North Carolina State University

Nuclear Reactor Program
Department of Nuclear Engineering

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25 August 1995

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 1994 through 30 June 1995. Please feel free to contact Mr. Perez at (919) 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

Donald J. Dudziak
Head, Department of Nuclear Engineering

PBP/CWM:sb
copy w/attachments:

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U. S. Nuclear Regulatory Commission

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Radiation Protection Committee

Chairman
Reactor Safety and Audit Committee

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DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 July 1994 - 30 June 1995

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

6.7.5.a Brief Summary

Full power reactor operations resumed in May 1995 after repairs to the primary cooling system were completed. Repairs consisted of building a subterranean concrete vault enclosing the new nitrogen-16 delay tank and previously buried primary cooling system pipes.

(1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

a.	Teaching and Short Courses	127.8	hours
b.	Faculty and Graduate Student Research	252.6	
c.	Isotope Production	84.9	
d.	Neutron Activation Analysis	938.4	
e.	Beam Tube Facilities	0.0	
f.	Nuclear Training (Utilities)	30.7	
g.	PULSTAR Reactor Training	8.5	
h.	Reactor Cal/Measurements & Surveillance	71.8	
i.	Reactor Health Physics Surveillance	6.5	
j.	Reactor Sharing	5.3	
	TOTAL	1,526.5	hours
	Same reporting period 1993-1994	1,936.3	hours

A cross section of experiments performed in the reactor:

a. Neutron Activation Analysis of filters, tissue, bone, protein solutions, hair, sediments/soil, rain/river water, vegetation, wood pulp, dyes, paper, electronic components, fibers, plastics, resins, coal, fly ash, graphite.
b. Reactor thermal power measurements for teaching laboratories.
c. Neutron diffusion length measurements in graphite and scattering from SiO_2 in the thermal column facility.
d. Determination of coolant flow rates using nitrogen-16 gamma.
e. Prompt gamma analysis of boron.
f. Neutron fluence and spectral measurements.
g. Transmutation of silicon for semiconductor research.
h. Radiation damage effects on scintillation fibers and photodiodes.

(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 or unexpected trends in reactor systems performance during this report period.

6.7.5.b Total Energy Output:

121.3 Megawatt · hours 5.1 Megawatt · days

Pulse Operations:

None

Reactor was Critical:

618.2 hours

Cumulative Total Energy Output Since Initial Criticality:

18,943.9 Megawatt · hours 789.3 Megawatt · days

6.7.5.c Number of Emergency and Unscheduled Shutdowns:

Unscheduled Shutdowns - 2 total

(1) Linear Channel Overpower Reverse (0.11 MW)
(2) Pneumatic Transfer sample failed to return

Inadvertent SCRAMs - 5 total

(3) Off-site power interruption - 1
(4) Spurious signals - 4

Explanation of (1) above:

The Linear Power Channel was indicating 85 kW when an electrical noise spike drove the channel to 110 kW causing an Overpower Reverse. The Linear Channel Reverse trips at 73.3% of any range. See 6.7.5.d below.

Explanation of (2) above:

An end cap on a polyethylene shuttle used in the pneumatic system cracked, separated and subsequently jammed the sample in the tube at the core terminus. A retrieval tool was fabricated and the shuttle and sample were recovered.

Explanation of (3) above:

self-explanatory

Explanation of (4) above:

A trip circuit in the Intermediate Range Channel and the Safety Channel will generate a SCRAM upon loss of forced primary flow or if the safety flapper valve opens when power is above 15 percent. Recently the PULSTAR Reactor has been operating up to 10 percent power in natural convection cooling mode with the safety flapper valve open in accordance with Section 3.9 of the PULSTAR Operations Manual. In this mode of operation, electrical noise spikes generated within the console electrical system instantaneously exceeded the trip circuit setpoint and generated a SCRAM. This was verified by testing several combinations of console switch movements which caused a SCRAM signal to occur. The Intermediate Range Channel was tested or calibrated after

each occurrence and found to be operational. Reactor operational limits were reduced to 8.5% power to give greater margin between the actual power level and the trip circuit setpoint, which helped to limit the number of electrical spikes that could cause a SCRAM. Since initial criticality most reactor operations were conducted at or near full power. During that time these trip circuits were always in their enabled state and as long as forced primary flow was present and the safety flapper valve was shut, no SCRAM would occur. A new Intermediate Range instrument has been purchased and is undergoing acceptance testing.

6.7.5.d Major Maintenance Operations:

(1) Investigation of random noise spikes displayed on the Linear Power Channel recorder indicated that they were not being generated in the amplifier, high voltage power supplies or in the recorder, so the Linear Power Channel compensated ionization chamber (CIC) was replaced with a spare. After calibrations were performed the reactor was returned to operation.

(2) As part of the effort to repair the 0.7 gallon per hour primary system leak discovered in late 1993, the excavated N-16 Delay Tank was moved to the PULSTAR bay for testing. The tank was designed to hold 100 psig at 100 °F. Normal operating pressure is about 18 psig (static head) with temperatures ranging from 70 to 120 °F. The first test performed was similar to the PULSTAR triennial surveillance hydrostatic pressure drop test, which pressurizes the system to 60 psig and the pressure decrease is monitored (due to valves in the system) and check for leaks. The N-16 Delay Tank held pressure and no leaks were observed. The second test pressurized and maintained a hydrostatic pressure of 85 psig (approximately 5 times normal operating pressure). While checking the tank for leaks after reaching 85 psig, a metallic snap sound was heard and then a very small water stream was observed near one of the dished ends of the tank. After several unsuccessful repair attempts by an ASME certified welder, a new 600 gallon tank was fabricated to ASME Unfired Pressure Vessel Code and installed in the primary piping system. In addition to the repairs, a subterranean vault enclosing the formerly buried tank and primary piping was also constructed. After testing and performing all pending surveillance, the PULSTAR was returned to full power operation.

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

1. Design Changes

   (a) DC 94-2 authorized the construction of the subterranean piping vault.

   (b) DC 94-3 installed a differential pressure alarm monitoring reactor building negative pressure.

   (c) DC 95-1 authorized the installation of a new Source Range Monitor in the reactor console to replace the original instrument.

2. Procedure Changes

   (a) PC 3-95 was Revision 13 to the PULSTAR Operations Manual. This documented the changes the Startup Checklists required by the new subterranean vault.

   (b) A total of eight procedures have been revised (minor editorial changes) and fifteen new Health Physics calibrations procedures have been reviewed and approved by the Radiation Protection Committee.

6.7.5.f Radioactive Effluent:

A. Liquid Waste (summarized by quarters)

1. Radioactivity Released During the Reporting Period:

Period	(a) No. of Batches	(b) Total μCi	(c)[1] Tot. Vol. Liters	(d)[2] Diluent Liters	(e) Tritium μCi
01 Jul - 30 Sep 94	4	78	1.1E4	8.5E5	2
01 Oct - 31 Dec 94	3	13	9.4E3	2.0E4	16
01 Jan - 31 Mar 95	6	40	1.7E4	1.0E5	38
01 Apr - 30 Jun 95	2	32	6.8E3	2.0E4	29

(f) 163 μCi total activity released during this reporting period.

(g) 85 μCi of tritium were released during this reporting period.

2. Identification of Fission and Activation Products:

The gross beta-gamma activity of the batches in (a) above were less than 2×10^{-5} μCi/ml. Isotopic analyses of these batches indicated low levels of typical corrosion and activation products.

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 1×10^{-7} μCi/ml (10 CFR 20 limit). Therefore, all batches were released to the sanitary sewer system.

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[1]Increases in the total volume discharged from 01 Jan 95 to 31 Mar 95 were due to hydrostatic testing and draining of the N-16 Tank and primary coolant piping.

[2]Based on gross beta activity only. Tritium did not require further dilution.

B. Gaseous Waste (summarized monthly)

1. Radioactivity Discharged During the Reporting Period (in Curies) for:

(a) Gases:

Year	Period	Total Time In Hours	Curies
1994	01 Jul - 31 Jul	720	8.2E-2
	01 Aug - 31 Aug	744	1.0E-1
	01 Sep - 30 Sep	720	7.2E-2
	01 Oct - 31 Oct	744	8.7E-2
	01 Nov - 30 Nov	720	6.3E-2
	01 Dec - 31 Dec	744	7.2E-2
1995	01 Jan - 31 Jan	744	9.0E-2
	01 Feb - 28 Feb	672	7.3E-2
	01 Mar - 31 Mar	744	7.5E-2
	01 Apr - 30 Apr	720	1.8E-1
	01 May - 31 May	744	1.5E-1
	01 Jun - 30 Jun	720	2.0E-1
	Totals	8,760	1.25

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

Filters from the particulate monitoring channel were analyzed upon removal. There was no particulate activity indicated on any filter during this reporting period.

2. Gases and Particulates Discharged During this Reporting Period:

(a) Gases:
Total activity of argon-41 release was 1.25 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 8.3×10^{-9} μCi/cc. This is below the regulatory limit of 1×10^{-8} μCi/cc. (10 CFR 20 Appendix B)

(b) Particulates:
See gaseous waste 1.(b) above.

Solid Waste from Reactor

1. Total volume of solid waste - 29 ft^3 (0.8 m^3)

2. Total activity of solid waste - 1 mCi

3. Dates of shipments and disposal:

02 May 95	Chem-Nuclear Systems Inc. (CNSI) - 14 ft^3 (0.4 m^3)
--	In storage awaiting disposal - 15 ft^3 (0.4 m^3)

6.7.5.g Personnel Radiation Exposure Report[3]

Twenty-five members of the faculty and staff were monitored for external radiation exposure during the reporting period. Fourteen of the twenty-five received measurable exposure which ranged from 0.010 to 0.030 rem. Total person-rem for the faculty and staff was 0.180.

Approximately 53 film badges were issued to graduate students, temporary staff, short course participants, and visitors. Radiation exposures ranged to 0.030 rem. The majority of these exposures were in the "no measurable exposure" range.

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

Radiation and contamination surveys performed within the facility by the PULSTAR staff indicate:

- external radiation levels in most areas were < 0.5 mrem/h
- contamination levels in most areas were not detectable
- when contamination was detected, the area or item was confined or decontaminated
- external radiation levels were as expected

[3]Compiled and prepared by the Radiation Protection Division.

6.7.5.i Description of Environmental Surveys Outside of the Facility

See Attachment A prepared by the Radiation Protection Division of the Department of Environmental Health and Safety.

Perimeter surveys performed by the PULSTAR staff indicate:

- external radiation levels were at background levels for most areas (10 μrem/h)
- contamination levels were not detectable
- Net external radiation levels ranged up to 20 μrem/h in some areas when the reactor was operating at power. However, external radiation levels were at background levels in routinely occupied spaces.

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT
OF
ENVIRONMENTAL HEALTH AND SAFETY

RADIATION PROTECTION DIVISION

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 1994 - JUNE 30, 1995

ATTACHMENT A

PREPARED BY

RALTON J. HARRIS
AND
JERILIN E. PAITH

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) Provide 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 THROUGH 2e)

Figures 2a through 2e show bar graphs of gross beta activity (fCi/cubic meter vs. week number). The highest gross beta activity observed was 31.5 $fCim^{-3}$ at the Riddick station during the week of 09-20-94. The annual campus average was 16.2 $fCim^{-3}$. Instances of missing data for a monitor station are due to pump and electric motor malfunctions, and power outages during building repairs in Riddick Hall.

Table 2.2 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

Table 2.3 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

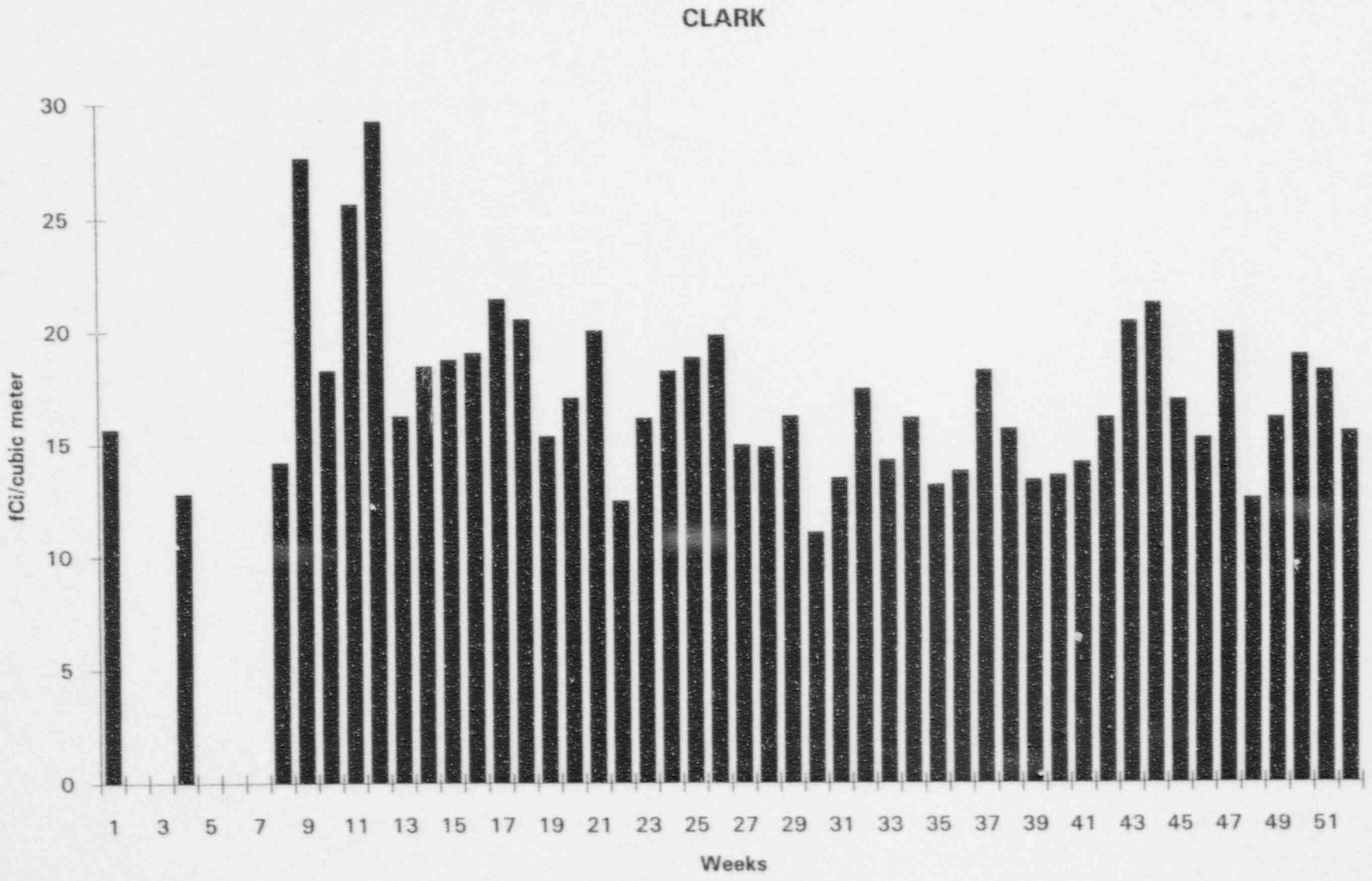
SITE	DIRECTION	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6

[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/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



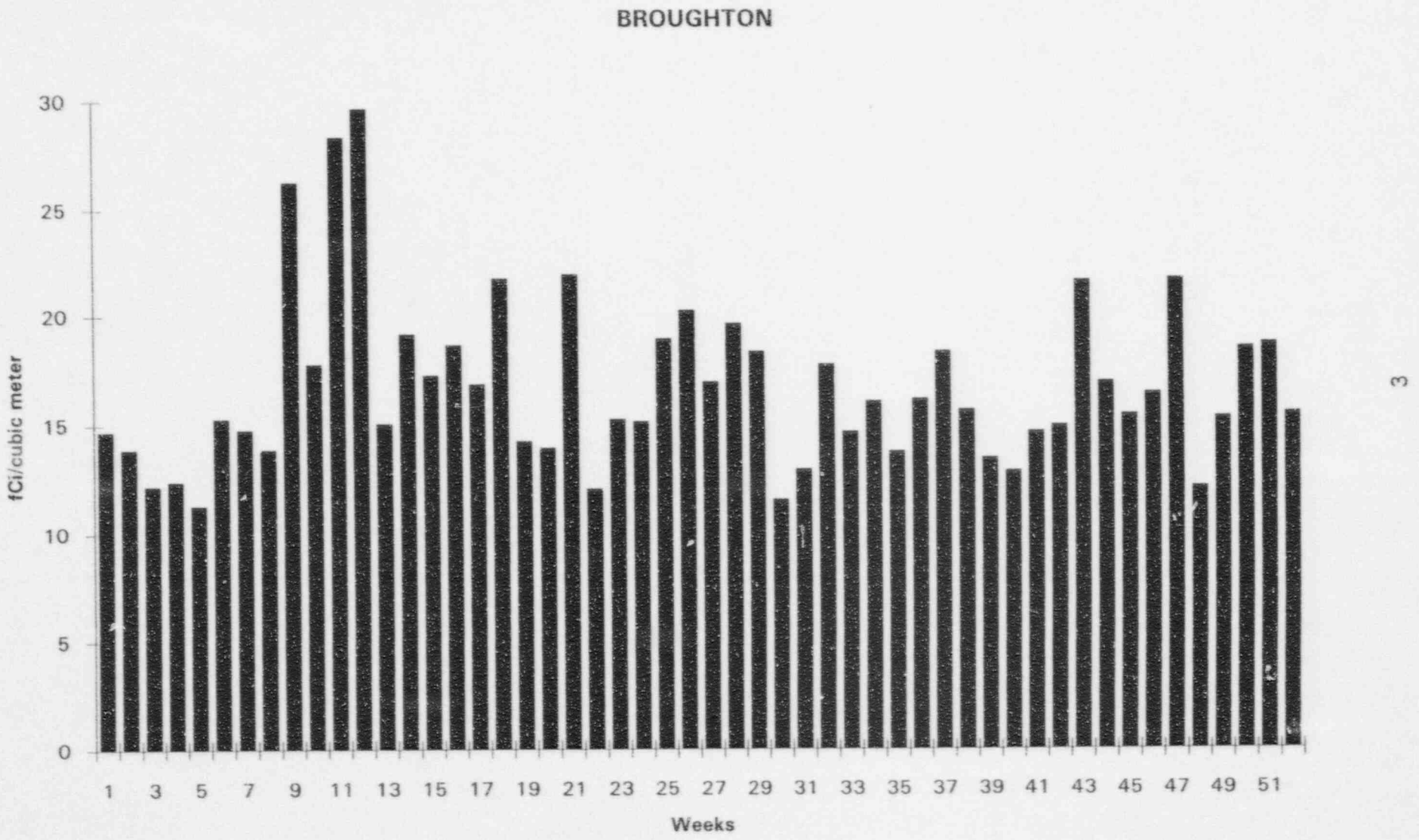
WEEK NUMBER FROM JUNE 28, 1994 THROUGH JUNE 29, 1995

JUNE 28 BEGINS AT WEEK #1

FIGURE 2b

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



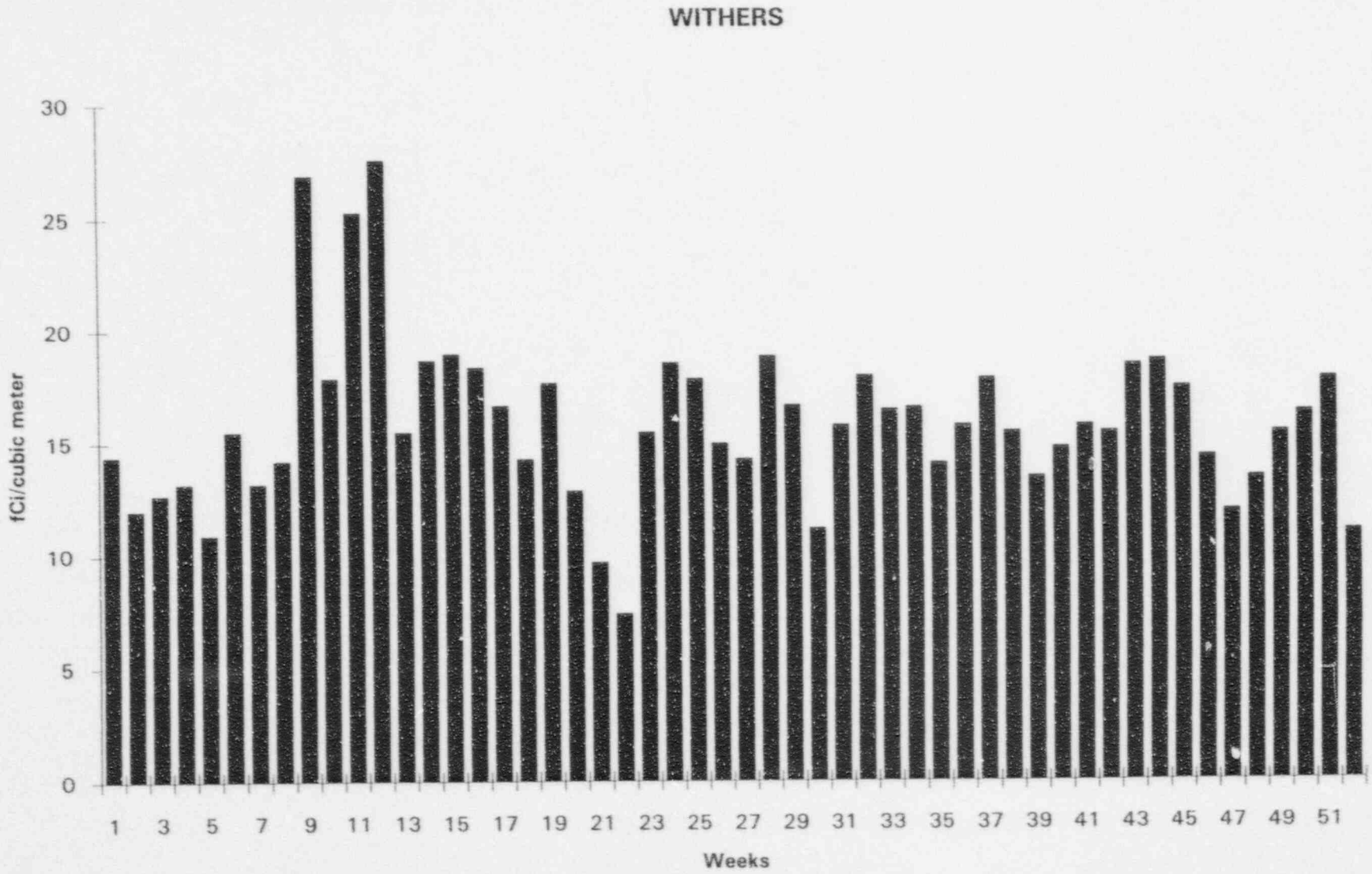
WEEK NUMBER FROM JUNE 28, 1994 THROUGH JUNE 29, 1995

JUNE 28 BEGINS AT WEEK #1

FIGURE 2c

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



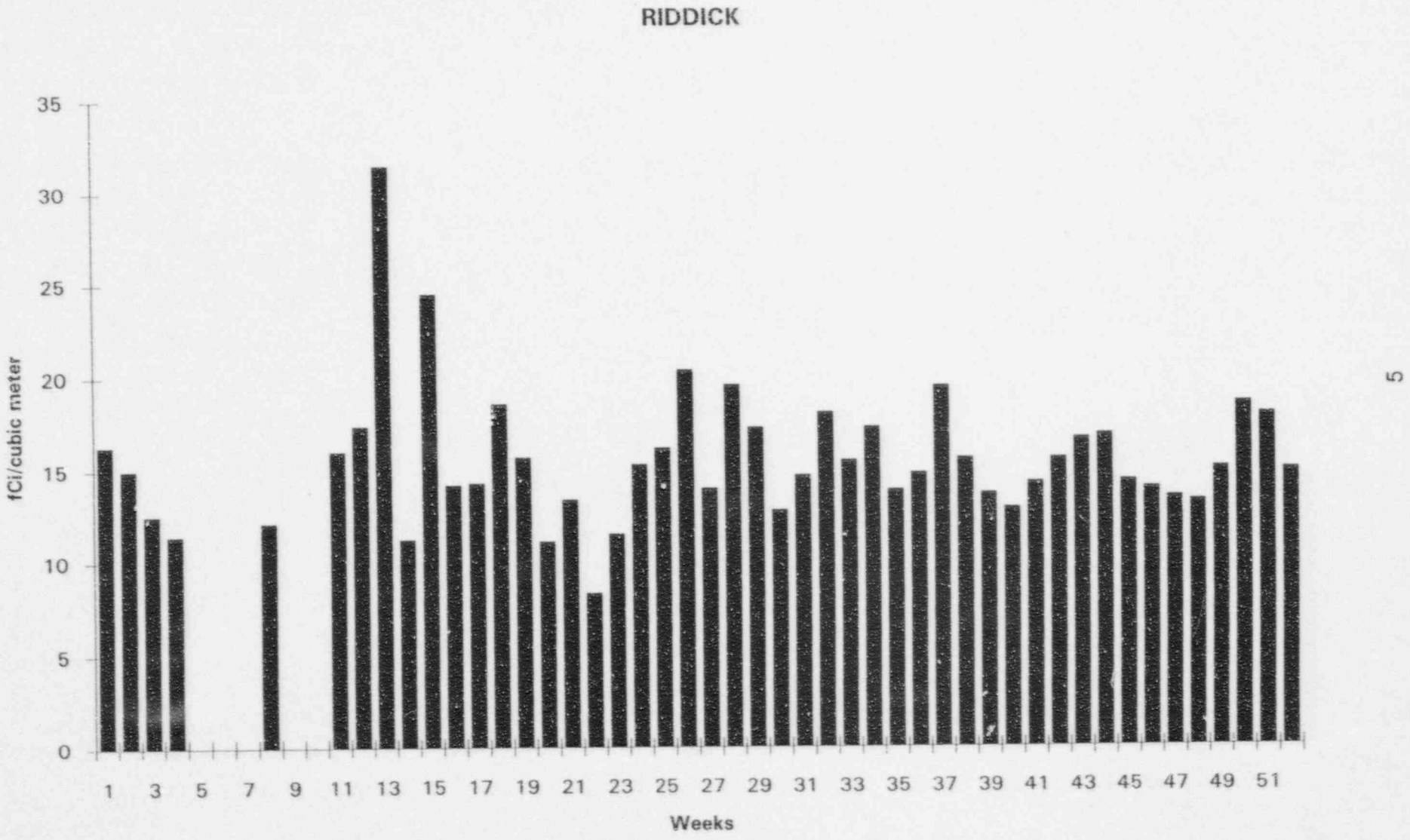
WEEK NUMBER FROM JUNE 28, 1994 THROUGH JUNE 29, 1995

JUNE 28 BEGINS AT WEEK #1

FIGURE 2d

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



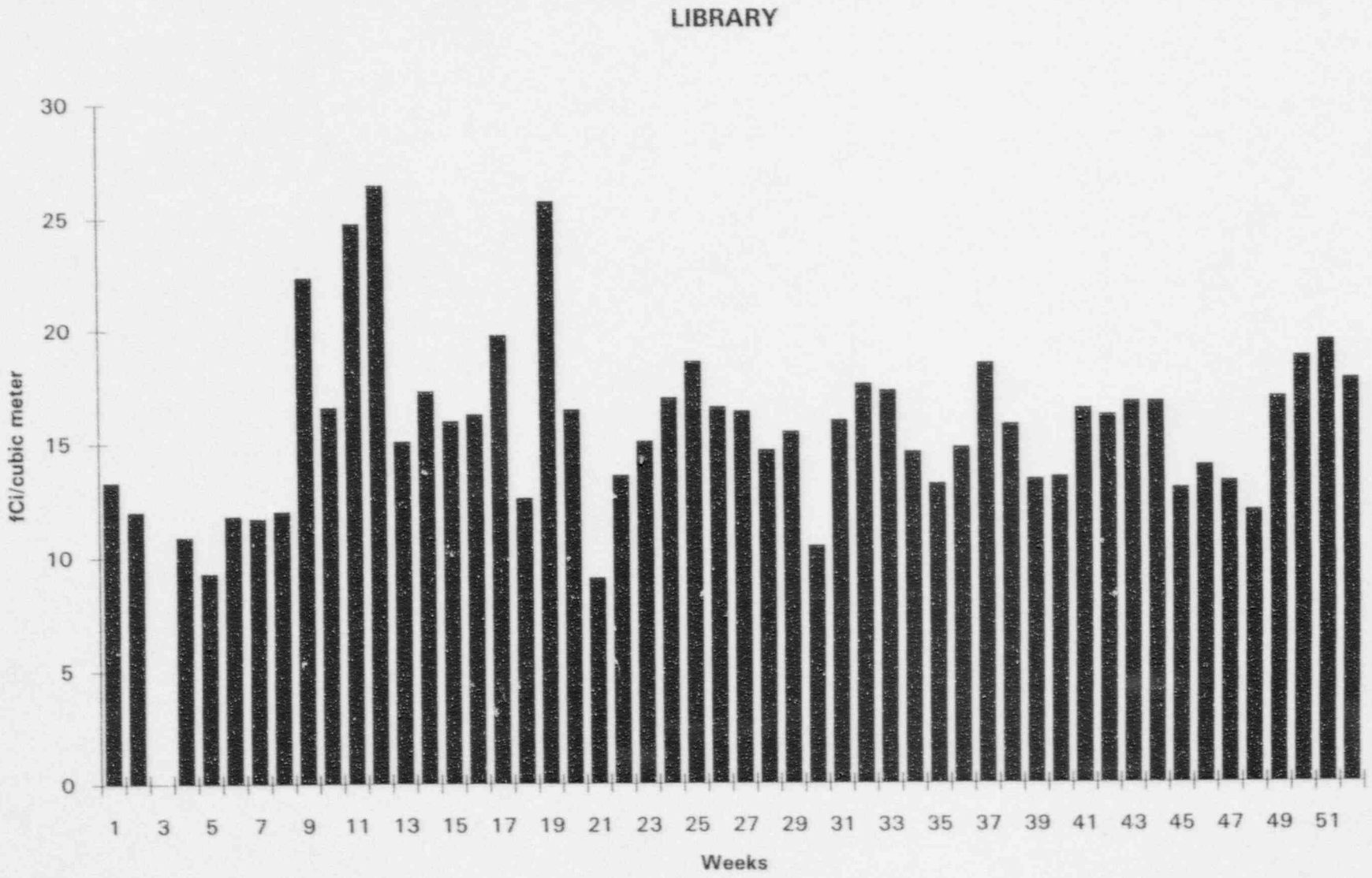
WEEK NUMBER FROM JUNE 28, 1994 THROUGH JUNE 29, 1995

JUNE 28 BEGINS AT WEEK #1

FIGURE 2e

AIRBORNE GROSS BETA ACTIVITY
N. C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT = 1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



WEEK NUMBER FROM JUNE 28, 1994 THROUGH JUNE 29, 1995

JUNE 28 BEGINS AT WEEK #1

Table 2.2 Aerially Transported Gamma Activity				(fCi m E-3)					
					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
1994									
06/28 - 07/05	0.18	0.25	0.30	0.54	0.28	2.30	0.25	0.45	1.41
07/05 - 07/12	0.26	0.42	0.39	0.60	0.33	3.10	0.39	0.46	1.96
07/12 - 07/20	0.27	0.45	0.38	0.63	0.34	3.10	0.42	0.49	2.14
07/20 - 07/26	0.17	0.40	0.33	0.59	0.30	2.80	0.29	0.37	1.43
07/26 - 08/02	0.19	0.39	0.33	0.59	0.30	3.10	0.32	0.36	1.47
08/02 - 08/09	0.30	0.58	0.51	0.85	0.46	4.50	0.50	0.53	2.24
08/09 - 08/17	0.19	0.39	0.35	0.65	0.35	3.30	0.33	0.44	1.52
08/17 - 08/23	0.19	0.37	0.35	0.58	0.33	3.10	0.38	0.39	1.58
08/23 - 08/30	0.20	0.38	0.34	0.57	0.31	3.10	0.34	0.37	1.58
08/30 - 09/06	0.18	0.32	0.30	0.50	0.29	2.70	0.31	0.33	1.39
09/06 - 09/13	0.19	0.39	0.34	0.54	0.29	2.80	0.35	0.35	1.45
09/13 - 09/20	0.17	0.33	0.26	0.53	0.28	2.70	0.29	0.33	1.33
09/20 - 09/27	0.16	0.32	0.29	0.47	0.28	2.40	0.27	0.35	1.26
09/27 - 10/06	0.15	0.28	0.28	0.40	0.23	2.30	0.26	0.28	1.17
10/06 - 10/12	0.15	0.31	0.26	0.48	0.26	2.40	0.26	0.33	1.16
10/12 - 10/19	0.15	0.30	0.26	0.43	0.22	2.30	0.28	0.28	1.16
10/19 - 10/25	0.18	0.36	0.28	0.49	0.23	2.60	0.29	0.29	1.51
10/25 - 11/01	0.16	0.29	0.23	0.40	0.23	2.30	0.25	0.28	1.27
11/01 - 11/08	0.16	0.30	0.24	0.46	0.27	2.20	0.24	0.31	1.29
11/08 - 11/15	0.16	0.29	0.25	0.43	0.29	2.30	0.26	0.31	1.31
11/15 - 11/22	0.18	0.31	0.26	0.44	0.29	2.40	0.27	0.33	1.38
11/22 - 11/29	0.19	0.32	0.28	0.43	0.28	2.60	0.29	0.30	1.46
11/29 - 12/06	0.17	0.31	0.36	0.66	0.49	2.30	0.24	0.34	1.32
12/06 - 12/13	0.17	0.27	0.34	0.63	0.43	2.40	0.25	0.33	1.29
12/13 - 12/20	0.17	0.29	0.25	0.53	0.36	2.10	0.24	0.31	1.29
12/20 - 12/29	0.13	0.22	0.23	0.43	0.26	1.90	0.20	0.37	0.96
12/29 - 01/04	0.18	0.36	0.31	0.54	0.33	2.5	0.3	0.43	1.41

Table 2.2 Aerially Transported Gamma Activity (fCi m E-3)

					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
1995									
01/04 - 01/11	0.16	0.31	0.29	0.47	0.27	2.2	0.24	0.38	1.22
01/11 - 01/19	0.17	0.32	0.28	0.48	0.28	2.5	0.29	0.34	1.28
01/19 - 01/26	0.19	0.34	0.30	0.50	0.29	2.50	0.29	0.33	1.26
01/26 - 02/02	0.17	0.33	0.29	0.48	0.28	2.50	0.29	0.32	1.30
02/02 - 02/09	0.18	0.32	0.31	0.46	0.29	2.6	0.27	0.31	1.29
02/09 - 02/16	0.16	0.31	0.3	0.45	0.28	2.5	0.26	0.3	1.33
02/16 - 02/23	0.19	0.35	0.33	0.47	0.31	2.6	0.25	0.36	1.38
02/23 - 03/02	0.18	0.32	0.34	0.49	0.32	2.5	0.27	0.35	1.31
03/02 - 03/09	0.16	0.31	0.33	0.48	0.35	2.6	0.28	0.38	1.29
03/09 - 03/16	0.17	0.3	0.32	0.49	0.33	2.5	0.26	0.33	1.28
03/16 - 03/23	0.18	0.29	0.3	0.47	0.31	2.5	0.27	0.32	1.29
03/23 - 03/30	0.16	0.3	0.3	0.48	0.3	2.6	0.29	0.34	1.32
03/30 - 04/06	0.18	0.31	0.33	0.50	0.31	2.60	0.31	0.33	1.27
04/06 - 04/13	0.16	0.33	0.35	0.43	0.30	2.50	0.30	0.30	1.26
04/13 - 04/20	0.17	0.34	0.38	0.41	0.33	2.60	0.31	0.31	1.35
04/20 - 04/27	0.19	0.31	0.35	0.39	0.36	2.50	0.33	0.30	1.29
04/27 - 05/04	0.18	0.30	0.34	0.38	0.35	2.50	0.34	0.29	1.31
05/04 - 05/11	0.16	0.30	0.28	0.44	0.28	2.30	0.25	0.35	1.24
05/11 - 05/18	0.18	0.33	0.32	0.45	0.26	2.40	0.27	0.29	1.23
05/18 - 05/25	0.17	0.32	0.35	0.41	0.27	2.50	0.29	0.31	1.30
05/25 - 06/01	0.18	0.26	0.30	0.47	0.28	2.40	0.26	0.41	1.39
06/01 - 06/08	0.19	0.36	0.34	0.46	0.29	2.40	0.27	0.38	1.35
06/08 - 06/15	0.17	0.34	0.33	0.45	0.30	2.50	0.28	0.36	1.33
06/15 - 06/22	0.17	0.33	0.39	0.40	0.31	2.50	0.29	0.37	1.35
06/22 - 06/29	0.18	0.34	0.38	0.37	0.30	2.50	0.28	0.36	1.33

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 and the Lake Wheeler Road Dairy. Previously, samples were obtained from the Randleigh Dairy Farm but it is no longer operational.

TABLE 3.1 I-131 IN COWS' MILK (pCi liter^{-1} $\pm$ 2 σ) LLD ~ 3 pCi liter^{-1}

	pCi liter^{-1}	
DATE	CAMPUS CREAMERY	LAKE WHEELER
JULY 1994	≤ 3.0	≤ 3.0
AUGUST 1994	≤ 3.0	≤ 3.0
SEPTEMBER 1994	≤ 3.0	≤ 3.0
OCTOBER 1994	≤ 3.0	≤ 3.0
NOVEMBER 1994	≤ 3.0	≤ 3.0
DECEMBER 1994	≤ 3.0	≤ 3.0
JANUARY 1995	≤ 3.0	≤ 3.0
FEBRUARY 1995	≤ 3.0	≤ 3.0
MARCH 1995	≤ 3.0	≤ 3.0
APRIL 1995	≤ 3.0	≤ 3.0
MAY 1995	≤ 3.0	≤ 3.0
JUNE 1995	≤ 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 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 1995.

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

*LLDα ~ 0.4 pCi liter^{-1} LLDβ ~ 0.4 pCi liter^{-1}

		pCi liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 1994	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
FOURTH QUARTER 1994	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
FIRST QUARTER 1995	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
SECOND QUARTER 1995	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4

*LLD VALUES ARE DETERMINED QUARTERLY

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER

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 1995

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.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} $\pm 2\sigma$)
DECEMBER 1994	NORTH CAMPUS	3.6 ± 0.1
DECEMBER 1994	SOUTH CAMPUS	2.6 ± 0.1
DECEMBER 1994	EAST CAMPUS	2.5 ± 0.1
DECEMBER 1994	WEST CAMPUS	2.5 ± 0.2
APRIL 1995	NORTH CAMPUS	2.8 ± 0.1
APRIL 1995	SOUTH CAMPUS	2.6 ± 0.1
APRIL 1995	EAST CAMPUS	2.7 ± 0.1
APRIL 1995	WEST CAMPUS	2.8 ± 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 1995

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 was located in 214 David Clark Laboratories during July, August, September, October 1994 and in Room 107 of the Environmental Safety Center during the remainder of this report period. A high exposure of 77.9 ± 9.4 mR was recorded for the control station during the period 01/05/95 to 04/25/95. An explanation for this elevated exposure is not available, but may have been due to a defective TLD. Table 6.1 gives the data for these seven (7) monitoring locations.

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 ± 2s)						
DATE	WITHERS	RIDDICK	BROUGHTON	LIBRARY	DAVID CLARK	PULSTAR STACK	CONTROL
* 04/04/94 - 06/30/94	10.6 ± 1.8	16.3 ± 2.6	11.9 ± 1.9	11.6 ± 3.0	10.0 ± 0.6	10.4 ± 1.1	11.4 ± 2.8
06/30/94 - 09/28/94	17.5 ± 2.1	25.0 ± 1.9	18.6 ± 1.8	20.5 ± 4.0	19.6 ± 3.1	14.7 ± 0.5	17.6 ± 1.3
09/28/94 - 01/11/95	15.6 ± 0.7	22.3 ± 2.3	17.1 ± 1.3	17.2 ± 0.6	22.7 ± 8.4	13.9 ± 0.2	17.0 ± 1.4
01/05/95 - 04/25/95	13.6 ± 2.6	18.0 ± 3.7	15.5 ± 5.0	16.2 ± 6.3	26.8 ± 8.8	12.1 ± 2.8	77.9 ± 9.4
04/25/95- 06/30/95	DATA NOT YET AVAILABLE FOR THESE DATES						

* THIS DATA WAS UNAVAILABLE FOR INCLUSION IN THE 1993-1994 REPORT.

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 Tables 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 IN WATER - INTERCOMPARISON STUDY 22 JULY 1994

The known value for gross alpha activity is 32.0 pCi/liter with an expected laboratory precision of 8.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS ALPHA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
29.0	33.0	30.0	2.09	0.295	30.66	0.20	-0.29

STATISTICAL SUMMARY OF 241 PARTICIPANTS

Statistic	Respondents	Non-outliers
Mean	30.33	29.74
Std. Dev.	11.61	10.11
Variance	134.79	102.31
% Coef. of Var.	38.28	34.01
% deviation of mean from known value	-5.21	-7.07
Nor. dev. of mean from known value	-0.14	-0.22
Median	29.33	29.33
% deviation	-8.33	-8.33
Nor. dev. of median from known value	-0.23	-0.26

TABLE 7.1b GROSS BETA ACTIVITY IN WATER - INTERCOMPARISON STUDY 22 JULY 1994

The known value gross beta activity is 10.0 pCi/liter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS BETA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
10.0	13.0	12.0	0.58	0.118	11.67	-1.12	0.58

STATISTICAL SUMMARY OF 241 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	18.02	Grand Avg	14.91
Std. Dev.	31.47		3.74
Variance	990.10		13.96
% Coef. of Var.	174.64		25.06
% deviation of mean from known value	80.17		49.06
Norm. dev. of mean from known value	0.25		1.31
Median	15.00		15.00
% deviation of median from known value	50.00		50.00
Nor. dev. of median from known value	0.16		1.34

TABLE 7.1c TRITIUM IN WATER - INTERCOMPARISON STUDY
5 AUGUST 1994

The known value for tritium activity is 0951 pCi/liter with an expected laboratory precision of 995 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{3}H

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
10894.0	10630.0	10422.0	303.53	0.339	10648.7	1.74	1.22

STATISTICAL SUMMARY OF 214 PARTICIPANTS

Statistic	Respondents	Non-outliers
Mean	9389.64	Grand Avg 9651.86
Std. Dev	1581 38	696.62
Variance	2500775.46	485284.69
% Coef. of Var.	16.84	7.22
% deviation of mean from known value	-5.64	-3.01
Norm. dev. of mean from known value	-0.35	-0.43
Median	9683.33	9710.00
% deviation of median from known value	-2.69	-2.42
Nor. dev. of median from known value	-0.17	-0.35

TABLE 7.1d GROSS ALPHA ACTIVITY AIR FILTER -- INTERCOMPARISON STUDY 26 AUGUST 1994

The known value for gross alpha activity is 35.0 pCi/filter with an expected laboratory precision of 9.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS ALPHA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
35.0	35.0	35.0	0.00	0.000	35.00	-0.36	0.00

STATISTICAL SUMMARY OF 214 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	39.50	Grand Avg	36.89
Std. Dev.	17.30		6.62
Variance	299.45		43.78
% Coef. of Var.	43.81		17.94
% deviation of mean from known value	12.85		5.40
Norm. dev. of mean from known value	0.26		0.29
Median	36.00		36.00
% deviation of median from known value	2.86		2.86
Nor. dev. of median from known value	0.06		0.15

TABLE 7.1e GROSS BETA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY 26 AUGUST 1994

The known value for gross beta activity is 56.0 pCi/filter with an expected laboratory precision of 10.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS BETA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
60.0	59.0	60.0	0.58	0.059	59.67	0.10	0.64

STATISTICAL SUMMARY OF 214 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	60.65	Grand Avg	59.08
Std. Dev.	14.97		7.23
Variance	224.13		52.21
% Coef. of Var.	24.68		12.23
% deviation of mean from known value	8.30		5.50
Norm. dev. of mean from known value	0.31		0.43
Median	58.33		58.33
% deviation of median from known value	4.17		4.17
Nor. dev. of median from known value	0.16		0.32

TABLE 7.1f ^{137}Cs ACTIVITY AIR FILTER - INTERCOMPARISON STUDY
26 AUGUST 1994

The known value for Cesium-137 activity is 15.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{137}Cs

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
18.0	18.0	18.0	0.00	0.000	18.00	0.49	1.04

STATISTICAL SUMMARY OF 214 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	17.17	Grand Avg	16.59
Std. Dev.	4.10		2.42
Variance	16.83		5.87
% Coef. of Var.	23.90		14.61
% deviation of mean from known value	14.40		10.59
Norm. dev. of mean from known value	0.53		0.66
Median	16.33		16.33
% deviation of median from known value	8.89		8.89
Nor. dev. of median from known value	0.33		0.55

TABLE 7.1g TRITIUM IN WATER - INTERCOMPARISON STUDY
10 MARCH 1995

The known value for tritium activity is 7435.0 pCi/liter with an expected laboratory precision of 774.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{3}H

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
7134.0	7357.0	7219.0	41.46	0.060	7236.67	-0.15	-0.46

STATISTICAL SUMMARY OF 186 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	7223.50	Grand Avg	7299.15
Std. Dev.	1020.24		682.97
Variance	1040885.03		466446.40
% Coef. of Var.	14.12		9.36
% deviation of mean from known value	-2.84		-1.83
Norm. dev. of mean from known value	-0.21		-0.20
Median	7236.67		7244.67
% deviation of median from known value	-2.67		-2.56
Nor. dev. of median from known value	-0.19		-0.28

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.

A comparison of this reporting period to previous years indicates low levels of naturally occurring radioactivity, and there seems to have been a general decline in ambient levels during the past five years. However, the magnitude of this apparent decrease is not large and should not be regarded as a substantiated trend.

9. ACKNOWLEDGMENTS

This office is greatly indebted to Mr. Bill Crocker and Mr. Dwight Dickens for their 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 and arrangement of this report are available due to the assistance of Ms. Jerilin E. Paith.

APPENDIX 1

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

Column 1,2,3: Laboratory results given in triplicate.

Column 4: Standard deviation (1s) of the experimental results.

Column 5: Normalized range value in "mean range + standard error of the range".

Column 6: Average value of the triplicate analysis.

Column 7: Normalized deviation from the grand average value of all laboratories expressed in σ_m units.

Column 8: 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 ^{3}H/liter on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

Sample	Result
X_1	3060 pCi/liter
X_2	3060 pCi/liter
X_3	3240 pCi/liter

Mean = $\overline{x}$

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

where N = number of results = 3

Experimental sigma = s

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

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

s = 103.9 pCi/liter

Range = r

r = | maximum result - minimum result |

r = | 3240 - 3060 |

r = 180 pCi/liter

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

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

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

$= (1556 - 604.4) \div 3$

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

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*Rosentein, 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.

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

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

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

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

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

Experimental sigma (all laboratories) = s_t

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

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

s_t = 149 pCi/liter

Grand Average = GA

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

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

GA = 3290 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 pCi/liter

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

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

ND' = - 0.8