Interim Report
1979-1980

Preoperational Radiological Environmental Monitoring Program

Shootering Canyon Uranium Project
Garfield County, Utah
NRC Docket No. 40-8698

Prepared for

Plateau Resources Limited

November 1980

Woodward-Clyde Consultants

Three Embarcadero Center, Suite 700, San Francisco, CA 94111

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1.0
INTRODUCTION

This report presents interim results of the preoperational radiological environmental monitoring program for the Shootering Canyon Uranium Project. The Environmental Report (ER) was submitted to the Nuclear Regulatory Commission (NRC) in May of 1978. The ER contained a description of the project site radiological environment based on measurements and samples taken at the site between June, 1977 and March, 1978. In addition to total radiation levels, as determined from thermoluminescent dosimeters (TLDs), radioactivity levels were determined for airborne particulates, radon, springs, wells, surface waters, soils, flora and fauna. These measurements and analyses led to the conclusion, stated in the ER, that the environment of the project site is not highly radioactive. The ER also contained descriptions of the preoperational radiological environmental monitoring program then in progress and the proposed operational monitoring program.

In August, 1978, both the preoperational and operational radiological environmental monitoring programs were modified in response to a request of the NRC, dated July 6, 1978. The modified programs were designed to comply as closely as possible with the requirements described in the NRC Branch Position - Preoperational Radiological Environmental Monitoring Programs for Uranium Mills, dated January 9, 1978.

This report contains results of the 1979-1980 preoperational radiological environmental monitoring program. Each major section of the report contains a description and of one of the major monitoring programs: air, water, soils, direct radiation, radon flux, and vegetation and fish sampling. Terrestrial food pathways were not monitored because no food crops are grown in the vicinity of the project. Livestock that occasionally forage in the area feed most of the year in areas remote from the site. Sampling of these animals would not provide analyses representative of the project area, thus no livestock sampling has been done. Each section includes a general description of the monitoring program, presentation of results and descriptions of the measurement or sampling procedures and analytical procedures.

Two remote locations were monitored for control purposes. One of these is the planned Ticaboo town site, approximately three miles south of the project site. The other is Bullfrog Basin Marina, an existing recreational complex on an area of Lake Powell, about 15 miles south of the project site. The locations of these remote monitoring areas are shown in Figure 1-1.

The project site monitoring of air particulates, atmospheric radon, thermoluminescent dosimeters (TLDs) radon flux and subsurface soils took place at 13 fixed monitoring stations. These 13 stations were located by site survey. The stations were numbered AP-1 through AP-4 and 5 through 13 and are so identified in this report. Table 1-1 shows the survey coordinates of the 13 monitoring stations and identifies the parameters monitored at each. Also identified in the table are the two remote monitoring locations (not surveyed) and the four seep locations at which surface water samples were collected.

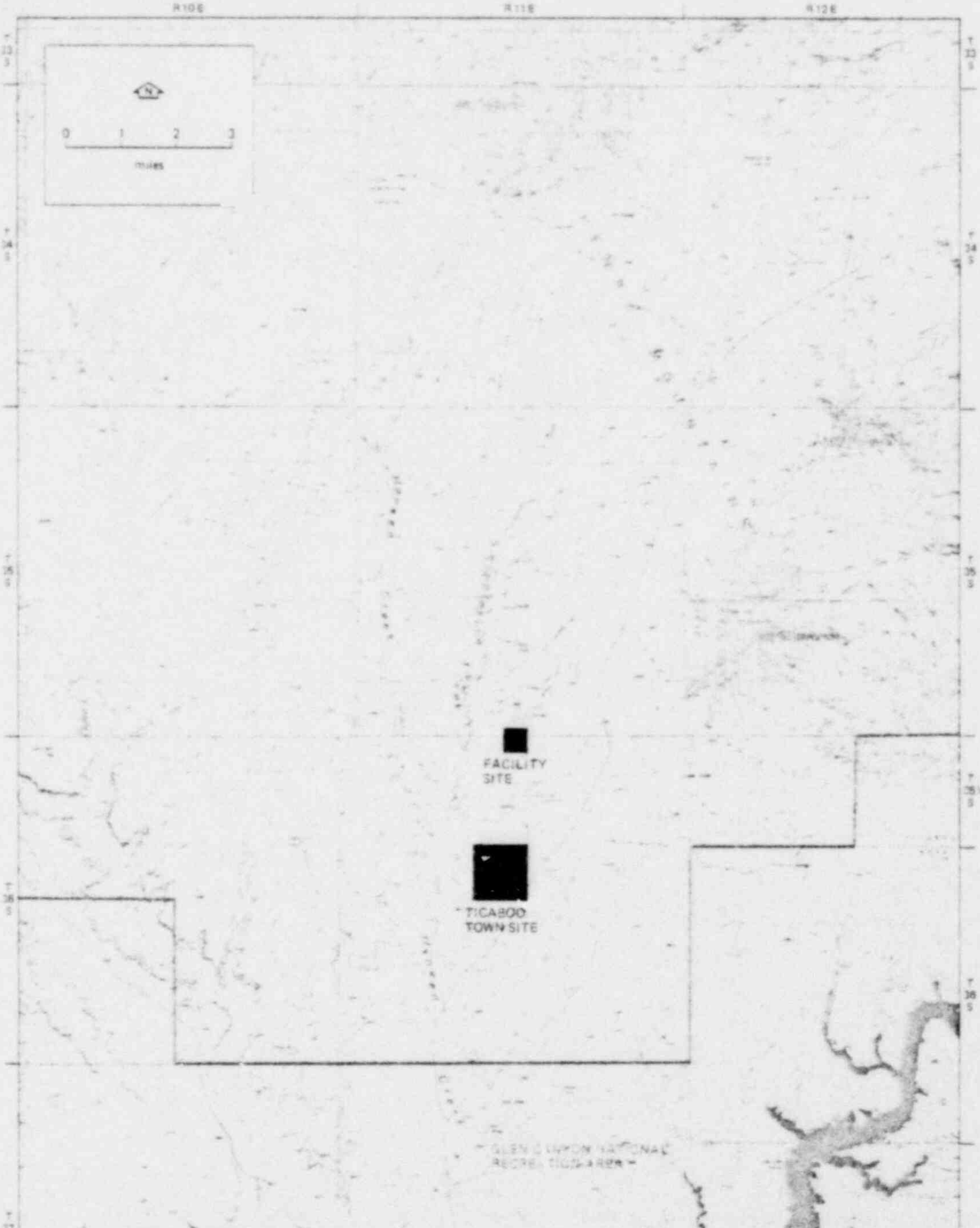

Figure 1-1. LOCATIONS OF FACILITY, BULLFROG BASIN MARINA, AND TICABOO TOWN SITE

Table 1-1. PREOPERATIONAL ENVIRONMENTAL MONITORING LOCATIONS

Location	Monitor	Elevation	Northing	Easting
#AP-1	Air Particulate, TLD, & Radon	4,510.9	56,244.5	61,734.4
#AP-2	Air Particulate, TLD, & Radon	4,580.9	58,286.8	64,017.4
#AP-3	Air Particulate, TLD, & Radon	4,538.6	59,407.4	63,487.8
#AP-4	Air Particulate, TLD, & Radon	4,486.1	59,301.8	61,972.9
#5	TLD	4,301.1	53,260.1	60,155.8
#5	Radon + 0	4,298.1	53,260.1	60,155.8
#5	Radon - 3	4,294.1	53,260.1	60,155.8
#5	Radon - 6	4,291.1	53,260.1	60,155.8
#6	TLD	4,372.8	55,384.7	61,210.2
#6	Radon + 0	4,369.8	55,384.7	61,210.2
#6	Radon - 3	4,366.8	55,384.7	61,210.2
#6	Radon - 4.5	4,362.3	55,384.7	61,210.2
#7	TLD	4,523.4	57,742.9	63,080.5
#7	Radon + 0	4,520.4	57,742.9	63,080.5
#7	Radon - 3	4,517.4	57,742.9	63,080.5
#7	Radon - 6	4,514.4	57,742.9	63,080.5
#8	TLD	4,558.6	59,896.7	64,456.2
#8	Radon + 0	4,555.6	59,896.7	64,456.2
#8	Radon - 3	4,552.6	59,896.7	64,456.2
#8	Radon - 6	4,549.6	59,896.7	64,456.2
#9	TLD	4,711.3	62,346.6	66,257.5
#9	Radon + 0	4,708.3	62,346.6	66,257.5
#9	Radon - 3	4,705.3	62,346.6	66,257.5
#9	Radon - 6	4,702.3	62,346.6	66,257.5
#10	Radon + 0	4,446.3	60,088.9	62,508.0
#10	Radon - 3	4,443.3	60,088.9	62,508.0
#11	Radon + 0	4,384.5	60,029.8	61,530.4
#11	Radon - 3	4,382.0	60,029.8	61,530.4
#11	Radon - 6	4,378.5	60,029.8	61,530.4
#12	Radon + 0	4,226.5	57,966.5	58,105.5
#12	Radon - 3	4,223.5	57,966.5	58,105.5
#12	Radon - 5	4,221.5	57,966.5	58,105.5
#13	Radon + 0	4,503.0	51,847.5	63,329.0
#13	Radon - 3	4,500.0	51,847.5	63,329.0
#13	Radon - 4.5	4,498.5	51,847.5	63,329.0
C-1	Air Particulate & TLD	Bullfrog Basin Marina		
C-1	Radon + 3			
C-2	Air Particulate & TLD	Ticaboo town site		
C-2	Radon + 3			
Seep #1	Surface Water	4,293.2	51,256.3	62,185.2
Seep #2	Surface Water	4,192.3	55,543.3	57,736.2
Seep #3	Surface Water	4,257.3	60,255.4	57,855.1
Seep #4	Surface Water	4,438.0	60,381.1	62,425.4

2.0 AIR SAMPLES

2.1 AIR PARTICULATES

General Description

Air particulates were sampled during two quarters of 1979 and two quarters of 1980. Sampling was accomplished at four stations on the project site (see Figure 2-1) and at Bullfrog Basin Marina and the six locations until the fourth quarter of 1979; therefore, limited 11 monitoring was completed prior to that time. The results of the air particulates monitoring program are shown in Table 2-1.

Sample Collection

Locations. The four locations in the project area are positioned approximately northwest, northeast, east and southwest from the center of the project site, at distances of about one-fourth mile. All are on or near the site boundary (fenceline). One remote station is at the planned Ticaboo town site. This location represents the only known point of residence within 10 kilometers of the site. Bullfrog Basin Marina, the second remote station is currently the nearest area of permanent residency. The prevailing wind directions at the project site are south and south-southwest and, to a lesser extent, north and north-northeast. Local topography exerts a dominant influence, creating a strong diurnal pattern in the northerly and southerly directions. Average wind speed is about six knots.

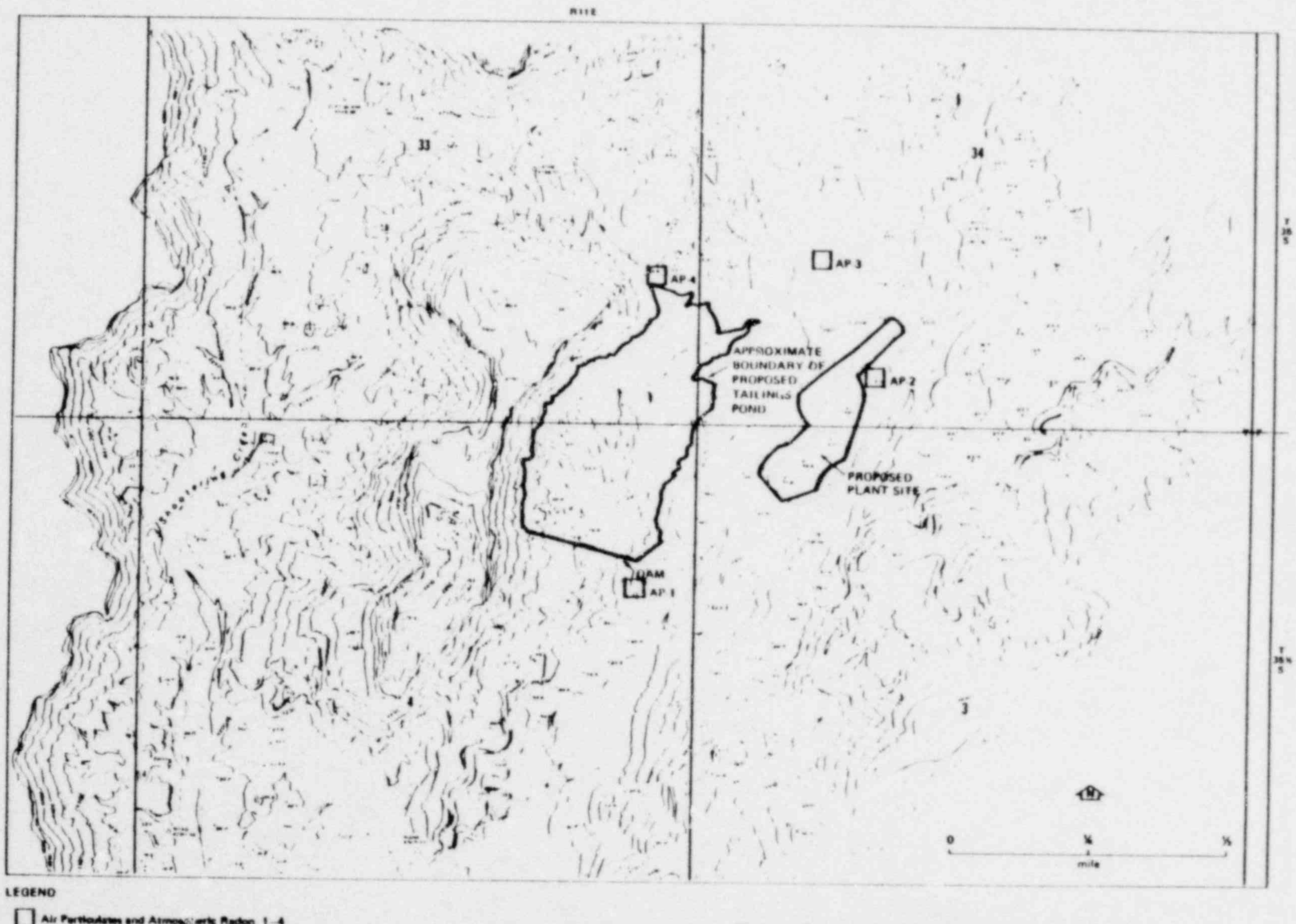

Figure 2-1. PREOPERATIONAL MONITORING LOCATIONS FOR AIR PARTICULATES AND ATMOSPHERIC RADON

Table 2-1. AIR SAMPLES

Date 3rd Qtr. 1979
Location AP-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	2.0E-16	-	4.0E-3
Th-230	1.4E-16	1.2E-16	4.7E-2
Ra-226	0.86E-16	0.26E-16	4.3E-3
Pb-210	220E-16	20E-16	2.8E-1

Date 4th Qtr. 1979
Location AP-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.48E-16	-	3.0E-3
Th-230	0.00	0.76E-16	0.00
Ra-226	0.74E-16	0.22E-16	3.6E-3
Pb-210	280E-16	20E-16	3.6E-1

Date 1st Qtr. 1980
Location AP-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	3.5E-16	1.0E-16	7.0E-3
Th-230	1.5E-16	1.4E-16	5.0E-2
Ra-226	1.3E-16	0.4E-16	6.5E-3
Pb-210	140E-16	10E-16	1.8E-1

Table 2-1. AIR SAMPLES

Date 2nd Qtr. 1980
Location AP-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.6E-16	0.3E-16	3.2E-3
Th-230	0.95E-16	0.47E-16	3.2E-2
Ra-226	0.7[illegible]E-16	0.21E-16	3.5E-3
Pb-210	170E-16	10E-16	2.1E-1

Date 4th Qtr. 1979
Location AP-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	3.2E-16	-	6.4E-3
Th-230	0.00	1.20E-16	0.00
Ra-226	1.52E-16	0.46E-16	7.6E-3
Pb-210	420E-16	20E-16	5.2E-1

Date 1st Qtr. 1980
Location AP-2*

Radionuclide	Concentration (μCi/ml)	Error Es[illegible]ate ([illegible])	%MPC
U-nat	2.8E-16	0.81E-16	5.6E-3
Th-230	0.0	1.0E-16	0.0
Ra-226	1.4E-16	0.4E-16	7.0E-3
Pb-210	1330E-16	20E-16	1.7

*Sampler elevated to 10 ft above surface level during 1st Qtr. 1980.

Table 2-1. AIR SAMPLES

Date 2nd Qtr. 1980
Location AP-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.5E-16	0.3E-16	3.0E-3
Th-230	0.97E-16	0.82E-16	3.2E-2
Ra-226	0.92E-16	0.28E-16	4.6E-3
Pb-210	180E-16	10E-16	2.3E-1

Date 3rd Quarter 1979
Location AP-3

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	3.3E-16	-	6.6E-3
Th-230	1.3E-16	0.5E-16	4.3E-2
Ra-226	0.49E-16	0.15E-16	2.4E-3
Pb-210	190E-16	10E-16	2.4E-1

Date 4th Qtr. 1979
Location AP-3

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	3.2E-16	-	6.4E-3
Th-230	3.8E-16	2.6E-16	1.3E-1
Ra-226	1.52E-16	0.46E-16	7.6E-3
Pb-210	360E-16	20E-16	4.4E-1

Table 2-1. AIR SAMPLES

Date 1st Qtr. 1980
Location AP-3*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.4E-16	0.4E-16	2.8E-3
Th-230	0.0	1.0E-16	0.0
Ra-226	1.3E-16	0.4E-16	6.5E-3
Pb-210	230E-16	10E-16	2.9E-1

Date 2nd Qtr. 1980
Location AP-3

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.4E-16	0.3E-16	2.8E-3
Th-230	1.2E-16	0.6E-16	4.0E-2
Ra-226	0.86E-16	0.26E-16	4.3E-3
Pb-210	160E-16	10E-16	2.0E-1

Date 4th Qtr. 1979
Location AP-4

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	2.6E-16	-	5.2E-3
Th-230	0.00	1.38E-16	0.00
Ra-226	2.2E-16	0.6E-16	1.1E-2
Pb-210	280E-16	20E-16	3.6E-1

*Sampler elevated to 10 ft above surface level during 1st Qtr. 1980.

Table 2-1. AIR SAMPLES

Date 1st Qtr. 1980
Location AP-4*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	2.6E-16	0.8E-16	5.2E-3
Th-230	1.5E-16	1.0E-16	5.0E-2
Ra-226	1.2E-16	0.3E-16	6.0E-3
Pb-210	250E-16	10E-16	3.1E-1

Date 2nd Qtr. 1980
Location AP-4

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.5E-16	0.3E-16	3.0E-3
Th-230	1.5E-16	0.7E-16	5.0E-2
Ra-226	0.38E-16	0.11E-16	1.9E-3
Pb-210	300E-16	10E-16	3.8E-1

Date 3rd Qtr. 1979
Location C-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.53E-16	-	1.1E-3
Th-230	0.49E-16	0.15E-16	1.6E-2
Ra-226	0.21E-16	0.06E-16	1.0E-3
Pb-210	140E-16	10E-16	1.8E-1

*Sampler elevated to 10 ft above surface level during 1st Qtr. 1980.

Table 2-1. AIR SAMPLES

Date 4th Qtr. 1979
Location C-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.88E-16	-	1.8E-3
Th-230	0.00	0.32E-16	0.00
Ra-226	0.52E-16	0.16E-16	2.6E-3
Pb-210	420E-16	20E-16	5.2E-1

Date 1st Qtr. 1980
Location C-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.48E-16	0.12E-16	9.6E-4
Th-230	0.76E-16	0.37E-16	2.5E-2
Ra-226	0.25E-16	0.08E-16	1.3E-3
Pb-210	210E-16	10E-16	2.6E-1

Date 2nd Qtr. 1980
Location C-1

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.30E-16	0.05E-16	6.0E-4
Th-230	0.22E-16	0.10E-16	7.3E-3
Ra-226	0.24E-16	0.07E-16	1.2E-3
Pb-210	170E-16	10E-16	2.1E-1

Table 2-1. AIR SAMPLES

Date 3rd Qtr. 1979
Location C-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	2.7E-16	-	5.4E-3
Th-230	2.6E-16	0.6E-16	8.7E-2
Ra-226	0.93E-16	0.28E-16	4.6E-3
Pb-210	98E-16	6E-16	1.2E-1

Date 4th Qtr. 1979
Location C-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	1.48E-16	-	3.0E-3
Th-230	0.98E-16	0.58E-16	3.2E-2
Ra-226	0.68E-16	0.20E-16	3.4E-3
Pb-210	320E-16	20E-16	4.0E-2

Date 1st Qtr. 1980*
Location C-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.81E-16	0.14E-16	1.6E-3
Th-230	0.62E-16	0.41E-16	2.1E-2
Ra-226	0.35E-16	0.10E-16	1.8E-3
Pb-210	200E-16	10E-16	2.5E-1

*Sampler elevated to 10 ft above surface level during 1st Qtr. 1980.

Table 2-1. AIR SAMPLES

Date 2nd Qtr. 1980
Location C-2

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	%MPC
U-nat	0.67E-16	0.08E-16	1.3E-3
Th-230	0.65E-16	0.46E-16	2.2E-2
Ra-226	0.25E-16	0.08E-16	1.3E-3
Pb-21	110E-16	10E-16	1.4E-1

Equipment. Each air particulate monitoring station is equipped with a General Metal Works Model GMWL 2000 high volume air sampling system, mounted in a shelter. The filters are Gelman Instrument Company Spector Grade type A/E glass fiber filters (Lot No. 5062040) and type A glass fiber filters (Lot No. 8326). Representative blank samples from both lots were analyzed by Eberline Instrument Company's laboratory in Albuquerque, New Mexico to determine activity levels in the unused filters.

Procedure. Air samplers were operated continuously or for one 24-hour period each seven days, depending on power availability. Filters were changed weekly, or at the conclusion of each 24-hour run. Filters were composited quarterly for each station.

Calibration. Calibrations were performed in accordance with manufacturer's procedures, using manufacturer's calibration equipment. Calibrations were performed for flow rates between 35 and 45 cubic feet per minute.

Sample Analysis

All filters were analyzed by Eberline Instrument Corporation. Information pertaining to Eberline laboratory procedures, calculations, quality control, etc. is contained in Appendix A.

2.2 RADON-222

General Description

Atmospheric radon-222 (Rn-222) monitoring was accomplished at the six air particulate locations via Track Etch* cups (radon cups) and Environmental Measurements, Inc. (EMI) composite radon samplers. Tables 2-2 and 2-3 contain the monitoring results from these methods. The monitoring locations are shown in Figure 2-1.

The Track Etch cups equipped with Rn-222 permeable membranes that prevent the intrusion of Rn-220 and Rn-222 daughter products, were used for continuous radon monitoring. Two radon cups were mounted three feet above the ground at each station. One cup at each station was collected monthly, and the other was collected quarterly. Each cup contained a detector sensitive to alpha decay from Rn-222 and its decay daughters within the cup. The average time-integrated Rn-222 concentration during the one- to three-month exposure period for each cup was estimated from the background-corrected alpha track density of the detector following etching. The Track Etch system requires no electrical power source in the field.

Composite Rn-222 samples were collected in tedlar bags for approximately 48-hour periods with EMI samplers. The bag samples were pumped into scintillation cells following collection, and the Rn-222 concentrations were determined by alpha scintillation counting of Rn-222 and its decay products in the cells.

*Track Etch is a service mark of Terradex Corporation. The process of radon detecting using track registration materials is covered by U.S. and foreign patents: USA 3,665.194; Australia 424,388 (1974); Canada 1972; S. Africa 68/3983; other patents issued and pending.

Table 2-2. AIRBORNE Rn-222 CONCENTRATIONS FROM RADON CUP MEASUREMENTS

Exposure Period February 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.45E-9	(-0.34E-9, 2.09E-9)
C-2	0.15E-9	(-0.36E-9, 1.39E-9)
AP-1	0.15E-9	(-0.36E-9, 1.39E-9)
AP-2	1.6E-9	(0.4E-9, 3.5E-9)
AP-3	0.45E-9	(-0.34E-9, 2.09E-9)
AP-4	0.15E-9	(-0.36E-9, 1.39E-9)

Exposure Period March 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.46E-9	(-0.35E-9, 2.14E-9)
C-2	0.73E-9	(0.19E-9, 2.54E-9)
AP-1	0.46E-9	(-0.35E-9, 2.14E-9)
AP-2	-0.35E-9	(-0.59E-9, 0.89E-9)
AP-3	-0.35E-9	(-0.59E-9, 0.89E-9)
AP-4	-0.35E-9	(-0.59E-9, 0.89E-9)

*The boundaries of the 95 percent confidence interval for the concentrations based upon Poisson statistics are given. (Number, Number) = (lower boundary of interval, upper boundary of interval).

Table 2-2. AIRBORNE Rn-222 CONCENTRATIONS FROM RADON CUP MEASUREMENTS

Exposure Period April 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.18E-9	(-0.44E-9, 1.67E-9)
C-2	0.70E-9	(-0.18E-9, 2.44E-9)
AP-1	0.18E-9	(0.44E-9, 1.67E-9)
AP-2	0.18E-9	(-0.44E-9, 1.67E-9)
AP-3	0.18E-9	(-0.44E-9, 1.67E-9)
AP-4	0.44E-9	(-0.34E-9, 2.04E-9)

Exposure Period May 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
^-1	0.87E-9	(-0.02E-9, 2.54E-9)
C-2	0.64E-9	(-0.17E-9, 2.23E 9)
AP-1	0.17E-9	(-0.41E-9, 1.58E-9)
AP-2	0.17E-9	(-0.41E-9, 1.58E-9)
AP-3	0.17E-9	(-0.41E-9, 1.58E-9)
AP-4	1.8E-9	(0.6E-9, 3.8E-9)

*The boundaries of the 95 percent confidence interval f^r the concentrations based upon Poisson statistics are given. (Number, Number) = (lower boundary of interval, upper boundary of interval).

Table 2-2. AIRBORNE Rn-222 CONCENTRATIONS FROM RADON CUP MEASUREMENTS Page 3 of 5

Exposure Period June 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.19E-9	(-0.46E-9, 1.76E-9)
C-2	1.5E-9	(0.3E-9, 3.6E-9)
AP-1	0.19E-9	(-0.46E-9, 1.76E-9)
AP-2	0.19E-9	(-0.46E-9, 1.76E-9)
AP-3	1.3E-9	(0.1E-9, 3.2E-9)
AP-4	0.99E-9	(-0.03E-9, 2.89E-9)

Exposure Period July 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.87E-9	(-0.02E-9, 2.54E-9)
C-2	0.17E-9	(-0.41E-9, 1.58E-9)
AP-1	0.64E-9	(-0.17E-9, 2.23E-9)
AP-2	0.17E-9	(-0.41E-9, 1.58E-9)
AP-3	0.17E-9	(-0.41E-9, 1.58E-9)
AP-4	0.17E-9	(-0.41E-9, 1.58E-9)

*The boundaries of the 95 percent confidence interval for the concentrations based upon Poisson statistics are given. (Number, Number) = (lower boundary of interval, upper boundary of interval).

Table 2-2. AIRBORNE Rn-222 CONCENTRATIONS FROM RADON CUP MEASUREMENT Page 4 of 5

Exposure Period August 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.18E-9	(-0.44E-9, 1.67E-9)
C-2	0.99E-9	(-0.03E-9, 2.89E-9)
AP-1	1.3E-9	(0.1E-9, 3.3E-9)
AP-2	0.35E-9	(-0.59E-9, 0.89E-9)
AP-3	0.46E-9	(-0.35E-9, 2.14E-9)
AP-4	0.19E-9	(-0.46E-9, 1.76E-9)

Exposure Period September 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	1.2E-9	(0.4E-9, 2.5 E-9)
C-2	**	
AP-1	0.73E-9	(-0.19E-9, 2.54E-9)
AP-2	1.5E-9	(0.3E-9, 3.6E-9)
AP-3	0.19E-9	(-0.46E-9, 1.76E-9)
AP-4	0.19E-9	(-0.46E-9, 1.76E-9)

*The boundaries of the 95 percent confidence interval for the concentrations based upon Poisson statistics are given. (Number, Number) = (lower boundary of interval, upper boundary of interval).

**Missing in field.

Table 2-2. AIRBORNE Rn-222 CONCENTRATIONS FROM RADON CUP MEASUREMENTS Page 5 of 5

Exposure Period 2nd Quarter 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.06E-9	(-0.15E-9, 0.56E-9)
C-2	0.06E-9	(-0.15E-9, 0.56E-9)
AP-1	0.06E-9	(-0.15E-9, 0.56E-9)
AP-2	0.06E-9	(-0.15E-9, 0.56E-9)
AP-3	0.23E-9	(-0.06E-9, 0.80E-9)
AP-4	0.14E-9	(-0.11E-9, 0.65E-9)

Exposure Period 3rd Quarter 1980

Location	Average Concentration (μCi/ml)	Error Estimate* (μCi/ml)
C-1	0.06E-9	(-0.15E-9, 0.56E-9)
C-2	**	
AP-1	0.06E-9	(-0.15E-9, 0.56E-9)
AP-2	0.06E-9	(-0.15E-9, 0.56E-9)
AP-3	0.06E-9	(-0.15E-9, 0.56E-9)
AP-4	0.06E-9	(-0.15E-9, 0.56E-9)

*The boundaries of the 95 percent confidence interval for the concentrations based upon Poisson statistics are given. (Number, Number) = (lower boundary of interval, upper boundary of interval).

**Missing in field.

Table 2-3. AIRBORNE RADON-222 CONCENTRATIONS DETERMINED BY THE ENVIRONMENTAL MEASUREMENTS, INC. COMPOSITE RADON SAMPLER

Location	Date	Avg. Concentration (μCi/ml)	Error Estimate (μCi/ml)	LLD (μCi/ml)
AP-1	8-23 thru 8-25-80	0.07E-9	0.09E-9	0.19E-9
AP-1	9-22 thru 9-24-80	0.19E-9	0.10E-9	0.21E-9
AP-2	8-25 thru 8-27-80	0.11E-9	0.10E-9	0.21E-9
AP-2	9-23 thru 9-25-80	0.16E-9	0.10E-9	0.21E-9
AP-3	8-18 thru 8-20-80	0.61E-9	0.10E-9	0.19E-9
AP-4	9-15 thru 9-17-80	0.52E-9	0.11E-9	0.26E-9
C-1	9-10 thru 9-12-80	0.15E-9	0.08E-9	0.14E-9*
C-1	9-16 thru 9-18-80	0.60E-9	0.13E-9	0.23E-9
C-2	9-9 thru 9-11-80	0.14E-9	0.11E-9	0.23E-9

*Based directly upon the estimated uncertainties in the sample and background counting. The estimated uncertainty in the sample counting was much larger than that of the background, thus causing an LLD calculated solely from the estimated background counting uncertainty (equation on p 2-25) to be underestimated.

Sample Collection

Locations. Radon monitoring locations were selected to coincide with the six air sampling locations, as recommended by R.G. 4.14.

Equipment. The Track Etch detector cups were provided by Terradex Corporation of Walnut Creek, California. Each plastic cup was 9.5 centimeters high and 6.8 centimeters in diameter at the mouth. The bottom of the cup was 5.4 centimeters in diameter and was fitted with a 0.8 x 2.5 centimeter Track Etch detector. The open mouth of each cup was covered with a semi-permeable plastic membrane. The membrane was used to prevent Rn-222 daughter products, Rn-220, dust, and moisture from entering the cup. Two cups were mounted three feet above ground level on a wooden stake at each monitoring location. Shields were installed in the field to protect the cups from solar radiation.

Environmental Measurement Laboratory, Inc. composite radon samplers consisted of a sampling hose, particulate filter, pulse pump, tedlar bag, and battery pack within an enclosed barrel. The 15-liter tedlar bags were relatively impermeable to Rn-222. A 25mm Gelman AE glass filter was utilized to prevent particulate Rn-222 decay products from entering the bags. Radon samples in tedlar bags were pumped through zinc sulfide, internally-lined scintillation cells. Both 0.5 and 1.4 liter cells were used. Scintillation cells were counted on an Eberline SAC-R5 alpha scintillation detector connected to an Eberline PS-2 scaler. The scaler from the Eberline RGM-1 continuous radon monitor was also utilized in the counting of some samples.

Procedure. At each of the radon cup stations, one cup was replaced each month and the other each quarter, thus providing an indication of the time-integrated average radon level at each station.

The cups were delivered to the site ready for use. Each cup was numbered by Terradex, before shipment.

Tedlar bag Rn-222 samples were collected via the EMI composite sampler. Air was intermittently pulled through a particulate filter in each sampler and into a tedlar bag for approximately a 48-hour period. The pulsar pumps were preset for approximately 17 second pulses with 1.7 milliters per pulse. Approximately 15 liter samples were thus obtained.

Calibration. No field calibrations were necessary for the radon cups. The pumps in the EMI composite samplers were precalibrated as mentioned previously. This was done semiannually.

Sample Analysis

Procedure. Upon receipt of exposed radon cups by Terradex Corporation, each Track Etch detector was etched, and the density of alpha tracks determined by counting under a microscope. The background-corrected alpha track density is proportional to the time-integrated radon concentration and length of exposure at the sample location.

Collected tedlar bag Rn-222 samples were filtered and pumped into scintillation cells. The scintillation cells were then counted on the previously described alpha detection system. The cells were not counted until at least 2-3 hours following cell filling so as to allow Rn-222 daughters to come to equilibrium.

Calibration. Two radon chambers at the Environmental Measurements Laboratory (EML) of the U.S. Department of Energy in New York City were used in the determination of the conversion constant for calculation of the average Rn-222 level from the alpha track density.

The earliest chamber (George 1979) was a two cubic meter plywood box with multi-port access and a filtered radium solution bubbler source. Room air was provided by a blower to adjust radon concentrations. Radon was measured with a continuous scintillation flask monitor (George 1976 and Thomas 1979). Radon daughters were measured hourly using the modified Tsivoglou method of Thomas (Thomas 1972). A radon level of 350 pCi/l was maintained during the calibration run.

A 20 cubic meter "walk-in" chamber at EML was more extensively used in later phases of the calibrations. This chamber was a small steel room with an air lock permitting entry for experimental set-up. The radon source was solid radium bromide. Dilution air to control radon level, in a range of 1-50 pCi/l, was supplied from laboratory air. The measured radon levels from point to point in the chamber were remarkably consistent. The radon measurement techniques were the same as those used for the two cubic meter chamber. It is estimated that radon levels were known with an accuracy of two percent (George 1979). Measurement precision was also in this range.

The overall calibration effort involved tests during 1979 with four different mounting configurations for the Track Etch detectors. Only the membrane covered cups (the same as those used for the Shootering Canyon project) are discussed here. Altogether, seven separate chamber exposure runs were completed, using a total of 80 membrane cup samples from 10 different detector batches. All exposed detectors were returned to Terradex Corporation for etching and track counting. At least 100 tracks were counted for each detector to keep the relative standard deviation to less than 10 percent due to counting statistics.

For each of the seven calibration exposure runs, the mean track density (tracks/mm^2) was divided by the radon exposure (in (pCi/l)-

days) to derive the calibration factor for that run. The mean calibration factor for all exposure runs was calculated by weighting the factor for each run by the number of replicates exposed in the run. For all of the membrane cup samples tested, the weighted mean calibration factor was 0.0223 tracks/mm^2 per (pCi/l)-day. The weighted standard deviation was 0.0050 tracks/mm^2 per (pCi/l)-day, and the relative standard deviation (RSD) was 22 percent. The membrane cup configuration calibration data are summarized in Table 2-4. During 1980, 25 additional calibration runs were made, extending the exposures down to one (pCi/l)-month. Data from these runs are in close agreement with data reported from previous runs.

Concentration Calculations. Average monthly Rn-222 concentrations in Ci/ml by substitution of background-corrected track densities into the following relation

$$C = (1.495E-9)D$$

where: C = average monthly Rn-222 concentration in µCi/ml,
D = net track density in tracks/mm^2 per month (normalized to a 30-day exposure period),
1.495 = (pCi/l)-month per tracks/mm^2.*

The scintillation cells and SAC-R5 unit used to measure tedlar bag Rn-222 concentrations are periodically calibrated by the Eberline Instrument Corporation. Cell calibration factors in cpm per pCi/l are obtained by Eberline via counting a known Rn-222 concentration on the SAC-R5 unit that will be used with the cells for field Rn-222 measurements.

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*1.495 (pCi/l)-month per tracks/mm^2 =

$$\frac{1}{(0.0223 \text{ tracks/mm}^2 \text{ per (pCi/l)-day}) (30 \text{ days/month})}$$

Table 2-4. TRACK ETCH CUP CALIBRATION DATA SUMMARY FOR MEMBRANE CUPS

Run ID No	Chamber	Duration (Days)	Average Radon Exposure Rate (pCi/l)	Number of Batches	Number of Replicates	Total Exposure (pCi/l)-days	Mean Tracks/mm^2	Calibration Factor
C	2m^3	21	350	1	5	7350	259	.0352
3-79	20m^3	79	25.6	1	5	2020	31.9	.0158
3-36	20m^3	36	11.6	1	5	418	9.7	.0232
3-115	20m^3	115	21.2	1	5	2440	41.8	.0171
4-30	20m^3	30	33.2	2	20	996	19.2	.0193
4-93	20m^3	93	32.6	2	20	3030	73.8	.0244
4-63	20m^3	63	32.1	2	20	2020	45.8	.0227

Weighted Mean Calibration Factor, Tracks/mm^2 per (pCi/l)-day .0223
Weighted Standard Deviation .0050
Relative Standard Deviation 22%

The Rn concentration of tedlar bag samples are obtained from the following relation

$$C = \frac{(S - B)(\exp \lambda t)}{K}$$

where: C = Rn-222 concentration in pCi/l,
S = sample counting rate in cpm,
B = background counting rate in cpm,
K = scintillation cell calibration factor in cpm per pCi/l,
λ = decay constant of Rn-222 = 2.1×10^{-6} sec^{-1},
t = decay time from the collection midtime to the counting midtime in seconds.

Sensitivity and Error Calculations. A Rn-222 exposure sensitivity at 50 percent relative standard deviation of 1.8 pCi/l-month has been calculated by Alter et al. (1980) for Track Etch film in the membrane cup configuration when 5.75 mm^2 of film is counted for tracks. The lower limits of detection (LLDs) for the radon cup measurements in Table 2-2 were estimated to range from 0.9 to 2.8 pCi/l for the monthly exposures and 0.5 to 0.6 pCi/l for the quarterly exposures based upon the calculation methodology outlined by Harley (1972). Both exposed detector and background track counting uncertainties were used in the calculations. The assumption of Gaussian statistics inherent in the calculation methodology, however, does not hold well for the small number of tracks recorded in the field-exposed detectors. A more sensitive track etch configuration, larger counting areas, and/or longer exposure times will be employed in the future to increase the measurement sensitivity.

Table 2-3 contains LLD estimates for Rn-222 concentrations determined via alpha scintillation counting of Rn-222 samples collected by the EMI composite samplers. The LLDs were calculated by the following relation

$$LLD = \frac{4.66\, S_b\, e^{\lambda t}}{K}$$

where: LLD = lower limit of detection,

4.66 = multiplicative factor for the standard deviation,

S_b = standard deviation of the background counting rate in cpm,

λ = decay constant for Rn-222 = 2.1E-6 sec^{-1},

t = time of decay from midpoint during sample collection to midpoint during counting (seconds),

K = scintillation cell calibration factor (cpm per pCi/l).

Error Calculations. The random error estimates associated with the radon cup Rn-222 concentrations in Table 2-2 are the upper and lower boundaries of the 95 percent confidence intervals for track counting. The intervals were calculated for total exposed film tracks based on the Poisson distribution due to the low number of tracks recorded. The uncertainty in the film background track counting was much lower than for the field-exposed detectors, and was therefore not included in the error estimation for the net track density. A systematic one standard deviation uncertainty of 22 percent is estimated for the calibration factor (Table 2-4).

The random error estimates associated with the Rn-222 concentrations for samples collected via the composite samplers were derived via the following relation

$$E = \frac{2(\sqrt{T/t_1{}^2 + S_\sigma{}^2})e^{\lambda t_2}}{K}$$

where: E = $\pm$ two sigma error (95 percent confidence level based upon Gaussian statistics),

T = total sample counts,

S_σ = uncertainty in the background counting rate in cpm,

t_1 = sample count time in minutes,

= Rn-222 decay constant = 2.1E-6 sec^{-1},

t_2 = time of decay from midpoint during sample collection to midpoint during counting in seconds,

K = scintillation cell calibration factor (cpm per pCi/l).

Quality Assurance. The Track Etch film is produced in batches. Each batch is large enough to provide about 35,000 individual detectors. Detectors selected randomly from each batch are calibrated concurrently with detectors from previous batches, to ascertain the batch-to-batch variability. Though the variability is negligible (excluding normal counting variations) complete batches are set aside exclusively for environmental measurements, as the need arises.

The background track density to be subtracted from the track densities of the detectors exposed in the field was determined by counting the tracks of approximately 100 detectors following their manufacture. An average background track density of 0.4 tracks/mm^2 was obtained. In addition, some detectors were checked monthly for evidence of aging effects. To date, no aging effects have been seen.

Each detector strip and its cup were serially numbered before shipment. On return from a project site, the detector numbers and cup numbers were matched with each other and with the returned data sheet entries. For environmental projects, the exposed detectors were counted manually by specially trained laboratory technicians. To maintain operator proficiency and keep performance within statistically acceptable limits, selected detectors were subjected to duplicate counts by different operators. Also, standard exposed detectors, with known track counts, were sometimes added to the sample group.

Analysis Results

Although airborne Rn-222 has been measured with radon cups from the period June 1979-August 1980 problems with excessive track densities due to cup labels were not solved until February 1980. Consequently, only second and third quarter 1980 data and monthly data from February 1980 to the present are presented in Table 2-2. The previously encountered label problems are now under control. All radon concentration data obtained via the EMI samplers for the six locations are contained in Table 2-3.

2.3 REFERENCES

Alter, H.W. and R.L. Fleischer. 1980. Passive Integrating Randon Monitor for Environmental Monitoring. Submitted to Health Physics June, 1980. 17 pp.

George A.C. 1976. Scintillation Flasks for the Determination of Low Level Concentrations of Radon. Proc. 9th Midyear Health Phys. Symp., Denver, CO., Feb.

George A.C. 1979. Private Communication.

Harley, J.H. (ed.). 1972. HASL Procedures Manual. HASL-300. U.S. Atomic Energy Commission, D-08-01 through D-08-03.

Thomas J.W. 1972. Measurement of Radon Daughters in Air. Health Phys., 23, 783.

Thomas J.W. and Countess R.J. 1979. Continuous Radon Monitor. Health Phys., 36, 734.

3.0

WATER SAMPLES

3.1 GROUND WATER

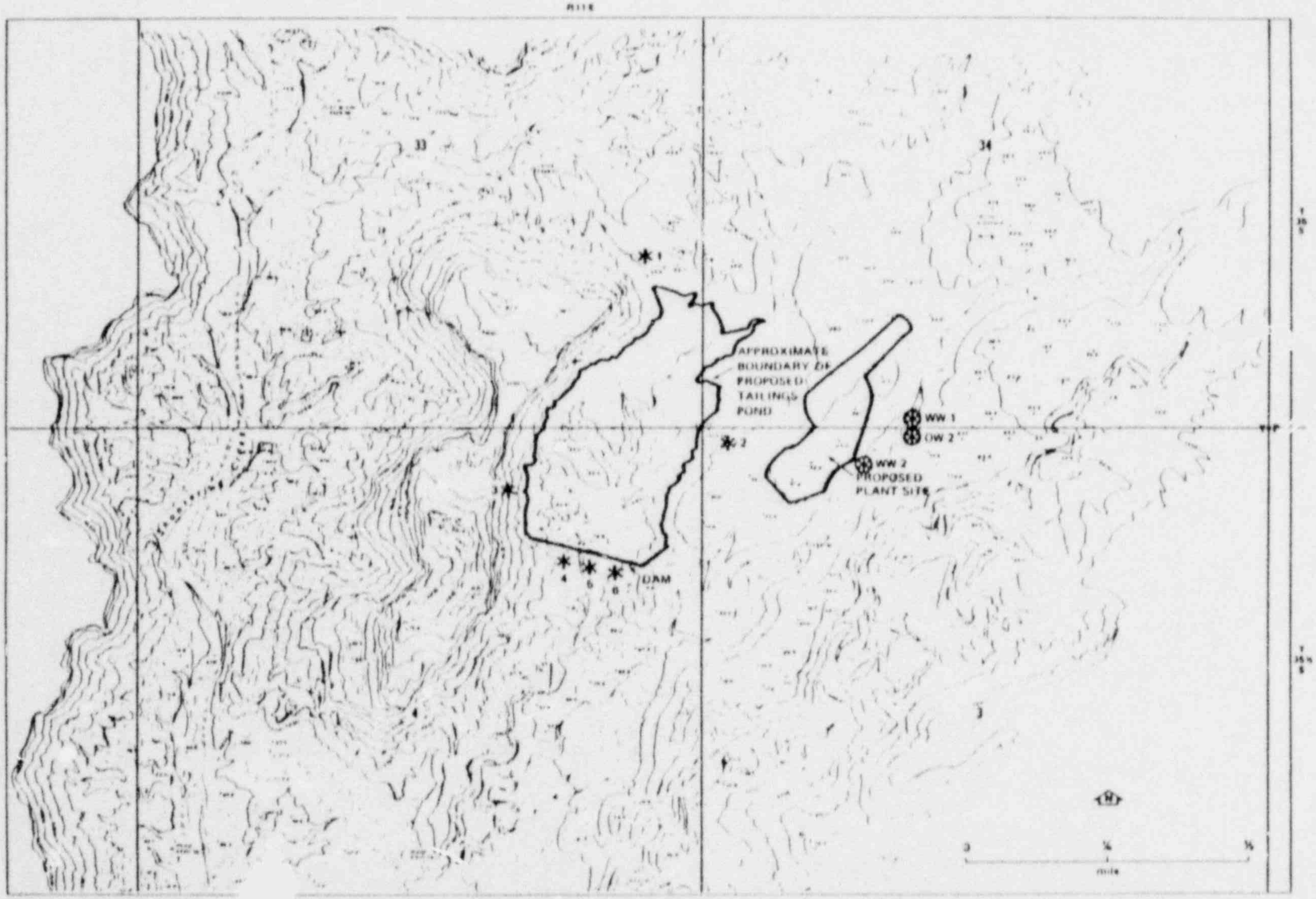
General Description

Groundwater samples were taken from six wells located near the periphery of the tailings impoundment (see Figure 3-1). The well to the north of the tailings impoundment is the up gradient control well. Three of the wells are located down gradient from the proposed dam, and two are located east and west of the tailings impoundment. The east groundwater monitoring well is near the site center. The monitoring wells were drilled to the base of the Entrada Sandstone aquifer (top of the Carmel formation) about 600 feet below the surface. Water level in the Entrada is about 215 feet below ground surface.

Two project water supply wells designated WW-1 and -2, located about 1/4 mile east of the site center, have also been sampled. In addition, two observation wells, designated OW-1 and -2, were completed in the Entrada Sandstone, up-gradient of the tailings pond. One of these, OW-2, was sampled as a second control for the other wells. The locations of the wells are also shown in Figure 3-1. Results of the sampling program are shown in Table 3-1.

Sample Collection

Locations. As recommended by NRC R.G. 4.14, three wells are hydrologically down gradient from the proposed tailings area and



LEGEND

✱ Monitor Wells, 1–6

⊛ Project Water Wells, WW 1 and 2 and OW 2

Figure 3-1. PREOPERATIONAL MONITORING LOCATIONS FOR GROUNDWATER

Table 3-1. GROUNDWATER SAMPLES

Date 6-79
Location WW-1
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2.2E-9	0.4E-9
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	0.52E-9	0.08E-9
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 9-12-79
Location WW-1
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	<3E-9*	-
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.07E-9	0.03E-9
Pb-210 (dissolved)	-	-
Po-210 (dissolved)	-	-

*LLD

Date 1-9-80
Location WW-1
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.35E-9	-
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	<0.20E-9*	-
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 4-2-80
Location WW-1
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.74E-9	0.27E-9
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	<0.20E-9*	-
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

*LLD

Date 4-15-80
Location WW-1
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.68E-9	0.27E-9
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	<0.20E-9*	-
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 6-79
Location WW-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.62E-9	0.24E-9
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	0.45E-9	0.07E-9
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

*LLD

Date 1-9-80
Location WW-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.66E-9	-
Th-230 (dissolved)	0.68E-9	0.50E-9
Ra-226 (dissolved)	<0.20E-9*	-
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 1-28-80
Location OW-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.74E-9	0.27E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.00	0.20E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 4-2-80
Location OW-2
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	0.74E-9	0.27E-9
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	0.23E-9	0.07E-9
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 9-26-79
Location RM-1
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	8.8E-9	-
Th-230 (dissolved)	0.00	0.05E-9
Ra-226 (dissolved)	1.9E-9	0.1E-9
Pb-210 (dissolved)	0.00	2.0E-9
Po-210 (dissolved)	0.00	1.0E-9

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 1-9-80
Location RM-1
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	< 0.41E-9*	-
Th-230 (dissolved)	< 0.20E-9*	-
Ra-226 (dissolved)	0.55E-9	0.07E-9
Pb-210 (dissolved)	< 0.50E-9*	-
Po-210 (dissolved)	< 0.20E-9*	-

Date 4-2-80
Location RM-1
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	1.6E-9	0.4E-9
Th-230 (dissolved)	0.73E-9	0.63E-9
Ra-226 (dissolved)	0.27E-9	0.08E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 9-6-79
Location RM-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	< 3E-9*	-
Th-230 (dissolved)	0.48E-9	0.24E-9
Ra-226 (dissolved)	0.93E-9	0.07E-9
Pb-210 (dissolved)	0.0	2.0E-9
Po-210 (dissolved)	0.0	1.0E-9

Date 1-9-80
Location RM-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.41E-9	-
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	0.24E-9	0.06E-9
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 4-2-80
Location RM-2
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.81E-9	0.27E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.00	0.20E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

*LLD

Date 1-25-80
Location RM-3
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	3.7E-9	0.5E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.46E-9	0.14E-9
Pb-210 (dissolved)	0.00	0.50-E
Po-210 (dissolved)	0.00	0.20E-9

Date 4-2-80
Location RM-3
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	6.2E-9	0.9E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.00	0.20E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

Table 3-1. GROUNDWATER SAMPLES

Date 9-6-79
Location RM-4
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	< 3E-9*	-
Th-230 (dissolved)	0.00	0.05E-9
Ra-226 (dissolved)	1.0E-9	0.1E-9
Pb-210 (dissolved)	0.0	2.0E-9
Po-210 (dissolved)	0.0	1.0E-9

Date 1-9-80
Location RM-4
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	7E-9	-
Th-230 (dissolved)	0.35E-9	0.21E-9
Ra-226 (dissolved)	2.3E-9	0.7E-9
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	< 0.20E-9*	-

*LLD

Date 4-11-80
Location RM-4
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.0	0.2E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.36E-9	0.11E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

Date 9-6-79
Location RM-5
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	<3E-9*	-
Th-230 (dissolved)	0.13E-9	0.09E-9
Ra-226 (dissolved)	0.50E-9	0.06E-9
Pb-210 (dissolved)	0.0	2.0E-9
Po-210 (dissolved)	0.0	1.0E-9

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 1-9-80
Location RM-5
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	20E-9	-
Th-230 (dissolved)	<0.20E-9*	-
Ra-226 (dissolved)	<0.20E-9*	-
Pb-210 (dissolved)	<0.50E-9*	-
Po-210 (dissolved)	<0.20E-9*	-

Date 4-2-80
Location RM-5
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	0.0	0.4E-9
Th-230 (dissolved)	0.00	0.20E-9
Ra-226 (dissolved)	0.24E-9	0.07E-9
Pb-210 (dissolved)	0.00	0.50E-9
Po-210 (dissolved)	0.00	0.20E-9

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 9-6-79
Location RM-6
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	< 3E-9*	-
Th-230 (dissolved)	0.15E-9	0.11E-9
Ra-226 (dissolved)	0.43E-9	0.10E-9
Pb-210 (dissolved)	0.0	2.0E-9
Po-210 (dissolved)	0.0	1.0E-9

Date 1-9-80
Location RM-6
Type Well

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	18E-9	-
Th-230 (dissolved)	< 0.20E-9*	-
Ra-226 (dissolved)	< 0.20E-9*	-
Pb-210 (dissolved)	< 0.50E-9*	-
Po-210 (dissolved)	< 0.20E-9*	-

*LLD

Table 3-1. GROUNDWATER SAMPLES

Date 4-2-80
Location RM-6
Type Well

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	< 0.4E-9*	-
Th-230 (dissolved)	< 0.20E-9*	-
Ra-226 (dissolved)	< 0.20E-9*	-
Pb-210 (dissolved)	< 0.50E-9*	-
Po-210 (dissolved)	< 0.20E-9*	-

*LLD

three other wells are near the other sides of the area, with one well being hydrologically up gradient. In addition, samples have been collected from three of the four other wells on the project site. These are the only wells within two kilometers of the site.

Equipment. The six tailings area wells were sampled with a bailer consisting of six feet of two-inch diameter PVC pipe, sealed and weighted at one end. The two project water supply wells and the observation well were sampled by pumping.

Procedure. Sampling at each of the monitoring wells included measurements of the water depth in the hole prior to sampling. Two gallons of water were bailed from each monitoring well. The temperature of each sample was measured. One gallon of each sample was filtered into a clean plastic container, using a 0.45 μm filter and treated with 19 milliliters (five ml/liter) of concentrated nitric acid before closing and shipping to the commercial analysis laboratory. The second gallon was shipped directly to the laboratory without filtering or adding preservatives.

Sampling of the water supply wells and the observation well was done by collecting water from the pump discharge lines. As noted above, each sample consisted of two gallons of water, one untreated and the other filtered with preservative added.

Sample Analysis

See Appendix A.

3.2 SURFACE WATER

General Description

Lake Powell, 13 miles downstream along Hansen Creek, is the nearest permanent water impoundment. Two surface samples were taken from Lake Powell, in March and June, 1980.

Near the project site, samples were taken from four seeps in the site vicinity. The seeps are located as shown in Figure 3-2. Samples were taken from each location in March and July of 1979.

Surface runoff samples were collected from three locations (shown in Figure 3-2) on Shootering Creek. Results of the sample analyses of surface waters are shown in Table 3-2.

Sample Collection

Locations. There are no permanent impoundments of surface water near the proposed facility. With the exception of Lake Powell (some 13 miles down the Hansen Creek drainage from the project site), no other impoundment exists in the region.

There are four springs/seeps in the project area. While these are more appropriately considered groundwater (expressed at the surface), they represent the only "standing" water available in the area. One spring, which flows at one to two gpm, is located in Lost Springs Wash approximately 1/2 mile north of the project site center. Another "spring" which maintains a "pool" about 1/2 liter in size is located approximately one mile south of the site center. Two seeps in Shootering Creek are located one mile northwest and one mile southwest of the site center.

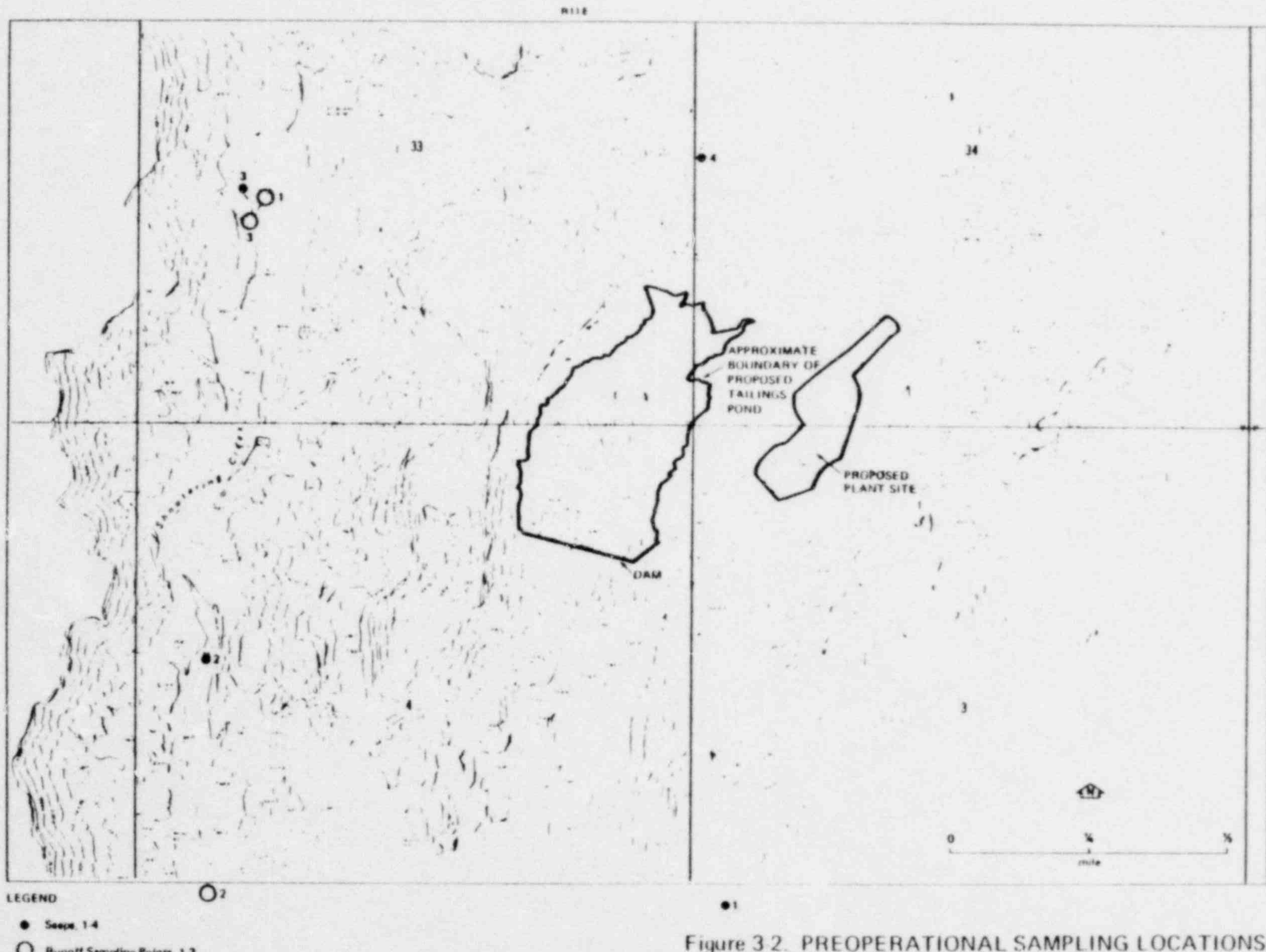


Figure 3.2. PREOPERATIONAL SAMPLING LOCATIONS FOR SURFACE WATER

Table 3-2. SURFACE WATER SAMPLES

Date 3-15-79
Location 1
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	-	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.22E-9	0.20E-9
Th-230 (suspended)	2.0E-8	1.1E-8
Ra-226 (dissolved)	0.71E-9	0.08E-9
Ra-226 (suspended)	3.1E-8	9.1E-10
Pb-210 (dissolved)	0.67E-9	0.39E-9
Pb-210 (suspended)	4.1E-8	1.2E-8
Po-210 (dissolved)	<0.20E-9*	-
Po-210 (suspended)	1.6E-8	5.5E-9

Date 7-17-79
Location 1
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	<3.4E-9*	-
U-nat (suspended)	1.7E-7	-
Th-230 (dissolved)	1.8E-9	0.8E-9
Th-230 (suspended)	1.1E-8	2.1E-9
Ra-226 (dissolved)	2.2E-9	0.1E-9
Ra-226 (suspended)	1.2E-8	1.1E-9
Pb-210 (dissolved)	5.8E-9	4.9E-9
Pb-210 (suspended)	1.1E-8	1.6E-9
Po-210 (dissolved)	0.0	3.0E-9
Po-210 (suspended)	1.8E-8	2.2E-9

*LLD

Date 3-15-79
Location 2
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	-	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.68E-9	0.43E-9
Th-230 (suspended)	3.9E-7	6.1E-8
Ra-226 (dissolved)	0.56E-9	0.07E-9
Ra-226 (suspended)	1.6E-6	6.1E-8
Pb-210 (dissolved)	0.47E-9	0.39E-9
Pb-210 (suspended)	7.9E-7	6.1E-8
Po-210 (dissolved)	<0.20E-9	-
Po-210 (suspended)	5.4E-7	2.4E-8

Date 7-17-79
Location 2
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	68E-9	-
U-nat (suspended)	1.1E-6	-
Th-230 (dissolved)	0.42E-9	0.35E-9
Th-230 (suspended)	4.6E-8	6.3E-9
Ra-226 (dissolved)	0.44E-9	0.04E-9
Ra-226 (suspended)	6.9E-8	5.8E-9
Pb-210 (dissolved)	0.0	2.0E-9
Pb-210 (suspended)	5.5E-8	7.5E-9
Po-210 (dissolved)	0.0	3.0E-9
Po-210 (suspended)	8.1E-8	1.2E-8

Table 3-2. SURFACE WATER SAMPLES

Date 1-15-80
Location 3*
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	24E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.67E-9	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.44E-9	0.36E-9
Po-210 (suspended)	-	-

Date 2-15-80
Location 3
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	28E-9	4E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.55E-9	0.46E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.90E-9	0.27E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

*Approximately 500 ft. downstream of actual location

Table 3-2. SURFACE WATER SAMPLES

Date 3-7-80
Location 3
Type Runoff

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	6.6E-9	0.9E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 3-11-80
Location Lake Powell, Hansen Creek Mouth
Type Impoundment

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2.8E-9	0.6E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.[illegible]	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 3-11-80*
Location Lake Powell, Hansen Creek Mouth*
Type Impoundment*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2.7E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.0	2.3E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.2E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	7.6E-9	2.5E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	0.2E-9
Po-210 (suspended)	-	-

Date 6-29-80
Location Lake Powell, Hansen Creek Mouth**
Type Impoundment*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.0	1.9E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.2E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.6E-9	2.1E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	0.4E-9
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**Analysis by Hazen Research.

Date 10-10-79
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	5E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.45E-9	0.06E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 11-15-79
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 12-17-79
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	< 3E-9*	-
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	< 0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 1-8-80
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	<0.4E-9*	-
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	< 0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	< 0.50E-9*	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	< 0.20E-9*	-
Po-210 (suspended)	-	-

*LLD

Table 3-2. SURFACE WATER SAMPLES

Date 2-6-80
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.64E-9	0.17E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 5-6-80*
Location 1*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.7E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	4.9E-9	3.2E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.3F-9	0.3E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.5E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.3E-9	0.4E-9
Po-210 (suspended)	-	-

*Duplicate Analysis by Hazen Research of Golden, CO.

Date 5-6-80
Location 1
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.30E-9	0.10E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.53E-9	0.36E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.20E-9	0.06E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 7-18-79
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	149E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.45E-9	0.42E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.49E-9	0.10E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.0E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	1.0E-9
PO-210 (suspended)	-	-

Date 8-15-79
Location 2
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	88E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.48E-9	0.33E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.95E-9	0.06E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 9-11-79
Location 2
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	81E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.05E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.21E-9	0.03E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Table 3-2. SURFACE WATER SAMPLES

Date 10-10-79
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	68E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.10E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 11-15-79
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	54E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 12-17-79
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	51E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 1-8-80
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	59E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9*	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9*	-
Po-210 (suspended)	-	-

*LLD

Date 2-6-80
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	59E-9	3E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 5-6-80
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	20E-9	2E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	< 0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	< 0.50E-9*	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	< 0.20E-9*	-
Po-210 (suspended)	-	-

*LLD

Table 3-2. SURFACE WATER SAMPLES

Date 5-6-80*
Location 2*
Type Seep*

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	26E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	1.6E-9	1.8E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.3E-9	0.3E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	2.2E-9	2.9E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.5E-9	0.4E-9
Po-210 (suspended)	-	-

Date 6-4-80
Location 2
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	28E-9	6E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.51E-9	0.15E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.

Table 3-2. SURFACE WATER SAMPLES

Date 6-4-80*
Location 2*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	69E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.8E-9	3.3E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.0	0.2E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 7-7-80
Location 2
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	27E-9	3E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9**	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 7-7-80*
Location 2*
Type Seep*

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	63E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	1.0E-9	1.9E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.6E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.8E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	0.2E-9
Po-210 (suspended)	-	-

Date 8-6-80
Location 2
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	24E-9	2E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9**	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 7-18-79
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	66E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.71E-9	0.67E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.81E-9	0.09E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.0E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	1.0E-9
Po-210 (suspended)	-	-

Date 8-15-79
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	31E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.49E-9	0.41E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	1.7E-9	0.1E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 9-11-79
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	34E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.05E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.32E-9	0.04E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 10-10-79
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	43E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.33E-9	0.05E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Table 3-2. SURFACE WATER SAMPLES

Date 11-15-79
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	18E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-[illegible]
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 1-8-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	22E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	< 0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	< 0.50E-9*	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	< 0.20E-9*	-
Po-210 (suspended)	-	-

*LLD

Date 2-6-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	24E-9	1E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 5-6-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	5.7E-9	0.7E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.70E-9	0.47E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 5-6-80*
Location 3*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	14E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.5E-9	1.1E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.5E-9	0.3E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.8E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.2E-9	0.4E-9
Po-210 (suspended)	-	-

Date 6-4-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	9.2E-9	1.4E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.37E-9	0.11E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

*Duplicate Analysis by Hazen Research of Golden, CO.
**LLD

Date 6-4-80*
Location 3*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	58E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.0	1.0E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.6E-9	0.6E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 7-7-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	8.3E-9	1.0E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.35E-9	0.11E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	< 0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 7-7-80*
Location 3*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	16E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	1.9E-9	2.6E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.0	0.4E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	3.0E-9	2.4E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	0.2E-9
Po-210 (suspended)	-	-

Date 8-6-80
Location 3
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	6.4E-9	0.7E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9**	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 7-18-79
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0	3E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.05E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.39E-9	0.10E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.0E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.0	1.0E-9
Po-210 (suspended)	-	-

Date 8-15-79
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	< 3E-9*	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.05E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.74E-9	0.05E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

*LLD

Table 3-2. SURFACE WATER SAMPLES

Date 9-11-79
Location Seep
Type 4

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	4E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.05E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.14E-9	0.03E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 10-10-79
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissclved)	34E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.67E-9	0.06E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 11-15-79
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	3E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.00	0.20E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	0.20E-9
Po-210 (suspended)	-	-

Date 1-8-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	2E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9*	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	<0.20E-9*	-
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9*	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9*	-
Po-210 (suspended)	-	-

*LLD

Table 3-2. SURFACE WATER SAMPLES

Date 2-6-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	1.3E-9	0.2E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.21E-9	0.06E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 5-6-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.37E-9	0.12E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.00	0.20E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.24E-9	0.07E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.00	0.50E-[illegible]
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.00	[illegible]
Po-210 (suspended)	-	-

Date 5-6-80*
Location 4*
Type Seep*

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	1.4E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	0.0	1.1E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.2E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	6.0E-9	2.3E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.1E-9	0.3E-9
Po-210 (suspended)	-	-

Date 6-4-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)
U-nat (dissolved)	0.56E-9	0.23E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	<0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.32E-9	0.10E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 6-4-80*
Location 4*
Type Seep*

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	1.3E-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	1.5E-9	3.6E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.30E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	-	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	-	-
Po-210 (suspended)	-	-

Date 7-7-80
Location 4
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	0.43E-9	0.14E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	< 0.20E-9**	-
Th-230 (suspended)	-	-
Ra-226 (dissolved)	< 0.20E-9**	-
Ra-226 (suspended)		-
Pb-210 (dissolved)	< 0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	< 0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Date 7-7-80*
Location 4*
Type Seep*

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	.68-9	-
U-nat (suspended)	-	-
Th-230 (dissolved)	1.0E-9	1.9E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.1E-9	0.6E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	0.0	2.5E-9
Pb-210 (suspended)	-	-
Po-210 (dissolved)	0.1E-9	0.3E-9
Po-210 (suspended)	-	-

Date 8-6-80
Location 4
Type Seep

Radionuclide	Concentration (µCi/ml)	Error Estimate (µCi/ml)
U-nat (dissolved)	0.37E-9	0.09E-9
U-nat (suspended)	-	-
Th-230 (dissolved)	0.16E-9	0.07E-9
Th-230 (suspended)	-	-
Ra-226 (dissolved)	0.27E-9	0.08E-9
Ra-226 (suspended)	-	-
Pb-210 (dissolved)	<0.50E-9**	-
Pb-210 (suspended)	-	-
Po-210 (dissolved)	<0.20E-9**	-
Po-210 (suspended)	-	-

*Duplicate analysis by Hazen Research of Golden, CO.
**LLD

Runoff was collected in two washes that border the project site. One is Lost Springs Wash (north of the project site), and the other is Shootering Creek (west of the project site). Because of the arid climate of the region, surface flows are quite erratic. Sampling was conducted monthly when flows occurred. Runoff sampling station, No. 3, immediately downstream of the junction of Lost Springs Wash with Shootering Creek, was substituted for No. 1 after the latter was eliminated by road construction.

Equipment. For collection of surface water samples, a clean, stainless steel bucket was used to collect the water sampled. The water was then transferred to clean, plastic one-gallon containers for shipment to the analysis laboratory. To provide for collection of water from the seeps/springs, a shallow hole was bored into each spring to a depth of about 18 inches below the standing water level. The hole was cased with a 12-inch diameter PVC pipe; the top of the pipe was mounted with a protective cap, and the bottom of the hole was lined with about six inches of stones or cobbles.

Procedure. Each water sample was collected with the stainless steel bucket and transferred to one of two one-gallon plastic containers. The temperature of each sample was measured. One gallon of each sample was filtered through a 0.45 μm filter and treated with 19 milliliters (five ml/liter) of concentrated nitric acid. The second gallon of each sample was left untouched. At the seeps/springs, standing water depth in the casing was measured.

Sample Analysis

See Appendix A.

4.0
VEGETATION AND FISH SAMPLES

4.1 VEGETATION

General Description

Grasses, shrubs and forbs were sampled at three locations on the project site (see Figure 4-1) during the months of December, 1979, and January, February and March, 1980. Results of the analyses of these samples are shown in Table 4-1. A control sampling location was established east of the Bullfrog Marina airport, and data from this location is also shown in Table 4-1, identified as Location 4.

Sample Collection

Locations. Three sample sites in the project area were selected on the basis that they appeared to be potential grazing areas, with enough vegetation available to make up adequate sample sizes. They are in the sectors having the highest predicted airborne radionuclide concentrations due to milling operations.

Equipment. No special equipment was used.

Procedure. Each plant specimen was pulled or dug from the soil by hand, being careful to include as much of the root system as possible. The samples were air dried, freed of adhering soil, and packed in marked plastic bags for transfer to the laboratory. The following plant species were collected:

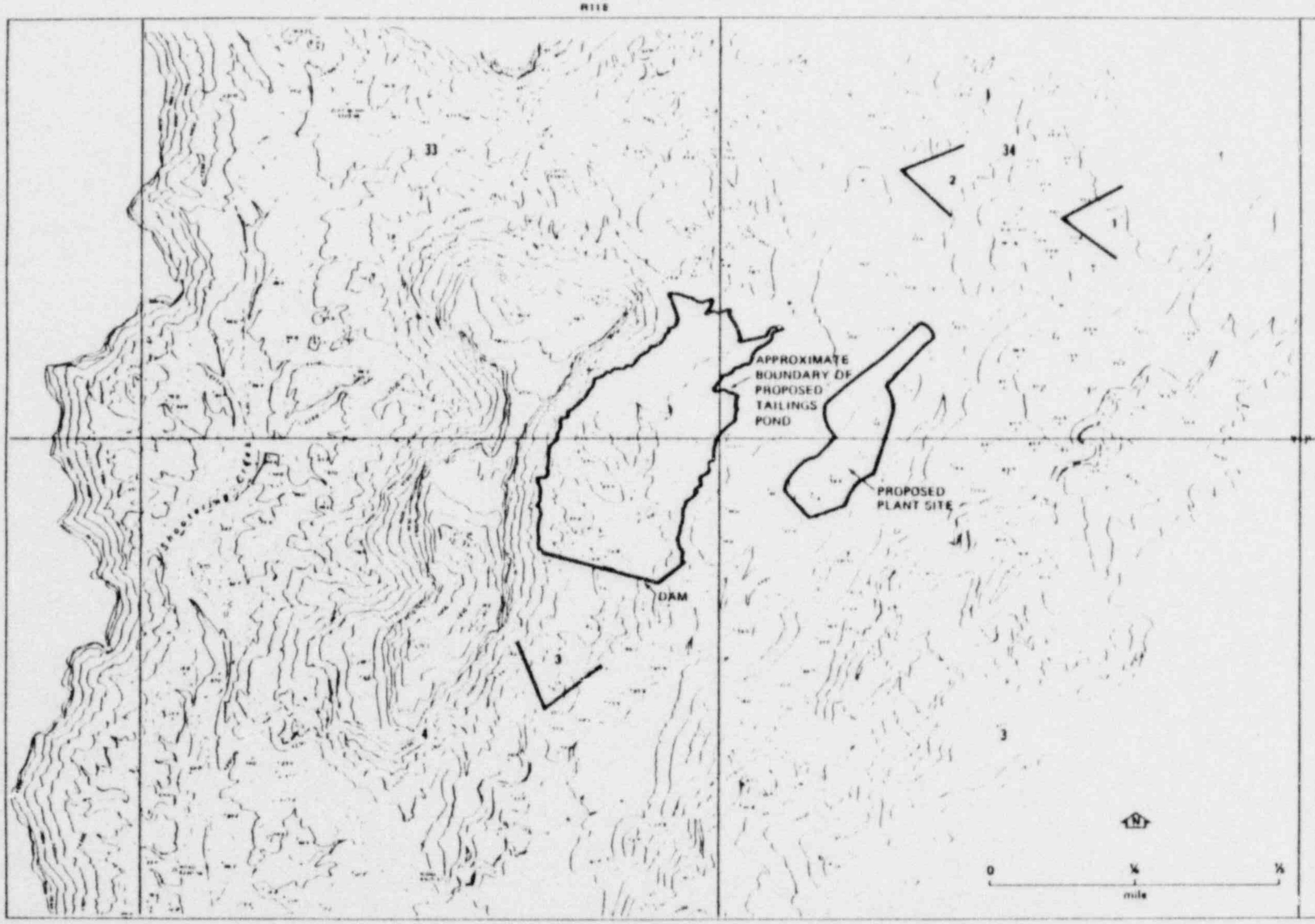


Figure 4-1. PREOPERATIONAL SAMPLING LOCATIONS FOR VEGETATION

Table 4-1. VEGETATION AND FISH SAMPLES

Date 11/29/79
Location 1
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	45E-6	-
Th-230	40E-6	8E-6
Ra-226	56E-6	17E-6
Pb-210	1300E-6	100E-6
Po-210	960E-6	80E-6

Date 11/29/79
Location 1
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	14E-6	-
Th-230	6.1E-6	2.4E-6
Ra-226	10E-6	3E-6
Pb-210	100E-6	80E-6
Po-210	46E-6	12E-6

Date 11/29/79
Location 1
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	13E-6	-
Th-230	5.4E-6	1.6E-6
Ra-226	23E-6	7E-6
Pb-210	250E-6	30E-6
Po-210	240E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 1/9/80
Location 1
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	62E-6	12E-6
Th-230	80E-6	21E-6
Ra-226	52E-6	16E-6
Pb-210	830E-6	40E-6
Po-210	440E-6	40E-6

Date 1/9/80
Location 1
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	20E-6	6E-6
Th-230	6.1E-6	1.3E-6
Ra-226	10E-6	3E-6
Pb-210	840E-6	50E-6
Po-210	150E-6	10E-6

Date 1/9/80
Location 1
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	74E-6	14E-6
Th-230	12E-6	5E-6
Ra-226	12E-6	4E-6
Pb-210	610E-6	30E-6
Po-210	350E-6	30E-6

Date 2/5/80
Location 1
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	56E-6	11E-6
Th-230	53E-6	13E-6
Ra-226	60E-6	18E-6
Pb-210	1700E-6	100E-6
Po-210	1600E-6	200E-6

Date 2/5/80
Location 1
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	16E-6	4E-6
Th-230	6.7E-6	2.2E-6
Ra-226	41E-6	12E-6
Pb-210	1100E-6	100E-6
Po-210	510E-6	120E-6

Date 2/5/80
Location 1
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	13E-6	3E-6
Th-230	6.5E-6	2.6E-6
Ra-226	14E-6	4E-6
Pb-210	770E-6	70E-6
Po-210	410E-6	90E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 3/4/80
Location 1
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	54E-6	7E-6
Th-230	40E-6	10E-6
Ra-226	73E-6	22E-6
Pb-210	1600E-6	100E-6
Po-210	1100E-6	100E-6

Date 3/4/80
Location 1
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	21E-6	3E-6
Th-230	8.3E-6	1.9E-6
Ra-226	50E-6	15E-6
Pb-210	600E-6	30E-6
Po-210	470E-6	40E-6

Date 3/4/80
Location 1
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	4.2E-6	0.81E-6
Th-230	4.7E-6	2.1E-6
Ra-226	20E-6	6E-6
Pb-210	500E-6	20E-6
Po-210	670E-6	40E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 11/29/79
Location 2
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	39E-6	-
Th-230	31E-6	8E-6
Ra-226	45E-6	14E-6
Pb-210	400E-6	40E-6
Po-210	380E-6	40E-6

Date 11/29/79
Location 2
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	45E-6	
Th-230	7.5E-6	2.5E-6
Ra-226	39E-6	12E-6
Pb-210	110E-6	20E-6
Po-210	110E-6	20E-6

Date 11/29/79
Location 2
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	6.5E-6	-
Th-230	5.4E-6	1.3E-6
Ra-226	20E-6	6E-6
Pb-210	84E-6	17E-6
Po-210	79E-6	17E-6

Date 1/9/80
Location 2
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	59E-6	15E-6
Th-230	61E-6	18E-6
Ra-226	42E-6	13E-6
Pb-210	840E-6	40E-6
Po-210	410E-6	40E-6

Date 1/9/80
Location 2
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	18E-6	5E-6
Th-230	5.7E-6	1.4E-6
Ra-226	11E-6	3E-6
Pb-210	850E-6	10E-6
Po-210	230E-6	10E-6

Date 1/9/80
Location 2
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	18E-6	6E-6
Th-230	6.7E-6	2.8E-6
Ra-226	8.5E-6	2.6E-6
Pb-210	480E-6	20E-6
Po-210	260E-6	20E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 2/5/80
Location 2
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	65E-6	10E-6
Th-230	52E-6	12E-6
Ra-226	57E-6	17E-6
Pb-210	1800E-6	100E-6
Po-210	950E-6	150E-6

Date 2/5/80
Location 2
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	81E-6	14E-6
Th-230	4.1E-6	1.5E-6
Ra-226	50E-6	15E-6
Pb-210	1100E-6	100E-6
Po-210	400E-6	70E-6

Date 2/5/80
Location 2
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	36E-6	5E-6
Th-230	8.5E-6	2.9E-6
Ra-226	22E-6	7E-6
Pb-210	210E-6	40E-6
Po-210	110E-6	50E-6

Date 3/3/80
Location 2
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	46E-6	5E-6
Th-230	20E-6	5E-6
Ra-226	62E-6	19E-6
Pb-210	1100E-6	100E-6
Po-210	680E-6	50E-6

Date 3/3/80
Location 2
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	20E-6	3E-6
Th-230	2.1E-6	0.5E-6
Ra-226	60E-6	18E-6
Pb-210	1600E-6	100E-6
Po-210	1100E-6	100E-6

Date 3/3/80
Location 2
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	16E-6	2E-6
Th-230	2.1E-6	0.9E-6
Ra-226	39E-6	12E-6
Pb-210	270E-6	20E-6
Po-210	330E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 11/30/79
Location 3
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	135E-6	-
Th-230	5.9E-6	2.1E-6
Ra-226	75E-6	22E-6
Pb-210	180E-6	80E-6
Po-210	160E-6	30E-6

Date 11/30/79
Location 3
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	30E-6	-
Th-230	13E-6	3E-6
Ra-226	55E-6	16E-6
Pb-210	39E-6	19E-6
Po-210	39E-6	19E-6

Date 11/30/79
Location 3
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	3.7E-6	-
Th-230	3.0E-6	1.6E-6
Ra-226	15E-6	4E-6
Pb-210	280E-6	30E-6
Po-210	270E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 1/9/80
Location 3
Type Grass

Radionuclide	Concentration (Ci/kg wet)	Error Estimate (Ci/kg)
U-nat	135E-6	20E-6
Th-230	110E-6	20E-6
Ra-226	73E-6	22E-6
Pb-210	850E-6	420E-6
Po-210	360E-6	50E-6

Date 1/9/80
Location 3
Type Forb

Radionuclide	Concentration (Ci/kg wet)	Error Estimate (Ci/kg)
U-nat	74E-6	20E-6
Th-230	12E-6	2E-6
Ra-226	19E-6	6E-6
Pb-210	810E-6	100E-6
Po-210	270E-6	10E-6

Date 1/9/80
Location 3
Type Shrub

Radionuclide	Concentration (Ci/kg wet)	Error Estimate (Ci/kg)
U-nat	37E-6	9E-6
Th-230	8.4E-6	3.5E-6
Ra-226	16E-6	5E-6
Pb-210	400E-6	20E-6
Po-210	300E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 2/5/80
Location 3
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	200E-6	41E-6
Th-230	61E-6	13E-6
Ra-226	69E-6	21E-6
Pb-210	490E-6	40E-6
Po-210	740E-6	140E-6

Date 2/5/80
Location 3
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	16E-6	3E-6
Th-230	7.5E-6	2.4E-6
Ra-226	59E-6	18E-6
Pb-210	1100E-6	100E-6
Po-210	450E-6	110E-6

Date 2/5/80
Location 3
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	13E-6	3E-6
Th-230	4.2E-6	1.5E-6
Ra-226	27E-6	8E-6
Pb-210	280E-6	50E-6
Po-210	100E-6	40E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 3/4/80
Location 3
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	95E-6	14E-6
Th-230	52E-6	13E-6
Ra-226	110E-6	40E-6
Pb-210	1000E-6	100E [illegible]
Po-210	910E-6	60E-6

Date 3/4/8[illegible]
Location 3
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	95E-6	7E-6
Th-230	4.3E-6	1.0E-6
Ra-226	68E-6	21E-6
Pb-210	130E-6	20E-6
Po-210	65E-6	16E-6

Date 3/4/80
Location 3
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	21E-6	3E-6
Th-230	1.1E-6	0.5E-6
Ra-226	97E-6	29E-6
Pb-210	360E-6	20E-6
Po-210	530E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 12/4/79
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	30E-6	-
Th-230	32E-6	9E-6
Ra-226	36E-6	11E-6
Pb-210	1000E-6	100E-6
Po-210	780E-6	60E-6

Date 12/4/79
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	11E-6	-
Th-230	2.2E-6	0.8E-6
Ra-226	67E-6	20E-6
Pb-210	210E-6	30E-6
Po-210	200E-6	30E-6

Date 12/4/79
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	6.5E-6	-
Th-230	2.3E-6	1.4E-6
Ra-226	46E-6	14E-6
Pb-210	36E-6	12E-6
Po-210	36E-6	12E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 1/9/80
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	56E-6	9.5E-6
Th-230	57E-6	12E-6
Ra-226	33E-6	10E-6
Pb-210	940E-6	30E-6
Po-210	460E-6	40E-6

Date 1/9/80
Location 4
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	22E-6	5E-6
Th-230	18E-6	3E-6
Ra-226	23E-6	8E-6
Pb-210	770E-6	20E-6
Po-210	220E-6	10E-6

Date 1/9/80
Location 4
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	13E-6	6E-6
Th-230	5.8E-6	5.4E-6
Ra-226	20E-6	7E-6
Pb-210	480E-6	30E-6
Po-210	290E-6	30E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 2/5/80
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	62E-6	10E-6
Th-230	43E-6	13E-6
Ra-226	39E-6	12E-6
Pb-210	2100E-6	200E-6
Po-210	1100E-6	200E-6

Date 2/5/80
Location 4
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	16E-6	2E-6
Th-230	3.0E-6	1.4E-6
Ra-226	41E-6	12E-6
Pb-210	890E-6	90E-6
Po-210	430E-6	80E-6

Date 2/5/80
Location 4
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	6.7E-6	1.6E-6
Th-230	2.2E-6	1.2E-6
Ra-226	5.3E-6	1.6E-6
Pb-210	270E-6	40E-6
Po-210	150E-6	50E-6

Date 3/4/80
Location 4
Type Grass

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	30E-6	5E-6
Th-230	11E-6	2E-6
Ra-226	33E-6	10E-6
Pb-210	930E-6	30E-6
Po-210	1200E-6	100E-6

Date 3/4/80
Location 4
Type Forb

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	9E-6	2E-6
Th-230	1.5E-6	0.6E-6
Ra-226	55E-6	16E-6
Pb-210	620E-6	30E-6
Po-210	460E-6	40E-6

Date 3/4/80
Location 4
Type Shrub

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	10E-6	1E-6
Th-230	1.7E-6	0.9E-6
Ra-226	41E-6	12E-6
Pb-210	240E-6	20E-6
Po-210	270E-6	20E-6

Table 4-1. VEGETATION AND FISH SAMPLES

Date 3/8/80
Location Lake Powell, Hansen Creek Mouth
Type Fish

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)
U-nat	0.00	0.40E-6
Th-230	0.00	0.20E-6
Ra-226	0.00	0.20E-6
Pb-210	0.00	0.50E-6
Po-210	0.00	0.20E-6

Plant	Preferred	Alternate
Grass	Indian ricegrass	Galleta
Forb	Desert trumpet	Globe mallow
Shrub	Mormon tea	Blackbrush

Sample Analysis

See Appendix A.

4.2 FISH

General Description

As noted in Section 1.0, no terrestrial food pathways were sampled, because no crops are grown in the area and livestock forage in the area only occasionally. Game fish were taken from Lake Powell in March, 1980. Results of the analysis are shown in Table 4-1.

Sample Collection

Locations. Lake Powell is the only water body in the region inhabited by game fish.

Equipment. Sport fishing tackle was used, with worms for bait.

Procedure. Traditional fishing continued as necessary to collect at least one kilogram of a single species. The resulting sample was frozen in a marked plastic bag for shipment to the laboratory.

Sample Analysis

See Appendix A.

5.0

SOIL AND SEDIMENT SAMPLES

5.1 SURFACE SOIL

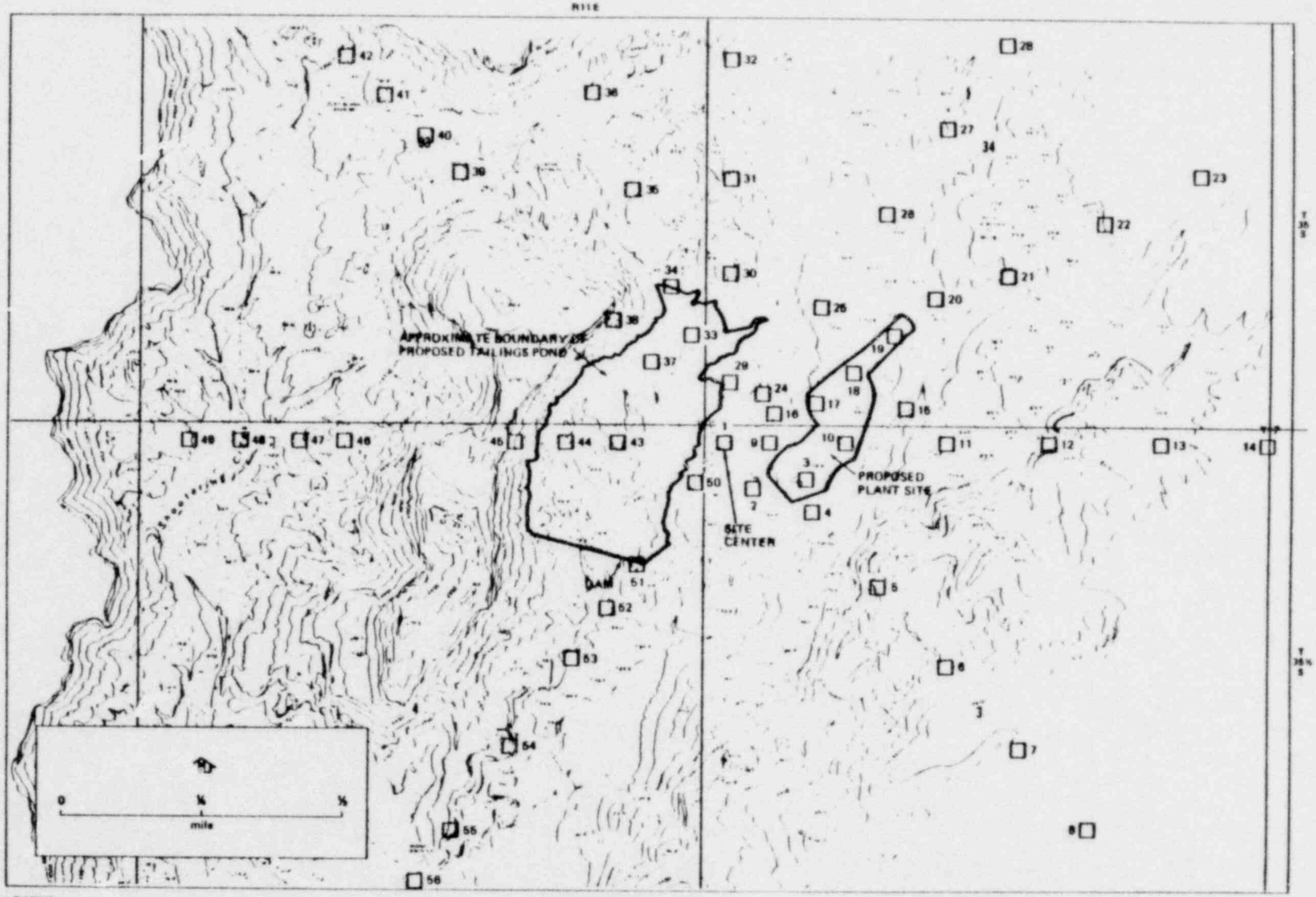
General Description

Surface soil samples were collected from 56 points in the project area (see Figure 5-1) before the start of site preparation activities. Similar samples were collected at the air sampling stations on site and at the planned Ticaboo town site and Bullfrog Basin Marina. Subsequent to initial site preparation activities, 29 surface soil samples were collected in or near disturbed areas. The locations of these "post-excavation" samples are shown in Figure 5-2. Surveyed locations of the post-excavation sampling points are shown in Table 5-1. Results of the sample analyses are shown in Tables 5-2 and 5-3 (baseline samples) and 5-4 and 5-5 (post excavation samples).

Sample Collection

Locations. Sample locations were designated by map coordinates on a radial grid laid out from the site center.

Procedure. Samples were collected at each location by compositing approximately 0.5 kilogram increments from 10 points in an area of about 100 square meters. Samples were taken to a depth of 5 centimeters using a 1.5-inch wide scoop. Each resulting 5 kilogram sample was then blended, coned, halved, and placed in identified plastic bags. One sample split was delivered to the laboratory for analysis, and the other was stored for possible future reference.



LEGEND

☐ Surface Soil Sample Locations, 1–56

Figure 5-1. PREOPERATIONAL MONITORING LOCATIONS FOR SURFACE SOILS

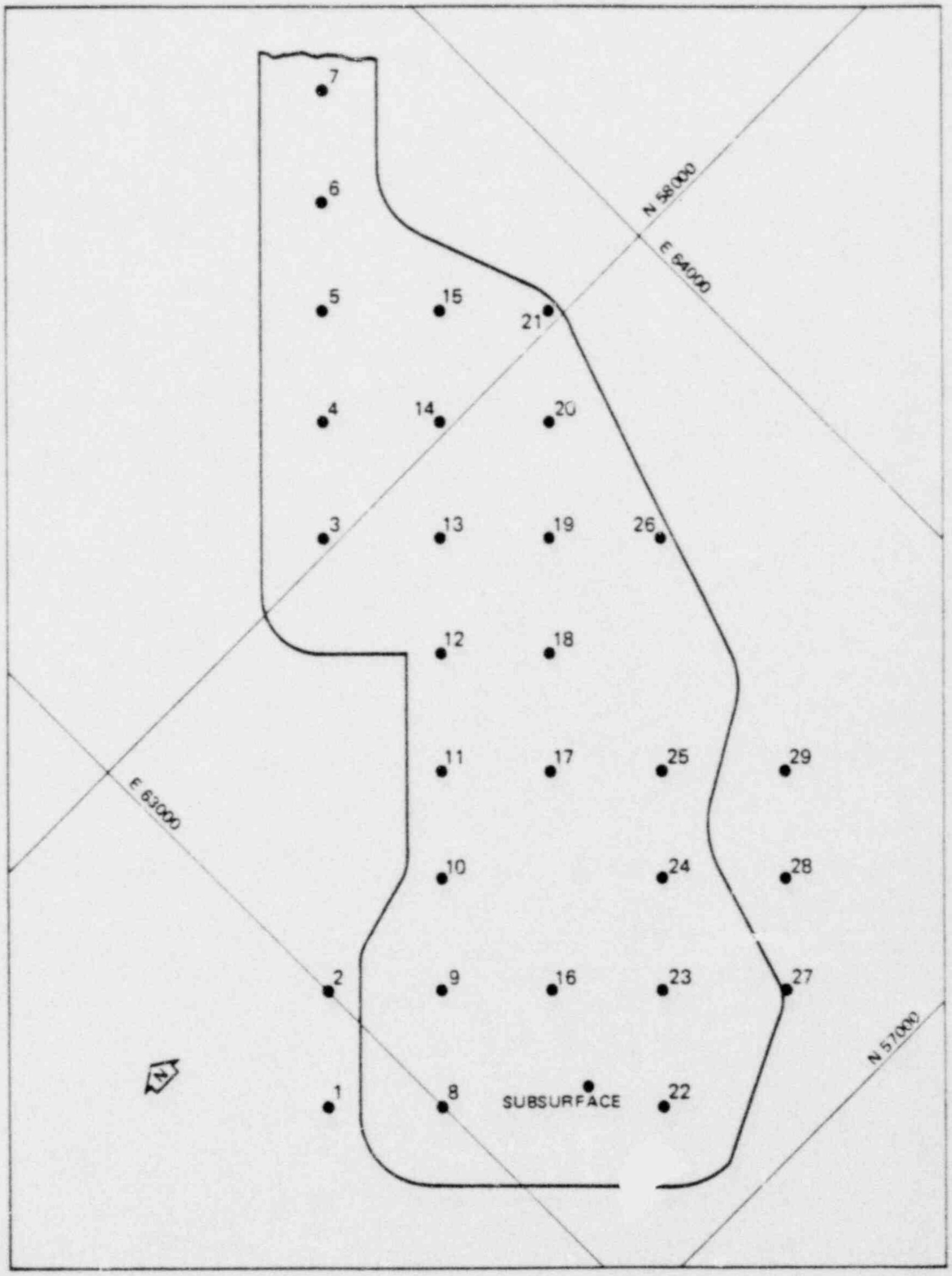


Figure 5-2. POST EXCAVATION SAMPLING LOCATIONS FOR SURFACE SOILS

Table 5-1. POST EXCAVATION GAMMA SURVEY AND SOIL SAMPLE LOCATIONS

Station Number	Northing	Easting
1	57486.0	62882.4
2	57587.9	62984.3
3	58009.2	63408.5
4	58114.4	63514.3
5	58222.1	63620.1
6	58326.8	63726.8
7	58432.9	63832.8
8	57376.2	62991.9
9	57477.1	63092.0
10	57583.6	63198.6
11	57692.2	63307.3
12	57799.9	63415.9
13	57899.9	63516.3
14	58005.2	63621.9
15	58111.4	63729.0
16	57375.9	63196.5
17	57587.7	63410.3
18	57694.3	63521.8
19	57794.7	63622.2
20	57898.7	63726.3
21	58004.0	63831.7
22	57175.4	63201.3
23	57273.2	63302.1
24	57375.7	63408.5
25	57478.2	63515.6
26	57689.7	63728.9
27	57161.3	63405.4
28	57274.0	63501.6
29	57380.9	63613.5

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 1 of 7

Date 5-17-79

Location 1

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.32E-6	0.12E-6
Th-230	0.45E-6	0.21E-6
Ra-226	0.18E-6	0.05E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 5-18-79

Location 4

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.36E-6	0.10E-6
Th-230	0.66E-6	0.41E-6
Ra-226	0.23E-6	0.07E-6
Pb-210	0.78E-6	0.47E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses)

Date 5-18-79

Location 10

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.37E-6	0.15E-6
Th-230	0.47E-6	0.21E-6
Ra-226	0.18E-6	0.05E-6
Pb-210	0.93E-6	0.48E-6
Po-210	-	-

Date 5-17-79

Location 25

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.74E-6	0.54E-6
Th-230	0.94E-6	0.79E-6
Ra-226	0.00	0.20E-6
Pb-210	0.55E-6	0.40E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 3 of 7

Date 5-17-79

Location 26

Tylpe Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.24E-6	0.15E-6
Th-230	0.15E-6	0.08E-6
Ra-226	0.07E-6	0.02E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 5-16-79

Location 30

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.48E-6	0.34E-6
Th-230	0.29E-6	0.17E-6
Ra-226	0.33E-6	0.10E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 4 of 7

Date 5-16-79

Location 44

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.59E-6	0.11E-6
Th-230	0.48E-6	0.20E-6
Ra-226	0.31E-6	0.09E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 5-19-79

Location 52

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.56E-6	0.19E-6
Th-230	1.3E-6	0.8E-6
Ra-226	0.27E-6	0.08E-6
Pb-210	1.9E-6	0.5E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 5 of 7

Date 8-6-79

Location AP-1

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.56E-6	0.20E-6
Th-230	1.2E-6	0.4E-6
Ra-226	0.62E-6	0.19E-6
Pb-210	1.4E-6	0.4E-6
Po-210	-	-

Date 8-6-79

Location AP-2

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.41E-6	0.14E-6
Th-230	0.28E-6	0.14E-6
Ra-226	0.22E-6	0.07E-6
Pb-210	0.91E-6	0.40E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 6 of 7

Date 8-6-79

Location AP-3

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.37E-6	0.13E-6
Th-230	0.46E-6	0.20E-6
Ra-226	0.19E-6	0.06E-6
Pb-210	1.0E-6	0.4E-6
Po-210	-	-

Date 8-6-79

Location AP-4

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.35E-6	0.09E-6
Th-230	0.37E-6	0.18E-6
Ra-226	0.19E-6	0.06E-6
Pb-210	0.69E-6	0.50E-6
Po-210	-	-

Table 5-2. PREOPERATIONAL SURFACE SOIL SAMPLES (Isotopic Analyses) Page 7 of 7

Date 8-6-79

Location C-1

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.31E-6	0.09E-6
Th-230	0.30E-6	0.15E-6
Ra-226	0.19E-6	0.06E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 8-6-79

Location C-2

Type Surface Soil

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.42E-6	0.15E-6
Th-230	0.25E-6	0.15E-6
Ra-226	0.20E-6	0.06E-6
Pb-210	1.8E-6	0.5E-6
Po-210	-	-

Table 5-3. PREOPERATIONAL SURFACE SOIL SAMPLES (Ra-266 Analysis) Page 1 of 4

Date 5-16-79 thru 5-19-79

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
1*	0.18E-6	0.05E-6
2	0.31E-6	0.03E-6
3	0.18E-6	0.03E-6
4*	0.23E-6	0.07E-6
5	0.26E-6	0.03E-6
6	0.21E-6	0.02E-6
7	0.60E-6	0.04E-6
8	0.35E-6	0.03E-6
9	0.16E-6	0.02E-6
10*	0.18E-6	0.05E-6
11	0.23E-6	0.03E-6
12	0.10E-6	0.02E-6
13	0.15E-6	0.04E-6
14	0.23E-6	0.04E-6
15	0.18E-6	0.03E-6
16	0.15E-6	0.02E-6
17	0.16E-6	0.02E-6
18	0.23E-6	0.03E-6
19	0.25E-6	0.03E-6
20	0.69E-6	0.04E-6

*Retabulated from Table 5-2.

Table 5-3. PREOPERATIONAL SURFACE SOIL SAMPLES (Ra-266 Analysis) Page 2 of 4

Date 5-16-79 thru 5-19-79

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
21	0.40E-6	0.04E-6
22	0.43E-6	0.04E-6
23	0.30E-6	0.03E-6
24	0.18E-6	0.03E-6
25*	0.00	0.20E-6
26*	0.07E-6	0.02E-6
27	0.48E-6	0.04E-6
28	0.19E-6	0.02E-6
29	0.18E-6	0.02E-6
30*	0.33E-6	0.10E-6
31	0.10E-6	0.03E-6
32	1.23E-6	0.05E-6
33	0.16E-6	0.03E-6
34	0.17E-6	0.03E-6
35	0.57E-6	0.04E-6
36	0.99E-6	0.06E-6
37	0.36E-6	0.04E-6
38	1.37E-6	0.72E-6
39	0.51E-6	0.04E-6
40	0.40E-6	0.04E-6

*Retabulated from Table 5-2.

Table 5-3. PREOPERATIONAL SURFACE SOIL SAMPLES (Ra-266 Analysis) Page 3 of 4

Date 5-16-79 thru 5-19-79

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
41	0.22E-6	0.03E-6
42	0.20E-6	0.03E-6
43	0.16E-6	0.02E-6
44*	0.31E-6	0.09E-6
45	0.48E-6	0.04E-6
46	0.36E-6	0.04E-6
47	0.21E-6	0.03E-6
48	0.54E-6	0.04E-6
49	[illegible]	0.04E-6
50	0.38E-6	0.03E-6
51	0.26E-6	0.03E-6
52*	0.27E-6	0.08E-6
53	0.27E-6	0.04E-6
54	1.46E-6	0.39E-6
55	0.21E-6	0.02E-6
56	0.13E-6	0.02E-6

*Retabulated from Table 5-2.

Table 5-3. PREOPERATIONAL SURFACE SOIL SAMPLES (Ra-266 Analysis) Page 4 of 4

Date 8-6-79

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
AP-1*	0.62E-6	0.19E-6
AP-2*	0.22E-6	0.07E-6
AP-3*	0.19E-6	0.06E-6
AP-4*	0.19E-6	0.06E-6
C-1*	0.19E-6	0.06E-6
C-2*	0.20E-6	0.06E-6

*Retabulated from Table 5-2.

Table 5-4. POST EXCAVATION SURFACE SOIL SAMPLES (Isotopic Analysis)

Date 2-13-80

Location 3

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	-	-
Th-230	-	-
Ra-226	0.18E-6	0.05E-6
Pb-210	0.25E-6	0.12E-6
Po-210	-	-

Date 2-13-80

Location 9

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.74E-6	0.07E-6
Th-230	0.44E-6	0.22E-6
Ra-226	0.43E-6	0.13E-6
Pb-210	-	-
Po-210	-	-

Table 5-4. POST EXCAVATION SURFACE SOIL SAMPLES (Isotopic Analysis)

Date 2-13-80

Location 10

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.60E-6	0.09E-6
Th-230	0.45E-6	0.13E-6
Ra-226	0.41E-6	0.12E-6
Pb-210	-	-
Po-210	-	-

Date 2-13-80

Location 11

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.81E-6	0.07E-6
Th-230	0.74E-6	0.22E-6
Ra-226	0.46E-6	0.14E-6
Pb-210	-	-
Po-210	-	-

Table 5-4. POST EXCAVATION SURFACE SOIL SAMPLES (Isotopic Analysis)

Date 2-13-80

Location 16

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.81E-6	0.07E-6
Th-230	0.57E-6	0.20E-6
Ra-226	0.56E-6	0.17E-6
Pb-210	0.94E-6	0.38E-6
Po-210	-	-

Date 2-13-80

Location 23

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.51E-6	0.07E-6
Th-230	0.34E-6	0.13E-6
Ra-226	0.44E-6	0.13E-6
Pb-210	-	-
Po-210	-	-

Table 5-4. POST EXCAVATION SURFACE SOIL SAMPLES (Isotopic Analysis)

Date 2-13-80

Location 24

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.49E-6	0.14E-6
Th-230	0.57E-6	0.22E-6
Ra-226	0.52E-6	0.16E-6
Pb-210	-	-
Po-210	-	-

Date 2-13-80

Location 25

Type Surface

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.74E-6	0.07E-6
Th-230	0.45E-6	0.14E-6
Ra-226	0.59E-6	0.18E-6
Pb-210	-	-
Po-210	-	-

Table 5-5. POST EXCAVATION SURFACE SOIL SAMPLES (Ra-226 Analysis) Page 1 of 2

Date 2-13-80

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
1	0.39E-6	0.12E-6
2	0.30E-6	0.09E-6
3*	0.18E-6	0.05E-6
4	0.40E-6	0.12E-6
5	0.26E-6	0.08E-6
6	0.23E-6	0.07E-6
7	0.21E-6	0.06E-6
8	0.27E-6	0.08E-6
9*	0.43E-6	0.13E-6
10*	0.41E-6	0.12E-6
11*	0.46E-6	0.14E-6
12	0.15E-6	0.05E-6
13	0.21E-6	0.06E-6
14	0.40E-6	0.12E-6
15	0.52E-6	0.16E-6
16*	0.56E-6	0.17E-6
17	0.44E-6	0.13E-6
18	0.48E-6	0.14E-6
19	0.38E-6	0.11E-6

*Data retabulated from Table 5-4.

Table 5-5. POST EXCAVATION SURFACE SOIL SAMPLES (Ra-226 Analysis) Page 2 of 2

Date 2-13-80

Location No.	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
20	0.28E-6	0.08E-6
21	0.16E-6	0.05E-6
22	0.67E-6	0.20E-6
23*	0.44E-6	0.13E-6
24*	0.52E-6	0.16E-6
25*	0.59E-6	0.18E-6
26	0.52E-6	0.16E-6
27	0.44E-6	0.13E-6
28	0.33E-6	0.10E-6
29	0.36E-6	0.11E-6

*Data retabulated from Table 5-4.

Sample Analysis

See Appendix A.

5.2 SUBSURFACE SOIL

General Description

Nine subsurface soil samples were collected on the project site. The sample locations are points 5 through 13 shown in Figure 5-3. Also, one post excavation sample was taken at the mill site center. Results of the sample analyses are shown in Tables 5-6 through 5-8.

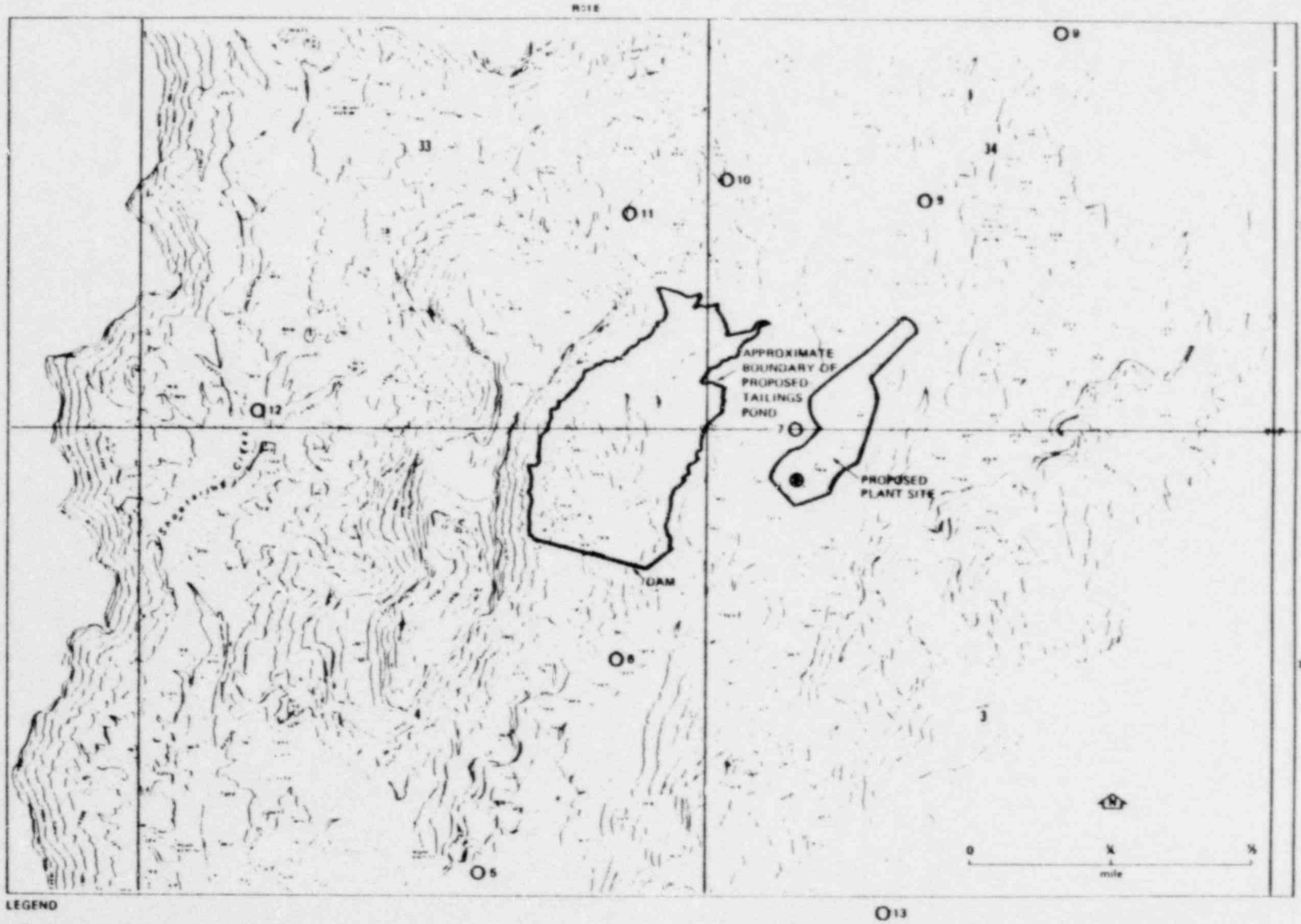
Sample Collection

Locations. The sampling points were chosen to coincide with the measuring points for radon flux and are distributed in four directions from the site center at distances ranging up to 1500 meters.

Procedure. Samples were collected to a depth of three feet and divided into one foot sections for analysis. Where possible, collection was by shoveling. In some cases, the use of a backhoe was necessary. The resulting 5 kilogram one-foot increment samples were then reduced in maximum particle size to 1/2 inch, blended, coned, halved, and placed in identified plastic bags. One sample split was delivered to the laboratory for analysis, and the other was stored for possible future reference.

Sample Analysis

See Appendix A.



LEGEND

O Preoperational Sample Points, 5–13

● Post Excavation Sample Point

Figure 5-3. PREOPERATIONAL AND POST EXCAVATION SAMPLING POINTS FOR SUBSURFACE SOILS

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES (Isotopic Analyses) Page 1 of 6

Date 6-26-79

Location 6

Type Subsurface

Portion analyzed 0 to 1' Depth

Radionuclide	Concentration (µCi/g)	Error Estimate (µCi/g)
U-nat	0.81E-6	0.14E-6
Th-230	1.1E-6	0.7E-6
Ra-226	1.1E-6	0.3E-6
Pb-210	0.54E-6	0.48E-6
Po-210	-	-

Date 6-26-79

Location 6

Type Subsurface

Portion analyzed 1' to 2' Depth

Radionuclide	Concentration (µCi/g)	Error Estimate (µCi/g)
U-nat	1.83E-6	0.27E-6
Th-230	1.2E-6	0.5E-6
Ra-226	0.61E-6	0.18E-6
Pb-210	0.82E-6	0.66E-6
Po-210	-	-

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES Page 2 of 6
(Isotopic Analyses)

Date 6-26-79

Location 6

Type Subsurface

Portion analyzed 2' to 3' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.22E-6	0.14E-6
Th-230	1.1E-6	0.5E-6
Ra-226	0.66E-6	0.20E-6
Pb-210	0.63E-6	0.40E-6
Po-210	-	-

Date 6-25-79

Location 7

Type Subsurface

Portion analyzed 0 to 1' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.34E-6	0.14E-6
Th-230	0.24E-6	0.20E-6
Ra-226	0.13E-6	0.04E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES Page 3 of 6
(Isotopic Analyses)

Date 6-25-79

Location 7

Type Subsurface

Portion analyzed 1' to 2' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.32E-6	0.06E-6
Th-230	1.4E-6	0.5E-6
Ra-226	0.21E-6	0.06E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 6-25-79

Location 7

Type Subsurface

Portion analyzed 2' to 3' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.35E-6	0.28E-6
Th-230	0.32E-6	0.13E-6
Ra-226	0.17E-6	0.05E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES (Isotopic Analyses) Page 4 of 6

Date 6-26-79

Location 8

Type Subsurface

Portion analyzed 0 to 1' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.41E-6	0.18E-6
Th-230	0.35E-6	0.17E-6
Ra-226	0.11E-6	0.03E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 6-26-79

Location 8

Type Subsurface

Portion analyzed 1' to 2' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.47E-6	0.32E-6
Th-230	0.33E-6	0.15E-6
Ra-226	0.11E-6	0.03E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES Page 5 of 6
(Isotopic Analysis)

Date 6-26-79

Location 8

Type Subsurface

Portion analyzed 2' to 3' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.60E-6	0.19E-6
Th-230	0.31E-6	0.14E-6
Ra-226	0.00	0.20E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 6-26-79

Location 11

Type Subsurface

Portion analyzed 0 to .' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.35E-6	0.10E-6
Th-230	0.46E-6	0.24E-6
Ra-226	0.23E-6	0.07E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-6. PREOPERATIONAL SUBSURFACE SOIL SAMPLES Page 6 of 6
(Isotopic Analysis)

Date 6-26-79

Location 11

Type Subsurface

Portion analyzed 1' to 2' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.57E-6	0.23E-6
Th-230	0.38E-6	0.23E-6
Ra-226	0.21E-6	0.06E-6
Pb-210	0.62E-6	0.45E-6
Po-210	-	-

Date 6-26-79

Location 11

Type Subsurface

Portion analyzed 2' to 3' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.95E-6	0.20E-6
Th-230	0.34E-6	0.15E-6
Ra-226	0.17E-6	0.05E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-7. PREOPERATIONAL SUBSURFACE SOIL SAMPLES (Ra-226 Analysis)

Date 6-26-79
Location 5
Type Subsurface

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	0.17E-6	0.03E-6
1'- 2'	0.22E-6	0.03E-6
2'- 3'	0.26E-6	0.03E-6

Date 6-26-79*
Location 6*
Type Subsurface*

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	1.1E-6	0.3E-6
1'- 2'	0.61E-6	0.18E-6
2'- 3'	0.66E-6	0.20E-6

Date 6-25-79*
Location 7*
Type Subsurface*

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	0.13E-6	0.04E-6
1'- 2'	0.21E-6	0.06E-6
2'- 3'	0.17E-6	0.05E-6

*Data retabulated from Table 5-6.

Table 5-7. PREOPERATIONAL SUBSURFACE SOIL SAMPLES (Ra-226 Analysis)

Date 6-26-79*
Location 8*
Type Subsurface*

Depth	Ra-226 Concentration (µCi/g)	Error Estimate (µCi/g)
0 - 1'	0.11E-6	0.03E-6
1'- 2'	0.11E-6	0.03E-6
2'- 3'	0.00E-6	0.20E-6

Date 6-26-79
Location 9
Type Subsurface

Depth	Ra-226 Concentration (µCi/g)	Error Estimate (µCi/g)
0 - 1'	0.36E-6	0.03E-6
1'- 2'	0.36E-6	0.04E-6
2'- 3'	0.30E-6	0.02E-6

Date 7-11-79
Location 10
Type Subsurface

Depth	Ra-226 Concentration (µCi/g)	Error Estimate (µCi/g)
0 - 1'	0.11E-6	0.03E-6
1'- 2'	0.06E-6	0.03E-6
2'- 3'	0.25E-6	0.03E-6

*Data retabulated from Table 5-6.

Table 5-7. PREOPERATIONAL SUBSURFACE SOIL SAMPLES (Ra-226 Analysis) Page 3 of 3

Date 6-26-79*
Location 11*
Type Subsurface*

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	0.23E-6	0.07E-6
1'- 2'	0.21E-6	0.06E-6
2'- 3'	0.17E-6	0.05E-6

Date 6-26-79
Location 12
Type Subsurface

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	0.51E-6	0.04E-6
1'- 2'	0.63E-6	0.05E-6
2'- 3'	0.45E-6	0.04E-6

Date 7-11-79
Location 13
Type Subsurface

Depth	Ra-226 Concentration (μCi/g)	Error Estimate (μCi/g)
0 - 1'	0.25E-6	0.03E-6
1'- 2'	0.26E-6	0.03E-6
2'- 3'	0.25E-6	0.03E-6

*Data retabulated from Table 5-6.

Table 5-8. POST EXCAVATION SUBSURFACE SOIL SAMPLES Page 1 of 2

Date 2-14-80

Location Site Center

Type Subsurface

Portion analyzed 0 to 1' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.58E-6	0.08E-6
Th-230	0.56E-6	0.17E-6
Ra-226	0.37E-6	0.11E-6
Pb-210	0.27E-6	0.12E-6
Po-210	-	-

Date 2-14-80

Location Site Center

Type Subsurface

Portion analyzed 1' to 2' Depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.68E-6	0.14E-6
Th-230	0.57E-6	0.21E-6
Ra-226	0.36E-6	0.11E-6
Pb-210	0.47E-6	0.13E-6
Po-210	-	-

Table 5-8. POST EXCAVATION SUBSURFACE SOIL SAMPLES Page 2 of 2

Date 2-14-80

Location Site Center

Typle Subsurface

Portion analyzed 2' to 3' depth

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.68E-6	0.14E-6
Th-230	0.79E-6	0.24E-6
Ra-226	0.43E-6	0.13E-6
Pb-210	0.39E-6	0.20E-6
Po-210	-	-

5.3 SEDIMENTS

General Description

Sediment samples were collected from nine project site locations, as shown in Figure 5-4, in June and September, 1979. Also, sediment samples were collected at each runoff sampling location and at the four seep locations (see Figure 3-1). In addition, a sediment sample was taken from Lake Powell in August, 1979. Results of the sediment sample analyses are shown in Table 5-9.

Sample Collection

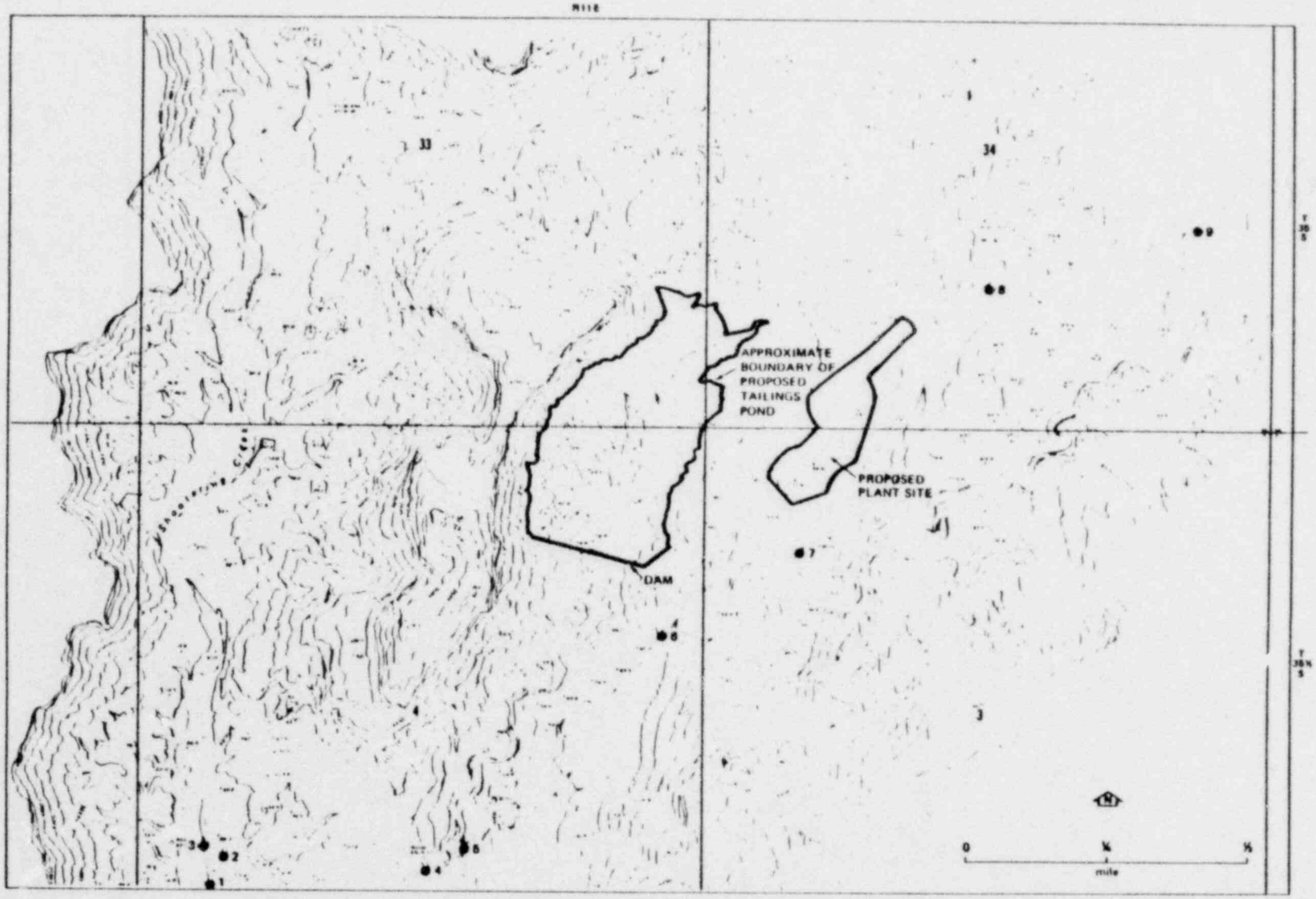
Locations. Sample locations were selected both upstream and downstream of the area of potential influence from milling activities.

Procedure. Samples were collected following recession of the high spring flow and again in late summer, following an extended period of low flow. Samples were collected at each location by compositing approximate 1.0 kilogram increments from five points. The material was taken to a depth of 10 centimeters using a 1.5-inch wide scoop. The resulting five kilogram samples were then reduced in maximum particle size to 1/2 inch, blended, coned, halved, and placed in identified plastic bags. One sample split was delivered to the laboratory for analysis, and the other was stored for possible future reference.

The Lake Powell samples were collected in a traverse across the mouth of Hansen Creek and composited for a representative sample. The resulting composite sample was then filtered, dried at 105°C, and placed in an identified plastic bag for delivery to the laboratory.

Sample Analysis

See Appendix A.



LEGEND

● Sediment Sampling Locations, 1-9

Figure 5-4. PREOPERATIONAL SAMPLING LOCATIONS FOR SEDIMENTS

Table 5-9. SEDIMENT SAMPLES

Date 8-15-79

Location 1

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.0E-6	-
Th-230	0.26E-6	0.08E
Ra-226	0.15E-6	0.04E-6
Pb-210	0.53E-6	0.22E-6
Po-210	0.29E-6	0.11E-6

Date 1-8-80

Location 1

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.81E-6	-
Th-230	0.38E-6	0.12E-6
Ra-226	0.49E-6	0.15E-6
Pb-210	0.53E-6	0.10E-6
Po-210	0.35E-6	0.11E-6

Table 5-9. SEDIMENT SAMPLES

Date 4-10-80

Location 1

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.30E-6	0.08E-6
Th-230	0.15E-6	0.11E-6
Ra-226	0.25E-6	0.08E-6
Pb-210	0.56E-6	0.32E-6
Po-210	0.21E-6	0.17E-6

Date 8-15-79

Location 2

Type Seep

Radionuclide	Concentration (μCi/g	Error Estimate (μCi/g)
U-nat	2.1E-6	-
Th-230	0.15E-6	0.07E-6
Ra-226	0.11E-6	0.03E-6
Pb-210	1.6E-6	0.3E-6
Po-210	0.66E-6	0.15E-6

Table 5-9. SEDIMENT SAMPLES Page 3 of 20

Date 11-15-79

Location 2

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.7E-6	-
Th-230	0.16E-6	0.07E-6
Ra-226	0.22E-6	0.07E-6
Pb-210	0.56E-6	0.23E-6
Po-210	0.26E-6	0.11E-6

Date 1-8-80

Location 2

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.1E-6	-
Th-230	0.81E-6	0.23E-6
Ra-226	0.56E-6	0.17E-6
Pb-210	0.86E-6	0.12E-6
Po-210	0.55E-6	0.12E-6

Table 5-9. SEDIMENT SAMPLES

Date 4-10-80

Location 2

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	0.10E-6
Th-230	0.42E-6	0.18E-6
Ra-226	0.30E-6	0.09E-6
Pb-210	0.35E-6	0.31E-6
Po-210	0.32E-6	0.19E-6

Date 7-7-80

Location 2

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (Ci/g)
U-nat	0.32E-6	0.04E-6
Th-230	0.19E-6	0.11E-6
Ra-226	0.60E-6	0.18E-6
Pb-210	0.42E-6	0.26E-6
Po-210	0.48E-6	0.05E-6

Table 5-9. SEDIMENT SAMPLES

Date 7-7-80*

Location 2*

Type Seep*

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	2E-6	-
Th-230	0.0	2.0E-6
Ra-226	0.4E-6	0.4E-6
Pb-210	0.4E-6	2.9E-6
Po-210	0.6E-6	0.4E-6

Date 8-15-79

Location 3

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	2.7E-6	-
Th-230	0.27E-6	0.10E-6
Ra-226	0.32E-6	0.10E-6
Pb-210	1.4E-6	0.2E-6
Po-210	0.80E-6	0.16E-6

*Duplicate research by Hazen Research, Golden, CO.

Table 5-9. SEDIMENT SAMPLES

Date 11-15-79

Location 3

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat*	4.3E-6	-
Th-230	0.49E-6	0.12E-6
Ra-226	0.48E-6	0.14E-6
Pb-210	0.44E-6	0.09E-6
Po-210	0.48E-6	0.13E-6

Date 1-8-80

Location 3

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.88E-6	-
Th-230	0.54E-6	0.15E-6
Ra-226	0.51E-6	0.15E-6
Pb-210	0.44E-6	0.10E-6
Po-210	0.44E-6	0.11E-6

Table 5-9. SEDIMENT SAMPLES

Date 4-10-80

Location 3

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.46E-6	0.16E-6
Th-230	0.48E-6	0.30E-6
Ra-226	0.38E-6	0.11E-6
Pb-210	0.45E-6	0.30E-6
Po-210	0.43E-6	0.20E-6

Date 7-7-80

Location 3

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.33E-9	0.05E-9
Th-230	0.14E-9	0.10E-9
Ra-226	0.81E-9	0.24E-9
Pb-210	0.41E-9	0.31E-9
Po-210	0.32E-9	0.09E-9

Table 5-9. SEDIMENT SAMPLES

Date 7-7-80*

Location 3*

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	2E-6	-
Th-230	0.5E-6	2.7E-6
Ra-226	0.6E-6	0.6E-6
Pb-210	2.3E-6	2.6E-6
Po-210	0.4E-6	0.4E-6

Date 8-15-79

Location 4

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.88E-6	-
Th-230	0.16E-6	0.08E-6
Ra-226	0.22E-6	0.07E-6
Pb-210	0.86E-6	0.14E-6
Po-210	0.63E-6	0.15E-6

*Duplicate analysis by Hazen Research of Golden, CO.

Table 5-9. SEDIMENT SAMPLES

Date 11-15-79

Location 4

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.0E-6	-
Th-230	0.09E-6	0.05E-6
Ra-226	0.00	0.05E-6
Pb-210	0.49E-6	0.11E-6
Po-210	0.56E-6	0.14E-6

Date 1-8-80

Location 4

Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	-
Th-230	0.43E-6	0.15E-6
Ra-226	0.36E-6	0.11E-6
Pb-210	0.62E-6	0.11E-6
Po-210	0.62E-6	0.13E-6

Table 5-9. SEDIMENT SAMPLES

Date 4-10-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.56E-6	0.13E-6
Th-230	0.49E-6	0.21E-6
Ra-226	0.26E-6	0.08E-6
Pb-210	0.52E-6	0.31E-6
Po-210	0.46E-6	0.21E-6

Date 7-7-80
Location 4
Type Seep

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.19E-9	0.03E-9
Th-230	0.18E-9	0.12E-9
Ra-226	0.35E-9	0.10E-9
Pb-210	0.33E-9	0.24E-9
Po-210	0.52E-9	0.11E-9

Table 5-9. SEDIMENT SAMPLES

Date 7-7-80*

Location 4*

Type Seep*

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1E-6	-
Th-230	0.5E-6	2.7E-6
Ra-226	0.6E-6	0.5E-6
Pb-210	2.8E-6	2.1E-6
Po-210	0.9E-6	0.5E-6

Date 8-14-79

Location Lake Powell (Hansen Creek arm)

Type Impoundment

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	2.2E-6	-
Th-230	1.2E-6	0.3E-6
Ra-226	2.1E-6	0.4E-6
Pb-210	1.7E-6	0.1E-6
Po-210	-	-

*Duplicate analysis by Hazen Research of Golden, CO.

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 1

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.74E-6	0.14E-6
Th-230	0.48E-6	0.20E-6
Ra-226	0.52E-6	0.16E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Date 9-12-79

Location 1

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.1E-6	0.2E-6
Th-230	0.63E-6	0.25E-6
Ra-226	0.50E-6	0.15E-6
Pb-210	1.1E-6	0.6E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79
Location 2
Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.95E-6	0.14E-6
Th-230	0.48E-6	0.19E-6
Ra-226	0.25E-6	0.08E-6
Pb-210	0.57E-6	0.44E-6
Po-210	-	-

Date 9-12-79
Location 2
Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.56E-6	0.11E-6
Th-230	0.34E-6	0.20E-6
Ra-226	0.28E-6	0.08E-6
Pb-210	0.48E-6	0.41E-6
Po-210	-	-

Date 6-14-79

Location 3

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	1.02E-6	0.20E-6
Th-230	0.78E-6	0.22E-6
Ra-226	0.44E-6	0.13E-6
Pb-210	0.49E-6	0.35E-6
Po-210	-	-

Date 9-12-79

Location 3

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.68E-6	0.07E-6
Th-230	0.58E-6	0.20E-6
Ra-226	0.43E-6	0.13E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 4

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.45E-6	0.14E-6
Th-230	0.54E-6	0.31E-6
Ra-226	0.23E-6	0.07E-6
Pb-210	0.41E-6	0.36E-6
Po-210	-	-

Date 9-12-79

Location 4

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.95E-6	0.14E-6
Th-230	0.74E-6	0.27E-6
Ra-226	0.27E-6	0.08E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 5

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.45E-6	0.10E-6
Th-230	0.38E-6	0.14E-6
Ra-226	0.21E-6	0.06E-6
Pb-210	0.79E-6	0.44E-6
Po-210	-	-

Date 9-12-79

Location 5

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.48E-6	0.07E-6
Th-230	0.49E-6	0.23E-6
Ra-226	0.20E-6	0.06E-6
Pb-210	0.61E-6	0.45E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 6

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	0.08E-6
Th-230	0.53E-6	0.27E-6
Ra-226	0.24E-6	0.07E-6
Pb-210	0.49E-6	0.48E-6
Po-210	-	-

Date 9-12-79

Location 6

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.45E-6	0.09E-6
Th-230	0.45E-6	0.20E-6
Ra-226	0.12E-6	0.04E-6
Pb-210	0.57E-6	0.44E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 5-14-79

Location 7

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	0.12E-6
Th-230	0.70E-6	0.26E-6
Ra-226	0.23E-6	0.07E-6
Pb-210	0.77E-6	0.43E-6
Po-210	-	-

Date 9-12-79

Location 7

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	0.12E-6
Th-230	0.20E-6	0.14E-6
Ra-226	0.15E-6	0.04E-6
Pb-210	0.00	0.20E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 8

Type Wash

Radionuclide	Concentration ($\mu Ci/g$)	Error Estimate ($\mu Ci/g$)
U-nat	0.62E-6	0.16E-6
Th-230	0.70E-6	0.25E-6
Ra-226	0.39E-6	0.12E-6
Pb-210	0.68E-6	0.54E-6
Po-210	-	-

Date 9-12-79

Location 8

Type Wash

Radionuclide	Concentration ($\mu Ci/g$)	Error Estimate ($\mu Ci/g$)
U-nat	0.62E-6	0.11E-6
Th-230	0.37E-6	0.19E-6
Ra-226	0.22E-6	0.07E-6
Pb-210	1.1E-6	0.5E-6
Po-210	-	-

Table 5-9. SEDIMENT SAMPLES

Date 6-14-79

Location 9

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.47E-6	0.11E-6
Th-230	0.53E-6	0.24E-6
Ra-226	0.26E-6	0.08E-6
Pb-210	1.0E-6	0.5E-6
Po-210	-	-

Date 9-12-79

Location 9

Type Wash

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)
U-nat	0.49E-6	0.07E-6
Th-230	0.37E-6	0.20E-6
Ra-226	0.25E-6	0.08E-6
Pb-210	1.1E-6	0.6E-6
Po-210	-	-

6.0 DIRECT RADIATION

6.1 GAMMA DOSE RATE MEASUREMENTS

General Description

Pre-excavation gamma dose rate measurements were made by Eberline Instrument Corporation at approximately 90 points on a radial grid centered on the project site as shown in Figure 6-1. On each radial arm, the measurement points were spaced at approximately 150 meter intervals, to a distance of about 1500 meters, except where the terrain prevented access. In addition, measurements were made at the airborne particulate monitoring sites. The measurement results for the pre-excavation survey are shown in Tables 6-1 and 6-2. A post-excavation survey was completed, covering 29 disturbed surface points on the project site as shown in Figure 6-2. The dates and results of the post-excavational survey are shown in Table 6-3.

Data Collection

Locations. Measurement points in the project area were selected to conform to the recommendation of NRC R.G. 4.14. Direct radiation was also measured at the six air particulate monitoring locations.

Equipment. The equipment used for the pre-excavation survey included Eberline Instrument Corporation's (EIC) sodium iodide scintillation probe (SPA-3) connected by a CA-5-36 cable to a scaler. Both PS-2 and PRS-2 scalers were used. The SPA-3/scaler combination was cross referenced to a Reuter Stokes EIC's pressurized ion chamber

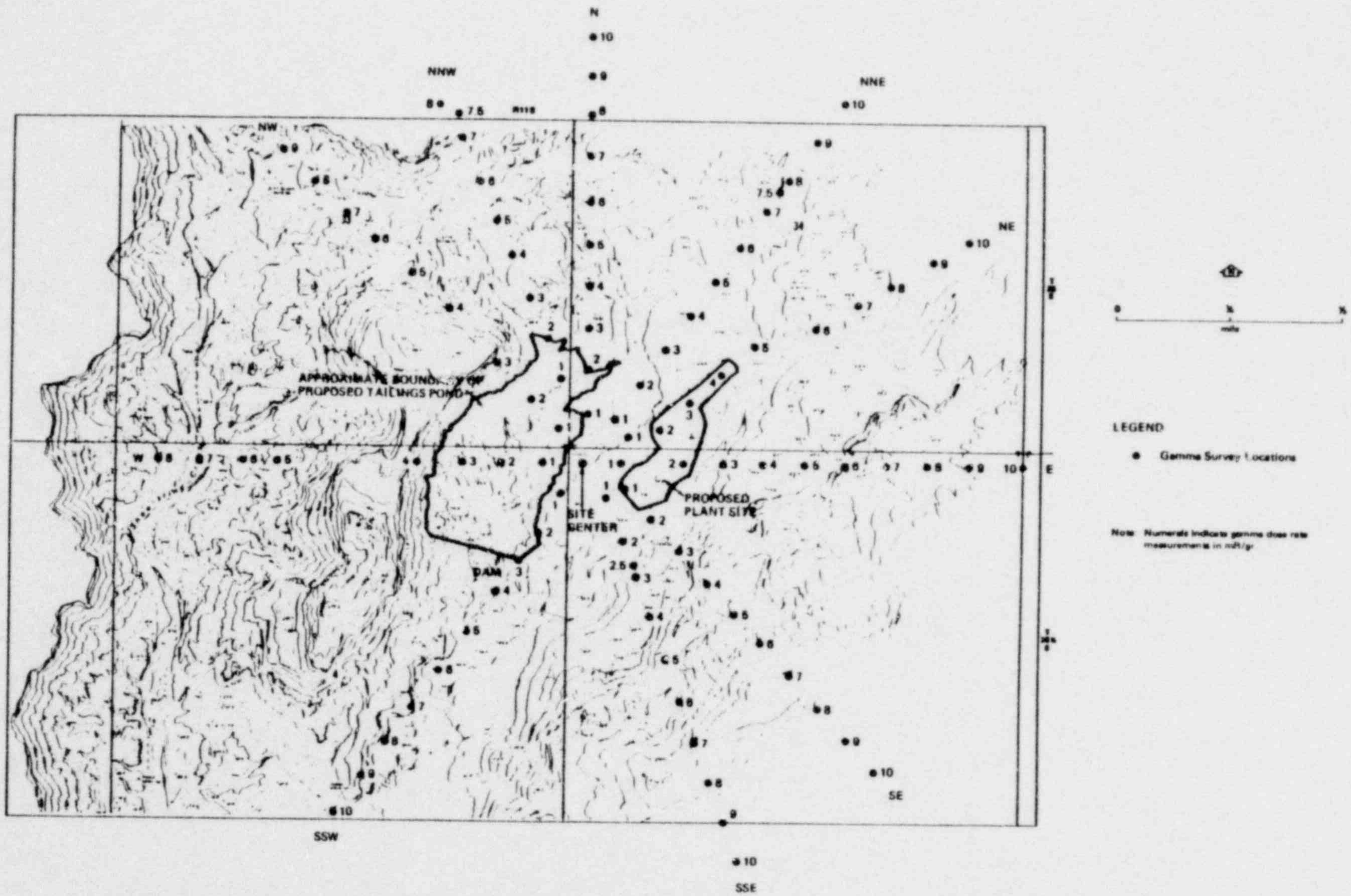


Figure 6-1. PRE EXCAVATION MONITORING LOCATIONS FOR GAMMA SURVEY

Table 6-1. PRE-EXCAVATION GAMMA SURVEY PORTABLE SCINTILLATOR MEASUREMENTS

Date 6-21-79

Location*	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
Site Center	11.2	0.7
Site Center	19.6	0.4
N1	10.9	0.7
N2	10.9	0.7
N3	11.1	0.7
N4	12.8	0.8
N5	12.0	0.8
N6	12.6	0.8
N7	14.1	0.9
N8	19.4	1.2
N9	17.6	1.1
N10	12.4	0.8
NNE1	12.5	0.8
NNE2	11.5	0.7
NNE3	10.1	0.6
NNE4	12.0	0.8
NNE5	14.0	C.9
NNE6	15.2	1.0
NNE6	15.3	0.4
NNE7	16.0	1.0
NNE7	15.9	0.4
NNE7.5	16.8	0.4
NNE8	15.8	0.4
NNE9	14.5	0.3
NNE10	15.3	0.4

*See Figure 6-1.

Table 6-1. PRE-EXCAVATION GAMMA SURVEY PORTABLE SCINTILLATOR MEASUREMENTS Page 2 of 3

Location*	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
NE1	11.0	0.3
NE2	12.7	0.3
NE3	12.1	0.3
NE4	17.2	0.4
NE5	15.5	0.4
NE6	15.3	0.4
NE7	15.7	0.4
NE8	17.0	0.4
NE9	16.6	0.4
NE10	15.7	0.4
E1	12.6	0.8
E2	16.4	1.0
E3	16.3	0.4
E4	14.8	0.4
E5	14.2	0.3
E6 thru E10**	-	-
SE1	12.7	0.8
SE1	11.8	0.3
SE2	14.5	0.3
SE3	14.4	0.3
SE4 thru SE10**	-	-
SSE1	12.3	0.8
SSE2	12.8	0.3
SSE2.5	14.1	0.3
SSE3	16.4	0.4
SSE4	16.0	0.4
SSE5 thru SSE10**	-	-

*See Figure 6-1.
**No reading taken due to rough terrain.

Table 6-1. PRE-EXCAVATION GAMMA SURVEY PORTABLE SCINTILLATOR MEASUREMENTS

Location*	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
SSW1	12.8	0.8
SSW2	16.5	1.0
SSW3	16.1	1.0
SSW4	16.0	1.0
SSW5	15.0	0.9
SSW6	16.4	1.0
SSW7	15.6	1.0
SSW8	17.1	1.1
SSW9	15.2	1.0
SSW10	12.4	0.8
W1	13.2	0.8
W2	12.9	0.8
W3	12.5	0.8
W4	15.5	1.0
W5 thru W8**	-	-
NW1	10.3	0.7
NW2	10.8	0.7
NW3	12.7	0.8
NW4	15.1	1.0
NW5	15.2	1.0
NW6	17.1	1.1
NW7	16.9	1.1
NW8	13.8	0.9
NW9	15.4	1.0
NNW1	10.1	0.6
NNW2	10.3	0.7
NNW3	10.4	0.7
NNW4	11.1	0.7
NNW5	12.2	0.8
NNW6	13.3	0.8
NNW7	16.7	1.1
NNW7.5	93.6	5.9
NNW8	15.9	1.0

*See Figure 6-1.
**No reading taken due to rough terrain.

Table 6-2. PRE-EXCAVATION GAMMA SURVEY

Pressurized Ionization Chamber Measurements

Location*	Exposure Rate (mR/qr)
Site Center	18.8
N1	20.4
NNE1	23.0
NNE2	20.6
NE1	19.7
NE2	19.7
E1	21.2
E2	24.7
SE1	20.6
SE2	23.9
SSE1	21.2
SSE2	20.1
SSW1	17.5
SSWZ	23.2
W1	20.1
W2	18.8
NW'	23.0
NW2	19.3

*See Figure 6-1.

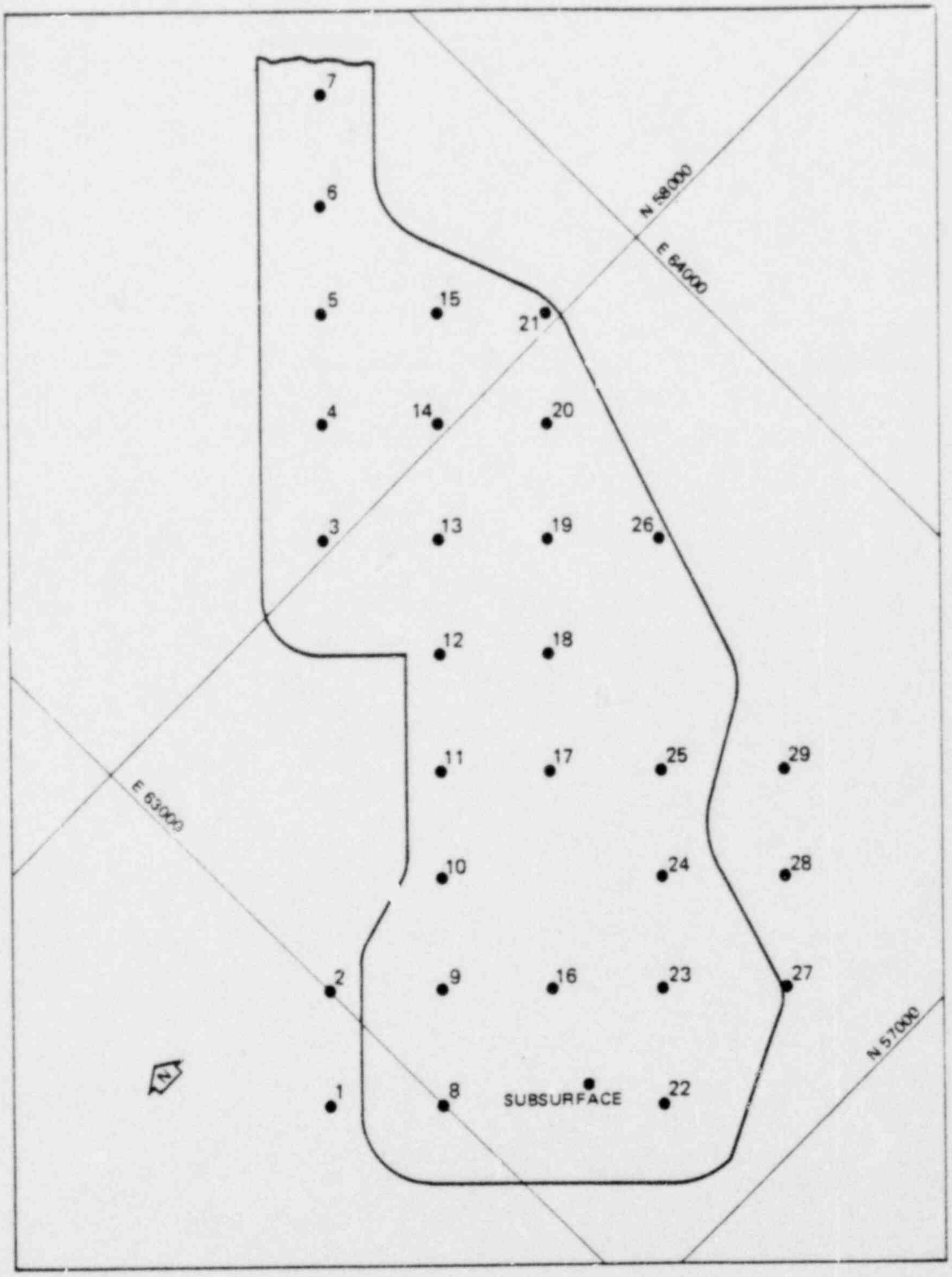


Figure 6-2. POST EXCAVATION MEASUREMENT LOCATIONS FOR GAMMA SURVEY

Table 6-3. POST-EXCAVATION GAMMA DOSE RATE MEASUREMENTS

Date 2-13-80

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
1	12.4	0.1
2	14.3	0.2
3	10.5	0.1
4	12.7	0.1
5	12.3	0.1
6	11.7	0.2
7	10.6	0.1
8	14.0	0.3
9	16.2	0.4
10	14.4	0.4
11	15.6	0.3
12	13.6	0.3
13	12.4	0.1
14	13.9	0.2
15	13.3	0.1
16	14.7	0.2

Table 6-3. POST-EXCAVATION GAMMA DOSE RATE MEASUREMENTS

Date 2-13-80

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
17	15.8	0.1
18	14.6	0.1
19	15.1	0.1
20	15.2	0.3
21	12.4	0.1
22	10.6	0.2
23	13.8	0.0
24	15.7	0.2
25	14.7	0.2
26	15.9	0.2
27	14.4	0.1
28	15.3	0.1
29	15.8	0.1

(traceable to NBS standard) based on comparative exposure to a known Ra-226 source and background gamma levels at the mine camp. The pressurized ion chamber was also used to obtain gamma measurements at several localities.

A SPA-3 probe with a PRS-1 scaler was used for the post-excavation survey. A calibration factor was again calculated from cross calibration with a pressurized ion chamber. This calibration was determined from background gamma levels alone and then with an added radium-226 source.

Procedure. At each field sampling location during both surveys, the SPA-3/scaler combination was mounted on a standard photographic tripod at a height of one meter above ground level. The measurement duration for counting with the PS-2 scaler was that needed to accumulate 1000 counts. The calibration factor was set into the internal circuitry and a readout in μR/hour was directly produced. A preset time of one minute was used for the PRS-2 scaler and direct readout was in counts per minute (cpm). These readings were later divided by the calibration factor.

The pressurized ion chamber was used at several locations during the pre-excavation survey to measure the gamma tables. Exposure times of 4-6 minutes were used.

Three timed counts of one minute duration each were obtained at each sampling locality with the PRS-1/SPA-3 system during the post excavation survey. A direct readout in μR/hour was obtained since the calibration factor was set into the internal circuitry of the PRS-1 scaler. An average exposure rate at each location was calculated from the three readings.

Data Reduction and Analysis

Exposure Rate Calculations. The counting rates in cpm for the SPA-3/scaler combinations were divided by the calibration factor in cpm per μR/hour to yield the μR/hour counting rates. This was done internally by the PS-2 and PRS-1 scalers. Calibration factors for the SPA-3/PS-2, SPA/PRS-2, and SPA/PRS-1 units of 1,040, 1,000, and 952 cpm per μR/hour, respectively were used. These were obtained by cross calibration with the pressurized ion chamber. Integrated μR readings from the pressurized ion chambers were divided by the exposure times to yield μR/hour exposure rates.

Error Estimates. Counting error estimates for the pre-excavation survey were calculated by the following relation for the SPA-3/scaler combinations:

$$E = \frac{2(2184)(1.0E-3)\sqrt{C}}{(T)(K)}$$

where: E = $\pm$ two sigma counting error in mR/quarter (95 percent confidence level)

C = number of counts,

T = counting time in minutes,

K = calibration factor in cpm per μR/hr,

2184 = hours/quarter.

1.0E-3 = mR/μR

Counting error estimates for the post excavational survey were obtained by the following relation:

$$E = \frac{(2)(2184)(1.0E-3)}{(K)} \qquad \frac{\Sigma(c - \bar{c})^2}{2}$$

where: E = $\pm$ two sigma counting error in mR/quarter (95 percent confidence level),

c = number of counts in each of 3 one minute counting intervals at a location,

$\bar{c}$ = calculated mean number of counts for the 3 one minute counting intervals,

K = calibration factor in cpm per μR/hr,

2184 = hours/quarter

1.0E-3 = mR/μR

Systematic errors exist in the calibration factor for the SPA-3 probes due to the differing gamma energy response characteristics of the pressurized ion chamber and portable survey instruments. These uncertainties in the calibration factors are estimated to be on the order of 50 percent. The estimated field systematic error for the pressurized ion chamber is $\pm$8 percent with 5 percent associated with the instrument and 3 percent error to correct for radium-226 spectral response relative to cobalt-60.

Quality Assurance. The SPA-3/scaler unit calibrations, by cross reference to a pressurized ion chamber traceable to an NBS standard, must be certified within the 90 day period immediately preceding the field measurements.

6.2 THERMOLUMINESCENT DOSIMETER SURVEY

General Description

In addition to the scintillation probe and pressurized ion chamber measurements, thermoluminescent dosimeters (TLD's) were installed in pairs at nine locations on the project site (see Figure 6-3) and at the Ticaboo town site and Bullfrog Basin Marina. One of each TLD pair was replaced at three month intervals. The TLD results are shown in Table 6-4. The TLD pairs were employed for back up and comparison with the direct gamma dose rate measurements.

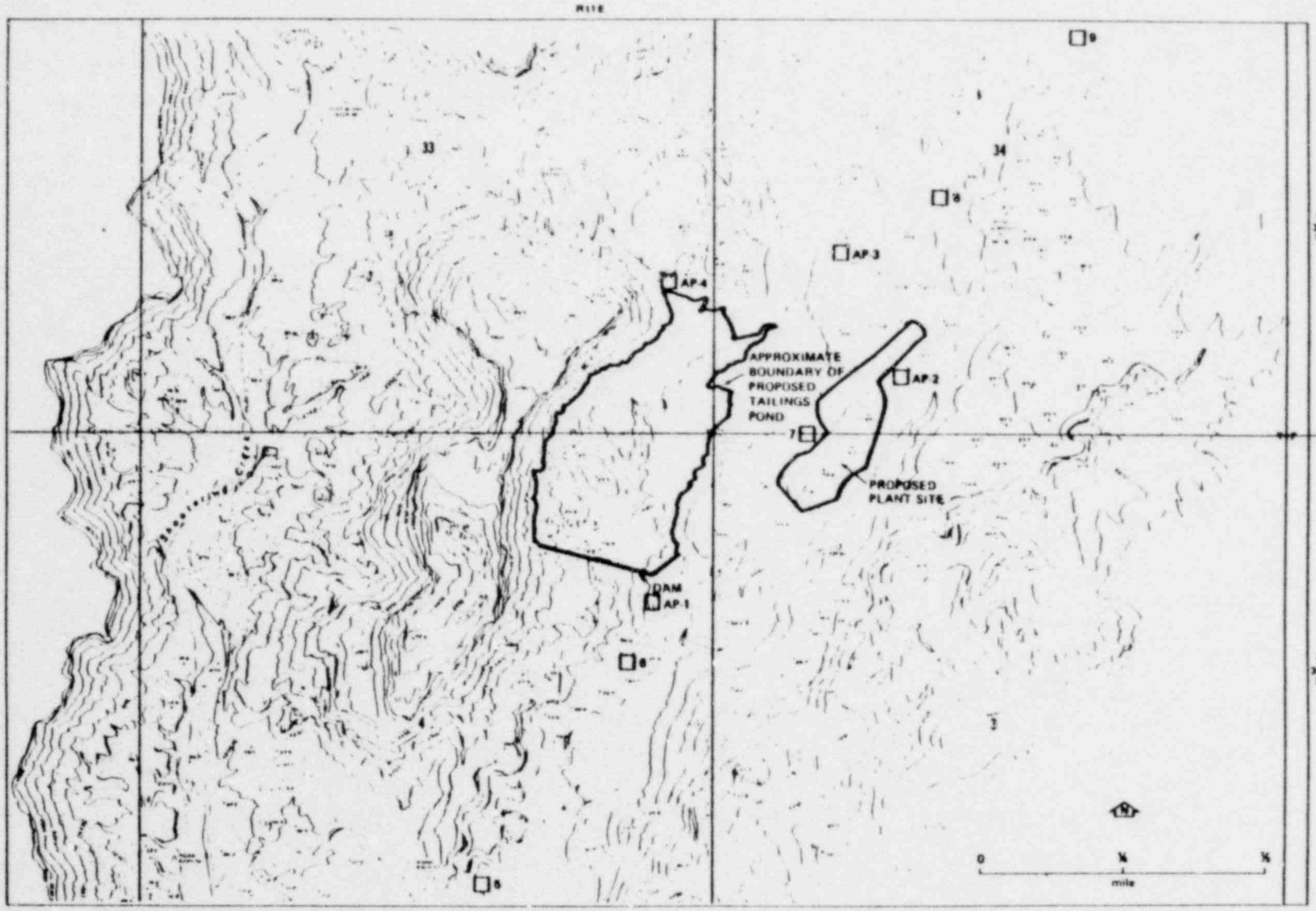


Figure 6-3. PREOPERATIONAL TLD SURVEY LOCATIONS

Table 6-4. THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Dates 7-3-79 to 10-3-79

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
1	25.4	5.0
2	23.3	4.0
3	21.3	3.7
4	21.3	9.4
5	21.5	2.3
6	26.0	2.9
7	21.2	4.9
8	21.2	3.9
9	23.1	6.5
C-1	20.7	5.2
C-2	21.3	5.9

Table 6-4. THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Dates 7-3-79 to 1-3-80

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
1	45.0 (20.7)*	108 (2.7)*
2	19.9	7.2
3	19.0	3.7
4	18.9	5.1
5	19.2	3.2
[illegible]	20.0	5.2
7	19.6	5.3
8	20.3	2.3
9	21.2	4.0
C-1	19.1	8.8
C-2	17.6	3.3

*Recalculated value, see text.

Table 6-4. THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Dates 1-3/4-79 to 4-1-80

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)
1	-	
2	25.4	3.9
3	23.9	4.8
4	26.7	8.6
5	25.4	3.6
6	25.1	2.9
7	25.2	8.0
8	25.7	7.3
9	26.5	4.6
C-1	22.4	4.1
C-2	24.7	2.5

TLD Analysis

The TLDs returned from the field were read by Eberline on an Eberline TLR-6 reader. The five chips in each dosimeter were preheated to 150°C for ten seconds and then read at 250°C for ten seconds. A background correction was made by subtracting an additional ten second reading on each chip from the first reading value. The average of the five chip readings in net mrem was then converted to mR/quarter by normalization of the exposure time. Random error terms were calculated from the following relation

$$E = \left(\sqrt{\frac{\Sigma(R - \bar{R})^2}{N-1}}\right) \quad \frac{2\ S}{\bar{R}}$$

where E = ± two sigma uncertainty, in mR/quarter, (95 percent confidence level),

R = net reading for each chip in a dosimeter in mrem,

$\bar{R}$ = average net reading for the chips in a dosimeter in mrem,

N = number of chips per dosimeter = 5 (unless some are damaged),

S = estimated dosimeter mR/quarter.

All dosimeters were annealed prior to placement in the field at 400°C for one hour. The TLR-6 reader was calibrated twice daily by reading TLD chips exposed to known quantities of gamma radiation. The dosimeters can detect total gamma exposures as low as 10 mR.

7.0
RADON FLUX

7.1 GENERAL DESCRIPTION

Radon-222 (Rn-222) fluxes at each of nine locations were estimated from measurements of soil gas Rn-222 concentrations at several depths and assumed values for the porosity and effective diffusion coefficient of the soil. The measurement localities are shown in Figure 7-1.

Soil gas Rn-222 concentrations were measured at each location by Track Etch cups provided by Terradex Corporation. These cups are described in Section 2.2 of this report.

It is recommended by R.G. 4.14 that Rn-222 flux measurements be made in three separate months during normal dry weather conditions in the spring through the fall. Table 7-1 shows the mean monthly precipitation in the site vicinity for 1980. The driest months are April-July. The soil gas Rn-222 measurements and estimated fluxes for these months are therefore reported in Table 7-2.

7.2 DATA COLLECTION

<u>Locations</u>

The nine radon flux locations coincide with the subsurface soil sampling locations. They include the site center and locations approximately 750 and 1500 meters from the center in four directions.

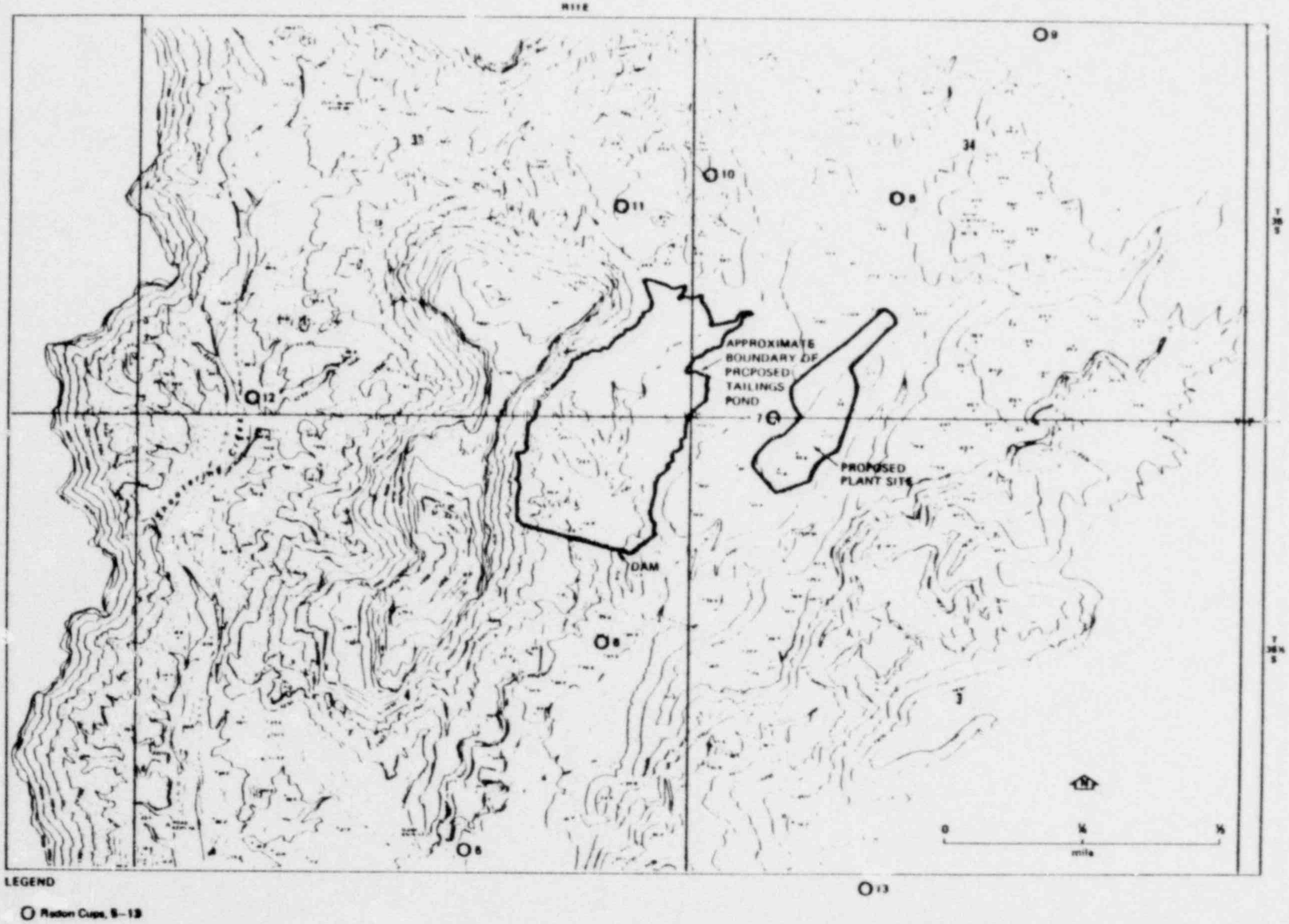


Figure 7-1. PREOPERATIONAL MONITORING LOCATIONS FOR RADON FLUX

Selection of the locations was governed in part by terrain and accessibility considerations.

Equipment

The Track Etch cups are described in Section 2.2 of this report.

Procedure

The levels of the cups at each location were designated as -0-, -3, and -6 feet for data recording purposes. The deepest cups at locations 6, 12, and 13, however, were at -4.0, -5.0, and -4.5 feet respectively. This was due to the presence of bedrock at depths shallower than 6 feet at these sites.

One of each pair of zero level cups was replaced monthly, and the other was replaced quarterly. The deeper cups were replaced monthly. The holes for the -3 and -6 cups were cased with PVC pipes, and the cups were mounted in the ends of smaller diameter pipes which were lowered into the casings. The tops of the pipes and casings, extending about a foot above the surface, were sealed with plastic bags. Care was taken to avoid blocking the membrane covered cup openings.

7.3 DATA ANALYSIS

Exposed Track Etch cups were returned to Terradex Corporation for analysis. The Terradex procedures, calculations, error estimates, lower limits of detection, calibration, and quality assurance have been described in Section 2.2 of this report.

Fluxes were estimated based on the following diffusion model:

$$J = 10\epsilon D\ (dC/dy)$$

where:

J = flux in pCi/m^2-sec

$10 = (10^{-3}\ l/cm^3)(10^4\ cm^2/m^2)$

ϵ = soil porosity

D = effective diffusion coefficient of soil (cm^2/sec)

(dC/dy) = vertical Rn-222 concentration gradient (pCi/l per cm).

The soil porosity was assumed to be 0.4. This value is typical of coarse sediments such as dune sand or gravel. An effective diffusion coefficient (diffusion coefficient divided by the porosity) of $3.6 \times 10^{-2}\ cm^2$/sec was assumed. This effective diffusion coefficient was determined for soil of similar physical characteristics by Kraner et al. (1964).

The Rn-222 concentration gradient was determined from the radon concentration versus depth data at each location via linear regression. The gradient was estimated to be the slope of the best fit line when the concentrations were plotted against depth. 'Zero' level cups were assumed to measure the Rn-222 concentrations at a depth of 0.5 feet for the gradient estimation.

The error terms for the fluxes in Table 7-2 are the random uncertainties at the 95 percent confidence level for the gradient estimates determined via regression. These error terms are uncertainties in the slopes of the best fit regression lines and were calculated by the equation

Table 7-2. RADON-222 FLUX ESTIMATES FROM SUBSURFACE RADON CUPS EXPOSED DURING THE DRIEST MONTHS OF 1980[a]

Location	Month	Rn-222 Concentration at Depth (pCi/l) 15.2 cm	91.4 cm	137 cm/152 cm	183 cm	Rn-222 Gradient (pCi/l per cm)	Flux Estimate (pCi/m^2-sec)	Error Estimate[d] (pCi/m^2-sec)
5[b]	May	17.2	171	-	352	1.99	0.3	0.0
	June	7.5	75.8	-	133	0.75	0.1	0.1
6[b]	June	3.4	110	131[e]	-	1.23	0.2	0.3
7[b]	April	14.8	49.2	-	70.9	0.33	0.1	0.1
	July	4.9	49.0	-	102	0.58	0.1	0.0
8[b]	April	17.3	70.3	-	219	1.22	0.2	0.5
	May	5.4	126	-	229	1.32	0.2	0.2
	July	4.2	50.1	-	91.6	0.52	0.1	0.1
9	May	24.3	382	-	846	4.90	0.7	0.2
	June	5.8	104	-	212	1.23	0.2	0.1
	July	9.4	143	-	337	1.96	0.3	0.2
10[c]	April	9.3	63.8	-	-	0.72	0.1	-
	May	17.2	176	-	-	2.08	0.3	-
	June	2.3	70.4	-	-	0.89	0.1	-
	July	2.7	75.8	-	-	0.96	0.1	-
11[b]	April	19.1	82.5	-	343	1.96	0.3	1.1
	July	7.3	86.1	-	114	0.62	0.1	0.4
[illegible]	April	45.3	132	- /172	-	0.94	0.1	0.2
	May	21.9	165	- /333	-	2.26	0.3	0.5
	June	4.0	66.1	- /135	-	0.95	0.1	0.2
	July	7.9	94.9	- /151	-	1.06	0.2	0.1
13	April	9.0	87.7	109/ -	-	0.84	0.1	0.3
	June	2.3	50.5	82.7/ -	-	0.66	0.1	0.0
	July	7.0	49.6	90.9/ -	-	0.68	0.1	0.2

[a]Estimated based upon

$J = 10\, D\epsilon (dC/dy)$

where

J = flux in pCi/m^2-sec

$10 = (10^{-3}\, l/cm^3)(10^4\, cm^2/m^2)$

ϵ = porosity of the soil (assumed to be 0.4)

D = effective diffusion coefficient of the soil (assumed to be $3.6 \times 10^{-2}\, cm^2/sec$)

dC/dy = radon-222 concentration gradient (calculated by linear regression from the radon-222 concentration determined via the radon cups

[b]Radon-222 concentrations and flux estimates are omitted for monthly data sets for which the correlation coefficient squared (R^2) for the best fit regression line is less than 0.9.

[c]Gradient determined from only two data points.

[d]Random errors at the 9? percent confidence level due to uncertainties in the slopes of the best fit regression lines to the Rn-222 concentrations versus depth data.

[e]122 cm depth.

$$E = J \left[\frac{(12.71)(\hat{\sigma} m)}{m} \right]$$

where

E = $\pm$ random uncertainty, at the 95 percent confidence level in pCi/m^2-sec

J = estimated flux in pCi/m^2-sec.,

12-71 = two-tailed t-statistic for the 95 percent confidence level and three concentration measurements,

$\hat{\sigma} m$ = standard deviation of the slope of the best fit regression line in pCi/l per cm,

m = slope of the best fit regression line in pCi/l per cm.

7.4 REFERENCES

Kraner, H.B., G.L. Schroeder, and R.D. Evans. 1964. Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations in The Natural Radiation Environment. Adams, J.A.S. and W.M. Lowder (eds.). pp 191-215.

APPENDIX A
EBERLINE INSTRUMENT CORPORATION
SAMPLE ANALYSIS INFORMATION*

A.1 INTRODUCTION

This appendix contains information provided by Eberline Instrument Corporation (EIC) regarding the laboratory analyses for the Shootering Canyon preoperational radiological environmental monitoring program. The analyses included:

- air particulate sampler filters,
- water, from various sources,
- vegetation and fish,
- soils and sediments, and
- thermoluminescent dosimeters.

The balance of the appendix is arranged in the following sections:

A.2 Description of Analytical Procedures,
A.3 Calculation Methods,
A.4 Lower Limit of Detection (LLD),
A.5 Description of Calibration Methods,
A.6 Description of Quality Control.

A.2 DESCRIPTION OF ANALYTICAL PROCEDURES

Internal tracer techniques and alpha spectrometry are used for specific isotopic concentrations of uranium and thorium. Ra-226 is precipitated with $BaSO_4$. Barium-radium-sulfate is dissolved in EDTA and transferred to an emanation tube and radon allowed to come to equilibrium. The radon-222 gas is collected by a de-emanation technique. Two aliquots will be analyzed for thorium, the first one without internal tracer to determine what isotopes are present and their relative concentrations. Samples analyzed for Pb-210 and Po-210 will be processed in duplicate with a known amount of Pb-210 and Po-210 spike added to one of the aliquots to determine chemical yield. Tracer values are determined by electrodeposition with an NBS or EPA solution standard of another isotope of the element, followed by alpha spectrometry and verified by internal proportional counting with corrections for impurities based on alpha spectrometry. All samples analyzed by alpha spectrometry will be counted 100 to 1000 minutes depending on sensitivity requirements. Samples with activity levels about 10nCi per sample will require special handling and will be processed in a special hot lab located outside the laboratory facilities. All samples of intermediate (50pCi to 10nCi) and high level (10nCi to 1μCi) activity will be totally dissolved taking a sample aliquot for the analysis. Low level activity (<50 pCi) samples will be analyzed in total. Sequential analyses will be performed on samples with small volume and low activity levels that require several analyses.

The stable analysis required will be completed according to procedures in Standard Methods for Examination of Water and Waste Water or the EPA Standard Procedure Manual.

A.3 CALCULATION METHODS

Natural Uranium

The activity concentrations of the individual uranium isotopes for each sample are summed to yield the total natural uranium concentration, in pCi/mass or pCi/volume.

Thorium - 230

$$D = (A/B)(C), \quad G = (E/F)(D), \quad J = \frac{(B)(100)}{(C)(H)(I)}, \quad \text{and}$$

$$2\sigma = 2(D \text{ or } G)\sqrt{\frac{1}{A} + \frac{1}{B}} \quad \text{where:}$$

A = isotope count,

B = spike count,

C = dpm/spike,

D = dpm/aliquot,

E = total volume,

F = aliquot volume,

G = dpm/sample,

H = detector efficiency,

I = length of count,

J = percent recovery.

Radium - 226

$$\text{pCi/l or g} = \frac{(C/T) - B}{E\ R\ D_1\ D_2\ I\ V}, \quad \text{and}$$

$$2\sigma = \frac{2\sqrt{C + BT}}{C - BT} \ (\text{pCi/l or g}) \quad \text{where:}$$

T_1 = Date bubbler sealed,
T_2 = De-emanation time and date,
T_3 = Time of count,
T = Count time (min or hr),
C = Gross counts,
B = Background (cph or cpm),
E = Calibration (cph/pCi or cpm/pCi),
R = Chemical recovery,
D_1 = Rn-222 decay T_2 to T_3,
D_2 = Rn-222 decay during count time,
I = Rn-222 ingrowth from T_1 to T_2,
V = Volume or weight (liter/gram).

Lead - 210

$$\text{pCi/unit} = \frac{(A/B) - C}{D\ E\ F\ G\ H\ I},$$ and

$$2\sigma = \frac{2\sqrt{C + BT}}{C - BT}\ (\text{pCi/unit})$$ where:

T_0 = Time of first milking,
T_1 = Time of second milking,
T_2 = Mid-time counting,
A = Gross counts,
B = Time,
C = Background cpm,
D = Efficiency cpm/dpm,
E = Bi-210 decay,
F = Bismuth recovery by AA,
G = (Pb) Lead recovery by AA,
H = Bi-210 ingrowth,
I = Volume or/weight.

Polonium - 210

$$pCi/unit = \frac{(A/B) - C}{D\ E\ F\ G}, \qquad \text{and}$$

$$2 = \frac{2\sqrt{A + BC}}{A - BC}\ (pCi/unit) \qquad \text{where:}$$

T_0 = Time of Po-210 separation,

T_1 = Mid-time of count,

A = Counts,

B = Minutes counted,

C = Background (cpm),

D = Efficiency,

E = Recovery from spike,

F = Po-210 decay (T_0 to T_1),

G = Aliquot analyzed.

A.4 LOWER LIMIT OF DETECTION (LLD)

$$LLD = \frac{4.66\ Sb}{2.22\ (E)\ (S)}, \qquad \text{where:}$$

Sb = Standard deviation of the background,

2.22 = dpm/pCi,

E = Fractional counting efficiency,

S = Sample size.

Representative LLDs for the EIC analyses performed for the baseline program are listed in Table A-1. These LLDs are applicable to most sample analyses.

Table A-1. LOWER LIMITS OF DETECTION FOR THE SAMPLE ANALYSES

Sample Type	Analysis	LLD (μCi/ml)
Air Particulates	Natural U	1.0E-16
	Th-230	1.0E-16
	Ra-226	1.0E-16
	Pb-210	1.0E-15
Groundwater/Surface water (dissolved, suspended)	Natural U	2.0E-10
	Th-230	2.0E-10
	Ra-226	2.0E-10
	Pb-210	5.0E-10
	Po-210	2.0E-10
		(μCi/kg wet)
Vegetation/Fish	Natural U	2.0E-7
	Th-230	2.0E-7
	Ra-226	5.0E-8
	Pb-210	1.0E-6
	Pu-210	1.0E-6
		(μCi/g dry)
Soil/Sediment	Natural U	2.0E-7
	Th-230	2.0E-7
	Ra-226	2.0E-7
	Pb-210	2.0E-7
	Po-210	2.0E-7

A.5 DESCRIPTION OF CALIBRATION METHODS

Measuring and Testing Equipment Calibration Policy

All equipment used to measure radiation, radioactive materials, or toxic materials shall be routinely calibrated at intervals appropriate to the measurement being performed.

Responsibility

Testing and calibration shall be performed by qualified technicians, under the direction of the Laboratory Supervisor or the Facility Manager.

Procedures

All tests and calibrations shall be performed in accordance with written procedures.

Certification and Certificates of Calibration

To the extent possible, primary calibration shall be traceable to the National Bureau of Standards. Records of traceability to NBS (e.g., certificates) shall be maintained along with records of routine calibrations of each instrument of measurement system.

Instruments

Specific calibration procedures are specified in procedures for each instrument type. The following procedures apply in a general way to all instrumentation used for radioactivity measurements.

1. Primary calibration is based on the use of solution standards from NBS, EPA, Amersham Searle, AEC-HASL, and others. Aliquots of these solutions are added to actual samples, which are then processed the same as routine samples. By processing, mounting, and counting the standards the same as routine samples, a correction can be made for a host of

factors; e.g., backscatter, self-absorption, geometry and counting efficiency. At least one spiked (standard) sample should accompany each group of routine samples counted. Exceptions to this may be made for alpha spectrometry when internal tracers are used with every sample and for gamma spectrometry when spiked samples in standard geometrics are retained for re-use.

2. A variety of sources may be used to check daily or weekly for proper instrument operation. Some of these are listed below along with specific applications.

Type of Source	Application
Electroplated SrY-90	Beta plateau determination; Beta efficiency checks.
Electroplated Pu-239	Alpha plateau; Alpha efficiency checks.
Electroplated alpha emitters, e.g., Pu-236, Pu-238, Pu-242, Am-241, Am-243, U-234, U-235, U-238, Th-230, Th-232.	Energy calibration of alpha spectrometer and counting efficiency checks.
Sr-85 solution	Direct gamma comparison with Sr-85 tracer in samples for strontium yield determination.

Gamma standards mounted in same geometries as samples	Energy calibration of gamma spectrometry and counting efficiency checks.
Scintillation solutions with H-3 or C-14.	Check constancy of day-to-day counting with the liquid scintillation counter.

3. The procedure for each instrument should specify: a) primary calibrations required; b) type and frequency of operational checks, e.g., plateau determination of counting efficiency checks; c) type of documentation required, and d) course of action when results are not within the specified range.

4. Maintenance should be provided promptly when operational checks indicate unacceptable instrument performance. Maintenance procedures specified by the manufacturer should be followed. Records will be kept of maintenance provided.

5. The instrument must be recalibrated when maintenance activities could have affected the previous calibration (e.g., a slight change in counting geometry).

6. Operational checks, maintenance, and calibration performance should be recorded in a log book. If reference to the log is cumbersome, pertinent calibration information, e.g. acceptable operational limits, may be attached to each instrument.

7. When an instrument is not operating properly, it should be tagged as "inoperative" with sufficient information to advise those who normally use the instrument concerning the nature of the problem. When the instrument has been fixed, the "inoperative" tag should be removed.

A.6 DESCRIPTION OF QUALITY CONTROL

Approximately 10 percent of the samples analyzed are QC samples, especially blanks, to check for cross-contaminations. Also, a lesser number of blind "known" samples or splits will be analyzed. The data for these QC samples are reported monthly. The technical director of the Nuclear Services Division will review these QC results and perform QA audits of the analytical laboratories as stated in the QA Manual. A copy of the monthly Quality Control Report prepared by the Albuquerque Laboratory to the Techical Director will be mailed to Plateau Resources upon request.