwater levels have increased from those measured in 1986. Figures 4-1 to 4-7 show the hydrographs for the observation wells. All observation wells except Observation Well #7 show a declining trend in water levels between 1978 and 1986. Observation Well #7 shows a slight increase in water levels between 1978 and 1986. No records are available for static water level measurements in the water supply wells within the Round Timber Well Field. For the period when water level data is available (1978 to 1986), average annual precipitation is equal to the historical record of 26.7 inches.

4.7 PUMPING RATES

Pumping rate records for the Round Timber Well Field are available for the period January 1979 to April 1986. Figure 4-8 shows the average daily pumping rates per year for 1979 to 1985. The average daily pumping rates for a year vary from 0.97 MGD in 1981 to 1.3 MGD in 1985, with an average daily pumping rate through this time period of 1.2 MGD. Figure 4-9 shows the average daily pumping rates per month, indicating the seasonal variability in water demand. The average daily pumping rates vary from a low of 0.48 MGD in December 1983 to 1.7 MGD in March 1986.

There are no records of actual pumping rates from individual wells in the Round Timber Well Field, however details of specific capacity for each well are available. This information is presented in Appendix D and suggests most wells are capable of pumping at a rate of between 100 and 200 gpm, assuming drawdown of the water level equal to about 30 percent of the saturated aquifer thickness under non-pumping conditions.

4.8 WATER QUALITY

There are no recent water quality data available for the Round Timber Ranch Well Field. However, Layne Western Co. (1964) indicated in a report titled "Groundwater Survey for the City of Altus, Oklahoma" that "in general the water appears to be of good quality". There are some concentrations of major cations, anions presented in this report, however most of these data are unreadable.

Discussions between the City of Altus and City of Vernon has indicated that nitrate concentrations at the Round Timber Ranch Well Field were approximately 8 mg/l during operation of the well field. Apparently a sample collected recently from one of the wells in the Round Timber Ranch Well Field had a concentration of nitrate of about 12 mg/l.

It should be noted that if the Round Timber Ranch Well Field is to be considered for use as a municipal water supply again, the wells should be sampled for water quality analyses. The chemical data collected should then be compared to drinking water standards. In addition, care should be taken to pump at rates that will not draw the water table down so much that the water table gradient becomes reversed near the Red River. This may result in the Red River water that has very high total dissolved solids recharging the well field. This could be avoided by maintaining a high water table between the river and well field.

Figure 4-1
Hydrograph for Round Timber Ranch Well Field Observation Well #1

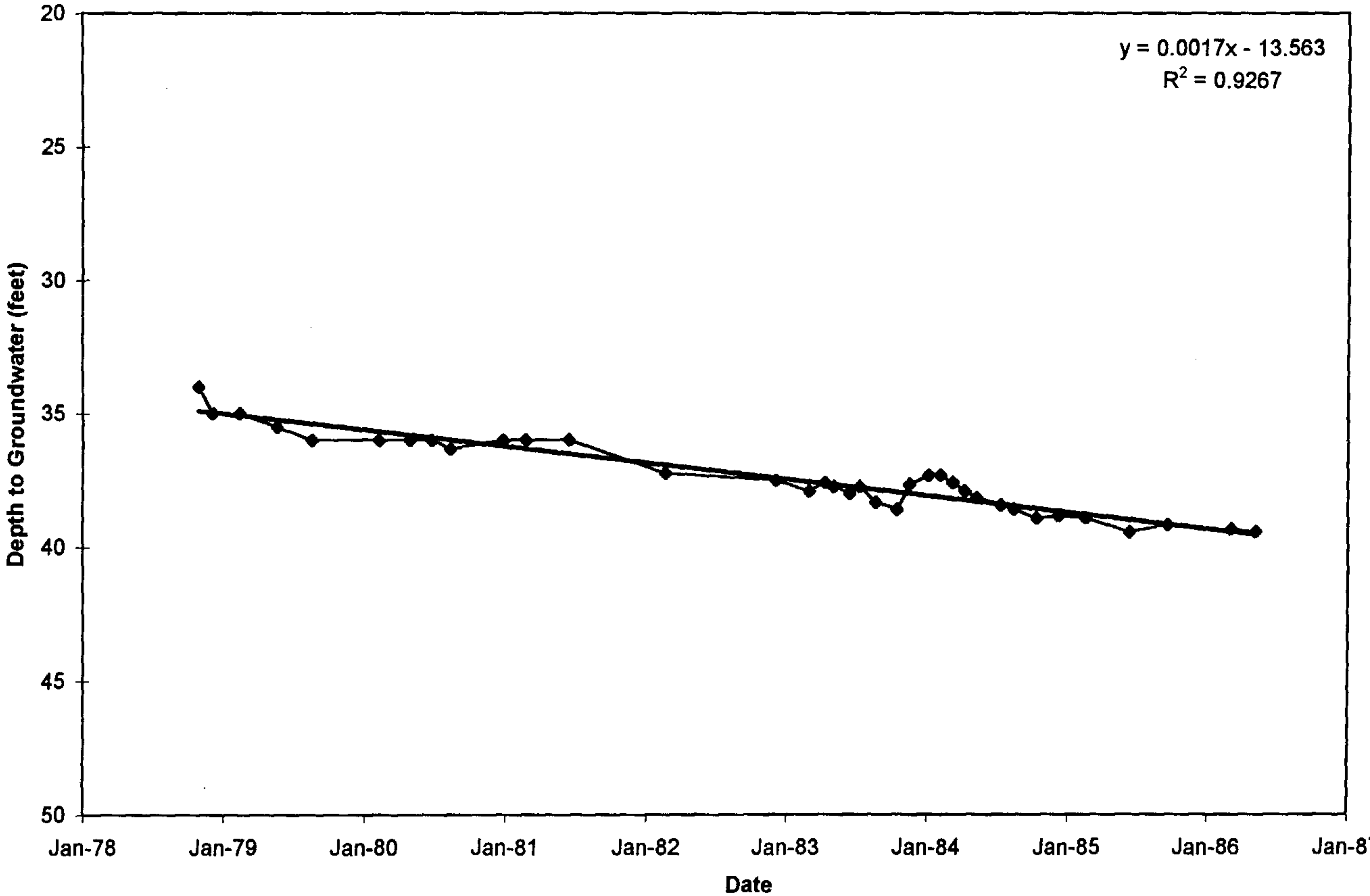


Figure 4-2
Hydrograph for Round Timber Ranch Well Field Observation Well #2

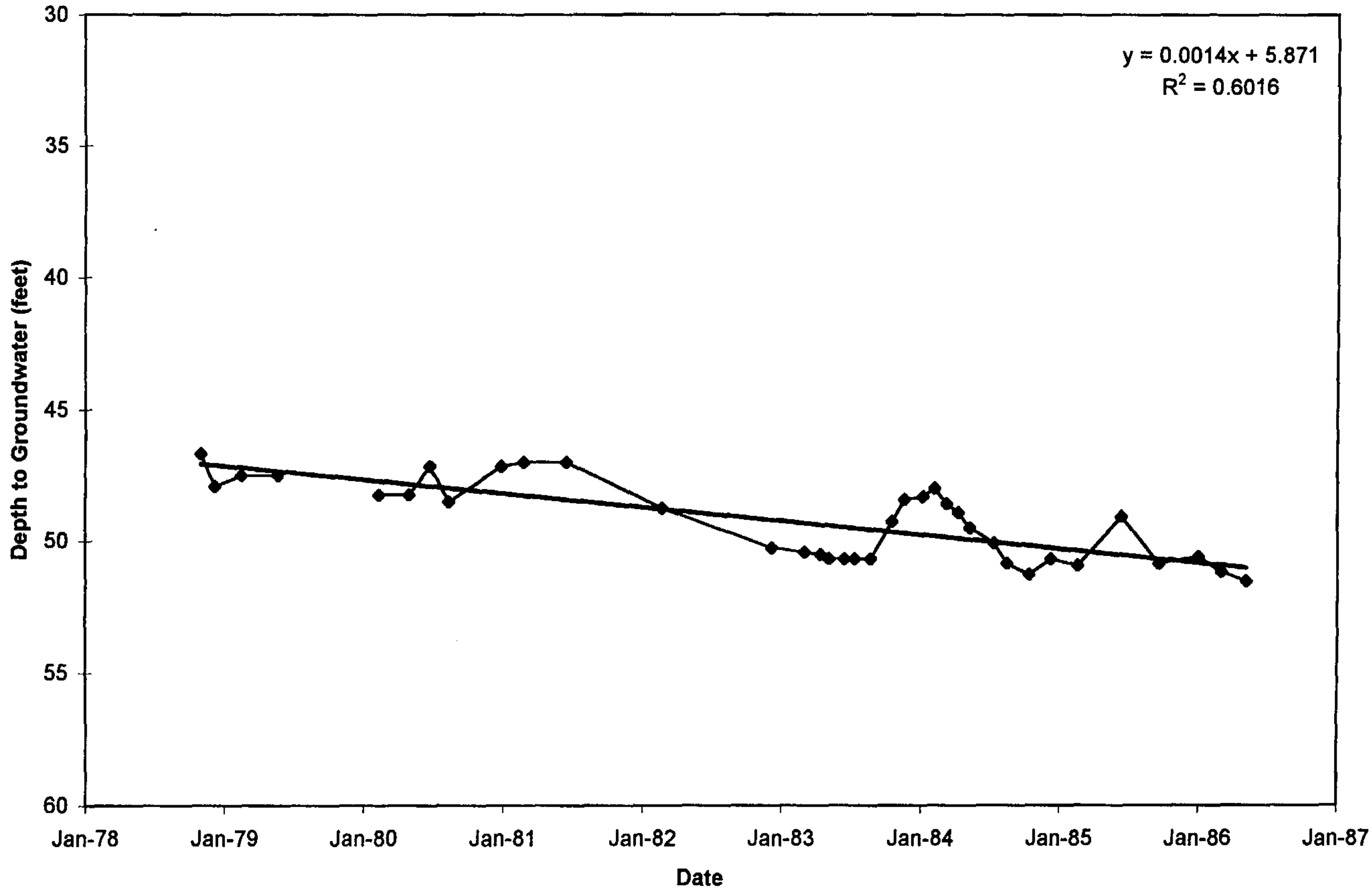


Figure 4-3
Hydrograph for Round Timber Ranch Well Field Observation Well #3

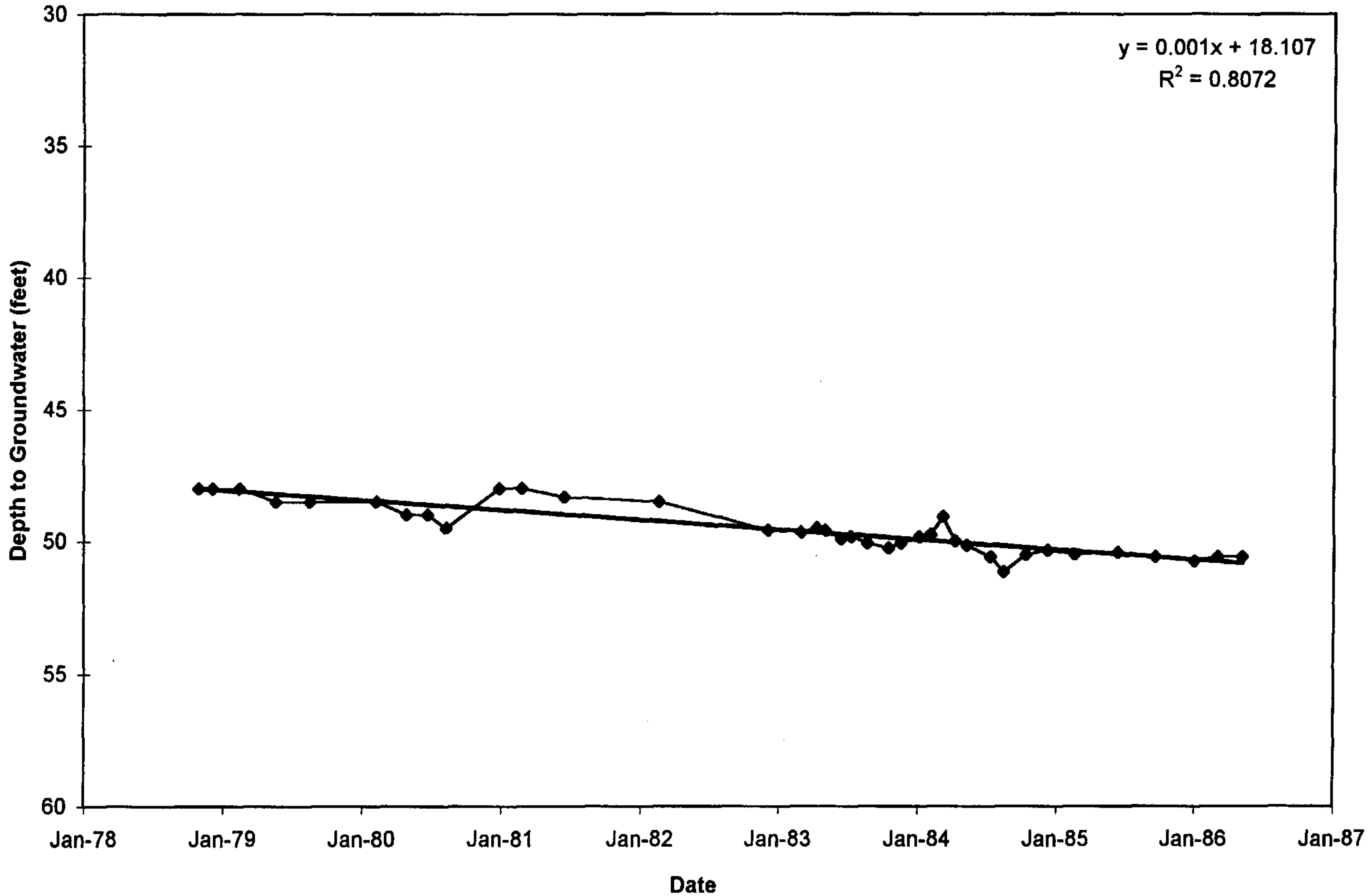


Figure 4-4
Hydrograph for Round Timber Ranch Well Field Observation Well #4

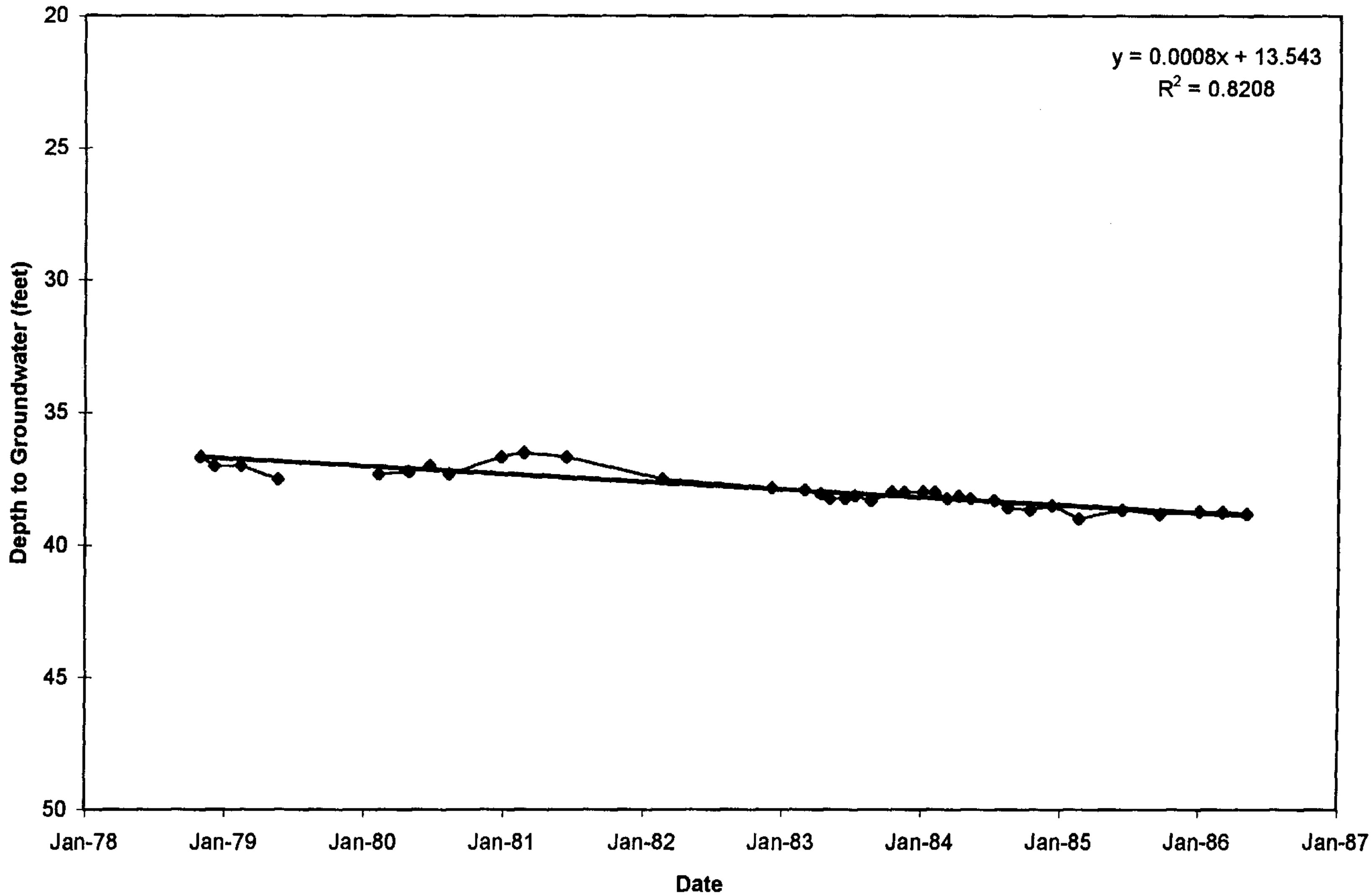


Figure 4-5
Hydrograph for Round Timber Ranch Well Field Observation Well #5

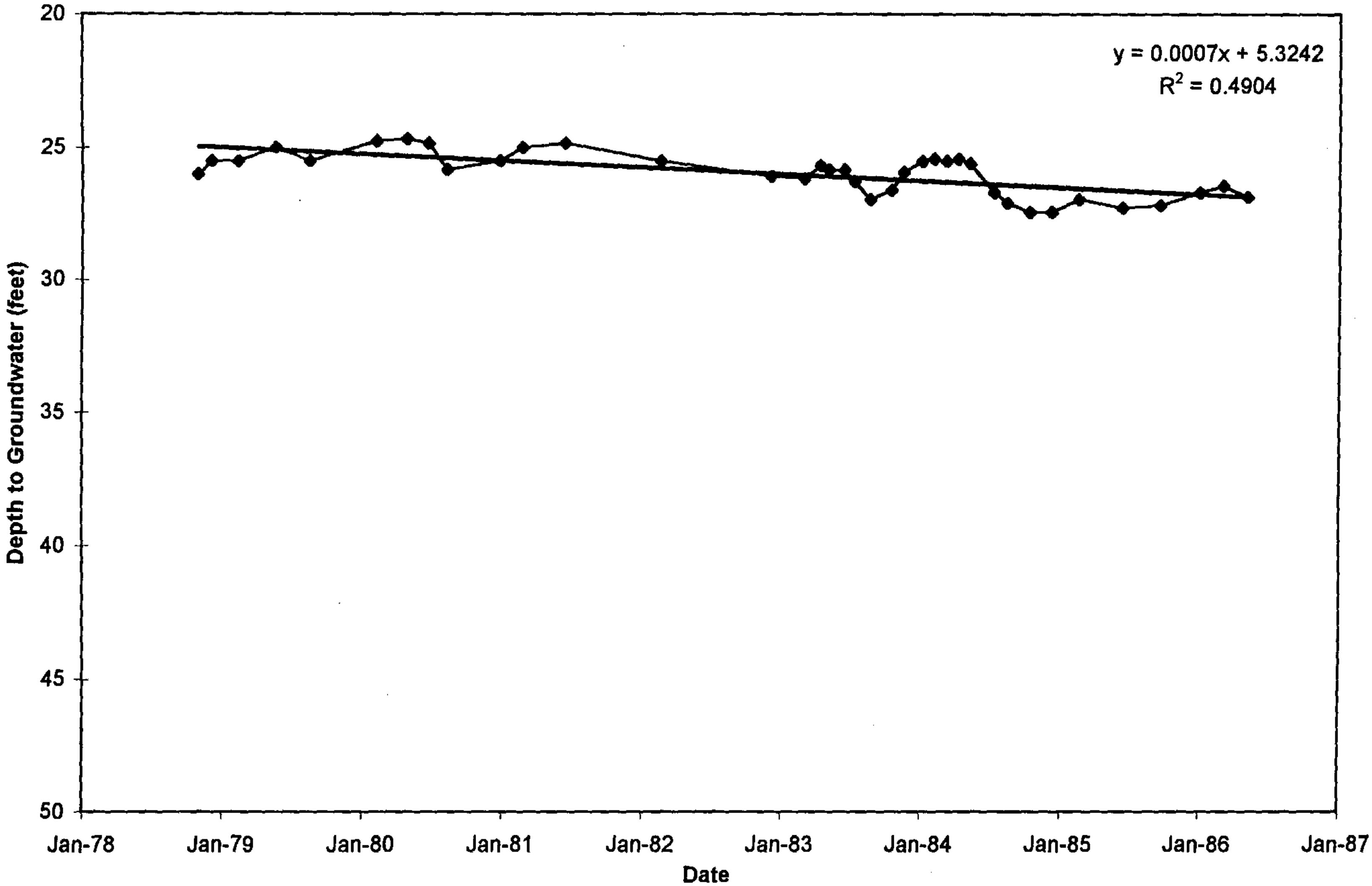


Figure 4-6
Hydrograph for Round Timber Ranch Well Field Observation Well #6

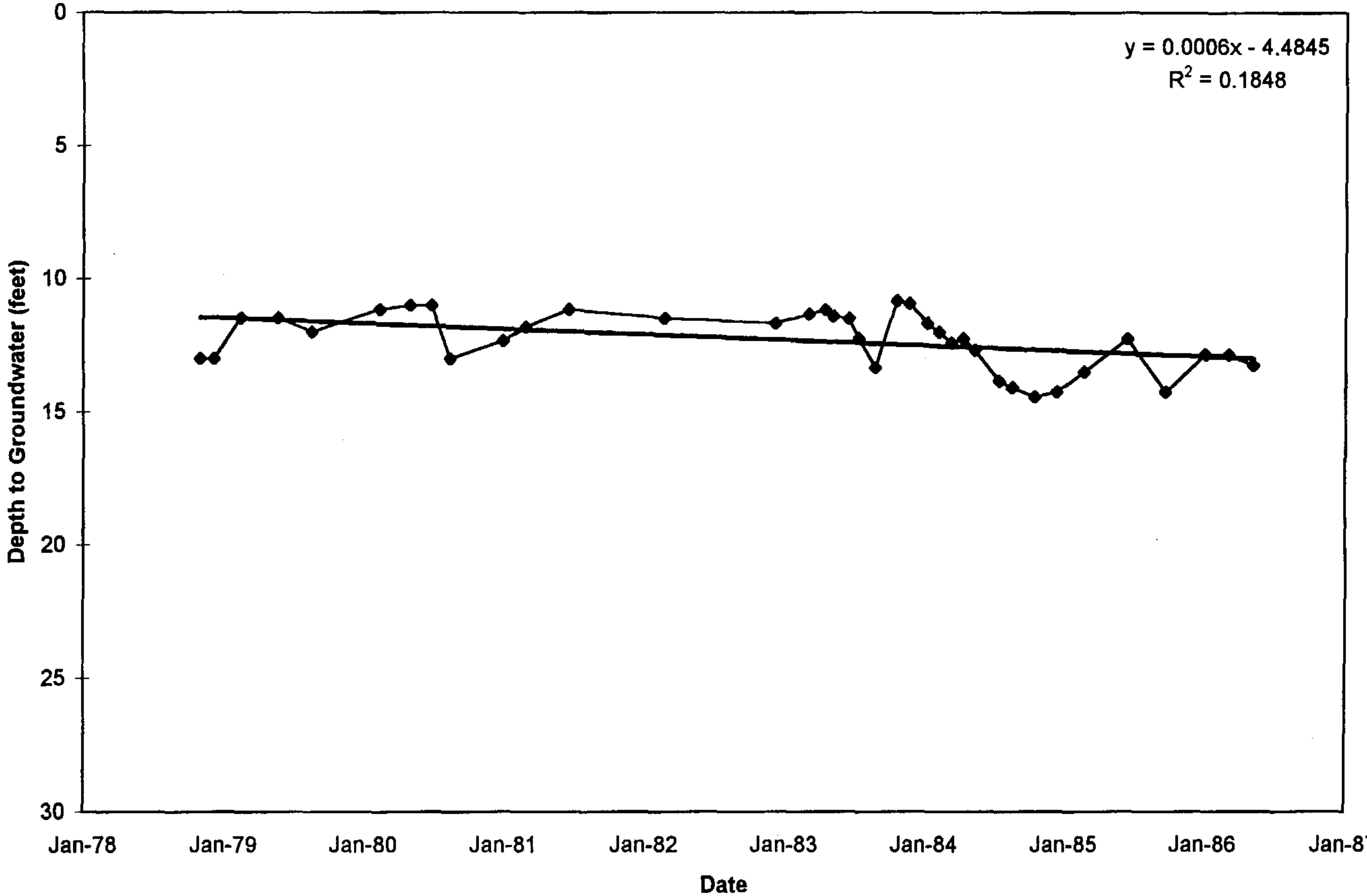


Figure 4-7
Hydrograph for Round Timber Ranch Well Field Observation Well #7

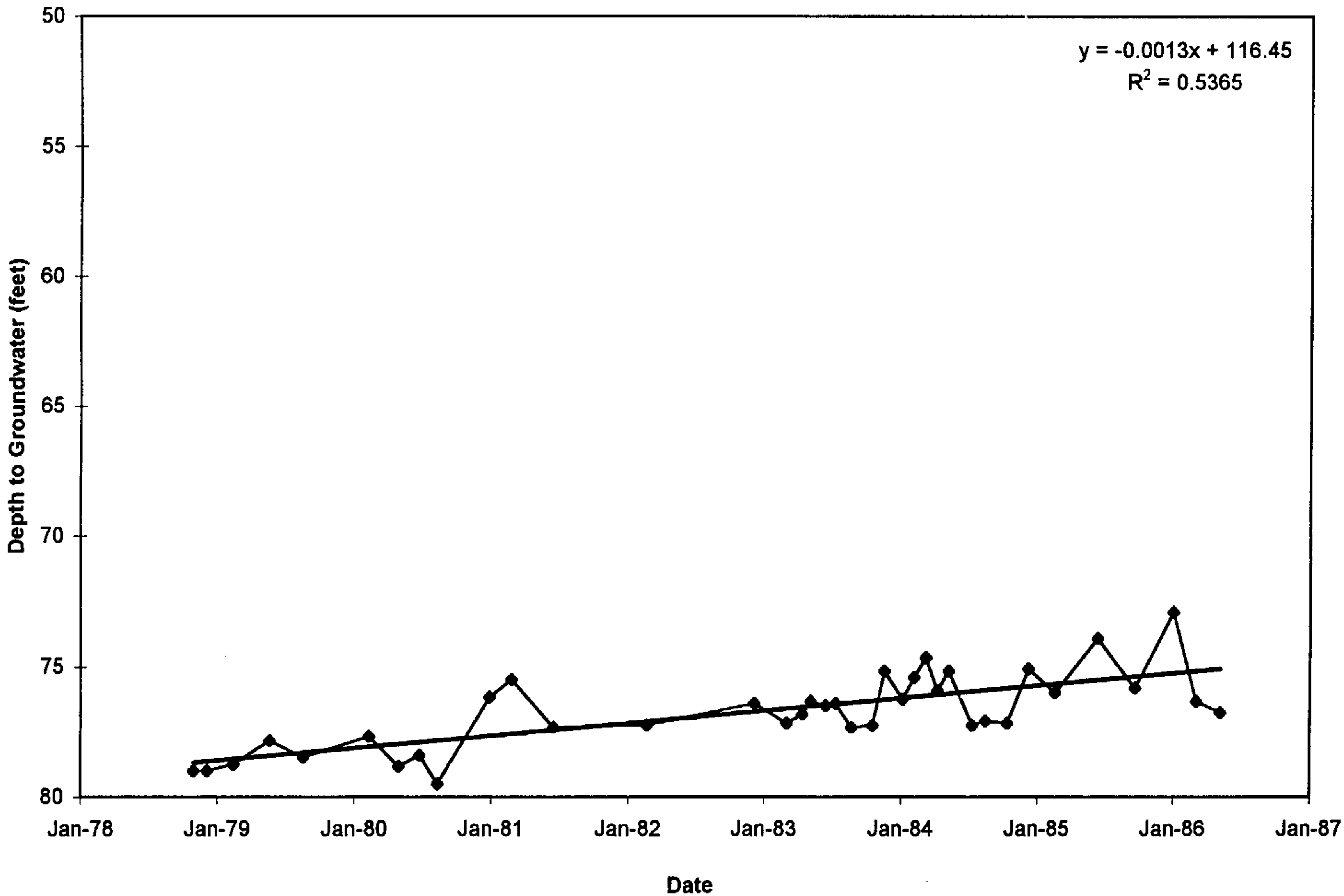


Figure 4-8
Round Timber Ranch Well Field Average Daily Pumping Rate Per Year

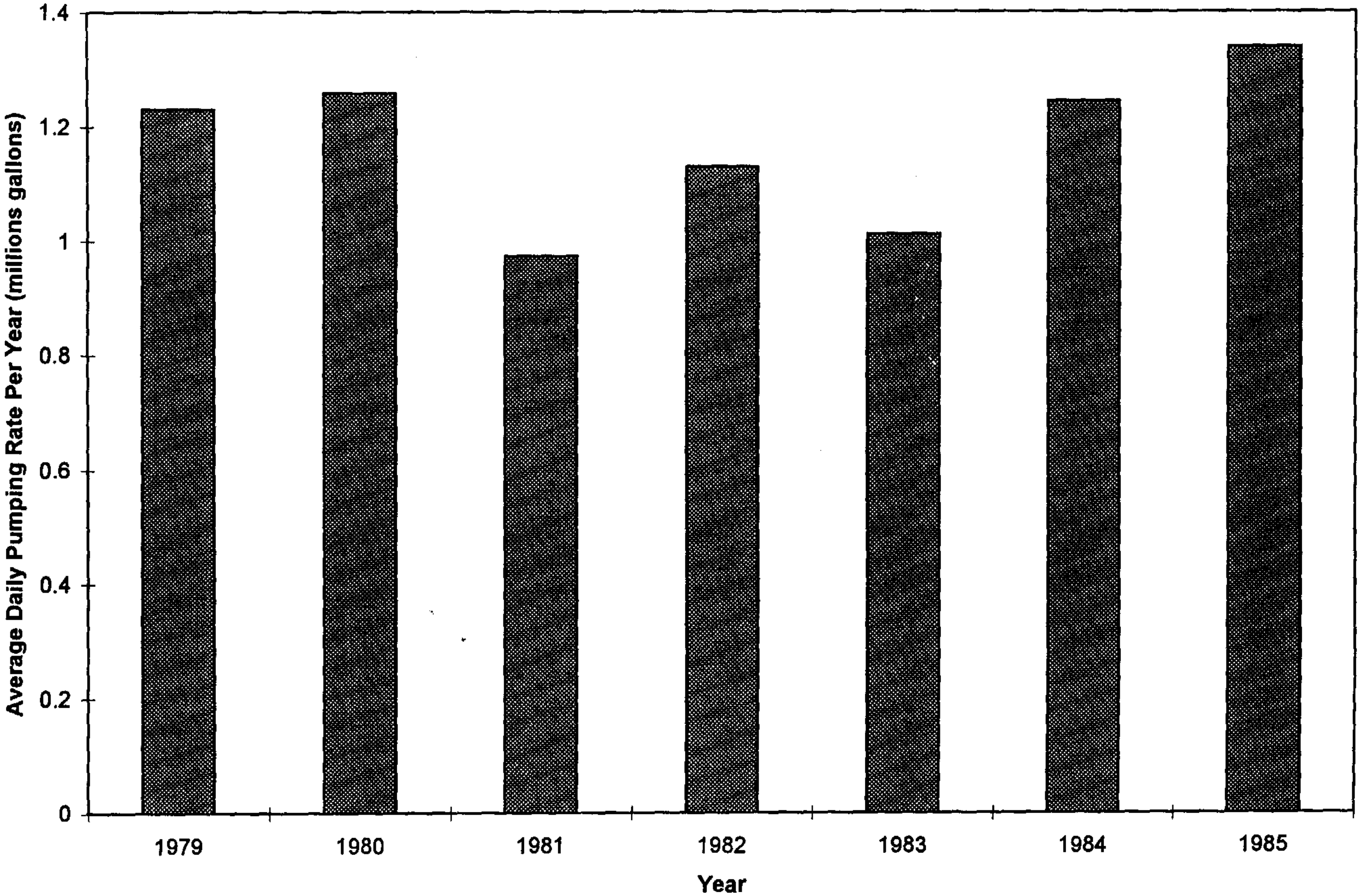
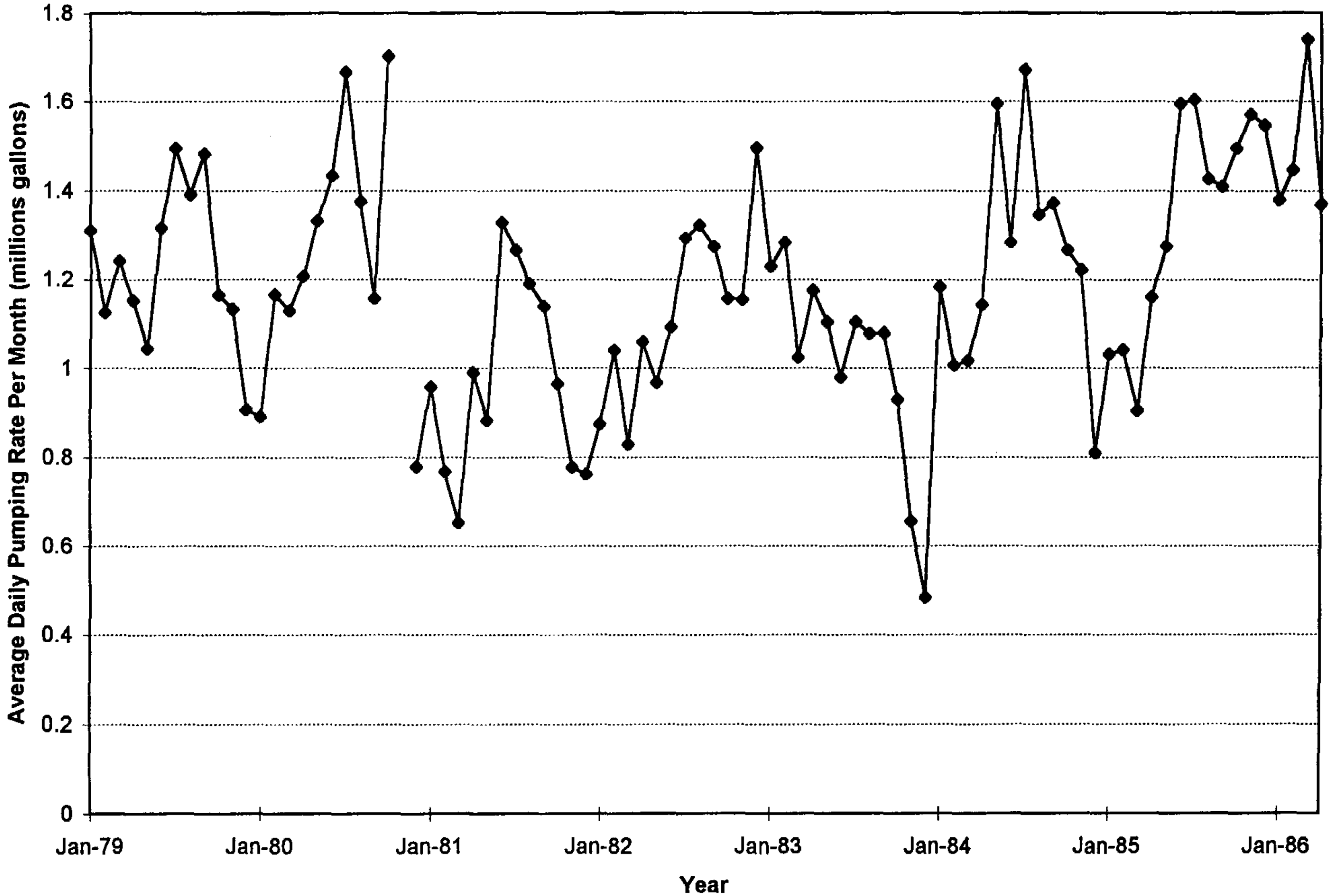


Figure 4-9
Round Timber Ranch Well Field Average Daily Pumping Rates Per Month



5.1 SATURATED THICKNESS OF AQUIFER

The current saturated thickness of the Seymour Aquifer at the Round Timber Ranch Well Field is unknown and cannot be determined with the available data. However, it is likely that the water levels have recovered significantly from the most recent water level records from the site which were measured while the well field was still being pumped in 1986. It would be conservative to assume the current water levels are equivalent to the beginning of the available water level records in 1978. Since pumping of the well field occurred prior to 1978, it is possible that the water levels have recovered to an elevation higher than the water levels observed in 1978. The depth to the water table measured in the observation wells in 1978 ranges from 13 to 79 feet. The depths of the water supply wells indicated on the drillers logs range from 58 feet to 113 feet. Data for the elevation of the top of the water supply wells or the location of the observation wells is not available. However, if we assume that the shallowest depth to the water table is related to the shallowest well, and the greatest depth to the water table is related to the deepest well, then the estimated saturated thickness of the Seymour Aquifer penetrated by the water supply wells in the Round Timber Ranch Well Field may range from approximately 34 feet to 45 feet.

If the City of Vernon decides to pursue Round Timber Ranch Well Field as a future water supply option, it is recommended that water levels and saturated thickness be determined at an early stage. This will provide important information for determining the available water resources at Round Timber Ranch Well Field which would be important input into the long-term water supply plan for the City of Vernon.

5.2 PRECIPITATION RATES COMPARED TO WATER LEVELS

The average annual change in water levels for each observation well in the Round Timber Ranch Well Field for the period of record (1978 to 1986) was estimated by fitting a linear trend line to the well hydrographs. The trend lines are shown on the hydrographs in Figures 4-1 to 4-7. The average annual changes in water levels for the entire well field was estimated by averaging the annual change in water levels for each well. The resulting average decline in water levels for all wells in the Round Timber Ranch Well Field is estimated to be 0.26 ft/year (3.1 inches/year) for the period 1978 to 1986.

For the period of groundwater level records presented in Figures 4-1 to 4-7 (1978 to 1986), average annual precipitation was equal to the long-term (1904 to 1997) historical annual average of 26.7 inches. Thus it is reasonable to assume that recharge to the Seymour Aquifer at Round Timber Ranch Well Field was approximately equal to the long-term average recharge rate between 1978 and 1986. Therefore the observed reduction in water levels during this time period is likely to be the result of the well field pumping rate exceeding the recharge rate during this period.

5.3 PUMPING RATES COMPARED TO WATER LEVELS

The average daily pumping rate for the Round Timber Well Field is 1.2 MGD for the period 1979 to 1985. There is no clear increasing or decreasing trend in the pumping rate through this time period. Based on the observation well hydrographs and the observation of average recharge rates during this time period, it is reasonable to conclude that the average pumping rate of 1.2 MGD is greater than the average volume of recharge to the well field.

5.4 SUMMARY OF LONG-TERM AVAILABILITY OF GROUNDWATER

If the Round Timber Ranch Well Field were rehabilitated for future water supply, it is likely that it could sustain an average rate of 1.2 MGD (440 million gallons per year) for a period exceeding 5 years given average recharge conditions. During an extended pumping period, groundwater levels would likely decline over a large area near the well field which could reduce the sustainable pumping rates. Likewise, if an extended drought occurs where recharge rates are below average, groundwater levels would likely decline. Therefore, if Round Timber Ranch Well Field was to be used as a long-term water supply, sustainable pumping rates are likely to be less than 1.2 MGD. In order to provide a more definitive estimate of the long-term sustainable pumping rate, additional groundwater level and pumping rate data are needed during an extended period of pumping.

6.1 LONG-TERM PUMPING RATES

Based on the available information, the principal conclusions regarding the Odell-Winston Well Field are:

- The well field could likely sustain a pumping rate of approximately 2.5 MGD (900 million gallons per year) assuming average rainfall rates and recharge conditions will prevail over the long term. This also assumes there is no increase in demand for groundwater from the Seymour Aquifer from other users in the area around the Odell-Winston Well Field.
- This estimate of sustainable pumping rate is based on available water level, pumping rate and precipitation data. These data indicate that average water levels in the Odell-Winston Well Field have been increasing slightly over the last decade. However, average precipitation and recharge rates over the last 10 years have been greater than the long-term average, and pumping rates have been decreasing slightly over the last decade.
- During an extended drought period when recharge rates are reduced it is likely that groundwater levels will decline and thus reduce sustainable pumping rates.
- Groundwater supply from the well field could be increased without significant effect on water level elevations by installing extra water supply wells outside the areas of drawdown caused by the existing well fields.

Based on the available information, the principal conclusions regarding the Round Timber Ranch Well Field are:

- If the well field were rehabilitated and pumped again in the future for water supply, it is likely that it could sustain an average rate of 1.2 MGD (440 million gallons per year) for a period of at least 5 years, assuming average rainfall rates and recharge conditions.
- If the well field is to be used for a longer period than 5 years, the sustainable pumping rate may have to be decreased from 1.2 MGD (440 million gallons per year). Alternatively, the number of wells could be increased by installing additional wells outside the area of the existing well field. In order to provide a more definitive estimate of the long-term sustainable pumping rate, additional groundwater level and pumping rate data are needed during an extended period of pumping.

6.2 WELL FIELD MANAGEMENT

Based on the available information, the following conclusions and recommendations are made to improve the management and efficiency of the Odell-Winston Well Field:

- During drought periods, when recharge is reduced, and during high demand periods, it is recommended that wells in the Winston Well Field should be pumped at higher rates than the Odell wells because the aquifer's saturated thickness is greater in the Winston Well Field area. However, it should be noted that this would probably result in an increased concentration of nitrate in the water supply because of the higher average nitrate concentrations in the Winston Well Field area.

- Recharge rates to the Odell and Winston Well Fields could be increased by building small dams and infiltration wells in surface water runoff drainage pathways.
- It is recommended that the City consider replacing the existing well pumps with variable rate pumps to allow more control over the pumping rates from individual wells. Variable rate pumps would allow the city to optimize the rate of supply from individual wells to minimize drawdown effects on surrounding wells, thus improving the City's capability to efficiently manage the well field. For instance, by varying pumping rates on a well-by-well basis, the City can increase or decrease pumping rates to minimize drawdowns and thus preserve the aquifer's saturated thickness. Of course, it is recognized that replacing pumps is expensive. Therefore, the City should weigh the advantages of well-by-well pump discharge control in comparison to pump replacement costs on a case-by-case basis as pumps need maintenance and repairs.
- During the lower demand period in winter, it is recommended that each well be shutdown for a short period to be rehabilitated. The rehabilitation should include cleaning out any sediment in the bottom of the well. Acid treatment of the wells may be used to remove encrustation, if present. Rehabilitation of the wells will improve the efficiency and production capacity of the wells. Rehabilitation of the wells is particularly important for the wells that are pumping sand (WW-5, WW-6, WW-7, WW-8, WW-15, WW-16 and WW-21) and those wells with sediment build-up in the base of the wells.
- While the pumps are removed from the wells, they should be inspected. Necessary maintenance or repairs should be made at this time.
- For the wells that are still using the original steel casing and screen without PVC casing and screen inserts, a downhole camera may be used to assess the condition of these screens at this time. If a screen were found to be badly corroded, then it would be worthwhile inserting a PVC screen into the well to prolong the life of the well.
- At the end of the well rehabilitation, it would be useful to perform a short-term aquifer pumping test on each well to determine the specific capacity. A short-term pumping test would involve pumping the well at a constant rate for a period of 4 to 8 hours while monitoring drawdown in the well. During this pumping test, all nearby wells should not be pumped. Based on these data, a specific capacity value can be calculated. Periodic calculation of specific capacity values from drawdown and production rate monitoring will provide a basis for assessing the well's pumping performance through time. For example, a reduction in the specific capacity may indicate plugging of the well screen. Other parameters which can indicate that the well or pump are in need of some attention include: changes in total well depth, changes in sand content of the water being pumped, changes in drawdown within the well, and changes in the pumping rate of the well.

Based on the available information, the following is a list of the minimum work that would be required to make the Round Timber Ranch Well Field operational:

- The water quality of the groundwater would have to be evaluated by collecting groundwater samples for analysis and comparing results to Texas Drinking Water Standards.
- Pumps would have to be checked, repaired and/or replaced.

- The electrical wiring to the pumps would have to be repaired.
- Well casings would have to be checked using a downhole television and PVC casings and screens inserted if required.
- Wells would have to be rehabilitated and redeveloped.
- The water conveyance pipeline would have to be checked and replaced or repaired where necessary.

6.3 COST SAVINGS AND WELL FIELD PROTECTION

The well field maintenance and replacement recommendations above are provided to improve the Odell-Winston Well Field efficiency and protect the well field for long-term supply. In addition, it is recommended that the City consider performing a well field optimization study to reduce the costs of water production. This project would involve conducting numerical modeling of the well-field and analyzing the major factors that control pumping costs. For instance, an optimization model may be developed to address the following factors:

- Minimize electricity use during periods when electrical rates are high. For example, if there is a variation in electric power billing rates to the City depending on time of usage, increasing pumping during off-peak times and decreasing pumping during peak times may substantially reduce costs.
- Reduce pipeline transmission costs. For example, minimizing temporal variations in pumping rates may reduce friction losses in pipes.
- Increase the pumping efficiency at each well. For example, pumping rates at each well may be adjusted to reduce the drawdown interferences with other wells and thus minimize pumping lifts of pumps.

The City may also reduce long-term pumping costs and protect their water resources for long-term supply by purchasing land around the Odell and Winston wells. Specifically it is recommended that the City of Vernon consider:

- Buying land around the Odell Well Field to create a 1-mile wide buffer zone around the well field to preclude other well users causing adverse drawdown effects by pumping nearby wells to meet irrigation demands. Creating such a buffer zone will reduce potential drawdown interferences with the Odell wells and thus reduce pumping costs.
- Purchasing additional land around Winston Well Field to increase the existing buffer zone to 1 mile wide and provide areas for expansion of the Winston Well Field for increased water supply.

The purchase of additional buffer zone land around the well fields will result in long-term groundwater quality improvement in the aquifer by allowing the City to control land use and thus reduce the source of nitrate contamination. Land uses should limit fertilizer use and reduce nitrate levels in soil.

Driscoll, F.G. 1995. "Groundwater and Wells." Second Edition, Johnson Screens.

Layne-Western Company. 1964. Groundwater Survey for City of Altus, Oklahoma.

Texas Department of Water Resources. 1979. Occurrence, Quality, and Quantity of Groundwater in Wilbarger County, Texas. Report 240.

Appendix A

City Of Vernon Precipitation Data

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1904**	**1919**	**1920**	**1921**	**1934**	**1935**	**1936**	**1937**	**1938**	**1939**
January				1.83	0.75		0.15	0.8	0.65	0.93	3.05
February				0.97	1.75		1.32	0	0	3.48	0.15
March		0	2.63	2.07	2.2		1.73	0.22	2.46	3	2.64
April		0.05	3.74	3.64	0.2		1.65	2.59	1.44	1.56	0.35
May		2.55	6.21		0	4.22	6.46	3.52	1.83	7.52	2.01
June		7.43	3.01		6	2.25	3.65	1.2	2.13	4.52	2.45
July		1.11	3.75			0.5	3.13	0.27	0.79	0.06	1.44
August		3.44	1.94			1.02	0.91	0	3.78	2.38	3.24
September			1.92			4.03	3.93	9.44	1.39	0.32	0
October			11.65			0.49	1.88	1.18	4.88	1.09	0.35
November			1.34	2.2		3.78	1.92	0.09	0.73	1.2	0.79
December			0.6	0.2		0.03	1.1	0.26	0.49	0.32	1.38
Total		14.58	36.79	10.91	10.9	16.32	27.83	19.57	20.57	26.38	17.85
Min		0	0.6	0.2	0	0.03	0.15	0	0	0.06	0
Max		7.43	11.65	3.64	6	4.22	6.46	9.44	4.88	7.52	3.24

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1940**	**1941**	**1942**	**1943**	**1944**	**1945**	**1946**	**1947**	**1948**	**1949**
January		0.25	1.81	0.17	0.03	1.64	2.89	1.18	0	0.61	3.69
February		2.13	3.28	0.59	0.12	2.45	3.89	1.14	0.25	1.78	0.8
March		0	0.9	0.89	1.71	1.7	1.01	1.14	0.94	1.45	1.91
April		2.64	5.38	5	3.35	2.29	1.85	0.75	3.27	0.9	1.65
May		2.35	10.24	1.19	6.16	0.41	1.35	2.34	8.02	6.25	5.29
June		2.21	6.14	1.85	4.39	2.68	2.77	3.33	0.9	5.4	4.55
July		0.69	4.88	1.82	0.21	1.49	1.99	0.18	0.84	2.95	0.33
August		2.53	3.44	2.89	1.01	1.69	2.8	1.21	0.29	0.09	2.78
September		2.93	1.35	5.3	1.94	1.29	5.76	5.89	0.62	0	3.39
October		2.21	9.59	3.69	0.06	2.49	1.18	2.42	4.12	1.82	4.98
November		3.11	0.65	0.48	0.83	1.85	0.65	2.67	2.09	0.2	0
December		0.74		2.8	2.82	1.33	0	2.91	2.43	0.07	1.17
Total		21.79	47.66	26.67	22.63	21.31	26.14	25.16	23.77	21.52	30.54
Min		0	0.65	0.17	0.03	0.41	0	0.18	0	0	0
Max		3.11	10.24	5.3	6.16	2.68	5.76	5.89	8.02	6.25	5.29

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**
January		0.51	0.29	0.91	0.15		1.69	0.39	0.53	2.35	0.22
February		2.16	2.45	0.5	0.33	0	1.38	0.8	1.5	1.24	0.13
March		0.01	0.74	1.57	2.38		2.76	0.11	2.08	2.34	0.26
April		2.18	0.76	2.89	2.94		1.19	0.03	8.77	2.05	2.62
May		4.65	6.76	8.43	0.75	9.01	6.8	3.84	11.33	3.32	7.41
June		2.39	6.41	0.05	1.39	2.22	6.66	0.25	4.88	1.88	6.31
July		4.09	1.93	2.42	0.88	0	1.1	1.17	3.01	7.07	3.53
August		2.99	4.08	0.62	1.43	0	2.05	0.27	0.06	0.76	0.39
September		2.68	1.4	0.11	0.02	0	8.15	0.73	1.32	1.94	4.52
October		0	5.49	0		0.72	5.11	3.45	5.06	0.32	5.08
November		0	0.14	1.43	0.35	0.1	0	0.34	4.49	1.49	1.23
December		0	0	1.46	0.16	0.21	0.13	1.88	0.12	0.9	3.8
Total		21.66	30.45	20.39	10.78	12.26	37.02	13.26	43.15	25.66	35.5
Min		0	0	0	0.02	0	0	0.03	0.06	0.32	0.13
Max		4.65	6.76	8.43	2.94	9.01	8.15	3.84	11.33	7.07	7.41

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1960**	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**
January		1.01	0.5	0.66	0.05	0.47	0.6	1.74	0	3.62	
February		1.69	1.92	0.27	0.57	2.62	0.92	0.57	0.08	1.59	2.4
March		0.74	3.66	0.43	1.72	1.23	0.26	0.64	0.4	2.15	2.06
April		0.24	0.08	4.33	0.44	0.64	2.48	2.6	7.38	1.78	0.41
May		4.6	0.96	1.02	6.72	3.55	3.76	1.33	1.61	4.65	6.12
June		3.54	4.89	7.58	4.34	1.66	1.3	0.62	2.31	1.84	2.96
July		2.73	4.52	2.99	0.5	0.22	1.46	1.88	1.81	4.87	3.22
August		1.51	0.59	0.18	0.69	4.12	1.37	5.21	0.12	2.25	1.71
September		1.32	3.35	5.83	0.44	3.49	3.33	5.81	2.2	1.04	4.99
October		8.3	1.68	3.16	0.24	0.89	3.71	0.7	2.92	1.56	4.08
November		0	3.18	2.09	2.78	3.77	0	0.17	0.15	2.77	0.83
December		2	0.82	0.86	0.95	0.71	0.82	0.16	0.45	0.56	0.95
Total		27.68	26.15	29.4	19.44	23.37	20.01	21.43	19.43	28.68	29.73
Min		0	0.08	0.18	0.05	0.22	0	0.16	0	0.56	0.41
Max		8.3	4.89	7.58	6.72	4.12	3.76	5.81	7.38	4.87	6.12

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**
January		0.16	0.25	0	3.31	0	1.76	0	1.7	0.48	0.87
February		0.68	0.7	0.38	1.58	0.1	2.01	0.13		2.47	0.27
March		5.04	0.1	1.86	4.36	1.05	0.61	1.42	0.68	0.89	2.5
April		1.58	0.97	2.57	3.41	2.8	1.05	4.08	5.86	0.66	1.4
May		1.92	3.47	3.97	0.62	2.87	7.49	2.38	8.66	4.01	6.72
June		1.22	1.55	2.1	2.62	2.12	4.41	2.77	1.91	2.37	2.61
July		0	0.95	0.8	4.83			0.97	0.52	0.11	1.78
August		0.76	4.42	3.18	0.48	3.54	4.47	1.85	4.12	3.13	6.73
September		3.73	5	2.12	6.28	6.01	3.23	4.12	0.17	4.25	0
October		1.2	3.95	6.32	2.05	2.41	1.47	4.77	1.31	0.38	1.86
November		0.28	0.52	1.86	1.52			0.47	0.76	1.25	1.25
December		0.18	2.29	0		0.38	1.49	0.13	0.02	0.46	1.75
Total		16.75	24.17	25.16	31.06	21.28	27.99	23.09	25.71	20.46	27.74
Min		0	0.1	0	0.48	0	0.61	0	0.02	0.11	0
Max		5.04	5	6.32	6.28	6.01	7.49	4.77	8.66	4.25	6.73

Station Name	VERNON 4 S										
Station ID	9346										
Param	Precipitation										
State	TEXAS										
County	WILBARGER										
Latitude	34:05:00										
Longitude	099:18:00										
Elevation	1200										
Start Year	1904										
End Year	1996										
Num Years	67										
Month		**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
January		1.36	0.11	1.75	2.43	0.07	0.95	0	0.73	0.87	0.67
February		0.45	0.6	1.34	2.11	0.35	1.89	1.11	2.72	0.05	1.88
March		0.73	1.08	1.8	2.77	2.33	3.59	0.54	2.35	1.28	1.12
April		2.96	2.84	0.84	2.06		4.16	2.35	0	2.32	0.09
May		4.67	3.43	9.04	3.18	1.27	1.57	3.94	9.29	0.22	3.43
June		1.09	5.14	4.19	3.6	0.62	5.01	2.81	4.22	2.31	4.93
July		0	1.21	1.91	2.05	1.03	0.96	1.8	1.1	3.28	0.69
August		0	3.94	2.49	0.27	2.74	1.88	2.98	4.5	1.01	3.15
September		2.25	1.61	1.66	1.23	0.41	3.79	13.25	2.81	7	5.97
October		0.07	3.22	0.2	10.98	3.27	6.7	6.73	0.39	0.05	0
November		1.19	0.41	2.21	1.41	3.34	0.15	2.38	0.31	0.37	0
December		1.41	0	1.35	0.67	3.89	0.3	0.65	1.93	0.48	0.26
Total		16.18	23.59	28.78	32.76	19.32	30.95	38.54	30.35	19.24	22.19
Min		0	0	0.2	0.27	0.07	0.15	0	0	0.05	0
Max		4.67	5.14	9.04	10.98	3.89	6.7	13.25	9.29	7	5.97

Station Name	VERNON 4 S									
Station ID	9346									
Param	Precipitation									
State	TEXAS									
County	WILBARGER									
Latitude	34:05:00									
Longitude	099:18:00									
Elevation	1200									
Start Year	1904									
End Year	1996									
Num Years	67									
Month		**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**		
January		1.86	2.41	2.69	0.94	0.01	0.83	0.5	0.3		
February		3.85	0	2.01	2.91	0.23	0.72	0	4.54		
March		3.78	0.94	2.35	3.84	2.22	2.01	2.14	0		
April		5.18	1.27	3.15	2.71	2.12	3.49	0.35	5.64		
May		3	3.84	3.16	4.57	5.34	8.65	1.23	2.51		
June		2.33	9.6	7.7	1.74	1.25	17.22	1.72	4.84		
July		5.15	6	1.97	1.2	3.77	2.92	1.93	0.37		
August		2.27	1.93	2.83	4.97	0.99	17.6	3.16	2.57		
September		1.8	8.27	2.26	1.27	2.17	5.41	3.42	7.4		
October		1.27	3.13	0	3.14	2.01	0.95		1.76		
November		3.05	0.82		0.59	3.35	1.6		0.8		
December		0.84	4.29	2.39	1.48	0.26	0.44		3.18		
Total		34.38	42.5	30.51	29.36	23.72	61.84	14.45	33.91		
Min		0.84	0	0	0.59	0.01	0.44	0	0		
Max		5.18	9.6	7.7	4.97	5.34	17.6	3.42	5.64		

Station Name	VERNON 4 S						
Station ID	9346						
Param	Precipitation						
State	TEXAS						
County	WILBARGER						
Latitude	34:05:00						
Longitude	099:18:00						
Elevation	1200						
Start Year	1904						
End Year	1996						
Num Years	67						
		1904-1997	**1989-1997**	**1988-1997**	**1950-1987**	**1978-1986**	**1960-1975**
Month		**Average**	**Average**	**Average**	**Average**	**Average**	**Average**
January		1.00	1.13	1.11	0.88	0.89	0.94
February		1.29	1.79	1.62	1.14	1.18	1.13
March		1.63	2.04	1.97	1.60	1.80	1.64
April		2.38	2.67	2.63	2.32	2.16	2.05
May		4.21	3.97	3.60	4.61	4.20	3.42
June		3.49	5.70	5.36	3.00	3.05	2.82
July		1.94	2.67	2.73	1.93	1.21	2.20
August		2.45	4.39	4.05	2.15	2.68	2.16
September		3.25	4.22	4.50	3.02	3.16	3.64
October		2.70	1.53	1.37	2.97	3.71	2.79
November		1.27	1.46	1.32	1.24	1.51	1.42
December		1.09	1.64	1.51	0.91	1.16	0.84
Total		26.71	33.22	31.76	25.75	26.72	25.05
Min							
Max							

Appendix B

Odell-Winston Well Field Pumping Rate Data

Odell - Winston Well Field Individual Well Average Daily Pumping Rates (gpm)

Date	Well Number																					Daily
	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Totals
3/1/98																						
3/2/98																						
3/3/98																						
3/4/98																						
3/5/98																						
3/6/98																						
3/7/98																						
3/8/98																						
3/9/98																						
3/10/98																						
3/11/98																						
3/12/98																						
3/13/98	243		166				229			159	236	293	243						270		269	2108
3/14/98	243		166				212			159	222	293	243								269	1807
3/15/98	239		170				218			159	224	293	243								269	1815
3/16/98	247		159				216			159	238	293	243						268		269	2092
3/17/98	233		165				216			159	218	293	243						272		269	2068
3/18/98	234		180				216			154	218	293	243						277		269	2084
3/19/98			174				216			154	245	293	243				270		297		269	2161
3/20/98	243		159				216			154	245	293	243						270		269	2092
3/21/98			168				216			154	245	293	243						274		269	1862
3/22/98	253		170				218			154	245	293	247						276		269	2125
3/23/98	259		155	180			212			154	245	293	237		450	275	252		272		269	3253
3/24/98	247		176				222			154	229	293	247	217					285		269	2339
3/25/98	245		180				218			154	229	293	241	217			248		324			2349
3/26/98	247		178				225			154	229	293	279	205			248		270		317	2645
3/27/98	239		168				229			143	252	303	260	217			288		299		348	2746
3/28/98	263		159				205			143	252	300	301	209			219		278			2329
3/29/98	283		174				212			143	252	300	275				219		313			2171
3/30/98	233		170				216			143	252	300	275				225		293			2107
3/31/98	253		176				209			143	252	300	275	209			230		297			2344
Individual Well Monthly Total	4204		3213	180			4121			2896	4528	5605	4824	1274	450	275	2199		4835		3893	
Individaul Well Daily Average	247.3		169.1	180			216.9			152.4	238.3	295	253.9	212.3	450	275	244.3		284.4		278.1	

Well Field Daily Average = 2237 gpm

Odell - Winston Well Field Average Daily Pumping Rates (gpm)

Date	Well Number	3	4		6															21	22	Daily Totals
4/1/98	275		170				[illegible]			[illegible]	252	300	[illegible]	[illegible]			[illegible]		268			2348
4/2/98	259		166				220			143	252	300	275	213			233		270			2331
4/3/98	249		161				222			143	252	300	285	207			233		276			2328
[illegible]	233		159				[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			233		278			2311
4/5/98	255		180				242				252	300	[illegible]	[illegible]			214		285			2359
4/6/98	247		180				222			143	252	300	271	217			214		291			2337
4/7/98	243		180				222			143	226	300	261	220			214		287			2296
4/8/98	239		170				222			143	233	300	277	203			214		287			2288
4/9/98	249		180				222			143	233	300	245	239			214		278			2303
4/10/98	249		161				222			143	233	300	247	209			214		295			2273
4/11/98	247		184				222			143	233	300	265	203			214		289			2300
4/12/98	283		172				222			143	233	300	245	207			214		285			2304
4/13/98	269		180				222			143	233	300	261	239			214		285			2346
4/14/98	235		180				222			143	233	300	249	239	434		211		285		375	3106
4/15/98	235		180				222			143	233	300	249	195			201		285		361	2604
4/16/98	235		180				222			143	233	300	249	242			201		285		361	2651
4/17/98			182				222			143	227	300	253	212			201		285		384	2409
4/18/98	247		163				222			143	226	300	245	221			201		285		390	2643
4/19/98	245		159				222			143	226	300	261	221			201		274		334	2586
4/20/98	269		172				218			152	229	312	243	220			225		248		373	2661
4/21/98			163				222			152	229	312	253	205			217		248		378	2379
4/22/98	245		163				222			152	226	312	241	230			219		274		384	2668
4/23/98	261		174				218			152	226	312	253	221			219		280		399	2715
4/24/98	261		174				233			152	226	312	253	229			219		280			2339
4/25/98	229		174				225			152	226	312	253	208			211		280		414	2684
4/26/98	229		174				214			152	226	312	253	190			225		280			2255
4/27/98			188				214			152	220	312	257	223			222		280		378	2446
4/28/98			163				214			152	231	312	249	220					272		250	2063
4/29/98			172				214			152	238	312	259	210					272		349	2178
4/30/98	263		172				214			152	231	312	245	182					272		348	2391
Individual Well Monthly Total	6251		5176				[illegible]			[illegible]	7022	[illegible]	[illegible]	[illegible]	434		[illegible]		8359		5478	
Individual Well Daily Average	250		173				221			[illegible]	234	304	257	[illegible]	434		216		279		365	

Well Field Total = 72902 gpm
Well Field Daily Average = 2430 gpm

Odell - Winston Well Field Average Daily Pumping Rates (gpm)

Date	Well Number																					Daily
	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Totals
5/1/98	263		157				214			152	231	312	259	227		250			272		408	2745
5/2/98	312		157				214			152	231	312	253	257					272		346	2506
5/3/98	312		157				214			152	231	312	261	214		309			272		346	2780
5/4/98	253		157				214			168	231	312	255	211		274			272		343	2690
5/5/98	253		157				214			168	231	312	255	175		257			272		343	2637
5/6/98	253		157				214			168	231	312	255	208		239			272		326	2635
5/7/98	202		157	177			214	239		168	231	312	255	201		239	247		272		326	3240
5/8/98	202		157	170			214			175	231	312	255	180	414	243	247		272		320	3392
5/9/98	279		166				248			175	220	312	250	225					272		378	2525
5/10/98	218		174				248			175	229	312	250	203		306			272		334	2721
5/11/98																						
5/12/98																						
5/13/98																						
5/14/98																						
5/15/98																						
5/16/98																						
5/17/98																						
5/18/98																						
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5/25/98																						
5/26/98																						
5/27/98																						
5/28/98																						
5/29/98																						
5/30/98																						
5/31/98																						
Individual Well Monthly Total	2547		1596	347			2208	239		1653	2297	3120	2548	2101	414	2117	494		2720		3470	
Individaul Well Daily Average	255		160	174			221	239		165	230	312	255	210	414	265	247		272		347	

Well Field Daily Average = 2787 gpm

Appendix C
Round Timber Ranch Well Logs

Well #2

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 2 at Test Hole No. 2-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-29-67
7. Date Started
Completed
8. Drill Crew Man Hrs.
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	10 @ 6 15 @ 7 Openings
Inner Casing	52		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 65-75 #7 @ 50-55
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8 x 16

Tons 22 8

12. SEALING CASING

Puddled Clay (Yes) (No)

With .... Bags Bentonite Added

or

With 1½ Yds. ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 77'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump

Permanent pump ......8...... in ...RK... Bowl ......5...... Stages

Length of column ......60...... Ft.

Length of Bowl ......4*...... Ft.

Length of suction ......5...... Ft.

B. Measured water level ......30.90...... Ft. from top of ......12...... In. dia. casing which is ......2...... Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

......3...... x ......4......

.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
7:00		0		30.90	0
8:00		205		45.08	14.18
9:00		205		45.08	14.18
10:00		205		45.00	14.10
11:00		205		44.90	14.00
12:00		205		44.90	14.00
1:00		205		44.90	14.00
2:00		205		44.80	13.90
3:00		205		44.90	14.00

15. Permanent ......Layne...... Pump No. .... installed by ....

Layne

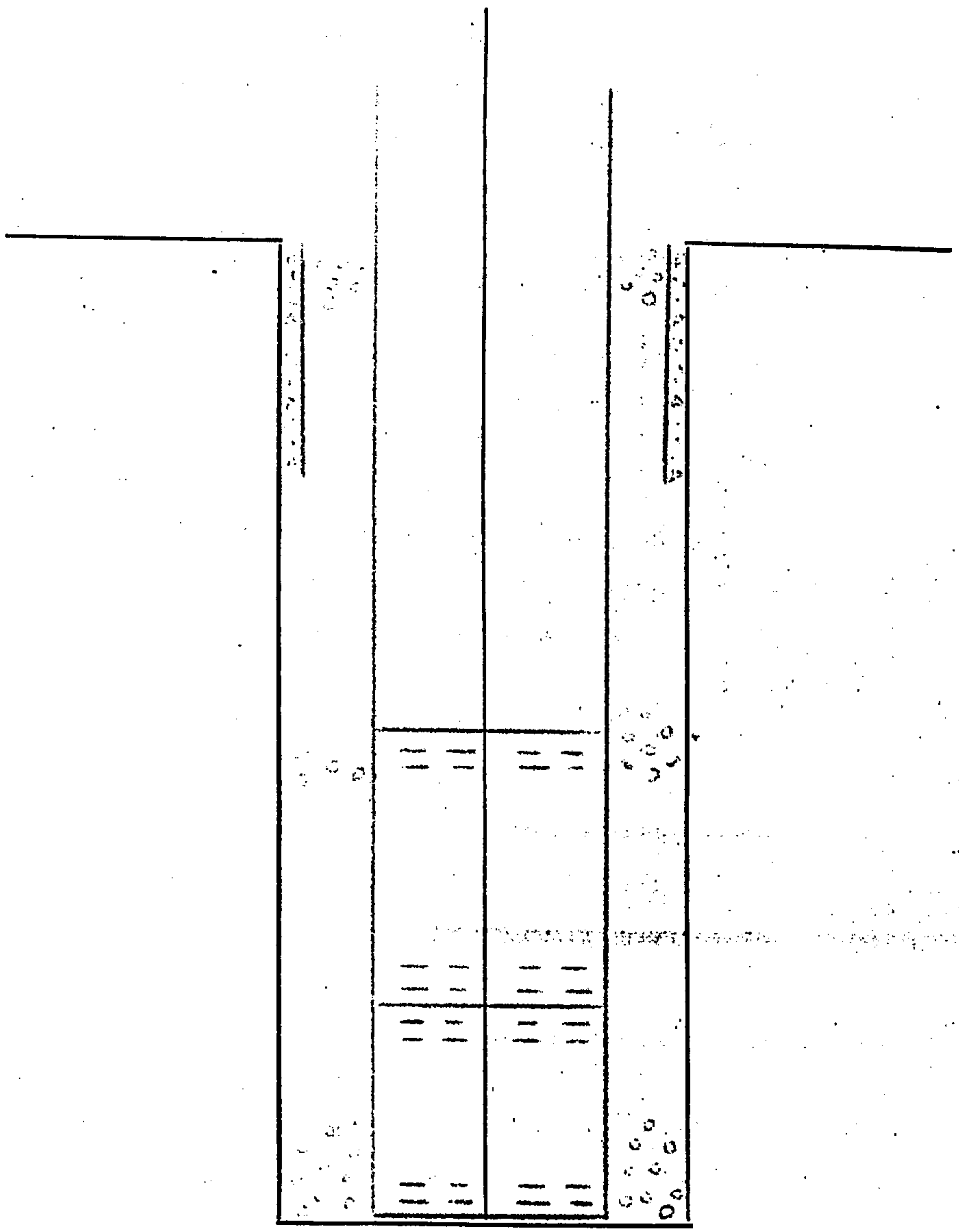
Permanent air line length .... Ft. Date ....

Month Day Year

LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			16		Fine to Med. Red Sand
16			28		Clayey Fine to Med. Red Sand
28			35		Slightly Clayey Fine to Med. Red Sand
35			40		Fine to Med. Red Sand
40			50		Fine to Med. Coarse Tan Sand
50			60		Fine to Coarse Sand & Some Fine Gravel, Tan
60			65		Fine to Coarse Sand & Fine Gravel, Tan
65			70		Fine to Coarse Sand & Fine to Med. Gravel, Tan
70			75		Fine to Coarse Sand & Gravel, Tan
75			80		Red Shale

CONSTRUCTION OF WELL

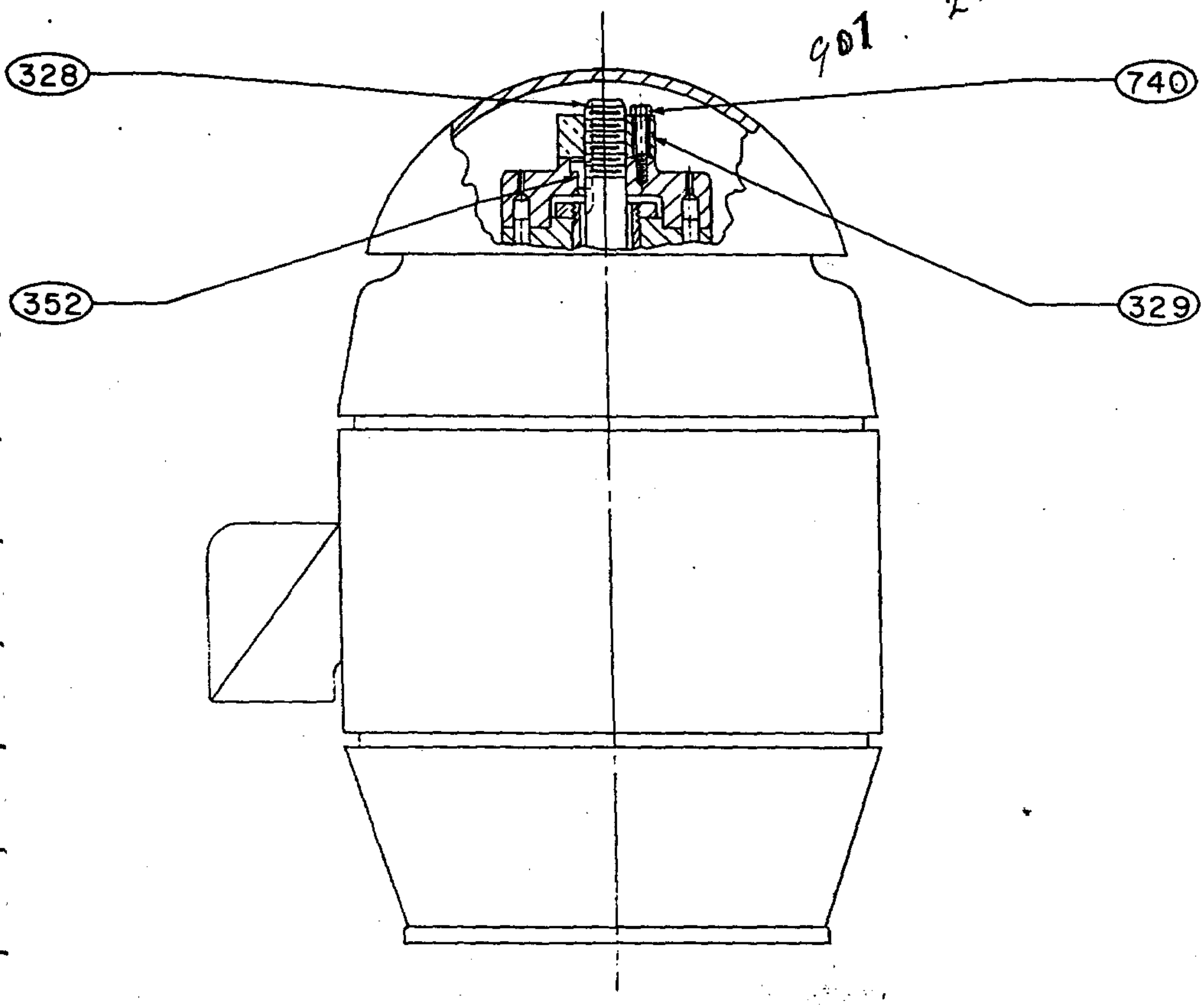


ADJUSTING NUT ASSEMBLY
VERTICAL HOLLOW SHAFT MOTOR

Layne

LAYNE & BOWLER INC MEMPHIS TENNESSEE.

901 . 275 . 1192



PART NO.		DESCRIPTION
3 2 8	7/8"	MOTOR DRIVE SHAFT
3 2 9	AN875	ADJUSTING NUT
3 5 2	F272	GIB. HEAD KEY (CLUTCH)
7 4 0	10-32-1¼	MACHINE SCREW (ADJUSTING NUT)

IN ORDERING REPLACEMENT PARTS, ALWAYS SPECIFY PARTS NO, DESCRIPTION, MOTOR SIZE, TYPE, & PUMP SERIAL NO.

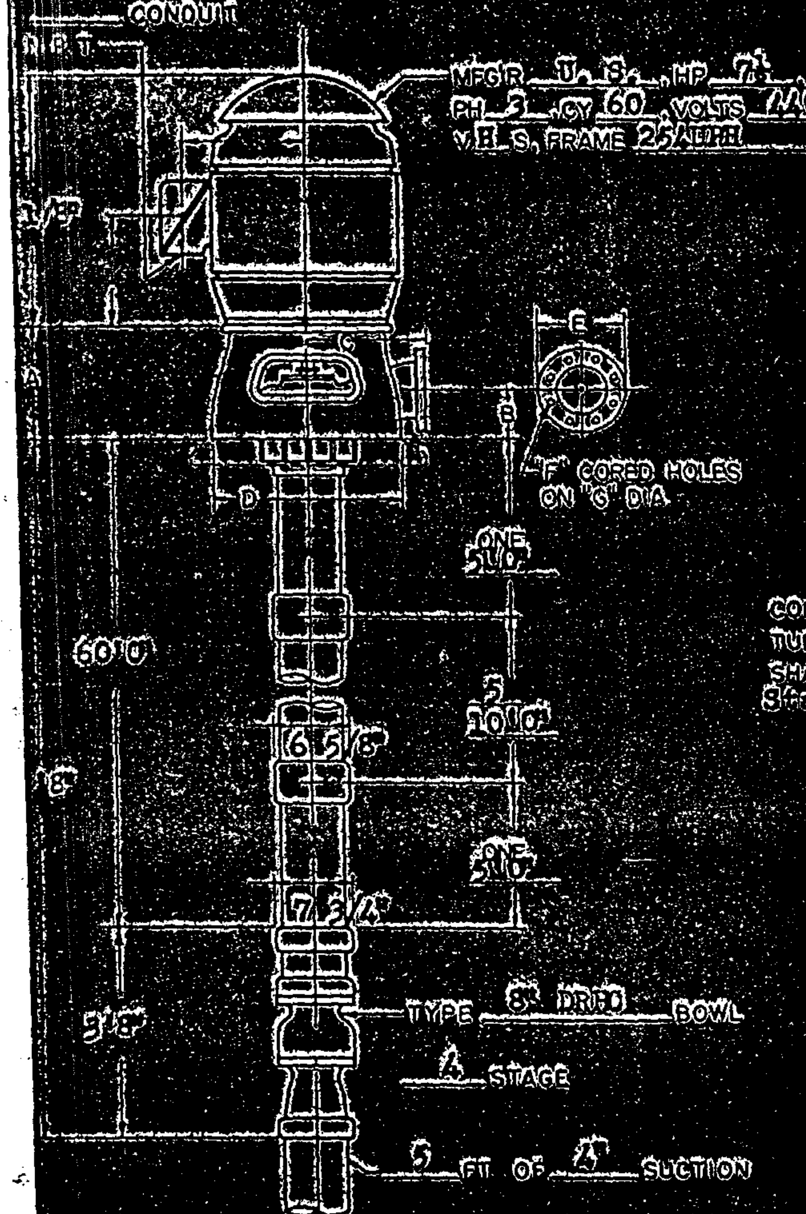
MOTOR MFG. U.S. H.P. 7 1/2 R.P.M. 1750

VOLTS 440 PHASE 3 CY. 60 FRAME 254UPH

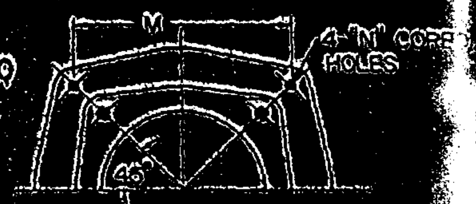
INSTALLATION PLAN

TYPE TF419 DISCHARGE HEAD

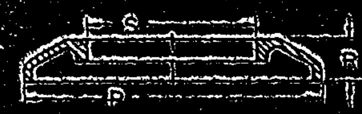
LAYNE & BOWLER INC. MEMPHIS, TENN.



USE THESE DIMENSIONS ONLY WHEN CERTIFIED BY FACTORY



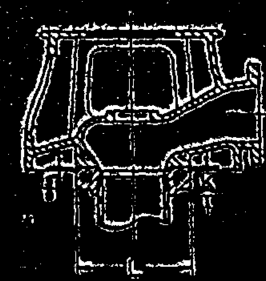
HOLES IN BASE PLATE



BASE PLATE

COLUMN 5"
TUBING ---
SHAFT 7/8"
Stainless Steel

HOLES IN BASE OF HEAD



SECTION THRU HEAD

CUSTOMER City Water Dept. (Well #2)
LOCATION Altus, Okla.
FOR APPROVAL
CERTIFIED [signature]

YOUR NO. F-10-698
OUR NO. 670-2555
PUMP NO. 57126
DATE June 29, 1967

GPM 175
TDH 113
RPM 1750
BHP

A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
[illegible]	6	11	15	9	8½	7½	4½	½	2½	10	6½	½	21	2	17
4	6	11	15	11	8½	9½	4½	½	2½	11	6½	½	21	2	17
[illegible]	6	14½	23	9	8½	2½	7	½	2½	10	20½	½	26½	2½	21½
5	6	14½	23	11	8½	9½	7½	½	2½	12½	20½	½	26	2½	21½
[illegible]	7	14½	23	[illegible]	8½	10	7	½	2½	[illegible]	20½	½	26	2½	21½
8	8½	14½	23	16	2-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF625	10	6½	8½	[illegible]	11	8	9½	23½	½	2½	21½	29	1	[illegible]	[illegible]	[illegible]
TF825	20	6½	8½	31	[illegible]	8	[illegible]	23½	½	3½	[illegible]	29	1	33	3½	[illegible]
TF1025	20	8½	8½	27	16	2-1	14½	23½	½	3½	16	29	1	28	[illegible]	[illegible]
TF1225	21	9½	8½	31	16	2-1	17	23½	½	3½	19	29	1	33	3½	[illegible]
TF1225	21	9	8½	31	16	2-1	17	23½	½	4½	21	29	1	[illegible]	[illegible]	[illegible]

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 3 at Test Hole No. 3-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE
7. Date Started
Completed
8. Drill Crew Man Hrs
9. Working Days
Drilling
Other

10. MATERIAL IN WELL	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	20		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	5 @ 6 15 @ 7 Openings
Inner Casing	49		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 62-67 #7 @ 47-62
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8 x 16
Tons 21 4

12. SEALING CASING

Puddled Clay (Yes) (No)

With .... Bags Bentonite Added
or Yds.
With 1¼ ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 69'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
   W-10
2. City, State Altus, Oklahoma
3. Well No. 3 at Test Hole No. 3-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	20		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	5 @ 6 15 @ 7 Openings
Inner Casing	49		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 62- #7 @ 47-6
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8 x 16

Tons 21 4

12. SEALING CASING

Puddled Clay (Yes) (No)

With .... Bags Bentonite Added

or

With 1¼ Yds. ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 69'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump
8 in. RK Bowl 5 Stages

Permanent pump

Length of column 50 Ft.

Length of Bowl 4± Ft.

Length of suction 5 Ft.

B. Measured water level 18.70 Ft. from top of 12 In. dia. casing which is 2 Ft. above ground.

C. Length of airline ______ Ft. from top of casing.

ORIFICE

3 x 4

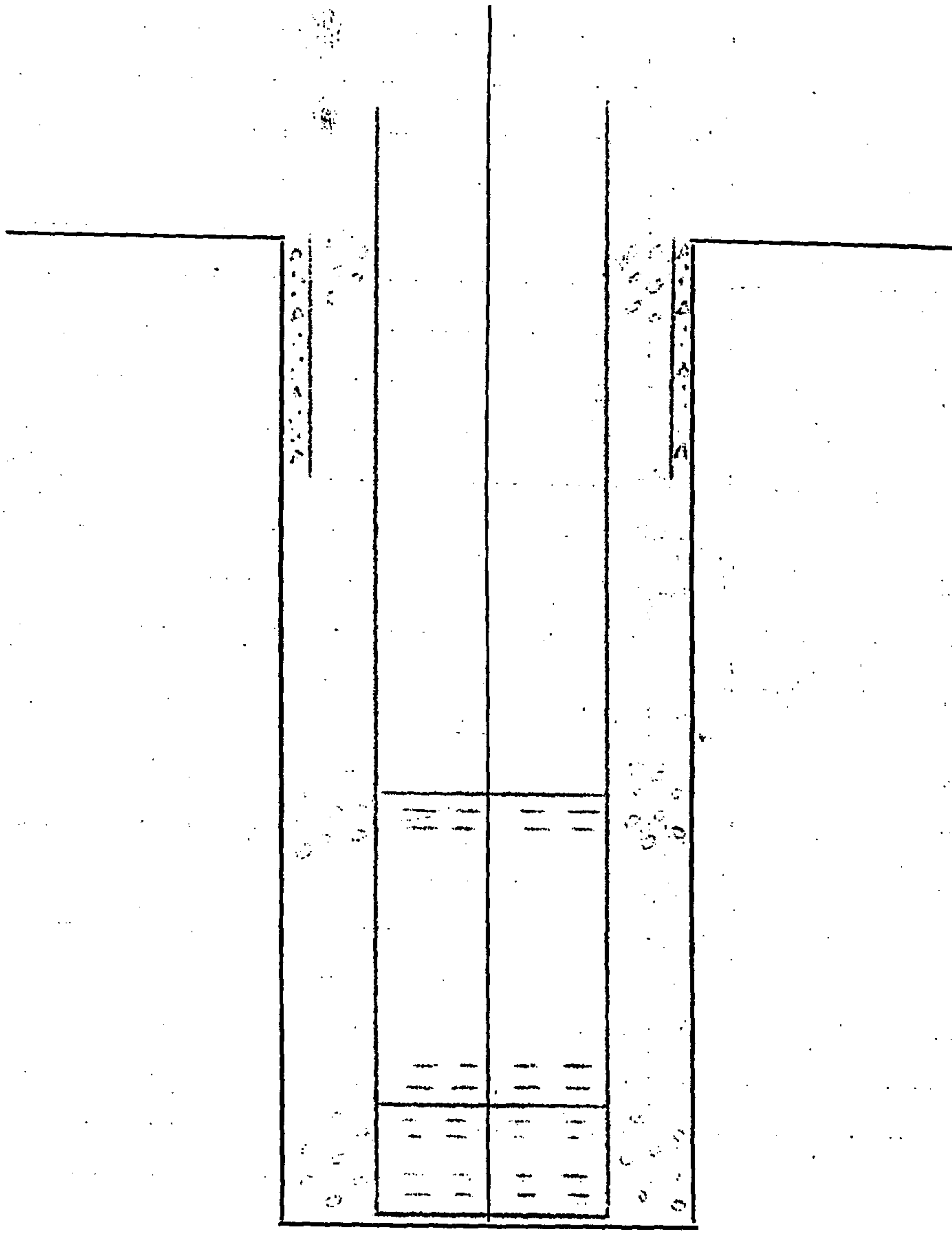
x

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
7:00		0		18.70	0
8:00		157		39.10	20.40
9:00		151		35.20	16.50
10:00		167		40.30	21.60
11:00		172		40.80	22.10
12:00		167		40.60	21.90
1:00		172		40.85	22.15
2:00		169		41.00	22.30
3:00		172		41.10	22.40

15. Permanent Layne (Layne) Pump No. ______ installed by ______

Permanent air line length ______ Ft. Date ______ Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

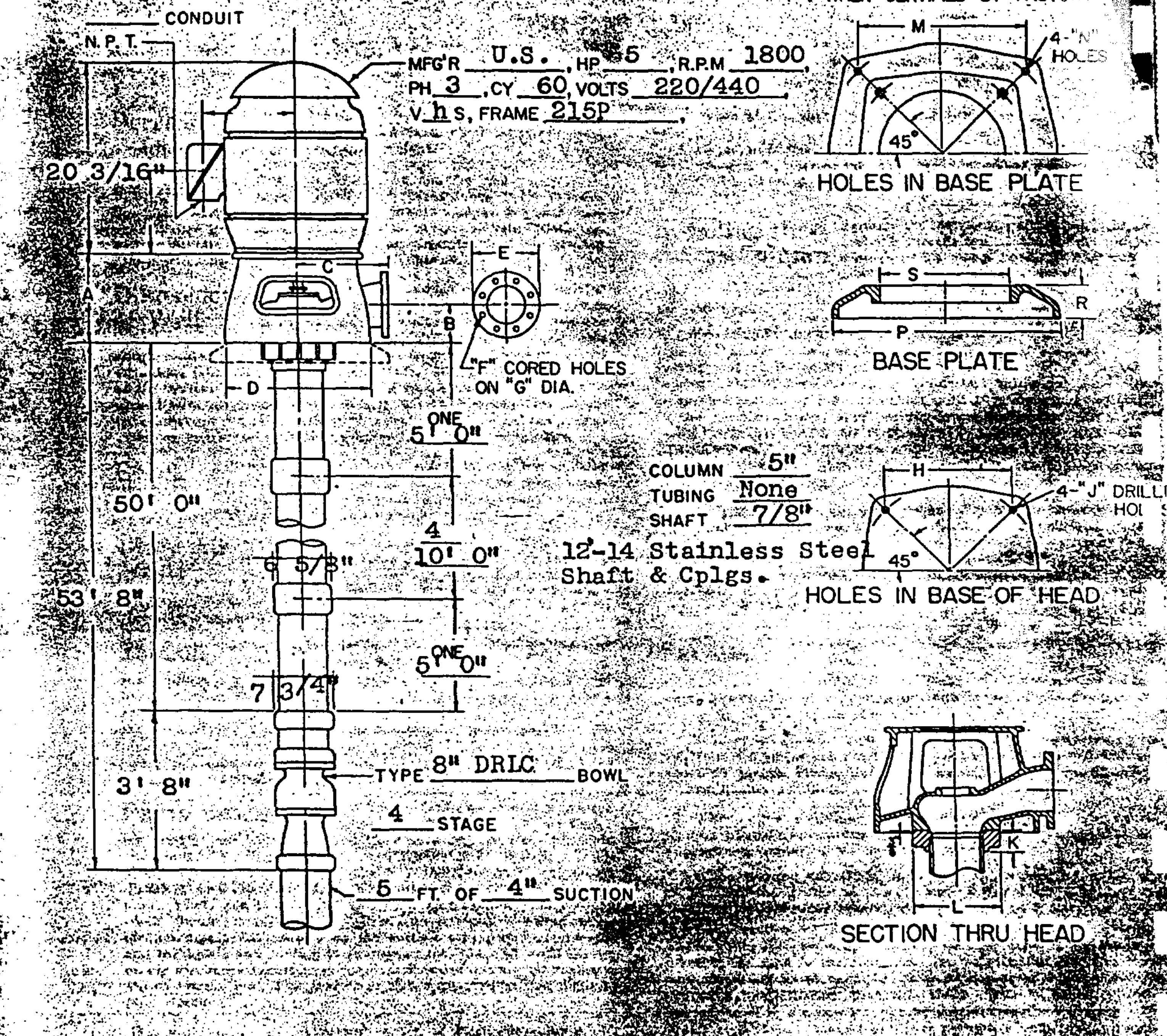
Ft.	In.	to	Ft.	In.	Formation
0			10		Fine to Med. Red Sand
10			30		Clayey Fine to Med. Red Sand
30			43		Slightly Clayey Fine to Med. Red Sand
43			44		White Clay
44			60		Fine to Coarse Sand & Fine Gravel - Some Med. Gravel, Tan, Loose
60			67		Fine to Coarse Sand & Gravel, Tan, Loose
67			70		Very Hard Sandy Red Shale

INSTALLATION PLAN

TYPE TF413 DISCHARGE HEAD

LAYNE & BOWLER INC. MEMPHIS, TENN.

USE THESE DIMENSIONS ONLY WHEN CERTIFIED BY FACTORY



Well No. 5

CUSTOMER: City Water Dept.
LOCATION: Altus, Oklahoma
FOR APPROVAL:
CERTIFIED: Tom Morrow

YOUR NO: W-10-701
OUR NO: 67D-3659
PUMP NO 57129
DATE: 6/13/67

G.P.M. 12
T.D.H. 92
R.P.M. 175
B.H.P.

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF413	13	6	11	18	9	8-3/4	7 1/2	14 1/2	11/16	2 13/16	10	16 13/16	7/8	21	12	17
TF613	14	6	11	18	11	8-3/4	9 1/2	14 1/2	11/16	2 7/8	11	16 13/16	7/8	21	12	17
TF418	13	6	14 1/2	23	9	8-3/4	7 1/2	17 [illegible]	[illegible]	2 13/16	10	20 [illegible]	[illegible]	26 1/2	2 [illegible]	21 [illegible]
TF618	15	6	14 1/2	23	11	8-3/4	9 1/2	17 [illegible]	[illegible]	2 7/8	12 1/2	20 [illegible]	[illegible]	26 1/2	2 [illegible]	21 [illegible]
TF818	18	7 [illegible]	14 1/2	23	13 1/2	8-3/4	11 [illegible]	17 [illegible]	1 [illegible]	3 [illegible]	13 1/2	20 [illegible]	[illegible]	26 1/2	2 [illegible]	21 [illegible]
TF1018	18	8 1/2	14 1/2	23	16	12-1	14 1/2	17 [illegible]	[illegible]	3 [illegible]	16	20 [illegible]	[illegible]	26 1/2	2 [illegible]	21 [illegible]
TF1218	20	9 [illegible]	16 1/2	26	19	12-1	17	19 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
TF625	13	8 1/2	18 1/2	31	11	8-3/4	9 1/2	23 [illegible]	[illegible]	2 7/8	12 1/2	29	1	36	[illegible]
TF825	20	8 1/2	18 1/2	31	13 1/2	8-3/4	11 1/2	23 [illegible]	[illegible]	3 [illegible]	13 1/2	29	1	38	[illegible]
TF1025	20	8 1/2	18 1/2	31	16	12-1	14 1/2	23 [illegible]	[illegible]	3 [illegible]	16	29	1	38	[illegible]
TF1225	21	9 [illegible]	18 1/2	31	19	12-1	17	23 [illegible]	[illegible]	3 [illegible]	19	29	1	38	[illegible]
TF1225	21	9 [illegible]	18 1/2	31	19	12-1	17	23 [illegible]	[illegible]	4 [illegible]	21	29	1	38	[illegible]
TF1425	21	10 [illegible]	18 1/2	31	21	12-1	18 1/2	23 [illegible]	[illegible]	4 [illegible]	21	29	1	38	[illegible]

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 4 at Test Hole No. 4-65
4. Well Location (attach map)
Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-29-67
7. Date Started
Completed
8. Drill Crew Man Hrs.
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25	12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	7 Openings
Inner Casing	49	12		.330	steel	~~Welded~~ Screwed	Spacing #7 @ 47-72
Outer Casing	12	34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
Size 4 x 8 8 x 16
Tons 12 14

12. SEALING CASING
Puddled Clay (Yes) (No)
With .... Bags Bentonite Added
or
With 1½ yds. ~~Bags~~ Cement
Seal Material Placed in Well With tremie pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 74'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments reverse rotary

14. PUMPING TEST

A.

Test pump 8 in RK Bowl 5 Stages

Permanent pump

Length of column 50 Ft.

Length of Bowl 4± Ft.

Length of suction 5 Ft.

B. Measured water level 24.10 Ft. from top of 12 In. dia. casing which is 2 Ft. above ground.

C. Length of airline ______ Ft. from top of casing.

ORIFICE

3 x 4

x

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
8:00		0		24.10	0
9:00		210		38.44	14.34
10:00		210		38.55	14.45
11:00		205		38.60	14.50
12:00		205		38.55	14.45
1:00		205		38.45	14.35
2:00		203		38.40	14.30
3:00		245		41.10	17.00
4:00		205		39.10	15.00

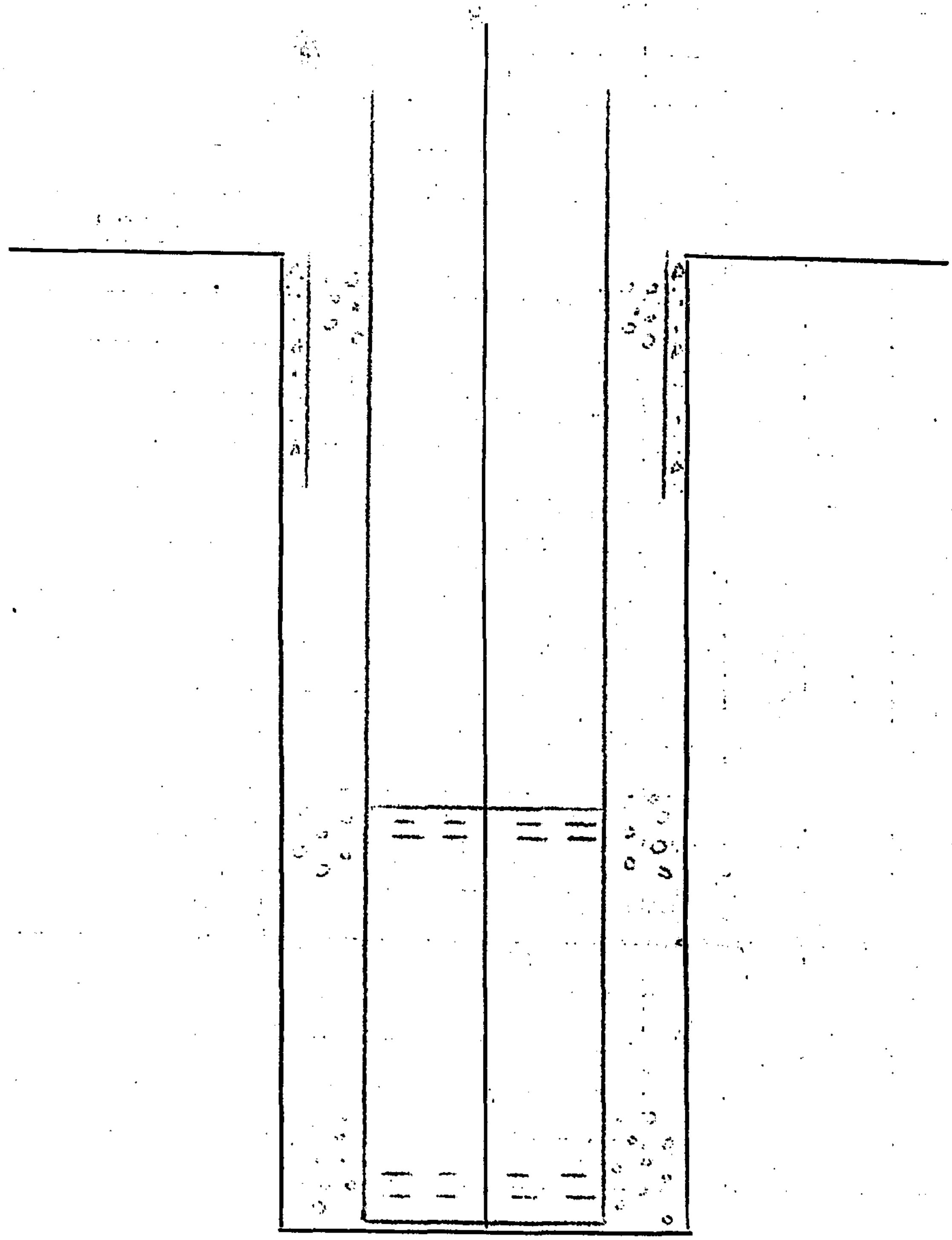
15. Permanent Layne Pump No. ______ installed by ______

Layne

Permanent air line length ______ Ft. Date ______

Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			10		Fine to Med. Red Sand
10			19		Clayey Fine to Med. Red Sand
19			42		Fine to Coarse Red Sand
42			48		Clayey Fine to Coarse Sand
48			55		Fine to Coarse Sand & Trace of Fine Gravel, Tan, Lo
55			65		Fine to Coarse Sand & Some Fine Gravel, Tan, Loose
65			72		Fine to Coarse Sand & Fine Gravel, Tan, Loose
72			77		Red Shale

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
   W-10
2. City, State Altus, Oklahoma
3. Well No. 5 at Test Hole No. 5-65
4. Well Location (attach map)
   Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-29-67
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25		12	7	.188	18-8 Stainless	Layne / Shutter ~~Keystone~~	7 / Openings #7 @ 35-80
Inner Casing	57		12		.330	steel	~~Welded~~ Screwed	
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8x16

Tons 14 14

12. SEALING CASING

Puddled Clay (~~Yes~~) (No)

With .... Bags Bentonite Added

or

With 1½ Yds. ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 82'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump

Permanent pump ..8.. in ..RK.. Bowl ..5.. Stages

Length of column ..50.. Ft.

Length of Bowl ..4±.. Ft.

Length of suction ..5.. Ft.

B. Measured water level ..22.50.. Ft. from top of ..12.. In. dia. casing which is ..2.. Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

..3.. x ..4..

.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
7:00		0		22.50	0
8:00		210		49.42	26.92
9:00		210		49.80	27.30
10:00		205		49.42	26.92
11:00		205		48.95	26.45
12:00		210		50.10	27.60
1:00		210		50.40	27.90
2:00		210		50.38	27.88
3:00		207		49.90	27.40

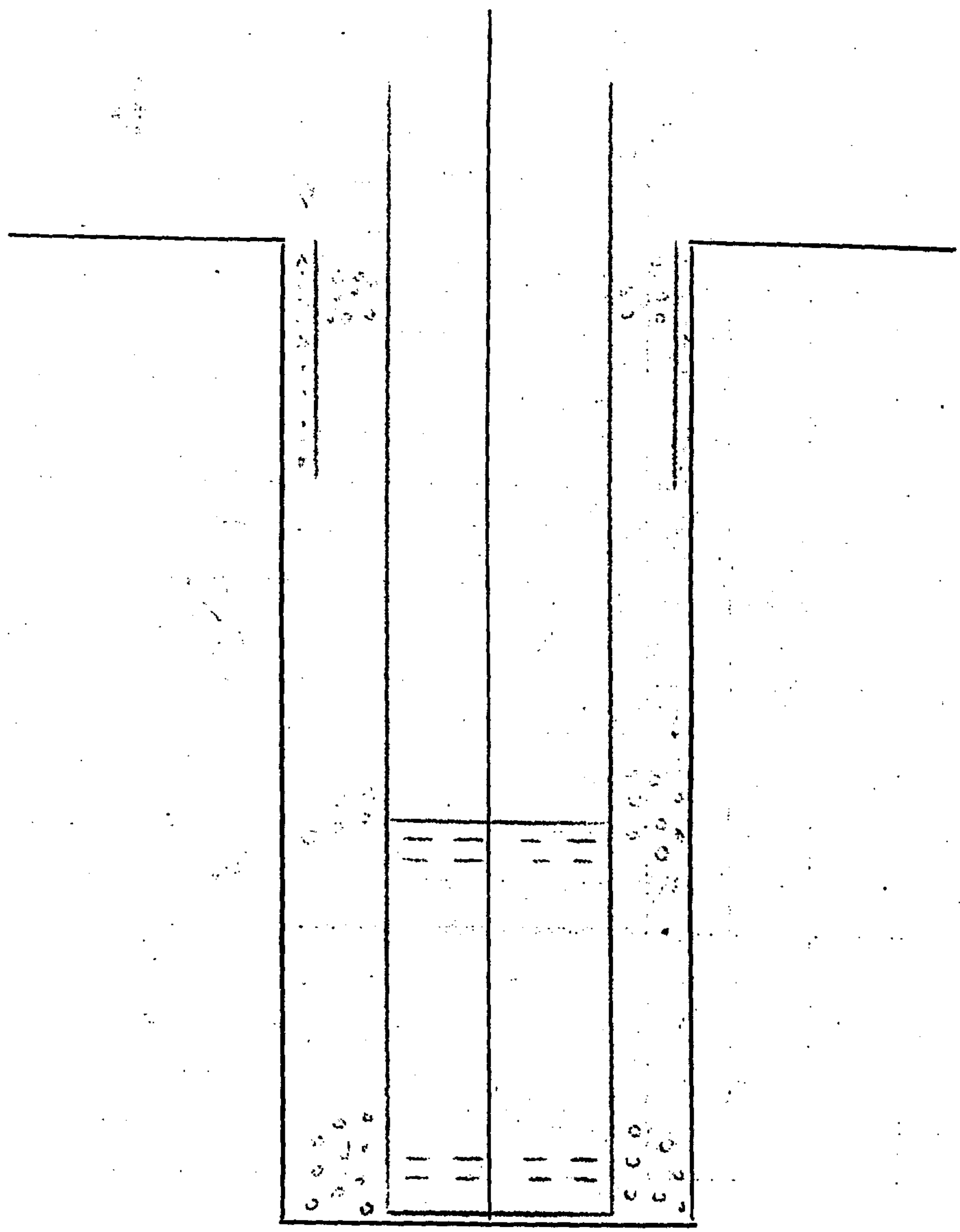
15. Permanent ..Layne.. Pump No. .... installed by ....

Layne

Permanent air line length .... Ft. Date ....

Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			6		Fine to Med. Sand
6			18		Fine to Med. Clayey Tan Sand
18			32		Fine to Coarse Slightly Clayey Tan Sand
32			56		Tan Sandy Clay
56			65		Fine to Coarse Tan Sand, Loose
65			75		Fine to Coarse Sand & Some Fine Gravel, Tan, Loose
75			80		Fine to Coarse Sand & Fine Gravel - Some Med. & Coarse Gravel, Tan, Loose
80			83		Very Hard Red Shale

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 6 at Test Hole No. 6-65
4. Well Location (attach map) Round Timber
Ranch, Texas

5. Driller Hoellering
6. DATE 4-29-67
7. Date Started
Completed
8. Drill Crew Man Hrs
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	30		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	20 @ 6 10 @ 7 Openings
Inner Casing	60		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 68-88 #7 @ 58-68
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
Size 4 x 8 8 x 16
Tons 24 8

12. SEALING CASING
Puddled Clay (~~Yes~~) (No)
With .... Bags Bentonite Added
or
With 1½ yds ~~Bags~~ Cement
Seal Material Placed in Well With tremie pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 90'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments reverse rotary

14. PUMPING TEST

A.

Test pump

Permanent pump ......8......in......RK......Bowl......5......Stages

Length of column ......60......Ft.

Length of Bowl ......4±......Ft.

Length of suction ......5......Ft.

B. Measured water level ...26.30... Ft. from top of ...12... In. dia. casing which is ...2... Ft. above ground.

C. Length of airline ....Ft. from top of casing.

ORIFICE

......3......x......4......

............x............

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
11:00		0		26.30	0
12:00		205		53.48	27.18
1:00		205		53.27	26.97
2:00		207		54.15	27.85
3:00		205		53.50	27.20
4:00		205		53.45	27.15
5:00		205		53.68	27.38
6:00		205		53.88	27.58
7:00		205		53.90	27.60

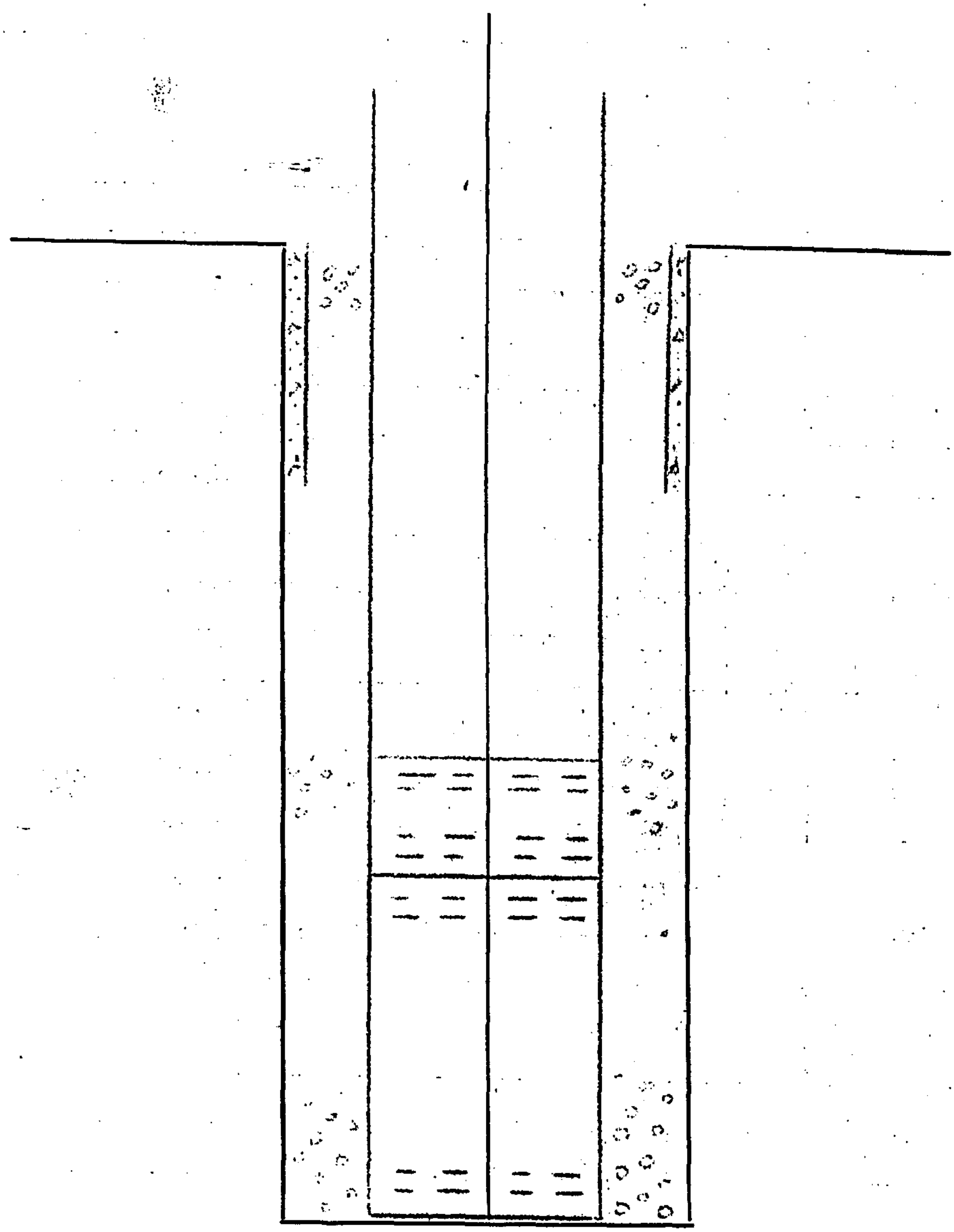
15. Permanent ......Layne...... Pump No. .... installed by ....

Layne

Permanent air line length ....Ft. Date............

Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			10		Fine to Med. Sand
10			20		Clayey Fine to Med. Sand, Gray
20			37		Fine to Med. Sand, Tan
37			57		Sandy Gray Clay
57			60		Fine to Med. Coarse Tan Sand
60			67		Fine to Coarse Tan Sand
67			68		Red Clay
68			73		Fine to Coarse Sand & Fine to Med. Gravel, Tan, Lo
73			74		Red Clay
74			80		Fine to Coarse Sand & Fine to Med. Gravel, Tan, Lo
80			88		Fine to Coarse Sand & Fine to Coarse Gravel, Tan, Loose
88			90		Red Shale

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus W-10	5. Driller Hoellering
2. City, State Altus, Oklahoma	6. DATE 4-29-67
	7. Date Started Completed
3. Well No. 7 at Test Hole No. 7-65	8. Drill Crew Man Hrs.
4. Well Location (attach map) Round Timber Ranch, Texas	9. Working Days Drilling Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	15@ 6 10 @ 7 Openings
Inner Casing	49		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 57--82 #7 @ 47-57
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8 x 16

Tons 23 6

12. SEALING CASING

Puddled Clay (~~Yes~~) (No)

With .... Bags Bentonite Added

or

With 1½ Yds. ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 74'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump

Permanent pump ....8.... in ....RK.... Bowl ....5.... Stages

Length of column ....50.... Ft.

Length of Bowl ....4±.... Ft.

Length of suction ....5.... Ft.

B. Measured water level ....26.30.... Ft. from top of ....12.... In. dia. casing which is ....2.... Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

....3.... x ....4....

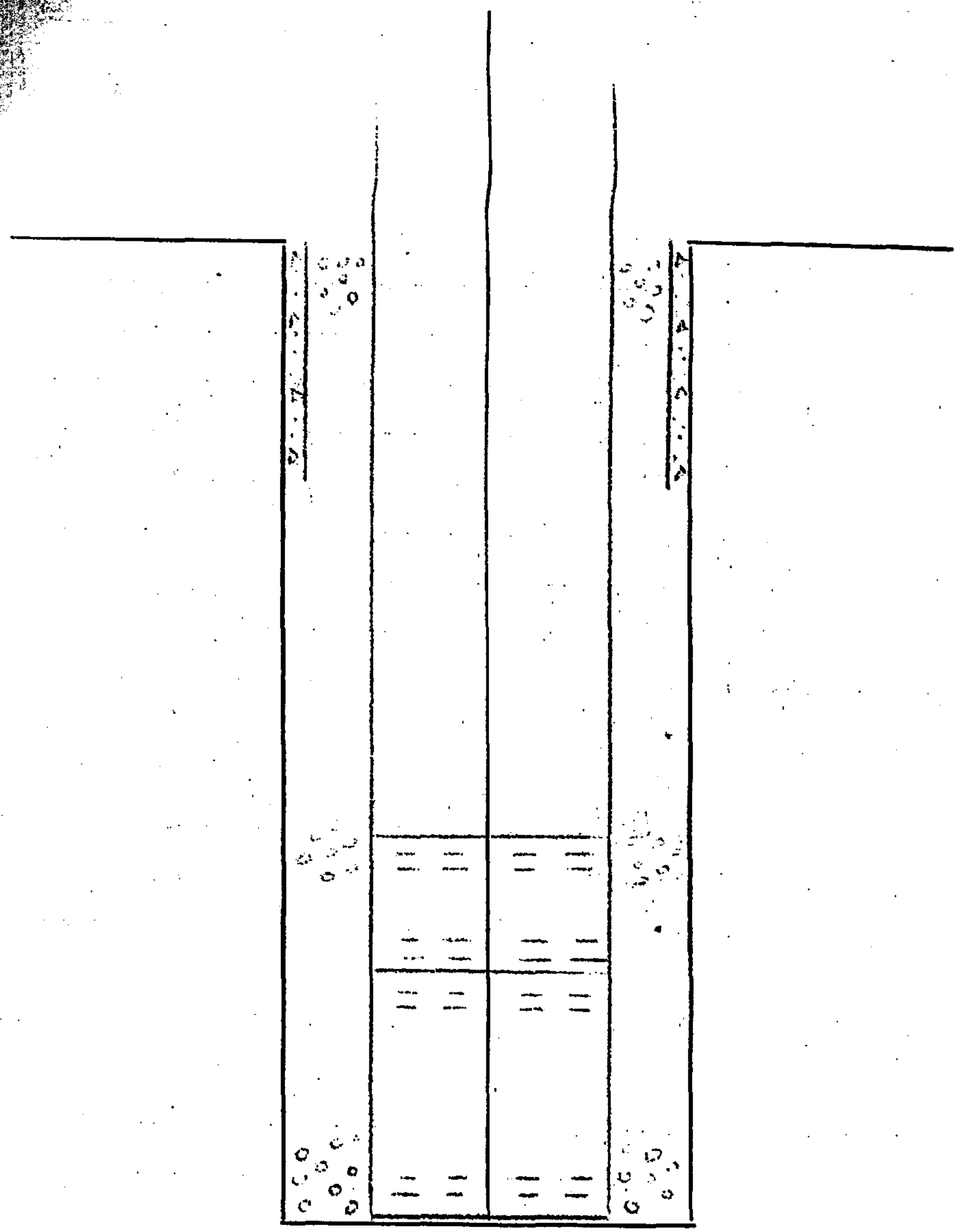
.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
1:00		0		26.30	0
2:00		205		34.40	8.10
3:00		205		34.40	8.10
4:00		205		34.38	8.08
5:00		205		34.40	8.10
6:00		205		34.42	8.12
7:00		205		34.42	8.12
8:00		205		34.40	8.10
9:00		205		34.43	8.13

15. Permanent ....Layne.... Pump No. .... installed by ....
Layne

Permanent air line length .... Ft. Date ....
Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			20		Sandy Clay
20			42		Fine to Coarse Sand & Gravel
42			43		Clay
43			72		Fine to Coarse Sand & Gravel

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
   W-10
2. City, State Altus, Oklahoma
3. Well No. 8 at Test Hole No. 8-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-29-67
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	25	12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	10 @ 6 15 @ 7 Openings
Inner Casing	57	12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 70-80 #7 @ 55-70
Outer Casing	12	34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
    Size 4 x 8   8 x 16
    Tons 24   7

12. SEALING CASING
    Puddled Clay (~~Yes~~) (No)
    With .... Bags Bentonite Added
    or
    With 1¼ Yds. ~~Bags~~ Cement
    Seal Material Placed in Well With tremie pipe
    Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
    A. Total Depth 82'
    (From Top of Inner Casing to Bottom of Well)
    B. Height of Inner Casing 2'
    (Above Ground Level)
    C. Distance to Top of Gravel 1'
    (From Ground Level)
    D. Diameter of Drill Hole 36"

    Comments reverse rotary

14. PUMPING TEST

A.

Test pump

8 in. RK Bowl 5 Stages

Permanent pump

Length of column 60 Ft.

Length of Bowl 4± Ft.

Length of suction 5 Ft.

B. Measured water level 31.35 Ft. from top of 12 In. dia. casing which is 2 Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

3 x 4

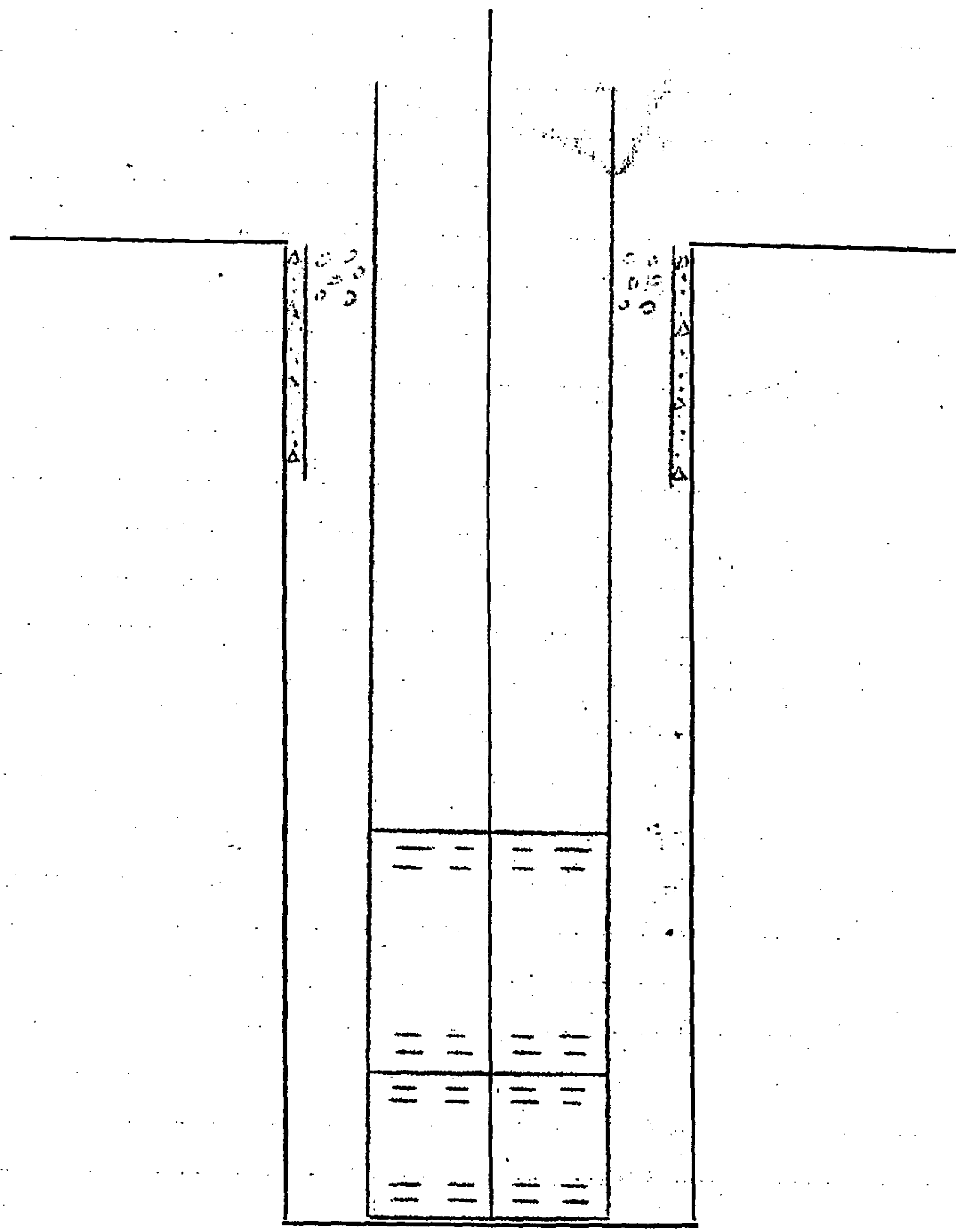
x

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
7:00		0		31.35	0
8:00		205		48.83	17.48
9:00		207		48.43	17.08
10:00		207		48.62	17.27
11:00		207		48.83	17.48
12:00		203		48.69	17.34
1:00		205		48.75	17.40
2:00		205		48.70	17.35
3:00		201		48.50	17.15

15. Permanent Layne Pump No. .... installed by ....
Layne

Permanent air line length .... Ft. Date ....
Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			6		Loose Sand
6			35		Sandy Clay
35			56		Fine to Med. Sand & Gravel
56			65		Fine to Coarse Sand & Gravel
65			80		Fine to Coarse Sand & Gravel with cemented streaks (not very hard)

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 9 at Test Hole No. 9-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-9-67
7. Date Started
Completed
8. Drill Crew Man Hrs.
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	25	12	7	.188	18-8 Stainless	Layne / Shutter, ~~Keystone~~	6 / Openings Spacing #6 @ 50-75
Inner Casing	51	12		.330	steel	~~Welded~~ Screwed	
Outer Casing	12	34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
Size 4 x 8
Tons 32

12. SEALING CASING
Puddled Clay (~~Yes~~) (No)
With .... Bags Bentonite Added
or
With 1½ ~~Bags~~ yds Cement
Seal Material Placed in Well With Tremie pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 76'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump 8 in RK Bowl 5 Stages

Permanent pump

Length of column 60 Ft.

Length of Bowl 4½ Ft.

Length of suction 5 Ft.

B. Measured water level 36.50 Ft. from top of 12 In. dia. casing which is 2 Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

3 x 4

x

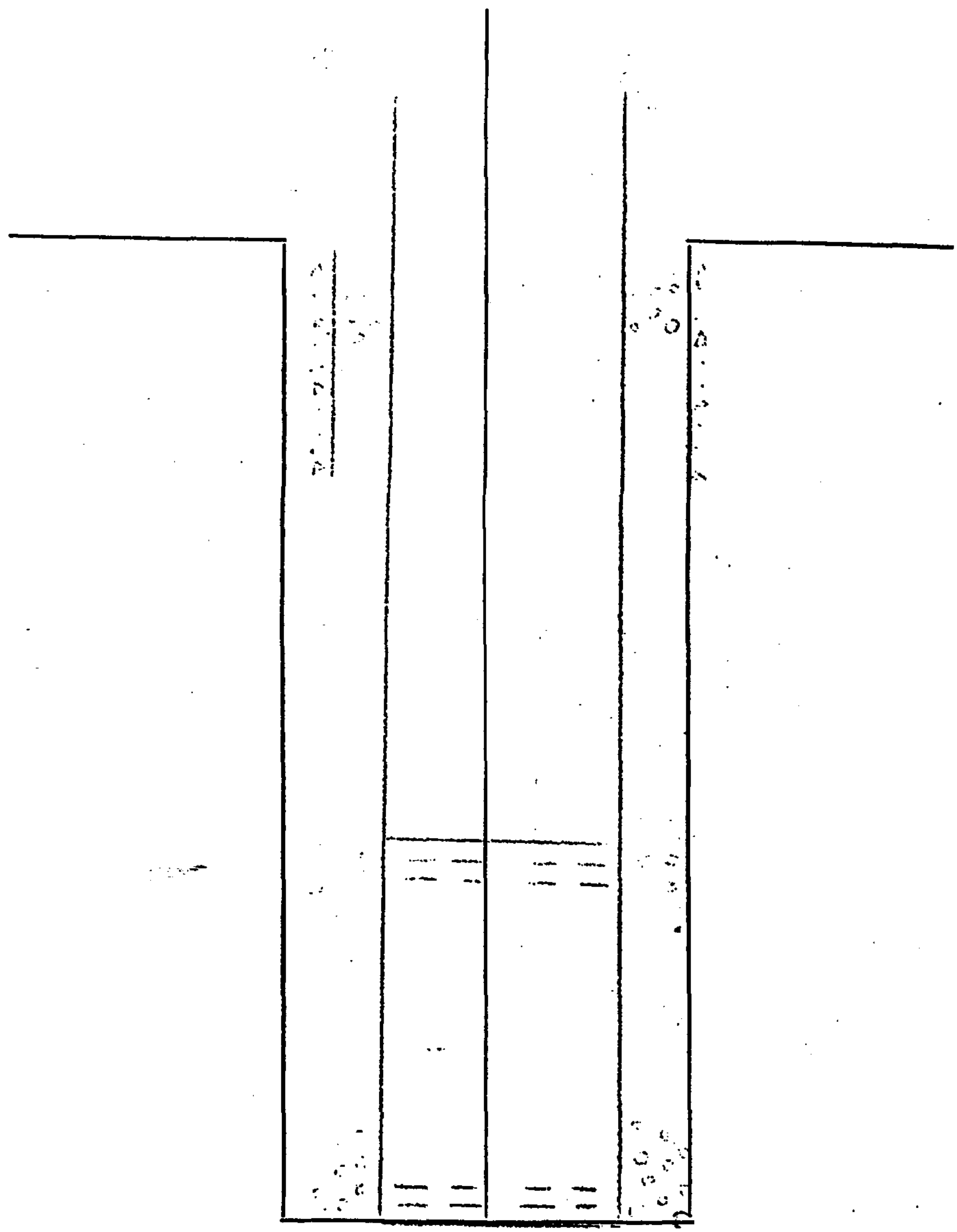
TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
10:00		0		36.50	0
11:00		201		53.08	16.58
12:00		203		45.79	19.29
1:00		203		55.95	19.45
2:00		203		56.22	19.72
3:00		203		56.62	20.12
4:00		203		56.79	20.29
5:00		203		57.05	20.55
6:00		203		57.65	21.15

15. Permanent Layne Pump No. .... installed by .... Layne

Permanent air line length .... Ft. Date ....

Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			7		Loose Fine Sand
7			37		Fine to Coarse Sand & Gravel
37			50		Fine to Coarse Sand & Gravel with Clay Lenses
50			52		Cemented Sand & Gravel
52			63		Fine to Med. Sand & Gravel
63			65		Cemented Sand
65			72		Med. to Coarse Sand & Gravel
72			76		Cemented Sand & Gravel, Very Coarse Gravel, Hard

Well #10

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 10 at Test Hole No. 10-65
4. Well Location (attach map) Round Timber Ranch
Texas

5. Driller Hoellering
6. DATE 4-9-67
7. Date Started
Completed
8. Drill Crew Man Hrs
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	20		12	7	.188	18-8 stainless	Layne Shutter ~~Keystone~~	7 Openings
Inner Casing	59		12		.330	steel	~~Welded~~ Screwed	Spacing #7 @ 57-'
Outer Casing	12		34		.281	steel	Welded ~~Seamed~~	

11. GRAVEL
Size 4 x 8 8 x 16
Tons 20 10

12. SEALING CASING
Puddled Clay (~~Yes~~) (No)
With .... Bags Bentonite Added
or
With 1½ Yds. ~~xxx~~ Bags Cement
Seal Material Placed in Well With tremie Pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 79'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments reverse rotary

14. PUMPING TEST

A.

Test pump

Permanent pump 8 ....in RK ....Bowl 5 ....Stages

Length of column 60 ....Ft.

Length of Bowl 4± ....Ft.

Length of suction 5 ....Ft.

B. Measured water level 39.13 .... Ft. from top of 12 ....In. dia. casing which is 2 .... Ft. above ground.

C. Length of airline ....Ft. from top of casing.

ORIFICE

3 x 4

x

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
		0			0
7:00				39.13	
8:00		205		56.68	17.55
9:00		207		56.93	17.80
10:00		207		56.83	17.70
11:00		207		57.86	18.73
12:00		207		57.53	18.40
1:00		207		57.35	18.22
2:00		205		57.33	18.20
3:00		205		57.53	18.40

15. Permanent Layne .... Pump No. .... installed by ....

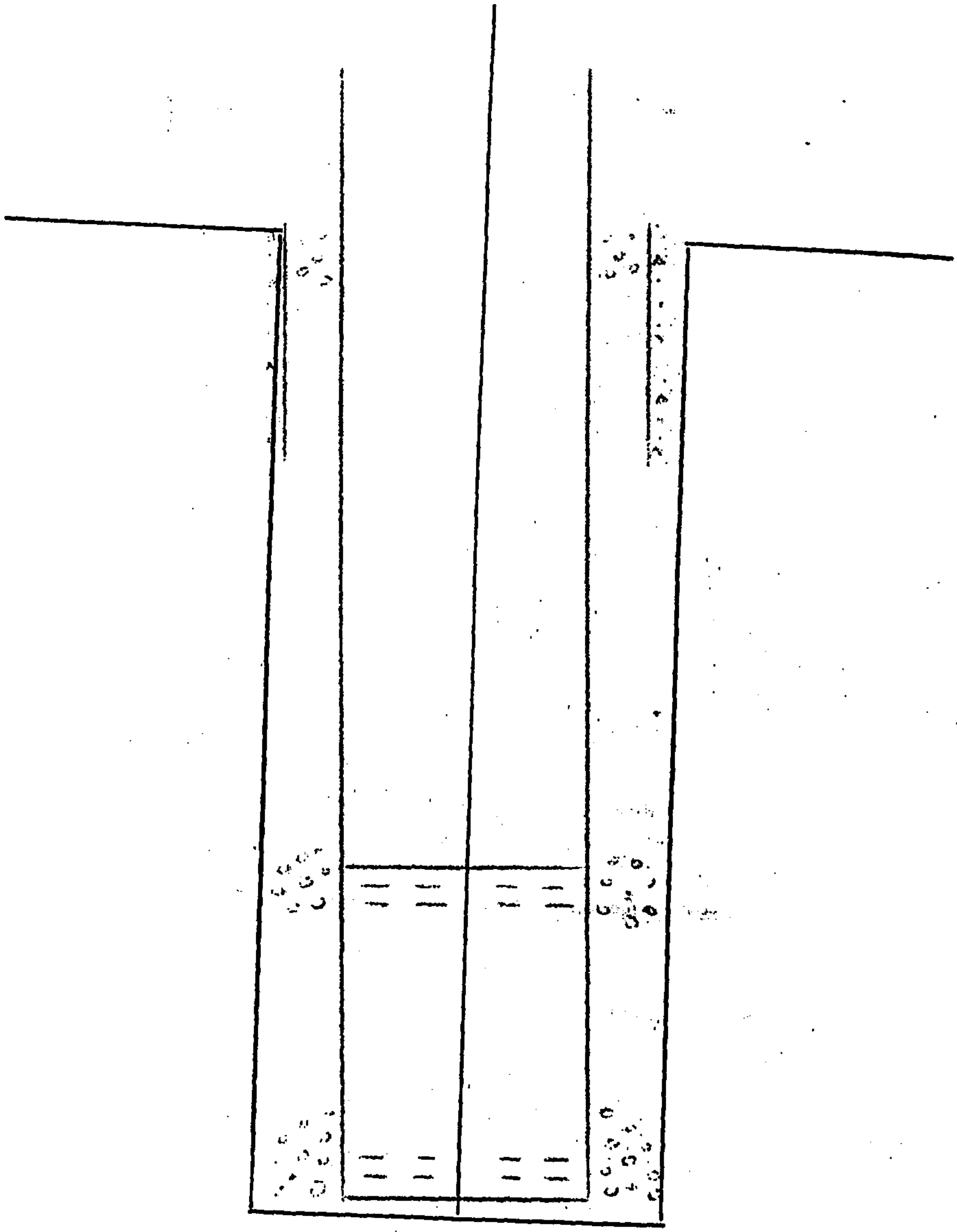
Permanent air line length ....Ft. Date............

Month Day Year

LOG OF WELL

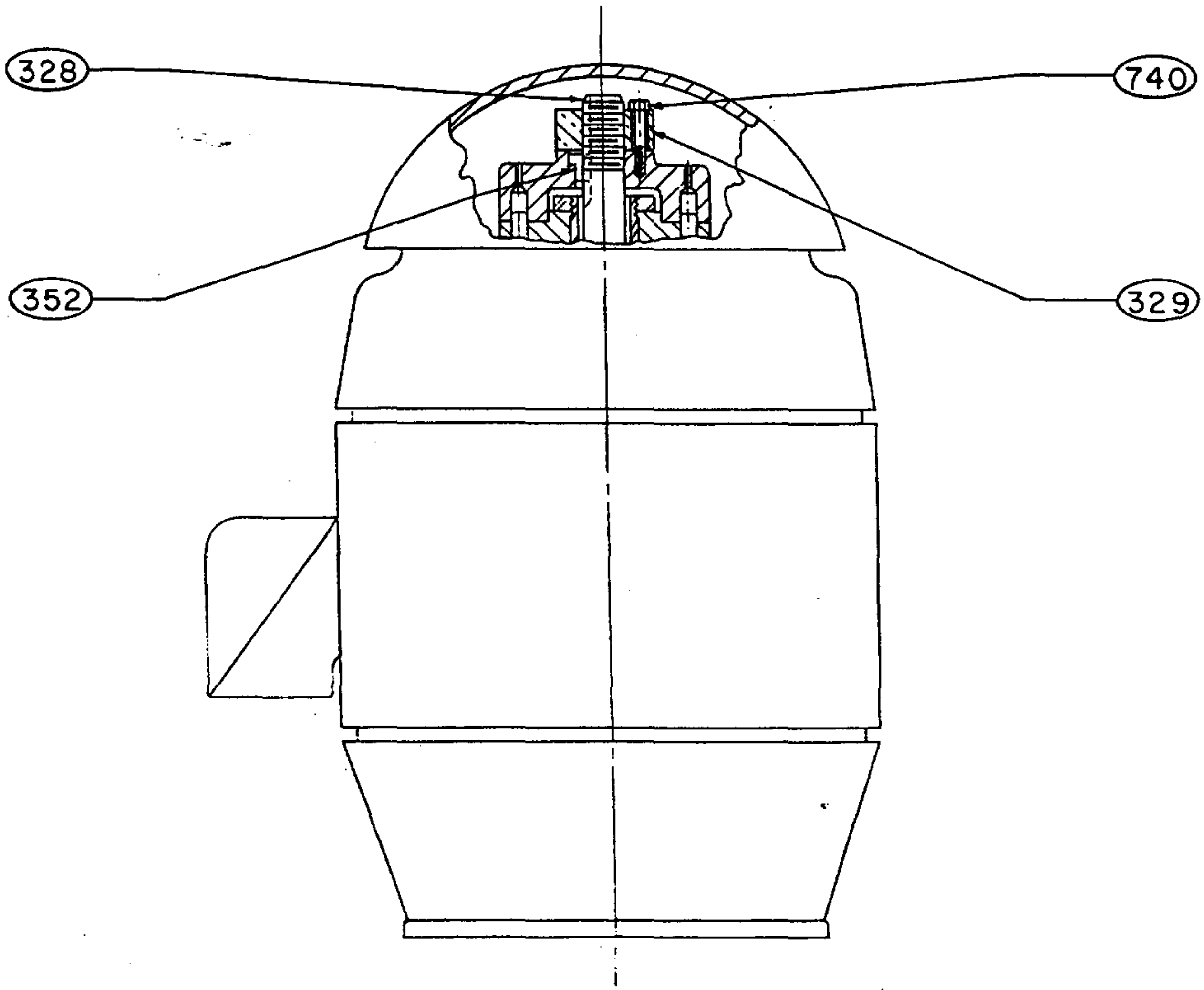
Ft.	In.	to	Ft.	In.	Formation
0			8		Loose Fine Sand
8			20		Sandy Clay
20			60		Fine to Med. Coarse Sand Fine Gravel
60			62		Gray Clay
62			70		Cemented Sand & Gravel
70			77		Fine to Coarse Sand & Gravel

CONSTRUCTION OF WELL



ADJUSTING NUT ASSEMBLY
VERTICAL HOLLOW SHAFT MOTOR

LAYNE & BOWLER INC MEMPHIS TENNESSEE.



PART NO.		DESCRIPTION
3 2 8	7/8"	MOTOR DRIVE SHAFT
3 2 9	AN875	ADJUSTING NUT
3 5 2	F272	GIB. HEAD KEY (CLUTCH)
7 4 0	10-32-1¼"	MACHINE SCREW (ADJUSTING NUT)

IN ORDERING REPLACEMENT PARTS, ALWAYS SPECIFY PARTS NO, DESCRIPTION, MOTOR SIZE, TYPE, & PUMP SERIAL NO.

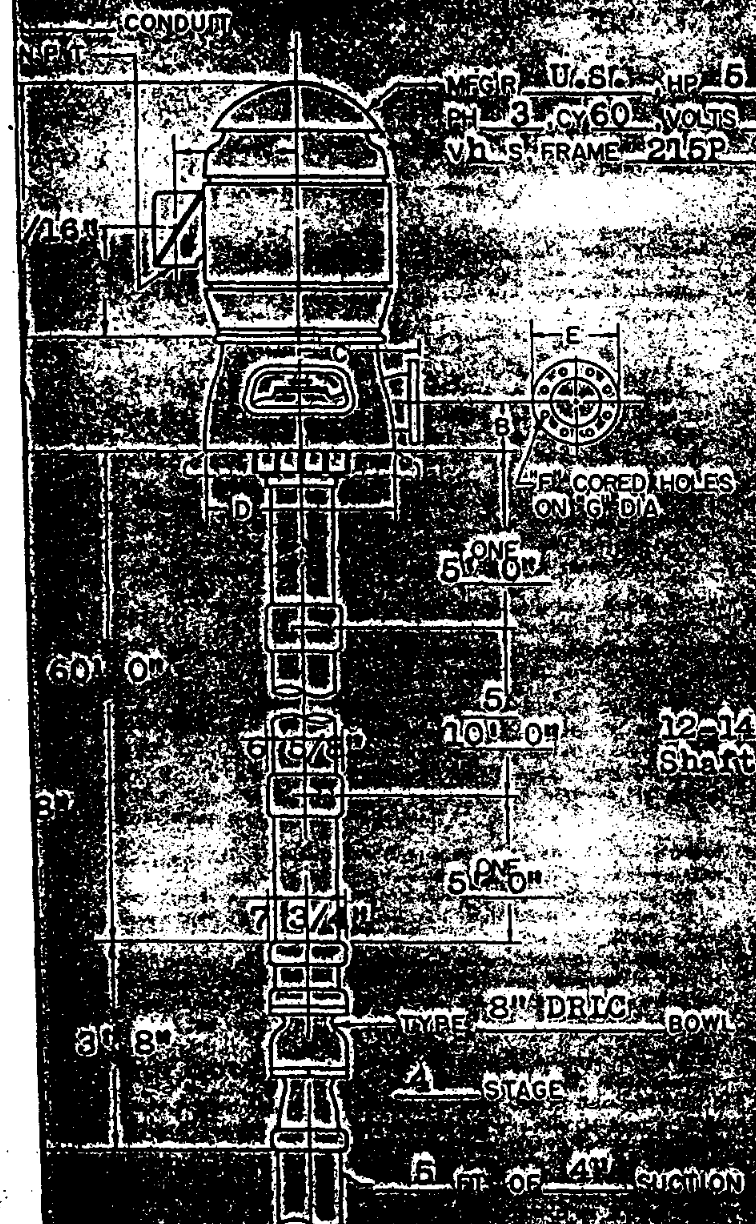
MOTOR MFG. U.S. H.P. 5 R.P.M. 1800

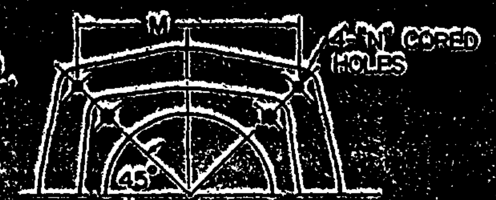
VOLTS 220/440 PHASE 3 CY. 60 FRAME 215 P.

INSTALLATION PLAN
TYPE TF413 DISCHARGE HEAD

LAYNE & BOWLER INC. MEMPHIS, TENN.

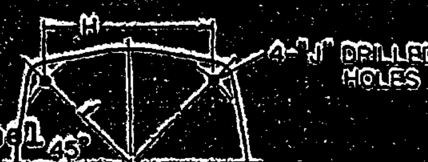
USE THESE DIMENSIONS ONLY WHEN CERTIFIED BY FACTORY



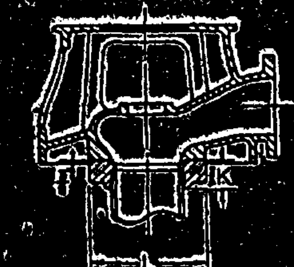


HOLES IN BASE PLATE

BASE PLATE



HOLES IN BASE OF HEAD



SECTION THRU HEAD

Well No. 10

OWNER City Water Dept.		YOUR NO W-10-706	GPM 125
LOCATION Altus, Oklahoma		OUR NO 670-[illegible]	TDH 102
APPROVAL		PUMP NO 57/134	RPM 1750
CERTIFIED Tom Morrow		DATE 6/14/67	BHP

A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
[illegible]	8	11	18	9	6½	7	14	[illegible]	2¼	10	16	[illegible]	21	2	17
[illegible]	6	11	18	11	6½	[illegible]	14	[illegible]	2¼	11	16	[illegible]	21	2	17
[illegible]	6	14½	23	9	6½	[illegible]	17	[illegible]	2¼	10	20	[illegible]	26	2½	21
[illegible]	6	14½	23	11	8½	[illegible]	17	[illegible]	2¼	12	20	[illegible]	26	2½	21
[illegible]	7½	14½	23	13½	8½	[illegible]	17	[illegible]	[illegible]	13½	20	[illegible]	26	2½	21
[illegible]	8½	14½	23	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF625	[illegible]	[illegible]	[illegible]	31	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	[illegible]	38	[illegible]	29
TF825	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	1	38	[illegible]	29
TF1025	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16	29	1	38	[illegible]	[illegible]
TF225	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	29	1	38	[illegible]	29
TF225	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	1	38	[illegible]	29

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 11 at Test Hole No. 11-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-2-67
7. Date Started
Completed
8. Drill Crew Man Hrs.
9. Working Days
Drilling
Other

10. MATERIAL IN WELL	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25		12	7	.188	18-8 Stainless	Layne Shutter ~~Keystone~~	7 Openings Spacing #7 @ 52-77
Inner Casing	54		12		.330	steel	~~Welded~~ Screwed	
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
Size 4 x 8 8 x 16
Tons 16 16

12. SEALING CASING
Puddled Clay ~~(Yes)~~ (No)
With .... Bags Bentonite Added
or
With 1¼ Yds ~~Bags~~ Cement
Seal Material Placed in Well With tremie pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 79'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments reverse rotary

14. PUMPING TEST

A.

Test pump

Permanent pump

8 in RK Bowl 5 Stages

Length of column 60 Ft.

Length of Bowl 4± Ft.

Length of suction 5 Ft.

B. Measured water level 34.70 Ft. from top of 12 In. dia. casing which is 2 Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

3 x 4

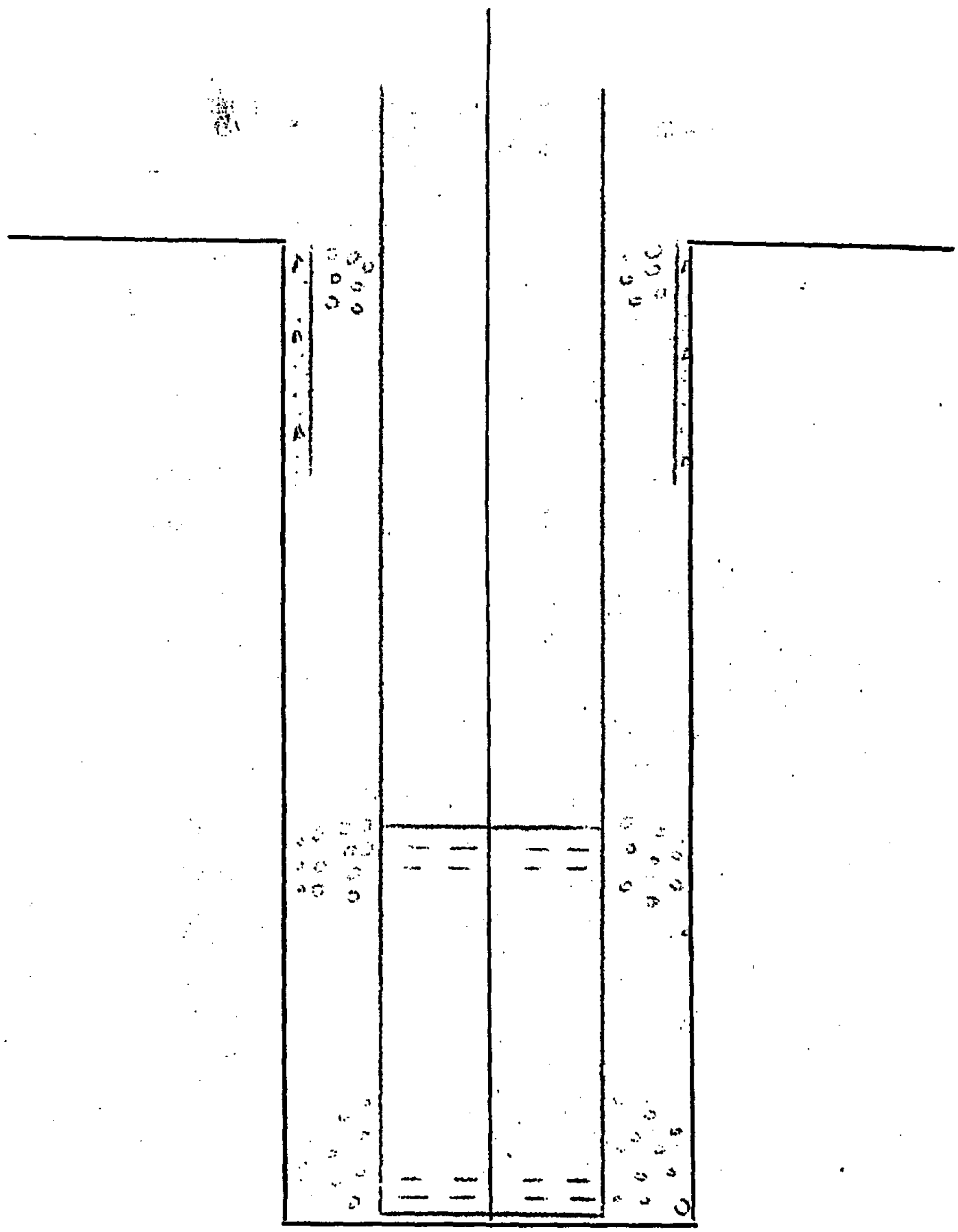
.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
3:30		0		34.70	0
4:30		205		47.80	13.10
5:30		205		48.08	13.38
6:30		205		48.16	13.46
7:30		205		48.20	13.50
8:30	--	205		48.23	13.53
9:30		205		48.30	13.60
10:30		205		48.27	13.57
11:30		205		48.33	13.63

15. Permanent Layne (Layne) Pump No. .... installed by ....

Permanent air line length .... Ft. Date .... Month Day Year

CONSTRUCTION OF WELL



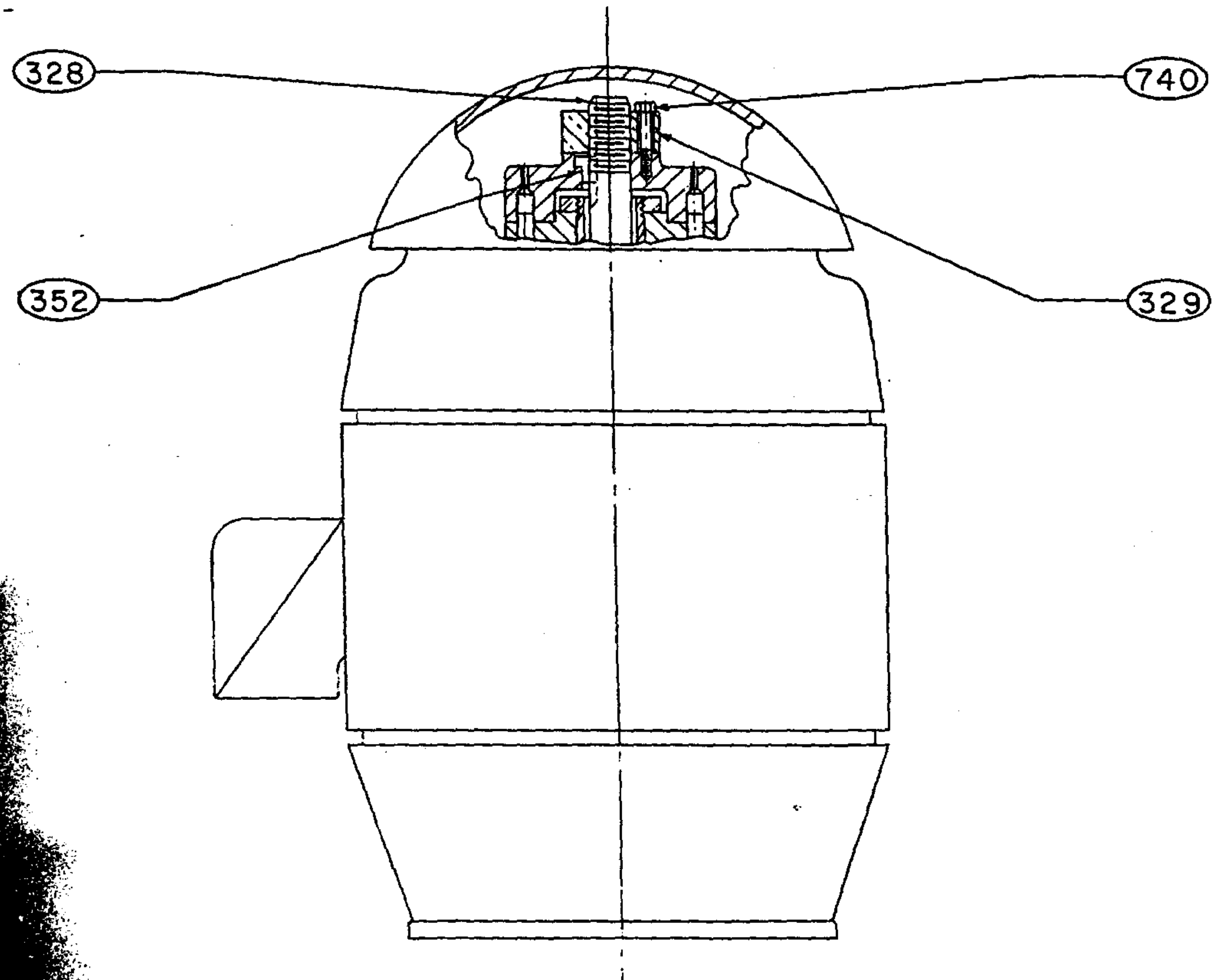
LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			7		Fine Sand
7			12		Fine Sand with Clay
12			35		Fine to Med. Sand
35			37		Sandy Clay
37			45		Fine to Coarse Sand & Gravel
45			46		Clay
46			54		Fine to Coarse Sand & Gravel
54			56		Cemented Sand & Gravel, Hard
56			77		Fine to Coarse Sand & Gravel with some cemented gravel spots.

ADJUSTING NUT ASSEMBLY
VERTICAL HOLLOW SHAFT MOTOR

Layne

LAYNE & BOWLER INC MEMPHIS TENNESSEE.



PART NO.		DESCRIPTION
328	7/8"	MOTOR DRIVE SHAFT
329	AN875	ADJUSTING NUT
352	F272	GIB. HEAD KEY (CLUTCH)
740	10-32-1¼"	MACHINE SCREW (ADJUSTING NUT)

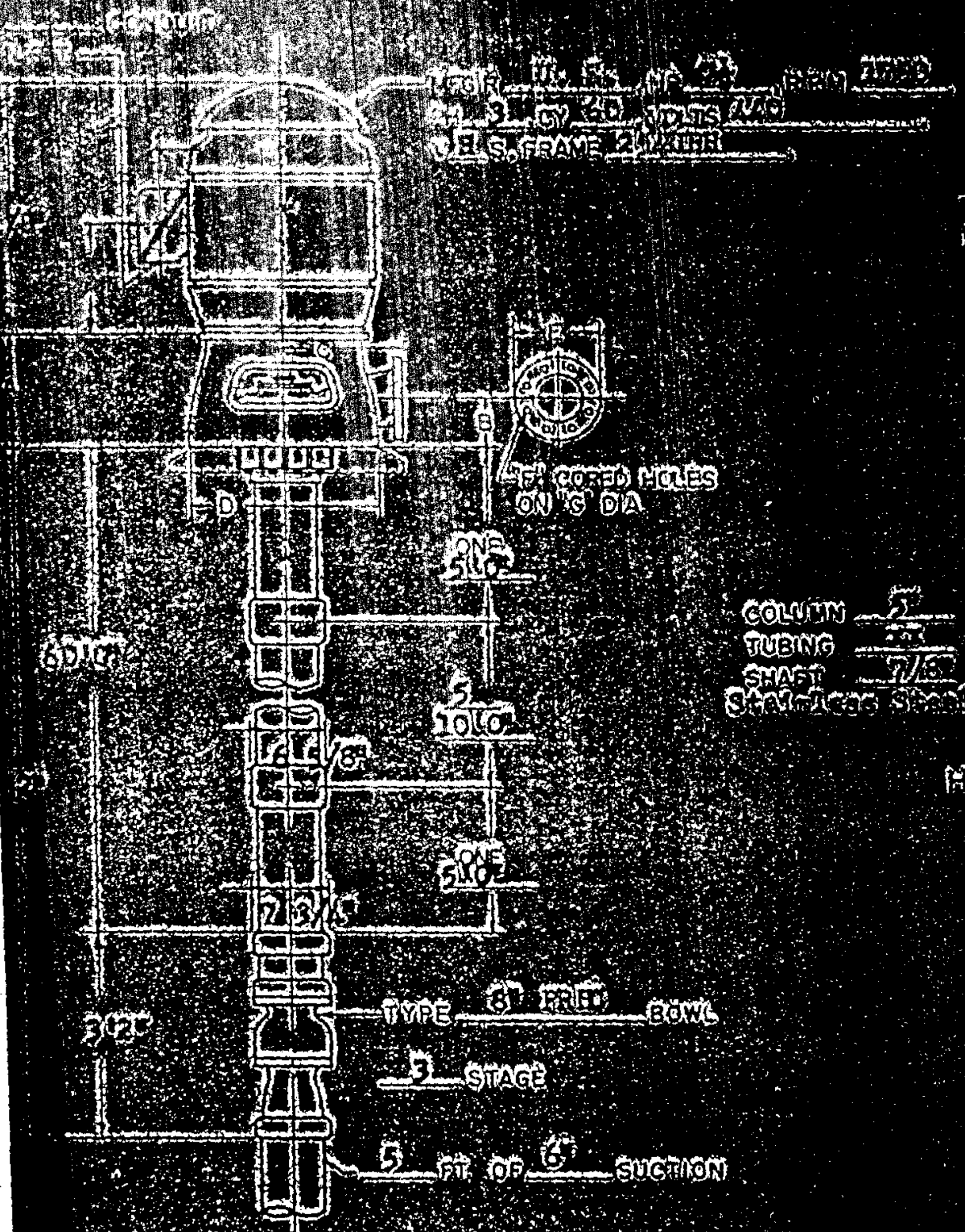
IN ORDERING REPLACEMENT PARTS, ALWAYS SPECIFY PARTS NO, DESCRIPTION, MOTOR SIZE, TYPE, & PUMP SERIAL NO.

MOTOR MFG. U.S. H.P. 7½ R.P.M. 1250

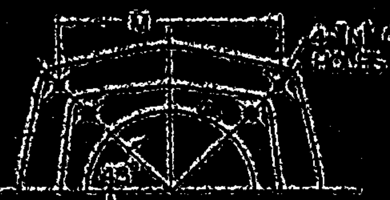
VOLTS 440 PHASE 3 CY. 60 FRAME 254UPH

INSTALLATION PLAN
TYPE [illegible] DISCHARGE HEAD

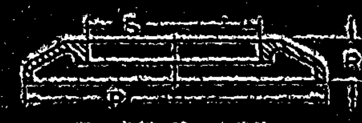
LAYNE & BOWLER INC. MEMPHIS, TENN.



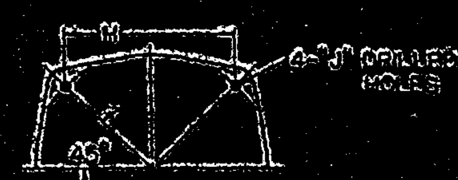
USE THESE DIMENSIONS ONLY WHEN CERTIFIED BY FACTORY



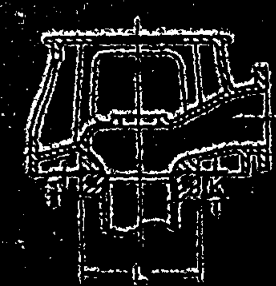
HOLES IN BASE PLATE



BASE PLATE



HOLES IN BASE OF HEAD



SECTION THRU HEAD

[illegible]MER [illegible]	YOUR NO [illegible]	GPM [illegible]
[illegible]ON [illegible]	OUR NO. [illegible]	TDH 23
[illegible] APPROVAL [illegible]	PUMP NO [illegible]	RPM [illegible]
[illegible]FIED [signature]	DATE [illegible]	BHP

[illegible]	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
[illegible]	6	11	18	9	8½	7½	4½	1½	2½	10	8	1½	21	2	17
[illegible]	6	11	18	12	8½	6½	6½	1½	2½	10	8	1½	21	2	17
[illegible]	6	14	23	9	8½	12	7½	1½	2½	10	20	1½	26	2½	21
[illegible]	6	[illegible]	23	11	8½	[illegible]	[illegible]	1½	2½	[illegible]	20	1½	26	2½	21
[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	1½	[illegible]	[illegible]	20	1½	26	2½	21
[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	1½	[illegible]	[illegible]	20	1½	26	2½	21

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TR625	15	[illegible]	[illegible]	31	11	8	[illegible]	[illegible]	1½	2½	[illegible]	29	1	[illegible]	[illegible]	29
TR825	20	[illegible]	[illegible]	31	[illegible]	[illegible]	[illegible]	[illegible]	1½	[illegible]	[illegible]	29	1	[illegible]	[illegible]	29
TR1025	20	[illegible]	[illegible]	31	[illegible]	21	[illegible]	[illegible]	1½	[illegible]	16	29	1	[illegible]	[illegible]	29
TR1225	21	[illegible]	[illegible]	31	[illegible]	21	17	[illegible]	1½	[illegible]	19	29	1	[illegible]	[illegible]	29
TR1225	21	[illegible]	[illegible]	31	[illegible]	21	17	[illegible]	1½	[illegible]	21	29	1	[illegible]	[illegible]	29
TR1425	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
   W-10
2. City, State Altus, Oklahoma
3. Well No. 12 at Test Hole No. 12-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 3-22-67
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25	12	7	.188	18-8 Stainless	Layne / Shutter ~~Keystone~~	10 @ #6 13 @ #7 Openings
Inner Casing	58	12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 72-8 #7 @ 62-7 52-5
Outer Casing	12	34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8 8 x 16

Tons 22 8

12. SEALING CASING

Puddled Clay (~~Yes~~) (No)

With .... Bags Bentonite Added

or

With 1¼ Yds. Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 84
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 1'6"
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

14. PUMPING TEST

A.

Test pump

Permanent pump ....8....in..RK....Bowl....5....Stages

Length of column ....60....Ft.

Length of Bowl ....4*....Ft.

Length of suction ....5....Ft.

B. Measured water level ....36.85.... Ft. from top of ....12....In. dia. casing which is ....1.5.... Ft. above ground.

C. Length of airline ....Ft. from top of casing.

ORIFICE

....3....x....4....

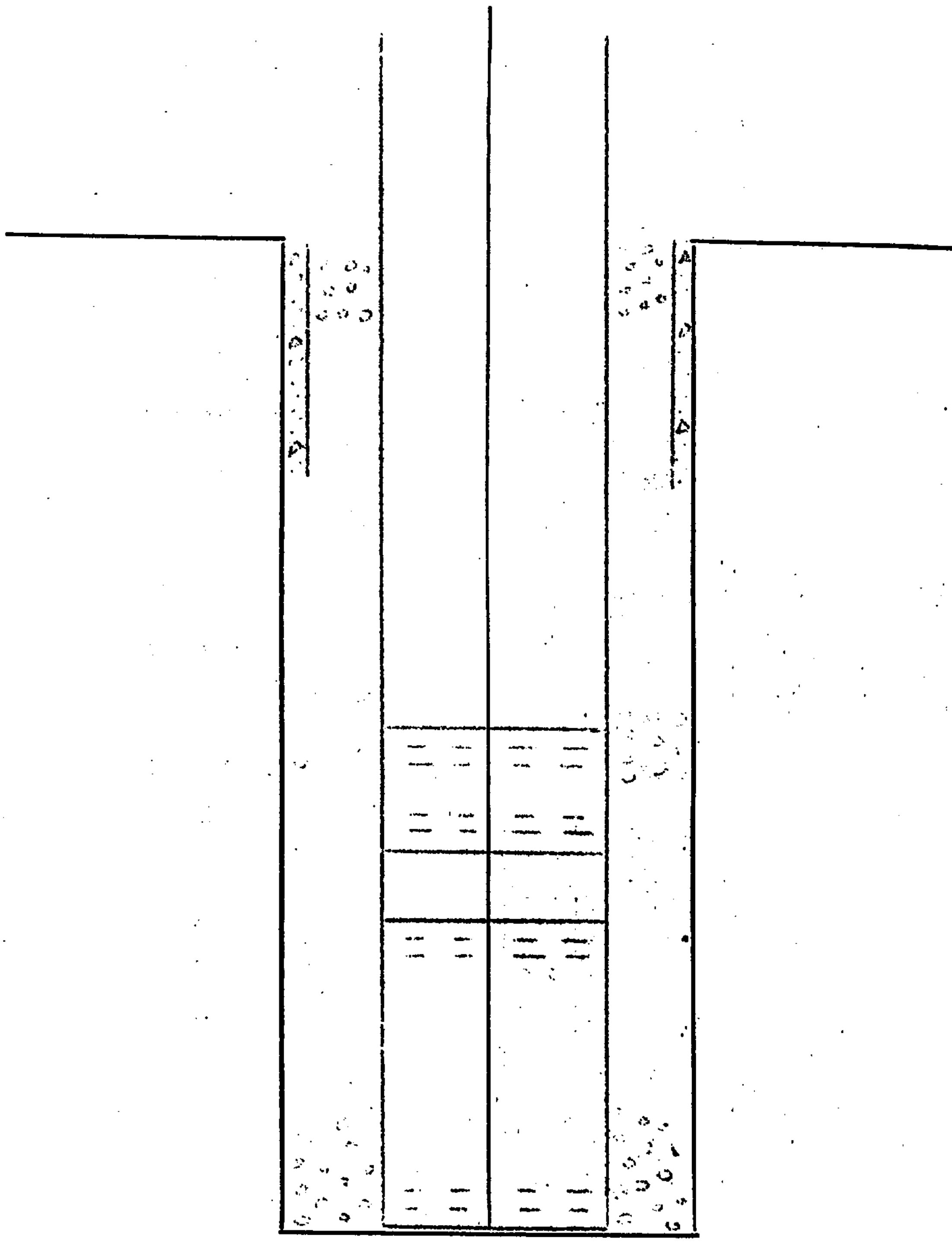
........x........

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
7:30		0		36.85	0
8:30		205		55.39	18.54
9:35		205		55.75	18.90
10:35		205		55.95	19.10
11:35		205		56.00	19.15
12.35		205		56.07	19.22
1:35		205		56.10	19.25
2:35		205		56.10	19.25
3:35		205		56.10	19.25

15. Permanent ....Layne.... Pump No. .... installed by ....
Layne

Permanent air line length ....Ft. Date........
Month Day Year

CONSTRUCTION OF WELL

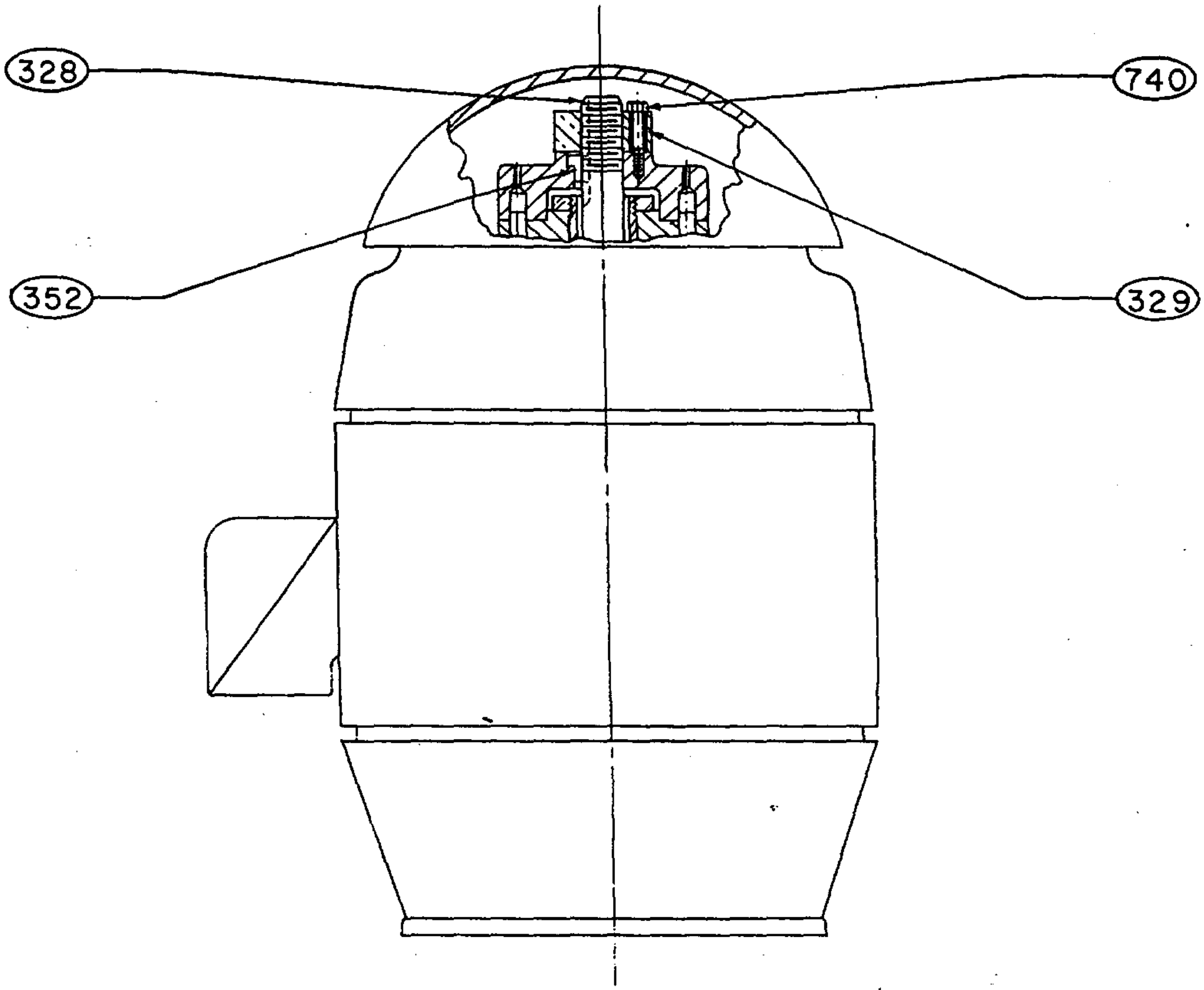


LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			15		Sandy Silty & Clay
15			32		Cemented Sand not hard
32			34		Clay
51			57		Fine to Coarse Sand & Gravel
57			62		Clay
62			72		Med. to Coarse Sand & Gravel with Clay
72			82		Med. to Coarse Sand& Gravel

ADJUSTING NUT ASSEMBLY
VERTICAL HOLLOW SHAFT MOTOR

LAYNE & BOWLER INC MEMPHIS TENNESSEE.



PART NO.		DESCRIPTION
3 2 8		MOTOR DRIVE SHAFT
3 2 9		ADJUSTING NUT
3 5 2		GIB. HEAD KEY (CLUTCH)
7 4 0		MACHINE SCREW (ADJUSTING NUT)

IN ORDERING REPLACEMENT PARTS, ALWAYS SPECIFY PARTS NO, DESCRIPTION, MOTOR SIZE, TYPE, & PUMP SERIAL NO.

MOTOR MFG.______________ H.P.______________ R.P.M. ______________

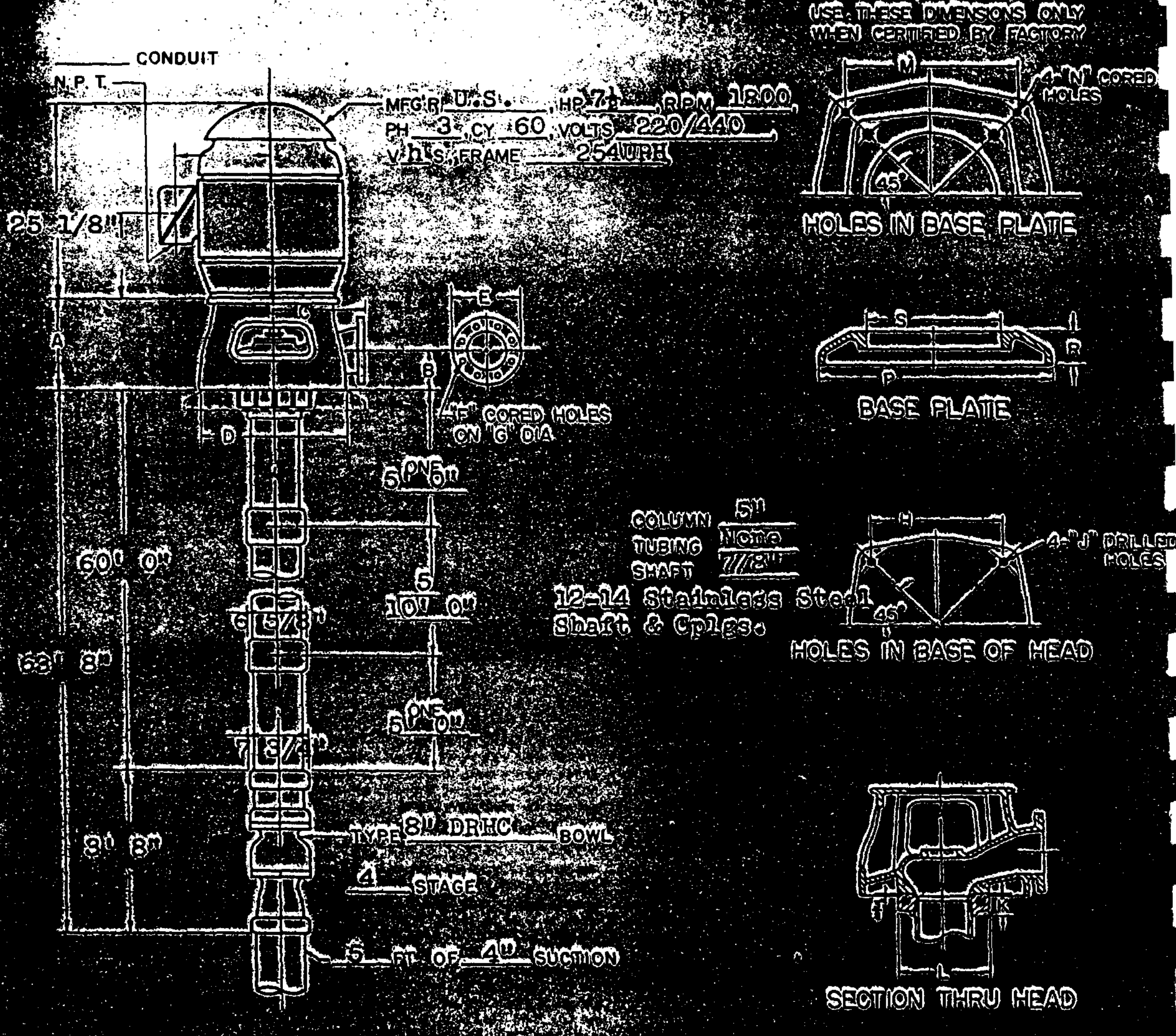
VOLTS________ PHASE________ CY. ________ FRAME ___________

Well 12

INSTALLATION PLAN

TYPE TF413 DISCHARGE HEAD

LAYNE & BOWLER INC. MEMPHIS, TENN.



Well No. 12

CUSTOMER City Water Dept.
LOCATION Altus, Oklahoma
FOR APPROVAL
CERTIFIED Tom Morrow

YOUR NO W-10-708
OUR NO 67D-3666
PUMP NO 57136
DATE 6/14/67

GPM 175
TDH 103
RPM 1750
BHP

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF413	13	6	11	18	9	[illegible]	7	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	21	2	17
TF613	14	6	11	18	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	21	2	17
TF418	15	6	[illegible]	23	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TF618	15	6	[illegible]	23	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TF818	18	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TF1018	18	[illegible]	[illegible]	23	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
TF625	[illegible]	[illegible]	[illegible]	31	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	[illegible]	[illegible]	[illegible]
TF825	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]
TF1025	20	[illegible]	[illegible]	31	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16	29	0	33	[illegible]
TF1225	21	[illegible]	[illegible]	31	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	29	0	[illegible]	[illegible]
TF1225	21	[illegible]	[illegible]	[illegible]	19	[illegible]	17	[illegible]	[illegible]	[illegible]	21	[illegible]	[illegible]	[illegible]	[illegible]
TF1425	[illegible]	[illegible]	[illegible]	31	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21	29	0	[illegible]	[illegible]

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
W-10
2. City, State Altus, Oklahoma
3. Well No. 13 at Test Hole No. 13-65
4. Well Location (attach map) Round Timber Ranch, Texas

5. Driller Hoellering
6. DATE 4-5-67
7. Date Started
Completed
8. Drill Crew Man Hrs.
9. Working Days
Drilling
Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	25		12	7	.188	18-8 Stainless	Layne Shutter, ~~Keystone~~	10 @ 6 15 @ 7 Openings
Inner Casing	64		12		.330	steel	~~Welded~~ Screwed	Spacing #6 @ 77-87 #7 @ 54.5-59. 67-77
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL
Size 4 x 8 8 x 16
Tons 24 8

12. SEALING CASING
Puddled Clay (~~Yes~~) (No)
With .... Bags Bentonite Added
or
With 1¼ Yds. ~~xxxx~~ Bags Cement
Seal Material Placed in Well With tremie pipe
Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS
A. Total Depth 89'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 2'
(Above Ground Level)
C. Distance to Top of Gravel 1'
(From Ground Level)
D. Diameter of Drill Hole 36"

Comments reverse rotary

14. PUMPING TEST

A.

Test pump
Permanent pump ....8........in........RK........Bowl........5........Stages

Length of column ....60........Ft.

Length of Bowl ....4±........Ft.

Length of suction ....5........Ft.

B. Measured water level ....41.50........Ft. from top of ....12........In. dia. casing which is ....2........ Ft. above ground.

C. Length of airline ....Ft. from top of casing.

ORIFICE

........3........x........4........

................x................

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
12:00		0		41.50	0
1:00		219		55.85	14.35
2:00		205		54.60	13.10
3:00		205		54.63	13.13
4:00		205		55.10	13.60
5:30		205		55.15	13.65
6:00		205		55.25	13.75
7:00		203		54.95	13.45
8:00		205		55.10	13.60

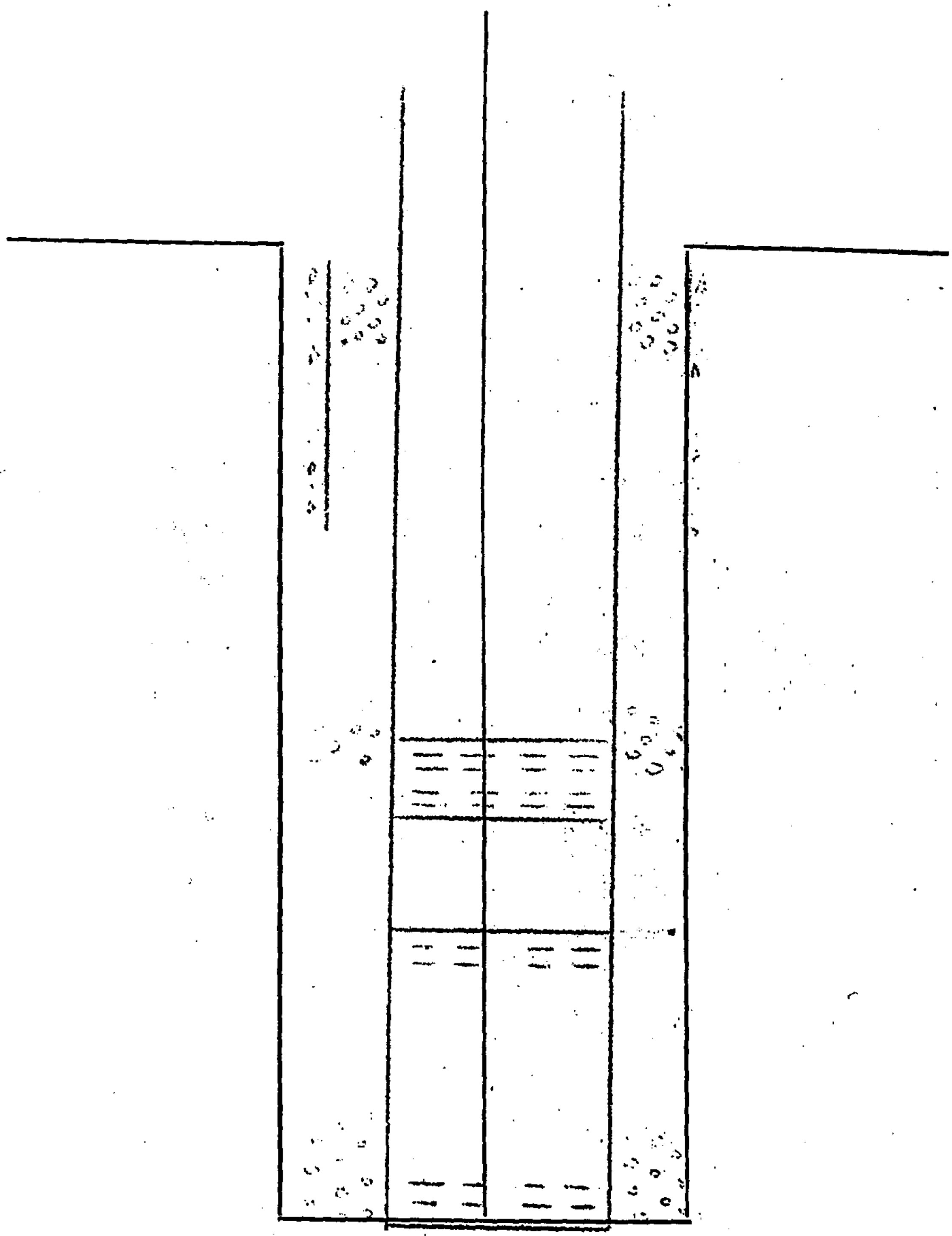
15. Permanent ....Layne........ Pump No. .... installed by ....
Layne

Permanent air line length ....Ft. Date................
Month Day Year

LOG OF WELL

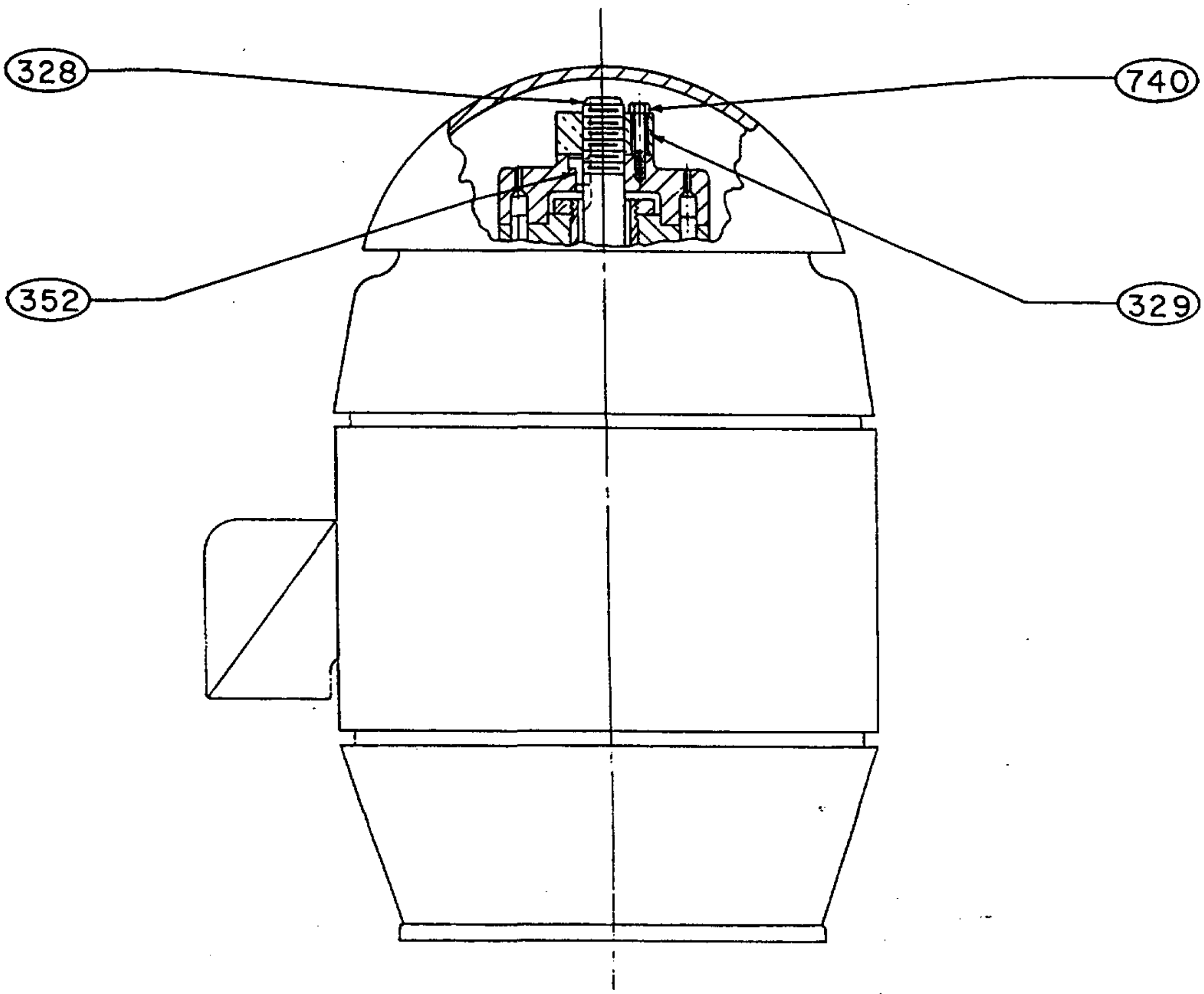
Ft.	In.	to	Ft.	In.	Formation
0			37		Sandy Silt & Clay
37			50		Fine to Coarse Sand - Some Clay
50			59	6	Fine to Coarse Sand & Gravel
59	6		68		Sandy Clay
68			76		Fine to Coarse Sand & Gravel
76			77		Cemented Sand, Hard
77			81		Fine to Coarse Sand & Gravel with Clay
81			82		Cemented Sand & Gravel, Hard
82			87		Med. to Coarse Sand & Gravel

CONSTRUCTION OF WELL



ADJUSTING NUT ASSEMBLY
VERTICAL HOLLOW SHAFT MOTOR

LAYNE & BOWLER INC MEMPHIS TENNESSEE.



PART NO.		DESCRIPTION
328	7/8"	MOTOR DRIVE SHAFT
329	AN875	ADJUSTING NUT
352	F272	GIB. HEAD KEY (CLUTCH)
740	10-32-1¼"	MACHINE SCREW (ADJUSTING NUT)

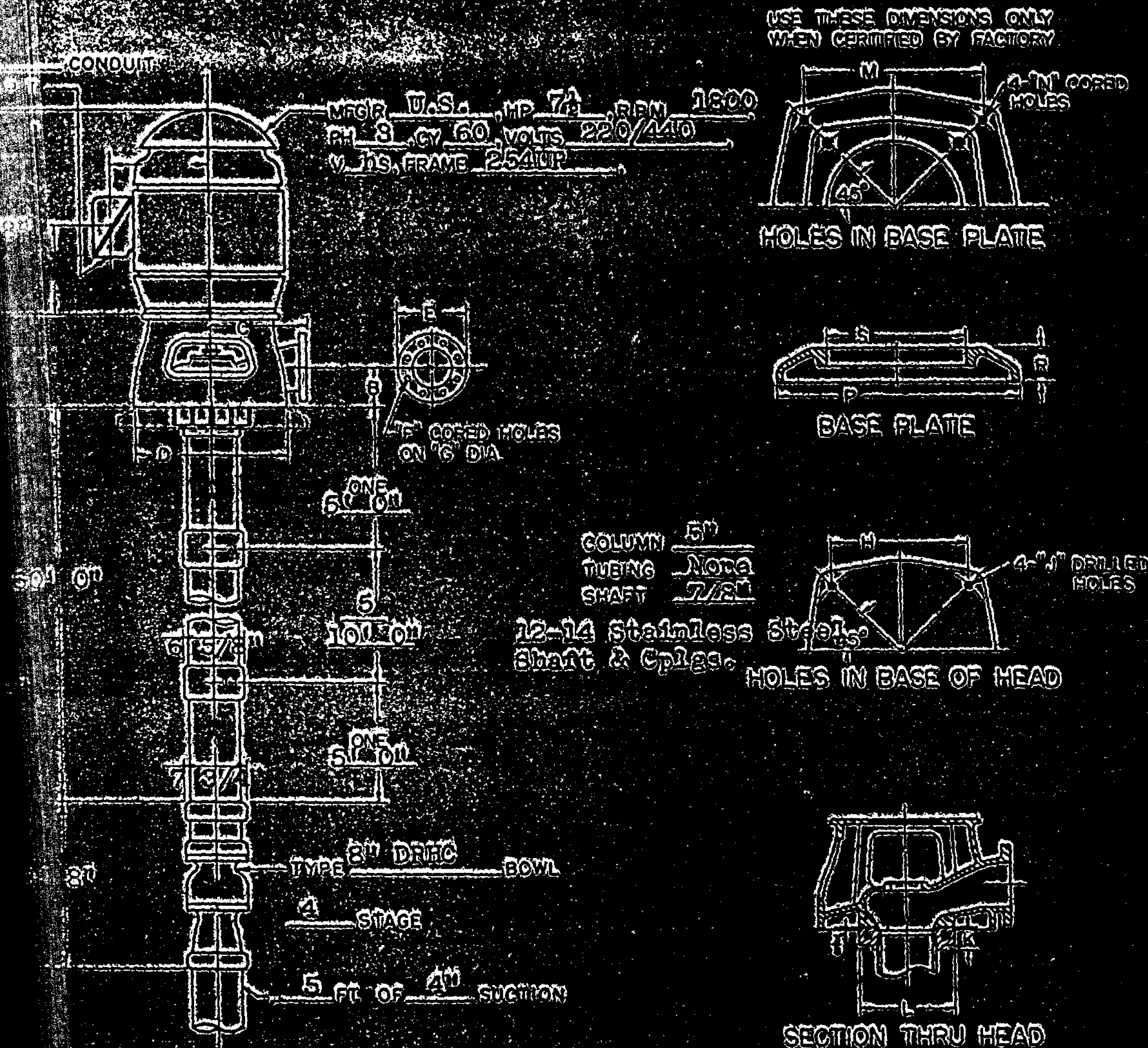
IN ORDERING REPLACEMENT PARTS, ALWAYS SPECIFY PARTS NO, DESCRIPTION, MOTOR SIZE, TYPE, & PUMP SERIAL NO.

MOTOR MFG. U.S. H.P. 7½ R.P.M. 1800

VOLTS 220/440 PHASE 3 CY. 60 FRAME 254UP

INSTALLATION PLAN
TYPE TF413 DISCHARGE HEAD

LAYNE & BOWLER INC. MEMPHIS, TENN.



Well No. 13

R City Water Dept.	YOUR NO W-10-709	GPM 175
Altus, Oklahoma	OUR NO 670-3667	TDH 105
ROVAL	PUMP NO 671-37	RPM 1760
Tom Morrow	DATE 6/14/67	BHP

[illegible]	D	E	F	G	H	J	K	L	M	N	P	R	S
[illegible]	12	9	8½	7½	4½	1½	2½	10	6½	¾	21	2	17
[illegible]	14	11	8½	9½	4½	1½	2½	11	6½	¾	21	2	17
[illegible]	23	9	8½	7½	12	1½	2½	10	20½	¾	26½	2½	24½
[illegible]	23	11	8½	9½	12	1½	2½	12½	20½	¾	26½	2½	24½
[illegible]	23	[illegible]	9	[illegible]	12	1½	3½	14½	20½	¾	26½	2½	24½

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF625	16	8½	9½	31	11	8½	9½	24½	1½	2½	12½	27	11	38	3½	29
TF825	20	8½	9½	31	[illegible]	12½	[illegible]	24½	1½	2½	12½	29	11	38	3½	29
TF1025	20	8½	9½	31	16	21	[illegible]	[illegible]	1½	3½	16	29	11	38	3½	29
TF1225	21	9½	9½	31	16	21	17	23½	1½	3½	19	29	11	38	3½	29
TF1225	21	9½	9½	31	19	21	17	23½	1½	4½	21	29	[illegible]	[illegible]	[illegible]	[illegible]

WELL INFORMATION

Layne-Western Company

1. CONTRACT City of Altus
   W-10
2. City, State Altus, Oklahoma
3. Well No. 16-A at Test Hole No. 16A-65
4. Well Location (attach map) Round Timber Ranch
   Texas
5. Driller Hoellering
6. DATE 4-2-67
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL

	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	10		12	7	.168	18-8 Stainless	Layne Shutter ~~Keystone~~	7 Openings
Inner Casing	50		12		.330	steel	~~Welded~~ Screwed	Spacing #7 @ 40-45 53-58
Outer Casing	12		34		.281	steel	Welded ~~Screwed~~	

11. GRAVEL

Size 4 x 8   8 x 16

Tons 12   10

12. SEALING CASING

Puddled Clay (~~Yes~~) (No)

With .... Bags Bentonite Added

or

With 1¼ Yds. ~~Bags~~ Cement

Seal Material Placed in Well With tremie pipe

Bottom of Well Screen Sealed With 3/8" steel plate

13. WELL DIMENSIONS

A. Total Depth 60'
(From Top of Inner Casing to Bottom of Well)

B. Height of Inner Casing 2'
(Above Ground Level)

C. Distance to Top of Gravel 1'
(From Ground Level)

D. Diameter of Drill Hole 36"

Comments Reverse Rotary

PUMPING TEST

A.

Test pump

Permanent pump ....8.... in. ....RK.... Bowl ....5.... Stages

Length of column ....50.... Ft.

Length of Bowl ....4±.... Ft.

Length of suction ....5.... Ft.

B. Measured water level ....31.40.... Ft. from top of ....12.... In. dia. casing which is ....2.... Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

....3.... x ....4....

.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
		0			0
11:30				31.40	
12:30		50		38.26	6.86
1:30		50		38.44	7.04
2:30		50		38.52	7.12
3:30		50		38.60	7.20
4:30		50		38.64	7.24
5:30		50		38.65	7.25
6:30		50		38.63	7.23
7:30		50		38.68	7.28

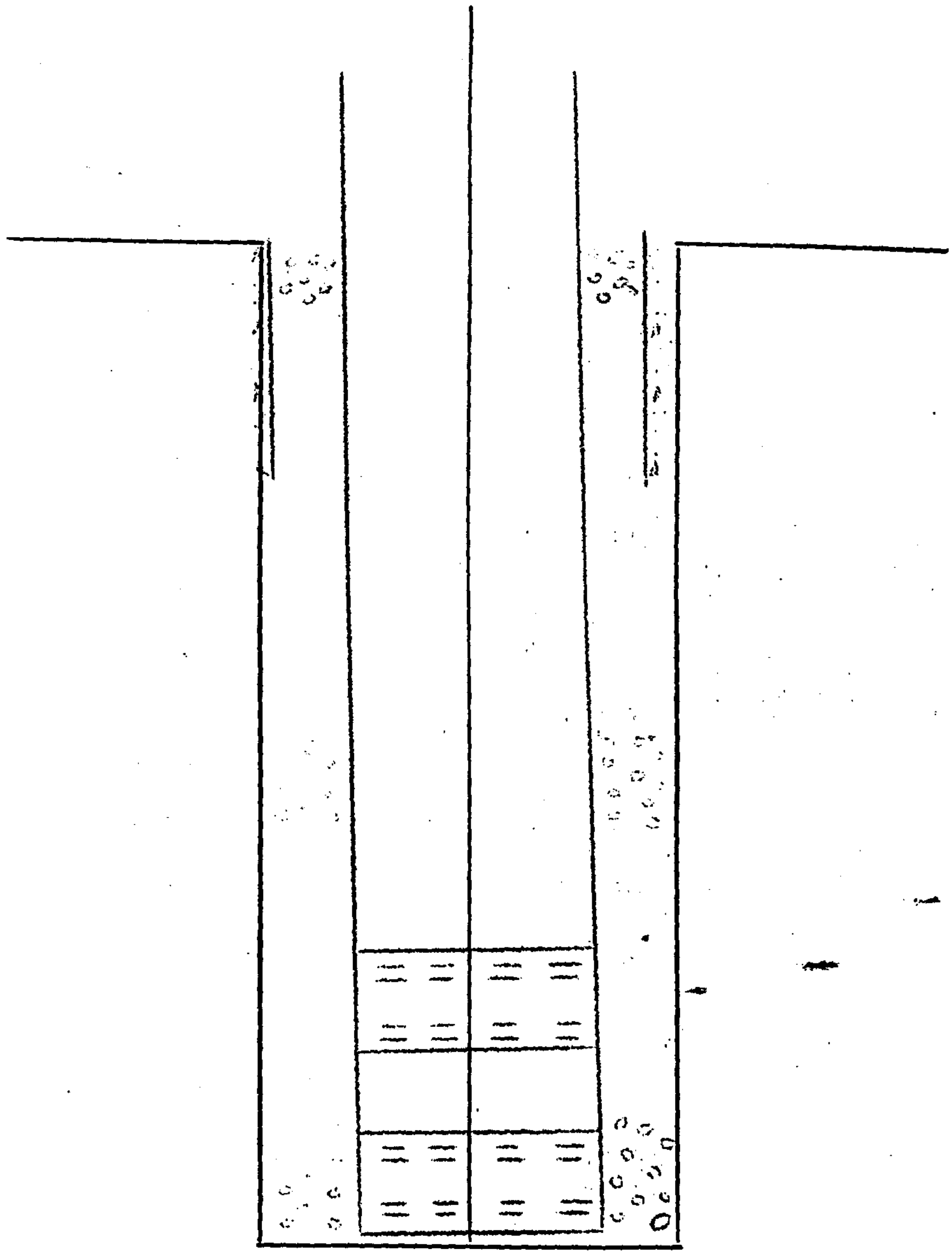
15. Permanent ....Layne.... Pump No. .... installed by ....

Permanent air line length .... Ft. Date ....
Month Day Year

LOG OF WELL

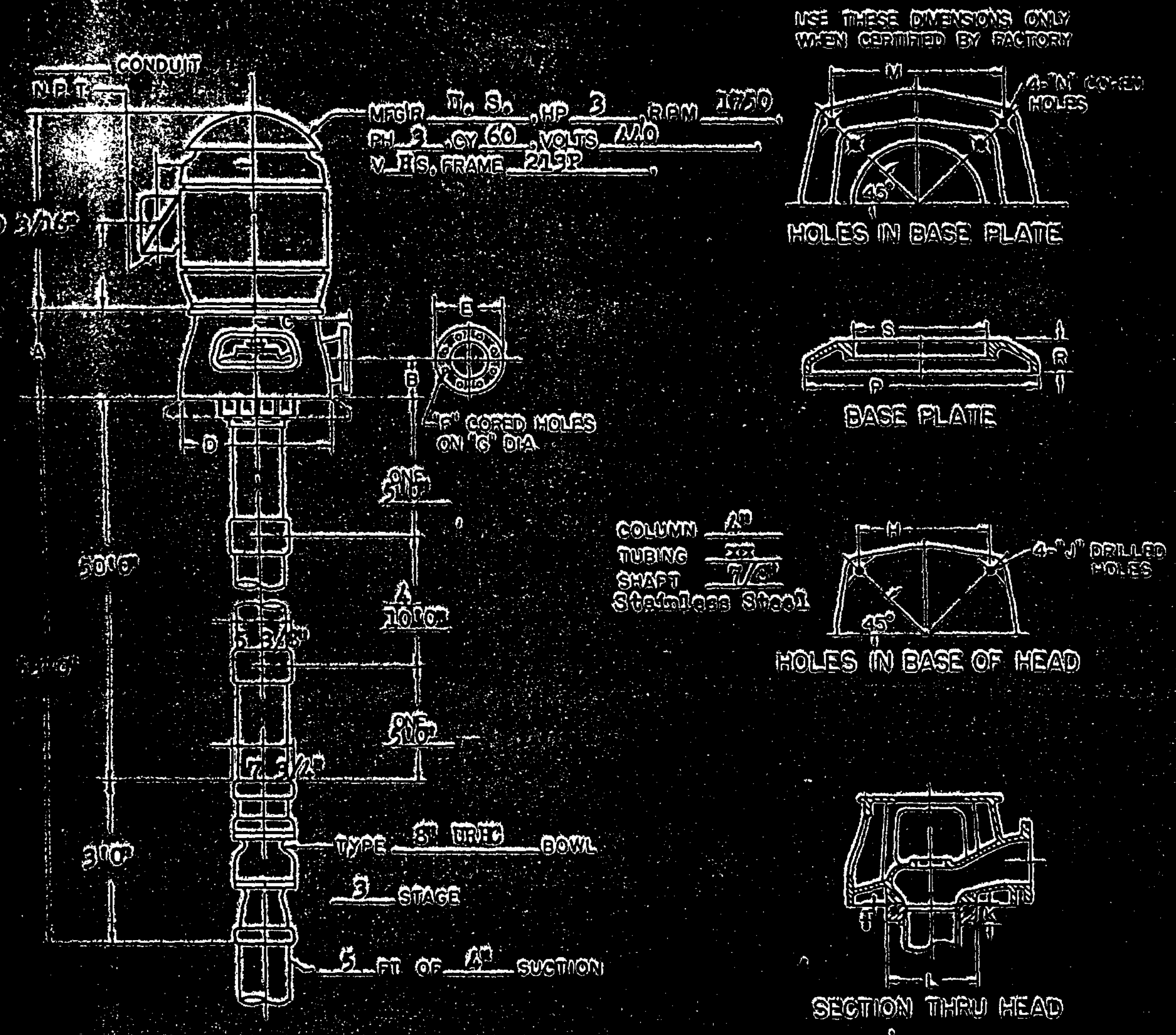
[illegible]	In.	to	Ft.	In.	Formation
0			20		Fine sand & Gravel
20			30		Fine to Med. Sand & Gravel
30			34		Sandy Red Clay
34			45		Firm to Coarse Sand & Gravel
45			50		Sandy Grey Clay
50			58		Med. to Coarse Sand & Gravel with lots of red clay lenses.

CONSTRUCTION OF WELL



INSTALLATION PLAN
TYPE TF413 DISCHARGE HEAD

LAYNE & BOWLER INC. MEMPHIS, TENN.



CUSTOMER City Water Dept. (Well L16-A)	YOUR NO [illegible]	GPM 60
LOCATION Altus, Okla.	OUR NO 670-2668	TDH 57
FOR APPROVAL	PUMP NO 57293	RPM 1750
CERTIFIED [signature]	DATE June 14, 1967	BHP

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
[illegible]	[illegible]	6	11	13	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	21	2	17
[illegible]	[illegible]	6	11	13	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	21	2	17
[illegible]	[illegible]	6	[illegible]	23	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	26	[illegible]	[illegible]
[illegible]	[illegible]	6	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	[illegible]	[illegible]

HEAD	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
TF625	16	[illegible]	[illegible]	31	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	1	38	[illegible]	29
TF825	20	[illegible]	[illegible]	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	1	38	[illegible]	29
TF1025	20	[illegible]	[illegible]	31	16	2-0	[illegible]	[illegible]	[illegible]	[illegible]	16	29	1	38	[illegible]	29
TF1225	21	[illegible]	[illegible]	31	19	2-0	17	[illegible]	[illegible]	[illegible]	19	29	1	38	[illegible]	29
TF1225	21	[illegible]	[illegible]	31	19	2-0	17	[illegible]	[illegible]	[illegible]	21	29	1	38	[illegible]	29

WELL INFORMATION

Layne-Western Co. Inc.

1. CONTRACT C. F. Mock (City of Altus)
   Job W926H
2. City, State Altus, Oklahoma
3. Well No. 17 at Test Hole No. 7-69
4. Well Location (attach map) See Map

5. Driller John Penner
6. DATE June 2, 1971
7. Date Started
   Completed
8. Drill Crew Man Hrs.
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25 0	12	7	.188	Stainless Steel	Layne Shutter	7 Openings
Inner Casing	77 6	12	—	.330	Steel	Welded	
Outer Casing	12 0	34	—	3/16	Steel	Welded	

11. GRAVEL
    Size Garden City #4 topping
    Tons 22 T. in bottom, 14 T in top.

12. SEALING CASING
    Puddled Clay (Yes) (No)
    With .... Bags Bentonite Added
    or
    With .... Bags Cement
    Seal Material Placed in Well With 12' of 34" cemented in
    Bottom of Well Screen Sealed With Stainless steel plate

13. WELL DIMENSIONS
    A. Total Depth 102-1/2' (From Top of Inner Casing to Bottom of Well)
    B. Height of Inner Casing 1' 6" (Above Ground Level)
    C. Distance to Top of Gravel 0 (From Ground Level)
    D. Diameter of Drill Hole 36"

Comments Reverse Circulation
12' of 34" surface casing cemented in top of well.

LW-39

14. PUMPING TEST

A.

~~Test pump~~

Permanent pump ....8 in PRHC Bowl 6 ....Stages

Length of column ....80........Ft.

Length of Bowl ....5........Ft.

Length of suction ....5........Ft.

B. Measured water level ....47.90.... Ft. from top of ....12....In. dia. casing which is ....1.5.... Ft. above ground.

C. Length of airline ....Ft. from top of casing.

ORIFICE

..................x..................

..................x..................

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
0		0		47.90	0
2 Hr.		201		67.90	20.00
4		201		68.30	20.40
6		201		68.30	20.40
8		201		67.20	19.30
10		201		67.65	19.75
12		201		67.10	19.20
14		201		67.15	19.25
16		201		67.40	19.50
18		201		67.65	19.75
20		201		67.80	19.90
22		201		68.10	20.20
24		201		68.10	20.20

15. Permanent ....Layne........ Pump No. .... installed by ....

Layne

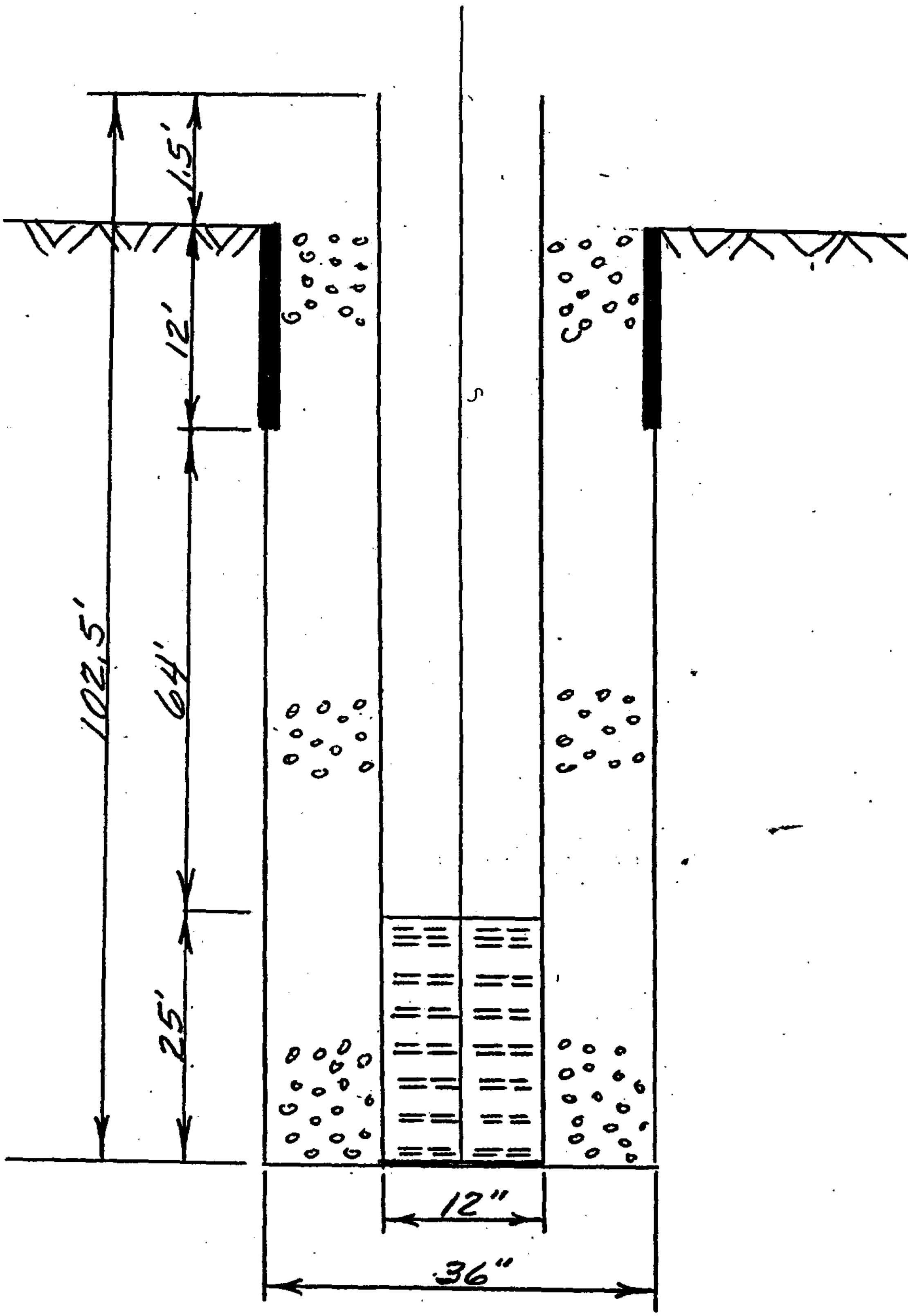
Permanent air line length ....80........Ft. Date..................

Month Day Year

LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			3		Sandy top soil
3			23		Fine sand - red
23			34		Fine sand - tan
34			37		Sandy clay
37			49		Fine to med. sand
49			71		Fine to coarse sand
71			72		Cemented sand and gravel - hard
72			82		Med. to coarse sand and gravel w/clay streaks
82			86		Med. to coarse sand and very coarse gravel
86			91		Coarse gravel - cemented hard
91			101		Coarse sand and very coarse gravel
101					Red shale

CONSTRUCTION OF WELL



C. F. MOCK, JR., FOR CITY OF ALTUS
GAGE HOLE 50' SOUTHWEST OF WELL NO. 17
MAY 30, 1971
BY LAYNE WESTERN COMPANY, INC.

Measurements from top of pipe

TIME	DRAWDOWN	WATER LEVEL
0 Min.	0	46' 5"
30	-	-
60	-	-
90	2' 4"	48' 9"
120	2' 5"	48' 10"
150	2' 5"	48' 10"
180	2' 5½"	48' 10½"
210	2' 6½"	48' 11½"
240	2' 6½"	48' 11½"
270	2' 5½"	48' 10½"
300	2' 4"	48' 9"
330	2' 4"	48' 9"
360	2' 5½"	48' 10½"
390	2' 6½"	48' 11½"
420	2' 7-3/4"	49' 3/4"
450	2' 7"	49'
480	2' 7"	49'
510	2' 8"	49' 1"
540	2' 8"	49' 1"
570	2' 7"	49'
600	2' 7"	49'
630	2' 8"	49' 1"
660	2' 8"	49' 1"
690	2' 7"	49'
720	2' 7"	49'
750	2' 8"	49' 1"
780	2' 8"	49' 1"
810	2' 8"	49' 1"
840	2' 8"	49' 1"
870	2' 8"	49' 1"
900	2' 8"	49' 1"
930	2' 9"	49' 2"
960	2' 9"	49' 2"
990	2' 9"	49' 2"
1020	2' 10"	49' 3"
1050	2' 10"	49' 3"
1080	2' 10"	49' 3"
1110	2' 10"	49' 3"
1140	2' 11"	49' 4"
1170	2' 11"	49' 4"
1200	2' 11"	49' 4"
1230	3' 0"	49' 5"
1260	3' 0"	49' 5"
1290	3' 0"	49' 5"
1320	3' 1"	49' 6"
1350	3' 1"	49' 6"
1380	3' 1"	49' 6"
1410	3' 1"	49' 6"
1440	3' 1"	49' 6"

TIME	GPM	DRAWDOWN	WATER LEVEL
900 Min.	201	19.30	67.20
930	201	19.50	67.40
960	201	19.50	67.40
990	201	19.60	67.50
1020	201	19.70	67.60
1050	201	19.75	67.65
1080	201	19.75	67.65
1110	201	19.80	67.70
1140	201	19.80	67.70
1170	201	19.85	67.75
1200	201	19.90	67.80
1230	201	19.85	67.75
1260	201	20.00	67.90
1290	201	20.10	68.00
1320	201	20.20	68.10
1350	201	20.20	68.10
1380	201	20.05	67.95
1410	201	20.20	68.10
1440	201	20.20	68.10

RECOVERY
WELL NO. 17

2 Min.		1.80	49.70
4		1.30	49.20
6		1.25	49.15
8		1.25	49.15
10		1.25	49.15
12		1.25	49.15
14		1.25	49.15
16		1.25	49.15
18		1.20	49.10
20		1.20	49.10
25		1.10	49.00
30		1.10	49.00

C. F. MOCK, JR., FOR CITY OF ALTUS
PUMPING TEST
MAY 30, 1971
BY LAYNE WESTERN COMPANY, INC.
WELL NO. 17

Measurements from top of casing

TIME	GPM	DRAWDOWN	WATER LEVEL
0 Min.	0	0	47.90
2	201	18.90	66.80
4	201	19.35	67.25
6	201	19.55	67.45
8	203	19.80	67.70
10	203	20.05	67.95
12	201	19.55	67.45
14	201	19.45	67.35
16	201	19.45	67.35
18	201	19.55	67.45
20	201	20.00	67.90
25	201	20.20	68.10
30	201	19.95	67.85
35	201	19.45	67.35
40	201	19.65	67.55
45	201	19.65	67.55
50	201	19.75	67.65
55	201	19.85	67.75
60	201	20.00	67.90
90	201	20.00	67.90
120	201	20.00	67.90
150	201	20.40	68.30
180	201	20.35	68.25
210	201	21.00	68.90
240	201	20.40	68.30
270	201	20.40	68.30
300	201	20.40	68.30
330	201	20.40	68.30
360	201	20.40	68.30
390	201	18.55	66.45
420	201	18.55	66.45
450	201	18.80	66.70
480	201	19.30	67.20
510	201	19.75	67.65
540	201	19.55	67.45
570	201	19.45	67.35
600	201	19.75	67.65
630	201	19.65	67.55
660	201	19.20	67.10
690	201	19.20	67.10
720	201	19.20	67.10
750	201	19.25	67.15
780	201	19.20	67.10
810	201	19.30	67.20
840	201	19.25	67.15
870	201	19.30	67.20

WELL INFORMATION

Layne-Western Co. Inc.

1. CONTRACT C. F. Mock (City of Altus)
   Job W926H
2. City, State Altus, Oklahoma
3. Well No. 18 at Test Hole No. 9-69
4. Well Location (attach map) See Map

5. Driller John Penner
6. DATE May 28, 1971
7. Date Started
   Completed
8. Drill Crew Man Hrs
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT.	LENGTH IN.	DIA. IN.	GAGE NO.	WALL THICK-NESS IN.	MATERIAL	TYPE	NO.
Screen	25	0	12	7	.188	Stainless Steel	Layne Shutter XXXXXX	7 Openings
Inner Casing	89	6	12	—	.330	Steel	Welded XXXX	
Outer Casing	12	0	34	—	3/16	Steel	Welded XXXX	

11. GRAVEL
   Size Garden City #4 topping
   Tons 24 in bottom - 15 in top

12. SEALING CASING
   Puddled Clay (Yes) (No)
   With .... Bags Bentonite Added
   or
   With .... Bags Cement
   Seal Material Placed in
   Well With 12' of 34" cemented in
   Bottom of Well Screen
   Sealed With Stainless steel plate.

13. WELL DIMENSIONS
   A. Total Depth 114' 6"
   (From Top of Inner Casing to Bottom of Well)
   B. Height of Inner Casing 1' 6"
   (Above Ground Level)
   C. Distance to Top of Gravel 0
   (From Ground Level)
   D. Diameter of Drill Hole 36"

Comments Reverse circulation
12' of 34" surface casing cemented in.

LW-39

14. PUMPING TEST

A.

~~Test~~ ..8.. in DRHC Bowl ..6.. Stages

Permanent pump

Length of column ..90.. Ft.

Length of Bowl ..5.. Ft.

Length of suction ..5.. Ft.

B. Measured water level ..64.80.. Ft. from top of ..12.. In. dia. casing which is ..1.5.. Ft. above ground.

C. Length of airline .... Ft. from top of casing.

ORIFICE

.... x ....

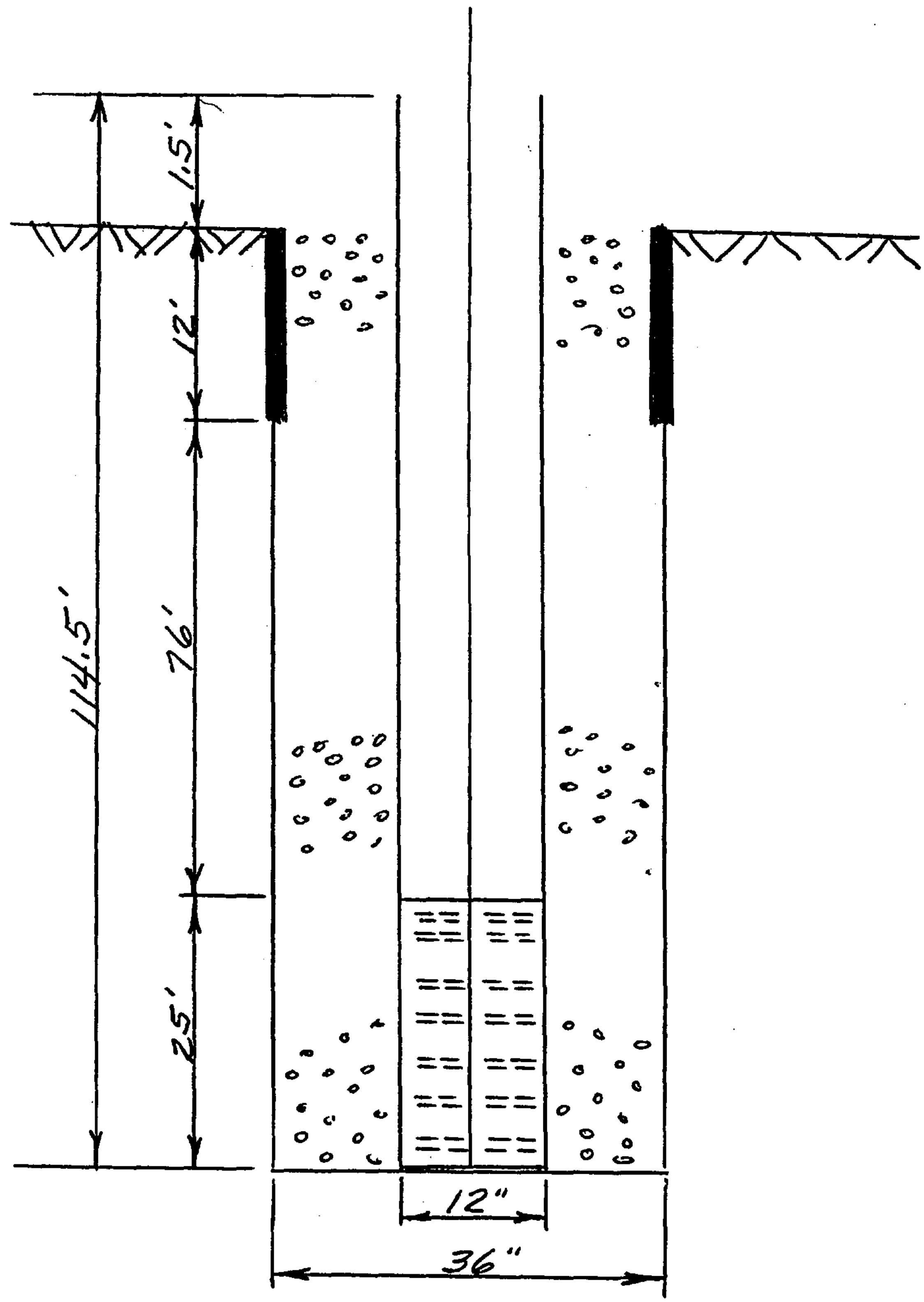
.... x ....

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
0		0		64.80	0
2 Hr.		151		82.45	17.65
4 Hr.		151		82.80	18.00
6 Hr.		151		82.80	18.00
8Hr.		151		82.90	18.10
10 Hr.		151		83.10	18.30
12 Hr.		151		83.00	18.20
14 Hr.		151		83.05	18.25
16 Hr.		151		83.00	18.20
18 Hr.		151		82.80	18.00
20 Hr.		151		82.50	17.70
22 Hr.		151		82.60	17.80
24 Hr.		151		82.20	17.40

15. Permanent ..Layne.. Pump No. .... installed by ....
Layne

Permanent air line length ..90.. Ft. Date ....
Month Day Year

CONSTRUCTION OF WELL



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			6		Sandy top soil
6			17		Fine sand
17			34		Fine to med. sand
34			42		Fine sand
42			81		Fine, med. and coarse sand
81			83		Brown clay
83			99		Fine to med. sand
99			100		Cemented sand - very hard
100			106		Med. sand and gravel
106			108		Coarse gravel - slightly cemented
108			110		Coarse gravel
110			113		Med. coarse to very coarse gravel

C. F. MOCK, JR., FOR CITY OF ALTUS
PUMPING TEST
MAY 27, 1971
By LAYNE WESTERN COMPANY, INC.
WELL NO. 18

Measurements from top of casing

TIME	GPM	DRAWDOWN	WATER LEVEL
0	0	0	64.80
2 Min.	151	17	81.80
4	151	17.2	82.0
6	151	17.3	82.10
8	151	17.3	82.10
10	151	17.3	82.10
12	151	17.4	82.20
14	151	17.4	82.20
16	151	17.5	82.30
18	151	17.6	82.40
20	151	17.55	82.35
25	151	17.55	82.35
30	151	17.55	82.35
35	151	17.80	82.60
40	151	17.90	82.70
45	151	17.90	82.70
50	151	17.80	82.60
55	151	17.70	82.50
60	151	17.55	82.35
90	151	17.65	82.45
120	151	17.65	82.45
150	151	17.90	82.70
180	151	18.00	82.80
210	151	18.00	82.80
240	151	18.00	82.80
270	151	18.00	82.80
300	151	18.00	82.80
330	151	18.00	82.80
360	151	18.00	82.80
390	151	17.85	82.65
420	151	18.00	82.80
450	151	18.00	82.80
480	151	18.10	82.90
510	151	18.20	83.00
540	151	18.25	83.05
570	151	18.30	83.10
600	151	18.30	83.10
630	151	18.20	83.00
660	151	18.20	83.00
690	151	18.20	83.00
720	151	18.20	83.00
750	151	18.25	83.05
780	151	18.30	83.10
810	151	18.25	83.05
840	151	18.25	83.05

TIME	GPM	DRAWDOWN	WATER LEVEL
870	151	18.20	83.00
900	151	18.25	83.05
930	151	18.25	83.05
960	151	18.20	83.00
990	151	18.20	83.00
1020	151	18.25	83.05
1050	151	18.25	83.05
1080	151	18.00	82.80
1110	151	17.60	82.40
1140	151	17.80	82.60
1170	151	17.70	82.50
1200	151	17.70	82.50
1230	151	17.70	82.50
1260	151	17.60	82.40
1290	151	17.60	82.40
1320	151	17.80	82.60
1350	151	17.80	82.60
1380	151	17.70	82.50
1410	151	17.70	82.50
1440	151	17.40	82.20

RECOVERY
WELL NO. 18

2 Min.	1.0'	65.80
4	.90	65.70
6	.70	65.50
8	.60	65.40
10	.60	65.40
12	.60	65.40
14	.55	65.35
18	.55	65.35
20	.50	65.30
25	.50	65.30
30	.45	65.25
60	.40	65.20

C. F. MOCK, JR., FOR CITY OF ALTUS
GAGE HOLE 50' SOUTHWEST OF WELL NO. 18
MAY 27, 1971
BY LAYNE WESTERN COMPANY, INC.

Readings from top of pipe

TIME	DRAWDOWN	WATER LEVEL
0 Min.	0	65' 8"
30	1' 4"	67'
60	1' 3"	66' 11"
90	1' 8"	67' 4"
120	1' 8"	67' 4"
150	1' 4"	67'
180	1' 6"	67' 2"
210	1' 5"	67' 1"
240	1' 3"	66' 11"
270	1' 3½"	66' 11½"
300	1' 4"	67'
330	1' 3½"	66' 11½"
360	1' 4"	67'
390	1' 8"	67' 4"
420	1' 9"	67' 5"
450	1' 9"	67' 5"
480	1' 10"	67' 6"
510	1' 10"	67' 6"
540	1' 10"	67' 6"
750	1' 10"	67' 6"
600	1' 10"	67' 6"
630	1' 10"	67' 6"
660	1' 10"	67' 6"
690	1' 10"	67' 6"
720	1' 10"	67' 6"
750	1' 10"	67' 6"
780	1' 10"	67' 6"
810	1' 10"	67' 6"
840	1' 10"	67' 6"
870	1' 10"	67' 6"
900	1' 10"	67' 6"
930	1' 10"	67' 6"
960	1' 10"	67' 6"
990	1' 10"	67' 6"
1020	1' 10"	67' 6"
1050	1' 10"	67' 6"
1080	1' 4"	67'
1110	1' 4"	67'
1140	1' 10"	67' 6"
1170	1' 10"	67' 6"
1200	1' 10"	67' 6"
1230	1' 10"	67' 6"
1260	1' 10"	67' 6"
1290	1' 10"	67' 6"
1320	1' 9"	67' 5"
1350	1' 11"	67' 7"
1380	2' 0"	67' 8"
1410	1' 10"	67' 6"
1440	1' 10"	67' 6"

Appendix D

Round Timber Ranch Well Field Specific Capacity Data

Round Timbers Ranch Well Field Pump Capacity Data

Well No.	Test Capacity (gpm)	Drawdown (feet)	Head of Water in Well (feet)	Percent Drawdown on Test (%)	Specific Capacity (gpm/ft dd)	30 Percent Drawdown (feet)	Well Caspacity at 30% Drawdown (gpm)	Recommended Pump Capacity (gpm)	Static Water Level (feet)	Drawdown at Recommended Pumping Capacity (feet)	Pumping Water Level (feet)	Well Depth (feet)	Column Pipe Length (feet)	Suction Pipe Length (feet)
1	205	21.80	38.35	57.00	9.40	11.50	108	125	35.65	15.30	48.95	74	60	5
2	205	14.80	46.10	32.00	13.85	13.90	192	175	30.90	12.60	43.50	77	60	5
3	170	22.40	50.30	44.50	7.60	15.10	115	125	18.70	16.40	35.10	69	50	5
4	210	15.00	50.00	30.00	14.00	15.00	210	175	24.10	12.50	36.60	74	50	5
5	210	27.40	59.50	46.00	7.66	17.90	137	125	22.50	16.30	38.80	82	50	5
6	205	27.60	63.70	43.30	7.42	19.10	142	125	26.30	16.80	43.10	90	60	5
7	205	8.13	47.70	17.00	25.20	14.30	360	250	26.30	10.00	36.30	74	50	5
8	205	17.15	50.65	33.80	11.94	15.20	181	175	31.35	14.70	46.05	82	60	5
9	203	21.15	39.50	53.50	9.60	11.80	113	125	36.50	13.00	49.50	76	60	5
10	205	18.40	40.00	46.00	11.14	12.00	137	125	39.13	11.00	50.13	79	60	5
11	205	13.63	44.30	31.00	15.00	13.20	198	175	34.70	11.70	46.40	79	60	5
12	205	19.25	47.15	41.00	10.65	14.10	150	175	36.85	16.40	53.25	84	60	5
13	205	13.60	47.00	29.00	15.00	14.10	218	175	41.50	11.70	53.20	89	60	5
16A	50	7.28	29.00	25.00	6.86	8.70	60	60	31.40	8.70	40.10	60	50	5
17	201											100.5		
18	151											113		

APPENDIX C

Water Distribution Study Pressure Results

Junction No.	Location	Static Pressure		Fireflow Pressure	
		Tested	Modeled	Tested	Modeled
50	Violet/Maiden	65	66	43	58
75	Sherman/Pease	80	67	45	55
79	Paradise/Pine	75	67	35	55
80	Cumb/S.Front.	60	66	55	59
108	D.Smith/Maiden	65	63	50	58
114	Wilb/D.Smith	70	62	50	51
119	Wilb/Mesquite	75	63	30	58
120	Wilb/Bowie	75	59	40	58
126	Wilb/Nabers	70	59	34	50
128	Wilb/Stephens	70	58	45	44
131	Texas/Nabers	65	59	55	47
132	Houston/Olive	60	61	55	56
135	Wheeler/Texas	65	60	55	54
141	Strahan/Maiden	65	60	52	54
142	Houston/Dean	65	62	50	53
143	Strahan/Bacon	75	61	50	55
145	Harrison/Bacon	75	60	45	53
149	Paradise/Houston	55	59	50	54
154	Strahan/S.Front	65	62	52	56
155	Nabers/N.Front	65	62	58	56
161	D.Smith/N.Front	75	64	54	58
164	Ross/N.Front	75	60	50	53
175	Wright/Mesquite	75	67	46	49
179	D.Smith/Mill	65	66	40	51
200	Cleburne/Lorance	65	59	45	50
201	Tolbert/Lorance	60	58	40	47
204	Ross/Bacon	65	60	38	38
206	Ross/1st	65	59	40	35
213	Cleburne/Kelly	65	59	45	48
215	Hillcrest/Kelly	60	56	36	43
222	Marshall/15th	65	57	23	33
225	Marshall/12th	60	56	35	41
235	Hillcrest/Augusta	72	58	15	12
246	Brewer/Palmer	65	57	20	25
248	Palmer/Woodland	60	56	20	24
253	US70/Horseshoe	60	56	26	28
263	Wilb/Stadium	65	55	25	45
267	Kelly/LomaLinda	55	56	24	20
270	Stadium/Paradise	60	54	30	39
277	Yamp/Roberts	60	54	40	45
283	Sand/Yampirika	55	54	38	48
286	Sand/Bismarck	60	50	30	36
287	Sand/Beaver	55	48	30	31
290	Bismarck/12th	65	52	36	40
293	Beaver/Roberts	55	50	36	31
294	Beaver/English	60	50	30	20
308	Yamp/Clair	55	53	34	38
312	Yamp/Franklin	60	52	30	34
324	Paradise/Nabers	65	56	50	50

325	Paradise/Wheeler	65	58	55	52
328	Yamp/Powell	60	52	40	44
329	Yamp/Stephens	65	53	46	47
331	Bismarck/Stephens	65	53	36	45
334	Bismarck/Wheeler	70	53	38	45
341	Main/Marshall	80	61	50	56
342	Marshall/D.Smith	65	61	55	54
348	Indian/Houston	65	55	46	50
351	Yamp/Mesquite	60	60	44	46
357	Bismarck/Pearl	75	62	50	50
358	Bismarck/Violet	75	61	50	48
359	Yampirika/Violet	70	63	46	51
360	Mansard/Pearl	75	61	40	50
361	Mansard/Violet	70	61	36	51
365	Paradise/Violet	70	65	50	53
366	Marshall/Violet	67	65	50	54
385	Main/Beaver	70	57	40	49
386	Main/PeterCooper	70	56	40	44
401	Beaver/Houston	60	52	50	49
406	Beaver/Wheeler	55	51	44	43
416	Sand/Country	50	41	22	18
417	Kennedy/Country	58	46	26	19
421	Foster/Kennedy	38	46	25	18
434	Cottonwd/Cresent	56	48	30	29
435	Cottonwd/TwinOaks	53	46	33	24
436	Martindale/TwinOaks	52	47	30	26
438	Cottonwd/Sunset	50	47	28	29
443	Sand/Sunset	52	47	32	27
444	Martindale/Sunset	50	46	30	21
469	Harrison/N.Front	75	61	56	53
511	Wilb/Houston	70	61	45	51
513	Main/Yamp	75	61	46	52
515	Main/Texas	70	63	50	55

Water and Wastewater Comprehensive Plan
City of Vernon in Conjunction with the Texas Water Development Board

Contract #98-483-243

Project 24614, Figure 2-1- Saturated Thickness of Aquifer Penetrated By Water Supply Wells, Odell-Winston Wellfield

Job No. VRN97341A, Plate 1.DWG – City of Vernon

Job No. VRN97341A, Plate 2

Job No. VRN97341A, Plate 3

Job No. VRN9734A, Plate 4

Job No. VRN97341A, Plate 5

Job No. VRN97341A, Plate 7

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926