INTERPRETATION OF GROUND WATER CHEMICAL QUALITY DATA

G.M. Zemansky
Compass Environmental, Inc., 3000 W. 19th Court, Lawrence, Kansas 66047-2300

ABSTRACT
Ground water is sampled to assess its quality for a variety of purposes. Whatever the purpose, it can only be achieved if results are representative of actual site conditions and are interpreted in the context of those conditions.

Substantial costs are incurred to obtain and analyze samples. Field costs for drilling, installing, and sampling monitoring wells and laboratory costs for analyzing samples are not trivial. The utility of such expenditures can be jeopardized by the manner in which reported results are interpreted as well as by problems in how samples were obtained and analyzed. Considerable attention has been given to standardizing procedures for sampling and analyzing ground water. Although following such standard procedures is important and provides a necessary foundation for understanding results, it neither guarantees that reported results will be representative nor necessarily have any real relationship to actual site conditions. Comprehensive data analysis and evaluation by a knowledgeable professional should be the final quality assurance step, it may indeed help to find errors in field or laboratory work that went otherwise unnoticed, and provides the best chance for real understanding of the meaning of reported results.

The focus of this paper is on the interpretative part of the process. Although formal interpretation necessarily comes late in a project, when data have been generated and the report is being written, it will be most useful if relevant elements can be integrated into the project from the beginning. When this is done, it increases the likelihood of achieving project objectives as well as understanding the data. To facilitate interpretation, the following steps should be included:

1. Collection, analysis, and evaluation of background data on regional and site-specific geology, hydrology, and potential anthropogenic factors that could influence ground water quality and collection of background information on the environmental chemistry of the analytes of concern.
2. Planning and carrying out of field activities using accepted standard procedures capable of producing data of known quality.
3. Selection of a laboratory to analyze ground water samples based on careful evaluation of laboratory qualifications.
4. The use of appropriate quality control/quality assurance (QC/QA) checks of field and laboratory work (including field blank, duplicate, and performance evaluation samples).
5. Comprehensive interpretation of reported analytical data by a knowledgeable professional. The analytical data must be accompanied by appropriate QC/QA data, be cross-checked using standard water quality checks and relationships where possible, and be correlated with information on regional and site-specific geology and hydrology, environmental chemistry, and potential anthropogenic influences.

Application of this sequence *of* steps and their importance in interpretation of ground water quality data are discussed in this paper. The discussion includes several illustrative case examples.

INTRODUCTION

There area number of reasons we might want to know about groundwater chemical quality. For example, we might be interested in using an aquifer as a source of water today or we may want to ensure that current practices haven't caused contamination so that ambient ground water quality remains legally acceptable whether or not it is used in the future. At first glance, you'd think that obtaining and interpreting ground water quality data would be a fairly straight forward exercise. Simply follow the usual scientific approach: (1) take a sample; (2) analyze it; and (3) compare analytical results to a set of criteria. However, obtaining reliable data and properly interpreting them turns out to be more complicated than that; even in the relatively simple case of surface water. When it comes to ground water, everything seems more complex.

To begin with, obviously, with ground water you can't just go down to the stream and get a sample. Because ground water is underground, you need to do more preparation in advance of sampling. This involves obtaining background subsurface information and an access point. Such information will be helpful, both in planning how to obtain a sample as well as in interpreting analytical results when they become available. Whether you use a standard monitoring well, direct push technology, or something else, getting access to sample isn't always easy and can influence the quality of the sample obtained. There are also a number of potentially confounding factors with regard to the next step of the process, laboratory analysis. Sample quality can change between the time a sample is obtained and the time it is analyzed and, even if it doesn't, the overall reliability of laboratory results is not the sure thing many people assume it is. Finally, selection of appropriate criteria to compare data to may not always be straight-forward. Relevant criteria may either not exist or be incomplete.

Comprehensive data interpretation by a knowledgeable professional should be the final quality assurance step of any project involving ground water quality data. It may indeed help to find errors in field or laboratory work that went otherwise unnoticed and provides the best chance for real understanding of the meaning of reported results. Proper project planning should prepare for this final step by obtaining relevant information early on and including relevant data collection into field segments of the project. The following steps must be integrated into and carried out throughout the project to facilitate final interpretation:

1. Collection, analysis, and evaluation of background data on regional and site-specific geology, hydrology, and potential anthropogenic factors that could influence ground water quality and collection of background information on the environmental chemistry of the analytes of concern.
2. Planning and carrying out of field activities using accepted standard procedures capable of producing data of known quality.
3. Selection of a laboratory to analyze ground water samples based on careful evaluation of laboratory qualifications.
4. The use of appropriate QC/QA checks (including field blank, duplicate, and performance evaluation samples).
5. Comprehensive interpretation of reported analytical data by a knowledgeable professional.

The analytical data must be accompanied by appropriate QC/QA data, be cross-checked using standard water quality checks and relationships where possible, and be correlated with information on regional and site-specific geology and hydrology, environmental chemistry, and potential anthropogenic influences.

BACKGROUND INFORMATION

Background information serves several functions: (1) it facilitates obtaining access to sample groundwater; (2) it provides guidance regarding selection of appropriate sampling methods and analytical variables; (3) it places ground water quality data into context; and (4) it provides a quality assurance check. The following background information is necessary to fulfill these functions: (1) regional and site-specific geology; (2) regional and site-specific hydrology; (3) information on the environmental chemistry of variables of concern to the project; and (4) broad information on potential anthropogenic influences including site conditions and possible contaminant sources. The latter includes not only those conditions which may have impacted ground water, but those which could have influenced sample quality as a result of installation and testing of monitoring wells or otherwise during the sampling process. For example, shallow contamination can be carried down into a deeper aquifer during field work and airborne chemicals may cause trace contamination of ground water samples if they enter an open borehole, monitoring well, or sample being placed into a container.

FIELD PROCEDURES

Access Points

The nature of subsurface conditions will influence the type of access point that is possible. Sample quality will also be impacted by the type of access point selected. Commonly used ground water access points include: (1) monitoring wells; (2) wells or piezometers installed for other purposes; and (3) direct push technology.

The nature of the access point has, in particular, a relationship to the level of total suspended solids (TSS) likely to be present in samples. TSS levels would be expected to be relatively high in samples obtained using direct push technology and low in samples obtained from a water supply well. Assuming proper design and installation (including development), TSS levels in samples obtained from monitoring wells will normally be low except where fine-grained materials are screened. However, development is something that is often neglected or treated in a pro-forma manner when monitoring wells are installed. Additional development, as opposed to routine purging, may also be required when there are long periods between sampling events. This is illustrated in Table 1, showing results for inorganic variables in unfiltered samples from a well that was properly developed prior to initial sampling but was not redeveloped when sampled again after two years.

Sampling Methods

Available sampling methods are often constrained by the type of access point utilized. Since they will have a direct bearing on sample quality, the sampling methods used must be taken into account in planning sampling events and in interpretation of the data obtained. This category includes consideration of both field equipment and procedures. For example, regulatory agencies are more frequently requiring analysis of unfiltered samples. This may introduce substantial variation into the process, particularly for inorganic variables.

Sample Handling and Preservation

The order of sampling, type of container, and sample preservation method utilized can affect the quality of samples analyzed in the laboratory. As discussed further below, U.S. Environmental Protection Agency (USEPA) specified sample preservation methods and maximum allowed holding times do not always ensure sample quality will not change between the field and laboratory analysis.

Field Analysis/Observations

Reliable sample preservation methods do not exist for some water quality variables. In other cases, field measurements carried out for other purposes (i.e., well purging) are routinely available and preferable (e.g., to laboratory analysis for the same variable) or field observations can be made that provide useful information otherwise lost if not recorded at the time. USEPA requires field analysis (by specifying immediate analysis) for only five variables: (1) chlorine residual; (2) pH; (3) dissolved oxygen (by probe); (4) sulfite; and (5) temperature.

The validity of some USEPA maximum holding times and preservation combinations is questionable. For example, although USEPA recognizes that pH and dissolved oxygen levels may change substantially if not analyzed in the field and therefore requires immediate analysis without holding for them, substantial changes in alkalinity may occur for the same reasons but 14 days holding time is allowed for this variable. Because it is allowed and more convenient, samples are frequently analyzed in the laboratory for alkalinity instead of the field. Similarly, USEPA allows maximum holding times of 48 hours and seven days for color and total suspended solids (TSS), respectively. USEPA also allows seven and 14 days holding time for unacidified and acidified volatile aromatic compounds, respectively. Both color and TSS may change substantially in samples over these allowed time frames and research has shown both substantial loss of volatile aromatic compounds in less than seven days in unacidified samples and that substantially greater holding times than 14 days are appropriate for many compounds when samples are acidified.[1]

When sampling ground water, field analysis should routinely occur for the purge variables conductivity, pH, and temperature, using appropriate equipment operated, calibrated, and maintained in accordance with manufacturer recommendations. The following field observations related to sample quality may also be made: (1) color; (2) odor; and (3) turbidity. Although this information is essentially "free" for the taking, it is often not recorded. In particular, the latter observation can provide at least a qualitative indication *of* the presence of TSS and their possible effect on inorganic variables. The difference that filtering makes in reported concentrations of many inorganic variables when unfiltered samples contain high solids concentrations is substantial and readily demonstrated with split samples.

LABORATORY ANALYSIS

Too often, the analytical laboratory for a project is selected on the basis of cost only. Such cost savings may prove to have been very expensively purchased if quality isn't also delivered. Laboratory qualifications should be carefully researched in advance of selection. This can be done by such things as reviewing historic results on performance evaluation samples, auditing the facility, submitting performance evaluation samples, and checking references. Checks should continue throughout the project with the appropriate use of blank, duplicate, and performance evaluation samples.

Unfortunately, no laboratory is perfect. Even the better laboratories often get some wrong answers when analyzing USEPA performance evaluation samples. These are in a relatively clean matrix, without the kinds of interferences that can complicate real world samples, and are being analyzed under test conditions. A laboratory would be foolish not to make its best effort on these samples. You can expect somewhat lower quality with regard to samples being routinely analyzed for the average client. Routine QC/QA and data validation practices are not the complete answer to data quality. In particular, the latter usually don't include various data cross-checks or take into account what is known about site conditions. In the worst case, laboratory reported analytical results can be more artifacts of the sampling and analysis process than representative of ambient ground water quality.

There are a number of factors which can influence laboratory results. But even when analytical laboratories are performing well, it should be recognized that: (1) at best, they can only analyze samples in the condition received; and (2) standard limits of precision and accuracy allow considerable variation. As noted above, a number of factors may result in samples reaching the laboratory which are less than representative of site conditions. Even when laboratory QC/QA requirements are met, the level of allowed variation limits the conclusions which can be based on laboratory data. USEPA Superfund acceptance criteria for percent recovery of matrix spikes (MS) and laboratory control standards (LCS) are shown in Table 2.[2,3]

Data reported by laboratories should be carefully reviewed or "validated" before being utilized. USEPA national functional guidelines for data review under Superfund are an example of typical validation guidelines. These specify a number of checks intended to assure that correct procedures were followed (e.g., holding times, calibration, blanks, matrix spikes and spike duplicates, and laboratory control standards). Although this type of review is useful, it is important to realize its limitations. The standard conclusion one consulting company uses after a successful validation process contains the statement that "the data collected during this investigation are valid as qualified for use in representing Site conditions and for use in risk assessments."[4] Since the validation process referred to doesn't take relevant site information or available data cross-checks into account, such a statement goes too far. Neither is it necessarily correct.

CASE EXAMPLES OF INTERPRETING GROUND WATER DATA
Organic Contamination at a Superfund Site
Trichloroethylene (TCE) groundwater contamination was recognized at a Superfund site. The presence of other halocarbons associated with TCE degradation, notably cis-1,2-dichloroethylene (c-1,2-DCE) and vinyl chloride, was also recognized. However, the potentially responsible party (PRP) claimed the TCE originated elsewhere and was part of a wider regional problem involving a number of sources and contaminants. Site work performed by the PRP in 1996 identified a variety of other compounds in samples from relatively deep wells drilled using air rotary equipment. The compounds reported in various samples fell within the following categories:

1. Volatile organic compounds (VOCs) -
   a. Halocarbons including TCE and TCE degradation products.
   b. Petroleum hydrocarbons, including aromatic compounds (e.g., xylenes).
   c. Trihalomethanes, particularly chloroform and bromodichloromethane.

2. Semivolatile organic compounds (SVOCs) -
   a. Petroleum hydrocarbons (benzoic acid and naphthalene).
   b. Phenol and other phenolic compounds.
   c. Phthalates, particularly bis(2-ethylhexyl)phthalate.

Review of these data indicated that other interpretations were much more likely. Among the reasons the data were suspect were the following:

1. With the exception of halocarbons, most of the compounds involved had not been reported in samples from shallow wells previously drilled using hollow-stem augers. Contamination in such cases generally moves from surface or near-surface sources downward. Furthermore, the concentrations involved were generally low and appeared to be randomly distribution rather than in a pattern suggesting any relationship to possible sources.

2. Air rotary drilling is a possible source of petroleum hydrocarbon and phenolic compound contamination.

3. Some of the boreholes had been left open to the atmosphere for substantial periods of time (i.e., on the order of months) after drilling before monitoring wells were installed in them. The ones open the longest were also adjacent to an Interstate Highway. Petroleum hydrocarbons have been identified in vehicle emissions and ambient urban air.[5] Research has also indicated the potential for petroleum hydrocarbons and phenolic compounds in urban air to be transported into ground water.[6,7]

4. PRP consultants had not decontaminated at least some downhole equipment (particularly water level indicators) when used between boreholes or between monitoring wells. This may cause cross-contamination.

5. THM contamination is common in chlorinated tap water from surface sources, but unusual in ambient ground water. Thousands of gallons of chlorinated tap water from a surface source known to contain substantial concentrations of trihalomethane compounds had been introduced into most of the boreholes as a part of the testing program during field work.

6. Phthalates are recognized by USEPA as a common SVOC laboratory contaminant.[8]

7. Background regional information strongly indicated the PRP was the source of halocarbon contamination and that there was no other more widespread regional problem involving halocarbons or other compounds.

Resampling in 1997 provided further confirmation of this interpretation. Data for the 19 wells sampled in both years are shown in Table 3 (parts a and b). With the exception of a reduced number of low concentration hits for phthalate compounds (which are recognized as common laboratory contaminants) and, in one case, a trihalomethane compound, only halocarbons were reported in 1997. This indicates that the various other compounds reported in 1996 samples were a transitory impact of drilling, testing, sampling, and analysis rather than regional ground water contamination. This transitory impact dissipated over time as a result of natural mechanisms such as flushing by ambient ground water flow and biodegradation. The change in apparent distribution of halocarbon contamination between 1996 and 1997 apparent from these results may also indicate that shallower contamination was carried downward by intrusive work performed in 1996 and that this also produced a transitory impact on ground water samples.

Ground/Surface Water Relationship at a RCRA Site
Ground water monitoring at landfills and other Resource Conservation and Recovery Act (RCRA) facilities is oriented towards ensuring that a release of contaminants, if it occurs, will be detected. In general, detection monitoring requires that data from wells downgradient of the facility and subject to impact in event of a release be statistically compared to data from upgradient background wells. If the comparison results in a statistically significant difference with a downgradient increase, a release is assumed. However, other regional conditions must be considered if such comparisons are to be useful.

In this case, there is a network of monitoring wells installed up and downgradient of a land treatment unit (LTU) located at a refinery adjacent to a major river. Statistical analysis showed that concentrations of some variables were elevated in downgradient wells and that the elevations were statistically significant. Did this mean that a release had occurred?

A linkage between the river and the adjacent alluvial ground water aquifer would be expected based on general principles. This was confirmed by analysis of two lines of evidence: (1) correlation of ground water elevations with river flow (a surrogate for stage); and (2) statistical analysis of water quality data. Time series plots of ground water elevations versus river flow showed an evident visual correlation, which was confirmed by linear regression analysis. The correlation was best for those wells closest to the river (correlation coefficient of 0.80) and decreased with distance from the river. A comparison of water quality data is supportive. Data indicating central tendency for upgradient monitoring wells and the river are presented for six variables in Table 4. For the three major ions in Table 4, including chloride, river concentrations far exceed those in upgradient ground water. In these cases, statistical analysis shows that concentrations in samples from downgradient monitoring wells are significantly higher than upgradient ground water. The reverse is true for the three elements listed. Their concentrations are higher in upgradient ground water than the river and statistical analysis shows that their levels in downgradient monitoring wells are significantly lower than upgradient.

Inorganic Water Quality at a Superfund Site
Consultants for a PRP at a Superfund site involving a limestone aquifer in the midwest US developed several theories regarding the nature of the aquifer involved based on their interpretation of data for inorganic constituents. Data for alkalinity, aluminum, calcium, iron, silica, sodium, and sulfate were prominent in their interpretation. However, these consultants did not consider relevant site-specific information and admitted they were unaware of the degree of variation that can occur in laboratory analysis of ground water samples that meet acceptance criteria (see Table 2).

A potentially important piece of site-specific information not considered by the PRP's consultants was that most of the borings involved had been drilled considerably deeper than the wells later installed in them. For the wells being installed in such deeper borings, boreholes were first partially filled by pouring in sodium bentonite chips. This occurred for about two-thirds of the relatively deep wells drilled. On the average, approximately one-third of the borehole was filled (i.e., 71 of 221 feet). This process undoubtedly resulted in the introduction of chemicals from the hydrating chips into the water (both as dissolved and suspended solids) as they fell through the water column. Of the analytes relevant to this site, sodium bentonite chips are typically composed of silica and oxides of aluminum, iron, calcium, sodium, magnesium, and potassium (in order of concentration). They also contain a small level of water soluble nitrate. Given the chemistry of silica and calcium and the likelihood that calcium in a limestone aquifer would be expected to already be near saturation, concentrations of these variables would probably not be greatly affected by this. However, concentrations of aluminum, iron, sodium, magnesium, and potassium could be and this appears to have been the case. The potential for this was increased by the fact that, although consultants for the PRP purged three well volumes immediately prior to sampling, they did not develop the monitoring wells after installation.

To evaluate the effect of filling boreholes with bentonite on inorganic ground water quality, monitoring wells sampled both during 1996 (shortly after installation) and 1997 (nearly a year since last sampled) were divided into two groups: (1) bentonite filled (BF); and (2) unfilled (UF). Median data for major cations, major anions, and several other variables grouped into these two categories for both 1996 and 1997 sampling events are presented in Table 5. The 1996 data clearly indicate impact from bentonite filling for most of the variables listed except calcium and silica, BF:UF ratios for sodium, aluminum, and iron indicate nearly an order of magnitude or greater level of enrichment for those variables as a result of bentonite filling. This is also evident in the STIFF diagrams of median grouped data in Figure 1. The STIFF diagram for unfilled wells (Figure 1a) is typical of what would be expected for a limestone aquifer.[9] There are several relatively minor differences between the STIFF diagram for bentonite filled wells (Figure 1b) and unfilled wells (Figure la), but by far the most notable difference is the sodium "bulge" to the lower left of the diagram. The impact of the bentonite appears to have been transitory. With the possible exception of nitrate, the enrichment appears to have been flushed away due to ambient ground water flow by the time wells were resampled nearly a year later. STIFF diagrams for both sets of wells (UF and BF) when resampled in 1997 were similar to each other and the one for unfilled wells in 1996 (Figure 1a).

The PRP's consultants pointed to two aspects of the data to support their interpretation that the aquifer involved was an "open" system (i.e., rapidly recharged from the surface throughout the aquifer): (1) abnormally high concentrations of aluminum and iron in samples from some relatively deep wells (exceeding solubility limits); and (2) lack of any apparent ground water evolution (change in quality along a flow line) between wells at higher elevations and those at lower elevations (a distance of roughly one mile). As discussed above and shown in Table 5, aluminum and iron enrichment appears to have been related to filling boreboles with sodium bentonite chips. Not knowing about this circumstance and since the overlying clay soils involved would be normally expected to be rich in silica as well as aluminum and iron, the consultants interpreting inorganic water quality data for the PRP felt compelled to provide another explanation why silica concentrations were not also enriched when aluminum and iron were. Their explanation was an assertion, without any data, that the soils were lateritic. Lateritic soils develop in hot, wet tropical climates subject to heavy rainfall when the intense chemical weathering that occurs under those conditions removes both soluble materials and much of the silica. Lateritic soils are not characteristic of the temperate climate midwest US.[10] A much more likely explanation for the relative magnitudes of aluminum, iron, and silica has to do with the manner in which samples were taken, preserved, and prepared for analysis. Samples to be analyzed for aluminum and iron are acidified in the field and digested in the laboratory. Since the samples involved were unfiltered, this meant that some particulate aluminum and iron would be included in the measurement. In contrast, samples to be analyzed for silica are not acidified in the field, but are filtered prior to analysis.

With respect to ground water "evolution," this phenomena has generally been documented on a regional rather than a site scale. This may be in part because very substantial "evolution" must occur to be detectable against a background of variation sampling and analysis introduced variation as well as environmental variation. For an extreme example, using the acceptance criteria of 75 to 125 percent recovery for matrix spike samples (see Table 2), a sample having a true value of 100 mg/L of calcium could be reported to have either 75 or 125 mg/L. Although the higher of these two numbers is 67 percent greater than the low number, either one would be within acceptance criteria. With enough sampling events and statistical analysis of data, it might be possible to detect an "evolutionary" change within acceptance criteria boundaries (e.g., a change from 50 to 65 mg/L along the flow path); however, the possibility of seeing this change with a single set of samples appears slim when so much variation is acceptable.

SUMMARY AND CONCLUSIONS

Comprehensive data interpretation by a knowledgeable professional should be the final quality assurance step of any project involving ground water quality data. It may indeed help to find errors in field or laboratory work that went otherwise unnoticed and provides the best chance for real understanding of the meaning of reported results. Proper project planning should prepare for this final step by obtaining relevant information early on and including relevant data collection into field segments of the project. The following steps must be integrated into and carried out throughout the project to facilitate final interpretation:

1 . Collection, analysis, and evaluation of background data on regional and site-specific geology, hydrology, and potential anthropogenic factors that could influence ground water quality and collection of background information on the environmental chemistry of the analytes of concern.
2. Planning and carrying out of field activities using accepted standard procedures capable of producing data of known quality.
3. Selection of a laboratory to analyze ground water samples based on careful evaluation of laboratory qualifications.
4. The use of appropriate QC/QA checks (including field blank, duplicate, and performance evaluation samples).
5. Comprehensive interpretation of reported analytical data by a knowledgeable professional.

The analytical data must be accompanied by appropriate QC/QA data, be cross-checked using standard water quality checks and relationships where possible, and be correlated with information on regional and site-specific geology and hydrology, environmental chemistry, and potential anthropogenic influences.

References Cited
1. USEPA holding times cited in this paragraph are from Table II of Part 136, Title 40, U.S. Code of Federal Regulations (40 CFR 136).
2. Office of Emergency and Remedial Response. 1994. USEPA contract laboratory program national functional guidelines for inorganic data review. Publication No. EPA 540/R-94/013, USEPA, Washington, DC, pp. 21-24 and 27-29.
3. USEPA Superfund contract laboratory program (CLP) statement of work (SOW) Form III VOA-1 and Form III SV-1.
4. Burns & McDonnell Waste Consultants, Inc. 1996. Quality control evaluation report 96-072-4 dated September. Kansas City, MO, p. 10-1.
5. Schleyer, R. 1991. Influence of the deposition of anthropogenic organic substances from the atmosphere on ground-water quality. IN: *Ground Water: Proceedings of the International Symposium,* G.P, Lennon, ed., American Society of Civil Engineers, pp. 293-298.
6. Harley, R.A., et al. 1992. Respeciation of organic gas emissions and the detection of excess unburned gasoline in the atmosphere. *ES&T*, Vol. 26, No. 12, pp. 2395-2408.
7. Pankow, J.F., et al. 1997. The urban atmosphere as a non-point source for the transport of MTBE and other volatile organic compounds (VOCs) to shallow groundwater. *ES&T*, Vol. 31, No. 10, pp. 2821-2828.
8. Office of Emergency and Remedial Response. 1994. USEPA contract laboratory program national functional guidelines for organic data review. Publication No. EPA 540/R-94/012, USEPA, Washington, DC, pp. 62-65.
9. Hounslow, A.W. 1995. Water Quality Data: Analysis and Interpretation, CRC Lewis Publishers, Boca Raton, FL, pp. 86-87.
10. Tarbuck, E.J. and F.K. Lutgens. 1992. *The Earth: An Introduction to Physical Geology*, 4th Ed., Macmillan Publishing Co., New York, pp. 130-131.

Table 1. Effect of Monitoring Well Development[1]

Variable	Spring 1994[2]	Summer 1996[3]
Calcium	92.	104.
Chloride	43.	58.3
Iron	0.08	5.53
Magnesium	2.4	2.84
Manganese	0.069	0.13
Potassium	ND	533
Sodium	5.8	6.38
Appearance	Clear	Turbid

1. Concentrations in mg/L. ND means non-detect at 1 mg/L.
2. New well developed and purged prior to sampling.
3. Well unused for two years. Three well volumes purged prior to sampling.

Table 2. USEPA Superfund Acceptance Criteria

Variable (USEPA Method)[1]	MS[2]	LCS[2]
Elements (6010)	75-125	80-120
VOCs (8240):		
Benzene	76-127	-
Trichloroethylene	71-120	-
SVOCs (8270):		
Pyrene	26-127	-
Phenol	12-110	-

1. Identification of variable and USEPA analytical method with example volatile and semivolatile organic compounds (VOCs and SVOCs, respectively).
2. Matrix spike (MS) and laboratory control sample (LCS) acceptance criteria in percent recovery. Inorganic criteria from USEPA national functional quidelines. Organic criteria from CLP SOW Forms III VOC-1 and SV-1.

Table 3a. Reported Organic Compounds

	Highest Concentrations[1]	
Category	1996	1997
VOCS:		
Halocarbon	236.	172.
Petroleum Hydrocarbon	29.6	ND
Trihalomethane	26.3	5.08
SVOCS:		
Petroleum Hydrocarbon	44.	ND
Phenolic	175.	ND
Phthalate	72.3	43.2

1. Highest reported concentration of any compound in category out of 19 wells sampled in both years.

Table 3b. Reported Organic Compounds

Category	Number of Wells Reported In[1]	
	1996	1997
VOCS:		
Halocarbon	6.	3.
Petroleum Hydrocarbon	2.	0.
Trihalomethane	12.	1.
SVOCS:		
Petroleum Hydrocarbon	3.	0.
Phenolic	7.	0.
Phthalate	12.	6.

1. Number of wells out of 19 sampled in both years in which any compound in the indicated category was reported at any concentration.

Table 4. Ground/Surface Water Relationship

Variable	Wells[1]	River[2]
Major Ions:		
Chloride	6.96	300.
Sodium	6.76	340.
Sulfate	323	150.
Elements:		
Arsenic	6.85	2.
Barium	725.	130.
Iron	13.2	0.01

1. Site data. Mean for upgradient monitoring wells (1994-1997).
2. USGSdata. Median for river at nearby gaging station (1981-1995),

Table 5. Grouped Inorganic Data[1]

Data Set	Major Cations			
	Ca	Mg	K	Na
1996 Data:				
BF	62.2	4.75	1.04	35.55
UF	59.4	2.97	.5	0.5
BF:UF Ratio	1.04	1.60	2.06	8.46
1997 Data:				
BF	58.66	4.47	.55	3.06
UF	58.48	4.02	.5	2.76
BF:UF Ratio	1.00	1.11	1.1	1.11
Data Set	Major Anions			
	HCO_3	Cl	NO_3	SO_4
1996 Data:				
BF	204.	7.31	12.8	33.5
UF	181.	5.82	6.69	16.6
BF:UF Ratio	1.13	1.26	1.91	2.02
1997 Data:				
BF	177.	3.93	7.62	10.2
UF	174.	4.65	4.52	9.5
BF:UF Ratio	1.02	0.845	1.69	1.07
Data Set	Other Variables			
	Al	Fe	Silica	TDS
1996 Data:				
BF	1.21	0.94	8.72	305.
UF	0.10	0.05	9.68	196.
BF:UF Ratio	12.1	18.8	0.901	1.56
1997 Data:				
BF	0.31	0.10	9.2	231.
UF	0.29	0.06	3.8	226.
BF:UF Ratio	1.06	1.67	2.42	1.02

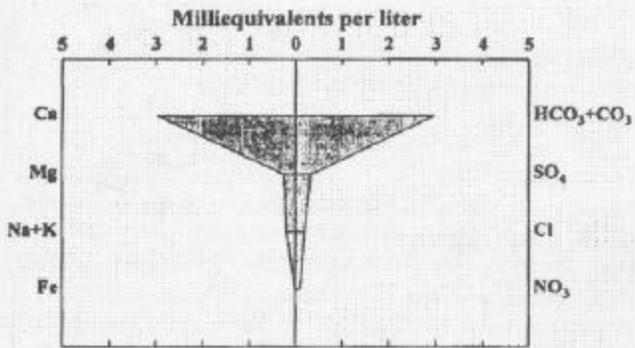1. All concentrations are median values for grouped data in units of mg/L.

Figure 1. Grouped Median Data STIFF Diagrams - 1996

a. Wells in unfilled boreholes (UF).

b. Wells in bentonite filled boreholes (BF).