CLEAN

Contract No. N62474-88-D-5086

Contract Task Order No. 0155

Navy Engineer-in-Charge: Michael McClelland
PRC Project Manager: James M. Sickles
PRC Assistant Project Managers: David Martinez
David Preston

NAVAL FACILITIES ENGINEERING COMMAND
WESTERN DIVISION
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

RADIATION SURVEY - DRYDOCK 4
FINAL REPORT

Prepared By

PRC ENVIRONMENTAL MANAGEMENT, INC.
135 Main Street, Suite 1800
San Francisco, CA 94105
415/543-4880

September 15, 1994

TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

1.0 INTRODUCTION

PRC Environmental Management, Inc. (PRC) was requested by the Naval Facilities Engineering Command, Western Division (WESTDIV), under Contract Task Order 0155, to perform a radiation survey of Drydock 4 at Naval Facilities Engineering Command, Western Division, Hunters Point Annex (HPA), in San Francisco, California. (See Figure 1). WESTDIV requested that PRC conduct additional radiation surveys based on the Navy's Radiological Affairs Support Office (RASO) review of gamma count rate results obtained from several locations in the drydock and the reported activity of radium-226 (^{226}Ra) in sediments. These additional radiation surveys were requested to (1) establish whether the gamma count rates at selected locations on the drydock floor were consistent with established site-specific background levels and (2) confirm the ^{226}Ra results in sediment samples using gamma spectroscopic analysis.

2.0 SUMMARY

PRC performed an environmental radiation survey of Drydock 4 on September 11 and 12, 1994. A combination of surface gamma count rate surveys, in situ gamma spectroscopy, and laboratory gamma spectroscopic analysis of sediment samples collected from the drydock were used to survey the drydock for radiation.

Results of the survey indicate that gamma radiation levels within the drydock are consistent with normally expected background levels. These levels do not pose any radiological health and safety hazards to the general public for unrestricted use. In situ gamma spectroscopy results indicate that the contributors to the total background gamma radiation are naturally occurring radioisotopes. These contributors to background gamma radiation include potassium-40 (^{40}K), ^{226}Ra and its decay daughters, and thorium-232 (^{232}Th) and its decay daughters. No radioisotopes associated with nuclear propulsion, specifically cobalt-60 (^{60}Co), were found. The concentration of cesium-137 (^{137}Cs), a component of fallout from nuclear weapons testing, was found in sediments at concentrations consistent with normally expected worldwide background levels.

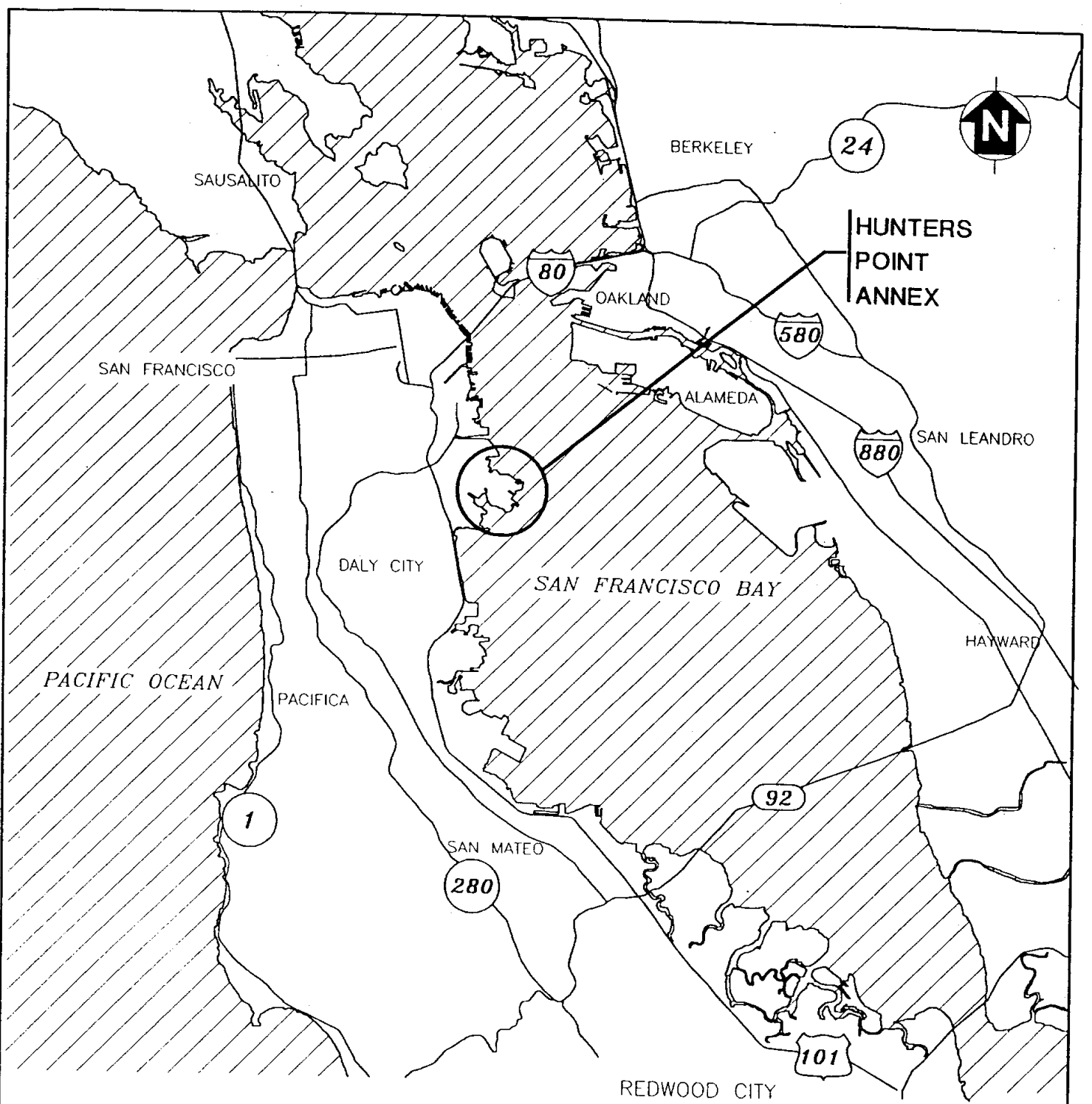


FIGURE 1
REGIONAL SETTING

W:\LSF\(044-0153).HP-LOC.DWG - 12/27/93 - PLOT 1=00 REV.0001

3.0 BACKGROUND

Over the past 40 years, Drydock 4 has been used for the repair of nuclear and non-nuclear powered naval vessels. In the mid 1940s, it may have been used during the radiological decontamination of non-target ships that participated in nuclear weapons testing in the south Pacific Ocean. Since it has been used for servicing of nuclear-powered ships, a radiological survey is required by the Navy to establish its safety prior to use by the general public.

A radiological survey of Drydock 4 was conducted in July 1994 by health physics personnel from Mare Island Naval Shipyard, (MINSY) Code 105.2. The survey was performed to establish whether Drydock 4 could be released by the Navy to the general public for unrestricted use. The survey identified a point source of gamma-emitting radioactive material that was identified as ^{226}Ra. The point source was removed and three sediment samples were collected for gamma spectroscopic analysis.

Results of the field radiation survey, conducted by MINSY personnel, indicated that in addition to the point source of ^{226}Ra, several areas exhibited gamma count rates that were greater than site-specific background levels. These areas were noted but were not investigated further to identify the source of elevated gamma activity.

Additionally, an elevated concentration of ^{226}Ra was found in a sediment sample collected in a drainage channel upstream from the point source. The analysis indicated that the ^{226}Ra activity was 9.72×10^{-6} microcuries per gram, or 9.72 picocuries per gram (pCi/g). The other two samples had 3.3 and 7.3 pCi/g of ^{226}Ra.

PRC compared the results of the MINSY survey for ^{226}Ra to those obtained following background soil sampling and analysis performed at HPA during the 1992 Surface Confirmation Radiation Survey (SCRS) (PRC 1992). The soil samples were collected and analyzed by TMA/Eberline, Albuquerque, New Mexico.

The highest result of the MINSY survey is almost 20 times more than typically expected ^{226}Ra background soil concentrations. Average background ^{226}Ra soil concentrations at HPA are approximately 0.5 pCi/g dry weight.

4.0 METHODS

The radiological survey consisted of (1) remarking existing grid coordinate locations on the drydock floor, (2) performing a 100 percent walkover gamma survey of the drydock floor area within each grid, (3) performing gamma spectroscopic measurements at each location where an anomalous gamma count rate was observed during the walkover survey, (4) performing gamma exposure rate measurements at each grid, and (5) collecting sediment samples for gamma spectroscopic analysis.

The draft technical memorandum that originally detailed this work called for gross beta/gamma and alpha surface contamination surveys of areas that exhibited elevated gamma count rates. Only one area in the drydock appeared to be slightly elevated. In situ gamma spectroscopy was performed in this area, but since this location was covered with approximately 4 inches of water, surface measurements were not appropriate.

4.1 GRID COORDINATE SYSTEM

To ensure that specific locations on the drydock floor were surveyed and to provide a semi-permanent method for identifying areas that were surveyed, the existing drydock grid coordinate system was used. As shown on Figure 2, the drydock grid system consists of 12- by 28-foot grids numbered alphanumerically.

4.2 SURVEY LOCATIONS

After reviewing previous radiation surveys of the drydock, RASO identified 22, 12- by 28-foot grids on the drydock floor that required further investigation. PRC performed a walkover gamma count rate and gamma exposure rate radiation survey of these grids at the following locations: A-1 through A-5, D-1, F-1, F-3, I-3, AE-3 through AN-3, AJ-4, AX-1, and BL-1. These grid locations

GRID SURVEYED TO ESTABLISH BACKGROUND (GAMMA COUNT RATE)			
GRID	GROSS GAMMA COUNT RATE RANGE (CPM)	AVERAGE GAMMA COUNT RATE RANGE (CPM)	GAMMA EXPOSURE RATE (uR/hr)
O–3	5075–6425	5750	6.0
AB–5	5420–6450	5935	6.5
AU–2	5420–6080	5750	6.5
BH–4	5200–5980	5590	6.0
X–2	5190–6250	5720	6.0
CE–1	4169–5811	4990	7.0
CE–5	3645–5689	4667	6.0
BT–1	3805–5733	4769	7.0
BT–5	3851–5569	4710	7.0
BF–3	3678–4959	4319	6.5
AR–1	3709–5223	4466	7.0
AR–5	3913–5298	4605	6.5
Z–5	3861–5703	4782	7.0
Z–1	3915–5820	4867	7.0
M–3	4.54–5420	4737	6.0

(GAMMA COUNT RATE)			
GRID	GROSS GAMMA COUNT RATE RANGE (CPM)	AVERAGE GAMMA COUNT RATE RANGE (CPM)	GAMMA EXPOSURE RATE (uR/hr)
A–1	4400–6350	5375	6.5
A–2	5050–6300	5675	6.5
A–3	5205–6320	5763	6.5
A–4	5300–6400	5858	6.5
A–5	5275–7300	6288	7.0
D–1	4171–6290	5231	7.0
F–1	4175–5920	5048	6.5
F–3	3900–5265	4583	7.0
I–3	4254–5765	5010	6.0
AE–3	3800–5675	4737	6.0
AF–3	4400–6200	5300	6.0
AG–3	3900–5100	4500	6.0
AH–3	4700–6100	5400	6.0
AI–3	4500–6300	5400	6.0
AJ–3	3630–5125	4378	6.0
AK–3	3840–5250	4545	6.0
AL–3	4300–6100	4925	6.0
AM–3	3725–5250	4488	6.0
AN–3	4400–6300	5350	6.0
AJ–4	3650–5050	4350	6.0
AX–1	4280–6250	5265	6.0
BL–1	3680–6170	4925	6.0

LEGEND:

- SURVEYED GRID AREA
- SEDIMENT SAMPLE LOCATION (DD0401)
- CASSION

DD0407

LONGTITUDINAL DRAINAGE GUTTER

TRANSVERSE BILGE BLOCK BEARER SLOTS

DD0406

DD0401

DETAIL A

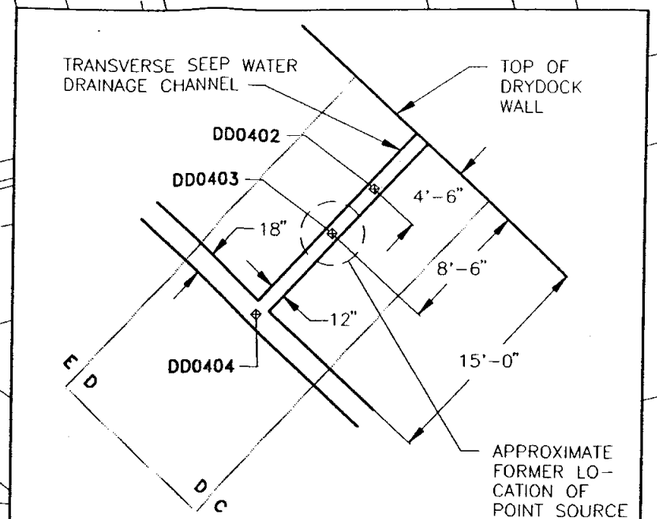
DD0409

DD0405

PUMP INTAKE SUMPS

DD0408

CASSION



DETAIL A– GRID D–1
FORMER LOCATION OF RADIUM–CONTAINING POINT SOURCE REMOVED BY MARE ISLAND CODE 105.2

50' 0 50' 100'
SCALE: 1" = 100'

KCH (SF):(044–0155)DRYDOCK4.DWG – 09/13/94 – PLOT 1=100 R002

FIGURE 2
DRYDOCK No. 4 RADIATION SURVEY GRID AND SAMPLE LOCATION MAP HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

are identified on Figure 2. Gamma count rate values for these grids were compared to site-specific background count rates.

4.3 BACKGROUND SURVEY LOCATIONS

Background count rates were collected at grid locations that had been identified by RASO as not requiring further investigation since previous surface frisking and gamma count rate survey results indicated no contamination was present. A total of 15, 12- by 28-foot grid locations were selected to establish background. PRC performed a walkover gamma radiation count rate survey and gamma exposure rate radiation survey at the following grid locations: Q-3, M-3, X-2, Z-1, Z-5, AB-5, AR-1, AR-5, AU-2, BF-3, BH-4, BT-1, BT-5, CE-1, and CE-5. These locations are identified on Figure 2.

A total of nine sediment samples were collected from the longitudinal drainage gutters and from the 4-foot diameter pipe beneath the gutters. These samples were collected for gamma spectroscopic analysis and their sampling locations are shown on Figure 2.

4.4 WALKOVER GAMMA SURVEY

The walkover gamma radiation survey was performed within each 12- by 28-foot grid square marked out on the drydock floor. PRC measured maximum and minimum gamma count rates by using sodium iodide (NaI) gamma radiation detectors that detect gamma energies between approximately 80 kilo electron volts (keV) and 3,000 keV. This energy range includes those gamma rays emitted by ^{226}Ra and its daughters. Detector responses were recorded and used to determine if detected gamma count rates at any grid location were significantly different from site-specific background.

Site-specific background was established after all background grids were surveyed. Each background grid surveyed provided a range of count rates. The mean count rate (maximum plus minimum divided by two) for each grid was recorded and a population frequency distribution was established using all of the mean gamma count rate values. Any grid section whose mean count rate exceeded three standard deviations of the population mean, or where elevated count rates were identified by the the health physics technician, was surveyed using in situ gamma spectroscopy. Gross gamma count

rates were measured using a Ludlum Instruments, Model 2221 rate meter/scaler analyzer coupled to a Ludlum Instruments, Model 44-10, 2- by 2-inch, unshielded NaI detector. The scaler gamma energy threshold was set at 80 keV and the single channel analysis function was disabled. Each instrument was source checked each day by PRC using a ^{137}Cs check source. None of the daily instrument responses varied more than two standard deviations from its control chart mean value.

4.5 IN SITU GAMMA SPECTROSCOPY

PRC used in situ gamma spectroscopy to collect a gamma spectrum at one location where NaI gamma count rates indicated slightly elevated gamma activity. The purpose of the in situ measurement was to identify the radioisotope contributing to the elevated gamma count rate at that location. Since the gamma spectrometer cannot be efficiency calibrated using the geometry replicating the drydock, only qualitative results are possible. Only the identification of specific gamma-emitting radioisotopes was possible in this geometry.

PRC used an EG&G Nuclear Instruments Nomad Plus portable gamma spectroscopy system. The equipment measures gamma energies within 4,000 channels over a spectrum covering a range of about 1,900 keV, from about 40 keV to 3 million electron volts (MeV). Each channel is approximately 0.5 keV wide. A 60 percent efficient, liquid-nitrogen-cooled High Purity Germanium (HPGe) detector was coupled to a multichannel buffer and laptop computer with an internal analytical software and isotope library.

4.6 GAMMA EXPOSURE RATE MEASUREMENTS

A Ludlum Model 19 gamma exposure meter was used to measure exposure rate at each grid location. The exposure meter provides measurements of the exposure rate in microRoentgen per hour (μR/hr). Each exposure measurement was collected in the center of each grid section at 3.0 feet above the surface. The exposure meter was checked each day using a ^{137}Cs check source.

4.7 SEDIMENT SAMPLE ANALYSIS

Sediment samples were counted using an EG&G Nuclear Instruments gamma spectroscopy system. A 60 percent efficient HPGe, P-Type, gamma detector was coupled to a NOMAD 92X multichannel analyzer. The instrument is capable of measuring energies from 40 keV to 10 MeV. However, PRC analyzed the sediment using a 4,000 channel sensitivity ranging between 40 keV and approximately 3 MeV.

The HPGe gamma spectroscopy system was operated in a laboratory setting and its detector housed inside a low background lead shield. This method provided both *qualitative and quantitative* evaluation of the gamma-emitting radioisotopes in the soil.

The gamma spectroscopic system was efficiency and energy calibrated using the response to certified mixed gamma standard plus Americium-241. The mixed gamma standard is an epoxy-based soil simulant contained in a 500 milliliter (ml) polyethylene sample collection jar, the same type that the soil samples are collected in.

The minimum detectable activity (MDA) for gamma spectroscopic measurements were calculated using the following formula:

$$MDA = 1.645 \times \frac{\sqrt{Background}}{Live\ Time}$$

MDA is a measure of how low an activity could be present and not detected by an analysis. For all peaks, the MDA value was calculated based on the background value for each peak. Background values were automatically selected for best fit by the data reduction software that supports the analysis package.

4.7.1 Analysis of ^{226}Ra in Sediments

Because of the time critical nature of this investigation, the typical analytical method used to determine the concentration of ^{226}Ra in soils and sediments was not performed. If fully quantitative

sample analysis is required for ^{226}Ra, the samples would have been placed in 500-ml screw-top plastic jars, the lids sealed with electrical tape, and the samples stored for 21 days to allow ^{226}Ra to reach equilibrium with one of its daughter isotopes, radon (^{222}Rn).

This equilibrium is required because it is very difficult to quantify ^{226}Ra by its 186 keV photopeak because naturally occurring uranium-235 (^{235}U) is usually present in soils. ^{235}U emits a gamma ray at 185.7 keV; approximately the same energy as ^{226}Ra; this photopeak interferes with the resolution of the 186 keV photopeak for ^{226}Ra.

If radon daughters are allowed to equilibrate within a sealed container, after 21 days the activity of bismuth-214 (^{214}Bi) will be equal to that of its long-lived parent, ^{226}Ra. The 609 keV photopeak of ^{214}Bi is then used to infer the activity of ^{226}Ra.

Because of the time constraints on this survey, this methodology was not used. In consultation and agreement with RASO, another semiquantitative method was used to approximate the activity of ^{226}Ra in the sediments. Because there was not enough time to allow radon to completely equilibrate with ^{226}Ra, and because the relative percentage of equilibration between these two species is unknown, an assumption about this percentage was made using equilibrium factors for radon daughter products. These equilibrium factors were obtained from the National Commission on Radiation Protection and Measurements, 1988, Report No. 97. As an approximation, an equilibrium value ratio of 1.0/0.7 for $^{222}Rn/^{214}Bi$ was used to calculate concentrations. The resulting activity calculated for ^{214}Bi per gram of sediment was divided by the 0.7 equilibrium factor. This normalized value was compared to the calculated activity per gram for the unresolved $^{235}U\backslash^{226}Ra$ photopeak. Based on telephone discussions with RASO's representative, Mr. Troy Blanton, the approximate ratio of gamma emissions that comprise the unresolved $^{226}Ra\backslash^{235}U$ peak is 56.7 percent due to ^{226}Ra and 43.3 percent due to ^{235}U.

As a further cross check, these values were compared to results for ^{226}Ra obtained during the 1992 SCRS background radiation survey soil samples.

5.0 RESULTS

The following section describes the results from the surface walkover radiation survey, in situ gamma spectroscopy, and sediment samples collected in the longitudinal drainage lines and gutters.

5.1 SURFACE WALKOVER GAMMA SURVEY

Results of the surface walkover gamma survey indicate that gamma count rates in all of the grid locations do not exceed normally expected count rates. The data points for background grids and for survey grids were plotted separately using a normal probability distribution that indicated none of the data exceeded three standard deviations of the mean count rate. Both background and survey data were then combined to form a larger population distribution. Again, none of the data points exceeded three standard deviations of the mean background count rate. Although one grid location had a slightly elevated gamma count rate, it was still within acceptable range of count rates. Nonetheless, this location was selected for in situ gamma spectroscopic measurement. The survey data are shown on Table 1. Background survey data are shown on Table 2. Probability plots of the data and statistical analysis results are provided in Appendix A.

5.2 IN SITU GAMMA SPECTROSCOPY

Results of in situ gamma spectroscopy detected only naturally occurring gamma-emitting radioactive materials. The results are qualitative only. Grid location A-5 was identified during the walkover gamma survey as potentially elevated. The elevated activity may have been due to (1) geometry. because at this location the detector is surrounded by concrete on three sides, or (2) elevated amounts of naturally occurring radioactive materials in the concrete aggregate. A copy of the report of identified peaks and the spectrum is provided in Appendix B.

5.3 SEDIMENT ANALYSIS

Sediment analysis identified no ^{60}Co above the average MDA of 0.03 pCi/g. ^{137}Cs was identified in 4 samples at levels ranging from 0.08 to 0.13 pCi/g. These levels of ^{137}Cs are well within

TABLE 1

GRIDS SURVEYED FOR ELEVATED GAMMA COUNT RATES IN DRYDOCK 4

Grid Location	Gross Gamma Count Rate Range (CPM)	Average Gamma Count Rate (CPM)	Gamma Exposure Rate (μR/hr)
A-1	4,400-6,350	5,375	6.5
A-2	5,050-6,300	5,675	6.5
A-3	5,205-6,320	5,763	6.5
A-4	5,300-6,400	5,858	6.5
A-5	5,275-7,300	6,288	7.0
D-1	4,171-6,290	5,231	7.0
F-1	4,175-5,920	5,048	6.5
F-3	3,900-5,265	4,583	7.0
I-3	4,254-5,765	5,010	6.0
AE-3	3,800-5,675	4,737	6.0
AF-3	4,400-6,200	5,300	6.0
AG-3	3,900-5,100	4,500	6.0
AH-3	4,700-6,100	5,400	6.0
AI-3	4,500-6,300	5,400	6.0
AJ-3	3,630-5,125	4,378	6.0
AK-3	3,840-5,250	4,545	6.0
AL-3	4,300-6,100	5,200	6.0
AM-3	3,725-5,250	4,488	6.0
AN-3	4,400-6,300	5,350	6.0
AJ-4	3,650-5,050	4,350	6.0
AX-1	4,280-6,250	5,265	6.0
BL-1	3,680-6,170	4,925	6.0

TABLE 2

GRIDS SURVEYED TO ESTABLISH BACKGROUND GAMMA COUNT RATES IN DRYDOCK 4

Grid Location	Gross Gamma Count Rate Range (CPM)	Average Gamma Count Rate (CPM)	Gamma Exposure Rate (μR/hr)
Q-3	5,075-6,425	5,750	6.0
AB-5	5,420-6,450	5,935	6.5
AU-2	5,420-6,080	5,750	6.5
BH-4	5,200-5,980	5,590	6.0
X-2	5,190-6,250	5,720	6.0
CE-1	4,169-5,811	4,990	7.0
CE-5	3,645-5,689	4,667	6.0
BT-1	3,805-5,733	4,769	7.0
BT-5	3,851-5,569	4,710	7.0
BF-3	3,678-4,959	4,319	6.5
AR-1	3,709-5,223	4,466	7.0
AR-5	3,913-5,298	4,605	6.5
Z-5	3,861-5,703	4,782	7.0
Z-1	3,915-5,820	4,867	7.0
M-3	4,054-5,420	4,737	6.0

TABLE 3

GAMMA SPECTROSCOPIC ANALYTICAL RESULTS FOR SEDIMENT SAMPLES COLLECTED IN DRYDOCK 4

Sample ID		Ra-226 Activity (pCi/g)	MDA (pCi/g)		Co-60 Activity (pCi/g)	MDA		Cs-137 Activity (pCi/g)	MDA
DD0401		0.58 ± 0.02	0.08		MDA	0.03		MDA	0.06
DD0402		0.76 ± 0.03	0.5		MDA	0.03		MDA	0.06
DD0403		1.20 ± 0.06	0.08		MDA	0.03		MDA	0.03
DD0404		1.34 ± 0.07	0.07		MDA	0.03		0.11 ± 0.002	0.03
DD0405		0.98 ± 0.02	0.03		MDA	0.02		0.05 ± 0.0004	0.03
$DD0405A_R$		1.05 ± 0.05	0.07		MDA	0.03		0.13 ± 0.002	0.03
DD0406		0.64 ± 0.03	0.08		MDA	0.03		MDA	0.05
DD0407		0.49 ± 0.02	0.07		MDA	0.03		0.08 ± 0.001	0.03
DD0408		0.93 ± 0.05	0.08		MDA	0.03		0.13 ± 0.002	0.03
DD0409		0.63 ± 0.02	0.06		MDA	0.03		MDA	0.06

MDA No activity was calculated for this isotope in this sample. The reported value is the calculated minimum detectable activity (MDA) using the Currie method. The MDA is a level of activity that is required to be in a sample before it can shown to be not due to background counts in the counting system.

R DD0405A was a second analysis of DD0405 using a counting time 2,000 seconds. Analysis of DD0405 was originally done using a counting time of 10,000 seconds. All other samples were counted for 2,000 seconds.

normally expected worldwide nuclear weapons fallout values of approximately 0.01 to 2.0 pCi/g. Levels of ^{226}Ra in samples ranged from 0.49 to 1.4 pCi/g. The soil concentration values for ^{226}Ra and ^{137}Cs are consistent with those measured in soils at HPA during the 1992 SCRS, and are shown on Table 3. The soil concentrations of ^{226}Ra and ^{137}Cs are listed in Appendix C.

6.0 DISCUSSION

The level of gamma activity within Drydock 4, the concentration of ^{226}Ra and ^{137}Cs, and the gamma exposure rate within the drydock have been measured and are within normally expected background levels for the San Francisco Bay area and for HPA in general. No gamma-emitting radioisotopes associated with nuclear propulsion were identified during the survey.

REFERENCES

National Commission on Radiation Protection and Measurements, 1988, Report No. 97.

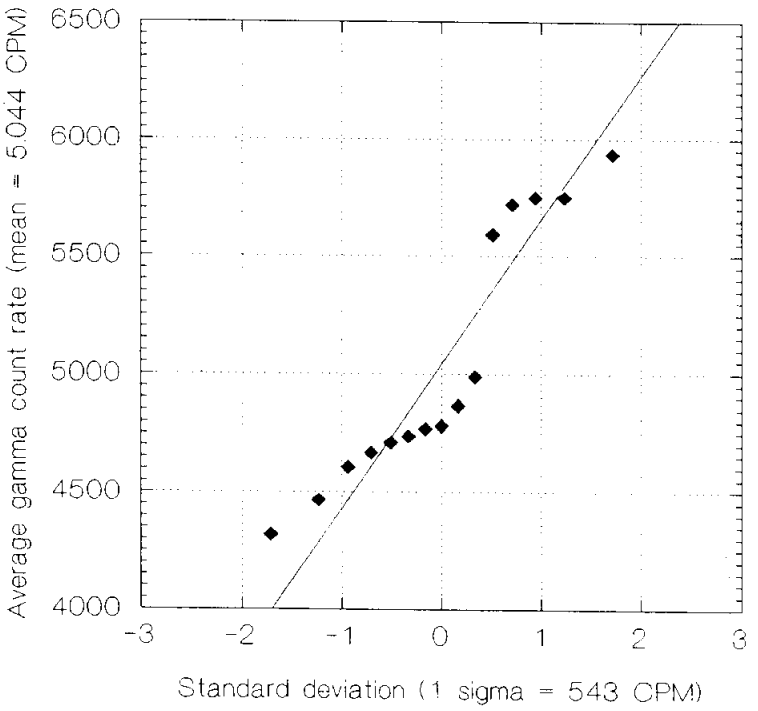
PRC Environmental Management Inc., (PRC) Surface Confirmation Radiation Survey, Naval Station Treasure Island, Hunters Point Annex, San Francisco, California. November 3, 1992.

PRC. 1993a. Navy CLEAN Ionizing Radiation Protection Program. June.

PRC. 1993b. Navy CLEAN Health and Safety program. April.

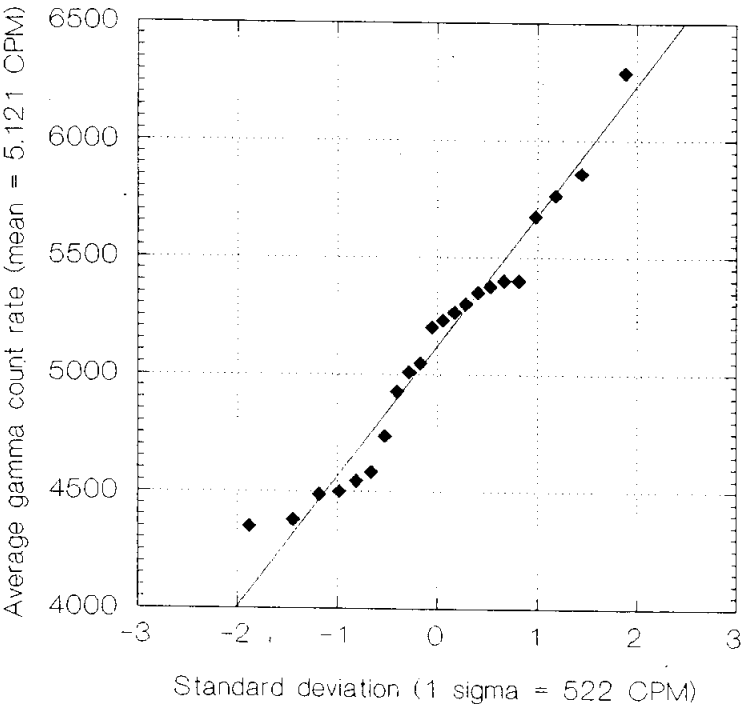
APPENDIX A
PROBABILITY PLOTS AND STATISTICAL ANALYSIS OF GAMMA COUNT RATE SURVEYS

Average background gamma count rates in Drydock 4



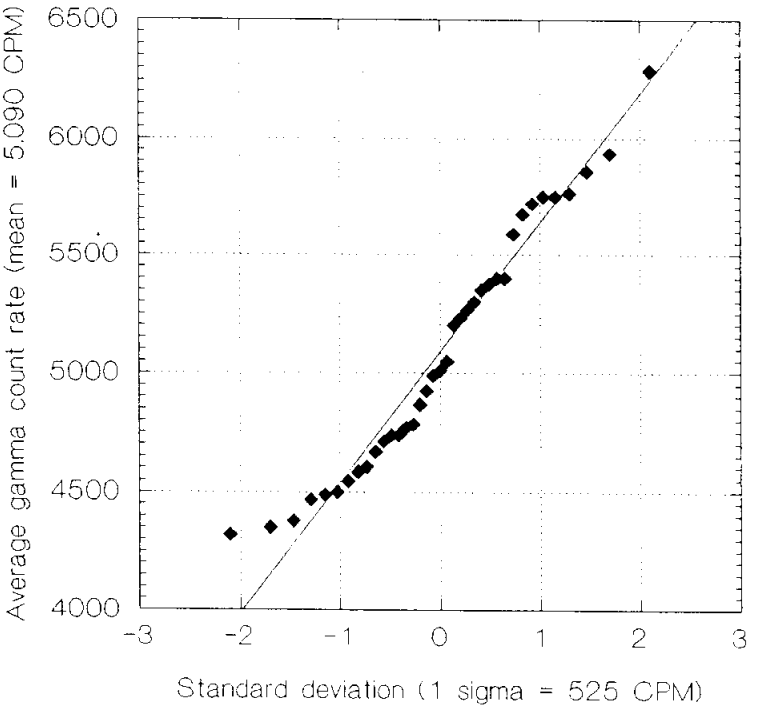
	GAMAVBK
N OF CASES	15
MINIMUM	4319.000
MAXIMUM	5935.000
RANGE	1616.000
MEAN	5043.800
STANDARD DEV	542.792
MEDIAN	4782.000

Average gamma count rates for grids surveyed in Drydock 4



	GAMAV
N OF CASES	22
MINIMUM	4350.000
MAXIMUM	6288.000
RANGE	1938.000
MEAN	5121.318
STANDARD DEV	522.150
MEDIAN	5215.500

Average background and grid survey gamma count rates in Drydock 4



	ALLGAM
N OF CASES	37
MINIMUM	4319.000
MAXIMUM	6288.000
RANGE	1969.000
MEAN	5089.892
STANDARD DEV	524.504
MEDIAN	5010.000

APPENDIX B
IN SITU GAMMA SPECTROSCOPY IDENTIFIED PEAK SUMMARY AND SPECTRUM

Sample description
Drydock 4 Grid A-5, Southwest Corner of Caisson
Hunters Point Annex, San Francisco, California

IN SITU MEASUREMENT
NO ACTIVITY / WEIGHT

Spectrum Filename: DD4CAIS.SPC

Acquisition information

Start time	12-Sep-94 16:46:28
Live time	1899
Real time	1917
Dead time	.92%
Detector/Geometry IDs	0 & 0

Detector system
MCB 9

Calibration
Filename: MXGAMST1.CLB
Created: 08-Sep-94 12:34:58 &

Zero offset .000 keV; Gain .500 keV/channel

Library Files
Main analysis library: NATURAL.LIB + ^{60}Co AND ^{137}Cs

Analysis parameters

Start channel	50 for an energy of 25.00keV
Stop channel	4048 for an energy of 2024.55keV
Peak rejection level	50.000%
Activity scaling factor	1.0000E+00 6.0900E-01 = 1.6420E+00
Detection limit method:	
Currie limit	
Additional random error:	1.0000000E+00
Additional systematic error:	1.0000000E+00

NOT USED FOR PEAK SUMMARY

Background width: best method (based on spectrum).

Corrections	Status	Comments
Decay correct to date	NO	
Decay during acquisition	NO	
Peaked background correction	YES	NEWBKG.PBC 07-Sep-94 18:12:30
Absorption (Internal)	NO	
Geometry correction	NO	
Random summing	NO	

NOT USED FOR PEAK SUMMARY

Energy calibration normalized difference: .0941

********** U N I D E N T I F I E D P E A K S U M M A R Y **********

PEAK CHANNEL	CENTROID ENERGY	BACKGROUND COUNTS	NET AREA COUNTS	INTENSITY CTS/SEC	UNCERT 1 SIGMA %	FWHM keV	SUSPECTED NUCLIDE	
149.77	74.88	8150.	307.	.162	42.00	.868	PBKA	D
154.07	77.02	5634.	442.	.233	24.50	.870	EU-152N	D
174.22	87.10	4349.	235.	.124	40.28	.879	EU-155	D
3693.53	1847.20	30.	104.	.055	15.20	1.290	BI-203	s

s Peak fails shape tests.
D Peak area deconvoluted.

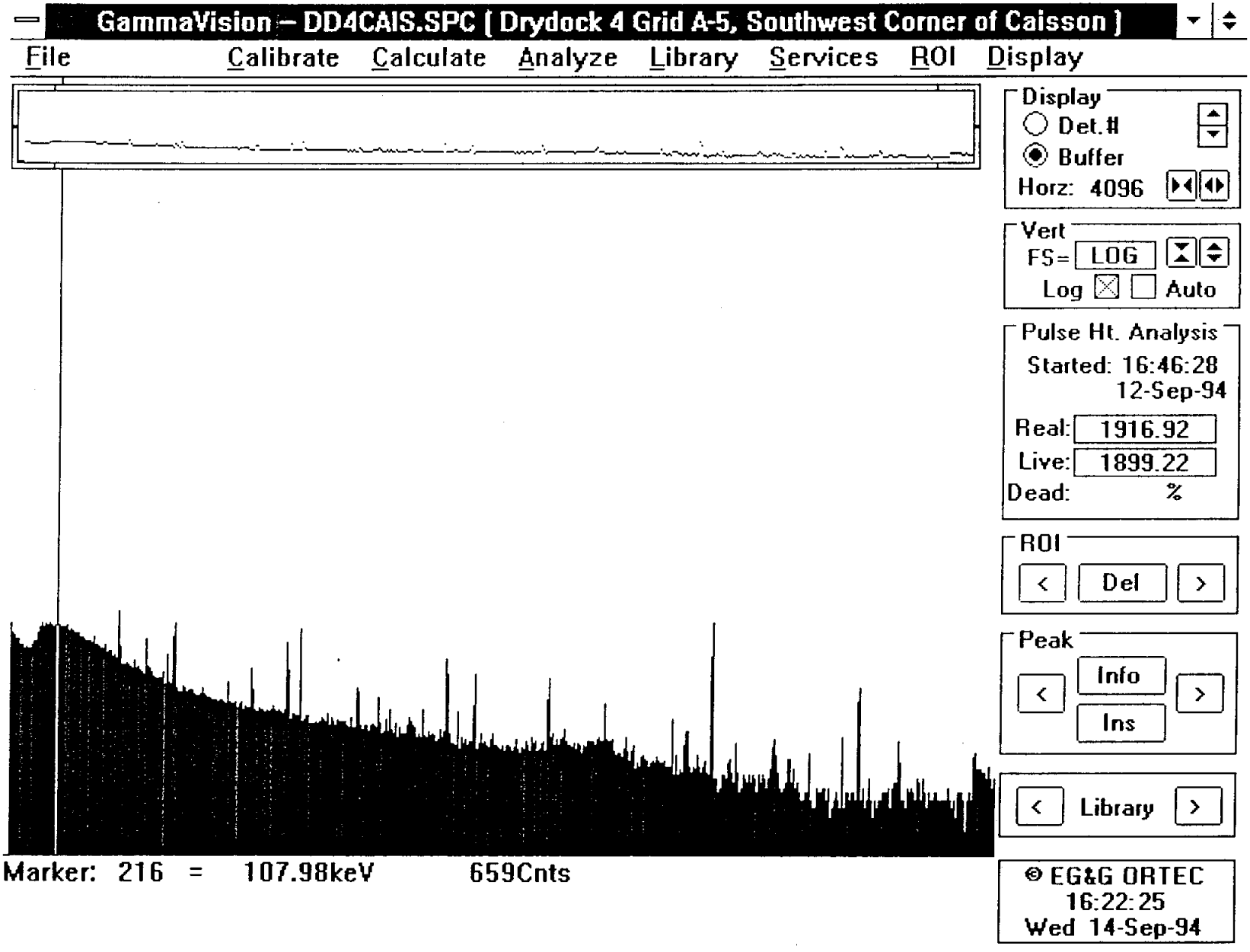
********** I D E N T I F I E D P E A K S U M M A R Y **********

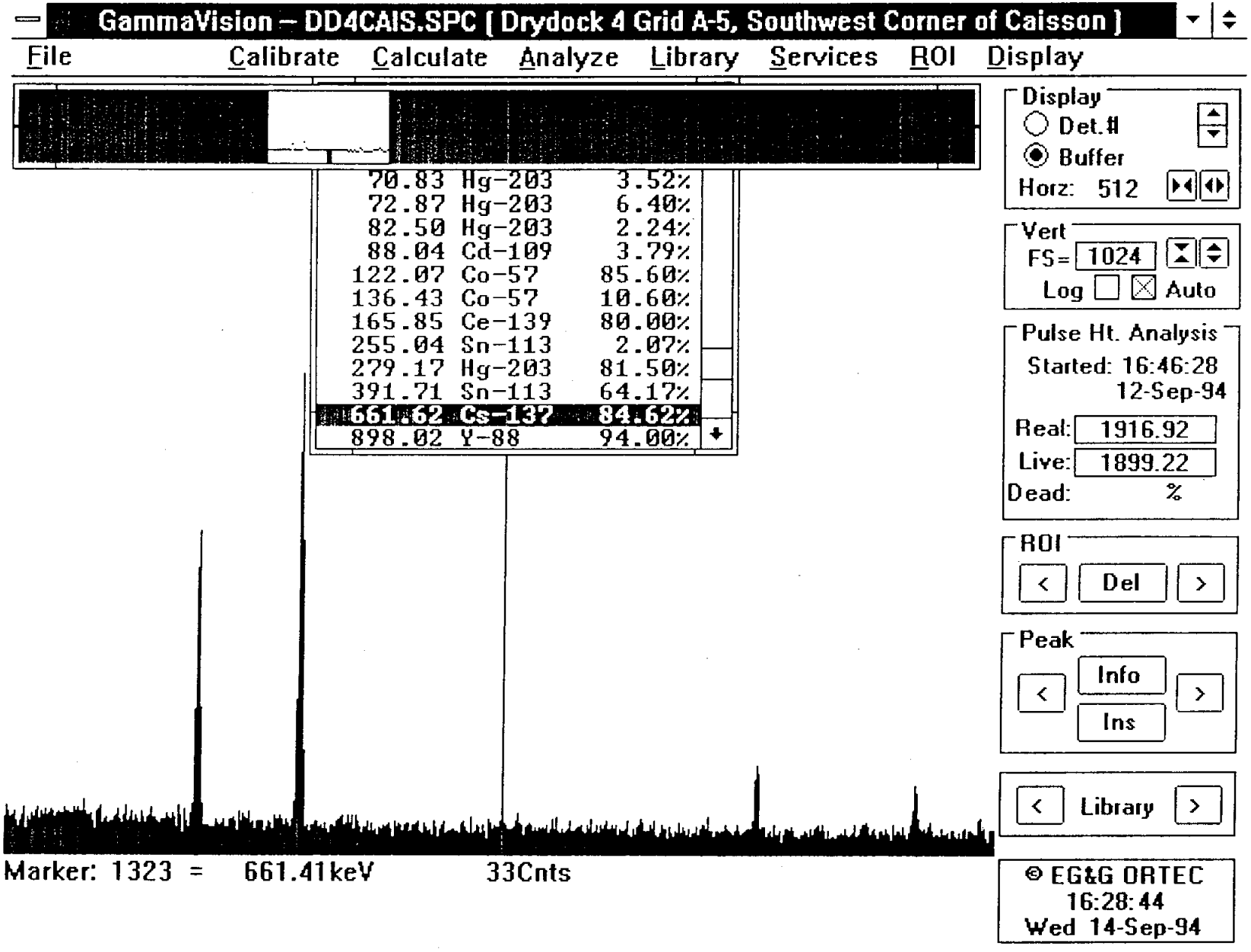
NUCLIDE	PEAK CHANNEL	CENTROID ENERGY	BACKGROUND COUNTS	NET AREA COUNTS	INTENSITY CTS/SEC	UNCERT 1 SIGMA %	FWHM keV
TH-231	50.53	25.26	1728.	72.	.038	116.07	1.030s
PA-231	54.73	27.36	2512.	0.	.000	.00	.823
CS-137	63.65	31.82	2657.	27.	.014	275.05	.827D
CS-137	64.39	32.19	2633.	51.	.027	144.24	.827D
CS-137	73.75	36.87	1380.	67.	.035	111.56	.629
PB-210	93.47	46.73	1320.	20.	.011	364.01	1.500s
TH-227	100.29	50.14	3212.	119.	.063	67.89	.844D
PB-214	106.47	53.23	2320.	6.	.003	1147.03	.847D
TH-234	126.20	63.09	3204.	214.	.113	75.12	1.383s
TH-230	136.00	67.99	1311.	49.	.026	128.78	.500
TH-227	159.46	79.72	4074.	23.	.012	385.38	.872D
TH-231	168.45	84.21	8257.	90.	.048	142.72	.876D
TH-228	168.77	84.37	7733.	40.	.021	314.44	.877D
TH-234	184.78	92.38	4064.	9.	.005	1042.26	.884D
TH-234	185.62	92.80	3910.	163.	.086	54.66	.884D
AC-228	198.84	99.41	4519.	113.	.059	158.37	.597s
U-235	218.35	109.16	11771.	25.	.013	605.00	.900D
TH-234	225.65	112.81	8478.	0.	.000	.00	.903D
PB-212	230.38	115.18	5206.	3.	.001	3732.74	.905D
RA-223	245.23	122.60	2993.	75.	.039	164.60	1.253s
AC-228	258.16	129.07	5155.	296.	.156	34.84	.918D
PA-234	262.61	131.29	4024.	82.	.043	110.39	.920D
TH-228	263.26	131.61	4076.	0.	.000	.00	.920D
U-235	287.67	143.82	2096.	63.	.033	145.89	.750
RA-223	288.39	144.18	2096.	0.	.000	.00	.750D
PA-234	304.29	152.13	3458.	127.	.067	122.83	.766s
RA-223	308.39	154.18	3900.	0.	.000	.00	.724D
U-235	326.70	163.33	4905.	170.	.090	58.68	.950D
TH-228	332.86	166.41	3014.	129.	.068	60.89	.952D
U-235	371.47	185.71	3012.	17.	.009	461.77	.970D

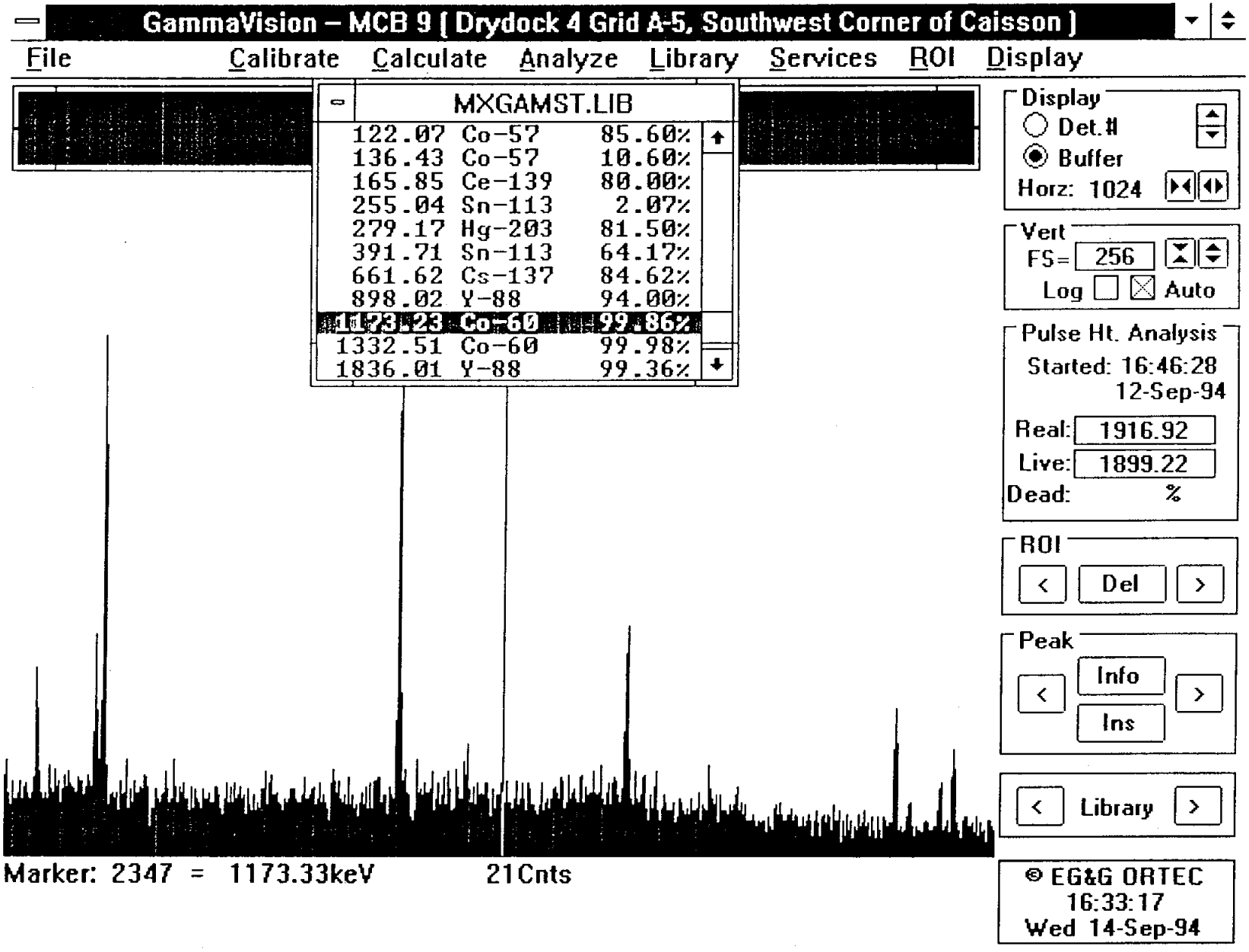
Nuclide	Channel	Energy	Background	Net area	Cnts/sec	Uncert	FWHM
RA-226	372.24	186.10	2705.	332.	.175	22.81	.970D
U-235	404.26	202.11	6391.	43.	.023	261.29	.985D
U-235	410.66	205.31	5017.	84.	.044	119.35	.988D
AC-228	418.55	209.25	2196.	196.	.103	34.52	.991D
TH-228	431.69	215.83	2336.	219.	.115	62.79	.559s
TH-227	471.98	235.97	7305.	136.	.072	89.32	1.015D
PB-212	477.31	238.63	4167.	1915.	1.008	5.29	1.018D
RA-224	482.02	240.99	3780.	193.	.102	45.58	1.020D
PB-214	484.01	241.98	2359.	294.	.155	24.12	1.021D
TH-227	512.53	256.24	2532.	114.	.060	63.22	1.034D
PB-214	517.63	258.79	1517.	101.	.053	55.65	1.036D
RA-223	538.83	269.39	4627.	104.	.055	93.41	1.045D
AC-228	540.53	270.24	4370.	179.	.094	52.70	1.046D
RN-219	542.31	271.13	4096.	64.	.034	142.03	1.047D
PB-214	549.11	274.53	2805.	45.	.024	166.83	1.050D
TL-208	554.76	277.36	1583.	157.	.083	36.67	1.052D
PA-231	566.44	283.20	788.	74.	.039	86.17	.955
PB-214	590.50	295.23	1722.	896.	.472	16.39	1.160s
PA-231	600.09	300.02	1179.	0.	.000	.00	1.431D
PB-212	601.51	300.73	1179.	243.	.128	42.87	1.431s
PA-231	605.35	302.65	512.	0.	.000	.00	.681D
RA-223	647.81	323.88	2162.	45.	.023	148.42	1.094D
AC-228	656.04	327.99	1273.	159.	.084	32.72	1.097D
TH-227	659.73	329.84	1119.	9.	.005	511.09	1.099D
PA-231	660.17	330.06	360.	0.	.000	.00	.250D
RA-223	676.61	338.28	1829.	0.	.000	.00	1.106
AC-228	677.41	338.68	1232.	597.	.314	19.92	1.363s
PB-214	704.09	352.02	1017.	1664.	.876	4.27	1.259
RN-219	803.41	401.68	760.	99.	.052	88.63	2.339s
AC-228	818.18	409.07	628.	145.	.076	49.58	1.540s
RA-223	888.01	443.98	434.	45.	.024	123.39	2.516s
AC-228	926.20	463.08	589.	234.	.123	35.07	1.046s
PB-214	974.16	487.06	622.	111.	.058	75.43	2.537s
TL-208	1021.73	510.85	808.	545.	.287	11.68	1.790s
PB-214	1160.33	580.15	1653.	61.	.032	95.76	1.311D
TL-208	1166.41	583.19	450.	1130.	.595	3.99	1.314D
BI-214	1218.81	609.40	397.	1762.	.928	3.15	1.435
CS-137	1323.25	661.62	489.	25.	.013	128.83	1.377D
BI-214	1330.92	665.45	322.	69.	.036	38.51	1.380D
PA-234	1400.75	700.38	236.	32.	.017	80.36	.597s
BI-212	1454.35	727.18	565.	276.	.146	13.56	1.429D
PA-234	1466.43	733.22	232.	32.	.017	69.63	1.434D
TL-208	1526.24	763.13	924.	42.	.022	102.38	1.457D
BI-214	1536.69	768.36	544.	203.	.107	17.71	1.461D
AC-228	1544.56	772.29	290.	60.	.032	42.11	1.464D
BI-212	1570.81	785.42	235.	78.	.041	30.09	1.474D
PB-214	1571.79	785.91	294.	19.	.010	128.88	1.475D
AC-228	1589.44	794.74	320.	175.	.092	23.29	1.725

Nuclide	Channel	Energy	Background	Net area	Cnts/sec	Uncert	FWHM
BI-214	1611.86	805.95	294.	59.	.031	59.56	1.396
AC-228	1671.37	835.71	497.	65.	.034	50.37	1.513D
PB-214	1678.01	839.03	357.	20.	.011	133.70	1.516D
TL-208	1721.89	860.97	343.	161.	.085	26.96	1.619s
PA-234	1767.56	883.81	185.	32.	.017	76.78	.533s
PA-234	1797.21	898.64	208.	30.	.016	90.71	.498s
AC-228	1822.37	911.22	315.	998.	.525	5.38	1.720
BI-214	1868.32	934.20	231.	157.	.083	22.38	1.441s
AC-228	1929.44	964.77	847.	175.	.092	24.76	1.609D
AC-228	1937.84	968.97	201.	515.	.271	5.87	1.612D
BI-212	2160.84	1080.50	144.	19.	.010	111.77	.697s
BI-214	2240.66	1120.43	194.	498.	.262	7.17	1.653
BI-214	2309.13	1154.67	217.	81.	.043	39.27	1.004s
CO-60	2344.43	1172.33	113.	17.	.009	107.14	.745s
BI-214	2476.10	1238.19	272.	246.	.130	17.19	1.888
BI-214	2561.63	1280.97	218.	56.	.029	60.92	.942s
CO-60	2664.67	1332.50	95.	19.	.010	102.80	.402s
BI-214	2755.57	1377.98	136.	172.	.090	16.31	1.928
BI-214	2802.60	1401.50	348.	51.	.027	53.47	1.906D
BI-214	2815.55	1407.98	134.	114.	.060	17.19	1.911D
K-40	2921.43	1460.94	138.	3336.	1.757	1.91	2.073
BI-214	3018.82	1509.66	76.	75.	.039	26.08	1.530
AC-228	3178.29	1589.43	96.	128.	.067	20.33	1.949s
BI-212	3240.12	1620.36	59.	61.	.032	31.43	.623s
BI-214	3323.06	1661.86	49.	47.	.025	28.88	1.150s
BI-214	3458.00	1729.36	22.	138.	.073	12.23	1.874
BI-214	3528.49	1764.63	41.	543.	.286	5.43	2.091
BI-214	3748.67	1874.78	13.	2.	.001	261.54	.355s

s Peak fails shape tests.
D Peak area deconvoluted.


GammaVision – DD4CAIS.SPC [Drydock 4 Grid A-5, Southwest Corner of Caisson]
File
Calibrate
Calculate
Analyze
Library
Services
ROI
Display
Display
Det.#
Buffer
Horz: 4096
Vert
FS= LOG
Log
Auto
Pulse Ht. Analysis
Started: 16:46:28
12-Sep-94
Real: 1916.92
Live: 1899.22
Dead: %
ROI
Del
Peak
Info
Ins
Library
Marker: 216 = 107.98keV 659Cnts
© EG&G ORTEC
16:22:25
Wed 14-Sep-94

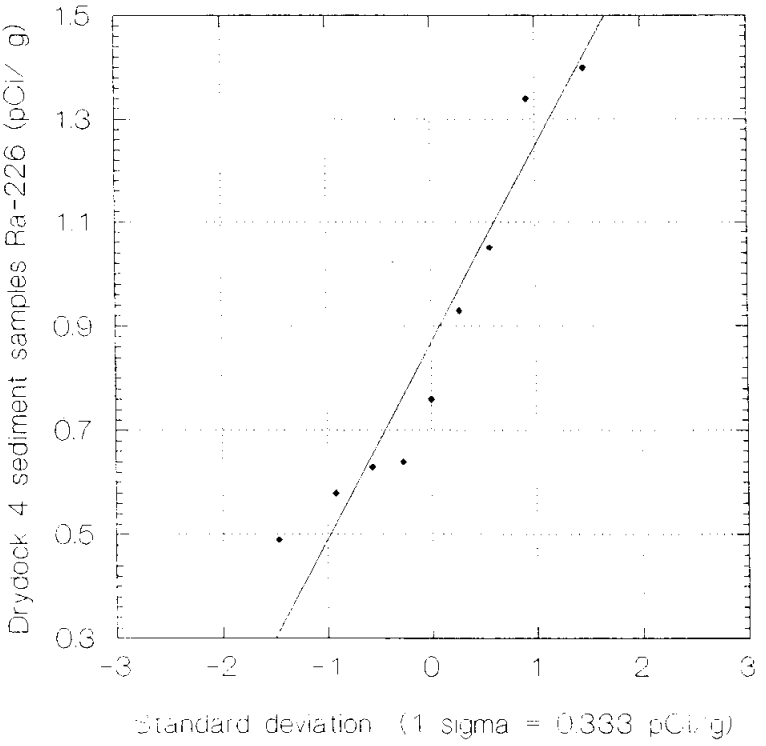

GammaVision – DD4CAIS.SPC [Drydock 4 Grid A-5, Southwest Corner of Caisson]
File
Calibrate
Calculate
Analyze
Library
Services
ROI
Display
70.83 Hg-203 3.52%
72.87 Hg-203 6.40%
82.50 Hg-203 2.24%
88.04 Cd-109 3.79%
122.07 Co-57 85.60%
136.43 Co-57 10.60%
165.85 Ce-139 80.00%
255.04 Sn-113 2.07%
279.17 Hg-203 81.50%
391.71 Sn-113 64.17%
661.62 Cs-137 84.62%
898.02 Y-88 94.00%
Display
Det.#
Buffer
Horz: 512
Vert
FS= 1024
Log
Auto
Pulse Ht. Analysis
Started: 16:46:28
12-Sep-94
Real: 1916.92
Live: 1899.22
Dead: %
ROI
Del
Peak
Info
Ins
Library
Marker: 1323 = 661.41keV 33Cnts
© EG&G ORTEC
16:28:44
Wed 14-Sep-94


GammaVision – MCB 9 [Drydock 4 Grid A-5, Southwest Corner of Caisson]
File
Calibrate
Calculate
Analyze
Library
Services
ROI
Display
MXGAMST.LIB
122.07 Co-57 85.60%
136.43 Co-57 10.60%
165.85 Ce-139 80.00%
255.04 Sn-113 2.07%
279.17 Hg-203 81.50%
391.71 Sn-113 64.17%
661.62 Cs-137 84.62%
898.02 Y-88 94.00%
1173.23 Co-60 99.86%
1332.51 Co-60 99.98%
1836.01 Y-88 99.36%
Display
Det.#
Buffer
Horz: 1024
Vert
FS= 256
Log
Auto
Pulse Ht. Analysis
Started: 16:46:28
12-Sep-94
Real: 1916.92
Live: 1899.22
Dead: %
ROI
Del
Peak
Info
Ins
Library
Marker: 2347 = 1173.33keV 21Cnts
© EG&G ORTEC
16:33:17
Wed 14-Sep-94

APPENDIX C

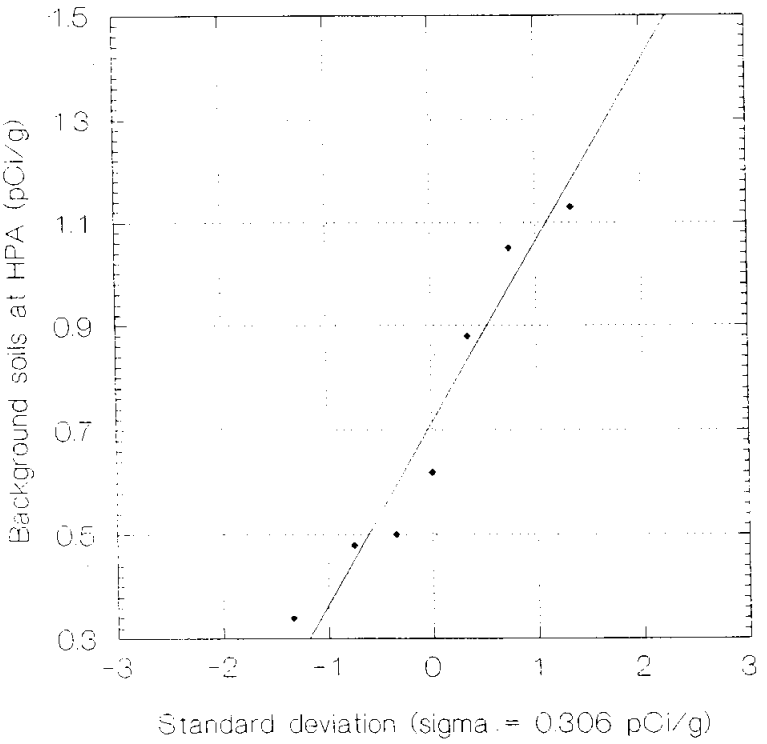
PROBABILITY PLOTS AND STATISTICAL ANALYSIS OF BACKGROUND ^{226}Ra SOIL CONCENTRATIONS FROM SCRS AND DRYDOCK 4 SURVEY

Concentration of radium-226 in Drydock 4 sediment



	RADIUM
N OF CASES	9
MINIMUM	0.490
MAXIMUM	1.400
RANGE	0.910
MEAN	0.869
STANDARD DEV	0.333
MEDIAN	0.760

Concentration of radium-226 in background soils at HPA



	BKRA226
N OF CASES	7
MINIMUM	0.340
MAXIMUM	1.130
RANGE	0.790
MEAN	0.714
STANDARD DEV	0.306
MEDIAN	0.620