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RESULTS AND INTERPRETATION OF GROUNDWATER DATA OBTAINED FROM
MULTIPOINT-INSTRUMENTED COREHOLES (GW-131 THROUGH GW-135),
FISCAL YEARS 1990 AND 1991

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EXECUTIVE SUMMARY

With the increased emphasis by Department of Energy personnel on assessing the environmental impact of past waste disposal practices at all of its facilities, there has been an associated increase in characterization activities that focus on delineating site-specific groundwater flow regimes and contaminant migration pathways. At the Oak Ridge Y-12 Plant, the complex geologic and hydrologic relationships require a more detailed understanding of the three-dimensional properties of groundwater flow regimes than can be obtained by conventional monitoring activities. Thus, as part of groundwater characterization activities conducted by the Environmental Surveillance Section staff of the Y-12 Plant Environmental Management Department, five existing deep core holes were instrumented with multiport monitoring systems to provide greatly enhanced resolution of the hydraulic and hydrochemical properties of the groundwater system within Bear Creek Valley. With a multiport system, it is possible to measure hydraulic head and hydraulic conductivity and collect water samples from multiple levels within a single borehole. In this report, multiport data collected during fiscal years (FYs) 1990 and 1991 are summarized, and interpretations of valley-wide potentiometric surfaces and hydrochemical regimes and a conceptual model of deep (greater than 500 ft) nitrate contaminant pathways are presented.

To date, four sets of pressure measurements have been obtained. Although there are significant differences in the hydraulic head profiles among the five wells, the general trend of the profiles for a given well is similar for each set of measurements. The pressure data suggest that lithologies and geologic structure, in part, control transient variations in hydraulic head, as well as in local and valley-wide hydraulic head distributions. In general, recharge is topographically driven from the ridges, as is expected in this region. Hydraulic head patterns in expected discharge areas are disturbed by the presence of what we interpret to be an artificially induced, isolated hydraulic head bulge within the Nolichucky Formation, but they do show convergent flow to the Maynardville Limestone. This observation is consistent with the hypothesis that the Maynardville Limestone acts as a hydraulic drain for Bear Creek Valley. Within the Maynardville, flow directions have not been definitively determined, but flow is apparently horizontal with local downward components. Flow along the valley in the study area is to the east from the S-3 Ponds area to Scarboro Road.

Preliminary water chemistry results indicate that there is evidence of regional-scale compositional changes in groundwater associated with increased residence time. Water types in the Bear Creek Valley–Chestnut Ridge system include: (1) calcium/magnesium bicarbonate, (2) sodium bicarbonate, (3) calcium/magnesium sulfate, (4) calcium/sodium/magnesium sulfate, and (5) sodium chloride. With increasing depth, and presumably increasing flow path length, there is a change in the dominant cations from calcium and magnesium to sodium. There is an analogous change with depth in dominant anion from bicarbonate to chloride in the shale-dominant lithologies and from bicarbonate to sulfate to chloride in the carbonate-dominant lithologies. The carbonate units are further distinguished from the shale units by the absence of sodium bicarbonate water and the stratification of calcium/magnesium sulfate water, both of which may be attributed to the mineralogy of the carbonates.

Groundwater samples obtained from Core Hole GW-134 contain elevated nitrate concentrations compared with known background levels observed elsewhere in Bear Creek Valley. We hypothesize that downdip migration of contaminated water from the S-3 Ponds is responsible for the nitrate contamination. It is likely that infiltration of dense acidic wastewater through the unlined base of the ponds resulted in immediate reactions (primarily with calcite) in carbonate intervals within the Nolichucky Formation. It is further hypothesized that the very reactive, dense wastewater was able to preferentially and aggressively attack calcite vein fillings and limestone beds and proceed to migrate down structural dip. The presence of an additional volume of water in the groundwater system (the wastewater) locally elevates the fluid pressure, and the increased pressures are expected to dissipate very slowly, apparently on the order of years. This process could explain the presence of the anomalous pressure bulge observed in GW-134. Because the source of the elevated fluid pressure no longer exists, the flow system is expected to ultimately return to a static pre–S-3 Ponds configuration.

INTRODUCTION

With the increased emphasis by Department of Energy personnel on assessing the environmental impact of past waste disposal practices at all of its facilities, there has been an associated increase in characterization activities that focus on delineating site-specific groundwater flow regimes and contaminant migration pathways. At the Oak Ridge Y-12 Plant, the complex geologic and hydrologic relationships require a more detailed understanding of the three-dimensional properties of groundwater flow regimes than can be obtained by conventional monitoring activities. Thus, as part of groundwater characterization activities conducted by the Environmental Surveillance Section staff of the Y-12 Plant Environmental Management Department, five existing deep core holes were instrumented with multiport monitoring systems to provide greatly enhanced resolution of the hydraulic and hydrochemical properties of the flow regime within Bear Creek Valley. With this system, it is possible to measure hydraulic head and hydraulic conductivity and collect water samples from multiple levels within a single borehole.

The core holes range in depth from 599 to 1,275 ft (King and Haase 1987). Four of the core holes (GW-132 through GW-135) are along a line traversing Bear Creek Valley and the northern flank of Chestnut Ridge near the former S-3 Ponds on the western end of the Y-12 Plant; the fifth core hole (GW-131) is located along geologic strike with GW-135 on Chestnut Ridge near the eastern end of the Y-12 Plant (Fig.1)

SITE GEOLOGY AND HYDROGEOLOGY

The geology of the Oak Ridge Reservation is typical of the Appalachian foreland fold and thrust belt: lower Paleozoic sedimentary lithologies are structurally repeated along regional thrust faults. Differential erosion of moderately to steeply dipping, fractured, and faulted strata form a sequence of long, narrow valleys and ridges. Generally, siltstone and dolostone are ridge-formers and the valleys are underlain by limestone and shale units. This valley-and-ridge topography strongly influences local near-surface hydrologic systems with ridges being recharge areas and discharge occurring at the topographic low point of the valleys.

Fig. 1. Location map for Core Holes GW-131 through GW-135.

The stratigraphy within the field site includes the Rome Formation, a siltstone/shale unit, the Conasauga Group, which consists of six formations; and the Copper Ridge Dolomite, the lower formation of the Knox Group (Figs. 2 and 3). The lower five formations of the Conasauga Group (Pumpkin Valley, Rutledge, Rogersville, Maryville, and Nolichucky) are all characterized by interlayered shale and limestone with shale being dominant. The upper formation in the Conasauga Group, the Maynardville Limestone, is a massive limestone with subordinate amounts of dolostone. The Conasauga Group underlies Bear Creek Valley, with the Maynardville Limestone continuing up part of the northern flank of Chestnut Ridge. The remainder of the northern flank and crest of Chestnut Ridge is underlain by the Copper Ridge Dolomite, a massive dolostone that is locally chert-rich.

All of the strata are faulted and pervasively fractured as a result of Alleghanian thrusting, and fracturing may have continued into the Mesozoic and Cenozoic because of erosion and unloading processes. Most fractures have been mineralized with calcite and do not influence the hydrologic system. However, those connected fractures that are open, or partially open, to fluids are considered to be the primary conduits for fluid movement. There are three primary fracture sets within the field area: (1) bedding-plane-parallel, (2) strike-parallel, bedding-plane-perpendicular, and (3) strike-perpendicular, bedding-plane-perpendicular. The bedding-plane-parallel set is considered to be the dominant fracture set because fracture length is not controlled by a lithology change. Thus, the fractures can extend for a long distance. In the field site, bedding strikes approximately parallel to the trend of the ridges (N55°E) (Fig. 1) and dips steeply (approximately 45°) to the grid-south. Hence, the dominant fracture set is at an oblique angle to land surface. The two other sets, which are bedding-plane-perpendicular, are much shorter because their length is commonly determined by the mechanical bed thickness of the various lithologies, generally on the order of 1 in to 1 ft. Hydraulically active fracture spacing within the intermediate and deep groundwater system (depths greater than 80–100 ft) has been estimated to be on the order of 100 ft (Solomon et al. in prep), but varies considerably as a function of depth below ground surface and lithology.

Fig. 2. Geology and multiport sampling zones for core holes GW-132 through GW-135. Profile is a strike-perpendicular section. Cr = Rome Formation, Cpv = Pumpkin Valley Shale, Crt = Rutledge Limestone, Crg = Rogersville Shale, Cm = Maryville Limestone, Cn = Nolichucky Shale, Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite. See Fig. 1 for location of cross section.

Fig. 3. Geology and multiport sampling zones for Core Holes GW-131 and GW-135. Profile is a strike-parallel section. Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite. See Fig. 1 for location of cross section.

MULTIPORT SYSTEM

The core holes used in this project (GW-131 through GW-135) were drilled in the summer of 1985 in an effort to characterize the subsurface geology of the region (King and Haase 1987). The core holes range in depth from 599 to 1275 ft and, with the exception of surface casing, were completed as open holes. The core holes remained open until March 1990 when a multiport system was installed in each.

On the basis of geophysical logs and packer testing results (King and Haase 1989), 7 to 10 sampling zones, 20 to 25 ft long, were selected in each well (Figs. 2 and 3). The zones were chosen to potentially sample at least one of the following features: (1) fluids from fractures or fracture zones, (2) matrix fluids with long residence times, (3) potential changes in fluid chemistry with depth, and (4) potential water chemistry signatures associated with a particular rock type (Dreier 1990). Each sampling zone contains a pumping port, which allows the interval to be purged, in addition to a measurement port for collecting samples and measuring pressure in the zone (Fig. 4). As a result, both pressure data and water samples are obtained from sampling zones.

The sampling zones are isolated from each other by one to three additional zones containing measurement ports, from which only pressure data are collected (Fig. 4). Thus, using data from both the sampling and measurement zones, it is possible to acquire a very detailed hydraulic head profile (25 to 41 measurements) from each well. The multiport completion design for Core Holes GW-131 through GW-135 is included in Appendix A.

PRESSURE MEASUREMENTS

Three sets of pressure data have been collected from Core Holes GW-131 through GW-135 between March 1990 and April 1991, and an additional set of measurements was obtained in July 1991 from Core Holes GW-134 and GW-135. To date, these data have not been corrected for possible density effects; however, density corrections should be minor and it is likely that they will only affect the lowest monitoring zones in GW-134 and GW-135. A thorough examination of density effects is included as part of FY 1992 activities. The pressure data are included in Appendix B. Regional flow patterns discussed in the following section are derived from hydraulic head profiles taken in April and May 1990. Earlier and subsequent profiles are believed not to represent ambient conditions

Fig. 4. Schematic diagram of components for a multiport system.

because of installation, purging, or sampling activities that disturb the pressure in zones with apparent very low hydraulic conductivity. Data from each well are described sequentially, beginning with the northern end of the strike-perpendicular transect (GW-132) and ending with the eastern end of the strike-parallel transect (GW-131). Hole GW-135 is the tie between the two transects (Fig. 1).

The hydraulic head profile for GW-132 (Fig. 5) shows essentially no vertical gradient above an elevation of 600 ft, possibly indicating dominant horizontal flow. Below 600 ft, the profile shows a very steep, step-like, upward gradient that may not represent final static conditions because the gradient has increased during the first year of pressure measurements. The change in gradient occurs below a gouge-rich fault zone with very low permeability and also is nearly coincident with the contact between the upper and lower Pumpkin Valley Formation. The lower Pumpkin Valley Formation is more silt-rich than the upper member and has much more massive beds because of pervasive bioturbation (Haase et al. 1985). Both geologic features may influence the location of the gradient change; however, at present, the relative importance of these features has not been determined or modeled.

Individual steps in the GW-132 hydraulic head profile below 600 ft include up to five neighboring sampling/measurement zones that show approximately the same hydraulic head. These groups of zones that behave in a similar manner may indicate geologic intervals characterized by local fracture interconnection and/or dominantly horizontal flow. In contrast, fracture connectivity between adjacent steps appears to be reduced as evidenced by the apparently discontinuous change in head. This would account for the similar head values within the steps but the overall steep upward gradient. A step-like profile is also observed for GW-135 (see below), another well close to a recharge area that shows a strong vertical gradient.

The hydraulic head profile for GW-133 (Fig. 6) shows an overall slight upward gradient from the lower Maryville Limestone. This is best observed in the April 25, 1990 (Fig. 6a) profile where the hydraulic head measurements are thought to be closest to static values. Other profiles are affected by activities within the borehole. For example, the earlier profile (March 27, 1990) shows the effects of packer squeeze, which occurs when water in the annulus of the multiport system becomes trapped between adjacent packers as they are inflated. The trapped water is compressed and the excess pressure dissipates gradually in

Fig. 5. Pressure profiles from GW-132.

Fig. 6. Pressure profiles from GW-133. A: All pressure profiles currently measured and geologic formations.
B: Pressure profiles measured before and after purging and sampling activities.

low permeability strata such as shale. The time for dissipation of packer squeeze effects is dependent on the permeability of the zone. Packer squeeze is particularly evident in the central portion of the borehole, which samples strata of apparent low hydraulic conductivity in the shale-rich lower Maryville Formation.

As further indication of the existence of low conductivity zones in GW-133, pressures measured from the same portion of the lower Maryville Formation also are strongly affected by purging and sampling (Fig. 6b). In this case, purging occurred approximately four months before, and sampling occurred approximately two months before, the pressure was measured on March 21, 1991. Measurement zones that surround a sampling zone show significant hydraulic head perturbations after purging and sampling. In some cases, the hydraulic head changes in neighboring zones are apparently greater than those in the sampled zone, although this may be a function of differential recovery rates after purging. At present, no hydraulic conductivity measurements have been collected from this borehole, so purging and recovery records from hydraulic head profiles are used to obtain a qualitative indication of hydraulic conductivity. The fact that purging a single zone affects several zones suggests a connection among the zones, either because of fracture connectivity in the rock matrix or because of a poor packer seal. Currently, the first interpretation is favored because of the large number of zones affected.

The hydraulic head profile for GW-134 (Fig. 7) is similar to that of GW-133 and shows a slight upward gradient; however, there is a pressure bulge superposed on the profile in the middle portion of the well. The bulge does not appear to be a transient phenomenon because it is evident in all four profiles. In the current conceptual model for this site, the bulge is considered to result from waste disposal activities and is discussed further in a subsequent section.

Lithologic differences within the formations penetrated by GW-134 appear to partially control local variations in pressure. The upper portion of GW-134 samples the Nolichucky Formation, which is informally divided into upper, middle, and lower units (Hatcher et al. in prep) because of lithologic and textural differences (Foreman et al. 1991), and the borehole extends into the Maryville Formation (Fig. 7). The upper Nolichucky, a limestone unit with local 1- to 5-ft shale beds, shows temporal fluctuations in hydraulic head on the order of 3 to 4 ft that cannot be attributed to purging or sampling activities (Fig. 7). Purging and sampling occurred before the March 1991 profile was measured, yet

Fig. 7. Pressure profile from GW-134.

the lowest pressure values were measured in July 1991. Thus the low pressures are not caused by partially depleting the surrounding rock matrix of groundwater by purging; rather, they may be the result of some other factor—presumably a weathered and possibly karstified transmissive limestone that allows fluctuations in groundwater pressure.

The middle Nolichucky, a shale-dominant unit with regularly spaced 1- to 2- ft-thick oolitic and skeletal packstone and grainstone (Foreman et al. 1991), shows relatively little time-dependent fluctuation in hydraulic head (Fig. 7). In contrast, the lower Nolichucky shows noticeable time-dependent fluctuations (up to 9 ft) between the last two hydraulic head profiles (March 19 and July 18, 1991) that are not related to purging or sampling (Fig. 7). This difference in pressure response may be the result of relative changes in hydraulic diffusivity (the ratio of hydraulic conductivity to specific storage) and can be indicative of the confining behavior of the strata. That is, the greater the hydraulic diffusivity of a unit, the greater the potential pressure fluctuations within the units, reflecting more of a confining behavior. The lower Nolichucky is a shale-dominant unit and is distinguished from the middle Nolichucky by the presence of calcareous siltstone and flat-pebble limestone conglomerate and the absence of oolitic and skeletal packstone and grainstone (Foreman et al. 1991). Presumably, it is this lithologic change in the carbonate portion of the rock that is responsible for the apparent change in hydraulic diffusivity and the observed pressure fluctuations.

The deepest monitoring zones in GW-134 sample the Maryville Formation (Fig. 7), a unit with approximately equal proportions of shale and limestone that is presumably characterized by low hydraulic conductivity. Sampling zone 3 was purged six months (January 2, 1991) and sampled twice (February 2, 1991 and May 30, 1991) before the last hydraulic head profile was obtained in July 1991. Pressures in the neighboring four zones have apparently been affected by the purging and have not recovered to April 1990 levels within this time period (Fig. 7).

The top portion of the hydraulic head profile for GW-135 (Fig. 8), above an elevation of 450 ft, corresponds to the Copper Ridge Dolomite and is located in a recharge area. The profile shows a steep, downward nominal 0.1 hydraulic gradient. The stepped portion of the pressure profile can be understood by considering observed variations in lithology. Examination of core material shows that in the zone between adjacent steps, the lithology is

Fig. 8. Pressure profiles from GW-135.

commonly a calcareous mudstone, presumably of low hydraulic conductivity. Within the steps, the lithology commonly contains large vugs that should provide a good hydraulic connection.

In contrast to the upper portion, the lower portion of the hydraulic head profile (below an elevation of 450 ft), which corresponds to the Maynardville Formation, is very flat and shows the lowest hydraulic head values observed in this strike-perpendicular transect (GW-132 through GW-135). The bottom five zones, which occur in the lower Maynardville Limestone and upper Nolichucky Shale, show elevated hydraulic heads with respect to the overlying intervals in 1990 but were lower during 1991. The characteristics of the GW-135 profile support current conceptual models of the the Maynardville Limestone as a hydraulic drain to Bear Creek Valley (Geraghty and Miller, Inc. 1985; Bailey 1988). In addition, the low hydraulic gradient is consistent with horizontal (or strike-parallel) flow within the Maynardville.

The hydraulic head profile for GW-131 (Fig. 9) can be divided into two relatively flat portions that correspond to the Copper Ridge Dolomite and Maynardville Limestone. Although there is a decrease in head suggesting that GW-131 is located in a recharge area, the profile for the Copper Ridge Dolomite is very flat in comparison to Copper Ridge Dolomite hydraulic head profiles measured from Core Hole GW-135 and may reflect predominantly lateral flow. The reason for the different character of the Copper Ridge profiles in GW-135 and GW-131 has not been investigated to date; however, it may be related to additional fracturing and greater fracture connection in the vicinity of GW-131. Other investigations (King and Haase 1987; Dreier and Koerber 1990) suggest the presence of a large-scale structure subparallel to Scarboro Road. Such a feature could be responsible for an increase in the number of hydraulically conductive fractures and could lead to a local reduction in hydraulic gradient. Continued investigation of hydraulic transmissivity and fracture connectivity in the Scarboro Road area is proposed for FY 1992 activities.

Similar to Core Hole GW-135, the Maynardville Limestone in GW-131 shows the lowest hydraulic head values observed in the borehole. The profile also shows elevated hydraulic heads at the base of the Maynardville which is consistent with similar observations noted in GW-135. Thus, results from both GW-135 and GW-131 support the thesis of the Maynardville Limestone as a hydraulic drain for the valley.

Fig. 9. Pressure profiles from GW-131.

Pressure Measurement Summary

On the basis of pressure measurements taken during April and May 1990, hydrologic cross sections can be prepared (Figs. 10 and 11). Although other contouring interpretations besides those shown are possible, interpretations presented in Fig. 10 are consistent with water chemistry results, which are discussed in the next section.

In general, the cross-valley (strike-perpendicular) section shows topographically driven recharge from the ridges, as is expected in this region. Discharge patterns are disturbed by the presence of an artificially induced, isolated pressure bulge within the Nolichucky Formation, but they do show convergent flow to the Maynardville Limestone. The origin of the pressure bulge is discussed in a following section. Within the Maynardville, flow directions have not been definitively determined, but flow is apparently horizontal with a local downward component. The along-valley (strike-parallel) section shows flow to the east from GW-135 to GW-131 (Fig. 11), a hydraulic gradient of about 0.04.

WATER CHEMISTRY

Between June 1990 and January 1991, selected zones from the five core holes were purged to prepare them for sampling. Because of the time and expense involved in sampling, a subset of the total number of sampling zones was chosen for initial monitoring. A summary of purging and sampling activities for 1990 and 1991 is presented in Appendix C; water chemistry results are presented in Appendix D.

Fig 10. Hydrologic cross section in strike-perpendicular section. Cr = Rome Formation, Cpv = Pumpkin Valley Shale, Cr = Rutledge Limestone, Crg = Rogersville Shale, Cm = Maryville Limestone, Cn = Nolichucky Shale, Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

Fig 11. Hydrologic cross sections in strike-parallel section. Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

Data Validation and Quality

The hydrochemical data in Appendix D have been validated by examining several measures of quality. Specifically, the following validation methods have been utilized:

- **Charge balance**
A measure of the completeness and accuracy of the analysis for the major cations (Na, K, Ca, Mg) and anions (alkalinity, Cl, F, SO₄, NO₃) measured in milliequivalents/L where,

$$\text{Charge balance} = \frac{[\sum \text{Cations} - \sum \text{Anions}]}{[\sum \text{Cations} + \sum \text{Anions}]}$$
- Comparison of filtered and unfiltered analyses
- Comparison of samples and blanks

Figure 12 is a frequency distribution of charge balance results for all unfiltered analyses presented in Appendix D, Tables D-1 to D-5. There are two significant features to note. First, GW-131-21 and GW-135-2 have large negative charge imbalances indicating a gross underestimation of the concentration of one or more cations or an overestimation of one or more anionic species. These samples were recollected and analyzed and found to contain substantially lower concentrations of key anions (sulfate and/or chloride) than were originally reported. Both analyses are reported in Appendix D. Ignoring these two outliers, the remaining distribution still shows a bias toward negative charge balances. Past experience with groundwater analyses from Bear Creek Valley (T. Early, ESD, ORNL, unpublished results) suggests that overestimation of the anions by the laboratory, especially in more mineralized samples, is common and may be the cause of this bias. However, the bias is small, and it is noted that two-thirds of the analyses lie within +/-5 percent of a perfect charge balance and all but one of the remaining are within +/-10 percent. We conclude that, in general, the analyses are of good quality with respect to the major cations and anions.

Fig. 12. Frequency distribution of charge balance results for all unfiltered analyses.

The unfiltered sample analyses should equal or exceed those for the filtered sample for all analytes. A deviation significantly in excess of 10 percent would indicate a probable analytical or sample stability problem. An example of a stability problem would be precipitation occurring within the sample prior to the time of filtration (e.g., due to changing redox conditions) that could lead to erroneously low results for some analytes.

Evaluation of the analyses in Tables D-1 to D-5 indicate that very few analytes show unacceptably large deviations between filtered and unfiltered samples. The most apparent problems exist for calcium in GW-132, Zone 13 and silicon in GW-132, Zone 21. Lesser deviations, but in excess of 10 percent, appear to exist only for relatively few trace constituents present at concentration levels of <0.1 mg/L in some samples.

A trip blank was included with the samples collected from GW-134 for organic analyses (Appendix D, Table D-6). It is possible to compare the sample and blank results as an indication of the reliability with which an analyte has been detected. It is noted that methylene chloride, a common laboratory contaminant, is detected in all samples and in the blank at about the same concentration level. Likewise, chloroform is detected at very low, but comparable levels in both the blank and the sample from Zone 33. We conclude that both chloroform and methylene chloride for these samples represent false positives and can be ignored.

Because of the preliminary nature of this investigation, duplicate samples were not collected. To do so would have significantly added to the cost and the sampling time required. Therefore, we are unable to make a comparison of duplicates. However, there are several instances in which samples from the same zone were collected at two different times (up to six months apart). For example, Zone 21 (GW-131), Zone 3 (GW-135), and Zones 33, 18, and 3 (GW-134 for specific conductance and pH only) all were sampled twice. Generally, there is a close similarity for most analytes for the paired samples, a fact suggesting that the hydrochemistry of these zones is stable.

The analytical laboratory applies data quality flags to analyses to assist the user in interpreting the results. The "B" flag (after methylene chloride in Table D-6) indicates an analyte present in the blank. A "J" flag (Table D-6) represents an analytical result below the laboratory quantitative limit, but for which an estimated value is possible. An "h" flag that appears next to some mercury results in Tables D-1 to D-5 indicates that the recommended holding time for mercury had been exceeded for those samples.

Borehole Circulation and Infiltration

As noted above, Core Holes GW-131 through GW-135 were drilled in the summer of 1985 and instrumented in March 1990. Hence, they were open for approximately five years; during this time water could potentially circulate within the borehole and migrate into the surrounding rock. However, we do not know if infiltration occurred within any of these boreholes. One approach for evaluating the potential for infiltration is through knowledge of the hydraulic conductivity of a specific zone and of the head difference that prevailed during the time the hole was open. The head profiles in Figs. 5 and 8 suggest that head differences in excess of 100 ft could exist between some zones in several boreholes (e.g. GW-132), although values of <20 ft are much more common. However, hydraulic conductivity values have not yet been measured in most of these zones. From our experience associated with purging activities, we believe that many of the sampling zones have relatively low hydraulic conductivity indicating a minimal opportunity for cross-contamination.

An independent, yet complementary, method of assessing borehole fluid circulation is through a consideration of vertical changes in hydrochemistry within the boreholes. For example, all of the zones sampled in GW-132 have similar chemistry. Coupled with the fact that purging was not difficult for these zones (i.e., relatively high K), and head differences of >100 ft exist between several zones (Fig. 5), we suspect that significant circulation may have occurred prior to installation of the monitoring system in the borehole. It is possible that the effects of borehole circulation on groundwater composition may not have been reversed by our purging activities in the borehole. Similarly, the water chemistry between Zones 5 and 17 in GW-133 and between Zones 30 and 39 in GW-135 is approximately the same and may represent monitored intervals for which extensive infiltration has occurred.

Many of the zones in GW-131, GW-134, and GW-135 have strongly contrasting hydrochemical properties, which suggests that extensive contamination involving these zones, either as the sources or recipients of infiltration, is minimal. Zone 3 in GW-135 is unusual in that it has a high concentration of chloride and a significant level of nitrate. The fact that none of the other zones in GW-135 contain much chloride or detectable nitrate suggests that zone 3 was not a source of contamination to the other monitored zones and that the analysis is representative of the chemistry in Zone 3.

Generally, it is impossible to rule out the possibility of some borehole circulation on the basis of hydrochemical arguments. For example, Zone 18 in GW-134 has nitrate contamination of 5530 mg/L, the highest level in the borehole. This zone also has the highest head and, therefore, may only be a source of the nitrate-contaminated water to other zones in the well. Every zone in GW-134 has nitrate contamination, so it is impossible to rule out Zone 18 as the source of this component. Nevertheless, the very fact that hydrochemical stratification is preserved in these boreholes (with the exception of GW-132) confirms that extensive circulation has not occurred.

Several future studies will be conducted to evaluate these effects. First, hydraulic testing of sampling zones will be undertaken and will permit numerical modeling of the infiltration process. Second, several zones are targeted to be purged extensively, with periodic sampling to determine whether or not systematic hydrochemical variations are consistent with borehole circulation results.

Evaluation of General Water Chemistry Types

Water from GW-132 is characterized as a sodium bicarbonate*-type with a pH greater than 9. As noted above, the nearly constant concentrations of sodium and bicarbonate in all sampled zones from this well may result from borehole circulation and infiltration (Fig. 13). Pressure measurements show that flow within the borehole would be from the bottom to the top of the hole, along a steep vertical gradient. Chemistry results indicate near compositional uniformity over all the sampling intervals, suggesting that fluid from the zone with the highest hydraulic head (bottom of hole) may have infiltrated into other intervals of lower hydraulic head and controlled the water chemistry in those zones.

The uppermost sampling interval in GW-133 contains a sodium/calcium bicarbonate-type water (Fig. 14). Water from all other zones is of a sodium bicarbonate-type with an increase in total dissolved solids (TDS) occurring with depth—up to 1,140 mg/L in the bottom interval. The increase in TDS appears to be related to rock–water reactions that lead to associated increases in pH (Toran and Saunders, in prep). In addition, the deepest sampling zone in GW-133 (Zone 3) was the most difficult zone to purge, reflecting an apparent lower hydraulic conductivity. The existence of apparent low hydraulic conductivity in association with increased sodium, TDS, and pH is suggestive of longer groundwater residence times for groundwater intersected by the bottom interval. Although GW-133 samples the Rutledge Limestone, the Rogersville Shale, and the Maryville Limestone, general geochemical changes observed within the sampling intervals do not correspond to stratigraphic changes, possibly due to the overall lithologic similarities in these shale-rich units.

The water chemistry from Core Hole GW-134 is strongly influenced by the presence of contamination associated with the S-3 Ponds wastewater facility, which lies to the northwest of the core hole (Fig. 10). From 1951 until 1985, dense (approximately 1.07 g/cm^3), highly acidic, nitrate-contaminated waste water was disposed of in these four ponds. Nitrate contamination is found in all zones sampled from this borehole.

* In this study, total alkalinity was measured in all groundwater samples and speciated by geochemical modeling. For samples with pH less than 9, total alkalinity results from the presence of bicarbonate ion. At higher pH, the relative amount of carbonate in comparison to bicarbonate increases. For all samples discussed, however, bicarbonate is the dominant anion present in the total alkalinity.

Fig. 13. Selected water chemistry of Core Hole GW-132.

Fig. 14. Selected chemistry results from core hole GW-133.

Rock–water interactions between the infiltrating, contaminated water and the underlying lithologies have resulted in the development of groundwaters with unusual hydrochemical properties. For example, water from the upper sampling zone is of a calcium (sodium) nitrate-type. All underlying sampling zones, except for the bottom zone, contain either a sodium bicarbonate- or sodium nitrate-type water; the bottom zone contains sodium chloride (nitrate)-type water. These relationships are illustrated more fully in the contaminant chemistry section.

Results from sampling at GW-135 show the most diverse water types of the five core holes (Fig. 15). In the upper portion of the Copper Ridge Dolomite, the water is of calcium magnesium bicarbonate-type, but changes to calcium (magnesium) sulfate-type at the base of this formation. Examination of core from this sampling interval shows localized gypsum beds that probably are responsible for the increased calcium and sulfate (Toran and Saunders, in prep).

The top of the Maynardville Limestone shows a return to a calcium/magnesium bicarbonate-type water that is replaced at depth by a calcium (sodium/magnesium) sulfate-type water. The sulfate-type water continues at least to a depth of approximately 1,150 ft below ground surface where a major fracture zone is encountered (see temperature log, Fig. 15b). Below this fracture, the water changes to a sodium chloride-type and the TDS levels show an abrupt increase to over 28,000 mg/L. Groundwater from Zone 3 is by far the most mineralized water yet discovered in Bear Creek Valley and probably is indicative of an old, sluggish, regional flow system.

Groundwater samples from GW-131 are calcium/magnesium (sodium) bicarbonate-type except for several zones within the Copper Ridge Dolomite that show marked increases in sulfate (Fig. 16). This is the same stratigraphic horizon where sulfate-rich water was encountered in GW-135. As in GW-135, gypsum is also present in core from GW-131 at this horizon.

Fig. 15. Selected chemistry results, temperature, and pressure data from Core Hole GW-135. (a) 0-1,000 ft depth below ground surface. (b) 900-1300 ft depth below ground surface. Note scale changes for several chemical constituents between 9a and 9b.

Fig. 16. Selected water chemistry, pressure, and temperature data from core hole GW-131.

At a depth of approximately 1,000 ft bgs, one sample zone (Zone 4) intersects a fracture that is easily identified on the temperature log (Fig. 16). In this zone, the water is similar to water from the upper zones in the well, suggesting that this fracture may be in communication with less-evolved, near-surface water or that cross-contamination occurred while the borehole was open. In contrast, Zone 8 produces a sodium bicarbonate (chloride)-type water.

Although GW-135 and GW-131 are located along strike and sample the same stratigraphy, there are noticeable differences in their respective water chemistries. Notably, calcium sulfate and highly concentrated sodium chloride-type waters are absent from the Maynardville Limestone in GW-131. The temperature logs from both wells define the existence of a fracture in the lower Maynardville Limestone. Although in GW-131 the fracture appears to be a conduit for relatively unmineralized calcium/magnesium bicarbonate-type water of shallow origin, in GW-135 the fracture is associated with calcium/sodium/magnesium sulfate-type water and its origin is less certain.

Water Chemistry Summary

Preliminary inspection of the water chemistry data shows the presence of at least five water types in the Bear Creek Valley--Chestnut Ridge system: (1) calcium/magnesium bicarbonate, (2) sodium bicarbonate, (3) calcium/magnesium sulfate, (4) calcium/sodium/magnesium sulfate, and (5) sodium chloride (Fig. 17). With increasing depth, and presumably increasing flow path length, there is a change in the dominant cation from calcium/magnesium to sodium in the shale-dominant lithologies (Fig. 18). There is an analogous change in the dominant anion from bicarbonate to chloride in both the shale- and carbonate-dominant lithologies (Fig. 18). The carbonate units are distinguished from the shale units by the absence of sodium bicarbonate water and the stratification of calcium/magnesium sulfate water, both of which may be attributed to mineralogical differences between shale and carbonates.

Fig. 17. Piper diagram of water chemistry from GW-131 through GW-135.

Fig. 18. Water-type regimes, strike-perpendicular section. Note that the effects of nitrate contamination in the vicinity of GW-134 have not been incorporated into the diagram. Cr = Rome Formation, Cpv = Pumpkin Valley Shale, Crt = Rutledge Limestone, Crg = Rogersville Shale, Cm = Maryville Limestone, Cn = Nolichucky Shale, Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

For GW-131 and GW-135, which are in carbonate lithologies, sodium chloride-type water appears in the deep zones (Figs. 18 and 19). This water type bears some resemblance to that observed in Zone 3 from GW-134 (without the nitrate) and, probably, represents water from an old, deep, regional flow system. Water from Zone 3 (GW-135) is highly mineralized and, while not as concentrated as the brines observed in Melton Valley (Switek et al. 1987, 1988), there are geochemical similarities among these groundwaters and possible similarities in origin. Haase (1991) evaluated hydrochemical stratification in a region further west in Bear Creek Valley for wells completed in the shale-dominant lithologies and has reached conclusions consistent with those presented in Fig. 18 for the northern part of the cross section. The reader is referred to this article for discussion of geochemical modeling results.

CONTAMINANT CHEMISTRY

As noted above, groundwater samples obtained from GW-134 contain elevated nitrate concentrations in comparison with known background levels observed elsewhere in Bear Creek Valley (Fig. 20). Nitrate concentrations in excess of 5,500 mg/L have been measured. It is believed that this contamination is associated with the S-3 Ponds that were located updip from GW-134 (Fig. 18). We hypothesize that downdip migration of contaminated water from the ponds is responsible for the contamination observed in groundwater samples from GW-134.

The depth concentration profile for nitrate in GW-134 shows several anomalies. The elevated concentration in the shallow part of the hole (1,340 mg/L) is associated with a transmissive part of the Nolichucky Shale; at present it is assumed that this zone encounters a nitrate plume occurring within a relatively shallow flow system.

Fig. 19. Water-type regimes, strike-parallel section. Cmn = Maynardville Limestone, Ccr = Copper Ridge Dolomite.

Fig. 20. Selected chemistry results and pressure data from core hole GW-134.

The greatest concentration of nitrate in GW-134 (5,520 mg/L) occurs at a depth of approximately 425 ft bgs. This zone (Zone 18) is located near the crest of the anomalous pressure bulge, which shows the highest hydraulic head values for the core hole (Fig. 20). Thus, the presence of nitrate in this zone at such a high concentration cannot be attributed to fluids from a shallow near-surface source circulating within the borehole and contaminating other zones during the time the hole was open. Because all other sampling zones in GW-134 have lower hydraulic head values than Zone 18, one cannot rule out the possibility of this zone as a source of nitrate contamination for other zones.

Nitrate levels increase again in the bottom zone of GW-134 to 3,070 mg/L. Possible flow pathways to this zone include down-dip migration along fractures. A deflection in the temperature log has been observed in the vicinity of Zone 3, which suggests the existence of fractures that are an active part of the groundwater flow system. Alternatively, borehole circulation and infiltration of nitrate-contaminated water may be a factor in the observed hydrochemical profile. However, the apparent low hydraulic conductivity of this zone (estimated from purging and pressure recovery records) suggests that it samples an aquitard/aquiclude, which would tend to minimize contamination effects due to borehole circulation.

Monitoring wells in the vicinity of the S-3 Ponds also show contamination by several organic constituents and radionuclides (e.g., uranium and Tc-99) (Geraghty & Miller 1988). Groundwater samples from Zones 33, 18, and 3 (the zones most highly contaminated with nitrate) in GW-134 were analyzed for selected organic and radionuclide constituents (Appendix D, Tables D-6 and D-7). In general, there is evidence that Tc-99 may have been observed in all three zones. These zones are being resampled and analyzed by more sensitive and precise techniques. There is no evidence for contamination of groundwater by volatile organic constituents, except in Zone 33, the shallowest zone tested.

On the basis of water chemistry and pressure measurement results, a conceptual model has been developed to explain the presence of nitrate at depths greater than 400 ft (Fig. 21). Very acidic and dense (density up to 1.07 g/cm^3 ; Jeter and Napier 1986) nitric acid wastewaters were disposed of in the S-3 Ponds, creating a transient pressure mound under the ponds (Geraghty and Miller 1985). Infiltration of this water through the unlined base of the ponds resulted in immediate reactions (primarily with calcite) in limestone intervals

Fig. 21. Conceptual model of nitrate contamination below the shallow groundwater flow system.

within the Nolichucky Shale. For this reason, shallow groundwater in this region frequently is characterized as a calcium/nitrate-type (the uppermost sample at GW-134 is of this type). It is further hypothesized that the very reactive, dense water from the S-3 Ponds was able to preferentially and aggressively attack calcite vein fillings and limestone beds within the Nolichucky Shale and proceed to migrate down structural dip. In addition, these dense acidic waters could take advantage of existing, partially closed bedding-plane fractures, presumably the dominant fracture type in this system. The depth and extent to which this reaction-created pathway extends are unknown, but are dependent on the amount of time available (the S-3 Ponds were operational between 1951 and 1985) and the kinetics of the specific reactions occurring.

The presence of an additional volume of water introduced into the groundwater system by: (1) a density contrast between wastewater and natural groundwater, (2) chemical reactions that create a favorable pathway to the groundwater system, and, possibly, (3) a superposed water mound (the S-3 Ponds) elevates the fluid pressure in the region surrounding the flow pathway. Because these rock units show very low hydraulic conductivities, locally on the order of 10^7 – 10^{-8} cm/s (King and Haase 1989), the increased pressures are expected to dissipate very slowly, apparently on the order of years. Hence, the introduced water is essentially trapped in a local cul-de-sac. This process could explain the presence of the anomalous pressure bulge observed in GW-134. Because the source of the elevated fluid pressure no longer exists, the flow system is expected to ultimately return to a static pre-S-3 Ponds configuration.

The level of contamination observed in GW-134 remains problematic because of the unexpected high nitrate concentrations. Based on available rough estimates of S-3 Ponds wastewater chemistry, initial nitrate concentrations were on the order of 50,000 mg/L (Jeter and Napier 1986). Thus measured nitrate levels in Zones 18 and 3 show only a 10 to 15 times dilution factor. These high concentrations may reflect a very low specific storage for this section of the Nolichucky Shale that is coupled with the relatively large volumes of wastewater introduced into the system. Alternatively, the concentrations may reflect a relatively high displacement rate of formation water by wastewater, possibly with density as a driving force. To date, these questions have not been quantitatively evaluated but will be addressed, together with other aspects of the conceptual model, in future studies.

SUMMARY

To date, four sets of pressure measurements have been collected from multiport instrumented wells. Although there are significant differences in the head profiles among the five wells, the general trend of the profiles for a given well is similar for each set of measurements. The pressure data suggest that lithologies and geologic structure, in part, control transient variations in hydraulic head, as well as in local and valley-wide hydraulic head distributions. In general, recharge is topographically driven from the ridges, as is expected in this region. Discharge patterns are disturbed by the presence of an artificially induced, isolated pressure bulge within the Nolichucky Formation, but they do show convergent flow to the Maynardville Limestone. This observation is consistent with the hypothesis that the Maynardville Limestone acts as a hydraulic drain for Bear Creek Valley. Within the Maynardville, flow directions have not been definitively determined, but flow is apparently horizontal with a local downward component. Flow along the valley is to the east from the S-3 Ponds area to Scarboro Road.

Preliminary water chemistry results indicate that there is evidence of regional-scale compositional changes in groundwater associated with increased residence time. Water types in the Bear Creek Valley–Chestnut Ridge system include: (1) calcium/magnesium bicarbonate, (2) sodium bicarbonate, (3) calcium/magnesium sulfate, (4) calcium/sodium/magnesium sulfate, and (5) sodium chloride. With increasing depth, and presumably increasing flow path length, there is a change in the dominant cation from calcium/magnesium to sodium. There is an analogous change in dominant anion from bicarbonate to chloride in the shale-dominant lithologies and from bicarbonate to sulfate to chloride in the carbonate-dominant lithologies. The carbonate units are further distinguished from the shale units by the absence of sodium bicarbonate water and the stratification of calcium/magnesium sulfate water, both of which may be attributed to the mineralogy of the carbonates.

Groundwater samples obtained from GW-134 contain elevated nitrate concentrations in comparison with known background levels observed elsewhere in Bear Creek Valley. We hypothesize that downdip migration of contaminated water from the S-3 Ponds is responsible for the nitrate contamination. Infiltration of dense, acidic wastewater through the unlined base of the ponds resulted in immediate reactions (primarily with calcite) in limestone intervals within the Nolichucky Formation. It is further hypothesized that the

very reactive, dense wastewater was able to preferentially and aggressively attack calcite vein fillings and limestone beds and proceed to migrate down structural dip. The presence of an additional volume of water in the groundwater system (the wastewater) locally elevates the fluid pressure, and the increased pressures are expected to dissipate very slowly, apparently on the order of years. This process could explain the presence of the anomalous pressure bulge observed in GW-134 and is substantiated by a coincident nitrate concentration anomaly. Because the source of the elevated fluid pressure no longer exists, the flow system is expected to ultimately return to a static pre-S-3 Ponds configuration.

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Appendix A

**COMPLETION TABLES,
GW-131 THROUGH GW-135**

WELL:		GW-131			
INSTALLATION DATE:		8-Mar-80			
TOP OF MP:		2.5 ft ags			
SURFACE CASING DEPTH:		43 ft			
COMPLETION ZONE		MEASUREMENT PORT			PUMPING PORT
Number	Interval depth bgs (ft)	Port depth bgs (ft)	True depth bgs (ft)	Elevation (amsl) (ft)	Port depth bgs (ft)
1	1064-1089	1075	1077.50	-66.20	1065
2	1049-1061	1060	1062.50	-51.20	
3	1014-1046	1025	1027.50	-16.20	
4	992-1011	1003	1005.50	5.80	1010
5	977-989	988	990.50	20.80	
6	948-974	963	965.50	45.80	
7	933-945	944	946.50	64.80	
8	903-930	914	916.50	94.80	929
9	888-900	899	901.50	109.80	
10	839-885	860	862.50	148.80	
11	794-836	815	817.50	193.80	
12	769-791	780	782.50	228.80	790
13	754-766	765	767.50	243.80	
14	709-751	730	732.50	278.80	
15	667-691	678	680.50	330.80	690
16	652-664	663	665.50	345.80	
17	607-649	628	630.50	380.80	
18	562-604	583	585.50	425.80	
19	537-559	548	550.50	460.80	
20	522-534	533	535.50	475.80	
21	497-519	498	500.50	510.80	508
22	482-494	493	495.50	515.80	
23	462-479	478	480.50	530.80	
24	437-459	458	460.50	550.80	448
25	422-434	433	435.50	575.80	
26	405-419	418	420.50	590.80	
27	390-402	401	403.50	607.80	
28	365-387	376	378.50	632.80	386
29	350-362	361	363.50	647.80	
30	283-347	326	328.50	682.80	
31	268-280	279	281.50	729.80	
32	238-265	259	261.50	749.80	249
33	223-235	234	236.50	774.80	
34	193-220	209	211.50	799.80	
35	178-190	189	191.50	819.80	
36	153-175	164	166.50	844.80	174
37	138-150	149	151.50	859.80	
38	0-135	134	136.50	874.80	
NOTE: all depths except for "true depth bgs" are measured along the borehole with no correction for borehole deviation.					
* MP = Westbay Multiport Casing, ags = above ground surface.					
* bgs = below ground surface, amsl = above mean sea level.					

WELL:		GW-132			
INSTALLATION DATE:		28-Mar-90			
TOP OF MP:		2.75 ft ags			
SURFACE CASING DPTH:		97 ft (Zone 27)			
COMPLETION ZONE		MEASUREMENT PORT			PUMPING PORT
Number	Interval depth bgs (ft)	Port depth bgs (ft)	True depth bgs (ft)	Elevation (amsl) (ft)	Port depth bgs (ft)
1	732-759	738	729.91	324.01	743
2	717-729	728	720.29	333.63	
3	685-714	696	689.47	364.45	
4	670-682	681	674.99	378.93	
5	640-667	646	641.17	412.75	656
6	625-637	636	631.50	422.42	
7	580-622	601	597.64	456.28	
8	565-577	576	573.37	480.55	
9	535-562	541	539.28	514.64	551
10	520-532	531	529.52	524.40	
11	490-517	501	500.18	553.74	
12	475-487	481	480.58	573.34	
13	450-472	461	460.96	592.96	471
14	435-447	446	446.23	607.69	
15	388-432	409	409.84	644.08	
16	373-385	384	385.20	668.72	
17	348-370	359	360.51	693.41	369
18	333-345	344	345.68	708.24	
19	278-330	299	301.11	752.81	
20	263-275	274	276.28	777.64	
21	238-260	249	251.41	802.51	259
22	223-235	234	236.47	817.45	
23	156-220	177	179.63	874.29	
24	141-153	152	154.66	899.26	
25	116-138	117	119.68	924.24	137
26	101-113	112	114.69	939.23	
27	0-98	87	89.75	964.17	
NOTE: all depths except for "true depth bgs" are measured along the borehole with no correction for borehole deviation.					
* MP = Westbay Multiport Casing, ags = above ground surface.					
* bgs = below ground surface, amsl = above mean sea level.					

WELL:		GW-133			
INSTALLATION DATE:		25-Mar-90			
TOP OF MP:		3.0 ft ags			
SURFACE CASING DPTH:		55 ft			
COMPLETION ZONE		MEASUREMENT PORT			PUMPING PORT
Number	Interval depth bgs (ft)	Port depth bgs (ft)	True depth bgs (ft)	Elevation (amsl) (ft)	Port depth bgs (ft)
1	546-599	552	550.61	475.25	557
2	531-543	542	540.90	484.96	
3	516-528	527	526.32	499.54	
4	501-513	512	511.71	514.15	
5	476-498	487	487.27	538.59	497
6	461-473	472	472.56	553.30	
7	451-458	457	457.81	568.05	
8	426-448	427	428.23	597.63	447
9	414-423	422	423.30	602.56	
10A	384-411	405	406.52	619.34	410
10B	384-411	395	396.65	629.21	410
11	369-381	380	381.82	644.04	
12	349-366	365	366.98	658.88	
13	334-346	345	347.18	678.68	
14	307-331	313	315.45	710.41	330
15	292-304	303	305.52	720.34	
16	272-289	288	290.61	735.25	
17	247-269	253	255.78	770.08	268
18	232-244	243	245.81	780.05	
19	187-229	218	220.87	804.99	
20	172-184	183	185.92	839.94	
21	147-169	158	160.94	864.92	168
22	132-144	143	146.00	879.86	
23	112-129	128	131.00	894.86	
24	92-109	93	96.00	929.86	108
25	77-89	88	91.00	934.86	
	0-74	No measurement port in section			
NOTE: all depths except for "true depth bgs" are measured along the borehole with no correction for borehole deviation.					
• MP = Westbay Multiport Casing, ags = above ground surface.					
• bgs = below ground surface, amsl = above mean sea level.					

WELL:		GW-134			
INSTALLATION DATE:		12-Mar-90			
TOP OF MP:		2.6 ft ags			
SURFACE CASING DPTH:		35 ft (zone 37)			
COMPLETION ZONE		MEASUREMENT PORT			PUMPING PORT
Number	Interval depth bgs (ft)	Port depth bgs (ft)	True depth bgs (ft)	Elevation (amsl) (ft)	Port depth bgs (ft)
1	809-837	810	784.64	220.99	
2	794-806	805	780.10	225.53	
3	769-791	785	761.87	243.76	790
4	754-766	765	743.62	262.01	
5	729-751	740	720.74	284.89	750
6	714-726	725	706.95	298.68	
7	669-711	690	674.71	330.92	
8	624-666	645	632.98	372.65	
9	607-621	620	609.59	396.04	
10	592-604	603	593.68	411.95	
11	567-589	578	570.06	435.57	588
12	552-564	563	555.87	449.76	
13	525-549	536	530.19	475.44	
14	510-522	521	515.86	489.77	
15	485-507	486	482.30	523.33	496
16	455-482	476	472.66	532.97	
17	440-452	451	448.56	557.07	
18	415-437	426	424.33	581.30	436
19	400-412	411	409.79	595.84	
20	385-397	396	395.22	610.41	
21	360-382	371	370.81	634.82	381
22	345-357	356	356.17	649.46	
23	315-342	331	331.66	673.97	
24	300-312	311	312.04	693.59	
25	275-297	286	287.43	718.20	296
26	260-272	271	272.64	732.99	
27	215-257	236	238.04	767.59	
28	200-212	211	213.24	792.39	
29	170-197	171	173.45	832.18	186
30	155-167	166	168.47	837.16	
31	135-152	146	148.60	857.03	
32	120-132	131	133.60	872.03	
33	95-117	106	108.60	897.03	116
34	85-92	91	93.60	912.03	
35	60-82	81	83.60	922.03	71
36	35-57	41	43.60	962.03	56
37	0-32	31	33.60	972.03	
NOTE: all depths except for "true depth bgs" are measured along the borehole with no correction for borehole deviation.					
* MP = Westbay Multiport Casing, ags = above ground surface.					
* bgs = below ground surface, amsl = above mean sea level.					

WELL:		GW-135			
INSTALLATION DATE:		14-Mar-90			
TOP OF MP:		2.2 ft ags			
SURFACE CASING DPTH:		80 FT (In Zone 41)			
COMPLETION ZONE		MEASUREMENT PORT			PUMPING PORT
Number	Interval depth bgs (ft)	Port depth bgs (ft)	True depth bgs (ft)	Elevation (amsl) (ft)	Port depth bgs (ft)
1	1230-1275	1231.00	1233.20	-55.42	
2	1215-1227	1226.00	1228.20	-50.42	
3	1185-1212	1206.00	1208.20	-30.42	1196
4	1168-1182	1181.00	1183.20	-5.42	
5	1153-1165	1164.00	1166.20	11.58	
6	1124-1150	1142.00	1144.20	33.58	1149
7	1109-1121	1120.00	1122.20	55.58	
8	1064-1106	1085.00	1087.20	90.58	
9	1004-1061	1030.00	1032.20	145.58	
10	989-1001	990.00	992.20	185.58	
11	959-986	965.00	967.20	210.58	975
12	944-956	955.00	957.20	220.58	
13	870-941	901.00	903.20	274.58	
14	855-867	866.00	868.20	309.58	
15	825-852	836.00	838.20	339.58	846
16	810-822	821.00	823.20	354.58	
17	765-807	786.00	788.20	389.58	
18	750-762	761.00	763.20	414.58	
19	720-747	731.00	733.20	444.58	741
20	705-717	716.00	718.20	459.58	
21	635-702	661.00	663.20	514.58	
22	620-632	631.00	633.20	544.58	
23	588-617	609.00	611.20	566.58	599
24	578-585	579.00	581.20	596.58	
25	563-575	574.00	576.20	601.58	
26	533-560	554.00	556.20	621.58	544
27	518-530	529.00	531.20	646.58	
28	488-515	499.00	501.20	676.58	
29	473-485	484.00	486.20	691.58	
30	443-470	459.00	461.20	716.58	469
31	428-440	439.00	441.20	736.58	
32	368-425	394.00	396.20	781.58	
33	353-365	364.00	366.20	811.58	
34	323-350	334.00	336.20	841.58	344
35	308-320	319.00	321.20	856.58	
36	273-305	284.00	286.20	891.58	
37	238-270	249.00	251.20	926.58	
38	223-235	234.00	236.20	941.58	
39	193-220	214.00	216.20	961.58	204
40	178-190	189.00	191.20	986.58	
41	0-175	164.00	166.20	1011.58	
NOTE: all depths except for "true depth bgs" are measured along the borehole with no correction for borehole deviation.					
* MP = Westbay Multiport Casing, ags = above ground surface.					
* bgs = below ground surface, amsl = above mean sea level.					

Appendix B

**PRESSURE DATA,
GW-131 THROUGH GW-135**

WELL: GW-131						
Measurement zone #	11-Mar-90 Pressure (psi)	11-Mar-90 Calc. head amsl (ft)	3-May-90 Pressure (psi)	3-May-90 Calc. head amsl (ft)	5-8-Mar-91 Pressure (psi)	5-8-Mar-91 Calc. head amsl (ft)
1	450.0	941.64	443.50	923.41	440.39	916.51
2	438.3	929.88	434.10	916.78	431.19	910.30
3	415.9	912.98	415.40	908.47	416.00	910.38
4	406.4	913.07	405.80	908.40	406.41	910.35
5	399.8	912.84	399.30	908.43	399.91	910.58
6	394.1	924.92	389.00	909.70	390.21	913.20
7	380.1	911.63	380.20	908.54	381.46	911.95
8	367.3	911.87	367.10	908.50	367.85	910.50
9	366.4	925.02	362.10	912.04	390.71	914.83
10	349.2	924.12	345.30	912.35	347.70	918.23
11	324.3	911.68	323.70	907.97	324.72	909.99
12	309.2	911.84	308.60	907.87	309.49	910.08
13	302.4	911.16	301.90	907.40	302.91	909.78
14	287.2	911.10	286.70	907.34	287.71	909.76
15	264.5	910.73	264.10	907.54	265.16	909.92
16	258.2	911.20	257.60	907.61	259.66	912.15
17	242.3	910.44	242.40	907.65	243.96	911.01
18	231.9	930.52	227.20	918.04	251.64	920.30
19	215.4	927.70	212.40	918.87	217.09	928.95
20	209.7	929.32	206.20	919.61	210.70	929.26
21	190.5	920.26	189.80	916.87	192.80	922.97
22	189.2	922.03	188.50	918.91	192.42	927.09
23	182.3	921.34	182.10	919.15	186.79	929.00
24	174.0	921.96	173.20	918.82	176.69	925.76
25	163.0	921.82	162.30	918.61	165.81	925.71

WELL: GW-131		11-Mar-90 Pressure (psi)	11-Mar-90 Calc. head amsl (ft)	3-May-90 Pressure (psi)	3-May-90 Calc. head amsl (ft)	5-8-Mar-91 Pressure (psi)	5-8-Mar-91 Calc. head amsl (ft)
Measurement zone #							
26		157.4	923.67	155.80	918.70	159.03	925.07
27		148.8	921.99	148.40	918.70	151.57	925.10
28		138.3	921.61	137.50	918.75	140.74	924.91
29		132.5	923.69	131.00	918.91	134.87	926.43
30		115.7	919.94	115.60	918.47	119.35	925.67
31		95.6	920.11	94.70	917.45	97.53	922.32
32		86.9	920.04	86.00	917.43	88.88	922.20
33		76.1	920.13	75.10	917.37	77.98	922.17
34		65.1	919.98	64.20	918.55	67.18	922.18
35		56.1	919.22	55.60	917.77	58.72	922.70
36		45.3	920.23	45.20	918.87	48.20	923.44
37		42.2	927.16	41.80	926.00	45.73	932.65
38		36.9	930.00	36.40	928.61	40.68	935.97

psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

* psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

WELL: GW-132						
Measuremen zone #	30-Mar-90 Pressure (psi)	30-Mar-90 Calc. head amsl (ft)	26-Apr-90 Pressure (psi)	26-Apr-90 Calc. head amsl (ft)	4-Mar-91 Pressure (psi)	4-Mar-91 Calc. head amsl (ft)
1	252.50	1110.02	364.70	1132.13	366.93	1137.54
2	250.40	1094.42	358.30	1127.19	352.37	1113.52
3	236.90	1095.52	344.90	1127.34	339.15	1113.94
4	230.50	1096.02	338.60	1127.04	332.87	1113.98
5	215.60	1096.02	323.90	1127.09	255.38	1114.04
6	211.30	1096.12	319.60	1127.23	313.94	1113.95
7	196.40	1077.12	292.40	1098.18	286.39	1084.30
8	185.70	1062.72	264.20	1057.46	260.40	1048.61
9	170.70	1062.52	248.90	1056.46	244.98	1047.12
10	166.40	1062.72	244.60	1056.21	241.00	1047.83
11	234.60	1062.52	231.60	1055.68	227.93	1046.83
12	228.00	1061.92	225.00	1055.27	221.34	1046.32
13	209.40	1043.62	206.60	1037.36	205.31	1033.94
14	202.30	1041.82	199.00	1034.70	195.66	1026.39
15	185.10	1039.12	182.70	1033.59	181.34	1029.70
16	174.30	1038.92	172.00	1033.75	169.43	1026.90
17	163.70	1039.52	161.30	1033.79	160.44	1030.91
18	160.00	1045.52	155.10	1034.85	153.71	1030.14
19	138.00	1039.42	135.40	1034.06	134.95	1031.47
20	126.50	1038.02	124.10	1032.94	123.38	1029.63
21	115.70	1038.02	113.50	1033.60	113.26	1031.07
22	109.20	1038.32	106.90	1033.40	106.53	
23	84.30	1037.92	81.90	1032.61	81.40	1029.25
24	73.00	1036.82	71.10	1032.83	70.40	1028.87
25	57.60	1036.32	55.80	1032.55	27.08	
26	54.50	1034.22	53.60	1032.35	53.57	1029.90
27	43.30	1033.32	43.20		44.55	1034.22

• psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

* psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

WELL: GW-133						
Measurement zone #	27-Mar-90 Pressure (psi)	27-Mar-90 Calc. head amsl (ft)	25-Apr-90 Pressure (psi)	25-Apr-90 Calc. head amsl (ft)	21-Mar-91 Pressure (psi)	21-Mar-91 Calc. head amsl (ft)
1	256.1	1032.31	255.2	1031.66	253.76	1027.15
2	250.6	1029.49	252.3	1034.74	251.98	1032.84
3	249.3	1041.09	246.1	1035.26	245.22	1031.90
4	242.2	1039.50	239.8	1035.56	238.83	1031.82
5	229.8	1035.54	229.4	1035.97	229.17	1033.98
6	225.2	1039.78	223.1	1036.27	222.83	1034.11
7	216.8	1035.61	216.2	1035.22	214.76	1030.26
8	203.9	1036.35	203.7	1036.02	201.99	1030.35
9	201.8	1035.29	201.7	1036.31	201.54	1034.35
10	192.8	1031.41	193.2	1032.48	192.44	1023.46
10		1024.37	188.5	1032.48	185.28	1030.16
11	188.1	1045.19	181.9	1032.27	179.21	1024.32
12	179.7	1040.62	175.1	1031.38	173.81	1026.71
13	166.4	1029.99	166.4	1031.40	166.59	1029.91
14	163.5	1055.48	156.8	1041.20	151.27	1026.35
15	158.5	1053.29	149.1	1033.16	145.43	1022.87
16	147.5	1043.20	141.7	1031.21	137.88	1020.23
17	126.1	1028.89	126.1	1030.17	125.01	1025.42
18	121.2	1027.46	121.9	1030.53	122.25	1029.04
19	110.8	1028.54	110.6	1029.53	111.35	1028.91
20	97.4	1032.70	94.5	1027.51	94.62	1025.34
21	83.0	1025.10	82.4	1024.65	83.73	1025.17
22	76.7	1025.40	76.3	1026.63	77.62	1026.04
23	71.5	1028.23	67.8	1022.09	68.66	1020.47
24	52.5	1020.29	53.0	1021.23	53.47	1020.38
25	50.4	1020.44	50.7	1020.84	51.91	1021.71

psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

* psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

WELL: GW-134								
Measure- ment Zone #	19-Mar-90 Pressure (psi)	19-Mar-90 Calc. head amsl (ft)	19-Apr-90 Pressure (psi)	19-Apr-90 Calc. head amsl (ft)	18-Mar-90 Mar-91 Pressure (psi)	18-Mar-90 Mar-91 head amsl (ft)	17-Jul-91 Pressure (psi)	17-Jul-91 Calc. head amsl (ft)
1			352.40	999.63	350.12	991.13	350.98	992.93
2	350.7	998.73	349.30	996.92	343.08	979.38	346.83	987.97
3			341.30	996.96	332.21	972.91	336.87	983.41
4	335.4	999.83	334.00	998.49	326.29	977.60	329.9	985.80
5	324.1	997.33	323.20	996.63	318.80	983.53	320.61	987.47
6	318.7	998.83	317.50	997.28	319.67	999.36	319.5	998.83
7	304.6	998.86	304.00	998.76	305.66	999.64	305.01	997.91
8	287.8	1001.75	288.1/277.2	1004.34	288.59	1002.31	287.84	1000.50
9	277.9	1003.73	270.30	1002.40	276.53	998.21	275.16	994.83
10	271.2	1003.23	262.30	1002.56	270.45	1000.26	269.23	997.51
11	263.1	1007.83	256.60	1007.90	263.91	1008.70	260.13	1000.10
12	257.0	1008.83	245.30	1008.70	257.07	1007.17	255.04	1002.60
13	245.6	1007.93	239.30	1008.81	245.07	1005.30	243.78	1002.80
14	239.0	1007.93	225.00	1009.23	239.58	1007.03	239.99	1008.00
15	225.3	1009.13	221.30	1010.64	224.91	1007.06	225.42	1008.30
16	221.1	1009.03	209.60	1011.14	221.64	1009.21	221.79	1009.60
17	209.3	1006.20	198.80	1008.32	210.26	1007.23	209.96	1006.60
18	198.4	1005.68	192.90	1007.98	199.68	1007.00	199.28	1006.30
19	192.6	1006.63	186.20	1008.98	193.80	1008.22	193.42	1007.40
20	185.9	1006.03	174.10	1008.14	187.31	1007.76	186.83	1006.90
21	173.1	1000.93	166.50	1004.75	175.38	1004.84	174.35	1002.50
22	166.6	1000.43	155.00	1001.92	167.15	1000.64	167.07	1000.60
23	155.0	998.53	145.90	1000.11	155.78	998.97	155.81	999.23

WELL: GW-134								
Measure- ment Zone #	19-Mar-90 Pressure (psi)	19-Mar-90 Calc. head amsl (ft)	19-Apr-90 Pressure (psi)	19-Apr-90 Calc. head amsl (ft)	18-Mar-90 Mar-91 Pressure (psi)	18-Mar-90 Mar-91 head amsl (ft)	17-Jul-91 Pressure (psi)	17-Jul-91 Calc. head amsl (ft)
24	145.7	996.96	134.50	998.92	146.80	997.82	146.42	997.38
25	134.8	996.97	127.50	997.28	135.41	996.43	135.04	995.75
26	127.7	999.26	112.10	995.84	128.50	995.29	128.06	994.55
27	112.3	994.23	100.70	995.46	113.03	994.36	112.71	993.81
28	101.2	994.03	83.20	994.01	101.96	993.81	101.4	992.71
29	83.7	993.83	80.60	993.66	84.65	993.75	84.06	992.60
30	81.7	993.93	71.60	992.64	82.20	993.09	81.19	990.98
31	73.2	994.33	64.50	991.82	73.64	993.44	72.47	990.97
32	67.4	995.93	53.80	990.37	66.96	993.06	65.38	989.69
33	56.4	995.53	47.40	990.69	56.14	993.32	54.79	990.29
34	49.7	995.13	42.90	990.92	49.72	993.42	48.42	990.65
35	45.4	995.13	25.90	990.54	45.31	993.36	43.99	990.45
36	14.3	982.63	22.50	991.33	28.21	994.05	27.08	990.36
37	22.6				27.15	1001.74	26.94	1001.40

psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

* psi = pounds per square inch, calc. = calculated, amsl = above mean sea level, ft = feet

WELL: GW-135									
Measure ment Zone #	23-Mar-90 Pressure (psi)	23-Mar-90 Calc. head amsl (ft)	18-Apr-90 Pressure (psi)	18-Apr-90 Calc. head amsl (ft)	13-Mar-91 Pressure (psi)	13-Mar-91 Calc. head amsl (ft)	16-Jul-91 Pressure (psi)	16-Jul-91 Calc. head amsl (ft)	
1	476.6		471.70	999.26	460.03	969.75	461.63	969.57	
2	474.8	1015.58	468.90	997.59	456.26	966.15	459.78	970.46	
3	466.5	1016.48	460.40	997.88	445.09	960.72	450.76	970.07	
4	459.4	1020.68	455.40	1012.68	439.98	974.32	437.79	965.74	
5	444.2	1002.58	439.00	991.09	436.63	983.89	436.18	979.32	
6	429.1	989.68	426.00	983.04	427.80	985.65	424.69	975.37	
7	419.7	990.08	416.40	982.99	418.40	986.41	415.16	975.87	
8	404.2	989.38	401.10	982.85	402.97	986.28	399.9	976.53	
9	380.4	989.38	377.30	982.44	379.23	987.05	376.17	977.78	
10	366.1	996.48	360.70	983.41	363.32	990.52	361.11	984.09	
11	352.4	989.68	374.80	982.77	351.33	988.04	348.37	979.90	
12	348.0	990.08	344.80	982.53	346.93	987.94	344.02	979.88	
13	324.1	988.98	321.20	982.23	323.04	987.07	320.05	979.46	
14	314.1	1000.98	306.90	984.44	308.58	988.49	305.88	982.21	
15	296.2	989.78	293.10	982.59	295.25	987.92	292.38	981.34	
16	289.7	996.88	286.50	982.77	288.73	987.96	285.73	981.02	
17	274.4	989.68	271.40	982.22	273.57	988.07	270.58	981.28	
18	263.6	989.78	260.50	982.66	262.72	988.20	259.75	981.28	
19	250.5	989.38	247.50	982.77	249.75	988.08	246.77	981.35	
20	244.7	991.28	241.20	983.63	245.75	993.96	242.03	985.42	
21	227.4	1002.98	222.80	995.76	219.85	989.88	221.12	992.29	
22	216.3	1004.78	213.40	1003.92	215.90	1010.84	215.21	1008.53	
23	208.9	1016.08	208.60	1015.18	208.99	1016.78	209.07	1016.36	

Appendix C

**PURGING AND SAMPLING ACTIVITIES,
FY90 AND 91**

Core hole	Measurement zone	Sampled	Purging status gals purged/ gals recommended	Purge again
GW-131	1	•	OK	
GW-131	4	•	OK	
GW-131	8	•	OK	
GW-131	12		OK	
GW-131	15	•	OK	
GW-131	21	•	OK	
GW-131	24		OK	
GW-131	28		OK	
GW-131	32	•	OK	
GW-131	36		OK	
GW-132	1	•	OK	YES
GW-132	5	•	OK	
GW-132	9	•	OK	
GW-132	13	•	OK	
GW-132	17		1.4/25	
GW-132	21	•	OK	
GW-132	25		1.2/25	YES
GW-133	1	•	61/65	YES
GW-133	5	•	OK	
GW-133	8		3.5/27	
GW-133	10	•	OK	
GW-133	14		0.7/15	
GW-133	17	•	OK	
GW-133	21		11./27	
GW-133	24	•	OK	YES
GW-134	3	•	OK	
GW-134	5		7.2/27	
GW-134	11	•	OK	
GW-134	15		3.7/22	
GW-134	18	•	OK	
GW-134	21		OK	
GW-134	25	•	OK	
GW-134	29	•	OK	
GW-134	33	•	OK	
GW-134	35		OK	YES
GW-134	36		OK	
GW-135	3	••	OK	
GW-135	6	•	OK	
GW-135	11	•	OK	
GW-135	15		6.4/22	
GW-135	19	•	OK	
GW-135	23	•	30/36	
GW-135	26		OK	
GW-135	30	•	OK	
GW-135	34	•	OK	
GW-135	39	•	OK	

Appendix D

**WATER CHEMISTRY DATA
GW-131 THROUGH GW-135**

TABLE D-1
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-131

BOREHOLE	ANALYTE	UNITS	METHODS	ZONE 32 SAMPLE DATE 10-01-90		ZONE 24 SAMPLE DATE 06-25-91		ZONE 21 SAMPLE DATE 10-02-90		ZONE 21 RESAMPLE DATE 04-29-91	
				UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED
	Aluminum	mg/L	EPA-6010	0.02	<0.02	0.068	0.049	0.038	0.046	0.098	0.095
	Antimony	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Arsenic	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	0.056	<0.05	<0.05
	Barium	mg/L	EPA-6010	0.043	0.044	0.021	0.02	0.048	0.049	0.04	0.039
	Beryllium	mg/L	EPA-6010	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
	Boron	mg/L	EPA-6010	0.022	0.012	0.12	0.15	0.13	0.14	0.15	0.15
	Cadmium	mg/L	EPA-6010	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Cadmium	mg/L	EPA-7131	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium	mg/L	EPA-6010	34	34	360	350	190	190	250	240
	Chromium	mg/L	EPA-6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Chromium	mg/L	EPA-7191	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Cobalt	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Copper	mg/L	EPA-6010	0.015	<0.004	<0.004	<0.004	0.0094	0.0058	0.0050	0.0052
	Iron	mg/L	EPA-6010	0.3	0.031	0.5	0.12	0.52	0.084	0.14	0.10
	Lead	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Lead	mg/L	EPA-7421	<0.004	<0.004	0.0047	<0.004	<0.004	<0.004	<0.004	<0.004
	Magnesium	mg/L	EPA-6010	18	19	200	200	110	110	120	120
	Manganese	mg/L	EPA-6010	0.011	0.0092	0.025	0.019	0.052	0.054	0.037	0.044
	Mercury	mg/L	EPA-7470	INSUFF	<0.0002	<0.0004 h	<0.0004 h	<0.0002	0.0004	<0.0004	<0.0002
	Molybdenum	mg/L	EPA-6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nickel	mg/L	EPA-6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Potassium	mg/L	EPA-6010	0.79	0.73	17	16	7.8	7.5	9.0	8.8
	Selenium	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Silicon	mg/L	EPA-6010	3.3	2.0	5.3	4.9	4.4	3.9	4.2	4.1
	Silver	mg/L	EPA-6010	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Sodium	mg/L	EPA-6010	1.1	1.0	11	11	11	9.9	11	11
	Strontium	mg/L	EPA-6010	0.042	0.031	13	13	4.4	4.4	5.0	4.9
	Thorium	mg/L	EPA-6010	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	Vanadium	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Zinc	mg/L	EPA-6010	0.04	0.0099	<0.002	<0.002	0.037	0.0030	0.045	0.0022
	Alkalinity	mg/L	SM-403	173		148		251		263	
	Bicarbonate	mg/L	SM-403	173		148		251		263	
	Carbonate	mg/L	SM-403	<1	<1	<1	<1	<1	<1	<1	<1
	Chloride IC	mg/L	EPA-300	2	<10	<10		11		7	
	Fluoride FIA	mg/L	EPA-300	0.2	2.1	2.1		1.3		1.5	
	Nitrate	mg/L	EPA-400	2	<10	<10		<10		<100	
	Sulfate	mg/L	EPA-300	4	1905	1905		1600		1120	
	Conductivity	umho/cm	EPA-120.1	290		2275		1210		1460	
	Temperature	Deg C	EPA-170.1	19.8		18		19.1		20.7	
	pH		EPA-150.1	7.9		7.3		7.5		7.4	

h holding time exceeded
INSUFF insufficient sample

TABLE D-1 cont.
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-131

BOREHOLE	UNITS	METHODS	ZONE 15		ZONE 12		ZONE 08		ZONE 04		ZONE 01	
			UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED
			ZONE 15	ZONE 15	ZONE 12	ZONE 12	ZONE 08	ZONE 08	ZONE 04	ZONE 04	ZONE 01	ZONE 01
			SAMPLE DATE 10-01-90	SAMPLE DATE 10-01-90	SAMPLE DATE 06-24-91	SAMPLE DATE 06-24-91	SAMPLE DATE 10-09-90	SAMPLE DATE 10-09-90	SAMPLE DATE 10-09-90	SAMPLE DATE 10-09-90	SAMPLE DATE 10-10-90	SAMPLE DATE 10-10-90
Aluminum	mg/L	EPA-6010	0.13	0.030	<0.020	<0.02	0.044	0.23	0.13	0.03	0.053	0.047
Antimony	mg/L	EPA-6010	<0.05	<0.050	<0.050	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	mg/L	EPA-6010	0.088	0.085	<0.050	<0.05	<0.05	0.075	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	EPA-6010	0.044	0.042	0.046	0.043	0.037	0.035	0.055	0.05	0.028	0.027
Beryllium	mg/L	EPA-6010	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Boron	mg/L	EPA-3010	0.13	0.11	0.13	0.11	0.42	0.42	0.084	0.1	0.13	0.13
Cadmium	mg/L	EPA-6010	<0.003	<0.003	<0.003	<0.003	<0.003	0.023	0.016	<0.003	<0.003	<0.003
Cadmium	mg/L	EPA-7131	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	mg/L	EPA-6010	70	62	37	36	43	35	67	61	71	65
Chromium	mg/L	EPA-6010	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	EPA-7191	0.011	<0.010	<0.010	<0.01	<0.01	0.038	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	EPA-6010	0.038	0.026	<0.004	<0.004	0.02	0.017	0.072	0.16	0.099	0.019
Iron	mg/L	EPA-6010	2.0	0.047	1.1	0.12	1.2	0.20	2.5	0.13	0.97	0.41
Lead	mg/L	EPA-6010	<0.050	<0.050	0.11	0.050	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead	mg/L	EPA-7421	0.019	<0.004	0.0075	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Magnesium	mg/L	EPA-6010	35	34	31	30	25	26	35	35	36	34
Manganese	mg/L	EPA-6010	0.042	0.028	0.035	0.024	0.040	0.030	0.036	0.025	0.16	0.13
Mercury	mg/L	EPA-7470	<0.0002	<0.0002	<0.0004 h	<0.0004 h	INSUFF	<0.0002	<0.0002	<0.0002	<0.0002	0.00025
Molybdenum	mg/L	EPA-6010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	mg/L	EPA-6010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	0.015	<0.01	<0.01	<0.01
Potassium	mg/L	EPA-6010	2.3	2.3	3.0	3.0	4.5	4.1	3.8	2.3	6.2	5.9
Selenium	mg/L	EPA-6010	<0.050	<0.05	<0.05	<0.05	<0.05	0.052	<0.05	<0.05	<0.05	<0.05
Silicon	mg/L	EPA-6010	3.9	3.6	4.8	4.4	4.5	4.7	3.7	3.7	5.2	5.0
Silver	mg/L	EPA-6010	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Sodium	mg/L	EPA-6010	20	18	40	41	110	110	26	31	88	83
Strontium	mg/L	EPA-6010	1.7	1.6	2.3	2.3	3.6	3.4	1.3	1.4	1.2	1.2
Thorium	mg/L	EPA-6010	<0.20	<0.20	<0.20	<0.2	<0.2	<0.2	<0.2	<0.20	<0.2	<0.2
Vanadium	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	mg/L	EPA-6010	0.053	0.0047	<0.002	<0.002	0.13	0.026	0.36	0.01	0.019	0.013
Alkalinity	mg/L	SM-403	242	256	256	257	257	280	280	323	323	323
Bicarbonate	mg/L	SM-403	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate	mg/L	EPA-300	19	25	25	85	85	16	16	24	24	24
Chloride IC	mg/L	EPA-300	0.5	0.9	0.9	<5	<5	0.3	0.3	0.5	0.5	0.5
Fluoride FIA	mg/L	EPA-400	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nitrate	mg/L	EPA-300	93	58	107	107	107	94	94	189	189	189
Sulfate	mg/L	EPA-120.1	650	650	650	800	800	800	800	820	820	820
Conductivity	umho/cm	EPA-170.1	21.6	20.3	20.3	20.4	20.4	24.5	24.5	21	21	21
Temperature	Deg C	EPA-150.1	7.8	7.3	7.3	7.60	7.60	7.50	7.50	7.42	7.42	7.42
pH												

h - holding time exceeded
INSUFF - insufficient sample

BOREHOLE GW-132		ZONE 21		ZONE 21		ZONE 13		ZONE 09		ZONE 05		ZONE 01	
ANALYTE		UNFILT.		FILTERED		UNFILT.		UNFILT.		UNFILT.		UNFILT.	
METHODS		SAMPLE DATE 10-12-90		SAMPLE DATE 10-12-90		SAMPLE DATE 10-12-90		SAMPLE DATE 10-16-90		SAMPLE DATE 10-07-90		SAMPLE DATE 10-70-90	
UNITS		UNFILT.		FILTERED		UNFILT.		UNFILT.		UNFILT.		UNFILT.	
Aluminum	mg/L	0.20	0.020	0.050	0.050	0.37	0.050	0.22	0.15	0.24	0.20	0.44	0.047
Antimony	mg/L	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Arsenic	mg/L	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Barium	mg/L	0.038	0.042	1.2	1.2	0.028	1.2	0.020	0.015	0.050	0.041	0.018	0.018
Beryllium	mg/L	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030	0.00030
Boron	mg/L	0.11	0.27	0.30	0.30	0.28	0.30	1.5	0.57	1.4	1.5	0.52	0.57
Cadmium	mg/L	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0032	0.0040	0.0030	0.0030
Cadmium	mg/L	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Calcium	mg/L	1.3	1.6	29	29	0.57	29	0.58	0.51	0.69	0.82	0.30	0.50
Chromium	mg/L	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Chromium	mg/L	0.010	0.014	0.010	0.010	0.010	0.010	0.010	0.010	0.012	0.010	0.01	0.01
Cobalt	mg/L	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Copper	mg/L	0.0073	0.012	0.017	0.016	0.017	0.016	0.016	0.015	0.042	0.011	0.028	0.0040
Iron	mg/L	1.4	0.13	1.0	0.17	1.0	0.17	0.34	0.16	0.18	0.099	0.54	0.090
Lead	mg/L	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.052	0.050	0.050	0.050	0.050
Lead	mg/L	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Magnesium	mg/L	0.17	0.22	0.10	0.062	0.10	0.062	0.067	0.057	0.089	0.11	0.072	0.092
Manganese	mg/L	0.017	0.012	0.019	0.062	0.019	0.062	0.010	0.0054	0.010	0.0075	0.011	0.0041
Mercury	mg/L	0.0002	0.0002	INSUFF	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0004	0.0002	0.00057
Molybdenum	mg/L	0.014	0.013	0.030	0.033	0.030	0.033	0.010	0.010	0.010	0.010	0.011	0.010
Nickel	mg/L	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.024	0.010	0.010
Potassium	mg/L	0.88	0.70	0.85	1.2	0.85	1.2	0.80	0.81	0.83	0.96	1.1	0.96
Selenium	mg/L	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Silicon	mg/L	1.4	4.9	4.4	5.5	4.4	5.5	6.7	1.8	7.5	7.1	3.7	6.6
Silver	mg/L	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
Sodium	mg/L	120	110	130	140	130	140	140	140	130	120	140	140
Strontium	mg/L	0.034	0.045	0.020	1.1	0.020	1.1	0.018	0.019	0.019	0.024	0.017	0.017
Thorium	mg/L	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Vanadium	mg/L	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Zinc	mg/L	0.020	0.0010	0.013	0.0084	0.013	0.0084	0.017	0.015	0.029	0.031	0.038	0.0089
Alkalinity	mg/L	267	267	230	230	230	230	250	246	246	246	303	303
Bicarbonate	mg/L	199	199	202	202	202	202	190	218	218	218	251	251
Carbonate	mg/L	68	68	28	60	28	60	60	28	28	28	52	52
Chloride IC	mg/L	1	1	1	1	1	1	1	1	1	1	1	1
Fluoride FIA	mg/L	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.6	1.0	1.0
Nitrate	mg/L	1	1	1	1	1	1	1	1	1	1	1	1
Sulfate	mg/L	12	12	12	12	12	12	12	11	11	11	25	25
Conductivity	umho/cm	475	475	503	435	503	435	435	500	500	500	490	490
Temperature	Deg C	21.1	21.1	24.5	19.2	24.5	19.2	19.2	24.0	24.0	24.0	14.2	14.2
pH		9.60	9.60	9.60	9.4	9.60	9.4	9.4	9.4	9.4	9.4	9.2	9.2

h - holding time exceeded

INSUFF - Insufficient sample

TABLE D-3
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-133

BOREHOLE	GW-133	ANALYTES	UNITS	METHODS	ZONE 24		ZONE 17		ZONE 10		ZONE 05		ZONE 01	
					UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED
					ZONE 24 SAMPLE DATE 12-28-90	ZONE 17 SAMPLE DATE 12-10-90	ZONE 10 SAMPLE DATE 12-20-90	ZONE 05 SAMPLE DATE 12-20-90	ZONE 01 SAMPLE DATE 01-09-91					
Aluminum	mg/L	EPA 6010	0.21	<0.02	13	0.72	1.1	0.30	2.2	0.51	13	1.8		
Antimony	mg/L	EPA 6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	mg/L	EPA 6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	EPA 6010	0.45	0.46	0.34	0.049	0.062	0.028	0.33	0.033	0.34	0.049	0.34	0.049
Beryllium	mg/L	EPA 6010	<0.0003	<0.0003	0.00049	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Boron	mg/L	EPA 6010	0.0047	0.077	0.27	0.29	0.18	0.18	0.21	0.21	0.19	0.21	0.19	0.21
Cadmium	mg/L	EPA 6010	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cadmium	mg/L	EPA-7131	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	mg/L	EPA 6010	20	21	4.4	1.6	1.0	0.89	1.3	1.3	19	1.6	<0.005	<0.005
Chromium	mg/L	EPA 6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	EPA-7191	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	EPA 6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	3.4	0.48	3.4	0.48
Copper	mg/L	EPA 6010	0.0078	<0.004	0.0095	0.0047	<0.0077	0.0052	0.0055	0.01	0.31	0.022	0.31	0.022
Iron	mg/L	EPA 6010	0.42	0.12	13	1.1	1.9	0.45	2.7	0.89	<0.0002	0.0003	<0.0002	0.0003
Lead	mg/L	EPA 6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	0.13	0.11	0.13
Lead	mg/L	EPA-7421	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.017	<0.01	0.017	<0.01
Magnesium	mg/L	EPA 6010	5.1	5.5	2.5	0.41	0.39	0.20	0.6	0.30	4.1	1.8	4.1	1.8
Manganese	mg/L	EPA 6010	0.026	0.023	0.13	0.02	0.018	0.0048	0.037	0.016	<0.005	<0.05	<0.005	<0.05
Mercury	mg/L	EPA-7470	0.00043	0.00021	<0.0002	0.00052	<0.0002	<0.0002	<0.0002	<0.0002	19	4.4	<0.0002	4.4
Molybdenum	mg/L	EPA 6010	<0.01	0.014	0.050	0.051	<0.01	0.042	0.017	<0.014	<0.006	<0.006	<0.006	<0.006
Nickel	mg/L	EPA 6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	280	290	280	290
Potassium	mg/L	EPA 6010	2.3	2.2	5.0	1.2	1.2	0.94	1.2	0.87	0.12	0.063	0.12	0.063
Selenium	mg/L	EPA 6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.2
Silicon	mg/L	EPA 6010	11	11	21	4.1	7.0	5.5	8.9	6.0	0.013	<0.005	0.013	<0.005
Silver	mg/L	EPA 6010	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.24	0.024	0.24	0.024
Sodium	mg/L	EPA 6010	55	52	170	170	170	170	180	180	614	290	614	290
Strontium	mg/L	EPA 6010	0.39	0.4	0.089	0.048	0.042	0.035	0.038	0.034	0.12	0.063	0.12	0.063
Thorium	mg/L	EPA 6010	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.20	0.20	0.20	0.20
Vanadium	mg/L	EPA 6010	<0.005	<0.005	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	0.013	0.0050	0.013	0.0050
Zinc	mg/L	EPA 6010	0.011	0.0087	0.063	0.0097	0.029	0.0094	0.019	0.017	0.24	0.024	0.24	0.024
Alkalinity	mg/L	SM-403	184		386		385		404		614		614	
Bicarbonate	mg/L	SM-403	184		312		287		304		542		542	
Carbonate	mg/L	SM-403	<1		74		98		100		72		72	
Chloride IC	mg/L	EPA-300	5		1		1		1		6		6	
Fluoride FIA	mg/L	EPA-340.2	0.3		2.0		1.2		1.4		5.6		5.6	
Nitrate	mg/L	EPA-400	<1		<1		<1		<1		1		1	
Sulfate	mg/L	EPA-300	7		14		595		20		56		56	
Conductivity	umho/cm	EPA-120.1	325		630		14		675		910		910	
Temperature	Deg C	EPA-170.1	17.4		17.8		14.8		14.4		14.3		14.3	
pH		EPA-150.1	8.1		9.2		9.4		9.3		9.0		9.0	

TABLE D-4
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-13

BOROHOLE GW-134												
ANALYTE	UNITS	METHODS	ZONE 33		ZONE 33		ZONE 29		ZONE 29		ZONE 25	
			UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED		
Aluminum	mg/L	EPA-6010	0.13	0.084			0.14	0.031	0.073			<0.02
Antimony	mg/L	EPA-6010	<0.05	<0.05			<0.05	<0.05	<0.05			<0.05
Arsenic	mg/L	EPA-6010	<0.05	<0.05			<0.05	<0.05	<0.05			<0.05
Barium	mg/L	EPA-6010	0.57	0.59			0.035	0.032	0.13			0.12
Beryllium	mg/L	EPA-6010	<0.0003	<0.0003			<0.0003	<0.0003	<0.0003			<0.0003
Boron	mg/L	EPA-6010	0.16	0.18			1.3	1.3	1.3			1.2
Cadmium	mg/L	EPA-6010	<0.003	<0.003			<0.003	<0.003	<0.003			<0.003
Cadmium	mg/L	EPA-7131	<0.002	<0.002			<0.002	<0.002	<0.002			<0.002
Calcium	mg/L	EPA-6010	280	280			1.5	1.4	4.0			3.9
Chromium	mg/L	EPA-6010	<0.01	<0.01			0.021	<0.01	0.010			0.010
Chromium	mg/L	EPA-7191	<0.01	<0.01			<0.01	<0.01	<0.01			<0.01
Chromium	mg/L	EPA-6010	<0.005	<0.005			<0.005	<0.005	<0.005			<0.005
Cobalt	mg/L	EPA-6010	<0.004	<0.004			<0.004	<0.004	0.0053			<0.004
Copper	mg/L	EPA-6010	0.032	0.0053			0.23	0.039	0.22			0.048
Iron	mg/L	EPA-6010	<0.05	<0.05			<0.05	<0.05	<0.05			<0.05
Lead	mg/L	EPA-7421	<0.004	<0.004			<0.004	<0.004	<0.004			<0.004
Lead	mg/L	EPA-6010	54	56			0.35	0.30	0.94			0.94
Magnesium	mg/L	EPA-6010	0.093	0.092			0.0039	0.0026	0.0058			0.0045
Manganese	mg/L	EPA-7470	<0.0002	<0.0004			<0.0002	<0.0002	<0.0002			<0.0002
Mercury	mg/L	EPA-6010	<0.01	<0.01			<0.01	<0.01	<0.017			<0.016
Molybdenum	mg/L	EPA-6010	<0.01	<0.01			0.011	<0.01	<0.01			<0.01
Nickel	mg/L	EPA-6010	7.0	7.4			1.6	1.4	3.2			3.2
Potassium	mg/L	EPA-6010	<0.05	<0.05			<0.05	<0.05	<0.05			<0.05
Selenium	mg/L	EPA-6010	5.0	5.3			2.9	2.7	3.0			2.7
Silicon	mg/L	EPA-6010	<0.006	<0.006			<0.006	<0.006	<0.006			<0.006
Silver	mg/L	EPA-6010	92	96			180	180	500			500
Sodium	mg/L	EPA-6010	1.4	1.4			0.10	0.096	0.37			0.36
Strontium	mg/L	EPA-6010	<0.2	<0.2			<0.2	<0.2	<0.2			<0.2
Thorium	mg/L	EC-1910			0.001							
Uranium Fluorometric	mg/L	EPA-6010	<0.005	<0.005			<0.005	<0.005	<0.005			<0.005
Vanadium	mg/L	SM-403	202				334		588			
Alkalinity	mg/L	SM-403	202				278		562			
Bicarbonate	mg/L	SM-403	<1				56		52			
Carbonate	mg/L	EPA-300	15				3		25			
Chloride IC	mg/L	EPA-340.2	0.2				0.2		6.2			
Fluoride FIA	mg/L	EPA-400	1340				76		616			
Nitrate	mg/L	EPA-300	11				8		54			
Sulfate	mg/L	EPA-120.1	1860				610		1790			
Conductivity	umho/cm	EPA-170.1	15.1				13.8		13.7			
Temperature	Deg C	EPA-150.1	7.00				8.80		8.70			
Ph												

TABLE D-4 cont.
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-134

BOREHOLE GW-134	ANALYTE	UNITS	METHODS	ZONE 18		ZONE 18		ZONE 11		ZONE 3		ZONE 3	
				UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED
				SAMPLE DATE 01-28-91	SAMPLE DATE 05-29-91	SAMPLE DATE 01-31-91	SAMPLE DATE 02-02-91	SAMPLE DATE 05-30-91					
	Aluminum	mg/L	EPA-6010	0.067	0.070	0.13	0.02	0.22	0.059				
	Antimony	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				
	Arsenic	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				
	Barium	mg/L	EPA-6010	1.5	1.5	0.28	0.19	3.0	2.8				
	Beryllium	mg/L	EPA-6010	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003				
	Boron	mg/L	EPA-6010	0.52	0.51	0.46	0.44	0.42	0.41				
	Cadmium	mg/L	EPA-6010	<0.003	<0.003	0.0044	<0.003	<0.003	<0.003				
	Cadmium	mg/L	EPA-7131	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002				
	Calcium	mg/L	EPA-6010	63	63	14	15	140	130				
	Chromium	mg/L	EPA-6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				
	Chromium	mg/L	EPA-7191	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				
	Cobalt	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
	Copper	mg/L	EPA-6010	0.061	0.058	0.041	0.023	0.087	0.084				
	Iron	mg/L	EPA-6010	0.39	0.26	0.61	0.12	0.84	<0.004				
	Lead	mg/L	EPA-6010	<0.05	<0.05	<0.05	<0.05	0.005	<0.05				
	Lead	mg/L	EPA-7421	<0.004	<0.004	<0.004	<0.004	<0.05	0.0052				
	Magnesium	mg/L	EPA-6010	14	14	4.0	3.9	38	38				
	Manganese	mg/L	EPA-6010	0.025	0.023	0.014	0.014	0.052	0.042				
	Mercury	mg/L	EPA-7470	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002				
	Molybdenum	mg/L	EPA-6010	<0.01	<0.01	0.015	0.016	0.02	0.02				
	Nickel	mg/L	EPA-6010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				
	Potassium	mg/L	EPA-6010	9.7	9.7	4.1	4.1	11	11				
	Selenium	mg/L	EPA-6010	0.13	0.13	0.063	0.051	0.14	0.13				
	Silicon	mg/L	EPA-6010	1.8	1.8	2.3	2.6	2.6	2.8				
	Silver	mg/L	EPA-6010	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006				
	Sodium	mg/L	EPA-6010	1900	1900	800	760	2600	2600				
	Strontium	mg/L	EPA-6010	5.9	6.0	1.3	1.2	13	13				
	Thorium	mg/L	EPA-6010	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2				
	Uranium Fluorometric	mg/L	EC-1910			0.001							<0.001
	Vanadium	mg/L	EPA-6010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
	Alkalinity	mg/L	SM-403	175		557		164					
	Bicarbonate	mg/L	SM-403	175		557		164					
	Carbonate	mg/L	SM-403	<2		<1		<1					
	Chloride IC	mg/L	EPA-300	<100		30		3370					
	Fluoride FIA	mg/L	EPA-340.2	1.7		5.9		2.2					
	Nitrate	mg/L	EPA-400	5520		1780		3070					
	Sulfate	mg/L	EPA-300	<100		50		105					
	Conductivity	umho/cm	EPA-120.1	8005		3225		11100					12000
	Temperature	Deg C	EPA-170.1	18.2		15.1		13.7					21.0
	Ph		EPA-150.1	7.70		7.90		7.20					

TABLE D-5
INORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-135

BOREHOLE GW-135		INORGANIC ANALY									
		ZONE 39 SAMPLE DATE 05-03-91	ZONE 34 SAMPLE DATE 05-03-91	ZONE 30 SAMPLE DATE 05-06-91	ZONE 23 SAMPLE DATE 05-07-91	ZONE 19 SAMPLE DATE 05-09-91	ZONE 11 SAMPLE DATE				
		UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED	UNFILT.	FILTERED
Aluminum	mg/L	0.021	0.030	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	0.096	0.088	0.67	0.58	0.60	0.60	0.60	0.60	0.60	0.60
Beryllium	mg/L	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Boron	mg/L	0.010	0.022	0.0092	0.031	0.025	0.025	0.025	0.025	0.025	0.025
Cadmium	mg/L	<0.003	<0.003	0.0059	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	mg/L	28	28	33	32	32	32	32	32	32	32
Chromium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	<0.004	<0.004	0.013	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Iron	mg/L	0.19	0.094	0.1	0.013	0.044	0.044	0.044	0.044	0.044	0.044
Lead	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Lead	mg/L	17	17	20	20	22	22	22	22	22	22
Magnesium	mg/L	0.067	0.046	<0.001	<0.001	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Manganese	mg/L	0.0042	<0.0004	0.00086	0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Mercury	mg/L	0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	mg/L	<0.01	0.019	0.017	<0.01	0.016	0.016	0.016	0.016	0.016	0.016
Nickel	mg/L	0.60	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Potassium	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	3.2	3.2	3.3	3.0	3.4	3.4	3.4	3.4	3.4	3.4
Silicon	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Silver	mg/L	0.58	0.52	0.37	0.56	0.45	0.45	0.45	0.45	0.45	0.45
Sodium	mg/L	0.011	0.0095	0.017	0.016	0.047	0.047	0.047	0.047	0.047	0.047
Strontium	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Thorium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium	mg/L	0.023	0.024	0.022	0.017	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080
Zinc	mg/L	150	150	150	150	177	177	177	177	177	177
Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate	mg/L	2	2	2	2	2	2	2	2	2	2
Carbonate	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloride IC	mg/L	2	2	2	2	2	2	2	2	2	2
Fluoride FIA	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate	mg/L	1	1	1	1	1	1	1	1	1	1
Sulfate	mg/L	2	2	2	2	2	2	2	2	2	2
Conductivity	umho/cm	265	265	295	295	280	280	280	280	280	280
Temperature	Deg C	20.2	20.2	19.7	19.7	17.1	17.1	17.1	17.1	17.1	17.1
pH		8.0	8.0	8.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4

h - holding time exceeded
INSUFF - Insufficient sample

TABLE D-5 cont.
 'SES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-135

BOREHOLE GW-135		ZONE 06		ZONE 06		ZONE 03		ZONE 03		ZONE 03	
		UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED	UNFLT.	FILTERED
		05-15-01	05-17-91	05-17-91	05-17-91	05-17-91	05-17-91	05-17-91	05-17-91	07-16-91	07-16-91
Aluminum	mg/L	0.038	0.073	0.082	0.082	0.073	0.082	0.073	0.082	0.073	0.082
Antimony	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	mg/L	0.033	0.037	0.03	0.03	0.037	0.03	0.034	0.032	0.048	0.047
Beryllium	mg/L	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0031	<0.0003
Boron	mg/L	0.47	0.77	0.84	0.84	0.77	0.84	2.8	2.8	3.1	3.2
Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	mg/L	200	340	320	320	1400	1300	1500	1500	1500	1500
Chromium	mg/L	0.021	0.019	0.029	0.029	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	0.005	0.019	0.012	0.012	<0.04	<0.04	0.52	0.52	0.52	0.055
Iron	mg/L	0.46	3.1	0.31	0.31	4.5	1.5	5.6	5.6	4.6	4.6
Lead	mg/L	<0.05	<0.05	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Lead	mg/L	<0.004	<0.004	0.067	0.067	0.4	0.34	<0.004	<0.004	<0.004	<0.004
Magnesium	mg/L	58	100	110	110	420	420	470	470	480	480
Manganese	mg/L	0.029	0.11	0.11	0.11	0.052	0.046	0.098	0.098	0.098	0.098
Mercury	mg/L	<0.0004	0.0005	<0.0004	<0.0004	0.00046	<0.0004	0.0004	0.0004	<0.0004	<0.0004
Molybdenum	mg/L	0.013	0.016	0.011	0.011	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/L	0.01	0.017	0.042	0.042	<0.1	<0.1	0.25	0.25	<0.1	<0.1
Potassium	mg/L	2.7	7.1	6.9	6.9	66	61	64	64	65	65
Selenium	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5
Silicon	mg/L	3.7	3.5	3.3	3.3	3.9	3.5	4.1	4.1	4.5	4.5
Silver	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Sodium	mg/L	32	510	510	510	9300	9500	9300	9300	9200	9200
Strontium	mg/L	3.6	2.4	2.4	2.4	22	22	27	27	28	28
Thorium	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<2	<2	<2	<2
Vanadium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05	<0.05
Zinc	mg/L	0.0045	0.88	0.0099	0.0099	0.28	0.097	0.52	0.52	0.25	0.25
Alkalinity	mg/L	160	160	160	160	97	86	86	86	86	86
Bicarbonate	mg/L	<1	<1	<1	<1	1	1	<1	<1	<1	<1
Carbonate	mg/L	580	580	580	580	153800	153800	16490	16490	0.9P	0.9P
Chloride IC	mg/L	0.4	0.4	0.4	0.4	1.0	1.0	0.9P	0.9P	135P	135P
Fluoride FIA	mg/L	<10	<10	<10	<10	1312	1312	325	325	44000	44000
Nitrate	mg/L	1623	1623	1623	1623	459	459	325	325	22.3	22.3
Sulfate	mg/L	3225	3225	3225	3225	21.0	21.0	6.4	6.4	6.4	6.4
Conductivity	umho/cm	20.6	20.6	20.6	20.6	7.4	7.4	7.4	7.4	7.4	7.4
Temperature	Deg C	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
pH											

h - holding time exceeded
 INSUFF. - Insufficient sample

TABLE D-6
VOLATILE ORGANIC ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-134

ANALYTE	UNITS	METHOD	ZONE 33	ZONE 18	ZONE 3	TRIP BLANK
1,1,1-Trichloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,1,2,2-Tetrachloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,1,2-Trichloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,1-Dichloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,1-Dichloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,2-Dichloroethane	ug/L	ACD-2440	<5	<5	<5	<5
1,2-Dichloroethane (total)	ug/L	ACD-2440	6	<5	<5	<5
1,2-Dichloropropane	ug/L	ACD-2440	<5	<10	<5	<10
2-Butanone	ug/L	ACD-2440	<10	<10	<5	<10
2-Hexanone	ug/L	ACD-2440	<10	<10	<5	<10
4-Methyl-2-pentanone	ug/L	ACD-2440	<10	<10	<5	<10
Acetone	ug/L	ACD-2440	<10	<5	<5	<5
Benzene	ug/L	ACD-2440	<5	<5	<5	<5
Bromodichloromethane	ug/L	ACD-2440	<5	<5	<5	<5
Bromoforn	ug/L	ACD-2440	<10	<10	<5	<10
Bromomethane	ug/L	ACD-2440	<5	<5	<5	<5
Carbon Disulfide	ug/L	ACD-2440	<5	<5	<5	<5
Carbon Tetrachloride	ug/L	ACD-2440	<5	<5	<5	<5
Chlorobenzene	ug/L	ACD-2440	<10	<10	<5	<10
Chloroethane	ug/L	ACD-2440	<10	<5	<5	2J
Chloroform	ug/L	ACD-2440	3J	<5	<5	<10
Chloromethane	ug/L	ACD-2440	<10	<5	<5	<5
Dibromochloromethane	ug/L	ACD-2440	<5	<5	<5	<5
Ethylbenzene	ug/L	ACD-2440	<5	<5	<5	18B
Methylene Chloride	ug/L	ACD-2440	16B	<5	<5	<5
Styrene	ug/L	ACD-2440	<5	<5	<5	<5
Tetrachloroethane	ug/L	ACD-2440	6	<5	<5	<5
Toluene	ug/L	ACD-2440	<5	<5	<5	<5
Trichloroethene	ug/L	ACD-2440	54	<5	<5	<10
Vinyl Acetate	ug/L	ACD-2440	<10	<10	<5	<10
Vinyl Chloride	ug/L	ACD-2440	<10	<5	<5	<5
Xylene (total)	ug/L	ACD-2440	<5	<5	<5	<5
cis-1,3-Dichloropropene	ug/L	ACD-2440	<5	<5	<5	<5
trans-1,3-Dichloropropene	ug/L	ACD-2440	<5	<5	<5	<5

B - Analyte detected in Trip Blank

J - Analytical result is less than Quantitation limit for method

TABLE D-7
 RADIONUCLIDE ANALYSES FOR GROUNDWATER SAMPLES FROM SELECTED ZONES IN BOREHOLE GW-134

GW-134		SAMPLE DATE: 05-29-91		ZONE 33		ZONE 18		ZONE 03	
ANALYTE	UNITS	METHOD	CONC.	2 SIGMA	CONC.	2 SIGMA	CONC.	2 SIGMA	
Strontium-90	pCi/L	EC-134	61.50	37.0	61.70	37.0	81.20	38.0	
Technetium-99	pCi/L	TP-1628	5.22E+03	1.7E+03	1.84E+03	1.6E+03	1.68E+03	1.6E+03	
Thorium-232	pCi/L	TP-1635	0.00	1.4	40.90	58.0	0.00	75.0	
Thorium-234	pCi/L	TP-1635	-1.68E+02	6.3E+02	1.80E+03	3.5E+02	1.07E+03	3.3E+02	

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