IMPACT OF ANIMAL WASTE LAGOONS ON GROUND WATER QUALITY:

An Update on Data Collected from March 1998 through November 1999

Section 319, Clean Water Act
Grant Year, FY 98
Final Report

Report of Groundwater Investigation Number 18

PAUL R. DAHLEN
RAYMOND M. MILOSH

GROUNDWATER SECTION
DIVISION OF WATER QUALITY

N.C. DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
RALEIGH, NORTH CAROLINA
JANUARY 2002

Table of Contents

Table of Figures

Acknowledgements

The authors wish to thank Mark Pritzl, Sandra Goodman-Cash, Walt Haven, Ted Mew, and Carl Bailey of the NC Division of Water Quality, Groundwater Section and Timothy Spruill of the US Geological Survey for their invaluable comments and suggestions following their review of this report.

Abstract

This report is a continuation of a three-year study of waste lagoon/land application operations at nine hog farms and two dairy farms in North Carolina funded by the United States Environmental Protection Agency from a grant enabled in Section 319 of the Clean Water Act. That study's objective was to determine whether animal waste lagoons constructed according to current Natural Resources Conservation Service (NRCS) standards adequately protect ground water quality.

Two of the nine swine operations and one of two dairy operations that were studied in North Carolina exhibit evidence that lagoon seepage is adversely impacting ground water. Electromagnetic surveying was useful at the two swine operation sites to identify and delineate the lagoon seepage plumes.

All 11 lagoons were reported to have been constructed using current NRCS standards; however, it was determined that one of the leaking swine farm lagoons was not constructed properly. Results from three of the swine farm lagoons are inconclusive due to well placement or construction.

Calculated ground water flow velocities at eight of the sites indicate that sufficient time has elapsed for lagoon seepage indicators to travel laterally from the lagoons to monitoring wells installed at each site. The ground water flow velocity could not be calculated for three sites, and wells were not suitably placed or screened in locations where lagoon seepage indicators would be detected at three sites.

Introduction

The North Carolina Division of Water Quality (DWQ), Groundwater Section (GWS), released a report entitled Impact of Animal Waste Lagoons on Ground Water Quality in June 1998. That report documented the work performed by Groundwater Section Hydrogeologist Elizabeth Morey and Hydrogeologic Technicians Ray Milosh, Wesley Childres and Mark Pritzl during a three-year study of waste lagoon/land application operations at nine hog farms and two dairy farms in North Carolina (fig. 1) (DWQ, 1998). The project was funded by the U.S. Environmental Protection Agency (EPA) from a grant enabled in Section 319 of the Clean Water Act. The objective of that study was to determine whether waste lagoons constructed according to current Natural Resources Conservation Service (NRCS) standards adequately protect ground water.

In defining whether ground water was adequately protected, the State's ground water quality rules were referenced. 15A NCAC, Subchapter 2L, Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina, defines review and compliance boundaries for non-discharge waste disposal systems. Ground water standards may not be exceeded beyond compliance boundaries, and review boundaries are placed midway between contaminant source boundaries and compliance boundaries for early warning of ground water quality problems.

Initial monitoring wells were placed approximately 125 and 250 feet downgradient from the waste lagoons at each site. These distances were meant to signify distances to review and compliance boundaries respectively. Downgradient flow direction was estimated based on topography. The original report states that inadequate time and resources were available to conduct comprehensive site investigations prior to placement and construction of the monitoring wells (DWQ, 1998). The report concluded that the study's objective could not be met due to the limited number of sites sampled and the insufficiency of time allowed for ground water migration.

EPA provided additional funding during fiscal year 1998 to monitor the eleven sites for two more years and evaluate ground water flow direction and velocity at each site. Electromagnetic (EM) surveys would also continue to be evaluated. This document is a report of the work completed in this additional two-year period. It must be noted that impact to the ground water from the spraying of wastewater onto fields was not addressed in this study. The Impact of Animal Waste Lagoons on Ground Water Quality report will be referred to in this document as the *original report*. Copies of the original report are available online at http://gw.ehnr.state.nc.us. The report can also be obtained by contacting the Groundwater Section at (919) 733-3221.

Ground Water Flow

In addition to verifying ground water flow directions, one objective of this additional study was to calculate ground water flow velocity at each site to determine if sufficient time had passed for possible lagoon leachates to impact monitoring wells. Slug tests were performed in wells at each site to estimate hydraulic conductivities in the vicinity of the monitoring wells. Boring logs were consulted to determine which wells drew water from the same aquifer. The authors are aware of the limitations of slug test data; however, due to time and resource constraints, aquifer tests could not be performed at the study sites.

Slug tests were performed using a Troll® pressure transducer/recorder in each well while a volume of water was removed from the well using a bailer. After recovery of the well was recorded, the same volume of water was introduced back into the well by lowering the full bailer while well recovery was again recorded.

Data from these slug tests were then analyzed using Starpoint Software's Super Slug® application. Slug-in test results were only used when the static water level was above the screened interval. The Bouwer and Rice analysis method was used to analyze the response test data, except where there appeared to be a confining layer above the aquifer. In these instances, the Horslev analysis method was used.

Ground Water Sampling

Ground water sampling continued on a quarterly basis for all sites except the Robeson site. Sampling was conducted monthly at the Robeson site. Ground water samples were analyzed for nitrite and nitrate (NO_2+NO_3), ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), potassium (K) and chloride (Cl). TKN is the total amount of organic and ammonia nitrogen in a sample.

In addition to these lagoon seepage indicators, the samples were also analyzed for phosphates (PO_4), calcium (Ca), copper (Cu), magnesium (Mg), manganese (Mn), zinc (Zn) and dissolved solids.

Ground water elevations were recorded during each sampling event. The sampling procedure and laboratory methods that were used are detailed in the original report.

Electromagnetic (EM) Surveys

EM surveys were conducted at selected sites to establish any changes from earlier surveys using a Geonics® Model EM 31 meter. To concentrate resources effectively, surveys were only conducted at sites where EM surveys had been valuable in the original study. These surveys were performed primarily to aid in placement of additional monitoring wells. A more detailed discussion of EM surveying in this study can be found in the original report.

Site Updates

The following sections detail the additional work completed and the results of that work at each site. Figure and graph scales are not constant for each site, so note any scale changes when reviewing the figures in this report. The sites are reviewed in alphabetical order.

Locations of Animal Waste Lagoon Ground Water Monitoring Sites

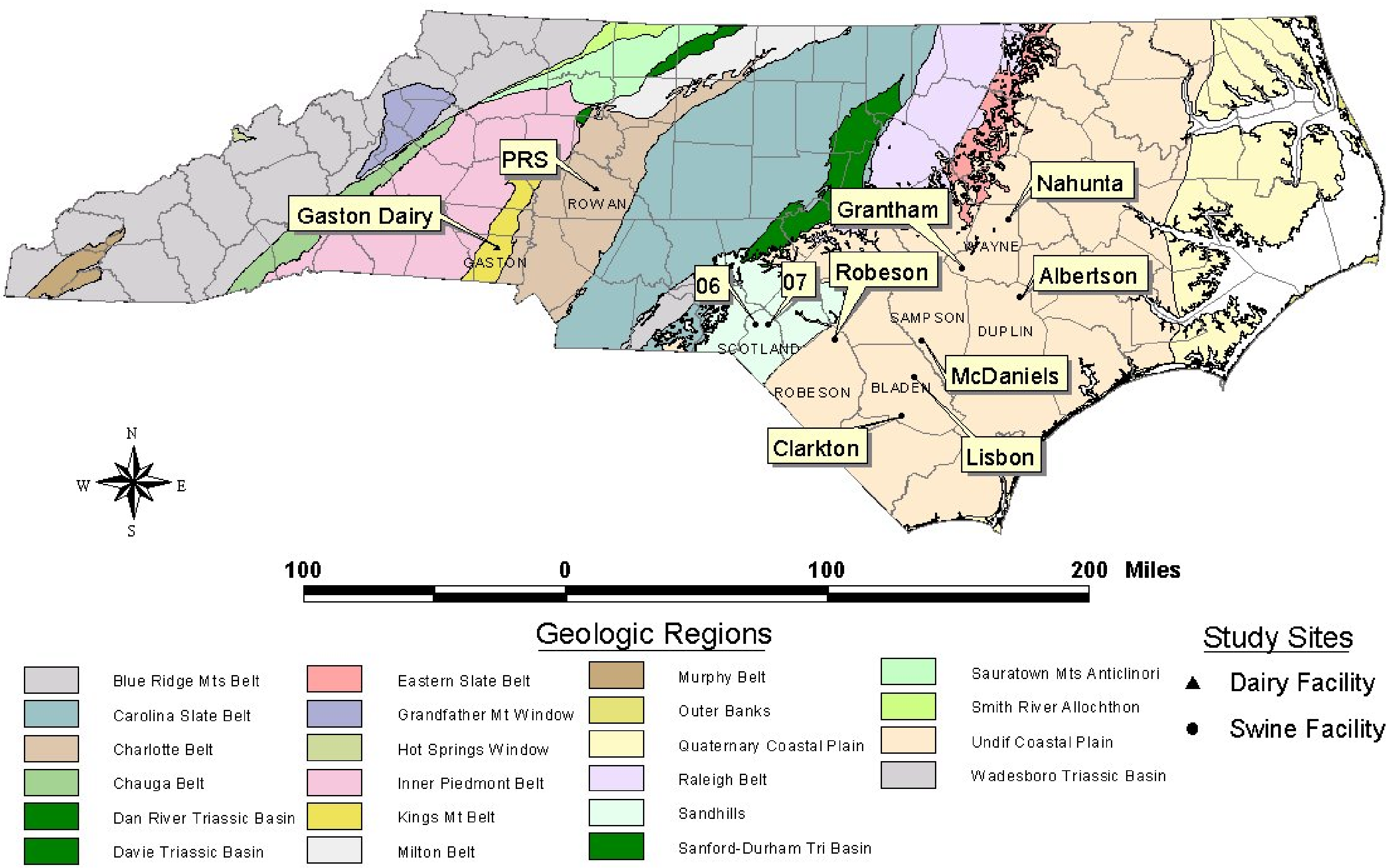


Figure 1

The 06 site is a swine operation located in an upland setting in the Sandhills area of the Coastal Plain. Ground and surface water from this site discharge into the Lumber River Basin.

Ground Water Flow

As indicated in the original report, the placement of the monitoring wells was in question (DWQ, 1998). The original wells were placed between the lagoon and a nearby stream, as ground water typically flows toward streams. Ground water elevations indicated that the water table being monitored for lagoon seepage was actually flowing away from the stream toward the lagoon (fig. 3). A surveying error was suspected, but after resurveying, it was determined that the ground water at the site was indeed flowing in a direction opposite to what would be expected. An employee at the facility mentioned that the farm supply well was approximately 300 feet deep and was used to produce the 3,000 gallons per day required to operate the hog houses. This well may be the cause of the unexpected ground water flow direction, as the ground water beneath the wells flows toward it, rather than toward a downgradient stream. Accordingly, the supply well was sampled and analyzed to see if it had high concentrations of constituents associated with lagoon seepage. Results showed low concentrations of constituents.

On May 15th and 22nd, 1997, Groundwater Section staff hand installed four piezometers (P1, P2, P3 and P4) with the intent of monitoring ground water elevations in a wider area around the lagoon. While hand auguring the holes for the piezometers, staff noted what appeared to be a perched water table atop a shallow clay layer. A review of well logs from the original wells at the site showed the same clay layer. When the initial monitoring wells were drilled, the presence of a perched system was noted, but it was assumed to be local and discontinuous. These wells were screened below the perched aquifer.

Water elevations in the four piezometers indicted that there was a silty sand aquifer above the continuous shallow clay layer that conducts ground water under the lagoon in the expected direction of ground water flow (fig. 4). Any lagoon seepage would likely be conducted toward a ground water discharge site within this shallower system, not in the deeper system.

On October 12 and 13, 1998, GWS staff installed five new shallow 1-inch diameter wells at the site with a Geoprobe® unit. Wells 06-7, 06-8, 06-9 and 06-10 were installed atop the shallow clay layer. They were placed to intercept any lagoon seepage. Well 06-7 did not produce enough water to collect a sample, but wells 06-8, 06-9, 06-10 and 06-P2 were monitored for lagoon seepage for the remainder of the study.

There is strong indication that the onsite supply well is affecting ground water flow at this site (fig. 3). The extent of this interference with the natural gradient in both aquifers is unknown, so no accurate determination of ground water flow velocity can be made.

Ground Water Sampling Results

Monitoring wells at this site were sampled three additional times since publication of the original report (fig. 7). Nutrient analyses indicate that the ground water in the surficial aquifer has higher concentrations of lagoon seepage indicators, but these nutrients may be coming from another source as discussed below.

On February 9, 1999, GWS staff noted that pastureland for a small herd of cattle had been expanded to include the land where monitoring wells 06-1,2,3,4,5,7,8,9 and 10 are placed. The cattle manure may be contributing to shallow ground water concentrations of nitrogen and Cl in these wells.
GWS staff also noted the installation of a "dead pit" approximately 75 feet south-southeast of well 06-6 while visiting the site on February 9, 1999. A dead pit is a long trench excavated to a depth of about 6 feet, which is used to dispose of dead hogs. Leaching from the dead pits could eventually impact ground water quality in the shallow downgradient wells. If concentrations of K, Cl and NO_3 rise in these wells, additional water analyses would be necessary to determine if the source is the lagoon, the cattle, or animal decomposition.

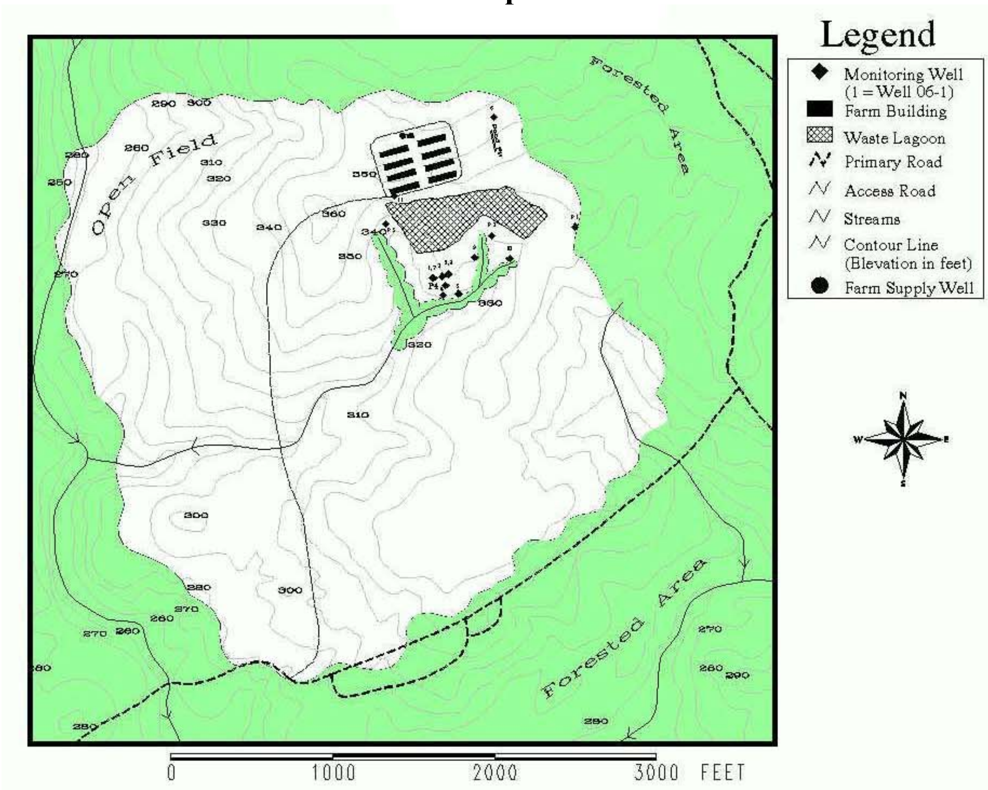
EM Surveys

On May 15, 1997, GWS staff conducted an EM survey around the lagoon. EM readings did not indicate any areas of anomalous readings around most of the lagoon except for the presence of a linear area of high conductivity beginning at the lagoon and heading toward an area of ground water discharge. Additional EM surveying showed the anomaly to be mostly at a depth of 9 to 12 feet and 50 to 60 feet wide near the lagoon and becoming narrower toward the stream. The length of the anomaly from the base of the lagoon to the woods line near the stream was approximately 190 feet. Piezometer 2 (06-P2) was installed at 130 feet from the lagoon in the center of the anomaly. Concentrations of dissolved solids, sulfate, NH_3, NO_3, Ca and K in the ground water sample from 06-P2 were approximately 10 times higher than concentrations in other wells at the site; however, none of the other constituents found in samples of the lagoon liquid were present in high concentrations in the sample. The source of the contaminants in the ground water in that area remains unknown.

Conclusion

Based on the analyses results from the monitoring wells and the onsite supply well, ground water at this site is being adequately protected from lagoon seepage.

06 Site Maps



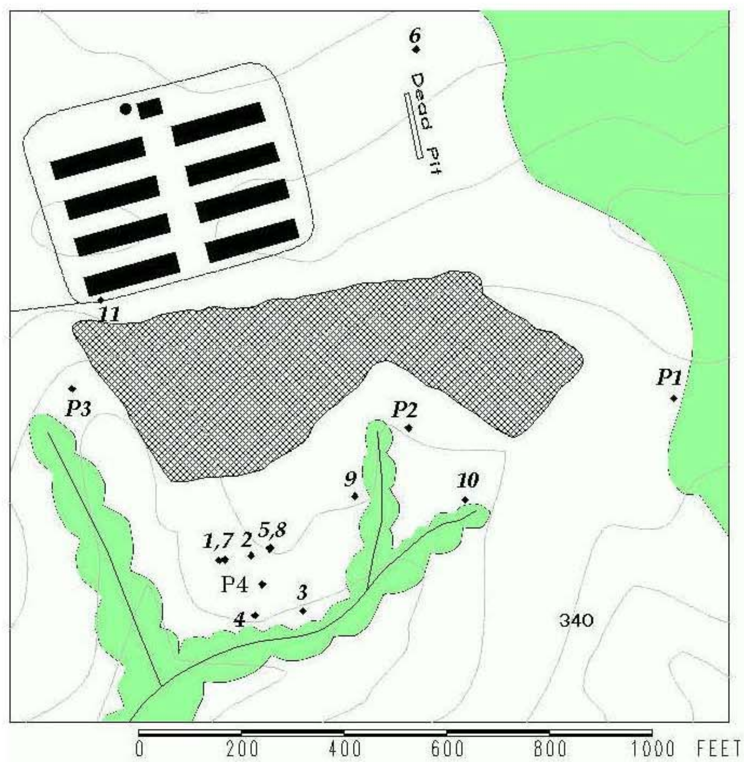


Figure 2

06 Site Ground Water Flow Map
First Confined Aquifer (6/9/99)

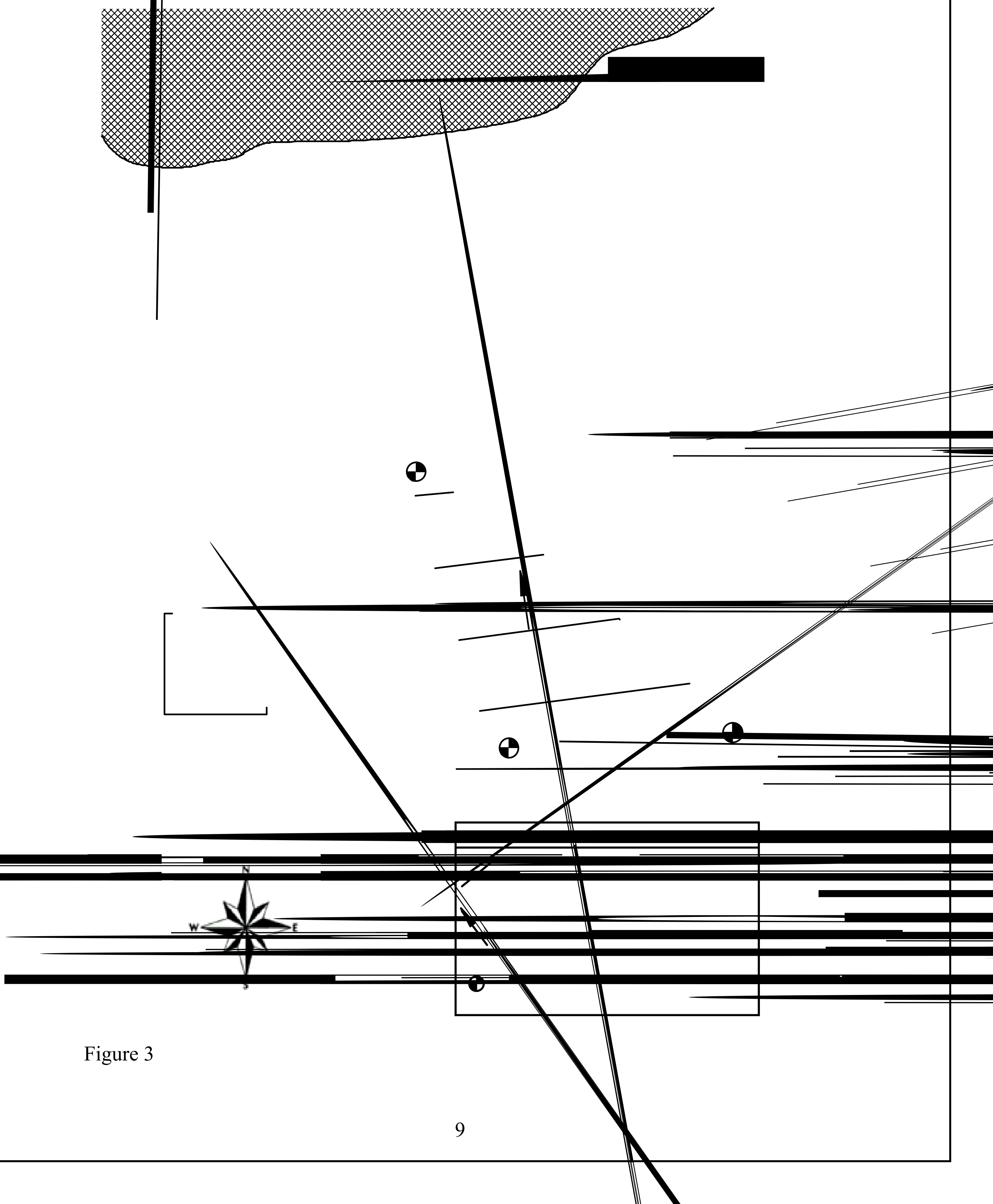


Figure 3

06 Site Ground Water Flow Map
Surficial Aquifer (2/9/99)

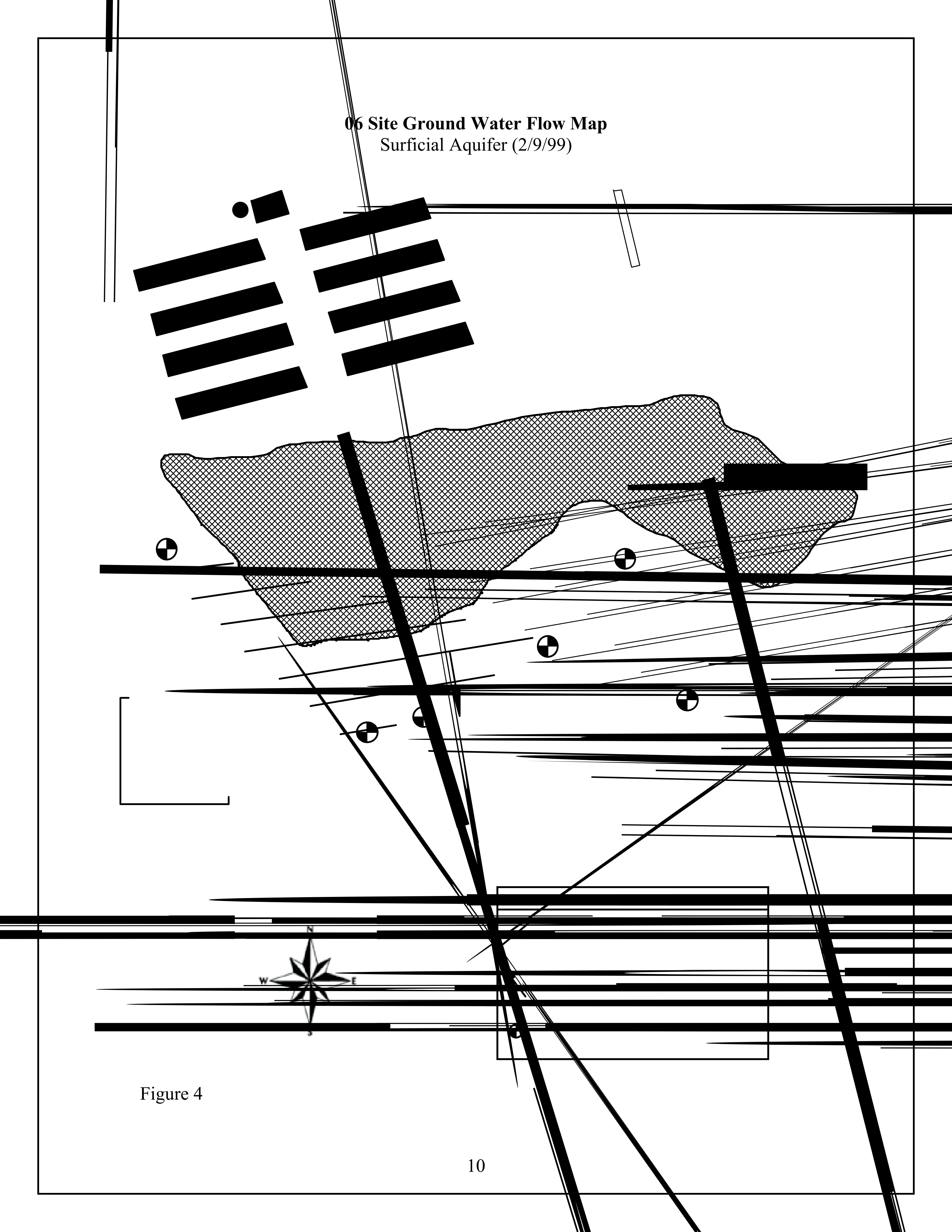
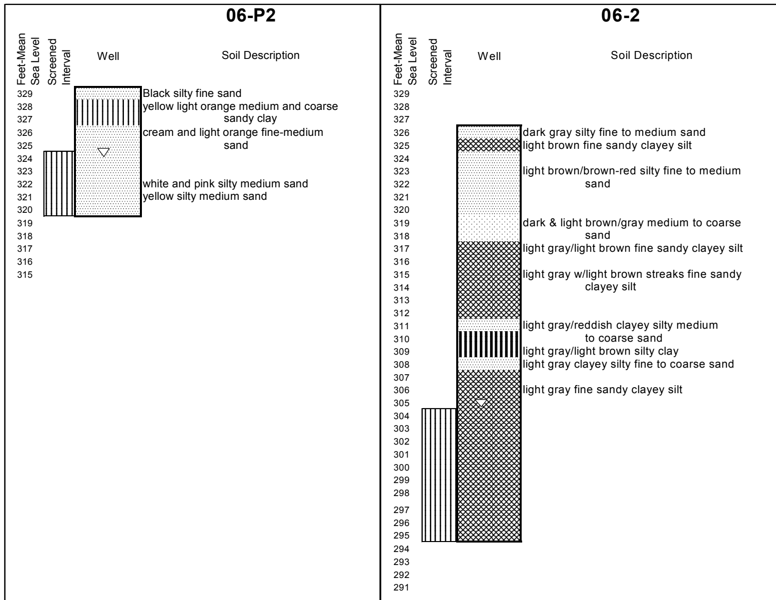
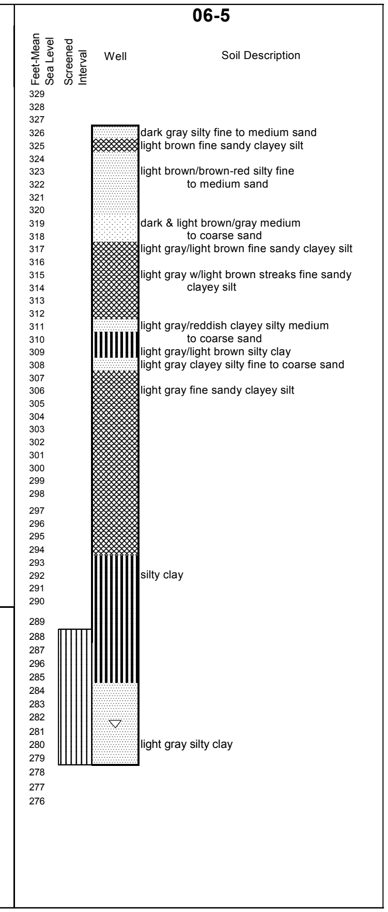


Figure 4

06 Site Well Logs and Aquifer Characteristics



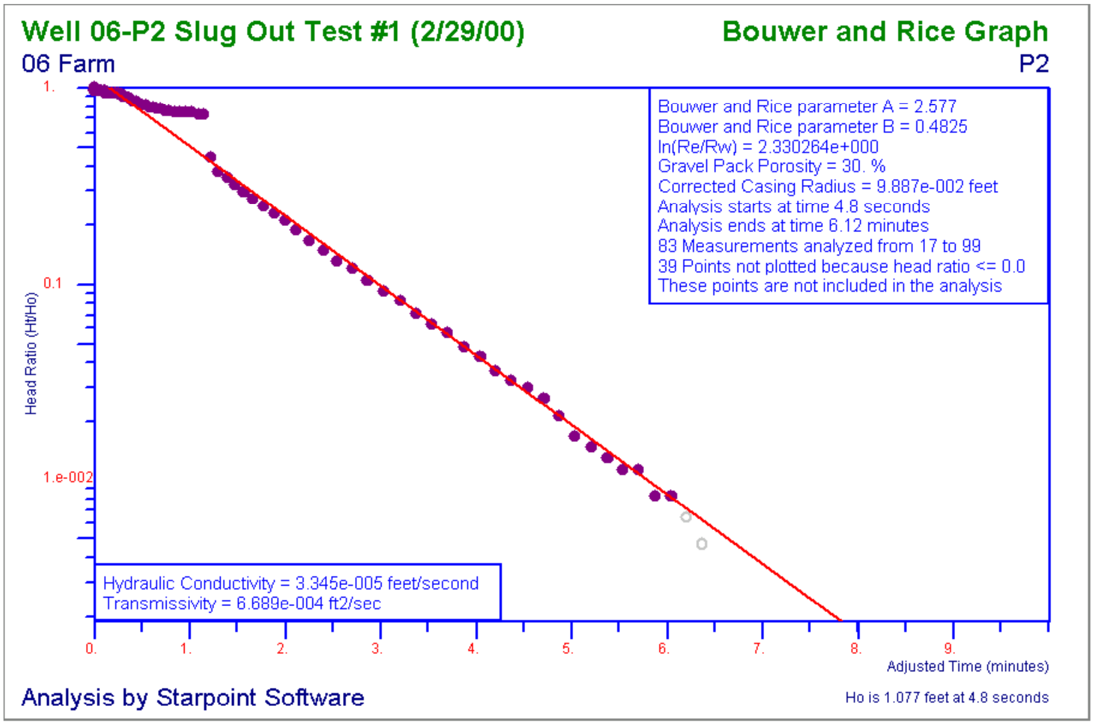


Slug Test ID	Out 1	Out 2	Out 3	In 1	In 2	Out 1	Out 2	Out 3	In 1	In 2
aquifer thickness (ft)	20	20	20	20	20	16	16	16	16	16
aquifer type	unconf	unconf	unconf	unconf	unconf	conf	conf	conf	conf	conf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	3	3	3	3	3	6	6	6	6	6
screen length (ft)	5	5	5	5	5	10	10	10	10	10
screen interval (ft)	4.2-9.2	4.2-9.2	4.2-9.2	4.2-9.2	4.2-9.2	22-32	22-32	22-32	22-32	22-32
water table to bottom of screen (ft)	**4.52**	**4.52**	**4.52**	**4.52**	**4.52**	10.1	10.1	10.1	10.1	10.1
static water level	4.68	4.68	4.68	4.68	4.68	21.9	21.9	21.9	21.9	21.9
porosity (%)	30	30	30	30	30	30	30	30	30	30
gradient (ft/ft)	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown
hydraulic conductivity (ft/sec)	3.35E-05	3.09E-05	1.85E-05			2.20E-05	2.47E-05	2.35E-05	2.62E-05	2.32E-05
average hydraulic conductivity (ft/sec)			**2.76E-05**							**2.39E-05**
velocity (ft/sec)										
velocity (ft/day)										
average velocity (ft/day)										
distance from lagoon to well	50.00	50.00	50.00			126.00	126.00	126.00	126.00	126.00
days to reach well										
average days to reach well										
years to reach well				X	X					
average Years to reach well										

Notes:
1) P2 is screened in the surficial aquifer; 06-2 in a confined aquifer
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) P2 is hand-augered.
4) P2 cannot use slug in - static water level is within the screened interval
5) ▽ =static water level
6) An accurate gradient cannot be determined due to possible interference from an onsite supply well

Figure 5

06 Site Representative Slug Test Analyses



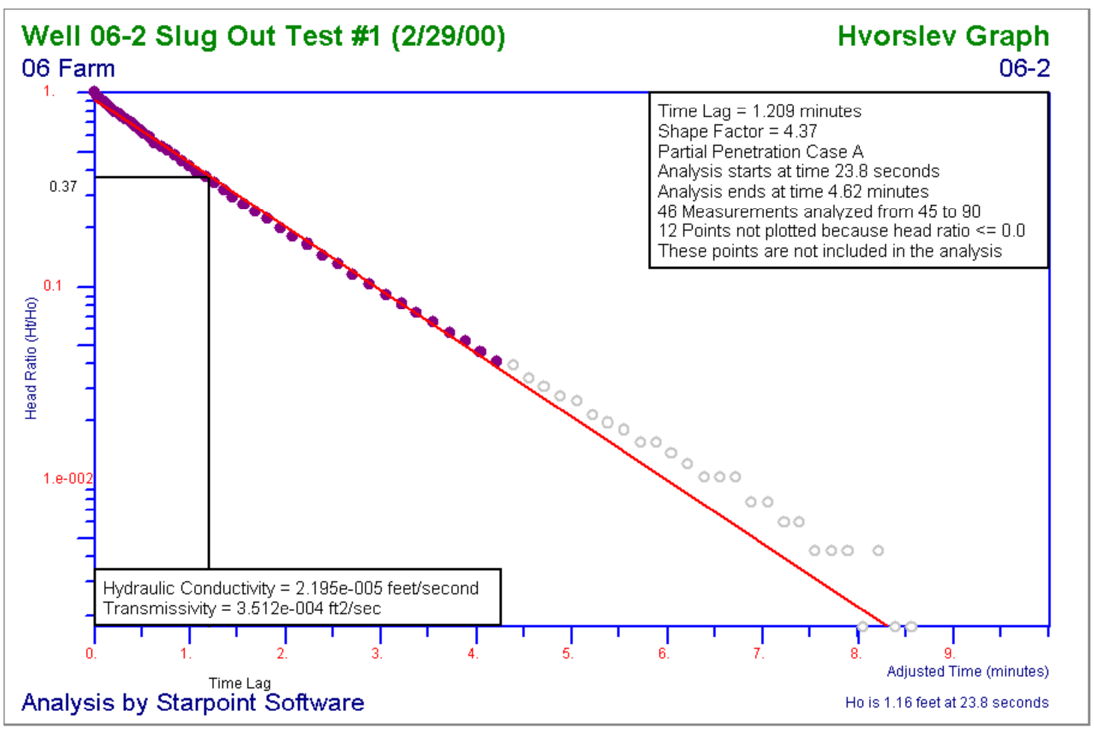


Figure 6

06 Site NO_3, TKN, NH_3 and K Sample Results

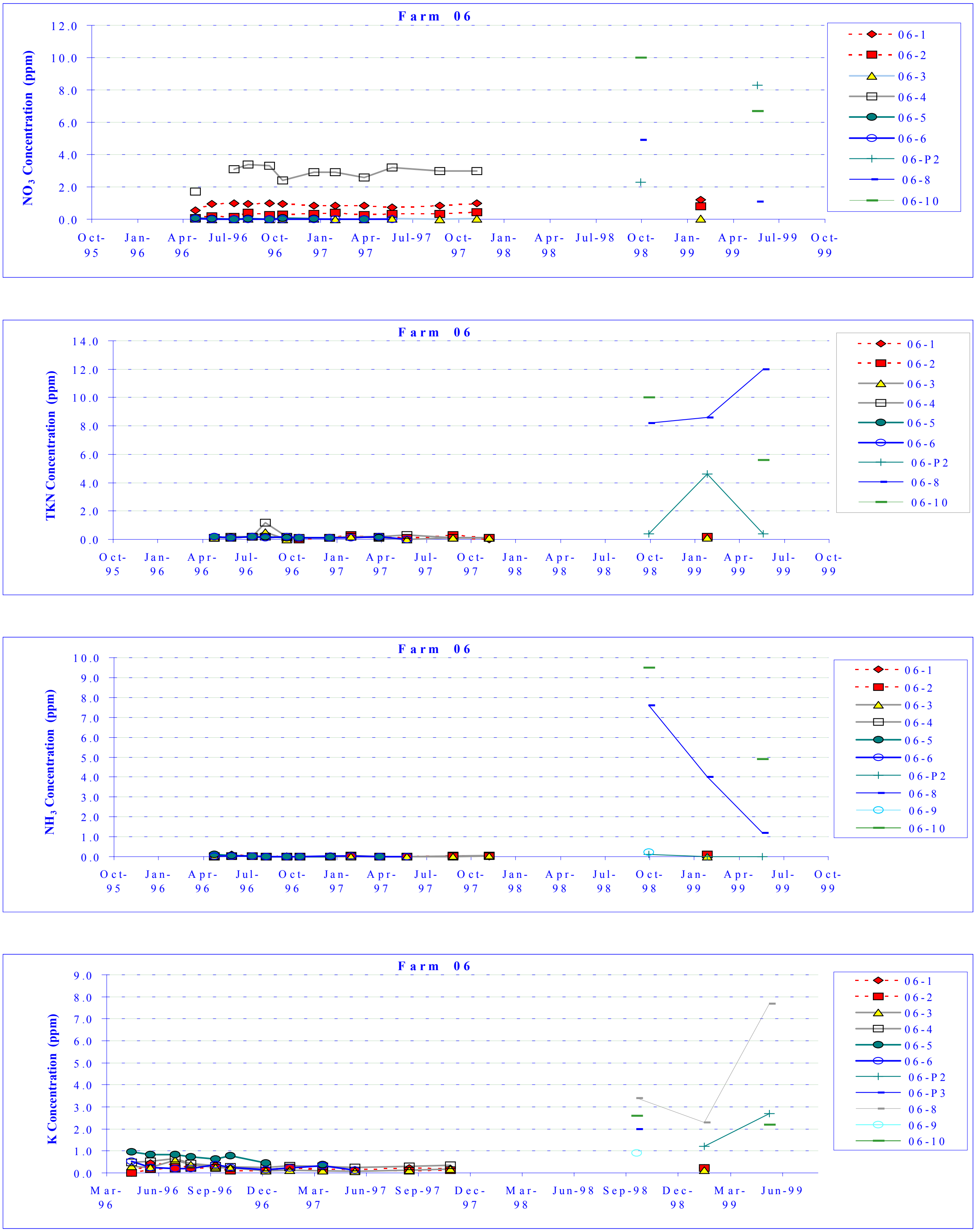
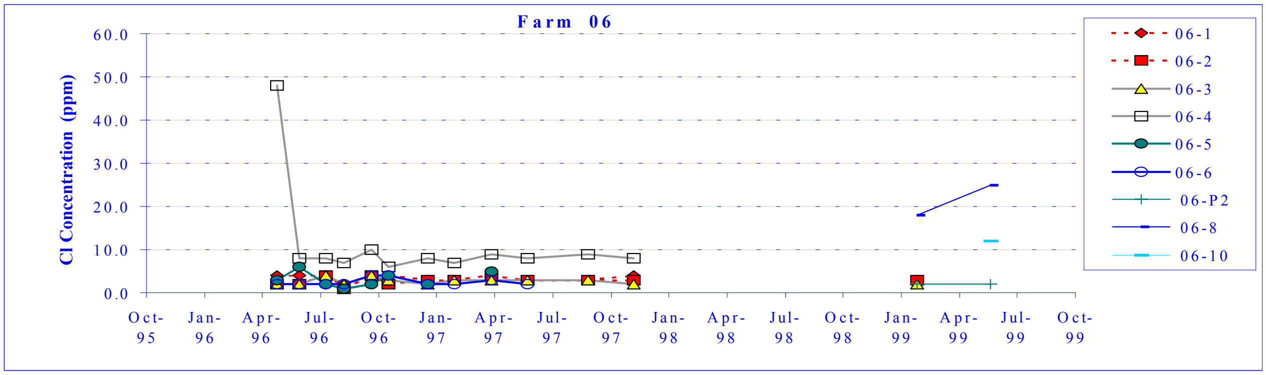


Figure 7 (1 of 2)

06 Site Cl Sample Results and Ground Water Elevation



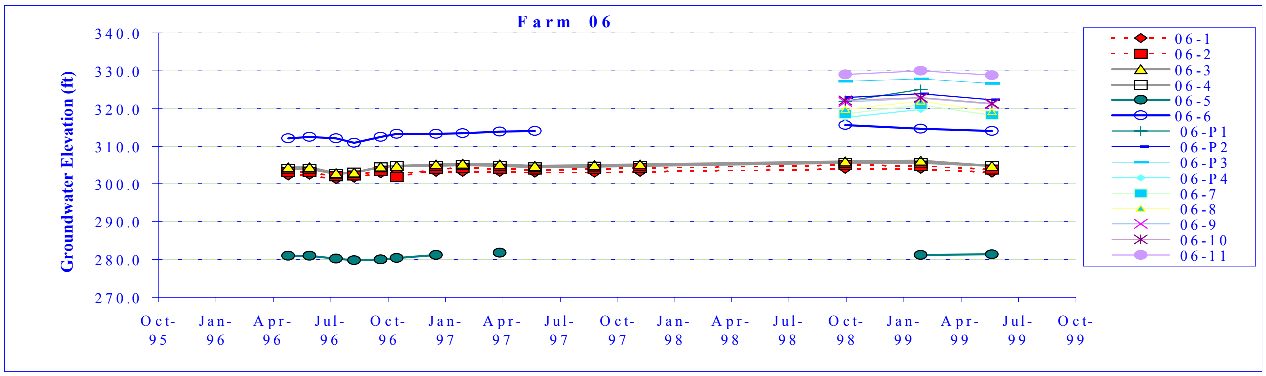


Figure 7 (2 of 2)

The 07 site is a swine operation located in an upland setting in the Sandhills area of the Coastal Plain. Ground and surface water from this site discharge into the Lumber River Basin.

Ground Water Flow

Ground water is flowing east-southeast at .07 feet per day, so time of travel for seepage indicators from the lagoon would be 4.55 years to well 07-1 and 3.77 years to well 07-2 (figs. 9-11). Sufficient time has been allowed to detect seepage indicators from the lagoon in well 07-2.

Ground Water Sampling Results

Monitoring wells at this site were sampled three additional times since the publication of the original report. There was a very slight increase of analyte levels in well 07-1, but NO_3 and Cl concentrations were well below the state's ground water standards (fig. 12). This could indicate some lagoon seepage, but more monitoring would be required to determine if this is the case and to what extent the seepage may be occurring.

EM Surveys

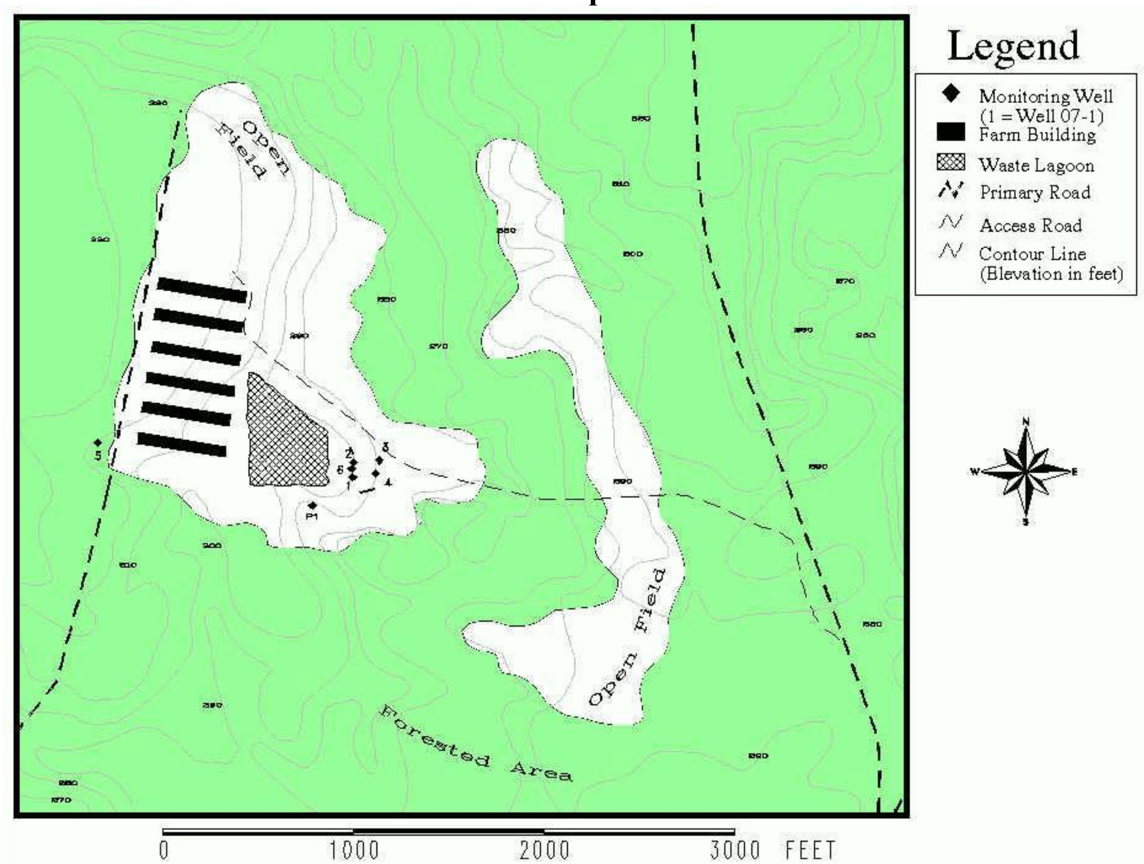
On June 5, 1997, an EM survey was conducted at the site. Readings were erratic around the area, indicating varied subsurface conditions, presumably due to clay lenses below the surface. One area, however, did show a roughly linear anomaly beginning at the lagoon and heading in the direction of ground water flow. The signal was faint, but the anomaly was strong enough that GWS staff decided to auger a hole and install a piezometer (P1), which could then be used to produce samples of the ground water for analysis. The piezometer was sampled two times. Dissolved solids and manganese were present in very high concentrations, and these constituents are likely what caused the high readings during the EM survey. The chemical makeup of these samples was quite different from the other wells' samples at the site, indicating a point source of manganese and dissolved solids. The constituent concentrations were not similar to those in the lagoon indicating that the ground water was not a result of lagoon seepage.

On October 26, 1998, GWS staff noted the excavation of two dead pits near the wells. One began about 70 feet north of 07-2 and trended north-northwest for 30 feet. It was already full and partly covered. The second began about 100 feet southeast of 07-1 and trended northeast for 75 feet. Decomposition of the hogs and the trash in these pits could adversely impact the shallow ground water and the monitoring wells.

Conclusion

Based on the analyses results and the site characteristics, ground water at this site is being adequately protected from lagoon seepage.

07 Site Maps



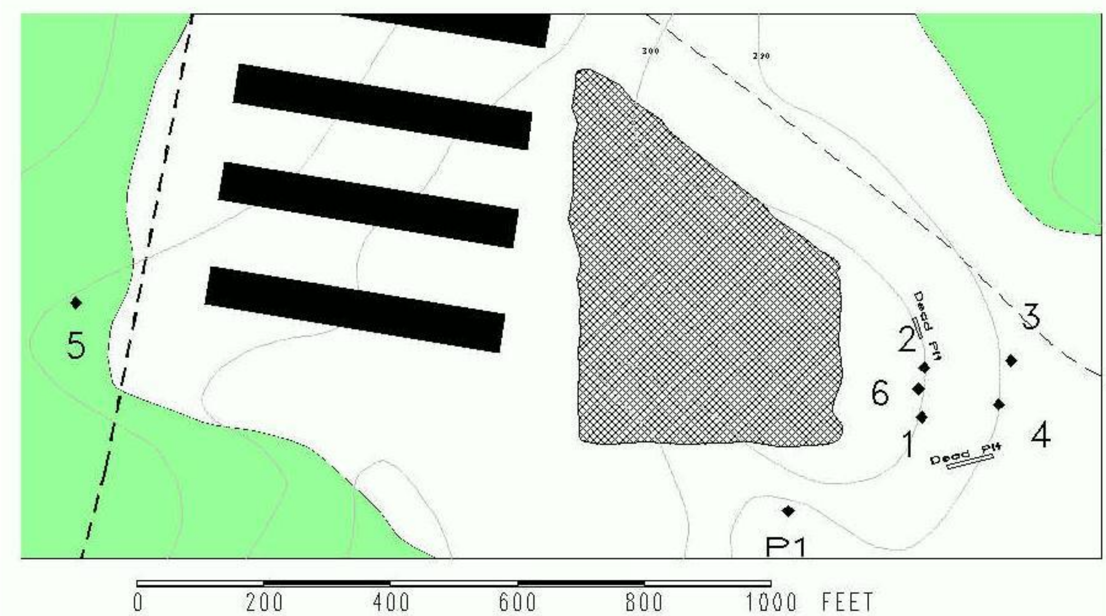


Figure 8

07 Site Ground Water Flow Map
(6/9/99)

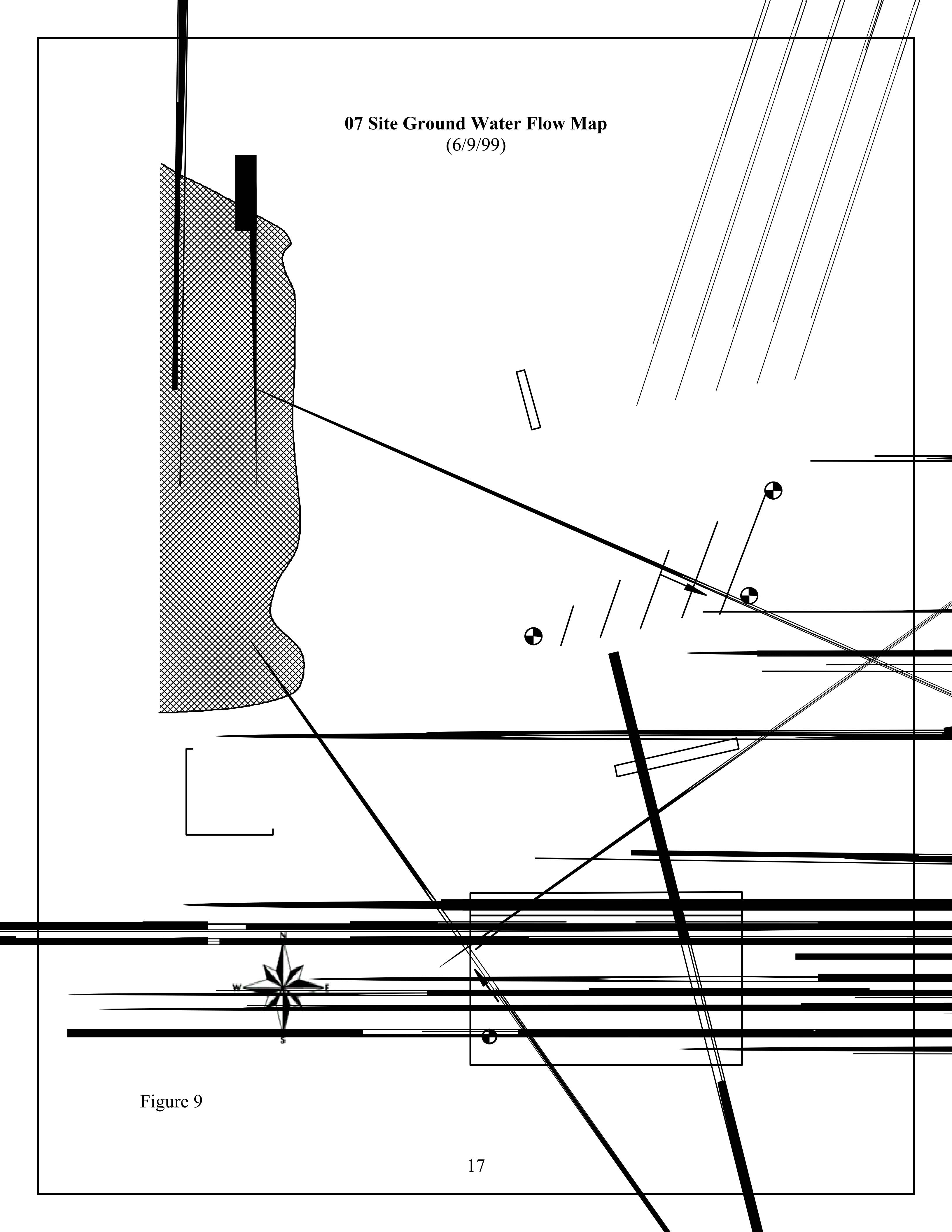
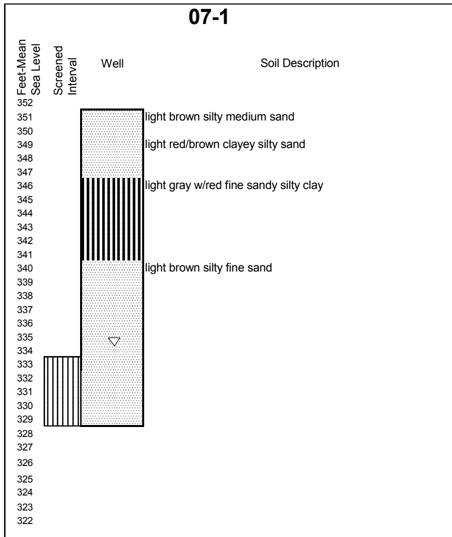
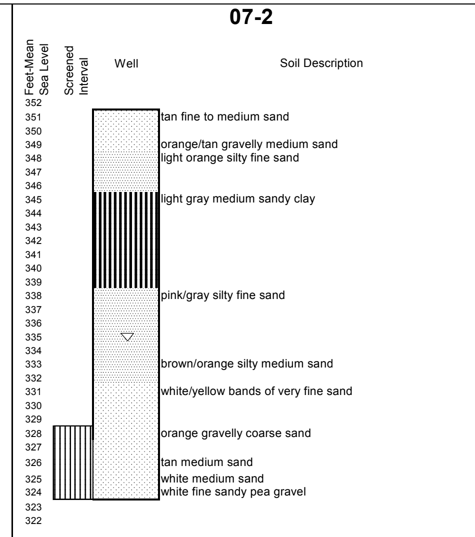
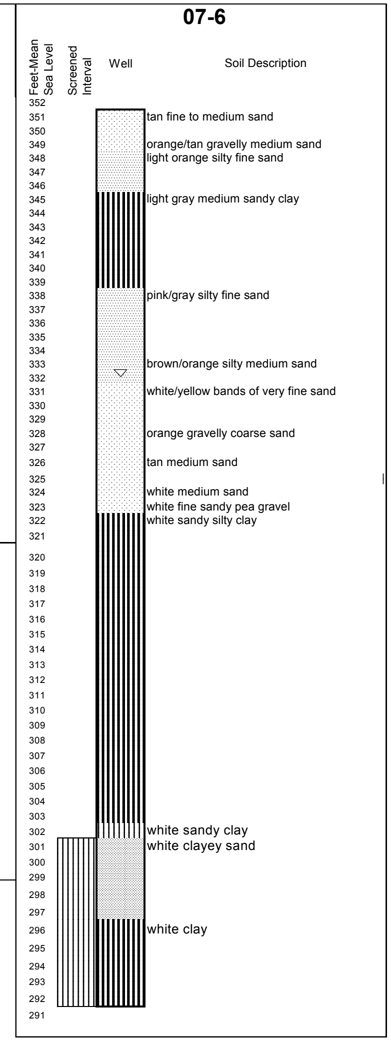


Figure 9

07 Site Well Logs and Aquifer Characteristics





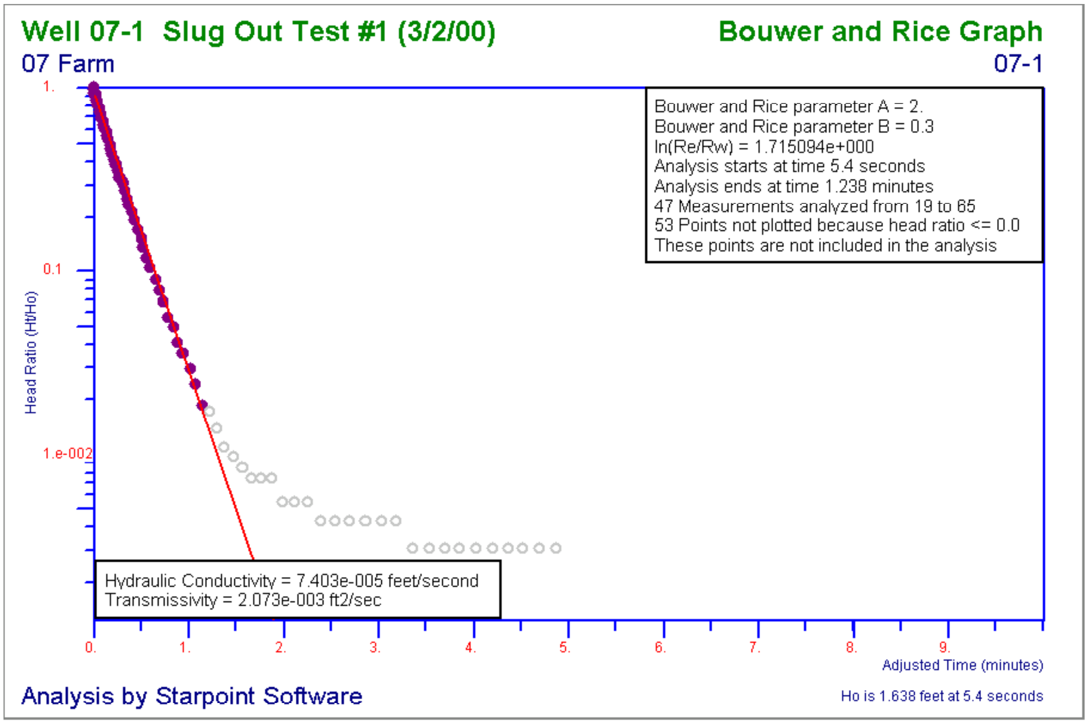


Slug Test ID	Out 1	Out 2	Out 3	In 1	In 2	In 3	Out 1	Out 2	Out 3	In 1	In 2	In 3
aquifer thickness (ft)	28	28	28	28	28	28	28	28	28	28	28	28
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	8	8	8	8	8	8	8	8	8	8	8	8
screen length (ft)	5	5	5	5	5	5	5	5	5	5	5	5
screen interval (ft)	18-23	18-23	18-23	18-23	18-23	18-23	23-28	23-28	23-28	23-28	23-28	23-28
water table to bottom of screen (ft)	6.7	6.7	6.7	6.7	6.7	6.7	11.12	11.12	11.12	11.12	11.12	11.12
static water level	16.3	16.3	16.3	16.3	16.3	16.3	16.88	16.88	16.88	16.88	16.88	16.88
porosity (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
gradient (ft/ft)	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034
hydraulic conductivity (ft/sec)	7.40E-05	7.59E-05	8.40E-05	7.43E-05	7.58E-05	7.49E-05	9.97E-05	9.78E-05	9.43E-05	9.63E-05	9.54E-05	9.21E-05
average hydraulic conductivity (ft/sec)						**7.65E-05**						**9.59E-05**
velocity (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
velocity (ft/day)	0.07	0.07	0.08	0.07	0.07	0.07	0.10	0.10	0.09	0.09	0.09	0.09
average velocity (ft/day)						**0.07**						**0.09**
distance from lagoon to well	124.00	124.00	124.00	124.00	124.00	124.00	129.00	129.00	129.00	129.00	129.00	129.00
days to reach well	1710.58	1667.77	1507.73	1705.28	1670.85	1691.84	1320.97	1346.49	1397.33	1368.44	1381.21	1431.03
average days to reach well						**1659.01**						**1374.24**
years to reach well	4.69	4.57	4.13	4.67	4.58	4.64	3.62	3.69	3.83	3.75	3.78	3.92
average Years to reach well						**4.55**						**3.77**

Notes:
1) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
2) ▽ =static water level

Figure 10

07 Site Representative Slug Test Analyses



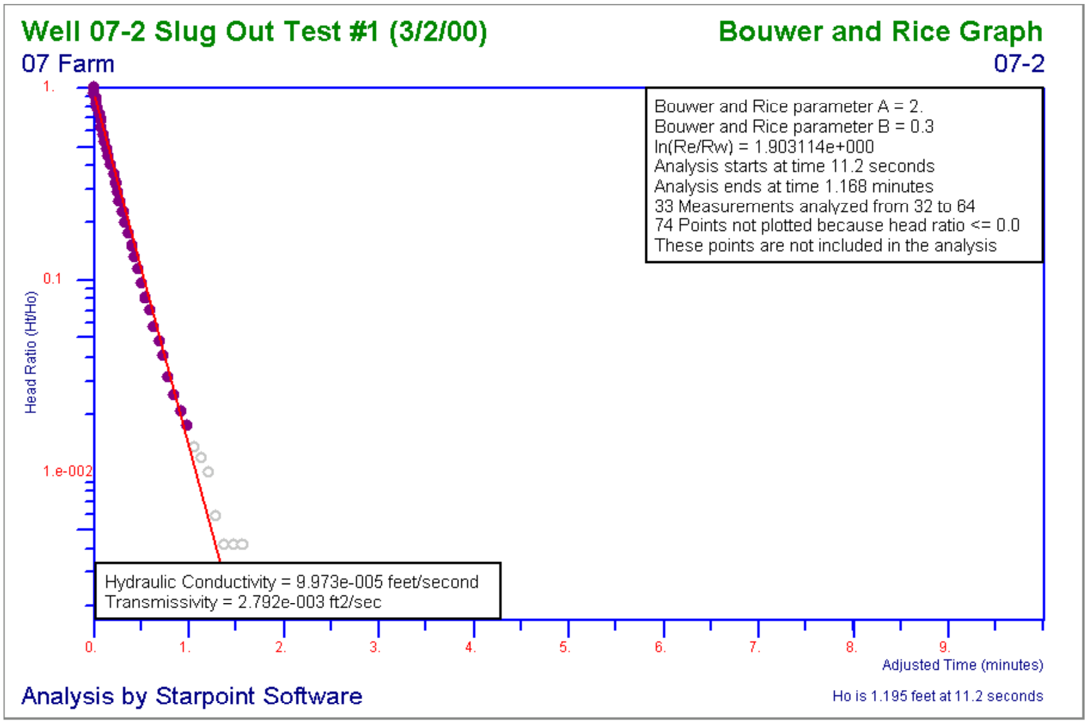
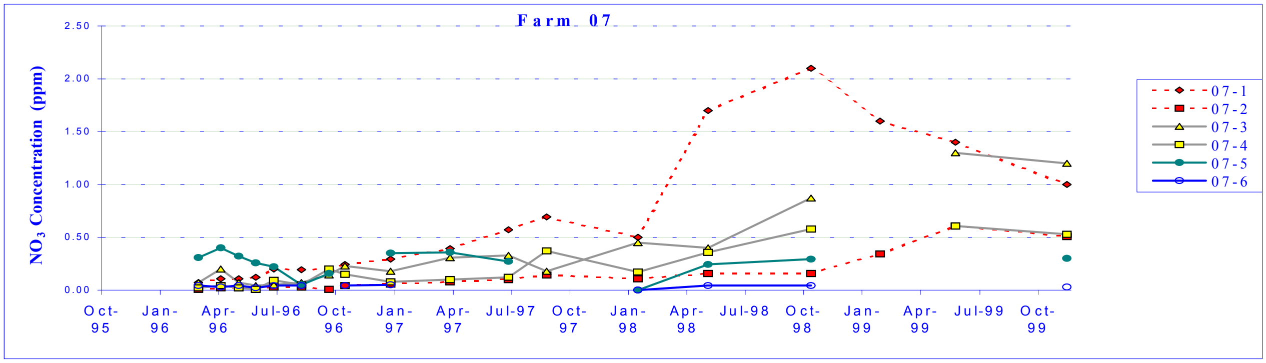
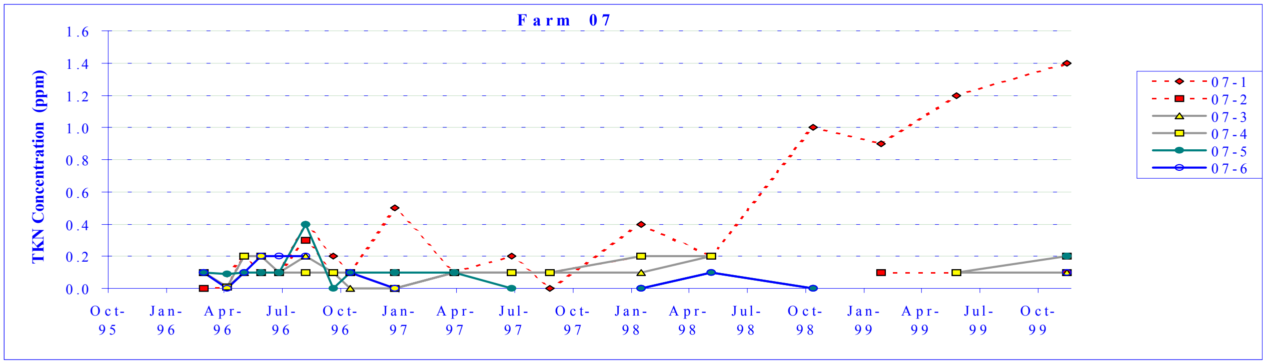
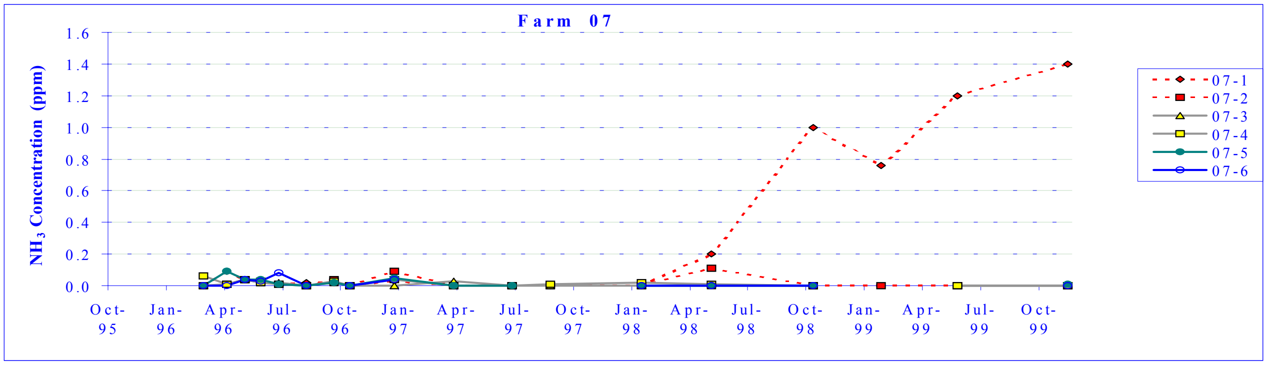


Figure 11

07 Site NO_3, TKN, NH_3 and K Sample Results







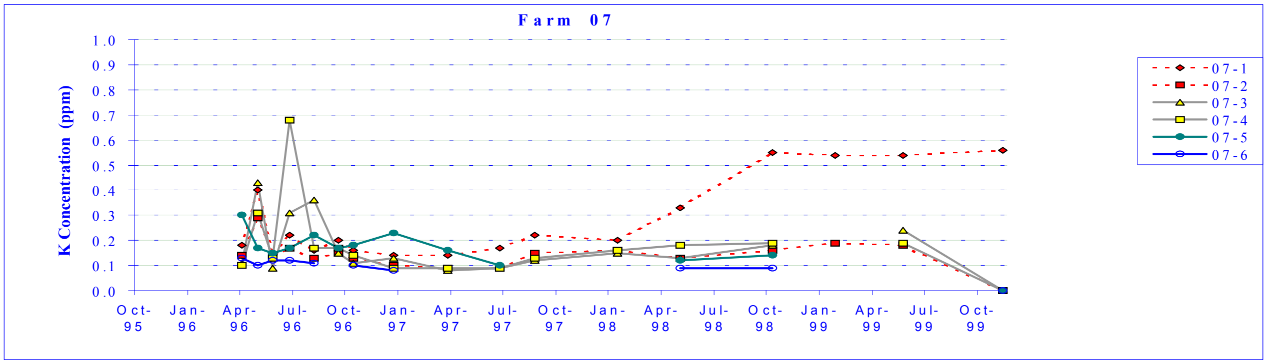
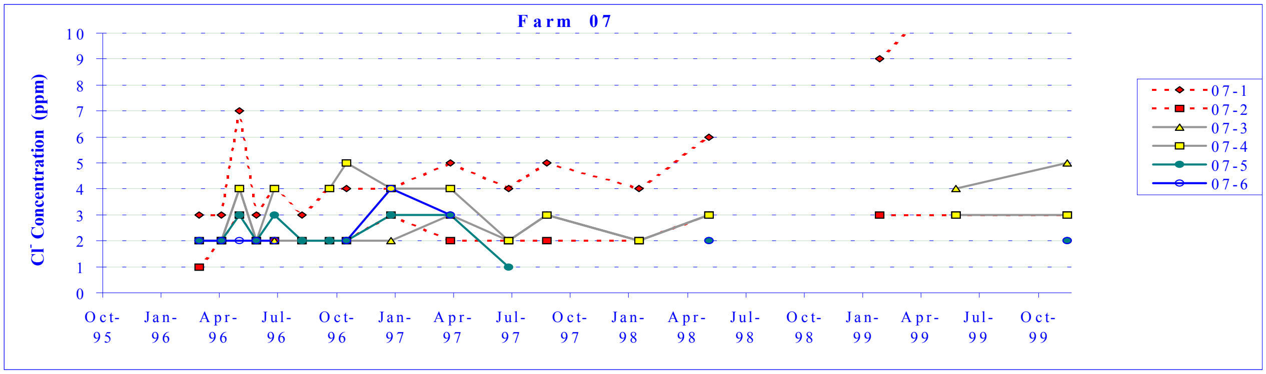


Figure 12 (1 of 2)

07 Site Cl Sample Results and Ground Water Elevation



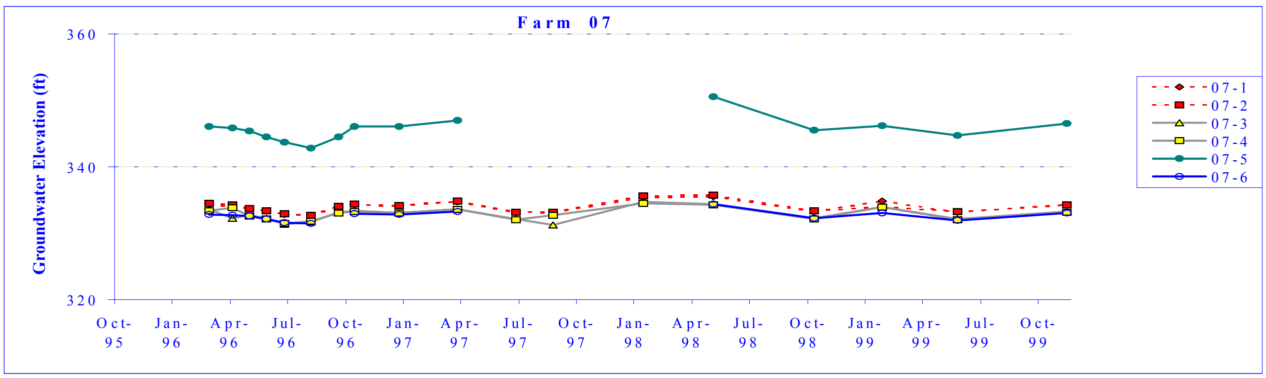


Figure 12 (2 of 2)

The Albertson site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Cape Fear River Basin.

Ground Water Flow

Ground water is flowing northwest and southwest at 0.1-0.17 feet per day, so time of travel for seepage indicators from the lagoon would be 2.06 years to well Alb-1 and 3.56 years to well Alb-2 (figs. 14-16). Sufficient time has elapsed to detect seepage indicators from the lagoon in well Alb-1.

Ground Water Elevations

Wells Alb-1 – Alb-6 were installed in December 1995 and January 1996. On March 25, 1996, wells Alb-7, 8 and 9 were installed at this site in cooperation with a U.S. Geological Survey study. The ground water elevations in Alb-5, Alb-7 and Alb-8 were higher than in other wells raising questions about aquifer characteristics at the site. Logs collected during drilling indicated the presence of a clay layer at relatively shallow depths in some of the wells. In an attempt to determine the extent of a potential confining unit, additional wells were installed at the site.

On April 21, 1997, a piezometer was installed northeast of the lagoon to provide a well log and to determine the water table elevation (Alb-P1). A minor clay layer was logged in this well.

On June 12, 1998, a second well was hand augured north of the lagoon in the woods (Alb-10). There was no clay layer logged at this location. Three additional one-inch-diameter wells (Alb-12 to Alb-14) were installed on July 14, 1998 by GWS staff using a Geoprobe®. Minor clay layers were logged at various depths. Based on boring logs of all wells at the site, GWS staff concluded that clay lenses were present, but that monitoring wells downgradient from the lagoon were installed in the water table aquifer.

Ground Water Sampling Results

Monitoring wells at this site were sampled four additional times since the publication of the original report, and there have been no significant changes in analyte concentrations (fig. 17). NO_3 has continued to decline in wells Alb-1, 2, 3, and 4. Analyses of stable nitrogen isotope $\delta^{15}N$ values at this site by USGS staff indicate that fertilizer from previous applications appears to be the source of the nitrate in ground water at this site (Timothy B. Spruill, U.S. Geological Survey, Oct. 4, 2001, personal commun.). No other lagoon seepage indicators have been detected in significant amounts in the wells.

EM Surveys

The site was surveyed on April 21, 1997. Results were inconclusive presumably due to the presence of clay lenses near the surface.

Conclusion

Based on the analyses results and the site characteristics, ground water at this site is being adequately protected from lagoon seepage.

Albertson Site Maps

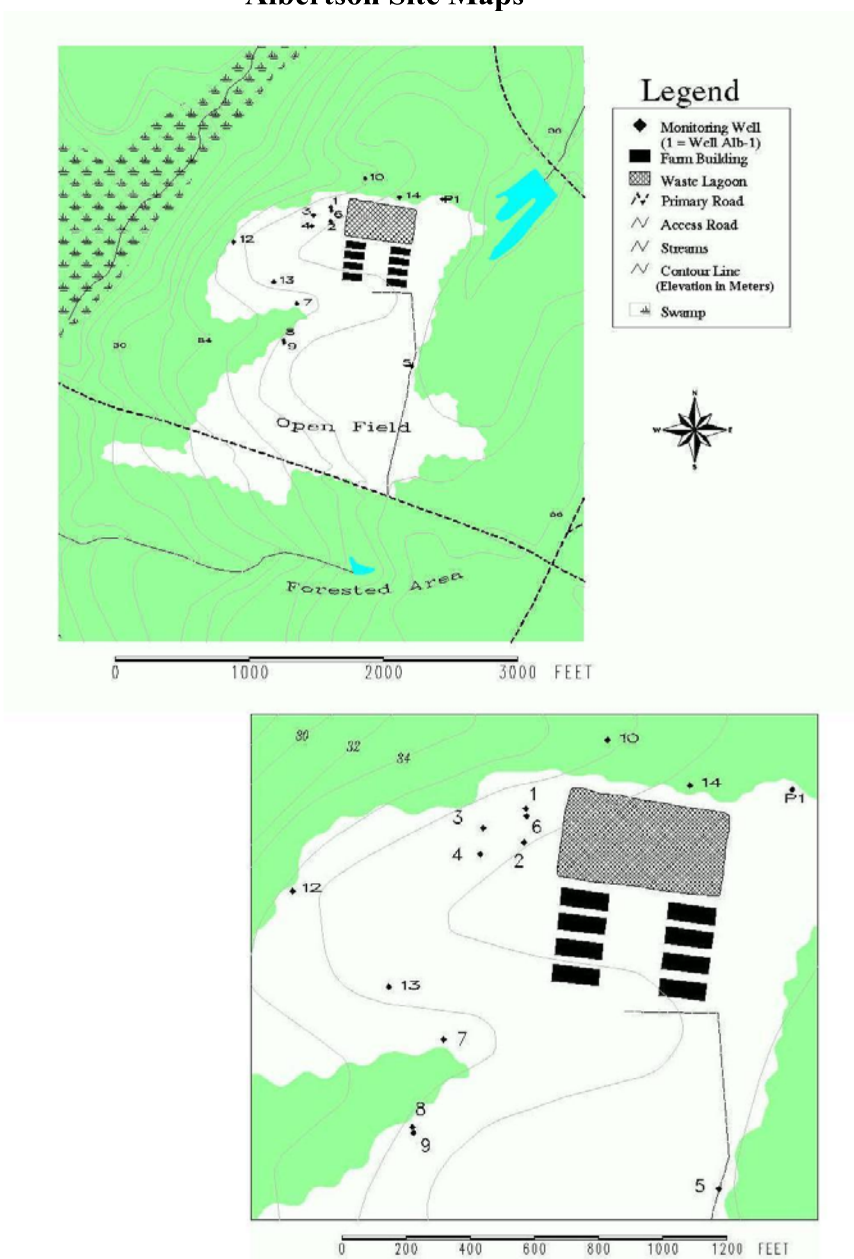


Figure 13

Albertson Site Ground Water Flow Map
(3/31/99)

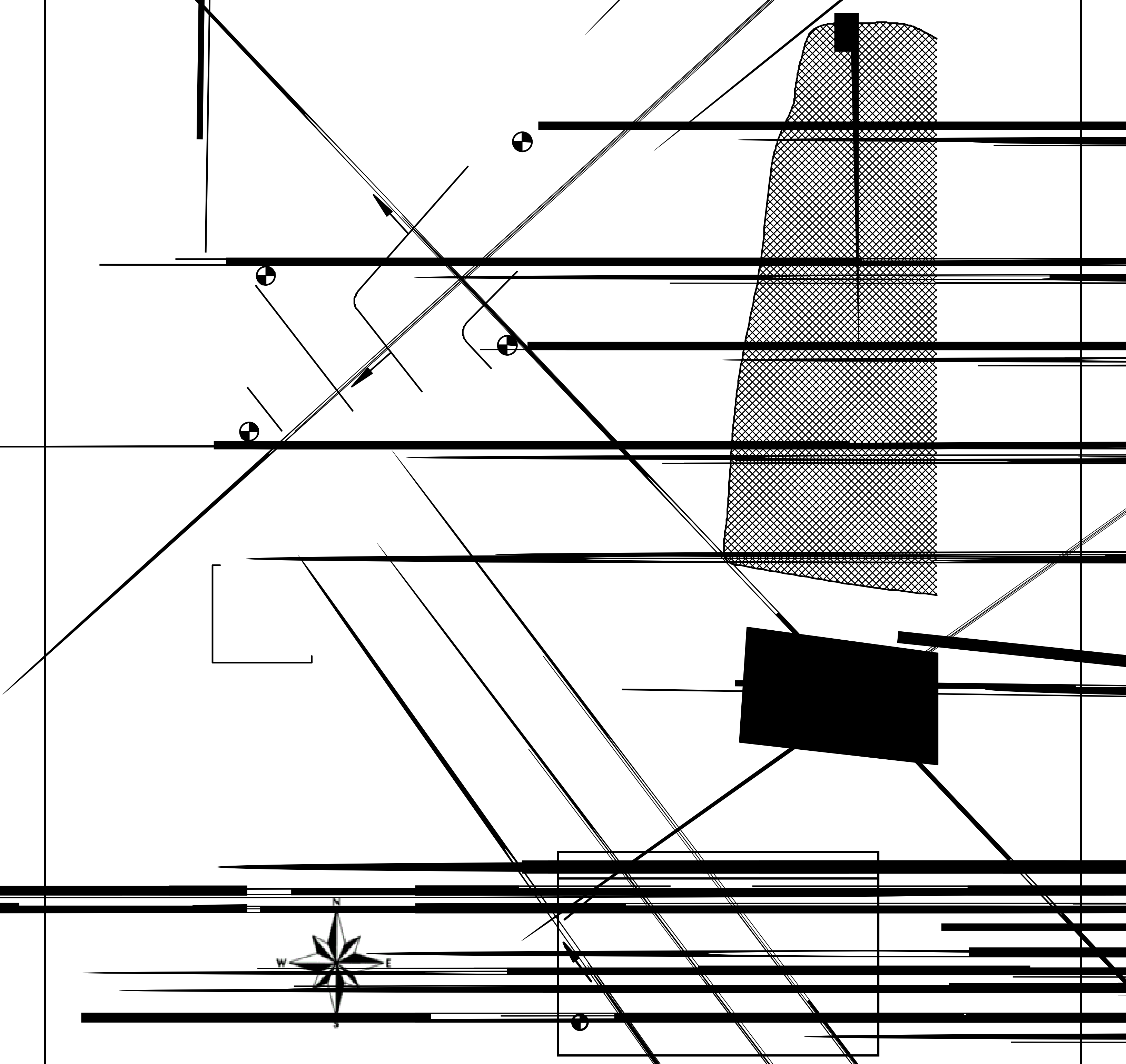
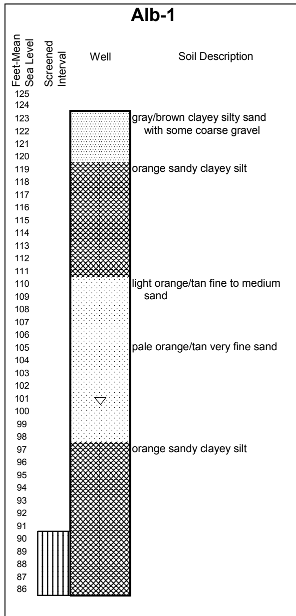
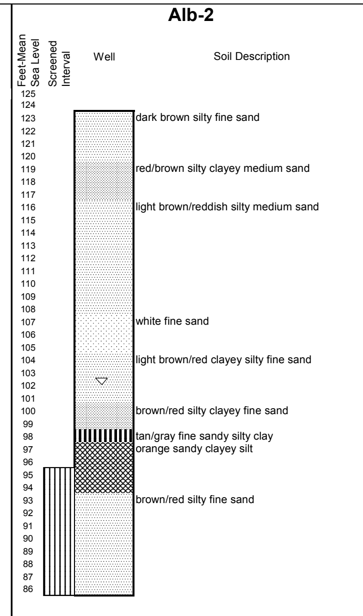
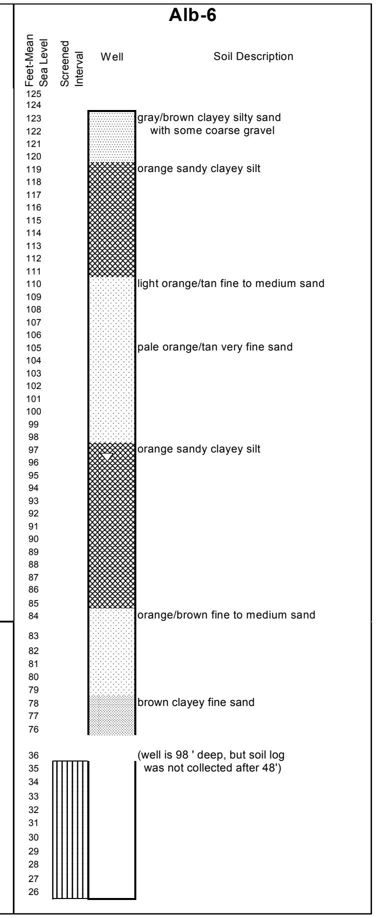


Figure 14

Albertson Site Well Logs and Aquifer Characteristics







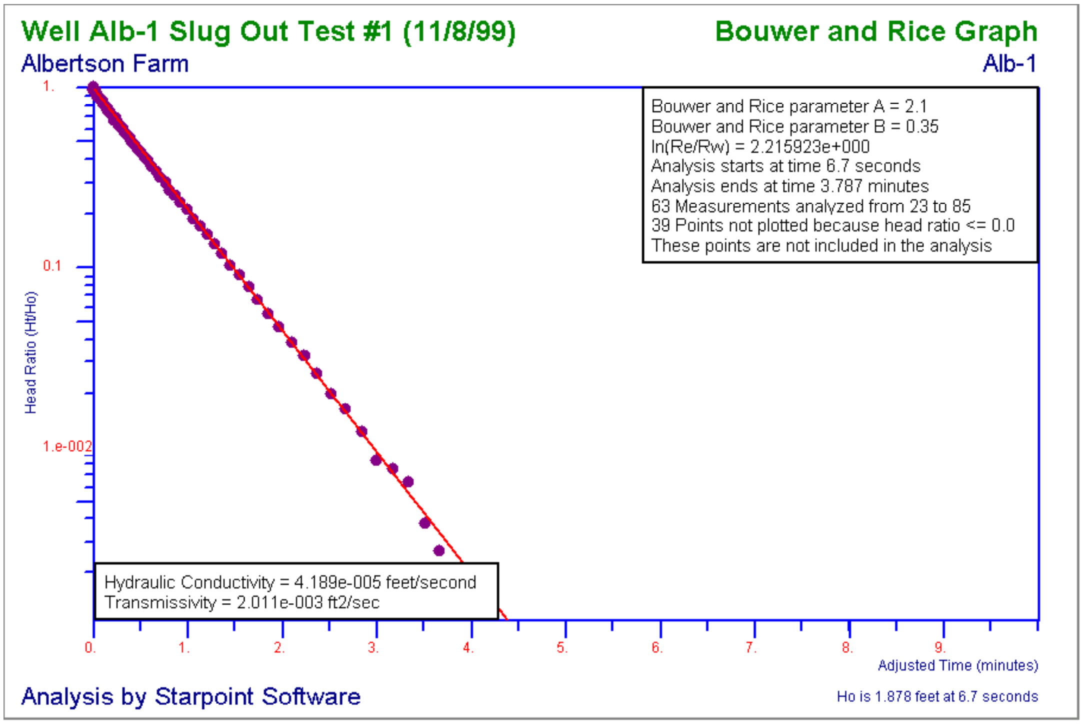
Slug Test ID	Out 1	Out 2	Out 3	In 1		Out 1	Out 2	Out 3	In 1	In 2
aquifer thickness (ft)	48	48	48	48		48	48	48	48	48
aquifer type	unconf	unconf	unconf	unconf		unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045		2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6		6	6	6	6	6
screen length (ft)	5	5	5	5		10	10	10	10	10
screen interval (ft)	33.5-38.5	33.5-38.5	33.5-38.5	33.5-38.5		28-38	28-38	28-38	28-38	28-38
water table to bottom of screen (ft)	16.71	16.71	16.71	16.71		16.4	16.4	16.4	16.4	16.4
static water level	24.14	24.14	24.14	24.14		23.74	23.74	23.74	23.74	23.74
porosity (%)	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.012	0.012	0.012	0.012		0.012	0.012	0.012	0.012	0.012
hydraulic conductivity (ft/sec)	4.19E-05	4.23E-05	4.04E-05	4.12E-05		2.36E-05	2.49E-05	2.49E-05	1.87E-05	2.46E-05
average hydraulic conductivity (ft/sec)				**4.15E-05**						**2.33E-05**
velocity (ft/sec)	2.01E-06	2.03E-06	1.94E-06	1.98E-06		1.13E-06	1.19E-06	1.19E-06	8.96E-07	1.18E-06
velocity (ft/day)	0.17	0.18	0.17	0.17		0.10	0.10	0.10	0.08	0.10
average velocity (ft/day)				**0.17**						**0.10**
distance from lagoon to well	129.00	129.00	129.00	129.00		124.00	124.00	124.00	124.00	124.00
days to reach well	742.55	735.70	769.74	754.43		1267.47	1203.21	1203.21	1601.48	1213.95
average days to reach well				**750.61**						**1297.86**
years to reach well	2.03	2.02	2.11	2.07		3.47	3.30	3.30	4.39	3.33
average Years to reach well				**2.06**						**3.56**

Notes:

1) Depth of the aquifer is unknown. Drillers encountered difficulty boring below 48'. Also, boring log says cutting were "moist" all the way down from the surface.
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) a "filter sock" was used over the .020 screen, could cause problems with fouling
4) ▽ =static water level

Figure 15

Albertson Site Representative Slug Test Analyses



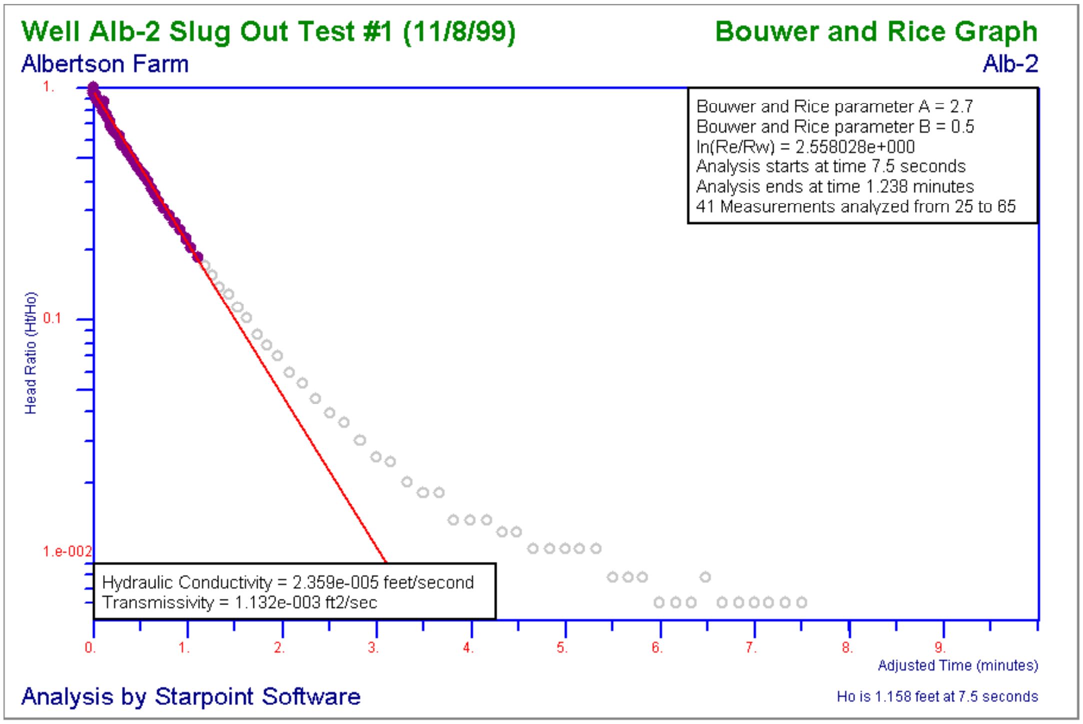
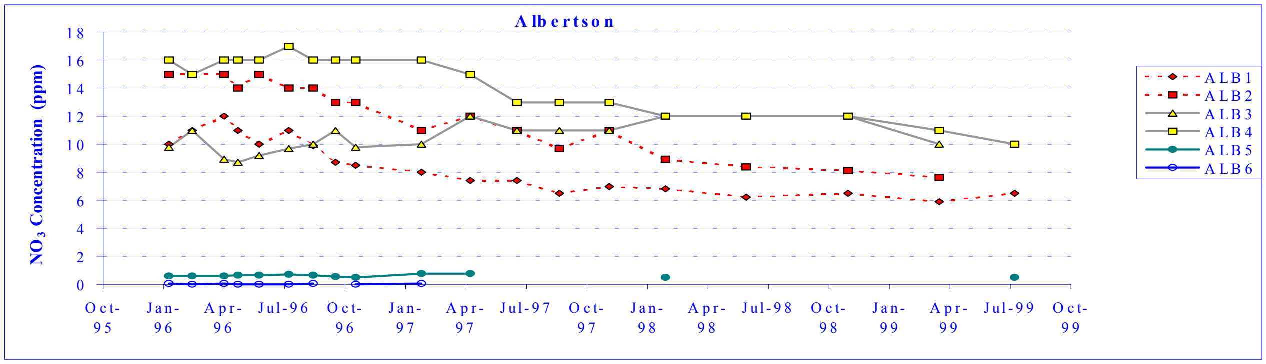
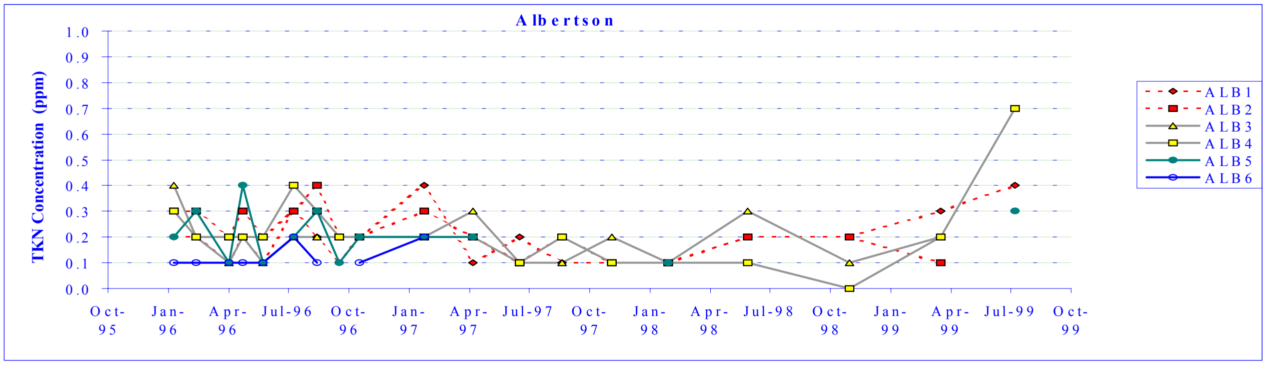
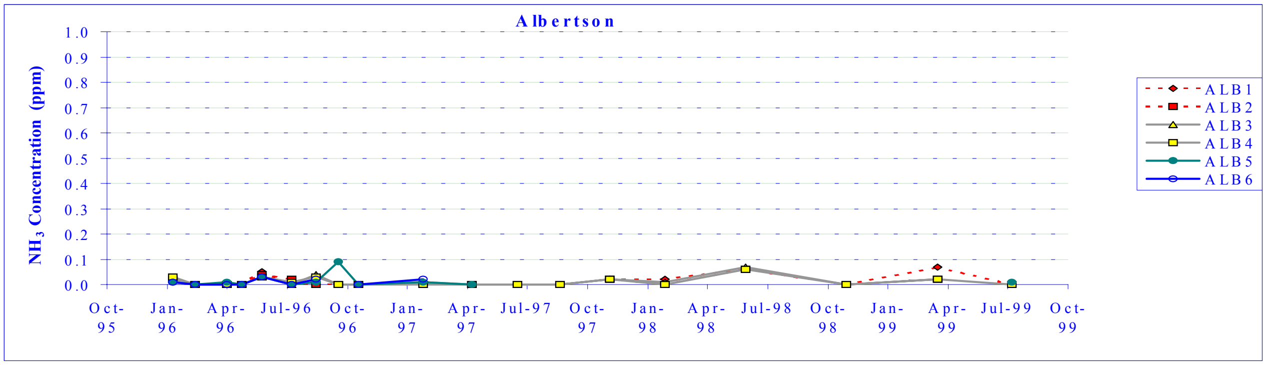


Figure 16

Albertson Site NO_3, TKN, NH_3 and K Sample Results







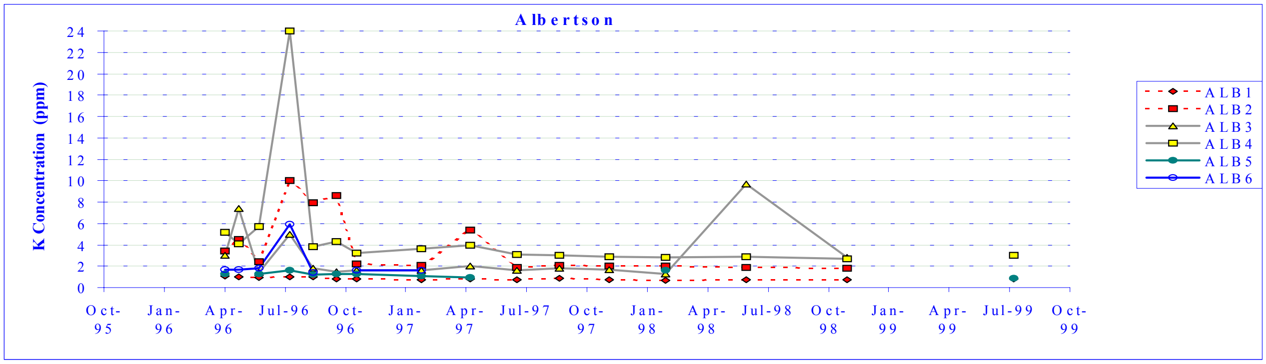
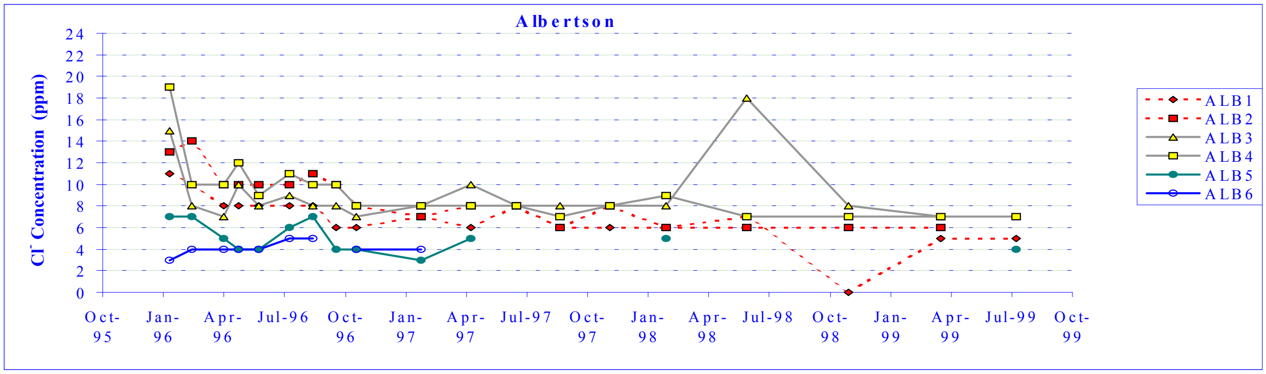


Figure 17 (1 of 2)

Albertson Site Cl Sample Results and Ground Water Elevation



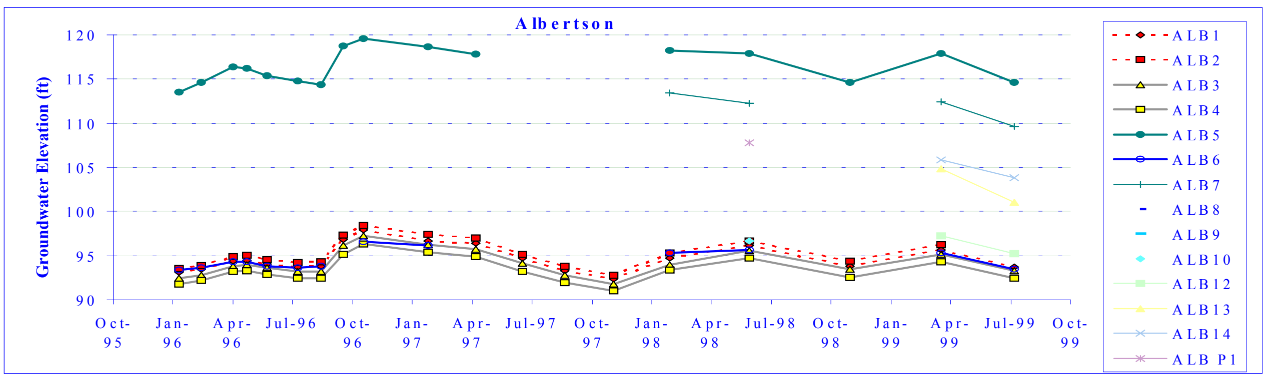


Figure 17 (2 of 2)

The Clarkton site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Lumber River Basin.

Ground Water Flow

Ground water is flowing northeast at 0.02-0.15 feet per day. It is unclear whether this wide range of ground water velocities shown in figure 21 results from variations in the aquifer media or slug test inaccuracies. According to boring logs, these wells are screened in the same aquifer, so it is probable that inaccurate slug test data causes this variance.

Wells were located in the estimated direction of ground water flow based on topographic relief. As figures 18 through 22 show, ground water flow is not perpendicular to topographic contour lines, but more toward the direction of the swamp to the north and the drainage feature to the east (fig. 18). Ground water flow was calculated using data from four sampling events during different times of the year with the same results (fig. 20). Due to the unanticipated flow direction, wells were not placed in a location where lagoon seepage indicators would be detected.

Ground Water Sampling Results

Monitoring wells at this site were sampled three additional times since the publication of the original report, and there have been no significant changes in analyte concentrations except for NO_3 in the background well (fig. 23). The background well, Cla-6, is located at the edge of a field which began receiving hog waste shortly after its installation. The higher concentrations of lagoon seepage indicators are presumably due to the impact of the sprayed effluent on the ground water.

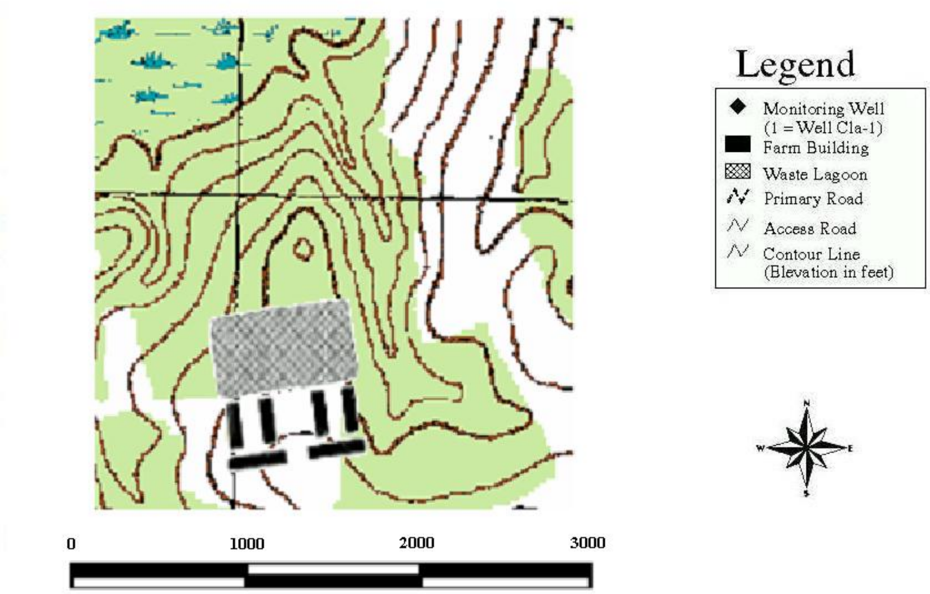
EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

No conclusions regarding lagoon seepage can be drawn at this site due to the placement of the wells.

Clarkton Site Maps



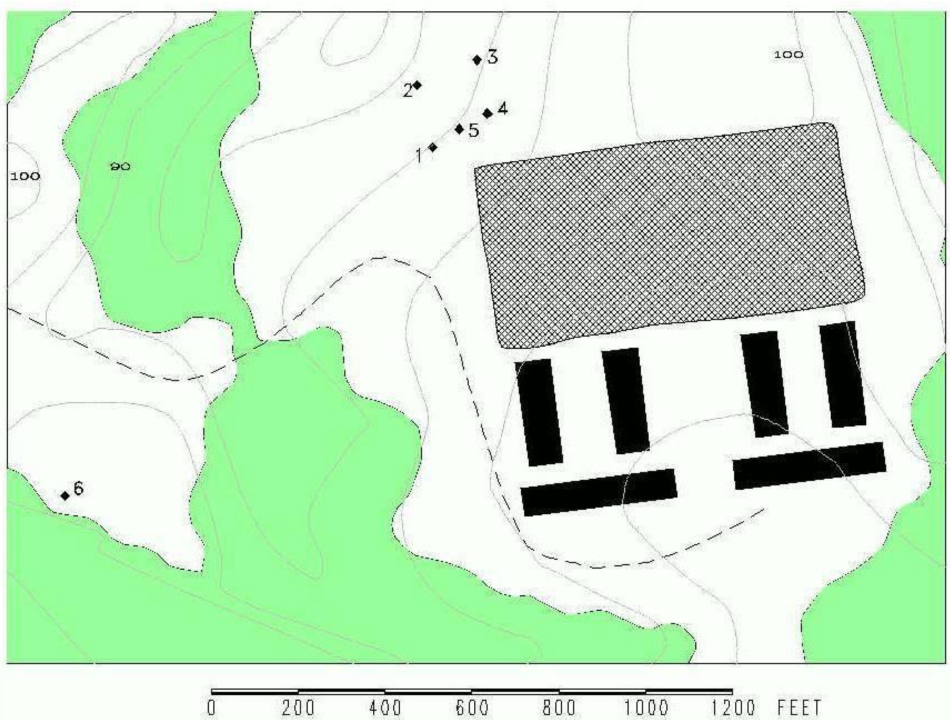


Figure 18

Clarkton Site Ground Water Flow Map
(5/6/99)

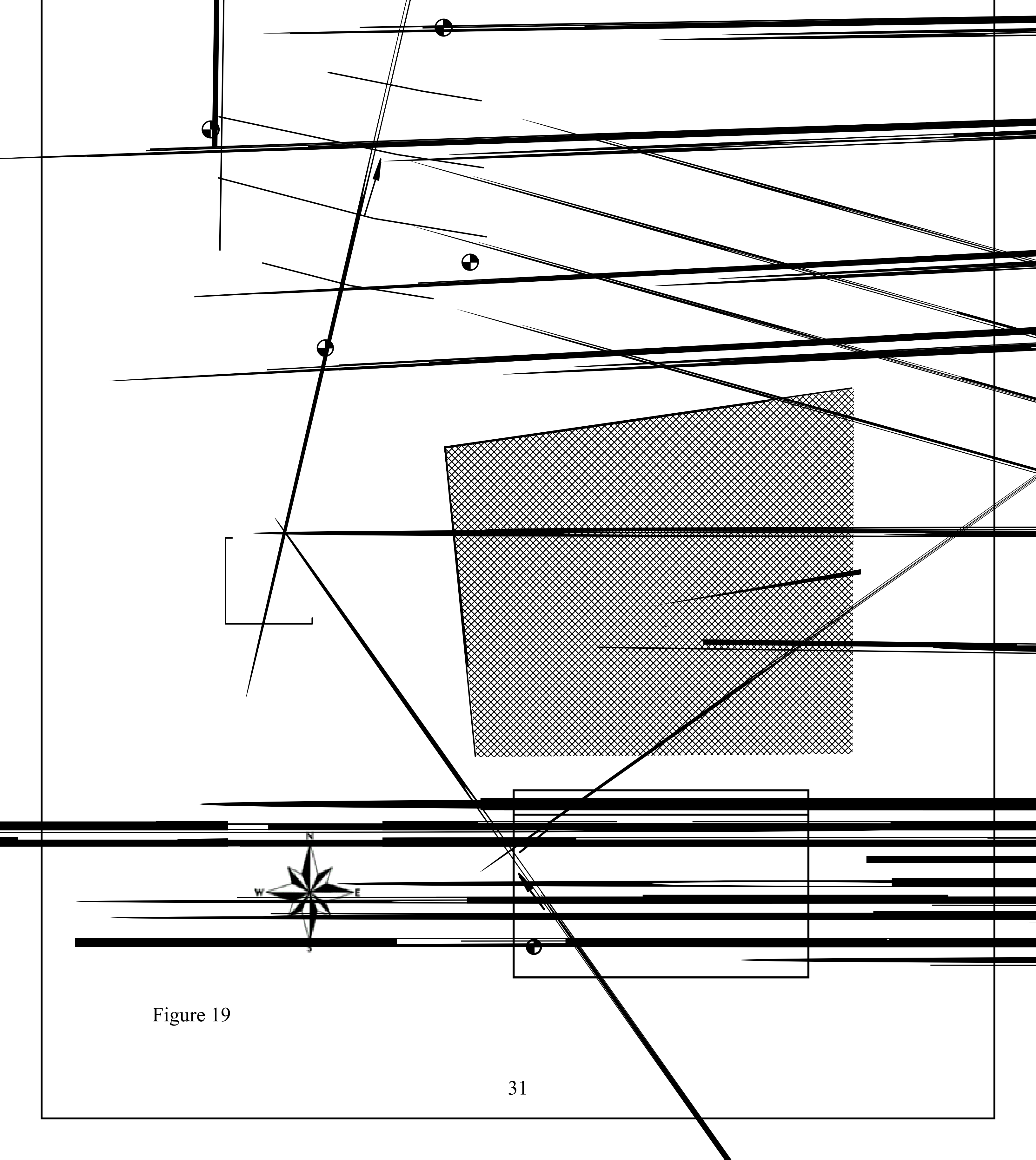


Figure 19

Clarkton Site Ground Water Flow Map
(11/97-5/99)

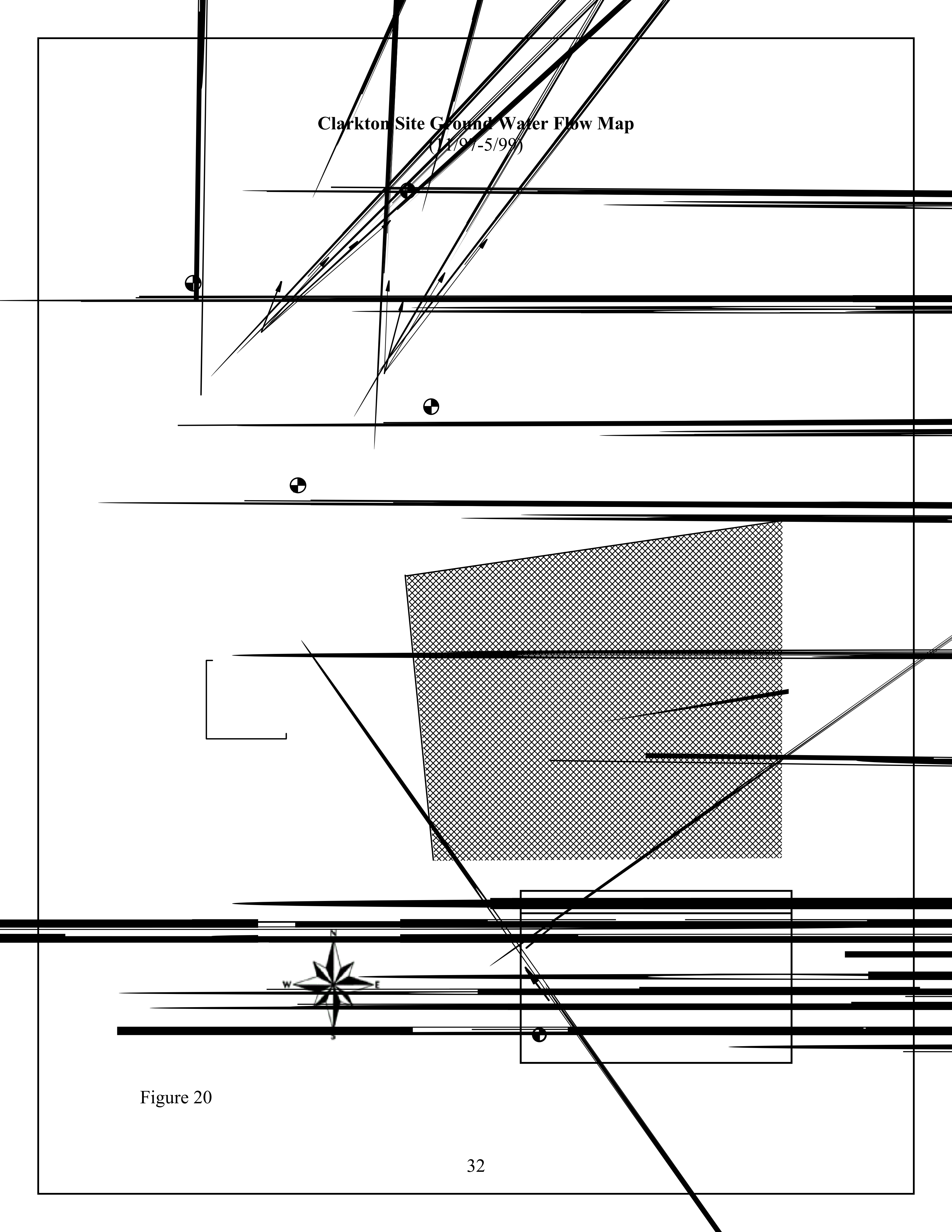
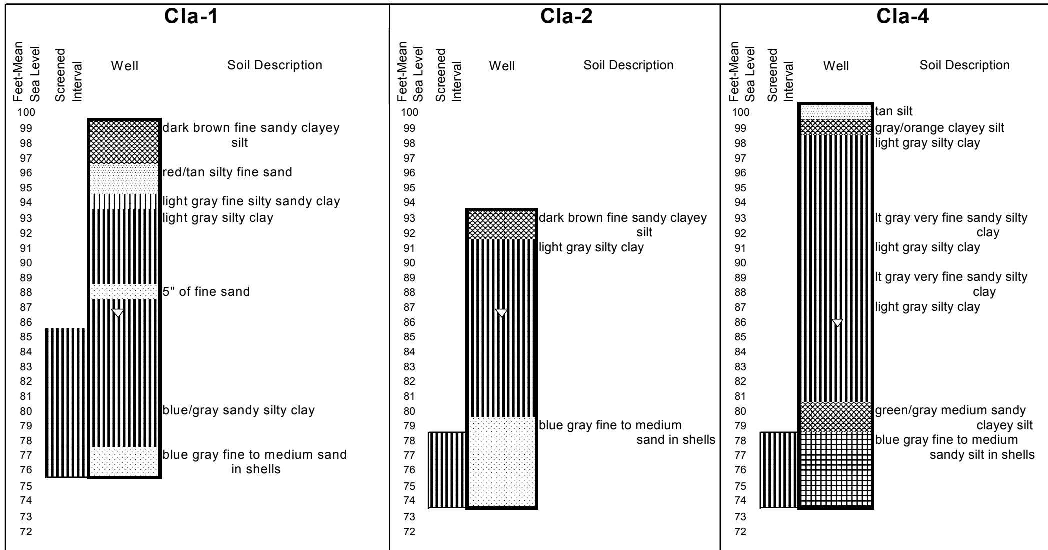
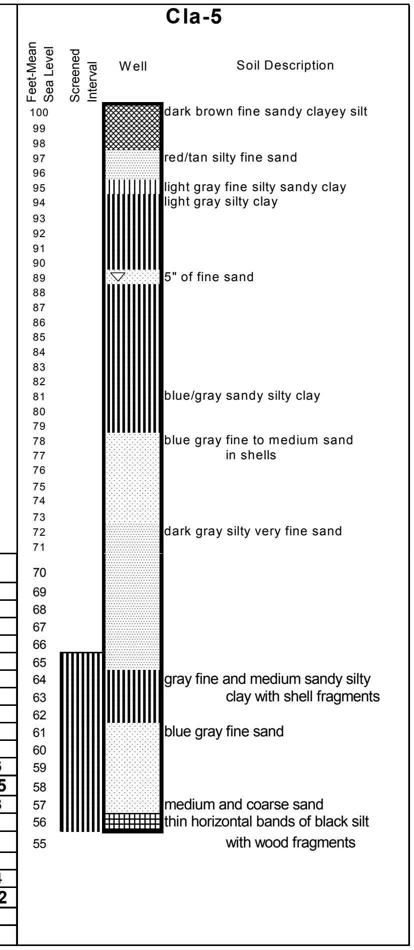


Figure 20

Clarkton Site Well Logs and Aquifer Characteristics



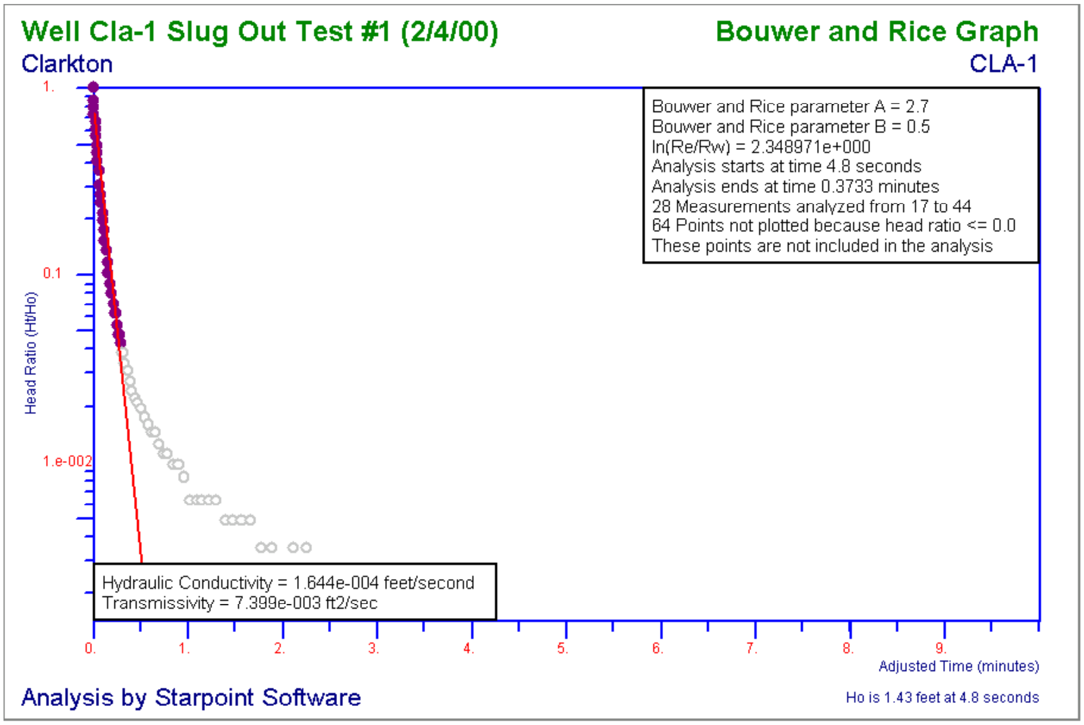


Slug Test ID	Out 1	Out 2	Out 3	In 1	In 2	Out 1	Out 2	In 1	In 2	Out 1	Out 2	In 1	In 2
aquifer thickness (ft)	45	45	45	45	45	45	45	45	45	45	45	45	45
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6	6	6	6
screen length (ft)	10	10	10	10	10	5	5	5	5	5	5	5	5
screen interval (ft)	14-24	14-24	14-24	14-24	14-24	15-20	15-20	15-20	15-20	22-27	22-27	22-27	22-27
water table to bottom of screen (ft)	10.21	10.21	10.21	10.21	10.21	11.90	11.90	11.90	11.90	11.33	11.33	11.33	11.33
static water level	13.79	13.79	13.79	13.79	13.79	8.10	8.10	8.10	8.10	15.67	15.67	15.67	15.67
porosity (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
hydraulic conductivity (ft/sec)	1.64E-04	1.71E-04	1.68E-04	1.61E-04	1.63E-04	3.37E-05	3.96E-05	3.60E-05	3.60E-05	9.19E-06	8.01E-05	9.32E-06	9.09E-06
average hydraulic conductivity (ft/sec)					**1.62E-04**				**3.63E-05**				**2.69E-05**
velocity (ft/sec)	1.71E-06	1.78E-06	1.74E-06	1.67E-06	1.70E-06	3.51E-07	4.12E-07	3.75E-07	3.74E-07	9.55E-08	8.33E-07	9.69E-08	9.45E-08
velocity (ft/day)	0.15	0.15	0.15	0.14	0.15	0.03	0.04	0.03	0.03	0.01	0.07	0.01	0.01
average velocity (ft/day)					**0.15**				**0.03**				**0.02**
distance from lagoon to well	125	125	125	101.00	101.00	234.00	234.00	234.00	234.00	109.00	109.00	109.00	109.00
days to reach well	846.176808	812.567	830.0207	699.45	687.90	7718.34	6581.16	7231.79	7239.83	13206.88	1514.99	13015.58	13347.84
average days to reach well					**693.67**				**7192.78**				**10271.32**
years to reach well	2.31829262	2.226211	2.274029	1.92	1.88	21.15	18.03	19.81	19.84	36.18	4.15	35.66	36.57
average Years to reach well					**2.12**				**19.71**				**25.46**

Notes:
1) Aquifer thickness is unknown
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) ▽ = static water level

Figure 21

Clarkton Site Representative Slug Test Analyses



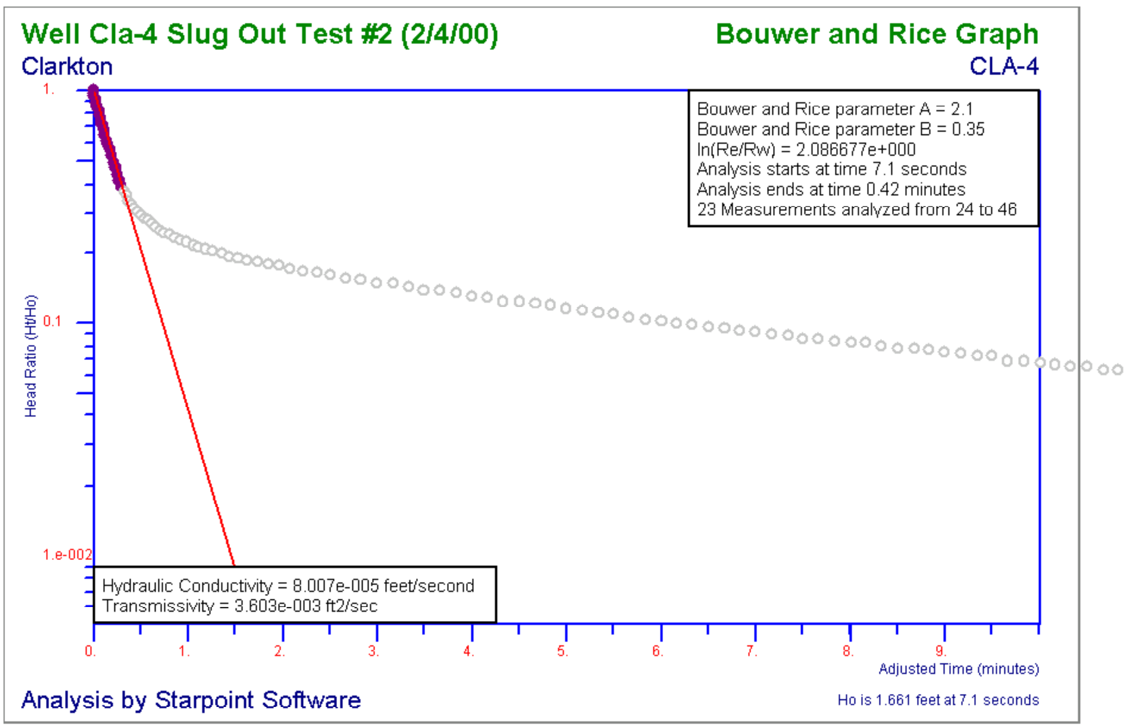


Figure 22

Clarkton Site NO3, TKN, NH3 and K Sample Results

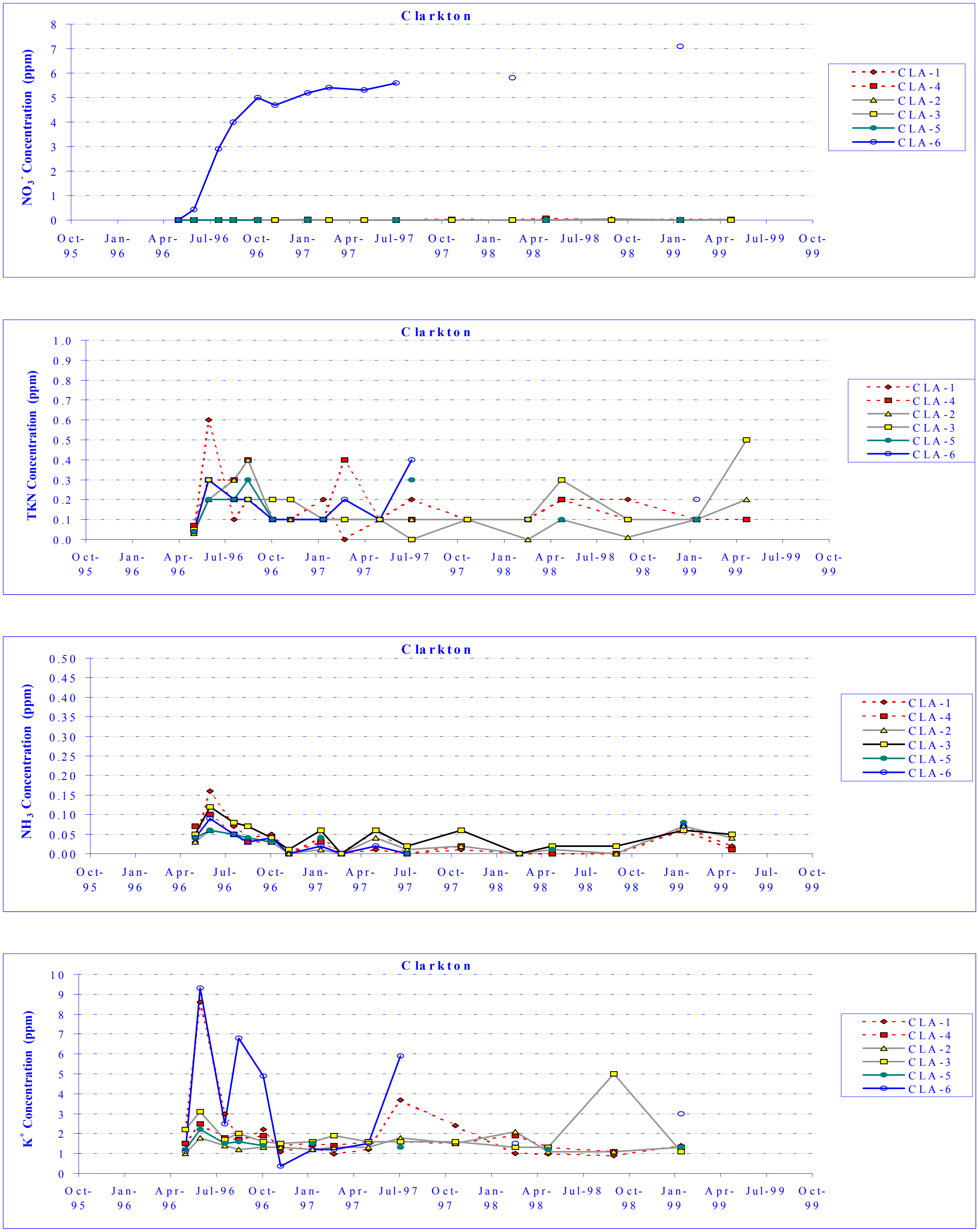
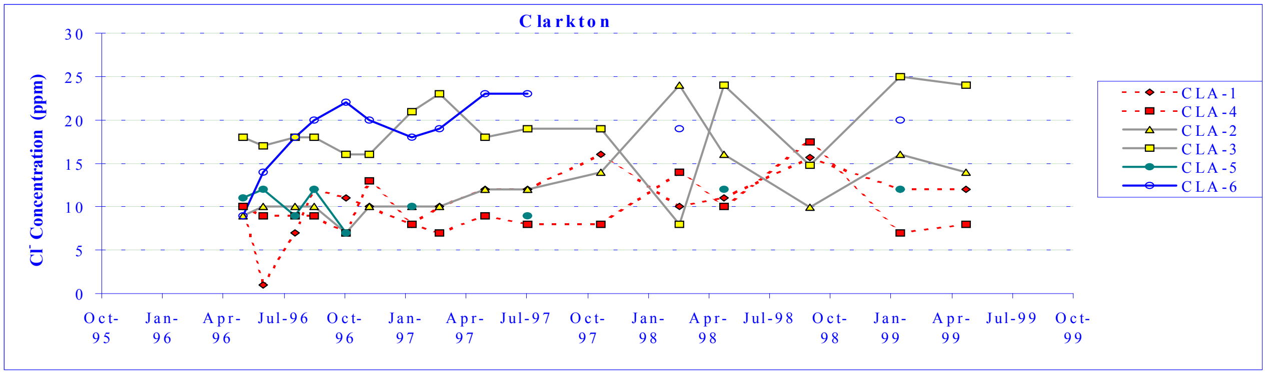


Figure 23 (1 of 2)

Clarkton Site Cl Sample Results and Ground Water Elevation



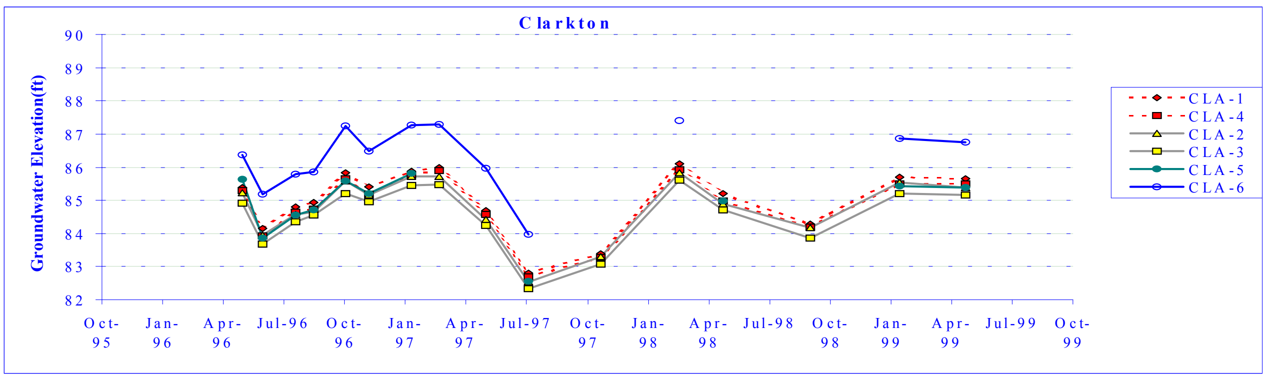


Figure 23 (2 of 2)

The Gaston Dairy site is located in the Piedmont physiographic province. Ground and surface water from this site discharge into the Catawba River Basin.

Ground Water Flow

Ground water is flowing northwest at 0.08-0.09 feet per day, so time of travel for seepage indicators from the lagoon would be 4.11 years to well GD-1 and 4.69 years to well GD-2 (figs. 25-27). The wells were installed in June 1996 and the final sample was collected on October 13, 1999. The wastewater storage pond was completed November 1993 to the improved NRCS construction standards implemented in 1996 in cooperation with the N.C. Cooperative Extension Service as a part of Best Management Practices project. According to the estimates, sufficient time had elapsed for seepage to impact the wells by Spring 1998.

Ground Water Sampling Results

Monitoring wells at this site were sampled four additional times since publication of the original report. NO_3 concentrations are still above the state ground water standard of 10 parts per million (ppm), but they are decreasing or stable in the sampled wells (fig. 28). TKN and NH_3 are also decreasing or stable in the sampled wells. Chloride concentrations in well GD-2 increased significantly during the final sampling event, but all other sampled well concentrations showed little change.

Discussion

The Gaston Dairy farm site has been in operation for more than 20 years. Wells GD-1 through GD-10 are or have been accessible to dairy cattle, although GD-9 and GD-10 are topographically uphill from the heaviest use areas and were the best wells to use as background wells. Prior to the start of this study, the Cooperative Extension Service installed fencing on either side of the stream and corrected erosion problems on the farm. The Extension Service intended to study the effects of erosion control and buffer areas on stream water quality. The Groundwater Section then cooperated with the study effort by installing wells on the farm to determine if ground water quality improved as it went from pastureland through the buffer.

Throughout the study, wells GD-4, GD-7 and GD-8 were located in pastureland, with GD-8 in a lightly used area and GD-4 in a heavily used area. GD-7 was installed in close proximity to the stream to intercept discharging ground water. Wells GD-5 and GD-6 were placed near the stream in a "stream buffer area" which was fenced off from access to the cattle. These wells were topographically just downhill from heavily used pastureland. Wells GD-1, GD-2 and GD-3 were also in the buffered area and so were not accessible to the cattle during the course of the study. In addition, the area upgradient of these wells was not accessible to the cattle. This area was fenced off and was occupied by waste lagoons, a storage and maintenance building and the milking parlor buildings.

This is important to note because it precludes the possibility of the shallow ground water in these three wells being impacted by infiltrating ground water from upgradient pastureland. The most likely source of contaminated ground water would be the lagoons, the maintenance shop or the milking parlor.

With wells GD-1, GD-2, GD-3, GD-5 and GD-6 in buffered areas, one would expect them all to produce ground water of static or improving quality over time. Since the publication of the original report, constituent concentrations in wells GD-1, GD-2, GD-3 and GD-4 have continued to be elevated. Beginning January 1998, the concentrations of constituents in GD-2 began changing to those associated with the arrival of the reducing conditions characteristic of undiluted waste lagoon seepage. The concentrations of chloride, potassium, NH_3 and TKN began increasing and the concentration of NO_3 dropped to zero. Slug test results estimated that it would take 4.1 to 4.7 years for any lagoon seepage to impact the wells. The arrival of the seepage indicators in well GD-2 4.2 years after completion of the lagoon supports the validity of the slug test estimation.

Wells GD-1 and GD-3 continue to have elevated concentrations of seepage indicators, but have not undergone the chemical change from oxidized to reduced conditions characteristic of lagoon seepage plumes. Despite the unusual chemical composition of the ground water, however, the high concentration of seepage indicators over the three and a half years of sampling leads the authors to conclude that the ground water in these wells is being impacted by either seepage from the lagoon or by concentrated wastewater infiltrating the ground water between the milking parlor and the lagoon. The arrival of the plume 4.2 years after completion of the lagoon correlates tightly with estimation of the ground water flow rate and points to the wastewater storage pond as the source.

At the conclusion of the first part of the study, staff from the Groundwater Section and the Gaston County Cooperative Extension Service sampled the wells to use results to aid the two research efforts. Eventually, Extension Service staff took over the sampling responsibilities. Several factors including staffing changes and differences in laboratory protocol led to the wells of interest not being routinely sampled from October 1998 through October 1999. As a result, more detailed analyses cannot be made.

EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

Based on the analyses results, ground water at this site is not being adequately protected from lagoon seepage.

Gaston Dairy Site Map

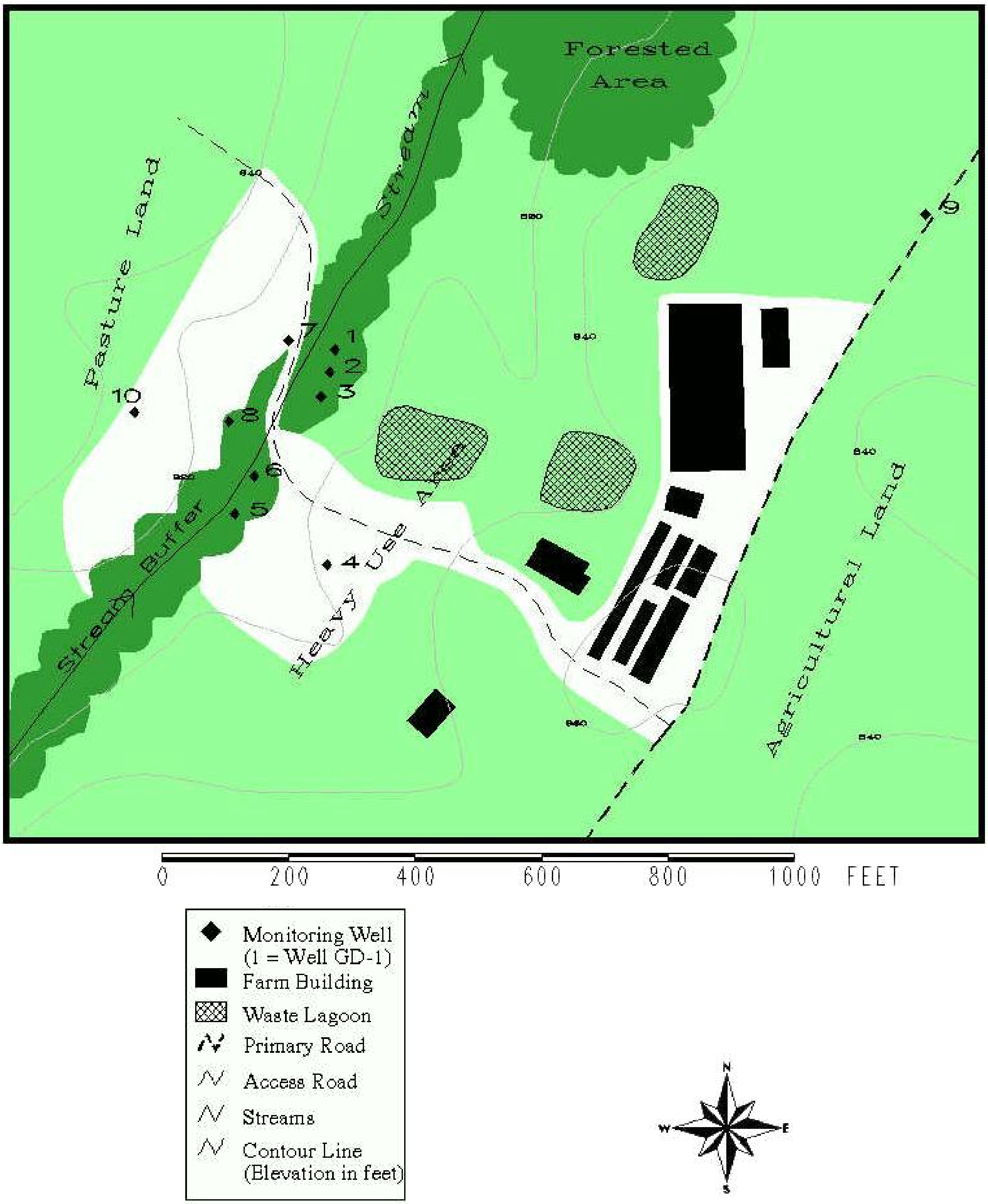


Figure 24

Gaston Site Ground Water Flow Map
(9/16/98)

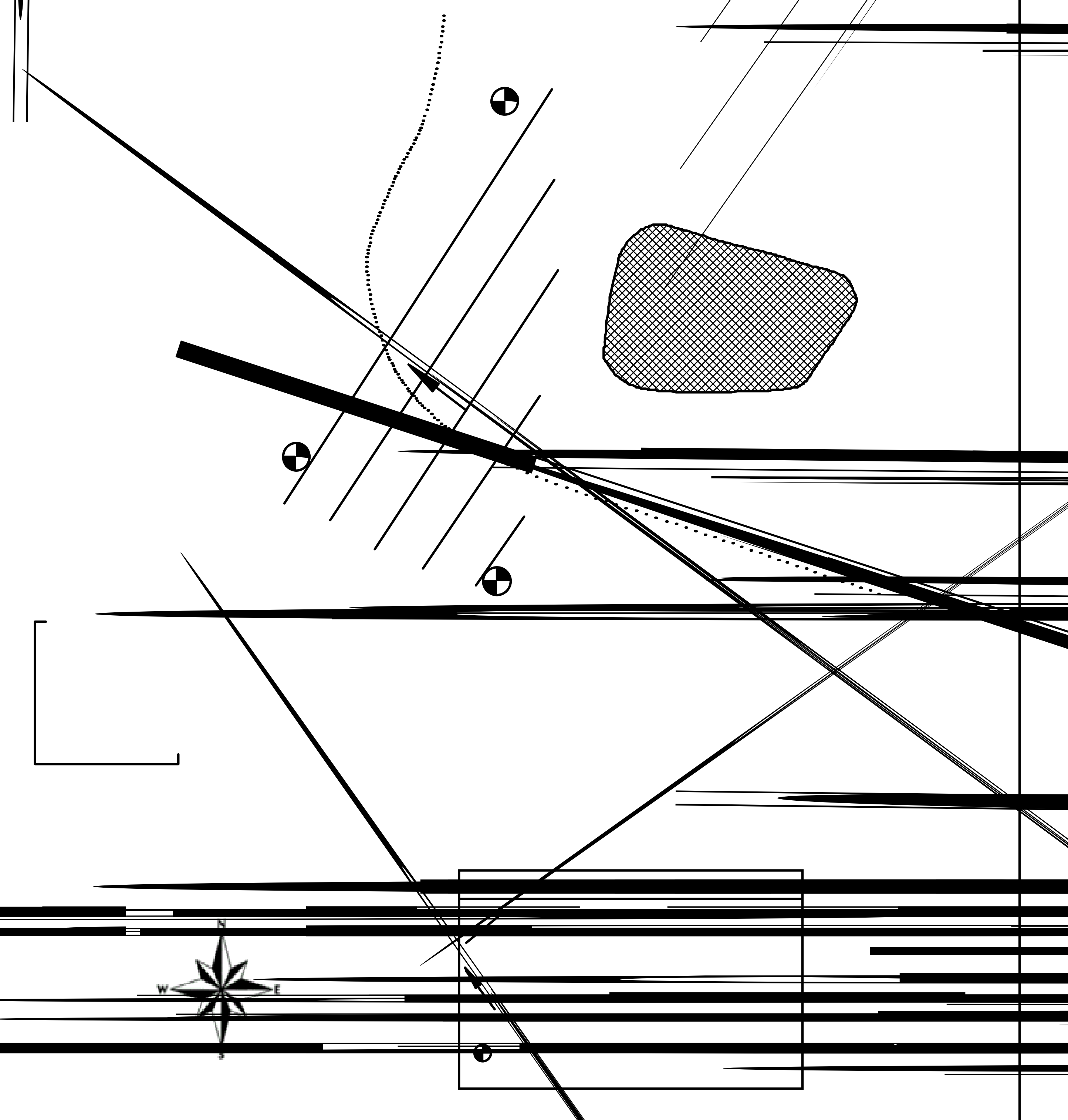
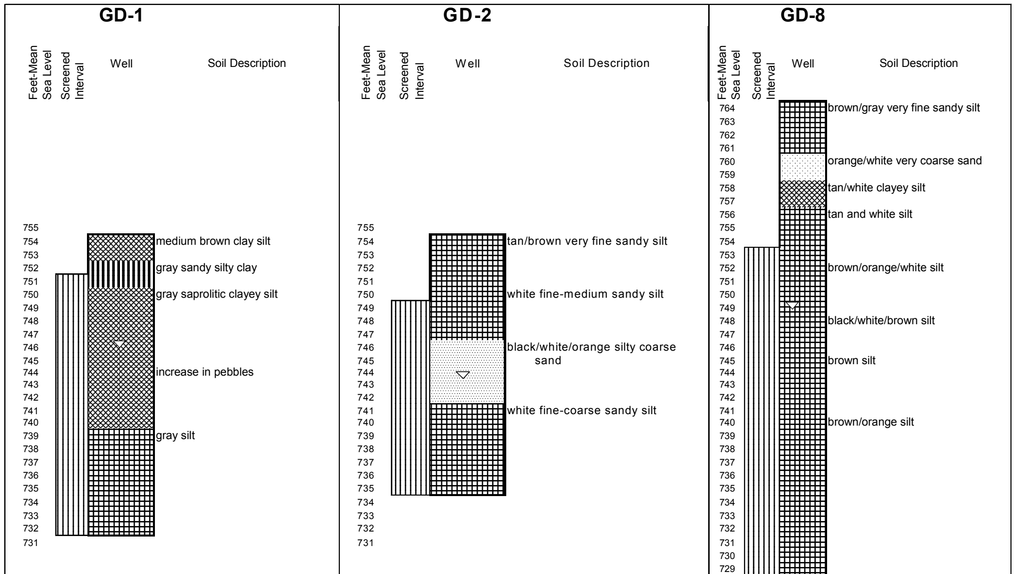


Figure 25

Gaston Site Well Logs and Aquifer Characteristics

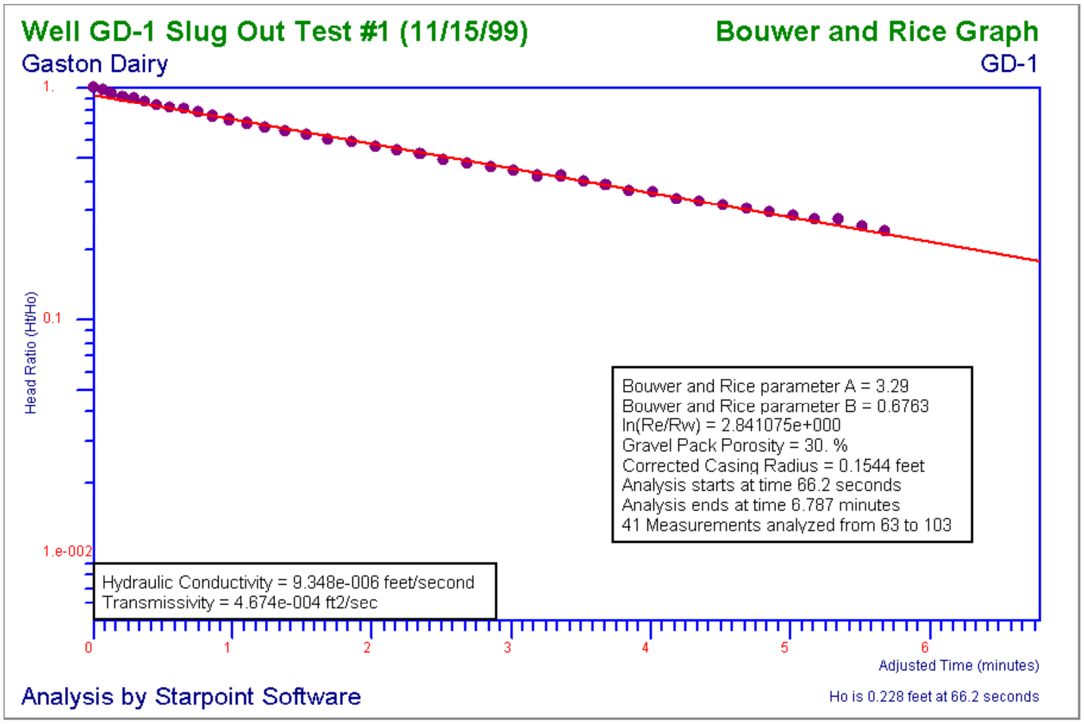


Slug Test ID	**Out 1**	**Out 2**	**Out 3**	**In 1**	**In 2**	**Out 1**	**Out 2**	**Out 3**	**In 1**	**In 2**
aquifer thickness (ft)	50	50	50	50	50	50	50	50	50	50
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6
screen length (ft)	20	20	20	20	20	10	10	10	10	10
screen interval (ft)	3.0-23.0	3.0-23.0	3.0-23.0	3.0-23.0	3.0-23.0	5.0-15.0	5.0-15.0	5.0-15.0	5.0-15.0	5.0-15.0
water table to bottom of screen (ft)	**14.91**	**14.91**	**14.91**	**14.91**	**14.91**	**7.44**	**7.44**	**7.44**	**7.44**	**7.44**
static water level	8.09	8.09	8.09			7.56	7.56	7.56		
porosity (%)	0.25	0.25	0.25			0.25	0.25	0.25		
gradient (ft/ft)	0.028	0.028	0.028			0.028	0.028	0.028		
hydraulic conductivity (ft/sec)	9.35E-06	8.98E-06	1.08E-05			8.36E-06	8.43E-06	8.05E-06		
average hydraulic conductivity (ft/sec)			**9.71E-06**					**8.28E-06**		
velocity (ft/sec)	1.05E-06	1.01E-06	1.21E-06			9.37E-07	9.44E-07	9.01E-07		
velocity (ft/day)	0.09	0.09	0.10			0.08	0.08	0.08		
average velocity (ft/day)			**0.09**					**0.08**		
distance from lagoon to well	140.00	140.00	140.00			137.00	137.00	137.00		
days to reach well	1547.67	1610.55	1339.59			1692.88	1679.83	1759.14		
average days to reach well			**1499.27**					**1710.62**		
years to reach well	4.24	4.41	3.67			4.64	4.60	4.82		
average Years to reach well			**4.11**	X	X			**4.69**	X	X

Notes:
1) Depth of the aquifer is unknown. I used 50 as an estimate. Deep well at 36 was still in saprolite.
2) boring logs in 1 and 2 show sandy silt, silty sand and silt
3) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
4) satic water level within screens; cannot use slug-in results
5) ▽ =static water level

Figure 26

Gaston Site Representative Slug Test Analyses



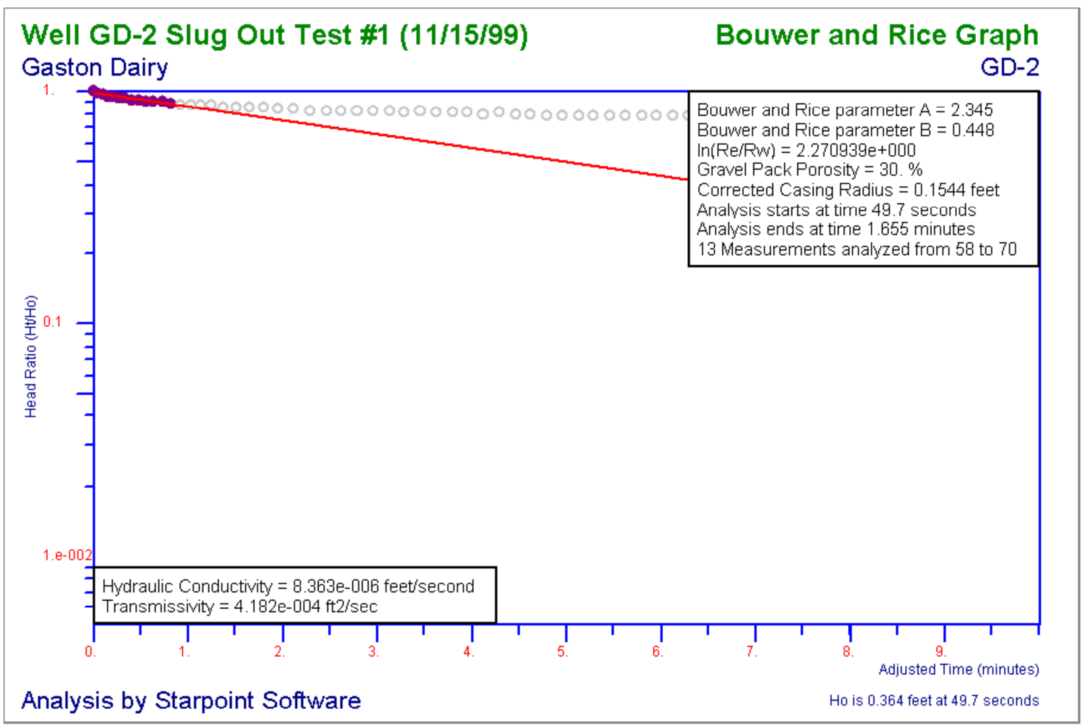
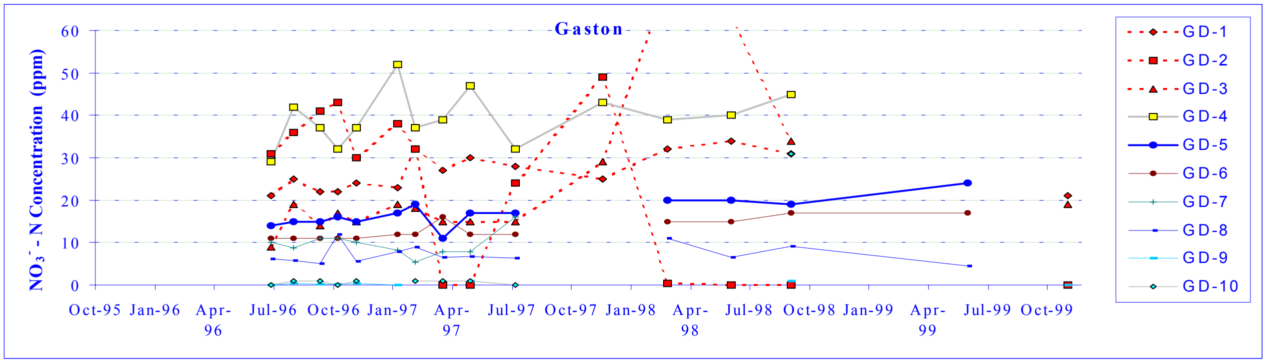
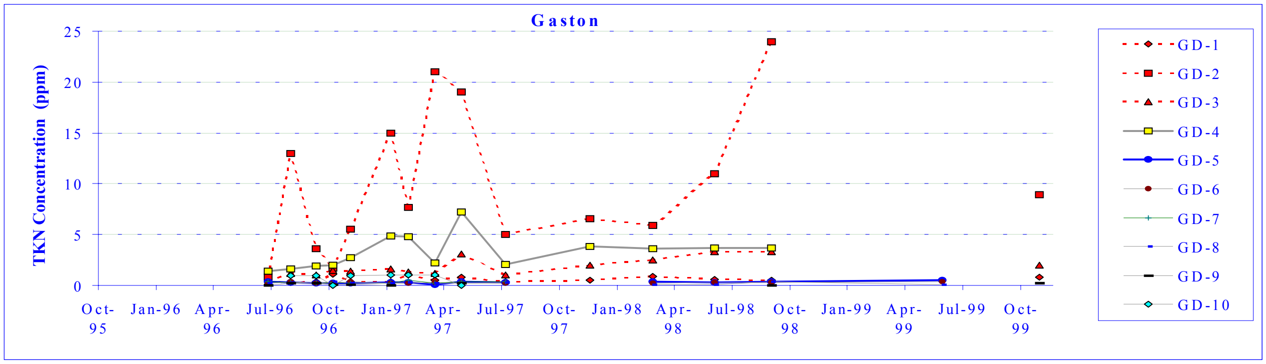
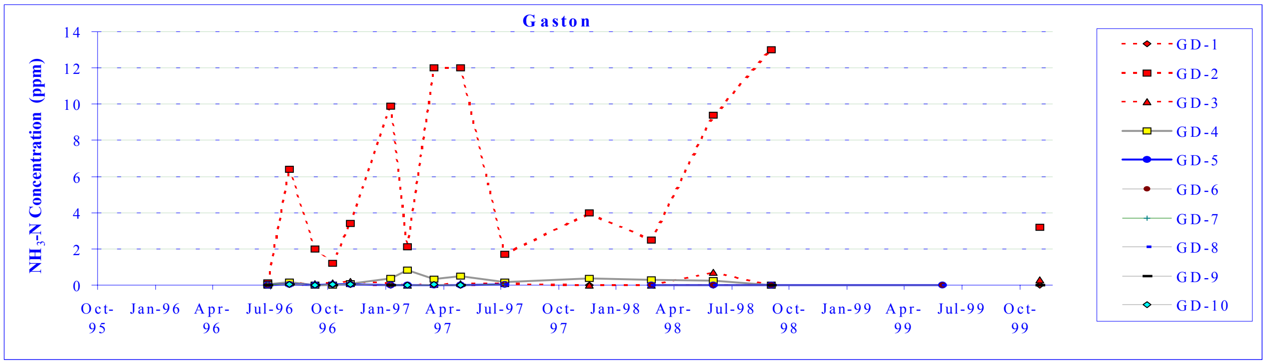


Figure 27

Gaston Site NO_3, TKN, NH_3 and K Sample Results







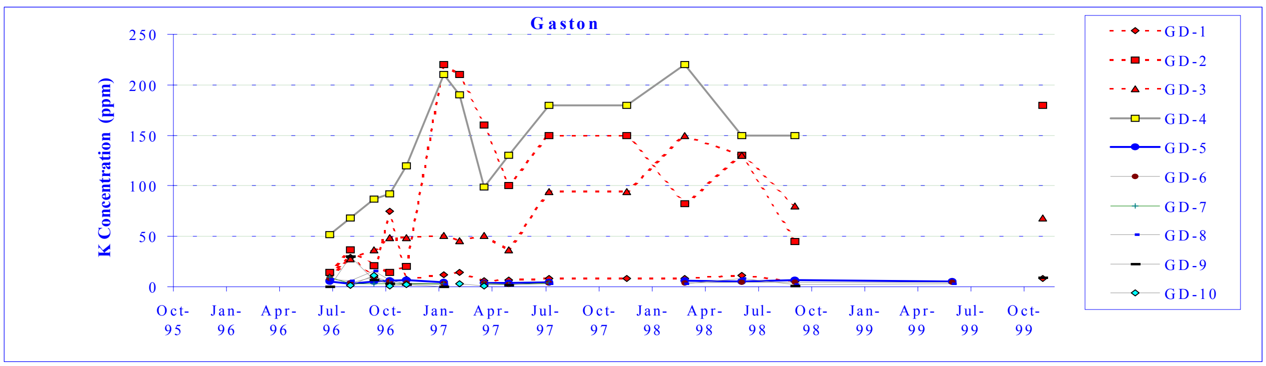
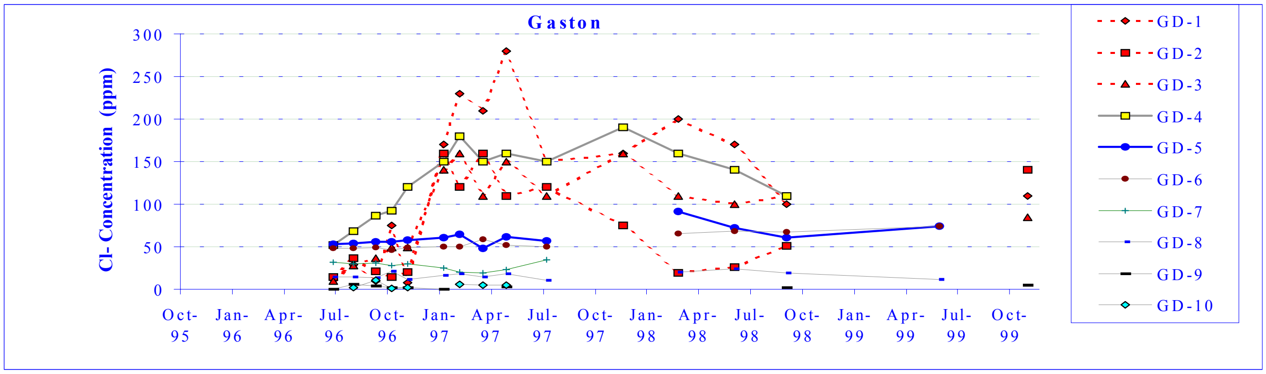


Figure 28 (1 of 2)

Gaston Site Cl Sample Results and Ground Water Elevation



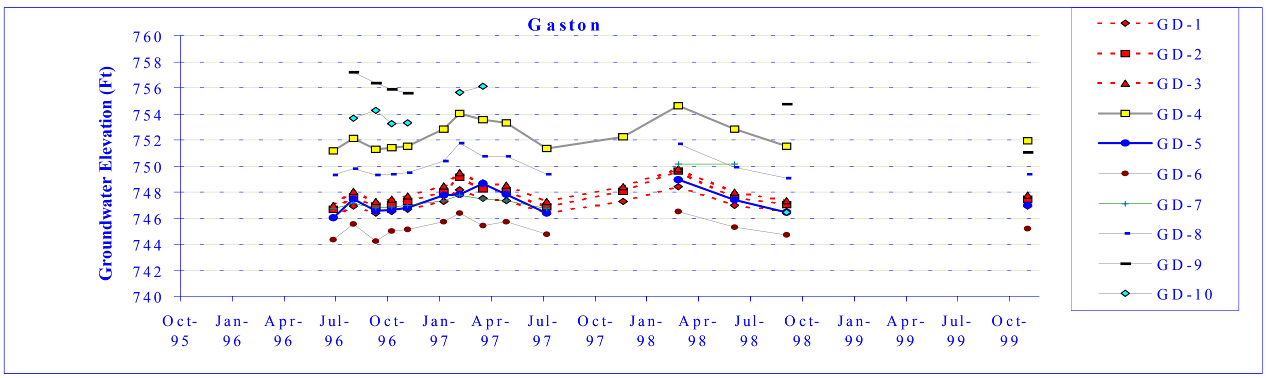


Figure 28 (2 of 2)

The Grantham site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Neuse River Basin.

Ground Water Flow

Ground water is flowing southeast at 0.83-1.39 feet per day in the surficial aquifer (figs 30-33). The magnitude of difference in the hydraulic conductivity values from slug-out tests and slug-in tests suggests that the water table may have been close enough to the top of the well screen that the slug-in tests were adversely affected. When slug-in values are not used, time of travel for seepage indicators from the lagoon to well Gra-1 is 0.41 years (fig. 32). Ground water is flowing southwest at 0.25 feet per day in the first confined aquifer, so time of travel for seepage indicators from the lagoon to well Gra-4 is 1.41 years (fig. 32). Sufficient time has elapsed to detect seepage indicators from the lagoon in these wells.

Ground Water Sampling Results

Monitoring wells at this site were sampled nine additional times since the publication of the original report. It was determined that most wells were screened in an aquifer beneath a clay confining layer, but three of the wells are screened in the surficial aquifer.

Beginning in October 1996, nitrate concentrations in well Gra-1 began to drop from slightly above 10 parts per million (ppm) to a low of 1 ppm by May 1998 (fig. 34). In March 1997, the chloride concentrations began a steady rise from less than 20 ppm toward a peak of 130 ppm by July 1998. Total nitrogen concentrations of 270 ppm nitrogen and the high concentrations of other seepage indicators such as chloride and dissolved solids were also reached in August 1998.

Well Gra-3 is screened in the same shallow system as Gra-1, but is 125 feet further downgradient from the lagoon. In October 1997, chloride concentrations increased from a constant concentration near 20 ppm to near 100 ppm for the remainder of the study (fig. 34). Other seepage indicators such as declining nitrate levels and rising levels of reduced forms of nitrogen were also noticeable by December 1998. Concentrations of these other seepage indicators points to a change in ground water chemistry at this well similar to changes found in wells impacted by lagoon seepage.

The seepage indicators in Gra-1 prompted GWS staff to look more closely at the EM surveys. A well (Gra-7) was hand installed in the anomalous area to the east-southeast of the lagoon on May 21, 1998. Lab results showed that there were high concentrations of seepage indicators with combined nitrogen levels of 614 ppm, peaking in August 1998 at 830 ppm. All other seepage indicators' concentrations also peaked at the same time.

Of the five wells originally placed in the estimated direction of ground water flow from under the lagoon, only Gra-1 and Gra-3 are screened above the first clay confining unit.

The hand installed well (Gra-7) was also screened above the confining unit. Only two wells were impacted by lagoon seepage and a third, Gra-3, had high concentrations of chloride – the most mobile seepage indicator.

The changes observed in Gra-3 were strongest in December 1998. There was roughly a four or six month delay in both the rise in chloride concentration and the change in nitrogen chemistry and concentration between the two wells located 125 feet from the lagoon and the one located 250 feet from the lagoon. An estimation of ground water movement between wells Gra-1 and Gra-3 using constituent concentration changes as a marker shows movement of 125 feet in five months or 300 feet per year. Results of slug tests performed on Gra-1 estimate ground water movement at about 350 feet per year. Considering the rough estimation nature of both of these calculations, these results support each other.

In the two wells closer to the lagoon (Gra-1 and Gra-7), the seepage indicator concentrations peaked in August 1998 and then fell until August 1999, indicating that the lagoon may have seeped for a period of time while it was new and eventually underwent physical or biological sealing referred to in literature (Ritter, et al, 1984: Miller, et al, 1985). NO_3 concentrations have been on the increase again since August 1999 in wells Gra-1, Gra-3, and Gra-7; however, no corresponding increase of Cl is noted prior to this NO_3 increase.

Seepage indicators in Gra-3 were much lower in concentration than in Gra-1. It could be argued that the contaminated ground water is undergoing significant treatment as it migrates toward a discharge. It would be necessary, however, to install additional monitoring wells downgradient from Gra-7 and to continue monitoring wells at this site to determine if the lagoon is actually sealing and contaminants in the ground water are being attenuated as they migrate downgradient. Sampling of these wells ended when contracts with the cooperators expired in December 1999.

EM Surveys

During an EM survey conducted on March 6, 1997 at the Grantham site, GWS staff noted an area of higher conductance east-southeast of the lagoon and a large area south of the lagoon, both of which were about four times more conductive than the rest of the site. The area to the south was quite large and oval shaped, and it encompassed wells Gra-1 through Gra-5. It didn't seem to lead right up to the lagoon like a seepage plume. The readings were assumed to be the result of the land surface dropping closer to a continuous clay layer. The area to the east-southeast was noted, but assumed to be a minor anomaly. A second EM survey conducted on September 24, 1997 showed the exact same readings. These indicators, coupled with seepage indicators in well Gra-1 prompted GWS staff to install Gra-7 in the area with the anomalous EM readings.

Conclusion

Based on the analytical results and the site characteristics, ground water at this site is not being adequately protected. Additional ground water monitoring could provide useful data and possibly change this conclusion.

This site is an example where the EM readings were definitely showing high conductance lagoon seepage but were overlooked, due to the unusual shape of the seepage plume. In future investigations, all anomalies should be investigated by asking the cooperator if anything is buried in the area and by hand installing monitoring wells.

Grantham Site Maps

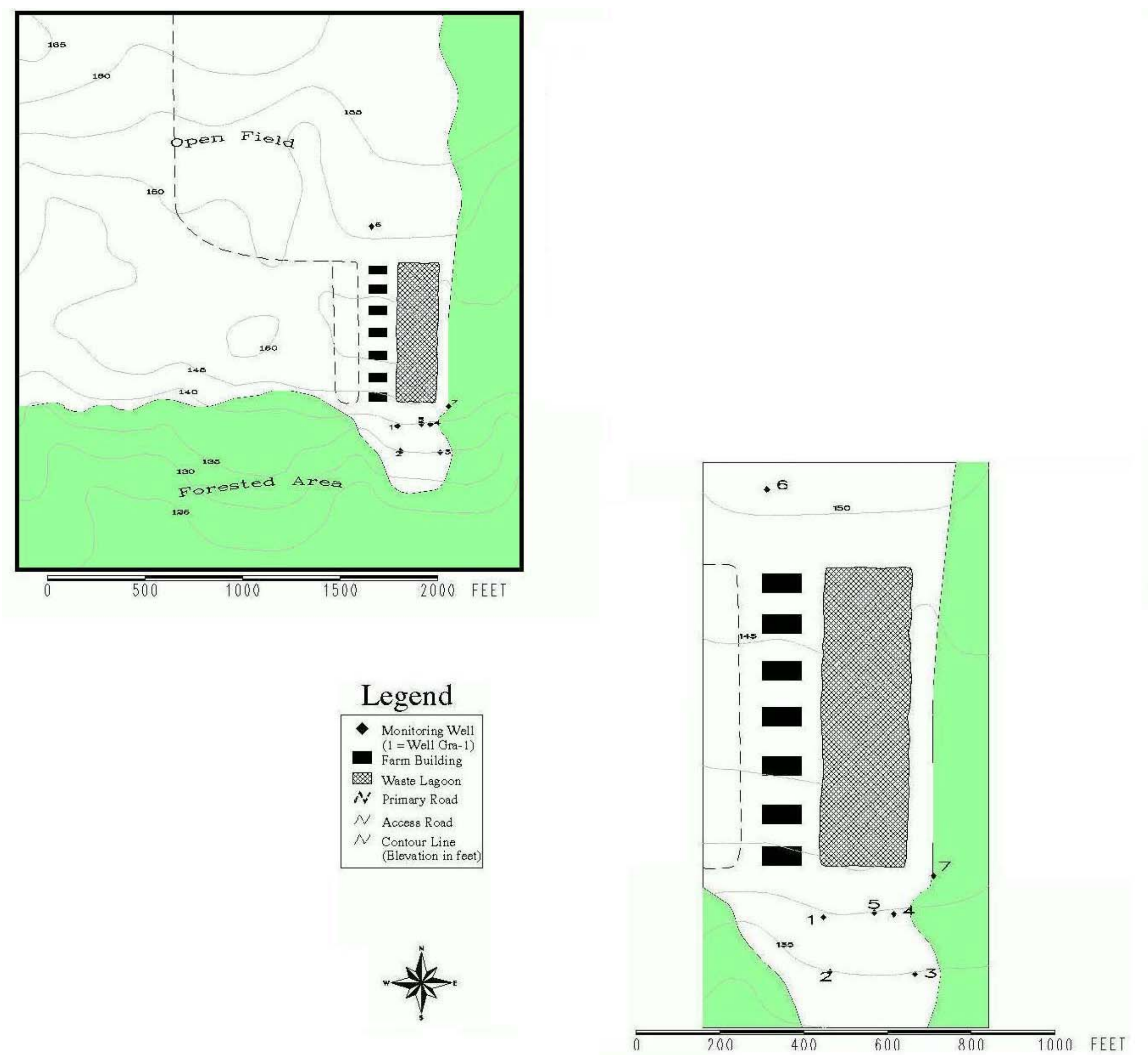


Figure 29

Grantham Site Ground Water Flow Map
(Surficial Aquifer - 10/13/99)

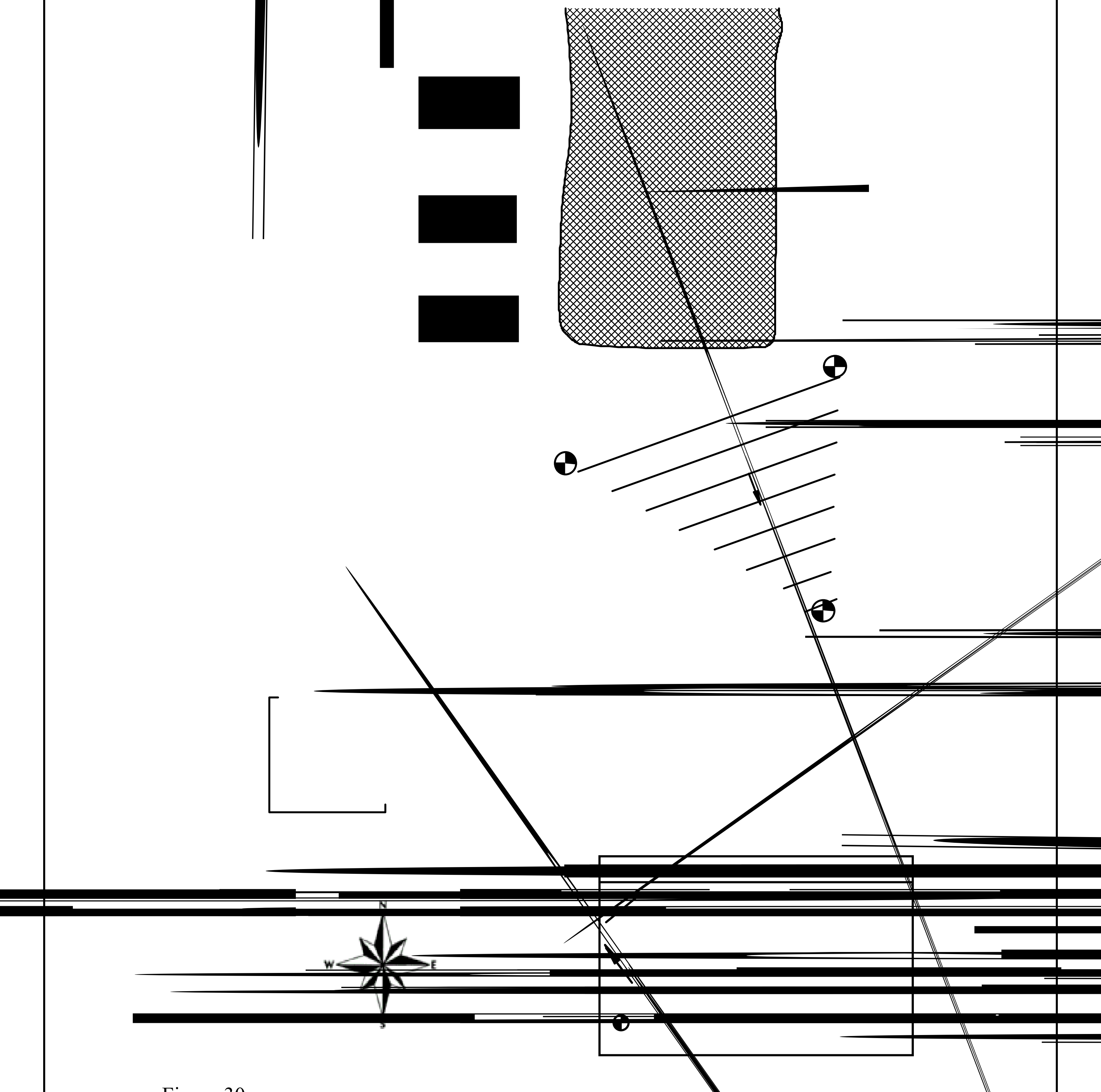


Figure 30

Grantham Site Ground Water Flow Map
(First Confined Aquifer - 10/13/99)

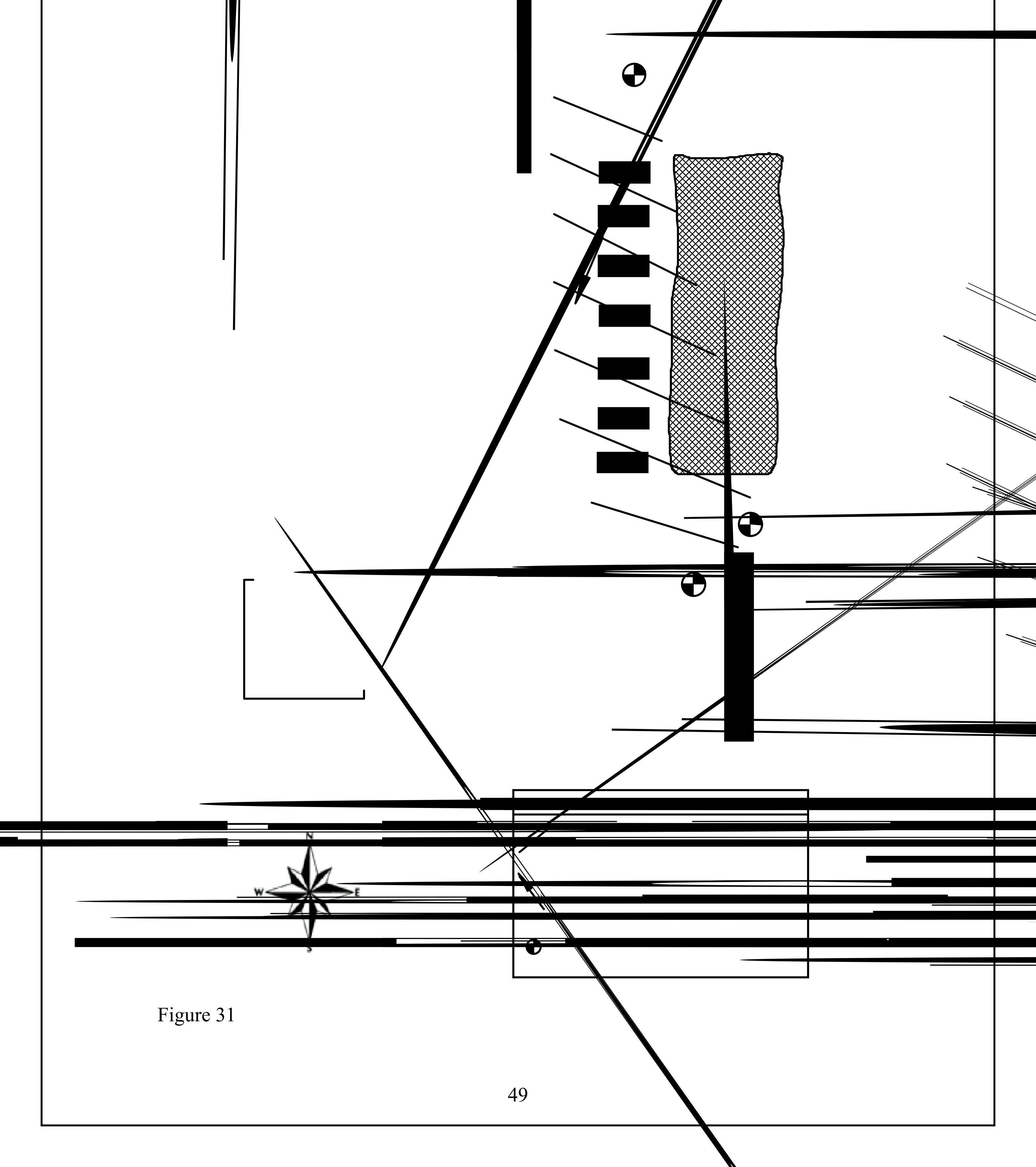
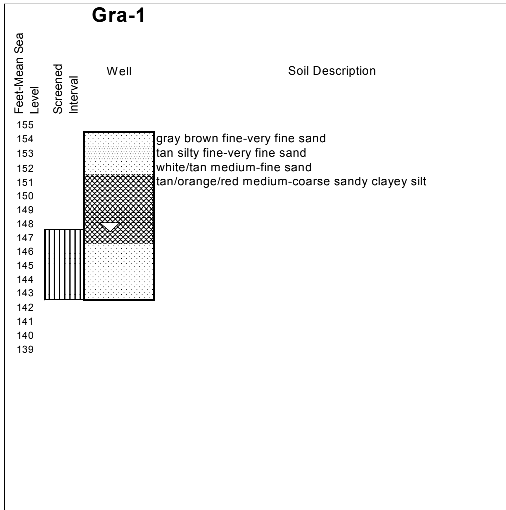
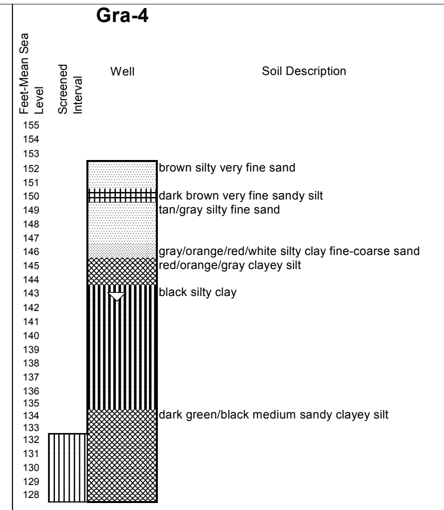
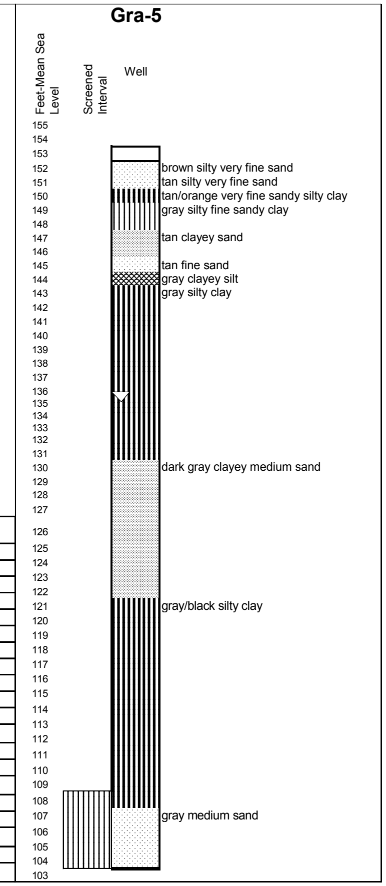


Figure 31

Grantham Site Well Logs and Aquifer Characteristics







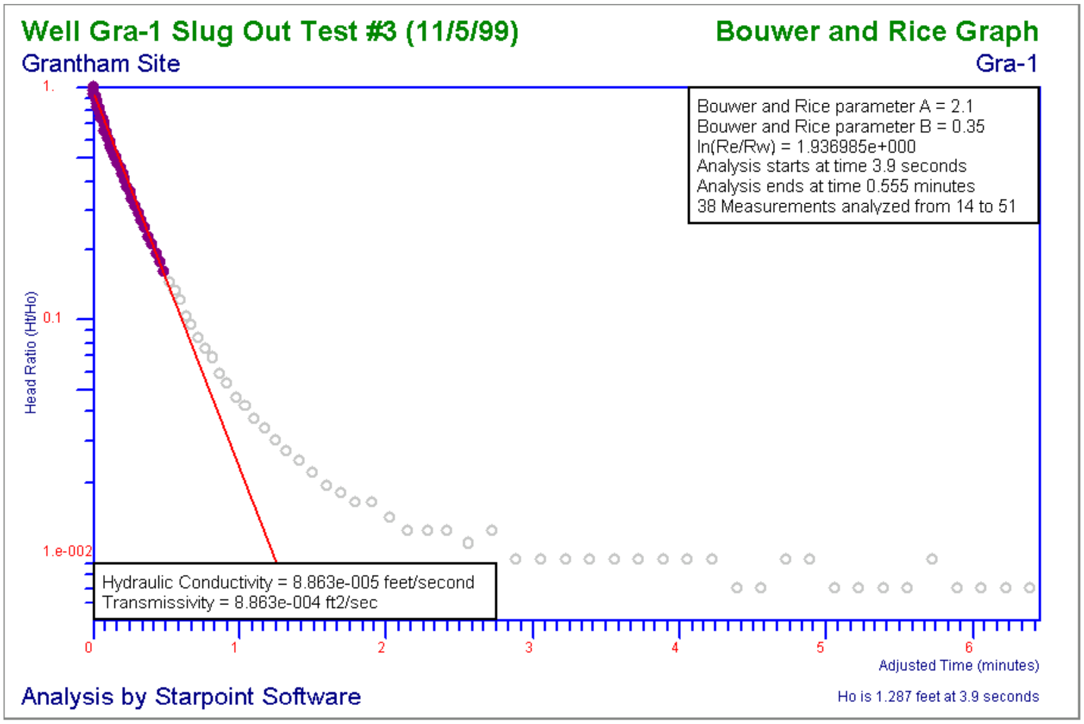
Slug Test ID	Out 1	Out 2	Out 3	Out 4	In 1	In 2	In 3	Out 1	Out 2	Out 3	In 1	In 2	In 3
aquifer thickness (ft)	10	10	10	10	10	10	10	10	10	10	10	10	10
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	conf	conf	conf	conf	conf	conf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6	6	6	6
screen length (ft)	5	5	5	5	5	5	5	5	5	5	5	5	5
screen interval (ft)	7.0-12.0	7.0-12.0	7.0-12.0	7.0-12.0	7.0-12.0	7.0-12.0	7.0-12.0	20-25	20-25	20-25	20-25	20-25	20-25
water table to bottom of screen (ft)	5.31	5.31	5.31	5.31	5.31	5.31	5.31	16.51	16.51	16.51	16.51	16.51	16.51
static water level	6.69	6.69	6.69	6.69	6.69	6.69	6.69	8.49	8.49	8.49	8.49	8.49	8.49
porosity (%)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.008	0.008	0.008	0.008	0.008	0.008
hydraulic conductivity (ft/sec)	8.89E-05	8.44E-05	8.86E-05	9.06E-05		1.52E-04	1.46E-04	9.62E-05	8.91E-05	9.33E-05	8.73E-05	8.07E-05	8.55E-05
average hydraulic conductivity (ft/sec)				**8.81E-05**			**1.49E-04**						**8.87E-05**
velocity (ft/sec)	9.66E-06	9.16E-06	9.62E-06	9.84E-06		1.65E-05	1.58E-05	3.08E-06	2.85E-06	2.99E-06	2.79E-06	2.58E-06	2.74E-06
velocity (ft/day)	0.83	0.79	0.83	0.85		1.42	1.37	0.27	0.25	0.26	0.24	0.22	0.24
average velocity (ft/day)				**0.83**			**1.39**						**0.25**
distance from lagoon to well	125.00	125.00	125.00	125.00		125.00	125.00	126.00	126.00	126.00	126.00	126.00	126.00
days to reach well	149.82	157.90	150.35	147.10		87.84	91.52	473.83	511.65	488.40	521.85	564.93	532.95
average days to reach well				**151.29**			**89.68**						**515.60**
years to reach well	0.41	0.43	0.41	0.40		0.24	0.25	1.30	1.40	1.34	1.43	1.55	1.46
average Years to reach well				**0.41**			**0.25**						**1.41**

Notes:

1) It appears from boring logs that wells 1 and 4 are in two different aquifers and that 1 is perched.
   Boring log shows a clay layer above the aquifer in 4
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) ▽ =static water level

Figure 32

Grantham Site Representative Slug Test Analyses



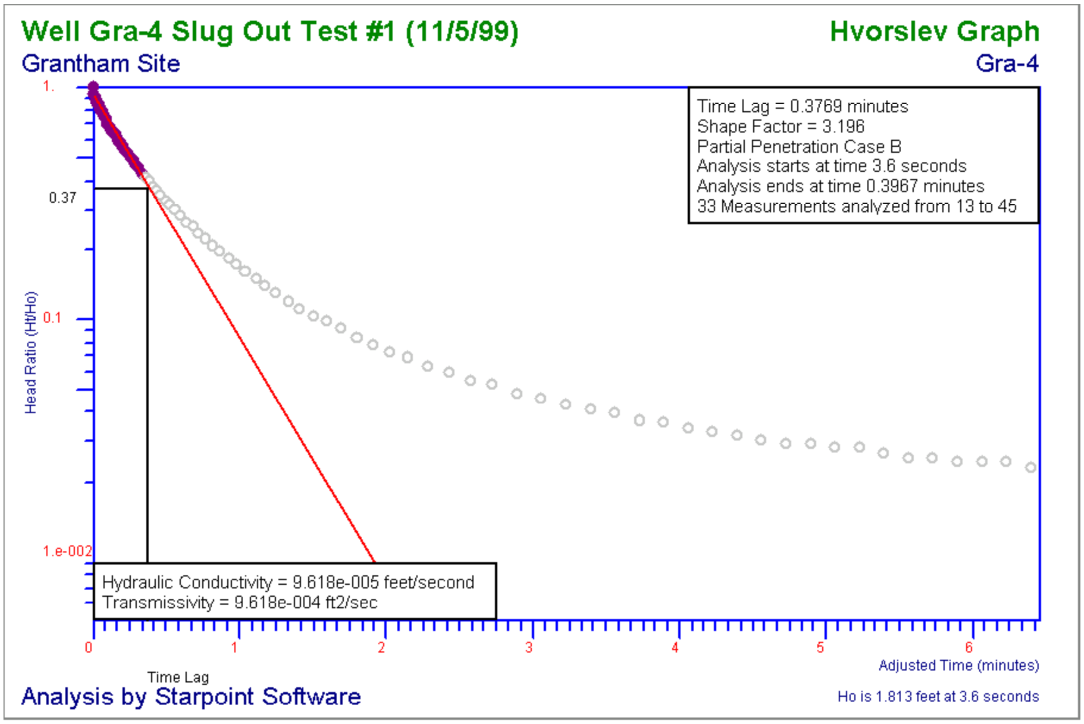
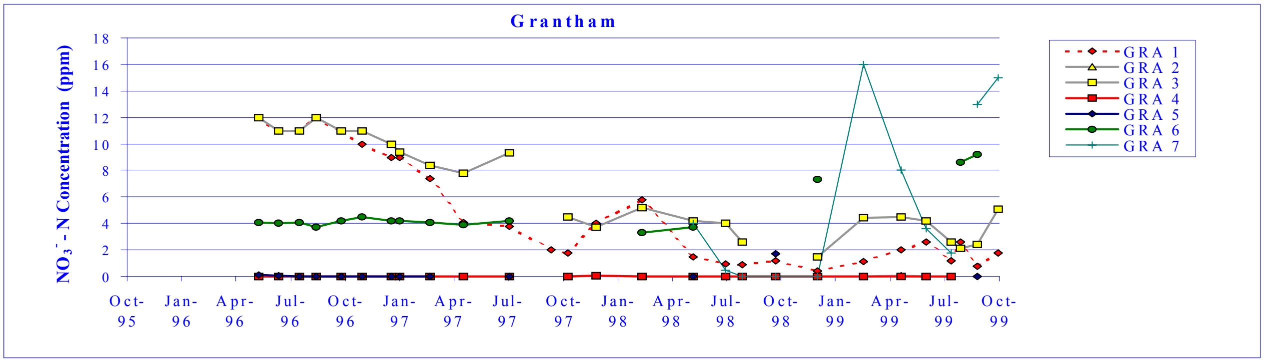
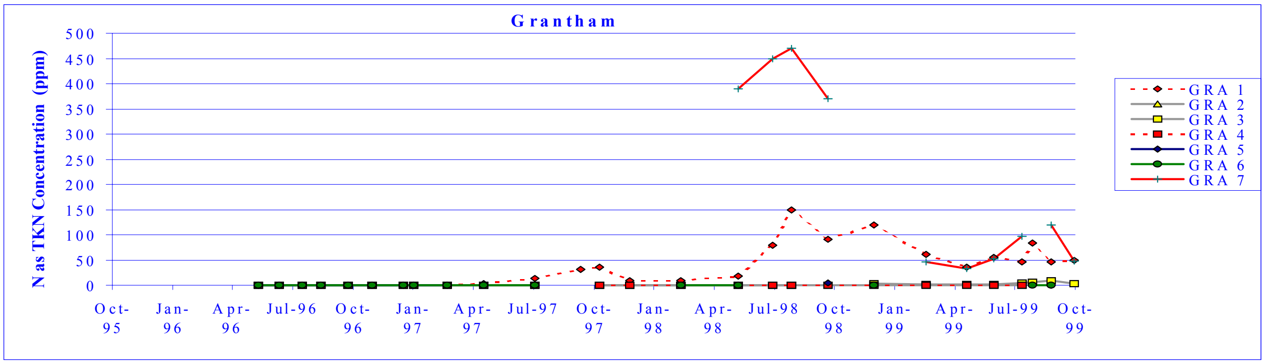
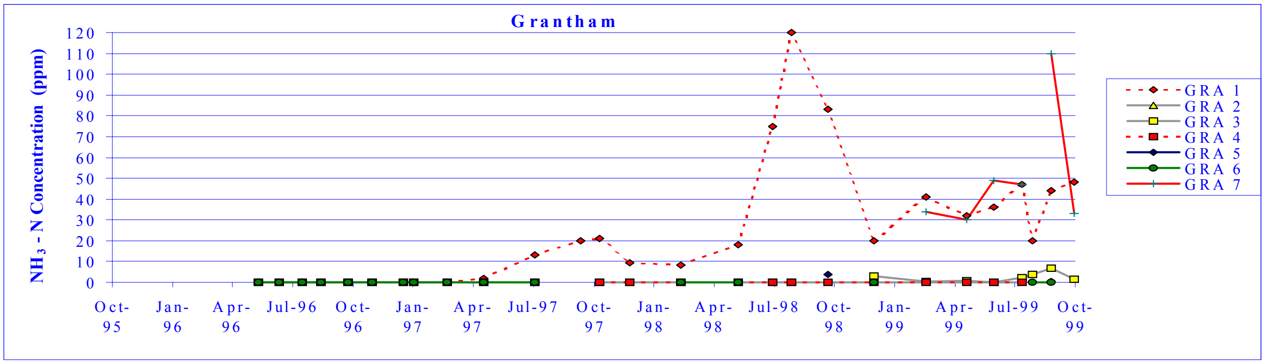


Figure 33

Grantham Site NO_3, TKN, NH_3 and K Sample Results







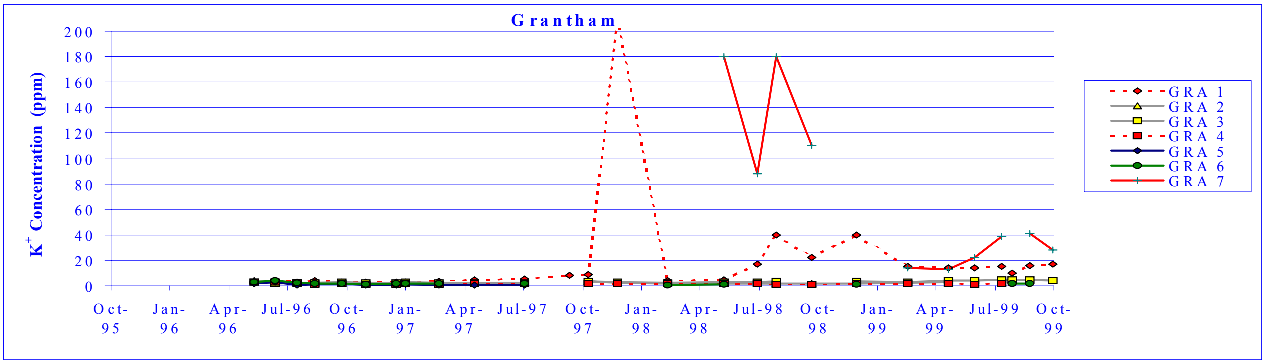
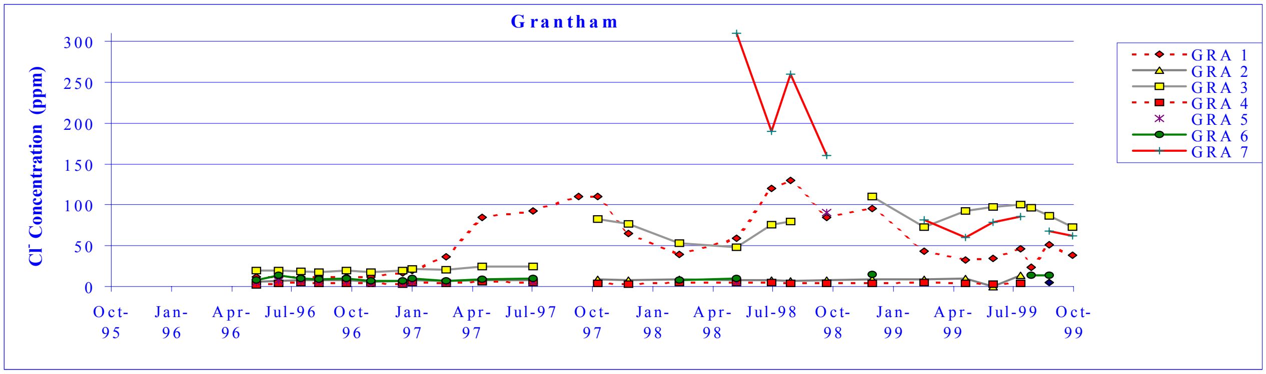


Figure 34 (1 of 2)

Grantham Site Cl Sample Results and Ground Water Elevation



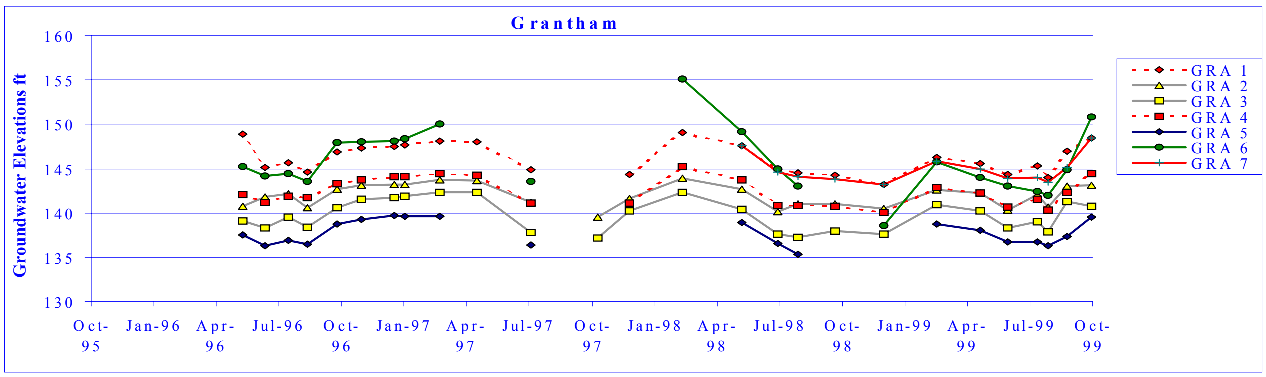


Figure 34 (2 of 2)

Lisbon Site Bladen County

The Lisbon site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Cape Fear River Basin.

Ground Water Flow

Ground water is flowing northwest at 0.36 feet per year in the surficial aquifer where wells Lis-1, Lis-3 and Lis-6 are screened, so time of travel for seepage indicators from the lagoon would be 1.81 years (using slug-out data only) to well Lis-3 (figs. 36-38). Wells Lis-4 and Lis-5 were placed correctly downgradient based on the flow direction, but these wells were screened in a deeper confined aquifer, so they would not detect seepage indicators in the surficial aquifer.

Ground Water Sampling Results

Monitoring wells at the site were sampled four additional times since the publication of the original report, and there have been no significant changes in analyte concentrations (fig. 39).

EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

No conclusions regarding lagoon seepage can be drawn at this site due to the placement of the well screens.

Lisbon Site Maps

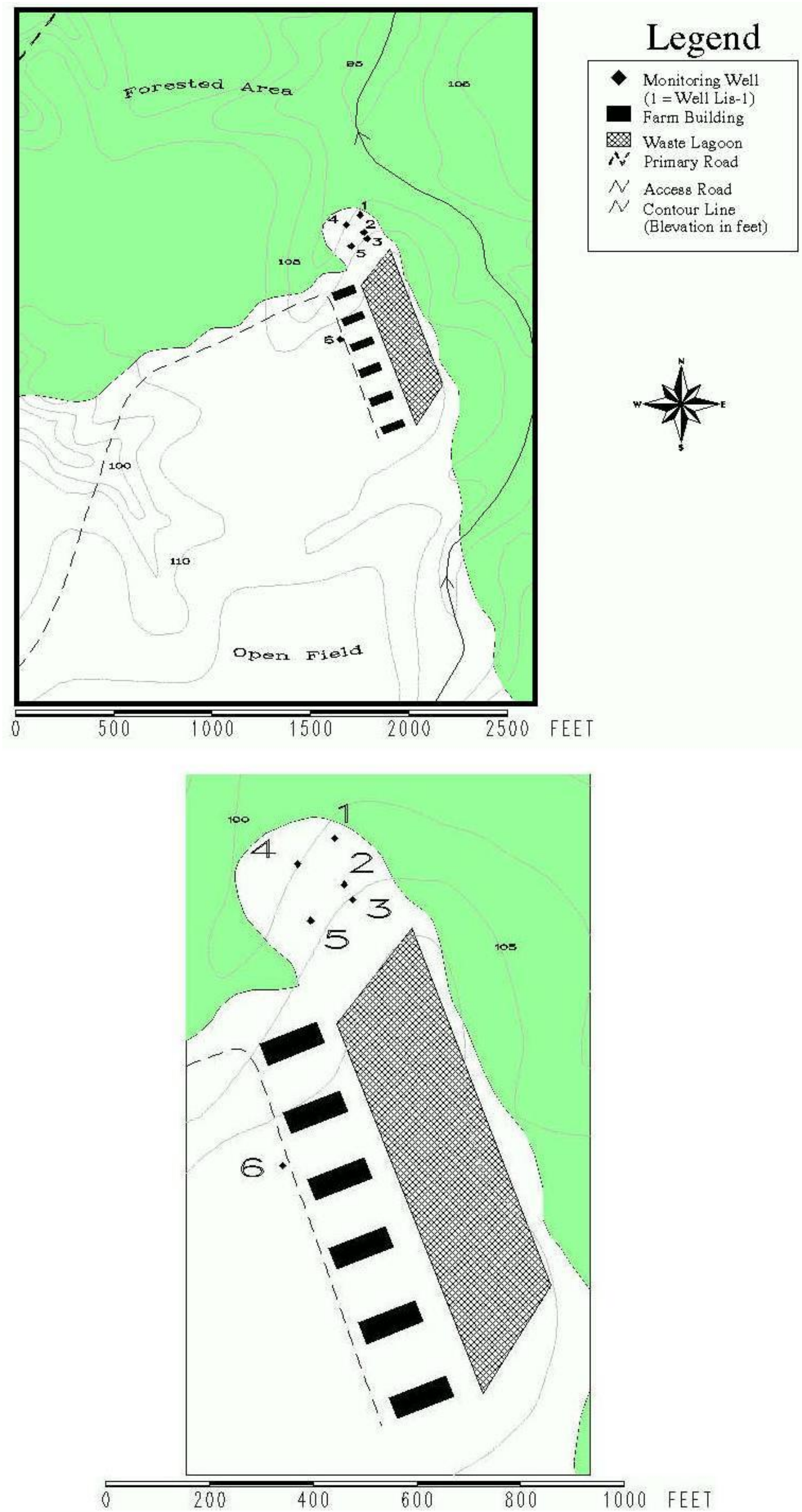


Figure 35

Lisbon Site Ground Water Flow Map
(5/19/99)

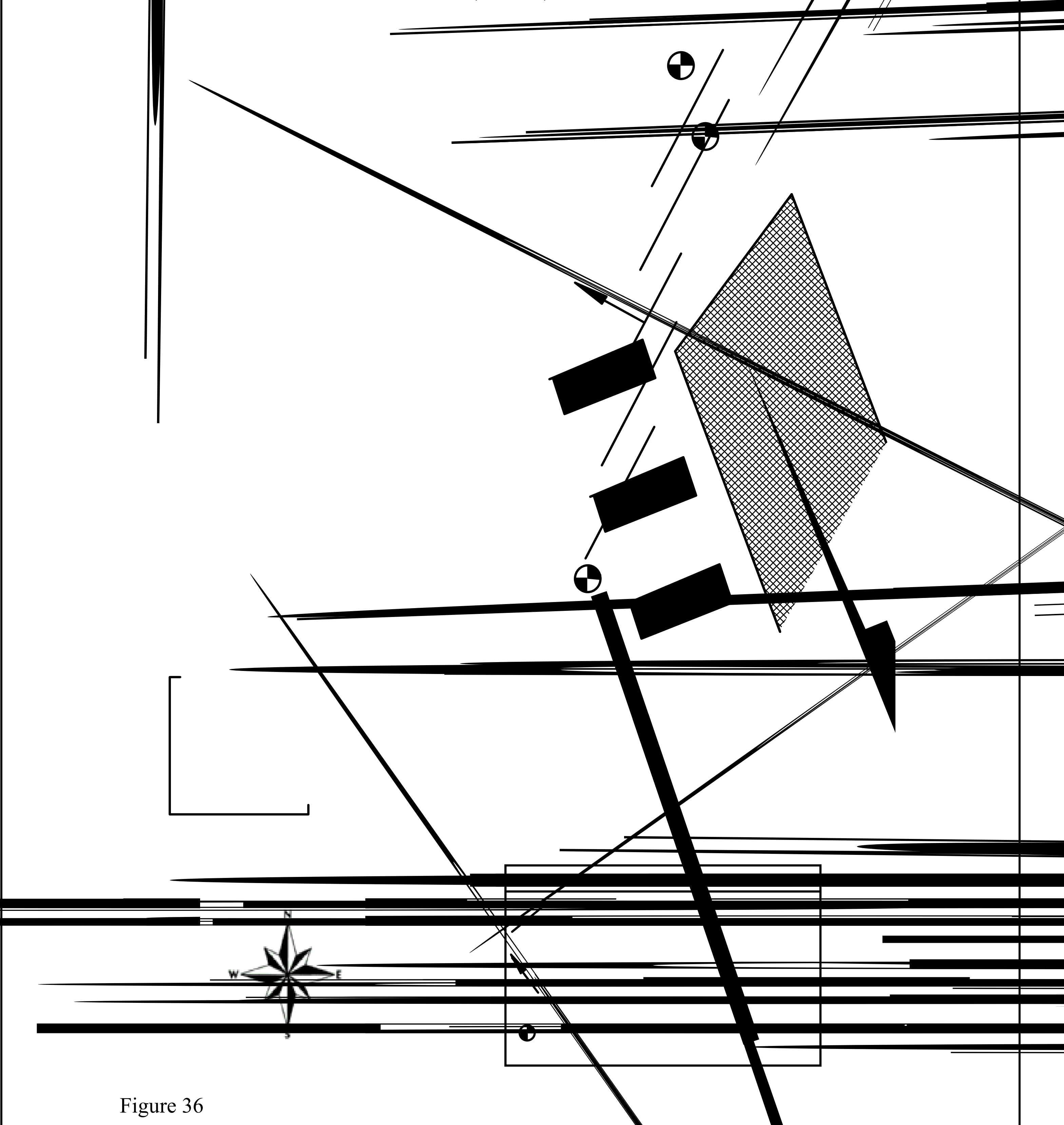
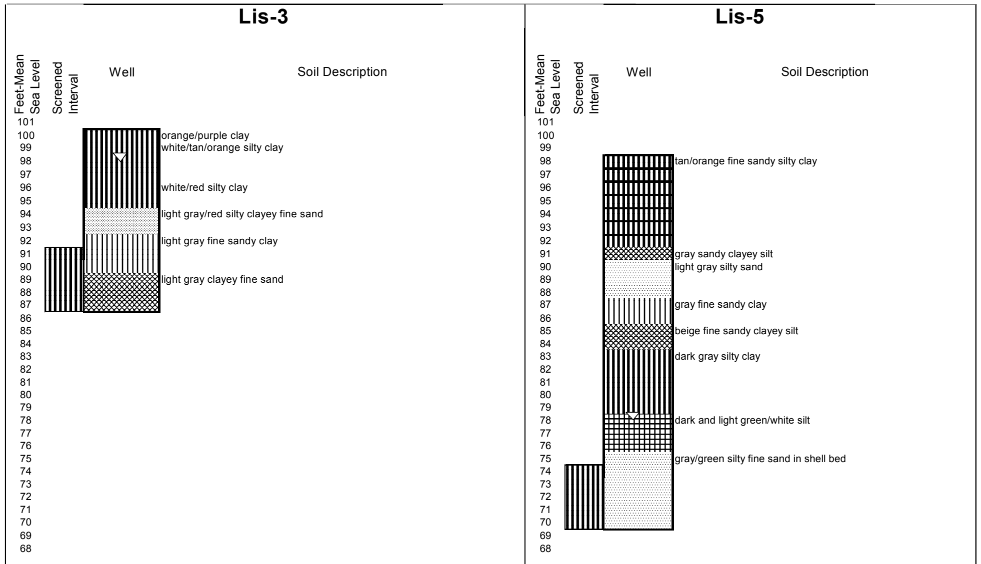


Figure 36

Lisbon Site Well Logs and Aquifer Characteristics

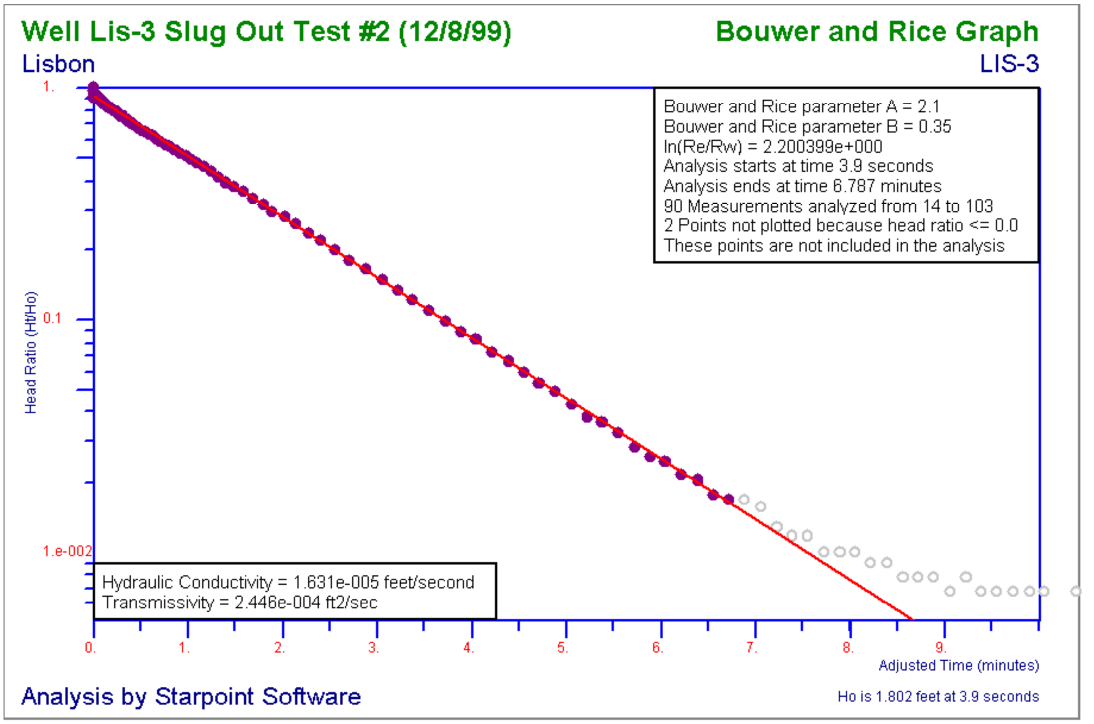


Slug Test	Out 1	Out 2	Out 3	Out 4	In 1	In 2	In 3	Out 1	Out 2	Out 3	Out 4	In 1	In 2
aquifer thickness (ft)	15	15	15	15	15	15	15	15	15	15	15	15	15
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	conf	conf	conf	conf	conf	conf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6	6	6	6
screen length (ft)	5	5	5	5	5	5	5	5	5	5	5	5	5
screen interval (ft)	9.0-14.0	9.0-14.0	9.0-14.0	9.0-14.0	9.0-14.0	9.0-14.0	9.0-14.0	24-29	24-29	24-29	24-29	24-29	24-29
water table to bottom of screen (ft)	10.10	10.10	10.10	10.10	10.10	10.10	10.10	8.13	8.13	8.13	8.13	8.13	8.13
static water level	3.90	3.90	3.90	3.90	3.90	3.90	3.90	20.87	20.87	20.87	20.87	20.87	20.87
porosity (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
hydraulic conductivity (ft/sec)	7.90E-06	1.63E-05	9.05E-06	1.49E-05	3.09E-05	3.69E-05	3.57E-05	9.74E-05	9.92E-05	1.29E-05	9.94E-05	1.06E-04	1.02E-04
average hydraulic conductivity (ft/sec)							**2.17E-05**						**1.01E-04**
velocity (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
velocity (ft/day)	0.13	0.27	0.15	0.25	0.51	0.61	0.59	1.62	1.65	0.21	1.65	1.75	1.69
average velocity (ft/day)							**0.36**						**1.67**
distance from lagoon to well	120.00	120.00	120.00	120.00	120.00	120.00	120.00	141.00	141.00	141.00	141.00	141.00	141.00
days to reach well	915.67	443.52	799.05	484.19	234.33	196.04	202.40	87.28	85.65	658.89	85.48	80.41	83.66
average days to reach well							**467.89**						**84.50**
years to reach well	2.51	1.22	2.19	1.33	0.64	0.54	0.55	0.24	0.23	1.81	0.23	0.22	0.23
average Years to reach well				**1.81**			**0.58**			**X**			**0.23**

Notes:
1) Well Lis-3 is in surficial aquifer; well Lis-5 is in a confined aquifer.
2) Depth of surficial aquifer is 15-19'; thickness of confined aquifer is unknown.
3) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
4) ▽ =static water level
5) X=anomalous value - not used.

Figure 37

Lisbon Site Representative Slug Test Analyses



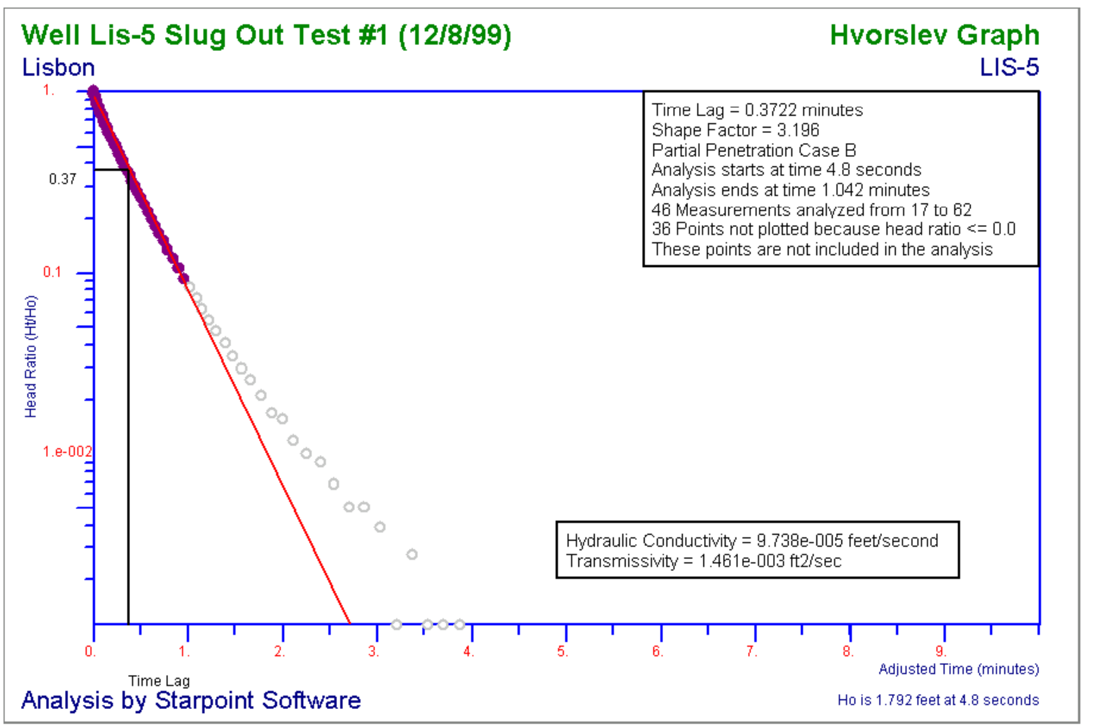
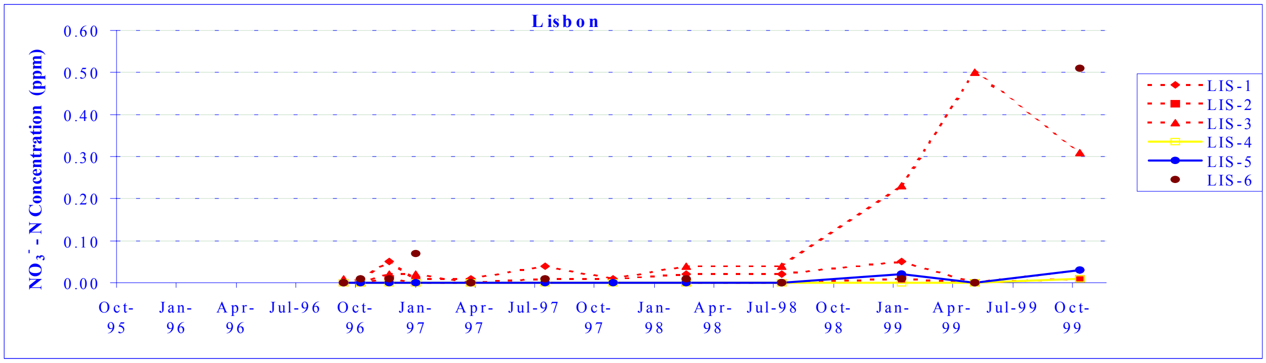
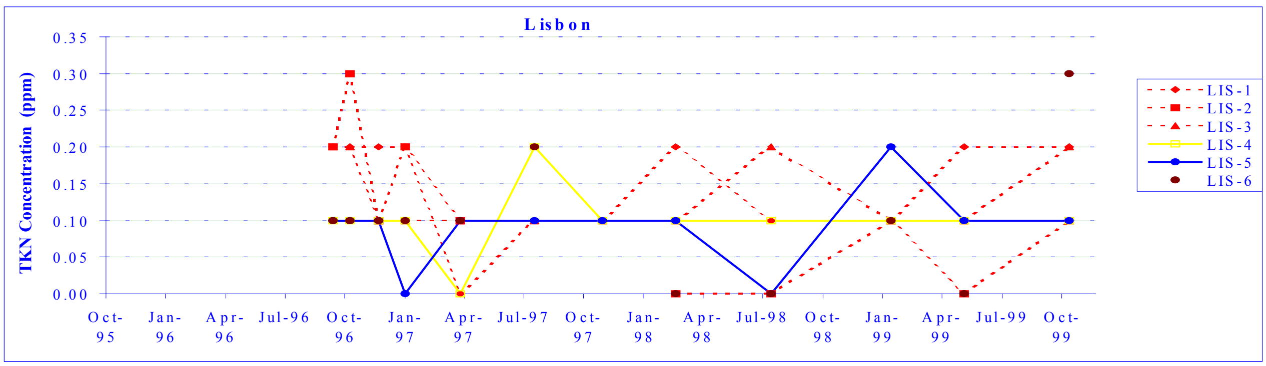
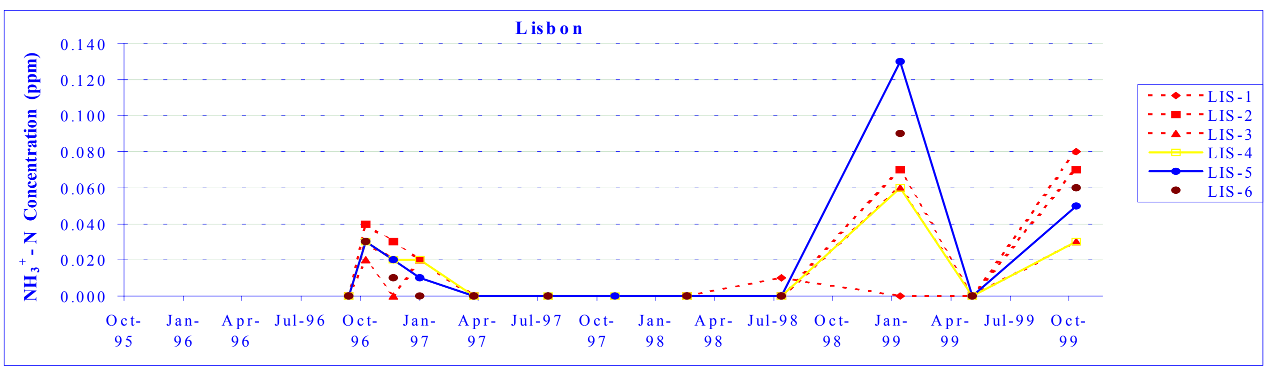


Figure 38

Lisbon Site NO_3, TKN, NH_3 and K Sample Results







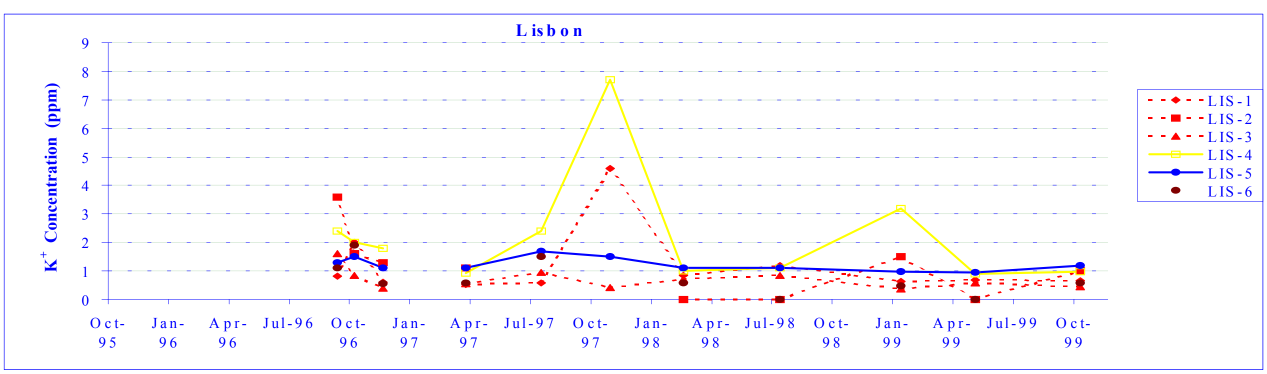
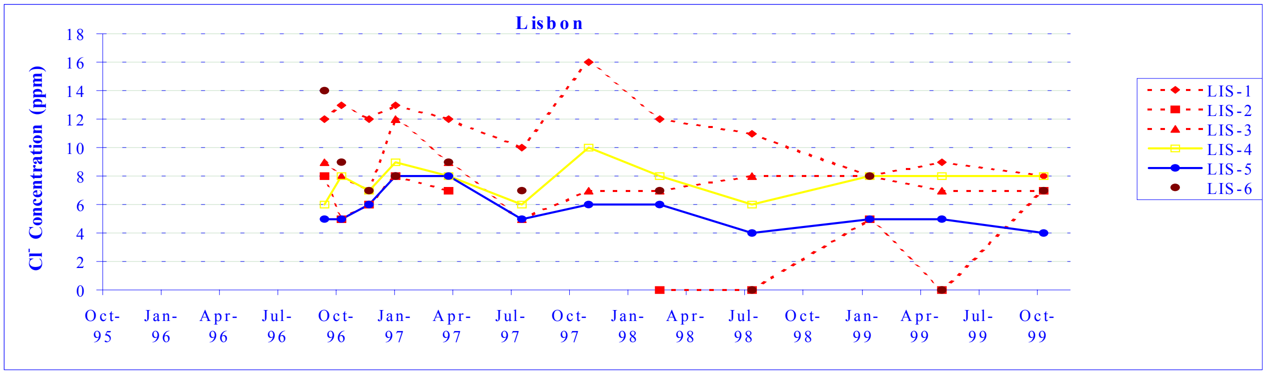


Figure 39 (1 of 2)

Lisbon Site Cl Sample Results and Ground Water Elevation



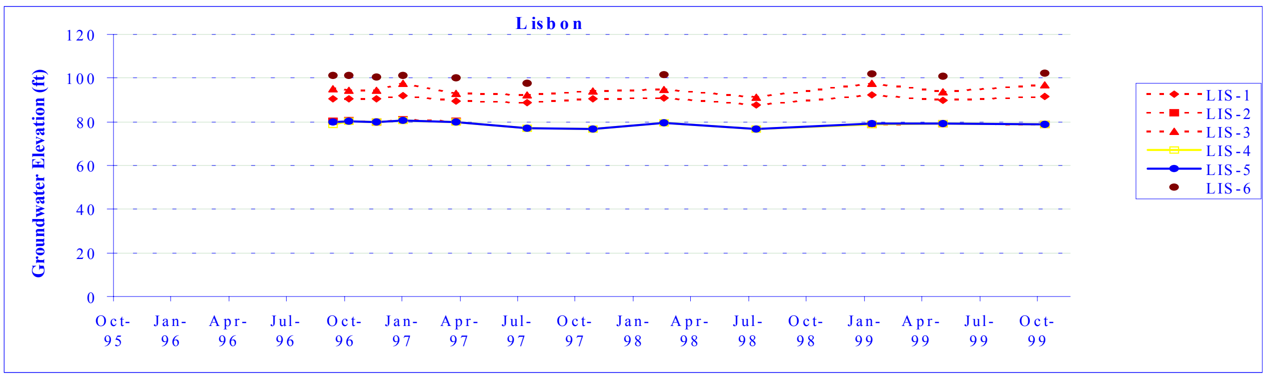


Figure 39 (2 of 2)

The McDaniels site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Cape Fear River Basin.

Ground Water Flow

Due to the placement of wells and screened intervals, ground water flow and velocity cannot be determined at this site. During the time period covered in the original report, it was thought that wells McD-3, McD-4, McD-7 and McD-8 were screened in the same aquifer. It is demonstrated, however, that wells McD-3 and McD-7 are most likely screened in a deeper confined aquifer (fig. 42). Based on topography, ground water should be flowing from well McD-4 toward well McD-8 and the intermittent stream, which is most likely situated above the confining layer (fig. 40).

Ground Water Sampling Results

Monitoring wells at this site were sampled five additional times since the publication of the original report (fig. 44). NO_3 concentrations were exceeding state ground water standards in well McD-4 at the time the original report was published. These concentrations have been cyclical since then. Concentrations of Cl have also exhibited this trend during the same time period in well McD-4.

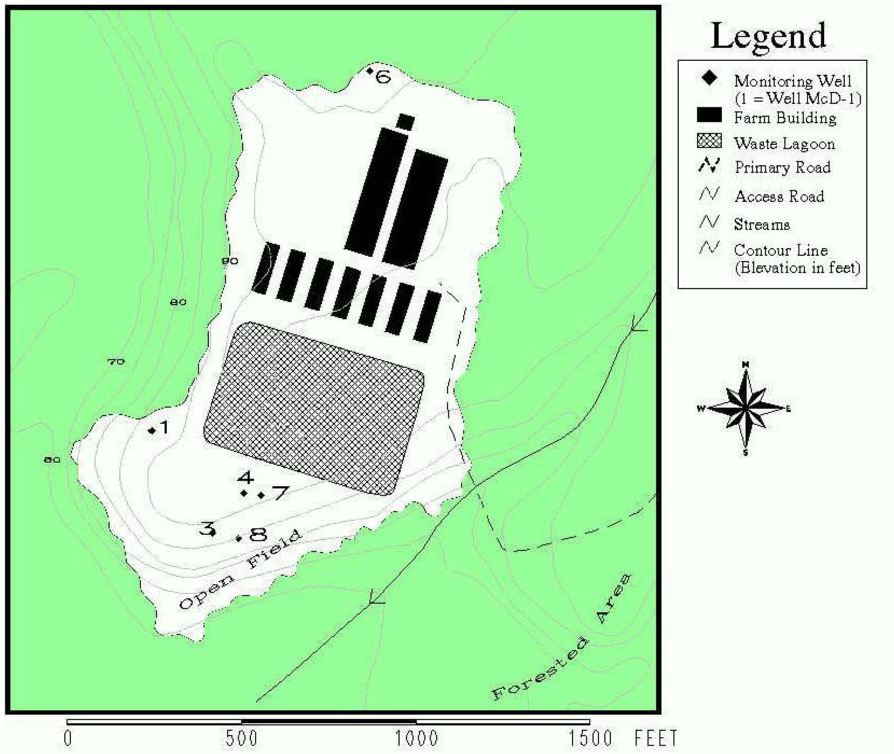
EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

Lagoon seepage indicators have been detected in well McD-4 on a somewhat continuous basis. The ground water flow direction from well McD-4 would need to be determined and monitoring wells placed downgradient in the shallow aquifer to determine if seepage indicators are decreasing. Additional monitoring wells would also need to be placed to the west-northwest and the southeast of the lagoon to monitor shallow ground water before any determination could be made about whether ground water is being protected from lagoon leakage (fig. 40).

McDaniels Site Maps



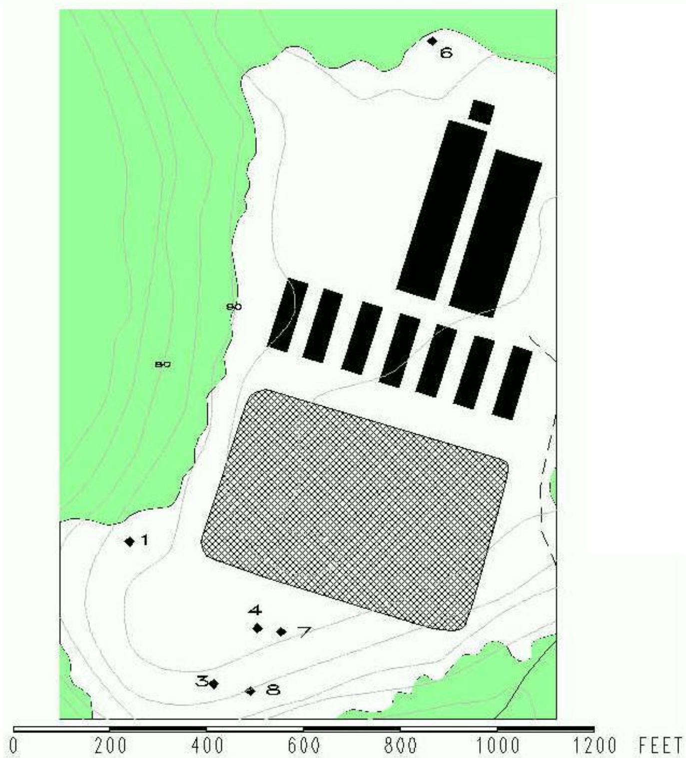
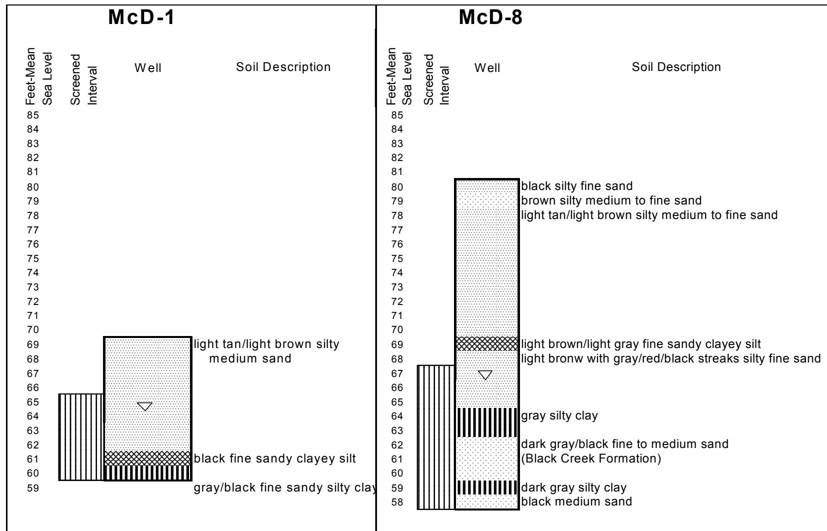
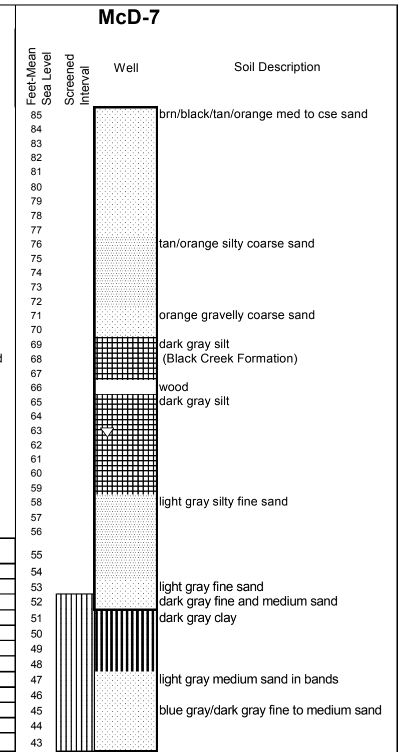


Figure 40

McDaniels Site Well Logs and Aquifer Characteristics





Slug Test ID	Out 2	Out 3	In 2	In 3	Out 1	Out 2	Out 3	In 1	In 2	In 3
aquifer thickness (ft)	25	25	25	25	25	25	25	25	25	25
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6
screen length (ft)	5	5	5	5	10	10	10	10	10	10
screen interval (ft)	4.5-9.5	4.5-9.5	4.5-9.5	4.5-9.5	13-23	13-23	13-23	13-23	13-23	13-23
water table to bottom of screen (ft)	**3.96**	**3.96**	**3.96**	**3.96**	**8.45**	**8.45**	**8.45**	**8.45**	**8.45**	**8.45**
static water level	5.54	5.54	5.54	5.54	14.55	14.55	14.55	14.55	14.55	14.55
porosity (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
gradient (ft/ft)	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
hydraulic conductivity (ft/sec)	3.13E-04	3.11E-04			4.70E-04	4.93E-04	4.73E-04			
average hydraulic conductivity (ft/sec)		**3.12E-04**					**4.79E-04**			
velocity (ft/sec)	7.21E-05	7.16E-05			1.08E-04	1.13E-04	1.09E-04			
velocity (ft/day)	6.23	6.19			9.35	9.80	9.39			
average velocity (ft/day)		**6.21**					**9.51**			
distance from lagoon to well	134.00	134.00			242.00	242.00	242.00			
days to reach well	21.52	21.66			25.89	24.70	25.77			
average days to reach well		**21.59**					**25.45**			
years to reach well	0.06	0.06	X	X	0.07	0.07	0.07	X	X	X
average Years to reach well		**0.06**					**0.07**			

Notes:
1) Range of depth to a narrow clay layer is 10-35'
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) cannot use slug-in because static water level is in the screen
4) ▽ =static water level

Figure 41

McDaniels Site Well Logs for Wells McD-3, McD-4, and McD-8

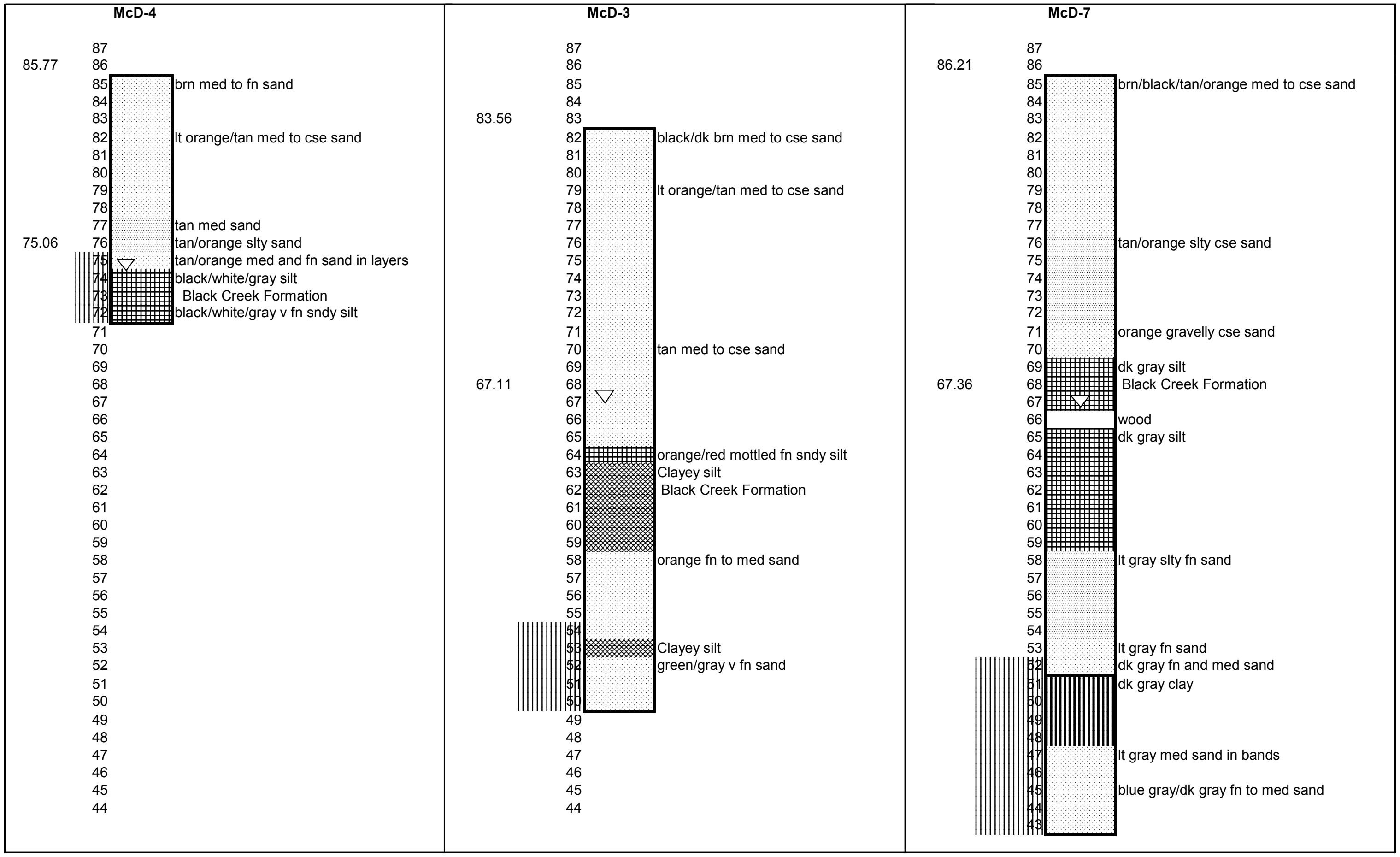
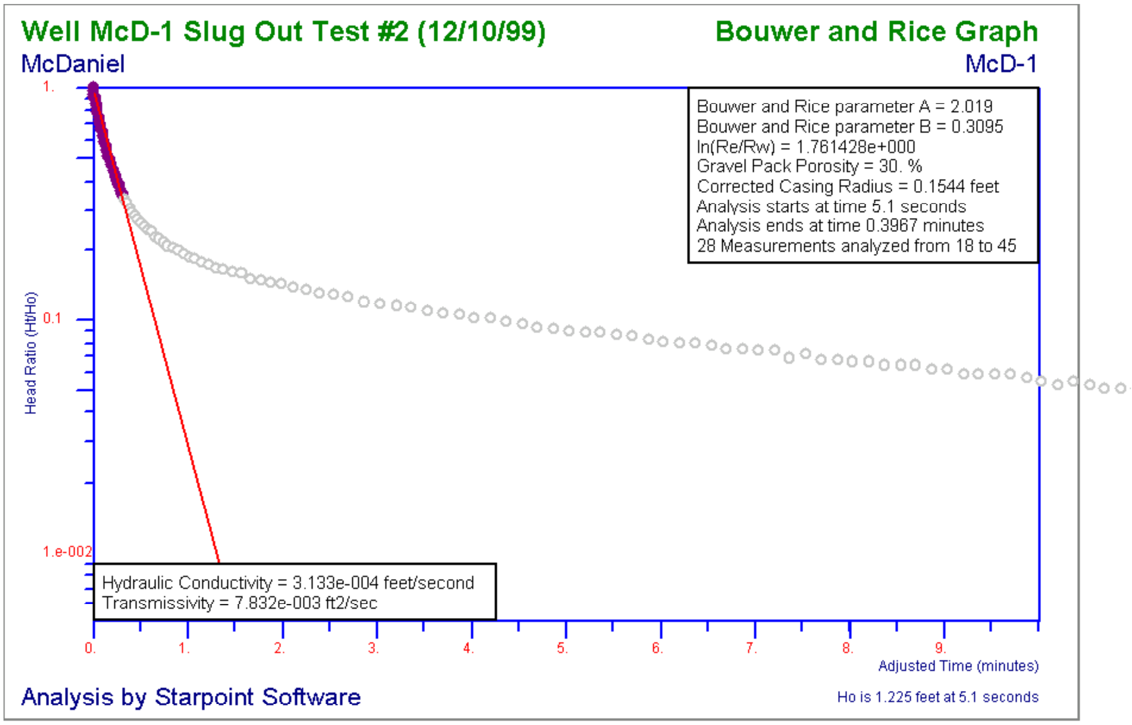


Figure 42

McDaniels Site Representative Slug Test Analyses



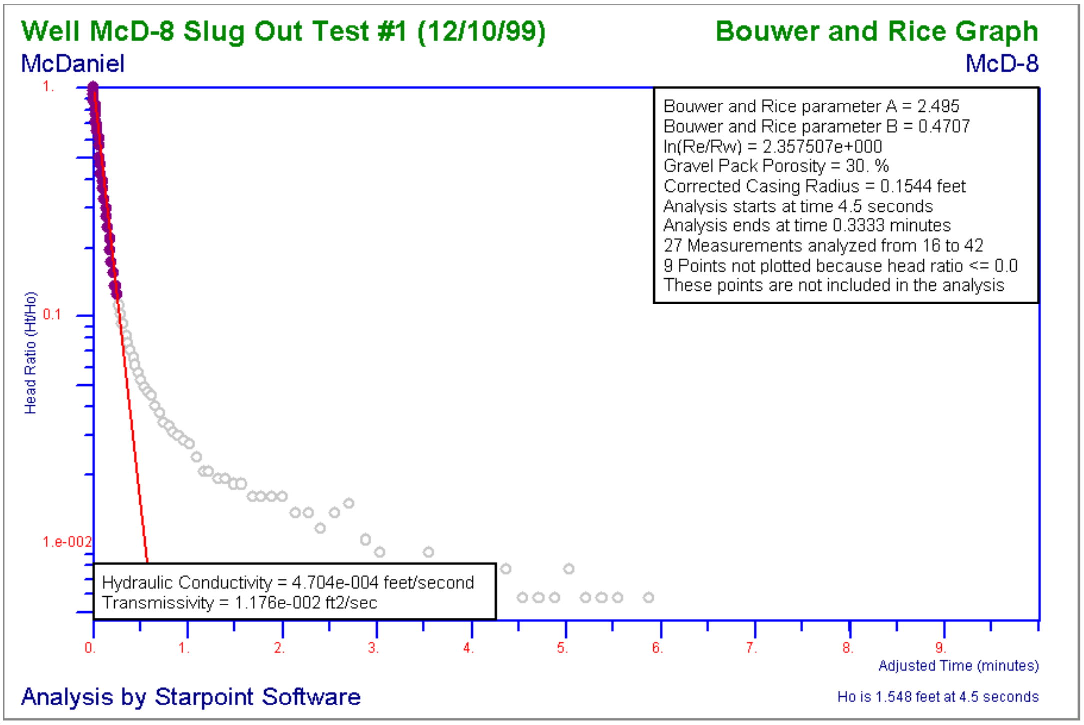


Figure 43

McDaniels Site NO_3, TKN, NH_3 and K Sample Results

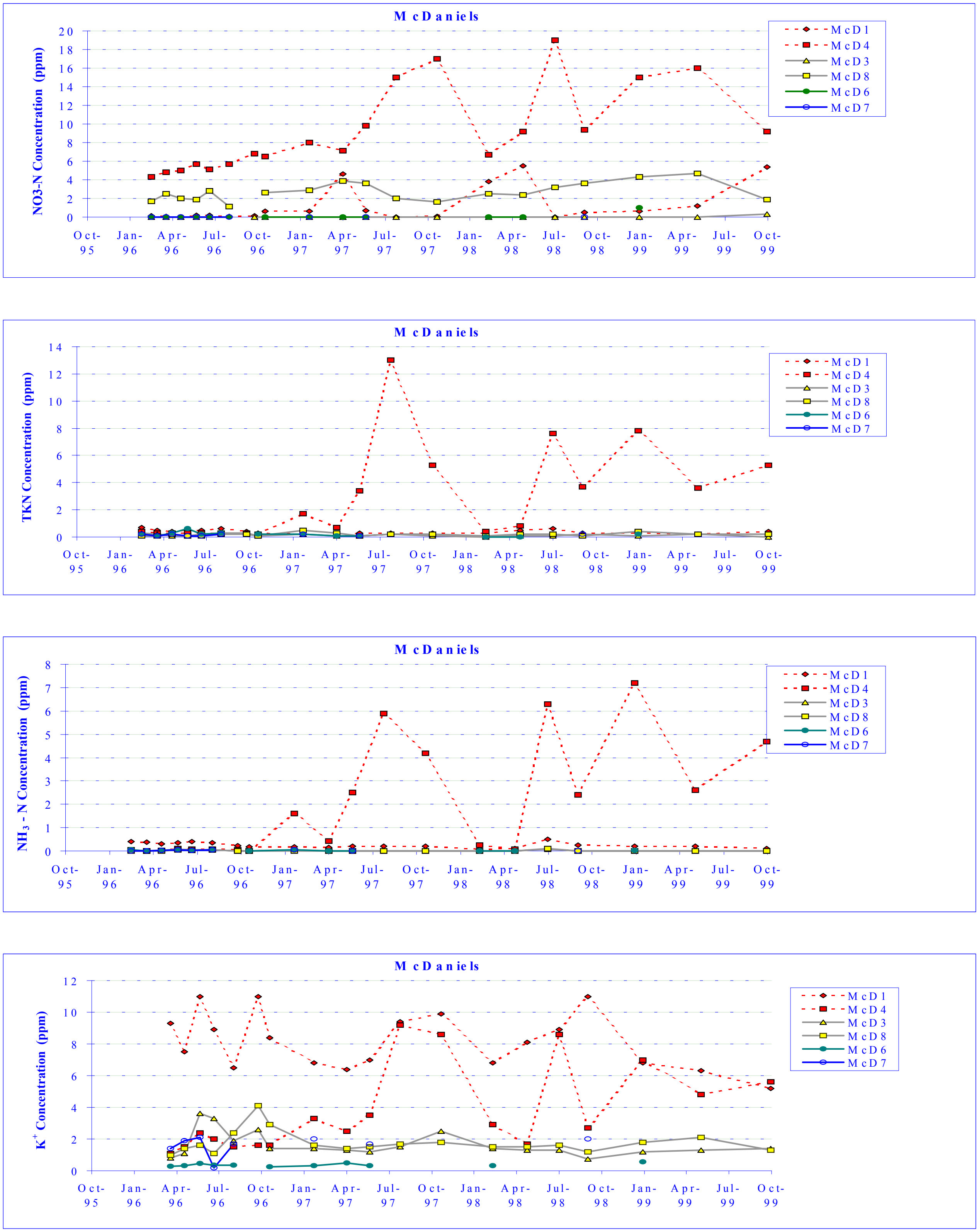
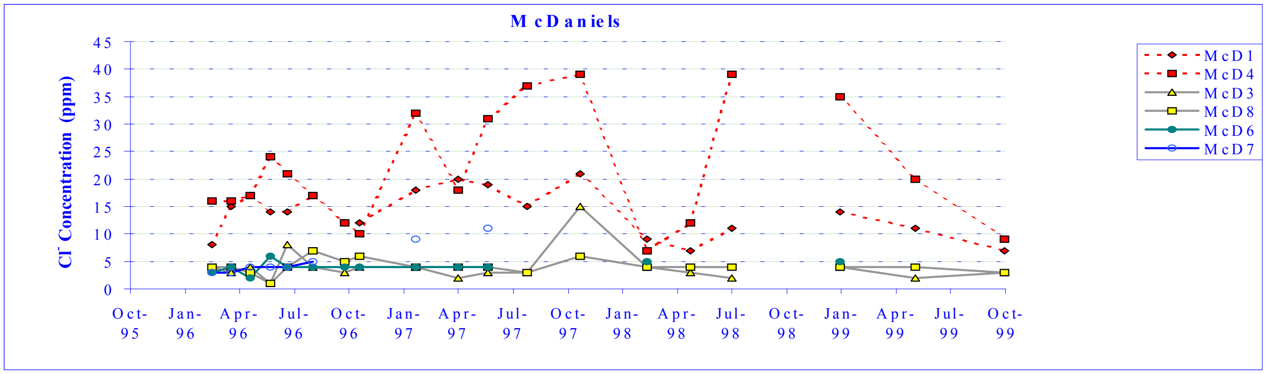


Figure 44 (1 of 2)

McDaniels Site Cl Sample Results and Ground Water Elevation



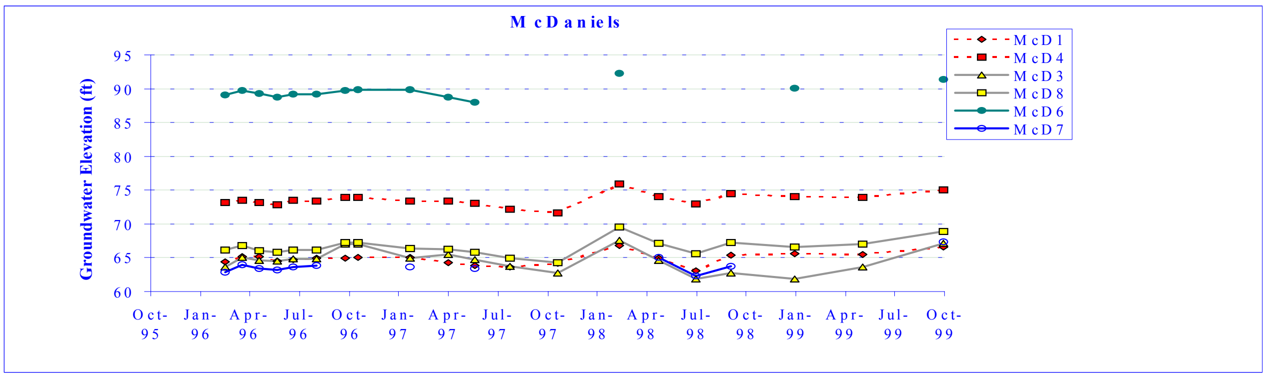


Figure 44 (2 of 2)

The Nahunta site is a swine operation located in an upland setting in the lower Coastal Plain. Ground and surface water from this site discharge into the Neuse River Basin.

Ground Water Flow

Ground water is flowing north-northeast at 6.50-6.70 feet per day, so time of travel to wells Nah-1 and Nah-8 would be .05 years (figs. 46-48). Sufficient time has elapsed to detect seepage indicators from the lagoon in these wells.

Ground Water Sampling Results

Monitoring wells at this site were sampled five additional times since the publication of the original report (fig. 49). Well Nah-8 was installed in October 1996 to replace Nah-3, which was damaged by farm machinery.

The concentrations of Cl and K began rising in wells Nah-1 and Nah-8 in October 1996. Cl and K are typically the first constituents to reach a well being impacted by lagoon seepage. During the February 1997 sampling, an accidental surface discharge of lagoon liquid was discovered, as it had become severe enough to be flooding the area surrounding these two wells. The leak was quickly repaired, but the lagoon liquid infiltrated the ground water and impacted the wells in a similar fashion to a seepage plume. As is typical with lagoon liquid impacting ground water, NO_3-N rose then fell as the anaerobic front of the plume reached the wells. During that time, NH_3 and TKN – the reduced forms of nitrogen – continued to rise. After the plume passed, levels of NH_3 and TKN began to fall along with levels of Cl and K. As oxidizing conditions were restored, nitrate (the oxidized form of nitrogen) concentrations again rose. The event seemed to have passed by summer 1999, but none of the levels had returned to background levels. This event, although typical in its effects on impacted wells was rather small in size and duration and did not produce constituent levels above state ground water standards in the impacted wells.

After the April 1999 sampling, constituent concentrations in wells Nah-1 and Nah-8 again began to show the typical patterns associated with lagoon seepage. As of October 1999, concentrations of K, NH_3 and TKN were higher than during the first plume and levels of NO_3 had again dropped to near zero.

Wells Nah-4 and Nah-5 have not exhibited any evidence of impacts from the lagoon spill. These wells are downgradient from wells Nah-1 and Nah-3 and are screened in the same aquifer (figs. 46, 47). This indicates that either the ground water is completely remediated or, more likely, that shallow ground water is discharged to the shallow ditch and narrow strip of wooded wetland between the two sets of wells. According to ditch and ground water elevation measurements, this ditch intercepts the water table. Grab samples collected from the ditch are inconclusive because it is unknown whether seepage indicators detected in the ditch come from runoff or ground water

EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

Several of the lagoon seepage indicators continue to be elevated in the wells nearest the lagoon, while concentrations in downgradient wells remain near or below background concentrations. Ground water at this site is being adequately protected from lagoon seepage; however, contaminants may be discharging into the ditch. Additional monitoring would determine if seepage indicator concentrations in the wells continued to increase, thus indicating a leaking lagoon.

Nahunta Site Map

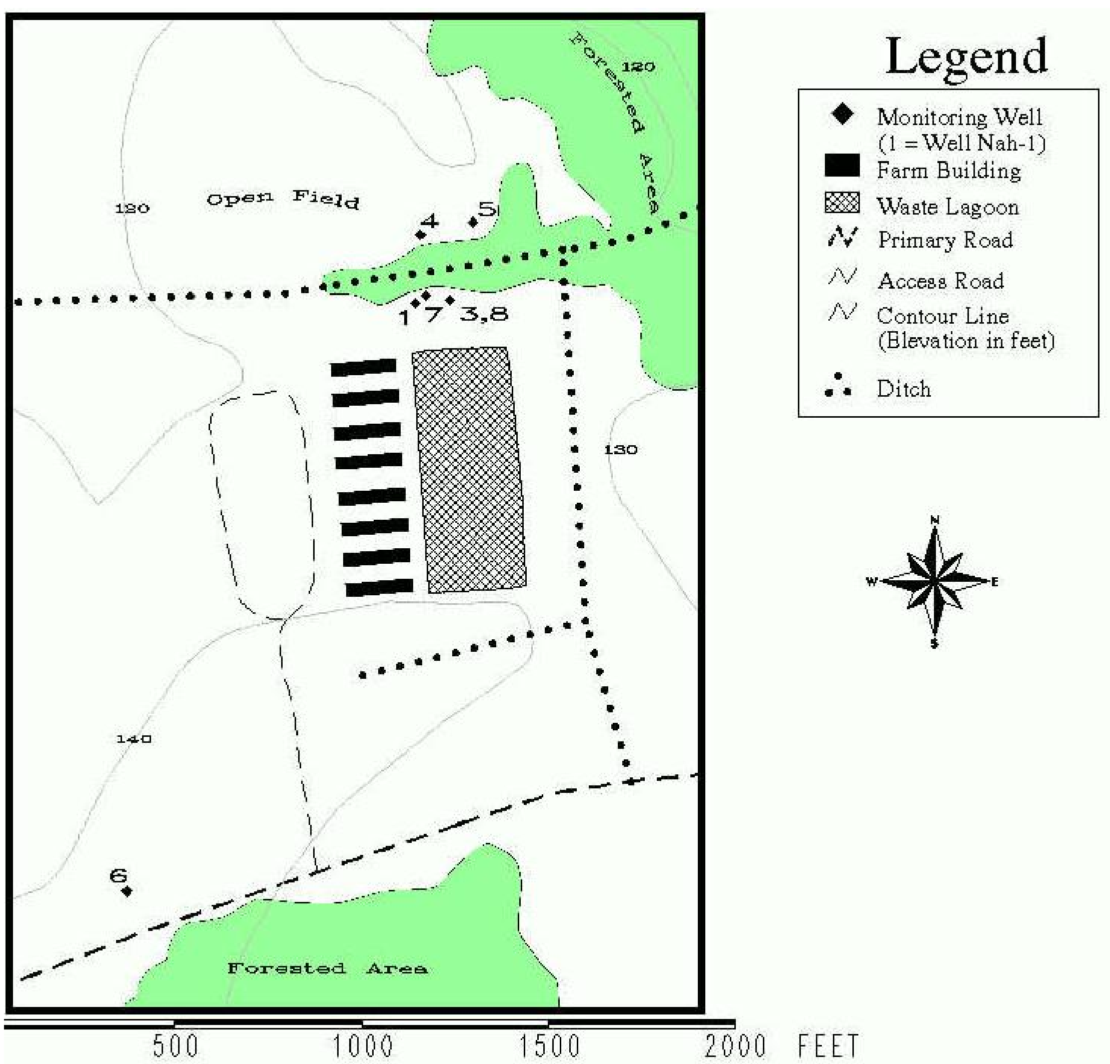
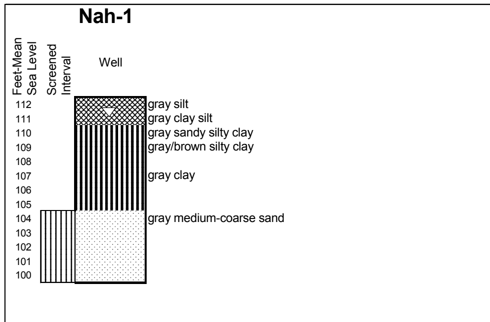


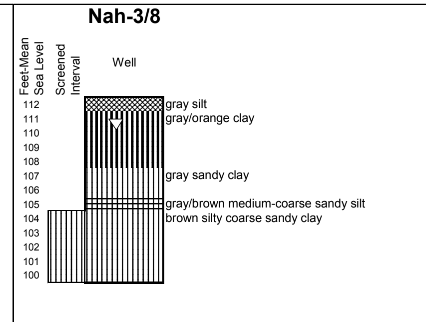
Figure 45

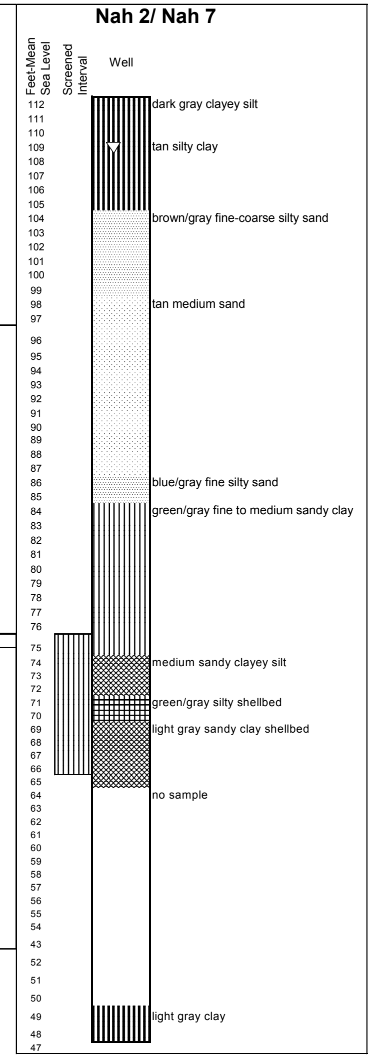
Nahunta Site Ground Water Flow Map
(6/27/96)

Figure 46

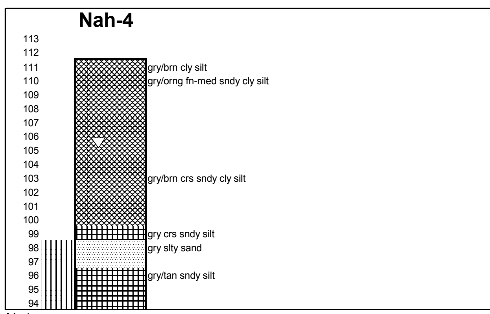
Nahunta Site Well Logs and Aquifer Characteristics

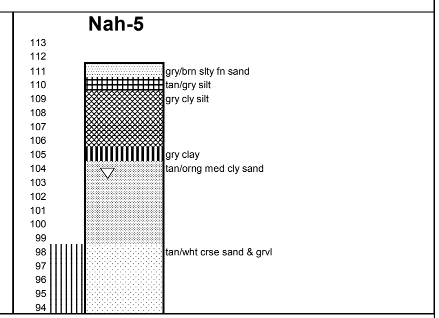






Slug Test ID	Out 1	Out 2	Out 3	Out 4	Out 5	In 1	In 2	Out 1	In 1
aquifer thickness (ft)	63	63	63	63	63	63	63	63	63
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6
screen length (ft)	5	5	5	5	5	5	5	5	5
screen interval (ft)	9.8-14.8	9.8-14.8	9.8-14.8	9.8-14.8	9.8-14.8	9.8-14.8	9.8-14.8	8.0-13.0	8.0-13.0
water table to bottom of screen (ft)	12.80	12.80	12.80	12.80	12.80	12.80	12.80	10.42	10.42
static water level	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.58	2.58
porosity (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
gradient (ft/ft)	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
hydraulic conductivity (ft/sec)	5.56E-04	5.58E-04	5.10E-04	5.38E-04	5.24E-04	5.45E-04	5.13E-04	6.00E-04	4.38E-04
average hydraulic conductivity (ft/sec)							**5.35E-04**		**5.19E-04**
velocity (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
velocity (ft/day)	6.97	6.99	6.39	6.74	6.56	6.82	6.43	7.51	5.49
average velocity (ft/day)							**6.70**		**6.50**
distance from lagoon to well	131.00	131.00	131.00	131.00	131.00	131.00	131.00	127.00	127.00
days to reach well	18.80	18.75	20.50	19.43	19.96	19.20	20.37	16.91	23.15
average days to reach well							**19.57**		**20.03**
years to reach well	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.06
average Years to reach well							**0.05**		**0.05**



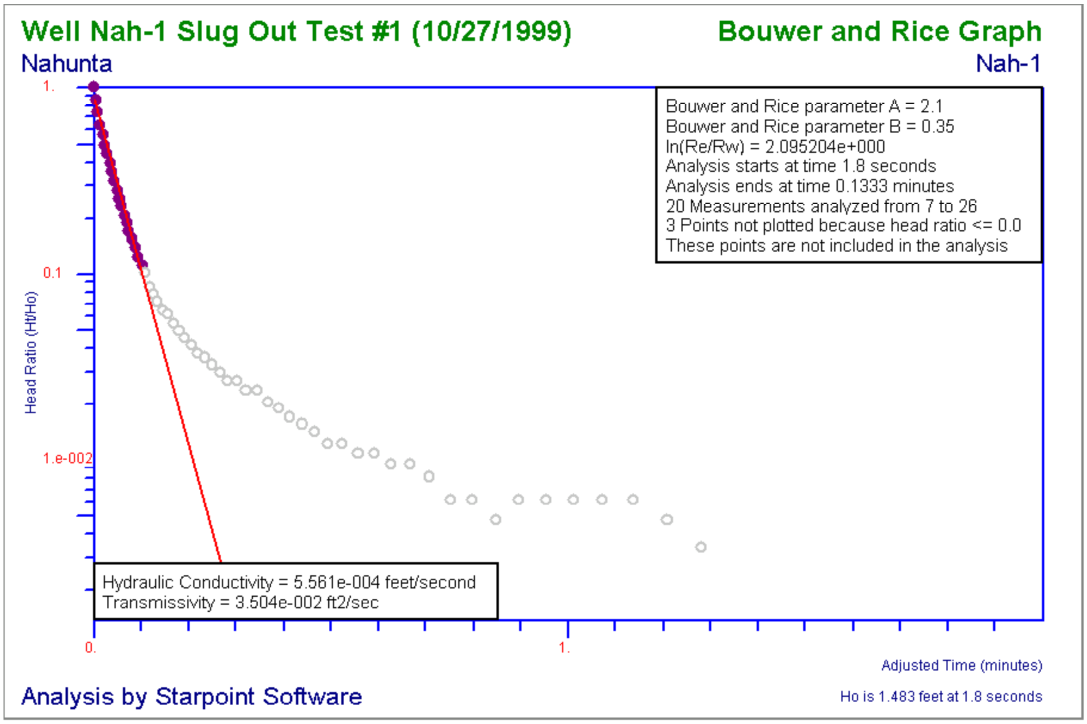


Notes:

1) surface release was discovered 2/97 during field visit. Seems to have impacted wells 1 and 8. Well construction should have been according to 2C.
2) migration of surface spill into surficial aquifer was rapid.
3) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
5) ▽=static water level

Figure 47

Nahunta Site Representative Slug Test Analyses



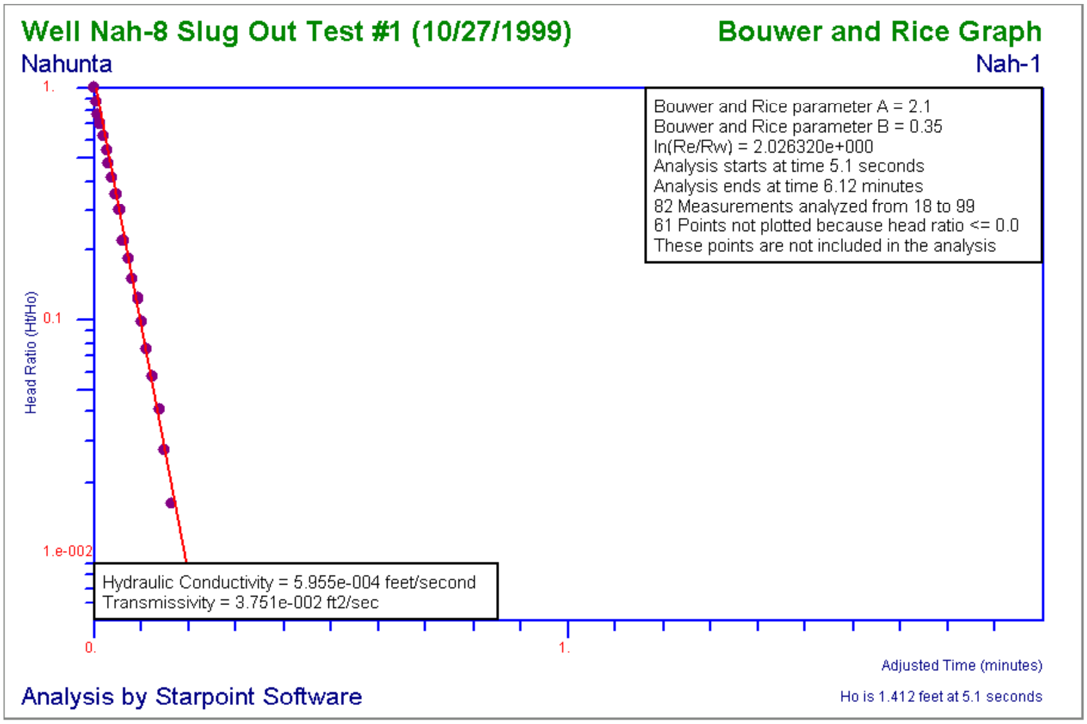


Figure 48

Nahunta Site NO_3, TKN, NH_3 and K Sample Results

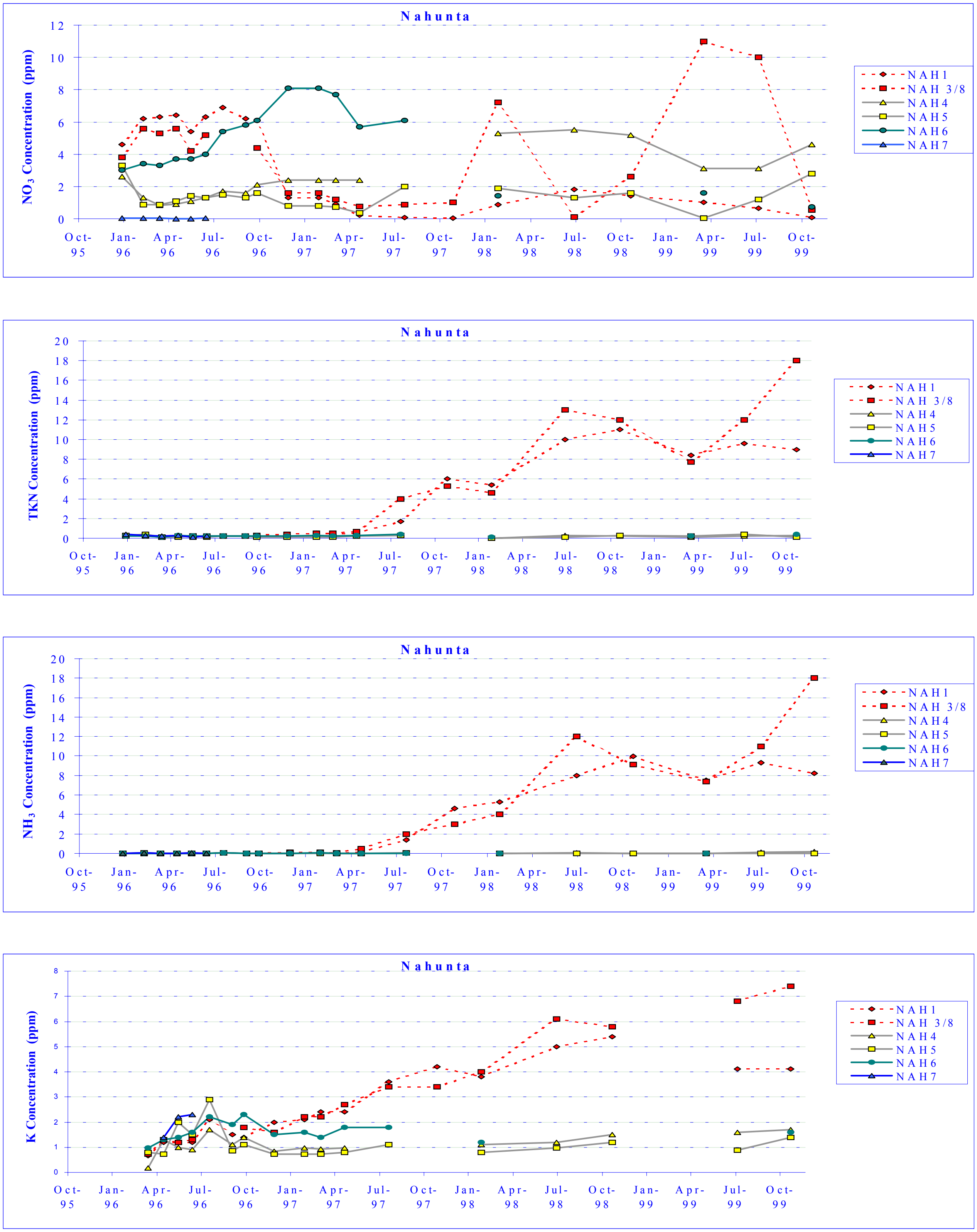
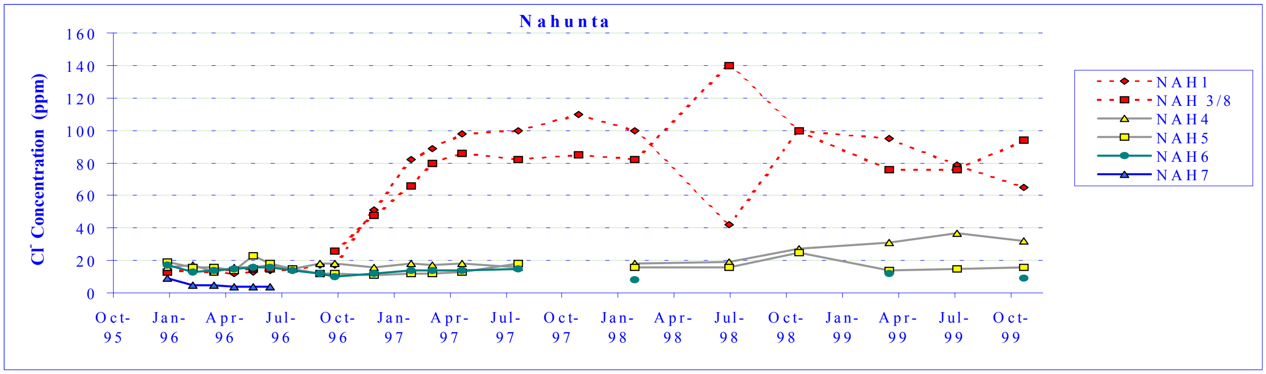


Figure 49 (1 of 2)

Nahunta Site Cl Sample Results and Ground Water Elevation



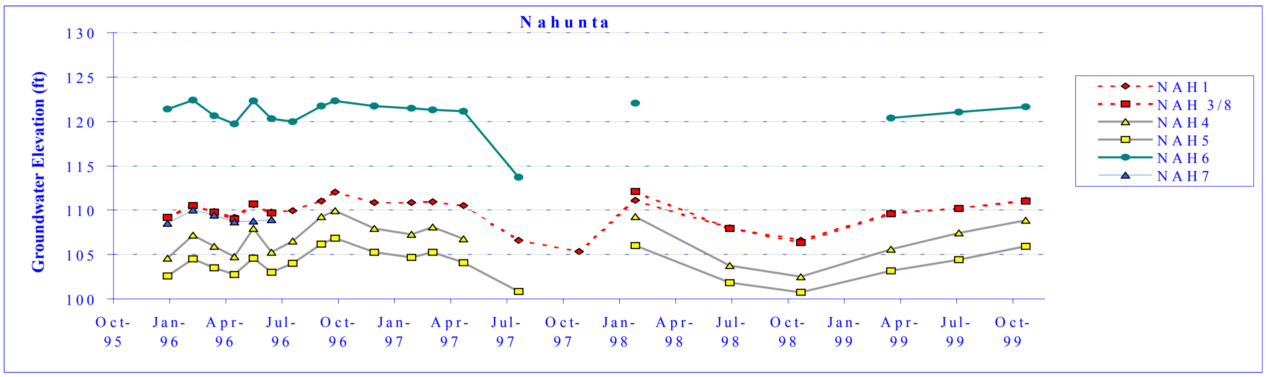


Figure 49 (2 of 2)

The PRS site is a dairy operation located in an upland setting in the Piedmont physiographic province. Ground and surface water from this site discharge into the Yadkin River Basin.

Ground Water Flow

Ground water is flowing southeast at .01-.21 feet per day, so time of travel for seepage indicators from the lagoon would be 16.45 years for well PRS-3 (note high content of clayey silt in the screened portion of the well) and 2.18 years for well PRS-2 (figs 51-53). Based on these slug tests, sufficient time has elapsed to detect seepage indicators from the lagoon in well PRS-2. NO_3 has been detected at a constant rate, but no other seepage indicators have been detected.

Ground Water Sampling Results

Monitoring wells at this site were sampled three additional times since publication of the original report, and there have been no significant changes in analyte concentrations with the exception of Cl in well PRS-4 (fig. 54). Cl concentrations increased to 120 parts per million in July 1998 and then started a slow decrease. The state ground water standard for Cl is 250 ppm. Well PRS-3 showed no increase in Cl concentrations during this time, so it is unlikely that the lagoon is the source of Cl in well PRS-4 as both are drawing water from the same sand unit as shown in the boring logs (fig. 52). Due to the characteristics of the regolith in the Piedmont, however, it is possible that Cl could travel from the lagoon to well PRS-4 without impacting well PRS-3. In the original report, the continued elevated concentrations of NO_3 in well PRS-2 and PRS-5 were attributed to grazing of cattle in the fields where the wells were installed; the lagoon was not suspected because no other seepage indicators were detected in the wells.

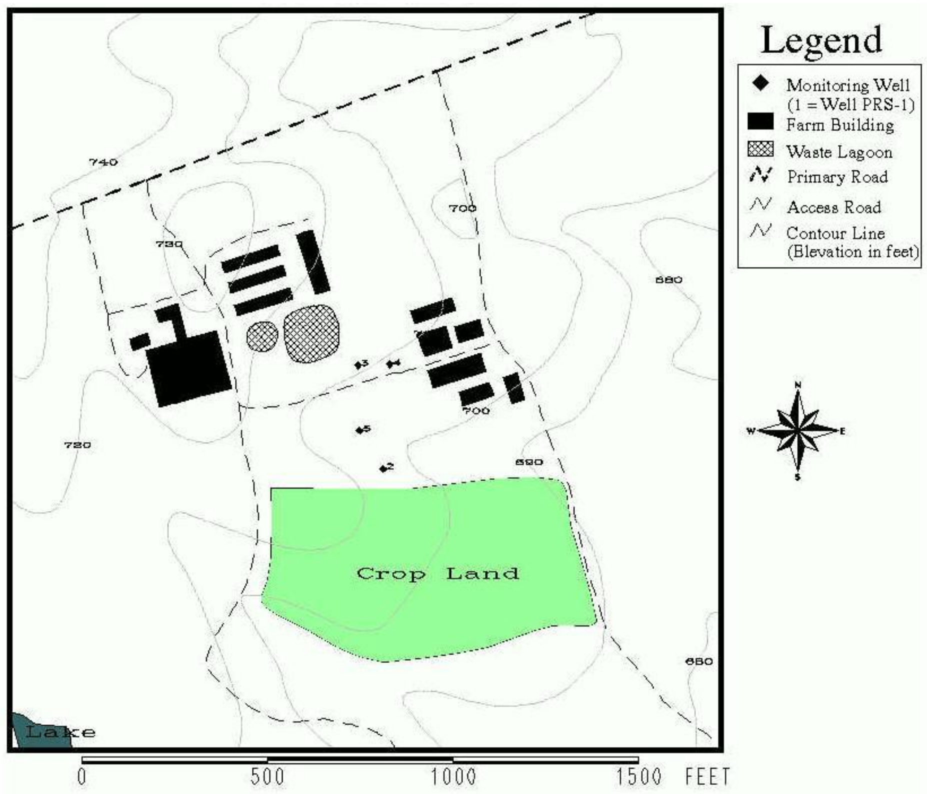
EM Surveys

Results of an earlier survey did not show any significant changes in conductivity.

Conclusion

Although it is possible that ground water could be flowing in preferential pathways and by-passing well PRS-3, there is no evidence that this is occurring. Therefore, based on the analyses results and the site characteristics, ground water at this site is being adequately protected from lagoon seepage.

PRS Site Maps



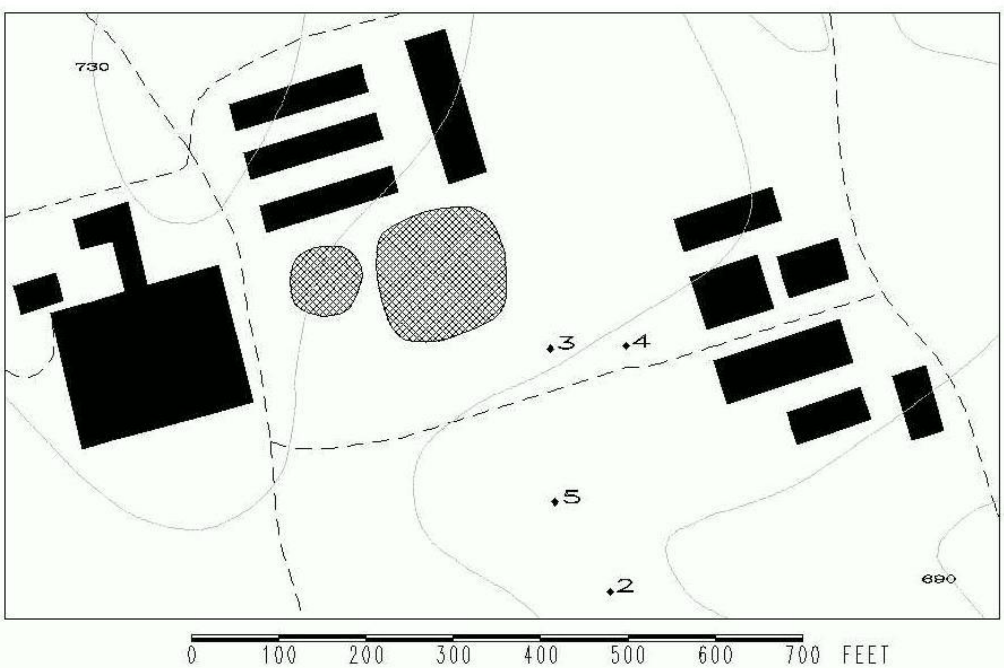


Figure 50

PRS Site Ground Water Flow Map
(7/29/98)

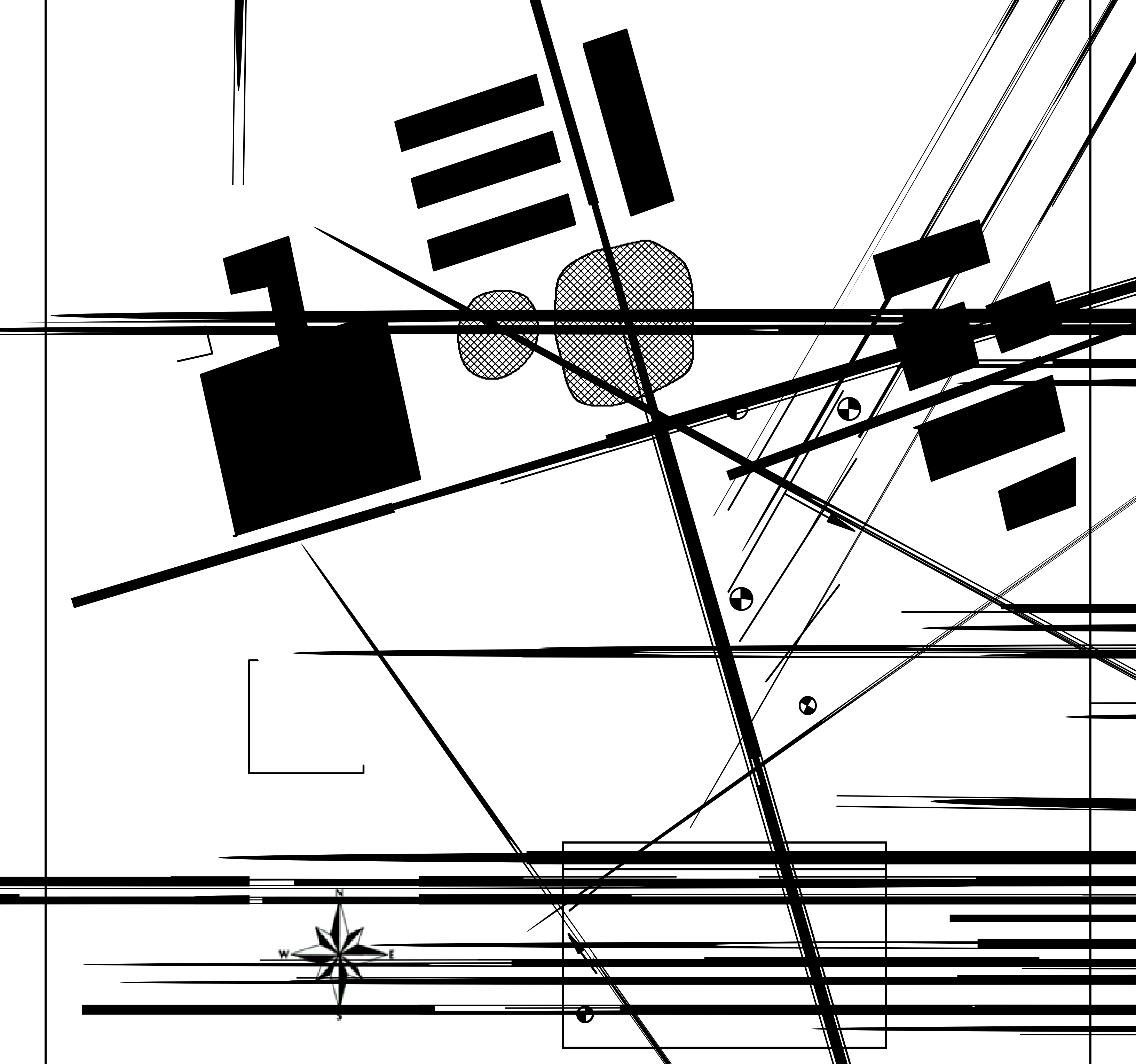
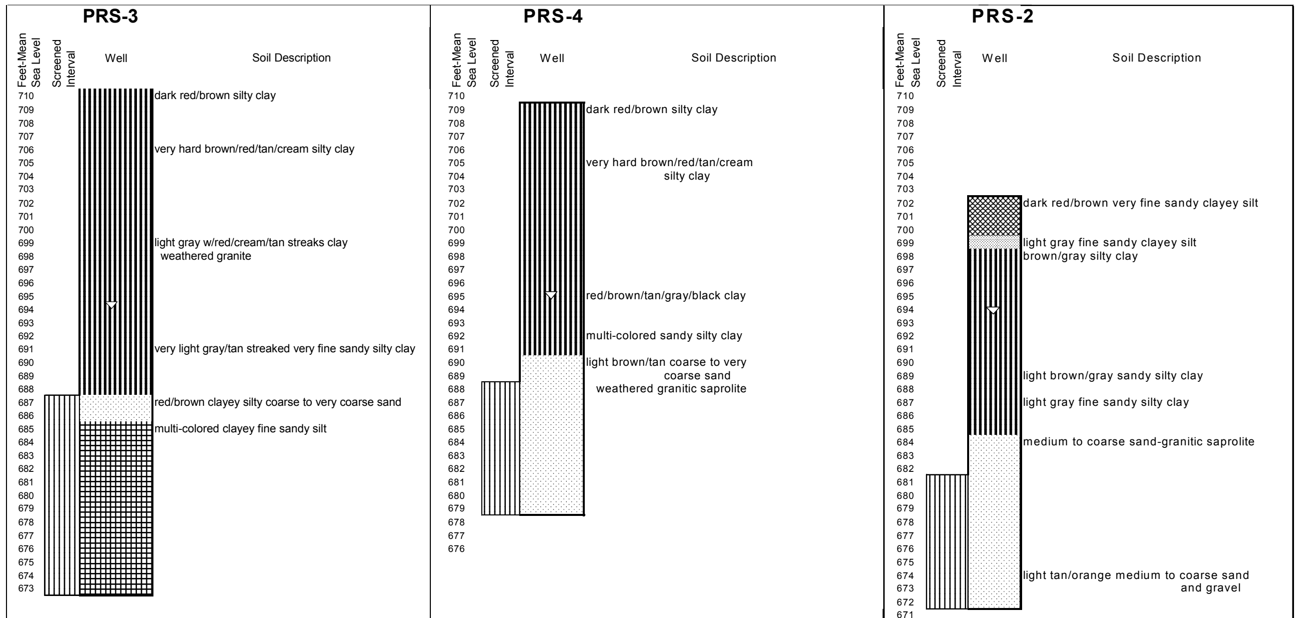


Figure 51

PRS Site Well Logs and Aquifer Characteristics

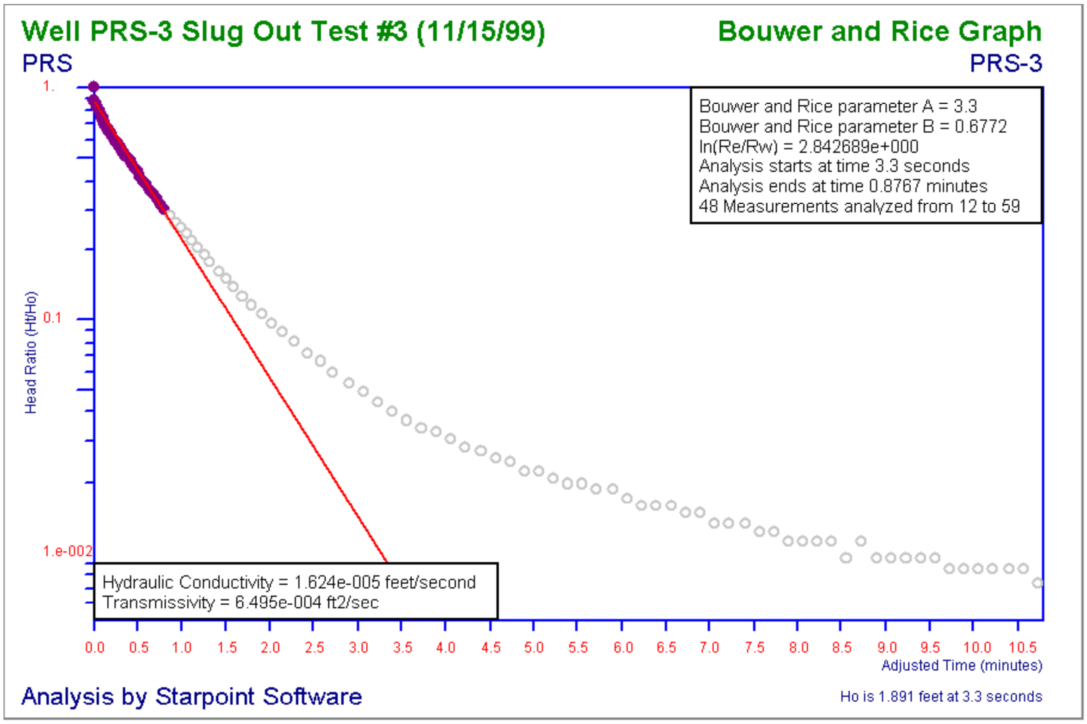


Slug Test ID	Out 1	Out 2	Out 3	In 1	In 2	In 3	Out 1	Out 2	Out 3	In 1	In 2	In 3
aquifer thickness (ft)	40	40	40	40	40	40	40	40	40	40	40	40
aquifer type	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf	unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	6	6	6	6	6
screen length (ft)	15	15	15	15	15	15	10	10	10	10	10	10
screen interval (ft)	22-37	22-37	22-37	22-37	22-37	22-37	20-30	20-30	20-30	20-30	20-30	20-30
water table to bottom of screen (ft)	21.11	21.11	21.11	21.11	21.11	21.11	15.15	15.15	15.15	15.15	15.15	15.15
static water level	15.89	15.89	15.89	15.89	15.89	15.89	14.85	14.85	14.85	14.85	14.85	14.85
porosity (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
hydraulic conductivity (ft/sec)	1.45E-05	1.63E-05	1.62E-05	1.61E-05	1.69E-05	1.55E-05	2.76E-04	2.70E-04	2.88E-04	2.14E-04	2.53E-04	2.41E-04
average hydraulic conductivity (ft/sec)						**1.59E-05**						**2.57E-04**
velocity (ft/sec)	1.39E-07	1.56E-07	1.56E-07	1.54E-07	1.62E-07	1.49E-07	2.65E-06	2.59E-06	2.76E-06	2.05E-06	2.43E-06	2.31E-06
velocity (ft/day)	0.01	0.01	0.01	0.01	0.01	0.01	0.23	0.22	0.24	0.18	0.21	0.20
average velocity (ft/day)						**0.01**						**0.21**
distance from lagoon to well	79.00	79.00	79.00	79.00	79.00	79.00	168.00	168.00	168.00	168.00	168.00	168.00
days to reach well	6586.79	5854.02	5864.84	5923.20	5652.52	6140.88	733.33	750.73	704.51	948.25	799.63	840.79
average days to reach well						**6003.71**						**796.21**
years to reach well	18.05	16.04	16.07	16.23	15.49	16.82	2.01	2.06	1.93	2.60	2.19	2.30
average Years to reach well						**16.45**						**2.18**

Notes:
1) Aquifer thickness is not known. The soil/saprolite portion is a minimum of 40' thick based on the boring logs.
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) ▽ =static water level

Figure 52

PRS Site Representative Slug Test Analyses



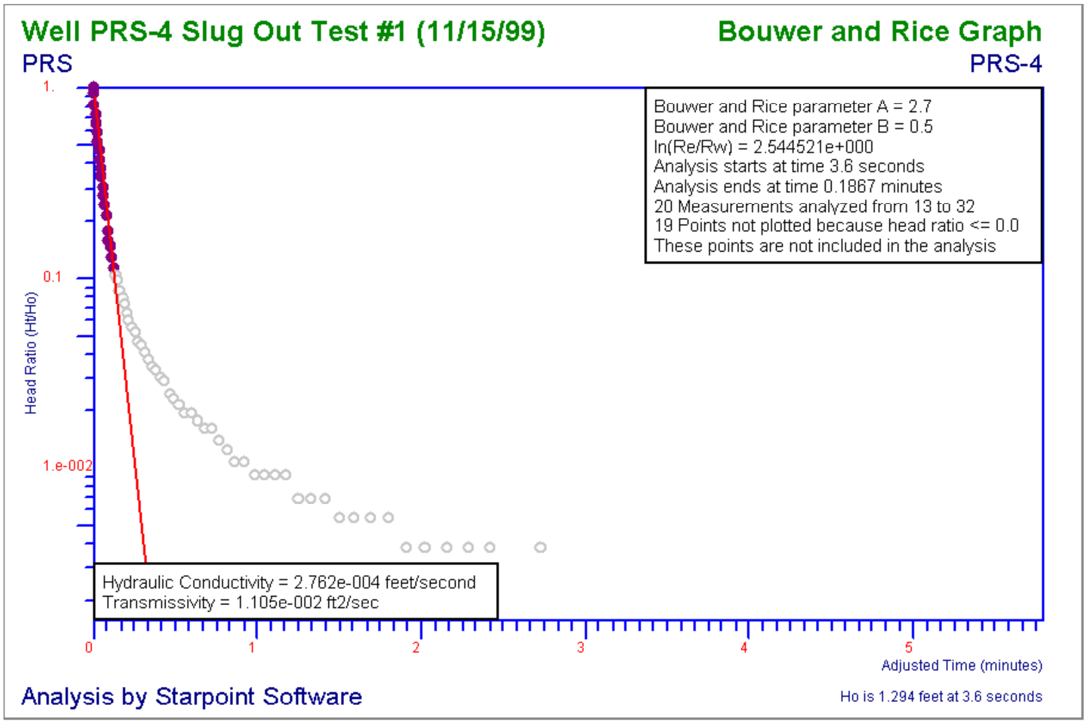
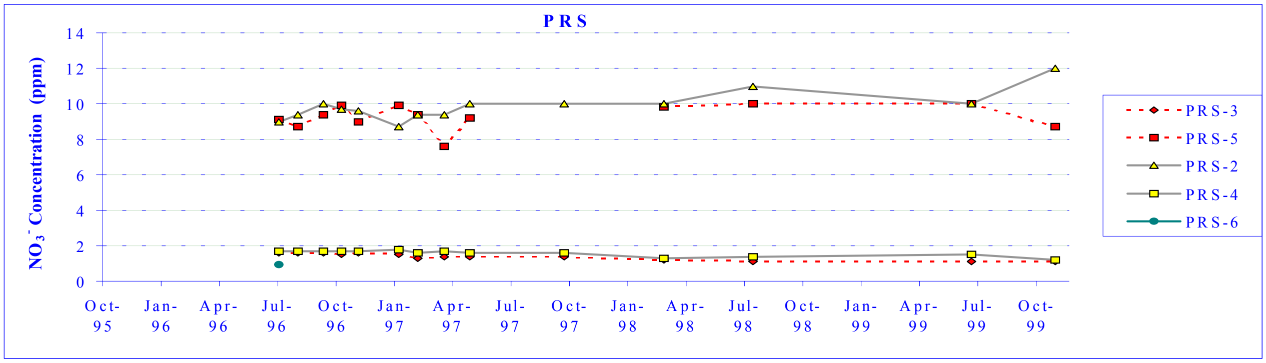
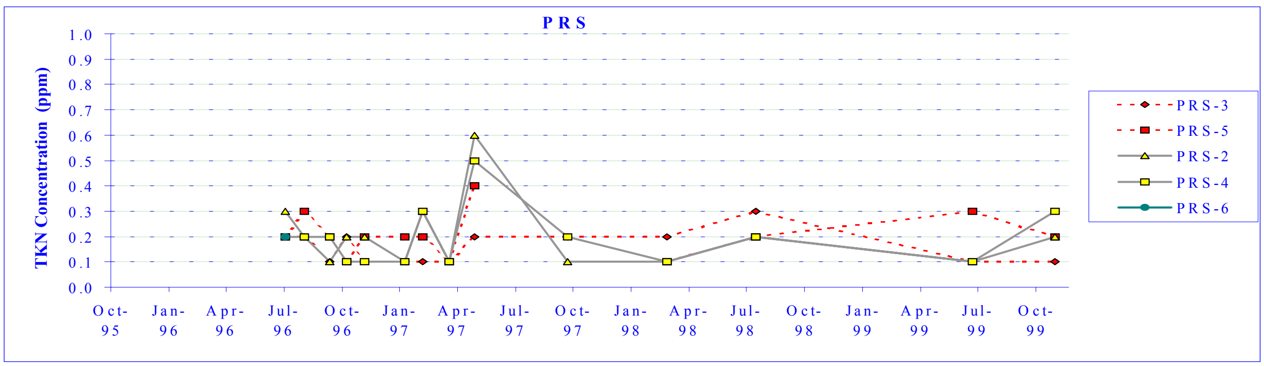
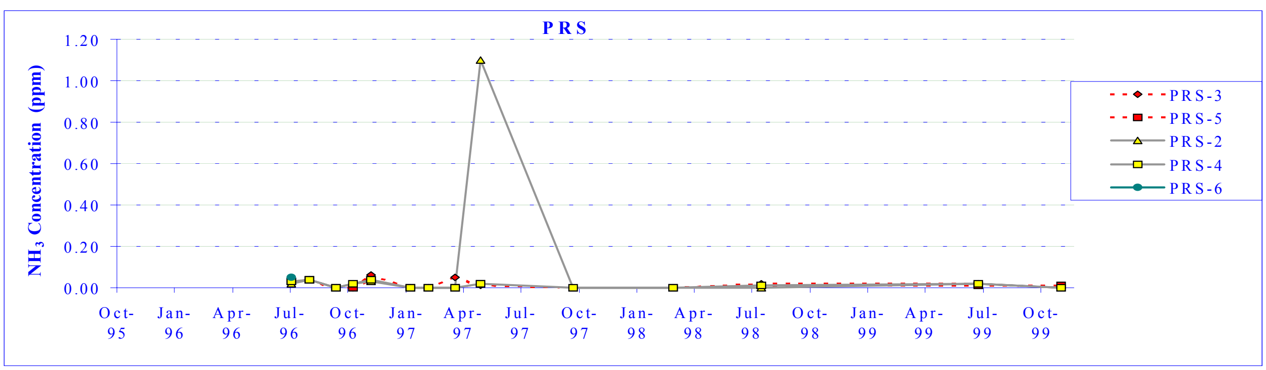


Figure 53

PRS Site NO_3, TKN, NH_3 and K Sample Results







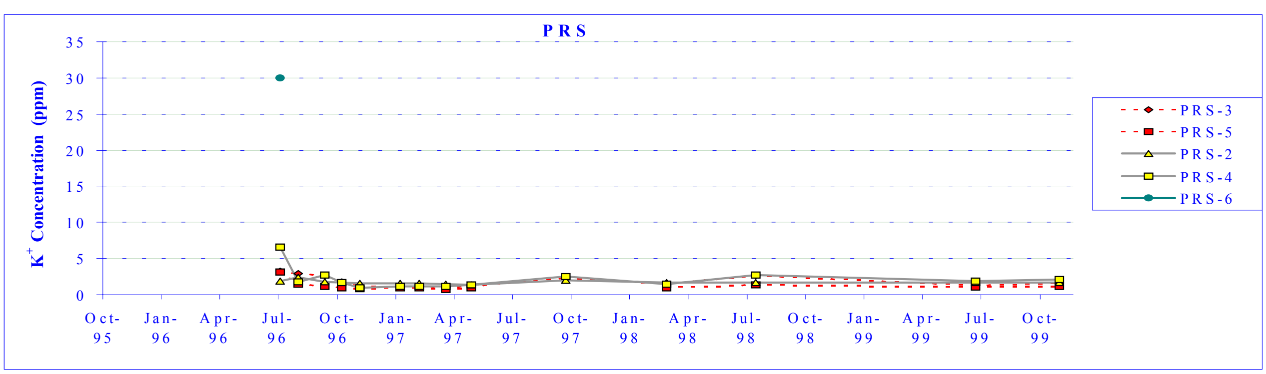
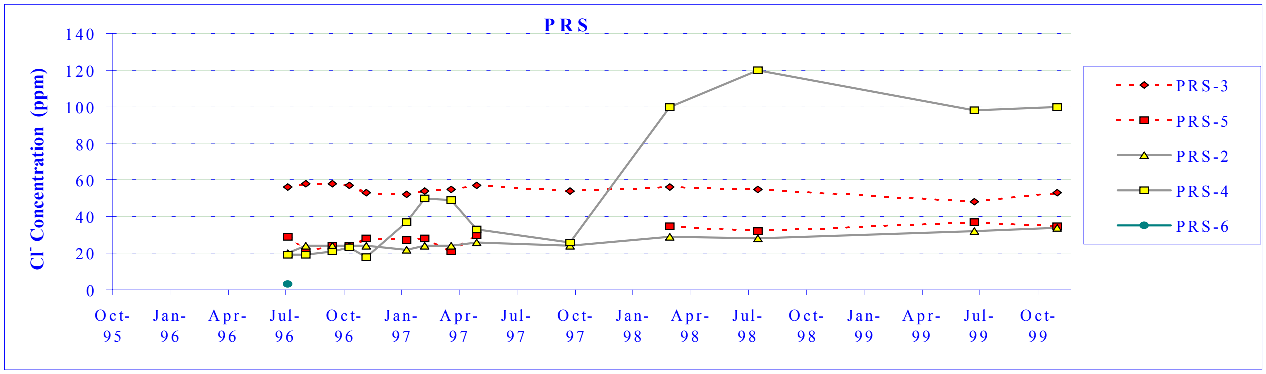


Fig 54 (1 of 2)

PRS Site Cl Sample Results and Ground Water Elevation



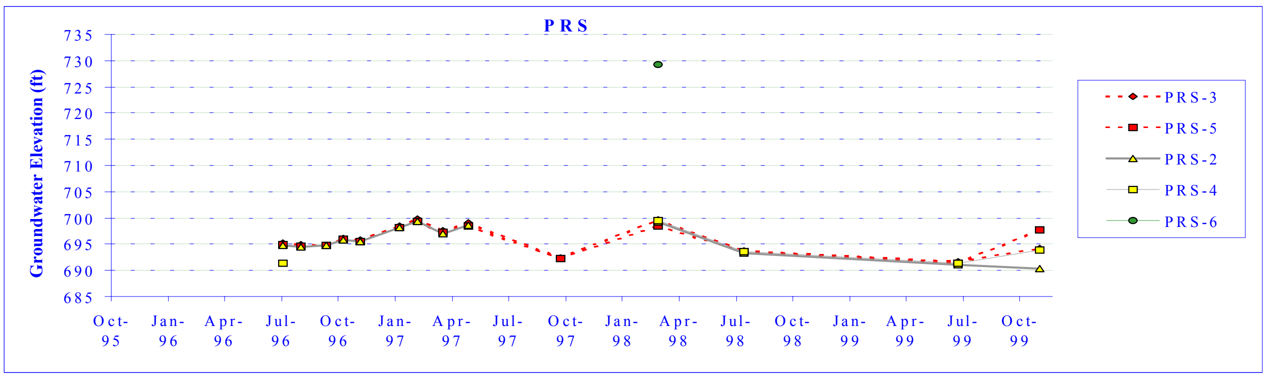


Fig 54 (2 of 2)

The Robeson site is a swine operation located in an upland setting in the Sandhills area of the lower Coastal Plain. Ground and surface water from this site discharge into the Lumber River Basin.

Ground Water Flow

Ground water is flowing in a southerly direction between 0.15 and 4.72 feet per day, so time of travel for seepage indicators from the lagoon would be between 0.03 and 2 years to reach the monitor wells (figs. 56-58). Sufficient time has been allowed to detect seepage indicators from the lagoon in these wells.

Ground Water Sampling Results

There have been 10 sampling events at this site since publication of the original report in June 1998 (fig. 59). Minor elevations of seepage indicators were detected in wells Rob-1 – Rob-6; however, major contaminant concentrations of TKN, NH_3 and K were consistently detected in most of the monitoring wells installed in the EM-detected plume. NO_3-N spiked in January, July and August 1999 in these newer wells.

EM Surveys & Additional Well Placement

On October 24, 1996, GWS staff conducted a “walk-over” EM survey at the Robeson site. The readings indicated three anomalies emanating from the lagoon in the general direction of ground water flow. Readings were seen to rise sharply from a background reading of approximately 4 to 5 millimhos per meter (mmho/m) to approximately 7 mmho/m in three specific places along the perimeter of the lagoon. A second line, approximately 20 feet further from the perimeter of the lagoon showed the same sharp increase in readings. Upon further investigation, one of the anomalies was likely due to underground piping or electrical wiring. A piezometer was installed in each of the other two linear anomalies, and ground water in the piezometers was pink or red colored and had a foul odor. Laboratory analysis indicated that the constituents of the samples were similar to the constituents in the lagoon liquid. The piezometers were sampled monthly until a permanent well named Rob-8 was installed in plume B and another named Rob 9 was installed in plume A on June 10, 1997 (fig. 55).

A second EM survey was conducted on August 11, 1997. EM readings indicated the same background levels of 4 to 6 mmho/m at the site. Plume A readings had increased to 10 mmho/m. Plume B readings had increased to 9 mmho/m. The higher readings indicate that the ground was more electrically conductive than during the previous survey. Higher constituent concentrations in the ground water could explain the change.

A third survey conducted on October 8, 1997 showed the same background levels and increases of readings at plumes A and B to 12 and 9.6 mmho/m, respectively.

On April 20, 1998, GWS staff conducted a fourth EM survey at the site to see if the plumes could be detected hundreds of feet from the lagoon berm as they migrated through a wooded swamp toward a stream. EM readings were collected in two transects across each plume to determine if the width and center of each plume could be found (fig. 55). Maneuvering the EM meter in thick woods was difficult so the transects were done where possible. The transects at plume A were at 180 and 240 feet from the lagoon berm. Background readings at transect A were in the range of 19 to 22 mmho/m presumably due to higher organic content in the soil or shallow ground water levels. The plume was detectable, nonetheless. It was approximately 60 to 80 feet wide and produced readings of 31 mmho/m in the center. Transect B background readings were in the 4 mmho/m range with a peak reading of 10 mmho/m over a 40-foot width.

Transects A and B in plume B were conducted at approximately 130 and 230 ft from the lagoon berm, respectively. Background readings were in the 10 mmho/m range for both transects. Transect A had a peak reading of 17 mmho/m occurring over about a 70 ft width. Transect B had a peak reading of 21 mmho/m over a width of 85 feet. Higher readings on transect B are probably the result of shallower ground water.

The GWS staff decided to collect very shallow and slightly deeper ground water samples from wells installed where each of the four transects crossed the plume. These samples would be analyzed to study chemical changes and concentration changes in the plume as it progressed toward a nearby swamp. They would also show if vertical differences in the wastewater plume existed as a result of contact with aerated soil, organic carbon, etc. Wells Rob-10 to Rob-17 were installed in four pairs to accomplish the task. Rob-10 to Rob-13 were installed in two pairs in plume A and Rob-14 to 17 were installed in pairs in plume B. Rob-18 was installed nearby plume B in an area not affected by the plume to act as a source of background ground water. As it was not possible to get drilling equipment in the woods, holes were hand augured with a 3.5” auger until flowing sand was encountered. The wells were constructed using 1.5” galvanized steel casings, stainless steel screens and cast iron points. They were driven with a drive hammer to the desired depth, grouted with bentonite clay, labeled and capped. Sampling was accomplished monthly with a Masterflex peristaltic pump through August 1999.

A final EM survey was conducted on August 31, 1999. Peak readings in transect A in plume A were unchanged except that higher readings were found in a 140-foot wide band. Transect B, however indicated that the plume had widened and strengthened significantly. Readings indicated that the plume was fairly concentrated in a 130-foot wide band with peak readings of 23 mmho/m.

Transect A in plume B indicated that the center of the plume had shifted about 30 feet east of the well nest and was about 80 feet wide. Transect B also indicated that the center of the plume was about 10 feet east of the well nest and was detectable over a 150 ft wide band. In support of the EM readings indicating that the plume had shifted away from the wells, analytical results of samples collected from Rob-14 and-15 indicate a steady decline in constituent concentrations over time.

Results generally indicate that the shallower wells were affected by oxidizing conditions as evidenced by high nitrate values. Seasonal variations in rainfall led to dilution and less oxidizing conditions in shallow wells during winter. Grab samples were taken from the stream located downgradient from the lagoon on August 31, 1999, and no seepage indicators were detected.

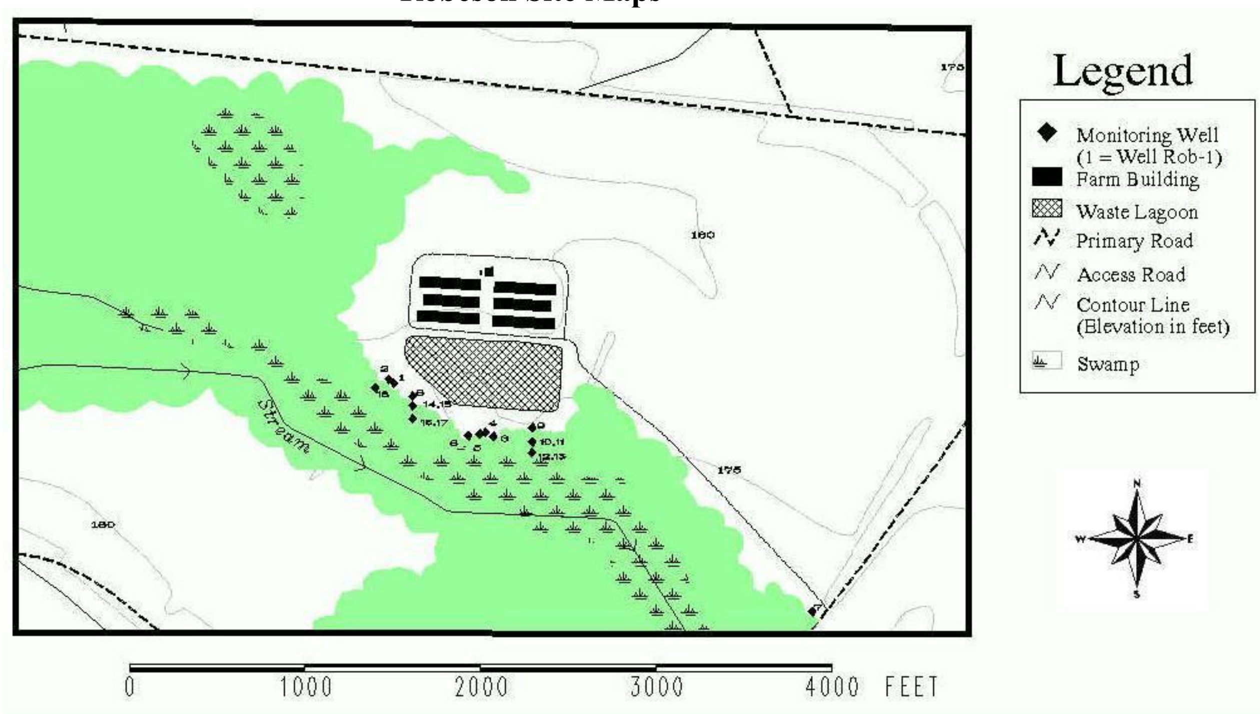
Conclusion

Contaminants from the lagoon are leaking into the ground water, and North Carolina ground water standards are being exceeded 250 feet from the lagoon. EM surveys detected the presence of the ground water contaminant plumes originating from this lagoon, and these surveys were successfully used to place additional monitoring wells to measure contaminant concentrations at this site.

The material used in the liner was obtained on site. GWS staff noted that the soils in the "borrow pit" contained too much silt to be considered suitable for use as a clay liner. In addition, a clay liner must be of a certain moisture content to be properly installed and compacted to form a very low-permeability liner. Groundwater Section staff were told by farm personnel that ground water was standing in the newly dug lagoon when installation of the clay liner was attempted.

Ground water is not being adequately protected from lagoon seepage at this site; however, NRCS standards were not adhered to during construction of the lagoon.

Robeson Site Maps



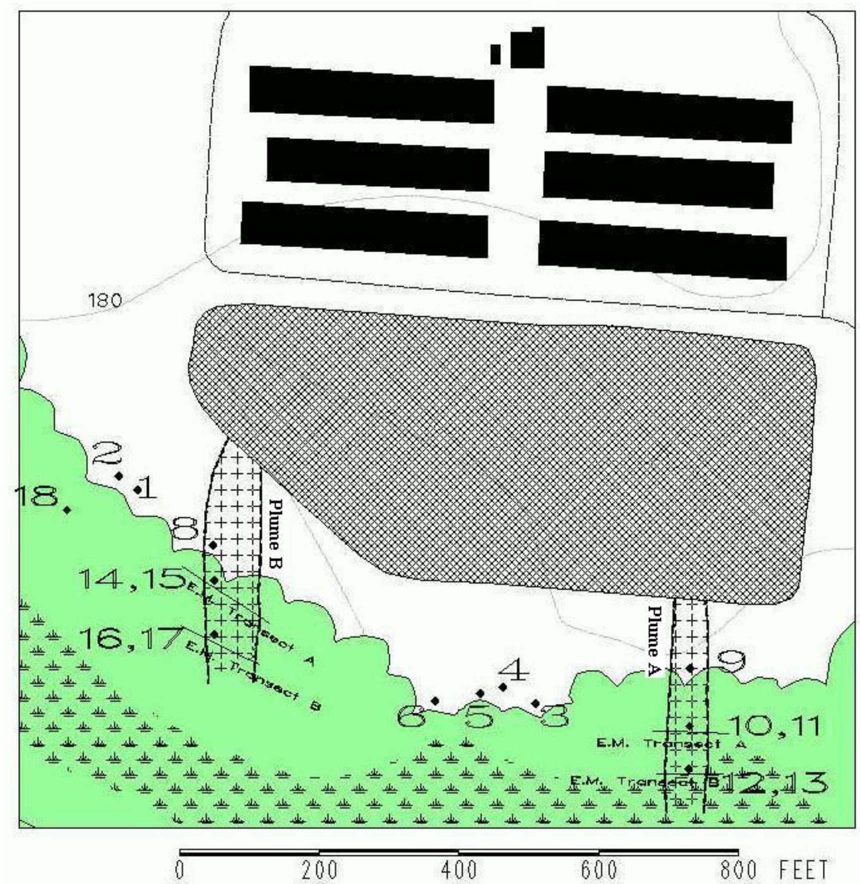


Figure 55

Robeson Site Ground Water Flow Map
(6/30/99)

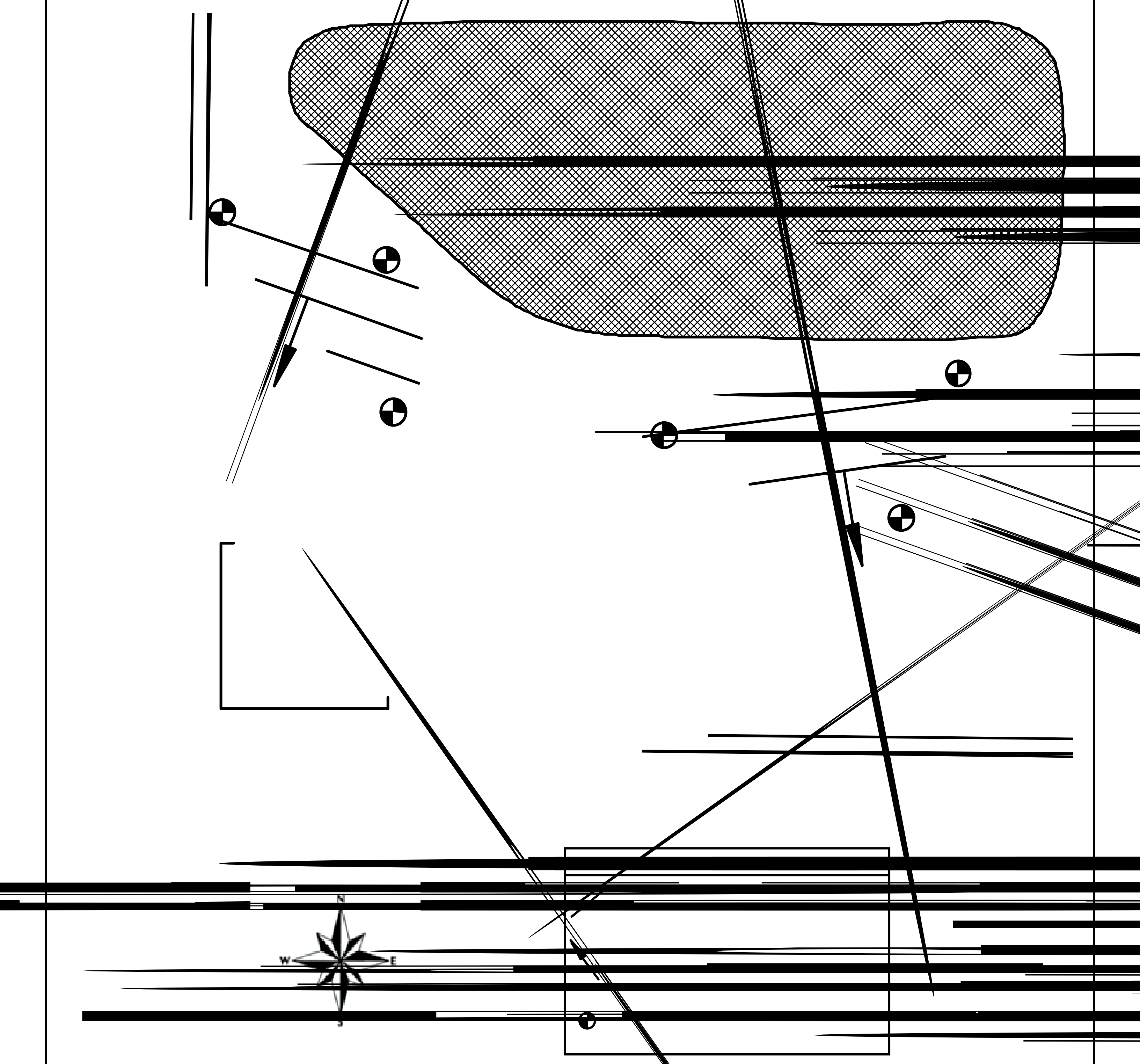
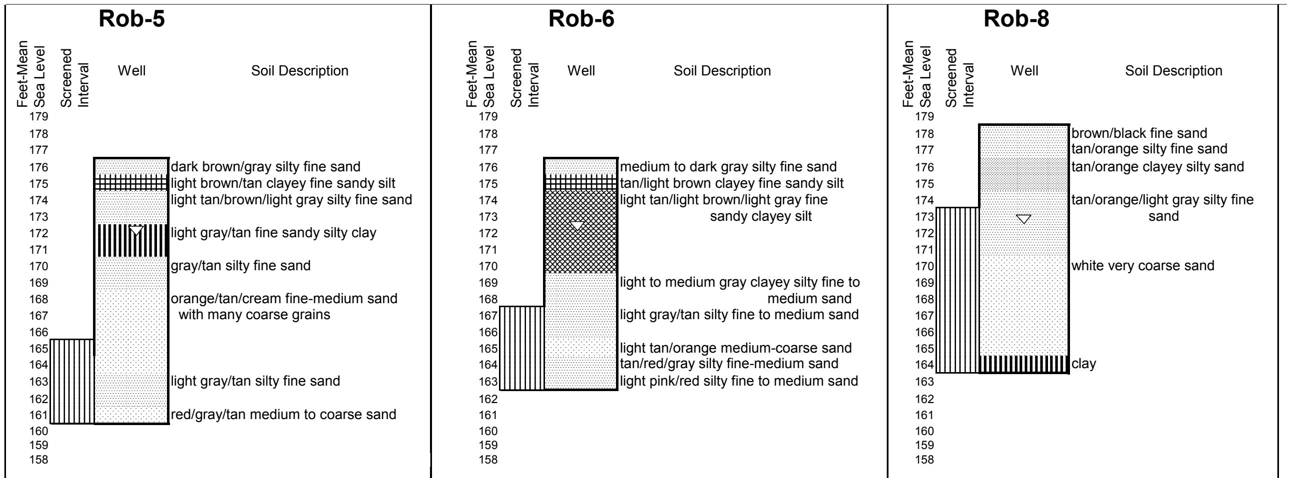


Figure 56

Robeson Site Well Logs and Aquifer Characteristics



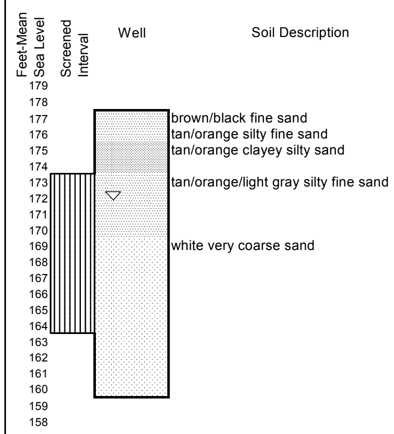
Slug Test ID	Out 1	Out 2	In 1	In 2	Out 1	In 1	In 3	Out 1	Out 2	In 1	In 2
aquifer thickness (ft)	25	25	25	25	25	25	25	25	25	25	25
aquifer type	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	6	6	6	6	6	6	6	8	8	8	8
screen length (ft)	5	5	5	5	5	5	5	10	10	10	10
screen interval (ft)	11-16	11-16	11-16	11-16	9-14	9-14	9-14	5-15	5-15	5-15	5-15
water table to bottom of screen (ft)	10.9	10.9	10.9	10.9	9.11	9.11	9.11	**9.41**	**9.41**	**9.41**	**9.41**
static water level	5.1	5.1	5.1	5.1	4.89	4.89	4.89	5.59	5.59	5.59	5.59
porosity (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.1	0.1	0.1	0.1
hydraulic conductivity (ft/sec)	5.42E-05	5.96E-05	5.68E-05	5.71E-05	1.35E-04	1.25E-04	1.36E-04	1.23E-04	1.51E-04		
average hydraulic conductivity (ft/sec)				**5.69E-05**			**1.32E-04**		**1.37E-04**		
velocity (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
velocity (ft/day)	0.15	0.16	0.15	0.15	0.36	0.34	0.37	4.23	5.20		
average velocity (ft/day)				**0.15**			**0.36**		**4.72**		
distance from lagoon to well	112.00	112.00	112.00	112.00	112.00	112.00	112.00	57.00	57.00		
days to reach well	766.57	697.70	732.12	727.63	307.99	331.32	306.63	13.46	10.95		
average days to reach well				**731.01**			**315.31**		**12.21**		
years to reach well	2.10	1.91	2.01	1.99	0.84	0.91	0.84	0.04	0.03	X	X
average Years to reach well				**2.00**			**0.86**		**0.03**		

Notes:
1) Depth of the aquifer is unknown. At least 24' according to Rob 2 log
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) a "filter sock" was used over the .020 screen, could cause problems with fouling
4) Diedrich 50 Drill Rig
5) slug in could not be used - static water level within the screen
6) ▽ =static water level

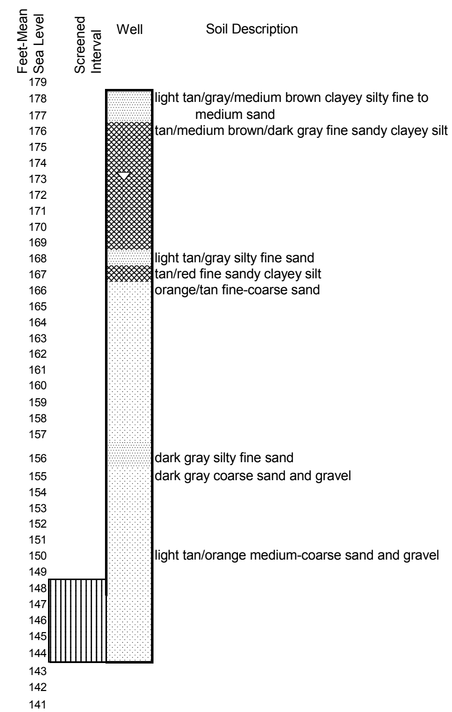
Figure 57 (1 of 2)

Robeson Site Well Logs and Aquifer Characteristics

Rob-9



Rob-2 (Deep Well)



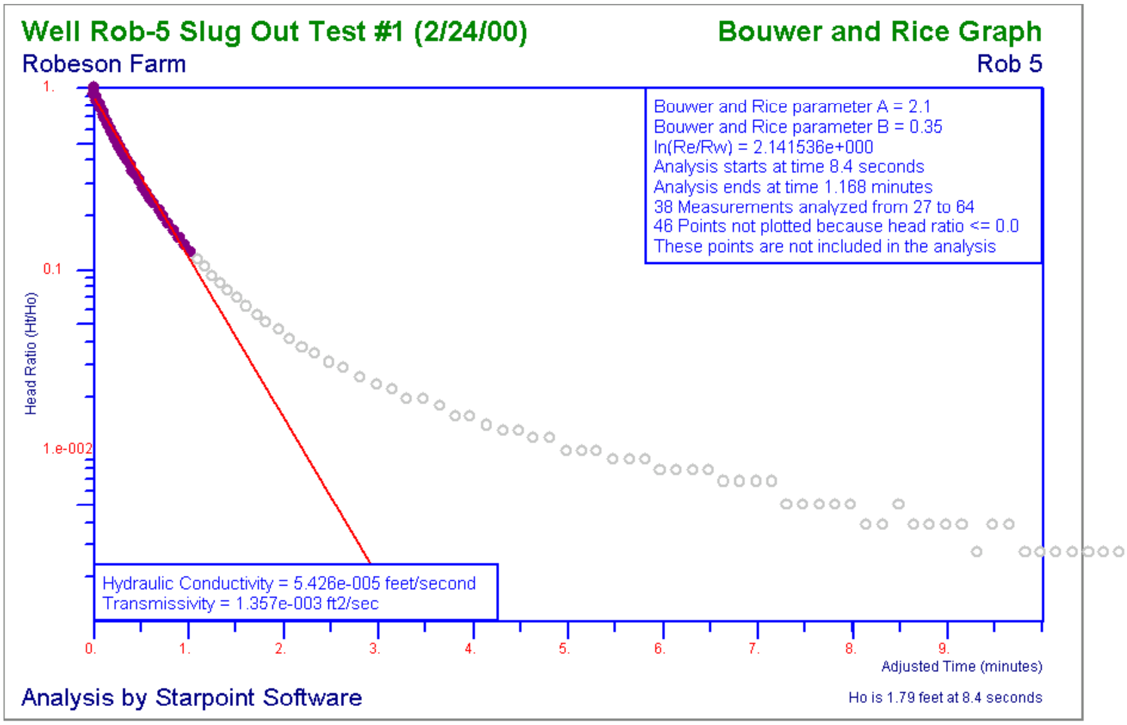
Slug Test ID	Out 1	Out 2	Out 3	In 1	In 1	In 3
aquifer thickness (ft)	25	25	25	25	25	25
aquifer type	Unconf	Unconf	Unconf	Unconf	Unconf	Unconf
well inner diameter (in)	2.045	2.045	2.045	2.045	2.045	2.045
boring diameter (in)	8	8	8	8	8	8
screen length (ft)	10	10	10	10	10	10
screen interval (ft)	4-14	4-14	4-14	4-14	4-14	4-14
water table to bottom of screen (ft)	**8.46**	**8.46**	**8.46**	**8.46**	**8.46**	**8.46**
static water level	5.54	5.54	5.54	5.54	5.54	5.54
porosity (%)	0.25	0.25	0.25	0.25	0.25	0.25
gradient (ft/ft)	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078
hydraulic conductivity (ft/sec)	2.62E-04	2.26E-04	2.36E-04			
average hydraulic conductivity (ft/sec)			**2.41E-04**			
velocity (ft/sec)	0.00	0.00	0.00			
velocity (ft/day)	0.71	0.61	0.64			
average velocity (ft/day)			**0.65**			
distance from lagoon to well	39.00	39.00	39.00			
days to reach well	55.20	63.90	61.36			
average days to reach well			**60.15**			
years to reach well	0.15	0.18	0.17	X	X	X
average Years to reach well			**0.16**			

Notes:

1) Depth of the aquifer is unknown. At least 24' according to Rob 2 log
2) porosity is estimated using chart from "Groundwater and Wells", Driscoll, F.G.
3) a "filter sock" was used over the .020 screen, could cause problems with fouling
4) Diedrich 50 Drill Rig
5) slug in could not be used - static water level within the screen
6) ▽ =static water level

Figure 57 (2 of 2)

Robeson Site Representative Slug Test Analyses



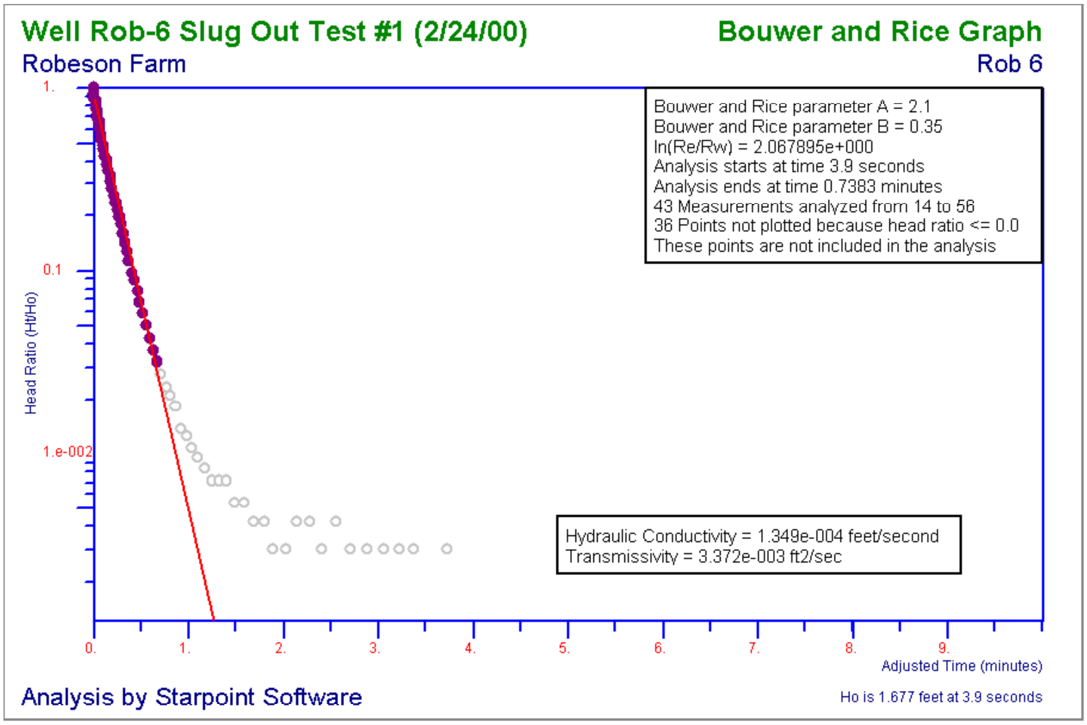
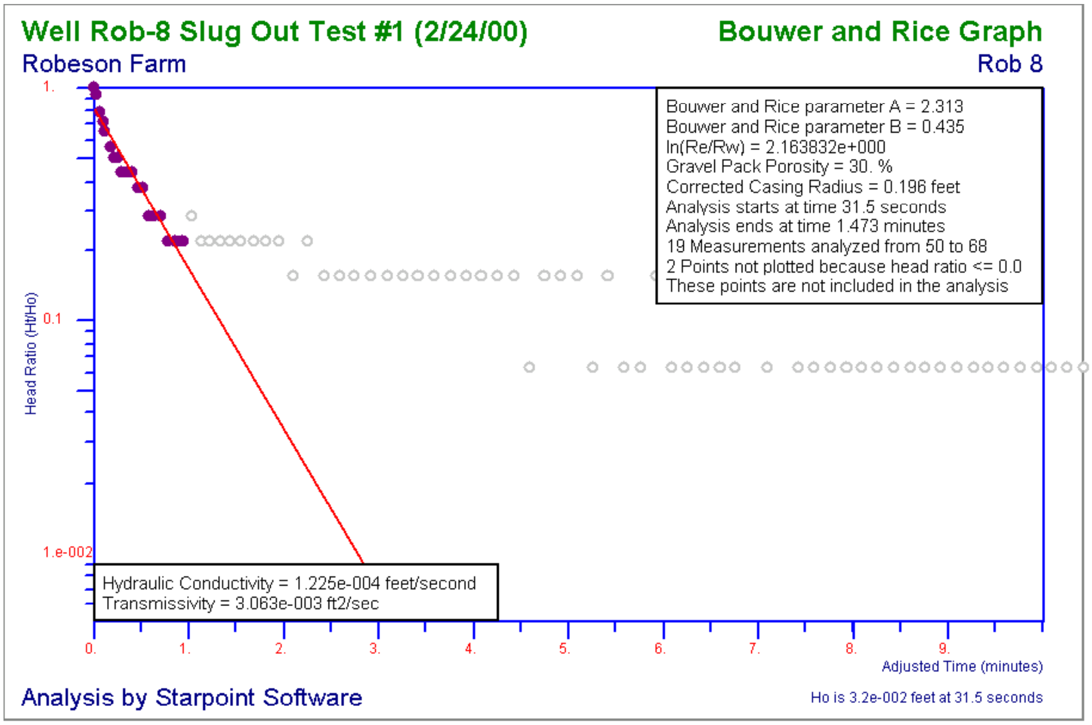


Figure 58 (1 of 2)

Robeson Site Representative Slug Test Analyses



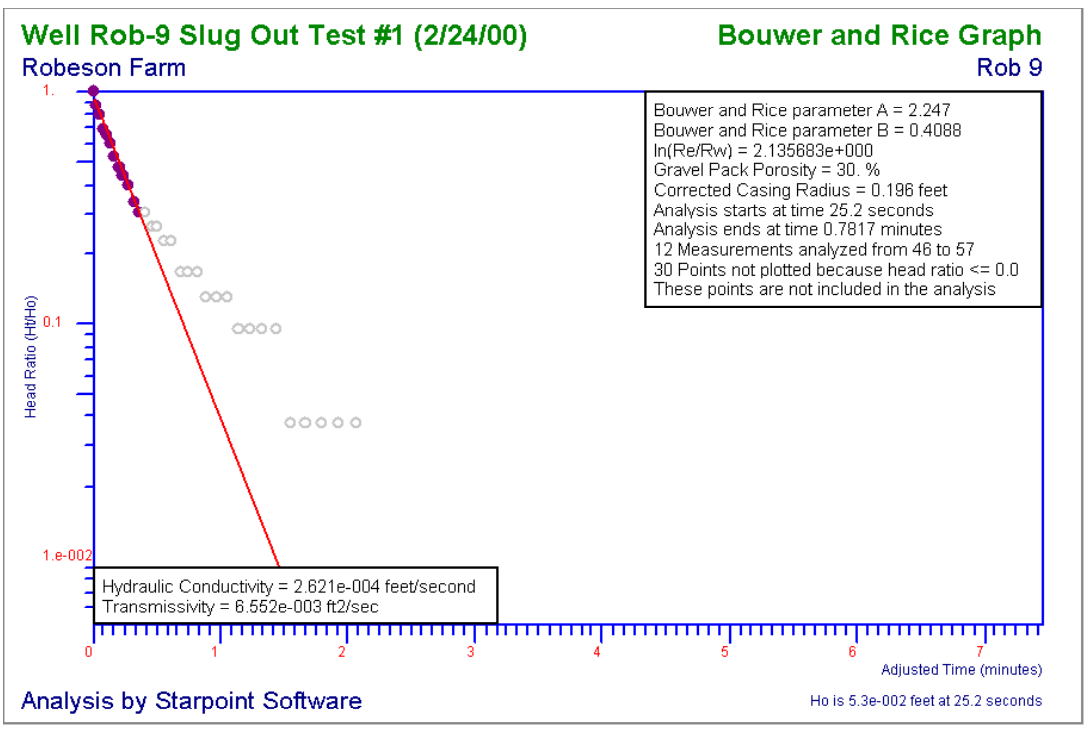


Figure 58 (2 of 2)

Robeson Site NO_3 and TKN Sample Results

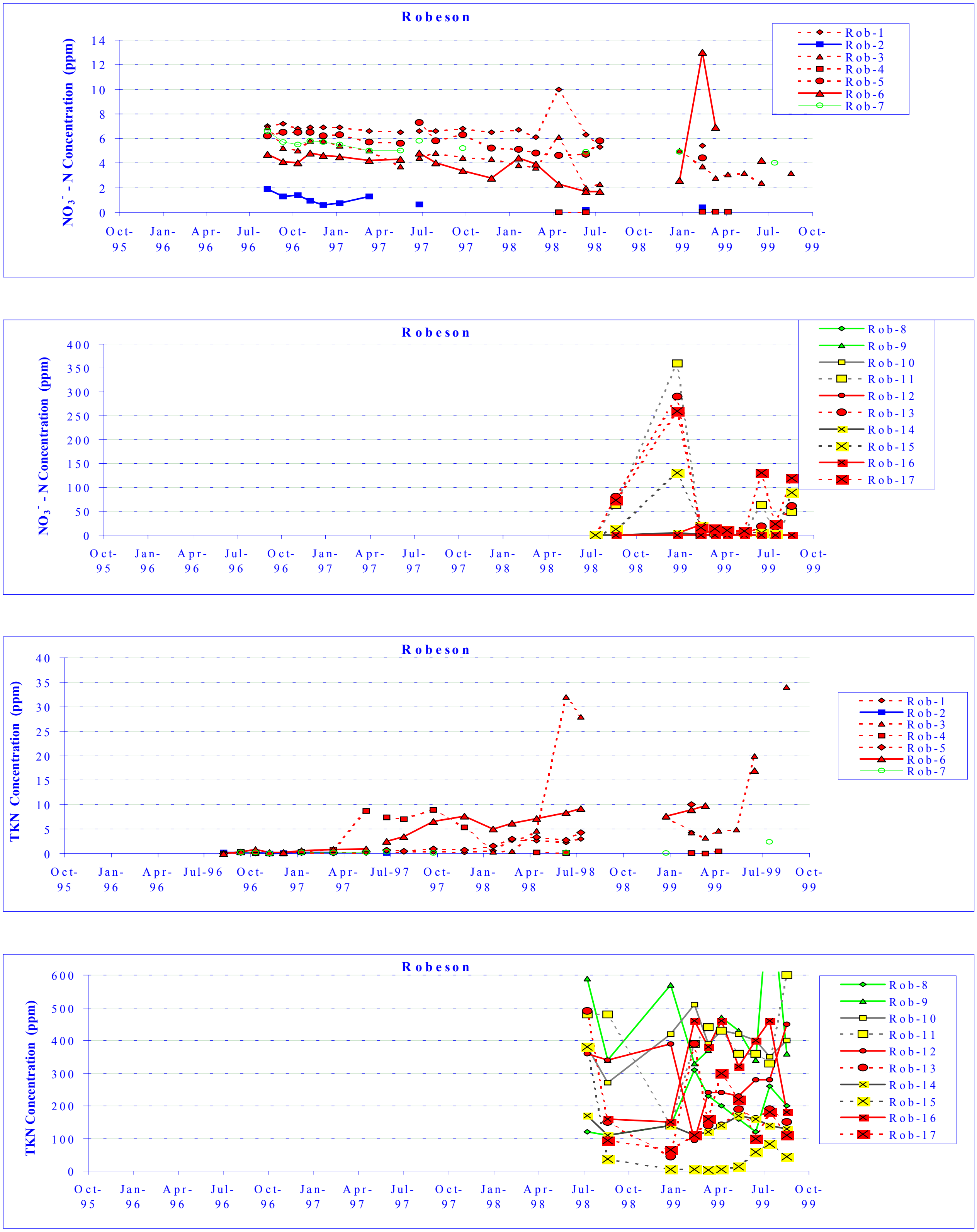


Figure 59 (1 of 4)

Robeson Site NH_3 and K Sample Results

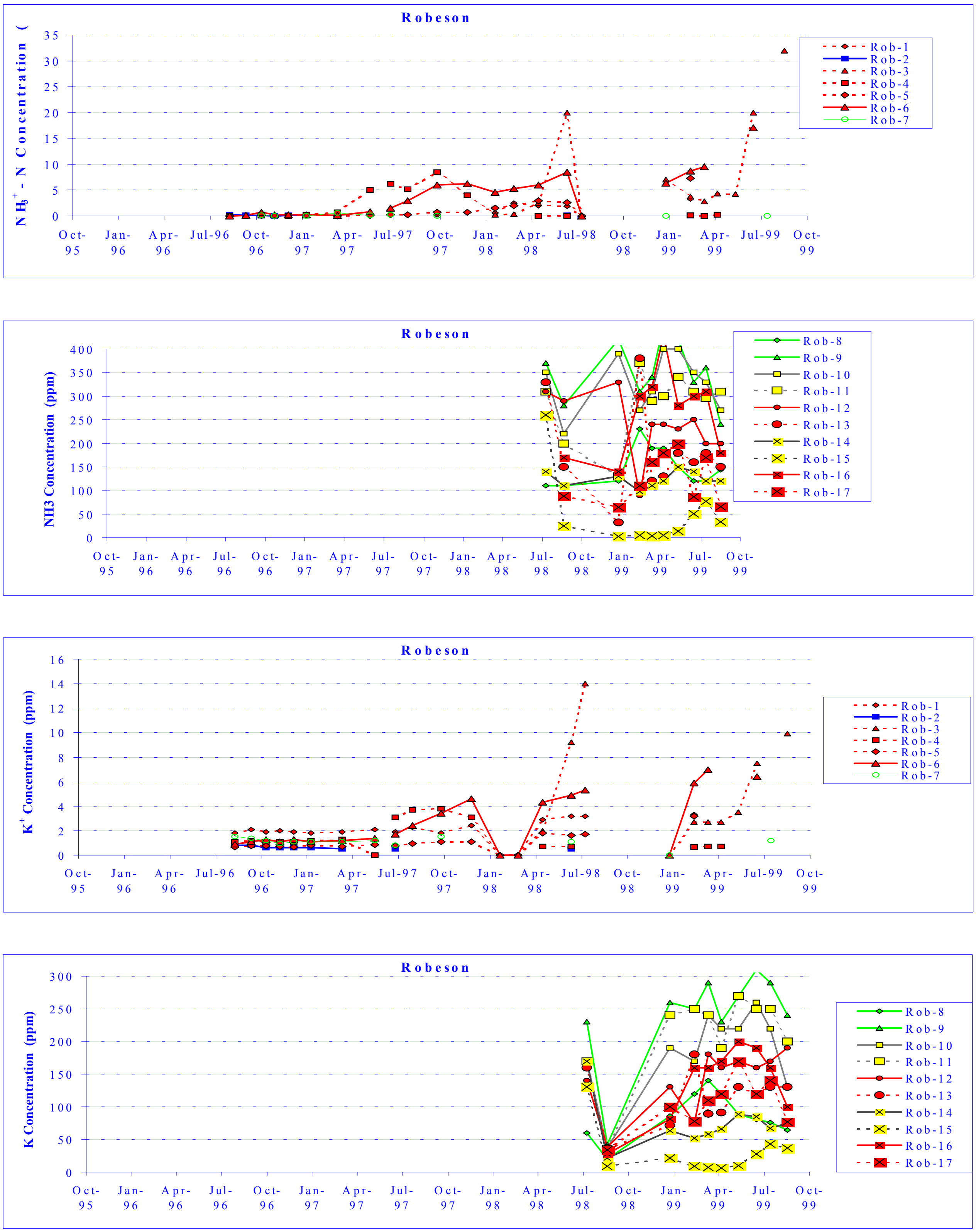
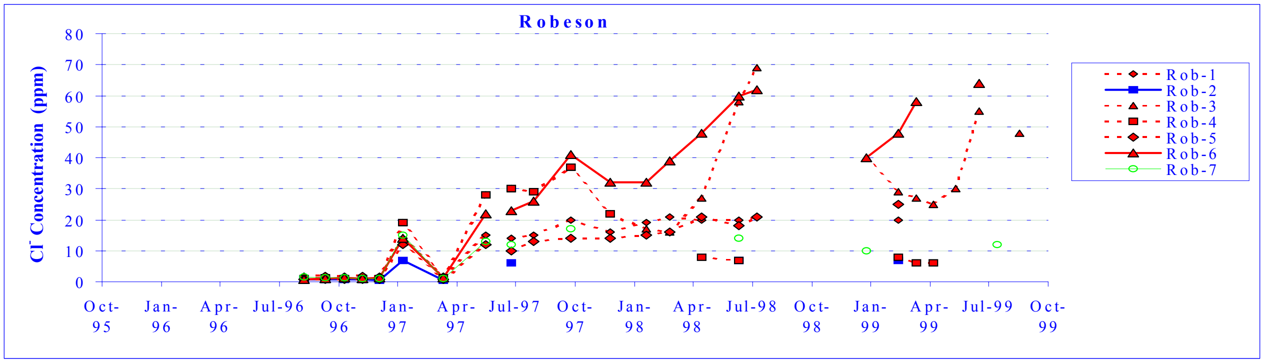
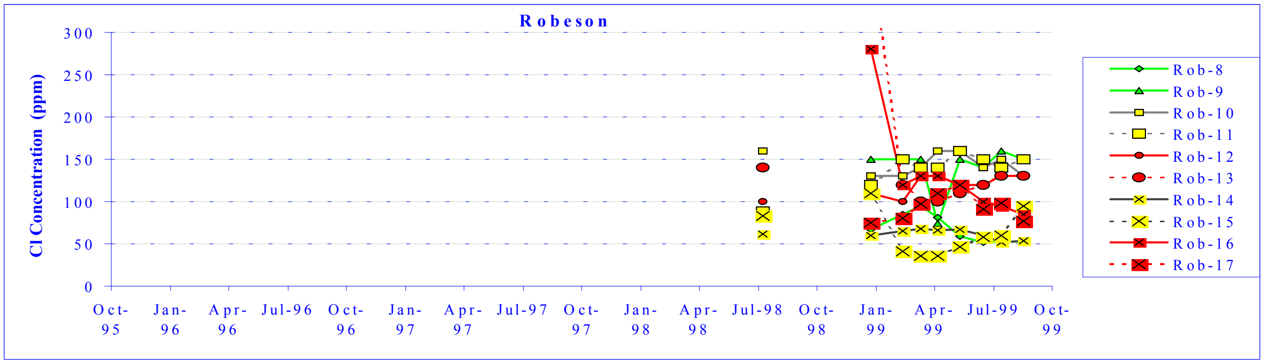
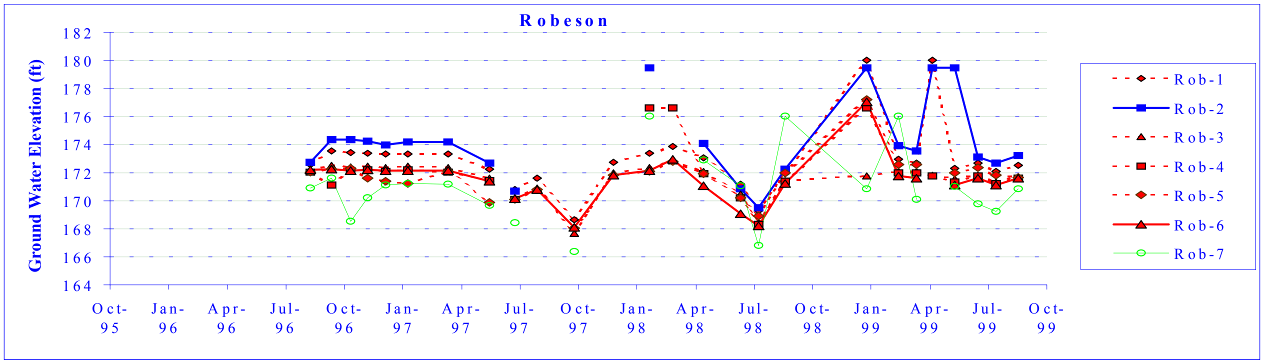


Figure 59 (2 of 4)

Robeson Site Cl Sample Results and Ground Water Elevation







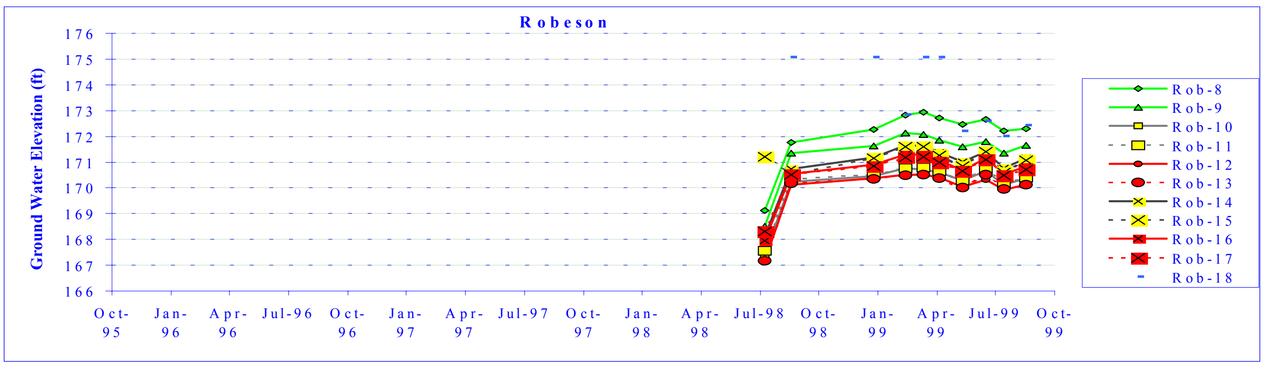
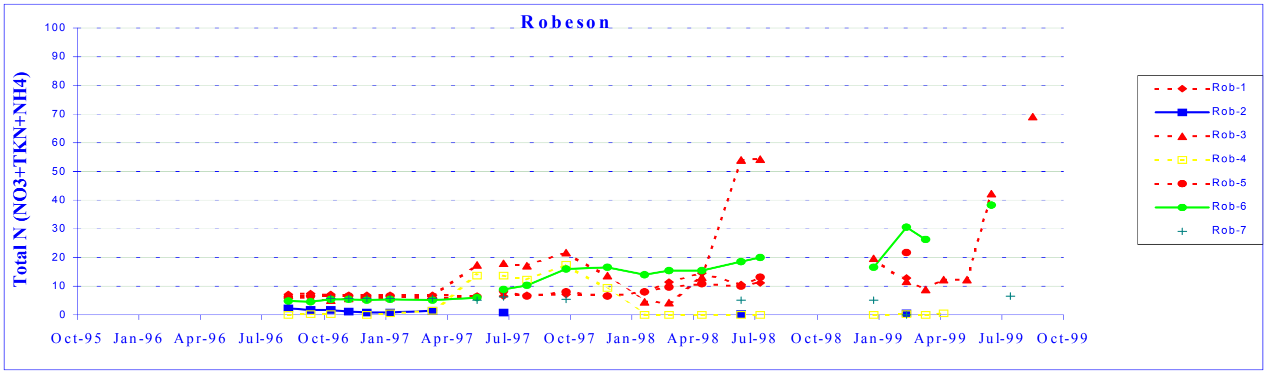


Figure 59 (3 of 4)

Robeson Site Total N (NO_3, NH_4, TKN) Sample Results



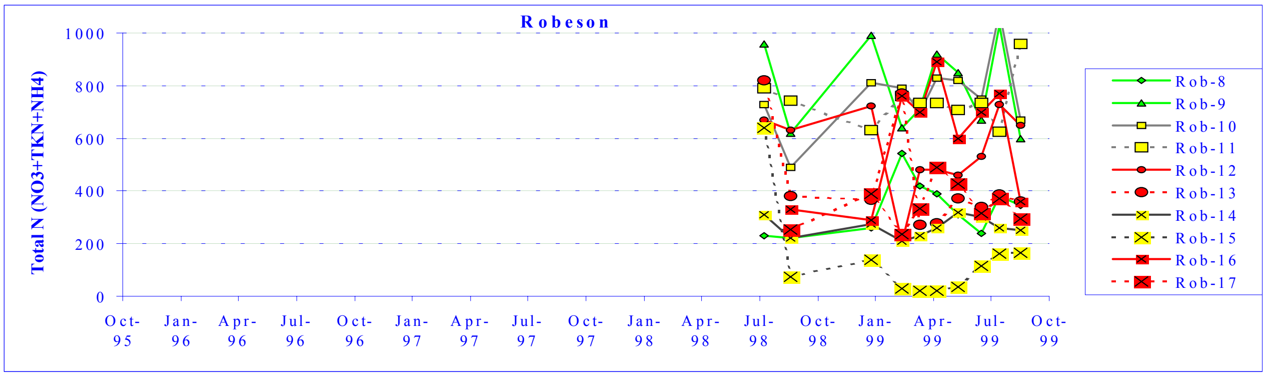


Figure 59 (4 of 4)

Report Conclusions

Three questions are addressed in this report: 1) Is electromagnetic (EM) surveying a useful tool in detecting lagoon seepage?; 2) Has sufficient time been allowed for lagoon seepage indicators to travel from the lagoons to the monitoring wells at the study sites?; and 3) Is ground water adequately protected when current NRCS standards are followed during construction of waste lagoons?

EM Surveying

EM surveying alone is not a useful tool to detect whether lagoons are leaking; however, it has been demonstrated on the Grantham and Robeson sites that EM surveying can be useful in some instances to identify and delineate the extent of an existing plume in shallow ground water.

Contaminant Travel Time

For the purpose of this report, we assume that seepage indicators will move at the same velocity as the ground water at a site. If this assumption is valid, calculated ground water flow velocities from eight of the eleven sites indicate that sufficient time has elapsed for seepage indicators to travel laterally from lagoons to the wells. Accurate ground water flow velocities could not be calculated for the 06, Clarkton or McDaniels sites.

Depth to the water table at the 07 and Albertson sites is greater than 15 feet, and travel time for seepage indicators from the bottom of the lagoon to the water table has not been included in the calculated travel times. Lagoon seepage indicators may not have had sufficient time to migrate to the monitoring wells due to the additional horizontal migration time to the ground water at these two sites.

Construction Standards

Ground water at nine swine and two dairy farms was monitored for the presence of lagoon seepage indicators. As indicated in the original report, two swine farms and one dairy farm exhibit evidence of lagoon seepage that is adversely impacting the ground water. The Robeson swine farm lagoon was not constructed properly. Results from the Clarkton, Lisbon, and McDaniel sites are inconclusive due to placement of the wells or well screens. The remaining four lagoons that were constructed according to 1993 NRCS standards were not causing adverse affects to the ground water due to lagoon seepage.

According to site records and interviews with the site owners, the Gaston Dairy and Grantham sites were both constructed to 1993 NRCS standards, yet both of these lagoons are leaking contaminants into the ground water at concentrations above the North Carolina ground water standards. According to eyewitness accounts, the Robeson site lagoon clay liner was not constructed properly, and it too is leaking contaminants into the ground water at concentrations above the standards.

Conclusions can only be drawn concerning the sites in this study. The limited number of sites that the Groundwater Section was allowed to access precludes extrapolation of any conclusions concerning all waste lagoons in the state. As the original report states, a much larger sample population must be represented before the adequacy of construction standards can be determined statewide. The authors of this report endorse the conclusion in the original report that ground water monitoring should be required on sites where ground water is vulnerable to contamination due to subsurface characteristics (DWQ, 1998). It must also be noted that this study did not measure the impact of land application operations on the ground water at these sites.

References

Driscoll, F.G., 1986, *Groundwater and Wells,* Second Ed. St. Paul, Minn., Johnson Division, 1108 p.

Miller, M.H., Robinson, J.B., and Gillham, R.W., 1985, *Self-Sealing of Earthen Liquid Manure Storage Ponds: I. A Case Study*. Journal of Environmental Quality, Volume 14, No. 4, p. 533-538.

North Carolina Division of Water Quality, Groundwater Section, 1998, *Impact of Animal Waste Lagoons on Ground-Water Quality*, Section 319, Clean Water Act Grant Year, FY 94 Final Report: Raleigh, North Carolina, N.C. Department of Environment and Natural Resources, 131 p.

Ritter, W.F., Walpole, E.W., and Eastburn, R.P., 1984, *Effect of an Anaerobic Swine Lagoon on Groundwater Quality in Sussex County, Delaware*. Agricultural Wastes, Vol, 10, p. 267-284