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## Geochemistry of Formation Waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary Data from the Rock Cover (RC) Wells

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Environmental Sciences Division  
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ORNL/RAP-5

ENVIRONMENTAL SCIENCES DIVISION

**GEOCHEMISTRY OF FORMATION WATERS IN THE LOWER  
CONASAUGA GROUP AT THE NEW HYDROFRACTURE FACILITY:  
PRELIMINARY DATA FROM THE ROCK COVER (RC) WELLS**

John Switek, C. Stephen Haase, and Stephen H. Stow

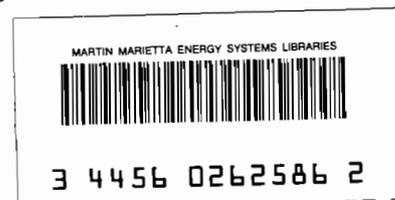
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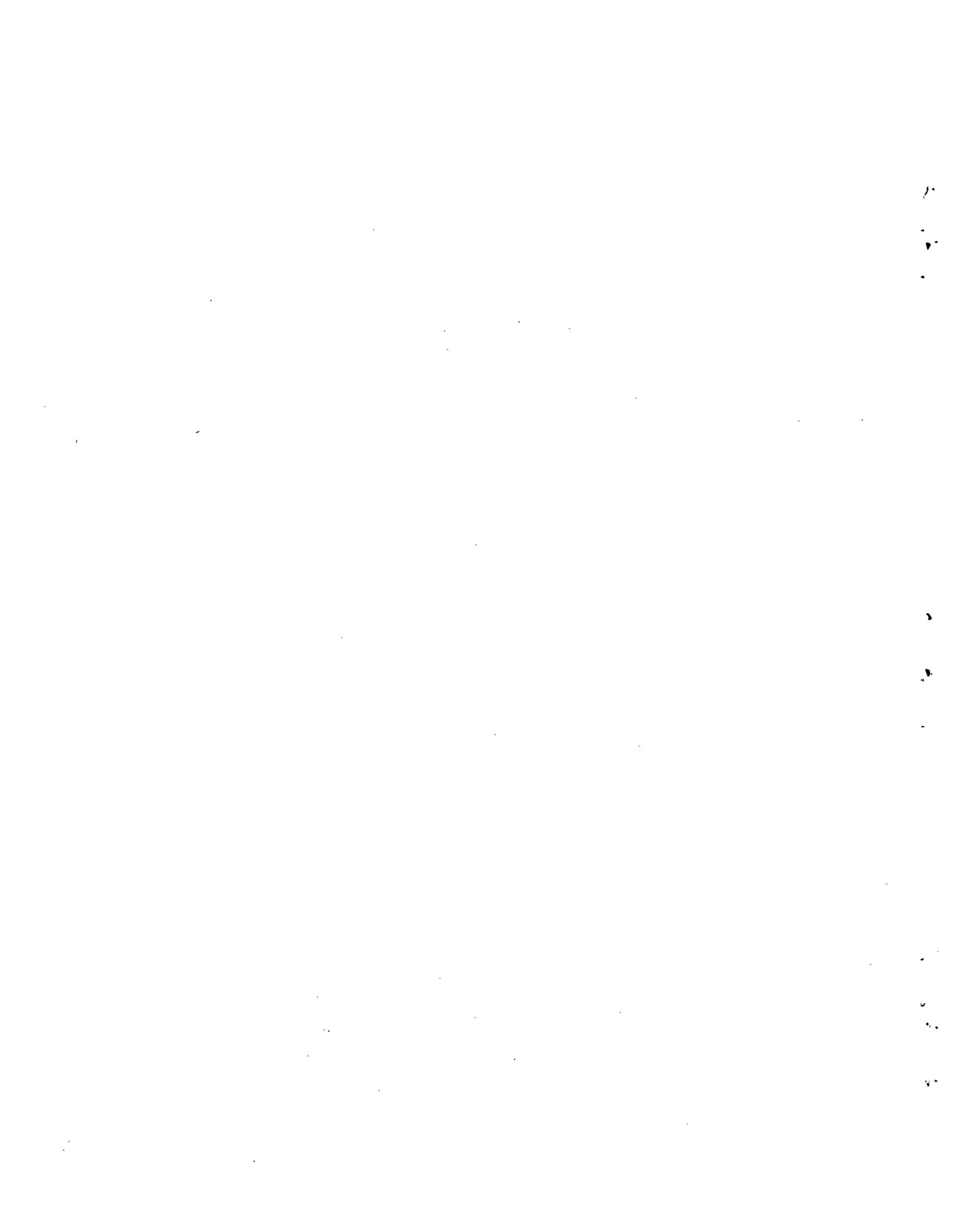
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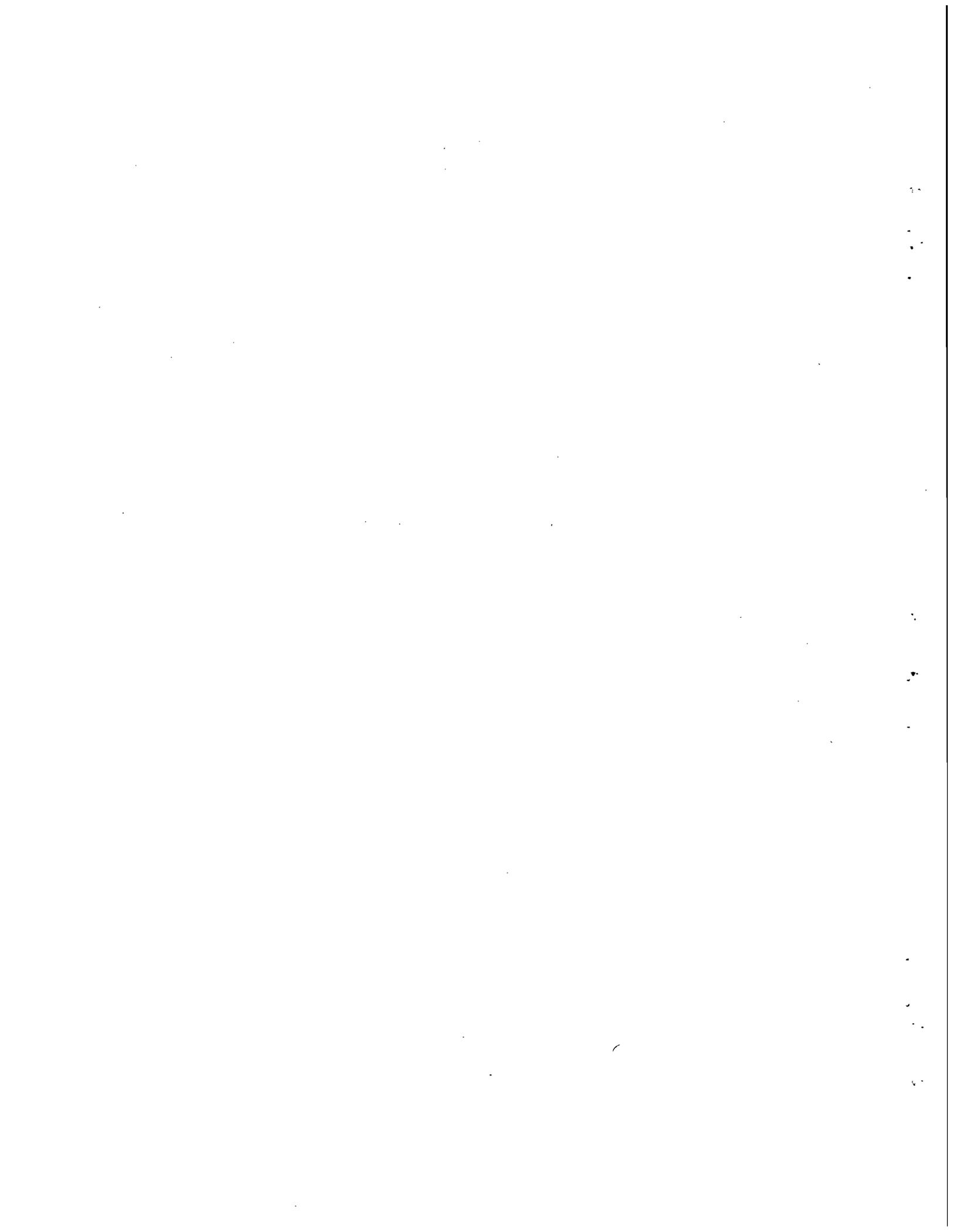
## ABSTRACT

J. Switek, C. S. Haase, and S. H. Stow. 1987. Geochemistry of Formation Waters in the Lower Conasauga Group at the New Hydrofracture Facility: Preliminary Data from the Rock Cover (RC) Wells. ORNL/RAP-5. 42 pp.

Rock cover (RC) wells surrounding the New Hydrofracture Facility were sampled in October 1983, January 1985, and May 1986. The eight wells are open to 30-m-long intervals in the Rogersville Shale and Rutledge Limestone that overlie the Pumpkin Valley Shale. The RC wells provide a means to sample indigenous formation water within these formations. Furthermore, because they overlie the host formation for injected waste-bearing grouts at the hydrofracture facility, the wells provide an opportunity to detect the presence of radionuclides in the overlying formations. Samples were analyzed for major, minor, and trace elements. Gross alpha, beta, and gamma spectral scans, along with specific analyses for  $^3\text{H}$ ,  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ , and  $^{137}\text{Cs}$ , were obtained.

The RC well waters are low-alkalinity, low-pH, Na-Ca-Mg-Cl brines. Total dissolved solid contents range between 150,000 and 200,000  $\mu\text{g/mL}$ . Compositional variability between individual wells and between various samplings of each well suggests that the subsurface hydrological system at the hydrofracture facility is not static.

Chemical and radionuclide data for the samples suggest the possibility that small amounts of waste-derived fluids have mixed with waters sampled in the RC wells. Whether the waste-derived fluid migrated upward from the Pumpkin Valley Shale or outward from the injection well casing cannot be determined with available data.



## 1. INTRODUCTION

Oak Ridge National Laboratory (ORNL) has disposed of liquid low-level radioactive waste by the subsurface injection process of hydrofracture (deLaguna et al. 1968; IAEA 1983; Weeren et al. 1985). In this process, the liquid radioactive wastes are incorporated into a cementitious slurry which is injected into a hydraulically fractured shale formation of the Conasauga Group at depths of approximately 300 m and is allowed to set into pancake-like grout sheets. The cementitious grouts serve as a waste form for the radioactive wastes and are the primary barrier to prevent waste migration into the accessible environment; a secondary barrier is provided by the low permeability of the shale formation into which the waste-bearing grout slurries are injected (Stow and Haase 1986). To evaluate the efficiency and effectiveness of both of these barriers to waste migration into the accessible environment, a detailed understanding of site geohydrology and formation water chemistries is essential (Haase et al. 1985a; Stow and Haase 1986). Research directed toward these objectives was initiated in 1983.

In August 1984 radioactively contaminated water was detected in two of three deep monitor (DM) wells 305 m from the New Hydrofracture Facility injection well. Evidence indicated that the hydrofracture operation was the source of contamination (Haase et al. 1985a,b). Since the discovery of contaminated groundwater at the New Hydrofracture Facility, research aimed at the characterization of the groundwater movement and chemistry in the Facility vicinity has been accelerated. The data presented in this report represent the initial results from the investigation of formation water chemistries in the shale where wastes are injected and in overlying and underlying strata.

The objective of this report is to present the analytical data for groundwater samples taken from the eight rock cover (RC) wells at the New Hydrofracture Facility. The subsurface interval sampled by the RC wells is separated from the injection zone by at least 50 m, and waters obtained from these wells should be representative of indigenous formation fluids. Samples from these wells can also be used to evaluate the possibility that hydrofracture-related fluids have migrated upward from the injection zone. Data for radionuclides and for major, minor, and trace non-radioactive constituents in the formation water occurring within strata immediately overlying the shales of the injection zone are presented. This report also contains background information on the RC wells and a preliminary general interpretation of the data. A report that contains more-complete data interpretation from the RC wells and other wells in the New Hydrofracture Facility vicinity will be issued in the future.

## 2. BACKGROUND

### 2.1 SITE GEOLOGY

The bedrock stratigraphy in the Oak Ridge vicinity consists of Cambrian through Ordovician age sediments. From oldest to youngest, the major stratigraphic units are the clastic Early Cambrian Rome Formation, the mixed clastic and carbonate Middle to Late Cambrian Conasauga Group, the carbonate Late Cambrian and Early Ordovician Knox Group, and the mixed carbonate and clastic Middle Ordovician Chickamauga Group (Stockdale 1951; McMaster 1963). The stratigraphic units crop out in a series of

southwest- to northeast-trending linear belts that are the result of northwesterly motion along several regionally persistent thrust faults. Strata within these belts are right-side up and dip to the southeast.

Details of the site geology are summarized by Haase (1983) and Haase et al. (1985a). The New Hydrofracture Facility is situated on the leading edge of the Copper Creek thrust sheet. The facility is situated on strata of the upper Conasauga Group, and the waste-bearing grouts are injected into the Pumpkin Valley Shale, a 100-m-thick shale-mudstone-siltstone formation that is the lowermost formation in the Conasauga Group (Haase 1982). Immediately above the Pumpkin Valley Shale, in the lower Conasauga Group, are a 30-m-thick limestone-shale formation (the Rutledge Limestone) and a 40-m-thick shale formation (the Rogersville Shale). Massive sandstones of the upper Rome Formation underlie the Pumpkin Valley Shale.

## 2.2 PREVIOUS WORK

High-chloride content formation waters in boreholes penetrating the lower Conasauga Group have been reported previously (deLaguna 1961; deLaguna et al. 1968; Jordan et al. 1969). The examples discussed by deLaguna involved retrieval of brine-like waters from several exploration boreholes in the vicinity of the site in Melton Valley. Wet core samples from several intervals of one of these boreholes (ORNL-JOY No. 1) crystallized salt while drying in core boxes after removal from the core tube (O. M. Sealand, personal communication 1983). No chemical data exist for the water sample, and the exact intervals where the high-chloride fluids were encountered were not recorded. Based on limited data, however, it was concluded that the high-chloride fluids originated from the dissolution of halite within the Conasauga Group and that such fluids occurred in insignificant quantities (deLaguna et al. 1968).

High-chloride waters were observed to slowly flow from boreholes that penetrated waste-bearing grout sheets injected at the Old Hydrofracture Facility (deLaguna et al. 1968; Jordan et al. 1969). Chemical data and radionuclide contents of these waters indicated that their composition represents a mixture of waste-derived fluids and the high-chloride formation waters indigenous to the lower Conasauga Group (see discussion section). High-chloride waters also were noted in the bleedback water from several injections at the Old Hydrofracture Facility (deLaguna et al. 1968).

## 2.3 HISTORY OF THE ROCK COVER WELLS

The New Hydrofracture Facility is surrounded by a network of observation and RC wells (Fig. 1) that are used to monitor pressure buildup in formations above the injection zone (IAEA 1983) during hydrofracture injections. Total depths of these wells range from 180 to 210 m. They are cased from the surface to within 30 m of the well bottom with 11.4-cm-OD steel casing that was pressure grouted in place. The lowermost 30 m of each well is uncased and open to bedrock. In all cases, the open intervals within the RC wells occur within the Rogersville Shale or the uppermost Rutledge Limestone formations of the Conasauga Group.

To obtain an accurate pressure buildup measurement, in the past, the RC wells have been "topped up" with tap water before an injection (H. O. Weeren, personal communication 1983) to ensure good hydraulic connection. Although this addition of tap water altered the

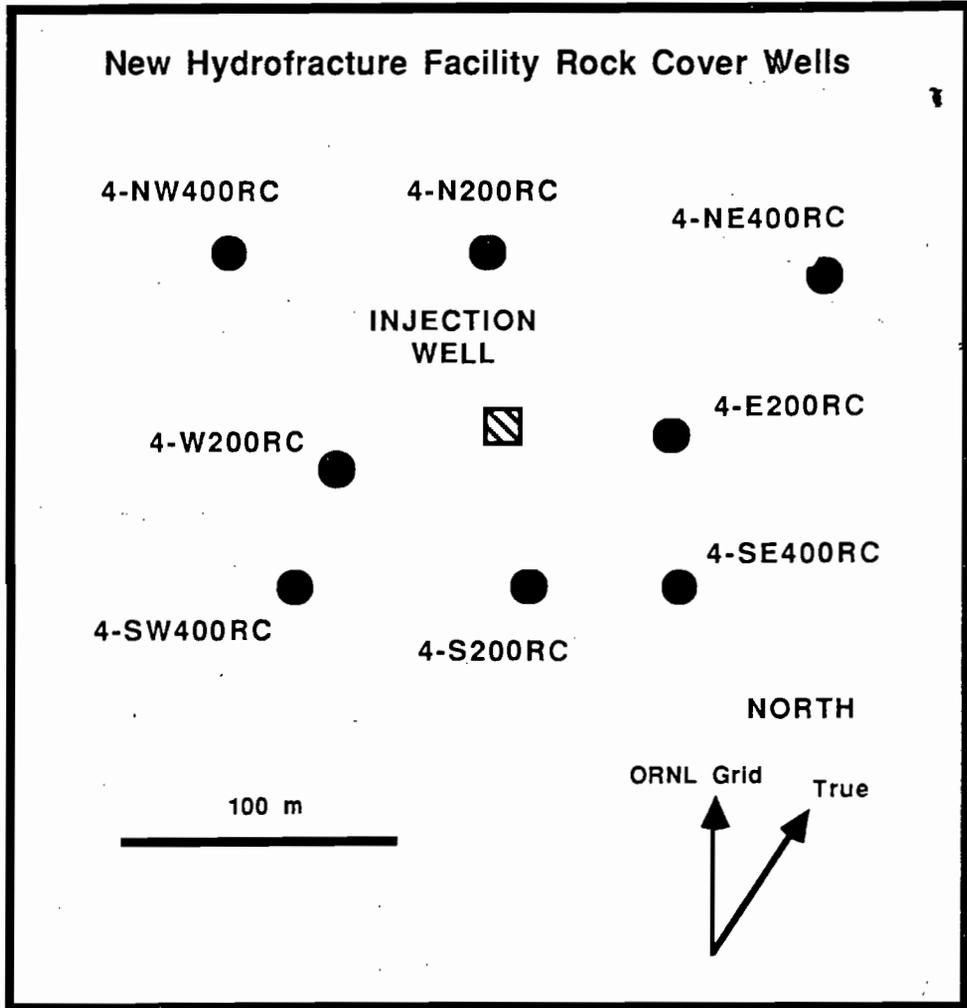


Fig. 1. Location map illustrating New Hydrofracture vicinity and the eight RC wells.

chemistry of the water in the RC wells to an undetermined extent, it was felt that by sampling only from the bottom of each well, a sample that might be representative of natural formation waters could be obtained.

### 3. METHODS

The first two series of samples reported in this report were taken in October 1983 and January 1985. Both series were obtained from the bottom of the RC wells in an "as is" condition. Before the wells were sampled for a third time, they were evacuated by swabbing in January 1986 to remove all water from the well bore. The wells were allowed to recover and flood with indigenous formation waters before sampling in May 1986.

#### 3.1 OCTOBER 1983 SAMPLING

In October 1983, when the tops of the RC wells were removed in preparation for sampling, water was noted flowing slowly from several of the casings (most noticeably, wells 4-W200RC, 4-NW400RC, 4-N200RC, and 4-NE400RC). Flow rates were estimated to be between 2 and 5 L/h. To allow fresh formation water to enter the well bore, the wells were allowed to flow for several days before sampling. Samples were taken from within 10 m of the bottom of each well by using a 2-L, polyvinyl chloride (PVC), ball-check-valve sampler raised and lowered by hand. Inspection of the sampler indicated a slight amount of leakage through the bottom ball-check valve, so some of the sample was lost during retrieval of the sampler.

Within 2 h after collection, the samples were filtered through a Whatman No.45 filter in the laboratory and divided into three aliquots for chemical and radionuclide analysis. Aliquots for the determination of anions and cations were drawn from the sample obtained on the initial downhole trip. The cation aliquot was acidified immediately after filtration. The third aliquot was a 2-L sample obtained for radionuclide analyses by another trip down each well, immediately following the initial sampling. The radionuclide aliquot was also filtered through a Whatman No. 45 filter and acidified within 2 h of collection.

#### 3.2 JANUARY 1985 SAMPLING

The wells were opened several days before the January 1985 sampling. Only minimal flows (<1 L/h) were observed in several wells (most notably, 4-NW400RC and 4-N200RC). A Mineral Logging Systems downhole fluid sampler was used. The wireline-operated sampling device seals a 1400-mL water sample at depth in a stainless steel tube and eliminates the possibility of sample mixing or contamination during sampler retrieval. Because of operational problems and the installation of seismic monitoring instruments in two wells in October, 1984, repeat samples were not obtained for wells 4-NW400RC, 4-W200RC, and 4-N200RC during the January 1985 sampling.

Immediately after the sampler reached the ground surface, the sample was removed, and pH, temperature, and conductivity were measured with a Hydro Lab meter (Model 4041). The sample was filtered in the field with a 0.45- $\mu$ m acetate membrane filter. During the field filtering, substantial amounts of iron oxide precipitated from the sample and repeatedly clogged the filters. Such iron oxide precipitation increased the time necessary to filter the

1400-mL sample to 30 to 45 minutes, and may have altered the sample's chemistry by stripping some of the dissolved metals from solution.

In the field the 1400-mL samples were divided into three aliquots for the various chemical and radiochemical analyses. Two of the aliquots consisted of 250-mL splits for cation and anion analysis. The cation aliquot was acidified to a pH value of <2.0 with 20 mL of 5 vol % nitric acid immediately after filtration for those samples that were filtered and immediately after removal from the sampler for the unfiltered samples. The anion aliquot was delivered to the laboratory unacidified. The third aliquot, approximately 900 mL, was acidified and delivered to the laboratory for radionuclide analyses. As with the cation aliquot, the radionuclide split was acidified with 30 mL of 5 vol % nitric acid immediately after filtration.

### 3.3 MAY 1986 SAMPLING

To aid well development so that the effects of tap water addition to the wells could be eliminated, the wells were swabbed in January 1986 to evacuate the standing column of water from the well bore. Sampling equipment and procedures for the May 1986 sampling were similar to those followed in January 1986 except that the samples were not filtered before acidification. As was noted above, iron oxide precipitation increased the time necessary to filter the 1400-mL sample to 30 to 45 minutes. During this time, iron oxide precipitation may have altered the chemistry of the samples by stripping some of the dissolved metals from solution. To eliminate that possibility, samples collected in May 1986 were not field filtered. Instead, after pH, temperature, and conductivity were measured, they were immediately divided into aliquots, as described previously. The aliquots for cation and radionuclide analyses were acidified with 20 mL of 5 vol % of nitric acid and were filtered with 0.45- $\mu$ m acetate filter paper after being returned to the laboratory. As before, the aliquot for anion analysis was left unfiltered.

### 3.4 ANALYTICAL PROCEDURES

All analyses were performed by the Analytical Chemistry Division (ACD) at ORNL. Anions were determined using a Dionex Model 16 Anion Analyzer. Cations were determined by inductively coupled plasma (ICP) spectrophotometry. Because of the high concentrations of sodium in the samples, and the related analytical problems caused by it, a pretreatment to strip most of the sodium from the samples was developed by ACD to allow better analysis for low-concentration species. This pretreatment procedure was applied to the samples taken in January 1985 and May 1986.

Radionuclide analyses consisted of gross alpha and beta counts and gamma spectral scans. Specific analyses also were conducted for  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ ,  $^{106}\text{Ru}$ , and  $^{90}\text{Sr}$  for all samples. Specific analyses for  $^{99}\text{Tc}$  and  $^3\text{H}$  were conducted only on the samples collected in October, 1983.

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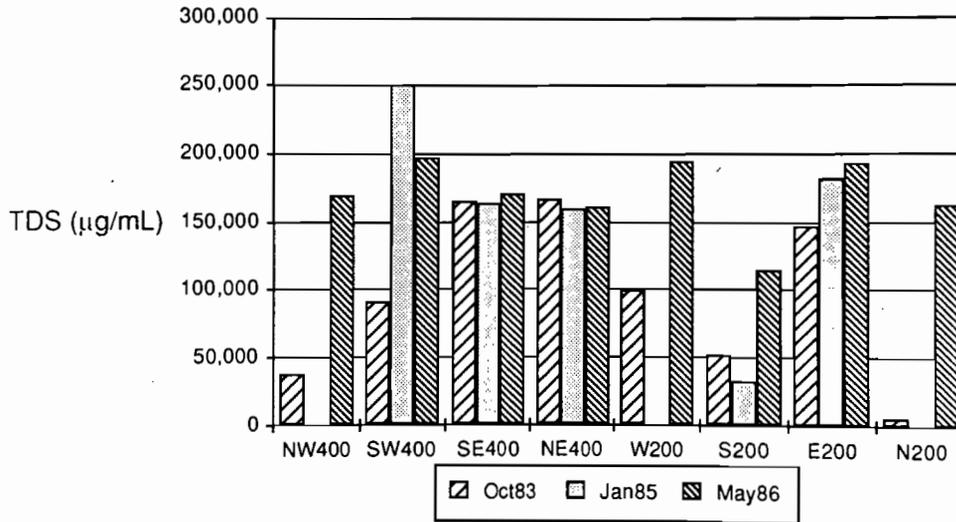


Fig. 2. Histogram illustrating total dissolved solids (TDS) obtained for samples from the RC wells. Blanks for the January 1985 samples for wells 4-NW400RC, 4-W200RC, and 4-N200RC indicate that no samples were taken at that time.

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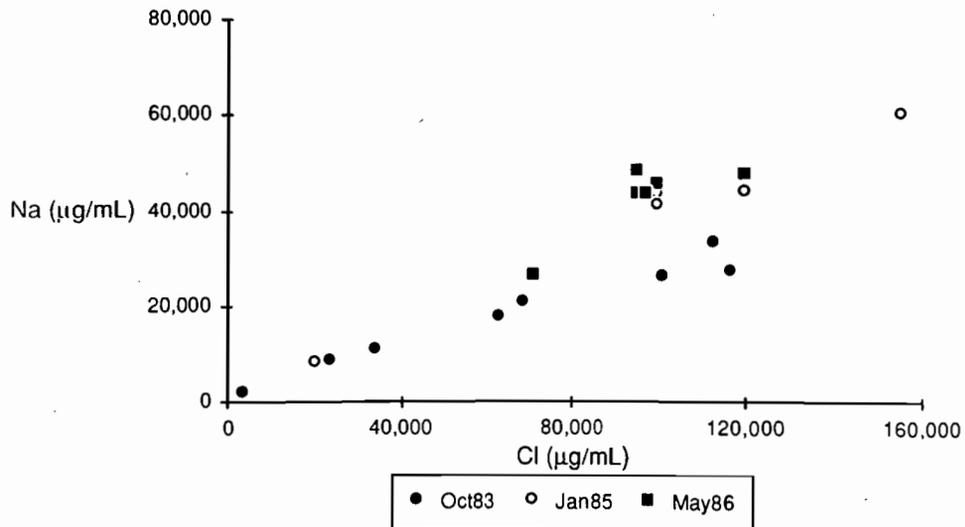


Fig. 3. Sodium vs chloride variation diagram for data from RC wells.

## 4. RESULTS

### 4.1 CHEMICAL DATA

Results of analyses of formation waters collected from the RC wells for the three samplings are presented in Appendices A through C (see rows 13 through 53). Total dissolved solids (TDS) values from samples taken before well development (October 1983 and January 1985) exhibit a large range of values, from 6,000 to 250,000  $\mu\text{g}/\text{mL}$  (Fig. 2). Values for TDS for the samples taken after well development (May 1986), exhibit significantly less variation, ranging from 115,000 to 200,000  $\mu\text{g}/\text{mL}$  (Fig. 2). Changes in TDS values for an individual well among the three samplings are widely variable. Wells 4-SE400RC and 4-NE400RC exhibit relatively constant TDS values with only slight differences between predevelopment and postdevelopment samples. Wells 4-SW400RC and 4-E200RC exhibit somewhat greater intrasample variability and have reverse changes between predevelopment and postdevelopment samplings; groundwater in 4-SW400RC has a lower TDS value after development; groundwater in 4-E200RC, however, exhibits a slight increase in TDS values after development. The remaining wells exhibit wide variations in TDS values, and postdevelopment samples always have substantially increased TDS values.

The waters are Na-Ca-Mg-Cl brines, with minor amounts of Sr and Br, and trace amounts of K, Ba, Li, Mn, and Fe. Predevelopment samples exhibit a wide range of major and minor element concentrations (see Figs. 3 through 7). Concentrations for major constituents are Na - from 2,100 to 60,000  $\mu\text{g}/\text{mL}$ , Ca - from 700 to 25,000  $\mu\text{g}/\text{mL}$ , Mg - from 168 to 5,300  $\mu\text{g}/\text{mL}$ , and Cl - from 3,200 to 155,000  $\mu\text{g}/\text{mL}$ . Postdevelopment concentration ranges exhibit significantly less variability (see Figs. 3 through 7). With the exception of sample 4-S200RC, all postdevelopment RC samples have sodium concentrations within the 44,000 to 49,000  $\mu\text{g}/\text{mL}$  range and chloride concentrations within the 95,000 to 120,000  $\mu\text{g}/\text{mL}$  range.

As a check on analytical accuracy, the charge balance between cations and anions for each analysis has been calculated (see rows 59 through 85 in Appendices A and B). In most samples, the summed negative and positive charges are within 15% of each other, suggesting that the reported elemental concentrations are correct and internally consistent. Several of the October 1983 analyses, however, have charge differences ranging up to 30%. Such large charge balance differences suggest a lack of internal consistency and an error for some of the reported elemental concentrations. The charge balance procedure does not indicate, however, which elemental concentrations are likely to be in error. Because of this, analyses with charge balance differences >15% were not considered further.

Analytical results for potassium in the October 1983 samples require further comment. A comparison of the potassium concentration data for the October 1983 and January 1985 samplings indicates more than an order of magnitude variation in potassium concentrations. Such a variation is not real but does reflect unreliable results for potassium in the October 1983 samples as a result of analytical problems caused by the high chloride concentrations in the samples (S. Bobrowski, personal communication 1984). Changes in analytical procedures by ACD after processing the October 1983 samples have solved the analytical difficulties associated with potassium analyses, and the January 1985 data reflect an accurate measure of the potassium concentration in the samples.

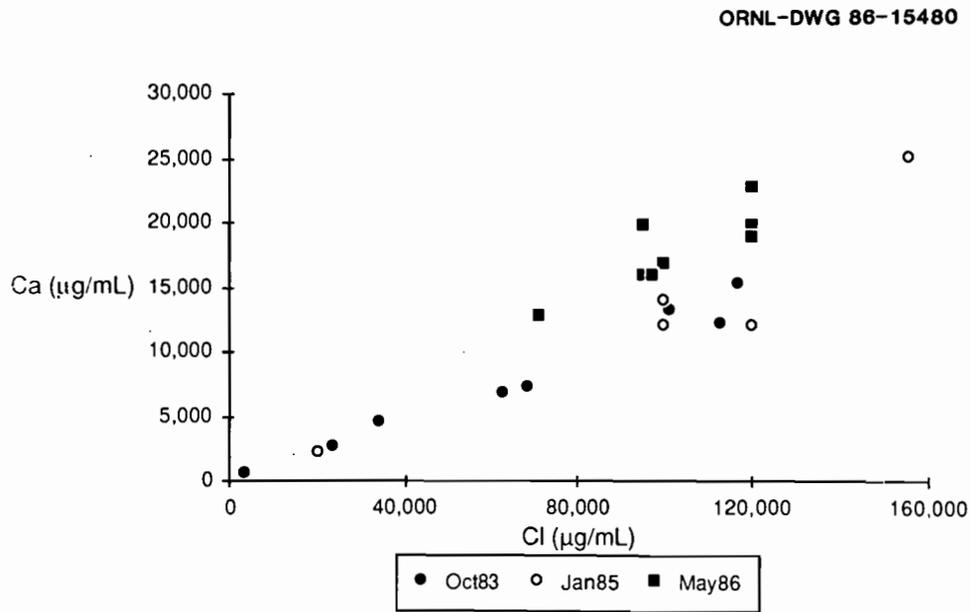


Fig. 4. Calcium vs chloride variation diagram for data from RC wells.

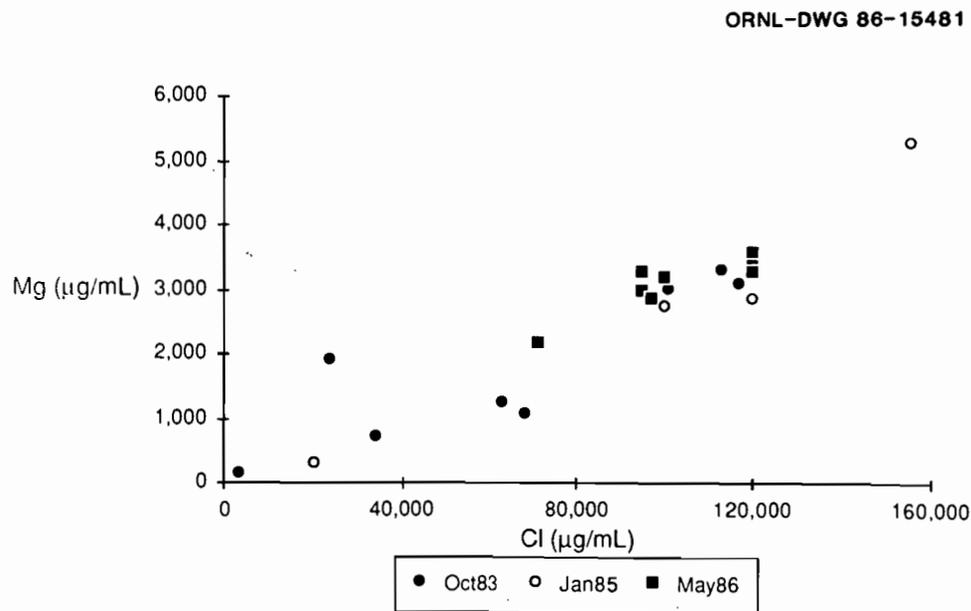


Fig. 5. Magnesium vs chloride variation diagram for data from RC wells.

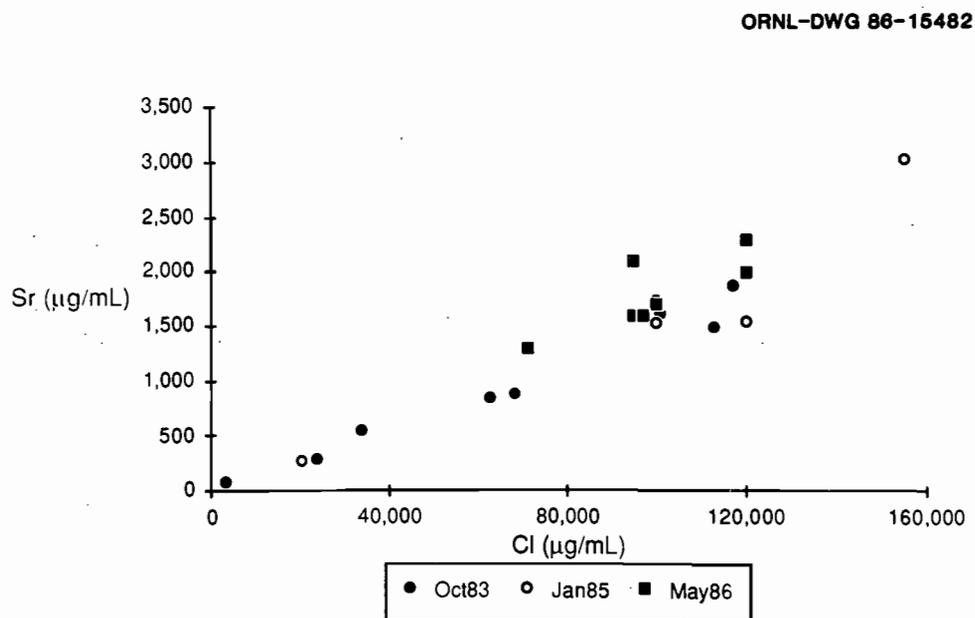


Fig. 6. Strontium vs chloride variation diagram for data from RC wells.

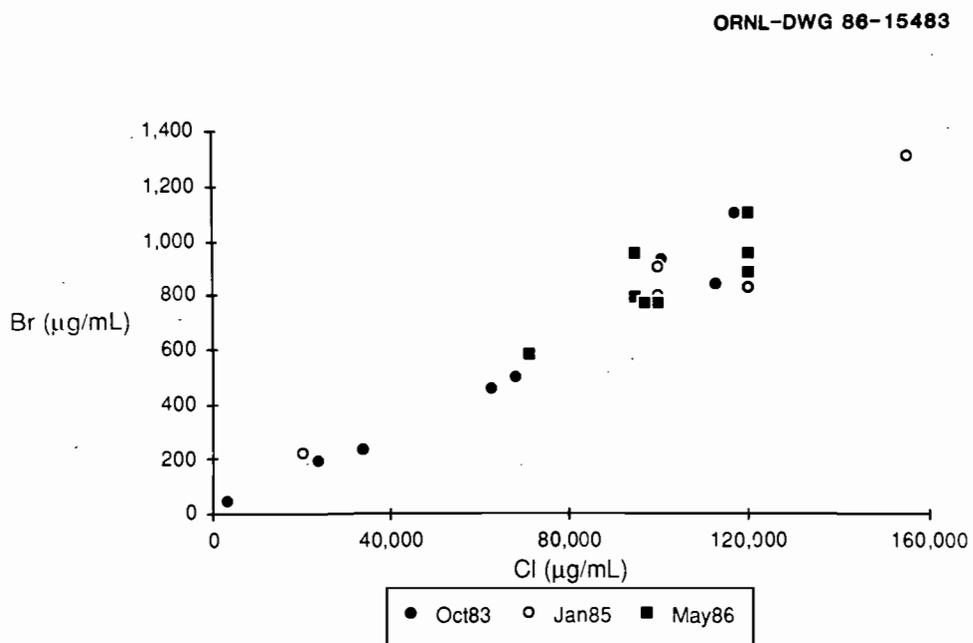


Fig. 7. Bromide vs chloride variation diagram for data from RC wells.

## 4.2 RADIONUCLIDE DATA

Results of radionuclide analyses of formation water samples from the RC wells are presented in Appendices A through C (rows 87 through 99). Radionuclide analyses were also performed on particles trapped during filtering of the October 1983 samples (Appendix D).

Trace amounts of  $^3\text{H}$ ,  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ , and  $^{137}\text{Cs}$  were detected in the filtrate from several RC wells. No consistent pattern of occurrence can be determined (for example, see Fig. 8, which illustrates  $^{90}\text{Sr}$  data for both predevelopment and postdevelopment samples). In most cases, activity values are accompanied by uncertainties of the same order of magnitude as the value (see Appendices A through C), suggesting that the levels detected are close to, or below, detection limits for the radionuclide in question.

Data for the particles trapped during filtering of the October 1983 samples indicate that widely variable, trace amounts of  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ , and  $^{137}\text{Cs}$  (see Appendix D) are associated with particulate material extracted from the samples (Fig. 9). Variable, but somewhat higher, concentrations of  $^{99}\text{Tc}$  are also noted. It is not known whether the radionuclides detected are associated with fine-grained particulates suspended in groundwater or whether they were stripped from solution in the groundwater by iron hydroxides that precipitated during the filtering process.

## 5. DISCUSSION

The analytical data for the three sets of RC samples indicate that the compositions of groundwaters sampled by the RC wells are generally similar to those observed in the DM wells (Haase et al. 1985b; Haase et al. 1987). The results from the RC wells will be discussed in two groups, those taken before well development, and those taken afterward.

### 5.1 Predevelopment Samples

Chemical trends exhibited by the October 1983 and January 1985 water samples from the RC wells suggest that the chemical composition of the samples resulted from the mixing of a NaCl-rich fluid and a NaCl-poor fluid. Samples from wells 4-SE400RC, 4-NE400RC, and 4-W200RC have compositions generally similar to those noted for groundwaters from DM wells open to the Rutledge Limestone and Rome Formations (Haase et al. 1987). Such similarity suggests that the NaCl-rich groundwaters in some of the RC wells are similar in composition to Na-Ca-Mg-Cl brines observed elsewhere in the New Hydrofracture Facility vicinity. Compositions of samples from the other RC wells fall on a generally linear trend, suggesting that the chemical composition of such samples may have resulted from the mixing of a NaCl-rich fluid and a NaCl-poor fluid. The NaCl-rich fluid in this mixing process would be the groundwater samples in wells 4-SE400RC through 4-W200RC. The NaCl-poor fluid involved in the mixing could be groundwater similar to that sampled in well DM3a-PV, or it could be the fire-hydrant water used to fill the wells for pressure measurement purposes. Because of the uncontrolled addition of fire-hydrant water to the RC wells, interpretation of chemical trends within the predevelopment RC samples is ambiguous.

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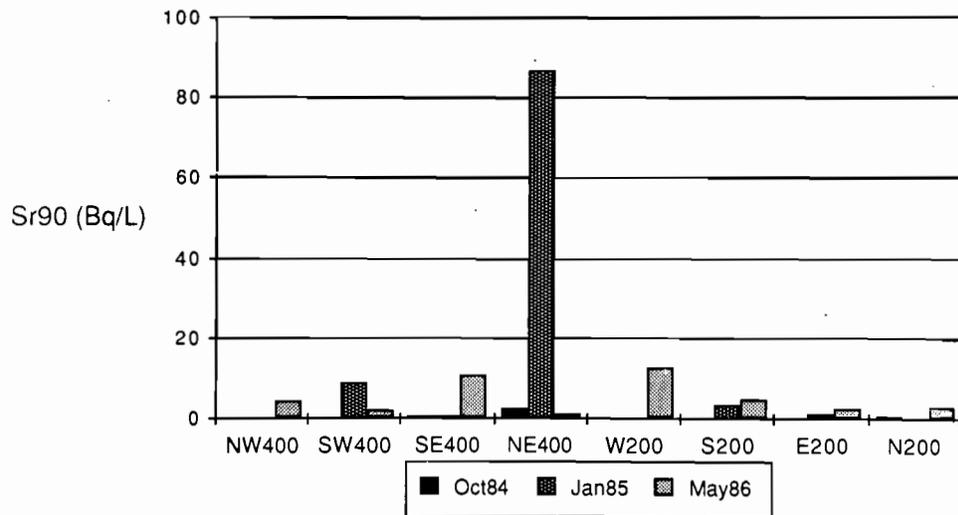


Fig. 8. Histogram illustrating  $^{90}\text{Sr}$  concentrations for RC wells. Blanks for the January 1985 samples for wells 4-NW400RC, 4-W200RC, and 4-N200RC indicate that no samples were taken at that time.

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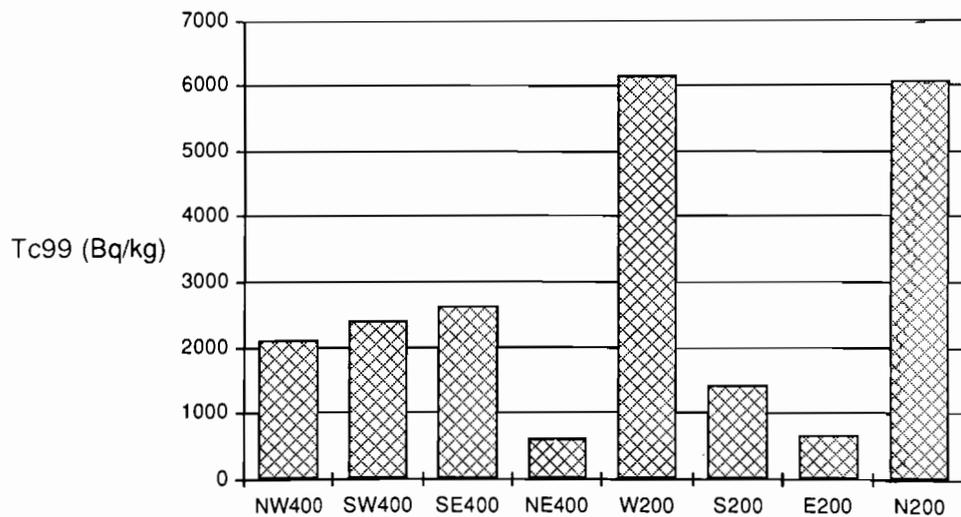


Fig. 9. Histogram illustrating  $^{99}\text{Tc}$  concentrations for particulates removed during filtering of the October 1983 samples of RC wells.

Despite the ambiguities associated with interpretation of chemical trends in the predevelopment samples, a comparison of data for each well between the two sampling times indicates significant changes in major and minor element concentrations. For example, wells 4-SW400RC, 4-S200RC, and 4-E200RC exhibited significant changes in TDS values (Fig. 2); TDS values for wells 4-SE400RC and 4-NE400RC, however, remained essentially constant. A comparison of the Na, Ca, Mg, and Cl concentrations for the wells exhibiting constant TDS values among samplings, however (see Appendices A and B), indicates that between samplings, Na concentrations increased, Ca concentrations remained relatively constant, and Cl and Mg concentrations decreased. During the intervening time between samplings, no additional fire-hydrant water was added to the RC wells, and the observed changes in water chemistry must be related to groundwater movement within strata surrounding the well.

## 5.2 Postdevelopment Samples

Variation diagrams illustrating the details of major element chemical trends for postdevelopment samples (May 1986) are presented in Figs. 10 through 13. Chemical data for the postdevelopment samples should be representative of the groundwaters in the strata open to the wells. Although the data are more tightly clustered and exhibit a smaller range of values than those for the predevelopment samples, the postdevelopment data still fall in a generally linear trend similar to that defined by the predevelopment samples (see Figs. 3 through 7). Overall, the data indicate that waters within the RC wells are similar to those from Rutledge Limestone and Rome Formation sampled in DM wells (Haase et al. 1987). In particular, the chloride and bromide concentrations are generally similar to those obtained for Rutledge Limestone and Rome Formation samples from the DM wells. Concentrations for sodium in most of the RC samples fall along, or close to, the main sodium vs chloride trend on the sodium variation diagram defined by data from most of the RC, and all of the DM, samples. Concentrations of sodium for three of the RC wells (4-SE400RC, 4-NE400RC, 4-N200RC), however, exhibit a slight enrichment in sodium with respect to the main trend (Fig. 10). The RC samples also exhibit a slight enrichment in calcium and magnesium with respect to a calcium vs chloride trend on the calcium variation diagram defined by the Rutledge Limestone and Rome Formation groundwaters. There is no readily apparent explanation for the differences in Na, Ca, and Mg concentrations between the RC and DM samples. Because the RC wells are finished predominantly in the Rogersville Shale, however, the differences may simply reflect natural groundwater chemistry differences among the various formations of the Conasauga Group (see Sect. 5.3).

## 5.3 Interaction with Waste-Derived Fluids

Liquid wastes disposed of at the New Hydrofracture Facility contain large amounts of sodium (10,000 to 30,000 ppm) and nitrate (5,000 to 25,000 ppm) and only moderate amounts of chloride (0 to 5,000 ppm) (Weeren 1984). Anomalous concentrations of any of these chemical parameters or significant concentrations of radionuclides, such as  $^3\text{H}$ ,  $^{90}\text{Sr}$ , and  $^{99}\text{Tc}$ , that are potentially mobile in formation waters similar to those observed in the RC wells would indicate the presence of waste-derived fluids.

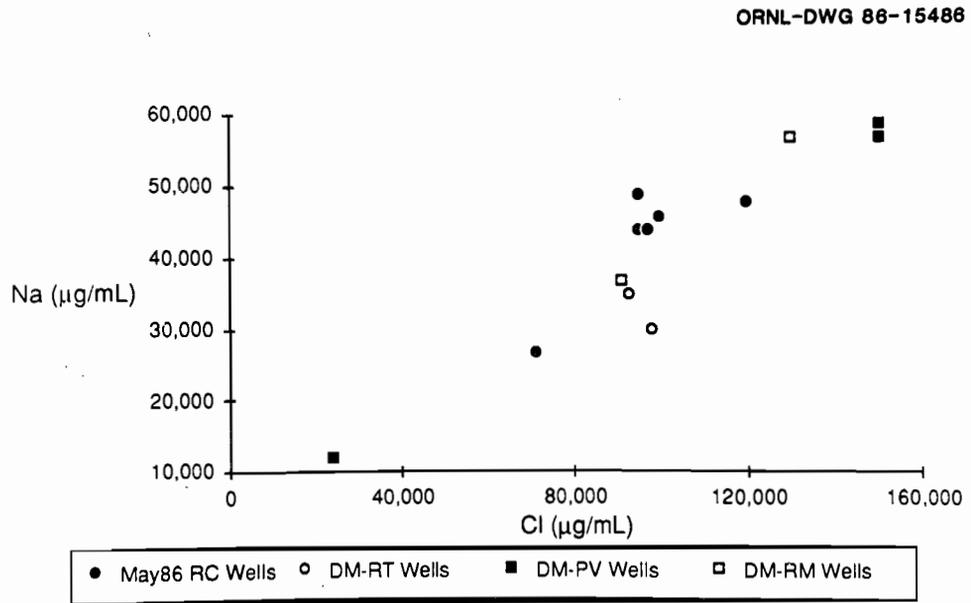


Fig. 10. Sodium vs chloride variation diagram for data for postdevelopment sampling of RC wells and January 1986 sampling of DM wells (DM data from Haase et al. 1987).

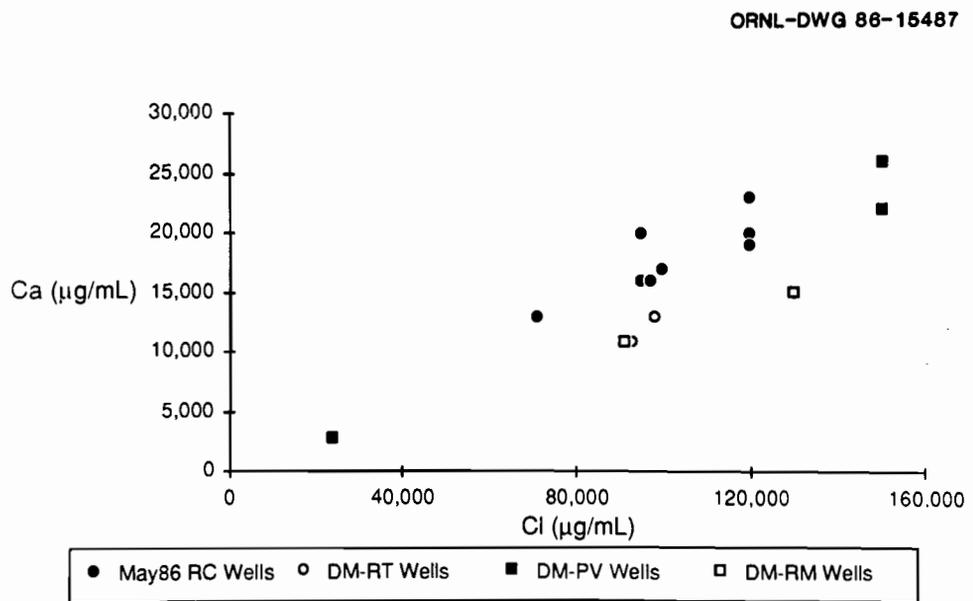


Fig. 11. Calcium vs chloride variation diagram for data for postdevelopment sampling of RC wells and January 1986 sampling of DM wells (DM data from Haase et al. 1987).

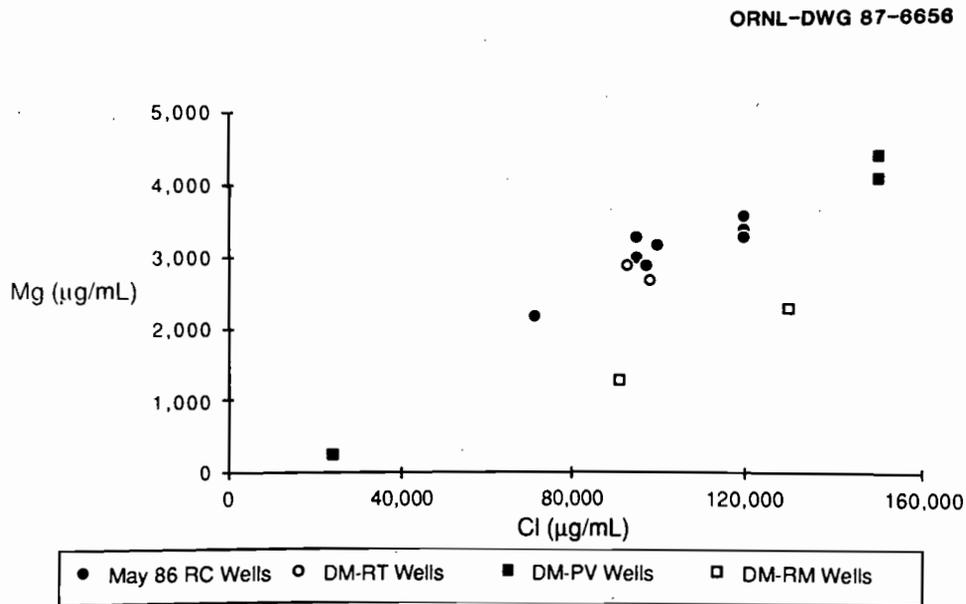


Fig. 12. Magnesium vs chloride variation diagram for data for postdevelopment sampling of RC wells and January 1986 sampling of DM wells (DM data from Haase et al. 1987).

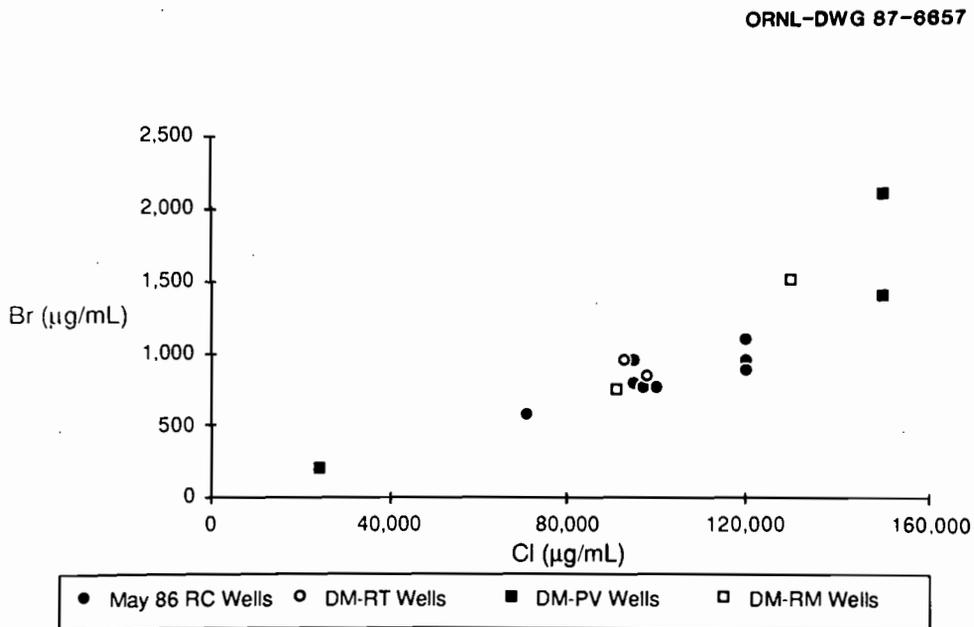


Fig. 13. Bromide vs chloride variation diagram for data for postdevelopment sampling of RC wells and January 1986 sampling of DM wells (DM data from Haase et al. 1987).

The slight sodium enrichments observed in samples from wells 4-SE400RC, 4-NE400RC, and 4-N200RC obtained in the May 1986 sampling might reflect the addition of some waste-derived sodium (Fig. 3). The sodium/chloride ratios for these samples are, however, only slightly greater than those for other RC samples, and are not significantly different from those observed in the DM wells (Fig. 10). Given the variability of major and minor element concentrations exhibited by all of the RC and DM samples, the significance of the slightly elevated sodium/chloride ratios for the three RC samples cannot be evaluated. Nitrate values for the RC wells (Fig. 14) are variable, but postdevelopment samples exhibit values ranging between 20 and 54  $\mu\text{g/mL}$ . Because naturally occurring groundwaters contain no nitrate, such values suggest that some waste-derived fluids have been added to the waters sampled by the RC wells. In previous examples, where groundwaters or bleedback fluids containing waste-derived fluids have been analyzed (deLaguna et al. 1968), the nitrate concentrations for such waters ranged from 300 to 10,000 ppm, and sodium/chloride ratios were substantially greater than those observed in the RC samples (see Fig. 15).

The principal radionuclide identified in postdevelopment RC samples is  $^{90}\text{Sr}$ , with concentrations ranging from 1 to 13 Bq/L (Fig. 16; see also Fig. 8). Such values are low and close to the level of detection for  $^{90}\text{Sr}$ . Because of this, measurements for  $^{90}\text{Sr}$  need to be confirmed by subsequent samples from the RC wells. Taken at face value, however, the  $^{90}\text{Sr}$  results suggest that small amounts of waste-derived fluids occur in the waters of the RC wells. Similarly, the occurrence of  $^{99}\text{Tc}$  associated with particulate matter in the October 1983 samples would also suggest the addition of some waste-derived fluids. Interpretation of the  $^{99}\text{Tc}$  data is ambiguous, however, because of uncertainty as to the amounts and exact origins of fluids and material that may have been added to the wells before development in January 1986.

Interpretation of chemical and radionuclide parameters that are indicative of the addition of waste-derived fluids to groundwaters sampled by the RC wells is complicated by the compositional variability of the waters and by the very low concentrations of radionuclides involved. Complete evaluation of the low concentrations of nitrate, and especially of  $^{90}\text{Sr}$ , in postdevelopment water samples will require additional samplings of the wells. If confirmed, the low concentrations of both indicators, however, suggest that the amount of waste-derived fluid is extremely small.

If subsequent samplings confirm the presence of waste-derived fluids in the RC wells, it is uncertain how such fluids may have entered the groundwater in the strata overlying the injection formation. At least two mechanisms for upward movement of such fluids can be postulated. Waste-derived fluids may have moved upward throughout a region surrounding the hydrofracture facility by simple flow in response to pressure gradients out of the underlying injection formation. Alternatively, they may have moved upward only in the immediate vicinity of the injection well and then migrated laterally outward to the RC wells. Other mechanisms can be postulated, and ultimate resolution of the questions surrounding this issue hinges on subsequent samples and data obtained from the RC wells.

## 6. RECOMMENDATIONS

Because of the apparent complexity of the groundwater system in the vicinity of the New Hydrofracture Facility, the RC wells should be sampled periodically in the future so that

ORNL-DWG 87-6658

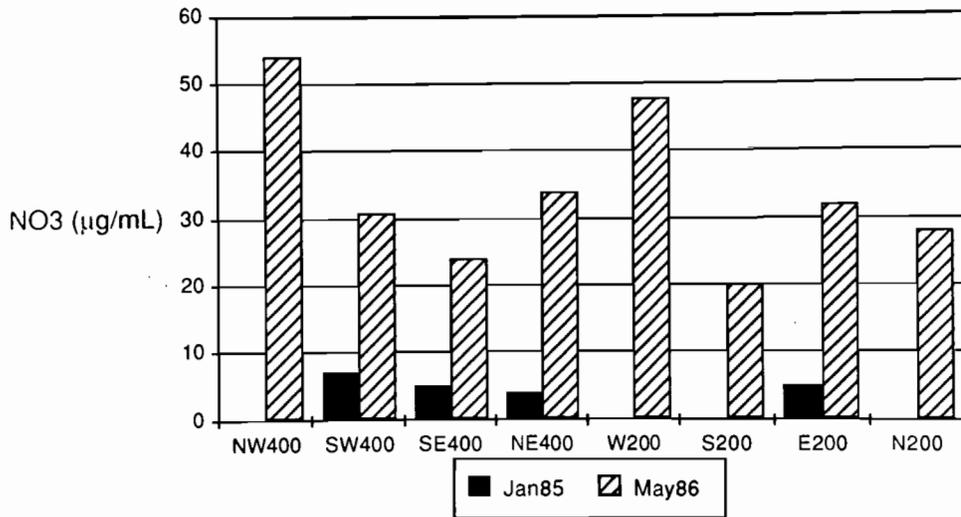


Fig. 14. Histogram illustrating nitrate concentrations for RC wells. Blanks for the January 1985 samples for wells 4-NW400RC, 4-W200RC, and 4-N200RC indicate that no samples were taken at that time.

ORNL-DWG 87-6660

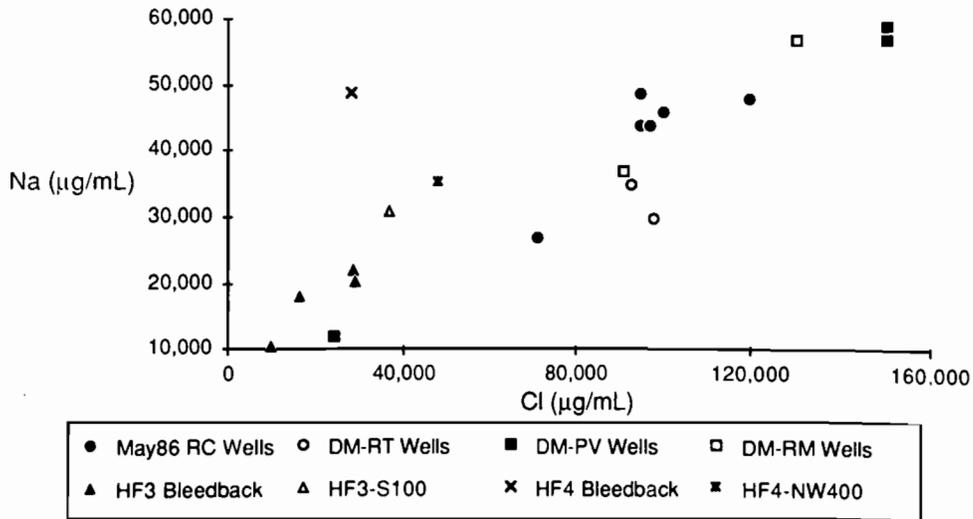


Fig. 15. Sodium vs chloride variation diagram for data for postdevelopment sampling of RC wells, January 1986 sampling of DM wells, hydrofracture bleedback waters, and groundwaters within immediate vicinity of grout sheets (DM data from Haase et al. 1987; bleedback and groundwater data from deLaguna et al. 1968).

ORNL-DWG 87-6659

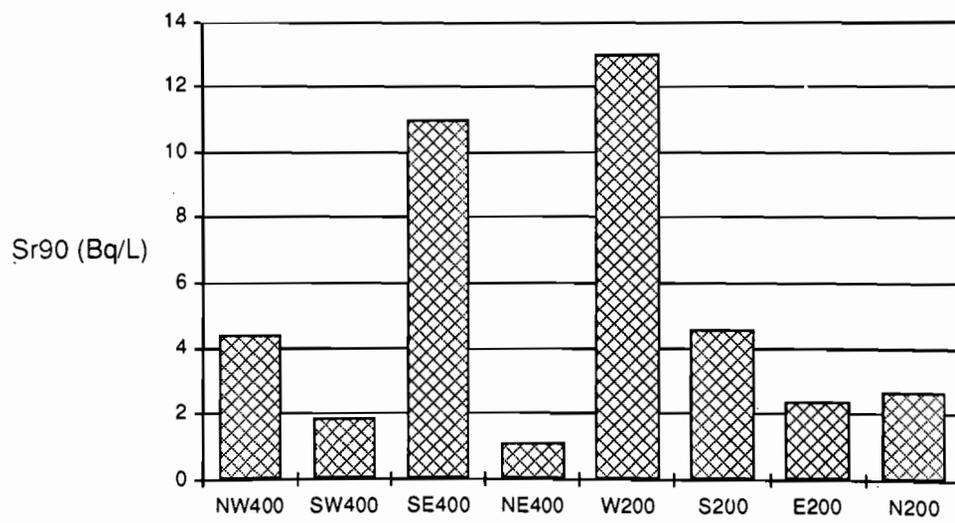


Fig. 16. Histogram illustrating  $^{90}\text{Sr}$  concentrations for postdevelopment sampling of RC wells.

long-term trends in groundwater chemistry can be established. Because of the proximity to the injection zone, the RC wells provide an important vantage point to document the groundwater chemistry for the underlying injection zone. Furthermore, RC wells at the Old Hydrofracture Facility should be developed and added to the periodic sampling activities. Such wells would provide important, additional observation points for the groundwater system at the hydrofracture site.

## 7. SUMMARY

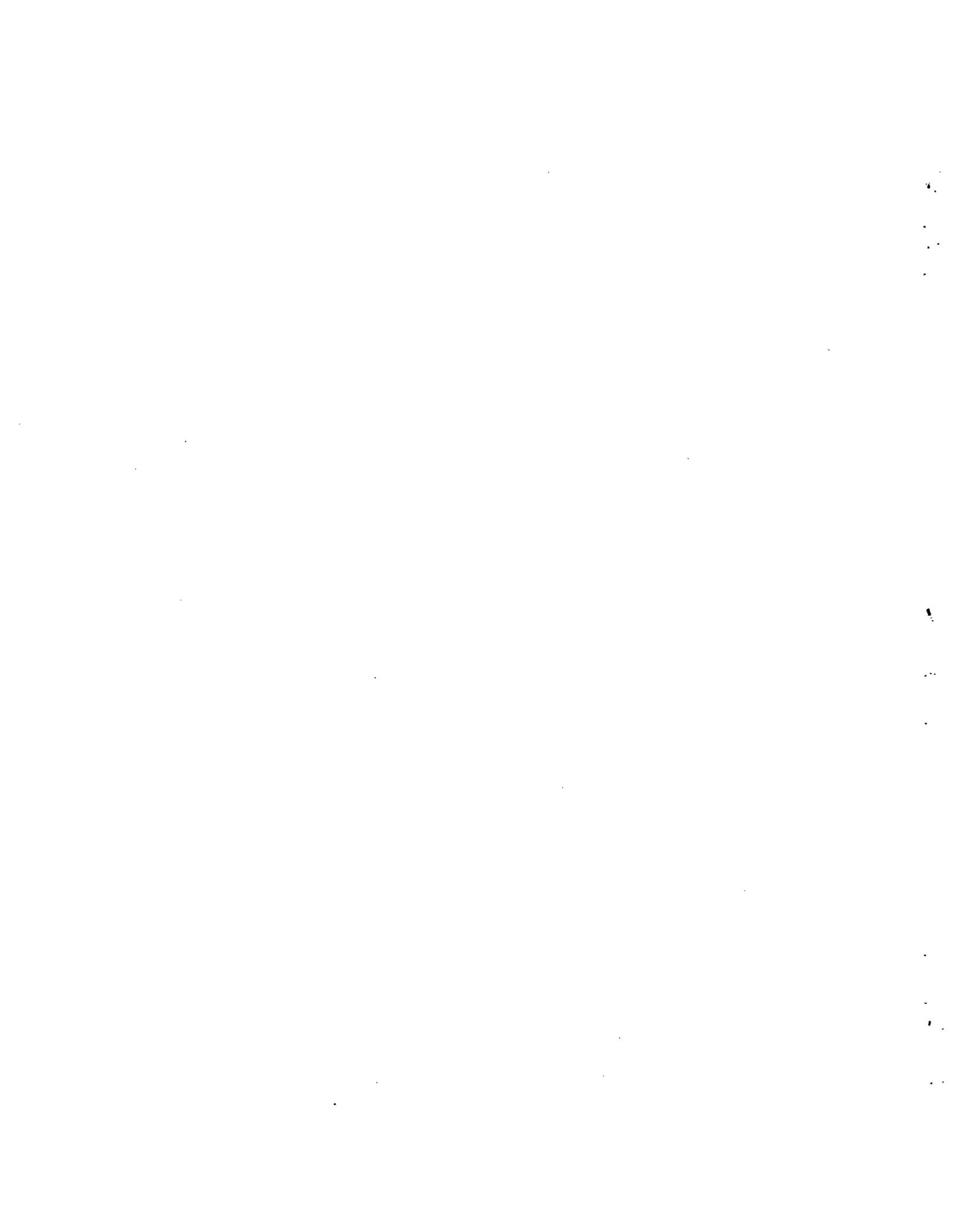
Sampling of the RC wells surrounding the New Hydrofracture Facility indicates that formation waters in the stratigraphic interval immediately overlying the injection zone are Na-Ca-Mg-Cl brines. Waters from the eight RC wells exhibit substantial compositional variability, both spatially and temporally.

Chemical and radionuclide data for the RC samples suggest that, at most, extremely small amounts of waste-derived fluids have been added to the groundwaters sampled by the RC wells. Whether the waste-derived fluids migrated upward from the underlying injection zone or outward from the immediate vicinity of the injection well casing cannot be determined from available data. Final evaluation of the issue will require additional samples so that the compositional variability exhibited by the water samples obtained to date can be better characterized.

## 8. REFERENCES

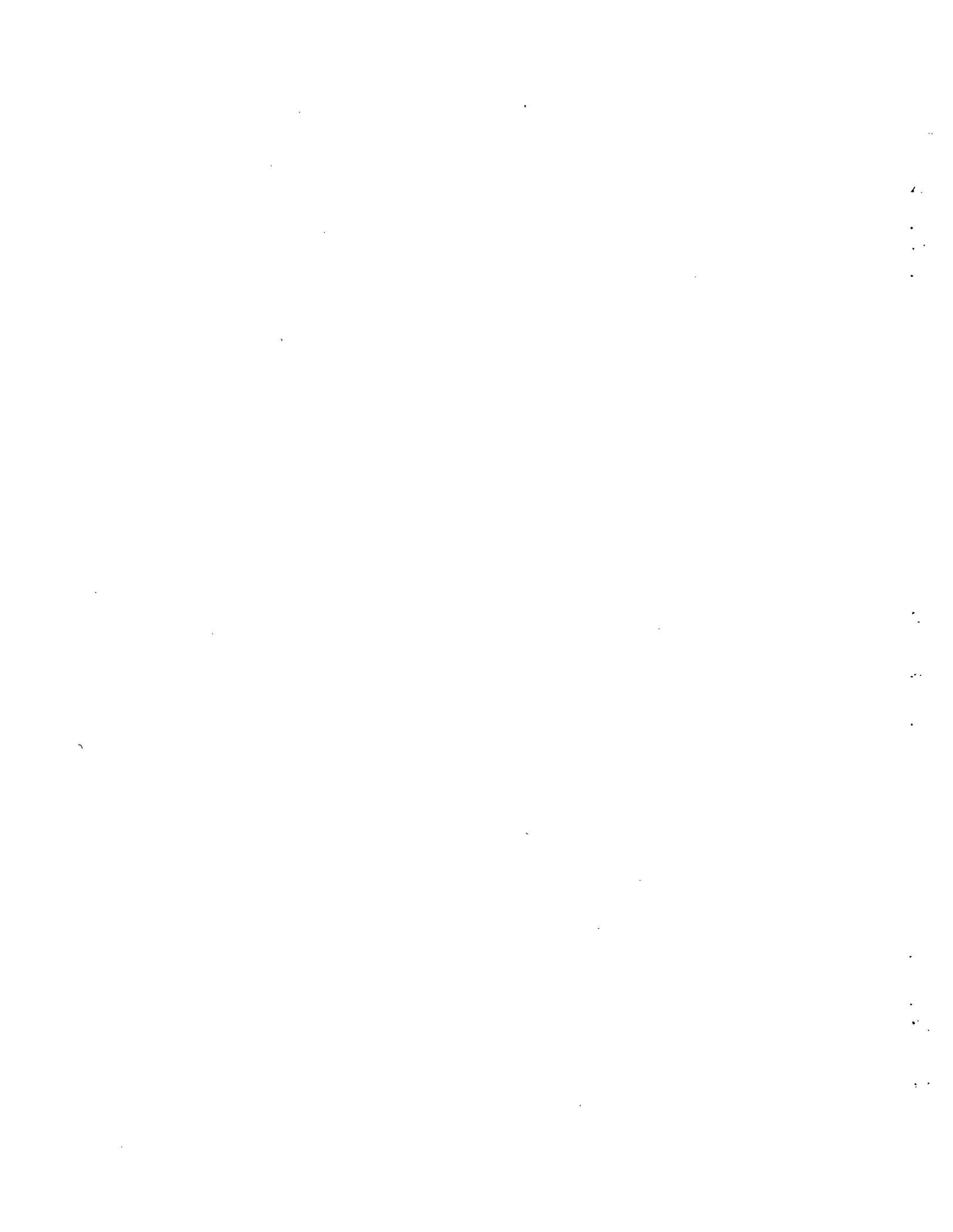
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### Appendix A

Analytical data for eight RC wells for the October 1983 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a component was looked for but not detected. Analytical uncertainties are within  $\pm 10\%$  of the value reported, unless otherwise indicated.



	1	2	3	4	5
1	SAMPLE ID	4-NW400RC	4-SW400RC	4-SE400RC	4-NE400-RC
2	Date Collected	Oct-83	Oct-83	Oct-83	Oct-83
3	Collected By	JS/CDF	JS/CDF	JS/CDF	JS/CDF
4	Sample Depth	570.0	690.0	690.0	570.0
5	pH	7.36*	7.49*	4.29*	4.35*
6	Temp, °C	nm	nm	nd	nm
7	Cond, µS/cm	nm	nm	nd	nm
8					
9	CHEMICAL DATA				
10	ACD Sample No.	2149	2150	2147	2148
11					
12	Cations, µg/mL				
13	Li	13.4	25.7	51.0	53.2
14	Na	8,890	18,300	33,700	27,700
15	K	1,430.0	3,520.0	8,460.0	17,300.0
16	Be	<0.1	<0.1	<0.3	<0.7
17	Mg	1,930	1,270	3,320	3,120
18	Ca	2,820	6,950	12,400	15,500
19	Sr	297	841	1,490	1,880
20	Ba	119.0	277.0	516.0	478.0
21	Ti	.4	1.1	1.9	4.9
22	V	<0.8	<1.5	<3.0	<7.5
23	Cr	<1.2	<2.3	<4.6	<11.5
24	Mn	<0.1	1.6	16.7	10.9
25	Fe	<1.0	<2.0	25.3	<10.0
26	Co	<0.7	<1.3	<2.6	<6.5
27	Ni	<5.5	<11.0	<22.0	<55.0
28	Cu	<1.6	<3.2	<6.4	<16.0
29	Zn	<0.9	<1.8	5.9	<9.0
30	Mo	<1.4	<2.7	<5.4	<13.5
31	Ag	<0.9	<1.8	<3.6	<9.0
32	Cd	<0.5	<0.9	<1.8	<4.6
33	B	<3.8	<7.6	<15.2	<38.0
34	Al	<2.9	<5.8	<11.6	<29.0
35	Si	<6.0	<12.0	<24.0	<60.0
36	Pb	<13.0	<26.0	<52.0	<130.0
37	P	<16.5	<33.0	<66.0	<165.0
38	As	<320.0	<64.0	<128.0	<320.0
39	Sb	<28.0	<14.0	<28.0	<70.0
40	Se	<215.0	<43.0	<86.0	<215.0
41					
42	Anions, µg/mL				
43	F	nm	nm	nm	nm
44	Cl	23,400	62,700	113,000	117,000
45	Br	190	460	839	1,101
46	I	nm	nm	nm	nm
47	NO3	<50.00	<50.0	<50.0	<50.0
48	SO4	<40.00	<40.0	<40.0	<40.0
49	S2-	nm	nm	nm	nm
50	PO4	nm	nm	nm	nm
51	Alkalinity as HCO3	16.3	20.9	.3	.2
52	TOC, µg/mL	nm	nm	nm	nm
53	TKN, mg/mL	nm	nm	nm	nm

	1	2	3	4	5
54					
55	SAMPLE ID	4-NW400RC	4-SW400RC	4-SE400RC	4-NE400-RC
56					
57	TDS	37,646	90,798	165,265	166,779
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	1.93	0.00	7.35	7.67
62	Na	386.72	796.05	1,465.95	1,204.95
63	K	36.57	0.00	216.32	442.36
64	Mg	158.76	104.47	273.10	256.65
65	Ca	140.72	346.81	618.76	773.45
66	Sr	6.78	19.20	34.02	42.92
67	Ba	1.73	4.03	7.51	6.96
68	Mn (2+)	0.00	0.06	0.61	0.40
69	Fe (2+)	0.00	0.00	0.91	0.00
70	Total Cations, meq	733.20	1,270.62	2,624.53	2,735.36
71					
72	Anions, meq/L				
73	F	0.00	0.00	0.00	0.00
74	Cl	660.11	1,768.77	3,187.73	3,300.57
75	Br	2.38	5.75	10.50	13.77
76	I	0.00	0.00	0.00	0.00
77	Alkalinity as HCO <sub>3</sub>	0.27	0.34	0.00	0.00
78	NO <sub>3</sub>	0.00	0.00	0.00	0.00
79	SO <sub>4</sub>	0.00	0.00	0.00	0.00
80	PO <sub>4</sub>				
81	Total Anions, meq	662.76	1,774.86	3,198.23	3,314.35
82					
83	Net Difference, meq	70.45	-504.25	-573.70	-578.99
84					
85	Percent Difference	-5.05	16.56	9.85	9.57
86					
87	RADIONUCLIDES				
88	ACD Sample No.				
89					
90	Gross Alpha, Bq/L	nm	nm	nm	nm
91	Gross Beta, Bq/L	nm	nm	nm	nm
92					
93	H <sub>3</sub> , Bq/L	10±30	29±34	nd	10±40
94	Co60, Bq/L	nd	nd	.31±.10	nd
95	Sr90, Bq/L	nd	nd	0.4±0.9	2.2±1.3
96	Tc99, Bq/L	0.64±0.23	0.07±0.2	0.83±0.19	0.27±0.26
97	Ru106, Bq/L	nm	nm	nm	nm
98	Cs137, Bq/L	nd	nd	0.52±0.11	nd
99	Th232, Bq/L	nm	nm	nm	nm

	6	7	8	9	10
1	SAMPLE ID	4-W200RC	4-S200RC	4-E200RC	4-N200RC
2	Date Collected	Oct-83	Oct-83	Oct-83	Oct-83
3	Collected By	JS/CDF	JS/LKH	JS/CDF	JS/CDF
4	Sample Depth	640.0	690.0	640.0	570.0
5	pH	7.53*	6.67*	3.48*	7.62*
6	Temp, °C	nm	nm	nm	nm
7	Cond, µS/cm	nm	nm	nm	nm
8					
9	CHEMICAL DATA				
10	ACD Sample No.	2153	2154	2151	2152
11					
12	Cations, µg/mL				
13	Li	37.4	18.7	40.6	4.0
14	Na	21,200	11,400	26,600	2,180
15	K	8,830.0	5,190.0	11,400.0	954.0
16	Be	<0.3	<0.1	<0.3	<0.1
17	Mg	1,110	736	3,040	168
18	Ca	7,410	4,810	13,400	717
19	Sr	890	551	1,620	79
20	Ba	302.0	162.0	498.0	18.9
21	Ti	2.6	1.5	2.3	.4
22	V	<3.0	<1.5	<3.0	<0.4
23	Cr	<4.6	<2.3	<4.6	<0.6
24	Mn	1.5	1.6	17.7	1.4
25	Fe	<4.0	<2.0	23.0	<0.52
26	Co	<2.6	<1.3	<2.6	<0.4
27	Ni	<22.0	<11.0	<22.0	<2.9
28	Cu	<6.4	<3.2	<6.4	<0.9
29	Zn	<3.6	<1.8	28.8	<0.5
30	Mo	<5.4	<2.7	<5.4	<0.7
31	Ag	<3.6	<1.8	<3.6	<0.5
32	Cd	<1.8	<0.9	<1.8	<0.3
33	B	<15.2	<7.6	<15.2	<2.0
34	Al	<11.6	6.8	<11.6	<1.5
35	Si	<24.0	<12.0	<24.0	<3.1
36	Pb	<52.0	<26.0	<52.0	<6.7
37	P	<66.0	<33.0	<66.0	<8.6
38	As	<128.0	<64.0	<128.0	<16.6
39	Sb	<28.0	<14.0	<28.0	<3.6
40	Se	<86.0	<43.0	<86.0	<11.2
41					
42	Anions, µg/mL				
43	F	nm	nm	nm	nm
44	Cl	68,200	33,700	101,000	3,200
45	Br	499	238	933	45
46	I			nm	nm
47	NO3	<50.0	<50.0	<50.0	<10.0
48	SO4	<40.0	<40.0	<40.0	<10.0
49	S2-	nm	nm	nm	nm
50	PO4	nm	nm	nm	nm
51	Alkalinity as HCO3	19.2	14.3	.0	47.1
52	TOC, µg/mL	nm	nm	nm	nm
53	TKN, mg/mL	nm	nm	nm	nm

	6	7	8	9	10
54					
55	SAMPLE ID	4-W200RC	4-S200RC	4-E200RC	4-N200RC
56					
57	TDS	99,611	51,597	147,091	6,408
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	5.39	2.69	5.85	0.58
62	Na	922.20	0.00	1,157.10	94.83
63	K	225.78	132.71	291.50	24.39
64	Mg	91.31	60.54	250.07	13.82
65	Ca	369.76	240.02	668.66	35.78
66	Sr	20.32	12.58	36.98	1.81
67	Ba	4.40	2.36	7.25	0.28
68	Mn (2+)	0.06	0.06	0.64	0.05
69	Fe (2+)	0.00	0.00	0.82	0.00
70	Total Cations, meq	1,639.21	450.96	2,418.88	171.54
71					
72	Anions, meq/L				
73	F	0.00	0.00	0.00	0.00
74	Cl	1,923.92	950.68	2,849.21	90.27
75	Br	6.24	2.98	11.67	0.56
76	I	0.00	0.00	0.00	0.00
77	Alkalinity as HCO3	0.31	0.23	0.00	0.77
78	NO3	0.00	0.00	0.00	0.00
79	SO4	0.00	0.00	0.00	0.00
80	PO4				
81	Total Anions, meq	1,930.48	953.89	2,860.88	91.61
82					
83	Net Difference, meq	-291.27	-502.93	-442.00	79.93
84					
85	Percent Difference	8.16	35.80	8.37	-30.38
86					
87	RADIONUCLIDES				
88	ACD Sample No.				
89					
90	Gross Alpha, Bq/L	nm	nm	nm	nm
91	Gross Beta, Bq/L	nm	nm	nm	nm
92					
93	H3, Bq/L	20±30	0.14±0.18	0.20±0.21	20±30
94	Co60, Bq/L	nd	nd	0.10±0.07	nd
95	Sr90, Bq/L	nd	nd	nd	0.40±0.19
96	Tc99, Bq/L	0.20±0.19	0.14±0.18	0.21±0.20	nd
97	Ru106, Bq/L	nm	nm	nm	nm
98	Cs137, Bq/L	nd	0.12±0.08	nd	nd
99	Th232, Bq/L	nm	nm	nm	nm

### Appendix B

Analytical data for five RC wells for the January 1985 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a component was looked for but not detected. Analytical uncertainties are within  $\pm 10\%$  of the value reported, unless otherwise indicated.



	1	2	3	4	5	6
1	SAMPLE ID	4-SW400RC	4-SE400RC	4-NE400RC	4-S200RC	4-E200RC
2	Date Collected	14Jan85	14Jan85	16Jan85	14Jan85	16Jan85
3	Collected By	JS/LKH	JS/LKH	JS/LKH	JS/LKH	JS/LKH
4	Sample Depth	600.0	685.0	580.0	590.0	640.0
5	pH	4.40	6.30	4.70	5.30	4.70
6	Temp, °C	10.80	10.40	11.20	10.70	10.90
7	Cond, µS/cm	>200,000	109,200	179,800	47,800	184,000
8						
9	CHEMICAL DATA					
10	ACD Sample No.	1656	1658	1659	1660	1661
11						
12	Cations, µg/mL					
13	Li	42.00	30.00	25.70	<10.0	59.80
14	Na	60,500.00	44,100.00	41,600.00	8,630.00	44,500.00
15	K	180.00	180.00	130.00	50.00	160.00
16	Be	<0.2		<0.1	<0.1	<0.1
17	Mg	5,300.00	2,790.00	2,770.00	331.00	2,880.00
18	Ca	25,200.00	14,100.00	12,200.00	2,370.00	12,200.00
19	Sr	3,020.00	1,740.00	1,530.00	266.00	1,540.00
20	Ba	770.00	547.00	463.00	58.70	599.00
21	Ti	<4.0	<2.0	<2.0	<1.0	<2.0
22	V	<6.0	<3.0	<3.0	<1.5	<3.0
23	Cr	2.74	<0.8	0.95	<0.4	0.94
24	Mn	21.30	12.30	25.50	1.49	13.70
25	Fe	21.88	<3.0	13.60	26.30	5.12
26	Co	<4.0	<2.0	<2.0	<1.0	<2.0
27	Ni	<12.0	<6.0	<6.0	<3.0	<6.0
28	Cu	<4.0	<2.0	<2.0	<1.0	<2.0
29	Zn	<4.0	<2.0	<2.0	<1.0	12.00
30	Mo	<4.0	<2.0	<2.0	<1.0	<2.0
31	Ag	<14.0	<7.0	<7.0	<3.5	<7.0
32	Cd	<1.8	<0.9	<0.9	<0.5	<0.9
33	B	<20.0	<10.0	<10.0	<5.0	<10.0
34	Al	<40.0	<20.0	<20.0	<10.0	<20.0
35	Si	<16.0	<8.0	<8.0	<4.0	<8.0
36	Pb	<40.0	<20.0	<20.0	<10.0	<20.0
37	P	<60.0	<30.0	<30.0	<15.0	<30.0
38	As	<40.0	<20.0	<20.0	<10.0	<20.0
39	Sb	<60.0	<30.0	<30.0	<15.0	<30.0
40	Se	<80.0	<40.0	<40.0	<20.0	<40.0
41						
42	Anions, µg/mL					
43	F	0.31	0.21	0.29	0.04	0.46
44	Cl	155,000.00	100,000.00	100,000.00	20,000.00	120,000.00
45	Br	1,300.00	900.00	800.00	220.00	830.00
46	I	<5.0	<5.0	<5.0	<5.0	<5.0
47	NO3	7.00	5.00	4.00	<2.0	5.00
48	SO4	<1.0	<1.0	<1.0	<1.0	<1.0
49	S2-	nm	nm	nm	nm	nm
50	PO4	<4.0	<4.0	<4.0	<4.0	<4.0
51	Alkalinity as HCO3	1.00	2.00	4.00	0.00	6.00
52	TOC, µg/mL	nm	nm	nm	nm	nm
53	TKN, mg/mL	nm	nm	nm	nm	nm

	1	2	3	4	5	6
54						
55	SAMPLE ID	4-SW400RC	4-SE400RC	4-NE400RC	4-S200RC	4-E200RC
56						
57	TDS	251,090	164,177	159,363	31,876	182,549
58						
59	CHARGE BALANCE					
60	Cations, meq/L					
61	Li	0.00	4.32	3.70	0.00	8.62
62	Na	2,631.75	1,918.35	1,809.60	375.41	1,935.75
63	K	0.00	4.60	3.32	1.28	4.09
64	Mg	435.98	229.51	227.86	27.23	236.91
65	Ca	1,257.48	703.59	608.78	118.26	608.78
66	Sr	68.95	39.72	34.93	6.07	35.16
67	Ba	11.21	7.96	6.74	0.85	8.72
68	Mn (2+)	0.78	0.45	0.93	0.05	0.50
69	Fe (2+)	0.78	0.00	0.49	0.94	0.18
70	Total Cations, meq	4,406.92	2,908.51	2,696.35	530.10	2,838.71
71						
72	Anions, meq/L					
73	F	0.02	0.01	0.02	0.00	0.02
74	Cl	4,372.55	2,821.00	2,821.00	564.20	3,385.20
75	Br	0.00	0.00	0.00	0.00	0.00
76	I	0.00	0.00	0.00	0.00	0.00
77	Alkalinity as HCO3	0.02	0.03	0.07	0.00	0.10
78	NO3	0.11	0.00	0.00	0.00	0.00
79	SO4	0.00	0.00	0.00	0.00	0.00
80	PO4					
81	Total Anions, meq	4,372.70	2,821.04	2,821.08	564.20	3,385.32
82						
83	Net Difference, meq	34.23	87.46	-124.73	-34.10	-546.61
84						
85	Percent Difference	-0.39	-1.53	2.26	3.12	8.78
86						
87	RADIONUCLIDES					
88	ACD Sample No.	23462	23464	23465	23466	23467
89						
90	Gross Alpha, Bq/L	100±400	180±300	50±260	20±70	220±320
91	Gross Beta, Bq/L	90±170	120±190	70±170	<40.0	120±190
92						
93	H3, Bq/L	<60.0	60±60	<50.0	<60.0	20±60
94	Co60, Bq/L	<0.5	<0.6	<0.6	<0.6	<0.6
95	Sr90, Bq/L	9.1±1.9	0.56±0.96	87±5	3.5±1.0	0.88±0.90
96	Tc99, Bq/L	<0.6	0.14±0.51	<0.4	<0.4	<0.4
97	Ru106, Bq/L	nm	nm	nm	nm	nm
98	Cs137, Bq/L	<0.5	<0.6	<0.6	<0.6	<0.5
99	Th232, Bq/L	nm	nm	nm	nm	nm

### Appendix C

Analytical data from the eight RC wells for the May 1986 sampling. Blank entries or the entry *nm* in the table indicate that no measurement was attempted. Asterisks indicate pH values obtained by laboratory measurement several days after sampling. The entry *nd* indicates a component was looked for but not detected. Analytical uncertainties are within  $\pm 10\%$  of the value reported, unless otherwise indicated.



	1	2	3	4	5
1	SAMPLE ID	4-NW400RC	4-SW400RC	4-SE400RC	4-NE400RC
2	Date Collected	21May86	23May86	20May86	21May86
3	Collected By	JS	JS	JS	JS
4	Sample Depth	580.0	600.0	690.0	580.0
5	pH	4.90	4.80	6.20	5.90
6	Temp, °C	16.40	17.50	16.80	17.90
7	Cond, µS/cm	177,700	194,200	190,300	176,200
8					
9	CHEMICAL DATA				
10	ACD Sample No.	1964	1965	1966	1967
11					
12	Cations, µg/mL				
13	Li	<100.0	<100.0	<100.0	<100.0
14	Na	46,000.00	48,000.00	49,000.00	44,000.00
15	K	nm	nm	nm	nm
16	Be	<1.0	<1.0	<1.0	<1.0
17	Mg	3,200.00	3,600.00	3,300.00	3,000.00
18	Ca	17,000.00	23,000.00	20,000.00	16,000.00
19	Sr	1,700.00	2,300.00	2,100.00	1,600.00
20	Ba	550.00	650.00	670.00	530.00
21	Ti	<10.0	<10.0	<10.0	<10.0
22	V	<5.0	<5.00	<5.00	<5.00
23	Cr	<20.0	<20.0	<20.0	<20.00
24	Mn	19.00	35.00	11.00	33.00
25	Fe	69.00	21.00	<15.0	47.00
26	Co	<5.0	<5.0	<5.0	<5.0
27	Ni	<30.0	<30.0	<30.0	<30.0
28	Cu	<10.0	<10.0	<10.0	<10.0
29	Zn	<10.0	<10.0	<10.0	<10.0
30	Mo	<20.0	<20.0	<20.0	<20.0
31	Ag	<25.0	<25.0	<25.0	<25.0
32	Cd	<2.5	<2.5	<2.5	<2.5
33	B	<40.0	<40.0	<40.0	<40.0
34	Al	<100.0	<100.0	<100.0	<100.0
35	Si	<100.0	<100.0	<100.0	<100.0
36	Pb	<100.0	<100.0	<100.0	<100.0
37	P	<150.0	<150.0	<150.0	<150.0
38	As	<50.0	<50.0	<50.0	<50.0
39	Sb	<100.0	<100.0	<100.0	<100.0
40	Se	<100.0	<100.0	<100.0	<100.0
41					
42	Anions, µg/mL				
43	F	0.44	0.41	0.14	0.30
44	Cl	100,000.00	120,000.00	95,000.00	95,000.00
45	Br	770.00	1,100.00	950.00	790.00
46	I	11.00	18.00	10.00	16.00
47	NO3	54.00	31.00	24.00	34.00
48	SO4	<50.0	<50.0	<50.0	<50.0
49	S2-	nm	nm	nm	nm
50	PO4	nm	nm	nm	nm
51	Alkalinity as HCO3	<2.0	<2.0	<2.0	<2.0
52	TOC, µg/mL	nm	nm	nm	nm
53	TKN, mg/mL	nm	nm	nm	nm

	1	2	3	4	5
54					
55	SAMPLE ID	4-NW400RC	4-SW400RC	4-SE400RC	4-NE400RC
56					
57	TDS	169,220	198,650	171,020	160,920
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	0.00	0.00	0.00
62	Na	2,001.00	2,088.00	2,131.50	1,914.00
63	K	0.00	0.00	0.00	0.00
64	Mg	263.23	296.14	271.46	246.78
65	Ca	848.30	1,147.70	998.00	798.40
66	Sr	38.81	52.51	47.94	36.53
67	Ba	8.01	9.46	9.76	7.72
68	Mn (2+)	0.69	1.27	0.40	1.20
69	Fe (2+)	2.47	0.75	0.00	1.68
70	Total Cations, meq	3,162.51	3,595.84	3,459.06	3,006.31
71					
72	Anions, meq/L				
73	F	0.02	0.02	0.01	0.02
74	Cl	2,821.00	3,385.20	2,679.95	2,679.95
75	Br	9.63	13.76	11.88	9.88
76	I	0.09	0.14	0.08	0.13
77	Alkalinity as HCO <sub>3</sub>	0.00	0.00	0.00	0.00
78	NO <sub>3</sub>	0.87	0.50	0.39	0.55
79	SO <sub>4</sub>	0.00	0.00	0.00	0.00
80	PO <sub>4</sub>				
81	Total Anions, meq	2,831.61	3,399.62	2,692.31	2,690.52
82					
83	Net Difference, meq	330.90	196.21	766.75	315.79
84					
85	Percent Difference	-5.52	-2.80	-12.46	-5.54
86					
87	RADIONUCLIDES				
88	ACD Sample No.	34216	34217	34218	34219
89					
90	Gross Alpha, Bq/L	61±48	18±35	32±48	22±33
91	Gross Beta, Bq/L	72±35	28±30	44±32	36±30
92					
93	H <sub>3</sub> , Bq/L	nm	nm	nm	nm
94	Co60, Bq/L	0.56±0.15	<0.1	<0.1	<0.1
95	Sr90, Bq/L	4.4±0.2	1.9±0.9	11±2	1.1±0.7
96	Tc99, Bq/L	nm	nm	nm	nm
97	Ru106, Bq/L	nm	nm	nm	nm
98	Cs137, Bq/L	0.69±0.14	0.64±0.12	1.1±.2	0.81±0.12
99	Th232, Bq/L	1.2±2	1.0±0.2	0.96±0.29	nd

	6	7	8	9	10
1	SAMPLE ID	4-W200RC	4-S200RC	4-E200RC	4-N200RC
2	Date Collected	26May86	22May86	20May86	21May86
3	Collected By	JS	JS	JS	JS
4	Sample Depth	400.0	597.0	645.0	400.0
5	pH	6.80	4.90	4.10	5.20
6	Temp, °C	20.40	18.20	nm	17.90
7	Cond, µS/cm	188,900	139,200	>200,000	168,600
8					
9	CHEMICAL DATA				
10	ACD Sample No.	1968	1969	1970	1971
11					
12	Cations, µg/mL				
13	Li	<100.0	<100.0	<100.0	<100.0
14	Na	48,000.00	27,000.00	48,000.00	44,000.00
15	K	nm	nm	nm	nm
16	Be	<1.0	<1.0	<1.0	<1.0
17	Mg	3,400.00	2,200.00	3,300.00	2,900.00
18	Ca	20,000.00	13,000.00	19,000.00	16,000.00
19	Sr	2,000.00	1,300.00	2,000.00	1,600.00
20	Ba	650.00	410.00	660.00	500.00
21	Ti	<10.00	<10.00	<10.00	<10.0
22	V	<5.00	<5.00	<5.00	<5.00
23	Cr	<20.00	<20.0	<20.0	<20.00
24	Mn	31.00	26.00	30.00	20.00
25	Fe	130.00	46.00	39.00	25.00
26	Co	<5.0	<5.0	<5.0	<5.0
27	Ni	<30.0	<30.0	<30.0	<30.0
28	Cu	<10.0	<10.0	<10.0	<10.0
29	Zn	<10.0	<10.0	<10.0	<10.0
30	Mo	<20.0	<20.0	<20.0	<20.0
31	Ag	<25.0	<25.0	<25.0	<25.0
32	Cd	<2.5	<2.5	<2.5	<2.5
33	B	<40.0	<40.0	<40.0	<40.0
34	Al	<100.0	<100.0	<100.0	<100.0
35	Si	<100.0	<100.0	<100.0	<100.0
36	Pb	<100.0	<100.0	<100.0	<100.0
37	P	<150.0	<150.0	<150.0	<150.0
38	As	<50.0	<50.0	<50.0	<50.0
39	Sb	<100.0	<100.0	<100.0	<100.0
40	Se	<100.0	<100.0	<100.0	<100.0
41					
42	Anions, µg/mL				
43	F	0.56	0.39	0.33	0.03
44	Cl	120,000.00	71,000.00	120,000.00	97,000.00
45	Br	950.00	580.00	880.00	770.00
46	I	15.00	11.00	18.00	15.00
47	NO3	48.00	20.00	32.00	28.00
48	SO4	<50.0	<50.00	<50.0	<50.0
49	S2-	nm	nm	nm	nm
50	PO4	nm	nm	nm	nm
51	Alkalinity as HCO3	<2.0	<2.0	<2.0	<2.0
52	TOC, µg/mL	nm	nm	nm	nm
53	TKN, mg/mL	nm	nm	nm	nm

	6	7	8	9	10
54					
55	SAMPLE ID	4-W200RC	4-S200RC	4-E200RC	4-N200RC
56					
57	TDS	195,000	115,490	193,840	162,770
58					
59	CHARGE BALANCE				
60	Cations, meq/L				
61	Li	0.00	0.00	0.00	0.00
62	Na	2,088.00	1,174.50	2,088.00	1,914.00
63	K	0.00	0.00	0.00	0.00
64	Mg	279.68	180.97	271.46	238.55
65	Ca	998.00	648.70	948.10	798.40
66	Sr	45.66	29.68	45.66	36.53
67	Ba	9.46	5.97	9.61	7.28
68	Mn (2+)	1.13	0.95	1.09	0.73
69	Fe (2+)	4.66	1.65	1.40	0.90
70	Total Cations, meq	3,426.59	2,042.41	3,365.32	2,996.39
71					
72	Anions, meq/L				
73	F	0.03	0.02	0.02	0.00
74	Cl	3,385.20	2,002.91	3,385.20	2,736.37
75	Br	11.88	7.26	11.01	9.63
76	I	0.12	0.09	0.14	0.12
77	Alkalinity as HCO3	0.00	0.00	0.00	0.00
78	NO3	0.77	0.32	0.52	0.45
79	SO4	0.00	0.00	0.00	0.00
80	PO4				
81	Total Anions, meq	3,398.01	2,010.60	3,396.88	2,746.57
82					
83	Net Difference, meq	28.59	31.82	-31.57	249.81
84					
85	Percent Difference	-0.42	-0.79	0.47	-4.35
86					
87	RADIONUCLIDES				
88	ACD Sample No.	34220	34221	34222	34223
89					
90	Gross Alpha, Bq/L	16±31	17±25	29±42	15±29
91	Gross Beta, Bq/L	27±29	45±30	15±28	27±29
92					
93	H3, Bq/L	nm	nm	nm	nm
94	Co60, Bq/L	<0.1	0.08±0.7	0.13±0.12	0.08±0.07
95	Sr90, Bq/L	13±2	4.6±1.1	2.4±1.0	2.7±1.0
96	Tc99, Bq/L	nm	nm	nm	nm
97	Ru106, Bq/L	nm	nm	nm	nm
98	Cs137, Bq/L	1.0±0.2	0.54±0.1	1.0±0.2	0.82±0.12
99	Th232, Bq/L	nd	nd	nd	0.56±0.16

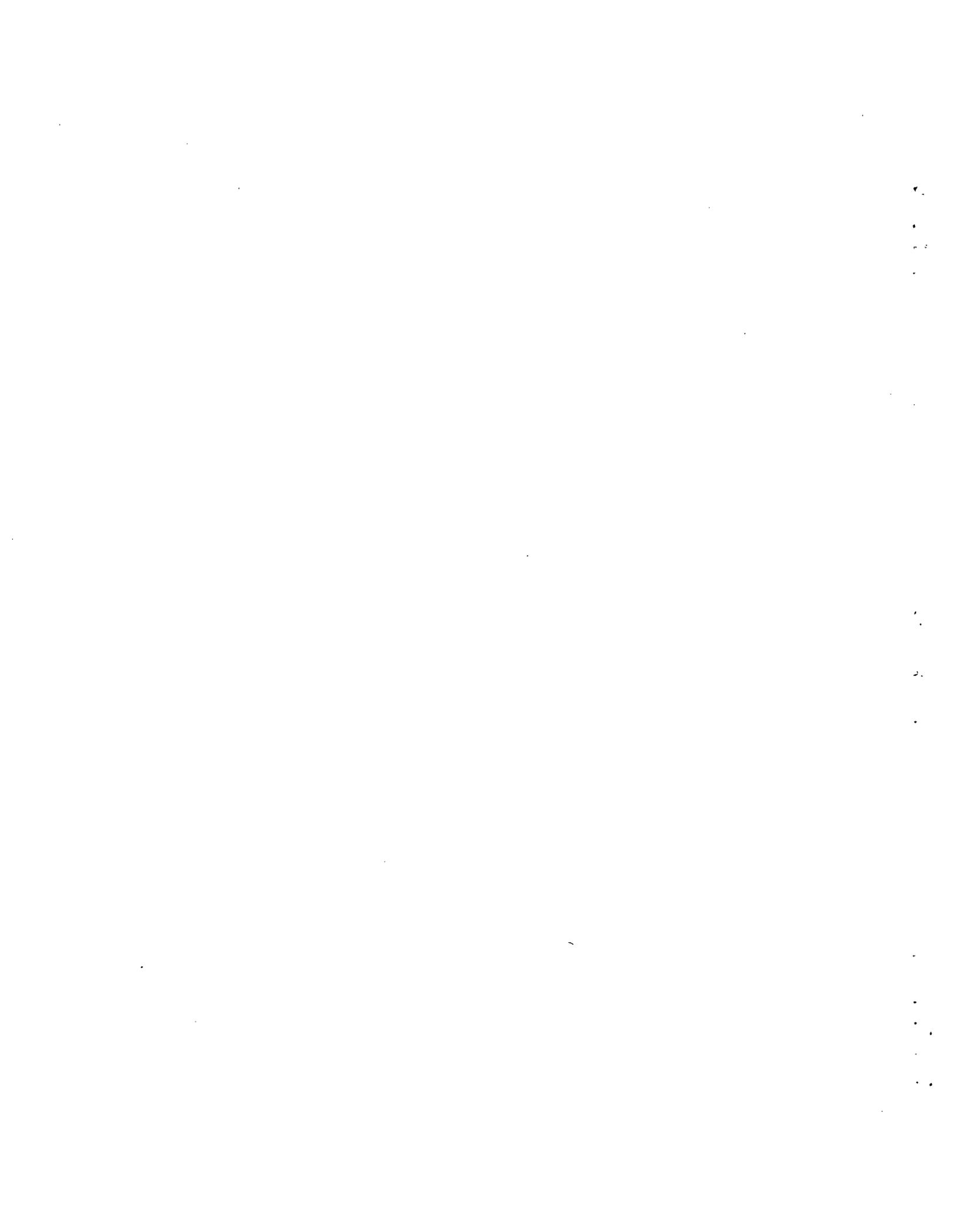
### Appendix D

Radiochemical data for particulates removed during filtering of samples from eight RC wells for the October 1983 sampling. Blanks entries or the entry *nm* in the table indicate that no measurement was attempted. The entry *nd* indicates a component was looked for but not detected. Analytical uncertainties are as indicated.



	1	2	3	4	5
1	SAMPLE ID	4-NW400RC	4-SW400RC	4-SE400RC	4-NE400RC
2	Date Collected	Oct-83	Oct-83	Oct-83	Oct-83
3	Collected By	JS/CDF	JS/CDF	JS/CDF	JS/CDF
4	Sample Depth	570	690	690	570
5					
6	RADIONUCLIDES				
7	ACD Sample No.				
8					
9	Gross Alpha, Bq/kg	nm	nm	nm	nm
10	Gross Beta, Bq/kg	nm	nm	nm	nm
11					
12	Co60, Bq/kg	nd	nd	185±47	nd
13	Sr90, Bq/kg	63±221	nd	406±170	92±138
14	Tc99, Bq/kg	2,122±320	2,401±200	2,647±243	617±199
15	Cs137, Bq/kg	nd	12.8±6.4	2,135±190	nd

	6	7	8	9	10
1	SAMPLE ID	4-W200RC	4-S200RC	4-E200RC	4-N200RC
2	Date Collected	Oct-83	Oct-83	Oct-83	Oct-83
3	Collected By	JS/CDF	JS/CDF	JS/CDF	JS/CDF
4	Sample Depth	640	690	640	570
5					
6	RADIONUCLIDES				
7	ACD Sample No.				
8					
9	Gross Alpha, Bq/kg	nm	nm	nm	nm
10	Gross Beta, Bq/kg	nm	nm	nm	nm
11					
12	Co60, Bq/kg	nd	nd	nd	nd
13	Sr90, Bq/kg	51.5±36.1	nd	147±107	34.5±20.7
14	Tc99, Bq/kg	6,179±1,030	1,436±308	669±139	6,091±677
15	Cs137, Bq/kg	nd	63±44	nd	nd



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