AN ABSTRACT OF THE THESIS OF

Kurt Shobe for the Master of Science in Physical Science Presented on November 27, 2000

Title: Analysis of Chloride Plume Migration Based on Aquifer Characteristics, Water Well Pumping Rate, Soil, and Stratigraphic Properties

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A study was performed to determine the fate and transport of chlorides in groundwater on and around a Central Kansas refinery. This was done by sampling monitoring wells over a four year period for chlorides and measuring static water level in these wells to determine groundwater flow. Groundwater modeling was also performed to determine the probable source location(s) for the chlorides noted in groundwater and project changes in chloride concentration and movement expected to occur in the future. In addition, chloride source identification was performed after the method of Whittemore to correlate and compare the chemical nature of groundwater taken from the monitoring wells with the postulated source regions. Source identification was also used to verify the results found as part of the groundwater modeling.

Process water for the refinery is taken from four pumping wells located in the northeast part of the refinery facility and operated continuously. These wells pump between 1325 and 3220 liters/min (350 and 850 gpm) and have been pumping long enough that drawdown from these wells has stabilized. The radius on influence for the four wells,

taken as a single system, is estimated at 1.3 km (0.8 mile) on the west side and up to 3.4 km (2 miles) on the east side of the facility. Chlorides located within the radius of influence of these are preferentially drawn to the wells over time.

Based on sampling data and a previous study by Whittemore (1997) two primary chloride source regions were identified. One was a shallow source located on the refinery property, consisting of an unlined impoundment that had contained refinery process water until closure and removal in 1994. The other primary source was the Johnson Oil Field, located approximately 3.4 km (2 miles) east of the refinery. The field contains chloride injection wells and formerly had unlined impoundments holding salt water that had been separated from the crude oil.

Groundwater modeling for the refinery and surrounding property confirmed these source regions and determined that the chloride plume was moving toward the refinery at the rate of approximately 67 meters (205 feet) per year. Source identification of groundwater taken from selected wells also verified these source regions and confirmed the modeling results.

Based on this rate of movement, historic chloride data from wells on and around the facility, and the distance from the source to the pumping wells, it is estimated that the chloride plume from the Johnson Well Field reached the onsite pumping wells approximately ten years ago. Transport time from the shallow onsite source and the pumping wells was estimated at slightly over seven years. The modeling results also indicate that the groundwater quality from the pumping wells will continue to decline over time without remedial action.

Analysis of Chloride Plume Migration Based on Aquifer Characteristics, Water Well Pumping Rate, Soil, and Stratigraphic Properties

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by
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CHAPTER 1

INTRODUCTION

The purpose of this research was to establish the amount, source, and areal extent of chlorides in the vicinity of the subject facility that are affecting or have the potential to affect groundwater quality in that portion of the Equus Beds Aquifer utilized by the facility as part of the refinery operations onsite. To accomplish this, monitoring wells were drilled and used in conjunction with existing wells to sample groundwater beneath the facility and measure its chloride content. The purpose of the groundwater sampling was to delineate the spatial patterns of existing chloride plumes in the vicinity of the refinery. Stratigraphic studies were undertaken to establish the predominant and/or preferential pathways for groundwater and solutes through the aquifer as a function of hydrostratigraphy. In addition, variations in aquifer thickness both on and around the refinery property were mapped to help understand the implications for the zone of influence for pumping wells at the refinery. Results of the stratigraphic work were verified through the use of groundwater modeling on and around the site to determine if the predicted preferential flow paths were indeed influencing groundwater flow. Finally, a chemical signature approach developed by Don Whittemore at the Kansas Geological Survey was used to differentiate between possible sources for chloride pollution measured in groundwater samples from the monitoring wells.

1.1 Refinery Description and Location

The facility studied is an 80,000 barrel per day (bpd) crude oil refinery. This facility is located on about 981 acres of land located approximately one-half mile south of the City of McPherson, Kansas (**Figure 1**). Petroleum refining operations began at this facility in 1933 and refining operations have continued to the present day.

Land use surrounding the refinery is predominantly agricultural (cash-grain operations). Exceptions include a radio station (KNGL) and a closed petroleum product terminal (Derby Refining Corporation) located adjacent to the southeast side of the refinery property, a sand pit located a quarter mile south-southwest of the refinery, and the McPherson Airport located a quarter mile northwest of the refinery.

1.1.2 Previous Investigations:

Since 1986, two separate geologic and hydrogeologic investigations have taken place on the refinery property. The following is a discussion of these investigations, including information pertinent to the present study. Previous studies that have been utilized to present the information contained below include:

- "National Cooperative Refinery Association Hydrogeologic Investigation and Monitoring Proposal"; A&M Engineering & Environmental Services, Inc. 1986.
- Hydrogeologic Investigation Report"; EEI Engineering Enterprises, Inc., 1988.

CHAPTER 2

GEOLOGIC SETTING

2.1 Topography

The region on which the refinery property is situated is a part of the Great Bend Physiographic Province. Topography in the vicinity of the refinery facility is relatively flat (0-1% slopes) (Rott, 1983). East and north of the facility topography ranges from gently sloping to sloping (1-8% slopes) as a result of the incisement of Bull Creek and Dry Turkey Creek into the underlying unconsolidated sediments.

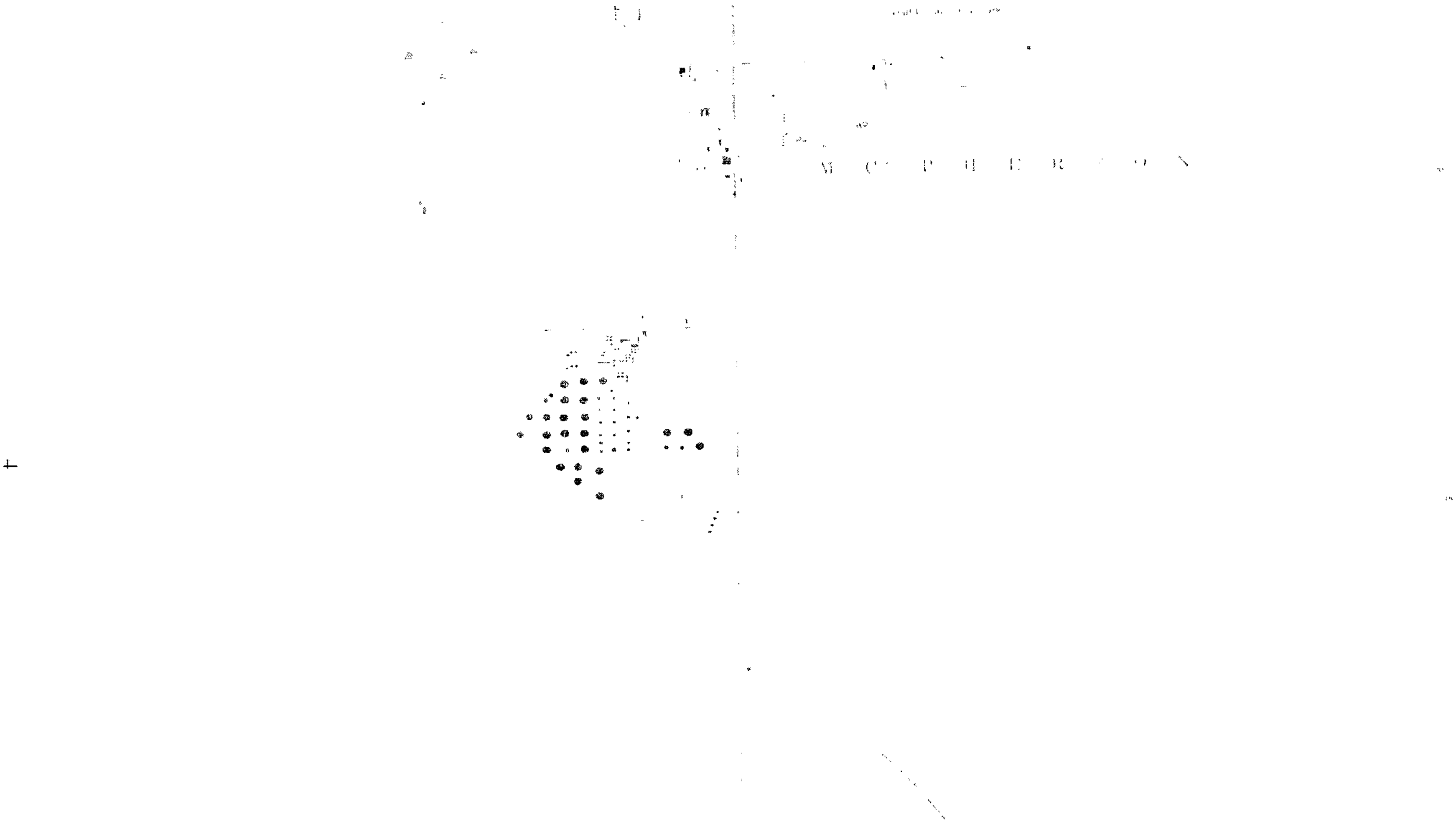


Figure 1 – Refinery and Surrounding Property (USGS 7.5 min. topo)

clay, silt, and gravel. The refinery lies on top of the McPherson formation that lies within the McPherson Valley which is a bedrock channel cut into underlying Permian formations when the ancestral Smoky Hill River flowed southward into the Arkansas River. The McPherson Formation varies in thickness, but is approximately 55-63 meters (170-190 feet) thick beneath the site. The upper part of the McPherson Formation is mainly clay and silty clay with thin (one meter or less) zones with carbonate concretions and silt in the upper 13-23 meters (40-70 ft). The lower part of the McPherson Formation is mainly sand and gravel with clay interbeds and tongues. The clay beds in the lower part range from a meter to 6.5-10 meters (20-30 feet) thick. An erosional unconformity separates the Pleistocene McPherson Formation from the underlying Permian Wellington Shale. The Wellington Shale is gray, bluish gray, and grayish green, medium soft to hard and calcareous, with thin argillaceous limestone and gypsum interbeds (McElwee, et. al. 1979, Spinazola, et. al., 1985). Water is scarce in the Wellington, however salt deposits are known to be imbedded in the shale and chloride rich groundwater has been reported from the Wellington (McElwee, et. al., 1981).

2.2.1 Results of Previous Studies at the Facility

The previous geologic studies performed onsite (see Section 1.1.2) show that the stratigraphic section above the Wellington at the site consists of about 16.5 meters (50 feet) of silt and clay, over 3-7 meters (10 to 20) feet of sand and fine gravel, overlying 10-13 meters (30 to 40 feet) of silty clay with fine sand. The basal unit consists of 7-13 meters (20-40 feet) of sand and gravel with clay lenses. The reports noted changes in stratigraphy from boring to boring, which was indicative of reworked stream deposits.

Soil samples (**Appendix 1**) taken from borings drilled to approximately 7 meters (20 feet) below ground level (bgl), in the vadose zone, reveal 65% to 85% clay, with silt comprising the vast majority of the remaining sediments. One remolded sample was tested for hydraulic conductivity and had a value of 4×10^{-6} cm/s. This indicates that recharge from the overlying vadose zone is minimal.

2.2.2 Geologic Information Gained as Part of the Current Study

2.2.2a Field Activities:

As part of the current study, sixteen (16) monitoring wells were drilled on and around the refinery facility in September and October 1999. Drilling logs for these wells can be found as part of **Appendix 1**. Six of these wells were completed in the upper part of the saturated zone (36-41 meters or 110 to 124 feet bgl), with the remaining ten completed to Wellington bedrock (between 49-60 meters or 150 to 183 feet bgl). An experienced field geologist was present during all drilling activities, with oversite provided by the author.

The shallow wells were advanced utilizing hollow stem augers, which allowed relatively undisturbed soil samples to be taken. As part of the drilling activities, these were collected and analyzed at five (5) foot (1.6 meter) intervals from ground surface to completed depth. For the deep wells, mud rotary drilling technique was utilized as hollow stem augers could not be advanced to bedrock. Soil samples from these wells were also collected at five (5) foot intervals. Due to the nature of the drilling technique, these samples were highly disturbed. However, the samples taken are felt to be fairly representative of the composition of the material at each sample depth, in particular those taken in the saturated zone. Most of the saturated zone samples were described as sand, with sand and gravel at lower depths. Samples taken from the saturated zone that contained appreciable clay content could be readily distinguished, even though these samples had been reworked by the drilling activities.

2.2.2b Stratigraphic Study

The stratigraphic sections across the site **(Figures 3 and 4)** were generated utilizing data from the monitoring wells completed in September and October 1999. The sections were made by constructing a N-S and E-W line across the site, respectively, which intersected as closely as possible the greatest number of wells. Distances between well logs were based on surveyed data, and the distances between wells on the cross-section were based on the interpolated location of each well placed on the transect line.

The stratigraphy revealed by the well logs shows a lithology primarily composed of alternating layers of sand and clay, with weathered shale and shale bedrock. Review of the N-S and E-W cross sections reveals a fairly consistent lithology across the study area, in good agreement with the results noted in Section 2.2 above. Thin, localized clay stringers and silt stringers are located at various depths within the sand; however the cross-sections do not indicate that any of these clay and silt lenses would be a significant deterrent to vertical groundwater migration.

Review of the E-W cross-section also shows that the saturated thickness increases westward underneath the refinery. Monitoring well 110D, the easternmost monitoring well, shows a saturated thickness of only about 16 meters (50 feet), while the recovery well (RW) on the westernmost side of the cross-section indicates a saturated thickness of nearly 26 meters (80 feet). In addition, it can be clearly seen that the sand content generally increases westward. The middle clay layer decreases in elevation eastward to the point that the clay intersects the static water level elevation. However, the clay layer pinches out west of 20S, leaving a continuous column of sand from approximately 475 meters (1450 feet) above mean sea level (msl) to bedrock at 436 meters (1330 feet) msl. **Figure 5** illustrates a plan view of the North-South and East-West cross sections for reference as to location of the cross sections in relationship to the facility.

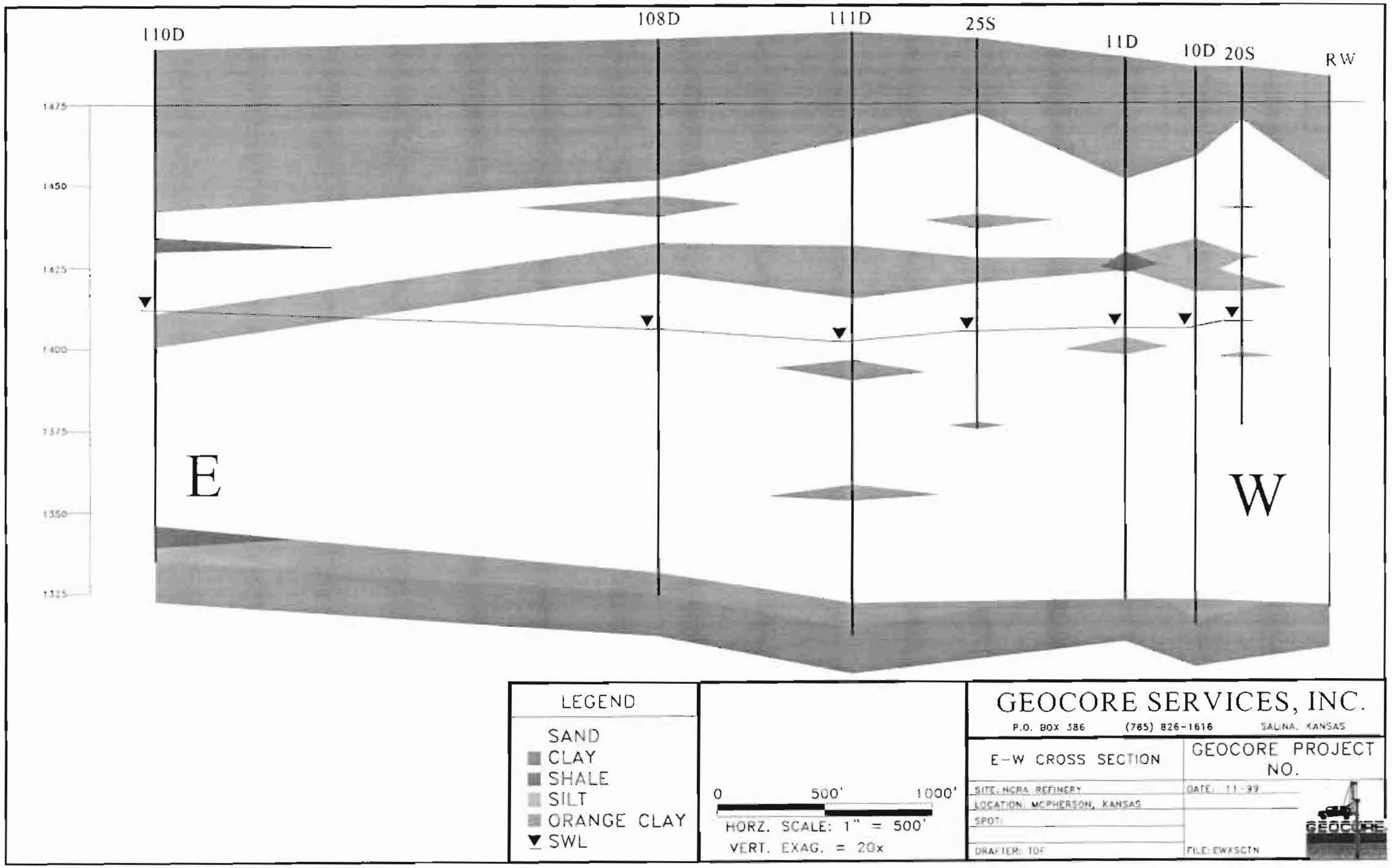


Figure 3 - East - West Cross Section

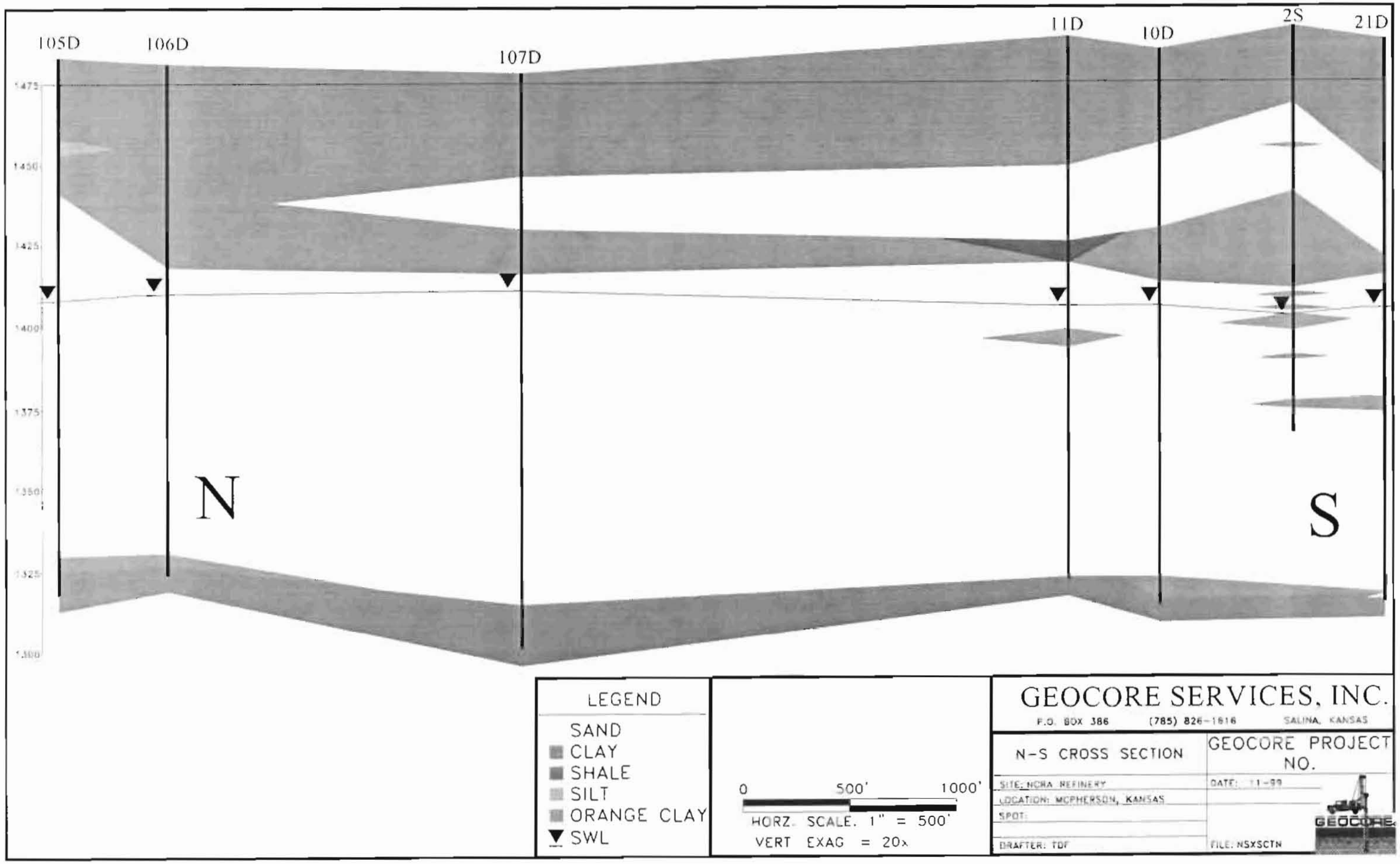


Figure 4 – North-South Cross Section

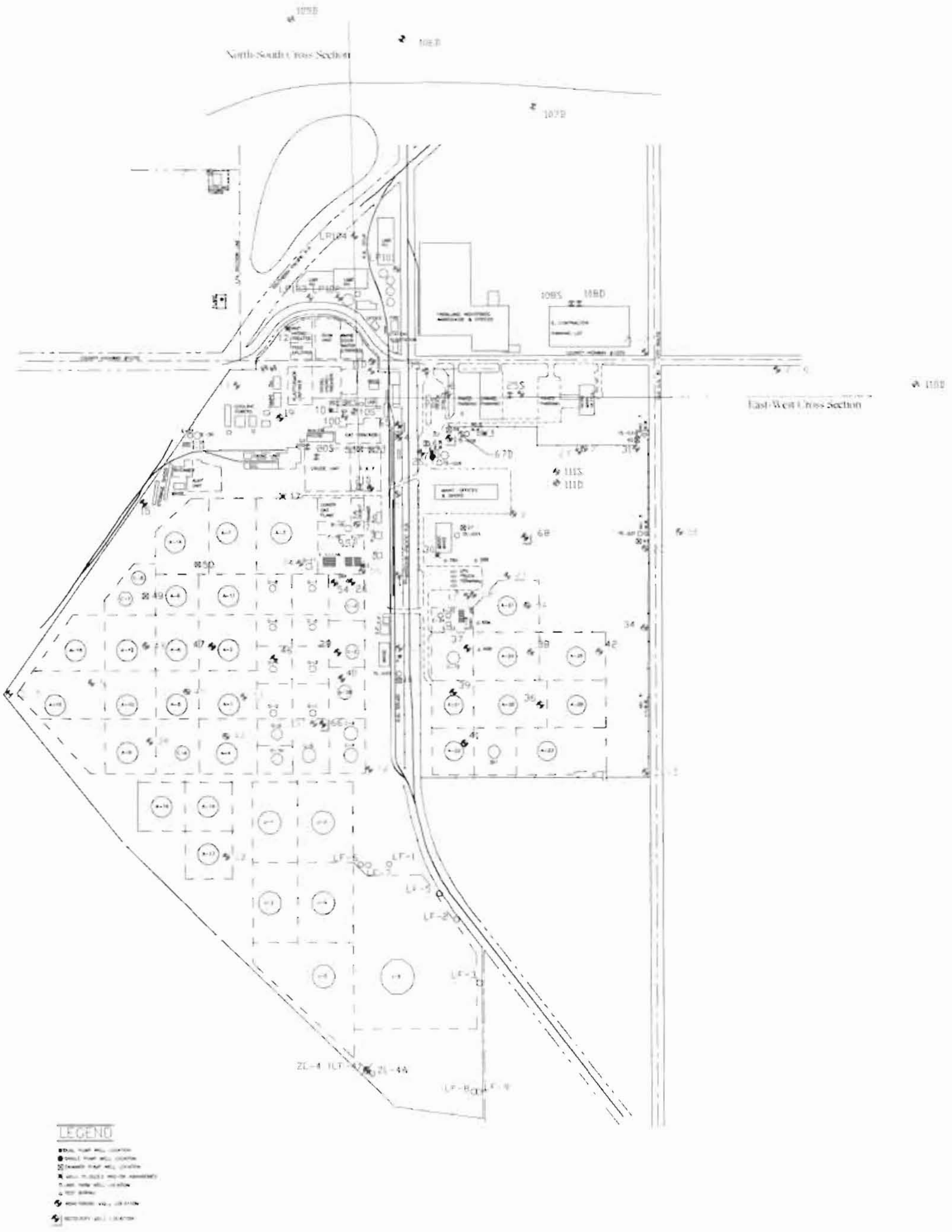


Figure 5 – North-South & East-West Cross Sections; Plan View

CHAPTER 3

AQUIFER IDENTIFICATION AND PROPERTIES

The sand and gravel units in the lower part of the Pleistocene McPherson Formation comprise the aquifer beneath the site. This aquifer is referenced as the "Equus Beds". The "Equus Beds" aquifer is an unconfined type. The hydraulic characteristics of the "Equus Beds" aquifer at the refinery have been determined from tests conducted on the monitoring wells and from published reports.

3.1 Results of Previous Investigations:

3.1.1 Aquifer Characteristics:

As noted above, the facility lies above the McPherson channel, an area characterized by deposits from ancient stream channels. Many of the sediments comprising the older part of the McPherson Formation, into which the McPherson channel was cut, were deposited by southward flowing streams. Streams contributing to the deposition entered from the north, northeast, and northwest. Smaller streams entered from the east and northeast. All streams were nearly at grade, resulting in the copious deposition of silt in the floodplain (EEI report to NCRA, 1986).

The saturated zone, known as the "Equus Beds" historically began at a depth of approximately 16 meters (50 feet) bgl. This upper part of the aquifer consisted of the 3 to 6 meter (10 to 20 foot) section of sand directly underlying the top 16 meters (50 feet) of clay and silt. Pumping at the refinery has reduced this zone and it is no longer found in the area of the refinery.

The saturated zone currently begins roughly 25 to 29 meters (75 to 90 feet) bgl at the site and varies in thickness due to changes in bedrock topography across the site. A maximum saturated thickness of 42 meters (128 feet) has been reported on the west side of the refinery and a minimum of 24 meters (74 feet) on the east side.

Chloride sampling of the four water supply wells was performed as part of the 1986 study and results of this sampling is given as **Figure 6**. It is evident from the results illustrated that chloride contaminants had not affected any of the pumping wells at that time.

3.1.2 Aquifer Hydraulics:

Groundwater flow in the area around the Refinery is strongly influenced by the presence of four large pumping wells located in the northeast corner of the facility **(see Figure 5 and maps, Appendix 4)**. The area of influence for these pumping wells was estimated at 1.3 km (0.8 mile) along the western edge and postulated to be at a similar range on the east side of the pumping wells. Both reports indicated that the pumping wells have established a dominant cone of depression influencing the groundwater flow in and around the refinery area. Groundwater flow absent of the pumping wells was reported to be toward the northeast at a low gradient, however no source is given to validate this assumption.

Figure 6 – Chloride Levels in the Pumping Wells, September 1986 (From A&M, 1986)

GROUND WATER QUALITY

Well No.	Date	pH	Specific Conductance	Chloride mg/L	Sulfate mg/L	TOC mg/L	TOH mg/L
W-1	9-25-86	8.1	550	37	23	37	0.02
W-2	9-25-86	7.4	670	49	58	34	0.04
W-3	9-25-86	10.6	510	32	36	13	0.03
W-4	9-25-86	7.1	500	41	22	52	0.02
Blank	9-25-86	*	*	0.4	0.7	4.0	0.02
P-3	5-7-81	6.8	900	240	25	28	*
P-6	5-7-81	6.8	1240	180	2	50	*
P-8	5-7-81	6.9	880	97	31	10	*
P-9	5-7-81	6.9	770	110	15	10	*

*No Analysis

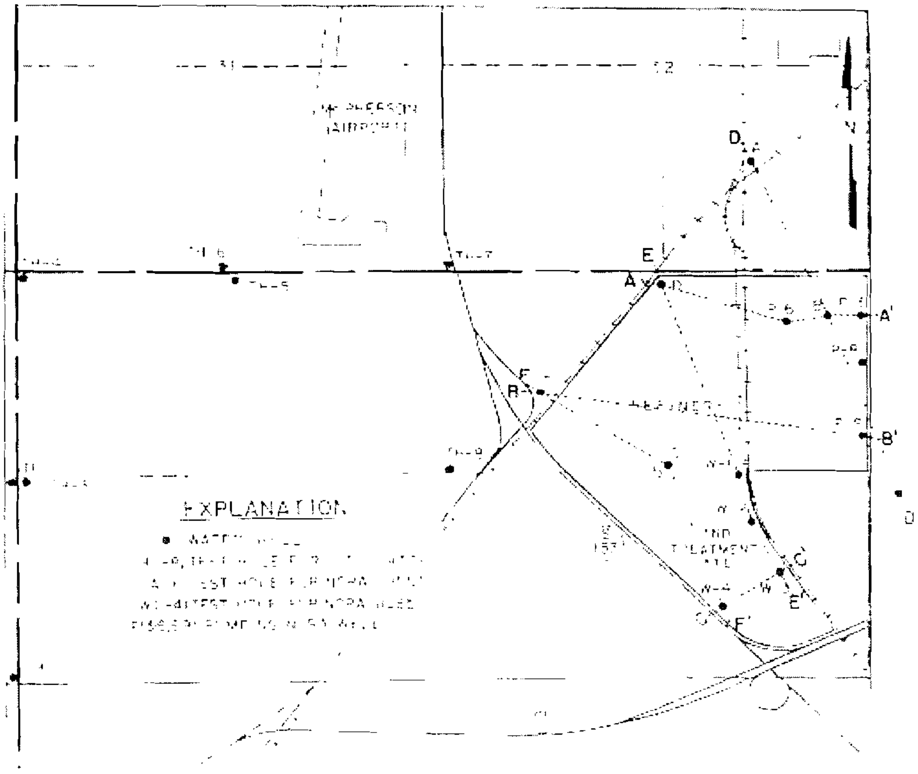
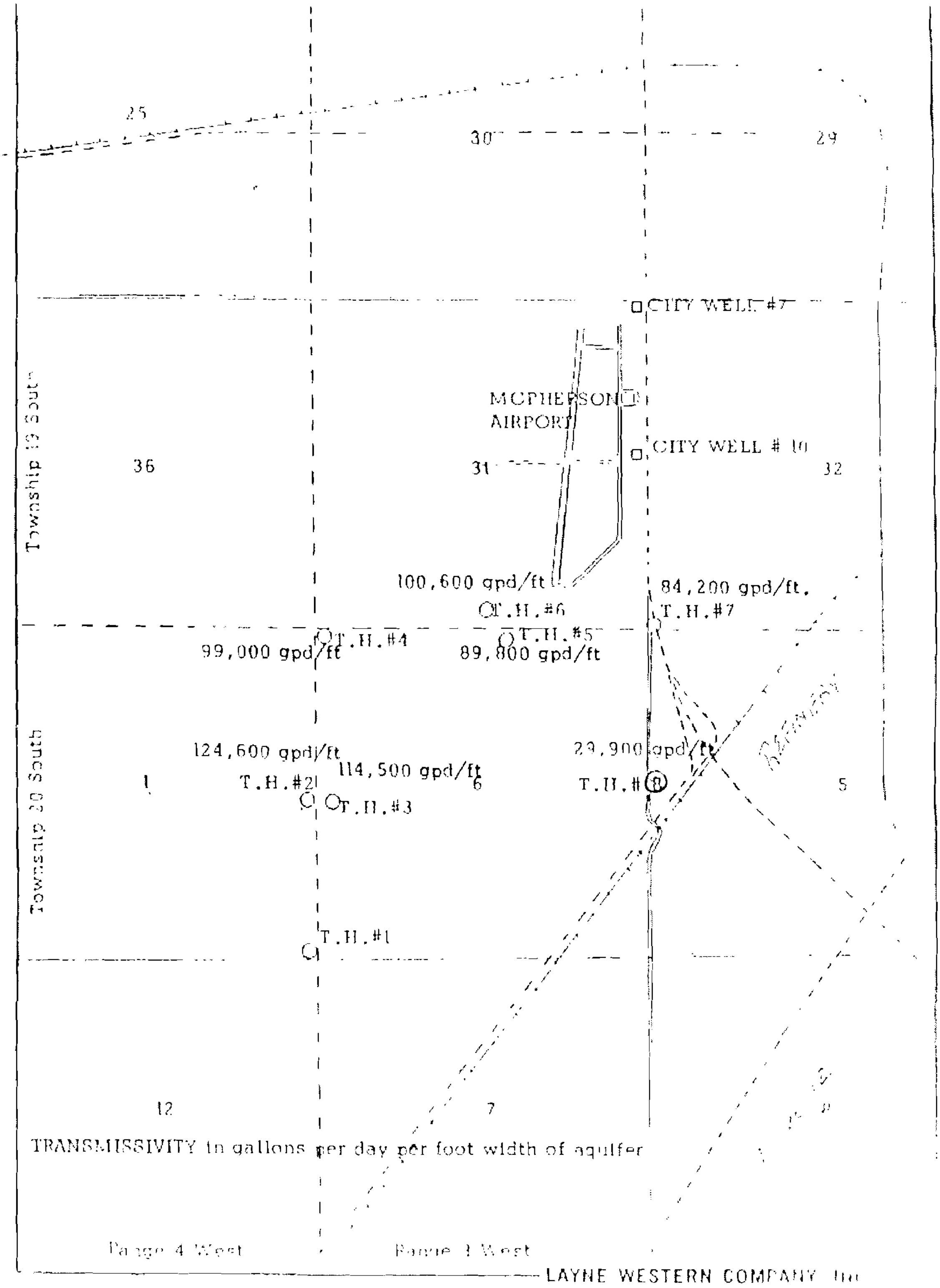


Figure 7 – Transmissivity Data (From A&M, 1986)



Transmissivity data was collected from a number of the wells drilled in 1986. Values ranged from a high of 1545 m^2/d (124,600 gpd/ft) on the far west side of the property to a minimum of 370 m^2/d (29,900 gpd/ft) on the east side (**See Figure 7**). Values from wells on the north side of the refinery indicated a transmissivity of approximately 1240 m^2/d (100,00 gpd/ft). No information is available for the south side of the facility. Transmissivity under the refinery was estimated to range from 248 to 620 m^2/d (20,000 to 50,000 gpd/ft). Pump tests were performed for selected wells as part of the study done in 1988. Results showed that the #10 water well was tested to have a transmissivity of 310 m^2/d (25,000 gpd/ft) and the #9 water well was tested to have a transmissivity of 646 m^2/d (52,100 gpd/ft). The previous studies do not present any information which might explain the variation s in the transmissivity values.

Permeability in the #9 water well was estimated at 1 X 10^{-1} cm/s. Water usage from the wells was estimated at an average of 7575 l/min (2000 gal/min), resulting in a yearly usage of 3226 acre-ft per year. The reported hydraulic conductivity values range from 3.7 to 14 m/d (90 to 340 gpd/ft^2). The vertical gradient was calculated for test wells completed in the area of the land treatment unit, located on the south side of the facility. The report indicated that vertical gradients was downward in the vicinity of 3 of the 4 wells, but were upward in the vicinity of "well 3", near the present location of LF-3.

3.2 Results from the Current Study

3.2.1 Aquifer Characteristics

As part of the current study, regional groundwater flow was studied to determine the potential for off-site migration of chlorides onto the refinery property. This information can be used in conjunction with the radius of influence for the four pumping wells to determine if chlorides from off-site would be preferentially transported to the pumping wells.

3.2.2 Groundwater Flow

Figure 8 shows the configuration of the water table in the vicinity of the study area. It was created using forty-five (45) water table elevation control points downloaded from the Kansas Geological Society (KGS) Wizard database. The regional groundwater flow around the refinery property is complex. The predominant flow directions in the area around the refinery are to the north, northwest, or west. In the immediate vicinity of the refinery it can be seen that groundwater flow converges toward the pumping wells on-site. Outside of the zone of influence of the pumping wells, it may also be moving west, toward the center of the McPherson Channel located west of the refinery.

It can also be seen that there is a groundwater divide (or a groundwater high) to the south of the refinery. Groundwater north of this divide flows preferentially north toward the Smoky Hill River; groundwater south of this divide flows south towards the Little Arkansas River. The pumping wells at the refinery will capture water moving west toward the center of the McPherson Channel, and will also capture water from the south which is preferentially moving north due to the groundwater divide. Water on the west side of the refinery which is captured by the pumping wells will be diverted from a north-north-west flow direction to an easterly flow direction. Likewise, water in the aquifer located north of the refinery captured by the pumping wells radius of influence will be diverted approximately 180 degrees from the regional flow direction.

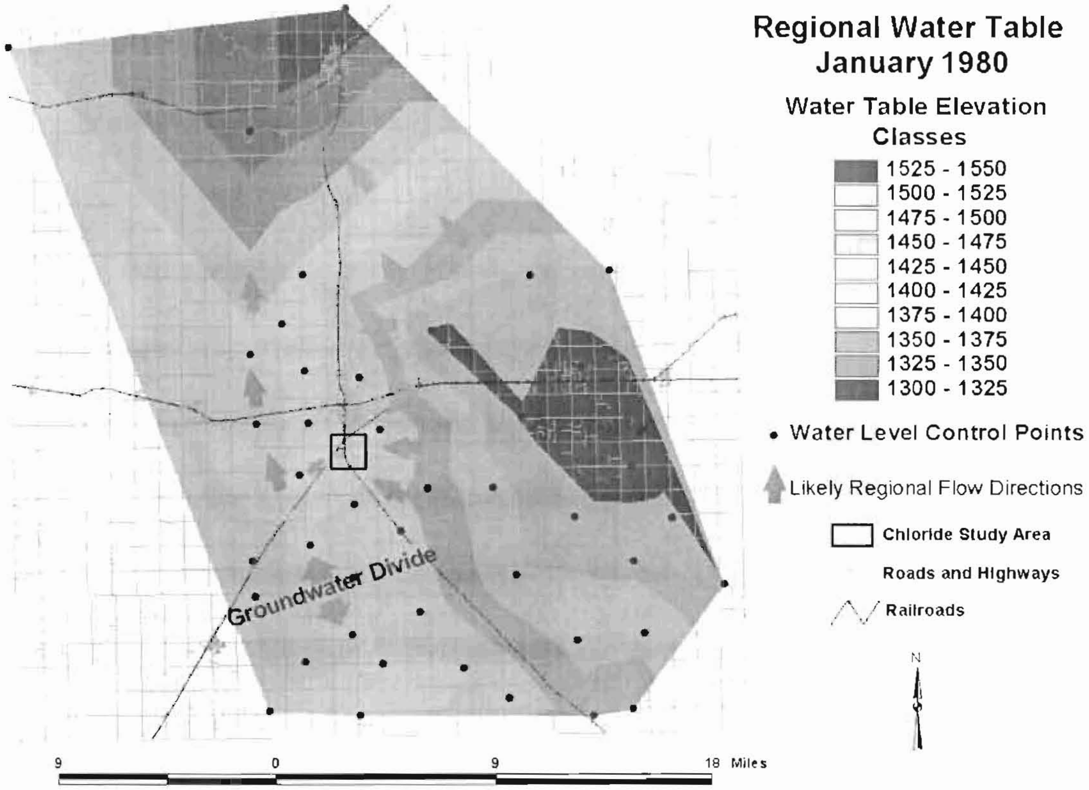


Figure 8 – Regional Groundwater Flow (ft MSL) 1980.

3.2.3 Saturated Thickness and Bedrock Topography

To better establish the saturated thickness within the study area, an interpolated grid of bedrock topography (**Figure 9,** taken from Sleezer, 2000) was prepared which encompassed a two square mile area centered on the refinery. This study area was further subdivided into the refinery study area and the chloride study area. The chloride study area was the extent of the area modeled using Groundwater Vistas™, a windows based groundwater model based on the USGS groundwater model ModFlow.

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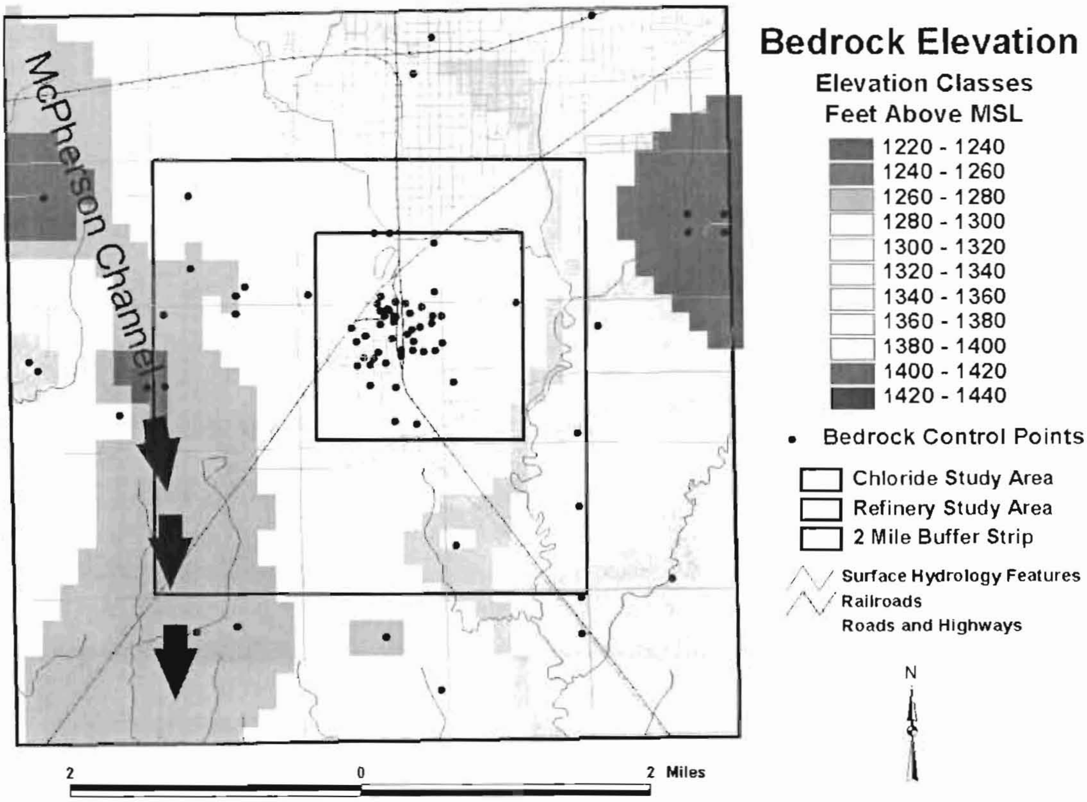

Figure 9 – Interpolated Bedrock Topography (ft MSL)

A review of **Figure 9** shows that the bedrock elevation within the map area varies significantly from west to east. Based on this figure, bedrock elevation on the east side of the chloride study area was estimated at 440 meters (1340 feet) above mean sea level (msl), while the bedrock elevation on the west side of the chloride study area was measured at 420 meters (1280 feet) msl.

The water table elevation (**Figure 10**) across the chloride study area was determined by measurement of static water level elevation in the refinery wells and

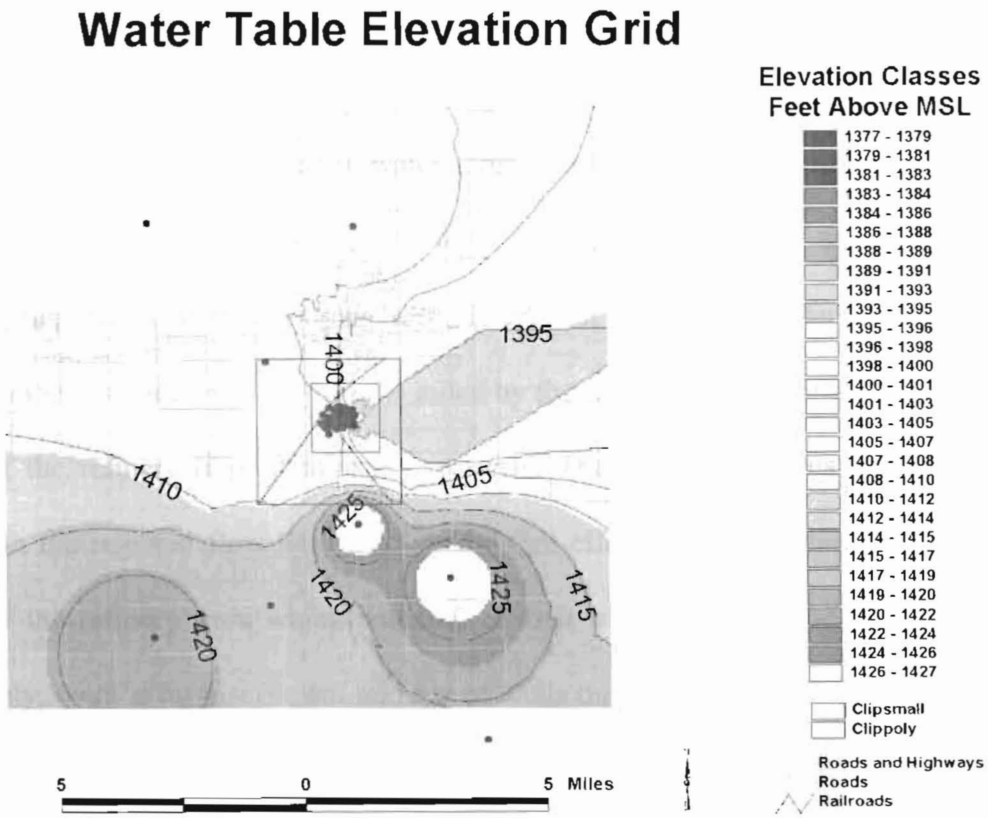

Figure 10 – Static Water Level Elevations (after Sleezer, 2000)

published values taken from the aforementioned KGS Wizard database. This indicates that static water levels vary from 462 meters (1410 feet) msl on the west side of the refinery to 456 meters (1390 feet) msl on the east side of the refinery.

Using these two views, the variability in saturated thickness across the chloride study area can be shown to vary from a minimum of approximately 16.4 meters (50 feet) on the east to a maximum of 42.6 meters (130 feet) on the west. This differential in saturated thickness indicates that the radius of influence for the pumping wells (taking all four wells as essentially one system) could be significantly greater on the east side of the refinery as opposed to the west side. This assumes that roughly an equal volume of water is pulled from the aquifer by the pumping wells on all sides.

3.2.4 Radius of Influence for the Pumping Wells

This information is significant when attempting to determine the potential source areas for the chlorides noted in water samples taken from the pumping wells. A larger radius of influence means that the area available for potential sources to be captured by the effects of the pumping wells is greater. In addition, a larger radius of influence on the east side of the refinery is aided by the fact that the regional flow on the east side of the refinery is predominantly westerly. Therefore, the radius of influence coupled with the regional flow will have an additive effect when determining the total area east of the refinery from which potential sources of chloride can be drawn from. Unfortunately, there is an insufficient number of wells on the east side of the refinery to make an accurate determination of the true radius of influence in this direction.

However, it was possible to estimate radius of influence on the west side of the refinery. **Figures 11-18** illustrate static water level elevation vs distance for all four of the pumping wells. As the wells operate 24 hours per day every day, it was not possible to establish the static water level elevation of the wells absent the effects of pumping. Therefore, it was not possible to establish the ambient static water level for comparison to measured values in monitoring wells at various distances from the pumping wells. Normally, this ambient value would be compared to the measured values taken while the pump test was ongoing and after the measurements had stabilized when attempting to discern the radius of influence.

To approximate the static water level recovery rate with distance, a best fit line was added to each graph in **Figures 11-14**. The radius of influence was estimated as the point at which the measured data intersects the best fit, or hypothetical recovery. It was postulated that the point at which the measured recovery rate was less than the hypothetical recovery rate would represent the extent of the pumping wells influence.

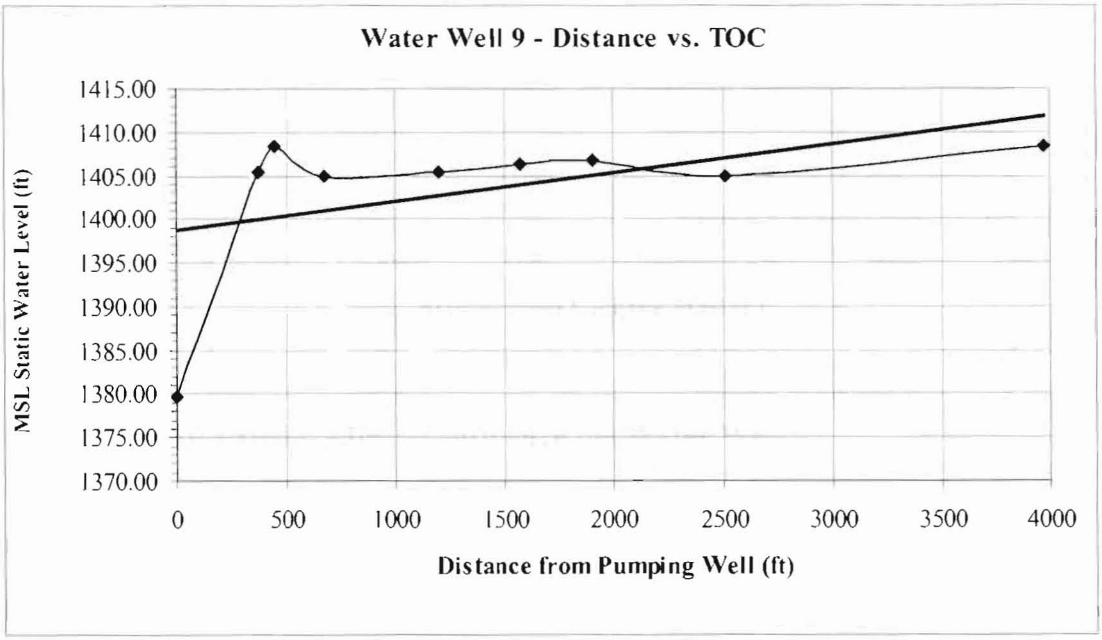

Figure 11 – Estimated Radius of Influence for Water Well 9

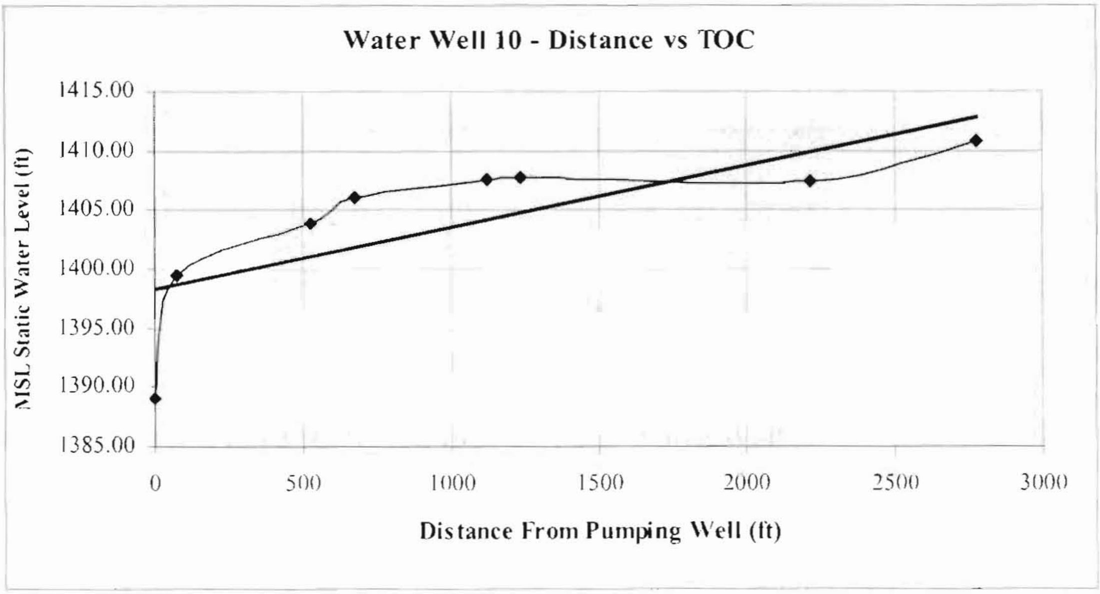

Figure 12 – Estimated Radius of Influence for Water Well 10

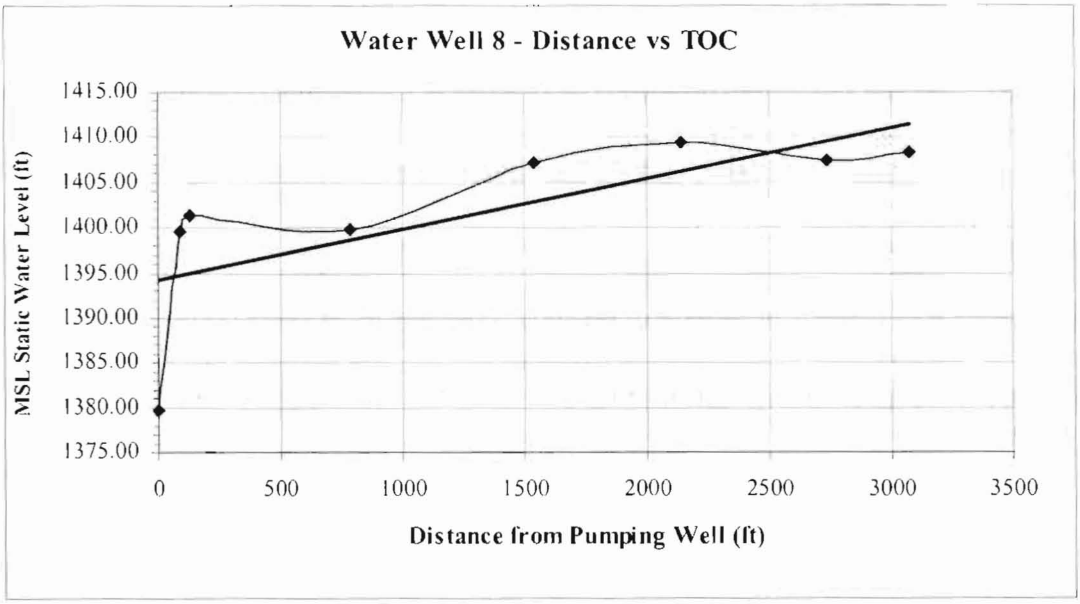

Figure 13 - Estimated Radius of Influence for Water Well

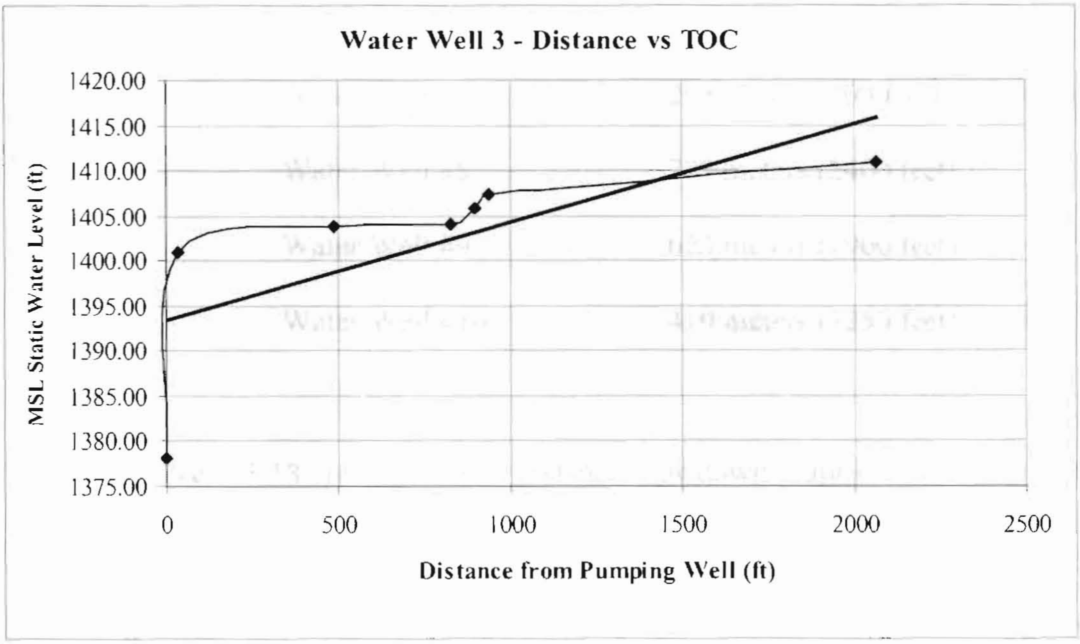

Figure 14 - Estimated Radius of Influence for Water Well 3

This assumption can be tested to a degree by comparisons between the intersection point and the approximate static water level elevation believed to be outside the radius of influence of the pumping wells. As noted earlier, the static water level elevation on the west side of the study area is approximately 1410 feet msl. The distance between the edge of the study area and the pumping wells is assumed to be at or beyond the effective radius of influence of the four well complex. This distance is approximately 1312 meters (4000 feet) from pumping well #9, which is in general agreement with the estimated radius of influence of 1.3 km (0.8 mile) given as part of a previous hydrogeologic investigation at the site (see Sec. 1.1.1 above).

Based on analysis of these graphs, the radius of influence for the four pumping wells were estimated as:

Water Well #3	295 meters (900 feet)
Water Well #8	787 meters (2400 feet)
Water Well #9	623 meters (1900 feet)
Water Well #10	410 meters (1250 feet)

Figures 15-18 are logarithmic distance drawdown graphs with a curve fitted to the measured data and taken out five log periods to estimate changes past the available distances. Correlation coefficients were calculated for each curve and are also shown on the graphs (R^2). This curve-fitting technique was utilized to estimate the static water level elevation changes with distance beyond the available data. These graphs suggest that the radius of influence may be somewhat greater than that indicated by **Figures 11-14**.

As can be seen from **Figures 15-18** below, the curves for water wells #3, #8, and #10 continue to increase slightly beyond the available data. As this is a theoretical curve, it is impossible to establish the point on the curve which intersects the actual static water level elevation. However, if 462 meters (1410 feet) msl is used as an estimate of this elevation, theses graphs indicate that the radius of influence for the pumping wells would be approximately:

Water Well #3	492 meters (1500 feet)
Water Well #8	1148 meters (3500 feet)
Water Well #9	820 meters (2500 feet)
Water Well #10	656 meters (2000 feet)

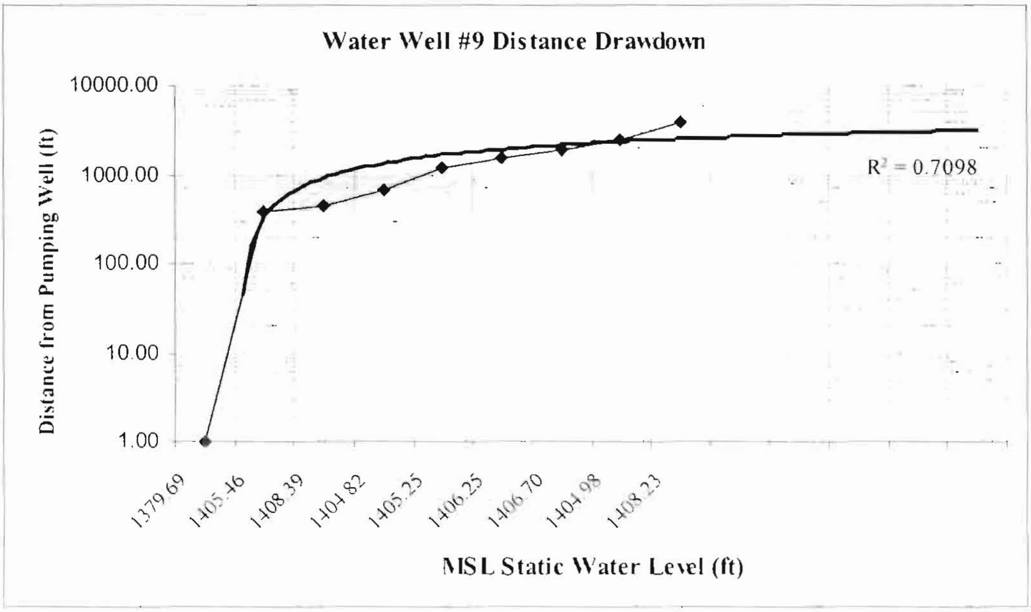

Figure 15 - Distance Drawdown Radius of Influence for Water Well 9

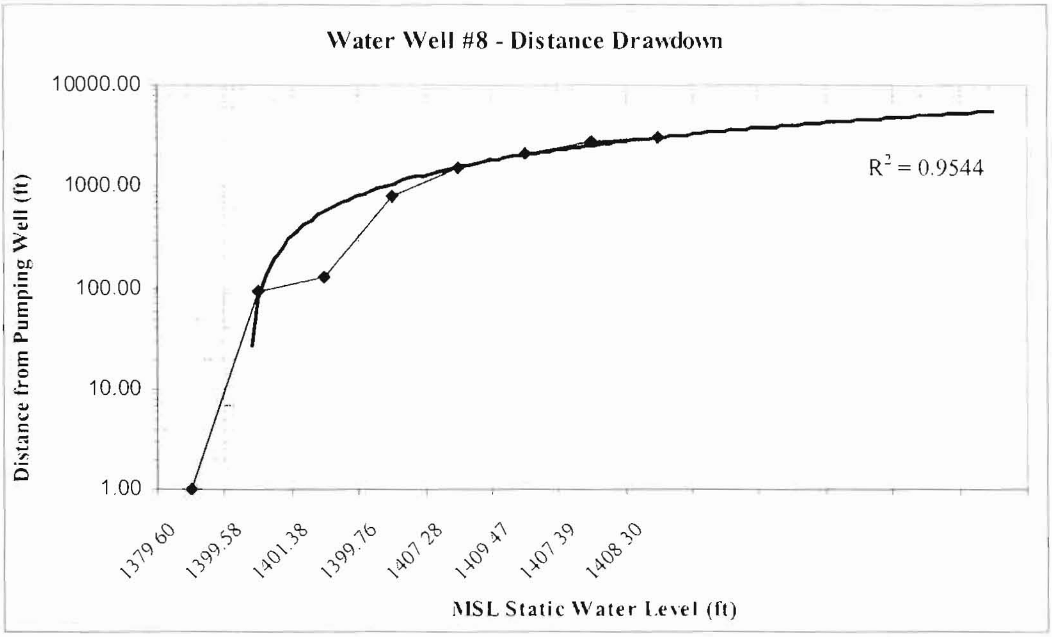

Figure 16 – Distance Drawdown Radius of Influence for Water Well 8

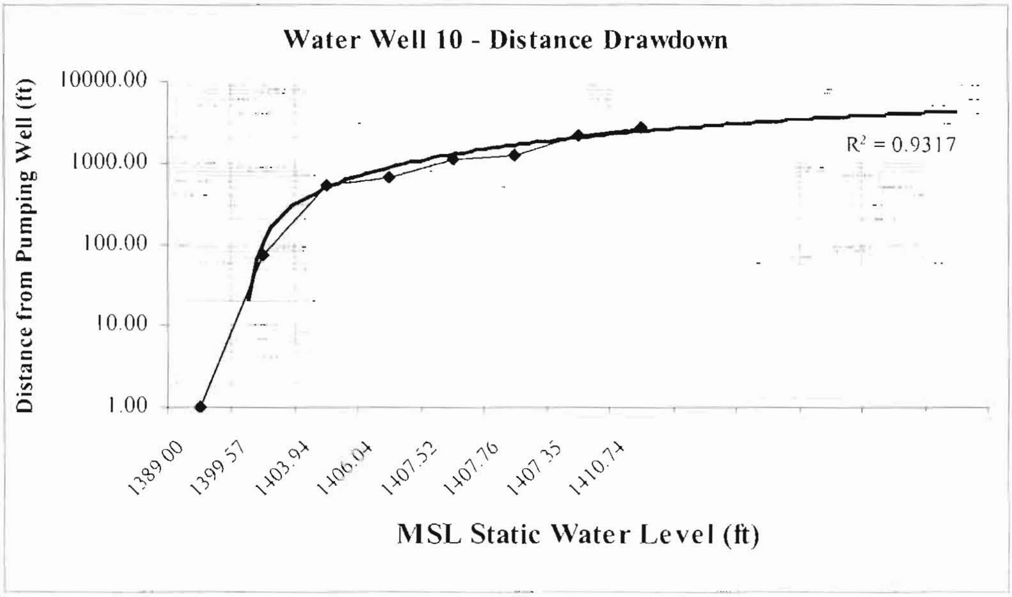

Figure 17 – Distance Drawdown Radius of Influence for Water Well 10

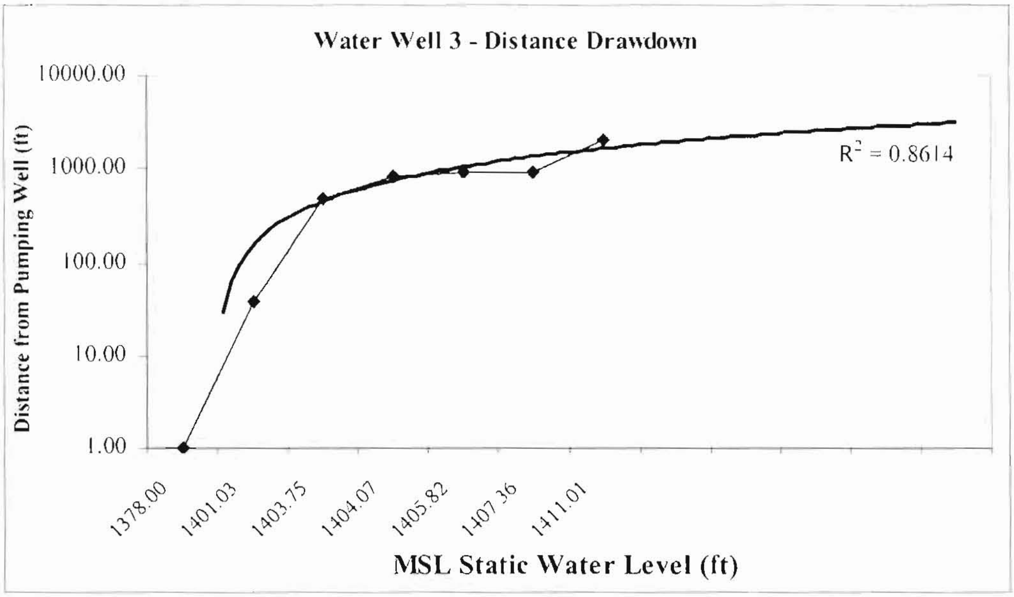

Figure 18 – Distance Drawdown Radius of Influence for Water Well 3

3.2.5 Storativity, Transmissivity, and Hydraulic Conductivity

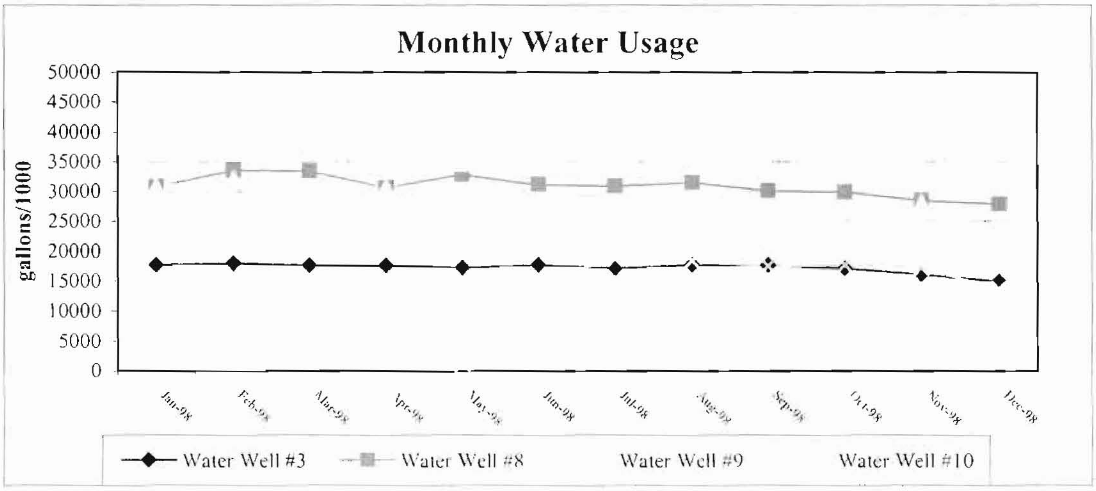

Figure 19 – Monthly Water Usage

Figure 19 illustrates the average pump rate for the water supply wells during 1998. Values shown here represent the average daily pump rate for each month of the year and each well. Using the Radius of Influence information contained above and the known average pump rate taken from refinery records (**Appendix 2**), aquifer characteristics were derived using the methods given as part of "Basic Groundwater Hydrology"; USGS Water Supply Paper 2220, Heath, 1991.

Table 1 – Average Pump Rate (gpm) for the Four Pumping Wells

Water Well #3		*Water Well #8*		*Water Well #9*		*Water Well #10*	
Mean	376.01	Mean	679.67	Mean	809.46	Mean	362.06
Median	380.00	Median	680.00	Median	840.00	Median	376.50
Mode	400.00	Mode	700.00	Mode	900.00	Mode	400.00
Standard Dev.	33.40	Standard Dev.	49.58	Standard Dev.	107.04	Standard Dev.	83.83
Minimum	40.00	Minimum	542.00	Minimum	195.00	Minimum	135.00
Maximum	430.00	Maximum	812.00	Maximum	970.00	Maximum	750.00
Count	338.00	Count	338.00	Count	338.00	Count	338.00

Table 2 – Average Depth to Water (bgl) for the Four Pumping Wells

Water Well #3		*Water Well #8*		*Water Well #9*		*Water Well #10*	
Mean	118.03	Mean	110.11	Mean	110.39	Mean	116.05
Median	118.00	Median	111.00	Median	110.00	Median	119.00
Mode	119.00	Mode	112.00	Mode	110.00	Mode	120.00
Standard Dev.	1.86	Standard Dev.	4.25	Standard Dev.	2.21	Standard Dev.	13.17
Minimum	105.00	Minimum	98.00	Minimum	103.00	Minimum	17.00
Maximum	121.00	Maximum	116.00	Maximum	118.00	Maximum	121.00
Count	123.00	Count	123.00	Count	123.00	Count	123.00

The Jacob Time-Drawdown analysis and Jacob Distance-Drawdown analysis was used to estimate the aquifer properties. Results shown in **Table 2** above were used to determine the average drawdown at each pumping well. Time-Drawdown analysis was used to determine the time required for the cone of depression to reach steady state. This calculation is based on the formula developed by Jacob (1950):

$$t_c = 7{,}200r^2S/T$$

Where t_c = the time in minutes at which steady state conditions exist, r = the outermost distance from the pumping well (in meters), S = the estimated storage coefficient (dimensionless), and T is the estimated transmissivity, in square meters per day.

Values used to determine the time to reach steady state were determined as follows:

The estimated Storage Coefficient (S) of $10^{-3}$was taken from Heath (1991). The outermost distance from the pumping well (r) was taken as 1304 meters (3975 feet), which was the measured distance from WW#9 to monitoring well ZL-5

Transmissivity was calculated from the formula given by Jacob (1950):

$$T = 70Q/\Delta S$$

Where Q = the pumping rate (in gal/min); taken from **Table 1** above, and ΔS = the drawdown across one log cycle (in feet), taken from **Figures 11-14** above. This equation is specifically tailored for English units; therefore the English unit results were then translated into metric values.

Transmissivity for well #9 is then:

$$T = 70(809.46 \text{ gpm})/2.77 \text{ feet}$$

$$T = 1900\ m^2/d\ (20{,}455\ ft^2/day)$$

Transmissivity was similarly calculated for each pumping well and is listed on **Table 3** below. The calculated values and the averages are:

Water Well #3	336.7 m^2/d (3625 ft^2/day)
Water Well #8	605 m^2/d (6517 ft^2/day)
Water Well #9	1900 m^2/d (20,455 ft^2/day)
Water Well #10	262 m^2/d (2822 ft^2/day)
Average of all wells	**776 m^2/d (8355 ft^2/day)**

The time required to reach steady-state conditions, using WW#9, is then:

$$t_c = 7{,}200r^2S/T$$

$$t_c = 7{,}200(1404^2\ m)(10^{-3})/(1900\ m^2/d)$$

$$t_c = 5537\ minutes$$

Time was similarly calculated for each pumping well and is listed on **Table 3** below. Using the information calculated above, storativity could be calculated using the formula by Jacob (1950):

$$S = Tt/640r_o^2$$

Where S = Storativity, T = Transmissivity, t = time, and r_o = distance from the pumping well to the point where the ambient static water level elevation at the pumping well intersects the zero-drawdown line (**see Figures 7-10**). This formula is also designed specifically for English units; however as Storativity is a unitless value, no unit conversion is necessary. Again using WW#9, the storativity is calculated as:

$$S = (20{,}455\ ft^2/day)(5537\ min) / 640\ (1900\ feet)^2$$

$$S = 0.05$$

Storativity was similarly calculated for each pumping well and is listed on **Table 3** below. Using the transmissivity values calculated above and the measured aquifer thickness known from the onsite monitoring wells, it was possible to calculate the hydraulic conductivity (***K***) at the pumping wells. The formula used to determine hydraulic conductivity was taken from Heath (1991) and is:

$$K = T/b$$

Where K = hydraulic conductivity (m/day), T = transmissivity, (m^2/d) and b = aquifer thickness (m). For water well #9, the hydraulic conductivity was calculated as:

$$K = (2736\ m^2/d\ ) / (31.2\ m)$$

$$K = 70.9\ m/day$$

Hydraulic Conductivity was calculated similarly for all wells and the values are listed in **Table 3** below.

Table 3 – Aquifer Characteristics

Pumping Well	Zero-Drawdown	Transmissivity	Storativity	Hydraulic	Time to Steady
	Intersection (ft)	(ft^2/day)	Unit less	Conductivity (ft/day)	State (min)
Water Well #3	900	3625	0.06	41.2	7961
Water Well #8	2400	6517	0.018	76.7	9914
Water Well #9	1900	20,455	0.05	216.3	5537
Water Well #10	1238	2822	0.056	36.7	22,798
Average	**1610**	**8355**	**0.046**	**92.7**	**11,553**

The average value for hydraulic conductivity is in good agreement with published reports (McElwee, et. al, 1979, Spinazola, et. al., 1985, Williams, et. al, 1949) which indicate that a hydraulic conductivity in the range of 33 m/d (100 ft/day) is expected at the site. Heath (1991) shows hydraulic conductivity for medium to coarse sand ranging from 3.3 to 33 m/d (10 to 100 ft/day), again in good agreement with the calculated numbers.

In an effort to verify the hydraulic conductivity values calculated above, the vertical potential gradient (VPG) was calculated for a number of the nested well clusters located across the study area. Hydraulic conductivity was then calculated at each well cluster.

The formula used for VPG was taken from Darcy's law (Heath 1991) and is:

$$VPG = dh/dl$$

Where

$$VPG = \frac{\text{shallow well water elevation (ft)} - \text{deep well water elevation (ft)}}{\text{mid-point of the shallow well screen(ft)} - \text{mid-point of the deep well screen (ft)}}$$

Hydraulic conductivity is also found using Darcy's equation (Heath 1991):

$$Q = KA(dh/dl)$$

Where Q = the pump rate (assumed to be 1 l/m) and A = the cross-sectional area (also assumed to be 1 m^2), K and dh/dl are as above. Rearranging terms and eliminating the unit values gives

$$K = dl/dh$$

Giving hydraulic conductivity as the inverse of VPG, assuming vertical flow of 1 liter per minute through an area of 1 square meter. Results for the calculations illustrated above are given below as part of **Table 4**

Top of casing (TOC) elevations were established by a registered land surveyor at the time the wells were completed. MSL SWL elevations were measured on November 15 and 16, 1999. Screen length and total depth measurements were taken from well logs. The average hydraulic conductivity calculated using the nested well clusters assuming unit values for area and pumping rate was 29.7 m/d (90.6 ft/day), which is in good agreement with the average calculated hydraulic conductivity value of 30.4 m/d (92.7 ft/day) found using the pumping wells.

Table 4 - Vertical Potential Gradient (dh/dl) and Hydraulic Conductivity (ft/d)

Monitoring Well	MSL TOC	MSL SWL	Screen Length	Total Depth	MSL Total Depth	Vert. Gradient (ft/ft)	Estimated K (ft/d)
10S	1487.240	1406.720	25.000	120.000	1367.240	0.201	4.969
10D	1487.510	1406.070	20.000	171.000	1316.510		
11S	1490.360	1405.990	30.000	88.000	1402.360	-0.005	214.000
11D	1491.640	1406.220	20.000	167.500	1324.140		
108S	1497.310	1405.820	25.000	110.000	1387.310	-0.006	159.909
108D	1497.220	1405.930	20.000	170.000	1327.220		
111S	1499.530	1400.050	25.000	110.000	1389.530	-0.020	50.523
111D	1499.190	1400.700	30.000	185.000	1314.190		
21S	1489.950	1406.080	30.000	83.000	1406.950	0.022	45.108
21D	1490.750	1404.690	20.000	173.000	1317.750		
20S	1488.500	1407.130	25.000	110.000	1378.500	0.034	29.147
20D	1488.270	1406.110	90.000	182.000	1306.270		

Note: Vertical gradient was calculated as dh/dl, using the midpoint of the screened interval to find dl.
K was estimated as the inverse of VPG (dl/dh); assuming a unit value of 1 for Q and A.
SWL elevations taken on November 15 and 16, 1999
Average K = 90.6 ft/d, average VPG = 0.004

3.2.6 Static Water Level Elevation and Water Table Configuration

As noted in **Figure 8** above, the regional groundwater flow in the area of the refinery is complex. **Figure 20** below shows the groundwater flow confined to the area of the chloride study. This figure was generated from water level measurements taken in November 1999 and includes the sixteen (16) newly completed wells onsite. A total of 113 wells (**Appendix 3**) were used to establish the water table configuration map shown below. As can be seen from the figure, water table elevations generally decrease from west to east across the refinery proper. The highest water table elevation is approximately

463 m (1410 feet) msl on the west side of the refinery. The water elevation decreases to a low of approximately 458 m (1395 feet) msl on the east side near the pumping wells.

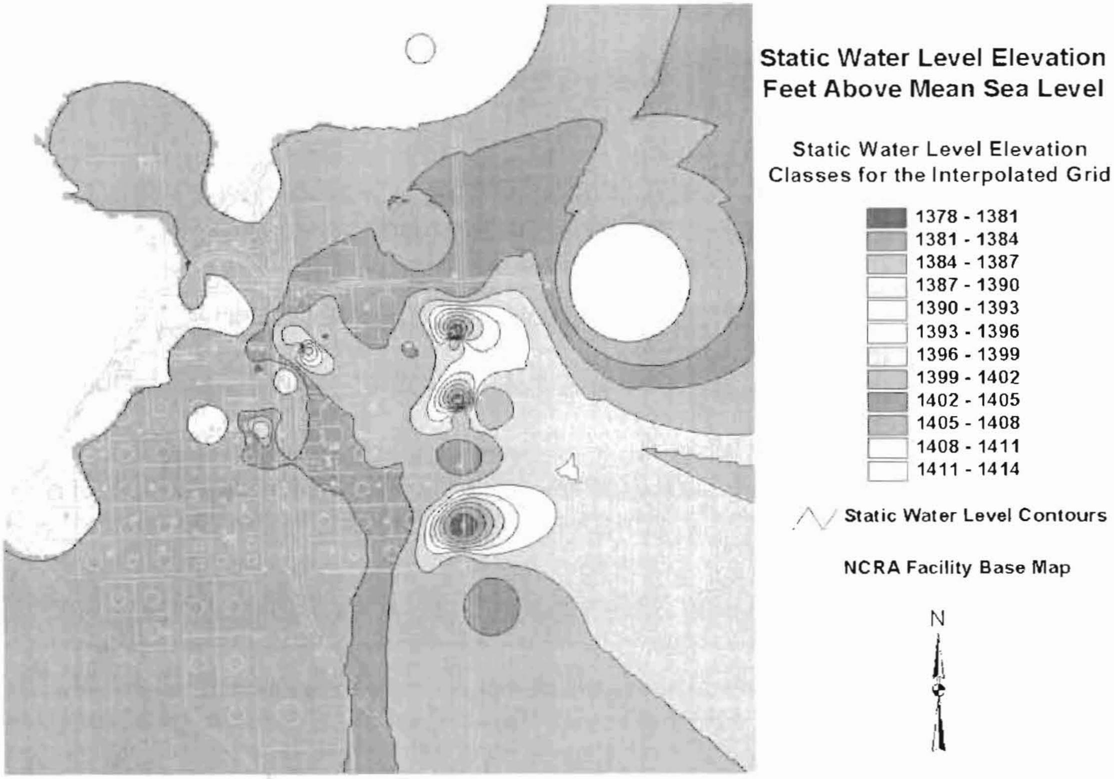

Figure 20 – November 1999 Water Table Configuration (ft MSL)

It can also be seen from the figure that there are very few data points available on the east side of the facility. Therefore, the elevations shown on this figure for the east side must be interpreted with caution. While available information (Whittemore, 1997) does indicate that the trend shown here is accurate, there is insufficient data available onsite to make definitive conclusions.

According to Kansas Geological Survey (KGS) Open File Report # 79-7, regional ground water flow direction in McPherson and vicinity is to the north-northwest

This is the natural direction of flow as determined by the KGS, however **Figure 20** above clearly indicates that the pumping wells have a significant effect on local direction of flow in the area of the refinery.

CHAPTER 4

FIELD STUDY RESULTS

4.1 Introduction

To discern the extent of the chloride levels across the site, samples were taken from onsite monitoring wells and analyzed to determine chloride concentrations. These samples were analyzed by the NCRA laboratory, which is a state certified lab. Separate sampling events were performed on August 1995, January 1999 and November 1999. Chloride concentration maps based on the results of these sampling events are included below and as **Appendix 4** and are labeled August 1995, January 1999 and November 1999.

For the August 1995 and January 1999 sampling events, selected wells were sampled based on location throughout the refinery. Wells for sampling were selected based strictly on location, without regard to depth and/or screened interval. As can be seen from the maps, the January 1999 event was considerably more comprehensive than the August 1995 event, and served in part to verify results noted as part of the earlier event.

Sources for chlorides within the process water can come from a number of process related areas. One of the major contributors to chloride concentration is saltwater naturally contained in the crude. As a general rule, crude is mixed with brine water in the formation it is taken from by the producing well. Separation of the crude/brine mixture is performed at the tank battery in the field and the crude is then transported to the refinery. However, separation is never complete and a small percentage (1% to 2%) of the brine remains emulsified in the crude.

Another reason why elevated chlorides may be found in the effluent is that the process water is recirculated three to four times before final release to the aeration pond (See Appendix 4). In addition, pond water can also used for process water. Consequently, the chloride levels can be concentrated over time before eventual release to the receiving stream.

Finally, it was discovered in 1995 that the water pumped by the water supply wells from the Equus Beds aquifer contained elevated levels of chloride. At the time of the initial study in August of 1995 the source of the elevated chlorides in the water from the supply wells was unknown. However, it was felt that the unlined lime ponds and/or water retention ponds located on the northwest side of the refinery (see maps Appendix 4) could have been a factor. Due to the radius of influence for the pumping wells, the chlorides could be drawn in from the area of the ponds once migration to groundwater had occurred.

However, the water would need to have migrated through approximately 16 m (50 feet) of low permeability clay. Previous analysis of the vadose zone material indicated a permeability on the order of 1 x 10-7 cm/s, which is the EPA standard required for Municipal Solid Waste Landfills. Therefore, without a preferential pathway, a long time period, or some other unknown variable, the possibility that migration to the groundwater had occurred from this source was initially thought to be small.

4.2 Results and Conclusions Drawn from the August 1995 Event

The August 1995 event consisted of the sampling and analysis of eighteen (18) monitoring wells and water supply wells located primarily on the north and east sides of the refinery. Of note, almost no sampling was done in the refinery operations area proper nor in the area of the refinery tank farm. A contour map of the August 1995 chloride levels is given below as **Figure 21**.

The August 1995 event had suggested that one potential source region for chlorides was the old Lime Ponds and possibly the water treatment ponds, both located on the northwest side of the refinery (see maps, Appendix 4). The Lime Ponds had been utilized for treatment of process water for a number of years until their removal in 1995. The water treatment ponds serve as the repository of both refinery stormwater runoff and treated process water before discharge through the National Pollutant Discharge Elimination System (NPDES) effluent to Bull Creek. Neither the Lime Ponds nor the treatment ponds were lined.

Historically, the process water was treated for hydrocarbons and other priority pollutants before discharge, as required by the NPDES permit. However, chloride has not been listed as a priority pollutant; therefore no treatment for chloride has been done. If the chlorides were able to migrate through the vadose zone, it was possible that these ponds could be a primary source of the chlorides found in the water supply wells. The ponds represented areas where at least the top few feet of soil and vadose zone material had been disturbed. Consequently, if no other changes were caused by construction, at least the pathway to groundwater was shortened. It is also conceivable that disturbing the native material in the vicinity of the ponds may have had some effect on the material below the ponds. There were no other sources suggested by the results of the August 1995 samples.

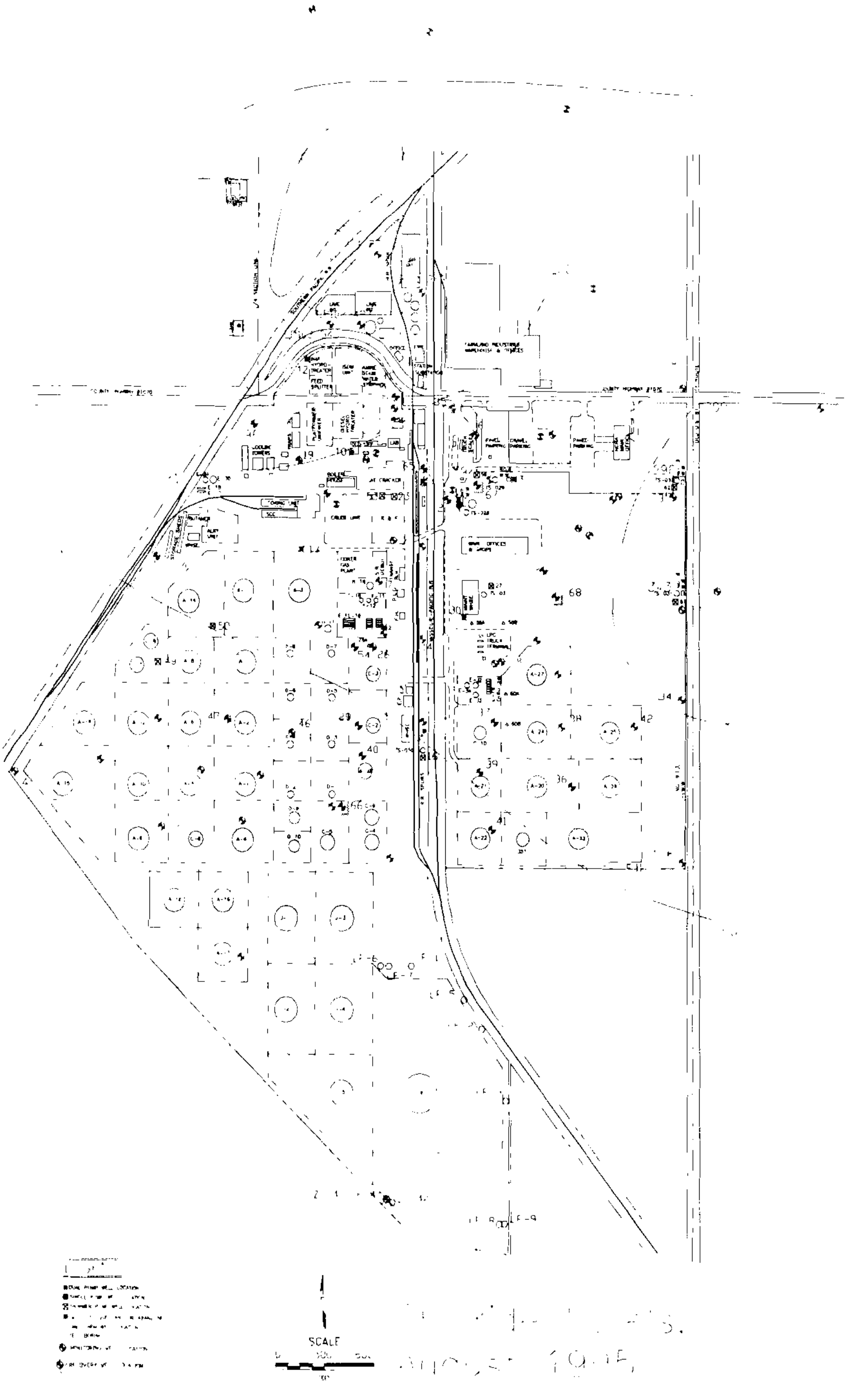

Figure 21 – August 1995 Chloride Levels

4.3 Results of January 1999 Sampling Event

The January 1999 sampling event was undertaken primarily to verify and expand the results of the August 1995 event. Consequently, more wells were sampled and the sample locations were chosen with these goals in mind. A total of twenty-five (25) wells were included in this analysis. A contour map of chloride concentrations is included below as **Figure 22.**

Analysis of the results (Appendix 3) do verify, in part, what was noted as part of the earlier event. The map indicates a narrow area approximately 100–130 m (300-400) feet wide either side of a line beginning at monitoring well ZL-1 and ending at WW-8 where chloride concentrations are at or above 150 mg/l. Sampling results indicate that background levels should be generally in the 50 mg/l to 150 mg/l range.

The shape of the plume indicated the possibility of a point source much smaller than the retention pond, and suggests that the area around the Lime Ponds may be the primary source. This is supported by the chloride levels noted in LP104 (71.4 mg/l) vs. LP102 (461.6 mg/l). If this is the case, then it would be expected that the chloride levels will slowly decline over the next few years, finally reaching and equilibrium level equivalent to the rate of influx from the vadose zone. This can be stated as the lime ponds have been removed, therefore, no source renewal is occurring there.

As the water retention pond extends north of the Lime Pond wells, it would be expected that any leakage from the pond might be noted in LP104 at comparable levels to LP102. While this was not noted in 1999, this circumstance was found in 1995, which could indicate generally decreasing concentrations coming from the pond.

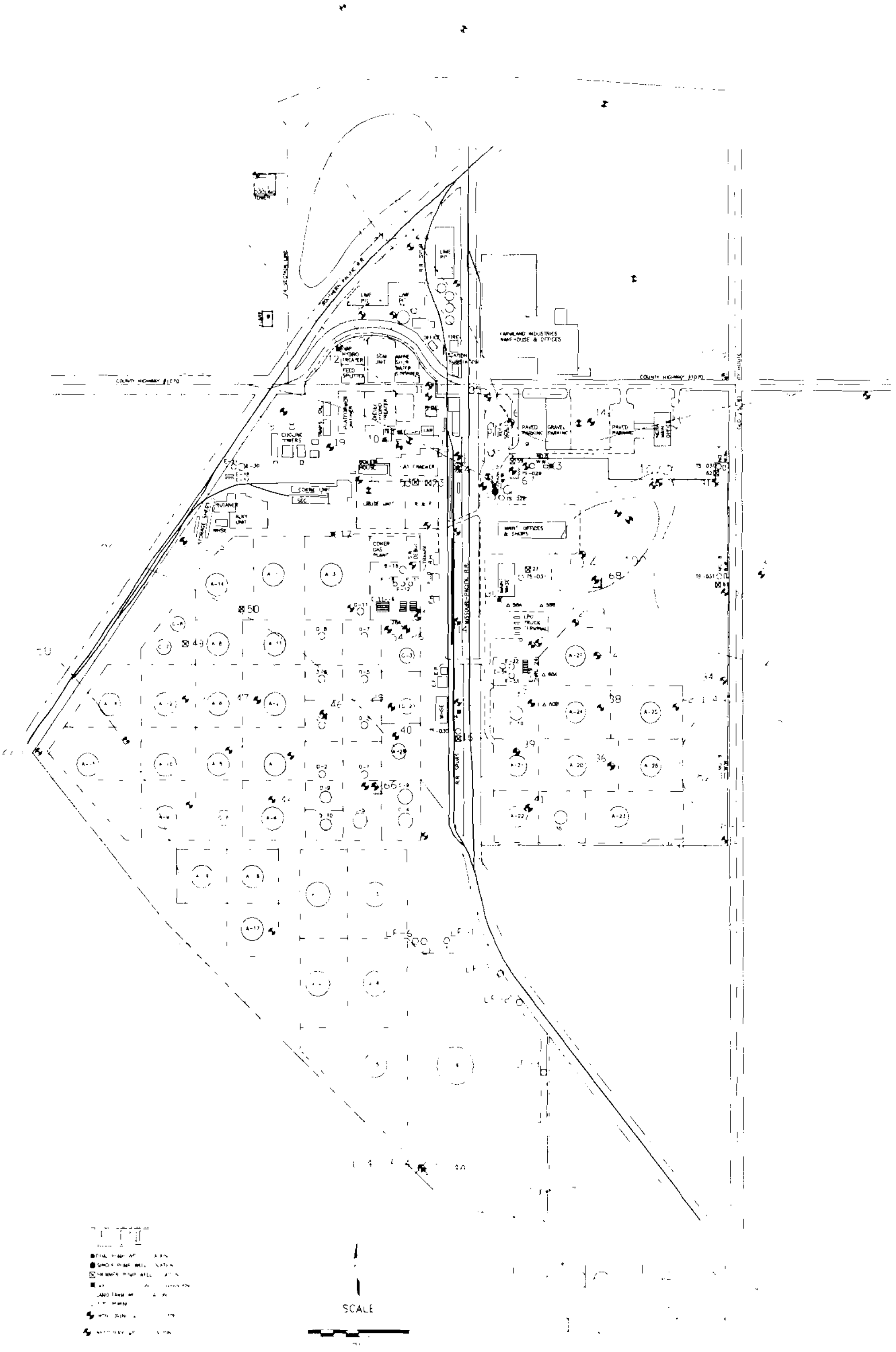

Figure 22 - Chloride Levels, January 1999

Another possibility considered at that time was that the radius of influence for the water supply wells, in particular WW-6 and WW-10, allows only a part of the plume from the big pond to be captured and moved southeast. Using the KGS number for hydraulic conductivity (100 ft/day), the transport time for water from the pond to WW-6, approximately 2,000 feet, is calculated as follows (after Heath, 1991).

$$\mathbf{V = KI/N}$$

Where ***V*** is the velocity, in m/day, ***K*** is the hydraulic conductivity, in m/day, ***I*** is the hydraulic gradient, in m/m, and ***N*** is the porosity. Using this formula, the travel time is computed as:

$$V = 33\ m/day(0.0005\ m/m)/0.2$$

$$V = 0.25\ m/day$$

The time required to move 660 m (2000 feet) is then roughly 7.3 years. Using the same formula, the transport time to WW-8, roughly 1150 m (3500 feet), approximately 12.7 years. This does not take into account the time required for movement through the vadose zone to the groundwater or any flow barriers that might be present underground in the aquifer. Use of the calculated site-specific average hydraulic conductivity of 30.4 m/day (92.7 ft/day) (**Table 3**) would result in similar fate and transport time.

As the overall groundwater flow direction absent the effects of the pumping wells is north-northwest, any plume from the pond would be expected to migrate in this direction, irrespective of influence from the on-site water supply wells. If this is the case, then chloride levels should significantly improve in the water supply wells located on the east side of the property (WW-8, WW-3) if WW-6 and WW-10 were shutdown. Based on the hydraulic conductivity discussed above, this should be noticeable in a relatively short time frame, on the order of six months or less. Theoretically, chloride levels in these wells would ultimately decrease to background. However, it must be noted that this scenario assumes that the lime ponds are the primary source, and does not take into consideration any chlorides migrating to the pumping wells from offsite to the east.

What could be fairly well established after the January 1999 event was that chlorides are migrating from the area around the Lime Ponds to the water supply wells. Questions still remained regarding other potential source areas and the level of chlorides which will be introduced at the water supply wells in the future.

Table 5 below illustrates the results of the August 1995 and January 1999 sampling events. Comparison between the chloride results from August 1995 and January 1999 indicate the following:

1.) The size and shape of the chloride plume had not appreciably changed.

2.) Outside the area of the greatest concentrations, the chloride results had not appreciably changed. In other words, background levels seem to be fairly consistent.

3.) Chloride concentrations in samples from the Lime Pond wells had decreased. In some cases the decrease was dramatic. For example, measured concentrations from LP104 have decreased from 853 mg/l in August 1995 to 71.4 mg/l in January 1998. MW13, southwest of the Lime Ponds, also indicated a decrease of 98.2 mg/l from the August 1995 level.

4.) Chloride concentrations in samples from the water supply wells located in the area of highest concentration had generally increased since August 1995. WW-8 concentrations had increased 102.1 mg/l, from 343 mg/l in August 1995 to 445.1 mg/l in January 1998. Concentrations in WW-3 also increased. The exception was WW-10, which indicated a decrease of 35.2 mg/l since 1995. However, this change is within the expected range of values when accounting for sampling and laboratory variability.

5.) Chloride concentrations in the sample from WW-9, located outside the area of highest concentration, had decreased 35.6 mg/l since August 1995.

6.) Samples from the KDHE well, MW56, and ZL6 are all in the 130 – 140 mg/l range, within what might be considered background concentrations. These results indicated that there was no significant chloride contribution currently being introduced from a source east of the refinery.

7.) Of the twenty-five (25) wells sampled, the following wells indicated increases from 1995: WW-8, WW-3, ZL-1, and ZL-6. Of these four, changes in only the first three can be considered statistically significant. However, only seventeen (17) wells were sampled in 1995, so it was not possible to compare results for eight of the wells. Significantly, WW-6 (351.4 mg/l) was one of the wells not sampled in 1995. This well is located in the middle of the high chloride concentration area.

Table 5 - Results of Chloride Sampling – January 1999 and August 1995
Presented in descending order of 1/99 Chloride concentration

Sample Well	Chloride (mg/l) 1/99	Chloride (mg/l) 8/95	Change 8/95 to 1/99
LP102	461.6	497	-35.4
WSW8	445.1	343	102.1
LP103	406.6	545	-138.4
WSW6	354.4	Na	Na
WSW3	351.7	296	55.7
ZL1	313.2	260	53.2
MW13	197.8	296	-98.2
ZL2	153.9	178	-24.1
WSW10	153.8	189	-35.2
MW25	142.9	Na	Na
MW15	142.9	154	-11.1
ZL6	137.4	118	19.4
MW56	137	Na	Na
KDHE well	131.9	Na	Na
MW43	120.9	Na	Na
MW8	109.9	Na	Na
ZL3	104.4	118	-13.6
MW42	104.4	Na	Na
LP101	101.7	343	-241.3
WSW9	82.4	118	-35.6
ZL4	76.9	83	-6.1
LP104	71.4	853	-781.6
MW9	60.4	Na	Na
LF9	54.9	83	-28.1
ZL5	22	95	-73
MW11	Na	204	Na

4.4 Results of the November 1999 Field Work and Sampling Event

After analysis of the first two events had been completed, a third sampling event was scheduled which was designed to complement a comprehensive study with regard to the facility and the chloride source/movement. This study addressed questions posed after analysis of the first events had been completed. These issues included:

1.) Chloride fate and transport.

2.) Chloride source areas (in particular from offsite).

3.) The concentration of chloride throughout the depth of the aquifer; ie; are the concentrations higher near the bottom or top.

4.) Influence of the pumping well screen location on chloride fate and transport.

5.) Influence of the aquifer stratigraphy on fate and transport of the chlorides.

6.) Influence of the vadose zone stratigraphy on the movement of chlorides into the aquifer.

7.) Future chloride levels in the pumping wells.

To address these items, it was necessary to perform a set of preliminary steps prior to sampling. First, in order to establish an accurate static water level elevation map, it was necessary to measure the top of casing (TOC), ground surface elevation (GSE), and horizontal locations for all wells to be used as part of the study. In addition, to determine the changes in chloride concentration with depth though the aquifer, it was necessary to drill a series of new monitoring wells. The completion of these new wells produced a series of clustered deep and shallow wells screened such that samples of the upper and lower aquifer could be taken independently at essentially the same geographic location.

To determine the extent of the chloride plume and to gain more information regarding the potential source region to the east, a series of perimeter wells was also completed. Finally, an investigation designed to better identify both vadose zone and aquifer stratigraphic properties was undertaken. Details regarding these preliminary steps are included below:

4.4.1 Determining the TOC and GSE for the Monitoring Wells

TOC and GSE data was generated for a total of 113 monitoring wells and pumping wells located on and around the facility. As part of the stratigraphy study, an additional 45 control points were obtained from the KGS Wizard database. This information did not include any of the refinery wells.

The elevation data was procured in a number of ways. Most of the elevations (horizontal and vertical) were measured in the field using a standard transit and stadia rod and/or global positioning system (GPS). For the sixteen new monitoring wells and the eleven landfarm monitoring wells, a Kansas registered land surveyor was employed to ascertain the TOC and GSE elevations for these wells.

Once the elevation data for all the wells had been found, it was then possible to accurately determine the static water level elevation across the site. This information was used to help determine the static water level elevation used as part of the groundwater modeling analysis. This information was also used to construct an accurate static water level elevation map for the facility and all associated areas where monitoring wells were located. A copy of this static water level map is included below as **Figure 23.**

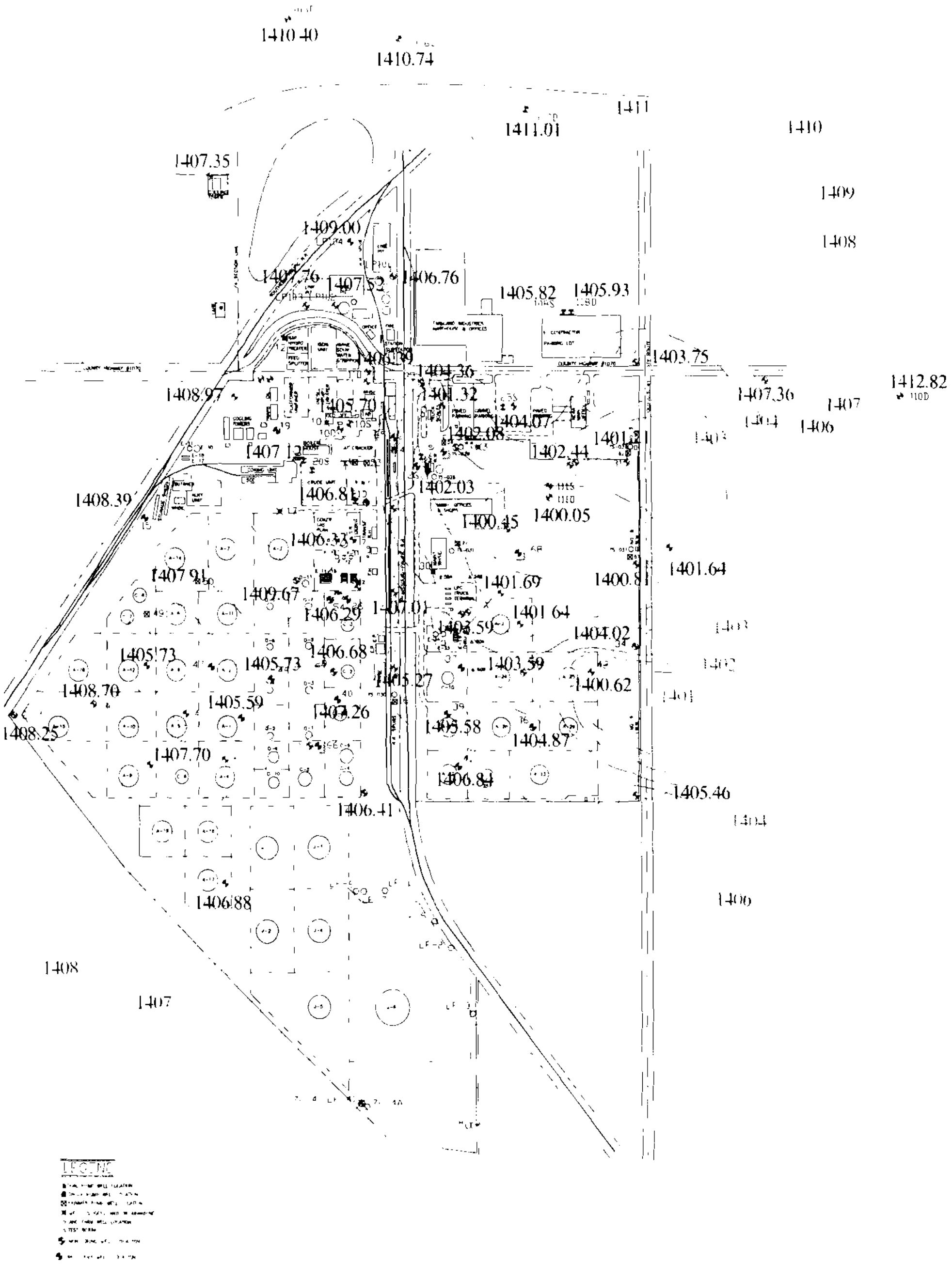

Figure 23 – Static Water Elevations (ft msl): Measured 11/16 & 11/17 1999.

4.4.2 Completion of the 16 New Monitoring Wells Onsite

In order to determine if there were any significant differences in the concentrations of chlorides between the upper and lower part of the aquifer, nested clusters of deep and shallow wells were completed at strategic points within the facility. The locations of these nested clusters were designed primarily to determine the extent of vertical and horizontal migration of chlorides from the area of the old lime ponds, a potential chloride source, to the pumping wells.

To accomplish this task, three "fencelines" were established at roughly equidistant locations between the old lime ponds and the pumping wells which intersected the area of chloride impact as determined by the results of the January 1999 sampling. **Figure 24** below shows the locations of the nested clusters. All of the fencelines were completed on the west side of pumping wells WW-3, WW-8 and WW-9, to minimize any impact that might be present from a source east of the refinery and concentrate efforts toward the lime ponds.

After careful study of logs for existing onsite monitoring wells, shallow or deep wells were drilled as close as possible to the existing wells to create a well pair, consisting of a shallow and a deep well. Six new shallow wells and 10 new deep wells were completed.

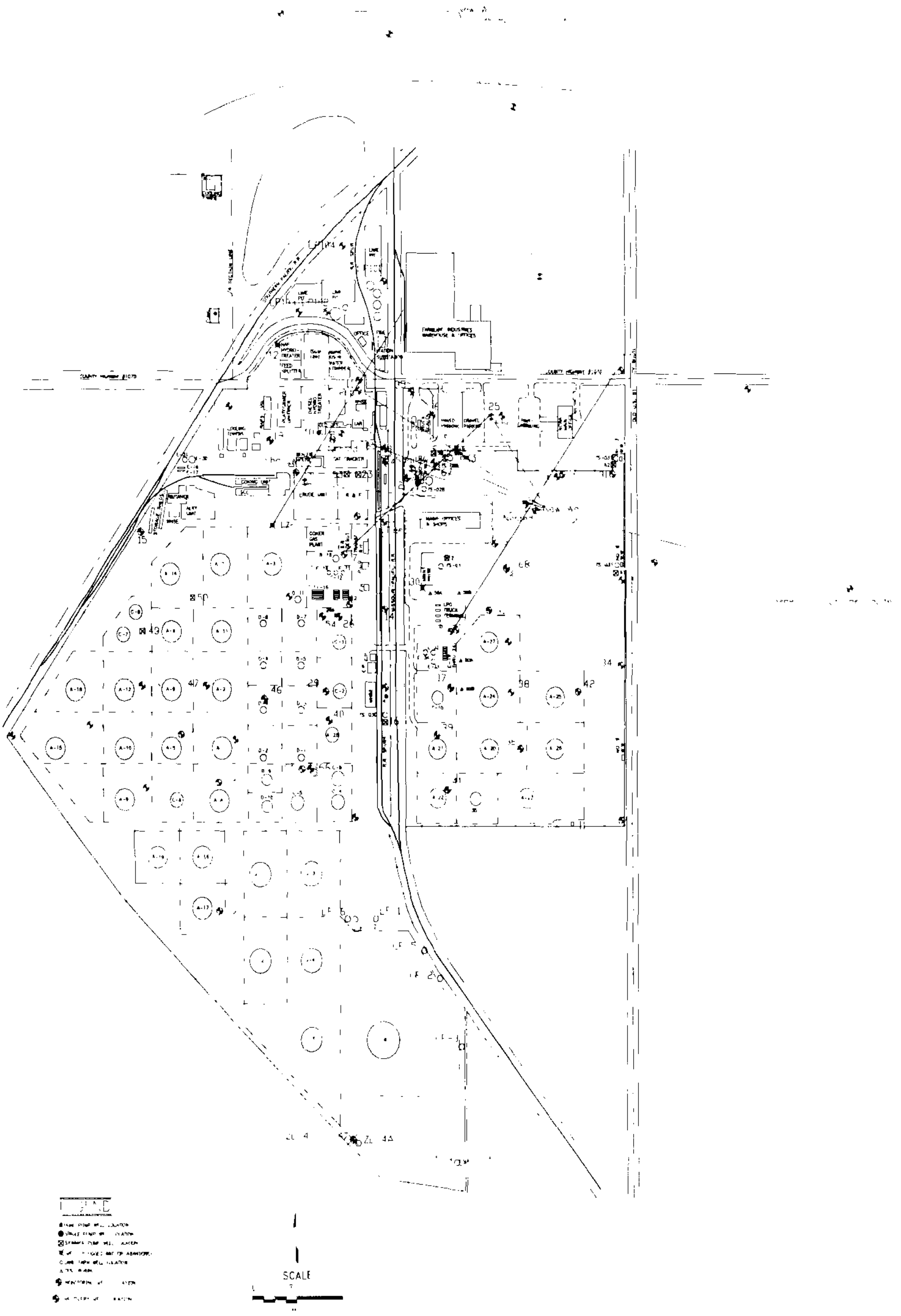

Figure 24 – Fenceline Locations for the Clustered Monitoring Wells

The screened interval of the shallow wells intersected, to the extent possible, the top of the saturated zone. Screen length in the new shallow wells was set at 6.6 meters (20 feet) and the wells were completed such that the top of the screened interval intersected the water table. For the deep wells, the screened interval was again set at twenty feet and the bottom of the screen intersected the base of the saturated zone as determined by examination of the drilling cuttings. Logs for these monitoring wells are included as **Appendix 2.**

4.4.1a Field Drilling Procedures

Six shallow monitoring wells (between 36 and 40.6 meters; 110 and 124 feet deep) were installed with hollow stem auger methods. Ten deep monitoring wells (between 49 and 60 meters; 150 and 183 feet deep) were installed using mud rotary drilling methods. All wells were completed with protective construction at the surface. All wells were developed to reduce the suspended sediment in and improve the conductivity of the well with the surrounding aquifer.

Borings for the six shallow monitoring wells were advanced with 4-1/4" hollow stem augers with inside drill stem and pilot bit. Soil sampling was conducted by withdrawing the center drill stem, removing the pilot bit and replacing it with a 2" split spoon sampler which was then advanced into the soil ahead of the augers. Soil samples were collected every 1.6 m (5 feet) with the split spoon method.

The shallow wells are constructed with 2" Schedule 40, threaded flush joint, PVC riser and 0.010 inch factory mill slotted screen. All screen and riser was clean and in sealed containers from the factory. A 0.010 to 0.020 inch sized gravel pack, clean and bagged by the supplier, is placed to approximately two feet above the top of the screened intervals. To minimize caving from the sidewalls of the boring, the sand was placed in 1.6 meter (5 foot) "lifts" and the tremmie pipe was kept to within two feet of the existing filter pack. A two foot bentonite seal was placed above the gravel pack and allowed to hydrate before grouting the remainder of the well. The neat cement grout was pumped through a tremmie pipe and forced to the surface from the bottom of the open portion of each boring. Each shallow well is completed at the surface with a one meter (three feet) square concrete apron and a steel protective cover with a traffic guard.

Mud rotary drilling was utilized for the ten deep wells using a truck mounted drill rig with a 9-1/2" drill bit. Rotary-drilled borings are produced by pumping drilling fluid through the rotating drill string (drill stem and bit) where the fluid forces the cuttings away from the bit and to the surface through the annulus. The cuttings drop out in a settling pit where the drilling fluid is taken up by the pump and circulated back down the drill string. The bore-hole is advanced by lowering the rotating drill string the length of each successive drill stem. After each stem is drilled down the boring, water is circulated to allow cleaning of the hole prior to the subsequent connection of an additional stem. The process is repeated until the desired total depth of the boring is reached. The lithologic conditions at this site necessitated the use of a bentonite gel additive to the drilling fluid. The gel increases the viscosity of the drilling mud and minimizes caving of the sidewalls. Once each boring was completed the drilling mud was displaced with fresh water prior to setting the well. The deep mud rotary-drilled borings were advanced until shale was encountered.

The deep wells were constructed with 4" Schedule 40 flush-joint, threaded PVC casing with factory mill slot .020 inch PVC screens. Each deep well was constructed with a 6.6 meter (20 foot) screened interval at the bottom of each boring.

Once the screen and casing had been placed into the borehole a filter pack of 0.010 to 0.020 inch sized filter sand was tremmied into the hole. The sand was placed while keeping the tremmie pipe within two feet of the top of the filter pack surrounding the well screen and casing to minimize sorting and reduce the chance of bridging. Once the sand had been tremmied to approximately 0.7 m (2 ft) above the screened interval a bentonite seal approximately 0.7 m (2 ft) thick was placed around the casing. After the bentonite seal was allowed to hydrate, the borehole was force tremmied from the bottom up with neat cement grout. All the wells were completed with a one meter square (three feet by three feet) concrete apron, and a steel protective cover and steel cage at the surface. All wells were capped with an expanding J-plug type cap.

Monitoring wells were developed to enhance the flow of water from the formation into the well and to remove any particulate matter from the gravel pack and the well casing. The wells were developed by surging water through the well screen and filter pack using the rig and a surge block, then pumping until the water was clear and free of visible sediment. Generally, the shallow wells were developed with a Waterra actuated foot valve and a 2" Grundfos Redi Flo submersible pump. The deep wells were developed with a 3" steel bailer and/or by air-lifting using a 4" submersible pump.

The on-site field geologist recorded the details of well design and construction for each monitoring. Well.

4.4.1b Field Sampling Procedures for the Wells

During advancement of the borings for the 2" wells (shallow wells) soil samples were collected at 1.6 meter (5 foot) intervals for lithologic observations and headspace analysis. An experienced field geologist examined each sample for descriptions of, but not limited to, color, texture, grain size, grain shape, sorting, and moisture content. A portion of each sample was collected for field headspace reading with a Foxboro Organic Vapor Analyzer (OVA) Flame Ionization Detector (FID). The instrument was calibrated according to the manufacturer's recommendations. Soil samples were not submitted to a laboratory for further analysis.

During advancement of the borings for the 4" wells (deep wells) sediment samples were collected at 1.6 meter (5 foot) intervals for lithologic observations only. The samples were collected by placing a sieve at the top of the borehole allowing the returning drill fluid to pass through while retaining the cuttings. The field geologist described each sample for, but not limited to, color, texture, grain size, grain shape, and sorting. Field screening or laboratory analysis for organic vapors was not conducted on the soil samples from rotary drilling.

4.4.3 Chloride Fate and Transport

Completion of the fencelines of shallow and deep wells allowed spatial comparisons of chloride concentrations between the upper and lower parts of the aquifer to be made. In particular comparisons of chloride concentration data from paired deep and shallow wells made it possible to determine if the chloride preferentially migrated vertically through the saturated zone. It was felt that due to density differences between fresh and brine water, the chlorides would tend to migrate toward the bottom of the aquifer with distance and thus chloride concentrations would be higher in the deeper wells. To test this hypothesis, the chloride concentrations in samples from the shallow and deep wells from the fenceline nearest to the lime pond wells (the source) could be compared to the chloride concentrations in each succeeding fenceline away from the source. If the results from the first fenceline indicated that the chloride levels were higher in the shallow wells and a reverse of this trend was noted with succeeding fencelines, this would indicate that the chlorides were migrating vertically through the saturated zone.

There was, however, an additional factor to consider when evaluating the chloride concentration data. The pumping wells should also be influencing the direction of chloride migration since the screened interval for these wells is roughly across the bottom 13 meters (40 feet) of the aquifer. Therefore, the pumping wells may preferentially cause vertical migration through the aquifer and add to any effect which would be caused by density differences between the fresh and brine water.

Table 6 lists the results of the chloride sampling for all wells sampled, and also breaks the wells into deep and shallow categories. Descriptive statistics of the results do not indicate any statistically significant differences between the data sets. **Figure 25** below graphically illustrates the concentration differences between the deep and the shallow wells. As can be seen from this graph, there is no significant difference indicated between chloride concentrations at the deep and shallow wells. However, this data was generated irrespective of location and only compares the overall average chloride concentration between the deep and shallow wells. In order to determine if vertical migration is taking place with distance, maps illustrating spatial variations in deep and shallow chloride concentration were generated.

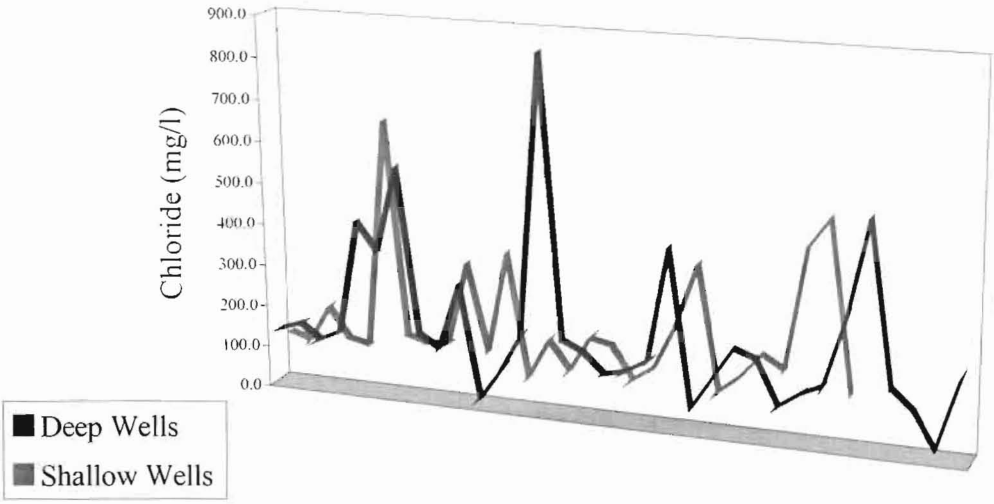

Figure 25 – Graphical Illustration of Chloride Concentration by Deep and Shallow Wells

Table 6 - Water Well Samples for Chloride, November 1999

Shallow Wells	mg/l cl
108S	141.2
111S	158.9
25S	123.6
LP-101S	147.1
LP-102S	**420.8**
LP-103S	**353.1**
LP-104S	**559.0**
MW-10S	164.8
MW-11S	135.3
MW-13S	294.2
MW-14S	23.5
MW-18S	94.2
MW-20S	182.4
MW-21S	**853.3**
MW-24S	188.3
MW-2S	164.8
MW-41S	117.7
MW-43S	129.5
MW-44S	158.9
MW-47S	**430.0**
MW-54S	58.8
MW-56S	135.3
MW-58S	211.8
MW-59S	194.0
MW62S	88.3
63S	123.6
MW-6S	311.9
ZL-1S	**540.0**
ZL-2S	161.8
ZL-3S	114.8
ZL-5S	29.4
ZL-6S	194.2

Deep Wells	Mg/l cl
105D	117.7
106D	103.0
107D	188.3
108D	117.7
111D	105.9
110D	**653.2**
34D	141.2
MW-10D	126.5
MW-11D	132.4
MW-15D	**329.5**
MW-16D	123.6
MW-20D	**364.9**
MW-21D	70.6
MW-25D	164.8
MW-26D	100.0
MW-2D	182.0
MW-35D	170.7
MW-37D	94.2
MW-38D	129.5
MW-50D	235.4
MW-53D	**382.5**
MW-60D	88.3
MW-67D	147.1
MW-8D	129.5
OIP RW S. HRT 17	188.3
RW-19D	158.9
WW-3D	**447.2**
WW-8D	**517.9**
WW-9D	117.7

Shallow Wells	
Mean	**218.5**
Median	**160.4**
Mode	**123.6**
Standard Deviation	176.4
Range	829.8
Minimum	**23.5**
Maximum	**853.3**
Count	32.0

Deep Wells	
Mean	**202.9**
Median	**136.8**
Mode	**117.7**
Standard Deviation	145.1
Range	582.6
Minimum	**70.6**
Maximum	**653.2**
Count	28.0

NOTE: Wells in bold = Chloride greater than 300 ppm

NOTE. Value for MW-21S is suspect and may be anomalous

Figures 26 and 27 below indicate that there does not appear to be a significant element of vertical migration across the site from the lime ponds to the water supply wells on the east side of the facility (water wells 3, 8, and 9). **Figure 26** showing the shallow wells, does indicate a nose of higher chloride levels pointing in the direction of water wells 6 and 10, however migration does not appear to have promulgated beyond these pumping wells. This map also shows a "bulls-eye" of high chloride in the area of the tank farm, centered around MW-47. This is believed to be a shallow onsite source which is situated far enough away from the pumping wells so that this area has not been significantly effected by the wells.

Figure 27, mapping the deep well chloride concentrations, does not show a significant increase in chloride concentrations with depth beyond water wells 6 and 10. In fact, it can be seen that the deep and shallow chloride levels are consistent in the area of the refinery between the pumping wells. In both cases, the chloride levels are generally below 150 ppm. However, the deep well map does indicate a potential source from both the west and the east. The chlorides from the west appear to be migrating into water wells 6 and 10, while the chlorides from the east are migrating primarily into water wells 3 and 8. Water well 9, located on the southeast corner of the refinery, is currently unaffected by either of these potential sources.

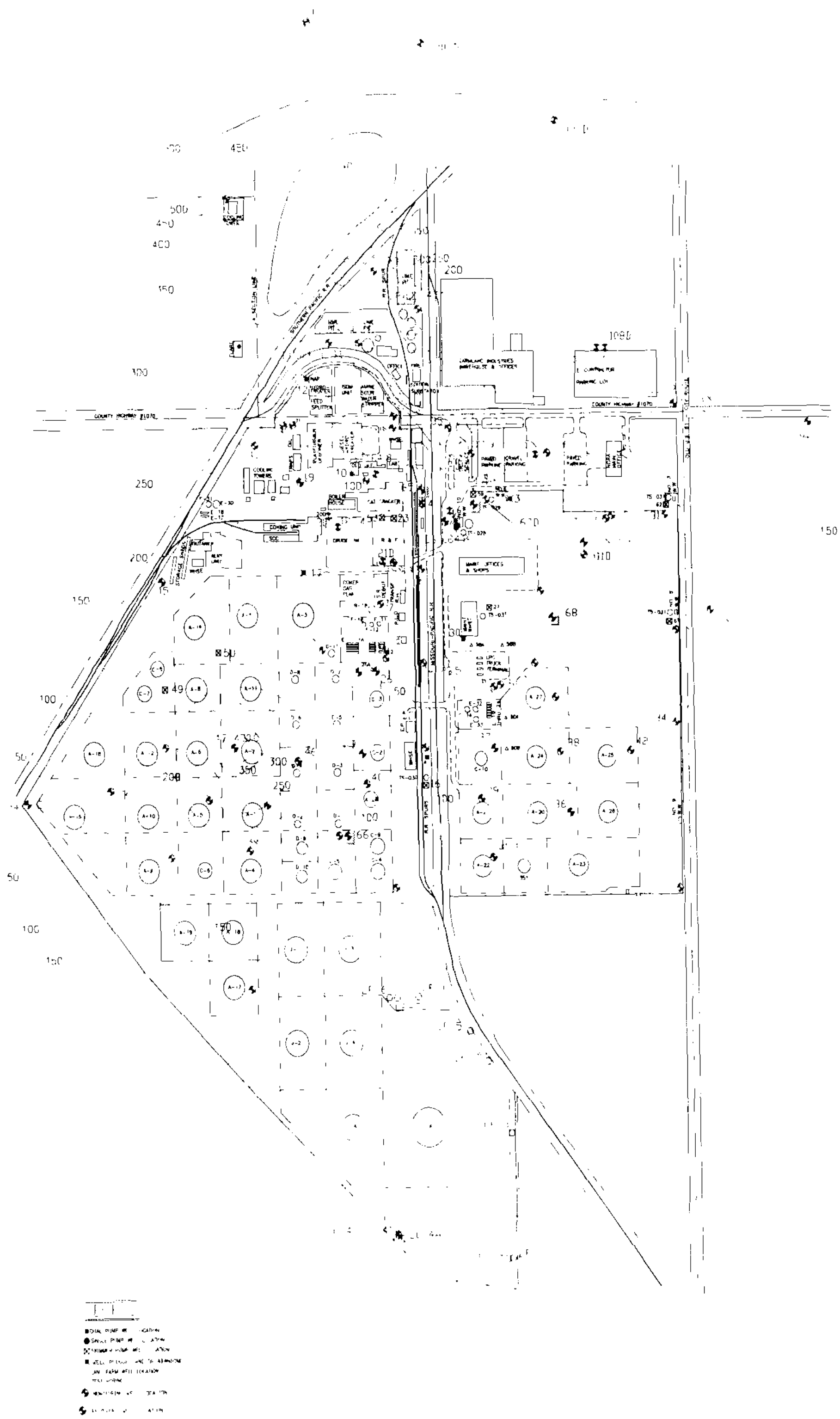

Figure 26 – Shallow Well Chloride Concentrations; November 1999

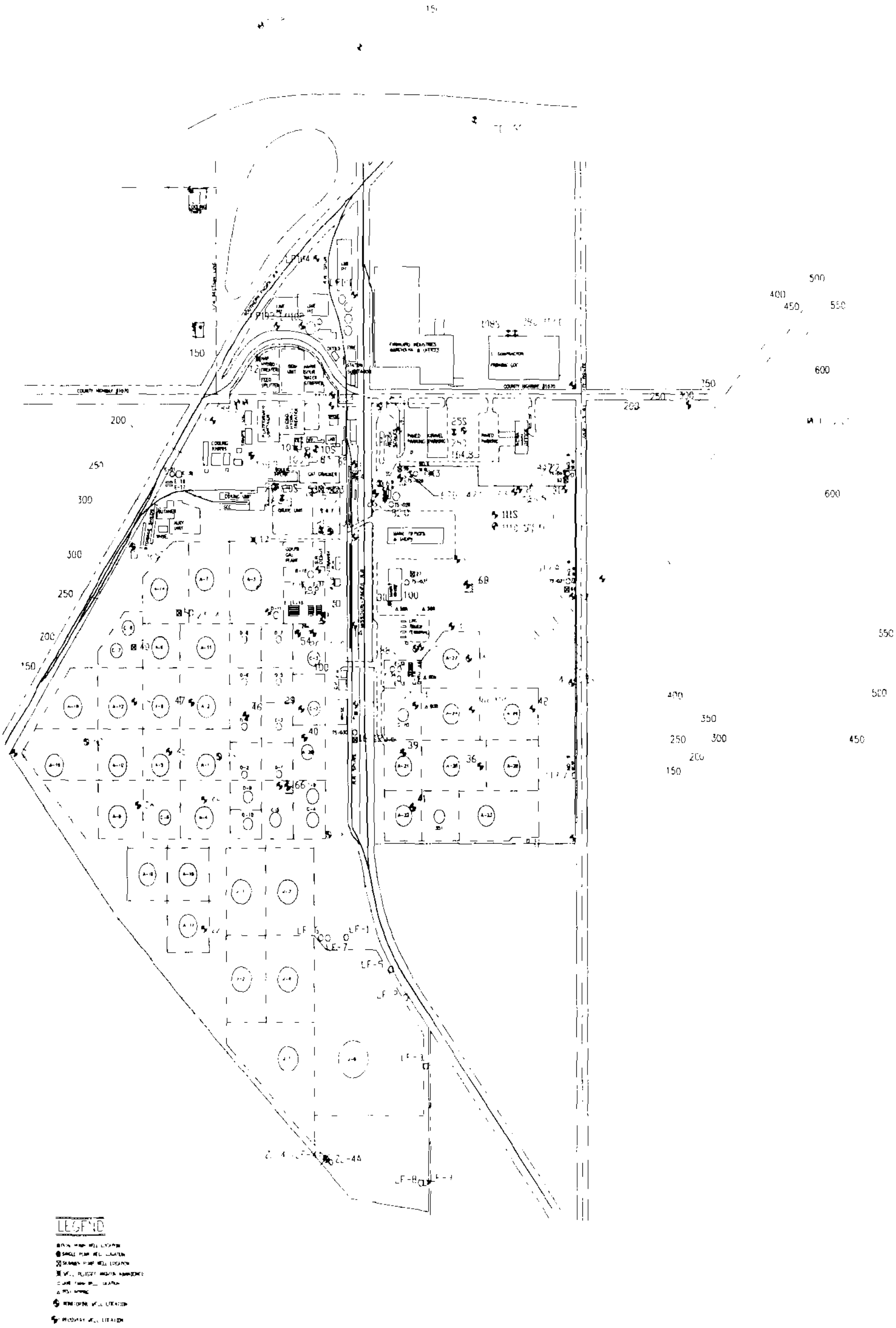

Figure 27 – Deep Well Chloride Concentrations; November 1999

The results from these maps indicate that chlorides migrating from the east are captured by water wells 3 and 8, while chlorides migrating from the west are captured by water wells 6 and 10. These results do not indicate that there is any significant overlap between water wells with regard to the capture of the chlorides. It must be noted that some liberty was taken in the interpretation of the map due to limited data outside the study area.

Figure 28 below is an ArcView generated map of chloride concentration, using all available data. Again, interpretation on the east side of the map must be viewed with some caution, due to lack of data in this region. Besides giving an overall view of the chloride concentrations, this map serves as a check for verification purposes of the information presented as part of **Figures 26 and 27**.

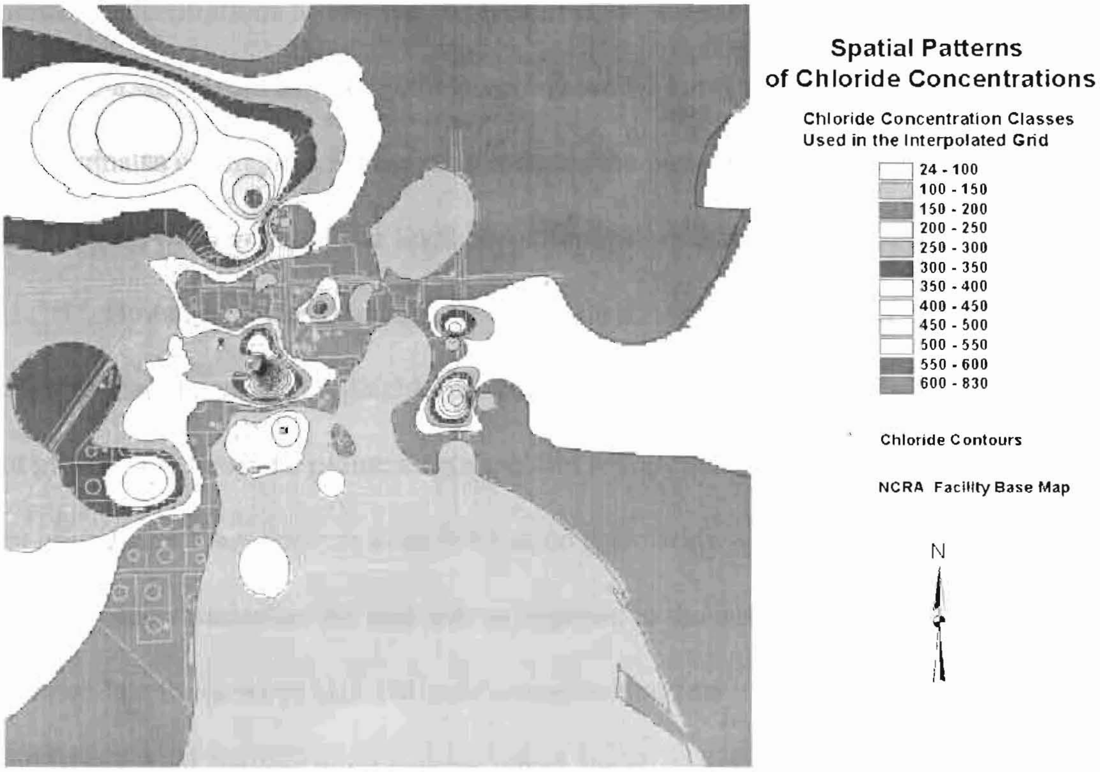

Figure 28 – Chloride Concentrations (ppm), November 1999

The ArcView generated map of chloride concentrations above verifies the chloride results seen on the shallow and deep well maps (**Figures 27 and 28** above), indicating a separation zone bounded essentially by the pumping wells. This map also indicates that sources from the east and the west provide the majority of chloride water intercepted by the pumping wells.

Figure 29 below illustrates chloride concentration contours and the static water level elevations as determined as part of the November 1999 sampling event. This figure does reveal evidence for a relationship between chloride concentration and static water level elevation, although there is not an absolute correlation. The relationship appears to be strongest on the east side of the facility. This indicates that the plume to the east is not a point source, as the pumping wells have an influence on the chloride plume. The chloride concentrations follow the changes in static water level elevation, which are caused to a significant degree by the pumping wells. This suggests that the plume to the east originates offsite, and is migrating towards the pumping wells due to the influence of the pumping wells on the water level elevations within the study area.

However, there appears to be very little relationship on the west side, which indicates that the areas of high chloride concentration noted on that side of the facility are not present due to offsite plume migration, but represent essentially point sources This can be stated as there appears to be little or no correlation with groundwater flow and chloride concentration on the east side as opposed to the west side. Therefore, it can be assumed that the areas of high chloride concentration found on the west side of that facility represent shallow point sources which the pumping wells have not yet significantly effected.

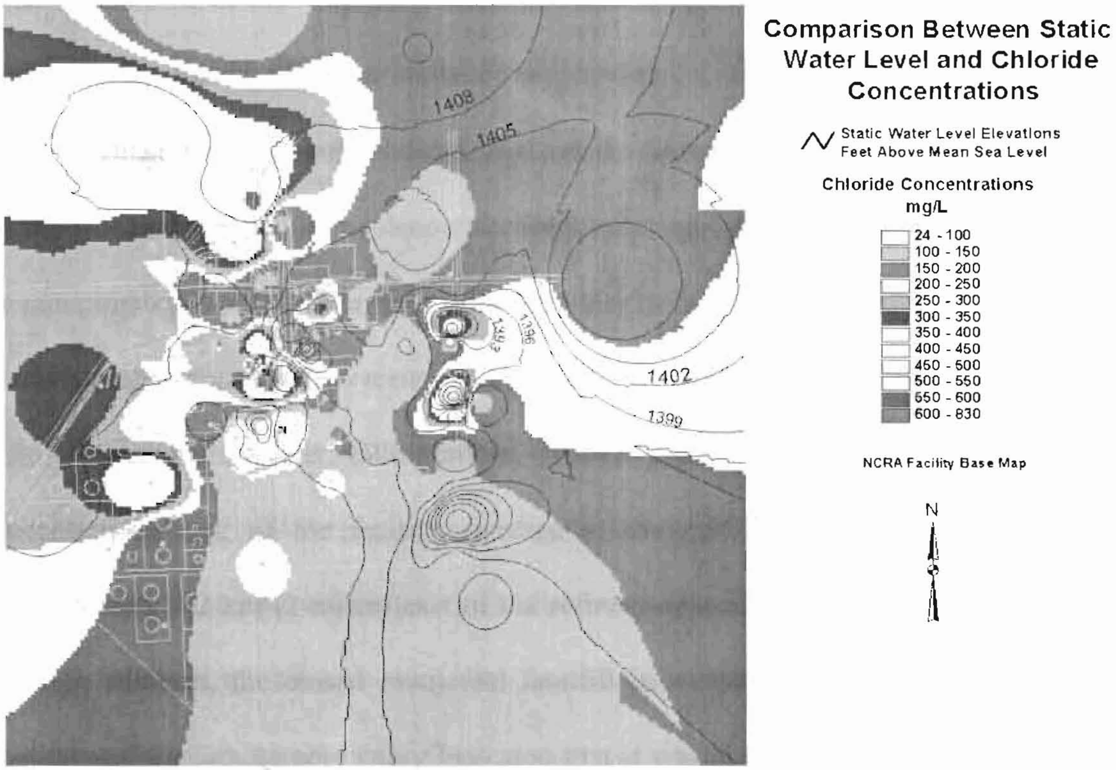

Figure 29 – Static Water Levels (ft msl) and Chloride Concentrations (ppm), 11/99

4.4.3a Chloride Migration from the East

With regard to chloride concentration migrating from the east, there does appear to be an element of vertical movement evident. This can be seen by reviewing the chloride levels in the shallow and deep monitoring wells in that area. Deep monitoring well MW-110D is located furthest east from pumping wells 3 and 8, followed by shallow well ZL-6 and finally shallow well MW-56, located approximately 16 meters (50 feet) from WW-8. The data shows that the highest concentration of chlorides is located in MW-110D, at 653.2 mg/l, followed by ZL-6 at 194.2 mg/l, and then MW-56 at 135.3 mg/l. A review of the concentrations taken from the pumping wells indicates much higher levels than noted in the shallow wells, with WW-3 at 447.2 mg/l and WW-8 at 517.9 mg/l. As noted earlier, the water wells are screened in the bottom 40 feet of the aquifer.

These results would indicate that on the east side of the facility, the highest chloride levels are found in the deeper section of the aquifer. This might also indicate that the pumping wells are preferentially drawing water from the deeper portion of the aquifer, which is probable given the screened interval of these wells.

Previous studies (Whittemore, 1997) have indicated that the chloride concentrations east of the facility increase to the east, reaching the highest levels approximately 3.2 km (2 miles) east of the refinery at the beginning of the Johnson Oil Field. In addition, the closed municipal landfill is located in approximately the same location and the Whittemore study indicated that it was also contributing to the elevated levels of chlorides found in this area.

Finally, the saturated thickness decreases with distance east of the refinery. The study referenced above found bedrock in the area of the landfill between 20 and 25 meters (62 and 75 feet) bgl, and saturated thickness at the landfill ranged from between 3.3 m (10 feet) on the east and 6.6 meters (20 feet) on the west. A well sampled approximately one mile west of the landfill, in the direction of the refinery, had a saturated thickness of approximately 10 meters (30 feet). Saturated thickness at the east edge of the study area is estimated at approximately 16 meters (50 feet) and was estimated at 43 meters (130 feet) on the west side of the study area, based on available well logs (Appendix 1).

The information listed above favors vertical migration of the chlorides originating from the landfill/well field for the following reasons:

1.) The reduced saturated thickness at the source indicates that less dilution will occur as the chlorides enter the groundwater, as the volume of water available for dilution is less in this area when compared to the saturated thickness west of the source area. Therefore, it would be expected that initial chloride concentration in the aquifer would be greatest here. Therefore, the density difference between the water at the source and the relatively fresh water to the west will be significant. In addition, the brine originating from the well field is also high in other naturally occurring material, such as bromide, sulfate, and sulfides, which will further increase the density of this water.

2.) Once the brine had contacted the bedrock, it would tend to remain at the bottom of the aquifer due to the density differences noted in (1) above. These same density differences would prevent significant mixing of the brine and fresh water as it migrated, except at the boundary zone.

3.) Assuming a relatively constant source renewal, as the brine moves laterally the surface area of the brine in contact with the fresh water increases, thereby promoting dilution of the chlorides with distance. However, the preferential location of the brine will remain at the bottom of the aquifer.

4.) As the brine reaches the pumping well radius of influence, the brine is preferentially moved into the area of the well and diluted by waters received at the well from the surrounding area within the radius of influence of the pumping well.

4.4.3b Chloride Migration from the West

The situation on the west side of the facility is much different that on the east side. Here saturated thickness is much greater, from 43 meters (130 feet) at the west edge of the study area to 56 meters (170 feet) or greater further west as the center of the McPherson channel is reached. In addition, there is no known offsite source that can explain the deep chloride concentrations or the shallow concentrations associated with monitoring well ZL-1.

It is possible that there is no offsite contaminant area as there is no data available outside the study area to the immediate west. Conversation with McPherson City officials has indicated that the chloride concentration of the water well located on the airport property approximately one mile northwest of the refinery exhibits chloride levels in the range of 30 to 50 ppm. However, this well is not located in an area that could be regarded as a source for the chlorides noted to the west of the refinery in any case. Comparison of the November 1999 chloride concentrations to the January 1999 concentrations for MW-15 and MW-13 reveal that the chlorides in both wells have significantly increased, on the order of 100 ppm or more. In January 1999 chloride concentrations in MW-13 and 15, were 197.8 ppm and 142.9 ppm, respectively. In November 1999 these concentrations were 294.2 ppm and 329.5 ppm, respectively. This represents an increase of 96.4 ppm for MW-13 and 186.6 ppm for MW-15.

Review of the August 1995 data shows that the chloride concentrations for MW-13 and 15 were 296 ppm and 154 ppm. These results suggest that MW-15 is the only well which has a recent and significant increase, as the 1995 level in MW-13 of 296 ppm is essentially the same value as the 294.2 ppm found in water taken from this well in

November 1999. Of note, the 1995 value from MW-15 (154 ppm) is essentially the same as the January 1999 value (142.9 ppm). **Table 7** below illustrates these changes:

Table 7 – Chloride Concentration Differences for MW-13 and MW-15.

Well	*August 1995*	*January 1999*	*November 1999*
MW-13	296	197.8	294.2
MW-15	154	142.9	329.5

Analysis of **Figure 28** shows that areal extent high chloride concentrations detected in the deep wells to the west is very limited in size, at least in the area studied. While it is conceivable that a plume less than 33 meters (100 feet) thick is being captured by WW-10 and moved across the site, it is more probable that the area indicated by the deep map represents a series of small source regions on the refinery itself that, when mapped, can appear to be a larger source potentially originating from offsite. **Figure 30** shows a similar point source at and around shallow well MW-47 and potentially around MW-21S. In both cases, isolated areas of high chloride concentration can be noted. Both of these cases probably represent evidence for small source regions onsite, potentially the result of a past release at the surface. In the case of MW-21S, this is potentially an anomalous result. Samples taken for the source study (see Section 6.0) were used to verify these results .

The overriding feature of interest from the West is the shallow chloride concentrations in the area of the lime ponds and retention ponds. An area of elevated chloride concentration stems from the lime ponds and it seems to be moving in of direction WW-10. However, this shallow chloride plume does not extend beyond the area of WW-10 Therefore, it appears that WW-10 effectively captures the high chloride waters and prevents this water from migrating further east.

With regard to the lime ponds potential to be a source region for chlorides, the chloride levels in monitoring wells LP-101, LP-102, and LP-103 have remained relatively consistent since August 1995. However, the result for LP-104 has varied considerably from 853 ppm in August 1995 to 71.4 ppm in January 1999 to 559 ppm in November 1999. After the January 1999 event, it was postulated that the retention pond was not an appreciable source as the value in LP-104 had been reduced drastically from the 1995 levels. However, the November 1999 results do not support that hypothesis. Further study may be needed to verify what contribution the aeration pond makes to the overall shallow concentration of chloride in this area.

In addition, the values from ZL-1, on the west side of the retention pond and several hundred feet west of the lime ponds, have consistently indicated elevated concentrations of chloride. In fact, the concentrations of chloride have consistently increased each sampling event, from a value of 260 ppm in August 1995 to 313.2 ppm in January 1999 to 540.0 ppm in November 1999. This well is removed a significant distance from any refinery operations area with the exception of the cooling towers, which cool fresh water that has not been in contact with process water. Therefore, a refinery source is unlikely although it is possible that a past release could have occurred in this area.

Groundwater movement in the area of ZL-1 and the lime ponds is primarily southeast, towards the pumping wells. Regional flow absent the effects of the pumping well is primarily north-northeast. This would mean that in order for the lime ponds to be the source of the elevated chlorides found at ZL-1, a groundwater flow reversal would have taken place at some time in this area. As the pumping wells have been in use since World War Two, this scenario is highly unlikely. Therefore, the chlorides found in ZL-1 are from the cooling towers, an old release, or an offsite source. In any event, they are migrating onto the refinery property and will add to the overall amount of chloride intercepted by the refinery pumping wells.

On a positive note, it does not appear that elevated concentrations of chloride are migrating offsite to the north. Deep wells 105D, 106D and 107D were completed as perimeter wells, and sampling results from all three of these wells indicate the chloride concentrations are at acceptable levels in their immediate vicinity.

CHAPTER 5

GROUNDWATER MODELING

5.1 Introduction

In order to understand the movement of potential chloride plumes and better establish source regions, it was necessary to develop a groundwater model, or numerical simulation, of the effects on the groundwater flow regime in the vicinity of the refinery by the pumping wells. The model selected for this process was Groundwater Vistas™, developed by Jim Rumbaugh. It is the first commercially available groundwater modeling program designed specifically to operate in a Windows environment and includes modules for MODFLOW, MODPATH, and MT3D, among others. This program also allows graphical interpretation of the results produced by these models.

5.2 Modeling Parameters

The area of the groundwater model was set up on a 4000 meter (12,200 foot) square grid centered on the refinery (**Figure 30**), which represents the area of the chloride study area shown on **Figure 20** above. The grid cell size was set at 100 meters (305 feet). As noted above, the pumping wells are screened in the bottom 40 feet of the aquifer. In addition, the stratigraphic studies discussed above have shown significant differences in lithology between the upper and lower aquifers, Therefore, a three-layered model was developed which allowed vertical changes in groundwater movement and chloride concentration to be noted.

Groundwater Vistas allows changes in lithology and aquifer characteristics to be incorporated into the model. Therefore, changes in bedrock and static water level elevations were incorporated into the model. In addition, it was possible to vary the hydraulic conductivity gradient across the study area in an attempt to simulate the changes believed to occur across the site and at the pumping wells in particular. Finally, measured levels of chloride concentration taken from monitoring and pumping wells located across the study area were introduced and plume maps were generated for the current situation and for future time steps. This included adjusting the boundary conditions to simulate the movement of a plume moving into the study area. The model used General Head boundary conditions, which allowed the greatest flexibility for adjusting the boundary conditions and simulated the conditions at the boundary with the greatest level of accuracy.

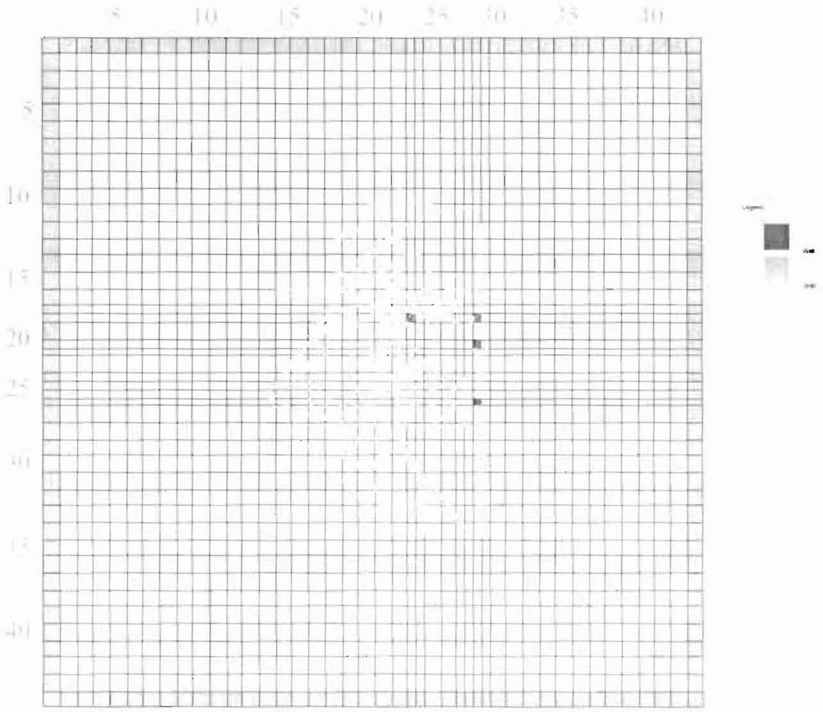

Figure 30 – Chloride Study Area with Grid

The modeling parameters used are given in **Table 8** below:

Table 8 – Groundwater Modeling Parameters

Parameter	**Value**	**Source**
Grid size	4000 m	n/a
Spacing (cell size)	100 m (50m at wells)	n/a
Storativity (x-y)	0.05	Field Data
Leakance (ft/yr)	0.01	KGS Report
Recharge (ft/yr)	6.85 X 10^{-4}	KGS Report
Hydraulic Conductivity X-Y (ft/day)	65 (E) to 165 (W)	Field Data
Hydraulic Conductivity Z (ft/day)	48	Field Data
Bottom Elevation (ft msl)	1280 (E) to 1340 (W)	Field Data
Static Water Level (ft msl)	1395 (E) to 1410 (W)	Field Data
Initial Chloride Concentration	varied based on well	Field Data

General Head Boundary Conditions	**East**	**West**	**North/South**
Hydraulic Conductivity (ft/day)	65	165	variable*
Saturated Thickness (ft)	50	130	variable*
Bottom Elevation (ft msl)	1340	1280	variable*
Static Water Level (ft msl)	1395	1410	variable*
Initial Chloride Concentration (ppm)	1200	0	0

Figure 31 – Cross-Sectional View of Numerical Model Output

Figure 31 above is a W-E cross-sectional view of the model layers, bedrock elevation, and topographic elevation. The first (top) layer extends to the surface, however this does not effect the model results. The calculated gradient across the study area for the bottom/top of the layers are 1.6 x 10^{-4} m/m and 7.9 x 10^{-4} m/m (4.7 x 10^{-4} ft/ft and 2.4 x 10^{-3} ft/ft), from top to bottom, respectively.

5.3 Modeling Calibration and Sensitivity Analysis

The values listed in **Table 8** above were established after many "trial and error" runs were calibrated against actual field data. Calibration was performed against "target" wells using measured data and a sensitivity analysis was performed to establish the values which most closely approximate the measured values. Results of these analyses are included below.

5.4 Modeling Results

The modeling results verified what had been postulated based on the observational results. **Figures32 (a-d)** below illustrates the drawdown and head contours for the study area given pumping rate and drawdown for the four supply wells listed in **Tables 1 and 2**.

Figures 32 (a-d) – Modeled Drawdown (Ft MSL) and Head (ft bgl) for the Four Pumping Wells

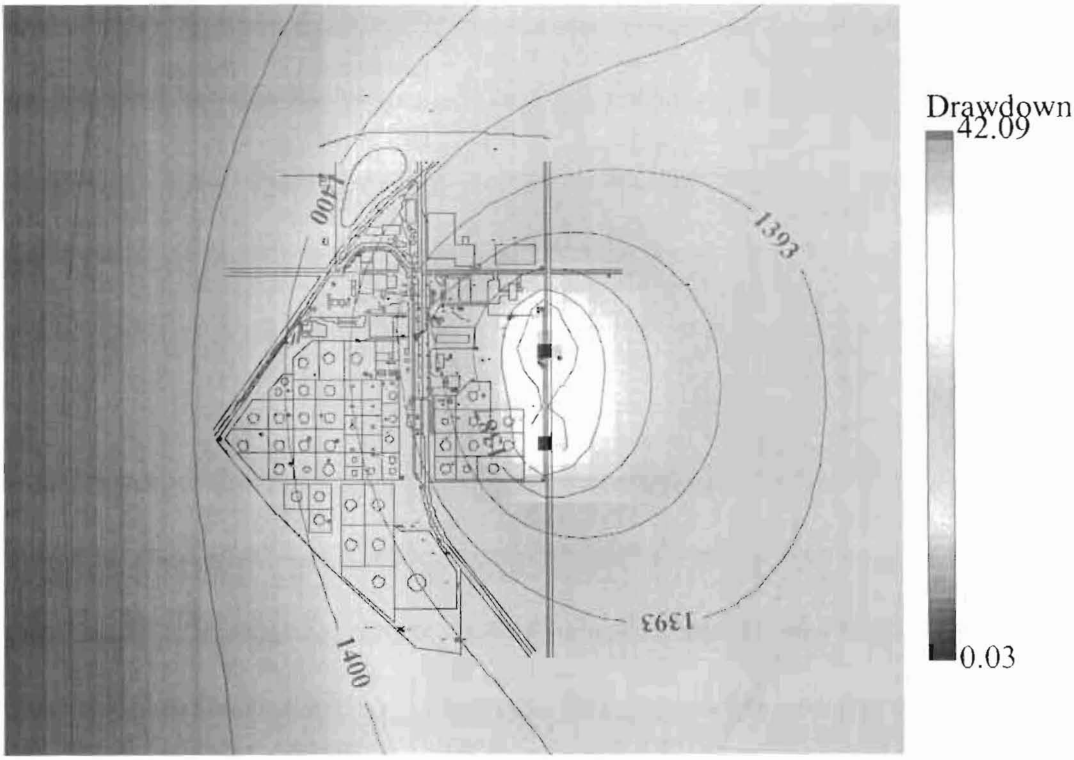

Figure 32a – Shallow Wells, Top Layer

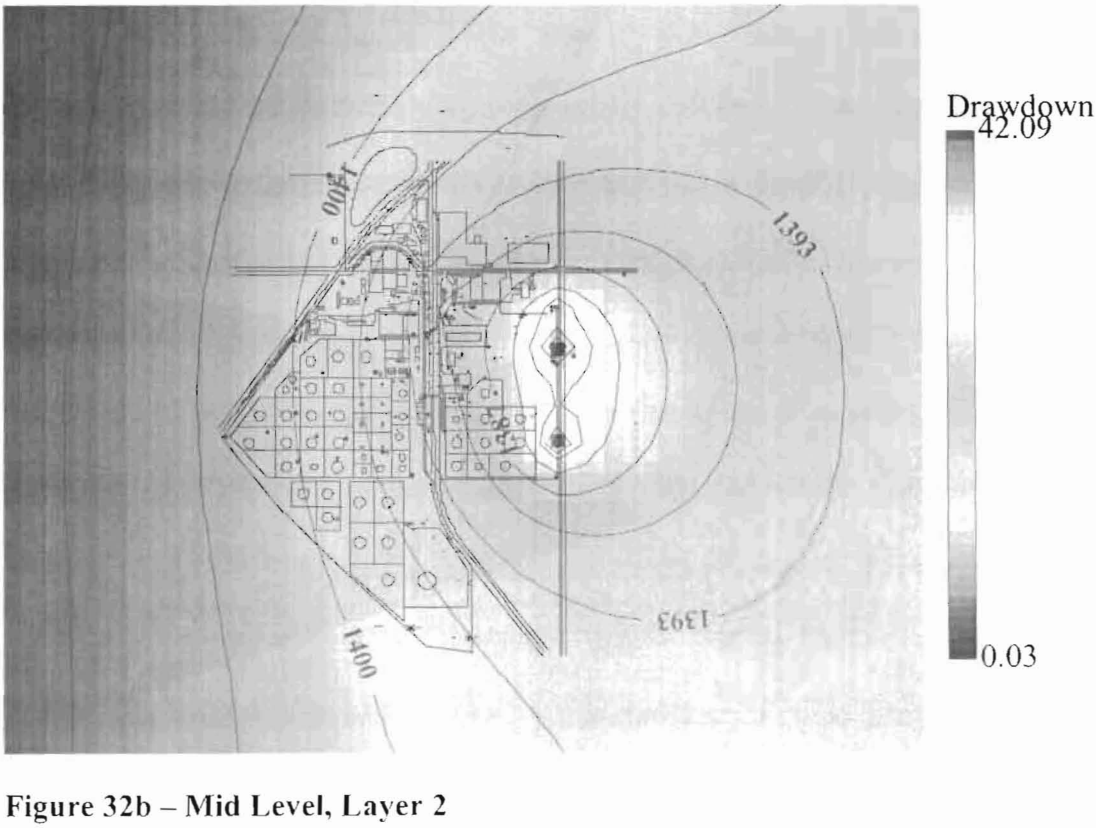

Figure 32b – Mid Level, Layer 2

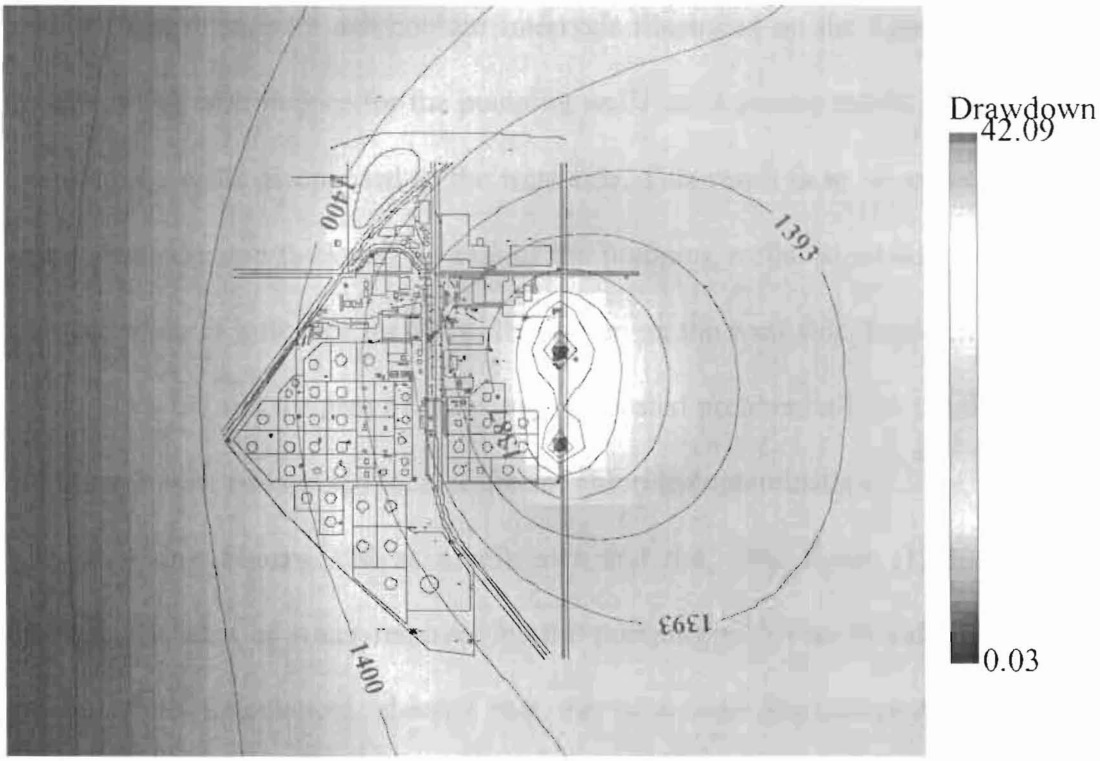

Figure 32c – Deep Wells. Layer 3

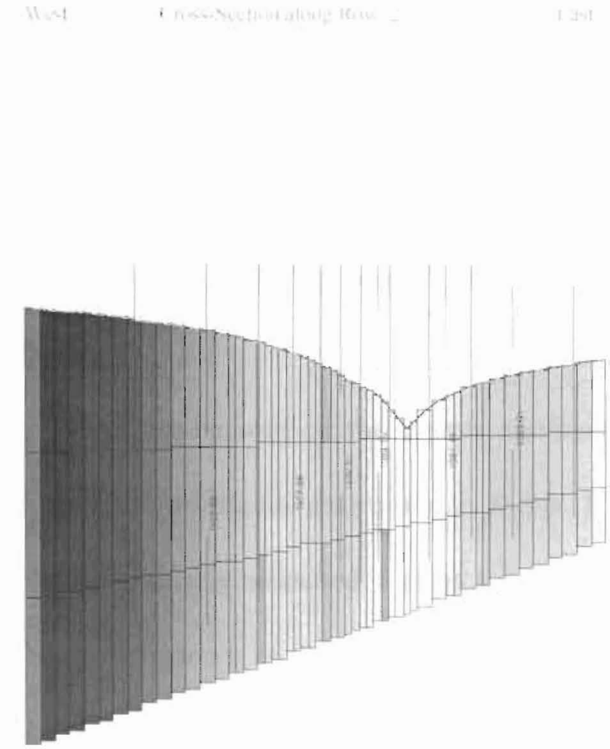

Figure 32d – Cross Sectional View

The drawdown and contour interrvals illustrated on the figures above indicate that the radius of influence for the pumping wells has a greater extent on the east side of the pumping wells as opposed to the west side. This result is to be expected due to the decreasing saturated thickness on east of the pumping wells. In addition, it can be seen that the radius of influence for the wells overlap on the west side (between WW-3, WW-8, and WW-10) and the area of drawdown is located preferentially in the direction of the old Lime Ponds, a suspected local source of chloride contamination.

Using **Figure 32d** as a reference and the 4000 meter (12,200 ft) grid for distance, the area of water removed by the pumping well can be calculated along this cross-section. Calculations showed that the west side displacement was 108161 m^2 (1,163,954 sq.ft.) and the east side was 43267 m^2 (465,468 sq.ft.), for a total water displacement of 151461 m^2 (1,629,422 sq.ft.). Of note, the area indicated here is nearly twice as great on the west side as the east side. It can be seen on **Figure 32d** that there is a greater distance from the pumping well to the model boundary on the west side as opposed to the east, which accounts for some of this difference. However, a good portion of this difference can be explained as the saturated thickness declines on the east side of the facility.

As can be seen on the figures, the maximum drawdown is 13.8 meters (42.09 feet), and the minimum drawdown is 9.8×10^{-3} meters (0.03) feet. This is in good agreement with the measured figures for drawdown taken from the pumping wells. A minimum drawdown of 9.8×10^{-3} meters suggests that the effective radius of influence for the pumping wells (at least on the west side) has been reasonably approximated by the area included as part of the chloride study. The figures show that the radius of influence of the pumping wells on the east side extends beyond the study boundary.

Figures 33–39 (a,b,c) below illustrate predicted changes in chloride concentration at the three levels studied for periods of 1, 2, 5, 7, 10, 15, and 20 years from the present. The simulation was run using the chloride concentrations measured as part of the November 1999 sampling event, and assumes a chloride concentrations of 1200 ppm at the east boundary of the study area. The chloride concentration at the east boundary was an interpolation based on known concentrations from the onsite monitoring wells and the values taken from the report prepared by Whittemore (1997), which has been previously referenced.

5.4.1 Discussion of the Model Simulations

5.4.1a Results from the One and Two Year Simulations:

The first two simulations illustrated in **Figures 33 and 34 (a,b,c)** show a logarithmic contour interval for the plume. As the "background" chloride concentration is assumed to be at zero for all of the study area except the boundary and the individual wells, the modeled concentrations can be theoretically modeled to a very low level, in this case to 0.01 ppm chlorides. In actuality, the background level is approximately 100 ppm, therefore the areal extent of the plume migration at these time intervals are portrayed by this contour interval

This initial logarithmic contour interval was chosen to represent not only the movement of the chloride plume (the 100 ppm interval), but the effects of the pumping wells on the movement of the plume and groundwater between the wells and the eastern boundary. Although the chloride concentration shown on these figures is unrealistically small, the contours do indicate the relative distance from the well at which the groundwater begins to show definite influence from the pumping wells.

Analysis of the model results for these two events shows that substantial plume movement has progressed only a short distance from the initial boundary after two years. These results also show that the plume (represented by the 100 ppm line) is progressing essentially parallel to the boundary. This suggests that the pumping wells exhibit a relatively small influence on the movement of the plume at this distance. This is to be expected as influence of the pumping wells is a function of distance as it pertains to how much pumping is affecting the hydraulic gradients. As the plume gets closer the influence of the pumping wells will increase because the steepness of the hydraulic gradient will increase.

Figures 33 and 34 also show a series of roughly circular lines around the northern half of the refinery. These lines represent the "zero" (or no chloride concentration) contour line for the individual wells on refinery property for which chloride levels were known and were included in the model. The end result, although somewhat difficult to ascertain, is roughly the extent of the chloride contamination onsite as determined by the available well data. This "zero" line is not absolutely accurate as not all of the well data is included at each level, however it does give some indication regarding the containment of the plume onsite due to the pumping wells.

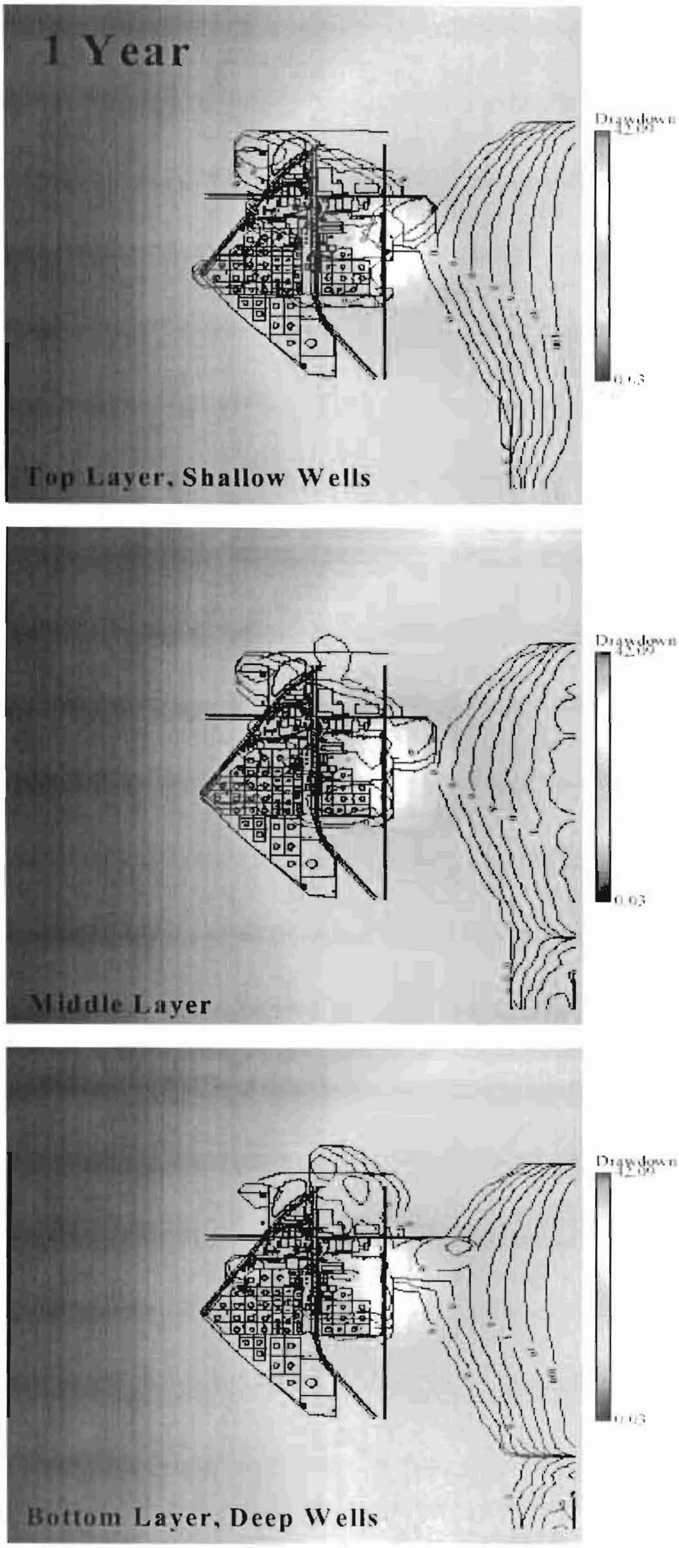

Figure 33 (a,b,c) - One year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

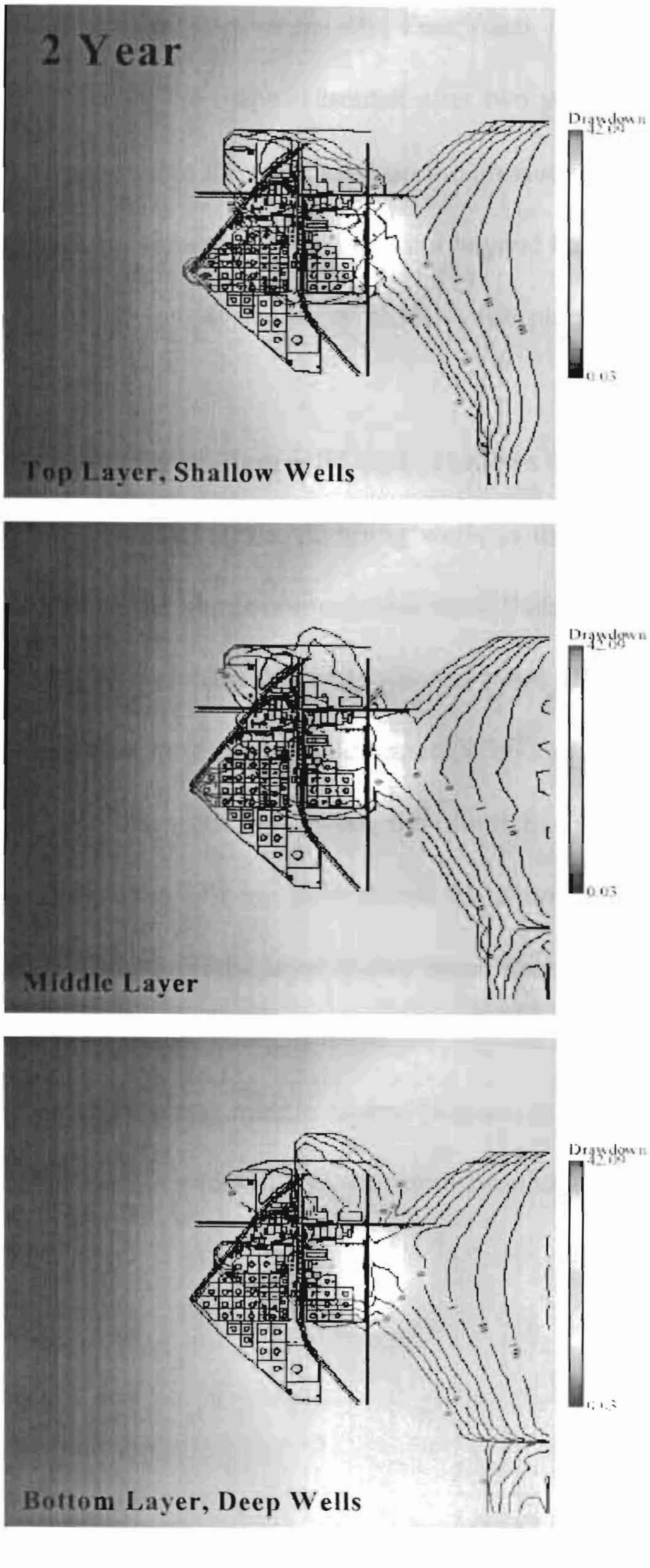

Figure 34 (a,b,c) - Two year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

5.4.1b Modeled Movement after Five Years

All of the maps presented after two years feature a contour interval set at 100 ppm as opposed to the scale used on the previous maps. This new interval was chosen as the plume movement at five years and beyond has progressed to the point that a smaller interval is no longer necessary to show the plume movement and the influence of the pumping wells.

Review of **Figures 35 (a, b, c)** shows that the plume has migrated about halfway from the boundary to the pumping wells in the lower layer, and a distinct "nose" has developed as the plume comes under the influence of the pumping wells. As can be seen from these figures, the plume is moving more towards WW-3 and WW-8 than WW-9, indicating that the plume should impact WW-3 and WW-8 prior to effecting WW-9.

In the upper two layers, the plume has progressed further in the top layer than the middle layer. The top layer shows the plume progression almost as far as the bottom layer, while the middle layer shows much less progress. As pumping is confined to the lowest layer of the model, it is unclear why the model indicates such a marked difference between the top and middle layers. Discussion with other modelers have indicated that the effects of drawdown may be more pronounced than expected, thus producing this effect.

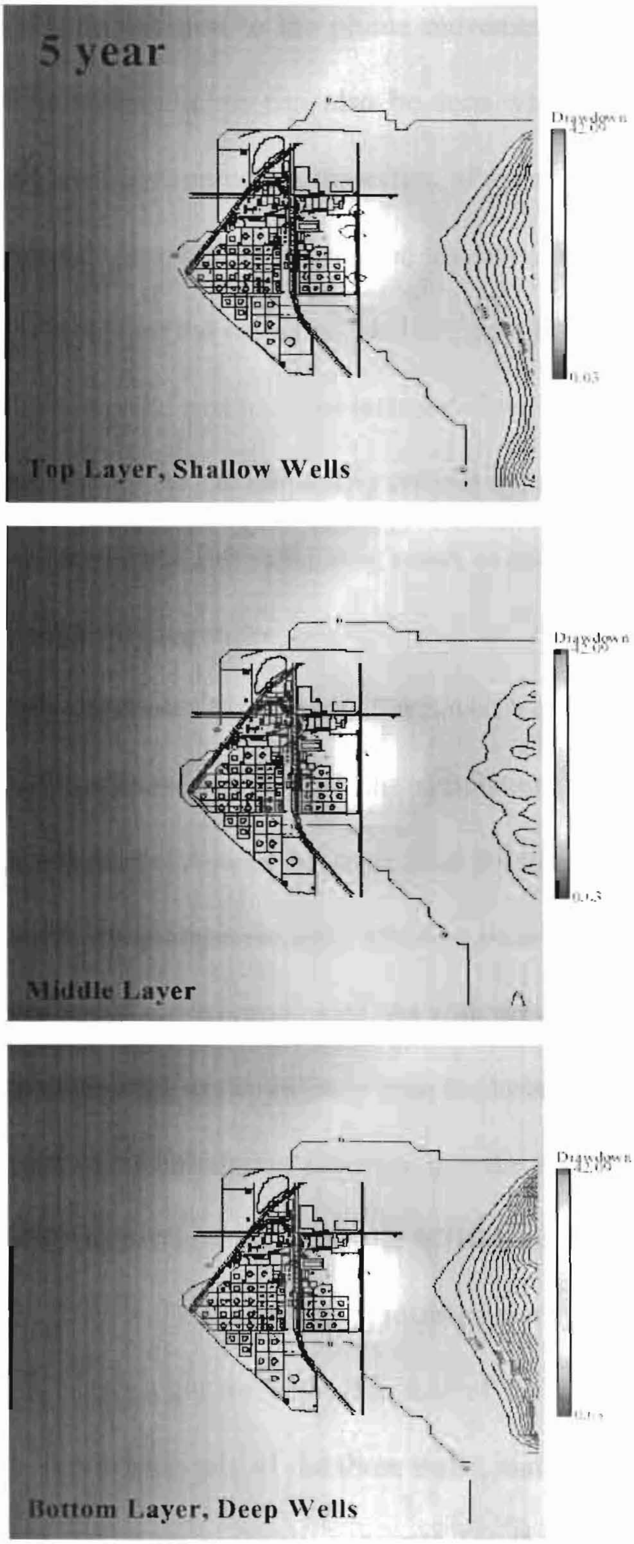

Figure 35 (a,b,c) - Five year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

In addition to the plume movement noted at this time period, the "zero" line concentration contour can also be seen which surrounds nearly all of the facility. As before, this line represents the extent of the chlorides as described by the concentration in the wells shown on the figures and the extent of the 1200 ppm boundary on the east side. Please note that the extent of the 1200 ppm boundary is estimated; therefore the zero line as shown on the east must be interpreted with caution. However, as noted above, the zero line as shown for the remaining areas is consistent with the chloride results found as part of the November 1999 sampling event, as shown in **Figures 27 and 28** above.

5.4.1c Modeled Movement after Seven Years

At seven years into the simulation, the 100 ppm line has nearly reached the pumping wells. As can be seen from **Figures 36 (a,b,c)** the edge of the plume at the lowest layer is approximately 100 feet from the highway, and the nose of the plume has become even more pronounced. As with previous examples, the upper layers of the plume have progressed slightly slower than the lowest layer.

This simulation suggests that the nose of the plume initially migrates beneath refinery property on the west side of the highway slightly south of WW-8, between WW-8 and WW-9. This intrusion point is primarily a function of the combined influences of the three pumping wells on this side of the property. As a general rule, WW-9 has the highest pumping rate of the three wells, and this higher pump rate was incorporated into the model. This probably accounts for the initial contact at a location other than a pumping well.

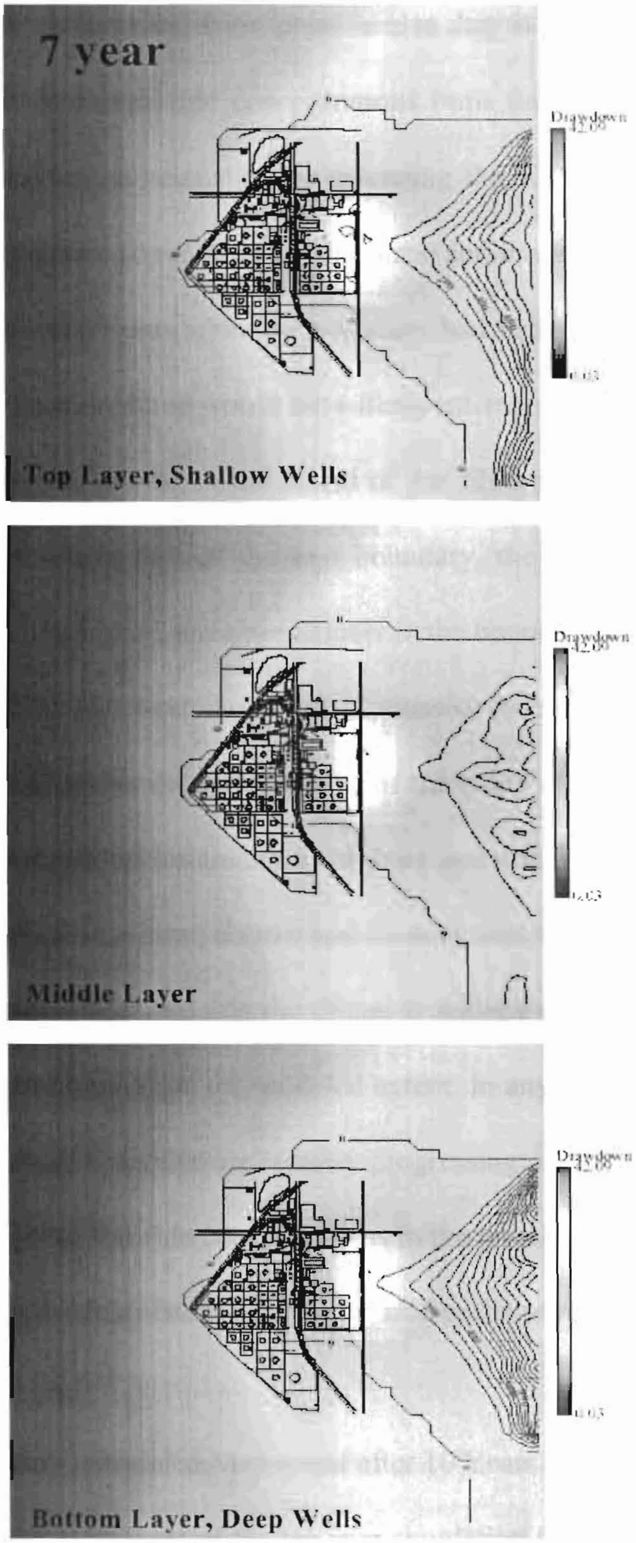

Figure 36 (a,b,c) - Seven year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

This intrusion point is also due to the initial position of the boundaries of the 1200 ppm chloride concentrations built into the eastern edge of the study area. It is probable that relocating or extending the 1200 ppm chloride level on the eastern edge would have some effect on the shape and interception point of the chlorides. For instance, if the 1200 ppm chloride boundary had been confined to the northern edge of the east border, the plume would have likely intercepted the property further north than the model shows. Likewise, if the extent of the 1200 ppm chloride level had been extended along the entire extent of the east boundary, the interception point and shape of the plume would probably have been closer to the boundary midpoint.

This situation is discussed because the actual extent of the chloride concentration on the east edge of the study area is not definitively known. It is possible that the chlorides are confined to an area smaller than that estimated, thereby producing a plume that is more narrow and focused than what the model currently indicates. However, it is also possible that the plume is wider than that estimated by the model, producing a larger plume than the modeled extent. In any event, the model results show that elevated levels of chlorides are steadily progressing onto the refinery property from the east. With regard to chloride concentrations in the remaining parts of the study area, the zero line has remained consistent when compared to the previous examples.

5.4.1d Modeled Movement after 10 Years

Review of the ten year simulation (**Figures 37a, b, c**) shows that the plume has reached pumping well WW-8 and the plume, represented by the 100 ppm line, is very near WW-9. Further review shows that the modeled concentrations are in fair agreement with the actual concentrations taken from these wells as part of the two sampling events taken in 1999.

Sampling data from November 1999 indicated that the chloride concentration in WW-9 was at 117.7 ppm and the concentration in WW-8 was at 517.9 ppm. January 1999 concentrations were at 82.4 ppm and 445.1 ppm, respectively. The ten-year model results indicate that the concentration of WW-9 should be in the 100 ppm range, and the concentration in WW-8 should be approaching 400 ppm. These model results compare well to the concentrations noted as part of the January 1999 sampling event, and are in fair agreement with the concentrations found in November 1999.

Based on the model results and the chloride concentrations found in the wells, it can be surmised that the plume currently impacting the water wells was located at approximately the east boundary of the study area about 10 years ago. This is also in fair agreement with the calculated velocity of the plume discussed in the summary section above. In addition, as noted above in **Figure 6**, chloride samples taken from September 1986 did not indicate any evidence of elevated chloride impact. It must be noted that there is some variability in the model results as the initial concentration in the study area is assumed to be zero everywhere but the east boundary or at individual monitoring wells. However, some of this variability is accounted for by assigning a value of 100 ppm to the edge of the plume.

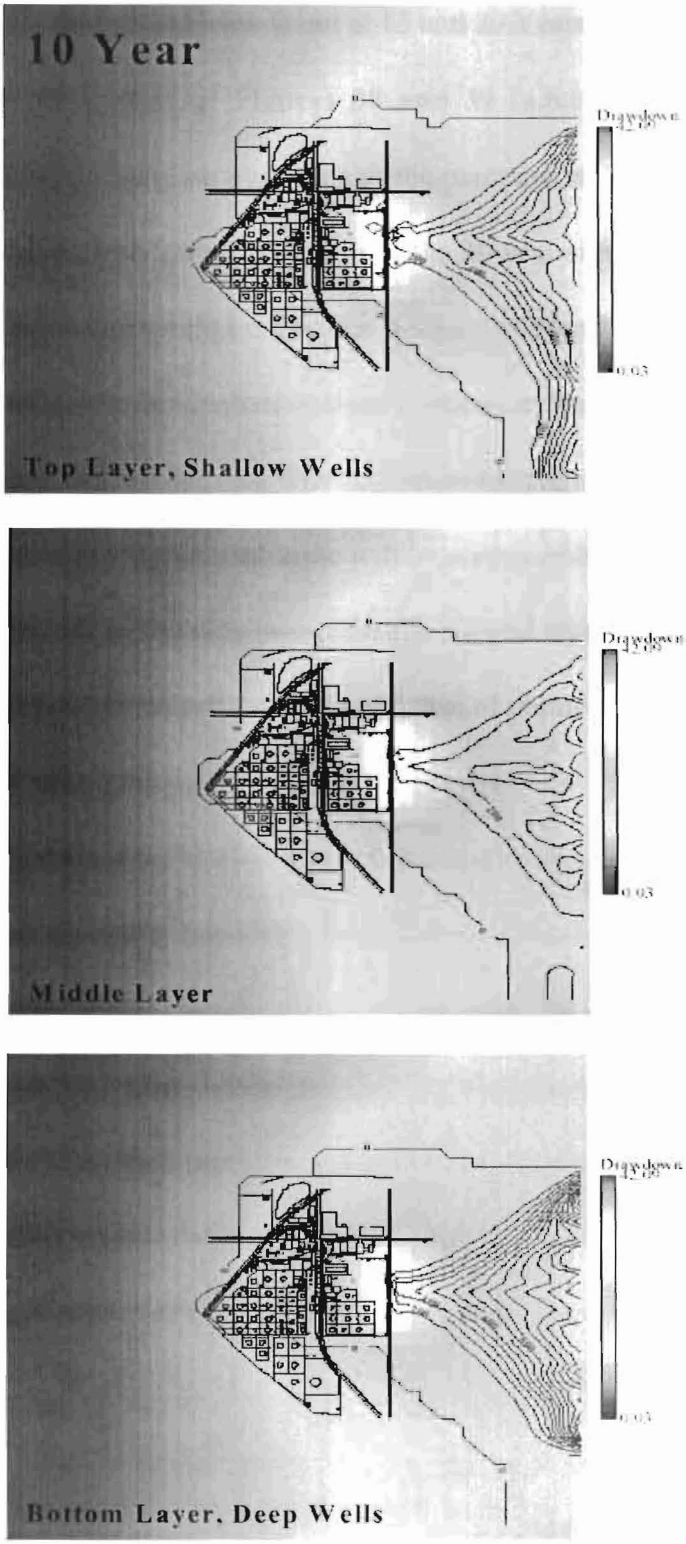

Figure 37 (a,b,c)- Ten year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

5.4.1e Modeled Movement at 15 and 20 Years

Review of **Figures 38 and 39 (a,b,c)** show that the chloride concentrations continue to increase over time at the pumping wells. However, the plume does not begin to significantly affect WW-9 until the 20-year simulation. In addition, it can be seen that the plume migrating onto the refinery property is contained by WW-8 and WW-9. Although the concentration lines continue to "bunch up" at and between these wells, the model does not indicate that migration occurs beyond these wells. Therefore, the model results suggest that the plume will be contained by the pumping wells as long as the wells are in use. In fact, the model results suggest that at least one of the wells could be taken out of service and still maintain control of plume migration.

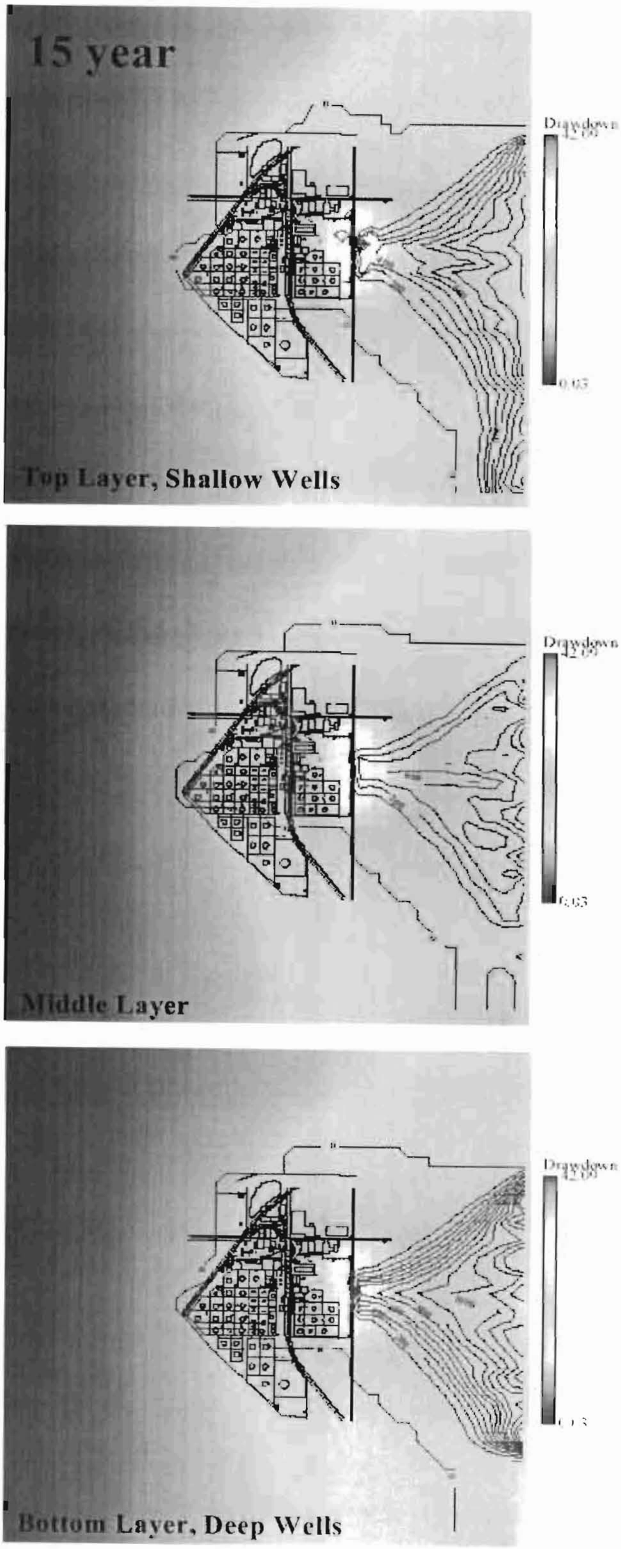

Figure 38 (a,b,c) - Fifteen year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary.

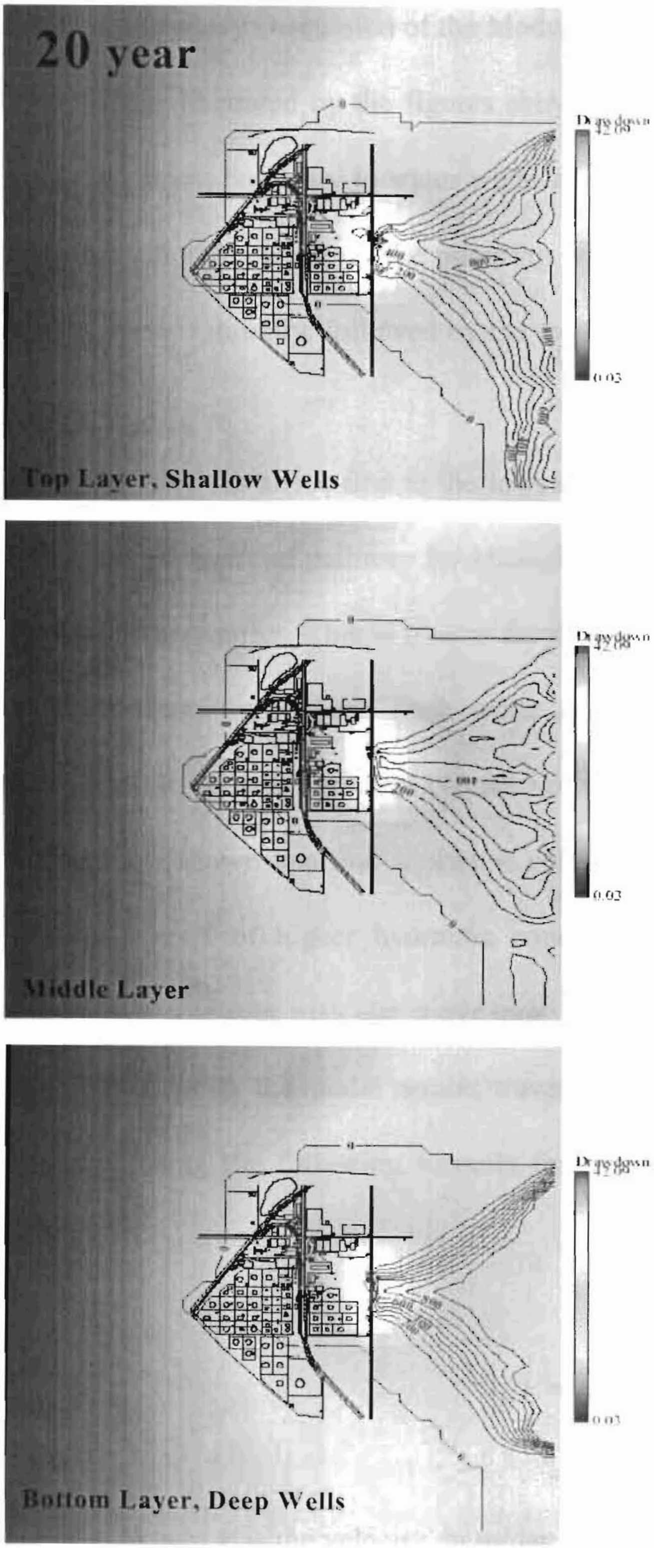

Figure 39 (a,b,c) - Twenty year simulation of chloride concentrations, 1200 ppm chloride concentration at the East boundary

5.4.2 Summary Discussion of the Model Results

As illustrated by the figures above, the model indicates a chloride travel time from the eastern boundary to water wells #3 and #8 of approximately 10 years. It can be seen that chlorides arrive at the pumping wells above background levels in the lowest layer (Layer 3) initially, followed by the top layer (Layer 1) and finally the middle layer (Layer 2).

Chlorides arrive first at the lowest layer for a number of reasons. As discussed above, the preferential pathway for chlorides originating east of the facility is along the bottom of the aquifer. This is due to the decreased saturated thickness near the source, density differences between fresh water and brine, and the location of the screened interval at the bottom 13 meters (40 feet) of the pumping wells. In addition, stratigraphic studies have shown that that aquifer is coarsest in the lower levels, indicating that this may be a zone of higher hydraulic conductivity. Therefore, water high in chloride migrating to this zone may also move more rapidly through this zone.

To verify the model results, travel time from the east boundary to the well was estimated using the following formula for average linear velocity (taken from Heath, 1991):

$$V = KI/N$$

Where V is the velocity, in m/day, K is the hydraulic conductivity, in m/day, I is the hydraulic gradient, in ft, and N is the porosity. Using this formula, the travel time is computed as:

$$V = 24.6\ m/day(0.004.92\ x\ 10^{-4}\ m/m)/0.2$$

$$V = 0.18\ m/day\ (0.56\ ft/day)$$

This equates to approximately 67.2 meters/year (205 feet/year), or 672 meters (2050 feet) over ten years. The distance between the eastern edge of the boundary and WW-3 and WW-8 is approximately 787 meters, or 2400 feet (after **Figure 21** above). The hydraulic conductivity (***K***) value of 24.6 m/day (75 ft/day) used above is based on the known conductivity changes across the entire site and approximates the average conductivity between the eastern edge of the boundary and the pumping wells. The value used for hydraulic gradient (***I***) also represents the overall hydraulic gradient across the study area. Given the potential range of input parameters, the difference between the modeled velocity and the calculated velocity is reasonable and does a fair job of validating the results of the model simulation.

Elevated chloride levels also reach the pumping wells in the top layer and the middle layers of the aquifer. The initial chloride concentration of 1200 ppm set at the east boundary of the study area was constant throughout the three layers of the model. This may not be strictly representative of the actual vertical concentration of chlorides at the boundary, however no data is available for the upper two layers at the boundary. This represents a conservative scenario and may overestimate the volume of the source.

What can be surmised to a degree from the upper layers of the aquifer is the transport rate absent the effects of active pumping in the upper two zones, as the water wells are screened in the lower portion of the aquifer. For the model, the pump rate was set at zero in both the upper and middle layer. Based on this, it can be postulated that transport of the chlorides in the upper layers is a function of the observed gradient, although the gradient is significantly effected by the pumping wells. This is of particular significance in the study area due to drawdown by the pumping wells across the study area.

CHAPTER 6

THE CHLORIDE SOURCE IDENTIFICATION STUDY

6.1 Introduction

Following completion and analysis of the November 1999 sampling event, a final phase of the study was undertaken to further define the source(s) of the chlorides found as part of the sampling. This effort also served as verification of the previous sampling results for a selected group of monitoring wells (**Table 10**) that exhibited potentially anomalous results or were located in areas of particular significance for the overall study.

In order to accomplish the source identification, Dr. Don Whittemore (KGS) was contacted. Dr. Whittemore has pioneered efforts in this area and has been employed in chloride source identification studies by the KGS and KDHE, including a 1997 study in the McPherson area. Identification of the chloride source(s) followed the geochemical methods of Whittemore (1984, 1988, 1995, 1997). These methods primarily include plots of the constituent mass ratios bromide/chloride and sulfate/chloride vs. chloride concentrations, and points for the water sample data and curves for the mixing of different source waters.

Each mixing curve is calculated using an algebraic equation for conservative mixing of two end-point waters. Conservative mixing equates to the simple mixing of water without chemical reactions that could alter the concentrations of one or both of the constituents. The intersection of the two mixing curves can be determined graphically or by solving for simultaneous algebraic equations. Logarithmic scales are used in the graphs to produce a more even distribution of points for large ranges in concentration than would be noted utilizing linear scales.

6.1.1 Results of the 1997 Whittemore Study

As briefly introduced in Section 4.0 above, a previous study undertaken by Whittemore (1997) indicated that the chloride concentrations east of the facility increase to the east, reaching the highest levels approximately 3.2 km (2 miles) east of the refinery at the beginning of the Johnson Oil Field. In addition, the closed municipal landfill is located in approximately the same location and the Whittemore study indicated that it was also contributing to the elevated levels of chlorides found in this area.

Figure 40 (after Whittemore, 1997) below illustrates the sampling locations utilized as part of the 1997 study. As can be seen on this figure, samples were taken from the area of the Johnson Well Field and the old Municipal Landfill, in addition to samples of domestic wells located between the well field and the refinery. **Table 9** (after Whittemore, 1997) below shows the chloride concentrations noted in samples taken from these locations. This table also indicates the concentrations of sulfate and bromide, along with the bromide/chloride and sulfate/chloride ratios for the waters.

The 1997 study revealed that brine waters originating from the Johnson Well Field had a Br/Cl ratio in the range of 43.8 to 45.3 (after multiplying by 10,000). Whittemore reported that oil field brine was the primary saltwater source for all of the points sampled as part of the study, and the ratios ranged from 28.6 to 42.1 (after multiplying by 10,000). For samples taken in areas outside the influence of the municipal landfill, Whittemore reported that the percent of total chlorides in the groundwater samples attributed to oil field brine was no less than 84%.

Table 9 shows that chloride concentrations in the Bowman and Tim Shaw domestic wells, located roughly 1.6 km (one mile) east of WW's 3, 8, and 9, were 2530 ppm and 3130 ppm, respectively. The John Shaw well, located approximately 2.4 km (1.5 miles) from the pumping wells, indicated a chloride concentration of 1566 ppm, and MW-7 located north of the John Shaw well but south of the old Municipal Landfill, showed a chloride concentration of 2360 ppm. Samples of the lease brine taken approximately 2 miles east of the water wells indicated chloride concentrations in excess of 100,000 ppm. The results of the initial study clearly show that brine from the Johnson Well Field has impacted the groundwater and is moving towards the refinery pumping wells.

Figure 40 – Locations of the Sampling Points

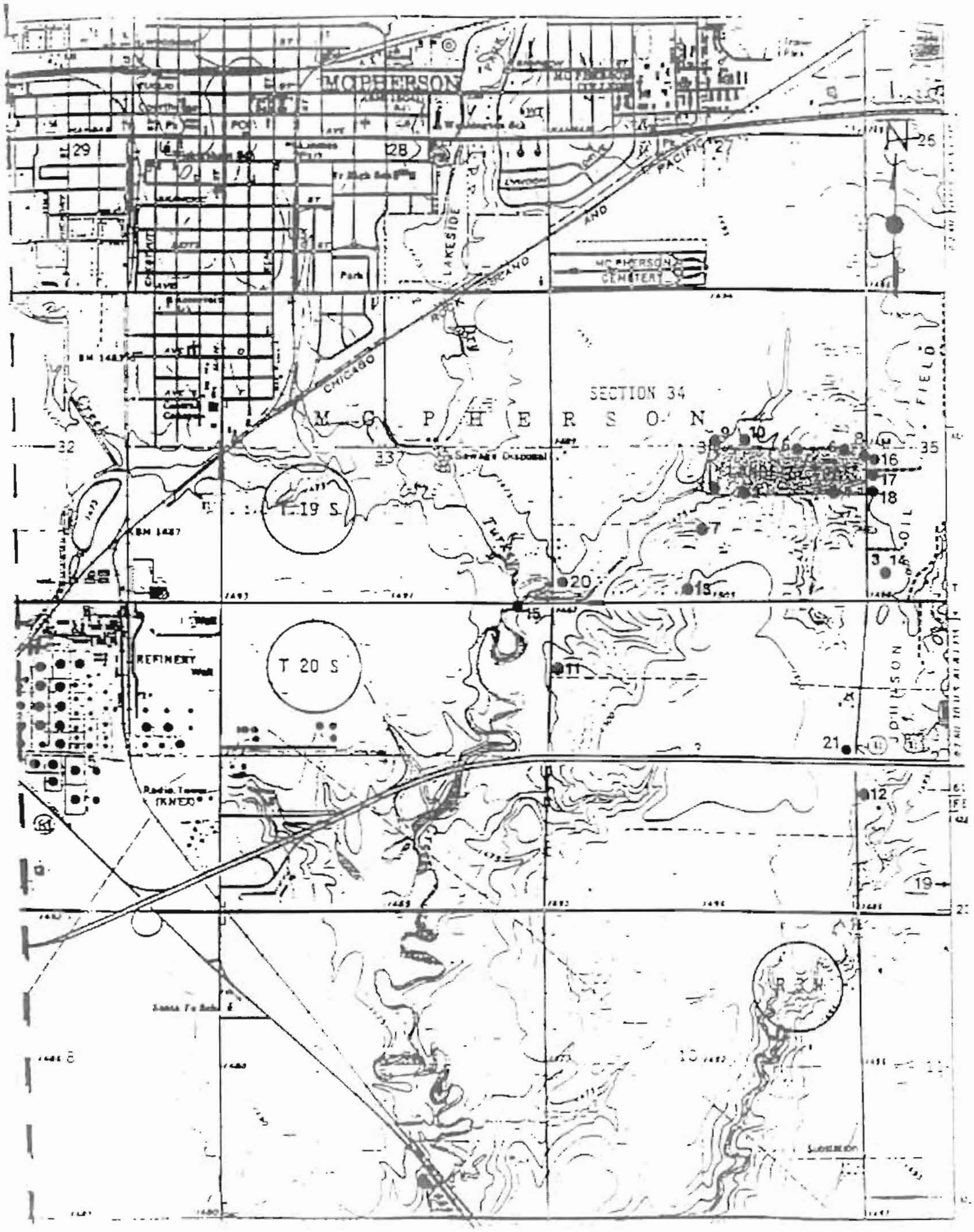

Table 9 – Results of the 1997 Whittemore Study

Map locator number	Sample identification	Location	Collection date	Date received	Date analysis completed	KGS project number	KGS lab number	Sp.C., lab pS/cm	SO_4 mg/L	Cl mg/L	Br mg/L	Br/Cl x 10^4	SO_4/Cl
16	Geoprobe #1	19-03W-35CBBB	3/6/97	3/10/97	3/26/97	BRID-001	970033	4773	111	1472	5.39	36.6	0.0754
17	Geoprobe #2	19-03W-35CBBC	3/6/97	3/10/97	3/26/97	BRID-002	970034		102	681	1.95	28.6	0.150
18	Geoprobe #3	19-03W-35CBCB	3/6/97	3/10/97	3/26/97	BRID-003	970035	3730	209	907	3.09	34.1	0.230
1	MW-1D	19-03W-34DBBC	9/22/97	9/25/97	11/3/97	BRID-004	970404	2880	37.8	386	1.63	42.1	0.0979
2	MW-2D	19-03W-34DBCA	9/22/97	9/25/97	11/3/97	BRID-005	970405	7395	202	2110	7.10	33.7	0.0957
4	MW-4	19-03W-34DACA	9/22/97	9/25/97	11/3/97	BRID-006	970406	3230	1766	154	0.49	31.6	11.5
5	MW-5D	19-03W-34DABB	10/1/97	10/8/97	11/3/97	BRID-009	970413	3580	144	828	2.62	31.6	0.174
6	MW-6D	19-03W-34DAAB	10/1/97	10/8/97	11/3/97	BRID-010	970414	2940	120	706	2.12	30.1	0.170
7	MW-7D	19-03W-34CDAB	10/2/97	10/8/97	11/3/97	BRID-011	970415	7810	90.0	2360	9.02	38.2	0.0381
8	MW-8	19-03W-34DAAA	10/1/97	10/8/97	11/3/97	BRID-012	970416	3500	1546	394	1.48	37.6	3.92
9	MW-9	19-03W-34ACCC	10/1/97	10/8/97	11/3/97	BRID-013	970417	3400	217	729	2.52	34.6	0.298
10	MW-10	19-03W-34ACCD	10/1/97	10/8/97	11/3/97	BRID-014	970418	3480	85.0	868	2.72	31.4	0.0979
11	Tim Shaw well	20-03W-03BBC	9/22/97	9/25/97	11/3/97	BRID-007	970407	9670	85.8	3130	12.4	39.7	0.0274
12	McBeath well	20-03W-02CBB	10/1/97	10/8/97	11/3/97	BRID-015	970419	2930	207	645	2.51	38.9	0.321
13	John Shaw well	19-03W-34CDD	10/1/97	10/8/97	11/3/97	BRID-016	970420	5480	191	1566	5.97	38.1	0.122
3	Johnson Lease brine	19-03W-35C	9/25/97	10/8/97	11/3/97	BRID-008	970412	173900	76	101500	457	45.0	0.0007
14	Johnson Lease brine	19-03W-35C	10/2/97	10/8/97	11/3/97	BRID-017	970421	181000	72	105000	475	45.3	0.0007
19	Johnson Oil Field	20-03W-02CD	6/3/83				83275	177000	2	78520	344	43.8	0.00003
15	Dry Turkey Creek	20-03W-04AAAB	10/1/97	10/8/97	11/3/97	BRID-018	970422	2095	90.7	509	0.69	13.5	0.178

Table 9 – Results of the 1997 Whittemore Study, Continued

Map locator number	Sample identification	Location	Collection date	Collection time	Date received	Date analysis reported	KDHE lab number	Collector
16	Geoprobe #1	19-03W-35CBBB	3/6/97	11:45	3/7/97	3/26/97	701104PT	Poyer/Dallen
18	Geoprobe #3	19-03W-35CBCB	3/6/97	15:45	3/7/97	3/26/97	701106PT	Poyer/Dallen
7	MW-7S	19-03W-34DAAB	10/1/96	14:45	10/2/96	10/8/96*	700582PT	Medina
7	MW-7D	19-03W-34CDAB	10/2/97	14:50	10/2/96	10/8/96*	700580PT	Medina
20	Bowman domestic well	19-03W-34CCC	9/12/96		9/13/96	11/3/97	700472PT	Medina/Poyer
13	John Shaw domestic well	19-03W-34CDD	10/1/97	15:45	10/2/96	10/8/96*	700581PT	Medina
21	Fred Johnson stock well	20-03W-03 ADD	11/25/38					

Sample identification	Ca mg/L	Mg mg/L	Na mg/L	Alkalinity as $CaCO_3$ mg/L	SO_4 mg/L	Cl mg/L	NO_3-N mg/L	Br mg/L	Br/Cl x 10^4	SO_4/Cl	NaCl
Geoprobe #1	639	125	96.6		102	1543		5.68	36.8	0.066	0.063
Geoprobe #3	503	73.2	132		198	959		3.39	35.4	0.206	0.138
MW-7S	396	47.8	437	363	78.1	1200	4.24			0.065	0.364
MW-7D	525	78.4	750	363	82.8	2030	5.85			0.041	0.369
Bowman domestic well	563	82.6	789		80.2	2530	6.71			0.032	0.312
John Shaw domestic well	345	58.2	542	206	109	1380	7.00			0.143	0.393
Fred Johnson stock well	508	180	202	60	2130	118	0.50			18.1	1.71

6.2 Discussion Regarding the Current Source Identification Study

6.2.1 Introduction

The source identification study was undertaken in an attempt to add further verification to the sampling and modeling results with regard to source(s) of the chlorides impacting the water wells at the facility. As noted above, the 1997 Whittemore study had produced a characteristic Br/Cl ratio that could be used for comparison against the results found from groundwater sampled from the wells used in the current study.

One potential drawback to the method is that since the refinery processes crude oil, and the chlorides found onsite might have been brought onto the facility via the crude oil processed, it might be difficult to distinguish between the Johnson oil field brine and the brine originating from crude processed at the facility. This assumes that the chemical characteristics of all oil field brine is similar to that found from samples of the Johnson oil field brine. In addition, it is known that the refinery has processed crude from the Johnson oil field for a number of years. Fortunately, the results of the sampling did indicate marked differences between the chemical characteristics of the groundwater from the sampled wells, which provided for effective comparison to the Johnson oil field results.

6.2.2 Results of the Current Source Identification Study

Table 10 below illustrates the monitoring wells from which groundwater samples were taken for purposes of source identification. As noted above, these wells were also chosen as verification for previous sampling results.

Table 10 – Source Identification Monitoring Points and Results (Based on Whittemore, 2000)

Well number		110 D	15 D	20 D	53 D	3 D	8 D	LP-102
Collection date	m/d/yr	3/15/00	3/15/00	3/15/00	3/15/00	3/15/00	3/15/00	3/15/00
Collection time	24 hr	10:41	11:50	12:05	12:25	11:19	11:30	13:00
Well depth	ft bls	156	150	150	158	160	158	100
Screened interval	ft bls	136-156	60-150	60-150	58-158	115-160	118-158	80-100
Lab Sp.C.	US/cm	2080	1600	1460	2220	1370	2080	2430
Na	Mg/L	95.5					74.5	
K	Mg/L	3.7					3.0	
HCO3	Mg/L	313					343	
Cl	Mg/L	476	250	174	397	238	484	305
SO4	Mg/L	45.2	8.5	3.2	0.5	46.7	35.5	360
NO3-N	Mg/L	4.2	0.1	0.4	0.9	0.4	2.8	16.0
Br (uncorrected)	Mg/L	1.890	0.703	1.024	0.664	0.763	1.905	0.876
Br (corrected)	Mg/L	1.88	0.64	0.68	0.24	0.70	1.89	0.75
I (total)	Mg/L	0.0147	0.0699	0.381	0.482	0.086	0.0251	0.147
IO3-I	Mg/L	0.0049	0.0008	<0.001	0.0052	0.0178	0.0081	0.0038
TDS	Mg/L	1097					1107	
Na/Cl	Mass ratio	0.201					0.154	
Ca/Mg	Mass ratio	12.5					10.9	
Ca/SO4	Mass ratio	6.19					8.45	
SO4/Cl	Mass ratio	0.0950	0.0340	0.0184	0.0013	0.196	0.0733	1.180
(Ca+Mg)/Na	Equiv. ratio	3.81					5.32	
Br(uncorrd)/Cl	x 10000	39.6	28.1	58.9	16.7	32.1	39.4	28.7
Br/Cl	x 10000	39.5	25.6	39.1	5.9	29.5	39.0	24.5

Table 10 – Source Identification Monitoring Points and Results (Based on Whittemore, 2000), Continued

Well number		LP-103	LP-104	MW-21 S	MW-47 S	ZL-1	ZL-6	
Collection date	m/d/yr	3/15/00	3/15/00	3/15/00	3/15/00	3/15/00	3/15/00	
Collection time	24 hr	13:20	14:20	12:40	11:40	13:50	10:59	
Well depth	ft bls	93	93	83	80	90	95	
Screened interval	ft bls	73-93	73-93	63-83	55-80	75-90	80-95	
Lab Sp.C.	uS/cm	2070	2600	4290	2370	1820	1190	
Na	mg/L		160			123		
K	mg/L		3.3			4.0		
HCO3	mg/L		411			445		
Cl	mg/L	254	519	1068	458	183	185	
SO4	mg/L	181	198	5.4	<2.5	272	35.9	
NO3-N	mg/L	0.2	12.4	2.6	1.1	20.2	0.2	
Br (uncorrected)	mg/L	0.675	0.667	1.192	3.460	0.404	0.371	
Br (corrected)	mg/L	0.64	0.66	0.07	3.11	0.39	0.37	
I (total)	mg/L	0.0469	0.0129	1.25	0.39	0.0172	0.015	
IO3-I	mg/L	0.0039	0.0055	0.0007	<0.001	0.0024	0.031	
TDS	mg/L		1533			1169		
Na/Cl	mass ratio		0.308			0.671		
Ca/Mg	mass ratio		18.8			15.1		
Ca/SO4	mass ratio		1.89			0.961		
SO4/Cl	mass ratio	0.713	0.382	0.0051	<0.005	1.486	0.194	
(Ca+Mg)/Na	Equiv. ratio		2.92			2.71		
Br(uncorrd)/Cl	x 10000	26.6	12.9	11.2	75.5	22.1	20.0	
Br/Cl	x 10000	25.1	12.7	0.6	67.9	21.3	20.0	

Review of the information contained in the table reveals differences between the chemical composition of groundwater taken from the various sampling points. These differences are discussed in further detail below. As can be noted upon review of the information discussed below, the results of the source identification study strongly support the modeling results and the field studies.

The source study analysis indicated that monitoring well MW-110D and water well #8 have the highest Br/Cl ratio correlation when compared to the ratio for the Johnson well field found as part of the 1997 Whittemore study. In addition, monitoring well ZL-6, a relatively shallow well located east of water wells 3, 8, and 9, also shows evidence of oil field brine contamination. The water from ZL-6 indicates mixing of oil field brine with fresh water, which is what the model results predict for a shallow well located in the area of ZL-6. The concentration of oil field brine noted in ZL-6 is most probably due to the influence of the cone of depression caused by the pumping wells, and associated mixing that will occur along the boundary between the brine and fresh zones.

The source study also showed that the shallow point sources found on the facility, including the area around the old lime ponds, indicated distinct chemical differences from the Johnson well field brine samples. The Br/Cl ratio is distinctly different for the shallow point source regions, and there is also a difference in the sulfate/chloride ratio, the iodide concentration, and the nitrate concentrations. While the study results do not definitively point to a source for these shallow onsite samples, the results do show that Johnson oil-field brine is not the primary source.

After review of the results from the current study, Whittemore divided the monitoring wells into five different groups, based on the chemical constituents found in the groundwater from each well (personal communication, 2000). These groups are discussed below:

Group 1: Waters with a substantial chloride contribution from oil-field brine

Well numbers WW#8 and 110D

Whittemore reported that groundwater taken from these wells exhibits a Br/Cl ratio similar to the groundwater contaminated by the Johnson oil field brine to the east of the NCRA area. The sulfate/chloride ratios are low as would be expected for a mixture of fresh groundwater in the Equus Beds aquifer with small amounts of oil brine. The inorganic iodine content from both samples is low. The cation and Na/Cl ratios for these samples indicated that cation exchange has occurred (adsorption of Na and release of Ca and Mg into solution) during the migration of the Na-Cl chemical type of saltwater source (oil brine) into the Equus Beds aquifer.

MW-110D is a deep well and is located furthest east. As previously noted, all indications are that this well should demonstrate the most pronounced impact from the Johnson well field brine. In addition, model results show that WW#8 is the water well initially impacted by the plume originating from offsite to the east. Therefore, the chemical results for these two wells are in agreement with all other elements of the study.

Group 2: Waters with a substantial chloride contribution from oil-field brine and a small contribution from an additional source low in sulfate, nitrate, and iodine

Well numbers WW#3, 15D, ZL-6

These samples fit the mixing of oil-brine with fresh ground water in the Equus Beds that have been affected by a small additional chloride source. The waters have relatively low sulfate/chloride ratios and low nitrate and iodine concentrations. WW#3 and ZL-6 are located on the east side of the facility. ZL-6 is a shallow well east of WW#3 but west of MW-110D, while WW#3 is one of the water wells located on the east side of the facility. The chemical results indicate that ZL-6 and WW#3 have been impacted by oil field brine, however not to the extent that WW#8 and MW-110D have been. The modeling and sampling results support this hypothesis. MW-15D is a shallow well located on the west side of the facility. The chemical results indicate that the contamination found in this well may consist of oil field brine, however given the location and the other chemical constituents, it is unlikely that the source is the Johnson oil field.

Group 3a: Water with a mixed chloride source that could include some oil brine contamination and some other saline water that has a high sulfate concentration.

Well number LP-103

This sample fits the mixing of oil field brine, saline water with a high sulfate concentration, and fresh ground water in the Equus Beds. The water has a substantially higher sulfate content and sulfate/chloride ratio than found in Group 2 but otherwise is similar based on low nitrate and iodine concentrations. Monitoring well LP-103 is a shallow well located in the area of the old lime ponds, a suspected chloride source. Chlorides from this well are postulated to originate from refinery sources as water in the old unlined lime ponds migrated through the vadose zone to the aquifer. The chemical results noted above support this hypothesis as a higher sulfate concentration would be expected for water that had been processed by the refinery, as sulfur and sulfur compounds are byproducts of the refining process.

It appears, therefore, that the source for the chlorides found in groundwater samples from this well originate primarily from brine waters processed by the refinery. However, it must be noted that the refinery uses water from the water wells that have been impacted by brine from the Johnson well field. Until the ponds were taken out of service in 1994, much of the process water would have been ultimately directed to the lime ponds. While the water wells have been recently impacted when compared to the total time the lime ponds were in service, it is possible that a portion of the water from this well and the other lime pond wells may include brine from the Johnson well field.

Group 3b: Water with a high nitrate content that has a mixed chloride source that could include some oil brine contamination and some other saline water that has a high sulfate concentration.

Well number ZL-1

This water fits the mixing of oil-brine and another saline water with a high sulfate concentration with fresh ground water in the Equus Beds. The water has a high nitrate content and a substantially higher sulfate content and sulfate/chloride ratio than the waters in Group 2 but has a low iodine concentration.

Monitoring well ZL-1 is located away from all refinery processes except the cooling towers, which are used to cool process water from the refinery. It is also located immediately adjacent to a farm field currently producing cash crops. The relatively high nitrate concentration is undoubtedly due to the proximity of the farm field and the use of a nitrogen containing fertilizer (such as ammonia or ammonium) on the field. The incidence of high sulfate concentrations may be attributed to the process water, as there is some loss due to spray as water is taken through the cooling towers. As in the case of the lime pond wells, a percentage of the chlorides may originate from Johnson oil field brine that was introduced to the refinery process system and was subsequently introduced into the groundwater by the infiltration of spray from the cooling towers.

Group 3c: Water with high nitrate and sulfate contents and elevated iodide concentration.

Well water LP-102

This sample has some similarities to water from well ZL-1 but has a much higher iodide content. This suggests that it has been affected by waters similar to Group 4a or 4b. As with the previous lime pond well samples, this sample had elevated sulfate levels and therefore the source is probably refinery process water.

Group 4a: Waters with a relatively high iodide content and bromide/chloride ratio and low sulfate and nitrate concentrations.

Well numbers MW-47 S and 20 D

Well water MW-47S has the highest Br/Cl ratio of all groundwater samples; the ratio is substantially greater than that of the Johnson oil field brine. Water from 20D has a much smaller chloride content than MW-47S, however it has a similar iodide content.

Whittemore proposed that water from MW-20D could possibly be a mixture of water from the MW-47S area with fresh ground water from the Equus Beds. While this is possible, based on groundwater flow, it is felt that based on the locations of the respective wells it is more probable that these wells represent separate point source releases of similar material at some point in the past.

One of the distinguishing differences between Johnson oil field brine and brine from shallow sources on the refinery property was the presence of elevated levels of iodide in the refinery samples when compared o the Johnson oil field samples. The source of the high iodide content is unknown, as there are no refinery processes that use iodine or iodine compounds. It is possible that brine from other oil fields contain a higher iodide content, however this is speculation. Additional sampling and analysis of brine from other oil fields supplying crude to the refinery would be necessary to determine the true source of elevated iodide concentrations.

Group 4b: Waters with a relatively high iodide content and low bromide/chloride ratio and low sulfate and nitrate concentrations.

Well numbers MW-21S and MW-53D

Well water MW-21S has the largest iodide concentration of all the ground water. Groundwater from MW-53D could possibly be a mixture of water from the MW-21S area with fresh ground water from the Equus Beds. MW-21S is a shallow well and MW-53D is a deep well; the wells are located approximately 16.4 meters (50 feet) apart. These wells are located close enough together so that the levels of iodide in the respective wells is governed by the migration rate of iodide through the aquifer from shallow to deep. As MW-21S is the shallow well and the source here is believed to be an onsite point source release, concentrations are higher in the shallow well. Continued monitoring of the wells over time should show a reduction in the difference between shallow and deep iodide concentrations.

Group 5: Water with a relatively low Br/Cl ratio, a high nitrate content and a moderately high sulfate concentration.

Well water LP-104

Whittemore reported that the Na/Cl ratio from this well indicated saline water had migrated into the Equus Bed aquifer that was predominantly Na-Cl in chemical type. He postulated that cation exchange has occurred during leaching and transport that has decreased the Na/Cl ratio over time. The Ca/Mg ratio is higher than for waters from wells 8D and 110D, suggesting that a saline water with an additional calcium source is included in the mixture affecting the ground water.

Monitoring well LP-104 is one of four wells completed in the area of the old lime ponds. As such, it would be expected that the chemical characteristics of this well would be similar to that found in samples from LP-102 and LP-103. With regard to the sulfate content of LP-103 and the nitrate content of LP-102, this is true. However, the Br/Cl ratio for LP-104 is approximately half that found in the other lime pond wells. One potential explanation for the differences between LP-104 and the other lime pond wells is that LP-104 is located closest to the presently used large retention pond. Water softening of the refinery process water that is sent to the retention pond prior to discharge to the receiving stream will result in higher calcium and magnesium concentrations in the ponds than would otherwise be naturally occurring. It is reasonable to suggest that infiltration from the retention pond has caused the differences in groundwater quality noted from this well. In particular, the higher Ca/Mg ratio and the calcium noted in groundwater from this well could stem from water supplied by the retention pond.

Whittemore had also suggested that this water could be affected by infiltration of water with a low bromide/chloride ratio such as wastewater from the municipal treatment plant of McPherson. The retention pond has many of the same characteristics as the municipal waste water, (such as drinking water that has been softened) as it receives process water that has been treated by the onsite NCRA water treatment system.

CHAPTER 7

SUMMARY & CONCLUSIONS

A variety of studies have been undertaken in an attempt to discern the source location, fate and transport of the elevated concentrations of chlorides that have been noted in monitoring wells and pumping wells on and around the refinery facility. These studies included sampling of the monitoring wells, spatial analysis of chloride concentration data, investigation of the stratigraphic and lithologic properties of the vadose and saturated zone (the Equus Beds aquifer), numeric modeling of ground water flow beneath the study area, and geochemical source identification analysis for the potential sources of chlorides. These studies have revealed that the chlorides noted in ground water in and around the facility probably originate from two separate sources. The principle source originates from the Johnson Well Field approximately 2 miles east of the refinery. The remainder of the elevated chloride concentrations originate from localized shallow point sources primarily within the refinery operations area and tank farm. These point sources are probably the result of past releases on the refinery property and do not represent offsite sources.

Numeric modeling studies indicate that the four onsite water supply wells are effectively controlling the extent of the chloride migration by capturing the plume(s) as it/they move into the water supply well radius of influence. As the radius of influence for the wells overlap, the wells can be regarded as a single system for purposes of plume migration control and remediation.

Study of spatial patterns of chloride concentration and numerical modeling results have shown that the shallow point source areas are being controlled by WW-10, located essentially in the middle of the refinery. Point sources controlled by this well include the area around the old lime ponds, and area in the refinery operations area roughly bounded by MW-21, MW-15 and MW-13. Another point source located in the tank farm, in the area around MW-47, appears to be within the radius of influence, but far enough away so that its migration is controlled to a lesser extent than the other point sources are.

The source originating from the Johnson Well Field is being controlled by the pumpage of water wells located on the east side of the facility (WW's 3, 8, and 9). Numerical studies have indicated that even after twenty years of migration, the east wells will continue to capture all of the chlorides migrating onto the refinery property. In addition, the numerical studies have shown that the chlorides will not migrate offsite, due in large part to the influence of the pumping wells, which divert the regional groundwater flow to the pumping wells. The net effect of the pumping wells has been to create an area on the refinery property between the pumping wells that is essentially free of elevated chlorides. Study has indicated that as long as the existing water wells continue to pump, this condition will remain stable.

It is believed that the overall quality of the water captured by the pumping wells will continue to decline over time. The practices that resulted in the shallow onsite sources have been largely eliminated and there is no longer any appreciable influx of brine from activities associated with the Johnson Well Field.

The Johnson Well Field and the Refinery have both been in operation since the 1930's. Environmental regulations designed to curtail sources of contamination from entering the groundwater have been in place only since the mid 1970's. Therefore, source infiltration occurred for at least 40 years before the environmental regulations and a heightened sense of awareness regarding potential damage to the environment was recognized, resulting in the implementation of source reduction measures.

Based on this and the results of the groundwater sampling, it is believed that these sources are generally large enough and there is enough source material trapped in the vadose zone that can migrate to the groundwater that no appreciable reduction in source renewal to the groundwater can be expected in the near future.

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Appendix 1

Well Logs

r: McPherson	NW ¼ NW ¼ NE ¼	5	T 20 S	R 3 E[✓ W]

ce and direction from nearest town or city street address of well if located within city?
S. Main, McPherson, Kansas

TER WELL OWNER: NCRA
Address, Box # : P.O. Box 1401
ate, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

ATE WELL'S LOCATION
H AN "X" IN SECTION BOX:

N	
NW	NE X
SW	SE

E
S

4 DEPTH OF COMPLETED WELL......163...... ft. ELEVATION: ....1482.89..........
Depth(s) Groundwater Encountered 1................ft. 2................ft. 3.................ft.
WELL'S STATIC WATER LEVEL..............ft. below land surface measured on mo/day/yr ....
Pump test data: Well water was ....NA....ft. after ....hours pumping..............gpm
Est. Yield ..NA...gpm: Well water was ....ft. after ....hours pumping..............gpm
Bore Hole Diameter ..9.625..in. to ......163.......ft., and...................in. to..............ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....
Was a chemical/bacteriological sample submitted to Department? Yes.........No..✓.....; If yes, mo/day/yr sample was submitted ✓
Water Well Disinfected? Yes No ✓

E OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued...... Clamped.....
Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded..............
[✓ PVC] 4 ABS 7 Fiberglass .... Threaded. ✓.........
sing diameter ......4......in. to .....63......ft., Dia ....in. to ....ft., Dia ....in. to ....ft.
height above land surface .....25.32.......in., weight ....lbs./ft. Wall thickness or gauge No. ....Sch. 80.....

OF SCREEN OR PERFORATION MATERIAL: 7 PVC 10 Asbestos-cement
Steel [✓ 3 Stainless steel] 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

N OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
Continuous slot 3 Mill slot [✓ 6 Wire wrapped] 9 Drilled holes
Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

N-PERFORATED INTERVALS: From ....63.......ft. to ......163......ft., From ....ft. to ....ft.
From ....ft. to ....ft., From ....ft. to ....ft.
GRAVEL PACK INTERVALS: From ....57.......ft. to ......163......ft., From ....ft. to ....ft.
From ....ft. to ....ft., From ....ft. to ....ft.

UT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....
Intervals: From ....0.....ft. to .....55.....ft., From .....55......ft. to .....57.....ft., From ....ft. to ....ft.

is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ...refinery.............
on from well? 0 How many feet? 0

	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	7	Clay, Dark Brown			
	20	Clay, Brown			
	30	Clay, Brown			
	35	Clay, Gray Brown			
	59	Sand,			
	70	Clay, Light Brown to Gray			
	85	Sand, Light Brown			
	100	Sand, Light Brown			
	120	Sand, Light Brown			
	125	Sand, Light Brown			
	145	Sand, Light Brown			
	150	Sand, Brown			
	160	Sand, Brown			RW , Abovegrade
	162	Sand, Brown			Project Name: NCRA Refinery
	163	Shale, Blue Gray			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) ....11/15/99.................. and this record is true to the best of my knowledge and belief.
Water Well Contractor's License No. ....527.......... This Water Well Record was completed on (mo/day/yr) ......11/15/99.......
the business name of GeoCore Services, Inc. by (signature)

STRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas partment of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

OFFICE USE ONLY
R
E/W
SEC.
¼
¼
¼

CATION OF WATER WELL:	Fraction			Section Number	Township Number	Range Number
ty: McPherson	NW ¼	NE ¼	NE ¼	5	T 20 S	R 3 E[✓ W]

nce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

N

NW	NE X
SW	SE

W E

S

4 DEPTH OF COMPLETED WELL.....170...... ft. ELEVATION: 1493.87
Depth(s) Groundwater Encountered 1.................ft. 2.................ft. 3.............ft.
WELL'S STATIC WATER LEVEL ....ft. below land surface measured on mo/day/yr
Pump test data: Well water was ....NA.... ft. after .... hours pumping .... gpm
Est. Yield ..NA... gpm: Well water was .... ft. after .... hours pumping .... gpm
Bore Hole Diameter ..9.625.. in. to ......172.......ft., and.................in. to...........ft.
WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....
Was a chemical/bacteriological sample submitted to Department? Yes.........No...✓....; If yes, mo/day/yr sample was submitted ✓
Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped ......
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ....
[✓ 2 PVC] 4 ABS 7 Fiberglass .... Threaded. ✓ ....
asing diameter ......4...... in. to ....150.... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.
g height above land surface .....34.44...... in., weight .... lbs./ft. Wall thickness or gauge No. ....Sch. 40.....
OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)
EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....
EN-PERFORATED INTERVALS: From.......150...... ft. to ......170......... ft., From.................. ft. to .... ft.
From.................. ft. to .... ft., From.................. ft. to .... ft.
GRAVEL PACK INTERVALS: From......147...... ft. to ......172......... ft., From.................. ft. to .... ft.
From.................. ft. to .... ft., From.................. ft. to .... ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....
t Intervals: From ......0...... ft. to ....144.... ft., From ....144.... ft. to ....147..... ft., From............ ft. to .... ft.
t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ...refinery.........
ction from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	10	Clay, Dark Brown	160	170	Sand, Brown
10	20	Clay, Brown	170	172	Shale, Blue Gray
0	30	Clay, Brown			
0	35	Clay, Brown			
5	38	Clay, Gray Brown			
8	40	Sand, Brown			
0	60	Sand, Brown			
0	64	Sand, Brown			
4	69	Clay, Gray Green			
9	80	Sand, Brown			
0	90	Sand, Brown			
0	94	Sand, Brown			
4	98	Sand, Brown			67D , Abovegrade
8	116	Sand, Brown			Project Name: NCRA Refinery
16	160	Sand, Brown			GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
was completed on (mo/day/year) ....11/15/99.................. and this record is true to the best of my knowledge and belief.
ss Water Well Contractor's License No. ....527.......... This Water Well Record was completed on (mo/day/yr) ....11/15/99.......
r the business name of GeoCore Services, Inc. by (signature) Dale Bell

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

CATION OF WATER WELL: | Fraction | Section Number | Township Number | Range Number

nty: McPherson | NE ¼ NW ¼ NE ¼ | 5 | T 20 S | R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?

00 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA

St. Address, Box # : P.O. Box 1401

State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources

Application Number:

OCATE WELL'S LOCATION
ITH AN "X" IN SECTION BOX:

N

X

NW	NE
SW	SE

W E

S

4 DEPTH OF COMPLETED WELL . . . . . 124 . . . . . ft. ELEVATION: . . . . 1492.35 . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . . NA . . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . . . 8 . . . . in. to . . . . . . 125 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well

1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)

2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. . . ✓. . . ; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

YPE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . . .

1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .

[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓ . . . .

asing diameter . . . . . . 2 . . . . . . in. to . . . . . 99 . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.

g height above land surface . . . . . 29.76 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

E OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement

1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .

2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EEN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)

1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes

2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EEN-PERFORATED INTERVALS: From . . . . 99 . . . . . . ft. to . . . . . . 124 . . . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . 97 . . . . . . ft. to . . . . . . 125 . . . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

t Intervals: From . . . . 0 . . . . . ft. to . . . . 94 . . . . . ft., From . . . . 94 . . . . . ft. to . . . . 97 . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well

Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well

Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]

Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . refinery . . . .

ction from well? 0 How many feet? 0

ROM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	16	Clay, Red Brown	94	101	Sand, Brown
16	24	Clay, Light Brown	101	103	Clay, Gray
24	30	Sand, Light Brown	103	115	Sand, Gray
30	36	Sand, Light Brown	115	118	Clay, Gray
36	38	Clay, Brown	118	125	Sand, Gray
38	43	Sand, Brown			
43	51	Sand, Brown			
51	68	Clay, Gray Brown			
68	72	Clay, Gray Brown			
72	81	Clay, Gray Brown			
81	82	Sand, Gray			
82	84	Clay, Gray Brown			
84	86	Sand, Gray			2S , Abovegrade
86	88	Clay, Gray			Project Name: NCRA Refinery
88	94	Clay, Orange Brown			GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction

was completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.

as Water Well Contractor's License No. . . . . 527 . . . . This Water Well Record was completed on (mo/day/yr) . . . . . . 11/15/99 . . . .

r the business name of GeoCore Services, Inc. by (signature) Dale Rolf

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

CATION OF WATER WELL:	Fraction	Section Number	Township Number	Range Number
ty: **McPherson**	**NW** ¼ **NE** ¼ **NE** ¼	**5**	T **20** S	R **3** E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: **NCRA**
St. Address, Box # : **P.O. Box 1401**
State, ZIP Code : **McPherson, Kansas 67460**

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

N

NW	NE X
SW	SE

W E
S

4 DEPTH OF COMPLETED WELL......**119**...... ft. ELEVATION: ....**1493.8**..........
Depth(s) Groundwater Encountered 1.................ft. 2.................ft. 3..........ft.
WELL'S STATIC WATER LEVEL.......... ft. below land surface measured on mo/day/yr ....
Pump test data: Well water was ....**NA**.... ft. after .... hours pumping .... gpm
Est. Yield ..**NA**... gpm: Well water was .... ft. after .... hours pumping .... gpm
Bore Hole Diameter ....**8**.... in. to ......**120**......ft., and.......... in. to.......... ft.
WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10] Monitoring well ✓ ....
Was a chemical/bacteriological sample submitted to Department? Yes.........No..✓....; If yes, mo/day/yr sample was submitted ✓
Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued...... Clamped......
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded..........
[✓ 2] PVC 4 ABS 7 Fiberglass .... Threaded. ✓..........
asing diameter ......**2**...... in. to .....**94**..... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.
g height above land surface .....**32.88**...... in., weight .... lbs./ft. Wall thickness or gauge No. .....**Sch. 40**.....
 OF SCREEN OR PERFORATION MATERIAL [✓ 7] PVC 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify)..........
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)
EEN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3] Mill slot 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify)..........
EEN-PERFORATED INTERVALS: From ......**94**...... ft. to ......**119**...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.
GRAVEL PACK INTERVALS: From ......**85**...... ft. to ......**119**...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

ROUT MATERIAL: [✓ 1] Neat cement 2 Cement grout [✓ 3] Bentonite 4 Other..........
t Intervals: From ......**0**..... ft. to ....**83**.... ft., From ....**83**..... ft. to .....**85**..... ft., From .... ft. to .... ft.
t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
 Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
 Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16] Other (specify below)
 Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ...**refinery**.....
ction from well? 0 How many feet? 0

ROM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	9	**Clay, Dark Brown**			
9	19	**Clay, Red Brown**			
19	24	**Clay, Light Brown**			
24	56	**Sand, Light Brown**			
56	61	**Clay, Light Brown**			
61	70	**Sand, Light Brown**			
70	78	**Clay, Gray**			
78	118	**Sand, Light Brown**			
118	120	**Clay, Red Brown**			
					25S , Abovegrade
					Project Name: NCRA Refinery
					GeoCore # 809 , #

CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1)] constructed, (2) reconstructed, or (3) plugged under my jurisdiction
 was completed on (mo/day/year) ....**11/15/99**.......... and this record is true to the best of my knowledge and belief.
 Water Well Contractor's License No. ....**527**.......... This Water Well Record was completed on (mo/day/yr) .....**11/15/99**.....
r the business name of **GeoCore Services, Inc.** by (signature) Dale Bl

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

CATION OF WATER WELL:	Fraction	Section Number	Township Number	Range Number
ty: McPherson	SE ¼ NW ¼ NE ¼	5	T 20 S	R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
00 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
ITH AN "X" IN SECTION BOX:

N

NW	X NE
SW	SE

W E
S

4 DEPTH OF COMPLETED WELL . . . . . 173 . . . . . ft. ELEVATION: . . . . 1488.38 . . .
Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.
WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .
Pump test data: Well water was . . . . NA . . . . ft. after . . . . hours pumping . . . . gpm
Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm
Bore Hole Diameter . . 9.625 . . in. to . . . . . . 173 . . . . . . ft., and . . . . in. to . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ . . . .

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. . . . . ✓ ; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . . .
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .
[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓ . . . .
asing diameter . . . . . . 4 . . . . . . in. to . . . . . 153 . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.
g height above land surface . . . . . 25.68 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

E OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . 153 . . . . . . ft. to . . . . . . 173 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.
GRAVEL PACK INTERVALS: From . . . . 150 . . . . . . ft. to . . . . . . 173 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .
t Intervals: From . . . . . . 0 . . . . . ft. to . . . . 148 . . . . ft., From . . . . 148 . . . . . ft. to . . . . 150 . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . refinery . . . .
tion from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	5	Clay, Dark Brown	171	172	Sand, Brown
5	15	Clay, Brown	172	173	Shale, Blue Gray
5	37	Clay, Gray Green			
7	43	Clay, Brown			
3	45	Sand, Brown			
5	50	Sand, Brown			
0	67	Sand, Brown			
7	73	Clay, Brown Gray			
3	90	Sand, Brown			
0	110	Sand, Brown			
10	115	Clay, Brown			
15	125	Sand, Brown			
25	165	Sand, Brown			21D , Abovegrade
65	170	Sand, Brown			Project Name: NCRA Refinery
70	171	Clay, Gray Green			GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
was completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.
s Water Well Contractor's License No. . . . . 527 . . . . This Water Well Record was completed on (mo/day/yr) . . . . . . 11/15/99 . . . .
r the business name of GeoCore Services, Inc. by (signature)

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

ATION OF WATER WELL: y: McPherson	Fraction NW ¼ NW ¼ NE ¼	Section Number 5	Township Number T 20 S	Range Number R 3 E [✓ W]

ce and direction from nearest town or city street address of well if located within city?
S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

	N	
	X	
W	NW | NE	E
	SW | SE	
	S	

4 DEPTH OF COMPLETED WELL ...... 110 ...... ft. ELEVATION: .... 0.

Depth(s) Groundwater Encountered 1. .... ft. 2. .... ft. 3. .... ft.

WELL'S STATIC WATER LEVEL .... ft. below land surface measured on mo/day/yr

Pump test data: Well water was ....NA.... ft. after .... hours pumping .... gpm

Est. Yield ..NA... gpm: Well water was .... ft. after .... hours pumping .... gpm

Bore Hole Diameter ....8.... in. to ......110...... ft., and .... in. to .... ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....

Was a chemical/bacteriological sample submitted to Department? Yes......... No...✓...; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped .....
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ....
[✓ 2 PVC] 4 ABS 7 Fiberglass .... Threaded. ✓

sing diameter ......2...... in. to ......85..... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.

height above land surface ....24....... in., weight .... lbs./ft. Wall thickness or gauge No. .... Sch. 40 .....

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

EN-PERFORATED INTERVALS: From ......85...... ft. to ......110...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

GRAVEL PACK INTERVALS: From ......83...... ft. to ......110...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

OUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....

Intervals: From ......0...... ft. to ....80..... ft., From ....80..... ft. to ....83..... ft., From .... ft. to .... ft.

is the nearest source of possible contamination:
Septic tank 4 Lateral lines 7 Pit privy 10 Livestock pens 14 Abandoned water well
Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well
Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage [✓ 16 Other (specify below)]
13 Insecticide storage ...refinery...

on from well? 0 How many feet? 0

	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	6	Clay, Dark Brown			
	18	Clay, Very Dark Brown			
	24	Sand, Dark Brown			
	30	Sand, Brown			
	33	Sand, Gray			
	46	Sand, Yellowish Brown			
	47	Clay, Gray			
	54	Sand, Brown			
	61	Sand, Brown			
	63	Clay, Gray			
	68	Sand, Brown Gray			
	73	Clay, Gray			
	92	Sand, Brown to Black			20S , Abovegrade
	94	Clay, Gray			Project Name: NCRA Refinery
	110	Sand, Gray			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) ....11/15/99............... and this record is true to the best of my knowledge and belief.
Water Well Contractor's License No. ....527......... This Water Well Record was completed on (mo/day/yr) ......11/15/99.
the business name of GeoCore Services, Inc. by (signature) Dale Bell

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OFFICE USE ONLY
T
R
E/W
SEC.
¼
¼
¼

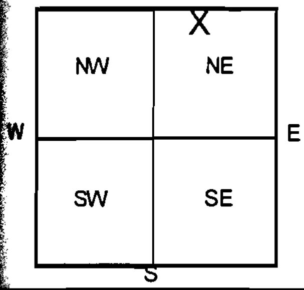
CATION OF WATER WELL: | Fraction | Section Number | Township Number | Range Number
ty: McPherson | NE ¼ NW ¼ NE ¼ | 5 | T 20 S | R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL ...... 166 ...... ft. ELEVATION: .... 1489.13 ....
Depth(s) Groundwater Encountered 1 .... ft. 2 .... ft. 3 .... ft.
WELL'S STATIC WATER LEVEL .... ft. below land surface measured on mo/day/yr ....
Pump test data: Well water was .... NA .... ft. after .... hours pumping .... gpm
Est. Yield .. NA ... gpm: Well water was .... ft. after .... hours pumping .... gpm
Bore Hole Diameter .. 9.625 .. in. to ..... 167.5 ..... ft., and .... in. to .... ft.
WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....
Was a chemical/bacteriological sample submitted to Department? Yes......... No..✓....; If yes, mo/day/yr sample was submitted ✓
Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped ......
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ....
[✓ 2] PVC 4 ABS 7 Fiberglass .... Threaded. ✓ ....
sing diameter .... 4 ...... in. to .... 146 .... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.
height above land surface ..... 30.12 ...... in., weight .... lbs./ft. Wall thickness or gauge No. .... Sch. 40

OF SCREEN OR PERFORATION MATERIAL [✓ 7] PVC 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3] Mill slot 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

EN-PERFORATED INTERVALS: From ...... 146 ...... ft. to ...... 166 ...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.
GRAVEL PACK INTERVALS: From ...... 143 ...... ft. to ...... 167.5 ...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

OUT MATERIAL: [✓ 1] Neat cement 2 Cement grout [✓ 3] Bentonite 4 Other ....
Intervals: From ...... 0 ...... ft. to .... 139 .... ft., From .... 139 .... ft. to .... 143 .... ft., From .... ft. to .... ft.

is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16] Other (specify below)
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ... refinery ......
tion from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	6	Clay, Dark Brown	120	135	Sand, Brown
	15	Clay, Light to Dark Brown	135	166	Sand, Brown
	30	Clay, Light Brown	166	167	Shale, Dark Gray
	35	Clay, Brown to Gray			
	40	Clay, Brown to Gray			
	50	Sand, Brown			
	63	Sand, Brown to Gray Brown			
	70	Clay, Gray Green			
	75	Sand, Light Brown			
	80	Sand, Brown			
	90	Sand, Dark Brown			
	96	Clay, Orange			
	99	Sand, Brown			11D , Abovegrade
	112	Sand, Brown			Project Name: NCRA Refinery
	120	Sand, Brown			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1)] constructed, (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) .... 11/15/99 .... and this record is true to the best of my knowledge and belief.
s Water Well Contractor's License No. .... 527 .... This Water Well Record was completed on (mo/day/yr) ...... 11/15/99 ......
the business name of GeoCore Services, Inc. by (signature)

STRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

CATION OF WATER WELL: | Fraction | Section Number | Township Number | Range Number

ity: McPherson | NW ¼ NW ¼ NE ¼ | 5 | T 20 S | R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?

0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA

St. Address, Box # : P.O. Box 1401

State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources

Application Number:

CATE WELL'S LOCATION
ITH AN "X" IN SECTION BOX:

N

X

NW	NE
SW	SE

W E S

4 DEPTH OF COMPLETED WELL . . . . . 169 . . . . . ft. ELEVATION: . . . . 1484.91 . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . . NA . . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . 9.625 . . in. to . . . . . . 171 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well

1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)

2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ . . . .

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. . . ✓ . . . ; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . .

1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .

[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓ . . . .

asing diameter . . . . . . 4 . . . . . . in. to . . . . . 149 . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.

g height above land surface . . . . . . 31.2 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . .

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement

1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .

2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)

1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes

2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . 149 . . . . . . ft. to . . . . 169 . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . 147 . . . . . . ft. to . . . . 171 . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

OUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

Intervals: From . . . . . . 0 . . . . . ft. to . . . . 142 . . . . ft., From . . . . 142 . . . . ft. to . . . . 147 . . . . . ft., From . . . . ft. to . . . . ft.

is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well

Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well

Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]

Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . refinery . . . .

ion from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	5	Clay, Dark Brown			
5	15	Clay, Brown			
15	29	Clay, Brown			
9	45	Sand, Brown			
5	53	Sand, Brown			
3	55	Sand, Brown			
5	61	Clay, Gray			
1	72	Clay, Gray Brown			
2	90	Sand, Brown			
0	112	Sand, Brown			
2	162	Sand, Brown			
2	169	Clay, Gray Green			
9	171	Shale, Blue Gray			10D , Abovegrade
					Project Name: NCRA Refinery
					GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction

s completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.

Water Well Contractor's License No. . . . . 527 . . . . This Water Well Record was completed on (mo/day/yr) . . . . 11/15/99 . . . .

the business name of GeoCore Services, Inc. by (signature)

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

nty: McPherson | 'NW ¼ NW ¼ NE ¼ | 5 | T 20 S | R 3 E [✓ W]

ance and direction from nearest town or city street address of well if located within city?

00 S. Main, McPherson, Kansas

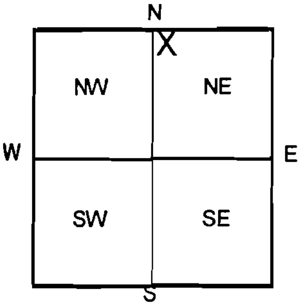
WATER WELL OWNER: NCRA

, St. Address, Box # : P.O. Box 1401

, State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

OCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL .....119..... ft. ELEVATION: ....1484.57..........

Depth(s) Groundwater Encountered 1............ft. 2............ft. 3............ft.

WELL'S STATIC WATER LEVEL .... ft. below land surface measured on mo/day/yr ....

Pump test data: Well water was ....NA.... ft. after .... hours pumping .... gpm

Est. Yield ..NA... gpm: Well water was .... ft. after .... hours pumping .... gpm

Bore Hole Diameter ....8.... in. to ......120.......ft., and............ in. to............ ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes.........No..✓......; If yes, mo/day/yr sample ✓ was submitted

Water Well Disinfected? Yes No ✓

YPE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped ......
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ....
[✓ 2 PVC] 4 ABS 7 Fiberglass .... Threaded. ✓

casing diameter ......2...... in. to .....94..... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.

ng height above land surface .....32.04...... in., weight .... lbs./ft. Wall thickness or gauge No. .....Sch. 40

E OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EEN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

EEN-PERFORATED INTERVALS: From ....94....... ft. to ......119....... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

GRAVEL PACK INTERVALS: From ....92....... ft. to ......120....... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

GROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....

ut Intervals: From ......0...... ft. to ....83.5.... ft., From ....83.5.... ft. to ....92.... ft., From .... ft. to .... ft.

t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
1 Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
2 Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
3 Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ...refinery..........

ction from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	7	Clay, Dark Brown			
7	11	Clay, Brown			
11	13	Sand, Brown			
13	17	Clay, Brown			
17	29	Sand, Gray			
29	38	Sand, Brown			
38	58	Sand, Brown Gray			
58	66	Clay, Brown			
66	78	Sand, Gray			
78	84	Sand, Gray			
84	86	Clay, Gray			
87	120	Sand, Gray			
					10S , Abovegrade
					Project Name: NCRA Refinery
					GeoCore # 809 , #

CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction

was completed on (mo/day/year) ....11/15/99.......... and this record is true to the best of my knowledge and belief.

s Water Well Contractor's License No. ....527......... This Water Well Record was completed on (mo/day/yr) ......11/15/99......

r the business name of GeoCore Services, Inc. by (signature) Dale Bal

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

OCATION OF WATER WELL:	Fraction			Section Number	Township Number	Range Number
nty: McPherson	SE ¼	NE ¼	NE ¼	5	T 20 S	R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
00 S. Main, McPherson, Kansas

WATER WELL OWNER: NCRA
, St. Address, Box # : P.O. Box 1401
, State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

OCATE WELL'S LOCATION
WITH AN "X" IN SECTION BOX:

N

NW	NE X
SW	SE

W E S

4 DEPTH OF COMPLETED WELL . . . . . 110 . . . . . ft. ELEVATION: . . . . 1497.23 . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . . NA . . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . . . 8 . . . . in. to . . . . . 110 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS:
5 Public water supply
8 Air conditioning
11 Injection well
1 Domestic
3 Feedlot
6 Oil field water supply
9 Dewatering
12 Other (Specify below)
2 Irrigation
4 Industrial
7 Lawn and garden only
[✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. . ✓. . . .; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

TYPE OF BLANK CASING USED:
1 Steel
[✓ 2 PVC]
3 RMP (SR)
4 ABS
5 Wrought iron
6 Asbestos-Cement
7 Fiberglass
8 Concrete tile
9 Other (specify below)
. . . .

CASING JOINTS: Glued . . . . . . Clamped . . . . . .
Welded . . . .
Threaded. ✓

asing diameter . . . . . 2 . . . . . in. to . . . . . 85. . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.

g height above land surface . . . . . 27.6 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

E OF SCREEN OR PERFORATION MATERIAL
1 Steel
2 Brass
3 Stainless steel
4 Galvanized steel
5 Fiberglass
6 Concrete tile
[✓ 7 PVC]
8 RMP (SR)
9 ABS
10 Asbestos-cement
11 Other (specify) . . . .
12 None used (open hole)

EEN OR PERFORATION OPENINGS ARE:
1 Continuous slot
2 Louvered shutter
[✓ 3 Mill slot]
4 Key punched
5 Gauzed wrapped
6 Wire wrapped
7 Torch cut
8 Saw cut
9 Drilled holes
10 Other (specify) . . . .
11 None (open hole)

EEN-PERFORATED INTERVALS: From . . . . 85. . . . . . . ft. to . . . . 110 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . 82. . . . . . . ft. to . . . . . . 110. . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

t Intervals: From . . . . . . 0 . . . . . ft. to . . . . . 80 . . . . . ft., From . . . . . 80 . . . . . ft. to . . . . . 82 . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination:
1 Septic tank
2 Sewer lines
3 Watertight sewer lines
4 Lateral lines
5 Cess pool
6 Seepage pit
7 Pit privy
8 Sewage lagoon
9 Feedyard
10 Livestock pens
11 Fuel storage
12 Fertilizer storage
13 Insecticide storage
14 Abandoned water well
15 Oil well/Gas well
[✓ 16 Other (specify below)]
. . . refinery . . . .

ction from well? 0

How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	4	Clay, Dark Brown			
4	9	Clay, Brown			
9	28	Clay, Red Brown			
28	33	Clay, Light Brown			
33	69	Sand, Brown			
69	77	Clay, Gray Brown			
77	107	Sand, Gray			
107	110	Clay, Light Red Brown			
					111S , Abovegrade
					Project Name: NCRA Refinery
					GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction

was completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.

as Water Well Contractor's License No. . . . . 527. . . . . This Water Well Record was completed on (mo/day/yr) . . . . . . 11/15/99. . . . .

r the business name of GeoCore Services, Inc. by (signature)

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

ty: **McPherson** | **SE** ¼ **NE** ¼ **NE** ¼ | **5** | T **20** S | R **3** E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: **NCRA**
St. Address, Box # : **P.O. Box 1401**
State, ZIP Code : **McPherson, Kansas 67460**

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

	N	
	NW	NE X
W		E
	SW	SE
	S	

4 DEPTH OF COMPLETED WELL . . . . . **183** . . . . . ft. ELEVATION: . . . . **1497.06** . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . **NA** . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . **NA** . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . **9.625** . . in. to . . . . . . **185** . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. . ✓. . . . ; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . .
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .
[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓ . . . .

asing diameter . . . . . . **4** . . . . . . in. to . . . . . **153** . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.

g height above land surface . . . . . **25.56** . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . **Sch. 40** . . . . .

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . . . **153** . . . . . . ft. to . . . . . . **183** . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . . . **151** . . . . . . ft. to . . . . . . **185** . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

t Intervals: From . . . . . **0** . . . . ft. to . . . . **148** . . . . . ft., From . . . . **148** . . . . . ft. to . . . . **151** . . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination:
Septic tank 4 Lateral lines 7 Pit privy 10 Livestock pens 14 Abandoned water well
Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well
Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage [✓ 16 Other (specify below)]
13 Insecticide storage . . . **refinery** . . . .

tion from well? **0** How many feet? **0**

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	10	**Clay, Dark Brown**			
	35	**Clay, Brown**			
	40	**Sand, Brown**			
	55	**Sand, Brown**			
	65	**Sand, Brown**			
	69	**Sand, Brown**			
	86	**Clay, Gray**			
	105	**Sand, Brown**			
	112	**Clay, Brown Gray**			
	145	**Sand, Brown**			
	150	**Clay, Gray Brown**			
	175	**Sand, Brown**			
	183	**Clay, Gray Green to Green White**			**111D , Abovegrade**
	185	**Shale, Blue Gray**			**Project Name: NCRA Refinery**
					GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction was completed on (mo/day/year) . . . . **11/15/99** . . . . and this record is true to the best of my knowledge and belief.

s Water Well Contractor's License No. . . . . **527** . . . . This Water Well Record was completed on (mo/day/yr) . . . . . **11/15/99** . . .

r the business name of **GeoCore Services, Inc.** by (signature)

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

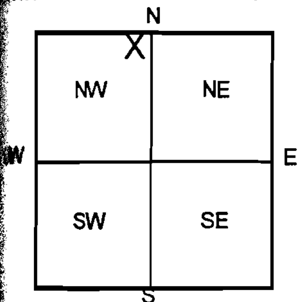
	Fraction	Section Number	Township Number	Range Number
y: McPherson	NE ¼ NE ¼ NW ¼	4	T 20 S	R 3 E [✓ W]

ce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL . . . . . 156 . . . . . ft. ELEVATION: . . . . 1492.28 . . . .
Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.
WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .
Pump test data: Well water was . . . NA . . . . ft. after . . . . hours pumping . . . . gpm
Est. Yield . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm
Bore Hole Diameter . . 9.625 . . in. to . . . . . 157 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10] Monitoring well ✓ . . . .
Was a chemical/bacteriological sample submitted to Department? Yes. . . . . No. ✓. . . . .; If yes, mo/day/yr sample was ✓ submitted
Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . .
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .
[✓ 2] PVC 4 ABS 7 Fiberglass . . . . Threaded. ✓
asing diameter . . . . . . 4 . . . . . . in. to . . . . . 136 . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . . . ft.
height above land surface . . . . . 29.76 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

OF SCREEN OR PERFORATION MATERIAL [✓ 7] PVC 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3] Mill slot 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . . . 136 . . . . . . ft. to . . . . . . 156 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.
GRAVEL PACK INTERVALS: From . . . . . . 133 . . . . . . ft. to . . . . . . 157 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

OUT MATERIAL: [✓ 1] Neat cement 2 Cement grout [✓ 3] Bentonite 4 Other . . . .
Intervals: From . . . . . . 0 . . . . . ft. to . . . . 130 . . . . ft., From . . . . 130 . . . . ft. to . . . . 133 . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16] Other (specify below)
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . refinery . . . .
tion from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	5	Clay, Dark Brown			
5	20	Clay, Red Brown			
0	53	Clay, Light Brown			
3	61	Sand, Brown			
1	66	Clay, Gray Green			
6	72	Sand, Brown			
2	85	Sand, Brown			
5	96	Clay, Grey Brown			
6	105	Sand, Brown			
5	125	Sand, Brown			
25	145	Sand, Brown			
5	152	Clay, Gray Green			
2	156	Clay, Blue Gray			110D , Abovegrade
6	157	Shale, Dark Blue			Project Name: NCRA Refinery
					GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1)] constructed, (2) reconstructed, or (3) plugged under my jurisdiction
was completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.
Water Well Contractor's License No. . . . . 527 . . . . This Water Well Record was completed on (mo/day/yr) . . . . . . 11/15/99 . . . .
r the business name of GeoCore Services, Inc. by (signature) Don Pell

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

ATION OF WATER WELL:	Fraction			Section Number	Township Number	Range Number
y: McPherson	SE ¼	SE ¼	SE ¼	32	T 19 S	R 3 E[✓ W]

ce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

N		
W	NW	NE
	SW	SE X
S		E

4 DEPTH OF COMPLETED WELL . . . . .110 . . . . . ft. ELEVATION: . . . . 1494.42 . . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . .NA . . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . . . 8. . . . in. to . . . . . . 110 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS:

5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . . . .No. . ✓. . . . ; If yes, mo/day/yr sample was submitted

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED:
1 Steel 3 RMP (SR) 5 Wrought iron 8 Concrete tile
[✓ 2 PVC] 4 ABS 6 Asbestos-Cement 9 Other (specify below)
7 Fiberglass . . . .

CASING JOINTS: Glued . . . . . . Clamped . . . . .
Welded . . . .
Threaded. ✓ . . . .

asing diameter . . . . . . 2 . . . . . . in. to . . . . . 85. . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.

height above land surface . . . . . 34.68 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

OF SCREEN OR PERFORATION MATERIAL
1 Steel 3 Stainless steel 5 Fiberglass [✓ 7 PVC] 10 Asbestos-cement
2 Brass 4 Galvanized steel 6 Concrete tile 8 RMP (SR) 11 Other (specify) . . . .
9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE:
1 Continuous slot [✓ 3 Mill slot] 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
2 Louvered shutter 4 Key punched 6 Wire wrapped 9 Drilled holes
7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . 85. . . . . . . ft. to . . . . . . 110 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . 80. . . . . . ft. to . . . . . . 110 . . . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

OUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

Intervals: From . . . . . . 0 . . . . . ft. to . . . . . 78 . . . . . . ft., From . . . . . 78 . . . . . . ft. to . . . . . 80 . . . . . . ft., From . . . . ft. to . . . . ft.

is the nearest source of possible contamination:
Septic tank 4 Lateral lines 7 Pit privy 10 Livestock pens 14 Abandoned water well
Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well
Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage [✓ 16 Other (specify below)]
13 Insecticide storage . . . refinery . . . .

ction from well? 0 How many feet? 0

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	8	Clay, Dark Brown	98	104	Sand, Light Brown
	18	Clay, Red Brown	104	110	Clay, Brown
	29	Clay, Light Brown			
	39	Sand, Light Brown			
	48	Sand, Light Brown			
	53	Clay, Gray Green			
	57	Clay, Tarnish Gray			
	68	Sand, Light Brown			
	72	Clay, Brown			
	85	Sand, Light Brown			
	86	Clay, Brown			
	89	Sand, Light Brown			
	93	Clay, Brown			108S , Abovegrade
	96	Sand, Light Brown			Project Name: NCRA Refinery
	98	Clay, Brown			GeoCore # 809 , #

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
was completed on (mo/day/year) . . . . 11/15/99. . . . . and this record is true to the best of my knowledge and belief.
s Water Well Contractor's License No. . . . . 527. . . . . This Water Well Record was completed on (mo/day/yr) . . . . . . 11/15/99. . . . . .
the business name of GeoCore Services, Inc. by (signature) Dale Bell

INSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

OFFICE USE ONLY
T
R
EW
SEC.
¼
¼
¼

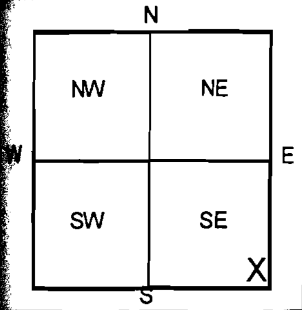
y: McPherson | SE ¼ | SE ¼ | SE ¼ | 32 | T 19 S | R 3 E [✓ W]

ce and direction from nearest town or city street address of well if located within city?
S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA
St. Address, Box # : P.O. Box 1401
State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL ...... 168 ...... ft. ELEVATION: .... 1494.5 ......

Depth(s) Groundwater Encountered 1. .... ft. 2. .... ft. 3. .... ft.

WELL'S STATIC WATER LEVEL .... ft. below land surface measured on mo/day/yr ....

Pump test data: Well water was .... NA .... ft. after .... hours pumping .... gpm

Est. Yield .. NA ... gpm: Well water was .... ft. after .... hours pumping .... gpm

Bore Hole Diameter .. 9.625 .. in. to ...... 170 ...... ft., and .... in. to .... ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....

Was a chemical/bacteriological sample submitted to Department? Yes......... No...✓....; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped ......
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ......
[✓ 2 PVC] 4 ABS 7 Fiberglass .... Threaded. ✓

sing diameter ...... 4 ...... in. to .... 148 .... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.

height above land surface ..... 32.64 ...... in., weight .... lbs./ft. Wall thickness or gauge No. .... Sch. 40

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

EN-PERFORATED INTERVALS: From .... 148 ...... ft. to .... 168 .... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

GRAVEL PACK INTERVALS: From .... 143 ...... ft. to .... 170 .... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

UT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....

Intervals: From ...... 0 ...... ft. to .... 141 .... ft., From ... 141 .... ft. to .... 143 .... ft., From .... ft. to .... ft.

is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ... refinery ....

ion from well? 0 How many feet? 0

	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	5	Clay, Dark Brown	130	135	Sand,
	15	Clay, Reddish Brown	135	150	Sand,
	30	Clay, Light Brown	150	160	Sand,
	40	Clay, Light Brown	160	162	Sand,
	45	Clay, Light Brown	162	164	Clay, Light Gray Pink
	50	Sand, Gray	164	168	Clay, Dark Blue Gray Pink
	57	Clay, Grayish Brown	168	169	Clay, Dark Blue Pink
	65	Sand,	169	170	Shale, Blue Light Gray
	75	Clay, Grayish Brown			
	85	Sand,			
	90	Sand,			
	95	Sand, Brown			
	100	Sand,			108D , Abovegrade
	110	Sand,			Project Name: NCRA Refinery
	130	Sand,			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) .... 11/15/99 .... and this record is true to the best of my knowledge and belief.
s Water Well Contractor's License No. .... 527 .... This Water Well Record was completed on (mo/day/yr) .... 11/15/99 ......
the business name of GeoCore Services, Inc. by (signature) Dale Bell

STRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

y: McPherson | NE ¼ NW ¼ SE ¼ | 32 | T 19 S | R 3 E [✓ W]

ce and direction from nearest town or city street address of well if located within city?

0 S. Main, McPherson, Kansas

ATER WELL OWNER: NCRA

St Address, Box # : P.O. Box 1401

State, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources

Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:

N

NW	NE
SW	X SE

W E

S

4 DEPTH OF COMPLETED WELL . . . . . 155 . . . . . ft. ELEVATION: . . . . . 1481.33 . . . . .

Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.

WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr . . . .

Pump test data: Well water was . . . . NA . . . . ft. after . . . . hours pumping . . . . gpm

Est. Yield . . NA . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm

Bore Hole Diameter . . 9.625 . . in. to . . . . . . 157 . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well

1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)

2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ . . . .

Was a chemical/bacteriological sample submitted to Department? Yes.........No...✓...; If yes, mo/day/yr sample was submitted ✓

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . .

1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .

[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓

asing diameter . . . . . . 4 . . . . . . in. to . . . . . 135 . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . . . ft.

height above land surface . . . . . 34.92 . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . Sch. 40 . . . . .

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement

1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .

2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)

1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes

2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EN-PERFORATED INTERVALS: From . . . . . . 135 . . . . . ft. to . . . . . 155 . . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

GRAVEL PACK INTERVALS: From . . . . . . 124 . . . . . ft. to . . . . . 157 . . . . . ft., From . . . . ft. to . . . . ft.

From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

OUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .

Intervals: From . . . . . 0 . . . . . ft. to . . . 121 . . . . ft., From . . . . 121 . . . . ft. to . . . 124 . . . . ft., From . . . . ft. to . . . . ft.

is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well

Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well

Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]

Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . refinery . . . .

on from well? 0 How many feet? 0

	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	5	Clay, Dark	140	145	Sand,
	8	Clay, Dark	145	150	Gravel,
	25	Clay, Grayish Brown	150	154	Clay, Blue Gray
	35	Clay, Light Brown to Gray	154	157	Shale, Blue Gray
	40	Clay, Light Brown			
	45	Clay, Light Grayish Brown			
	50	Clay, Light Grayish Brown			
	63	Clay, Light Grayish Brown			
	65	Sand,			
	85	Sand,			
	100	Sand,			
	110	Sand,			
	125	Sand			106D , Abovegrade
	135	Sand,			Project Name: NCRA Refinery
	140	Gravel,			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction

completed on (mo/day/year) . . . . 11/15/99 . . . . and this record is true to the best of my knowledge and belief.

Water Well Contractor's License No. . . . . 527 . . . . This Water Well Record was completed on (mo/day/yr) . . . . . 11/15/99 . . . . . .

the business name of GeoCore Services, Inc. by (signature) Dale Bell

TRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas ment of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

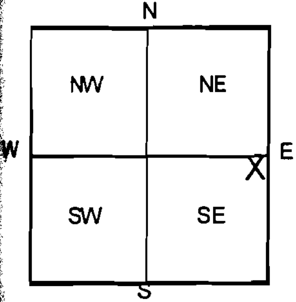
	Fraction	Section Number	Township Number	Range Number
y: McPherson	NE ¼ NE ¼ SE ¼	32	T 19 S	R 3 E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
0 S. Main, McPherson, Kansas

ATER WELL OWNER: **NCRA**
St Address, Box # : **P.O. Box 1401**
State, ZIP Code : **McPherson, Kansas 67460**

Board of Agriculture, Division of Water Resources
Application Number:

CATE WELL'S LOCATION
TH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL ...... **158** ...... ft. ELEVATION: ...... **1477.59** ......

Depth(s) Groundwater Encountered 1. .... ft. 2. .... ft. 3. .... ft.

WELL'S STATIC WATER LEVEL .... ft. below land surface measured on mo/day/yr ....

Pump test data: Well water was .... **NA** .... ft. after .... hours pumping .... gpm

Est. Yield .. **NA** ... gpm: Well water was .... ft. after .... hours pumping .... gpm

Bore Hole Diameter .. **9.625** .. in. to ..... **177** ...... ft., and .... in. to .... ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓

Was a chemical/bacteriological sample submitted to Department? Yes......... No...✓...; If yes, mo/day/yr sample was submitted

Water Well Disinfected? Yes No ✓

PE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued ...... Clamped .....
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded ....
[✓ 2 PVC] 4 ABS 7 Fiberglass .... Threaded. ✓

asing diameter ...... **4** ...... in. to .... **138** .... ft., Dia .... in. to .... ft., Dia .... in. to .... ft.

g height above land surface ..... **50.28** ...... in., weight .... lbs./ft. Wall thickness or gauge No. .... **Sch. 40** ....

OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) ....
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) ....

EN-PERFORATED INTERVALS: From ...... **138** ...... ft. to ...... **158** ...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

GRAVEL PACK INTERVALS: From ...... **123** ...... ft. to ...... **177** ...... ft., From .... ft. to .... ft.
From .... ft. to .... ft., From .... ft. to .... ft.

OUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....

Intervals: From ...... **0** ...... ft. to .... **121** .... ft., From .... **121** .... ft. to .... **123** .... ft., From .... ft. to .... ft.

is the nearest source of possible contamination:
Septic tank 4 Lateral lines 7 Pit privy 10 Livestock pens 14 Abandoned water well
Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well
Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage [✓ 16 Other (specify below)]
13 Insecticide storage ... **refinery** ....

tion from well? **0** How many feet? **0**

TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
5	Clay, Brown	115	118	Sand,
10	Clay, Black	118	150	Sand,
15	Clay, Dark Brown	150	158	Sand, Brown
18	Clay, Gray	158	163	Sand, Blue Gray
23	Clay, Brown	163	170	Shale, Blue Gray
32	Clay, Brown	170	175	Shale, Red
40	Sand, Brown	175	177	Shale, Blue
45	Sand,			
48	Sand,			
55	Clay, Gray			
62	Clay, Gray Tan			
70	Sand,			
82	Sand,			107D , Abovegrade
90	Sand,			Project Name: NCRA Refinery
115	Sand,			GeoCore # 809 , #

NTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) .... **11/15/99** .... and this record is true to the best of my knowledge and belief.
Water Well Contractor's License No. .... **527** .... This Water Well Record was completed on (mo/day/yr) .... **11/15/99** ....
the business name of **GeoCore Services, Inc.** by (signature) Dale Ralf

STRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

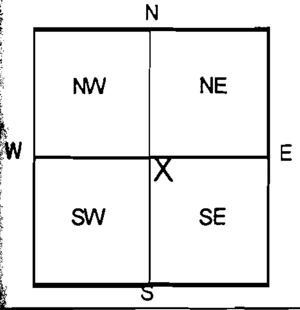
OCATION OF WATER WELL:	Fraction	Section Number	Township Number	Range Number
nty: **McPherson**	**NW** ¼ **NW** ¼ **SE** ¼	**32**	T **19** S	R **3** E [✓ W]

nce and direction from nearest town or city street address of well if located within city?
00 South Main, McPherson, Kansas

VATER WELL OWNER: **NCRA**
St. Address, Box # : **P.O. Box 1401**
State, ZIP Code : **McPherson, Kansas 67460**

Board of Agriculture, Division of Water Resources
Application Number:

OCATE WELL'S LOCATION
VITH AN "X" IN SECTION BOX:



4 DEPTH OF COMPLETED WELL . . . . . **158** . . . . . ft. ELEVATION: . . . . **1482.68** . . . .
Depth(s) Groundwater Encountered 1. . . . . ft. 2. . . . . ft. 3. . . . . ft.
WELL'S STATIC WATER LEVEL . . . . ft. below land surface measured on mo/day/yr
Pump test data: Well water was . . . **NA** . . . . ft. after . . . . hours pumping . . . . gpm
Est. Yield . . **NA** . . . gpm: Well water was . . . . ft. after . . . . hours pumping . . . . gpm
Bore Hole Diameter . . **9.625** . . in. to . . . . . **165** . . . . . . ft., and. . . . . in. to. . . . . ft.

WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ . . . .

Was a chemical/bacteriological sample submitted to Department? Yes. . . . . .No. . ✓. . . . ; If yes, mo/day/yr sample ✓ was submitted
Water Well Disinfected? Yes No ✓

YPE OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued . . . . . . Clamped . . . . .
1 Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded . . . .
[✓ 2 PVC] 4 ABS 7 Fiberglass . . . . Threaded. ✓ . . . .
casing diameter . . . . . . **4** . . . . . . in. to . . . . **138** . . . . ft., Dia . . . . in. to . . . . ft., Dia . . . . in. to . . . . ft.
g height above land surface . . . . . **27.96** . . . . . . in., weight . . . . lbs./ft. Wall thickness or gauge No. . . . . **Sch. 40** . . . . .

E OF SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify) . . . .
2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)

EEN OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
1 Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
2 Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify) . . . .

EEN-PERFORATED INTERVALS: From . . . . . . **138** . . . . . . ft. to . . . . . . **158** . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.
GRAVEL PACK INTERVALS: From . . . . . . **133** . . . . . . ft. to . . . . . . **165** . . . . ft., From . . . . ft. to . . . . ft.
From . . . . ft. to . . . . ft., From . . . . ft. to . . . . ft.

ROUT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other . . . .
t Intervals: From . . . . . **0** . . . . . ft. to . . . . **127** . . . . ft., From . . . . **127** . . . . ft. to . . . . **133** . . . . . ft., From . . . . ft. to . . . . ft.

t is the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
Septic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
Sewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
Watertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage . . . **refinery** . . . .
ion from well? **0** How many feet? **0**

OM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
	8	**Clay, Very Dark Brown**	**115**	**125**	**Sand,**
	12	**Clay, Reddish Brown**	**125**	**135**	**Sand,**
	15	**Clay, Reddish Brown**	**135**	**150**	**Sand,**
	25	**Clay, Brown**	**150**	**153**	**Sand,**
	30	**Silt, Brown**	**153**	**158**	**Clay, Pale Yellow**
	42	**Clay, Brown**	**158**	**165**	**Shale, Gray**
	45	**Sand, White**			
	50	**Sand,**			
	55	**Sand,**			
	60	**Sand,**			
	70	**Sand,**			
	75	**Sand, Tan**			
	80	**Sand,**				**105D , Abovegrade**
	105	**Sand,**			**Project Name: NCRA Refinery**
	115	**Sand,**			**GeoCore # 809 , #**

ONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
s completed on (mo/day/year) . . . . **11/15/99** . . . . and this record is true to the best of my knowledge and belief.
s Water Well Contractor's License No. . . . . **527** . . . . This Water Well Record was completed on (mo/day/yr) . . . . **11/16/99** . . . . . .
r the business name of **GeoCore Services, Inc.** by (signature) Dale Bell

NSTRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

r: McPherson | NW ¼ | NW ¼ | NE ¼ | 5 | T 20 S | R 3 E[✓ W]

e and direction from nearest town or city street address of well if located within city?
S. Main, McPherson, Kansas

TER WELL OWNER: NCRA
t Address, Box # : P.O. Box 1401
te, ZIP Code : McPherson, Kansas 67460

Board of Agriculture, Division of Water Resources
Application Number:

ATE WELL'S LOCATION
H AN "X" IN SECTION BOX:

	N	
	NW	NE X
		E
	SW	SE
	S	

4 DEPTH OF COMPLETED WELL......150...... ft ELEVATION: 1482.72
Depth(s) Groundwater Encountered 1..............ft 2..............ft 3..............ft
WELL'S STATIC WATER LEVEL .... ft below land surface measured on mo/day/yr ....
Pump test data: Well water was ....NA.... ft after .... hours pumping .... gpm
Est. Yield ..NA... gpm: Well water was .... ft after .... hours pumping .... gpm
Bore Hole Diameter ..9.625.. in. to ......150....... ft., and................ in. to.............. ft
WELL WATER TO BE USED AS: 5 Public water supply 8 Air conditioning 11 Injection well
1 Domestic 3 Feedlot 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
2 Irrigation 4 Industrial 7 Lawn and garden only [✓ 10 Monitoring well] ✓ ....
Was a chemical/bacteriological sample submitted to Department? Yes.........No...✓.....; If yes, mo/day/yr sample ✓ was submitted
Water Well Disinfected? Yes No ✓

OFFICE USE ONLY T R E/W SEC. ¼ ¼ ¼

E OF BLANK CASING USED: 5 Wrought iron 8 Concrete tile CASING JOINTS: Glued...... Clamped.....
Steel 3 RMP (SR) 6 Asbestos-Cement 9 Other (specify below) Welded..........
[✓ PVC] 4 ABS 7 Fiberglass .... Threaded. ✓
sing diameter ......4...... in. to .....60..... ft., Dia .... in. to .... ft., Dia .... in. to .... ft
height above land surface .....33.12...... in., weight .... lbs./ft. Wall thickness or gauge No. ....Sch. 80.....
F SCREEN OR PERFORATION MATERIAL [✓ 7 PVC] 10 Asbestos-cement
Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 11 Other (specify)..............
Brass 4 Galvanized steel 6 Concrete tile 9 ABS 12 None used (open hole)
N OR PERFORATION OPENINGS ARE: 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
Continuous slot [✓ 3 Mill slot] 6 Wire wrapped 9 Drilled holes
Louvered shutter 4 Key punched 7 Torch cut 10 Other (specify)..............
N-PERFORATED INTERVALS: From ....60....... ft to ......150....... ft., From .... ft to .... ft
From .... ft to .... ft., From .... ft to .... ft
GRAVEL PACK INTERVALS: From ....57....... ft to ......150....... ft., From .... ft to .... ft
From .... ft to .... ft., From .... ft to .... ft
UT MATERIAL: [✓ 1 Neat cement] 2 Cement grout [✓ 3 Bentonite] 4 Other ....
ervals: From ......0...... ft to ....51..... ft., From ....51..... ft to ....57..... ft., From .... ft to .... ft
the nearest source of possible contamination: 10 Livestock pens 14 Abandoned water well
eptic tank 4 Lateral lines 7 Pit privy 11 Fuel storage 15 Oil well/Gas well
ewer lines 5 Cess pool 8 Sewage lagoon 12 Fertilizer storage [✓ 16 Other (specify below)]
atertight sewer lines 6 Seepage pit 9 Feedyard 13 Insecticide storage ...refinery.......
n from well? 0 How many feet? 0

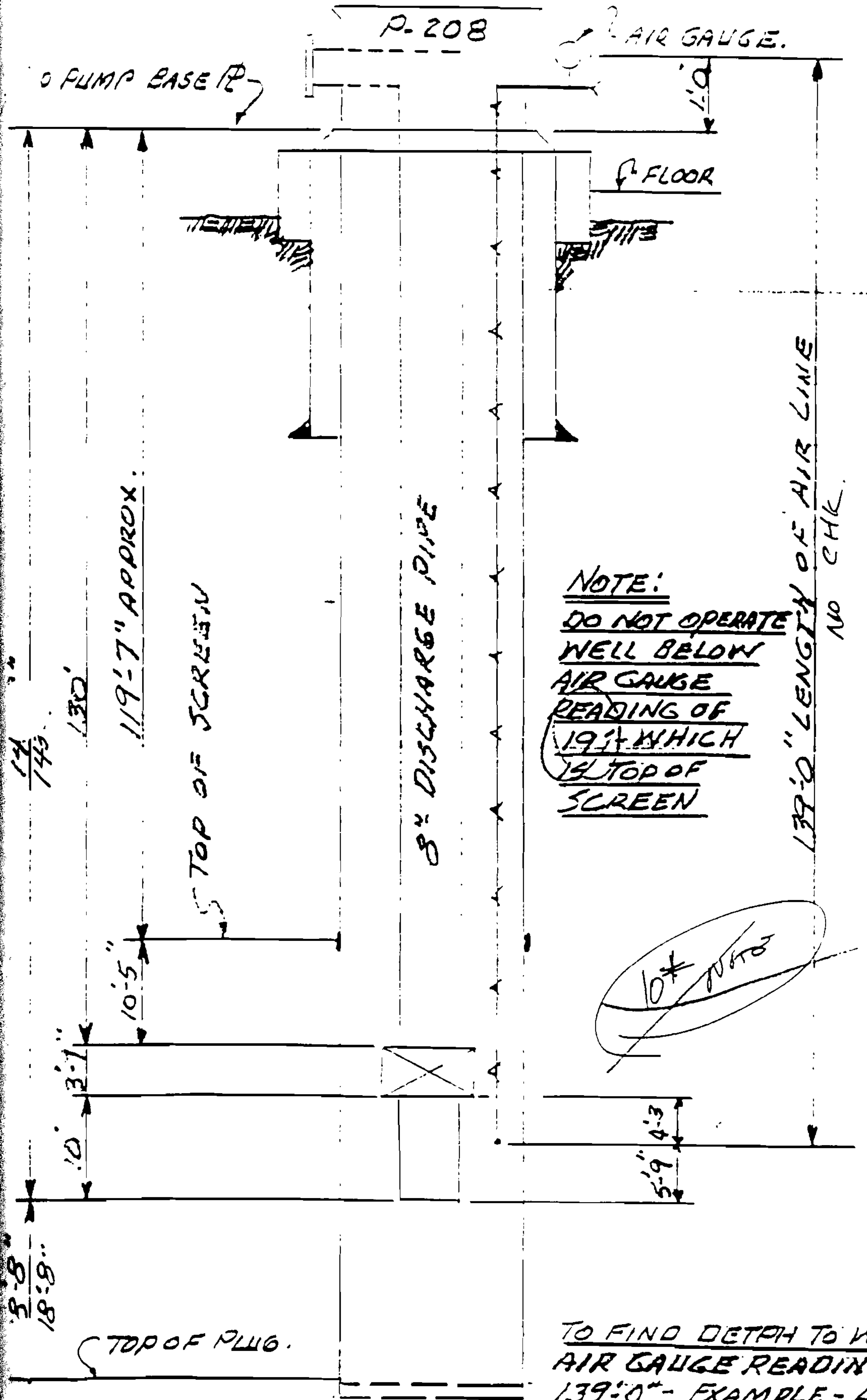
TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
8	Clay, Dark Brown			
20	Clay, Brown			
30	Clay, Brown			
35	Clay, Gray Brown			
55	Sand, Gray Brown			
59	Sand, Brown			
70	Clay, Gray Brown			
75	Sand, Brown			
85	Sand, Brown			
100	Sand, Brown to Red Brown			
110	Sand, Brown			
125	Sand, Brown to Red Brown			
140	Sand, Brown			RW/MW , Abovegrade
150	Sand, Brown			Project Name: NCRA Refinery
				GeoCore # 809 , #

TRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was [✓ (1) constructed], (2) reconstructed, or (3) plugged under my jurisdiction
completed on (mo/day/year) ....11/15/99.................. and this record is true to the best of my knowledge and belief.
Water Well Contractor's License No. ....527......... This Water Well Record was completed on (mo/day/yr) ......11/15/99.
e business name of GeoCore Services, Inc. by (signature) Dale Roll

TRUCTIONS: Use typewriter or ball point pen. *PLEASE PRESS FIRMLY* and *PRINT* clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas rtment of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

AIR LINE INSTALLATION

1-28-82



NOTE:
DO NOT OPERATE WELL BELOW AIR GAUGE READING OF 19'± WHICH IS TOP OF SCREEN

AIR GAUGE READING'	DEPT TO WA
54'	85'
53'	86
52	87'
51'	88
50'	89
49'	90
48	91
47	92
46'	93
45'	94
44	95
43'	96'
42'	97
41'	98
40	99
39'	100
38'	101
37'	102
36'	103
35'	104
34'	105
33'	106
32'	107
31'	108
30'	109
29'	110
28'	111
27'	112
26	113
25'	114
24'	115
23'	116
22'	117
21'	118
20'	119
19'	120
18'	121

TO FIND DETPH TO WATER - SUBTRACT AIR GAUGE READING IN FEET FROM 139'-0" - EXAMPLE - AIR GAUGE READS 54' - THEN 139'-54' = 85' TO WATER

* STATIC LEVEL - 1-28-82'
** TOP SCREEN.

LEH - 1-28-82

NCRA-A-14,055

Jenny Water We

This sheet is to be filled in and mailed to office upon completion of well #3

Globe Oil Co. McPherson, Kansas — June 9, 1941.
Name of job — Date

HYNE Well No. 3 — Hugh Rushton
Driller's name

Their Well =

1. Is there a plug in well yes

2. Thickness of plug 4" wood-10"concrete inches

3. Log of Well:

			Formation				Formation
0	to	1	Soil	71	to	87	Coarse Sand & Gr.
1	to	48	Clay	87	to	90	Clay
48	to	58	Sandy Clay	90	to	115	Coarse Sand
58	to	62	Fine Sand	115	to	120	Med. Fine Sand
62	to	66	Coarse Sand	120	to	161'6"	Coarse Sand Gravel
66	to	71	Clay		to		

4. Depth of well (ground level to top of plug) 160'3" feet

5. Size and lengths of material left in well:

45 feet of 18 inch shutter ~~concrete~~ screen

by by shutter cone

118 feet of 18 inch inside blank casing

10 feet of 30 inch outside blank casing

6. Amount of gravel used in well 50 ton yards

7. Work on well began May 14, 1941
Date

8. Well was completed June 7, 1941
Date

9. Number of working days 22

10. Test of well:

Power used Electric Motor

Duration of test 10 hours

g. p. m. pumped 1000

From ground level { Standing water level 72' feet

From ground level { Pumping water level 111' feet

Drawdown 39' feet

2.5
0.4
39
3

11. Pump No. was installed in this well by Rushton
Installer's Name

12. Remarks:

NCRA - A - 14002

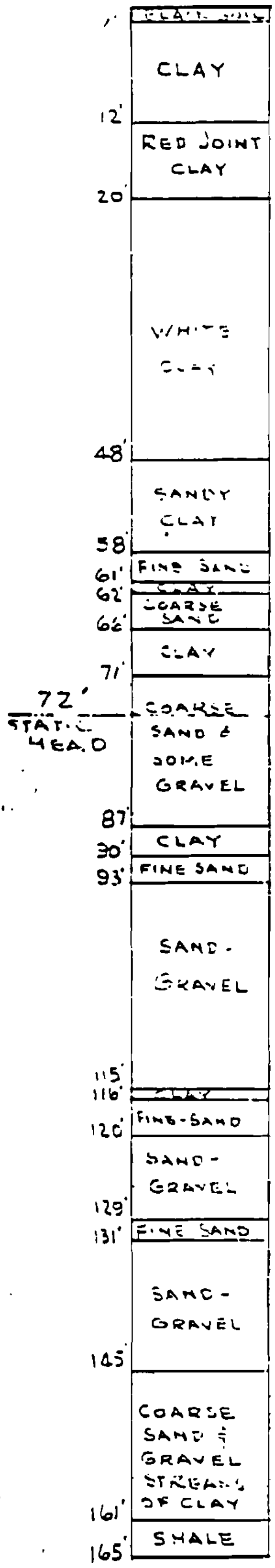
JOB NO.

Drwg. HCRA-A-14,

LOCATION- NE-NE-NE¼ Sec. 5 Twp. 20s Rge. 3w

State Log No. 94
State Well No. 122

WATER WELL NO. 3

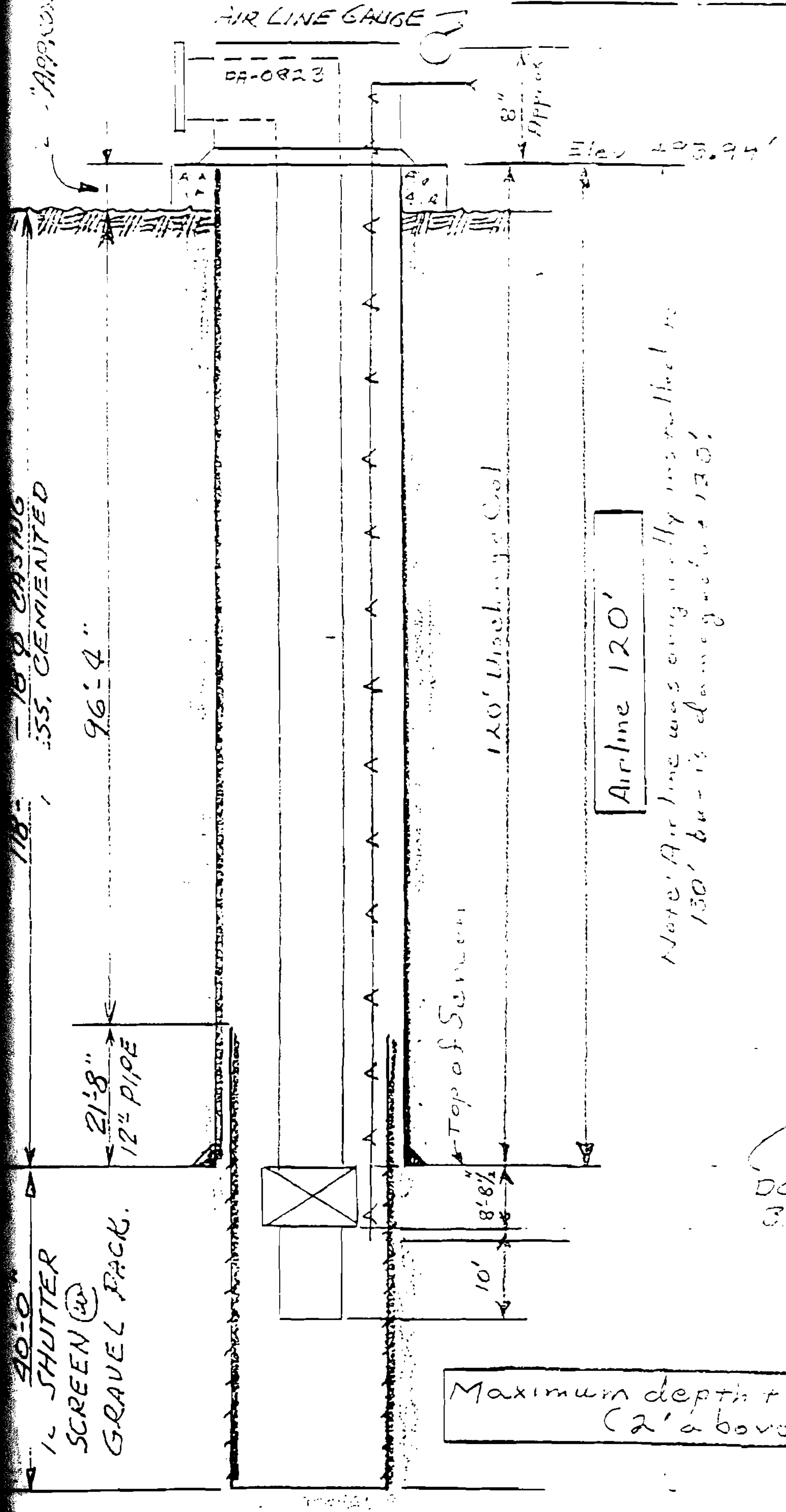


DATA	DATE
WELL DRILLED BY LANE WELLS	MAY 1, 1941
(1) DRILLED 38" HOLE 161'-3" INTO SHALE	
(2) LENGTH OF 8" DISCHARGE PIPE FROM PUMP TO BASE OF MOTOR 96'-1"	
(3) LENGTH OF PUMP FLANGE TO FLANGE 3'-5"	
(4) SUCTION PIPE FROM PUMP 25'-0"	
(5) 18" SLUTTER SCREEN NO.4 MADE FROM NO.8 GA. IRON 45'-0"	
(6) 18" BLANK CASING MADE FROM NO.4 GA IRON 116'-1"	
(7) USED GRAVEL OF $\frac{1}{8}$" TO $\frac{1}{4}$"	
(8) 30" SURFACE CASING 10' LONG WAS INSTALLED AND CEMENTED INTO BASE	
(9) WATER LEVEL BEFORE 10 HOUR TEST WAS 72'-0" FROM GROUND	
(10) AFTER 10 HOURS WATER LEVEL WAS STANDING AT 70'-4"	
(11) WELL TEST WAS RUN FOR 10 HOURS ON JUNE 6, 1941	
RESULTS OF PUMPING TEST	JUNE 6, 19

AVERAGE DRAW DOWN 111 FT.
" PRESSURE 56#0"
" ORFICE READING 42 INCHES
" G.P.M. 1,005

STATIC HEAD 72 FT.

AIR LINE INSTALLATION



AIR LINE READING (FT)	DEPTH T WATER
36	84
35	85
34	86
33	87
32	88
31	89
30	90
29	91
28	92
27	93
26	94
25	95
24	96
23	97
22	98
21	99
20	100
19	101
18	102
17	103
16	104
15	105
14	106
13	107
12	108
11	109
10	110
9	111
8	112
7	113
6	114
5	115
4	116'
3	117'
2	118'

DO NOT OPERATE BELOW 118'

Maximum depth to water 118'
(2' above screen)

NCRA-A-14,040 REV. 5

5/6/

#8 water well

This sheet is to be filled in and mailed to office upon completion of well

1. National Cooperative Refinery Association (Name of Job) — 8-20-57 (Date)

2. McPherson (City) — Kansas (State)

3. Layne Well No. 4 — Roy Senior (Driller's Name)
NCRA #8

4. Well location: 600' south of Layne Well No. 3.
Give Distance and Direction from Permanent Land Mark so Well can be Accurately Located Several Years f

5. Work began 8-2-57; work completed 8-20-57. Number of working days

6. Diameter, length and type of material left in well:

7. 40 feet of 12" Shutter screen made of Bronze No. 4 o
(Shutter, Concrete, Keystone) (Armco, Bronze, Stainless Steel, Concrete) (Mesh)

8. 21'8" feet of 12 inch inside casing made of Std. Pipe with Welded con
(Armco, Std. Pipe, Concrete) (Riveted, Welded, Screw)

9. 119'4" feet of 18 inch outside casing made of Std. Pipe with Welded con
(Armco, Std. Pipe) (Riveted, Welded, Screw)

10. 10 yards of gravel used in well. Size 1/8 X 3/8

11. Test of well. Did you use test or permanent pump? Test — 12" (Size of Bowl) — Sta

12. Pump No. ; geared head No. ; ratio ; r. p. m. ; pulley diam.
7" Oil Lub Column

13. Power used Eng. (Electric Motor, Engine); horse power ; voltage ; r. p. m. ; pulley diam. ; r. p.
Big Continental - Drive Shaft

14. Size of orfice 10 inch, by 8 inch. Orifice tube reading 9.5 inches.

15. Pumping test—measurements from ground level:

36
28 | 1016.00
84
176
168

Time	G. P. M.	Static	Drawdown	Pumpin
8:30	1016	73'	24'6"	97'6"
9:30	1016	73'	27'7"	100'
10:30	1016	73'	28'	101'
11:30	1016	73'	28'	101'
12:30	1016	73'	28'	101'
1:30	1016	73'	28'	101'
2:30	1016	73'	28'	101'

16. Recovery in 5 minutes Full, in 1 Hour Full

17. Customer's pump No. 14023A was installed in this well by

NCRA-A-14,013

Was well under-reamed? Yes From 117'4" feet to 158 feet. bottom
By Reverse Rotary Method From ______ feet to ______ feet.
From ______ feet to ______ feet.

If all screen was not placed at bottom, state how it was spaced.

From ______ feet to ______ feet; from ______ feet to ______ feet; from ______ feet to ______ feet.

Depth of well (from ground level to top of plug) 158 feet 0 inches.

Was cement placed around or between any of the casings? Yes

If so, state where, how much and method used. 117'4" of 18" O.D., 3/8" Wall pipe was pressure cemented in 22" hole by Halliburton. 142 bags of cement were used.

Log of well from ground level:

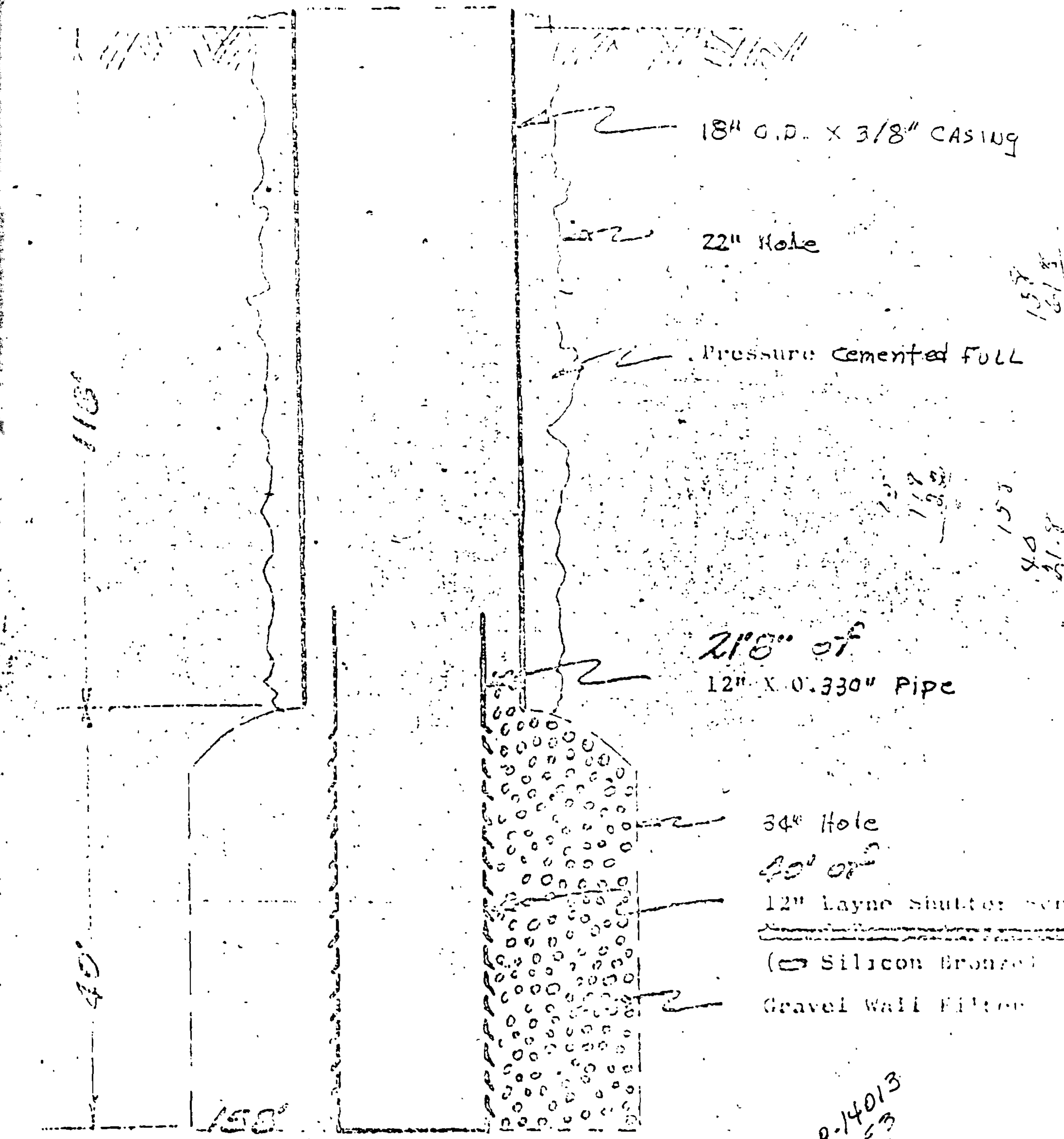
Feet		Feet	Formation
0	to	2	Soil
2	to	60	Brown clay, some yellow clay streaks,
	to		some sandy streaks
60	to	65	Soft sandy gray clay with coarse sand lenses
65	to	71	Coarse sand and gravel, clean and
	to		loose
71	to	73	Soft sandy gray clay
73	to	74'6"	Coarse sand and gravel
74'6"	to	76	Soft sandy gray clay
76	to	94	Med. to coarse sand, a few clay
	to		streaks
94	to	96	Brown sandy clay
96	to	110	Med. to coarse sand and gravel
110	to	145	Med. to coarse sand and gravel,
	to		few thin clay streaks
145	to	158	Coarse sand and gravel and thicker
	to		clay streaks
[illegible]	to	158'	Green Soft Shale
	to		
	to		

FOR SKETCH

Remarks:
18" casing left 2' above ground, making total depth from top of pipe 159'.
119'4" of 18" pipe.

NCRA-A-14013
2 of 2

WELL No. 3



NCRA-A-14013
3 of 3

LAYNE-WESTERN CO.
ENGINEERING DEPT.
WICHITA, KANSAS
DATE July 23, 19 57
Final- 8-20-57

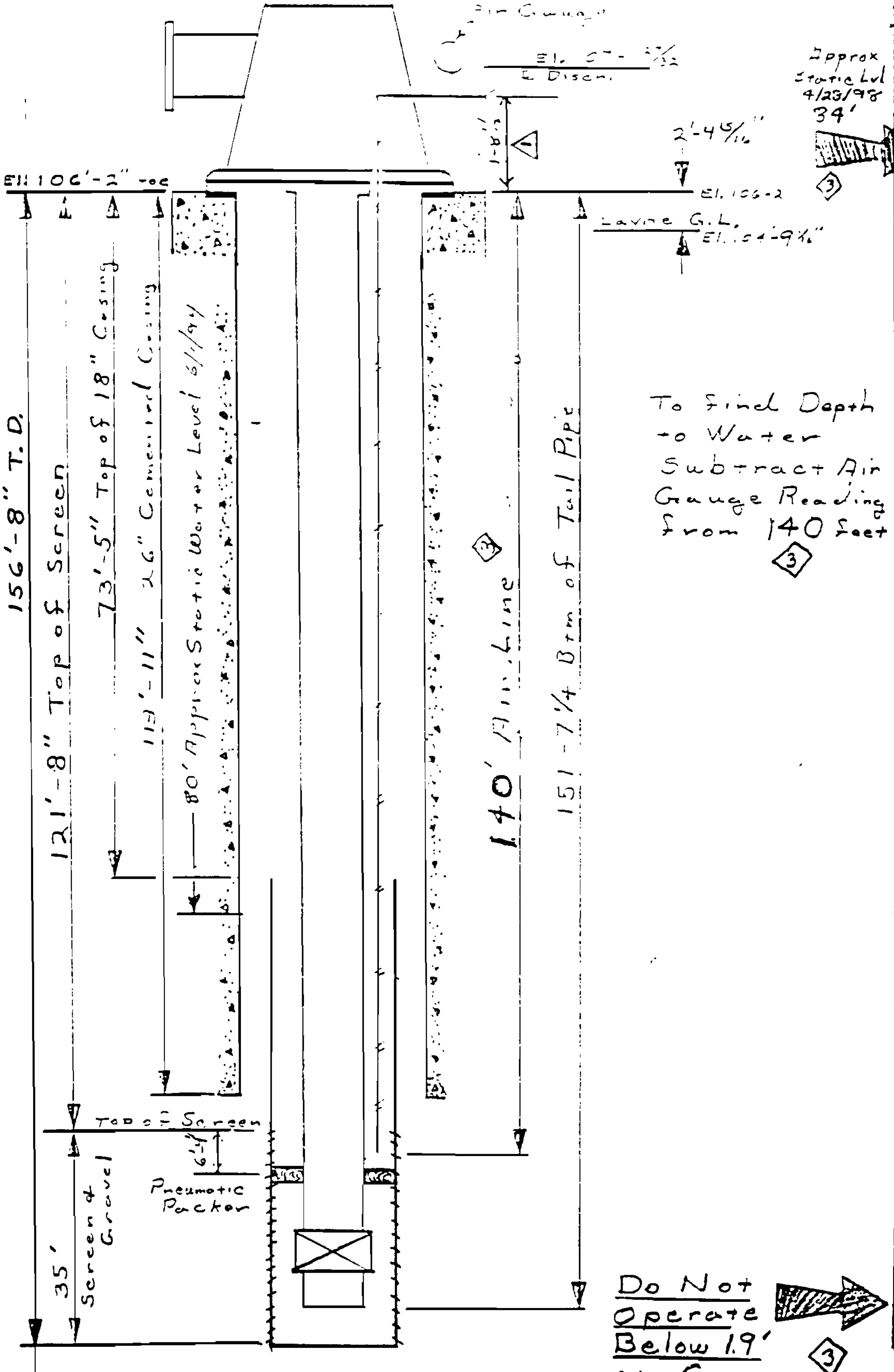
JOB: National Cooperative Refinery Associatio
LOCATION: Main Plant, McPherson, Kansas
NEW WATER WELL - WELL NUMBER THREE
Layne Well No. [illegible]
NCRA [illegible] No 3

③

WATER WELL NO. C

Air Line Installation - 5/2/87
VCRA-A-14063 Rev. 1 5/25/93
P. SONNEDECKER Rev 2 6/11/94 RLW
Rev 3 4/23/98 RLS ③

Layne Top of Casing = 106'-2½"



To Find Depth to Water Subtract Air Gauge Reading from 140 feet ③

Air Gauge Reading (Feet)	Depth to Water (Feet)
60	80
59	81
58	82
57	83
56	84
55	85
54	86
53	87
52	88
51	89
50	90
49	91
48	92
47	93
46	94
45	95
44	96
43	97
42	98
41	99
40	100
39	101
38	102
37	103
36	104
35	105
34	106
.33	107
32	108
31	109
30	110
29	111
28	112
27	113
26	114
25	115
24	116
23	117
22	118
21	119
20	120
19	121

Do Not Operate Below 19' ③

WELL INFORMATION

Layne-Western Co. Inc.

1. CONTRACT National Cooperative Refinery Association
2. City, State McPherson, Kansas
3. Well No. 10 at Test Hole No. 2-86
4. Well Location (attach map) NE¼, NW¼, NE¼, Sec. 5, T-20-S, R-3-W, McPherson County, Kansas

5. Driller J. Watkins
6. DATE 2/10/87
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	35' 6"	18"	—	—	18-8 Type 304 SS	Wire Wrap [illegible]	.070" Openings
Inner Casing	5' 0" 40' 0"	18" 18"	—	.180 .375	18-8 Type 304 SS Carbon Steel	Welded [illegible]	
Outer Casing	114'0"	—	—	.375	Carbon Steel	Welded [illegible]	

11. GRAVEL

Size 1/8 x 1/2 Miles

Tons 18

12. SEALING CASING

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

With .... Bags Bentonite Added

or

With .... Bags Cement

Seal Material Placed in Well With Haliburton 2" tremie

Bottom of Well Screen Sealed With S. Steel

13. WELL DIMENSIONS

A. Total Depth 156' 9"
(From Top of Inner Casing to Bottom o
Well)

B. Height of Inner Casing 2' 6"
(Above Ground Level)

C. Distance to Top of Gravel 99'
(From Ground Level)

D. Diameter of Drill Hole 30" & 38"

Comments Reverse rotary

LW-39

11. PUMPING TEST

A.

~~Test pump~~

Permanent pump ......11...in.BHC......Bowl..........7...Stages

Length of column ....140...........Ft.

Length of Bowl ....7...........Ft.

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

B. Measured water level 77' 10" Ft. from top of ...26....In. dia. casing which is 2' 6"........ Ft. above ground.

C. Length of airline ......140......Ft. from top of casing.

ORIFICE

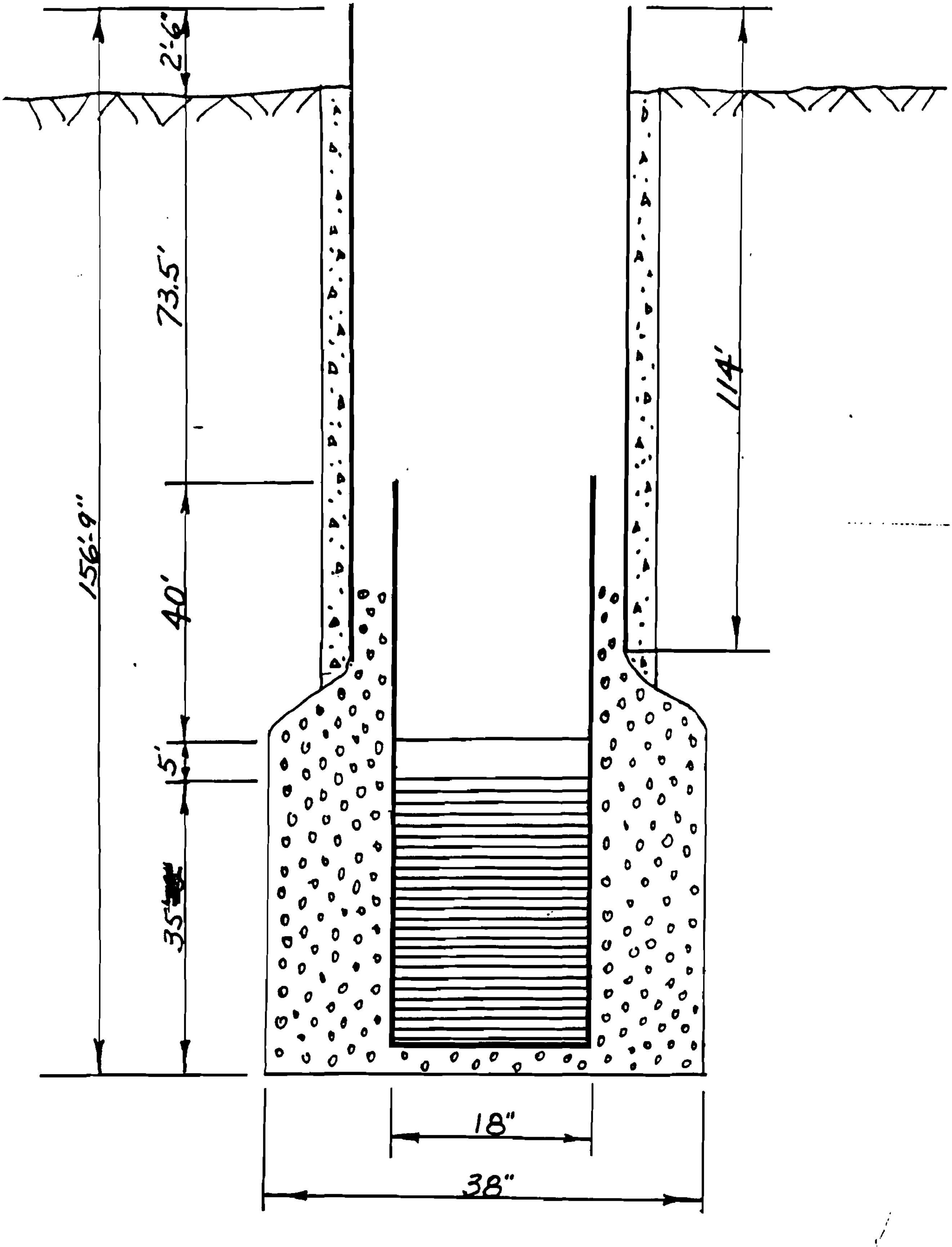
..............................x..............................

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

TIME	INCHES ORIFICE MANOMETER	GPM	ALT. GAGE READING	WATER LEVEL	DRAW DOWN
0	-	0		77' 10"	0
1 Hr.		699		119' 7"	41' 9"
2		699		119' 9½"	41' 11½"
3		699		119' 9½"	41' 11½"
4		699		119' 9½"	41' 11½"
5		699		119' 9½"	41' 11½"
6		699		119' 9½"	41' 11½"
7		699		119' 9½"	41' 11½"
8		699		119' 9½"	41' 11½"
RECOVERY		0			
15 Min.		0			9' 0"
30		0			8' 8"
45		0			8' 5"
60		0			8' 3"

15. Permanent ....Layne.......... Pump No. .....106352.......... installed by ....
Layne

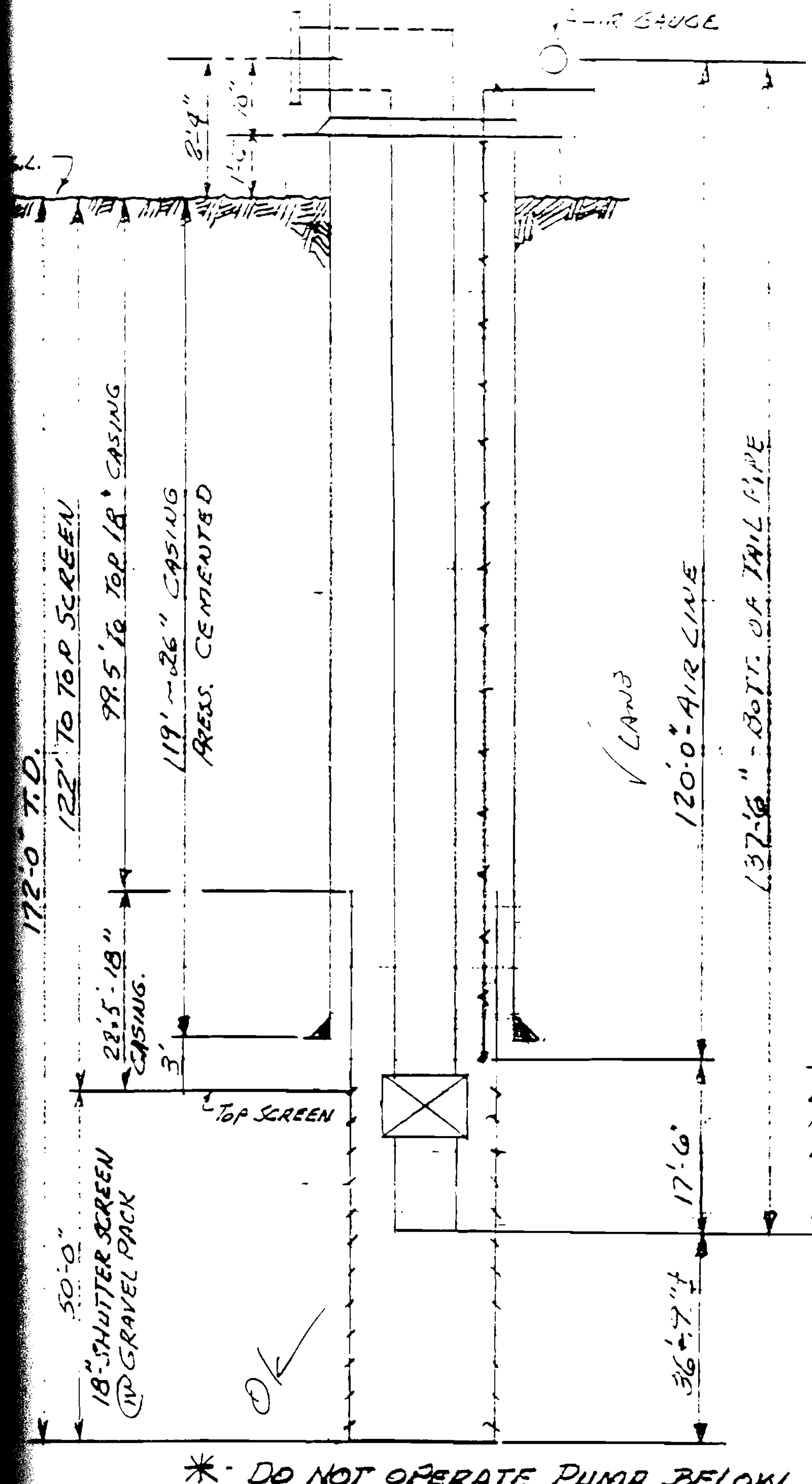
Permanent air line length ....140..........Ft. Date..............................
Month Day Year


2'-6"
156'-9"
73.5'
114'
40'
5'
35'
18"
38"

LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			5		top soil
5			17		brownish red clay
17			40		gray clay
40			55		fine sand with clay
55			68		fine to coarse sand
68			80		clay with fine sand streaks
80			112		med. sand & gravel w/clay streaks
112			120		clay with fine sand
120			155		fine to med. sand w/thin clay lens
155			160		gray shale

AIR-LINE INSTALLATION - 3-29-72
(PUMP INSTALL: SEE NCRA-B-14034)



AIR GAUGE READINS'	DEPTH TO WATER.	AIR GAUGE READINS'	DEPTH TO
45'	75	22'	98
44'	76'	21'	99
43'	77'	20'	100
42'	78'	19'	101
41'	79'	18'	102
40'	80'	17'	103
39'	81'	16'	104
38'	82'	15'	105
37'	83'	14'	106
36'	84'	13'	107
35'	85'	12'	108
34'	86'	11'	109
33'	87'	10'	110
32'	88'	9'	111
31'	89'	8'	112
30'	90'	7'	113
29'	91'	6'	114
28'	92'	5'	115
27'	93'	4'	116
26'	94'	3'	117
25'	95'	2'	118
24'	96'	1'	119
23'	97'	0'	120'

TO FIND DEPTH TO WATER: SUBTRACT AIR GAUGE READIN IN FEET FROM 120-0 EXAMPLE:- AIR GAU READS 20' - THEN. 120'-0 - 20 = 100-0" TO WATER.

NCRA-A-14,041.
REV. 2

* - DO NOT OPERATE PUMP BELOW 0' ON AIR GAUGE = (2' ABOVE SCREEN)

-39-82

Refinery Water Well

RECEIVED
JAN 24 1972
N. C. R. A.
REFINING DIVISION

WELL INFORMATION

Layne-Western Co. Inc.

1. CONTRACT National Co-op Refinery Assoc.
Purchase Order No. 17727
2. City, State McPherson, Kansas
Job W128S
3. NCRA Well No. 9 at Test Hole No. 1-70
L #5
4. Well Location (attach map)

5. Driller R. Wells
6. DATE January 15, 1972
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	50	18	7	.188	Type 304 - 18/8 Stainless Steel	#134 Layne Shutter XXXX	4 Openings
Inner Casing	22.50	18		.375	API - 5L Smls Casing	Welded XXXX	
Outer Casing	121	26	3	.25	New Structural Casing	Welded XXXX	

11. GRAVEL
Size (Larned) 1/8" x 3/8"
Tons 18 T.

12. SEALING CASING
Puddled Clay · (XXX) (No)
With ...... Bags Bentonite Added
or
With 300 Bags Cement, Halliburton
Seal Material Placed in
Well XXX 120' to G.L.
Bottom of Well Screen
Sealed With Stainless Steel Plate

13. WELL DIMENSIONS
A. Total Depth 173'
(From Top of Inner Casing to Bottom of Well)
B. Height of Inner Casing 1'
(Above Ground Level)
C. Distance to Top of Gravel 101
(From Ground Level)
D. Diameter of Drill Hole 30" to 120'
38" hole to 173.

Comments Reverse Circulatio
Drill Method.

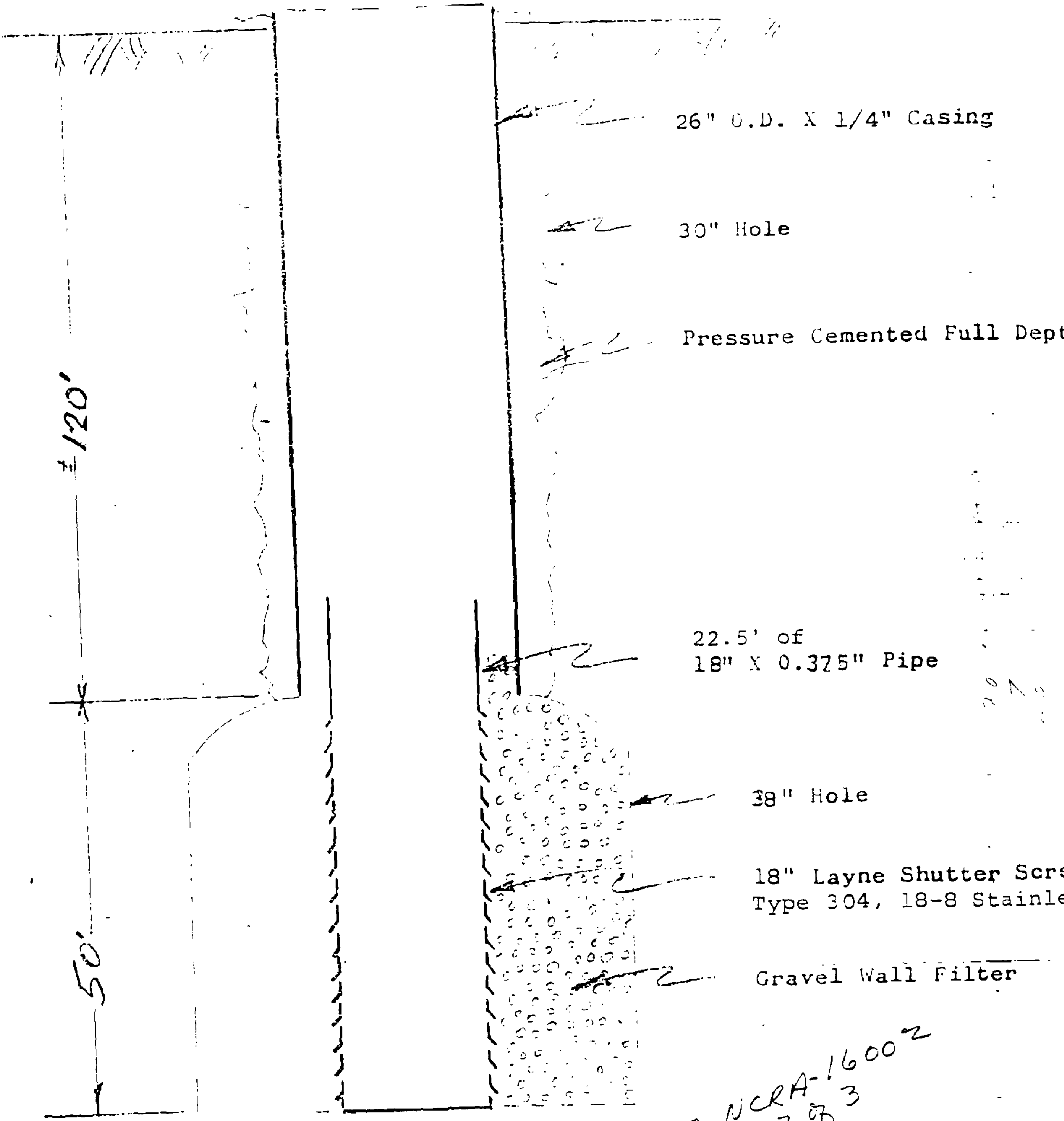
LW-39

F-NCRA-16,002

National Co-op Refinery Ass

WELL No. 9

(as constructed)



F-NCRA-16002
3 of 3

LAYNE-WESTERN CO.
ENGINEERING DEPT.
WICHITA, KANSAS

JOB: National Cooperative Refinery Association
LOCATION: ~~Main Plant, McPherson, Kansas~~
NEW WATER WELL - - WELL NUMBER NINE

LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			2		Top soil
2			45		Brown and tan clay
45			65		Fine to coarse sand
65			77		Tan clay
77			92		Fine to coarse sand and gravel
92			97		White clay
97			117		Med. to coarse sand and gravel
117			122		White clay
122			172		Fine to coarse sand and fine to med. gravel
					w/some clay lenses
172			180		Green and blue shale

F-NGRA-16002
2 of 7

Table 1

SUMMARY OF LABORATORY TEST DATA

REPORT TO: A & M Engineering & Environmental Services, Inc.

LABORATORY NO. SW #A-000703

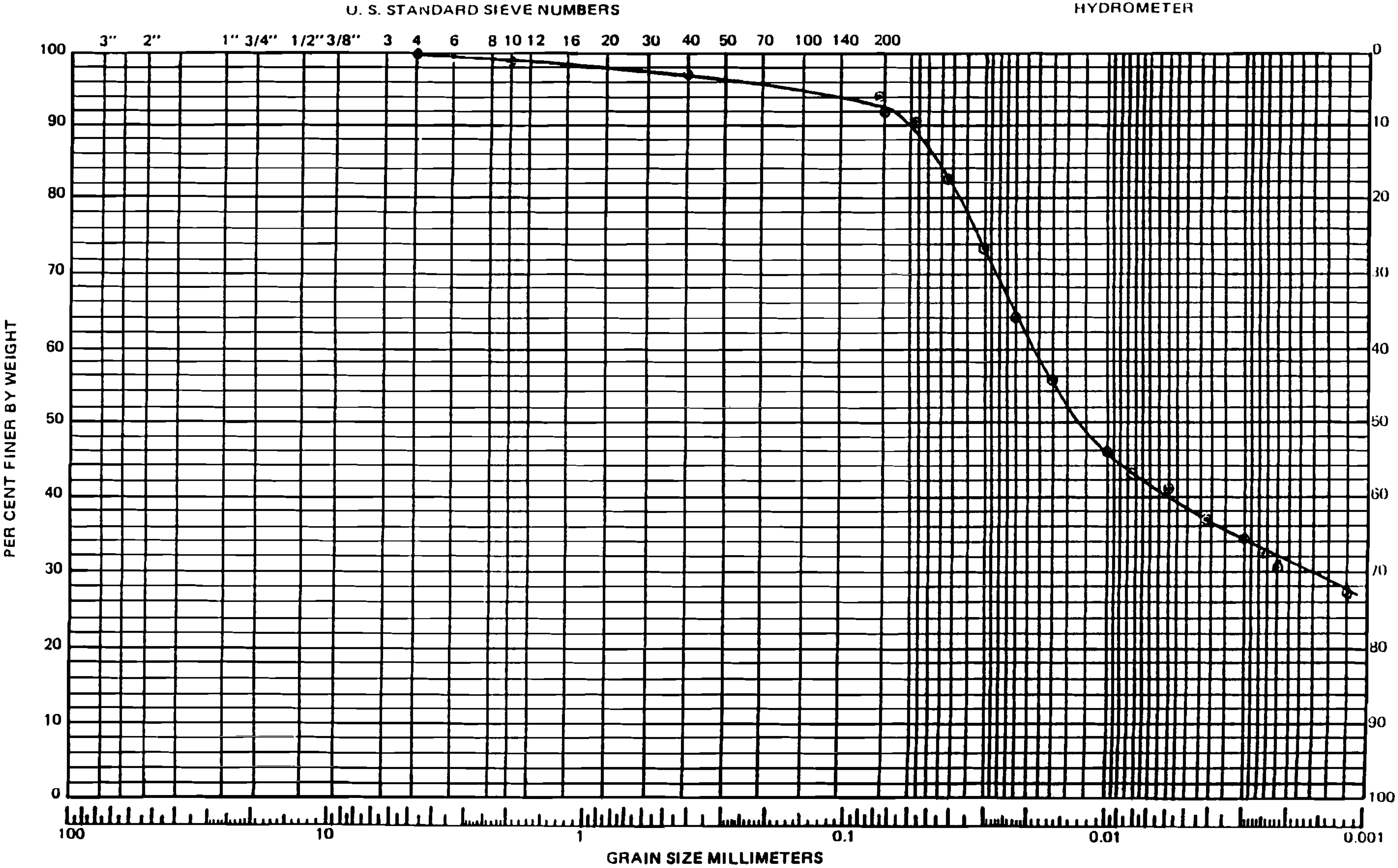
PROJECT: NCRA

DATE: September 9, 1986

BORING NO.	DEPTH IN FEET	MOISTURE CONTENT %	DRY DENSITY pcf	ATTERBERG LIMITS			COMPRESSION ksf	STRAIN %	LATERAL PRESSURE psi	TYPE FAILURE	GRADATION % PASSING				OTHER TESTS
				LL	PL	PI					#4	#10	#40	#200	
A	0-3	25.4		46	17	29						100	99	97	
	3-5	23.3		49	18	31					99	98	97	95	
	5-6	24.2		48	16	32					99	97	95	89	See Grain Size Dist Curv
B	0-3	18.6		44	16	28						100	99	98	
	3-5	19.1		40	17	23					100	99	97	92	See Grain Size Dist Curve
	5-6	19.2		44	17	27					99	99	98	97	
B-3	5-6.5	19.1		46	17	29						100	98	93	
	6-15	23.0		51	17	34						100	100	96	See Grain Size Dist Curv
	15-20	18.9		44	14	30					99	98	97	94	
W-1	25-31.5	7.6		20	19	1					98	98	97	76	See Grain Size Dist Curv
B-1	5-6	13.4	98.8												
Remolded		13.4	97.8												K(remolded) = 4x10^{-6} cm/

STEWART, WHITE AND ASSOCIATES, INC.

GRAIN SIZE DISTRIBUTION DIAGRAM



GRAVEL		SAND			SILT	CLAY
COARSE	FINE	COARSE	MEDIUM	FINE		

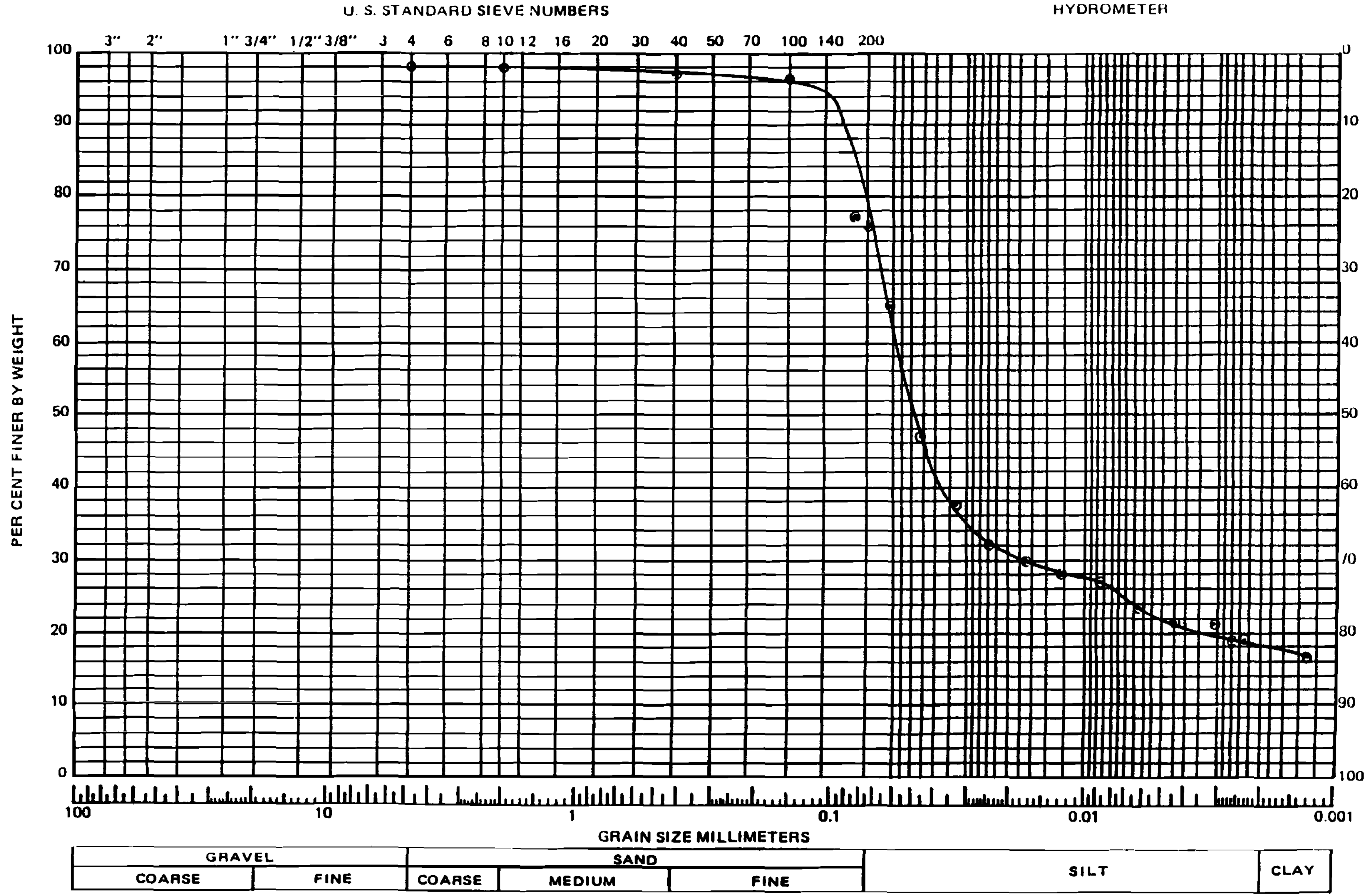
PROJECT: NCRA

IDENTIFICATION: B 3-5

STEWART WHITE AND ASSOCIATED, INC.

Fig 7

GRAIN SIZE DISTRIBUTION DIAGRAM



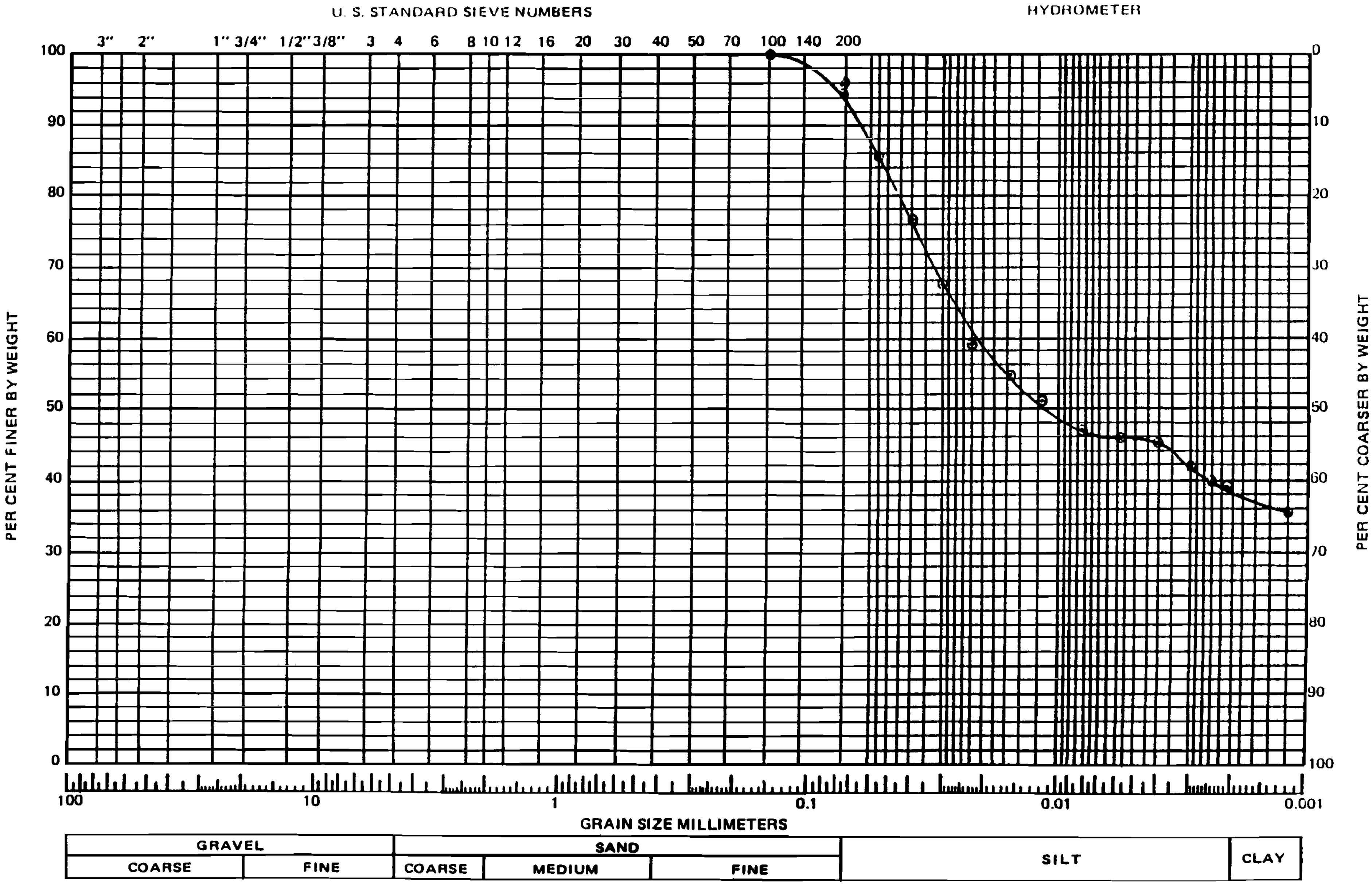
PROJECT: NCRA

IDENTIFICATION: W-1 25'-31.5'

Fig 8

STEWART, WHITE AND ASSOCIATED, INC.

GRAIN SIZE DISTRIBUTION DIAGRAM



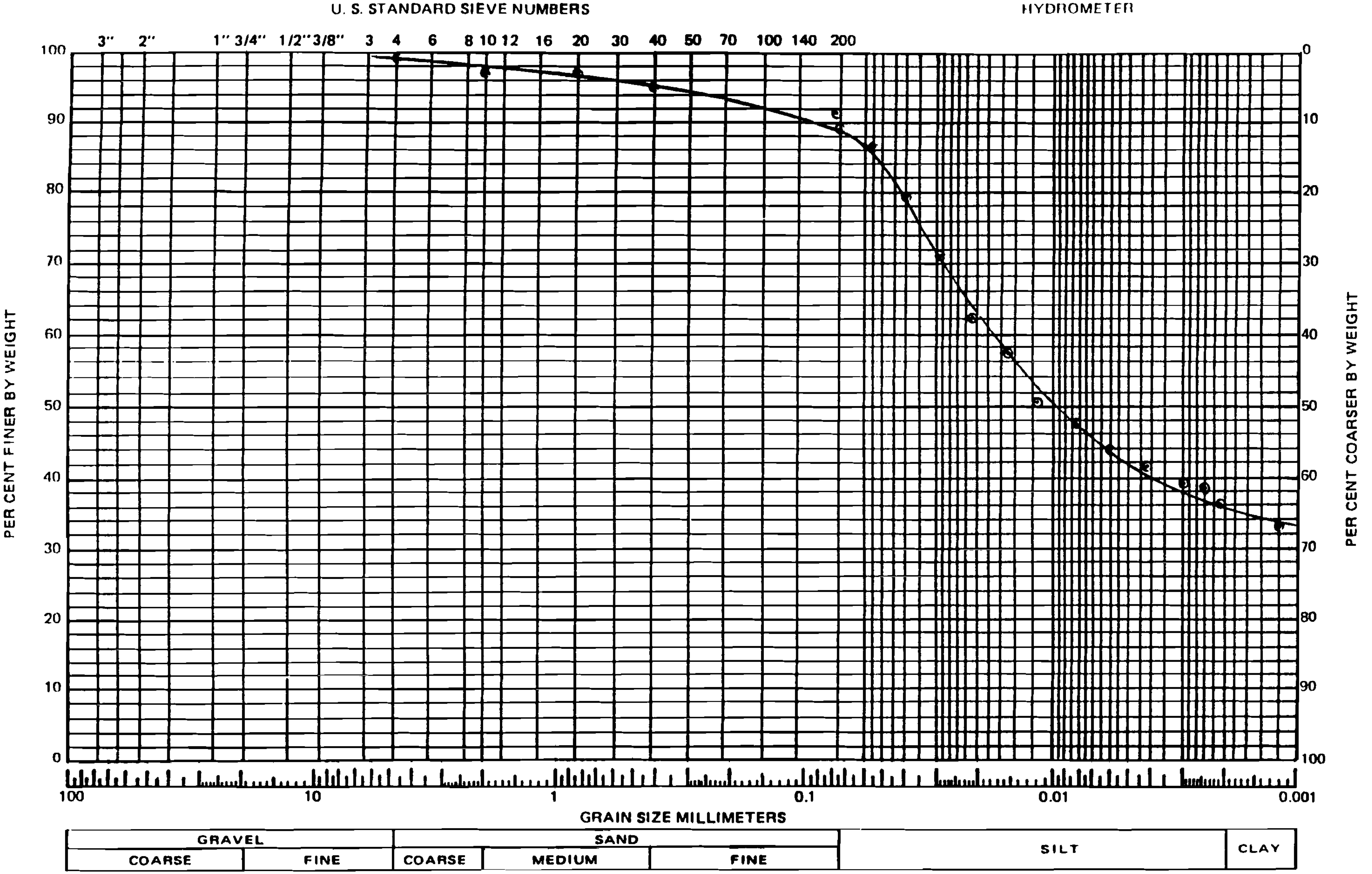
PROJECT: NCRA

IDENTIFICATION: B-3 6-15

STEWART WHITE AND ASSOCIATED INC

Fig 9

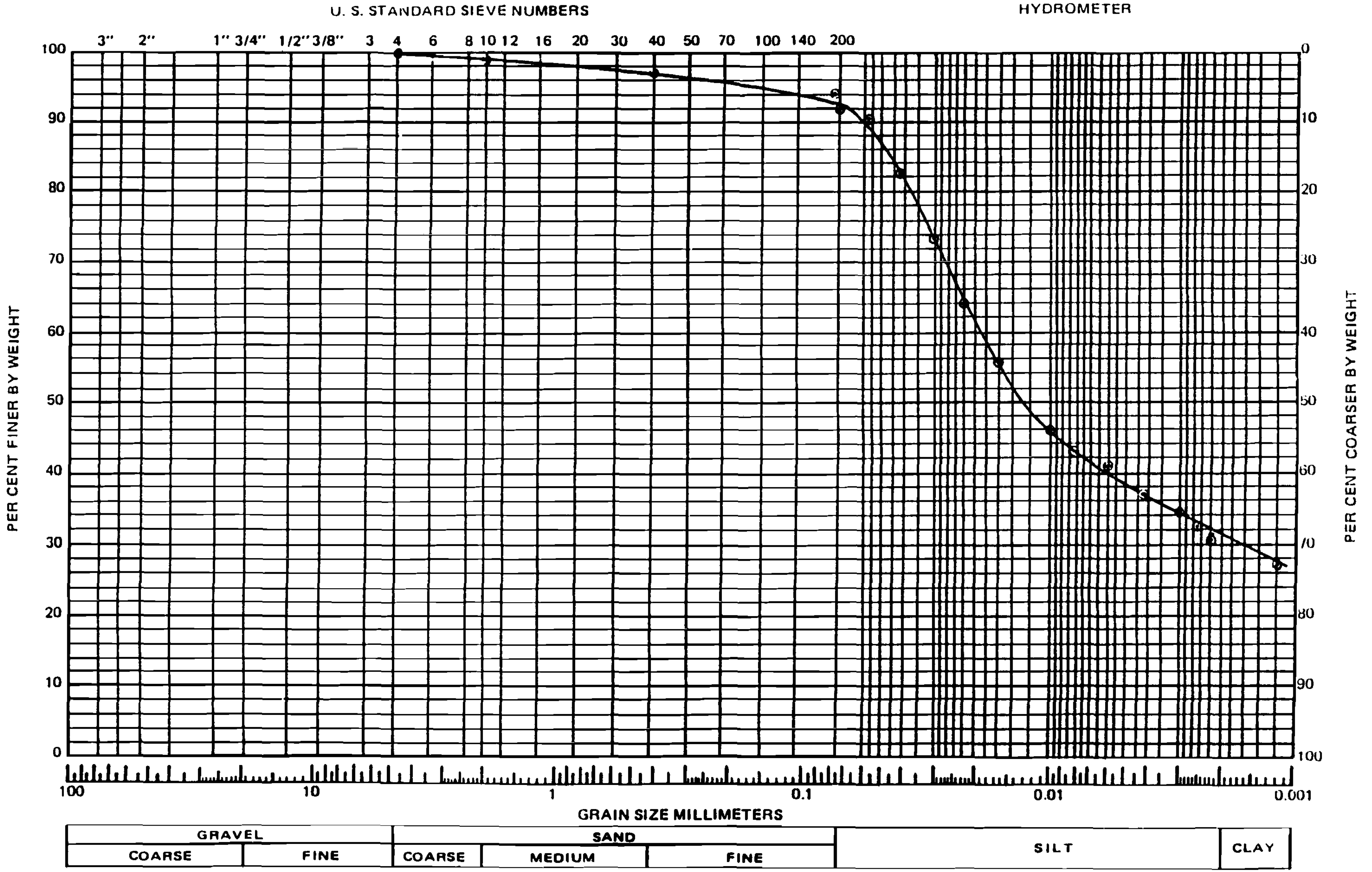
GRAIN SIZE DISTRIBUTION DIAGRAM



PROJECT: NCRA

IDENTIFICATION: A 5-6

GRAIN SIZE DISTRIBUTION DIAGRAM

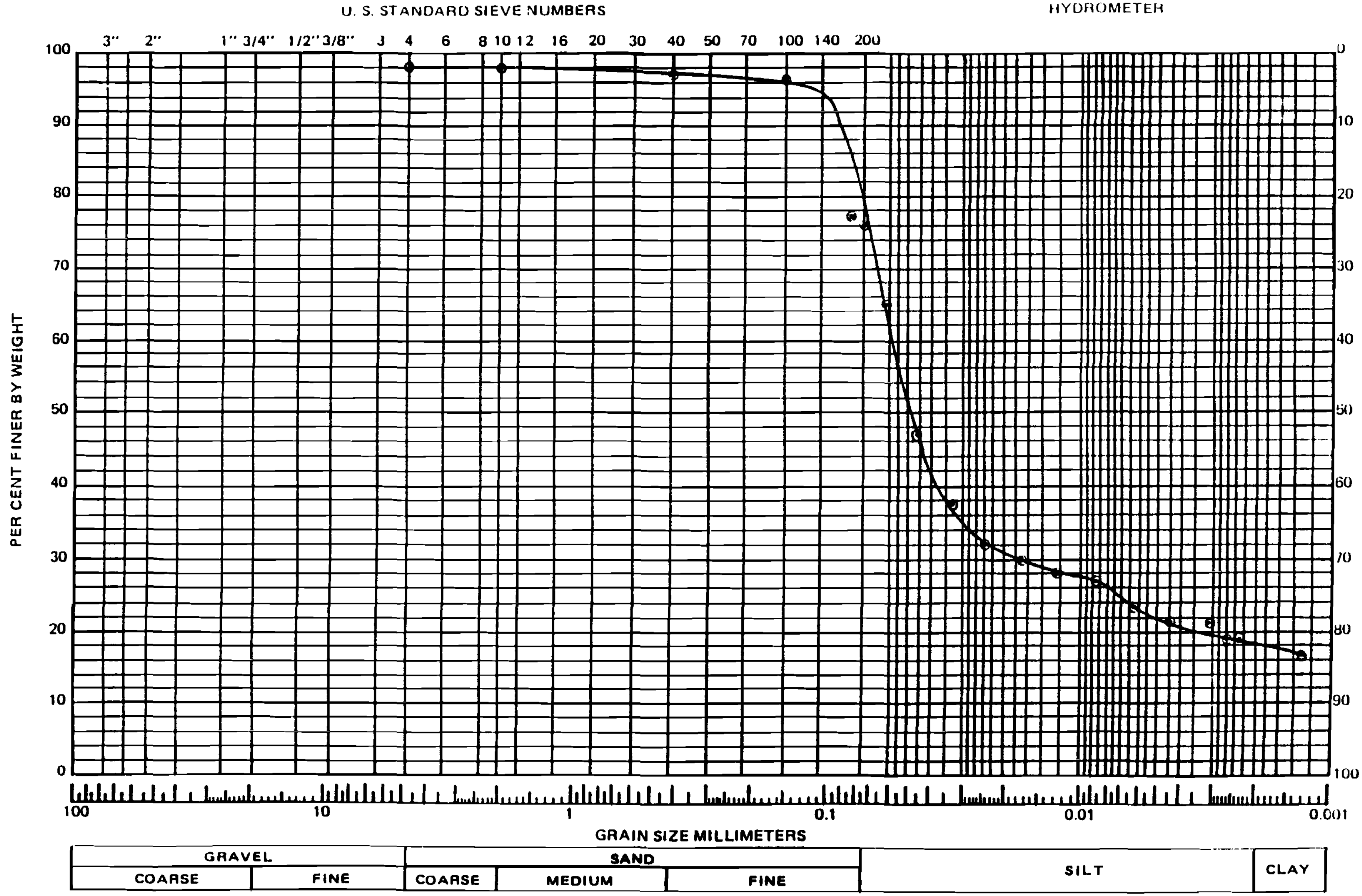


PROJECT: NCRA

IDENTIFICATION: B 3-5

STEWART, WHITE AND ASSOCIATED, INC.

GRAIN SIZE DISTRIBUTION DIAGRAM



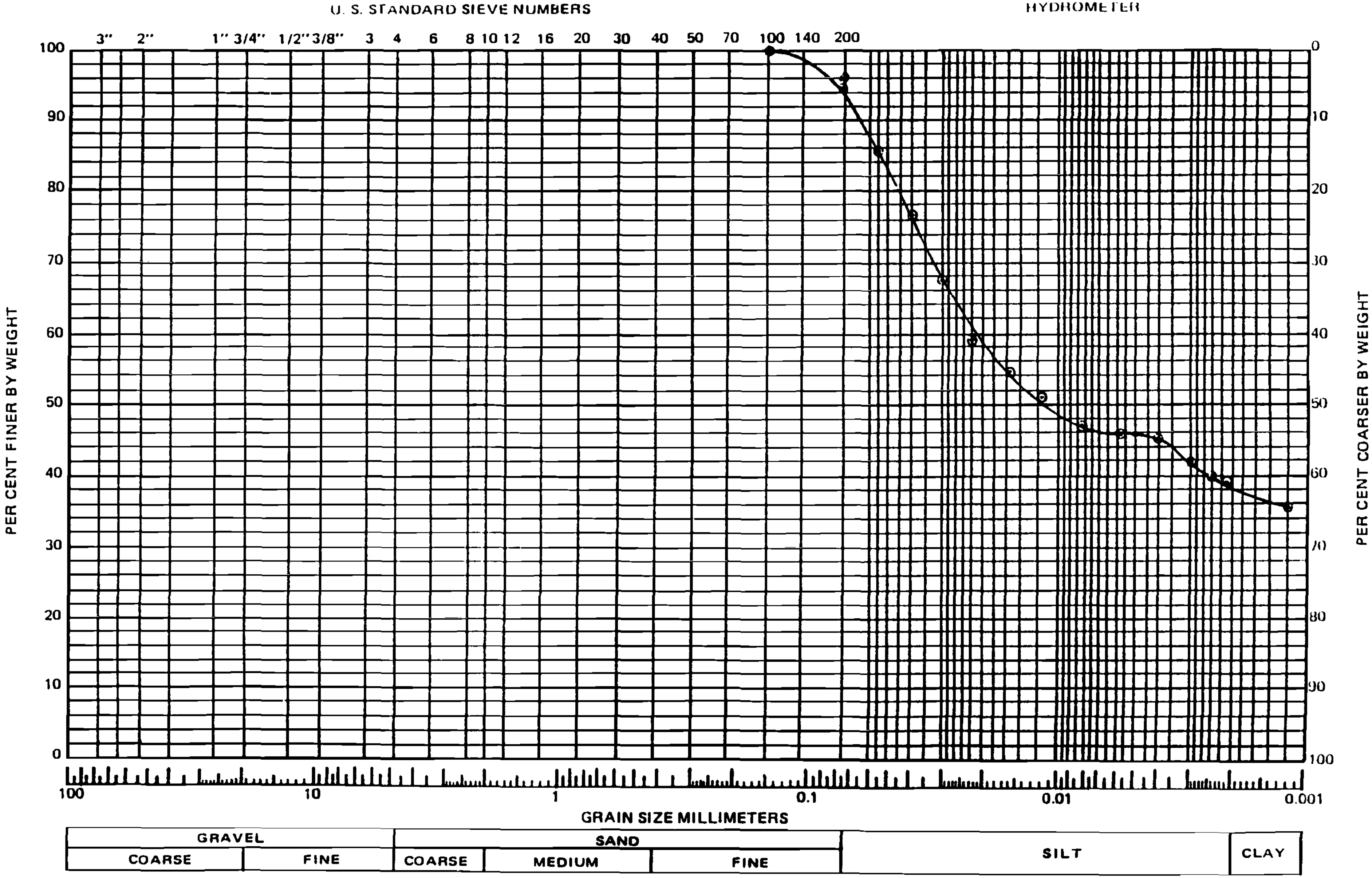
PROJECT: NCRA

IDENTIFICATION: W-1 25'-31.5'

STEWART, WHITE AND ASSOCIATED, INC.

Fig 8

GRAIN SIZE DISTRIBUTION DIAGRAM



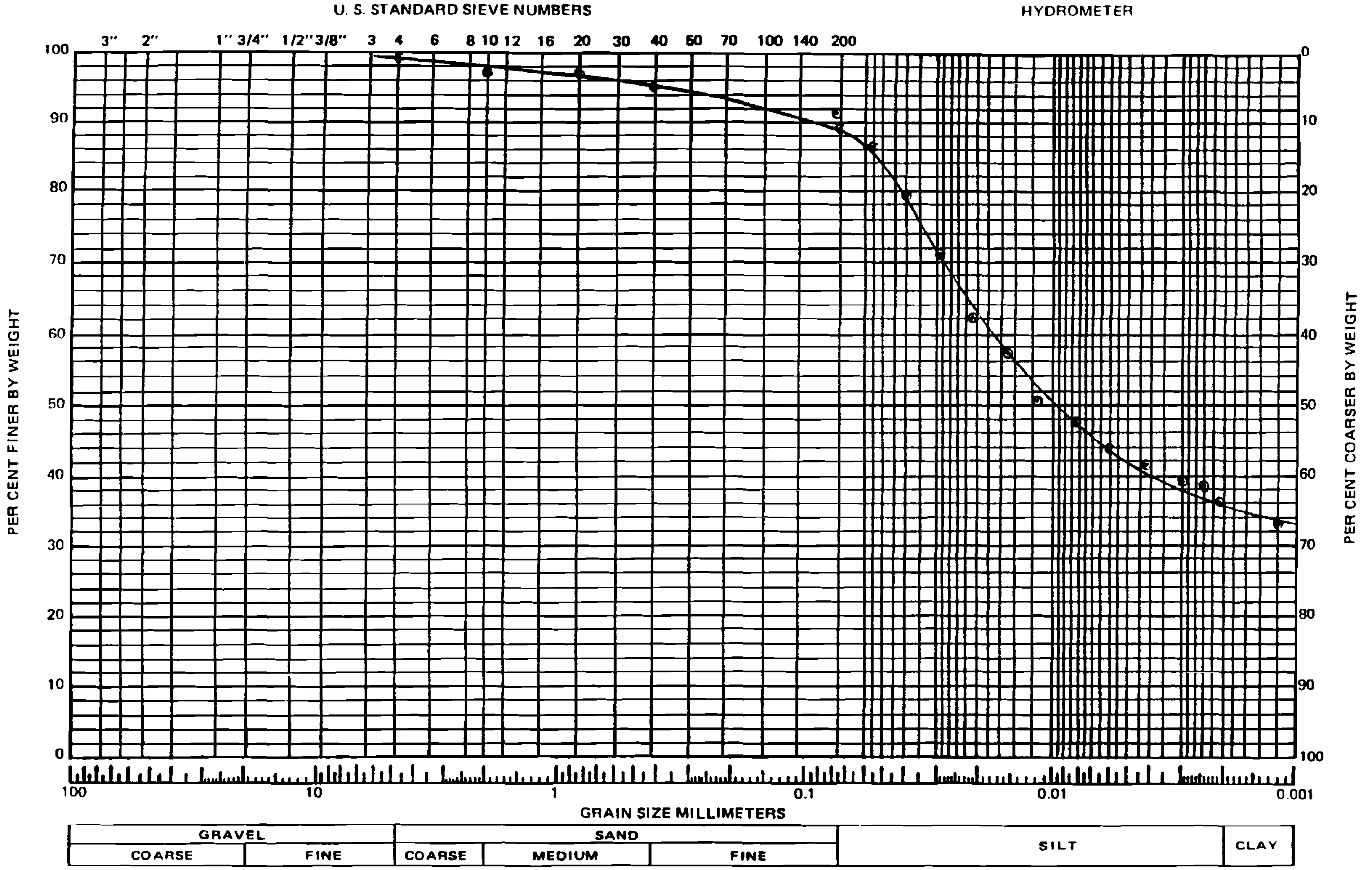
PROJECT: NCRA

IDENTIFICATION: B-3 6-15

Fig 9

STEWART, WHITE AND ASSOCIATED, INC.

GRAIN SIZE DISTRIBUTION DIAGRAM



PROJECT: NCRA

IDENTIFICATION: A 5-6

Fig

Appendix 2

Water Well Pumping Data

Appendix 2

Data Used to Determine the Average Pumping Rate for the Four Water Supply Wells

Date	WW3	WW8	WW9	WW10
30-Apr-98	400	710	680	409
01-May-98	400	790	670	235
02-May-98	396	800	750	303
03-May-98	399	749	725	305
04-May-98	405	745	770	344
05-May-98	402	734	780	456
06-May-98	399	741	780	452
07-May-98	427	770	790	322
08-May-98	398	760	795	216
09-May-98	400	750	800	208
10-May-98	404	675	840	294
11-May-98	395	640	780	345
12-May-98	40	665	800	440
13-May-98	400	670	590	305
14-May-98	420	672	630	353
15-May-98	420	670	700	220
16-May-98	400	680	700	190
17-May-98	403	690	725	151
18-May-98	350	687	620	175
19-May-98	420	628	710	200
20-May-98	400	710	760	345
21-May-98	410	704	800	436
22-May-98	397	660	790	441
23-May-98	401	706	790	468
24-May-98	394	706	795	398
25-May-98	401	690	860	217
26-May-98	400	688	890	263
27-May-98	400	688	725	179
28-May-98	405	689	900	353
29-May-98	399	720	800	452
30-May-98	405	575	760	348
31-May-98	403	707	860	440
01-Jun-98	399	700	850	452
02-Jun-98	400	689	850	478
03-Jun-98	398	698	900	474
04-Jun-98	400	700	890	475
05-Jun-98	403	718	880	269
06-Jun-98	410	700	910	455
07-Jun-98	392	728	850	449
08-Jun-98	340	707	840	468
09-Jun-98	400	710	870	466
10-Jun-98	420	705	820	226
11-Jun-98	398	701	840	460
12-Jun-98	375	707	840	460
13-Jun-98	400	705	850	341
14-Jun-98	400	740	850	455
15-Jun-98	408	745	850	309
16-Jun-98	410	715	850	452
17-Jun-98	412	708	825	441

18-Jun-98	395	722	900	457
19-Jun-98	400	745	830	453
20-Jun-98	397	720	860	452
21-Jun-98	385	727	850	450
22-Jun-98	392	701	800	447
23-Jun-98	397	717	860	446
24-Jun-98	402	737	860	449
25-Jun-98	400	711	850	442
26-Jun-98	395	709	970	447
27-Jun-98	391	744	850	456
28-Jun-98	388	743	850	465
29-Jun-98	400	705	850	419
30-Jun-98	398	718	830	455
01-Jul-98	417	762	800	435
02-Jul-98	391	698	820	449
03-Jul-98	412	805	700	470
04-Jul-98	406	810	825	410
05-Jul-98	395	736	825	420
06-Jul-98	395	743	825	423
07-Jul-98	425	812	820	478
08-Jul-98	380	700	880	410
09-Jul-98	412	720	825	480
09-Jul-98	412	720	825	480
10-Jul-98	400	720	800	430
11-Jul-98	400	760	875	440
12-Jul-98	422	721	850	385
13-Jul-98	420	711	825	190
14-Jul-98	394	736	850	385
15-Jul-98	380	765	875	420
16-Jul-98	413	740	825	412
17-Jul-98	423	718	800	484
18-Jul-98	405	747	875	439
19-Jul-98	390	677	800	437
20-Jul-98	405	774	925	483
21-Jul-98	400	735	860	464
22-Jul-98	400	637	810	440
23-Jul-98	401	729	800	450
24-Jul-98	420	802	750	361
25-Jul-98	420	713	825	425
26-Jul-98	400	695	750	404
27-Jul-98	400	730	900	390
28-Jul-98	406	596	740	303
29-Jul-98	392	688	810	419
30-Jul-98	400	785	750	340
31-Jul-98	395	767	870	430
01-Aug-98	400	675	780	400
02-Aug-98	410	660	820	391
03-Aug-98	409	619	770	426
04-Aug-98	389	677	850	505
05-Aug-98	419	680	800	480
06-Aug-98	396	688	850	440
07-Aug-98	400	700	760	198

07-Aug-98	395	660	850	400
08-Aug-98	410	754	880	406
10-Aug-98	410	732	870	419
11-Aug-98	398	712	870	463
12-Aug-98	399	688	880	438
13-Aug-98	390	748	750	480
14-Aug-98	397	715	900	430
15-Aug-98	410	746	900	210
16-Aug-98	395	700	900	408
17-Aug-98	395	645	810	403
18-Aug-98	405	758	900	425
19-Aug-98	391	648	800	451
20-Aug-98	407	685	900	460
21-Aug-98	407	730	880	430
22-Aug-98	411	721	760	415
23-Aug-98	400	668	835	416
23-Aug-98	422	740	890	360
25-Aug-98	411	670	745	415
26-Aug-98	402	682	890	428
27-Aug-98	395	695	900	417
28-Aug-98	400	700	900	200
29-Aug-98	300	675	900	200
30-Aug-98	400	670	750	422
31-Aug-98	400	660	800	415
01-Sep-98	406	650	600	391
02-Sep-98	412	673	725	406
03-Sep-98	320	683	800	195
04-Sep-98	413	796	900	431
05-Sep-98	408	682	770	412
06-Sep-98	407	693	900	426
07-Sep-98	389	718	775	437
10-Sep-98	391	666	675	420
11-Sep-98	399	691	600	390
12-Sep-98	404	700	870	422
12-Sep-98	390	667	710	422
13-Sep-98	420	665	810	404
13-Sep-98	400	682	800	416
14-Sep-98	400	730	890	410
15-Sep-98	400	630	600	450
16-Sep-98	392	773	900	374
17-Sep-98	405	685	860	416
18-Sep-98	410	690	810	401
19-Sep-98	404	704	810	418
20-Sep-98	400	718	900	441
21-Sep-98	405	760	890	420
22-Sep-98	400	730	890	440
23-Sep-98	400	670	890	400
24-Sep-98	400	680	850	390
25-Sep-98	400	720	890	440
26-Sep-98	410	747	900	420
27-Sep-98	415	753	900	427
28-Sep-98	402	679	900	410

29-Sep-98	400	680	790	480
30-Sep-98	408	638	900	444
30-Sep-98	408	638	900	444
01-Oct-98	400	623	900	439
02-Oct-98	391	619	890	446
03-Oct-98	380	640	890	390
04-Oct-98	368	595	480	380
05-Oct-98	370	668	890	420
06-Oct-98	370	735	890	300
07-Oct-98	370	610	790	415
08-Oct-98	380	730	900	240
09-Oct-98	383	570	600	293
10-Oct-98	381	628	700	397
11-Oct-98	395	620	900	460
12-Oct-98	376	610	900	444
13-Oct-98	398	670	900	450
14-Oct-98	368	620	900	432
15-Oct-98	360	664	895	418
16-Oct-98	365	630	895	410
17-Oct-98	365	694	895	415
18-Oct-98	350	684	890	293
19-Oct-98	357	602	800	294
20-Oct-98	354	575	895	350
21-Oct-98	364	714	900	437
22-Oct-98	362	641	670	376
23-Oct-98	360	673	890	400
24-Oct-98	355	612	660	412
25-Oct-98	347	642	850	406
26-Oct-98	352	618	800	254
27-Oct-98	360	640	775	315
28-Oct-98	350	645	870	421
29-Oct-98	338	631	770	398
30-Oct-98	346	635	720	400
31-Oct-98	350	618	775	430
01-Nov-98	355	656	720	395
02-Nov-98	350	620	620	390
03-Nov-98	348	665	880	208
04-Nov-98	355	675	810	312
05-Nov-98	356	695	900	312
06-Nov-98	350	675	900	353
07-Nov-98	350	641	890	350
08-Nov-98	330	670	890	260
09-Nov-98	340	650	890	230
10-Nov-98	350	650	700	300
11-Nov-98	350	620	720	340
12-Nov-98	330	700	890	190
13-Nov-98	340	620	610	310
14-Nov-98	340	748	900	310
15-Nov-98	346	672	900	300
16-Nov-98	363	667	900	429
17-Nov-98	382	627	690	383
18-Nov-98	351	643	890	307

19-Nov-98	355	650	900	400
20-Nov-98	349	620	620	390
21-Nov-98	340	643	605	304
22-Nov-98	342	707	890	305
23-Nov-98	350	673	890	309
24-Nov-98	338	633	900	400
25-Nov-98	355	636	825	320
26-Nov-98	356	657	640	250
27-Nov-98	356	661	900	290
28-Nov-98	349	648	720	357
29-Nov-98	360	656	720	366
30-Nov-98	347	716	900	292
01-Dec-98	351	660	780	291
02-Dec-98	347	542	425	282
03-Dec-98	352	730	890	300
04-Dec-98	350	675	640	337
05-Dec-98	354	630	725	250
06-Dec-98	368	630	575	248
07-Dec-98	357	660	775	250
08-Dec-98	340	627	825	250
08-Dec-98	330	656	825	244
10-Dec-98	350	730	780	135
11-Dec-98	357	586	700	258
12-Dec-98	352	604	700	291
13-Dec-98	360	601	700	292
14-Dec-98	351	715	750	213
15-Dec-98	359	727	770	200
16-Dec-98	347	620	680	237
17-Dec-98	351	667	710	170
18-Dec-98	360	610	640	300
19-Dec-98	350	730	850	350
20-Dec-98	350	650	890	300
21-Dec-98	340	700	800	250
22-Dec-98	332	642	680	197
23-Dec-98	346	669	710	193
24-Dec-98	349	685	900	193
25-Dec-98	347	627	690	342
26-Dec-98	345	744	900	409
27-Dec-98	349	685	895	445
28-Dec-98	358	735	895	400
29-Dec-98	350	693	745	350
30-Dec-98	360	725	895	375
31-Dec-98	356	665	865	400
01-Jan-99	325	615	440	400
02-Jan-99	352	650	870	354
03-Jan-99	320	670	620	404
04-Jan-99	313	702	650	299
05-Jan-99	328	640	675	194
06-Jan-99	349	733	895	194
07-Jan-99	348	740	895	415
08-Jan-99	340	663	890	184
09-Jan-99	350	646	750	287

10-Jan-99	320	690	890	260
11-Jan-99	370	660	900	370
12-Jan-99	377	768	900	340
13-Jan-99	380	725	268	440
14-Jan-99	340	740	900	392
15-Jan-99	360	718	900	246
16-Jan-99	400	661	825	321
17-Jan-99	370	700	900	389
18-Jan-99	329	700	900	390
19-Jan-99	390	670	900	375
20-Jan-99	356	700	270	314
21-Jan-99	350	650	195	350
22-Jan-99	350	690	686	750
23-Jan-99	353	665	600	337
24-Jan-99	360	605	900	200
25-Jan-99	351	628	750	345
26-Jan-99	350	578	720	341
27-Jan-99	340	610	790	341
28-Jan-99	358	639	900	339
29-Jan-99	348	604	725	342
30-Jan-99	342	621	750	243
31-Jan-99	337	594	650	235
01-Feb-99	338	671	900	243
02-Feb-99	350	590	875	250
03-Feb-99	340	582	890	295
04-Feb-99	348	607	890	350
05-Feb-99	340	630	730	350
06-Feb-99	350	650	890	360
07-Feb-99	365	679	880	371
07-Feb-99	345	660	890	370
08-Feb-99	360	620	790	350
09-Feb-99	345	627	825	361
10-Feb-99	357	638	675	344
11-Feb-99	348	700	900	420
12-Feb-99	344	654	810	386
13-Feb-99	430	664	900	356
14-Feb-99	400	660	900	378
15-Feb-99	400	665	900	379
16-Feb-99	352	700	900	402
17-Feb-99	350	700	900	365
18-Feb-99	365	656	800	368
19-Feb-99	375	700	900	391
20-Feb-99	350	700	900	290
21-Feb-99	430	674	900	370
22-Feb-99	416	687	900	363
23-Feb-99	401	648	900	370
24-Feb-99	370	609	750	347
25-Feb-99	400	680	890	365
26-Feb-99	374	633	500	355
27-Feb-99	365	693	930	370
28-Feb-99	360	684	890	356
01-Mar-99	350	644	870	350

01-Mar-99	351	665	900	392
03-Mar-99	390	660	860	360
04-Mar-99	343	610	800	295
05-Mar-99	375	682	870	366
06-Mar-99	316	694	870	395
08-Mar-99	400	696	900	375
09-Mar-99	368	650	910	377
10-Mar-99	395	625	875	368
11-Mar-99	362	662	910	280
12-Mar-99	400	665	890	330
13-Mar-99	360	664	840	346
14-Mar-99	348	670	625	228
15-Mar-99	360	588	725	290
16-Mar-99	346	615	770	262
17-Mar-99	350	666	825	357
18-Mar-99	350	610	780	301
19-Mar-99	376	588	760	264
20-Mar-99	358	568	755	300
21-Mar-99	345	574	825	295
22-Mar-99	324	557	800	253
23-Mar-99	349	658	850	352
24-Mar-99	354	636	870	273
25-Mar-99	333	575	700	266
26-Mar-99	358	700	910	322
27-Mar-99	365	630	800	293
28-Mar-99	345	661	900	346
29-Mar-99	350	680	900	344
30-Mar-99	340	638	620	287
31-Mar-99	372	705	890	329

Appendix 3

Water Well Data

ater Level Elevations

			3 15 99						4 15 99						5 15 99						6 15 99				
D		TOC Elevations	DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	DTP	MSL DTP	DTW	MSL DTW	Corrected DTW
E		1489 32																							
V	1	1494 63																							
V	2A	1495 2																							
V	3	1494 24																							
V	5	1495																							
V	5D	1494 4																							
V	5S	1494 3																							
V	6	1493 64																							
V	7	1494																							
V	8	1493 56		1493 56		1493 56		1493 56				1493 56		1493 56		1493 56		1493 56		1493 56		1493 56		1493 56	
V	9	1494 28																							
V	10 ZL4A	1494 84																							
V	11	1498 8																							
	101	1490 05																							
	102	1486 77																							
	103	1485 52																							
	104	1484 62																							
	111D	1499 19																							
	1	1492 86																							
	2S	1494 83																							
	3	1493 32																							
	4	1492 31																							
	5	1491 15	79 50	1411 65	81 60	1409 55	81 34	1409 81	79 75	1411 40	81 86	1409 29	81 60	1409 55	79 40	1411 75	81 42	1409 73	81 17	1409 98	79 30	1411 85	81 33	1409 82	81 08
	6	1494 71	90 90	1403 81	93 90	1400 81	93 53	1401 19	90 90	1403 81	93 74	1400 97	93 39	1401 33	90 70	1404 01	93 90	1400 81	93 50	1401 21	91 90	1402 81	93 92	1400 79	93 67
	7	1490 77	84 60	1406 17	85 10	1405 67	85 04	1405 73	84 56	1406 21	85 10	1405 67	85 03	1405 74	84 33	1406 44	84 55	1406 22	84 52	1406 25	84 30	1406 47	84 50	1406 27	84 48
	8	1501 04	99 36	1401 68	99 80	1401 24	99 75	1401 30	98 70	1402 34	98 71	1402 33	98 71	1402 33	99 10	1401 94	99 90	1401 14	99 80	1401 24	99 46	1401 58	100 50	1400 54	100 37
	9	1492 84	90 52	1402 32	93 35	1399 49	92 99	1399 85	89 50	1403 34	91 30	1401 54	91 08	1401 77	90 57	1402 27	93 90	1398 94	93 48	1399 36	90 90	1401 94	94 25	1398 59	93 83
	10	1486 68																							
	10D	1487 51																							
	10S	1487 24																							
	11S	1490 36	84 67	1405 69	85 40	1404 96	85 31	1405 05	84 97	1405 39	85 40	1404 96	85 35	1405 01	84 90	1405 46	85 20	1405 16	85 16	1405 20	84 75	1405 61	85 18	1405 18	85 13
	11D	1491 64																							
	12	1484 56																							
	13	1485 6	76 95	1408 65	77 83	1407 77	77 72	1407 88	77 10	1408 50	77 97	1407 63	77 86	1407 74	77 00	1408 60	77 65	1407 95	77 57	1408 03	76 94	1408 66	77 45	1408 15	77 39
	14	1490 81	84 62	1406 19	84 62	1406 19	84 62	1406 19	84 40	1406 41	84 40	1406 41	84 40	1406 41	84 23	1406 58	84 23	1406 58	84 23	1406 58	84 44	1406 37	84 44	1406 37	84 44
	15	1488 39	80 42	1407 97	80 42	1407 97	80 42	1407 97	80 60	1407 79	80 60	1407 79	80 60	1407 79	80 30	1408 09	80 30	1408 09	80 30	1408 09	80 16	1408 23	80 16	1408 23	80 16
	16	1491 86	85 70	1406 16	85 70	1406 16	85 70	1406 16	85 71	1406 15	85 71	1406 15	85 71	1406 15	85 50	1406 36	85 50	1406 36	85 50	1406 36	85 66	1406 20	85 66	1406 20	85 66
	17	1487 15																							
	18	1491 8	84 78	1407 02	84 78	1407 02	84 78	1407 02	84 80	1407 00	84 80	1407 00	84 80	1407 00	84 68	1407 12	84 68	1407 12	84 68	1407 12	84 70	1407 10	84 70	1407 10	84 70
	19	1486 46	In Use		In Use																				
	20D	1488 27	81 77	1406 50	82 45	1405 82	82 37	1405 91	81 90	1406 37	82 60	1405 67	82 51	1405 76	81 73	1406 54	82 70	1405 57	82 58	1405 69	81 65	1406 62	82 58	1405 69	82 46
	20S	1488 5																							
	21S	1489 95	83 60	1406 35	83 60	1406 35	83 60	1406 35	83 42	1406 53	83 45	1406 50	83 45	1406 50	83 30	1406 65	83 30	1406 65	83 30	1406 65	n/a		n/a		
	21D	1490 75																							
	22	1492 08	85 42	1406 66	85 42	1406 66	85 42	1406 66	85 47	1406 61	85 47	1406 61	85 47	1406 61	85 30	1406 78	85 30	1406 78	85 30	1406 78	85 26	1406 82	85 26	1406 82	85 26
	23	1491 49																							
	24	1487 47	77 98	1409 49	77 98	1409 49	77 98	1409 49	87 10	1400 37	87 10	1400 37	87 10	1400 37	77 90	1409 57	77 90	1409 57	77 90	1409 57	77 81	1409 66	77 81	1409 66	77 81
	25	1494 9							91 29	1403 61	91 30	1403 60	91 30	1403 60							91 81	1403 09	91 81	1403 09	91 81
	25S	1496 54																							
	26	1492 13	85 91	1406 22	88 02	1404 11	87 76	1404 37	84 94	1407 19	88 00	1404 13	87 62	1404 51	85 76	1406 37	88 00	1404 13	87 72	1404 41	85 80	1406 33	88 20	1403 93	87 90
	27	1493 81																							
	28	1491 23	82 58	1408 65	84 10	1407 13	83 91	1407 32	Flooded		Flooded				82 44	1408 79	83 95	1407 28	83 76	1407 47	82 38	1408 85	83 80	1407 43	83 62
	29	1490 82	83 78	1407 04	85 00	1405 82	84 85	1405 97	Flooded		Flooded				83 67	1407 15	84 60	1406 22	84 48	1406 34	83 65	1407 17	84 76	1406 06	84 62
	30	1493 21																							
	31	1495 14																							
	32	1494 87	92 74	1402 13	94 20	1400.67	94 02	1400 85	92 25	1402 62	93 44	1401 43	93 29	1401 58	92 10	1402 77	94 20	1400 67	93 94	1400 93	93 08	1401 79	95 05	1399 82	94 80
	33	1492 69	84 65	1408 04	87 31	1405 38	86 98	1405 71	84 75	1407 94	87 61	1405 08	87 25	1405 44	84 45	1408 24	87 50	1405 19	87 12	1405 57	84 30	1408 39	87 92	1404 77	87 47
	34	1493 43	89 24	1404 19	89.24	1404 19	89 24	1404 19	88 75	1404 68	88 76	1404 67	88 76	1404 67	89 95	1403 48	89 95	1403 48	89 95	1403 48	89 70	1403 73	89 70	1403 73	89 70
	35	1493 17	88 40	1404 77	89 00	1404 17	88 93	1404 25	88 30	1404 87	89 09	1404 08	88 99	1404 18	88 24	1404 93	89 03	1404 14	88 93	1404 24	88 26	1404 91	89 10	1404 07	89 00
	36	1494 41	89 70	1404 71	89 70	1404 71	89 70	1404 71	89 69	1404 72	89 69	1404 72	89 69	1404 72	Flooded		Flooded				89 70	1404 71	89 70	1404 71	89 70
	37	1493 81	88 02	1405 79	89 58	1404 23	89 39	1404 43	88 10	1405 71	89 30	1404 51	89 15	1404 66	Flooded		Flooded				88 29	1405 52	89 26	1404 55	89 14
	38	1494 09	91 10	1402 99	91 93	1402 16	91 83	1402 26	Flooded		Flooded				91 35	1402 74	91 35	1402 74	91 35	1402 74	91 40	1402 69	92 80	1401 29	92 63
	39	1493 84	88 00	1405 84	88 56	1405 28	88.49	1405 35	Flooded		Flooded				Flooded		Flooded				88 05	1405 79	88 80	1405 04	88 71
	40	1490 21	83 14	1407 07	83 53	1406 68	83 48	1406 73	Flooded		Flooded				83 00	1407 21	83 37	1406 84	83 32	1406 89	83 00	1407 21	83 55	1406 66	83 48
	41	1494 42	87 76	1406 66	87 76	1406 66	87 76	1406.66	87 82	1406 60	87 82	1406 60	87 82	1406 60	Flooded		Flooded				87 75	1406 67	87 75	1406 67	87 75
	42	1494 04	92 20	1401 84	93 20	1400 84	93 08	1400 97	Flooded		Flooded				Flooded		Flooded				Flooded		Flooded		
	43	1494 38	92 00	1402 38	92 90	1401 48	92 79	1401 59	91 15	1403 23	91 45	1402 93	91 41	1402 97	92 30	1402 08	92 54	1401 84	92 51	1401 87	92 41	1401 97	93 63	1400 75	93 48
	44	1491 7	83 66	1408 04	85 06	1406 64	84 89	1406 82	Flooded		Flooded				83 55	1408 15	84 90	1406 80	84 73	1406 97	83 47	1408 23	85 00	1406 70	84 81
	45	1491 34																							
	46	1488 81	Flooded		Flooded				Flooded		Flooded				Flooded		Flooded								
	47	1489 12	81 18	1407 94	82 63	1406 49	82 45	1406 67	81 13	1407 99	82 32	1406 80	82 17	1406 95	80 10	1409 02	81 15	1407 97	81 02	1408 10					
	48	1487 73	79 55	1408 18	80 47	1407 26	80 36	1407 38	Flooded		Flooded				Flooded		Flooded								
	49	1488 5																							
	50	1486 76	78 14	1408 62	79 70	1407 06	79 51	1407 26	78 36	1408 40	79 85	1406 91	79 66	1407 10	78 04	1408 72	79 40	1407 36	79 23	1407 53	77 93	1408 83	79 31	1407 45	79 14
	51	1492 05	84 33	1407 72	87 68	1404 37	87 26	1404 79	84 53	1407 52	87 50	1404 55	87 13	1404 92	84 25	1407 80	87 51	1404 54	87 10	1404 95	84 20	1407 85	87 70	1404 35	87 26
	52	1490 04	Flooded		Flooded				Flooded		Flooded				Flooded		Flooded				Flooded		Flooded		
	53	1489 06	83 80	1405 26	85 70	1403 36	85 46	1403 60	84 05		85 45				84 00		85 90				n/a		n/a		
	54	1491 74	84 75	1406 99	85 45	1406 29	85 36	1406 38	84 70	1407 04	85 47	1406 27	85 37	1406 37	84 55	1407 19	85 43	1406 31	85 32	1406 42	84 78	1406 96	85 45	1406 29	85 37
	55	1487 7	82 95	1404 75	83 35	1404 35	83 30	1404 40	83 95	1403 75	83 96	1403 74	83 96	1403 74	82 75	1404 95	83 35	1404 35	83 28	1404 43	83 01	1404 69	83 40	1404 30	83 35
	56	1492 04							89 54	1402 50	89 55	1402 49	89 55	1402 49							91 04	1401 00	91 05	1400 99	91 05
	57	1492 09	85 83	1406 26	87 60	1404 49	87 38	1404 71	86 03	1406 06	87 26	1404 83	87 11	1404 98	85 70	1406 39	87 40	1404 69	87 19	1404 90	85 75	1406 34	86 70	1405 39	86 58
	58	1494 32	90 64	1403 68	90 65	1403 67	90 65	1403 67	90 24	1404 08	90 24	1404 08	90 24	1404 08	90 68	1403 64	90 69	1403 63	90 69	1403 63	90 89	1403 43	90 90	1403 42	90 90
	59	1493 93	91 43	1402 50	93 30	1400 63	93 07	1400 86	91 30	1402 63	92 63	1401 30	92 46	1401 47	91 22	1402 71	93 42	1400 51	93 15	1400 79	91 56	1402 37	93 45	1400 48	93 21
	60	1494 02	90 64	1403 38	90 93	1403 09	90 89	1403 13	90 12	1403 90	90 12	1403 90	90 12	1403 90	90 70	1403 32	90 90	1403 12	90 88	1403 15	90 83	1403 19	91 04	1402 98	91 01
	61	1493 95																			92 30	1401 65	94 63	1399 32	94 34
	62	1495 16	93 75	1401 41	94 93	1400 23	94 78	1400 38	92 43	1402 73	92 80	1402 36	92 75	1402 41	92 70	1402 46	95 53	1399 63	95 18	1399 98	93 00	1402 16	96 31	1398 85	95 90
	63	1501 82	99 30	1402 52	99 83	1401 99	99 76	1402 06	98 89	1402 93	98 90	1402 92	98 90	1402 92	99 34	1402 48	99 86	1401 96	99 80	1402 03	99 71	1402 11	100 47	1401 35	100 38
	64	1494 82	92 68	1402 14	93 35	1401 47	93 27	1401 55	Flooded		Flooded				Flooded		Flooded				93 07	1401 75	94 65	1400 17	94 45
	65	1492 1	88 00	1404 10	90 80	1401 30	90 45	1401 65																	
	66	1490 48							83 29	1407 19	84 10	1406 38	84 00	1406 48	83 14	1407 34	83 88	1406 60	83 79	1406 69	83 10	1407 38	83 82	1406 66	83 73
	67S	1493 4																							
	67D	1496 74																							
	68	1493 79	In Use		In Use																				
	69																								
	105D	1485 16																							
	106D	1484 24																							
	107D	1481 78																							
	108D	1497 22																							
	108S	1497 31																							
	110D	1494 76																							
	111S	1499 53																							
2	2	1495 63	90 95	1404 68	100 20	1395 43	99 04	1396 59	89 98	1405 65	100 00	1395 63	98 75	1396 88	90 20	1405 43	100 45	1395 18	99 17	1396 46	90 33	1405 30	100 70	1394 93	99 40
	70	1485																							
	71	1485 48																							
	3	1494 91																							
	6	1494																							
	8	1494 6																							
	9	1490 69																							
	1	1486 46							78 88	1407 58	78 88	1407 58	78 88	1407 58											
	2	1495 92							92 32	1403 60	92 32	1403 60	92 32	1403 60											
	3	1487 25							80 71	1406 54	80 71	1406 54	80 71	1406 54											
	4	1494 6							84 38	1410 22	84 38	1410 22	84 38	1410 22											
	5	1491 62							83 42	1408 20	83 42	1408 20	83 42	1408 20											
	6	1494 06							88 83	1405 23	88 83	1405 23	88 83	1405 23											

	7/15/99						8/15/99						9/15/99						10/15/99						11/15/99
Corrected		MSL		MSL	Corrected	Corrected		MSL		MSL	Corrected	Corrected		MSL		MSL	Corrected	Corrected		MSL		MSL	Corrected	Corrected	
MSL DTW	DTP	DTP	DTW	DTW	DTW	MSL DTW	DTP	DTP	DTW	DTW	DTW	MSL DTW	DTP	DTP	DTW	DTW	DTW	MSL DTW	DTP	DTP	DTW	DTW	DTW	MSL DTW	DTP
1493.56		1493.56		1493.56		1493.56		1493.56		1493.56				1493.56		1493.56		1493.56		1493.56		1493.56		1493.56	
																									92.80
[illegible]	79.31	1411.84	81.26	1409.89	81.02	1410.13	79.37	1411.78	81.45	1409.70	81.19	1409.96	79.50	1411.65	81.68	1409.47	81.41	1409.74	79.22	1411.93	81.20	1409.95	80.95	1410.20	79.07
[illegible]	90.93	1403.78	94.14	1400.57	93.74	1400.97	91.00	1403.71	93.94	1400.77	93.57	1401.14	90.90	1403.81	94.30	1400.41	93.88	1400.84	90.50	1404.21	94.02	1400.69	93.58	1401.13	90.20
[illegible]	84.27	1406.50	84.48	1406.29	84.45	1406.32	84.43	1406.34	84.78	1405.99	84.74	1406.03	84.62	1406.15	84.82	1405.95	84.80	1405.98	84.45	1406.32	84.82	1405.95	84.77	1406.00	84.32
[illegible]	99.50	1401.54	100.13	1400.91	100.05	1400.99	99.22	1401.82	99.66	1401.38	99.61	1401.44	99.52	1401.52	101.55	1399.49	101.30	1399.74	99.20	1401.84	100.05	1400.99	99.94	1401.10	99.00
[illegible]	90.93	1401.91	94.00	1398.84	93.62	1399.22	91.00	1401.84	94.00	1398.84	93.63	1399.22	93.74	1399.10	93.74	1399.10	93.74	1399.10	90.77	1402.07	93.42	1399.42	93.09	1399.75	90.49
																									77.15
																									76.84
[illegible]	[illegible]	1405.53	85.20	1405.16	85.15	1405.21	84.63	1405.73	85.22	1405.14	85.15	1405.21	84.70	1405.66	84.93	1405.43	84.90	1405.46	84.28	1406.08	84.30	1406.06	84.30	1406.06	84.00
																									85.74
[illegible]	[illegible]	1408.70	77.24	1408.36	77.20	1408.40	76.80	1408.80	77.25	1408.35	77.19	1408.41	76.88	1408.72	77.34	1408.26	77.28	1408.32	76.65	1408.95	77.00	1408.60	76.96	1408.64	76.50
[illegible]	[illegible]	1406.03	84.78	1406.03	84.78	1406.03	85.65	1405.16	85.65	1405.16	85.65	1405.16	85.85	1404.96	85.85	1404.96	85.85	1404.96	84.27	1406.54	84.27	1406.54	84.27	1406.54	83.80
[illegible]	[illegible]	1408.24	80.15	1408.24	80.15	1408.24	80.20	1408.19	80.20	1408.19	80.20	1408.19	80.35	1408.04	80.35	1408.04	80.35	1408.04	80.12	1408.27	80.12	1408.27	80.12	1408.27	80.00
[illegible]	[illegible]	1406.14	85.72	1406.14	85.72	1406.14	86.00	1405.86	86.00	1405.86	86.00	1405.86	86.30	1405.56	86.30	1405.56	86.30	1405.56	85.59	1406.27	85.60	1406.26	85.60	1406.26	85.37
[illegible]	[illegible]	1407.11	84.69	1407.11	84.69	1407.11	84.82	1406.98	84.82	1406.98	84.82	1406.98	85.00	1406.80	85.00	1406.80	85.00	1406.80	84.67	1407.13	84.67	1407.13	84.67	1407.13	84.55
[illegible]	[illegible]	[illegible]	82.58	1405.69	82.46	1405.81	81.60	1406.67	82.95	1405.32	82.78	1405.49	81.70	1406.57	83.10	1405.17	82.93	1405.35	81.38	1406.89	82.15	1406.12	82.05	1406.22	81.17
																									81.37
[illegible]	[illegible]	[illegible]	83.20	1406.75	83.20	1406.75	83.20	1406.75	83.20	1406.75	83.20	1406.75	83.43	1406.52	83.43	1406.52	83.43	1406.52	83.30	1406.65	83.30	1406.65	83.30	1406.65	83.14
																									85.83
[illegible]	[illegible]	[illegible]	85.23	1406.85	85.23	1406.85	85.35	1406.73	85.35	1406.73	85.35	1406.73	85.50	1406.58	85.50	1406.58	85.50	1406.58	85.25	1406.83	85.25	1406.83	85.25	1406.83	85.20
[illegible]	[illegible]	[illegible]	78.90	1408.57	78.90	1408.57	86.75	1400.72	87.10	1400.37	87.06	1400.41	78.00	1409.47	78.15	1409.32	78.13	1409.34	77.80	1409.67	77.84	1409.63	77.84	1409.64	77.80
[illegible]	[illegible]	[illegible]	91.71	1403.19	91.71	1403.19	91.66	1403.24	91.66	1403.24	91.66	1403.24	91.86	1403.04	91.86	1403.04	91.86	1403.04							90.96
[illegible]	[illegible]	[illegible]	[illegible]	1403.63	88.24	1403.89	n/a		n/a				86.38	1405.75	90.33	1401.80	89.84	1402.29	85.53	1406.60	89.10	1403.03	88.65	1403.48	85.35
[illegible]	[illegible]	[illegible]	[illegible]	1407.46	83.37	1407.86	82.45	1408.78	84.05	1407.18	83.85	1407.38	82.58	1408.65	84.26	1406.97	84.05	1407.18	82.40	1408.83	83.80	1407.43	83.63	1407.61	82.34
[illegible]	[illegible]	[illegible]	[illegible]	1406.02	84.67	1406.16	83.90	1406.92	85.80	1405.02	85.56	1405.26	84.12	1406.70	86.20	1404.62	85.94	1404.88	83.74	1407.08	84.65	1406.17	84.54	1406.28	83.63
[illegible]	[illegible]	[illegible]	[illegible]	1399.77	94.88	1399.99	93.48	1401.39	94.70	1400.17	94.55	1400.32	93.13	1401.74	94.63	1400.24	94.44	1400.43	92.94	1401.93	94.42	1400.45	94.24	1400.64	92.73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.40	1405.29	Blocked		Blocked				84.78	1407.91	88.00	1404.69	87.60	1405.09	84.37	1408.32	87.48	1405.21	87.09	1405.60	84.23
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89.84	1403.59	89.79	1403.64	89.80	1403.63	89.80	1403.63	89.77	1403.66	89.77	1403.66	89.77	1403.66	89.52	1403.91	89.53	1403.90	89.53	1403.90	89.27
[illegible]	[illegible]	[illegible]	[illegible]	1403.91	89.15	1404.02	88.34	1404.83	89.20	1403.97	89.09	1404.08	88.30	1404.87	89.10	1404.07	89.00	1404.17	87.95	1405.22	88.40	1404.77	88.34	1404.83	87.72
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89.83	1404.58	89.81	1404.60	89.82	1404.59	89.82	1404.59	90.00	1404.41	90.00	1404.41	90.00	1404.41	89.70	1404.71	89.70	1404.71	89.70	1404.71	89.54
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89.24	1404.57	Flooded		Flooded				88.85	1404.96	89.75	1404.06	89.64	1404.17	88.16	1405.65	89.20	1404.61	89.07	1404.74	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92.49	1401.60	91.54	1402.55	92.80	1401.29	92.64	1401.45	91.83	1402.26	93.80	1400.29	93.55	1400.54	91.23	1402.86	92.30	1401.79	92.17	1401.92	91.03
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88.76	1405.08	88.25	1405.59	89.10	1404.74	88.99	1404.85	88.37	1405.47	89.28	1404.56	89.17	1404.67	87.98	1405.86	88.55	1405.29	88.48	1405.36	87.83
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.55	1406.66	Flooded		Flooded				Flooded		Flooded				83.10	1407.11	83.10	1407.11	83.10	1407.11	82.95
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.81	1406.61	87.90	1406.52	87.90	1406.52	87.90	1406.52	88.00	1406.42	88.00	1406.42	88.00	1406.42	87.69	1406.73	87.70	1406.72	87.70	1406.72	87.56
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94.66	1399.38	92.80	1401.24	94.58	1399.46	94.36	1399.68	92.86	1401.18	95.25	1398.79	94.95	1399.09	92.44	1401.60	94.17	1399.87	93.95	1400.09	92.13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93.63	1400.75	92.50	1401.88	94.00	1400.38	93.81	1400.57	93.55	1400.83	94.80	1399.58	94.64	1399.74	92.16	1402.22	93.25	1401.13	93.11	1401.27	91.90
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84.72	1406.98	Blocked		Blocked				Flooded		Flooded				83.50	1408.20	84.87	1406.83	84.70	1407.00	83.43
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.69	1405.13	Flooded		Flooded				Flooded		Flooded				81.44	1407.37	83.80	1405.01	83.51	1405.31	81.35
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.86	1407.26	81.05	1408.07	82.54	1406.58	82.35	1406.77	81.15	1407.97	82.80	1406.32	82.59	1406.53	81.00	1408.12	82.07	1407.05	81.94	1407.18	80.89
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79.92	1407.81	Flooded		Flooded				Flooded		Flooded				79.34	1408.39	80.10	1407.63	80.01	1407.73	79.25
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78.88	1407.88	77.95	1408.81	79.60	1407.16	79.39	1407.37	78.10	1408.66	79.81	1406.95	79.60	1407.16	77.90	1408.86	79.25	1407.51	79.08	1407.68	77.80
[illegible]	[illegible]	[illegible]	[illegible]				84.42	1407.63	88.13	1403.92	87.67	1404.38	84.63	1407.42	88.20	1403.85	87.75	1404.30	84.24	1407.81	87.45	1404.60	87.05	1405.00	84.15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.39	1408.65	Flooded		Flooded				Flooded		Flooded				81.39	1408.65	81.40	1408.64	81.40	1408.64	81.34
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85.57	1403.49	83.96	1405.10	86.25	1402.81	85.96	1403.10	84.15	1404.91	86.60	1402.46	86.29	1402.77	83.53	1405.53	85.66	1403.40	85.39	1403.67	83.20
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85.37	1406.37	n/a		n/a				85.80	1405.94	85.80	1405.94	85.80	1405.94	84.77	1406.97	85.80	1405.94	85.67	1406.07	84.60
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.56	1404.14	87.00	1400.70	87.16	1400.54	87.14	1400.56	84.56	1403.14	84.56	1403.14	84.56	1403.14	83.10	1404.60	83.10	1404.60	83.10	1404.60	82.80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91.04	1401.00	90.92	1401.12	90.93	1401.11	90.93	1401.11	91.93	1400.11	91.94	1400.10	91.94	1400.10							90.40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.47	1404.62	86.10	1405.99	88.40	1403.69	88.11	1403.98	86.37	1405.72	88.49	1403.60	88.23	1403.87	85.77	1406.32	87.22	1404.87	87.04	1405.05	85.60
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91.00	1403.32	91.25	1403.07	91.25	1403.07	91.25	1403.07	91.84	1402.48	91.84	1402.48	91.84	1402.48	90.73	1403.59	90.75	1403.57	90.75	1403.57	90.41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93.36	1400.57	91.46	1402.47	93.65	1400.28	93.38	1400.55	91.47	1402.46	94.30	1399.63	93.95	1399.98	91.25	1402.68	93.13	1400.80	92.90	1401.04	90.90
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91.27	1402.75	91.11	1402.91	91.26	1402.76	91.24	1402.78	91.82	1402.20	92.20	1401.82	92.15	1401.87	90.75	1403.27	91.10	1402.92	91.06	1402.96	90.33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94.32	1400.84	92.82	1402.34	93.70	1401.46	93.59	1401.57	92.90	1402.26	96.10	1399.06	95.70	1399.46	92.78	1402.38	95.00	1400.16	94.72	1400.44	92.16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100.07	1401.75	99.50	1402.32	99.70	1402.12	99.68	1402.15	99.78	1402.04	101.05	1400.77	100.89	1400.93	99.37	1402.45	99.87	1401.95	99.81	1402.01	99.25
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94.27	1400.55	Flooded		Flooded				Flooded		Flooded				92.89	1401.93	93.75	1401.07	93.64	1401.18	92.62
[illegible]	[illegible]	[illegible]	[illegible]				83.28	1407.20	84.33	1406.15	84.20	1406.28	83.44	1407.04	84.68	1405.80	84.53	1405.96	83.05	1407.43	83.98	1406.50	83.86	1406.62	82.97
																			91.80	91.80	93.12	-93.12	92.96	-92.96	91.49
[illegible]	[illegible]	[illegible]	100.74	1394.89	99.44	1396.19	90.30	1405.33	100.82	1394.81	99.51	1396.13	91.25	1404.38	101.75	1393.88	100.44	1395.19	90.18	1405.45	100.80	1394.83	99.47	1396.16	89.15
													80.70	1404.78	85.70	1399.78	85.08	1400.41							
																			79.11	1407.35	79.11	1407.35	79.11	1407.35	
																			92.17	1403.75	92.17	1403.75	92.17	1403.75	
																			86.70	1400.55	86.70	1400.55	86.70	1400.55	
																			80.85	1413.75	80.85	1413.75	80.85	1413.75	
																			84.29	1407.33	84.29	1407.33	84.29	1407.33	
																			83.27	1410.79	83.27	1410.79	83.27	1410.79	

DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	11 16 99 DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	11 17 99 DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	11 18 99 DTP	MSL DTP	DTW	MSL DTW	Corrected DTW	Corrected MSL DTW	12 15 99 DTP	MSL DTP	DTW	MSL DTW	Corrected DTW
	1493 56		1493 56																							
																83 29	1406 76	83 29	1406 76	83 29	1406 76					
																79 25	1407 52	79 25	1407 52	79 25	1407 52					
																77 76	1407 76	77 76	1407 76	77 76	1407 76					
										75 62	1409 00	75 62	1409 00	75 62	1409 00											
				98 49	1400 70	98 49	1400 70	98 49	1400 70																	
																						Pipe in Hole		Pipe in Hole		
92 80	1402 03	92 80	1402 03							93 08	1401 75	93 08	1401 75	93 08	1401 75											
																						Cement in Pipe		Cement in Pipe		
																						Pipe in Hole		Pipe in Hole		
81 00	1410 15	80 76	1410 39																			n a		n a		
93 88	1400 83	93 42	1401 29							90 08	1404 63	93 86	1400 85	93 39	1401 32							80 05	1414 66	81 16	1413 55	81 02
84 46	1406 31	84 44	1406 33																			84 20	1406 57	84 28	1406 49	84 27
99 50	1401 54	99 44	1401 60	99 00	1402 04	99 33	1401 71	99 29	1401 75													98 40	1402 64	98 76	1402 28	98 72
92 66	1400 18	92 39	1400 45																			89 97	1402 87	91 57	1401 27	91 37
																						Not There		Not There		
77 16	1410 35	77 16	1410 35	81 81	1405 70	81 81	1405 70	81 81	1405 70																	
76 84	1410 40	76 84	1410 40	80 69	1406 55	80 69	1406 55	80 69	1406 55																	
84 00	1406 36	84 00	1406 36	83 95	1406 41	83 97	1406 39	83 97	1406 39													83 90	1406 46	83 90	1406 46	83 90
85 74	1405 90	85 74	1405 90	85 75	1405 89	85 75	1405 89	85 75	1405 89																	
																						Not There		Not There		
76 65	1408 95	76 63	1408 97																			76 50	1409 10	76 55	1409 05	76 54
83 80	1407 01	83 80	1407 01							84 20	1406 61	84 21	1406 60	84 21	1406 60							83 60	1407 21	83 60	1407 21	83 60
80 00	1408 39	80 00	1408 39	80 00	1408 39	80 00	1408 39	80 00	1408 39													80 03	1408 36	80 03	1408 36	80 03
85 38	1406 48	85 38	1406 48							85 43	1406 43	85 45	1406 41	85 45	1406 41							85 26	1406 60	85 26	1406 60	85 26
																						Not There		Not There		
84 55	1407 25	84 55	1407 25							84 73	1407 07	84 74	1407 06	84 74	1407 06							84 45	1407 35	84 45	1407 35	84 45
																						In Use		In Use		
81 80	1406 47	81 72	1406 55	81 17	1407 10	81 70	1406 57	81 63	1406 64													81 10	1407 17	81 50	1406 77	81 45
81 37	1407 13	81 37	1407 13	81 38	1407 12	81 38	1407 12	81 38	1407 12																	
83 14	1406 81	83 14	1406 8'																			83 08	1406 87	83 08	1406 87	83 08
85 83	1404 92	85 83	1404 92	85 84	1404 91		1490 75	10 73	1480 02																	
85 20	1406 88	85 20	1406 88																			85 17	1406 91	85 '8	1406 90	85 18
																						Pipe in Well		Pipe in Well		
77 80	1409 67	77 80	1409 67							77 64	1409 83	77 87	1409 60	77 84	1409 63							77 90	1409 57	78 00	1409 47	77 99
90 96	1403 94	90 96	1403 94																			90 57	1404 33	90 57	1404 33	90 57
				92 48	1404 06	92 47	1404 07	92 47	1404 07																	
88 73	1403 40	88 31	1403 82							85 32	1406 81	88 90	1403 23	88 45	1403 68							84 00	1408 13	89 40	1402 73	88 73
																						Pump in Use		Pump in Use		
83 70	1407 53	83 53	1407 70																			83 33	1407 90	83 80	1407 43	83 74
84 21	1406 61	84 14	1406 68																			83 60	1407 22	84 00	1406 82	83 95
																						Not There		Not There		
																						Pipe in Hole		Pipe in Hole		
94 25	1400 62	94 06	1400 81																			92 17	1402 70	93 52	1401 35	93 35
87 51	1405 18	87 10	1405 59																			84 20	1408 49	87 60	1405 09	87 18
89 27	1404 16	89 27	1404 16	89 41	1404 02	89 41	1404 02	89 41	1404 02													88 95	1404 48	88 96	1404 47	88 96
88 97	1404 20	88 81	1404 36							87 62	1405 55	87 88	1405 29	87 85	1405 32							87 38	1405 79	87 61	1405 56	87 58
89 54	1404 87	89 54	1404 87																			89 44	1404 97	89 44	1404 97	89 44
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91 84	1402 25	91 74	1402 35							91 02	1403 07	91 86	1402 23	91 76	1402 34							90 80	1403 29	91 35	1402 74	91 28
88 32	1405 52	88 26	1405 58																			87 70	1406 14	88 00	1405 84	87 96
82 95	1407 26	82 95	1407 26																			82 90	1407 31	82 90	1407 31	82 90
87 57	1406 85	87 57	1406 85							87 58	1406 84	87 58	1406 84	87 58	1406 84							87 48	1406 94	87 49	1406 93	87 49
93 60	1400 44	93 42	1400 62																			Flooded		Flooded		
92 80	1401 58	92 69	1401 69							91 87	1402 51	92 81	1401 57	92 69	1401 69							91 64	1402 74	91 70	1402 68	91 69
84 70	1407 00	84 54	1407 16							83 30	1408 40	84 65	1407 05	84 48	1407 22							83 77	1407 93	84 45	1407 25	84 37
																						Blocked		Blocked		
83 33	1405 48	83 08	1405 73																			81 41	1407 40	82 64	1406 17	82 49
81 78	1407 34	81 67	1407 45							80 81	1408 31	91 75	1397 37	90 38	1398 74							80 78	1408 34	87 67	1401 45	86 81
79 90	1407 83	79 82	1407 91																			Flooded		Flooded		
																						In Use		In Use		
79 00	1407 76	78 85	1407 91							78 98	1407 78	78 98	1407 78	78 98	1407 78							77 90	1408 86	79 00	1407 76	78 86
87 15	1404 90	86 78	1405 28																			84 24	1407 81	86 60	1405 45	86 31
81 34	1408 70	81 34	1408 70																			Flooded		Flooded		
85 24	1403 82	84 99	1404 08																			83 03	1406 03	84 75	1404 31	84 54
85 57	1406 17	85 45	1406 29							84 51	1407 23	85 58	1406 16	85 45	1406 29							84 46	1407 28	85 45	1406 29	85 33
92 80	1394 90	91 55	1396 15																			82 54	1405 16	82 54	1405 16	82 54
90 40	1401 64	90 40	1401 64																			89 90	1402 14	89 90	1402 14	89 90
87 00	1405 09	86 83	1405 27																			85 56	1406 53	86 60	1405 49	86 47
90 43	1403 89	90 43	1403 89							90 42	1403 90	90 68	1403 64	90 65	1403 67							90 02	1404 30	90 03	1404 29	90 03
92 33	1401 60	92 15	1401 78							90 88	1403 05	92 36	1401 57	92 18	1401 76							90 20	1403 73	91 15	1402 78	91 03
90 63	1403 39	90 59	1403 43							90 40	1403 62	90 44	1403 58	90 44	1403 59							89 93	1404 09	89 93	1404 09	89 93
																						In Use		In Use		
94 14	1401 02	93 89	1401 27	92 69	1402 47	94 13	1401 03	93 95	1401 21													92 10	1403 06	92 88	1402 28	92 78
99 34	1402 48	99 33	1402 49	99 24	1402 58	99 40	1402 42	99 38	1402 44													98 64	1403 18	98 64	1403 18	98 64
93 26	1401 56	93 18	1401 64																			Flooded		Flooded		
																						In Use		In Use		
83 66	1406 82	83 57	1406 91																			82 95	1407 53	83 61	1406 87	83 53
																						In Use		In Use		
										94 66	1402 08	94 66	1402 08	94 66	1402 08											
																						In Use		In Use		
93 02	-93 02	92 83	-92 83																			9C 90	-90 90	92 30	-92 30	92 13
				74 75	1410 41	74 75	1410 41	74 75	1410 41																	
				73 50	1410 74	73 50	1410 74	73 50	1410 74																	
				70 77	1411 01	70 77	1411 01	70 77	1411 01																	
				91 29	1405 93	91 29	1405 93	91 29	1405 93																	
				91 49	1405 82	91 49	1405 82	91 49	1405 82																	
				81 94	1412 82	81 94	1412 82	81 94	1412 82																	
				97 22	1402 31	99 80	1399 73	99 48	1400 05																	
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				77 19	1407 81	77 19	1407 81	77 19	1407 81													76 84	1408 16	76 84	1408 16	76 94
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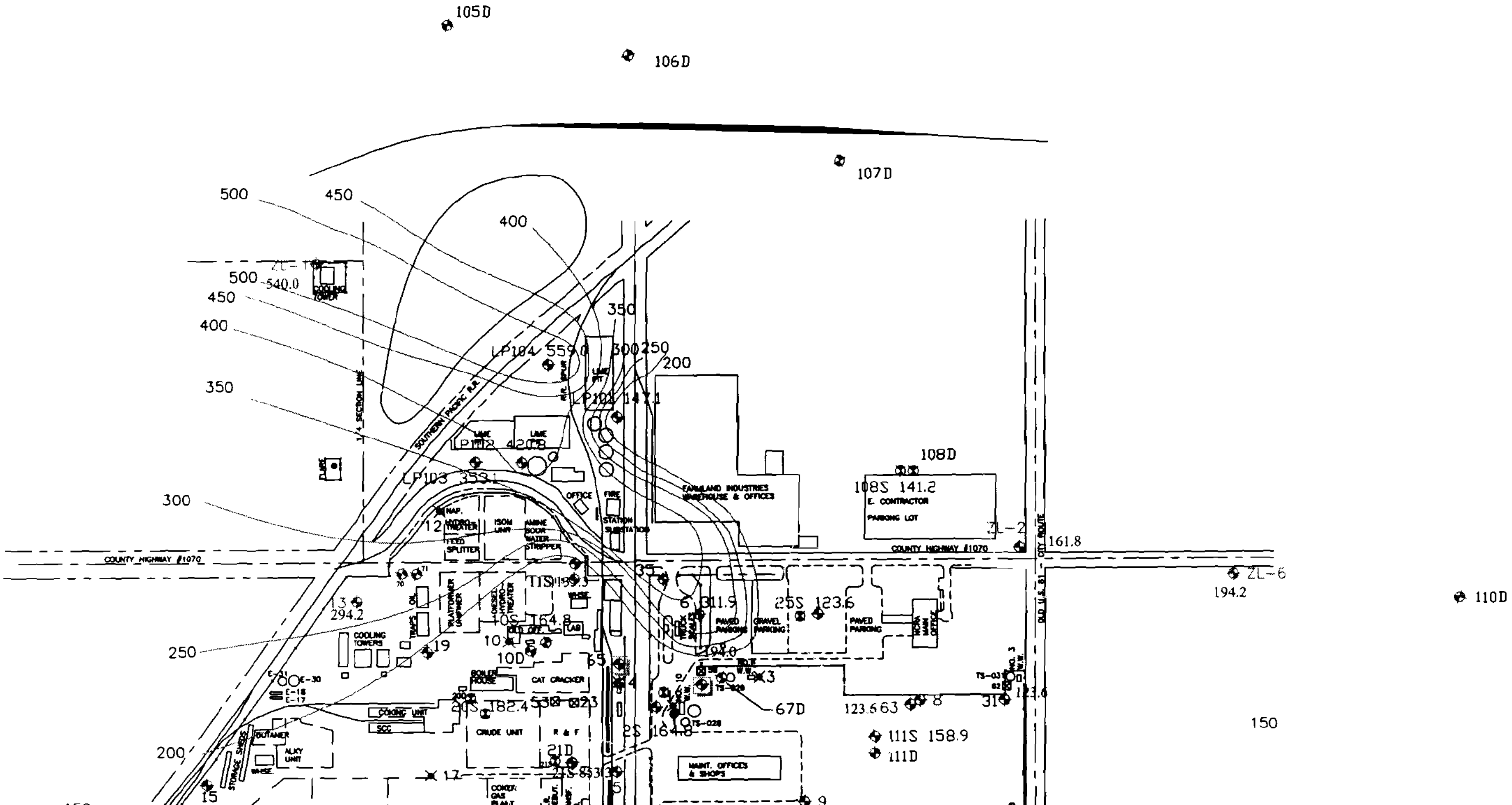
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107D
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108S 141.2
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COOLING TOWER
ZL-2
161.8
ZL-6
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LP101 147.1
LP102 420.8
LP103 353.1
SOUTHERN PACIFIC R.R.
R.R. SPUR
LIME PIT
LIME PIT
1/4 SECTION LINE
FLARE
FARMLAND INDUSTRIES WAREHOUSE & OFFICES
COUNTY HIGHWAY #1070
OLD U.S. 81 - CITY ROUTE
OFFICE
FIRE STATION
SUBSTATION
NAP. HYDRO-TREATER
FEED SPLITTER
ISOM UNIT
AMINE BOOR WATER STRIPPER
PLATFORMER UNIFINER
DIESEL HYDRO-TREATER
OLD OFF.
LAB
WHSE.
COOLING TOWERS
TRAPS
OIL
BOILER HOUSE
CAT CRACKER
COKING UNIT
SCC
CRUDE UNIT
R & F
BUTANER
ALKY UNIT
WHSE
STORAGE SHEDS
COKER GAS PLANT
PAVED PARKING
GRAVEL PARKING
PAVED PARKING
MAIN OFFICE
MAINT. OFFICES & SHOPS
12
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294.2
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10S 164.8
11S 139.3
20S 182.4
21D
2S 164.8
25S 123.6
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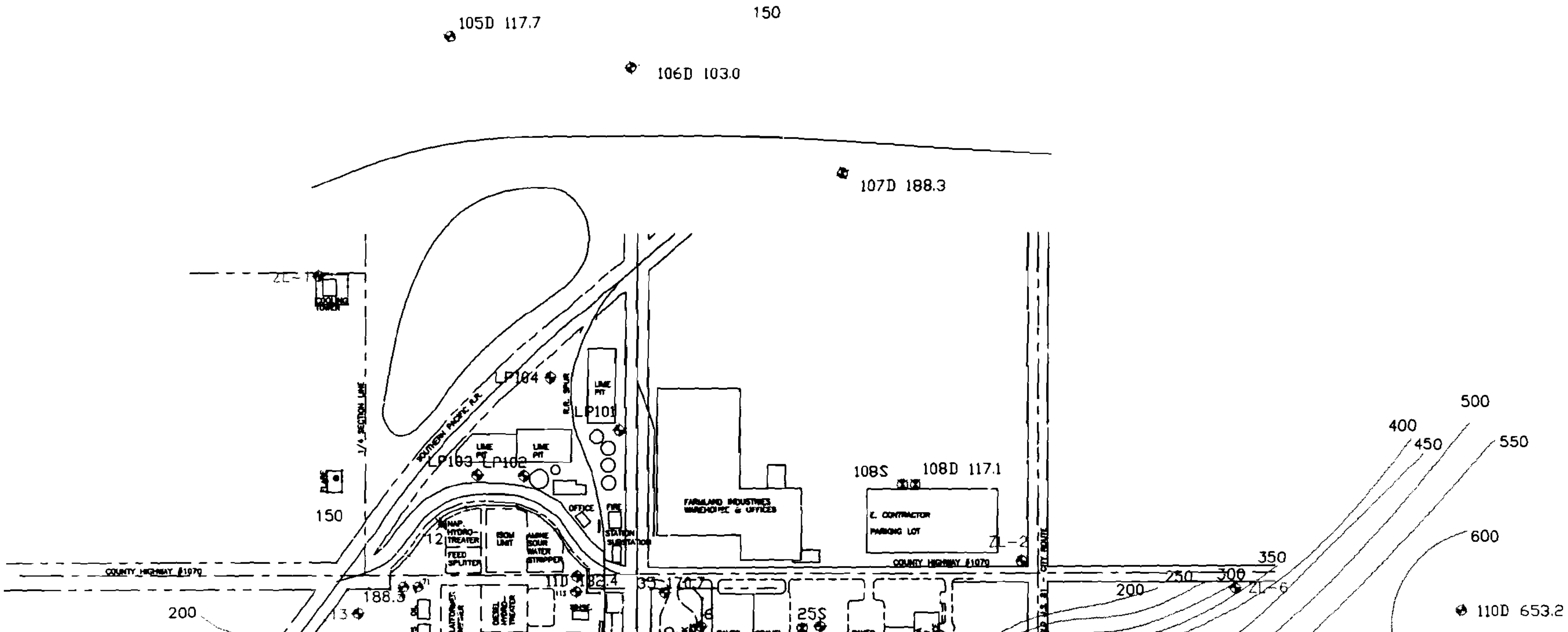
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1/4 SECTION LINE
FLARE
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SOUTHERN PACIFIC R.R.
LP104
R.R. SPUR
LIME PIT
LP101
LIME PIT
LIME PIT
LP103
LP102
OFFICE
FIRE
STATION
SUBSTATION
NAP. HYDRO-TREATER
12
FEED SPLITTER
ISOM UNIT
AMINE SOUR WATER STRIPPER
COUNTY HIGHWAY #1070
110
182.4
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DIESEL HYDRO-TREATER
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25S
FARMLAND INDUSTRIES WAREHOUSE & OFFICES
108S
108D 117.1
E. CONTRACTOR PARKING LOT
ZL-2
COUNTY HIGHWAY #1070
CITY ROUTE
U.S. 81
200
250
300
350
ZL-6
400
450
500
550
600
110D 653.2

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Date

Analysis of Chloride Plume Migration Based on
Aquifer Characteristics, Water Well Pumping Rate,
Soil, and Stratigraphic Properties
Title of Thesis/Research Project

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