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Sources and pathways of bacterial contamination of groundwater resources within a rural Montana subdivision

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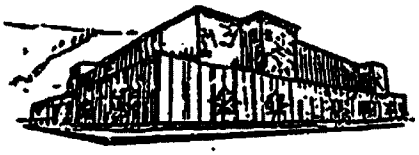

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SOURCES AND PATHWAYS OF BACTERIAL CONTAMINATION OF GROUNDWATER RESOURCES WITHIN A RURAL MONTANA SUBDIVISION

by

Heather Perry

B.S. Slippery Rock University of Pennsylvania, 1996

presented in partial fulfillment of the requirements

for the degree of

Master of Science

The University of Montana

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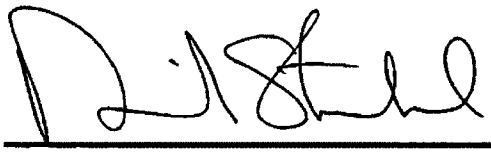
Approved by:

Chairperson



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Sources and Pathways of Bacterial Contamination of Groundwater Resources Within a Rural Montana Subdivision

Director: William W. Woessner WWW 5/31/01

This study focused on bacterial contamination of domestic wells in the Roman Creek-Touchette Lane Special Management Area, located 25 km west of Missoula, MT, where as many as 50% of wells show elevated total coliform concentrations. Domestic wells in the area are finished in shallow and deep sand and gravel aquifer systems which are separated by 75-150 ft of fine sands and silts. Potential sources identified were: natural bacteria populations, surface water exfiltration, irrigation ditch exfiltration, and septic effluent. Possible pathways by which domestic wells are impacted included: downward vertical hydraulic gradients, windows in the confining unit, leakage along well casings, and leakage into the well casing/distribution systems. The scope of the problem was analyzed by sampling domestic wells for total/fecal coliform and gross inorganic chemistry during seasonal high and low water table. Specific sources were analyzed by instrumenting three sites with multi-level wells adjacent to domestic wells and septic drainfields. Sampling of instruments and potential sources for total/fecal coliforms as well as gross inorganic chemistry was performed in order to identify the overall bacterial source to the area. Pathways were evaluated by measuring water levels in instruments and domestic wells, drafting cross-sections, performing pumping tests, conducting a tracer test, and through the use of numerical simulations. Results of broad sampling indicate that domestic wells are contaminated seasonally by a bacterial source. Total coliform contamination ranged from 2 to 25% during seasonal low and high water table, respectively, over the course of the study. Results of site-specific sampling indicate that the shallow groundwater in the vicinity of domestic wells is contaminated with total coliform bacteria. In general, concentrations of inorganic constituents decreased with depth. However, on a site with a contaminated domestic well during the site specific study, concentrations of chemical indicators of septic system effluent increased with depth. Final results of sampling analyses point to septic system effluent as the most probable source of bacterial contamination to groundwater in the area. Pathway analysis indicated that the most probable avenue by which deep domestic wells are impacted is by leakage of shallow contaminated groundwater into the well distribution system. Shallow wells are being impacted principally by extraction of groundwater impacted by septic waste.

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I would like to express my gratitude to the Missoula Valley Water Quality District for funding this project. Thanks Peter Nielsen, Jon Harvala, Chris Cerquone, Marylou Gilman and especially Steve Wright, for providing me with field assistance and guidance throughout the study. Thank you to my committee members Dr. William Woessner (for all of your supervision, direction, and motivation) and Dr. Gray Thompson (Department of Geology), and Dr. James Gannon (Department of Biological Sciences). Thank you to all of the residents of the SMA who allowed me to sample their wells; especially the participants in the site-specific study, the Fall, Iddings, and Johnston families. Finally, special thanks to my mom, dad, Shawn, and the rest of my friends and family for all of your love and support.

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CHAPTER 1: INTRODUCTION

With the increasing reliance on groundwater as a source of potable water, bacteriological contamination has become an important issue (Sworobuk et al., 1987). Currently, over 100 million Americans drink groundwater (Yates, 1986, Tuthill et al., 1998). Approximately 75% of municipal water suppliers use some groundwater and over 90% of rural residents rely solely on groundwater. There is such a dependence on groundwater that an estimated 1 million new wells are drilled in the United States each year (Bitton & Gerba, 1984). Groundwater is generally assumed to be free from microbial pathogens due to the natural filtration that takes place as water percolates to the zone of saturation (Sworobuk et al., 1987, Tuthill et al., 1998). However, Craun (1979) showed that from 1971-1977 almost half of the outbreaks of waterborne diseases were caused by consumption of untreated or inadequately treated groundwater (Table 1). From 1991-1998, 67% of waterborne disease outbreaks resulted from the consumption of well water that was inadequately treated (37%), untreated (27%), or had problems with the distribution systems (26%) (Anonymous, 1993, Kramer et al., 1996, Levy et al., 1998, Barwick et al., 2000). Because of both the dependence on groundwater as a source of potable water and the high potential for microbial contamination of this resource, additional research is needed to identify the controls on bacterial transport and pathogen survival in groundwater systems.

Contamination Sources

Coliform bacteria in groundwater can originate from numerous sources; including land application of sewage sludge, leachate from landfills, urban runoff/recharge, agricultural practices, and natural populations existing in soil or groundwater (Bitton &

Gerba, 1984; Freeze & Cherry, 1979; Jewell & Seabrook, 1979; Wiggins, et al., 1999). Another potential source, septic tank effluent, is the most frequently reported cause of groundwater contamination in the United States (Yates, 1986). Approximately 1/3 of the population uses septic systems for sewage disposal (Robertson et al., 1991). This amounts to over 800 billion gallons of wastewater discharged to the subsurface per year, making septic systems the greatest volumetric source of effluent discharged to groundwater. Due to improper installation and maintenance, and inadequate separation between drainfields and groundwater and drainfields and wells, septic systems become sources of groundwater contamination (Tuthill et al., 1998). The threat of microbial contamination of groundwater is only likely to rise as the number of septic systems in use increases at a rate of 0.5 million/year.

Table 1. Causes of Waterborne Disease in the U.S. 1971-1977 (Craun, 1979).

	Outbreaks	Cases Of Illness
1. Use of Untreated Water:		
Surface Water	25	6060
Groundwater	57	4539
Springs	8	935
	90	11534
2. Treatment Deficiencies:		
Surface-Water Systems	19	3599
Groundwater Systems	38	10829
Spring-Water Systems	4	1179
	61	15607
3. Distribution System Deficiencies:	26	9058
4. Miscellaneous and Unknown	15	558

Purpose/Goals

This work focuses on the nature of bacterial behavior in groundwater systems, the source of the bacterial contaminants, and the mechanisms by which microbes impact domestic wells in the western part of the Missoula Valley. Specific objectives include:

1. Identification of sources contributing to coliform contamination of drinking water supplies by analyzing available databases as well as new data gathered during the course of this study.

2. Documenting coliform contamination rates of domestic wells in the Special Management Area (SMA) during periods of high and low water table.

3. Defining water table/potentiometric surface fluctuations throughout the year.

4. Characterization of the chemistry and microbiology of the shallow groundwater associated with three individual septic systems and water supplies.

5. Identification of potential pathways by which the contamination reaches domestic wells.

This thesis is organized into 6 chapters. Chapter 2 presents an overview of the character and properties of the Enterobacteraceae. Site history and conditions are reviewed in chapter 3. Methods used in this study are discussed in chapter 4. Results are presented in chapter 5. A discussion of the study is given in chapter 6. The final chapter (7) contains research conclusions and recommendations.

CHAPTER 2: ENTEROBACTERACEAE

Coliforms comprise a phylogenetically unique group of enteric bacteria within the Enterobacteraceae. These bacteria are important in groundwater systems as they are used as indicators of potential fecal contamination (Close et al., 1989, Tuthill et al., 1998). Coliforms are characterized as being gram-negative, facultatively aerobic, non-spore forming rods, which ferment lactose within 18-24 hrs at 35°C (Madigan et al., 2000).

Coliforms are rod-shaped and do not have the ability to form endospores, resting structures that allow bacterial species to withstand environmental stresses, such as heat and desication. The lack of endospore formation is included in the definition of coliforms to differentiate them from Bacillus species, a ubiquitous group of bacteria that often give false positive results in coliform tests. Metabolically, coliforms preferentially carry out aerobic respiration in the presence of oxygen. Because coliforms are facultative, they have the ability to carry out fermentation when oxygen becomes limited or absent.

There are many pathogens, organisms with the ability to cause disease in the host, within the coliform group. These include Escherichia coli and Klebsiella species. These bacteria cause such diseases as gastroenteritis, pneumonia, dysentery, and urinary track infections. The most important common carrier of the pathogens is water, however it is not practical to analyze water for all pathogenic organisms that are potentially present (Madigan, 2000). It is possible to analyze water for the overall presence of microorganisms. The coliform family consists of a group of organisms with many different sources, including those that inhabit the intestinal tract of warm-blooded mammals. The term fecal coliform refers to a subset of the total coliform group containing bacteria which can ferment lactose at higher temperatures and which have only one true source, the intestinal tract. Total coliforms are used as indicator organisms because most members are associated with the intestinal tract of warm-blooded animals where coliforms are present in large numbers. The presence of coliforms in a water sample suggests the possibility of fecal contamination of that water supply. Coliforms have similar survival rates to pathogens in the environment and they behave similarly to

pathogens during water purification processes. Therefore, the presence of coliform bacteria indicates that water may be contaminated with pathogenic microorganisms from either human or animal sources.

Bacterial Transport

To gain insight into the threat posed by microbial contamination, it is critical to understand the factors controlling transport of bacteria to groundwater. Two major factors affecting microbial transport are mechanical filtration and adsorption. As effluent percolates into the subsurface it is subjected to the two components of physical filtration, straining and sedimentation. Straining is a process whereby bacteria are retained by pores having a smaller diameter than the bacteria. The average length of a rod-shaped prokaryote (E. coli) is 1.0-3.0 μm and the average width is 0.5–1.0 μm (Madigan, 2000). Straining can result in "bridging" across a pore, where bacteria accumulate and effectively decrease the pore diameter. In this instance, the accumulating bacteria become the filter for effluent continuing to percolate downward. Sedimentation occurs when bacteria aggregate on grain surfaces within the pores due to the "slimy" nature of the cell surface. Bitton et al. (1974) showed that the removal of bacteria at a given depth in the subsurface is inversely proportional to grain size. This can be interpreted as meaning that as grain size increases, removal of bacteria decreases, presumably because cells move freely in larger pores or because the surface area to volume ratio is inversely proportional to grain size, so adsorption surface area increases with decreasing grain size. Krone et al. (1958) used breakthrough curves from column experiments to describe the process of mechanical filtration (Figure 1). At the onset of the experiment the relative concentration of bacteria in the effluent increases to a maximum. As straining and

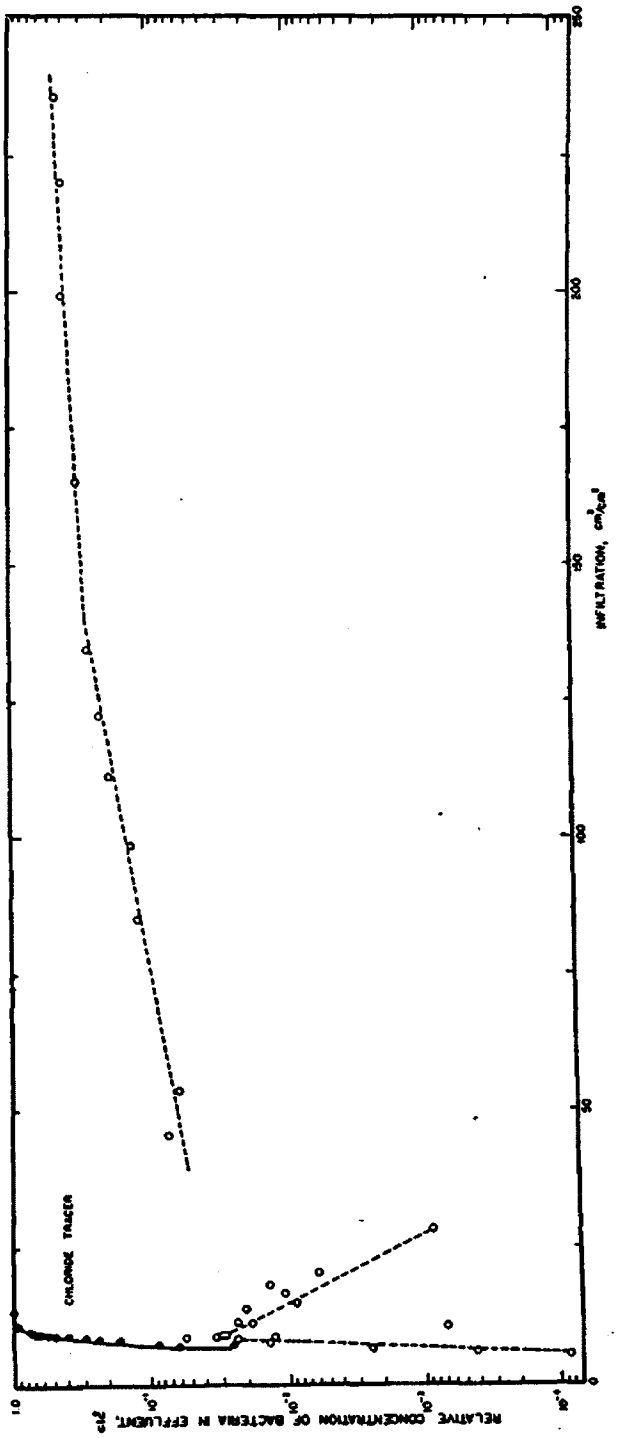

Figure 1. Breakthrough curve for the arrival of E.coli through coarse sand (Krone, 1958). Open circles represent the bacterial breakthrough curve, closed circles represent the chloride breakthrough curve, and the infiltration rate of effluent through the column is given in cm^3/cm^3.

sedimentation take place near the top of the column, bacterial concentration in the effluent decreases. Accumulating bacteria soon saturate all available straining sites near the surface of the column. Due to a mechanical instability of accumulating cells in the presence of flowing water, the cells begin to slough off and are transported downward in the column. These cells are subsequently removed in straining sites lower in the column, creating an advancing saturation front. This advancing front results in a rapid increase in bacterial concentration of the effluent. Once all available sites within the column are filled, sedimentation becomes the dominant removal mechanism, and the breakthrough curve levels off. Experiments on the effect of saturated vs. unsaturated effluent flow on straining and sedimentation yielded similarly shaped breakthrough curves with a lower retention of microbes.

Adsorption of bacterial cells to sediment, due to the ionic charge of the cell, is another factor influencing the transport of microbial contamination to groundwater systems. The number and availability of sites where adsorption can occur is an important determinant of bacterial retention. Materials such as clays, organic matter, and iron oxides have large numbers of available sites; therefore an increase in these components in the subsurface will increase adsorption (Hendry et al., 1999). Bitton and Gerba (1984) noted that clays provide ideal adsorption sites due to their small size, platy structure, and large surface area to volume ratio. Experiments by Bitton et al. (1974) showed that there was an increase in bacterial retention with an increase in clay content. The effect of pH on adsorption has been well documented (Bitton et al, 1974, Reddy, et al., 1981, Simoni et al., 1998, and Hendry et al., 1999). They demonstrated that as pH decreases, bacterial adsorption increases. This is due to the higher proton concentration in acidic

environments, which decreases repulsive forces between negatively charged sediments and bacterial cells. The presence of cations in solution will also increase adsorption of bacteria by decreasing repulsion (Simoni et al., 1998, Hendry et al., 1999). Bitton and Gerba (1984) cited experiments confirming this trend. Adsorption of coliforms was higher during column experiments using tap water with higher ionic strength (cations) than with deionized water. Another influence includes the presence of soluble organics (which decrease adsorption due to competition for sites).

Bacterial Survival

Bitton and Gerba (1984) noted that most enteric bacteria die-off rapidly outside of the gastrointestinal tract. Bitton et al. (1983) reported a $T_{1/2}$ (time required to reduce a microbial population by one order of magnitude) of 6.5 days for E. coli. Many environmental factors influence the survival of bacteria in natural systems including: available nutrients, moisture, pH, temperature, sunlight, and the presence of other microbes. Reddy et al. (1981) reported that the die-off of bacteria is a first order reaction that can be described by the equation: $M_t = M_0 \exp\{-k\}$; where M_t is the bacterial concentration at time t, M_0 is the initial bacterial concentration, and $-k$ is the net die off rate constant (rate constant for cellular division – rate constant for bacterial die off). Table 2 lists rate constants for enteric microorganisms under various environmental conditions.

Certain nutrients and trace elements must be present in the environment for bacteria to survive (Madigan et al., 2000). Macronutrients, those required by cells in large amounts, include: carbon, nitrogen, phosphorous, sulfur, potassium, magnesium, calcium, sodium, and iron. These elements are essential, as they are used in cellular

biosynthesis. Micronutrients, those required in small amounts, include various trace metals and play a role in enzyme structure. Coliforms are chemoheterotrophs, meaning they use reduced organic chemicals as both a source of energy (electron donors) and a source of carbon. Although coliforms have very simple nutritional requirements, Tate (1978) showed that E. coli survived longer in organic rich sediments than in mineral sediments. Because sewage sources of microbial contamination have high organic and nutrient concentrations, bacterial survival should not be limited by availability of required growth factors.

Coliforms, by definition, do not have the ability to form resting structures (such as endospores), and are therefore subject to desiccation when moisture becomes limited. Although lack of water is not a factor in groundwater systems or effluents, it may become important as bacteria percolate from a source through the zone of aeration. Experiments by Beard (1940) showed that bacteria survived longer in various soil types during the rainy season than during seasons with lower rainfall. Similar results were reported by Reddy et al. (1981), where net die-off rate constants increased with decreasing soil moisture (Table 2).

All microorganisms have an optimum temperature for growth (Madigan et al., 2000). Although some bacteria flourish under extreme temperatures (psychrophiles and thermophiles), coliforms are mesophiles, with an optimum temperature for growth of 37-40°C. At elevated temperatures, proteins undergo denaturation, a process where biological properties of proteins are lost. As proteins play key roles in catalysis of chemical reactions and cellular structure, irreversible damage to proteins results in death

Table 2. First-order die-off rate constants for some organisms found in soil-water systems (Reddy et al., 1981).

Microorganism	Season or Temp, C	Half-Life (hours)	Remarks	Reference
Escherichia coli	5	110.9	In Water	McFeters & Stuart (1972)
	10	72.3	Estimated From	
	15	33.8	half-lives	
	20	16.8		
	25	12.0		
E.coli				
pH = 2.5	10	2.6	In water, at several	
4.0	10	28.7	pH levels	
5.0	10	41.6		
6.0	10	55.4		
7.0	10	52.0		
10.0	10	23.4		
12.0	10	2.6		
Total Coliforms		41.6	In water medium	Mahloch (1974)
Fecal Coliforms		41.6		
Fecal Coliforms		26.0	In water medium	Canale et al. (1973)
Fecal Coliforms	20	75.6		Bhagat et al. (1972)
Fecal Coliforms	9-12.5	17.0	rates calculated	McFeters et al. (1974)
			from half-lives, die	
			off rates in water	
			medium	
Coliforms		17.5	From raw sewage	
Fecal Coliforms	10	66.7	In storm water	Geldreich et al. (1968)
			samples containing	
			bacteria stored at	
			varying temperatures	
Shigella dyseneriae	9-12.5	22.5		McFeters et al. (1974)
Shigella sonni		24.5	Die-off rates in well	
			water medium	
Shigella flexneri		26.8		
Vibrio cholerae		7.2	Well water medium	

of the microbe. Experiments have shown that as temperature decreases below a bacterial species' minimum, gelling or freezing of the cytoplasmic membrane occurs (Madigan, 2000). As the membrane must be in a fluid state, the gelling results in improper nutrient transport or proton gradient formation, and cell growth no longer occurs.

Survival trends of bacteria due to variations in pH are similar to those of temperature. Table 2 indicates that net die-off rate constants increase with decreasing pH. Bitton and Gerba (1984) noted that pH can affect both the viability of cells and the availability of nutrients. Although some bacteria (acidophiles) can take advantage of the natural proton motive force at low pH levels, coliforms are subject to protein denaturation in acidic environments.

The presence of other microbes in the environment has been shown to have antagonistic effects on enteric bacteria. Experiments by Lamka et al. (1980), showed that Bacillus species, pseudomonads, Flavobacterium species, Actinomyces, and Micrococcus species inhibit growth by out competing coliforms for available nutrients. Samples with higher heterotrophic counts had lower coliform concentrations than samples with lower concentrations of heterotrophic bacteria. Reddy et al. (1981) reported that indigenous populations might secrete antibiotics or other substances which are toxic to coliforms. In addition to competition for nutrients, enteric bacteria are subject to predation. England et al. (1993) reported that when bacteria were added to sterile soil samples, no decline in numbers occurred. However, when bacteria were added to soil samples containing protozoans, bacterial concentration decreased while protozoan concentration increased.

CHAPTER 3: SITE CONDITION AND HISTORY

This study focuses on microbial contamination of groundwater in the Roman Creek – Touchette Lane Special Management Area (SMA), Missoula County, where as many as 50% of household wells show elevated coliform contamination levels. The Roman Creek-Touchette Lane Special Management Area (SMA), located approximately 25 km west of Missoula, MT, encompasses the western half of Section 27, all of Section 28, and the eastern half of Section 29, Township 15 North, Range 21 West (Figures 2a and 2b). The SMA was set up by the Missoula City-County Health Department in October of 1986 because wells sampled showed "abnormally" high coliform contamination rates, and was formally adopted into departmental regulations (Section XV-D) on July 1, 1994 (MCCHD, 1994).

The SMA is located in a western trending portion of the Missoula Valley (Clifford, 1992). The Frenchtown area is bounded to the north by Precambrian bedrock overlain by Tertiary sediments and colluvium and to the south by the Clark Fork River. There are three major river terraces in the vicinity of the SMA. The lowest terrace is located to the south and represents the modern Clark Fork River floodplain. The highest, located along the north slope of the valley, and the middle terrace are relic fluvial landforms.

The subsurface stratigraphic units in the vicinity of the SMA consist of Tertiary deposits, Lake Missoula sediments, and river deposits. The four primary units include, from top to bottom: 2-8 ft of sandy loam soil (thought to be an overbank deposit) (Unit 1), 5-30 ft of sand and gravel (Unit 2), 75-140 ft of interbedded silts, fine sands, and clays with local gravel lenses (Unit 3), and a deep sand and gravel deposit of unknown

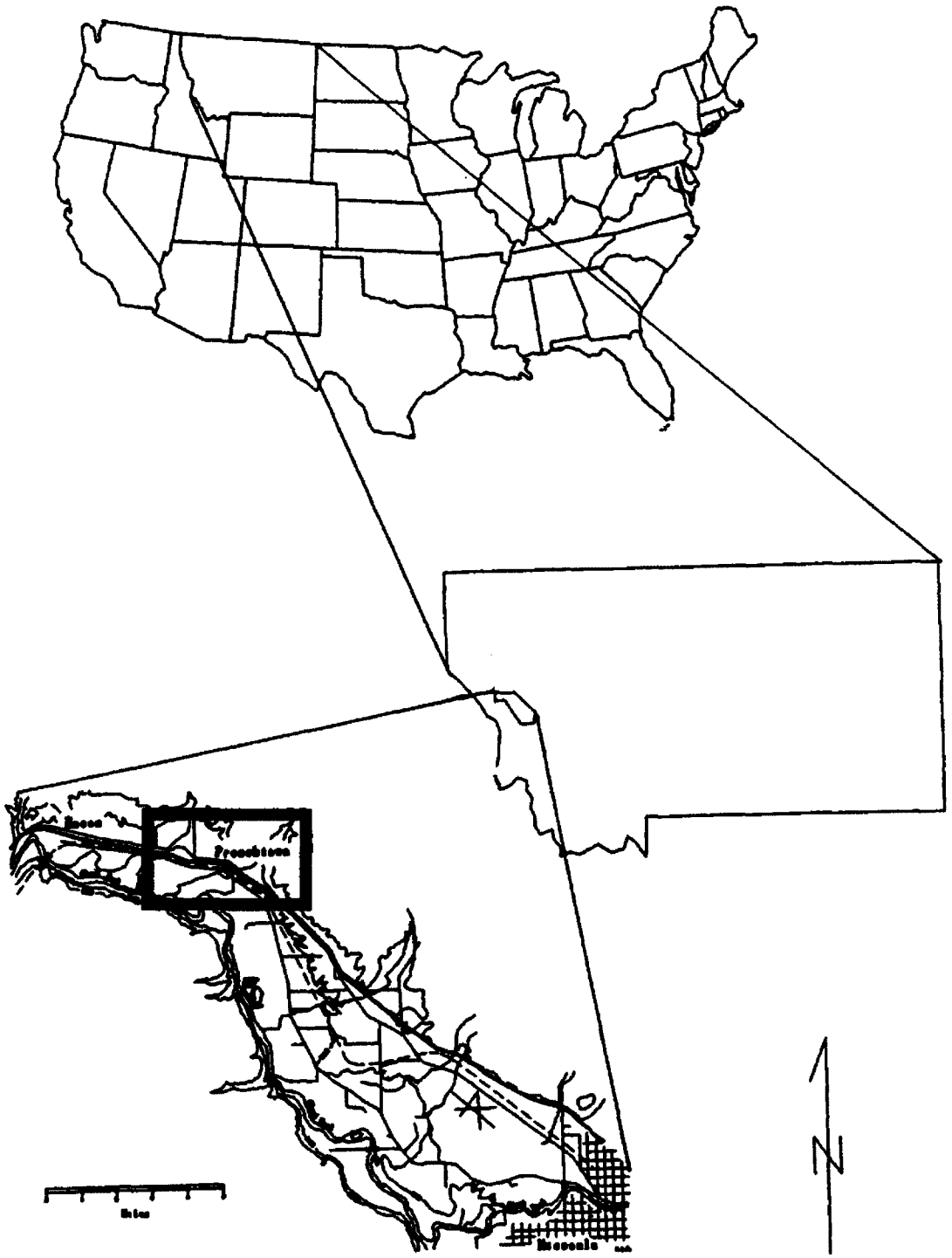

Figure 2a. Location of the SMA in Frenchtown, MT (outlined in black). (Clifford, 1992).

Figure 2b. Location of the Roman Creek - Touchette Lane Special Groundwater Management Area.

thickness (Unit 4) which unconformably overlies Tertiary sediments. Curry (1978) suggests deposition of the upper units in this part of the valley is related to a large medial sandbar that formed in the center of the valley during a glacial Lake Missoula outburst. Clifford (1992) interpreted Unit 4 as being deposited by fluvial processes during early Pleistocene glacial and interglacial periods. He suggests Unit 3 was deposited as lake sediments during pre-Pinedale and early stages of Pinedale Glacial Lake Missoula. Unit 3 coarsens from silty sand in the SMA to gravel, cobbles, and boulders to the southeast (towards Hellgate Canyon). Unit 2 consists of fluvial sediments deposited by the Clark Fork River.

The two aquifers in the area are in the sand and gravel deposits (Units 2 and 4). The shallower gravel (Unit 2) forms an unconfined to leaky confined aquifer, which receives discharge from septic systems as well as infiltrating precipitation and surface water. Few wells are finished in the shallow aquifer, most wells are drilled through the shallow aquifer to the deep sand and gravel aquifer (Unit 4). The nature of the 75-140 foot-thick deposit (Unit 3) separating Units 2 and 4 is of particular interest as it forms the confining layer between the aquifer systems. Unit 3 is continuous in the south, however it has been suggested that it may thin and vary to the north resulting in permeable "windows" between the aquifers. The depth below land surface to both the water table and the potentiometric surface ranges from 4-17 ft and groundwater in both systems generally flows to the southwest (Figure 3). The shallow groundwater seems to be influenced by irrigation. Both the water table and groundwater temperature fluctuate seasonally, high groundwater and highest temperatures coincide with peak flow in the irrigation ditch in late August/early September (Figures 4 and 5).

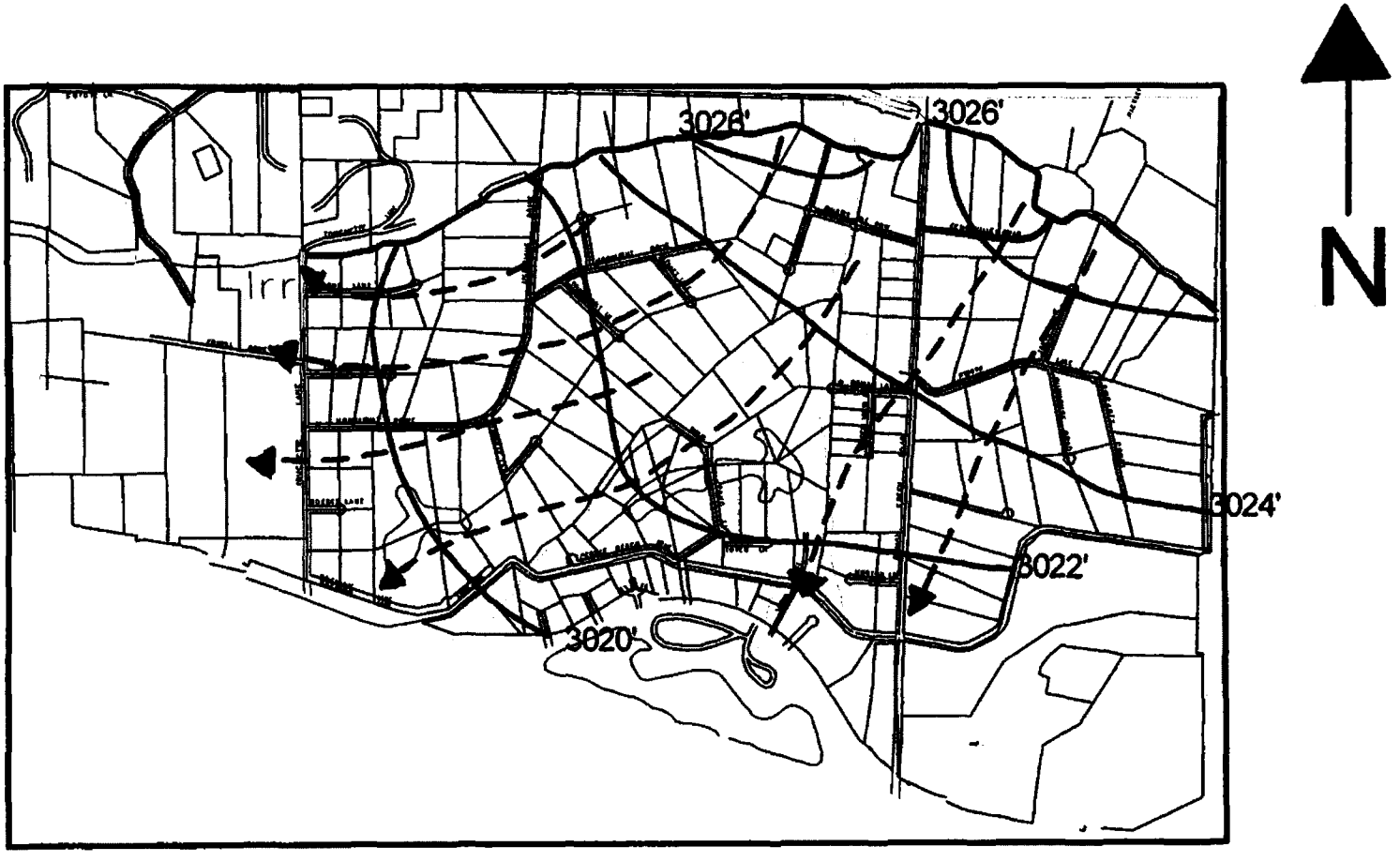

Figure 3. Regional Groundwater Flow Direction June, 1993 (Lambert, 1996).

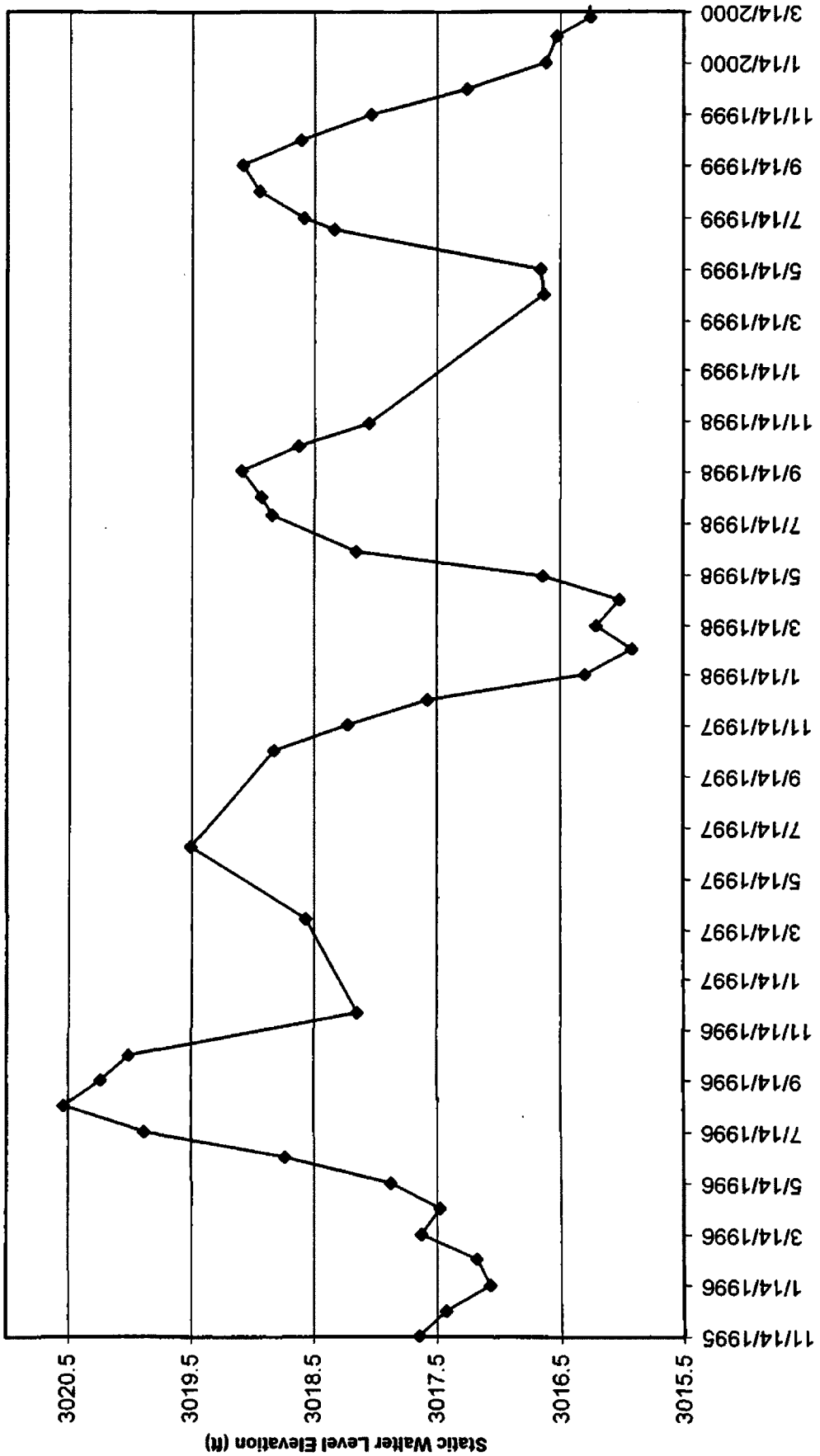

Figure 4. Hydrograph of the Shallow Aquifer.

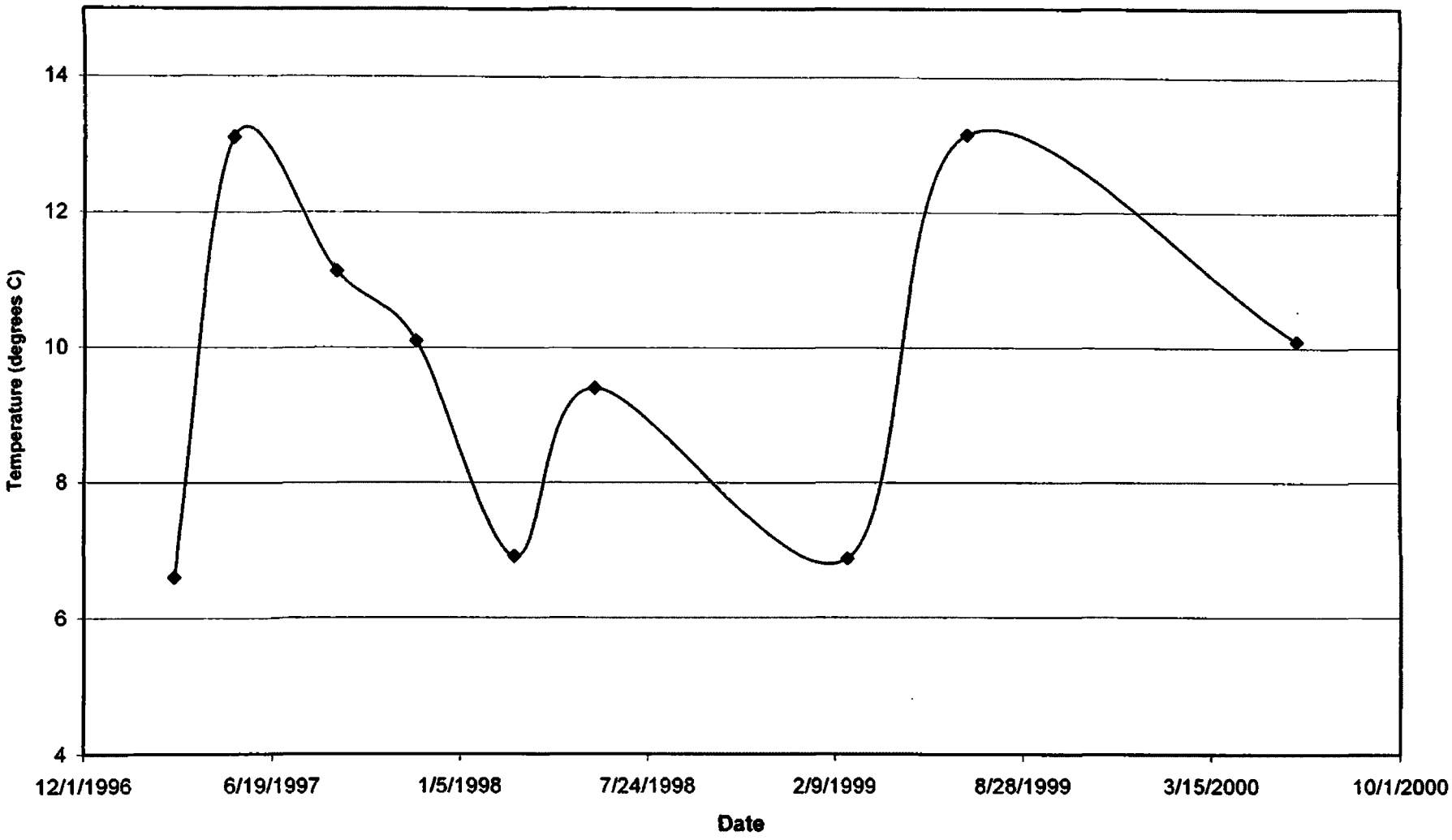

Figure 5. Temperature vs. Time - Touchette Well

A bacterial contamination issue was brought to light in September of 1986 when residents along Larson Lane (NW corner of Section 28) began to report that groundwater levels were as much as two feet higher than normal, as evidenced by the ponding groundwater adjacent to the Frenchtown Irrigation Ditch (MCCHD, 1986). Concerned that the high groundwater was resulting in inadequate separation distances between the water table and septic drainfields, the Health Department conducted eight rounds of bacterial sampling of wells in the area from 1986 to 1999. The proportion of wells showing contamination varied from 16% to 66% during the eight sampling rounds (Figure 6). As a result of the earliest sampling, the Missoula City County Health Department ceased issuing subsurface sewage disposal permits on October 3, 1986 within the SMA (MCCHD, 1986). The cause of the high groundwater was unknown, but was thought to be due to either a broken headgate on the northern irrigation ditch near lot 28-24A or to dredging of the irrigation ditch earlier in the year (MCCHD, 1987). The ban on new septic permits was lifted later in October of 1986, however only lots platted prior to the SMA could be issued permits. The sampling also showed that rates of contamination are highest in late summer and early autumn, coinciding with seasonally high groundwater (Figure 4). No apparent spatial pattern to the contamination was observed and only a few wells consistently tested positive or negative. More frequently, a well will test positive in one round of sampling, then negative in the next round of sampling, then positive again, and vice versa. Despite the inconsistent nature of the contamination, 50% of all wells ever sampled have tested positive for coliform bacteria at least once (Figure 7). This can be compared with the 15-19% average rate of coliform contamination in unsewered areas of Missoula County (MCCHD, 1996).

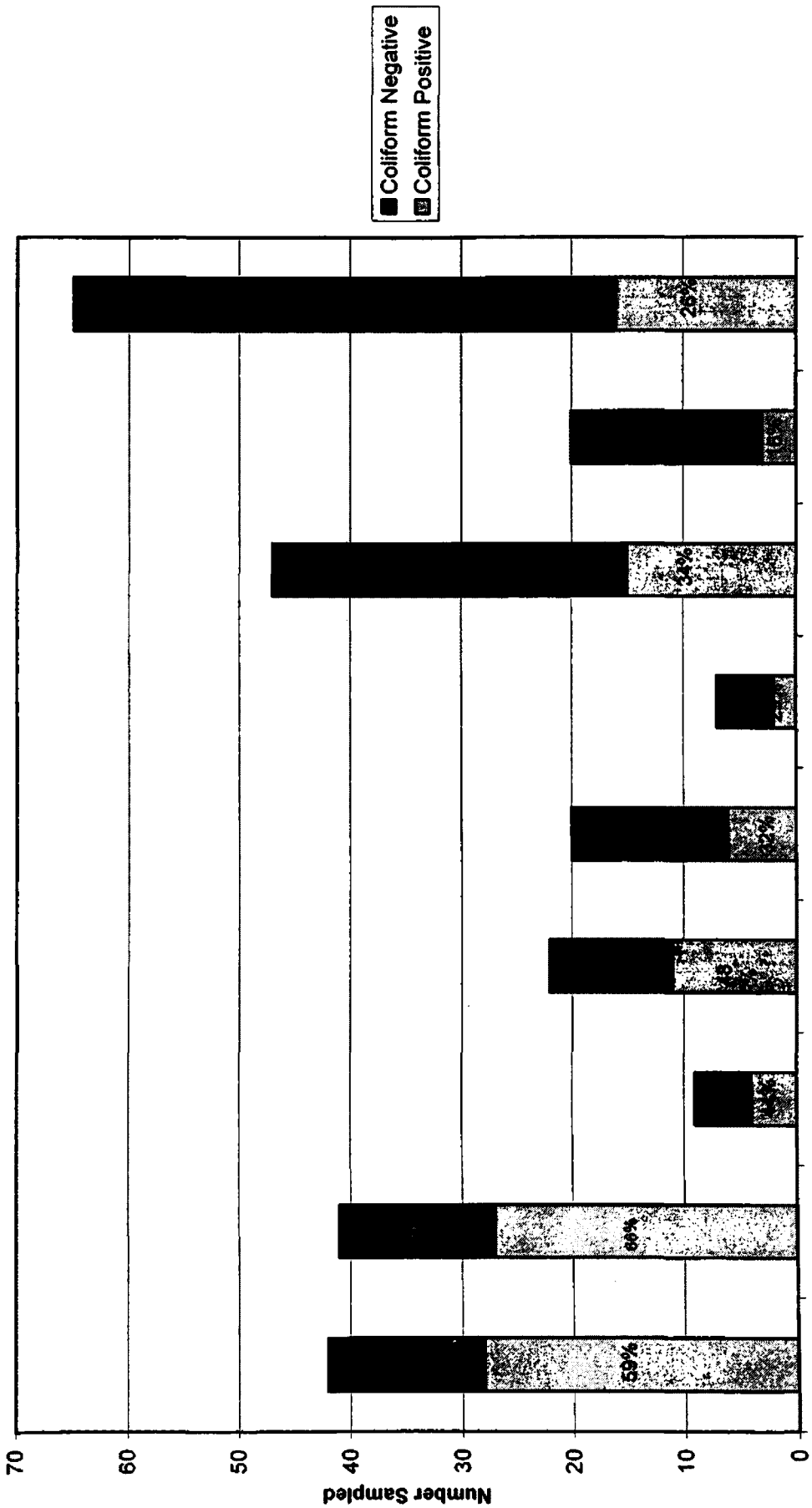

Figure 6. Coliform Sampling Events

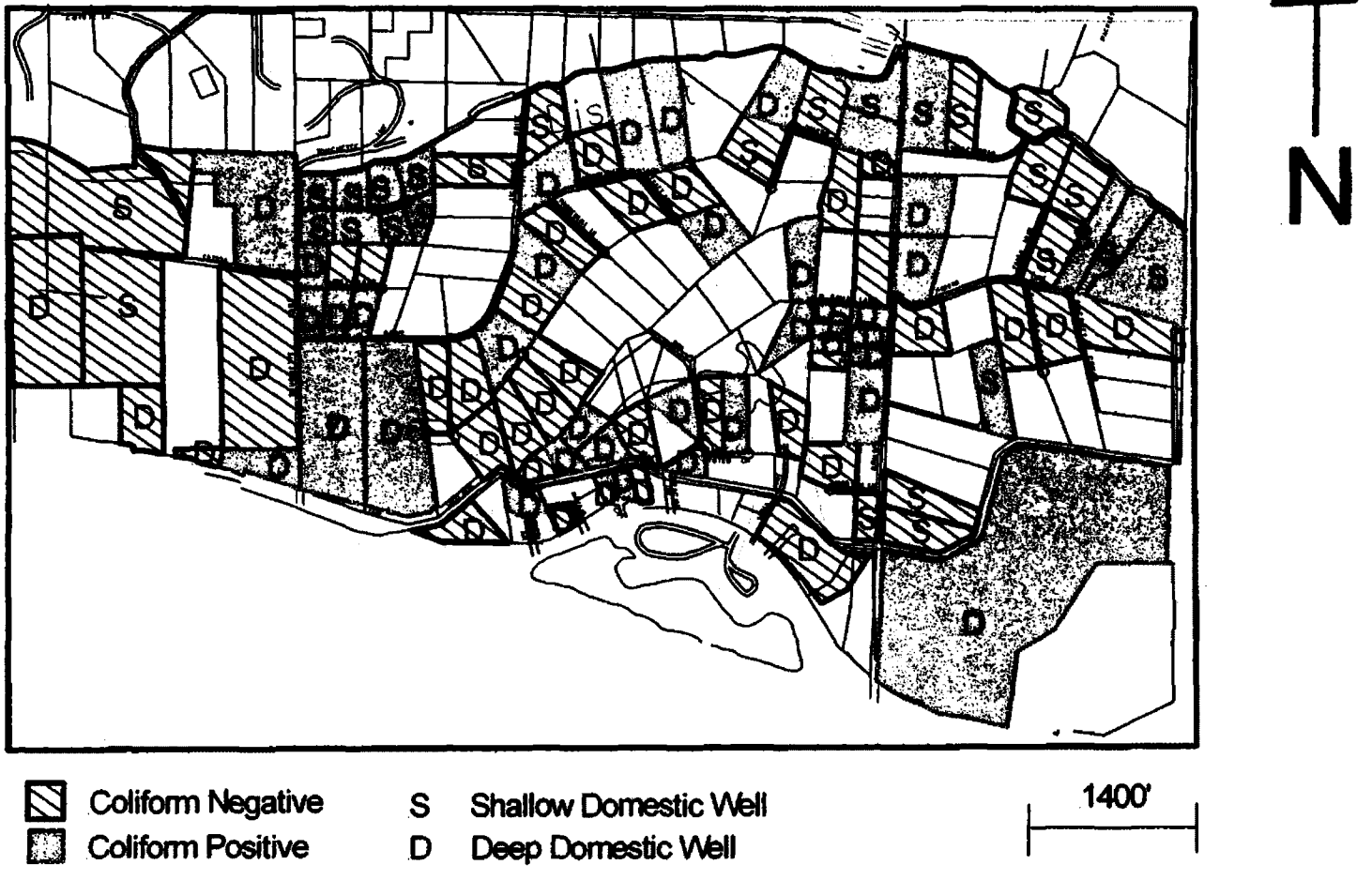

Figure 7. Distribution Of Coliform In All Wells Sampled At Least Once From 1986-1999

CHAPTER 4: METHODS

A primary step in resolving the issue of microbial contamination at the study site is to identify all potential sources. Possible sources include septic system effluent, surface water exfiltration from streams, irrigation ditches and ponds, a natural soil/groundwater bacteria population, and the groundwater distribution systems (Figure 8). Both shallow wells in the area, finished at depths of 25-30 feet, and the more common deep wells, finished at depths of 170-190 ft, show signs of bacterial contamination (Appendix A). This study focused on a site-specific investigation of bacterial contamination based on the approach outlined in Figure 9. Driller's logs for domestic wells were inventoried and wells were classified as either being deep or shallow. The classification was based on cross-sections from this and previous studies. Water levels were measured and fluctuations were monitored to establish periods of high and low water table. Domestic wells and surface water sources were sampled for total/fecal coliforms during both high and low water table, and for gross chemistry during high water table. Speciation of coliforms was performed in order to identify possible natural populations.

Next, a site-specific investigation was performed to gather further information about the shallow groundwater system. Three sites were selected, instrumented with multi-level wells, and sampled (multi-level wells, domestic wells, and potential sources) during both seasonal high and low water table. Well samples were compared to potential source samples to evaluate which, if any, sources were contributing to contamination of the shallow groundwater and subsequently, domestic wells. Next, potential pathways by

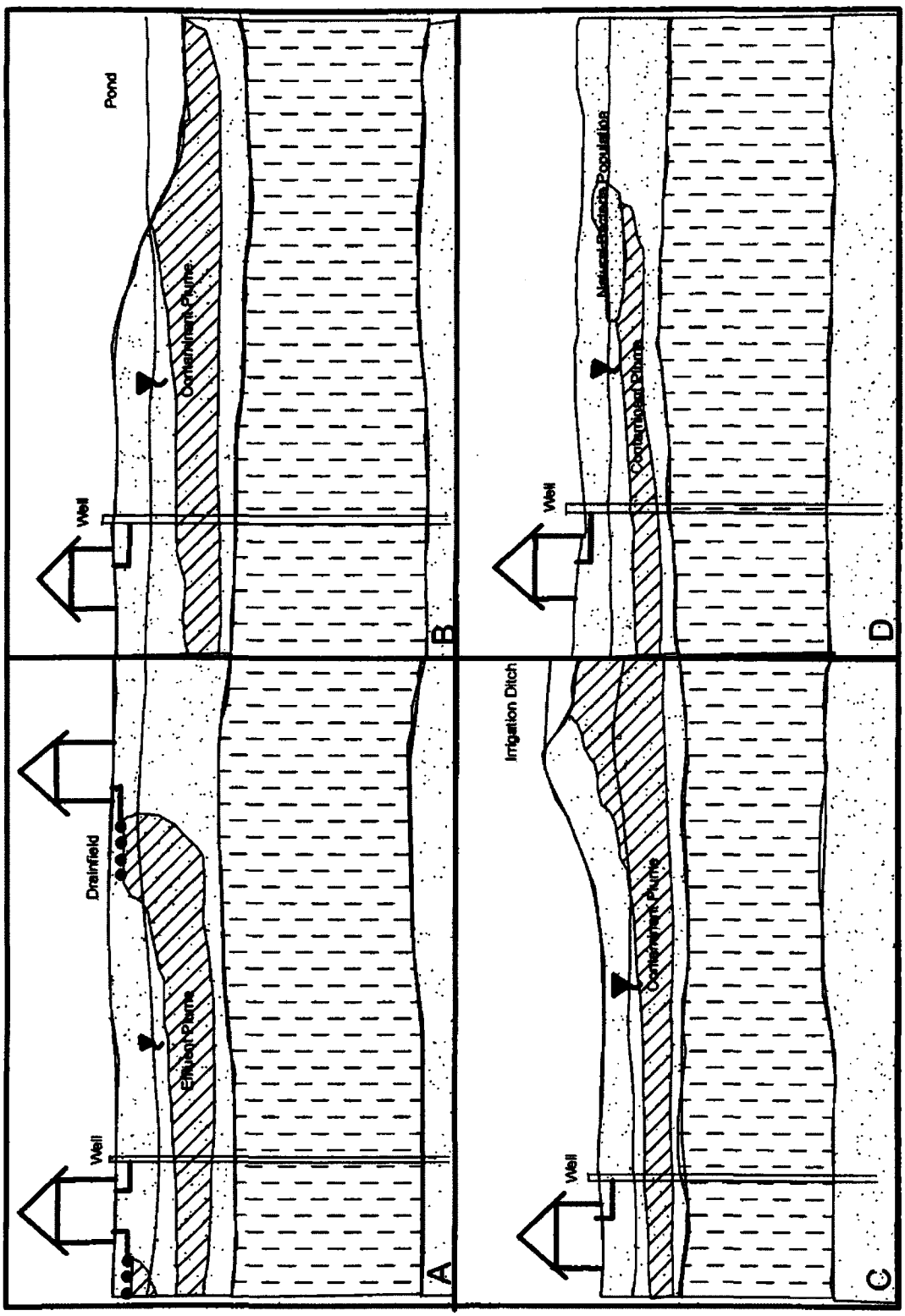

Figure 8. Potential Sources Of Bacterial Contamination To Groundwater Systems.

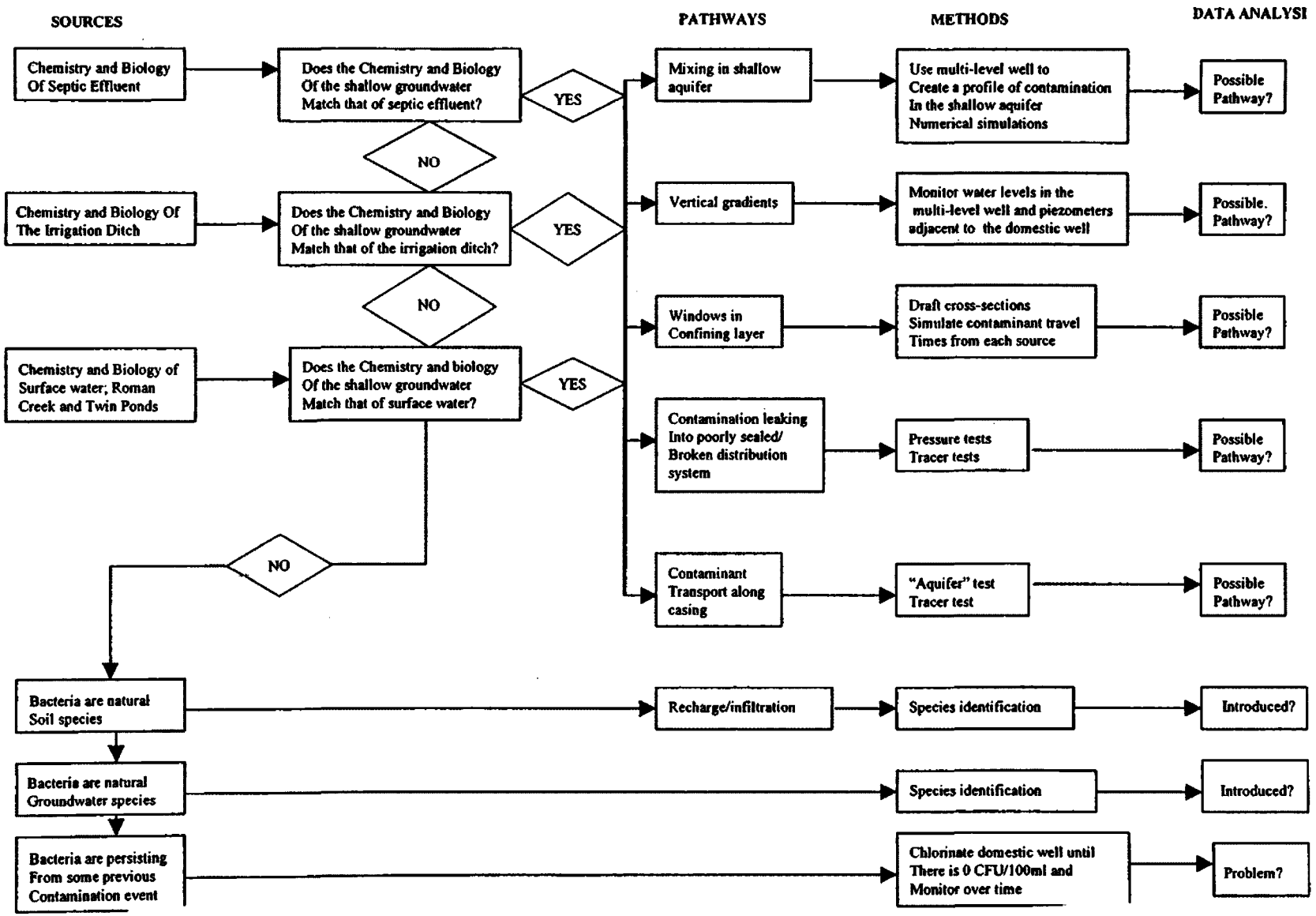

Figure 9. Flowchart illustrating the interpretive logic used in the site-specific investigation.

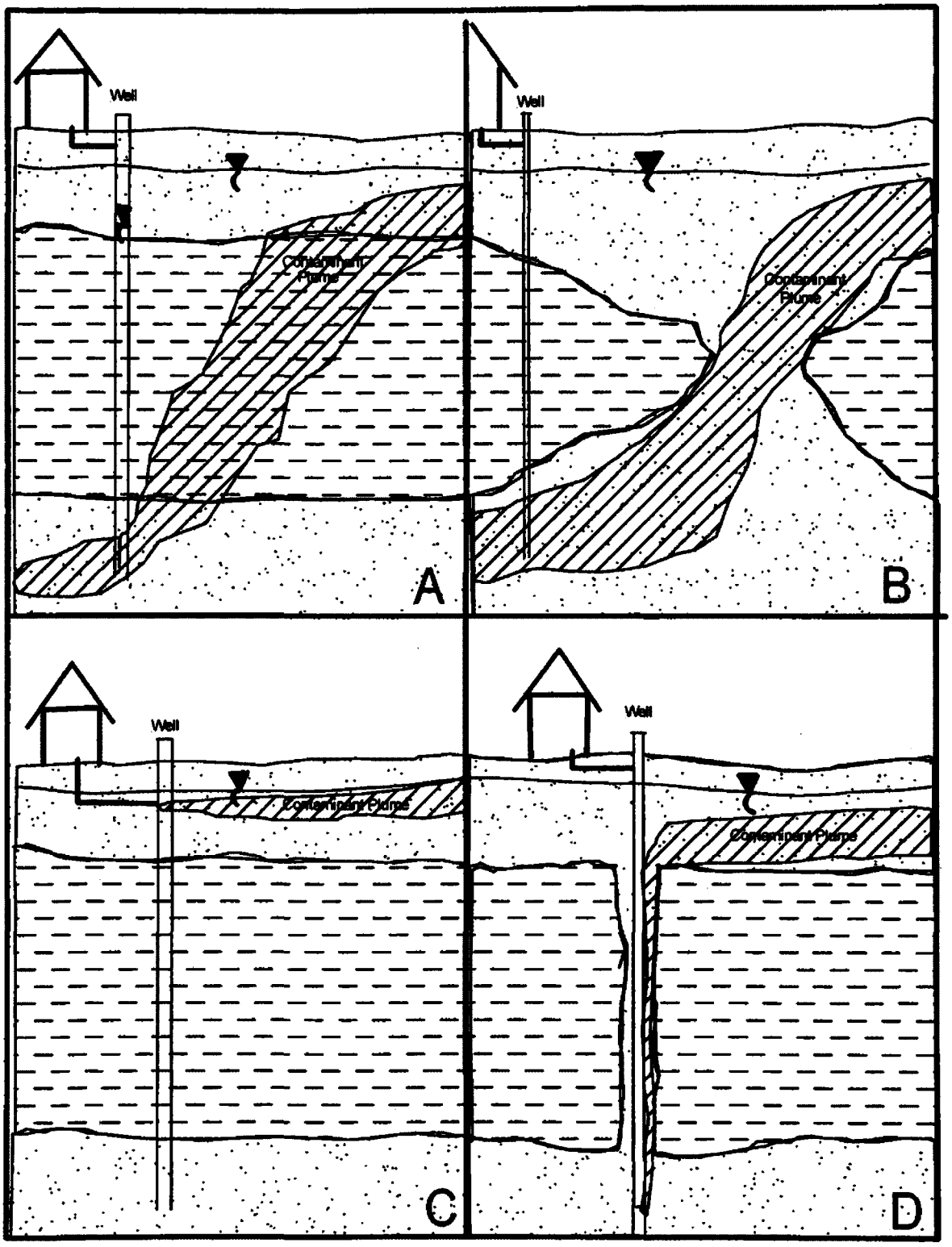

Figure 10. Potential Pathways By Which Contamination Reaches Deep Domestic Wells

which contaminated shallow groundwater reaches deep domestic wells were evaluated (Figures 9 and 10). Pathway analysis involved the use of multi-level well samples, species identification, cross-sections, pumping tests, tracer tests, and numerical simulations.

Cross-Sections

In order to identify and locate potential windows in Unit 3 and to gain a better understanding of the aquifer systems, cross-sections were drafted based on driller's logs. A line of section was selected on a basemap, and the driller's logs and top of casing elevations were obtained for all wells along that line. The depths below the top of the well casing and thickness of stratigraphic units were plotted on with a horizontal scale of 1:280, 1:500, and 1:800 and a vertical scale of 1:32. This yielded vertical exaggerations of 9X, 16X, and 25X. Once the wells along the line of section were plotted, stratigraphic units were correlated. Cross-sections were drafted for one east/west line and two north/south lines.

Water Level Measurement

All multi-level and domestic wells (of unknown elevation) were surveyed for vertical control. Domestic wells that were surveyed in previous Health Department studies (using a Missoula county benchmark) served as benchmarks for this study. Casing elevations can be found in Appendix A. Water level measurements were taken with an electric sounder during seasonal high water table (August/September, 1999) and seasonal low water table (March, 2000) (Slope Indicator Company). Water level measurements were taken from multi-level wells in May, June, and August 2000. Complete methodology for water level measurement can be found in Appendix B.

Sampling Protocol

Water samples from domestic wells were drawn from either the frost-free hydrant or the spigot closest to the well. This was done in order to ensure that the water did not pass through a filter, softener, or other purification device. The hydrant/spigot was turned on and any stagnant water in the well casing was purged for 10-15 minutes. Following the purge, the hydrant/spigot was disinfected with 70% isopropyl alcohol prep pads until no dirt/rust was present on the pads. Water was then purged for two additional minutes to rinse away alcohol residue. Samples for water chemistry were collected in clean bottles provided by Murdock Environmental Lab at the University of Montana. The bottles were first rinsed with water to be sampled and then filled and capped.

Microbiology samples were collected in sterile bottles provided by the MCCHD using standard techniques (APHA, 1992). Bottles were not rinsed as they were amended with sodium thiosulfate (used to neutralize chlorine ions). The bottles were filled and then capped. All samples were immediately placed on ice in a cooler following collection.

Surface water samples were collected from Roman Creek (between lots 28-6A and 28-8D, Appendix A), the northern and southern irrigation ditches (at the intersection with Touchette Lane, Appendix), and the eastern pond along Twin Pond Lane (at site 28-5B1, Appendix A). Samples for water chemistry were collected in clean bottles provided by Murdock Environmental Lab. The bottles were first rinsed with water to be sampled and then filled with a depth-integrated sample and capped. Microbiology samples were collected in sterile bottles provided by the MCCHD using standard techniques (APHA, 1992). Bottles were not rinsed as they were amended with sodium thiosulfate (used to

neutralize chloride ions). The bottles were filled with a depth-integrated sample and then capped. All samples were immediately placed on ice in a cooler following collection.

Sample Analysis

Samples for water chemistry were taken to Murdock Environmental Laboratory within 48 hours for analysis. Any necessary filtration of samples for gross chemistry was done in the laboratory. Cation concentrations in each sample were quantified using EPA method 200.7. Anion concentrations were quantified using EPA method 300. The Alkalinity of each sample was determined through the use of an alkalinity titration. Standard QA/QC procedures such as field blanks, duplicates, and spikes were used.

Samples for microbial analysis were taken to the MCCHD lab. All samples were analyzed for total and fecal coliform using a presence/absence test (IDEXX, Inc.). Total and fecal coliform concentrations were quantified through a most probable number technique using a Quanti-Tray®. For QA/QC purposes, duplicates were run on 10% of the samples and a total coliform membrane filter method was used on 5% of the samples. Species identification was performed on 14% of the samples using the prepackaged API 20E system from bioMerieux Vitek, Inc. Complete details concerning bacterial analysis and species identification can be found in Appendix C.

Characterization of the Shallow Groundwater System

Site Selection

As little was known about the shallow groundwater system, three sites from the study group were chosen for detailed examination. Two of these sites were instrumented to evaluate how septic systems and water table position effected the water quality and one served as a control site. Locations of domestic wells relative to septic drainfields and

surface water were inventoried, based on Health Department Records and interviews with residents, and plotted on a site map. Next, water table elevations were plotted and groundwater flowpaths generated from previous investigations at this site (Figure 11). Final sites were selected based on historical contamination rates and resident interest (Figure 12).

Multi-Level Well Construction and Installation

Multi-level well design was modified from Pickens, et al. (1981). The main piezometers of the instruments were constructed from two lengths of 0.50-inch diameter CPVC pipe. Multi-level sampling ports consisted of 0.25-inch (outer diameter) polyethylene tubing attached to the outside of the CPVC using plastic cable ties. Holes were drilled over the lower inch of all piezometers and ports to increase the open area, and nylon mesh was used to prevent blockage of the "screened" intervals. Complete instrument construction details can be found in Appendix D.

On selected sites, multi-level wells were installed up-gradient from domestic wells and down-gradient from septic drainfields using a Geoprobe®. Casing was driven to a depth of 20 ft below land surface and was then drawn back so that the bottom of the piezometer was finished at a depth of seven feet below the water table. Boreholes were packed with Colorado Silica to a depth of four feet below land surface and with bentonite from a depth of four feet to land surface. Completions consisted of either one-inch PVC or cap standing one foot above land surface or of a flush-mounted two-inch PVC adaptor/plug. All instruments were disinfected with a 10% chlorine bleach solution following installation. Complete installation details can be found in Appendix D.

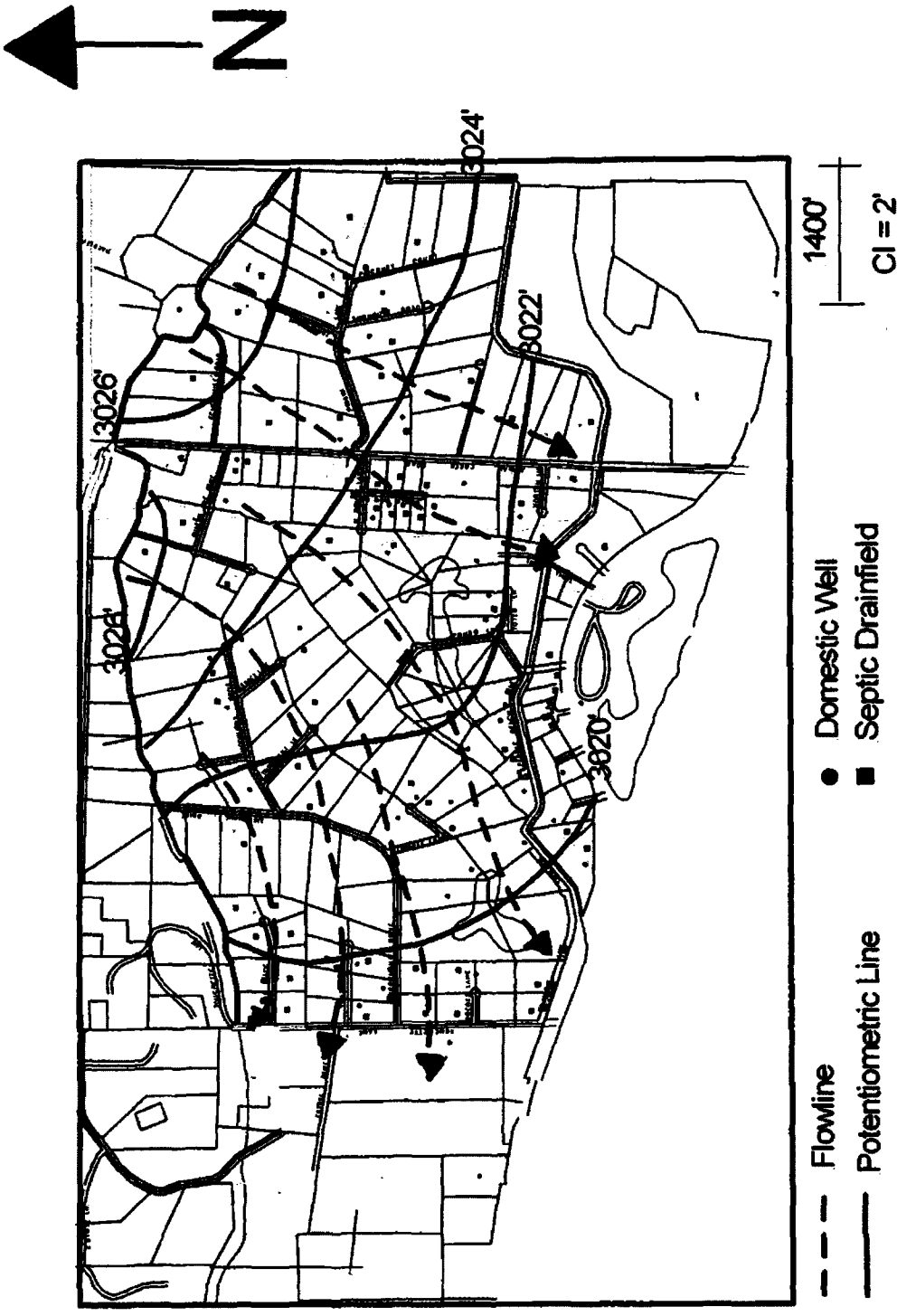

Figure 11. Locations of Domestic Wells and Septic Drainfields Within the SMA

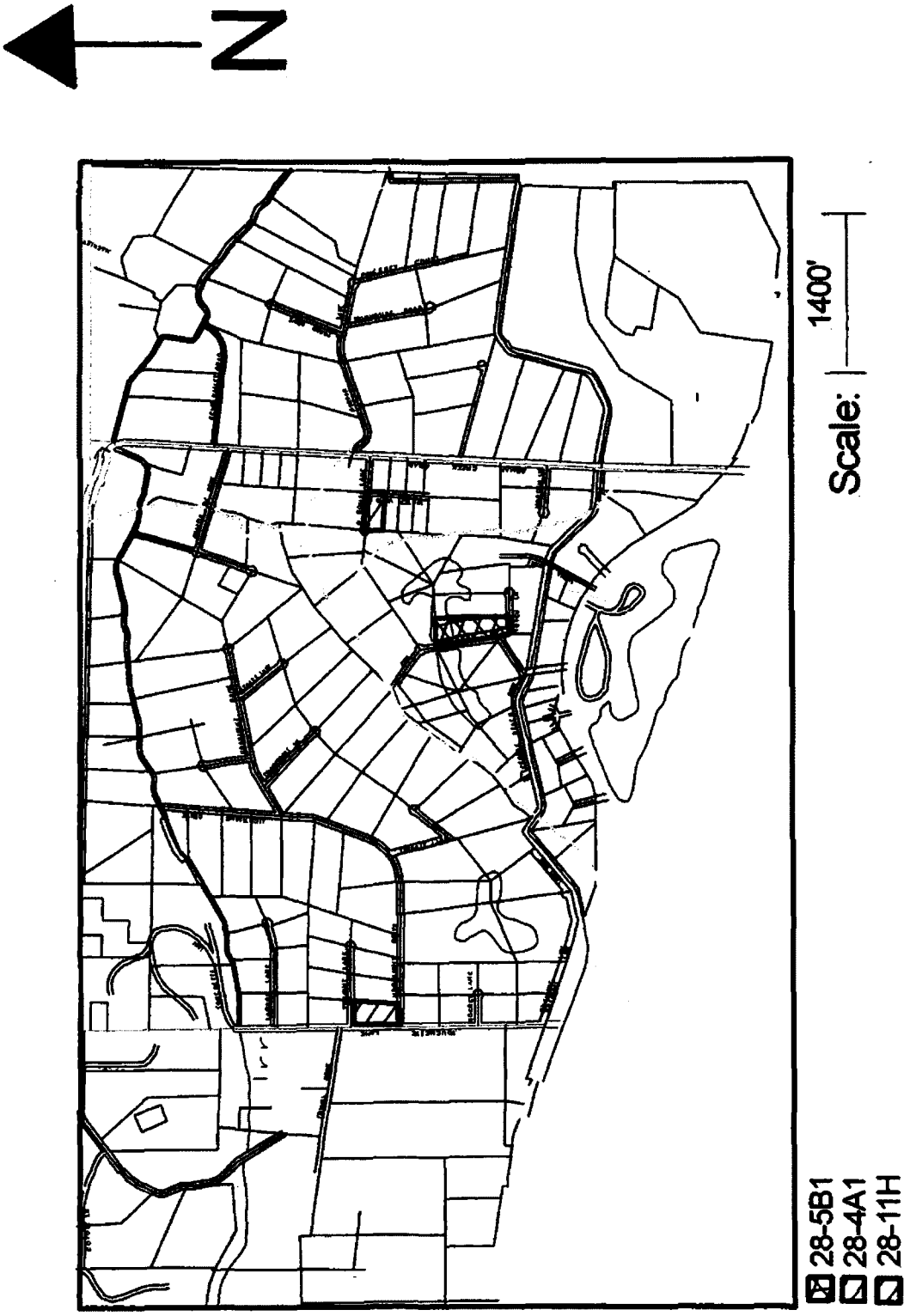

Figure 12. Location of Sites Chosen For Instrumentation.

Multi-Level Well Sampling Protocol

Multi-level wells were sampled using a peristaltic pump and sterile flexible 0.25" Masterflex® tubing attached to the polyethylene ports. Since the CPVC piezometer portion of the multi-level wells have a larger diameter than the tygon tubing, 20' of 0.25" polyethylene tubing was disinfected by washing with a 70% isopropyl alcohol solution and placed down the piezometer portion of the well. Water was then purged from the ports for approximately 10 minutes. During the purge time two to three measurements of pH, temperature, and conductivity were taken using a Corning™ Electrochemistry Meter. Samples for water chemistry were collected in clean bottles provided by Murdock Environmental Lab. The bottles were first rinsed with water to be sampled and then filled and capped. Microbiology samples were collected in sterile bottles provided by the MCCHD using standard techniques (APHA, 1992). Bottles were not rinsed as they were amended with sodium thiosulfate (used to neutralize chloride ions). The bottles were filled and then capped. All samples were immediately placed on ice in a cooler following collection.

Pathway Analysis

Pumping Tests

Traditional aquifer tests are performed to obtain values for hydraulic properties of the aquifer (Lohman, 1992). Drawdown tests were performed in the SMA only to test the hypothesis that shallow groundwater was being drawn into distribution systems of domestic wells finished in the deep aquifer. Static water level measurements were taken in the domestic well and the multi-level well adjacent to the domestic well. Next, the frost-free hydrant or spigot was turned on so that the pump would begin drawing down

water in the well casing. Additional hydrants/spigots were turned on as was necessary to maintain pump activity. Immediately after the pump switched on, water level measurements were taken in the domestic well and the well piezometer every 0.5 minutes for 20 minutes. After twenty minutes elapsed, measurements were taken every minute for 20 minutes. Water level measurements were taken every five to ten minutes after 40 minutes elapsed. Pumping rate was measured every ten minutes during the drawdown test. Hoses attached to the running hydrant(s)/spigot(s) were run to a five gallon bucket. The time required to fill the bucket was measured and the pumping rate was calculated in gallons per minute. The drawdown tests continued until the water level in the domestic well reached steady state.

Tracer Test

A tracer test was performed at site 28-11H (Figure 12) to further test the hypothesis that shallow groundwater was being drawn into the distribution system of the domestic well through short circuits in the distribution/plumbing system. The tracer used was sodium chloride and conductivity measurements were the method of tracer detection using Corning Electrochemsitry and HACH meters. Background concentration of total dissolved solids in the SMA was approximately 150 ppm producing a background conductivity of approximately 300 μS. Ideal tracer concentration would be high enough to be detected and dense enough so that the tracer is not easily diluted or dispersed. Desired concentration of the tracer was one order of magnitude higher than background, or 10,000 ppm, yielding a conductivity of 20,000 μS/cm in a 55-gallon drum. Initial attempts at the tracer test indicated that 55 gallons of tracer would take an unreasonable amount of time to gravity drain. As it was desired that the tracer be injected as a slug, the

amount of NaCl required to yield a conductivity of 20,000 μS/cm in 55 gallons of water (1.89 kg) was added to a five-gallon bucket. This resulted in a tracer concentration of 100,000 ppm with a conductivity of 200,000 μS/cm.

At the onset of the tracer experiment, static water levels were measured in the domestic well and the well piezometer. Two frost-free hydrants were turned on so that the pump would switch on and remain on during the entire experiment. A flow-through cell was attached to one of the hoses from the hydrant so that conductivity measurements could be taken with a HACH® Conductivity Meter. Water level and conductivity measurements were taken periodically after the onset of the experiment. Once the cone of depression in the domestic well reached steady state, the tracer was injected. Twenty feet of polyethylene tubing was placed down the piezometer portion of the multi-level well. A section of tygon tubing ran from the bucket containing the tracer to the polyethylene tubing, allowing the tracer to gravity drain. Tracer injection took 4.45 minutes. Following tracer injection, conductivity measurements from the domestic well were taken every five minutes. Water level measurements were taken from the domestic well and the well piezometer every ten minutes. The tracer experiment continued for 120 minutes following tracer injection.

Numerical Simulations

In order to estimate bacterial transport and travel times through the groundwater systems, simple numerical simulations were run for site 28-11H (the only domestic well that was coliform positive during the site-specific investigation) (Figure 12). The model grid was 1000 ft by 1000 ft with a nodal spacing of 25 ft. The model had three layers of varying thickness based on drillers logs. Layer 1 (Units 1 & 2) was 20 ft thick, layer 2

(Unit 3) was 160 ft thick, and layer 3 (Unit 4) was 40 ft thick. A horizontal hydraulic conductivity of 800 ft/d was assigned to layer 1 (Lauerman, 1999). Hydraulic conductivities of 1.00 ft/d and 700 ft/d for layers 2 and 3 respectively were based on averages cited in Fetter (1994) for silty sand and sand and gravel. Vertical hydraulic conductivity values one-tenth the magnitude of the horizontal hydraulic conductivities were assigned to all layers. Initial boundary conditions were based on a worst-case scenario where only a vertical (no horizontal) hydraulic gradient of 0.038 ft/ft existed between the upper and lower aquifers. This value was derived from field measurements of water levels in domestic and multi-level wells. Constant head cells served as the boundary conditions for layers 1 and 3 and were set at the elevations measured for the shallow and deep aquifers in August 2001 (seasonal high groundwater). Heads for layers 1 and 3 were set at 3018.00 ft and 3012.00 ft respectively. No flow cells were assigned as the boundary conditions in layer 2. When a well was used in a simulation, it was screened in layer 3 and pumped at a rate of 10.00 gallons per minute. A particle was added to layer 1 adjacent to the domestic well to simulate the transport of bacteria. Groundwater flow and particle transport were simulated using MODFLOW and MODPATH as formulated in Visual Modflow (WHI, 1999).

The first two simulations involved the use of all initial conditions with and without a pumping well (Figure 13a). This was done to evaluate bacterial travel times under a best-case scenario. The next simulations were used to evaluate bacterial transport time to the domestic well in the presence of a corridor of high hydraulic conductivity along the well casing. Vertical hydraulic conductivity along the casing in layer 2 was

varied from 10 ft/d, to 1000 ft/d, to 1000000 ft/d. These simulations were run both with and without a pumping well (Figure 13b).

The next simulations added horizontal hydraulic gradients to layers 1 and 3. Gradients used were those measured from the shallow and deep aquifers in August 2001 (0.0014 ft/ft and 0.00076 ft/ft respectively). Constant head cells were set for the east and west boundaries for layers 1 and 3 based on the hydraulic gradients and no flow cells were used as the north and south boundary conditions for layers 1 and 3 as well as for all boundaries for layer 2. The first two simulations were run using the initial properties set in the model with and without a pumping well (Figure 13c). The next simulations were run to estimate bacterial transport to the domestic well in the presence of a leaky corridor along the well casing both with and without a pumping well (Figure 13d). Vertical hydraulic conductivities were varied from 10 ft/d, to 1000 ft/d, to 1000000 ft/d.

The final simulations were run to evaluate bacterial transport times to domestic wells in the presence of a leaky pitless adaptor opening in layer 1. Layer 1 was broken up into five layers of equal thickness and a small screened interval was added to the domestic well below the water table. The first two simulations were run using only a vertical hydraulic gradient both with and without a pumping well (Figure 13e). The final simulations were run in the presence of both a horizontal and vertical hydraulic gradient both with and without a pumping well (Figure 13f).

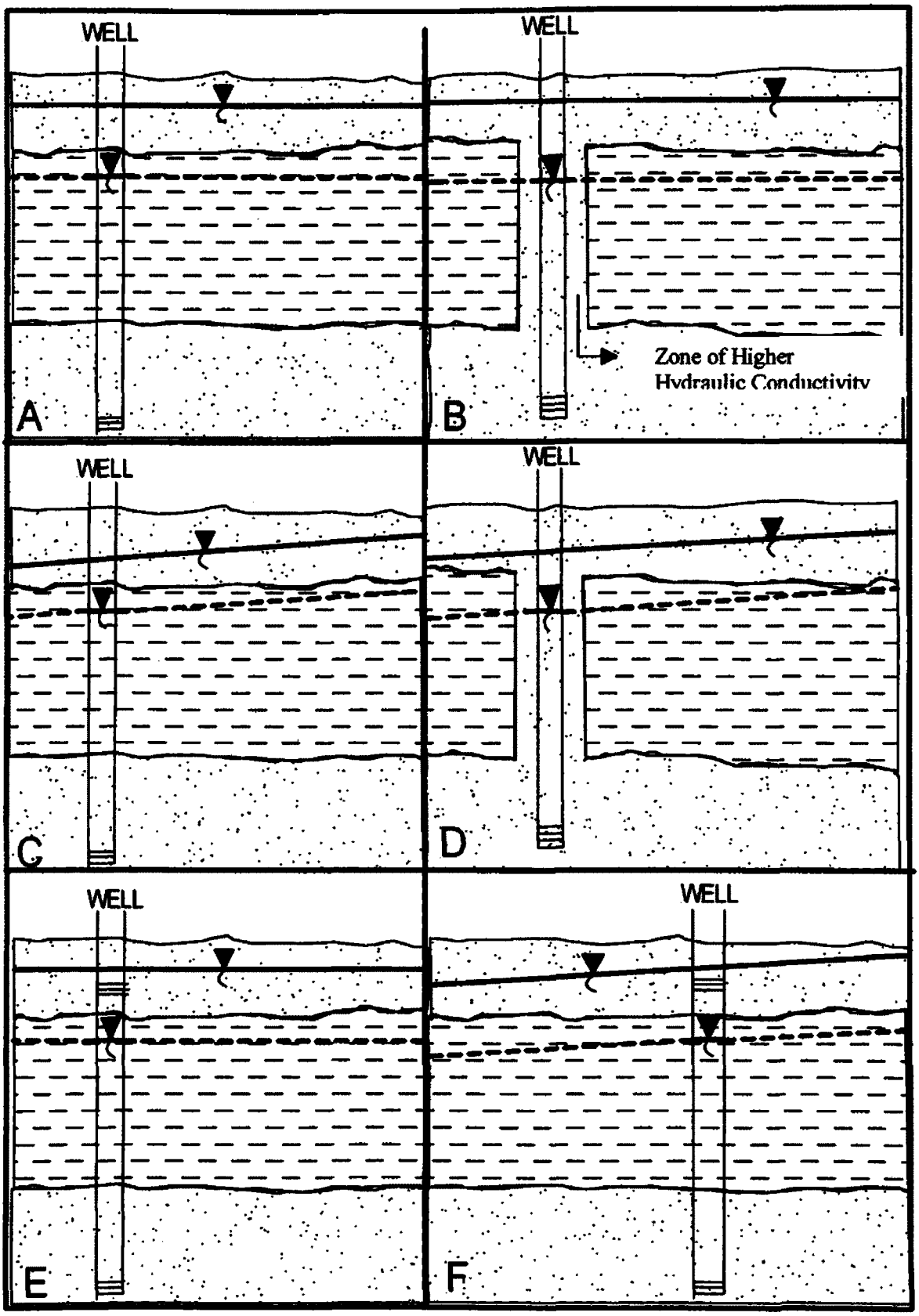

Figure 13. Conceptual Models Used In Numerical Simulations

CHAPER 5: RESULTS

Stratigraphic Results

Cross sections were drafted along three lines in the SMA, two North/South and one East/West (Figures 14, 15, 16, and 17). Well logs were fairly consistent along the East/West and North/South lines. The upper aquifer (Unit 2) consists of sand and gravel with some clay lenses, and is about 20 feet thick. The next layer (Unit 3) is recorded as predominantly sand on well logs, but is actually closer to silty sand - sand. Local lenses of clay and very little gravel exist and the layer ranges in thickness from 19-150 ft. Unit 3 does thin to the north (as recorded on well log 28-21A2 and 28-13A2), but there is no indication that the layer pinches out to the north, nor is there any indication of the presence of a continuous window of high conductivity material on the 56 well logs reviewed. Unit 4 consists of sand and gravel of an unknown thickness, as none of the wells completely penetrate this layer.

Water Level/Potentiometric Results

Water level measurements were taken from domestic wells in August 1999 and March 2000. Water levels in the shallow aquifer were highest in late summer/early autumn and lowest in late winter/early spring, while water levels fluctuations in the deep aquifer were negligible (Figure 4). A complete database of water level results can be found in Appendix A. In August 1999, groundwater in the shallow aquifer generally flowed to the southwest, although there was a stronger southerly flow in the eastern portion of the SMA (Figure 18). The average hydraulic gradient across the SMA was 0.0014 ft/ft during this sample period. In March 2000, groundwater flowed south/southwest across the SMA with a hydraulic gradient of 0.0011 ft/ft (Figure 18).

Figure 14. Location of Lines-Of-Section.

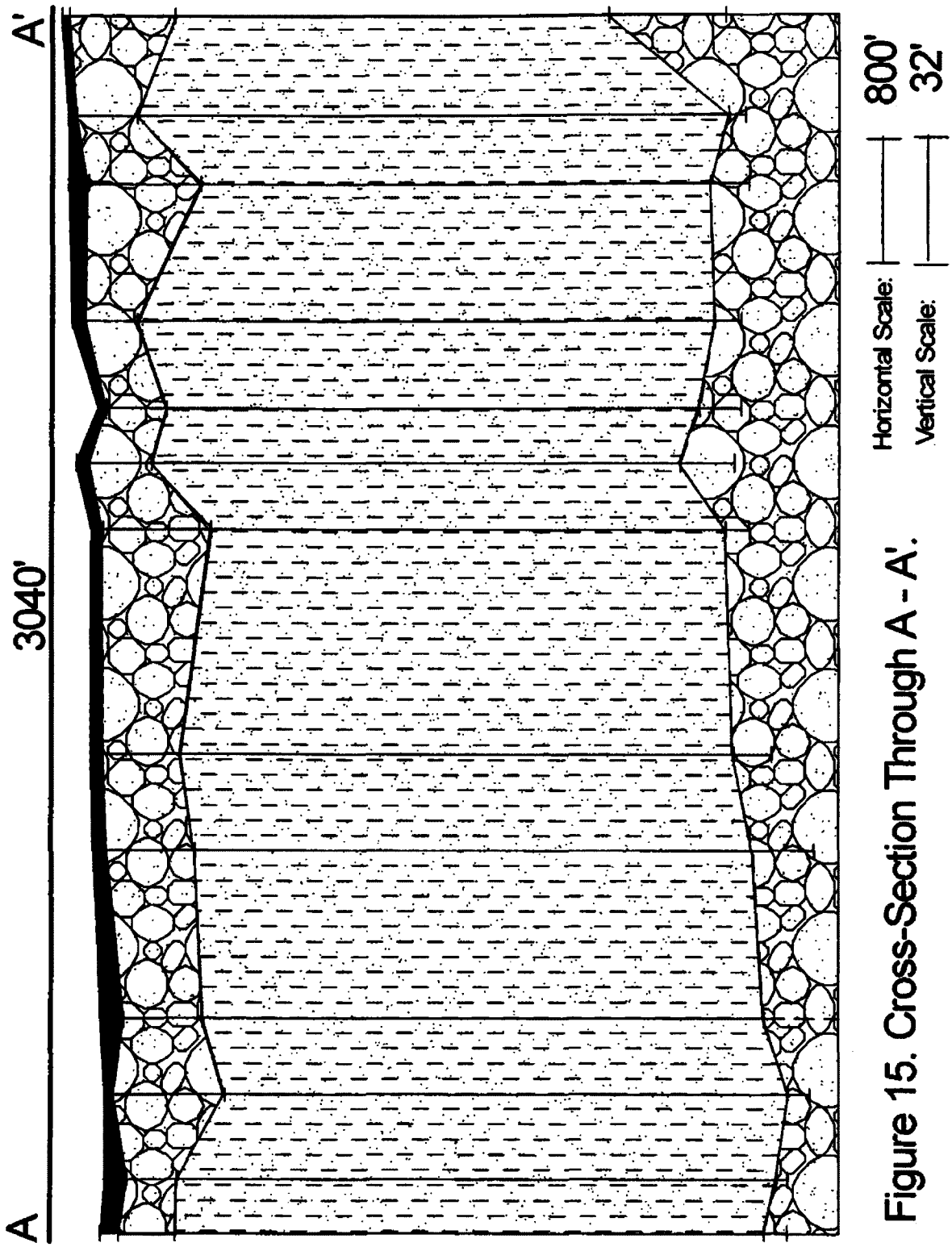

Figure 15. Cross-Section Through A - A'.

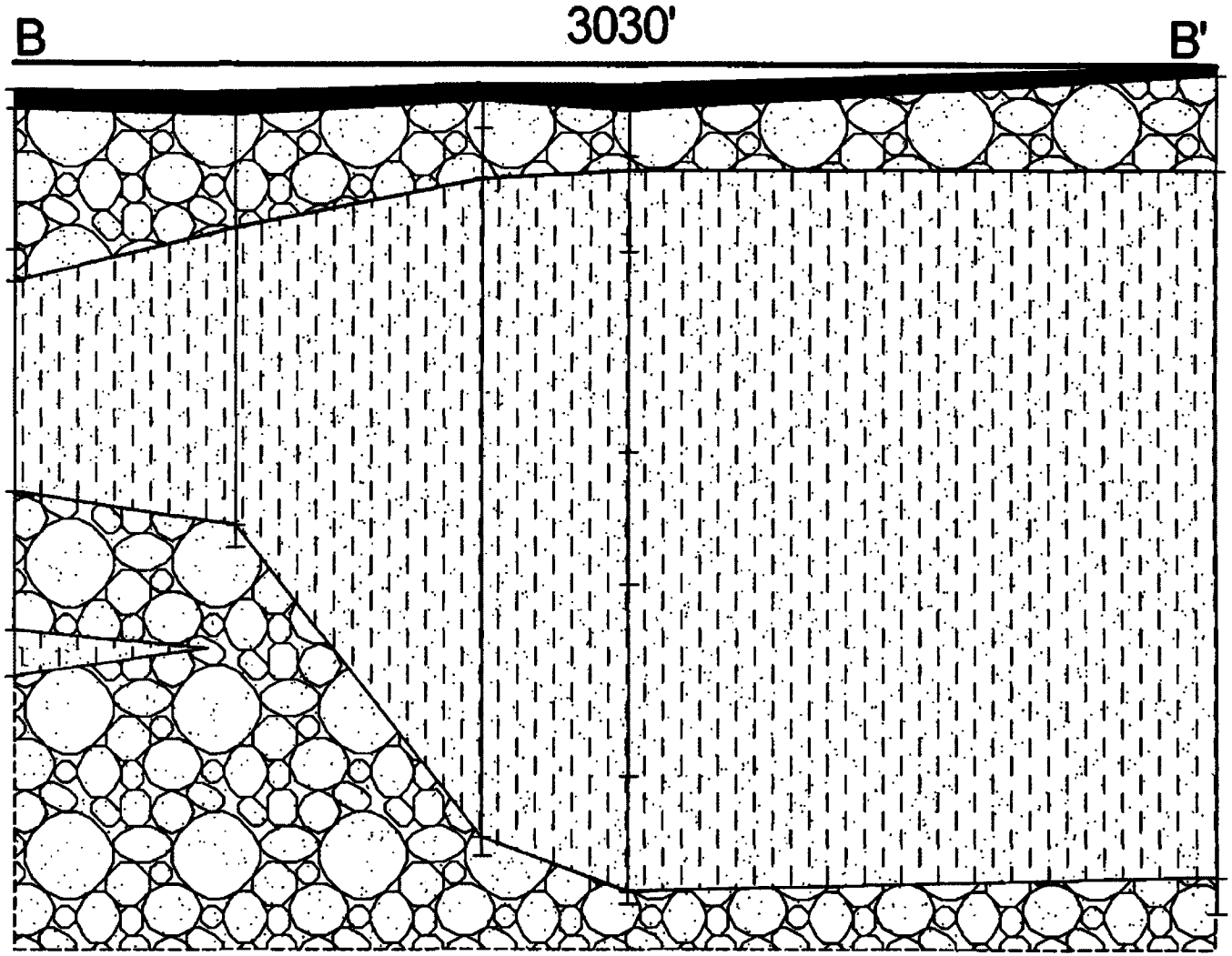

Figure 16. Cross-Section Through B - B'

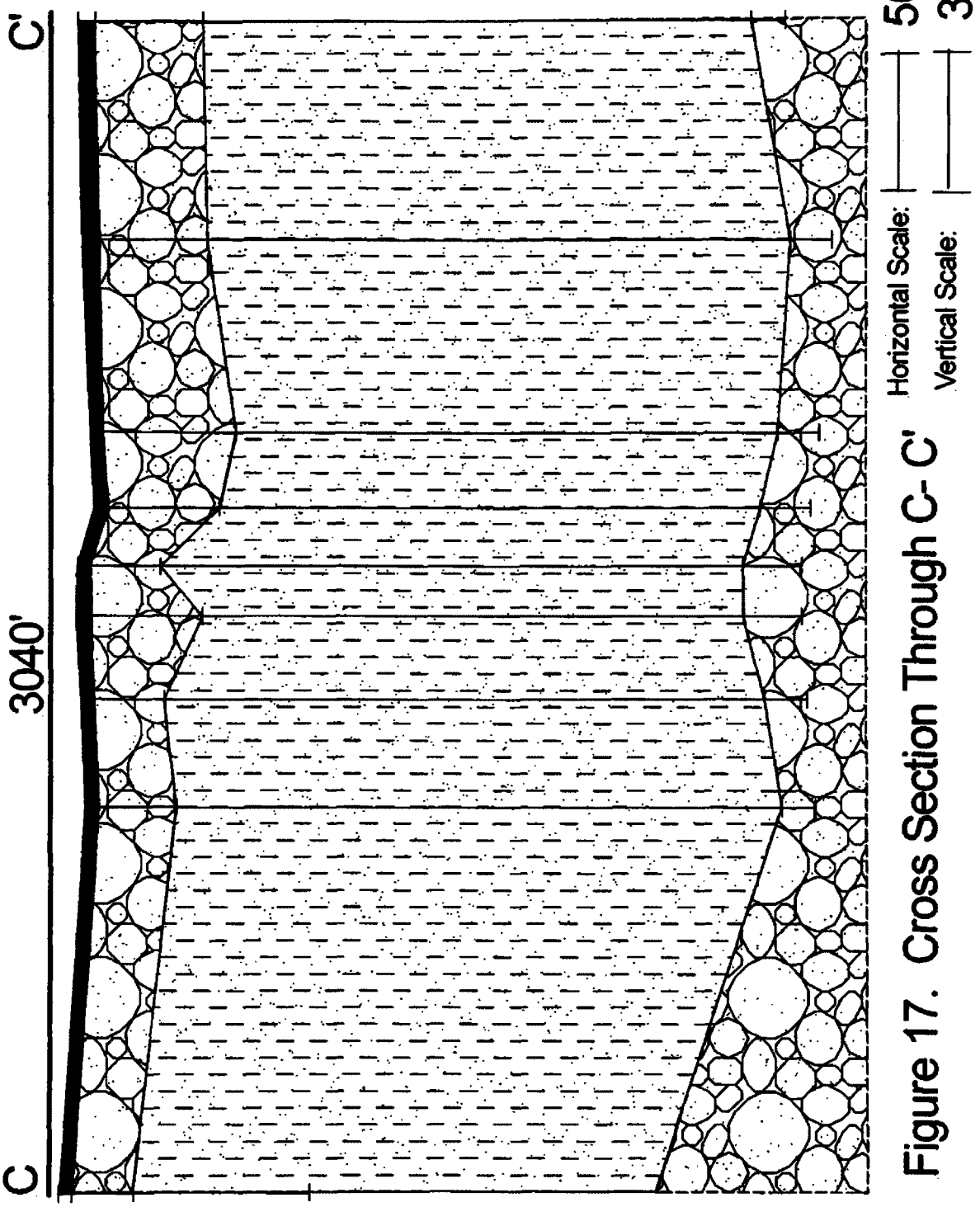

Figure 17. Cross Section Through C- C'

Although the flow direction and hydraulic gradients did not vary significantly, it is interesting to note that actual water level measurements fluctuated as much as seven feet between season high and low water table.

Groundwater in the deep aquifer flowed west across the SMA with a hydraulic gradient of 0.00076 ft/ft during August 1999 and with a hydraulic gradient of 0.00057 ft/ft during March 2000 (Figure 19). Divergent flow was present in the south-central portion of the SMA during both August 1999 and March 2000. This pattern can most likely be attributed to either the presence of a zone of lower conductivity material or a thinning of the deep aquifer.

The presence of vertical hydraulic gradients between the two aquifer systems was investigated in May, June, and August 2000 using project installed piezometers adjacent to the domestic wells (Table 3). Water levels taken immediately after instrument installation showed the presence of an average upward vertical gradient between the shallow and deep aquifers of 0.012 ft/ft (Table 3). As the water table in the shallow aquifer rose during the summer, the trend shifted from an upward gradient to an average downward vertical gradient of 0.043 ft/ft (Table 3). Upward vertical gradients likely persist throughout most of the year. The seasonal rise in the water table during late summer months brings about the change in gradient. The length of time that the downward gradient exists is most likely proportional to the length of time the water table remains at an elevation greater than approximately 3016 ft (a level higher than the potentiometric surface). As the potentiometric surface remains fairly constant (average fluctuations are +/- 0.25

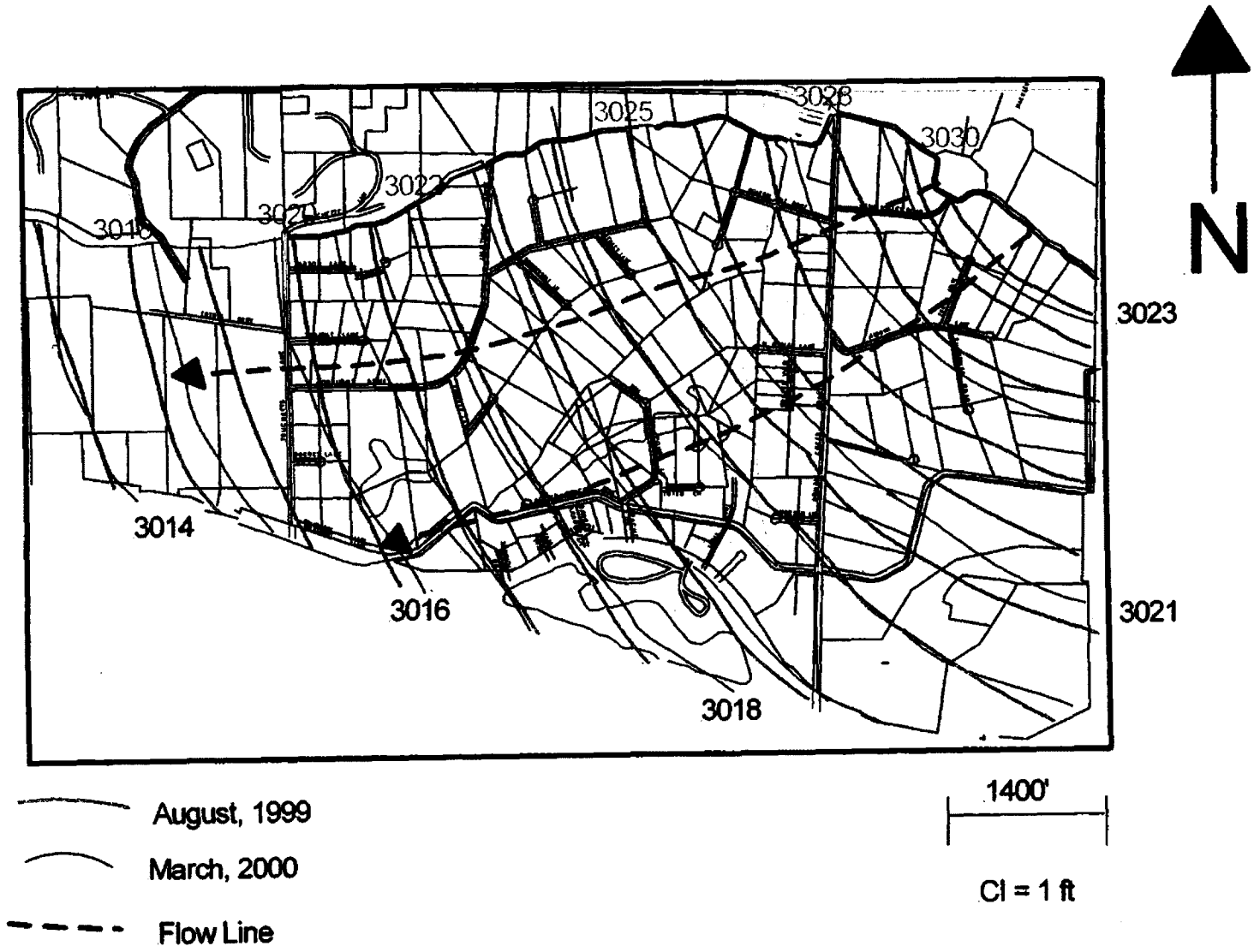

Figure 18. Water Table Map of the Shallow Aquifer

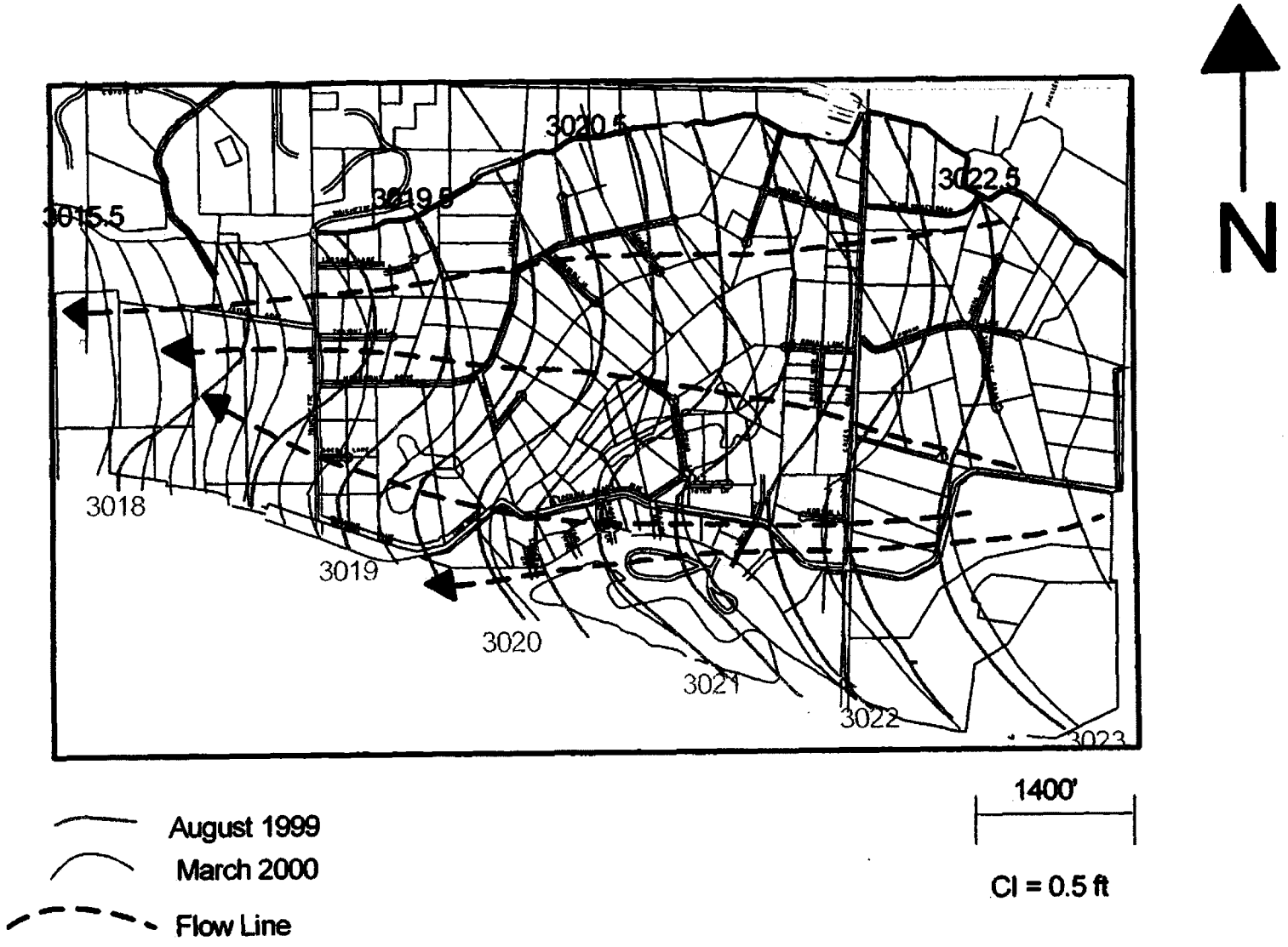

Figure 19. Potentiometric Map of the Deep Aquifer

ft), the magnitude of the vertical gradient is dependent on water table fluctuations. The more extreme the fluctuations are (positive or negative) the larger the vertical gradient will be.

Table 3. Elevation Data (in feet) For Domestic Wells and Multi-Level Wells on Instrumented Sites

WELL	TOC	DATE	DTW	POT	DATE	DTW	POT	Depth	Gradient
4A1-DW	3035.32	7-Jun	16.8	3018.52	16-Aug	18.9	3016.47	174	0.049
4A1-W	3033.29	7-Jun	8.29	3025.00	16-Aug	9.10	3024.19	17.0	
4A1-S	3033.37	7-Jun	10.3	3023.06	16-Aug	10.2	3023.19	18.8	
5B1-DW	3034.21	17-May	14.9	3019.31	15-Aug	19.1	3015.10	178	0.043
5B1-W	3032.78	17-May	12.1	3020.69	15-Aug	10.9	3021.90	19.0	
5B1-S	3027.38	29-Jun	6.78	3020.60	15-Aug	5.22	3022.16	19.7	
POND				3021.42					
11H-DW	3027.69	17-May	11.8	3015.89	15-Aug	15.7	3012.00	175	0.038
11H-W	3025.63	17-May	8.17	3017.46	15-Aug	7.68	3017.95	19.0	
11H-S	3026.72	17-May	8.83	3017.89	15-Aug	8.09	3018.63	19.0	

TOC = Top Of Casing Elevation
DTW = Depth to Water Below the TOC
POT = Elevation of either the Water Table or Potentiometric Surface
Depth = Total Depth of Domestic or Multi-Level Well
Gradient = Downward Vertical Hydraulic Gradient (ft/ft) Between the Shallow and Deep Aquifers on Instrumented Sites

WATER QUALITY SAMPLING RESULTS

Domestic Wells

These data will be discussed by first presenting the sampling results during a period of high water table and then the results of sampling during a period of low water table.

Bacterial Results – High Water Table

Sixty-five domestic wells in the SMA were sampled for total and fecal coliforms during seasonal high water table, from August 16 to August 26, 1999. A complete database of results can be found in Appendix E. Of the 65 wells sampled, 16 tested

positive for total coliforms using the Quanti-Tray® MPN analysis, yielding a 25% contamination rate (Figure 20). No fecal coliform contamination was found during this sampling round. The average coliform concentration found in the wells that tested positive for total coliform ranged from 1.000 to >200.5 Colony Forming Units (CFU)/100 mL and averaged 53.04 CFU/100 mL. Three sites had concentrations higher than 150.0 CFU/100 mL, and one site had coliform concentrations that were too numerous to be counted by the MPN method used.

In order to test the reliability of the presence/absence method, fourteen contaminated domestic wells were randomly selected for total coliform membrane filter (TCMF) analysis. In most cases, the initial result was confirmed. There were two exceptions. Site 28-6C1 (Appendix A) tested positive for total coliform during the initial sampling with a concentration of 13.70 CFU/100 mL, however there was no growth on the plate for the TCMF analysis. This well was resampled twice and analyzed using both the QT and TCMF methods. None of these samples tested positive for total or fecal coliform using either method. Site 27-8D tested negative for total/fecal coliform in the initial sampling round (Appendix A). When a TCMF analysis was conducted, one large pink colony grew on the plate. The site was sampled two more times and analyzed using both methods, however neither samples tested positive for total coliform. These inconsistencies can most likely be attributed to inadvertent contamination either in the lab or in the field or due to true variations in the field conditions.

Nine of the wells from the initial study group (of 65 wells) were selected for coliform speciation using the API 20E system. Seven of these sites were coliform positive and two sites were coliform negative. The samples were first plated on mEndo

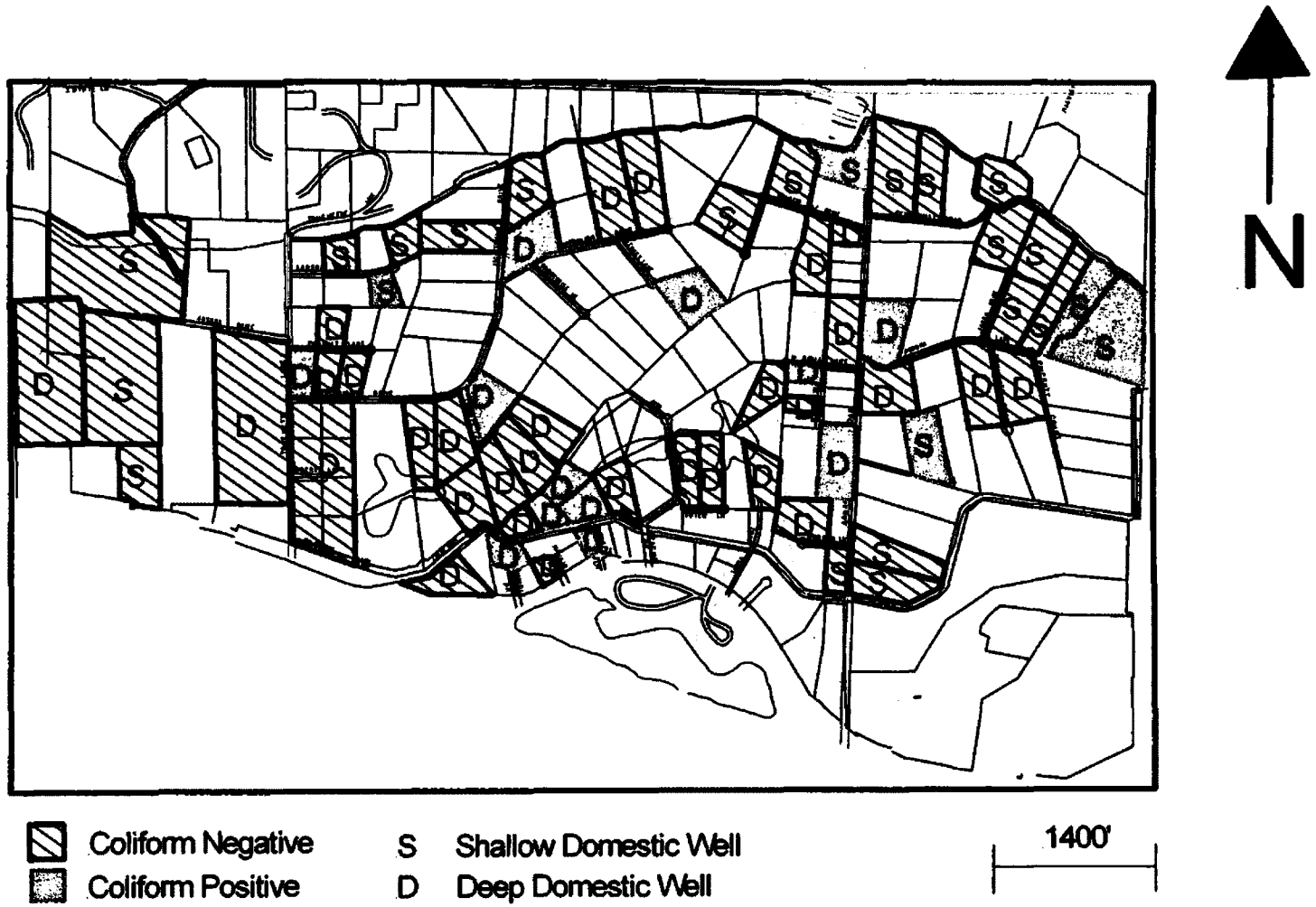

Figure 20. Sample Distribution, August 1999

using the TCMF technique. After incubation for 24 hours, four colony morphologies were found: colonies with a green sheen, colonies that were dark red, colonies that were dark pink with a thin colorless rim, and colorless colonies. All but the colorless colonies were counted as total coliforms. No fecal coliform confirmation test was done, as the speciation served as the confirmation. Red colonies from six samples were speciated using the API method. Three yielded doubtful or unreliable profiles (Table 4). Three of the samples produced the same identification code, which yielded no discrimination of species. The bacteria were either species of the Enterobacter or Citrobacter genera. Green sheen colonies from five samples were speciated (Table 4). Two samples yielded very good identification of Serratia fonticola and Citrobacter braakii and three samples yielded good identification of Citrobacter braakii and Enterobacter intermedius. Pink colonies from three samples were speciated (Table 4). One sample yielded an acceptable identification of Chromobacterium violaceum. Two sampled resulted in no discrimination among Serratia liquefaciens, Serratia marcescens, Serratia fonticola, Enterobacter aerogenes, Citrobacter koserii-farmerii, or Kluvera species. Colorless colonies from two samples were speciated (Table 4). Both samples yielded a doubtful or unreliable profile.

In addition to the domestic wells, both the north and south irrigation ditches were sampled for coliforms. The concentrations were 860.0 and 610.0 CFU/100 mL respectively. The majority of the colonies were either green sheen or pink, but a few red colonies were also present on the plates. When speciation with the API 20E system was attempted, all colonies yielded unreliable or doubtful profiles. The inconclusive results

Table 4. Speciation Results For Samples Taken From Domestic Wells in August 1999.

RED COLONIES			
Site	**Id Code**	**Id Accuracy**	**Species**
28-7A	3304553	No Discrimination	Enterobacter cloacae, Citrobacter braakii,
			Enterobacter amnigenus 2
28-11H	3304553	No Discrimination	Enterobacter cloacae, Citrobacter braakii,
			Enterobacter amnigenus 2
28-2A2B	3304553	No Discrimination	Enterobacter cloacae, Citrobacter braakii,
			Enterobacter amnigenus 2
28-6B	3046121	Doubtful Profile	N/A
27-2B1	3046123	Doubtful Profile	N/A
27-4B2	1046120	Unreliable Profile	N/A
GREEN SHEEN COLONIES			
Site	**Id Code**	**Id Accuracy**	**Species**
28-2A2B	5104753	Very Good Id	Serratia fonticola
27-4B2	3744573	Good Id	Citrobacter braakii
27-2B1	3704553	Very Good Id	Citrobacter braakii
27-7D	1104553	Good Id	Enterobacter intermedius
28-7A	1104553	Good Id	Enterobacter intermedius
PINK COLONIES			
Site	**Id Code**	**Id Accuracy**	**Species**
27-7D (1)	5304763	No Discrimination	Serratia liquefaciens, Serratia marcescens,
			Serratia fonticola, Enterobacter aerogenes
27-4B2	2242000	Acceptable Id	Chromobacterium violaceum
27-7D (2)	1144173	No Discrimination	Cluvera spp., Citrobacter coserii-farmerii
COLORLESS COLONIES			
Site	**Id Code**	**Id Accuracy**	**Species**
28-2B1D	2042120	Doubtful Profile	N/A
27-4B1	0000000	Unreliable Profile	N/A

could be due to the fact that this system is generally used for clinical samples, and is not as accurate for environmental isolates.

Inorganic Chemistry Results – High Water Table

Twenty-three domestic wells from the study set were randomly sampled and analyzed for chemical indicators of septic effluent contamination during seasonal high water table, from August 16 to August 26, 1999. Samples were taken from wells with depths ranging from 28 ft to 184 ft. Chloride concentrations ranged from 0.720-2.53 mg/L, with an average of 1.56 mg/L in deep wells and from 1.05-2.23 mg/L with an average of 1.66 mg/L in shallow wells (Table 5). Fluoride concentrations ranged from 0.0600-0.210 mg/L, with an average of 0.110 mg/L in deep wells and from 0.0100-0.190 mg/L with an average of 0.110 mg/L in shallow wells (Table 5). Nitrate concentrations ranged from levels below the detection limit of 0.0100 mg/L to 0.950 mg/L, with an average of 0.360 mg/L in deep wells and from below the detection limit to 0.510 mg/L with an average of 0.290 mg/L in shallow wells (Table 5). Sulfate concentrations ranged from 5.48-15.00 mg/L, with an average of 9.58 mg/L in deep wells and from 5.92-15.2 mg/L with an average of 11.0 mg/L in shallow wells (Table 5).

Electrical conductance, temperature, and pH were measured in 44 of the 65 wells in the study set. These measurements were not made on all of the wells due to complications with the electrochemistry meter. The pH measurements ranged from 7.16-8.15 and averaged 7.69 in deep wells (Table 6) and from 6.76-8.47, with an average of 7.34 in shallow wells (Table 7). Electrical conductance ranged from 236-458 µS and averaged 329 µS in deep wells (Table 6) and from 224-577 µS, with an average of 382 µS in shallow wells (Table 7). The highest conductivities were found in the northeastern portion of section 27, where shallow wells are located close to the irrigation ditch. Temperatures ranged from 11.5-14.9°C and averaged 13.3°C in deep wells

Table 5a. Inorganic Chemistry Results From Deep Domestic Wells Sampled in August 1999.

Lot	Cl-	F-	NO_3-	SO_4^{-2}	PH	EC	Temp	Well
	ppm	ppm	ppm	ppm		µS	°C	Depth
27-1A	2.03	0.0600	BD	15.0	N/A	N/A	N/A	75.0
27-2B1	1.45	0.0800	BD	8.84	N/A	N/A	N/A	180
27-7A	1.56	0.0600	0.240	10.8	N/A	N/A	N/A	176
28-2B1B	2.42	0.0700	0.900	13.8	8.15	332	13.4	168
28-4A1	1.48	0.150	0.0600	10.2	7.45	377	13.7	174
28-4A2	1.43	0.0900	0.0900	9.87	N/A	N/A	N/A	174
28-5B1	0.890	0.170	0.410	5.53	7.72	267	12.1	178
28-6C1	1.05	0.180	0.490	6.33	7.69	267	12.6	180
28-8D	2.53	0.0600	0.950	14.4	N/A	N/A	N/A	184
28-11H	0.720	0.180	0.120	5.48	7.77	260	13.2	172
28-6I	1.10	0.0800	0.450	6.52	8.01	268	12.9	176
28-10	2.43	0.110	0.910	14.1	8.13	332	17.7	175
28-20B2	1.60	0.0800	BD	8.96	8.15	410	14.3	175
28-23D	1.24	0.210	BD	5.79	N/A	N/A	N/A	107
29-A'	2.20	0.0700	0.810	12.1	N/A	N/A	N/A	175
28-7A	0.900	0.0800	0.290	5.50	N/A	N/A	N/A	180
AVERAGES	1.56	0.110	0.410	9.58	7.88	314	13.2	166
High	2.53	0.210	0.950	15.0	8.15	410	14.3	184
Low	0.720	0.0600	BD	5.48	7.45	260	12.1	75.0

Table 5b. Inorganic Chemistry Results From Shallow Domestic Wells Sampled in August, 1999.

Lot	Cl-	F-	NO3-	SO4-2	pH	EC	Temp	Well
	ppm	ppm	ppm	ppm		µS	°C	Depth
27-3D	2.11	0.0300	0.510	12.2	N/A	N/A	N/A	46.5
27-8D	1.51	0.190	0.450	14.8	7.00	303	13.6	28.0
27-8C	2.23	0.190	0.480	15.2	N/A	N/A	N/A	30.0
27-7D	1.13	0.170	0.210	10.7	7.56	306	13.5	106
28-18	2.01	0.0100	0.360	8.69	7.44	354	12.6	32.0
28-13A4	1.58	0.0700	BD	9.24	N/A	N/A	N/A	120
29-H	1.05	0.130	BD	5.92	8.48	261	13.2	40.0
AVERAGES	1.66	0.110	0.290	11.0	7.62	306	13.2	57.5
High	2.23	0.190	0.510	15.2	8.48	354	14.3	120
Low	1.05	0.0100	BD	5.92	7.00	261	12.6	28.0

(Table 6) and from 10.1-14.9°C, with an average of 12.9°C in shallow wells (Table 7). The highest measurements of 17.0-18.0°C are erroneous and can most likely be attributed to malfunctions in the probe due to high ambient air temperatures.

Table 6. Electrochemistry Results From Deep Domestic Wells, August 1999.

Lot	Well Depth	pH	Electrical Conductance	Temperature
	ft		µS	°C
27-6A	179	7.47	424	13.0
27-6D	180	7.61	433	12.1
28-2A1	180	7.58	361	13.8
28-2A2B	180	7.95	331	13.3
28-2B1B	168	8.13	328	13.4
28-2B1D	132	7.76	374	13.7
28-3B2	180	7.69	267	12.1
28-4A1	174	7.45	377	13.7
28-4B4	175	7.65	254	13.4
28-5A3	166	7.35	341	14.9
28-5B1	178	7.71	265	12.1
28-5B2	191	7.64	267	12.4
285B4	195	7.71	267	13.2
28-6A	180	7.67	306	13.6
28-6B	203	7.66	302	14.4
28-6C1	180	7.69	267	12.6
28-6C2	180	7.70	262	13.8
28-6I	176	8.04	267	12.9
28-7A	180	7.90	260	13.1
28-7B	174	7.95	303	13.8
28-8A	156	8.06	236	12.7
28-8B	202	8.01	293	12.9
28-10	180	8.06	330	17.7
28-11H	172	7.75	262	13.2
28-14C	115	7.39	436	12.8
28-20A1	178	7.16	350	13.2
28-20A2A	180	7.28	384	12.2
28-20B2	175	8.15	420	14.3
28-24A	120	7.33	422	13.5
28-24D	165	7.68	342	13.7
29-G	250	7.30	459	11.5
Average	176	7.69	329	13.3
Maximum	250	8.15	459	14.9
Minimum	115	7.16	236	11.5

Table 7. Electrochemistry Results From Shallow Domestic Wells, August 1999.

Lot	Well Depth	pH	Electrical Conductance	Temperature
	ft		µS	°C
27-1B	75.0	7.59	385	18.0
27-9	Not Known	7.31	384	10.1
27-3B	45.5	7.35	402	12.4
27-3C	30.0	7.30	448	13.4
27-4A	42.0	7.12	577	11.9
27-4B1	42.5	7.00	559	12.9
27-4B2	42.0	6.76	576	11.2
27-7D	106	7.56	306	13.5
27-8D	28.0	7.00	267	13.6
27-8C	32.0	7.30	291	14.5
28-18	32.0	7.46	343	12.6
28-21A2	52.0	7.16	327	10.1
28-21B1	33.5	7.37	224.	13.5
29-H	40.0	8.47	261	13.2
Average	46.2	7.34	382	12.9
Maximum	106	8.47	577	14.9
Minimum	28.0	6.76	224	10.1

Bacterial Results – Low Water Table

Fifty-three domestic wells were sampled for total and fecal coliforms during seasonal low water table, from March 14 to March 30, 2000. Twelve sites from the original study set of 65 were omitted due to change of property ownership, scheduling conflicts, or lack of resident interest. A complete list of results can be found in Appendix E. Of the wells sampled, only one tested positive for total coliforms (this well tested negative in August 1999) and none tested positive for fecal coliforms, yielding a contamination rate of 2% (Figure 21). Samples were analyzed using a one-bottle presence/absence method, rather than a Quanti-Tray® method, during this sampling round, therefore coliform concentrations were not quantified.

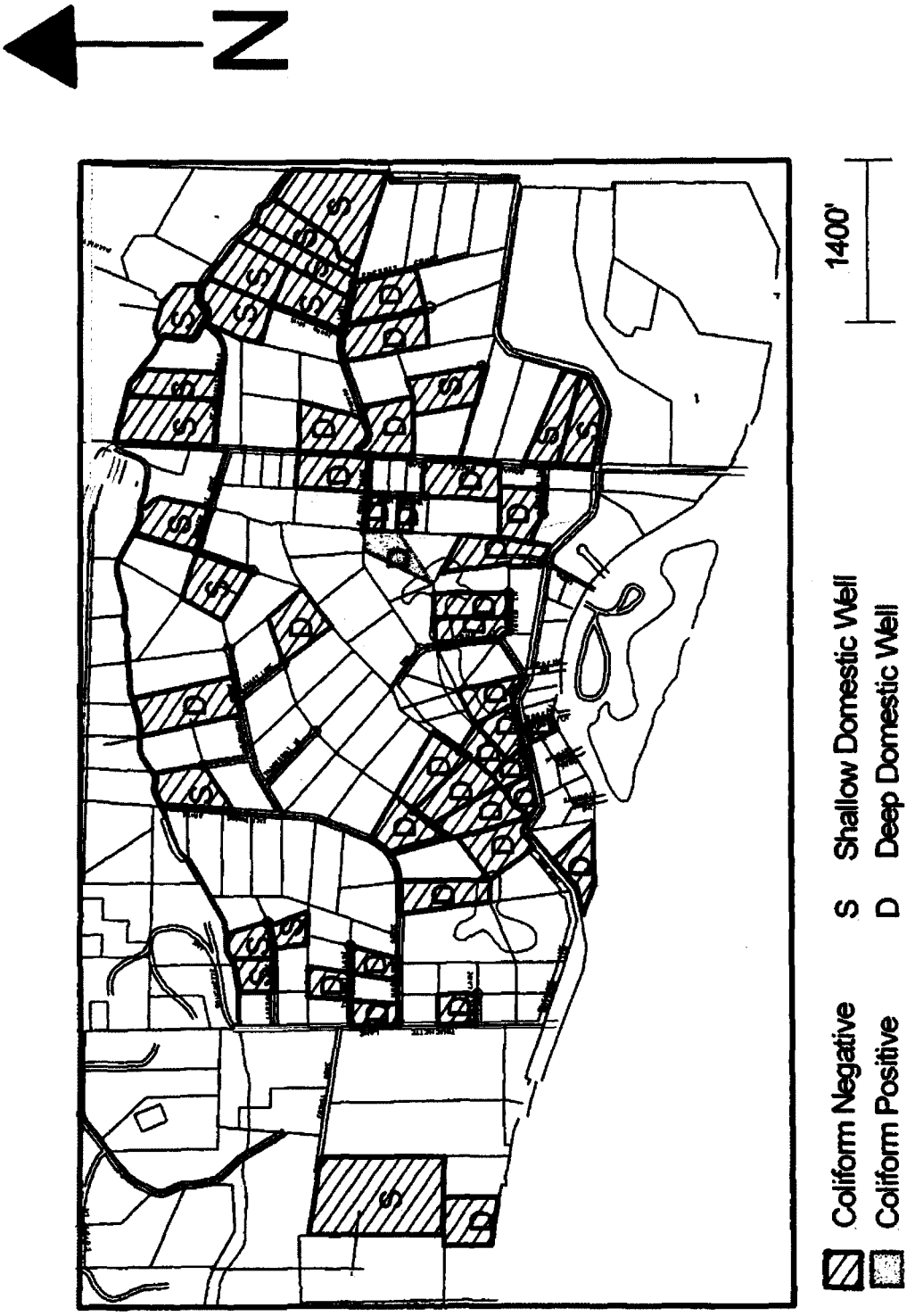

Figure 21. Sample Distribution, March 2000

MULTI-LEVEL WELLS

Initial (May and June 2000) Bacterial Results

Six multi-level sampling wells were installed at three sites on May 6 and June 5, 2000 (Figures 12, 22, 23, 24, 25, 26, and 27). The instruments were allowed to equilibrate in the shallow aquifer for 2-11 days before being sampled. Initial samples for total/fecal coliforms as well as general chemistry analysis were taken from each multi-level port and potential surface water sources on May 17 and June 7, 2000. The water table was 0.500-1.00 ft lower than it would be during seasonal high water table in August 2000. The majority of the ports on multi-level wells, with the exception of site 28-11H, showed no bacterial contamination with either total or fecal coliforms (Table 8).

At site 28-11H, the ten-foot port on the instrument adjacent to the septic drainfield had total coliform concentrations exceeding the quantification limit of the Quanti-Tray® MPN method used, however, no fecal coliform bacteria were detected. Total coliform bacteria were also detected in the multi-level well adjacent to the domestic well. The ten-foot and fourteen-foot ports showed total coliform concentrations of 8.500 and 325.6 CFU/100 mL respectively (Table 8). No fecal coliform bacteria were detected in water from these ports. Total and fecal coliforms were not detected in water from any ports at either of the other two sites. This may be due to shorter time interval between multi-level well installation and sampling. Sites 28-4A1 and 28-5B1 (septic well) were only allowed to equilibrate for two days after installation, compared to 11 days for site 28-11H and the domestic well/piezometer on site 28-5B1. The two-day time period may have been insufficient for equilibration with the system or the instruments may have been installed outside the influence of the drainfield.

Table 8. Results From Initial Sampling of Multi-Level Wells and Surface Water Sources.
Sampling Dates: May 17, 2000* and June 8, 2000**

Site	Depth Below Water Table (ft)	TC CFU/100mL	FC CFU/100 mL
11H-DW*	N/A	<1	<1
11HS-10*	2.17	>2419	<1
11HS-12*	4.17	<1	<1
11HS-14*	6.17	<1	<1
11HS-19*	11.2	<1	<1
11HW-10*	2.83	8.500	<1
11HW-12*	4.83	<1	<1
11HW-14*	6.83	325.6	<1
11HW-19*	11.8	<1	<1
4A1-DW**	N/A	<1	<1
4A1S-11.8**	1.49	<1	<1
4A1S-13.8**	3.49	<1	<1
4A1S-18.8**	8.49	<1	<1
4A1W-12**	3.71	<1	<1
4A1W-17**	8.71	<1	<1
5B1-DW*	N/A	<1	<1
5B1S-10.7**	3.92	<1	<1
5B1S-12.7**	5.92	3.100	<1
5B1W-19*	7.41	<1	<1
North Ditch*	N/A	307.6	37.90
South Ditch*	N/A	290.9	53.80
Roman Creek**	N/A	14.50	<1
Twin Pond**	N/A	>2419	816.4

In May and June 2000, total coliform concentrations in the surface water samples ranged from 14.50 CFU/100mL to a level greater than the quantification limit of the MPN method (Table 8). Fecal coliform concentrations ranged from a <1.000 to 816.4 CFU/100 mL (Table 8). Samples taken from Roman Creek showed the lowest total/fecal coliform concentrations, while samples from Twin Pond showed the highest bacterial concentrations.

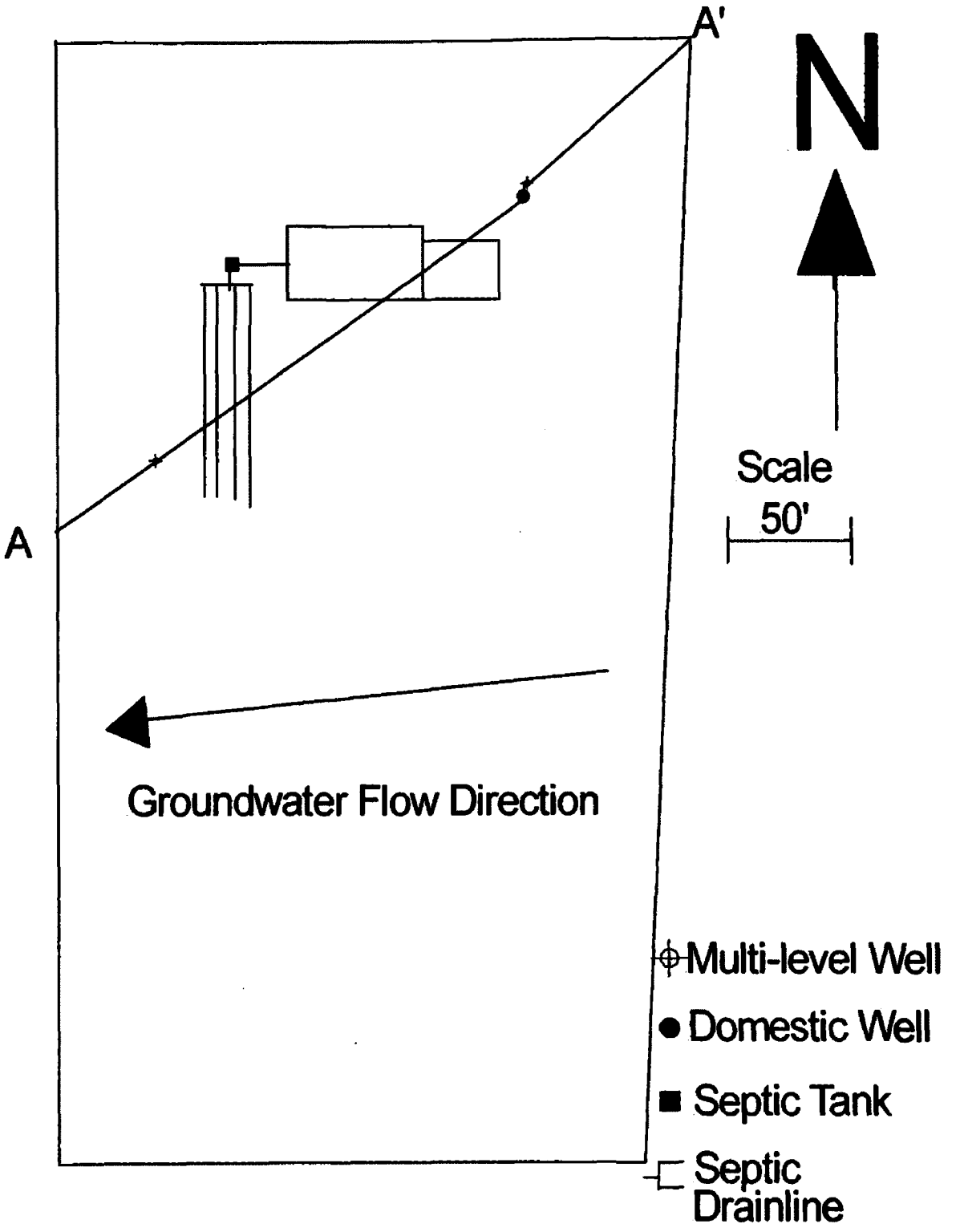

Figure 22. Map of Site 28-11H

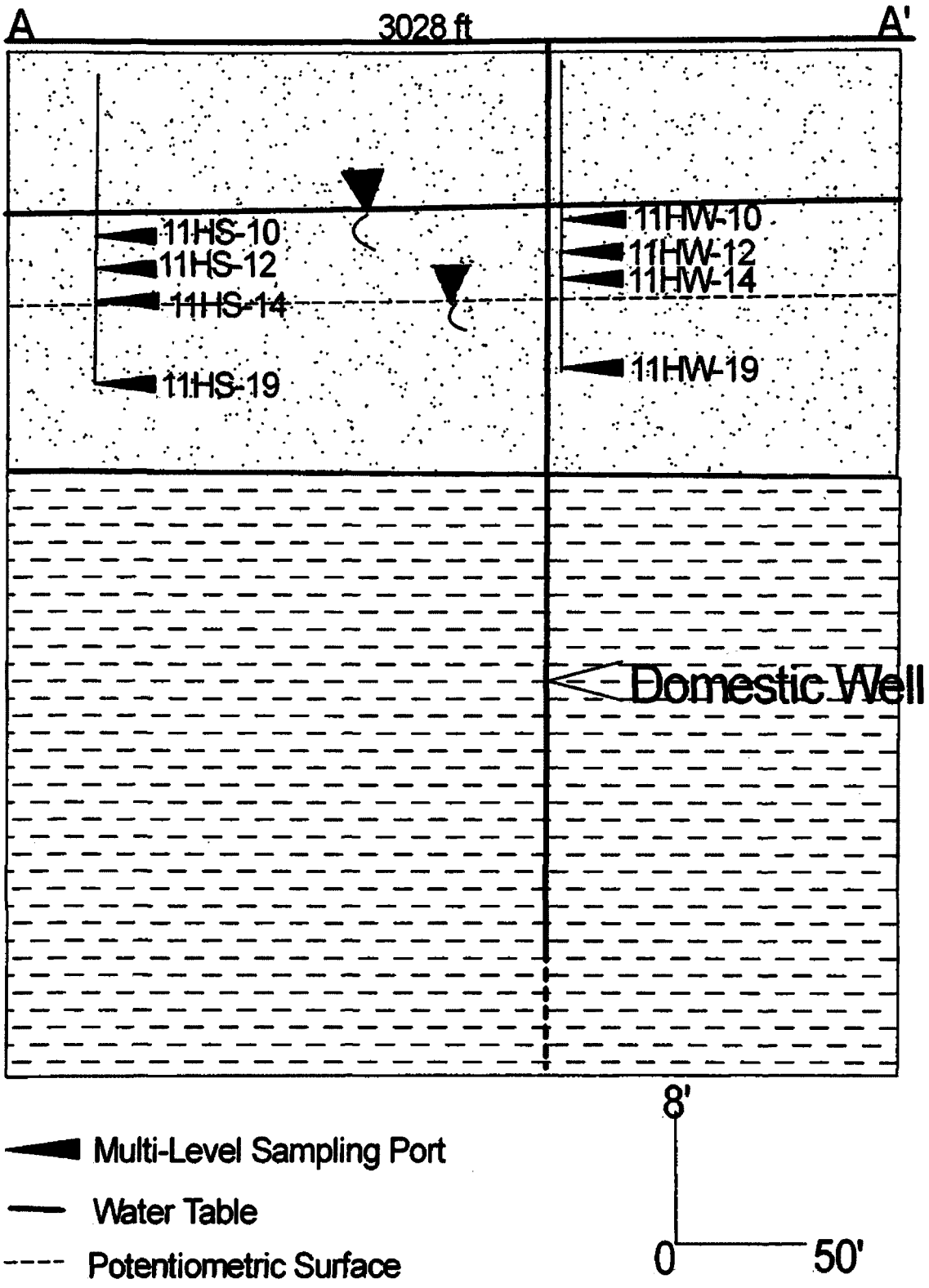

Figure 23. Cross-Section Through Site 28-11H

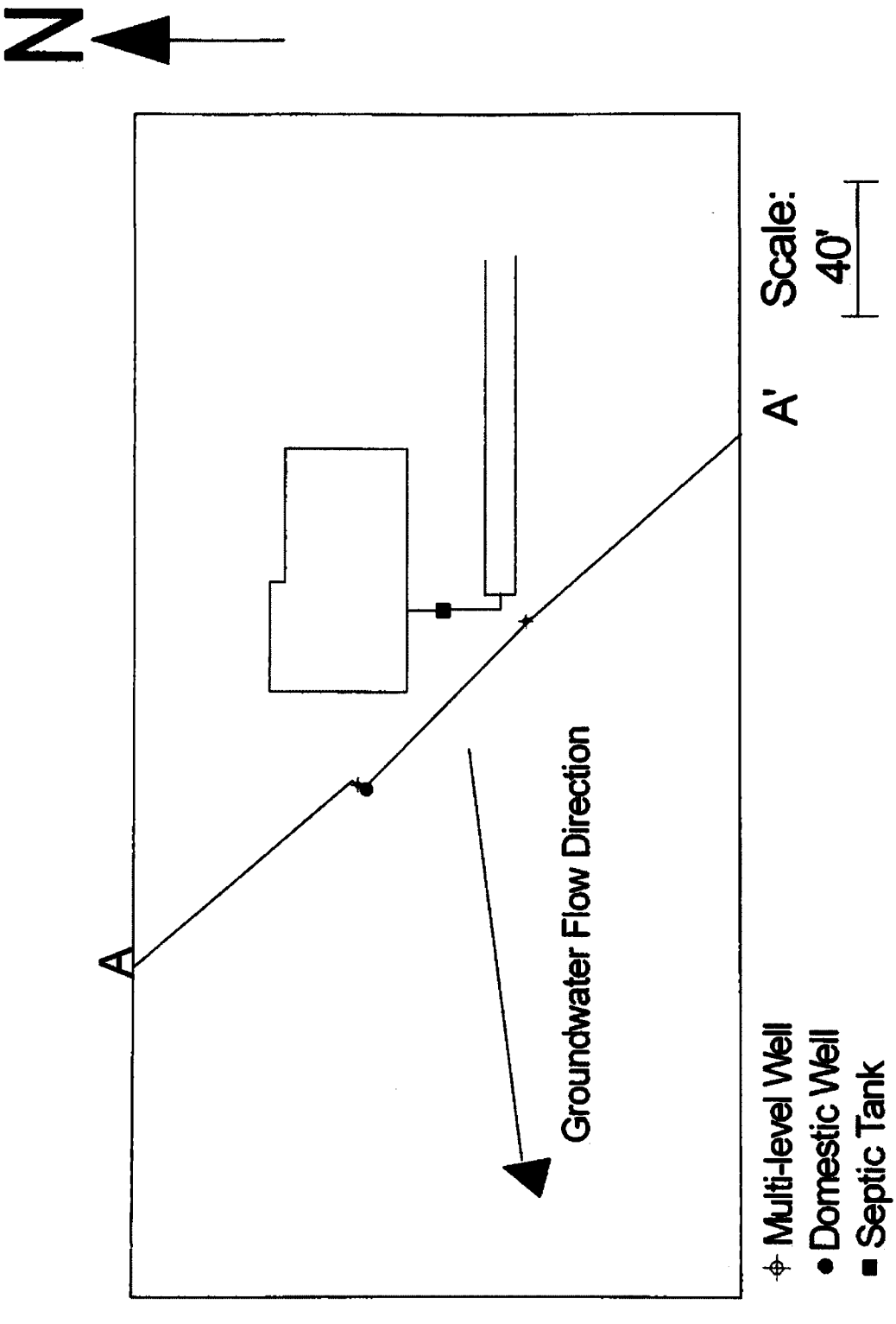

Figure 24. Map of Site 28-4A1

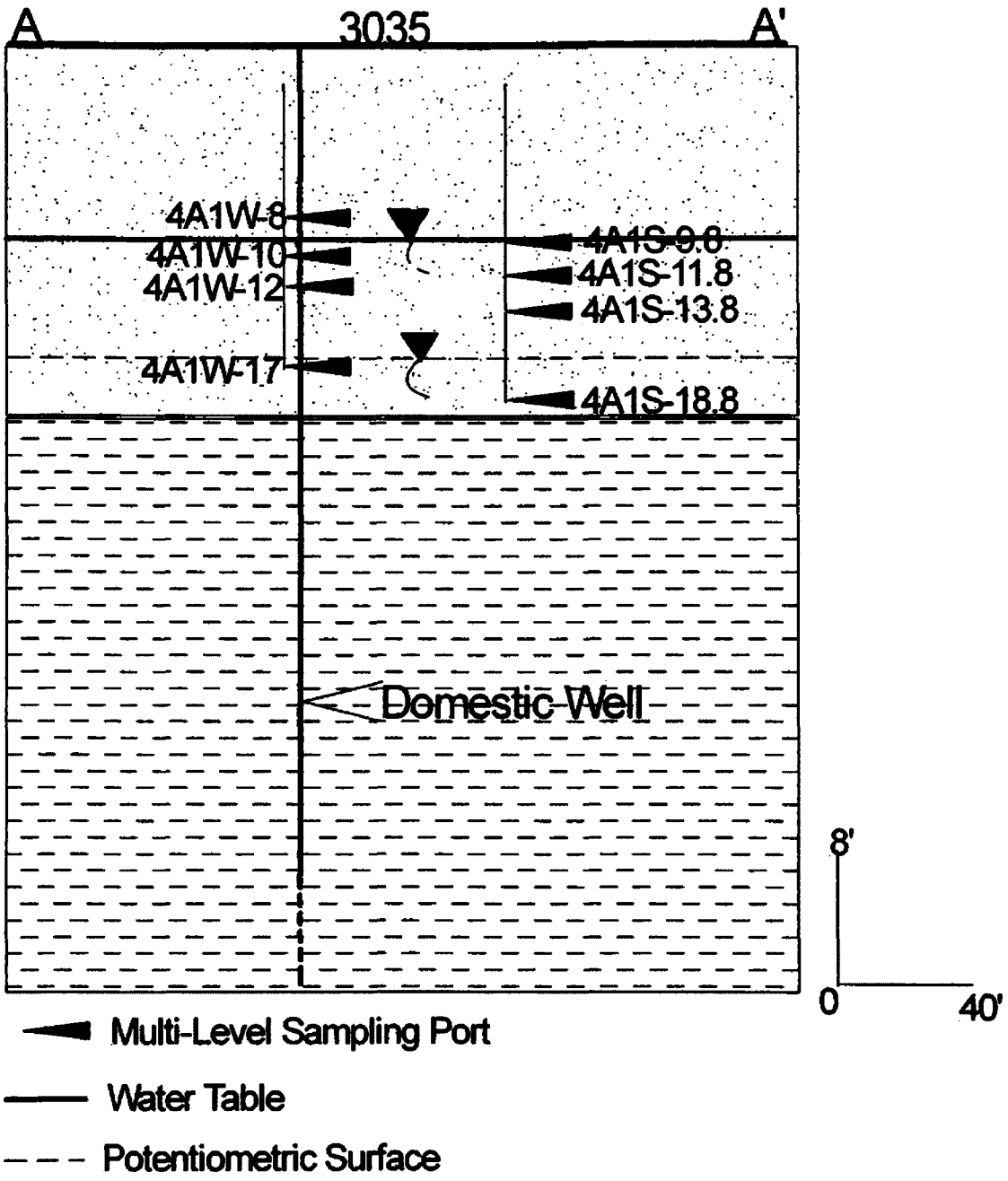

Figure 25. Cross-Section Through Site 28-4A1

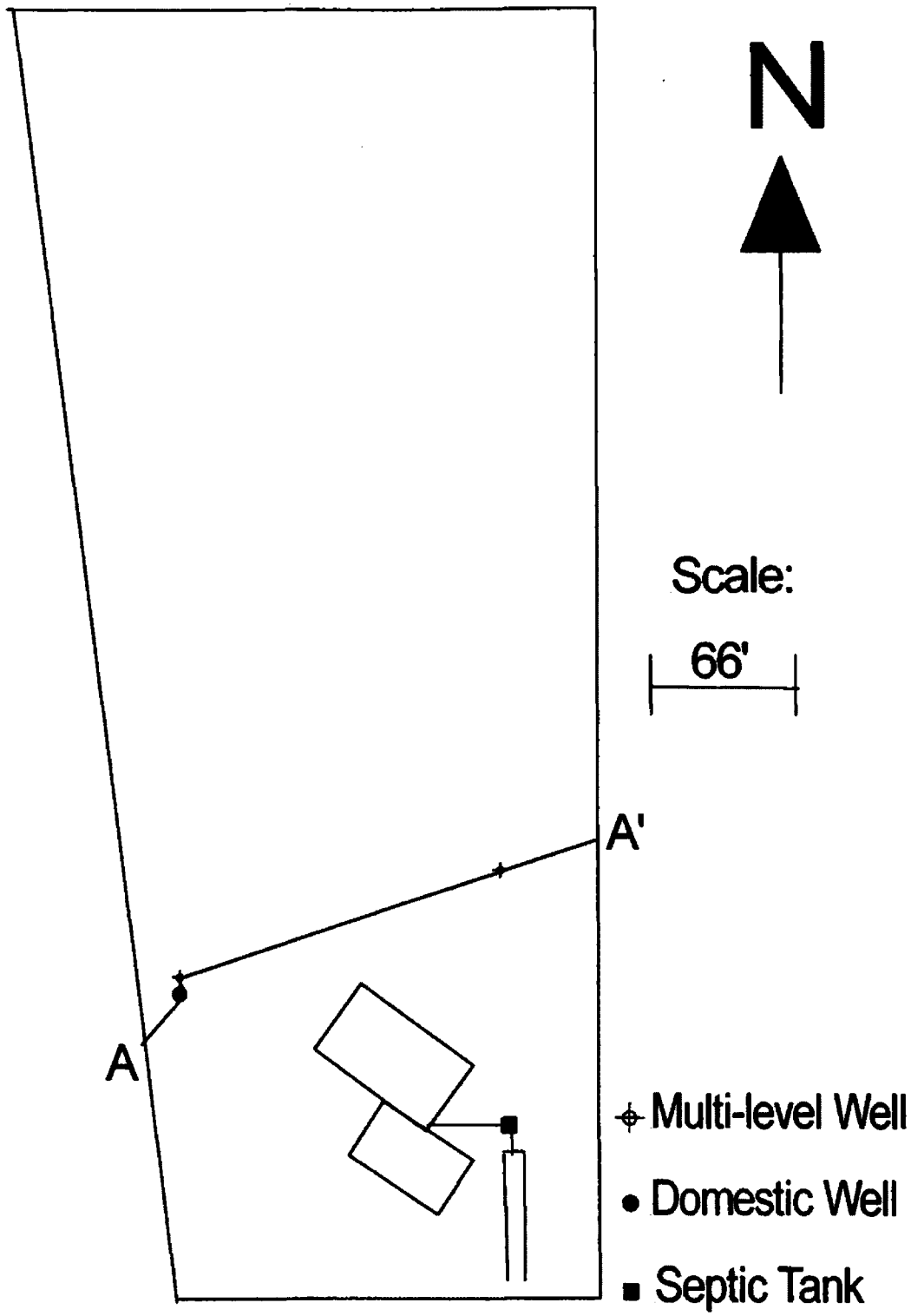

Figure 26. Map of Site 28-5B1

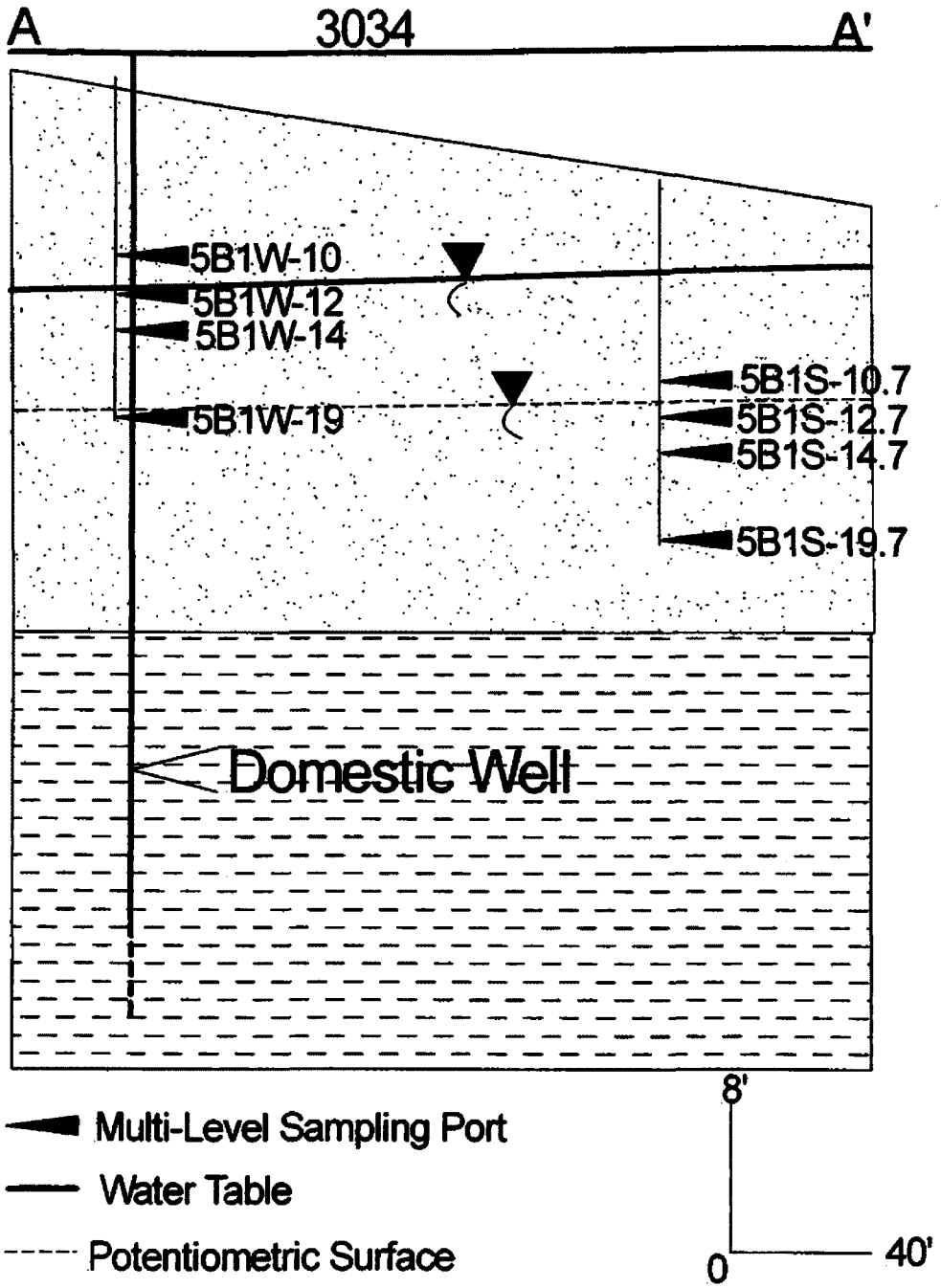

Figure 27. Cross-Section Through Site 28-5B1

Initial (May and June 2000) Inorganic Chemistry Results

In addition to bacterial analysis, multi-level wells and surface water sources were sampled for general chemistry. A complete table of results from the chemical analyses can be found in Appendix F. Bicarbonate concentrations varied little, ranging from a low of 108.8 ppm (at site 4A1A-11.8) to 227.2 ppm (at site 11HS-10) (Table 9). The majority of the samples had concentrations close to the average of 174.3 ppm. Fluoride concentrations were close to the detection limit of 0.100 mg/L on most sites, ranging from levels below the detection limit of 0.100 ppm to 0.230 ppm (at site 4A1S-11.8), with an average of 0.150 ppm (Table 9). Chloride concentrations varied depending on multi-level well location. Concentrations ranged from levels below the detection limit of 1.50 ppm to 29.2 ppm, with an average of 9.09 ppm (Table 9). In general, the highest concentrations were found in the multi-level wells adjacent to septic drainfields, particularly the shallower ports. It is interesting to note that samples from port 11HW-19 and 5B1W-19 had concentrations of 8.83 and 9.20 ppm respectively. Although these ports were the deepest on the multi-level wells adjacent to the domestic wells, they showed the highest chloride concentrations. Nitrate concentrations showed similar trends, ranging from <0.250 ppm to 32.6 ppm, with an average of 5.30 ppm (Table 9). The highest concentrations were found in instruments adjacent to the drainfields, and the concentration decreased rapidly with depth below the surface. Sulfate concentrations ranged from levels below the detection limit of 5.00 ppm to 31.7 ppm, with an average of 12.9 ppm (Table 9). Concentrations varied between sites, but were generally highest in shallow ports of multi-level wells adjacent to drainfields. The exception is site 28-5B1 where samples from most ports and the domestic well had concentrations of five to six

Table 9. Inorganic Chemistry Results for Multi-Level Wells and Surface Water Sources, Sampling Dates May 17, 2000* and June 8, 2000**

Site	Depth Below W.T. (ft)	Bicarb. mg/L	Fluoride mg/L	Chloride mg/L	Nitrate mg/L	Sulfate mg/L	Sodium mg/L	EC µS
11H-DW*	N/A	130.4	0.150	<1.50	<0.250	5.64	6.71	276
11HS-10*	2.17	227.2	0.100	29.2	32.6	31.7	40.6	895
11HS-12*	4.17	199.2	<0.100	9.12	6.03	13.0	18.7	501
11HS-14*	6.17	215.2	<0.100	10.4	5.05	13.3	20.5	538
11HS-19*	11.2	193.2	<0.100	11.0	1.34	8.65	9.30	454
11HW-10*	2.83	194.4	0.100	3.42	0.590	7.00	6.69	399
11HW-12*	4.83	174.8	<0.100	3.71	0.590	7.28	5.91	383
11HW-14*	6.83	176.0	0.070	4.00	0.610	7.47	6.12	401
11HW-19*	11.8	173.6	<0.100	8.83	0.910	8.12	9.62	462
4A1-DW**	N/A	186.4	0.190	1.60	<0.250	9.77	8.89	390
4A1S-11.8**	1.49	108.8	0.230	25.0	23.2	23.5	28.8	563
4A1S-13.8**	3.49	189.2	0.180	7.24	0.950	17.3	8.84	460
4A1S-18.8**	8.49	199.6	0.160	6.21	0.660	17.8	8.02	460
4A1W-12**	3.71	194.0	0.180	5.85	0.810	16.8	9.74	443
4A1W-17**	8.71	195.6	0.200	5.00	0.420	18.2	7.54	424
5B1-DW*	N/A	129.6	0.140	<1.50	0.400	5.65	5.04	309
5B1S-10.7**	3.92	131.2	0.150	7.74	<0.250	6.47	10.0	329
5B1S-12.7**	5.92	140.4	0.160	6.95	<0.250	<5.00	10.4	291
5B1W-19*	7.41	153.2	<0.100	9.20	<0.250	13.9	11.0	448
N. Ditch*	N/A	75.20	<0.100	<1.50	<0.250	8.96	2.73	
S. Ditch*	N/A	75.20	<0.100	<1.50	<0.250	8.91	2.81	
Rom. Cr.**	N/A	119.6	<0.100	<1.50	<0.250	<5.00	1.90	
T. Pond**	N/A	99.20	0.140	6.84	<0.250	10.5	9.07	
Average		174.3	0.150	9.09	5.30	12.9	12.2	443
Minimum		108.8	<0.100	<1.50	<0.25	<5.00	5.04	276
Maximum		227.2	0.230	29.2	32.6	31.7	40.6	894

parts per million. The highest sulfate concentration was from the deepest port on the multi-level well adjacent to the domestic well. Sodium concentrations ranged from 5.04 to 40.6 ppm, with an average of 12.2 ppm (Table 9). Concentrations at each site followed trends similar to that of sulfate. Electrical conductance ranged from 276 to 895 µS, with an average of 443 µS (Table 9). In general, conductivity was highest in multi-level wells adjacent to septic drainfields, and decreased with depth below the surface. Site 28-5B1 is

the exception. This highest conductivity at this site was found in the deepest port of the multi-level well adjacent to the domestic well. Based on inorganic analysis, it appears septic effluent's impact on groundwater extends to a depth of between 0.00 and greater than 12 ft below the water table in the vicinity of the drainfield. This is similar to work reported by Lambert, 1996 and Woessner et al., 1996.

Results from surface water samples taken in May and June 2000 can be found in Table 9, a complete table of results can be found in Appendix F. Concentrations of the chemical indicators of septic effluent contamination were lower in surface water sources than in samples from the multi-level wells. In general Twin Pond samples showed the highest concentrations of all chemical constituents, while the other three sources had similar (lower) concentrations.

High Water Table Bacterial Results

All ports on the six multi-level wells as well as potential surface water sources and domestic wells on instrumented sites were sampled during the seasonal high water table, August 15-16, 2000. A complete table of results from bacterial and general chemistry analyses can be found in Appendix E. Once again, no fecal coliform bacteria were detected in any of the domestic or multi-level wells.

Only one of the instrumented sites showed contamination of the domestic well. Site 28-11H had a total coliform concentration of 1203 CFU/100 mL (Table 10). At this site, total coliform bacteria were detected in only the ten-foot port of the septic drainfield multi-level well. This port had a total coliform concentration of 10.60 CFU/100 mL (Table 10). The 14 and 19-foot ports on the instrument adjacent to the

Table 10. Bacterial Results From Multi-Level Wells and Surface Water Sources
Sampling Dates: August 15, 2000* and August 16, 2000**

Site	Depth Below Water Table (ft)	TC CFU/100mL	FC CFU/100 mL
11H-DW*	N/A	1203	<1
11HS-10*	2.91	10.60	<1
11HS-12*	4.91	<1	<1
11HS-14*	6.91	<1	<1
11HS-19*	11.9	<1	<1
11HW-10*	3.32	<1	<1
11HW-12*	5.32	<1	<1
11HW-14*	7.32	11.00	<1
11HW-19*	12.3	>2419	<1
4A1-DW**	N/A	<1	<1
4A1S-11.8**	1.62	46.40	<1
4A1S-13.8**	3.62	4.100	<1
4A1S-18.8**	8.62	2.000	<1
4A1W-10**	0.900	<1	<1
4A1W-12**	2.90	52.00	<1
4A1W-17**	7.90	20.10	<1
5B1-DW*	N/A	<1	<1
5B1S-10.7*	5.48	<1	<1
5B1S-12.7*	7.48	2.000	<1
5B1W-19*	8.62	>2419	<1
North Ditch**	N/A	1554	90.90
Roman Creek**	N/A	1300	4.100
Twin Pond*	N/A	>2419	77.10

domestic well showed coliform concentrations of 11.00 and >2419.20 CFU/100 mL, respectively (Table 10).

More bacterial contamination was found in the multi-level wells at site 28-4A1. Total coliforms were detected in the 12 and 17-foot ports of the instrument adjacent to the domestic well. These ports had total coliform concentrations of 52.00 and 20.10 CFU/100mL, respectively (Table 10). The multi-level well adjacent to the drainfield had total coliform concentrations that decreased with depth beneath land surface. The 11.8,

13.8, and 18.8-foot ports had concentrations of 46.40, 4.100, and 2.000 CFU/100 mL, respectively (Table 10).

At site 28-5B1, the deepest port on the instrument adjacent to the domestic well showed a total coliform concentration greater than the quantification limit of the MPN method used (2419 CFU/100 mL) (Table 10). The multi-level well adjacent to the drainfield had a concentration of 2.000 CFU/100 mL in the 12.7-foot port (Table 10).

During a period of seasonal high water table, August 2000, surface water samples had higher concentrations of total coliforms than groundwater samples, ranging from 1300 CFU/100 mL in Roman Creek to >2419 CFU/100 mL in Twin Pond (Table 10). Fecal coliform concentrations ranged from 4.10 CFU/100 mL in Roman Creek to 90.90 CFU/100 mL in the northern irrigation ditch. The southern irrigation ditch was not sampled, as it draws water from the same source as the northern ditch.

High Water Table Inorganic Chemistry Results

A complete list of results from chemical analyses can be found in Appendix F. Bicarbonate concentrations were similar to the earlier sampling round, ranging from 128.4 to 236.2 mg/L with an average of 179.3 mg/L (Table 11). Chloride concentrations ranged from <1.00 to 16.1 mg/L, with an average of 7.84 mg/L (Table 11). Nitrate concentrations ranged from <0.100 to 21.6 mg/L, with an average of 3.29 mg/L (Table 11). Chloride and nitrate concentrations were lowest in the domestic wells on all three instrumented sites. Concentrations in the multi-level wells were highest in the shallowest ports, particularly those adjacent to drainfields, and decreased with depth below land surface. The septic instrument at site 28-11H followed this trend, however the instrument adjacent to the domestic well (11H-DW) did not. Concentrations of both

Table 11. Inorganic Chemistry Results From Multi-Level Wells and Surface Water Sources, Sampling Date: August 15, 2000* and August 16, 2000**

Site	Depth Below W.T. (ft)	HCO_3^- mg/L	Fl^- mg/L	Cl^- mg/L	NO_3^- mg/L	NH_4^+ mg/L	SO_4^{-2} mg/L	Na^+ mg/L	EC µS
11H-DW*	N/A	128.4	<0.2	<1.00	<0.100	<0.5	5.51	7.39	294
11HS-10*	2.91	236.2	<0.2	16.1	12.9	<0.5	18.1	37.0	718
11HS-12*	4.91	188.4	<0.2	8.72	2.66	<0.5	9.66	13.0	471
11HS-14*	6.91	192.0	<0.2	8.31	1.60	<0.5	8.87	12.3	454
11HS-19*	11.9	193.2	<0.2	7.70	1.16	<0.5	8.52	9.81	455
11HW-10*	3.32	211.2	<0.2	6.52	0.840	<0.5	7.97	9.13	496
11HW-12*	5.32	185.2	<0.2	7.90	0.950	<0.5	8.45	9.26	453
11HW-14*	7.32	188.4	<0.2	7.87	1.00	<0.5	8.13	9.30	451
11HW-19*	12.3	188.8	<0.2	8.55	1.15	<0.5	8.66	9.81	464
4A1-DW**	N/A	186.8	<0.2	1.44	<0.100	<0.5	10.6	10.6	407
4A1S-11.8**	1.62	132.0	<0.2	9.46	21.6	<0.5	38.5	13.6	581
4A1S-13.8**	3.62	187.6	<0.2	7.55	1.46	<0.5	15.3	12.1	461
4A1S-18.8**	8.62	203.8	<0.2	8.32	1.16	<0.5	16.5	12.5	518
4A1W-10**	0.900	180.4	<0.2	4.48	1.02	<0.5	14.3	10.1	433
4A1W-12**	2.90	180.4	<0.2	4.46	0.950	<0.5	14.7	10.0	429
4A1W-17**	7.90	194.8	<0.2	3.13	0.560	<0.5	15.2	8.05	475
5B1-DW*	N/A	130.8	<0.2	<1.00	0.410	<0.5	5.42	5.60	309
5B1S-10.7*	5.48	152.4	<0.2	9.69	<0.100	<0.5	1.99	11.3	329
5B1S-12.7*	7.48	163.6	<0.2	10.7	<0.100	<0.5	2.69	10.6	291
5B1W-19*	8.62	161.6	<0.2	10.1	<0.100	<0.5	8.96	11.6	448
N. Ditch**	N/A	111.2	<0.2	2.67	<0.100	<0.5	16.1	5.41	
Rom. Cr.**	N/A	85.20	<0.2	<1.00	<0.100	<0.5	4.61	2.37	
Twin Pond*	N/A	135.6	<0.2	11.2	<0.100	<0.5	14.9	11.0	359
Average		179.3		7.84	3.29		11.4	11.7	447
Minimum		128.4		1.44	0.410		1.99	5.60	291
Maximum		236.2		16.1	21.6		38.5	37.0	718

chloride and nitrate increased slightly with depth in this instrument. Fluoride and ammonia concentrations were below the practical quantification limit in all samples taken during this round of sampling (Table 11). Sulfate concentrations ranged from 1.99 to 38.5 mg/L with an average of 11.4 mg/L (Table 11). Sodium concentrations ranged from 5.60 to 37.0 mg/L, with an average of 11.7 mg/L (Table 11). These constituents followed

the same general trends as nitrate and chloride. Electrical conductance ranged from 291 to 718 µS and averaged 447 µS. On all sites, conductivity was lowest in the domestic wells and highest in the shallowest ports of multi-level wells, decreasing with depth beneath land surface.

Surface water samples had lower concentrations of all constituents than groundwater samples during seasonal high water table, August 2000. In general, Roman Creek had the lowest concentrations of anions, while Twin Pond had the highest (with the exception of sulfate). Fluoride, chloride, nitrate, and ammonia concentrations in Roman Creek Samples were below the practical quantification limit (Table 11). In the other samples, only fluoride, nitrate, and ammonia concentrations were below the PQL (Table 11). Bicarbonate concentrations ranged from 85.20 to 135.6 mg/L. Chloride concentrations ranged from <1.00 to 11.2 mg/L. Sulfate and sodium concentrations ranged from 4.61 to 16.1 mg/L and 2.37 to 11.0 mg/L respectively (Table 11).

Pumping Test Results

Pumping tests were performed on the three-instrumented sites on August 23, 2000 and August 31, 2000; in order to evaluate the hypothesis that contaminated shallow groundwater is being drawn into the domestic wells. Domestic wells were pumped at a constant rate, while water level measurements were made in both the multi-level and domestic wells. The presence of drawdown in the multi-level wells would support the hypothesis. Data tables showing test results can be found in Appendix G.

The time-drawdown curve for both the domestic and multi-level wells at site 28-11H can be found in figure 28. There was a rapid initial drawdown in the domestic well of 10.9 ft in the first 2.5 minutes. Total drawdown during the experiment was 15.2 ft and

it took approximately 12 minutes for the cone of depression to reach steady state (the longest time of the three sites). Depth to water in the multi-level well remained fairly constant throughout the experiment. There was an initial drawdown of 0.610 ft recorded in the first 2.5 minutes, but that can be attributed to measurement error. The pumping rate remained constant at approximately 10 gallons per minute throughout the test.

Figure 29 shows the time-drawdown curves for the pumping test at site 28-4A1. Drawdown in the domestic well was rapid, taking only two minutes for the cone of depression to reach steady state. Total drawdown during the experiment was 1.42 ft, much lower than the drawdown observed at site 28-11H. There was no significant drawdown recorded in the multi-level well. The water table elevation remained fairly constant at slightly more than 3024 ft. The pumping rate fluctuated slightly between 9.68 and 10.3 gallons per minute, averaging 9.94 gallons per minute.

The time-drawdown curves for site 28-5B1 can be found in figure 30. Drawdown in the domestic well at this site was the lowest of all the sites measured. The little drawdown that was observed at this site was rapid, taking only 0.50 minutes for the cone of depression to reach steady state (the shortest time of the three sites). The maximum drawdown in the domestic well during the experiment was 0.33 ft. The depth to water in the multi-level well remained constant throughout the pumping test at approximately 11.03 ft. The pumping rate fluctuated slightly between 11.1 and 12.5 gallons per minute, averaging 11.9 gallons per minute. The higher pumping rate at this site was due to the fact that it was necessary to run two hydrants to maintain pump activity.

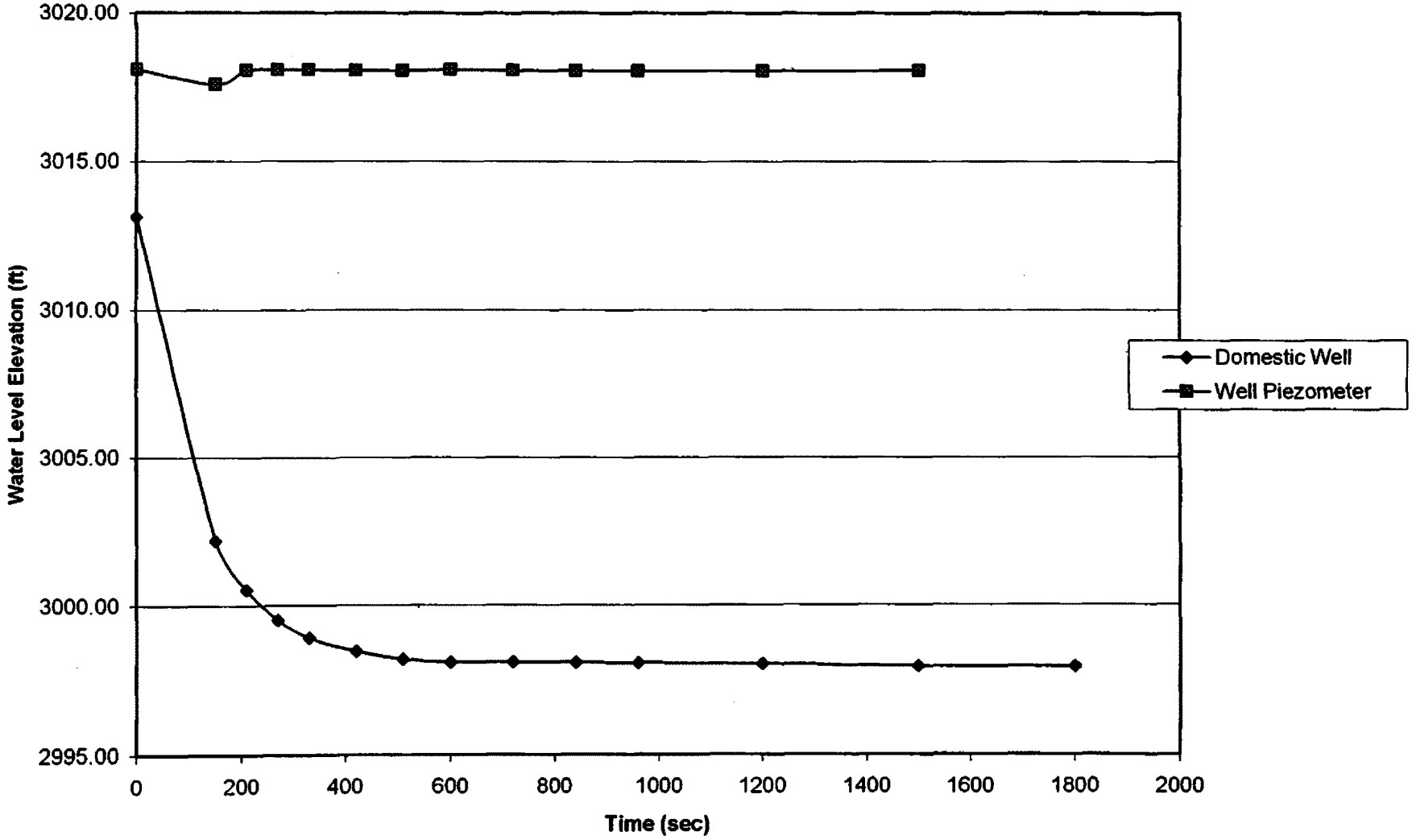

Figure 28. Drawdown Test For 28-11H

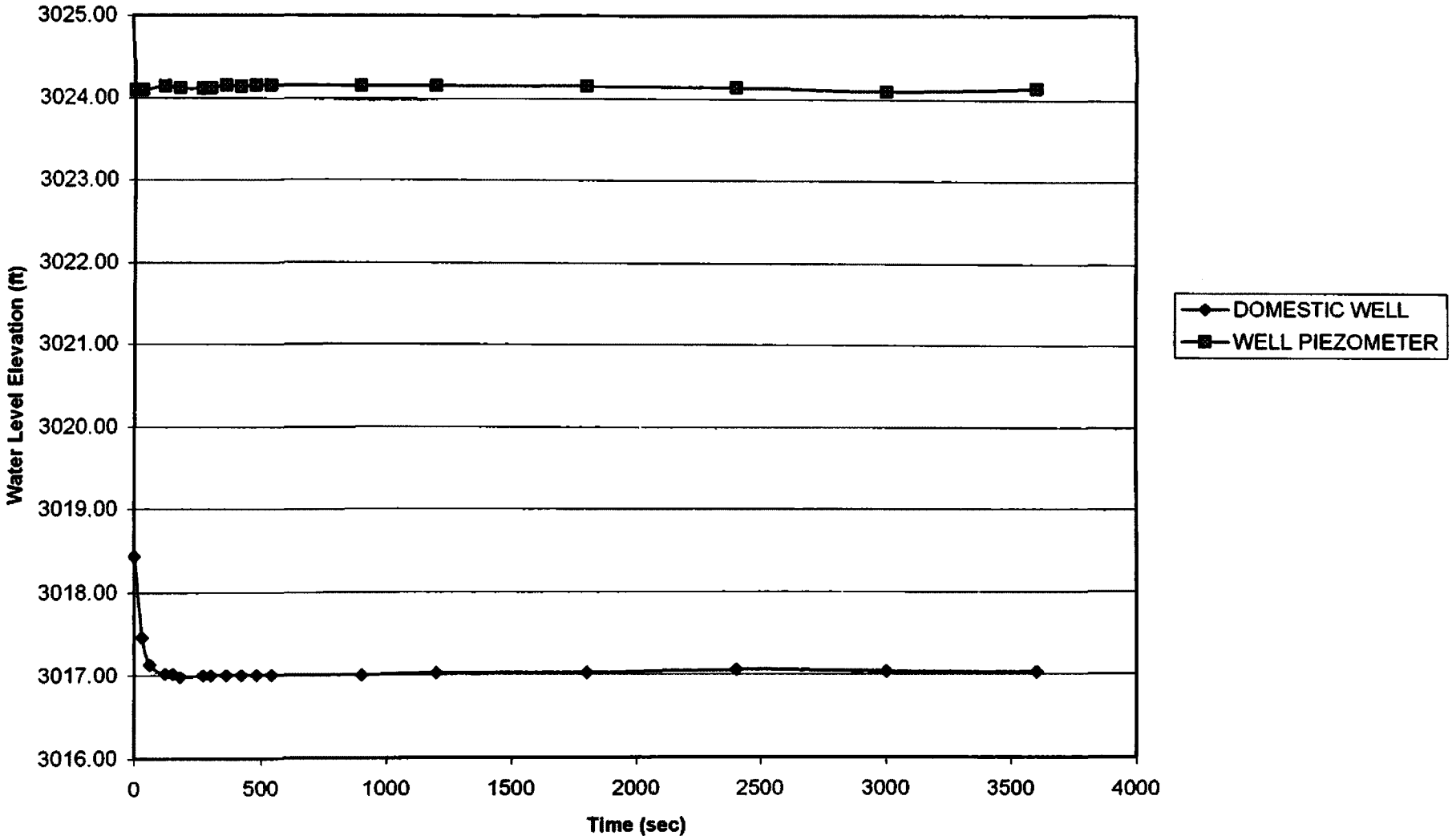

Figure 29. DRAWDOWN TEST FOR 28-4A1

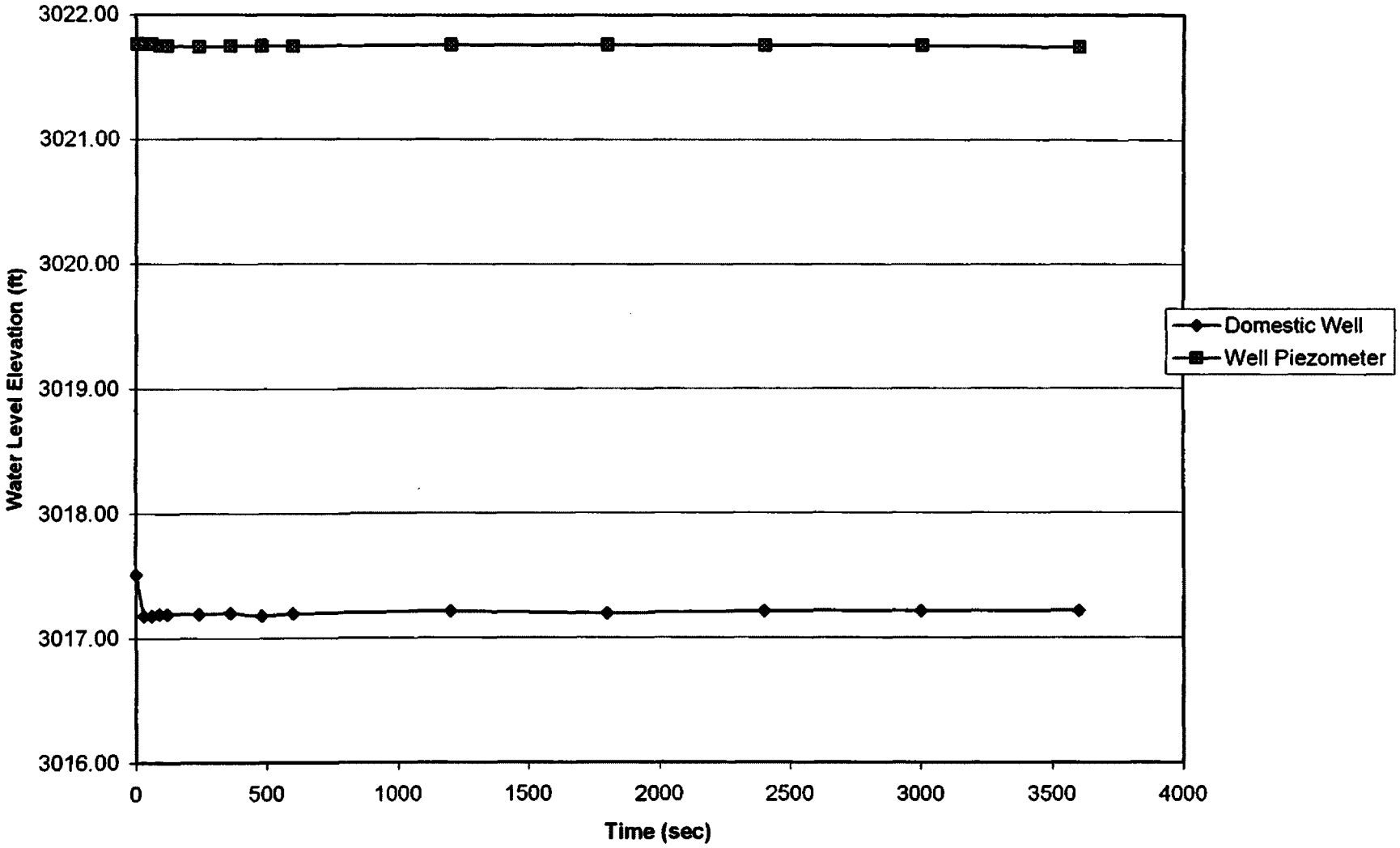

Figure 30. Drawdown Test For 28-5B1

Tracer Test Results

On October 4, 2000 a NaCl tracer test was performed on site 28-11H to further test the hypothesis that contaminated shallow groundwater is being drawn into domestic wells. Results from the tracer experiment can be found in the data tables in Appendix H. Drawdown results during the tracer experiment were similar to those observed during the pumping test performed earlier (Figure 31). It is interesting to note that the potentiometric surface of the deep aquifer, as measured in the domestic well, was actually higher than the water table in the shallow aquifer. This would theoretically result in an upward vertical gradient between the two aquifers. A total drawdown of 17.9 ft was observed in the domestic well, while no significant drawdown was observed in the multi-level well. It took approximately 20 minutes for the cone of depression in the domestic well to reach steady state, at which time the tracer was injected.

Initial measurements of conductivity and temperature were made before tracer injection. Background conductivity in the domestic well, as observed in previous sampling events, was approximately 271 μS. Initial conductivity measurements during the first 20 minutes of the tracer experiment averaged 325 μS/cm. The difference between the values can be attributed to the fact that different conductivity meters were used during previous sampling events and the tracer experiment. At one minute after injection the conductivity was measured to be 320 μS/cm (165.5 ppm TDS) (Figure 32). This value slowly decreased throughout the experiment to a measurement of 263 μS/cm (132.4 ppm TDS) at 120 minutes. Temperature measurements remained constant at 10.7-10.8°C during the tracer test (Figure 33). There is no clear evidence that the tracer entered the well/distribution system during the course of the experiment.

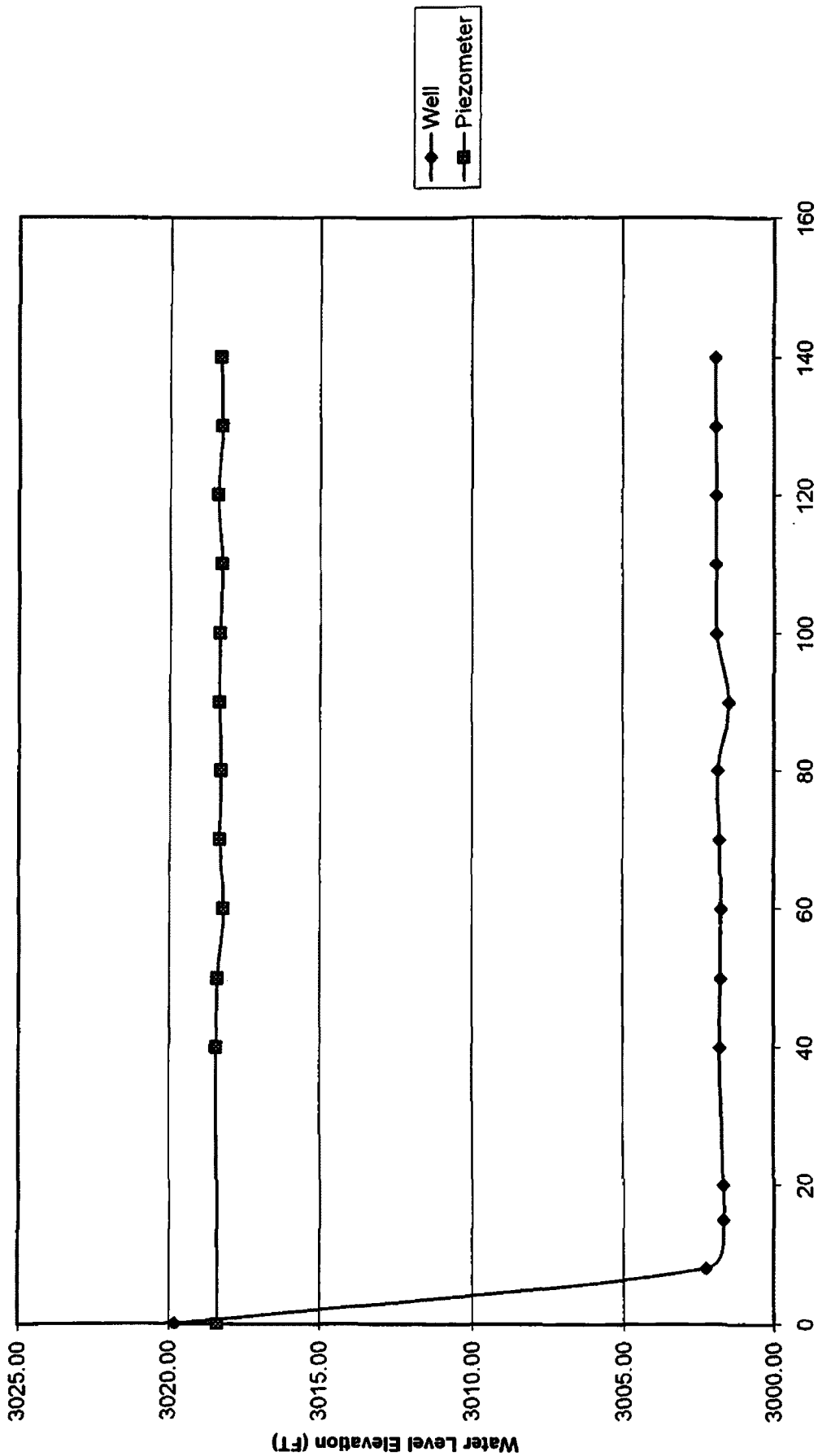

Figure 31. Drawdown During Tracer Test

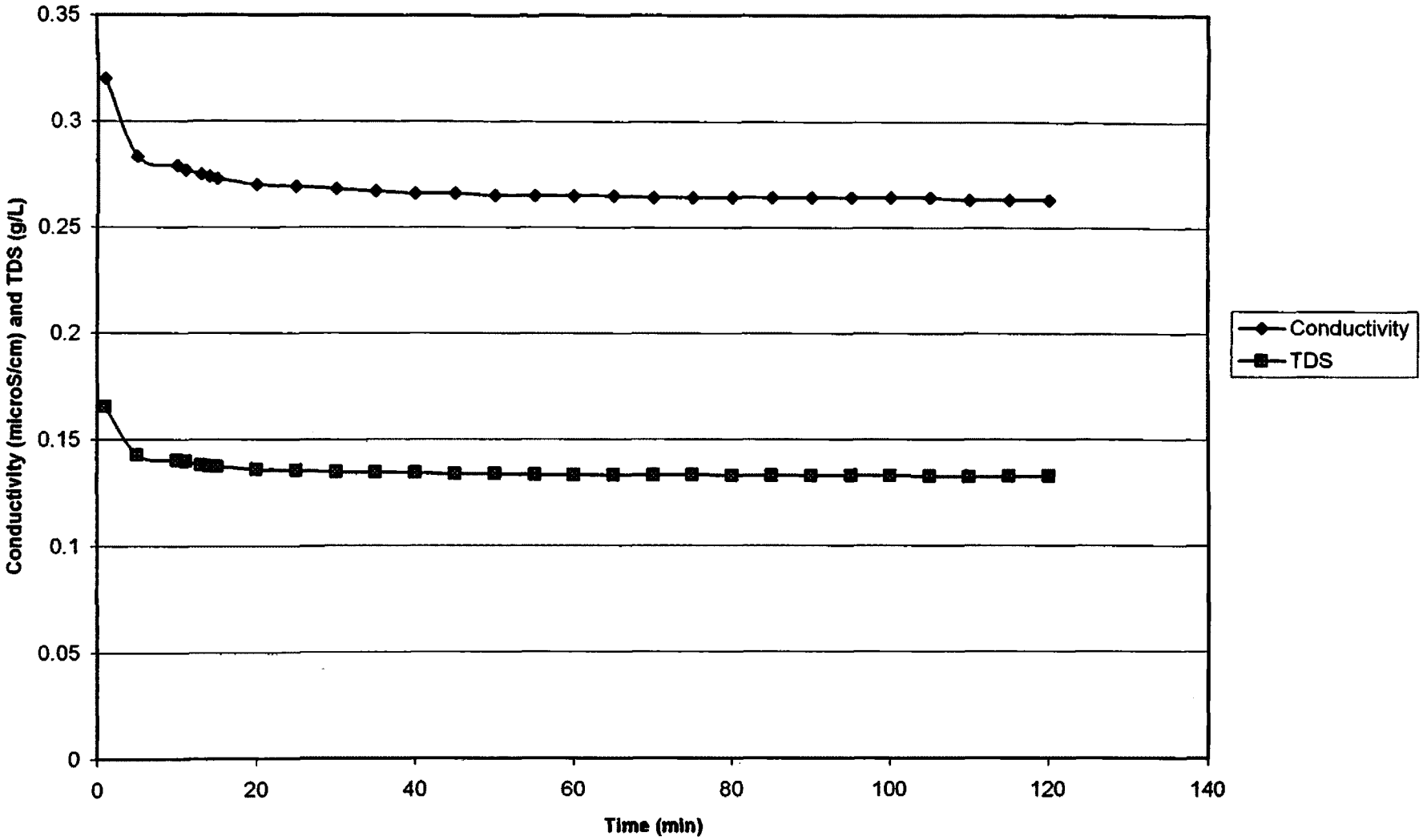

Figure 32. Conductivity During Tracer Test

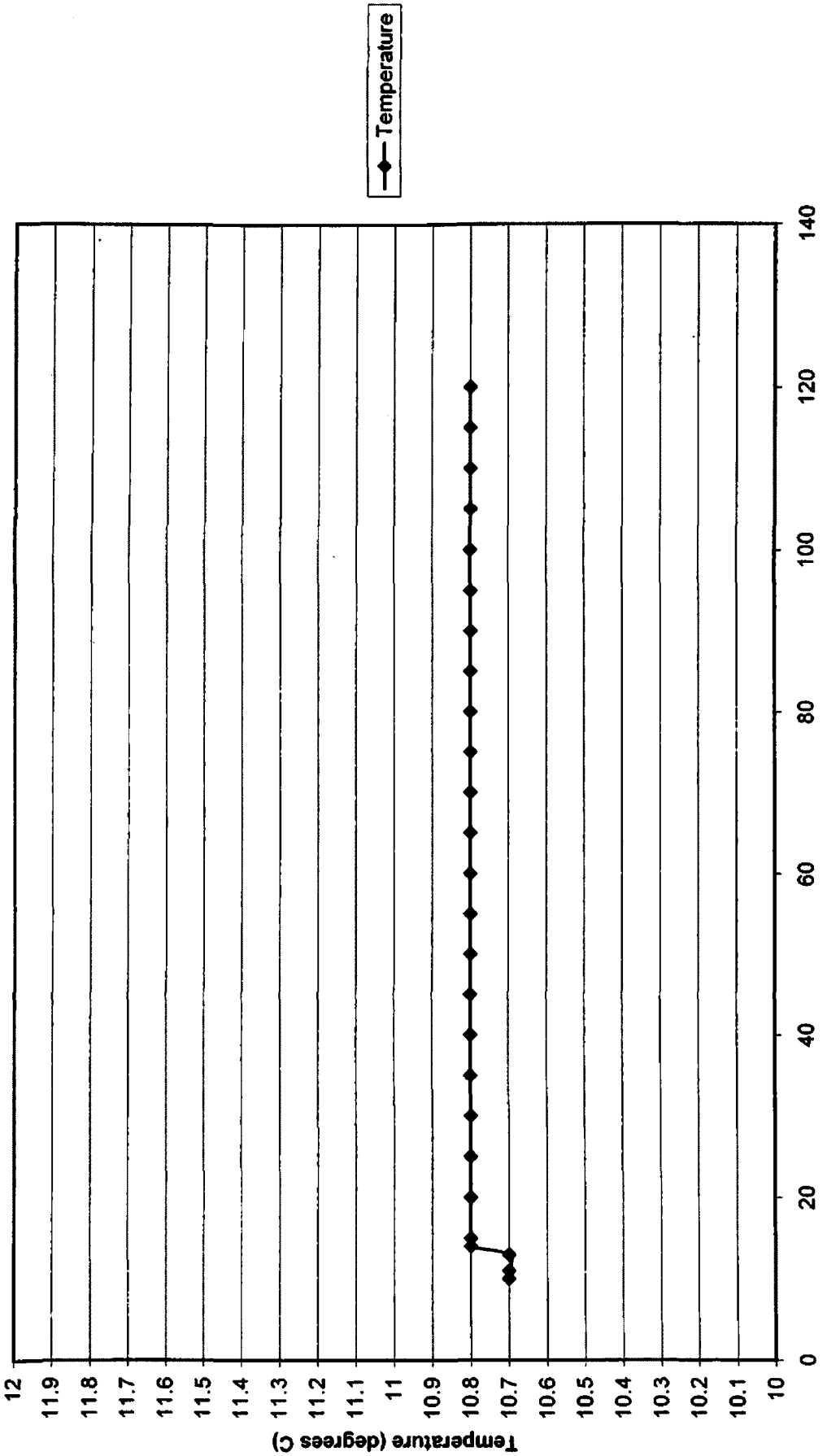

Figure 33. Temperature During Tracer Test

Numerical Simulation Results

The initial model simulations run were to estimate travel time of bacteria to domestic wells under conditions where no pathway existed except vertical hydraulic gradients using particles in the model to represent bacteria. A complete database of model results can be found in Appendix I. The model predicted a travel time of 10,000 days for bacteria under these conditions both with and without a pumping well (Table 12). When horizontal flow was added to the aquifer systems, the particles were transported out of the model area and never reached the well in layer 3 (both with and without a pumping well) (Table 12).

The next group of simulations were run in order to evaluate travel times of bacteria to domestic wells in the presence of a corridor of higher conductivity along the well casing (Table 12). Travel times decreased from 10,000 days in the initial simulations to 3 days in the presence of a leaky corridor along the casing when only a vertical (no horizontal) gradient was present. In the presence of horizontal flow in the aquifers, travel times decreased from a situation where the bacteria never reached the well to 3.5 days when a leaky corridor along the well casing existed (Table 12).

The final simulations were used to estimate bacterial travel times to domestic wells when a leaky pitless adaptor was present. In the situation where only a vertical hydraulic gradient existed, the travel time was 10,000 days without a pumping well and 10 days with a pumping well (Table 12). When horizontal flow was added the bacteria never entered the well when it was not pumping (Table 12). Once pumping began, bacteria reached the well in 2 days (Table 12).

Table 12. Travel Times of Particles to domestic wells under varying conditions, results given in days.

Vertical K Layer 2 (ft/d)	Vertical Gradient No Well	Vertical Gradient Well	Horizontal Flow No Well	Horizontal Flow Well
0.1	2000	2000	N/A	N/A
10	110	110	N/A	N/A
1000	4	4	4.5	4.5
1000000	3	3	3.5	3.5
Leaky Pitless-Adaptor	2000	10	N/A	2

CHAPTER 6: DISCUSSION

The primary purpose of this study was to investigate the cause of persistent coliform contamination of domestic wells in the Roman Creek – Touchette Lane Special Groundwater Management Area by evaluating the sources and pathways by which bacteria impact these wells. The concern of Health Department Officials over the past 15 years has been that domestic wells are being contaminated with septic effluent and that further development of the area will lead to additional loading of the shallow groundwater with effluent resulting in contamination of new wells. In order to resolve these issues, the study followed a logical sequence of data gathering and interpretation outlined in Figure 9. Despite the attempt to follow this rational procedure, several site complexities existed. These included: the apparently random nature of the contamination with respect to well depth, location, and time; variations in well construction due to development within the SMA over time; the use of data collected by different individuals over a period of 15 years; and seasonal fluctuations in water table, irrigation of pastures and agricultural fields, and operation of the Frenchtown Irrigation Ditch.

Evaluation of Potential Sources Of Contamination To The Shallow Aquifer

The hypothesis of the study is that the shallow groundwater is being contaminated by bacterial source(s) and that deep wells are being impacted by groundwater seeping from the upper aquifer. The total coliform family consists of many species of bacteria that have numerous sources, including natural soil species. It has also been suggested that the bacterial source may be a result of a previous event that resulted in well/distribution system contamination and that these impacts have persisted.

Natural Soil/Groundwater Species and Residual Impacts

During the course of the study, domestic wells were sampled over time in order to evaluate seasonal differences in the contamination. If the bacteria were natural soil or groundwater species of the area, or were persisting from some previous event, one would expect the bacteria to be present in water samples regardless of when the samples were collected. Sampling during seasonal high water table in August of 1999 yielded a contamination rate of 26%. When the majority of these wells were resampled during seasonal low water table in March of 2000, only 2% (one well) tested positive for Total Coliform. If the bacteria were a natural soil population, higher water use (irrigation) in the summer months could result in percolation of the bacteria into the groundwater system. In this scenario the highest contamination rates would be found down-gradient from areas where the land is used for agricultural purposes. The contamination over time, however, has spread throughout the area, with no apparent relationship to location of heavy irrigation (Appendix E). Additionally, species within the total coliform family are chemoorganotrophic bacteria, and therefore a natural groundwater population would not exist as their metabolic needs could not be met. Total coliform bacteria would have

to be introduced to the system from some contamination source. Therefore, the difference in contamination rates and the random nature of the bacterial contamination within the SMA makes a natural bacterial population or a past event resulting in contamination unlikely as potential sources of the bacteria to either the deep or shallow aquifer (Table 13).

Figure 13. Evaluation of Potential Sources and Pathways To Shallow Wells (O) and Deep Wells (X).

Source	Not Likely	Possible	Likely
Natural Soil or Groundwater Species	X O		
Surface Water (Twin Pond/Roman Cr)	X	O	
Irrigation Ditch		X O	
Septic Effluent			X O
Pathways			
Mixing Within Shallow Aquifer	X	O	
Vertical Gradients	X	O	
Windows In Unit 3	X		
Leakage Along Well Casings	X		
Leakage in Distribution System		X	

Surface Water Exfiltration

Surface water, such as Twin Ponds and Roman Creek, was examined as another potential source of bacterial contamination. Both surface water sources were sampled for inorganic chemistry and total/fecal coliforms over time during the study. Results of sample analysis can be found in Appendices E and F. Roman Creek has levels of inorganic constituents lower than that of groundwater sampled from domestic wells during all sample rounds. Levels of inorganic ions from samples taken from Twin Pond more closely matched that of groundwater. This is because Twin Pond is essentially

groundwater which has filled pits excavated for sand and gravel production. The higher levels of some constituents, such as chloride, in Twin Pond can be attributed to inflow of septic effluent from the residences surrounding the ponds. Total coliform levels were higher in Roman Creek and Twin Pond (Tables 8 and 10; Appendix E) than most domestic wells sampled. Additionally, fecal coliform bacteria were found in surface water samples, while no fecal coliforms were detected in domestic well samples. Reddy, et al. (1981) found that total and fecal coliforms had similar survival rates (half life of 41.6 hours) in a water medium (Table 2). The high levels of bacteria in the surface water sources indicate that exfiltration of these waters is a potential source of total and fecal coliform contamination to shallow groundwater in the central to western portion of the SMA. The problem with selecting either Roman Creek or Twin Pond as the overall source of contamination in the area is that groundwater flows to the south/southwest, therefore contamination from these surface waters could only impact wells down-gradient (Figures 18 and 19). Additionally, non-irrigation ditch surface waters represent a constant, rather than a seasonal source, of bacteria. Therefore, if surface water (Twin Pond or Roman Creek) were the source, then the contamination would be found at equal rates regardless of the time of year. Because the contamination is found throughout the entire SMA, including the eastern section (Appendix E) with seasonal variations, it is unlikely that these surface waters are the overall source of contamination to both shallow and deep wells in the area (Table 13).

Irrigation Ditches

The irrigations ditches are additional potential sources of contamination to groundwater in the SMA. The southern ditch is perched slightly above the SMA land

surface and flows through coarse gravels, while the northern irrigation ditch sits on a terrace above the SMA and flows through finer grained materials. Both ditches flow east to west across the entire SMA (Appendix A), but due to groundwater flow direction, only the northern ditch could be a potential source to the entire SMA. The southern ditch could only be a potential local source of contamination to the newer developments along Frontage Road (Appendix A). Like Roman Creek, the levels of inorganic constituents in the irrigation ditches were generally lower than those found in groundwater samples (Tables 5, 9, and 11). Samples from the irrigation ditches indicated the presence of both total and fecal coliforms (Tables 8 and 10). At first glance, it seems as though the irrigation ditches are possible sources of contamination. The ditches are only used during the summer months when contamination rates are the highest and they have high levels of coliform bacteria. It is unlikely, however, that the irrigation ditches are the overall source of contamination in the SMA. For example: the distance along a groundwater flowpath from the northern ditch to site 28-11H is approximately 6300 ft. At a groundwater velocity of 3.8 ft/d (calculated from velocity = hydraulic conductivity * hydraulic gradient / porosity), it would take 1600 days for bacteria to reach this site, assuming no filtration or adsorption of bacterial cells. Given the total coliform concentration of 1550 CFU/100 mL in the ditch sampled August, 2000, and the T1/2 reported by Reddy, et al, 1981, total coliform bacteria would only survive seven days in the shallow aquifer. Therefore, the northern ditch might contribute to some of the contamination locally (shallow wells along Larson Lane), but it is very unlikely that bacteria could survive long enough to be transported from the irrigation ditches to all areas of the SMA where contamination has been found (Table 13).

Septic Effluent

The final source of contamination evaluated in this study is septic effluent. This source has been the focus of the study, as the hypothesis is that the seasonal rise in the water table results in inadequate separation between drainfields and the water table. The result is contamination of the shallow groundwater with septic effluent. This is the most likely source as all residences in the SMA use septic systems to dispose of domestic wastes. Drainfields are found throughout the entire area and represent a regional, rather than a local, source of contamination. Although septic systems are a continuous source, it is the rise in the water table elevation throughout summer months that results in groundwater contamination, making them a seasonal source of bacteria. Septic effluent in the Frenchtown area is characterized as having high levels of chloride (13.8-42.9 mg/L), nitrate (0.200-21.2 mg/L), sulfate (8.40-16.2 mg/L), and sodium (23.0-60.1 mg/L) (Lauerman, 1999). A good example of contaminant levels in groundwater receiving septic effluent can be seen in multi-level well port 11HS-10 (Tables 9 and 11). Chloride levels range from 16.1-29.2 mg/L, nitrate levels range from 12.9 to 32.6 mg/L, sodium levels range from 37.0-40.6 mg/L, and sulfate levels range from 18.1-31.7 mg/L. Additionally, high levels of total coliforms are found in septic effluent. It is interesting to note that no fecal coliforms were found in samples of groundwater from any multi-level well adjacent to a drainfield, even in 28-11HS (an instrument clearly sampling impacted groundwater). Although some samples from domestic wells had levels of certain constituents (sulfate) close to the lower range of septic effluent, all other ion levels of were generally much lower in domestic wells than in effluent. Multi-level wells were installed adjacent to domestic wells on three sites to evaluate whether the shallow

groundwater near these deep wells was contaminated. Levels of chemical indicators of septic effluent in these instruments were near the lower range found in septic effluent and in August 2000, chloride and nitrate levels increased with depth at site 28-11H). Additionally, coliforms were found in the lower ports of instruments adjacent to domestic wells. These results indicate that the shallow groundwater does show contamination and septic effluent is the most likely source, and this source is found in the vicinity of well casings (Table 13).

Pathway Evaluation, Within The Shallow Aquifer and To The Deep Aquifer

Mixing Within the Shallow Aquifer

The first step in pathway analysis was to install and sample multi-level wells on three sites in order to create a vertical profile of the chemistry and biology of the shallow aquifer. Background concentrations of constituents have been established by sampling the Touchette Lane Monitoring Well over time. Background chloride concentrations average 7.00 mg/L, nitrate 1.31 mg/L, calcium 61.1 mg/L, bicarbonate 203 mg/L, sulfate 10.5 mg/L, sodium 9.30 mg/L, magnesium 15.0 mg/L, and potassium 3.00 mg/L (MCCHD, 1994). The multi-level wells adjacent to domestic wells have gross inorganic chemistry concentrations that are fairly close to background, with slight variations with depth (Tables 9 and 11). The multi-level wells adjacent to drainfields generally have general ionic concentrations higher than background in the shallowest ports, but these levels drop off to background levels quickly with depth (Tables 9 and 11). Because certain multi-level well ports show an increase in some constituents with depth, it is possible that shallow domestic wells can become contaminated due to mixing within the aquifer (Table 13). Although mixing in the shallow aquifer is an unlikely source to deep

wells, it is a possible source to shallow wells. This pathway could not be completely evaluated because the deepest ports on the instruments were finished at depths of 19 ft below land surface, while shallow wells are finished 30-50 ft below land surface (Appendix A).

Vertical Gradients

Piezometers adjacent to domestic wells were used to measure vertical gradients present between the two aquifer systems in the SMA. Throughout most of the year, upward vertical gradients exist under un-pumped conditions. During the late summer months the water table in the shallow aquifer rises in response to runoff and irrigation. During the seasonal water table rise, the trend switches from an upward to a downward vertical gradient. If large enough, this vertical gradient provides a potential to drive contaminated shallow groundwater into the finer-grained Unit 3 and towards the deep aquifer. Numerical simulations were performed to evaluate the time it would take for water in the upper aquifer to be transported through Unit 3 to the deep aquifer. Simulations that assume the well borehole through Unit 3 is sealed indicated that with only a vertical hydraulic gradient (no simulation of actual flow within the upper and lower aquifers), it would take up to 10,000 days for shallow groundwater to reach the deep aquifer, regardless of whether a domestic well was pumping or not (Appendix I). The presence of a horizontal gradient in the shallow aquifer of 0.0014 ft/ft (that found in August, 2000) resulted in bacteria being preferentially transported horizontally, never reaching the deep aquifer. These simulations indicate that vertical gradients within a continuous thickness of Unit 3 are not sufficient to transport bacteria to the deep aquifer system (Table 13). A downward vertical hydraulic gradient, however, is a possibly

pathway for contamination of shallow wells. The total coliform bacteria detected in samples from multi-level wells indicate that the contamination migrated deeper into the system between the initial sampling in May/June 2000 and high water table sampling in August 2000 (Tables 8 and 10). This trend could be due to an increasing downward vertical hydraulic gradient which forced the contamination deeper in the shallow aquifer throughout the summer.

Windows In Unit 3

The two sand and gravel aquifers in the SMA are separated by a deposit of finer grained material, which restricts transport of bacteria from the shallow aquifer to the deep aquifer. It has been suggested that Unit 3 may thin or pinch out to the north, resulting in direct contact between the aquifers. It is also possible that more permeable "windows" in this deposit are present in the SMA. If present, direct contact between the aquifers could facilitate bacterial transport. Three cross-sections were drafted to evaluate these scenarios (Figures 15, 16, and 17). Although Unit 3 does thin slightly in areas to the north, there is no indication of any direct contact between the aquifers. Therefore, this is an unlikely pathway by which bacterial contamination impacts deep domestic wells (Table 13).

Leakage Along Well Casings

Although numerical simulations indicate that vertical gradients alone are not sufficient to transport bacteria through the fine grained material in Unit 3 to the deep aquifer system, it is possible if gaps along wells casings exist transport rates between aquifers would increase. Numerical simulations used to represent the unlikely condition that well casings passing through Unit 3 are not fully sealed and a continuous zone

around the casing between Units 2 and 4 is present results in the transport time decreasing from 10,000 days to as little as 3.5 days (Appendix I). If there are gaps in the material equal to a vertical hydraulic conductivity of 10 ft/d and no horizontal gradient exists, the travel time decreases to 110 days (Table 2). This is still a time that exceeds the survival rate of coliforms. If the vertical hydraulic conductivity along the casing reaches 1000 ft/d (the equivalent of a zone of coarse sand and gravel existing continuously along the entire casing), the travel time decreases to 4 days. This is a travel time that is within the survival rate of coliforms in groundwater systems. The travel time decreases to 3 days if the vertical hydraulic conductivity along the casing increases to a point that there is no restriction of flow (Kz >=1000000ft/d). With the presence of a horizontal hydraulic gradient in the shallow aquifer, the vertical conductivity of the material along the casing must reach a level of 1000 ft/d before the potential for vertical transport of bacteria exceeds the horizontal. Although numerical simulations indicate that there are some situations in which bacteria can be transported to the deep aquifer in times within their life span (Reddy, et al., 1981), it is unlikely a these situations exists under field conditions. When a well is drilled, material below the water table collapses around the casing. Although some gaps may exist, it is highly unlikely that there is a corridor of unrestricted vertical flow along any well casing in the SMA (Table 13).

Leak in Distribution System/Pitless Adaptors

A final pathway for contaminant transport is through leaks/breaks in well casing and/or distributions system, such as insufficient casing welds or a poorly sealed pitless adaptor at frost-free hydrants or at pipe joints. The distribution lines which supply water to the residence consist of a pipe running perpendicularly from the well to the house,

buried at a depth of about six feet below land surface. If there is an inadequate seal of the pitless adaptor, or of any other juncture along the pipe (such as a frost free hydrant), then there is the potential for contamination to be introduced into the distribution system. Numerical simulations indicated that if the water table rose to a level above the assumed burial depth of six feet below land surface and if an avenue into the casing or piping was present, then the travel time of bacteria to a domestic well could be as little as two days (Appendix I). There are times when the water table in the SMA reaches these levels. This is especially apparent along Larson Lane in the northwest corner of Section 28. Groundwater ponding adjacent to the irrigation ditch is common in late summer, and depth to water in these wells is less than the burial depth of the distribution systems. This pathway could not be evaluated on any of the instrumented sites through pumping or tracer tests, as the water table on these sites never reached the assumed six foot burial depth during the study period (Table 13).

The pathways discussed in the previous sections are all plausible, some more so than others. The most likely avenue for bacterial contamination to impact deep domestic wells is leakage into distribution system (Table 13). All of the pathways, however, are dependent on the shallow aquifer containing contaminated groundwater. Results from chemical and bacterial samples of water taken from multi-level wells indicate that the shallow groundwater is being impacted by some seasonal bacterial source, most likely septic effluent (Table 13).

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

This study of the Roman Creek – Touchette Lane Special Groundwater Management Area provided the following conclusions:

1. The subsurface geology consists of the documented units described in previous studies. Cross-sections indicate that there is no observed direct contact between the two aquifers through either permeable "windows" or a pinching out of Unit 3 to the north.

2. The shallow groundwater fluctuates seasonally due to spring run-off and irrigation. The magnitude of water table fluctuations measured in domestic wells between seasonal high water table in late summer and season low water table in spring ranged from 3.07 ft to 7.39 ft and averaged 4.42 ft.

3. The potentiometric surface in the SMA fluctuated little during the study. The magnitude of fluctuations measured in deep domestic wells between seasonal high and seasonal low water table ranged from 0.01 ft to 0.87 ft and averaged 0.53 ft.

4. Although hydraulic gradients in both the shallow and deep aquifers varied, groundwater in both systems flows to the south/southwest.

5. There is seasonal bacterial contamination of domestic wells in the SMA, ranging from 2% during seasonal low water table to 26% during seasonal high water table.

6. The shallow groundwater in the vicinity of deep domestic wells is contaminated by a bacterial source, most likely septic effluent.

7. The most likely pathway by which contaminated shallow groundwater reaches deep domestic wells is by leakage into distribution systems.

The conclusions of this study indicate that shallow groundwater is likely being contaminated by septic effluent, and that contaminated groundwater is most likely impacting domestic wells by leakage into the distribution system. Further development of the area will result in additional loading of the shallow aquifer with septic effluent, however if the pathways identified in this study are correct, contamination of new

domestic wells could most likely be avoided through: restrictions allowing only development of deep wells, adequate grouting of well casings into Unit 3, and sealing of the well/distribution system.

The results of this study leave many unanswered questions regarding the nature of the bacterial contamination. A detailed microbial/viral study of groundwater in the SMA, such as DNA fingerprinting of the microbial ecology in each potential source, could help to identify which is resulting in bacterial contamination of domestic wells. Additionally, recent studies by Trest et al. (1999) indicate that drilled domestic wells can become contaminated with coliforms originating from bio-aerosols in the vicinity of the well head. Although examining this potential source was beyond the scope of this study, any future investigations should take this information into consideration. Source identification could also be analyzed by developing a mixing model which incorporates ion ratios of each potential source. More sophisticated numerical simulations and tracer studies could aid in the identification of the pathway by which bacteria reach deep domestic wells. Additionally, this study was conducted during a relatively "dry" year. Monitoring of the area for at least one more cycle of high/low water table during a year more representative of average precipitation should be conducted.

Resolution of the SMA issue could be accomplished in two phases. Step one would be to determine whether or not the deep aquifer system is being contaminated by shallow groundwater leaking from the upper aquifer. This could be accomplished by drilling wells fully grouted into Unit 3 with secure casing welds into the deep aquifer adjacent to existing which have shown consistent contamination over time. If sampling of these new wells over time indicates no total coliform contamination of the deep

aquifer, the existing wells finished in the area must be being impacted by shallow groundwater leaking along the well casing or into the distribution system. This can also be evaluated using existing deep wells, such as the well used by lots 28-11B and 28-11C, which have been sampled on numerous occasions over time and have been consistently coliform negative (Appendix E). The next step would be to construct a fully sealed distribution system. If sampling over time indicates that this new well/distribution system is providing coliform free water, then it can be assumed that new wells constructed in this manner can provide potable water to new development in the area. Additionally, existing wells could be retrofitted to meet standards set by "model" wells. As all wells in the area would be providing potable water, the SMA restrictions would no longer be necessary.

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Appendix A

Well Data

Location of Wells/Lots Within The SMA

Lot	Well Depth	Driller	Date Drilled	Date	DTW	TOC
27-1A	75.0	Jerome	12/15/77	31-Aug	18.22	3040.53
27-1B	53.0	Jerome?	5/14/98	30-Aug	12.94	3041.57
27-2B1	180	Jerome	2/1/95	2-Sep	13.95	3036.98
27-3B	45.5	CKC	11/1/93	31-Aug	12.22	3041.19
27-3C	24.0	Jerome	7/1/81	30-Aug	9.260	3039.81
27-4A	41.0	Jerome	6/18/77	31-Aug	11.30	3039.50
27-4B2	42.5	Camp	4/13/78	3-Sep	12.36	3040.57
27-6A	179	Camp	9/4/96	30-Aug	15.58	3037.57
27-6D	180	Jerome	8/20/79	8-Sep	14.64	3037.67
27-7A	176	Jerome	6/10/92	30-Aug	16.40	3037.72
27-7D	106	Magstadt	6/27/77	7-Sep	14.70	3037.74
27-8C	28-30	Measured		7-Sep	11.83	3036.01
27-9	N/A	N/A		3-Sep	26.28	3058.37
28-2A1	180	Krass	5/31/96	2-Sep	13.83	3034.12
28-2A2B	175	Jerome		2-Sep	12.36	3032.80
28-2B1B	168	Jerome	9/22/94	2-Sep	9.780	3030.60
28-2B1D	173	Jerome	5/25/95	2-Sep	12.69	3033.85
28-3B2	180	Jerome	6/11/90	7-Sep	13.51	3035.53
28-4A1	174	Jerome	3/28/84	30-Aug	13.84	3035.32
28-4A2	174	Jerome	3/29/84	31-Aug	14.22	3036.03
28-4A3	174	Jerome	3/29/84	30-Aug	15.01	3036.04
28-4B4	175	Jerome	4/12/93	7-Sep	9.810	3032.02
28-5A3	174	Jerome	7/16/98	30-Aug	11.19	3032.50
28-5B1	178	Jerome	4/30/96	2-Sep	12.51	3034.21
28-5B2	180	Jerome	5/26/98	3-Sep	14.26	3036.04
28-5B4	180	Jerome	4/14/97	3-Sep	11.33	3033.25
28-6A	190	Jerome	5/24/98	2-Sep	11.94	3032.67
28-6B	190	Jerome	5/25/98	3-Sep	12.65	3033.43
28-6C1	180	Jerome	6/10/92	2-Sep	15.59	3036.50
28-6C2	180	Camp	1/29/92	8-Sep	14.00	3034.52
28-6I	176	Jerome	12/17/96	3-Sep	12.72	3033.56
28-7A	180	Jerome	6/12/95	1-Sep	13.63	3033.54
28-7C	175	Jerome	8/27/91			3033.59
28-7D	173	Kane	6/29/95	1-Sep	13.61	3033.63
28-8A	160	Measured		31-Aug	14.17	3032.40
28-8B	197	Camp	9/1/95	31-Aug	14.52	3033.11
28-8D	184	Smith	4/13/94	3-Sep	12.28	3028.47
28-11F	180	Camp	3/11/85	1-Sep	8.830	3027.59
28-11H	172	Measured		1-Sep	12.66	3027.69
28-13A2	120	Jerome	6/18/84	8-Sep	5.200	3025.37
28-13A4	97	Jerome	5/17/84	1-Sep	9.330	3026.02
28-13D	100	Jerome	12/12/85	7-Sep	5.840	3026.41
28-14C	115	CKC	12/9/92	31-Aug	11.00	3028.835
28-17D	155	Jerome	4/12/93	1-Sep	13.91	3031.395
28-18	32	CKC	6/29/83	3-Sep	9.290	3035.08

Lot	HIGH POT	DATE	DTW	LOW POT
27-1A	3022.31	21-Mar	18.48	3022.05
27-1B	3028.63	21-Mar	18.77	3022.80
27-2B1	3023.03			
27-3B	3028.97			
27-3C	3030.55	21-Mar	16.34	3023.47
27-4A	3028.20			
27-4B2	3028.21	21-Mar	18.13	3022.44
27-6A	3021.99	21-Mar	16.00	3021.57
27-6D	3023.03			
27-7A	3021.32	22-Mar	16.27	3021.45
27-7D	3023.04	21-Mar	16.10	3021.64
27-8C	3024.18			
27-9	3032.09	21-Mar	33.67	3024.70
28-2A1	3020.29	29-Mar	14.10	3020.02
28-2A2B	3020.44			
28-2B1B	3020.82			
28-2B1D	3021.16	14-Mar	13.15	3020.70
28-3B2	3022.02	22-Mar	14.16	3021.37
28-4A1	3021.48	21-Mar	13.51	3021.81
28-4A2	3021.81			
28-4A3	3021.03	22-Mar	14.70	3021.34
28-4B4	3022.21			
28-5A3	3021.31	22-Mar	10.80	3021.70
28-5B1	3021.70	22-Mar	13.22	3020.99
28-5B2	3021.78	22-Mar	15.00	3021.04
28-5B4	3021.92	22-Mar	12.14	3021.11
28-6A	3020.73	22-Mar	12.34	3020.33
28-6B	3020.78	14-Mar	13.08	3020.35
28-6C1	3020.91	14-Mar	16.11	3020.39
28-6C2	3020.52	14-Mar	14.01	3020.51
28-6I	3020.84	22-Mar	13.00	3020.56
28-7A	3019.91	15-Mar	14.50	3019.04
28-7C		15-Mar	14.50	3019.09
28-7D	3020.02	15-Mar	14.47	3019.16
28-8A	3018.23	15-Mar	12.82	3019.58
28-8B	3018.59			
28-8D	3016.19			
28-11F	3018.76	15-Mar	8.410	3019.18
28-11H	3015.03	15-Mar	8.930	3018.76
28-13A2	3020.17	15-Mar	8.370	3017.00
28-13A4	3016.69	15-Mar	12.40	3013.62
28-13D	3020.57	15-Mar	9.040	3017.37
28-14C	3017.84			
28-17D	3017.49			
28-18	3025.79	22-Mar	13.72	3021.36

Lot	Well Depth	Driller	Date Drilled	Date	DTW	TOC
28-20A1	178	Measured		8-Sep	10.62	3037.34
28-20B2	175	Jerome	8/12/92	8-Sep	9.260	3032.07
28-21A2	51.0	Jerome	3/31/83	3-Sep	13.55	3040.41
28-23D	150			31-Aug	12.38	3028.99
28-24A	78.0	Jerome?	2/2/95	31-Aug	9.980	3028.43
28-24C				31-Aug	12.62	
28-24D	165	Jerome	9/12/90	1-Sep	12.25	3028.41
29-				30-Aug	11.93	3031.14
29-				7-Sep	11.97	3031.14
29-				22-Sep	12.11	3031.14
29-A12	248	Western	5/13/74	8-Sep	10.96	3028.75
29-A13	40.0	Kane	10/1/92	8-Sep	12.66	3028.75
29-A16	150			8-Sep	12.15	3028.62

Lot	HIGH POT	DATE	DTW	LOW POT
28-20A1	3026.72			
28-20B2	3022.81			
28-21A2	3026.86	22-Mar	18.50	3021.91
28-23D	3016.61	30-Mar	14.69	3014.30
28-24A	3018.45	30-Mar	13.71	3014.715
28-24C	-12.62			
28-24D	3016.16			
29-	3019.21	14-Mar	15.46	3015.68
29-	3019.17	15-Mar	15.45	3015.69
29-	3019.03	21-Mar	15.33	3015.81
29-A12	3017.79			
29-A13	3016.09			
29-A16	3016.47	30-Mar	12.93	3015.69

Appendix B

Water Level Measurement

Methodology

Water Level Measurement

When measuring the water level in a domestic well, the residents were first asked not to use water inside the residence, to ensure that the pump would not kick on during measurement, drawing down the water level. Next either the cap (if removable) or the plug on the well cap was removed. The pit-less adaptor was located, and the probe of the water level indicator was lowered into the casing on the opposite side. Once the probe hit the standing water in the casing the instrument sounded and the depth to water from the top of the casing was read, to within 0.01 ft, from the scale on the cable. The cable was then lifted slightly and lowered three to four times to ensure accurate measurement of the water level. If the pump kicked on, then the measurement was not taken until the water returned to the static level in the casing. Following pump shut off, water level recovery was monitored with the electric tape. The cable was lowered to the water level, and then raised slightly. When the water level rose to the level that the probe was at, the cable was raised slightly again. This process was repeated until the water level ceased to rise. At this time, the depth to water from the top of the casing was measured.

Appendix C

Microbial Analysis/

Species Identification

Bacterial Analysis

Samples for microbial analysis were taken to the MCCHD lab. All samples were analyzed for total and fecal coliform using a presence/absence test (IDEXX, Inc.). This test involved the use of a prepackaged media (Colilert®), which was added to each sample bottle using standard techniques (APHA, 1992). The media contains growth factors selective for the metabolism of coliform species, a pH indicator (to confirm lactose fermentation), and MUG. After incubation for 24 hours at 35°C, the samples were compared to a standard. Lactose fermentation is a characteristic of coliforms, therefore if a sample contained coliforms, it would change from colorless to a shade of yellow, due to the pH indicator. Any sample that changed from colorless to a shade of yellow darker than or equal to the standard was positive for total coliform. Once the presence or absence of total coliform was established, the positive samples were examined under a black light. If a sample fluoresced under the black light, it was positive for both total and fecal coliforms. If the sample did not fluoresce, then it was positive for total coliform, but negative for fecal coliform. Fecal coliform bacteria are a subset of the total coliform group and are differentiated by their ability to ferment lactose with gas production at higher temperatures than other coliform species. Additionally, while the total coliform group consists of a variety of ubiquitous species, the only true source of fecal coliforms is the gastrointestinal tract of warm blooded mammals.

Coliform concentrations were quantified through a most probable number (MPN) technique using a Quanti-tray®. After a sample was inoculated, it was poured into either a 51 or 97 well Quanti-tray®. The tray was then sealed and the samples were incubated for 24 hours at 35°C. Following incubation, the trays were compared to a standard. The

number of wells darker than or equal to the shade of yellow of the standard was related to the total coliform concentration using a MPN chart. Positive samples were then examined under a black light for fecal coliform. The number of wells that fluoresced under a black light was related to the fecal coliform concentration using the same MPN chart. Duplicates were run on 10% of the water samples for QA/QC purposes. QA/QC is performed on each box of Colilert®. Samples containing known species (Escherichia coli, Klebsiella pneumoniae, and Pseudomona aeruginosa) are inoculated with the media and samples are incubated for 24 hours at 35°C. Following incubation, the samples are compared to the standard. The P. aeruginosa sample should remain colorless and should not fluoresce, as it is a non-coliform species. The K. pneumoniae sample should change from colorless to a shade of yellow darker than or equal to the standard, as it is a total (not fecal) coliform. The E. coli sample should turn yellow and fluoresce, as it is a fecal coliform. If any of the tests do not yield the expected results, then that shipment of media is not used.

Species Identification

As the presence/absence tests only indicate the presence of total and fecal coliform, attempts at coliform speciation were made. Prepackaged API 20E® test strips from bioMerieux Vitek, Inc. were used for species identification. Water samples were taken in accordance with established protocol. Samples were taken to the MCCHD laboratory for analysis. Rather than the presence/absence test, a plating technique (total coliform membrane filtration) was used for coliform analysis. Water samples were run through a vacuum onto a 47mm sterilized filter with a pore size of 0.45 μm (GelmanSciences). The filter was transferred to a sterile plate containing mEndo, a

medium selective for the growth of coliform species (DIFCO Laboratories). The plates were then incubated for 24 hours at 35°C. Following incubation, red, pink, and green-sheen colonies were counted as coliforms under a stereoscope.

Although only red, pink, and green-sheen colonies were counted as coliforms, all colonies on each plate were speciated. Using sterile inoculating sticks, the colonies were transferred from the plates to sterile test tubes containing 15 ml of a 5% NaCl solution. The solution was stirred to disperse bacterial cells equally throughout the test tube. The solution was then pipetted into cupules, containing various substrates, on the API 20E test strips. Certain cupules were overlain with sterile mineral oil to produce an anaerobic environment during incubation. The test strips were placed into incubating trays containing 5 ml of sterile water and were incubated for an additional 24 hours at 35°C.

Following the second incubation, the results of the API 20E test strips were compared to a standard result sheet. Each cupule on the test strips contained a different substrate and the bacteria were speciated based on the metabolic reaction to each substrate. Some cupules required the addition of a reagent before the results could be read. Each cupule was read as having the substrate metabolized (positive) or not metabolized (negative) based on a specified color change. The results fore each test strip were recorded on a standard data sheet. Based on the reaction to the substrates, a seven-digit code was produced for each test strip (bacterial colony). The seven-digit code was then compared against a database and the probable coliform species was identified.

Appendix D

Multi-Level Well Construction

And Installation

Multi-Level Well Construction

Multi-level well design was modified from Pickens, et al. (1981). The main piezometers of the instruments were constructed from two lengths of 0.50-inch diameter CPVC pipe. The two lengths were joined by a 0.50-inch CPVC couple adhered with PVC cement. Sixteen 0.11 in diameter holes were drilled into the lower two inches of the CPVC and the piezometers were left open-ended. In order to prevent sediment from clogging the screened interval, the end of the piezometers were covered with nylon paint straining mesh. A single layer of nylon mesh was wrapped twice around the CPVC, then folded back to cover the bottom and secured with two 0.50-inch diameter rubber "O" rings.

Multi-level sampling ports were constructed from 0.25-inch (outer diameter) polyethylene tubing. To increase the open area of the ports, sixteen 0.0625-inch diameter holes were drilled over the lower one-inch and the tubing was left open-ended. To prevent blockage of open-area, the "screened" interval was covered with nylon paint straining mesh as described above. Three sampling ports were constructed for each multi-level well. The ports were attached to the outside of the CPVC at intervals of 5, 7, and 9 feet from the bottom with four inch plastic cable ties.

Instrument Installation

On Selected sites multi-level wells were installed adjacent to (up-gradient) the domestic well and down-gradient from the septic drainfield using a Geoprobe®. Five foot lengths of two inch casing were pushed to a depth of 20 ft below land surface. At the initial site (28-11H), the casing was then pulled back one foot and the sediment was

allowed to collapse in the borehole (Figure 12). This was done so that the CPVC piezometer would be finished at a depth of 19 ft below land surface with polyethylene ports at 14 ft, 12 ft, and 10 ft below land surface. Water level was measured in the casing to be approximately 12 ft below land surface, using an electric sounder. At subsequent sites, after the water level was measured, the casing was pulled back so that the CPVC piezometer would be finished at a depth of seven feet below the water table, with the lowest port at two feet below the water table, the middle port approximately at the water table, and the highest port two feet above the water table to allow for seasonal rise. This

Depths of Multi-Level Well Ports Below Land Surface.

Site	Piezometer (ft below surface)	First Port (ft below surface)	Second Port (ft below surface)	Third Port (ft below surface)	Additional Ports (ft below surface)
28-11H, well	19	14	12	10	
28-11H, septic	19	14	12	10	6
28-5B1, well	19	14	12	10	
28-5B1, septic	19.7	14.7	12.7	10.7	
28-4A1, well	17	12	10	8	
28-4A1, septic	18.8	13.8	11.8	9.8	

was done in order to maintain consistency between sites. Following casing adjustment, the multi-level wells were placed in the casing with the sampling ports facing up-gradient. The multi-level wells were held in place with smaller diameter pipe as the casing was pulled up and sediment collapsed in the borehole below the water table. After all of the casing was withdrawn, the borehole was packed with Colorado silica sand to within four feet of land surface. The borehole was then sealed with bentonite from four

feet to land surface in order to prevent surface water from filtering into the multi-level well.

Two different surface completions were used. The first completion consisted of one inch PVC pipe/cap embedded in the Bentonite placed over the multi-level well. This type of completion was not flush-mounted and was positioned one foot above land surface. On sites where lawn care was a concern, the completions were flush mounted. The second type of completion consisted of two inch PVC adapters and threaded plugs. Plated steel dowels with 0.1875-inch diameter were drilled perpendicularly into the adapter in a radial pattern in order to prevent the completion from spinning when the cap was removed. The completion was stabilized by embedding it in the bentonite. Following installation, the CPVC piezometer was disinfected by rinsing with a 10% bleach solution. The polyethylene ports were disinfected with a 10% bleach solution using a peristaltic pump. The solution was injected into each port for two minutes, the port was then pumped for two minutes. The well development process was repeated for five minutes at which time it was recorded whether or not each port was producing water.

Appendix E

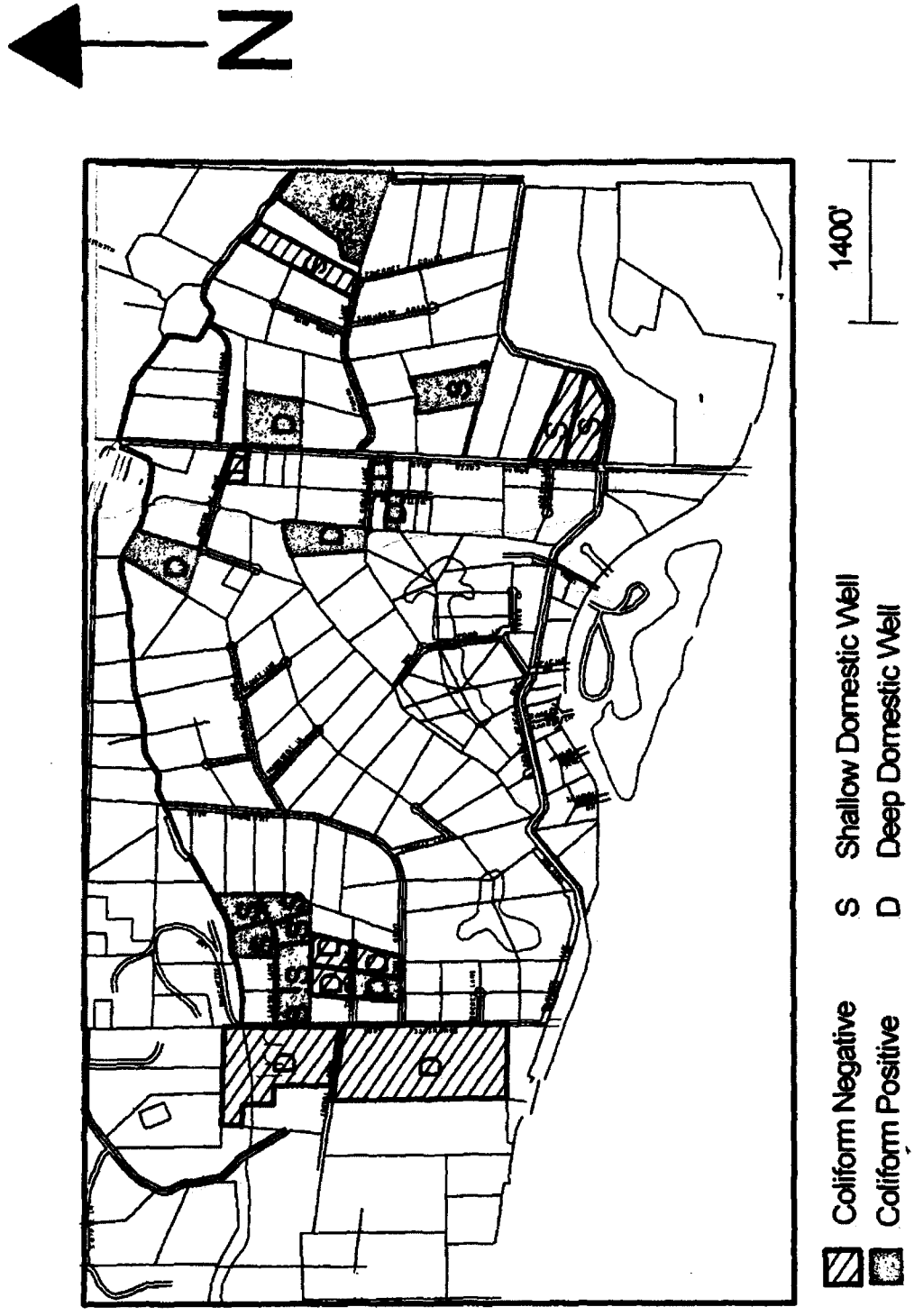
Bacterial Results

Parcel	Sept	Oct	Jan	Apr	Jul	Aug	Sept	Sept	Aug	Mar	Aug
	86	86	87	87	94	94	94	95	99	00	00
27-B		Neg				Pos	Pos				
27-1A		Pos							Neg	Neg	
27-1B									Neg	Neg	
27-2A1	Pos	Pos	Pos	Pos							
27-2B1									Pos	Neg	Pos
27-3B									Neg	Neg	
27-3C		Neg							Neg	Neg	
27-3D							Neg		Neg	Neg	
27-4A	Neg	Neg					Pos		Neg	Neg	
27-4B1		Neg							Pos	Neg	
27-4B2	Pos	Pos					Pos		Pos	Neg	Pos
27-5A2A		Neg		Neg							
27-6A									Neg	Neg	
27-6D		Neg							Neg	Neg	
27-7A							Neg		Neg	Neg	
27-7c-e	Pos	Pos		Pos			Neg		Pos	Neg	Pos
27-8C	Neg	Neg		Neg					Neg	Neg	
27-8D	Neg	Neg		Neg			Neg		Neg	Neg	
27-9									Neg	Neg	
28-1A2					Neg		Neg				
28-2A1									Neg	NEG	
28-2A2B									Pos		
28-2B2A					Pos			Neg			
28-2B1B									Neg		
28-2B1D									Pos	Neg	Neg
28-2B2B								Neg			
28-3A1							Neg		Neg		
28-3B2									Neg	NEG	
28-3C1		Pos		Neg							
28-4A1		Pos					Pos		Pos	Neg	
28-4A2	CGWC	Pos	Neg	Pos							
28-4A3		Pos					Neg		Neg	Neg	
28-4A4		Neg									
28-4B1	Pos					Neg	Neg	Neg			
28-4B2		Neg					Pos				
28-4B3		Pos		Pos			Pos				
28-4B5						Neg	Pos	Neg	Pos	Neg	Neg
28-5A3									Neg	Pos	Neg
28-5B1									Neg	NEG	
28-5B2						Pos			Neg	NEG	
28-5B4									Neg	NEG	
28-6A									Neg	NEG	
28-6B									Pos	Neg	Pos
28-6C1									Pos	Neg	Neg

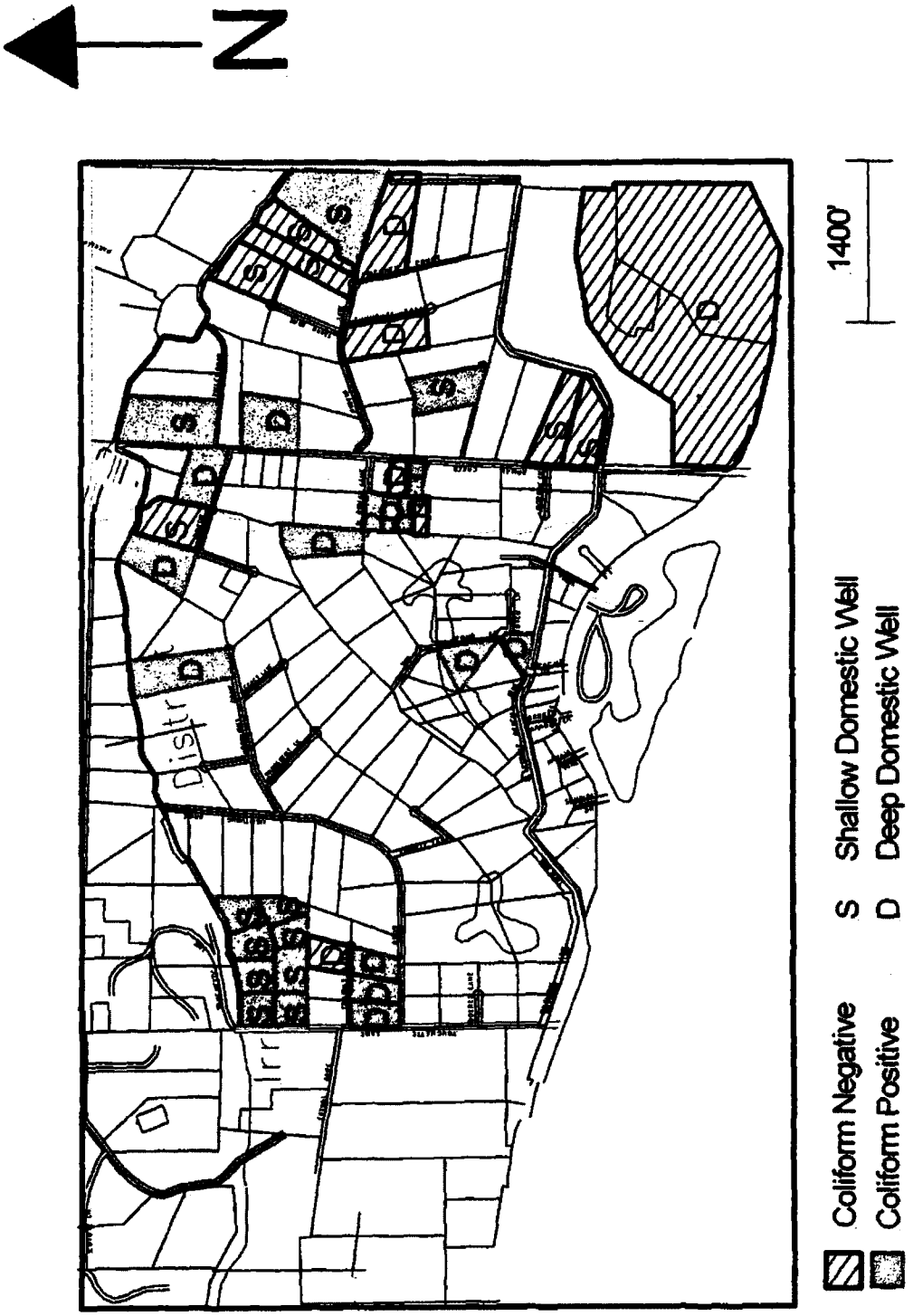
Parcel	Sept 86	Oct 86	Jan 87	Apr 87	Jul 94	Aug 94	Sept 94	Sept 95	Aug 99	Mar 00	Aug 00
28-6C2									Pos	Neg	Pos
28-6G		Pos		Pos							
28-6I									Neg	NEG	
28-7A									Pos	Neg	Neg
28-7B							Neg	Neg	Neg	NEG	
28-7C									Neg	Neg	
28-7D									Neg	Neg	
28-8A								Neg	Neg	Neg	
28-8B									Neg		
28-8D									Neg	NEG	
28-9				Pos							
28-10						Neg	Pos	Neg	Neg	NEG	
28-11A							Pos	Neg			
28-11B?	Neg							Neg	Neg	Neg	
28-11C	Neg	Neg			Neg						
28-11F	Neg	Pos	Neg	Pos	Neg		Neg		Neg	Neg	
28-11G	Pos	Pos		Pos			Neg		Neg		
28-11H		Pos	Pos	Pos			Neg		Pos	Neg	
28-13A1		Pos			Pos		Neg	Pos			
28-13A2		Pos		Pos	Pos		Neg	Neg	Neg	Neg	Neg
28-13A3	Pos	Pos	Neg	Neg				Neg			
28-13A4	Pos	Pos		Neg	Neg		Neg	Neg	Neg	Neg	Neg
28-13B	CGWC	Pos	Pos	Neg			Neg				
28-13C	Pos	Pos	Neg	Neg	Neg		Pos				
28-13D	Pos	Pos	Neg		Pos		Neg		Pos	Neg	
28-13E	Pos	Pos		Pos							
?	Pos										
28-14C							Neg		Neg		
28-15A								Pos			
28-15D					Neg		Neg	Neg			
28-16A					Neg		Neg	Neg			
28-17A					Neg						
28-17B							Neg				
28-17D						Neg	Pos		Pos	NEG	Pos
28-18		Neg		Neg					Neg	Neg	
28-19D	Pos	Pos		Neg		Neg	Neg				
28-20A1									Neg		
28-20A2A	Neg								Neg		
28-29B2							Neg		Neg	Neg	
28-21A1	Neg	Pos									
28-21A2		Neg							Neg	Neg	
28-21B2		Pos					Pos				
28-21B1							Neg		Pos		
28-23C		Pos	Pos						Neg		

Parcel	Sept 86	Oct 86	Jan 87	Apr 87	Jul 94	Aug 94	Sept 94	Sept 95	Aug 99	Mar 00	Aug 00
28-23D					Pos				Neg	NEG	
28-24A					Neg				Neg	NEG	
28-24D					Neg		Pos	Neg	Pos		
28-24C					Neg		Neg				
28-36A	Neg										
29-A3	Neg						Pos	Pos			
29-A									Neg		
29-A'	Neg				Neg		Neg		Neg	NEG	
29-C							Neg		Neg	NEG	
29-1					Pos		Pos	Neg			
29-2					Neg		Neg				
29-G							Neg		Neg		
29-H									Neg	NEG	

Pos = Total Coliform Positive
Neg = Total Coliform Negative

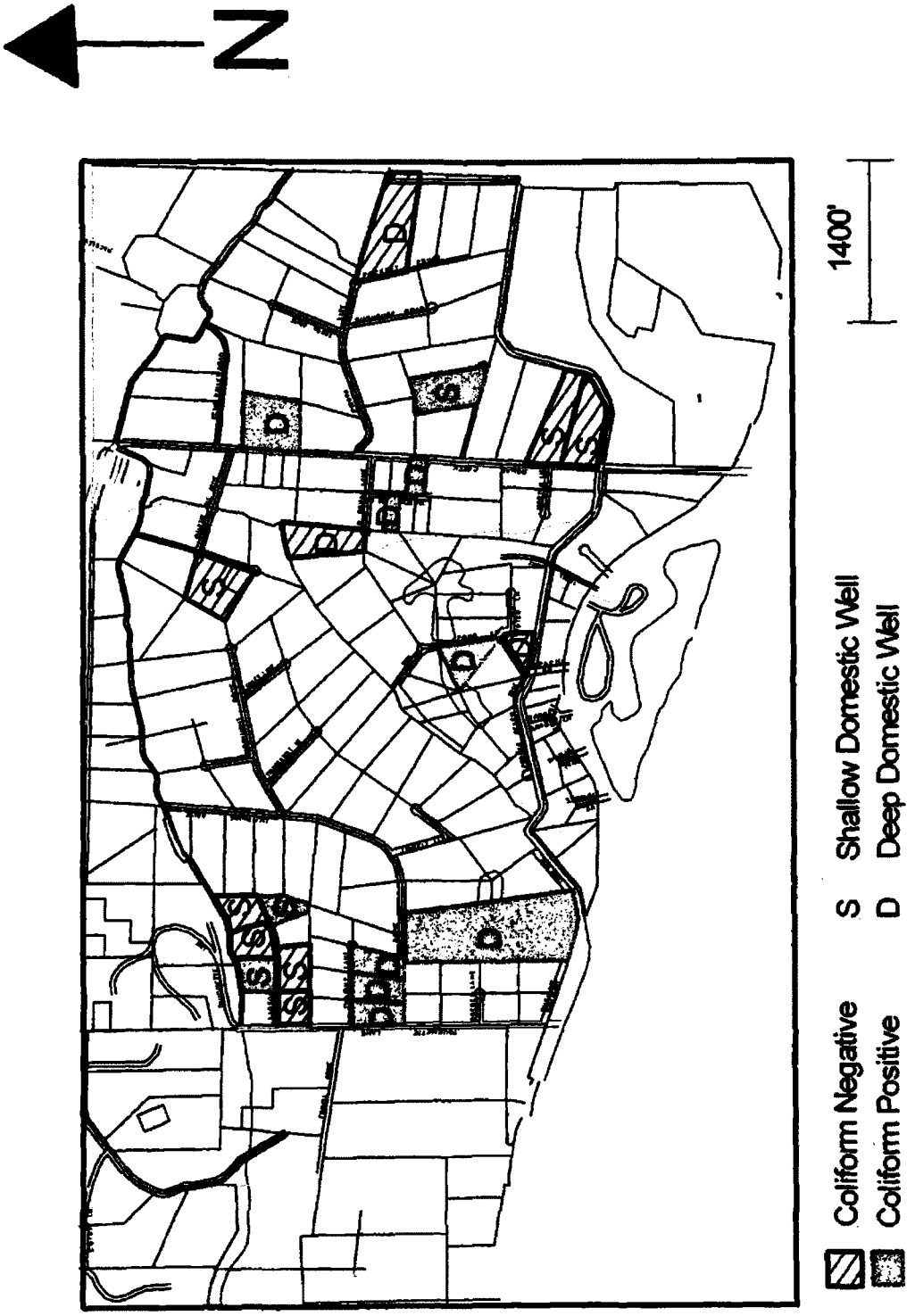


Sample Distribution, September 1986

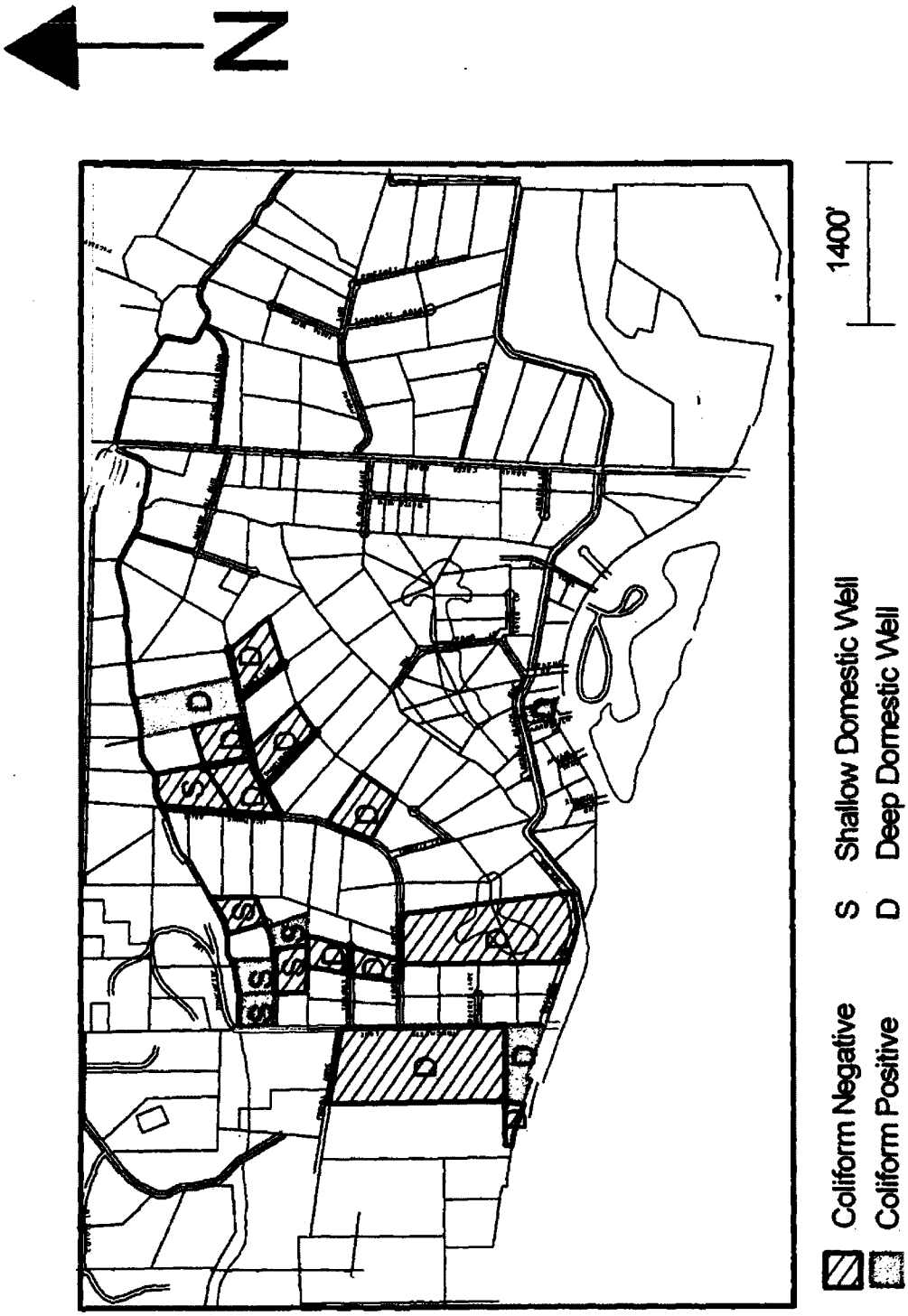


Sample Distribution, October 1986

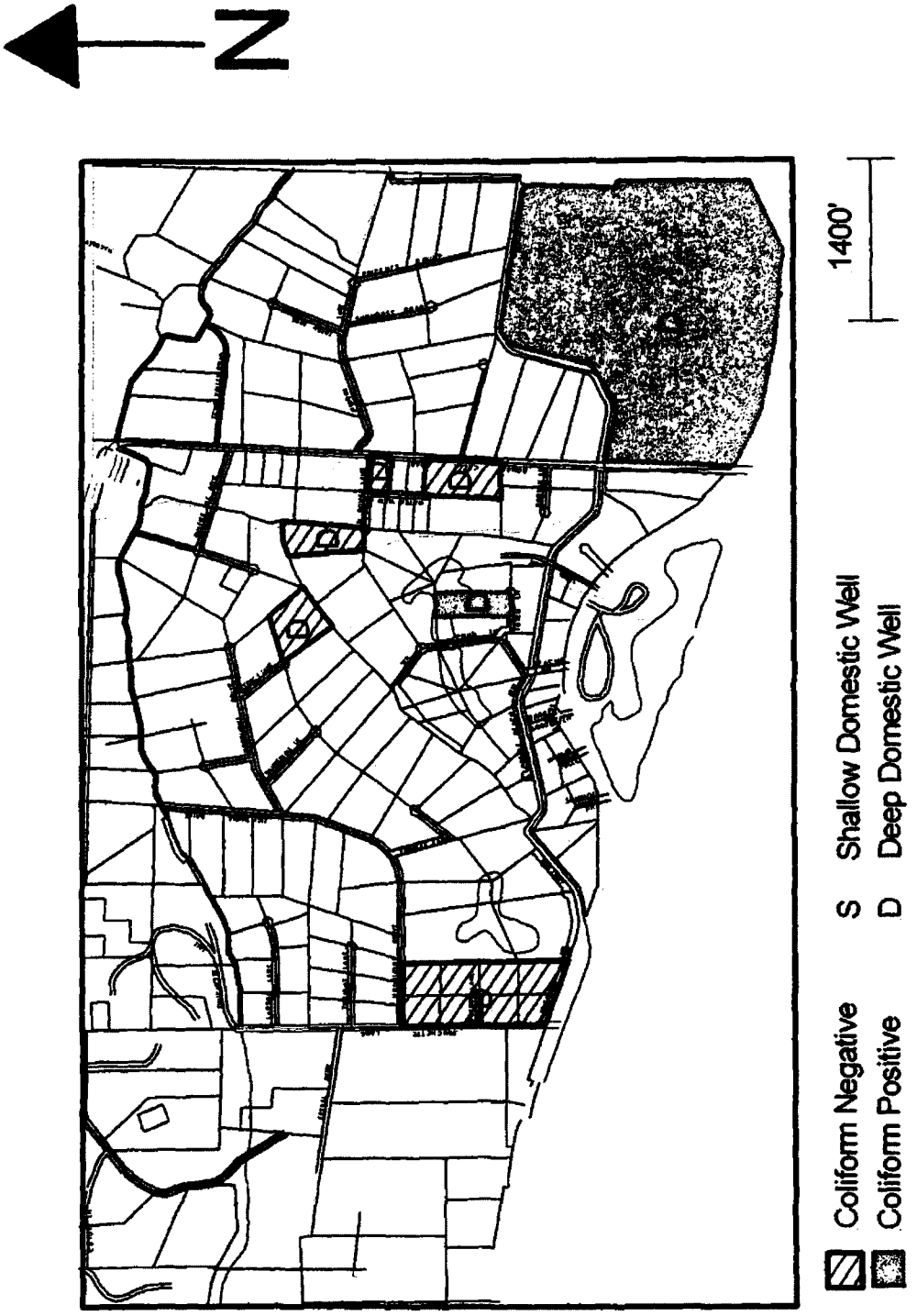
Sample Distribution, January 1987



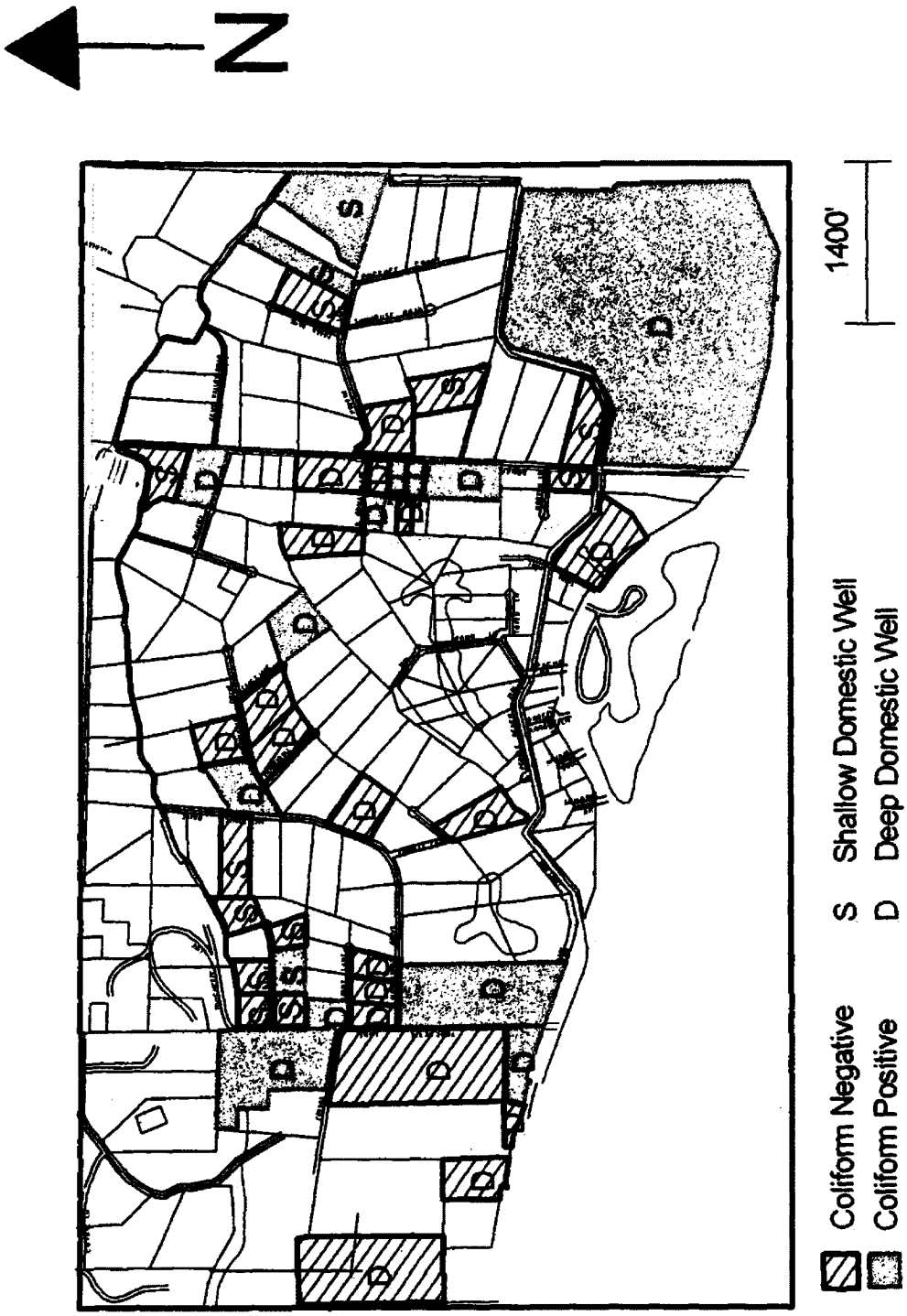
Sample Distribution, April 1987



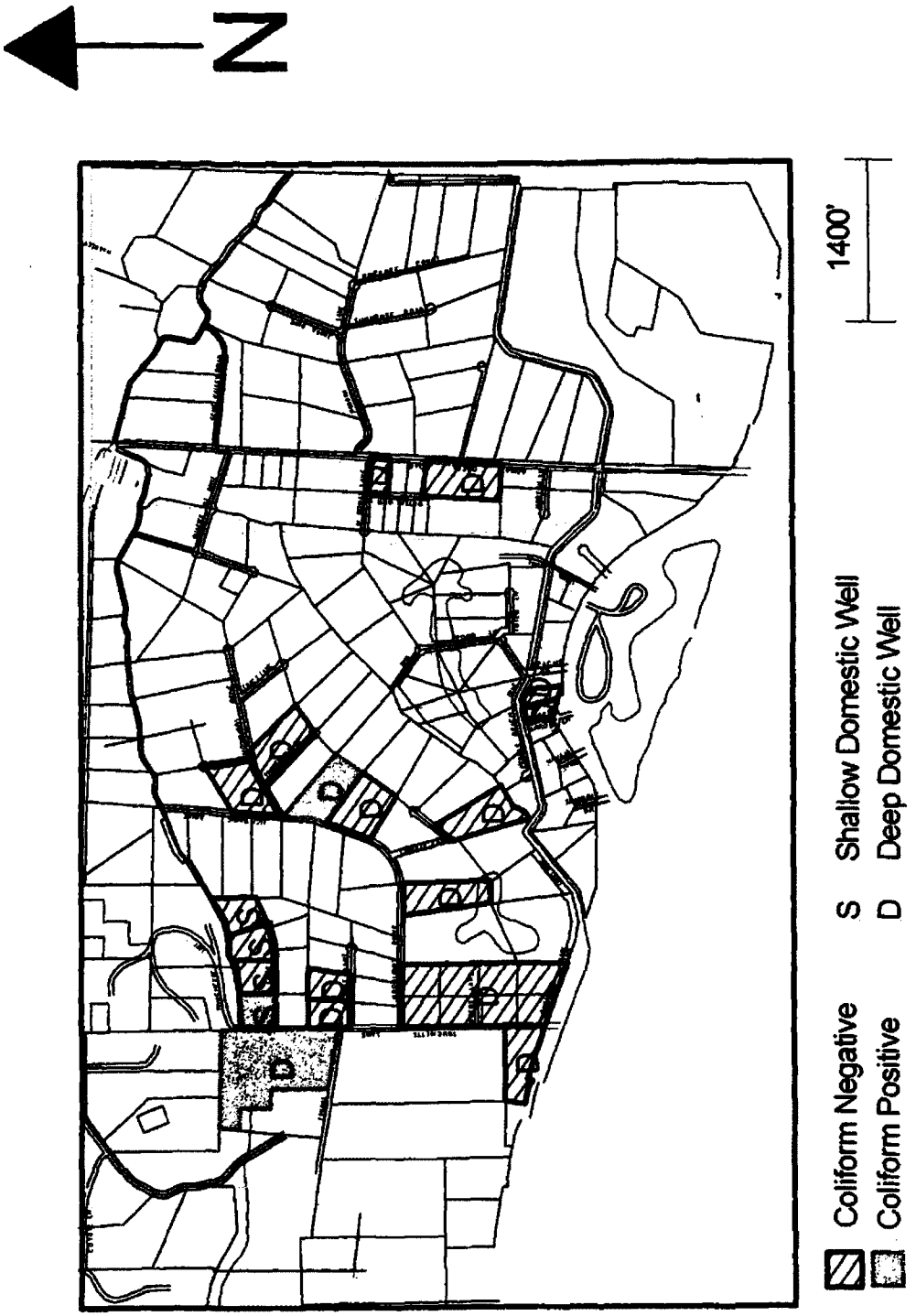
Sample Distribution, July 1994



Sample Distribution, August 1994



Sample Distribution, September 1994



Sample Distribution, September 1995

Appendix F

Inorganic Chemistry Data

Original Data

Sample Name	Date	Analyst	Fluoride	Chloride	Nitrite	Nitrate	PO_4^{-2}	Sulfate
QC SPEX (6-12)	8/18/99	LB	1.48	21.2	0.916	5.13	2.14	19.60
1/5 QC SPEX (6-12)	8/18/99	LB	0.310	4.12	0.173	2.10	0.484	4.58
STD1	8/18/99	LB	0.0100	2.50	0.0857	0.127	0.141	5.30
STD2	8/18/99	LB	0.204	5.02	0.203	0.250	0.209	9.77
STD3	8/18/99	LB	1.01	27.3	1.05	1.28	1.06	50.30
STD4	8/18/99	LB	2.10	47.0	2.03	2.47	2.01	100.00
27-1A 8/16/99	8/18/99	LB	0.063	2.03	0.00	0.00	0.00	14.90
27-3D 8/16/99	8/18/99	LB	0.0323	2.11	0.00	0.507	0.00	12.20
27-7A 8/16/99	8/18/99	LB	0.057	1.56	0.00	0.244	0.00	10.80
28-4A3 8/16/99	8/18/99	LB	0.0875	1.43	0.00	0.0855	0.00	9.87
27-2B1 8/16/99	8/18/99	LB	0.0812	1.45	0.00	0.00	0.00	8.84
28-8D 8/16/99	8/18/99	LB	0.0616	2.53	0.00	0.955	0.00	14.40
28-13A4 8/16/99	8/18/99	LB	0.0673	1.58	0.00	0.00	0.00	9.24
29-A' 8/16/99	8/18/99	LB	0.0742	2.20	0.00	0.806	0.00	12.10
28-23D 8/16/99	8/18/99	LB	0.214	1.24	0.00	0.00	0.00	5.79
28-6I 8/17/99	8/18/99	LB	0.0787	1.10	0.00	0.450	0.00	6.52
28-18AB 8/17/99	8/18/99	LB	0.0117	2.01	0.00	0.360	0.00	8.69
28-7A 8/17/99	8/18/99	LB	0.0833	0.899	0.00	0.295	0.00	5.49
29-H 8/17/99	8/18/99	LB	0.134	1.05	0.00	-0.032	0.00	5.92
28-20B2 8/17/99	8/18/99	LB	0.0806	1.60	0.00	0.00	0.00	8.96
28-10C 8/17/99	8/18/99	LB	0.105	2.43	0.00	0.906	0.00	14.1
28-2B1B 8/17/99	8/18/99	LB	0.0716	2.42	0.00	0.902	0.00	13.8
27-7A 8/16/99 LD	8/18/99	LB	0.0571	1.57	0.00	0.258	0.00	10.9
27-7A 8/16/99 SPIKE	8/18/99	LB	0.279	6.56	0.194	0.458	0.151	19.6
28-6I 8/17/99 SPIKE	8/18/99	LB	0.33	6.19	0.204	0.641	0.155	15.5
28-6I 8/17/99 LD	8/18/99	LB	0.132	1.03	0.00	0.443	0.00	6.64
1/2 STD1	8/18/99	LB	-0.0397	1.32	0.036	0.045	0.00	3.18
STD1	8/18/99	LB	-0.0381	2.69	0.0956	0.136	0.108	5.41
STD2	8/18/99	LB	0.113	5.10	0.170	0.229	0.199	9.96
STD3	8/18/99	LB	1.06	27.0	1.05	1.29	1.02	51.2
STD4	8/18/99	LB	2.16	47.6	2.06	2.50	2.00	101
std1	8/24/99	LB	0.089	0.260	0.098	0.131	0.0882	1.59
std2	8/24/99	LB	0.251	1.22	0.188	0.257	0.197	2.94
std3	8/24/99	LB	1.11	2.93	0.993	1.25	0.987	15.0
std4	8/24/99	LB	1.96	4.96	2.00	2.49	1.98	29.9
1/10 QC spex	8/24/99	LB	0.227	1.83	0.0962	0.984	0.194	1.98
1/4 QC spex	8/24/99	LB	0.374	5.03	0.232	2.50	0.481	4.71
autocal1	8/24/99	LB	0.100	0.250	0.100	0.125	0.100	1.50
autocal2	8/24/99	LB	0.200	0.500	0.200	0.250	0.200	3.00
autocal3	8/24/99	LB	1.00	2.50	1.00	1.25	1.00	15.0

Sample Name	Date	Analyst	Fluoride	Chloride	Nitrite	Nitrate	PO_4^{-2}	Sulfate
autocal4	8/24/99	LB	2.00	5.00	2.00	2.50	2.00	30.0
lab blank 1	8/24/99	LB	0.00	0.0282	0.00	0.104	-0.046	0.373
28-5B1	8/24/99	LB	0.175	0.894	0.00	0.409	0.00	5.53
28-6C1	8/24/99	LB	0.177	1.05	0.00	0.485	0.00	6.33
27-8C	8/24/99	LB	0.189	2.23	0.00	0.477	0.00	15.2
28-11H	8/24/99	LB	0.182	0.718	0.00	0.118	0.00	5.48
27-8D	8/24/99	LB	0.187	1.51	0.00	0.452	0.00	14.8
28-4A1	8/24/99	LB	0.152	1.48	0.00	0.062	0.00	10.2
27-7D	8/24/99	LB	0.179	1.49	0.00	0.223	0.00	18.3
28-5B1 Duplicate	8/24/99	LB	0.175	0.889	0.00	0.400	0.00	5.55
28-5B1 Spike	8/24/99	LB	0.307	1.19	0.191	0.610	0.0382	7.67
lab blank 2	8/24/99	LB	0.165	0.0565	0.00	0.072	0.00	0.545
std1	8/24/99	LB	0.0891	0.286	0.102	0.128	0.0899	1.55
std2	8/24/99	LB	0.305	0.481	0.201	0.244	0.219	2.87
std3	8/24/99	LB	0.955	2.48	1.02	1.26	1.00	15.2
std4	8/24/99	LB	1.99	5.07	1.99	2.50	2.01	30.1

Sample Name	Date	Time	Ag3280	Al3961	As1890	Ba4934	Be2348	Ca318H	Cd2265	Co2286	Cr2677	Cu3247	Fe259L
PQL (mg/L)			0.002	0.007	0.008	0.0002	0.0001	0.07	0.001	0.0008	0.002	0.002	0.005
11HS-19 051700	6/19/2000	17:17	BPQL	BPQL	BPQL	0.1602	BPQL	56.79	BPQL	BPQL	BPQL	BPQL	BPQL
4A1S-19 060700	6/19/2000	18:20	BPQL	BPQL	BPQL	0.0948	BPQL	65.19	BPQL	BPQL	BPQL	BPQL	BPQL
11 HDW 051700	6/19/2000	18:01	BPQL	BPQL	BPQL	0.2704	BPQL	34.46	BPQL	BPQL	BPQL	BPQL	0.026
S. DITCH 051700	6/19/2000	17:05	BPQL	BPQL	BPQL	0.1034	BPQL	20.52	BPQL	BPQL	BPQL	0.002	0.01
11 HW-10 051700	6/19/2000	18:04	BPQL	BPQL	BPQL	0.1634	BPQL	51.85	BPQL	BPQL	BPQL	BPQL	BPQL
11HS-10 051700	6/19/2000	17:37	BPQL	BPQL	BPQL	0.4669	BPQL	104.8	BPQL	0.001	BPQL	0.016	0.008
11HS-12 051700	6/19/2000	17:33	BPQL	BPQL	BPQL	0.1943	BPQL	63.34	BPQL	BPQL	BPQL	0.003	BPQL
11HS-14 051700	6/19/2000	17:13	BPQL	BPQL	BPQL	0.2009	BPQL	64.03	BPQL	BPQL	BPQL	0.004	BPQL
11HW-12 051700	6/19/2000	17:41	BPQL	BPQL	BPQL	0.1455	BPQL	51.43	BPQL	BPQL	BPQL	BPQL	BPQL
11HW-14 051700	6/19/2000	18:36	BPQL	BPQL	BPQL	0.1525	BPQL	51.23	BPQL	BPQL	BPQL	BPQL	BPQL
11HW-19 051700	6/19/2000	17:29	BPQL	BPQL	BPQL	0.1534	BPQL	53.94	BPQL	BPQL	BPQL	BPQL	BPQL
4A1S-12 060700	6/19/2000	18:32	BPQL	BPQL	BPQL	0.2926	BPQL	47.86	BPQL	BPQL	BPQL	0.023	0.015
4A1W-12 060700 1200	6/19/2000	18:08	BPQL	BPQL	BPQL	0.088	BPQL	62.17	BPQL	BPQL	BPQL	BPQL	BPQL
4A1W-17 060700	6/19/2000	18:16	BPQL	BPQL	BPQL	0.1239	BPQL	63.79	BPQL	0.0025	BPQL	BPQL	BPQL
5B1-19 051700	6/19/2000	17:45	BPQL	BPQL	BPQL	0.1285	BPQL	41.14	BPQL	BPQL	BPQL	BPQL	BPQL
5B1-DW 051700	6/19/2000	18:12	BPQL	BPQL	BPQL	0.3002	BPQL	34.79	BPQL	BPQL	BPQL	0.009	BPQL
N. DITCH 051700	6/19/2000	17:09	BPQL	BPQL	BPQL	0.1027	BPQL	20.42	BPQL	BPQL	BPQL	BPQL	0.01
ROMAN CREEK 060700	6/19/2000	18:40	BPQL	BPQL	BPQL	0.0121	BPQL	37.82	BPQL	BPQL	BPQL	BPQL	BPQL

BPQL=Below Practical Quantification Limit

Sample Name	K_7698	Li6707	Mg293H	Mn2605	Mo2020	Na330H	Ni2316	Pb2203	S 1807	Si2516	Sr4215	Tl3234	V 3110	Zn2138
PQL	0.1	0.002	0.05	0.0003	0.002	0.18	0.001	0.02	0.007	0.02	0.0003	0.002	0.003	0.0003
11HS-19 051700	2.7	0.002	14.93	0.0083	BPQL	9.3	BPQL	BPQL	3.06	9.54	0.0791	BPQL	BPQL	0.0036
4A1S-19 060700	2.3	0.003	15.15	0.1098	0.002	8.02	BPQL	BPQL	6.351	9.86	0.0821	BPQL	BPQL	0.0022
11 HDW 051700	1.9	0.003	10.39	0.0147	BPQL	6.71	BPQL	BPQL	1.882	11.1	0.1054	BPQL	BPQL	0.0019
S. DITCH 051700	1	0.003	6.63	0.0015	BPQL	2.81	BPQL	BPQL	2.854	4.78	0.0782	BPQL	BPQL	0.0015
11 HW-10 051700	2.4	0.003	18.6	0.0113	BPQL	6.69	BPQL	BPQL	2.572	10.43	0.0866	BPQL	BPQL	0.0014
11HS-10 051700	6.9	0.008	20.21	0.2159	0.003	40.64	0.004	BPQL	11.59	11.3	0.2162	BPQL	0.005	0.002
11HS-12 051700	3.1	0.003	15.6	0.0075	BPQL	18.66	0.001	BPQL	4.863	10.84	0.1037	BPQL	BPQL	0.0014
11HS-14 051700	3.1	0.003	16.12	0.0032	BPQL	20.5	BPQL	BPQL	4.918	11.77	0.0967	BPQL	BPQL	0.0014
11HW-12 051700	2.4	0.002	13.82	BPQL	BPQL	5.91	BPQL	BPQL	2.555	9.82	0.0723	BPQL	BPQL	0.002
11HW-14 051700	2.4	0.002	13.79	BPQL	BPQL	6.12	BPQL	BPQL	2.574	9.89	0.073	BPQL	BPQL	0.001
11HW-19 051700	2.8	0.003	14.16	0.0032	BPQL	9.62	BPQL	BPQL	2.855	9.64	0.0742	BPQL	BPQL	0.0033
4A1S-12 060700	10.8	0.003	14.16	0.0326	0.003	28.79	0.005	BPQL	8.047	11.63	0.1246	BPQL	BPQL	0.0014
4A1W-12 060700 1200	2.2	0.002	14.93	0.0249	BPQL	9.74	BPQL	BPQL	5.973	10	0.0826	BPQL	BPQL	BPQL
4A1W-17 060700	2.5	0.004	14.86	0.16	0.023	7.54	0.002	BPQL	6.463	9.42	0.0811	BPQL	BPQL	0.0016
5B1-19 051700	2.4	0.003	14.51	0.0191	BPQL	10.94	BPQL	BPQL	4.837	8.13	0.0812	BPQL	BPQL	0.0012
5B1-DW 051700	1.5	0.003	10.97	0.0004	BPQL	5.04	BPQL	BPQL	1.873	11.18	0.093	BPQL	BPQL	0.0015
N. DITCH 051700	1	0.003	6.61	0.0023	BPQL	2.73	BPQL	BPQL	2.844	4.75	0.0773	BPQL	BPQL	0.0025
ROMAN CREEK 060700	1.2	BPQL	7.38	0.0007	BPQL	1.9	BPQL	BPQL	1.365	6.28	0.0411	BPQL	BPQL	BPQL

BPQL = Below Practical Quantification Limit

Sample Name	Collection Date	Fluoride	Chloride	N in Nitrite	N in Nitrate	Sulfate
Method Detection Limit (ppm)	6/8/00 13:33	0.1	1.5	0.1	0.25	5
Roman Creek 060700	6/8/00 16:26	BPQL	BPQL	BPQL	BPQL	BPQL
4AI-DW 060700	6/8/00 16:16	0.186	1.60	BPQL	BPQL	9.77
4AIS-12 060700	6/8/00 17:27	0.231	25.0	BPQL	23.2	23.5
4AIS-14 060700	6/8/00 16:57	0.177	7.24	BPQL	0.955	17.3
4AIS-19 060700	6/8/00 16:46	0.163	6.21	BPQL	0.663	17.8
4AIW-12 060700	6/8/00 16:06	0.180	5.85	BPQL	0.809	16.8
4AIW-17 060700	6/8/00 15:46	0.197	5.00	BPQL	0.422	18.2
5B1S-10 060800	6/8/00 17:07	0.153	7.74	BPQL	BPQL	6.47
5B1S-12 060800	6/8/00 17:17	0.163	6.95	BPQL	BPQL	BPQL
Twin Pond 060800	6/8/00 15:56	0.143	6.84	BPQL	BPQL	10.5

BPQL = Below Practical Quantification Limit

#	Sample Name	Ag3280	Al3961	Al3961	As1890	Ba2335	Ba4934
1	STD1	10.5	86.9	107.1	0.465	0.159	8019
2	low Na						
3	Blank	2.75	0.244	0.929	0.00375	-0.0002	-0.783
4	USGS T143	0.0206	0.0232	0.00240	0.0158	0.0787	0.0832
5	EPA 200.15 BLANK	-0.0002	0.0005	-0.00160	0.00130	0.00	0.00
6	EPA 200.15 BLANK_RQ	0.0191	0.493	0.493	0.512	0.503	0.508
7	250ML BOTBLK 060800	0.0003	0.0007	-0.0009	0.0004	0.0003	0.0002
8	AMBER BOTBLK 060800	0.0003	0.0011	-0.0004	0.0006	0.00	0.00
9	ANION BOTBLK 060800	0.0003	0.0002	-0.0009	0.00110	0.0003	0.0002
10	5B1S-12 060800	0.0002	0.0027	-0.0146	0.00580	0.103	0.109
11	TWIN POND 060800	0.0003	0.0065	-0.00960	0.00250	0.0526	0.0539
12	TWIN POND 060800 93%	0.0003	0.0061	-0.00900	0.00230	0.0489	0.0501
13	TWIN POND 060800 _RQ	0.0185	0.491	0.495	0.512	0.571	0.548
14	USGS T143	0.0203	0.0226	0.00390	0.0156	0.0781	0.0828
15	5B1S-10 060800	0.0002	0.0025	-0.0142	0.00200	0.104	0.111
16	4A1S-14 060700	0.0007	0.00	-0.0193	0.00230	0.0922	0.0981
17	4A1-DW 060700	0.0005	0.0002	-0.0173	0.00290	0.398	0.400
18	AMBER BOTBLK 060800	0.0004	0.0006	-0.00120	0.0006	0.0001	0.00
19	EPA 200.15 BLANK	-0.0002	0.0005	-0.0007	0.00100	0.00	0.00
20	USGS T143	0.0198	0.0224	0.00340	0.0166	0.0779	0.0820
21	5B1-DW 050700 HCL	0.0004	0.0021	-0.0154	0.00550	0.294	0.299
22	11HW-10 050700 HCL	-0.0001	0.0026	-0.0165	0.00350	0.164	0.164
23	TWIN POND 060800 HCL	0.0004	0.0064	-0.00850	0.00300	0.0504	0.0520
24	N.DITCH 051700 HCL	0.0003	0.0047	-0.0120	0.00160	0.0981	0.103
25	4A1S-19 060700 HCL	0.00	0.0015	-0.0182	0.00110	0.0897	0.0954
26	4A1S-19060700HCL93%	0.00	0.0014	-0.0170	0.00100	0.0834	0.0887
27	4A1S-19060700HCL9_RQ	-0.0046	0.0007	-0.403	-5.14	77.8	0.00280

#	Sample Name	Be2348	Ca318H	Cd2265	Co2286	Cr2677
1	STD1	35.3	0.415	0.0319	0.0211	0.0295
2	low Na					
3	Blank	-0.0172	-7E-05	-0.0001	0.00007	0.00003
4	USGS T143	0.00812	54.1	0.0202	0.0177	0.0388
5	EPA 200.15 BLANK	0.00	-0.00490	0.00	0.00	0.0007
6	EPA 200.15 BLANK_RQ	0.101	19.2	0.207	0.201	0.498
7	250ML BOTBLK 060800	2E-05	0.0266	-0.0001	0.00	0.0006
8	AMBER BOTBLK 060800	0.00	0.0551	-0.0001	0.00	0.0003
9	ANION BOTBLK 060800	0.00	0.0402	-0.0001	0.00	0.00
10	5B1S-12 060800	0.00	30.0	-0.0002	0.0009	0.0004
11	TWIN POND 060800	0.00	16.3	-0.0001	0.00	0.00
12	TWIN POND 060800 93%	0.00	15.2	-0.0001	0.00	0.00
13	TWIN POND 060800 _RQ	0.102	37.0	0.212	0.209	0.511
14	USGS T143	0.00816	53.7	0.0201	0.0176	0.0377
15	5B1S-10 060800	1E-05	32.6	0.00	0.0003	-0.0002
16	4A1S-14 060700	1E-05	63.7	-0.0002	0.00	0.00
17	4A1-DW 060700	0.00	50.9	-0.0002	0.00	0.0004
18	AMBER BOTBLK 060800	0.00	0.0571	-0.0001	-0.0001	0.0005
19	EPA 200.15 BLANK	0.00	0.00570	0.00	0.00	0.0004
20	USGS T143	0.00814	53.9	0.0201	0.0175	0.0368
21	5B1-DW 050700 HCL	0.00	35.5	0.0001	0.00	0.0006
22	11HW-10 050700 HCL	1E-05	52.8	0.00	-0.0001	0.0003
23	TWIN POND 060800 HCL	1E-05	16.2	0.0002	-0.0001	0.00
24	N.DITCH 051700 HCL	1E-05	20.9	0.0002	-0.0001	0.00
25	4A1S-19 060700 HCL	1E-05	65.9	0.0001	0.0002	-0.0002
26	4A1S-19060700HCL93%	1E-05	61.3	0.0001	0.0002	-0.0002
27	4A1S-19060700HCL9_RQ	-0.915	29.2	23.5	31.0	2.43

#	Sample Name	Cu3247	Fe232H	Fe239H	Fe259L	K7664
1	STD1	199	0.00596	0.0225	0.124	35.6
2	low Na					
3	Blank	-0.713	0.00026	0.00	0.00059	4.23
4	USGS T143	0.0230	0.210	0.237	0.225	2.39
5	EPA 200.15 BLANK	-0.0002	-0.0002	0.0007	0.0005	-0.0611
6	EPA 200.15 BLANK_RQ	0.495	0.501	0.504	0.499	4.98
7	250ML BOTBLK 060800	-0.0001	0.0001	0.0001	0.0001	-0.0449
8	AMBER BOTBLK 060800	0.0004	-0.0005	0.0004	-0.0001	-0.0521
9	ANION BOTBLK 060800	0.0001	0.00	0.00	-0.0004	-0.0535
10	5B1S-12 060800	0.00340	0.00110	0.00930	0.00280	2.52
11	TWIN POND 060800	0.00490	0.00640	0.0132	0.00800	1.96
12	TWIN POND 060800 93%	0.00450	0.00600	0.0122	0.00740	1.82
13	TWIN POND 060800 _RQ	0.488	0.523	0.534	0.522	6.91
14	USGS T143	0.0230	0.208	0.2354	0.222	2.34
15	5B1S-10 060800	0.00300	0.00180	0.00910	0.00370	2.44
16	4A1S-14 060700	0.0003	0.00080	0.00800	0.00300	2.17
17	4A1-DW 060700	-0.0003	0.00640	0.0153	0.00850	2.00
18	AMBER BOTBLK 060800	0.0002	-0.0003	0.00	0.00	-0.0601
19	EPA 200.15 BLANK	0.0002	0.0008	0.0001	0.00	-0.0650
20	USGS T143	0.0226	0.208	0.235	0.221	2.33
21	5B1-DW 050700 HCL	0.00870	0.00100	0.00940	0.00300	1.44
22	11HW-10 050700 HCL	0.0004	0.00100	0.00840	0.00290	2.10
23	TWIN POND 060800 HCL	0.00100	0.00670	0.0125	0.00770	1.85
24	N.DITCH 051700 HCL	0.00220	0.00890	0.0128	0.0108	0.888
25	4A1S-19 060700 HCL	-0.0001	0.00220	0.00990	0.00450	2.05
26	4A1S-19060700HCL93%	-0.0001	0.00200	0.00920	0.00420	1.91
27	4A1S-19060700HCL9_RQ	0.00100	81.6	73.8	70.4	-28.1

#	Sample Name	K_7698	Li6707	Mg293H	Mn2605	Mo2020
1	STD1	15.1	159	101	0.494	0.00982
2	low Na					
3	Blank	0.578	0.503	0.0296	0.00001	-0.00009
4	USGS T143	2.52	0.0167	10.6	0.0173	0.0382
5	EPA 200.15 BLANK	0.0253	0.00	0.00530	0.00	0.0002
6	EPA 200.15 BLANK_RQ	5.01	0.589	5.07	0.498	0.200
7	250ML BOTBLK 060800	0.0193	0.0001	0.00950	0.00	0.0005
8	AMBER BOTBLK 060800	0.00990	-0.0001	0.0319	0.00	0.0002
9	ANION BOTBLK 060800	0.0186	0.0001	0.00930	0.00	0.0001
10	5B1S-12 060800	2.66	0.00320	12.4	0.539	0.00330
11	TWIN POND 060800	2.06	0.00300	13.9	0.0109	0.0009
12	TWIN POND 060800 93%	1.91	0.00280	12.9	0.0102	0.0008
13	TWIN POND 060800_RQ	6.88	0.598	17.9	0.525	0.207
14	USGS T143	2.53	0.0167	10.5	0.0172	0.0384
15	5B1S-10 060800	2.66	0.00280	12.6	0.0940	0.00270
16	4A1S-14 060700	2.34	0.00270	14.9	0.0221	0.00190
17	4A1-DW 060700	2.11	0.00310	14.9	0.0145	0.00140
18	AMBER BOTBLK 060800	0.0171	0.0001	0.0277	0.00	0.0001
19	EPA 200.15 BLANK	0.0178	0.00	0.00720	0.00	0.0001
20	USGS T143	2.54	0.0166	10.4	0.0171	0.0382
21	5B1-DW 050700 HCL	1.57	0.00320	10.8	0.0004	0.00140
22	11HW-10 050700 HCL	2.38	0.00310	18.4	0.0113	0.00150
23	TWIN POND 060800 HCL	2.02	0.00290	13.8	0.00990	0.0006
24	N.DITCH 051700 HCL	1.02	0.00270	6.54	0.00230	0.00100
25	4A1S-19 060700 HCL	2.32	0.00310	15.0	0.110	0.0024
26	4A1S-19060700HCL93%	2.16	0.00290	14.0	0.102	0.0022
27	4A1S-19060700HCL9_RQ	-13.5	-0.2787	0.0947	85.5	24.4

#	Sample Name	Na330H	Na588L	Ni2316	P 1782	Pb2203
1	STD1	0.0144		0.02973	0.585	0.00449
2	low Na		114			
3	Blank	0.0004	8.14	0.00003	0.00147	0.00007
4	USGS T143	31.3	27.0	0.0762	0.0259	0.0910
5	EPA 200.15 BLANK	0.0115	0.00390	0.0002	-0.00110	0.0002
6	EPA 200.15 BLANK_RQ	11.1	9.01	0.509	1.04	0.497
7	250ML BOTBLK 060800	0.362	0.362	0.0001	0.0001	0.0002
8	AMBER BOTBLK 060800	0.559	0.772	0.00	-0.00160	-0.0004
9	ANION BOTBLK 060800	0.420	0.536	0.0002	-0.0001	-0.0001
10	5B1S-12 060800	10.3	11.0	0.00220	0.0425	-0.0003
11	TWIN POND 060800	9.07	9.60	0.0006	0.0119	0.00100
12	TWIN POND 060800 93%	8.44	8.93	0.0005	0.0110	0.0009
13	TWIN POND 060800 _RQ	20.4	16.7	0.526	1.05	0.516
14	USGS T143	30.9	27.3	0.0755	0.0261	0.0900
15	5B1S-10 060800	10.0	10.7	0.00110	0.0390	0.00110
16	4A1S-14 060700	8.84	9.58	0.0009	0.0903	0.00120
17	4A1-DW 060700	8.89	9.79	0.0003	0.0397	0.00170
18	AMBER BOTBLK 060800	0.662	0.779	0.0001	0.0002	-0.0008
19	EPA 200.15 BLANK	-0.162	0.00610	0.0002	-0.0003	-0.0007
20	USGS T143	31.0	27.4	0.0754	0.0261	0.0888
21	5B1-DW 050700 HCL	4.78	5.62	0.0003	0.0546	0.0002
22	11HW-10 050700 HCL	6.35	7.10	0.0004	0.0480	0.00110
23	TWIN POND 060800 HCL	9.43	9.95	0.0003	0.0110	0.0001
24	N.DITCH 051700 HCL	2.45	3.14	0.0006	0.0056	-0.0008
25	4A1S-19 060700 HCL	7.56	8.37	0.0009	0.0085	0.00100
26	4A1S-19060700HCL93%	7.03	7.78	0.0009	0.0079	0.00100
27	4A1S-19060700HCL9_RQ	2901.7	-13.8	77.3	-10.2	86.8

#	Sample Name	Si2124	Si2516	Sn1899	Sr4215	S 1807
1	STD1	352	1598	0.00301	7150	0.065
2	low Na					
3	Blank	1.03	4.61	0.00006	1.41	0.00011
4	USGS T143	14.1	13.5	0.00310	0.3157	7.06
5	EPA 200.15 BLANK	0.0001	0.0001	-0.0003	0.00	0.0027
6	EPA 200.15 BLANK_RQ	5.75	5.73	0.203	0.511	4.69
7	250ML BOTBLK 060800	0.0165	0.0165	-0.0004	0.0001	0.0271
8	AMBER BOTBLK 060800	0.0836	0.0844	-0.0001	0.0001	0.0477
9	ANION BOTBLK 060800	0.0153	0.0151	-0.0002	0.0001	0.0347
10	5B1S-12 060800	11.7	11.3	0.0008	0.0586	0.829
11	TWIN POND 060800	10.0	9.64	0.0002	0.0467	3.57
12	TWIN POND 060800 93%	9.32	8.97	0.0002	0.0434	3.32
13	TWIN POND 060800 _RQ	15.1	14.3	0.2104	0.543	8.36
14	USGS T143	14.1	13.4	0.00270	0.313	7.06
15	5B1S-10 060800	10.8	10.2	0.0003	0.0642	2.31
16	4A1S-14 060700	10.4	9.98	0.0007	0.0841	6.30
17	4A1-DW 060700	12.0	11.4	0.0008	0.147	3.56
18	AMBER BOTBLK 060800	0.0853	0.0856	-0.0003	0.00	0.0481
19	EPA 200.15 BLANK	-0.00110	-0.00120	-0.0003	0.00	0.00390
20	USGS T143	14.1	13.3	0.00270	0.3102	7.06
21	5B1-DW 050700 HCL	11.8	11.2	0.0006	0.0939	1.95
22	11HW-10 050700 HCL	11.3	10.5	0.0002	0.0862	2.67
23	TWIN POND 060800 HCL	10.1	9.54	0.0006	0.0463	3.58
24	N.DITCH 051700 HCL	4.95	4.81	0.0002	0.0773	2.92
25	4A1S-19 060700 HCL	10.5	9.89	0.0007	0.0819	6.52
26	4A1S-19060700HCL93%	9.80	9.20	0.0007	0.0762	6.06
27	4A1S-19060700HCL9_RQ	2.10	2.04	39.4	0.0027	1410

#	Sample Name	Ti3234	V 3110	Y_3774	Y_4128	Zn2138
1	STD1	122	88.7	X 2991.9	X 29.293	645
2	low Na				X 27.165	
3	Blank	6.86	-0.310	X 2820.1	X 23.820	0.373
4	USGS T143	0.0002	0.0303	X 5.050	X 4.944	0.0190
5	EPA 200.15 BLANK	-0.0002	-0.0001	X 4.758	X 4.072	0.00
6	EPA 200.15 BLANK_RQ	0.102	0.204	X 5.255	X 4.963	0.508
7	250ML BOTBLK 060800	0.0002	-0.0001	X 4.973	X 4.269	-0.0001
8	AMBER BOTBLK 060800	0.00	-0.0002	X 5.046	X 4.358	-0.0002
9	ANION BOTBLK 060800	0.00	0.0001	X 5.001	X 4.302	-0.0005
10	5B1S-12 060800	-0.0004	0.0005	X 5.095	X 4.844	0.0015
11	TWIN POND 060800	-0.0001	0.0005	X 5.043	X 4.777	0.0003
12	TWIN POND 060800 93%	0.00	0.0005	X 4.690	X 4.443	0.0002
13	TWIN POND 060800 _RQ	0.101	0.197	X 4.928	X 4.903	0.499
14	USGS T143	0.0002	0.0294	X 5.079	X 4.935	0.0190
15	5B1S-10 060800	-0.0003	0.0009	X 5.148	X 4.888	0.00
16	4A1S-14 060700	-0.0001	0.0015	X 5.062	X 4.950	0.0038
17	4A1-DW 060700	-0.0001	0.0008	X 5.070	X 4.883	0.00
18	AMBER BOTBLK 060800	0.00	0.00	X 5.003	X 4.327	-0.0002
19	EPA 200.15 BLANK	-0.0003	0.00	X 4.719	X 4.087	0.00
20	USGS T143	0.0002	0.0293	X 5.044	X 4.912	0.0188
21	5B1-DW 050700 HCL	-0.0002	0.0016	X 5.113	X 4.849	0.0033
22	11HW-10 050700 HCL	-0.0003	0.0006	X 5.048	X 4.967	0.0023
23	TWIN POND 060800 HCL	-0.0001	0.0007	X 5.051	X 4.763	0.0006
24	N.DITCH 051700 HCL	0.00	0.0003	X 5.116	X 4.750	0.0018
25	4A1S-19 060700 HCL	-0.0003	0.0009	X 5.063	X 4.985	0.0041
26	4A1S-19060700HCL93%	-0.0003	0.0008	X 4.708	X 4.636	0.0038
27	4A1S-19060700HCL9_RQ	0.0004	0.001	X .0258	X -.0983	0.0618

Sample Name	Date	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate
std1	8/17/00	0.0852	1.26	0.104	0.109	0.0259	2.45
std2	8/17/00	0.244	1.99	0.211	0.186	0.1682	2.84
std3	8/17/00	0.974	9.96	1.00	0.998	1.00	14.9
std4	8/17/00	1.99	20.1	1.99	2.00	2.00	30.0
1/2 qcspex(1-15)	8/17/00	1.44	8.41	0.397	3.61	1.94	10.7
1/10 qcspex(1-15)	8/17/00	0.270	1.56	0.073	0.837	0.406	2.24
autocal1	8/17/00	0.100	1.00	0.100	0.100	0.100	1.50
autocal2	8/17/00	0.200	2.00	0.200	0.200	0.200	3.00
autocal3	8/17/00	1.00	10.0	1.00	1.00	1.00	15.0
autocal4	8/17/00	2.00	20.0	2.00	2.00	2.00	30.0
5BIW-19 8/15/00	8/17/00	0.137	10.1	0.00	0.0497	0.00	8.96
11HW-19 8/15/00	8/17/00	0.128	8.55	0.00	1.15	0.00	8.66
11HW-14 8/15/00	8/17/00	0.119	7.87	0.00	0.996	0.00	8.13
11HW-12 8/15/00	8/17/00	0.124	7.90	0.00	0.952	0.00	8.45
11HW-10 8/15/00	8/17/00	0.158	6.52	0.00	0.837	0.00	7.97
11H-DW 8/15/00	8/17/00	0.184	0.835	0.00	0.0993	0.00	5.51
11HS-12 8/15/00	8/17/00	0.130	8.72	0.00	2.56	0.535	9.66
11HS-19 8/15/00	8/17/00	0.127	7.70	0.00	1.16	0.0129	8.52
11HS-19 8/15/00 Spike	8/17/00	0.278	8.93	0.205	1.25	0.247	10.6
5BIW-19 8/15/00 Dup	8/17/00	0.136	10.1	0.00	0.0595	0.00	8.75
Blank	8/17/00	0.00	0.00	0.0433	0.00	-0.104	0.308
std1	8/17/00	0.0811	1.08	0.103	0.0938	0.0648	1.62
std2	8/17/00	0.230	1.83	0.197	0.185	0.207	2.98
std3	8/17/00	0.948	9.89	1.01	0.995	1.02	15.0
std4	8/17/00	2.01	20.2	1.99	2.01	2.00	30.0
North Ditch 8/16/00	8/17/00	0.154	2.67	0.00	0.00	0.00	16.1
11HS-14 8/15/00	8/17/00	0.144	8.31	0.00	1.60	0.588	8.87
11HS-10 8/15/00	8/17/00	0.186	16.1	0.00	-4.28	2.72	18.12
Ronan Creek 8/16/00	8/17/00	0.107	0.573	0.00	-9E-04	0.00	4.61
5BIS-12 8/15/00	8/17/00	0.132	10.7	0.00	0.00	-0.00887	2.69
5BIS-10 8/15/00	8/17/00	0.142	9.69	0.00	0.00	-0.0236	1.99
Twin Pond 8/15/00	8/17/00	0.142	11.2	0.00	0.0346	0.00	14.9
5B1-DW 8/15/00	8/17/00	0.173	0.939	0.00	0.407	-0.0425	5.42
5B1-DW 8/15/00 spike	8/17/00	0.315	2.57	0.194	0.570	0.195	7.90
North Ditch 8/16/00 Dup	8/17/00	0.158	2.61	0.00	0.00	0.00	16.1
Blank	8/17/00	0.00	0.00	0.00	0.00	0.00	0.322
std1	8/17/00	0.154	1.03	0.101	0.0901	0.0297	1.52
std2	8/17/00	0.226	1.82	0.195	0.185	0.198	2.93
std3	8/17/00	0.952	9.93	1.03	1.02	0.972	15.0
std4	8/17/00	2.02	20.2	1.99	2.02	2.00	30.1
4AIS-19 8/16/00	8/17/00	0.129	8.31991	0.00	1.16	0.00	16.5
4AIS-14 8/16/00	8/17/00	0.131	7.55	0.00	1.46	0.0694	15.3
4AIS-12 8/16/00	8/17/00	0.145	9.46	0.00	-40.6	1.11	38.5
4AIW-19 8/16/00	8/17/00	0.128	3.13	0.00	0.560	0.00	15.2
4AIW-14 8/16/00	8/17/00	0.135	4.46	0.00	0.955	0.00	14.7

Date	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate	Sulfate
4AI-DW 8/16/00	8/17/00	0.145	1.44	0.00	0.049	0.00	10.6
4AIW-12 8/16/00	8/17/00	0.138	4.48	0.00	1.02	0.00	14.3
4AIW-12 8/16/00 spike	8/17/00	0.294	6.05	0.202	1.13	0.218	16.0
4AIS-19 8/16/00 Dup	8/17/00	0.129	8.34	0.00	1.16	0.00	16.4
lab blank	8/17/00	0.00	0.00	0.00	0.118	0.00	0.365
prep blank 081700	8/17/00	0.00	0.00	0.00	0.0008	0.00	0.316
LFB 081700	8/17/00	0.224	1.87	0.198	0.187	0.122	2.83
Blank	8/17/00	0.00	0.00	0.00	0.00	0.00	0.458
std1	8/17/00	0.153	1.02	0.100	0.0930	0.0429	1.56
std2	8/17/00	0.217	1.82	0.195	0.187	0.156	2.90
std3	8/17/00	0.951	9.96	1.03	1.03	0.999	15.0
std4	8/17/00	2.07	20.3	2.03	2.03	2.05	30.2
std1	8/18/00	0.155	1.01	0.103	0.0913	0.105	1.63
std2	8/18/00	0.223	1.80	0.192	0.188	0.110	2.86
std3	8/18/00	0.948	9.85	1.01	1.00	0.999	15.0
std4	8/18/00	2.01	20.1	1.99	2.00	2.02	30.0
11HS-12 diluted 1/2	8/18/00	0.0882	4.17	0.00	1.33	0.238	4.85
11HS-10 diluted 1/10	8/18/00	0.0521	1.47	0.00	1.29	0.161	1.77
4AIS-12 diluted 1/10	8/18/00	0.0465	0.922	0.00	2.17	0.0164	3.70
11HS-12 diluted 1/2 LD	8/18/00	0.0817	4.16	0.00	1.33	0.825	5.82
11HS-12 diluted 1/2 SPIKE	8/18/00	0.236	5.65	0.185	1.39	0.342	6.86
4AIS-12 diluted 1/20	8/18/00	0.00	0.560	0.00	1.08	-0.0255	1.81
STD1	8/18/00	0.0766	1.06	0.096	0.0954	0.0369	1.50
STD2	8/18/00	0.112	2.10	0.192	0.199	0.127	2.81
STD3	8/18/00	0.815	0.00	0.00	0.00	0.0337	0.00
STD4	8/18/00	0.348	0.00	0.00	0.00	0.00	0.00

Analytical Report
Murdock Environmental Laboratory
June 21, 2000

Sample Name	*HGAAS:* Date of Analysis	Analyst	As via HGAAS (mg/L)	%rsd	*Alkalinity:* Date of Analysis	Analyst	HCO3 (mg/L)	*IC**:* Date of Analysis	Fluoride	Chloride	N-Nitrite	N-Nitrate	Sulfate
Practical Quantifiable Limit (mg/L)			*0.0005*						*0.1*	*1.5*	*0.1*	*0.25*	*5*
11HDW 051700	06/13/00	ED/AY/NS	0.0047	1%	5/17/00	ED	130.4	5/19/00 20:17	0.15	BPQL	BPQL	BPQL	5.64
11HS-10 051700	06/15/00	ED/AY/NS	0.0074	1%	5/17/00	ED	227.2	5/19/00 17:24	0.10	29.24	BPQL	32.59	31.68
11HS-12 051700	06/13/00	ED/AY/NS	0.0050	2%	5/17/00	ED	199.2	5/19/00 19:46	BPQL	9.12	BPQL	6.03	13.09
11HS-14 051700	06/13/00	ED/AY/NS	0.0032	1%	5/17/00	ED	215.2	5/19/00 17:55	BPQL	10.36	BPQL	5.05	13.25
11HS-19 051700	06/13/00	ED/AY/NS	0.0019	4%	5/17/00	ED	193.2	5/19/00 17:14	BPQL	11.04	BPQL	1.34	8.65
11HW-10 051700	06/13/00	ED/AY/NS	0.0027	3%	5/17/00	ED	194.4	5/19/00 19:16	0.10	3.42	BPQL	0.59	7.00
11HW-12 051700	06/13/00	ED/AY/NS	0.0023	1%	5/17/00	ED	174.8	5/19/00 17:45	BPQL	3.71	BPQL	0.59	7.28
11HW-14 051700	06/13/00	ED/AY/NS	0.0022	2%	5/17/00	ED	176	5/19/00 18:05	0.07	4.00	BPQL	0.61	7.47
11HW-19 051700	06/13/00	ED/AY/NS	0.0025	1%	5/17/00	ED	~~173.6~~	5/19/00 16:54	~~BPQL~~	~~8.83~~	~~BPQL~~	~~0.91~~	~~8.12~~
4A1-DW 060700	06/13/00	ED/AY/NS	0.0029	1%	6/8/00	AY	186.4	6/8/00 16:16	0.19	1.60	BPQL	BPQL	9.77
4AIS-12 060700	06/13/00	ED/AY/NS	0.0048	1%	6/8/00	AY	108.8	6/8/00 17:27	0.23	25.01	BPQL	23.21	23.53
4A1S-14 060700	06/13/00	ED/AY/NS	0.0013	3%	6/8/00	AY	189.2	6/8/00 16:57	0.18	7.24	BPQL	0.95	17.34
4A1S-19 060700	06/13/00	ED/AY/NS	0.0008	5%	6/8/00	AY	199.6	6/8/00 16:46	0.16	6.21	BPQL	0.66	17.78
4A1W-12 060700	06/13/00	ED/AY/NS	0.0011	5%	6/8/00	AY	194	6/8/00 16:06	0.18	5.85	BPQL	0.81	16.80
4A1W-17 060700	06/13/00	ED/AY/NS	BPQL	45%	6/8/00	AY	~~195.0~~	6/8/00 15:46	~~0.20~~	~~5.00~~	~~BPQL~~	~~0.42~~	~~16.21~~
5B1-19 051700	06/13/00	ED/AY/NS	0.0015	3%	5/17/00	ED	153.2	5/19/00 20:07	BPQL	9.20	BPQL	BPQL	13.85
5B1-DW 051700	06/13/00	ED/AY/NS	0.0055	1%	5/17/00	ED	129.6	5/19/00 19:26	0.14	BPQL	BPQL	0.40	5.65
5B1S-10 060800	06/13/00	ED/AY/NS	0.0017	2%	6/8/00	AY	131.2	6/8/00 17:07	0.15	7.74	BPQL	BPQL	6.47
5B1S-12 060800	06/13/00	ED/AY/NS	0.0054	1%	6/8/00	AY	140.4	6/8/00 17:17	0.16	6.95	BPQL	BPQL	BPQL
N. Ditch 051700	06/13/00	ED/AY/NS	0.0013	2%	5/17/00	ED	75.2	5/19/00 17:04	BPQL	BPQL	BPQL	BPQL	8.96
Roman Creek 051700	06/13/00	ED/AY/NS	BPQL	5%	6/8/00	AY	119.6	6/8/00 16:26	BPQL	BPQL	BPQL	BPQL	BPQL
S. Ditch 051700	06/13/00	ED/AY/NS	0.0015	3%	5/17/00	ED	75.2	5/19/00 19:36	BPQL	BPQL	BPQL	BPQL	8.91
Twin Pond 060800	06/13/00	ED/AY/NS	0.0010	3%	6/8/00	AY	99.2	6/8/00 15:56	0.14	6.84	BPQL	BPQL	10.50

**Note: 3 samples had $N\text{-}NO_3$ concentrations which exceeded the original method limits. A new method was constructed and the samples were re-run at the following date/times:

11HS-10 051700	*5/25/00 16:55*
11HS-12 051700	*5/25/00 19:17*
11HS-14 051700	*5/25/00 17:15*

Sample Name	Date	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate
Practical Quantification Limit		**0.200**	**1.00**	**0.100**	**0.100**	**1.00**	**1.50**
11H-DW 8/15/00	8/17/00	<0.200	<1.00	<0.100	<0.1	<1.00	5.51
11HS-10 8/15/00	8/17/00	<0.200	16.1	<0.100	12.9	2.72	18.1
11HS-12 8/15/00	8/17/00	<0.200	8.72	<0.100	2.66	<1.00	9.66
11HS-14 8/15/00	8/17/00	<0.200	8.31	<0.100	1.60	<1.00	8.87
11HS-19 8/15/00	8/17/00	<0.200	7.70	<0.100	1.16	<1.00	8.52
11HW-10 8/15/00	8/17/00	<0.200	6.52	<0.100	0.840	<1.00	7.97
11HW-12 8/15/00	8/17/00	<0.200	7.90	<0.100	0.950	<1.00	8.45
11HW-14 8/15/00	8/17/00	<0.200	7.87	<0.100	1.00	<1.00	8.13
11HW-19 8/15/00	8/17/00	<0.200	8.55	<0.100	1.15	<1.00	8.66
4AI-DW 8/16/00	8/17/00	<0.200	1.44	<0.100	<0.100	<1.00	10.6
4AIS-12 8/16/00	8/17/00	<0.200	9.46	<0.100	21.6	1.11	38.5
4AIS-14 8/16/00	8/17/00	<0.200	7.55	<0.100	1.46	<1.00	15.3
4AIS-19 8/16/00	8/17/00	<0.200	8.32	<0.100	1.16	<1.00	16.5
4AIW-12 8/16/00	8/17/00	<0.200	4.48	<0.100	1.02	<1.00	14.3
4AIW-14 8/16/00	8/17/00	<0.200	4.46	<0.100	0.950	<1.00	14.7
4AIW-19 8/16/00	8/17/00	<0.200	3.13	<0.100	0.560	<1.00	15.2
5B1-DW 8/15/00	8/17/00	<0.200	<1.00	<0.100	0.410	<1.00	5.42
5BIS-10 8/15/00	8/17/00	<0.200	9.69	<0.100	<0.100	<1.00	1.99
5BIS-12 8/15/00	8/17/00	<0.200	10.7	<0.100	<0.100	<1.00	2.69
5BIW-19 8/15/00	8/17/00	<0.200	10.1	<0.100	<0.100	<1.00	8.96
North Ditch 8/16/00	8/17/00	<0.200	2.67	<0.100	<0.100	<1.00	16.1
Ronan Creek 8/16/00	8/17/00	<0.200	<1.00	<0.100	<0.100	<1.00	4.61
Twin Pond 8/15/00	8/17/00	<0.200	11.2	<0.100	<0.100	<1.00	14.9

QUALITY CONTROL							
11HS-12 diluted 1/2	8/18/00	<0.200	4.17	<0.100	1.33	<1.00	4.85
11HS-12 diluted 1/2 LD	8/18/00	<0.200	4.16	<0.100	1.33	<1.00	4.96
duplicate % diff		NA	0.400%	NA	0.300%	NA	2.20%
5BIW-19 8/15/00	8/17/00	<0.200	10.1	<0.100	<0.100	<1.00	8.96
5BIW-19 8/15/00 Dup	8/17/00	<0.200	10.1	<0.100	<0.100	<1.00	8.75
duplicate % diff		NA	0.200%	NA	NA	NA	2.30%
4AIS-19 8/16/00	8/17/00	<0.200	8.32	<0.100	1.16	<1.00	16.5
4AIS-19 8/16/00 Dup	8/17/00	<0.200	8.34	<0.100	1.16	<1.00	16.4
duplicate % diff		NA	0.30%	NA	0.100%	NA	0.500%
North Ditch 8/16/00	8/17/00	<0.200	2.67	<0.100	<0.100	<1.00	16.1
North Ditch 8/16/00 Dup	8/17/00	<0.200	2.61	<0.100	<0.100	<1.00	16.1
duplicate % diff		NA	2.20%	NA	NA	NA	0.100%
11HS-12 diluted 1/2	8/18/00	<0.200	4.17	<0.100	1.33	<1.00	4.85
11HS-12 diluted 1/2 LD	8/18/00	<0.200	4.16	<0.100	1.33	<1.00	4.96
duplicate % diff		NA	0.400%	NA	0.300%	NA	2.20%
11HS-12 diluted 1/2	8/18/00	<0.200	4.17	<0.100	1.33	<1.00	4.85
11HS-12 diluted 1/2 SPIKE	8/18/00	0.240	5.65	0.190	1.39	<1.00	6.96
spike added		0.200	2.00	0.200	0.200	0.200	3.00
%spike recovery		118%	95.0%	93.0%	95.0%	######	86.0%
11HS-19 8/15/00	8/17/00	<0.200	7.70	<0.100	1.16	<1.00	8.52
11HS-19 8/15/00 Spike	8/17/00	0.280	8.93	0.200	1.25	<1.00	10.7
spike added		0.200	2.00	0.200	0.200	0.200	3.0
%spike recovery		139%	100%	102%	102%	######	99.0%

4AIW-12 8/16/00	8/17/00	<0.200	4.48	<0.100	1.02	<1.00	14.3
4AIW-12 8/16/00 spike	8/17/00	0.290	6.05	0.200	1.13	<1.00	16.0
spike added		0.200	2.00	0.200	0.200	0.200	3.00
%spike recovery		147%	101%	101%	106%	######	103%
5B1-DW 8/15/00	8/17/00	<0.200	<1.00	<0.100	0.410	<1.00	5.42
5B1-DW 8/15/00 spike	8/17/00	0.320	2.57	0.190	0.570	<1.00	7.90
spike added		0.200	2.00	0.200	0.200	0.200	3.00
%spike recovery		158%	129%	97.0%	101%	######	101%
lab blank	8/17/00	<0.200	<1.00	<0.100	0.120	<1.00	<1.50
LFB 081700	8/17/00	0.220	1.87	0.200	0.190	<1.00	2.83
spike added		0.200	2.00	0.200	0.200	0.200	3.00
%spike recovery		112%	93.0%	99.0%	40.0%	######	94.0%
1/10 qcspex(1-15)	8/17/00	0.270	1.56	<0.100	0.840	<1.00	2.24
True value		0.300	1.75	0.0800	0.850	0.430	2.25
ACCEPTABLE RANGE		0.27-0.33	0.34-2.28	0.17-0.23	0.72-0.98	0.36-0.47	1.25-2.91
within spec?		Yes	yes	NA	yes	NA	yes
1/2 qcspex(1-15)	8/17/00	1.44	8.41	0.400	too high	too high	10.7
True value		1.50	8.75	0.400	4.25	2.13	11.3
ACCEPTABLE RANGE		1.35-1.65	7.00-9.68	0.36-0.44	3.61-4.89	2.04-2.22	9.45-12.73
within spec?		yes	yes	yes	NA	NA	yes

Sample Name	Analysis Date	Analyst	HCO3 (mg/L)
11 H-DW	8/17/00	AY	128.4
11 HS-10	8/17/00	AY	236.4
11 HS-10 LD	8/17/00	AY	236.0
11 HS-12	8/17/00	AY	188.4
11 HS-14	8/17/00	AY	192.0
11 HS-19	8/17/00	AY	193.2
11 HW-10	8/17/00	AY	211.2
11 HW-12	8/17/00	AY	185.2
11 HW-14	8/17/00	AY	188.4
11 HW-19	8/17/00	AY	188.8
11 HW-19 LD	8/17/00	AY	190.0
4A1-DW	8/17/00	AY	186.8
4A1S-12	8/17/00	AY	132.0
4A1S-14	8/17/00	AY	187.6
4A1S-19	8/17/00	AY	204.4
4A1S-19 LD	8/17/00	AY	203.2
4A1W-12	8/17/00	AY	180.4
4A1W-14	8/17/00	AY	180.4
4A1W-19	8/17/00	AY	194.8
5B1-DW	8/17/00	AY	130.8
5B1S-10	8/17/00	AY	152.4
5B1S-12	8/17/00	AY	163.6
5B1W-19	8/17/00	AY	161.6
NORTH DITCH	8/17/00	AY	111.2
ROMAN CREEK	8/17/00	AY	85.20
TWIN POND	8/17/00	AY	135.6
11 HS-10	8/17/00	AY	236.4
11 HS-10 LD	8/17/00	AY	236.00
% diff duplicates			0.200%
11 HW-19	8/17/00	AY	188.8
11 HW-19 LD	8/17/00	AY	190.0
% diff duplicates			0.600%
4A1S-19	8/17/00	AY	204.4
4A1S-19 LD	8/17/00	AY	203.2
% diff duplicates			0.600%

Sample Name	Analysis Date	Analyst	NH4-N (mg/L)
11 H-DW	8/17/00	LB	<0.500
11 HS-10	8/17/00	LB	<0.500
11 HS-10 LD	8/17/00	LB	<0.500
11 HS-12	8/17/00	LB	<0.500
11 HS-14	8/17/00	LB	<0.500
11 HS-19	8/17/00	LB	<0.500
11 HW-10	8/17/00	LB	<0.500
11 HW-12	8/17/00	LB	<0.500
11 HW-14	8/17/00	LB	<0.500
11 HW-19	8/17/00	LB	<0.500
11 HW-19 LD	8/17/00	LB	<0.500
4A1-DW	8/17/00	LB	<0.500
4A1S-12	8/17/00	LB	<0.500
4A1S-14	8/17/00	LB	<0.500
4A1S-19	8/17/00	LB	<0.500
4A1S-19 LD	8/17/00	LB	<0.500
4A1W-12	8/17/00	LB	<0.500
4A1W-14	8/17/00	LB	<0.500
4A1W-19	8/17/00	LB	<0.500
5B1-DW	8/17/00	LB	<0.500
5B1S-10	8/17/00	LB	<0.500
5B1S-12	8/17/00	LB	<0.500
5B1W-19	8/17/00	LB	<0.500
NORTH DITCH	8/17/00	LB	<0.500
ROMAN CREEK	8/17/00	LB	<0.500
TWIN POND	8/17/00	LB	<0.500
NORTH DITCH	8/17/00	LB	<0.500
NORTH DITCH LD	8/17/00	LB	<0.500
NORTH DITCH SPIKE	8/18/00	LB	1.14
% diff duplicates			NA
% SPIKE RECOVERY			114%
5B1S-12	8/17/00	LB	<0.500
5B1S-12 LD	8/17/00	LB	<0.500
5B1S-12 SPIKE	8/17/00	LB	0.810
% diff duplicates			NA
% SPIKE RECOVERY			132%
4A1W-12	8/17/00	LB	<0.500
4A1W-12	8/17/00	LB	<0.500
4A1W-12	8/17/00	LB	1.09
% diff duplicates			NA
% SPIKE RECOVERY			109%

Sample Name	Date	Al3961	As1890	Ba2335	Be2348	Ca318H	Cd2265
PQL		0.005	0.005	0.0005	0.0001	0.05	0.001
4A1S-14 8/16/00	8/23/00	<0.005	<0.005	0.093	<0.0001	56.8	<0.001
4A1W-19 8/16/00	8/23/00	<0.005	<0.005	0.113	<0.0001	57.9	<0.001
NORTH DITCH 8/16/00	8/23/00	<0.005	<0.005	0.132	<0.0001	30.1	<0.001
11 HS-14 8/15/00	8/23/00	<0.005	<0.005	0.173	<0.0001	54.4	<0.001
4A1W-12 8/16/00	8/23/00	<0.005	<0.005	0.094	<0.0001	53.5	<0.001
4A1W-14 8/16/00	8/23/00	<0.005	<0.005	0.082	<0.0001	53.9	<0.001
11 HS-12 8/15/00	8/23/00	<0.005	<0.005	0.180	<0.0001	56.2	<0.001
11 HS-10 8/15/00	8/23/00	<0.005	0.013	0.329	<0.0001	72.4	<0.001
4A1S-19 8/16/00	8/23/00	<0.005	<0.005	0.095	<0.0001	61.3	<0.001
TWIN POND 8/15/00	8/23/00	<0.005	<0.005	0.107	<0.0001	29.9	<0.001
4A1-DW 8/16/00	8/23/00	<0.005	<0.005	0.390	<0.0001	46.6	<0.001
4A1-DW 081600	8/23/00	<0.005	<0.005	0.407	<0.0001	51.2	<0.001
ROMAN CREEK 8/16/00	8/23/00	<0.005	<0.005	0.006	<0.0001	19.2	<0.001
5B1S-12 8/15/00	8/22/00	<0.005	0.011	0.137	<0.0001	35.4	<0.001
5B15-10 8/15/00	8/23/00	<0.005	<0.005	0.126	<0.0001	33.8	<0.001
5B15-12 8/15/00	8/23/00	<0.005	0.008	0.137	<0.0001	34.9	<0.001
11 HW-12 8/15/00	8/23/00	<0.005	<0.005	0.159	<0.0001	54.7	<0.001
11 HW-19 8/15/00	8/23/00	<0.005	<0.005	0.162	<0.0001	55.7	<0.001
11 HW-14 8/15/00	8/23/00	<0.005	<0.005	0.161	<0.0001	55.2	<0.001
11 HS-19 8/15/00	8/23/00	<0.005	<0.005	0.164	<0.0001	54.8	<0.001
5B1W-19 8/15/00	8/23/00	<0.005	<0.005	0.122	<0.0001	39.4	<0.001
5B1-DW 8/15/00	8/23/00	<0.005	0.005	0.285	<0.0001	32.8	<0.001
11 HW-10 8/15/00	8/23/00	<0.005	<0.005	0.178	<0.0001	53.4	<0.001
11 H-DW 8/15/00	8/23/00	<0.005	<0.005	0.250	<0.0001	32.5	<0.001
4A1S-12 8/16/00	8/23/00	<0.005	<0.005	0.307	<0.0001	63.6	<0.001

Sample Name	Date	Co2286	Cr2677	Cu3247	Fe259L	K7664	Li6707
PQL		0.003	0.005	0.003	0.001	0.5	0.002
4A1S-14 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.33	0.003
4A1W-19 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.013	2.27	0.004
NORTH DITCH 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.014	1.67	0.005
11 HS-14 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.71	0.003
4A1W-12 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.75	0.003
4A1W-14 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.20	0.003
11 HS-12 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.95	0.003
11 HS-10 8/15/00	8/23/00	<0.003	<0.005	0.012	0.006	6.13	0.008
4A1S-19 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.003	2.09	0.003
TWIN POND 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.011	3.58	0.004
4A1-DW 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.004	1.99	0.003
4A1-DW 081600	8/23/00	<0.003	<0.005	<0.003	0.004	2.03	0.003
ROMAN CREEK 8/16/00	8/23/00	<0.003	<0.005	<0.003	0.004	0.92	<0.002
5B1S-12 8/15/00	8/22/00	<0.003	<0.005	<0.003	0.004	3.34	0.004
5B15-10 8/15/00	8/23/00	<0.003	<0.005	0.003	0.003	3.39	0.004
5B15-12 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.004	3.25	0.004
11 HW-12 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.69	0.003
11 HW-19 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.73	0.003
11 HW-14 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.70	0.003
11 HS-19 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.46	0.003
5B1W-19 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.30	0.003
5B1-DW 8/15/00	8/23/00	<0.003	<0.005	0.010	0.002	1.55	0.003
11 HW-10 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.002	2.40	0.004
11 H-DW 8/15/00	8/23/00	<0.003	<0.005	<0.003	0.009	1.88	0.003
4A1S-12 8/16/00	8/23/00	<0.003	<0.005	0.011	0.006	5.02	0.003

Sample Name	Date	Mg293H	Mn2605	Mo2020	Na5688	Ni2316
PQL		0.1	0.0005	0.003	0.05	0.002
4A1S-14 8/16/00	8/23/00	13.2	<0.0005	<0.003	12.1	<0.002
4A1W-19 8/16/00	8/23/00	13.2	0.133	0.022	8.05	<0.002
NORTH DITCH 8/16/00	8/23/00	8.95	0.001	<0.003	5.41	<0.002
11 HS-14 8/15/00	8/23/00	13.6	<0.0005	<0.003	12.3	<0.002
4A1W-12 8/16/00	8/23/00	12.5	0.001	<0.003	10.1	<0.002
4A1W-14 8/16/00	8/23/00	12.7	0.001	<0.003	10.0	<0.002
11 HS-12 8/15/00	8/23/00	13.8	<0.0005	<0.003	13.0	<0.002
11 HS-10 8/15/00	8/23/00	14.6	0.138	<0.003	37.0	0.003
4A1S-19 8/16/00	8/23/00	14.3	0.002	<0.003	12.5	<0.002
TWIN POND 8/15/00	8/23/00	13.6	0.013	<0.003	11.0	<0.002
4A1-DW 8/16/00	8/23/00	14.2	0.018	<0.003	10.3	<0.002
4A1-DW 081600	8/23/00	15.3	0.018	<0.003	10.9	<0.002
ROMAN CREEK 8/16/00	8/23/00	7.67	<0.0005	<0.003	2.37	0.003
5B1S-12 8/15/00	8/22/00	12.1	1.385	<0.003	9.38	0.002
5B15-10 8/15/00	8/23/00	12.9	0.038	<0.003	11.3	<0.002
5B15-12 8/15/00	8/23/00	15.0	1.410	<0.003	11.8	0.002
11 HW-12 8/15/00	8/23/00	13.9	<0.0005	<0.003	9.26	<0.002
11 HW-19 8/15/00	8/23/00	14.2	0.002	<0.003	8.24	<0.002
11 HW-14 8/15/00	8/23/00	13.9	<0.0005	<0.003	9.30	<0.002
11 HS-19 8/15/00	8/23/00	14.4	0.001	<0.003	9.81	<0.002
5B1W-19 8/15/00	8/23/00	13.7	0.029	<0.003	11.6	<0.002
5B1-DW 8/15/00	8/23/00	9.88	<0.0005	<0.003	5.60	<0.002
11 HW-10 8/15/00	8/23/00	20.4	<0.0005	<0.003	9.13	<0.002
11 H-DW 8/15/00	8/23/00	9.90	0.013	<0.003	7.39	<0.002
4A1S-12 8/16/00	8/23/00	16.0	<0.0005	<0.003	13.6	0.002

Sample Name	Date	P 1782	Pb2203	S 1807	Si2516	Sn1899
PQL		0.01	0.01		0.02	0.003
4A1S-14 8/16/00	8/23/00	0.0896	<0.01	5.05	9.83	<0.003
4A1W-19 8/16/00	8/23/00	<0.0100	<0.01	5.04	8.78	<0.003
NORTH DITCH 8/16/00	8/23/00	<0.0100	<0.01	4.97	3.84	<0.003
11 HS-14 8/15/00	8/23/00	0.582	<0.01	3.04	10.0	<0.003
4A1W-12 8/16/00	8/23/00	0.0355	<0.01	4.78	9.98	<0.003
4A1W-14 8/16/00	8/23/00	0.0192	<0.01	4.83	9.90	<0.003
11 HS-12 8/15/00	8/23/00	0.488	<0.01	3.29	9.81	<0.003
11 HS-10 8/15/00	8/23/00	2.50	<0.01	6.26	12.0	<0.003
4A1S-19 8/16/00	8/23/00	0.0154	<0.01	5.43	10.4	<0.003
TWIN POND 8/15/00	8/23/00	<0.0100	<0.01	4.64	7.38	<0.003
4A1-DW 8/16/00	8/23/00	0.0410	<0.01	3.31	10.2	<0.003
4A1-DW 081600	8/23/00	0.0441	<0.01	3.48	10.9	<0.003
ROMAN CREEK 8/16/00	8/23/00	<0.0100	<0.01	1.53	3.44	<0.003
5B1S-12 8/15/00	8/22/00	0.0591	<0.01	0.924	9.50	<0.003
5B15-10 8/15/00	8/23/00	0.0515	<0.01	0.773	11.2	<0.003
5B15-12 8/15/00	8/23/00	0.0581	<0.01	1.01	11.7	<0.003
11 HW-12 8/15/00	8/23/00	0.0495	<0.01	2.86	9.22	<0.003
11 HW-19 8/15/00	8/23/00	0.0462	<0.01	2.93	9.33	<0.003
11 HW-14 8/15/00	8/23/00	0.0465	<0.01	2.90	9.19	<0.003
11 HS-19 8/15/00	8/23/00	0.0641	<0.01	2.95	9.65	<0.003
5B1W-19 8/15/00	8/23/00	0.0248	<0.01	2.81	7.74	<0.003
5B1-DW 8/15/00	8/23/00	0.0510	<0.01	1.83	9.72	<0.003
11 HW-10 8/15/00	8/23/00	0.0490	<0.01	2.70	10.4	<0.003
11 H-DW 8/15/00	8/23/00	0.0336	<0.01	1.85	9.96	<0.003
4A1S-12 8/16/00	8/23/00	1.02	<0.01	12.7	8.85	<0.003

Sample Name	Date	Sr4215	Ti3234	V 3110	Zn2138
PQL		0.0005	0.005	0.005	0.001
4A1S-14 8/16/00	8/23/00	0.0728	<0.005	<0.005	0.001
4A1W-19 8/16/00	8/23/00	0.0734	<0.005	<0.005	0.001
NORTH DITCH 8/16/00	8/23/00	0.103	<0.005	<0.005	0.001
11 HS-14 8/15/00	8/23/00	0.0869	<0.005	<0.005	0.001
4A1W-12 8/16/00	8/23/00	0.0728	<0.005	<0.005	0.001
4A1W-14 8/16/00	8/23/00	0.0718	<0.005	<0.005	0.002
11 HS-12 8/15/00	8/23/00	0.0840	<0.005	<0.005	0.002
11 HS-10 8/15/00	8/23/00	0.157	<0.005	0.007	0.002
4A1S-19 8/16/00	8/23/00	0.0763	<0.005	<0.005	0.002
TWIN POND 8/15/00	8/23/00	0.0560	<0.005	<0.005	0.002
4A1-DW 8/16/00	8/23/00	0.136	<0.005	<0.005	0.002
4A1-DW 081600	8/23/00	0.147	<0.005	<0.005	0.002
ROMAN CREEK 8/16/00	8/23/00	0.0274	<0.005	<0.005	<0.001
5B1S-12 8/15/00	8/22/00	0.0582	<0.005	<0.005	<0.001
5B15-10 8/15/00	8/23/00	0.0642	<0.005	<0.005	<0.001
5B15-12 8/15/00	8/23/00	0.0683	<0.005	<0.005	<0.001
11 HW-12 8/15/00	8/23/00	0.0731	<0.005	<0.005	<0.001
11 HW-19 8/15/00	8/23/00	0.0739	<0.005	<0.005	<0.001
11 HW-14 8/15/00	8/23/00	0.0742	<0.005	<0.005	<0.001
11 HS-19 8/15/00	8/23/00	0.0742	<0.005	<0.005	<0.001
5B1W-19 8/15/00	8/23/00	0.0759	<0.005	<0.005	<0.001
5B1-DW 8/15/00	8/23/00	0.0828	<0.005	<0.005	<0.001
11 HW-10 8/15/00	8/23/00	0.0948	<0.005	<0.005	<0.001
11 H-DW 8/15/00	8/23/00	0.0983	<0.005	<0.005	<0.001
4A1S-12 8/16/00	8/23/00	0.134	<0.005	<0.005	<0.001

Sample Name	Date	Al3961	As1890	Ba2335	Be2348
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	<0.005	<0.005	0.162	<0.0001
11 HW-19 8/15/00 PD	8/23/00	<0.005	<0.005	0.164	<0.0001
% difference duplicates		NA	NA	1%	NA
4A1W-19 8/16/00	8/23/00	<0.005	<0.005	0.113	<0.0001
4A1W-19 8/16/00 PD	8/23/00	<0.005	<0.005	0.115	<0.0001
% difference duplicates		NA	NA	1%	NA
11 HS-19 8/15/00	8/23/00	<0.005	<0.005	0.164	<0.0001
11HS-19 8/15/_RQ	8/23/00	0.516	0.402	0.698	0.104
spike added		0.5	0.5	0.5	0.1
SPIKE % RECOVERY		103%	**80%**	109%	104%
4A1-DW 8/16/00	8/23/00	<0.005	<0.005	0.390	<0.0001
4A1-DW 081_RQ	8/23/00	0.534	0.416	0.924	0.104
spike added		0.5	0.5	0.5	0.1
SPIKE % RECOVERY		107%	**83%**	112%	104%
PREP BLANK 8/17/00	8/23/00	<0.005	<0.005	<0.0005	<0.0001
Blank	8/23/00	<0.005	<0.005	<0.0005	<0.0001
Blank	8/23/00	<0.005	<0.005	<0.0005	<0.0001
CAL BLANK	8/23/00	<0.005	<0.005	<0.0005	<0.0001

Sample Name	Date	Ca318H	Cd2265	Co2286	Cr2677
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	55.7	<0.001	<0.003	<0.005
11 HW-19 8/15/00 PD	8/23/00	56.6	<0.001	<0.003	<0.005
% difference duplicates		2%	NA	NA	NA
4A1W-19 8/16/00	8/23/00	57.9	<0.001	<0.003	<0.005
4A1W-19 8/16/00 PD	8/23/00	58.8	<0.001	<0.003	<0.005
% difference duplicates		1%	NA	NA	NA
11 HS-19 8/15/00	8/23/00	54.8	<0.001	<0.003	<0.005
11HS-19 8/15/_RQ	8/23/00	71.2	0.211	0.213	0.535
spike added		20	0.2	0.2	0.5
SPIKE % RECOVERY		101%	105%	107%	107%
4A1-DW 8/16/00	8/23/00	46.6	<0.001	<0.003	<0.005
4A1-DW 081_RQ	8/23/00	67.4	0.229	0.213	0.537
spike added		20	0.2	0.2	0.5
SPIKE % RECOVERY		120%	115%	106%	107%
PREP BLANK 8/17/00	8/23/00	<0.05	<0.001	<0.003	<0.005
Blank	8/23/00	<0.05	<0.001	<0.003	<0.005
Blank	8/23/00	<0.05	<0.001	<0.003	<0.005
CAL BLANK	8/23/00	<0.05	<0.001	<0.003	<0.005

Sample Name	Date	Cu3247	Fe259L	K7664	Li6707
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	<0.003	0.002	2.7	0.003
11 HW-19 8/15/00 PD	8/23/00	<0.003	0.002	2.8	0.003
% difference duplicates		NA	29%	2%	0%
4A1W-19 8/16/00	8/23/00	<0.003	0.013	2.3	0.004
4A1W-19 8/16/00 PD	8/23/00	<0.003	0.013	2.3	0.003
% difference duplicates		NA	4%	2%	3%
11 HS-19 8/15/00	8/23/00	<0.003	0.002	2.5	0.003
11HS-19 8/15/_RQ	8/23/00	0.504	0.543	7.4	0.539
spike added		0.5	0.5	5	0.6
SPIKE % RECOVERY		101%	108%	101%	89%
4A1-DW 8/16/00	8/23/00	<0.003	0.004	2.0	0.003
4A1-DW 081_RQ	8/23/00	0.530	0.534	6.9	0.532
spike added		0.5	0.5	5	0.6
SPIKE % RECOVERY		106%	106%	101%	88%
PREP BLANK 8/17/00	8/23/00	<0.003	<0.001	<0.5	<0.002
Blank	8/23/00	<0.003	<0.001	<0.5	<0.002
Blank	8/23/00	<0.003	<0.001	<0.5	<0.002
CAL BLANK	8/23/00	<0.003	<0.001	<0.5	<0.002

Sample Name	Date	Mg293H	Mn2605	Mo2020	Na5688
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	14.2	0.002	<0.003	8.24
11 HW-19 8/15/00 PD	8/23/00	14.3	0.002	<0.003	8.29
% difference duplicates		0%	0%	NA	1%
4A1W-19 8/16/00	8/23/00	13.2	0.133	0.022	8.05
4A1W-19 8/16/00 PD	8/23/00	13.3	0.134	0.023	8.09
% difference duplicates		1%	1%	2%	1%
11 HS-19 8/15/00	8/23/00	14.4	0.001	<0.003	9.81
11HS-19 8/15/_RQ	8/23/00	18.4	0.543	0.216	18.88
spike added		5	0.5	0.2	10
SPIKE % RECOVERY		100%	108%	108%	98%
4A1-DW 8/16/00	8/23/00	14.2	0.018	<0.003	10.26
4A1-DW 081_RQ	8/23/00	19.6	0.550	0.215	20.45
spike added		5	0.5	0.2	10
SPIKE % RECOVERY		127%	107%	107%	109%
PREP BLANK 8/17/00	8/23/00	<0.1	<0.0005	<0.003	0.12
Blank	8/23/00	<0.1	<0.0005	<0.003	0.19
Blank	8/23/00	<0.1	<0.0005	<0.003	0.20
CAL BLANK	8/23/00	<0.1	<0.0005	<0.003	0.13

Sample Name	Date	Ni2316	P 1782	Pb2203	S 1807
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	<0.002	0.05	<0.01	2.928
11 HW-19 8/15/00 PD	8/23/00	<0.002	0.05	<0.01	2.986
% difference duplicates		NA	4%	NA	2%
4A1W-19 8/16/00	8/23/00	<0.002	<0.01	<0.01	5.042
4A1W-19 8/16/00 PD	8/23/00	<0.002	<0.01	<0.01	5.108
% difference duplicates		NA	NA	NA	1%
11 HS-19 8/15/00	8/23/00	<0.002	0.06	<0.01	2.950
11HS-19 8/15/_RQ	8/23/00	0.530	1.06	0.540	7.822
spike added		0.5	1	0.5	5
SPIKE % RECOVERY		106%	100%	108%	102%
4A1-DW 8/16/00	8/23/00	<0.002	0.04	<0.01	3.305
4A1-DW 081_RQ	8/23/00	0.536	1.07	0.536	8.534
spike added		0.5	1	0.5	5
SPIKE % RECOVERY		107%	103%	107%	109%
PREP BLANK 8/17/00	8/23/00	<0.002	<0.01	<0.01	0.001
Blank	8/23/00	<0.002	<0.01	<0.01	0.001
Blank	8/23/00	<0.002	<0.01	<0.01	0.000
CAL BLANK	8/23/00	<0.002	<0.01	<0.01	0.000

Sample Name	Date	Si2516	Sn1899	Sr4215	Ti3234
LABORATORY DUPLICATES AND SPIKES					
11 HW-19 8/15/00	8/23/00	9.3	<0.003	0.074	<0.005
11 HW-19 8/15/00 PD	8/23/00	9.4	<0.003	0.074	<0.005
% difference duplicates		1%	NA	0%	NA
4A1W-19 8/16/00	8/23/00	8.8	<0.003	0.073	<0.005
4A1W-19 8/16/00 PD	8/23/00	8.8	<0.003	0.074	<0.005
% difference duplicates		0%	NA	1%	NA
11 HS-19 8/15/00	8/23/00	9.7	<0.003	0.074	<0.005
11HS-19 8/15/_RQ	8/23/00	13.8	0.214	0.572	0.101
spike added		5	0.2	0.5	0.1
SPIKE % RECOVERY		96%	107%	100%	101%
4A1-DW 8/16/00	8/23/00	10.2	<0.003	0.136	<0.005
4A1-DW 081_RQ	8/23/00	15.2	0.214	0.666	0.109
spike added		5	0.2	0.5	0.1
SPIKE % RECOVERY		114%	107%	108%	109%
PREP BLANK 8/17/00	8/23/00	<0.02	<0.003	<0.0005	<0.005
Blank	8/23/00	<0.02	<0.003	<0.0005	<0.005
Blank	8/23/00	<0.02	<0.003	<0.0005	<0.005
CAL BLANK	8/23/00	<0.02	<0.003	<0.0005	<0.005

Sample Name	Date	V 3110	Zn2138
LABORATORY DUPLICATES AND SPIKES			
11 HW-19 8/15/00	8/23/00	<0.005	<0.001
11 HW-19 8/15/00 PD	8/23/00	<0.005	0.002
% difference duplicates		NA	NA
4A1W-19 8/16/00	8/23/00	<0.005	0.001
4A1W-19 8/16/00 PD	8/23/00	<0.005	<0.001
% difference duplicates		NA	######
11 HS-19 8/15/00	8/23/00	<0.005	<0.001
11HS-19 8/15/_RQ	8/23/00	0.198	0.508
spike added		0.2	0.5
SPIKE % RECOVERY		99%	102%
4A1-DW 8/16/00	8/23/00	<0.005	0.002
4A1-DW 081_RQ	8/23/00	0.210	0.534
spike added		0.2	0.5
SPIKE % RECOVERY		105%	106%
PREP BLANK 8/17/00	8/23/00	<0.005	0.003
Blank	8/23/00	<0.005	<0.001
Blank	8/23/00	<0.005	<0.001
CAL BLANK	8/23/00	<0.005	<0.001

Sample Name	Date	Al3961	As1890	Ba2335	Be2348
OUTSIDE STANDARDS					
USGST143	8/23/00	0.024	0.015	0.079	0.008
USGST143	8/23/00	0.024	0.016	0.078	0.008
USGST143	8/23/00	0.024	0.014	0.077	0.008
USGST143	8/23/00	0.025	0.015	0.079	0.008
USGST143	8/23/00	0.025	0.015	0.078	0.008
AVERAGE		0.0242	0.0151	0.0783	0.008
WITHIN ACCEPTABLE RANGE		YES	YES	YES	YES
REPORTED ABSOLUTE VALUE		0.0221	0.0152	0.0819	0.0085
ACCEPTABLE LOW		0.0055	0.0128	0.0729	0.0072
ACCEPTABLE HIGH		0.0387	0.0176	0.0909	0.0098
USN_IPC	8/23/00	0.502	0.482	0.512	0.478
ABSOLUTE VALUE		0.5	0.5	0.5	0.5
% DIFF FROM KNOWN		0.3%	-3.7%	2.5%	-4.5%

Sample Name	Date	Ca318H	Cd2265	Co2286	Cr2677
OUTSIDE STANDARDS					
USGST143	8/23/00	53.4	0.020	0.017	0.037
USGST143	8/23/00	53.6	0.020	0.017	0.036
USGST143	8/23/00	53.0	0.019	0.017	0.036
USGST143	8/23/00	53.5	0.020	0.017	0.037
USGST143	8/23/00	53.4	0.020	0.017	0.037
AVERAGE		53.378	0.0195	0.0171	0.0365
WITHIN ACCEPTABLE RANGE		YES	YES	YES	YES
REPORTED ABSOLUTE VALUE		53.7	0.0191	0.017	0.037
ACCEPTABLE LOW		49.3	0.0161	0.0146	0.0318
ACCEPTABLE HIGH		58.1	0.0221	0.0194	0.0422
USN_IPC	8/23/00	9.393	0.568	0.532	0.518
ABSOLUTE VALUE		10	0.5	0.5	0.5
% DIFF FROM KNOWN		-6.1%	13.6%	6.4%	3.6%

Sample Name	Date	Cu3247	Fe259L	K7664	Li6707
OUTSIDE STANDARDS					
USGST143	8/23/00	0.023	0.238	2.5	0.017
USGST143	8/23/00	0.024	0.232	2.4	0.017
USGST143	8/23/00	0.022	0.235	2.5	0.017
USGST143	8/23/00	0.023	0.239	2.5	0.017
USGST143	8/23/00	0.023	0.240	2.5	0.017
AVERAGE		0.023	0.2367	2.485	0.0172
WITHIN ACCEPTABLE RANGE		YES	YES	YES	YES
REPORTED ABSOLUTE VALUE		0.0223	0.222	2.5	0.018
ACCEPTABLE LOW		0.0185	0.194	2.08	0.0138
ACCEPTABLE HIGH		0.0261	0.25	2.92	0.0222
USN_IPC	8/23/00	0.509	0.524	4.934	0.488
ABSOLUTE VALUE		0.5	0.5	5	0.5
% DIFF FROM KNOWN		1.8%	4.7%	-1.3%	-2.4%

Sample Name	Date	Mg293H	Mn2605	Mo2020	Na5688
OUTSIDE STANDARDS					
USGST143	8/23/00	10.4	0.018	0.038	33.41
USGST143	8/23/00	10.4	0.018	0.038	33.75
USGST143	8/23/00	9.9	0.018	0.037	32.22
USGST143	8/23/00	10.3	0.018	0.038	33.12
USGST143	8/23/00	10.3	0.018	0.037	33.46
AVERAGE		10.261	0.0178	0.0375	33.192
WITHIN ACCEPTABLE RANGE		YES	YES	YES	YES
REPORTED ABSOLUTE VALUE		10.4	0.0182	0.0361	34
ACCEPTABLE LOW		9.4	0.0144	0.0275	30.8
ACCEPTABLE HIGH		11.4	0.022	0.0447	37.2
USN_IPC	8/23/00	10.130	0.512	0.523	10.340
ABSOLUTE VALUE		10	0.5	0.5	10
% DIFF FROM KNOWN		1.3%	2.5%	4.5%	3.4%

Sample Name	Date	NI2316	P 1782	Pb2203	S 1807	Si2516
OUTSIDE STANDARDS						
USGST143	8/23/00	0.074	0.02	0.089	6.977	12.6
USGST143	8/23/00	0.074	0.02	0.089	6.963	12.5
USGST143	8/23/00	0.073	0.02	0.087	6.892	12.0
USGST143	8/23/00	0.074	0.02	0.089	7.046	12.6
USGST143	8/23/00	0.074	0.02	0.090	6.981	12.6
AVERAGE		0.0736	0.0232	0.0887	6.9718	12.45
WITHIN ACCEPTABLE RANGE		YES	NA	YES	YES	YES
REPORTED ABSOLUTE VALUE		0.071		0.0834	6.86	10.94
ACCEPTABLE LOW		0.061		0.0692	6.46	9.3
ACCEPTABLE HIGH		0.081		0.0976	7.26	12.58
USN_IPC	8/23/00	0.523	0.496	0.512	0.515	0.609
ABSOLUTE VALUE		0.5	0.5	0.5	0.5	0.5
% DIFF FROM KNOWN		4.7%	-0.7%	2.5%	2.9%	21.8%

Sample Name	Date	Sn1899	Sr4215	Ti3234	V 3110	Zn2138
OUTSIDE STANDARDS						
USGST143	8/23/00	<0.003	0.300	<0.005	0.028	0.0180
USGST143	8/23/00	<0.003	0.304	<0.005	0.028	0.0180
USGST143	8/23/00	<0.003	0.284	<0.005	0.026	0.0170
USGST143	8/23/00	<0.003	0.297	<0.005	0.028	0.0180
USGST143	8/23/00	<0.003	0.296	<0.005	0.028	0.0180
AVERAGE		#DIV/0!	0.2962	#DIV/0!	0.0277	0.0178
WITHIN ACCEPTABLE RANGE		#DIV/0!	YES	#DIV/0!	YES	YES
REPORTED ABSOLUTE VALUE			0.306		0.0300	0.0200
ACCEPTABLE LOW			0.276		0.024	0.0156
ACCEPTABLE HIGH			0.336		0.036	0.0244
USN_IPC	8/23/00	0.480	0.512	0.511	0.503	0.510
ABSOLUTE VALUE		0.500	0.500	0.500	0.500	0.500
% DIFF FROM KNOWN		-4.00%	2.30%	2.20%	0.600%	1.90%

Appendix G

Pumping Test Data

Drawdown Test for 28-11H

Time (MIN)	Time (SEC)	TOC-DW (FT)	DTW-DW (FT)	POT-DW (FT)	TIME (SEC)	TOC-PW (FT)	DTW-PW (FT)	POT-PW (FT)	TIME (Min)	Q Gal/Min
0	0	3027.69	14.56	3013.13	0	3025.63	7.54	3018.09	0	10.71
2.5	150	3027.69	25.49	3002.20	30	3025.63	8.06	3017.57	10	10.34
3.5	210	3027.69	27.15	3000.54	180	3025.63	7.57	3018.06	20	10.00
4.5	270	3027.69	28.17	2999.52	240	3025.63	7.56	3018.07	30	10.00
5.5	330	3027.69	28.77	2998.92	300	3025.63	7.56	3018.07		
7	420	3027.69	29.23	2998.46	390	3025.63	7.57	3018.06		
8.5	510	3027.69	29.48	2998.21	480	3025.63	7.58	3018.05		
10	600	3027.69	29.59	2998.10	570	3025.63	7.55	3018.08		
12	720	3027.69	29.60	2998.09	660	3025.63	7.56	3018.07		
14	840	3027.69	29.62	2998.07	780	3025.63	7.58	3018.05		
16	960	3027.69	29.64	2998.05	900	3025.63	7.58	3018.05		
20	1200	3027.69	29.68	2998.01	1260	3025.63	7.58	3018.05		
25	1500	3027.69	29.75	2997.94	1830	3025.63	7.56	3018.07		
30	1800	3027.69	29.76	2997.93						

Drawdown Test for 28-4A1

Time (Sec)	TOC-DW (FT)	DTW-DW (FT)	POT-DW (FT)	Time (SEC)	TOC-PW (FT)	DTW-PW (FT)	WT-PW (FT)	Time (MIN)	Q Gal/Min
0	3035.32	16.88	3018.44	0	3033.29	9.20	3024.09	0	9.68
30	3035.32	17.85	3017.47	30	3033.29	9.20	3024.09	10	9.68
60	3035.32	18.18	3017.14	120	3033.29	9.15	3024.14	15	10.00
120	3035.32	18.30	3017.02	180	3033.29	9.17	3024.12	30	10.34
150	3035.32	18.30	3017.02	270	3033.29	9.18	3024.11	60	10.00
180	3035.32	18.34	3016.98	300	3033.29	9.17	3024.12		
270	3035.32	18.32	3017.00	360	3033.29	9.14	3024.15		
300	3035.32	18.32	3017.00	420	3033.29	9.15	3024.14		
360	3035.32	18.32	3017.00	480	3033.29	9.14	3024.15		
420	3035.32	18.32	3017.00	540	3033.29	9.14	3024.15		
480	3035.32	18.32	3017.00	900	3033.29	9.14	3024.15		
540	3035.32	18.32	3017.00	1200	3033.29	9.14	3024.15		
900	3035.32	18.32	3017.00	1800	3033.29	9.14	3024.15		
1200	3035.32	18.30	3017.02	2400	3033.29	9.15	3024.14		
1800	3035.32	18.30	3017.02	3000	3033.29	9.19	3024.10		
2400	3035.32	18.26	3017.06	3600	3033.29	9.15	3024.14		
3000	3035.32	18.28	3017.04						
3600	3035.32	18.30	3017.02						

Drawdown Test for 28-5B1

TIME (SEC)	TOC-DW (FT)	DTW-DW (FT)	POT-DW (FT)	TOC-PW (FT)	DTW-PW (FT)	POT-PW (FT)	TIME (MIN)	Q GAL/MIN
0	3034.21	16.70	3017.51	3032.78	11.02	3021.76	5	12.00
30	3034.21	17.03	3017.18	3032.78	11.02	3021.76	10	12.00
60	3034.21	17.03	3017.18	3032.78	11.02	3021.76	20	12.50
90	3034.21	17.02	3017.19	3032.78	11.03	3021.75	30	11.11
120	3034.21	17.02	3017.19	3032.78	11.03	3021.75	40	12.00
240	3034.21	17.02	3017.19	3032.78	11.04	3021.74	60	12.00
360	3034.21	17.01	3017.20	3032.78	11.03	3021.75		
480	3034.21	17.03	3017.18	3032.78	11.03	3021.75		
600	3034.21	17.02	3017.19	3032.78	11.03	3021.75		
1200	3034.21	17.00	3017.21	3032.78	11.02	3021.76		
1800	3034.21	17.02	3017.19	3032.78	11.02	3021.76		
2400	3034.21	17.00	3017.21	3032.78	11.02	3021.76		
3000	3034.21	17.00	3017.21	3032.78	11.02	3021.76		
3600	3034.21	17.00	3017.21	3032.78	11.03	3021.75		

Appendix H

Tracer Test Data

Site 28-11H

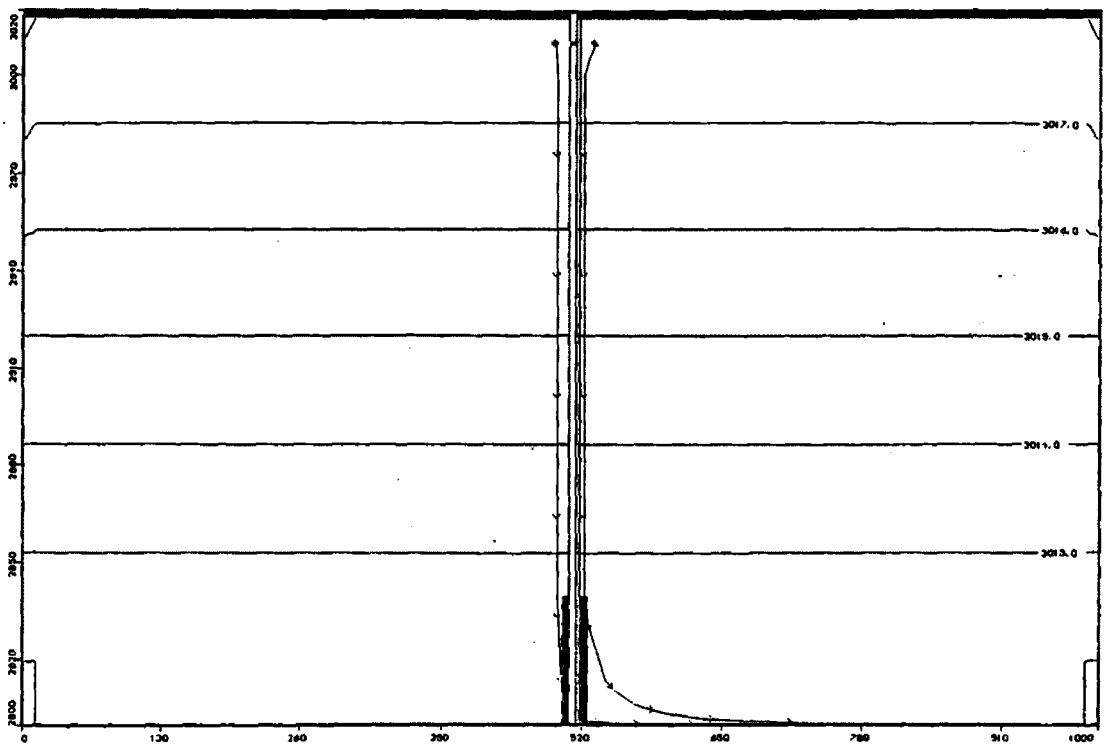
TIME (Min)	Well TOC (FT)	Well DTW (FT)	Well Pot. (FT)	TIME (Min)	Piezo. TOC (FT)	Piezo. DTW (FT)	Piezo. WT (FT)
0	3027.69	7.88	3019.81	0	3025.63	7.25	3018.38
8	3027.69	25.45	3002.24	40	3025.63	7.21	3018.42
15	3027.69	26.03	3001.66	50	3025.63	7.25	3018.38
20	3027.69	26.03	3001.66	60	3025.63	7.42	3018.21
40	3027.69	25.93	3001.76	70	3025.63	7.30	3018.33
50	3027.69	25.97	3001.72	80	3025.63	7.33	3018.30
60	3027.69	25.97	3001.72	90	3025.63	7.30	3018.33
70	3027.69	25.90	3001.79	100	3025.63	7.30	3018.33
80	3027.69	25.85	3001.84	110	3025.63	7.38	3018.25
90	3027.69	26.22	3001.47	120	3025.63	7.25	3018.38
100	3027.69	25.82	3001.87	130	3025.63	7.38	3018.25
110	3027.69	25.81	3001.88	140	3025.63	7.33	3018.30
120	3027.69	25.81	3001.88				
130	3027.69	25.80	3001.89				
140	3027.69	25.80	3001.89				

Time (Min)	Conductivity µS/cm	TDS mg/L	TDS g/L	Temperature °C
1	0.32	165.50	0.17	
5	0.28	142.50	0.14	
10	0.28	140.10	0.14	10.70
11	0.28	139.40	0.14	10.70
13	0.28	137.90	0.14	10.70
14	0.27	137.50	0.14	10.80
15	0.27	137.20	0.14	10.80
20	0.27	135.90	0.14	10.80
25	0.27	135.20	0.14	10.80
30	0.27	134.70	0.13	10.80
35	0.27	134.20	0.13	10.80
40	0.27	133.90	0.13	10.80
45	0.27	133.60	0.13	10.80
50	0.27	133.40	0.13	10.80
55	0.27	133.30	0.13	10.80
60	0.27	133.10	0.13	10.80
65	0.27	133.00	0.13	10.80
70	0.26	133.00	0.13	10.80
75	0.26	132.90	0.13	10.80

Time (Min)	Conductivity µS/cm	TDS mg/L	TDS g/L	Temperature °C
80	0.26	132.80	0.13	10.80
85	0.26	132.80	0.13	10.80
90	0.26	132.70	0.13	10.80
95	0.26	132.80	0.13	10.80
100	0.26	132.60	0.13	10.80
105	0.26	132.40	0.13	10.80
110	0.26	132.30	0.13	10.80
115	0.26	132.40	0.13	10.80
120	0.26	132.40	0.13	10.80

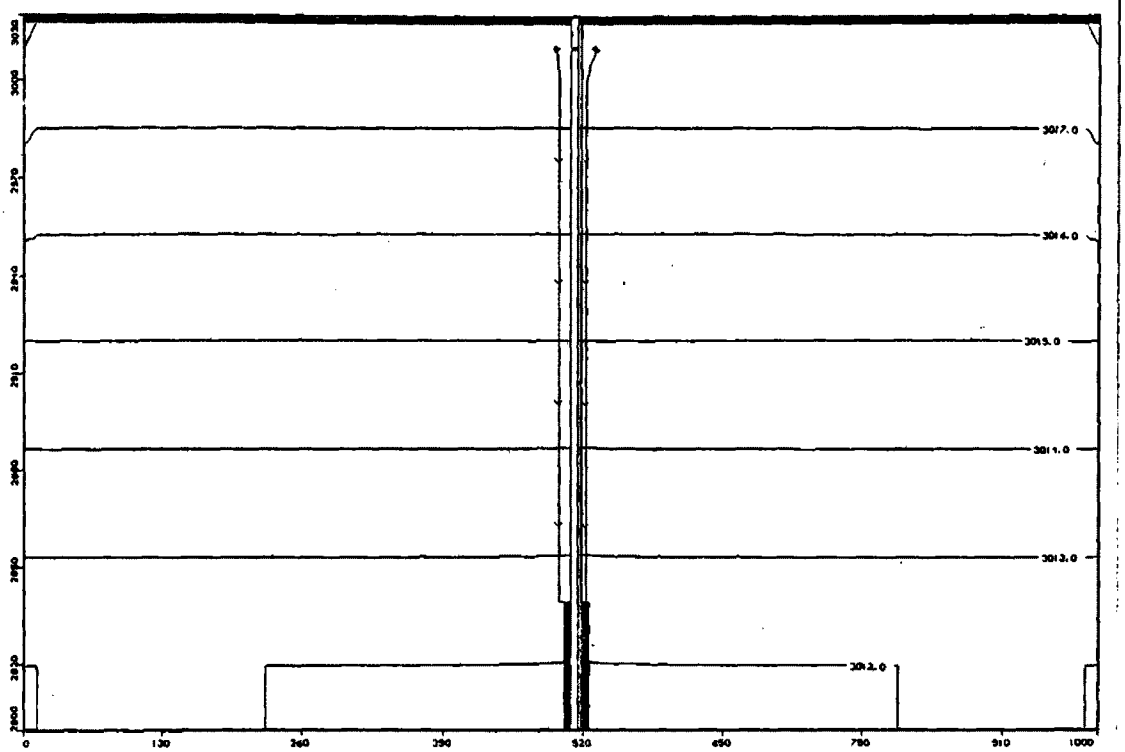
Appendix I

Numerical Simulation Results



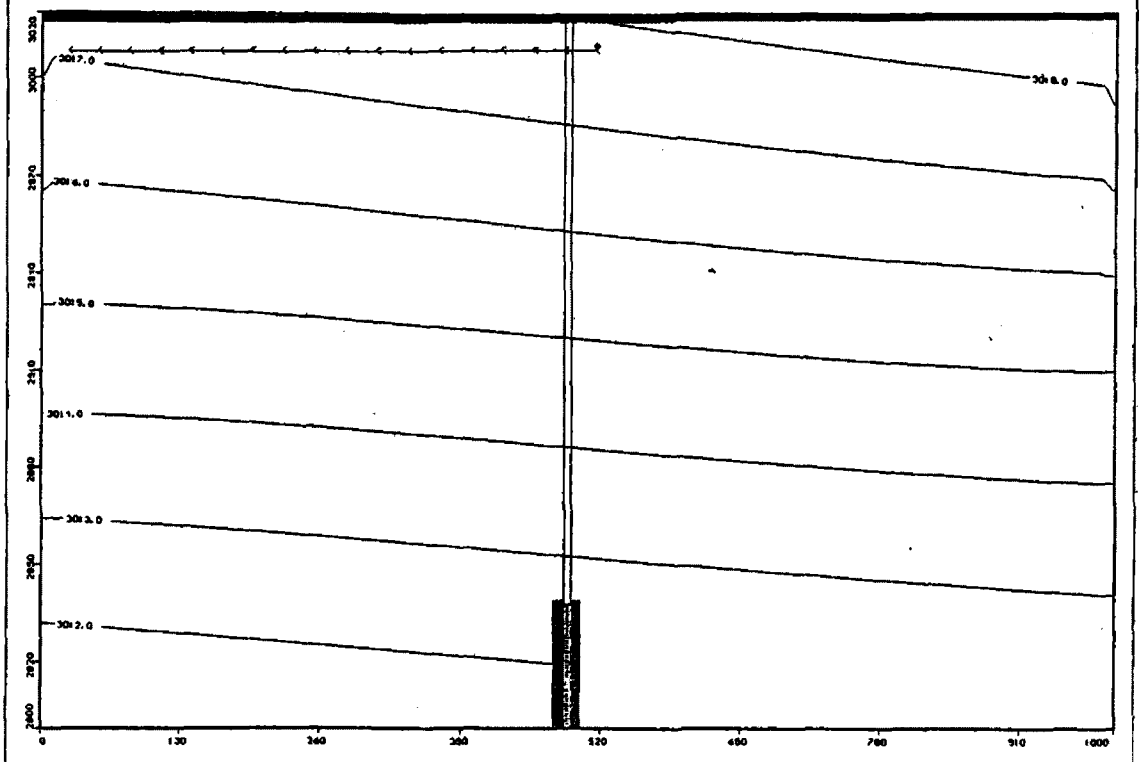
University of Montana - Missoula, MT
Project: vert gradient, no well
Description: No Pumping Well
Modeller: Arrows every 2000 days

Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Column: 20



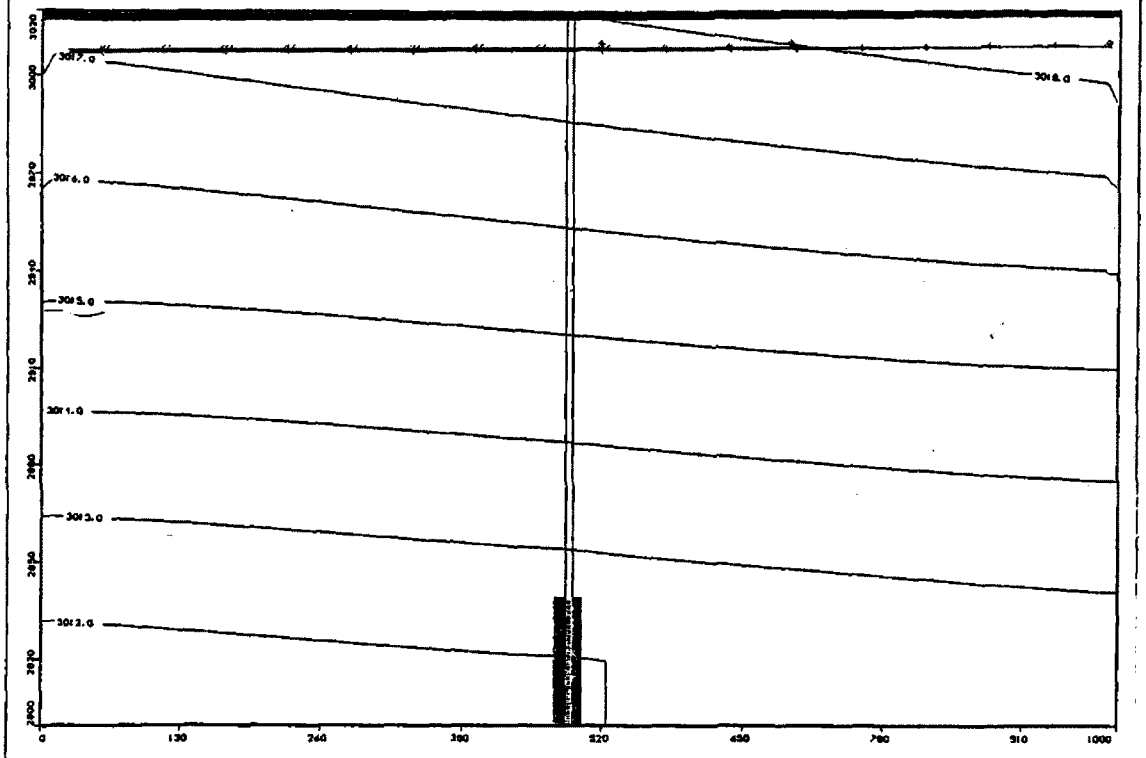
University of Montana - Missoula, MT
Project: vert gradient
Description: Pumping Well = 10gpm
Modeller: Arrows every 2000 days

Visual MODFLOW v.2.60. (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Column: 20

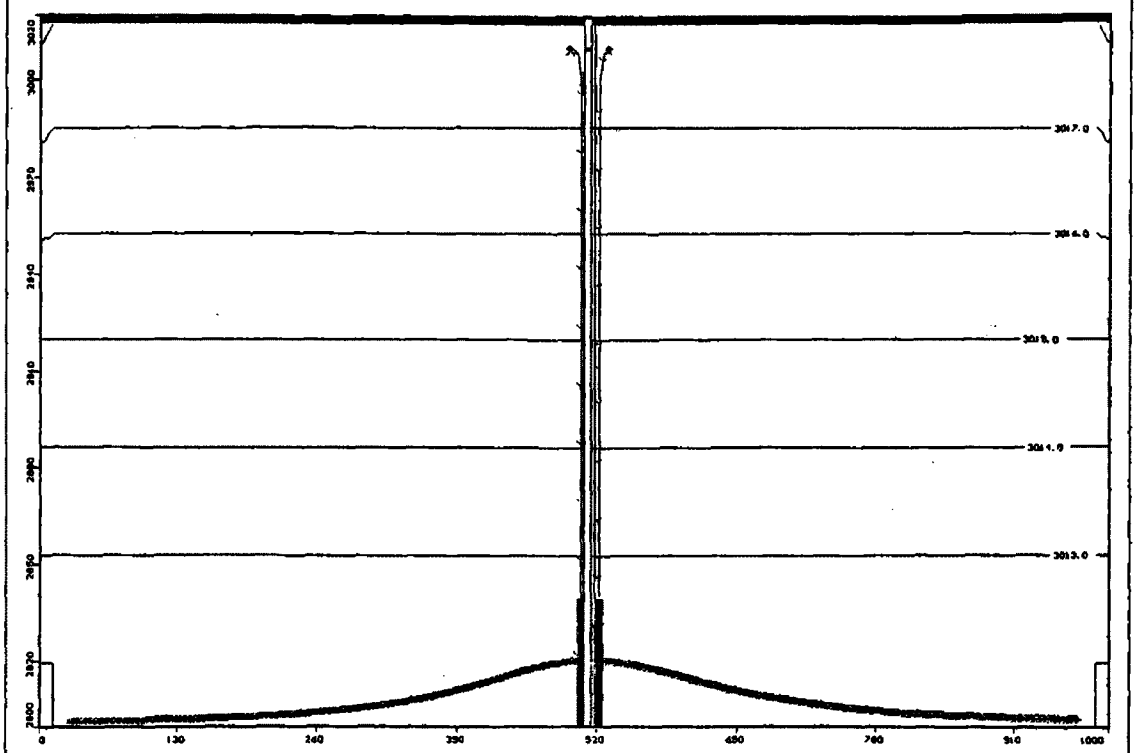


University of Montana – Missoula, MT
Project: vert gradient, Horiz.grad
Description: No Well, L2 Kz=.1
Modeller: Arrows every 5 days

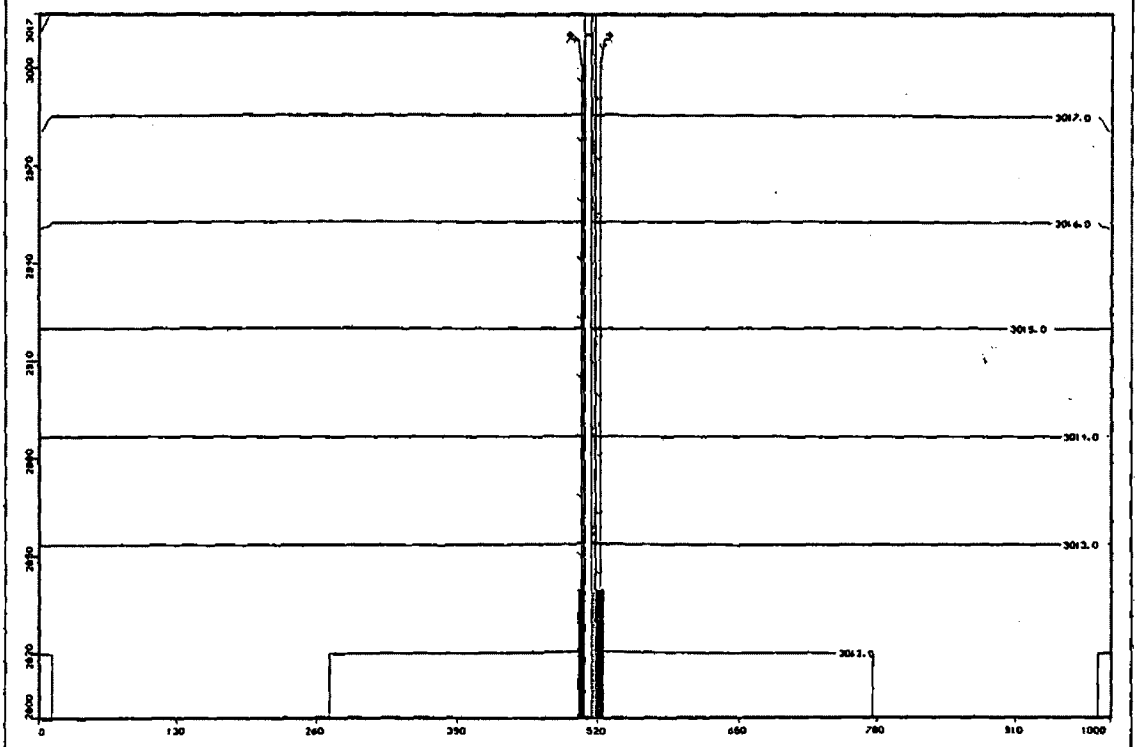
Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20



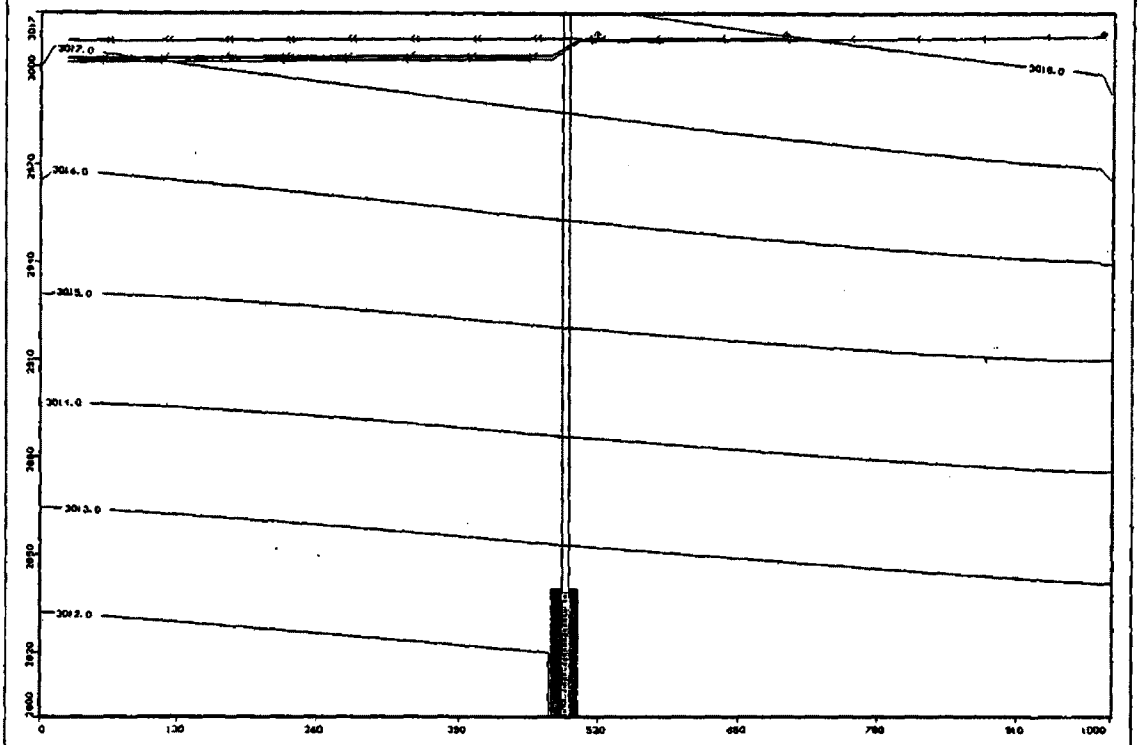
University of Montana - Missoula, MT Project: vert gradient, Horiz.grad Description: Well, L2 Kz=.1 Modeller: Arrows every 10 days	Visual MODFLOW v.2.60. (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Row: 20



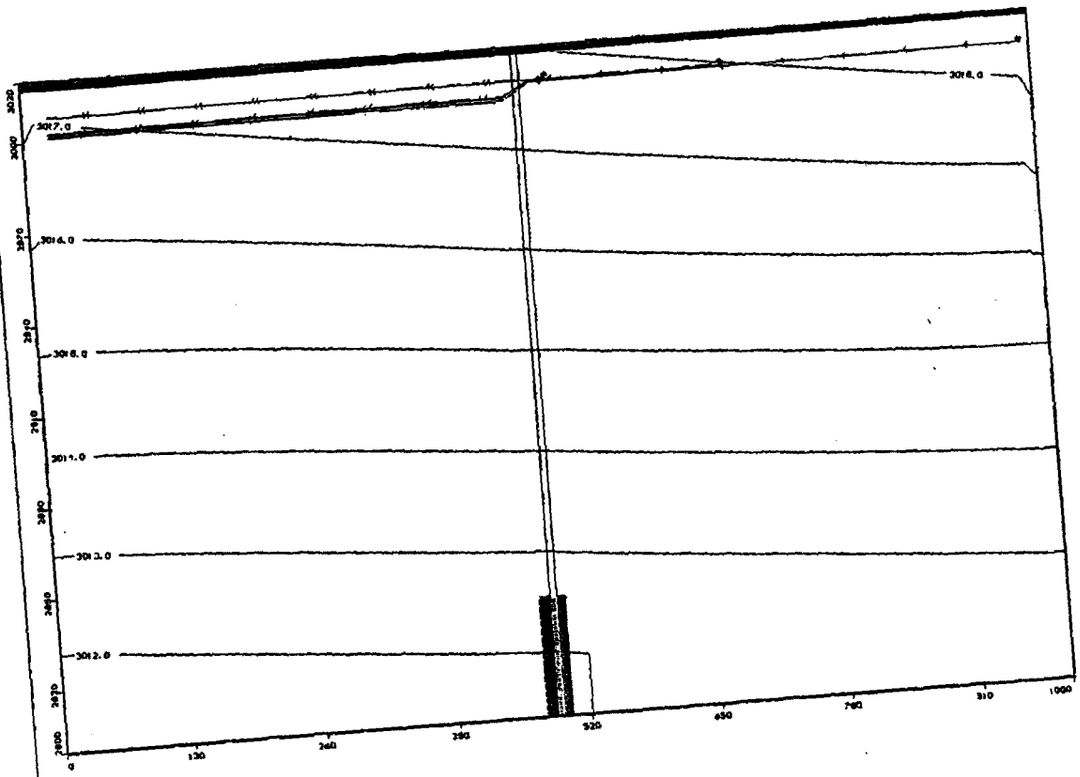
University of Montana – Missoula, MT Project: vert gradient, No Well Description: Leaky casing, L2 Kz=10 Modeller: Arrows every 10 days	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Column: 20



University of Montana – Missoula, MT Project: vert gradient, Well 10gpm Description: Leaky casing, l2 Kz=10 Modeller: Arrows every 10 days	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Column: 20

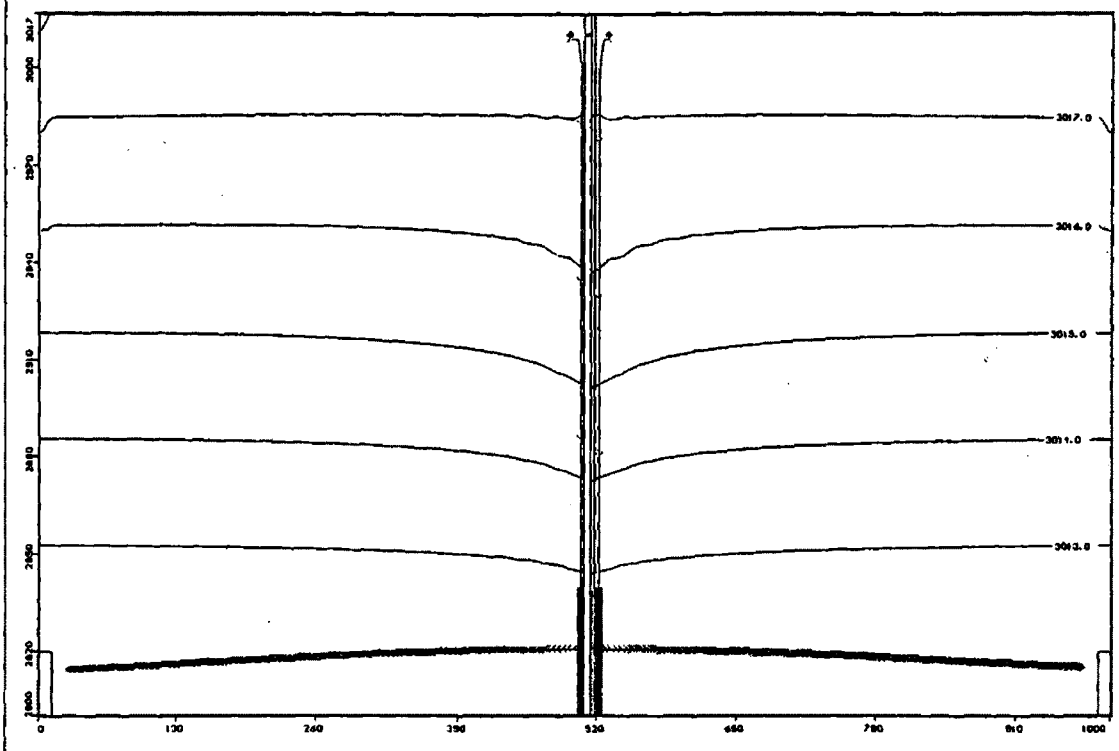


University of Montana - Missoula, MT Project: vert gradient, Horiz.grad Description: No Well, L2 Kz=10 Modeller: Arrows every 10 days	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Row: 20



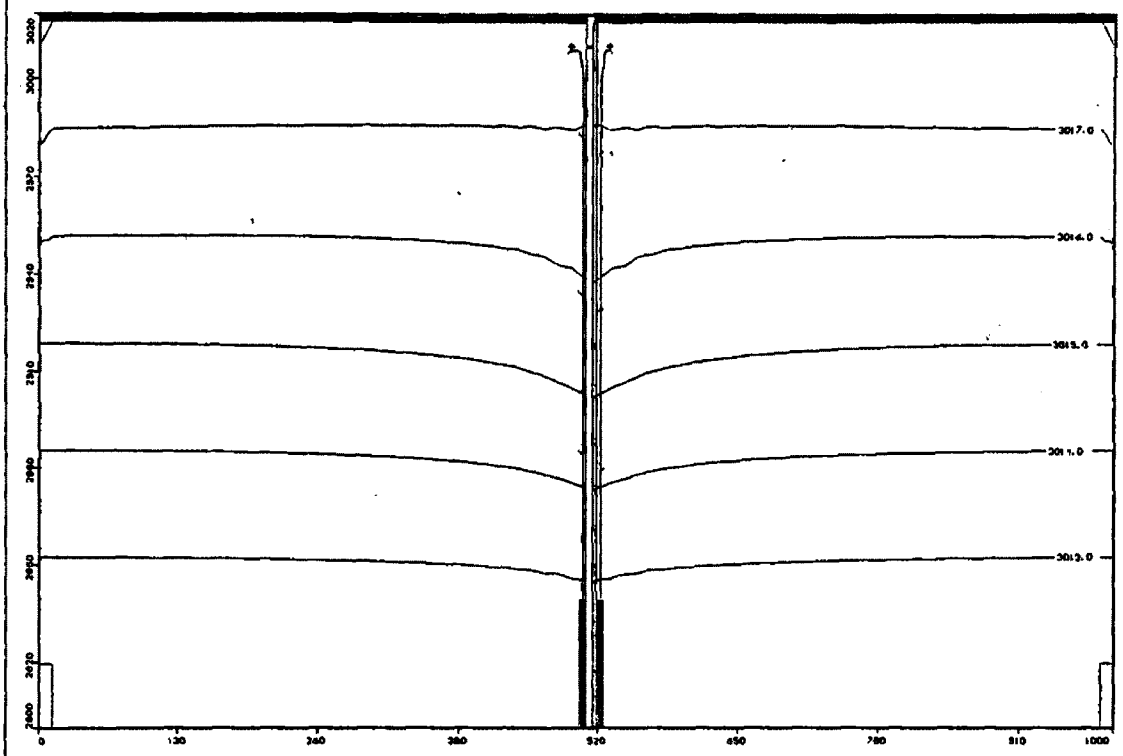
University of Montana - Missoula, MT
Project: vert gradient, Horiz.grad
Description: Well L2 Kz=10
Modeller: Arrows every 10 days

Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20

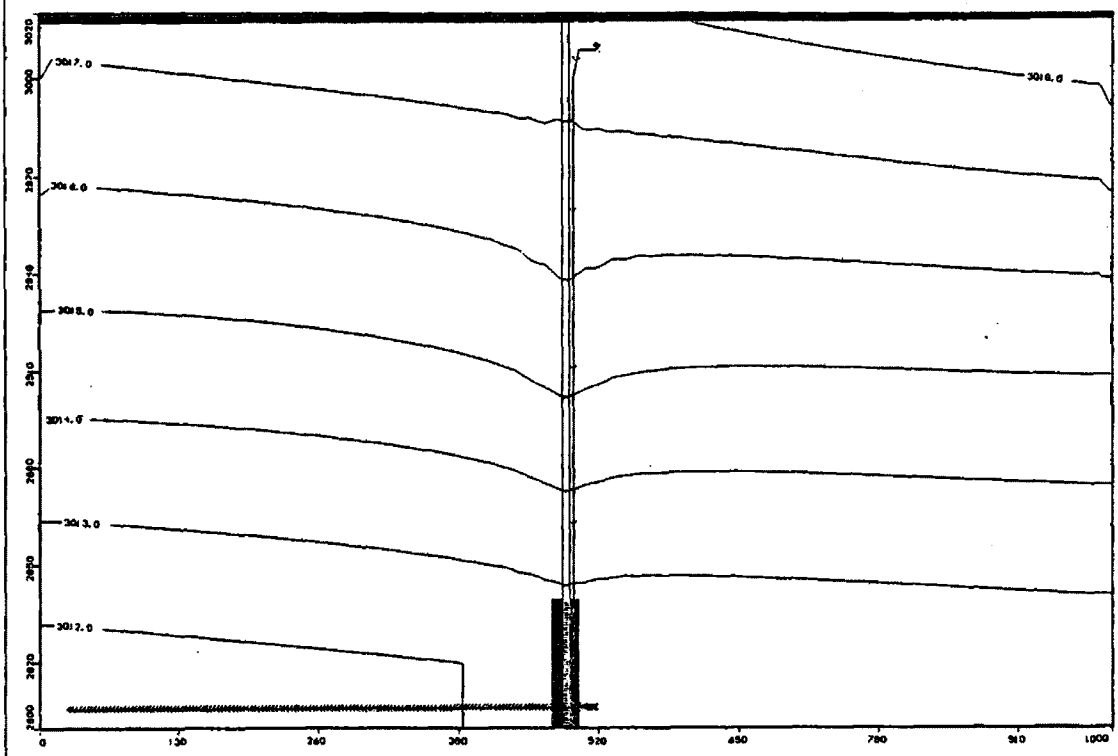


University of Montana – Missoula, MT
Project: vert gradient, No Well
Description: Leaky casing, L2 Kz=1000
Modeller: Arrows every 1 day

Visual MODFLOW v.2.60, (C) 1995–1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Column: 20

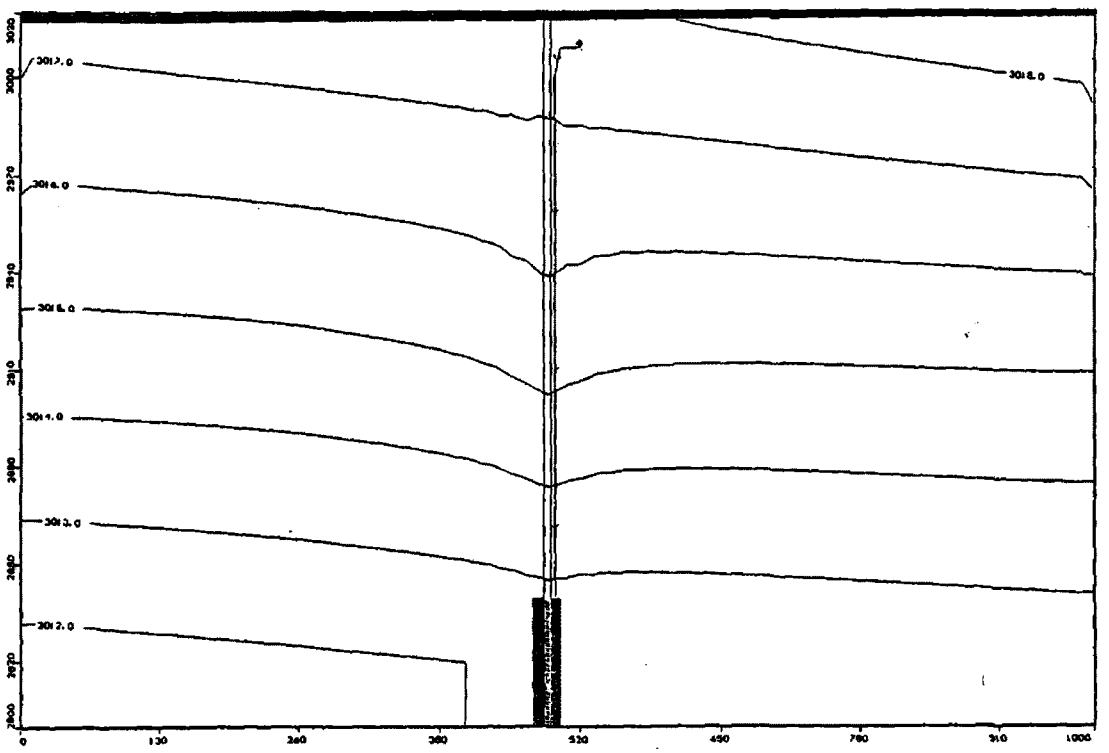


University of Montana - Missoula, MT Project: vert gradient,Well=10gpm Description: Leaky casing, L2 K2=1000 Modeller: Arrows every 1 day	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Column: 20

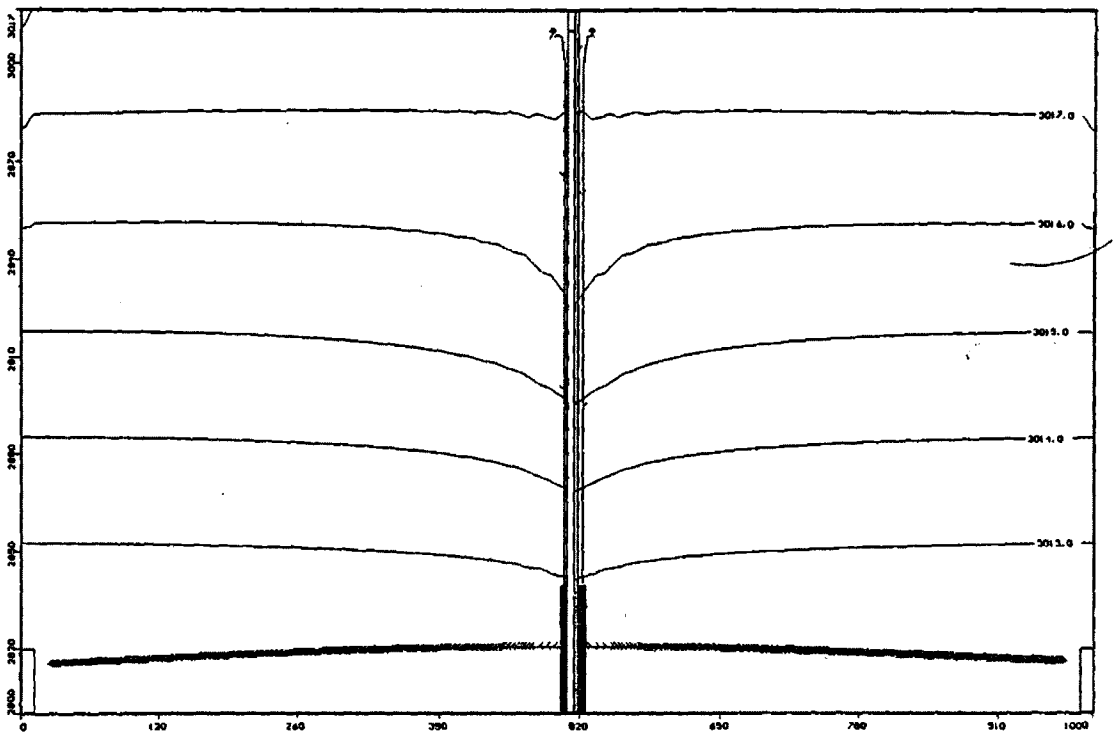


University of Montana - Missoula, MT
Project: vert gradient, Horiz.grad
Description: No Well, L2 Kz=1000
Modeller: Arrows every 1day

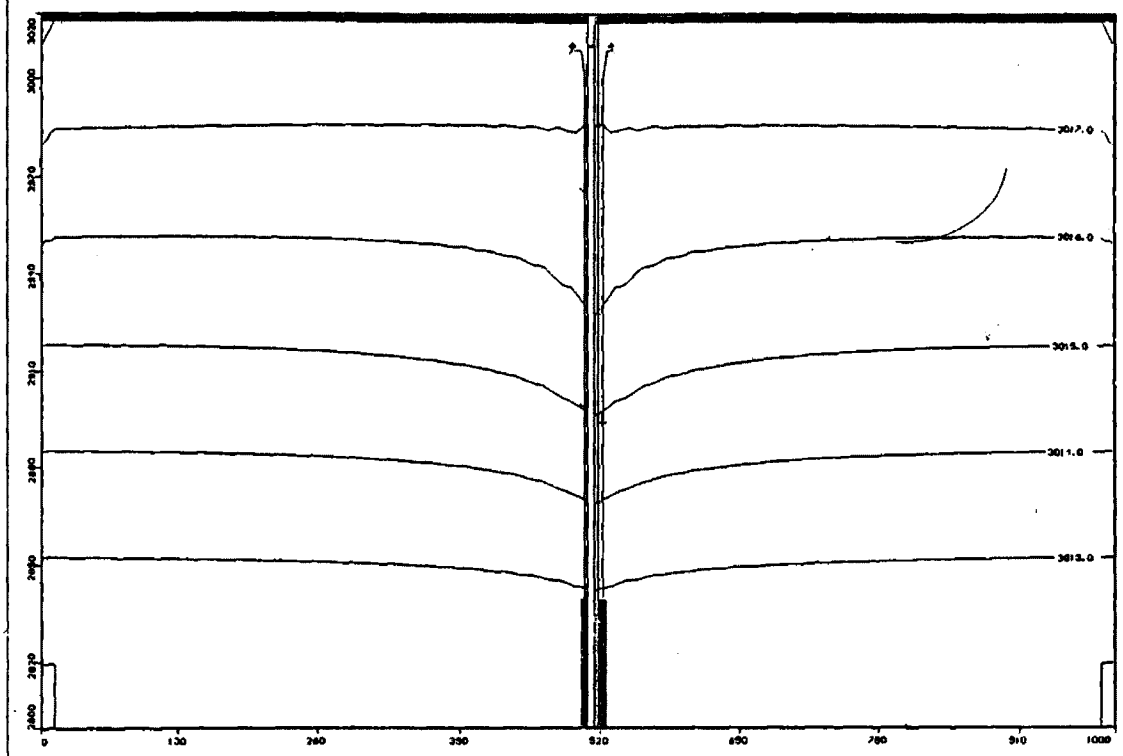
Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20



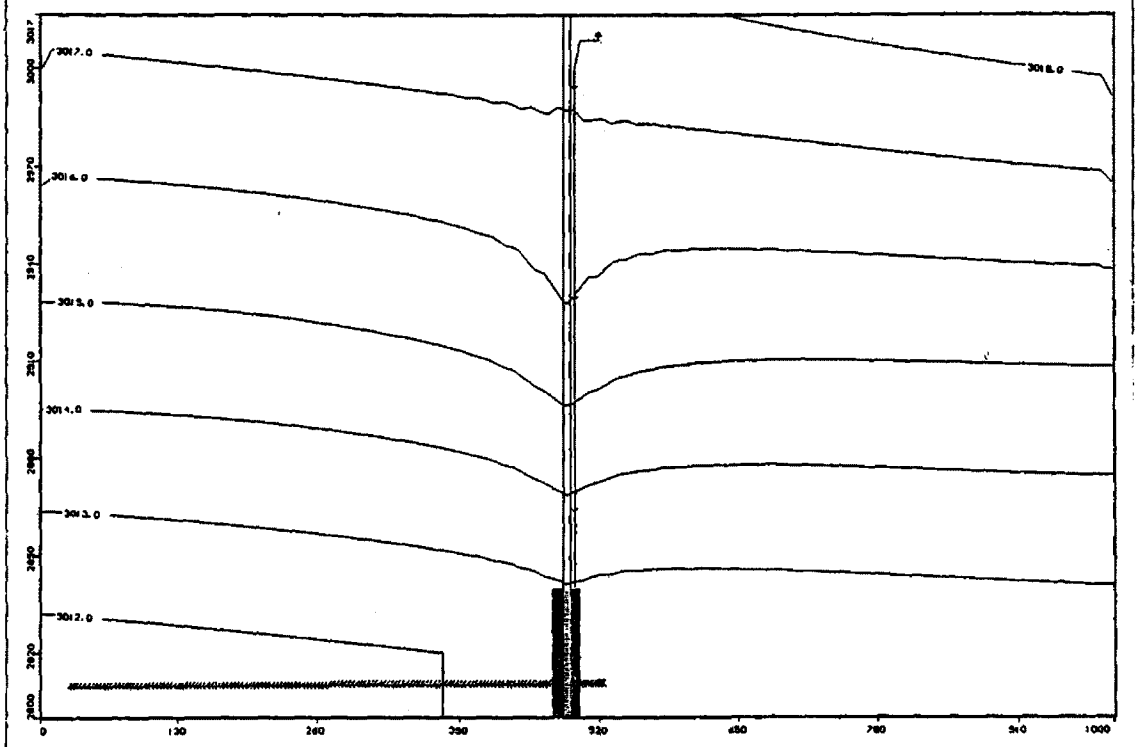
University of Montana - Missoula, MT Project: vert gradient, Horiz.grad Description: Well, L2 Kz=1000 Modeller: Arrows every 1day	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Row: 20



University of Montana - Missoula, MT Project: vert gradient. No Well Description: Leaky cas.,L2,Kz=1000000 Modeller: Arrows every 1 day	Visual MODFLOW v.2.60. (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Column: 20

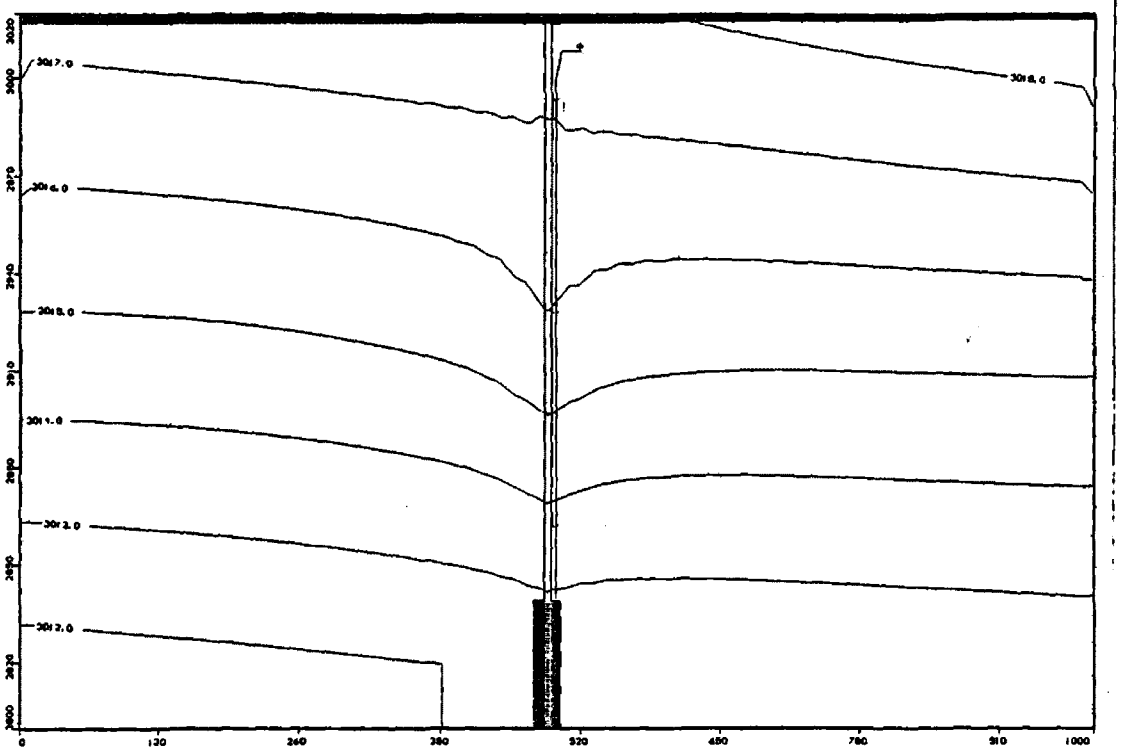


University of Montana – Missoula, MT Project: vert gradient, Well=10gpm Description: Leaky cas.,L2,Kz=1000000 Modeller: Arrows every 1 day	Visual MODFLOW v.2.60, (C) 1995–1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Column: 20

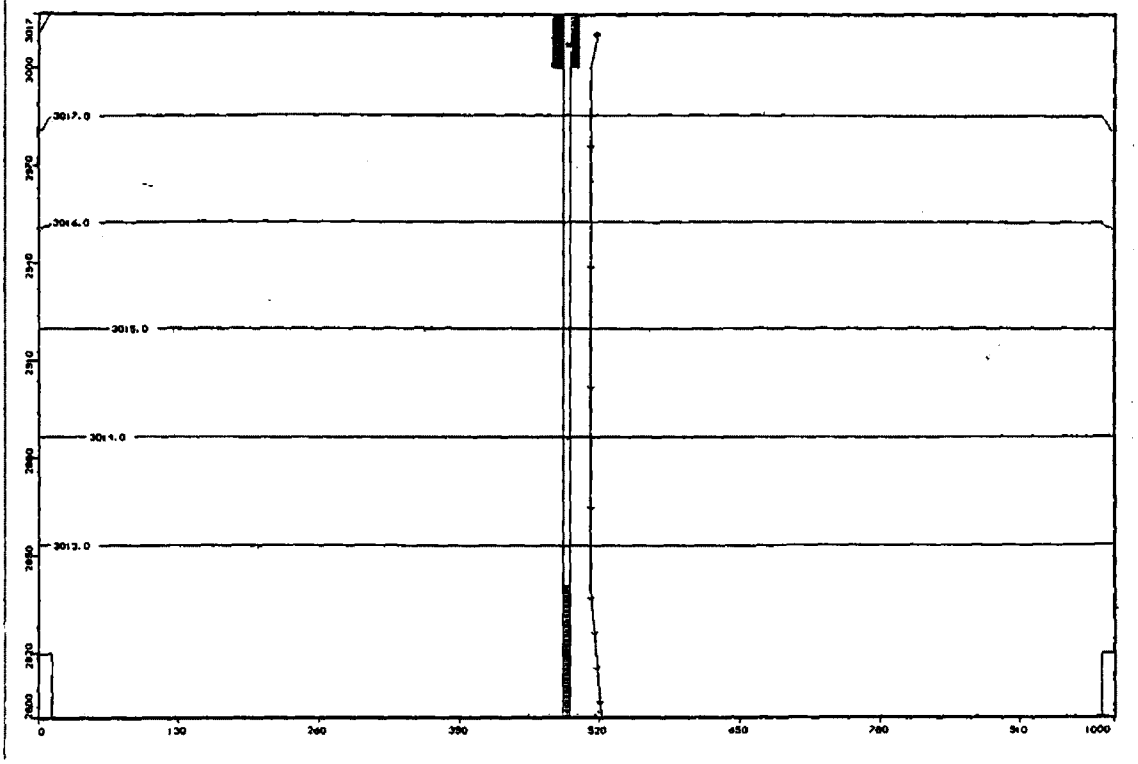


University of Montana – Missoula, MT
Project: vert gradient, Horiz.grad
Description: No Well, L2 Kz=1000000
Modeller: Arrows every 1day

Visual MODFLOW v.2.60, (C) 1995–1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20

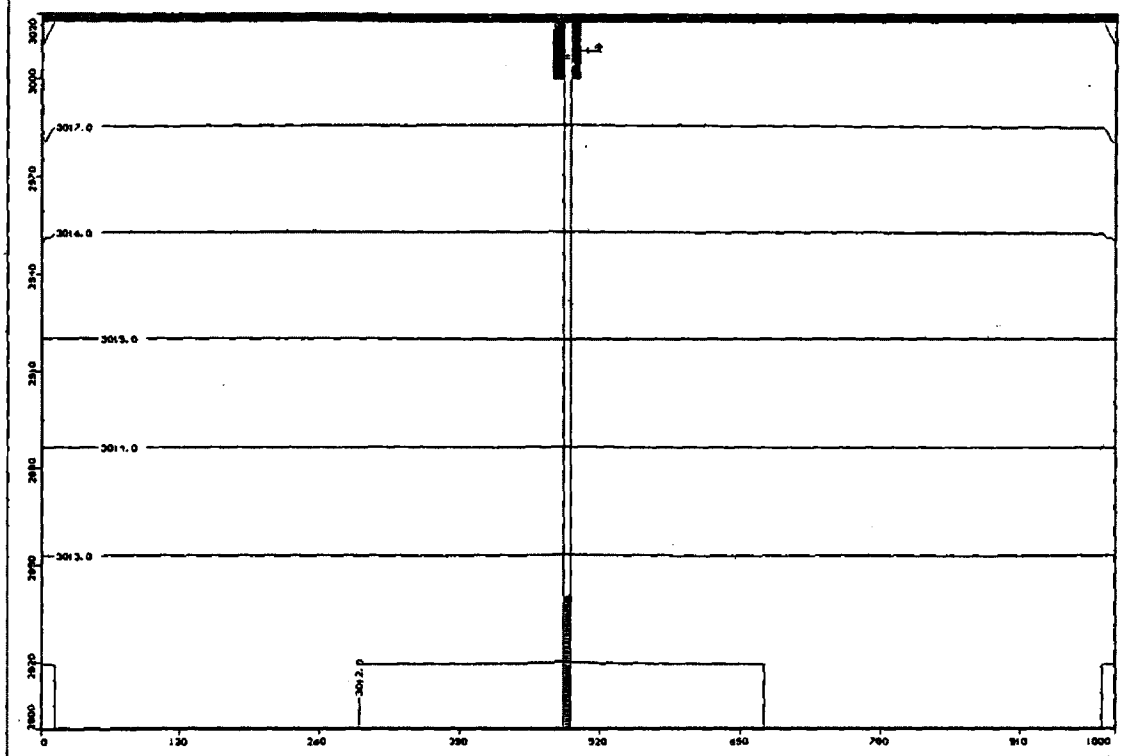


University of Montana - Missoula, MT Project: vert gradient, Horiz.grad Description: Well, L2 Kz=1000000 Modeller: Arrows every 1day	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Row: 20



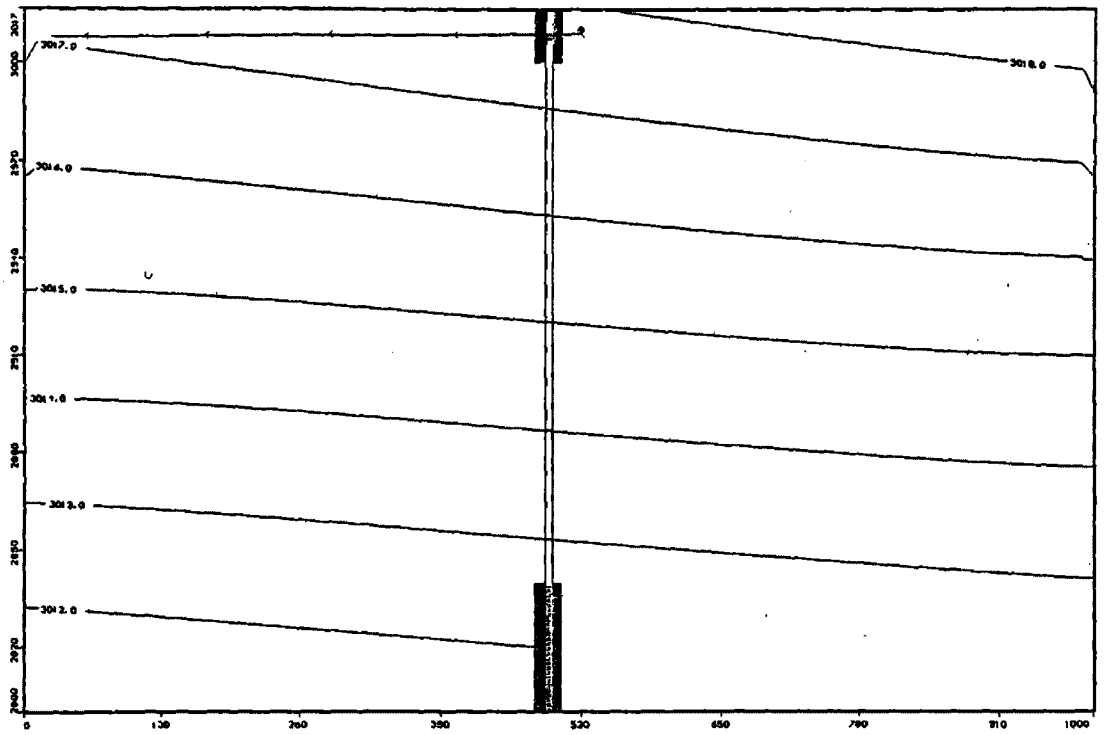
University of Montana - Missoula, MT
Project: vert gradient, No Well
Description: Leaky Pitless
Modeller: Arrows every 2000 day

Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20



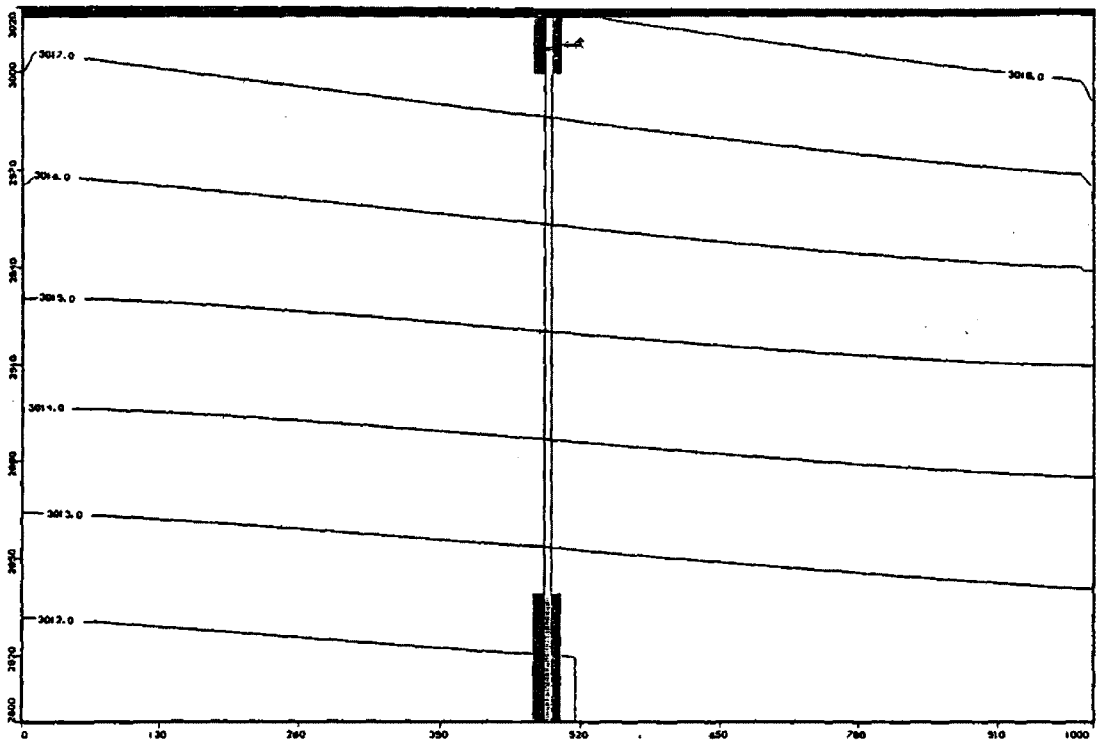
University of Montana - Missoula, MT
Project: vert gradient, Well
Description: Leaky Pitless
Modeller: Arrows every 10 days

Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20



University of Montana - Missoula, MT
Project: vert gradient, Horiz.grad
Description: No Well, Leaky P/A
Modeller: Arrows every 20 days

Visual MODFLOW v.2.60, (C) 1995-1997
Waterloo Hydrogeologic Software
NC: 40 NR: 40 NL: 3
Current Row: 20



University of Montana - Missoula, MT Project: vert gradient, Horiz.grad Description: Well, Leaky P/A Modeller: Arrows every 1 day	Visual MODFLOW v.2.60, (C) 1995-1997 Waterloo Hydrogeologic Software NC: 40 NR: 40 NL: 3 Current Row: 20