RCN 218-070-07-20

DEMONSTRATION OF INNOVATIVE APPLICATIONS OF TECHNOLOGY FOR THE CT-121 FGD PROCESS

Plant Yates

Environmental Monitoring Program Report: First Quarter 1996 (Final)

DOE DE-FC22-90PC89650
SCS C-90-00284

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Demonstration of Innovative Applications of Technology for the CT-121 FGD Process

Plant Yates

Environmental Monitoring Program Report: First Quarter 1996

This progress report summarizes activities associated with the environmental monitoring program (EMP) during the first calendar quarter of 1996 for the U.S. Department of Energy's Innovative Clean Coal Technology project entitled "Demonstration of Innovative Applications of Technology for the CT-121 FGD Process." This demonstration project was conducted at Georgia Power Company's Plant Yates Unit 1, located near Newnan, Georgia, until January 1995, when operational responsibility was permanently transferred to Georgia Power Company from Southern Company Services, Inc., manager of the demonstration project.

No further operational testing is planned, and monitoring under the EMP is now limited to groundwater monitoring.

Post-operational-phase groundwater monitoring is being conducted. A report of monitoring results for the previous quarter (fourth quarter of 1995) is attached.

Attachment

Groundwater Monitoring Report for The Fourth Quarter of 1995

Table of Contents

List of Figures

List of Tables

1.0 Introduction

This report summarizes the results of groundwater monitoring performed during the fourth calendar quarter of 1995 as part of the environmental monitoring program (EMP) for the U.S. Department of Energy's Innovative Clean Coal Technology project entitled "Demonstration of Innovative Applications of Technology for the CT-121 FGD Process." This demonstration project is being conducted at Georgia Power Company's Plant Yates Unit 1, located near Newnan, Georgia.

1.1 Project Summary

The purpose of this ICCT project is to demonstrate the use of the Chiyoda Thoroughbred-121 flue gas desulfurization process as a means of reducing SO_2 and particulate emissions from pulverized-coal utility boilers that use medium-sulfur coal. This project is also designed to demonstrate the lower cost and higher reliability of the CT-121 process compared to conventional wet limestone FGD processes.

The demonstration project at Plant Yates consists of four distinct test periods:

- Period 0: Site Preparation, Construction, and Startup of the Demonstration Project (including background groundwater monitoring [29 months]);
- Period 1: Baseline Testing at Low Particulate Loading—ESP In Service (12 months);
- Period 2: Testing at High Particulate Loading—ESP Detuned or Out of Service (12 months); and
- Period 3: Post Demonstration Groundwater Testing and Gypsum Byproduct Evaluation.

Period 2 ended in December 1994. Groundwater monitoring was initiated in Period 0 and will continue through Period 3.

1.2 Purpose and Scope of Groundwater Monitoring

The CT-121 process produces gypsum, which is being disposed of in an on-site stacking area where the solids are concentrated as they are allowed to settle, dewater, and dry. The

gypsum and gypsum/fly ash stacking area is lined with a synthetic liner to minimize the potential for adverse impacts on the groundwater. Requirements for the liner, leachate collection system, and groundwater monitoring are specified in the permit issued by the Georgia Department of Natural Resources (DNR). One requirement is the regular monitoring of groundwater before, during, and for two years after the demonstration program. The purpose of this monitoring is to demonstrate that the gypsum stacking area can be operated in an environmentally benign and acceptable manner.

In 1990, five groundwater monitoring wells were installed in the vicinity of the proposed gypsum stacking area. These wells were used to monitor baseline groundwater quality prior to construction of the stacking area. Monitoring was conducted every two months from September 1990 through July 1991. Table 1 is a summary of the parameters that were monitored during this period. The results of this monitoring activity were summarized in the report "Environmental Monitoring Program Report of Preconstruction Monitoring: 1990-1991 Background Water Quality."

Following the preconstruction monitoring period, and as a DNR permit requirement, two additional monitoring wells were installed in 1992. The locations of all seven monitoring wells are shown in Figure 1. Because of a delay in the commencement of Phase 1 testing, an additional round of preoperational groundwater monitoring was conducted on September 3-4 and October 14, 1992. The results of this monitoring effort were presented in the report "Interim Data Report of Preoperational Groundwater Monitoring: September 3-4 and October 14, 1992."

Operational-phase groundwater monitoring, performed on a quarterly basis, was initiated in the fourth quarter of 1992. Monitoring was conducted for the suite of parameters shown previously in Table 1. Samples were analyzed each quarter for all parameters shown except for radionuclides, which are monitored semiannually.

Beginning in the second quarter of 1994, monitoring is also being performed quarterly for total organic halides (TOX) and annually for volatile organic compounds (VOCs). Theses parameters have been added to comply with requirements of the permit issued by the Environmental Protection Division of the Georgia DNR.

Table 1. EMP Groundwater Monitoring Parameters

pH	Conductivity	Temperature
Eh	Alkalinity	Total Dissolved Solids
Bromide	Chloride	Total Organic Carbon
Fluoride	Nitrate-Nitrite	Sulfate
Trace Elements (Dissolved)		
Silver	Aluminum	Arsenic
Boron	Barium	Beryllium
Bismuth	Calcium	Cadmium
Cobalt	Copper	Chromium
Mercury	Iron	Potassium
Lithium	Magnesium	Manganese
Molybdenum	Sodium	Nickel
Phosphorus	Lead	Sulfur
Antimony	Selenium	Silicon
Tin	Strontium	Tellurium
Titanium	Thallium	Uranium
Vanadium	Tungsten	Zinc
Other		
Radionuclides		

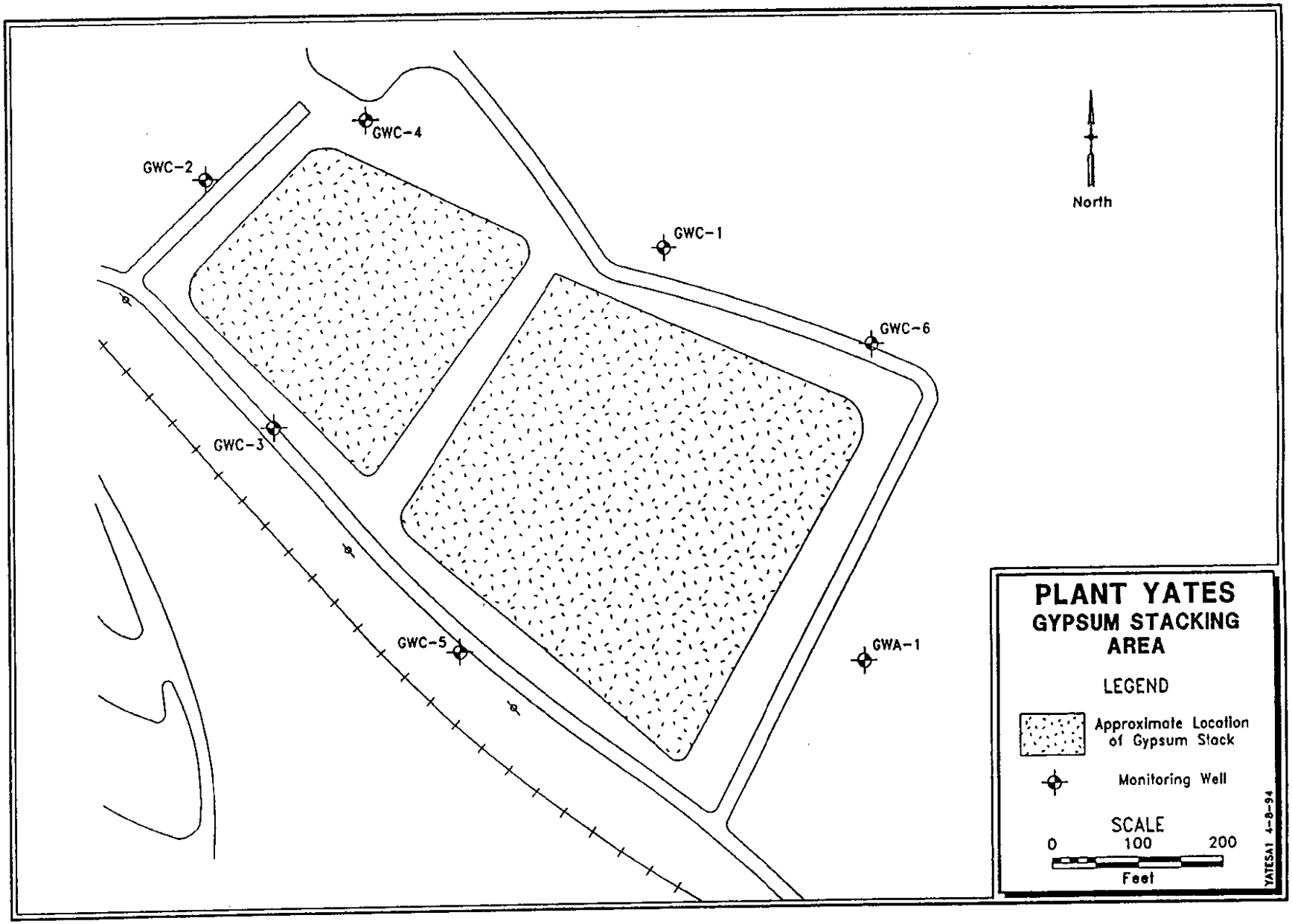


Figure 1. Locations of Groundwater Monitoring Wells

The post-demonstration groundwater monitoring period began in the first quarter of 1995 and will be conducted over a period of two years for the same parameters and at the same frequency as during the operational phase.

1.3 Report Contents

This report presents the results of quarterly post-demonstration-phase groundwater monitoring for the fourth calendar quarter of 1995. The groundwater monitoring wells were sampled on December 12-13, 1995.

Section 2 is a brief summary of the sampling and analytical methods used in conducting the monitoring. Results of the monitoring are presented in Section 3. Results of quality assurance/quality control (QA/QC) activities associated with sample analyses are summarized in Section 4. Tables of historical trends for selected parameters, and the results for field and laboratory duplicates, are given in the appendices.

2.0 Sampling and Analytical Methods

This section describes the methods used to obtain and analyze groundwater samples. These methods were specified in Radian's "Test Plan for Groundwater Monitoring Around the Plant Yates Gypsum Stacking Area," August 30, 1990, as amended.

2.1 Sampling Methods

The QED Well Wizard dedicated sampling system was used to purge the monitoring wells and collect samples. The Well Wizard system utilizes a dedicated Teflon® bladder pump and portable air compressor to extract groundwater samples.

To ensure the collection of a representative sample, standing water was removed from each well by purging a minimum of three wetted casing volumes. Conductivity, pH, redox potential, and temperature were monitored and recorded on field sampling forms during purging. Samples were collected after these indicator parameters stabilized and (1) after at least three wetted casing volumes of water were removed or (2) immediately following recovery if a well was purged dry.

Samples were obtained from the upgradient well (GWA-1) and five of the six downgradient wells (GWC-1, GWC-2, GWC-3, GWC-4, and GWC-5). Only a small amount of

groundwater was present in the upgradient well GWA-1, and a complete set of samples could not be collected from this well. As has been the case during all previous rounds of monitoring, well GWC-6 could not be sampled since it was unproductive and contained no water. Table 2 summarizes the groundwater samples collected during this monitoring period.

Table 2. Summary of Groundwater Samples Collected at Plant Yates on December 12-13, 1995

Well ID	Sample ID	Analyses
GWA-1	GWA-1-20-1	Anions, TOX, and Metals[a]
GWC-1	GWC-1-20-1	Anions, TOC, TOX, and Metals
GWC-2	GWC-2-20-1	Anions, TOC, TOX, and Metals
GWC-3	GWC-3-20-1 GWC-3-20-2	Anions, TOC, TOX, and Metals Anions, TOC, TOX, and Metals
GWC-4	GWC-4-20-1	Anions, TOC, TOX, and Metals
GWC-5	GWC-5-20-1	Anions, TOC, TOX, and Metals
GWC-6	None	Well dry; no samples collected

[a] A complete set of samples could not be obtained because only a small amount of groundwater was present in the well.

To preserve the integrity of the groundwater samples before analyses, proper sample containment, preservation, holding time duration, shipment, and chain-of-custody procedures were followed. Sample containers, preservation methods, and maximum holding times are summarized in Table 3.

2.2 Analytical Procedures

The analytical methods used in this program are listed in Table 4. There were no deviations from these methods.

3.0 Summary of Results

The results of the fourth-quarter 1995 groundwater monitoring are presented in Table 5. The concentrations of all of the monitored dissolved constituents in the groundwater near the gypsum stacking area continue to be low.

Table 3. Sample Containers, Preservation Method, and Maximum Holding Times

Bottle Label	Containers [a]	Parameter	Preservation Method	Maximum Holding Time (days)
Total Organic Carbon	500-mL Amber Glass	Total Organic Carbon	H_2SO_4 pH<2	28
Anions/TDS	1-L Plastic	Bromide	4 °C	28
		Chloride	4 °C	28
		Fluoride	4 °C	28
		Nitrate-Nitrite	4 °C	28
		Sulfate	4 °C	28
		Total Dissolved Solids	4 °C	7
TOX	250-mL Amber Glass, no headspace	Total Organic Halogens	H_2SO_4 pH<2	28
VOCs	(2) 40-mL VOA Vials	Volatile Organics	HCl pH<2	14
Metals	1-L Plastic	Trace Metals	Filtered On Site Ultrex II HNO_3 pH<2	180
Radioactivity	(3) 1-L Plastic	Radium 226, Radium 228, Gross Alpha, Gross Beta, Gross Gamma	Filtered On Site Ultrex II HNO_3 pH<2	180

[a] Sample containers supplied by either I-Chem or Eagle Picher.

Table 4. Analytical Methods

Parameter	Technique	Reference
pH	Potentiometry	EPA 150.1
Conductivity	Specific Conductance	EPA 120.1
Temperature	Temperature Probe	EPA 170.1
Eh	Electrometry	ASTM D1498
Alkalinity	Titrimetric or Colorimetric	EPA 310.1 or 310.2
Bromide	Ion Chromatography	EPA 300
Chloride	Ion Chromatography	EPA 300
Total Organic Carbon	Combustion/IR	EPA 415.1
TOX	Carbon Adsorption/Combustion/ Electrolytic Titration	SW-846 Method 9020A
VOCs	GC/MS	SW-846 Method 8260
Fluoride	SIE	EPA 340.2
Nitrate/Nitrite	Colorimetry	EPA 353.1
Sulfate	Ion Chromatography	EPA 300
Total Dissolved Solids	Filtration/Evaporation/Gravimetry	EPA 160.2
Mercury	On-site Filtration/Cold Vapor AA	EPA 245.1
Trace Elements	On-site Filtration/AA and ICP-AES	EPA 200.7, 7421 (Cr), 7060 (As), 7421 (Pb), 7041 (Sb), 7740 (Se), and 7841 (Tl)
Radium 226 and 228	Proportional Counter	ASTM D2460
Gross Alpha	Proportional Counter	ASTM D1943
Gross Beta	Proportional Counter	ASTM D1890
Gross Gamma	Gamma Ray Spectrometer	ASTM D2459

Legend:

AA = Atomic absorption spectrophotometry
SIE = Specific ion electrode
ICP-AES = Inductively coupled plasma-atomic emission spectrometry
IR = Infrared detection.
GC/MS = Gas chromatography/mass spectroscopy

References:

EPA "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, revised March 1983.
ASTM = American Society for Testing and Materials, *Annual Book of ASTM Standards.*
SW-846 "Test Methods for Evaluating Solid Waste," SW-846, 3rd Ed., November 1986.

(Fourth Quarter 1995)

GWC-4-20-1	GWC-5-20-1
4.89	5.28
196	53
18.6	17.4
325	235

Table 5 (continued)

Parameter	GWA-1-20-1	GWC-1-20-1	GWC-2-20-1	GWC-3-20-1[a]	GWC-4-20-1	GWC-5-20-1
Potassium (mg/L)	1.93[c]	<0.883	<0.883	<0.883	<0.883	1.23[c]
Lithium (mg/L)	<0.00297	<0.00297	<0.00297	<0.00297	<0.00297	<0.00297
Magnesium (mg/L)	6.51	4.23	1.96	1.26	12.6	6.02
Manganese (mg/L)	<0.00365	<0.00365	<0.00365	<0.00365	<0.00365	<0.00365
Molybdenum (mg/L)	<0.0192	<0.0192	<0.0192	<0.0192	<0.0192	<0.0192
Sodium (mg/L)	3.50	4.44	7.11	5.14	8.00	5.82
Nickel (mg/L)	0.0286[c]	<0.0218	0.0286[c]	<0.0218	<0.0218	0.0286[c]
Phosphorus (mg/L)	<0.141	<0.141	<0.141	<0.141	0.408[c]	<0.141
Lead (mg/L)	<0.00126	<0.00126	<0.00126	<0.00126	<0.00126	<0.00126
Sulfur (mg/L)	11.1	0.218[c]	1.53	0.125	1.12	2.77
Antimony (mg/L)	0.00247[b,c]	0.00128[b,c]	0.00147[b,c]	<0.000919[b]	0.00124[b,c]	<0.000919[b]
Selenium (mg/L)	<0.000821	<0.000821	0.00166[c]	0.000840[c]	0.00120[c]	0.00121[c]
Silicon (mg/L)	13.2	10.0	12.9	5.18	11.4	16.2
Tin (mg/L)	<0.0350	<0.0350	<0.0350	<0.0350	<0.0350	<0.0350
Strontium (mg/L)	0.0242	0.0156	0.0115[c]	0.00369[c]	0.0332	0.0160
Tellurium (mg/L)	<0.00449	<0.00449	<0.00449	<0.00449	<0.00449	<0.00449
Titanium (mg/L)	0.00289[b,c]	0.00711[b,c]	0.00219[b,c]	0.00265[b,c]	0.0115[b]	0.0160[b]
Thallium (mg/L)	<0.00232	<0.00232	<0.00232	<0.00232	<0.00232	<0.00232
Uranium (mg/L)	<0.0676	<0.0676	<0.0676	<0.0676	<0.0676	<0.0676
Vanadium (mg/L)	<0.00679	<0.00679	<0.00679	<0.00679	<0.00679	<0.00679
Tungsten (mg/L)	<0.0759	<0.0759	<0.0759	<0.0759	<0.0759	<0.0759
Zinc (mg/L)	0.0131[b,c]	0.00664[b,c]	<0.00362[b]	0.0160[b,c]	0.0130[b,c]	0.0184[b]
TOX (µg/L)	<11.7	<11.7	<11.7	<11.7	<11.7	<11.7

[a] A duplicate sample (GWC-3-20-2) was collected from this well.
[b] Detected in the method blank.
[c] Less than five times the detection limit; results are expected to be less accurate as concentrations approach the detection limit.
NM = Not measured due to insufficient sample.

To help determine whether the material in the gypsum stacking area is having an impact on groundwater quality, the monitoring data for a selected number of representative species from all of the monitoring rounds conducted to date were tabulated and examined. The representative species selected are those present in appreciable concentrations in the gypsum slurry, including the major cations and anions (i.e., calcium, magnesium, chloride, and sulfate), as well as several other indicator parameters such as pH, TDS, conductivity, and alkalinity. The complete set of historical data for these species is provided in Appendix A. The measured concentrations of some selected species are shown as functions of chronologically-ordered sampling periods. In Figures 2 through 4, data are presented for the upgradient well, GWA-1, and two downgradient wells, GWC-2 and GWC-4. The locations of these wells were shown previously in Figure 1. Samples were not obtained this quarter from downgradient well GWC-6.

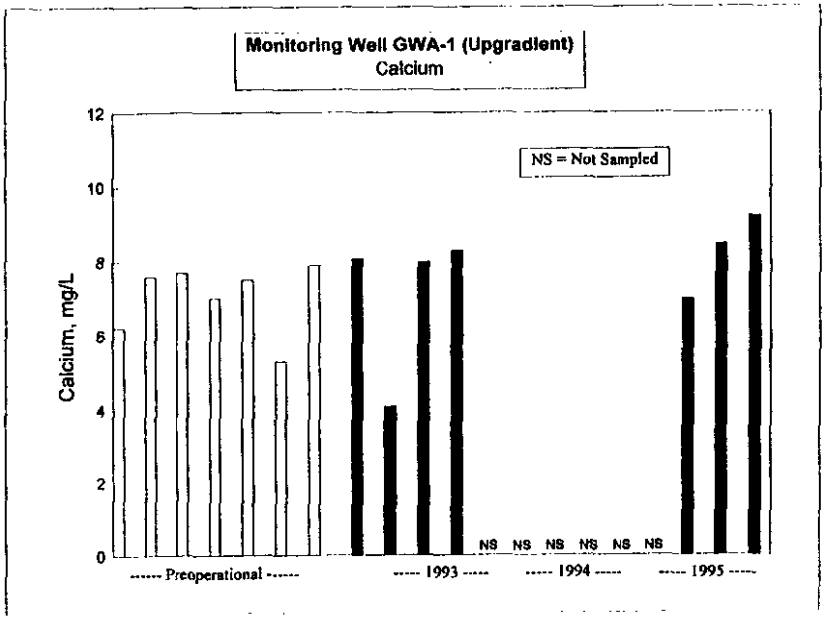
For well GWC-2, the measured concentrations of all monitored parameters are generally close to the historically-observed concentrations of these species. After declining slightly last quarter, the concentrations of calcium, magnesium, and chloride in well GWC-4 increased slightly, continuing a generally upward trend that began in the fourth quarter of 1993. These higher levels may be due, at least in part, to a leak from the gypsum pond that occurred on July 24, 1993, in the vicinity of well GWC-4. Although the contaminant levels in the groundwater at this location continue to be higher than they were prior to the time of the gypsum pond leak, they are still quite low. For example, the latest chloride concentration is less than 16% of the maximum concentration recommended in the National Secondary Drinking Water Standards (i.e., 40.5 mg/L versus 250 mg/L).

4.0 Summary of QA/QC Activities

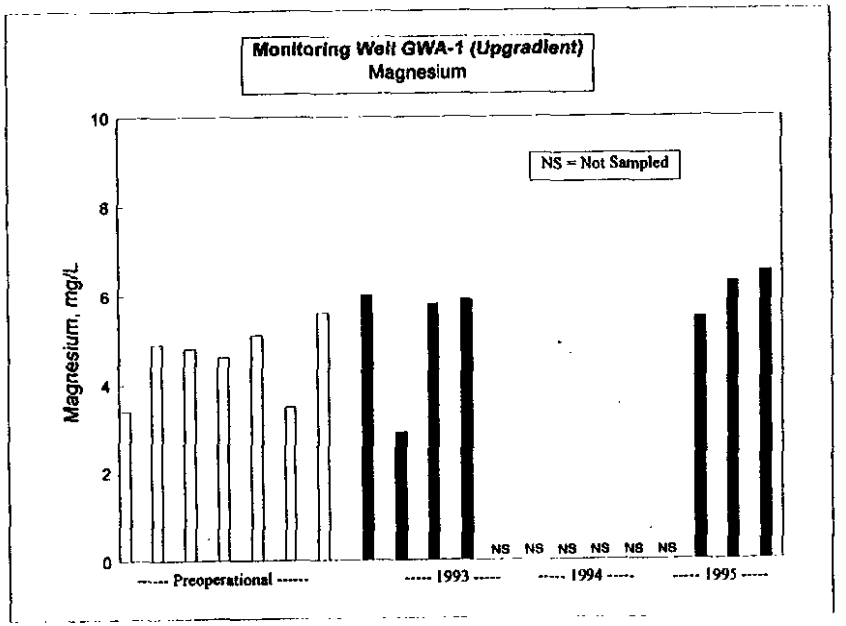
A number of QA/QC activities are being performed, as specified in the project's EMP, to assure that the data obtained meet project objectives. These include the following:

- Groundwater samples were split for independent analysis by a laboratory selected by SCS.

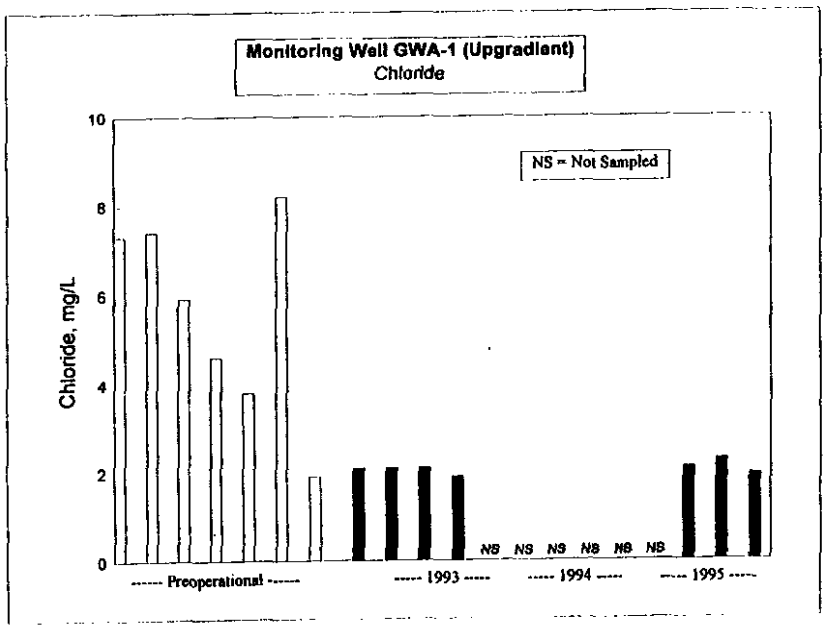
- Established sampling and analytical methods were specified and used. All samples were analyzed within the specified holding times, as outlined in Section 2. There were no deviations from the specified methods during this quarter's monitoring effort.



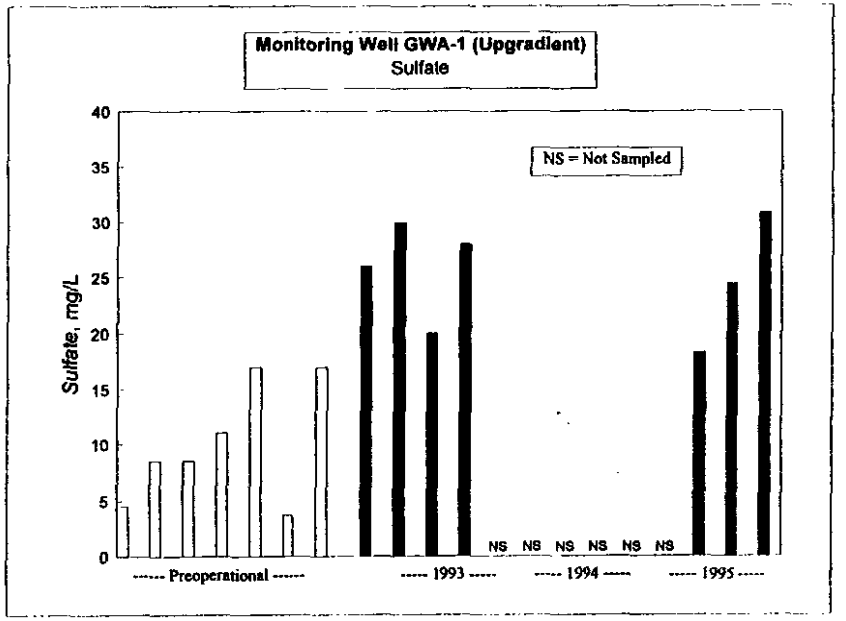
(a) Calcium



(b) Magnesium

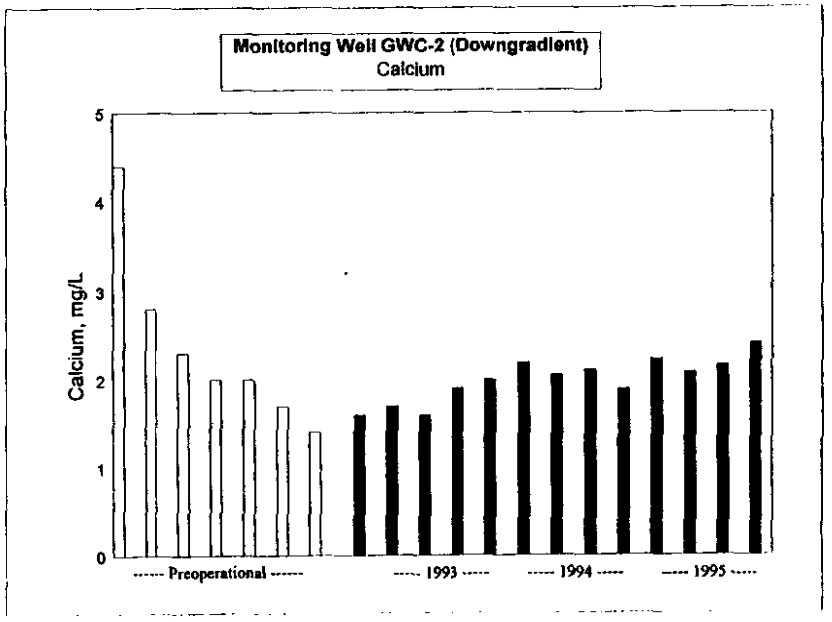


(c) Chloride

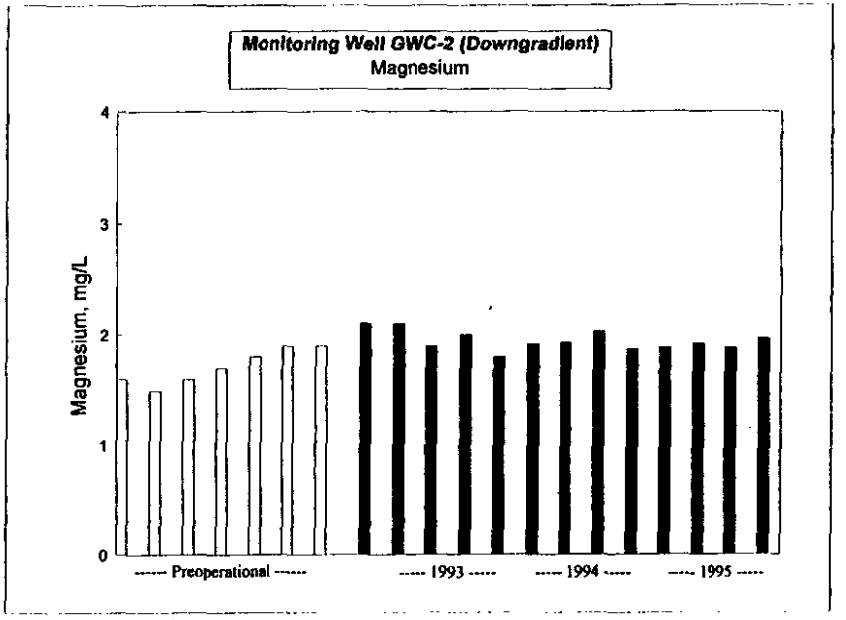


(d) Sulfate

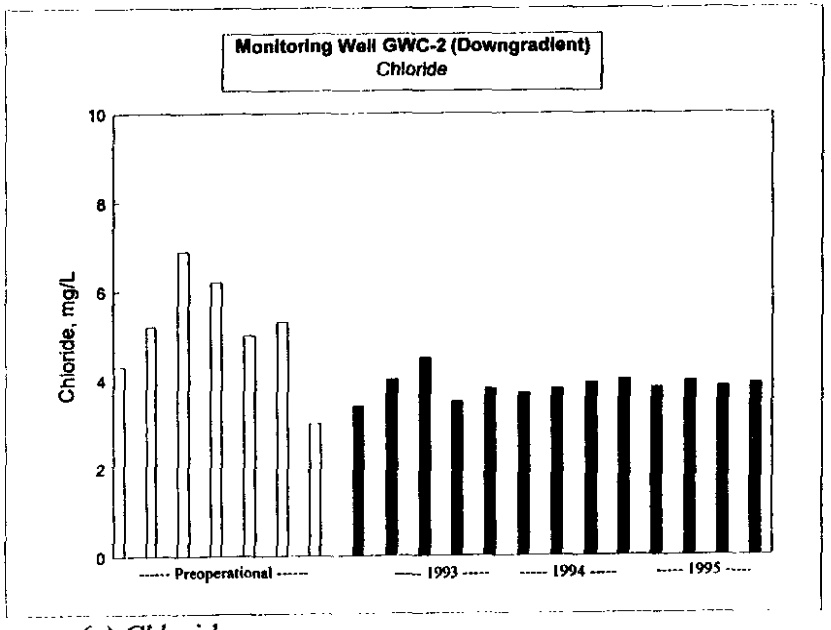
Figure 2. Historical Data for Representative Species from Well GWA-1 (Upgradient)



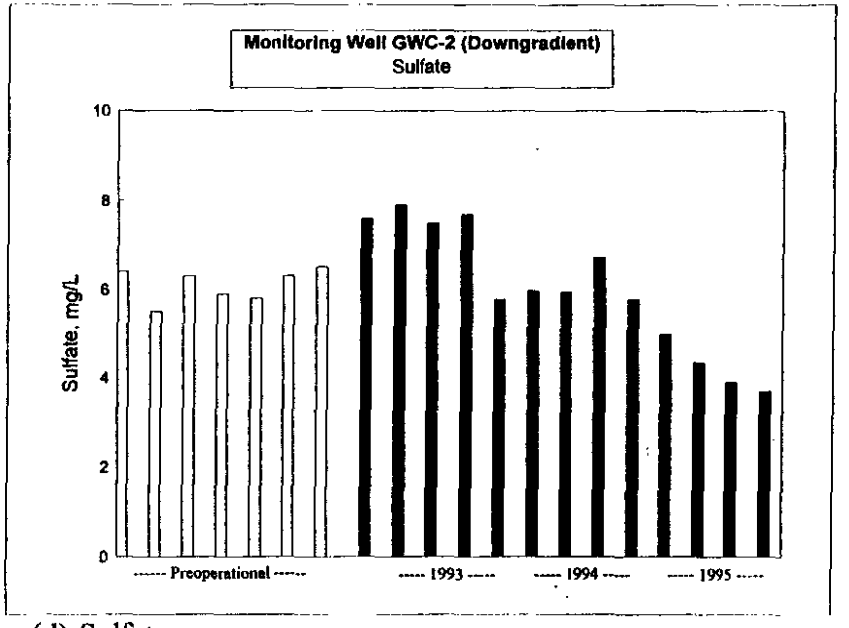
(a) Calcium



(b) Magnesium

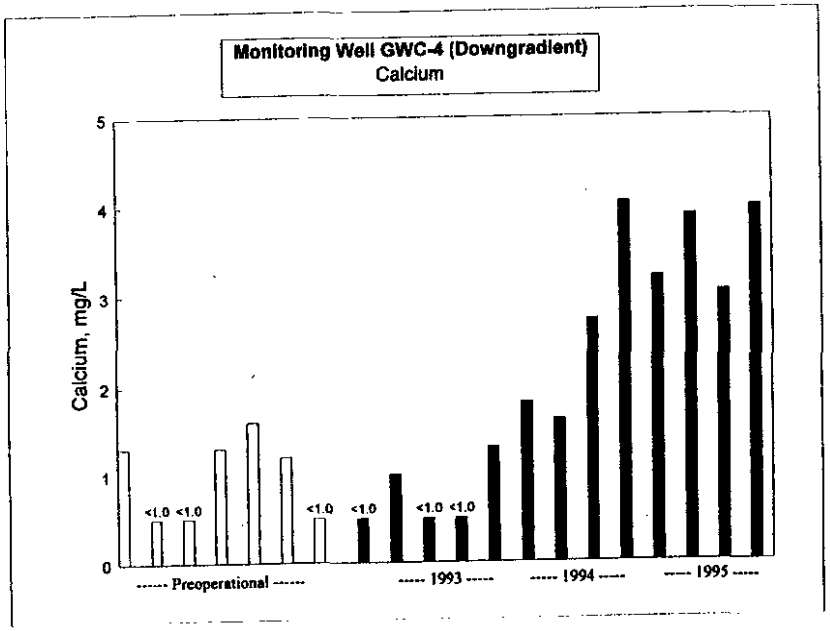


(c) Chloride

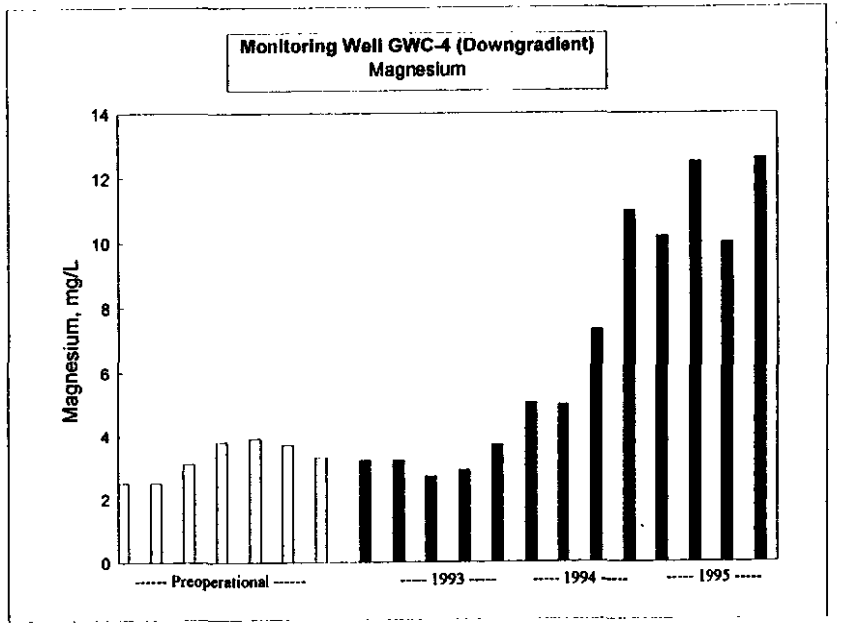


(d) Sulfate

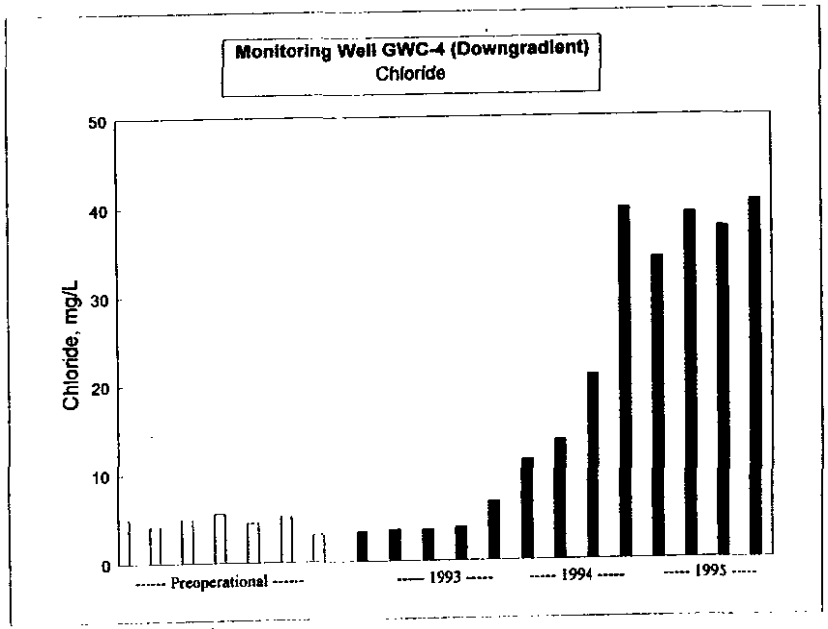
Figure 3. Historical Data for Representative Species from Well GWC-2 (Downgradient)



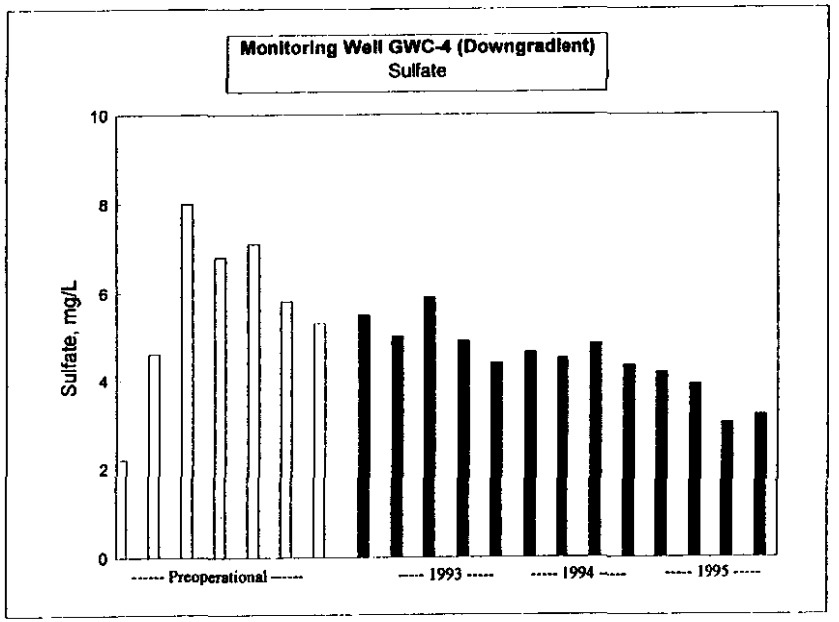
(a) Calcium



(b) Magnesium



(c) Chloride



(d) Sulfate

Figure 4. Historical Data for Representative Species from Well GWC-4 (Downgradient)

- Chain-of-custody procedures established in the test plan for this project were observed.

- In the laboratory, method blanks, control samples, and matrix spikes were analyzed in conjunction with the sample analyses, following recognized good laboratory practice. Specified recovery limits (typically 80% to 120%) were met for most analytes in the laboratory control samples. Recoveries of silicon in the matrix spike samples were high (i.e., from 206% to 278%), and low for antimony (i.e., 68% to 71%) and one of two spikes analyzed for silver (i.e., 70% recovery), making the results for these analytes somewhat suspect.

- Duplicate samples were obtained in the field and analyzed for all parameters. Replicate analyses were performed for a smaller number of parameters.

The results of the analysis of field and laboratory duplicates are summarized in Table 6 for those parameters measured above the detection limit in at least one sample. Complete results are provided in Appendix B. Differences in the duplicate analyses results were small for most species (i.e., less than about ±10%). Larger differences between sample duplicates were obtained for TDS, nitrate-nitrite, iron, silicon, titanium, and zinc. The duplicate analyzed for TDS was slightly above the acceptable limit (21% versus 15% specification); reanalysis of this sample gave results comparable to those for the primary sample.

Table 6. Results for Duplicate Samples—Fourth Quarter 1995

Parameter	Units	Sample GWC-3-20-1	Field Duplicate GWC-3-20-2	% Diff.[a]	Duplicate Analysis GWC-3-20-2	% RPD[b]	Spec. Limit
Total Dissolved Solids	mg/L	36.0	42.0	14	34.0	21	15
Chloride	mg/L	3.52	3.45	-2	3.50	1	20
Fluoride	mg/L	0.0307[c]	0.0302[c]	-2	0.0281[c]	7	20
Sulfate	mg/L	0.233	<0.0491	NC	<0.0491	NC	20
Nitrate-Nitrite as N	mg/L	0.328	0.406	19	0.414	2	20
Aluminum	µg/L	0.0338[d]	<0.0270	NC			
Arsenic	mg/L	0.0012[d]	<0.000887	NC			
Boron	mg/L	0.0330[d]	<0.0105	NC			
Barium	mg/L	0.00973	0.00865[c]	-12			
Calcium	mg/L	0.436	0.390	-12			
Cobalt	mg/L	0.0103[d]	<0.00987	NC			
Iron	mg/L	0.0511[d]	0.238	79			
Magnesium	mg/L	1.26	1.14	-11			
Sodium	mg/L	5.14	5.03	-2			
Sulfur	mg/L	0.125[d]	<0.118	NC			
Antimony	mg/L	<0.000919	<0.000919	NC			
Selenium	mg/L	0.000840[d]	<0.000821	NC			
Silicon	mg/L	5.18	0.242	-2040			
Strontium	mg/L	0.00369[d]	0.00369[d]	0			
Titanium	mg/L	0.00265[c,d]	0.00199[c,d]	-33			
Zinc	mg/L	0.0160[c,d]	0.0106[c,d]	-51			

[a] % Difference = ([GWC-3-20-2] - [GWC-3-20-1]) x 100/[GWC-3-20-1].

[b] RPD = Relative Percent Difference, defined as follows:

$$RPD = \frac{(\text{Larger Value} - \text{Smaller Value})}{(\text{Larger Value} + \text{Smaller Value})/2} \times 100\%.$$

[c] Detected in the method blank

[d] Value is less than five times the detection limit; results are expected to be less accurate as concentrations approach the detection limit.

NC = Not computed.

Appendix A

Historical Monitoring Data for Selected Parameters

Table A-1. Historical Monitoring Data for Selected Parameters

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWA-1 (Formerly CW-1)											
pH	5.86	6.27	5.6	6.7	6.05	5.94	6.4	5.7	6.82	6.1	5.9
Conductivity	98	114	112	121	104	85	116	101	128	100	110
Alkalinity	15.6	22.3	25.8	27.1	25	16.4	35.4	22.7	28	27	24.8
TDS	94	87	86	84	90	77	99	110	110	116	99
Chloride	7.3	7.4	5.9	4.6	3.8	8.2	1.9	2.1	2.1	2.1	1.9
Sulfate	4.5	8.5	8.5	11	17	3.7	17	26	30	20	28
Calcium	6.2	7.6	7.7	7	7.5	5.3	7.9	8.1	4.1	8.0	8.3
Magnesium	3.4	4.9	4.8	4.6	5.1	3.5	5.6	6.0	2.9	5.8	5.9
Sodium	4.2	4.8	4.9	4.3	4.4	3.8	4.1	4.2	4.0	4.4	4.3
Silicon	9.8	11	14	16	17	9.6	15	17	11	18	17

Parameter	Round 12 5 Jan 94	Round 13 22-23 Mar 94	Round 14 21-22 Jun 94	Round 15 31 Aug 94	Round 16 20-21 Dec 94	Round 17 28-29 Mar 95	Round 18 13-14 Jun 95	Round 19 11-12 Sep 95	Round 20 12-13 Dec 95		
Well: GWA-1 (Formerly CW-1) (Continued)											
pH	NS	NS	NS	NS	NS	NS	6.31	6.38	6.08		
Conductivity	NS	NS	NS	NS	NS	NS	116	165	118		
Alkalinity	NS	NS	NS	NS	NS	NS	28.6	23	NM		
TDS	NS	NS	NS	NS	NS	NS	108	114	93		
Chloride	NS	NS	NS	NS	NS	NS	2.10	2.27	1.94		
Sulfate	NS	NS	NS	NS	NS	NS	18.3	24.4	30.8		
Calcium	NS	NS	NS	NS	NS	NS	6.98	8.47	9.21		
Magnesium	NS	NS	NS	NS	NS	NS	5.47	6.30	6.51		
Sodium	NS	NS	NS	NS	NS	NS	4.29	4.53	3.50		
Silicon	NS	NS	NS	NS	NS	NS	16.6	17.6	13.2		

Table A-1 (continued)

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWC-1 (Formerly CW-2)											
pH	6.09	5.79	5.62	5.93	6.04	5.96	6.1	4.5	5.83	6.0	6.0
Conductivity	81	70	72	63	63	66	78	57	67	57	61
Alkalinity	21.7	22.9	24.4	22.1	20.5	25.8	27.8	23.3	22.5	24.1	27.3
TDS	81	51	59	52	48	64	64	68	43	74	70
Chloride	3.5	2.8	3.1	3.4	2.8	2.5	2.5	2.6	2.6	2.6	2.5
Sulfate	7.6	5	2.8	<0.05	1.2	1.5	3.2	3.3	2.2	<2.5	2.6
Calcium	3.9	3.6	3.8	3.2	3.4	3.6	4.3	4.0	8.8	4.1	4.1
Magnesium	2.3	2.5	2.8	2.2	2.4	2.5	3.2	3.0	6.2	2.9	3.0
Sodium	5.9	5.2	4.3	4.1	4.2	4.1	4.0	4.0	4.2	4.0	3.8
Silicon	9	9	9.2	11	11	11	11	12	16	12	12
Parameter	Round 12 5 Jan 94	Round 13 22-23 Mar 94	Round 14 21-22 Jun 94	Round 15 31 Aug 94	Round 16 20-21 Dec 94	Round 17 28-29 Mar 95	Round 18 13-14 Jun 95	Round 19 11-12 Sep 95	Round 20 12-13 Dec 95		
Well: GWC-1 (Formerly CW-2) (Continued)											
pH	6.1	5.89	5.91	6.09	6.09	6.05	5.70	6.00	5.92		
Conductivity	74	61	60	68	76	77	66	79	82		
Alkalinity	29.9	25	30.1	25	22	29.1	31.0	31	31.2		
TDS	22	66	56	64	46	63	72	58	49		
Chloride	3.5	2.43	2.77	2.71	2.68	2.64	2.76	2.77	2.45		
Sulfate	3.3	1.75	1.77	1.64	1.19	1.23	1.10	1.06	<0.0491		
Calcium	5.1	4.72	4.65	5.00	4.50	5.30	5.12	5.12	5.86		
Magnesium	3.7	3.14	3.39	3.70	3.33	3.65	3.83	3.80	4.23		
Sodium	4.3	4.12	4.16	4.32	4.10	4.21	4.15	4.28	4.44		
Silicon	12.7	11.9	11.9	11.8	10.9	10.9	11.8	12.3	10.0		

Table A-1 (continued)

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWC-2 (Formerly CW-3)											
pH	5.64	5.6	5.04	5.5	4.97	5.65	5.5	4.6	5.29	5.4	5.6
Conductivity	76	69	64	66	33	71	66	56	67	56	49
Alkalinity	23.5	19.3	15.2	16.9	12.2	17.5	18.2	17.3	12.5	14.1	15.9
TDS	76	50	55	55	63	65	79	71	68	77	60
Chloride	4.3	5.2	6.9	6.2	5	5.3	3.0	3.4	4.0	4.5	3.5
Sulfate	6.4	5.5	6.3	5.9	5.8	6.3	6.5	7.6	7.9	7.5	7.7
Calcium	4.4	2.8	2.3	2	2	1.7	1.4	1.6	1.7	1.6	1.9
Magnesium	1.6	1.5	1.6	1.7	1.8	1.9	1.9	2.1	2.1	1.9	2.0
Sodium	7.3	7.4	6.9	7	7.5	7.6	7.5	7.4	7.5	6.7	6.8
Silicon	10	10	9.3	12	11	11	11	13	12.0	11	13

Parameter	Round 12 5 Jan 94	Round 13 22-23 Mar 94	Round 14 21-22 Jun 94	Round 15 31 Aug 94	Round 16 20-21 Dec 94	Round 17 28-29 Mar 95	Round 18 13-14 Jun 95	Round 19 11-12 Sep 95	Round 20 12-13 Dec 95		
Well: GWC-2 (Formerly CW-3) (Continued)											
pH	5.75	5.5	5.72	5.63	5.34	5.53	5.39	5.41	5.45		
Conductivity	53	57	59	60	66	65	65	67.5	67		
Alkalinity	15.7	14	16.2	7.0	6.9	13.3	14.5	13.5	13.0		
TDS	27	76	58	60	65	63	64	54	53		
Chloride	3.8	3.7	3.79	3.92	4.00	3.81	3.97	3.83	3.91		
Sulfate	5.78	5.97	5.95	6.73	5.78	4.98	4.33	3.90	3.68		
Calcium	2.0	2.19	2.05	2.11	1.89	2.23	2.08	2.16	2.41		
Magnesium	1.8	1.92	1.93	2.03	1.87	1.88	1.92	1.88	1.96		
Sodium	7.0	7.15	7.09	7.17	6.96	6.79	6.85	6.94	7.11		
Silicon	12.9	13.3	13.0	12.9	12.2	12.2	13.4	13.5	12.9		

Table A-1 (continued)

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWC-3 (Formerly CW-4)											
pH	5.4	5.15	4.8	4.73	6.19	5.08	5.25	3.8	5.23	5.2	5.3
Conductivity	40	35	30	34	32	35	32	27	33	27	27
Alkalinity	11.5	15.2	9.9	11	7	11.1	10.0	8.9	7.0	8.5	9.1
TDS	50	35	31	34	39	41	28	37	44	52	21
Chloride	3	2.8	3.2	3.4	3.1	3.1	2.0	2.3	2.7	2.9	2.8
Sulfate	2.6	2.1	<0.05	<0.05	0.9	1.5	1.7	2.6	1.6	<2.5	<2.5
Calcium	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Magnesium	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sodium	4.4	4.5	4.3	4.1	4.6	4.3	4.1	4.0	4.1	3.9	3.8
Silicon	8	7.8	3.9	8.5	8.6	8.3	8.3	9.3	9.0	8.7	9.2
Parameter	**Round 12 5 Jan 94**	**Round 13 22-23 Mar 94**	**Round 14 21-22 Jun 94**	**Round 15 31 Aug 94**	**Round 16 20-21 Dec 94**	**Round 17 28-29 Mar 95**	**Round 18 13-14 Jun 95**	**Round 19 11-12 Sep 95**	**Round 20 12-13 Dec 95**		
Well: GWC-3 (Formerly CW-4)											
pH	5.5	5.18	5.43	5.41	5.06	5.10	5.10	5.02	5.27		
Conductivity	22	28	29	30	36	36	37	45	39		
Alkalinity	9.3	7.5	8.5	77	4.8	8.6	8.5	9.0	9.1		
TDS	<8.7	42	36	39	30	44	52	37	36		
Chloride	2.8	2.77	2.76	2.91	3.02	3.15	3.13	3.64	3.52		
Sulfate	<0.06	1.38	1.52	<0.0471	1.01	<0.0471	0.968	0.595	0.233		
Calcium	<1.0	0.392	0.321	0.328	0.335	0.441	0.314	0.389	0.436		
Magnesium	<1.0	0.962	0.935	1.00	1.02	1.10	1.08	1.21	1.26		
Sodium	4.1	4.35	4.14	4.17	4.34	4.39	4.47	4.83	5.14		
Silicon	9.7	10.1	9.16	9.15	8.94	8.97	8.90	9.94	5.18		

Table A-1 (continued)

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWC-4 (Formerly CW-5)											
pH	5.34	4.97	4.8	4.6	5.03	5.4	5.05	3.9	5.04	5.2	5.2
Conductivity	62	62	66	72	54	70	72	58	64	52	54
Alkalinity	12.5	15.3	13.1	15.1	8.6	14.2	11.5	8.0	6.0	6.9	7.0
TDS	61	52	60	51	58	64	61	65	63	55	44
Chloride	5	4.2	5	5.6	4.5	5.2	3.1	3.4	3.6	3.6	3.8
Sulfate	2.2	4.6	8	6.8	7.1	5.8	5.3	5.5	5.0	5.9	4.9
Calcium	1.3	<1.0	<1.0	1.3	1.6	1.2	<1.0	<1.0	1.0	<1.0	<1.0
Magnesium	2.5	2.5	3.1	3.8	3.9	3.7	3.3	3.2	3.2	2.7	2.9
Sodium	5.4	5.8	5.3	5.1	5	5.2	4.8	4.9	4.7	4.4	4.4
Silicon	9.9	9.1	4.7	9.7	9.2	10	8.6	9.5	8.7	8.3	9.3
Parameter	**Round 12 5 Jan 94**	**Round 13 22-23 Mar 94**	**Round 14 21-22 Jun 94**	**Round 15 31 Aug 94**	**Round 16 20-21 Dec 94**	**Round 17 28-29 Mar 95**	**Round 18 13-14 Jun 95**	**Round 19 11-12 Sep 95**	**Round 20 12-13 Dec 95**		
Well: GWC-4 (Formerly CW-5) (Continued)											
pH	5.2	4.98	5.2	5.10	4.92	5.10	4.98	4.79	4.89		
Conductivity	63	72	81	108	188	163	148	180	196		
Alkalinity	9.2	5.0	10.3	5.0	3.8	9.0	4.6	4.5	4.2		
TDS	20	64	75	93	110	113	132	123	107		
Chloride	6.7	11.3	13.5	20.8	39.7	34.1	39.1	37.5	40.5		
Sulfate	4.4	4.64	4.50	4.83	4.34	4.18	3.91	3.03	3.21		
Calcium	1.3	1.81	1.62	2.73	4.04	3.21	3.89	3.03	3.99		
Magnesium	3.7	5.05	4.98	7.32	11.0	10.2	12.5	10.0	12.6		
Sodium	5.0	5.33	4.87	5.80	7.86	7.63	8.61	8.42	8.00		
Silicon	9.8	9.91	9.18	9.91	10.1	9.36	10.0	10.4	11.4		

Table A-1 (continued)

Parameter	Baseline Monitoring							Round 8 29-30 Dec 92	Round 9 30-31 Mar 93	Round 10 21 Jun 93	Round 11 23-24 Sep 93
	Round 1 6 Sep 90	Round 2 2 Nov 90	Round 3 8-9 Jan 91	Round 4 11 Mar 91	Round 5 8 May 91	Round 6 1-2 Jul 91	Round 7 3-4 Sep 92				
Well: GWC-5											
pH							5.6	4.4	6.13	5.4	5.6
Conductivity							61	60	54	41	40
Alkalinity							14.8	13.5	12.5	10.2	11.5
TDS							91	86	67	56	50
Chloride							1.8	2.6	2.7	2.9	2.5
Sulfate							8.8	10	7.4	6.7	5.5
Calcium							2.1	2.7	2.2	1.6	1.4
Magnesium							1.9	2.3	1.8	1.5	1.4
Sodium							6.0	6.2	5.7	5.5	5.2
Silicon							12	14	13	12	12
Parameter	**Round 12 5 Jan 94**	**Round 13 22-23 Mar 94**	**Round 14 21-22 Jun 94**	**Round 15 31 Aug 94**	**Round 16 20-21 Dec 94**	**Round 17 28-29 Mar 95**	**Round 18 13-14 Jun 95**	**Round 19 11-12 Sep 95**	**Round 20 12-13 Dec 95**		
Well: GWC-5 (Continued)											
pH	7.0	5.38	5.42	5.53	5.57	5.52	5.60	5.20	5.28		
Conductivity	39	43	45	43	47	50	52	60	53		
Alkalinity	10.8	8.6	10.8	13.0	11.2	9.5	8.5	11.0	9.1		
TDS	29	53	61	61	45	50	64	64	45		
Chloride	2.6	2.34	2.48	2.67	2.70	2.54	2.62	2.70	2.93		
Sulfate	5.3	6.56	7.65	6.68	5.75	6.45	6.64	6.80	7.20		
Calcium	1.3	1.65	1.38	1.26	1.20	1.51	1.31	1.48	1.97		
Magnesium	1.3	1.6	1.55	1.46	1.32	1.59	1.73	1.78	6.02		
Sodium	5.5	5.74	5.77	5.38	5.43	5.34	5.54	6.12	5.82		
Silicon	11.4	11.8	11.3	10.5	10.3	10.3	11.1	11.5	16.2		

Appendix B

QA/QC Results

Table B-1. Results for Duplicate Samples—Second Quarter 1995

Parameter	Units	Sample GWC-3-20-1	Field Duplicate GWC-3-20-2	% Diff.[a]	Duplicate Analysis GWC-3-20-2	% RPD[b]	Spec. Limit
Total Dissolved Solids	mg/L	36.0	42.0	14	34.0	21	15
Bromide	mg/L	<0.0181	<0.0181	NC	<0.0181	NC	20
Chloride	mg/L	3.52	3.45	-2	3.50	1	20
Fluoride	mg/L	0.0307[c]	0.302[c]	-2	0.0281[c]	7	20
Sulfate	mg/L	0.233	<0.0491	NC	<0.0491	NC	20
Total Organic Carbon	mg/L	<0.117	<0.117	NC	<0.117	NC	20
Nitrate-Nitrite as N	mg/L	0.328	0.406	19	0.414	2	20
Total Organic Halides	µg/L	<11.7	<11.7	NC	<11.7	NC	20
Silver	mg/L	<0.00600	<0.00600	NC			
Aluminum	mg/L	0.0338[d]	<0.0270	NC			
Arsenic	mg/L	0.0012[d]	<0.000887	NC			
Boron	mg/L	0.0330[d]	<0.0105	NC			
Barium	mg/L	0.00973	0.00865[c]	-12			
Beryllium	mg/L	<0.00180	<0.00180	NC			
Bismuth	mg/L	<0.00504	<0.00504	NC			
Calcium	mg/L	0.436	0.390	-12			
Cadmium	mg/L	<0.00262	<0.00262	NC			
Cobalt	mg/L	0.0103[d]	<0.00987	NC			
Copper	mg/L	<0.00302	<0.00302	NC			
Chromium	mg/L	<0.005558	<0.00558	NC			
Mercury	mg/L	<0.000039	<0.000039	NC			
Iron	mg/L	0.0511[d]	0.238	79			
Potassium	mg/L	<0.883	<0.883	NC			
Lithium	mg/L	<0.00297	<0.00297	NC			
Magnesium	mg/L	1.26	1.14	-11			
Manganese	mg/L	<0.00365	<0.00365	NC			
Molybdenum	mg/L	<0.0192	<0.0192	NC			
Sodium	mg/L	5.14	5.03	-2			
Nickel	mg/L	<0.0218	<0.0128	NC			
Phosphorus	mg/L	<0.141	<0.141	NC			
Lead	mg/L	<0.00126	<0.00126	NC			
Sulfur	mg/L	0.125[d]	<0.118	NC			

Table B-1 (continued)

Parameter	Units	Sample GWC-3-20-1	Field Duplicate GWC-3-20-2	% Diff.[a]	Duplicate Analysis GWC-3-20-2	% RPD[b]	Spec. Limit
Antimony	mg/L	<0.000919	<0.000919	NC			
Selenium	mg/L	0.000840[d]	<0.000821	NC			
Silicon	mg/L	5.18	0.242	-2040			
Tin	mg/L	<0.0350	<0.0350[d]	NC			
Strontium	mg/L	0.00369[d]	0.00369[d]	0			
Tellurium	mg/L	<0.00449	<0.00449	NC			
Titanium	mg/L	0.00265[c,d]	0.00199[c,d]	-33			
Thallium	mg/L	<0.00232	<0.00232	NC			
Uranium	mg/L	<0.0676	<0.0676	NC			
Vanadium	mg/L	<0.00679	<0.00679	NC			
Tungsten	mg/L	<0.0759	<0.0759	NC			
Zinc	mg/L	0.0160[c,d]	0.0106[c,d]	-51			

[a] % Difference = (GWC-3-20-2 - GWC-3-20-1)/GWC-3-20-1 x 100%.

[b] RPD = Relative Percent Difference, defined as follows:

$$\text{RPD} = \frac{\text{(Larger Value - Smaller Value)}}{\text{(Larger Value + Smaller Value)/2}} \times 100\%.$$

[c] Detected in the method blank.

[d] Value is less than five times the detection limit; results are expected to be less accurate as concentrations approach the detection limit.

NC = Not computed.