North Carolina State University

Nuclear Reactor Program
Department of Nuclear Engineering

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31 August 1993

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: **NCSU PULSTAR Annual Report**
Docket No. 50-297

Dear Sir:

In compliance with Section 6.7.5 of the North Carolina State University PULSTAR Technical Specifications, our Nuclear Reactor Program staff has prepared the attached Annual Report for the period 01 July 1992 through 30 June 1993. Please feel free to contact Mr. Perez at 515-4602 if you have any questions or comments.

Sincerely,

Pedro B. Perez
Associate Director
Nuclear Reactor Program

Charles W. Mayo
Director, Nuclear Reactor Program
Engineering

Donald J. Dudziak
Head, Department of Nuclear

PBP/CWM:sb
copy w/attachments:

Director of Regulatory Operations, Region II
U. S. Nuclear Regulatory Commission

Dr. Frederick J. Fuller, Chairman
Radiation Protection Committee

Dr. James A. Mulholland, Chairman
Reactor Safeguards Advisory Group

Dr. Tildon H. Glisson, Interim Dean
College of Engineering

Mr. Stephen J. Bilyj
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Environmental Health and Safety Center

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1/1

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

For the Period: 01 July 1992 - 30 June 1993

The following report is submitted in accordance with Section 6.7.5 of the PULSTAR Technical Specifications:

6.7.5.a Brief Summary

(1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

a.	Teaching and Short Courses	134.5	hours
b.	Faculty and Graduate Student Research	766.0	
c.	Neutron Activation Analysis	1,257.0	
d.	Beam Tube Facilities	15.2	
e.	Nuclear Training (Utilities)	334.7	
f.	PULSTAR Reactor Training	33.1	
g.	Reactor Cal/Measurements & Surveillance	104.0	
h.	Reactor Health Physics Surveillance	13.2	
i.	Reactor Sharing	7.0	
	TOTAL	2,664.7	hours
	Same reporting period 1991-1992	2,716.6	hours

A cross section of experiments performed in the reactor include:

a. Neutron Activation Analysis of filters, animal tissue, bone, protein solutions, hair, sediments/soil, rain/river water, vegetation, wood pulp, dyes, paper, electronic components, fibers, glass, plastics, resins, quartz, coal, fly ash, graphite, steel, etc.
b. Reactor thermal power measurements for teaching laboratories.
c. Neutron diffusion length measurements in graphite.
d. Neutron Radiography of B_4C absorber rods and carbon cloth.
e. Prompt gamma analysis of silicon wafers.
e. Neutron fluence and spectral measurements.
f. Excess reactivity measurements using a beryllium reflector.
g. Excess reactivity measurements replacing eight original fuel assemblies with new fuel.
h. Transmutation of silicon for semiconductor research.

(2) Changes in Performance Characteristics Related to Reactor Safety:

None

(3) Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has revealed no significant nor unexpected trends in reactor systems performance during this report period.

6.7.5.b Total Energy Output:

798.4 Megawatt·hours 33.3 Megawatt·days

Pulse Operations:

None

Reactor was Critical:

1,051.9 hours

Cumulative Total Energy Output since Initial Criticality:

18,464.9 Megawatt·hours 739.4 Megawatt·days

6.7.5.c Number of Emergency and Unscheduled Shutdowns:

Unscheduled Shutdowns - 7 total

(1) Suspended object in pool fell on thermal column extension.
(2) Unable to transfer to Intermediate Range (2).
(3) Loss of secondary cooling.
(4) Irradiation facility malfunction.
(5) Estimated criticality calculation error.
(6) Improper instrumentation response.

Inadvertent SCRAMs - 8 total

(7) Operator error - 4
(8) Spurious signals - 3
(9) Manual SCRAM - 1

Explanation of (1) above:

A epoxy test specimen suspended along the East wall of the pool settled on the thermal column extension near the core when its string broke.

Explanation of (2) above:

The Intermediate Range compensation voltage was set too high. This prevented observing proper overlap between the Source Range and the Intermediate Range Channels during a routine startup. The voltage was properly set and the reactor run was continued.

Explanation of (3) above:

Building water was secured for maintenance by Physical Plant personnel. During that time the cooling tower make-up water was supplied by a 5/8 inch hose. The reactor operator received a high temperature alarm from the secondary side of the heat exchanger. The make-up flow rate was adjusted and the reactor run was continued.

Explanation of (4) above:

The rotational exposure ports irradiation facility drive gear disengaged. The gear train was realigned and the facility was returned to service.

Explanation of (5) above:

The reactor operator did not allow for the reactivity gain associated with the replacement graphite reflectors and criticality occurred just below the Estimated Criticality Position.

Explanation of (6) above:

The Linear Power Channel recorder responded too slowly to power changes. The recorder feedback gain was adjusted for the proper response and the reactor run was continued.

Explanation of (7) above:

Improper operation of the Linear Level Power Channel range switch by Nuclear Power Plant trainees (NT) and PULSTAR Reactor trainees (PRT) (4).

Explanation of (8) above:

Set point drift of a pressure-electric switch occurred in the Primary Coolant Flow Measuring Channel (3).

Explanation of (9) above:

Burlington Engineering Laboratories was evacuated by fire alarm because of a natural gas leak in the South Wing.

6.7.5.d Major Maintenance Operations:

None

6.7.5.e Changes in Facility, Procedures, Tests, and Experiments:

1. Design Changes

   (a) DC 91-4 installed a new radiation monitoring equipment in the PULSTAR Reactor Building.

2. Procedure Changes

   (a) PC 17-93 was Revision 9 to the PULSTAR Operations Manual. This document change was required by the relocation of a liquid nitrogen tank away from the reactor bridge and added new requirements to the PULSTAR Bay contamination surveys.

   (b) PC 26-93 is Revision 10 to the PULSTAR Operations Manual. This revision is awaiting approval by the Radiation Protection Committee.

   (c) In all, twenty-two procedures have been revised (most just minor editorial changes) and one new procedure was written to verify the reactivity worths of all the control rods (gang). Most have already been reviewed and approved.

6.7.5.f Radioactive Effluents:

Liquid Waste (summarized by quarters)

1. Radioactivity released during the reporting period:

Period	(a) No. of Batches	(b) Total μCi	(c) Tot. Vol. Liters	(d) Diluent Liters	(e) Tritium μCi
01 Jul - 30 Sep 92	1	88.69	6.84×10^3	2.14×10^5	52.66
01 Oct - 31 Dec 92	3	131.38	1.25×10^4	3.15×10^5	102.29
01 Jan - 31 Mar 93	0	-	-	-	-
01 Apr - 30 Jun 93	1	56.10	5.46×10^3	1.36×10^5	55.4

(f) 276.90 μCi total activity released during this reporting period.

(g) 210.35 μCi of tritium were released during this reporting period.

2. Identification of Fission and Activation Products:

The gross alpha-beta-gamma activity of the batches in (a) above were less than 4×10^{-5} μCi/ml (the maximum specific activity given in Health Physics Procedure HP 20-2). An isotopic analysis of these batches indicated only background activity.

3. Disposition of liquid effluent not releasable to Sanitary Sewer System:

All batches of 1(a) above when diluted by campus water (2.80×10^6 liters; the minimum daily campus intake) resulted in activity considerably less than 4×10^{-7} μCi/ml (10 CFR 20 limit). Therefore, all batches were released to the sanitary sewer system.

Gaseous Waste (summarized monthly)

1. Radioactivity discharged during the reporting period (in Curies) are as follows:

   (a) Gases:

Year	Period	Total Time In Hours	Curies
1992	22 Jun - 22 Jul	743.81	0.904
	22 Jul - 20 Aug	695.42	0.323
	20 Aug - 21 Sep	792.58	0.412
	21 Sep - 20 Oct	719.25	0.369
	20 Oct - 18 Nov	722.16	0.265
	18 Nov - 17 Dec	722.25	0.311
	17 Dec - 15 Jan	713.25	0.317
1993	15 Jan - 12 Feb	696.25	0.331
	12 Feb - 12 Mar	677.33	0.283
	12 Mar - 07 Apr	646.75	0.218
	07 Apr - 06 May	723.16	0.427
	06 May - 01 Jun	615.50	0.182
	01 Jun - 01 Jul	720.00	0.269
	Totals	8,577.71	4.611

   (b) Particulates with a half-life of greater than eight days:

   Filters from the particulate monitoring channel were analyzed upon removal and again the following week. There was no particulate activity ((b) above) indicated on any filter during this reporting period.

2. Gases and particulates discharged during this reporting period:

   (a) Gases:

   The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 1.46×10^{-8} μCi/cc.

(b) Particulates:

See gaseous waste 1(b) above.

Solid Waste from Reactor

1. Total volume of solid waste - 0.2 m^3 (7 $ft.^3$)
2. Total activity of solid waste - 0.009 mCi
3. Dates of shipments and disposal:

30 March 1993 Chem-Nuclear Systems Inc. (CNSI)

6.7.5.g Personnel Radiation Exposure Report[1]

Twenty three members of the faculty and staff were monitored for external radiation exposure during the reporting period. Fourteen of the twenty-three received measurable exposure which ranged from 0.010 to 0.080 Rem. Total exposure for the faculty and staff was 0.430 Rem.

Approximately 252 film badges were issued to graduate students and temporary staff, 209 for short courses, and 341 film badges were issued for visitors. No significant radiation exposures were reported. The majority of these exposures were in the "no measurable exposure" range.

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[1]Compiled and prepared by the Radiation Protection Office.

6.7.5.h Summary of Radiation and Contamination Surveys Within the Facility

Neither the radiation nor the contamination surveys indicated any trend or shift of data from past experience or surveys.

6.7.5.i Description of Environmental Surveys Outside of the Facility

See Attachment A

NOTE: The July to September 1992 data in Table 6.1 of the Environmental Report for Attachment A was lost by the contractor. The PULSTAR records for gaseous effluent were carefully examined for that same reporting period. The data displayed predictable levels well within the historical release rates.

RADIATION PROTECTION OFFICE
NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT
FOR THE PERIOD
JULY 1, 1992 - JUNE 30, 1993

RALTON J. HARRIS
ENVIRONMENTAL HEALTH PHYSICIST

TABLE OF CONTENTS

1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

1) Providing information that assesses the adequacy of the protection of the university community and the public-at-large;

2) Meeting requirements of regulatory agencies;

3) Verifying radionuclide containment in the reactor facility;

4) Meeting legal liability obligations; and

5) Providing public assurance and acceptance.

2. AIR MONITORING (TABLES 2.1, 2.2, AND 2.3; FIGURES 2a THRU 2e)

Figures 2a thru 2e show bar graphs of gross beta activity (fCi/cubic meter vs. week number). The highest gross beta activity observed was 23.6 fCi m^{-3} and the yearly campus average was 14.8 fCi m^{-3}. Missing data for the Clark station (week #51 - 06/15/93 to 06/22/93) is due to an electric motor malfunction. Missing data for the Riddick station (weeks #7 & 8 - 08/11/92 to 08/25/92) is due to two separate electric power outages. Missing data for the Withers station (week #17 - 10/21/92 to 10/27/92) is due to roofing work which prevented access to the sampling station.

Table 2. 2. lists LLD values for several gamma emitters which would be indicative of fission product activity. LLD values, for the period 03/03/93 to 06/29/93, are increased by a factor of approximately 2 to 3 for the radionuclides in Table 2.2. This is due to a planned reduction in the sampling rate in an attempt to minimize the chances of pump malfunctions. These increased LLD values are far below any action level. No gamma activity due to any of these radionuclides was detected.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

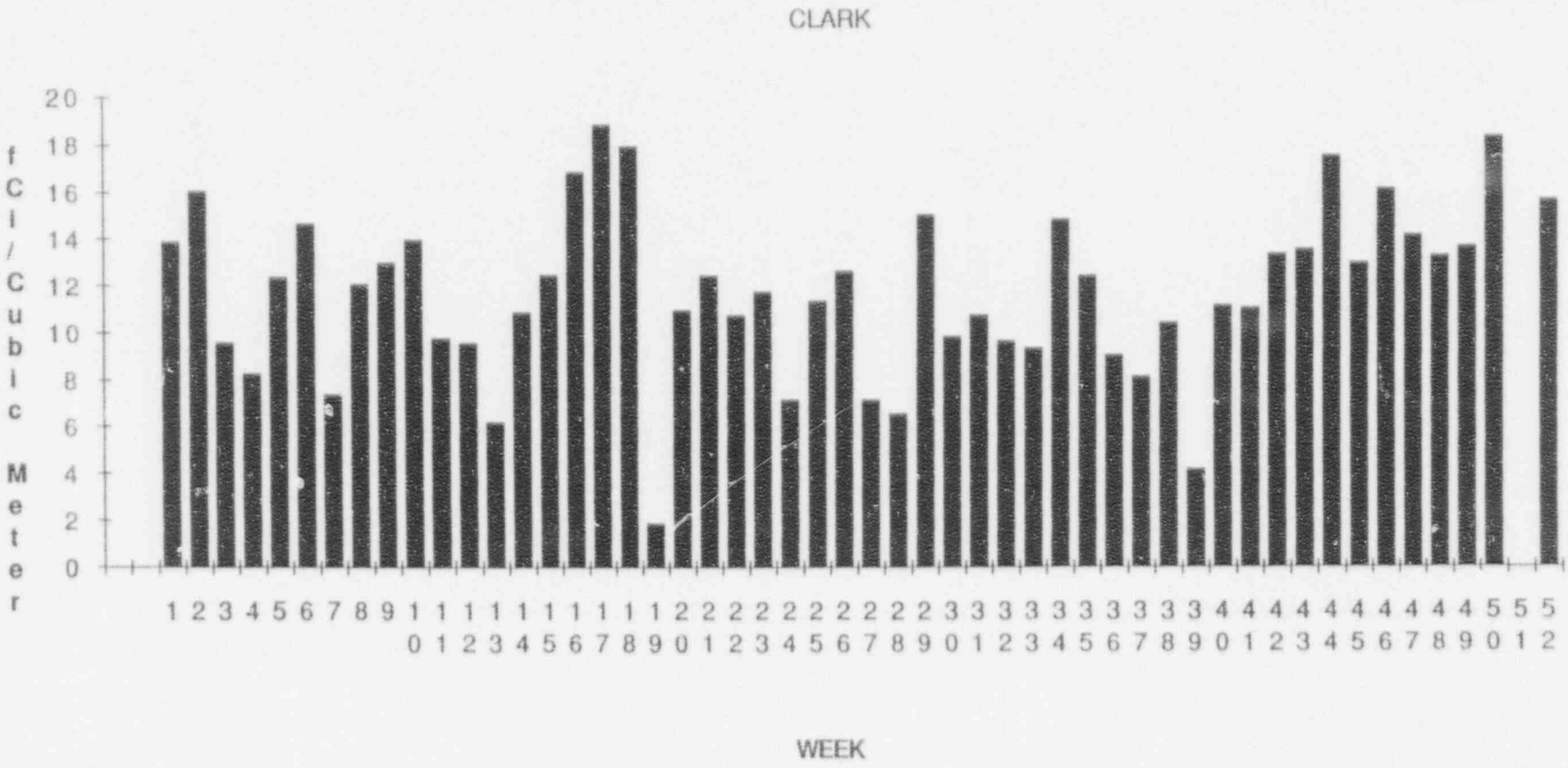
SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6

[1]DIRECTION-DIRECTION FROM REACTOR STACK
[2]DISTANCE-DISTANCE FROM REACTOR STACK
[3]ELEVATION-ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

FIGURE 2a

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD=1 fCi/CUBIC M



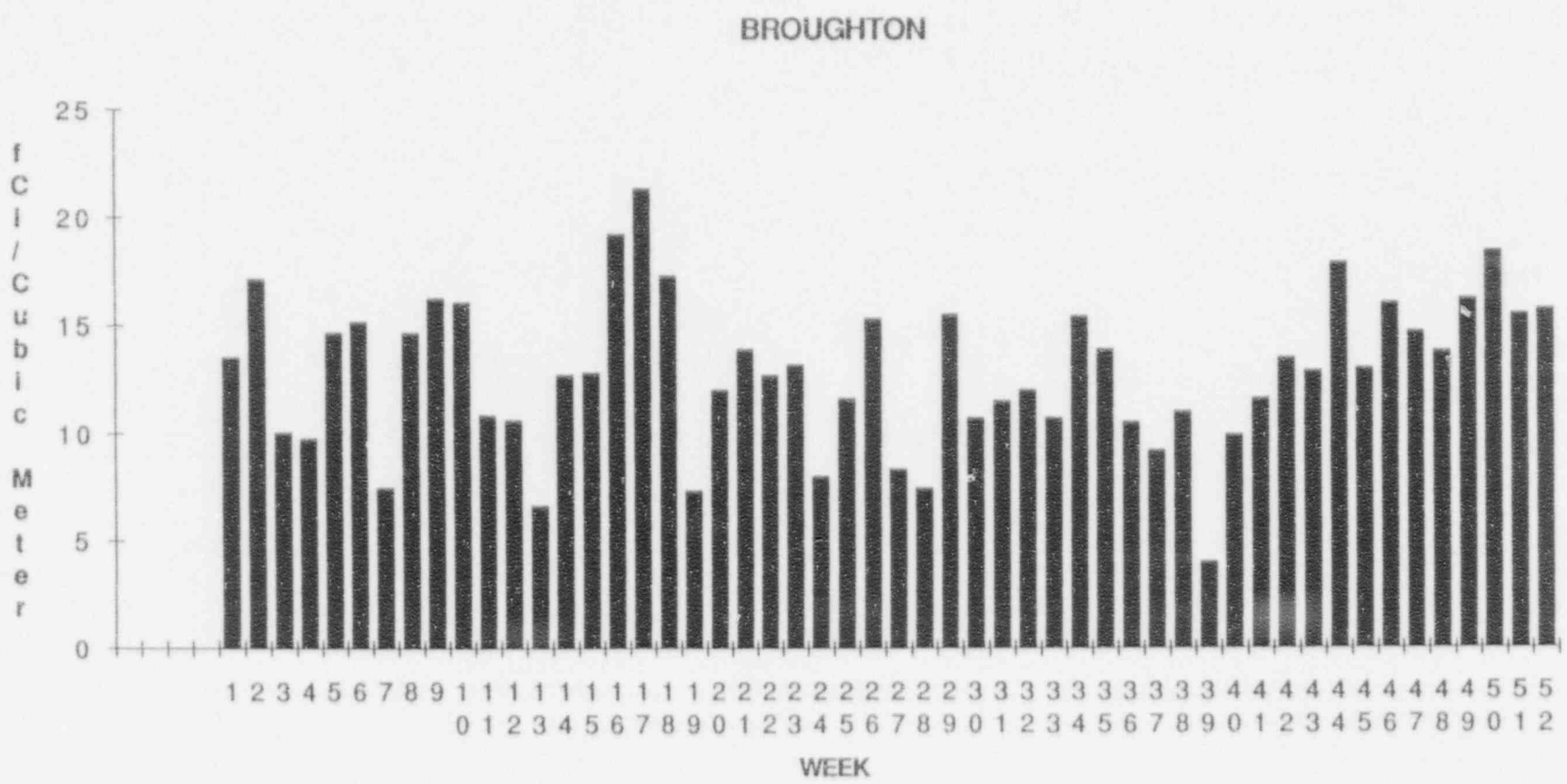
WEEK NUMBER FROM JULY 01, 1992 THROUGH JUNE 29, 1993

JULY 01 BEGINS AT WEEK #1

FIGURE 2b

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD~1 fCi/CUBIC M

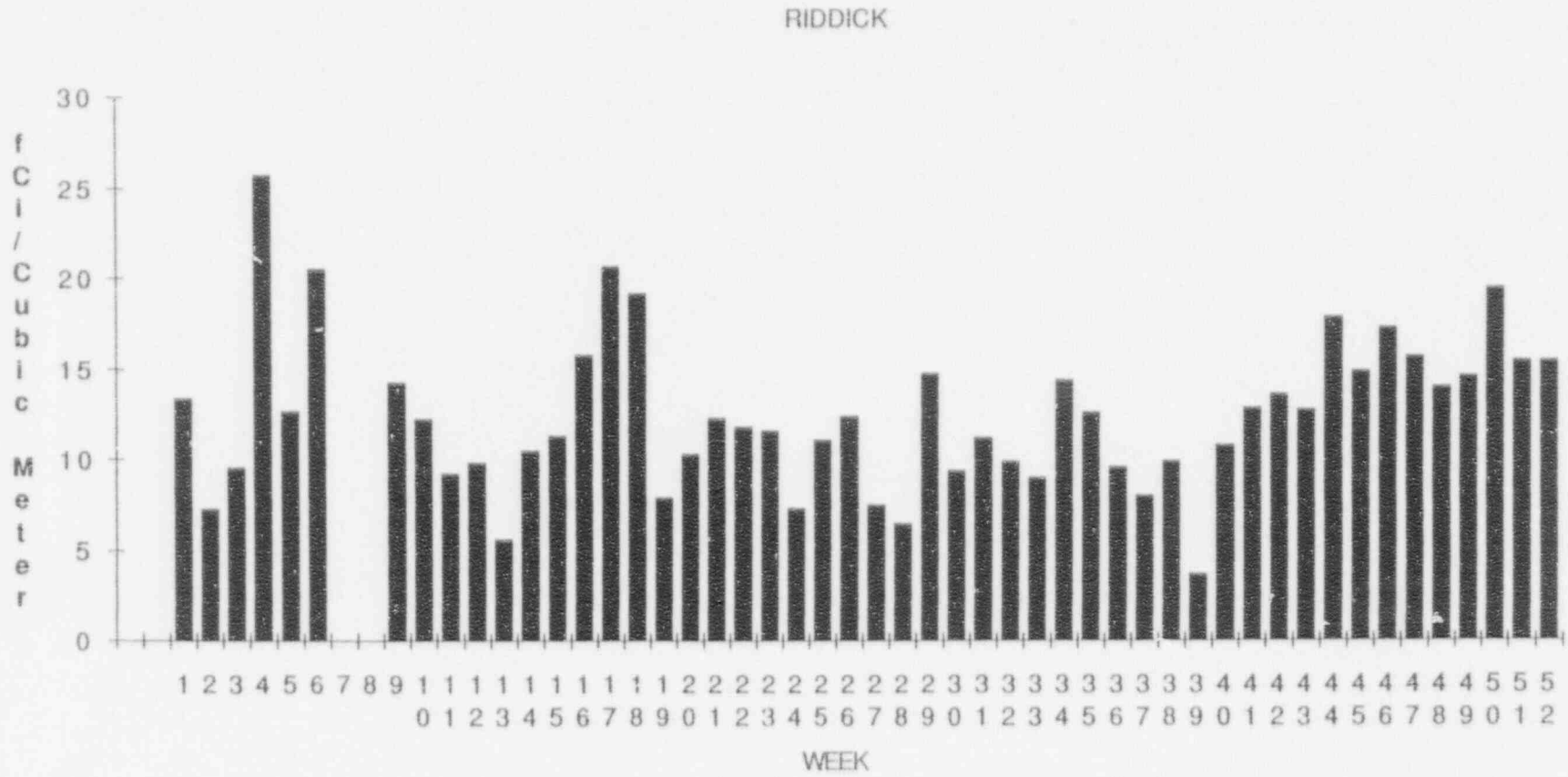


WEEK NUMBER FROM JULY 01, 1992 THROUGH JUNE 29, 1993
JULY 01 BEGINS AT WEEK #1

FIGURE 2c

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD~1 fCi/CUBIC M

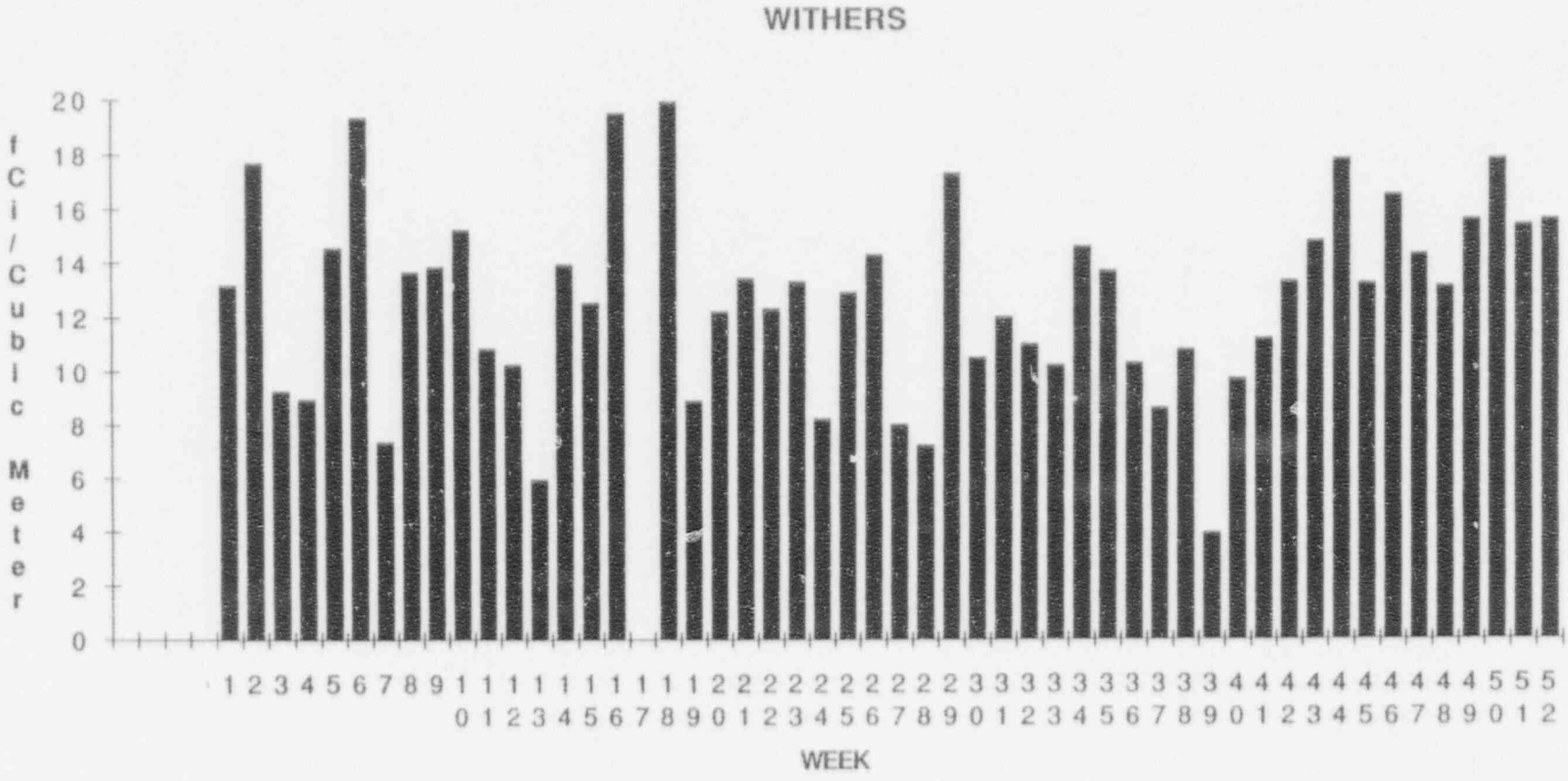


WEEK NUMBER FROM JULY 01, 1992 THROUGH JUNE 29, 1993
JULY 01 BEGINS AT WEEK #1

FIGURE 2d

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD 1 fCi/CUBIC M



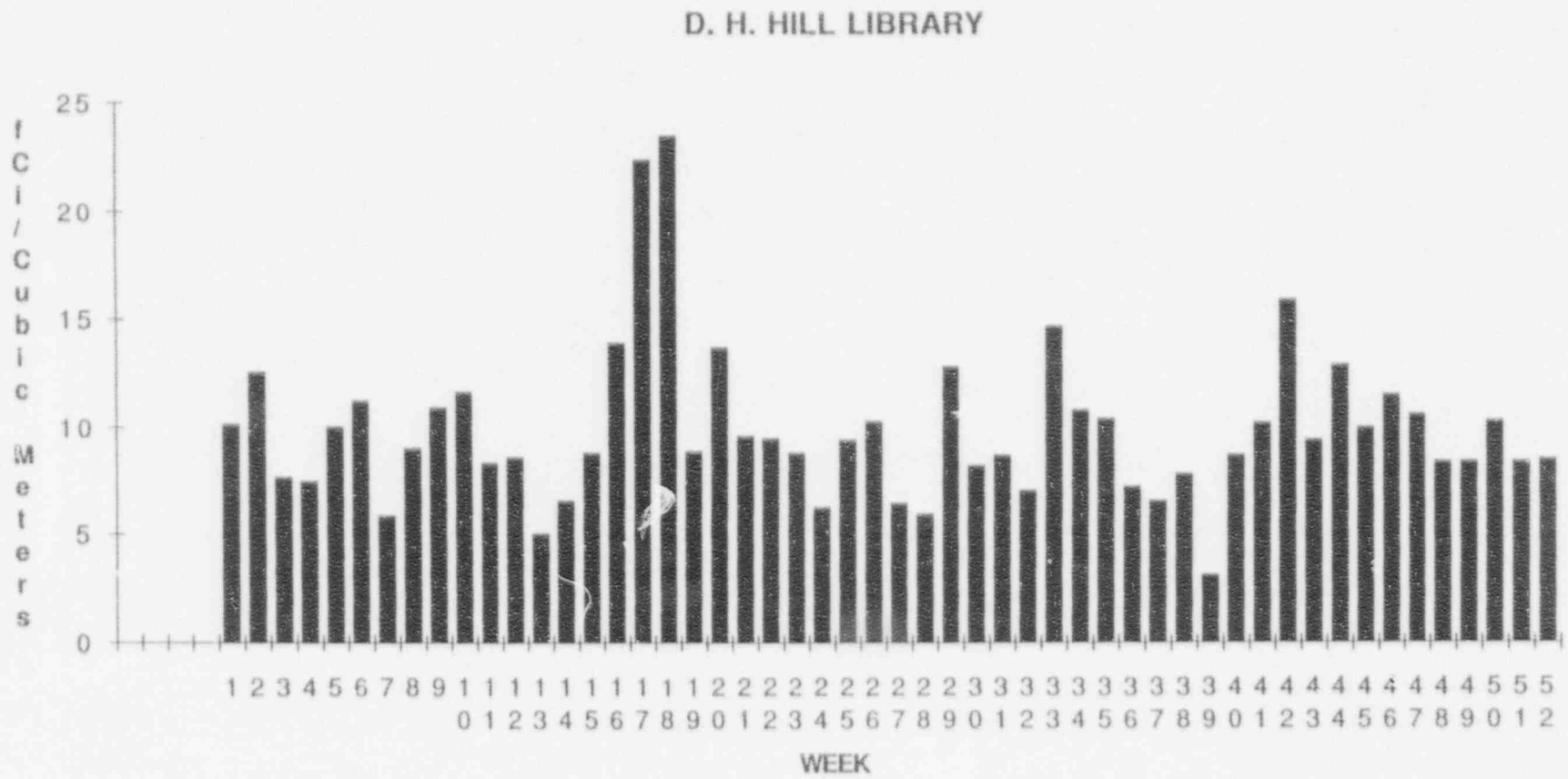
WEEK NUMBER FROM JULY 01, 1992 THROUGH JUNE 29, 1993

JULY 01 BEGINS AT WEEK #1

FIGURE 2e

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT=1000 fCi/CUBIC M
ALERT LEVEL=500 fCi/CUBIC M
LLD~1 fCi/CUBIC M



WEEK NUMBER FROM JULY 01, 1992 THROUGH JUNE 29, 1993

JULY 01 BEGINS AT WEEK #1

TABLE 2.2

TABLE 2.2 AERIALLY TRANSPORTED GAMMA ACTIVITY				(ICi m E-3)					
					NUCLIDES				
SAMPLING PERIOD 1992	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
07/01 - 07/07	0.08	0.15	0.14	0.25	0.15	1.00	0.11	0.2	0.61
07/07 - 07/15	0.07	0.12	0.11	0.20	0.11	0.85	0.18	0.15	0.53
07/15 - 07/22	0.08	0.14	0.12	0.21	0.11	0.93	0.12	0.15	0.56
07/22 - 07/28	0.08	0.16	0.13	0.23	0.11	0.96	0.12	0.15	0.64
07/28 - 08/04	0.07	0.13	0.10	0.19	0.10	0.91	0.10	0.14	0.57
08/04 - 08/11	0.09	0.17	0.14	0.23	0.12	1.1	0.12	0.16	0.69
08/11 - 08/18	0.11	0.21	0.20	0.27	0.15	1.4	0.16	0.18	0.82
08/18 - 08/25	0.14	0.24	0.22	0.30	0.19	1.7	0.19	0.24	1.1
08/25 - 09/01	0.09	0.16	0.21	0.21	0.12	1.1	0.12	0.17	0.70
09/01 - 09/08	0.12	0.21	0.19	0.27	0.16	1.3	0.16	0.21	0.94
09/08 - 09/15	0.07	0.12	0.10	0.18	0.10	0.88	0.10	0.13	0.56
09/15 - 09/22	0.11	0.19	0.17	0.25	0.15	1.3	0.15	0.19	0.85
09/22 - 09/29	0.09	0.16	0.15	0.21	0.13	1.1	0.13	0.17	0.72
09/29 - 10/06	0.07	0.13	0.11	0.19	0.10	0.91	0.12	0.14	0.57
10/06 - 10/13	0.07	0.13	0.12	0.18	0.11	0.96	0.11	0.14	0.59
10/13 - 10/21	0.07	0.13	0.11	0.19	0.10	0.89	0.12	0.13	0.55
10/21 - 10/27	0.12	0.23	0.22	0.34	0.20	1.7	0.21	0.24	0.96
10/27 - 11/03	0.10	0.21	0.15	0.28	0.15	1.3	0.17	0.19	0.74
11/03 - 11/09	0.11	0.20	0.18	0.25	0.14	1.3	0.16	0.19	0.81
11/09 - 11/17	0.08	0.14	0.13	0.24	0.13	1.1	0.12	0.18	0.62
11/17 - 11/24	0.09	0.16	0.14	0.22	0.12	1.2	0.15	0.15	0.65
11/24 - 12/01	0.07	0.14	0.10	0.19	0.10	0.96	0.13	0.14	0.56
12/01 - 12/07	0.09	0.18	0.14	0.21	0.13	1.2	0.15	0.17	0.67
12/07 - 12/15	0.06	0.12	0.12	0.21	0.13	0.84	0.10	0.18	0.51
12/15 - 12/21	0.09	0.16	0.15	0.28	0.16	1.1	0.14	0.21	0.66
12/21 - 12/29	0.07	0.11	0.13	0.23	0.13	0.83	0.10	0.20	0.52

ALL DATA IN TABLE 2.2 ARE LLD VALUES.

TABLE 2.2 AERIALLY TRANSPORTED GAMMA ACTIVITY (fCi m E-3)									
					NUCLIDES				
SAMPLING PERIOD 1992-93	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
12/29 - 01/05	0.09	0.17	0.17	0.28	0.18	1.20	0.14	0.24	0.69
01/05 - 01/11	0.08	0.15	0.15	0.26	0.15	1.00	0.13	0.20	0.66
01/11 - 01/19	0.07	0.13	0.11	0.20	0.10	0.84	0.10	0.14	0.47
01/19 - 01/26	0.08	0.15	0.12	0.20	0.11	1.00	0.13	0.16	0.59
01/26 - 02/01	0.09	0.17	0.15	0.24	0.13	1.1	0.14	0.18	0.67
02/01 - 02/09	0.08	0.12	0.13	0.22	0.14	0.97	0.11	0.21	0.57
02/09 - 02/17	0.08	0.16	0.14	0.24	0.15	1.2	0.12	0.20	0.65
02/17 - 02/24	0.11	0.18	0.16	0.27	0.17	1.4	0.15	0.24	0.84
02/24 - 03/02	0.12	0.21	0.21	0.36	0.23	1.7	0.18	0.35	1.00
03/02 - 03/09	0.10	0.15	0.17	0.33	0.22	1.3	0.14	0.31	0.76
03/09 - 03/16	0.09	0.18	0.17	0.30	0.19	1.2	0.14	0.27	0.74
03/16 - 03/23	0.11	0.18	0.16	0.28	0.19	1.4	0.16	0.27	0.79
03/23 - 03/30	0.09	0.16	0.13	0.24	0.16	1.2	0.13	0.19	0.68
03/30 - 04/07	0.16	0.33	0.25	0.46	0.26	2.2	0.26	0.37	1.3
04/07 - 04/13	0.25	0.41	0.36	0.64	0.39	3.4	0.37	0.49	1.9
04/13 - 04/20	0.19	0.36	0.28	0.48	0.27	2.5	0.28	0.35	1.5
04/20 - 04/27	0.18	0.34	0.26	0.44	0.26	2.2	0.25	0.32	1.3
04/27 - 05/04	0.18	0.32	0.48	0.76	0.55	2.5	0.29	0.87	1.60
05/04 - 05/11	0.17	0.34	0.43	0.73	0.56	2.6	0.28	0.76	1.5
05/11 - 05/18	0.17	0.33	0.37	0.64	0.46	2.5	0.26	0.65	1.4
05/18 - 05/25	0.16	0.33	0.33	0.54	0.41	2.3	0.27	0.59	1.4
05/25 - 06/02	0.11	0.20	0.21	0.34	0.21	1.7	0.18	0.28	0.97
06/02 - 06/08	0.14	0.23	0.25	0.40	0.24	2.00	0.21	0.31	1.2
06/08 - 06/15	0.13	0.27	0.23	0.39	0.26	1.9	0.21	0.34	1.1
06/15 - 06/22	0.20	0.38	0.32	0.48	0.33	2.8	0.33	0.38	1.4
06/22 - 06/29	0.22	0.43	0.33	0.52	0.34	3.00	0.35	0.43	1.9

ALL DATA IN TABLE 2.2 ARE LLD VALUES.

TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi m^{-3})

NUCLIDE	REGULATORY LIMIT	ALERT LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS ALPHA	20	10	4
GROSS BETA	1000	500	100
Cs-137	5×10^5	10	2
Ce-144	2×10^5	100	0
Ru-106	2×10^5	30	0
I-131	1×10^5	10	0

Reference: Environmental Radiation Surveillance Report 1986-88, State of N.C. Radiation Protection Section

3. MILK (TABLE 3.1)

Milk samples are collected each month from the Campus Creamery, the Lake Wheeler Road Dairy and the Randleigh Dairy Farm.

The FDA's Preventive Action Guide (PAG) for I-131 is 1.5 X 10^4 pCi/liter for infants. All analyses during this period show activities at least three (3) orders of magnitude below the PAG.

The analyses are performed in duplicate and the higher value is reported in each case.

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TABLE 3.1 I-131 IN COWS' MILK (pCi liter^{-1} ± 1 σ) LLD ~ 3 pCi liter^{-1}

	pCi liter^{-1}		
DATE	CAMPUS CREAMERY	LAKE WHEELER	RANDLEIGH
JULY 1992	≤ 2.0	≤ 2.0	≤ 2.0
AUGUST 1992	≤ 2.0	≤ 2.0	≤ 2.0
SEPTEMBER 1992	≤ 2.0	≤ 2.0	≤ 2.0
OCTOBER 1992	≤ 2.0	≤ 2.0	< 2.0
NOVEMBER 1992	≤ 2.0	≤ 2.0	≤ 2.0
DECEMBER 1992	≤ 2.0	≤ 2.0	≤ 2.0
JANUARY 1993	≤ 3.0	≤ 3.0	≤ 3.0
FEBRUARY 1993	≤ 3.0	≤ 3.0	≤ 3.0
MARCH 1993	≤ 3.0	≤ 3.0	≤ 3.0
APRIL 1993	≤ 3.0	≤ 3.0	≤ 3.0
MAY 1993	≤ 3.0	≤ 3.0	≤ 3.0
JUNE 1993	≤ 3.0	≤ 3.0	≤ 3.0

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON) and exits (OFF) the campus. The LLD values for gross alpha and beta activities are ~ 0.4 pCi liter^{-1} and ~ 0.4 pCi liter^{-1}, respectively. For gross alpha activity the Alert Level is 5 pCi liter^{-1} and the Regulatory Limit is 15 pCi liter^{-1}. For gross beta activity the Alert Level is 12.5 pCi liter^{-1} and the Regulatory Limit is 50 pCi liter^{-1}. Samples with gross alpha or beta activities exceeding these Alert Levels would require gamma analysis to identify the radionuclides present. The LLD values in Table 4.2 are for the second quarter of 1993.

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TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi liter^{-1} $\pm$ 2 σ)

***LLD $_{\alpha}$ ~ 0.4 pCi liter^{-1} LLD$_{\beta}$ ~ 0.4 pCi liter^{-1}**

		pCi liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 1992	ON	< 0.3	1.4 ± 0.3
	OFF	< 0.3	< 0.4
FOURTH QUARTER 1992	ON	< 0.3	< 0.4
	OFF	< 0.3	1.7 ± 0.4
FIRST QUARTER 1993	ON	< 0.4	1.6 ± 0.4
	OFF	< 0.4	0.44 ± 0.3
SECOND QUARTER 1993	ON	< 0.4	1.7 ± 0.4
	OFF	< 0.4	< 0.5

*LLD VALUES ARE DETERMINED QUARTERLY

TABLE 4.2 LOWER LIMITS OF DETECTION FOR SEVERAL GAMMA EMITTERS IN SURFACE WATER FROM NCSU ERSL ANALYSIS

NUCLIDE	LLD (pCi liter^{-1})
Co-60	0.4
Zn-65	0.7
Cs-137	0.3
Cs-134	0.4
Sr-85	0.4
Ru-103	0.3
Ru-106	3.0
Nb-95	0.4
Zr-95	0.5

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1993

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5. VEGETATION (TABLE 5.1 and 5.2)

Table 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. The reported activities are all below the Alert Level of 20 pCi gram $^{-1}$. Table 5.2 lists LLD values for several gamma emitters. No gamma activity due to any of these radionuclides has been observed in campus vegetation. The beta and gamma activities are reported as pCi per gram of green vegetation.

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TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION *LLD ~ 0.5 pCi g^{-1}

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
DECEMBER 1992	NORTH CAMPUS	2.4 ± 0.1
DECEMBER 1992	SOUTH CAMPUS	4.0 ± 0.2
DECEMBER 1992	EAST CAMPUS	2.8 ± 0.1
DECEMBER 1992	WEST CAMPUS	2.4 ± 0.1
APRIL 1993	NORTH CAMPUS	2.4 ± 0.1
APRIL 1993	SOUTH CAMPUS	3.8 ± 0.2
APRIL 1993	EAST CAMPUS	2.3 ± 0.1
APRIL 1993	WEST CAMPUS	2.3 ± 0.1

*LLD values are determined semiannually

Table 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

NUCLIDE	LLD (pCi gram^{-1})*
Co-60	0.01
Zn-65	0.02
Cs-137	0.01
Cs-134	0.01
Sr-85	0.01
Ru-103	0.01
Nb-95	0.01
Zr-95	0.02

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1993

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Teledyne Isotopes for determination of ambient gamma exposures. The dosimeters are $CaSO_4$ doped with dysprosium and have a manufacturer-stated sensitivity of 0.5 ± 0.15 mR (90% C.L.). Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and also at the top of the PULSTAR Reactor stack. A control station is located in 214 David Clark Laboratories. Table 6.1 gives the data for these seven (7) sampling locations. Data for the period 07/13/92 to 09/30/92 was lost by the contractor and is not available.

The observed exposures are those expected to be produced by background radiations in this area of North Carolina. The data of Table 6.1 agrees well with the state-wide average exposure rate of ~ 18 - 20 mR per quarter year.

TABLE 6.1	ENVIRONMENTAL TLD EXPOSURES (mR/QUARTER YEAR ± 2σ)							
DATE		WITHERS	RIDDICK	BROUGHTON	LIBRARY	DAVID CLARK	PULSTAR STACK	CONTROL
* 04/07/92 -	07/13/92	16.8 ± 2.3	22.6 ± 2.2	17.0 ± 1.8	20.8 ± 2.1	13.5 ± 1.2	12.3 ± 3.2	15.8 ± 2.2
** 07/13/92 -	09/30/92			CONTRACTOR LOST DATA				
09/30/92 -	12/30/92	4.5 ± 1.0	24.7 ± 5.0	17.1 ± 1.8	19.1 ± 3.3	13.6 ± 0.8	11.6 ± 0.9	15.0 ± 1.6
***12/30/92 -	04/08/93	4.7 ± 0.4	7.0 ± 0.6	4.8 ± 0.6	5.6 ± 0.3	4.1 ± 0.7	3.6 ± 0.3	4.7 ± 0.4
04/07/93 -	06/27/93			DATA NOT YET AVAILABLE FOR THESE DATES				

* THIS DATA WAS UNAVAILABLE FOR INCLUSION IN THE 1991-92 REPORT.

** THIS DATA WAS LOST BY THE CONTRACTOR.

***THE DATA FOR THE PERIOD 12/30/92 TO 04/08/93 WAS REPORTED BY THE CONTRACTOR IN UNITS OF mR/MONTH.

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory of the Radiation Protection Office has participated in the U. S. EPA Environmental Laboratory Intercomparison Studies Program during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques. The results of the intercomparison studies are given in Table 7.1 a-g. All samples are analyzed in triplicate and reported as an average value with an experimental sigma (1s).

Appendix 1 gives an explanation of the quantities listed in the tables and an example calculation.

TABLE 7.1a GROSS ALPHA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY - 28 AUGUST 1992

The known value for gross alpha activity is 30.0 pCi/filter with an expected laboratory precision of 6.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

ALPHA

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
CA	29.0	28.0	29.0	0.58	0.074	28.67	-0.48	-0.29

STATISTICAL SUMMARY OF 189 PARTICIPANTS

Statistic	Respondents	Non-outliers
Mean	31.25	Grand Avg 30.87
Std. Dev.	6.10	5.27
Variance	37.20	27.77
% Coef. of Var.	19.52	17.07
% deviation of mean from known value	4.17	2.92
Norm. dev. of mean from known value	0.21	0.17
Median	30.00	30.00
% deviation of median from known value	0.00	0.00
Norm. dev. of median from known value	0.00	0.00

TABLE 7.1b GROSS BETA A\ ITY AIR FILTER - INTERCOMPARISON STUDY - 28 AUGUST 1992

The known value for gross beta activity is 69.0 pCi/filter with an expected laboratory precision of 10.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

BETA

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)(known)	
QA	75.0	75.0	73.0	1.15	0.118	74.33	0.41	0.92

STATISTICAL SUMMARY OF 189 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	72.79	Grand Avg	71.98
Std. Dev.	11.62		6.43
Variance	134.92		41.38
% Coef. of Var.	15.96		8.94
% deviation of mean from known value	5.49		4.32
Norm. dev. of mean from known value	0.33		0.46
Median	72.00		71.83
% deviation of median from known value	4.35		4.11
Norm. dev. of median from known value	0.26		0.44

TABLE 7.1c ^{137}Cs ACTIVITY AIR FILTER INTERCOMPARISON STUDY - 28 AUGUST 1992

The known value for Cesium-137 activity is 18.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

137 Cs

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)(known)	
QA	17.00	17.00	17.00	0.00	0.000	17.00	-0.93	-0.35

STATISTICAL SUMMARY OF 189 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	235.16	Grand Avg	19.68
Std. Dev.	1954.83		2.94
Variance	3821351.09		8.62
% Coef. of Var.	831.29		14.92
% deviation of mean from known value	1206.42		9.32
Norm. dev. of mean from known value	0.11		0.57
Median	19.67		19.67
% deviation of median from known value	9.26		9.26
Norm. dev. of median from known value	0.00		0.57

TABLE 7.1d GROSS ALPHA ACTIVITY IN WATER - INTERCOMPARISON STUDY -18 SEPTEMBER 1992

The known value for gross alpha activity is 45.0 pCi/liter with an expected laboratory precision of 11.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS ALPHA

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)(known)	
QA	43.0	45.0	43.0	1.15	0.107	43.67	1.14	-0.21

STATISTICAL SUMMARY OF 219 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	37.75	Grand Avg	36.46
Std. Dev.	15.78		11.52
Variance	248.99		136.73
% Coef. of Var.	41.80		31.59
% deviation of mean from known value	- 16.12		- 18.97
Norm. dev. of mean from known value	- 0.46		- 0.74
Median	35.00		34.67
% deviation of median from known value	- 22.22		- 22.96
Norm. dev. of median from known value	- 0.63		- 0.90

TABLE 7.1e GROSS BETA ACTIVITY IN WATER - INTERCOMPARISON STUDY
-18 SEPTEMBER 1992

The known value for gross beta activity is 50.0 pCi/liter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS BETA

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
CA	48.0	49.0	48.0	0.577	0.118	48.33	-0.097	-0.579

STATISTICAL SUMMARY OF 219 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	59.38	Grand Avg	48.61
Std. Dev.	114.45		9.14
Variance	13098.83		83.51
% Coef. of Var.	192.75		18.80
% deviation of mean from known value	18.76		-2.78
Norm. dev. of mean from known value	0.08		-0.15
Median	49.00		48.67
% deviation of median from known value	-2.00		-2.67
Norm. dev. of median from known value	-0.01		-0.15

TABLE 7.1f TRITIUM IN WATER - INTERCOMPARISON STUDY - 23 OCTOBER 1992

The known value for tritium activity is 5962.0 pCi/liter with an expected laboratory precision of 596.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{3}H

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)(known)	
CA	4402.0	4379.0	3936.0	262.66	0.462	4239.00	-5.11	-5.01

STATISTICAL SUMMARY OF 172 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	6201.84	Grand Avg	5997.40
Std. Dev.	4667.63		565.83
Variance	21786750.49		320164.99
% Coef. of Var.	75.26		9.43
% deviation of mean from known value	4.02		0.59
Norm. dev. of mean from known value	0.05		0.06
Median	5953.33		5961.67
% deviation of median from known value	- 0.15		0.01
Norm. dev. of median from known value	0.00		0.00

TABLE 7.1g TRITIUM IN WATER - INTERCOMPARISON STUDY - 19 JUNE 1992*

The known value for tritium activity is 2125.0 pCi/liter with an expected laboratory precision of 347.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{3}H

Lab	Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)(known)	
CA	2468.0	2564.0	2539.0	49.81	0.163	2523.67	2.11	1.99

STATISTICAL SUMMARY OF 179 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	2188.82	Grand Avg	2101.61
Std. Dev.	814.49		221.34
Variance	663389.97		48993.22
% Coef. of Var.	37.21		10.53
% deviation of mean from known value	3.00		-1.10
Norm. dev. of mean from known value	0.08		-0.11
Median	2094.33		2090.00
% deviation of median from known value	-1.44		-1.65
Norm. dev. of median from known value	-0.04		-0.16

*These results have been included in this report as they were received after submission of the 1991-92 report.

8. CONCLUSIONS

The data obtained during this period do not show any fission product activities. The observed environmental radioactivity is due primarily to radon progeny, primordial radionuclides (e.g., K-40) and those radionuclides (e.g., Be-7) which originate in the upper atmosphere as the result of cosmic ray interactions. These facts justify the conclusion that the PULSTAR Reactor facility continues to operate safely and does not release fission product materials into the environment.

9. ACKNOWLEDGMENTS

This office is greatly indebted to Mr. Bill Crocker for his untiring efforts in collecting the environmental samples. Great appreciation is also expressed to Mr. Thomas Brackin for his work in repairing the air samplers.

The graphs in this report are available due to the assistance of Mr. Worth Bowman, and the entire arrangement and typing are due to the excellent efforts of Mrs. Ginger Davis.

APPENDIX 1

The vertical columns in Tables 7 are identified as columns 1-8 from left to right.

Column 1: Laboratory identification code (e.g., QA).

Columns 2, 3, 4: Laboratory results given in triplicate.

Column 5: Standard deviation (1s) of the experimental results.

Column 6: Normalized range value in "mean range + standard error of the range".

Column 7: Average value of the triplicate analysis.

Column 8: Normalized deviation from the grand average value of all laboratories expressed in σ_m units.

Column 9: Normalized deviation from the known value expressed in σ_m units.

The following example calculation gives a set of data, the mean value, the experimental sigma, and the range. These statistics provide measures of the central tendency and dispersion of the data.

The normalized range is computed by first finding mean range, R, the control limit, CL, and the standard error of the range, σ_R. The normalized range measures the dispersion of the data (precision) in such a form that control charts may be used. Control charts allow one to readily compare past analytical performance with present performance. In the example, the normalized range equals 0.3 which is less than 3 which is the upper control level. The precision of the results is acceptable.

The normalized deviation is calculated by computing the deviation and the standard error of the mean, σ_m. The normalized deviation allows one to measure central tendency (accuracy) readily through the use of control charts. Trends in analytical accuracy can be determined in this manner. For this example, the normalized deviation is -0.7 which falls between +2 and -2 which are the upper and lower warning levels. The accuracy of the data is acceptable.

Finally, the experimental error of all laboratories, the grand average, and the normalized deviation from the grand average are calculated in order to ascertain the performance of all the laboratories as a group. Any bias in methodology or instrumentation may be indicated by these results.

EXAMPLE CALCULATIONS

Experimental data:

Known value = μ = 3273 pCi ^3H/liter urine on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

Laboratory	Sample	Result
D	x_1	3060 pCi/liter
D	x_2	3060 pCi/liter
D	x_3	3240 pCi/liter

Mean = $\bar{x}$

$$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

where N = number of results = 3

Experimental sigma = s

$$s = \sqrt{\frac{\sum_{i=1}^{N} (x_i)^2 - \frac{\left(\sum_{i-1}^{N} x_i\right)^2}{N}}{N - 1}}$$

$$s = \sqrt{\frac{(3060)^2 + (3060)^2 + (3240)^2 - \frac{(3060 + 3060 + 3240)^2}{3}}{2}}$$

s = 103.9 pCi/liter

Range = r

r = | maximum result - minimum result |

r = | 3240 - 3060| = 180 pCi/liter

for $r \leq R$, $x = 0$

then $r = w\overline{R} + x\sigma_R = w\overline{R}$

or $w = \dfrac{r}{\overline{R}}$

therefore $w + x = w + 0 \quad \dfrac{r}{\overline{R}}$

since $r < \overline{R}$, $(180 < 604.4)$

$$w + x = \frac{180}{604.4}$$

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

$$D = \overline{x} - \mu$$

$$= 3120 - 3273$$

$$D = -153 \text{ pCi/liter}$$

Standard error of the mean = σ_m

$$\sigma_m = \frac{\sigma}{\sqrt{N}}$$

$$= \frac{357}{\sqrt{3}}$$

$$\sigma_m = 206.1 \text{ pCi/liter}$$

$$ND = \frac{D}{\sigma_m}$$

$$= \frac{-153}{206.1}$$

$$ND = -0.7$$

Control limit = CL

$CL = (\mu \pm 3\sigma_m)$

Warning Limit = WL

$WL = (\mu \pm 2\sigma_m)$

Range Analysis (RNG ANLY)*

Mean range = $\overline{R}$

$\overline{R} = d_2\sigma$ where d_2** = 1.693 for N = 3

$= (1.693)\ (357)$

$\overline{R} = 604.4$ pCi/liter

Control limit = CL

$CL = \overline{R} + 3\sigma_R$

$= D_4\overline{R}$ where D_4** = 2.575 for N = 3

$= (2.575)\ (604.4)$

$CL = 1556$ pCi/liter

Standard error of the range = σ_R

$\sigma_R = (R + 3\sigma_R - \overline{R}) \div 3$

$= (D_4\overline{R} - \overline{R}) \div 3$

$= (1556 - 604.4) \div 3$

$\sigma_R = 317.2$ pCi/liter

Let range = $r = w\overline{R} + x\sigma_R = 180$ pCi/liter

Define normalized range = $w + x$

for $r > \overline{R}$, $w = 1$

then $r = w\overline{R} + x\sigma_R = \overline{R} + x\sigma_R$

or $x = \dfrac{r - \overline{R}}{\sigma_R}$

therefore $w + x = 1 + x = 1 + \dfrac{r - \overline{R}}{\sigma_R}$

*Rosenstein, M., and A. S. Goldin, "Statistical Techniques for Quality Control of Environmental Radioassay," AQCS Report Stat-1, U.S. Department of Health Education and Welfare, PHS, November 1964.

**From table "Factors for Computing Control Limits," Handbook of Tables for Probability and Statistics, 2nd Edition, The Chemical Rubber Co., Cleveland, Ohio, 1968, p. 454.

Experimental sigma (all laboratories) = s_t (See Figure 2)

$$s_t = \sqrt{\frac{\sum_{i=1}^{N} (x_i)^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N}}{N - 1}}$$

$$= \sqrt{\frac{162639133 \quad \frac{(49345)^2}{15}}{14}}$$

$$s_t = 149 \text{ pCi/liter}$$

Grand average = GA

$$GA = \frac{\sum_{i=1}^{N} x_i}{N}$$

$$= \frac{49345}{15}$$

$$GA = 3290 \text{ pCi/liter}$$

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

$$D' = \bar{x} - GA$$

$$= 3120 - 3290$$

$$D' = -170 \text{ pCi/liter}$$

$$ND' = \frac{D'}{\sigma_m}$$

$$= \frac{-170}{206.1}$$

$$ND' = -0.8$$