GROUNDWATER MANGANESE STUDY OF THE STEVENS POINT AIRPORT WELLFIELD

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Submitted in partial fulfillment of the requirements of the degree

MASTER OF SCIENCE

IN

NATURAL RESOURCES (WATER CHEMISTRY)

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

June 2006

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ABSTRACT

The factors controlling manganese concentrations at two wells in the Stevens Point Airport Wellfield were examined in this study. One of the wells, Well 6, was a high capacity conventional well with high manganese concentrations (mean: 0.35 mg/L). The other well, Well 10, was a high capacity collector well with low manganese concentrations (mean: 0.05 mg/L). Groundwater monitoring wells were installed to provide information on soils, hydrogeology, and geochemistry. The wells showed that high groundwater manganese concentrations were coincident with high dissolved organic carbon, low DO/redox potential, and availability of soil manganese oxides.

The high manganese concentrations at Well 6 coincided with induced surface water recharge from the riparian zone. This recharge provided an influx of dissolved organic carbon from organic matter soils. Groundwater DO/redox potential in the flow path was low, consistent with up-gradient depletion by aerobic microbial processes. The reduction sequence was present in the Well 6 flowpath with DO depletion, followed by nitrate and manganese reduction. The sequence of reduction appeared to be dictated by availability of electron acceptors and organic carbon electron donor. In the upper portions of the aquifer, manganese reduction prevailed. In the lower portions of the aquifer, nitrate reduction prevailed where nitrate was available. Sulfate and iron were available as electron acceptors throughout the flowpath but were not reduced.

The lower manganese concentrations at Well 10 coincided with a large surface water contribution. Induced surface water recharge of groundwater developed an extensive zone of DOC influx, but manganese concentrations were lower than those at Well 6. The close proximity of the well and river (surface recharge source), fine soils in the shallower interval, deep screening of the collector well, and coarse soils at the well screen depth interval apparently resulted in a deep flow path and short travel time. Groundwater in this flow path had geochemistry similar to the river water and redox potential may not be sufficiently reduced for manganese reduction to occur in most of the aquifer. This appeared to limit manganese release even though river and riparian recharge resulted in an influx of DOC in the presence of soil manganese oxides. There was evidence of a

small reduction zone of iron and manganese in the shallow groundwater recharge zone likely attributable to DOC influx from riparian recharge. It appeared the kinetics of manganese reduction and organic matter oxidation limit manganese release in this flowpath as travel times were short and the reduction reaction incomplete.

TABLE OF CONTENTS

SECTION		PAGE
TITLE PAGE	....	i
SIGNATURE PAGE	....	ii
ABSTRACT	....	iii
TABLE OF CONTENTS	....	iv-v
LIST OF TABLES	....	vi
LIST OF FIGURES	....	vii
LIST OF APPENDICES	....	viii

TEXT

BACKGROUND 1
- INTRODUCTION 1
- LITERATURE 1

STUDY AREA 8
METHODS 14
- MONITORING WELLS AND MINI-PIEZOMETERS 14
- WELL 6 INSTALLATIONS 15
- WELL 10 INSTALLATIONS 17
- SOIL TESTING METHODS 19
- WATER SAMPLE GEOCHEMICAL TESTING METHODS 19

RESULTS AND DISCUSSION 21
- SOIL TESTING 21
- HYDROGEOLOGICAL TESTING 28
- GROUNDWATER FLOW CHARACTERIZATION FROM WATER LEVEL MEASUREMENTS 30
- HYDRAULIC CONNECTION DETERMINATION OF RIVER AND AQUIFER USING MINI-PIEZOMETERS AND TEMPERATURE PROFILING 37
- WELL 6 AREA GEOCHEMISTRY 42
- WELL 10 AREA GEOCHEMISTRY 54

SUMMARY AND CONCLUSIONS 67

REFERENCES 70

LITERATURE CITED 70
APPENDICES 71

LIST OF TABLES

TABLE NUMBER		PAGE
1	Manganese Reduction Mechanisms	5
2	Regional Pumping Well Hydrogeology Information	9
3	Airport Wellfield Pumping Well Information	10
4	Monitoring Well Information	16
5	Soil Particle Size Summary	21
6	Soil Iron and Manganese Testing Results	25
7	Well 6 and 10 Hydrogeological Conditions	29
8	Well 6 Area Groundwater Gradient and Travel Time Summary	31
9	Well 10 Area Groundwater Gradient and Travel Time Summary	31
10	Well 6 Source Water Origin Summary	45
11	Well 10 Source Water Origin Summary	62

LIST OF FIGURES

FIGURE NUMBER		PAGE
1	Manganese pH / pe Diagram	2
2	Sequence of Important Redox Processes	3
3	Typical Reduction Pathways	4
4	Organic Matter Oxidation Model by Iron and Manganese Reducing Bacteria	6
5	Regional Wellfield and Groundwater Flow Map	9
6	Airport Wellfield Study Site Map	11
7	Regional Groundwater Flow Model	13
8	Well 6 Monitoring Well and Mini-piezometer Well Map	17
9	Well 10 Monitoring Well and Mini-piezometer Well Map	18
10	Soil Particle Size Summary for Well 6 Transect	22
11	Soil Particle Size Summary for Well 10 Transect	23
12	Soil Iron and Manganese Concentrations	26
13	Test Pit Soil Porosity Summary	27
14	Area Water Table Map	28
15	Typical Flow Paths for Pumping Wells in a Shallow Unconfined Aquifer with Nearby Surface Water Source	30
16	Focused Recharge Illustration During Over Bank Conditions	32
17	Comparison of Well 6 Transect Water Table Elevations During Static and Pumping Conditions.	33
18	Riparian Inundation Event and Organic Soils Photographs	34
19	Well 6 Area Groundwater Flow Paths	35
20	Well 10 Area Groundwater Flow Paths	36
21	Well 6 Area Mini-piezometer Testing Results	38
22	Well 10 Area Mini-piezometer Testing Results	39
23	Well 10 Area Temperature Gradient Map – December 1996	41
24	Well 6 Transect DO Cross Sectional Profile	43
25	Well 6 Transect DOC Cross Sectional Profile	44
26	Well 6 Transect Nitrate Cross Sectional Profile	46
27	Well 6 Transect Sulfate Cross Sectional Profile	47
28	Well 6 Transect Chloride Cross Sectional Profile	48
29	Well 6 Transect Total Hardness Cross Sectional Profile	49
30	Well 6 Transect Manganese Cross Sectional Profile	51
31	Well 6 Transect Iron Cross Sectional Profile	52
32	Well 6 Transect pH Cross Sectional Profile	53
33	Well 10 Transect DO Cross Sectional Profile	55
34	Well 10 Transect DOC Cross Sectional Profile	56
35	Well 10 Transect Nitrate Cross Sectional Profile	58
36	Well 10 Transect Sulfate Cross Sectional Profile	59
37	Well 10 Transect Chloride Cross Sectional Profile	60
38	Well 10 Transect Total Hardness Cross Sectional Profile	61
39	Well 10 Transect Manganese Cross Sectional Profile	63
40	Well 10 Transect Iron Cross Sectional Profile	64
41	Well 10 Transect pH Cross Sectional Profile	65

LIST OF APPENDICES

APPENDIX
REFERENCED

NUMBER		PAGE
1	Airport Wellfield Pumping Well Data Summary Over Study Period	72
2	Monitoring Well Installation Summary and Soil Boring Logs	74
3	Transect Water Levels – March to September 1997	82
4	Transect Geochemical Summary Table	91

BACKGROUND

INTRODUCTION

Manganese can be a problem in water supplies because it is oxidized to a precipitated solid when exposed to oxidizing conditions in the well and distribution system. Manganese is a mineral commonly found in geologic alluvial deposits in groundwater aquifers. It occurs in aqueous solution in a dissolution process, where it is chemically reduced from mineral forms to the soluble manganous (Mn^{+2}) ion. Manganese oxidation can lead to clogging of the well screen and gravel pack causing a loss in production and well specific capacity. Distribution system problems include formation of black solids that cause poor aesthetic quality due to taste, odor, and micriobial acitivity associated with accumulated sediments.

Manganese concentrations at the City of Stevens Point Wisconsin Airport Wellfield exceed the 0.05 mg/L USEPA Secondary Maximum Contaminant Level (SMCL) standard in three of five wells. The wells are located in a shallow unconfined aquifer in the Plover River glacial alluvial valley. Manganese concentrations are managed at the wellfield by well blending and chemical sequestration. This treatment technique is only partially effective and further treatment would require installation of expensive manganese removal systems.

This study was undertaken because a better understanding of the factors that control manganese concentrations could provide information to improve management of this water quality issue. Manganese concentrations may be better controlled by use of this information applied to future well pumping strategies, or placement and capacity of new wells.

LITERATURE

The presence of iron and manganese in groundwater results from the solution of rock and sediment minerals including oxides, sulfides, carbonates, and silicates containing these metals. Iron and manganese appearance in groundwater requires conditions that dissolve the solid and permit the metal to remain in solution. Figure 1 shows the stability of manganese solids and soluble manganese under different pH/pe conditions.

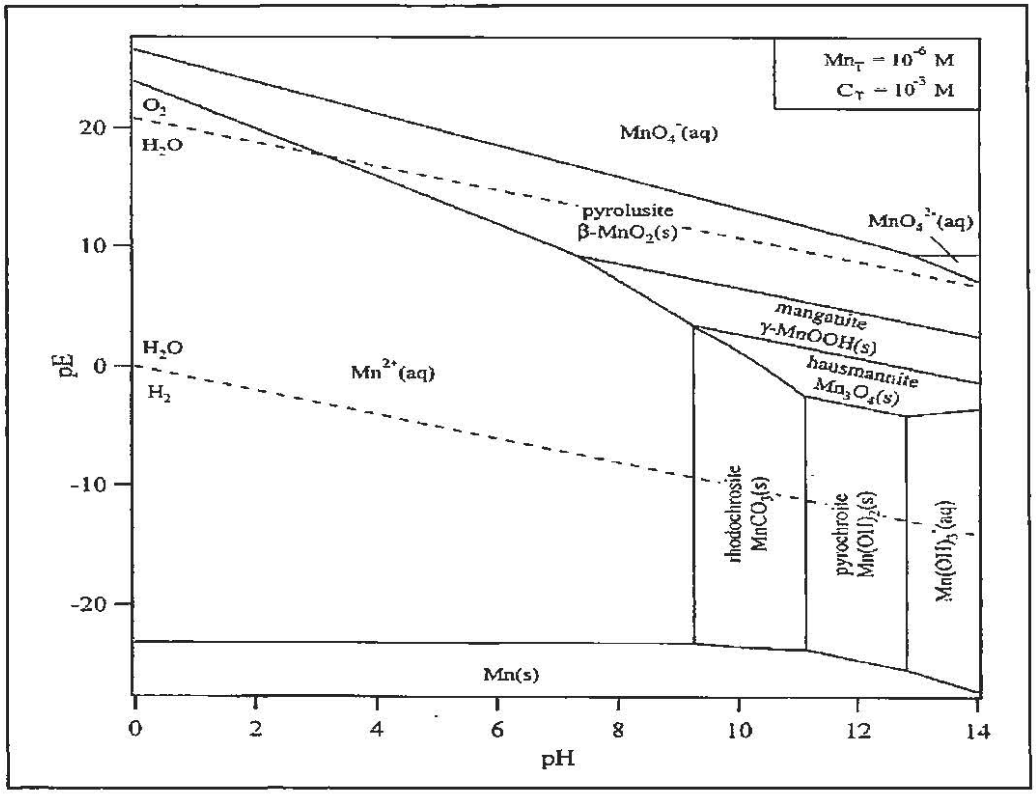
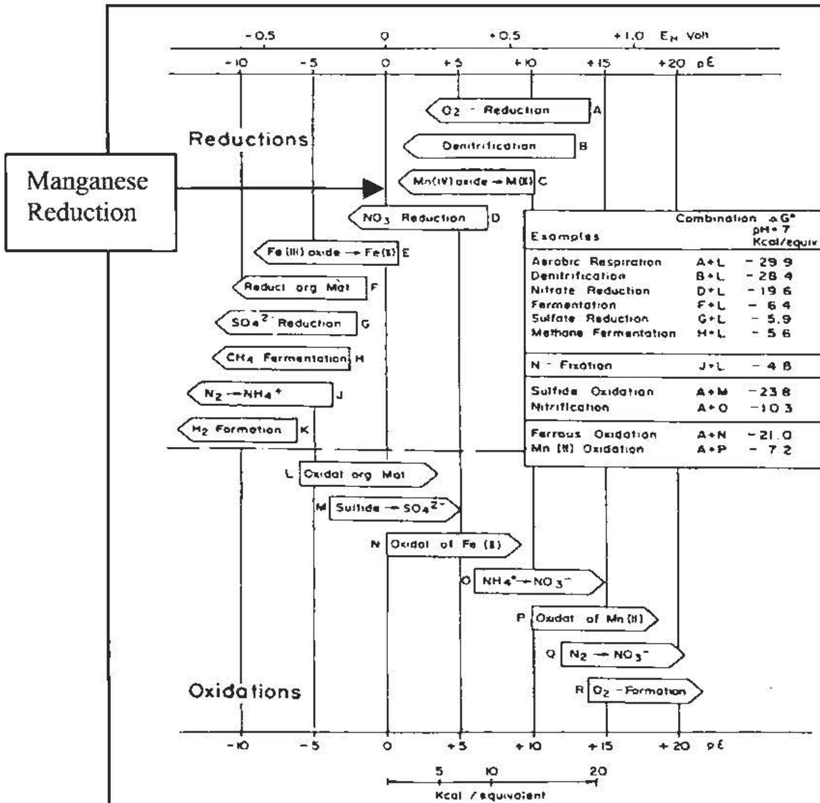


Figure 1 - Manganese pH / pe Diagram

Because iron and manganese oxides limit dissolved concentrations to very low concentrations in the absence of strong complexing agents, elevated solution concentrations usually require reducing conditions. In groundwater aquifers, manganese reduction occurs within a sequence of potential reduction reactions (Figure 2). The reduction series generally follows the redox sequence of oxygen (highly oxidized condition), nitrate, manganese, iron, sulfate, and methane fermentation (highly reduced condition).

Redox reactions occur by abiotic and microbial means (Lovely, 1991; Appelo, 1994). Abiotic reactions are those driven strictly by redox equilibrium without microbial influence. Microbial reactions are those driven by enzymatic action of bacteria. Many reactions proceed only at significant rates when mediated by bacterial catalysis (Appelo, 1994). An example is the reduction of sulfate by organic matter that occurs in aquifers and marine environments. Bacterial catalysis by *Desulfovibrio* allows this reaction to proceed rapidly in natural environments under the same environmental conditions where the reaction is otherwise immeasurably slow.



Appelo, C.A.J. and D. Postma, 1994.

Figure 2 - Sequence of Important Redox Processes

Microbial reduction of inorganic compounds can occur either by assimilative or dissimilative mechanisms. Direct assimilation of inorganic compounds by the microorganisms is assimilative metabolism. This can occur most notably with NO_3^-, SO_4^{2-}, or CO_2. Dissimilative metabolism is coupling of oxide compounds as electron acceptors with organic matter oxidation. Oxygen and oxide minerals such as MnO_2 serve as electron acceptors for dissimilative metabolism. Organic compounds are the energy source for dissimilative metabolism and serve as electron donors. Dissimilative metabolism has become increasingly recognized as the important mineral cycling mechanism for organic matter consumption in natural environments (Madigan, 2000).

Figure 3 is an illustration of multiple microbial pathways of dissimilative organic matter oxidation (Zehnder, 1988). The figure illustrates the interrelationships of organic matter breakdown, redox potential, and various microbial reduction pathways of dissimilatory organisms. Each of the pathways utilize oxygen or alternate electron acceptors to oxygen in metabolizing fermentation breakdown products. Microbial manganese reduction takes place in the range of approximately 200 to 600 mV.

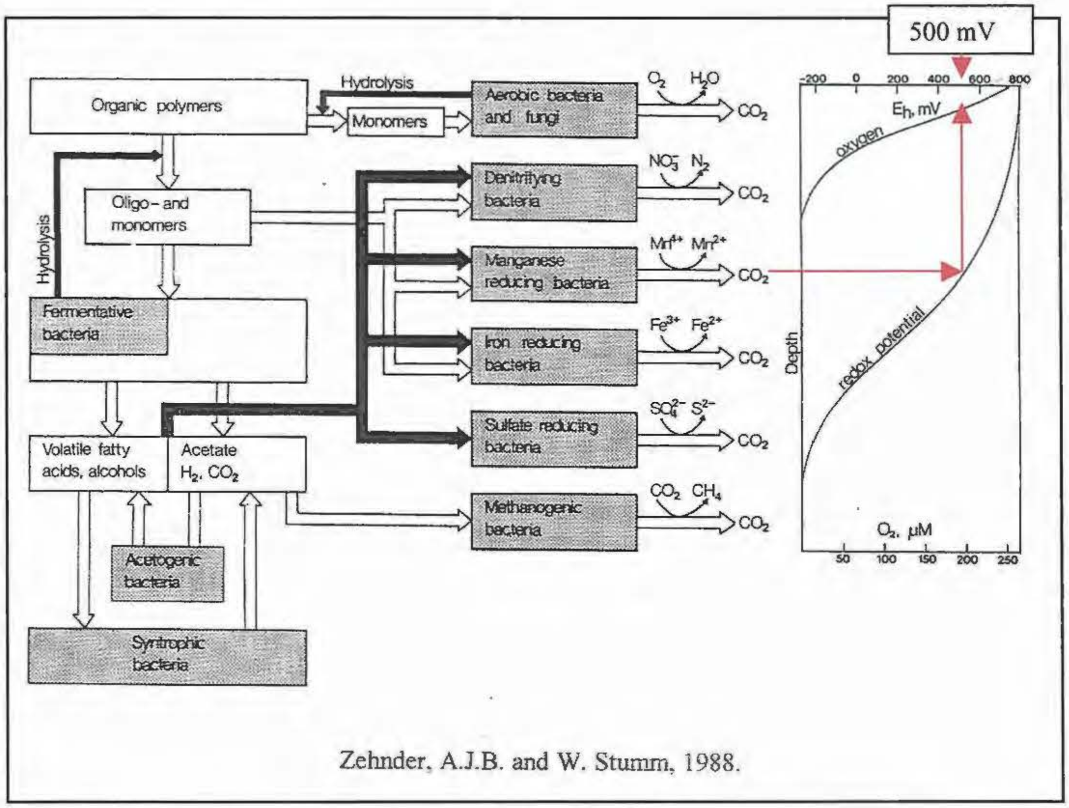


Figure 3 - Typical Reduction Pathways

Lovely (Lovely, 1991) was the first to comprehensively describe the processes that are known to control manganese reduction. Lovely described five potential mechanisms for manganese reduction (Table 1).

Mechanisms 1 through 4 are various forms of abiotic manganese reduction. Mechanisms 1 and 2 follow the conventional redox half reaction:

$MnO_2 + 4H^+ + 2e^- \leftrightarrow Mn^{2+} + 2\,H_2O$

Table 1 – Manganese Reduction Mechanisms

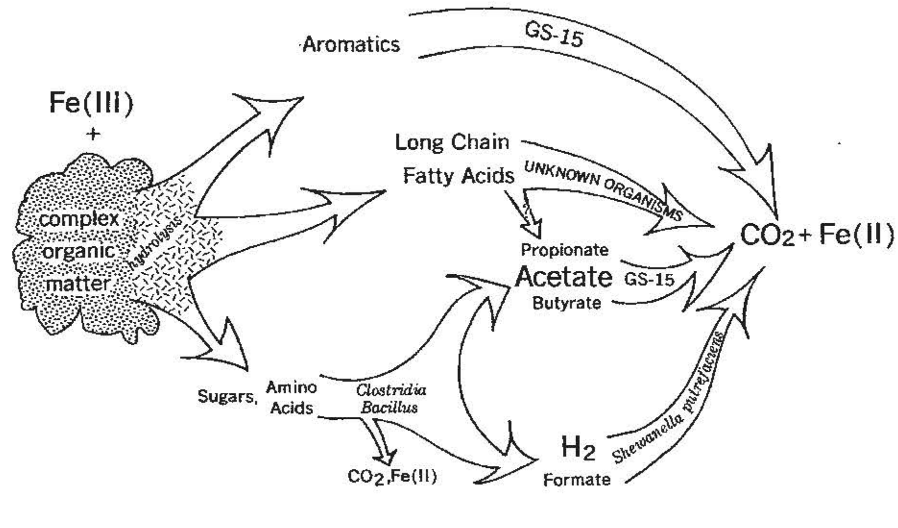
No.	Mechanisms	Description
1	Chemical Redox Reduction	Manganese concentration dictated by prevailing redox equilibrium (eh / pH).
2	Microbially Induced Chemical Redox Reduction	Prevailing microbial processes such as nitrate, iron or sulfate reduction create redox conditions that facilitate chemical redox reduction of manganese.
3	Non-Enzymatic Manganese Reduction by Organic Compounds	Organic species reduce manganese directly including oxalate, pyruvate, glucose, and xylose.
4	Non-Enzymatic Manganese Reduction by Inorganic Compounds	Inorganic species are reaction couples with manganese including Fe^{2+}, NO_2^-, HS^-, H_2O_2.
5	Enzymatic Iron and Manganese Reducing Bacteria	Dissimilative bacteria reduce iron and manganese as electron acceptors in oxidation of organic carbon.

Mechanisms 3 and 4 involve manganese reduction through redox coupling with other compounds. Lovely identifies redox coupling of manganese oxides with Fe^{2+} (Mechanism 4) and microbially mediated dissimilative reduction (Mechanism 5) as the predominant reduction mechanisms.

Microbially mediated manganese oxide reductive dissolution occurs under the following reaction:

$$CH_2O + 2\ MnO_2 + 4H^+ \rightarrow 2\ Mn^{2+} + 3H_2O + CO_2$$

The role of this pathway in the reductive dissolution of both iron and manganese oxides has been the focus of many studies (Myers and Nealson, 1988; Lovely et al, 1989). Figure 4, taken from Lovely (1991), illustrates how these reactions can occur in microbially mediated systems (Lovely, 1991). This model shows that microbial iron and manganese reduction can occur through multiple organic pathways. Lovely identified *Geobacter metallireducens* GS-15, a gram negative rod of approximately 3 by 0.5 micron in size. It was isolated in pure culture as a strict aerobe that metabolizes acetate, utilizing iron and manganese as the sole electron acceptor. GS-15 was also shown to metabolize propionate, butyrate, valerate, pyruvate, ethanol, and other organic compounds.



Model for the oxidation of complex organic matter with Fe^{3+} as the sole electron acceptor, with example organisms that may catalyze reactions. A similar model applies with Mn^{4+} as the sole electron acceptor.

Source: Lovely, 1991

Figure 4 - Organic Matter Oxidation Model by Iron and Manganese Reducing Bacteria

Previous research has shown the importance of reductive manganese release on water quality. Studies by Petrunic and MacQuarrie (2005) and Thomas (1994) included field observation and lab experiments related to identifying causes of manganese at Fredericton, New Brunswick, Canada water production wells. Thomas found that high manganese concentrations in the groundwater aquifer were caused by extensive surface water recharge from the St. Johns River. It was estimated that two thirds of the wellfield water supply originated as surface water induced recharge. Wells with high surface water recharge were found to have higher manganese concentrations. It was concluded that microbial oxidation of organic matter from induced surface water recharge was coupled to manganese reduction. The study also found manganese concentrations increased over time as microbial populations became established in areas of high induced recharge rates. Research by Petrunic and MacQuarrie studied the presence and activity of microbial manganese reduction in test columns where acetate was introduced in the presence of manganese oxide containing soils from the Fredericton aquifer. The presence of microbial manganese reduction was verified as the primary source of manganese reduction. It was also concluded that manganese reduction only accounted for a fraction of organic consumption. A mass balance showed that a majority of acetate was consumed by fermentation reactions. These studies identified microbially mediated manganese reduction as the primary source of manganese at the site when reducible manganese oxides and labile DOC were available.

Manganese reduction in Black Sea sediments was studied by Thandrup (2000). Microbial manganese reduction was an important terminal electron accepting process in organic matter oxidation. Microbial manganese reduction dominated where manganese oxide was abundant under anoxic conditions, and accounted for 25 to 73 percent of organic matter oxidation. Below the manganese reduction zone, sulfate reduction accounted remaining organic matter oxidation. Fe^{2+} and nitrate were absent as electron acceptors.

These studies show that numerous factors control manganese dissolution and a comprehensive analysis of conditions related to water source pathways and geochemistry is necessary to identify manganese controlling conditions at any given site.

STUDY AREA

To understand the sources of manganese in the Stevens Point Wellfield, this study examined the geochemistry in the groundwater flowpaths near two wells. The wells examined were Well 6, a high capacity conventional well with an average manganese concentration of 0.35 mg/L and Well 10, a high capacity collector well with a lower manganese concentration averaging 0.05 mg/L.

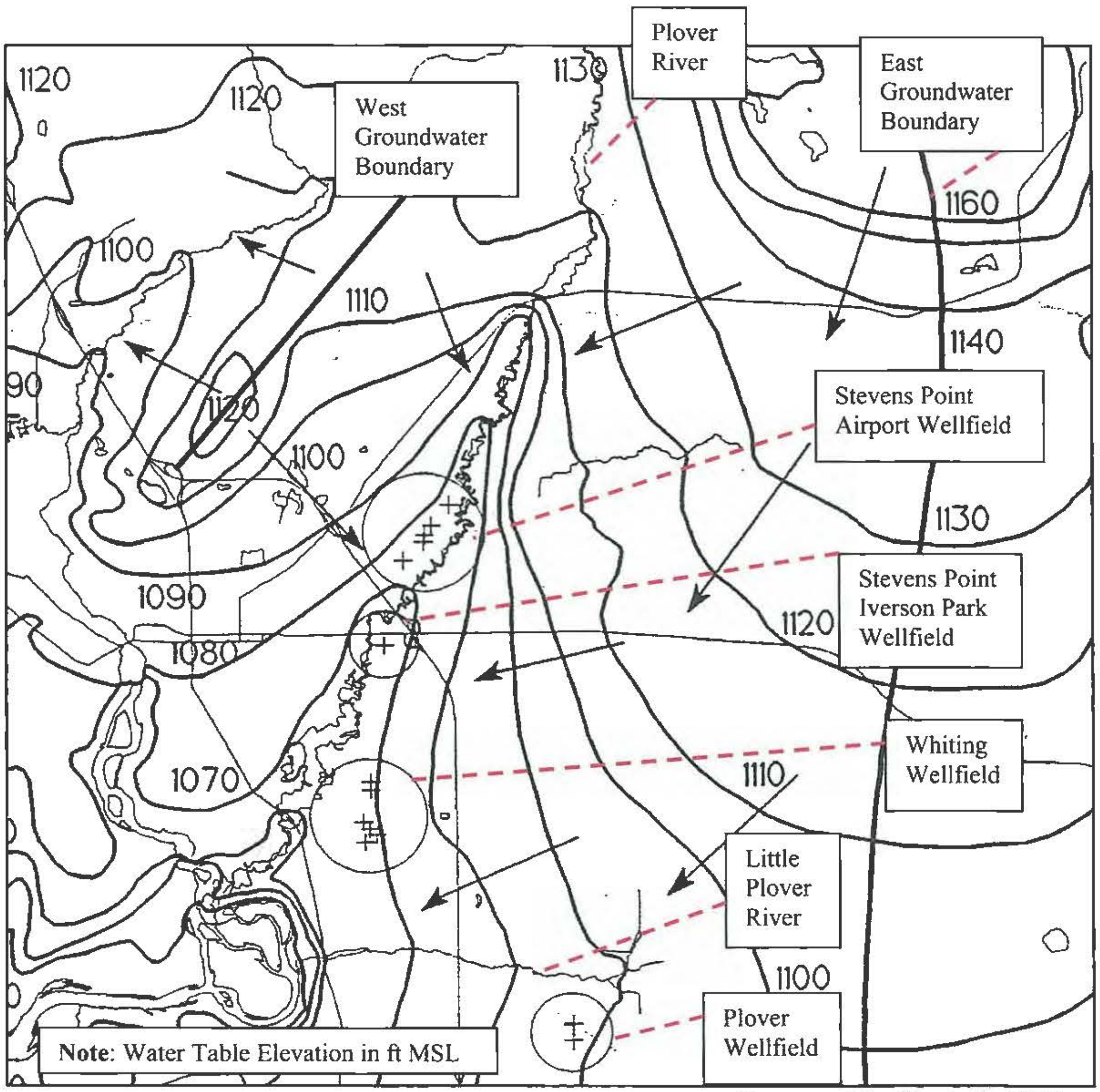
The regional aquifer is shallow and unconfined. Aquifer materials generally consist of sand and gravel glacial outwash from the Pleistocene era. The glacial outwash was primarily a uniformly laid sand with some gravel, and little silt or clay (Holt, 1965; Clayton, 1986). The vertical anisotropy of hydraulic conductivity ranges from 1:2 to 1:20 as a reflection of deposition character. The outwash was deposited over the Plover River Precambian bedrock valley. The bedrock surface generally slopes from north to south with significant local variations.

The study area is located in the Plover River glacial alluvial valley in Central Wisconsin. There are many municipal and private wells within this highly productive aquifer. Regional municipal supplies include those of Stevens Point, Whiting, and Plover, Wisconsin. The City of Stevens Point has two separate wellfields: the Airport Wellfield to the north, and Iverson Park Wellfield to the south (Figure 5). The study site was at the Airport Wellfield. Figure 6 is a study site map showing the local wellfield with adjacent features including: Stevens Point Airport (west), City of Stevens Point (west), and Plover River (east). The Wellfield is a relatively undeveloped area that is also used for recreation and is bisected by a recreational trail.

A regional water study by Kraft, et al. (1996) provides additional details regarding the regional and local aquifer. Table 2 summarizes the hydrogeologic parameters for Stevens Point Wells 6 and 10, and Plover Well 1.

Table 2 – Regional Pumping Well Hydrogeology Information

Well	Hydraulic Conductivity (m/s x 10^{-4})	Specific Yield	Saturated Thickness (ft)	Specific Capacity (gpm/ft)
Stevens Point #6	44.3	0.25	83	343 @ 2400 gpm
Stevens Point #10	38.5	0.30	63	100 @ 1340 gpm
Plover #1	8.37	0.08	31.1	40 @ 1000 gpm



Source: Kraft, et al, 1996

Figure 5 – Regional Wellfield and Groundwater Flow Map

Figure 5 shows that the regional water table generally flows toward the Plover River and Little Plover River. In the Airport Wellfield area, groundwater flows from the northeast and northwest to the Plover River. Groundwater boundaries in the Airport Wellfield area are approximately 2 ½ miles to the west and 5 miles to the east.

Specific capacity is a measure of well productivity, and it is highest at Stevens Point Airport Wellfield Wells 6 and 10 than the four other regional wellfields (Table 2). Soils are well sorted medium to coarse glacial outwash sands with a gravel component. The variation in saturated thickness between Wells 6 and 10 is due the vertical transition associated with a local bedrock low in the southern portion of the wellfield.

The Airport Wellfield has five wells within an area of approximately ¾ mile as shown in Figure 6. Table 3 summarizes well information from this location.

Table 3 – Airport Wellfield Pumping Well Information

Well	Manganese Conc. (mg/L)	Normal Pumping Rate (gpm)	Average Pumpage (MGD)	Average Pumpage (cfs)	Average Pumpage (MG/Mo.)	% of Wellfiled Pumpage
6	0.316	1500	1.82	2.81	55.9	27
7	0.320	1500	0.87	1.35	25.8	12
8	0.000	1000	0.67	1.04	19.8	10
9	0.000	1000	0.74	1.15	21.8	11
10	0.042	2400	2.76	4.28	84.1	40

Note: Data colleted from study period from March 1997 to October 1998

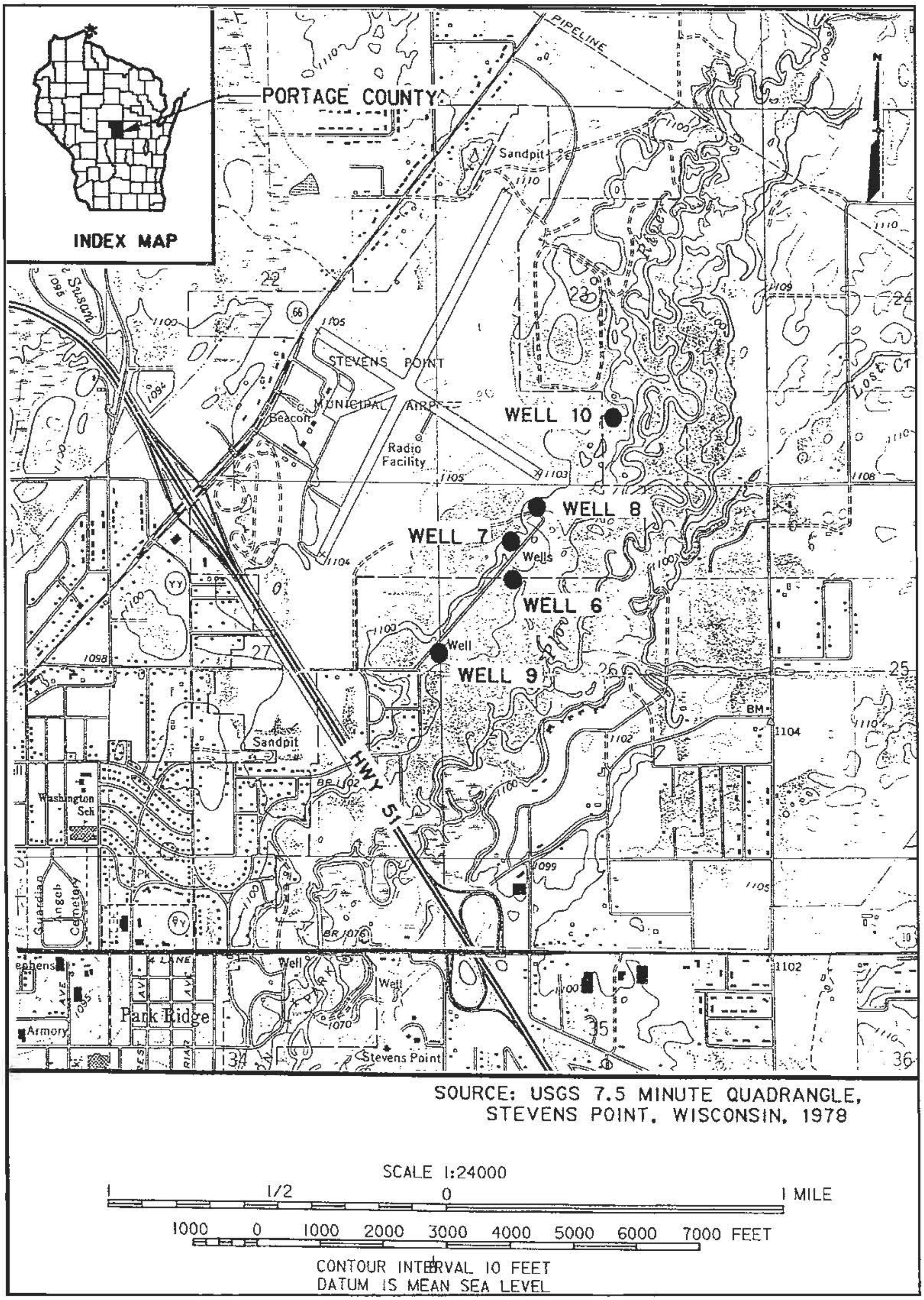


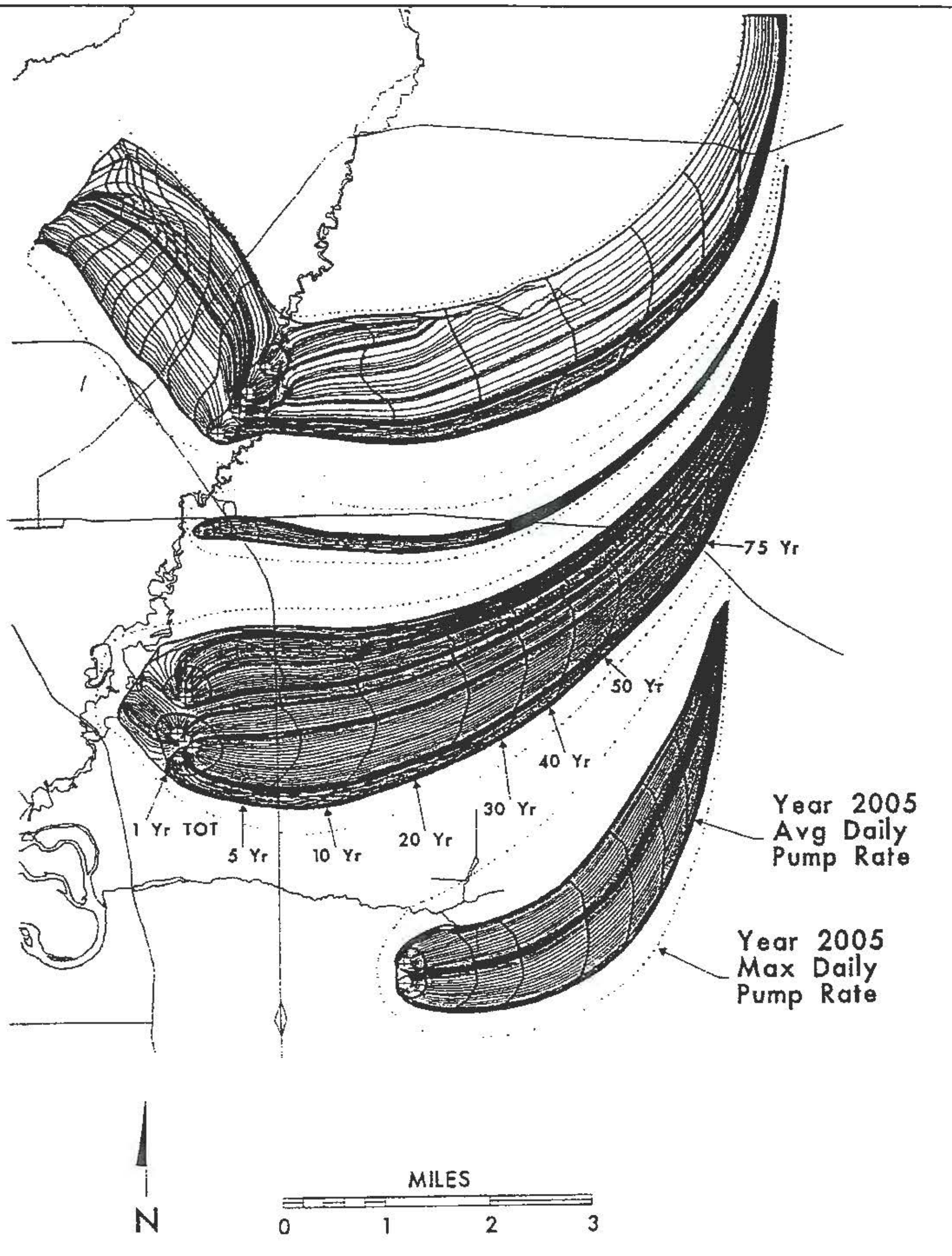
Figure 6 – Airport Wellfield Study Site Map

Well 6 is a high capacity conventional well installed in 1965 with manganese concentrations up to 0.5 mg/L, ten times the USEPA drinking water Secondary Maximum Contaminant Level Standard (SMCL). It is located 1,100 feet from the Plover River and normally operated at a rate of 1,500 gpm. Well 7 is a nearby similar conventional well located within 300 feet of Well 6. Although not a subject well of this study, it is significant as a source of combined pumpage with Well 6, with intersecting zones of contribution that create a single local pumping center.

Well 10 represents a newer well with lower manganese concentrations. It is a high capacity collector well installed in 1995. It is located 500 feet from the Plover River backwater area that receives regular stream contribution. The well design capacity is 3,600 gpm and it is normally operated at a rate of 2,400 gpm.

Results from a regional groundwater flow model (Kraft, et.al., 1996) are provided in Figure 7. This model shows the recharge area of the Airport Wellfield. The zones of contribution are reflected in this Figure in terms of 1, 5, 10, etc years of travel. More closely spaced time of travel lines indicate slower groundwater movement. The times of travel extend further to the east than the west by a factor of two to three. This reflects the greater degree of recharge from the east and northeast compared to the west and northwest. Modeling results have some uncertainty in the easterly delineated zone of contribution due to the unknown fate of well flow paths at river cells (Kraft, et al., 1996).

Manganese is the significant water quality issue at the Airport Wellfield. Average manganese concentrations at the Airport Wellfield wells from city data collected over the study period (1997 to 1998) are listed in Appendix 1. Manganese treatment is generally necessary for acceptable drinking water quality at concentrations above the 0.05 mg/L SMCL. A detailed description of area water quality issues is provided in a recent regional water study (Kraft et al., 1996).



Zones-of-contribution and times-of-travel for the Stevens Point, Whiting, and Plover municipal wellfields using MODPATH. Source: Kraft, et al, 1996

Source: Kraft, 1996

Figure 7 – Regional Groundwater Flow Model

METHODS

Test data was collected for the study by examination of pumping well analysis, soil analysis, hydrogeology, and groundwater geochemistry. To characterize the geochemistry and hydrogeology in groundwater flowpaths, groundwater monitoring wells were installed. Soil testing was performed during monitoring well installation to characterize hydrogeologic conditions of the aquifer and measure manganese concentrations.

MONITORING WELLS AND MINI-PIEZOMETERS

Monitoring well nests were installed along transects from Wells 6 and 10 to the Plover River and associated riparian areas (Figures 8 and 9). These transects were the most direct route between the pumping well and river in these areas. A monitoring well installation summary is provided in Appendix 2. Mini-piezometers were installed in riparian and riverbed locations to provide additional hydrogeological information.

Monitoring wells and a river gauge were installed in May and June, 1996. The monitoring wells consisted of 1.25 inch inner diameter schedule 40 PVC. Both glued and threaded fitting piping were used. All newly installed wells were drilled by a hollow stem auger on a truck mounted boring rig from the Wisconsin Geological Survey. Newly installed wells at Nests T and W were installed by hand auger because they were located in lowland riparian areas without truck access. Boring Logs for new wells installed by the drill rig are provided in Appendix 2. Soil samples were not available for hand augered wells. Additional information regarding each of the transect monitoring well locations is provided in Table 3.

Mini-piezometers were installed in the Plover River streambed and associated riparian areas suspected to be in or near the Well 6 and 10 cones of depression (Figures 8 and 9). The mini-piezometers were used to monitor groundwater movement in to or out of the river. This groundwater movement was determined to be upwelling (water in), downwelling (water out), or neutral relative to stream surface. Mini-piezometers consisted of 0.25 inch internal diameter poly tubing that have a one inch area of perforation at the bottom serving as the screen. Mini-piezometers are installed to a depth between 12 and 14 inches with "stick-up" of up to six additional feet for piezometric surface elevation measurement. Mini-piezometers function similarly to wells in that water elevation in the tube represents the piezometric surface elevation. Water elevations within mini-piezometers were visually observed at a level relative to the river surface.

Flow characteristics in the study area were determined from monitoring well and mini-piezometer potentiometric elevations. Monitoring well potentiometric surface elevations were determined by an audible signal measuring tape. The distance from the potentiometric surface was measured to the surveyed top of the well pipe. Elevations were collected at approximately one to two month intervals between March and September 1997. Elevations from several other monitoring wells in the wellfield were collected one time in November 1998.

WELL 6 INSTALLATIONS

Well 6 transect information is provided in Figure 8. The transect extended from Well 6 to approximately 80 feet east of the Plover River and included five monitoring well nests, one single well, and one river gauge. Table 4 provides elevations of well pipe top, bottom, and screen, and typical water depths for a single sample period (August 26, 1997). D Nest is a reference well east of the Plover River, approximately 2000 feet north of the Well 6 transect. This well nest represents groundwater conditions outside of Well 6 influence. Mini-piezometers were installed in the Plover River along the Well 6 transect and included 6-R-0S through 6-R-3S.

Table 4 – Monitoring Well Information

Location	Well Surface (top of pipe) (MSL)	Well Depth (ft)	Well Bottom (MSL)	Screen Center (MSL)	Screen Top (MSL)	8/26/1997 - Example Water Levels: Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
WE6	1092.55	89.55	1003.00	1025.00	1038.00	40.40	1052.15	40.40
V26	1090.68	26	1062.68	1065.18	1067.68	22.96	1067.72	
V32	1090.60	32	1056.60	1059.10	1061.60	22.90	1067.70	
V46	1090.70	46	1042.70	1045.20	1047.70	23.10	1067.60	
V55	1090.65	55	1033.65	1036.15	1038.65	23.06	1067.59	
V65	1090.70	65	1023.70	1026.20	1028.70	23.11	1067.59	
V75	1090.68	75	1013.68	1016.18	1018.68	23.07	1067.61	
U15	1082.67	15	1065.67	1068.17	1070.67	13.83	1068.84	
U25	1082.66	25	1055.66	1058.16	1060.66	13.81	1068.85	
U35	1082.69	35	1045.69	1048.19	1050.69	13.85	1068.84	
U45	1082.41	45	1035.41	1037.91	1040.41	13.57	1068.84	
U55	1082.41	55	1025.41	1027.91	1030.41	13.58	1068.83	
U65	1082.42	65	1015.42	1017.92	1020.42	13.58	1068.84	
B20	1082.16	20	1060.16	1062.66	1065.16	12.95	1069.21	
B30	1082.84	30	1050.84	1053.34	1055.84	13.65	1069.19	
B40	1081.91	40	1039.91	1042.41	1044.91	12.73	1069.18	
B50	1082.88	50	1030.88	1033.38	1035.88	13.71	1069.17	
B65	1082.11	65	1015.11	1017.61	1020.11	12.93	1069.18	
B70	1082.87	70	1010.87	1013.37	1015.87	13.68	1069.19	
E5	1074.44	5	1067.44	1069.94	1071.44	Not Avail	Not Avail	
E10	1073.71	10	1061.71	1064.21	1066.71	3.99	1069.72	
E37	1073.25	37	1034.25	1036.75	1039.25	3.54	1069.71	
F5	1075.34	5	1068.34	1070.84	1073.34	4.82	1070.52	
F10	1074.68	10	1062.68	1065.18	1067.68	4.17	1070.51	
PLR6	1074.84	6.4 (staff)	1068.44	N/A	N/A	3.74	1071.10	2.66
MW39	1072.98	10	1060.98	1063.48	1065.98	2.25	1070.73	
D20	1083.34	20	1061.34	1063.84	1066.34	7.86	1075.48	
D40	1083.40	40	1041.40	1043.90	1046.40	8.50	1074.90	
D60	1083.46	60	1021.46	1023.96	1026.46	8.14	1075.32	
WE10	1102.29	90.29	1012.00	1014.00	1018.00	33.90	1068.39	33.90
S30	1094.58	30	1062.58	1065.08	1067.58	22.94	1071.64	
S40	1094.21	40	1052.21	1054.71	1057.21	22.32	1071.89	
S50	1094.16	50	1042.16	1044.66	1047.16	22.27	1071.89	
S60	1094.17	60	1032.17	1034.67	1037.17	22.31	1071.86	
S70	1094.57	70	1022.57	1025.07	1027.57	22.71	1071.86	
S80	1094.60	80	1012.60	1015.10	1017.60	22.78	1071.82	
Q30	1096.46	30	1064.46	1066.96	1069.46	23.98	1072.48	
Q40	1095.99	40	1053.99	1056.49	1058.99	23.60	1072.39	
Q60	1096.00	60	1034.00	1036.50	1039.00	23.62	1072.38	
Q90	1096.52	90	1004.52	1005.52	1006.52	24.10	1072.42	
T7	1077.36	7	1068.36	1070.86	1073.36	4.53	1072.83	
T15	1077.36	15	1060.36	1062.86	1065.36	4.55	1072.81	
T20	1077.14	20	1055.14	1057.64	1060.14	4.35	1072.79	
W5	1077.84	5	1070.84	1073.34	1075.84	4.56	1073.28	
W10	1077.79	10	1065.79	1068.29	1070.79	4.54	1073.25	
W15	1078.08	15	1061.08	1063.58	1066.08	4.81	1073.27	
PLR10	1079.15	6.4 (staff)	1072.75	N/A	N/A	4.36	1074.79	2.04
MW47	1077.29	10	1065.29	1067.79	1070.29	3.85	1073.44	
C20	1082.20	20	1060.20	1062.70	1065.20	5.76	1076.44	
C40	1081.60	40	1039.60	1042.10	1044.60	5.67	1075.93	
C60	1082.10	60	1020.10	1022.60	1025.10	5.87	1076.23	

Notes: River depth to water is 6.4 feet (top of guage) minus guage reading

Well bottom, screen center, and screen top elevations are estimates based on a 2.0 foot stick up to pipe top surveyed elevation

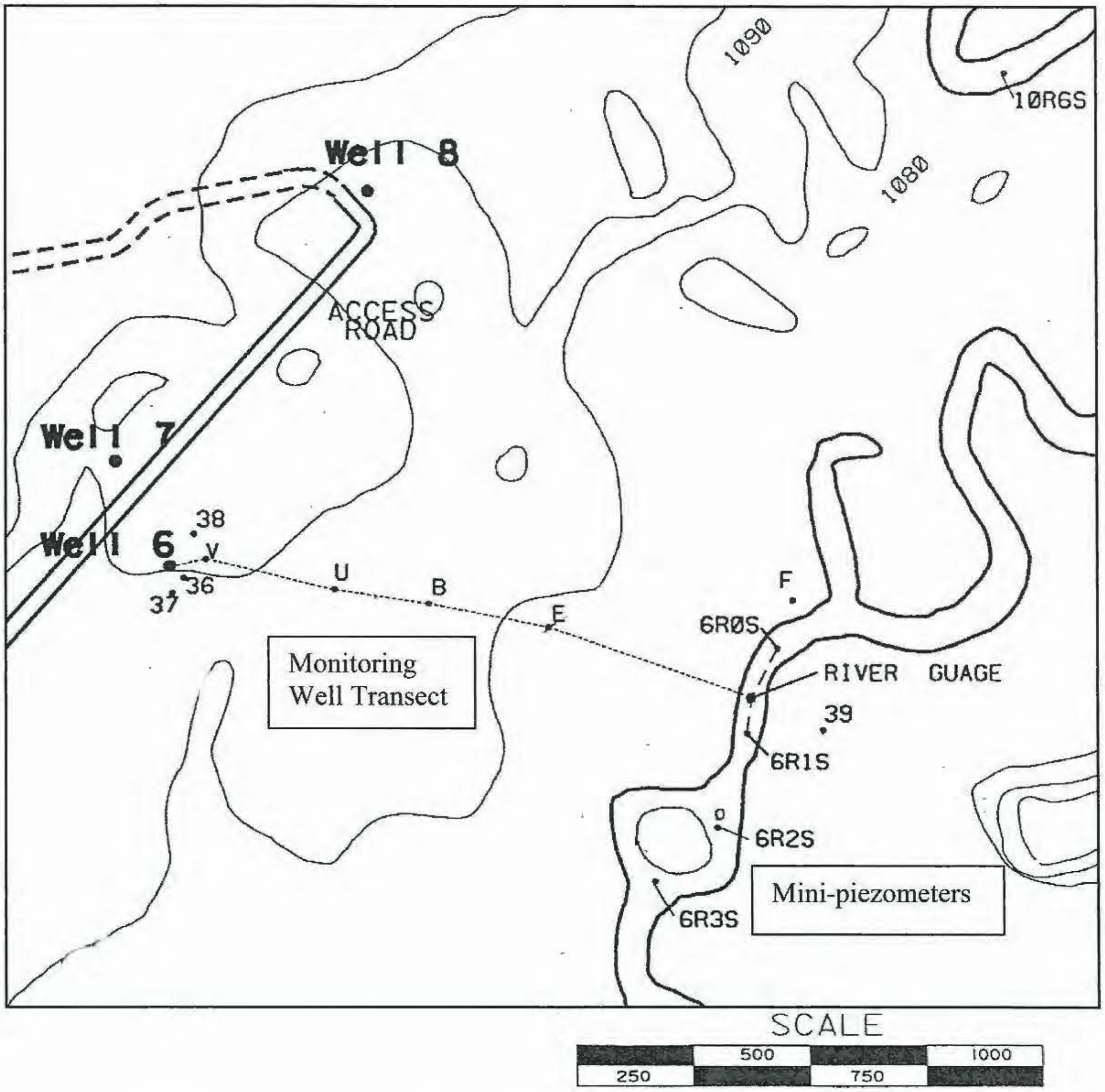


Figure 8 – Well 6 Monitoring Well and Mini-piezometer Well Map

WELL 10 INSTALLATIONS

Well 10 transect information is provided in Figure 9. The Well 10 transect extended from Well 10 to approximately 125 feet east of the Plover River. It included four monitoring well nests, one single well, and one river gauge. Additional information regarding each of the transect monitoring well locations is provided in Table 4. The C Nest is a reference well east of the Plover River, approximately 1300 feet north of the Well 10 transect. This well nest represents groundwater conditions with minor Well 10 influence. The R Nest and Q Nest wells were installed at the site of pre-existing wells. R Nest wells formerly known as OW-4A (35 ft) and OW-4B (90 ft) were previous installations associated with the Well 10 test well. Q Nest wells formerly known as OW-2A (30 ft) and OW-4B (90 ft) were previous installations also associated with the Well 10 test well. R Nest was developed to understand the influence on water quality at a monitoring well near the northeast lateral based on anticipated flow from the north (Figure 5). Mini-piezometers were installed in the Plover River and associated riparian areas. The five backwater riparian area mini-piezometers were 10-B-A through 10-B-E. The nineteen Plover River mini-piezometers installed were 10-R-9N through 10-R-6S. A larger number of mini-piezometers were installed in the Well 10 Plover River area because the Well area of influence was found to be quite extensive.

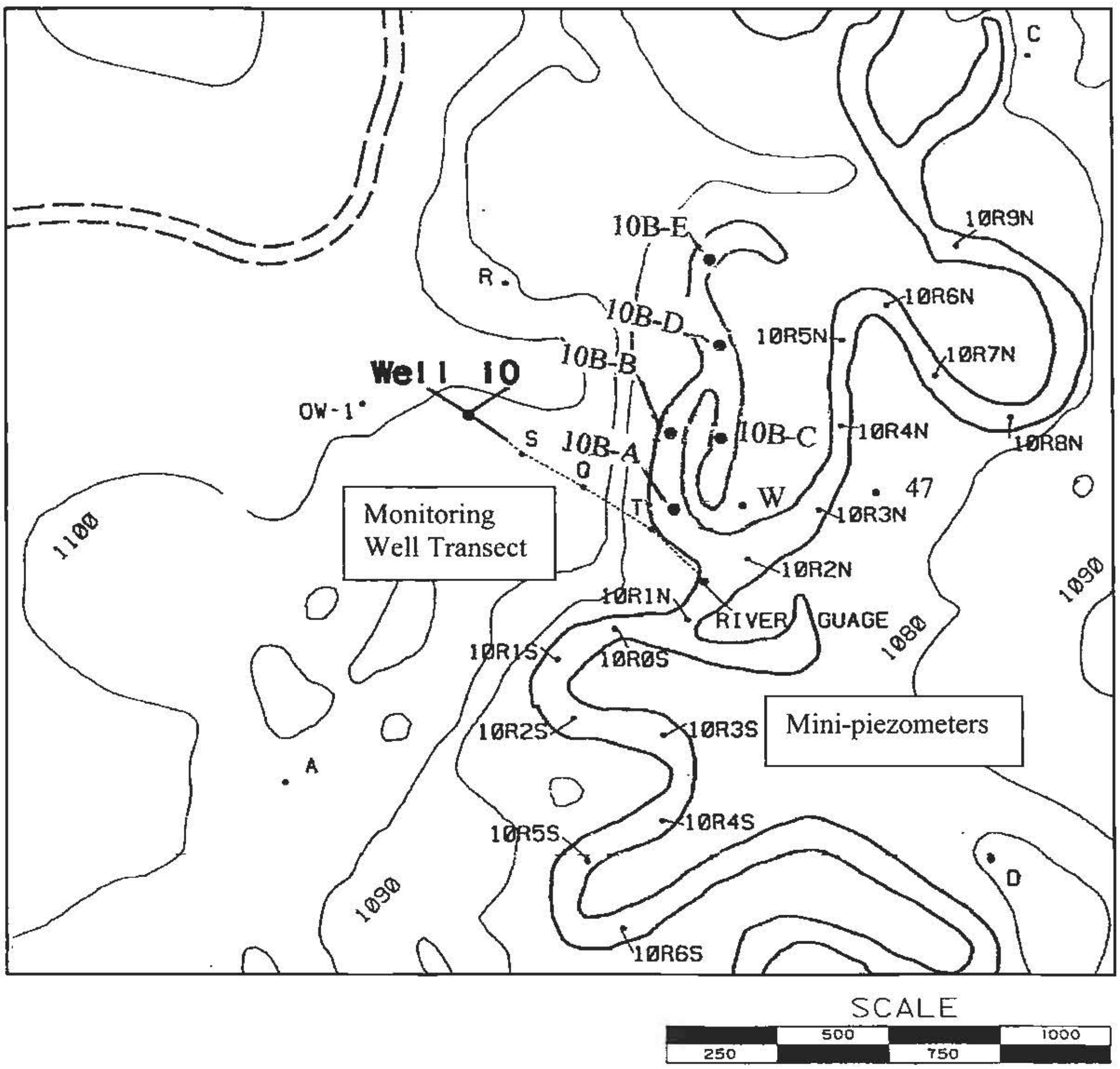


Figure 9 – Well 10 Monitoring Well and Mini-piezometer Well Map

SOIL TESTING METHODS

Soils were collected and characterized during monitoring well installation. Monitoring wells were installed by drill rig using hollow stem auger drilling methods. Soils were sampled by split spoon at 10 foot intervals. Soils were classified and logged in Soil Boring Logs (Appendix 2). Soil chemistry analysis for iron and manganese was performed by University of Wisconsin-Stevens Point Environmental Task Force Laboratory. The soil analysis included nitric acid digestion and atomic absorption flame analysis for total iron and manganese by SW-846 Method 6010. Particle size analysis was performed by University of Wisconsin-Stevens Point Environmental Task Force Laboratory. Testing included sieve screening using sieve sizes 18, 35, 60, 140, 270, and greater than 270. The corresponding sizes for these sieves include 0.884 mm, 0.417 mm, 0.246 mm, 0.110 mm, 0.053 mm, and less than 0.053 mm.

Additional testing was done in the Well 10 area in the October and November 1996 in association with a soil physics course that included soil porosity testing and a subsurface temperature profile. Porosity was measured at three soil pits in the Well 10 riparian area. The soil pits were located near T Nest (Pit 1), W Nest (Pit 2), and MW-47 (Pit 3) in the Plover River Riparian area (Figure 9). Soil samples were collected in the pit excavations at 10 cm intervals down to 60 cm. Soil porosity was determined from bulk desity and particle density testing. Soil temperature was determined using a push rod with a temperature thermocouple that was pushed down to the depth of temperature measurement.

WATER SAMPLE GEOCHEMICAL TESTING METHODS

Water samples were collected and tested from transect monitoring wells, the Plover River, and the R Nest (near Well 10). Samples were collected in three sampling rounds including March, May, and July, 1997. Additional samples were collected at some well nests in 1996 shortly after well installation. Samples were collected from monitoring wells by pumping at a rate of approximately 2 gallons per minute. The wells were purged with a minimum of five well volumes prior to sampling. Samples were collected from the pump discharge hose directly into sample containers dedicated for each group of testing parameters. Sample testing included analysis of field parameters and laboratory parameters. Field samples were tested immediately after collection for dissolved oxygen (DO), temperature, pH, redox potential (eh), and conductivity. Laboratory samples were preserved after sample collection and analyzed for: dissolved organic carbon (DOC), chemical oxygen demand (COD), UV254, manganese, iron, nitrate, total alkalinity, calcium hardness, total hardness, sulfate, chloride, sodium, and potassium. DOC samples were analyzed by Enviroscan Laboratory in Rothschild, Wisconsin by USEPA Method 415.2. All other laboratory parameters were analyzed by UWSP Environmental Task Force Laboratory by USEPA approved methods.

RESULTS AND DISCUSSION

SOIL TESTING

The soils in the Wells 6 and 10 transects were primarily sands ranging from fine to coarse size. Table 5 and Figures 10 and 11 show the particle size summary. Based on differences between median and 90^{th} percentile particle sizes (D50 and D90), it appears the particles were more uniform in the Well 6 transect than the Well 10 transect.

Table 5 – Soil Particle Size Summary

Monitoring Well Boring	D_{10} (mm)	D_{50} (mm)	D_{90} (mm)	Bulk Density (g/cm^3)	Particle Density (g/cm^3)
B10	0.13	0.22	0.37	1.57	2.63
B20	0.05	0.16	0.35	1.47	2.10
B30	0.10	0.18	0.24	1.55	2.43
B40	0.09	0.21	0.36	1.73	2.34
B50	0.09	0.19	0.35	1.60	2.43
B60	-	-	-	-	-
B70	0.08	0.19	0.38	1.57	2.47
Q10	0.07	0.18	0.35	1.42	2.78
Q20	0.11	0.18	0.26	1.54	2.73
Q30	0.07	0.15	0.26	1.59	2.52
Q40	0.08	0.16	0.24	1.58	2.53
Q50	0.07	0.14	0.25	1.66	2.62
Q60	0.10	0.25	0.54	1.72	2.68
S70	0.08	0.27	0.60	1.67	2.47
S80	0.08	0.25	0.60	1.67	2.38
S85	0.02	0.16	0.43	1.25	2.03
T10	0.09	0.19	0.37	1.25	2.03
Note:	Water Table Depth B = 11 ft Q = 21ft S = 21 ft				

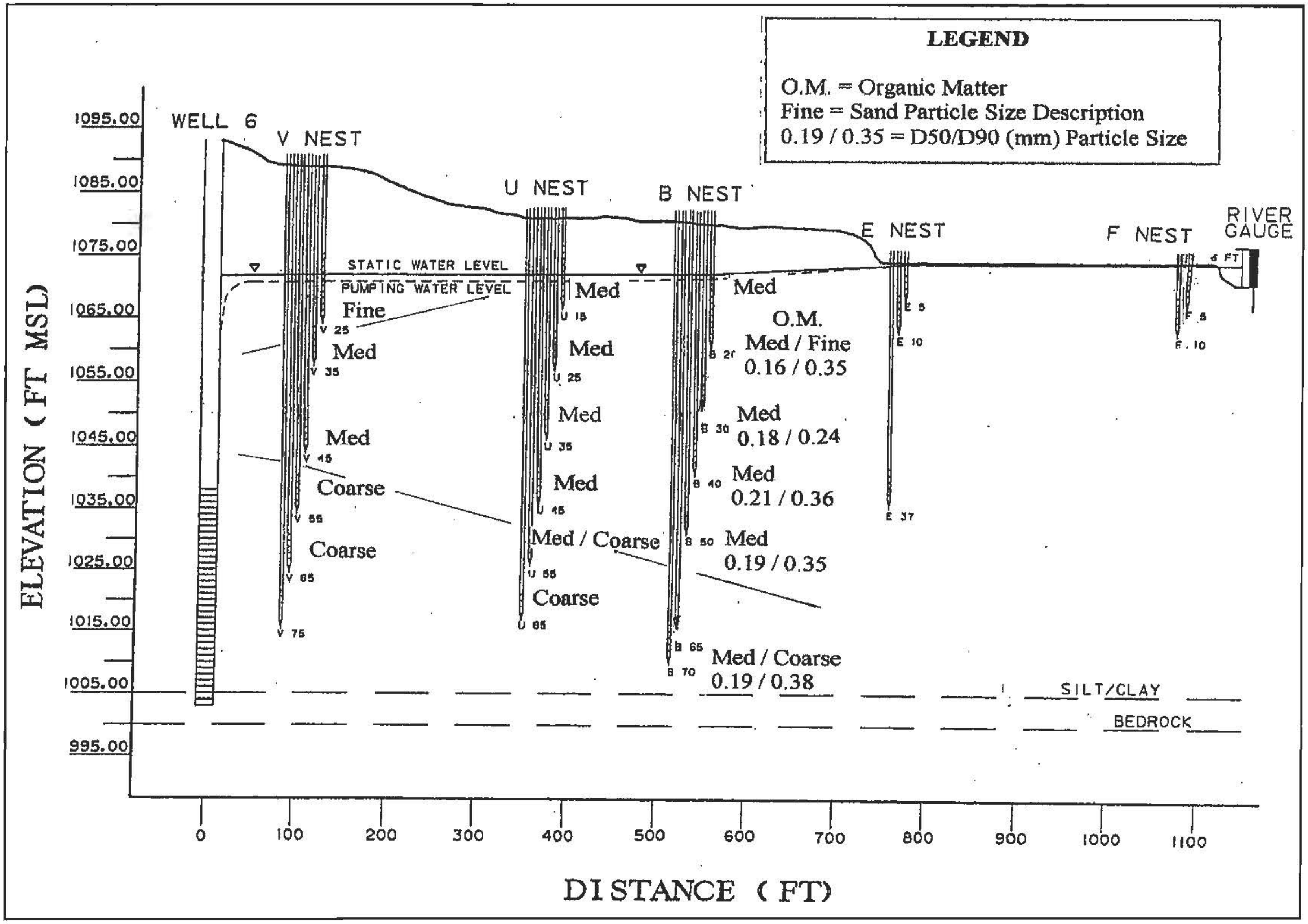


Figure 10 – Soil Particle Size Summary for Well 6 Transect

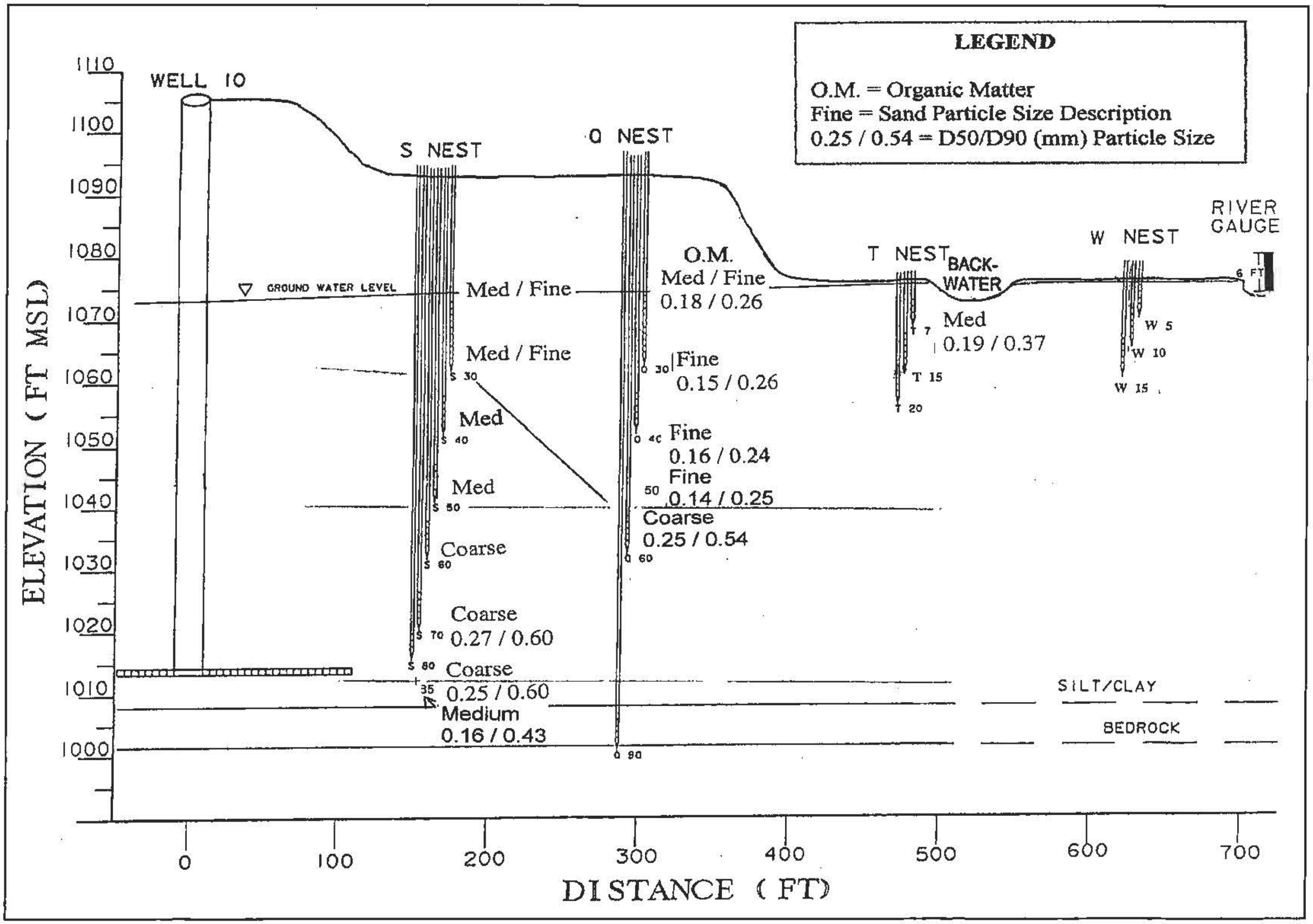


Figure 11 – Soil Particle Size Summary for Well 10 Transect

Figure 10 summarizes the soil particle size for the Well 6 transect. There was minor particle size stratification with soils primarily medium to coarse in size. The greatest particle size in the B Nest of the Well 6 transect was in the 40 to 70 foot depth interval. The coarser soils were found at greater depth and nearer Well 6. Black organic matter was found in sample B20, indicating a source of organic carbon near the groundwater table in the flowpath adjacent to the Plover River riparian area. Overall, Well 6 transect soils would be expected to transmit groundwater flow relatively evenly and at high rates.

Figure 11 summarizes the soil particle size for the Well 10 transect. There was significant particle size variation in the Well 10 flowpath. Soils are coarser nearest to Well 10 and in the deep strata (60 feet and greater). Well 10 transect soils would be expected to transmit groundwater flow unevenly with higher rates in the deeper strata.

The total iron and manganese concentration in soils along the Well 6 and 10 transects are summarized in Table 6 and Figure 12. Well 6 transect monitoring well soil samples include those from B Nest, U Nest, and V Nest. Figure 12 shows that manganese concentrations range from approximately 30 to 80 mg/kg. Manganese was present throughout the aquifer. Iron concentrations were found at significantly higher concentrations than manganese and range from approximately 2,000 to 5,000 mg/kg. Iron was also present throughout the aquifer. Well 10 transect monitoring well soils were sampled at the T Nest, Q Nest, and S Nest. Figure 12 shows that manganese concentrations were highly variable and ranged from 5 to 100 mg/kg. The highest manganese concentrations were found in the deeper soil depths where particle size was coarser. Iron concentrations range from 27 to 5,000 mg/kg. Iron occurrence patterns followed the same concentration pattern as manganese.

Porosity was measured at three soil pits in the Well 10 riparian area near T Nest (Pit 1), W Nest (Pit 2), and MW-47 (Pit 3) in the Plover River Riparian area. Porosity is an indicator of organic matter content and values greater than 0.4 indicate higher organic matter content in these soils. Figure 13 shows that porosity is higher than 0.4 at each of the test pits, ranging down to 20 to 30 cm in depth. Porosity is consistently approximately 0.4 below this interval. This indicates that organic matter content is high in the surface soils throughout the riparian area and lower beneath the surface interval.

Table 6 – Soil Iron and Manganese Testing Results

LOCATION	SAMPLE DEPTH (FT)	SAMPLE DATE	TOTAL Iron (mg/kg)	TOTAL Mn (mg/kg)
WELL 6				
B Nest	10	05/20/96	661.9	58.3
	20	05/20/96	5382.8	71.3
	30	05/20/96	3946.9	56.5
	40	05/20/96	4619.7	60.6
	50	05/20/96	1798.3	39.0
	60	05/20/96	268.5	78.3
U Nest	10	06/20/96	3644.9	46.3
	20	06/20/96	2227.3	32.6
	30	06/20/96	2677.3	44.5
	40	06/04/96	2588.7	34.5
	50	06/04/96	3698.2	82.7
	60	06/04/96	3131.2	75.3
V Nest	10	05/31/96	1603.5	58.5
	20	05/31/96	2057.0	31.9
	30	05/31/96	2487.3	30.7
	40	05/31/96	3210.4	33.9
	50	05/31/96	4194.8	79.5
	60	05/31/96	3293.9	55.3
WELL 10				
Q Nest	10	05/29/96	961.4	23.3
	20	05/29/96	71.2	34.4
	30	05/29/96	349.3	4.9
	40	05/29/96	27.0	13.1
	50	05/31/96	2506.2	27.6
	60	05/31/96	5029.0	64.9
R Nest	10	05/28/96	2135.8	77.8
	20	05/28/96	794.1	32.5
	30	05/28/96	259.2	36.5
	40	05/28/96	54.2	32.3
	50	05/28/96	174.9	18.9
	60	05/28/96	990.8	30.9
S Nest	10	07/09/96	2745.3	66.2
	20	07/09/96	1582.7	36.2
	30	07/09/96	1264.3	25.8
	40	07/09/96	1507.9	34.6
	50	07/09/96	2617.7	35.6
	60	07/09/96	1894.9	57.2
	70	07/09/96	4034.5	98.8
	80	07/09/96	3093.3	71.3
	85	07/09/96	8470.8	305.0
T Nest	10	05/30/96	1441.4	12.3
	15	05/30/96	1394.6	13.4

WELL #6 WELL #10

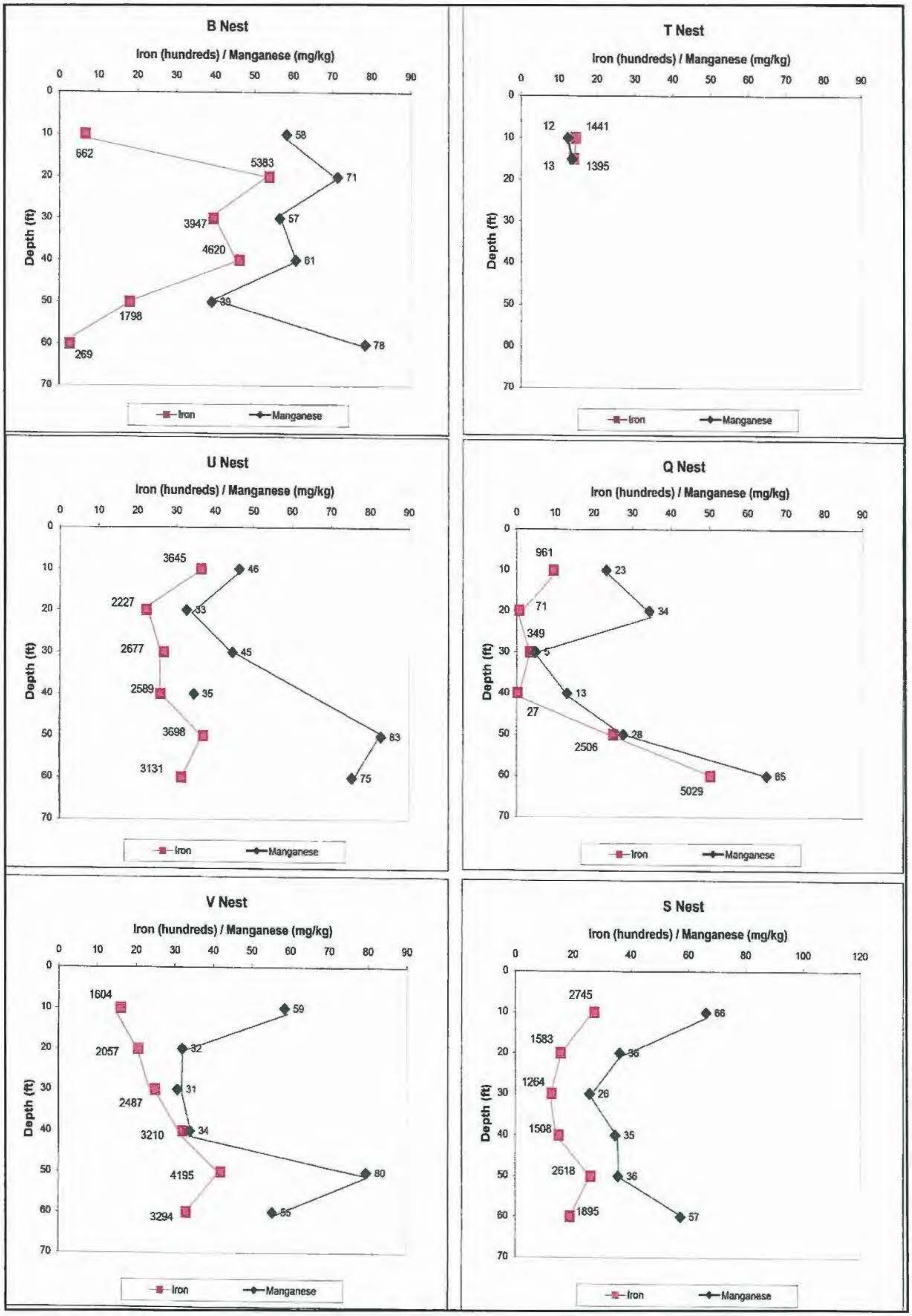
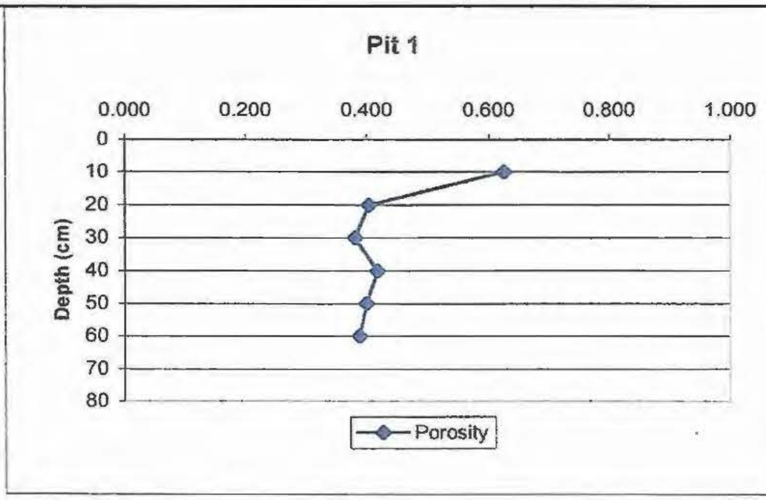
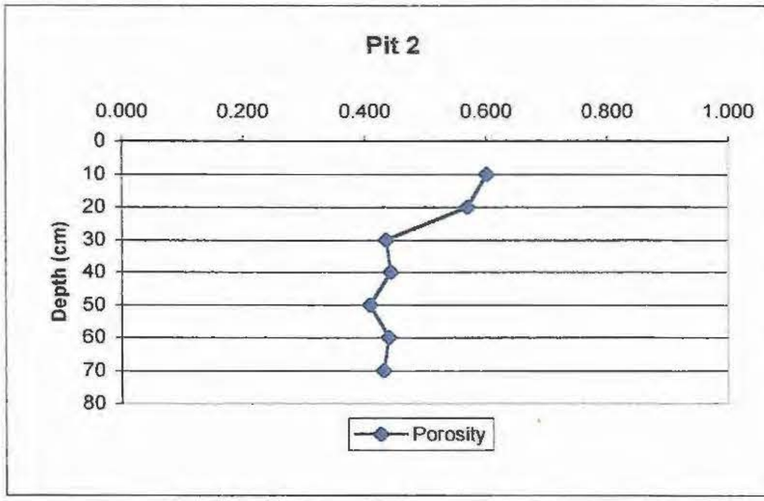


Figure 12 – Soil Iron and Manganese Concentrations

Pit	Depth (cm)	Porosity
1	10	0.626
	20	0.404
	30	0.380
	40	0.418
	50	0.400
	60	0.388
	70	



Pit	Depth (cm)	Porosity
2	10	0.601
	20	0.569
	30	0.435
	40	0.443
	50	0.409
	60	0.440
	70	0.431



Pit	Depth (cm)	Porosity
3	10	0.802
	20	0.730
	30	0.416
	40	
	50	
	60	
	70	

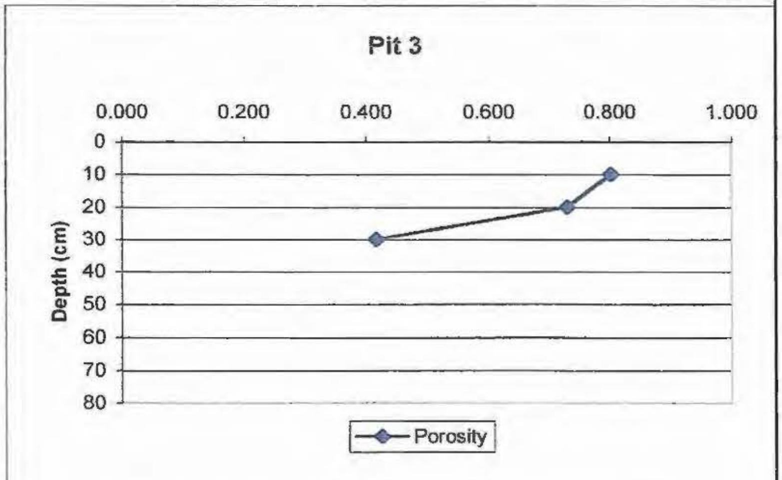
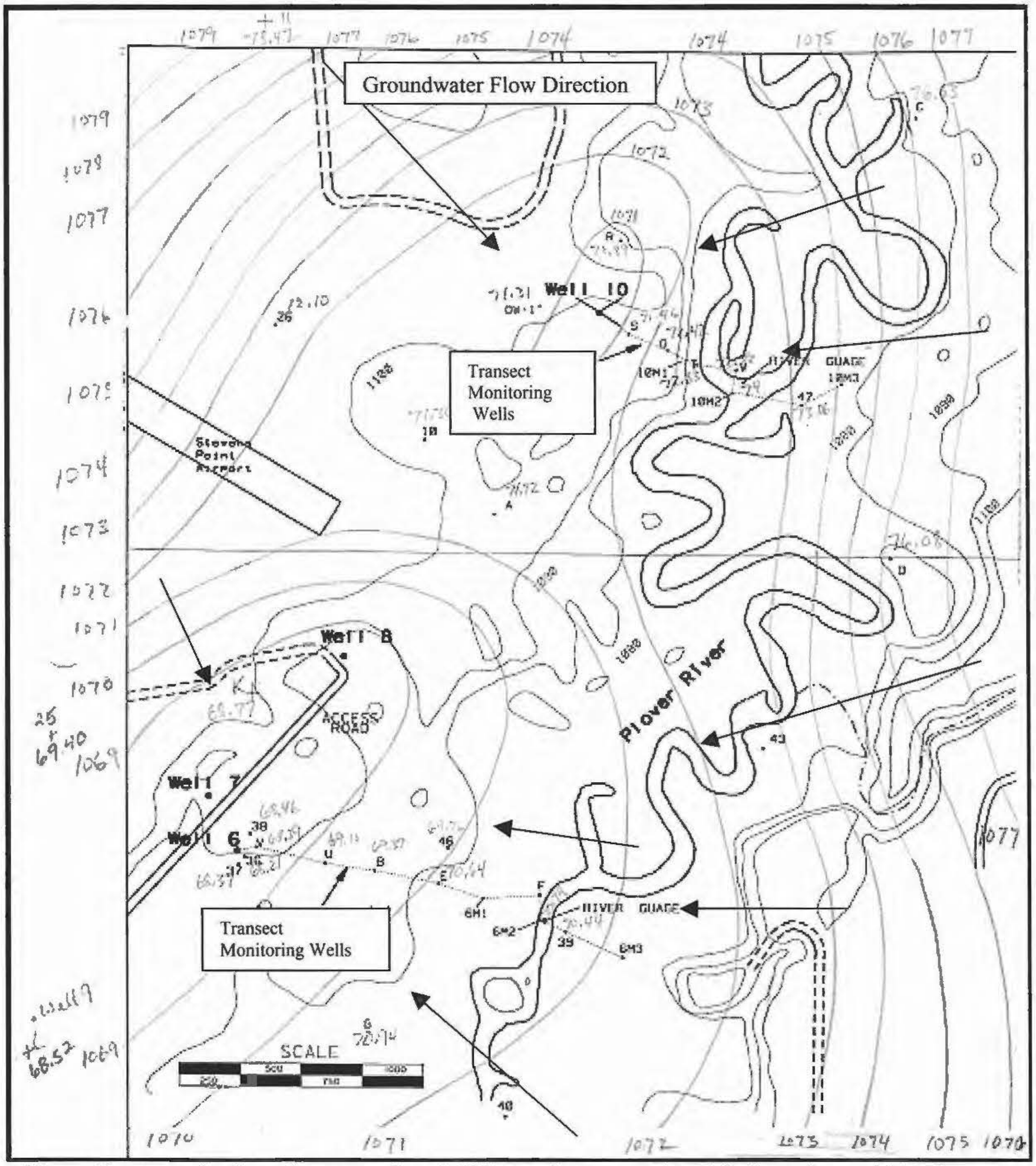


Figure 13 – Test Pit Soil Porosity Summary

HYDROGEOLOGICAL TESTING

Hydrogeologic testing includes wellfield area water level mapping, transect water levels, transect hydrogeology summary, streambed and riparian area groundwater flow analysis, and wellfield area water balance.



Note: Contours in feet above sea level. Where shown sea level is feet above 1000 ft

Figure 14 – Area Water Table Map

A wellfield area water level map was developed from water level readings at area wells on November 7, 1998. An area water table map is provided in Figure 14. Groundwater contours are consistent with the regional groundwater flow map (Figure 6) and suggest major zones of contribution from the northwest (west of Plover River) and northeast (east of Plover River).

Large pumping centers are shown in Figure 14 surrounding each of the pumping wells, changing the natural groundwater flow patterns. One large pumping center surrounds Wells 6, 7, and 8. A second pumping center surrounds Well 10. The water table map contours show how groundwater from the aquifer beneath the Plover River could induce recharge from the River. The steep groundwater gradient east of the Plover River near Well 10 shows the Plover River as a partially penetrating groundwater boundary in this area and suggests the river is a greater source of groundwater contribution in the area east of Well 10 than in the Well 6 area. Flow contribution in this area from east of the Plover River also varies at C Nest, indicating fluctuation in the partially penetrating Plover River groundwater boundary. In contrast, the groundwater boundary east of Well 6 extends well east of the Plover River, showing more significant contribution from river underflow than Well 10.

The capacity of an aquifer to transmit water is defined by the hydraulic conductivity and transmissivity. Hydraulic conductivity is directly related to the rate of flow through the aquifer. The transmissivity is the amount of flow through the aquifer, as the product of hydraulic conductivity and saturated thickness. Aquifer capacity for the Well 6 and 10 areas was evaluated for both literature and calculated values (Table 7).

Table 7 – Well 6 and 10 Hydrogeological Conditions

Well	Hydraulic Conductivity			Saturated Thickness	Transmissivity (T)
	Literature (Kraft, et al., 1996)		Calculated[1]		
	(m/s x 10^{-4})	(gpd/ft^2)	(m/s x 10^{-4})	(m)	(m^2/s)
6	44.3	9392	97.2	25.3	9684
10	38.5	8162	76.8	19.2	6387

Notes: [1] Calculated by Hazen Approximation

Table 7 shows that the hydraulic conductivity is slightly higher at Well 6. Hydraulic conductivity results indicate that literature and calculated values are similar. The transmissivity was about 30 percent higher in the Well 6 area, primarily due to the greater aquifer thickness in this area. These results indicate that the Well 6 area had a greater capacity for water transmission. This is reflected in the greater specific capacity at Well 6 compared to Well 10 (see Table 2).

GROUNDWATER FLOW CHARACTERIZATION FROM WATER LEVEL MEASUREMENTS

Water level measurements were used to characterize groundwater flow direction and velocity in the Well 6 and Well 10 transects (Appendix 3). The gradient between V Nest and E Nest was chosen to represent the stable area groundwater gradient that was not subject to daily changes in well pumpage or river flow at the Well 6 transect (Table 8). The gradient between S Nest and T Nest was chosen for Well 10 (Table 9). Results show that both Wells 6 and 10 project a cone of depression that extend outward to the Plover River and associated riparian areas as illustrated by Figure 15. Winter, et al (1998) have described this effect as common in shallow unconfined aquifers the type in this study. It also describes that recharge of the shallow ground water from the surface sources commonly affects water quality between the well and stream, as well as water quality at the pumping well.

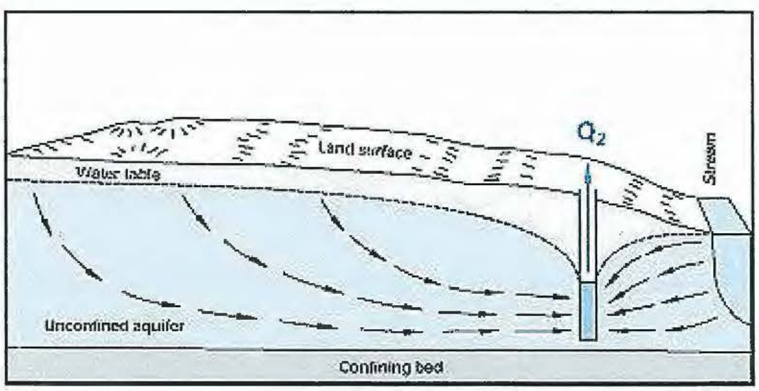


Figure 15 – Typical Flow Paths for Pumping Wells in a Shallow Unconfined Aquifer with Nearby Surface Water Source

Table 8 – Well 6 Area Groundwater Gradient and Travel Time Summary

WELL 6 AREA - V Nest to E Nest				
Date	GW Gradient (ft)	GW Gradient (ft/ft)	GW Velocity (ft/day)	GW Travel Time (days)
9/96	0.88	0.00126	6.3	110.9
3/97	1.92	0.00274	13.8	50.8
4/97	1.00	0.00143	7.2	97.6
5/97	2.10	0.00300	15.1	46.5
7/97	2.28	0.00326	16.4	42.8
8/97	2.12	0.00303	15.2	46.0
9/97	2.28	0.00326	16.4	42.8
3/98	1.08	0.00154	7.7	90.7
Average	1.71	0.00244	12.2	66.0

Notes:
$K = 44.3 \times 10^{-4}$ M/S ; 1255 ft/day ; 9392 gpd/ft^2 (Kraft, 1996)
SY = 0.25
V = K (Gradient)/SY
Distance V to E = 700 feet

Table 9 - Well 10 Area Groundwater Gradient and Travel Time Summary

WELL 10 AREA - S Nest to T Nest				
Date	GW Gradient (ft)	GW Gradient (ft/ft)	GW Velocity (ft/day)	GW Travel Time (days)
9/96	0.93	0.00264	9.6	36.4
3/97	0.97	0.00277	10.1	34.8
4/97	1.19	0.00340	12.4	28.3
5/97	1.39	0.00397	14.4	24.3
7/97	1.23	0.00351	12.8	27.4
8/97	0.92	0.00263	9.6	36.6
9/97	1.22	0.00349	12.7	27.6
3/98	N/A	N/A	N/A	N/A
Average	1.12	0.00320	11.6	30.8

Notes:
$K = 38.5 \times 10^{-4}$ M/S ; 1090 ft/day ; 8162 gpd/ft^2 (Kraft, 1996)
SY = 0.30
V = K (Gradient)/SY
Distance S to T = 350 feet

Tables 8 and 9 also show that the average calculated gradient at Well 10 was greater than Well 6. A higher gradient between the well and surface water source at Well 10 could indicate that there is more draw on the surface source at Well 10 than Well 6. The Well 6 gradient also showed more variability than Well 10. This may be due to the difference in focused recharge affect at the pumping wells during riparian area flooding events.

Focused recharge is illustrated in Figure 16 (Winter, et al, 1998), where flooding over bank conditions cause recharge of the adjacent upland areas. Focused recharge due to riparian area flooding can greatly increase groundwater recharge nearer the pumping well, resulting in a shallower cone of depression gradient. This effect was observed in April 1997 in the Well 6 area where flooding conditions caused reduction in the gradient to 1.00 feet, while it was commonly greater than 2 feet during the dryer months of May to September 1997 when no riparian flooding occurred. There was no significant change in the gradient at Well 10 over this same period as focused recharge apparently had less impact on the groundwater gradient due to the more limited riparian zone area.

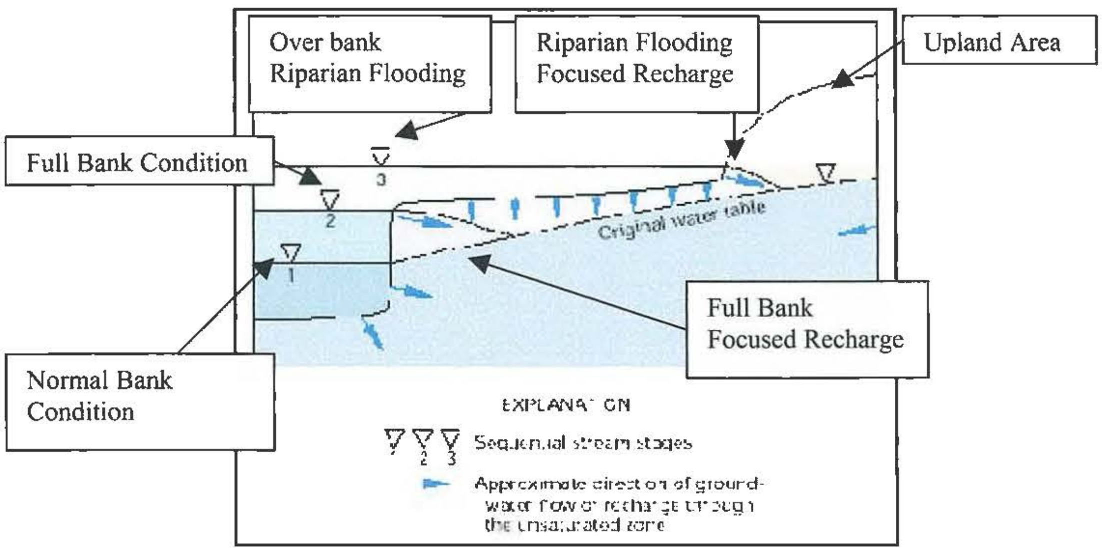


Figure 16 – Focused Recharge Illustration During Over Bank Conditions

The Plover River commonly overflows its banks from spring runoff and high precipitation events, resulting in riparian area inundation two or three times each year. Figure 17 shows the typical riparian area flooding event. On May 28, 1996 it was noted that the Well 6 riparian area flooded to a depth of approximately 2 feet in the E Nest area. Figure 18 includes photographs of this event. The riparian area west of the Plover River in the Well 6 area is approximately 400 feet wide. The river water inundating the riparian area creates focused recharge and drains to the groundwater. The water table can be much as 4.5 feet lower during dry periods compared to significant inundation events such as that recorded in late May and early June 1996. Under long term pumping conditions the gradient is well below the riparian surface and soil moisture drains by gravity from this zone to the water table. During inundation or wet conditions the riparian zone is saturated. The groundwater in this area also gains dissolved organic carbon (DOC) as the riparian zone contribution leaches the organic matter from this zone. The cycles of growth and decay of dense ground vegetation and leaf litter provide a source of DOC.

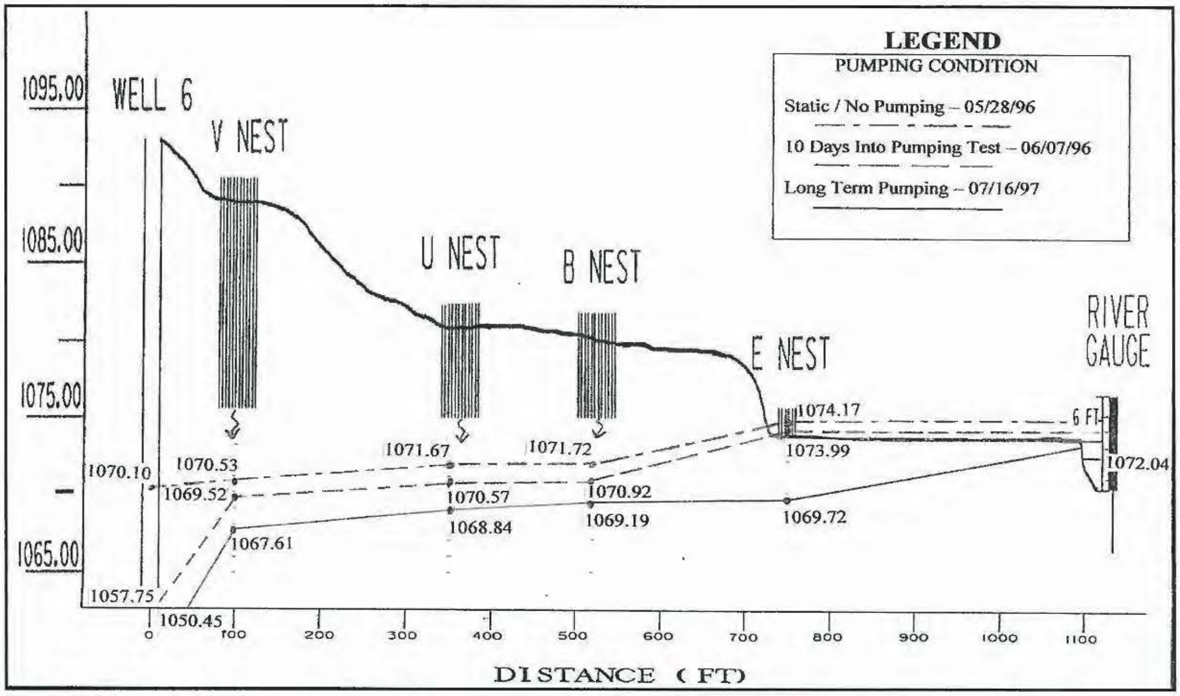


Figure 17 – Comparison of Well 6 Transect Water Table Elevations During Static and Pumping Conditions

The effects of well pumping on Well 6 transect water table levels were examined at static and pumping conditions (Figure 17). Riparian flooding is an additional variable, as the flooding occurred at the start of the drawdown test. Results show that groundwater levels were influenced significantly by Well 6 pumping throughout the transect. After more than one year of pumping it was observed that Well 6 drawdown was 20 feet, and terrestrial monitoring well (V to B Nest) drawdown was 2.5 to 3 feet. This indicates that Well 6 pumping strongly influenced the extent of the pumping well cone of depression.

A similar drawdown test was not conducted at Well 10 because this well could not be shut down for an extended period of time. Significant differences are expected between Wells 6 and 10 regarding the role of the riparian zone and river contribution. Figure 8 shows that the 1080 foot MSL contour closely approximates the start of the riparian zone. The riparian zone is smaller in the Well 10 area compared to the Well 6 area. The Plover

River is also approximately half the distance to the well at Well 10 compared to Well 6. As a result, it is expected that the riparian zone contribution would be lower in the Well 10 area.

Figure 18 – Riparian Inundation Event and Organic Soils Photographs

Groundwater velocity and travel time results for the Well 6 and 10 areas calculated using the measured gradient and known hydrogeological conditions (Table 7) are presented in Tables 8 and 9. Groundwater velocity is similar in the two transects. Groundwater travel times from the river to Well 10 are significantly less than at Well 6 due to the distance of travel. The groundwater travel times from the Plover River average 66 days at Well 6 and 31 days at Well 10.

Groundwater flow direction in the two dimensional cross section of the transects is shown in Figures 19 and 20. This is a two dimensional approximation of radial flow pattern to the pumping wells. The lowest potentiometric level of each well nest is shown in bold print as an indication of the direction of groundwater flow. Water level information shown is from August 1997 (Appendix 3).

Groundwater flow in the Well 6 flow path is generally horizontal with some vertical migration from surface sources. Flow contribution is primarily from regional groundwater with periodic riparian recharge and minor river influence. This is illustrated

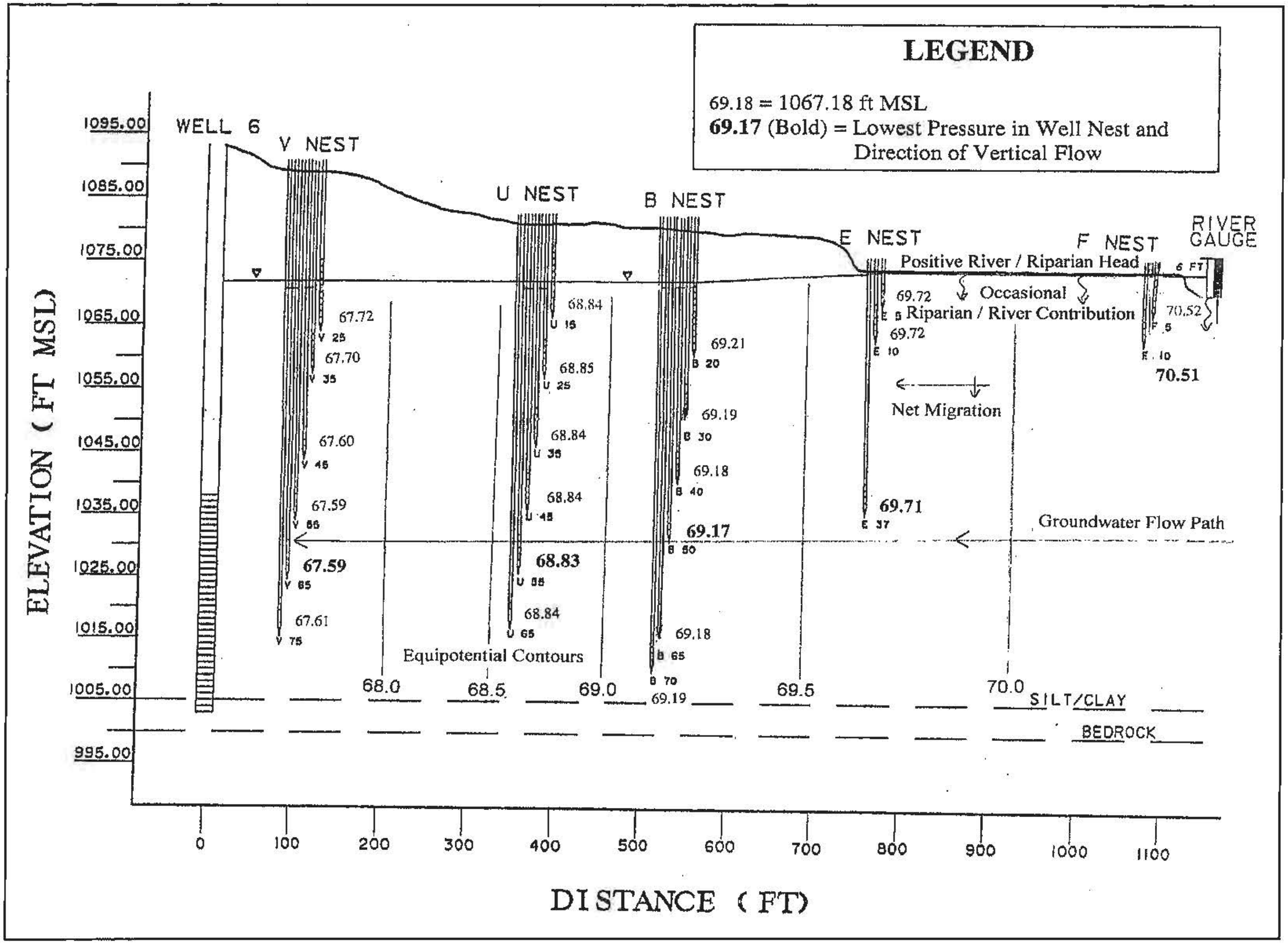


Figure 19 – Well 6 Area Groundwater Flowpaths

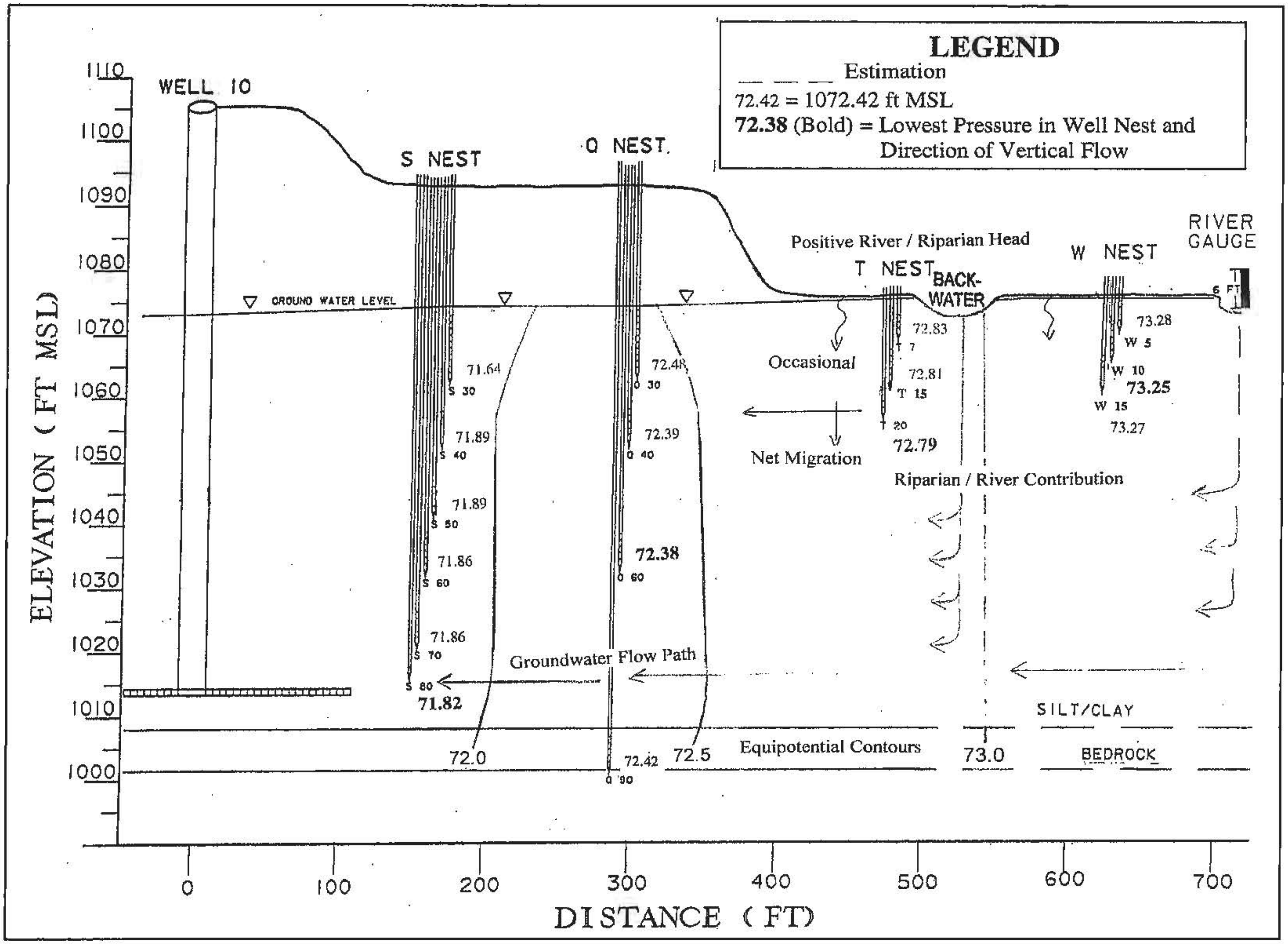


Figure 20 – Well 10 Area Groundwater Flowpaths

by increased equipotential line spacing in the riparian and river areas. Riparian zone vertical contribution would be most significant during inundation and precipitation events. Vertical migration would be much more limited during dry periods. Groundwater contribution originating from the easterly direction would be a mixture of local and regional groundwater.

Groundwater flow in the Well 10 flow path is different than Well 6. The flow path is horizontal near the well, but has a greater vertical contribution nearer the Plover River than found at Well 6. This shows the effect of significant river contribution in the Well 10 area. This effect is also shown by area water table map (Figure 14) where there is a lower gradient between Well 10 and the Plover River, and a much steeper gradient east of the Plover River.

HYDRAULIC CONNECTION DETERMINATION OF RIVER AND AQUIFER USING MINI-PIEZOMETERS AND TEMPERATURE PROFILING

The location of mini-piezometers installed in the Well 6 and Well 10 river, and backwater area of Well 10, are shown in Figure 8. Mini-piezometers were monitored in two sampling events in May/June and July/August 1996. Upwelling and downwelling flow was determined by the timed falling head test performed at each installation. The falling head test calculation provides an estimate of upwelling or downwelling velocity (ft/day).

Well 6 area mini-piezometer testing results are provided in Figure 21. Well 6 results for June testing indicate slight flow from the aquifer to the stream (upwelling) during both sampling events. Upwelling velocities were between 0 and 1.0 ft/day at the river installations during both sampling events. Results show that Well 6 did not induce strong recharge from the stream at the transect location.

Well 10 area mini-piezometer testing results are shown in Figure 22. The testing in May showed a range of upwelling and downwelling conditions in both the river and backwater riparian locations. May river upwelling velocities were highest in the northern section

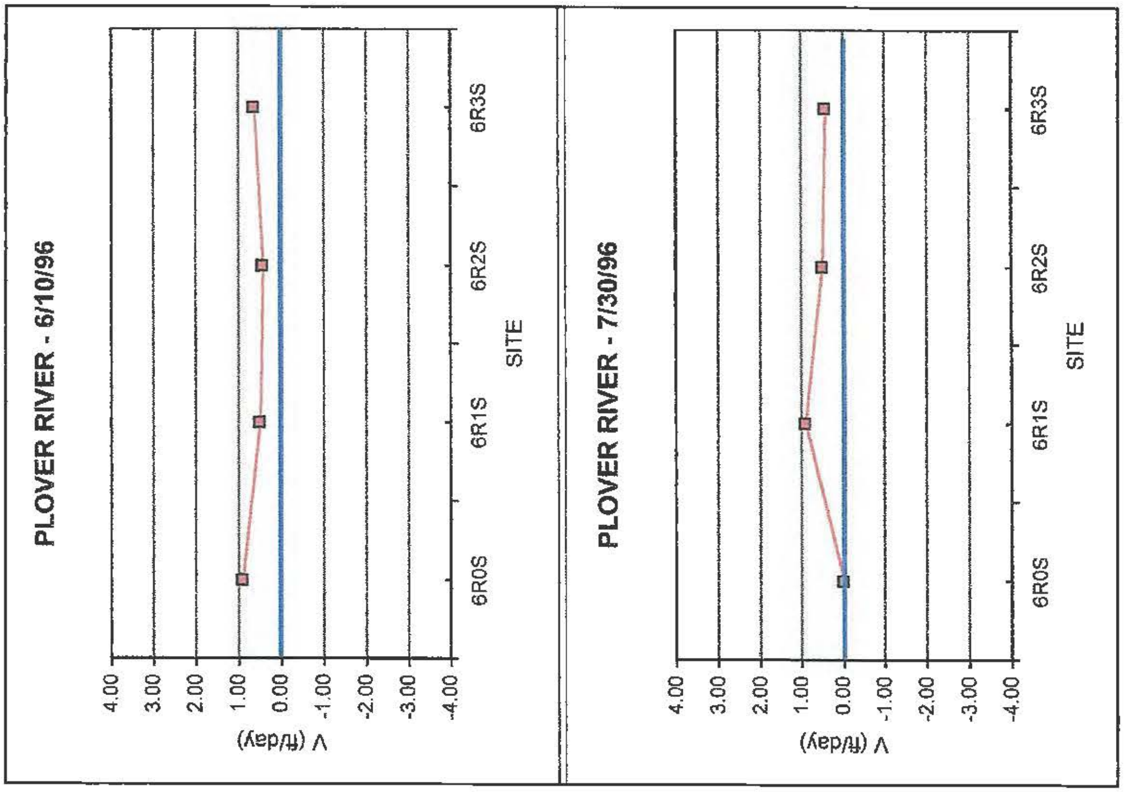


Figure 21 – Well 6 Area Mini-piezometer Testing Results

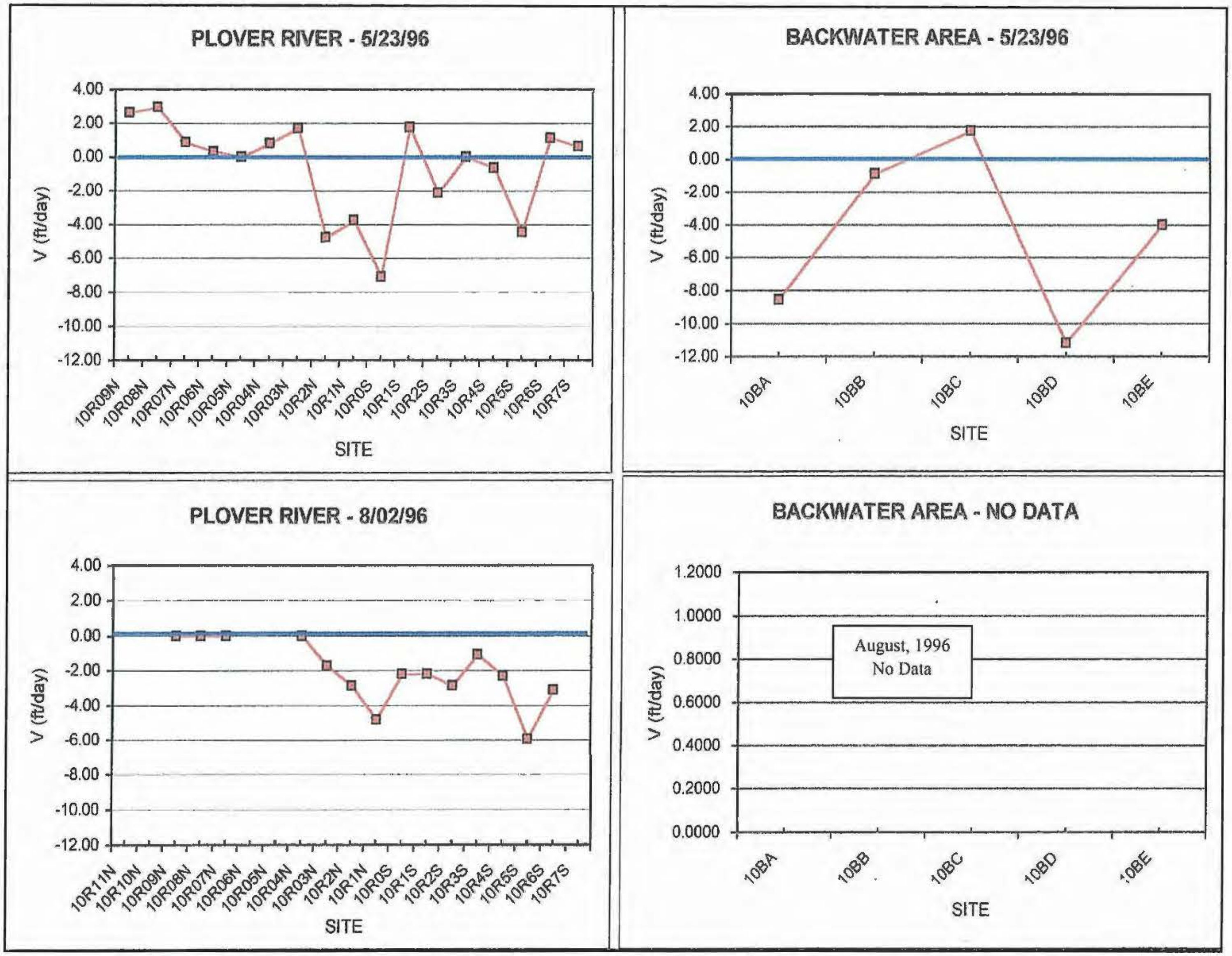


Figure 22 – Well 10 Area Mini-piezometer Testing Results

(2.95 ft/day at 10-R-09N). Downwelling velocities were focused in a narrow band of river area roughly in line with the Well 10 transect to the river. The greatest downwelling was found at 10-R-0S (7.08 ft/day). May backwater riparian area velocities have several extreme downwelling velocities, with the lowest at 11.2 ft/day. The backwater riparian area was not tested in August as the mini-piezometers could not be re-located in the silty bottom materials. Downwelling velocities were noted at ten river mini-piezometer locations with flow velocity greater than 1.0 ft/day. This represented a river segment of approximately 2,000 feet in length from 10-R-3N south to 10-R-6S. The highest downwelling velocities were at 10-R-1N and 10-R-5S (5 to 6 ft/day). Both locations are southeast of Well 10.

Well 10 mini-piezometer results indicated that there was strong river downwelling and suggests the well pumping induced significant groundwater recharge from the river and backwater. Downwelling also extended over a large area of influence. The downwelling effect was visually observed as water routinely flowed up (north) into the backwater area from 10-R-2N toward 10-B-A and 10-B-B. This effect was most notably observed during dryer periods.

A temperature study was conducted at Well 10 in December 1996 to evaluate the extent of downwelling penetration of cold surface waters (<1 degree C) into the groundwater during the early winter. The test was conducted at several mini-piezometer and monitoring well nests installed in the upland riparian, backwater riparian, and Plover River areas along the Well 10 transect. Mini-piezometers were installed in these areas at depths up to 10 feet below ground surface. Monitoring well depths extended to 20 feet. The temperature measurements (Figure 23) showed vertical cold water temperature incursions at locations 10M1, T Nest, 10M2, and 10M6. This pattern was indicative of downwelling flow originating from both the backwater area and Plover River. The low temperatures below the backwater and river were consistent with a relatively short time period (30 to 60 days) of cold river water entering the aquifer.

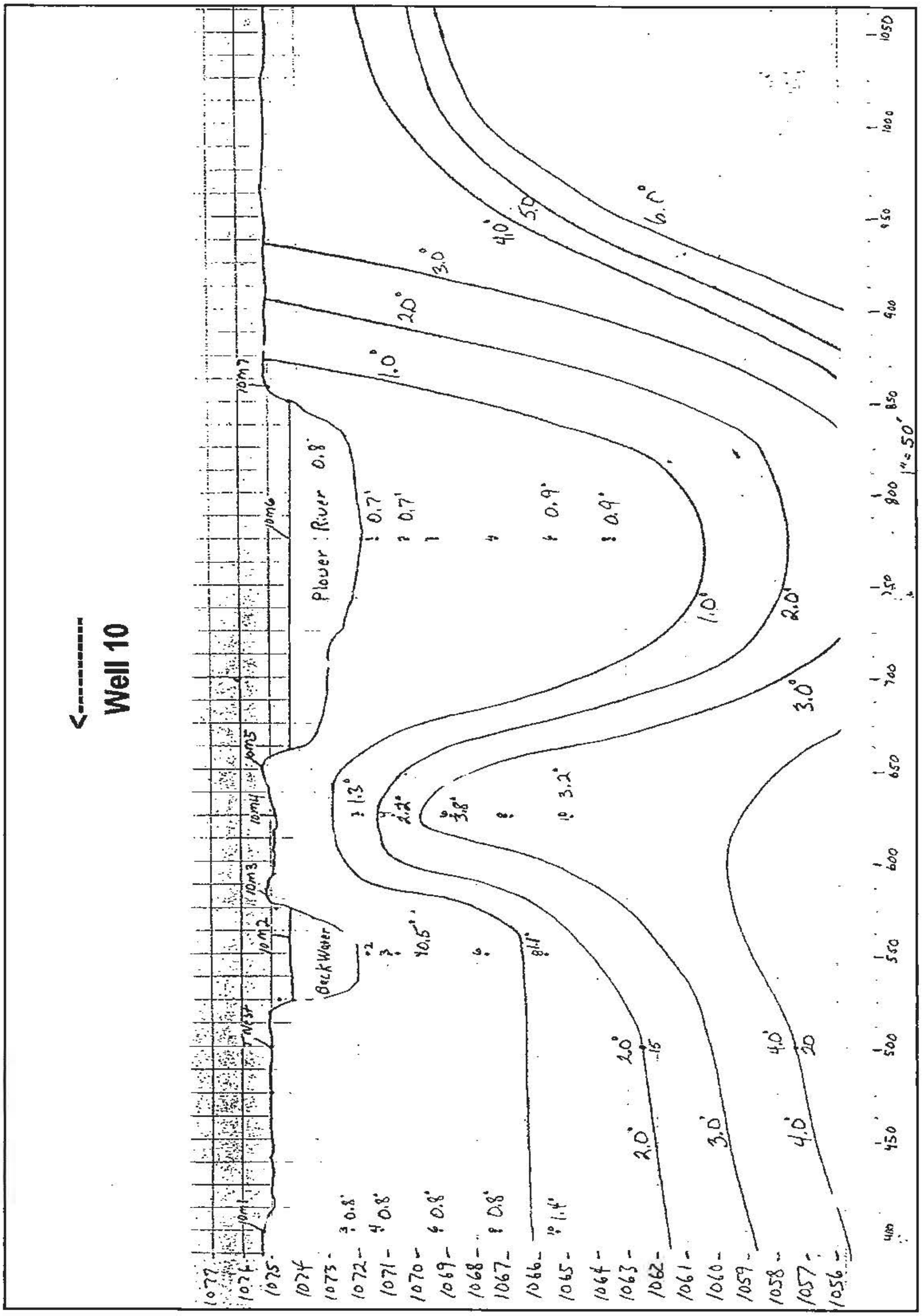


Figure 23 – Well 10 Area Temperature Gradient Map – December 1996

WELL 6 AREA GEOCHEMISTRY

Samples were collected for geochemical testing at Well 6 area locations in March, May, and July 1997, and at selected locations in 1996. Testing results are summarized in Appendix 4. Well 6 geochemical testing results are illustrated in Figures 24 through 32. The Figures show average values over the collection period and interpolated transect iso-concentration lines.

DO and DOC results from the Well 6 transect are shown in Figures 24 and 25. These parameters are key indicators of reducing conditions in the flowpath. DO concentrations were high (greater than 10 mg/L) in the upper portions of the aquifer below the upland recharge area, indicating that recharge from this area was high in DO. DO concentrations were low (less than 0.1 mg/L) beneath the riparian and river areas, indicating that recharge from this area is DO consuming. The transition of DO concentrations is sharp between the terrestrial and riparian zone recharge areas, indicating that DO is rapidly consumed when high DOC water from the riparian zone mixes along the flow path. DO is depleted completely in the 20 foot zone between wells B 20 and B 40. DOC concentrations suggest a plume of DOC originating from the riparian zone. DOC concentrations were high (greater than 6 mg/L) in the riparian recharge area represented by E Nest, indicating this area is a significant source of DOC in the flowpath. High concentrations of DOC are associated with leaching of surface water through the organic mat that contributes significant flow to groundwater recharge. The DOC plume dissipates to a large extent when reaching 1025 ft. MSL at well U55. Microbial consumption would be expected to be significant and rapid along this zone as a rich food source. Dispersion would also reduce DOC concentrations. The DOC plume originating at E Nest has resulted in complete DO depletion in the 200 foot distance to well B 40 at 1040 ft. MSL. Results show that a high DOC concentration plume was closely related to DO dissipation. The transition zone is consistent with hydrogeological information that showed significant riparian zone recharge contributed to local and regional groundwater recharge in the Well 6 flowpath.

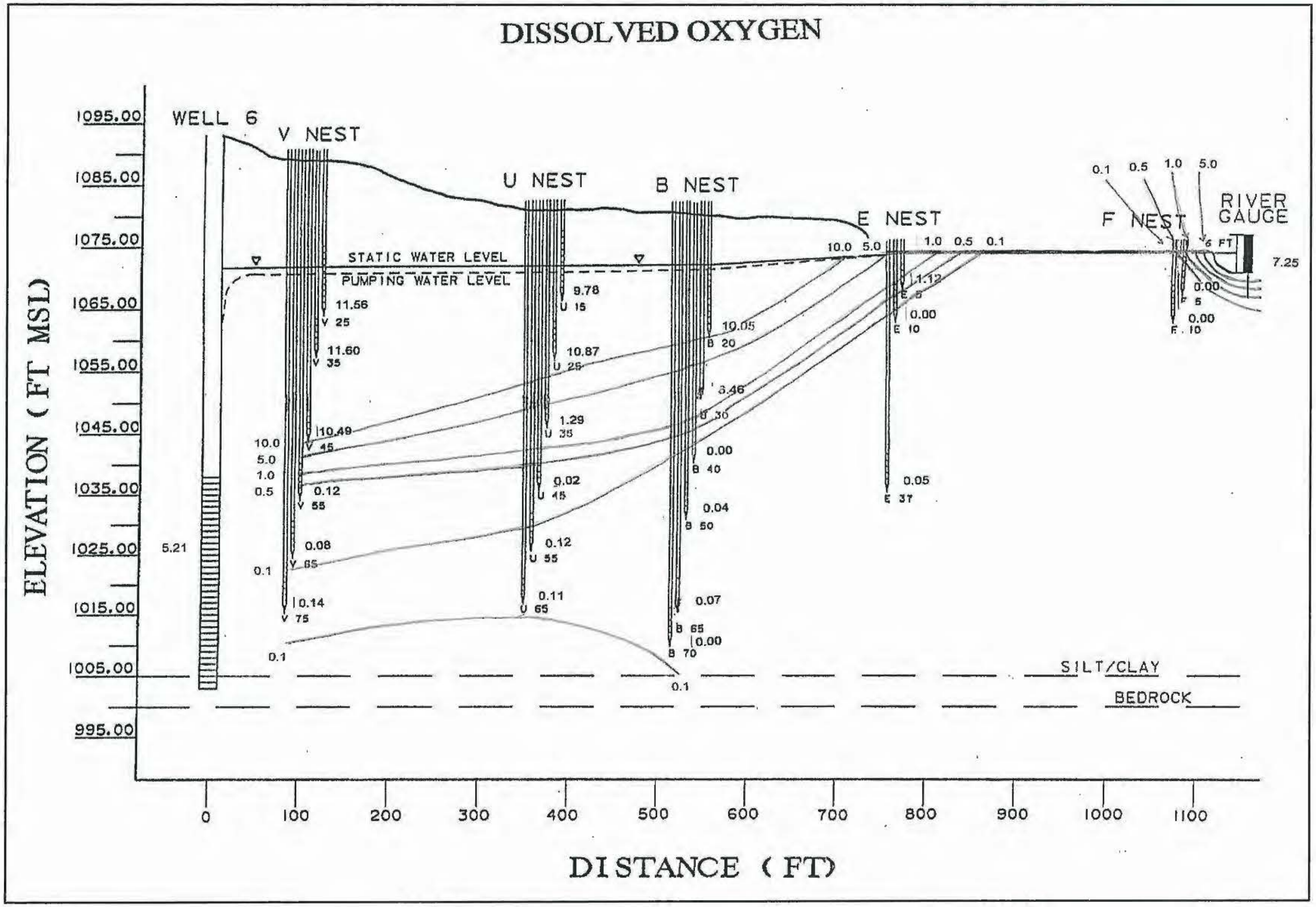


Figure 24 – Well 6 Transect DO Cross Sectional Profile

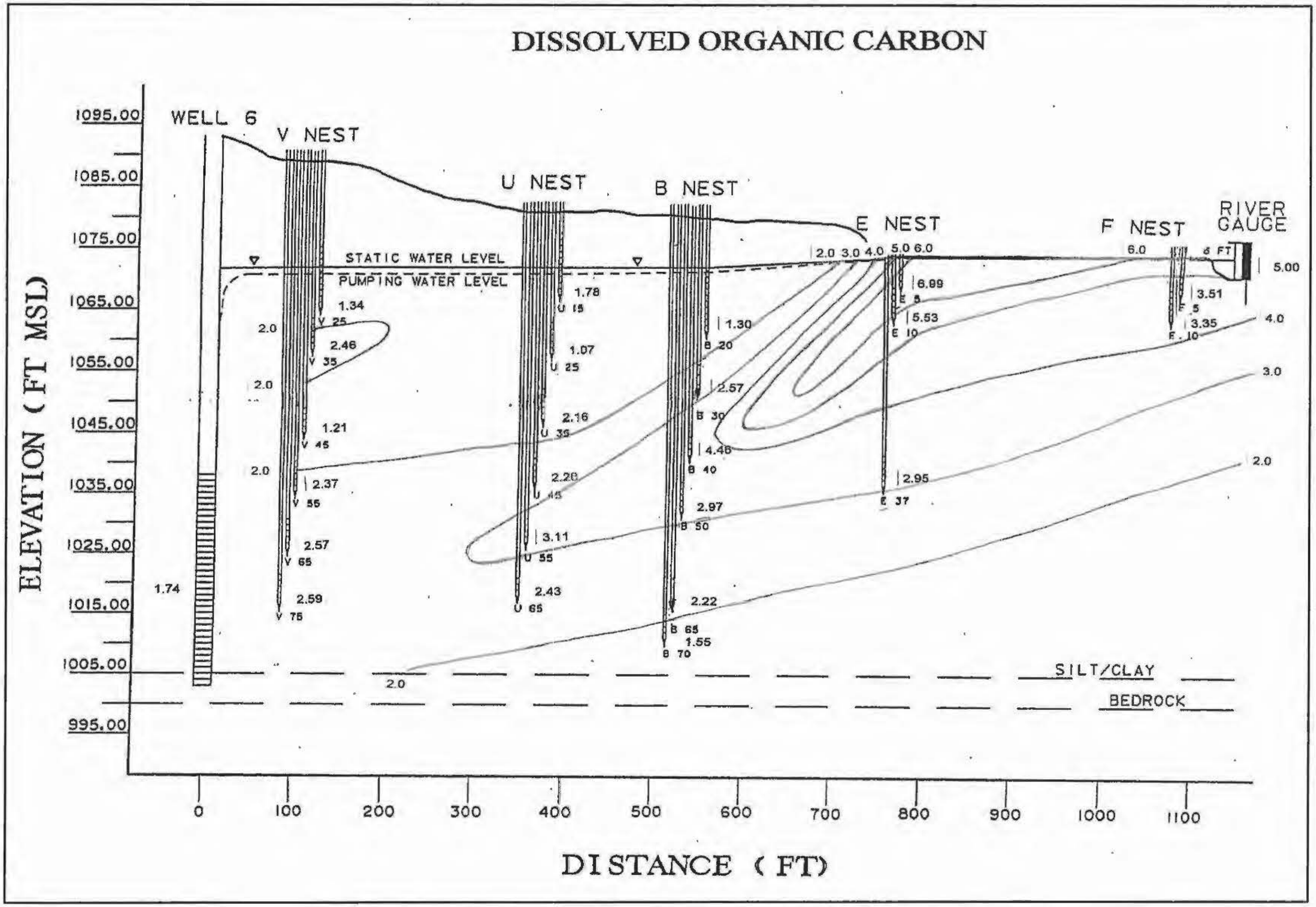


Figure 25 – Well 6 Transect DOC Cross Sectional Profile

Nitrate results (Figure 26) show a distinct nitrate plume that extends horizontally in the 1020 to 1040 ft. MSL depth range. The plume appears to originate from high nitrate concentrations with the significant underflow component of Well 6 recharge. The nitrate plume dissipation is coincident with DOC plume dissipation in this zone. Nitrate concentrations are nearly 4 mg/L at well B50 and depleted to background levels (1.1 mg/L) in the 200 foot zone to U55. Nitrate reduction can occur by microbial processes where nitrate serves as an electron acceptor for organic matter oxidation in the absence of oxygen. Rapid nitrate reduction in this zone suggests the presence of anaerobic type reduction that is dependent upon DOC introduction in the Well 6 flowpath.

Sulfate results are shown in Figure 27. The reduction of sulfate is expected after nitrate, manganese, and iron (Figure 3). Results show a sulfate plume extending horizontally and at the same depth interval as the nitrate plume (1020 to 1040 ft MSL). Background sulfate concentrations are approximately 13 mg/L, and are 27 mg/L in the center of the plume at 1030 ft. MSL. The plume differs from nitrate in that it continues to Well 6 and there is no evidence of sulfate depletion in the flow path.

Chloride and total hardness are shown in Figures 28 and 29. Chloride and total hardness are inert indicator parameters that are an indication of water origin. Results confirm underflow in a similar plume pattern to sulfate at 1020 to 1040 ft. MSL. Table 10 is a comparison of approximate concentrations of chloride, sulfate, and total hardness (Figures 27 thorugh 29). Well 6 concentrations are similar to the river underflow. The comparison shows that other sources contribute to underflow based on diluted concentrations at Well 6.

Table 10 – Well 6 Source Water Origin Summary

Contribution Sources	Sulfate (mg/L)	Chloride (mg/L)	Total Hardness (mg/L)
Underflow	25	15	225
Plover River	9	8	188
Riparian Zone	6	2	180
Upland Zone	9	0	110
Well 6	20	10	196

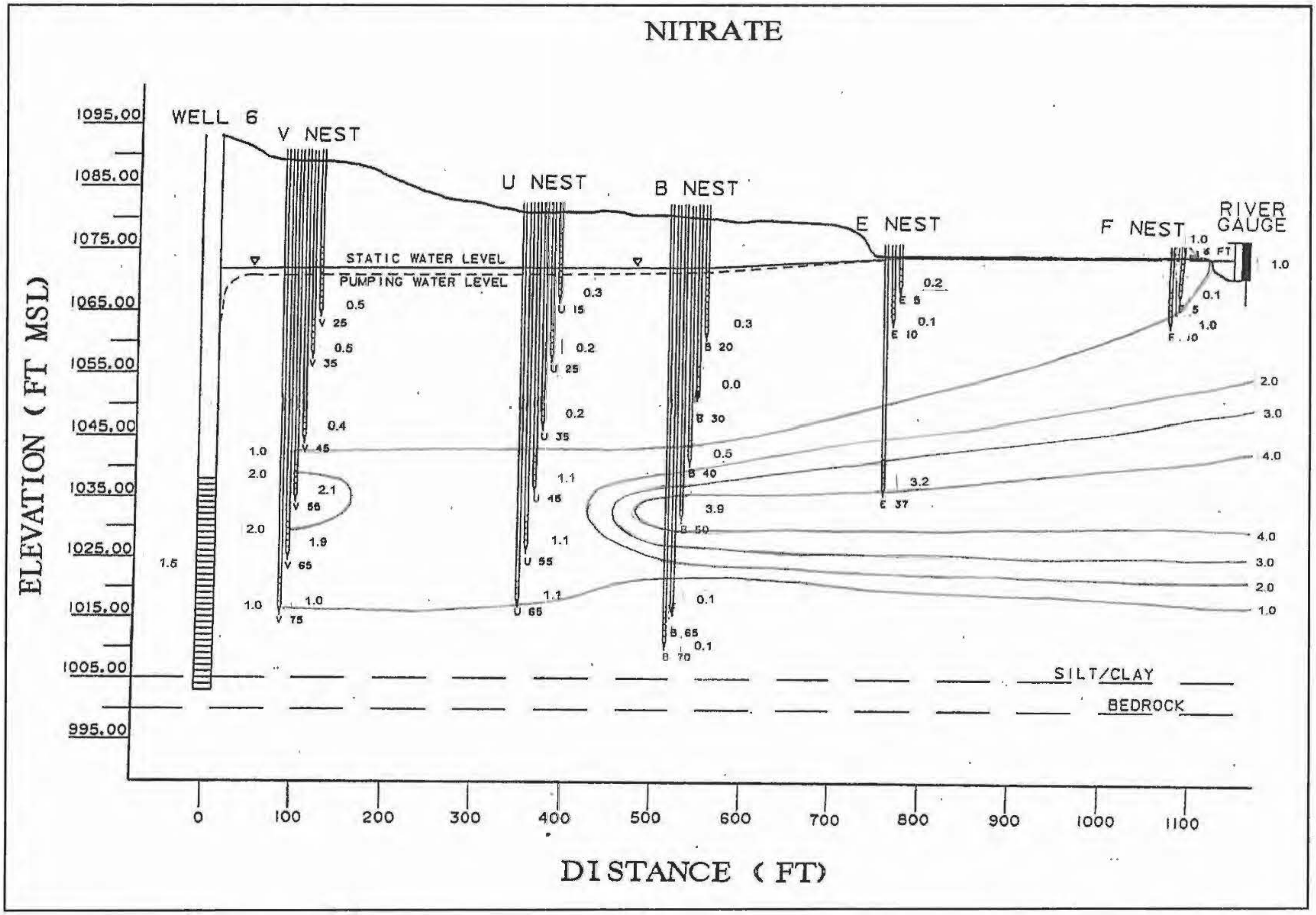


Figure 26 – Well 6 Transect Nitrate Cross Sectional Profile

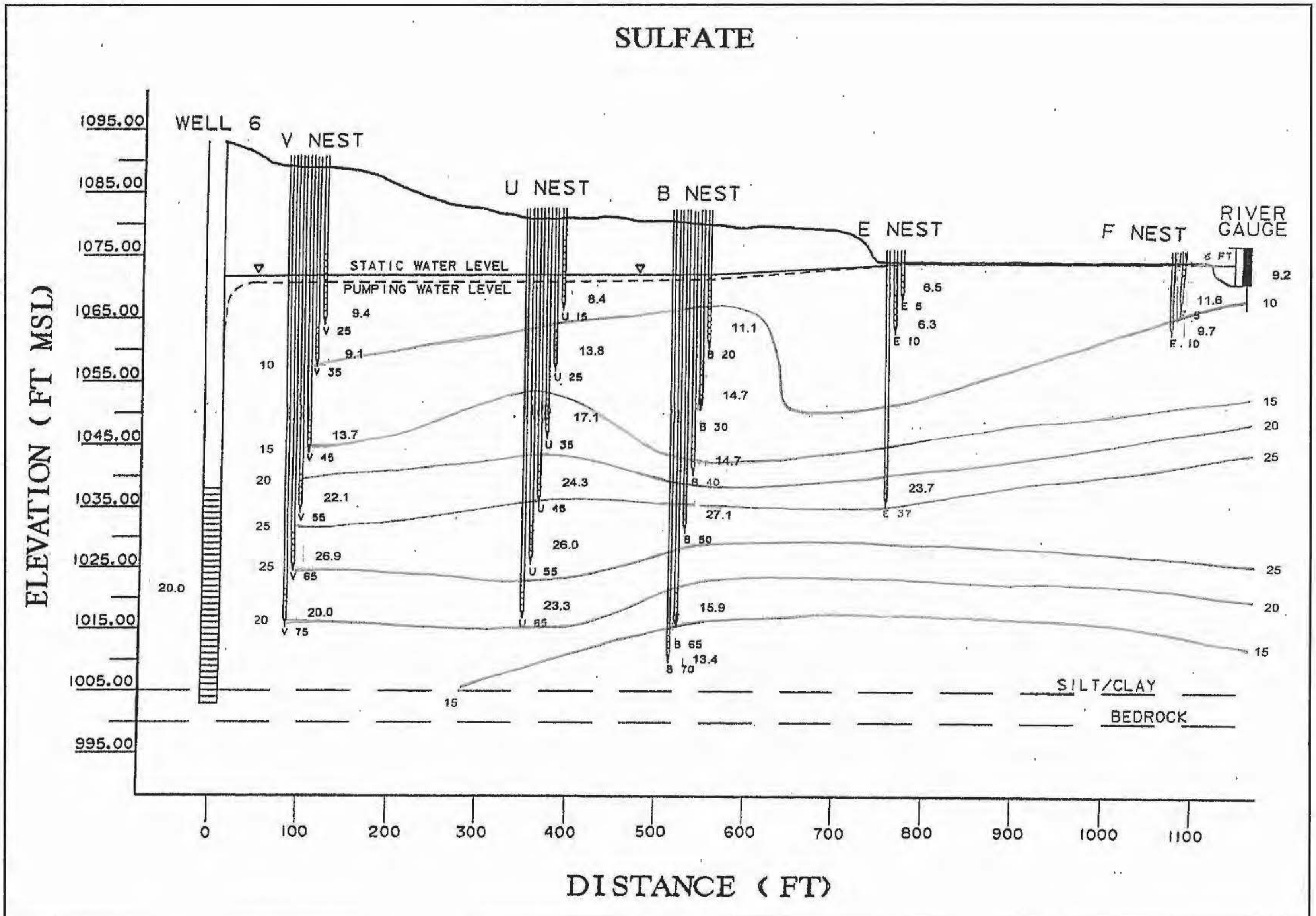


Figure 27 – Well 6 Transect Sulfate Cross Sectional Profile

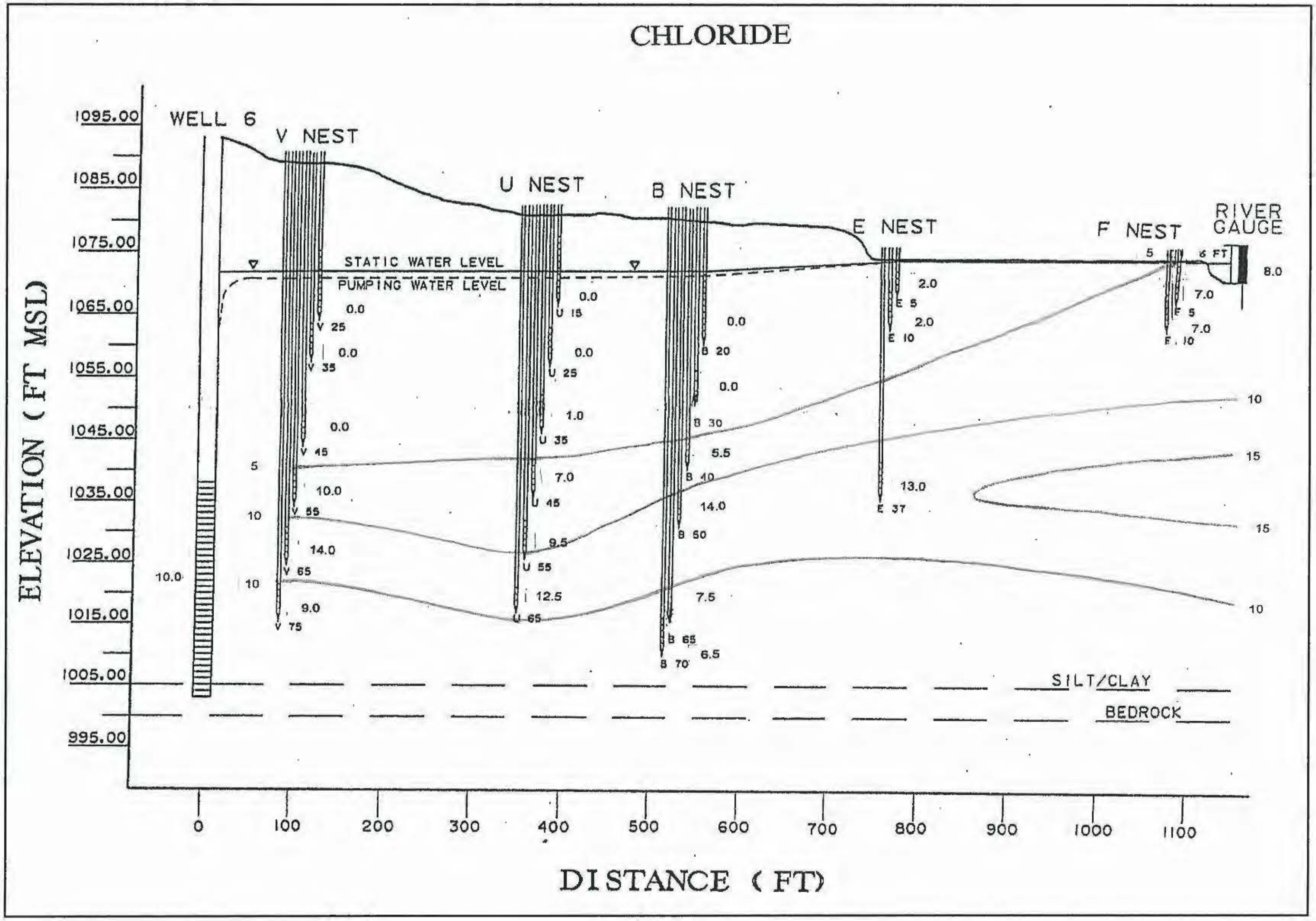


Figure 28 – Well 6 Transect Chloride Cross Sectional Profile

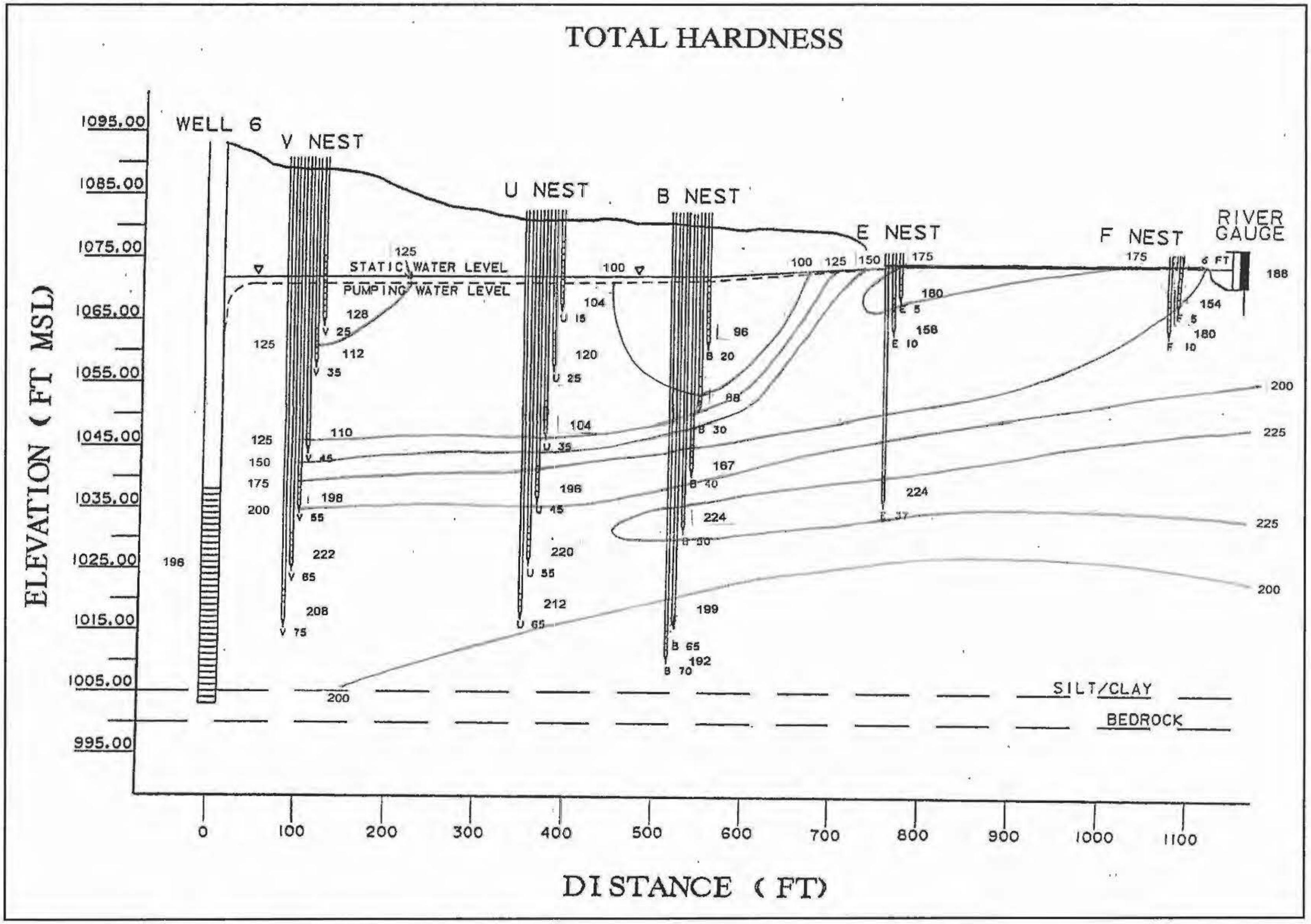


Figure 29 – Well 6 Transect Total Hardness Cross Sectional Profile

Manganese results from the Well 6 transect are shown in Figure 30. Dissolved manganese forms a plume that begins between the E and B Nests. Concentrations are greater than 0.6 mg/L in a large area extending from B Nest to Well 6. The plume originates in the area of DOC dissipation, with the center of the plume at 1020 to 1040 ft. MSL. Rapid manganese reduction in this zone suggests the presence of anaerobic type reduction that is dependent upon DOC introduction in the Well 6 flowpath. This indicates that manganese serves as an electron acceptor for organic matter oxidation in the absence of oxygen similar to nitrate.

Iron results are shown in Figure 31. Iron is not found in the flowpath at a concentration greater than 0.1 mg/L. Iron was found at higher concentrations at F Nest wells, but is related to local conditions at the stream bank. Occurrence at this location is isolated and does not migrate to the flowpath. Iron reduction is also subject to microbial reduction as an alternate electron acceptor. The presence of manganese and lack of iron in the flowpath is explained by the absence of geochemical conditions favoring iron reduction. There may be sufficient manganese and nitrate to oxidize the organic matter, but DOC is consumed and pH/eh redox equilibrium alone does not favor iron reduction.

The pH results are shown in Figure 32 as a distinct pH difference between flowpath contribution sources. Riparian pH is approximately 7.0 to 7.25, underflow is approximately 7.25 to 7.5, and upland wells are generally greater than 7.5. Well 6 flowpath pH is most indicative of underflow at 7.25 to 7.5. pH depression would be expected in areas of high microbial respiration due to generation of carbon dioxide. The lower pH observed in the riparian zone may be due to this respiration. The lower pH of the riparian contribution, as well as higher pH of upland component is likely buffered by the alkalinity of significantly greater contribution from the underflow. The underflow pH prevails and any evidence of pH depression as a microbial byproduct is not apparent after mixing of the zones.

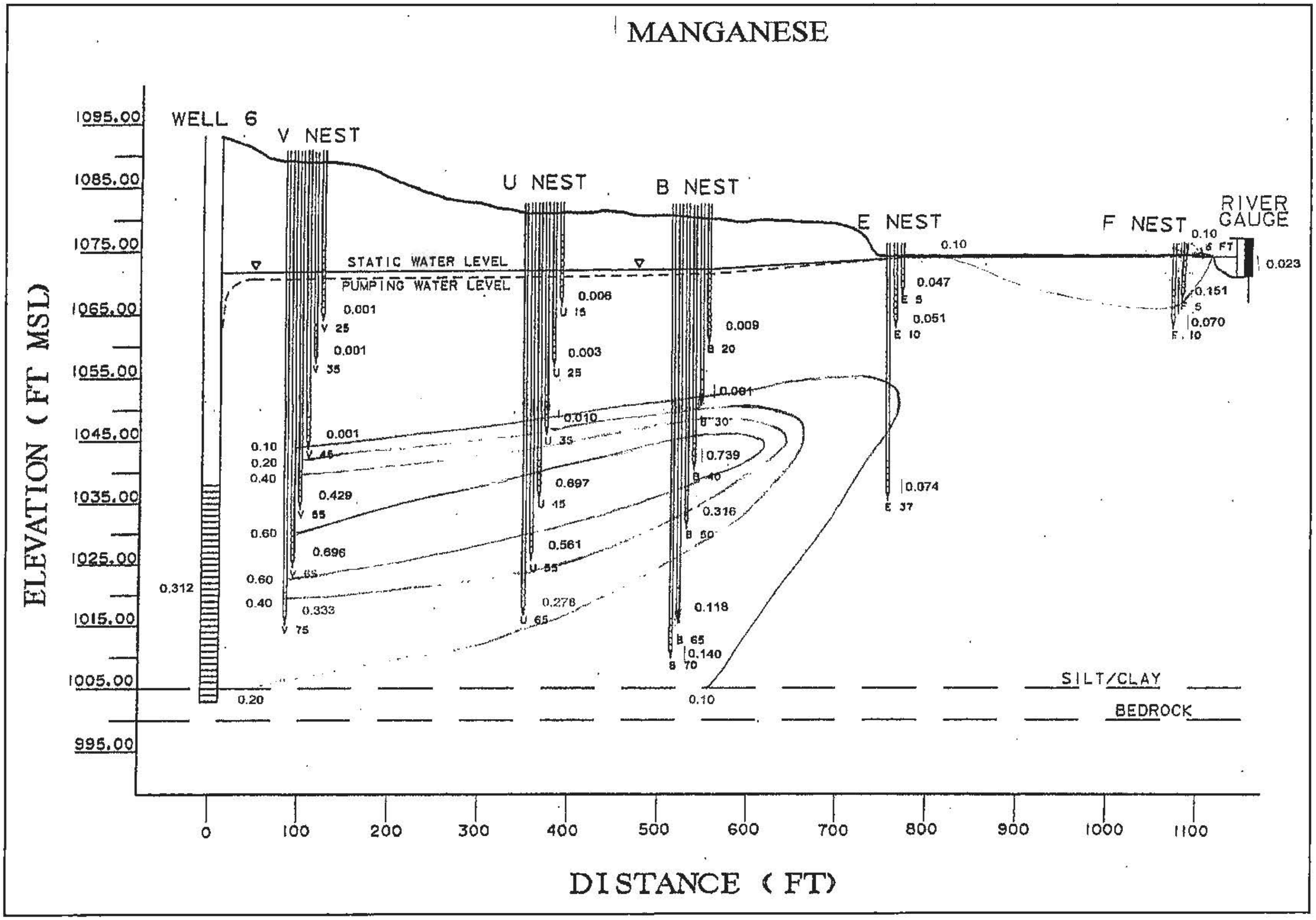


Figure 30 – Well 6 Transect Manganese Cross Sectional Profile

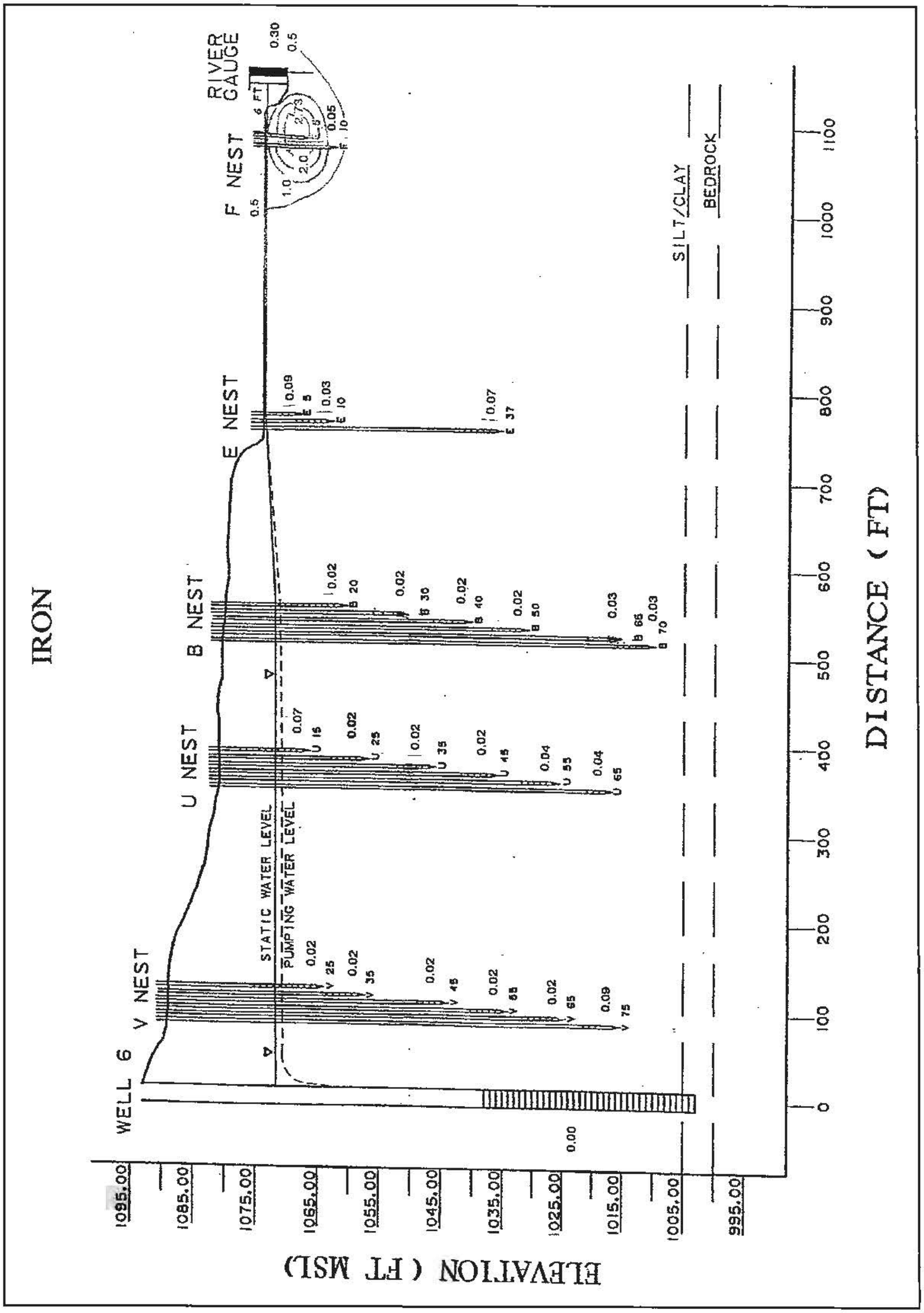


Figure 31 – Well 6 Transect - Iron Cross Sectional Profile

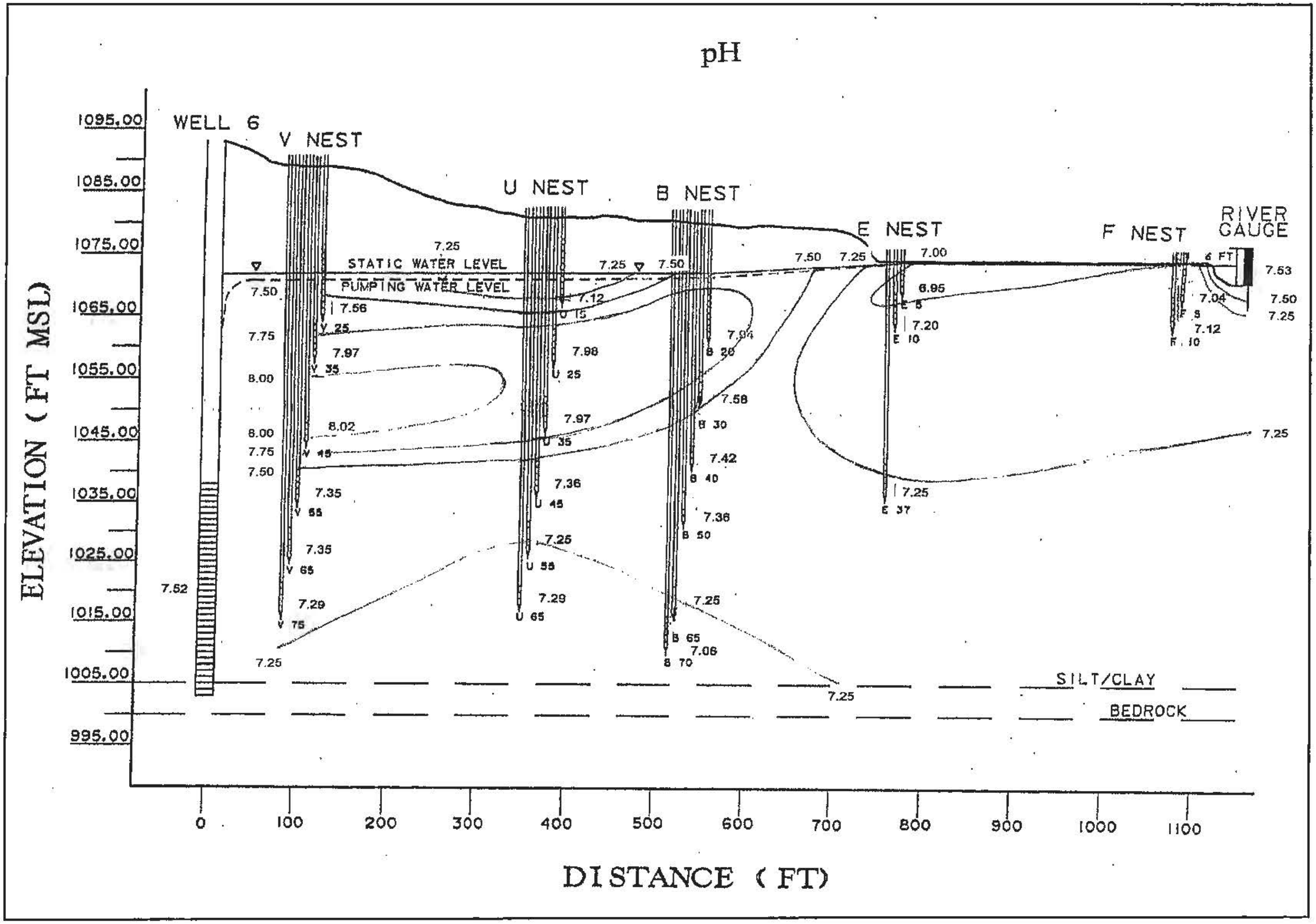


Figure 32 – Well 6 Transect pH Cross Sectional Profile

The reduction sequence in the Well 6 area shows that DOC introduction results in DO depletion, followed manganese reduction and nitrate reduction. The sequence of reduction is dictated by availability of electron acceptors and organic carbon electron donor. In the upper portions of B Nest, manganese is the highest energy yield electron acceptor that is available, and manganese reduction prevails. In the lower portions of the B Nest, nitrate from underflow contribution provides a higher energy electron acceptor, and nitrate reduction prevails. Sulfate and iron are available as electron acceptors throughout the flowpath but are not likely reduced due to DOC depletion by manganese, oxygen, or nitrate.

WELL 10 AREA GEOCHEMISTRY

Samples were collected for geochemical testing at Well 10 area locations in March, May, and July 1997, and at selected locations in 1996. Testing results are summarized in Appendix 4. Well 10 geochemical testing results are illustrated in Figures 33 through 41. Figures show average values over the collection period and interpolated iso-concentration lines.

DO and DOC results are shown in Figures 33 and 34. Results are variable depending upon location in the flowpath. The upper groundwater zone receives recharge from the riparian area and Plover River backwater. It has a high DOC concentration plume (6 mg/L). The DOC plume is closely related to the upper boundary of DO dissipation. DO was depleted throughout a zone originating from the riparian and backwater area and extending to the 1025 ft. to 1055 ft. depth interval near Well 10. High concentrations of DOC were also found at W Nest (8 mg/L). This area is an island / peninsula (see Figure 14) that was found to contribute little DOC to the flowpath. This may be because the area has a dense hard pan at approximately 10 feet in depth and is surrounded by water that provides a much larger flowpath contribution. The deeper aquifer receives a large contribution from the Plover River as well as some underflow. Deep aquifer testing did not show a distinct DOC plume similar to that found in the shallow zone. DOC concentrations decreased from 5 mg/L to 2 mg/L in the flowpath extending to the 1010 to 1025 ft. depth interval near Well 10. This dissipation may be due to aerobic bacterial consumption and mixing with low DOC underflow. It was an important finding that DO

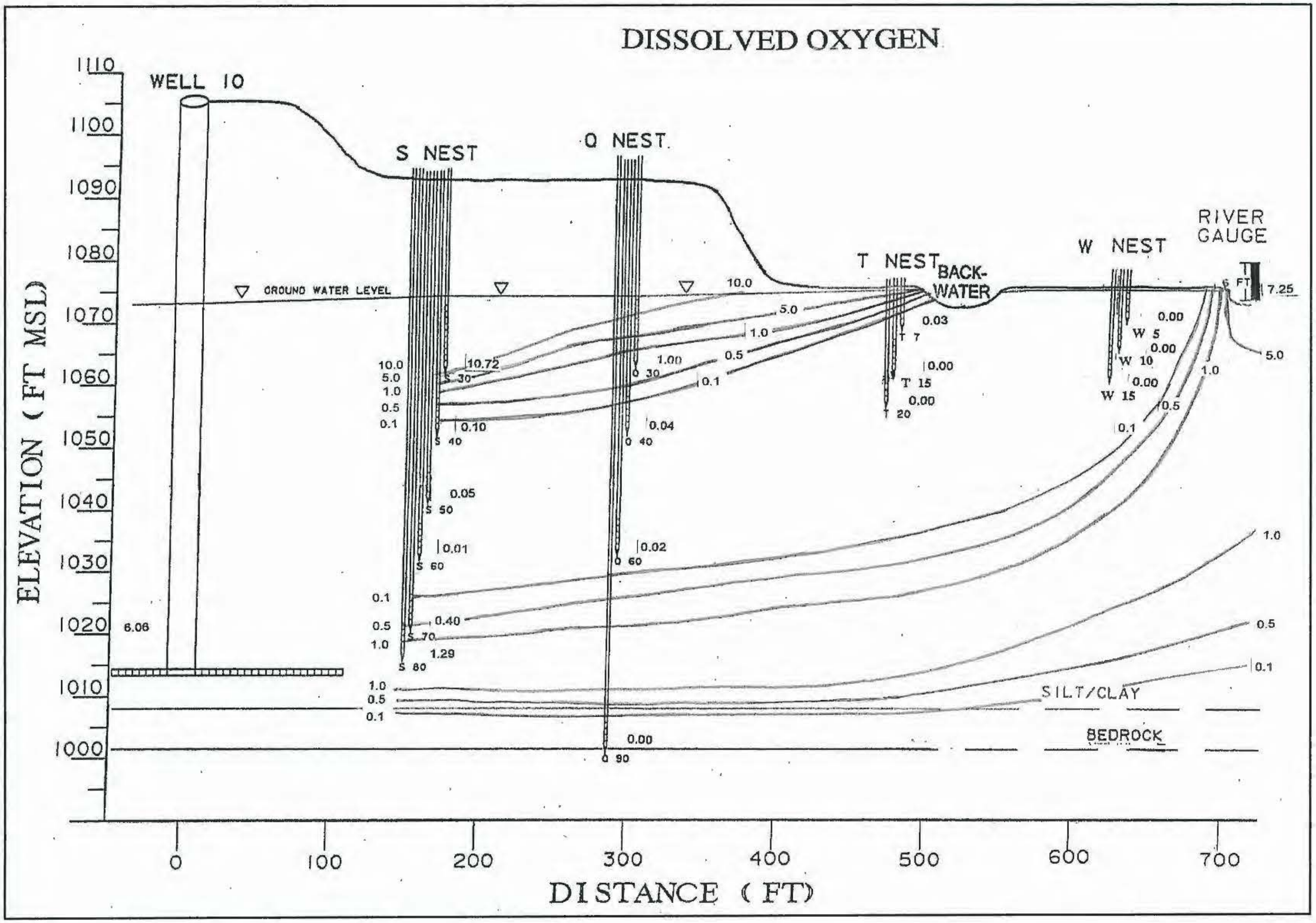


Figure 33 – Well 10 Transect DO Cross Sectional Profile

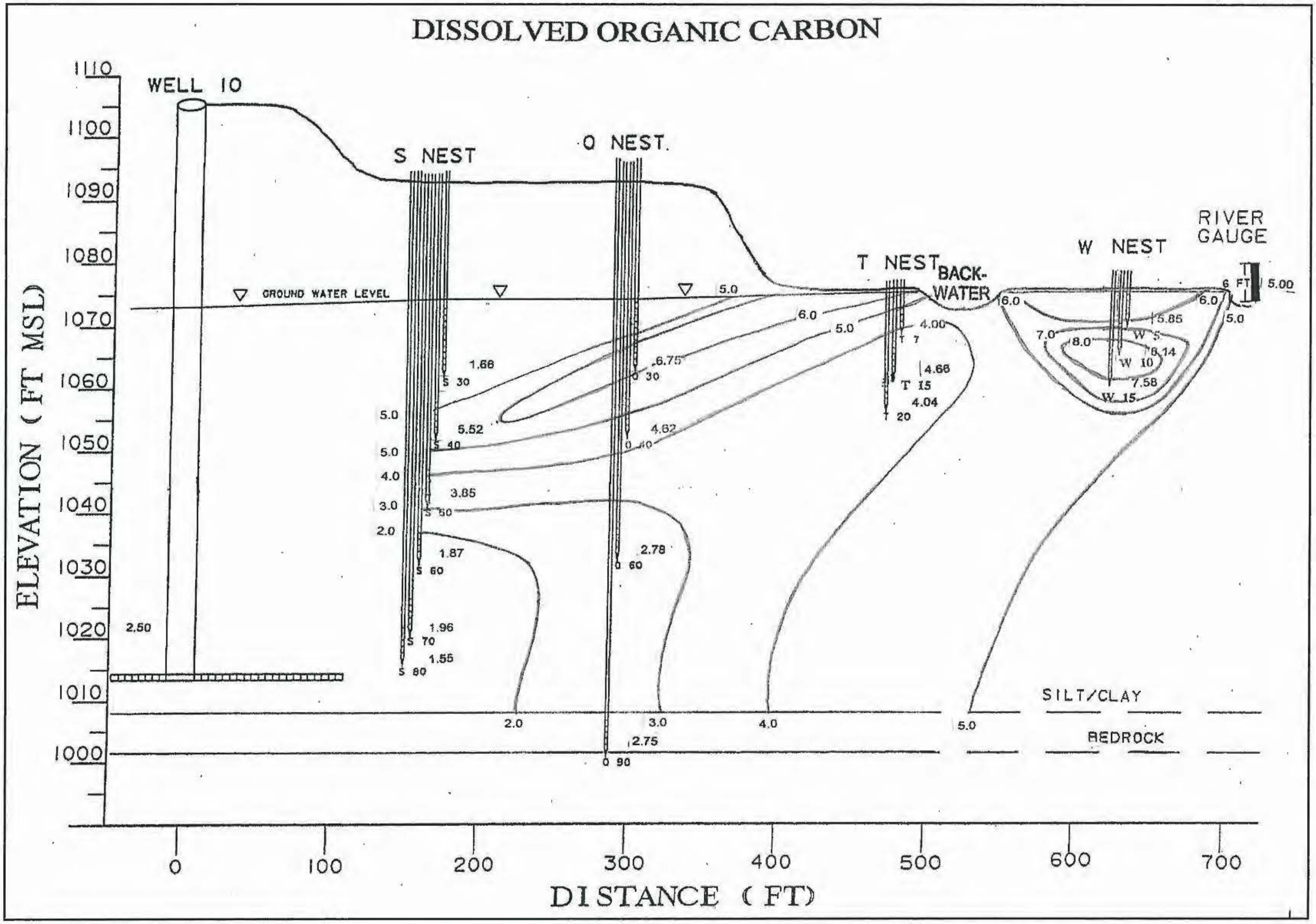


Figure 34 – Well 10 Transect DOC Cross Sectional Profile

concentrations were not completely dissipated in the flowpath. DO concentrations remained greater than 1 mg/L near Well 10 at the caisson lateral elevation of 1015 ft. MSL. This indicates that deep recharge reached Well 10 before DO was completely depleted.

Nitrate results (Figure 35) show that there was little nitrate change in either the shallow or deep zone. Nitrate was low (1 mg/L) in surface sources that comprise the majority of Well 10 contribution from the easterly direction. A slightly higher nitrate concentration of 1.8 mg/L at well S80 reflects the minor contribution from the higher nitrate underflow. It is important to note that nitrate concentrations were higher at Well 10 (3.2 mg/L) than any location in the easterly flowpath shown in Figure 35. This shows that there was significantly greater high nitrate regional groundwater contribution from the northeast and westerly Well 10 laterals. The hydrogeological section of the study indicated that the northeast lateral would capture most of the higher nitrate regional groundwater obtained east of Well 10.

Sulfate results (Figure 36) are similar to that found for nitrate. There is little sulfate change throughout the shallow or deep zone.

Chloride and total hardness are shown in Figures 37 and 38. Chloride and total hardness are inert indicator parameters. There is little chloride and total hardness change throughout the shallow or deep zone. This indicates that the river and riparian contribution dominates groundwater flowpath geochemistry. Table 11 is a comparison of approximate concentrations of chloride, sulfate, and total hardness (Figures 36 to 38) that are geochemical indicators of source water origin. Well 10 concentrations are closest to the surface water source concentrations that include the Plover River, backwater, and riparian zone. This is consistent with hydrogeological data that indicated the Plover River and backwater were the major source of recharge to Well 10.

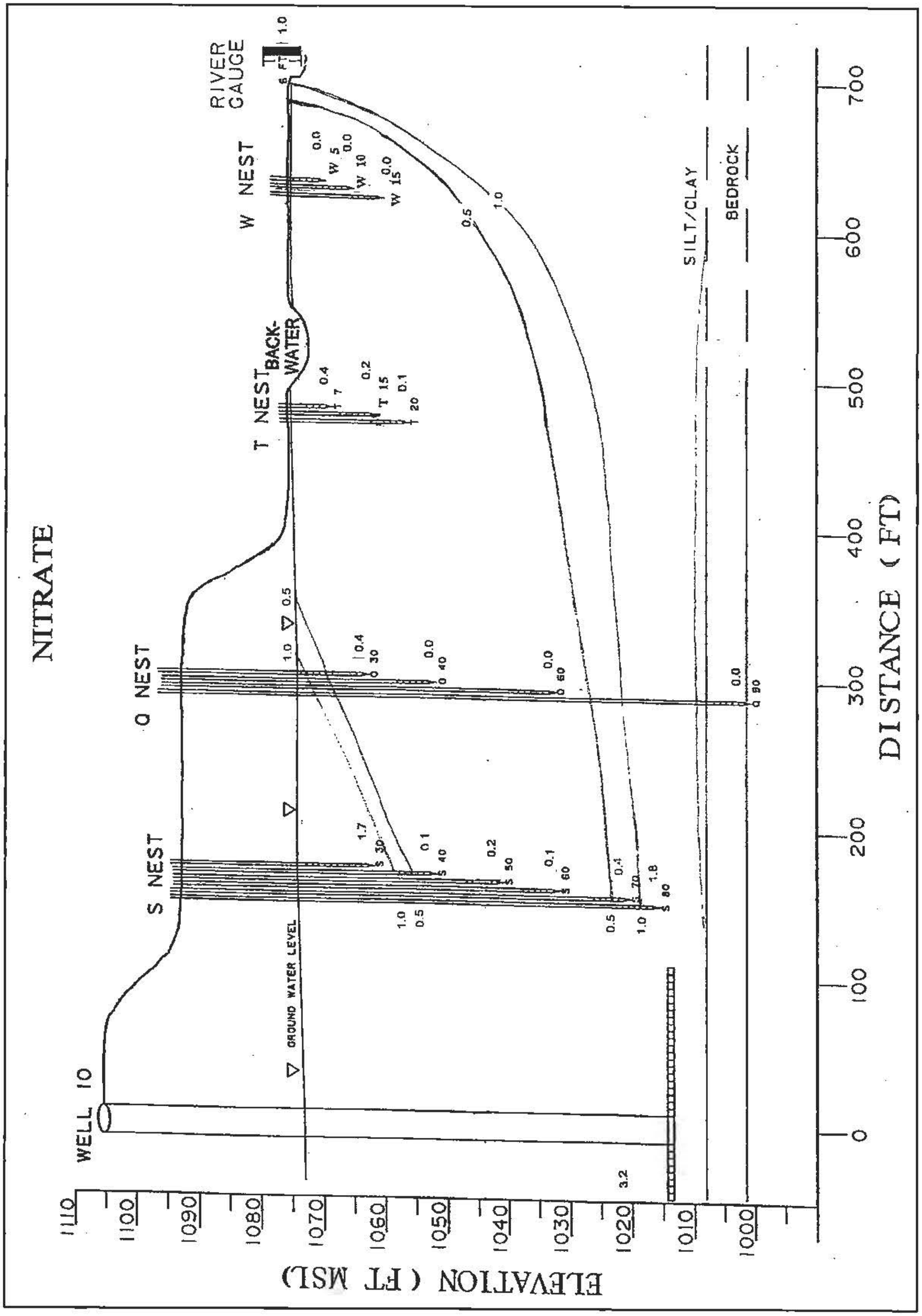


Figure 35 – Well 10 Transect Nitrate Cross Sectional Profile

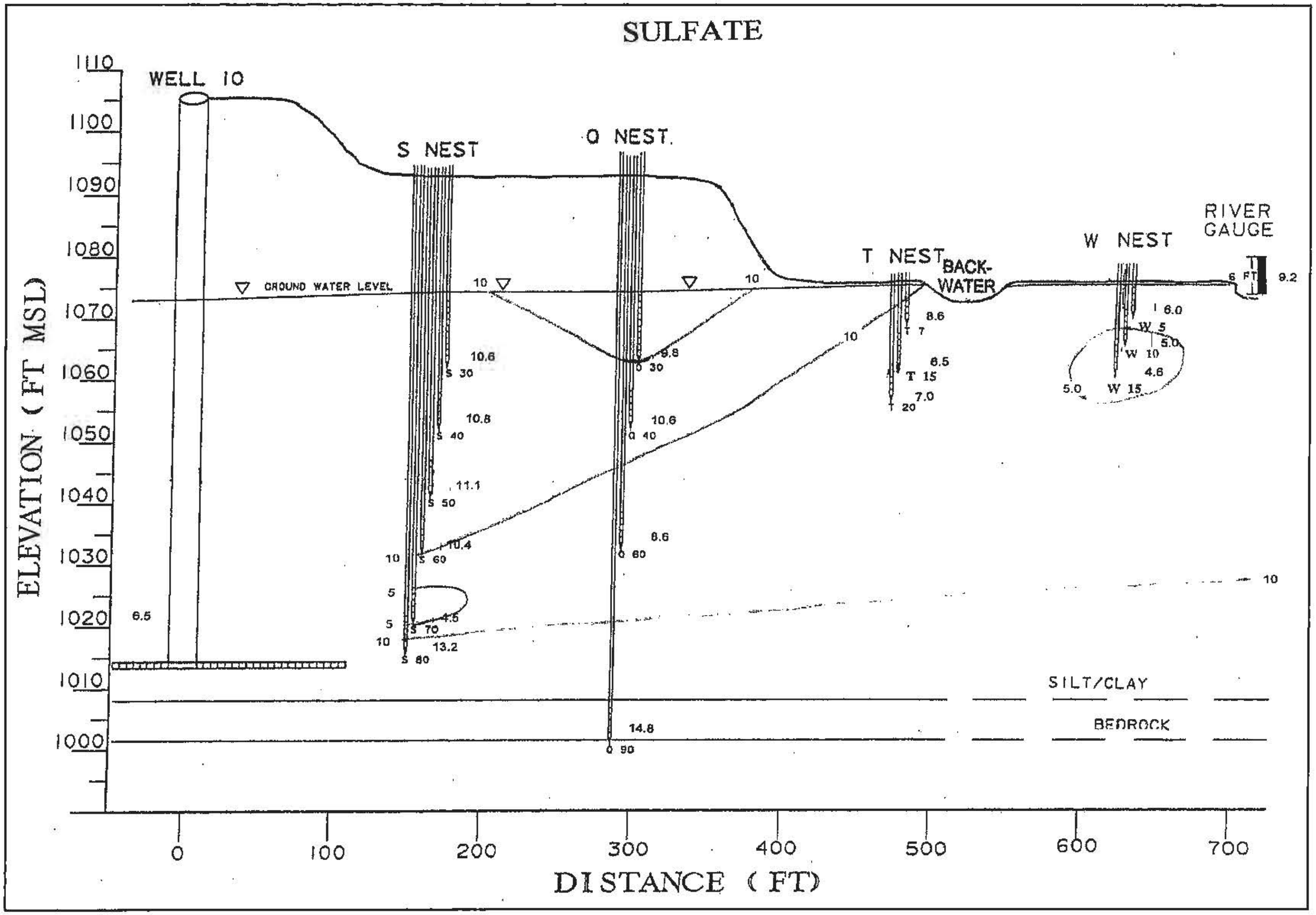


Figure 36 – Well 10 Transect Sulfate Cross Sectional Profile

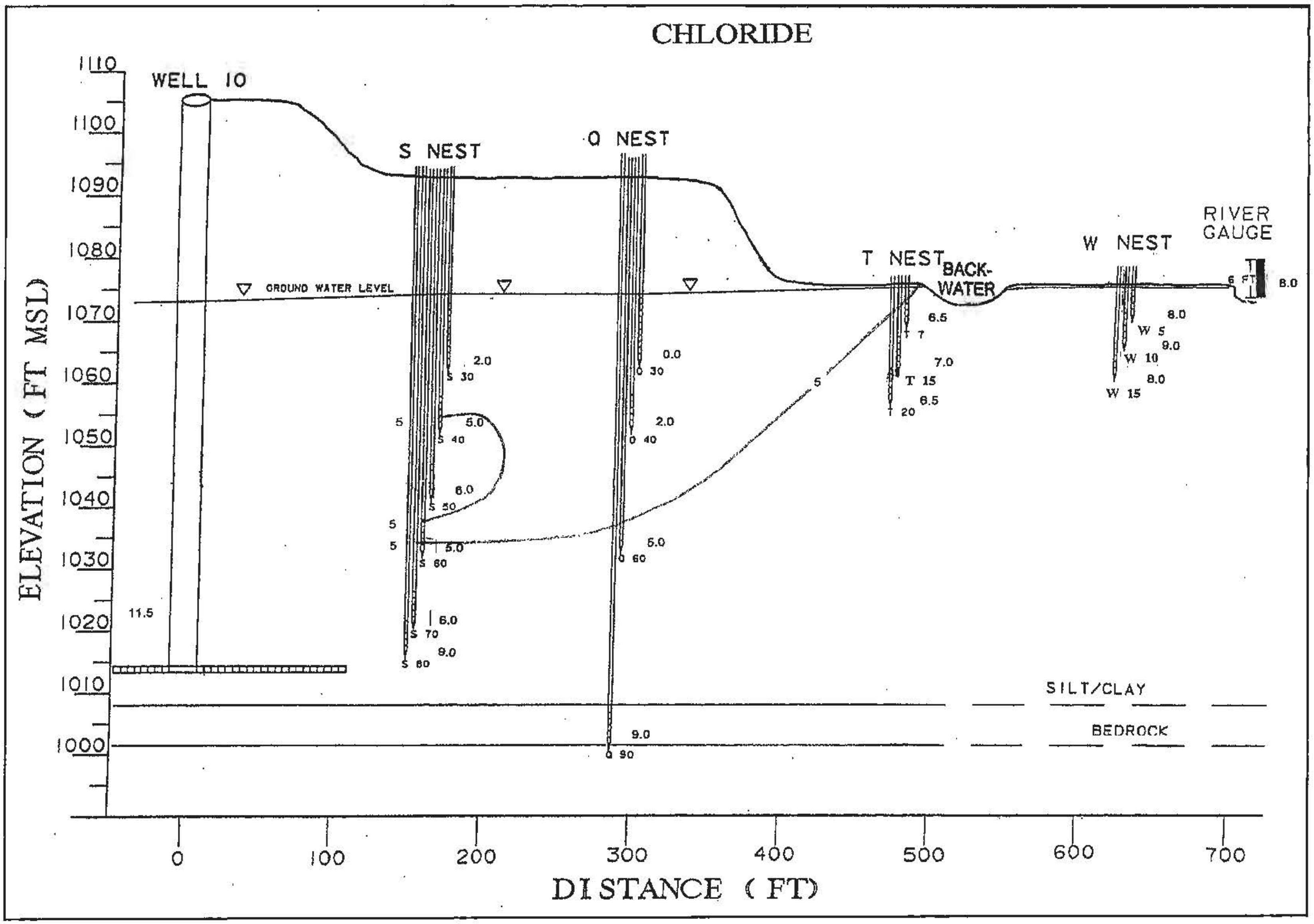


Figure 37 – Well 10 Transect Chloride Cross Sectional Profile

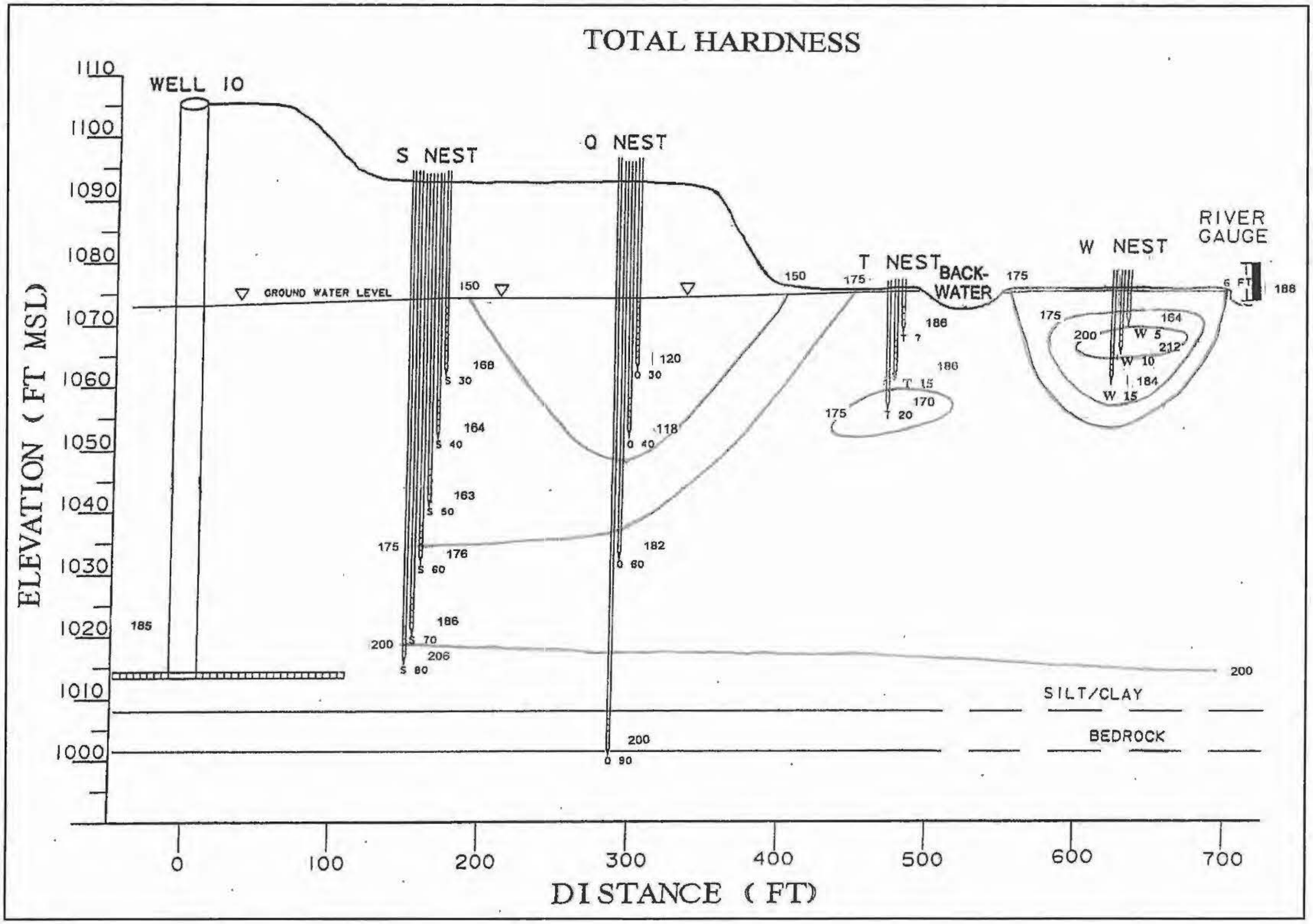


Figure 38 – Well 10 Transect Total Hardness Cross Sectional Profile

Table 11 – Well 10 Source Water Origin Summary

Contribution Sources	Sulfate (mg/L)	Chloride (mg/L)	Total Hardness (mg/L)
Underflow	25	15	225
Plover River	9	8	188
Backwater	9	8	188
Riparian Zone	10	5	150
Well 10 SE Lateral	8.9	7.5	196

Note: An average of wells S70 and S80 represents contribution to Well 10 southeast lateral

Manganese results are shown in Figure 39. Manganese concentrations are less than 0.1 mg/L throughout the flowpath. The highest concentration of manganese in the flowpath is 0.096 mg/L at well S40. These low mangese concentrations likely reflect the absence of reducing conditions in the flowpath. Although DOC concentrations exceed 1 mg/L, apparently this DOC is more recalcitrant or travel times too short to substantially deplete DO in the flowpath. Manganese found at well S40 occurs along the high DOC plume (5.5 mg/L) in the absence of DO. It is likely that higher manganese concentrations did not have sufficient travel time and distance to develop redox series reduction reactions along this zone.

Iron results are shown in Figure 40. Iron concentrations were limited overall in the flowpath but were found at high concentrations at two confined locations. The most important was at S40 where the iron was greater than 3 mg/L. This indicates that an iron plume was beginning to develop at this location. Full development of the reduction zone may be restricted by groundwater travel distance and time. Iron was found at W Nest wells and is related to local conditions at the stream bank. Occurrence at this location appeared isolated and unlikely to migrate in the flowpath.

pH results are shown in Figure 41. Results show a pH difference between flowpath contribution sources. Riparian pH is approximately 7.0 to 7.25 and Plover River pH is approximately 7.5. The Well 10 shallow flowpath pH is most indicative of the lower pH associated with the riparian area. The pH is less than 7 in this flowpath at well S40,

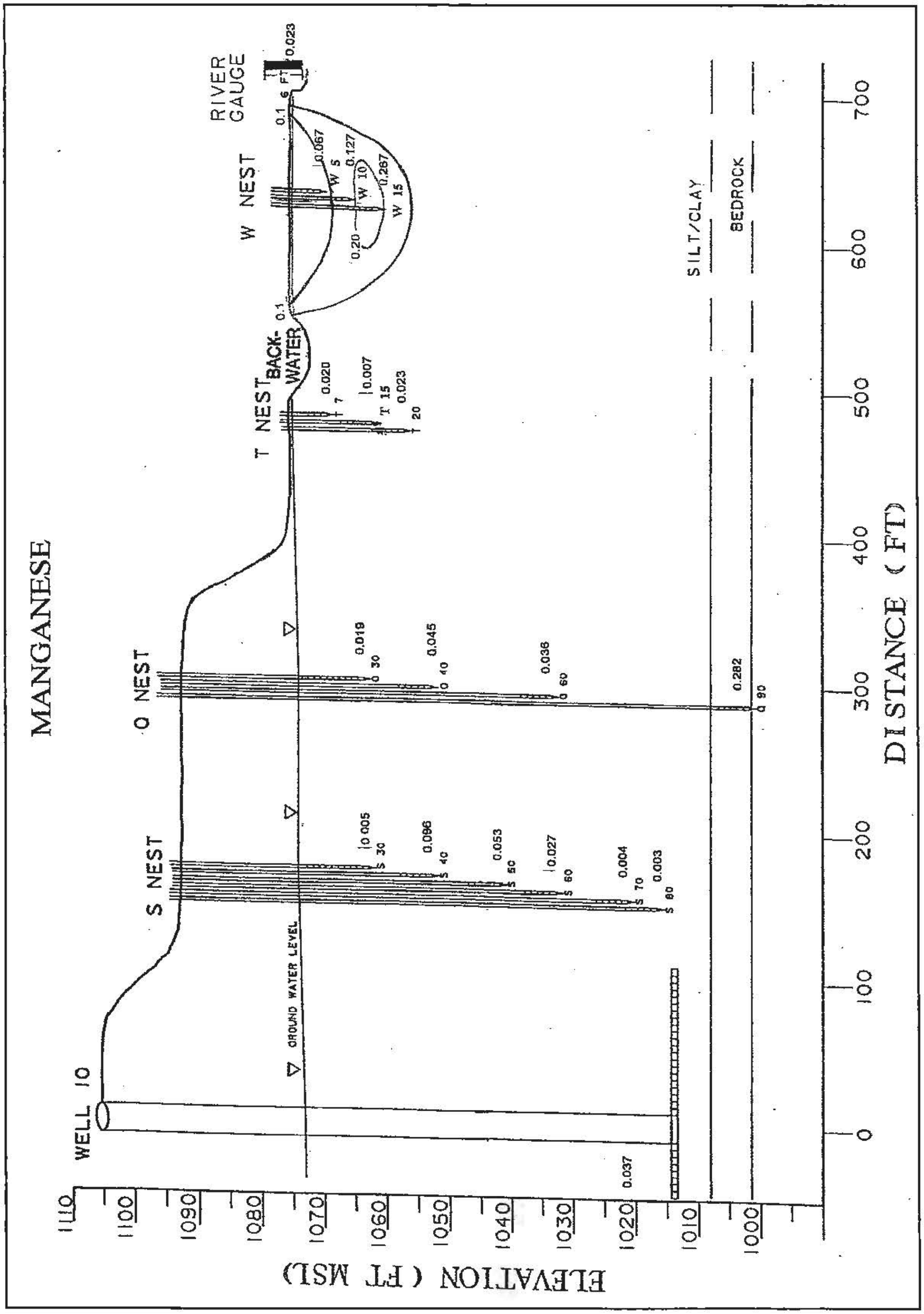


Figure 39 – Well 10 Transect Manganese Cross Sectional Profile

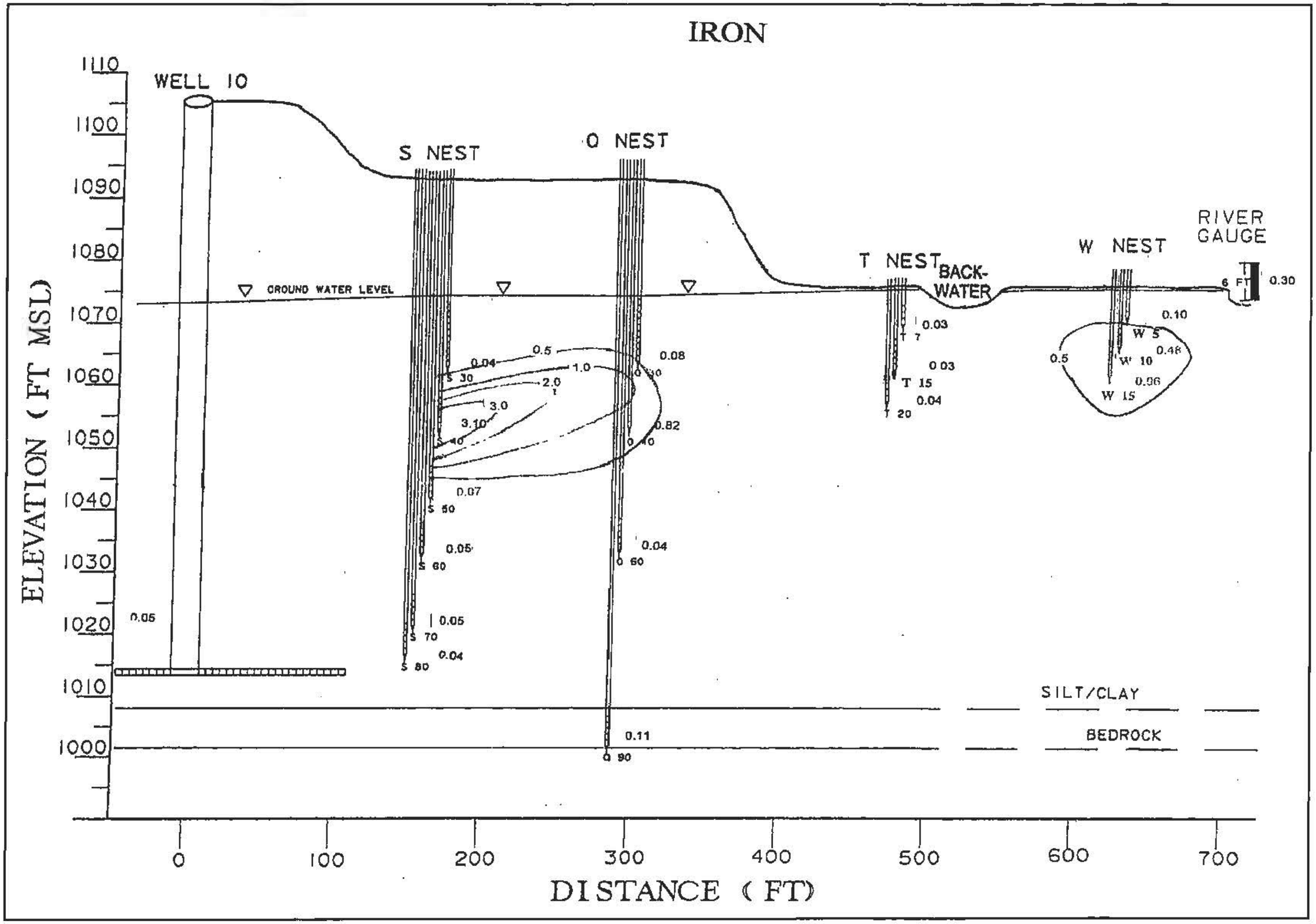


Figure 40 – Well 10 Transect - Iron Cross Sectional Profile

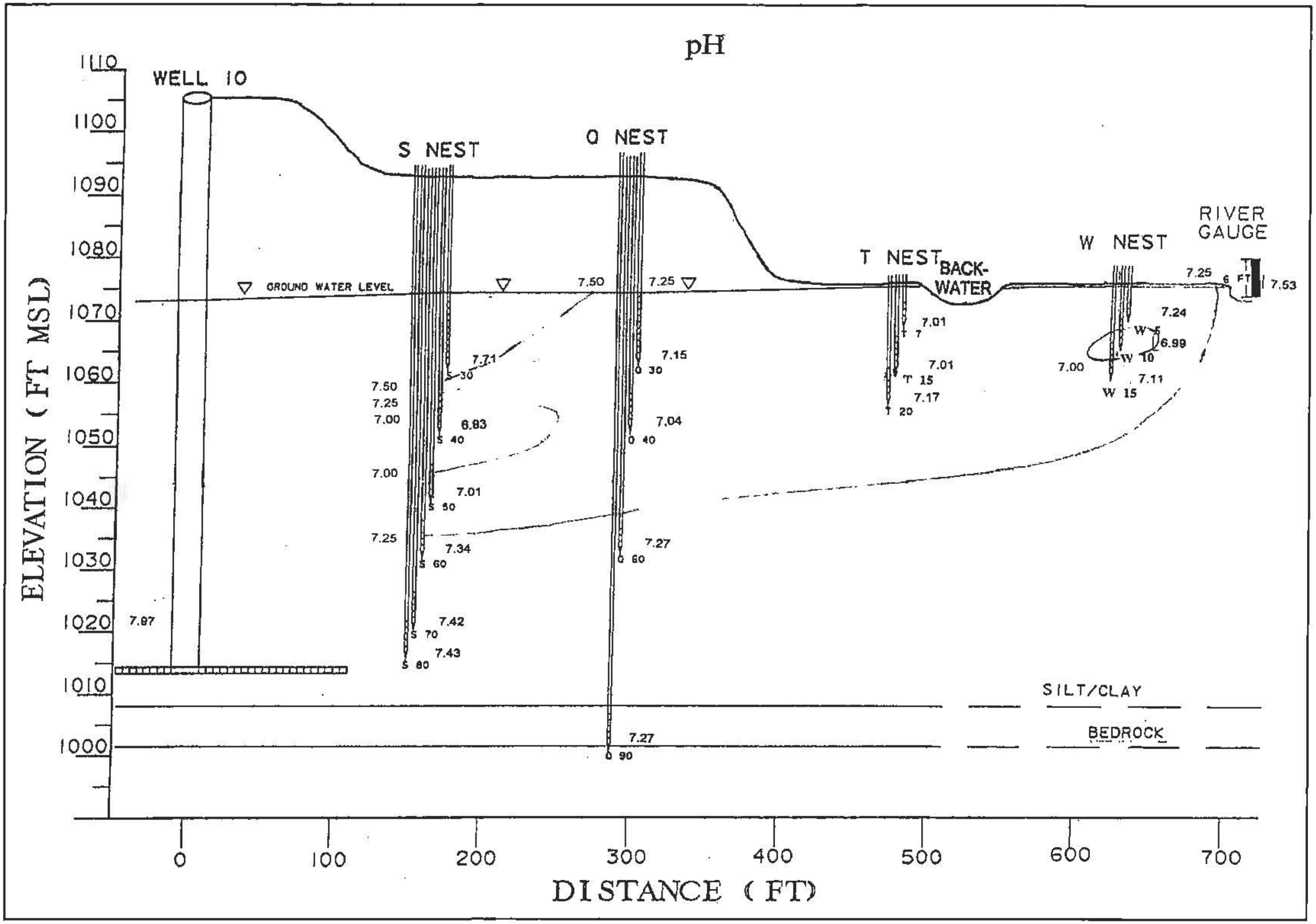


Figure 41 – Well 10 Transect pH Cross Sectional Profile

indicating that low pH in this area is the likely cause of iron dissolution. The lower pH observed along the shallow riparian zone contribution may be due to aerobic microbial respiration. The pH in the deep zone is higher at approximately 7.4. There is no significant reduction in pH from the river source through the deep flowpath indicating that carbon dioxide generation from microbial respiration is not significant enough to alter pH in this zone.

The Well 10 geochemistry shows DOC was present at higher concentrations in the shallow flowpath than the deep flowpath. The deep flowpath appears to originate from the Plover River as the major source of water supply to the Well 10 southeast lateral. DO was not depleted sufficiently in this flowpath to cause alternate electron acceptor reduction. This is likely attributable to the coarse soils in the deep zone and proximity to surface water recharge from the Plover River. There was a small amount of manganese reduction in the shallow flowpath, attributable to the riparian zone high DOC concentrations and finer soils in this zone. This flowpath contained the elements required for manganese reduction observed at Well 6, but development may be limited due to short travel time, and this may be be a relatively small proportion of water entering the well. If Well 10 were located further from the Plover River, reduction zones may have developed to a greater extent in the shallow flowpath.

SUMMARY AND CONCLUSIONS

Manganese concentrations in the groundwater near two wells in the Stevens Point Airport Wellfield were examined in this study. One of the wells, Well 6, was a high capacity conventional well with high manganese concentrations (0.35 m/L). The other well, Well 10, was a high capacity collector well with low manganese concentrations (0.05 mg/L). Well 10 has a significantly greater pumping rate and was closer to the Plover River than Well 6. Groundwater monitoring wells were installed to provide information on soils, hydrogeology, and geochemistry. Mini-piezometers were installed in the river and area monitoring wells were used to provide additional hydrogeological information.

This study showed high groundwater manganese concentrations were found concurrent with high dissolved organic carbon, low DO/redox potential, and soil manganese oxides. Reduction of manganese in the soil is the source of manganese in the wells. Differences in manganese concentrations at the well appeared to relate to differences in the amount of surface water contribution to recharge, distance to surface water recharge source, and groundwater DO/redox potential.

High manganese concentrations in the groundwater near Well 6 were found in areas with induced surface water recharge from the riparian zone. This recharge provides DOC from the organic soils and high DOC concentrations in the groundwater flowpath. Dissolved oxygen was depleted in the flow path from aerobic microbial processes. The rapid DO depletion is followed by manganese reduction in the absence of nitrate. In the lower portions of the aquifer, nitrate from underflow contribution provides a higher energy electron acceptor, and nitrate reduction prevails. Sulfate and iron are available as electron acceptors throughout the flowpath but are not reduced due to kinetic limitations and DOC depletion by higher energy reduction reactions.

Manganese concentrations were lower at Well 10. High pumping rates from the Well 10 collector well resulted in a large recharge contribution from the Plover River. Induced surface water recharge of groundwater at Well 10 led to DOC influx but little manganese reduction. The proximity of the well to surface water, deep screening of the collector well, fine soils in the shallower interval, and coarse soils at the well screen depth interval may contribute to significant water flow in this deep flowpath with a short travel time. This flowpath had geochemistry similar to the river water and redox potential was not sufficiently reduced for manganese reduction to occur, as dissolved oxygen was available at the well screen depth interval. This appears to be a limiting factor to manganese formation even though river and riparian recharge provided DOC in the presence of soil manganese oxides. There was minor reduction of iron and manganese in the shallow groundwater recharge zone likely attributable to the high DOC influx from limited riparian recharge. The absence of manganese reduction results from slow organic matter oxidation or slow manganese reduction rates relative to the rapid travel time in these flowpaths.

The most important factor for manganese reduction appears to be well location relative to surface recharge sources. Minimization of riparian zone recharge relative to other sources is important, as contribution from this zone appears to influence DOC influx and corresponding manganese reduction greater than any other factor. Examples of low manganese conventional (Well 9) and collector wells (Well 10) are currently in operation. Well 9 should be further examined to ascertain the important factors that limit manganese concentrations at this well. Well 10 is a low manganese concentration collector well detailed in this study. Both could be used as models for existing and future wells.

Reducing supply well pumpage at Wells 6 and 7 may require addition of a new well or wells. Siting of a new well for minimizing manganese concentrations would most reliably have the same characteristics as either the Well 10 collector well or Well 9 conventional well. New well installations have inherent uncertainty in water quality however due to the multitude of inter-related factors controlling hydrogeology and geochemistry.

Potential future work could include the following:

1) This study identified a geochemical pattern consistent with a microbial induced manganese reduction linked to DOC influx. Further research could verify enzymatic microbially mediated iron and manganese reduction. This could be

scale study would consist of a small reactor unit containing wellfield soils and groundwater. The unit would be operated and monitored more closely for indicator parameters such as H_2 concentrations, a redox potential flow cell, and appropriate microbial sample collection and testing for organism identification. A recent similar study was performed by in Frederickton, New Brunswick, Canada (Petrunnic, et. al., 2005).

2) Conduct further study on manganese in-situ treatment as a method of manganese control. In-situ treatment may be tested on the bench unit and/or existing field monitoring wells and remediation wells. A potential in-situ treatment study may include focusing on the use of nitrate as an alternative electron acceptor to soil manganese. The goal of nitrate introduction would be to replace the manganese reduction with nitrate. Nitrate reduction is a self destructive reduction process where DOC is consumed and nitrate is reduced to gaseous molecular nitrogen.

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APPENDICES

1 **Airport Wellfield Pumping Well Data Summary Over Study Period**

2 **Monitoring Well Installation Summary and Soil Boring Logs**

3 **Transect Water Levels – March to September 1997**

4 **Transect Geochemical Summary Table**

APPENDIX 1

AIRPORT WELLFIELD PUMPING WELL DATA SUMMARY OVER STUDY PERIOD

APPENDIX 1
GROUNDWATER PUMPAGE - AIRPORT WELLFIELD
UWSP MANGANESE STUDY

Date	Well 6		Well 7		Well 8		Well 9		Well 10		Combined Wells 6 and 7	
	Mn (mg/L)	Pumpage (MG/mo)	Mn (mg/L)	Pumpage (MG/mo)	Mn (mg/L)	Pumpage (MG/mo)	Mn (mg/L)	Pumpage (MG/mo)	Mn (mg/L)	Pumpage (MG/mo)	Mn (mg/L)	Pumpage (MG/mo)
3/97	0.462	-	0.282	-	0.003	-	0.001	-	0.032	-	-	-
4/97	0.325	69.12	0.293	12.34	0.000	8.5	0.000	7.27	0.028	85.29	-	81.46
5/97	0.307	75.95	0.267	18.16	0.000	22.01	0.000	10.75	0.020	86.09	-	94.11
6/97	0.315	86.21	0.287	39.71	0.000	22.38	0.000	9.06	0.032	82.96	-	125.92
7/97	0.356	88.53	0.307	32.24	0.000	28.19	0.000	11.99	0.034	87.00	-	120.77
8/97	0.283	84.78	0.239	27.70	0.000	16.25	0.000	8.82	0.030	81.81	-	112.48
9/97	0.280	71.40	0.241	16.32	0.000	0.87	0.000	18.40	0.032	84.83	-	87.72
10/97	0.290	53.98	0.249	24.12	0.000	15.21	0.000	25.28	0.030	86.61	-	78.10
11/97	0.273	11.00	0.271	19.41	0.000	29.38	0.000	36.84	0.033	84.44	-	30.41
12/97	0.340	42.35	0.313	18.89	0.000	12.84	0.000	12.75	0.042	85.78	-	61.24
1/98	0.311	36.66	0.279	23.34	0.000	23.64	0.000	17.82	0.036	40.94	-	60.00
2/98	0.414	28.22	0.387	20.86	0.000	15.72	0.000	73.12	0.044	78.40	-	49.08
3/98	0.334	17.28	0.371	14.14	0.000	11.14	0.000	22.51	0.033	89.46	-	31.42
4/98	0.400	33.60	0.300	26.50	0.000	22.81	0.000	19.53	0.100	84.65	-	60.10
5/98	0.300	62.66	0.300	44.10	0.000	42.2	0.000	18.25	0.000	94.02	-	106.76
6/98	0.400	50.48	0.400	27.65	0.000	30.63	0.000	21.54	0.100	92.03	-	78.13
7/98	0.200	59.93	0.400	47.79	0.000	42.18	0.000	25.18	0.000	93.12	-	107.72
8/98	0.200	67.55	0.400	35.96	0.000	12.92	0.000	30.20	0.100	88.33	-	103.51
9/98	0.333	71.25	0.376	30.57	0.003	11.68	0.001	23.91	0.045	87.84	-	101.82
10/98	0.345	51.82	0.382	9.89	0.005	8.11	0.001	21.44	0.047	84.83	-	61.71
Average	0.316	55.24	0.320	26.48	0.000	20.42	0.000	22.59	0.042	84.07	-	81.72
Average (MGD)		1.82		0.87		0.67		0.74		2.76		2.69
Average (cfs)		2.81		1.35		1.04		1.15		4.28		4.16
Rate (gpm)		1467		1399		970		960		1931		2866
											Wellfield Total	6.86 MGD 10.62 cfs

APPENDIX 2

MONITORING WELL INSTALLATION SUMMARY AND SOIL BORING LOGS

Well 6 Area

Seven locations are included in the Well 6 transect that extend from Well 6 to approximately 80 feet east of the Plover River (Figure 10). The locations include five monitoring well nests, one single well, and one river gauge. Information regarding transect locations include:

LOCATIONS	TOTAL WELLS	PRE-EXISTING WELLS	NEW WELLS	DISTANCE FROM WELL 6 (ft)
V Nest (Depth – ft)	6	0	6 (26,32,46,55,65,75)	75
U Nest (Depth – ft)	6	0	6 (15,25,35,45,55,65)	350
B Nest (Depth – ft)	6	3 (20,40,65)	3 (30,50,70)	520
E Nest (Depth – ft)	3	3 (5,10,37)	0	760
F Nest (Depth – ft)	2	2 (5,10)	0	1000
River Gauge (Depth – ft)	1 (Staff Gauge)	0	1 (6.4)	1100
MW-39 (Depth – ft)	1	1 (10)	0	1250

Well 10 Area

Six locations are included in the Well 10 transect that extend from Well 10 to approximately 125 feet east of the Plover River (Figure 10). The locations include four monitoring well nests, one single well, and one river gauge. Information regarding transect locations include:

LOCATIONS	TOTAL WELLS	PRE-EXISTING WELLS	NEW WELLS	DISTANCE FROM WELL 10 (ft)
S Nest (Depth – ft)	6	0	6 (30,40,50,60,70,80)	120
Q Nest (Depth – ft)	4	2 (30,90)	2 (40,60)	300
T Nest (Depth – ft)	3	0	3 (7,15,20)	470
W Nest (Depth – ft)	3	0	3 (5,10,15)	600
River Gauge (Depth – ft)	1 (Staff Gauge)	0	1 (6.4)	680
MW-47 (Depth – ft)	1	1 (10)	0	900

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☐ Emergency Response ☐
☐ Wastewater ☐
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76

Page ____ of ____

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
UWSP Mn Study	_ _ _ _ _ _ _ _	Nest V

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Wis Geological Survey	05/31/96 (MM DD YY)	05/31/96 (MM DD YY)	Hollow stem

DNR Facility Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			____ Feet MSL	____ Feet MSL	3.5 inches

Boring Location
State Plane ________ N, ________ E S/C/N Lat ________
SW 1/4 of SE 1/4 of Section 24, T 24 N, R 8 E/W Long ________
Local Grid Location (If applicable) ☐ N ☐ E ____ Feet ☐ S ____ Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Portage		Stevens Point

Sample Number	Length Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
		Different drill method used		well sorted med tex sands - moist	SP									
1	—		10											
2	—		20	well-sorted med tex sands; drill shows a progression from med-fine to med sands downward but well-sorted throughout ms	SP									
3			30	moderately-well sorted med tex. sands WET	SP									
4			40	well-sorted med tex sands WET	SP									
5			50	sands poorly sorted coarse tex to gravelly wet	SW									
6			60	sands well-sorted coarse tex wet	SP									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Manny E. Mil[illegible] Firm:

This form is authorized by Chapters 144.147 and 162, Wis. Stats. Completion of this report is mandatory. Penalties: Forfeit not less than $10 nor more than $5,000 for each violation. Fined not less than $10 or more than $100 or imprisoned not less than 30 days, or both for each violation. Each day of continued violation is a separate offense, pursuant to ss 144.99 and 162.06, Wis. Stats.

State of Wisconsin
Department of Natural Resources

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☐ Emergency Response ☐ U
☐ Wastewater ☐ W
☐ Other ____________

77

SOIL BORING LOG INFORMATION
Form 4400-122 7-91

Page ____ of ____

Facility/Project Name	License/Permit/Monitoring Number	Boring Number	
UW-SP Manganese Study	_ _ _ _ _ _ _	Well Nest UB2	
Boring Drilled By (Firm name and name of crew chief)	**Date Drilling Started**	**Date Drilling Completed**	**Drilling Method**
Wisconsin Geological Survey	05/22/96 (MM DD YY)	__/__/__ (MM DD YY)	Hollow Stem

DNR Facility Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			____ Feet MSL	____ Feet MSL	____ inches

Boring Location
State Plane ____________ N, ____________ E S/C/N Lat ________
SE 1/4 of NW 1/4 of Section 26, T 24 N, R 8 (E)/W Long ________

Local Grid Location (If applicable)
____ Feet ☐ N ☐ S ____ Feet ☐ E ☐ W

County	DNR County Code	Civil Town/(City)/ or Village
Portage	____	Stevens Point

Sample Number	Sample Length Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/Comments
1	18	3	10	Moderately well-sorted fine to coarse sand, trace fine gravel ~ wet	SP									▽
[illegible]	12	4	20	same										
3	15	6	30	Well sorted fine to Medium sand, trace of fine gravel, wet	SP									
4	[illegible]		40	~~moderate-sorted~~ Poorly sorted [illegible] sand to fine gravel wet [illegible]	SW									
5	[illegible]		50	[illegible] sorted [illegible] to fine gravel [illegible]	SW									
6	[illegible]		60	same as 50' [illegible] gravel.	SW									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
Mary E. Muell	

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78

SOIL BORING LOG INFORMATION

Form 4400-122 7-91

Page ____ of ____

Facility/Project Name: UW-Stevens Point / Manganese Study	License/Permit/Monitoring Number: — — — — — — —	Boring Number: Well nes B	
Boring Drilled By (Firm name and name of crew chief): Wis. Geological Survey	Date Drilling Started: 05/20/96 (MM DD YY)	Date Drilling Completed: 05/20/96 (MM DD YY)	Drilling Method: Hollow Stem
DNR Facility Well No. / WI Unique Well No. / Common Well Name	Final Static Water Level ____ Feet MSL	Surface Elevation ____ Feet MSL	Borehole Diameter ____ inches

Boring Location
State Plane ______ N, ______ E S/C/N Lat ______
SE 1/4 of NW 1/4 of Section 26, T 24 N, R 8 (E)/W Long ______

Local Grid Location (If applicable) ____ Feet ☐ N ☐ S ____ Feet ☐ E ☐ W

County: Portage | DNR County Code: ____ | Civil Town/(City)/ or Village: Stevens Point

Sample Number	Length Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/Comments
1	14	8	10	Well sorted medium to coarse sand with some pebbles, moist	SP									10 ft ▽
2	16	16	20	Poorly sorted fine sand with silt, to pebbles of 1 in, some black organic matter, wet	SM/SW									
3	16	16	30	Well sorted fine to medium sand with one pebble to 1.5 in., wet	SP									
4	14	20	40	Poorly sorted medium to coarse sand with .5-1 in. pebbles, wet	SW									
5	16	11	50	Poorly sorted fine to coarse sand with some pebbles (granite), .2-1 in,	SW									
6	0	16	60	very small amount of fine gravel (spoon washed out)	—									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature | Firm

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☐ Wastewater ☐ V
☐ Other ______

79

SOIL BORING LOG INFORMATION
Form 4400-122 7-91

Page ___ of ___

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
UWSP Mn Study	___ ___ ___ ___	Nest S

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
(WIS) Geological & U.W Ext. Natural History Survey	07/09/96 (MM DD YY)	07/09/96 (MM DD YY)	Auger Peel

DNR Facility Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			___ Feet MSL	___ Feet MSL	___ inches

Boring Location
State Plane ______ N, ______ E S/C/N Lat ______
SE 1/4 of NW 1/4 of Section 26, T24 N, R 8 (E)/W Long ______

Local Grid Location (If applicable)
______ Feet ☐ N ☐ S ______ Feet ☐ E ☐ W

County	DNR County Code	Civil Town/(City) or Village
		Stevens Point

Sample Number	Length Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/Comments
1		NA	10	well-sorted, v. fine sands occasional v. sm pebble moist, No O.M.	SP									
2			20	well-sorted, med fine sands moist NO O.M	SP									
3			30	well-sorted medfine sands wet No O.M.	SP									
4			40	well-sorted medium sands wet NO O.M.	SP									
5			50	Poorly sorted med-coarse to coarse sands wet NO O.M.	SW									
6			60	V. Poorly sorted coarse sands & pebbles wet NO O.M.	SW									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm

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Department of Natural Resources

samples taken 3 ft from 60' well

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☐ Emergency Response ☐ U
☐ Wastewater ☐ V
☐ Other ______

80

SOIL BORING LOG INFORMATION
Form 4400-122 7-91

Page ______ of ______

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
U.W.S.P.	_ _ _ _ _ _ _ _	Well Nest Q

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Wis. Geological Survey	05/30/96 (MM DD YY)	05/30/96 (MM DD YY)	Hollow Stem

DNR Facility Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			______ Feet MSL	______ Feet MSL	4½ inches

Boring Location
State Plane ______ N, ______ E S/C/N | Lat ______
SW 1/4 of SE 1/4 of Section 23, T 24 N, R 8 E/W | Long ______

Local Grid Location (If applicable)
______ Feet ☐ N ☐ S ______ Feet ☐ E ☐ W

County	DNR County Code	Civil Town/City/ or Village
Portage Co.	______	Stevens Point

Sample Number	Length Recovered (in)	Blow Counts	Depth in Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
1.		5	10	sand poorly sorted - fine to v. fine texture 1-1½% gravel ~3 sm. blotches O.M	SP									
		4	20	sand well sorted med texture no gravel very small O.M. mottling	SP									
3		5	30	sand well-sorted fine (coarse to) homogeneous no gravel no O.M. moist	SP									
4		9	40	well-sorted fine to v. fine no gravel moist no O.M.	SP									
5			50	moderately well sorted fine to med text. no gravel NO OM v. moist	SP									
6			60	Poorly sorted fine sand to gravel ½" wet	SW									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Mary E. Mech | Firm

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Department of Natural Resources

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- ☐ Wastewater ☐
- ☐ Other ____________

81

SOIL BORING LOG INFORMATION

Form 4400-122 7-91

Page ____ of ____

Facility/Project Name: U.W. Stevens Point - Mn Study	License/Permit/Monitoring Number: — — — — — —	Boring Number: Well Nest R	well 10
Boring Drilled By (Firm name and name of crew chief): Wis. Geological Survey	Date Drilling Started: 05/28/96 (MM DD YY)	Date Drilling Completed: 05/28/96 (MM DD YY)	Drilling Method: Hollow stem
DNR Facility Well No. / WI Unique Well No. / Common Well Name	Final Static Water Level: 1065.5 Feet MSL	Surface Elevation est: 1098.5 Feet MSL	Borehole Diameter: 4¼ inches
Boring Location: State Plane ______ N, ______ E S/C/N; SW 1/4 of SE 1/4 of Section 23, T 24 N, R 8 E/W	Lat ______ Long ______	Local Grid Location (If applicable): ______ Feet ☐ N ☐ S ______ Feet ☐ E ☐ W	
County: Portage	DNR County Code: ______	Civil Town/City/ or Village: Stevens Point	

Sample Number	Sample Length Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
1		4	10	med to well sorted fine tex sparse gravel distinct Layered O.M./sand middle (some ...) sand	SP									
2		2	20	well-sorted fine to med sand sm portion O.M., moist	SP									
3		≈6	30	well-sorted fine sand No Gravel sm streak O.M. in middle at Water Table (wet)	SP									
4		2	40	well-sorted fine sand... No gravel NO O.M. WET	SP									
5		11	50	Poorly sorted med + fine sands No gravel, NO O.M. wet	SW									
6			60	Poor to med sorted med & fine sand some gravel mid sample ... gravel at bottom of sample, some ...	SW									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm

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* moist observations are inaccurate: prior well was dug & water used to wet soil

APPENDIX 3

TRANSECT WATER LEVELS – MARCH TO SEPTEMPER 1997

TABLE 5-4
Transect Water Levels - 3/24/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
WE6	03/27/97	1092.55	39.00	1053.55	39.00 (pumping)
V26	03/24/97	1090.68	22.27	1068.41	
V32	03/24/97	1090.60	22.12	1068.48	
V46	03/24/97	1090.70	22.71	1067.99	
V55	03/24/97	1090.65	22.69	1067.96	
V65	03/24/97	1090.70	22.69	1068.01	
V75	03/24/97	1090.68	22.70	1067.98	
U15	03/24/97	1082.67	13.61	1069.06	
U25	03/24/97	1082.66	13.57	1069.09	
U35	03/24/97	1082.69	13.58	1069.11	
U45	03/24/97	1082.41	13.28	1069.13	
U55	03/24/97	1082.41	13.29	1069.12	
U65	03/24/97	1082.42	13.29	1069.13	
B20	03/24/97	1082.16	12.73	1069.43	
B30	03/24/97	1082.84	13.43	1069.41	
B40	03/24/97	1081.91	12.51	1069.40	
B50	03/24/97	1082.88	13.46	1069.42	
B65	03/24/97	1082.11	12.71	1069.40	
B70	03/24/97	1082.87	13.43	1069.44	
E5	03/30/97	1074.44	4.53	1069.91	
E10	03/26/97	1073.71	3.79	1069.92	
E37	03/26/97	1073.25	3.35	1069.90	
F5	03/30/97	1075.34	3.76	1071.58	
F10	03/30/97	1074.68	3.11	1071.57	
PLR6	03/27/97	1074.84	3.73	1071.11	2.67 (Well 6 Staff)
MW39	03/30/97	1072.98	1.26	1071.72	
D20	03/27/97	1083.34	7.97	1075.37	
D40	03/27/97	1083.40	8.03	1075.37	
D60	03/27/97	1083.46	8.07	1075.39	
WE10	03/27/97	1105.35	34.50	1070.85	34.50 (pumping)
S30	03/28/97	1094.58	23.27	1071.31	
S40	03/28/97	1094.21	22.90	1071.31	
S50	03/28/97	1094.16	22.85	1071.31	
S60	03/28/97	1094.17	22.90	1071.27	
S70	03/28/97	1094.57	23.27	1071.30	
S80	03/28/97	1094.60	23.31	1071.29	
Q30	03/27/97	1096.46	24.60	1071.86	
Q40	03/27/97	1095.99	24.14	1071.85	
Q60	03/27/97	1096.00	24.14	1071.86	
Q90	03/27/97	1096.52	24.61	1071.91	
T7	03/27/97	1077.36	5.08	1072.28	
T15	03/27/97	1077.36	5.08	1072.28	
T20	03/27/97	1077.14	4.88	1072.26	
W5	04/13/97	1077.84	Not Avail	Not Avail	
W10	04/13/97	1077.79	Not Avail	Not Avail	
W20	04/13/97	1078.08	Not Avail	Not Avail	
PLR10	03/27/97	1079.15	4.70	1074.45	1.70 (Well 10 Staff)
MW47	03/30/97	Not Avail	Not Avail	Not Avail	
C20	03/27/97	1082.2	Not Avail	Not Avail	
C40	03/27/97	1081.6	5.68	1075.92	
C60	03/27/97	1082.1	5.88	1076.22	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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TABLE 5-5
Transect Water Levels - 4/13/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
WE6	04/13/97	1092.55	22.30	1070.25	22.30
V26	04/13/97	1090.68	20.41	1070.27	
V32	04/13/97	1090.60	20.27	1070.33	
V46	04/13/97	1090.70	20.15	1070.55	
V55	04/13/97	1090.65	20.05	1070.60	
V65	04/13/97	1090.70	20.08	1070.62	
V75	04/13/97	1090.68	20.06	1070.62	
U15	04/13/97	1082.67	11.74	1070.93	
U25	04/13/97	1082.66	11.71	1070.95	
U35	04/13/97	1082.69	11.73	1070.96	
U45	04/13/97	1082.41	11.46	1070.95	
U55	04/13/97	1082.41	11.46	1070.95	
U65	04/13/97	1082.42	11.46	1070.96	
B20	04/13/97	1082.16	10.96	1071.20	
B30	04/13/97	1082.84	11.65	1071.19	
B40	04/13/97	1081.91	10.72	1071.19	
B50	04/13/97	1082.88	11.69	1071.19	
B65	04/13/97	1082.11	10.92	1071.19	
B70	04/13/97	1082.87	11.65	1071.22	
E5	04/13/97	1074.44	2.84	1071.60	
E10	04/13/97	1073.71	2.10	1071.61	
E37	04/13/97	1073.25	1.67	1071.58	
F5	04/13/97	1075.34	3.15	1072.19	
F10	04/13/97	1074.68	2.51	1072.17	
PLR6	04/13/97	1074.84	2.35	1072.49	4.05 (Well 6 Staff)
MW39	04/13/97	1072.98	0.80	1072.18	
D20	04/13/97	1083.34	Not Avail	Not Avail	
D40	04/13/97	1083.40	Not Avail	Not Avail	
D60	04/13/97	1083.46	Not Avail	Not Avail	
WE10	04/13/97	1105.35	36.30	1069.05	32.70 (pumping)
S30	04/13/97	1094.58	21.22	1073.36	
S40	04/13/97	1094.21	20.89	1073.32	
S50	04/13/97	1094.16	20.85	1073.31	
S60	04/13/97	1094.17	20.90	1073.27	
S70	04/13/97	1094.57	21.28	1073.29	
S80	04/13/97	1094.60	21.35	1073.25	
Q30	04/13/97	1096.46	22.45	1074.01	
Q40	04/13/97	1095.99	22.10	1073.89	
Q60	04/13/97	1096.00	22.12	1073.88	
Q90	04/13/97	1096.52	22.57	1073.95	
T7	04/13/97	1077.36	2.75	1074.61	
T15	04/13/97	1077.36	2.86	1074.50	
T20	04/13/97	1077.14	2.88	1074.26	
W5	04/13/97	1077.84	2.77	1075.07	
W10	04/13/97	1077.79	2.76	1075.03	
W20	04/13/97	1078.08	3.17	1074.91	
PLR10	04/13/97	1079.15	3.52	1075.63	2.88 (Well 10 Staff)
MW47	04/13/97	1077.29	2.38	1074.91	
C20	04/13/97	1082.2	Not Avail	Not Avail	
C40	04/13/97	1081.6	Not Avail	Not Avail	
C60	09/27/97	1082.1	Not Avail	Not Avail	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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TABLE 5-6
Transect Water Levels - 5/21/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
WE6	05/21/97	1092.55	39.10	1053.45	39.10 (pumping)
V26	05/21/97	1090.68	22.91	1067.77	
V32	05/21/97	1090.60	22.81	1067.79	
V46	05/21/97	1090.70	22.91	1067.79	
V55	05/21/97	1090.65	22.90	1067.75	
V65	05/21/97	1090.70	22.91	1067.79	
V75	05/21/97	1090.68	22.89	1067.79	
U15	05/21/97	1082.67	13.83	1068.84	
U25	05/21/97	1082.66	13.81	1068.85	
U35	05/21/97	1082.69	13.83	1068.86	
U45	05/21/97	1082.41	13.55	1068.86	
U55	05/21/97	1082.41	13.56	1068.85	
U65	05/21/97	1082.42	13.56	1068.86	
B20	05/21/97	1082.16	12.88	1069.28	
B30	05/21/97	1082.84	13.58	1069.26	
B40	05/21/97	1081.91	12.65	1069.26	
B50	05/21/97	1082.88	13.62	1069.26	
B65	05/21/97	1082.11	12.85	1069.26	
B70	05/21/97	1082.87	13.59	1069.28	
E5	05/21/97	1074.44	4.55	1069.89	
E10	05/21/97	1073.71	3.81	1069.90	
E37	05/21/97	1073.25	3.37	1069.88	
F5	05/21/97	1075.34	4.05	1071.29	
F10	05/21/97	1074.68	3.71	1070.97	
PLR6	05/21/97	1074.84	3.35	1071.49	3.05 (Well 6 Staff)
MW39	05/21/97	1072.98	2.18	1070.80	
D20	05/21/97	1083.34	7.49	1075.85	
D40	05/21/97	1083.40	7.56	1075.84	
D60	05/21/97	1083.46	7.60	1075.86	
WE10	05/21/97	1105.35	34.10	1071.25	34.10 (pumping)
S30	05/21/97	1094.58	22.76	1071.82	
S40	05/21/97	1094.21	22.41	1071.80	
S50	05/21/97	1094.16	22.35	1071.81	
S60	05/21/97	1094.17	22.37	1071.80	
S70	05/21/97	1094.57	22.87	1071.70	
S80	05/21/97	1094.60	22.86	1071.74	
Q30	05/21/97	1096.46	24.03	1072.43	
Q40	05/21/97	1095.99	23.60	1072.39	
Q60	05/21/97	1096.00	23.61	1072.39	
Q90	05/21/97	1096.52	24.07	1072.45	
T7	05/21/97	1077.36	4.12	1073.24	
T15	05/21/97	1077.36	4.17	1073.19	
T20	05/21/97	1077.14	3.99	1073.15	
W5	05/21/97	1077.84	4.20	1073.64	
W10	05/21/97	1077.79	4.10	1073.69	
W15	05/21/97	1078.08	4.33	1073.75	
PLR10	05/21/97	1079.15	4.36	1074.79	2.04 (Well 10 Staff)
MW47	05/21/97	1077.29	3.64	1073.65	
C20	05/21/97	1082.2	5.34	1076.86	
C40	05/21/97	1081.6	5.23	1076.37	
C60	05/21/97	1082.1	5.43	1076.67	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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TABLE 5-7
Transect Water Levels - 7/03/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
WE6	07/03/97	1092.55	42.10	1050.45	42.10 (pumping)
V26	07/03/97	1090.68	23.43	1067.25	
V32	07/03/97	1090.60	23.37	1067.23	
V46	07/03/97	1090.70	23.50	1067.20	
V55	07/03/97	1090.65	23.45	1067.20	
V65	07/03/97	1090.70	23.46	1067.24	
V75	07/03/97	1090.68	23.44	1067.24	
U15	07/03/97	1082.67	14.31	1068.36	
U25	07/03/97	1082.66	14.30	1068.36	
U35	07/03/97	1082.69	14.32	1068.37	
U45	07/03/97	1082.41	14.04	1068.37	
U55	07/03/97	1082.41	14.05	1068.36	
U65	07/03/97	1082.42	14.06	1068.36	
B20	07/03/97	1082.16	13.42	1068.74	
B30	07/03/97	1082.84	14.11	1068.73	
B40	07/03/97	1081.91	13.18	1068.73	
B50	07/03/97	1082.88	14.15	1068.73	
B65	07/03/97	1082.11	13.38	1068.73	
B70	07/03/97	1082.87	14.13	1068.74	
E5	07/03/97	1074.44			
E10	07/03/97	1073.71	4.23	1069.48	
E37	07/03/97	1073.25	3.78	1069.47	
F5	07/03/97	1075.34	4.96	1070.38	
F10	07/03/97	1074.68	4.31	1070.37	
PLR6	07/03/97	1074.84	3.60	1071.24	2.80 (Well 6 Staff)
MW39	07/03/97	1072.98	2.64	1070.34	
D20	07/03/97	1083.34	8.21	1075.13	
D40	07/03/97	1083.40	8.30	1075.10	
D60	07/03/97	1083.46	8.32	1075.14	
WE10	07/03/97	1105.35	34.50	1070.85	34.50 (pumping)
S30	07/03/97	1094.58	23.10	1071.48	
S40	07/03/97	1094.21	22.73	1071.48	
S50	07/03/97	1094.16	22.67	1071.49	
S60	07/03/97	1094.17	22.72	1071.45	
S70	07/03/97	1094.57	23.11	1071.46	
S80	07/03/97	1094.60	23.18	1071.42	
Q30	07/03/97	1096.46	24.41	1072.05	
Q40	07/03/97	1095.99	23.97	1072.02	
Q60	07/03/97	1096.00	23.98	1072.02	
Q90	07/03/97	1096.52	24.45	1072.07	
T7	07/03/97	1077.36	4.65	1072.71	
T15	07/03/97	1077.36	4.65	1072.71	
T20	07/03/97	1077.14	4.46	1072.68	
W5	07/03/97	1077.84	4.64	1073.20	
W10	07/03/97	1077.79	4.87	1072.92	
W15	07/03/97	1078.08	4.63	1073.45	
PLR10	07/03/97	1079.15	4.00	1075.15	2.40 (Well 10 Staff)
MW47	07/03/97	1077.29	3.91	1073.38	
C20	07/03/97	1082.2	8.11	1074.09	
C40	07/03/97	1081.6	8	1073.60	
C60	07/03/97	1082.1	8.2	1073.90	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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Transect Water Levels - 8/26/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
Well 6	08/26/97	1092.55	40.40	1052.15	40.40 (pumping)
V26	08/26/97	1090.68	22.96	1067.72	
V32	08/26/97	1090.60	22.90	1067.70	
V46	08/26/97	1090.70	23.10	1067.60	
V55	08/26/97	1090.65	23.06	1067.59	
V65	08/26/97	1090.70	23.11	1067.59	
V75	08/26/97	1090.68	23.07	1067.61	
U15	08/26/97	1082.67	13.83	1068.84	
U25	08/26/97	1082.66	13.81	1068.85	
U35	08/26/97	1082.69	13.85	1068.84	
U45	08/26/97	1082.41	13.57	1068.84	
U55	08/26/97	1082.41	13.58	1068.83	
U65	08/26/97	1082.42	13.58	1068.84	
B20	08/26/97	1082.16	12.95	1069.21	
B30	08/26/97	1082.84	13.65	1069.19	
B40	08/26/97	1081.91	12.73	1069.18	
B50	08/26/97	1082.88	13.71	1069.17	
B65	08/26/97	1082.11	12.93	1069.18	
B70	08/26/97	1082.87	13.68	1069.19	
E5	08/26/97	1074.44	Not Avail	Not Avail	
E10	08/26/97	1073.71	3.99	1069.72	
E37	08/26/97	1073.25	3.54	1069.71	
F5	08/26/97	1075.34	4.82	1070.52	
F10	08/26/97	1074.68	4.17	1070.51	
PLR6	08/26/97	1074.84	3.74	1071.10	2.66 (Well 6 Staff)
MW39	08/26/97	1072.98	2.25	1070.73	
D20	08/26/97	1083.34	7.86	1075.48	
D40	08/26/97	1083.40	8.50	1074.90	
D60	08/26/97	1083.46	8.14	1075.32	
Well 10	08/26/97	1105.35	33.90	1071.45	33.90 (pumping)
S30	08/26/97	1094.58	22.94	1071.64	
S40	08/26/97	1094.21	22.32	1071.89	
S50	08/26/97	1094.16	22.27	1071.89	
S60	08/26/97	1094.17	22.31	1071.86	
S70	08/26/97	1094.57	22.71	1071.86	
S80	08/26/97	1094.60	22.78	1071.82	
Q30	08/26/97	1096.46	23.98	1072.48	
Q40	08/26/97	1095.99	23.60	1072.39	
Q60	08/26/97	1096.00	23.62	1072.38	
Q90	08/26/97	1096.52	24.10	1072.42	
T7	08/26/97	1077.36	4.53	1072.83	
T15	08/26/97	1077.36	4.55	1072.81	
T20	08/26/97	1077.14	4.35	1072.79	
W5	08/26/97	1077.84	4.56	1073.28	
W10	08/26/97	1077.79	4.54	1073.25	
W15	08/26/97	1078.08	4.81	1073.27	
PLR10	08/26/97	1079.15	4.36	1074.79	2.04 (Well 10 Staff)
MW47	08/26/97	1077.29	3.85	1073.44	
C20	08/26/97	1082.20	5.76	1076.44	
C40	08/26/97	1081.60	5.67	1075.93	
C60	08/26/97	1082.10	5.87	1076.23	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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TABLE 5-9
Transect Water Levels - 9/12/97
UWSP Manganese Study

Location	Date	Well Elevation (MSL)	Depth to Water (ft)	Water Elevation (MSL)	Guage Reading (ft)
Well 6	09/12/97	1092.55	42.10	1050.45	42.10 (pumping)
V26	09/12/97	1090.68	23.43	1067.25	
V32	09/12/97	1090.60	23.37	1067.23	
V46	09/12/97	1090.70	23.50	1067.20	
V55	09/12/97	1090.65	23.45	1067.20	
V65	09/12/97	1090.70	23.46	1067.24	
V75	09/12/97	1090.68	23.44	1067.24	
U15	09/12/97	1082.67	14.31	1068.36	
U25	09/12/97	1082.66	14.30	1068.36	
U35	09/12/97	1082.69	14.32	1068.37	
U45	09/12/97	1082.41	14.04	1068.37	
U55	09/12/97	1082.41	14.05	1068.36	
U65	09/12/97	1082.42	14.06	1068.36	
B20	09/12/97	1082.16	13.42	1068.74	
B30	09/12/97	1082.84	14.11	1068.73	
B40	09/12/97	1081.91	13.18	1068.73	
B50	09/12/97	1082.88	14.15	1068.73	
B65	09/12/97	1082.11	13.38	1068.73	
B70	09/12/97	1082.87	14.13	1068.74	
E5	09/12/97	1074.44	Not Avail	Not Avail	
E10	09/12/97	1073.71	4.23	1069.48	
E37	09/12/97	1073.25	3.78	1069.47	
F5	09/12/97	1075.34	4.96	1070.38	
F10	09/12/97	1074.68	4.31	1070.37	
PLR6	09/12/97	1074.84	3.73	1071.11	2.67 (Well 6 Staff)
MW39	09/12/97	1072.98	2.64	1070.34	
D20	09/12/97	1083.34	8.21	1075.13	
D40	09/12/97	1083.40	8.30	1075.10	
D60	09/12/97	1083.46	8.32	1075.14	
Well 10	09/12/97	1105.35	34.50	1070.85	34.50 (pumping)
S30	09/12/97	1094.58	23.10	1071.48	
S40	09/12/97	1094.21	22.73	1071.48	
S50	09/12/97	1094.16	22.67	1071.49	
S60	09/12/97	1094.17	22.72	1071.45	
S70	09/12/97	1094.57	23.11	1071.46	
S80	09/12/97	1094.60	23.18	1071.42	
Q30	09/12/97	1096.46	24.41	1072.05	
Q40	09/12/97	1095.99	23.97	1072.02	
Q60	09/12/97	1096.00	23.98	1072.02	
Q90	09/12/97	1096.52	24.45	1072.07	
T7	09/12/97	1077.36	4.65	1072.71	
T15	09/12/97	1077.36	4.65	1072.71	
T20	09/12/97	1077.14	4.46	1072.68	
W5	09/12/97	1077.84	4.64	1073.20	
W10	09/12/97	1077.79	4.87	1072.92	
W15	09/12/97	1078.08	4.63	1073.45	
PLR10	09/12/97	1079.15	4.70	1074.45	1.70 (Well 10 Staff)
MW47	09/12/97	1077.29	3.91	1073.38	
C20	09/12/97	1082.20	8.11	1074.09	
C40	09/12/97	1081.60	8.00	1073.60	
C60	09/12/97	1082.10	8.20	1073.90	

Note: River depth to water is 6.4 feet (top of guage) minus guage reading

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FIGURE
WELL 6 TRANSECT WATER LEVELS
UWSP MANGANESE STUDY
1997

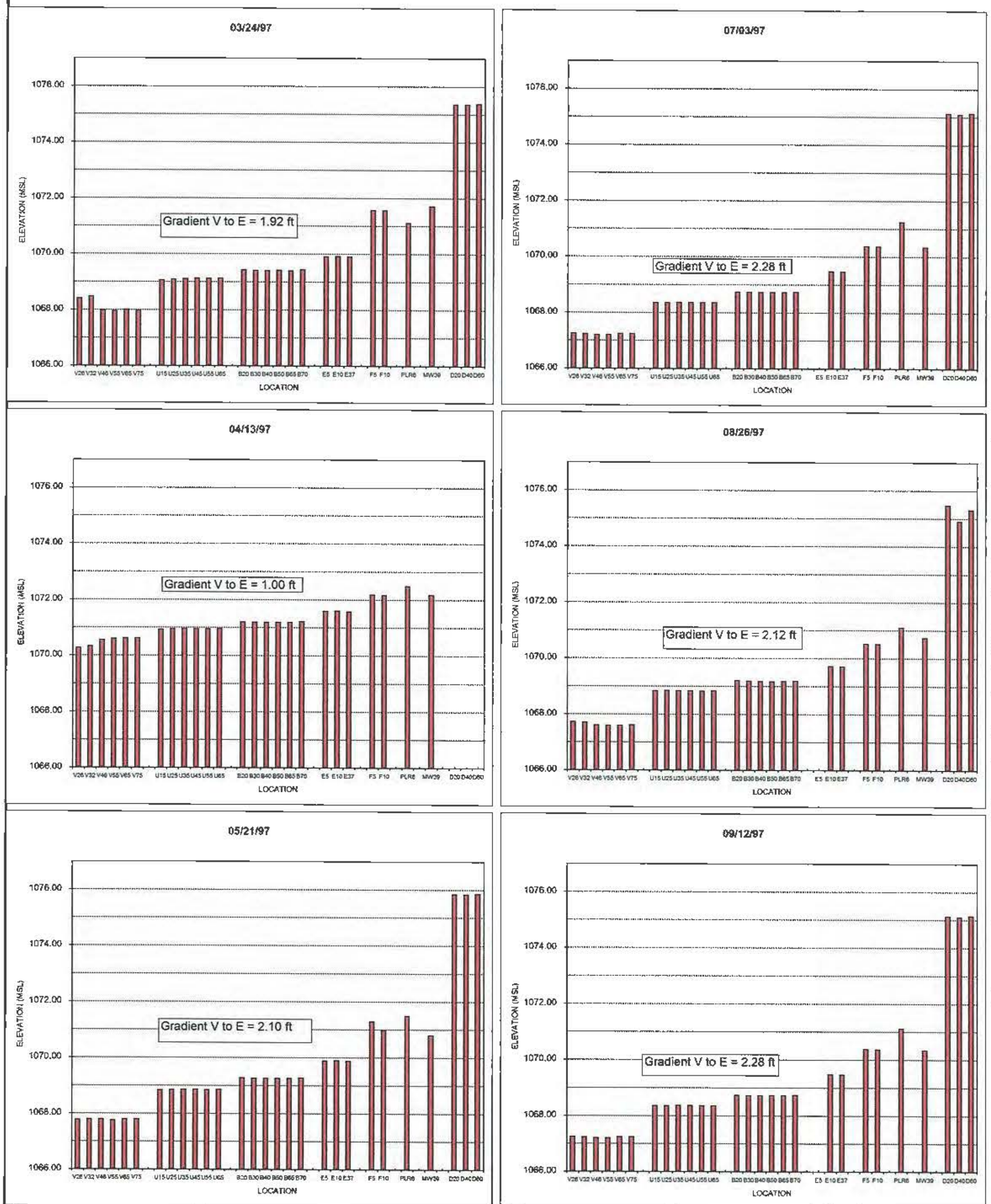
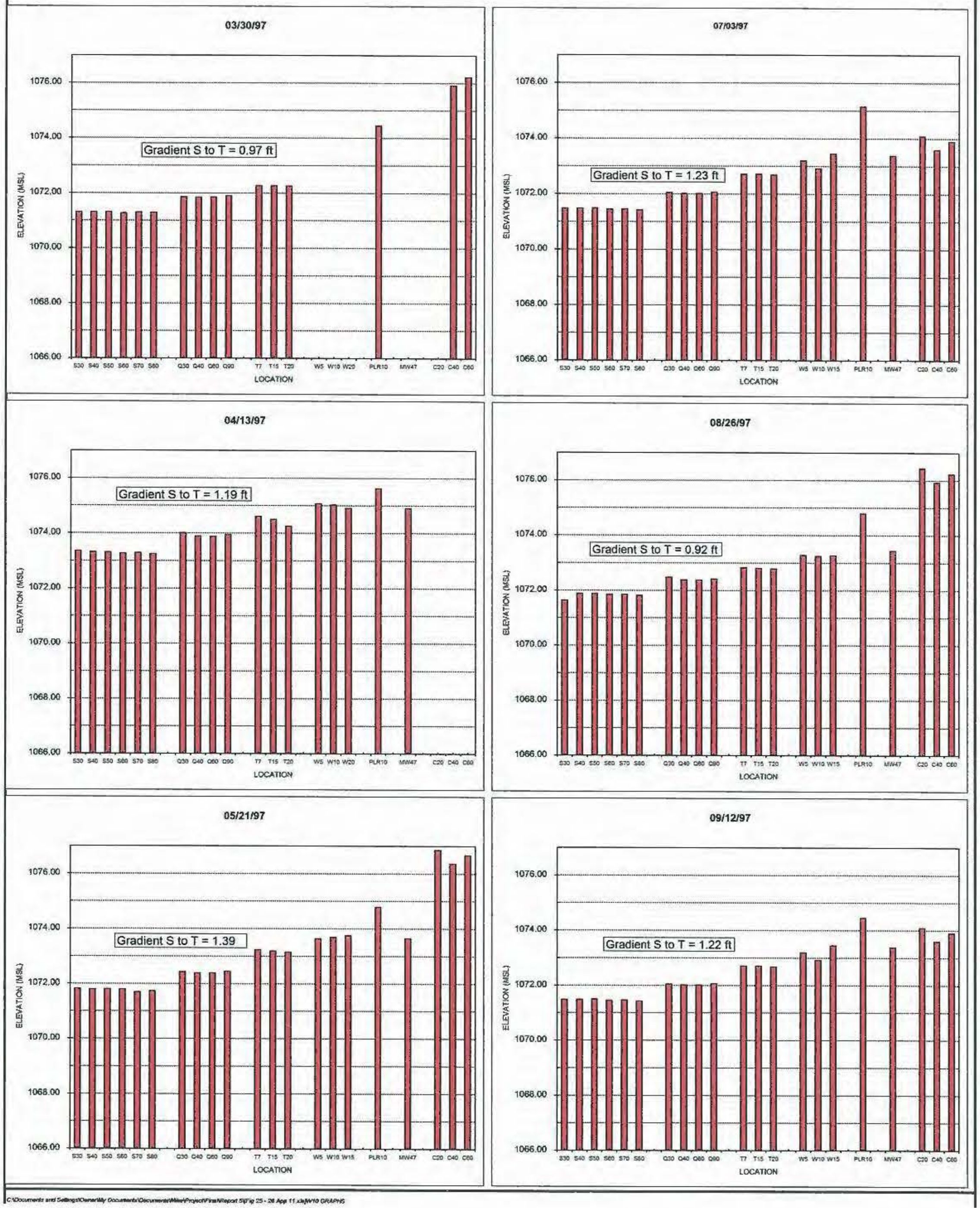


FIGURE
WELL 10 TRANSECT WATER LEVELS
UWSP MANGANESE STUDY
1997



APPENDIX 4
TRANSECT GEOCHEMICAL SUMMARY TABLE

TABLE 10
WATER QUALITY TESTING DATA
UWSP MANGANESE STUDY

Well ID	Sample Date	Temp (Degr C)	DO (mg/l)	pH	eh (mv)	Cond (umhos/cm)	DOC (mg/l)	COD (mg/l)	UV254 (abs)	Mn (mg/l)	Nitrate (mg/l)	Alk (mg/l)	Ca Hard (mg/l)	Tot Hard (mg/l)	Sulfate (mg/l)	Cl (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)
Well 6	03/27/97	10.4	3.45	7.1	211	395	1.41	0	0.012	0.289	1.3	168	112	196	-	-	-	-	-
	06/06/97	10.1	5.4	7.52	233	398	2.06	6.3	0.06	0.335	1.6	167	108	196	20	10	2.74	0.85	<0.02
	07/16/97	10	5.01	7.6	230	410	<1.3	-	-	-	-	-	-	-	-	-	-	-	-
V25	07/05/96		12.95	7.56	-	-	-	0.1	-	0.001	0.4	112	-	128	-	6	-	-	0.02
	03/25/97	12	11.61	7.33	107	237	-	-	-	-	-	-	-	-	-	-	-	-	-
	05/27/97	10	11.21	7.55	243	270	1.22	<3	0.02	<.001	1	114	68	144	9	<1	1.2	0.4	<.02
	07/16/97	9.2	11.5	7.89	281	282	1.46	4.9	0.045	<.005	0.5	112	64	120	9.8	<1	1.06	-	0.03
V35	07/05/96		13.15	7.85				9.6		0.001	0.5	132		136		7			0.02
	03/25/97	13	11.9	7.81	115	200				-									
	05/27/97	11.3	11.25	8.32	248	236	3.61	<3	0.03	<.001	1.2	100	60	112	9	<1	0.8	0.5	<.02
	07/16/97	8.2	11.3	8.09	282	224	<1.3	4.3	0.035	<.005	0.5	107	60	112	9.1	<1	0.88		0.03
V45	07/05/96		10.76	7.79				11.6		0.001	0.6	132		148		8			0.02
	03/25/97	12.6	7.95	6.86	21	208	1.21	3.8	0.004	0.001	0.4	104	64	112					
	05/27/97	12.5	10.42	8.38	238	260	2.75	<3	0.007	<.001	0.3	106	68	104	13.5	<1	1	0.5	<.02
	07/16/97	8.7	10.55	8.24	269	236	<1.3	4.6	0.046	0.005	0.2	101	76	108	13.8	<1	1.13		<.02
V55	07/05/96		0.02	7.36				<0.1		0.191	1	176		184		10			0.02
	03/24/97	10.8	0.2	6.44	155	375	2.37	4.1	0.017	0.32	2.5	172	116	212					
	05/27/97	12.8	0.1	7.33	215	411	3.57	6	0.016	0.537	1.7	159	120	196	21	8	2	0.8	<.02
	07/16/97	8.5	0.13	7.54	231	440	<1.3	5.2	0.01	0.654	2.8	156	124	200	23.1	10	2.13		0.02
V65	07/05/96		0.01	7.3				6.6		0.548	0.6	192		192		5			0.02
	03/24/97	10.3	0.25	6.52	23	408	2.57	0	0.018	0.676	5	188	140	228					
	05/27/97	17	0	7.49	196	413	2.59	6.7	0.015	0.716	1.1	177	136	216	25	14	2.4	1	0.04
	07/16/97	9	0.14	7.39	219	496	<1.3	<3	0.044	0.721	2.7	173	148	228	28.8	15	2.29		<.02
V75	07/05/96		0.19	7.19				5.2		0.411	0.5	-		188		7			0.1
	03/24/97	10.8	0.14	7.04	196	375	2.59	0	0.014	0.335	1.2	187	136	212					
	05/27/97	17	0	7.49	196	413	2.86	3.9	0.016	0.331	0.7	175	128	204	19	9	2.5	0.9	0.09
	07/16/97	9.6	0.14	7.38	248	540	2.57	5.2	0.023	0.327	1.4	180	148	212	21	11	2.35		0.02
V75dup	03/24/97	10.8	0.14	7.04	195	390	1.79	0	0.013	0.32	<0.2	184	124	214					
	04/02/97	8.9	0	7.34	146	410	1.94	0	0.018	0.341	1.2	179	120	212					
U15	06/20/96		11.52	7.18				86.2		0.006	1.9	100		108		1			0.04
	03/25/97	5.8	9.46	7.06	128	185				-	-								
	05/28/97	6.9	9.1	7.71	296	195	2.25	5.3	0.024	0.004	0.3	89	56	104	9.5	<1	0.7	0.4	0.07
	07/16/97	9.9	10.1	6.96	261	275	<1.3	11.6	0.047	0.009	0.2	80	52	84	7.3	<1	0.74		0.2
U25	06/20/96		11.22	7.76				0.1		0.003	0.2	104		120		<1			0.02
	03/25/97	8.6	10.51	7.12	127	210													
	05/28/97	7.6	10.4	8.49	282	230	0.83	3.5	0.005	0.004	0.4	117	88	128	14	<1	0.9	0.5	0.03
	07/16/97	8.4	11.6	8.19	261	213	<1.3	5.4	0.015	<.005	0.2	96	68	84	13.6	<1	1.12		0.02
U35	06/20/96		0.02	7.82				6.8		0.01	<0.2	104		120		1			0.02
	03/24/97	7.8	1.63	6.52	140	198	2.16	5.9	0.01	0.01	0.2	88	41	88					
	05/28/97	8.7	0.98	8.38	254	180	2.52	<3	0.013	0.008	0.2	80	60	88	12	<1	0.7	0.3	<.02
	07/16/97	8.6	1.6	8.11	272	157	<1.3	10.5	0.007	0.919	2.9	164	120	206	22.2	9	2.35		<.02
U35 dup	07/16/97	8.6	1.59	7.51	274	158	<1.3	4	0.031	0.006	<0.2	68	48	84	11.9	<1	0.82		<.02
	07/23/97							<3	0.012	0.005	0.2	64	52	280	12.1	<1	0.9		<.02
U45	06/20/96		0.02	7.27				0.1		0.687	0.6	168		188		7			0.03
	03/24/97	8.3	0.02	6.69	153	390	2.59	0	0.016	0.707	1.3	166	120	196					
	05/28/97	9	0	7.81	230	358	2.28	8.1	0.016	0.757	0.8	156	116	196	19	7	2	0.8	0.02
	07/16/97	8.6	0.02	7.45	230	418	1.3	7.1	0.027	0.573	3.1	180	144	232	29.6	15	2.34		<.02
U55	06/20/96		0.01	7.19				13.2		0.547	0.2	188		196		7			0.04
	03/24/97	8.1	0.26	7.1	154	460	2.61	3.8	0.017	0.57	2.5	188	136	232					
	05/28/97	9	0	7.67	219	411	3.6	9.5	0.017	0.561	1.1	171	120	220	26	12	2.2	0.9	0.04
	07/16/97	8.8	0.22	7.31	224	460													
U65	06/01/96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	03/24/97	6.8	0.07	6.76	153	423	2.43	4	0.018	0.258	1.1	180	108	212					
	05/28/97	9.3	0.11	7.59	176	408	2.48	<3	0.014	0.291	1.1	176	120	212	23	12	2.2	1	0.04
	07/16/97	9.2	0.22	7.29	229	448	<1.3	8.2	0.053	0.278	1.7	180	220	224	23.6	13	2.36		0.03
B20	05/20/96		9.7	7.31				0.1		0.06	0.4	128		124					0.01

TABLE 10
WATER QUALITY TESTING DATA
UWSP MANGANESE STUDY

Well ID	Sample Date	Temp (Degr C)	DO (mg/l)	pH	eh (mv)	Cond (umhos/cm)	DOC (mg/l)	COD (mg/l)	UV254 (abs)	Mn (mg/l)	Nitrate (mg/l)	Alk (mg/l)	Ca Hard (mg/l)	Tot Hard (mg/l)	Sulfate (mg/l)	Cl (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)
	03/25/97	9.5	8.89	7.95	175	248				-									
	05/27/97	12.9	10.39	8.28	210	209		<3	0.01	0.005	0.3	79	56	96	11	<1	0.8	0.5	0.02
	07/16/97	8.3	10.6	7.93	262	250	<1.3	3.5	0.007	0.009	0.2	80	52	92	11.2	<1	1.02		0.04
B30	05/20/96		6.6	6.94				20.1		0.001	<0.2	84		68					0.01
	03/25/97	6.7	5.79	8.05	227	170				-									
	05/27/97	10.5	7.12	7.5	229	163	3.83	6.2	0.012	0.003	0.2	56	48	88	16.5	<1	0.6	0.4	0.02
	07/16/97	8.2	6.31	7.65	256	150	<1.3	3.7	0.011	<.005	<0.2	61	36	88	12.9	<1	0.77		0.02
B40	05/20/96		0.2	6.98				0.1		0.754	<0.2	156		164					0.01
	03/25/97	9	0	7.7	212	345	4.46	10.6	0.031	0.731	0.7	152	100	170					
	05/27/97	11	0	7.6	206	349	5.15	3.2	0.025	0.747	0.2	142	100	160	15	3	1.8	0.7	0.02
	07/16/97	8	0	7.24	234	339	2.64	8.9	0.049	0.731	0.9	152	92	196	14.3	8	2.03		0.17
B50	05/20/96		0.1	6.96				4.4		0.273	<0.2	184		184					0.02
	03/25/97	10.9	0.04	7.41	147	530	2.97	6.2	0.015	0.35	6.6	188	152	272					
	05/27/97	11	0	7.58	193	429	3.35	11.1	0.014	0.323	2.9	166	128	220	26	12	2.4	0.9	0.02
B50	07/16/97	7.9	0.03	7.31	220	458	<1.3	5.8	0.039	0.309	4.9	168	128	228	28.2	16	2.35		0.04
B50 Dup	03/25/97	8.4	0	7.56	199	585	2.33	3.5	0.013	0.366	<0.2	188	168	272					
	04/02/97	9	0	7.31	136	570	3.57	10.9	0.016	0.353	6.7	192	160	270					
	07/16/97	7.9	0.03	7.35	217	442	<1.3	6.6	0.021	0.307	4.9	169	128	232	28.5	17	2.33		0.04
	08/11/97							7.6	0.018	0.305	4.1	169	124	229	24.7	15	2.57		0.02
B60	05/20/96		0.2	7.02				6.2		0.089	<0.2	188		192					0.01
	03/25/97	10.1	0.14	7.36	163	380	2.22	9.9	0.016	0.098	0.2	180	124	194					
	05/28/97	11	0	7.44	182	400	2.22	<3	0.012	0.137	0.2	176	128	204	15	6	2	0.9	0.35
	07/16/97	9.1	0	7.14	216	373	<1.3	10.4	0.059	0.144	<0.2	172	112	204	16.7	9	1.92		0.03
B70	05/20/96		0.1	6.97				<0.1		0.129	<0.2	192		176					0.04
	03/25/97	7.9	0	6.45	161	400	1.55	6.2	0.013	0.122	0.2	180	120	192					
	05/28/97	10	0	7.48	202	398	2.22	6	0.015	0.15	0.2	173	108	192	12	6	2	0.9	0.03
	07/16/97	9.2	0	7.14	235	374	<1.3	3.5	0.01	0.164	<0.2	168	100	204	14.7	7	1.99		0.02
E5	05/20/96		1.6	6.95				16.4		0.074	<0.2	176		180					0.01
	03/26/97	8.7	1.12	6.55	319	430	6.36	14.8	0.059	0.047	0.3	196	128	220					
	05/29/97	8.7	1.04	7.17	166	282	7.62	18.7	0.064	0.042	0.2	110	88	116	6.5	2	2.1	0.7	0.16
E5 dup	05/29/97	8.7	1.05	7.18	175	275	7.62	20	0.064	0.042	0.2	112	72	120	6	2	2	0.7	0.17
	06/17/97	10.2	0	7.64	251	413	10.1	22.6	0.058	0.032	0.2	105	76	108	5.9	3	2.18	0.82	-
E10	05/20/96		0.1	7.14				15.2		0.057	<0.2	76		188					0.02
	03/26/97	7.8	0	7.2	312	380	3.72	5.8	0.039	0.058	0.2	180	104	184					
	05/29/97	6.1	0	7.31	184	228	7.12	14.1	0.057	0.042	0.2	110	68	104	6	2	1.7	0.5	0.04
	07/16/97	9.8	0	7.2	256	250	5.53	14.4	0.075	0.044	<.2	114	72	132	6.5	2	1.83		0.03
E37	05/20/96		0.1	6.95				11.6		0.076	<0.2	80		180					0.08
	03/26/97	10.1	0	7.25	288	570	2.95	5.2	0.015	0.083	7.4	188	156	280					
	05/29/97	8	0.15	7.24	213	440	3.73	10.5	0.014	0.072	3.6	180	136	232	27	14	2.2	0.8	0.07
	07/16/97	7.1	0	7.43	239	422	1.68	<3	0.023	0.065	2.7	174	120	216	20.4	12	2.56		0.02
F5	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/11/97	10.3	0	6.81	192	292	5.72	22.4	0.082	0.201	0.2	124	72	140	12	7	3.33	0.54	3.9
	07/16/97	20	0	7.27	243	410	<1.3	10.9	0.134	0.101	<0.2	152	100	168	11.1	7	3.06		1.56
F10	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/11/97	7.2	0	7.07	228	329	5.39	15.9	0.03	0.08	2	147	100	160	10.5	7	3.43	1.05	0.07
	07/16/97	17.7	0	7.16	235	410	<1.3	7.2	0.08	0.059	<0.2	161	108	200	8.9	7	3.36		0.02
MW-39	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/11/97	8.2	0	6.98	231	256	10.1												
	07/16/97	11	0	7.14	214	450	<1.3	5.5	0.027	0.009	3.5	154	164	216	33.6	12	2.01		<.02
D20	06/16/97	6.7	0	6.76	272	121	2.93	4.3	0.002	0.001	1.1	21	24	40	20	<1	1.54	0.52	<.02
	07/16/97	7.5	9.01				<1.3												
D40	03/27/97	12.6	0.03	6.88	16	333	3.33	0	0.016	0.254	8.2	144	124	210					
	06/16/97	7.6	0	6.97	219	542	3.28	10	0.014	0.279	8.8	144	120	208	17.5	17	2.28	0.86	<.02
	07/16/97	7.5	0	6.89	205	452	<1.3	<3	0.02	0.273	8.9	140	120	208	17.6	18	2.36		0.09
D60	06/16/97	8.1	0	7.06	224	598	4.05	7.6	0.038	0.183	11	168	152	244	22.5	22	2.66	0.83	<.02
	07/16/97	7.8	0	7.13	198	483	1.36	<3	0.024	0.193	10.5	170	148	252	24.2	22	2.75		0.04

TABLE 10
WATER QUALITY TESTING DATA
UWSP MANGANESE STUDY

Well ID	Sample Date	Temp (Degr C)	DO (mg/l)	pH	eh (mv)	Cond (umhos/cm)	DOC (mg/l)	COD (mg/l)	UV254 (abs)	Mn (mg/l)	Nitrate (mg/l)	Alk (mg/l)	Ca Hard (mg/l)	Tot Hard (mg/l)	Sulfate (mg/l)	Cl (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)
Well 10	03/28/97					230	3.3	<3	0.03	0.039	3.6			210		13	2.5		0.05
	06/06/97	6.8	5.41	8.68	236	400	2.5	7.9	0.064	0.034	2.7	155	108	160	6.5	10	3.01	0.84	<0.02
	07/16/97	10.1	6.7	7.25	202	385	1.46												
R35	05/30/96	-	9.23	6	-	-	-	2.9	-	0.005	0.6	-	-	28	-	<1	-	-	0.01
	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/03/97	7.3	14.2	6.38	269	73	4.15	5.74	0.012	0.001	0.3	32	20	32	5.5	<1	0.8	0.3	0.06
	07/16/97	7.6	3.21	6.77	269	76	2.21	11.6	0.051	<.005	<0.2	24	20	40	5.7	<1	0.86		0.03
R45	05/30/96	-	0.25	6.57	-	-	-	8.1		0.142	<0.2	-	-	172	-	5	-	-	1.23
	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/03/97	8.9	0.08	7.27	231	331	7.89	20.5	0.056	0.113	0.2	136	80	144	10	3	2.1	0.6	0.99
	07/16/97	8.1	0	7.55	243	287	6	17.9	0.069	0.107	<0.2	120	80		10	3	2.15		0.88
R45 dup	07/16/97	8.1	0	7.52	234	290	6	17.6	0.101	0.109	<0.2	120	76	144	10.5	3	2.15		0.91
	08/22/97	-	-	-	-	-	3.7	19	0.072	0.113	<0.2	121	84	136	11	5	2.25		0.91
R65	05/30/96	-	0.14	6.93	-	-	-	0.1	-	0.028	1.1	-	-	168	-	6	-	-	0.04
	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/03/97	8.5	0	7.27	219	443	3.3	6.72	0.021	0.027	2.4	176	120	208	14.5	9	2.4	0.9	0.05
	07/16/97	7.2	0	7.6	218	478	1.64	9.5	0.05	0.027	5	164	136	232	20.9	14	2.67		0.02
R65 dup	06/03/97	8.5	0	7.29	220	458	2.57	<3	0.023	0.028	2.4	174	112	204	14.5	8	2.4	0.9	0.05
	06/16/97	8.2	0	7.39	240	465	4.01	9	0.019	0.024	2.9	168	116	204	15.5	9	2.67	0.91	-
R90	05/30/96	-	0.09	7.1	-	-	-	3.68	-	0.005	3.9	-	-	200	-	11	-	-	0.01
	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/03/97	7.7	0.06	7.33	201	570	2.5	3.44	0.013	0.002	9.6	177	136	248	27	19	2.3	0.9	0.05
	07/16/97	7.1	0	7.73	205	571	<1.3	<3	0.031	0.008	7	177	152	256	29.2	22	2.58		0.02
S30	07/09/96	-	11.01	7.66	-	-	-	0.1	-	0.001	1.7	-	-	168	-	2	-	-	0.05
	03/28/97	12	4.47	6.7	35	300	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/02/97	9.6	11.45	7.89	224	385	2.01	7.8	0.012	<.001	1.3	159	100	176	9.5	2	2.3	0.7	0.04
	07/16/97	9.9	10.42	7.76	265	309	<1.3	4.4	0.014	<.005	2.4	134	88	148	11.7	2	2.29		0.02
S40	07/09/96	-	0.23	6.79	-	-	-	28.4	-	0.089	<0.2	-	-	168	-	4	-	-	0.15
	03/28/97	15.2	0.03	6.64	35	325	6.75	16.3	0.113	0.089	0.2	144	100	152	-	-	-	-	-
	06/02/97	10.8	0	7.09	193	378	5.52	18.7	0.085	0.103	0.2	148	88	160	10	5	2.4	0.8	3.4
	07/16/97	9.7	0.16	7.07	207	340	3.11	14	0.096	0.107	<.2	164	112	176	11.6	7	2.74		3.1
S50	07/09/96	-	0.12	6.68	-	-	-	0.1	-	0.029	<0.2	-	-	120	-	3	-	-	0.07
	03/28/97	15	0	6.91	131	335	4.27	7	0.041	0.053	0.2	164	112	174	-	-	-	-	-
	06/02/97	7.5	0	7.11	210	372	3.85	<3	0.024	0.058	0.2	302	92	176	12	6	2.4	1.1	0.07
S50	07/16/97	8.7	0.1	7.22	224	293	1.54	9.3	0.032	0.053	0.2	132	100	152	10.2	7	2.48		0.03
S60	07/09/96	-	0.02	7.04	-	-	-	18.4	-	0.021	<0.2	-	-	168	-	5	-	-	0.06
	03/28/97	10.4	0	7.26	117	360	1.87	0	0.024	0.031	0.6	188	132	208	-	-	-	-	-
	06/02/97	2.4	0	7.63	215	320	4.02	10.2	0.033	0.023	0.2	141	84	160	8.5	5	2.6	0.5	0.05
	07/16/97	11.2	0.14	7.42	227	371	1.87	7.9	0.038	0.04	<.2	168	104	184	12.3	8	3.44		0.05
S60dup	03/28/97	7	0	7.4	117	340	2.43	5.2	0.032	0.021	7.1	184	120	204	-	-	-	-	-
	04/02/97	8.7	0	6.43	62	435	2.49	8.2	0.022	0.029	0.6	192	128	204					
S70	07/09/96		0.03	7.07	-	-	-	6.8	-	0.006	<0.2	-	-	180	-	5		-	0.19
	03/28/97	6.2	3.75	7.38	139	330	1.87	4.1	0.019	0	1.7	184	120	204	-	-	-	-	-
	06/02/97	2.4	0.09	7.61	215	361	3.95	10.2	0.033	<.001	0.5	160	92	184	0.5	6	2.7	0.6	0.05
	07/16/97	9.7	0.7	7.45	238	365	1.96	8.2	0.034	0.008	0.3	169	108	188	8.5	8	3.35		0.04
S70dup	06/02/97	2.5	0.1	7.61	218	361	3.57	-	0.036	<.001	0.5	182	96	180	10	6	2.6	0.7	0.03
	06/17/97	3.6	0	7.5	253	598	4.72	11.3	0.026	0.002	0.5	163	100	168	8.7	6	3	0.7	-
S80	07/09/96	-	0	6.96	-	-	-	4.8	-	0.001	0.2	-	-	176	-	7	-	-	0.34
	03/28/97	6.3	3.3	7.37	126	425	1.55	4.1	0.022	0.001	1.9	196	136	216	-	-	-	-	-
	06/17/97	3.5	2.51	7.53	205	400	4.42	7.05	0.017	<.001	1.7	174	92	200	13	9	2.5	0.8	0.03
	07/16/97	7.7	0.07	7.49	228	388	<1.3	7.9	0.026	<.005	2.2	166	116	212	13.3	12	3.28		0.04
Q30	05/29/96	-	0.94	6.32	-	-	-	0.1	-	0.019	<0.2	-	-	132	-	<1	-	-	0.04
	03/26/97	12.3	0.15	7.19	150	365	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/04/97	9.7	2.13	7.15	252	182	9.28	18.2	0.047	0.025	1	56	<4	72	8.5	<1	1.7	0.8	0.08
	07/16/97	6.4	1.06	7.14	221	234	4.22	7.6	0.046	0.006	0.4	106	76	120	11	6	2.43		0.12
Q40	05/29/96	-	0.13	6.52	6.52	-	-	27.4	-	0.077	<0.2	-	-	140	-	1	-	-	1.36

TABLE 10
WATER QUALITY TESTING DATA
UWSP MANGANESE STUDY

Well ID	Sample Date	Temp (Degr C)	DO (mg/l)	pH	eh (mv)	Cond (umhos/cm)	DOC (mg/l)	COD (mg/l)	UV254 (abs)	Mn (mg/l)	Nitrate (mg/l)	Alk (mg/l)	Ca Hard (mg/l)	Tot Hard (mg/l)	Sulfate (mg/l)	Cl (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)
	03/26/97	12.6	0.03	6.88	16	333	4.62	11	0.086	0.056	0.2	152	96	166	-	-	-	-	-
	06/16/97	7.5	0.04	7.2	225	197	6.87	19.93	0.063	0.029	<0.2	76	48	88	8	2	1.6	1	0.82
	07/16/97	5.1	0	7.19	223	189	4.56	16.1	0.072	0.033	<.2	75	60	96	13.2	4	2.02		0.74
Q40 dup	07/16/97	6.8	2.21	7.17	224	173	6.03	45.6	0.068	0.032	<0.2	76	56	92	12.6	5	1.98		0.8
	07/23/04	-	-	-	-	-	-	16.4	0.076	0.032	<0.2	79	60	96	10.4	4	2.01		0.81
Q60	05/29/96	-	0.24	6.81	-	-	-	11.3	-	0.06	<0.2	-	-	180	-	4	-	-	0.01
	03/27/97	6.3	0	7.3	42	370	1.95	7	0.018	0.027	0.6	184	132	200	-	-	-	-	-
	06/16/97	2.5	0	7.37	216	342	5.46	13.77	0.032	0.025	<0.2	153	92	160	8.5	5	2.7	0.7	0.04
	07/16/97	6.7	0.04	7.24	210	375	2.78	9.6	0.04	0.044	<.2	172	108	184	8.7	8	3.52		0.05
Q90	05/29/96	-	0.15	6.98	-	-	-	4	-	0.278	<0.2	-	-	184	-	5	-	-	0.06
	03/27/97	13.4	0	7.1	44	420	2.05	0	0.016	0.28	0.2	188	140	204	-	-	-	-	-
	06/16/97	6.8	0	7.43	217	438	2.75	3.73	0.011	0.284	<0.2	175	112	200	15	9	1.9	0.8	0.13
	07/16/97	14.5	0	7.46	213	395	4.09	<3	0.01	0.284	<0.2	177	120	200	14.6	11	2.11	-	0.11
T7	05/30/96	-	0.05	6.77	-	-	-	20.5	-	0.041	0.2	-	-	168	-	-	-	-	0.02
	03/26/97	6.8	7.22	6.51	127	390	2.25	0	0.023	0.002	2	176	128	200	-	-	-	-	-
	06/03/97	15.1	0	7.5	229	422	5.7	5.74	0.039	0.004	0.6	166	100	180	8.52	6	2.9	1.2	0.03
	07/16/97	22.2	0	7.25	236	480	4	20.4	0.057	0.036	<0.2	180	124	192	8.7	7	3.11		0.47
T15	05/30/96	-	0.01	6.65	-	-	-	24.9		0.001	<0.2	-	-	168	-	-	-	-	0.01
	03/26/97	6	0	7.06	152	378	2.63	3.5	0.022	0.011	0.4	184	120	204	-	-	-	-	-
	06/03/97	11.9	0	7.33	224	408	4.66	6.07	0.034	0.003	0.4	170	96	168	8.5	6	2.8	1.6	0.03
	07/16/97	20.9	0	6.96	257	502	7.39	28.4	0.062	0.038	<0.2	208	168	208	4.5	8	3.55		0.14
T20	06/27/96	-	0.32	6.69	-	-	-	24.5	-	0.001	<0.2	-	-	156	-	-	-	-	0.01
	03/26/97	6.1	0	7.12	150	380	2.55	3.2	0.024	0.032	0.2	188	120	200	-	-	-	-	
	06/03/97	11.1	0	7.21	222	399	6.25	3.77	0.036	0.014	0.3	152	100	168	8	6	2.6	1.9	0.04
	07/16/97	20.9	0	7.23	233	410	4.04	19	0.071	0.034	<0.2	164	104	172	5.9	7	3.04	-	0.06
T20 dup	06/03/97	11	0	7.19	222	395	4.4	12.63	0.033	0.014	0.3	152	96	172	8	5	2.7	1.9	0.05
	06/17/97	12.7	0	7.54	252	625	5.49	12.6	0.036	0.02	0.2	182	112	180	2.6	7	3.12	1.41	-
W5	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/06/97	10	0	7.13	234	356	7.77	-	-	-	-	-	-	-	-	-	-	-	-
	07/16/97	19.7	0	7.35	227	430	3.93	15.7	0.089	0.067	<0.2	168	108	164	6	8	3.3	-	0.1
W10	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/06/97	9.2	0	6.92	218	337	8.75	-	-	-	-	-	-	-	-	-	-	-	-
	07/16/97	17.2	0	7.05	208	412	7.53	24.4	0.065	0.127	<0.2	216	144	212	5	9	3.28		0.48
W15	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/06/97	8.4	0	7.02	220	332	11.7	-	-	-	-	-	-	-	-	-	-	-	-
	07/16/97	15.3	0	7.19	213	495	3.45	19.3	0.037	0.267	<0.2	184	120	184	4.6	8	3.57		0.96
MW-47	3/97	NO SAMPLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	06/06/97	6.2	0	6.92	234	239	6.63	28.9	0.072	0.069	0.2	90	60	100	9	3	3.12	1.5	1.82
	07/16/97	11.1	0	6.76	203	378	27.2	9.8	0.129	0.081	<0.2	136	76	152	8.8	8	3.15		4.1
C20	06/11/97	6.2	9.5	7.71	244	187	4.66	<3	0.002	0.002	0.6	76	52	84	10.5	<1	1.23	0.61	<.02
	07/16/97	7.2	11.49	8.45	225	148	<1.3	<3	0.004	<.005	0.4	69	48	92	10.6	<1	1.21	-	<.02
C40	03/27/97	12.3	0.15	7.19	150	365	1.06	0	0.01	0.002	13.6	144	152	248					
	06/11/97	7.4	0.3	7.07	191	582	3.84	<3	0.006	0.002	14.7	140	140	252	27.5	24	2.56	0.89	0.02
	07/16/97	7.4	0.92	7.11	195	470	<1.3	<3	0.012	<.005	14.3	141	144	248	25.6	25	2.64	-	<.02
C60	06/11/97	7.8	0	6.96	191	582	5.96	8.3	0.019	0.009	11.8	175	152	264	25	22	2.89	0.84	0.02
	07/16/97	7.8	0.12	6.84	196	515	<1.3	<3	0.026	0.011	11.8	173	160	268	24.4	23	2.95	-	0.02
Plover Riv	03/27/97			4.8	170	350	3.67	3.8	0.038	0.039	1.6	<4	-	174	-	8	2.69	-	0.38
	06/17/97	20.2	9.5	6.85	8.57	238	5	11	0.033	0.023	1	172	112	188	8.5	7	3.14	1.08	0.3
	07/16/97	21	5	8.2	220	416	32.3	7.3	0.028	0.015	0.8	181	120	204	9.9	16	3.54	-	0.03

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